EMC CCB (Decisional Brief)
February 17, 2017

GDAS/GFS V14.0.0 Upgrades for Q3FY2017

Presented by:

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Chief, Global Climate and Weather Modeling Branch

Based on work done by EMC NEMS, DA, Land Surface, Ensembles, Waves, Hurricane Teams, GCWMB, various NPS downstream code managers and external evaluators

GDAS/GFS Version 14.0.0
Status as of 02/17/2017

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Project Information & Highlights

Leads: Vijay Tallapragada (EMC), Becky Cosgrove (NCO)

Scope: Transition GDAS/GFS to NEMS infrastructure on Cray, improve deep & shallow convection schemes, and address rapid temp drop & wet bias. GDAS upgrades include Near Surface Sea Temp (NSST) and additional data for GDAS and GLDAS.

Expected benefits: Prepare for unified modeling infrastructure, improve general forecast skill with emphasis on near surface fields

Dependencies: Satisfactory external evaluation

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Schedule

Milestones & Deliverables	Date	Status
Freeze system code; deliver to NCO if applicable	10/28/16	completed
Complete full retrospective/real time runs and evaluation	1/31/17	completed
EMC CCB	2/1/17 → **2/17**	today
Final OD Science Briefing & deliver final codes to NCO	2/21/17	Scheduled
Downstream code delivery	**2/21/17**	Scheduled
Issue Technical Information Notice	2/15/17 → **2/23**	on track
Complete 24-hr parallel production test	3/17/17	on track
Complete 30-day evaluation and IT testing	5/??/17	on track
Operational Implementation	5/??/17	on track

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Issues/Risks/Concerns

Risk 1: Upstream/Downstream dependencies of GFS in NEMS; **Mitigation**: Work with NCO to address upstream/downstream dependencies.

Risk 2: Complex T&E requirements due to Cray availability; **Mitigation**: Run the parallels on production machine

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Resources

Staff: 4 Fed FTEs + 10 contractor FTEs; including Dev (Physics, DA, and Infrastructure)

Funding Source: STI/Base

Compute: parallels: 1200 nodes for 3 months (devmax/devonprod); 800 nodes for 9 months (devhigh); **EMC Dev**: ~1200 nodes for 12 months

Archive: 2PB

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

Review of GFS2017 changes

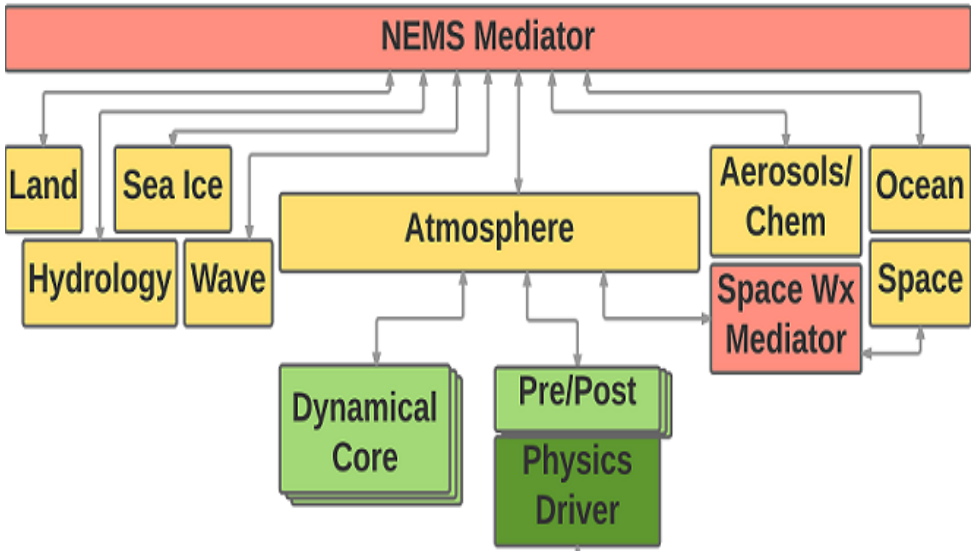
- **NEMS superstructure and infrastructure**
- **Upgraded land parameterizations, higher resolution land surface climatologies, new surface albedo data (should improve surface upward radiation, near-surface fields and reduce patchiness)**
- **Fix to excessive cooling of 2m temperatures during sunset (00Z)**
- **Changes to cumulus convection parameterization that should help to *improve summertime precipitation forecasts***
- **NSST's that represent diurnal warming effects and sub-layer cooling**
- **Assimilation of additional data (some GPS data, AMVs, and some radiances), minor bug fixes mostly related to cloud water and preparation for future satellites (JPSS, GOES-16, COSMIC-2)**
- **Rayleigh damping reduced by 50% in the upper stratosphere above 2 hPa**

GDAS/GFS in NEMS

(*NOAA Environmental Modeling System)*

- Shared, portable, high performance software superstructure and infrastructure
- Common superstructure for all NCEP models.
- Modularize large pieces of the models
- Divide atmospheric models down into Dynamics and Physics components.
- Take history file I/O outside the science parts into a common Write component.
- Keep science code and parallelization codes same as before.

