Center Update -- NCEP Environmental Modeling Center

NATIONAL WEATHER SERVICE

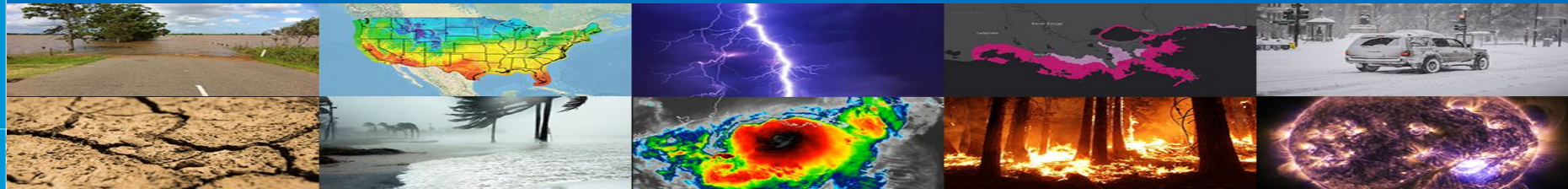
Fanglin Yang

Physics and Dynamics Division

NOAA/NWS/NCEP Environmental Modeling Center

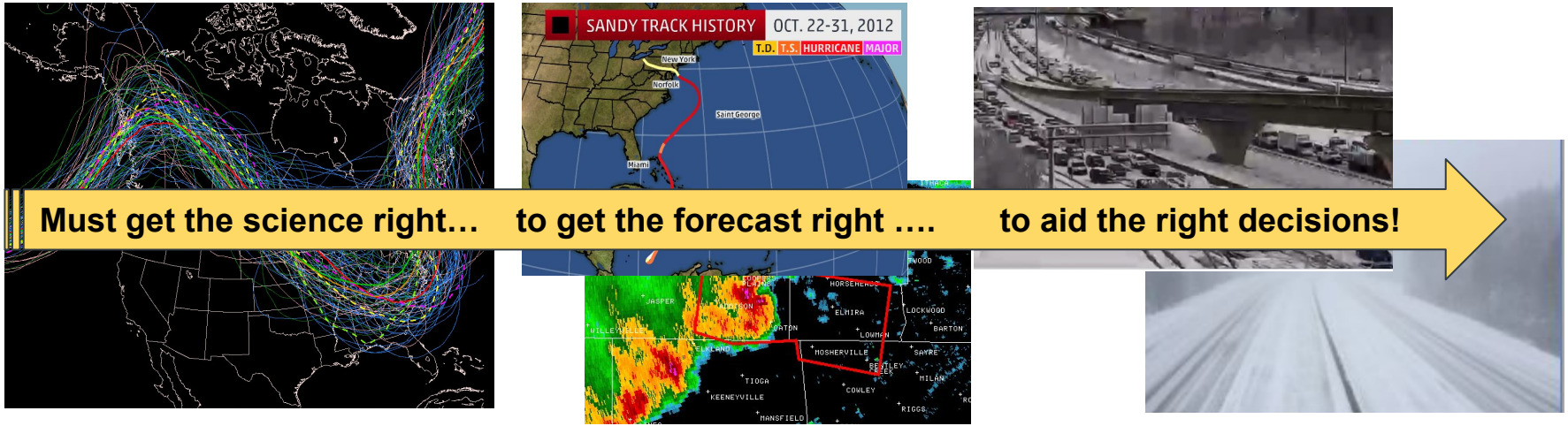
Acknowledgment: This presentation is made possible with contributions from EMC management, developers and community collaborators.. NOAA NWS/OSTI and OAR/WPO program offices are acknowledged for providing funding support for some of the results described in this presentation.

39th WGNE workshop, November 4-8, *Météo-France, Toulouse, France*



Mission of NCEP Environmental Modeling Center (NCEP)

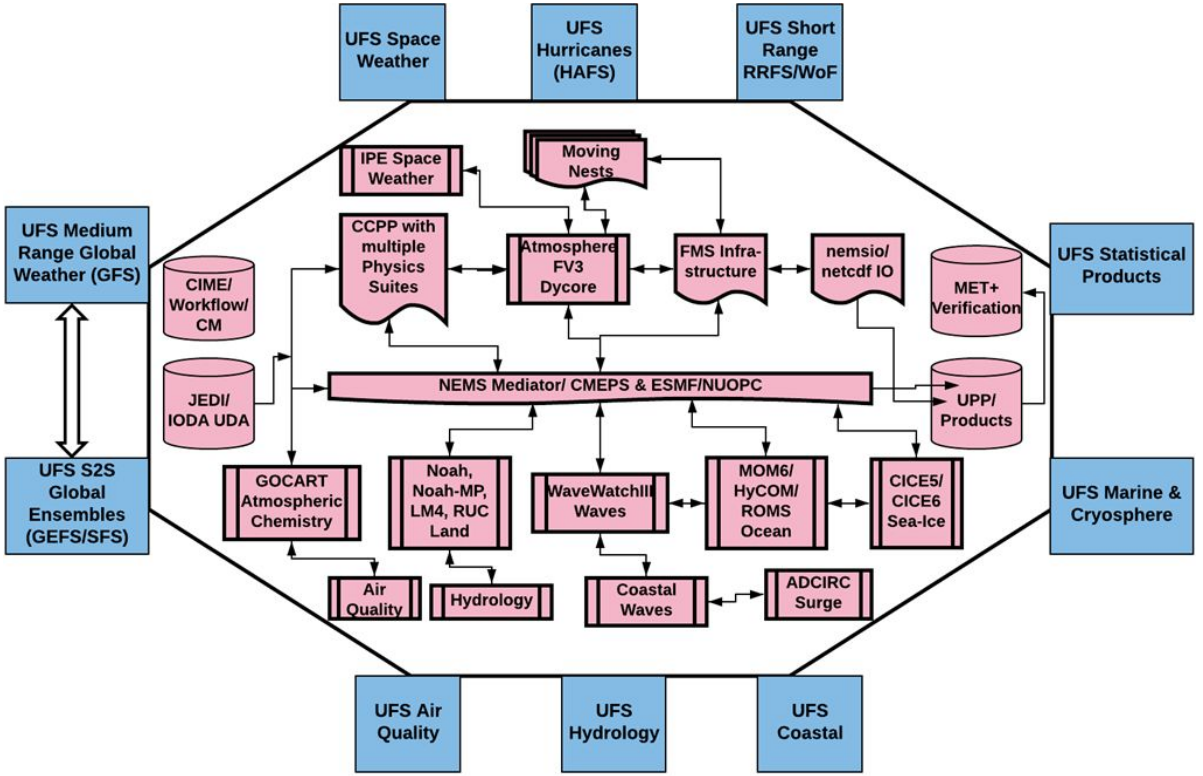
EMC develops, improves and monitors data assimilation systems and models of the atmosphere, ocean, land surface and coupled system, using advanced methods developed internally and cooperatively with scientists from universities, NOAA Labs, other government agencies, and the international scientific community. The operational modeling suite provides the **foundational numerical guidance** that US National Weather Service (NWS) scientists and forecasters rely on in making **forecasts, warnings, and decision support service products**.



