NCEP OD Science and Decisional Briefs
October 1, 2018 (slides 2-73)
and April 1, 2019 (slides 74-94)

Implementation of NGGPS/FV3GFS V1.0

GDAS/GFS V15 for Q2FY2019

NCEP OD Science and Decisional Brief
-October 1, 2018

Implementation of NGGPS/FV3GFS V1.0

Presented by:

GDAS/GFS V15.0.0 for Q2FY2019

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NCEP/EMC

A Major Advancement and Foundation for NOAA's Unified Forecast System

Quad Chart

GDAS/GFS Version 15
Status as of September 20, 2018

Project Information & Highlights

Leads: Vijay Tallapragada & Fanglin Yang (EMC), Steven Earle (NCO)

Scope: FV3 based GFS with upgrades to GFS physics including GFDL microphysics, ozone and water vapor photochemistry parameterizations.

Expected benefits: Initial FV3 based operational GFS with improved forecast skills

Dependencies: NCO and satisfactory evaluation by stakeholders and downstream products

Schedule

Milestones & Deliverables	Date	Status
EMC/NCO EE2 kick off meeting	1/4/18	Completed
Freeze model code and data assimilation system	3/15/18	Completed
Complete full retrospective/real time runs and evaluation	9/10/18	Completed
Field evaluation	9/24/18	In Progress
Conduct CCB and deliver final system code to NCO	9/24/18	In Progress
Deliver Service Change Notice to NCO	11/01/18	In Progress
Complete 30-day evaluation and IT testing	1/20/19	planned
Operational Implementation	1/24/19	planned

Issues/Risks

Risk: Not enough computational resources to run the EMC parallels; **Mitigation**: Run the real time parallels on WCOSS prod, and run multiple streams of retrospective experiments on multiple machines such as CRAY and DELL. Entire DELL (prod+dev) were dedicated for running 10 streams of FV3GFS experiments in the summer of 2018.

Risk: Insufficient NWAVE bandwidth for archiving FV3GFS retrospective/real-time runs to HPSS; **Mitigation:**Options: (a) buy more bandwidth for NWAVE; (b) restrict archives to limited data (will have negative impacts on downstream evaluations); (c) rerun the cases with missing/reduced HPSS archives at a later time.

Risk: Increased forecast file size and output variables requires 160% increase in online disk and HPSS storage; **Mitigation**: TBD (need NCO to acquire more disks)

EMC | NCO | Red text indicates change from previous quarter

Resources

Staff: 3 Fed FTEs + 10 contractor FTEs; including Dev (FV3, physics, DA, post processing, V&V, and infrastructure)

Funding Source: STI/NGGPS

Compute: EMC Dev: (+100%); **Parallels:** (+100%); **Ops**: 360 nodes HWM

Archive: Parallels: 7 PB HPSS for 3-year retros; **Ops**: 10.6TB online and 2.8TB HPSS per cycle (+160%)

R Management Attention Required | Y Potential Management Attention Needed | G On Target

On Target

Topics

- Review of Science changes
- Test Plan and Evaluation Strategy
- Evaluation of FV3GFS performance
- Downstream user and model evaluation
- Evaluation from Stakeholders
- Resources

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

GSM has been in service for NWS operations for 38 years !

5

NGGPS FV3GFS-v1 Transition to Operations

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

Configuration:

- **FV3GFS C768 (~13km deterministic)**
- **GFS Physics + GFDL Microphysics**
- **FV3GDAS C384 (~25km, 80 member ensemble)**
- **64 layer, top at 0.2 hPa**
- **Uniform resolution for all 16**

Schedule:

- **3/7/18: code freeze of FV3GFS-V1 (GFS V15.0)**
- **3/30/18: Public release of FV3GFS-V1**
- **4/1 – 1/25/19: real-time EMC parallel**
- **5/25 – 9/10/18: retrospectives and case studies (May 2015 – September 2018; three summers and three winters)**
- **9/24/2018: Field evaluation due; EMC CCB**
- **10/01/2018: OD Brief, code hand-off to NCO**
- **12/20/2018-1/20/2019: NCO 30-day IT Test**
- **1/24/2019: Implementation**

Model: Infrastructure & Physics Upgrades

- Integrated FV3 dycore 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.
- Modify convection schemes to reduce excessive cloud top cooling
- Updated Stochastic physics
- Improved NSST in FV3
- Use GMTED2010 terrain to replace TOPO30 terrain

Major Science Changes: GFDL FV3 Dycore and Microphysics

GSM

Spectral
Gaussian
Hydrostatic
64-bit precision

↓

GFDL FV3

Finite-volume
Cubed-Sphere
non-hydrostatic
32-bit precision

Physics still runs at 64-bit precision

Zhao-Carr MP

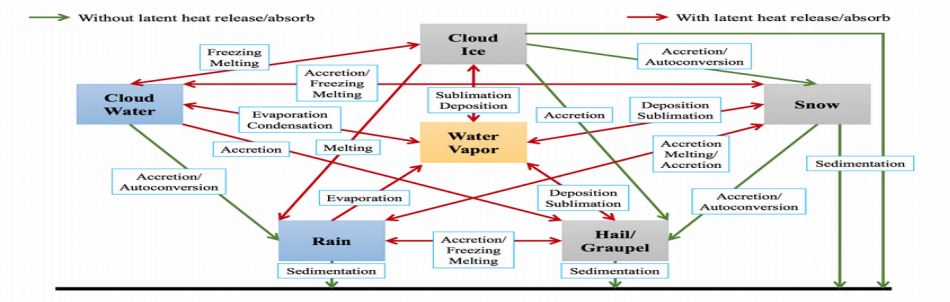
Prognostic could species: one total cloud water

↓

GFDL MP

Prognostics cloud species : five
Liquid, ice, snow, graupel, rain

more sophisticated cloud processes



GDAS: Infrastructure Changes

- Improved GSI code efficiency

- The GSI does not currently have the capability to operate on a non-rectangular grid. Forecasts are therefore provided via the FV3 write-grid component on the Gaussian grid required by the GSI. **Increments are interpolated back on the cube-sphere grid** within the FV3 model itself.

- Both the analysis and EnKF components are now performed at **one-half of the deterministic forecast resolution** (increased from one-third in current operations) and is now C384 (~26km) instead of 35km. This reduced issues when interpolating between ensemble and control resolutions.

- **Tropical cyclone relocation** is **omitted** from the implementation, as is the full field **digital filter**.

- The current operational GDAS/GFS system uses a total (non-precipitating) cloud condensate, whereas the FV3-GFS has **five separate hydrometeor** variables.

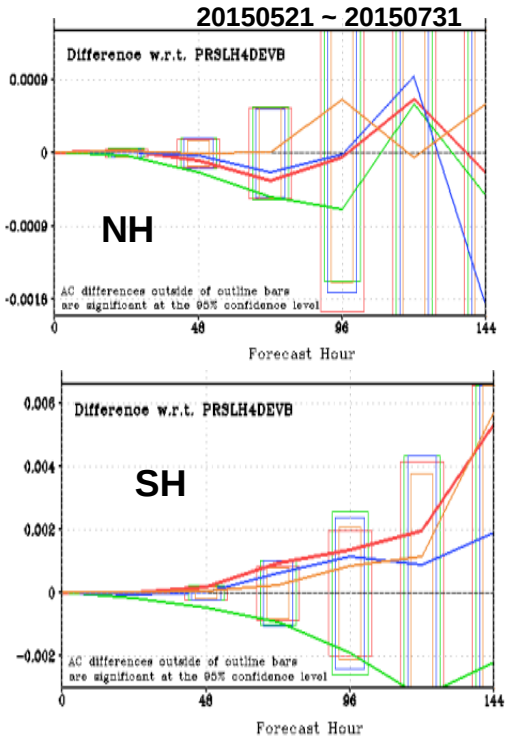
From: DA Team

DA: Observation Changes

- **ATMS** has been upgraded from **clear-sky to all-sky** assimilation to be consistent with the AMSU-A sensors.
- **CrIS on Suomi-NPP** was upgraded to use the **full spectral resolution** (FSR) data stream – consistent with CrIS on NOAA-20 (moisture and pressure).
- CrIS and ATMS on NOAA-20 as well as GOES-16 winds were made operational in 2018 and this is reflected in the FV3-GFS package. CrIS has slightly modified observation errors and thinning compared to operations.
- Turn on **10 water vapor channels for IASI**.
- Turn on **Megha-Tropiques Saphir** (humidity)

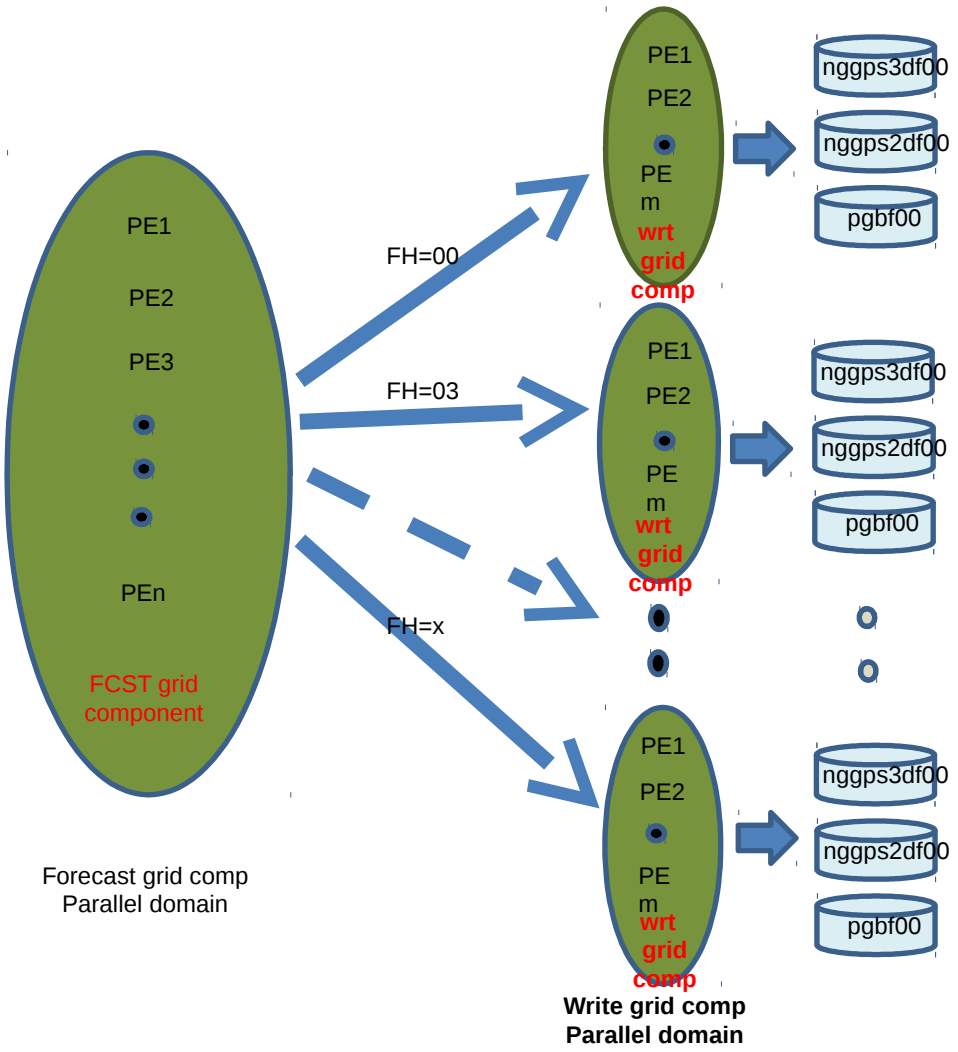
500hPa HGT ACC
ATMS Change to All-Sky

Cntl: Clear-Sky ATMS
All-Sky ATMS
(other curves are alternative configurations for all-aky)



From: DA Team

New Parallelized NEMS FV3 Write Grid Component



GFDL FMS writes files in native cubed sphere grid in six tiles, one file for each tile in netcdf format with ***all output times at once***.

NEMSIO writes

- history files in **cubed sphere grid** in six tiles, one file one tile in netcdf format at a ***specific output time***
- history files in **global Gaussian grid**, one file for global ***at a specific output time*** in either **netcdf** format or **NEMSIO** format

From : Jun Wang

Post Processing Upgrade and Changes

➢**Changes in products:**

- **Vertical velocity from FV3GFS is dz/dt in m/s, but omega will be derived in UPP using hydrostatic equation and still be provided to users**
- **GFS station time series BUFR data will output nonhydrostatic dz/dt only**
- **Global aviation products have been adjusted to new MP and FV3 dynamic core**

➢**Several new products are added:**

- **More cloud hydrometers predicted by the advanced microphysics scheme**
- **Global composite radar reflectivity derived using these new cloud hydrometers**
- **Isobaric (3D) cloud fractions**
- **Continuous accumulated precipitation**
- **Complete list can be found in this Google Sheet**

➢**GFS DNG products over Guam will be discontinued. EMC has coordinated with users to switch to new and better products.**

From: Hui-ya Chuang & Wen Meng

Other Notable Mid-Stream Changes

(responding to feedback from real-time evaluation)

➢**NSST related issues**

- **Initial discovery of odd convection in FV3GFS (Mark Klein, WPC)**
  - **Fixed an issue with climatological tendencies applied to the model (4x/day!)**
- **Too Cold FV3GFS SSTs in some shallow waters, and in North Pacific (Alaska Region)**
  - **Introduced climatological updates to the GDAS cycle, and increased the length scale of the NSST background error to 100 km**

➢**Degraded Hurricane Intensity:**

- **Initial version of FV3GFS (with hord=6) significantly degraded hurricane intensity forecast skill (EMC, GFDL, NHC)**
  - **Changed the horizontal advection to hord = 5 (recommended by GFDL) to alleviate the hurricane intensity degradation**

➢ **Synchronization of zenith angle scaling factor:**

- **Incorrect scaling factor impacting time control calculation of radiation (EMC)**
  - **Corrected the time step calculation (minor impact)**

➢ **Low level turbulence:**

- **Weak low level turbulence in FV3 GTG NCAR algorithm (Steve Lack, AWC)**
  - **Corrected min altitude to start computing GTG at surface instead of 20000 ft**

Retrospective and Real-Time Parallels

- Multiple streams of retrospective parallel were carried out to cover the period from May 2015 through May 2018.

- The real-time parallel started in May 2018 was moved from CRAY to DELL in August.

Retrospectives & Real-Time

http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/gfs2019b
Comparing NEMS GFS with FV3GFS.

MEG evaluation page

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

Real-Time Comparison with International models

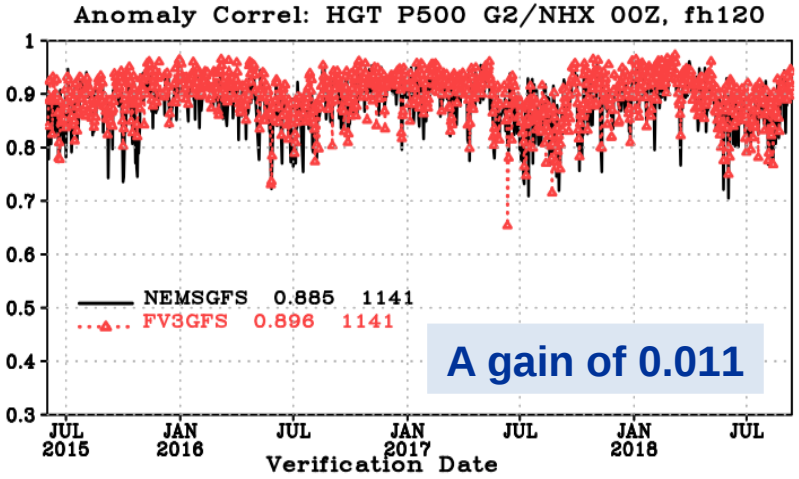
http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb/

Evaluation of Q2FY19 GDAS/GFS Upgrade:

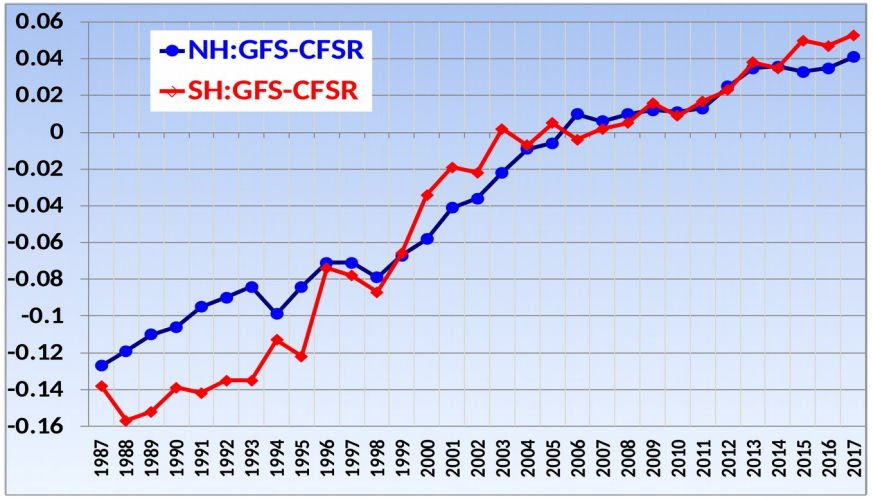
EMC Perspective

NH 500-hPa HGT Anomaly Correlation
(20150601 ~ 20180912)

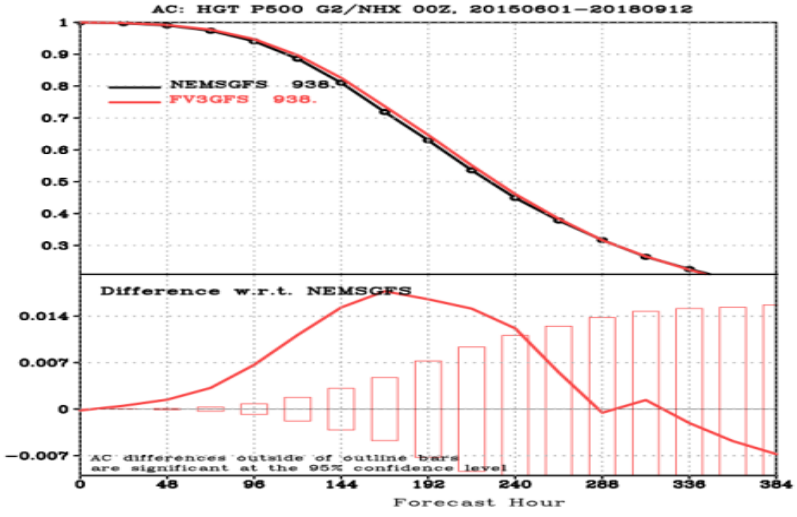
Day-5



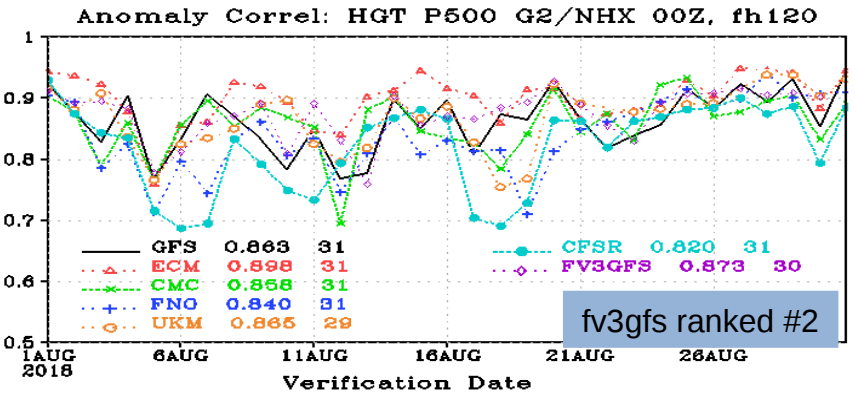
Annual Mean day-5 ACC, GFS - CFSR



Die-off



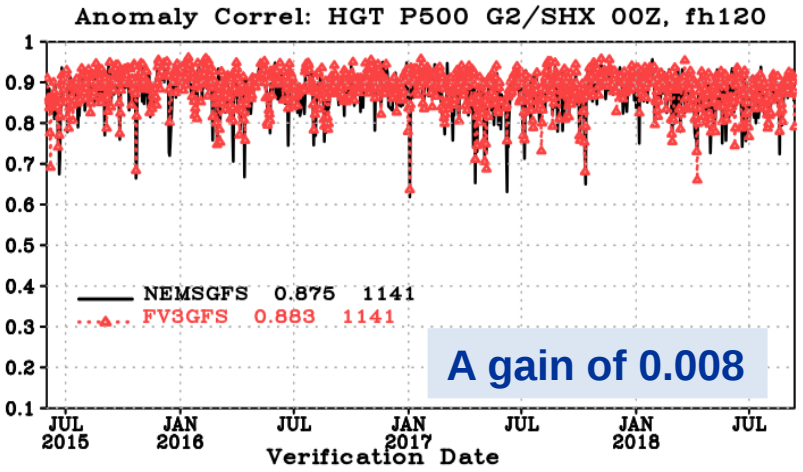
Major International NWP, August 2018 Mean

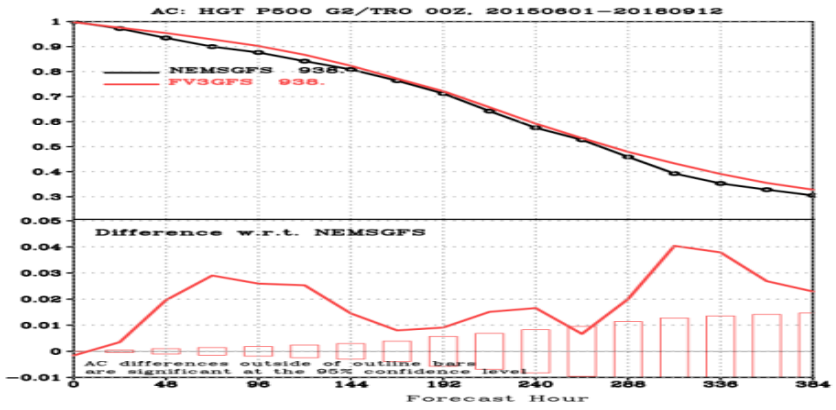


Increase is significant up to day 10

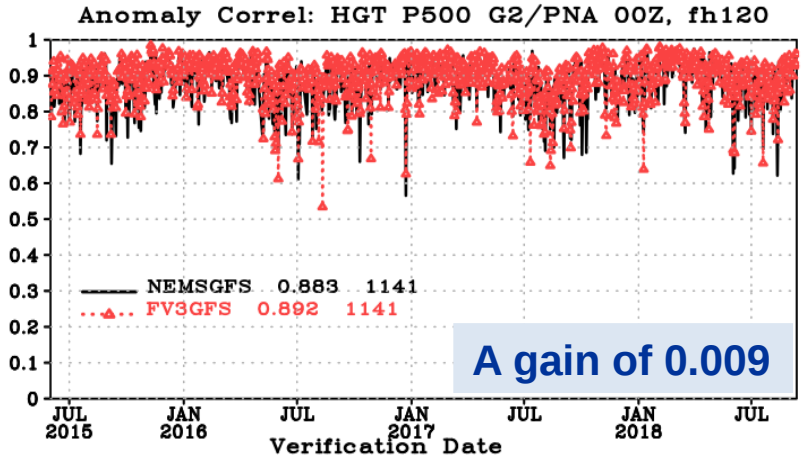
SH and N. America 500-hPa HGT ACC
(20150601 ~ 20180912)

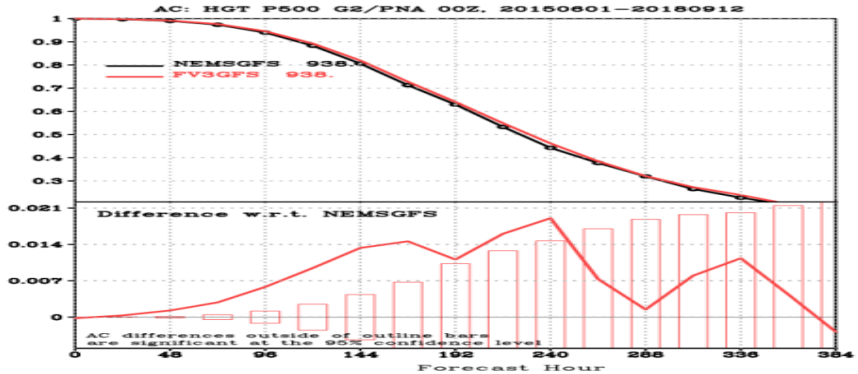
SH





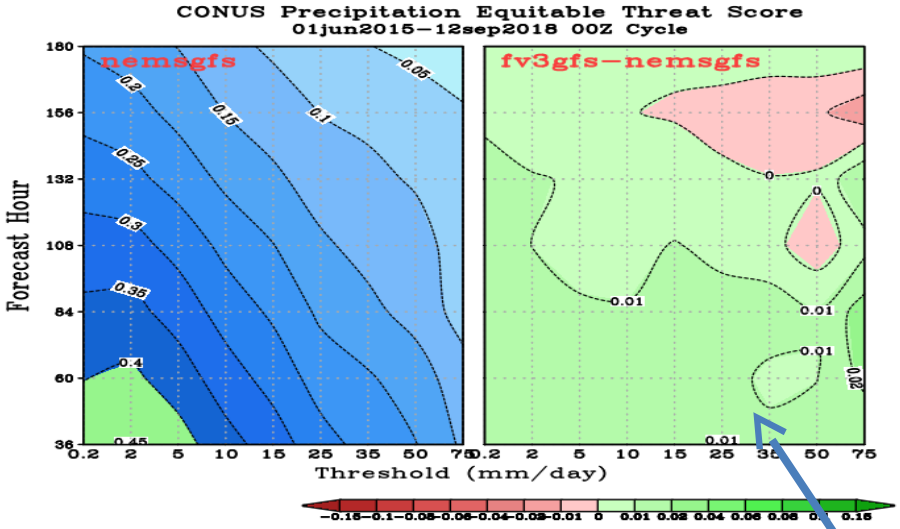
Pacific North America

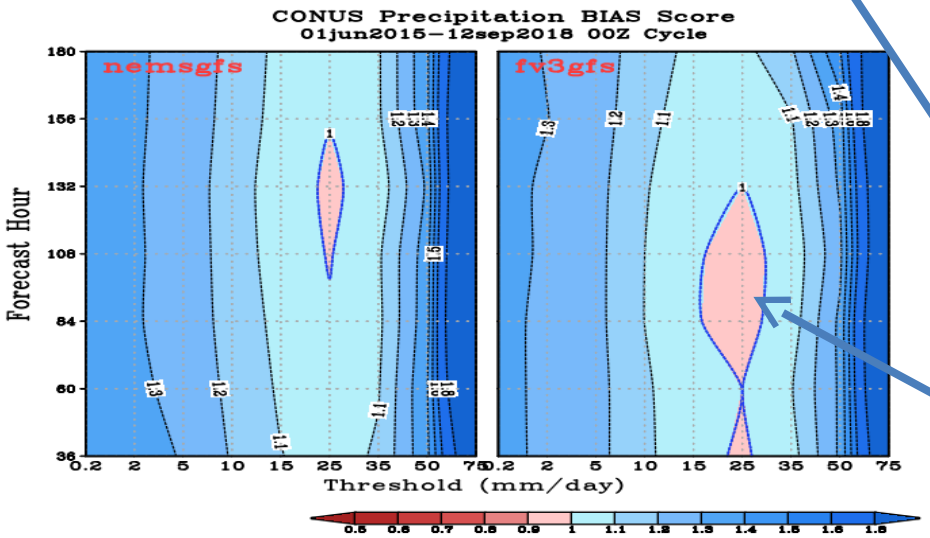




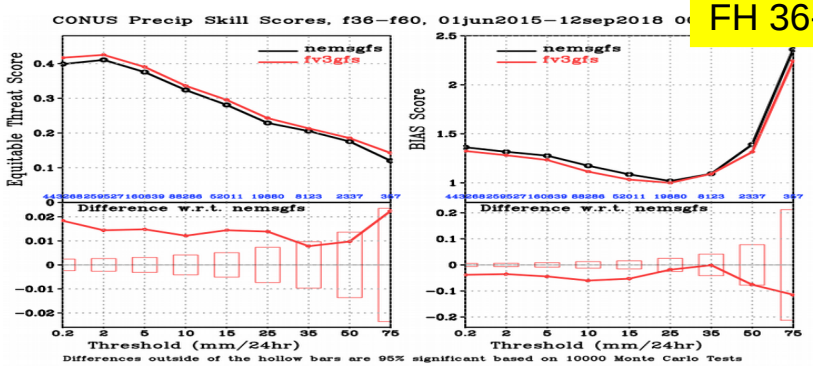
CONUS Precip ETS and BIAS SCORES

00Z Cycle, verified against gauge data, 20150601~ 20180912

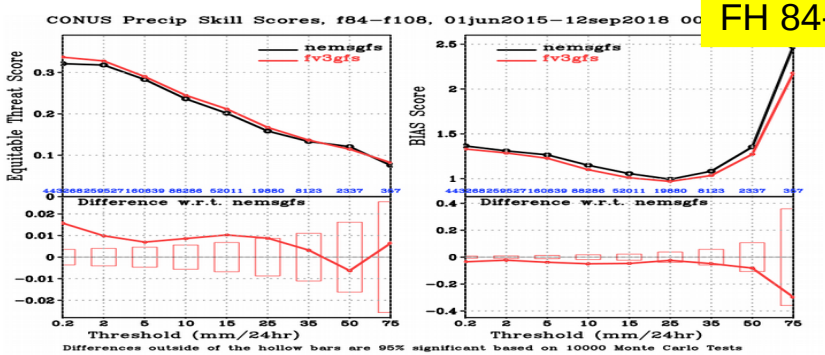




FH 36-60



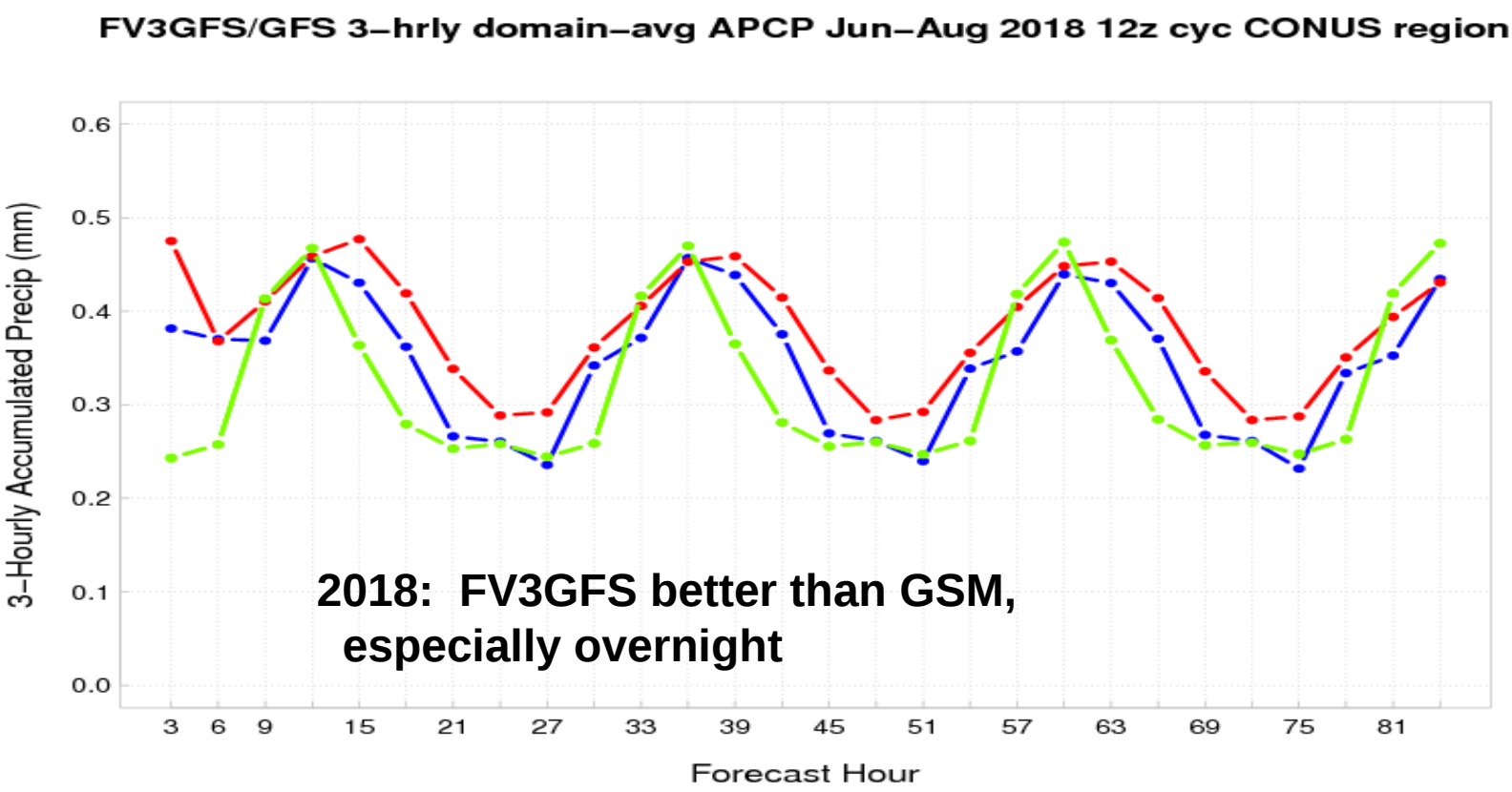
FH 84-108



- Improved ETS scores for almost all thresholds and at all forecast length
- Reduced wet bias for light rains
- Slightly worsened dry bias for moderate rain categories

