Status and Plan in Developing and Implementing Medium-Range Weather, Subseasonal and Seasonal (S2S) Forecast Systems at NOAA/NWS

Yan Xue

Program Manager, Weeks 3-4 Program & SFS Project
NOAA/NWS/OSTI/Modeling Program Division

NATIONAL WEATHER SERVICE

GEWEX_LS4P-II Workshop, Dec 10, 2023, San Francisco

AGU Town Hall: 13:00 - 14:00 PST, Friday, December 15, 2023

Status and Plan in Developing and Implementing Medium-Range Weather, Subseasonal and Seasonal (S2S) Forecast Systems Based on the Unified Forecast System at NOAA

Agenda:

Program Office:

William Komaromi, IMSG: Introduction to the town hall
Yan Xue, NWS/OSTI: Overview of UFS MRW and S2S Applications
Jessie Carman, OAR/WPO: NOAA Grants for UFS S2S Applications

Penalists:

Fanglin Yang, NWS/NCEP/EMC: Global Forecast System (GFS)
Avichal Mehra, NWS/NCEP/EMC: Global Ensemble Forecast System (GEFS)
Neil Barton, NWS/NCEP/EMC: Seasonal Forecast System (SFS)
Cristiana Stan, George Mason University: Diagnostics and Analysis
Wanqiu Wang, NWS/NCEP/CPC: S2S metrics and forecast products

Q & A

Unified Forecast System

The Unified Forecast System (UFS) is a community-based coupled Earth modeling system, designed to support the Weather Enterprise and also be the source system for NOAA's operations.

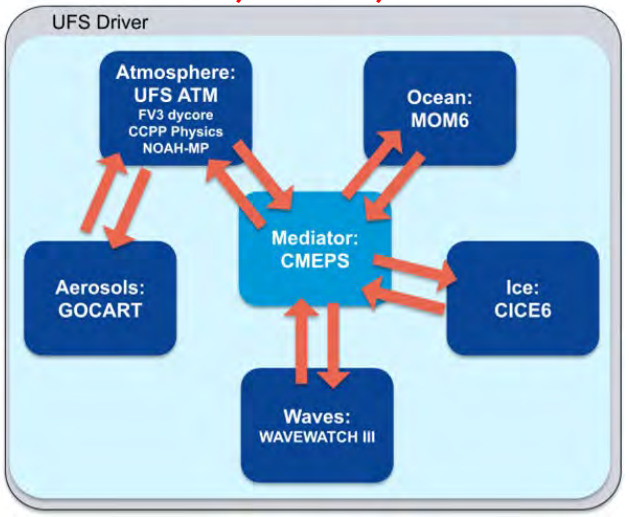
- Community components in UFS
  - Model infrastructure: ESMF, NUOPC, CMEPS
  - Atmosphere model: FV3 dycore, CCPP Physics
  - Ocean model: MOM6
  - Ice model: CICE6
  - Wave model: WW3
  - Aerosol model: GOCART
  - Land model: Noah-MP (currently)
  - Data assimilation: Joint Effort for Data assimilation Integration (JEDI)
- Each component has its own authoritative repository.

UFS Research-to-Operations (UFS R2O) Project

Developing the next-generation global and regional forecast systems and transition to NOAA operations in FY23 and beyond

Jointly supported by NOAA NWS and OAR

MRW/S2S Applications:
GFSv17, GEFSv13, SFSv1



Global Forecast System v17 Upgrade

(Deterministic Forecast up to 16 days)

