UFS based Global Modeling Updates

Weather, Sub-Seasonal and Seasonal Forecast Systems
SIP Annex 1

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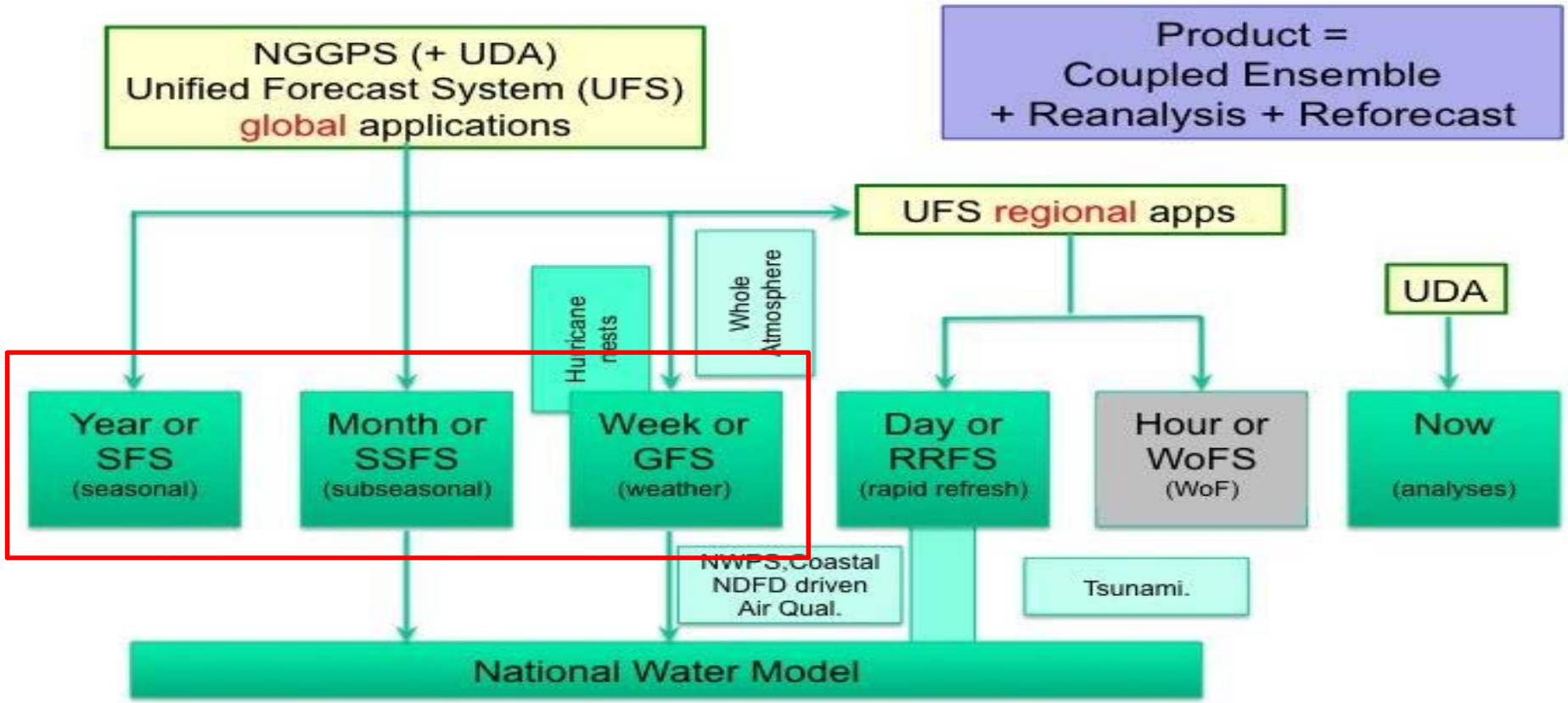
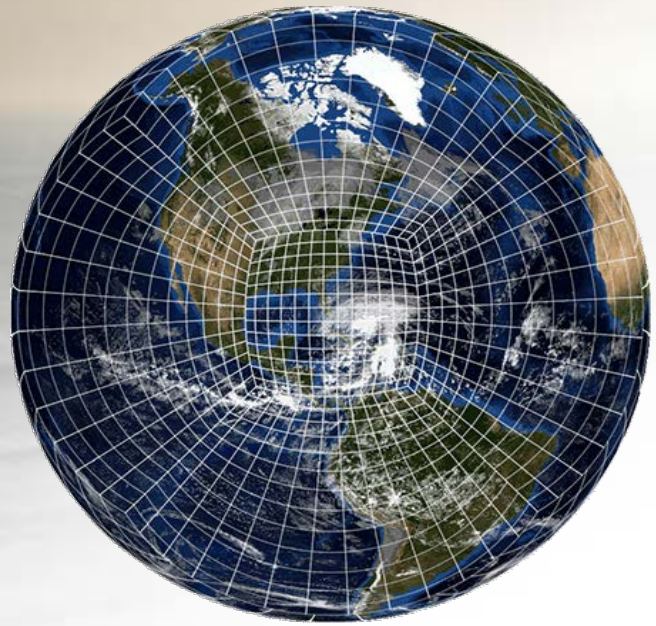
Moving Towards Unified Forecast System for NWS Operational Applications



FV3 Dycore and Global Models

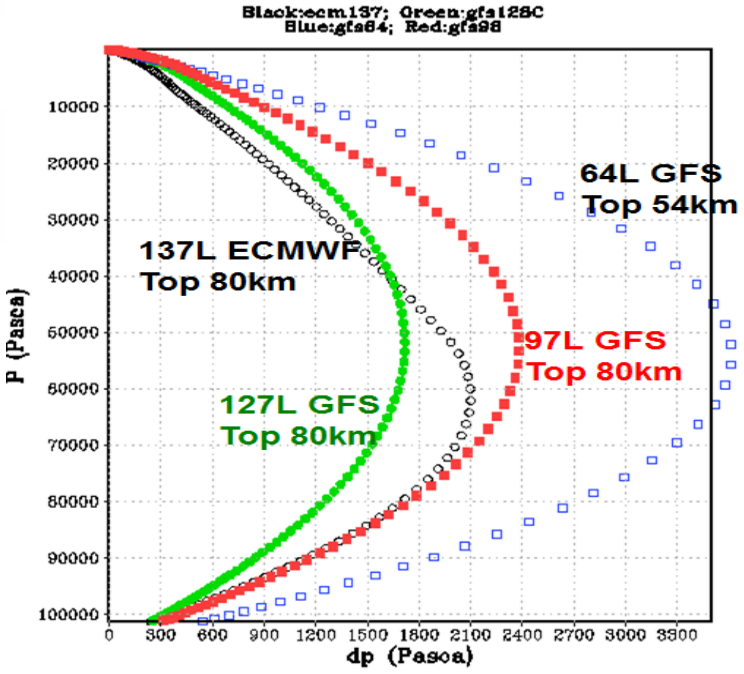
GFS/GDAS v15.1

- **Operational implementation scheduled for June 12, 2019**



GFS/GDAS v16

- **Configuration**
  - **Increased resolution**
  - **Advanced Physics**
  - **Coupled to Wave Model**
  - **Improved Data Assimilation**
- **Planned for implementation in Q2FY21**



NGGPS FV3GFS-v1 (GFS v15.1) Transition to Operations

FV3GFS is being configured to replace spectral model based GFS (NEMS GSM) in operations on or about June 12, 2019

Configuration of GDAS/GFS V15.0.0:

- FV3GFS C768 (~13km deterministic)
- GFS Physics + GFDL Microphysics + New O_3 and H_2O Chemistry
- FV3GDAS C384 (~25km, 80 member ensemble), SPPT, SKEB & SHUM, improved NSST, All-sky ATMS, 10 more IASI channels, full spectral CrIS, Megha Tropiques, no TC relocation/digital filter
- 64 layer, top at 0.2 hPa, high-res GMTED2010 terrain
- Uniform resolution for all 16 days of forecast

Product Changes:

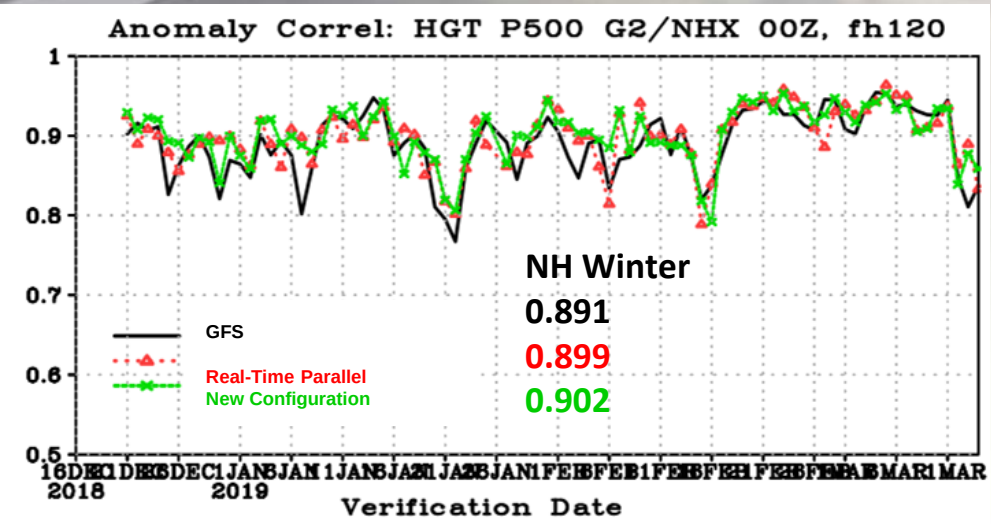
- Non-hydrostatic vertical velocity dz/dt in m/s (in addition to omega)
- More prognostic cloud hydrometers
- Global composite radar reflectivity
- Isobaric (3D) cloud fractions
- Continuous accumulated precipitation (in addition to 6-hr buckets)

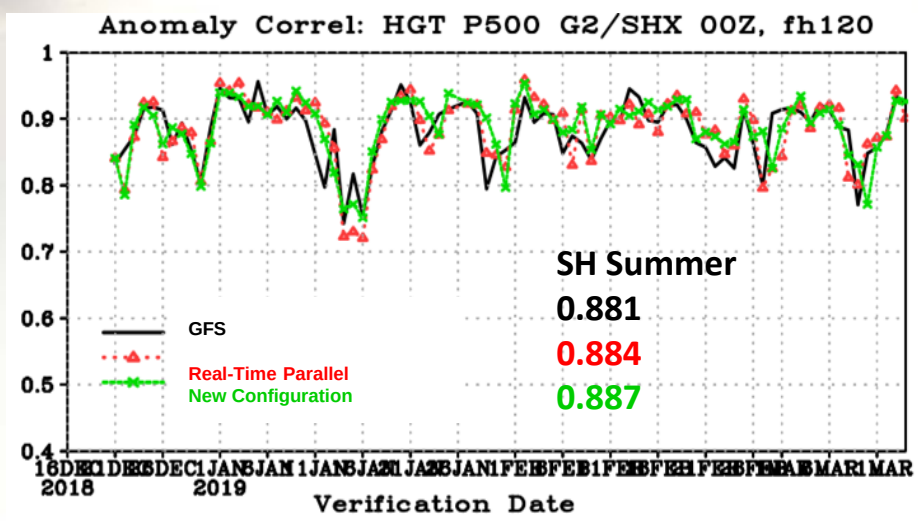
Issues identified with real-time FV3GFS over the winter

