The Installation and Evaluation of FV3 Dycore and Advanced Physics in GFS for Q1FY19 Operational Implementation

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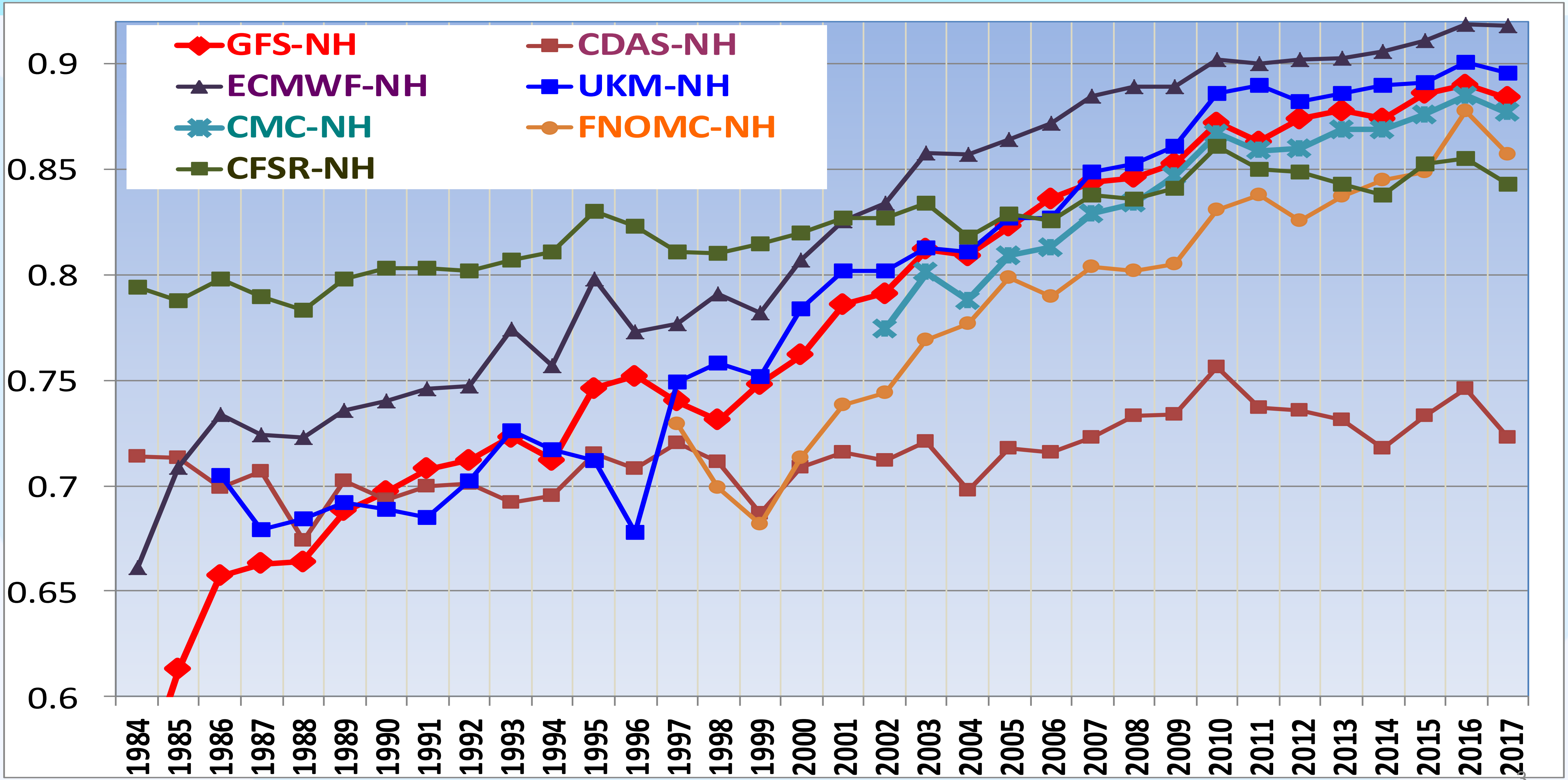
Change History of GFS Configurations

Mon/Year	Lev	Truncations	Z-cor/dyncore	Major components upgrade
Aug 1980	12	R30 (375km)	Sigma Eulerian	first global spectral model, rhomboidal
Oct 1983	12	R40 (300km)	Sigma Eulerian	
Apr 1985	18	R40 (300km)	Sigma Eulerian	GFDL Physics
Aug 1987	18	T80 (150km)	Sigma Eulerian	First triangular truncation; diurnal cycle
Mar 1991	18	T126 (105km)	Sigma Eulerian	
Aug 1993	28	T126 (105km)	Sigma Eulerian	Arakawa-Schubert convection
Jun 1998	42	T170 (80km)	Sigma Eulerian	Prognostic ozone; SW from GFDL to NASA
Oct 1998	28	T170 (80km)	Sigma Eulerian	the restoration
Jan 2000	42	T170 (80km)	Sigma Eulerian	first on IBM
Oct 2002	64	T254 (55km)	Sigma Eulerian	RRTM LW;
May 2005	64	T382 (35km)	Sigma Eulerian	2L OSU to 4L NOAH LSM; high-res to 180hr
May 2007	64	T382 (35km)	Hybrid Eulerian	SSI to GSI
Jul 2010	64	T574 (23km)	Hybrid Eulerian	RRTM SW; New shallow cnvtion; TVD tracer
Jan 2015	64	T1534 (13km)	Hybrid Semi-Lag	SLG; Hybrid EDMF; McICA etc
May2016	64	T1534 (13km)	Hybrid Semi-Lag	4-D Hybrid En-Var DA
Jun2017	64	T1534 (13km)	Hybrid Semi-Lag	NEMS GSM, advanced physics
JAN 2019	64	FV3 (13km)	Finite-Volume	NGGPS FV3 dycore, GFDL MP

Annual Mean NH 500hPa HGT Day-5 AC

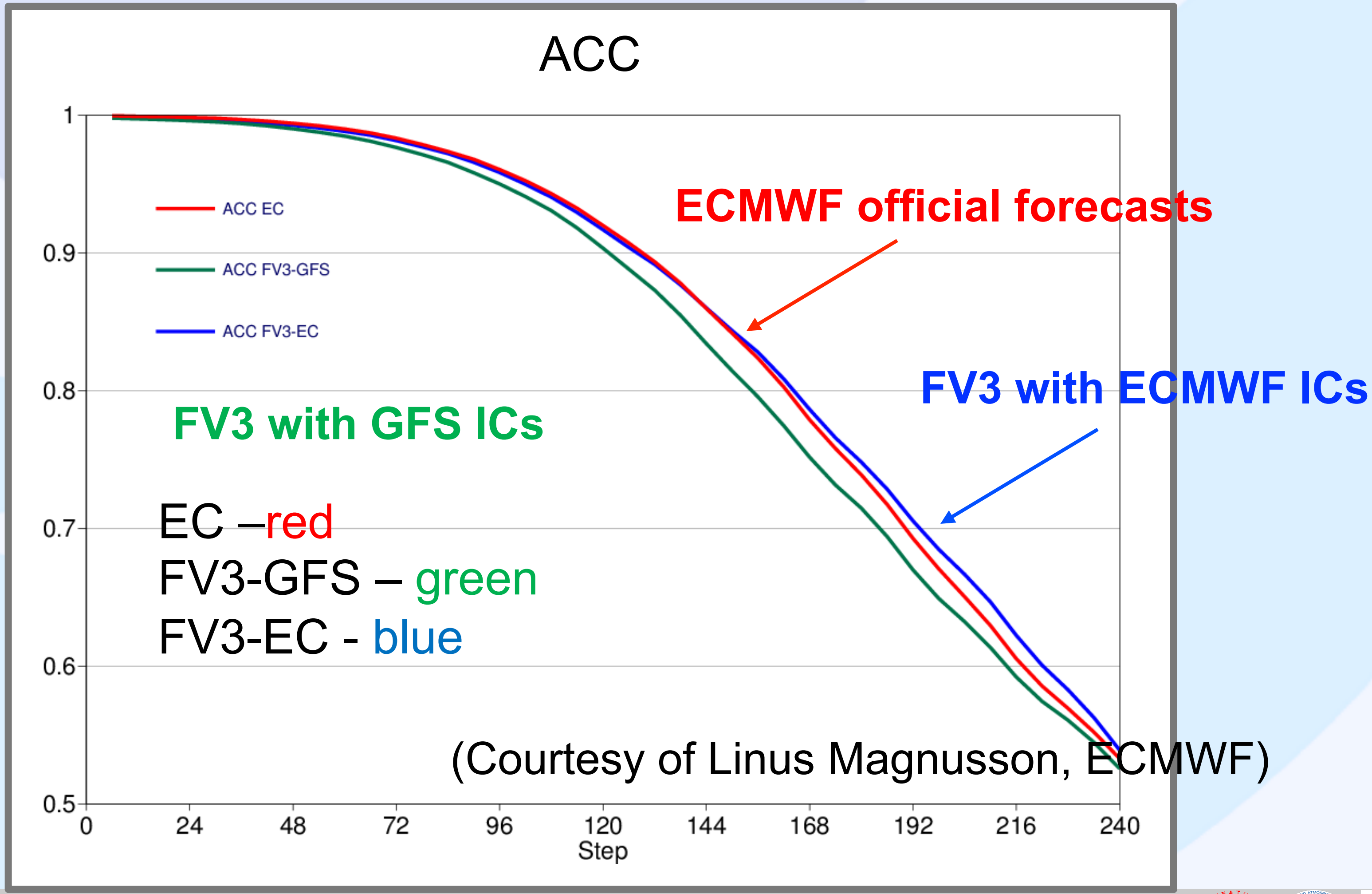


NGGPS: Forecast Experiment with GFS and ECMWF ICs (from SJ Lin)

(August 2015 to August 2016, every 5th day = 73 cases)

500-mb Anomaly Correlation Coefficient

SJ Lin has showed us the potential. It is now up to us to make it happen



First Version of NGGPS FV3GFS for Operation

FV3GFS is being configured to replace spectral model (NEMS GSM) in operations in Q2FY19

Configuration:

- FV3GFS C768 (~13km deterministic);
- FV3GDAS C384 (~25km, 80 member ensemble);
- 64 layer, top at 0.2 hPa;
- Uniform resolution for all 16 days
- Real-Time data made available through para-NOMADS
- FV3GFS evaluation entry page: http://www.emc.ncep.noaa.gov/users/Alicia.Bentley/fv3gfs

Schedule:

- 3/7/18: code freeze of FV3GFS-V1 (GFS V15.0)
- 3/30/18: Public release of FV3GFS-V1 code
- 4/1 – 1/25/19: real-time EMC parallels
- 5/25 – 9/10/18: retrospectives and case studies (May 2015 – September 2018; three summers and three winters)
- 9/24/2018: Field evaluation due
- 9/27/2018: OD Brief, code hand-off to NCO
- 12/20/2018-1/20/2019: NCO 30-day IT Test
- 1/24/2019: Implementation

