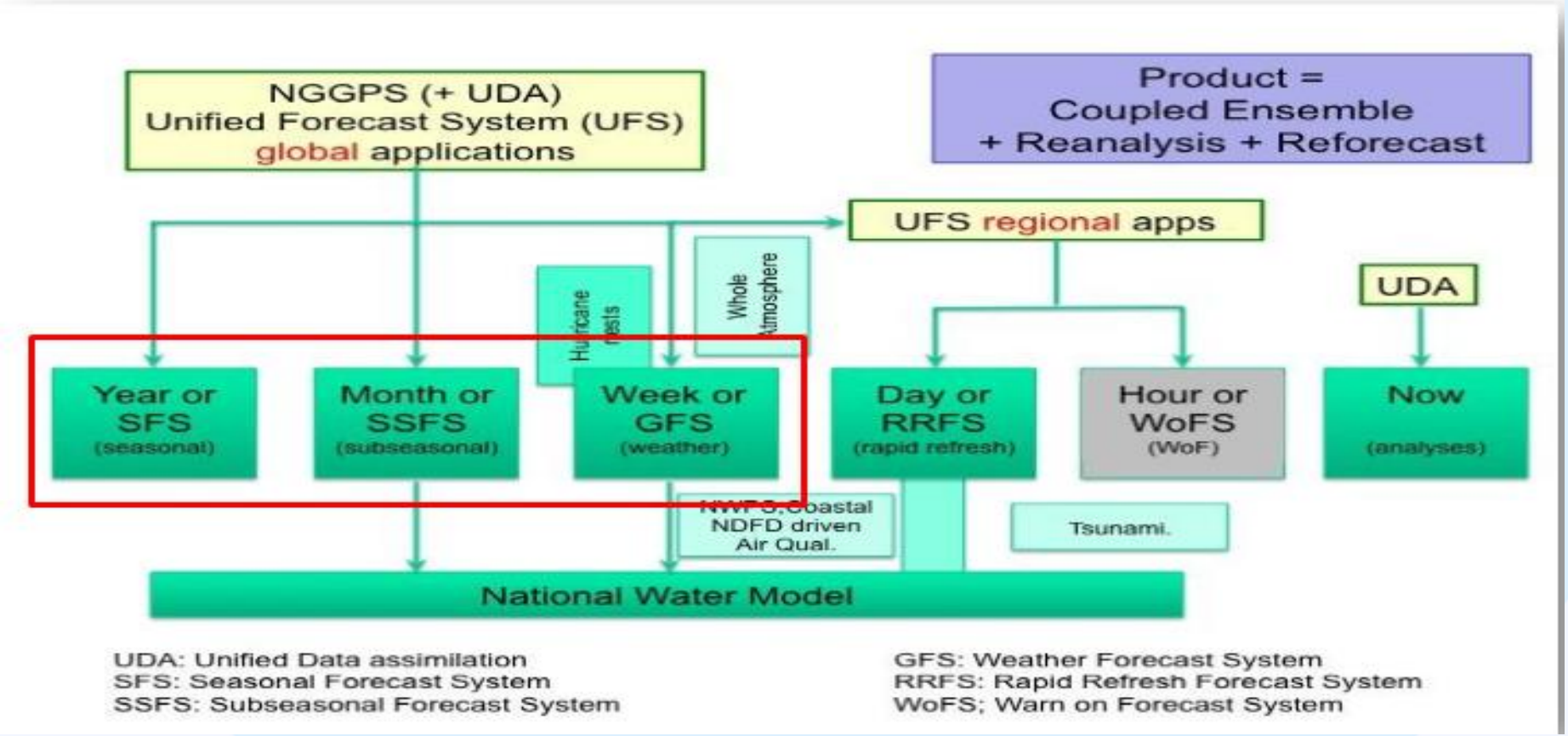
NGGPS

Unified Forecast System Development and Operational Implementation Plans at NCEP / EMC

Vijay Tallapragada
Chief, Modeling and Data Assimilation Branch
NOAA/NWS/NCEP/EMC

EMC-CWB Mini Workshop
Taipei, Taiwan, May 21-24, 2019

Moving Towards Unified Forecast System for NWS Operational Applications



NGGPS FV3GFS-v1 Transition to Operations

HIGHLIGHTS: BOTTOMLINE UPFRONT

- Changing the model 'engine' from Spectral to Finite Volume Cubed Sphere Dynamic Core (FV3)
- FV3GFS begins to address several outside committee recommendations and is the first application of the Unified Forecast System (UFS), implemented less than three years since the NGGPS dynamic core was chosen
- Unprecedented Development: Inclusive of NCEP/GFDL /PSD/GSD effort, and step towards community based model development (two public releases through Vlab abd Github.com)
- Unprecedented Evaluation: A total of 16 organizations in NOAA (all 6 NWS regions, 8 National Centers, ARL and MDL) assessed 3.5 years of retrospective data. 9 approved, 7 neutral.
- Overall provides numerical guidance to the weather enterprise equal to or better than that currently provided by the operational GFS, with some exceptions.