	GFSv16: Implementation Mar 2021	GFSv17: Target Implementation Mar 2026
Model	FV3/Noah WW3 (one-way coupling)	FV3/Noah_MP MOM6/CICE6/WW3 (two-way coupling)
Resolution	C786L127 (13km, 80km top)	C786L127 or C1152L127 (13km or 9km, 80km top)
Physics	GFDL MP, sa-TKE-EDMF, non-orographic GWDs	Thompson MP, CA, UGWD, tuning of convection, surface and PBL physics schemes MERRA-2 aerosol climatology
Forecast Cadence	GSI, GLDAS 16 days from 00Z, 06Z, 12Z and 18Z	GSI, JEDI Ocean/Sea Ice, JEDI Snow 16 days from 00Z, 06Z, 12Z and 18Z
Evaluation	2 year retrospective and real-time runs MEG Group, Field evaluation focusing on hurricane, winter storms, severe weather, extreme temp and prec. Evaluation of impacts on downstream models	2 year retrospective and real-time runs MEG Group, Field evaluation focusing on hurricane, winter storms, severe weather, extreme temp and prec., sea ice, ocean, wave Evaluation of impacts on downstream models

Global Ensemble Forecast System v13 Upgrade

(Ensemble Forecast up to 48 days)

	GEFSv12: Implementation Sep 2020	GEFSv13: Target Implementation Mar 2026
Model	FV3/Noah WW3/GOCART (one-way coupling)	FV3/Noah_MP MOM6/CICE6/WW3/GOCART (two-way coupling)
Resolution	C384L64 (~25km, 55km top)	C384L127 (~25km, 80km top)
Physics	GFDL MP, Stochastic physics (SPPT, SKEB)	GFSv17 physics + Stochastic physics (SPPT, SKEB, ocean)
Realtime (31 members)	GSI, GLDAS 16 days (06Z, 12Z and 18Z), 31 members 35 days (00Z), 31 members	GSI, JEDI Ocean/Sea Ice, JEDI Snow 16 days (06Z, 12Z and 18Z), 31 members 48 days (00Z), 31 members
31-years Reforecast (6/11 members)	GEFSv12 reanalysis (CFSR) in 2000-2019 (1989-1999) 16 days, every day, 5 members 35 days, every Wednesday, 11 members	Replay to ERA5 Atmos, ORAS5 Ocean/Sea Ice, Noah_MP spin up, snow DA in 1994-2024 16 days, every day, 6 members 48 days, every Monday, Thursday, 11 members
Evaluation	Weather/hurricane: 2.5 year retrospective experiments Subseasonal: 31-year reforecasts	Weather/hurricane/waves: 2.5 year retrospective experiments Subseasonal: 31-year reforecasts

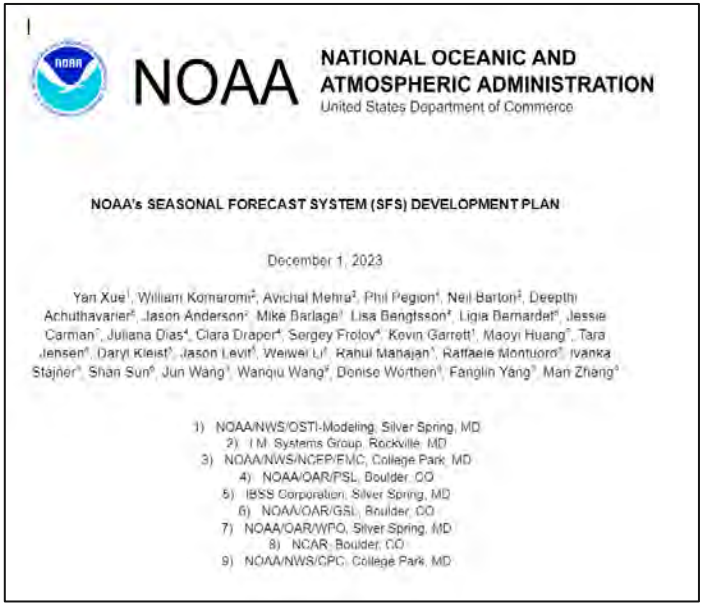
NOAA's Seasonal Forecast System Development Plan

GOALS:

- **Develop SFSv1 as a replacement of Climate Forecast System version 2 (CFSv2), a more-than decade-old system**
- **Address common errors in CFSv2 and North American Multi-Model Ensemble (NMME)**
- **Release reanalysis & reforecast data sets to the community**

