40th WGNE workshop
November 3-7, *Beijing, China*

Center Update
NCEP Environmental Modeling Center

Fanglin Yang

Acknowledgment: This presentation is made possible with contributions from EMC management, developers and community collaborators. NOAA NWS/OSTI and OAR/WPO program offices are acknowledged for providing funding support for some of the results described in this presentation.

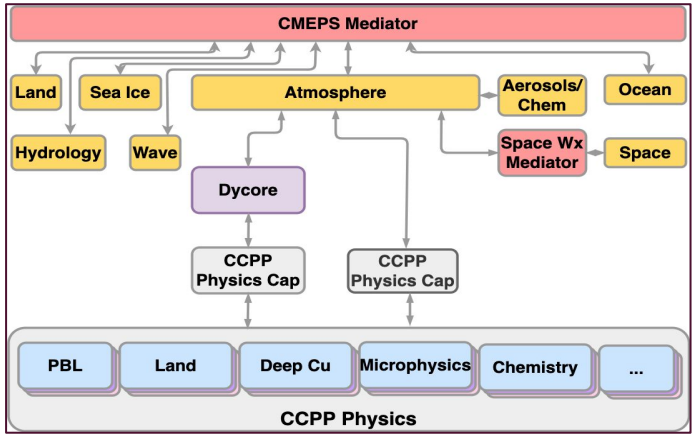
Environmental Modeling Center
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NWS Transformation

The National Weather Service (NWS) is transforming its science, technology, and operations to deliver more accurate, timely, and actionable environmental intelligence. Key efforts include advancing the **Unified Forecast System (UFS)**, **improving data assimilation, integrating AI/ML, and leveraging cloud infrastructure**. The transformation also expands **Impact-Based Decision Support Services (IDSS)** to help partners make informed decisions during high-impact events. By **modernizing its workforce**, tools, and partnerships, NWS is enhancing forecast accuracy, service delivery, and national resilience to weather, water, and climate hazards.

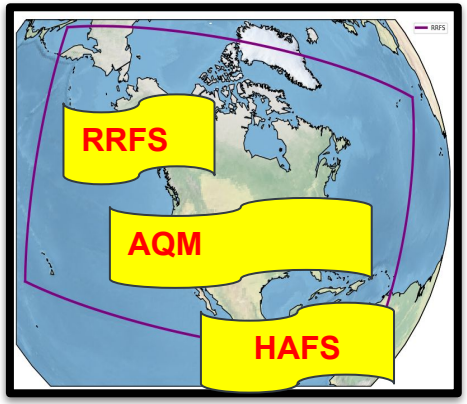
As part of the NWS transformation effort, the NCEP **Environmental Modeling Center (EMC)** and the OSTI **Meteorological Development Laboratory (MDL)** are being merged to streamline model development, testing, and operational transition. The new **Model Development Center (MDC)** will integrate EMC's numerical weather prediction expertise with MDL's applied modeling, statistical post-processing, and decision-support capabilities. This consolidation will strengthen collaboration, improve efficiency, and enhance consistency across the NWS modeling enterprise, enabling faster delivery of improved forecast guidance and services.

NOAA is collaborating with the US weather and climate science community to develop the next generation fully coupled earth system modeling capability for both research and operational forecast applications across different temporal and spatial scales.



- WAVEWATCH III wave
- CICE6 sea-ice
- GOCART aerosols
- CMAQ air quality

- CMEPS mediator
- FV3 dycore
- CCPP physics
- MOM6 ocean
- Noah-MP LSM

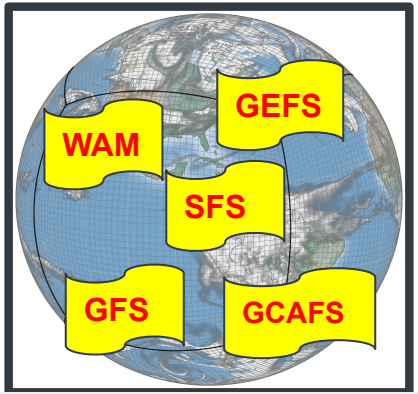


Regional:

HAFS - Hurricane Analysis and Forecast System (parent 4km; nest 2km)

RRFS - North America Rapid Refresh Forecast System (3km)

AQM - North American Air Quality Model (12km)



Global:

GFS - Medium-Range Deterministic Weather Forecast Model (9km)

GEFS- Global Ensemble Sub-Seasonal Forecast System (25km)

SFS - Seasonal Forecast System (50km)

WAM - Whole Atmospheric Model (up to 500 km; 50km)

GCAFS- Global Chemistry and Aerosol Forecast System (25km)

Joint Effort for Data assimilation Integration

Infrastructure for Unified Data Assimilation

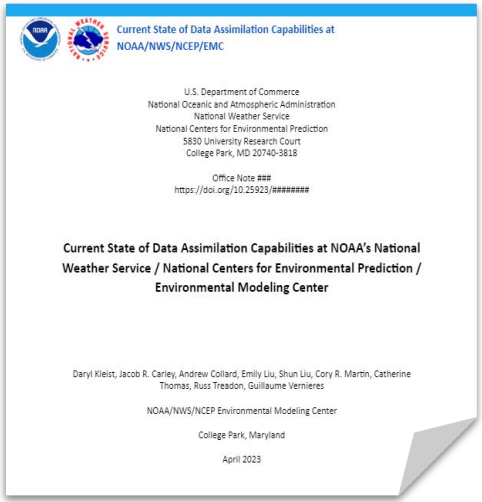
GSI in operations since 2007, but portions of the code are 30+ years old

JEDI is a project within the Joint Center for Satellite Data Assimilation (JCSDA)

JEDI provides a software infrastructure for DA that:

1. **is model agnostic (but requires an interface to models!)**
2. **is generic and portable**
3. **does not impose specific methodologies or algorithms**
4. **allows to share efforts (new observation types, etc.) across different orgs.**

[History & Current Status]


Current State of Data Assimilation Capabilities at NOAA/NWS/NCEP/EMC

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Centers for Environmental Prediction
5830 University Research Court
College Park, MD 20740-3818

Office Note ###
https://doi.org/10.25923/########

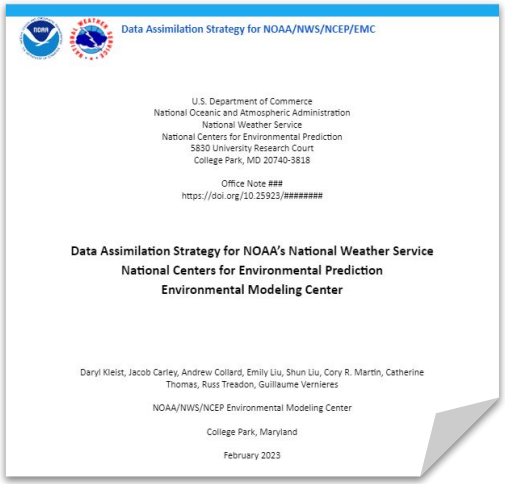
Current State of Data Assimilation Capabilities at NOAA's National Weather Service / National Centers for Environmental Prediction / Environmental Modeling Center