See Talk from Fanglin

Summary -- Benefits & Concerns

Benefits:

- (significantly) Improved 500-hpa anomaly correlation
- Intense tropical cyclone deepening in GFS not observed in FV3GFS
- FV3GFS tropical cyclone track forecasts improved (within 5 days)
- Warm season diurnal cycle of precipitation improved
- Multiple tropical cyclone centers generated by GFS not seen in FV3GFS forecasts or analyses
- General improvement in HWRF and HMON runs
- New simulated composite reflectivity output is a nice addition
- Some indication that fv3gfs can generate modest surface cold pools from significant convection

Concerns:

- FV3GFS can be too progressive with synoptic pattern
- Precipitation dry bias for moderate rainfall
- SST issues – North Pacific and lakes are too cold in the transition season
- Spurious secondary (non-tropical) lows show up occasionally in FV3GFS since the advection scheme change was made
- *Both GFS and FV3GFS struggle with inversions*
- *Both GFS and FV3GFS often has too little precip on the northwest side of east coast cyclones*

Issues identified with real-time FV3GFS over the winter

- EMC has addressed two issues with the previously evaluated release target of the FV3GFS (noted via social media and continued internal evaluation):
  - **Unrealistically large accumulation of snow under certain conditions**
  - **Exacerbated cold bias in the lower atmosphere**
  - GFS v15 Implementation was paused pending investigation & mitigation of these issues
- EMC has determined at least one cause of excessive snow (snowflag) and two causes of some of the exaggerated cold bias in the lower atmosphere (zenith angle bug fix and super-saturation constraint in the DA)
- EMC implemented three changes to the model (GFS v15.1):
  - Fractional snowflag for better accounting of frozen precip reaching ground
  - Improved cloud-radiation interactions
  - Relaxed supersaturation constraint in the DA

GFS v15.1 Implementation Schedule

- The pause for GFS v15 was lifted on May 6, 2019, and NCEP is proceeding with the implementation of GFS v15.1 based on approvals from NWS Executive Council.
- The 30-day IT stability test started on May 10, 2019.
- Implementation date is currently scheduled for June 12, 2019 pending successful completion of the IT test.
- The current operational GFS (GFS v14) will continue to run in parallel through September 30, 2019 before it is officially retired from production.
- PNS for GFS v15.1 is available at: https://www.weather.gov/media/notification/pns19-09gfs_v15_1.pdf
- SCN for GFS v15.1 is available at: https://www.weather.gov/media/notification/scn19-40gfs_v15_1.pdf

GFS V16: Major Upgrades to Deterministic Global Model

Model resolution:

- Increased vertical resolution from 64 to 127 vertical Levels and raise model top from 54 km to 80 km; Increased horizontal resolution from 13 km to 10 km (depending on operational resources)

Dynamics: New advection algorithms from GFDL

Advanced physics chosen from Physics Test Plan:

- PBL/turbulence: K-EDMF => sa-TKE-EDMF
- Land surface: Noah => Noah-MP
- Gravity Wave Drag: => unified gravity-wave-drag
- Radiation: updates to cloud-overlap assumptions,
- Microphysics: Improvements to GFDL MP

Coupling to WaveWatchIII

- Two-way interactive coupling of atmospheric model with Global Wave Model (GWM)

Data Assimilation Upgrades:

- Local Ensemble Kalman Filter (LETKF), including early cycle updates in support of GEFS
- 4-Dimensional Incremental Analysis Update (4DIAU)
- Stochastic Kinetic Energy Backscatter (SEKB) based land surface perturbations
- Stratospheric humidity increments
- Improved Near Surface Sea Temperature (NSST) analysis
- Land Data Assimilation
- Shifting and Lagging Ensemble Members to expand ensemble size
- Improved cloud analysis
- Delz increments

See Talks from Fanglin & Daryl

Global Wave Model Coupled to GFS v16

New Global spatial grid mosaic,

- Global core resolution increased from ½ degree to ⅙ degree,
- Arctic Polar grid resolution increased from 18 km to 9 km,
- Added Antarctic Polar Stereographic Grid with 9 km resolution,
- High resolution CONUS grids: Hawaii, Puerto Rico 4 min grids.

Addition of wave-current interactions - RTOFS surface currents,

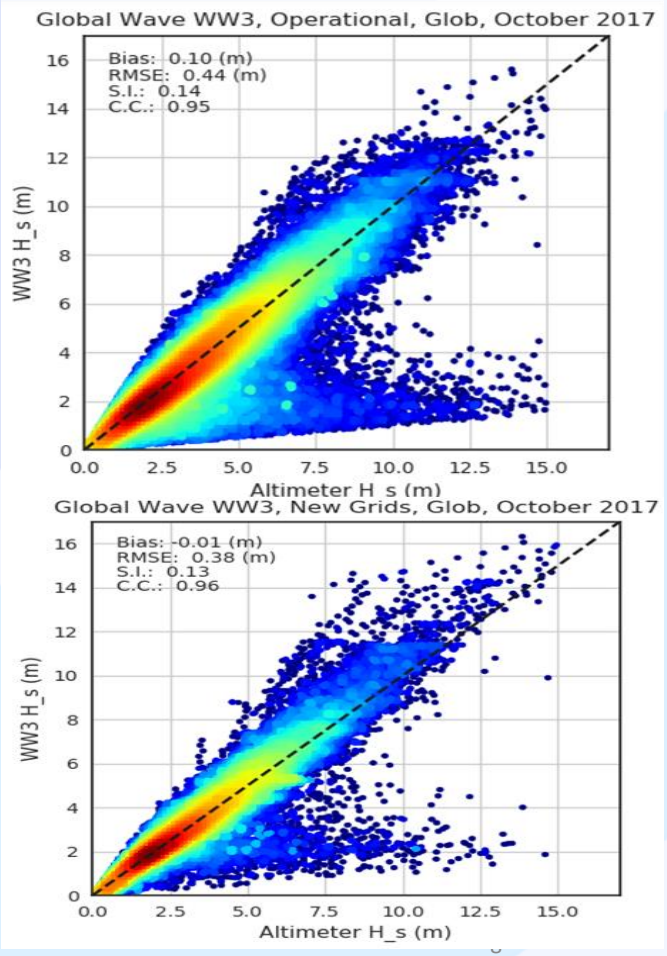
- Improve forecasts in Gulf Stream (OPC requirement).