Real-time and retrospective parallels for evaluation

	Period	Machine	Status and comments
Real-time (Stream 0)	05/25/2018 ~ 01/24/2019	CRAY Prod	Running GFSMOS, GEMPAK, AWIPS, BUFRSND included
2017/18 Winter-Spring (Stream 1)	12/01/2017 ~ 05/31/2018	DELL	Running GFSMOS and BUFRSND included
2017 Summer-Fall (Stream 2)	06/01/2017 ~ 11/20/2017	CRAY Dev	Running GFSMOS and BUFRSND included
2016/17 Winter-Spring (Stream 3)	12/01/2016 ~ 05/31/2017	DELL	running
2016 Summer-Fall (Stream 4)	5/20/2016 ~ 11/30/2016	CRAY Dev	running
2015/16 Winter-Spring (Stream 5)	11/20/2015 ~ 05/31/2016	Gaea/Jet	In planning
2015 Summer-Fall (Stream 6)	5/01/2015 ~ 11/20/2015	DELL	running

Changes in Disk Usage -- one cycle

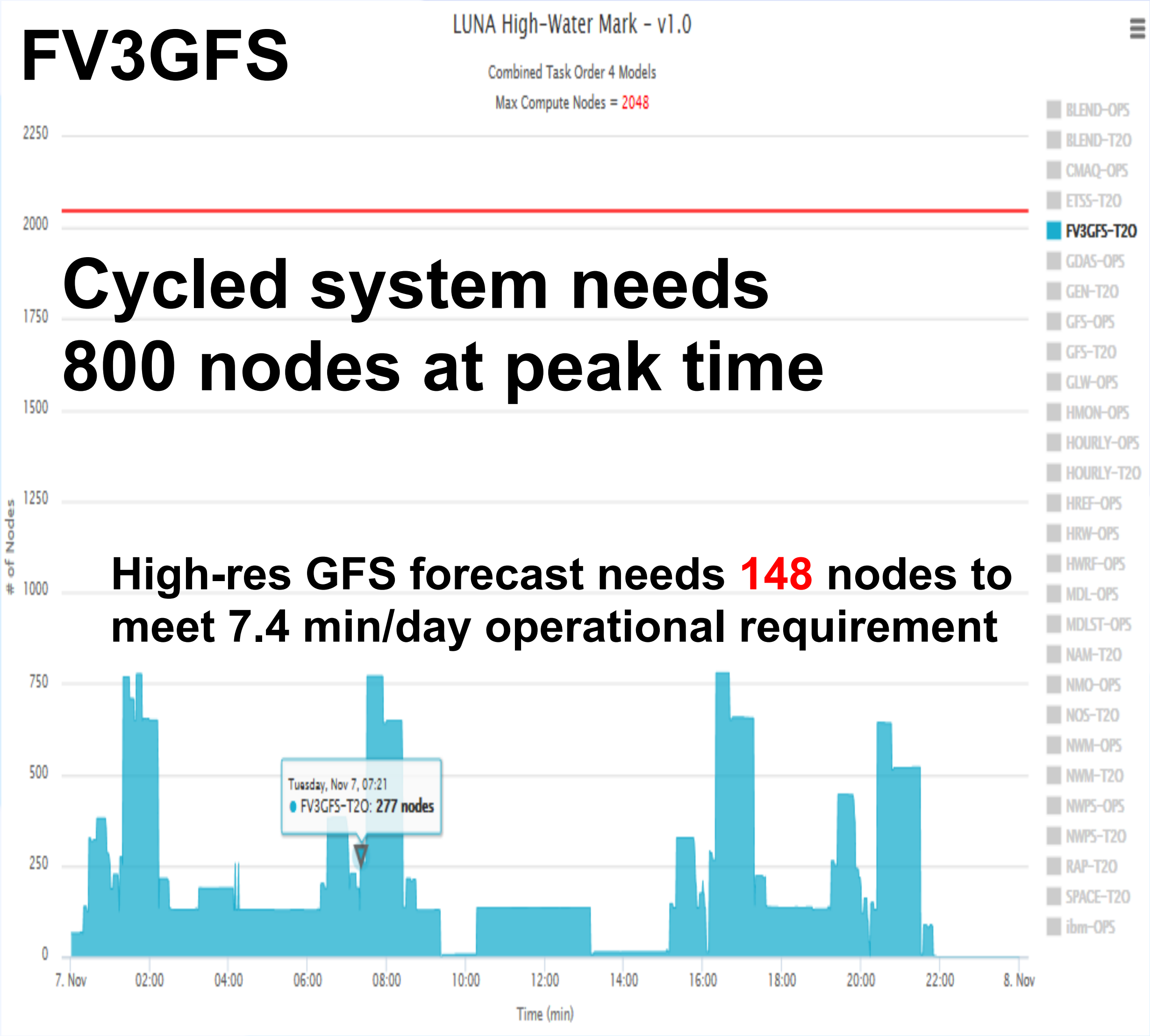
~130% increase

	anl+forecast	products & misc	total
ops gfs	1.70 TB	0.30 TB	2.0 TB
ops GDAS	0.157 TB	0.029 TB	0.186 TB
ops ENKF	1.831 TB	0.043 TB	1.874 TB
ops total			4.06 TB
FV3 GFS	2.91	0.30	3.21
FV3 GDAS	0.471	0.029	0.50
FV3 ENKF	5.493	0.043	5.536
FV3 total			9.246 TB

Ops GDAS and ENKF are run at T574 (1152x576), while FV3GFS is run at C384, e.g. T766 (1532x768). This is equivalent to a 77.7% increase in forecast file size. Factoring in the increase of output variables, **ENKF and GDAS file size will increase by 200%.**

Computation Resource Requirement -- HWM Test

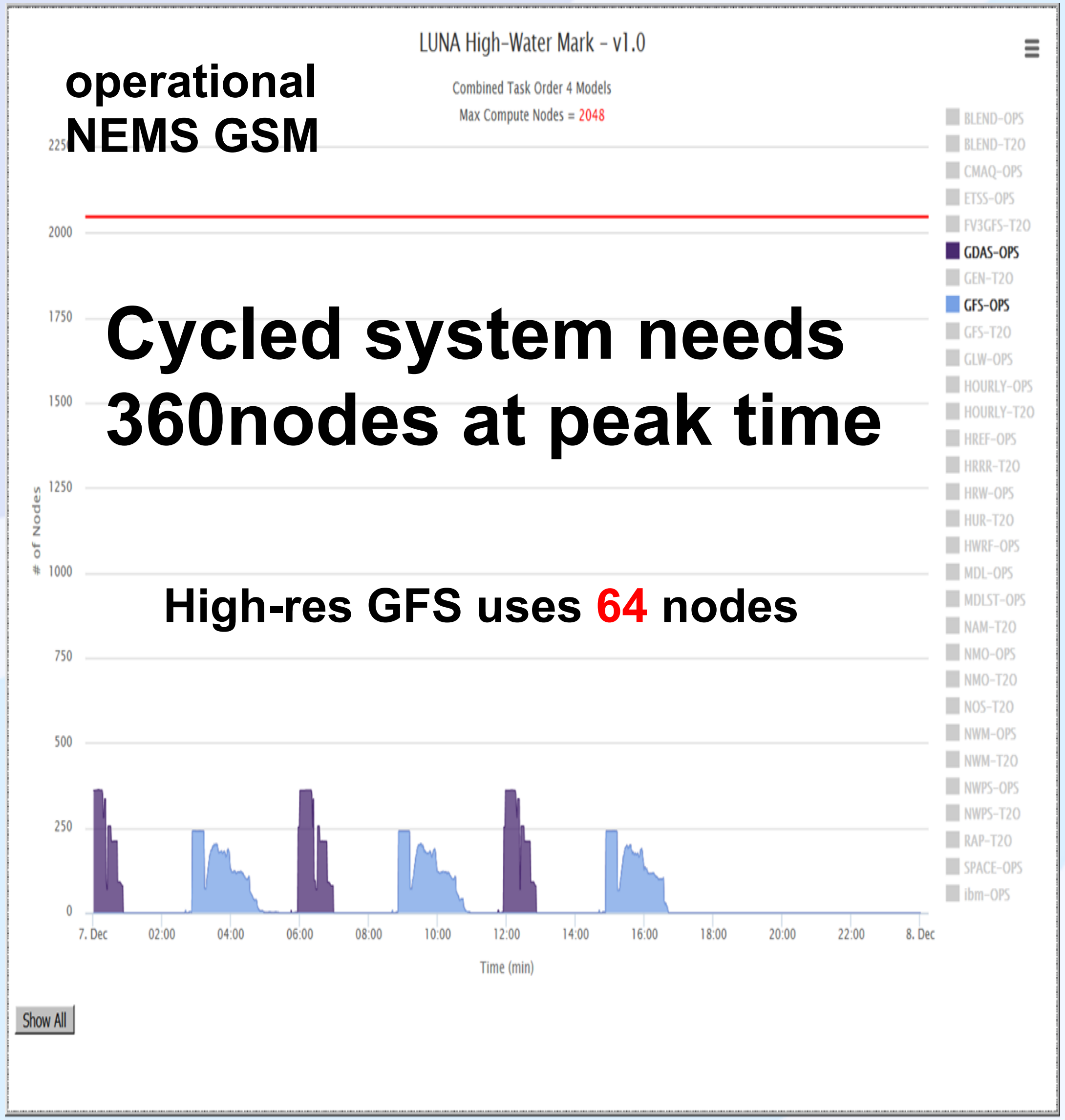
FV3GFS



Cycled system needs 800 nodes at peak time

High-res GFS forecast needs 148 nodes to meet 7.4 min/day operational requirement

operational NEMS GSM



Cycled system needs 360nodes at peak time

High-res GFS uses 64 nodes

FV3GFS: Infrastructure and Physics Upgrades

- Integrated FV3 into NEMS
- Added IPD in NEMSfv3gfs
- Newly developed write grid component -- write out model history in native cubed sphere grid and Gaussian grid
- Replaced Zhao-Carr microphysics with the more advanced GFDL microphysics
- Updated parameterization of ozone photochemistry with additional production and loss terms
- New parameterization of middle atmospheric water vapor photochemistry
- a revised bare soil evaporation scheme.
- Updated Stochastic physics
- Improved NSST in FV3
- Use GMTED2010 terrain to replace TOPO30 terrain

Data Assimilation – GSI, Interfaces, and Observation

- **Improved GSI efficiency**

- **Update GSI IO to ingest FV3GFS forecasts and provide analysis for FV3GFS.**

- **Update GSI to process additional cloud species from GFDL microphysics**

- **Compute increments of layer pressure and thickness hydrostatically from increments of surface pressure and temperature.**

- **Increase in ensemble resolution from roughly 39km to 25km.**

- **Adaptation of stochastic physics parameterizations from NEMS GSM with the exception of SKEB to provide model uncertainty estimate.**

- **Observations: add IASI moisture channels , ATMS all-sky radiances, Megha-Tropiques Saphir data, ASCAT data from MetOp-B, newNOAA-20 CrIS and ATMS data**

Workflow Unification

- Almost all scripts adopted from the NEMS GFS were rewritten for the FV3GFS
- The old psub/pend job submission system is replaced by Rocoto drivers
- The 4-package superstructure workflow was merged into one package with a flat structure
- All JJOBS were rewritten. Both EMC parallels and NCO operation will use the same JJOBS
- EMC parallels and NCO operation follow the same file name convention and directory structure

An important achievement to simplify and unify the GFS systems between the development (EMC) and operation (NCO)

POST and Downstream Processing

- Precipitation products with both 6-hour bucket and continuous accumulation are provided

- Velocity from FV3GFS is dz/dt in m/s instead of omega in pa/s. Omega is diagnosed in the UPP and provided to users.

