NCEP Modeling and Data Assimilation Plans

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With acknowledgements to EMC colleagues Daryl Kleist, Geoff Manikin, and Logan Dawson for slides and content

and

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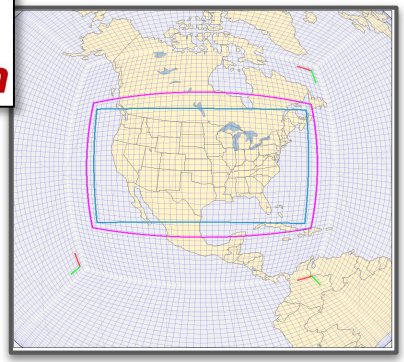
NOAA/National Severe Storms Laboratory
NOAA/Geophysical Fluid Dynamics Laboratory

Outline

- Data assimilation
  - Algorithms
  - Obs
- Unification plans
  - Global
  - Convective-scale
- *If time* 3DRTMA

UFS
Unified Forecast System



Only focusing on the atmosphere in this talk!

Current Status of Data Assimilation

- *Ensembles and hybrids* are now state-of-the science, operational for global NWP at most centers
  - Regional systems leverage global EnKF information (at NCEP)
  - Direct connection to ensemble prediction systems
- NCEP has largely pursued adjoint-free developments
  - For 4D, implementation of ***hybrid 4DEnVar*** for GDAS/GFS
  - This is the starting point for FV3-GFS

Data Assimilation → Some Grand Challenges

- Through workshops, the following "Grand Challenges" have been identified:
  - Coupled assimilation across earth system
  - Multi-scale DA across temporal and spatial scales (from convective to global)
  - Increase in volume and types of observations (radar, hyperspectral sounders, crowd sourced)
  - Representation of system uncertainty & model error, including for the coupled system
  - Non-Gaussianity and nonlinearity in errors (background, observation, and model)
- Must consider data assimilation problems within context of future HPC
- Improve use of current observing system
  - E.g. satellite and radar data (radial wind, dual pol variables, etc.)
- Data Latency → data need to arrive in time

Thanks to Daryl Kleist for material on this slide

Data Assimilation Moving Forward

- Unified, coupled data assimilation for unified, coupled modeling approach (seamless)
  - Bridging gaps from nowcasting, Warn-on-Forecast, convective scale, large scale
- Targeted research around grand challenge areas
- Invest in facilitating infrastructure such as Joint Effort for Data Assimilation Integration (JEDI)
- Better use of current obs and prepare for new generation of measurements
- **Short term:** Focused efforts on Hybrid/EnVar @ global and CAM
  - ***Draft test plan for our own inter-comparison between Hybrid 4DEnVar and Hybrid 4DVar (with FV3 TL/AD)***
  - Scale dependent hybrids (weights, localization), shifting/lagging, multi-resolution
  - CAM DA is a multiscale issue and requires development!
- **Longer term:** Dealing with non-Gaussianity and nonlinearity more directly

Thanks to Daryl Kleist for material on this slide

Unification Efforts

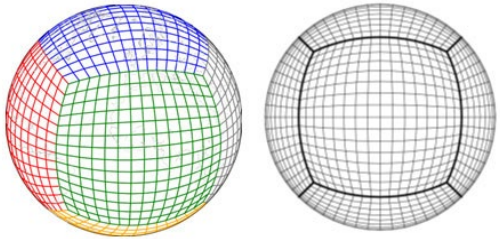
Simplifying the Production Suite

- Move toward the **Unified Forecast System**

- In 2016, the GFDL **finite-volume cubed-sphere (FV3)** dynamical core was selected to be the **cornerstone of future NCEP modeling** efforts

- Allows NCEP to focus development on a **single system**

- Initial work focused on developing the **Next-Generation Global Prediction System (NGGPS)**



  - **FV3GFS**, transition of the Global Forecast System to the FV3 dynamical core, is the first step toward implementing NGGPS