Improved Precipitation Diurnal Cycle

SUMMER 2018 CONUS DOMAIN-AVG PCP



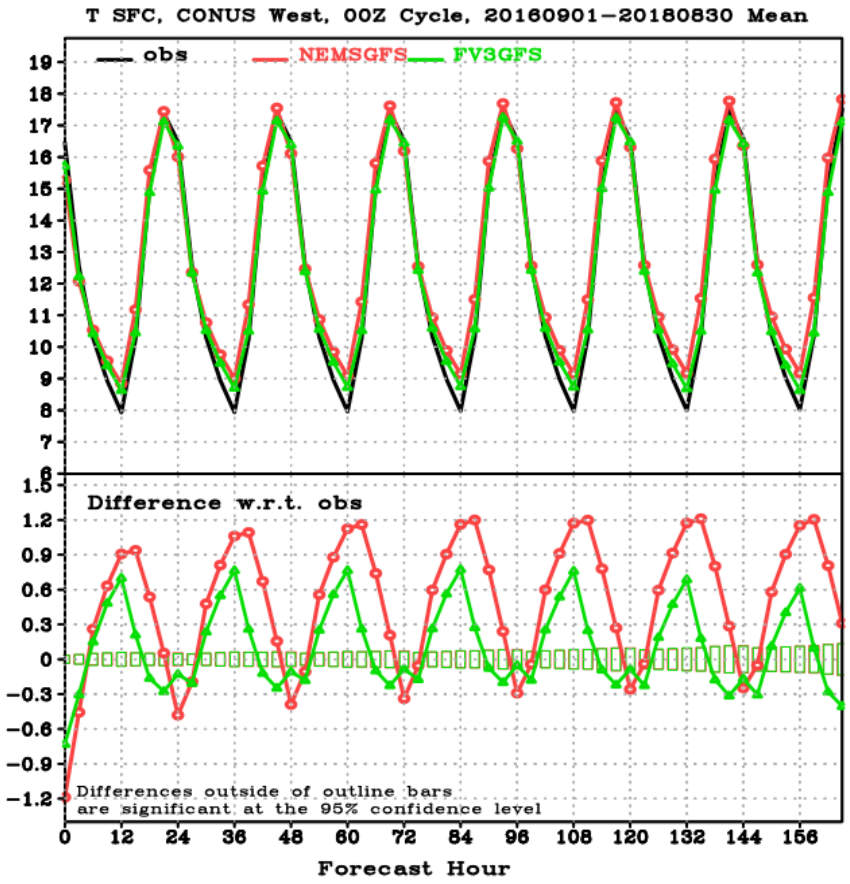
FV3GFS **ops GFS** **OBS**

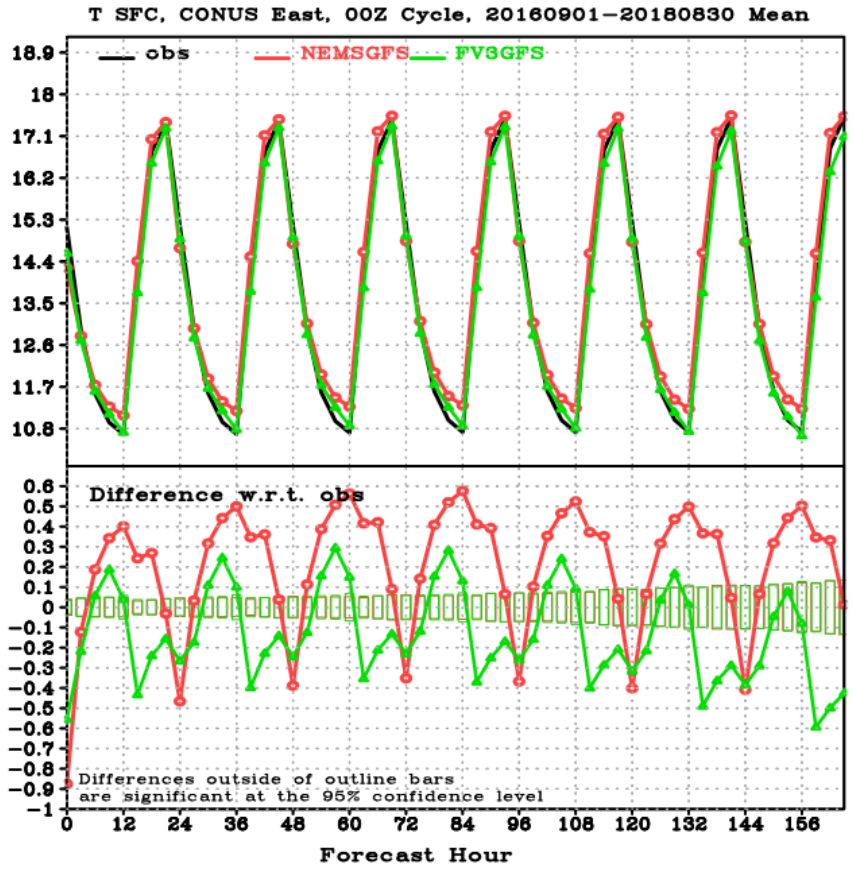
From: Ying Lin

CONUS 2-m Temperature

Verified against Station Observations, 3-year mean

WEST OBS GFS FV3GFS **EAST**





Slight FV3GFS improvement in both the min and the max

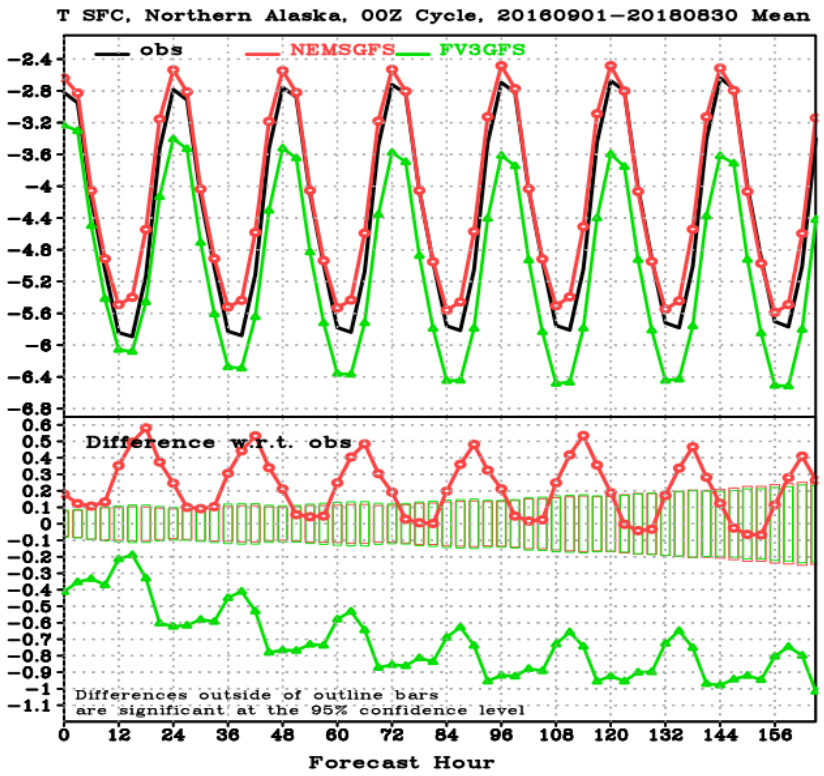
2-m Temperature over Alaska

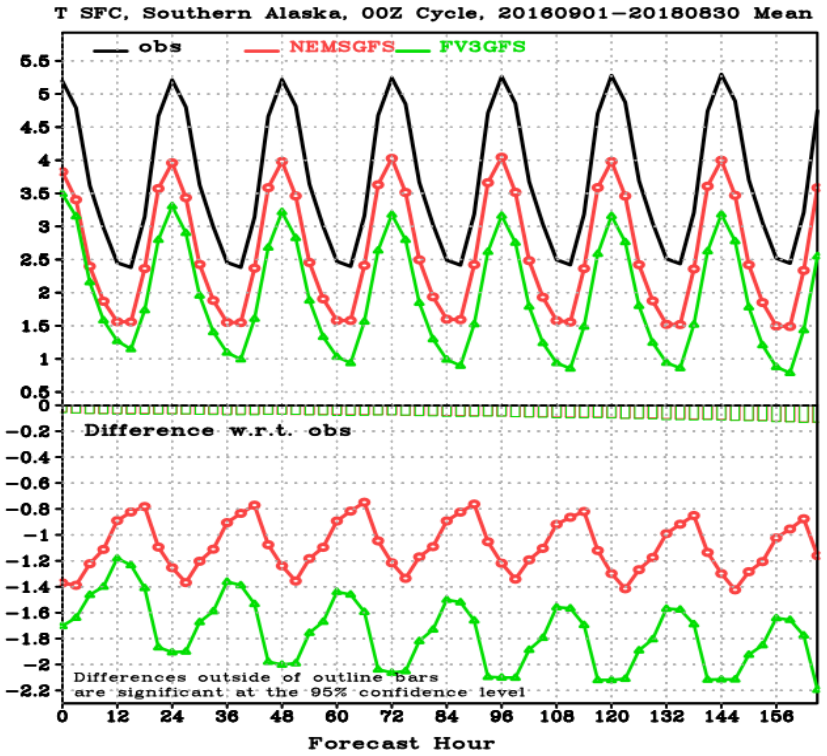
Verified against Station Observations, 3-year mean

NORTH ALASKA

OBS GFS FV3GFS

SOUTH ALASKA





FV3GFS has large cold bias !

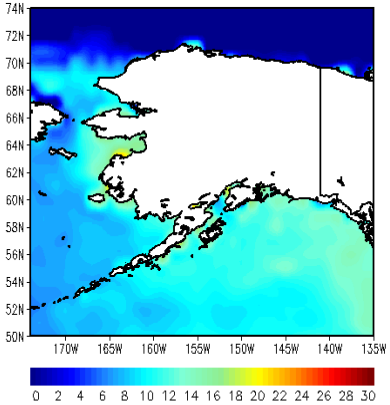
Likely caused by a cold NSST and an overestimate (underestimate) of cloud in summer (winter)

Impact of NSST Fix on SST and 2m Temperature

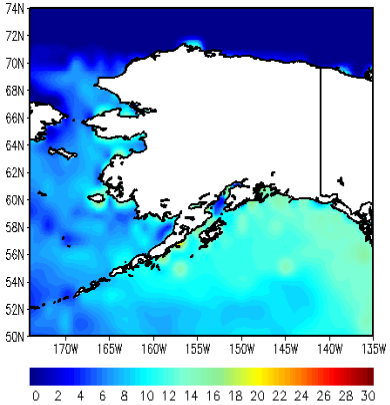
Cycle 2018071600 f24 Valid 2018071700
Sea Surface Temperatures (°C)

Cycle 2018071600 f24 Valid 2018071700
2m Temperature [F]

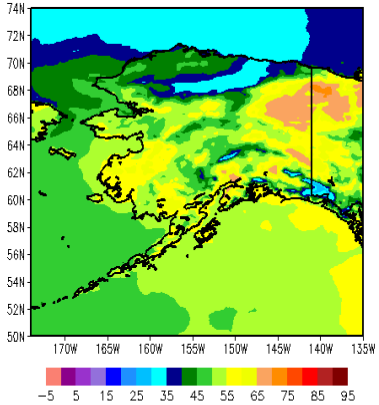
FV3GFS SST test



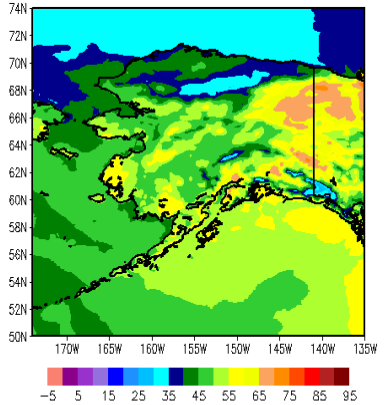
FV3GFS real-time



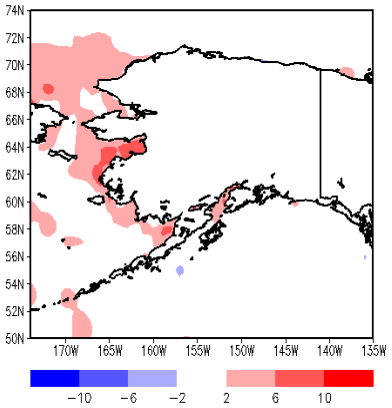
FV3GFS SST test



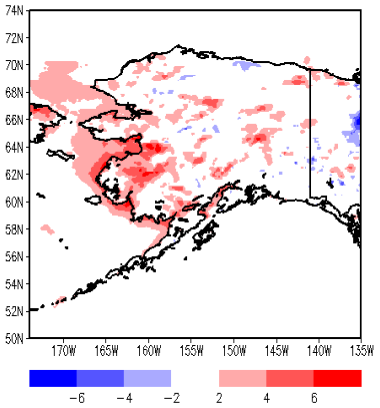
FV3GFS real-time



FV3GFStest−FV3GFSrealtime



FV3GFStest−FV3GFSrealtime



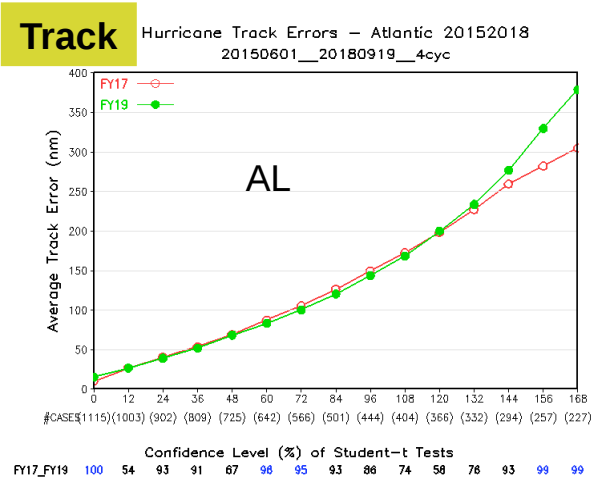
F24 valid 00Z

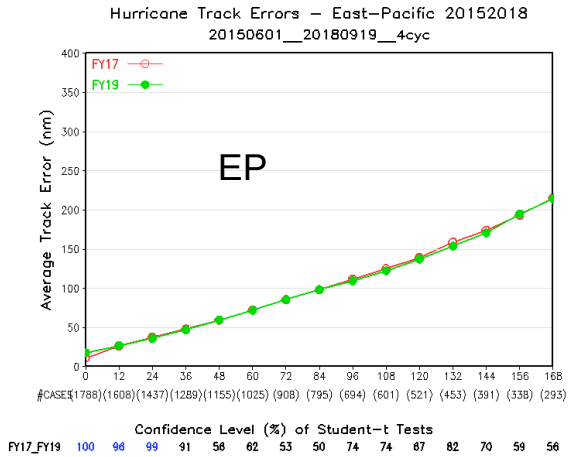
Hurricane Track and Intensity

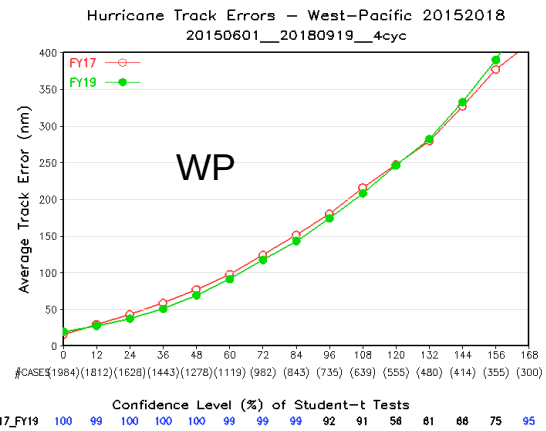
20150601 ~ 20180919

Red: NEMS GFS; Green FV3GFS

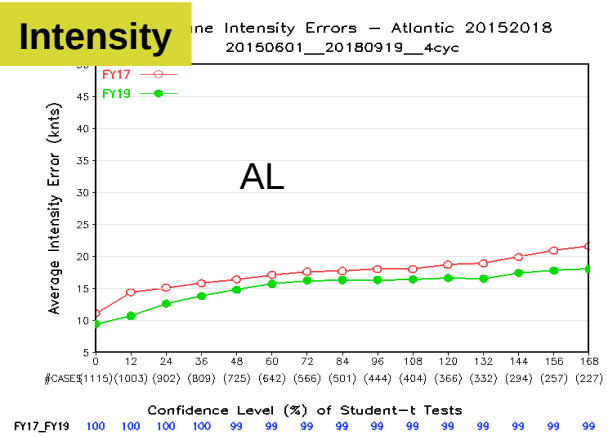
Track

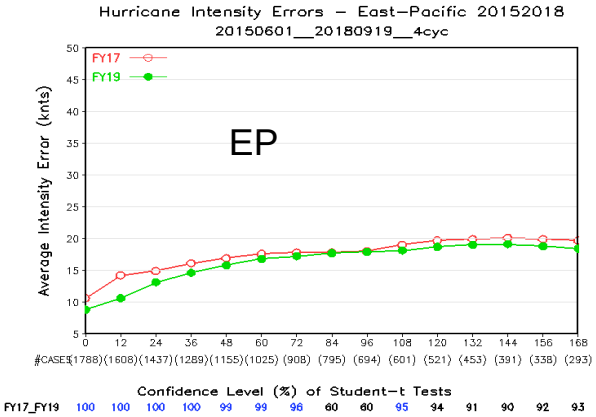


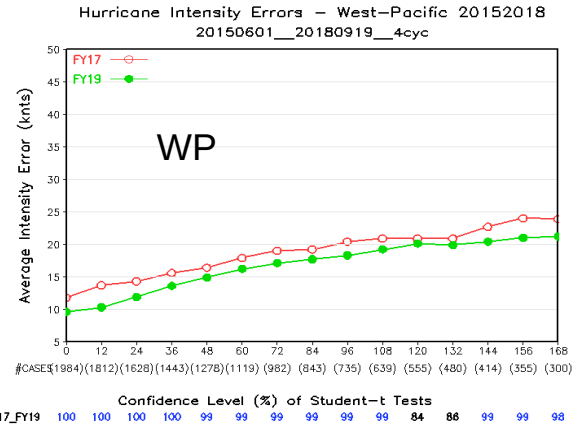




Intensity





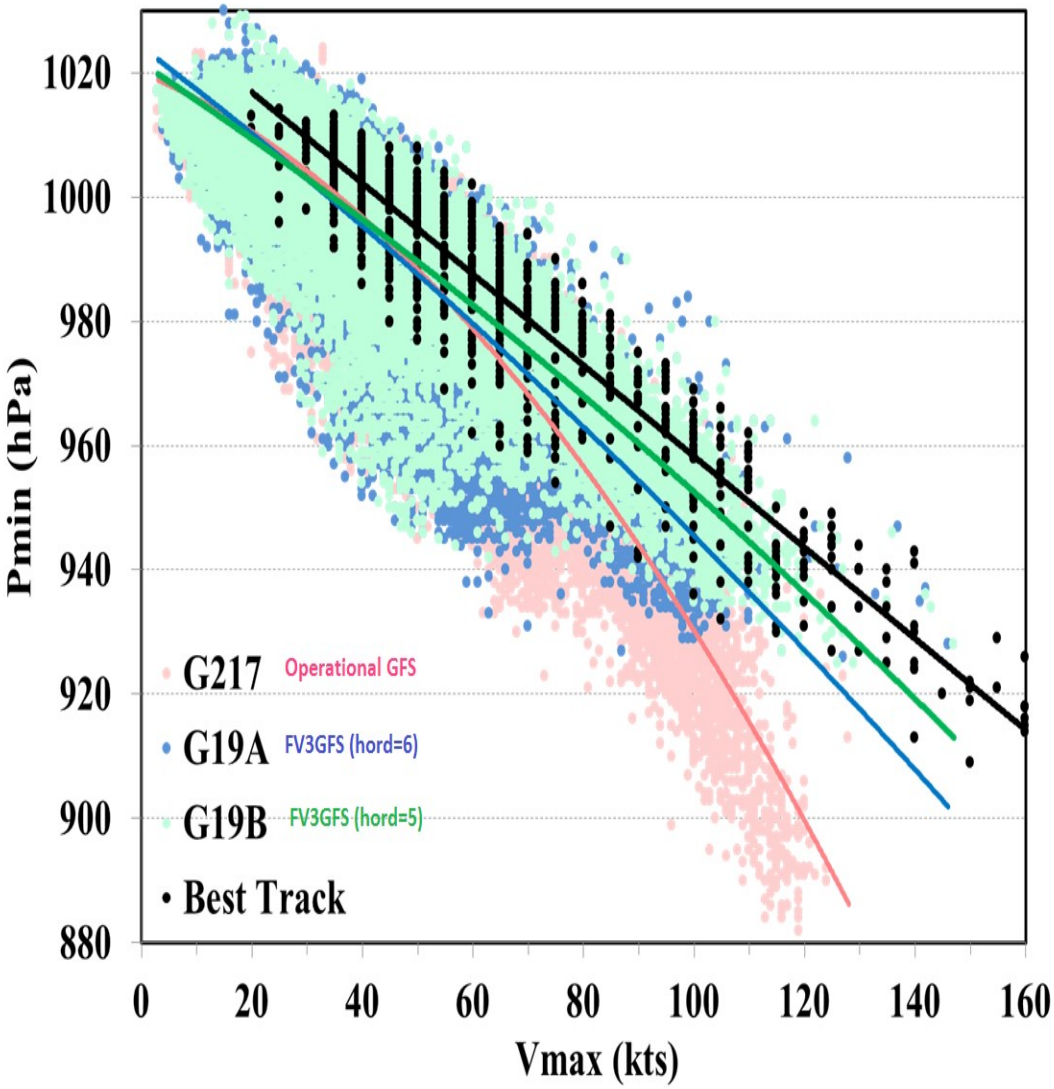


- **Intensity is improved over all basins**
- **Tracks in AL and WP are improved for the first 5 days except at FH00, and degraded in day 6 and day 7. Track in EP is neutral**

Improved Wind-Pressure Relationship

FV3GFS shows a much better W-P relation than ops GFS for strong storms

For FV3GFS, W-P relation with hord=5 is better than hord=6

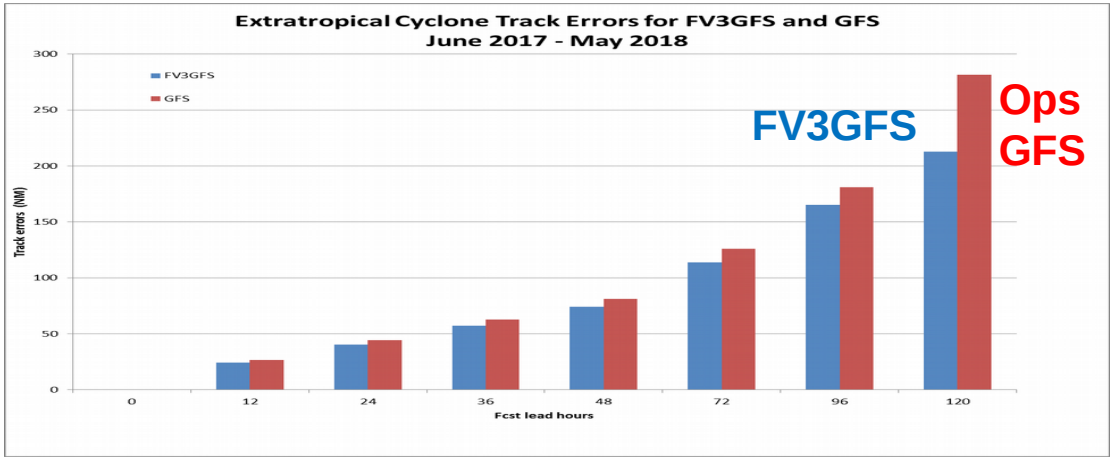


Graph made by HWRF group

Extratropical Cyclone Track

Jun 2017 ~ May 2018

FV3GFS extra-tropical storm track errors are consistently smaller than that of GFS. Error at 120 hour is substantially smaller. (Unit: NM)



Track errors

FCST hr	0	12	24	26	48	72	96	120
FV3GFS	0.0	24.09	40.38	57.04	73.91	113.66	165.22	212.75
GFS	0.0	26.59	44.17	62.87	81.08	125.89	180.85	281.57
diff	0.0	-2.50	-3.79	-5.83	-7.17	-12.23	-15.63	-68.82

Number of cases

FCST hr	0	12	24	26	48	72	96	120
FV3GFS	15490	14895	13904	10069	6231	2285	799	239
GFS	16672	16156	15031	10906	6776	2563	925	281
diff	-1182	-1261	-1127	-837	-545	-278	-126	-42

FV3GFS captures slightly smaller number of cases.

From: Guang-Ping Luo

Summary of various evaluation metrics

Evaluation	Remarks
Precipitation	**Slight improvement in skill for most forecast lengths, especially for lighter amounts.** *Dry bias for mid-range thresholds.* **Warm season diurnal cycle improved**
2m T	**Overall similar, but slight improvement with FV3GFS for the min and max values**
2 m T_d	**Very similar results for GFS and FV3GFS.** *Slightly worse in early morning in east*
10 m Winds	**Very similar results for GFS and FV3GFS. Slightly better timing with diurnal cycle for FV3GFS in east and west**
Visibility	**Less coverage of reduced visibility in FV3GFS due to using instantaneous precip rate; more FV3GFS coverage of extremely low visibility events. Unclear if improved**
Ozone	**FV3GFS does much better job conserving ozone**
Stratospheric water vapor	**FV3GFS greatly improved middle atmospheric water vapor**

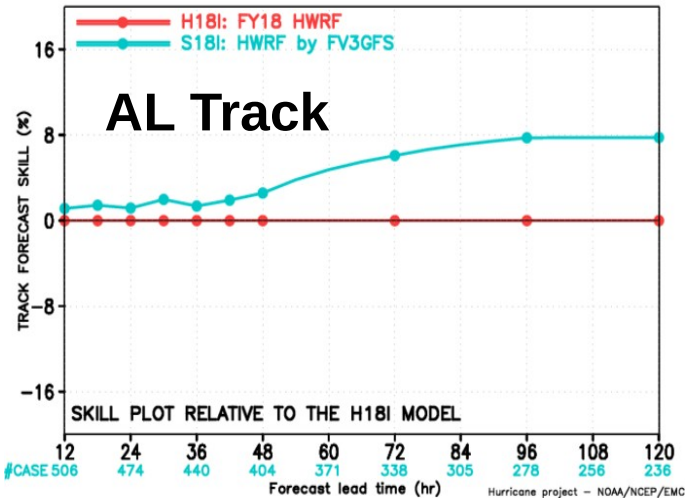
Summary of various evaluation metrics

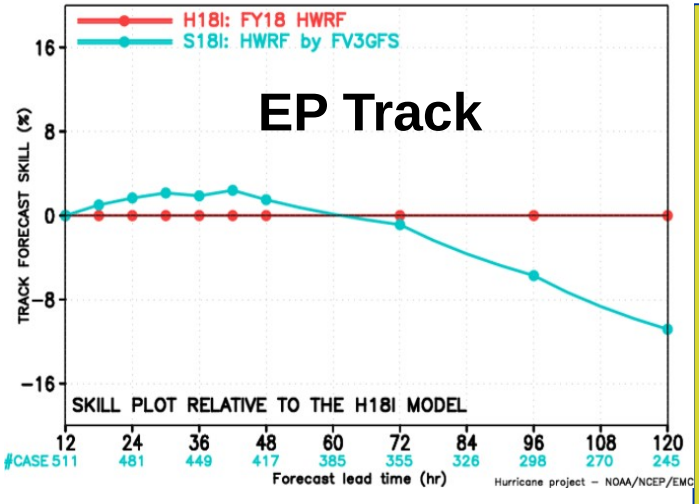
Evaluation	Remarks
Fit-to-radiosondes	GFS and FV3GFS winds too weak, but FV3GFS is closer to obs. FV3GFS winds better in troposphere *but worse in stratosphere*
Fit-to-analyses	FV3GFS reduced GFS cold bias in middle to upper stratosphere. *FV3GFS wind RMS worse in stratosphere but comparable to EC*
500 mb ACC	Large improvement for FV3GFS across globe – statistically significant gains out to day 10
Hurricane Tracks	Overall FV3GFS improvement *but worse at days 6-7 in ATL basin*
Hurricane Intensity	FV3GFS is better in all basins. Do not see unrealistic deepening
TC Wind-Pressure Relationship	Much improved in FV3GFS, especially since HORD change made
TC Genesis	FV3GFS has overall higher POD *but also has higher FAR*.
HWRF	Intensity/Track improvements in ATL, mixed in East PAC
HMON	Track improvements; intensity slightly worse early but then better
Waves	Most statistics similar, but FV3GFS waves have positive bias (GFS has negative bias of same magnitude)
GEFS	All standard verification scores improved using FV3GFS

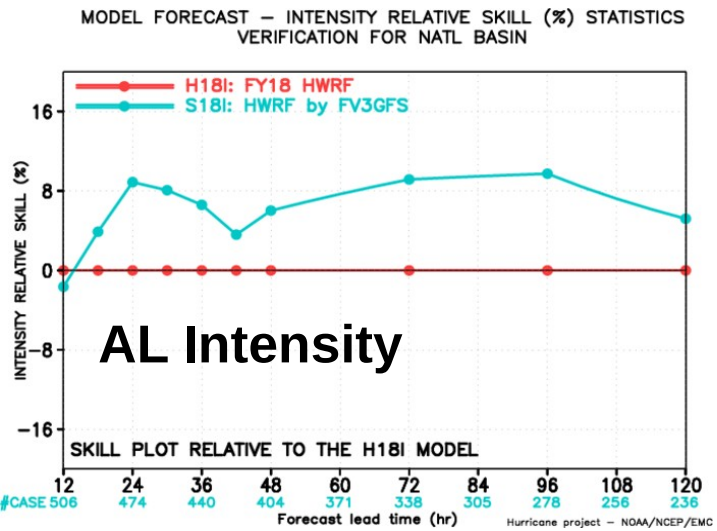
Evaluation by downstream models and product users

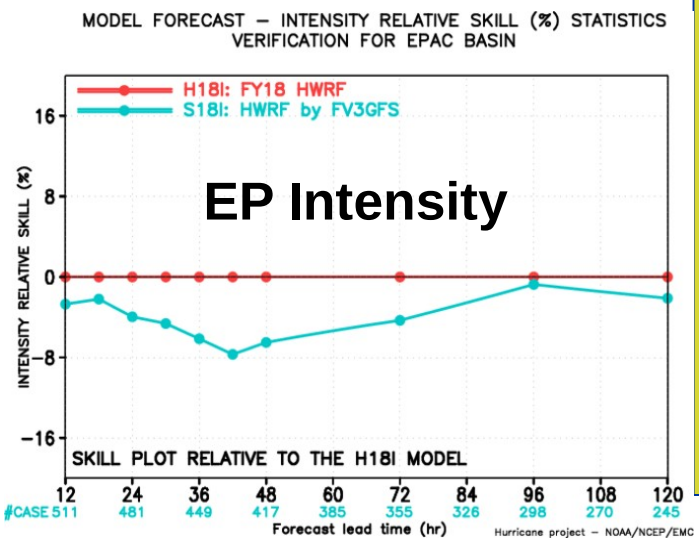
FY18 HWRF Testing with FV3GFS

Priority Storms, Early Model









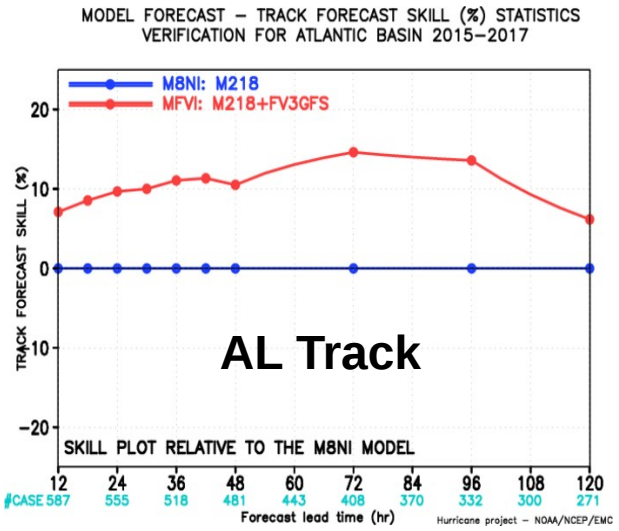
ATL: There is good improvement in track skill especially for longer lead times Intensity skill improvements are evident at all lead times

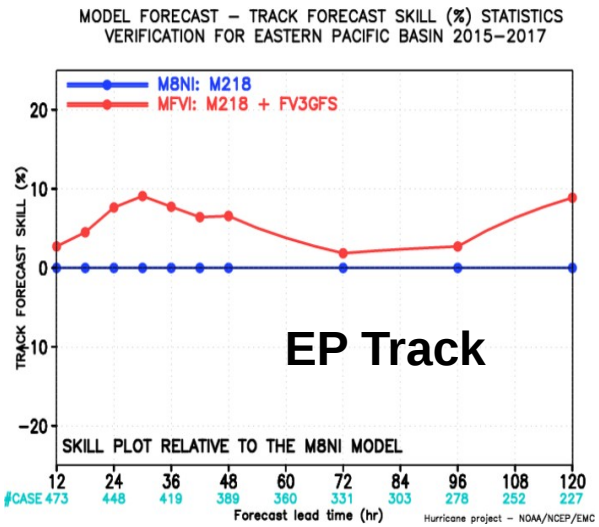
EPAC: Track skill is improved for the first 2 days, behind for Days 4 and 5.
Intensity skill is behind for the first 3 days, neutral beyond.

From: Avichal Mehra

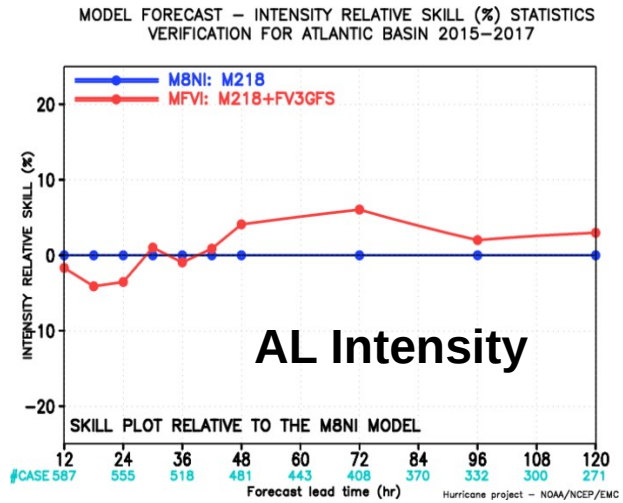
FY18 HMON Testing with FV3GFS

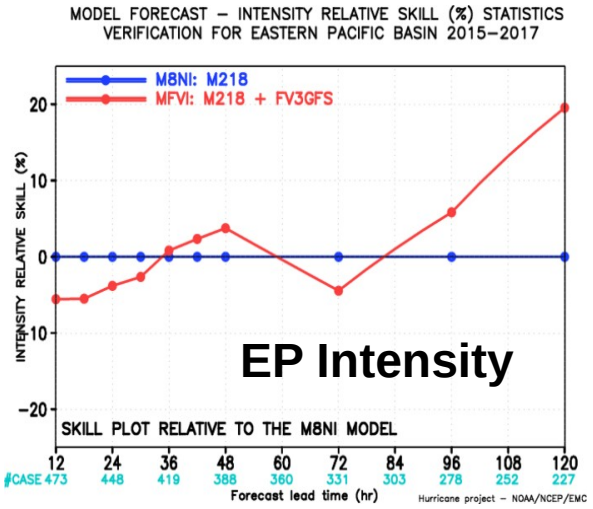
Priority Storms, Early Model





AL: improvement in **track** skill for all lead times peaking at around 14 % (at Day 3) while giving an **average improvement of 10%. Intensity** skill improvements start after Day 2 with **4-6% improvements at Day 2 and 3.**

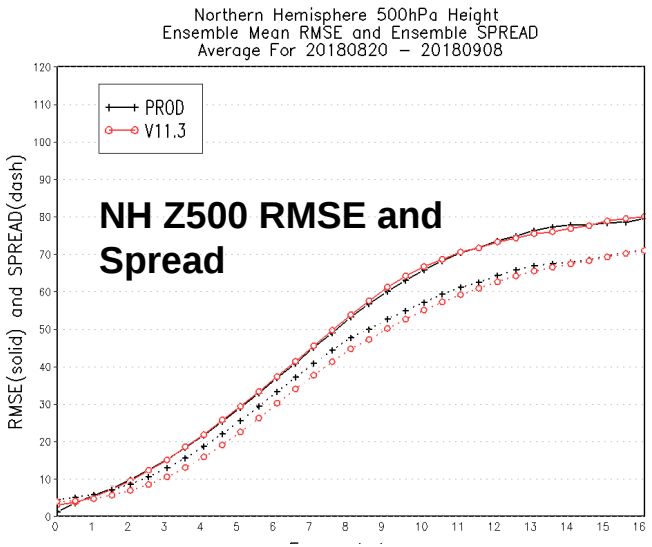


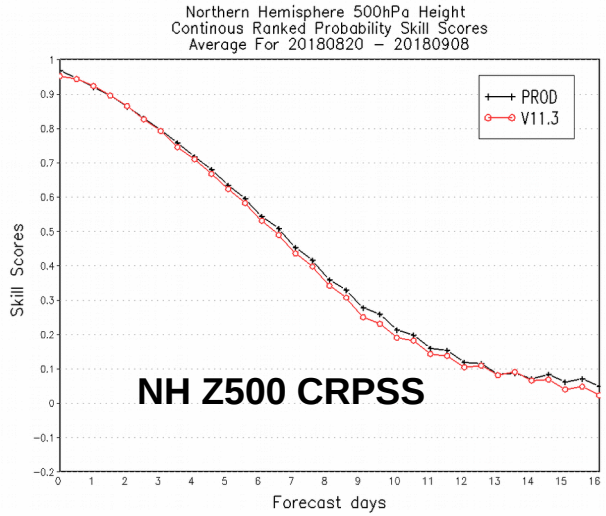


EP: improvement in track skill for early lead times peaking at around 10 % (at hr 30) and once again at Day 5 while giving improvement at **all lead times**. **Intensity** relative skills are **neutral till Day 3** and significantly **positive at Day 4 (6%) and Day 5 (20%).**

From: Avichal Mehra

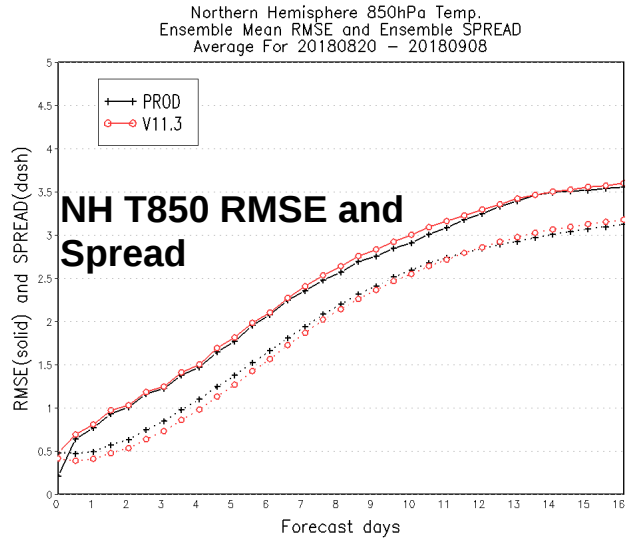
Operational GEFS initialized with FV3GFS (Summer)