- More cloud hydrometers predicted by the advanced microphysics scheme are included in the products.

- Radar reflectivity derived using these new cloud hydrometers will also be added to GFS products.

- Height, pressure, and vertical velocity will be non-hydrostatic computed in model instead of being derived hydrostatically in Unified Post Processor.

This Google Sheet contains a complete list of product changes.

Utilities

- New nc2nemsio and regrid-nemsio for converting 6-tile netcdf files to global lat-lon grid
- "global_cycle": Updated to run on the cubed-sphere grid. Added MPI to process multiple tiles simultaneously. Added update of NST fields using Gaussian increments from GSI.
- "global_chgres": Incorporated GFDL logic required for fv3 core. Ensure consistency between the NST TREF field and SST at isolated lakes.
- New utility "gaussian_sfcanl" - creates a gaussian surface analysis file from the tiled analysis files produced by global_cycle.
- New program "enkf_chgres_recenter" - Interpolates atmospheric fields from one Gaussian grid to a lower-res Gaussian grid. Required by ENKF recentering step.

Evaluation Webpages

http://www.emc.ncep.noaa.gov/users/Alicia.Bentley/fv3gfs
Overall page

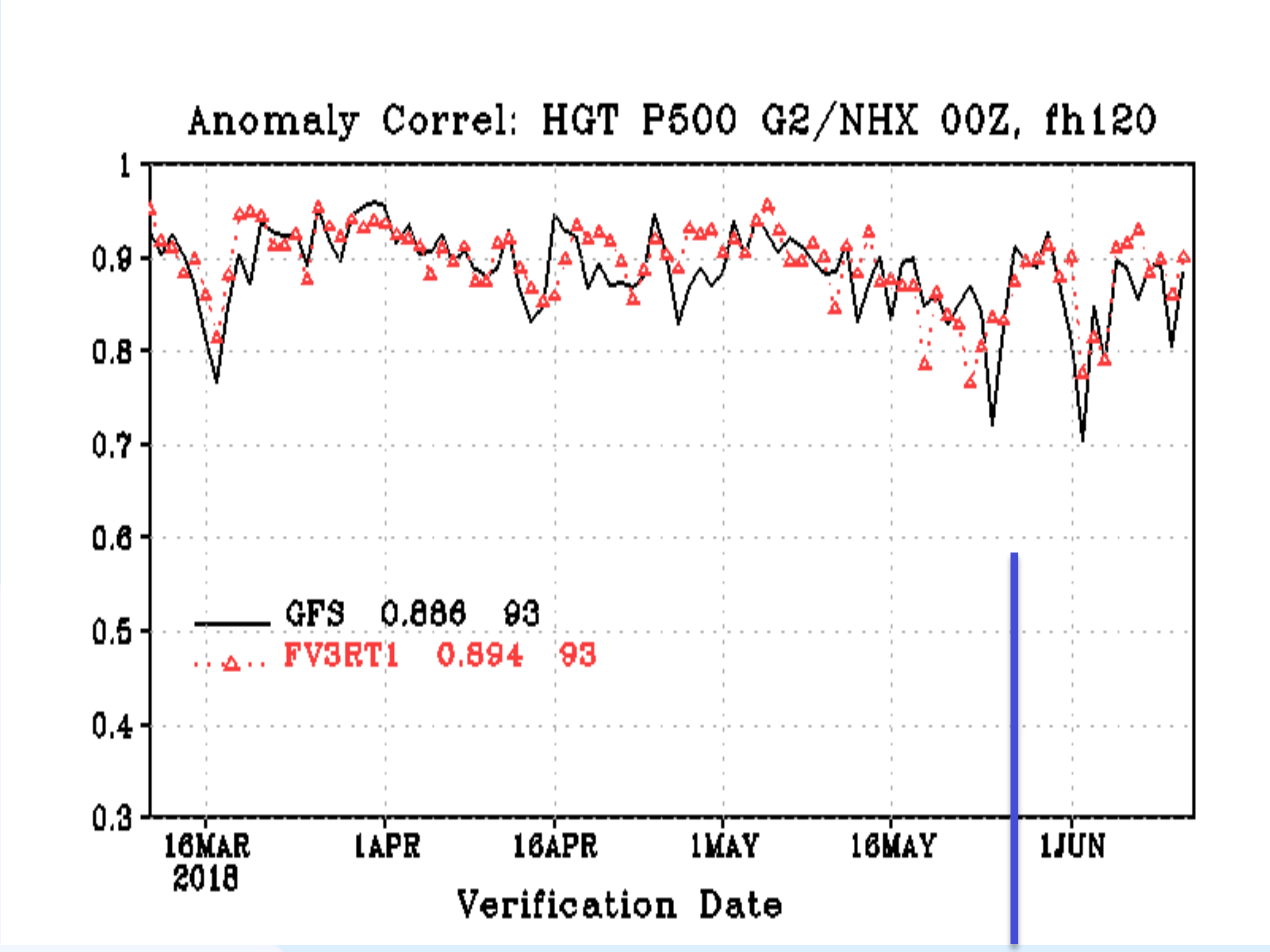
http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt1/
real-time parallel

http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/fv3q2fy19retro2
2017 summer retro

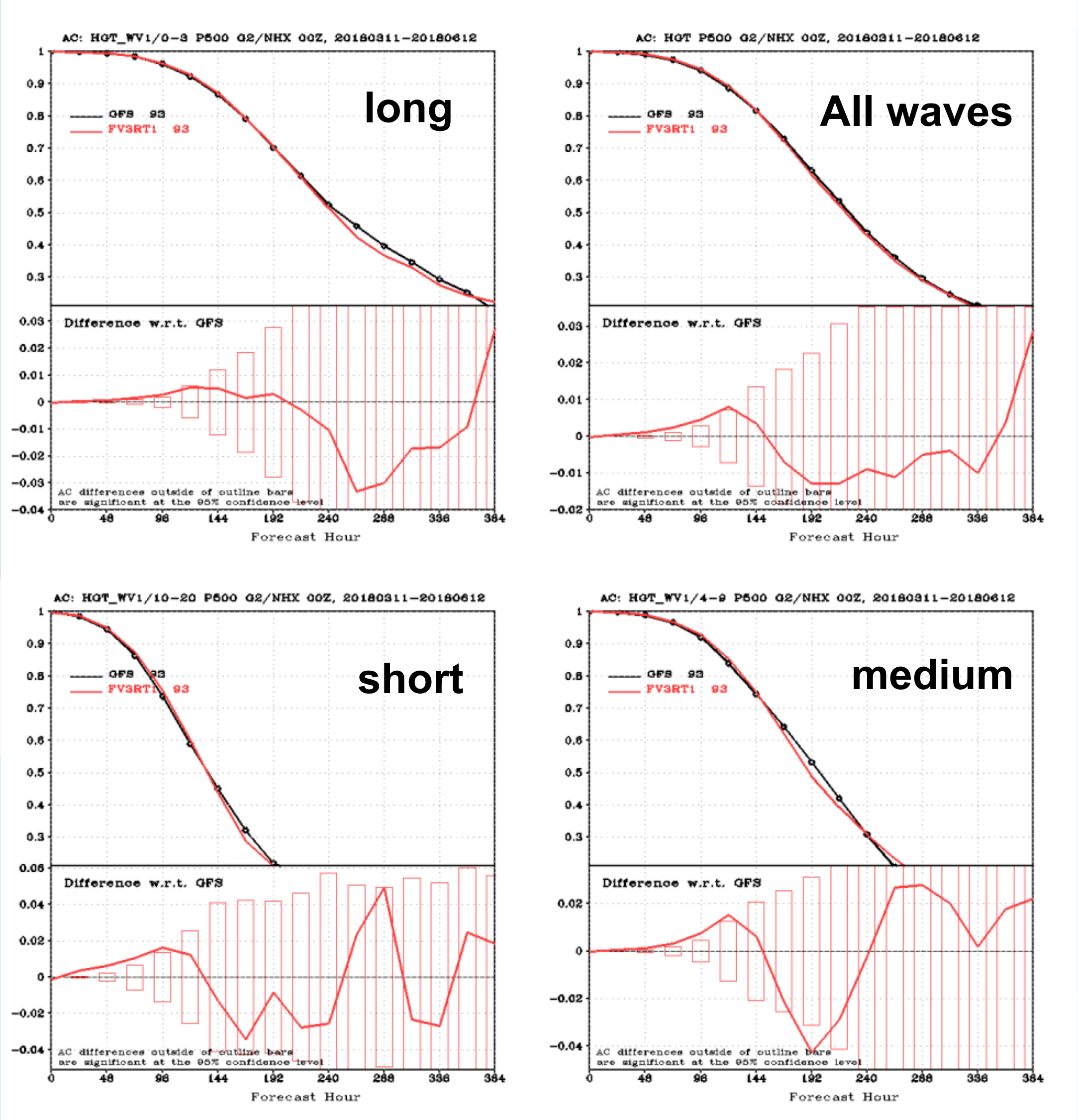
http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/fv3q2fy19retro4
2016 summer retro

http://www.emc.ncep.noaa.gov/mmb/ylin/pcpverif/scores.fv3/ QPF
http://www.emc.ncep.noaa.gov/gc_wmb/tdorian/meg/index.html bufrsnd

