Participant Welcome Packet

Unifying Innovations in Forecasting Capabilities Workshop

A Unified Forecast System (UFS) Collaboration Powered by the Earth Prediction Innovation Center (EPIC)

Dates:
Monday, September 8, 2025 - Friday, September 12, 2025

Time:
Monday: 11:30 AM – 4:00 PM MDT
Tuesday 9:00 AM – 7:00 PM MDT
Wednesday: 9:00 AM – 5:45 PM MDT
Thursday 9:00 AM - 4:45 PM MDT
Friday: 9:00 AM – 4:00 PM MDT

Location:
University Corporation for Atmospheric Research (UCAR) Center Green in Boulder, Colorado, and Online

Table of Contents

Goals

1. Share the current status of and future plans for the community-based Unified Forecast System.
2. Share successes and challenges related to contributing to the Unified Forecast System.
3. Identify ways academia, industry, and operations can work together to enhance the Unified Forecast System, accelerate their own contributions, and measure their success.

Objective

To build on the existing collaboration between the public, private, and academic sectors within the Weather Enterprise. By highlighting the importance of community building and the shared goal of advancing the UFS, the workshop serves as a key event for fostering enhanced communication and collaboration. UIFCW25 is about engaging and uniting our efforts to advance forecasting capabilities for a more informed future. The theme for this year's workshop is Building a Stronger UFS Community Through Collaboration and Knowledge Sharing.

In-Person, Virtual, and Hybrid Logistics

In-person

Address: NCAR & UCAR Center Green Campus CG 1, 3080 Center Green Drive,
Boulder, Colorado, 80301

Parking: Parking is free and available in the Center Green Campus parking lot.

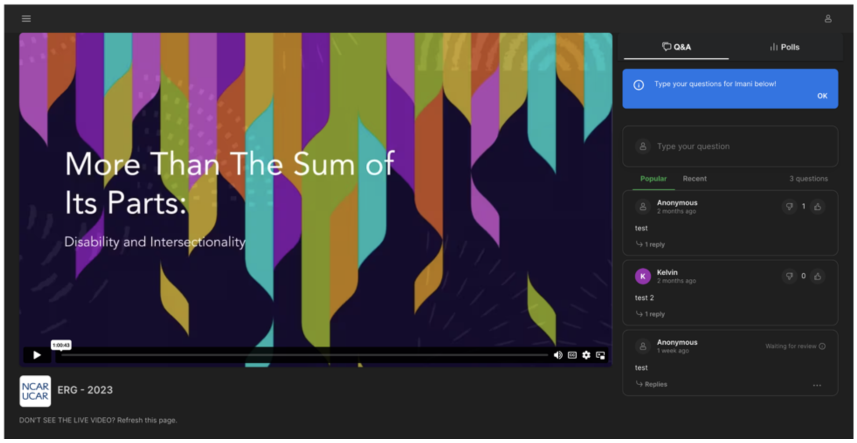
Lunch: Lunch will be provided to ALL in-person attendees by UCAR catering during the scheduled 1-hour lunch break each full day of the workshop (Tuesday – Friday). However, federal employees are **REQUIRED** to pay for lunch if they intend to participate in the lunches. Lunch will be served through the honor system.

Virtual

Most presentations will be livestreamed. The livestream will be available on EPIC's website at epic.noaa.gov. Your online engagement platform will be through Slido. Your virtual hub for the workshop will be on EPIC's website, utilizing the SLIDO software.

SLIDO

Slido will be directly embedded onto the EPIC Community Portal, where you can watch the livestream and interact and chat with other attendees. A sample image of the SLIDO software is below:



More Than The Sum of Its Parts:

Disability and Intersectionality

Type your questions for Imani below!

Type your question

Anonymous
2 months ago
test
1 reply

Kelvin
2 months ago
test 2
1 reply

Anonymous
1 week ago
Waiting for review
test
Replies

DON'T SEE THE LIVE VIDEO? Refresh this page.

Hybrid

See the above info; come and go as you please.

About EPIC

The Earth Prediction Innovation Center (EPIC) is fundamentally transforming the landscape of Earth system prediction by championing collaborative partnerships across government, academia, and industry. EPIC is dedicated to driving innovative infrastructure, integrating groundbreaking technologies like Artificial Intelligence (AI) into Numerical Weather Prediction (NWP). Beyond technological advancement, EPIC is committed to training the next generation of atmospheric scientists, fostering a skilled workforce prepared to tackle complex environmental challenges. Our core mission includes advancing Earth System Modeling capabilities through the Unified Forecast System (UFS) framework, sustaining an open science, community-driven approach that accelerates research to operations.

About UFS

The Unified Forecast System (UFS) is a community-based, coupled, comprehensive Earth modeling system. UFS numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. It is designed to support the Weather, Water, and Climate Enterprise and to be the basis for NOAA's operational Earth system modeling applications.

The UFS community includes researchers, developers, and users from NOAA, academia, federal agencies, and the private sector. The UFS supports research and development in the community and accelerates the transition of research to operations.

About UFS-R2O

The UFS-R2O Project is a major collaborative effort focused on transitioning UFS applications and new research innovations into the NWS National Centers for Environmental Prediction (NCEP) operational modeling suite. The project is supported and managed by both the NWS Office of Science and Technology Integration (OSTI) Modeling Program, and the OAR Weather Program Office (WPO) Joint Technology Transfer Initiative (JTTI), enabling partnerships and opportunities for joint development of next generation, UFS-based operational systems across organizations including the NCEP Environmental Modeling Center (EMC), , OAR labs, the Developmental Testbed Center (DTC), and multiple academic partners.

The UFS-R2O Project began in July 2020, and the first three years of the project (Phase I; July 2020 - June 2023) resulted in many accomplishments, leading to significant advancements in developing the FV3-based systems including the Hurricane Analysis and Forecast System (HAFS) version 1, the regional Rapid Refresh Forecast System (RRFS) version 1, the Global Forecast System (GFS) version 17 and Global Ensemble Forecast System (GEFS) version 13. Phase II of the project (July 2023 - June 2026) will continue to develop and improve global, regional, and hurricane prediction systems and their components for data assimilation, physics, atmospheric composition, infrastructure, and verification and post-processing.

Connect With Us

Slido will be your go-to online hub to chat with speakers and connect with other attendees. We will also be sharing updates and information through X when you use **#UIFCW25.**

You can also follow @NOAAEPIC on X, @NOAAEPIC on Instagram, or on Earth Prediction Innovation Center | LinkedIn for the latest news from EPIC.

Please email support.epic@noaa.gov with any questions or concerns.

WiFi Information: A wireless connection is available through the WiFi name, *UCAR Visitor*. No password is required.

Daily Agenda

*SUBJECT TO CHANGES, please refer to EPIC's website at epic.noaa.gov for important updates

Monday, September 8th

All times Mountain Daylight Time

11:30 am **Virtual Poster Slam (Virtual Participants Only)**

Joshua Kublnick, NOAA/OAR/WPO/EPIC

Virtual Attendees: Livestream Link
The virtual poster slam provides a unique opportunity for the virtual audience to participate and engage in the virtual poster slam to hear authors present their posters. If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

VIRTUAL POSTER PRESENTERS

11:12 am - Atieh Alipour - NeurOCAST: A Neural Operator-Based Model for Bias Correction in Forecast Guidance (abstract)

11:15 am - Barry Baker - Introduction of NOAA's new UFS based operational prototype, the Global Chemistry and Aerosol Forecast System (GCAFS) v1 (abstract)

11:18 am - Zhihong Chen - Investigation of data driven background ensemble covariance from Graphcast toward Hurricane data assimilation and prediction (abstract)

11:21 am -Linlin Cui - Development of a Coupled Atmosphere-Ocean Model for Subseasonal-to-Seasonal Forecasting (abstract)

11:24 am - Fariborz Daneshvar - Evaluating the effect of wave and hydrology coupling on tropical cyclone driven storm surge (abstract)

11:27 am - Oliver Elbert - Keeping Pace: Unlocking AI and Exascale with Domain Specific Languages (abstract)

11:30 am - David Harrison - Assessing the Skill and Sensitivity of AI-Generated Global NWP Emulators in the NOAA HWT Spring Forecasting Experiment (abstract)

11:33 am - Aryan Harooni - An Agentic LLM Framework for Fast and Interpretable Data Queries: Application to STOFS (abstract)

11:36 am - Mansur Ali Jisan - A Containerized WCOSS2 Environment for Collaborative Development of Operational Ocean Forecast Systems (abstract)

11:39 am - Yu-Shin Kim - Impact of Assimilating Atmospheric Boundary Layer Observations on the Rapid Intensification of Hurricane Idalia (2023) in Self-cycled HAFS-JEDI System (abstract)

11:42 am - Conor Lewellyn - Generative Data Assimilation of Weather Observations for High-Resolution CONUS-wide Weather State Estimation (abstract)

11:45 am - Siqi Li - Development of a Coupled FVCOM-NWM Model for Ocean–Hydrology Interaction (abstract)

11:48 am - Jianjun Liu - Improving GFS Surface Fields Using a Deep Learning Bias Correction Model (abstract)

11:51 am - Yonggang Liu - Storm Surge and Coastal Inundation Nowcasts/Forecasts During Hurricanes Helene and Milton (abstract)

11:54 am - Thiruvengadam Padmanabhan - Improving Background Error Covariance and Square Root Estimation with the Convolution Neural Network (CNN) in the Gain Form Ensemble Transform Kalman filter (GETKF) (abstract)

11:57 am - Li Pan - Application of Aerosol Budget Analysis method to two generations of NOAA global aerosol forecast models (abstract)

12:00 pm - Benjamin Ruston - JEDI Skylab - Observation Assessment and Evaluation (abstract)

12:03 pm - Rohit Shukla - Harnessing Machine Learning and Explainable AI to Predict Phytoplankton Blooms and Identify Key Drivers in Freshwater Reservoirs (abstract)

12:06 pm - Jacob Steinberg - Toward Improved Forecasts of U.S. East Coast Sea Level: development of a dynamical downscaling framework to simulate North Atlantic circulation and physically inform sub-annual forecast skill. (abstract)

12:09 pm - Younes Tebbaai - Advancing Forecasting Capabilities of Dust and Health Impact through the Saharan Oscillation Index and Machine Learning (abstract)

12:12 pm - Lixia Wang - The Evaluation of a Data Assimilative Northeast Coastal Operational Forecast System in 2021 (abstract)

12:15 pm - Yongming Wang - Generating Cost-Saving Surrogate Background Ensemble with GNN-based MAPcast for Estimating Multi-Scale Background Error Covariances (abstract)

12:18 pm - Xuguang Wang - Understanding sampling error characteristics in ensemble-based estimates of land-atmosphere coupled background error covariances in a dryline CI case study (abstract)

12:21 pm - Fei Ye - Empowering Communities through Flexible and Semi-Automated 3D Coastal Modeling in STOFS-3D-Atlantic (abstract)

12:24 pm - Hyungju Yoo - Upgrading STOFS-3D-Atlantic: A Bias Correction Method for Improved Total Water Level Predictions (abstract)

1:00 pm **Training 1 | Compile and Run the UFS Global- Workflow using a Container Image (Singularity) on a variety of Platforms**

In-person attendees: Room 2126
Virtual attendees: *See Participant Instruction Email*

1:00 pm **Training 2 | Artificial Intelligence in Weather Modeling Training**

In-person attendees: North Bay
Virtual attendees: *See Participant Instruction Email*

5:00 pm **Hike With Alison Gregory**

Enjoy scenic trails behind the NCAR Mesa Lab. The length of the hike can vary based on attendees interest. The free UCAR/NCAR shuttle will leave Center Green at 4:33 pm and arrive at Mesa Lab by 5 pm. The last shuttle back to Center Green is at 6:00 pm. Local rideshare options are also available. If driving, free parking is available in the NCAR Mesa Lab parking lot.

Hike Location: Approximately 20 minutes from Center Green.

Meet at NCAR - Table Mesa Trail
1850 Table Mesa Dr
Boulder, CO 80305

Tuesday, September 9th

All times Mountain Daylight Time

8:00 am **Registration**
In-Person Attendees: Registration will begin in the UCAR Center Green lobby.

Virtual Attendees: If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

9:00 am **Welcome and Kickoff**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Jan Ising, NOAA/OAR/WPO/EPIC

9:15 am **Opening Remarks by Dr. Everette Joseph, NCAR Director**
Dr. Everette Joseph, NSF NCAR

9:30 am **State of the Earth Prediction Innovation Center (EPIC) and the Unified Forecast System (UFS)**
Kevin Garrett, NOAA/NWS/OSTI
Maoyi Huang, NOAA/OAR/WPO/EPIC
Vijay Tallapragada, NOAA/NWS/NCEP EMC
Saeed Moghimi, NOAA/NOS/OCS

10:15 am	**Break**
10:45 am	**Testing and Continuous Integration Updates** *Alex Richert, RedLine Performance Solutions/NOAA EMC* *Marshall Ward, NOAA/OAR/Geophysical Fluid Dynamics Laboratory (GFDL)*
11:30 am	**Current Status of Earth System Models** *Alistair Sellar, UK Met Office* *David Lawrence, NSF NCAR (abstract)*
12:00 pm	**Lunch**
1:00 pm	**Data Assimilation Update and Discussion** *Jan Ising, NOAA/OAR/WPO/EPIC* *Xuguang Wang, University of Oklahoma/CADRE* *John Ten Hoeve, NOAA/OAR/WPO* *Tom Auligne, UCAR-JCSDA* *Dan Holdaway, NOAA/NWS/NCEP/EMC* *Zhaoxia Pu, University of Utah* *Moderated by Jan Ising*
2:00 pm	**UFS Coupling: How the UFS Is Being Expanded to Include Additional Environmental Modeling Components** *Ligia Bernardet, NOAA GSL/DTC* *Ann Tsay, UCAR* *Hendrik L. Tolman, NOAA/NWS/OSTI*
3:00 pm	**Break**
3:30 pm	**NOAA's AI Transformation** *Robert Redmon, NOAA/NESDIS/NCEI/NCAI (abstract)* *Jun Wang, NOAA/NWS/NCEP/EMC*
4:00 pm	**Keynote: Coupled modeling to improve marine weather forecasts of winds and**

waves for maritime shipping
Stephen G. Penny, Sofar Ocean (abstract)

4:30 pm **Meet The Community Panel Discussion**
Panelists:
Serena Lipari, Pacific Northwest National Laboratory
Craig Setzer, Royal Caribbean Group
Patricia Vollmer, Department of Defense (DoD)/NORAD & US Northern Command
Andrew Winters, University of Colorado Boulder

Moderated by Hendrik L. Tolman, NOAA/NWS/OSTI

5:45 pm **Networking Mixer at UCAR Center Green lobby**
Paul Schlatter, NOAA/NWS Boulder Weather Forecast Office (abstract)

7:15 pm **Informal Gathering at** Avery Brewery Taproom and Restaurant
4910 Nautilus Ct. N (10 minutes from Center Green)

Wednesday, September 10th

All times Mountain Daylight Time

8:00 am **Registration**
In-Person Attendees: Registration will begin in the UCAR Center Green lobby.

Virtual Attendees: If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

9:00 am **Welcome and Kickoff**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Shira Francis, NOAA/NWS/OSTI-M/IBSS

9:05 am **NOAA - Current Status and Priorities**
Steve Smith, NOAA/NWS

Mark Osler, NOAA/NOS
Gina Eosco, NOAA/OAR/WPO

9:20 am **Student/Lapenta Presentations**

9:20 am - Rowin Smith - The UFS Student Experience: Accomplishments, Challenges, and Recommendations (abstract)

9:30 am - Michael Kwadwo Benneh - Aerosol Data Assimilation Using Global Chemistry And Aerosol Forecast System (Gcafs)/Jedi (abstract)

9:40 am - McKenzie Larson - Evaluation of initial condition blending within MPAS to inform RRFSv2 (abstract)

9:50 am - Shreyas Dhavale - Case studies of the Monsoon Onset Vortex and early season Monsoon features using the UFS coupled model (abstract)

10:00 am - Anna Glodzik - Evaluating UFS Heat and Moisture Fluxes Using Eddy Covariance Observations from the New York State Mesonet (abstract)

10:15 am **Break**

10:25 am **New User/Student Parallel Track Begins**
In-person attendees: North Bay
Virtual attendees: Livestream Link

10:45 am **UFS Community Social Science Survey Results**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Alison Gregory, UCAR CPAESS
Hannah Love, Divergent Science LLC

11:15 am **UFS Coastal Project Overview**
Saeed Moghimi, NOAA/NOS/OCS

12:00 pm **Lunch**

1:00 pm **Parallel Sessions with Q&A**

UFS APPLICATION - GLOBAL APPLICATIONS ACROSS SCALES

In-person attendees: South Bay

Virtual attendees: Livestream Link

Moderated by Fanglin Yang, NWS/NCEP/EMC

1:00 pm - Catherine Thomas - Overview of the Next Global Forecast System GFSv17 (abstract)

1:12 pm - Bing Fu - GEFSv13 updates (abstract)

1:24 pm - Philip Pegion - NOAA's Seasonal Forecast System (abstract)

1:36 pm - Justin Perket- 2-Way Coupling the GFDL Land Model with FV3 Atmosphere in UFS (abstract)

1:48 pm - Lisa Bengtsson - Improving Tropical Variability in the UFS for S2S Prediction (abstract)

2:00 pm - Jian-Wen Bao - Numerical behavior of two land surface models as a significant contributor to biases in the UFS prediction of CAPE over the CONUS (abstract)

2:12 pm - Benjamin Moore - Impacts of tropical forecast errors on weeks 3–4 extreme precipitation predictions over California during winter 2022–23 (abstract)

2:24 pm - Daniel R. Adriaansen - New Capabilities for Evaluating Land-Atmosphere Coupling in UFS Prototypes using METplus (abstract)

2:36 pm - Wei Huang - Run SFS global-workflow on AWS (abstract)

2:48 pm - Juliana Dias - Development of an MJO test bed to support UFS global applications (abstract)

Parallel Sessions Regarding

SESSION ON CROSS-CUTTING - DATA ASSIMILATION

In-person attendees: Center Bay

Virtual attendees: Livestream Link

Moderated by Sergey Frolov, NOAA/OAR/PSL

1:00 pm - Jonathan (JJ) Guerrette - Evaluation of the Tomorrow.io Microwave Sounder constellation with a JEDI-UFS-based and GDAS-inspired NWP system (abstract)

1:12 pm - Ming Hu - Progress of implementing MPAS-JEDI for next version of the operation Rapid Refresh Forecast System (abstract)

1:24 pm - Christian Sampson - A Hybrid Tangent Linear Model in JEDI (abstract)

1:36 pm - Peter Jan van Leeuwen - On the efficient implementation of non-Gaussian observation errors in existing DA schemes (abstract)

1:48 pm - Sergey Frolov - Towards end-to-end machine learning models that combine forecast with data assimilation (abstract)

2:00 pm - Clara Draper - Land Data Assimilation Activities for Global NWP at NOAA (abstract)

2:12 pm - Lindsey Hayden - Space Weather Data Assimilation Capabilities in the JEDI System (abstract)

2:24 pm - Hyun-Sook Kim - Marine JEDI system and MOM6 analysis for application to improve UFS-HAFS forecast (abstract)

3:00 pm **Break**

3:30 pm **Emerging Technologies: Artificial Intelligence / Machine Learning**

In-person attendees: Center Bay
Virtual attendees: Livestream Link

3:30 pm - Jun Wang - Data-driven MLWP model development for global weather forecasts (abstract)

3:45 pm - Sergey Frolov - NOAA EAGLE: research to operations pipeline for AI weather models at NOAA (abstract)

4:00 pm - David Hall - Enhancing the Unified Forecast System with NVIDIA Earth-2: AI Research in Emulation, Downscaling, and Data Assimilation (abstract)

4:15 pm - Corey Potvin - Enhancing WoFSCast Calibration and Sharpness with a Probabilistic Loss (abstract)

4:30 pm - Ling Lu - A Physics-informed Machine Learning Algorithm for Satellite, In-situ and High-frequency Radar Data Assimilation Preprocessing for West Coast Forecast System using Joint Effort for Data Integration Framework: WCOFS-JEDI-AI (abstract)

4:45 pm - James Conley - AI-Enabled UFS: Fortran to CUDA Code Translation for Accelerated Computing (abstract)

5:00 pm **Creating Better Feedback Loops Between Users and Developers Panel Discussion**
Panelists:
Kodi Berry, NOAA/OAR/NSSL
Michelle Harrold, NSF NCAR/RAL/DTC
Logan Poole, NOAA/NWS
Leticia Williams, NOAA/NWS
Castle Williamsberg, FedWriters Supporting NOAA/OAR/WPO (abstract)

Moderated by Alicia Bentley, NOAA/NWS/EMC

5:45 pm **Adjourn**

Wednesday, September 10th - *New User/Student Parallel Track*

All times Mountain Daylight Time

10:00 am **Registration**
In-Person Attendees: Registration will begin in the UCAR Center Green lobby.

Virtual Attendees: If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

10:25 am **Welcome and Kickoff**
In-person attendees: North Bay

Virtual attendees: Livestream Link

Jason R. Anderson, NOAA/NWS/OSTI-Modeling

10:30 am **Overview of Operational Models**
Vijay Tallapragada, NOAA/NWS/NCEP/EMC

11:30 am **UFS 101: Introduction to the Unified Forecast System**
Hendrik L. Tolman, NOAA/NWS/OSTI

12:00 pm **Lunch**

1:00 pm **Intro to Data Assimilation, Artificial Intelligence and Machine Learning**
Daryl Kleist, NOAA/NWS/NCEP/EMC
Stephen Haddad, UK Met Office

1:30 pm **Academic Research that benefits NOAA**
Sen Chiao, Howard University/NOAA Cooperative Science Center in Atmospheric Sciences and Meteorology (NCAS-M) (abstract)
Sarah Lu, University at Albany, SUNY
Benjamin Cash, George Mason University
Joseph Chan, Department of Geography, The Ohio State University

2:30 pm **Break**

3:00 pm **Starting Your Career in NOAA: Resources and Getting Your Foot in the Door**
Alison Gregory, UCAR CPAESS
Logan Poole, NOAA/NWS
Tracy Fanara, Inspector Planet, Project ENKI
Jennifer Vogt, NOAA/OAR/WPO/EPIC

Moderated by Mike Ek, NSF NCAR/RAL

3:45 pm **Early Career Professionals: Effective Ways to Network**
Karimar Ledesma-Maldonado, Northern Illinois University
Jacob Carstens, University of North Dakota, Department of Atmospheric Sciences
Aaron Pratt, NOAA/OAR/WPO
Segayle C. Thompson, PhD., NOAA/OAR/WPO

Hendrik L. Tolman, NOAA/NWS/OSTI
Mike Ek, NSF NCAR/RAL
Benjamin Patrick Woods, NOAA/OAR/WPO

Moderated by Mike Ek, NSF NCAR/RAL

4:30 pm **Adjourn**

Thursday, September 11th

All times Mountain Daylight Time

8:00 am **Registration**
In-Person Attendees: Registration will begin in the UCAR Center Green lobby.

Virtual Attendees: If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

9:00 am **Welcome and Kickoff**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Rowin Smith, Colgate University, NOAA William M. Lapenta Internship

9:15 am **Research to Operations (R2O) facets and how to engage in R2O to advance the UFS**
Kevin Garrett, NOAA/NWS/OSTI
Jordan Dale, NOAA/OAR/WPO
Andrea J. Ray, Ph.D., NOAA/OAR/Physical Sciences Lab (PSL)

Panelists:
Kevin Garrett, NOAA/NWS/OSTI
Jordan Dale, NOAA/OAR/WPO
Andrea J. Ray, Ph.D., NOAA/OAR/PSL
Jim Nelson, NOAA/NWS/WPC
Chandra Kondragunta, NOAA/OAR/WPO
Jacob Carley, NOAA/NWS/NCEP/EMC

Moderated by Andrea J. Ray, Ph.D., NOAA/OAR/PSL

9:30 am **Training 3 | Introduction to Running Idealized Test Cases via the UFS Hierarchical System Development (HSD) Framework**
In-person attendees: Room 2603
Virtual attendees: *See Participant Instruction Email*

9:30 am **Training 4 | NOAA AI Learning Journeys Tutorial**
In-person attendees: Room 2126
Virtual attendees: *See Participant Instruction Email*

10:15 am **US Navy's Earth System Prediction Capability Efforts by Naval Meteorology and Oceanography Enterprise**
Shastri Paturi, Fleet Numerical Meteorology and Oceanography Center (FNMOC) (abstract)

10:45 am **Fire Behavior Model Being Coupled to the UFS**
Pedro Jimenez, NSF NCAR (abstract)

11:15 am **Poster Session (In person Participants)**
If you are present in person, you will walk along the parameters of the lobby and along the catwalk (2nd floor) and engage with our in-person presenters as you would at any other poster session.

Abstracts for both the in-person and virtual posters can be found next to the names of the authors below.

IN-PERSON POSTERS

Ronnie Abolafia-Rosenzweig - Enhancing snowpack physics in Noah-MP land model to improve S2S prediction of precipitation and droughts (abstract)

Niraj Agarwal - Utilizing UFS Coupled Model Outputs to Build Independent and Coupled Earth System Emulators (abstract)

John Albers - Developing an S2S Forecast System for Predicting US Coastal Inundation Risk (abstract)

Joao Marcos Azevedo Correia de Souza - The roadmap to developing the new NOAA coupled reanalysis (abstract)

Jian-Wen Bao - A process comparison of two PBL schemes in the Unified Forecast System in a case study of fog forecast (abstract)

Michael Barlage - Impacts of a Modified Surface Representation in UFS/NoahMP Simulations (abstract)

Jorge Humberto Bravo Mendez - Exploring MPAS-A outputs on its native hexagonal mesh with Python (abstract)

John Edward Murray Brown - The U. S. Navy Earth System Prediction Capability: Overview and Future Developments (abstract)

Maggie Bruckner - Assessing biomass burning emissions in UFS-Chem version 1 during the 2023 AGES+ field campaign (abstract)

D. Alex Burrows - Supporting AI/ML Weather Prediction in NOAA: A Flexible Verification Pipeline with wxvx (abstract)

Forest Cannon - Impact of Tomorrow.io's Satellite Constellation on Global Precipitation Observation and Prediction (abstract)

Randy Chase - ICgen: A method to generate initial conditions from Tomorrow.io's constellation of microwave sounders using score based data assimilation (abstract)

Nate Crossette - Multi-scale background error localization using SABER spectral filters with MPAS (abstract)

Jack Elston - Into the Tempest: Black Swift's Autonomous Eye in the Hurricane Providing Critical Data for Improved UFS and Ecological Understanding (abstract)

Gonzalo A. Ferrada - Predicting Fire Emissions for subseasonal-to-seasonal (S2S) Forecasts (abstract)

Yanjun Gan - Advancing Snow Temperature Data Assimilation in Global Forecast System (GFS) (abstract)

Maria Gehne - Tropical Variability in GraphCast vs GFSv16: What does the Neural Network learn? (abstract)

Maxfield Green - Tomorrow.io operates a km-scale weather prediction model adapted from generative corrective diffusion (abstract)

Jayesh K. Gupta - Weather Foundation Models: Global to Regional to Hyper-local (abstract)

Clementine Hardy Gas - Enabling And Validating Ensemble Data Assimilation Scenarios In JEDI / FV3-Based Models Using The SkyLab Workflow (abstract)

Christina Holt - Packaging UFS Applications for Use in Community-based Development (abstract)

Michael Hosek - Quantifying the Value of Convection-Allowing Global-Nested Ensembles for Extended-Range Severe Weather Forecasting (abstract)

Bo Huang - Evaluation of Aerosols Forecast Skill in GCAFS Using NOAA's Global Aerosol Reanalysis Product (abstract)

Bo Huang - Improving Computational Efficiency of JEDI GETKF for Coupled UFS Applications (abstract)

Wei Huang - Run global-workflow with Singularity container (abstract)

Faozia Anzum Itu - Simulation of Landfall Dynamics and Influencing Factors of Cyclone Remal Using High-Resolution WRF-ARW Model (abstract)

Christiane Jablonowski - Informing the Dynamical Core Choices for the UFS: FV3 and MPAS (abstract)

Isidora Jankov - HRRRCast: a data-driven emulator for regional weather forecasting at convection allowing scales (abstract)

Christina Kalb - New Capabilities in METplus Verification for Subseasonal to Seasonal Scales (abstract)

Jong Kim - UFS Data Assimilation Community Support Framework and Infrastructure for the Research-to-Operations Process (abstract)

Jong Kim - UFS Weather Model Architectural Layout, Hierarchical Testing Framework, and Application Development for Continuous Code Integration (abstract)

Anna Kimball - Accelerating Forecast Innovation: EPIC's Collaborative Framework and HPC-Driven Transparency (abstract)

Samantha Kramer - EPIC's Unified Forecast System Short Range Weather App for Wildland Fire (abstract)

Michael Kavulich, Jr. - Verifying smoke and dust predictions from RRFS prototypes using METplus within the UFS SRW Application (abstract)

Weiwei Li - Diagnosing Air-Sea Interaction and Marine Boundary Layer Processes in NOAA's Seasonal Forecast System Using DYNAMO Cases (abstract)

Yonggang Liu - Storm Surge and Coastal Inundation Nowcasts/Forecasts During Hurricanes Helene and Milton (abstract)

Panagiotis Mitsopoulos - Impact of LETKF Data Assimilation of Remote Sensing Observations on the Wind and Wave Analysis (abstract)

Anamaria Navarrete - Analysis of Extreme Wildfire Events in North America During the 2025 Fire Season Using Observations and RRFS-Smoke Model Output (abstract)

Andrew Newman - Noah-MP optimization to improve UFS S2S hydrometeorological prediction in the Western United States (abstract)

Natalie Perlin - A Study of Building and Running UFS Short-Range Weather App on MacOS Platforms: Success Stories and Test Cases (abstract)

Mariah Pope - The NOAA Anemoi Experience: scalable and user-friendly tools for training AI weather prediction models (abstract)

Jonathan Poterjoy - Toward High-Frequency Bayesian Assimilation in the UFS Using Local Particle Filters (abstract)

Clairisse Reiher - Characteristics of North American Polar–Subtropical Jet Stream Superpositions and Related Challenges in Numerical Modeling (abstract)

Christopher Rozoff - A dynamical ensemble approach to characterizing uncertainties in the prediction of air quality downstream of massive wildfires (abstract)

Christian Sampson - Continuous Data Assimilation in JEDI (abstract)

Henry Santer - Non-parametric estimates of passive microwave sensed sea ice observation errors using CICE6 and kernel embeddings of conditional distributions (abstract)

Patrick Skinner - Progress in Developing an MPAS-Based Warn-on-Forecast System (abstract)

Zach Shrader - Empowering Forecasting Innovation Through EPIC Community Engagement and User Support (abstract)

Timothy Andrew Smith - Development of a Data Driven Global Weather Model with High Resolution over the US (abstract)

Ryan Sobash - Comparing convective hazard forecasts derived from AI NWP, MPAS, and GEFS ensembles during 2025 (abstract)

Cristiana Stan - A Comparison of MJO Teleconnections predicted by UFS and Neural GCM (abstract)

Hendrik L. Tolman - The state of the UFS in 2025 (abstract)

Chong-Chi Tong - Bridging the Gaps: Satellite Observations and Forecasting Atmospheric Rivers (abstract)

Ufuk Turuncoglu - Generic co-processing capability in the Unified Forecast System Weather Model (UFS-WM) (abstract)

Joannes Jacobus Westerink - Advancing STOFS 2D Global Accuracy with Direct Lunar-Solar Traction Forcing and In-Line Self Attraction and Loading Terms (abstract)

Valery Yudin - Towards Space Weather Application in UFS: Whole Atmosphere Model Development and Simulations (abstract)

Cheng Zheng - A Hybrid Dynamical-Machine Learning Forecast Tool for Subseasonal Precipitation Prediction Based on ENSO and the MJO (abstract)

12:00 pm **Lunch Break**

1:00 pm **Parallel Sessions with Q&A**

UFS APPLICATION – COASTAL, MARINE, OCEANS AND ECOLOGY

In-person attendees: North Bay

Virtual attendees: Livestream Link

Moderated by Tracy Fanara, Inspector Planet, Project ENKI

1:00 pm - Ayumi Fujisaki-Manome - NOAA Unified Forecast System Coastal Applications Team (UFS CAT) Model Evaluation (abstract)

1:10 pm - Joseph Knisely - Obstacles for High-Resolution HAFS over the Entire Atlantic Basin (abstract)

1:20 pm - Kristin N. Barton - Progress on the Development of an Arctic Regional Coupled UFS Application (UFS-Arctic) (abstract)

1:30pm - Scott Durski - Coupling CICE to SCHISM in UFS coastal: Lessons learned while working towards a coupled ice-ocean forecast system for Alaska (abstract)

1:40 pm - William Ramstrom - Multiple Moving Nests and Telescoping Nests Advancements for HAFS (abstract)

1:50 pm - Saeed Memari - Real-World Evaluation of the UFS Coastal Application: Two-Way Coupled Wave–Circulation Modeling during the 2021 Hurricane Season (abstract)

2:00 pm - Joseph Zhang - Development of a new operational forecast system for southeastern US (SECOFS) (abstract)

2:10 pm - Yunfang Sun - Development and Implementation of Regression Tests and Applications within the UFS-Coastal Framework (abstract)

2:20 pm - HaoCheng Yu - Recent SCHISM coupling development under NOAA's UFS-coastal framework (abstract)

2:30 pm - Ali Abdolali - Triton-c: Wind Wave Modeling on Unstructured Grids Using a Modern C++ Framework (abstract)

2:40 pm - Kathryn Newman - Recent METplus advancements for verifying HAFS forecasts (abstract)

Parallel Sessions Regarding

UFS APPLICATION – SHORT-RANGE WEATHER (SRW) APPLICATION, RAPID REFRESH FORECAST SYSTEM (RRFS) AND MODEL FOR PREDICTION ACROSS SCALES (MPAS)

In-person attendees: Center Bay
Virtual attendees: Livestream Link

Moderated by Curtis Alexander, NOAA/OAR/GSL

1:00 pm - Matthew E. Pyle - Updates on Rapid Refresh Forecast System Version 1 (abstract)

1:15 pm - Israel Jirak - Evaluation of RRFSv1 during the 2025 NOAA HWT Spring Forecasting Experiment (abstract)

1:30 pm - Dustin Swales - Implementation of the MPAS Dynamical Core in the Unified Forecast System Weather Model (abstract)

1:45 pm - Clark Evans - NOAA/GSL Model Development and Forecasting Activities Toward RRFSv2 Using MPAS (abstract)

2:00 pm - Adam Clark - MPAS evaluations for severe weather forecasting during the 2025 NOAA/Hazardous Weather Testbed Spring Forecasting Experiment (abstract)

2:15 pm - Michelle Harrold - Recent advancements in METplus for RRFS and MPAS verification (abstract)

2:30 pm - Curtis Alexander - A Discussion on Sustaining SRW/CAM Development Agility While Advancing UFS Capabilities (abstract)

Parallel Sessions Regarding

UFS APPLICATION – AIR QUALITY, ATMOSPHERIC COMPOSITION, AEROSOLS (INCLUDING SMOKE, DUST AND FIRE CAPABILITIES)

In-person attendees: South Bay
Virtual attendees: Livestream Link

Moderated by Ravan Ahmadov, NOAA/GSL

1:00 pm - Barry Baker - Progress on the development of Configurable ATmospheric Chemistry (CATChem) v2 component within NOAA's Unified Forecasting System (UFS) (abstract)

1:12 pm - Li Zhang - Fire Aerosol Prediction in NOAA's Global Aerosol Systems and its Impact on Subseasonal to Seasonal (S2S) Forecasting (abstract)

1:24 pm - Yaping Wang - JEDI based data assimilation for the NOAA Global Chemistry and Aerosol Forecast System (GCAFS) (abstract)

1:36 pm - Barry Baker - Development of NEXUSv2 as a new component in the Unified Forecast System for applications to air composition modeling for AQMv8 and the Configurable ATmospheric Chemistry (CATChem) Component (abstract)

1:48 pm - Jian He - Incorporating gas-phase chemistry into the Unified Forecast System (UFS) for global air quality applications (abstract)

2:00 pm - Ravan Ahmadov - Evaluation of the RRFS-Smoke-Dust Model During the 2025 Fire Season in North America (abstract)

2:12 pm - Patrick Campbell - Advancements in NOAA's Unified Forecast System-Air Quality Model (UFS-AQM) to improve our nation's air quality forecasting capabilities (abstract)

2:24 pm - Daniel Tong - Developing a global 1km anthropogenic emission dataset to support multiscale atmospheric composition modeling (abstract)

2:36 pm - Haiqin Li - Aerosol dependency of the Community Convective Clouds (C3) scheme in the Unified Forecast System (UFS) Weather Model (abstract)

2:48 pm - Emily Faber - First Implementation of a Reflectance Derived Sediment Supply Map in the UFS and Analysis of Impacts on AOD and Dust Emission. (abstract)

3:00 pm **Break**

3:30 pm **MPAS Collaborations & Community Engagement**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Panelists:
Christiane Jablonowski, University of Michigan
Bill Skamarock, NSF NCAR
Ligia Bernardet, NOAA GSL/DTC
Kathryn Newman, NSF NCAR/DTC
Lou Wicker, NOAA/OAR/NSSL

Moderated by
Kate Fossell, NSF NCAR
Jeff Beck, NOAA/GSL

3:45 pm **Tour of the National Science Foundation (NSF) National Center for Atmospheric Research (NSF NCAR) NCAR Mesa Lab**
1850 Table Mesa Drive, Boulder, CO, 80305
Sign-up sheet at registration table.