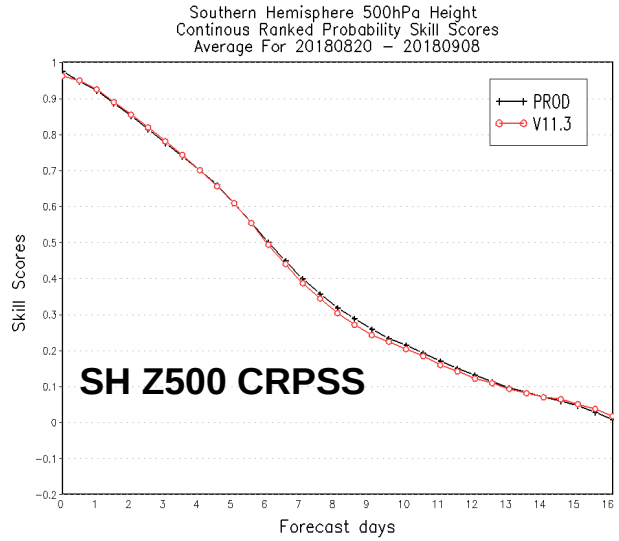




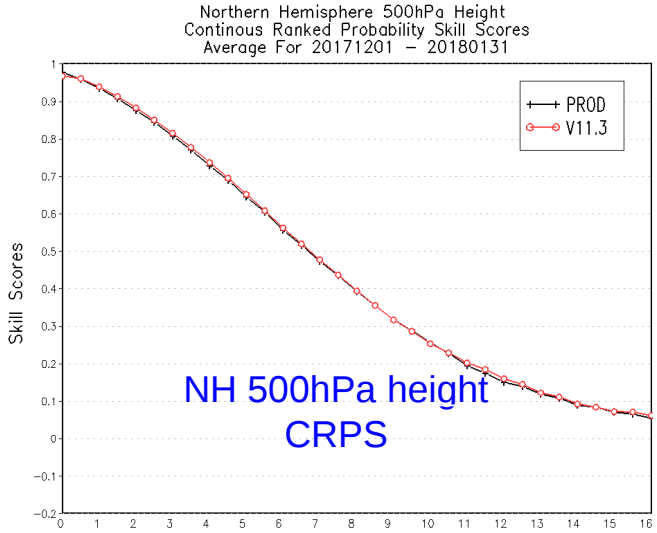
Prod
Initialized with FV3GFS

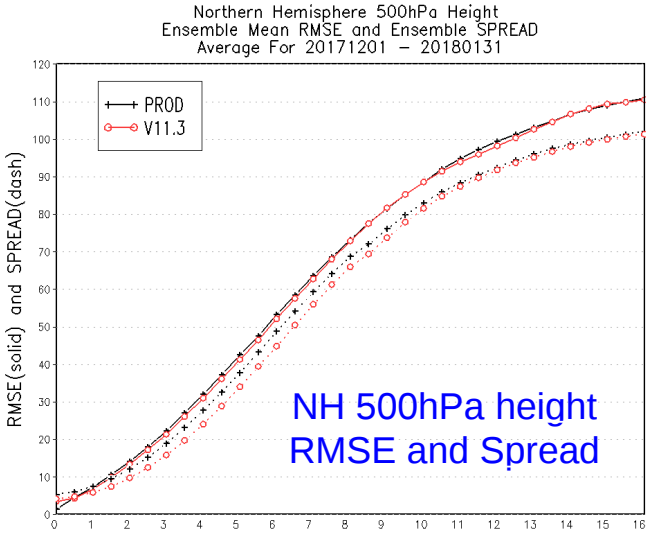
Mostly neutral impact

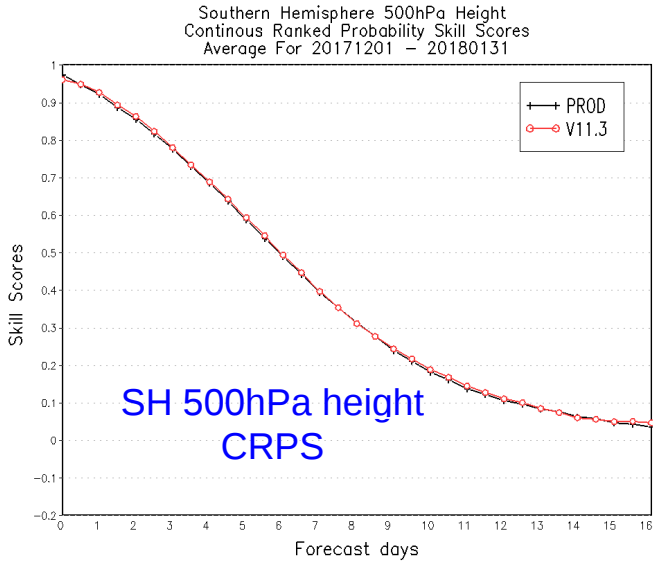


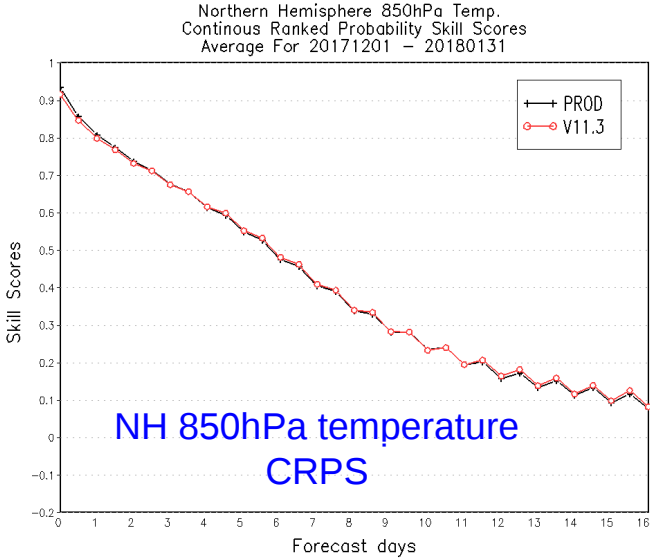


Operational GEFS initialized with FV3GFS (Winter)







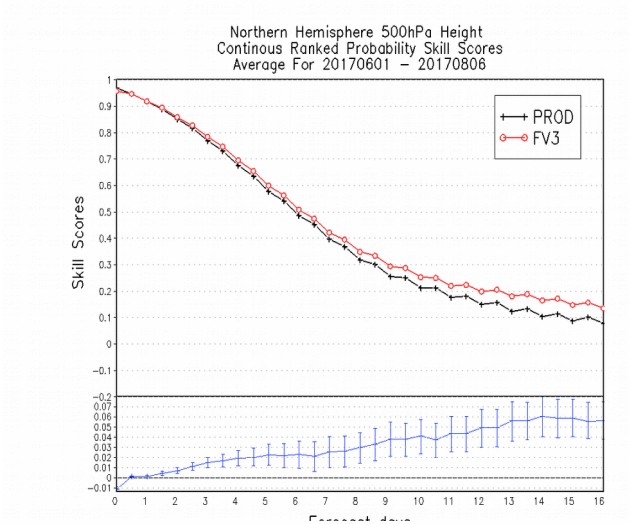


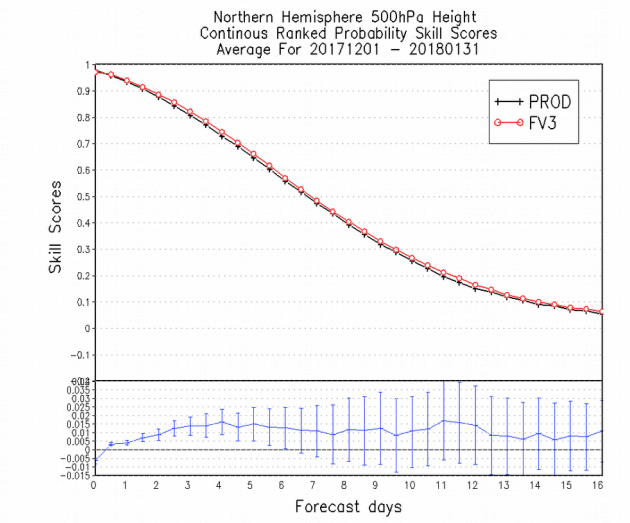
Prod
Initialized with FV3GFS

GEFS w/FV3GFS slightly better than oper. GEFS

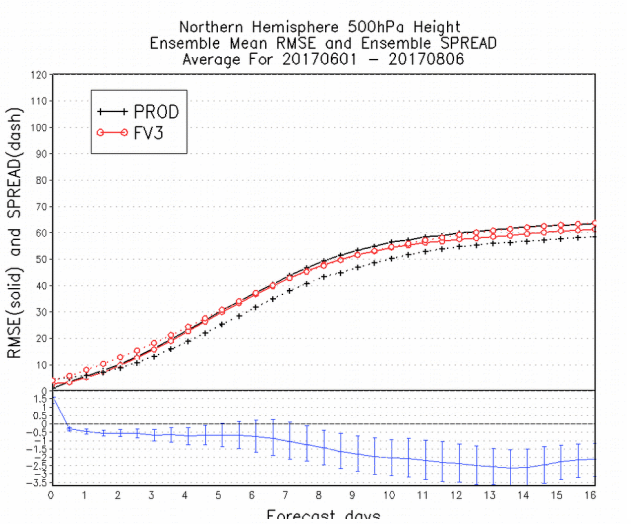
GEFSv12 Testing with FV3GFS: Z500

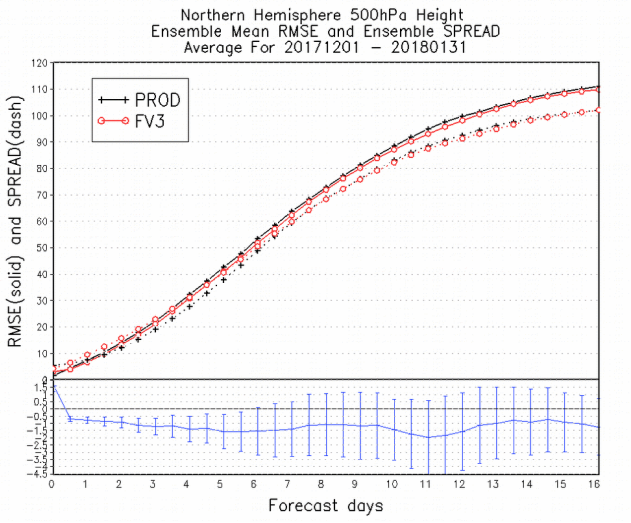
CRPS





RMSE and Spread





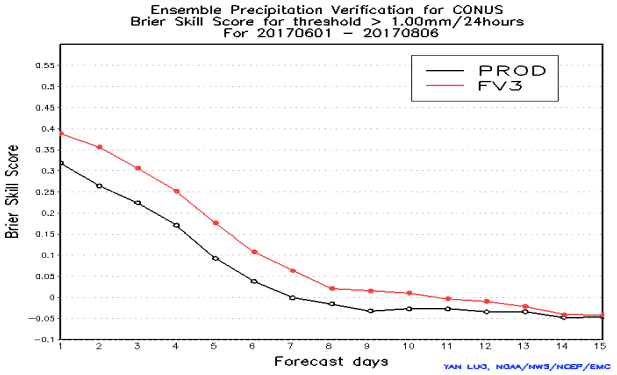
Warm Season

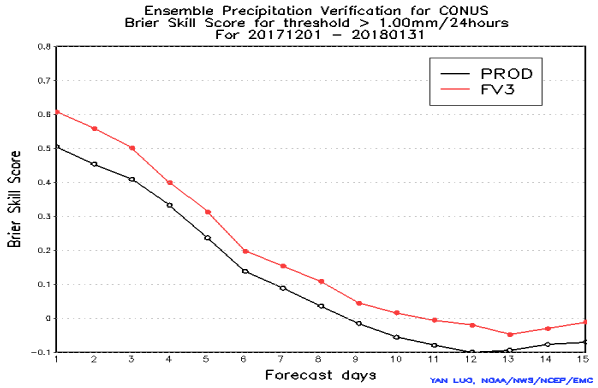
- **GEFS (v12 beta) overall outperforms OPS-GEFS (v11) in terms of various standard verification scores**

Cold Season

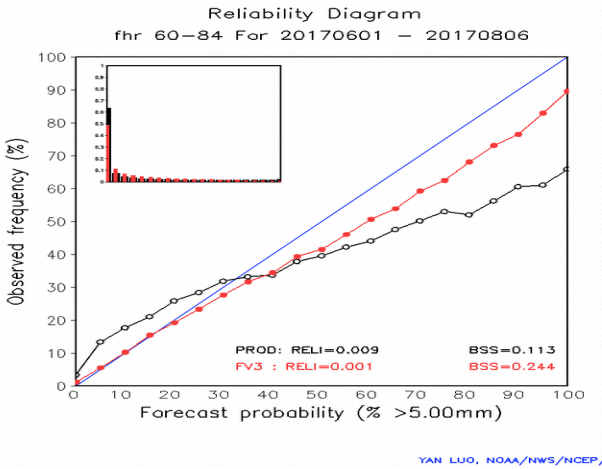
GEFSv12 Testing with FV3GFS: CONUS Precipitation

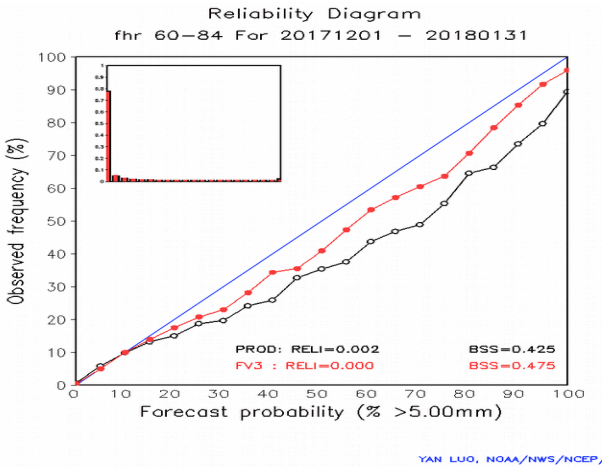
>1mm BSS





60-84hr forecast >5mm Reliability





Warm Season

- Precipitation forecast is significantly improved compared with OPS-GEFS (v11), especially for reliability.

Cold Season

Global Wave Model Testing with FV3GFS

- Nowcast wave heights generated by NCEP's Global Wave Model
  - GSM forcing (left)
  - FV3 forcing (right)
- Retrospective: June 2017
- Relative to wave heights from ALTIKA altimeter

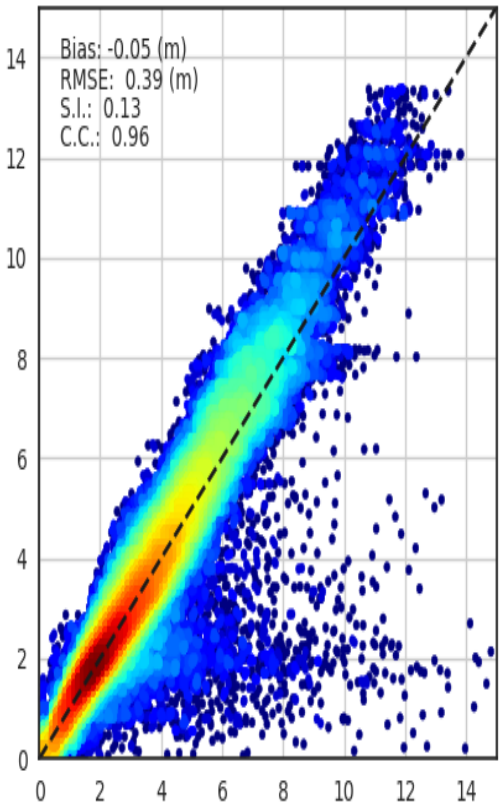
- **Consistent results for mean conditions at all ranges**

- **FV3-forced waves positive bias**

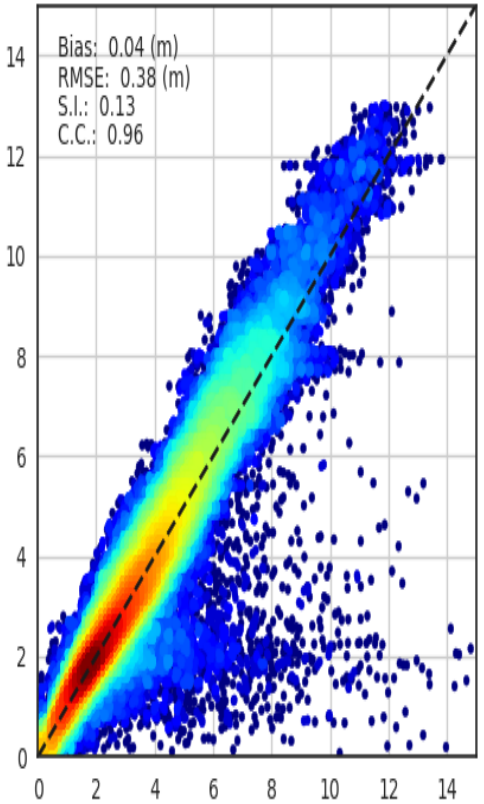
- **GSM negative bias of same magnitude**

- All other statistics, similar

GSM-forced Wave

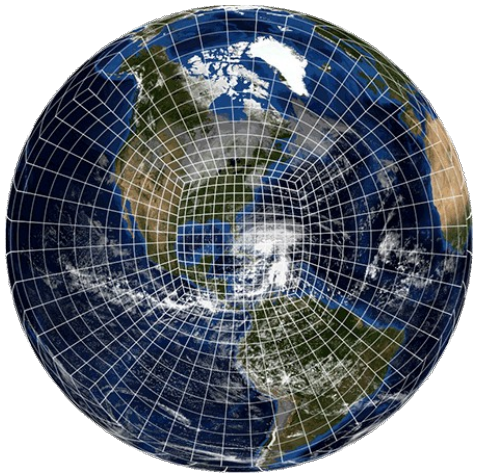


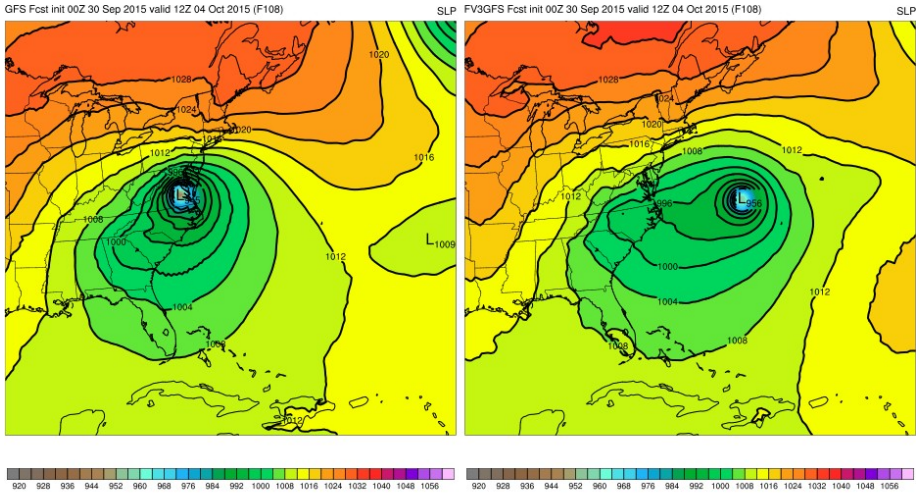
FV3-forced Wave

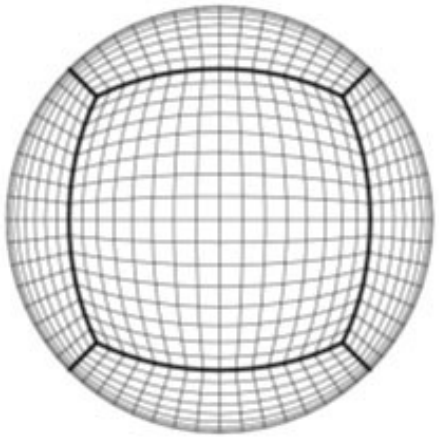


From: Henrique Alves

THE MODEL EVALUATION GROUP
INDEPENDENT ASSESSMENT of the FV3GFS







Geoff Manikin, Alicia Bentley, Logan Dawson, Tracey Dorian

NCEP/EMC Model Evaluation Group

1 October 2018

THE INITIAL EXPECTATIONS (from 5/3/18 MEG KICKOFF WEBINAR)

- Since most of the physics are the same as currently being run in the GFS, we overall don't expect large systematic differences
- The primary goal of this evaluation is to make sure that there are no major problems with the FV3 and that it at least matches overall GFS performance
- With validation of the FV3 core in the Global Forecast System, work can begin on FV3GFS V2 (with further advancements in physics and resolution)

Official Evaluation Website

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

TIMELINE

FV3GFS Code Frozen	Parallel Runs Begin	Evaluation Period (Start - End)	Recommendations from Field Due	NCEP Director Briefing	Code Handoff to NCO	IT Test Period (Start - End)	Implementation Date
3/7/18	4/1/18	5/25/18 - 9/10/18	9/24/18	10/1/18	10/1/18	~12/20/18 - ~1/20/19	~1/24/19

SUMMARY

FV3GFS MEG Evaluation Summary - Presented by Geoff Manikin (9/20/18 MEG Meeting)
NCEP/EMC CCB Presentation - Presented by Fanglin Yang (9/24/18 CCB Meeting)
FV3GFS NOAA/NWS Evaluation Summary - Presented by Logan Dawson (9/27/18 MEG Meeting)

INFORMATION

FV3 Dynamical Core Information - Developed by GFDL
FV3GFS Evaluation Overview - Presented by Geoff Manikin (5/3/18 MEG Meeting)
FV3GFS SST Issue and Fix - Presented by Geoff Manikin (5/24/18 MEG Meeting)
FV3GFS Soil Moisture, Reflectivity, Visibility - Presented by Geoff Manikin (5/31/18 MEG Meeting)
FV3GFS Statistical Update - Presented by Logan Dawson (6/14/18 MEG Meeting)
FV3GFS Inst. Precip. Rate, Reflectivity, Visibility - Presented by Alicia Bentley/Logan Dawson (6/28/18 MEG Meeting)
MEG Evaluation of FV3GFS Retrospectives - Presented by Logan Dawson (7/19/18 MEG Meeting)
FV3GFS Statistical Update - Presented by Alicia Bentley (8/9/18 MEG Meeting)
FV3GFS East Coast Winter Storm Retrospectives - Presented by Tracey Dorian/Alicia Bentley/Logan Dawson (8/16/18 MEG Meeting)
FV3GFS Tropical Cyclone Status Update - Presented by Vijay Tallapragada (8/16/18 NHC Briefing)
FV3GFS North Atlantic/East Pacific TC Retrospectives - Presented by Geoff Manikin (8/23/18 MEG Meeting)
FV3GFS Western U.S. Retrospectives - Presented by Alicia Bentley (9/6/18 MEG Meeting)
FV3GFS Alaskan Retrospectives - Presented by Tracey Dorian (9/6/18 MEG Meeting)
FV3GFS Cold SST Concerns (e.g., Alaska's Cook Inlet) - Presented by Logan Dawson (9/6/18 MEG Meeting)
FV3GFS Products Update - Presented by Logan Dawson (9/13/18 MEG Meeting)
FV3GFS QPF Statistics - Presented by Tracey Dorian (9/13/18 MEG Meeting)
FV3GFS QPF Retrospectives - Presented by Alicia Bentley (9/13/18 MEG Meeting)

DATA

FV3GFS Data - Available on Para NOMADS
List of New Output Parameters - Maintained by Hui-ya Chuang

REAL-TIME GRAPHICS/OUTPUT

FV3GFS Analyses and Guidance (Note: GFS = FV3GFS) - Maintained by NCEP/NCO
GFS vs. FV3GFS Forecast Comparisons - Maintained by Geoff Manikin
GFS vs. FV3GFS Plume Comparisons - Maintained by Tracey Dorian
GFS vs. FV3GFS Sounding Comparisons - Maintained by Tracey Dorian
NAM vs. FV3GFS vs. GFS Comparisons - Maintained by Eric Rogers
FV3GFS vs. GFS MOS Comparisons - Maintained by NOAA/NWS/MDL

VERIFICATION

NCEP/EMC Model Evaluation Group (MEG) - Maintained by Geoff Manikin
NCEP/EMC MEG Past Presentations - Available to NOAA email addresses only
NCEP/EMC QPF Verification Scores for FV3GFS Runs - Maintained by Ying Lin
NCEP/EMC Daily Precipitation Verification (FV3GFS included) - Maintained by Ying Lin
NCEP/EMC Fit-to-Observations (Fit2Obs) for FV3GFS - Maintained by Suranjana Saha and Jack Woollen

NCEP/EMC Global Model Experimental Forecast Performance Statistics (Real-time Parallel) - Maintained by FV3GFS Parallel Execution Group
Retrospective Forecast Performance Statistics [Full Period (June 2015-September 2018)]
Retrospective Forecast Performance Statistics [December 2017-May 2018]
Retrospective Forecast Performance Statistics [May 2017-November 2017]
Retrospective Forecast Performance Statistics [December 2016-May 2017]
Retrospective Forecast Performance Statistics [May 2016-November 2016]
Retrospective Forecast Performance Statistics [December 2015-May 2016]
Retrospective Forecast Performance Statistics [May 2015-November 2015]

RETROSPECTIVES

FV3GFS Retrospective Case Studies - Images by NCEP/EMC MEG
MEG Evaluation of FV3GFS Retrospectives - Presented by Logan Dawson (7/19/18 MEG Meeting)
FV3GFS East Coast Winter Storm Retrospectives - Presented by Tracey Dorian/Alicia Bentley/Logan Dawson (8/16/18 MEG Meeting)
FV3GFS North Atlantic/East Pacific TC Retrospectives - Presented by Geoff Manikin (8/23/18 MEG Meeting)
FV3GFS Western U.S. Retrospectives - Presented by Alicia Bentley (9/6/18 MEG Meeting)
FV3GFS Alaskan Retrospectives - Presented by Tracey Dorian (9/6/18 MEG Meeting)
FV3GFS QPF Retrospectives - Presented by Alicia Bentley (9/13/18 MEG Meeting)

FEEDBACK

VLAB - FV3 Evaluation Forum - Monitored by NCEP/EMC MEG

Update:
1. If you email FV3GFS-Feedback.VLab@noaa.gov, a post will appear in the forum and forum subscribers will get an email from vlab.notifications@noaa.gov.
2. If you reply to the email from vlab.notifications@noaa.gov, forum subscribers will get an email and your response will appear in the forum.

Non-VLab members who email the forum will be identified as "Anonymous". If you write to the forum as a non-VLab member, please identify yourself in your email.

HIGHLIGHTS of THE GOOD

1. 500 MB SCORES ARE EXCELLENT, AND OTHER STATS ARE GENERALLY AS GOOD AS THE GFS

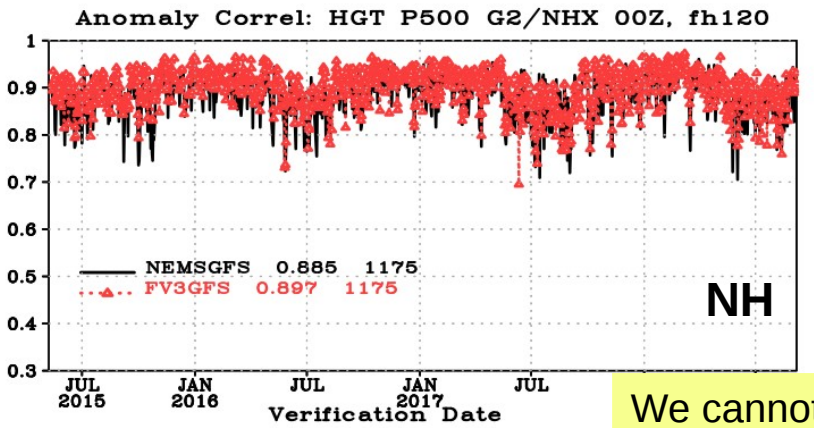
2. INTENSE TROPICAL DEEPENING NOT SEEN IN FV3GFS

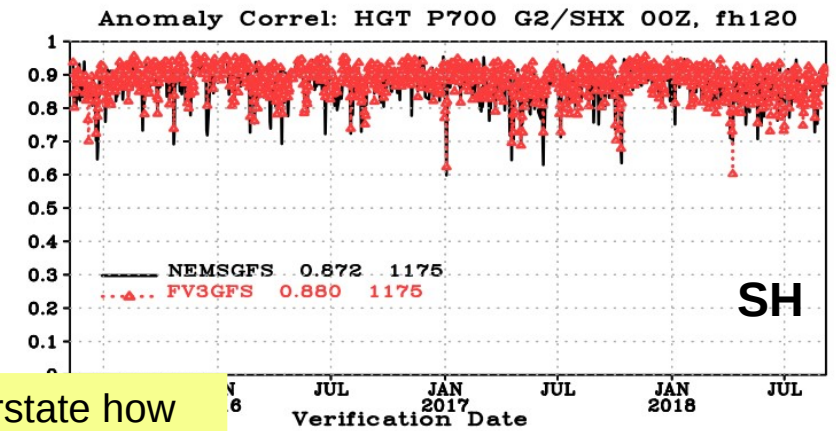
3. DOUBLE-LOW CENTERS NOT SEEN IN FV3GFS FORECASTS OR ANALYSES

4. FV3GFS SEEMS TO BE ABLE TO GENERATE MODEST SFC COLD POOLS

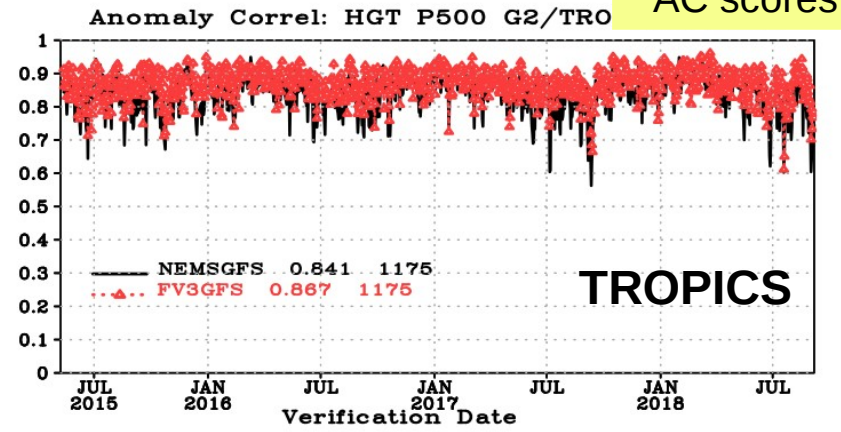
5. SIMULATED COMPOSITE REFLECTIVITY IS A NICE ADDITION TO THE OUTPUT

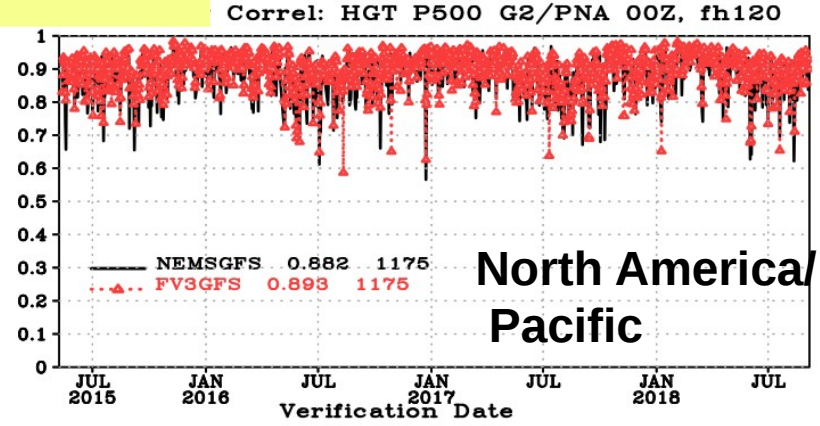
DAY 5 500 mb AC SCORES





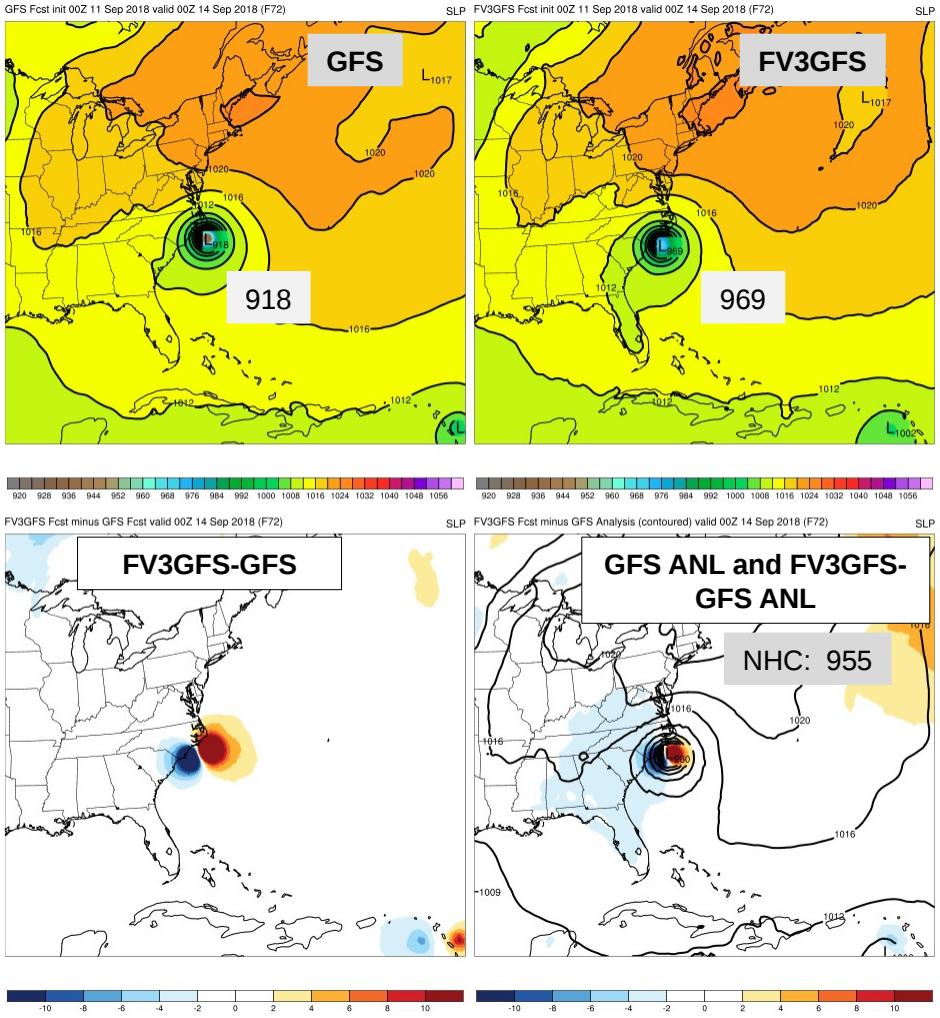
We cannot overstate how impressive the cumulative AC scores are.