Daryl Kleist, Jacob R. Carley, Andrew Collard, Emily Liu, Shun Liu, Cory R. Martin, Catherine Thomas, Russ Treadon, Guillaume Vernieres

NOAA/NWS/NCEP Environmental Modeling Center

College Park, Maryland

April 2023


Data Assimilation Strategy for NOAA/NWS/NCEP/EMC

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Data Assimilation Strategy for NOAA's National Weather Service National Centers for Environmental Prediction Environmental Modeling Center

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College Park, Maryland

February 2023

[10 Year Strategy]

Unifying Physics Parameterizations for Major UFS Applications

	GFSv17 (9 km) & GEFSv13 (25 km) SFS.v1 (50 km) WAM (100km)	RRFSv1 (3-km) (multi-physics ensemble)	HAFSv2 (5.4/1.8 km)	AQMv7 (12km) aka Inline-CMAQ
Deep Convection	sa-SAS	GF and sa-SAS	sa-SAS	sa-SAS
Shallow Convection	sa-SAS	MYNN-EDMF	sa-SAS	sa-SAS
Microphysics	Thompson MP	Thompson MP & NSSL MP	Thompson MP & GFDL MP	GFDL MP
Radiation	RRTMG	RRTMG	RRTMG	RRTMG
Surface Layer	GFS	MYNN & GFS	GFS	GFS
PBL	sa-TKE-EDMF	MYNN-EDMF & TKE-EDMF	sa-TKE-EDMF	sa-TKE-EDMF
Land	NOAH-MP	RUC	NOAH LSM	NOAH LSM
oro and non-oro GWD	uGWP v1	N/A	uGWP.v1 (oro)	uGWP.v0
SS-GWD & TOFD	Yes	Yes	Yes	No

Global Model Development Priorities: GFSv17

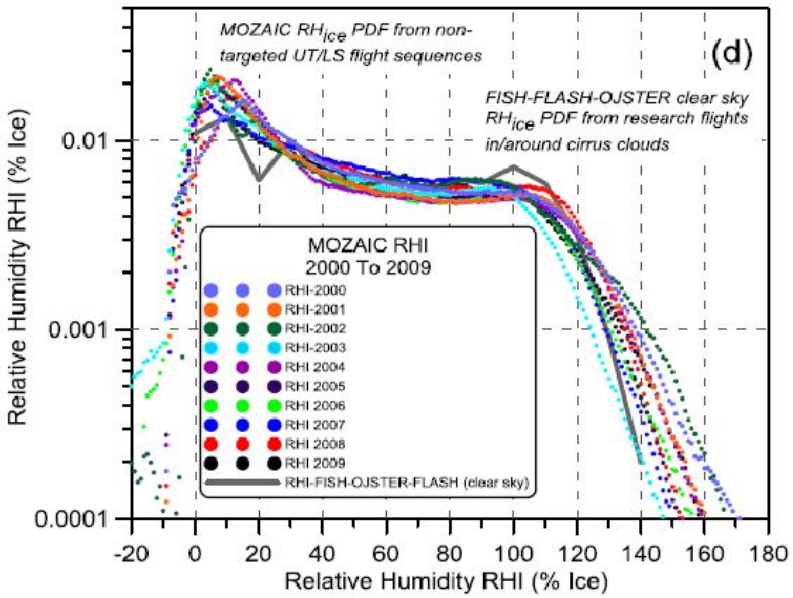
- Fully Coupled forecast model (atmosphere, land, ocean, ice, wave)
- Higher resolution (9-km)
- Major physics improvements including Noah-MP land model, PBL, convection, gravity waves, and Thompson Microphysics
- Unstructured Wave grids w/2-way coupling

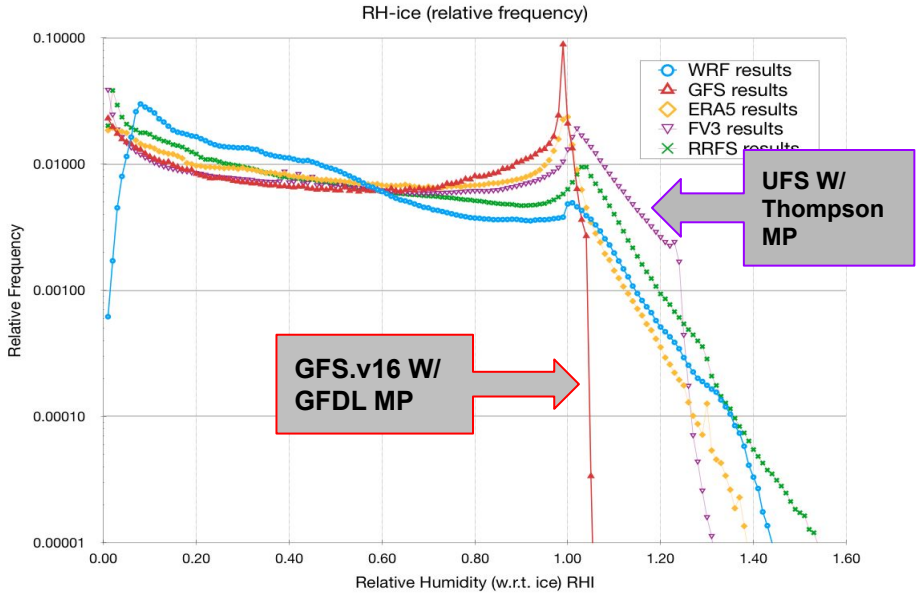
Scheduled for operational implementation in Q4FY26

Weakly Coupled DA

- **Atmosphere**
  - GSI-based hybrid 4DEnVar deterministic analysis
  - GSI-based 4D-LETKF ensemble analysis
- **Marine**
  - **Sea-ice Ocean and Coupled Analysis** (**SOCA**): ocean and sea ice are strongly coupled
  - JEDI-based 3DVar-FGAT for deterministic analysis
  - Ensemble forecast will be coupled and recentered about the deterministic analysis
- **Land**
  - JEDI-based 2DVar for **snow DA**
  - GSI-based 4D-LETKF for **soil moisture and soil temperature** DA (strongly coupled with atmosphere)