Transitioning Isolated Production Suites to Unified Forecast System (UFS) Applications

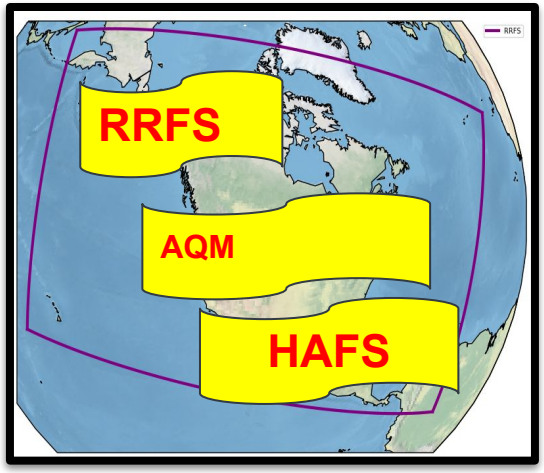
"UFS is configurable into multiple applications that span local to global domains and predictive time scales from less than an hour to more than a year."

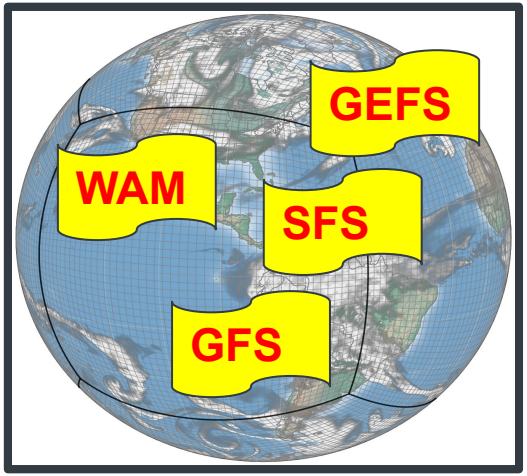
Conceptual UFS applications in production covering all NPS applications, maintaining the dependencies between the applications and products.



Major UFS Applications:

SRW/CAM





MRW/S2S

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)

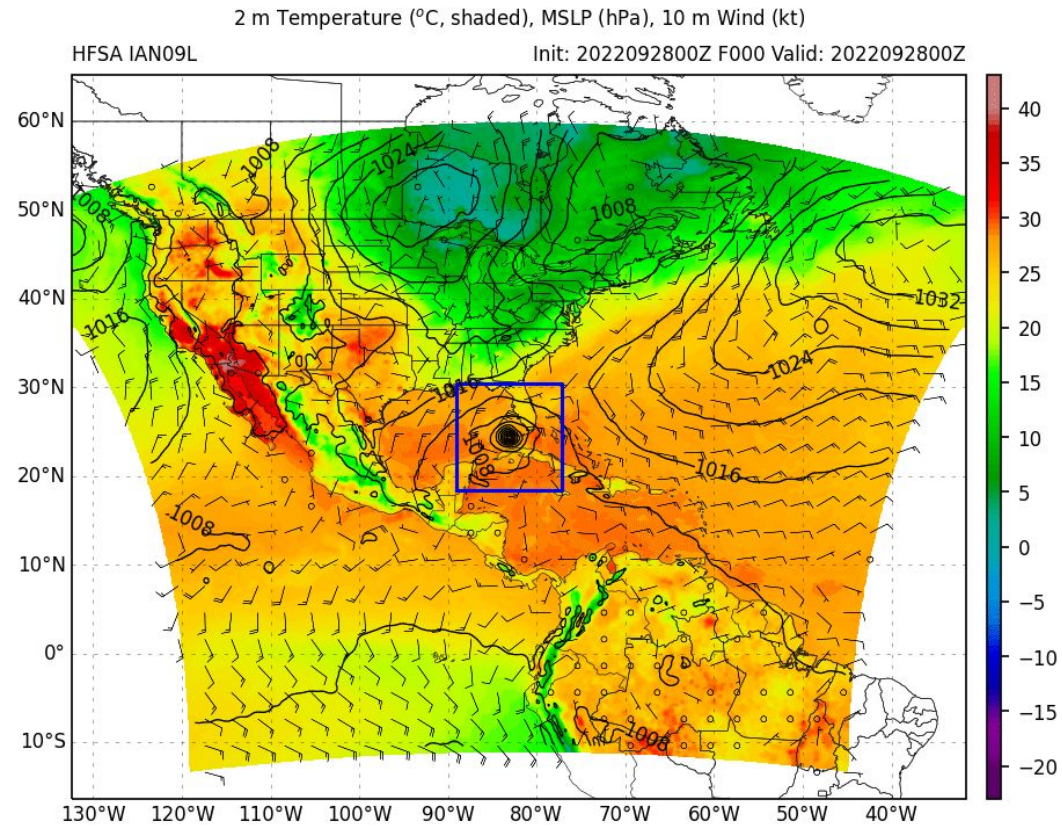
SFS - Seasonal Forecast System (??)

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

Recent Operational Modeling Achievements

Model version#	Name	Implementation date
RTMA/URMAv2.10.5	**Real Time and UnRestricted Mesoscale Analysis**	1/24/2023
GLWUv2	**Great Lakes Waves-Unstructured Forecast System**	5/9/2023
HAFSv1	**Hurricane Analysis and Forecast System**	6/27/2023
NAEFSv7	**North American Ensemble Forecast System**	12/5/2023
EVSv1	**EMC Verification System**	3/26/2024
AQMv7	**Air Quality Model**	5/14/2024
HAFSv2	**Hurricane Analysis and Forecast System**	7/16/2024

HAFSv1 Implemented for 2023 Hurricane Season



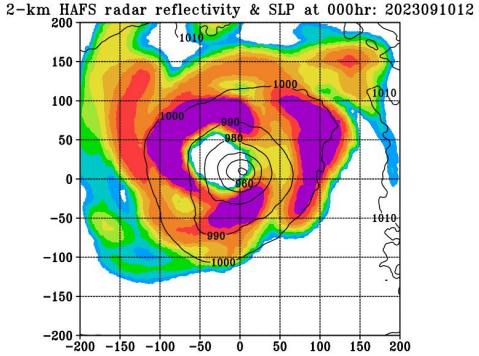
HAFS Development Objectives:

- Use cloud resolving resolutions within nests (static, telescopic and moving) and coupled domains
- Improve physics schemes by using observations to enhance the accuracy of coupled simulation of physical processes for TC's
- Advance inner-core and satellite DA algorithms for TCs; ingest new observations and adopt advanced DA algorithms