The warm season diurnal pcp plot (shown earlier) also shows impressive improvement

Intense Tropical Cyclone deepening in GFS not observed in FV3GFS

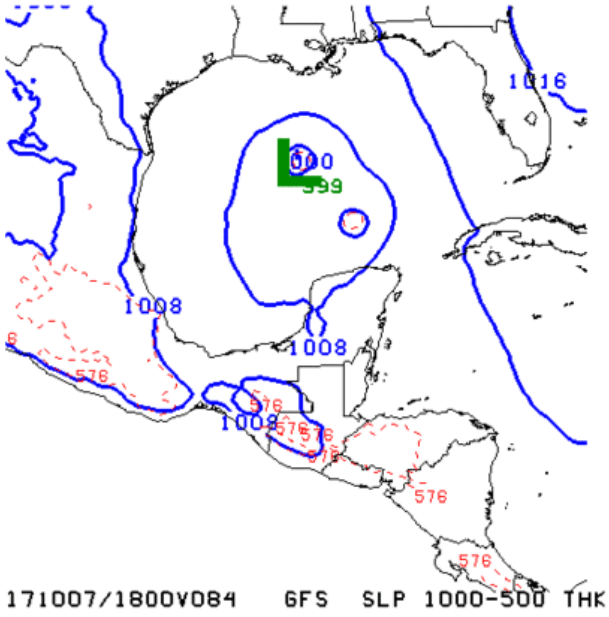


FLORENCE
00z 9/11/18 F72

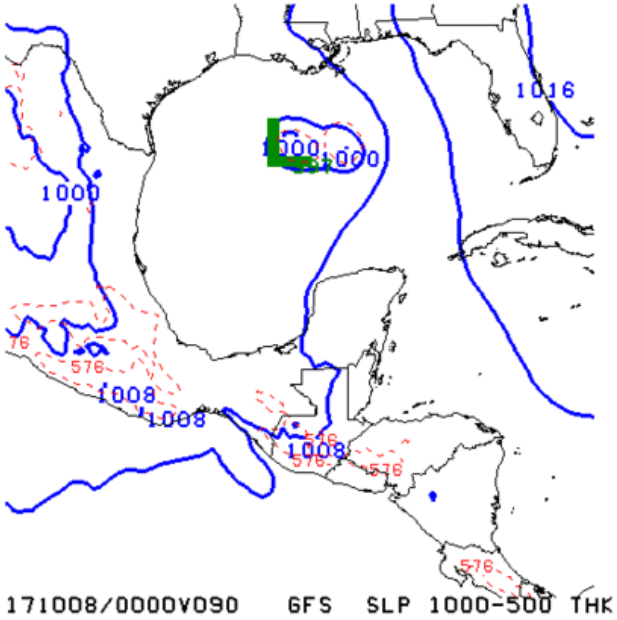
KEY:
Blue = FV3GFS is stronger (lower MSLP)

Red = FV3GFS is weaker (higher MSLP)

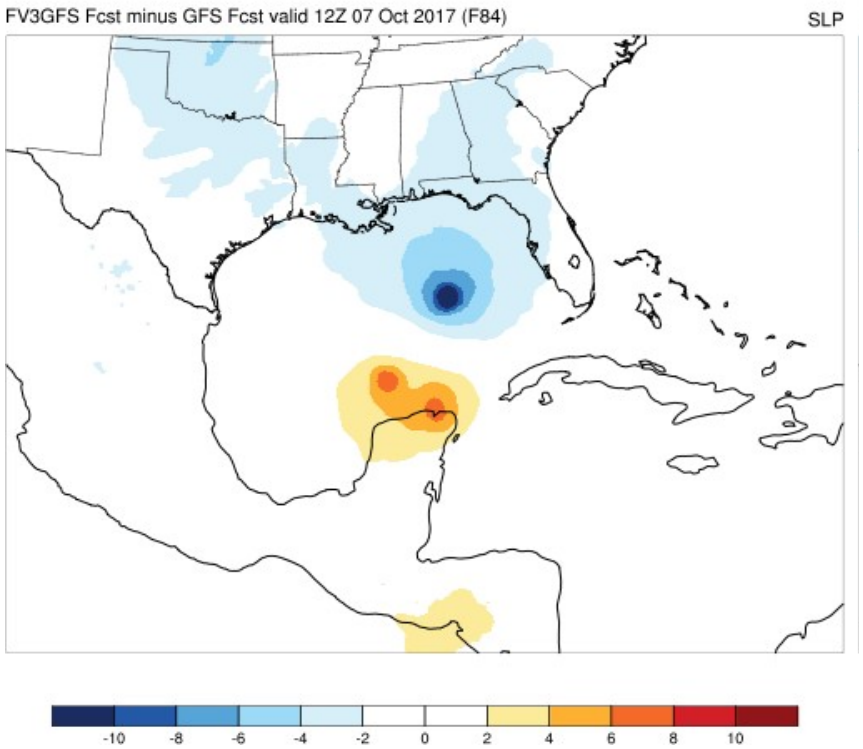
MULTIPLE TROPICAL CYCLONE CENTERS GENERATED BY GFS NOT SEEN IN FV3GFS FORECASTS or ANALYSES



GFS FCSTS for NATE



NATE SLP FV3GFS - GFS

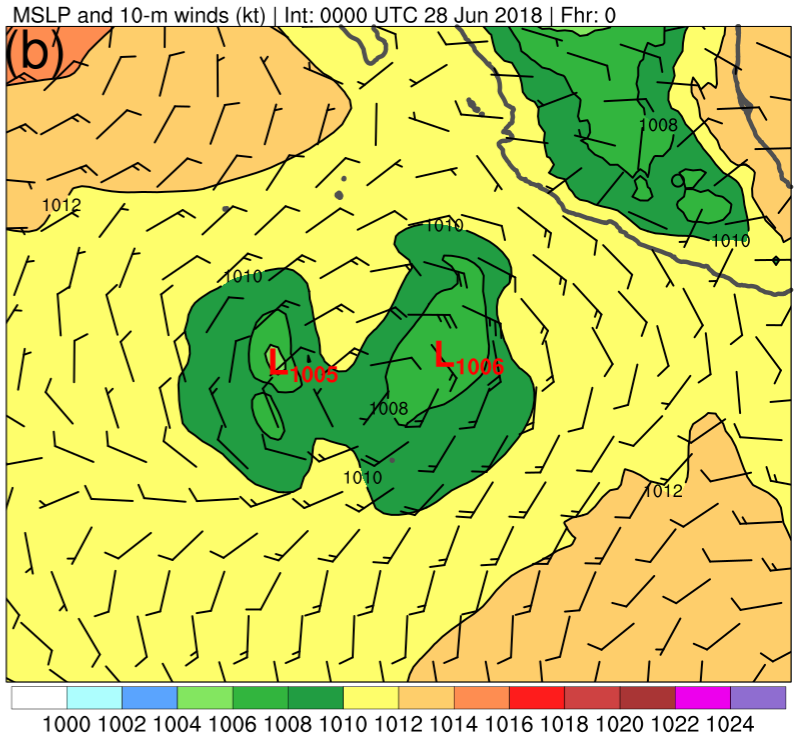


THIS FV3GFS-GFS SLP DIFFERENCE PLOT SUMS UP MULTIPLE CYCLES OF THE NATE CASE NICELY:

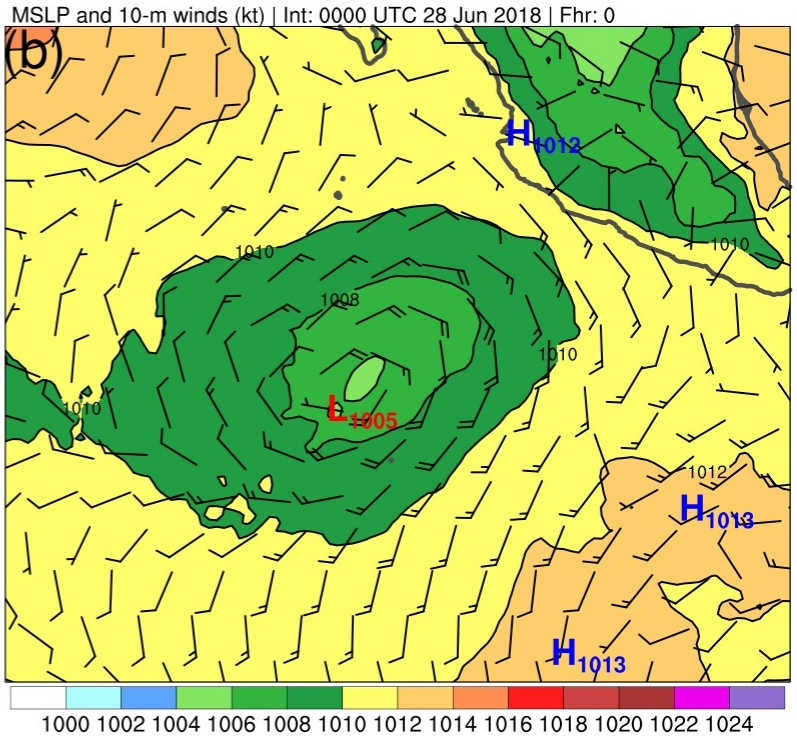
1) FV3GFS STRONGER THAN GFS (correct)
2) FV3GFS FASTER THAN GFS (too fast)
3) **GFS HAD PROBLEMS WITH DOUBLE LOW STRUCTURE THAT WERE MUCH LESS PREVALENT IN FV3GFS (correct)**

6/28/18 00z F00

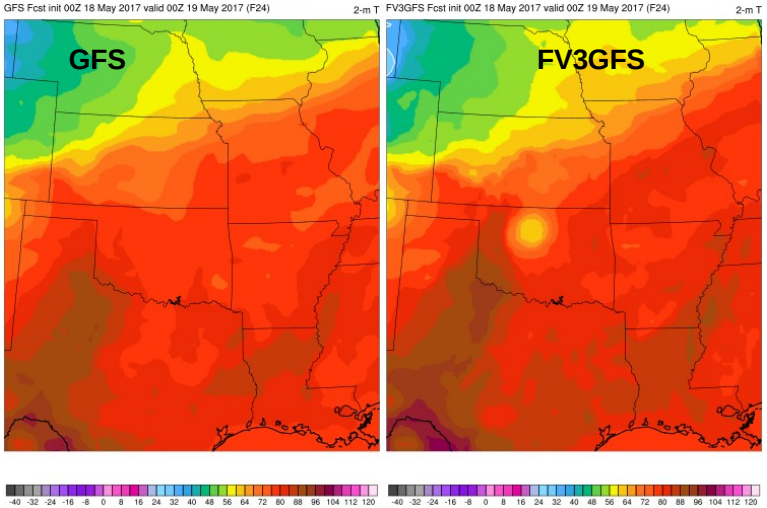
GFS

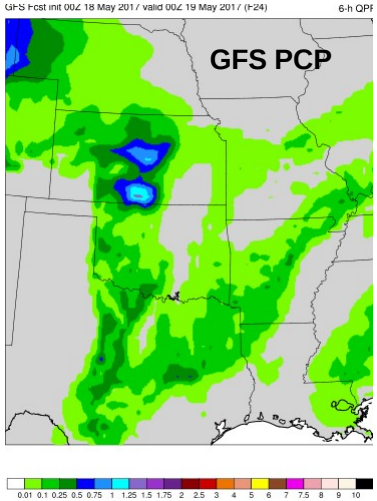


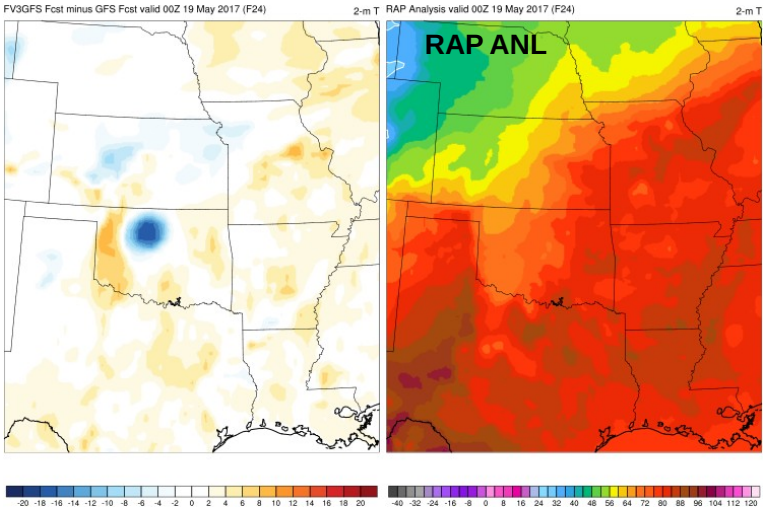
FV3

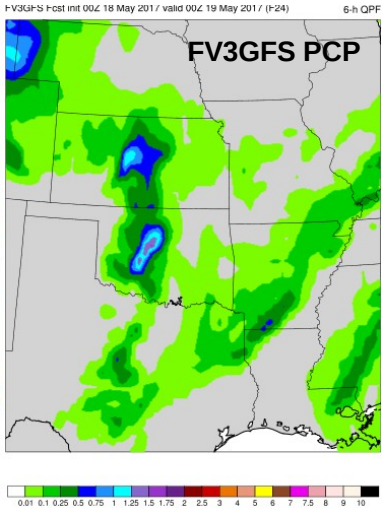


SOME INDICATION THAT FV3GFS CAN GENERATE MODEST SFC COLD POOLS FROM SIGNIFICANT CONVECTION

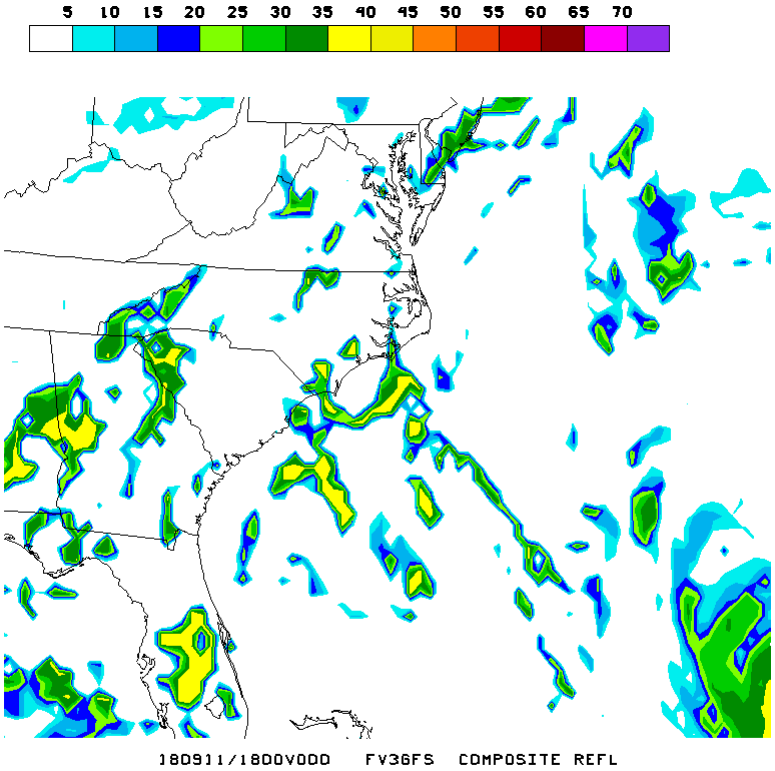








NEW SIMULATED COMPOSITE REFLECTIVITY OUTPUT IS A NICE ADDITION



SOME CONCERNS

1. FV3GFS CAN BE TOO PROGRESSIVE WITH SYNOPTIC PATTERN

2. WARM-SEASON DRY QPF BIAS FOR MID AND UPPER THRESHOLDS

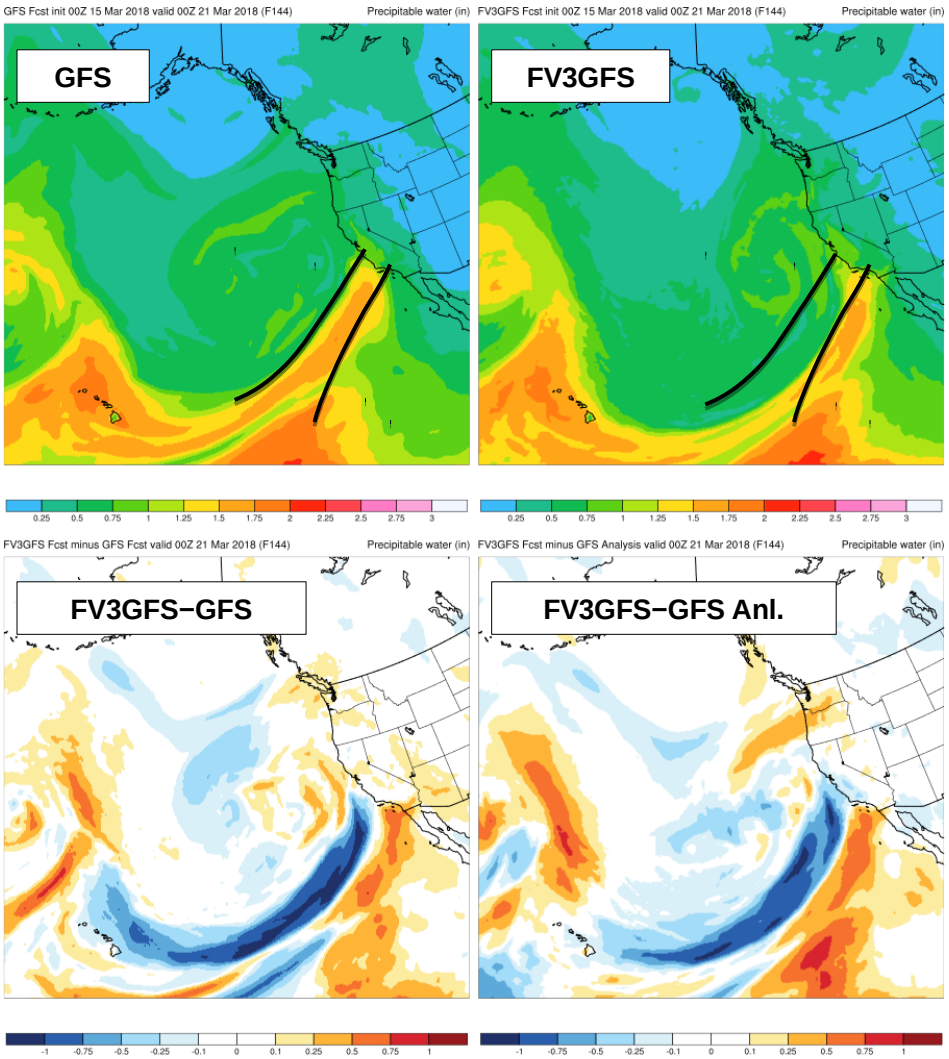
3. SST ISSUES

4. OCCASIONAL SPURIOUS SECONDARY LOWS SINCE HORD CHANGE
   WAS MADE

5. EXTREME 2-M TEMPS

6. LOW 500 MB HEIGHT BIAS

FV3GFS TOO PROGRESSIVE



3/21/18 00Z F144 PW

MAIN POINTS:

- GFS shifts AR west before FV3GFS
- FV3GFS is more progressive with AR than GFS

KEY:
Blue = FV3GFS is drier (lower PW)

Red = FV3GFS is wetter (higher PW)

Black lines denote analyzed AR axis

FV3GFS – GFS 500mb HGT BLIZZARD of 2016

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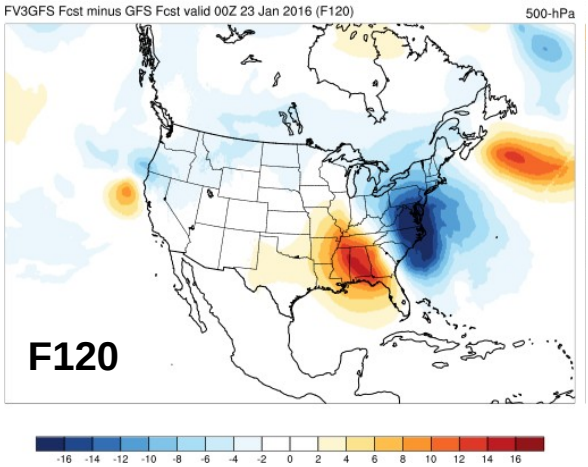
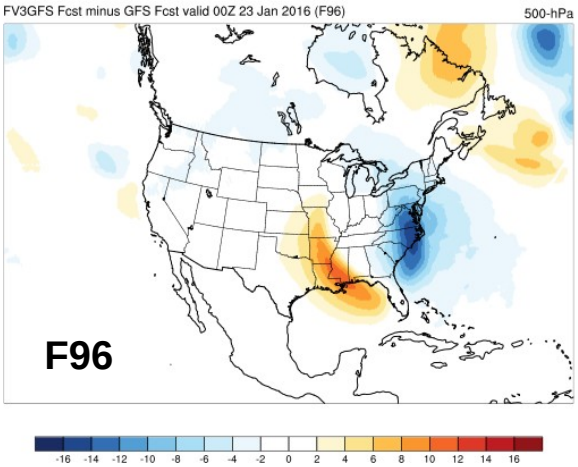
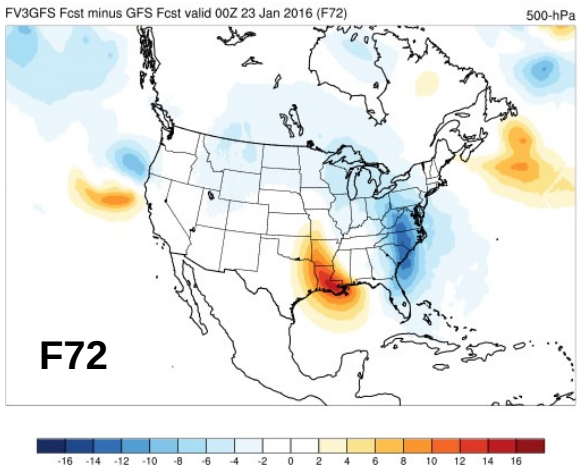
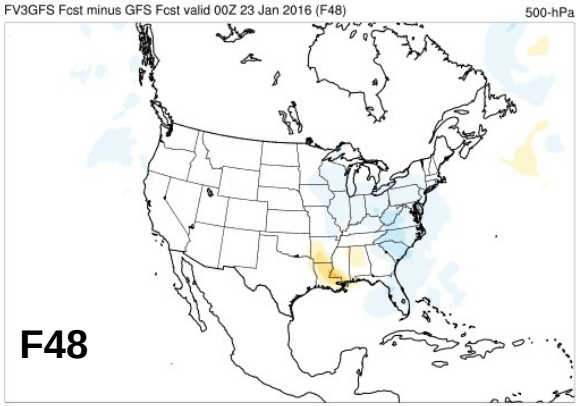


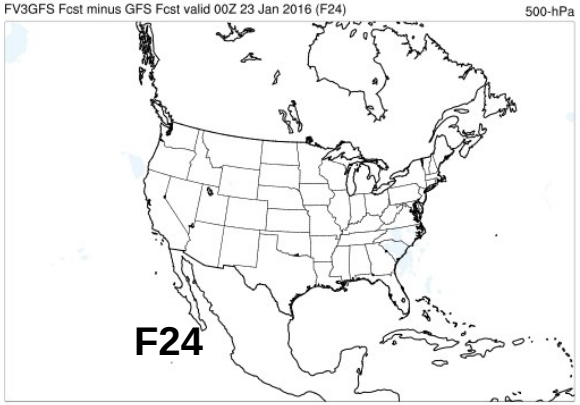




Blue = FV3GFS has lower heights

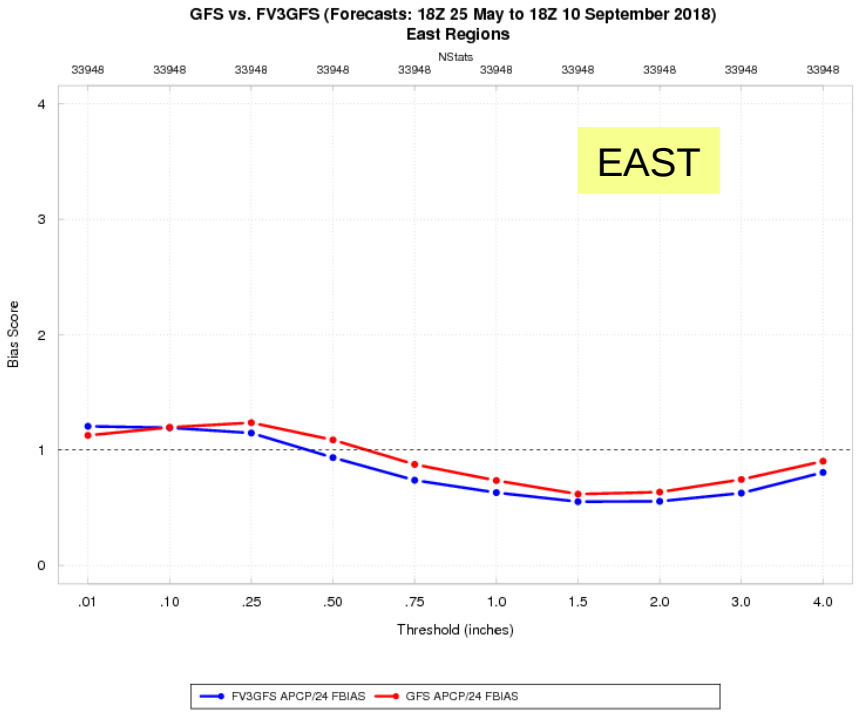
Red = FV3GFS has higher heights

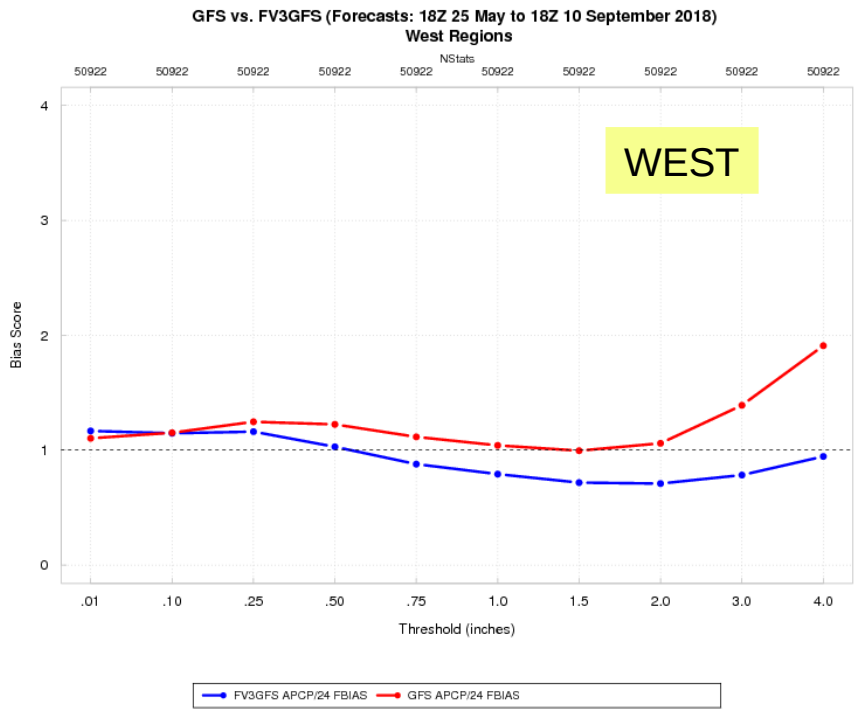




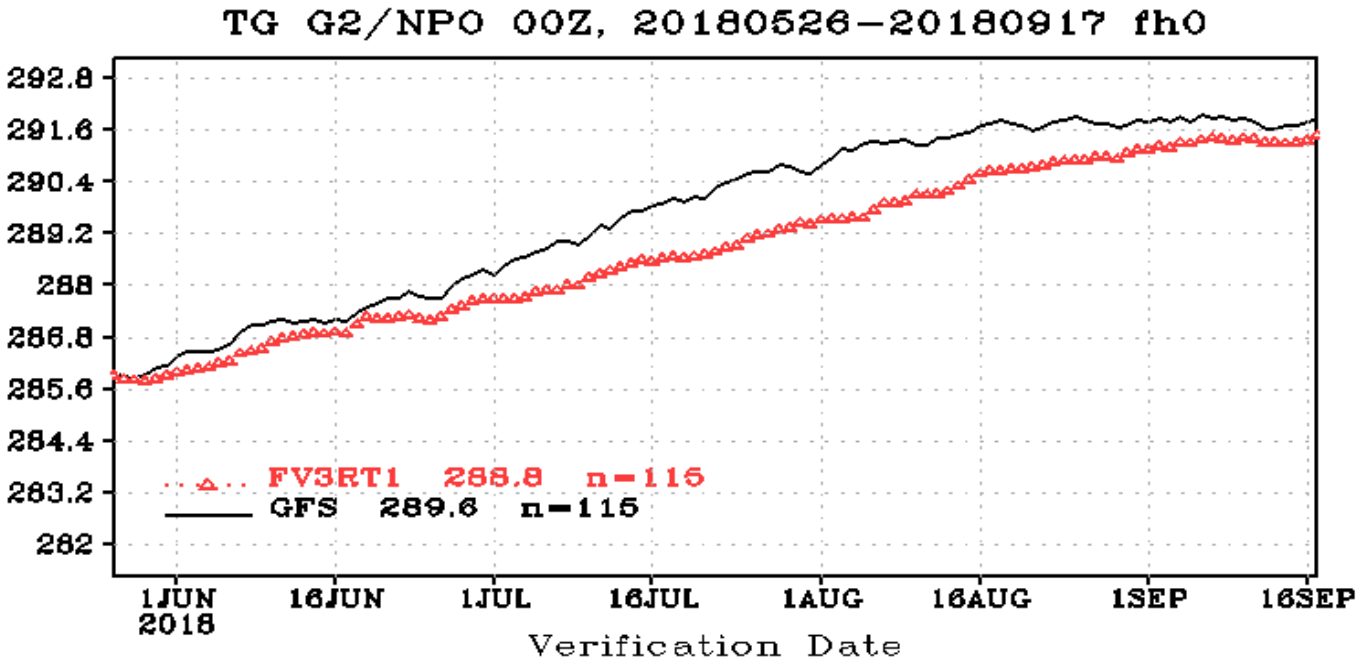
CLEARLY TOO PROGRESSIVE in MEDIUM RANGE; DIFFS GET SMALLER CLOSER to VERIFYING TIME

WARM SEASON DRY QPF BIAS FOR MID AND UPPER-RANGE AMOUNTS



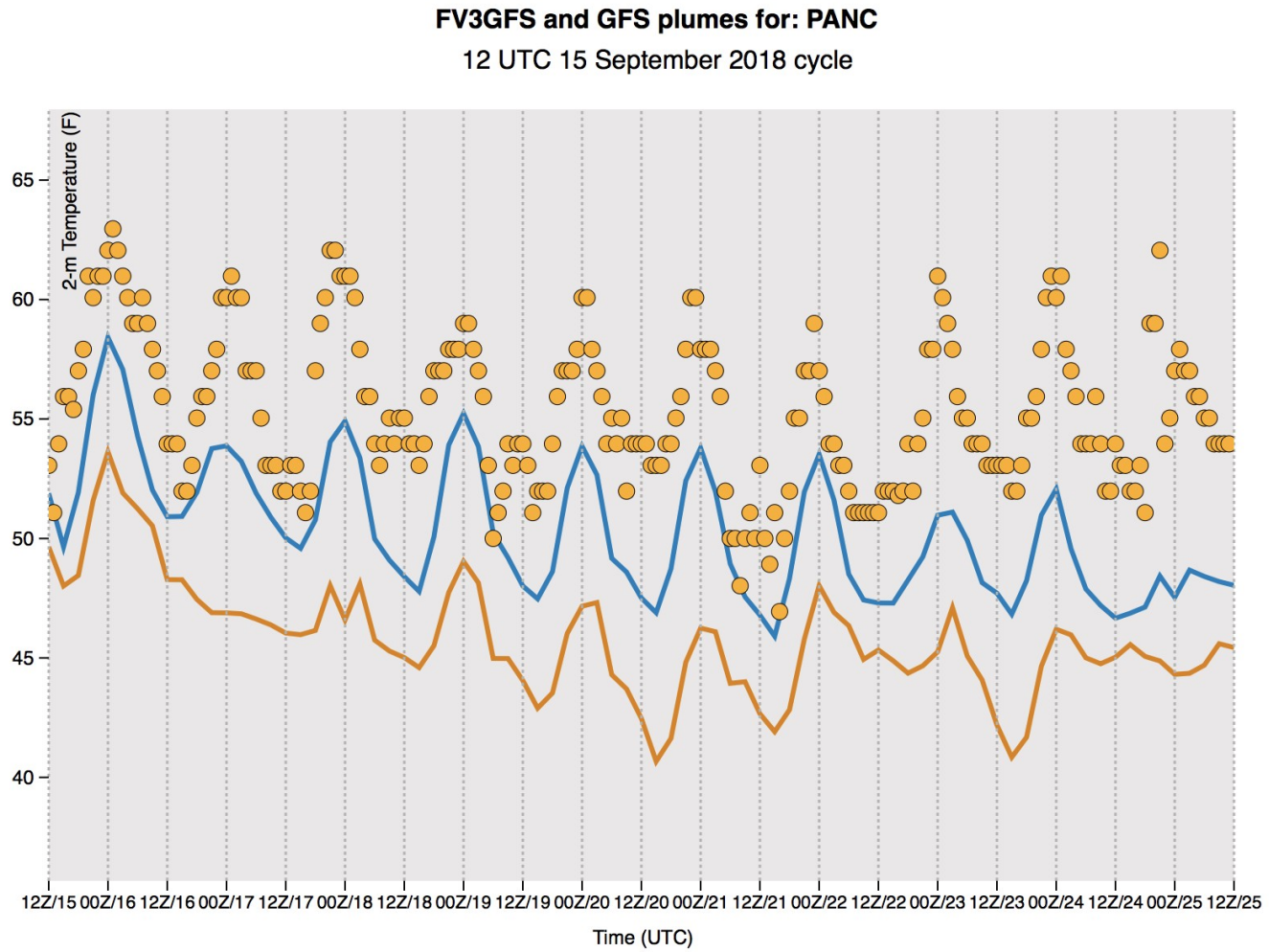


SST ISSUES



MEAN SST in NORTHERN PACIFIC OCEAN – CLEARLY COLDER IN FV3GFS

SAMPLE PLUMES of 2-mT at ANCHORAGE, AK



GFS

FV3GFS

OBS

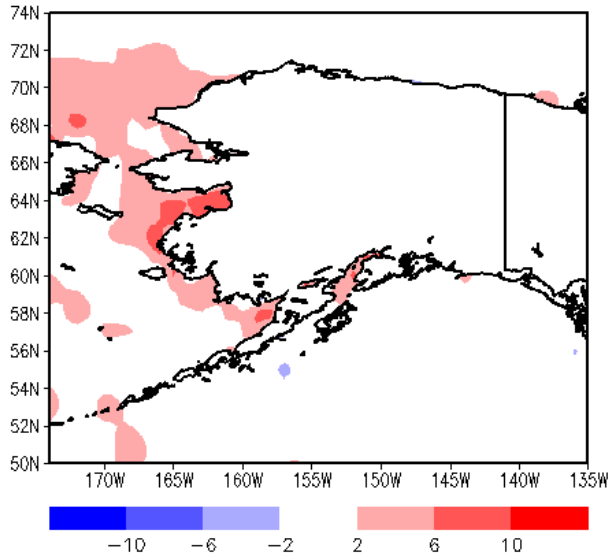
RECENT NSST CHANGES ARE ENCOURAGING

Cycle 2018071600 f24 Valid 2018071700
Sea Surface Temperatures (°C)

F24 valid 00Z

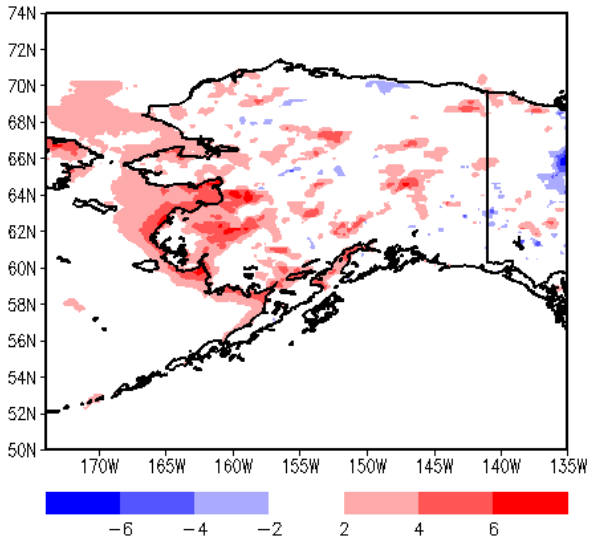
Cycle 2018071600 f24 Valid 2018071700
2m Temperature [F]

FV3GFStest–FV3GFSrealtime

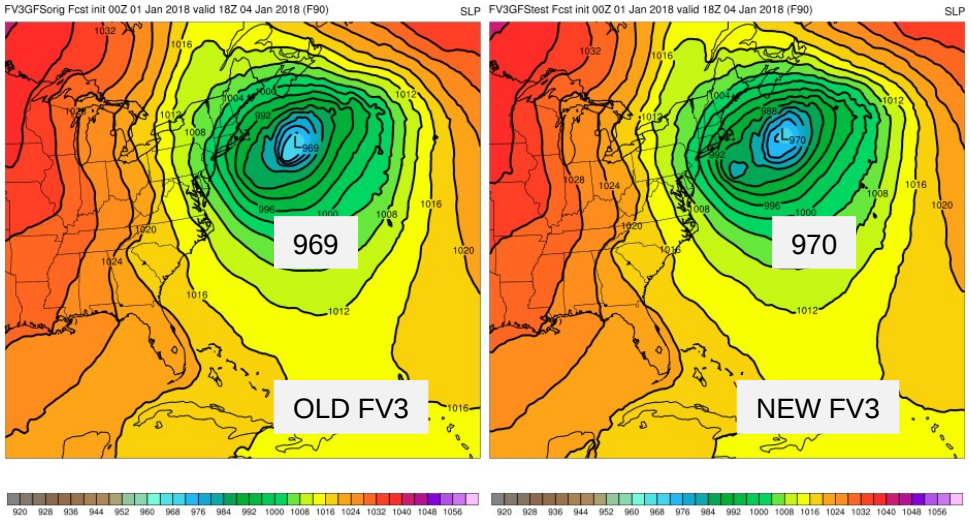


RED indicates where run with new SST is wamer

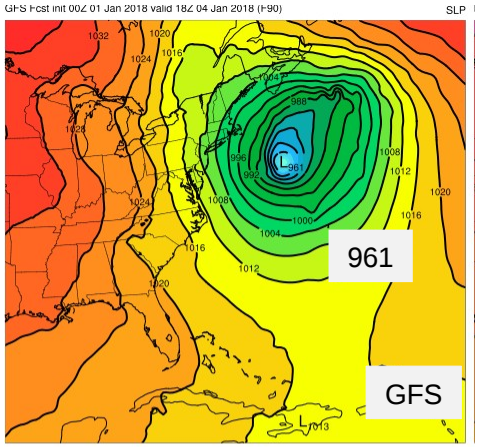
FV3GFStest–FV3GFSrealtime



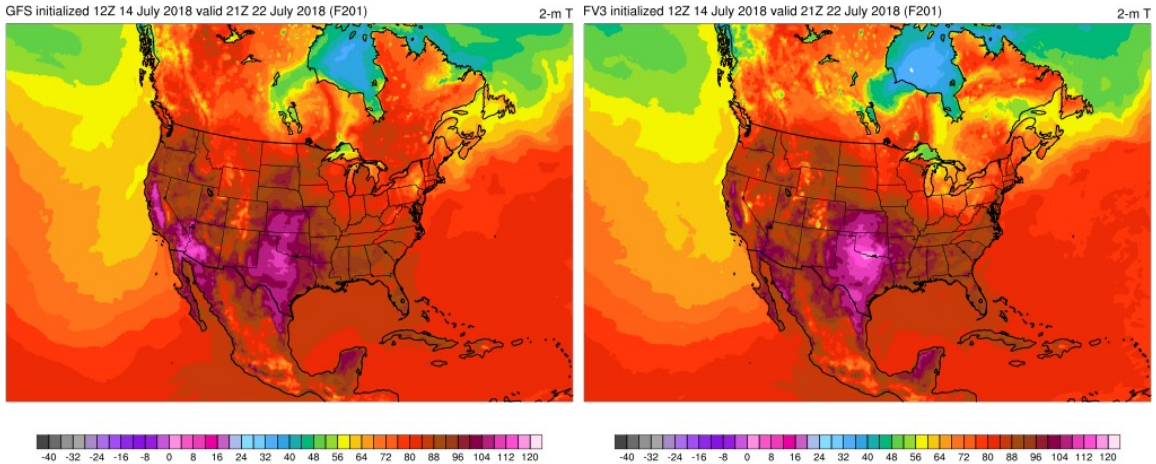
SPURIOUS SECONDARY (NON-TROPICAL) LOWS SHOW UP OCCASIONALLY IN FV3GFS SINCE THE HORD CHANGE WAS MADE