    - *Going into operations with GFS v15* Early 2019

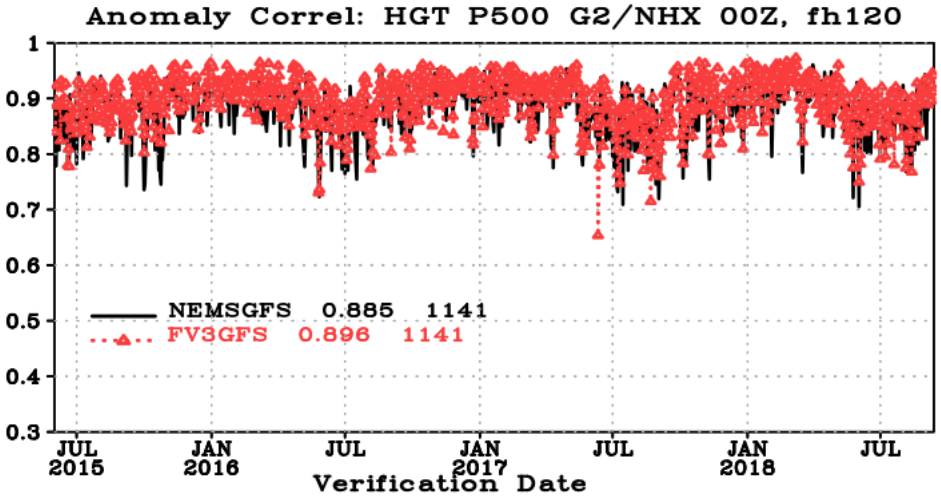
Global

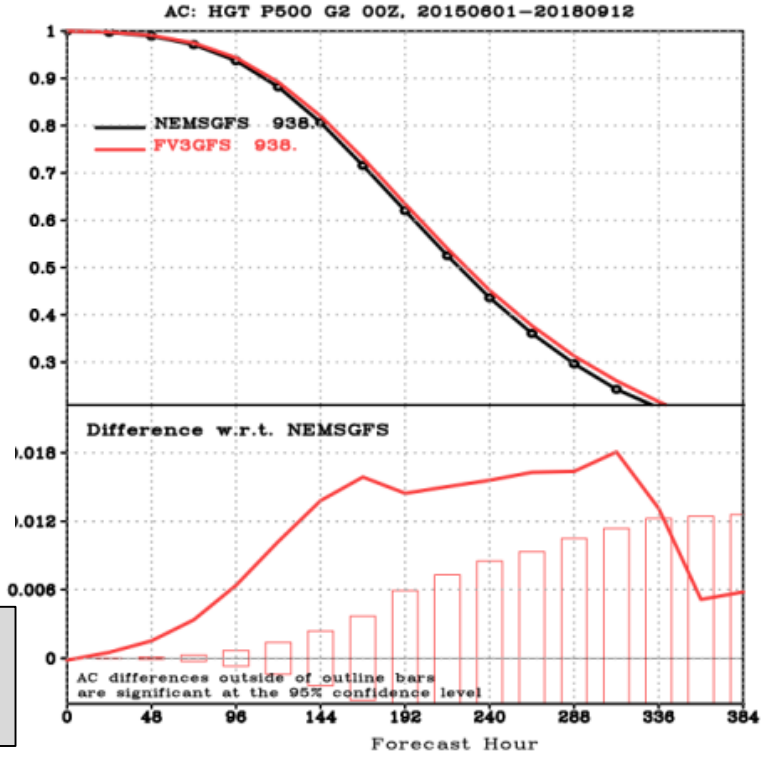
Configuration for FV3GFSv1 (GFSv15)

- FV3GFS C768 (~13km deterministic) and C384 (~25km) EnKF members
- 64 levels and 0.2 hPa model top
- Replaced the spectral model core with the FV3 dynamical core
- Largely uses GFS physics package
  - *Except* Upgraded to use the GFDL microphysics scheme

Will be implemented in early 2019 as GFSv15

FV3GFS Highlights: 500 mb Stats





FV3GFS shows statistically significant improvement in 500 mb AC scores through Day 14