4:15 pm **Generation of Grid-Mesh with Multi-Refinements for using MPAS to Predict Severe Weather over Multiple Regions**
Shuxia Zhang, Metropolitan State University (abstract)

4:45 pm **Adjourn**

Friday, September 12th

All times Mountain Daylight Time

8:00 am **Registration**
In-Person Attendees: Registration will begin in the UCAR Center Green lobby.

Virtual Attendees: If you have any general questions about UIFCW, you can ask them in the SLIDO chat space.

9:00 am **Welcome and Kickoff**
In-person attendees: Center Bay
Virtual attendees: Livestream Link

Alison Gregory, UCAR CPAESS

9:15 am **Community Engagement/Collaboration**
9:15 am - Joshua Kublnick - Enabling Community Success Through EPIC User Support Services (*abstract*)

9:22 am - Chandra Kondragunta - Synergy between Joint Technology Transfer Initiative and Earth Prediction Innovation Center in Advancing NOAA's Unified Forecast System (*abstract*)

9:29 am - Breanna Vanderplow - Advancing Community Ocean and Coastal Modeling by Harnessing the Power of the Cloud (*abstract*)

9:36 am - Tracy Hertneky - The Common Community Physics Package: A Unified Framework for Physics Development, Testing, and Operational Transition (*abstract*)

9:43 am - Edward Snyder - Rethinking spack-stack support: a containerized approach (*abstract*)

10:15 am **Break**

10:45 am **UFS Coastal Code Development, Applications, and Use Cases**

	Saeed Moghimi, NOAA/NOS/OCS *Ufuk Turuncoglu, NSF NCAR* *Mansur Ali Jisan, NOAA/NOS/CO-OPS*
11:15 am	**Commercial Weather Observations** *Michael Hurowitz, Weather Stream* *Thomas Cavett, Tomorrow.io*
12:00 pm	**Lunch**
1:00 pm	**Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)/Citizen Science** *Noah Newman, Colorado State University/CoCoRaHS*
1:30 pm	**NOAA WPO's Weather Program Office Innovation for Next Generation Scientists (WINGS) Fellowship Transition** *Emily Faber, UMBC/UCAR* *Joseph Knisely, UMD/WINGS* *Shreyas Dhavale, North Carolina State University/UCAR* *Elena Fernandez, University at Albany, SUNY* *Lucas Howard, CU Boulder/UCAR CPAESS* *Kaitlin Pereira, Colorado School of Mines/UCAR* *Moderated by Cindy Bruyère, SPS CPAESS/UCAR*
2:00 pm	**"Pair and Share" Action Items Activity** *Facilitated by* *Alison Gregory, UCAR CPAESS* *Tracy Fanara, Inspector Planet, Project ENKI* *Jennifer Vogt, NOAA/OAR/WPO/EPIC*
3:30 pm	**Debrief: Findings, Recommendations and Closing Statements** *Kevin Garrett, NOAA/NWS/OSTI* *Maoyi Huang, NOAA/OAR/WPO/EPIC* *Keven Blackman, Raytheon* *Rowin Guyot Smith, Colgate University, NOAA William M. Lapenta Internship* *Shuxia Zhang, Metropolitan State University*

4:00 pm **Adjourn – Travel Home!**

Additional Training Opportunities

Workshops/Training & Room Location

All times Mountain Daylight Time

Date	**Time**	**Event**	**Location**
Monday, September 8th	1:00pm - 4:00pm	Training 1 | Compile and Run the UFS Global- Workflow using a Container Image (Singularity) on a variety of Platforms Register here	Room 2126
Monday, September 8th	1:00pm - 4:00pm	Training 2 | Artificial Intelligence in Weather Modeling Training Register here	North Bay Auditorium
Thursday, September 11th	9:30am 12:00pm	Training 3 | Introduction to Running Idealized Test Cases via the UFS Hierarchical System Development Framework Register here	Room 2603
Thursday, September 11th	9:30am 12:00pm	Training 4 | NOAA AI Learning Journeys Tutorial *We have reached capacity for this training, registration is closed.*	Room 2126

Abstracts

Organized by session

Invited Presentations

Coupled modeling to improve marine weather forecasts of winds and waves for maritime shipping

Steve Penny*

Sofar operates a global network of free drifting and moored in situ metocean buoys called Spotters. Since 2019, Sofar has run an operational wave forecast system that assimilates the Spotter data and satellite altimeter observations in order to produce 4x-daily operational global wave forecasts, using wind forcing from external forecast products. For the last few years, Sofar has been developing a coupled forecast system using model components of the UFS - including the FV3-GFS (GFDL SHiELD version) and WaveWatchIII, with a ESMF/NUOPC coupler framework and the CMEPS mediator, in order to allow ocean surface observations from Spotters and satellites to also enhance forecasts of surface winds and as a consequence extend wave forecast skill. In our latest evaluation, we have found that the new coupled forecast system produces marine wind forecasts that outperform ECMWF's HRES (49r1) out to 40 hours and wave forecasts that outperform out to 100 hours, on average, compared to observations. Through Cooperative Research and Development Agreements with GFDL, EMC, and the Navy, we are continuing to advance the coupled modeling configuration to further improve forecast performance at the air-sea interface, as we plan a full rollout of our coupled model for 4x-daily operational forecasts of marine winds and waves.

From Day One to Done: Co-Producing Research with the People Who Will Use It

Castle Williamsberg*, Isha Renta, and Abigail Arnold - WPO’s Portfolio Analysis and Research Transitions Program

For research to deliver real-world impact, it must move beyond publications into the environments where end users can apply it to improve decisions, services, and outcomes. This doesn’t happen by chance—it requires intentional, early, and sustained engagement with those who will use the results. End users bring essential operational insights that can shape research questions, identify constraints, and ensure outputs meet real needs.

This presentation will share practical strategies for creating meaningful feedback loops between researchers and end users both before and throughout the R&D lifecycle. Drawing from NOAA’s Weather Program Office experience, we’ll explore best practices for early engagement, integrating user input throughout the R&D process, and maintaining two-way communication despite organizational and cultural barriers. By fostering trust, shared ownership, and continuous feedback, researchers can co-produce solutions that are both scientifically robust and operationally relevant—maximizing the societal value of their work.

Integrating the Community into the Development, Use, and Support of the Community Earth System Model (CESM)

David Lawrence*

The Community Earth System Model (CESM) is a collaborative, community modeling effort between researchers at the NSF National Center for Atmospheric Research (NCAR), universities, and other national and international research institutions. CESM is used for multiple purposes, including investigations of past and current climate, projections of future climate change, and subseasonal-to-decadal Earth system predictions. To keep CESM at the leading edge of climate and Earth system modeling and related science requires continuous developments, improvements, testing, and subsequent applications of the model to various problems. As the scope of the CESM project becomes increasingly expansive and complex to encompass a hierarchy of scales, machine learning, and complex extremely large data set analysis, the scale of the effort to meet the CESM research community needs is beyond the capacity of NSF NCAR to complete on its own. Consequently, the CESM Project involves contributions from scientists and software engineers at all career levels from many national and international institutions. Here, we will review the successes and limitations of the governance structure for CESM and ongoing efforts to engage the broader research community in the development, use, and support of the CESM. In particular, we will review community contributions to the forthcoming 3rd version of CESM, CESM3.

NWS Boulder: Impact-Based Decision Support Services and the Importance of Accurate NWP

Paul Schlatter*

The National Weather Service (NWS) Forecast office in Boulder, Colorado serves 22 counties across north central and northeast Colorado. With every weather impact possible like tornadoes, blizzards, downslope winds, hail, flash flooding, and fires, really everything other than tropical, and almost 5 million people along the I-25 urban corridor, there is no shortage of decision support service needs for their core partners across the region. This talk will explain the importance of Impact-based Decision Support Services (IDSS) through the lens of a winter storm, and a destructive fire; two high impact weather events common to the Front Range of Colorado. The presentation will walk you through the types of products and services delivered by the NWS Boulder office, and why it is critical to have accurate forecast information from Numerical Weather Prediction (NWP), including probabilistic information. Examples will highlight the full spectrum of IDSS delivered by the NWS Boulder office, from daily weather briefings, event-specific briefings, partner virtual briefings, to deployments (embedded with partners).

NOAA’s AI Transformation

Rob Redmon* and Monica Youngman*

NOAA's mission science and service delivery are being rapidly transformed, fueled by advancements in Artificial Intelligence, data-driven modeling and deeper connections between humans and information services. NOAA has been using forms of machine learning for many years, e.g. to post-process weather forecasts, for geophysical retrievals of satellite data and identifying, detecting and monitoring ocean biology. The recent increase in volume and complexity of Earth observations and curated training data along with flexible specialized high performance compute environments, and cross domain fusion (e.g. merging natural hazards, economics, supply chain resilience) has led to a new AI revolution for Earth system modeling, predictive capabilities, and agentic interaction.

The NOAA Center for Artificial Intelligence (NCAI) is actively engaged in a coordinated effort to advance AI research and application across NOAA. As part of this initiative, NCAI is committed to fostering a strong community of practice and accelerating the integration of trustworthy and responsible AI into NOAA’s core mission areas, including those related to the Unified Forecast System (UFS). We recognize the transformative potential of AI to enhance forecast performance, improve efficiencies, and innovate how NOAA's data assets are used.

This presentation will summarize NOAA’s AI strategy and NCAI’s implementation activities with a focus on empowering the UFS and other communities through collaboration and knowledge sharing. We’ll detail the formation of NCAI’s Community of Practice, highlighting available AI-ready resources, including data standards and workforce training resources. We invite the audience to raise critical questions and discussion that would aid NOAA and NCAI in advancing NOAA’s forecasting capabilities and strengthening the UFS community.

Two decades of partnership with NOAA Line Offices: Challenges and Opportunities for the NOAA Center for Atmospheric Sciences and Meteorology (NCAS-M)

Sen Chiao*, Terri Adams, and Belay Demoz

The NOAA Center for Atmospheric Sciences and Meteorology (NCAS-M) is one of the four cooperative science centers funded through the NOAA José E. Serrano Educational Partnership Program (EPP) within the Office of Education (NOAA/OEd). While Howard University serves as the lead for NCAS-M we are a consortium of universities including University of Texas, El Paso; Jackson State University; San Jose State University; University of Maryland, Baltimore County; University of Puerto Rico, Mayagüez; University of Maryland, College Park; and State University of New York-Albany.

Currently, NCAS-M collaborates with NOAA and NOAA stakeholders in support of this mission in three thematic areas: 1) Innovative observations for advancing climate, weather, and air quality analysis and prediction; 2) Interdisciplinary scientific research to support modeling and forecasting activities for building community resilience against extreme weather, water, atmospheric, and climate events; 3) Integrated research in support of building public safety through Impact-Based

Decision Support Services (IDSS). This presentation will highlight some recent research progress in hurricane modeling, machine learning on atmospheric rivers, air quality bias correction, and the atmospheric boundary layer.

The U. S. Navy Earth System Prediction Capability: Overview and Future Developments

Stephanie Rushley, Richard Allard, Charlie Barron, Jonathan Cristophersen, William Crawford, Maria Flatau, Debbie Franklin, David Hebert, Gregg Jacobs, Matthew Janiga, Tommy Jensen, David Kuhl, Robert Linzell, Fei Liu, Justin McLay, E. Joseph Metzger, Michael Phelps, P. Alex Reinecke, Carolyn Reynolds, James Ridout, Erick Rogers, Clark Rowley, Jay Shriver, Gerhard Theurich, Prasad Thoppil, Marcela Ulate, Timothy Whitcomb, Jake Zappala, Luis Zamudio, and Shastri Paturi

The Navy Earth System Predictability Capability (Navy ESPC) is a global coupled forecast system that consists of the NAVy Global Environmental Model (NAVGEM) atmosphere model, the HYbrid Coordinate Ocean Model (HYCOM) and the Community Ice CodE (CICE). This system has been developed to meet the U. S. Navy needs for high-resolution global environmental forecasts on timescales from days to months, and a unique aspect of the system is the eddy resolving ocean model at the ensemble and deterministic resolutions. Navy ESPC-E (ensemble) v1 (version 1), consisting of weekly 45-day 16-member ensemble forecasts, became operational in August 2020. Navy ESPC-E v1 products are used by the Joint Typhoon Warning Center for tropical cyclone genesis and the National Ice Center for resupply mission and exercise planning. New capabilities and upgrades in Navy ESPC version 2 include one-way coupling to the WAVEWATCH III wave model, an extension of the NAVGEM top from 72 to 110 km and improved representation of the middle atmosphere, the inclusion of arctic land-fast ice in CICE, increased NAVGEM horizontal resolution and inclusion of ocean tides in the ensemble configuration. The deterministic system, Navy ESPC-D v2, is currently undergoing operational testing by Fleet Numerical Meteorology and Oceanography Center (FNMOC). The ensemble system, Navy ESPC-E v2, is currently undergoing pre-transition validation testing. Performance of Navy ESPC v2 compared to Navy ESPC v1 and stand-alone prediction systems will be summarized for both the deterministic and ensemble versions. Future upgrades to Navy ESPC will include improvements to the data assimilation and ensemble design, and eventual replacement of NAVGEM with the Navy's next generation atmospheric model NEPTUNE (The Navy Environmental Prediction system Using a Nonhydrostatic Engine).

Fire Behavior Model Being Coupled to the UFS

Pedro Jimenez*

This presentation will provide an overview of the newly integrated Community Fire Behavior Model (CFBM) within the UFS. The presentation will also describe how coupled fire-atmosphere interactions can be simulated on high-resolution nested grids making it possible to forecast the progression of wildland fires. The use of the Short-Range Weather (SRW) Application v3.0.0 to run the coupled fire-atmosphere simulations will be also described.

Generation of Grid-mesh with Multi-refinements for Using MPAS to Predict Severe Weather over Multiple Regions

Shuxia Zhang* and Richard Carpenter

The unique feature of NCAR's Model for Prediction Across Scales (MPAS) is its flexibility with spatial grid resolution. That has enabled forecasters/researchers to increase the grid resolutions where special attention is needed while lowering the resolution in the remaining areas to speed up the forecasting process. This functionality is extremely valuable to the Warn-on-Forecasting System (WoFS) in achieving longer warning lead time on severe weathers, especially with respect to running MPAS at high resolution globally, e.g., NFS NCAR 3-km Global Forecasts.

The figure enclosed below shows one of our grid mesh configurations (5km resolution in US, Europe and part of Australia, 20km resolution elsewhere), which has enabled DTN to operationally deliver weather analytics with higher resolution over the regions of business interest. Our grid-mesh consists of multiple refinements with arbitrary geographical shape. That is different from the grid meshes provided by the MPAS team, in which the refinements are limited to simple circles and/or ellipses. In the presentation, we will share the technical procedure using JIGSAW(GEO) that generates the grid meshes of high quality and better representation of multiple regional characters. The objective is to help the community better harness the benefit of MPAS cross-scale capability

Student Session

The UFS Student Experience: Accomplishments, Challenges, and Recommendations

Rowin Smith* - Colgate University Student, NOAA Lapenta Intern

Students are a necessary part of a sustainable weather modeling community, yet their limited knowledge and resources means they require special consideration to be able to be involved community members. In this presentation, I review my experience working with, contributing to, and promoting the Unified Forecast System (UFS) as a student intern. Through the NOAA Lapenta Internship Program, I gained this experience as the UFS Student Ambassador for 2025, which gave me in-depth exposure to the UFS community and software ecosystem as well as to EPIC. This report covers my learning process, the challenges I faced, the goals I achieved, and my future involvement with the UFS. I will also present the products of my internship, including my social media campaign and my SRW tutorial. I also detail feedback as to how the UFS can be improved to better accommodate students. My experience and recommendations will provide a student perspective that can inform the development of a robust and sustainable UFS community.

Advancing Aerosol Data Assimilation with the Unified Forecast System (UFS) - Aerosols/JEDI by Assimilating Caliop Aerosol Profiles

Michael K. Benneh*, Cheng-Hsuan Lu, Chih-Wei Wei, Aara'L Yarber, Corey R. Martin, and Sen Chiao

Aerosol representation remains a key source of uncertainty in Earth system prediction, particularly within operational frameworks like the Unified Forecast System (UFS). Although the GOCART aerosol module has been used extensively, the representation of emissions and simplification of aerosol processes lead to forecast uncertainty. These simplifications contribute to persistent biases in aerosol horizontal and vertical structure as well as temporal variations.

This study is a collaborative research project including Howard University, SUNY Albany, NOAA/EMC, and JCSDA. The joint effort is under the Consortium for Advanced Data Assimilation Research and Education (CADRE). Our objective is to further advance aerosol DA capabilities with JEDI by assimilating CALIOP aerosol profiles. Using model output from the UFS-Aerosols, the CALIOP satellite simulator maps from model space to observations space and enables direct comparison between model and observation aerosol characteristics. This diagnostic approach allows for a consistent comparison between model output and CALIOP spaceborne lidar retrievals, helping identify structural deficiencies in aerosol prediction and representation.

By improving the representation of aerosol layers in the initial conditions, forecast accuracy can be enhanced without modifying the underlying aerosol scheme. This work supports the ongoing integration of satellite observations into operational workflows and contributes to more enhanced forecasting and prediction in UFS.

Evaluation of initial condition blending within MPAS to inform RRFSv2

McKenzie L. Larson* (CU Boulder), Jeff Beck (NOAA/GSL), Michelle Harrold (NSF NCAR/RAL), Will Mayfield (NSF NCAR/RAL), Craig Schwartz (NSF NCAR/MMM), Aaron Johnson (U of Oklahoma), and Vanderlei Vargas (NOAA/GSL, CIRA)

"The method used to integrate global information into regional NWP models can substantially impact model accuracy. Typically, global information is fed into regional models via lateral boundary conditions, but model drift may occur if large-scale information is not continuously introduced into the regional domain. To mitigate this problem, partial cycling is traditionally applied, a method which interrupts the continuous hourly cycling during the day to restart and force the regional simulations with global data. The Rapid Refresh (RAP) has demonstrated forecast improvement by utilizing the partial cycling algorithm, and as a result, the High-Resolution Rapid Refresh (HRRR) has benefited from this paradigm, as it is initialized each hour from the RAP. Unfortunately, partial cycling is complex and computationally extensive, so research is underway to replace this algorithm with a more efficient and straightforward method to incorporate global information into regional models.

Our study implements initial condition (IC) blending into regional models, rather than partial cycling. IC blending involves blending higher resolution regional initial conditions with those that come from a global model, such as the Global Forecast System (GFS). We show results from blending Ensemble Kalman Filter higher resolution ICs with Global Ensemble Forecast System coarser resolution ICs to initialize the Model for Prediction Across Scales (MPAS) for simulations covering a 3-km CONUS domain. The goal of this study is to inform future development of the flagship, convection-allowing model, the Rapid Refresh Forecast System (RRFS). Given promising results, we hope to implement IC blending within RRFSv2 in the near future."

Case studies of the Monsoon Onset Vortex and early season Monsoon features using the UFS coupled model

Shreyas Dhavale*, Dr. Anantha Aiyyer, and Dr. Cristiana Stan

The Monsoon Onset Vortex (MOV) forms in the Arabian Sea during the onset phase of the Indian Summer Monsoon. The track and intensity of the MOV affect the early-season monsoon rainfall, mainly over the west coast of India. In this paper, we study the forecasts of past MOV cases in the years 2011, 2014 and 2015 and their impacts on the monsoon rainfall in the Unified Forecast System (UFS) subseasonal to seasonal (S2S) prototypes (P5, P6, and P8). Out of the three MOV cases, the 2015 MOV is forecasted better across the UFS S2S prototypes. The possible factors influencing MOV forecasts in the UFS are analyzed through feature-based diagnostics. Our findings show that predicting the Somali Jet index as well as the mesoscale-to-synoptic-scale evolution of deep convection is likely to result in more accurate MOV forecasts. The implications of MOV forecasts on early-season monsoon rainfall are discussed through these MOV cases. The UFS also captures the relationship between the Somali Jet index and monsoon rainfall over India for the earlier part of the monsoon. However, it underestimates the anomalous increase in rainfall corresponding to a stronger Somali Jet. Overall, the UFS S2S prototypes P6 and P8 better forecast the MOV cases compared to P5.

Evaluating UFS Heat and Moisture Fluxes Using Eddy Covariance Observations from the New York State Mesonet

Anna Glodzik*, Scott Miller, Sarah Lu, Jason Covert, Andrew Newman, Mike Ek, Kathryn Newman, and Helin Wei

A common strategy to improve weather model forecasts is to increase the model's resolution, which requires more computing power and the inclusion of updated dynamic and physical processes to handle smaller-scale features. The Geophysical Fluid Dynamics Laboratory has developed the 13-km System for High-resolution prediction on Earth-to-Local Domains (SHiELD) for global weather prediction and the 3.25-km eXperimental-SHiELD (X-SHiELD) for global storm-resolving simulation. However, the 13-km model is not sufficient for some high-impact weather systems, but the computational expense of the 3.25-km model has not been affordable for regular use. In this study, we introduce a 6.5-km version of SHiELD, designed to bridge the gap between medium-range global weather prediction and global storm-resolving simulation while remaining feasible for real-time forecasts. This model operates in the "gray zone" (at grid spacings of 10 km or below), where thunderstorms are partially resolved, necessitating adjustments to physical parameterizations originally designed for coarser resolutions. Comparative analyses with the 13-km SHiELD over a three-year hindcast period show significant improvements in global, regional, tropical cyclone, and continental convection predictions. These findings demonstrate that the 6.5-km SHiELD can be used to advance weather prediction by effectively addressing both synoptic weather systems and specific storm-scale phenomena in a single global model.

UFS Application – Global Applications Across Scales

Overview of the Next Global Forecast System GFSv17

Catherine Thomas*, Jessica Meixner, and Ruiyu Sun

"The Environmental Modeling Center (EMC) is working towards the next operational implementation of the Global Forecast System, GFSv17, which leverages the Unified Forecast System (UFS) and the UFS community at large. A major goal for GFSv17 is to employ a UFS-based fully coupled atmosphere-land-ocean-ice-wave model. The coupled model will be part of a weakly coupled data assimilation system, with new non-atmospheric data assimilation components based on the Joint Effort for Data assimilation Integration (JEDI) software. There will also be greater alignment with the Global Ensemble Forecast System (GEFS) in both model and infrastructure development as well as more consistent GEFS initialization through a new early cycle ensemble analysis from the GFS. In addition, the existing atmospheric model and data assimilation algorithms will have major upgrades, including updates to atmospheric physics, land modeling, and the inclusion of multiscale data assimilation.

This presentation will provide an overview of the GFSv17 system along with the current status and future plans. Details of the existing component updates as well as full resolution cycling experiment results will also be shared."

GEFSv13 updates

Bing Fu* and Neil Barton

As we are approaching the final stage of GEFSv13 development, a major change has been made regarding the aerosol component in GEFSv13. Instead of including prognostic aerosol for all the ensemble members, the final decision is to remove the GOCART model in the GEFSv13. A new deterministic forecast system, namely, Global Chemistry and Aerosol Forecast System (GCAFS) has been developed to replace the aerosol component in GEFSv12. GEFSv13 re-forecast has started based on Unified Forecast System (UFS) High Resolution Prototype 4 (HR4) without the aerosol component. Some early evaluations for re-forecast show consistent improvement as we found in some previous miniset tests. We will present the results from these early evaluations with a focus of comparison between the current re-forecast and current operational GEFSv12 in both medium range weather forecast and subseasonal time scale prediction.

NOAA's Seasonal Forecast System

Philip Pegion* NOAA/PSL, Neil Barton NOAA/EMC, and Xiaqiong (Kate) Zhou NOAA/EMC"

NOAA is in the second year of developing the Seasonal Forecast System (SFS), which is slated to replace the Climate Forecast System version 2 (CFSv2) in 2028. Several sets of reforecasts have been carried out by the Environmental Modeling Center which show vast improvements over CFSv2. This early success has motivated EMC to start a near real-time experimental version of the SFS later this fall.

We will show results from the developmental runs, highlighting the success and ongoing challenges. In addition we will describe the upcoming experimental system, and give an overview of the SFS implementation plan which was drafted in the spring of 2025.

2-Way Coupling the GFDL Land Model with FV3 Atmosphere in UFS

Justin Perket* (Princeton University), Elena Shevliakova (NOAA GFDL), and Sergey Malyshev (NOAA GFDL)

The Geophysical Fluid Dynamics Laboratory (GFDL) Land Model version 4.0 (LM4.0) has been successfully coupled with the FV3 atmosphere within UFS via a NUOPC/ESMF driver. This marks the first bi-directional implementation of LM4 outside the GFDL modeling environment. LM4.0 provides a detailed representation of terrestrial processes; including hydrology, vegetation dynamics, and land-atmosphere energy exchanges; making it well-suited for subseasonal to seasonal timescales. This work enhances the scientific capabilities of UFS and introduces increased modularity for land models operating through the mediator, enabling greater standardization and interoperability. We present the technical and scientific strategies of the LM4.0-FV3 coupling, along with results from free-running coupled simulations initialized with offline (data-atmosphere) spinup states.

Improving Tropical Variability in the UFS for S2S Prediction

Lisa Bengtsson*

A realistic representation of the tropical mean state and its variability is critical in global modeling, as the tropics act as an engine for Earth’s general circulation and influence weather far beyond the equator. This presentation summarizes recent efforts to improve convection parameterizations in NOAA’s Unified Forecast System (UFS) and explores how initial state differences and ocean coupling affect subseasonal-to-seasonal (S2S) predictability. Emphasis is placed on the role of stochasticity, subgrid organization, and scale-adaptive behavior in advancing tropical variability forecasts. New advancements in the representation of convective updraft vertical velocity will also be presented.

Numerical behavior of two land surface models as a significant contributor to biases in the UFS prediction of CAPE over the CONUS

Jian-Wen Bao*, Sara Michelson, Weizhong Zheng, and Evelyn Grell

The lower flux boundary conditions for the atmospheric model over land in the Unified Forecast System (UFS) are specified using either the NOAH-MP or the NOAH land surface model. Ongoing evaluation and diagnosis of forecasts from UFS prototypes for global and regional applications have identified an underestimation of surface-based convective available potential energy (CAPE) over the central continental United States (CONUS) during daytime hours. This CAPE underestimation is linked to uncertainties in how the atmosphere-land interaction is represented in these UFS prototypes.

In this presentation, we will compare the two land surface models available in the UFS, with a focus on atmosphere-land interaction processes. We will demonstrate how the numerical behavior of these models, when used as the lower flux boundary conditions for the atmospheric model, contributes to the CAPE underestimate in both global and regional forecast applications of the UFS over the central CONUS. Using the results from our comparison of the two land surface models, we will revisit the long-standing debate regarding the level of detail and complexity required in a land surface model to effectively provide adequate lower flux boundary conditions for the atmospheric model in operational weather forecast applications.

Impacts of tropical forecast errors on weeks 3–4 extreme precipitation predictions over California during winter 2022–23

Benjamin J. Moore*, Juliana Dias, Andrew Hoell, Stefan Tulich, Maria Gehne, John Albers, Cory Baggett, and Emerson LaJoie

This study examines UFS experiments in which model prognostic variables are nudged toward reanalysis in the tropics to assess the effects of tropical errors on weeks 3–4 predictions of two long-lasting extreme precipitation events in California during winter 2022–23. For both events, the first spanning late-December to mid-January and the second spanning late-February to early-March, nudging yields significantly improved predictions for the large-scale flow over the North Pacific but not necessarily for the precipitation accumulations in California. Comparison of the results for the two events highlights that subseasonal prediction of California precipitation extremes requires accurately forecasting predictable signals linked to tropical forcing, as well as midlatitude synoptic-scale dynamics. For the December–January event, which is poorly predicted in the non-nudged "control" forecast, nudging results in especially large improvements in the weeks 3–4 California precipitation forecast as well as decreases in ensemble spread. These improvements correspond to improved prediction of the onset, persistence, and phasing of the North Pacific wave pattern. This pattern fosters landfall of successive cyclones and atmospheric rivers over California. For the February–March event, nudging yields improved prediction of the amplitude and persistence of a blocking ridge over the eastern Pacific but mixed results for the California precipitation downstream. In this latter event, ensemble spread in the nudged forecasts remains large, and the precipitation forecast accuracy depends strongly on the representation of midlatitude synoptic-scale Rossby waves breaking near the West Coast on the eastern flank of the blocking ridge.

New Capabilities for Evaluating Land-Atmosphere Coupling in UFS Prototypes using METplus

Daniel R. Adriaansen*, Andrew Newman, Brianne Nelson, Kathryn Newman, Anna Glodzik, Scott Miller, Cheng-Hsuan (Sarah) Lu, John Halley Gotway, George McCabe, Mike Ek, and Michelle Harrold

The enhanced Model Evaluation Tools (METplus) suite includes a core set of verification tools written in C++, as well as a set of Python wrappers to make configuring and running the C++ tools easy and efficient. Additionally, visualization and diagnostic calculations in METplus are provided by the METplotpy and METcalcpy Python modules. This collection of software allows users to design complex workflows for a wide range of applications. In an upcoming coordinated software release, METcalcpy will include updates containing new land-atmosphere coupling (LAC) metrics for the community. These metrics include Convective Triggering Potential (CTP) and Humidity Index (HI), and the Terrestrial Coupling Index (TCI). The metrics can be called from within METplus or outside of METplus if a user desires. New METplus use cases are also included in the software release that demonstrate applying these metrics for forecast process diagnostics and verification of land-atmosphere interactions and land and near-surface states. These along with additional land-atmosphere use cases applied to UFS prototype reforecasts will be presented, as well as an overview of the range of METplus capabilities for land-atmosphere verification.

Run SFS global-workflow on AWS

Wei Huang* and Neil Barton

Global-workflow is used to run NOAA-EMC numerical models as a single package. With the successful implementation of global-workflow on AWS, EPIC has worked closely with the NOAA-EMC SFS team and interested researchers to use global-workflow on AWS to run SFS. EPIC will also share the benchmark results and the experience of how to run global-workflow more efficiently.

Development of an MJO test bed to support UFS global applications

Juliana Dias*, Maria Gehne, Cristiana Stan, Stefan Tulich, and Yan Wang

We developed an MJO-focused testbed to advance NOAA's subseasonal-to-seasonal (S2S) forecasting capabilities, using the Global Ensemble Forecast System (GEFS) as a demonstration platform. This testbed framework is broadly applicable across S2S forecast systems, including the Unified Forecast System (UFS) global applications. Our analysis targets a subset of winter MJO events from 1999 to 2023, consistent with the existing GEFSv13 reforecast database. We selected cases where convection is strongest over the Indian Ocean at initialization to evaluate MJO propagation from a mature state and its subsequent tropical-extratropical teleconnections. This presentation assesses the performance of these MJO cases within the GEFS framework, providing a benchmark for future GEFS developments and improvements to NOAA's broader S2S prediction systems. To support this effort, we also generated tropical-nudged ensemble forecasts that are configured analogously to the GEFS reforecast system including the same MJO cases. The nudging technique reduces forecast errors in the tropics, helping to assess how improved MJO prediction can enhance higher-latitude forecasts in the weeks 2-4 range. We will also outline planned model experiments that build on these MJO test cases to further advance S2S forecasting skill.