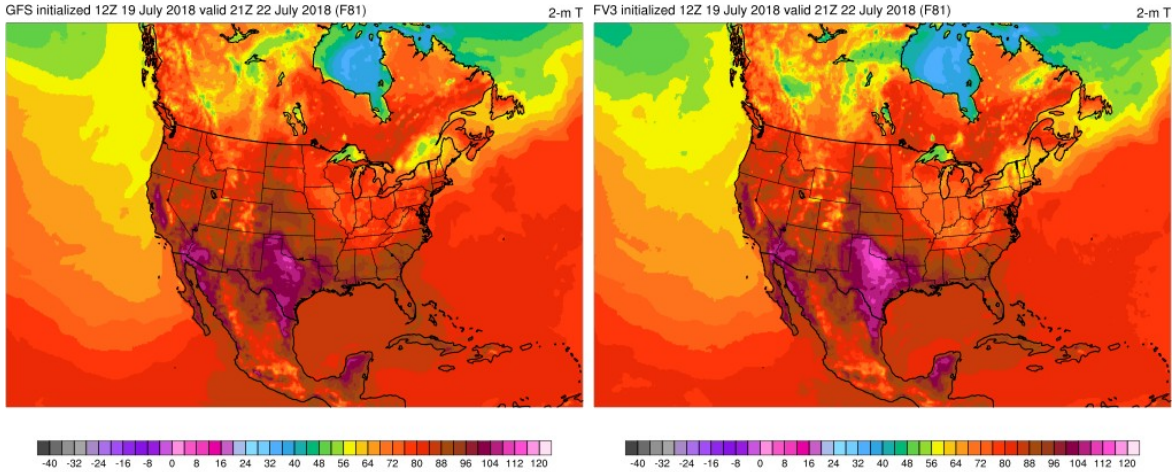
1/1/18 00z F90



EXTREME 2-m TEMPS



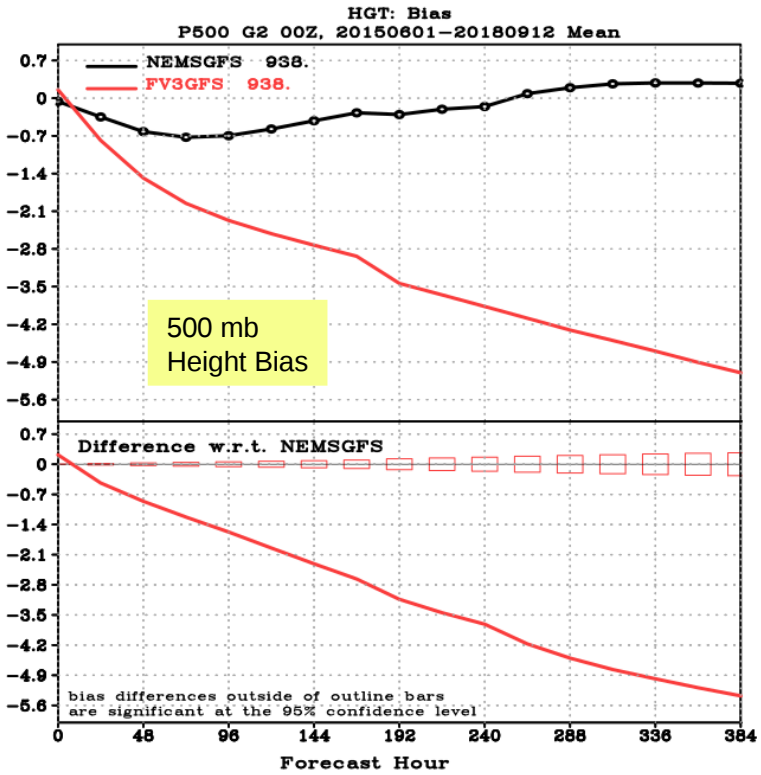
GFS **FV3GFS**

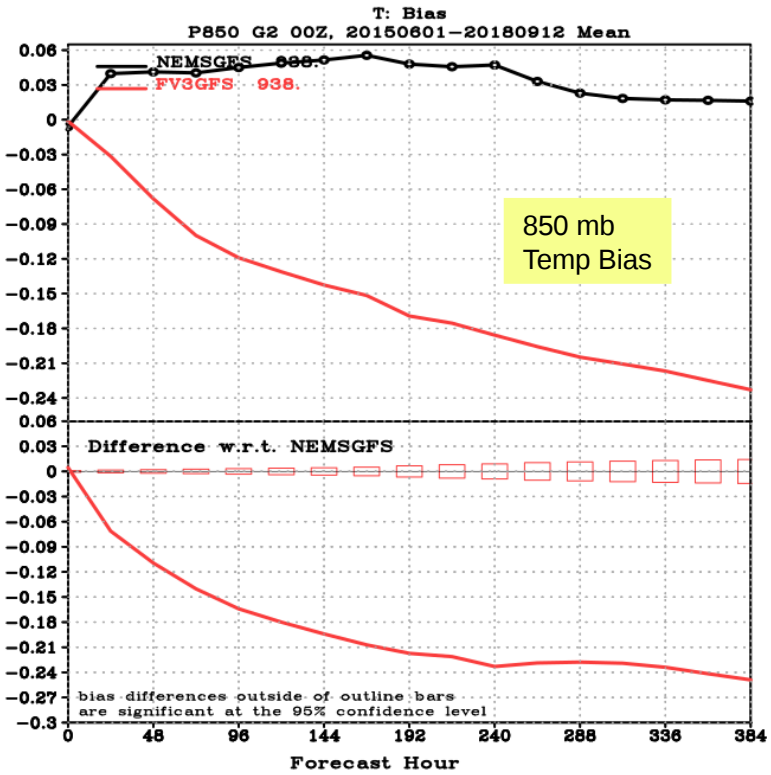


The extremely hot temps, seen during the spring, seemed to disappear after the SST bug was fixed in late May, but there was still occasional evidence of the problem later in summer

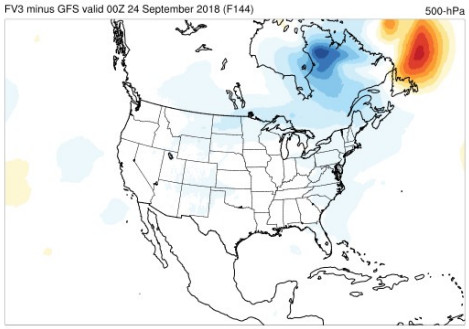
MID-LEVEL HEIGHT BIAS GROWS MORE NEGATIVE WITH FORECAST LENGTH

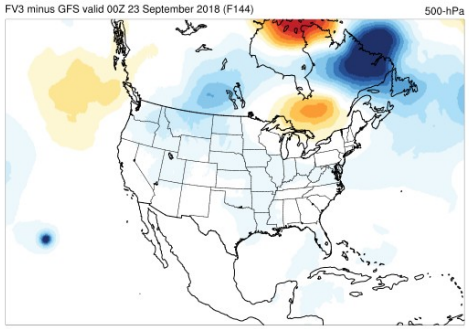
FV3GFS **GFS**

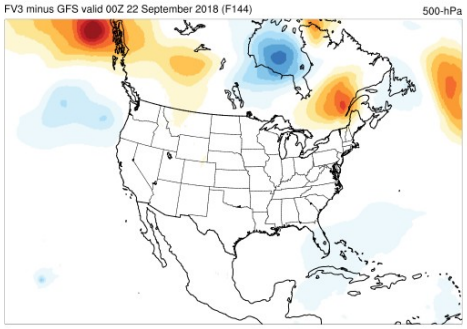


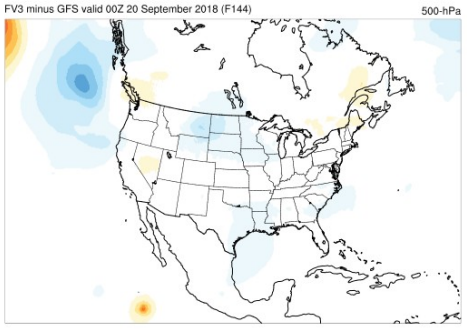


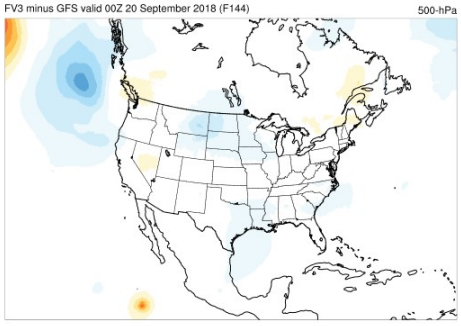
500 mb Height FV3GFS – GFS for a recent 8-day period

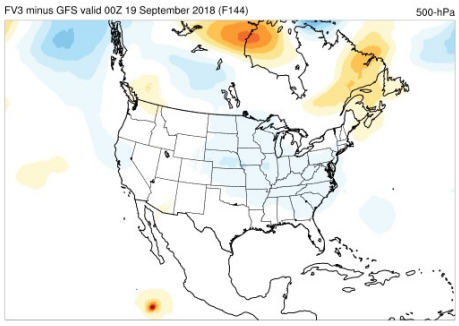


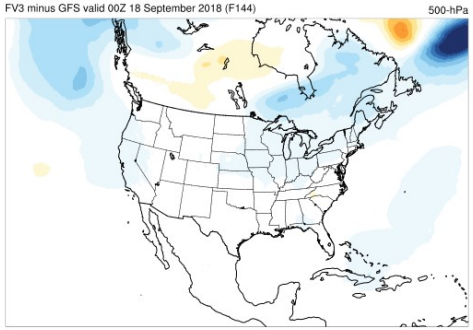


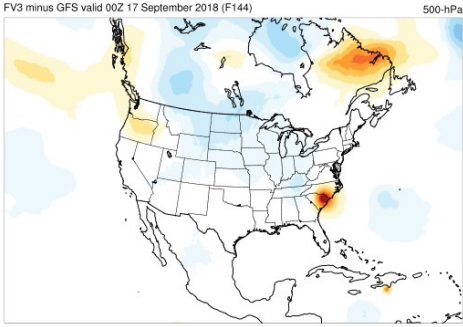


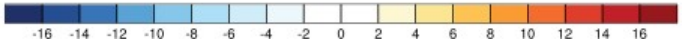












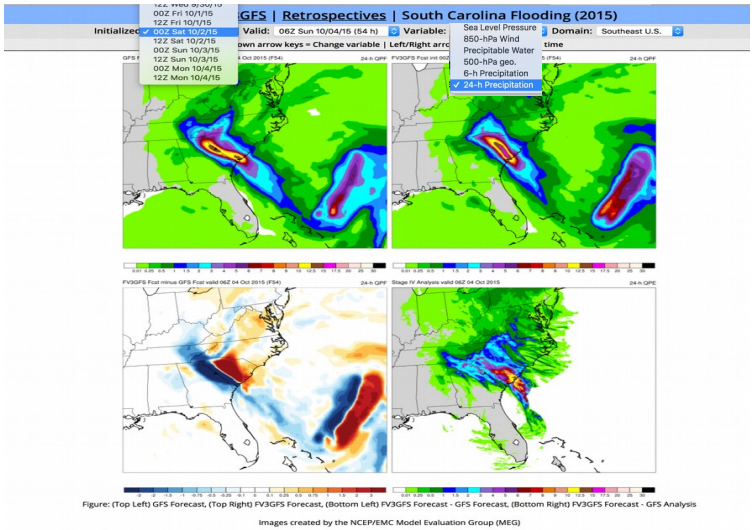
BLUE: FV3GFS HAS LOWER HEIGHTS
ORANGE/RED: GFS HAS LOWER HEIGHTS

MORE BLUE THAN ORANGE ON THESE MAPS, SEEMINGLY CONFIRMING THE BIAS

RETROSPECTIVE CASES

- Done to help the field gain confidence in the FV3GFS for high-impact events of multiple types
- Made ALL graphics available – no cherry picking
- Devoted several MEG briefings to retro reviews
- Helped the MEG identify systematic biases and improvements

Most cases were overall neutral, but a few stood out



Some common themes

- FV3GFS is progressive
- No more extreme TC deepening
- TCs are fast in FV3GFS

2018

"Bomb" Cyclone (3-5 January)
TC Gita (3-22 February)
Mid-Atlantic Windstorm (2-3 March)
Albany, NY, Snowstorm (2-3 March)
New England Nor'easter (7-8 March)
Californian Atmospheric River (21-23 March)
Alaskan Cyclone (23-26 April)

2017

Western U.S. Atmospheric River (6-11 February)
"Pi Day" Blizzard (13-15 March)
Mississippi Valley Flood (25 April-7 May)
Great Plains Severe Weather (18-19 May)
TC Cindy Flooding (19-24 June)
July Nor'easter (29-30 July)
TC Noru (19 July-9 August)
Interior CA Extreme Temps (1-2 August)
TC Harvey (16 August-2 September)
TC Irma (30 August-13 September)
TC Maria (16 September-2 October)
Alaskan Cyclone (26-28 September)
TC Nate (3-11 October)
Southern Snowstorm (7-10 December)
Cold Air Outbreak (25 Dec 2017-7 Jan 2018)

2016

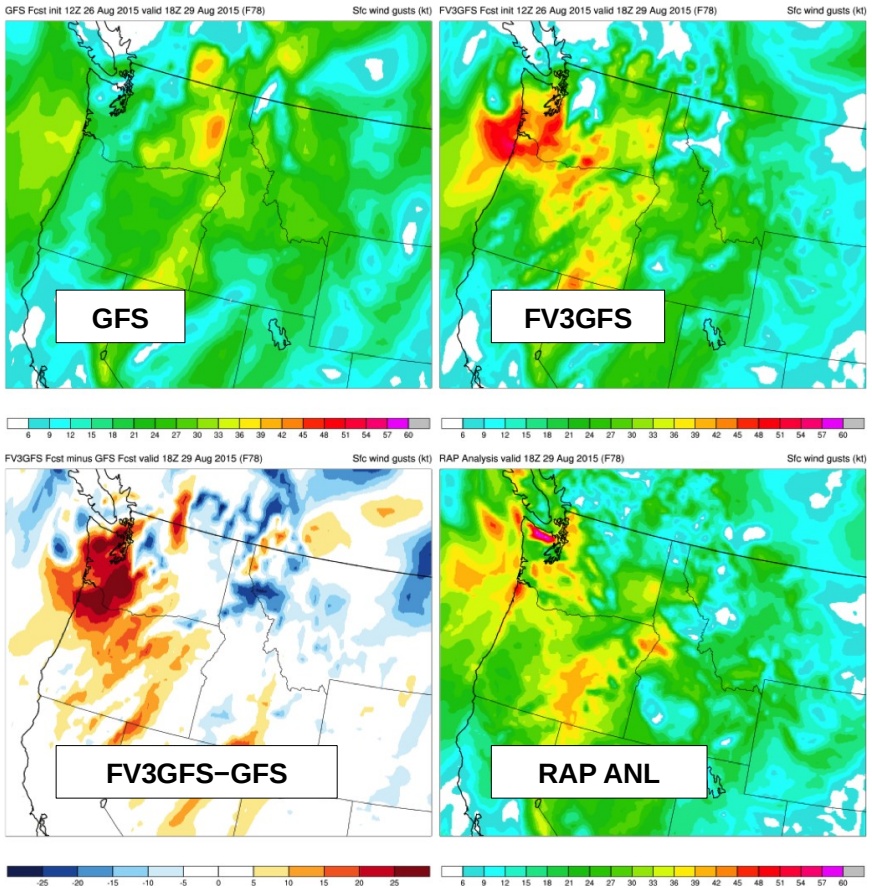
Blizzard of 2016 (21-24 January)
TC Winston (7-26 February)
TC Amos (13-25 April)
Central U.S. Severe Weather Outbreak (26-27 April)
TC Matthew (28 September-10 October)
TC Nicole (4-20 October)
Pacific Northwest Windstorm (13-16 October)

2015

TC Soudelor (29 July-12 August)
TC Erika (24-28 August)
Pacific Northwest Windstorm (29 August)
TC Ida (18-27 September)
TC Joaquin (26 September-15 October)
South Carolina Flooding (1-5 October)
TC Patricia (20-24 October)

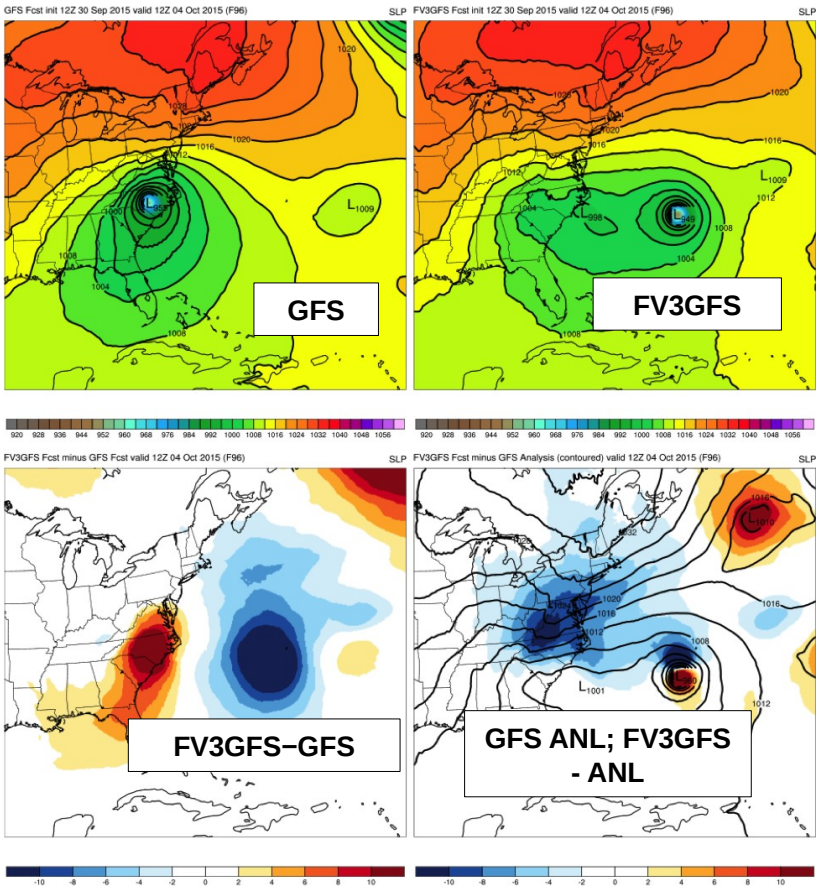
TWO GREAT RETROSPECTIVE CASES OF NOTE

Pacific Northwest Windstorm
12Z 8/26/15 Cycle F78



FV3GFS captured wind threat before GFS

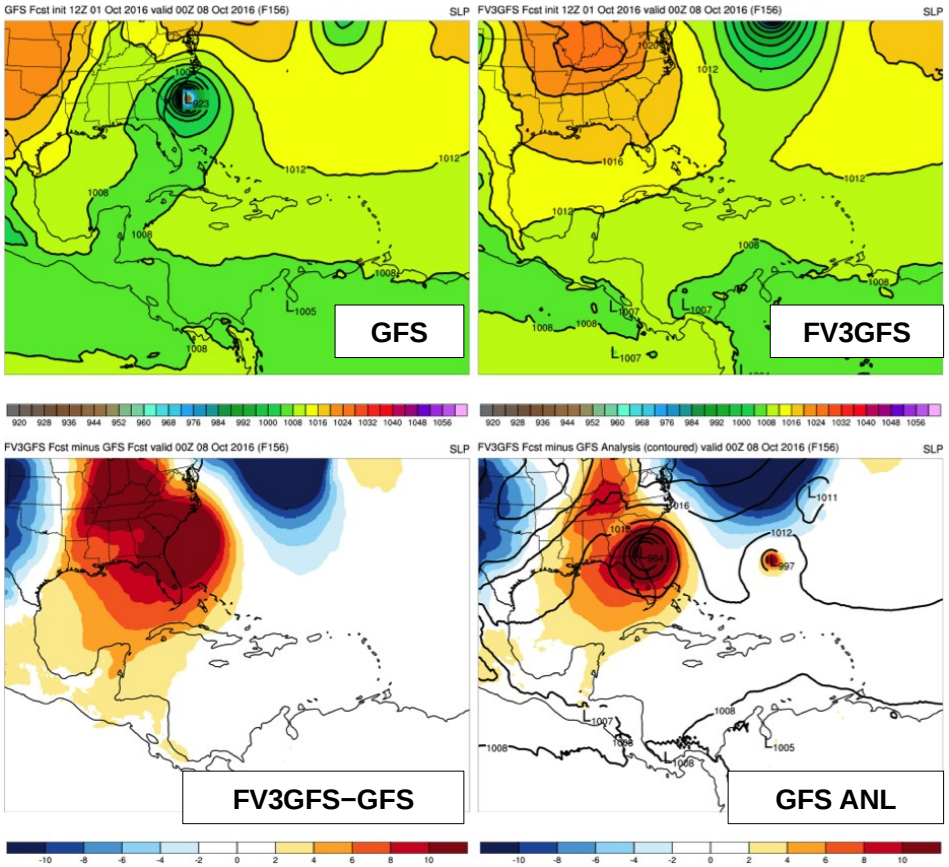
Hurricane Joaquin
12Z 10/4/15 Cycle F96



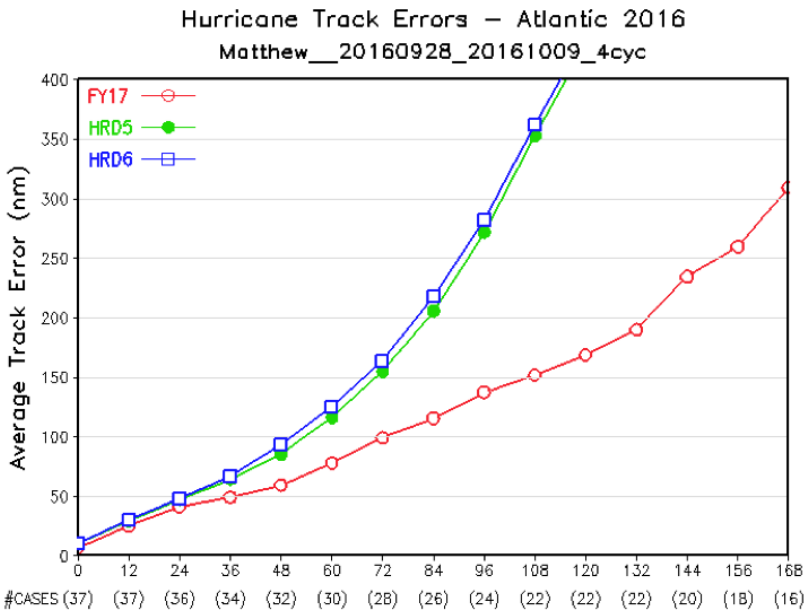
FV3GFS correctly moved away from landfall sooner

ONE POOR RETROSPECTIVE CASE

Hurricane Matthew
12Z 10/1/15 Cycle F156



FV3GFS captured wind threat before GFS



Fast forward speed + progressive synoptic flow may combine to give larger day 6-7 errors

FINAL MEG THOUGHTS

- The synoptic overview statisistcal scores are impressive, as is the reduction of overnight convection
- Most other statistical scores show neutral performance or slight improvement
- Elimination of extreme intensification and overall TC track improvement are huge advantages to the FV3GFS system
- Largest concern is the clear tendency of FV3GFS medium range runs to be too progressive – believe that this is the most important point to communicate to forecasters
- Other concerns include some SST issues (now mitigated), extreme heat, occasional spurious secondary low centers, fast tropical cyclones, and a slightly drier precip bias for mid and high thresholds

While there are some legitimate concerns, the MEG believes that the large improvement in 500 mb AC scores, warm season diurnal cycle, TC track improvement, and elimination of TC double centers and extreme TC intensification justify going forward with this implementation, especially in the context of the FV3GFS setting the table for larger NGGPS improvements going forward

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
Western Region	Neutral	Saw daily differences, some positive and some negative
Central Region	Neutral	QPF, convective diurnal cycle,and winds better. Unsure about winter performance
Southern Region	Implement	Believe that FV3GFS performs similarly to GFS
Eastern Region	Implement	Parallel and retro performance matches GFS
Pacific Region	Neutral	FV3GFS better on TC track. Mixed results on intensity. Some concerns with TC performance in SH and on recent cases.
Alaska Region	Conditionally Implement (if SST issues are addressed)	FV3GFS captures turbulence in mountain wave/downslope events. Cold 2m temperature bias at least partially due to SST issues
SOO-based STI national team	Implement	Mixed performance on high-impact cases; progressive bias, tropical better

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
AWC	Neutral	**Most parameters similar;** *some concern about visibility*
CPC	Implement	**Overall similar performance; ozone is improved, and q is much more realistic**
OPC	Implement	**Impressed by 500 mb ACC scores and improved cyclone tracks;** *FV3GFS mixes out shallow inversions*
NHC	Neutral	**Mixed results for track/intensity**. *FV3GFS would degrade multi-model track consensus by 6-7% at day 7.*
SPC	Neutral	**Overall neutral synoptic performance**. *GFS low biases for instability and 2m dew points are worsened in severe wx environ.*
SWPC	No Evaluation	
WPC	Implement	**FV3GFS corrects northward convective displacement bias;** *concerned by progressive troughs and dry QPF bias*

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Endorsements from Stakeholders

Office	Recommendation	Remarks
ARL	Implement	Overall comparable performance; would like time-averaged DZDT added
MDL	Implement	No degradation to MOS or LAMP
OWP	Neutral	*Dry QPF bias at higher thresholds*

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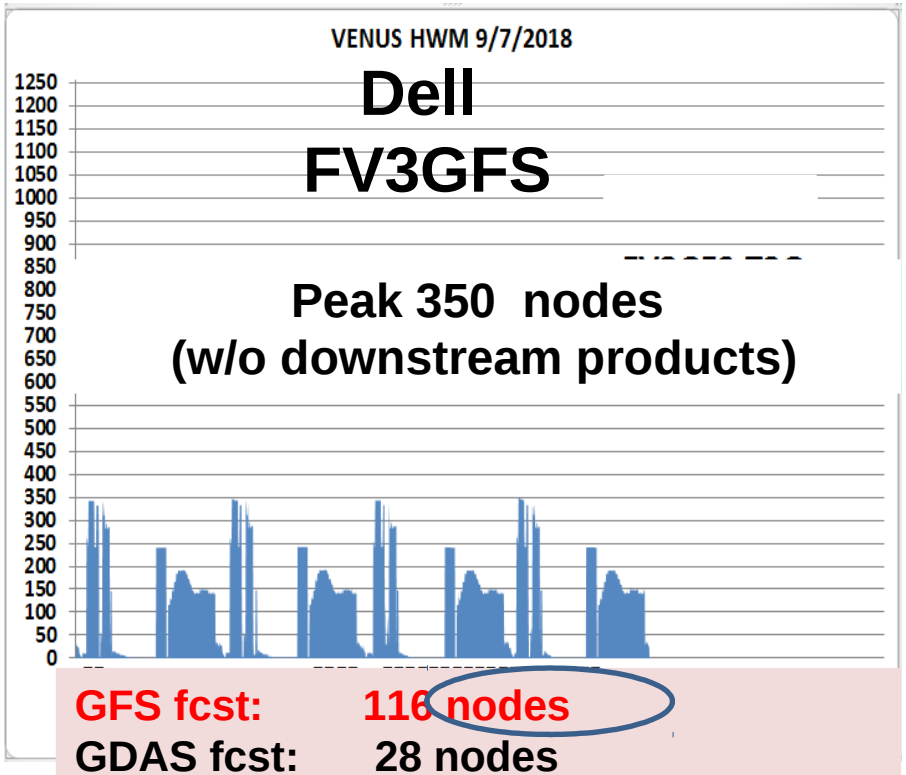
Resource Requirements for GFS/GDAS V15.0.0

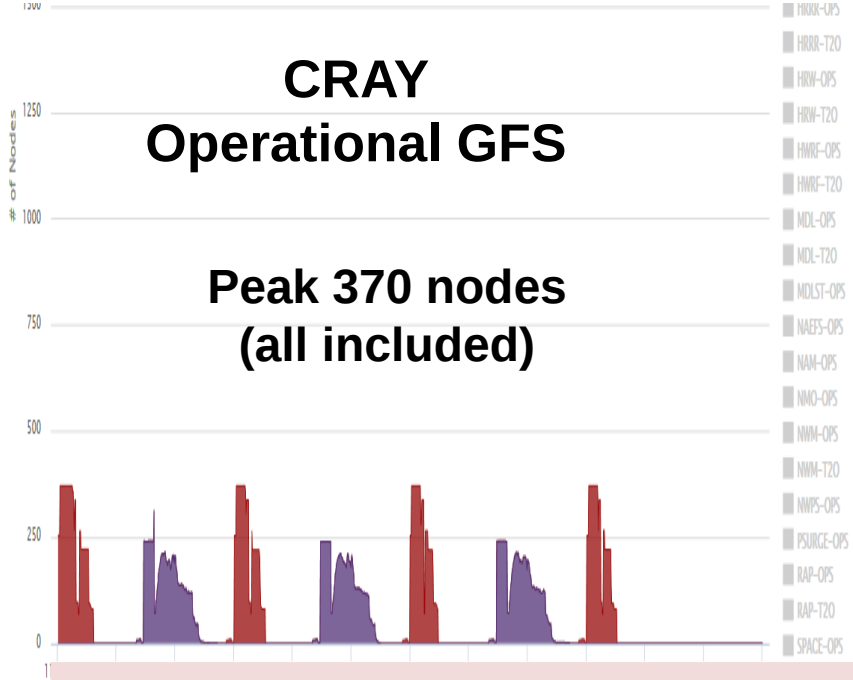
Resource Requirements: High Water Mark Test

With detailed node distribution

FV3 is more expensive to run than GSM



GFS fcst: 116 nodes
GDAS fcst: 28 nodes
Analysis: 240 nodes
ENKF fcst: 280 nodes



GFS fcst: 65nodes
GDAS fcst: 55 nodes
Analysis: 240 nodes
ENKF fcst: 200 nodes

Dell has 28 processors per node while Cray has 24 processors per node

From: Russ Treadon, Fanglin Yang, Matt Pyle

Timing Test and Forecast Configuration

RUN TIME (minutes)	J-Job prod	J-Job para	prod (minutes)	para (minutes)	para-prod
gfs_analysis	JGFS_ANALYSIS	JGLOBAL_ANALYSIS	22.9	26.8	4.2
gfs_forecast (0-10 days)	JGFS_FORECAST_HIGH	---	78.5	75.5	-3
gfs_forecast (11-16days)	JGFS_FORECAST_LOW	---	11.3	45.3	34
gfs_forecast (0-16 days)	---	JGLOBAL_FORECAST	89.8	120.8	31
gdas_analysis_high	JGDAS_ANALYSIS_HIGH	JGLOBAL_ANALYSIS	29.7	30.7	1.0
gdas_forecast_high	JGDAS_FORECAST_HIGH	JGLOBAL_FORECAST	12.3	11.7	-0.6

Highlights:

- current operational GFS runs at T1534 (13 km) for the 1st 10 days, then at T574 (35 km) up to 16 days
- V3GFS runs at the same C768 resolution (~13 km) up to 16 days
- Operational GFS write hourly output for the 1st 5 days, 3 hourly up to 10 days, then 12 hourly up to 16 days
- FV3GFS writes hourly output for the 1st 5 days, then 3 hourly up to 16 days

- **FV3GFS analysis will be 4.2 minutes slower than current operation; day-10 products will be delivered 3 minutes earlier; day-16 product will be delayed by 31 minutes.**
- **GDAS cycles remains almost the same in terms of timing (+/- 1.0 minutes)**

Changes in HPSS Archives
per cycle

	Ops GFS	Proposed for FV3GFS
Tarball naming convention	gfs.yyyymmddhh.sigma.tar enkf.yyyymmdd_hh.anl.tar enkf.yyyymmdd_hh.fcs.tar enkf.yyyymmdd_hh.fcs03.tar enkf.yyyymmdd_hh.fcs09.tar enkf.yyyymmdd_hh.omg.tar gdas.yyyymmddhh.tar gdas.yyyymmdd_radmonhh.ieee.tar gfs.yyyymmddhh.anl.tar gfs.yyyymmddhh.pgrb2_0p25.targ fs.yyyymmddhh.pgrb2_0p50.tar gfs.yyyymmddhh.pgrb2_1p00.tar gfs.yyyymmddhh.sfluxgrb.tar	gfs.targfs_flux.tar gfs_nemsioa.tar gfs_restarta.tar gdas.targdas_restarta.targdas_restartb.targfs.pgrb2_0p25.targfs.pgrb2_0p50.targfs.pgrb2_1p00.tarenkf.gdas.tarenkf.gdas_grp01.tarenkf.gdas_grp02.tarenkf.gdas_grp03.tarenkf.gdas_grp04.tarenkf.gdas_grp05.tarenkf.gdas_grp06.tarenkf.gdas_grp07.tarenkf.gdas_grp08.tarenkf.gdas_restarta_grp01.tarenkf.gdas_restarta_grp02.tarenkf.gdas_restarta_grp03.tarenkf.gdas_restarta_grp04.tarenkf.gdas_restarta_grp05.tarenkf.gdas_restarta_grp06.tarenkf.gdas_restarta_grp07.tarenkf.gdas_restarta_grp08.tar
permanent	**1171 GB**	**1858 GB**
2-year	**55 GB**	**991 GB**
total	**1226 GB**	**2849 GB**

- *All tarball names are changed*
- *nemsioa.tar: saving forecast history nemsio files 3-hourly up to 84 hours for running **stand-alone FV3***
- *2-year "991GB" : saving forecast history nemsio files 6-hourly from 90 to 384 hours. (optional)*

Summary -- Benefits

From Full MEG Assessment

- (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

Summary -- Benefits

Other Benefits

- FV3GFS with advanced GFDL MP provides better initial and boundary conditions for driving standard 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

Summary -- Concerns

From MEG assessment

- FV3GFS can be too progressive with synoptic pattern
- Precipitation dry bias for moderate rainfall
- Extremely hot 2-m temperatures
- SST issues – may be mitigated with code update
- 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*

Other Concerns

- T2m over Alaska is too cold, likely caused by cold NSST and/or cloud microphysics issue in the Arctic region – may be mitigated with SST fix
- NHC reported that FV3GFS degraded track forecast of hurricanes (initial wind > 65 kts) in the Atlantic basin

Summary

The primary objectives of Q2FY19 GDAS/GFS upgrade are met:

- Implementation of FV3 Dynamic Core & GFDL Microphysics
- Upgrades to LSM and Ozone/H2O Physics
- Upgrades to GDAS with increased resolution for EnKF and new satellite data sets
- Extensive evaluation based on 3.5year retrospective and real-time experiments
- Favorable evaluation & endorsement from stakeholders.

EMC requests NCEP Director to approve implementation of Q2FY19 FV3GFS package into operations.

Thank you

Decisional Briefing to the NCEP OD

Addressing Upcoming FV3GFS Changes

EMC's Recommendations for Implementation of GFS v15.1

NOAA Environmental Modeling Center

April 1, 2019

The Issues

- 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

- EMC has determined at least one cause of excessive snow and two causes of some of the exaggerated cold bias in the lower atmosphere.

- Additional Obs-Proc and DA related changes proposed for inclusion in GFSv15.1

KEY FACTS AND FINDINGS SO FAR

- A July 2018 bug fix to address erroneous snow in the tropics inadvertently contributed to the excessive snow issue. A fix to ameliorate (but not completely remove) excessive snow using a fractional snow flag is straightforward.
- A September 2018 bug fix to address erroneous solar zenith angle in the radiation inadvertently exaggerated an existing cold bias. We have identified a remedy that reduces the cold bias.
- We have a proposed fix for a supersaturation constraint in data assimilation to address cold polar low-level temperatures; this fix also reduces the cold bias.
- Results from the New Configuration with the proposed fixes have confirmed mitigation of the issues while retaining the benefits demonstrated during the 3+year retrospective experiments.