Objective Physics Retuning,

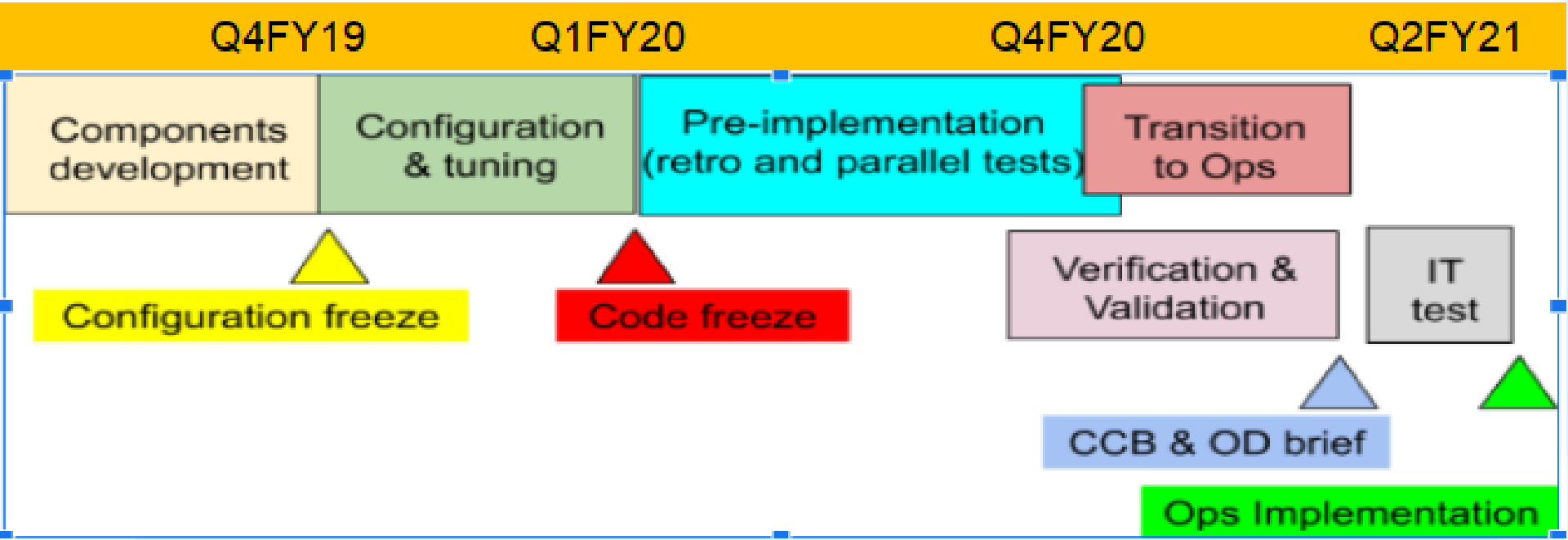
- Reduction of Hs RMS error and bias, adjustment to FV3.

AWIPS products redesigned,

- Elimination of legacy products, address customer needs.

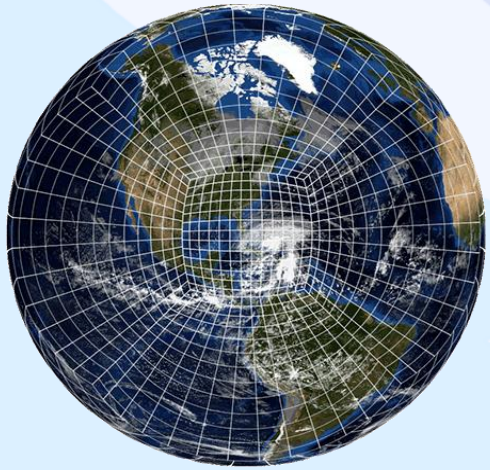


GFS V16 Implementation Schedule



Sub-Seasonal Forecast System (GEFS v12)

Global Ensemble Forecast System GEFS v12



- **Configuration**
  - **C384L64 (~25km)**
  - **31 members, 4 cycles/day**
  - **35 days forecast**
- **Q3FY18: Start to produce 20 years (1999-2018) reanalysis**
- **Q1FY19: Start to produce 30 years (1989-2018) reforecast**
- **Q4FY19: Start to produce retrospective runs (2-3 years)**
- **Q1FY20: Start users evaluation**
- **Q3FY20: Implement FV3GEFS operational version (v12)**

See Talk from Yuejian

Global Wave Ensemble (GWES) Coupled to GEFS v12

Coupling to GEFS v12: Provide initial framework for transition to unified, fully-coupled systems at NCEP,

New global grids: Improve overall model skill, and match requirements for inclusion of wave products to NAEFS,

- Global core resolution increased from ½ degree to ¼ degree,
- Inclusion of Arctic Polar grid with 18km resolution.