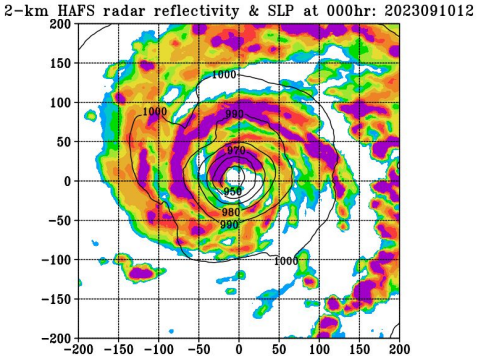
New in 2024: HAFSv2

HAFSv2 implemented on July 16, 2024

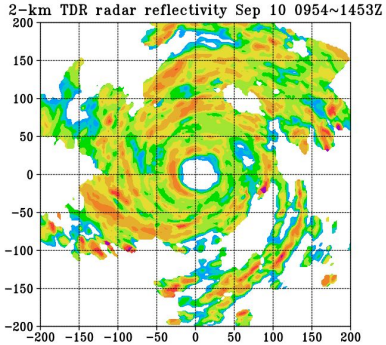
Upgrade: Relocating and Cycling Hydrometeors/Vertical Velocity



HAFSv1



HAFSv2

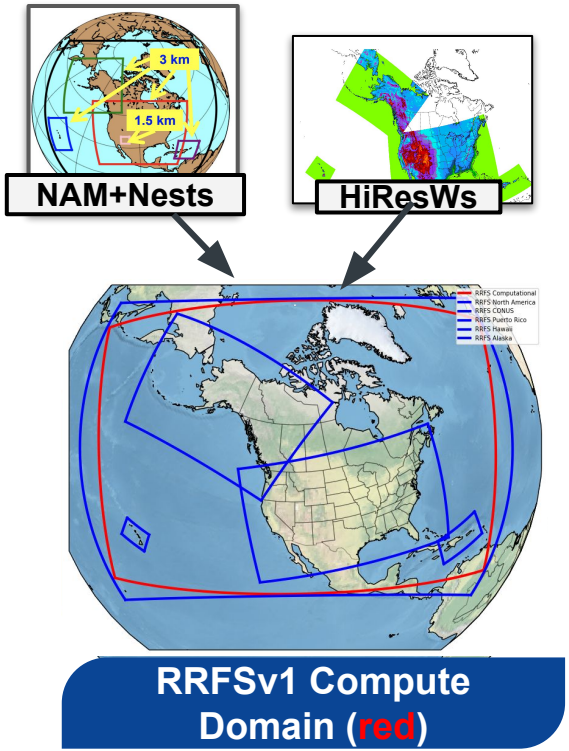


Obs: TDR data

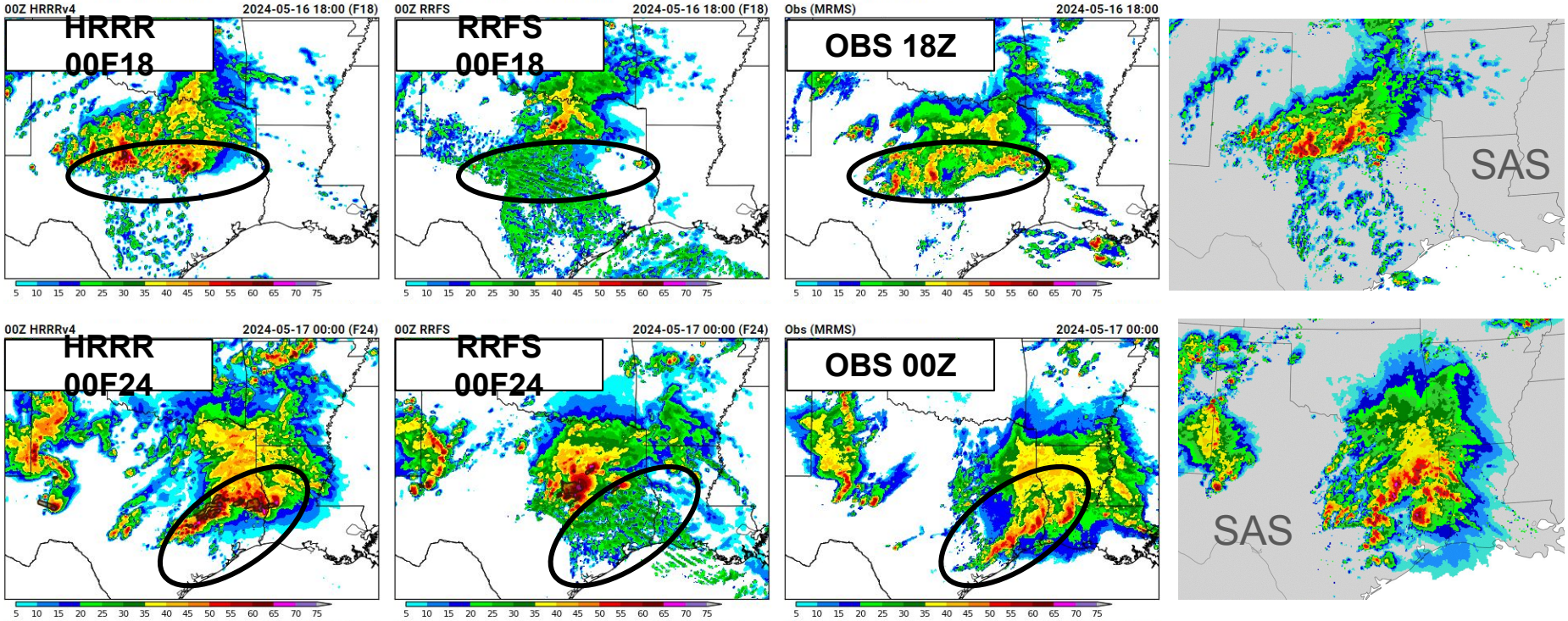
Rapid Refresh Forecast System (RRFS)

- 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: implementation date TBD**
- **RRFSv2**
  - Transition from FV3 dynamical core to MPAS
  - *Adding American Samoa and Micronesia Support to improve service to underserved communities*

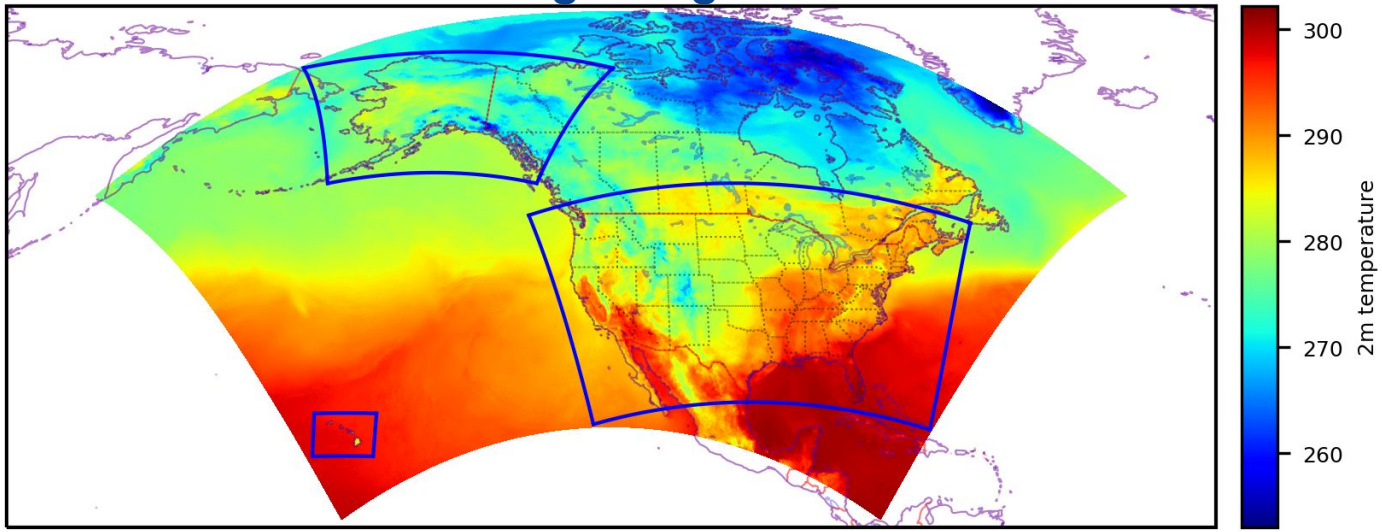


Sensitivity of RRFS forecast to parameterized convection scheme -- recent change to saSAS improved RRFSv1 forecast