MAIN POINTS

- The proposed New Configuration with the bug fixes and science updates retains previously established benefits of using the FV3GFS model compared to the spectral GFS v14:
  - 500mb AC improved
  - Precipitation ETS score and diurnal cycle improved
  - Tropical cyclone tracks improved up to day 5
- Largest issue: cold bias remains larger than in the configuration used during the 3-year retrospective evaluation period

- EMC is recommending to implement the proposed New Configuration given the following:
  - Extended field evaluation not recommended as these changes largely improve, or mitigate, previous errors
  - Little impact seen to overall model metrics

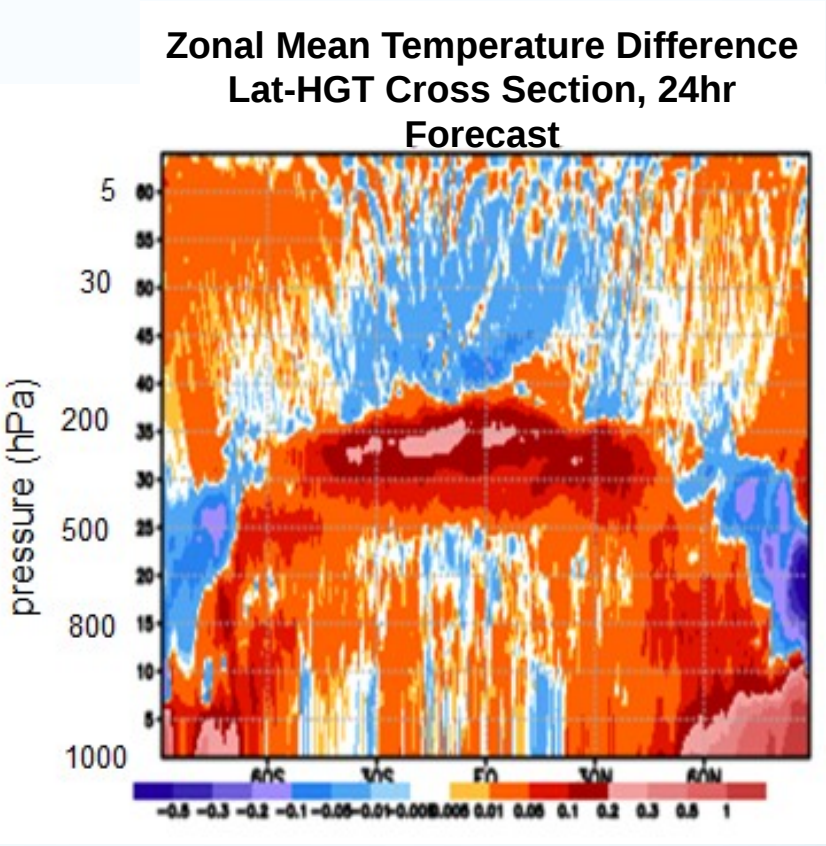
Mitigation of the cold bias

Physics:

- Adopting an improved cloud radiation interaction in the new configuration reduces long-wave cooling in the troposphere, and indirectly increases heating in the PBL and near-surface due to mixing, warming the troposphere.

Data Assimilation:

- Adjustment to supersaturation constraint in the new configuration reduces the cold bias in the polar regions near surface.



Impact of improved cloud-radiation interactions: Warm the atmosphere (recovers much of the cold bias in the lower troposphere)

GFDL is acknowledged for their contribution to the implementation of the improved cloud-radiation interaction scheme in the new configuration.

Testing of New Configuration

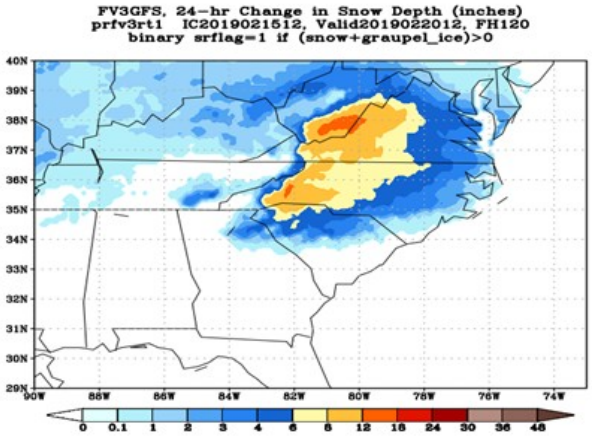
- **New Configuration includes all three fix/updates in : 1) fractional snow/ice/graupel flag, 2) cloud-radiation interaction, 3) supersaturation adjustment in DA**

TEST PERIODS

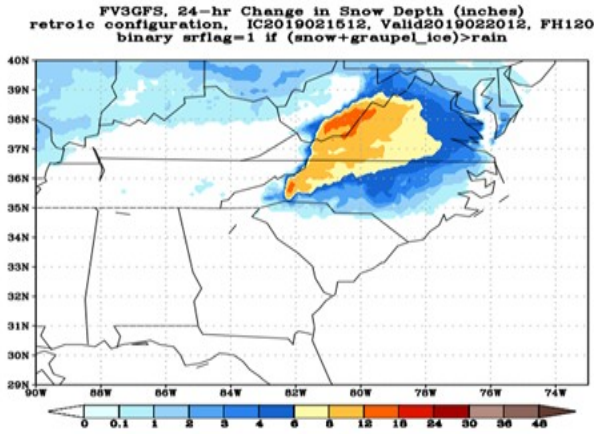
- **Winter experiment with cycled DA (12/15/2018 - realtime)**
  https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt3/
- **Hurricane season experiment with cycled DA (8/26/18 - 10/31/18)**
  https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt3s/
- **Selected summer cases (forecast-only experiments)**

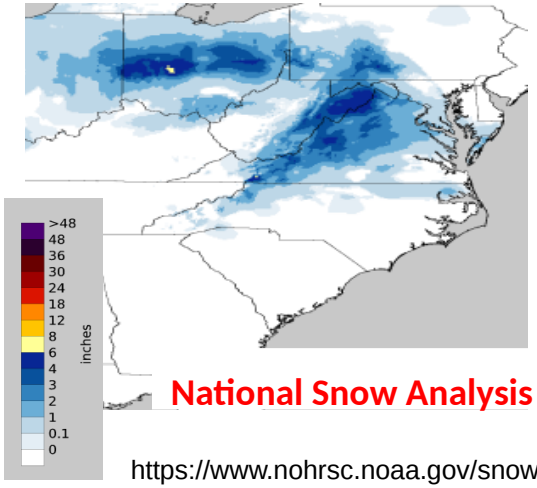
Investigation of the Excessive Snowfall in 5-day forecasts valid 02/20/2019

Real-time Parallel



"Retro" Parallel (IC from prfv3rt1)

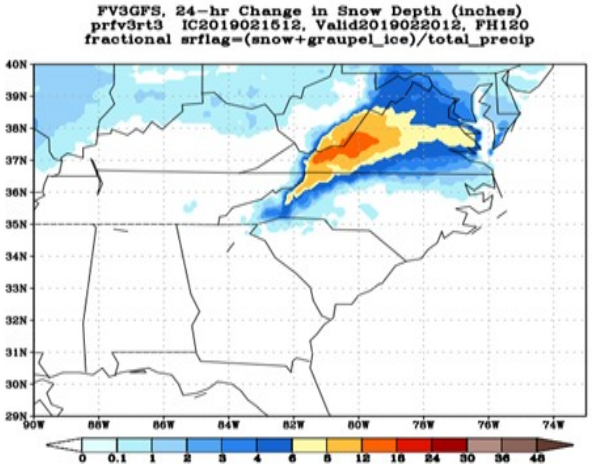




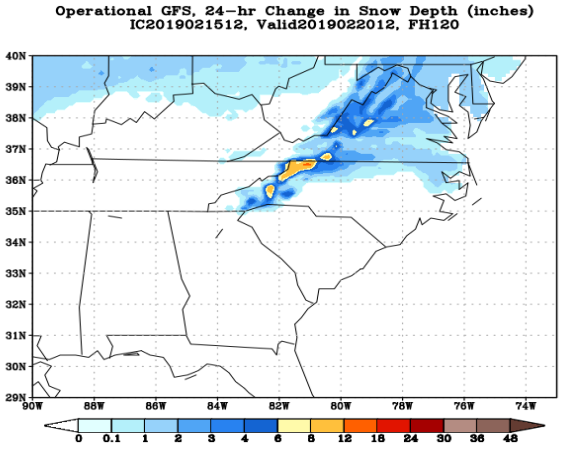
National Snow Analysis

https://www.nohrsc.noaa.gov/snowfall/

New Configuration



Operational GFS



"Retro" version of the model still produces more snow than observed, and has more snow than the new configuration. While this is encouraging, note that the "retro" test was initialized from a "cold" initial state.

This case is a mid-range forecast under marginally cold conditions.

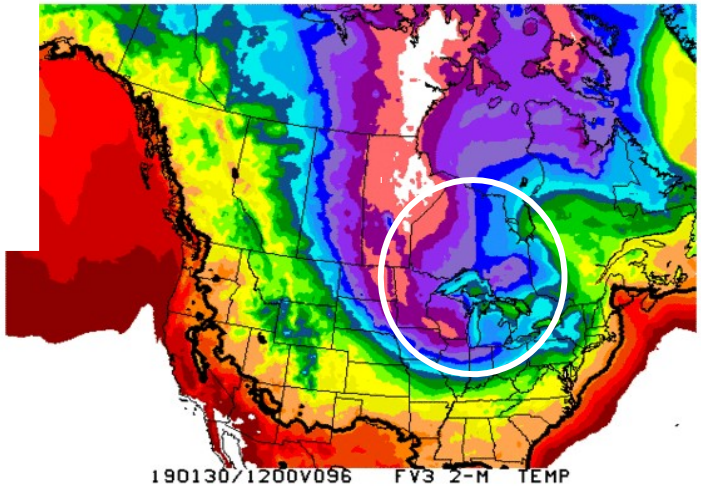
The Arctic Blast of Late January 2019

12z 1/26/19 CYCLE F96

New Para warmer New Para colder

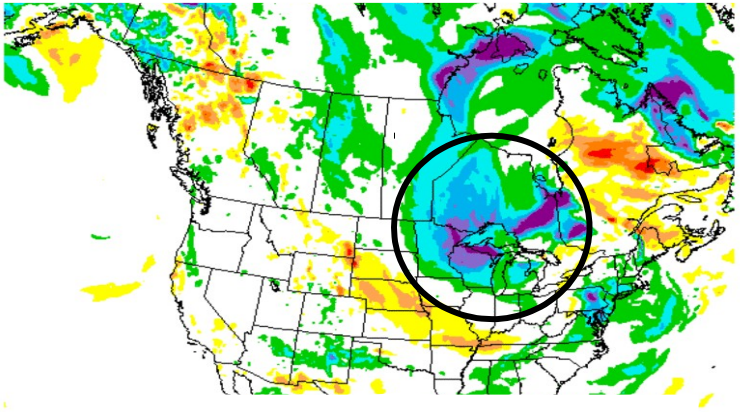
-10 -8 -6 -4 -2 2 4 6 8 10

Real Time Para

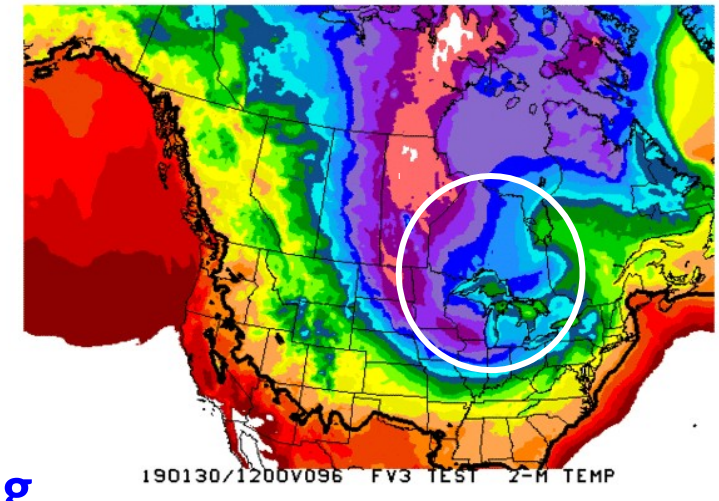


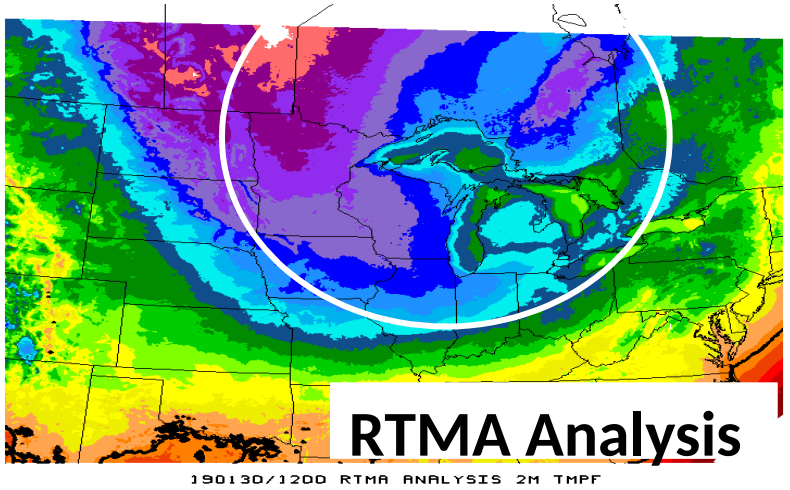
55 45 35 25 15 5 -5 -15 -25 -35 -45

Real Time Para – New Config



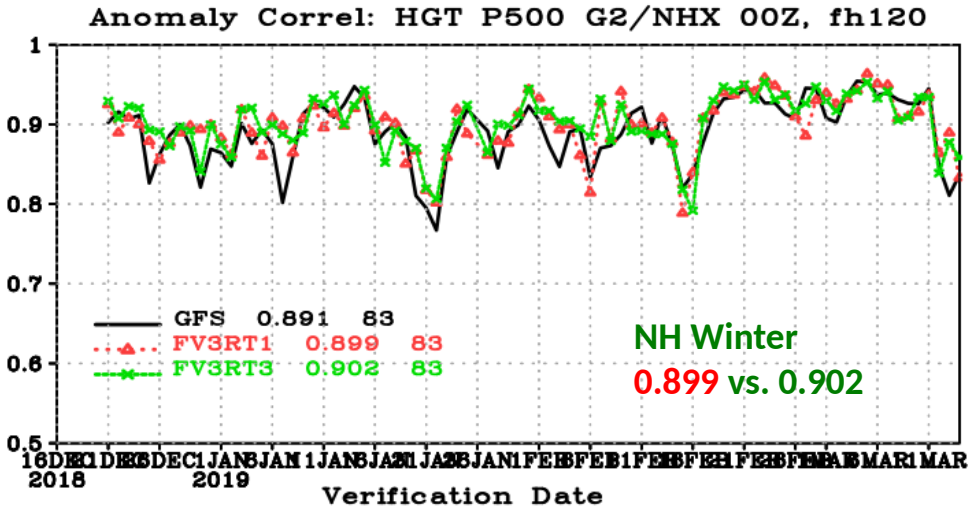
New config

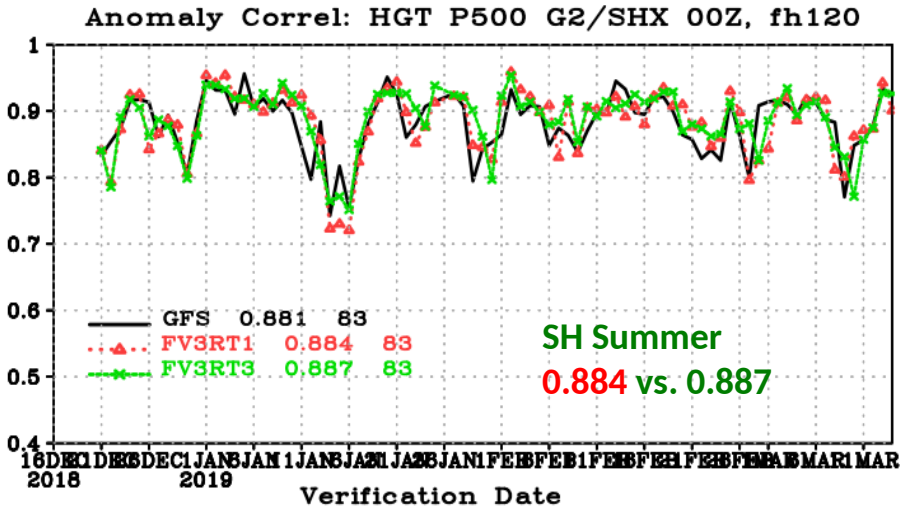


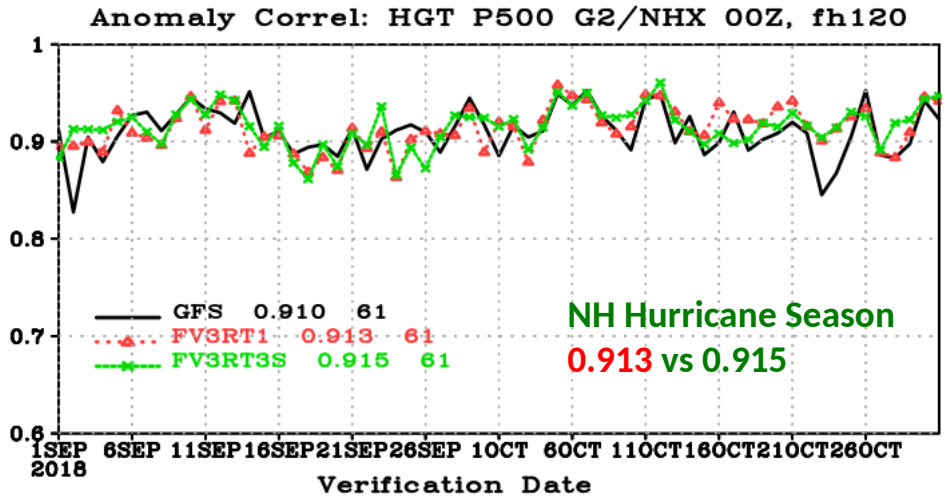


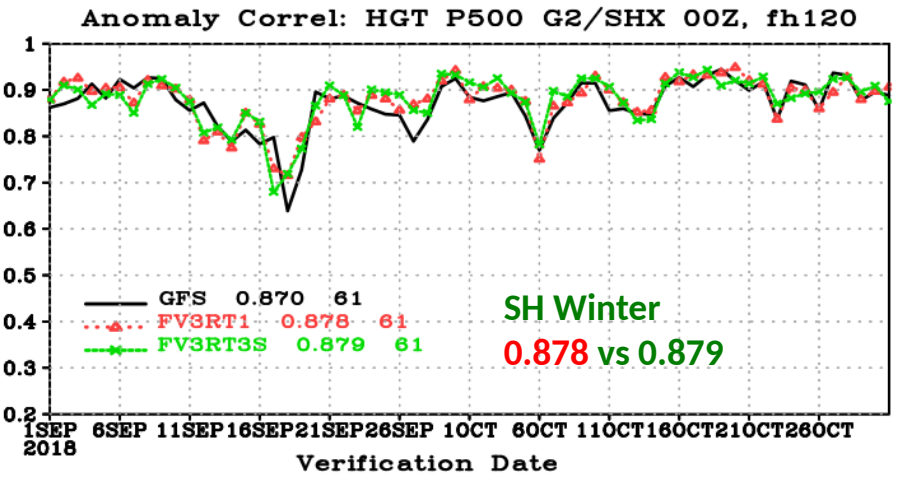
New configuration is warmer than real-time parallel and while it is still too cold, it shows a clear improvement.

Statistical evaluation

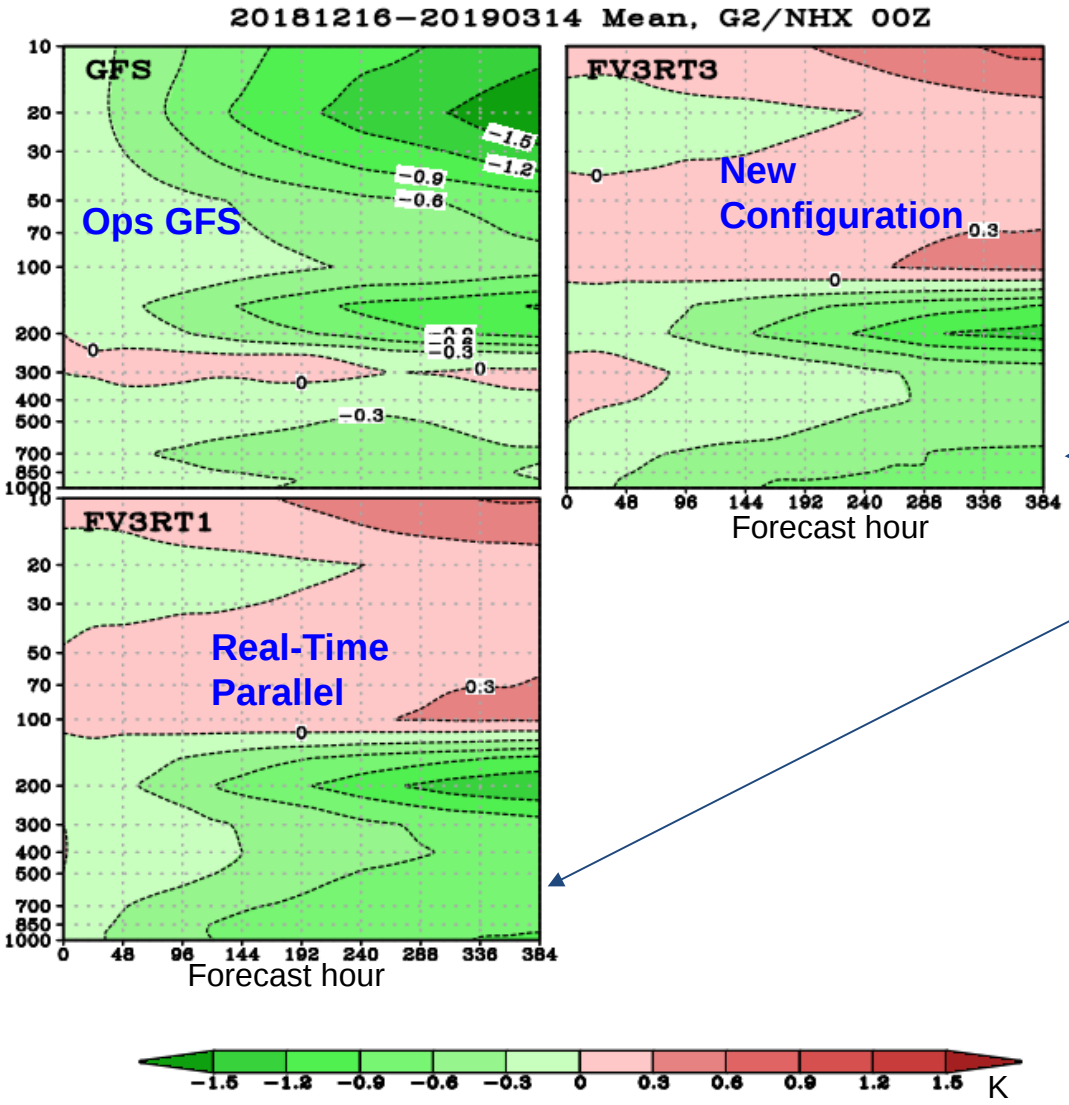








NH Temperature Biases Relative to Own Analyses

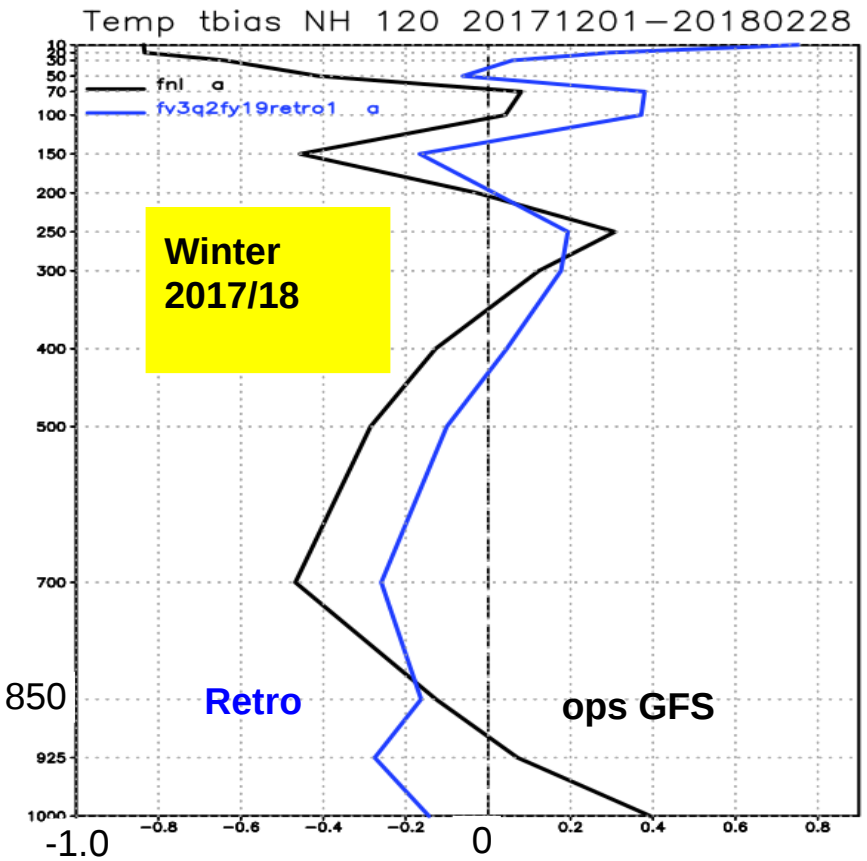


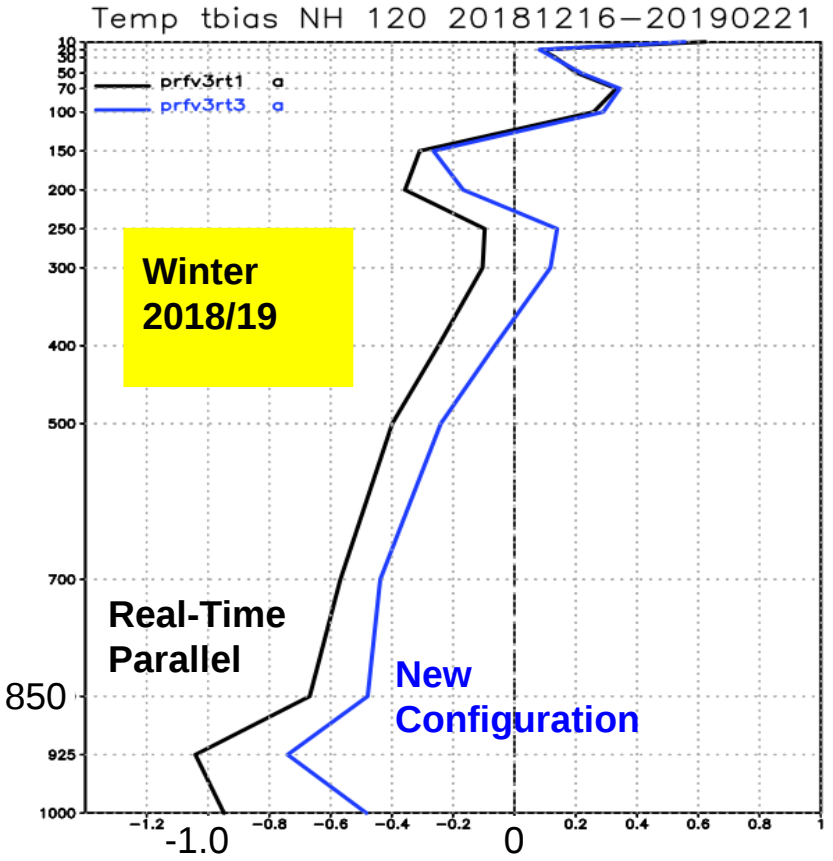
2018/19 Winter

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

Performance of New Configuration compared to Retros and operational GFS

NH day-5 temperature bias wrt radiosondes (scales differ)

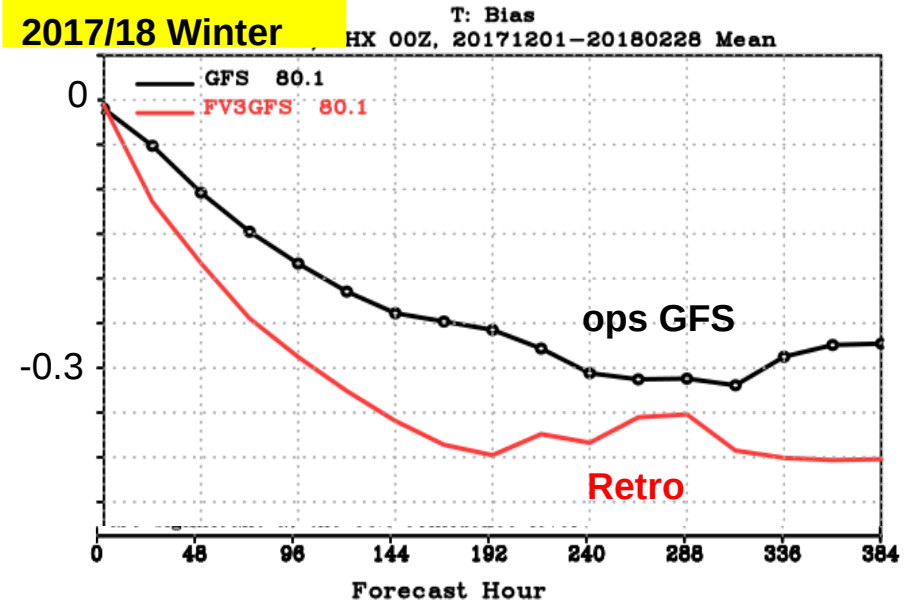




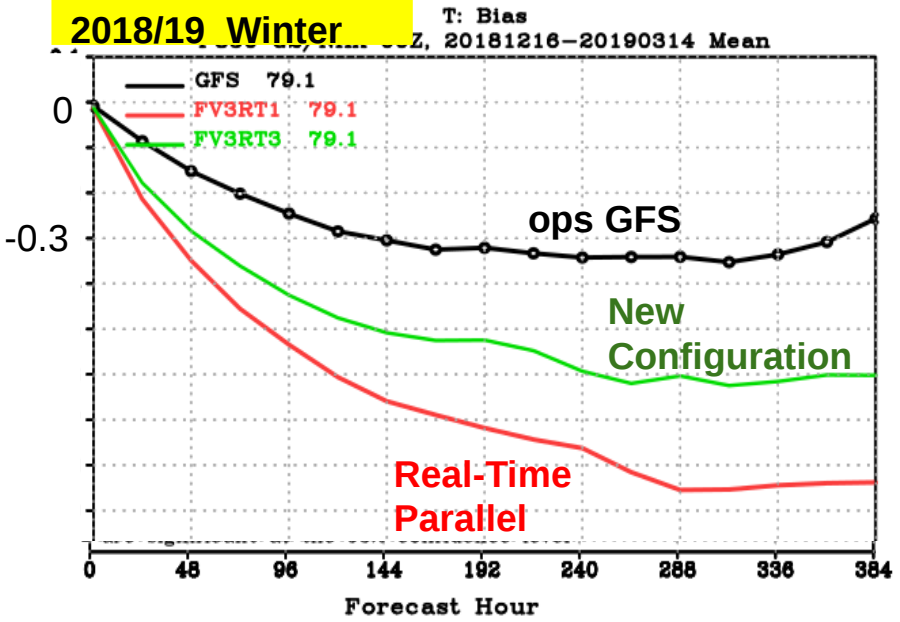
- Cold bias in the lower atmosphere exists in retro runs.
- Real-time parallel exacerbated the cold bias.
- New Configuration reduced the cold bias.