Objective Physics Retuning: Reduction of Hs RMS error and bias, adjustment of wave model physics to FV3 forcing.

See Talk from Jessica

FV3GFS-Chem in GEFS v12

Transition GOCART to FV3GFS dycore as GEFS control member

- **Resolution Increase:** C384, L64 to 120 hours 4x/day
- **Biomass burning emission:** NESDIS Global Biomass Burning Emission Product (GBBEPx) on FV3 C384 grid
  - Awaiting NESDIS operational implementation (Mid June 2019)
- **Dust emission:** AFWA scheme from WRF-Chem
- **Sea-salt:** NASA GEOS-Chem
- **Sulfate:** CEDS emissions + NASA chemistry
- **Dimethyl sulfate over oceans:** old NASA version
  - Reconciling w/ latest NASA sources, background chemistry
- **Convective transport:** Grell-Freitas mass flux in chemistry
- **PBL transport:** in chemistry
  - Future: consistency with Met transport
- **Deposition/scavenging:** in chemistry
  - Future: consistency with microphysics, convection, land models

See Talk from Vijay/Daryl on Thursday

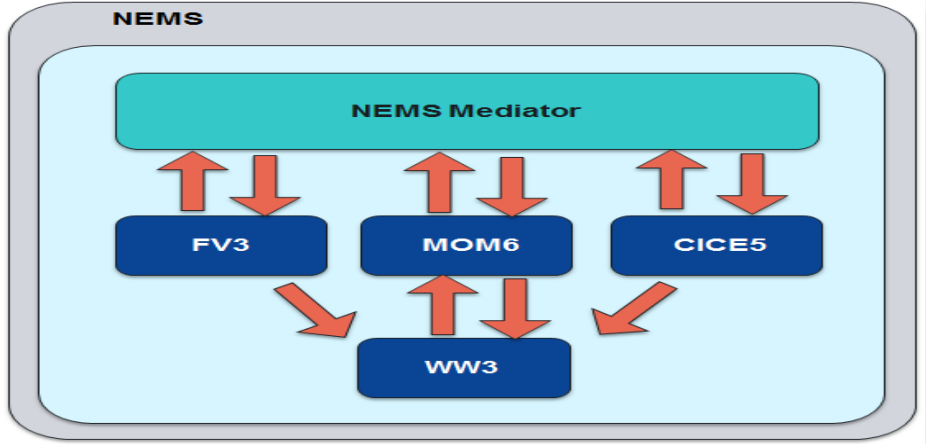
Coupled UFS Applications for sub-seasonal and seasonal predictions

GEFS (Ensemble) v13: First coupled system for sub-seasonal predictions

- FV3+MOM6+CICE5+WWW3+GOCART Coupled Model
- Advanced Physics
- FY22: Implement GEFS v13.0

Seasonal Forecast System (SFS v1.0/CFS v3)

- Fully coupled Unified Forecast System
- Seasonal ensemble forecasts with reanalysis and reforecasts
- Fully coupled DA
- FY23: Implement SFS v1.0



Coupled System Benchmark Experiments

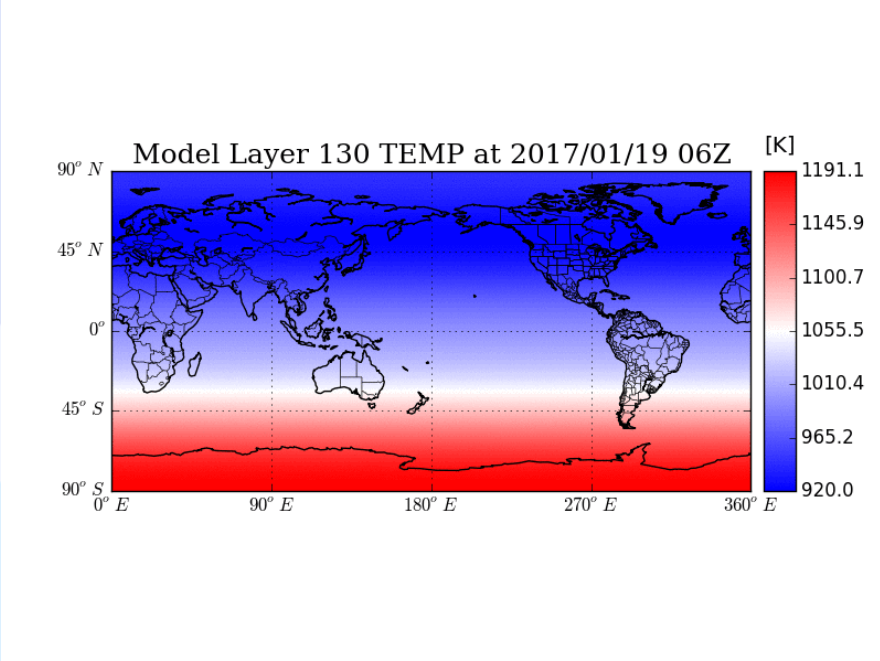
- **Q1FY19: Benchmark 1 FV3-MOM6-CICE5 system completed**
  - **Q4FY19:**
  - **Benchmark 2: FV3GFS+MOM6+CICE5 with ocean and ice ICs from 3DVAR (pre-JEDI)**
  - **Benchmark 3: Benchmark 2 but with CPC ice analysis**
  - **Benchmark 4: FV3GFS+MOM6+CICE5+WW3**
  - **Benchmark 5: Benchmark 4 but with Fractional Masks**
  - **FY20:**
  - **Benchmark 6: FV3GFS+MOM6+CICE5+WW3 (weakly coupled, initialized w/marine JEDI)**
  - **Benchmark 7: Physics Tuning Experiments**
  - **Prototype GEFSv13: Marine Component Perturbations**
  - **Extend benchmark runs to 9 months and longer, physics tuning, optimization (seasonal scales)**