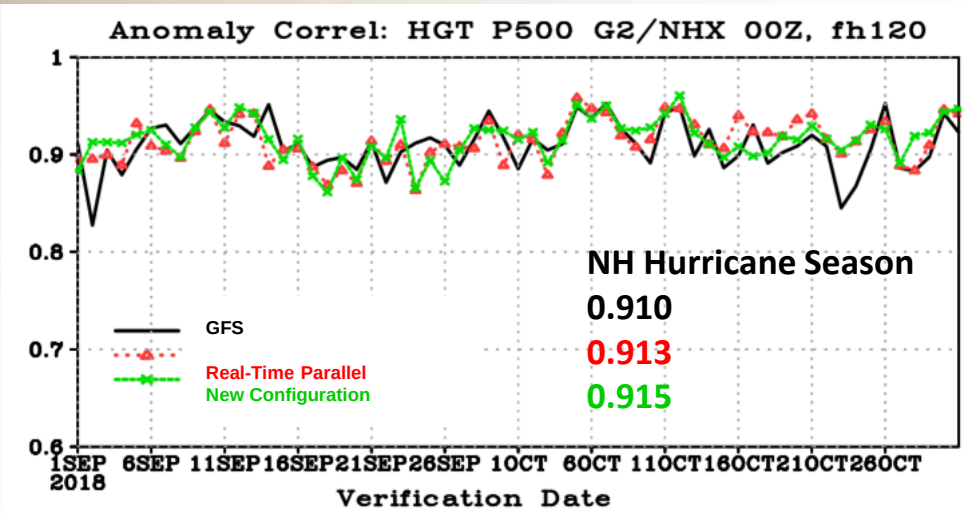
- EMC has addressed two issues with the previously evaluated release target of the FV3GFS (noted via social media and continued internal evaluation):
  - **Unrealistically large accumulation of snow under certain conditions**
  - **Exacerbated cold bias in the lower atmosphere**
  - GFS v15 Implementation 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

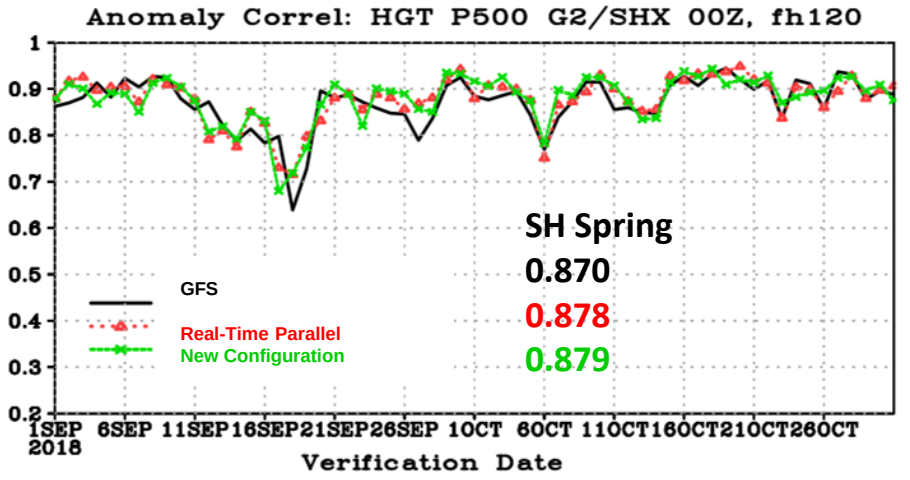
Statistical evaluation

Operational GFS vs. Real-Time Parallel vs. New Configuration



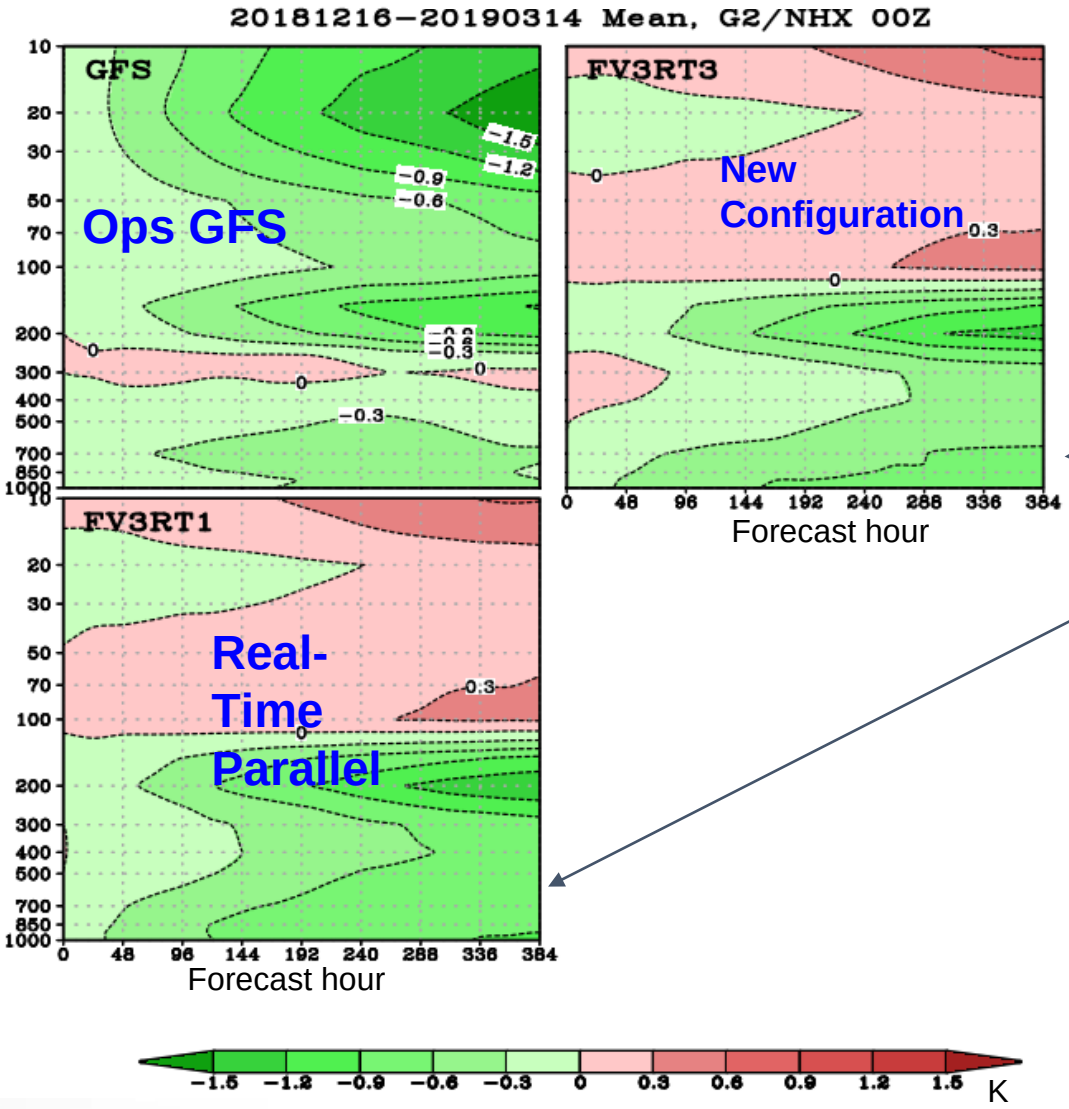






500 hPa ACCs from New Configuration shows significant improvement over GFS for 5-day forecasts

NH Temperature Biases Relative to Own Analyses

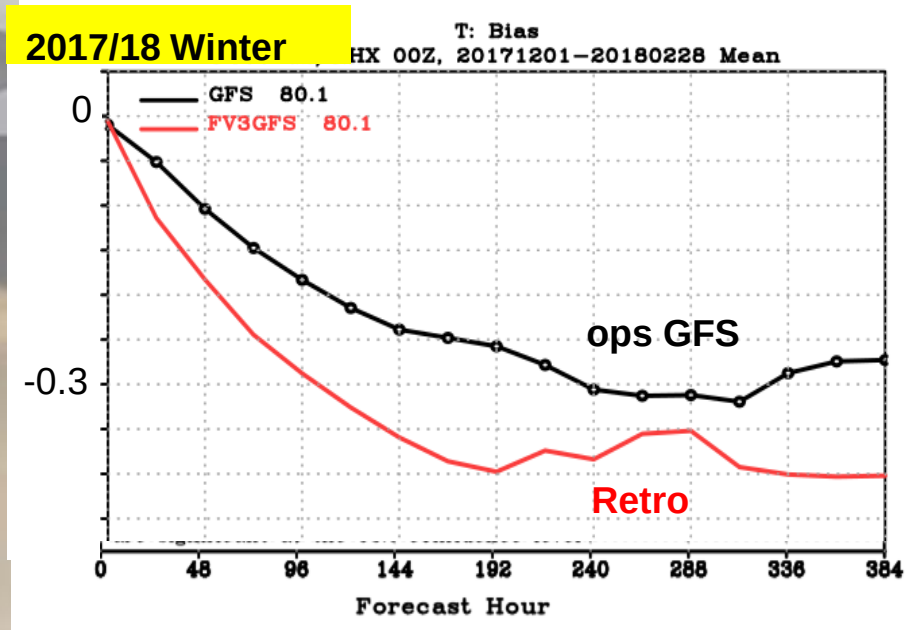


2018/19 Winter

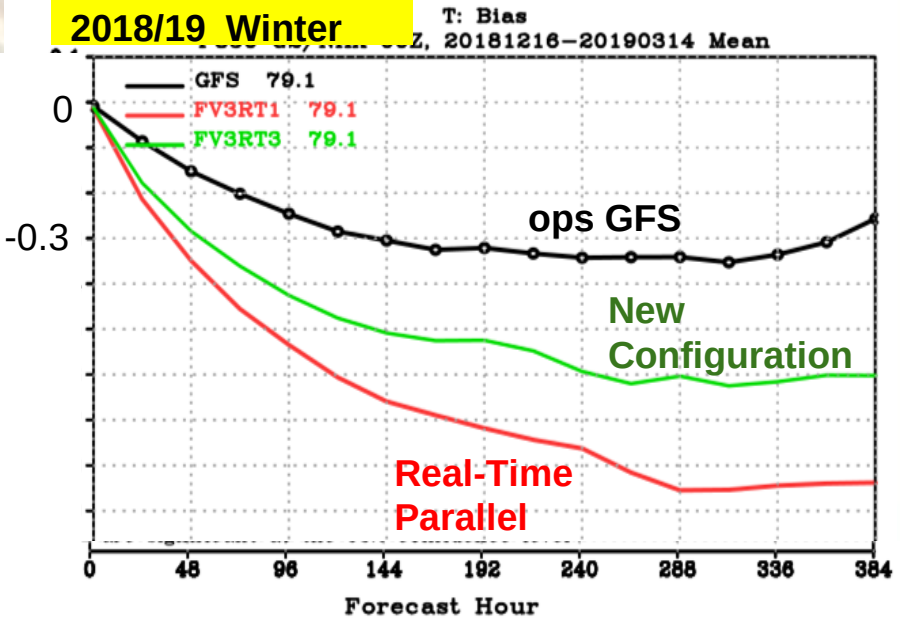
The cold bias in the lower troposphere is reduced in the New Configuration compared to the previous real time parallel