Cross-Cutting – Data Assimilation

Evaluation of the Tomorrow.io Microwave Sounder constellation with a JEDI-UFS-based and GDAS-inspired NWP system

Jonathan J. Guerrette* (Tomorrow.io), Ryan Honeyager (Tomorrow.io), Joe Munchak (Tomorrow.io), and Arun Chawla (Tomorrow.io)

"The Tomorrow.io Microwave Sounder (TMS) is the next generation of NASA's Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission with passive microwave sounders (PMWS). The TMS constellation uses a combination of sun-synchronous and inclined orbits, with a goal of global sub-hourly revisits. The multi-orbit constellation and TMS sensitivity to clouds and precipitation inspired novel solutions for observation error modeling and variational bias correction (VarBC).

We present real impacts of TMS on NWP with Observing System Experiments (OSEs) using the Joint Effort for Data assimilation Integration (JEDI) and the NOAA atmosphere-only Unified Forecast System (UFS). The OSE control assimilates multiple TMS instruments, PMWSs ingested in the NOAA Global Data Assimilation System (GDAS), and other conventional and remotely sensed observations. Non-TMS instrument configurations emulate public JEDI-UFS prototypes from the NOAA Environmental Modeling Center (EMC). We estimate that two TMS instruments in independent orbits achieve water vapor forecast accuracy improvements similar to two Advanced Technology Microwave Sounder (ATMS) instruments at one to three day lead times, and 50% of ATMS tropospheric temperature improvements at one to two days. TMS impacts are largest in the tropics and northern hemisphere, while ATMS impacts are largest in the southern hemisphere. Additional results with more TMS instruments will be divulged if they are ready.

This work leverages public and private investment, including software tools from the public sector. JEDI TMS configurations are ready for the next phase of the O2R2O pathway."

Progress of implementing MPAS-JEDI for next version of the operation Rapid Refresh Forecast System

Ming Hu*, NOAA GSL, Shun Liu, NOAA NWS NCEP EMC, Guoqing Ge, CU/CIRES, Samuel Degelia, Lynker@ NOAA NWS NCEP EMC, Chunhua Zhou, CU/CIRES, Xiaoyan Zhang, SAIC@ NOAA NWS NCEP EMC, Sijie Pan, CU/CIRES, Donald Lippi, Lynker@ NOAA NWS NCEP EMC, Junjun Hu, CU/CIRES Masanori Oigawa, JMA/Numerical Prediction Development Center, Ting Lei Lynker@ NOAA NWS NCEP EMC, Ruifang Li, CU/CIRES, Haidao Lin, NOAA GS, David Dowell, NOAA GSL, Keenan Eure, CSU/CIRA, Matthew Pyle, NOAA NWS NCEP EMC, Terra Ladwig, NOAA GSL, Daniel.Holdaway NOAA NWS NCEP EMC, and Daryl Kleist NOAA NWS NCEP EMC

In the past several years, NOAA's Global Systems Laboratory (GSL) and Environmental Predication center (EMC) have teamed up to build the first version of the Rapid Refresh Forecast System (RRFSv1), which is an operational regional high frequency convection allowance data assimilation and forecast system to provide critical high frequency and resolution weather information for saving lives and improving economic smooth activities. The RRFS development team is actively building the second version of the Rapid Refresh Forecast System (RRFSv2), which is built upon the Model for Prediction Across Scales-atmosphere (MPAS) with the Joint Effort for Data assimilation Integration (JEDI).

MPAS and JEDI are developed from the research community. Both need enhancement and complete assessment to be able to integrate into the operational forecast systems. RRFS data assimilation team conducted extensive tuning, tests, and evaluation of JEDI analysis functions with all the available observation types, such as 3DVar, 3DEnVar, and hybrid 3DEnVar, LGETKF analysis with conventional, radar, satellite radiance observations. This presentation will share those testing results and the configure of the MPAS-JEDI for implementing it in a regional high-frequency cycling data assimilation system.

A Hybrid Tangent Linear Model in JEDI

C. Sampson* (UCAR, JCSDA) Key Contributors: T. Fearon, T. Hill (Met Office, UK) Y. Trémolet, A. Shlyaeva , M. Abdi-Oskouei, J. Barré, S. Lu, S.-W. Wei, and C. Gas (UCAR, JCSDA)

4d-Var has been shown to provide some of the most reliable weather forecasts to date, but is not without its pitfalls. In particular, 4d-Var depends heavily on a tangent linear model (TLM) and an adjoint to the tangent linear model. While conceptually simple, coding these two elements is extremely time intensive and difficult. A small change in the larger weather model can induce months of work on its TLM and adjoint delaying the benefits of improvements on the model side. In this talk I will introduce the Hybrid Tangent Linear Model (HTLM), developed in [Payne 2021], which is aimed at avoiding these pitfalls as well as present a generic implementation of it in the JEDI system. Because of that generic implementation, I will also highlight the reduction in linearization errors we observe using several different models, GEOS, GFS, and SOCHA. The HTLM works by leveraging any available incomplete TLM (perhaps dynamics only) along with a nonlinear ensemble, by first forwarding an ensemble of perturbations with it and then sampling on vertical columns to find coefficients for a corrective update of the TLM forwarded perturbation. The generic implementation of the HTLM in JEDI provides the opportunity for any model with a JEDI interface to do 4d-Var assimilation with it.

On the efficient implementation of non-Gaussian observation errors in existing DA schemes

Peter Jan van Leeuwen*, Colorado State University and Chih-Chi Hu, Princeton University Alan Geer, ECMWF

Observation errors are often non-Gaussian, related to representation error, bounded observables, or nonlinearity. However, in most operational data assimilation applications the Gaussian assumption is used. Our evolving-Gaussian method incorporates non-Gaussian observation errors into data assimilation methods that use Gauss-Newton-based outer loops, such as incremental variational methods and iterative Ensemble Kalman filters. The key idea is to locally approximate the gradient of the non-Gaussian cost function by using an adaptive Gaussian cost function during the minimization. Because we do not require changing the cost function for different observation error pdfs, the evolving-Gaussian method is not restricted to any parametric pdf form, which facilitates its implementation in a full-scale operational weather forecasting system without adding to the computational cost. We show in an idealized experiment that the evolving-Gaussian method is able to successfully identify the mode of the posterior for a non-Gaussian observation error pdf. We also demonstrate the evolving-Gaussian method in an operational-quality weather forecast system, the Integrated Forecasting System (IFS), with the assimilation of all-sky microwave radiances. The results indicate promising signs of improvement for the short-term forecast of low-tropospheric water vapor, cloud and precipitation in the tropics, albeit with some degradations in the temperature.

Towards end-to-end machine learning models that combine forecast with data assimilation

NOAA PSL: Sergey Frolov*, NOAA; Laura Slivinski; Tim Smith, MITRE: Matt Bender, Kelsey Lieberman, Joshua DaRosa, Nick Silverman, Chris Miller, Nick Krall, Mohammad Alam, Alex Philp, and NVIDIA: Noah Brenowitz

Machine learning (ML) models trained on the reanalysis record are now the most computationally efficient way to provide highly accurate forecasts for the medium range weather given the initial state generated by the traditional (highly computationally expensive) data assimilation methods. Can we use the power of the ML methods to enable faster, more accurate data assimilation? This presentation introduces a new method (ADD-DA) that aims to estimate a correction to the operational GDAS initial condition that will minimize the error of the ML forecast. Results from an early prototype of this system will be presented.

Land Data Assimilation Activities for Global NWP at NOAA

Clara Draper*, Cory Martin, Jiarui Dong, Tseganeh Gichamo, Catherine Thomas, Youlong Xia, and Yuan Xue

As a part of the GFSv17 update to NOAA's global NWP system, NOAA is implementing a major upgrade to our land data assimilation system. This will include an update to our current snow depth analysis, and implementation of our first global soil moisture and soil temperature analysis. The new snow depth analysis will be a 2-dimensional Variational (2DVar) assimilation, implemented using the Joint Center for Satellite Data Assimilation (JCSDA)'s Joint Effort for Data assimilation Integration (JEDI) platform. The 2DVar assimilate station snow depth observations and satellite snow cover observations. The soil moisture and soil temperature analysis will be a strongly coupled land/atmosphere EnKF. The EnKF is already applied to the atmosphere in our operational DA system, and is being expanded to also assimilate screen-level temperature and humidity observations and to update the soil moisture and soil temperature. This presentation will review both of the above data assimilation systems, and present results of recent experiments testing the impact of the new land data assimilation on forecast performance.

Space Weather Data Assimilation Capabilities in the JEDI System

Lindsey Hayden*, Hui Shao, Dave Kuhl, John Haiducek, Victoriya Forsythe, Ben Ruston, Francois Hebert, and Evan Parker

The Joint Effort for Data assimilation Integration (JEDI) data assimilation system is a model agnostic data assimilation software that is the product of a coordinated effort by the Joint Center for Satellite Data Assimilation (JCSDA) and its partner organizations: NASA, NOAA, US Navy and Air Force, and the UK Met Office. It is developed with the goal of rapid adaptation and integration of new and emerging sensors and data types. To that end, the JEDI software is designed with reusability in mind, so that new models and techniques can be implemented with ease and minimal repeated code. JEDI has developed unified forward operators (UFO) and these have been previously applied mostly for neutral atmospheric data assimilation.

This work introduces the first effort to introduce space weather data assimilation capabilities into the JEDI system, taking advantage of what has been developed in JEDI UFO. Observations from two instruments are considered in this work, ionosondes and space-based radio occultation (RO). Both measure electron density. Ionosondes are profile measurements of electron density produced by a ground based high frequency radio transmitter. RO measures the total electron density along the path of the GPS signal through the atmosphere. The background of the electron density for JEDI is provided by the Python implementation of the International Reference Ionosphere (PyIRI). It is a climatological model that was developed at the U.S. Naval Research Laboratory (NRL) in order to run the widely used, climatological International Reference Ionosphere (IRI) model at significantly reduced computational cost. This climatological reference can be used as a baseline to evaluate against other Ionospheric models that develop interfaces to JEDI. Converters have been developed to store the data in the Interface for Observation Data Access (IODA) format used by JEDI. We are developing the forward operators necessary to transform the PyIRI model data to observation space by leveraging existing JEDI forward operators. Ionosonde forward operators will be based on those established for radiosonde observations and ionospheric RO measurements will utilize the strategies developed for the neutral atmosphere. Future work will include the utilization of this newly developed framework for observations in a JEDI based pseudo-cycling assimilation system, as a stepping stone for full cycling with physics based models, such as future versions of the UFS.

Marine JEDI system and MOM6 analysis for application to improve UFS-HAFS forecast

Hyun-Sook Kim*, HeeSook Kang, Travis Sluka, Guillaume Vernieres, Yongzuo Li, and Xugunag Wang

A new ocean data assimilation system, known as the Marine Joint Effort for Data assimilation Integration (JEDI), has been introduced to produce three-dimensional analysis of regional Modular Ocean Model version 6 (MOM6) at a 1/12-d horizontal resolution for the year 2022. The overarching goal is to provide accurate initial conditions for regional UFS-HAFS forecasting. Evaluation results of the MOM6 analysis indicate improved forecast skill, notably in the correcting locations and strengths of the major thermal frontal current in the North Atlantic Ocean, upper-layer stratification, and the salinity structure in the Atlantic hurricane corridor. The assimilated general circulation of the Gulf of America and Caribbean Sea is better represented by recovering the influx into the Caribbean and to the Gulf of America. Detailed assessment results are presented.

Emerging Technologies: Artificial Intelligence (AI) / Machine Learning (ML)

Data-driven MLWP model development for global weather forecasts

Jun Wang*, Linlin Cui, Jianjun Liu, Xiao Luo, Wei Li, Bing Fu, Zhan Zhang, Lin Zhu, Jiayi Peng, and Jacob Carley

Machine learning technology has been applied to the weather and climate prediction field and demonstrated outstanding forecast performance with superior efficiency that traditional numerical weather prediction (NWP) models are unable to compete with. In the past couple of years, we have built experimental MLWP global deterministic and ensemble applications. Both systems are based on GraphCast and trained with NCEP Global Data Assimilation System (GDAS) data and several other data sets using operational GFS and GEFS initial conditions as input. These two applications comprise the initial version of NOAA's Experimental AI Global and Limited-area Ensemble (EAGLE) system.

In this presentation, we will provide an overview of the continuous development for the two global applications. First, the loss function in the deterministic application has been updated to include the use of a spherical harmonic representation to improve hurricane intensity forecasts and to include an update to the pressure level weights to refine the vertical structure of the model state. Second, a hybrid MLWP and NWP global ensemble forecast system has been developed. Results are evaluated against the operational GEFSv12. A near real-time experiment has also been set up. Third, to further expand the global forecast, work is in progress to develop an MLWP global coupled model. The atmosphere and ocean components were developed using the Spherical Fourier Neural Operators (SFNO) ML architecture, and the air-sea coupling procedure was designed. Future work to further improve the forecast performance and to implement the EAGLE system into operations will also be discussed.

NOAA EAGLE: research to operations pipeline for AI weather models at NOAA

Sergey Frolov*, Jun Wang, Isidora Jankov, Jacob Carley, Keven Blackman, Daryl Kleist, Travis Wilson, Linlin Cui, John Ten Hoeve, and Maoyi Huang

This presentation introduces project EAGLE (Experimental AI Global and Limited-area Ensemble forecast system)—NOAA's environment to demonstrate, test, and transition to operations AI weather forecast models at NOAA. The current version of EAGLE produces daily global deterministic and ensemble forecasts using GraphCast, from Google DeepMind, and fine-tuned on NOAA's Global Data Assimilation System (GDAS) data as inputs and training targets.

Once fully implemented, EAGLE will establish an open system for testing and verifying AI-based global and limited-area ensemble forecasts using NOAA's trusted operational forecast metrics. Project EAGLE will provide a research-to-demonstration pipeline that will identify promising AI forecast innovations across the community, facilitate inclusion of innovation in a near-real-time demonstration environment, and expedite integration of proven innovations into future operational implementations. This near-real-time environment will enable NOAA to experiment and utilize the best community practices for deploying advanced AI systems and disseminating their output to users at scale. We expect that the future AI models from NOAA will leverage common AI model infrastructure based on the Anemoi open-source framework from the European Centre for Medium-Range Weather Forecasts (ECMWF) and several of its Member States.

This presentation will review the state of project EAGLE implementation.

Enhancing the Unified Forecast System with NVIDIA Earth-2: AI Research in Emulation, Downscaling, and Data Assimilation

David Hall*, Mike Pritchard, Karthik Kashinath, and Noah Brenowitz

The Joint Center for Satellite Data Assimilation (JCSDA) and its partners recently introduced the Joint Effort for Data assimilation Integration (JEDI) SkyLab application, a tool to estimate observation impact on analyses and short-range forecasts. JEDI provides a demonstration application of an integrated Earth System DA capability (atmosphere, ocean, sea ice, land surface, aerosols, and trace gasses). A variety of emerging observing systems are continuously being interfaced with JEDI across the multiple components of the Earth System. The use of well-established observing systems is continuously being improved in Skylab. The goal of the JEDI SkyLab application is to be a vehicle to decrease the timeline for operational implementation by creating configurations for these observing systems.

The JCSDA OBS team is the primary developer of the Unified Forward Operator (UFO) component of the JEDI system. In this component, version 3 of the Community Radiative Transfer Model (CRTM) is employed for use with a large range of environmental monitoring sensors.

We will cover a general overview of the JEDI SkyLab application and show evaluation techniques that have been developed to monitor the impact of observations. An ability to compare the response of system changes in the observation statistics will also be demonstrated. Lastly, we will demonstrate the use of CRTM for an emerging sensor, the TROPICS microwave sounder, in an Observation Simulation Experiment (OSE). Also shown will impact on the Skylab application and response seen in the other observing systems, such as radiosondes and programs of record sounders such as ATMS.

Enhancing WoFSCast Calibration and Sharpness with a Probabilistic Loss

Corey K. Potvin* and Montgomery L. Flora

Global AI weather prediction (AIWP) models trained on traditional (e.g., MSE) loss functions produce overly smooth deterministic forecasts and underdispersive ensemble forecasts. The WoFSCast, a 3-km AIWP limited-area model designed to emulate forecasts from NSSL's Warn-on-Forecast System (WoFS), inherits these same limitations. As demonstrated in ECMWF's Artificial Intelligence Forecasting System (AIFS), however, training AIWP models with a probabilistic loss function can enable spatially sharper, more calibrated forecasts. In particular, adopting a modified Continuous Ranked Probability Score (CRPS) loss function and a model noise injection method for generating mini-ensemble predictions during training allows the AIFS-CRPS to achieve similar sharpness and calibration as a diffusion-based AIFS at inference. Following the AIFS-CRPS strategy, we have developed a WoFSCast-CRPS that mitigates the forecast smoothing and underdispersion exhibited by the original WoFSCast. Spread-error ratios suggest the WoFS-CRPS produces better calibrated ensemble forecasts than the WoFS itself, at least for composite reflectivity. In this presentation, we will summarize subjective impressions of standard WoFSCast ensemble forecasts from participants in the 2025 HWT Spring Forecasting Experiment; overview our implementation of the WoFSCast-CRPS; present objective and subjective results demonstrating the improvements of WoFSCast-CRPS over the standard WoFSCast; and highlight next steps in WoFSCast development.

A Physics-informed Machine Learning Algorithm for Satellite, In-situ and High-frequency Radar Data Assimilation Preprocessing for West Coast Forecast System using Joint Effort for Data Integration Framework: WCOFS-JEDI-AI

Ling Liu*

A Machine Learning Algorithm based on coastal ocean dynamics has been developed for Satellite, In-situ and High-frequency Radar data for the West Coast Operational Forecast System (WCOFS) using the Joint Effort for Data Integration Framework: WCOFS-JEDI-AI. Three neural networks are trained for the WCOFS sea surface temperature, surface velocity and vertical profiles of temperature and salinity based on their unique physical dynamics. The sea surface temperature is trained using the Convolutional Neural Network with a fully connected output layer based on the ocean heat flux balance. The surface velocity and vertical temperature and salinity profiles are separately trained through a feed forward deep neural network based on the Quasi-Geostrophic Ocean model. The primary data sets are temperature and salinity profiles, sea surface temperature, surface velocity, surface wind stress, air temperature, pressure and humidity and span at least one year with a minimum of seven days per season. The data sets are split 80%/20% for training and verification. The WCOFS-JEDI-AI uses JEDI's Interface for Observation Data Access (IODA) to produce the surface and vertical profiles of temperature, salinity and current velocity. The calculated Mean Absolute Error (MAE) offers a new way of determining the Jacobian matrix to quantify the output uncertainties WCOFS-JEDI-AI significantly reduces computation time by at least two orders of magnitude compared to traditional dynamic modeling approaches and scales linearly with the number of processed training profiles. WCOFS-JEDI-AI products are comparatively verified with the WCOFS model products and the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA).

AI-Enabled UFS: Fortran to CUDA Code Translation for Accelerated Computing

Wilson Conley*, Fin Nguyen, and Marie Nguyen

The Joint Effort for Data Assimilation Integration (JEDI) provides a data assimilation framework for Earth system prediction. JEDI is a collaborative project run by the Joint Center for Satellite Data Assimilation (JCSDA) supported by NOAA, NASA, U.S. Air Force, U.S. Navy, and UK Met Office. The interagency partnership is key to transition data assimilation research to operational modeling systems and academic communities. This transition is possible through robust computational infrastructure, comprehensive testing, open-source software, and agile development.
JEDI requires a large number of software packages to build and run experiments using several forecast models such as the Unified Forecast System (UFS), the Goddard Earth Observing System (GEOS), the Modular Ocean Model (MOM6), the Model for Prediction Across Scales (MPAS), the Navy Environmental Prediction sysTem Utilizing the NUMA corE (NEPTUNE), and the Met Office LFRic. In order to support multiple configurations of the JEDI software on High Performance Computing systems, commercial clouds, workstations, and laptops, a package management software stack (spack-stack) developed by JCSDA, the NOAA Environmental Modeling Center (EMC) and the U.S. Earth Prediction Innovation Center (EPIC) is used.

Built on top of spack-stack, JCSDA's Skylab Earth System Data Assimilation is an end-to-end system that features the following JEDI components: the Experiments and Workflow Orchestration Kit (EWOK), a data store for observation and model data called the Research Repository for Data and

Diagnostics (R2D2), and an Interface for Observation Data Assimilation (IODA) to handle observational data. Skylab utilizes JEDI to model the atmosphere, ocean, sea-ice, soil moisture, snow, aerosols, and trace gasses. With a system this advanced, continuous integration and automated testing is key to rapid and effective code development at the research and production levels.

This presentation covers the JEDI infrastructure team's development efforts for the next-generation data assimilation system by leveraging cloud computing environments for research, development, and near real-time applications of JEDI. Developing a Continuous Integration/Continuous Delivery (CI/CD) pipeline using tools such as GitHub, Docker containers, various Amazon Web Services (AWS), and CodeCov enables the rapid testing and implementation of emerging technologies. The future of data assimilation lies in the ability to support new software environments and integrate new datasets in a ready-to-use format for research and operations in a matter of days.

Virtual Posters

NeurOCAST: A Neural Operator-Based Model for Bias Correction in Forecast Guidance

Atieh Alipour*, Fariborz Daneshvar, Soroosh Mani , Gregory Seroka, Lei Shi, Zizang Yang, Yuji Funakoshi, Georgios Britzolakis, Edward Payson Myers, Kamyar Azizzadenesheli, and Saeed Moghimi

In both weather forecasting and ocean modeling, we typically use numerical models to solve governing partial differential equations. However, representing all contributing factors in a model accurately is often computationally expensive or infeasible. Even when these factors are included, the model may still produce inaccurate results. This is because many of the model inputs are themselves outputs from other models, introducing errors and biases during the forecast period. As a result, the simulated total water levels often deviate from observed values. To address this, bias correction methods can be applied to enhance the accuracy of the model output. Here, we introduce NeurOCAST, a neural operator-based deep learning model designed to correct biases in the National Oceanic and Atmospheric Administration's (NOAA) Global Two-Dimensional Surge and Tide Operational Forecast System (STOFS-2D-Global) water level forecast guidance. The key strength of NeurOCAST is its ability to learn the underlying function of spatiotemporal outputs from limited observations and generalize to gridded outputs, an approach that remains a relatively underexplored area, particularly for oceanic/coastal forecast guidance. Compared to the similar implementation of the neural operator in the seismology field, NeurOCAST is over 20 times more efficient. This improvement is particularly important when working with large datasets such as those in weather and oceanic modeling. Our findings indicate that NeurOCAST improves water level accuracy with over 80% reduction in bias. These advancements strengthen and support coastal resilience and safe marine navigation by providing more accurate prediction of water levels.

Introduction of NOAA’s new UFS based operational prototype, the Global Chemistry and Aerosol Forecast System (GCAFS) v1

Barry Baker*, Cory Martin, Li Pan, Yaping Wang, Andrew Tangborn, Partha S. Bhattacharjee, Fanglin Yang, Youhua Tang, Bing Fu, Raffaele Montuoro, Li (Kate) Zhang, Bo Huang, and Jerome Barre

NOAA's Global Chemistry and Aerosol Forecast System (GCAFS) is a next-generation, global prediction system scheduled for operational release in 2026. Built on the Unified Forecast System (UFS), GCAFS will provide real-time forecasts of aerosols and atmospheric composition to support air quality management, public health, climate monitoring, and hazard response.
At its core, GCAFS couples NOAA’s FV3 dynamical core with the GOCART2G aerosol module and an updated suite of anthropogenic and natural emissions. It incorporates the FENGSHA dust emission scheme to improve the representation of windblown mineral dust, enabling more accurate predictions of dust storms and long-range transport. The system assimilates satellite-derived aerosol observations to refine its forecasts, with performance evaluated against satellite and ground-based measurements.

GCAFS represents the evolution of NOAA’s operational GEFS-Aerosols system, building on its capabilities with improved physics, updated emissions, enhanced data assimilation, and operational integration. This advancement marks a critical milestone in NOAA’s efforts to unify weather and atmospheric composition forecasting.

Investigation of data driven background ensemble covariance from Graphcast toward Hurricane data assimilation and prediction

Zhihong Chen* and Xuguang Wang, Multiscale data Assimilation and Predictability Lab (MAP), University of Oklahoma

Cost-effective data-driven global forecasting models show promise compared to the traditional numerical weather prediction (NWP) model. Background ensemble covariances (BEC) are crucial for ensemble-based data assimilation (DA). However, rather limited studies so far have examined the fidelity of the data-driven model in producing the BEC. Such a study is even more limited for hurricane data assimilation and prediction.

We evaluate the BEC from Graphcast against that of GEFS for Hurricane Lee (2023) in both its NON-rapid-intensification (NON-RI) and rapid intensification (RI) phases. Ensemble spread, background ensemble correlations (BECr) and structures are evaluated.

Within the TC vortex, GraphCast shows smaller spreads but larger BECr and BECr tendencies. Graphcast’s emulation of BECr tendency shows less skills when GEFS’s relative BECr tendencies are small. Graphcast BECr and BECr tendency estimations have inferior skills for RI than non-RI phases, especially for moisture, possibly due to the incapacity of Graphcast in emulating the complex thermodynamic processes. For the near TC environment, principal-component analysis reveals lower total eigenvalues and a flatter eigen-spectrum for the BEC of Graphcast. Graphcast reproduces the leading modes in GEFS BEC for NON-RI but fails to produce the ridge shift mode of GEFS in the RI.

For the TC–environment interaction, BEC between TC intensity and 500-hPa geopotential height of Graphcast matches that of GEFS well in non-RI yet deteriorates in RI.

Overall, GraphCast captures the key BEC structures of Hurricane Lee but under-represents spread and exhibits systematic BECr biases. The performance in the NON-RI is superior to in the RI.

Development of a Coupled Atmosphere-Ocean Model for Subseasonal-to-Seasonal Forecasting

Linlin Cui*, Jun Wang, and Jacob Carley

"Subseasonal-to-seasonal (S2S) forecasting remains one of the most challenging problems in Earth system science due to the complex, nonlinear interactions between the atmosphere and ocean across a range of spatial and temporal scales. Recent progress in machine learning weather prediction models offers a promising alternative by enabling data-driven modeling of dynamical systems at scale.

In this study, we developed a machine learning coupled atmosphere-ocean model designed for S2S forecasting, leveraging a Spherical Fourier Neural Operator (SFNO) architecture. In this framework, the atmospheric (6-h time step) and oceanic (24-h time step) components are trained independently on their respective datasets from the NOAA Unified Forecast System (UFS) replay data, then coupled during inference through physically motivated boundary exchanges. Specifically, the atmospheric model provides 2-m temperature, 10-m wind speed, precipitable water, and pressure reduced to mean sea level as surface forcing to the ocean model, while the ocean model returns sea surface temperature as boundary forcing to the atmosphere. This exchange is carried out every 24 hours, enabling a dynamic two-way interaction between the components.

The coupled system exhibits stable simulation for long-range forecasts and preserves the annual climatological cycle. We demonstrate the model's capability by evaluating its prediction skills on the prognostic variables and in forecasting the El Niño-Southern Oscillation (ENSO). Our results suggest that machine learning methods can provide new insights into earth system dynamics and predictability. As a next step, we aim to collaborate with the NOAA Physical Sciences Laboratory to build a fully coupled Earth system model."

Evaluating the effect of wave and hydrology coupling on tropical cyclone driven storm surge

Fariborz Daneshvar*, Soroosh Mani, William Pringle, Felicio Cassalho, Saeed Moghimi, and Edward Myers

The goal of this study is to quantify the impact of atmospheric forcing, inland hydrology, and wave coupling on tropical cyclone driven coastal flooding in flood prone Florida estuaries. Hurricane Helene (2024) and Milton (2024) were used as the case study. In this study, the Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) was used to simulate the coastal ocean in 2-D. Generalized Asymmetric Holland Model (GAHM), National Water Model (NWM), and the third generation Wind Wave Model (WWM) were also used to couple atmospheric forcing, inland hydrology, and wave effects respectively. Results show that integration of inland hydrology and waves would result in up to 0.5 m higher elevation (than the simulation with atmospheric forcing alone) in some locations. Comparison of models' simulations with observed water levels also shows that adding inland hydrology and waves will result in more pronounced inundation at observation locations. Outcome of this study will provide a more accurate assessment of tropical cyclone driven compound flooding for early warning and post-storm assessment.

Keeping Pace: Unlocking AI and Exascale with Domain Specific Languages

Oliver Elbert*, Frank Malatino, Janice Kim, Andrew Brooks, Ryan Mullhall, Lucas Harris, and Rusty Benson

The era of exaflop forecasting has arrived. From increased resolution and larger ensemble sizes to more realistic model parameterizations, the latest generation of supercomputing hardware allows us to greatly improve the skill and detail of weather and climate models. Simultaneously, advances in AI/ML modeling such as machine-learned bias-correcting algorithms and fully data-driven weather forecasts, are rapidly reshaping the field. However, both exascale compute and ML modeling depend on making efficient use of GPUs. Weather and climate models will need to adapt in order to unlock the power of these technologies, and the use of domain-specific programming languages (DSLs) offers an opportunity to incorporate both at once.

We present Pace, an atmospheric model written in Python using NDSL, the NOAA-NASA DSL middleware library. Pace contains Python ports of the FV3 dynamical core and SHiELD physics parameterizations, and also integrates the pyRTE-RRTMGP radiation code. Pace exhibits perfect weak scaling and achieves greater than 5x speedups over Fortran. NDSL provides a simple interface to the GT4Py DSL that allows us to compile Pace for a variety of hardware backends, and allows for easy coupling to machine learning model components as in any Python code. NDSL provides a simple platform for model development, with all of the infrastructure needed to build a fully-functional weather model, and access to the entire Python ecosystem from jupyter notebooks to pdb and Pytest. We show preliminary results from high-resolution tropical cyclone simulations and discuss prospects for future scientific and modeling development.

Assessing the Skill and Sensitivity of AI-Generated Global NWP Emulators in the NOAA HWT Spring Forecasting Experiment

David Harrison*, Tim Supinie, Israel Jirak, and Adam Clark

AI-generated global numerical weather prediction models are rapidly growing in capability and application across the weather enterprise. These fully AI-based emulators provide global weather forecasts that have been shown to statistically perform equal to or better than that of traditional numerical weather prediction (NWP) while requiring significantly less computational time and resources. While these objective results are promising, AI NWP emulators have had only limited testing for real-time operational forecasting applications. To address this need, five AI-generated NWP emulators were evaluated as part of NOAA's 2025 Hazardous Weather Testbed Spring

Forecasting Experiment (SFE), including Huawei Cloud's Pangu-Weather, Google's GraphCast, Microsoft's Aurora, and ECMWF's Artificial Intelligence/Integrated Forecasting System (AIFS). Experiment participants subjectively assessed the skill and usefulness of each system by analyzing the prognostic 500- and 850-mb geopotential height and wind, 2-m temperature, and 6-h QPF (when available). These forecasts were assessed alongside the operational GFS and ECMWF at forecast times of 156 – 180 hours and compared to GFS, ECMWF, and Multi-Radar/Multi-Sensor QPE analyses in a blinded evaluation. The experiment also tested the AI emulators' sensitivity to initial conditions by subjectively rating and comparing models initialized using GFS and ECMWF initial conditions. This presentation will detail the design of the AI NWP emulator evaluation and provide preliminary results from the experiment.

A Containerized WCOSS2 Environment for Collaborative Development of Operational Ocean Forecast Systems

Mansur Ali Jisan*, Zachary Cobell, Soroosh Mani, Zizang Yang, Yunfang Sun, Ufuk Turuncoglu, and Saeed Moghimi

NOAA's operational models are designed to run on Weather and Climate Operational Supercomputing System 2 (WCOSS2). However, due to access and package restrictions, WCOSS2 cannot be used for model development purposes, especially when external collaborators are involved. This work presents a Docker-based container solution that emulates the WCOSS2 environment to provide a consistent model development environment. It is currently configured to support the Storm Surge and Tide Operational Forecast System (STOFS).

The container is built through a multi-stage process based on Rocky Linux 9 and includes core components such as SLURM job scheduling, SCHISM and ADCIRC ocean models, and the NCEP software stack. Forecast workflows are executed using a directory structure that mirrors the NCEP Central Operations data tank hierarchy. Input datasets such as GFS, HRRR, RTOFS, and NWM are mounted from NOAA's ParallelWorks storage using Docker volume mapping, allowing the container to process data as if operating within WCOSS2. The container currently supports end-to-end STOFS-3D Atlantic workflows, including preprocessing, nowcast/forecast, and post-processing, without requiring changes to operational scripts.

This containerized environment enables reproducible, platform-independent development of operational forecast systems, allowing NOAA teams and external collaborators to contribute directly to workflow development, model validation, and testing without relying on a specific computing environment. By preserving WCOSS2-compatible paths and runtime behavior, the container ensures operational fidelity while lowering barriers to collaboration. Although currently configured for STOFS-3D Atlantic, the modular framework is extensible and suitable for prototyping other ocean, weather, or coupled forecasting systems, including the UFS Weather Model to accelerate research-to-operations transitions.

Understanding sampling error characteristics in ensemble-based estimates of land-atmosphere coupled background error covariances in a dryline CI case study

Aaron Johnson* and Xuguang Wang

The output of the Unified Forecast System (UFS)-based coupled model that entails hindcasts with time-integration of 12 months over the years 1991-2022 is assessed for the forecast skill. The UFS model is run at 1° horizontal resolution for the atmosphere and ocean and vertically has 64 atmosphere and 75 ocean layers. The model prototype also covers five time-lagged ensemble members initialized on May 21-25, respectively. The horizontal structure of correlation, root-mean-square error (RMSE), and bias of sea surface temperature (SST) field are studied in comparison with the observational OISST dataset. It is shown that SST correlation (RMSE) decreases (increases) with lead months, while the spatial patterns of correlation (and RMSE) are similar at various lead times.