See Talk from Jessica on Wednesday

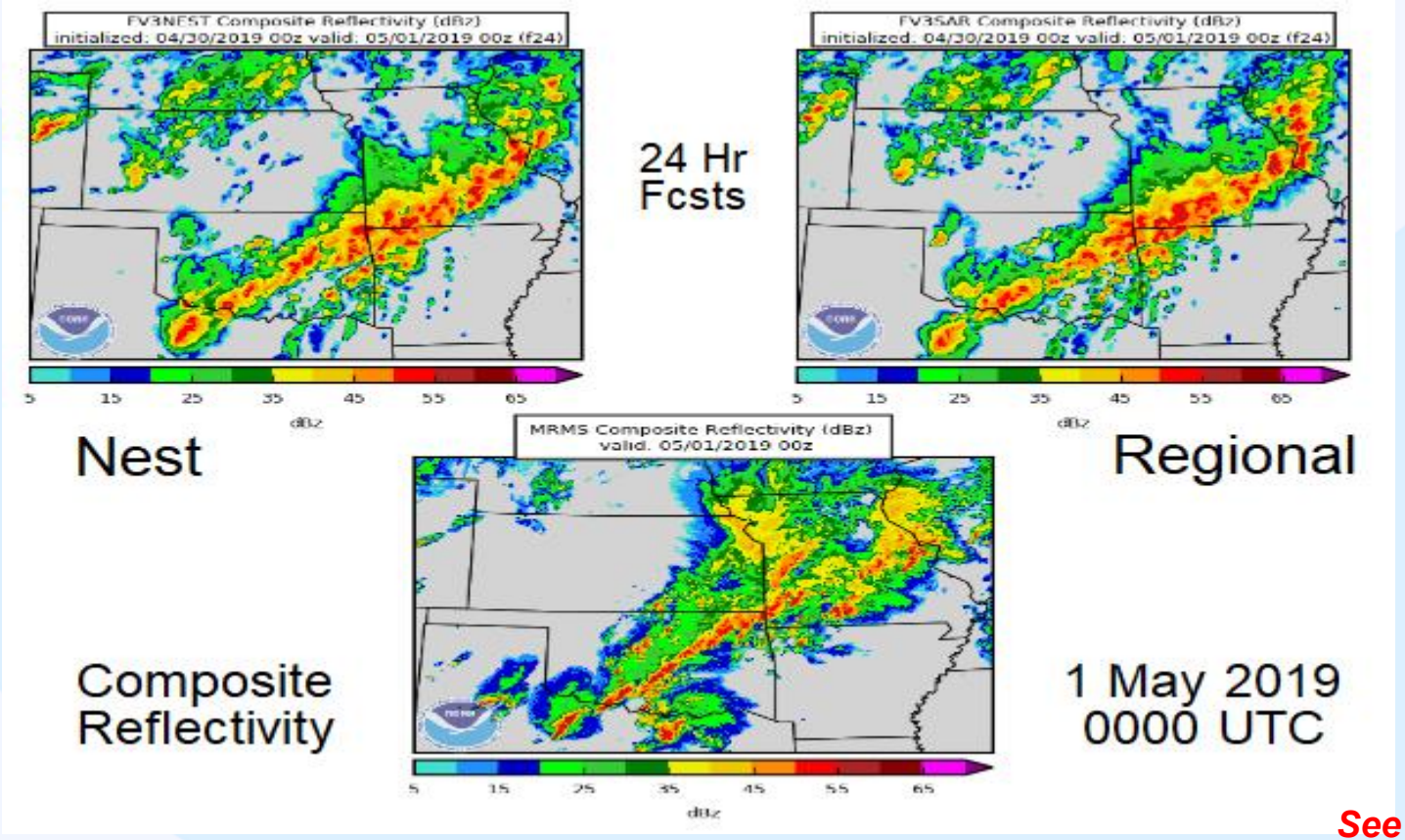
FV3 based Deep Atmosphere Dynamics for WAM/IPE

Joint development plan for Space Weather Applications: (EMC/GFDL/SWPC/CU Collaboration)