NH 850-hPa Temperature Biases Relative to Own Analyses

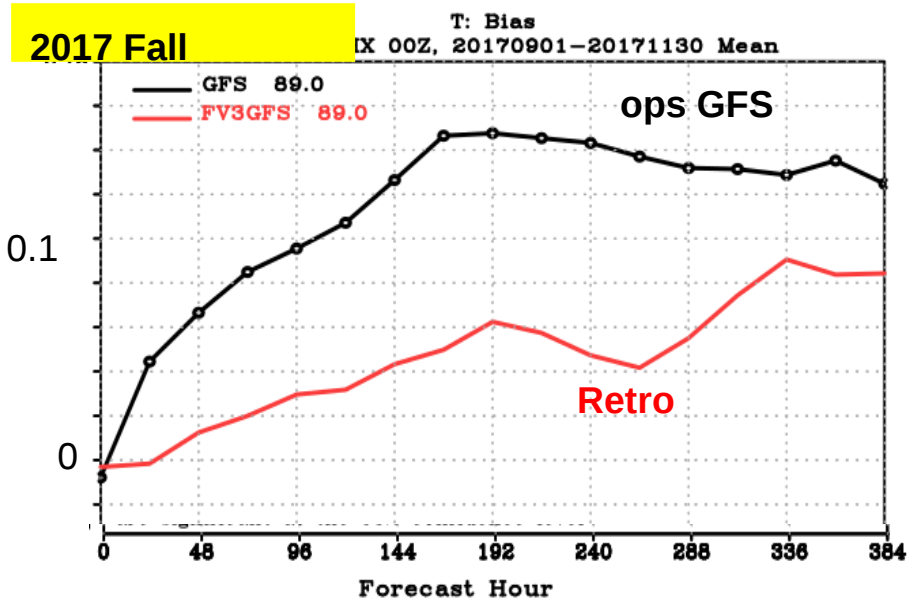
2017/18 Winter



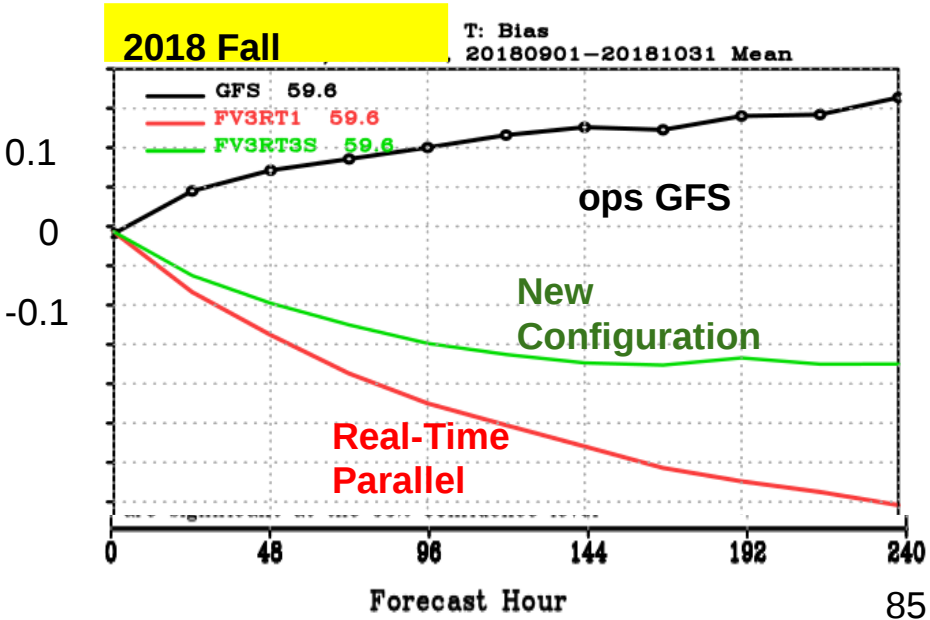
2018/19 Winter



2017 Fall

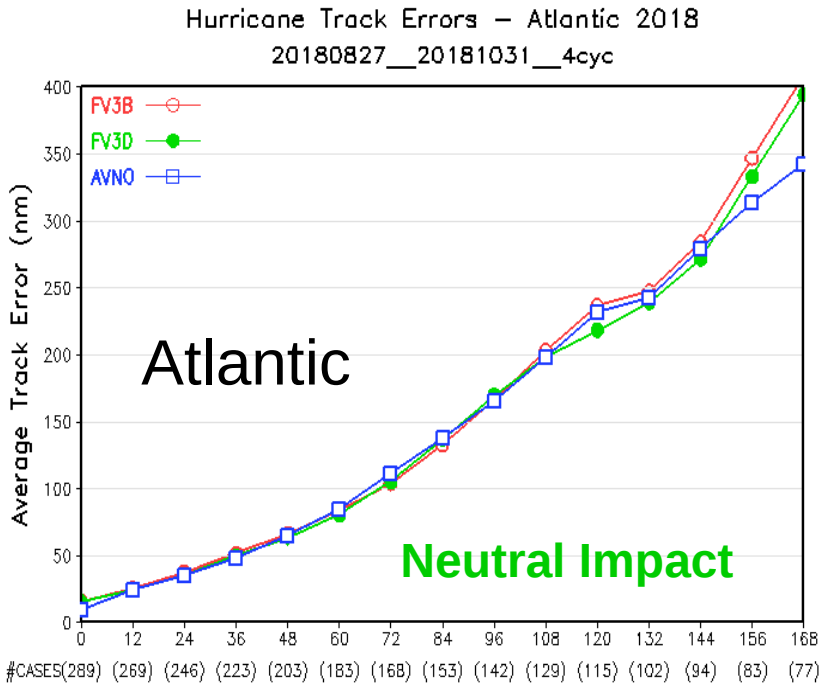


2018 Fall



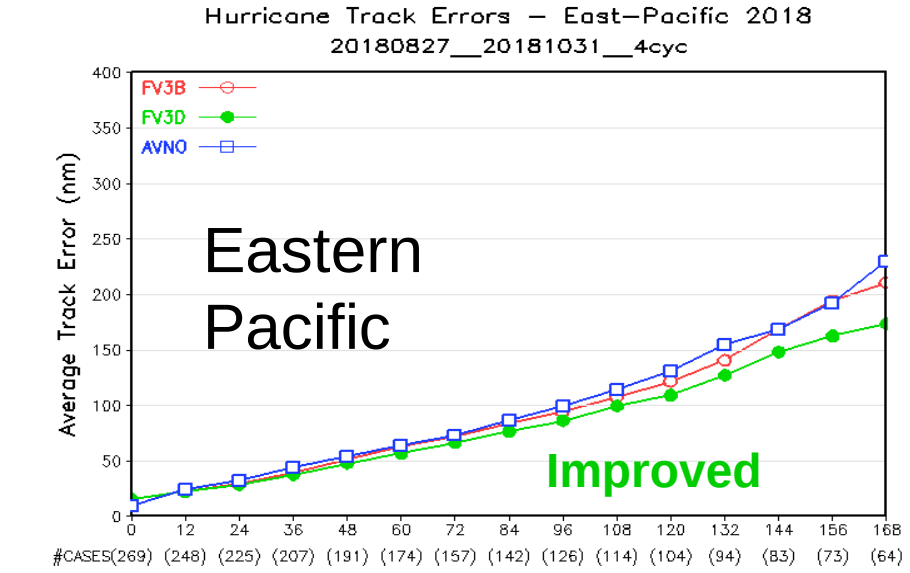
Tropical cyclone results

Mean Track Errors, 27Aug2018 ~ 31 Oct 2018



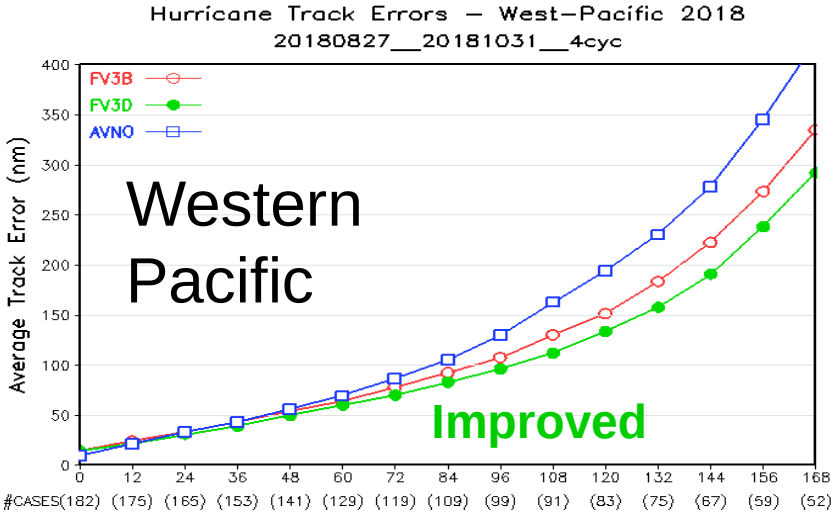
Confidence Level (%) of Student–t Tests

FV3B_FV3D	87	97	97	90	91	84	60	76	62	87	92	75	79	74	71
FV3B_AVNO	100	90	93	96	71	54	89	76	57	67	64	62	60	92	98
FV3D_AVNO	100	59	52	78	68	78	82	53	64	50	80	59	68	84	98



Confidence Level (%) of Student–t Tests

FV3B_FV3D	62	73	86	96	98	99	97	98	99	97	99	96	98	99	99
FV3B_AVNO	100	92	98	99	94	72	62	71	88	88	95	97	50	58	91
FV3D_AVNO	100	98	99	99	99	99	98	99	99	99	99	99	98	99	99

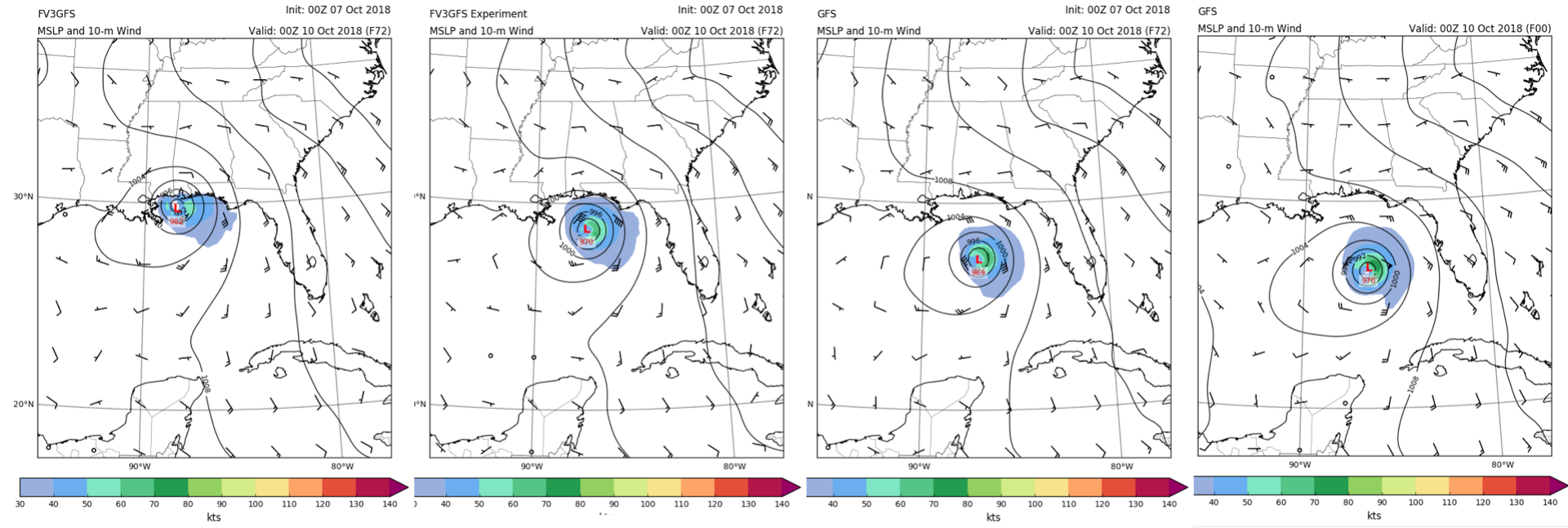


Confidence Level (%) of Student–t Tests

FV3B_FV3D	62	99	98	99	99	98	99	99	98	99	94	95	94	92	95
FV3B_AVNO	99	99	65	50	81	93	95	97	99	99	99	99	98	97	96
FV3D_AVNO	99	58	97	98	99	99	99	99	99	100	99	99	99	99	99

FV3B: Real-Time Parallel
FV3D: New Configuration
AVNO: Operational GFS

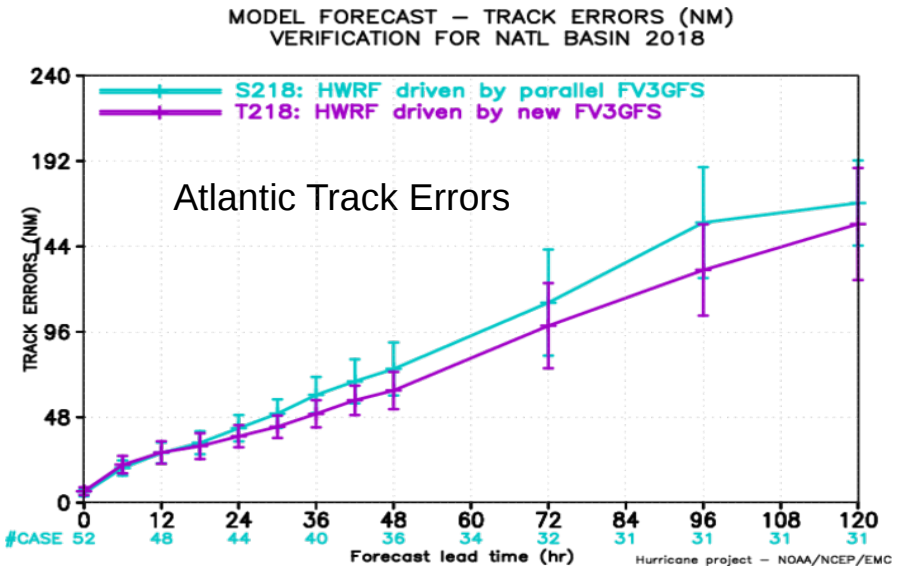
Hurricane Michael 72 h forecast example

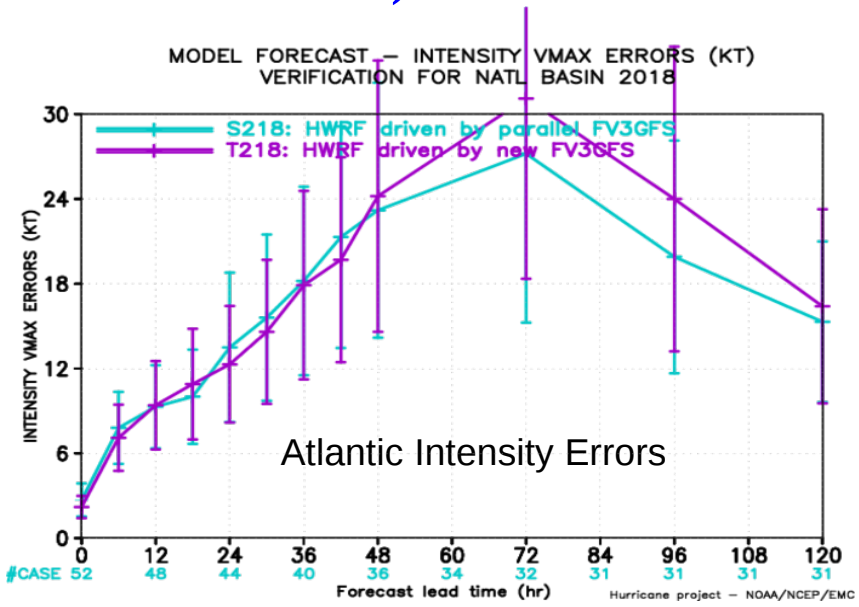


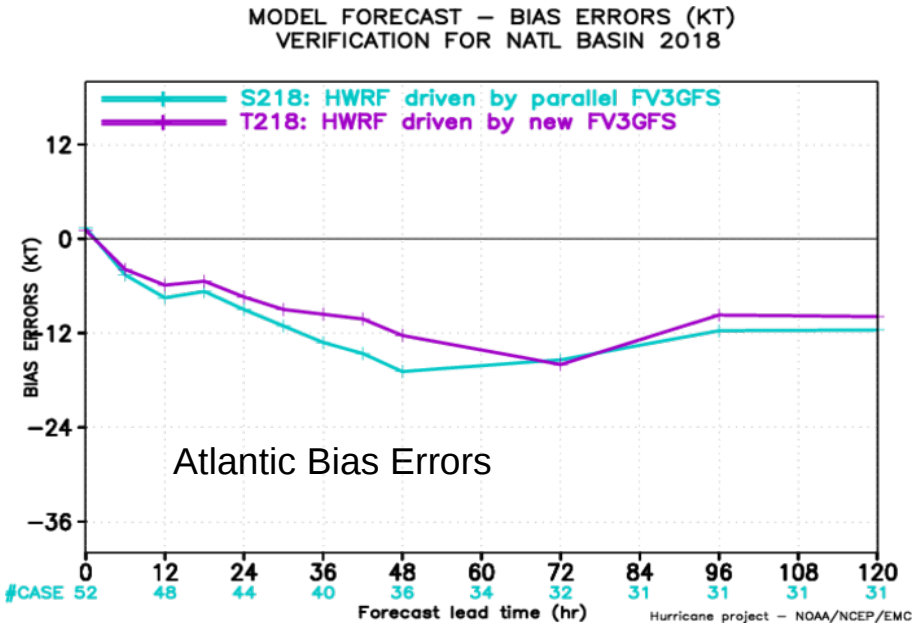
FV3GFS Real-Time | **New Configuration** | **GFS FCST** | **GFS ANL**

- **New Configuration is slightly slower than the real time parallel, but still too fast.**
- **Intensity in the New Configuration is significantly improved (lower center pressure).**

Early results from HWRF runs with New FV3 Para for 2018 Hurricane Season (Hurricanes Leslie, Michael and Florence)







ST18: HWRF w/real-time FV3GFS
T218: HWRF w/new FV3 Parallel

- Tracks improved significantly (~10-15%)
- Intensity neutral/improved through 48 hrs, degraded afterwards.
- Intensity bias improved.

More storms are being added to the sample

Summary of Evaluation and EMC Recommendation

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*

Code changes related to the model (GFS v15.1):

- **Fractional Snow Flag:**
  - The cloud model (GFDL MP) predicts rain, snow, graupel and ice falling on the ground. Convective parameterization also predicts rain and snow. Redefine snow flag in the LSM (srflag) as a fractional number between frozen precipitation and total precipitation.
- **Zenith angle bug fix**:
  - A bug in the computation of solar zenith angle was discovered in September 2018 after all retrospective parallels had been completed. It causes a slight shift of the solar radiation diurnal cycle and adds more solar energy to the system. This bug has been fixed.
- **Enhanced cloud-radiation interactions:**
  - In the retrospective and real-time parallels, total cloud condensate from GFDL MP is partitioned into water and ice clouds using an empirical temperature dependent function. Cloud ice effective radius is parameterized as a function of cloud mixing ratio and temperature. Cloud water effective radius is prescribed but set differently over land and ocean. In the new configuration, individual hydrometeors are directly fed into radiation. Snow and graupel are combined together. Cloud effective radii are derived from different empirical functions for different hydrometeors that vary with hydrometeor mixing ratio and temperature.
- **Restart capability:**
  - NCO requires, in case of a computer crash, the forecast model can be restarted at a crashing point instead of rerunning the model from the beginning to ensure timely product delivery and downstream model application. The model and workflow have been updated to write out restart files at a given interval, and to restart GFS forecast with these files at a break point. Continuously accumulated fields including precipitation are added to the restart files to maintain their continuity in forecast output before and after a computer crash.

Code changes related to observation/DA upgrades for GFS v15.1 (originally planned for July 2019)

- **Modifications to GSI related to satellite data:**
  - Add ECMWF AMV quality control to address known deficiencies with GOES AMVs
  - Monitor GOES-17 AMVs, and assimilate pending evaluation after May update
  - Assimilate Meteosat-11 SEVIRI channels 5 and 6
  - Place NOAA-19 SBUV/2 in monitor mode due to degrading quality
  - Assimilate NPP OMPS profile and total column ozone
  - Monitor Metop-C AMSUA and MHS, assimilate select Metop-C AMSU and MHS channels pending evaluation
- **Modifications to ObsProc and GSI related to SST:**
  - Add code to process drifting and moored buoy data and assimilate pending evaluation
- **GSI upgraded to tag fv3da.v1.0.42**

Recommendation from EMC

EMC proposes to implement the new configuration of FV3GFS (GFSv15.1) with the following changes:

- **Fractional snow flag,**
- **Zenith angle bug fix,**
- **Enhanced cloud-radiation interactions, and**
- **Modified supersaturation constraint in DA**

In addition, EMC proposes to add the following updates to GFSv15.1:

- **Implement “restart” capability**
- **Include ObsProc and DA related changes to address monitoring/assimilation of upcoming GOES-17 and METOP-C satellite data and revised drifting/moored buoy SST data (in preparation for July 2019 upgrade)**

Backup Slides for 10/1/2018 brief

Backup slides for 4/1/2019 briefing

Possible Options

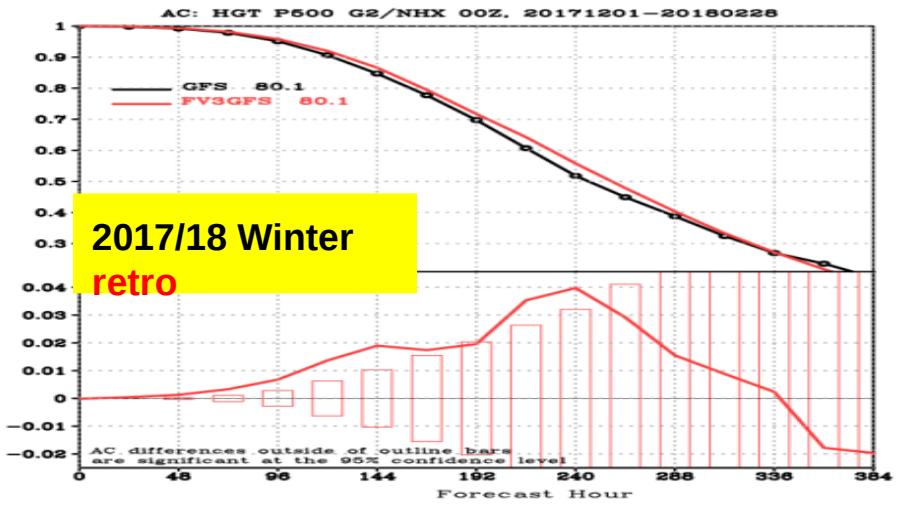
1. Implement the model configuration used for the retrospectives with snow flag fix. (Reintroduces bug in solar zenith angle)
2. **Continue to evaluate New Configuration with four changes to the code (snow flag, zenith angle, cloud-radiation interactions, supersat constraint in DA) with hurricane and winter storm seasons with intent to implement. - EMC RECOMMENDED**
3. Continue to run GFSv14 operationally and implement FV3-based GFS with NGGPS v2 (127 levels, advanced physics, etc)

Note: Given the attention to the erroneous snow quantities, the option to forgo a change in the FV3 snow parameter was not considered.

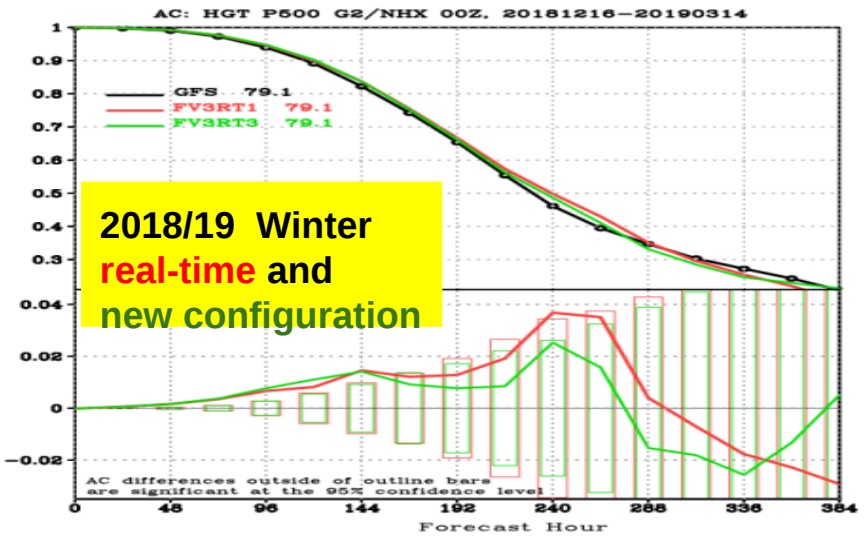
Analysis of options

Options	**Implement the model configuration used for the retrospectives with two modifications:** - Implement NSST. This decreased the cold bias in Alaska. Required for Alaska Region sign-off. - Proposed srflag fix. better snow output.	**Target June 2019 implementation with four changes to the code in New Parallel with hurricane and winter storm seasons**: - Proposed srflag fix - Radiation bug fix to correct solar zenith angle - Cloud-radiation interactions using individual hydrometeors - Supersaturation parameter in the DA	**Continue to run GFSv14 operationally and implement FV3-based GFS with NGGPS v2 (127 levels, advanced physics, etc)**
Pros	- very close to model configuration used in the retrospectives and field evaluation - to date, srflag fix impact on model behavior itself is limited - better snow and low-level temperature fields relative to version with changes	- all four changes improve physical realism and correct outright errors - evidence to date suggest improvements to snow and cold bias issues with little impact on other model metrics - to date, srflag fix impact on model integration itself is limited - some improvement to hurricane track forecasts, compared to retrospective runs - important model metrics - including 500-hPa ACC, precipitation ETS score and diurnal cycle, and tropical cyclone tracks- show improvement over GFSv14	- GFS is still a good model - focus on developing NGGPSv2
Cons	- known major bug in SW radiative fluxes: incorrect diurnal cycle with a phase shift excessive SW radiation impact on air quality predictions - this model version was not run for 2018/19 winter - messaging issues with implementing a known bug	- not as thoroughly tested as the retro config. - fewer user eyes on the results - risk that any or all of these will produce side-effects unseen in test runs	- missed opportunity to realize improvements using FV3GFS including 500 AC scores, precipitation ETS scores and diurnal cycle, wind-pressure relationship for tropical cyclones, and improved tracks and intensity - some wasted effort - messaging problems - downstream products prepared for FV3GFS implementation - risks delay to FV3GEFS, which contains similar issues

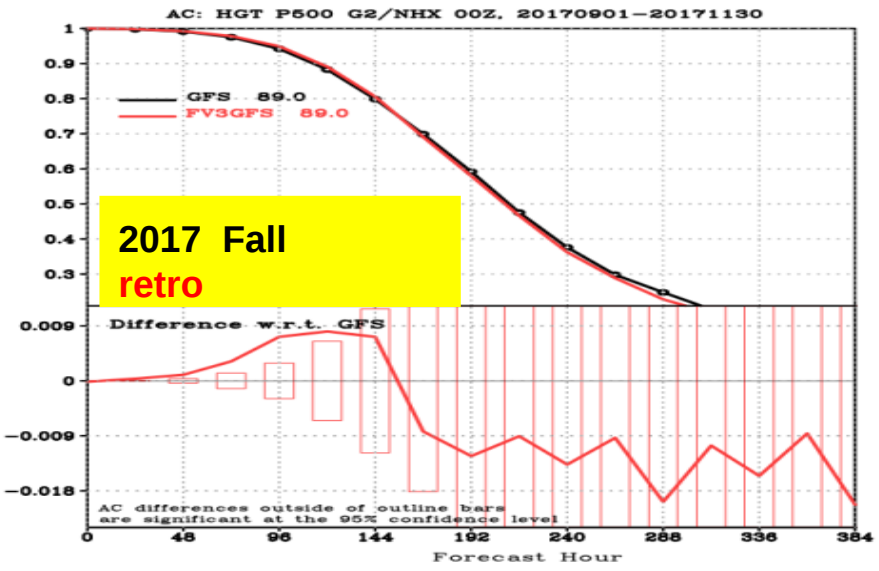
NH 500-hPa Height ACC
The improvement is seen in both the retros and new runs



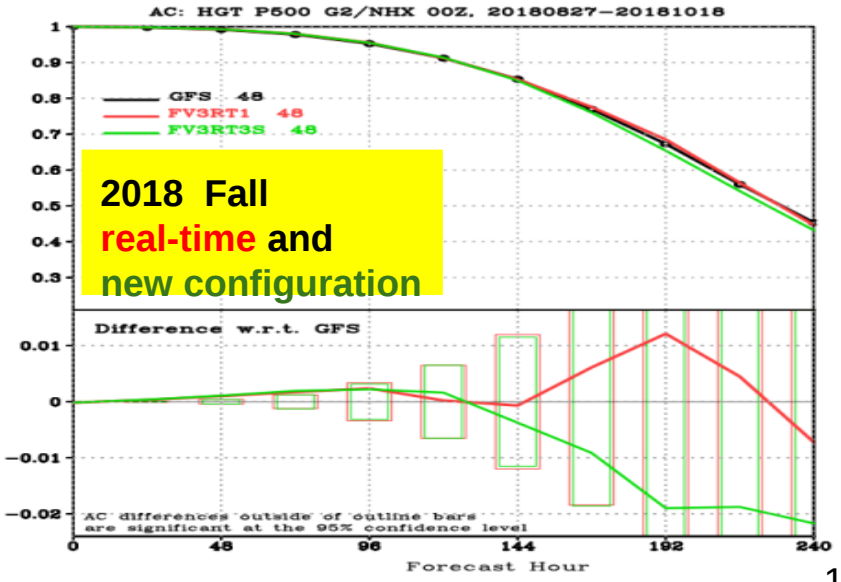
2017/18 Winter
retro



2018/19 Winter
real-time and
new configuration

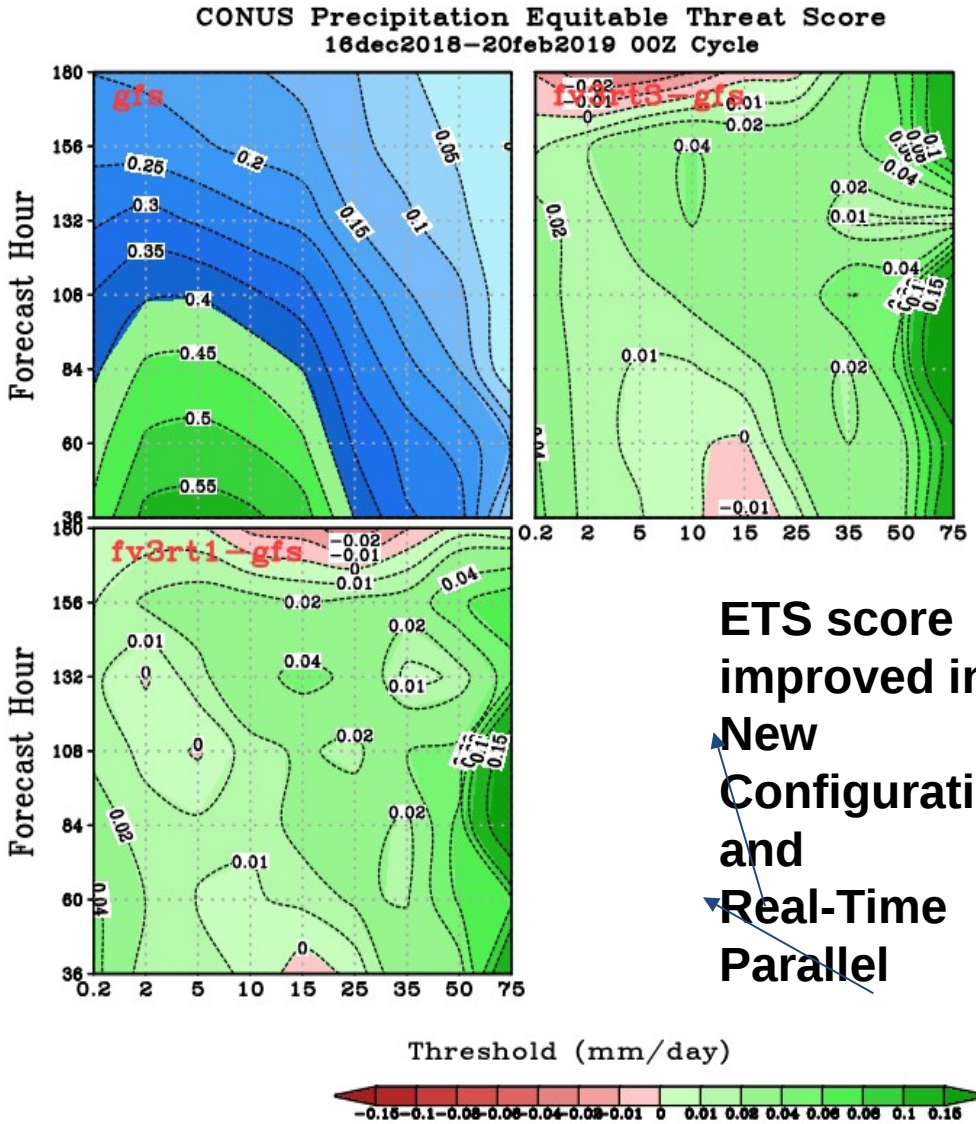


2017 Fall
retro

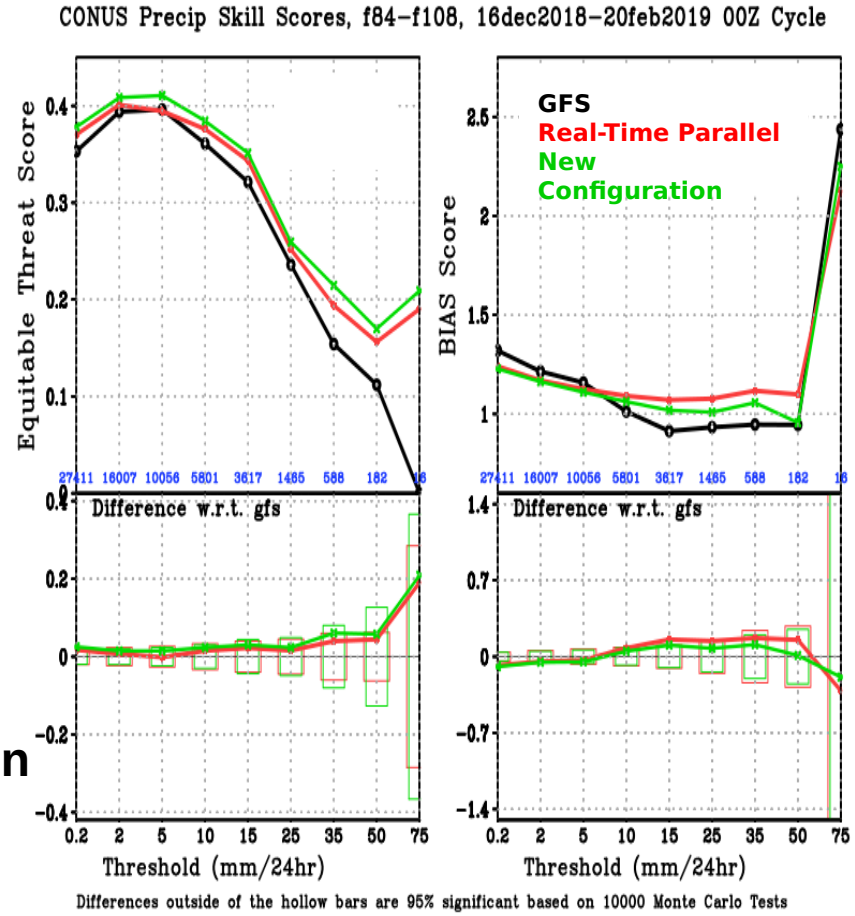


2018 Fall
real-time and
new configuration

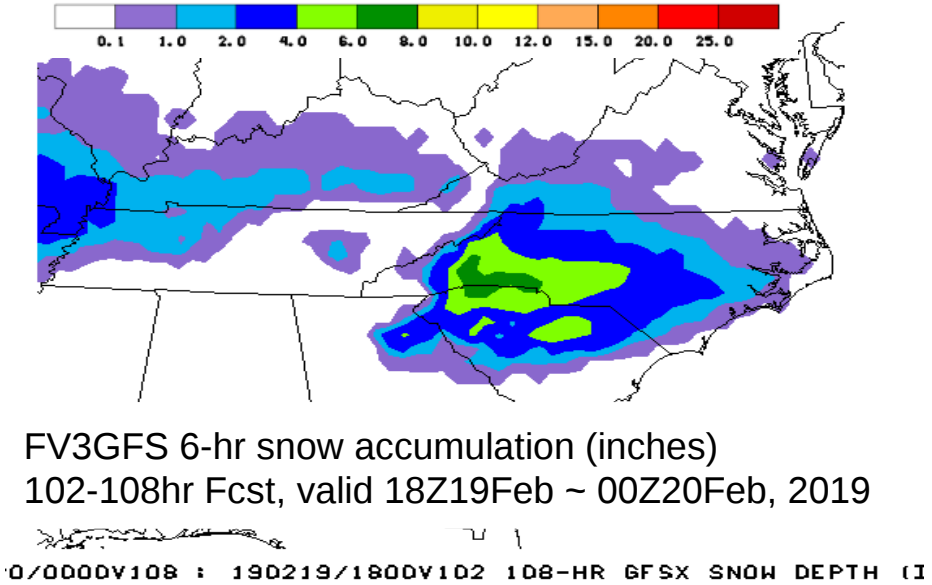
Precipitation ETS and BIAS Scores
Winter 20181216 ~ 20190220, Verified against Gauge Obs.



ETS score improved in: New Configuration and Real-Time Parallel



Issue #1
Excessive Snowfall in FV3GFS



FV3GFS 6-hr snow accumulation (inches)
102-108hr Fcst, valid 18Z19Feb ~ 00Z20Feb, 2019

FV3GFS predicts wide spread snowfall over NC, KY, northern GA, and northern SC, which was not consistent with other forecast guidance

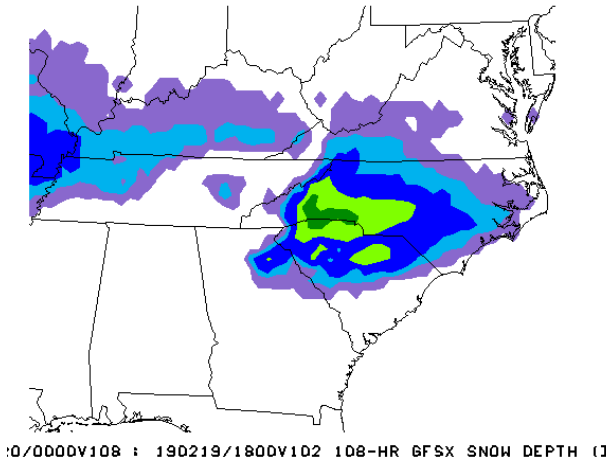
One cause: snow depth calculation in the model

- Prior to July 2018, if there was more liquid precipitation than frozen, the land surface model (LSM) ignored the frozen precipitation and would not melt it, even in warm environments.
- A fix was put in July 2018 so that when *any* frozen precip is present, the LSM treats *all* precip (frozen and liquid) as frozen. In a warm environment, the LSM will melt it, but in colder environments, snow depth will be overestimated.