NEMS Component Schematic



<u>Significant speed-up of NEMS GSM (w/77 nodes):</u>

- Use gmalloc library for better malloc/free performance (reduced runtime from 6400+ to 5700 seconds)
- Recode the I/O for the quilts (reduced runtime from 5700 seconds to 5100+ seconds)
- Replace ESMF DEGMM with MKL DGEMM (reduced runtime from 5100 seconds to 4300 seconds)

Major science issues addressed in the Q3FY17 GFS upgrade

Surface Parameters (Land Surface Upgrades):

- Cold temperature bias over snow
  - » Alaska, NW, NE
- Stable boundary
- Land-Atmosphere Decoupling
- Surface exchange coefficient (Ch)
- Snow albedo too large

Precipitation (Convection Scheme Upgrades):

- “socialist” rain (too much drizzle)
- “popcorn” precipitation in western US in summer
- convective fraction increased when resolution increased to 13 km

SST (Replace RTGSST with new NSST):

- Oceanic vertical temperature structure near surface due to the diurnal warming and sub-layer cooling physics processes

Land Surface Changes for NEMS GFS

- IGBP 20-type land classifications and STASGO 19-type soil classifications
- The new MODIS-based snow free albedo
- The new MODIS-based maximum snow albedo
- Diurnal albedo treatment
- Unify two snow fields between radiation driver and Noah LSM
    - Snow cover
    - Snow albedo
- Fix excessive cooling of T2m during sunset
- Increase ground heat flux under the deep snow

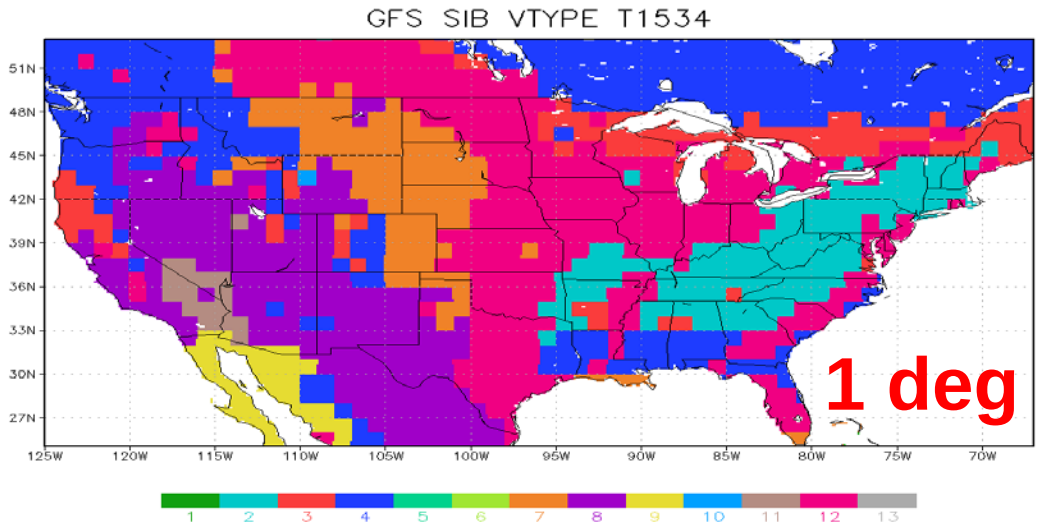
New IGBP Land Classification

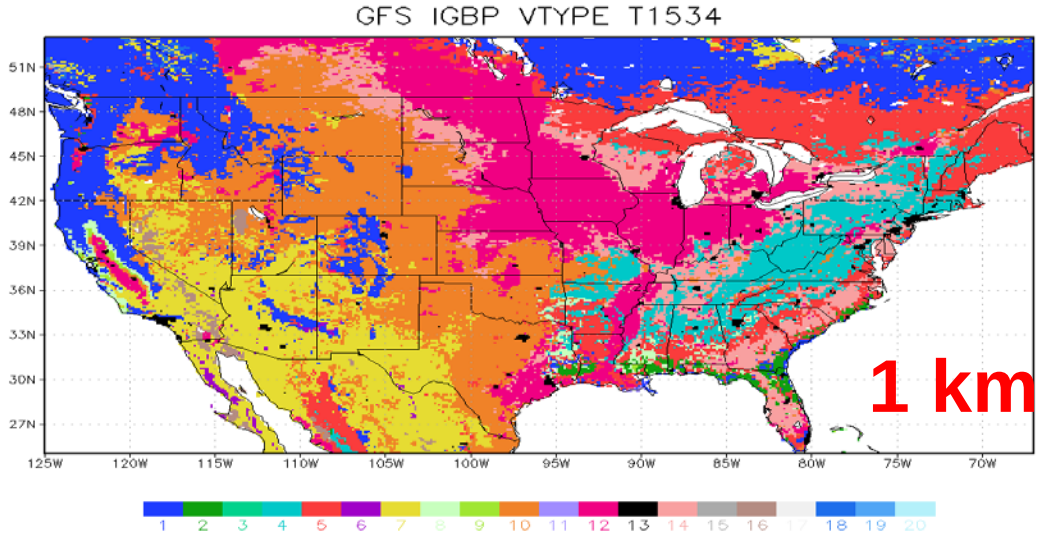
Old

1: broadleaf-evergreen trees
2: broadleaf-deciduous trees
3: broadleaf and needleleaf trees
4: needleleaf-evergreen trees
5: needleleaf-deciduous trees (larch)
6: broadleaf trees with groundcover
7: groundcover only (perennial)
8: broadleaf shrubs with perennial groundcover
9: broadleaf shrubs with bare soil
10: dwarf trees and shrubs with groundcover (tundra)
11: bare soil
12: cultivations (same parameters as type 7)
13: glacial ice

New

1: Evergreen Needleleaf Forest
2: Evergreen Broadleaf Forest
3: Deciduous Needleleaf Forest
4: Deciduous Broadleaf Forest
5: Mixed Forests
6: Closed Shrublands
7: Open Shrublands
8: Woody Savannas
9: Savannas
10: Grasslands
11: Permanent wetlands
12: Croplands
13: Urban and Built-Up
14: Cropland/natural vegetation mosaic
15: Snow and Ice
16: Barren or Sparsely Vegetated
17: Water
18: Wooded Tundra
19: Mixed Tundra
20: Bare Ground Tundra