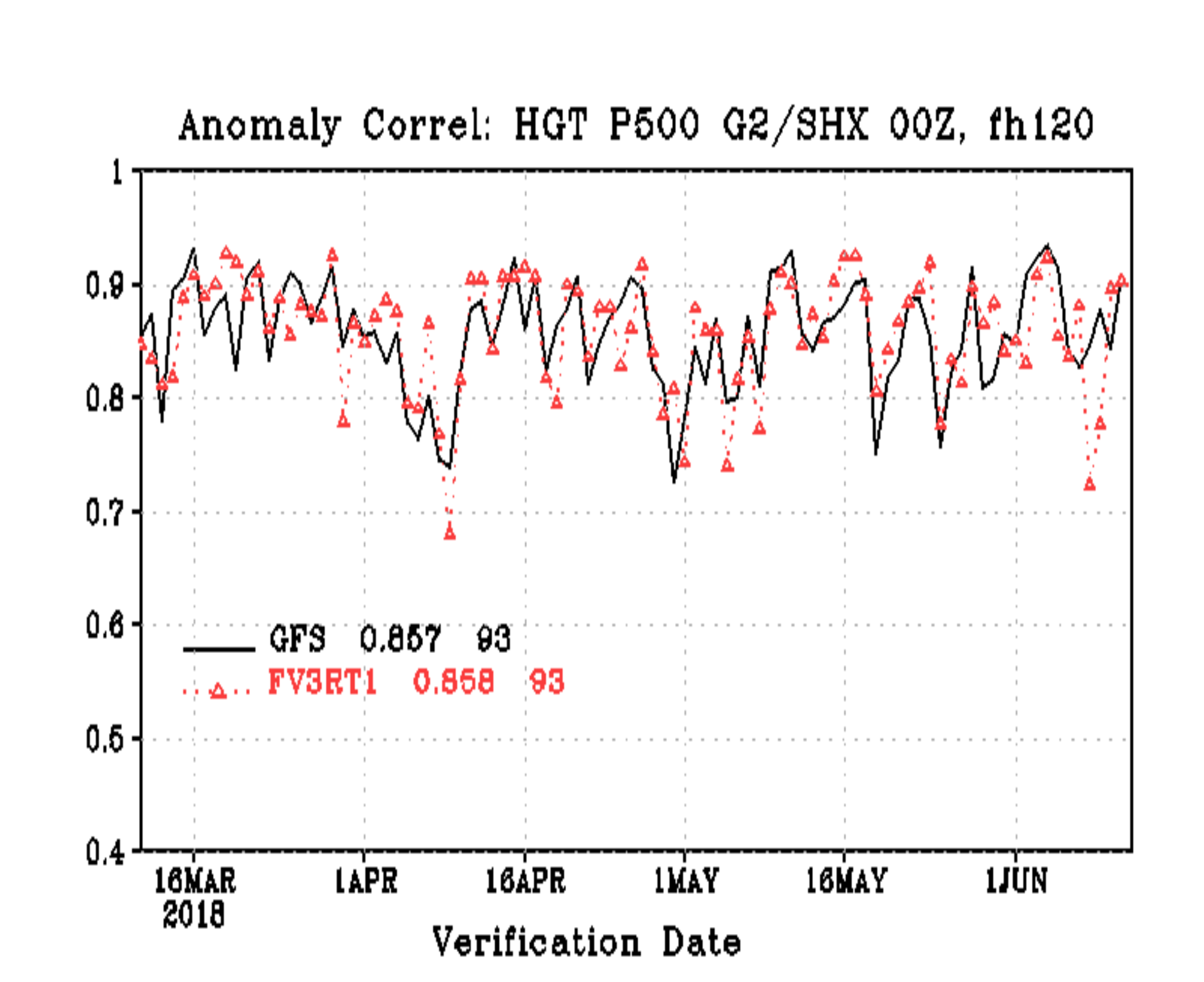
Real-time experiments with fully cycled FV3GFS+GFDL MP
NH 500-hPa HGT ACC

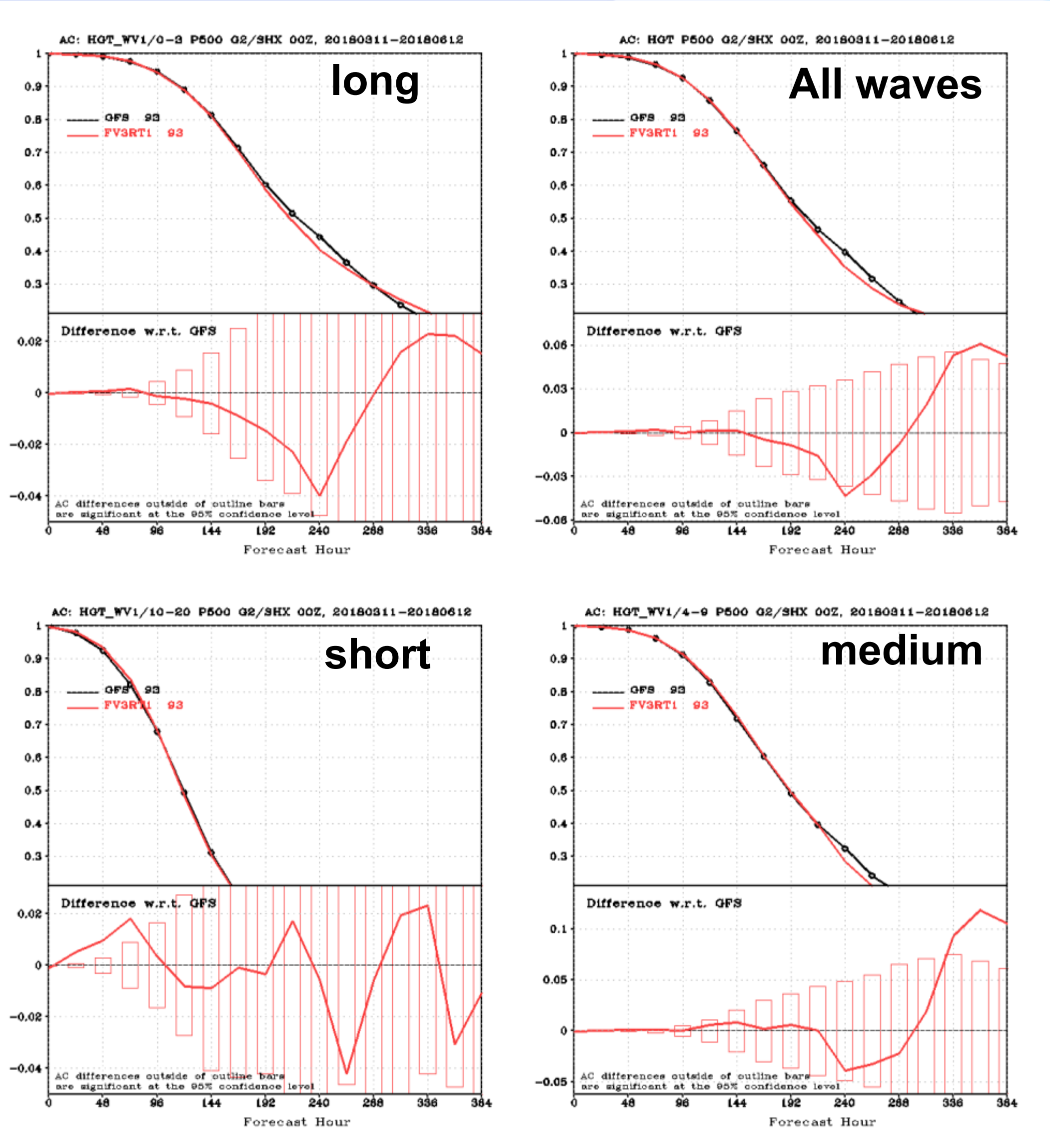


May 25, NSST Fix



Real-time experiments with fully cycled FV3GFS+GFDL MP
SH 500-hPa HGT ACC

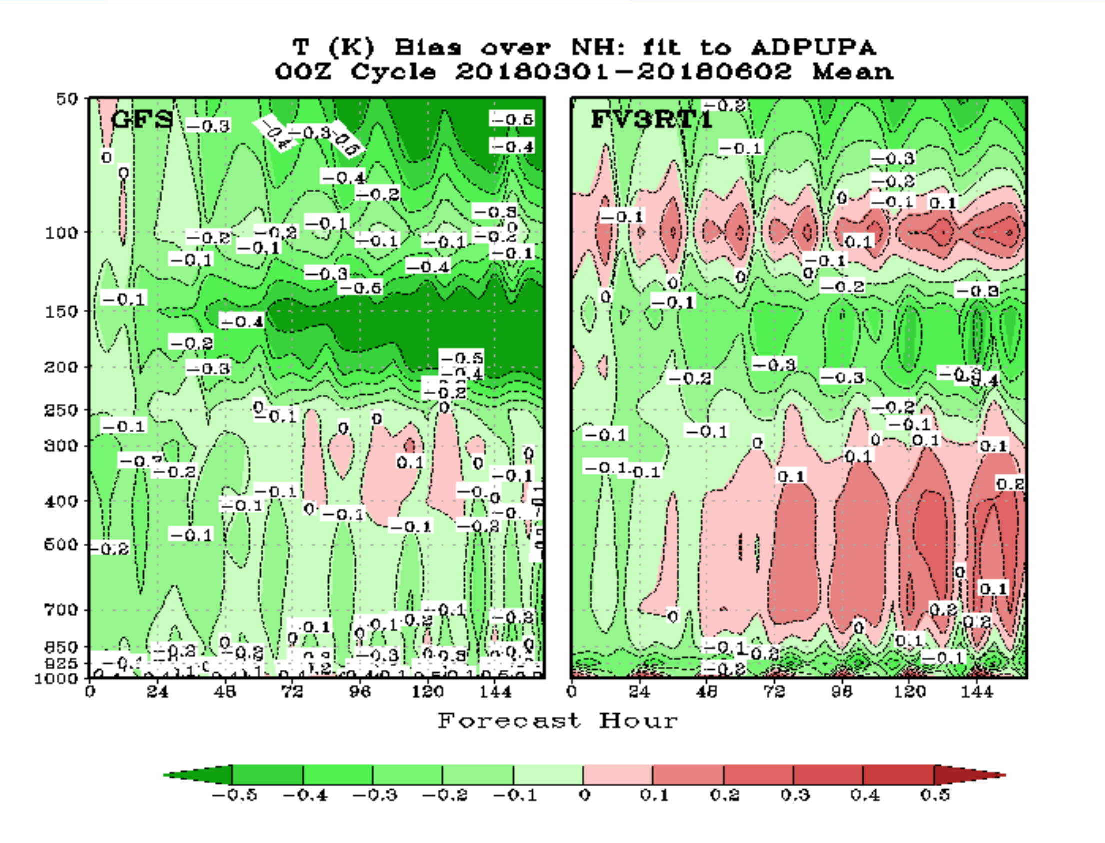




Real-time experiments with fully cycled FV3GFS+GFDL MP (Spring 2018)