SFS will be:

- **Enabled to run in the cloud**
- **Incorporated into UFS repositories**
- **Provided to community through the Earth Prediction Innovation Center (EPIC)**



NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
United States Department of Commerce

NOAA's SEASONAL FORECAST SYSTEM (SFS) DEVELOPMENT PLAN

December 1, 2023

Yan Xue[1], William Komaromi[2], Avichal Mehra[3], Phil Pegion[4], Neil Barton[2], Deepthi Achuthavarier[5], Jason Anderson[2], Mike Barlage[1], Lisa Bengtsson[4], Ligia Bernardet[6], Jessie Carman[7], Juliana Dias[4], Clara Draper[4], Sergey Frolov[4], Kevin Garrett[1], Maoyi Huang[7], Tara Jensen[8], Daryl Kleist[3], Jason Levit[1], Weiwei Li[1], Rahul Mahajan[1], Raffaele Montuoro[1], Ivanka Stajner[3], Shan Sun[6], Jun Wang[1], Wanqiu Wang[4], Denise Worthen[1], Fanglin Yang[3], Man Zhang[1]

1) NOAA/NWS/OSTI-Modeling, Silver Spring, MD
2) I.M. Systems Group, Rockville, MD
3) NOAA/NWS/NCEP/EMC, College Park, MD
4) NOAA/OAR/PSL, Boulder, CO
5) IBSS Corporation, Silver Spring, MD
6) NOAA/OAR/GSL, Boulder, CO
7) NOAA/OAR/WPO, Silver Spring, MD
8) NCAR, Boulder, CO
9) NOAA/NWS/CPC, College Park, MD

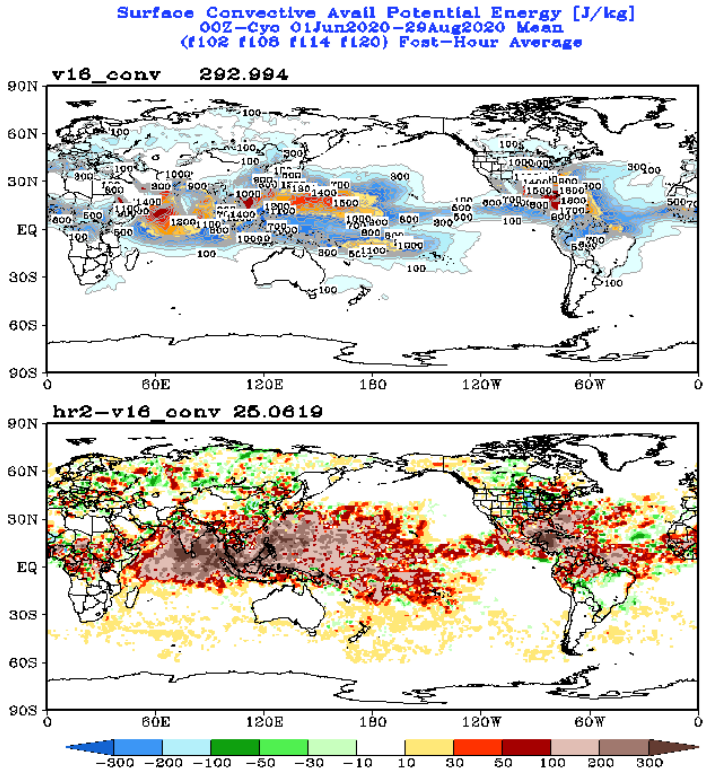
SFS Application Team established with participation from NWS, OAR, DTC and EPIC in October, 2023

SFS Development Plan in revision

Physics and Land Advancements in GFSv17/GEFSv13

POCs: Fanglin Yang
Mike Barlage

- Two-moment cloud microphysics scheme (GFDL MP --> Thompson MP)
- New land model (NOAH LSM --> NOAH-MP LSM)
- New small-scale gravity wave and turbulent orographic form drag parameterizations
- New parameterization for convective organization
- New Prognostic-Stochastic and Scale-Adaptive Cumulus Convection Closure
- New stochastic physics in the ocean, land-surface and the atmosphere
- New positive definite tracer advection (TVD) scheme in convection and PBL
- New capability for coupling between aerosols and physics