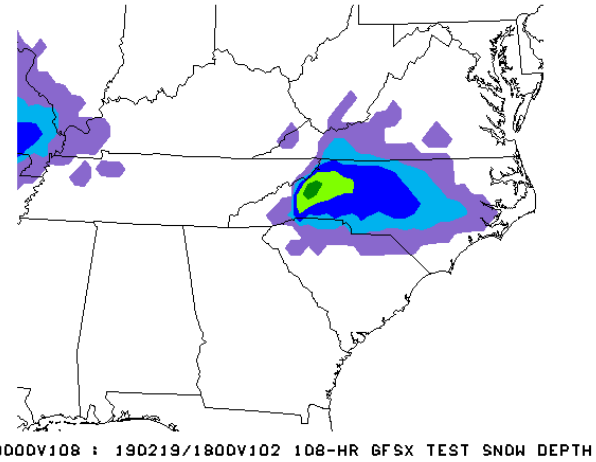
Issue #1
Excessive Snowfall in FV3GFS

Mitigation: Use only the frozen part of precipitation falling on the ground to compute snow depth inside the LSM

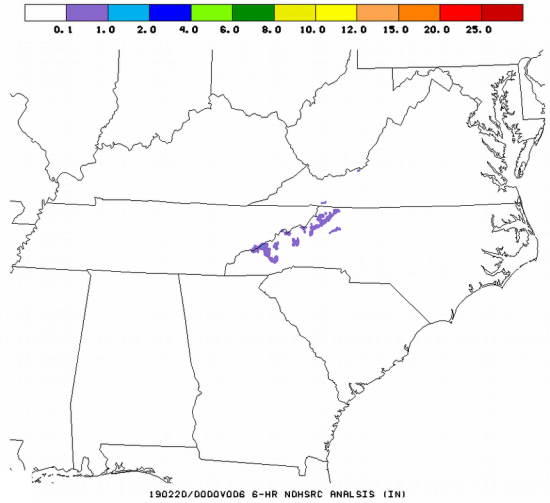
6-hr snow accumulation valid for 18Z19Feb~00Z20Feb, 2019



real-time parallel
102-108hr Fcst



sensitivity expt. with fractional srflag 102-108hr Fcst



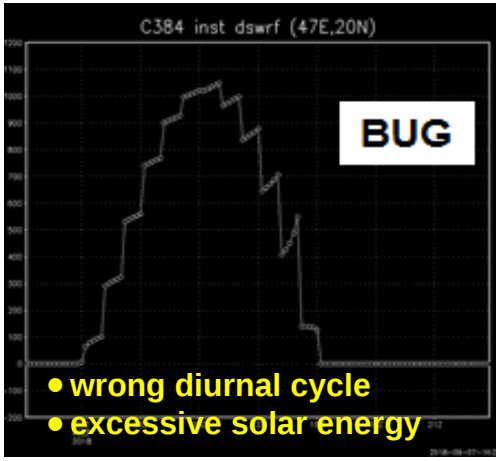
NOHRSC Analysis

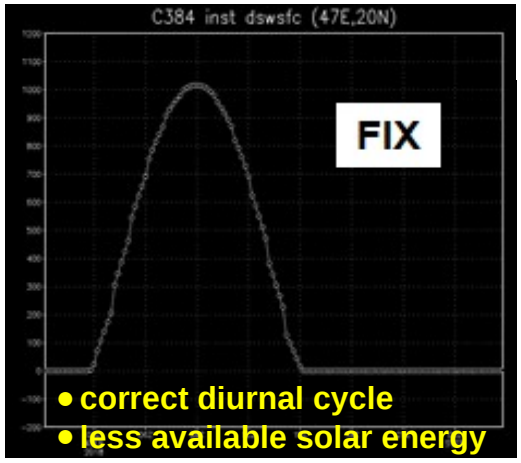
Excessive snow amounts reduced in the experiment, still exhibits over-prediction (could be linked to cold bias in the lower troposphere - issue #2)

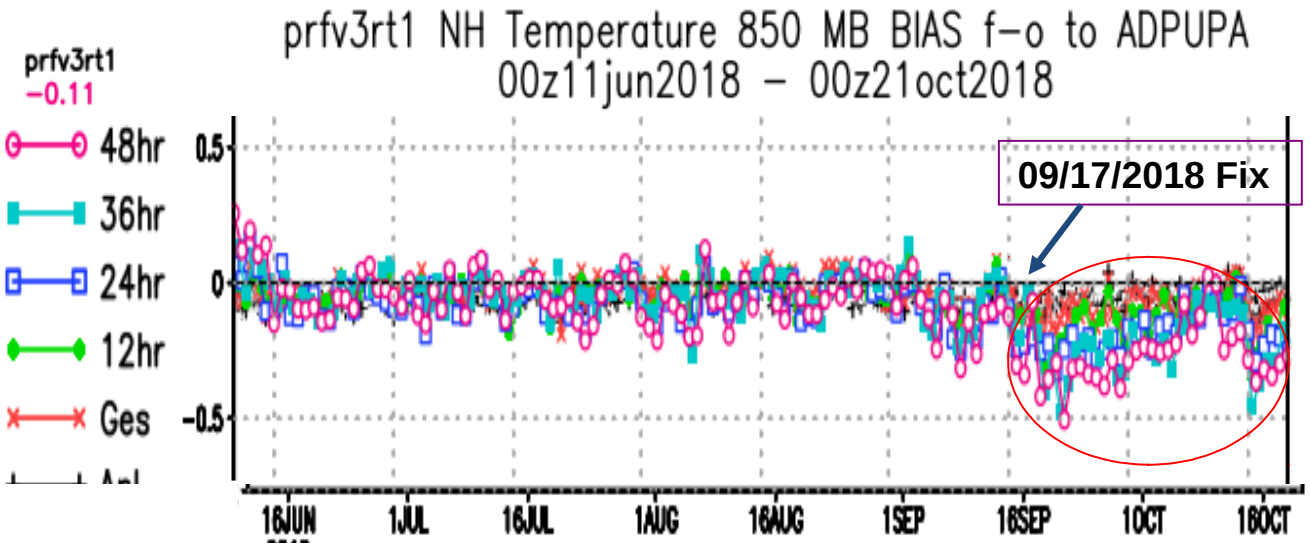
Issue #2
Exacerbated cold bias in the lower atmosphere

The cause: Bug fix for erroneous Solar Zenith Angle computation in the radiation

Hrly surface downward SW radiation



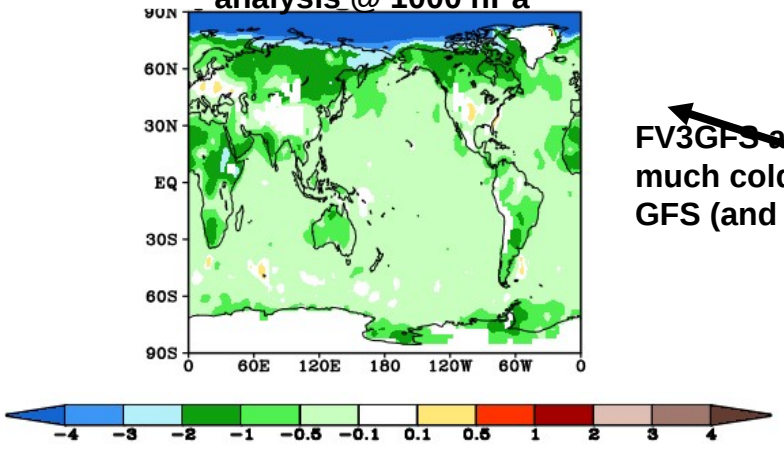




The bug fix was introduced on Sept. 17, 2018 in the real-time parallel, which coincided with signs of increased cold bias in the lower troposphere.

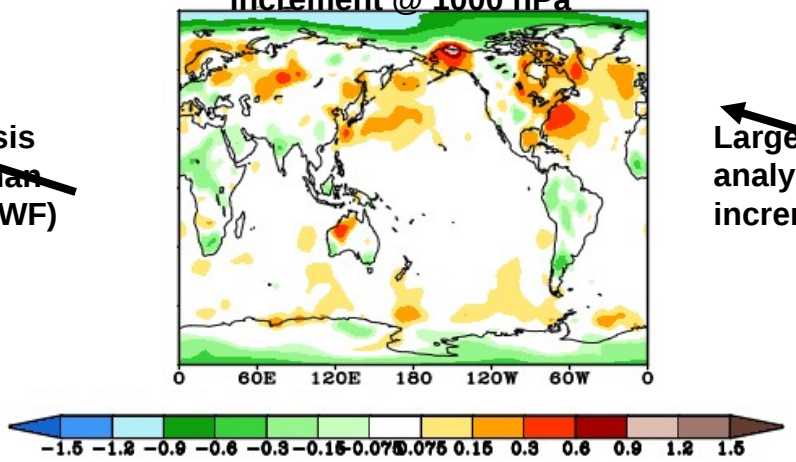
Issue #2
Exacerbated cold bias in the lower atmosphere

FV3GFS – GFS temperature analysis @ 1000 hPa



FV3GFS analysis much colder than GFS (and ECMWF)

FV3GFS temperature analysis increment @ 1000 hPa



Large negative analysis increment

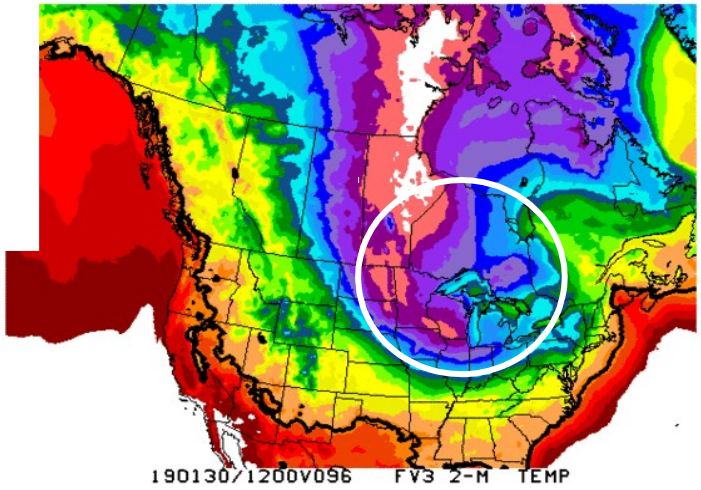
The cause: FV3GFS analysis has a stronger constraint on supersaturation than GFS at very low levels near the pole in cold season (combination of more grid points & physics changes)

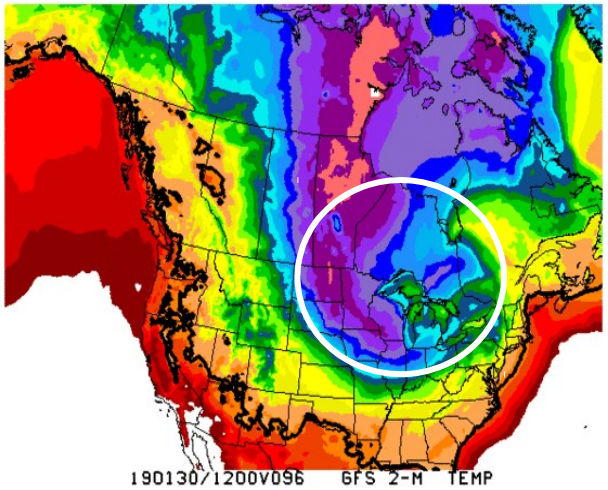
- Analysis has a weak constraint on the amount of supersaturation allowed. The impact of the constraint depends on the density of gridpoints.
- The GFS and FV3GFS have different gridpoint densities near the poles, so the constraint must be weighted differently. They are not in the old FV3GFS configuration.

The Arctic Blast of Late January 2019

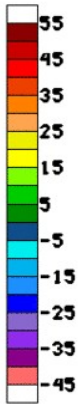
12z 1/26/19 CYCLE F96

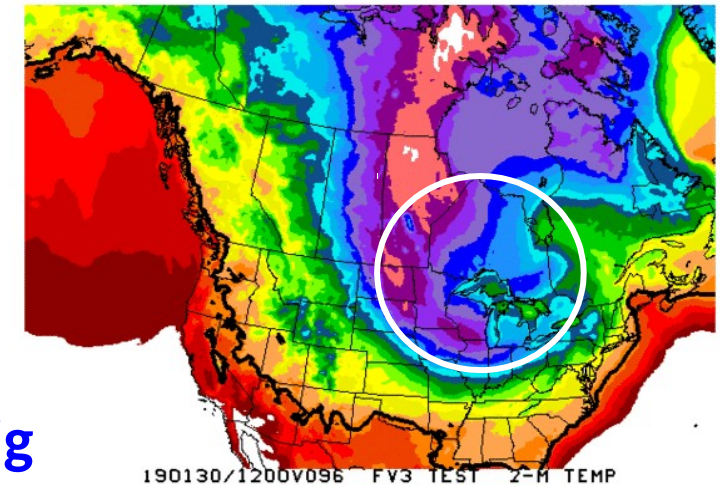
Real Time Para



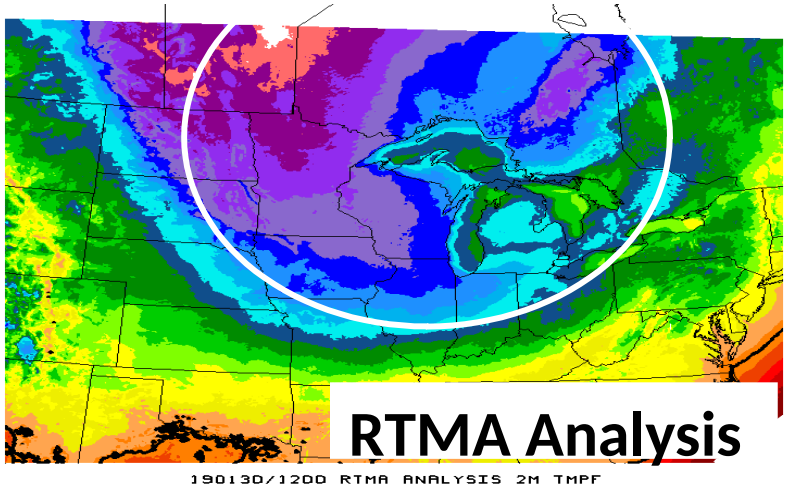


OPS GFS





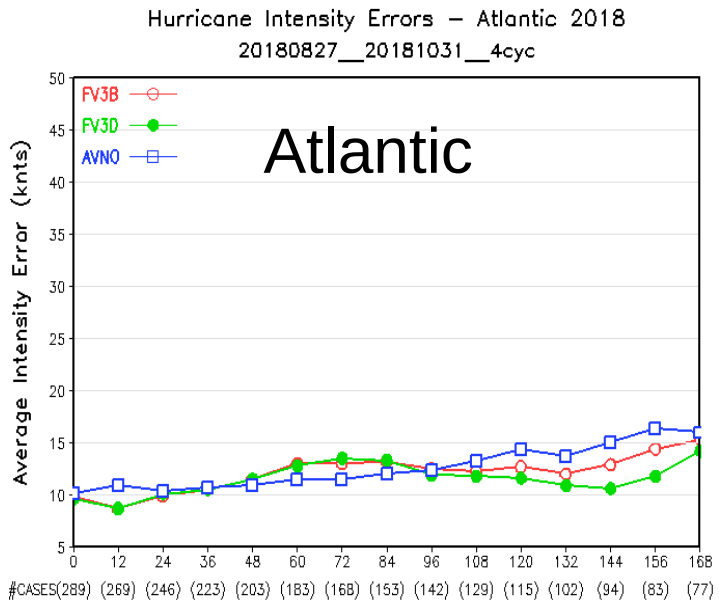
New config



RTMA Analysis

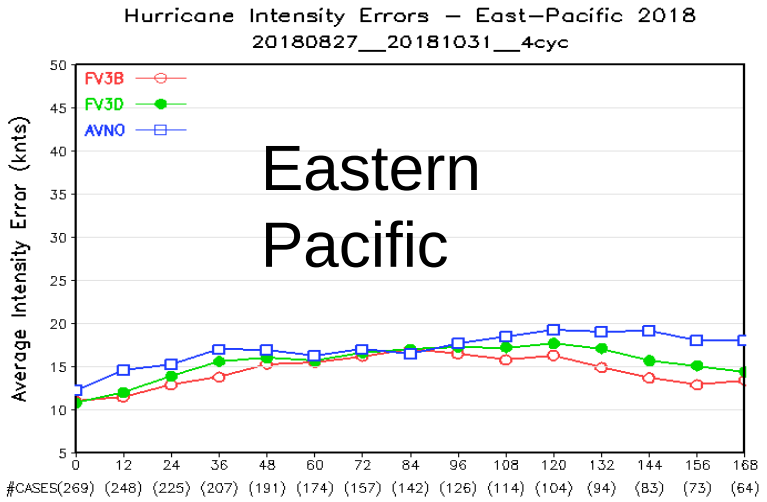
New configuration is warmer than real-time parallel and while it is still too cold, it shows a clear improvement.

Mean Intensity Errors, 27Aug2018 ~ 31Oct 2018



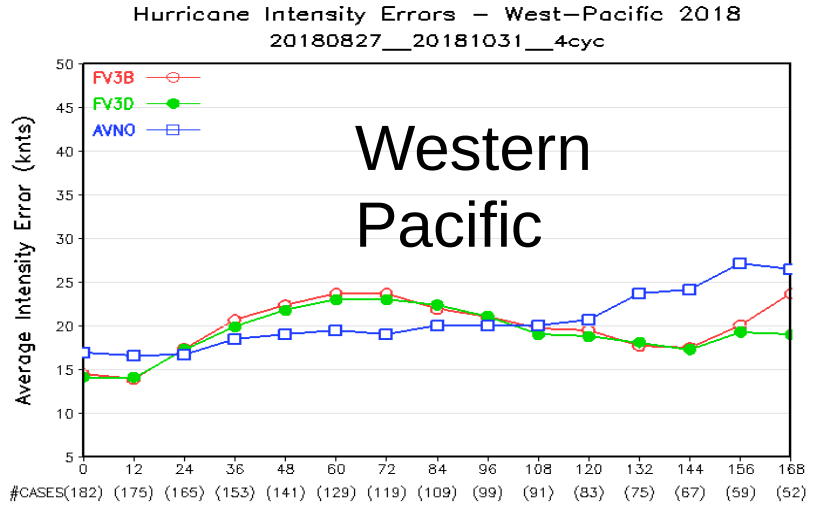
Confidence Level (%) of Student–t Tests

FV3B_FV3D	72	50	74	51	51	69	85	58	87	77	89	87	97	97	77
FV3B_AVNO	87	100	89	63	87	99	99	95	55	84	91	89	93	83	62
FV3D_AVNO	96	100	79	63	89	99	99	97	76	93	99	97	99	99	81



Confidence Level (%) of Student–t Tests

FV3B_FV3D	68	88	99	99	89	62	67	51	85	94	92	99	99	99	88
FV3B_AVNO	99	100	99	99	98	83	80	65	84	98	98	99	99	99	99
FV3D_AVNO	99	99	99	98	92	78	70	68	63	89	93	97	99	99	99

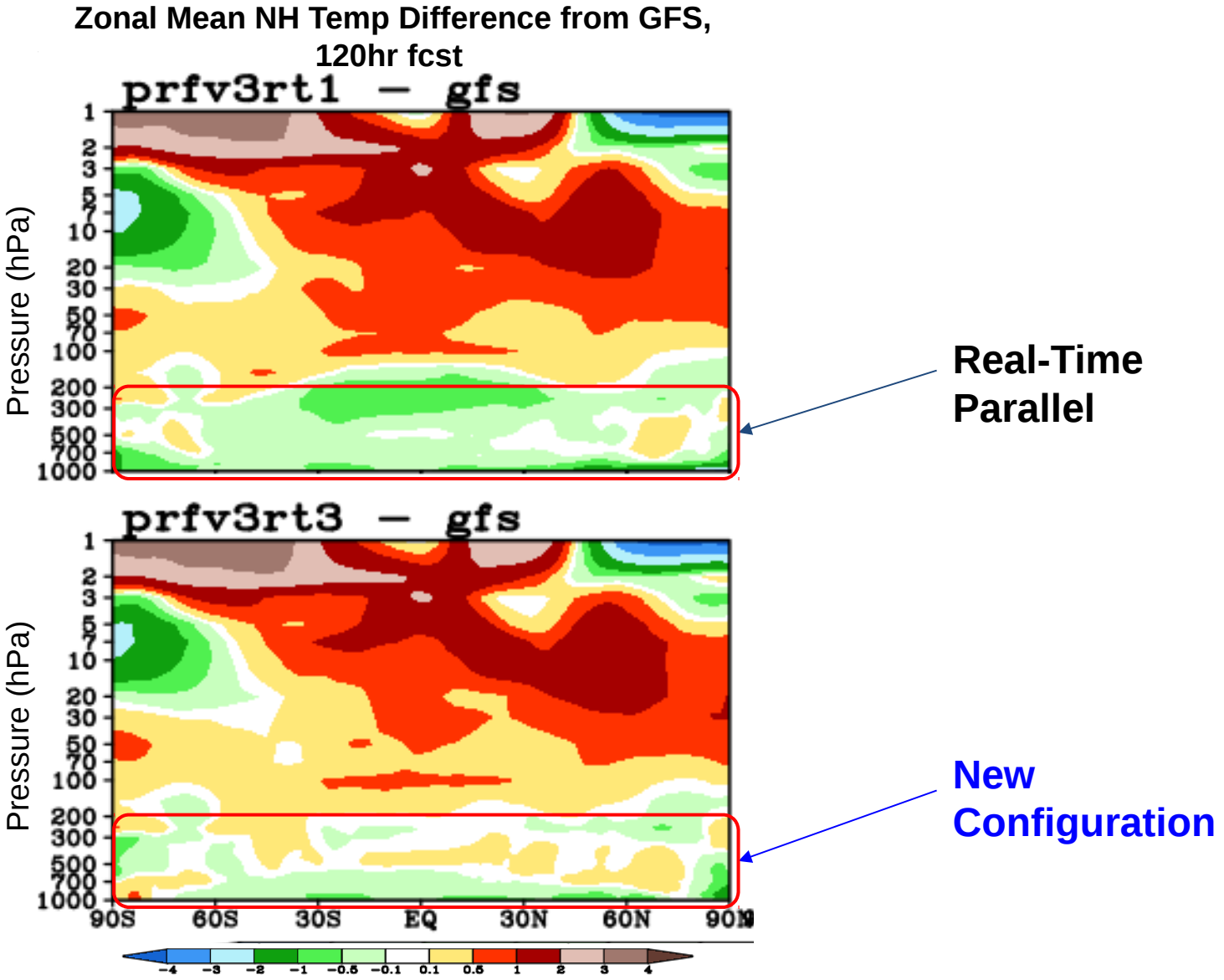


Confidence Level (%) of Student–t Tests

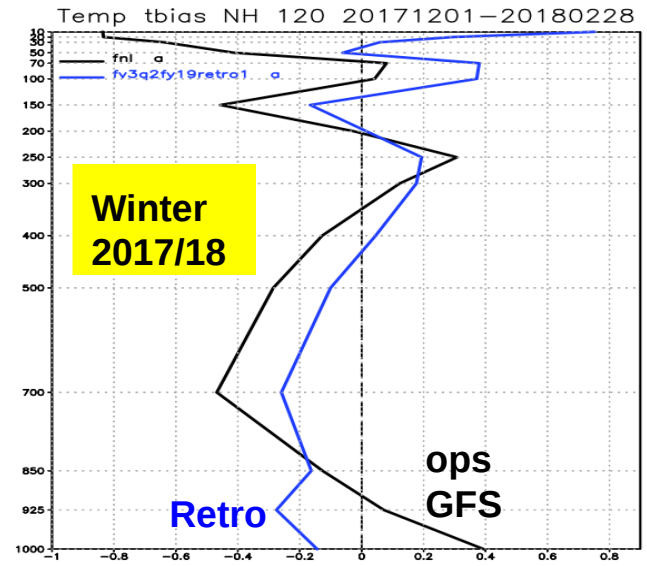
FV3B_FV3D	78	62	58	91	81	90	89	77	55	83	86	63	58	73	99
FV3B_AVNO	99	99	87	99	99	99	100	99	87	64	83	99	99	99	87
FV3D_AVNO	99	99	80	98	99	99	99	99	86	81	93	99	99	99	99

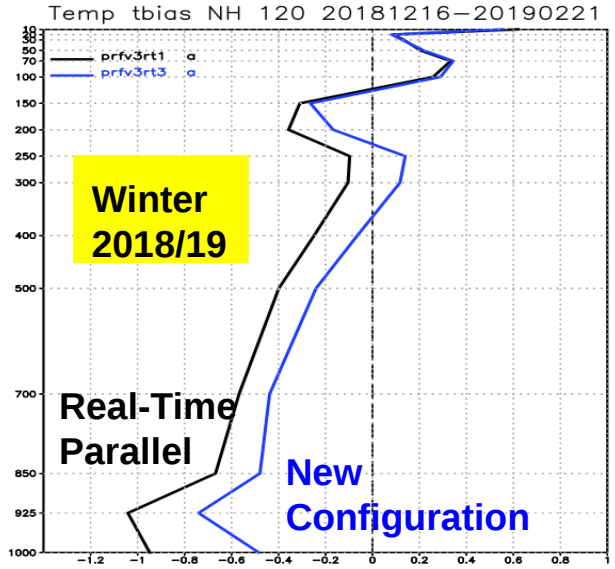
FV3B: Real-Time Parallel
FV3D: New Configuration
AVNO: Operational GFS

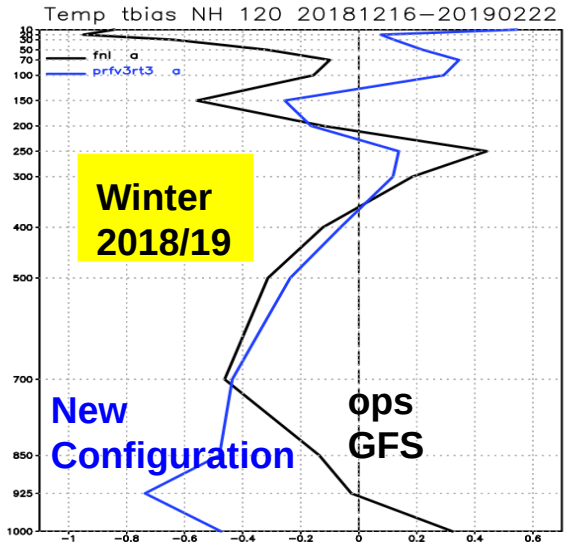
Tropospheric temperature cold bias reduced (Winter 2018/19)

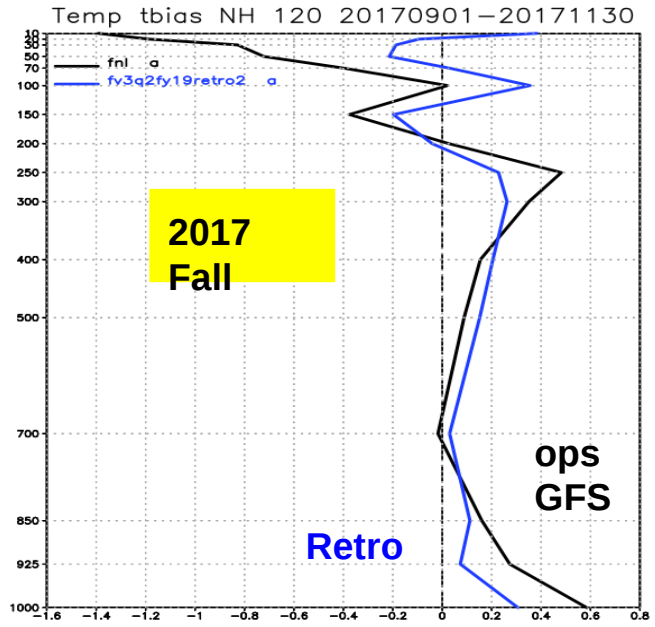


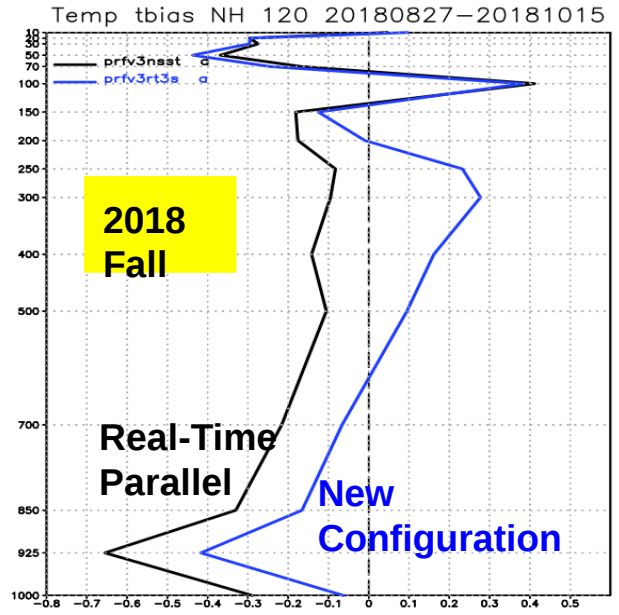
Comparison of NH day-5 fit-to-robs for the New Configuration with that for the "3-year retro" package

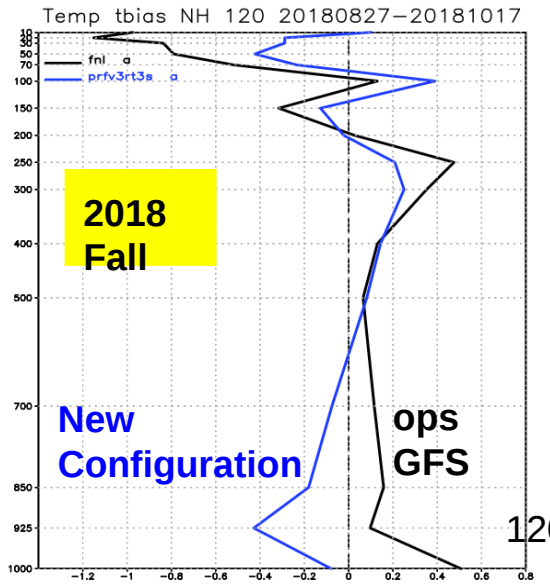






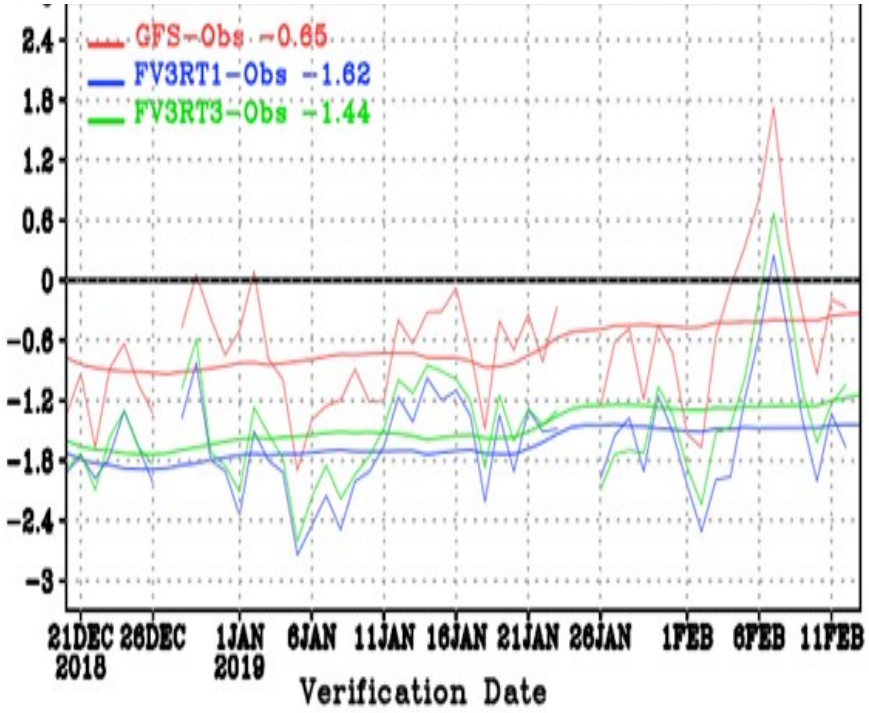


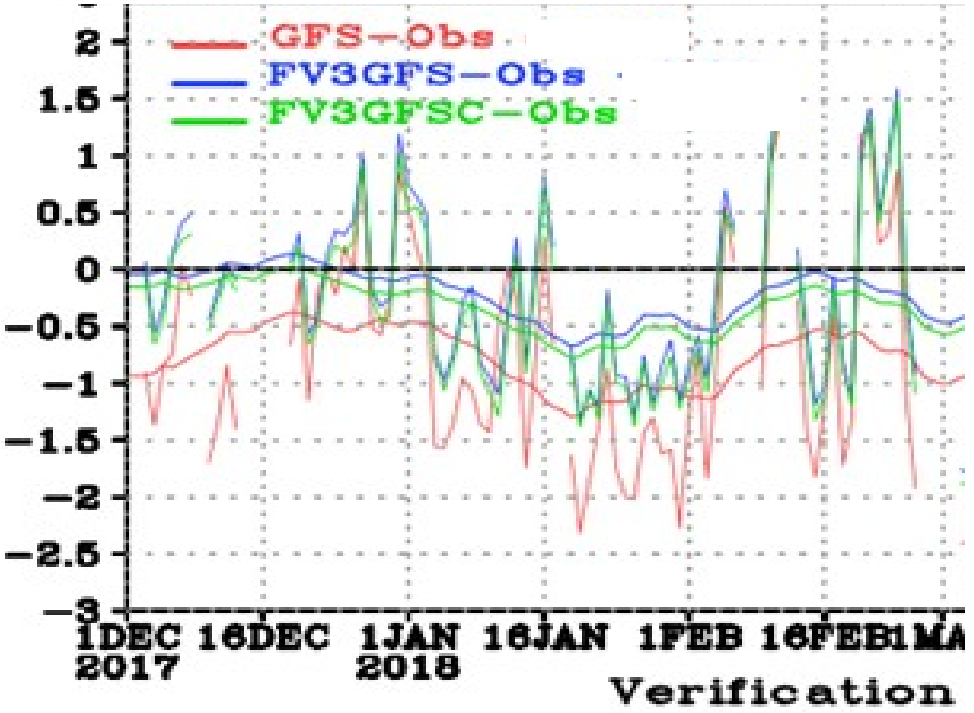




Surface temperature over CONUS West:

New Configuration is warmer than real-time parallel, but colder than observations and GFS





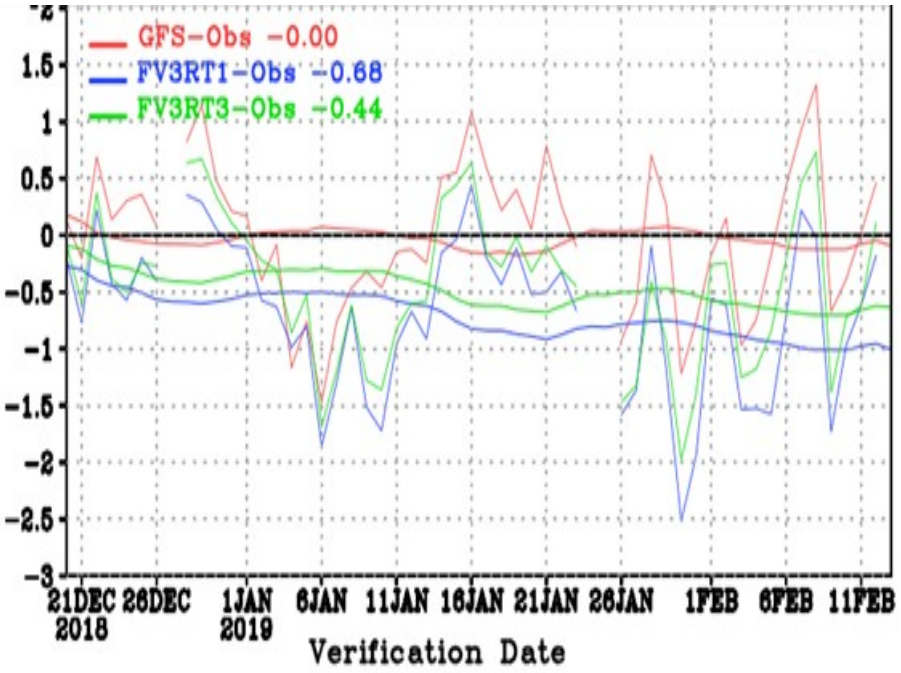
Retrospective run is warmer than GFS

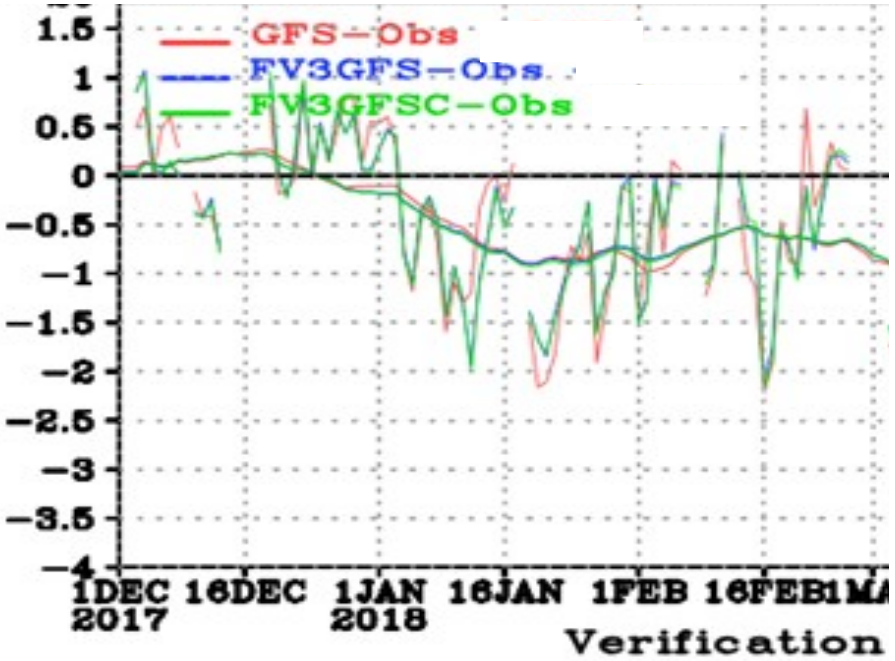
Real time, surface temperature verification for 48h forecast over CONUS West:
https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt3/g2o/g2o_00Z/sfc/fo_fh48_T_SFC_west.png

Retro, surface temperature verification for 48h forecast over CONUS West:
https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/fv3q2fy19retro1c/g2o/g2o_00Z/sfc/fo_fh48_T_SFC_west.png

Surface temperature over CONUS East:

New Configuration is warmer than real-time parallel, but colder than observations and GFS





Retrospective run is similar to GFS

Real time, surface temperature verification for 48h forecast over CONUS East:
https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt3/g2o/g2o_00Z/sfc/fo_fh48_T_SFC_east.png

Retro, surface temperature verification for 48h forecast over CONUS East:
https://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/fv3q2fy19retro1c/g2o/g2o_00Z/sfc/fo_fh48_T_SFC_east.png

Post-implementation changes related to observation/DA upgrades for GFS v15.1

- GOES-17 AMVs and Metop-C AMSUA/MHS are not yet dumped. Once dumped these datasets will only be MONITORED in the current rt4 configuration. GSI fix file changes are required to assimilate the data.
- Drifting and moored buoy data is not yet dumped. In addition to dumping the data, a ObsProc script needs to be updated to include the additional buoy data in the nsstbufr file. Once dumped and added to nsstbur the extra buoy data will be ASSIMILATED without any additional changes.
- Post-implementation changes:
  - Change usage flags in two fix files
    - global_convinfo.txt: assimilate GOES-17 AMVs
    - global_satinfo.txt: assimilate Metop-C AMSUA & MHS