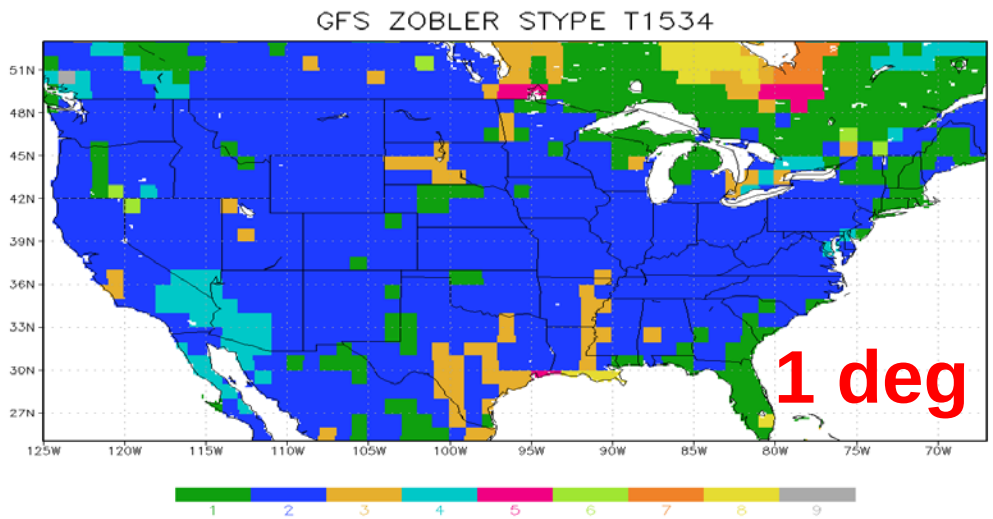
New STASGO Soil Classification

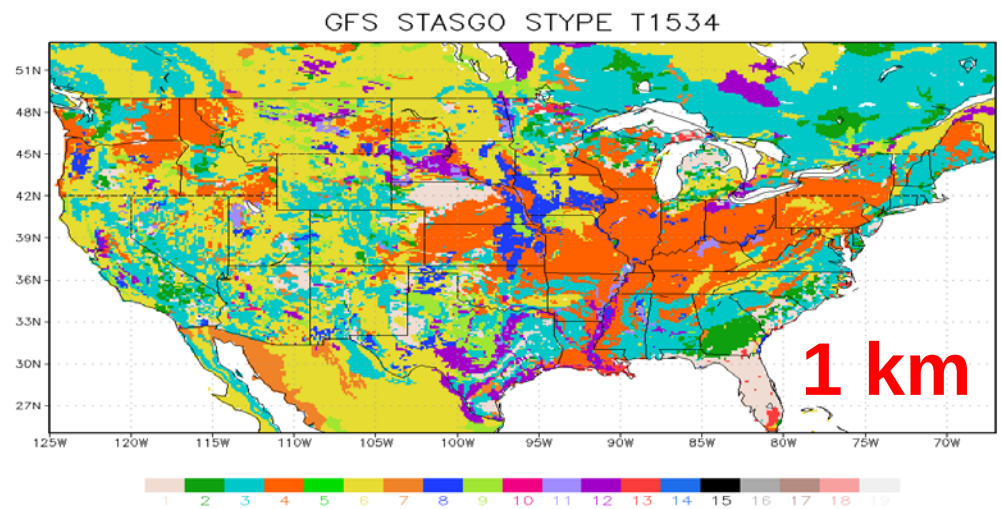
Old

1: loamy sand
2: silty clay loam
3: light clay
4: sandy loam
5: sandy clay
6: clay loam
7: sandy clay loam
8: loam
9: glacial ice

New

1: sand
2: loamy sand
3: sandy loam
4: silt loam
5: silt
6: loam
7: sandy clay loam
8: silty clay loam
9: clay loam
10: sandy clay
11: silty clay
12: clay
13: organic material
14: water
15: bedrock
16: other (land-ice)
17: playa
18: lava
19: white sand





Improving the Stable Surface Layer in GFS

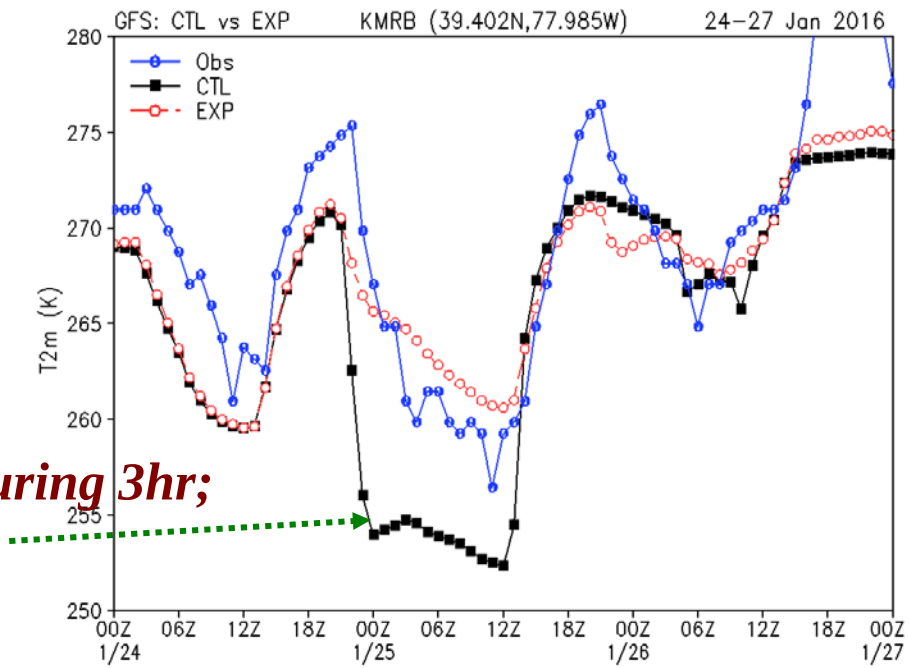
Introduction of a stability parameter constraint that prevents the land-atmosphere system from fully decoupling:

$$z/L < z/L|_M = \ln(z/z_0)/[2*\alpha*(1-z_0/z)]$$

Here z is the height, L is the Obukhov length, $z0$ is the momentum roughness length, and α=5.