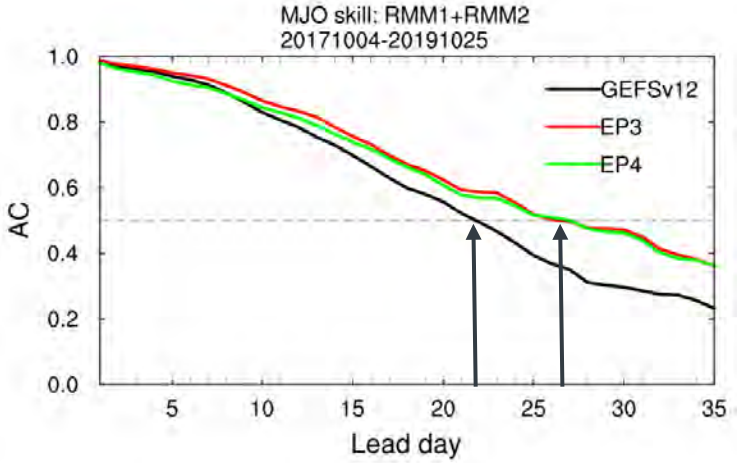
CAPE low bias reduced

Advancements from GEFSv12 to GEFSv13

POCs: Avichal Mehra
Bing Fu

- **1st fully-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.**
- **Thompson microphysics scheme replacing GFDL microphysics scheme, NOAH-MP replacing NOAH LSM and other ATM physics updates**
- **Adding ocean stochastic physics to represent uncertainties from ocean prediction**
- **Forecast length increases from 35 days to 48 days**

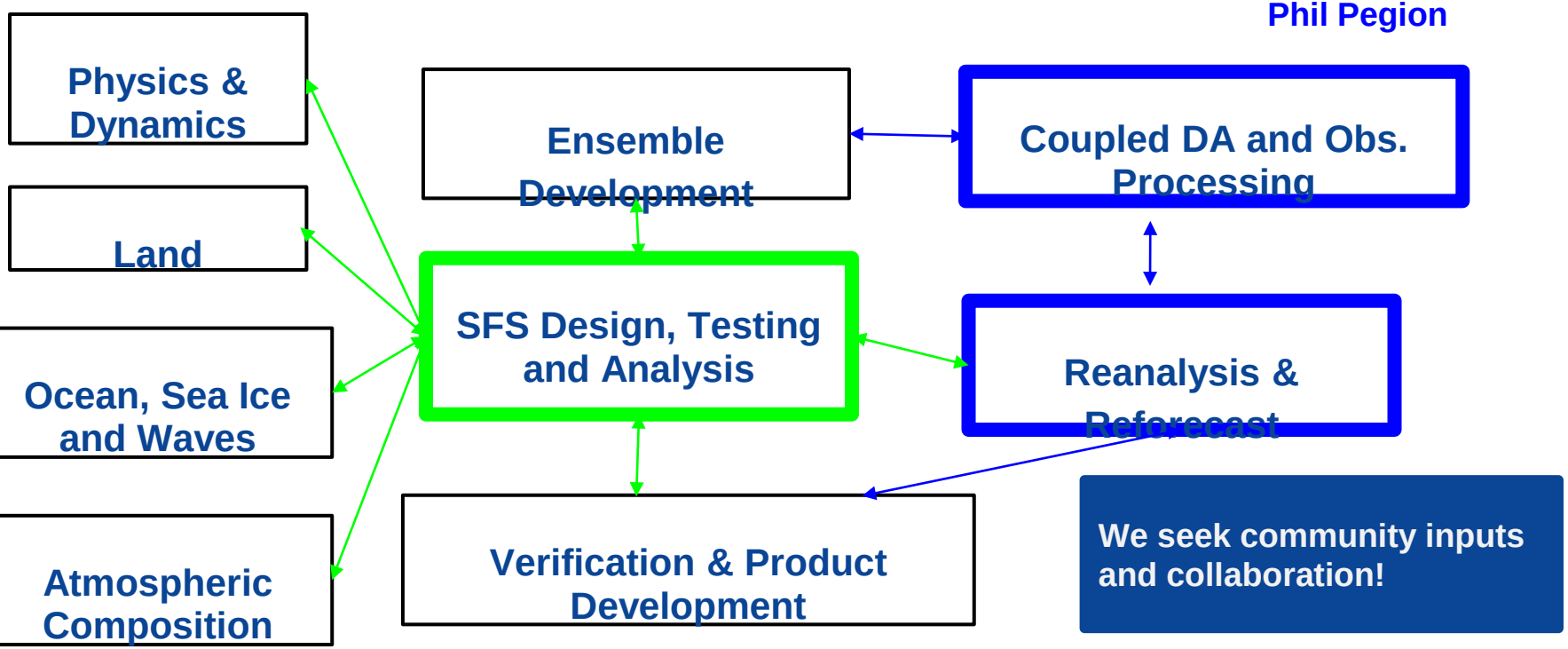
Four Ensemble Prototypes (EP1 - EP4) completed, preliminary results are encouraging.



