NATIONAL WEATHER SERVICE

Overview of the Next Global Forecast System: GFSv17

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Overview of GFS

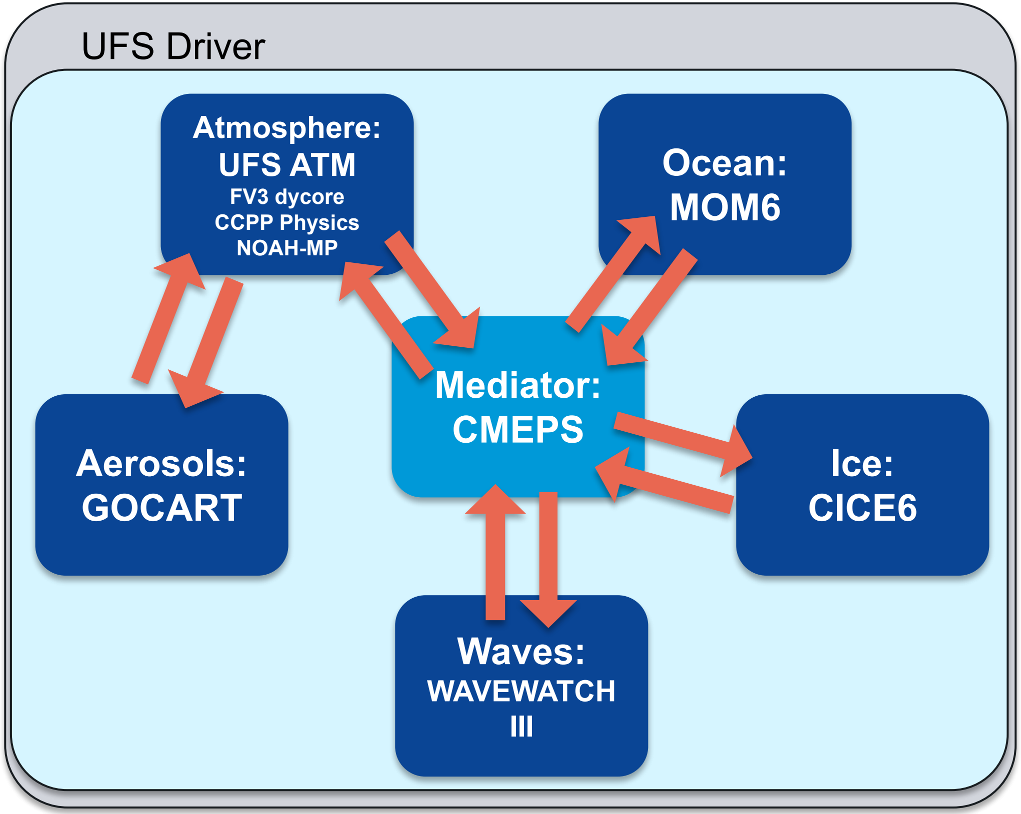
- Global deterministic model
- Run 4 times a day out to 16 days
  - Hourly output for first 120 hours
  - 3 hourly for days 6-16
- Global Data Assimilation System (GDAS)
  - 80 ensemble members
- Provides initial and/or boundary conditions for multiple downstream forecast systems including the Global Ensemble Forecast System (GEFS)

Goals/Scope of GFSv17

- Coupled forecast model (atm, land, ocn, ice, wav)
- Improved DA with JEDI for non-atm components
- Towards consolidation of NCEP production suite
- Improve on known issues in GFSv16

System Overview

- **Coupled system resolutions**
  - Atmosphere/land:
    - Forecast: C768 or C1152, L127
    - Analysis/DA Ensemble: C384 L127
  - Ocean
    - ¼° tripolar
    - 75 layers (41 or 75 in Analysis/DA Ensemble)
  - Sea ice
    - ¼° tripolar
  - Waves
    - Unstructured grid
    - Undecided if will be included in DA ensemble
  - Aerosol
    - Included in GDAS deterministic forecast
    - No aerosol-radiation interaction
- **GFS and GEFS will be separate systems**
  - Infrastructure will be as unified as possible
  - Implementation planned for the same day