Courtesy of NWS/SPC and Shun Liu at EMC

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



AQMv7 implemented on May 14, 2024

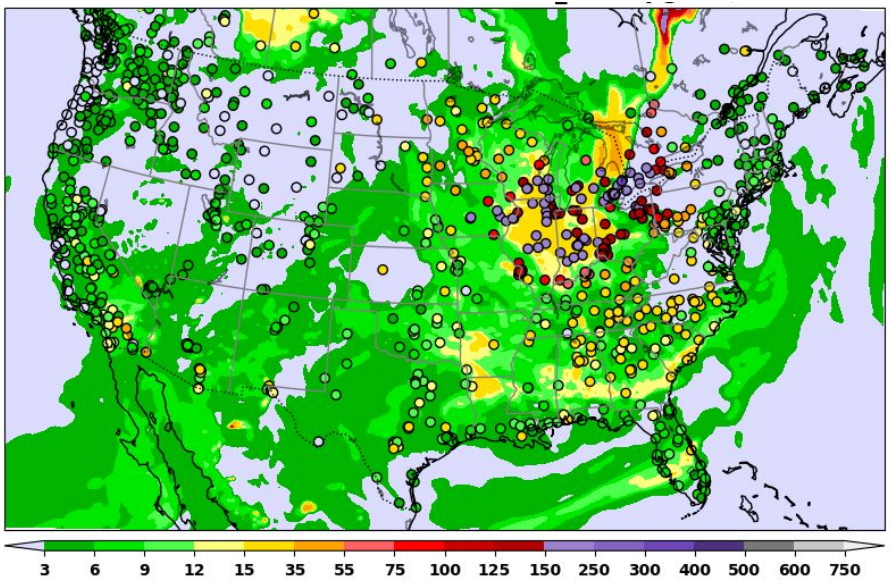
- **<u>Near-real-time</u> online-CMAQ has run since July 2022 over the North American large domain that covers all 3 current operational product domains: CONUS, AK and HI.**
- **Updates have been integrated into this near-real-time run to build the AQMv7 system**

- Updated LBC (GEOS 5 + GEFS-Aerosols) and wet deposition
- Fengsha dust module
- Bias correction for ozone and PM2.5
- Post-processing for 8h ozone maximum and daily average PM2.5

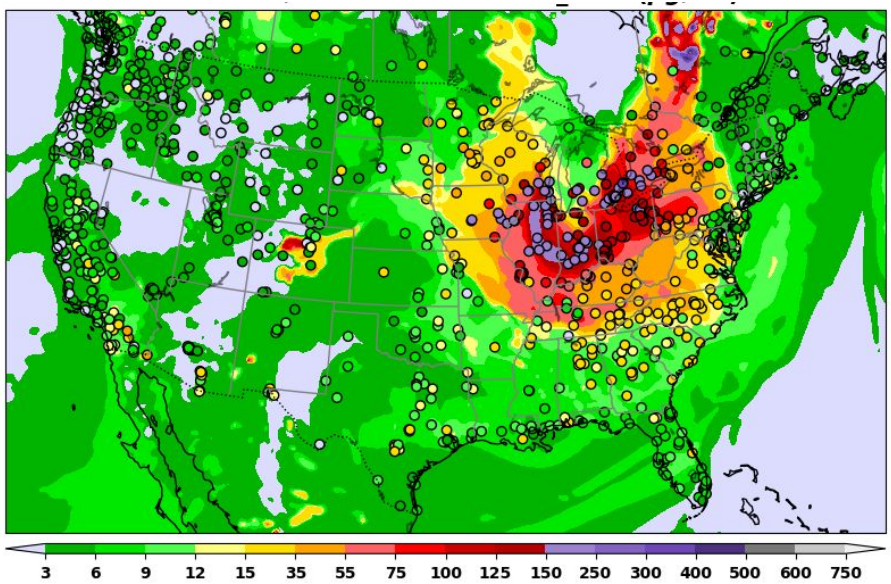
- Hourly RAVE wildfire emissions over the North American domain
- Anthropogenic and biogenic emissions for this domain (NEI 2016v1 plus global)

Quebec fires: PM2.5 prediction on June 26, 2023

Operational AQMv6



AQMv7 candidate



- AQMv7 candidate system (right) predicted higher PM2.5 (ug/m3) in the Eastern US due to Quebec fires using RAVE (ABI+VIIRS) emissions, showing better agreement with AirNow observations compared to operational prediction (left)

Highlights of recent global model development activities and achievements

Physics Development for the Global Model: GFSv16/GEFSv12 --> UFS-based GFSv17/GEFSv13/SFSv1/WAMv2

Items highlighted in blue color had also been included in HAFS.v1 and V2

Introduced

- a **two-moment cloud microphysics** scheme (GFDL MP --> **Thompson MP**)
  - Improved the cloud radiation interaction capabilities
  - Introduce Semi-Lagrangian Sedimentation for improved stability and cost
- a **new land model** (NOAH LSM --> NOAH-MP LSM)
- **new small-scale gravity wave** and **turbulent orographic form drag** parameterizations
- a **new** parameterization for **convective organization**, and a new **Prognostic**-Stochastic and Scale-Adaptive **Cumulus Convection Closure**
- **new stochastic physics** in the ocean, land-surface and the atmosphere
- a **new positive definite tracer advection (TVD)** scheme in convection and PBL
- new capability for **coupling between aerosols and physics**
- **new land/ocean/lake masks, new ice climatology, and surface composites over fractional grid**

Improved

- **cumulus convection** schemes and **boundary layer** schemes to address model systematic biases
- **gravity wave drags and mountain blocking**
- **coupling of the land model and surface layer** schemes.