Also, preliminary results of ocean variables, including potential temperature, zonal currents, and salinity at the upper ocean (0-200 m depth), will be discussed in the context of seasonal forecasts. We compare UFS ocean outputs with those from ORAS5-ECMWF (Ocean Reanalysis System 5 prepared by the European Center for Medium-Range Weather Forecasts) regridded into 1° horizontal resolution (the original ORAS5 dataset is at 0.25° resolution). We will investigate how the vertical structure of ocean fields in our model prototype is similar/different from those of high-resolution ORAS5 reanalysis. This study is important for the model accuracy in our UFS-based model prototype for seasonal time scales.

Impact of Assimilating Atmospheric Boundary Layer Observations on the Rapid Intensification of Hurricane Idalia (2023) in Self-cycled HAFS-JEDI System

Yu-Shin Kim and Xuguang Wang

The rapid intensification (RI) of tropical cyclones is strongly influenced by air–sea interactions, particularly the exchange of heat and moisture across the interface. The atmospheric boundary layer (ABL), representing the atmospheric component of this interface, plays a critical role by modulating the inflow of warm, moist air from the ocean surface—the primary energy source for tropical cyclone development. During Hurricane Idalia (2023), a targeted field campaign collected unique ABL observations using dropsondes and a Saildrone. This study investigates the impact of assimilating these observations on the simulation of Idalia's RI using the self-cycled Hurricane Analysis and Forecast System (HAFS) within the Joint Effort for Data assimilation Integration (JEDI) framework. Two data assimilation (DA) cycling experiments are conducted: one assimilating all available observations, including targeted ABL data (All OBS), and another excluding ABL observations (No ABL). Relative to the All OBS experiment, the No ABL experiment produces lower 2-m temperatures and underestimates the tropical cyclone's intensity. The All OBS experiment more accurately reproduces the observed peak intensity of Idalia as a Category 4 tropical cyclone, underscoring the value of assimilating targeted ABL observations for improving RI forecasts in coupled prediction systems.

Generative Data Assimilation of Weather Observations for High-Resolution CONUS-wide Weather State Estimation

Conor Lewellyn*, Noah Brenowitz, Simon Byrne, Karthik Kashinath, Nick Krall, Chris Miller, Neal Pan, and Nick Silverman

Traditional methods for weather prediction and forecasting are often limited by computational intensity. Data assimilation (DA) techniques incorporate observations or model information to constrain physics-based models for initial conditions and to launch forecasts using numerical weather prediction (NWP) models. Forecasting and nowcasting rely on high-resolution DA which can be a complex process leveraging numerous model outputs and observations. Machine learning (ML) approaches for weather prediction enable rapid generation of accurate weather predictions at reduced computational intensity. Recent work has focused on pairing generative artificial intelligence (AI) model outputs with novel data assimilation techniques to enable rapid weather state estimation for data-sparse areas. This work builds on previous regional applications of a generative diffusion and score-based data assimilation approach for weather state estimation through the generation and evaluation of CONUS-wide weather state estimates at both 3-km and 1-km spatial resolution. Results along with initial evaluation and comparison to traditional high-resolution weather prediction methods will be presented.

Development of a Coupled FVCOM-NWM Model for Ocean–Hydrology Interaction

Siqi Li*, Changsheng Chen, Alexander Prusevich, Lu Wang, Qichun Xu, Tom Shyka, and Tej Sai Kakumanu

An ocean–hydrology coupling framework was developed by integrating the National Water Model (NWM) with the Finite Volume Community Ocean Model (FVCOM) via the Earth System Modeling Framework (ESMF). This online coupling enables the dynamic and continuous injection of river discharge from NWM into FVCOM, improving the representation of coastal–riverine interactions. River discharge from NWM's one-dimensional river network is mapped onto FVCOM's unstructured coastal grid, enabling data exchange across models with differing spatial structures. A new approach, the Route-Informed Discharge Injection (RIDI) method, is then applied to distribute river discharge along the routing network rather than concentrating it at a single coastal point. By spreading the freshwater input over a broader region, RIDI reduces abrupt elevation gradients and enhances numerical stability, particularly in high-resolution unstructured grids. As NWM does not simulate water temperature, river temperature is incorporated using either offline outputs from the Water Balance Model (WBM) or predictions from a pre-trained Physics-Informed Neural Network (PINN) based on hydrologic and meteorological inputs. River salinity is defined empirically or based on observations. The coupled system is applied to the Casco Bay region in the Gulf of Maine to simulate a compound flood event driven by the interaction of storm surge and inland runoff. The current design also retains the potential for coupling with a wave model (SWAVE) and an atmospheric model (WRF) within the same ESMF-based framework.

A Physics-based Machine Learning Algorithm for Satellite, In-situ and High-frequency Radar Data Assimilation Preprocessing for West Coast Forecast System using Joint Effort for Data Integration Framework: WCOFS-JEDI-AI

Ling Liu*

A Machine Learning Algorithm based on coastal ocean dynamics has been developed for Satellite, In-situ and High-frequency Radar Data for the West Coast Forecast System using Joint Effort for Data Integration Framework: WCOFS-JEDI-AI. Artificial intelligence technique is applied to the West Coast Operational Forecast Systems using the Joint Effort for Data Integration (JEDI) framework to calculate the satellite sea surface temperature, high-frequency radar surface current velocity and the in-situ temperature and salinity profiles. The algorithm produces both the surface and vertical profiles of the temperature, salinity. Additional products such as heat potential, heat flux, mixed layer depth could also be derived from the primary products. The generated Mean Absolute Error (MAE), taking the mean of the absolute differences of the predicted values from the actual values, offers a new way of calculating the Jacobian during the cost function minimization and quantifying the uncertainties of the algorithm's outputs. The reduced computation time that is estimated to be two orders of magnitude increases the potential of processing much larger amounts of satellite and glider data, also saving tremendous computing power. This study introduces the WCOFS-JEDI-AI algorithm, discusses its applications to the satellite, glider and high-frequency radar data, as well as provides an initial assessment for the surface and vertical profiles of the temperature and salinity parameters.

Improving Background Error Covariance and Square Root Estimation with the Convolution Neural Network (CNN) in the Gain Form Ensemble Transform Kalman filter (GETKF)

Thiruvengadam Padmanabhan*, Xuguang Wang, and Yongming Wang

The motivation for this study originates from the lack of stream data, such as flow or stage during flood events in many remote communities, which are misinformed regarding the associated risks of flooding during an extreme storm event such as hurricanes, tropical storms, convective systems, and other storm events. Because they are typically located in rural areas where there is little to no interest investment in installing gauges to extend forecasting services, this study was conducted to develop a simple approach to reach this community by creating a hydraulic two-dimensional model and using any nearby gage within the basin of study to be used as a reference point relative to the location of the community. The methodology for calibration consists of creating or obtaining an existing fully HEC-RAS 2D model, using the meteorological tools use the rain-on-grid approach, selecting storms that had occurred within the basin of study, adding an infiltration layer to account for the losses and using the observation flow and stage gage data from the storm event to ensure the losses and other calibration parameters reflect the natural behavior of the river basin. Once the calibration is sensible, simulate a probable forecasted inundation for a remote community by assuming forecasted precipitation will impact that location.

Application of Aerosol Budget Analysis method to two generations of NOAA global aerosol forecast models

Li Pan*, Partha S. BhattacharjeeCory Martin, Barry Baker, Fanglin Yang, Andrew Tangborn,Yaping Wang, Youhua Tang, Bing Fu, Raffaele Montuoro, and Li (Kate) Zhang

This study aims to evaluate the Hurricane Analysis and Forecast System (HAFS) forecasts for the environmental flow of Hurricane Idalia (2023). Accurate forecasting of tropical cyclone tracks is critical for mobilizing localized disaster preparedness operations. Uncertainty in TC track forecasts would increase when forecasting for longer lead times. In this study, HAFS-A 00Z and 06Z forecasts for Hurricane Idalia were used for a comparative case analysis alongside ERA5 Reanalysis. The analysis of this study spans three days, beginning at day 0 to day +3 for Hurricane Idalia. To further study the environmental flow on track forecasts in the HAFS, differences from the ERA5 in the 500 hPa steering flow and geopotential heights were evaluated to identify how the large-scale condition in the HAFS resulted in track deviations. Forecasts from 00Z and 06Z each show notable track uncertainty, particularly in lag days +2 to +3. Differences in 500 hPa geopotential heights suggest that improper modeling of a trough south of Hurricane Idalia misdirects winds, creating predominantly zonal flow within the HAFS hurricane track. Further study of other cases is necessary to understand other possible large-scale patterns within the HAFS model and enhance the product in service of regions at risk of experiencing hurricane landfall.

JEDI Skylab - Observation Assessment and Evaluation

Benjamin Ruston*, Hui Shao, Fabio Diniz, François Vandenberghe, Lindsey Hayden, Benjamin Johnson, Cheng Dang, and Hailing Zhang

The Joint Center for Satellite Data Assimilation (JCSDA) is a partnership between agencies (NOAA, NASA, U.S. Air Force and Navy, and the UK Met Office). There are two JCSDA projects highly relevant and impactful to the current and future development of the UFS. The data assimilation architecture, the Joint effort for data assimilation integration (JEDI), has created an abstracted data assimilation system from the models themselves as it has interfaces for models such as the UFS, UK Met Office LFRic, US Navy NEPTUNE, and NCAR MPAS. This allows collaborative development and partner exchange, while the code is managed in an agile framework. A separation of concerns approach is taken, with the simulation of the observations performed by the Unified Forward Operator (UFO). The UFO component also is interfaced with a second key JCSDA project, the Community Radiative Transfer Model (CRTM). The CRTM can be used for satellite radiances in the Microwave (MW) and Infrared (IR), reflectances in the Visible (VIS), and reflectivities from space-borne radar. At the JCSDA, the JEDI Skylab system has been created to evaluate observation capabilities and validate these for partners. This is critical for both research-to-operation (R2O) and feedback from operations and transition efforts back into the common JEDI framework.

The JCSDA extensively uses the MPAS (NCAR) and UFS core FV-3 (NOAA) models. Initializations can be readily executed by using the NOAA GFS and GEFS outputs available publicly through services such as Amazon Web Services (AWS) simple storage service (S3) buckets. Using the JEDI Skylab system we have developed and demonstrated the various UFO observation filters, variational bias correction and observation error models over wide-ranging observations used by the partner agencies. We have used JEDI Skylab to assist our partners and in particular NOAA NESDIS and the USAF to examine new observations provided from the commercial sector. Using JEDI Skylab we have created end-to-end evaluations ingesting all data and initial conditions, pre-processing the data to the common JEDI format defined collaboratively in the Interface for Observation Data Access (IODA) component. Recently we have updated our evaluation capability to include the WeatherBenchX tools and evaluation framework developed by Google. We will present results from work done using a JEDI Skylab environment, verified against the ERA-5 re-analysis and to other observation types. We will provide examples of how JEDI configuration offers flexibility and ease in both integration and customization, creating opportunities for new users to engage more readily with the JEDI system. JEDI-enabled systems are in use currently at NOAA, NASA, the US Air Force and Navy and the UK Met Office; additionally, JEDI is being used by the private sector such as The Weather Company and Tomorrow.io, providing new opportunities to interact and collaborate.

Harnessing Machine Learning and Explainable AI to Predict Phytoplankton Blooms and Identify Key Drivers in Freshwater Reservoirs

Rohit Shukla*

Climate change and eutrophication have exacerbated the frequency of phytoplankton blooms worldwide, necessitating advanced tools for proactive water quality monitoring and prediction to mitigate risks to public health and aquatic ecosystems. While machine learning (ML) models are increasingly employed for water quantity and quality prediction, their black-box nature often limits their utility for effective water management.

To address this limitation, this study utilizes four machine learning algorithms—Extreme Gradient Boosting (XGBoost), Random Forest (RF), Gradient Boosting Machine (GBM), and Categorical Boosting (CatBoost)—to predict phytoplankton (as chlorophyll a) concentrations in Falling Creek Reservoir (FCR) and Beaverdam Reservoir (BVR), Virginia, USA. These two water sources provide drinking water to communities and have historically exhibited phytoplankton blooms. To enhance the interpretability of these ML models, we integrated explainable artificial intelligence (XAI) techniques, including Shapley Additive Explanations (SHAP) and partial dependence analyses (PDPs) and Interactive analyses , into our framework. XGBoost exhibited high predictive accuracy. SHAP analysis further identified seasonality as the primary driver of chlorophyll in BVR, while deep-water oxygen concentrations were found to be the key factor in FCR. These findings highlight the value of comparative modeling efforts at the individual reservoir scale, as even closely co-located water bodies may exhibit very different patterns and drivers in chlorophyll. As a result, this study advances the integration of ML and XAI into adaptive environmental strategies, demonstrating their potential for real-time chlorophyll forecasting systems. These forecasts are being submitted to the Virginia Ecoforecast Reservoir Analysis (VERA) Challenge and contributing to our larger multi-model comparison of phytoplankton bloom forecasts.

Toward Improved Forecasts of U.S. East Coast Sea Level: development of a dynamical downscaling framework to simulate North Atlantic circulation and physically inform sub-annual forecast skill

Jacob Steinberg* (NOAA GFDL), John Krasting (NOAA GFDL), and Andrew Ross (NOAA GFDL)

Leveraging a recently developed high-resolution regional ocean model (NOAA GFDL's NWA12), we construct an ensemble of dynamically downscaled ocean hindcasts to explore and assess US East Coast sea level variability and sub-annual forecast skill. This framework utilizes NOAA GFDL's SPEAR climate model as boundary forcings and allows for spatial and temporal patterns in improvements to coastal forecast skill to be linked to their physical drivers. Results reveal downscaling improvements, relative to SPEAR, to be a strong function of latitude and dynamical regime, with increased skill and variability resolved south of Cape Hatteras. This analysis demonstrates the importance of accurately simulating large scale patterns of atmospheric and ocean circulation, but also the need for high resolution ocean simulations to resolve complex continental shelf, continental slope, and boundary current dynamics that all impact coastal sea level across timescales. Through collaborations with NOAA's Climate Ecosystems and Fisheries Initiative as well as at NOAA Physical Sciences Laboratory, we present a framework for regularly running and assessing dynamically downscaled sub-annual forecasts of coastal sea level that can be mechanistically linked to ocean and atmospheric variability.

The Evaluation of a Data Assimilative Northeast Coastal Operational Forecast System in 2021

Lixia Wang*, Jiangtao Xu, Aijun Zhang, Wei Wu, Changsheng Chen, Qichun Xu, Siqi Li, Lu Wang, Lucila Houttuijn Bloemendaal, and Edward Myers

NOAA's National Ocean Service (NOS) has been jointly developing and testing a new data assimilative U.S. Northeast Coast Operational Forecast System (NECOFS) based on the Finite Volume Community Ocean Model (FVCOM) developed by the University of Massachusetts - Dartmouth (UMASSD) - WHOI research team. The goal of this project is to operationally implement NECOFS on NOAA's Weather and Climate Operational Supercomputing System (WCOSS) by 2027. This presentation will focus on model performance from a 6-month hindcast simulation (July 1 – December 31, 2021) by comparing NECOFS outputs with observations and outputs from the existing NOS Operational Forecast Systems (OFS) of the New York-New Jersey OFS (NYOFS), the Chesapeake Bay OFS (CBOFS), the Delaware Bay OFS (DBOFS), and the Gulf of Maine OFS (GOMOFS). The hindcast simulation is driven by a full suite of forcing conditions including tidal and non-tidal water levels, 3D-currents, water temperature, and salinity from the Real Time Ocean Forecast System (RTOFS) on the lateral open ocean boundary; along with meteorological forcing from the North American Model (NAM) on the surface and river discharges from USGS observations. NECOFS assimilates the satellite absolute dynamic topography, sea surface temperature (SST), and in-situ observations of temperature, salinity, and currents. NECOFS provides comparable results in water level as the existing OFS, and significantly improves water temperature due to the assimilation of satellite SST and in-situ observations. The inclusion of in-situ currents observations did not demonstrate noticeable improvements in model performance.

Generating Cost-Saving Surrogate Background Ensemble with GNN-based MAPcast for Estimating Multi-Scale Background Error Covariances

Yongming Wang* and Xuguang Wang

Given the increasingly high degrees of freedom in state-of-the-art numerical weather prediction (NWP) models, the computational cost of generating the background ensemble for ensemble-based data assimilation can be enormous. The issue becomes more problematic for convection-allowing models with fine model grid sizes. Machine learning (ML) methods have shown great potential in emulating numerical models in a cost-effective manner. However, rather limited studies train and explore the ML-based surrogate for the short-term background ensemble. This study will train an emulator for this purpose and evaluate the emulator in estimating multi-scale background error covariances across synoptic and convective scales.

Specifically, this study trains a regional emulator, MAPcast, by refactoring GraphCast (Lam et al., 2023) using the historical convection-allowing resolution MPAS forecasts. The background error covariances, a critical quantity for data assimilation, derived from the surrogate background ensemble forecasts, are evaluated against the ensemble forecasts from the real MPAS model. Our evaluation indicates that the surrogate ensemble replicates the MPAS ensemble in the forecasts of state variables and storm structures. Their corresponding background error covariances show similarities in the estimate of variance and spatial correlations at varied scales.

An Overview of Physics Development and Dycore Updates for UFS Applications across Scales

Fanglin Yang*, Lisa Bengtsson, and Ligia Berbardet

The Gain-form of the Local Ensemble Transform Kalman Filter (LGETKF) has been implemented in the Joint Effort for Data assimilation Integration (JEDI) with the Model for Prediction Across Scales - Atmosphere (MPAS-A) (i.e., MPAS-JEDI). LGETKF applies vertical localization in model space and is particularly convenient for assimilating satellite radiance data, which does not have an explicit vertical height assigned for each channel. The additional efforts are made to optimize ensemble analysis procedures and improve the computational efficiency in the cycling workflow of MPAS-JEDI’s LGETKF analysis. The quality control, bias correction, all-sky observation error model, and cloudy observation operator within the JEDI framework are employed to enable MPAS-JEDI’s LGETKF to assimilate satellite radiance observations in all-weather situations, in addition to conventional observations and clear-sky radiances. To optimize assimilation configurations in LGETKF, a series of sensitivity experiments are conducted to evaluate the impact of adding all-sky window-channel AMSU-A radiances above the conventional observations and clear-sky radiances from AMSU-A’s temperature sounding channels and MHS’s water vapor channels. It is found that a combination of relaxation to prior perturbation (RTPP) and relaxation to prior spread (RTPS) aids LGETKF in maintaining the ensemble spread across cycles. A smaller horizontal localization scale proves preferable for all-sky AMSU-A radiance assimilation. The performance of all-sky radiance assimilation in LGETKF is evaluated through two one-month global cycling experiments with 80 ensemble members at 60 km grid spacing, with and without assimilation of all-sky AMSU-A radiances. Verification against Global Forecast System (GFS) analyses illustrates the benefits of all-sky assimilation in reducing short-term and 7-day forecast errors of almost all variables, despite some slight degradations on temperature. Further observation space verification demonstrates that the all-sky assimilation of LGETKF can improve the forecasts with a better fit to satellite winds and all-sky radiances. In addition, short-term ensemble forecasts initialized from LGETKF analyses are used as ensemble background error covariance (BEC) in deterministic cycling hybrid-3DEnVar. The results underscore the advantages of using the ensemble BEC from all-sky LGETKF over that from clear-sky LGETKF. Overall, MPAS-JEDI's LGETKF shows robust and stable performance in all-sky radiance assimilation and holds great potential for both research and operation applications.

Empowering Communities through Flexible and Semi-Automated 3D Coastal Modeling in STOFS-3D-Atlantic

Fei Ye*, Joseph Zhang, Haocheng Yu, Hyung-Ju Yoo, Zizang Yang, Felicio Cassalho, Fariborz Daneshvar, Soroosh Mani, Greg Seroka, Saeed Moghimi, and Edward Myers

The three-dimensional component of NOAA's Surge and Tide Operational Forecast System for the Atlantic (STOFS-3D-Atlantic) is advancing with a growing focus on community engagement through reproducible, flexible, semi- or fully automated workflows. Key innovations include tools that support automated mesh generation and model setup for complex compound flood simulations across the coastal transition zone. These tools simultaneously allow domain-wide mesh quality control and targeted, high-resolution refinement for local applications.

This presentation highlights how such flexibility serves the diverse needs of both modeling teams and coastal stakeholders. We demonstrate how the automated meshing process has been applied in locations like Wilmington, North Carolina—enabling users to locally refine resolved features for fine-scale flooding simulations. Another example is the Morganza to the Gulf (MTG) hurricane protection project area in coastal Louisiana, where direct stakeholder feedback led to improved levee representation, enhanced mesh fidelity, and more accurate localized inundation predictions—demonstrating effective two-way collaboration between model developers and end-users. We also briefly present how the techniques of STOFS-3D-Atlantic have supported the development of related applications, such as probabilistic flood forecasts, the automated meshing tool OCSMesh, and STOFS-3D-Alaska that incorporates hydrodynamic-wave-sea ice coupling.
These examples underscore the value of shared, modular workflows that empower the community to generate, customize, and apply operational-grade 3D unstructured-grid high resolution coastal models for both science and planning. By integrating scalable automation with user-informed improvements, STOFS-3D-Atlantic is increasingly evolving into a collaborative platform for coastal resilience, risk communication, and decision support, including marine navigation applications.

Upgrading STOFS-3D-Atlantic: A Bias Correction Method for Improved Total Water Level Predictions

Hyungju Yoo*, Haocheng Yu, Y. Joseph Zhang, Fei Ye, Wenfan Wu, Saeed Moghimi, Gregory Seroka, Zizang Yang, and Edward Myers

Accurate Total Water Level (TWL) forecasts are vital for coastal flood management. Despite the demonstrated skill of NOAA's STOFS-3D-Atlantic (Three-Dimensional Surge and Tide Operational

Forecast System), residual biases persist largely due to uncertainties in the Digital Elevation Model (DEM) and the omission of physical processes such as thermal expansion. To improve the model performance, we introduced a bias correction method for STOFS-3D-Atlantic, built on the SCHISM framework.

We evaluated model biases using data from ~140 NOAA tide gauges along the Atlantic and Gulf coasts. Hierarchical Clustering and Principal Component Analyses revealed regionally and temporally consistent bias patterns, highly correlated with thermosteric sea level analyzed fields from NOAA NCEI database. Building on these findings, we developed a dynamic correction scheme that calculates bias from the two days preceding each forecast and applies it as a uniform offset to the ocean-side non-tidal boundary elevation.

Year-long simulations for 2018 and 2024, including major events like Hurricanes Florence and Michael, demonstrate substantial reductions in RMSE and improved correlation for TWL and subtidal components across nearly all NOAA stations.
This method offers a computationally efficient way to account for the missing steric effect, significantly enhancing the physical realism and accuracy of operational TWL forecast guidance in STOFS-3D-Atlantic.

In Person Posters

Enhancing snowpack physics in Noah-MP land model to improve S2S prediction of precipitation and droughts

Ronnie Abolafia-Rosenzweig*, Cenlin He, Michael Barlage, Tzu-Shun Lin, Karl Rittger

One important contributor to uncertainties in precipitation and drought S2S predictions is snowpack-precipitation-soil moisture feedback, which affects precipitation and other weather characteristics over timescales of days to months. As a land component of NOAA Unified Forecast System (UFS), the Noah-MP land surface model (LSM) suffers from some systematic biases in snowpack modeling. In these studies, we enhance model parameterizations for snow compaction and ground snow cover fraction in Noah-MP with the ultimate goal of improving UFS S2S predictions of precipitation and droughts over the western US. These process-level snowpack enhancements substantially reduce the Noah-MP systematical snow and surface albedo biases, modestly reduce 2-m air temperature biases, and experimental simulations are evaluating corresponding impacts on precipitation and drought prediction.

Utilizing UFS Coupled Model Outputs to Build Independent and Coupled Earth System Emulators

Niraj Agarwal*, Timothy A. Smith, Sergey Frolov, and Laura Slivinski

Several machine learning emulators have been successful in replicating atmospheric conditions for medium-range weather forecasts with an accuracy comparable to advanced atmospheric models, all while significantly reducing computational costs. Most of these emulators are trained on the ERA5 reanalysis dataset from ECMWF. We utilize the UFS-Replay dataset that nudges the UFS model outputs to the ERA5 and ORAS5 reanalyses. We have developed a flexible machine learning framework based on Google DeepMind's GraphCast codebase that allows for both single-component (e.g., atmosphere) and multi-component (e.g., atmosphere plus oceans) emulator development – by altering the propagating state vector. The proposed framework provides flexibility as well as strong explicit coupling between the earth system components that can potentially resolve the multi-component covariances, required for strongly coupled data assimilation.

We have successfully trained and validated an atmosphere-only emulator and are now focused on building an atmosphere plus surface ocean emulator, as well as an ocean-only emulator for medium- to extended-range forecasts intervals. The atmosphere plus surface ocean emulator has shown promising results: (i) the atmospheric variables show non-negligible impacts with respect to the atmosphere-only outputs, and (ii) error statistics for ocean variables lie within the range projected by other ocean emulators. However, developing a 3D ocean-only emulator is more complex, needing careful considerations in problem formulation, feature space, loss definition, and hyperparameter tuning due to the slow dynamics of the ocean and inherent correlations among ocean variables and across vertical depths. We will present the latest developments from both emulators, along with lessons learned and future directions.

Developing an S2S Forecast System for Predicting US Coastal Inundation Risk

John R. Albers*, Matthew Newman, Laura McGee, Magdalena Balmaseda, William Sweet, Yan Wang, and Tongtong Xu

Developing predictions of coastal flooding risk on subseasonal-to-seasonal (S2S) timescales is an emerging priority for NOAA. Currently, monthly high tide flooding outlooks consider tide predictions, a sea surface height (SSH) trend component, and persistence. To improve the utility of the current outlooks, future developments will need to replace persistence with SSH forecasts that account for climate signals that are potentially predictable on S2S timescales (e.g., ENSO). To do so, SSH forecasts will consist of, at least in part, output from dynamical forecast models, including the UFS (here GEFSv13 is considered) and ECMWF's IFS.

A first step towards incorporating SSH forecasts includes assessing the ability of current operational models to predict the non-tidal residual (NTR) component of water levels at US coastal gauge stations, which will establish a baseline for NTR forecast skill that the GEFSv13 will need to meet for operational needs. On weekly time scales, IFS SSH predictions evaluated at the tide gauges are more skillful than persistence for nearly all regions for leads between 2 to 6 weeks. When these SSH forecasts are post-processed to include the inverse barometer effect, IFS skill exceeds that of persistence for week 1 as well. Overall, the IFS has sufficiently high levels of deterministic and probabilistic skill to be used in support of operational coastal flood guidance on subseasonal timescales. To assess the utility of the UFS for producing similar guidance, subseasonal NTR skill of the newly available GEFSv13 hindcasts is compared to the IFS.

The roadmap to developing the new NOAA coupled reanalysis

Joao Marcos Azevedo Correia de Souza*, Adam Schneider, Jessica Knezha, Sherrie Fredrick, Sergey Frolov, Jeff Whitaker, Laura Slivinski, and Philip Pigeon

Incorporating coupled processes in Earth System Models is essential for accurately simulating and predicting states of the ocean and atmosphere, especially on subseasonal to seasonal (S2S) time scales. Although such models are scientifically robust, they present a challenge for operations due to their complexity and large computational cost. The cost of running these models increases multi-folds when data assimilation (DA) is taken into consideration. NOAA's Unified Forecast System (UFS) is one such comprehensive earth system model.

The new versions of NOAA's operational medium-range deterministic system (Global Forecast System, GFS), subseasonal-to-seasonal ensemble prediction system (Global Ensemble Forecast System, GEFS), and Seasonal Forecast System (SFS) will incorporate five fully coupled components of the Earth system (i.e., atmosphere, land, ocean, sea-ice, aerosols). This replaces the legacy system that only incorporated atmosphere, land, and ocean waves. The added complexity allows for inclusion of additional sources of predictability through inter-component feedback, allows more accurate initialization of each component through advances in DA, and brings model physics improvements to reduce model biases.

In parallel to the effort of implementing the coupled system operationally, the Physical Sciences Laboratory is developing a global reanalysis that will be used as a testbed for experimentation focusing on the improvement of S2S system, provide initial conditions for reforecasts, and establish the framework for the implementation of strongly coupled data assimilation and the use of machine learning emulators to accelerate the data assimilation process.

Here we describe the plans for the development of the coupled reanalysis and our preliminary results.

A process comparison of two PBL schemes in the Unified Forecast System in a case study of fog forecast

Evelyn Grell, Sara Michelson, and Jian-Wen Bao*

We present an investigation in which two planetary boundary layer (PBL) schemes are compared at the parameterized physical process level in a fog forecast case study. The two PBL schemes in question are two options in the Unified Forecast System (UFS) for global and regional applications. We investigated the difference between the two schemes using both 3-D regional and single-column configurations of the UFS. We found that there are no significant differences in terms of parameterized physical processes. The two schemes differ mainly in the closure assumptions and the magnitudes of parameters used in the parameterization formulations. Both schemes have their own error characteristics in representing essential processes for fog formation, pointing to the uncertainty in PBL process parameterizations when observations and realistic LES baselines are insufficient for process evaluation.

Impacts of a Modified Surface Representation in UFS/NoahMP Simulations

"Michael Barlage*, Joe Olson, Cenlin He, Zhe Zhang, Ronnie Abolafia-Rosenzweig, and Tzu-Shun Lin

The current NoahMP implementation in UFS and MPAS assumes a two-tile representation of the surface where the two tiles are quasi-independent. Separate energy balances are calculated over a vegetated and non-vegetated surface, then area-averaged to send back to the atmosphere. These tiles overlay a single soil column, where the total soil/snow interface flux is used as a top boundary condition for soil/snow thermodynamic updates. In addition, for the vegetated tile, the energy balance is calculated first for the canopy and then for the sub-canopy. This approach, though conservative, can make the calculated fluxes inconsistent with the diagnostic temperature/moisture calculated in the model. Furthermore, due to the low roughness length of bare ground and decreased turbulent interactions below canopy, this method can result in a decoupling of the soil with the atmosphere.

A new approach is implemented and tested where a single "blended" tile is used to represent distributed vegetation elements producing a single energy and water flux for the model tile. The method also attempts to better represent land-atmosphere interactions through approximating the impact of turbulent mixing between canopy elements resulting in stronger coupling between the atmosphere and the soil. To achieve a better representation of the surface, additional datasets are used to estimate the vegetation cover using satellite imagery.

This presentation will show the impact of incorporating a new representation of the NoahMP vegetation structure in UFS simulations evaluated against surface temperature/moisture measurements and flux tower observations.

Exploring MPAS-A outputs on its native hexagonal mesh with Python

Jorge Bravo*

Standardized spatial formats are frequently used when working with data from different models, such as atmospheric, oceanic, or climatic models. These often include gridded data structures, like raster or vector-based formats, depending on the type and resolution of the data.

Vector data represents geographic features by combining attribute information from a database with geometries, such as points, lines, and polygons. On the other hand, Raster data represents information as a regular grid of square cells or pixels, if it is an image, where each cell holds a value corresponding to the phenomenon being measured (e.g., elevation, temperature, land cover). However, in regions with irregular geometry, such as coastlines or terrain boundaries, or areas where greater detail is required, an unstructured mesh can be used to more accurately capture complex real-world features.

Different models across a range of scientific fields make use of unstructured meshes. A notable example is the Model for Prediction Across Scales Atmosphere (MPAS-A), an advanced atmospheric model designed to accurately represent weather systems at both regional and global scales. It makes use of a special unstructured mesh that resembles a honeycomb, allowing variable resolution across the globe. This allows MPAS-A to simulate the atmosphere in high resolution over specific regions, capturing small-scale weather phenomena such as thunderstorms, while maintaining lower resolution elsewhere to efficiently model large-scale atmospheric dynamics.

While the unstructured honeycomb mesh offers flexibility and precision in modeling, it has a notable drawback. Although the data obtained from the MPAS-A model are stored in NetCDF format and can be considered a type of raster, their processing relies on correctly identifying vertices, edges, and centroids. As a result, they lack straightforward and efficient plotting methods, making rapid visual assessment more challenging.

Although there are software tools (e.g. ParaView) that can handle and visualize unstructured meshes, they often come with a steep learning curve, which can become a barrier when quick progress is needed. Similarly, while certain programming languages and libraries support visualization, they come with their limitations. For instance, NCAR Command Language (NCL) has been discontinued. Although Python offers powerful libraries for working with unstructured data, they did not fully meet our needs during the evaluation and visualization work with data obtained from MPAS-A.

Python is currently one of the most popular scripting languages for manipulating scientific data, such as NetCDF, and offers straightforward tools for data visualization. In this work, we introduce a new tool that was custom-built to display MPAS-A data rapidly and efficiently. This is an alternative to default functions that automatically generate triangulated meshes from unstructured data. Our approach also avoids the use of slow for-loops to create individual polygons. Instead, we plot MPAS-A data directly on its native grid, treating each data value as a cell. This approach not only enables interactive visualizations, such as animations or widgets for exploring variables over time, but also significantly reduces rendering time, making it well-suited for applications where rapid data display is essential.

The U. S. Navy Earth System Prediction Capability: Overview and Future Developments

Stephanie Rushley, Richard Allard, Charlie Barron, Jonathan Cristophersen, William Crawford, Maria Flatau, Debbie Franklin, David Hebert, Gregg Jacobs, Matthew Janiga, Tommy Jensen, David Kuhl, Robert Linzell, Fei Liu, Justin McLay, E. Joseph Metzger, Michael Phelps, P. Alex Reinecke, Carolyn Reynolds, James Ridout, Erick Rogers, Clark Rowley, Jay Shriver, Gerhard Theurich, Prasad Thoppil Marcela Ulate, Timothy Whitcomb, Jake Zappala, Luis Zamudio, and Shastri Paturi

The Navy Earth System Predictability Capability (Navy ESPC) is a global coupled forecast system that consists of the NAVy Global Environmental Model (NAVGEM) atmosphere model, the HYbrid Coordinate Ocean Model (HYCOM) and the Community Ice CodE (CICE). This system has been developed to meet the U. S. Navy needs for high-resolution global environmental forecasts on timescales from days to months, and a unique aspect of the system is the eddy resolving ocean model at the ensemble and deterministic resolutions. Navy ESPC-E (ensemble) v1 (version 1), consisting of weekly 45-day 16-member ensemble forecasts, became operational in August 2020.