Expected Benefits of GFSv17

- ## Atmosphere
  - Removal of the negative tracer values that occurred from the PBL and convection schemes
  - Improvement of forecasts of low-level inversions
  - Enhancement of the underestimated surface-based convective available potential energy (CAPE)
  - Improvement of hurricane forecasts
  - Reduction of the nighttime cold 2m temperature biases over CONUS forested regions
  - Reduction of the CONUS 10m wind speed biases
  - Improvement of radiation and cloud coupling
  - Improvement of air-sea coupling and atmospheric dominant modes
  - Improvement of MRW forecasts of large-scale flow pattern and precipitation events
  - Improvement of MJO prediction
  - If 9km: Providing higher resolution lateral and boundary conditions for running downstream applications.
- ## Wave
  - Address low bias in high amplitude wave events
  - Improved swell forecasts in the Pacific
  - Possibly increase the global resolution or add high resolution coastal nests (unstructured grids)

Expected Benefits of GFSv17

- **Coupling**
  - New ocean and ice components, providing a consistent atmosphere-ocean-ice-wave deterministic forecast
  - Based on ECMWF, UKMet and ECCC, *possible* impact of coupling:
    - Improve general skill in the middle and upper troposphere
    - Largest impacts to be in relation to tropical cyclones:
      - Track, central pressure, intensity, and false alarms
      - Note, there is no guarantee we will see this in GFSv17

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Mogensen, K., L. Magnusson, J.-R. Bidlot & F. Prates. Ocean coupling in tropical cyclone forecasts. *ECMWF Newsletter* No. 154 (2018).
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ATM Physics

- **Description of ATM physics potential upgrades**
  - **Cumulus Convection**: positive definite mass flux; stochastic convective organization; improved MJO prediction with prognostic closure; optimization; improved CAPE forecast; improved hurricane forecasts
  - **Planetary Boundary Layer (PBL)**: positive definite mass flux; optimization; improved surface inversion forecast; improved CAPE forecast; improved hurricane forecasts
  - **Surface Layer**: sea spray parameterization; optimization
  - **Microphysics (MP)**: replacing GFDL MP scheme with Thompson MP scheme - improving computational instability and forecast accuracy of cloud hydrometers and radiative fluxes in the tropics
  - **Gravity wave drag (GWD)**: small-scale gravity wave drag; turbulent orographic form drag; updates of orographic GWD, mountain blocking, and non-stationary GWD
  - **Radiation**: improving radiation and cloud interactions
  - **Aerosol**: OPAC data replaced by MERRA2 aerosol climatology
  - **Albedo and Emissivity over Fractional Grid**

Land Component

- **NOAH-MP Land Surface Model (LSM)**
  - Replacing Noah LSM with Noah-MP LSM
  - Noah-MP uses multiple options for key land-atmosphere interactions; (a) a tiled approach to separate vegetation and bare soil, (b) a dynamic vegetation scheme, (c) a multi-component, separate vegetation canopy, (d) canopy radiative transfer with shading geometry, (e) a multi-layer snow pack, (f) canopy heat storage; increase number of soil layers and depth of soil column
  - Update vegetation type from MODIS to VIIRS
  - Update land-sea mask using VIIRS dataset

Joint Effort for Data assimilation Integration (JEDI)

- **JEDI is a project within the Joint Center for Satellite Data Assimilation (JCSDA)**
- **JEDI provides a software infrastructure for data assimilation that**
  - is model agnostic
  - is generic and portable, from toy models running on laptops to operational Earth system coupled models running in the cloud.
  - enables DA on the model native grid
  - does not impose one specific DA methodology or algorithm
  - provides a framework for rapid uptake of new observations into operations with generic observation handling and modeling
  - encourages implementation of model-independent observation operators [Unified Forward Operator (UFO)]
  - provides a unified Interface for Observation Data Access (IODA)
  - is adaptable to exascale computing
- **JEDI is for scientific exploration and operational forecasting.**
- **The keys to success are separation of concerns and interfaces.**