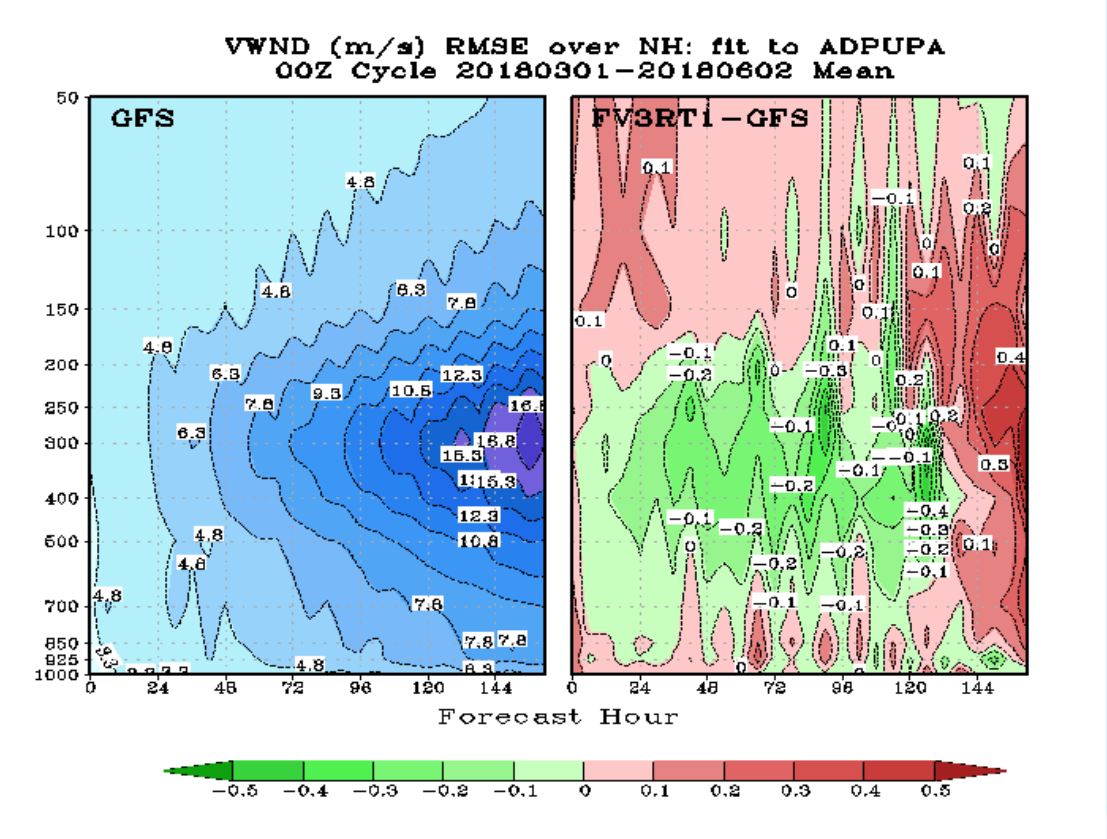
http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt1/g2o/g2o_00Z/index.html

NH Temp, fit to RAOBS



- Reduced cold bias in the lower stratosphere and near the tropopause.
- Warm bias in the troposphere

NH Wind RMSE, fit to RAOBS

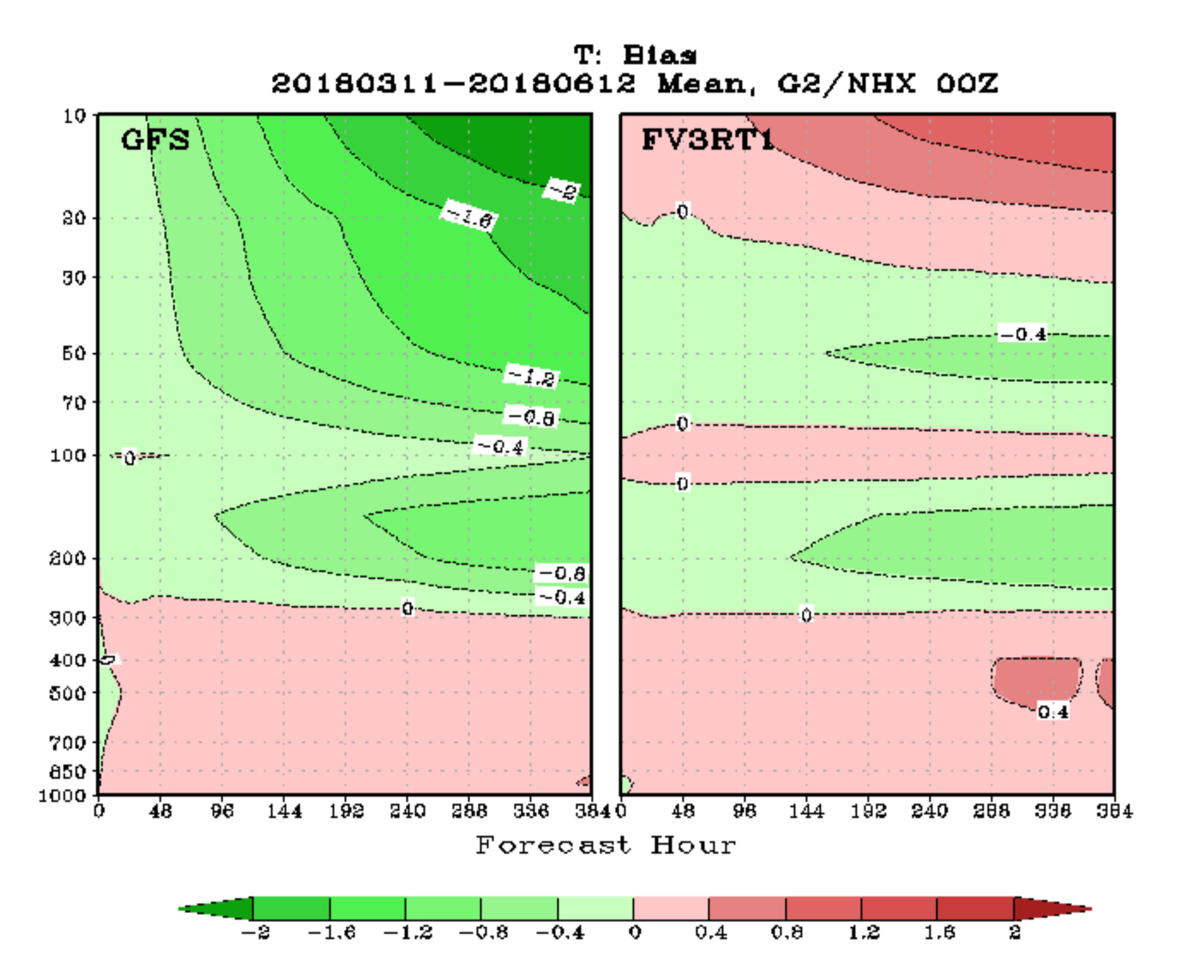


- Reduced wind RMSE in the troposphere up to 5 days. Slightly worse in the lower stratosphere

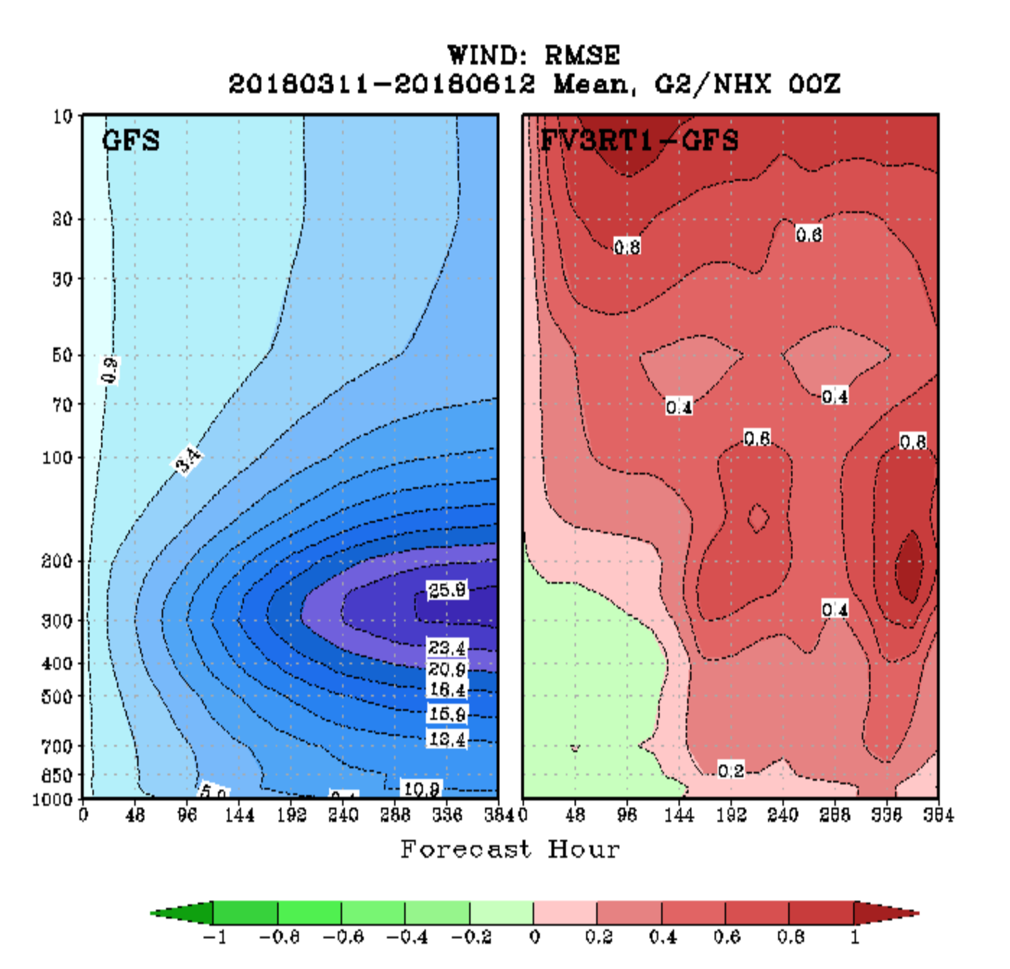
Real-time experiments with fully cycled FV3GFS+GFDL MP (Spring 2018)