Improving Supersaturation and Supercooled Cloud Water in Microphysics

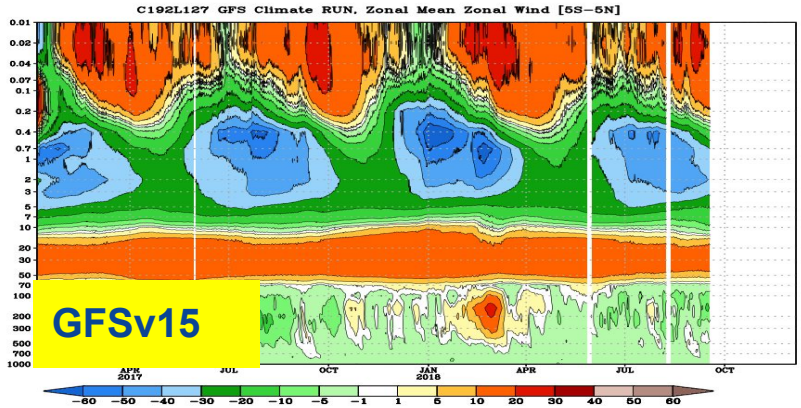


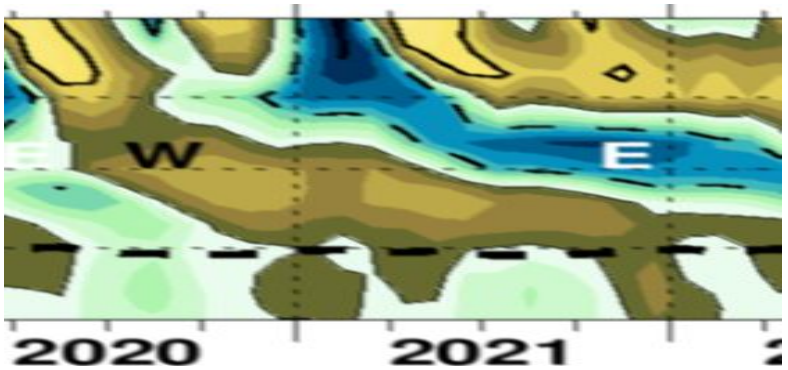


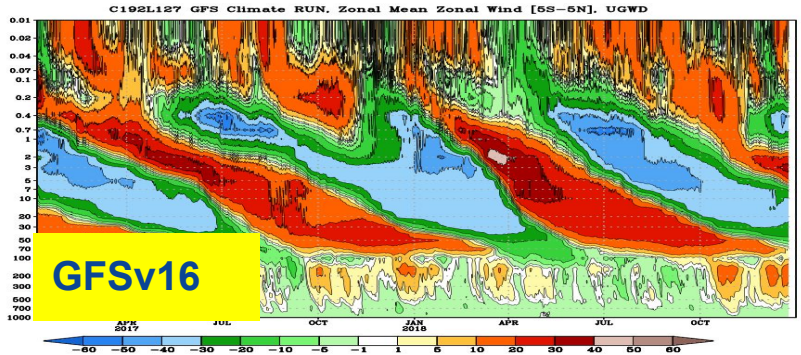
Observed frequency distribution (PDF) of RH relative to ice (RHI) from MOZAIC flight-level obs.

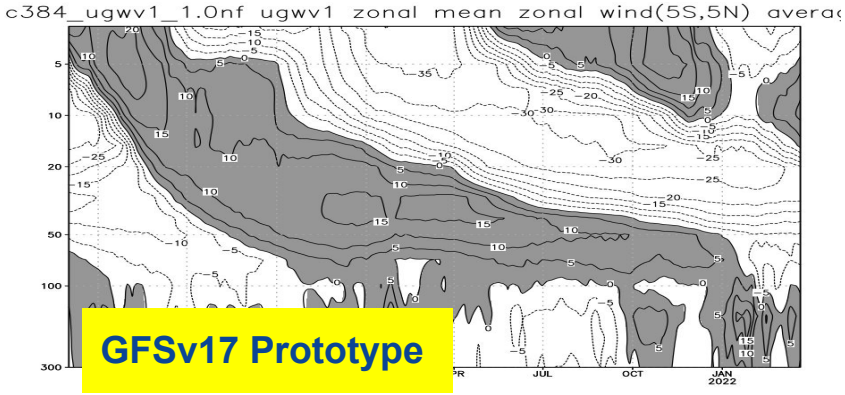
RHI PDF from various models (Credit: Greg Thompson). **Supercooled cloud water is a hazard to aviation**