- **Extend FV3 vertical domain to be the same as GSM WAM**
- **Adiabatic mode of FV3**
- **Extend to WAM domain with WAM cold-start IC**
- **Use GFS physics with Rayleigh damping**
- **Add diffusivity, conductivity, viscosity for upper-layer integration**
- **Add WAM physics and multi gases thermodynamics**
- **Add deep-atmosphere dynamics**
- **Couple to IPE using NUOPC mediator**

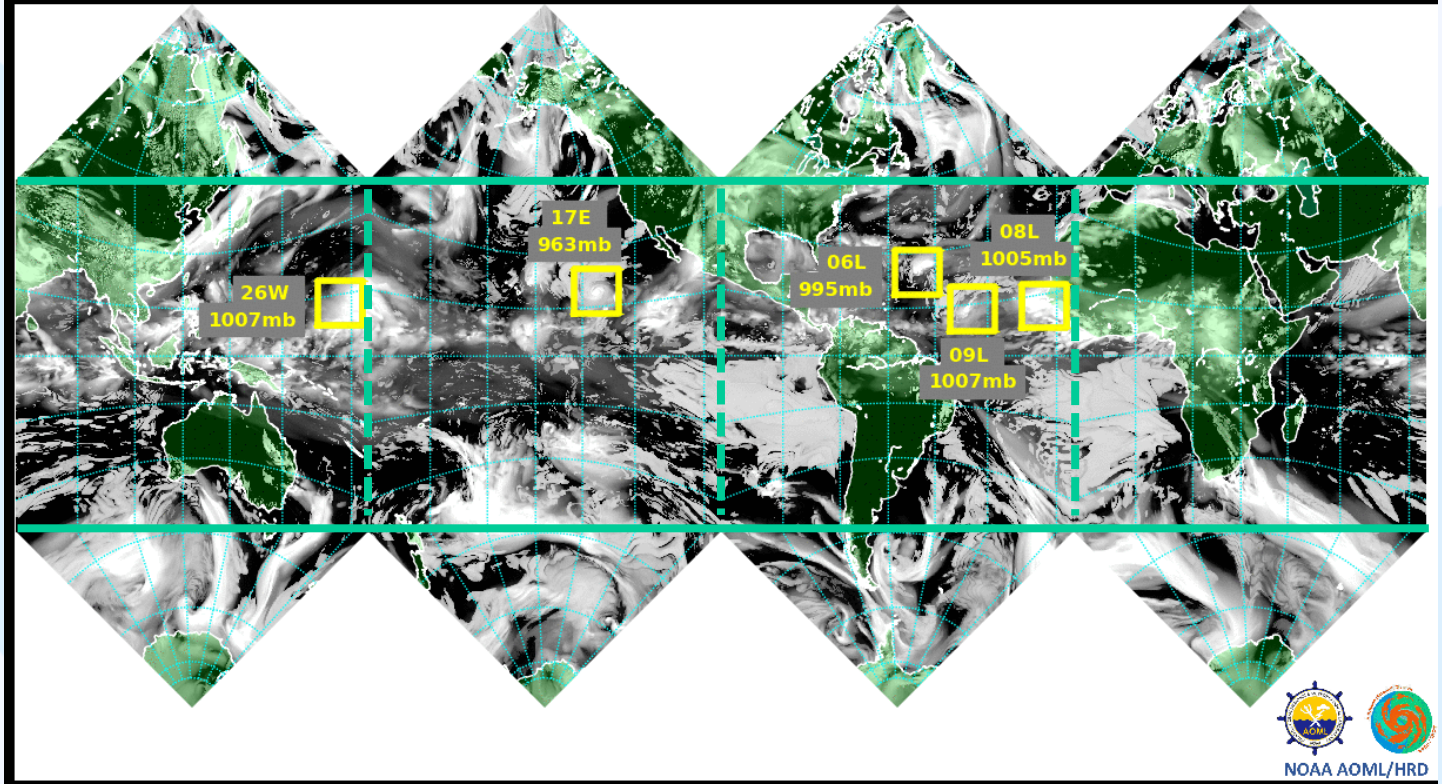


FV3 Real-Time Stand-Alone Regional and Global Nested CAM Testing



See Tom's Talk

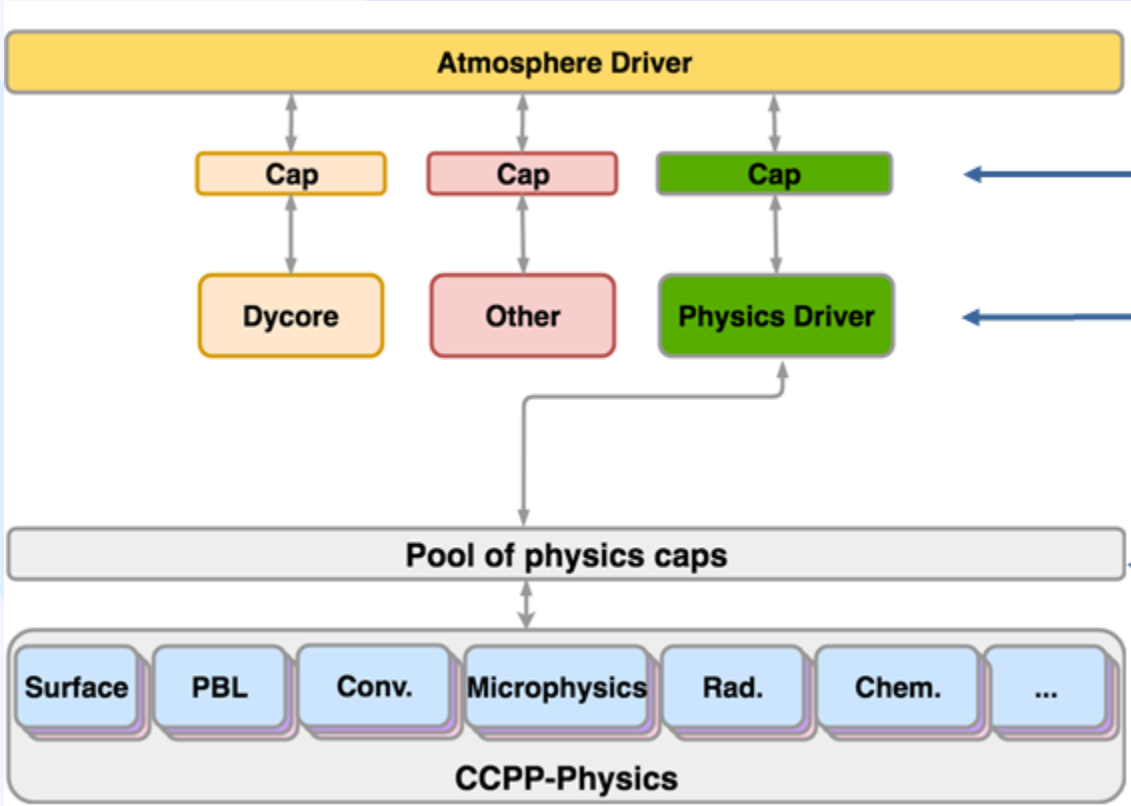