GFS Test: 00Z, 2016-01-24 Cycle

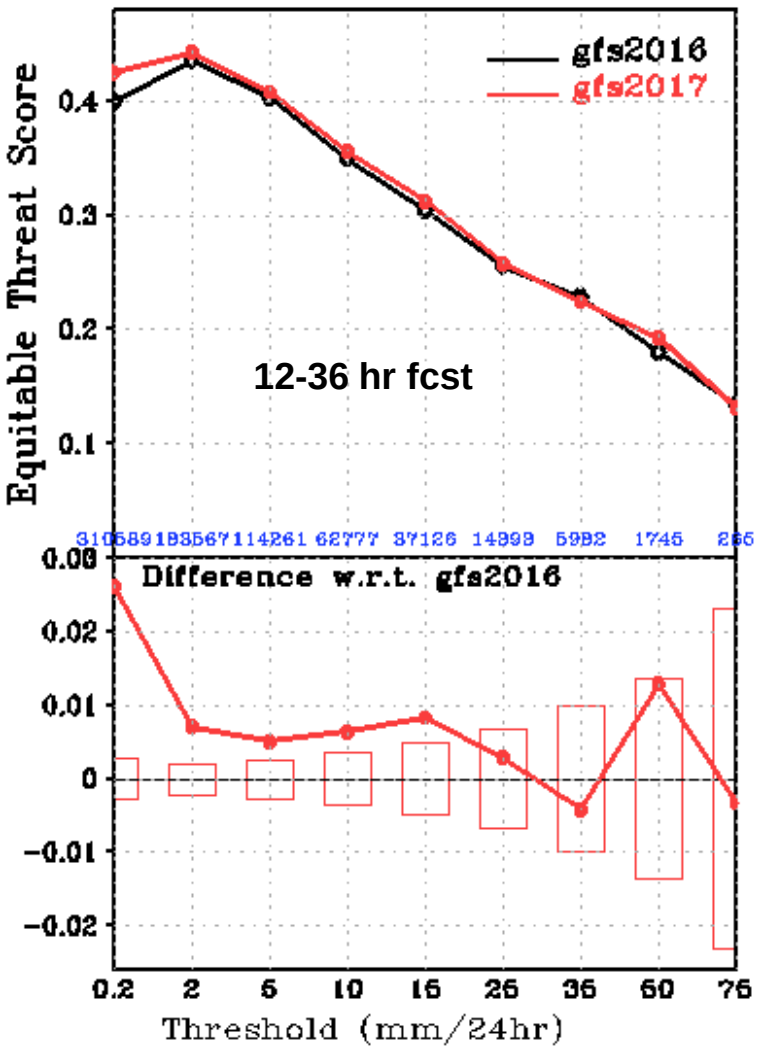
T2m @ MRB Martinsburg RGNL, WV



CTL: Rapidly cooling more than 15 °C during 3hr;
EXP: Substantially improved

Update GFS convection scheme

- Scale-aware, aerosol-aware parameterization
- Rain conversion rate decreases with decreasing air temperature above freezing level.
- Convective adjustment time in deep convection proportional to convective turn-over time with CAPE approaching zero after adjustment time.
- Cloud base mass flux in shallow convection scheme function of mean updraft velocity.
- Convective inhibition (CIN) in the sub-cloud layer additional trigger condition to <u>suppress unrealistically spotty rainfall</u> especially over high terrains during summer
- Convective cloudiness enhanced by suspended cloud condensate in updraft.
- Significant improvement especially CONUS precip in summer.



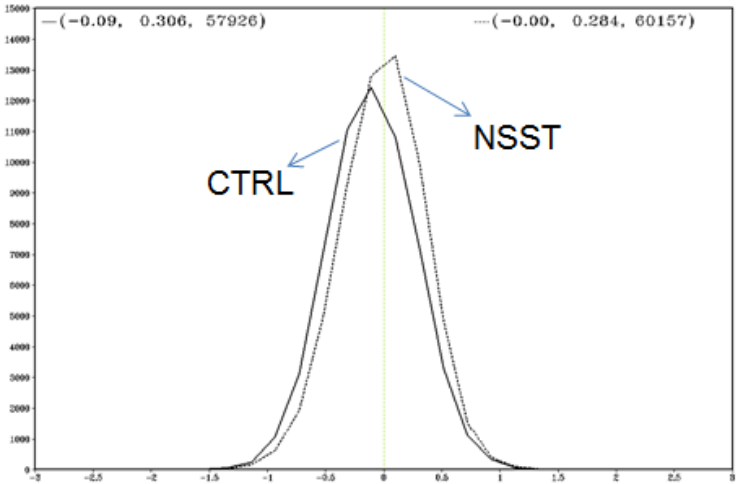
Near Surface Sea Temperature (NSST)

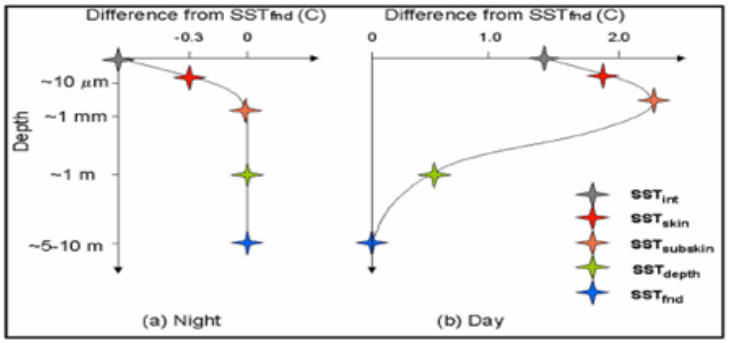
The NSST in the NCEP GFS:

- Near-Surface Sea Temperature describes oceanic vertical temperature structure near surface due to the diurnal warming and sub-layer cooling physics processes

- SST, satellite data assimilation, and weather forecasting improved by analyzing SST together with atmospheric analysis variables with advanced GSI data assimilation techniques and resolving SST diurnal variability in the prediction

(O-B) Histogram for one IASI window channel, 10-day statistics. Improved by NSST in bias, rms and number of used data





Schematic showing (a) idealized nighttime vertical temperature deviations from the foundation SST and (b) idealized daytime vertical temperature deviations from the foundation SST in the upper ocean. From Donlon and the GHRSST-PP Science Team (2005). Courtesy of C. J. Donlon.