Land: **Noah**
PBL: **TKE-EDMF**
Microphysics: **GFDL MP**
Deep convection: **saSAS**
Shallow convection: **saMF**
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

GFS.v16 Physics Package

Land: **Noah-MP**
Fractional grid and Compositing surface layer variables, albedo/emissivity
PBL: **TKE-EDMF**
Reduced background diffusivity, limit PBL updraft overshoot.
Microphysics: **GFDL MP**
Deep convection: **saSAS**
Stricter trigger criteria, reduced entr. rate, reduced rain evap. rate
Shallow convection**: saMF**
Radiation:**RRTMG**
MERRA2 aerosols
Gravity wave drag: **uGWDv0**

Land: **Noah-MP**
Tuning, use CICE albedo in atm, new ice climatology, VIIRS based land/lake mask, spun up land IC's.
PBL: **TKE-EDMF**
Positive definite mass flux scheme, reduced entrainment rate
Microphysics: **Thompson MP +**
Semi-Lagrangian Sedimentation + refined ice microphysics
Deep convection: **saSAS**
Cellular automata convective org scheme.
Positive definite mass flux scheme
Shallow convection: **saMF**
Positive definite mass flux scheme
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

Land: **Noah-MP**
Bug-fixes
PBL: **TKE-EDMF**
Microphysics: **Thompson MP**
Improve radiative fluxes and cloud cover
Deep convection: **saSAS**
Prognostic closure
Shallow convection: **saMF**
Prognostic closure
Radiation:**RRTMG**
Couple convective cloud to radiation
Gravity wave drag: **uGWDv0**

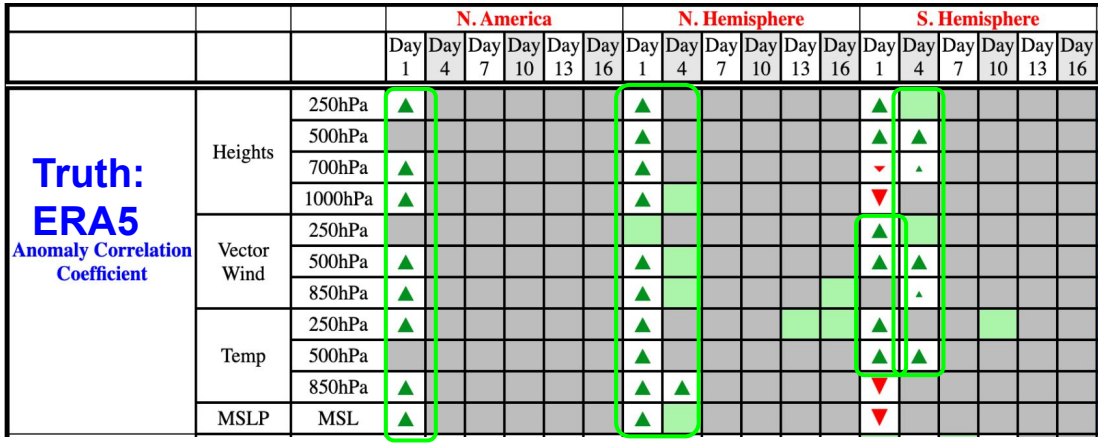
Land: **Noah-MP**
Bug-fixes
PBL: **TKE-EDMF**
wind shear effect and TKE dependent entrainment.
CONUS CAPE enhancement
Microphysics: **Thompson MP**
Reduce stratus and downwelling rad. fluxes
Deep convection: **saSAS**
wind shear effect and TKE dependent entrainment
Shallow convection: **saMF**
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

Land: **Noah-MP**
PBL: **TKE-EDMF**
Microphysics: **Thompson MP**
Deep convection: **saSAS**
Shallow convection: **saMF**
Radiation:**RRTMG**
Address excessive large net SW net to ocean at low sun angles
Gravity wave drag: **uGWDv1**
Omega vertical velocity
Convective cloud water in radiation and cloud fraction
Improved damping mechanisms
New MERRA2 aerosol climatology

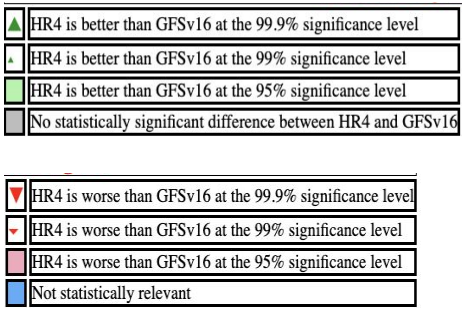
UFSR2O physics/dynamics development coordination
Fanglin Yang, Lisa Bengtsson

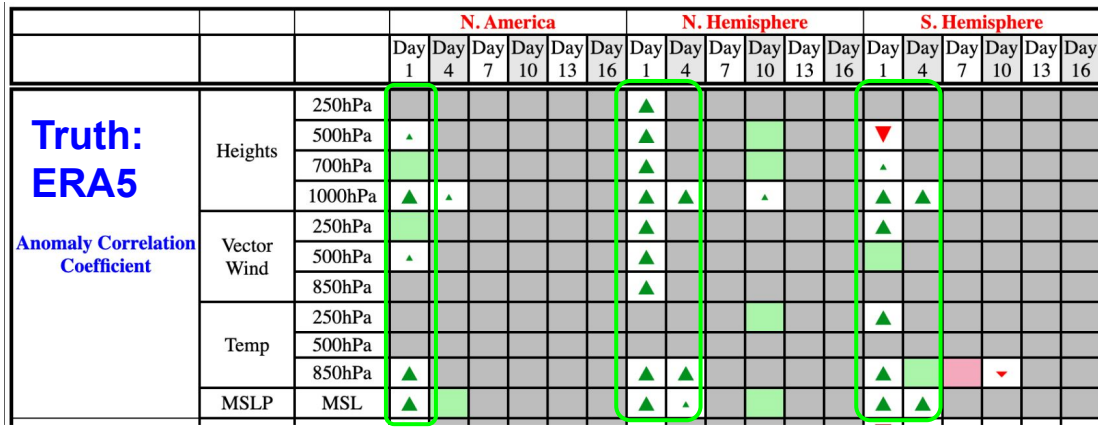
Acknowledgement to ALL UFS coupled/infrastructure/physics/dynamics/DA developers, application/project leads , and evaluators!

Medium-Range Forecast:
GFSv17 (9km) Prototypes Compared current operation GFSv16 (13-km)