Better forecasts of the QBO with improved GWD parameterizations



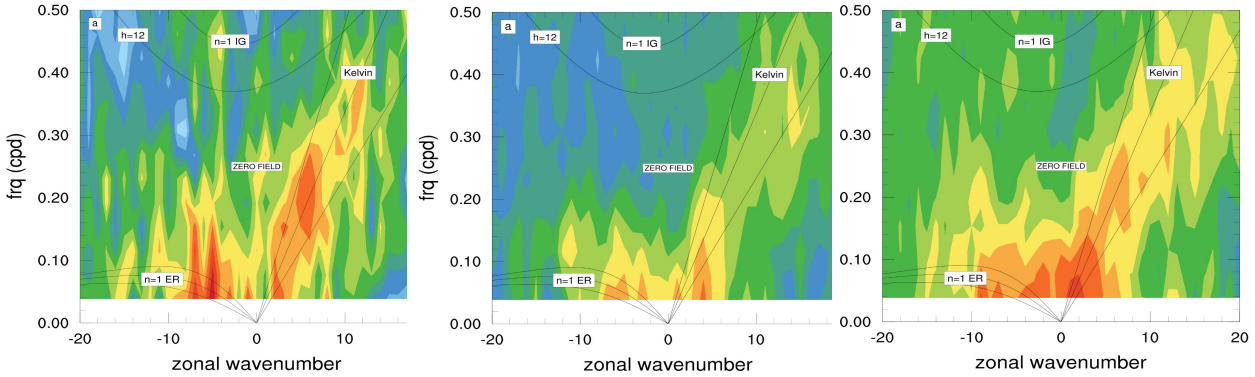


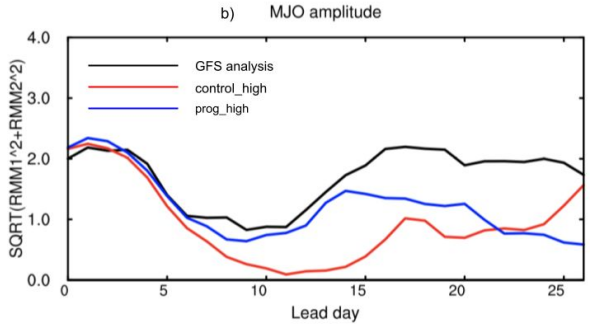


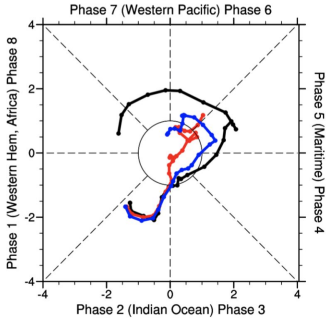


Convection scheme updates to improve MJO and CCEW prediction

a) ERA5 b) control GFSv16 c) prog closure





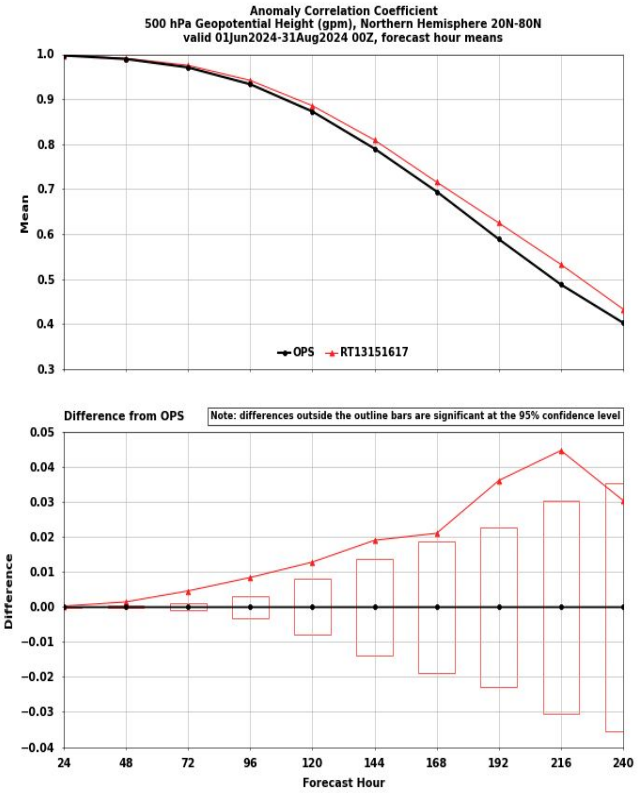


Courtesy of Lisa Bengtsson

A Prognostic-Stochastic and Scale-Adaptive Cumulus Convection Closure for Improved Tropical Variability and Convective Gray-Zone Representation in NOAA's Unified Forecast System (UFS)

Entered in UFS coupled prototype HR1 -> GFSv17/GEFSv13

GFSv17 retrospective Experiment (Summer 2024)



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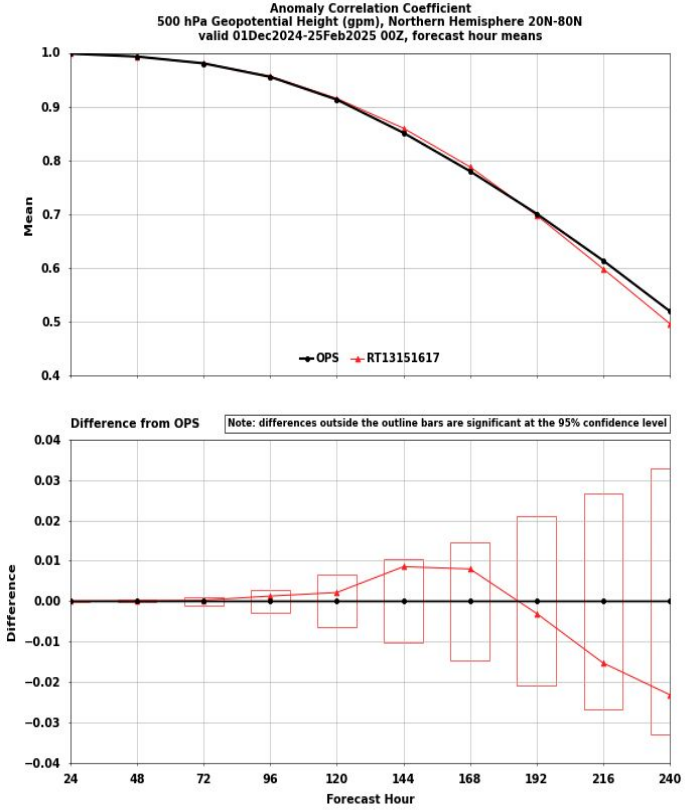
Scorecard Symbol Legend

▲	rt13_15_16_17_stream2 is better than gfs at the 99.9% significance level	▼	rt13_15_16_17_stream2 is worse than gfs at the 99.9% significance level
▵	rt13_15_16_17_stream2 is better than gfs at the 99% significance level	▾	rt13_15_16_17_stream2 is worse than gfs at the 99% significance level
	rt13_15_16_17_stream2 is better than gfs at the 95% significance level		rt13_15_16_17_stream2 is worse than gfs at the 95% significance level
	No statistically significant difference between rt13_15_16_17_stream2 and gfs		Not statistically relevant

GFSv17 retrospective Experiment (Winter 2024-25)



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		10hPa	▼	▲	-		-		▼	▼	▼	▼	▼	▼	▲	▲	▲	▲	▲	▲	▼	▲	▲	▲	▼	▼

Scorecard Symbol Legend

▲ rt13_15_16_17_stream3 is better than gfs at the 99.9% significance level	▼ rt13_15_16_17_stream3 is worse than gfs at the 99.9% significance level
* rt13_15_16_17_stream3 is better than gfs at the 99% significance level	* rt13_15_16_17_stream3 is worse than gfs at the 99% significance level
rt13_15_16_17_stream3 is better than gfs at the 95% significance level	rt13_15_16_17_stream3 is worse than gfs at the 95% significance level
No statistically significant difference between rt13_15_16_17_stream3 and gfs	Not statistically relevant