Navy ESPC-E v1 products are used by the Joint Typhoon Warning Center for tropical cyclone genesis and the National Ice Center for resupply mission and exercise planning. New capabilities and upgrades in Navy ESPC version 2 include one-way coupling to the WAVEWATCH III wave model, an extension of the NAVGEM top from 72 to 110 km and improved representation of the middle atmosphere, the inclusion of arctic land-fast ice in CICE, increased NAVGEM horizontal resolution and inclusion of ocean tides in the ensemble configuration. The deterministic system, Navy ESPC-D v2, is currently undergoing operational testing by Fleet Numerical Meteorology and Oceanography Center (FNMOC). The ensemble system, Navy ESPC-E v2, is currently undergoing pre-transition validation testing. Performance of Navy ESPC v2 compared to Navy ESPC v1 and stand-alone prediction systems will be summarized for both the deterministic and ensemble versions. Future upgrades to Navy ESPC will include improvements to the data assimilation and ensemble design, and eventual replacement of NAVGEM with the Navy's next generation atmospheric model NEPTUNE (The Navy Environmental Prediction sysTem Using a Nonhydrostatic Engine).

Assessing biomass burning emissions in UFS-Chem version 1 during the 2023 AGES+ field campaign

Maggie Bruckner*, Jian He, Congmeng Lyu, Rebecca H. Schwantes, Liam Thomspon, Li Zhang, Barry Baker, Larry Horowitz, Vaishali Naik, Zachary Moon, Georg Grell, Ravan Ahmadov, Jordan Schnell, Siyuan Wang, Alan Gorchov Negron, Brian McDonald, and the AEROMMA Science Team.

The Unified Forecast System with Chemistry (UFS-Chem) is a global atmospheric chemistry and composition modeling system under development that will provide a unified, flexible framework for including chemical and aerosol processes. Here we apply UFS-Chem version 1, which incorporates the chemistry component from the GFDL Atmosphere Model version 4.1 (AM4.1), for May-September 1, 2023. During this period, smoke from Canadian wildfires hazardously degraded surface air quality in the US and the AGES+ (AEROMMA+CUPiDs, GOTHAAM, EPCAPE, STAQS, and others) field campaign took substantial field measurements around major North American megacities. We find that the initial implementation of the Blended Global Biomass Burning Emissions Product (GBBEPx) and its mapping into ozone precursors and aerosols leads to an underestimation of CO associated with the Canadian wildfires and an overestimation of CO associated with biomass burning in Central Africa. Within this work we examine the impacts of increased horizontal resolution and modified emission factor schemes on UFS-Chem predictions. The results of these experiments are assessed through comparison with satellite data, ground-based measurements, and aircraft measurements.

Supporting AI/ML Weather Prediction in NOAA: A Flexible Verification Pipeline with wxvx

D. Alex Burrows*, Anil Kumar, Mariah Pope, and Paul Madden

With the recent ubiquitous development of artificial intelligence/machine learning (AI/ML) algorithms to complement numerical weather prediction, EPIC, along with other NOAA agencies such as EMC, PSL, and GSL have been experimenting with global AI/ML forecast systems. To support this effort within NOAA, EPIC is considering multiple frameworks for forecast verification including EMC's verification system (EVS) and GSL's wxvx system. EVS and wxvx are both wrapper workflows that support the Model Evaluation Toolkit (MET) and METPlus.

While EVS is essentially hardcoded on the NCEP's WCOSS supercomputer, requires nearly a dozen spack-type modules installed, and runs a 31-day and 90-day verification, wxvx was designed to be flexible, handling output from physically-based and AI/ML-based forecast systems through the use of YAML configuration files. Also, since it provides pre-built MET/METplus executables for Linux systems (via its sibling met2go package), it does not require dozens of module loads, making it portable to NOAA, non-NOAA, and cloud provider machines. In addition through YAML configurations, the output statistics can be flexible to the number of forecast cycles and forecast lengths.

Specifically, EPIC will use wxvx to verify model output from the ECMWF's Anemoi framework. This talk will focus on the verification with wxvx and describe the current state and future plans. The current capability of wxvx includes global and regional verification for grid-to-grid comparison of forecasts. In active development is the extension to grid-to-obs verification. In the future and in support of EPIC's community framework, various verification statistics will be hosted at EPIC's web portal (epic.noaa.gov) along with Anemoi forecast output.

Impact of Tomorrow.io's Satellite Constellation on Global Precipitation Observation and Prediction

Forest Cannon*, Brandon Taylor, Randy Chase, Ethan Nelson, and Joe Munchak

The lack of a skillful and reliable high-resolution ensemble is a great challenge for the forecasters in NHC and JTWC to issue TC intensity, structure change, and hazard probability forecasts. To fulfill the gap, the Hurricane Analysis and Forecast System (HAFS) based ensemble prediction system (EPS) was ported to the Amazon Web Service cloud, which was running in real-time in 2023 to provide hurricane probabilistic forecast guidance for NHC forecasters. The stochastic physics in the HAFS ensemble includes Stochastically Perturbed Physics Tendencies (SPPT), Stochastically Kinetic Energy Backscatter (SKEB), and Stochastically Perturbed PBL Humidity (SHUM). The initial and lateral boundary conditions were generated from the NCEP operational GEFS 21-member forecast data. The performance of the HAFS ensemble for 2023 Atlantic hurricane forecasts was compared with the global GEFS and ECMWF ensemble forecasts. This demonstrates the advantages of the higher resolution regional ensemble forecasts for hurricane track, intensity, Rapid Intensification (RI) probability, and hazards probability guidance. The 2024 HAFS ensemble will include the Vortex Initialization, Data Assimilations, and more Stochastic Parameter Perturbations, which is expected to provide better probability forecast guidance for the 2024 Atlantic storms.

ICgen: A method to generate initial conditions from Tomorrow.io's constellation of microwave sounders using score based data assimilation

Randy Chase*, Forest Cannon*, Brandon Taylor, Ethan Nelson, S. Joseph Munchak, and Arun Chawla

Weather forecasts depend on accurate atmospheric initial conditions, traditionally generated through data assimilation (DA) techniques that are computationally intensive and slow to converge. As Earth observation shifts toward high-frequency, low-latency satellite constellations, traditional DA methods struggle to keep pace. To address this, we explore Score-based Data Assimilation (SDA), an AI-driven alternative that offers fast inference, native ensemble generation, and the flexibility to ingest multi-modal, variable-length data.

This work evaluates SDA using Tomorrow.io's constellation of microwave sounders. Based on NASA's TROPICS design, each Tomorrow.io Microwave Sounder (TMS) features 12 channels spanning 91–204 GHz, targeting all-sky retrievals of temperature and humidity. We use Level-2 retrievals derived from bias-corrected brightness temperatures. With seven satellites launched and more planned, the constellation aims for global revisit rates under one hour—ideal for rapid-refresh global forecasts.

We introduce ICgen, an initial condition generator that combines SDA with TMS observations to produce input fields for large-scale AI weather models like FourCastNet. We train an unconditional diffusion model on ERA5 to simulate weather states, then guide the generation process using TMS retrievals via SDA. This enables generation of globally consistent, observation-informed initial states in minutes.

Our results highlight the potential of combining low-latency LEO data with fast AI-based DA systems to produce operationally viable, rapid-refresh forecasts. We also evaluate if TMS-driven initial conditions can yield skillful medium-range forecasts, enabling a streamlined forecasting paradigm powered by new-space sensors and AI-native assimilation.

Multi-scale background error localization using SABER spectral filters with MPAS

Nate Crossette*, Marek Wlasak, Mayeul Destouches, Byoung-Joo Jung, Francois Hebert, and Anna Shlyaeva

In data assimilation, background error covariances (encoded in the B-matrix) can be estimated on-the-fly from an ensemble of perturbed forecasts. Due to computational limitations, only a limited number of ensemble "members" can be produced and used to estimate a B-matrix. So, the resulting estimated B-matrix is prone to sampling noise, typically in the form of spurious covariances at large spatial separations. The application of a localization matrix through an element-wise Schur product can preserve covariances up to a certain length-scale while removing the generally spurious covariances beyond a chosen length-scale. However, background covariances can occur at a variety of scales, from convective (short) to synoptic (long), so the ability to localize ensemble covariances at multiple scales allows for an improved analysis. The UK Met Office originally implemented generic multi-scale localization with spectral filtering methods in the SABER (System Agnostic Background Error Representation) package for use in their global DA system. SABER's generic covariance models are developed with the intention to allow for application into new systems with minimal effort. This presentation will show the progress towards applying the generic spectral filtering methods for multi-scale ensemble localization to the MPAS (Model Prediction Across Scales) model.

Into the Tempest: Black Swift's Autonomous Eye in the Hurricane Providing Critical Data for Improved UFS and Ecological Understanding

Jack Elston*

"Addressing persistent data gaps in the dynamic coastal, marine, and ocean environment, particularly within severe weather systems like hurricanes, remains critical for enhancing the Unified Forecast System (UFS). Black Swift Technologies (BST) offers a transformative approach through its advanced Unmanned Aerial Systems (UAS), providing unprecedented in-situ data from previously inaccessible regions, directly relevant to advancements in the Hurricane Analysis and Forecast System (HAFS) and broader ecological understanding.

BST's presentation will showcase the capabilities and impact of its S0 Air-Deployed UAS, a purpose-built platform for boundary layer observations in tropical cyclones. Developed through collaboration with NOAA, the S0 is designed to mimic the operational paradigm of radio dropsondes while offering significantly enhanced data density and cost-effectiveness. This low-cost, air-deployable system is engineered to gather critical kinematic and thermodynamic data, including 3D winds, pressure, temperature, humidity, and sea surface temperature, within the challenging lower altitudes of hurricanes.

The technical impressiveness of the S0 lies in its ability to conduct autonomous targeted observations, even in extreme conditions characterized by sea spray and heavy precipitation. Notably, during the 2024 hurricane season, BST's UAS achieved record-breaking data collection, including over 20 hours of low-level storm data and the measurement of the fastest recorded gust speed on Earth in Hurricane Milton. The presentation will delve into the sensor integration and data delivery mechanisms that enable the provision of high-resolution, real-time data to NWS servers, attracting the attention of meteorologists and highlighting the practical utility for operational forecasting.

Furthermore, BST’s expertise extends beyond data acquisition to include advanced UAS navigation and sensor reactive control schemes, allowing for modifications of flight plans based on real-time measurements. This capability ensures targeted sampling and characterization of critical atmospheric features, providing a more comprehensive dataset for assimilation into advanced models like HAFS.

By significantly increasing the temporal and spatial sampling within hurricane environments, Black Swift Technologies’ UAS platforms are contributing to improved understanding of storm dynamics and intensification processes, which are foundational to enhancing the predictive capabilities of the UFS for coastal and marine regions. While the primary focus is on hurricane applications, the high-fidelity environmental data collected by BST’s UAS also holds potential for informing ecosystem predictions by providing detailed atmospheric and surface condition information relevant to ecological modeling. This presentation will underscore how BST’s innovative UAS technology serves as a powerful tool for advancing the UFS and its applications across coastal, marine, ocean, and ecological domains.

Predicting Fire Emissions for subseasonal-to-seasonal (S2S) Forecasts

Gonzalo A. Ferrada*, Li (Kate) Zhang, Yunyao Li, Ziheng Sun, Shan Sun, Daniel Tong, Gonzalo A. Ferrada, Li (Kate) Zhang, Yunyao Li, Ziheng Sun, Shan Sun, and Daniel Tong

We currently face two major challenges in fire weather prediction. The first is the substantial uncertainty in fire emissions, reflected by significant discrepancies among existing wildfire emission inventories. To minimize the uncertainty of existent fire emission inventories, we developed an Ensemble Fire emission inventory (EnsemFire) based on 7 different fire emission inventories and applied it into the UFS-Aerosols model, which is an Unified Forecast System (UFS) fully coupled (Atmosphere-Ocean-Sea Ice-Wave-Aerosols) model for S2S prediction. We performed experiments to quantify and evaluate the fire aerosol performance in the UFS-Aerosols model for August 2016, August 2017 and March 2018. EnsemFire outperformed NOAA's operational fire emission inventory, GBBEPx v4, by reducing biases and root-mean-square errors of aerosol optical depth in the UFS when compared against MERRA-2 reanalysis. The second is the challenge of forecasting fire emissions in advance and effectively incorporating them into subseasonal-to-seasonal (S2S) prediction systems. To address this, we employed statistical and machine learning (ML) methods to predict fire emissions for S2S prediction (next 35–45 days). The predicted fire emission is underestimated without capturing the daily variation when using the statistical method, while the results of using ML method to predict fire emissions on the S2S scale are encouraging, demonstrating significantly better performance compared to statistical methods. The fire emissions predicted by the ML method closely align with observed emissions from GBBEPx v4 and EnsemFire, capturing day-to-day variations remarkably well.

Advancing Snow Temperature Data Assimilation in Global Forecast System (GFS)

Yanjun Gan* and Clara S. Draper

Accurate numerical weather prediction (NWP) requires reliable initialization of all Earth system components, especially the land surface, which influences atmospheric processes through energy and moisture exchanges. In a previous study with NOAA's Global Forecast System (GFS), a coupled land/atmosphere Ensemble Kalman Filter (EnKF) was used to introduce a soil moisture and soil temperature analysis from the assimilation of standard atmospheric observations and screen-level temperature and humidity. Since the presence of snow on the surface insulates the soil from the atmosphere, this approach does not update the soil states under snow. The current work tests whether the coupled land/atmosphere EnKF can be expanded to also do a snow temperature analysis. The EnKF assimilates the standard atmospheric observations plus screen-level temperature and humidity, and updates the atmosphere, first-layer snow temperature, and soil temperature and soil moisture, with the goal of producing physically consistent land surface analyses. A series of experiments are conducted to assess the added value of expanding the EnKF to also analyze snow temperature.

Tropical Variability in GraphCast vs GFSv16: What does the Neural Network learn?

Maria Gehne*, Vijit Maithel, Juliana Dias, and Brandon Wolding

Machine Learning based weather prediction (MLWP) is becoming increasingly common. Trained on reanalyses, these models incorporate no underlying physical equations, but rather learn common patterns in the data. The largest advantage of MLWP is the reduction in computing resources for each forecast compared to traditional numerical weather prediction (NWP).

Here we consider 3 years of the Global Forecast System v16 (GFSv16) operational forecasts and two versions of GraphCast. The GraphCast versions are identical in their training on ERA5 reanalysis and differ in their initial conditions, GFS vs Integrated Forecast System (IFS).

We evaluate these models for their representation of tropical dynamics and coupling to large-scale convection. A well-known characteristic of MLWP is that forecasts tend to be more “smooth” than NWP forecasts and analyses. We quantify this behavior using space-time power and coherence spectra and show that MLWP forecasts loose power at higher wavenumbers and frequencies very quickly with lead time. This leads to less small-scale variability and higher coherence for larger-scale phenomena in MLWP, for example for convectively coupled Kelvin waves. Further we show preliminary results for precipitation-convection coevolution and differences in GraphCast forecasts related to the initial conditions.

Tomorrow.io operates a km-scale weather prediction model adapted from generative corrective diffusion

Maxfield Green*, Forest Cannon, Brandon Taylor, Mariah Pope, Arun Chawla, Randy Chase, Luke Conibear, and Kushal Keshavamurthy

FOCUS is a regression- and diffusion-based forecasting system adapted from NVIDIA’s CorrDiff architecture. FOCUS emulates mesoscale physical processes while flexibly conditioning on diverse inputs at inference time. The system ingests global NWP ensemble forecasts alongside near real-time observations, including radar, geostationary satellite imagery, and site-level sensors. The pairing of these data contributes to a locally calibrated dispersive representation of large and mesoscale weather evolution. Forecasts are evaluated using station-level (METAR) verification metrics, demonstrating improved skill for core variables such as 2-meter temperature. Further, using specifically trained variants of the model, we extend beyond core variables to challenging phenomena like hail. FOCUS currently supports automated guidance across the U.S. via Tomorrow.io’s API and platform, with ongoing expansion into non-CONUS regions, including experimental domains in South America and Africa.This work represents a step toward globally scalable, observation-aware probabilistic guidance that complements and extends traditional NWP.

Weather Foundation Models: Global to Regional to Hyper-local

Cristian Bodnar, Nikhil Shankar, and Jayesh K. Gupta*

Weather foundation models (WFMs) have recently set new benchmarks in global forecast skill, yet their adaptability to sector-specific operational needs remains largely unexplored. In this talk, we demonstrate how a 1.5B-parameter WFM can be fine-tuned on domain-specific observational data to deliver hyper-local, asset-level forecasts critical for weather-sensitive operations.

Using specific case-studies, including transmission-line weather stations, wind-farm met masts, and specialized sensors, we show how this approach transforms global models into precision tools for operationally critical forecasts.

Our results demonstrate that WFMs, when post-trained with modest amounts of high-fidelity sector-specific data, can serve as a versatile foundation for next-generation operational intelligence across diverse weather-impacted domains, from energy and transportation to emergency management. We discuss the generalizable methodology for adapting global weather models to hyper-local applications and the implications for building resilient, weather-aware systems across critical infrastructure sectors.

Enabling And Validating Ensemble Data Assimilation Scenarios In JEDI / FV3-Based Models Using The SkyLab Workflow

Clémentine Gas*, Yannick Trémolet, and Ricardo Todling

The Ensemble Data Assimilation (EDA) approach involves using multiple model simulations, each initialized with slightly different conditions. The goal is to account for uncertainty in the model and the observations and create an ensemble of analyses to represent the probability distribution of the analysis. From the EDA we can generate an ensemble of forecasts, used for decision making purposes and the ensemble contribution in the background error matrix representation ("ensemble B"). This method has been shown to be effective in improving the accuracy and uncertainty estimates of forecasts and has been widely used in weather forecasting applications.

The Joint Center for Satellite Data Assimilation (JCSDA) has developed a comprehensive workflow (SkyLab) to facilitate the execution of diverse EDA scenarios. These scenarios can involve different instruments, algorithm choices such as background error covariance or cost function, and even different weather models. The SkyLab workflow serves as the orchestrator, driving the underlying JEDI code (Joint Effort for Data assimilation Integration) to execute the different EDA experiments.

In this study, we present an overview of our workflow's architecture and an analysis of the results provided by EDA experiments in the context of JEDI/FV3-based models assimilation: the primary focus is to compare the performance of the EDA with that of the traditional LETKF (Local Ensemble Transform Kalman Filter) approach used in operations. Key metrics such as ensemble spread and forecast error of the high resolution are analyzed, highlighting the strengths and weaknesses of an EDA approach.

The findings from this study will contribute to the ongoing efforts to optimize the JEDI/FV3-based models data assimilation system for more reliable atmospheric simulations.

An Agentic LLM Framework for Fast and Interpretable Data Queries: Application to STOFS

Aryan Harooni*, Hooman Moghimi, Atieh Alipour, and Saeed Moghimi

We present a novel system that leverages function-calling large language models (LLMs) in conjunction with a higher-level coordinating LLM to enable agentic behavior in data querying and interpretation tasks. This architecture separates structured data retrieval from reasoning, allowing one model to interface directly with local functions and another to orchestrate high-level goals, interpret results, and engage in natural dialogue. We evaluate this approach on STOFS water level data, demonstrating significant improvements in the efficiency and usability of complex data access. Our results show that combining callable functions with agentic orchestration enables nonexpert users to extract meaningful insights from structured datasets through simple natural language interaction, reducing both time and technical overhead.

Assess snowpack impact on S2S predictions of drought within global UFS SFS modeling framework

Cenlin He (NSF NCAR)*, Weiwei Li (NSF NCAR), Ronnie Abolafia-Rosenzweig (NSF NCAR), Michael Barlage (NOAA GSL), and Tzu-Shun Lin (NSF NCAR)

Winter and spring snowpack anomalies could affect summer precipitation and drought conditions in many global regions through land memory and feedback among snow, soil moisture, and precipitation. In this study, we assess the global UFS/NoahMP simulations of summer precipitation and drought conditions affected by an improved treatment of winter and spring snowpack physics in Noah-MP land surface model within the UFS SFS modeling framework. The improved snowpack physics have been recently developed by our team to better capture the observed snow density and snow cover fraction in western U.S. mountains as well as reduce surface temperature bias in the coupled WRF/NoahMP model. Here, we aim to quantify the global impact of this new snow scheme on S2S prediction of precipitation and drought to evaluate if the prediction is improved as well. We aim to assess this across C96, C192, and C384 UFS spatial resolutions.

Packaging UFS Applications for Use in Community-based Development

Christina Holt*, Paul Madden, Emily Carpenter, and Janet Derrico

Using the NOAA Global Systems Lab's MPAS App, an application that builds, configures, and runs the Model for Prediction Across Scales in a variety of configurations of scientific interest via a workflow that also executes pre- and post-processing components, we explore options for packaging, publishing, and using NWP components in research and operational environments to meet the needs of a diverse user community.

The MPAS App is a research-ready application built around the uwtools Python package. Its capabilities include running retrospective and real-time runs for cold-start regional and global forecasts initialized from operational model data. Efforts to expand it to include ensemble capabilities and data assimilation are underway. The App leverages pytest and pytest-regressions for rigorous testing, featuring a broad suite of regression tests that range from lightweight to run on user workstations to computationally expensive, requiring significant HPC resources.

In this talk, we outline plans to package and release the App as a traditional Python package via Conda, while maintaining pip compatibility for use cases that do not support it. We also demonstrate how the utilities for configuring and running an experiment can be seamlessly integrated into the NCO-required structure traditionally expressed as collections of bash and Python scripts.

Quantifying the Value of Convection-Allowing Global-Nested Ensembles for Extended-Range Severe Weather Forecasting

Michael J. Hosek*, Kimberly A. Hoogewind, Adam J. Clark, Lucas Harris, Kai-Yuan Cheng, and Linjiong Zhou

Background/objectives: Convection-allowing model (CAM) ensembles produce valuable information on convective mode and evolution that coarser, convection-parameterizing models cannot. This information aids forecasters in formulating severe weather outlooks at lead times of 1 to 2 days. At longer lead times, there is not an operational ensemble CAM capacity available in the United States, so forecasters rely on environmental information from convection-parameterized model ensembles to assess severe convection potential. Little has been done to study the value of CAM ensembles for extended-range severe weather forecasts outside of testbed experiments. In this study, we objectively quantify the severe weather forecast skill of a CAM ensemble and compare it to a convection-parameterized ensemble through lead day 15.

Methods: Random Forests (RFs) are used to construct daily severe convection forecasts from ensemble forecast information. The CAM ensemble is identical to the convection-parameterized ensemble except for a 2-way nested CAM over the contiguous United States, enabling a direct comparison of how valuable simulated storm attributes are to the RF forecast.

Results: The nested-CAM ensemble RF improved daily severe weather forecasts through both objective and subjective forecast verification through day 7. Interrogation of the RF via explainable-AI techniques showed that simulated updraft helicity is the key predictor which improved RF forecast skill.

Conclusions: A CAM ensemble would provide value in severe weather forecasting out through at least day 7. The RF methodology can be used to compare other convection-parameterized/CAM ensembles (e.g., different dynamical cores) and also provide insight into which variables contribute to a difference in performance.

Evaluation of Aerosols Forecast Skill in GCAFS Using NOAA’s Global Aerosol Reanalysis Product

Bo Huang* and Mariusz Pagowski

A five-year (2018-2022) global aerosol reanalysis was produced using NOAA’s Global Chemistry and Aerosol Forecast System (GCAFS) model and the Joint Effort for Data assimilation Integration (JEDI). To evaluate aerosol forecast skill in GCAFS, two sets of 120 ten-day forecasts were produced, initialized at 00Z on the 1st and 15th of each month in 2018-2022 from the reanalysis and the model free run, respectively. Our evaluation focused on total aerosol optical depth (AOD). Validation against AErosol RObotic NETwork (AERONET) AOD showed that the GCAFS forecasts initialized from the reanalysis outperformed those from the model free run, reducing AOD biases beyond ten days and improving correlations up to six days. Furthermore, we calculated the anomaly correlation coefficients (ACC) for AOD in the GCAFS forecasts relative to the Visible Infrared Imaging Radiometer Suite (VIIRS) AOD climatology from NOAA NESDIS. The GCAFS forecasts initialized from the reanalysis maintained a higher global mean AOD ACC for up to six days, though falling below 0.5 at Day 3. In contrast, the global mean AOD ACC of the GCAFS forecasts initialized from the model free run dropped below 0.5 on Day 1. We are currently assessing the seasonal variability of the AOD forecast skill in GCAFS using ACC relative to both VIIRS and AERONET AOD climatology. The results will be presented.

Improving Computational Efficiency of JEDI GETKF for Coupled UFS Applications

Bo Huang*, Sergey Frolov, Jeffrey S. Whitaker ,Cory R. Martin, Wei Huang, Travis J. Elless, Anna Shlyaeva, and Steve Herbener

The ensemble component of NOAA's current operational atmospheric data assimilation (DA) system employs the gain-form ensemble transform Kalman filter (GETKF), with the model-space localization applied in the vertical and observation-error inflation in the horizontal. GETKF was recently implemented in the Joint Effort for Data assimilation Integration (JEDI), as part of NOAA's Research-to-Operations (R2O) effort to utilize JEDI for future operational Unified Forecast System (UFS) applications. To match the computational efficiency of the existing operational GETKF implementation based on the Gridpoint Statistical Interpolation (GSI), NOAA PSL and NOAA EMC are optimizing JEDI GETKF in collaboration with the Joint Center for Satellite Data Assimilation (JCSDA). Recent enhancements to JEDI GETKF include optimization of load balancing, memory usage and interpolation routines, and implementation of "reduce obs space" feature and linearized observer for ensemble perturbations. Initial tests showed that these enhancements enabled JEDI GETKF to approach the wall-clock-time performance of the operational GSI-based implementation. Our current work focuses on improving I/O in JEDI GETKF and conducting cycling experiments using the NOAA EMC global workflow. We will further compare its performance with the operational GSI GETKF in a more complete operational observation configuration. Detailed enhancements of JEDI GETKF and its cycling experiment results will be presented.

Run global-workflow with Singularity container

Wei Huang*, Mark Potts, David Burrows, and Rahul Mahajan

Global-workflow is used to run NOAA-EMC numerical models as a single package. It needs compiler and spack-stack to compile and run on multiple platforms. With compiler and spack-stack are continuously updating, so it has to update on every platform, which is tedious and time consuming. By using singularity containers, one can just use the same compiler, and build spack-stack based on this compiler and pack them together within a singularity image file (SIF), then one can use such singularity containers on all platforms. EPIC has used a container with ubuntun, with intel compiler, and spack-stack 1.6.0 to compile global-workflow and make it able to run on AWS, and NOAA on-premises computer ursa.

Simulation of Landfall Dynamics and Influencing Factors of Cyclone Remal Using High-Resolution WRF-ARW Model

Faozia Anzum Itu* and Md. Saiful Islam

Timely and accurate simulation of tropical cyclone dynamics is vital for disaster preparedness and risk mitigation. This study investigates the landfall characteristics and influencing factors of Cyclone Remal using the WRF-ARW (v4.6.0) model with a 9 km resolution. The simulation period spanned

May 25 (0000 UTC) to May 27 (0900 UTC) using NCEP FNL data. The model effectively captured key storm parameters, including sea level pressure, wind speed, and rainfall distribution. Simulated minimum central pressure (980 hPa) closely matched the observed 978 hPa, while maximum sustained wind speed was marginally overestimated. The predicted track showed a mean positional error of 101.49 km and low timing error, demonstrating improved track accuracy closer to landfall. Vertical profiles revealed strong convective activity, a persistent moist core, and a warm anomaly up to 100 mb, indicative of a well-organized system. Surface latent heat and moisture flux peaked before landfall, fueling storm intensity. Post-landfall decay was realistically represented through declining humidity and fluxes. The model successfully reproduced rainfall bands and low-level vorticity fields, enhancing interpretation of storm evolution. This study underscores the utility of high-resolution WRF simulations in operational forecasting and highlights areas for improving track and intensity prediction, particularly in data-sparse oceanic regions. Insights from this work contribute to refining early warning strategies in the North Indian Ocean basin.

Informing the Dynamical Core Choices for the UFS: FV3 and MPAS

Christiane Jablonowski* and Timothy Andrews

The dynamical core for the Unified Forecast System (UFS) is the FV3 finite-volume dynamics package on the cubed-sphere grid, which was developed at NOAA's Geophysical Fluid Dynamics Laboratory. Currently, FV3 drives all UFS prediction models, including the convection-allowing UFS Short-Range Weather (SRW) application and its pre-operational Rapid Refresh Forecast System version 1 (RRFSv1). However, efforts are now underway to also consider an alternative dynamical core for future RRFS releases, which is the Model for Predictions Across Scales (MPAS) dynamics package developed at NCAR.

This paper further informs these dynamical core choices for the UFS. In particular, it sheds enhanced light on the dissipation characteristics of both FV3 and MPAS, evaluates their physics-dynamics coupling philosophies, and compares the representation of convection-dominated motions in both dynamics packages. This is accomplished via a suite of idealized test cases, which include examples from the 2025 Dynamical Core Model Intercomparison Project (DCMIP-2025), such as a new squall line test case on a reduced-size Earth. Particular attention is paid to the convergence characteristics of the dynamical cores as well as the numerical stability of the dissipation mechanisms.

HRRRCast: a data-driven emulator for regional weather forecasting at convection allowing scales

Daniel Abdi, Isidora Jankov*, Paul Madden, Vanderlei Vargas, Timothy Smith, Sergey Frolov, Monte Flora, and Corey Potvin

The High-Resolution Rapid Refresh (HRRR) model is an operational weather forecasting system that provides high-resolution, timely forecasts across the contiguous United States (CONUS). To augment and accelerate this capability, we are developing a data-driven emulator of HRRR using advanced machine learning techniques. Our objective is to deliver computationally efficient alternatives that match or exceed the accuracy of traditional numerical weather prediction models.

Our development has primarily focused on ResHRRR, a ResNet-based architecture. ResHRRR leverages convolutional neural networks enhanced with squeeze-and-excitation blocks and Feature-wise Linear Modulation (FiLM) to improve predictive accuracy. It also supports probabilistic forecasting via the Denoising Diffusion Implicit Model (DDIM). To handle longer lead times, we train a single model to forecast multiple horizons (1h, 3h, and 6h) and employ a greedy rollout strategy for prediction.

When tested on composite reflectivity across the full CONUS at a reduced resolution of 6 km with three ensemble members, ResHRRR outperforms HRRR at the 20 dBZ threshold and achieves comparable performance at 30 dBZ.

This work extends the StormCast model (Pathak et al., 2024) in several key ways:

- Training on the full HRRR domain,
- Extending lead times beyond 1 hour,
- Training directly on analysis data (rather than inadvertently using +1h forecasts after analysis as in StormCast),
- Incorporating future GFS forecasts as inputs, enabling a downscaling component that significantly improves long-lead prediction accuracy.
- Detailed results will be presented at the upcoming workshop.

The JCSDA Community Radiative Transfer Model (CRTM) : A Community R2O model

Benjamin T. Johnson (UCAR/JCSDA)*, Cheng Dang (UCAR/JCSDA), Yingtao Ma (NOAA/STAR), Isaac Moradi (NASA GMAO), Patrick Stegmann (NASA Code 613), and Lucas Howard (CU Boulder)

The Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) is a key enabling technology for the simulation of and assimilation of satellite radiance observations in numerical weather prediction systems. CRTM provides fast, flexible, and accurate simulation of top-of-atmosphere radiances and Jacobians, making it a critical component of the observation operators used within the Unified Forecast System (UFS), including both the legacy GSI and the JEDI data assimilation systems. CRTM currently simulates sensors operating in Ultraviolet, Visible, near-Infrared, Infrared, Submillimeter and Microwave wavelengths, with plans to expand to Far-Infrared in the future.

This presentation will provide an overview of CRTM as a mature Research-to-Operations (R2O) model, highlighting its transparent development practices, open-source governance, and strong alignment with community needs. We will describe recent scientific and technical advances, including improved emissivity handling, expanded sensor support, and increased portability. We'll also discuss ongoing efforts to support aerosol and cloud assimilation. Finally, we introduce CRTM-AI, a new hybrid modeling effort aimed at augmenting traditional radiative transfer with neural network emulation to enable faster, more scalable assimilation of hyperspectral and microwave data in future UFS configurations.

New Capabilities in METplus Verification for Subseasonal to Seasonal Scales

Christina Kalb*, John Opatz, Mrinal Biswas, Michelle Harrold, John Haley-Gotway, Minna Win-Gildenmeister, and George McCabe

Verification and diagnostic activities are important contributors to the processes of using and improving models. The METplus system was designed to allow multiple verification options in a consistent framework with a quick setup. It originated with the Model Evaluation Tools (MET), developed over 15 years ago to provide reproducible and consistent statistical evaluation, and has since evolved into an umbrella verification and diagnostic system that contains several components. These components include METcalcpy, METplotpy, METdataio, and the ability to create Python scripts combining the different METplus components for truly flexible verification options. Over the past few years, many diagnostic and verification metrics have been added to the METplus system to examine the predictability of phenomena on subseasonal to seasonal time scales.

This presentation will provide an update and description on some of the new metrics and capabilities available within METplus for subseasonal to seasonal verification. Specific examples include a new case using the Seasonal Forecast System (SFS) 2-meter temperature that highlights METplus' ability to utilize separate climatologies for the forecast and observational datasets. This new capability is also used in another new use case demonstrating the evaluation of SFS 1-meter soil moisture over a 30-year time period. This soil moisture use case includes a calculation of the 30-year climatology as well as computation of statistics and the creation of graphics to display the results. Examples of the setup and output from these use cases will be demonstrated.