Verification against own analyses

NH Temp Bias

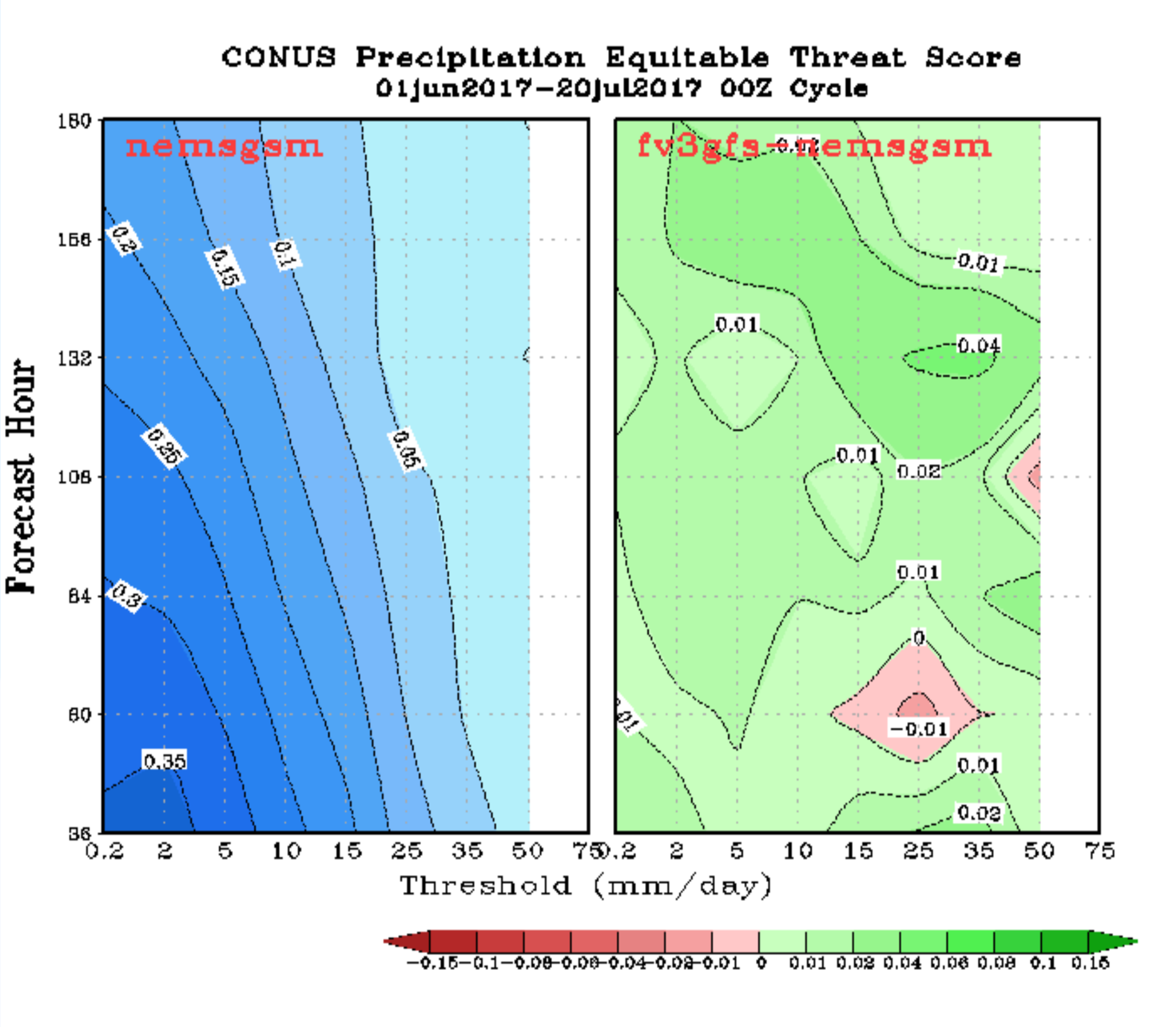


NH Wind RMSE

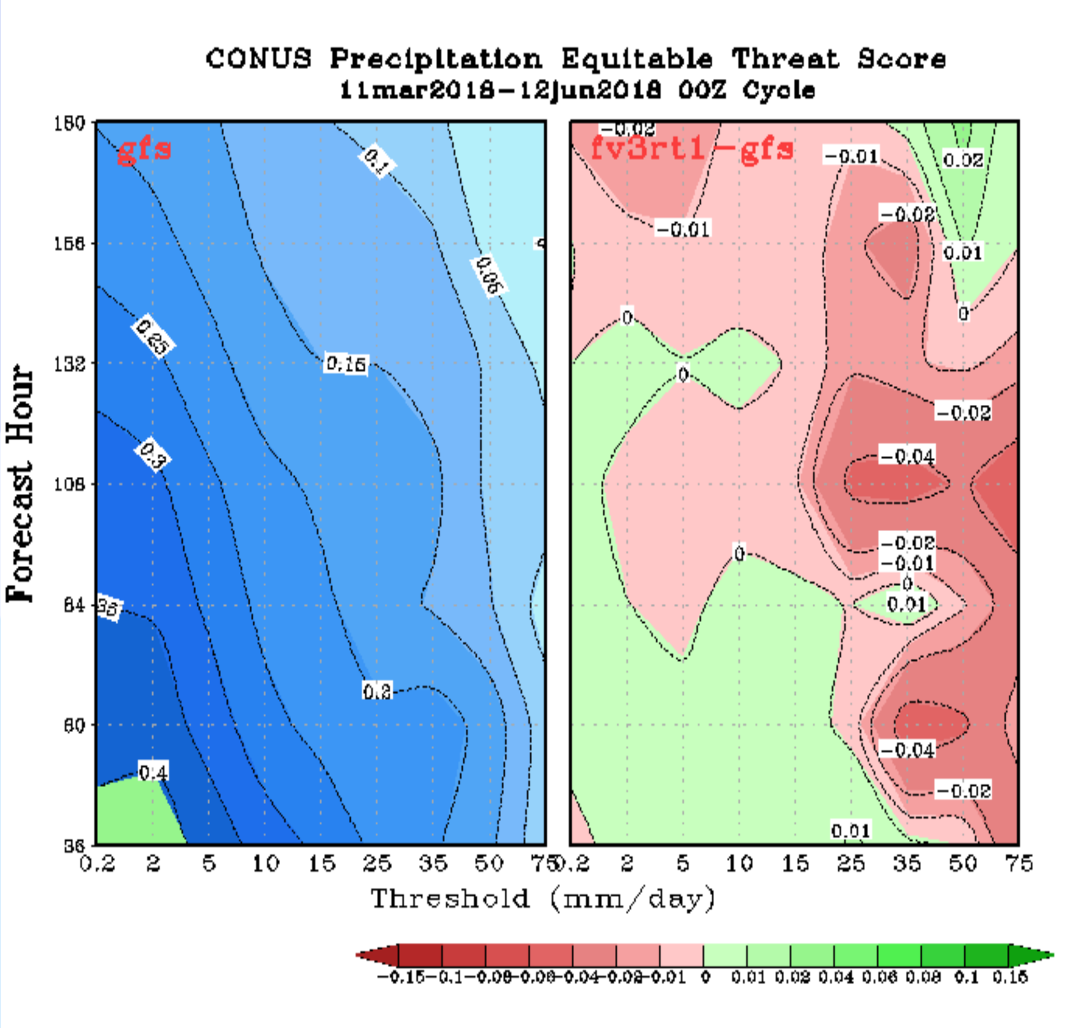


CONUS Precip ETS and Bias Scores

2016 summer

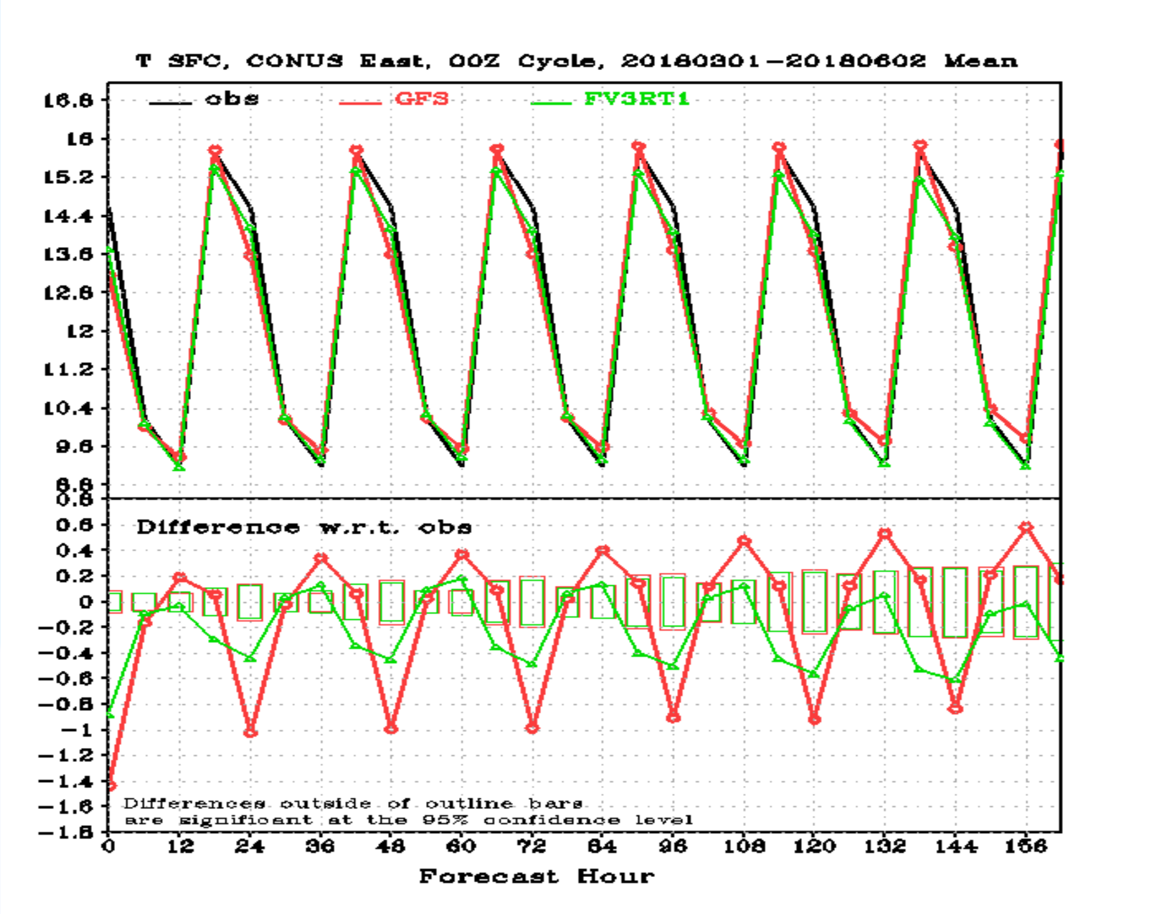


Real time

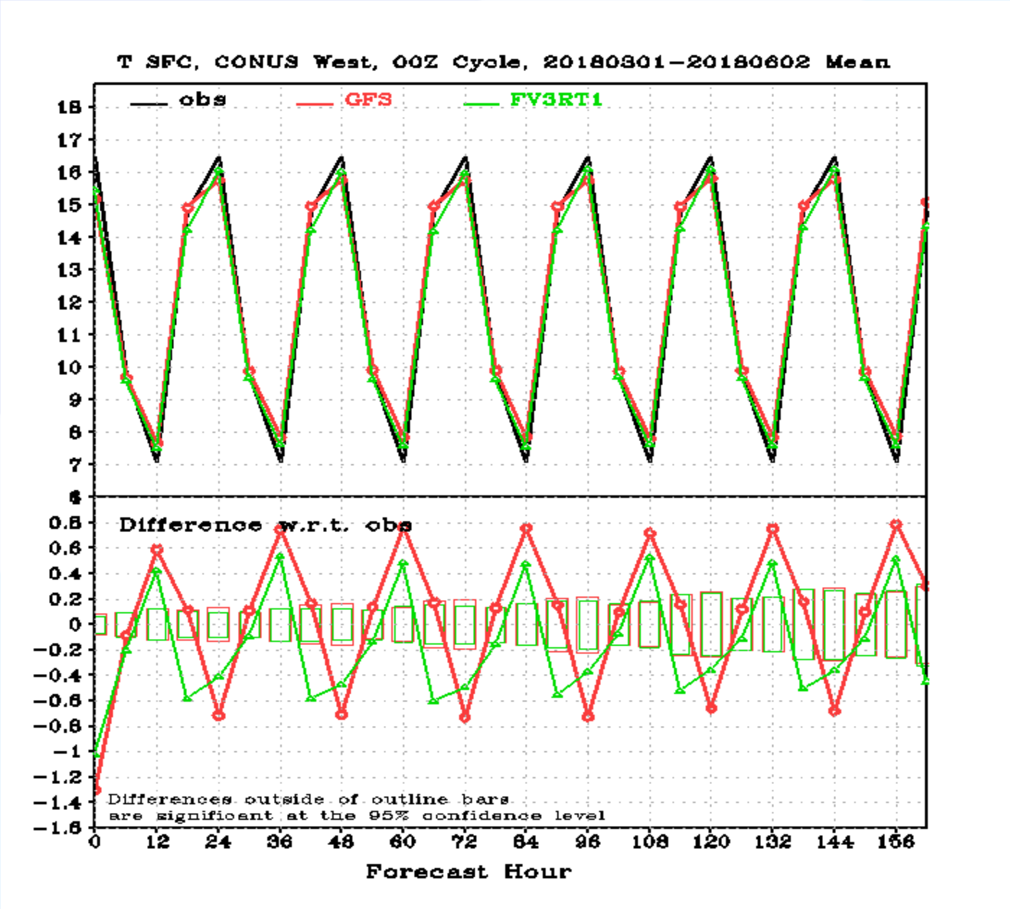


Real-time experiments with fully cycled FV3GFS+GFDL MP (Spring 2018)

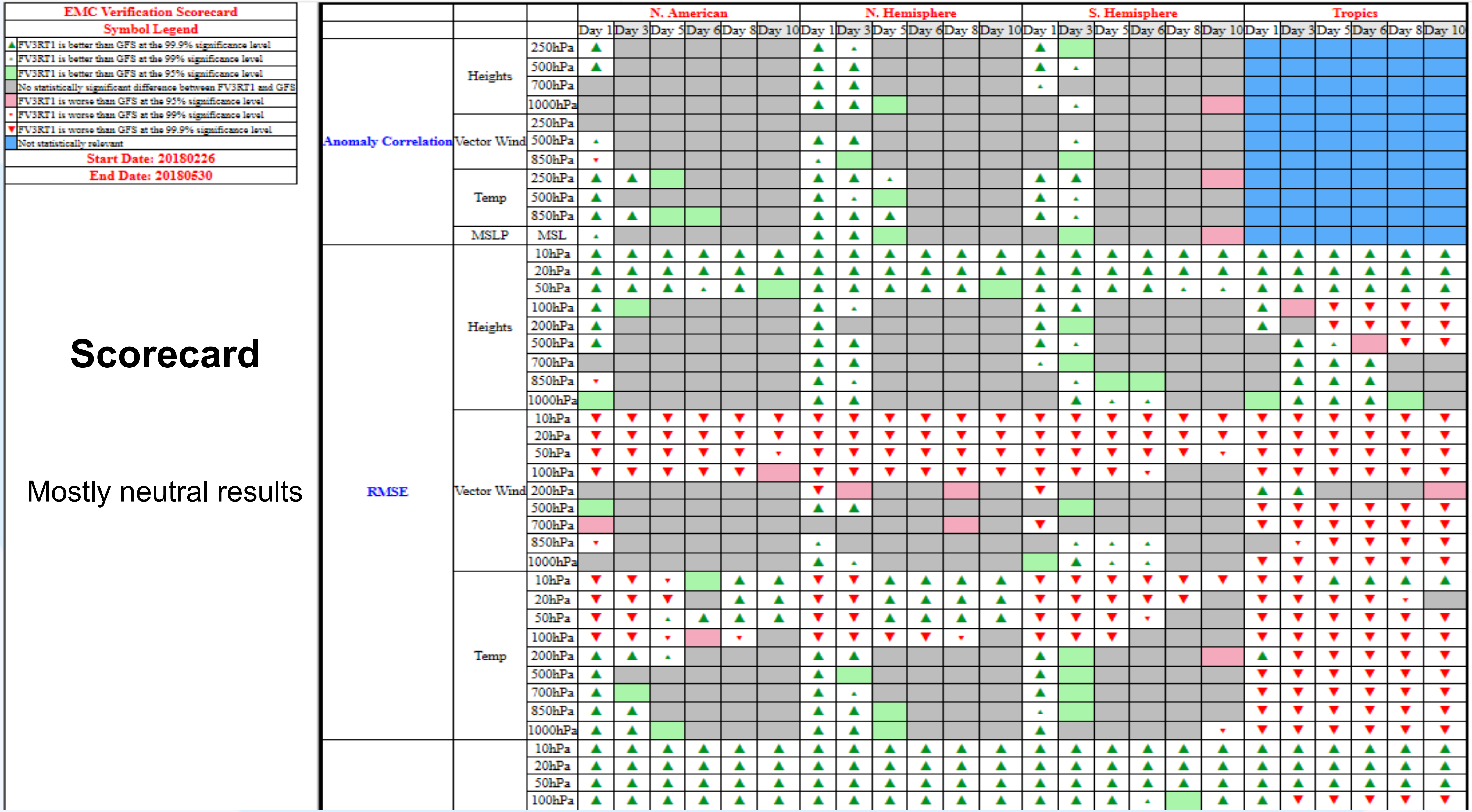