NH 850-hPa Temperature Biases Relative to Own Analyses

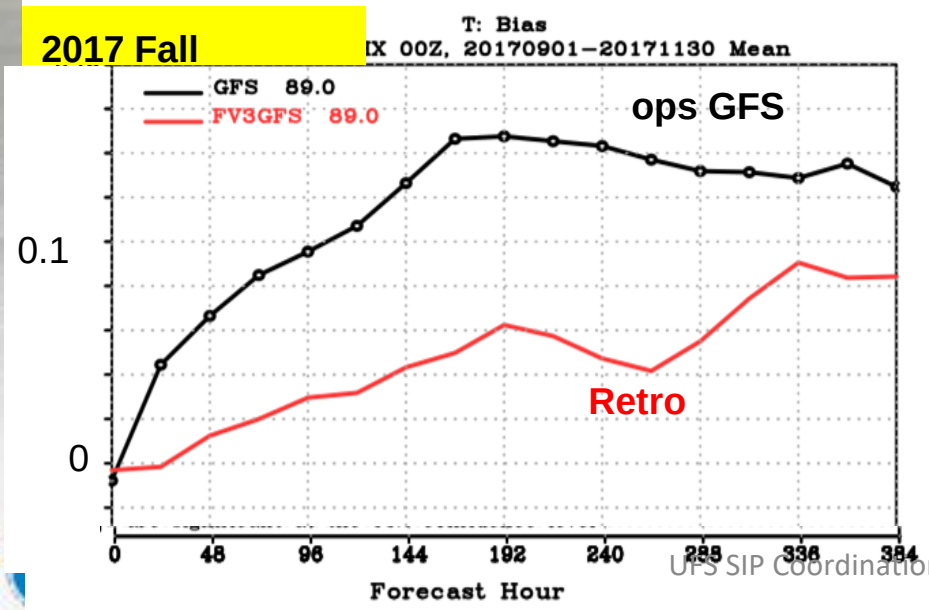
2017/18 Winter



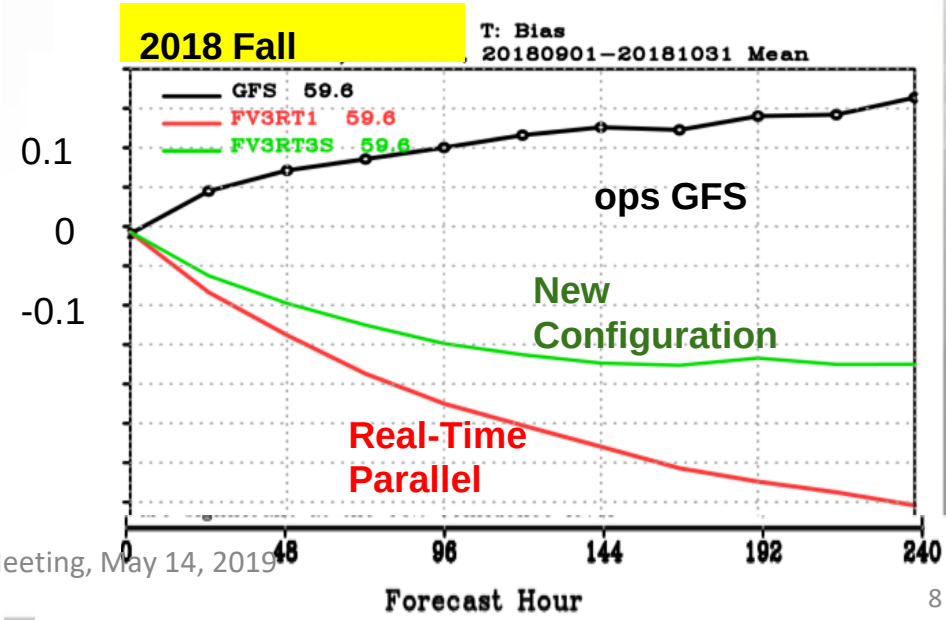
2018/19 Winter



2017 Fall



2018 Fall



Improvements over operational GFS in retrospective runs

✓ = Retained in the new configuration

- ✓ (significantly) Improved 500-hpa anomaly correlation (NH and SH)
- ✓ 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
- FV3GFS with advanced GFDL MP provides better initial and boundary conditions for driving stand alone FV3, and for running downstream models that use advanced MP.
- FV3 based GEFS V12 showed significant improvements when initialized with FV3GFS
- ✓ Improved ozone and water vapor physics and products
- Improved extratropical cyclone tracks
- ✓ Improved precipitation ETS score (hit/miss/false alarm)
- Overall reduced T2m biases over CONUS

Documented concerns include:

- FV3GFS can be too progressive with synoptic pattern
- Precipitation dry bias for moderate rainfall
- Extremely hot 2-m temperatures observed in mid-west
- Spurious secondary (non-tropical) lows show up occasionally in FV3GFS since the advection scheme change was made
- ✓ T2m over Alaska is too cold, likely caused by cold NSST and/or cloud microphysics issue in the Arctic region – **mitigated with NSST fix**
- NHC reported that FV3GFS degraded track forecast of hurricanes (initial wind > 65 kts) in the Atlantic basin
- *Both GFS and FV3GFS struggle with inversions*
- *Both GFS and FV3GFS often has too little precip on the northwest side of east coast cyclones*

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

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,

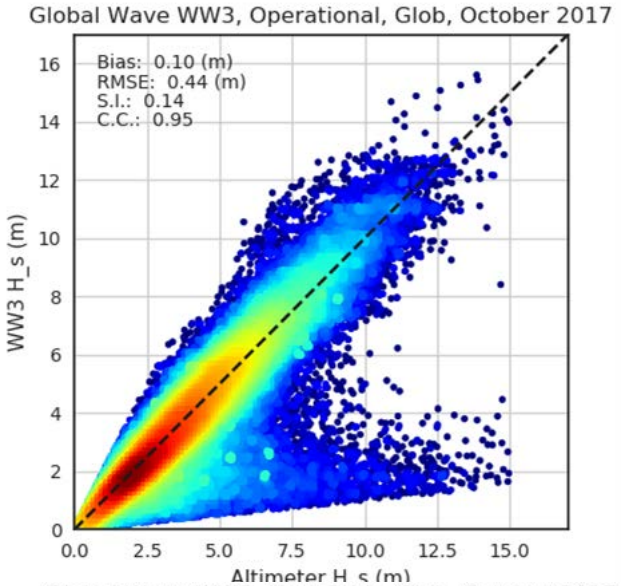
- Improve forecasts in Gulf Stream (OPC requirement).

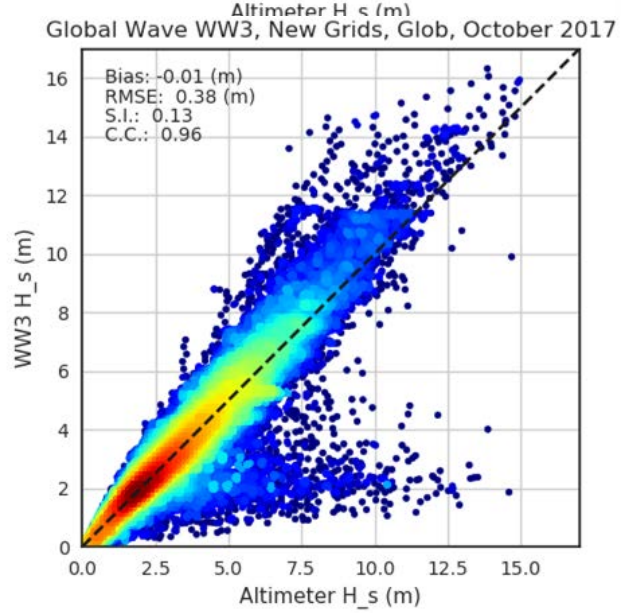
Objective Physics Retuning,

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

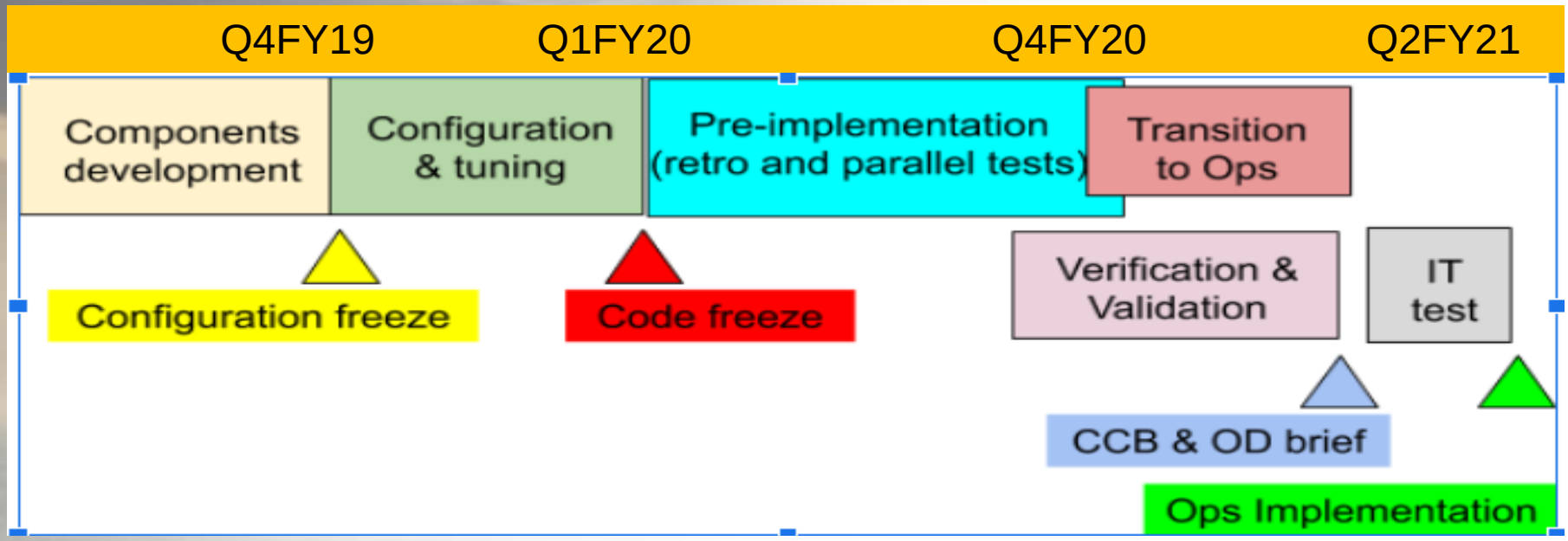
AWIPS products redesigned,

- Elimination of legacy products, address customer needs.