Thanks to Logan Dawson for material this slide

Some FV3GFS Highlights

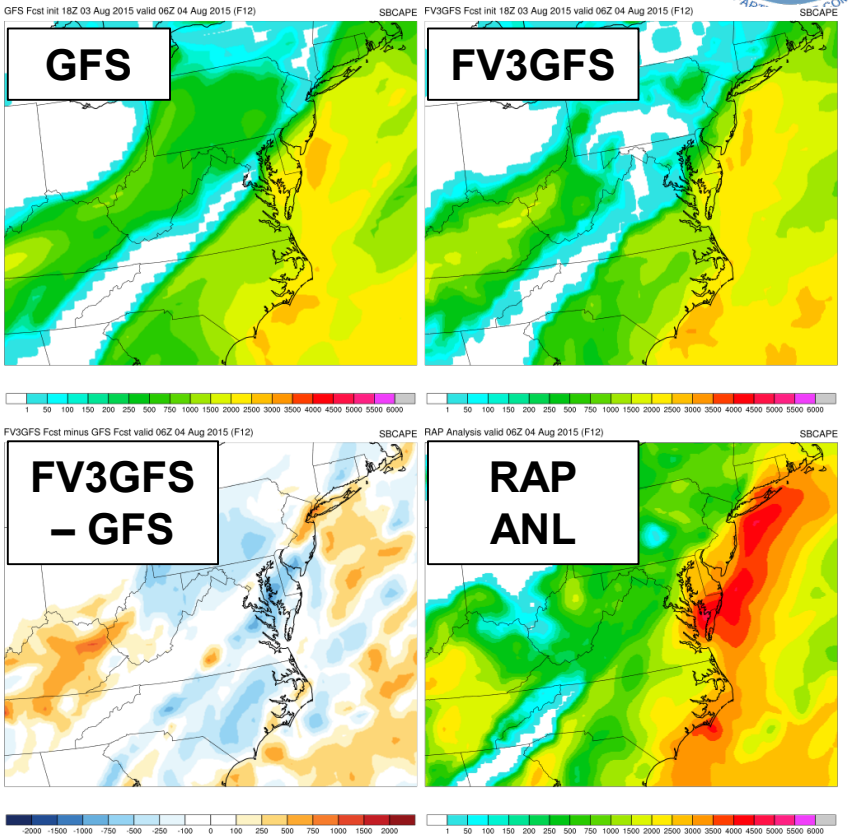
- Improvements:
  - FV3GFS provides **some improvements to tropical cyclone forecasts**
    - Intense tropical cyclone deepening seen in GFS is not observed
    - FV3GFS produces a much more physical TC pressure–wind relationship
  - **Warm season diurnal cycle** of precipitation is **improved**
  - **FV3GFS can match or exceed GFS performance on high-impact cases**
- Areas Needing More Work:
  - **Atlantic TC track forecasts are significantly degraded on Days 6 and 7**
  - **Precipitation appears smoother over terrain** in the FV3GFS

Thanks to Logan Dawson and the MEG for material this slide

Beyond FV3GFS: NGGPSv1

- FV3GFS is a step in the right direction and **lays the foundation for NGGPS and UFS**
- **NGGPSv1** will aim to make **significant advances in global NWP**
  - Will look to overhaul entire physics suite
  - Additional DA advancements
  - Potentially increase vertical resolution
- Will target common GFS issues such as **QPF distribution in East Coast winter storms** and **over-mixing in PBL/thermodynamic profiles** (for inversions, instability, etc.)

Goal is to implement NGGPSv1 in FY2021



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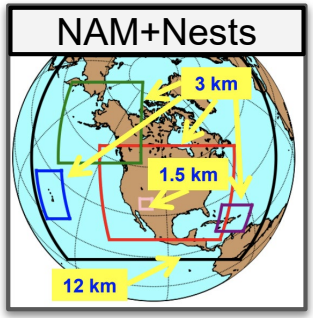
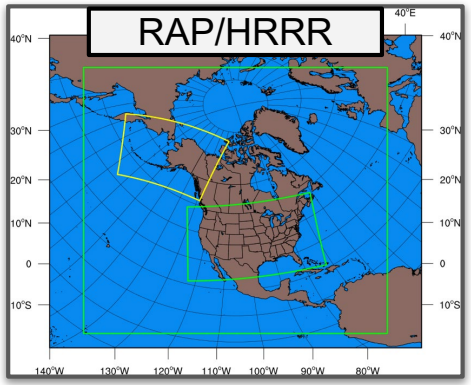
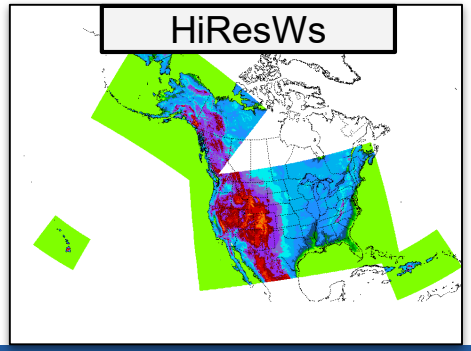
CAM