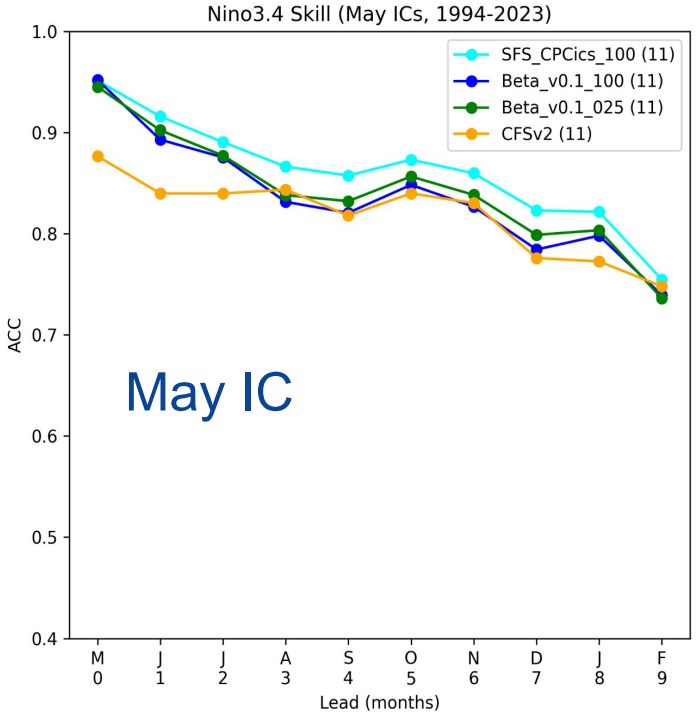
Dates: 20241201-20250225

Global Model Development Priorities

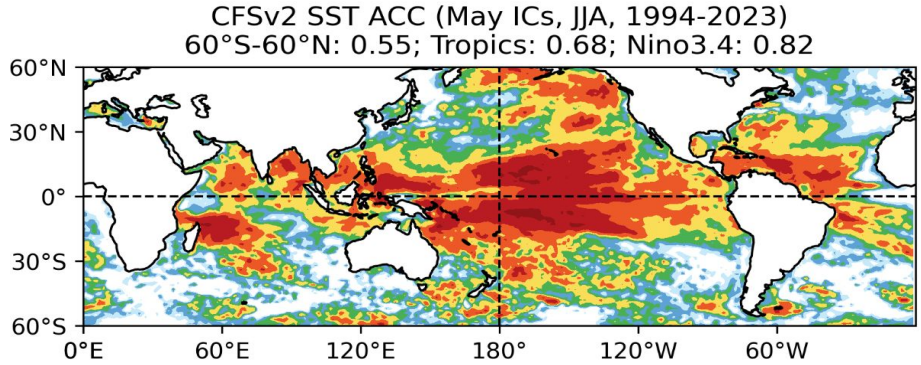
SFS to replace CFSv2

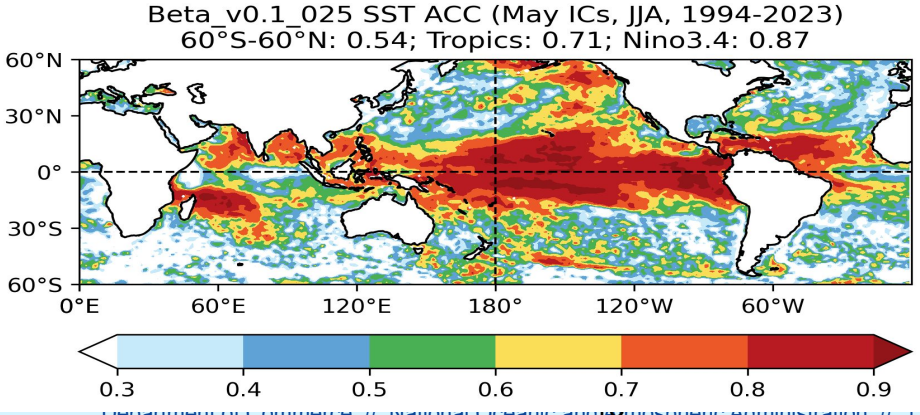
	CFSv2	SFS
Atmosphere	T126/L64, GSM	**C192L127 (~50m), FV3-hydro**
Land	Noah 4 level soil model	**NOAH-MP**
Ocean	2-way coupling with MOM4 (0.25°-0.5°, tripole grid, 40 Levels)	**2-way coupling with MOM6 (0.25° tripole grid, 75 layers)**
Sea Ice	2-way coupling with SIS1 (0.5° tripole grid, 5 ice thickness categories)	**2-way coupling with CICE6 (0.25° tripole grid, 7 ice thickness categories)**

SFSv1 Beta (11 ensemble members)



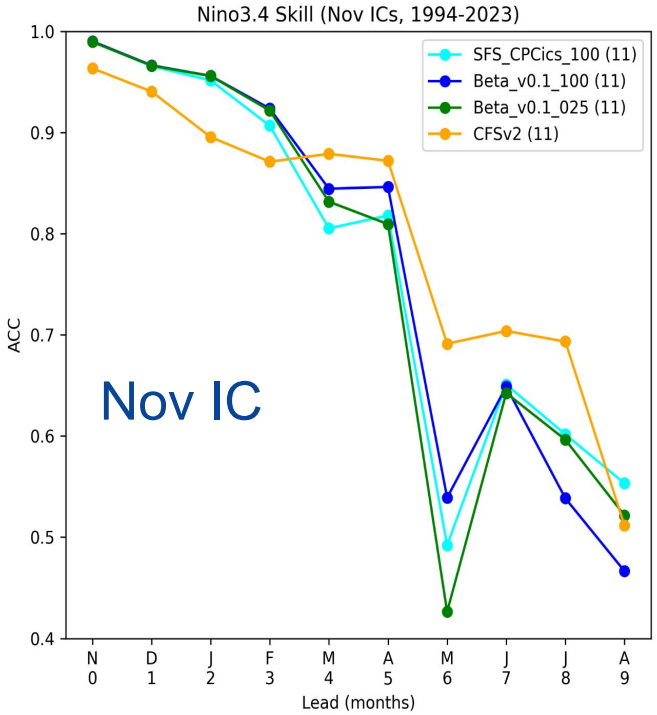
JJA SST Anomaly Correlations



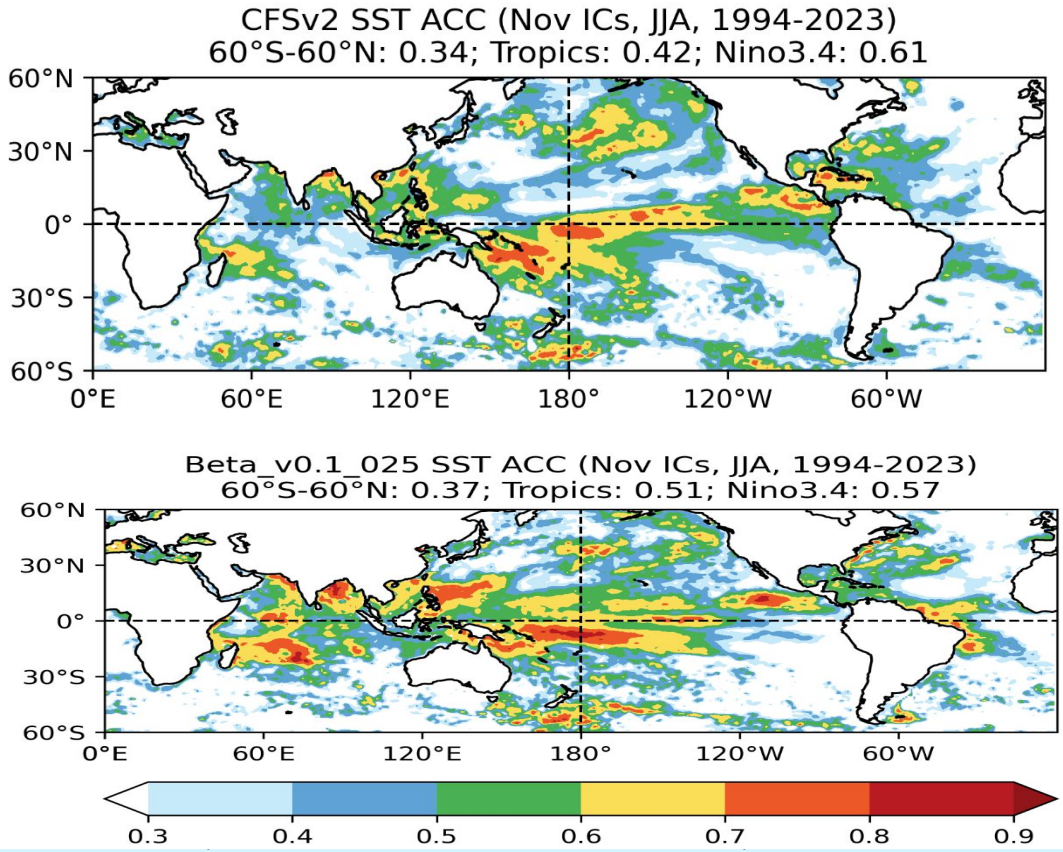


results provided by: Yanyun Liu, Wanqiu Wang, Jieshun Zhu, Johnna Infanti, Arun Kumar