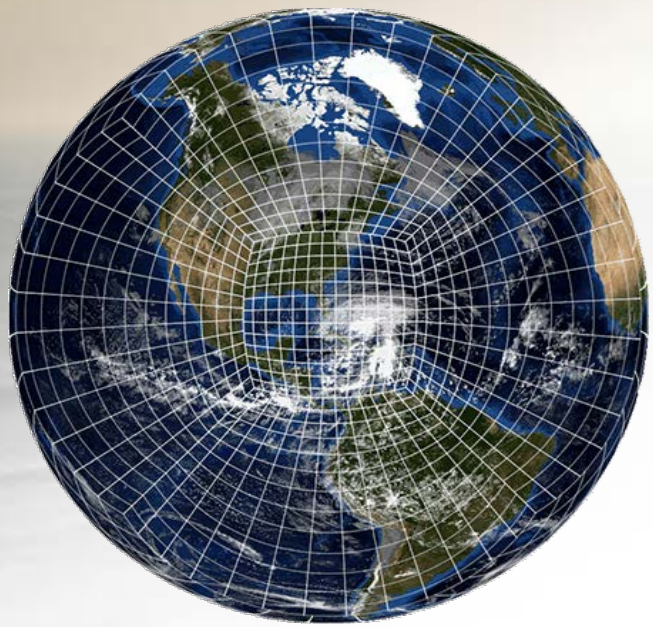
GFS V16 Implementation Schedule



Detailed Project Plan and Charter being developed: Draft version

Sub-Seasonal Forecast System

Global Ensemble Forecast System GEFS v12



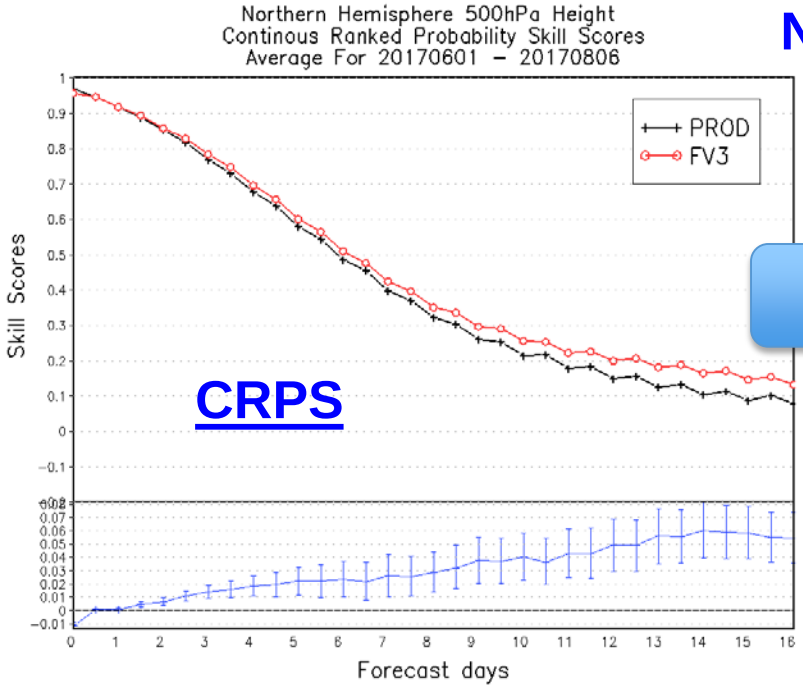
- **Configuration**
  - **C384L64 (~25km)**
  - **31 members, 4 cycles/day**
  - **35 days forecast**
- **Q3FY18: Start to produce 20 years (1999-2018) reanalysis**
- **Q1FY19: Start to produce 30 years (1989-2018) reforecast**
- **Q4FY19: Start to produce retrospective runs (2-3 years)**
- **Q1FY20: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

FV3-GEFS V12 Operational configuration

- **Model**
  - FV3GEFS (C384L64) with GFDL MP
- **Initial perturbations**
  - FV3EnKF analysis (early run) or FV3EnKF f06
  - No TS relocation for FV3EnKF
- **Stochastic perturbations for atmosphere**
  - SKEB, SPPT (5-Scales) and SHUM (0.004)
- **Boundary forcing for weeks 3&4 forecast**
  - 2-tiered SST approach
- **Unification of Production Suite**
  - **One-way coupling to Wave Ensembles**
  - **One-way coupling to GOCART (GEFS control member replaces NGAC)**
  - ***Possible retirement of SREF ???***