Current Status - Quite a bit

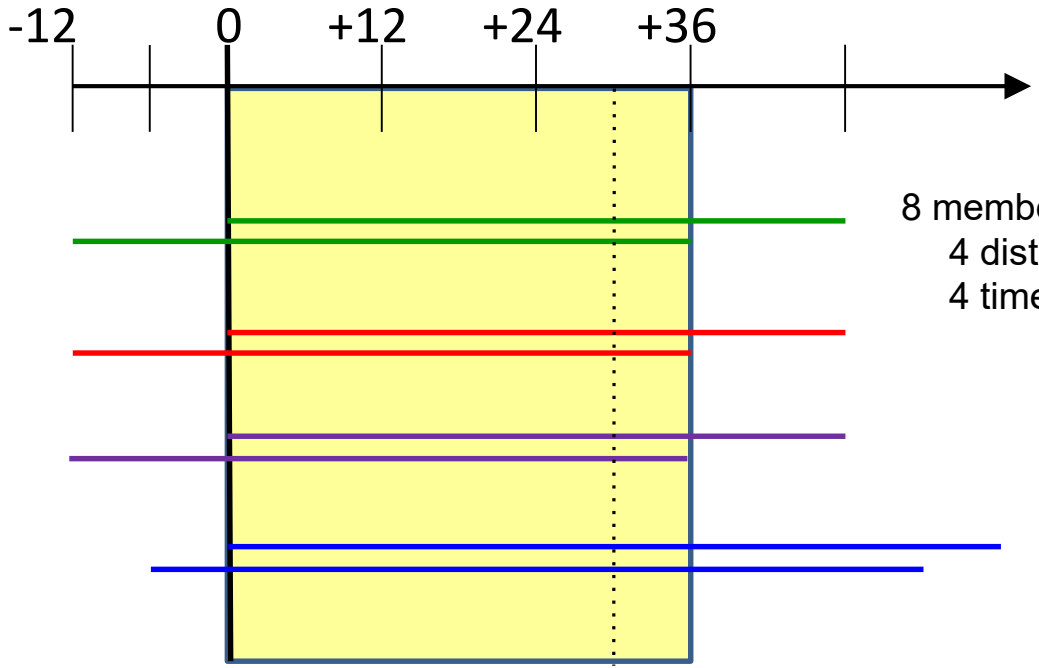
- Cover CONUS + OCONUS in a large variety of capacities
- NAM + Nests
- HRRR CONUS and Alaska
- HiRes Windows
  - ARW and NMMB members for each domain
- Much of this has been consolidated in the HREF
  - High Resolution Ensemble Forecast system
  - Motivated by the successes of the SSEO from SPC







The HREF v2



HiresW – ARW
(RAP init)

HiresW – NMMB
(RAP init)

HIRESW - “mem2” ARW
(NAM init)

NAM NEST - NMMB
(NAM init) **CONUS ONLY**

8 members for CONUS
4 distinct members
4 time lagged

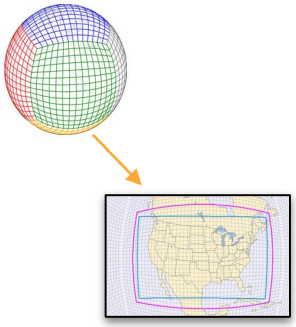
2018 HWT results: HREF rated higher than other formally constructed CAM ensembles for severe weather guidance in subjective evaluations

*Covers CONUS, Alaska, Hawaii, and Puerto Rico

What's Next?

- NAM was frozen at version 4 (March 2017)
- HiRes Window systems are currently frozen
- RAP/HRRR has one more upgrade scheduled ~FY20
- The HREF was a natural step forward in aggregating much of the CAM output into an ensemble
  - But the underlying components of HREF are frozen or about to be - *so what's next*?

FV3-CAM Timeline → Rapid Refresh Forecast System



Freeze all non-FV3 CAM systems

CAM Development Continues

Demonstration FV3-CAM ensemble DA + forecast system - evaluate against HREF. Continue physics testing/advancement.

FY18/19

Development underway
standalone/regional, nesting, DA, physics, etc.