T2m, fit to sfc Obs, CONUS East



T2m, fit to sfc Obs, CONUS West



Slightly reduced T2m bias



Scorecard

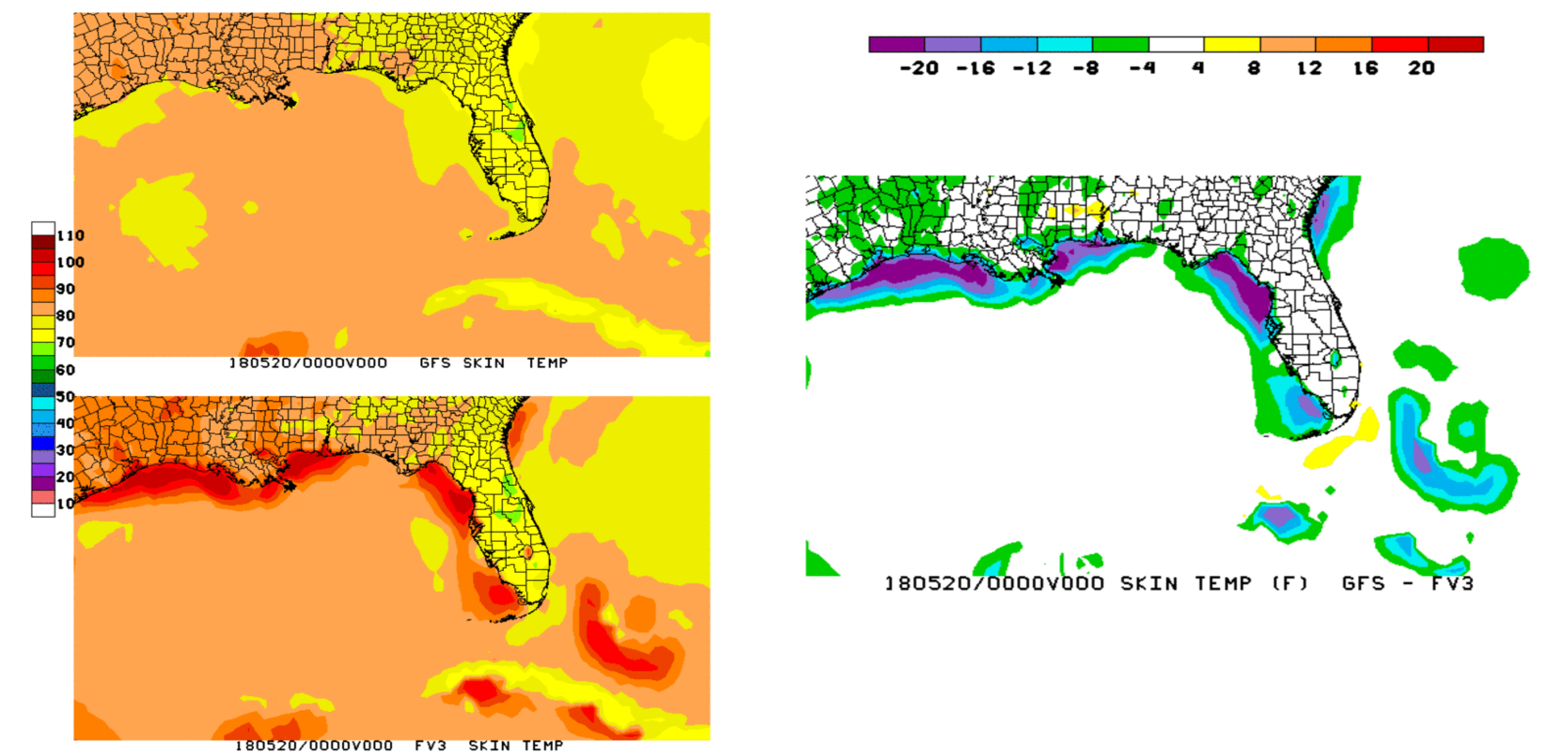
Mostly neutral results

MEG DISCUSSION 5/24/18

PROBLEMS with the FV3GFS SST

Ops gfs

fv3gfs



By Geoff Manikin

The Cause

- The order in which the physics and dynamics are called differs in the FV3GFS compared to the NEMS GFS