Verifying smoke and dust predictions from RRFS prototypes using METplus within the UFS SRW Application

Michael Kavulich, Jr.*, Michelle Harrold, Gerard Ketefian, Jeff Beck, Will Mayfield, and Vanderlei Vargas

The inclusion of simulated smoke and dust particles in the upcoming Rapid Refresh Forecast System (RRFS) promises to add valuable data for predictions that protect human health and property. This is not only due to the direct ability for these variables to inform advisories on impacts to human health, but the impact of smoke on meteorological fields, especially for large-scale and high-end wildfire events. In the Developmental Testbed Center (DTC) we have, over the past few years, introduced a robust framework of verification tasks in the Unified Forecasting System (UFS) Short-Range Weather (SRW) Application based on the enhanced Model Evaluation Tools (METplus). These verification tasks can not only be used to verify output from the SRW against real-world observations, but can evaluate staged data from prototypes of the RRFS, comparing model output to observations, other forecasts/analyses, or both. In this presentation, we will describe the implementation of METplus-based verification of smoke-and-dust-related air quality variables in the framework of the UFS SRW App. Furthermore, we will present the results achieved with this verification framework on RRFS prototypes with smoke and dust output, as well as plans for future verification in the UFS, both within SRW and across other UFS Applications.

UFS Data Assimilation Community Support Framework and Infrastructure for the Research-to-Operations Process

Jong Kim*, Chan-Hoo Jeon, Edward Snyder, and Gillian Petro

Data assimilation (DA) is a key component in the development of the Unified Forecast System (UFS). The ability to combine observations and model predictions to create more reliable initial conditions will improve the predictability and accuracy of the UFS Weather Model forecast system. The Joint Effort for Data assimilation Integration (JEDI) system, developed by the Joint Center for Satellite Data Assimilation (JCSDA) in collaboration with NOAA and cross-agency partners, allows for faster development and research-to-operations (R2O) for advanced DA to meet the requirements of the UFS. A JEDI-based UFS land DA workflow system has been developed and presented as a prototype for the DA community support framework. Various Agile software configuration methods are used to continuously synchronize the land analysis capability against the operational Global Forecast System (GFS), including the JEDI Configuration Builder (JCB) and Unified Workflow Tools. In partnership with the Consortium for Advanced Data Assimilation Research and Education (CADRE), EPIC aims to build the UFS data assimilation software infrastructure and support framework and accelerate the DA community workforce pipeline development and R2O process through training and outreach. In this presentation, we summarize the current status of the UFS Land DA System and future plans to support both the Land DA System and additional DA applications.

UFS Weather Model Architectural Layout, Hierarchical Testing Framework, and Application Development for Continuous Code Integration

Jong Kim*, Fernando Andrade Maldonado, Michael Lueken, Chan-hoo Jeon, Gillian Petro, Benjamin Koziol, and Brian Weir

As a community-based, coupled, comprehensive Earth modeling system, the Unified Forecast System (UFS) and its applications continue to evolve to support local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. As part of the UFS code consolidation process, an increasing number of high-level regression and workflow end-to-end test cases are being integrated to ensure that various test parameters meet the goals of operational and development projects. These parameters cover compiler and build options, coupled model configuration and applications, model resolution and grid, physics suites, input/output (IO), parallel threading and decomposition, model input file options, cycle dates, etc. To streamline the UFS software development lifecycle and facilitate an efficient Research-to-Operations (R2O) pipeline, software architecture and infrastructure layers are constantly updated for an Agile release of the UFS Weather Model and applications. In this presentation, we provide an overview of the UFS development ecosystem, where continuous code integration processes and tools are applied in the hierarchical testing framework, including Jenkins automation tools, containers, spack-stack, Unified Workflow tools, etc.

Accelerating Forecast Innovation: EPIC’s Collaborative Framework and HPC-Driven Transparency

Anna Kimball* and Kris Booker

The NOAA Earth Prediction Innovation Center (EPIC) program has enabled an accelerated pace of numerical weather prediction innovation through their collaboration with government, academic, and enterprise sectors. Utilizing a common modeling framework, the UFS (Unified Forecast System), has allowed once siloed atmospheric modeling groups to effectively collaborate. However, the greater challenge has come from constraints that kept organizations from accessing high performance computing platforms capable of running new modeling innovations at scale. EPIC has solved this dilemma by providing UFS community contributors public access to detailed insights from these high performance computing (HPC) platforms. Every contribution considered for integration is extensively tested through a CI/CD pipeline on various NOAA research and development high performance computing system (RDHPCS) platforms with performance capabilities similar to the Weather and Climate Operational Supercomputing System (WCOSS-2). Systematically capturing data such as walltime and corehours for each model run provides contributors with detailed insights into computational efficiency and resource usage. This enables the community to track the evolution of model updates over time, offering quick insight into how performance and efficiency improve successively. The design supports future integration of scientific forecast skill, allowing users to correlate computational costs with forecast accuracy. The data collected is processed and displayed to contributors through the EPIC Community Portal creating more transparency between EPIC and the broader community. This openness empowers contributors, researchers, and developers to identify trends, compare model versions, and contribute to continuous model refinement. Ultimately, strengthening the feedback loop between operational teams and the user community, accelerating improvements in forecasting quality and operational efficiency.

EPIC’s Unified Forecast System Short Range Weather App for Wildland Fire

Samantha Kramer*, Ben Kirtman, and Natalie Perlin

Wildfires have become increasingly destructive in recent decades and their impacts are felt nationwide. Forecasters rely on fire weather metrics such as vapor pressure deficit and wind speed to estimate where and when conditions have the potential to exacerbate wildfire management efforts. These estimations are critical for (1) wildfire response and safety, (2) allocation of resources, and (3) communication of risk. As the impacts and extent of wildfires expand, we also need to expand the length and availability of fire weather forecast variables. Subseasonal forecast products (forecast through 35-45 days) are now available from the Unified Forecast System (UFS) Mid-Range product but are largely untested for fire needs. Our cross-sector approach has identified key fire weather metrics and what level of forecast skill, reliability, and testing must be done to earn trust and ensure future use of fire weather forecast data at multiple lead times.

Evaluation of the UFS Mid-Range forecasts show promise for several key fire weather indicators such as temperature and vapor pressure deficit. Wind forecasts at all lead weeks demonstrate a low-magnitude bias and limited variability when compared to observations across the Continental U.S. To solve this key problem, the Earth Prediction Innovation Center (EPIC) Short Range Weather

Application (SRW App) was implemented to dynamically downscale wind speed forecasts for key wildfire case studies. We will show results of dynamically downscaled winds compared to observations, reanalysis, and native grid UFS data, as well as the implications for use in fire weather applications.

Diagnosing Air-Sea Interaction and Marine Boundary Layer Processes in NOAA's Seasonal Forecast System Using DYNAMO Cases

Weiwei Li*, Shan Sun, Jimy Dudhia, and Man Zhang

To support the development of the NOAA Seasonal Forecast System (SFS), the Developmental Testbed Center (DTC), collaborating with the SFS developmental team, conducted evaluations of air-sea interactions and their interplay with moist physics and other model components in the Unified Forecast System (UFS). Two cases from the Dynamics of the Madden-Julian Oscillation Field Campaign (DYNAMO) field campaign were simulated using the fully-coupled UFS configuration at C384 (~25 km) resolution with the High-Resolution 4 (HR4) physics prototype, aiming to identify any issues that might exist even at higher resolution.

Results reveal delayed peaks in surface heat fluxes, a drier lower troposphere, suppressed diurnal amplitude, and reduced column-integrated moist static energy (MSE) compared to observations or reanalysis. The MSE budget analysis suggests that the weakened diurnal MSE signal and atmospheric dryness cannot be explained by advection or surface flux biases. Time-height composites of local MSE tendency indicate inefficient boundary layer development and limited vertical energy transport, likely contributing to delayed convective initiation and shallow vertical growth. These findings highlight potential issues in the model physics that may limit the skill for the source of predictability on subseasonal-to-seasonal (S2S) timescales, such as the Madden-Julian Oscillation (MJO) and monsoonal systems.

Improving GFS Surface Fields Using a Deep Learning Bias Correction Model

Jianjun Liu*, Jun Wang, Linlin Cui, Wei Li, and Jacob Carley

Numerical weather prediction (NWP) models provide essential weather forecasts but still exhibit systematic errors. NCEP recently developed a U-Net-based bias correction model that incorporates a convolutional block attention module to enhance feature representation through attention mechanisms. Initially applied to reduce bias in 2-m temperature (T2m) over the CONUS domain with promising results, the model is extended in this study to correct GFSv16 forecasts of four variables over the global domain: T2m, 2-m dewpoint temperature (DPT2m), and maximum/minimum 2-m temperature (Tmax/Tmin). Specifically, T2m and DPT2m models were trained with ERA5 data, while Tmax/Tmin with GDAS data from March 2021 to February 2024. Evaluation from March 2024 to March 2025 showed that the models significantly improve the annual and seasonal means of GFS forecasts in terms of mean bias and root-mean-square error (RMSE). Notably, models trained on limited lead times (72 h for T2m and DPT2m; 24 h and 72 h for Tmax and Tmin) generalized effectively across the full range of 6-384 h. Compared to original GFS forecasts, the models achieved reductions in mean bias (RMSE) by 52.3% (22.4%) for T2m, 95.7% (23.2%) for DPT2m, 85.8% (10.2%) for Tmax, and 80.1% (9.2%) for Tmin, with variable improvements across different lead times. These results highlight the effectiveness of the proposed deep learning-based bias correction for global NWP forecasts. Future work will extend this framework to additional GFS variables and the upcoming GFSv17 products.

Storm Surge and Coastal Inundation Nowcasts/Forecasts During Hurricanes Helene and Milton

Yonggang Liu*, Haibo Xu, Kaili Qiao, Sebin John, Sieu-Cuong San, Robert H. Weisberg, Jing Chen, Lianyuan Zheng, Sherryl Gilbert, Steven A. Murawski, Gary T. Mitchum, and Thomas K. Frazer

A daily automated coastal water level (storm surge) nowcast/forecast guidance system has been developed by the USF Ocean Circulation Lab based on the West Florida Coastal Ocean Model (WFCOM) and the very high-resolution Tampa Bay Coastal Ocean Model (TBCOM). Both models are configured to perform realistic simulations of ocean circulation and water levels which are then combined with tide gauge observations to provide 3-day hindcasts and 3.5-day forecasts of coastal water level along the West Florida coast (http://ocgweb.marine.usf.edu/Models/SeaLevel/). The experimental product was maintained during the approach and passage of Hurricanes Helene and Milton, and provided critical storm surge forecasts to a broad suite of stakeholders including the public. The system successfully predicted the water level set-up and set-down along the west Florida coast three days in advance of each hurricane, with improved forecasts realized each day prior to landfall. The TBCOM-inundation forecast system was also activated during Hurricane Helene. This modeling system extends its dense grid onto the land, facilitating simulation of inundation and flooding associated with storm surge in coastal areas. During Hurricane Helene, areas of severe inundation were identified along the coastal periphery of Tampa Bay and forecasts were accessible two days in advance of landfall.

Impact of LETKF Data Assimilation of Remote Sensing Observations on the Wind and Wave Analysis

Panagiotis Mitsopoulos*, Malaquias Pena, and Manuel Pondeca

This study demonstrates the impact of assimilating remote sensing data on the significant wave height and surface wind speed analysis.

The motivation is to provide analysis fields to enhance the wind-wave monitoring and improve the forecast verification in the Continental United States (CONUS).

The GEFS-wave 30-member ensemble is used as the background field. Local Ensemble Transform Kalman Filter (LETKF) weakly coupled data assimilation experiments were conducted in the CONUS, assimilating observations from ten satellite altimeters and five scatterometers. All experiments were performed over six months using observations from 1 January to 1 July 2024.

The flow-dependent analysis reveals mesoscale features in the long-term statistics (Bias, RMSE, Scatter Index), which also indicate the analysis improvement when compared to the background field and a set of independent, non-assimilated observations. A case study of a storm in the Pacific highlights the spatial impact of assimilating observations at the analysis time, and the relationship with the ensemble spread is discussed.

Data denial experiments show the positive impact on the analysis RMSE spatially, both on the CONUS and the observation locations. The control run assimilates the total number of observations and the performance of the trial runs after assimilating a percentage of the initial observation dataset is assessed with respect to the control run and the background fields. It was found that once observations are removed, the analysis RMSE is increased significantly at the locations of the observations and also on the whole domain.

Overall, the results demonstrate the influence of satellite altimeter data on the wave analysis and the wind scatterometers on the surface wind speed analysis, both improving the statistics at the analysis time and contributing to a better representation of the state at the ocean surface.

Analysis of Extreme Wildfire Events in North America During the 2025 Fire Season Using Observations and RRFS-Smoke Model Output

Anamaria Navarrete*, Ravan Ahmadov, Jordan Schnell, Minsu Choi, and Sudheer Bhimireddy.

Earth is warming at an unprecedented rate, with the ten warmest years on record occurring in the most recent decade. As global temperatures rise, some regions will experience earlier snow and ice melt along with reduced precipitation rates. This combination exacerbates wildfire risk, making it crucial to deepen our understanding and improve current forecasting systems to prepare communities better. My research project aims to evaluate NOAA's next-generation coupled weather-smoke model - Rapid Refresh Forecasting System (RRFS) with Smoke by verifying its output against satellite and ground-based observations during recent North American wildfire events. In May and June 2025, numerous wildfires ignited in Canada, producing massive smoke plumes that negatively impacted air quality in surrounding regions. Some of these wildfires generated massive pyrocumulonimbus (pyroCb) clouds. By analyzing the synoptic meteorological conditions in North America and smoke transport patterns during the events, we aim to determine how smoke plumes were transported into the midwestern US. We also analyze the processes that led to the formation of pyroCbs and the potential for additional fire ignitions. To conduct this analysis, the Model EvaLuation using Observations, DIagnostics and Experiments Software (MELODIES) with the Model and ObservatioN Evaluation Toolkit (MONET) was utilized. The aerosol optical depth data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and other platforms are used to investigate the smoke concentrations. Satellite imagery, thermodynamic diagrams, and surface analysis maps will also be examined to understand the state of the atmosphere during the specified period.

Noah-MP optimization to improve UFS S2S hydrometeorological prediction in the Western United States

Andrew Newman*, Yifan Cheng, Andrew Bennett, Thomas Enzminger, Kathryn Newman, Arezoo RafieeiNasab, Ethan Gutmann, and Andrew Wood

The land states and fluxes greatly influence land-atmosphere coupling in many regions. As Noah-MP will become the land surface model in next generation UFS applications, it is essential to ensure that the model can simulate high-fidelity land states and fluxes in the coupled modeling system. In this study, we specifically focus on optimizing the parameters in Noah-MP to better simulate hydrometeorology as well as terrestrial hydrology in the coupled system, with an emphasis on precipitation, snow, soil moisture, and streamflow. Typically, uncoupled land model optimization is performed using data atmospheres, which ignores the coupled land-atmosphere feedback and may compromise the usability of optimized land parameters in coupled systems. To address this challenge, we are using both the offline Noah-MP and the single column model (SCM) with Noah-MP in selecting sensitive parameters and model optimization because these models allow rapid iteration of test configurations with at least 1-D land-atmosphere interactions. In addition, we aim to reveal the differences in sensitive parameter selection by conducting sensitivity experiments using both standalone Noah-MP and in the SCM. We present an initial testbed where we have configured the UFS land model to Ameriflux sites and the Southern Great Plains site within the SCM to perform model experiments. We will present initial results quantifying the biases in energy and hydrologic fluxes using a variety of metrics focused on process understanding.

A Study of Building and Running UFS Short-Range Weather App on MacOS Platforms: Success Stories and Test Cases

Natalie Perlin*, Cameron Book, Lauren Frederick , and Ben Kirtman

The presented work demonstrates a development approach of running the UFS Short-Range Weather (SRW) App on MacOS platforms. It also highlights the potential of using MacOS independent platforms to broaden access to advanced weather modeling beyond traditional HPC and cloud environments, which may facilitate independent research, academia, and operational forecasting, particularly in local hazard prediction scenarios, such as wildfires.

All the UFS applications require software libraries as a prerequisite, which are managed by a spack-stack package developed at JCSDA. The outline and details of the software setup process are presented, and comparative performance metrics across different MacOS systems are shown as well. A community test validated the application’s robustness and installation consistency. As a practical application, the study focused on wildfire test cases in Southern California, using a 1-km grid box size domain centered over Ventura, including the recent Mountain Fire (November 2024). Model input data for initial and lateral boundary conditions were used from NOAA HRRR and RRFS forecasts available through AWS S3 archives. Wildfire spread is often fueled by high wind conditions, and thus the goal of the studies was to improve wind prediction accuracy for 18-30 hour forecasts. Although the UFS Fire model was not yet integrated into the SRW App at the time of testing, the framework establishes a foundation for future inclusion, enhancing wildfire prediction capabilities. Overall, the results demonstrate that MacOS platforms can support rapid, localized weather modeling and testing, offering an alternative to traditional HPC resources for operational and research applications

The NOAA Anemoi Experience: scalable and user-friendly tools for training AI weather prediction models

Mariah Pope*, Timothy A. Smith, Sergey Frolov, Daniel Abdi, Isidora Jankov, D. Alex Burrows, and Anil Kumar

The proliferation of data-driven weather prediction has produced several models that are competitive with the skill of traditional numerical weather prediction (NWP) at a fraction of the cost. However, re-training of the published models with custom (NOAA) data can be a cumbersome process due to hardware setup, staging data, and efficiently scaling the model. This burden creates a steep learning curve for users that is a barrier to quick scientific iteration and progress. We present a framework of community tools for developing machine learning weather models using ufs2arco from the NOAA Physical Sciences Laboratory (PSL) and Anemoi from the European Centre for Medium-Range Weather Forecasting (ECMWF) to guide users through training their own models using a combination of NOAA and ECMWF datasets. First, the ufs2arco package enables users to quickly create large training datasets from existing data in the cloud, and is specifically designed to improve access to NOAA data. Anemoi then provides an easily customizable framework for developing and testing graph-based machine learning weather prediction models. Together, ufs2arco and Anemoi establish a comprehensive, data-driven framework that we are currently able to run using on-prem or cloud-based resources. We guide users through environment setup, data preparation, model training, and inference execution. Finally, we demonstrate the efficiency and flexibility of this framework and provide benchmark metrics on computational speed and cost. Overall, this work makes NOAA data easily accessible for machine learning model development, and makes the ECMWF Anemoi framework more readily deployable.

Toward High-Frequency Bayesian Assimilation in the UFS Using Local Particle Filters

Jonathan Poterjoy*

We present findings from a prototype Bayesian data assimilation system for global weather prediction within the Unified Forecast System (UFS). This system performs hourly data assimilation with a localized particle filter and is evaluated in a configuration comparable to an ensemble Kalman filter (EnKF) using the same ensemble size, localization strategy, and Gaussian assumptions for observation likelihoods. Initial results demonstrate that the localized particle filter achieves comparable performance to the EnKF across a range of meteorological fields, suggesting that fully nonlinear and non-Gaussian methods can be viable at global scales with practical update frequencies. While this initial implementation restricts likelihood evaluation to Gaussian errors—consistent with Kalman-based frameworks—the particle filter formulation offers flexibility for future enhancements, including non-Gaussian state-dependent likelihoods and improved depiction of complex, non-Gaussian distributions with larger ensembles. These capabilities have the potential to improve the assimilation of satellite observations and better capture non-Gaussian atmospheric forecast uncertainty. This work represents an initial effort toward applying particle filters for Bayesian data assimilation for a UFS global weather application.

Characteristics of North American Polar–Subtropical Jet Stream Superpositions and Related Challenges in Numerical Modeling

Clairisse Reiher*

The polar and subtropical jet streams occasionally merge horizontally and align vertically to form a single wind speed maximum referred to as a jet superposition. Prior work has found that superposed jets constitute a dynamic environment particularly conducive to high-impact weather, including heavy precipitation and intense near-surface winds. However, no previous study has attempted to assess the skill with which jet superpositions are predicted by numerical weather prediction models, or how well jet superpositions are represented in climate models. This presentation will motivate the need for such studies by providing an overview of the temporal and spatial characteristics of North American jet superposition events, along with the frequency and intensity of attendant high-impact weather events. We further demonstrate how dynamical and thermodynamical processes on multiple scales can influence the occurrence of jet superposition events. Based on these relationships, we motivate several potential approaches for investigating the predictability of superposed jets in numerical weather prediction models and evaluating their physical representation in climate models. To perform such analyses, we introduce an identification scheme capable of detecting superposed jets during September-May in the ECMW Reanalysis version 5 (ERA5). We demonstrate that this scheme can be applied in real-time to forecasts from the Global Ensemble Forecast System (GEFS) and employed for future predictability studies.

Accelerating AI/ML Operationalization for Earth System Prediction with Red Hat OpenShift AI

David Robertson*, Jason Cadmus, Andres Romero, Roderick Moore, and Mohammad Waheed, Red Hat AI Specialist

Background/Objectives: Advancing Earth system prediction, particularly weather forecasting, requires robust AI/ML models. However, moving models from experimentation to production is complex and time-consuming, particularly in terms of the multi-level complexity of the architectural layouts of the fully coupled Unified Forecast System (UFS) development process. This operationalization gap hinders AI-based parametrization and accuracy techniques in high-resolution multiscale weather forecasting, data assimilation, and post-processing. As a NOAA EPIC partner, Red Hat aims to close this gap for the support of the UFS community from the enterprise platforms.

Methods: Red Hat OpenShift AI, a comprehensive MLOps platform, accelerates AI development and delivery across hybrid-cloud environments. It provides streamlined model development, serving (with efficient vLLM inference), and monitoring. The platform supports diverse hardware accelerators and distributed workloads. InstructLab tools enable precise model alignment and fine-tuning with domain-specific data for specialized forecasting. Its open-source nature ensures flexibility and integration with hybrid cloud solutions across both cloud environments and on-premises infrastructure.

Results/Conclusions: Red Hat OpenShift AI offers the trusted foundation to rapidly deploy generative and predictive AI models. This accelerates AI/ML operationalization, delivering enhanced efficiency, flexibility, and scalability for weather modeling across hybrid clouds. We are dedicated to empowering the Weather Enterprise, with NOAA EPIC, to leverage cutting-edge AI for a more informed UFS future.

Developing and Operationalizing Brightband's AI-Data Assimilation System

Drew Bollinger (Brightband), Gideon Dresdner (Brightband), Zac Espinosa (Brightband), Ryan Keisler (Brightband), Alex Kleeman (Brightband), Hans Mohrmann (Brightband), and Daniel Rothenberg (Brightband)*

Recent advancements in machine learning weather prediction (MLWP) have outperformed traditional numerical weather prediction models in accuracy and efficiency yet they typically rely on traditional analysis or reanalysis data for initialization. To address this limitation, we introduce AIDA, a machine learning data assimilation system that estimates the global analysis state using multiple sources of Level 1 observational data, including satellite radiances and in situ measurements. The analysis state produced by AIDA can be used to initialize different MLWP forecast models, thus enabling an end-to-end observations-to-forecast MLWP system.

In this talk we discuss key technical considerations taken during the development of AIDA, including model architecture and the design problem the model intends to solve. AIDA has evolved through several iterations since first released in early 2025, and we highlight trade-offs and opportunities between the initial diffusion-based technique it incorporated versus competing approaches such as Aardvark Weather.

We further highlight the companion NNJA-AI project, which produced a high-quality, cloud–optimized and ML-ready dataset of diverse, multi-modal atmospheric observations which comprised the bulk of AIDA’s training dataset. NNJA-AI is publicly available and published on multiple cloud providers. The data is directly accessible from object storage, or through an open-source Python SDK, which is designed to aid users in discovering, interacting with, and subsetting data from the NNJA-AI archive for their own purposes.

Finally, we discuss the integration of AIDA with several open-source MLWP modeling systems including AIFS, and demonstrate Brightband’s operational capabilities to consume observational data in real-time to generate end-to-end AI forecasts leveraging AIDA and AIFS.

A dynamical ensemble approach to characterizing uncertainties in the prediction of air quality downstream of massive wildfires

Christopher Rozoff*, Rajesh Kumar, Stefano Alessandrini, Padhrig McCarthy, Jared Lee, and Wenfu Tang

Each day, many forecast centers across the world, including NOAA, are tasked with predicting pollutants like ozone (O3) and fine particulate matter (PM2.5). These predictions help guide advisories and societal decision processes aimed at reducing humanity’s detrimental exposure and risks tied to poor air quality. Unfortunately, air quality forecasts still suffer from errors emanating from the driving datasets, inaccurate emissions, and a yet incomplete understanding of air quality processes.

This talk presents a parsimonious (6-member) and skillful dynamical ensemble that characterizes key uncertainties in air quality downstream of massive wildfires. The basis of this system is NOAA's Unified Forecast System (UFS) Air Quality Model (AQM). An initial 31-member ensemble is run during the historical US wildfire season of 2020 (15 August - 30 September). Ensemble perturbations for this 31-member ensemble are generated with perturbations to the meteorological and chemical initial and lateral boundary conditions, along with perturbations to the anthropogenic and biomass burning emission input data. A down-selection process retaining the majority of ensemble variability while maximizing skill in near-surface PM2.5 predictions leads to a 6-member ensemble. From there, two plume-rise perturbations are applied to the biomass burning emissions in UFS AQM for the 6 members, yielding an 18-member ensemble. The down-selection procedure is carried out again to obtain a final 6-member ensemble. We will present ensemble performance during the 2020 US wildfire season and in the out-of-sample period of 25 May-14 July 2023 when historical Canadian wildfires sent hazardous plumes of smoke into the north-central and eastern US.

Continuous Data Assimilation in JEDI

JCSDA: C. Sampson*, Y. Tremolet, S. Herbener, A. Griffin, and E. Lingerfelt, C. Gas

In operational settings, useful observations valid in a given data assimilation (DA) window may arrive after a data assimilation cycle has begun leading to a loss of potentially important information in the assimilation step. Continuous DA allows us to avoid that information loss by adding newly arrived observations between outer loops. JCSDA is developing three new continuous DA modes for the JEDI system. In the first any newly arrived observations are added before beginning the next outer loop. The second also adds newly arrived observations but allows for a shift forward of the end of the DA window. And finally, the third adds newly arrived observations while shifting both the beginning and the end of the DA window between outer loops. The genericity of JEDI extends these abilities to any model with a JEDI interface. In this talk I will present the implementation of these new modes and present initial results on how they affect DA when cycling.

Non-parametric estimates of passive microwave sensed sea ice observation errors using CICE6 and kernel embeddings of conditional distributions

Henry Santer* and Jonathan Poterjoy

Most data assimilation schemes currently used for research or operational prediction rely on an accurate characterization of observation error statistics. When this assumption is not well met, errors are likely to arise in both the resulting analysis and in the analysis uncertainty itself. Observations of sea ice concentration have errors that are difficult to characterize due to their high degree of non-Gaussianity and state dependence. As a result, the current operational approach of prescribing a fixed Gaussian observation error variance for sea ice concentration is insufficient. This is especially relevant on shorter time scales, over which sea ice modulates heat and moisture fluxes into and out of the atmosphere that are pertinent to weather prediction. We introduce a method for estimating the state-dependent, fully nonparametric distribution of uncertainty for observations based on kernel embeddings of conditional distributions, and leverage output from pre-production UFS experiments with a coupled ocean-atmosphere-sea ice model to estimate error distributions for passive microwave-sensed sea ice concentration observations. Preliminary results demonstrate the strong dependence of sea ice concentration observation errors on sea ice concentration itself. Next, we present an alternative approach of directly estimating the likelihood of sea ice concentration observations given components of the underlying model state, which foregoes the need for an explicit observation forward operator. Finally, we outline plans for further testing of these uncertainty quantification methods using Observing System Simulation Experiments with CICE6 and sequential data assimilation strategies that are currently in the process of being implemented within JEDI/UFS workflows.

Progress in Developing an MPAS-Based Warn-on-Forecast System

Patrick Skinner*, Yunheng Wang, Thomas Jones, Nusrat Yussouf, Louis Wicker, Craig Schwartz, Soyoung Ha, Chris Kerr, Derek Stratman, Brian Matilla, and Kent Knopfmeier

The goal in developing a Warn-on-Forecast System (WoFS) using the Model for Prediction Across Scales (MPAS) dynamic core is to match or exceed the forecast skill of the current cloud-based WoFS (Cb-WoFS) that uses the WRF dynamic core. In this study we compare short-term (0-6 hr) thunderstorm forecasts for several high-impact severe weather events from 2024 and 2025 using MPAS-WoFS with the Ensemble Adjustment Kalman Filter (EAKF) data assimilation system from NCAR’s Data Assimilation Research Testbed (DART) to real-time Cb-WoFS forecasts using the Gridpoint Statistical Interpolation Ensemble Kalman Filter (GSI-EnKF) data assimilation System.

Composite reflectivity forecasts from the two systems are verified against Multi-Radar Multi-Sensor (MRMS) observations using object- and grid-based spatial verification methods. Evaluations are designed to quantify bulk and specific differences in thunderstorm prediction accuracy between the two systems. Specific aspects of forecast quality to be evaluated include: 1) What are the bulk differences in deterministic and probabilistic thunderstorm prediction? 2) What are the differences in diagnostic properties of simulated thunderstorms such as area, shape, and intensity? 3) How does accuracy vary with storm size, does higher effective resolution in MPAS produce more accurate predictions of smaller storms? 4) What are the differences in accuracy with observed storm age, how quickly do the systems spin up an accurate analysis of storms immediately following convection initiation? Answering these questions will assess current performance and inform the next steps in development of a real-time MPAS-WoFS for the Unified Forecast System.

Empowering Forecasting Innovation Through EPIC Community Engagement and User Support

Aaron Jones, Charlene Barone, Zach Shrader*, Laura Generosa, Maryia Davis, Jef Dodson, Jessica Wheeler, Casey Seyb, Priya Pillai, Joshua Kublnick, and Keven Blackman

The Earth Prediction Innovation Center (EPIC) is dedicated to accelerating contributions to the Unified Forecast System (UFS) by engaging the community and providing community members with the necessary tools and knowledge to contribute innovations to our Nation's forecasting and modeling systems. The EPIC Community Engagement (ECE) team supports EPIC's innovation through several initiatives, including community training events and the annual Unifying Innovations in Forecasting Capabilities Workshop (UIFCW). It also publishes and publicizes dynamic content on social media, the EPIC Community Portal (ECP), GitHub, and other platforms to meet the community's evolving needs and to remove barriers to innovation.

As part of its role in promoting community work, ECE has supported outreach efforts for emerging initiatives such as EAGLE-AI by assisting with infographic design and helping publish blog content to the ECP, broadening the reach of early releases and updates. The User Support (US) team complements ECE's efforts by updating UFS application documentation, compiling technical FAQs, and monitoring support requests. The US team provides ECE with immediate feedback on community engagement efforts, which allows ECE to adjust content and outreach strategies based on community needs and requests. This collaboration results in a responsive support environment that rapidly evolves to meet the community's needs, ensuring that users and developers have the support they require to innovate within our national forecasting systems.

Development of a Data Driven Global Weather Model with High Resolution over the US

Timothy A. Smith*, Mariah Pope, Sergey Frolov, Daniel Abdi, and Isidora Jankov

One of the main goals of NOAA's Physical Sciences Laboratory (PSL) is to improve our forecasts and understanding of precipitation events and extremes. To this end, we are especially focused on forecasting Atmospheric River (AR) events and their impacts on the Western United States. ARs are fundamentally multiscale in nature. They carry moisture over thousands of kilometers from the tropics to the West Coast, but once on land, they are influenced by interactions with topography that is highly variable over small horizontal scales. Thus, it is a difficult modeling challenge to accurately forecast these events, and accurately characterize their impacts, which are important for resource management.

We are therefore motivated to develop a model that captures the multiscale nature of phenomena like ARs with an all-in-one, data driven approach. We present a graph based neural network forecast model, trained on archived NOAA Global Forecast System (GFS) and High Resolution Rapid Refresh (HRRR) data, such that it has a horizontal resolution of ¼ degree (~28km) globally, with further refinements to <10km over the contiguous United States. We present an evaluation of the model's ability to capture medium range weather, both globally and over CONUS. Additionally, AR case studies are presented, and we discuss progress and challenges related to accurately forecasting precipitation in a data driven model at high resolution.

Comparing convective hazard forecasts derived from AI NWP, MPAS, and GEFS ensembles during 2025

Ryan Sobash*, Zhanxiang Hua, David Ahijevych, and Craig Schwartz

In February 2025, we began generating daily 104-member Day 1–8 ensemble forecasts with two AI NWP emulators: PanguWeather and FengWu. These global 0.25° forecasts are initialized daily at 00 UTC with ECMWF ensemble ICs. The emulator-based forecasts are then downscaled with a decoder-only transformer to produce probabilistic convective hazard predictions over the CONUS for each forecast day, using NWS storm reports for training. The AI-NWP forecasts are available in real-time at http://ensemble.ucar.edu.

In this presentation, we will describe the forecast system and discuss the skill of the Day 1–8 emulator-based convective hazard forecasts during the February – July 2025 period, including highlighting forecasts from several high-impact cases. To evaluate the emulator-based predictions against those derived from physics-based ensembles, we generated hazard forecasts based on the GEFS during February – July 2025 and from a global variable-resolution MPAS ensemble that was run daily in April – May 2025 during the 2025 NOAA Hazardous Weather Testbed. The 8-member MPAS ensemble provided convection-permitting forecasts over CONUS to 5.5 days.

Preliminary results indicate that the emulator-based hazard forecasts are competitive with the GEFS and MPAS ensembles, and outperform both systems in the medium-range (i.e., days 3–6). Even though the emulator-based forecasts are experimental and started this year, they have already been positively received by NWS forecasters. Implications of these findings for high-impact weather prediction will be discussed. Future plans, including expanding the emulator-based ensemble to O(1000) members will also be highlighted.