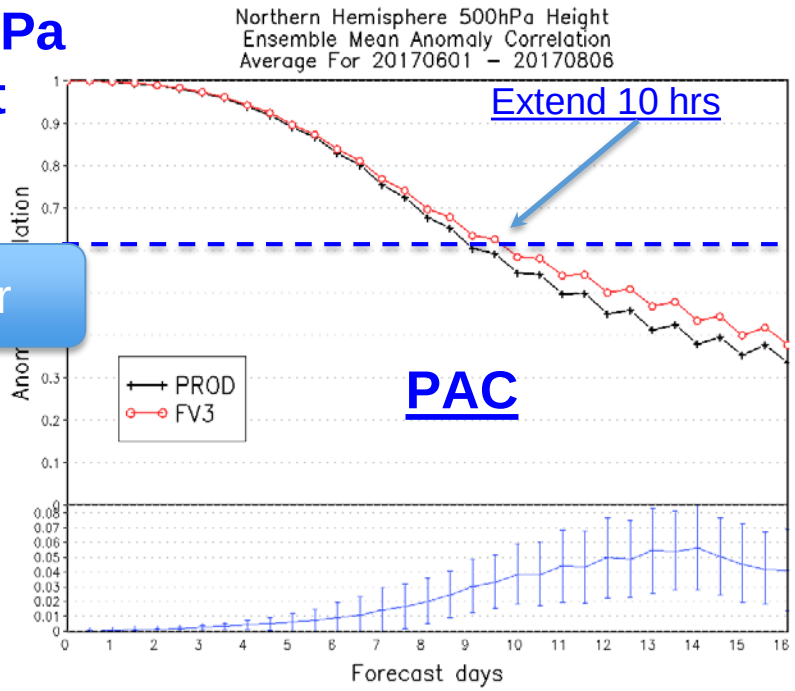
Configuration Finalized – Q3FY19

NH 500hPa height

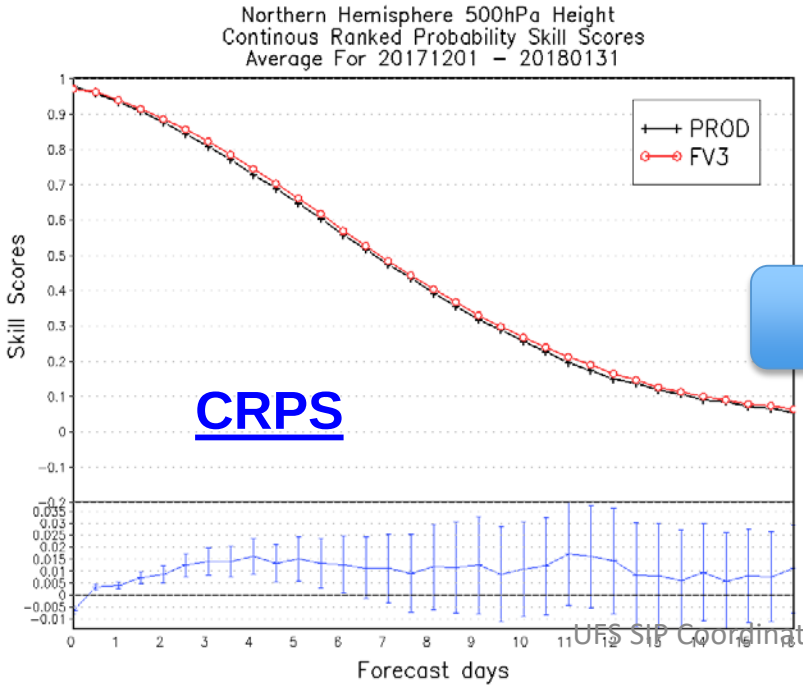


CRPS

Summer

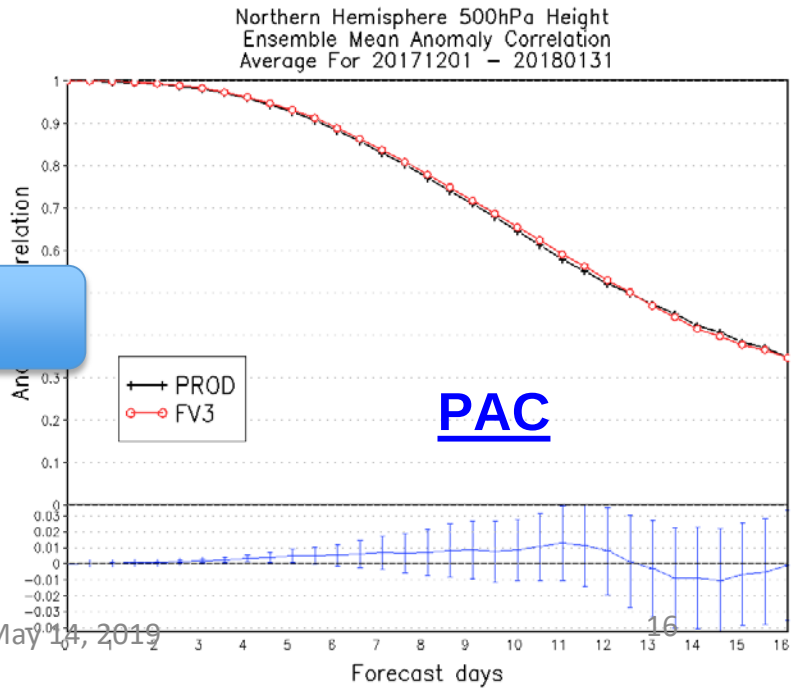


PAC

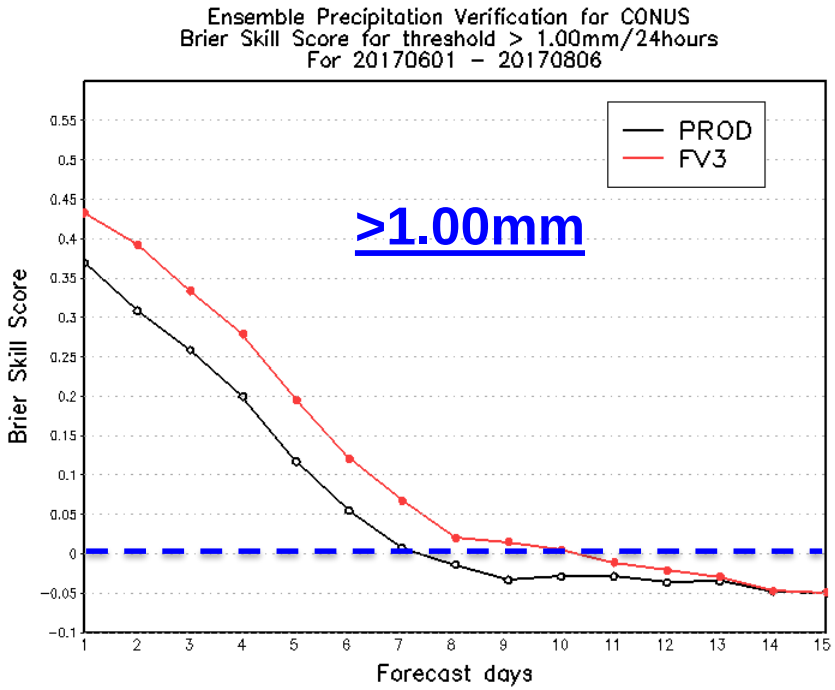


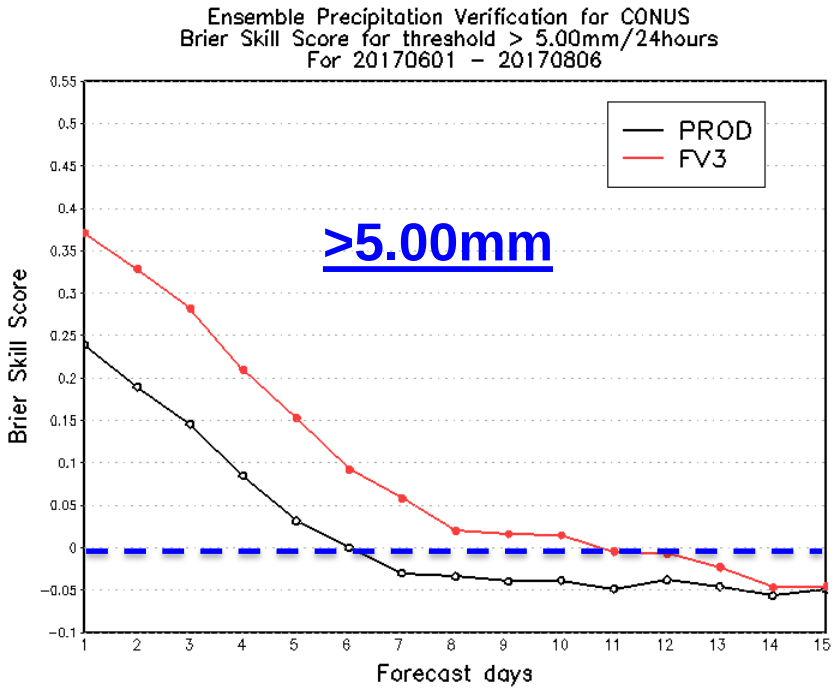
CRPS

Winter



PAC


Ensemble Precipitation Verification for CONUS
Brier Skill Score for threshold > 1.00mm/24hours
For 20170601 - 20170806
PROD
FV3
≥1.00mm
Brier Skill Score
Forecast days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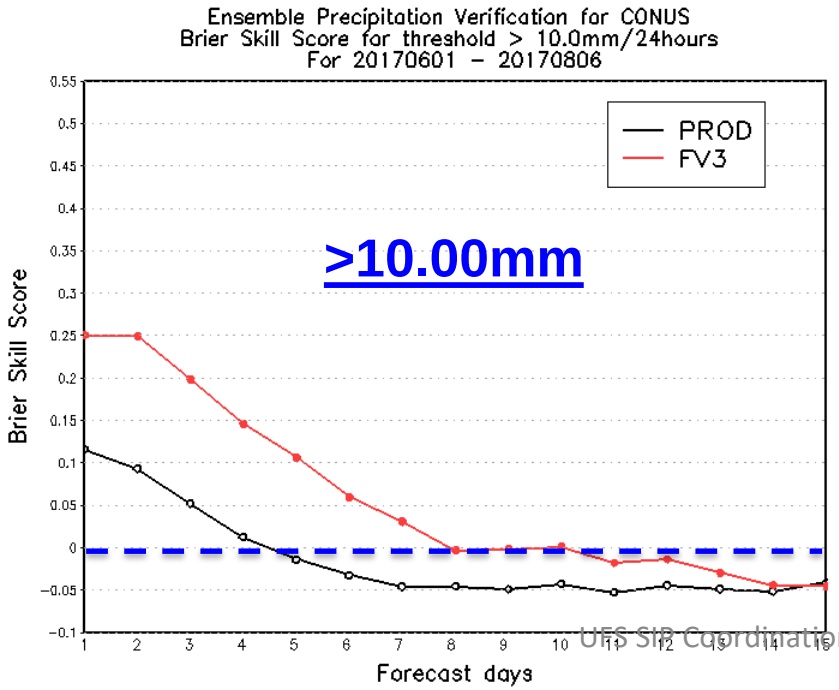
For 20170601 - 20170806
PROD
FV3
≥5.00mm
Brier Skill Score
Forecast days


Ensemble Precipitation Verification for CONUS
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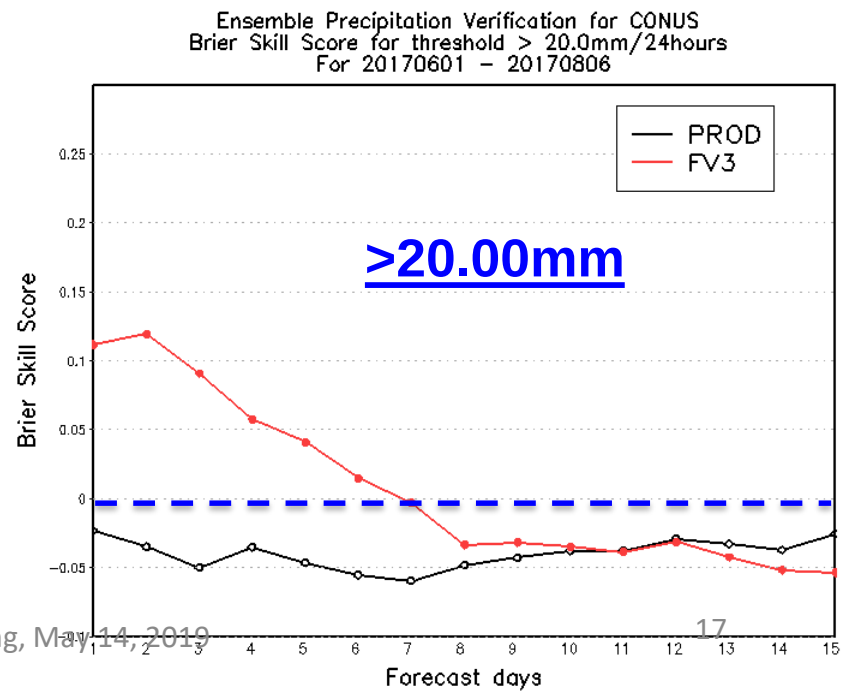
For 20170601 - 20170806
PROD
FV3
≥10.00mm
Brier Skill Score
Forecast days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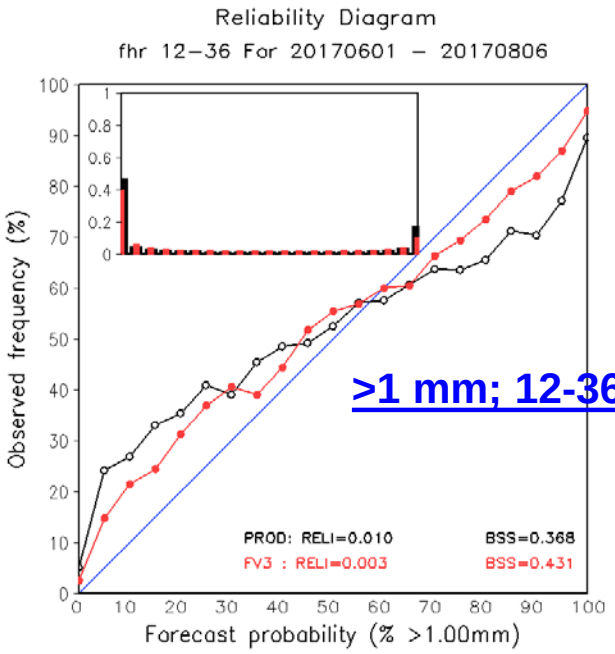
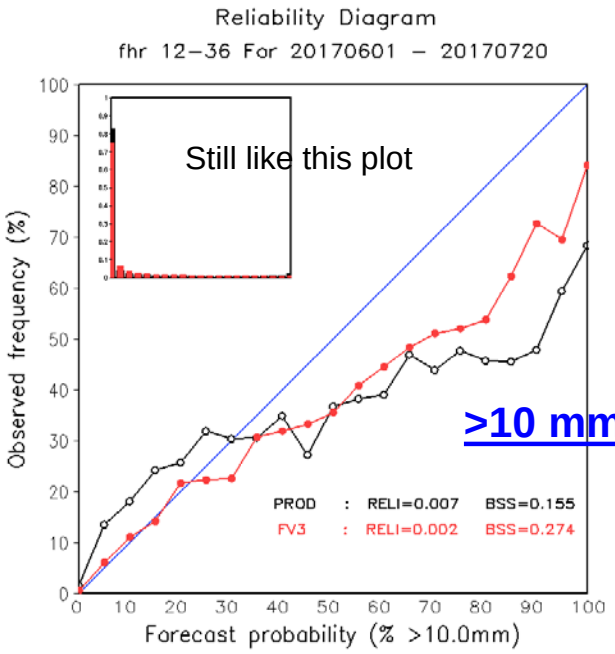
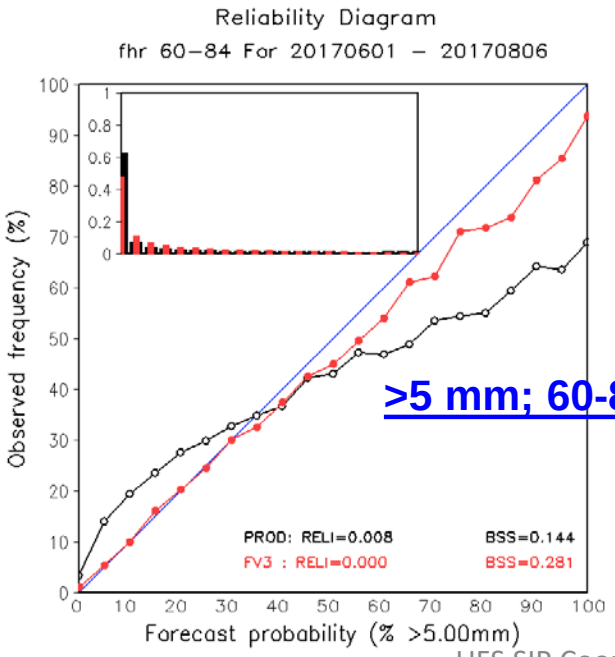
For 20170601 - 20170806
PROD
FV3
≥20.00mm
Brier Skill Score
Forecast days