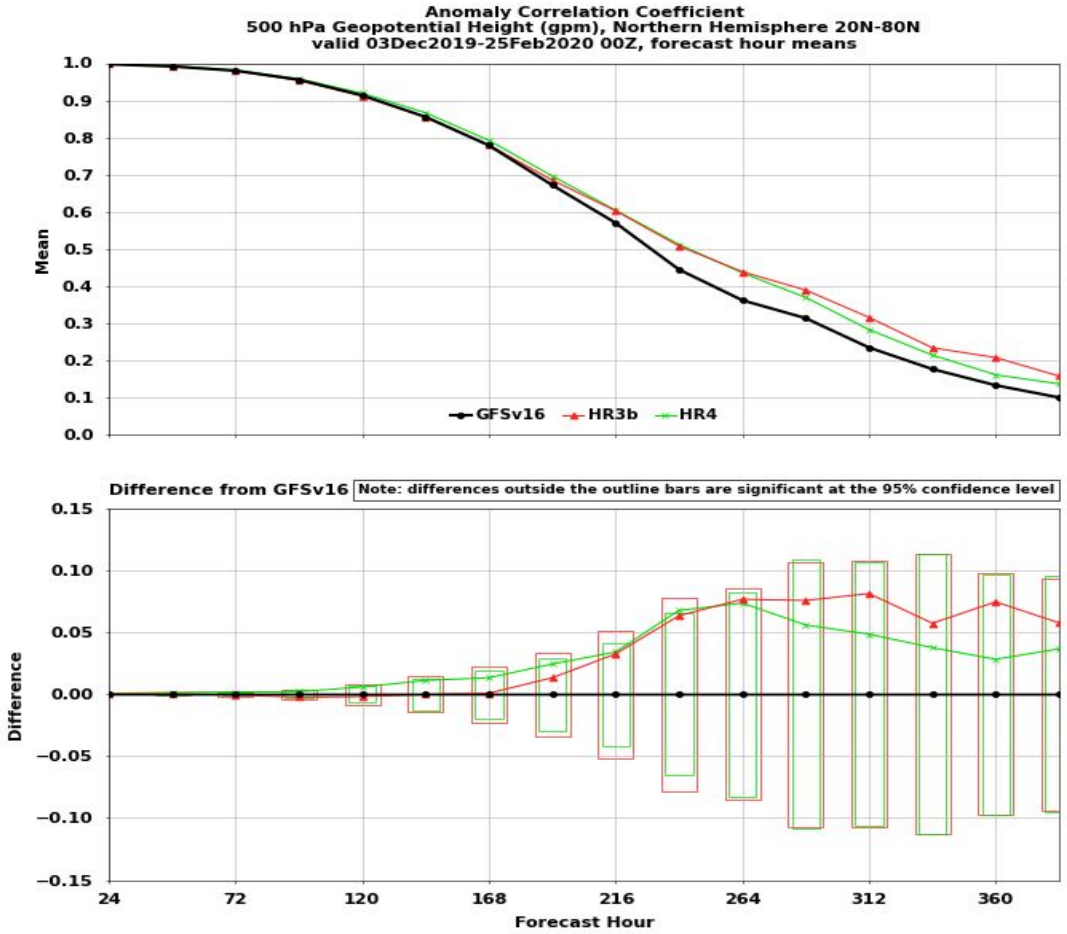


JJA



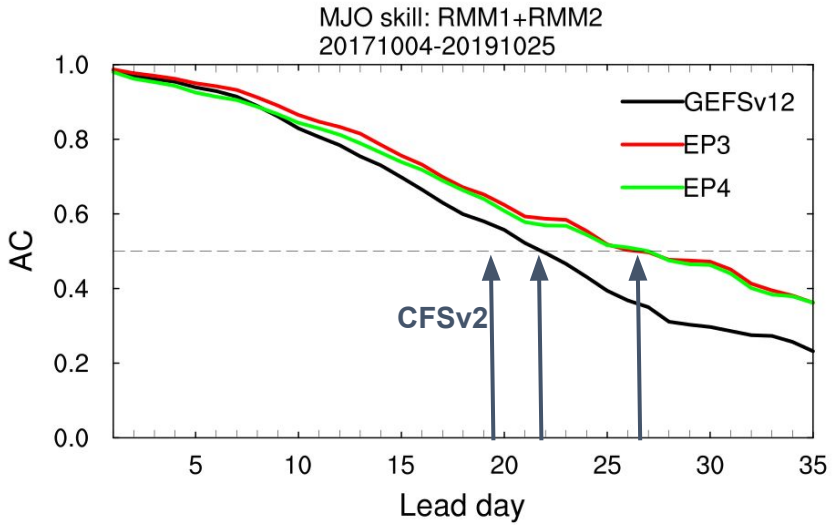


DJF



Comparison of Northern Hemisphere 500-hPa Height Anomaly Correlations: This analysis compares the Northern Hemisphere 500-hPa height anomaly correlations in the winter of 2019/20 between the current operational model (GFSv16 at a 13-km grid resolution) and two experimental versions of GFSv17 (HR3b and HR4 at a 9-km grid resolution). GFSv16 is an atmospheric model initialized through data assimilation, while the experimental GFSv17 is a fully coupled atmos-ocean-ice-wave model initialized using replay initial conditions. All models were verified against the ECMWF IFS analysis. Hollow bars in the lower panel indicate differences between GFSv17 and GFSv16 that are statistically significant at the 95% level based on the Student's t-test. (Plot produced by Lydia Stefanova).

Sub-Seasonal Forecast
Earlier GEFSv13 Prototypes: Improvement in MJO Forecast Skills

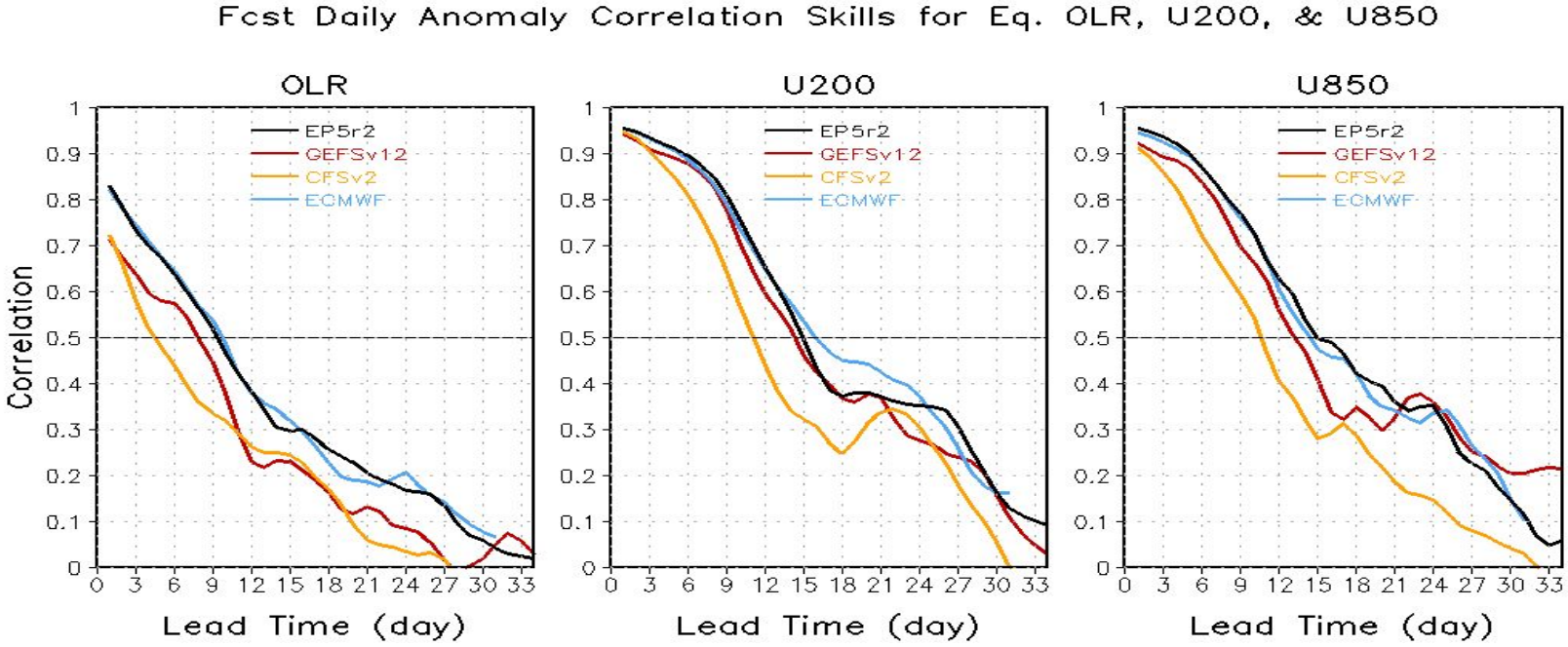


EP3 and EP4 both have higher MJO skill (RMM1+RMM2) than GEFSv12 for longer lead times (extend skill for 4-5 days).