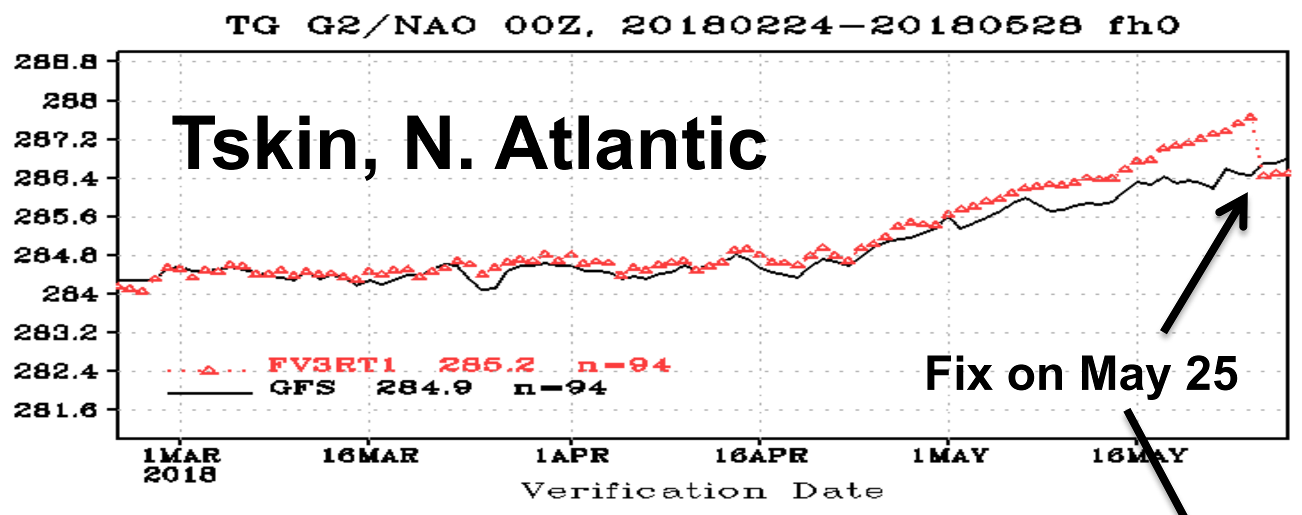
- There is a check on whether to modify the NSST foundation temperature with climatological tendencies in the code

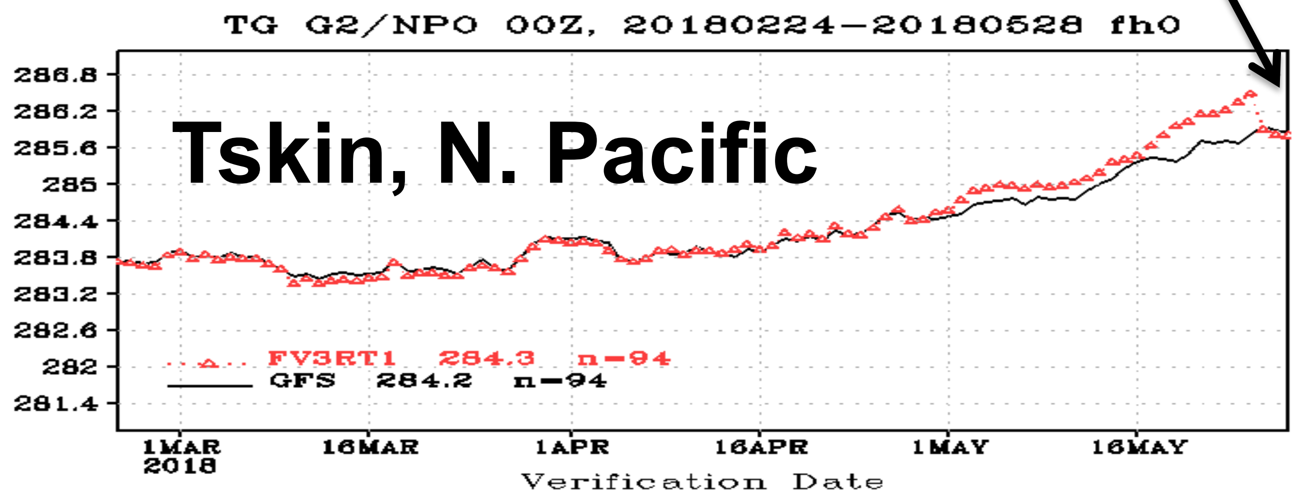
- It's not invoked in the GFS, but due to the changed order of operations in the FV3GFS, the tendencies were applied to that model (4x/day!)

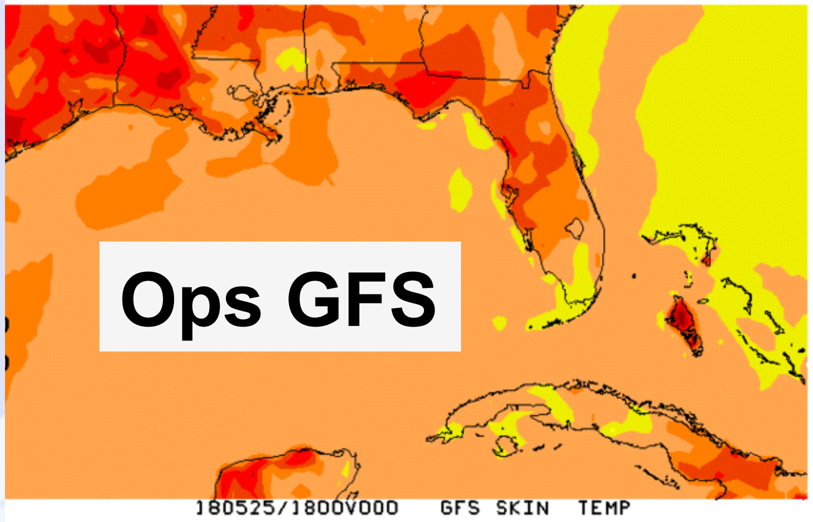
- So there was a gradual accumulation of warmth in some areas of water, with the largest increments applied to shallow water

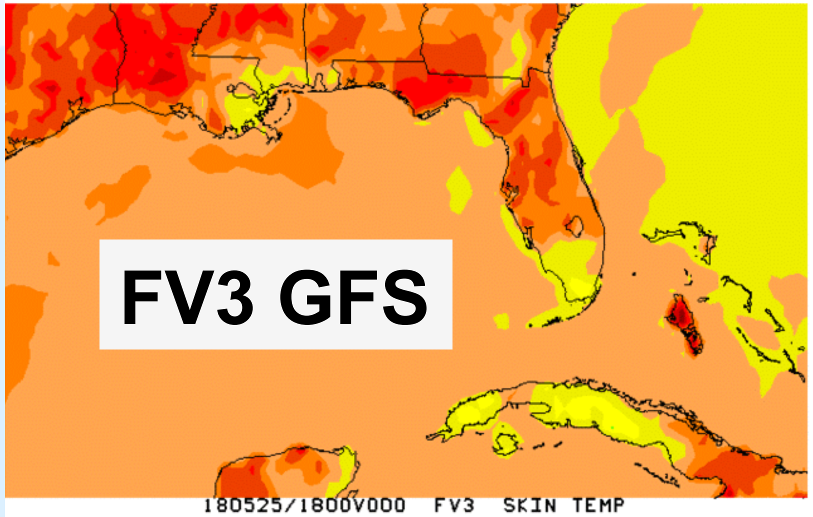
The error accumulated slowly with time and became apparent during the transition season.

After the Fix









Thank you

Advanced Physics for Q2FY20 L127 FV3GFS

Physical Processes	Operational Physics (Evolved)	Advanced Physics*
Radiation	RRTMG/McICA	RRTMgP (scale and aerosol aware, w/sub-grid scale clouds)
Penetrative convection and Shallow convection	Scale Aware SAS & Mass Flux Shallow Convection	Scale-aware Chikira-Sugiyama & Arakawa-Wu; Grell-Freitas
Turbulent transport (PBL)	Hybrid EDMF	CS+SHOC (unified convection & turbulence); TKE-based moist EDMF
Cloud microphysics	Zhao-Carr	GFDL-MP, Morrison-Gettleman; Thompson
Gravity wave drag	Orographic GWD Stationary convective GWD	Unified representation of GWD
Ozone Photochemistry	NRL simplified scheme	Modified NRL scheme; water vapor Photochemistry
Land surface model (LSM)	Noah	Noah and LIS; Freshwater lake "*FLake*" model
SST	NSST	NSST

***Includes aerosol chemistry (NGAC) module**

FV3GFS Implementation Plan (proposed)

Implementation Plan for FV3-GFS (FY2017-2020)

FV3GFS	FY17 Q1	FY17 Q2	FY17 Q3	FY17 Q4	FY18 Q1	FY18 Q2	FY18 Q3	FY18 Q4	FY19 Q1	FY19 Q2	FY19 Q3	FY19 Q4	FY20 Q1	FY20 Q2	% complete
FV3 Documentation	Evaluate, prepare and document FV3 dycore for GFS														90%
FV3 Dycore in NEMS		Implement FV3 dycore in NEMS													100%
FV3 Dycore with GFS Physics + GFDL MP			Couple FV3 to GFS physics (NUOPC physics driver) perform forecast-only experiments, tuning and testing												100%
Preliminary GSI/EnKF DA for FV3			Develop DA techniques and use new data												100%
Cycled FV3GFS experiments					Cycled experiments, Real-time and 3-yr retrospective experiments, field evaluation										30%
Post Processing					Adapt post-processing & downstream to FV3 Dycore										90%
Operational Implementation									Transition fv3gfs to operation						30%
Advancement of FV3GFS							Further advancements of FV3GFS with inputs from NGGPS and community contributions & Global-Meso unification (Unified Model Development)						Advanced version of FV3GFS to operations		30%

FV3 dycore and global models: GFS

Completed

- **Q3FY17**: Implement FV3 into NEMS
- **Q4FY17**: Couple FV3 to GFS Physics+ GFDL Microphysics & complete forecast only experiment for benchmark evaluation
- **Q4FY17**: Adapt existing DA techniques for FV3.
- **Q1FY18**: Update DA to ingest and properly process additional cloud hydrometers and non-hydrostatic pressure and height fields.
- **Q1FY18**: Complete Pre/Post processing, verification, and downstream product generation
- **Q2FY18**: Code freeze of FV3GFS-beta, run real-time parallel

Near-term Milestones

- **Q2FY18: FV3GFS-beta V1 public release**
- **Q2&Q3FY18**: 3-year retrospectives and case studies, real-time EMC parallel, downstream products generation, testing downstream NPS models, science evaluation, NCEP Center engagement
- **Q4FY18**: final field evaluation, OD Brief, code handoff and public release of operational code, 30-day IT testing.
- **12/1/18: FV3GFS V15 operational implementation**
- **Q4FY18**: Advanced physics; increased resolution and enhanced DA
- **Q2FY19**: Finalize FY19 FV3GFS implementation configuration
- **Q3FY19**: Conduct real-time parallels and 3-year retrospective experiments
- **Q4FY19**: Complete 3 year retro & real time parallel and Evaluation
- **Q1FY20: FV3GFS V16 operational implementation**