Changes in Global Data Assimilation System (GDAS)

1. Near Sea-Surface Temperature Analysis.
2. Readiness for CrIS Full Resolution Data and add/extend RARS and DBNet capability (JPSS, GOESR)
3. Fix to cloud water increment bugs.
4. Changes to land surface type specification for CRTM.
5. Inclusion of Megatropiques SAPHIR radiance assimilation.
6. Inclusion of GPM/GMI radiance assimilation.
7. Turn on VIIRS AMVs.
8. Log-Normal wind QC for AMVs.
9. Use GOES clear-air water vapour winds.
10. Inclusion of extra GNSS-RO observations.

Test Plan & Model Upgrade Evaluation Strategy

Real-Time and Retrospective Parallels:

Three Summers (2014-16) and Two winters (2015-2016) and Real-Time

1. **GCWMB real time (prnemsrn)**
   period: 2016101800 - real time

2. **GCWMB 2015 summer retrospective (pr4rn_1505)** period: 2015050100 - 2016010200 (246 days)

3. **GCWMB 2015 winter retrospective (pr4rn_1512)**
   period: 2015121500 - 2016051518 (151 days)

4. **GCWMB 2016 summer retrospective (pr4rn_1605)** period: 2016050100 - 2016103018 (184 days)

5. **GCWMB 2014 summer retrospective part1 (pr4rn_1405) → Use ROCOTO Automation**
   period: 2014050100 - 2014073118 (92 days)

6. **GCWMB 2014 summer retrospective part2 (pr4rn_1408) → Use ROCOTO Automation**
   period: 2014073100 - 2014110518 (98 days)

Evaluation Procedures:

- **Involve field in real-time and retrospective evaluation of science upgrades**
- **Identify case studies and provide data for extended evaluation period beyond last 30-day parallel**
- **NCO 30-day parallel is only for IT evaluation**

Evaluation of Q3FY17 GDAS/GFS Upgrade:

EMC Perspective

Anomaly Correlations & RMSE: GFSX vs. GFS; 2014 05 15 – 2017 02 01;

verified against own analyses

			N. American						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
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Biases: GFSX vs. GFS

			N. American						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
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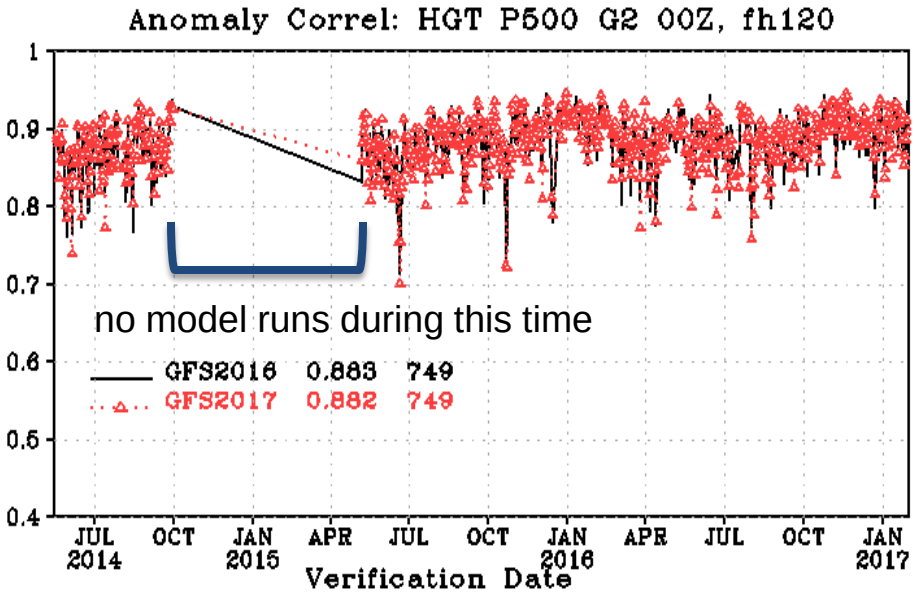
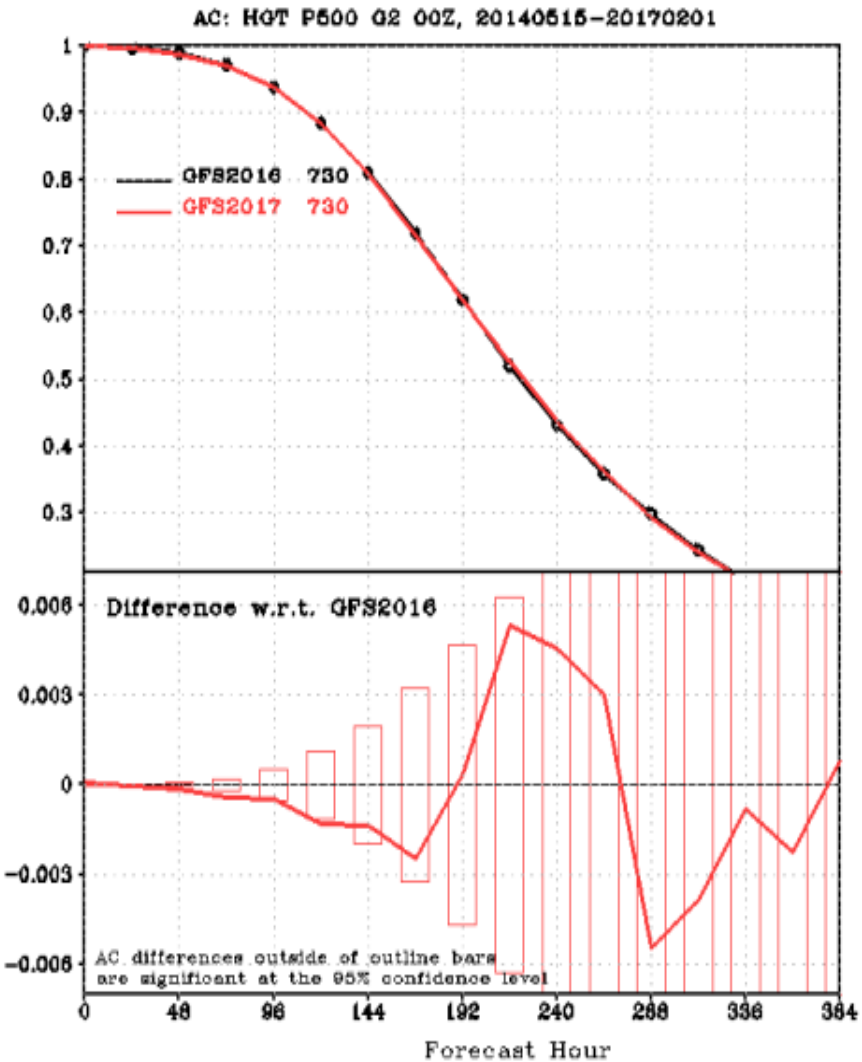
Overall, improvements to stratospheric evaluations metrics