Weakly Coupled DA Overview

- **Atmosphere**
  - GSI-based hybrid 4DEnVar deterministic analysis
  - GSI-based 4D-LETKF ensemble analysis
  - Additional early cycle ensemble analysis for GEFS initialization (if resources allow)
- **Marine**
  - Sea-ice Ocean and Coupled Analysis (SOCA): ocean and sea ice are strongly coupled
  - JEDI-based hybrid 3DEnVar for deterministic analysis
  - JEDI-based 3D-LETKF for ensemble analysis
- **Land**
  - JEDI-based 2D OI for snow
  - Possible LETKF (GSI or JEDI) for soil moisture and soil temperature
- **Aerosol**
  - JEDI-based 3DVar
  - Initializes central analysis only (no ensemble perturbations)

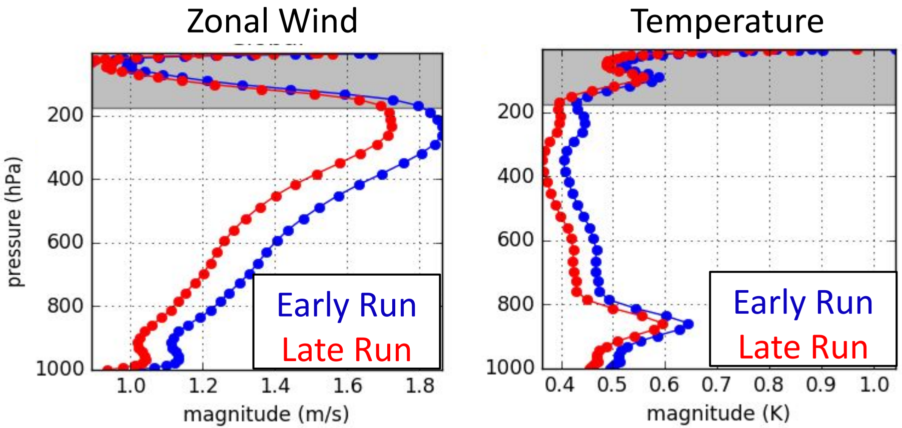
Atmospheric DA (GSI)

- **Early Cycle EnKF**
- **Accommodations for Thompson Microphysics**
  - Modify GSI interface to ingest new number concentration variables
  - Additional optimizations (e.g. error model, cloud optical table)
- **Other Radiance/All Sky Assimilation Upgrades**
  - Upgrade to CRTM 3.0
- **Scale-Dependent Localization**
  - Leveraging work recently merged to GSI repo by Sho Yokota (visitor from JMA) and OU-MaP for RRFS.
- **New Observations**

Early Cycle EnKF

- In operations, the GEFS initializes using the 6 hour forecast from the previous cycle's GDAS ensemble.
- Running the EnKF update in the early cycle will **allow the GEFS to initialize using an ensemble analysis from the same cycle**, providing a greater connection between the GFS and GEFS.
- The early cycle has fewer observations available → increased ensemble spread
- A late cycle EnKF would still be run as it is now in operations.
- The size of the ensemble for the early cycle EnKF will be dependent on available resources.