A Comparison of MJO Teleconnections predicted by UFS and Neural GCM

Cristiana Stan*

The mechanisms through which MJO affects the weather patterns in the boreal winter extra-tropics are evaluated in two sets of retrospective forecasts of the period April 2011-March 2018. One set is generated with the physics-based NOAA model, the Unified Forecast System (UFS) Prototype 8 (P8). The second set is produced with a GCM that combines a differential solver for atmospheric dynamics with a neural network based on learned physics, the NeuralGCM.

The MJO teleconnections are evaluated using the STRIPES index for geopotential and precipitation, the pattern correlation and relative amplitude for the tropospheric pathway and using the strength of the polar vortex and stratosphere-troposphere coupling for the stratospheric pathway.

The presentation will emphasize the similarities and differences between the UFS P8 and NeuralGCM in predicting the MJO teleconnections.

Advancing Forecasting Capabilities of Dust and Health Impacts through the Saharan Oscillation Index and Machine Learning

Younes Tebbaai*

The Saharan Oscillation Index (SaOI), which is a new climate index created based on pressure variations existing between the Azores High and the Sahelian low over Niamey, could serve as a regional precursor for dust outbreaks and air quality in North Africa. This study attempts to understand the dynamic interaction of SaOI with temperature, precipitation, and sea surface temperature (SST), PM10 concentration, and dust aerosol optical depth (DAOD), with emphasis on forecasting and public health.

Methods:
Seasonal and lagged correlation analyses were performed on the SaOI and environmental variables by relying on reanalysis datasets (ERA5) and station-based PM10 data from 2003 to 2024. After that, to attain a forecast of high PM10 episodes and heat-/dust-related health risks using the SaOI signals, machine learning (random forest and XGBoost) models were used to develop an early warning system.
Results:

Our analysis establishes the existence of strong seasonal associations between the SaOI phases and the PM10 levels, SST patterns, and precipitation anomalies, particularly in spring and winter. These seasonal relationships display spatial-phase coherence over North Africa, the Sahel, and the tropical Atlantic. According to the machine learning models, the model shows high skill in predicting extreme PM10 events and supports SaOI as a leading indicator.

Conclusions:
SaOI emerged as physically relevant information in dust forecasting and related health hazards at the regional level. Using SaOI information in early warning systems will ensure the collaborative end-user engagement under a single platform that offers one of the novel, scalable mitigation approaches to climate-sensitive pollutants and preparedness under a changing climate.
Keywords: Saharan Oscillation Index, Forecasting, PM10, Dust Events, Machine Learning

The state of the UFS in 2025

Hendrik L. Tolman, NOAA/NWS/OSTI*

The Unified Forecast System (UFS) is rapidly becoming a full open source research and operations capability. NOAA uses the UFS to simplify its Production Suite of operational models, and to accelerate the rate of improvement of the Production Suite. The broader research community uses the UFS to accelerate research, and simplify the Transition to Operations process. The poster will lay out the present state of development of the UFS in terms of which community models are presently making up the base code stack of the UFS, and represents an update of a similar poster presented at UIFCW 2024. THe previous assessment will be expanded with identifying languages used in various components, as well as the need for software and development workflow modernization. As in last year's poster the general code stack is mapped to UFS application releases, UFS applications in production and UFS applications is research.

Bridging the Gaps: Satellite Observations and Forecasting Atmospheric Rivers

Chong-Chi Tong*, Leif Swenson, Sergey Frolov, Laura Slivinski, and Kelly Mahoney

Improving the prediction of atmospheric rivers (ARs) — major drivers of extreme precipitation events along the U.S. West Coast — is a key objective of NOAA's Atmospheric River prediction project. This study supports that effort by evaluating how to better leverage satellite observations through data assimilation (DA) to enhance AR forecasts. Particular emphasis is placed on utilizing observations from polar-orbiting satellite sensors, such as ATMS, which offer global coverage, ideal for capturing critical atmospheric fields (e.g., temperature, moisture, cloud contents, etc.) associated with the evolving ARs. For this workshop, we present preliminary findings on the AR estimation skill of several existing systems, including the Replay and 3DVAR systems (NOAA PSL) and the operational GDAS EnKF, evaluated against both ATMS and dropsonde observations. The generally large brightness temperature (BT) errors in both forecasts and analyses, particularly within the AR regions, suggest significant room for optimizing the use of similar satellite observations for such a task.

In addition to evaluating DA system performance, we performed a systematic assessment of AR forecast skill using both the operational GFS and two machine learning (ML) models initialized with GFS initial conditions, GraphCast and Pangu-Weather, for multiple significant events taking place in early 2023. Reconnaissance dropsonde missions were actively flown during these events, which provides an ideal dataset for cross-verification. Objective metrics based on integrated vapor transport (IVT), including amplitude and location-based errors, were used to quantify forecast performance. While GFS forecasts generally captured the large-scale structure of ARs, substantial errors in both intensity and position were observed across several cases. ML-based forecasts exhibited varying skill depending on the event and lead time, with notable underperformance in certain cases. Informed by the observed forecast limitations, we plan to select a subset of the more challenging AR events identified here for upcoming DA experiments, where the relative impact of various factors in assimilating satellite observations, such as data selection (i.e., sensitivity-based channel prioritization and thinning), observation error specification, and localization length scales, will be systematically investigated. More details regarding the methodology and configuration of the experiments will be presented at the workshop.

Generic co-processing capability in the Unified Forecast System Weather Model (UFS-WM)

Ufuk Turuncoglu* and Saeed Moghimi

As the complexity of the earth system modeling applications increases significantly in terms of represented physical processes and their nonlinear interactions, our ability to process and interact with the vast amount of data produced by those applications is fundamentally changed and pushed the community to develop new and novel data processing approaches such as co-processing and in situ visualization. The Unified Forecast System (UFS) is one of the real examples of such a complex, multi-component modeling system that aims to replace existing NOAA's operational model suite and applications by unifying different modeling applications and configurations. The main objective of this study is to increase interoperability and close the gap between Earth system models and novel data-processing tools by providing an easy-to-use, efficient, generic, and standardized modeling environment for interacting with large data. The newly developed NUOPC complaint data processing component (GeoGate) can interact with any NUOPC-based model component to bring co-processing support and allow gaining insight from data flowing from multiple Earth system model components and using it to make timely, data-driven decisions. The new component is initially integrated with UFS Coastal and facilitates to process unstructured ocean model output in S-104 format and support model development efforts as a part of the existing regression testing (RT) framework. In addition, its plugin-based design enables it to extend its functionality such as Interacting with different programming languages (i.e. Python) to process the data, and having online interaction with AL/ML and data processing tools while the model is running.

Advancing STOFS 2D Global Accuracy with Direct Lunar-Solar Traction Forcing and In-Line Self Attraction and Loading Terms

Joannes J. Westerink*, Damrongsak Wirasaet, Albert Cerrone, Aman Tejaswi, Maria Contreras, Coleman Blakely, Shintaro Bunya, Zach Cobell, Edward Myers, Saeed Moghimi, Greg Seroka, Yuji Funakoshi, Liujuan Tang, Lei Shi, Chris Massey, and Margaret Owensby

NOAA’s global total coastal water level modeling system, the Surge and Tide Operational Forecast System 2D+ Global (STOFS 2D+ Global,), considers a range of forcing mechanisms including tidal forcing, self attraction and loading terms, GFS-FV3 winds and atmospheric pressure, hydrology, thermohaline circulation and CICE sea ice. STOFS 2D+ Global is driven by the ADvanced Circulation (ADCIRC) solver, a massively parallel finite element community code for free-surface hydrodynamics, which is continually refined in order to accommodate better physics and numerics and evolving computer architectures. STOFS 2D+ Global is presently the most accurate non-data assimilative published global hydrodynamics model and is the only U.S. based operational global total water level modeling system focused on the coastal ocean and floodplain. STOFS 2D Global is run operationally four times per day by NOAA NCEP since 2020 and forecast and hindcast skill have been steadily improving with annual/bi-annual upgrades.

We have now incorporated a much more comprehensive and efficient lunar-solar traction based tidal forcing which is time based and incorporates the full spectrum of lunar-solar forcing without relying on harmonic decompositions and subsequent resynthesis. In addition, we have implemented an inline parallel self attraction and loading algorithm that computes the spherical harmonic transformations directly on the unstructured mesh which in fact becomes efficient for large processor counts. We explore how individual harmonics and the spectrum improves with both the direct lunar/solar forcing as well as with our in-line SAL implementation as we increase both mesh resolution as well as the number of modes.

Towards Space Weather Application in UFS: Whole Atmosphere Model Development and Simulations

V. A. Yudin(NOAA/NESDIS/SWO and CUA)*, K. Viner (CPI), T. Fuller-Rowell (NOAA/SWPC and CU/CIRES), S. I. Karol (CU/CIRES), W. Chen (NOAA/NCEP/EMC), T.-W. Fang (NOAA/SWPC), I. Azeem (NOAA/NESDIS/SWO), and F. Yang (NOAA/NCEP/EMC)

The Unified Forecast System (UFS) is based on the Finite Volume Cubed sphere (FV3) dynamical core and physics employed in the operational weather predictions by GFS-v16 (released in 2021). The neutral dynamics component of the Space Weather (SW) Application, the Whole Atmosphere Model (WAM, top lid at ~500-600 km), is still utilizing the spectral dynamics core of GFS-v11 and physics of GFS-v13 (released in 2016). The WAM predictions substantially deviate from the UFS/GFS performance in the troposphere and stratosphere. This paper describes the first WAM prototype with FV3 dynamics (FV3WAM) and its capability to represent the tidal dynamics driving the plasma component and SW predictions during geomagnetic storms, as well as seasonal and annual retrospective hindcasts. The new model contains all recent upgrades of advanced dynamics and physics of GFS-v16/17 orchestrated with the upper atmosphere physics. Lessons learned during the FV3WAM development and evaluation will be highlighted. The Smagorinsky framework of Large Eddy Simulation (SLES) in the mesoscale FV3WAM configuration has been designed to substitute the sub-grid column Gravity Wave (GW) drag physics onto three-dimensional mesoscale eddy viscosity, heat conductivity and diffusion. The FV3WAM-C96L196 and WAM-T62L150 (spectral dycore) simulations are assessed against the empirical reference models of the upper atmosphere, modern reanalyses, and space-borne observations. The evaluation of simulations by data displays major issues of the SW operational model regarding its ability to predict the large-scale climate from the surface to ~150 km, and demonstrates the advanced predictive skills of FV3WAM, as the next SW application in UFS.

Advancing UFS Physics Unification through A Hierarchical Testing Framework

**Man Zhang (DTC, CU/CIRES and NOAA/GSL)*, Weiwei Li (DTC and NSF NCAR/RAL), Evelyn Grell (DTC, CU/CIRES and NOAA/PSL), Jimy Dudhia (DTC and NSF NCAR/MMM), Tracy Hertneky (DTC and NSF NCAR/RAL), Julia Simonson (DTC, CU/CIRES and NOAA/GSL),
Fanglin Yang (NOAA/NWS/EMC), Lisa Bengtsson (NOAA/PSL), and Ligia Bernardet (NOAA/GSL)**

To support the Unified Forecast System (UFS) vision of physics unification across scales and applications, the Developmental Testbed Center (DTC) contributes to the systematic testing and evaluation (T&E) of both operational and developmental physics suites, including the GFSv17/GEFSv13 suite. With FY24 funding, this effort has expanded to assess the performance of the developmental GFSv17/GEFSv13 physics suite for NOAA's Seasonal Forecast System (SFSv1) application, which demands skillful forecasts at extended lead times and coarser spatial resolutions. In collaboration with UFS physics leads and developers, this work focuses on key physical processes, particularly those related to the persistent sea surface temperature (SST) warm bias in SFS prototypes and the representation of mixed-phase Arctic clouds across scales. Special attention is given to how cloud, precipitation and cloud–radiation interactions may contribute to this SST bias in challenging regimes such as marine stratocumulus, North Pacific extratropical systems, and Southern Ocean low clouds. The sensitivity of cloud properties to cloud microphysics schemes and

model configurations, especially physics and microphysics timesteps, is also systematically explored.

A hierarchical T&E approach spans horizontal resolutions from 100 km to 3 km, leveraging the Common Community Physics Package (CCPP) across a range of applications including the Single Column Model (SCM), NOAA's Rapid Refresh Forecast System (RRFS), GFS/GEFS, and SFS. Key findings emphasize the strong sensitivity of cloud–radiative responses to various regimes and model configurations, as well as challenges in simulating high-latitude mixed-phase clouds, informing future improvements in unified physics for extended-range forecasting.

A Hybrid Dynamical-Machine Learning Forecast Tool for Subseasonal Precipitation Prediction Based on ENSO and the MJO

Cheng Zheng (Stony Brook University)*, Hyemi Kim (Ewha Womans University), Emerson LaJoie (NOAA CPC), and Edmund Kar-Man Chang (Stony Brook University)"

Precipitation over North America is significantly modulated by the El Niño–Southern Oscillation (ENSO) and the Madden–Julian Oscillation (MJO). Statistical tools that leverage the observed states of these two predictors can provide skillful subseasonal precipitation forecasts and are currently used to support operational subseasonal outlooks. Here, we present a novel hybrid dynamical–machine learning prediction tool for subseasonal precipitation that substantially outperforms conventional statistical methods.

We apply machine learning techniques, including neural networks and gradient boosting, to learn relationships between the predictors (ENSO and the MJO) and precipitation on subseasonal timescales using large ensemble climate simulations. As shown in previous studies, training on large ensemble climate simulations yields superior performance in predicting subseasonal precipitation compared to statistical tools trained solely on observational data. In addition to using the observed MJO state as a predictor, incorporating forecasts of MJO evolution from dynamical models can further enhance prediction skill, since the evolution of the MJO modulates its impact on midlatitude precipitation. Our hybrid tool integrates dynamical MJO forecasts, which is also bias-corrected by utilizing a previously developed deep learning tool. Despite the decreasing skill in MJO predictions at longer lead times, we find that incorporating MJO predictions out to week 4 still improves subseasonal precipitation forecasts for weeks 3–4.

The hybrid tool outperforms the-state-of-the-art dynamical models over the continental US during some seasons, especially in fall and early winter. The tool is now under further development for application in an operational environment.

UFS Application – Coastal, Marine, Oceans and Ecology

Multiple Moving Nests and Telescoping Nests Advancements for HAFS

William Ramstrom*, Lewis Gramer, Andrew Hazelton, and Sundararaman Gopalakrishnan

Developments continue to advance moving-nest functionality in HAFS, a Unified Forecast System (UFS) application, for a variety of operational and research configurations. Nesting allows higher resolution to capture details of tropical cyclone circulation while efficiently modeling the larger-scale circulation with coarser grid cells. Higher resolution for the inner core of tropical cyclones will continue to be desirable into the foreseeable future, eventually reaching large eddy scales.

We are running a basin-scale HAFS real time parallel experiment for 2025 covering much of the North Atlantic and East Pacific hurricane basins with moving nests for up to 4 concurrent tropical cyclones out to 7 days, named HAFS-M. We will present forecast accuracy results from the 2024 season and preliminary numbers from the beginning of the 2025 season.

Moving telescoping nests will be implemented this fall and winter to allow 2 or more levels of nests, for a variety of scales for operational and research purposes. Potential uses include two level nesting similar to HWRF, some coarser parent domains in ensemble runs, as well as LES-scale inner nests for research cases. We will discuss the implementation of telescoping nests in HAFS and our plans for real-time parallel tests for the 2026 season.

Obstacles for High-Resolution HAFS over the Entire Atlantic Basin

Joseph Knisely* and Jonathan Poterjoy

The Hurricane Analysis and Forecast System (HAFS), NOAA's FV3-based tropical cyclone (TC) forecasting system, features flexible model configurations for both operational and research purposes. In particular, HAFS can operate with a large, static analysis domain that permits the uninterrupted assimilation of measurements basin-wide. This feature opens new research directions for TC prediction, and allows us to reexamine model configurations used for operational forecasting and produce accurate analyses of record for past events. For this presentation, we introduce a series of numerical experiments performed over the 2022 TC season to examine the effect of model resolution on a fully-cycling, basin-scale data assimilation framework, particularly with regard to model physics. These experiments feature forecast configurations that closely resemble operational configurations but are probabilistic and bridge issues with radiance bias correction and high-resolution error covariance specification. Given that the data assimilation configuration is nearly self-contained and continuously cycling, we use domain-wide error characteristics to assess how expanding the HAFS-B inner-domain would impact both TC and near-storm environments. We find that using a basin-wide 3-km grid spacing analysis—in place of the current 6-km parent domain grid specification—induces large changes in cloud coverage, height, and composition that contribute to significant air mass biases across the domain. We also produce ensembles of storm-centric forecasts that resemble the operational HAFS configuration, but are initialized from basin-scale analyses, and find that the resulting air mass biases heavily influence TC predictions. These findings, among others, help inform decisions on future studies within the same self-contained HAFS framework.

Progress on the Development of an Arctic Regional Coupled UFS Application (UFS-Arctic)

Kristin N. Barton*, Amy Solomon, I-Kuan Hu, Lisa Bengtsson, Christopher J. Cox, David Clemens-Sewall, Dmitry S. Dukhovskoy, and Philip Pegion

The Arctic region is home to vital ecosystems, communities, and industries, including fisheries and shipping. To enhance forecasting capabilities in this rapidly changing environment, the NOAA Physical Sciences Laboratory (PSL) is developing a fully-coupled, regional Arctic application within the Unified Forecast System (UFS) to provide short- to medium-range forecasts as a successor to the current experimental Coupled Arctic Forecast System (CAFS). Transitioning to UFS infrastructure supports weather and research community engagement, streamlined model development, and enhanced access to forecast products. The project involves two main components: application development and Arctic-focused improvements of physics parameterizations. Application development is focused on establishing a regional coupled Arctic configuration, covering the entire sea ice domain, using the FV3 (CCPP), MOM6, CICE6, and Noah-MP components of UFS. The current configuration uses a nominal 10km resolution grid for the ocean and ice, with a 50km grid for the atmosphere. Future work will explore further resolution refinements and additional UFS components, such as WW3 and GOCART. Initial and lateral boundary conditions are sourced from GFS (atmosphere), RTOFS (ocean), GEFSv13 Replay (ice), with work underway to transition to GEFSv13 Replay datasets for all components. Physics development efforts include: (1) incorporating the PUMAS cloud microphysics scheme into the Common Community Physics Package (CCPP); (2) developing a new mixed-layer parameterization scheme to better represent top-down mixing in Arctic stratocumulus; and (3) refining melt pond representation in CICE6 to better match observations. This presentation will discuss recent progress on the UFS-Arctic project and invite community feedback to guide future work.

Coupling CICE to SCHISM in UFS coastal: Lessons learned while working towards a coupled ice-ocean forecast system for Alaska

Joseph Smith, Scott Durski*, Alexander Kurapov, Joseph Zhang, Fellicio Cassalho, Dan Yu, Edward Myers, and Saeed Moghimi

Efforts are underway on the development of a three-dimensional (3D) prediction system for the Alaska region that two-way couples the Los-Alamos National Laboratory ice model CICE to the unstructured grid ocean circulation model SCHISM (the Semi-implicit Cross-scale Hydroscience Integrated System Model) as parts of the Unified Forecast System (UFS). The objective is to develop a system that will provide predictions of the total sea level along the Western Alaska coast, tidal and non-tidal currents over the shelf and around the Aleutian Islands, and ice parameters of interest to the navigational community (ice extent, concentration, thickness, motion, deformation, etc.). Towards this end we have implemented both a standalone version of CICE (using atmospheric and oceanic data layers) and a two-way ocean-coupled version utilizing the National Unified Operational Prediction Capability Interoperability Layer (NUOPC) for the Bering Sea. The standalone sea ice implementation has been extensively validated against satellite estimates of sea ice concentration and sea ice thickness (for thin ice) for the 2018-19 and 2019-20 winter seasons. Model-observation intercomparisons of the coupled ice-ocean model have also been undertaken with additional comparisons to temperature and salinity at shelf moorings. In this presentation, in addition to demonstrating the performance of the new coupled model we reflect on the lessons learned in the coupled model implementation process of within NUOPC. We discuss where collaborations were successfully leveraged to advance the project and what bottlenecks arose that slowed the development at various stages.

NOAA Unified Forecast System Coastal Applications Team (UFS CAT) Model Evaluation

Ayumi Fujisaki-Manome*, Greg Seroka, John Kelley, Shachak Pe'eri, Joe Sienkiewicz, Jesse Feyen, Olivia Doty, Kayo Ide, Brendan Gramp, Fred Ogden, Tracy Fanara, Edward Myers, Saeed Moghimi, Timothy Cockerill, Wei Wu, Eric Anderson, Kaitlin Huelse, Saeed Memari, Cristina Forbes, Yonggang Liu, Sebin John, Cuong Sieu San, Haibo Xu, Emanuele Di Lorenzo, Kyungmin Park, Spenser Wipperfurth, Natalia Sannikova, Vasily Titov, Yong Wei, Cigdem Akan, Soroosh Mani, Carolyn Lindley, Ilya Rivin, and Andres Tejada

NOAA's National Ocean Service (NOS) operates a suite of numerical coastal ocean forecast modeling systems to provide short-range forecast guidance of water levels, water temperature, currents, and salinity for estuaries, the coastal ocean and the Great Lakes of the United States. NOS continuously works to improve its forecast modeling capabilities to better support marine navigation, search and rescue operations, and ecological forecasting. Efforts are underway across NOAA and partners to improve its future modeling capabilities by following the Unified Forecast System (UFS) framework for modeling Earth systems. The UFS framework seeks to have an open, community-based, coupled, comprehensive Earth modeling system that can accelerate the advancement of environmental forecast models and their transition into NOAA's operations. Over the past three years, an NOS Water Initiative funded project has been conducted by the UFS Coastal Applications Team to help advance NOS' operational numerical coastal ocean modeling capability. The project has two major goals: 1) to evaluate potential coastal ocean models for the coastal ocean model components of the UFS in various potential applications and 2) to train the next generation of coastal ocean modelers to accelerate the research to operations (R2O) process within NOS. This presentation overviews the summary of the four rounds of the model evaluation process, and discusses the project's outcomes, challenges, and lessons learned so far.

Real-World Evaluation of the UFS Coastal Application: Two-Way Coupled Wave–Circulation Modeling during the 2021 Hurricane Season

Saeed Memari*, Eric J. Anderson, Ayumi Fujisaki-Manome, Gregory Seroka, Ufuk Turuncoglu, and Yunfang Sun

Accurate coastal forecasting requires resolving dynamic interactions between waves and circulation, particularly in estuarine and nearshore environments. This study presents recent enhancements to the NOAA Unified Forecast System (UFS) Coastal Application that enables fully two-way coupling between the WAVEWATCH III (WW3) spectral wave model and the Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) for hydrodynamics. This modular framework supports flexible integration of best-in-class models, enabling robust and extensible configurations for a wide range of coastal applications. We applied the coupled UFS Coastal system to New York Harbor, a well-observed region characterized by complex bathymetry, intense navigational activity, and exposure to extreme weather events. The model was evaluated during hurricane season in summer 2021. Observational datasets from NOAA tide gauges and NDBC wave buoys were used to validate the model output, focusing on significant wave height, peak wave period, water surface elevation, temperature, and current velocity. Results indicate that two-way coupling improves the fidelity of wave and hydrodynamic predictions compared to uncoupled configurations. Beyond scientific accuracy, the study assessed operational readiness of the coupled system for real-time forecasting. The UFS Coastal architecture supports real-time data ingestion through the Community Data Components (CDEPS), is scalable on high-performance computing platforms, and leverages the existing UFS infrastructure for workflow automation. These advancements illustrate the potential of UFS Coastal as a unified, flexible, and scalable modeling platform for coastal hazard prediction. The demonstrated improvements in simulating wave-current interactions, storm surge, and total water levels provide a strong foundation for transitioning this capability into NOAA operations.

Development of a new operational forecast system for southeastern US (SECOFS)

Joseph Zhang*, Hyungju Yoo, Dan Yu, Lucila Houttuijn Bloemendaal, Saeed Moghimi, Yi Chen, Machuan Peng, Xu Chen, Ufuk Turuncoglu, Rachel Tang, and Ed Myers

Natural hazards such as coupled inland-coastal compound flooding are persistent threats to coastal communities. With BIL funding support, we are developing a new 3D southeastern coast operational forecast system (SECOFS) that covers from Chesapeake Bay to Florida Panhandle, and a disjoint domain for Puerto Rico. The final SECOFS implementation is envisioned to be a UFS application in which CDEPS (data cap) will provide forcing to a coupled SCHISM-WW3 application. Coupling with inland hydrology component, i.e. National Water Model (NWM) or NextGen, is one-way at 10 m above sea level to account for compound effect. We are actively engaging end users and stakeholders throughout the project, and have so far incorporated numerous suggestions on the SECOFS mesh from navigation managers who gathered feedback from community users. The 3D system has been validated in hindcast mode, including total water level, currents and tracers (temperature and salinity). Through SECOFS we are also exploring the feasibility of the new agile DevOps for rapid prototyping of new OFS, via an IOOS cloud sandbox.

Development and Implementation of Regression Tests and Applications within the UFS-Coastal Framework

Yunfang Sun*, Ufuk Turuncoglu, Ann Tsay, Hao-Cheng Yu, Joseph Zhang, Ali Abdolali, Jana Haddad, Mansur Jisan, Panagiotis Velissariou, Felicio Cassalho, Soroosh Mani, Xu Chen, Zizang Yang, Lei Shi, Denise Worthen, Ali Salimi-Tarazouj, Saeideh Banihashemi, Joseph Smith, Lucila J. Houttuijn Bloemendaal, Ed Myers, and Saeed Moghimi

Accurate coastal predictions require rigorous and systematic model evaluations to ensure reliability and reproducibility, especially in coastal regions characterized by dynamic wave-current interactions. Here we describe the development and implementation of standardized regression tests for the NOAA's Unified Forecast System Coastal Application (UFS-Coastal). Utilizing observational data collected at the U.S. Army Corps of Engineers Field Research Facility (FRF) for Duck, North Carolina, we designed robust testing configurations to evaluate multiple model setups, including hydrodynamic-only (CDEPS+SCHISM), wave-only (CDEPS+WAVEWATCH III [WW3]), and fully coupled wave-current simulations (SCHISM+WW3). The coupled experiments assessed two wave-current coupling methods: the traditional depth-integrated Longuet-Higgins radiation stress formulation, and the advanced three-dimensional (3D) vortex-force coupling approach. Simulations are forced using spatially uniform but temporally varying observed atmospheric conditions, enabling targeted validation of sea surface elevation, nearshore currents, significant wave height, and wave spectra. Continuous Integration and Continuous Delivery (CI/CD) workflows are already operational for other regional UFS-Coastal test cases, and future work will extend these automated CI/CD processes to the Duck regression tests, with public availability anticipated in the near future. In addition, we demonstrate the scalability of UFS-Coastal by applying it to a larger Atlantic domain, performing simulations of Hurricane Ian (2022). This large-domain application further highlights the framework's capability for operational forecasting of storm surge, coastal flooding, and wave dynamics at regional scales.

Recent SCHISM coupling development under NOAA's UFS-coastal framework

HaoCheng Yu*, Joseph Zhang, Yunfang Sun, Ali Abdolali, Ufuk Turuncoglu, Joseph Smith, and Saeed Moghimi

As a coastal ocean component inside UFS-Coastal, SCHISM is being actively coupled with other earth system models (ESMs) components including wave, atmosphere, ice, etc, under UFS framework. In this study, we demonstrate the two-way coupling development between SCHISM and WW3 and its applications including a pre-operational Atlantic case (SECOFS). All exchange variables are carefully checked against standard-alone SCHISM-WWM to ensure a correct coupling. Models deliver reasonable results and coupling effects can be clearly seen. Furthermore, similar efficiency as the original stand-alone models can be achieved and only small overheads are added. This new development has also benefited other coupling work for other components like CICE and FV3. Some preliminary results from the coupled SCHISM-WW3 will be presented.

Impact assessment of the Tomorrow.io Microwave Sounder (TMS) constellation on the forecast

Jonathan J. Guerrette, Ryan E. Honeyager, S. Joseph Munchak, Stylianos Flampouris

The Tomorrow.io Microwave Sounder (TMS) satellite constellation is set to begin launching this year. This constellation will include up to 18 satellites, positioned in a combination of sun-synchronous and 45-degree inclined orbital planes, providing sub-hourly global revisit rates. The onboard instrument is an enhanced version of the TROPICS (Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats) design, featuring an onboard calibration target and improved digital signal processing.

Pre-launch preparations involved simulating TMS observations using the Community Radiative Transfer Model (CRTM) and an internal radiance simulation package (RadSim). These simulations supported retrieval studies and Observation System Simulation Experiments, running 6-hour data assimilation and forecast cycles over two months at a 13 km resolution on a cubed-sphere grid. These experiments based on the Unified Forecast System have yielded several significant outputs that allow the impact assessment of the TMS constellation in various configurations. To reach this level, the instrument configurations for the Joint Effort for Data assimilation Integration (JEDI) system have been developed, and the quality control and observation error models for TMS in clear-sky and all-sky conditions have been established. These pre-launch studies prove that the assimilation of TMS radiances improves precipitation characterization and water vapor-dependent fields. In this presentation, we discuss the forecast impacts when TMS data is assimilated in clear-sky and all-sky configurations and provide estimates on the benefits of increasing the number of TMS satellites.

Triton-c: Wind Wave Modeling on Unstructured Grids Using a Modern C++ Framework

Ali Abdolali*, Aron Roland, Ty Hesser, David Honegger, Thomas Huxhorn, Mary Bryant, Jane M. Smith, and Heloise Michaud

We introduce Triton-c, a next-generation wind wave model developed in modern C++ to align with current academic practices and improve computational portability, including future GPU acceleration. Unlike traditional Fortran-based models such as WAVEWATCH III, Triton-c offers streamlined development, improved maintainability, and significantly enhanced performance. Preliminary benchmarks on global unstructured grids show major speedups in both parallel scalability and single-core efficiency. The model supports hybrid MPI+OpenMP parallelism and SIMD vectorization, with architecture-conscious design to enable seamless future GPU integration. Triton-c provides a flexible platform for accurate and efficient wave prediction across spatial scales, from global oceans to coastal regions. Ongoing validation and performance assessments—particularly under extreme events—demonstrate the model's potential for both operational forecasting and climate-scale simulations.

Recent METplus advancements for verifying HAFS forecasts

Kathryn Newman (NSF NCAR and DTC)*, John Halley Gotway (NSF NCAR and DTC), Michael Kavulich (NSF NCAR and DTC), Brianne Nelson (NSF NCAR and DTC), Minna Win-Gildenmeister (NSF NCAR and DTC), and Samuel Trahan (CIRES at NOAA GSL and DTC)

The Hurricane Analysis and Forecast System (HAFS) is the next generation operational modeling system for predicting tropical cyclones and is the hurricane application of NOAA’s Unified Forecast System (UFS). Developed by the Environmental Modeling Center (EMC) with contributions from community partners, HAFS undergoes continuous development to incorporate both scientific advancements and technical innovations. To enable rapid and reproducible performance assessment of evolving HAFS configurations, the Developmental Testbed Center (DTC) has developed verification tools and a workflow for tropical cyclone verification. The enhanced Model Evaluation Tools (METplus) system was developed and continues to be enhanced to meet the needs of both the research and operational communities. METplus provides a flexible and extensible suite of verification tools designed to operate across a broad range of spatial and temporal scales. Recent advancements for tropical cyclone verification include the establishment of a framework for rapid evaluation of HAFS prototype forecasts, enhancements to storm-centric verification tools (i.e., TC-RMW and RMW-analysis), extension of gridded and point verification in storm-relative coordinates, and improvements in visualization capabilities to better support interpretation of results.

Additionally, a new application of METplus' ensemble verification capabilities for HAFS is underway to support HAFS ensemble forecast development. This presentation will detail the design and implementation of the HAFS verification framework, summarize recent enhancements to METplus specific to tropical cyclone evaluation, and outline future efforts aimed at unifying verification approaches across UFS applications to support consistent model development and intercomparison.

UFS Application – Short Range Weather (SRW) Application, Rapid Refresh Forecast System (RRFS), and Model for Prediction Across Scales (MPAS)

Updates on Rapid Refresh Forecast System Version 1

Matthew E. Pyle*, Curtis R. Alexander, Jacob R. Carley, Terra Ladwig, Shun Liu, and Ming Hu

The Rapid Refresh Forecast System (RRFS) is a regional 3 km ensemble and deterministic forecasting system, based on the Unified Forecast System (UFS), and targeting an implementation into NWS operations early in 2026. This talk will summarize the scientific and technical changes made to RRFS over the last year, and share results from runs made with the final scientific configuration. Issues that arose during the RRFS evaluation period will be reviewed, and the remaining steps toward the operational implementation of RRFS will be described.

Toward Basic Characterization of Machine Learning Methods Applied to Computational Geophysical Flows

Jorge E. Guerra and Daniel Abdi

As we encounter a moment of rapid adoption of Machine Learning (ML) as an alternative toolkit for the forecasting of environmental systems, questions remain about the interpretability and physicality of end-to-end ML forecasting engines. In order to continue an effort to bring greater interpretability and adoption of ML techniques, we present examples of direct relationships between simple (shallow) ML regression models and known results from applied numerical analysis. Our approach is focused on generating pure training data in the sense that it comes from common one-to-one mathematical mappings such as elementary functions/function compositions and their analytical derivatives over a discretized 1-D domain. We hypothesize that an ML regression model presented with such data must converge to an object that approximates discrete differentiation operators known from the literature. We present a few examples of such objects re-discovered in this context, starting with a simple 5-point convolutional layer model reproducing the common 4th order centered finite difference formula. Furthermore, we investigate the influence of grid resolution on the regression/learning process and establish proper convergence criteria for such simplified models. Lastly, we outline this approach as a complementary means of discovering potentially novel numerical differentiation methods with specific properties.