SFSv1 Beta (11 ensemble members)



JJA SST Anomaly Correlations

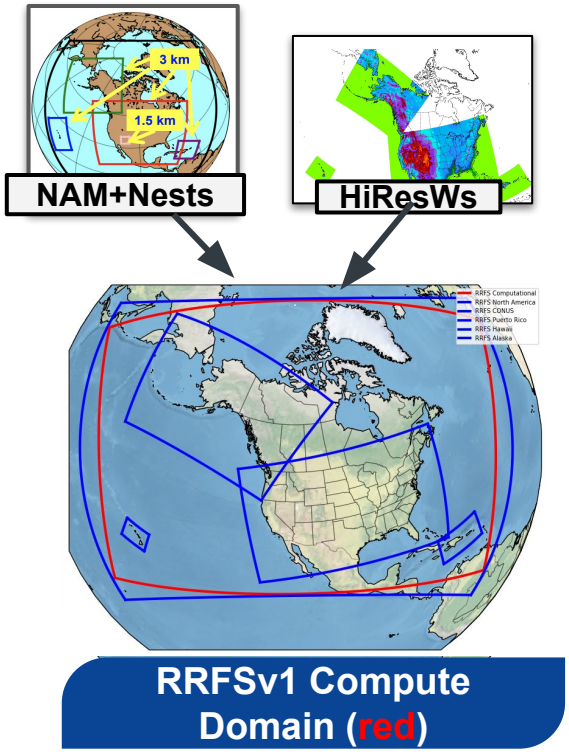


results provided by: Yanyun Liu, Wanqiu Wang, Jieshun Zhu, Johnna Infanti, Arun Kumar

Regional Model: Rapid Refresh Forecast System (RRFS)
A UFS Application

- Currently based on FV3 dynamical core Limited Area Model
- Hourly updated
- 3 km grid spacing over North America
- 65 vertical layers
- Hybrid 3DEnVar assimilation (30 members)
- Includes Smoke & Dust
- Deterministic forecasts to *at least* 18h every hour
- Deterministic & Ensemble forecasts to 48+h every 6 hours

- **RRFSv1 will be implemented into operations in early 2026**
- **RRFSv2**
  - Transition from FV3 dynamical core to MPAS
  - *Adding American Samoa and Micronesia Support to improve service to underserved communities*



Hurricane Modeling at EMC

HAFSv1.0 implemented in June 2023,

- First UFS-based application in operation

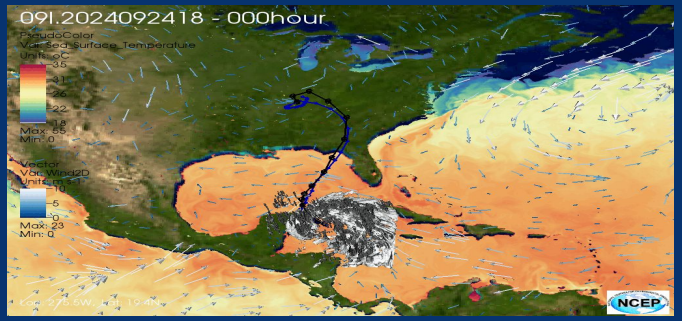
HAFSv2.0 implemented in July 2024

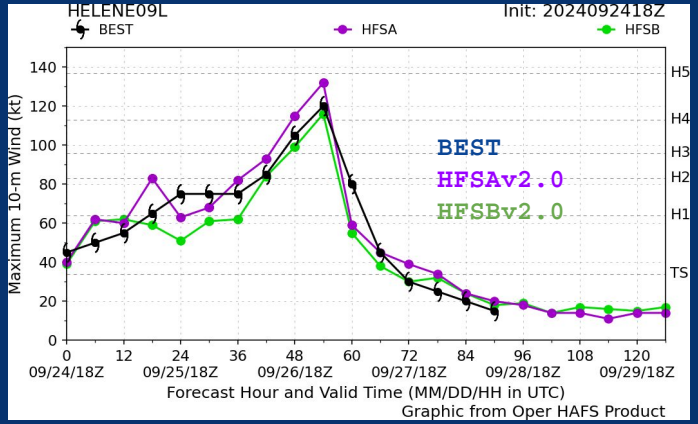
- Increased horizontal resolutions,
- improved model efficiency and stability
- Improved Vortex Initialization
- Improved inner-core data assimilation system
- Introduced new ocean model MOM6

Future Directions

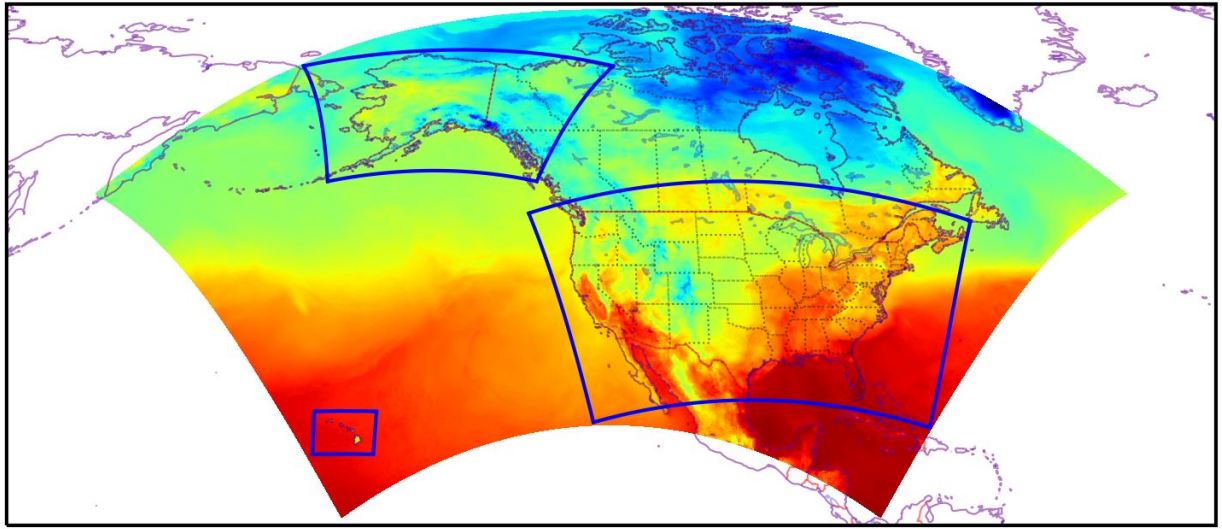
- Multiple storm basin scale prediction
- AI-HAFS ensemble
- Merging HAFS with GFS