- 1st NCEP ***ocean and sea ice coupled*** global ensemble forecast system including coupling between atmos-land-ocean-sea ice-aerosol-waves
- Model vertical resolution increase from ***64 to 127 layers*** with a ***model top of 80km.***
- Adding ***ocean stochastic physics*** to represent uncertainties from ocean prediction
- Forecast length increases from ***35 days to 48 days***

Sub-Seasonal Forecast
Latest GEFSv13 Prototypes (limited samples): Improvement in MJO Forecast Skills

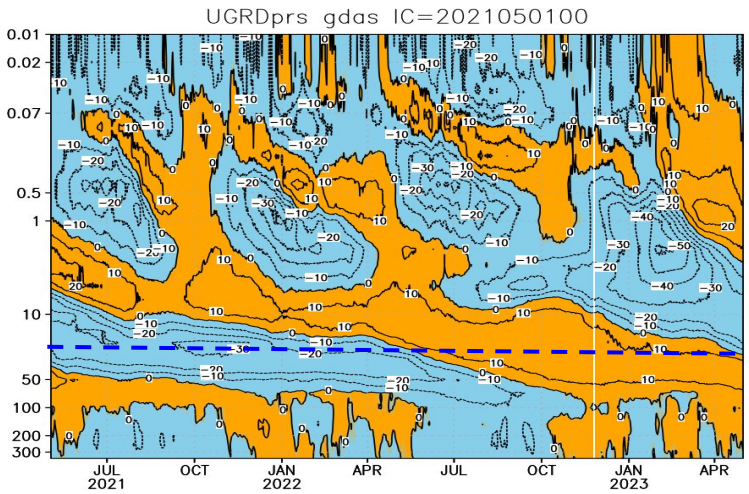
Eq. OLR, U200, & U850 Correlation Skill Variation with Lead Time



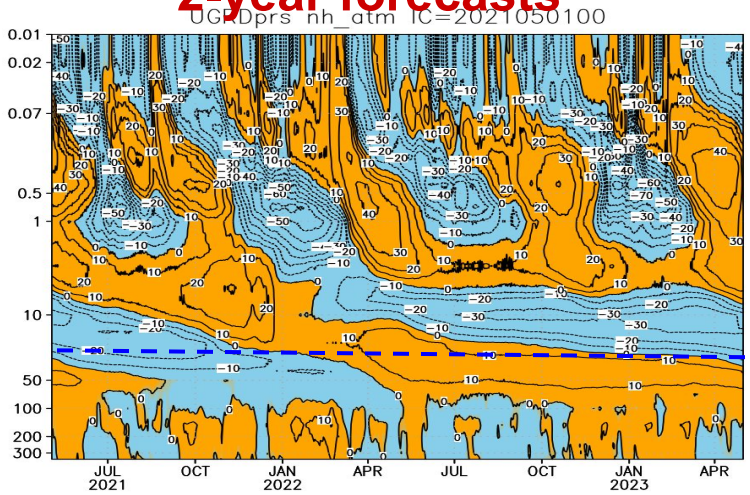
Courtesy of Mingyue CHen (CPC)

Seasonal Forecast:
QBO improved in NOAA prototype Seasonal Forecast System (SFS, 50-km)