Evaluation of RRFSv1 during the 2025 NOAA HWT Spring Forecasting Experiment

Israel Jirak*, Adam J. Clark, David Harrison, Jake Vancil, and Tim Supinie

The 2025 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE2025) was conducted from 28 April – 30 May with participation from forecasters, researchers, and model developers from around the world. The focus of SFE2025 was to evaluate the FV3-based Rapid Refresh Forecast System version 1 (RRFSv1), including RRFS deterministic and RRFS Ensemble Forecast System (REFS) components. The RRFSv1 is proposed for operational implementation in the National Weather Service to enable the retirement of several deterministic CAMs and the High Resolution Ensemble Forecast (HREF) system. Several deterministic and ensemble evaluations were conducted to compare the performance of the RRFS and REFS to operational baselines. For the deterministic evaluations, the 0000 and 1200 UTC runs of the RRFS were compared to the operational NAM CONUS Nest and HiResWindow runs for Day 1 (i.e., valid f12-f36 and f00-f24, respectively) and the 2100 and 0000 UTC runs of the RRFS were compared to the operational HRRR for the first twelve hours (i.e., valid f00-f12). For the ensemble evaluations, the 0000 UTC REFS was compared to the HREF for Day 1 (i.e., valid f12-f36) and the 1200 UTC REFS was compared to the HREF for Day 1 (i.e., valid f00-f24) and Day 2 (i.e., valid f24-f48). The subjective evaluation results of these RRFS and REFS forecasts from the SFE2025 will be discussed alongside objective verification statistics, offering evidence regarding the overall operational readiness of the RRFS and REFS for severe weather forecasting.

Implementation of the MPAS Dynamical Core in the Unified Forecast System Weather Model

Dustin Swales*, Grant Firl, Soren Rasmussen, Vanderlei Vargas, Ligia Bernardet, and Lulin Xue

Recently, efforts have begun to adopt the dynamical core from MPAS-Atmosphere within the Unified Forecast System (UFS) Weather Model (UWM). Currently, the UWM atmospheric component relies on a single dynamical core, FV3, for all forecasting applications. The UWM atmospheric component was not designed from the “ground-up” to accommodate multiple dynamical cores, and consequentially including the MPAS dynamical core comes with many challenges.

Here we will provide an overview on the status of the technical effort to include the MPAS dynamical core within the UWM. This will include how we handle the coupling between the Common Community Physics Package (CCPP) and multiple dynamical cores within the UWM ecosystem.

NOAA/GSL Model Development and Forecasting Activities Toward RRFSv2 Using MPAS

Clark Evans*, Curtis R. Alexander, Ligia R. Bernardet, Terra T. Ladwig, Ming Hu, David C. Dowell, and Trevor I. Alcott (all affiliated with the NOAA/OAR/Global Systems Laboratory, Boulder, CO)

NOAA's Global Systems Laboratory (GSL) seeks to improve Earth-system prediction across all weather-related hazards including severe convective storms, intense rainfall, winter storms, tropical systems, and phenomena such as wildfire smoke and pollen. GSL has a rich legacy in developing modeling systems for NOAA operations, including the WRF-ARW–based Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR), and in contributing to the development of Finite-Volume Cubed-Sphere (FV3)-based Unified Forecast System (UFS) applications such as the first version of the Rapid Refresh Forecast System (RRFSv1) and the Global Forecast System (GFS).

Predictive needs are increasingly blurring boundaries between regions and global applications given the value of convection-allowing resolutions for representing precipitating phenomena and increasing global forecast skill. Further, there is increasing stakeholder need for finer-scale modeling systems that can explicitly resolve convection, fire-weather behavior, and urbanization influences. GSL is using MPAS to address these needs and advance GSL's mission of developing forecast systems that deliver solutions.

This presentation will provide an overview of MPAS development and forecasting activities with which GSL is involved. These include convection-allowing regional MPAS and JEDI data assimilation development toward RRFSv2 and experimental uniform- and variable-resolution global MPAS applications to test physical parameterizations' scale-adaptiveness and to explore new frontiers in data assimilation. Forecast performance in both real-time and retrospective testbed applications will be presented. The presentation will also briefly discuss other MPAS-related developments and applications at GSL, including 1-km regional fire- and severe-weather forecasts, stochastic method implementations, and work toward integrating the MPAS dynamical core in the UFS.

MPAS evaluations for severe weather forecasting during the 2025 NOAA/Hazardous Weather Testbed Spring Forecasting Experiment

Adam Clark*, Kent Knopfmeier, Yunheng Wang, Nusrat Yussouf, Israel Jirak, Louis Wicker, Clark Evans, David Dowell, Craig Schwartz, Ryan Sobash, Michael Duda, and William Skamarock

For the third consecutive year, convection-allowing regional and global configurations of the Model for Prediction Across Scales (MPAS) were tested for severe weather forecasting applications during the 2025 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE 2025), which ran 28 April – 30 May. These MPAS configurations were contributed by the NOAA/National Severe Storms Laboratory (NSSL), NOAA/Global Systems Laboratory (GSL), and the NSF National Center for Atmospheric Research (NCAR). NSSL provided three CONUS-domain, 3-km grid-spacing configurations initialized from the Rapid Refresh Forecast System version 1 (RRFSv1) and High-resolution Rapid Refresh (HRRR). GSL provided two MPAS configurations, which are being tested to form the foundation for RRFSv2, and have the most up-to-date physics suites tuned for MPAS.

Finally, NCAR provided an 8-member MPAS ensemble that uses a global 13-km grid-spacing domain with a refined 3-km mesh over the CONUS providing forecasts to 132 hours, along with a first-of-its-kind global 3-km grid-spacing configuration with forecasts to 60 hours. Daily model evaluations assessed performance characteristics alongside the HRRR, RRFS, High-Resolution Ensemble Forecast System (HREF), RRFS Ensemble Forecast System (REFS), and other experimental systems. Ultimately, these tests are helping advance the use of MPAS within NSSL's Warn-on-Forecast System (WoFS), and exploring potential use within the framework of NOAA's Unified Forecast System (UFS) initiative. This talk will present preliminary results from these evaluations and highlight notable cases of interest.

Recent advancements in METplus for RRFS and MPAS verification

Michelle Harrold (NSF NCAR & DTC)*, John Halley Gotway (NSF NCAR & DTC), Jeff Beck (NOAA/GSL & DTC), Dan Adriaansen (NSF NCAR & DTC), Michael Kavulich (NSF NCAR & DTC), Will Mayfield (NSF NCAR & DTC), and Gerard Ketefian (CIRES at NOAA/GSL and DTC)

The enhanced Model Evaluation Tools (METplus) system continues to evolve to meet the growing needs of the operational and research communities for robust, flexible, and scalable model verification and diagnostic capabilities. METplus offers a suite of core tools, Python wrappers, and complementary diagnostic and plotting Python modules that support a wide range of temporal and spatial scales. Recent advancements have expanded METplus capabilities for verifying high-resolution, short-range weather forecasts from the Rapid Refresh Forecast System (RRFS) and the Model for Prediction Across Scales (MPAS). Enhancements, developments, and new use cases include: 1) verification of smoke and dust fields, 2) support for unstructured grid data, enabling direct evaluation of MPAS forecasts, 3) a new tool for evaluating paired forecast-observation datasets, 4) code refactoring and optimization for improved run times, and 5) inclusion of new verification capabilities in the SRW App. These features and upgrades will help streamline the verification workflow for next-generation forecasting systems and prototypes within the Unified Forecast System (UFS) framework. This presentation will highlight these developments with examples from short-range weather applications, including verification of RRFS and MPAS output.

A Discussion on Sustaining SRW/CAM Development Agility While Advancing UFS Capabilities

Curtis Alexander, NOAA/Global Systems Laboratory (GSL)*, Boulder, CO, Louis Wicker, NOAA/National Severe Storms Laboratory (NSSL), Norman, OK, Jacob Carley, NOAA/Environmental Modeling Center (EMC), College Park, MD, Matthew Pyle, NOAA/Environmental Modeling Center (EMC), College Park, MD, Christiane Jablonowski, University of Michigan (UM), Ann Arbor, MI, and Kate Fossell, NSF National Center for Atmospheric Research (NCAR), Boulder, CO

The Unified Forecast System Short-Range Weather Convection Allowing Model (SRW/CAM) team has simultaneously demonstrated support for the UFS SRW application through three major releases over the past five years that include increasingly sophisticated forecast capabilities while also exploring new pathways to address forecast challenges at the finer convective scales including adoption of the Model Prediction Across Scales (MPAS) dynamic core. While inclusion of new UFS application components such as the dynamic core, data assimilation infrastructure and/or physics suites adds complexity to the system it also offers the potential to realize a fully-coupled (model and DA) UFS capability that can operate efficiently and effectively over very-high-resolution limited areas to coarser global domains. However, this complex infrastructure must be balanced against the desire to maintain agile model components that can exist outside of this UFS infrastructure (stand-alone MPAS for example) with lower barriers of entry that can be attractive to both the broader research community but also facilitate rapid progress towards operational transitions. Motivating and maintaining both inside and outside development tracks while avoiding common challenges such as code divergence is the focus of this discussion that will be facilitated by UFS SRW/CAM team leadership.

UFS Application – Air Quality, Atmospheric Composition, Aerosols (including smoke, dust and fire capabilities)

Progress on the development of Configurable ATmospheric Chemistry (CATChem) v2 component within NOAA's Unified Forecasting System (UFS)

Barry Baker*, Rebecca Schwantes, Wei Li, Zachary Moon, Jian He, Li Zhang, Colin Harkins, Meng Li, Quazi Rasool, Siyuan Wang, Greg Frost, Brian McDonald, Ravan Ahmadov, Jordan Schnell, Maggie Bruckner, Georg Grell, Patrick Campbell, Margaret Marvin, Youhua Tang, Matthew Dawson, and Beiming Tang

NOAA's Unified Forecasting System (UFS) is a community-based Earth modeling system designed to support NOAA's operational forecasts. In addition to the operational numerical weather prediction applications, the current UFS weather model could be configured for various composition forecast needs through coupling with different chemistry components of varying complexity. NOAA's needs for air composition forecasting contains various levels of complexity from simplistic tracers, or simplified aerosol representations such as that found in NASA's 2nd generation GOCART, to complex gas and aerosol phase forecasts for research and operational use. Currently, the UFS uses multiple chemical component models for atmospheric composition, each with a different level of complexity which include NASA's GOCART for global aerosol simulations and the EPA Community Multiscale Air Quality Model (CMAQ) for NOAA's National Air Quality Forecast Capability (NAQFC). The multiple chemistry-related processes are duplicated across the different chemistry models within the UFS, making it less efficient to maintain and improve the code. Here, we aim to develop the Configurable Atmospheric Chemistry (CATChem) component v2 that includes all chemical and aerosol processes needed to perform atmospheric chemistry and composition simulations within the UFS framework through a flexible, easy to modify, and well-documented infrastructure. Innovative research capabilities for improving gas-phase chemistry and aerosol processes will also be added, such as options to use gas-phase chemical mechanisms and aerosol schemes of varying complexity, ability to easily couple different mechanisms to different physics options, and to connect to a more flexible emissions processing system. The flexibility of CATChem will make the

UFS applicable for both research and operational forecasting needs within the unified chemistry component. Through the development of CATChem, we will also engage with the atmospheric chemistry research community to efficiently and promptly include research advances within the UFS, which is critical to ensure that NOAA continues to provide state-of-the-art forecasts for air quality and atmospheric composition prediction. CATChem is available from the UFS-Community GitHub page, https://github.com/ufs-community/CATChem.

Fire Aerosol Prediction in NOAA's Global Aerosol Systems and its Impact on Subseasonal to Seasonal (S2S) Forecasting

Li (Kate) Zhang*, Georg A. Grell, Gonzalo A. Ferrada, Shan Sun, Partha S. Bhattacharjee, Ben Green, Haiqin Li, Jordan Schnell, Anders A. Jensen, Ravan Ahmadov, Ligia Bernardet, Yunyao Li, Ziheng Sun, Daniel Tong, Li Pan, Barry Baker, Bing Fu, Fanglin Yang, and Raffaele Montuoro

There are two global chemistry and aerosol forecast systems currently under development at NOAA, both of which are fully coupled online with the Unified Forecast System (UFS), encompassing ocean, sea ice, wave and land surface components for Subseasonal to Seasonal (S2S) forecasting: UFS-Aerosols and UFS-Chem. The UFS-Aerosols model is planned for operational implementation within Global Forecast System (GFS) as Global Chemistry and Aerosol Forecast System (GCAFS.v1), replacing the current operational GEFS-Aerosols v12.3, which incorporates NASA's 2nd-generation GOCART aerosol model. The UFS-Chem development is an extensive collaboration between NOAA Oceanic and Atmospheric Research (OAR) laboratories and NCAR. The aerosol component currently implemented in UFS-Chem is based on the operational GEFS-Aerosols v12.3, adapted within the Common Community Physics Package (CCPP) framework. Compared to GEFS-Aerosols v12.3, UFS-Chem includes significant enhancements to the aerosol component, such as inline aerosol radiative forcing, large-scale wet deposition, and fire emissions. Recently, inline large-scale wet deposition and aerosol indirect feedback via the Thompson aerosol-aware microphysics scheme have been implemented into both UFS-Aerosols and UFS-Chem to improve subseasonal-to-seasonal (S2S) forecast capabilities, complementing the existing treatment of aerosol direct and semi-direct radiative feedbacks. Additionally, machine learning methods have been developed to enhance fire emission predictions for S2S forecasts. The performance of both UFS-Aerosols and UFS-Chem in predicting fire aerosols and their impacts on S2S forecasts is being evaluated and compared using observations from reanalysis data, ground-based measurements, and satellite data.

JEDI based data assimilation for the NOAA Global Chemistry and Aerosol Forecast System (GCAFS)

Yaping Wang*, Andrew Tangborn, Cory Martin, Li Pan, Partha S. Bhattacharjee, Barry Baker, Fanglin Yang, Youhua Tang, Bing Fu, Raffaele Montuoro, Li (Kate) Zhang, Bo Huang, Jerome Barre

The NOAA Global Chemistry and Aerosol Forecast System (GCAFS) is expected to begin operations in 2026. It will include an aerosol data assimilation capability for the first time and will use the Joint Effort for Data Assimilation Integration (JEDI) system. JEDI is a community developed model independent assimilation system for Earth sciences data assimilation, and will eventually be used for all of the NOAA Unified Forecast System (UFS) components. In the current aerosol implementation, aerosol optical depth observations from the Visible Infrared Imaging Radiometer Suite (VIIRS) NPP, NOAA-20 and 21 instruments are assimilated into the GCAFS model, with increments applied to 14 aerosol species. Because of computational limitations, aerosol forecast error covariance is estimated using a variance partition method for standard deviations and a diffusion method for error correlations. The former simulates an ensemble using nearby grid points while the latter solves the diffusion equation with an impulse source on the model grid. The computed standard deviations are rescaled independently for the individual aerosol species, through comparisons with independent observations and reanalyses. The DA component also employs a variational bias correction scheme, and it is being tested with a variety of predictor variables.

Testing of the GCAFS system is currently being conducted through comparisons with VIIRS, Moderate Resolution Imaging Spectroradiometer (MODIS) and Aerosol Robotic Network (AERONET) observations, along with Modern Era Reanalysis-2 (MERRA2) and Copernicus Monitoring Service (CAMS) aerosol reanalyses.

Development of NEXUSv2 as a new component in the Unified Forecast System for applications to air composition modeling for AQMv8 and the Configurable ATmospheric Chemistry (CATChem) Component

Barry Baker*, Zachary Moon, Raffaele Montuoro, Patrick Campbell, Rebecca Schwantes, Jian He, Youhua Tang, Beiming Tang, and Wei Li

The past decade has experienced rapid advances in global aerosols and atmospheric composition (AAC) model prediction capabilities. AAC models are key components of unified forecast systems that often employ an Earth System Model Framework (ESMF; i.e., a high-performance, flexible software infrastructure for building and coupling weather, climate, and related Earth science models) for weather and climate predictions. Emissions of trace gases and primary aerosols are a critical component of AAC models and are often the most important component to ensure accurate predictions of trace species distributions. However, developing these emissions inputs to AAC models is often a laborious, time-consuming process, especially to ensure that the datasets are suitable for a range of spatial scales and applications. Furthermore, inventory-based emission inputs are subject to a bottom-up approach that is prepared separately (offline) and suffers distinct time lags from the AAC models, which affects both the timing and accuracy of trace gas predictions. In this work, the Harvard-NASA Emission Component (HEMCO) is serving as the foundation of a new unified emissions modeling framework, which is already capable of utilizing numerous emissions datasets (both global and regional), can be run offline (inventory-based) or online (processed-based), is extended to be fully ESMF-compliant. Here we present the development of the NOAA Emissions and eXchange Unified System version 2 (NEXUS), which will interface with different NOAA AAC models, including both global and regional models for both operational and research-oriented applications. An overview of the NEXUS system and its integration into the UFS will be given. This includes examples of model-ready anthropogenic emissions using a combination of global and regional anthropogenic emission inventories with the NEXUS platform.

Incorporating gas-phase chemistry into the Unified Forecast System (UFS) for global air quality applications

Jian He*, Li Zhang, Rebecca H. Schwantes, Barry Baker, Larry Horowitz, Vaishali Naik, Congmeng Lyu, Zachary Moon, Georg Grell, Ravan Ahmadov, Jordan Schnell, Kai Yang, Zigang Wei, Siyuan Wang, Kai-Lan Chang, Alan M. Gorchov Negron, Aihua Zhu, Shobha Kondragunta, Eric C. Apel, Ilann Bourgeois, Róisín Commane, Samuel R. Hall, Alan Hills, Rebecca S. Hornbrook, Jeff Peischl, Kirk Ullmann, Gonzalo González Abad, Zolal Ayazpour, Caroline Nowlan, and Brian C. McDonald

The Unified Forecast System (UFS) is a community-based Earth modeling system designed to support operational forecasts at the National Oceanic and Atmospheric Administration (NOAA), while also facilitating the integration of research advances from the broader scientific community. The Configurable ATmospheric Chemistry (CATChem) library is being developed to include comprehensive chemical and aerosol processes for representing atmospheric chemistry and composition through a flexible, easy-to-modify, and well-documented infrastructure. Here CATChem version 1.0 (v1.0) is linked to the UFS High Resolution 3 configuration to create the Unified Forecast System with Chemistry (UFS-Chem) v1.0. The configurability of UFS-Chem enables its use for both research and operational applications, reducing time and effort for transitions to operations and enhancing collaboration with the research community. As a first step towards this goal, the gas-phase chemistry from the Atmosphere Model version 4.1 (AM4.1), developed at NOAA Geophysical Fluid Dynamics Laboratory (GFDL), is incorporated into the CATChem library and linked to the UFS as the first UFS-Chem configuration for global air quality applications. The simulated atmospheric compositions are generally consistent with those in GFDL-AM4.1 and agree well with surface observations, aircraft measurements, and satellite retrievals, demonstrating atmospheric chemistry is reasonably well represented in the model. This work documents model uncertainties and biases in UFS-Chem v1.0 to help prioritize further improvements in emissions and process-level representations. The new global configuration is shown to be robust in representing atmospheric chemistry and composition and serves as a foundation for future development.

Evaluation of the RRFS-Smoke-Dust Model During the 2025 Fire Season in North America

R. Ahmadov, H. Li*, J. Romero-Alvarez, J. Schnell, S. Bhimireddy, E. James, M. Hu, P. Bhattacharjee, B. Baker, S. Kondragunta, and C. Xu, F. Li

Vegetation fires emit large amounts of smoke, which consists of various gas and aerosol species. These pollutants can significantly impact air quality and weather. Therefore, timely and accurate prediction of smoke concentrations from vegetation fires is crucial. In this talk, NOAA's experimental Rapid Refresh Forecasting System coupled with smoke and dust (RRFS-SD) will be presented. The new RRFS-Smoke-Dust (RRFS-SD) model is currently running in real time by NCEP [https://rapidrefresh.noaa.gov/RRFS-SD/]. The model grid covers all of North America at a 3 km spatial resolution. The model is initialized every hour by assimilating the latest meteorological observations and ingesting Fire Radiative Power (FRP) data from the Regional Hourly Advanced Baseline Imager (ABI) and the Visible Infrared Imaging Radiometer Suite (VIIRS) Emissions (RAVE) product. The RAVE FRP data are used to estimate biomass burning emissions and fire heat fluxes in the RRFS-SD model.

This presentation will discuss the current state of smoke forecasting capabilities in the RRFS-SD model and highlight insights gained from real-time testing during the 2025 fire season. During this period, parts of Central and North America experienced intense wildfires. Smoke from these fires in Central America and Canada impacted air quality across the United States.
The model's performance is evaluated using meteorological data, PM2.5 and PM10 observations, aerosol optical depth measurements from the AERONET network and JPSS satellites, as well as other remote sensing observations. Fire plume injection simulated by RRFS-SD is evaluated by using the satellite observations. An analysis of smoke transport from Canadian wildfires into the U.S. during June 2025 will also be presented.

Advancements in NOAA's Unified Forecast System-Air Quality Model (UFS-AQM) to improve our nation's air quality forecasting capabilities

Patrick Campbell*, Youhua Tang, Barry Baker, Kai Wang, Wei Li, Beiming Tang, Wei-Ting Hung, Irena Ivanova, Margaret Marvin, Zachary Moon, Daniel Tong, Siqi Ma, B.H. Baek, Jianping Huang, Ho-Chun Huang, Brian Curtis, Anna Smoot, Hongli Wang, Hyundeok Choi, Haixia Liu, Raffaele Montuoro, Fangling Yang, Shobha Kondragunta, Fangjun Li, and Xiaoyang Zhang

The National Air Quality Forecast Capability (NAQFC), based on NOAA's Unified Forecast System (UFS) and the integrated air quality model (UFS-AQM), provides daily forecasts of surface ozone and $PM_{2.5}$ concentrations up to 72 hours in advance across North America. The initial implementation of this online-coupled system, referred to as AQM version 7 (AQMv7), marked a major milestone in operational air quality forecasting that also further enhanced the predictability of wildfire air quality impacts across the U.S. Building on this foundation, here we will provide an overview of several key upgrades being developed for the upcoming AQM version 8+ (AQMv8+). These scientific enhancements include 1) Chemistry and Deposition Updates: Upgrade of the Community Multiscale Air Quality (CMAQ) model (as the chemical submodule used in the AQM) chemical mechanism and dry deposition processes. 2) Physics Updates: Integration and testing of the latest Global Forecast System Version 17 physics suite. 3) Emissions Updates: High-resolution anthropogenic emissions for the U.S. combined with updated global emissions inventories, improved near-real-time fire emissions, online soil nitrogen emissions, and meteorology-induced emissions. 4) Sub-Canopy Effects: More detailed representation of vegetative sub-canopy impacts on pollutant chemistry and vertical turbulent transport. 5) Dust and Boundary Conditions: Updated Fengsha windblown dust parameterization and enhanced aerosol lateral boundary conditions. Here we will present examples of the improved UFS-AQMv8+ performance based on these advancements and recent prototype experiments.

Developing a global 1km anthropogenic emission dataset to support multiscale atmospheric composition modeling

Daniel Tong*, Siqi Ma, Hannah Fang, BH Baek, Patrick Campbell, Youhua Tang, and Barry Baker

Emissions of criteria air pollutants (CAPs) are the main drivers of many environmental challenges and a key input to Chemical Transport models such as the UFS-Air Quality Model. Accurate high-resolution mapping of these emissions is essential for identifying emission sources and understanding their environmental and climatic impacts. This study introduces the Global Neighborhood Emission Mapping Operation (NEMO-Global), a dataset to map global anthropogenic CAPs emissions at 0.01° (1km) spatial resolution worldwide. NEMO-Global is developed from country-level emission data provided by the Emissions Database for Global Atmospheric Research (EDGAR). Fine-scale spatial allocation is achieved through distributing the emission sources using spatial proxies, factors representing the portion of a source in each grid derived from geographical, statistical, or satellite data. Preliminary mapping of agricultural sources shows good agreement with EDGAR's 0.1° resolution data, supporting the reliability of our spatial processing methodology. We will further generate spatial proxies across all emission sectors, representing area, line, and point sources, and examine the spatial and temporal patterns of CAPs. NEMO-Global will provide the first high-resolution mapping of CAPs at a global scale, offering critical support for applications including local to global aerosol and atmospheric composition modeling.

Aerosol dependency of the Community Convective Clouds (C3) scheme in the Unified Forecast System (UFS) Weather Model

Haiqin Li*, Georg A. Grell, and Saulo Freitas

A physics suite, which includes the aerosol-aware double moment Thompson-Eidhammer microphysics scheme (TH-E MP), the scale-aware and aerosol-aware Community Convective Cloud (C3) parameterization, and the MYNN-EDMF boundary layer and shallow cloud scheme, is under development at NOAA. We recently implemented a simple approach to improve the aerosol representation in these parameterizations, particularly TH-E and C3, and tested them in the UFS. Sea salt, dust, biomass burning, and anthropogenic aerosol emissions have been embedded as CCPP-compliant subroutines. The prognostic emissions of sea salt and organic carbon are combined to represent the “water friendly” aerosol emission, while the prognostic emissions of dust are used to represent “ice friendly” aerosol emission for TH-E MP. We previously examined how this aerosol representation modified the aerosol indirect feedback against a Control run with GOCART climatological aerosols when using the TH-E scheme in the global UFS forecast with C768 (~13km) horizontal resolution and 127 vertical levels. There are significant cloud-radiation responses to the aerosol differences, and the severely positive precipitation bias over Europe and North America in the Control run was significantly alleviated when applying this aerosol emission method for indirect feedback. In order to foster collaboration across NOAA on development of convective parameterization, a new version of the C3 parameterization, which adds several features from the currently operational SAS scheme to the Grell-Freitas parameterization, is under development. Here we further study the aerosol-awareness of the C3 convective parameterization through the cloudwater-rainwater conversion and precipitation efficiency processes. The aerosols are consistent between TH-E microphysics and C3 convection. This study indicates that aerosol-physics interactions using a very simple and computationally efficient approach have significant impacts on the numerical weather prediction in the UFS applications.

First Implementation of a Reflectance Derived Sediment Supply Map in the UFS and Analysis of Impacts on AOD and Dust Emission.

Emily Faber*, Barry Baker, and Adriana Rocha Lima

Mineral dust is an important part of the climate system we live in. Dust hotspots emit thousands of tons of dust annually with the help of local meteorology and soil characteristics. Aerosolized dust impacts everything from agriculture to air quality. Using MODIS reflectance data in the NIR, SWIR, red, green, and blue wavelengths, a non-static source map was derived and includes information about location of one of the most abundant sediment types – alluvial sediments. This map is then utilized in the UFS within the FENGSHA dust emission scheme. The resulting AOD and dust emission data is compared to observations as well as model runs using two other supply maps – the topographic source map and an idealized maximum erodibility map. We present a case study from the 2020 Godzilla dust storm and results from a year-long model run. AOD is compared between model and observations, and dust emission mass and location difference are discussed. Limitations of this first implementation are also presented.

Community Engagement/Collaboration

Enabling Community Success Through EPIC User Support Services

Joshua Kublnick*

The Earth Prediction Innovation Center (EPIC) User Support (US) team serves as a vital connector between Unified Forecast System (UFS) developers and the broader user community by delivering timely, responsive, and comprehensive support services. Key responsibilities include monitoring and responding to inquiries through the EPIC support email and GitHub Discussions, ensuring users receive consistent and accurate guidance. The team also leads the development, maintenance, and continuous improvement of technical documentation ranging from updates tied to new releases to the creation of new resources that simplify onboarding and usage. To further empower the community, the US team creates and curates both written and video tutorials, stages data required for experimentation and development, and produces Frequently Asked Questions (FAQs) based on recurring user needs. This support spans both developer-focused and general community audiences, ensuring that contributors at all levels have the tools and knowledge to succeed. By actively engaging with users, addressing technical barriers, and collaborating across EPIC, the US team plays a critical role in driving innovation and accessibility within the UFS ecosystem.

Synergy between Joint Technology Transfer Initiative and Earth Prediction Innovation Center in Advancing NOAA’s Unified Forecast System

Chandra Kondragunta* and Maoyi Huang

In FY2016, the National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research’s (OAR) appropriation included an increase of $6M to create a new program called the Joint Technology Transfer Initiative (JTTI). OAR received increased funding in the subsequent years in support of this program. OAR carried out this program in coordination with the

National Weather Service (NWS), and in cooperation with the American weather enterprise. JTTI's main mission is to transition promising matured weather research from the American Weather Enterprise to the NWS operations. Additionally, NOAA established the Earth Prediction Innovation Center (EPIC) program in 2019 whose mission is to serve as the catalyst for community research and modeling focused on informing and accelerating advances in our nation's operational NWP forecast modeling systems. Within OAR, the Weather Program Office (WPO) is responsible for managing both the JTTI and EPIC programs. While the missions of these two programs are different, the synergy between these programs is essential to successfully complete the R2O2R loop. In terms of execution, the path of the research transition overlaps between these two programs. While JTTI transitions community weather research to the NWS operations, EPIC supports the community modeling infrastructure in forms of the Unified Forecast System (UFS) applications that are similar to operational versions to the community to effectively communicate operational priorities and accelerate transition of modeling innovations to operations. In this paper, we present how JTTI and EPIC work synergistically to complete the R2O2R loop and advance UFS.

Advancing Community Ocean and Coastal Modeling by Harnessing the Power of the Cloud

Breanna Vanderplow*, Michael Lalime, Tiffany Vance, Katherine Moore Powell, Patrick Tripp, Zachary Wills, Mykel Alvis, and Micah Wengren

Ocean and coastal modeling is essential to NOAA's mission, but challenges including collaboration across NOAA and external partners, access to funding and resources, and community engagement often hinder progress. To address these challenges, NOAA's Integrated Ocean Observing System and partners developed the Coastal Modeling Cloud Sandbox, which serves as a research and development platform with shared access to cloud computing and data storage to support collaborative model development, testing, and optimization between NOAA and external partners. The Sandbox provides a scalable, customizable environment with configurations and tools similar to those on NOAA's Research and Development High Performance Computing systems, which could support the development and transition of Unified Forecast System (UFS) compatible coastal and ocean models to operations. The first models run in the Sandbox included NOAA's Operational Forecast Systems (OFS) and a 12-year hindcast of the University of Washington's LiveOcean model. Since then, various NOAA offices have utilized the Sandbox to cloud-optimize and accelerate development of models including the Coastal Ocean Reanalysis (CORA), STOFS-2D-Global, and the National Water Model. Current efforts include engaging external partners to run the Northeast Coastal Operational Forecast System (NECOFS), the Southeast Coastal Operational Forecast System (SECOFS), and the East Coast Community Ocean Forecast System (ECCOFS) together as an integrated East Coast Forecast System for eventual transition to operations. The Sandbox fosters interdisciplinary collaboration, prioritizes user engagement, and provides a pathway to enhance UFS forecasting capabilities through a community-driven approach to model development that addresses the needs of communities impacted by coastal hazards.

The Common Community Physics Package: A Unified Framework for Physics Development, Testing, and Operational Transition

Tracy Hertneky*, Grant Firl, Dustin Swales, Soren Rasmussen, Lulin Xue, Jimy Dudhia, Mike Kavulich, Ligia Bernardet, Man Zhang, Sam Trahan, and Weiwei Li

The Common Community Physics Package (CCPP) contains a collection of physical atmospheric parameterizations along with a framework which connects the physics to a host model's dynamical core. It is designed to support physics research and development across the broader scientific research community and provides a pathway for transitioning innovations from research to operations. The package also includes a Single Column Model (SCM) which acts as a simplified host model enabling hierarchical testing and evaluation of physical parameterizations in isolation from dynamical feedback.

The CCPP is a core component of the Unified Forecast System (UFS), which is a community-based, coupled, Earth system modeling designed to support a range of forecast applications across different times scales and spatial domains. It also serves as the atmospheric physics infrastructure for NOAA’s current and future operational implementations. Its modular and interoperable design has led to adoption beyond NOAA, including by the Navy Research Laboratory’s NEPTUNE model and ongoing integration into several NCAR modeling systems.

The CCPP SCM supports forcing datasets from a variety of field campaigns to simulate diverse weather regimes. It also offers the capability to generate cases from regional and global UFS applications, a feature further enhanced in the version 7.0.0 release. These capabilities make the SCM a valuable tool for testing physical parameterizations in a controlled environment and accelerating development prior to integration into full forecast systems.

Rethinking spack-stack support: a containerized approach

Edward Snyder*, Mark Potts, Cameron Book, Ratko Vasic, Natalie Perlin, and Rick Grubin

Spack-stack is a python based package manager that has been created and supported by Joint Center for Satellite Data Assimilation (JCSDA), the National Oceanic and Atmospheric Administration’s (NOAA) Environmental Modeling Center (EMC) and Earth Prediction Innovation Center (EPIC), and the U.S. Naval Research Laboratory (NRL) to build their respected software. It has quickly become a crucial software component to various unified forecast system (UFS) and Joint Effort for Data assimilation Integration (JEDI) models and applications; as it provides the packages and libraries required to build and run UFS and JEDI applications. Although spack-stack is supported by JCSDA, EMC, NRL, and EPIC, maintenance and deployment time has increased on the EPIC side with the expansion of the spack-stack to other EPIC-supported NOAA Tier-1 platforms. Discussion is on-going on how to address spack-stack maintenance and support with automation and containerization being thoroughly examined. This presentation will discuss the current state of EPIC spack-stack support, walk through the different spack-stack automation and containerization approaches, and lay out the benefits, hurdles, and drawbacks of each method, and survey potential avenues for the adoption and integration of these approaches.

Planning Committee

A huge thank you and congratulations to the UIFCW25 Planning Committee!

Aaron Jones, Aaron Pratt, Alex Alder, Alison Gregory, Ben Green, Ben Woods, Christopher Domanti, Cliff Mass, Eric Aligo, Farida Adimi, Gillian Petro, Gudrun Magnusdottir, Hendrik Tolman, Iman Gohari, Jacob Carley, Jan Ising, Jeff Beck, Jennifer Leaman, Jennifer “Jen” Vogt, Jessica Martinez, Jessica Wheeler, Jian-Wen Bao, Jimmy Dudhia, John E Brown, Kathryn Newman, Krishna Kumar, Logan Poole, Maoyi Huang, Mark Olsen, Michael Barlage, Mike Ek, Rahul Mahajan, Rowin Smith, Shira Francis, Shuxia Zhang, Tracy Fanara, Zach Shrader, and Keven Blackman