HAFS: What do multiple moving nests look like in global model?



06L: Florence
08L: Helene
09L: Isaac
17E: Olivia
26W: Mangkhut

See my talk on Thursday

Physics-Dynamics Coupling Architecture



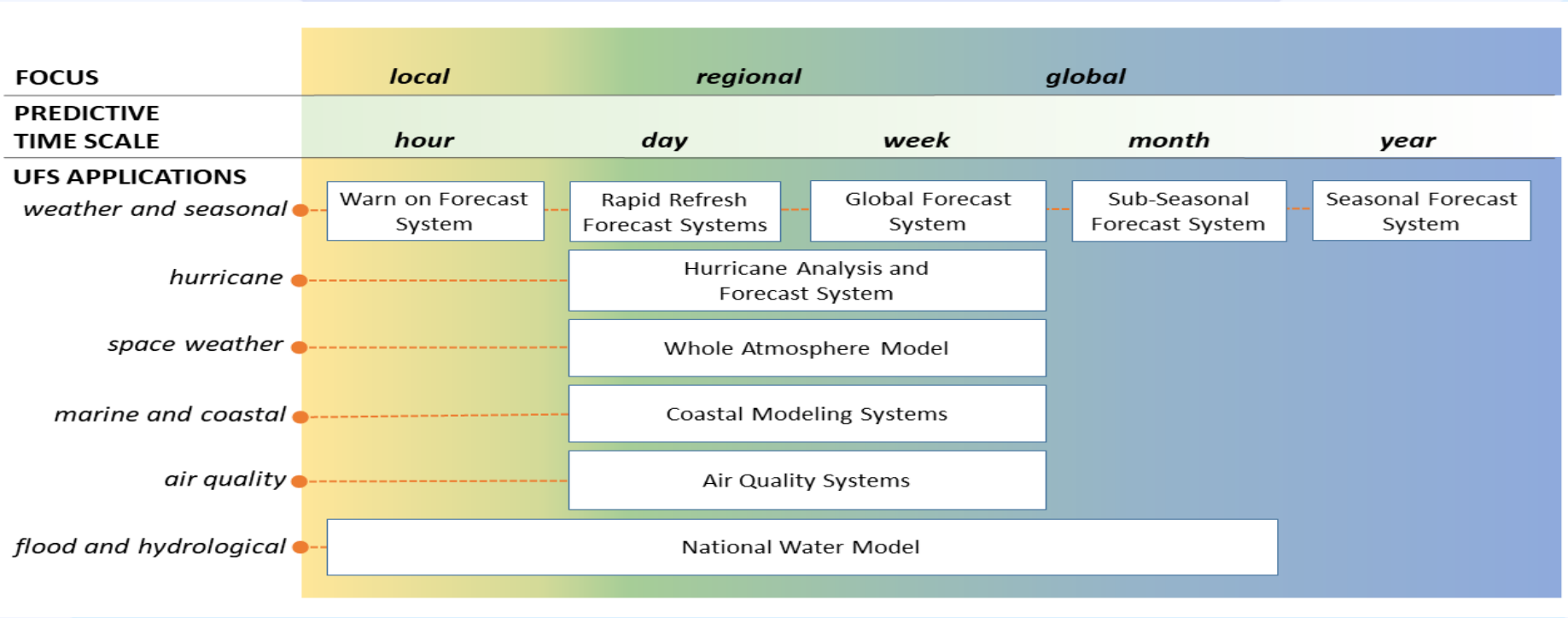
Host application cap with auto-generated code from host metadata

CCPP-Framework used before/at compile time and during run

Physics caps (auto-generated)

Parameterizations

Scope of UFS



UFS applications span predictive timescales (less than an hour to more than a year) and focus on multiple spatial scales (local to global).