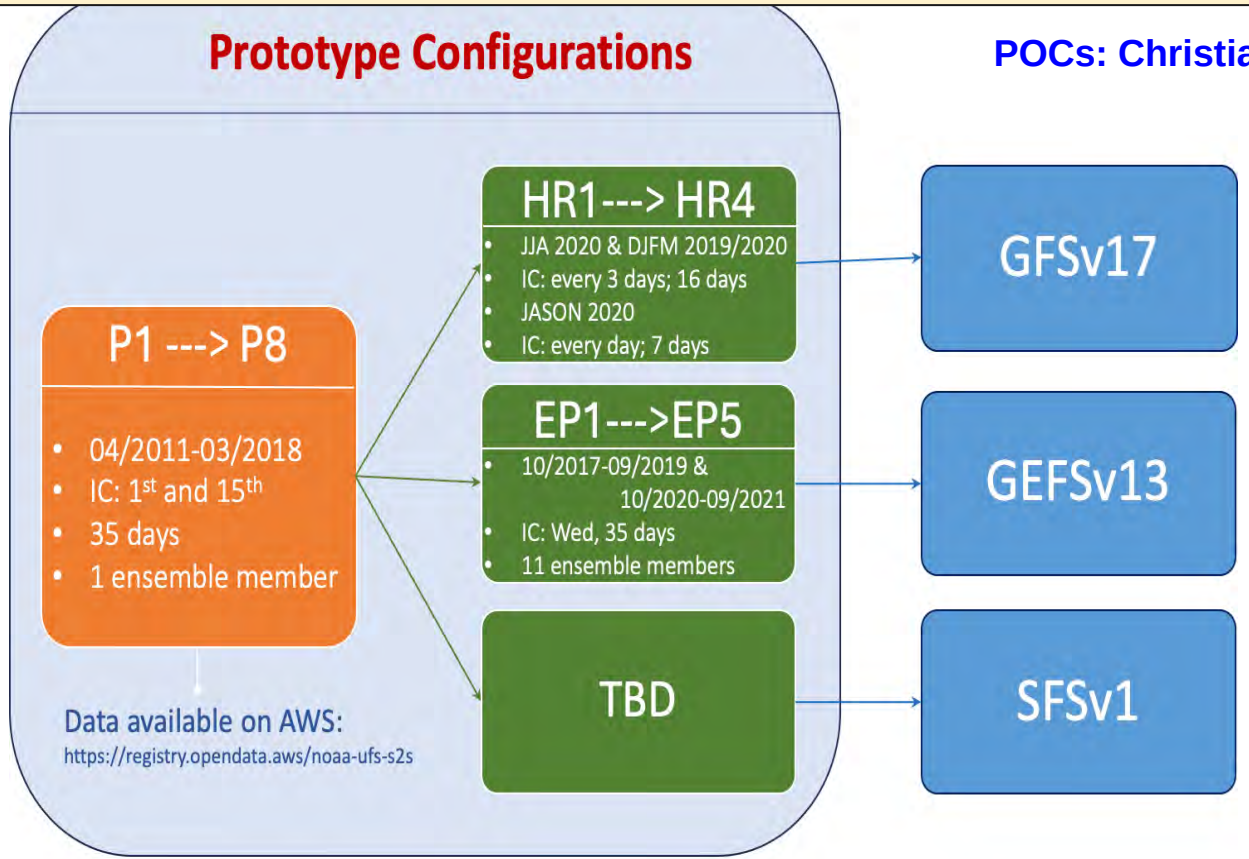
EP3 and EP4 both have higher MJO skill (RMM1+RMM2) than GEFSv12 for longer lead times (extend skill for 4-5 days).