Q2FY20

Q4FY20

HREFv3
Replace poorly performing members with FV3-CAM

FY21

~FY22

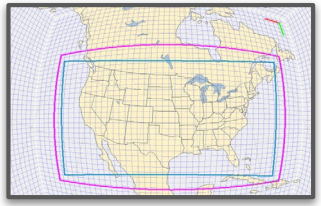
RRFSv1
Implement RRFSv1 pending favorable evaluation

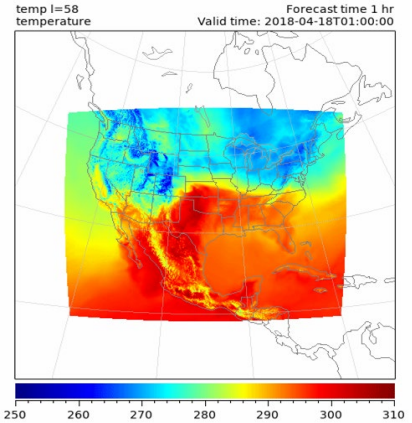
Rapid Refresh Forecast System → To replace HREF, HRRR, NAM + nests, HiResWs

Timeline may be revised as development matures/progresses

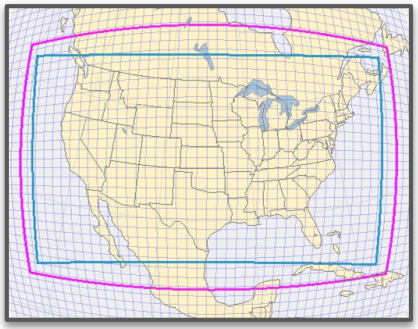
Highlights → Standalone Alone Regional

- FV3 is a global model with a nest capability
- Need a standalone grid option for CAM applications
- *Why?*
  - *Extra resources are not needed for a global parent*
  - *Rapid updates in DA are much more feasible*
- Obvious potential drawback
  - *Boundary data from an external forecast cannot be as accurate as those provided by a parent to a nest every timestep during the integration*
- Recent tests show standalone is 2x faster!





Current DA Testing



Coldstart from FV3-GFS Parallel

60 hr 3 km forecast

6 hour forecast at 3 km

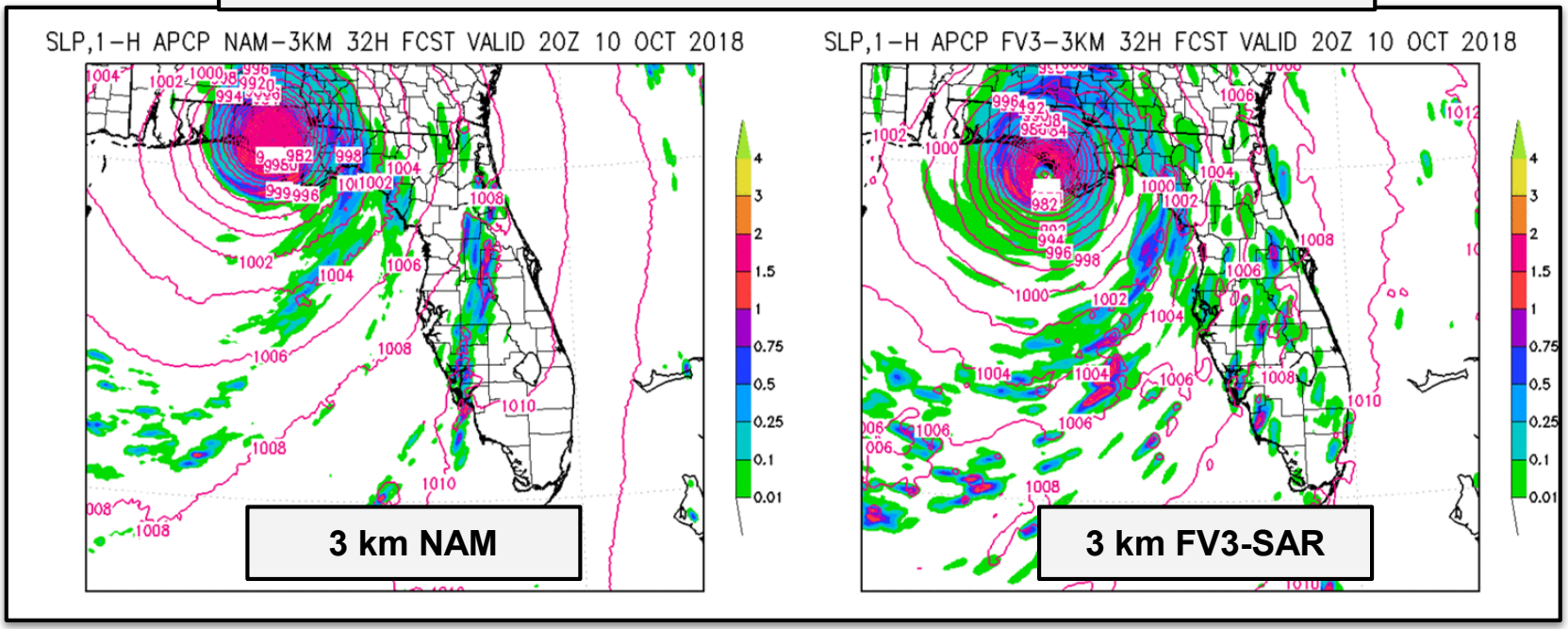
Hourly hybrid 3DEnVar assimilation

- Using global EnKF members
- Assimilates all data used in NAM CONUS nest
- *NO* cloud analysis and reflectivity derived latent heating
- *NO CAM ensemble at this time*