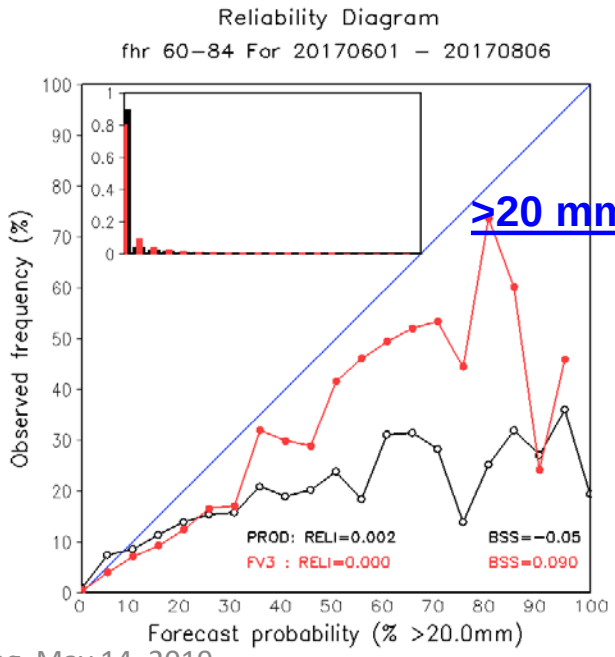
>1 mm; 12-36 hrs



>10 mm; 12-36 hrs

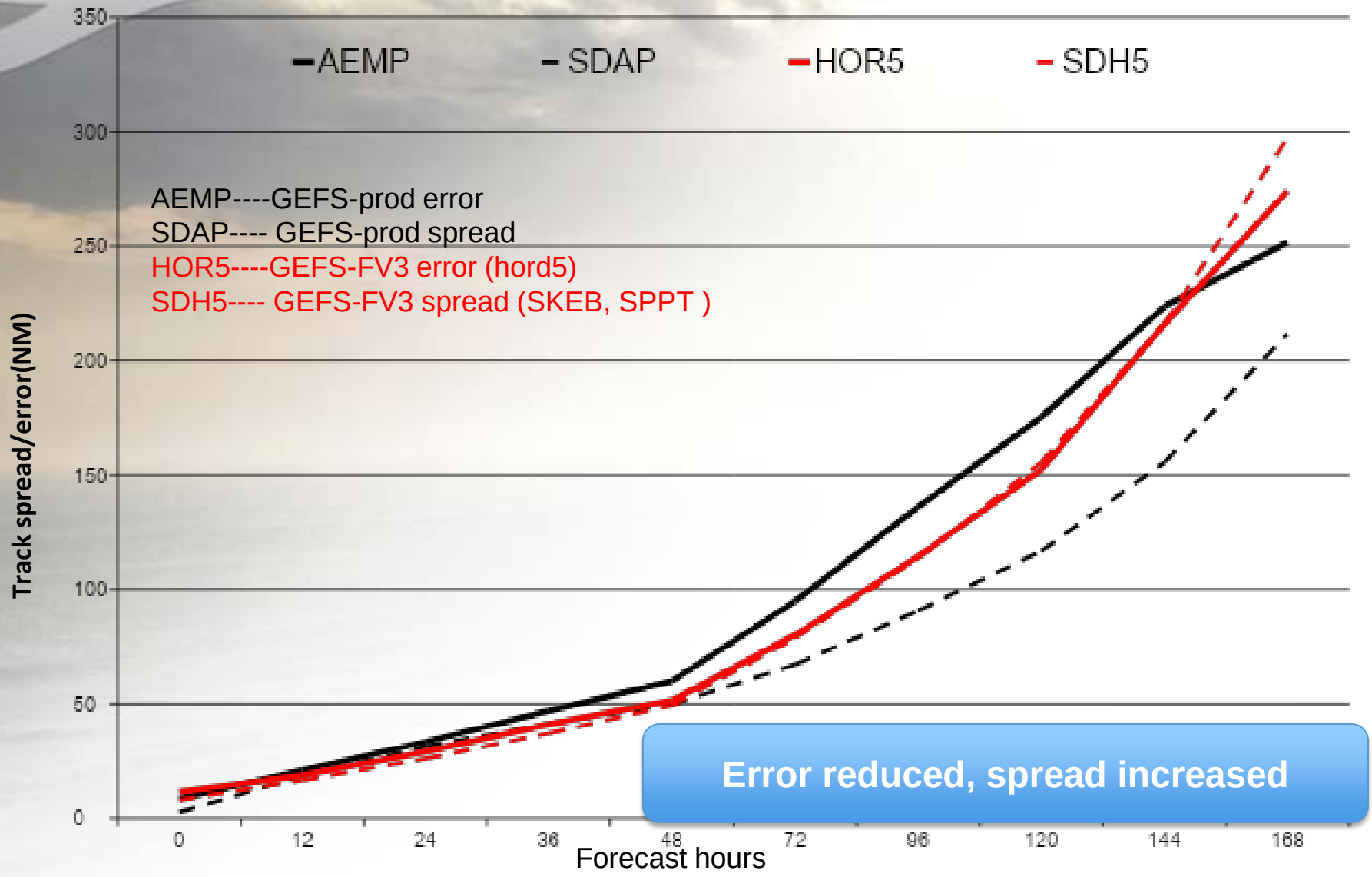


>5 mm; 60-84 hrs

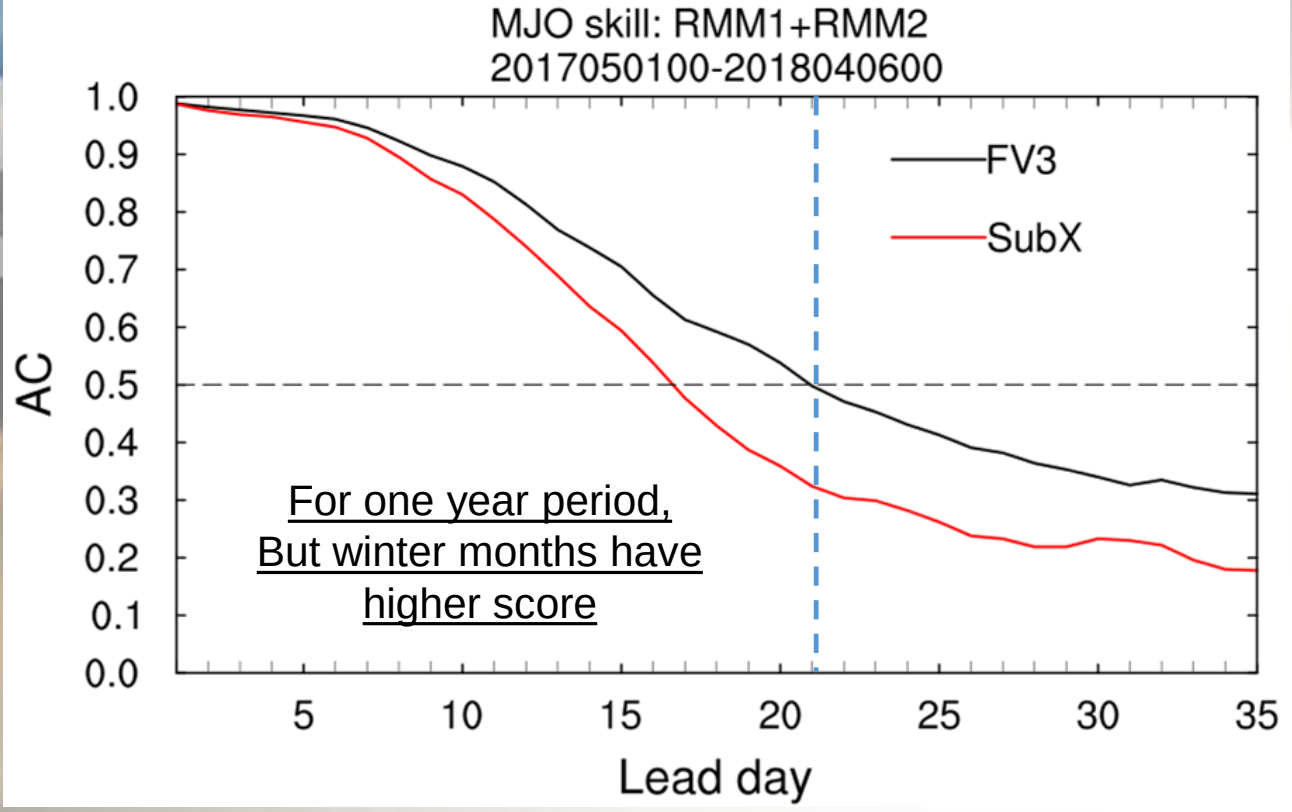


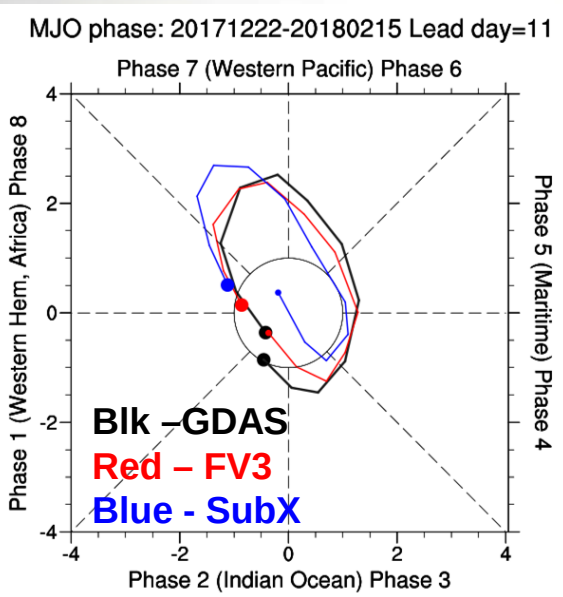
>20 mm; 60-84 hrs

Atlantic TC, AL08-15, 2017

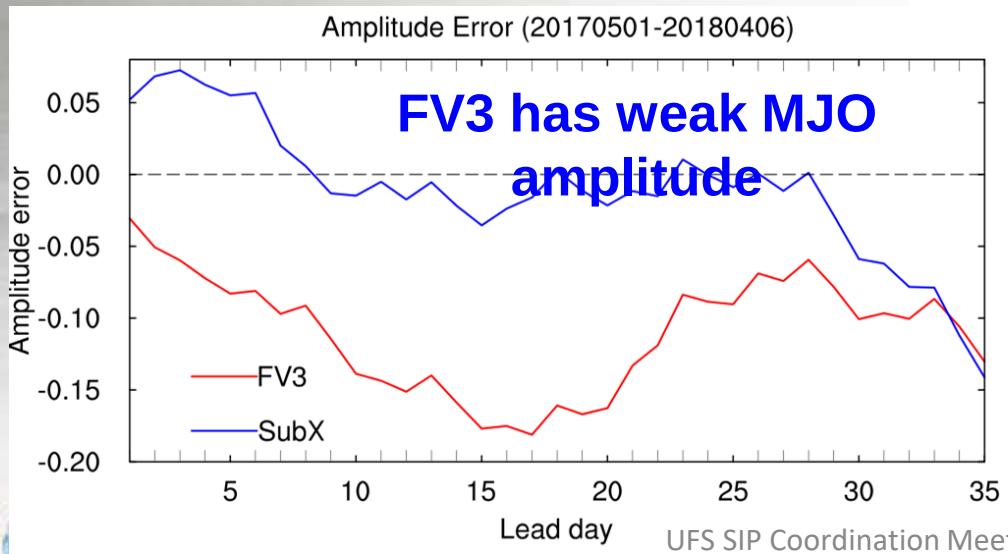


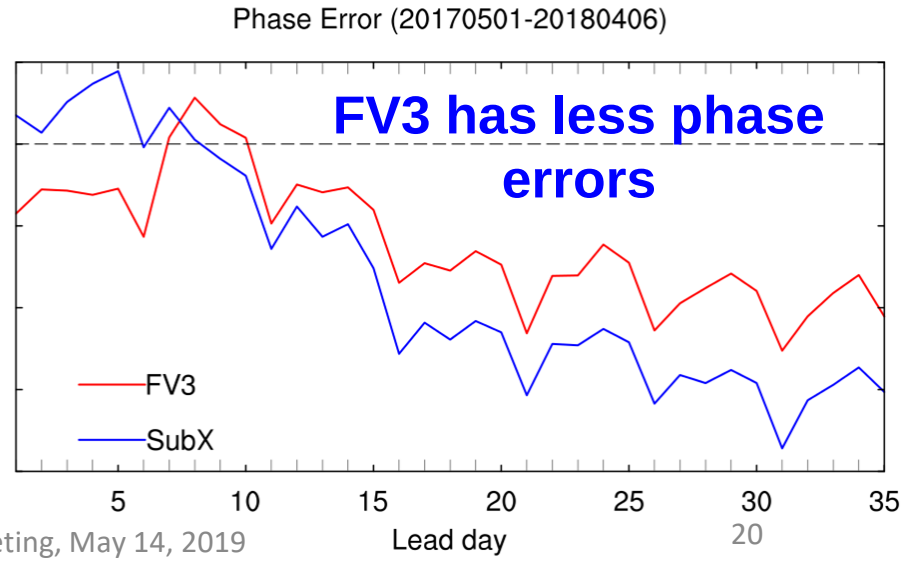
CASES	146	138	131	123	114	99	86	74	65	53





Example of one MJO phase (lead – 11 days)





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.