Seasonal Forecast System Application Team

Co-Leads: Avichal Mehra, Neil Barton
Phil Pegion



Evaluation of MRW/S2S Applications during the Development



MRW/S2S Applications Evaluation and Remaining Challenges

Accomplishments

- P1-P8 evaluated with respect to: *mean biases and anomaly correlation* (for each model component); *tropical variability* (MJO, Indian monsoon); *troposphere-stratosphere coupling*, *impact of tropical SST biases on ENSO*, *land-atmosphere interactions.* P1-P7 results published in a NOAA Technical Report.
- P5: extremes in *precipitation & temperature* (T2m, T2m min & T2m max)
- P5 & P6: *MJO-teleconnections* (impact of number of vertical layers)
- P6 and P8: impact of *tropical SST biases* on forecast skill of *surface weather* over CONUS

Challenges

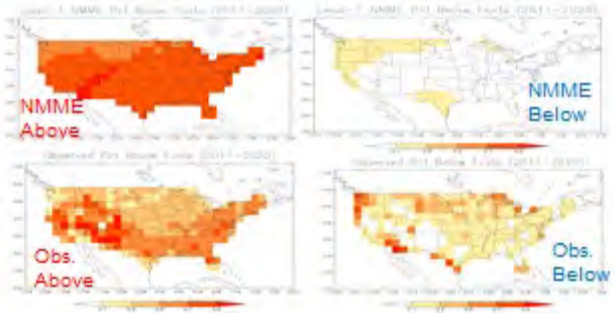
- Ocean, sea-ice and aerosol variability underexplored
- Impact of aerosol impact on the S2S forecast skill
- Impact of initial conditions (various datasets) on the error growth
- Diagnosing and understanding sources of model errors with *sensitivity experiments*
- Limited statistical significance of results: *need of longer experiments and larger ensemble size*

Forecaster's Needs

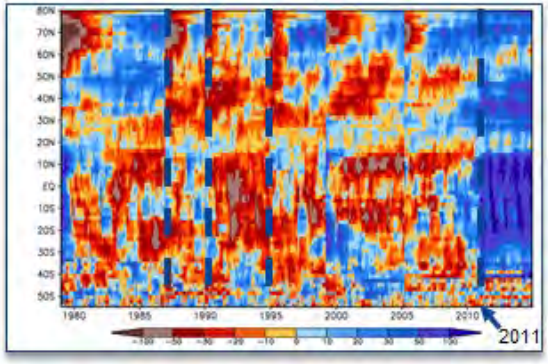
POCs: Wanqiu Wang, Jon Gottschalck

- METplus-based verification and diagnostics package for UFS S2S Applications
- Minimizing temporal discontinuities in initial conditions (soil moisture, ocean, sea ice)
- Minimizing inconsistency between retrospective and real-time forecasts
- Reducing SST trend errors in the Tropics
- Reducing biases in surface temperature forecast (too frequent above-normal and too few below-normal forecast)
- Reducing occurrence of ENSO false alarms
- Reducing tropical cyclone false alarms
- Improving land surface initial conditions, e.g. soil moisture, soil temperature and snow conditions
- Improving predictions of MJO propagation across Maritime Continent
- Artificial intelligence and machine learning algorithms for post-processed products