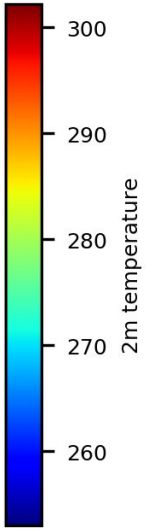
Hurricane Helene 09L, initialized at 2024092418

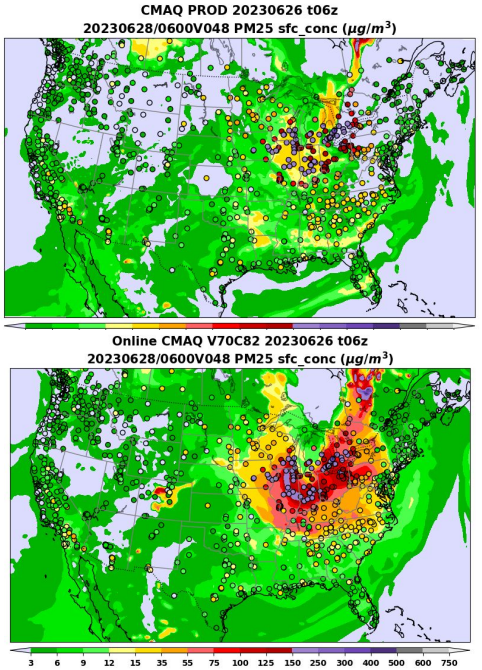




AQMv7: Online-CMAQ in UFS on a single large North American domain







- **AQMv7 became operational in May 2024. It was the first UFS-based AQ modeling system with online meteorology and chemistry interaction, covers the North American large domain, replacing the previous offline model that ran over CONUS, AK and HI, separately.**
- **Primary products are ozone PM2.5**

- Hourly RAVE wildfire emissions over the North American domain
- Anthropogenic and biogenic emissions for this domain (NEI 2016v1 plus global)

UFS-AQM v8.0 Development and Implementation

- Upgrade the Common Community Physics Package (CCPP) to align with the version used in the Global Forecast System (GFS) v17.
- Upgrade CMAQ from version 5.2.1 to version 5.4.
- Update the National Emission Inventory (NEI) from 2016 to 2019.
- Refine fire emission representations and activate Volatile Organic Compound (VOC) emissions from wildfires.
- Improve $PM_{2.5}$ bias correction during intense wildfire events.
- The implementation is scheduled for **2026**

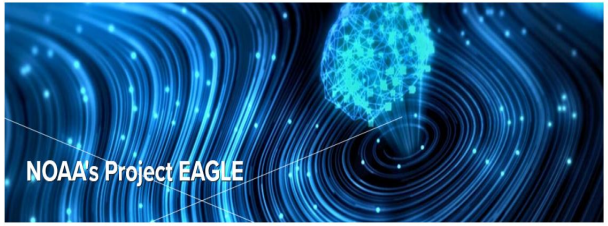
New Project: Global Chemistry and Aerosol Forecast system (GCAFS)

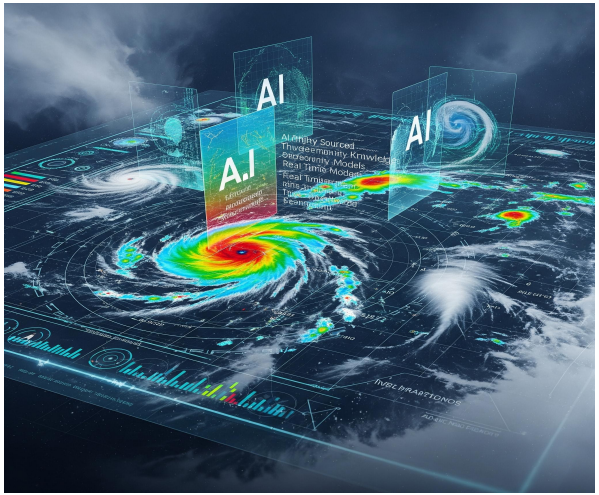
Combining global aerosol, chemistry and regional AQ modeling

- With **nested domains** for regional high-res air quality forecasting
- Including **O3, NOx, SO2, CO, CH4, NH3** etc, and various aerosol components (including dust, sea salt, sulfate, black carbon, and organic matter)
- Provide O3 and other trace gases for radiation calculation in UFS global applications, including GFS/GEFS/SFS
- Include **fire behavior modeling**
- **Data assimilation** of aerosols and trace gas species
- **Reanalyses for AI/ML applications**

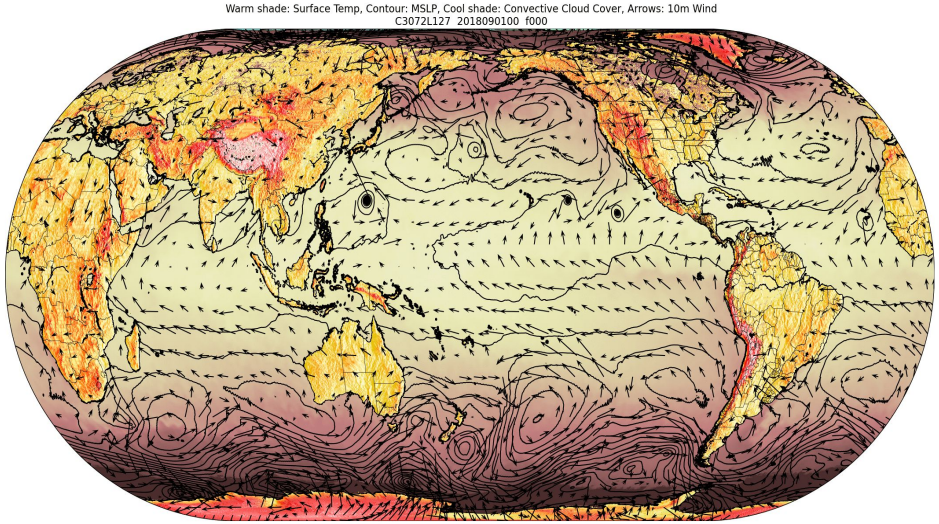
Major Ongoing AI/ML Activities

- Global systems : AI-GFS, AI-GEFS, HGEFS, AI-GCAFS
- Regional systems: AI-HAFS, AI-RRFS
- ML Bias Correction
- Direct from Observations with OCELOT
- Generative AI: for scientific software development
- Collaboration with AI4NWP, NOAA Research Labs, and Private Sector
- Plan move toward Anemoi framework