- The GSI system has been developed to interface directly with the FV3 native grid for a tile or nest input
- Configuration similar to 3 km NAM CONUS nest
- **Very much in experimental/sandbox testing mode**

Current DA Testing

32h Forecasts of Hurricane Michael



Example → meant to demonstrate progress on key components

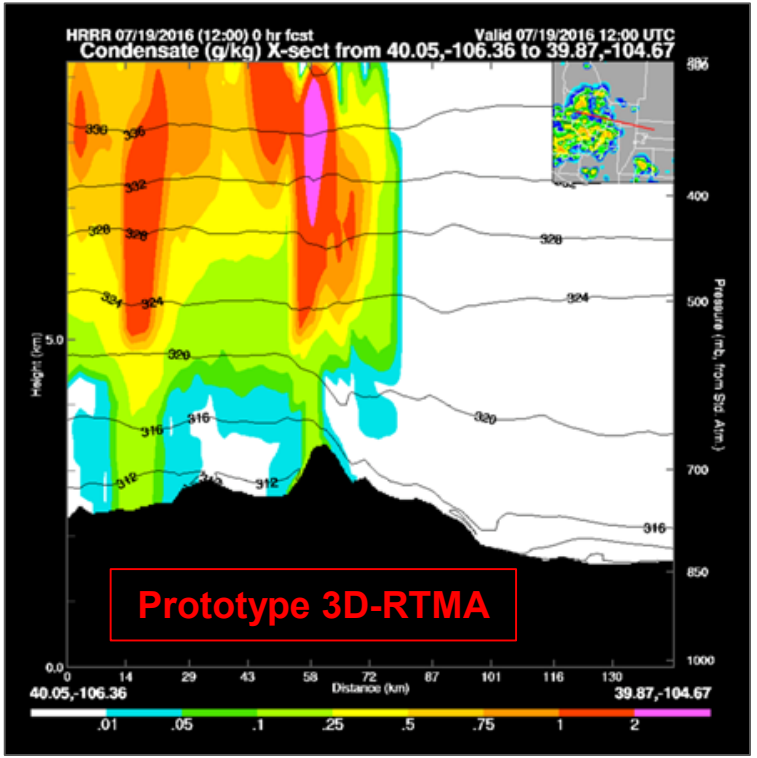
Revisiting the CAM Timeline

- RAPv5/HRRRv4 dev and final implementation
  - Now to Q2 FY20
- Transition work of existing Meso/CAM capabilities to FV3-CAM
  - Now to Q4 FY20
  - HREFv3
- Rapid Refresh Forecast System [RRFS]
  - Q4 FY20 to ~FY22
  - Rapid update, hybrid EnVar DA and forecast system
  - Replaces NAM/NAM nests/RAP/HRRR
- EMC/GSD/NSSL/GFDL/DTC/etc. collaboration!

Real Time Mesoscale Analysis
[if time]

3D Real Time Mesoscale Analysis

- 3 Year Plan to Develop 3D-RTMA
  - With sub-hourly updates
  - CONUS + Alaska
- JTTI + FAA funded joint development effort between EMC + ESRL/GSD
- Real time, rapid updated analysis of 3D atmospheric fields
  - Severe and aviation weather parameters
  - Analysis of hydrometeor and cloud fields
- Challenges
  - Latency, analysis error/uncertainty



Thanks to ESRL/GSD for this figure

Summary

- Progress is picking up very quickly
- DA:
  - Short term: Hybrids/EnVars
  - Longer term: Dealing with non-Gaussianity and nonlinearity more directly
  - Challenges: Multiscale DA, coupled DA, etc.
- Global:
  - FV3 dynamic core implementation in early 2019
  - Physics and increased vertical resolution in 2021
- CAM:
  - Rapid Refresh Forecast System ~2022
  - Challenge: Effective, ‘good’ spread from *single core* CAM ensemble? etc.
- Thanks! Questions?

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