Wind speed bias has decreased --GFSX has stronger, more realistic winds

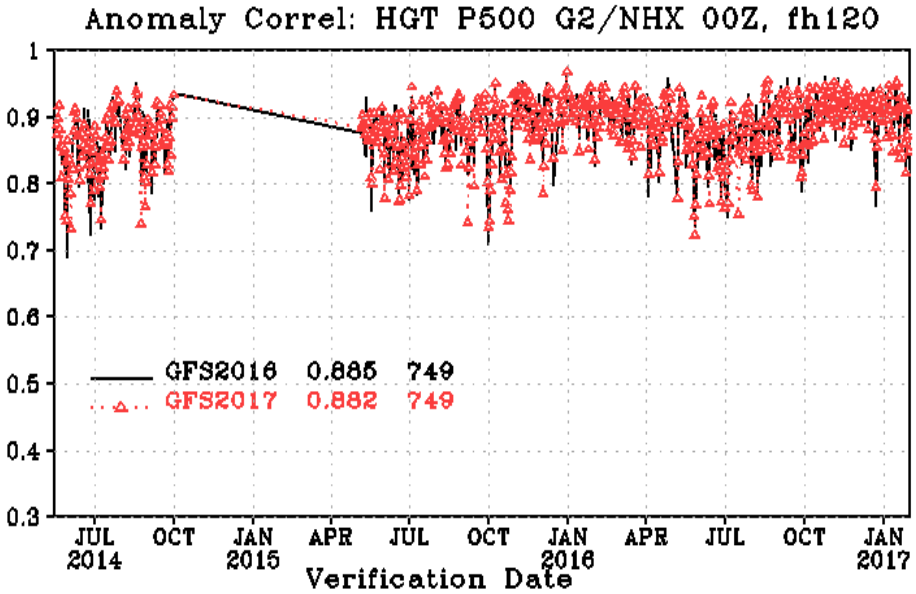
ACC for Day-5 500 hPa Heights: Globe

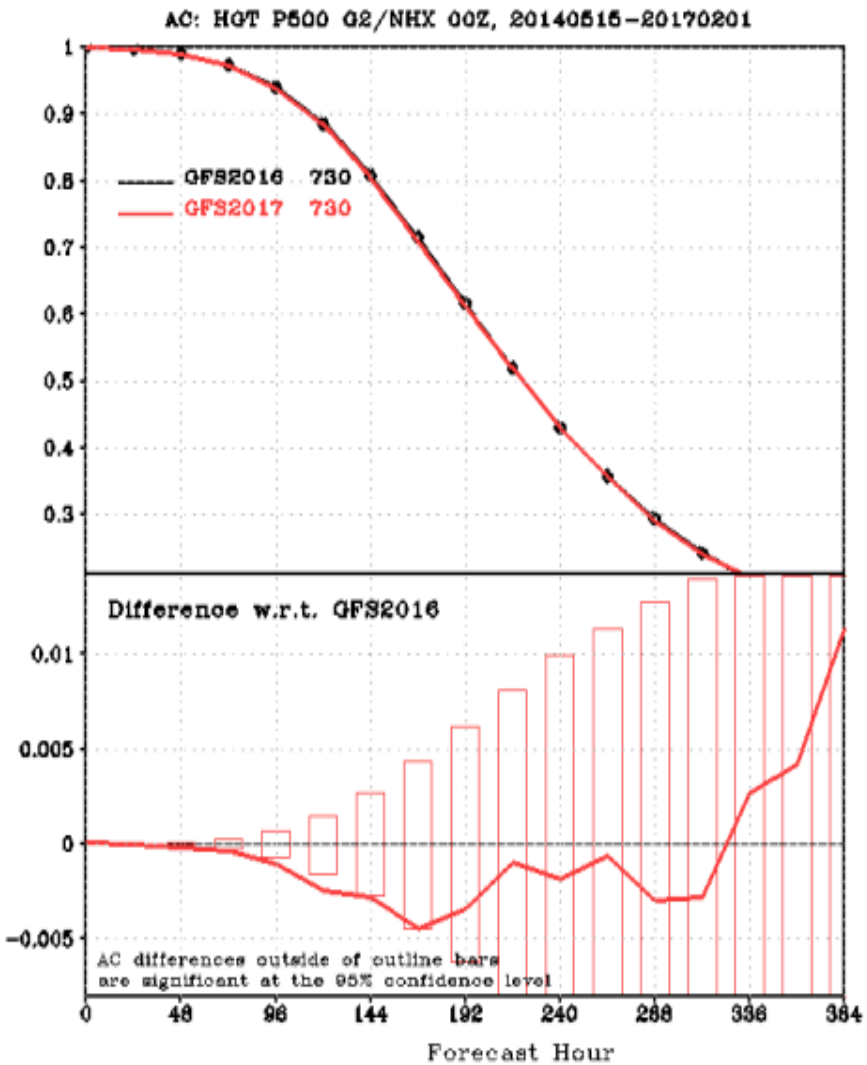




0.01 decrease in AC
Statistically insignificant decrease at early forecast hours

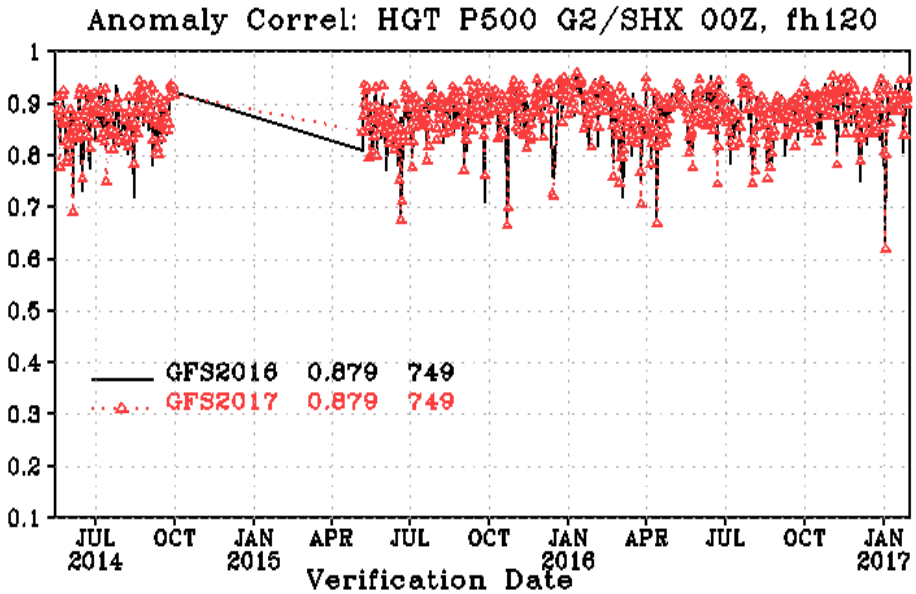
ACC for Day-5 500 hPa Heights: Northern Hemisphere