FV3GFS-Chem in GEFS v12

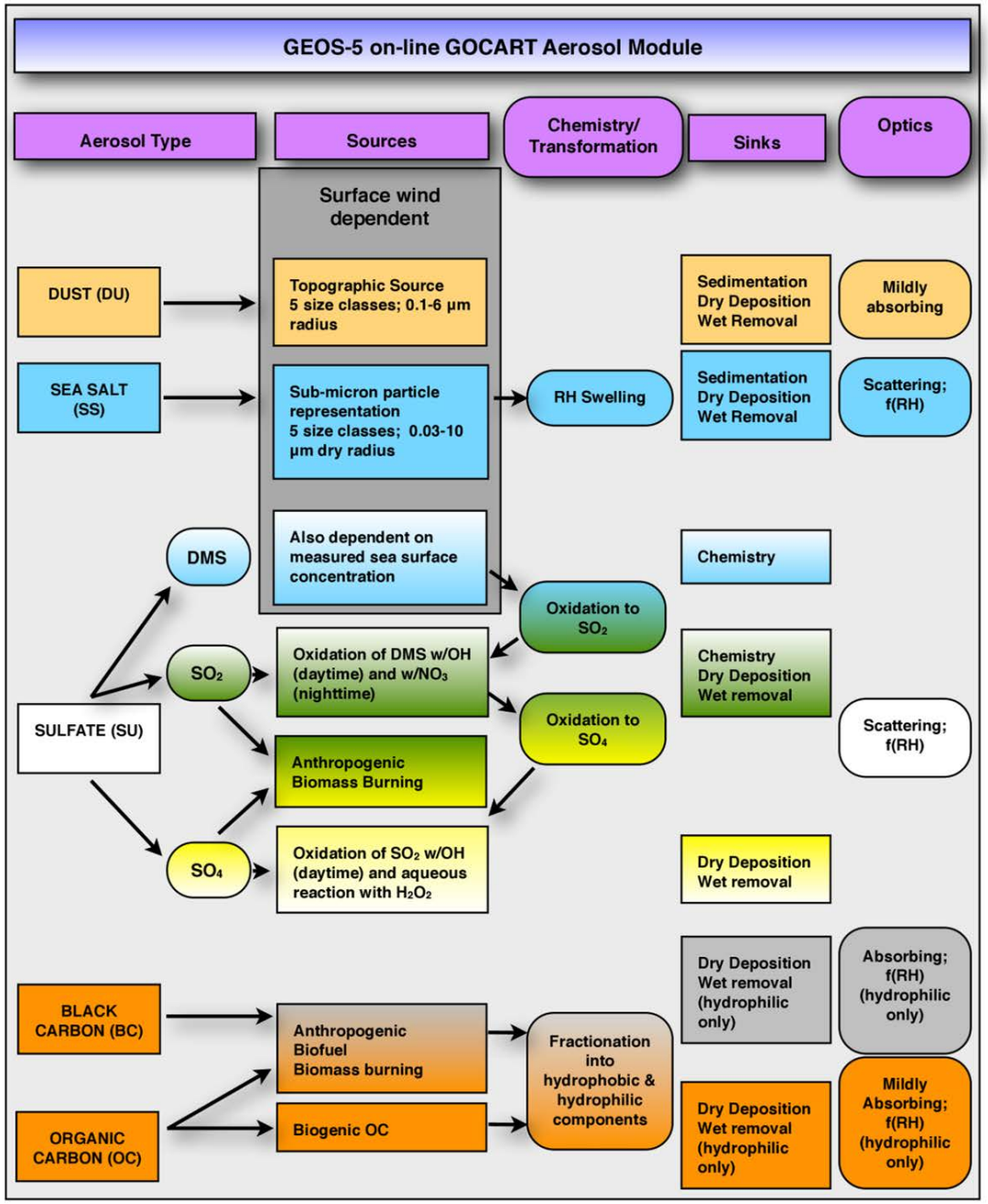
Transition GOCART to FV3GFS dycore as GEFS control member

- **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
  - ARL Fengsha dust will not be ready for Q4FY20
- **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

GOCART Module

In-line chemistry advantage

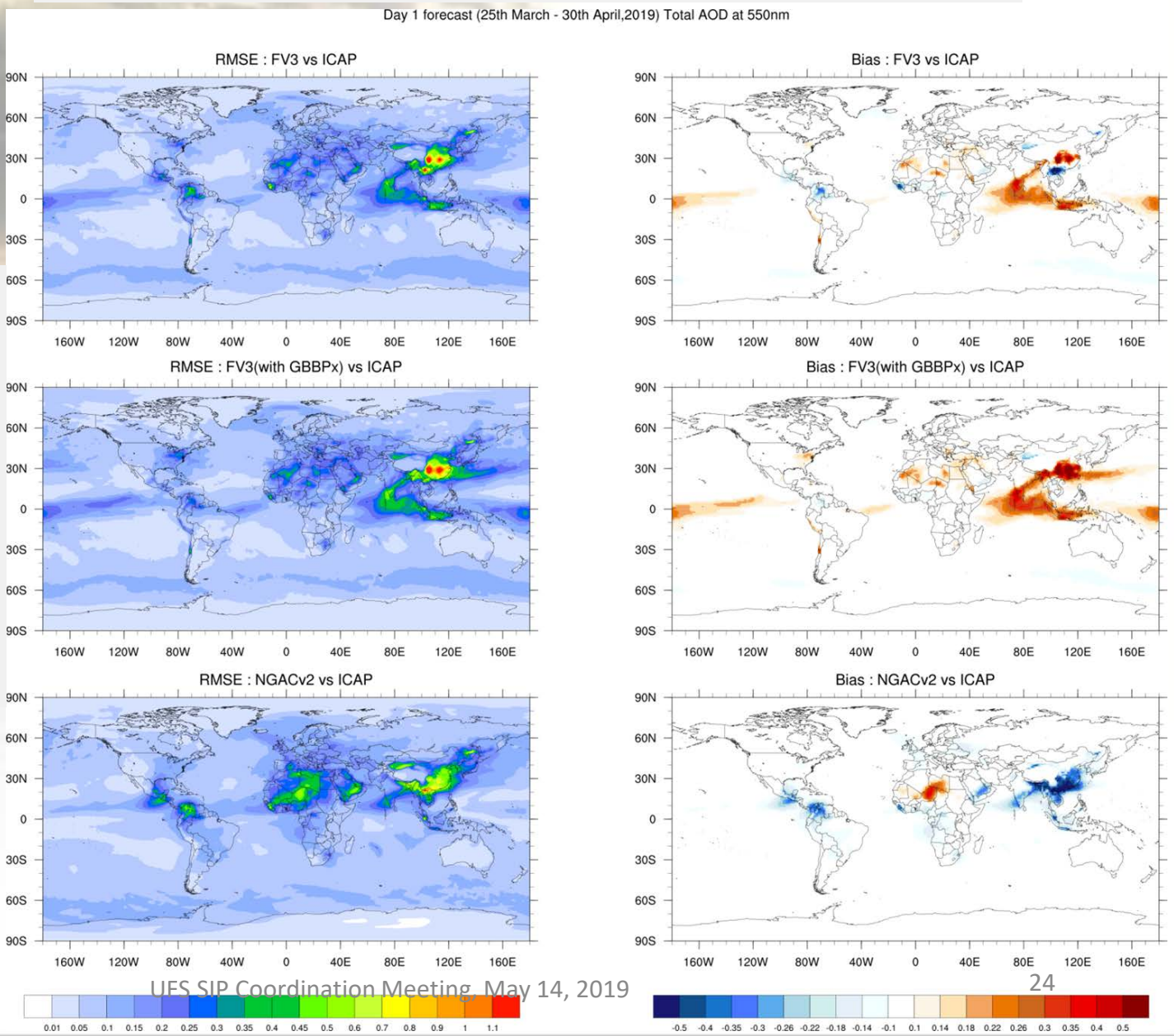
- Consistency: no spatial-temporal interpolation, same physics parameterization
- Efficiency: lower overall CPU costs and easier data management
- Interaction: Allows for feedback to meteorology



GOCART diagram provided by Peter Colarco (GSFC)

NGAC aerosol forecasts vs ICAP MME

Total AOD monthly avg difference for April 2019 (24hr forecast)



FV3GFS-Chem:

Improved dust forecast over Sahara

High AOD near and biomass burning

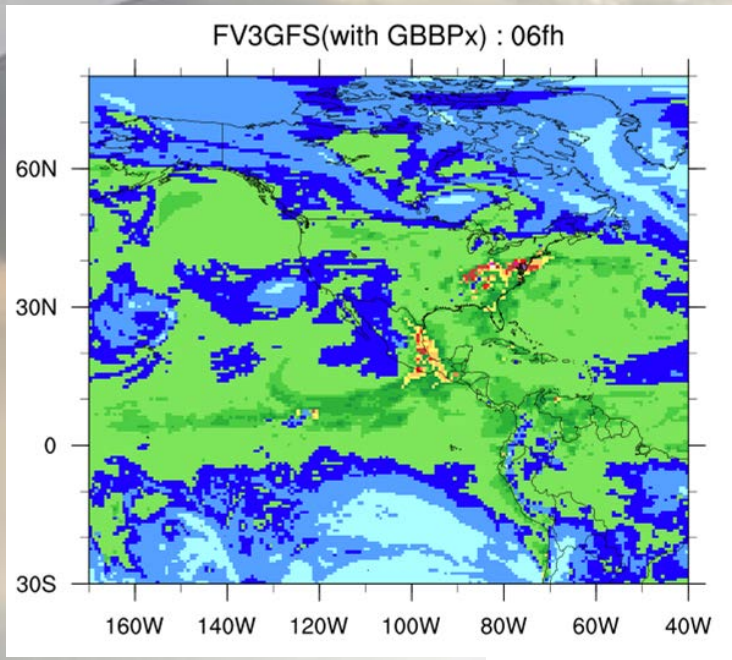
- *Testing 3D plume rise*

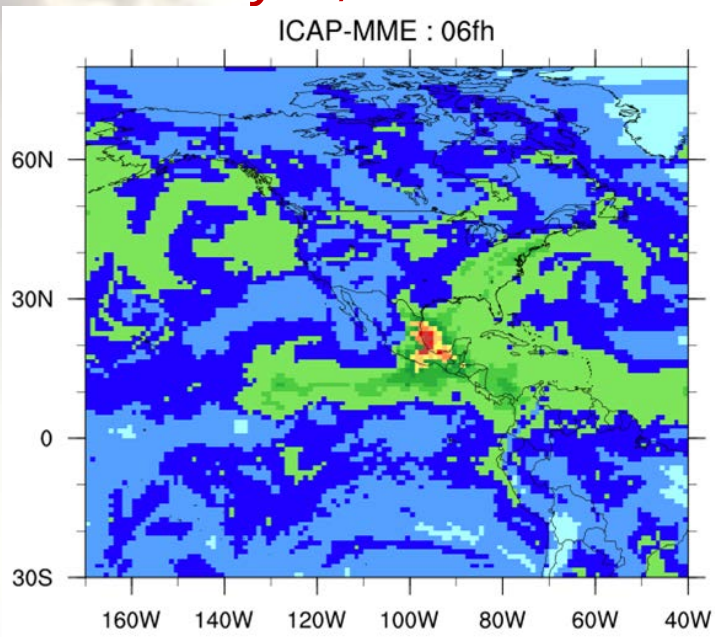
High AOD over tropics

- too much vertical transport
- inefficient scavenging
- *Testing inline physics scavenging*

FV3GFS-Chem vs Satellite observations

North America: May 5, 2019



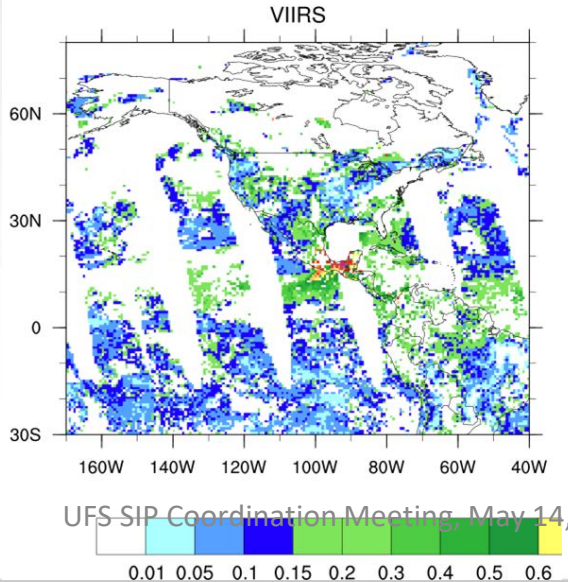


FV3GFS-Chem

Captures Central American Fires

Overpredicts sulfates in NE

- GSD GOCART used not consistent w/ NASA Community version yet



Expected benefits & Schedule for GEFS v12

Increased resolution, membership and forecast length:

- **25 km resolution, 31 members, 4 times per day out to 16 days, once per day out to 35 days**
- **30 year GEFS reforecasts once per day, 5 members out to 16 days, once per week 11 members out to 35 days**
- **General Improvements in Ensemble Model Performance**
  - NH 500hPa height CRPS and spread at all lead times
  - NH 850hPa temperature skill, spread, uncertainty distribution & bias
  - NH zonal winds (850hPa and 250hPa)
  - Tropical zonal winds (850hPa and 250hPa)
  - **Tropical storms: Reduced error and increased spread**
  - **Precipitation: significant improvement from current operations especially for reliability – much enhanced spread**
  - **MJO: Better overall skill. Less phase error, but weaker amplitude**