Frequency of First Season Forecast Temperature for 2011-2020



CFSR Soil Moisture Anomaly Zonal Mean



Please send your feedback and suggestions to

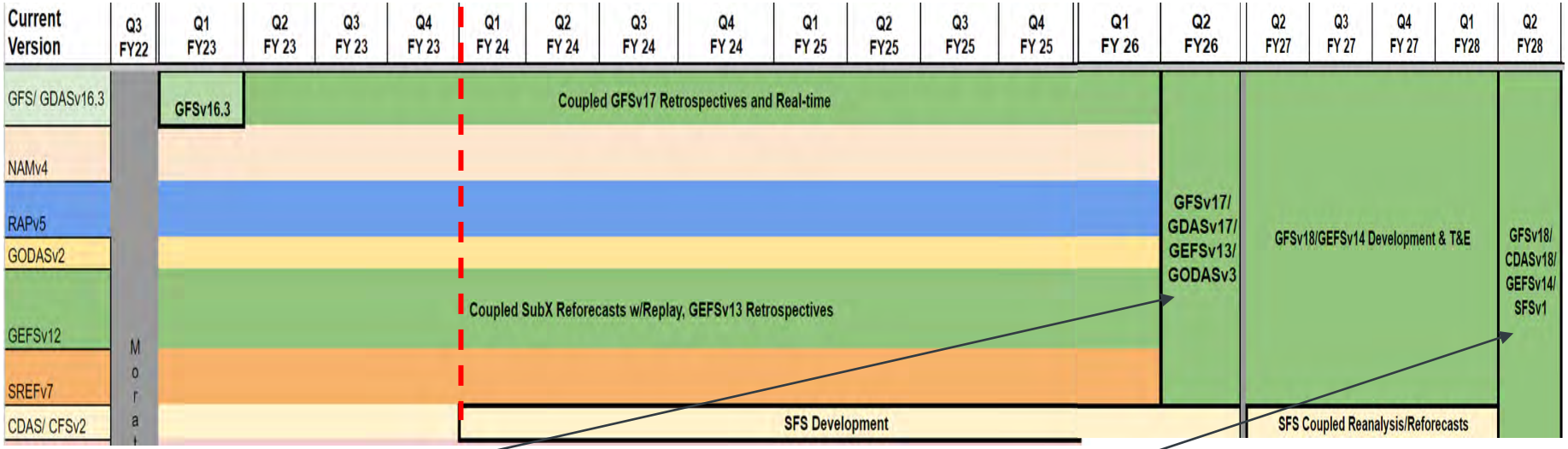
nws_modeling_pmo@noaa.gov

AGU Town Hall website

Extra slides

Transitioning to UFS-based Applications

EMC Implementation Plan FY23-27



Q2FY26:

GFSv17: Deterministic forecast (0-16 days)

GEFSv13: Ensemble forecast (0-48 days)

Q2FY28:

GFSv18: Deterministic forecast (0-16 days)

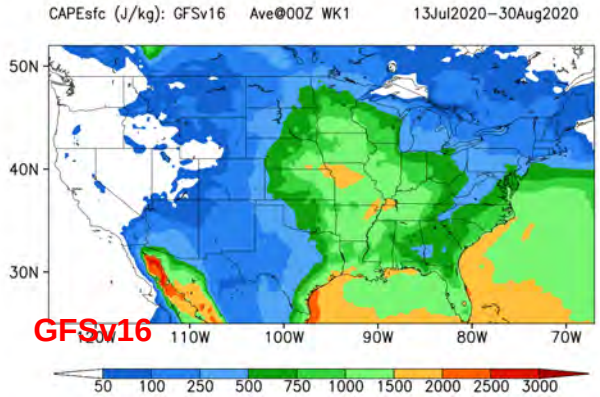
GEFSv14: Ensemble forecast (0-48 days)