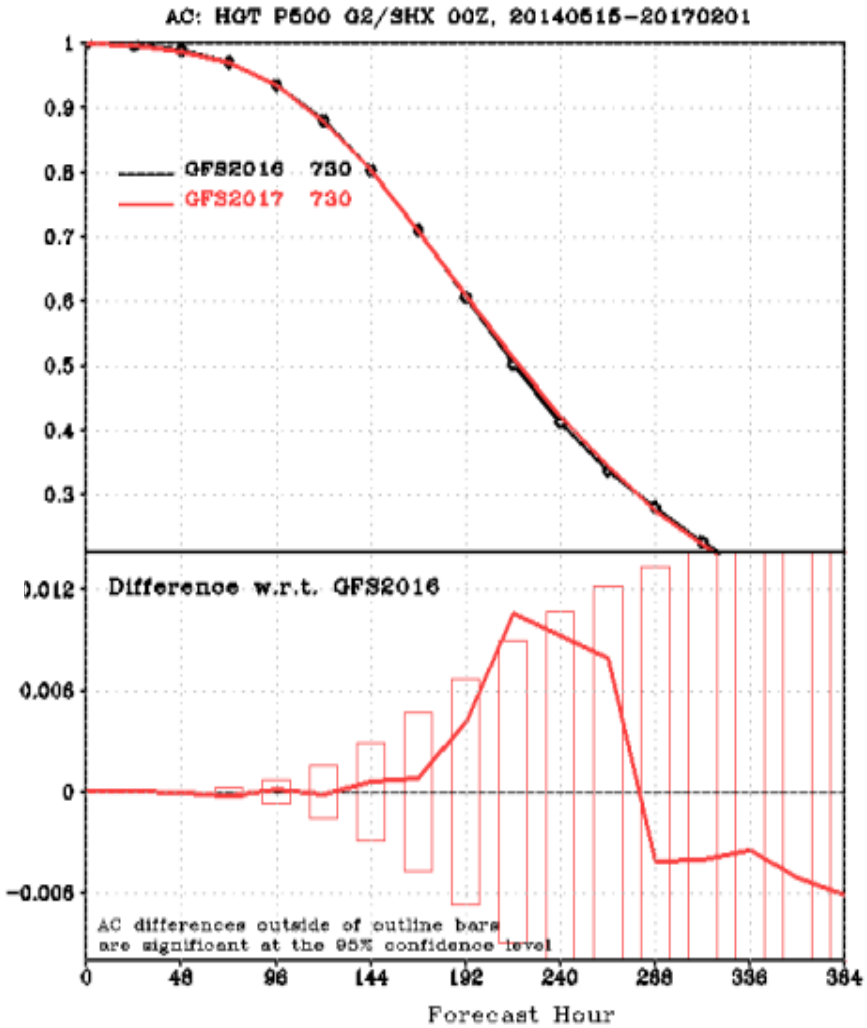




0.03 decrease in AC

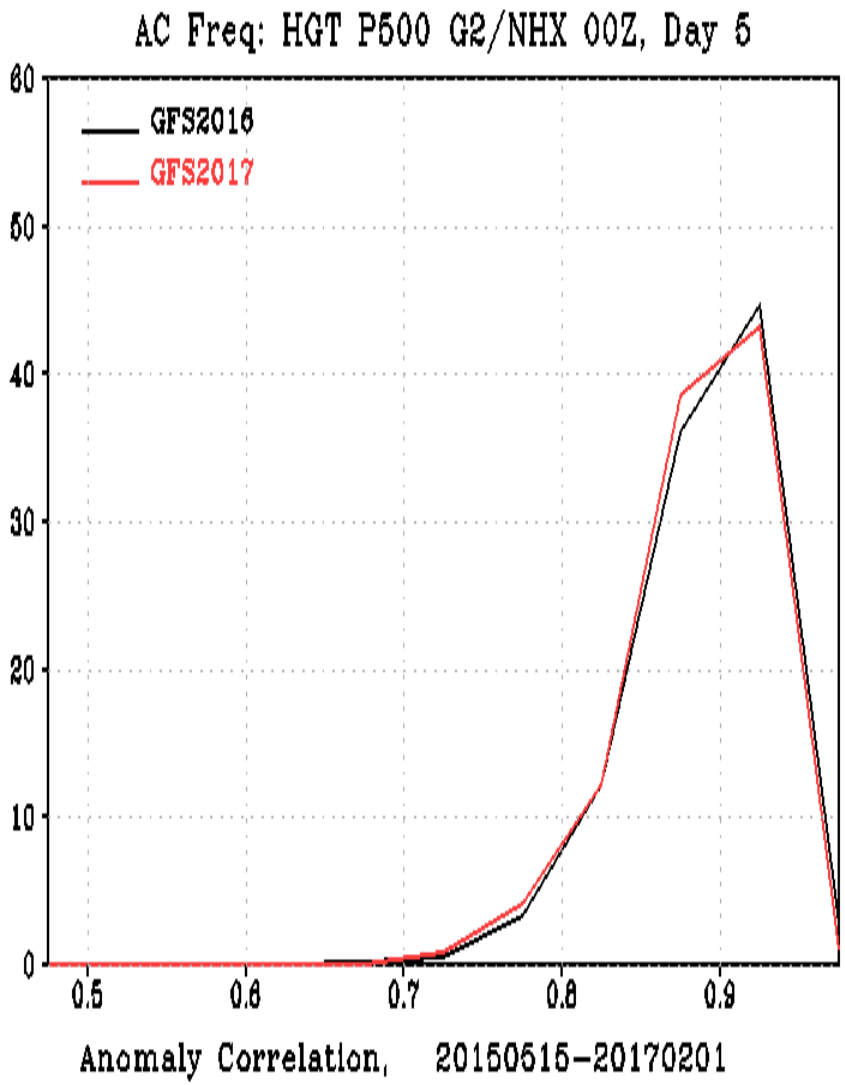