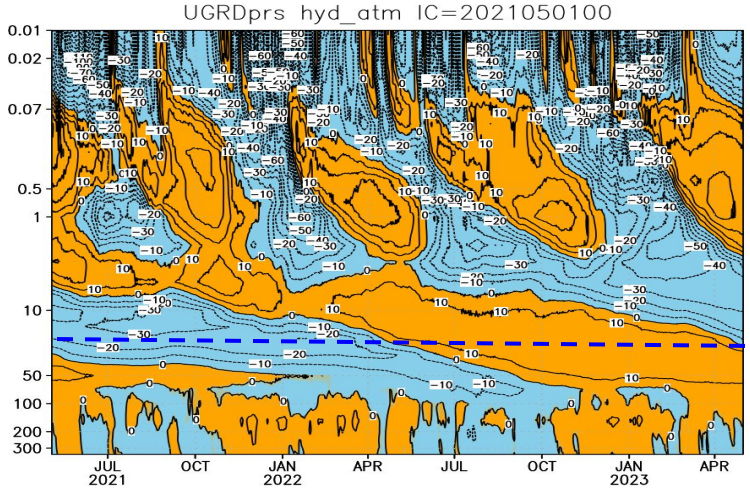
GDAS



2-year forecasts

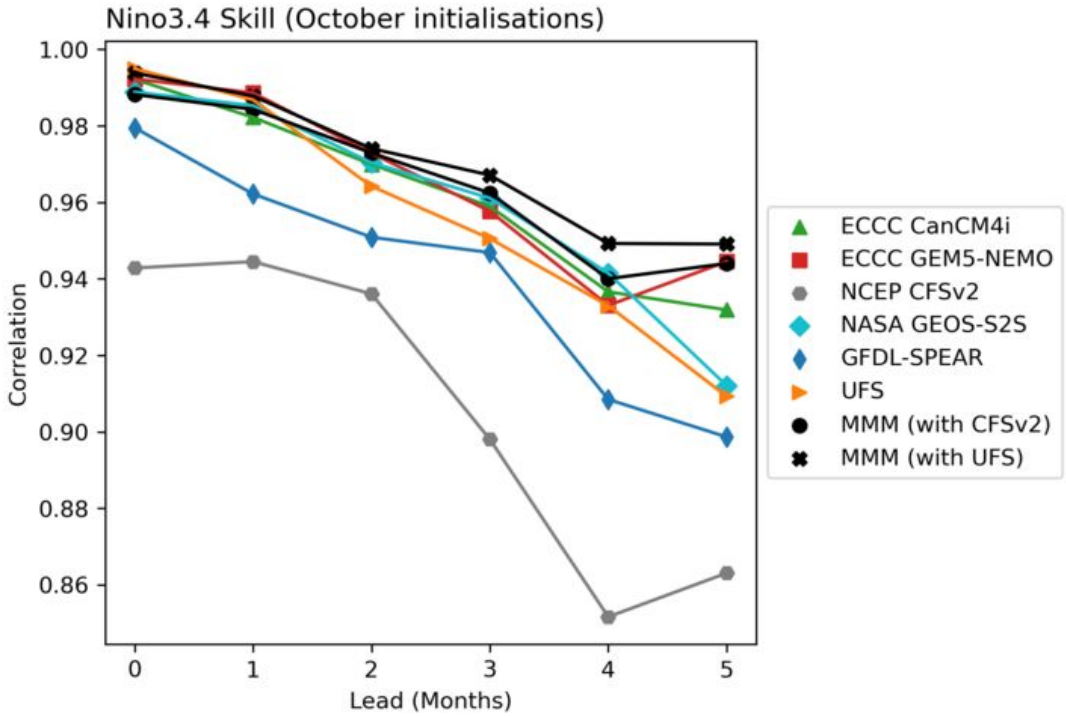


NH_atm



HYD_atm

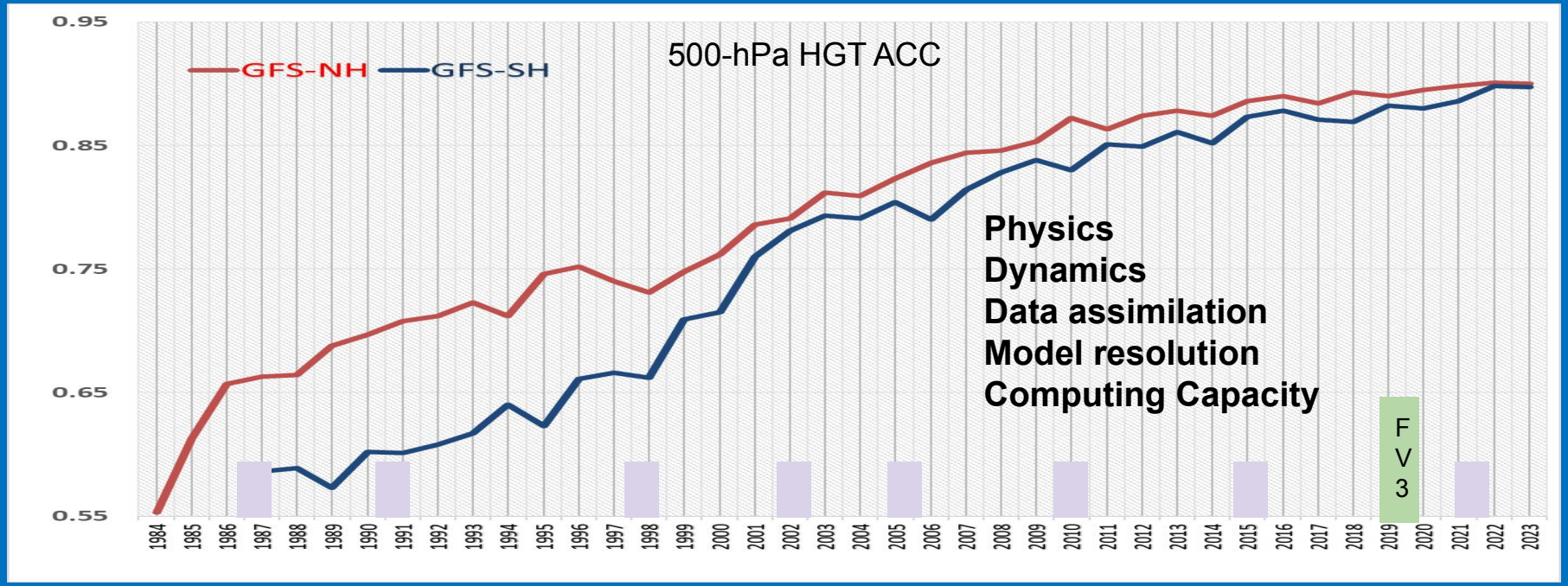
Seasonal Forecast, very early result (100km atmos, 1-deg ocean)



- 30 years of reforecasting with ensembles
- Initial results are encouraging

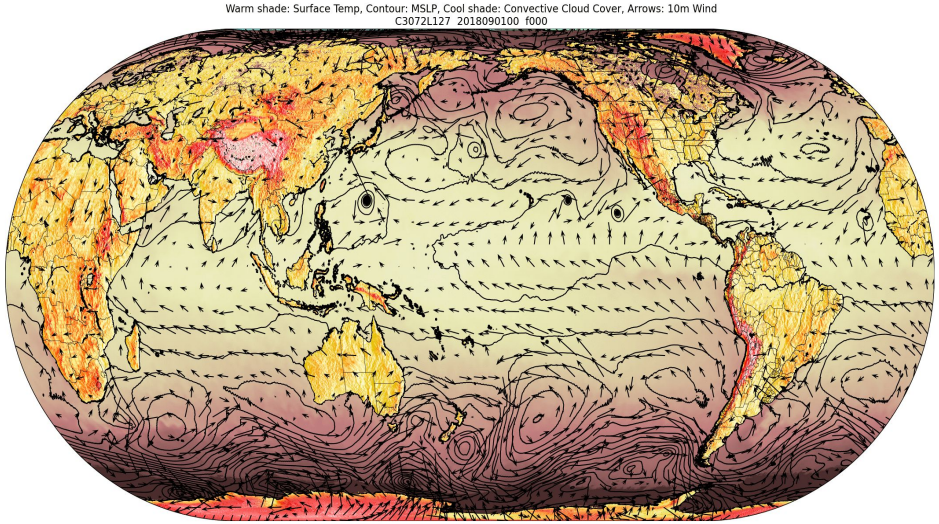
POC: Phillip Pegion (PSL)

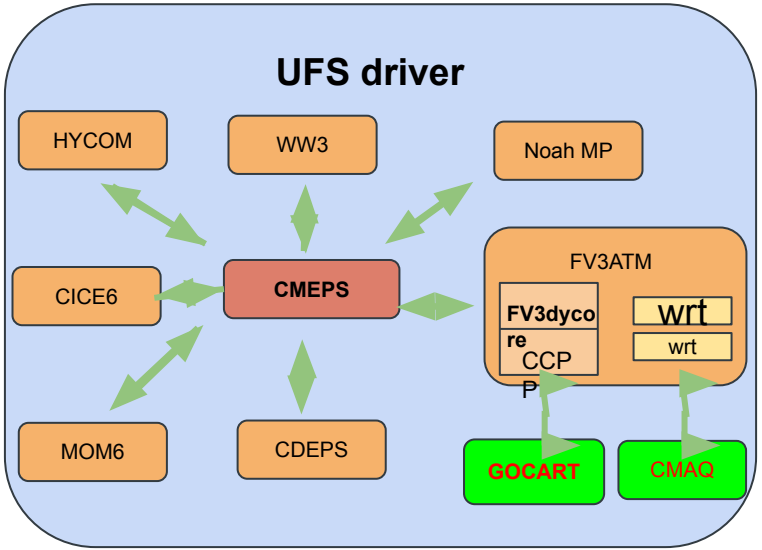
History of GFS Forecast Skill and Model Horizontal Resolution



1984 R40L12 300km	1987 T80L18 150km	1991 T126L18 105km	1998 T170L42 80km	2002 T254L64 55km	2005 T382L64 35km	2010 T574L64 23km	2015 T1534L64 13km	2021 C768**L127** 13km

Thank you


Warm shade: Surface Temp, Contour: MSLP, Cool shade: Convective Cloud Cover, Arrows: 10m Wind
C3072L127 2018090100 f000


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