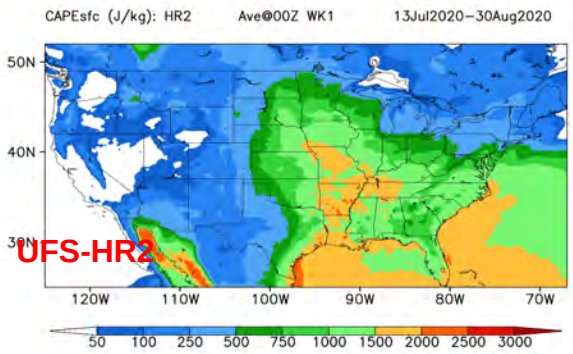
SFSv1: Seasonal Forecast System (0-12 months)

Major Goals for GFSv17 Update

- Enhance predictability through improved atmospheric physics, improved land model, and improved representation of interactions across model components
- Enhance predictability through improved initialization with a weakly coupled data assimilation
- Desired improvements compared to GFSv16:
  - MJO propagation and intensity
  - **Low bias in CAPE,** low-level inversions,10n wind speed bias
  - Mixed-phase clouds and supercooled liquid clouds
  - Hurricane track errors and false alarm rate

CAPE

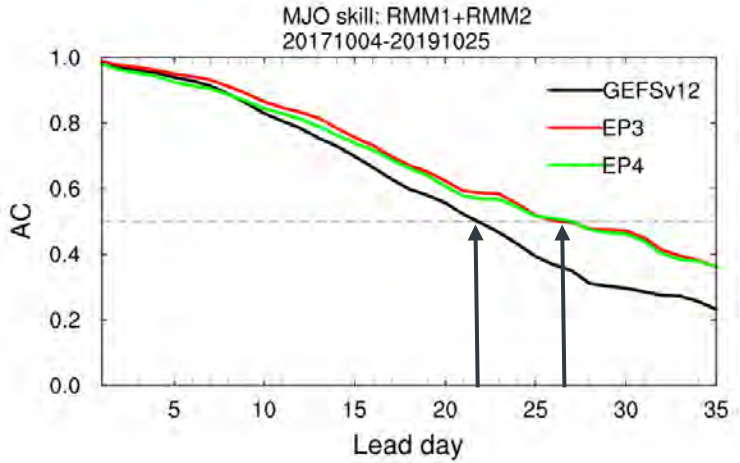




Major Goals for GEFSv13 Update

- Desired improvements compared to GEFSv12:
  - **MJO** propagation and intensity, extend useful skill by 5-10 days
  - CRPS skill extended; brier skill scores of CONUS PQRF extended
  - West coast and Arctic air mass forecast improved
  - Hurricane track and intensity forecast improved
  - Forecast of Z500, T2m, Prec, tropical cyclone improved
  - Forecast of Sudden Stratospheric Warming improved

Four Ensemble Prototypes (EP1 - EP4) completed, preliminary results are encouraging.



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

Investing in the UFS

NOAA Programs that Support UFS

- **NWS/OSTI Modeling Programs:** NGGPS, Weeks 3&4, HFIP
- **OAR/WPO Programs:** EPIC, JTTI, S2S, Atmospheric Composition
- **Disaster Supplementals FY18, FY19, FY22 and Bipartisan Infrastructure Legislation FY22**

UFS Research-to-Operations (UFS R2O) Project

- **UFS R2O Phase I (FY20-23) with 5 year vision**
- **UFS R2O Phase II (FY24-26) including Transition to Operation**
- Developing the next-generation global and regional forecast systems and transition to NOAA operations in **FY23 and beyond**
- Jointly supported by **NOAA NWS and OAR**
- Community team (NOAA, NCAR, JCSDA, Academia)
- Website: **https://vlab.noaa.gov/web/ufs-r2o**