Global
6 Hour
Forecast
Ensemble
Spread

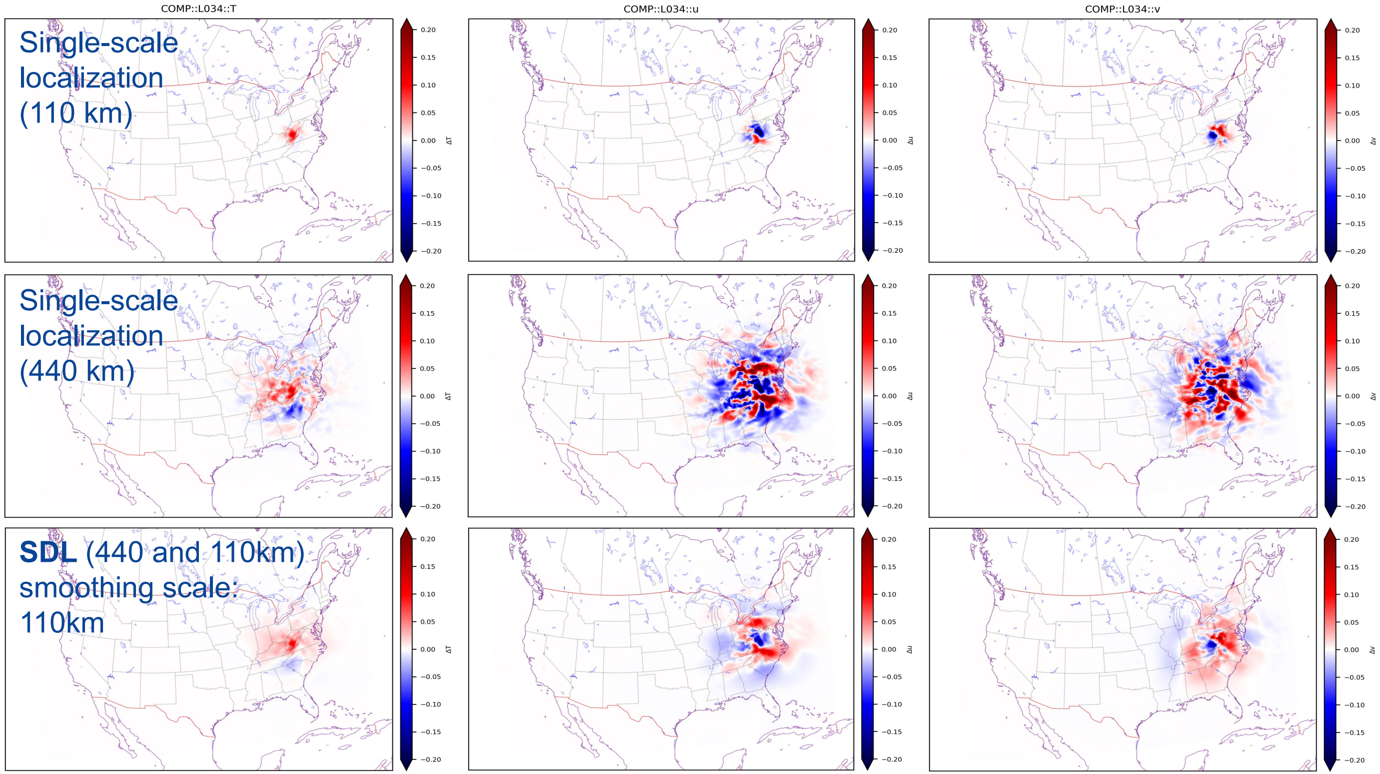


Scale-Dependent Localization

- **Initial testing performed in RRFS.**
- **Variable- and time-dependent localization are available as well.**

Analysis increment (L34) in assimilation of 500-hPa temperature

Figures from Sho Yokota (JMA)



temperature (K) | zonal wind (m/s) | meridional wind (m/s)

Summary

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  - Improved DA with JEDI for non-atm components
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- **Related talks**
  - Day 1
    - Bing Fu (NCEP/EMC): NOAA's Global Ensemble Forecast System (GEFS): operational GEFSv12 and development of GEFSv13
  - Day 2
    - Neil Barton (NCEP/EMC): Including Sea Ice and Ocean Models in GEFS
    - Jessica Meixner (NCEP/EMC): The Wave Component of the Global Ensemble Forecast System
  - Day 3
    - Clara Draper (OAR/PSL): Accounting for land model uncertainty in numerical weather prediction ensemble systems: toward ensemble-based coupled land/atmosphere data assimilation

Questions

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