Thank you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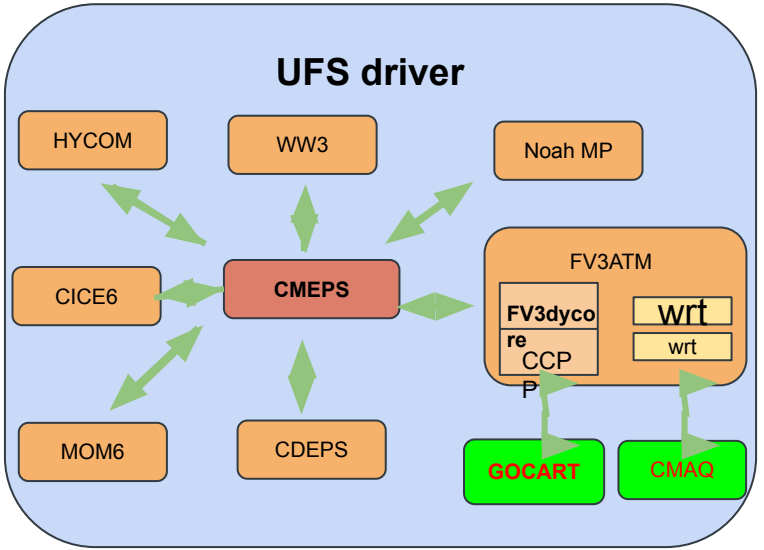
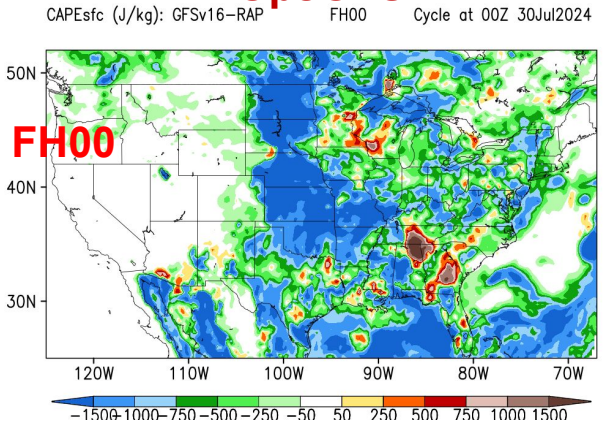
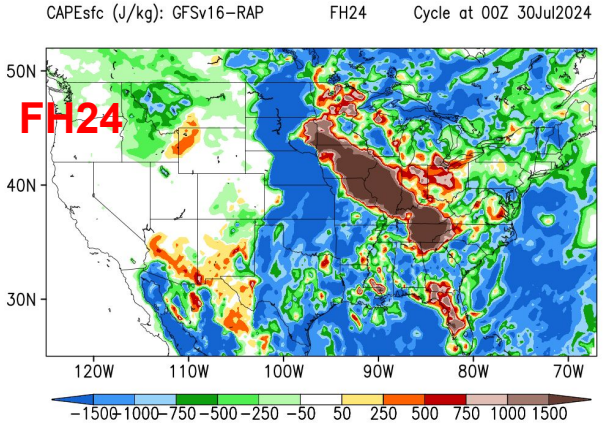
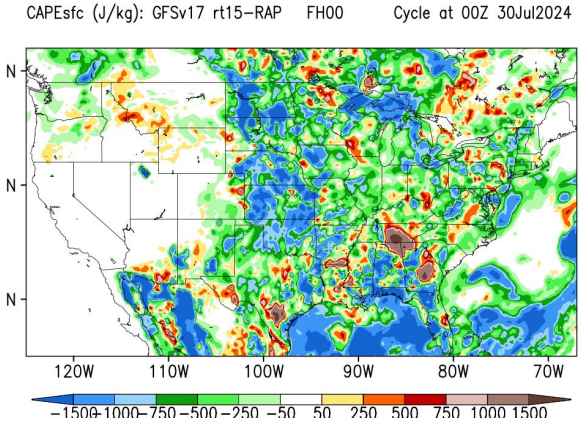
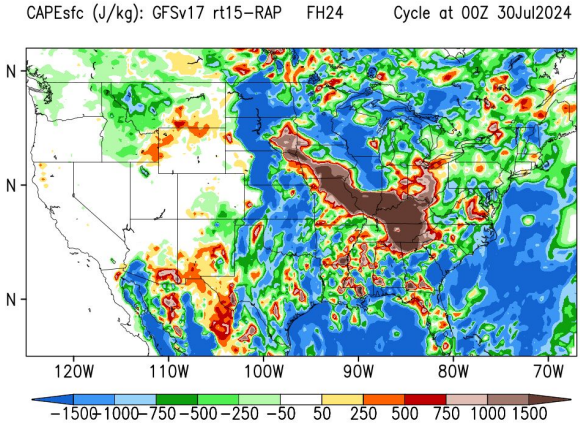
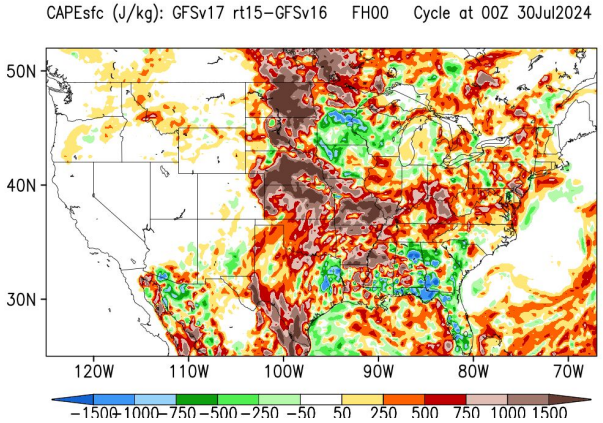
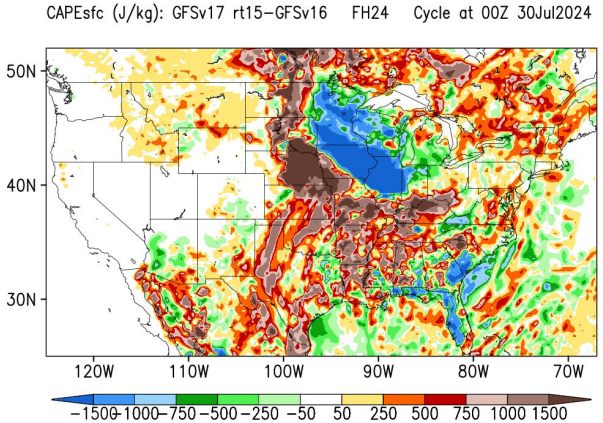
C3072L127 2018090100 f000


UFS driver
HYCOM
WW3
Noah MP
CICE6
CMEPS
FV3ATM
FV3dyco
re
CCP
P
wrt
wrt
MOM6
CDEPS
GOCART
CMAQ

CAPE (J/kg) FH00/24 ICs: 00Z 30 JUL 2024

OpsGFS





GFSv17 rt13