Schedule for implementation: Late Summer 2020

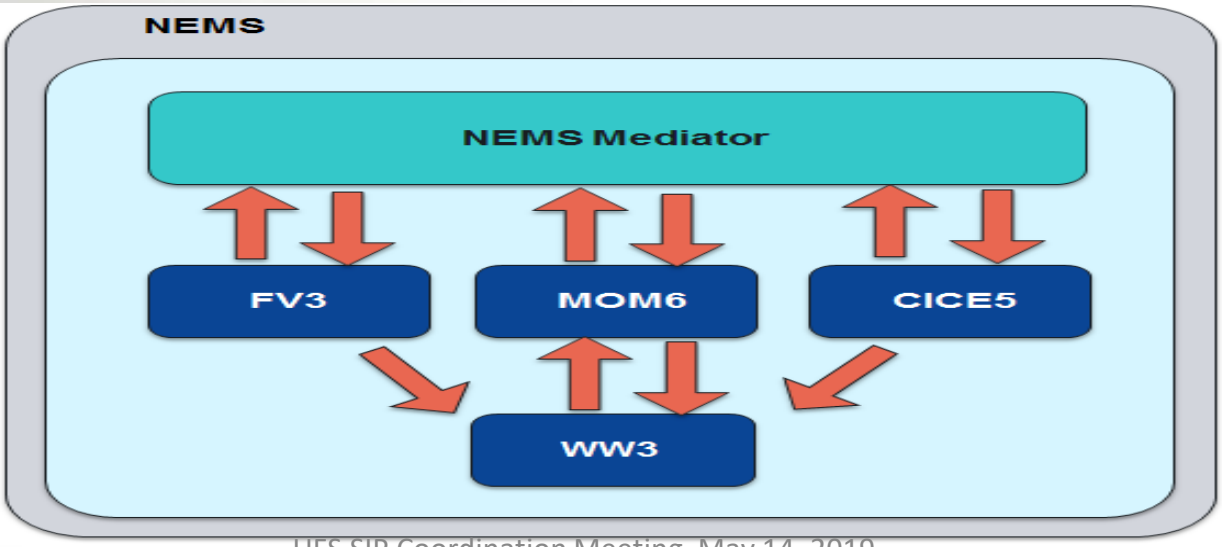
Coupled UFS Applications for sub-seasonal and seasonal predictions

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

- FV3+MOM6+CICE5+WW3+ 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

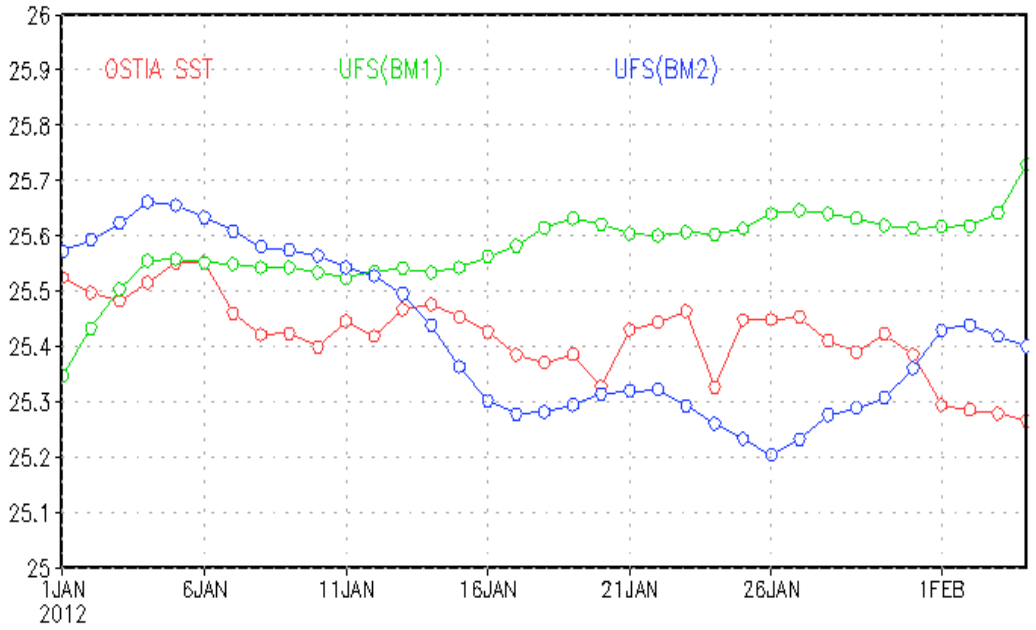
- **Q1FY19: Benchmark 1 FV3-MOM6-CICE5 system completed**

- **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**

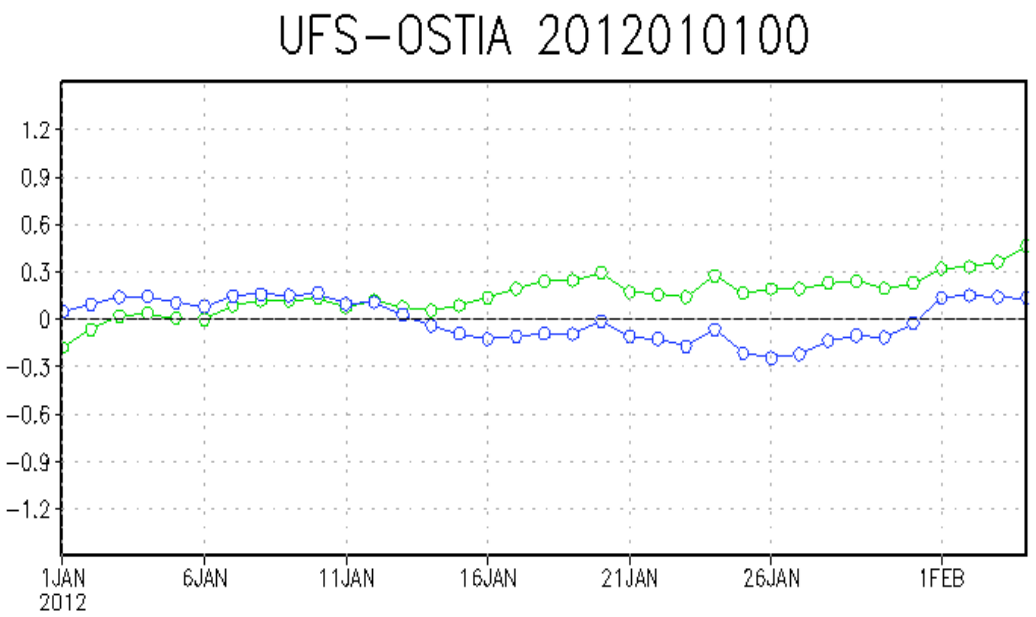
- **FY20:**
- **Benchmark 6: FV3GFS+MOM6+CICE5+WW3 (weakly coupled, initialized w/marine JEDI)**
- **Benchmark 7: Physics Tuning Experiments**
- **Prototype GEFSv13: Marine Component Perturbations**
- **Extend benchmark runs to 9 months and longer, physics tuning, optimization (seasonal scales)**

	Tag	Code tag	General Description of Updates	Initial Conditions				Time Steps					
				FV3	MOM6	CICE5	WW3	FV3	CICE	MOM 6	MOM6 dt_therm	Slow Cpl	Fast Cpl
Benchmark 1	UFS_p1	v2.0.0	First Benchmark	CFSR	CFSR	CFSR	n/a	450	900	900	3600	1800	1800
Benchmark 2	UFS_p2	v3.0.1	Updated ocean/ice ICs; slow/fast coupling; MOM6 unified cap; updated FV3 code (post radiation bug fix & microphysics updates)	CFSR	3Dvar CPC	CFSR	n/a	450	450	900	1800	1800	450

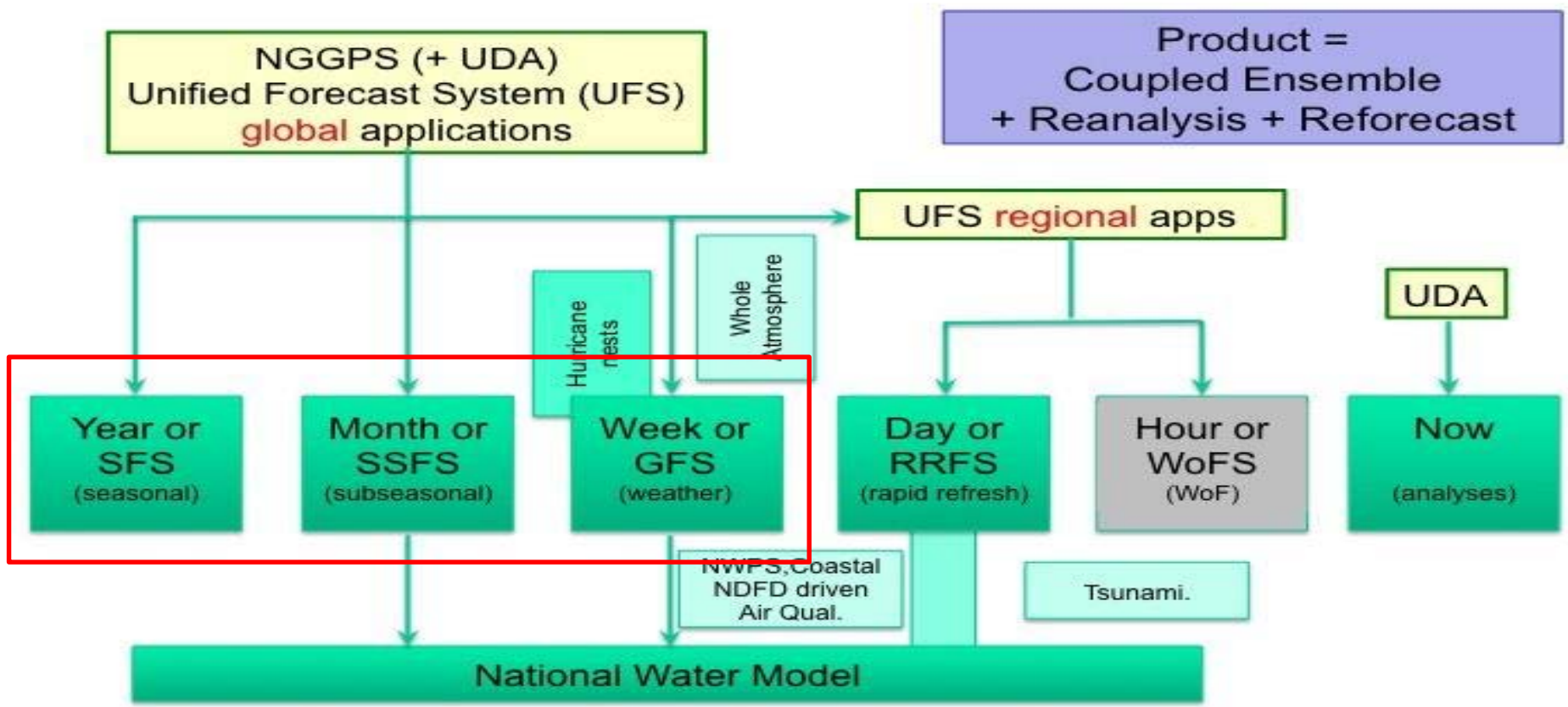
Nino 3.4 index 20120101



OISTIA
UFS BM1
UFS BM2



Summary: Making Substantial Progress towards UFS based Global Applications



Questions?