Shared Community Infrastructure

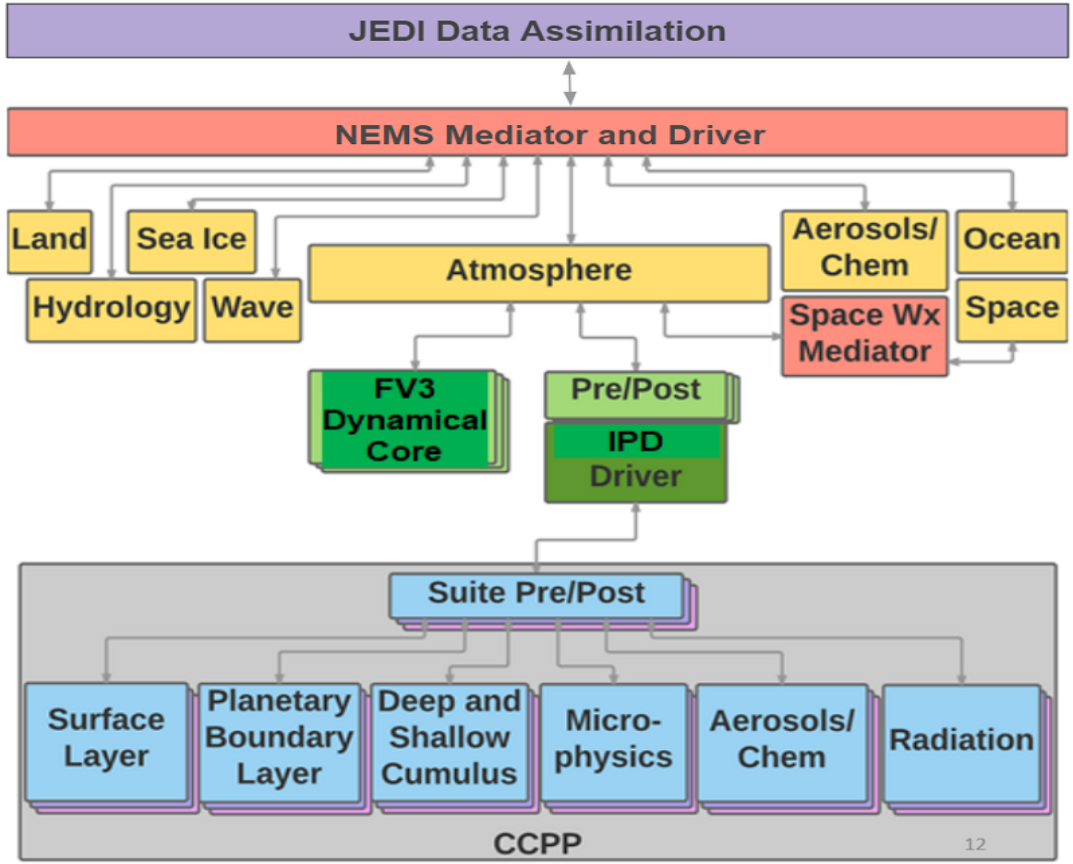
Infrastructure for data assimilation: Joint Effort for Data assimilation Integration (**JEDI**)

Infrastructure for coupling models together:

- NOAA Environmental Modeling System (**NEMS**) coupler
- based on the Earth System Modeling Framework (**ESMF**)
- using National Unified Operational Prediction Capability (**NUOPC**) conventions

Infrastructure for interoperable physics:

- Common Community Physics Package (**CCPP**) framework



NCAR-NOAA Infrastructure MOA: Work Areas

1. Coupling components
New ESMF/NUOPC mediator (CMEPS/NEMS)

2. Interoperable atmospheric physics
CCPP & CPF frameworks

3. Community-friendly workflow
CIME - CROW unification, CIME Case Control System

4. Hierarchical model development capabilities
Extensions of CIME data models, unit, and system testing

5. Forecast Verification: Comparison to Observations
Extension of MET+

6. Software Repository Management
NCAR manage_externals tool

7. User / Developer Support
DTC and CESM Capabilities


UNIVERSITY of WASHINGTON
ILLINOIS
UNIVERSITY AT ALBANY
UNIVERSITY OF MARYLAND
CHINA METEOROLOGICAL ADMINISTRATION
HIWPP
GEORGE MASON UNIVERSITY
INPE
NOAA NESDIS STAR
PENNSTATE
UNIVERSITY OF NORTH DAKOTA
Earth System Research Laboratory
Serving Society through Science
FLORIDA STATE UNIVERSITY 1851
NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION
NCEP
WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON
UNIVERSITY OF HAWAI'I
Colorado State University
GFDL
NOAA
CENTRAL WEATHER BUREAU
Stony Brook University
COLUMBIA UNIVERSITY
THE UNIVERSITY OF UTAH