ACC for Day-5 500 hPa Heights: Southern Hemisphere

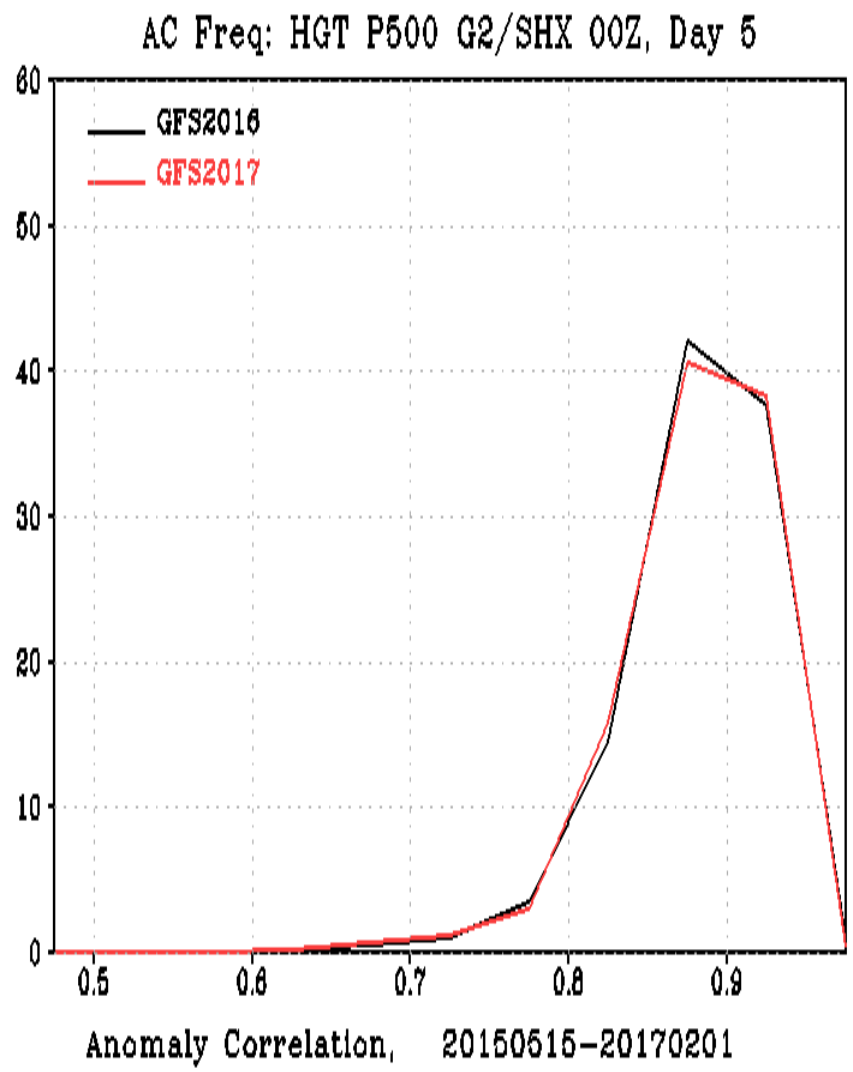




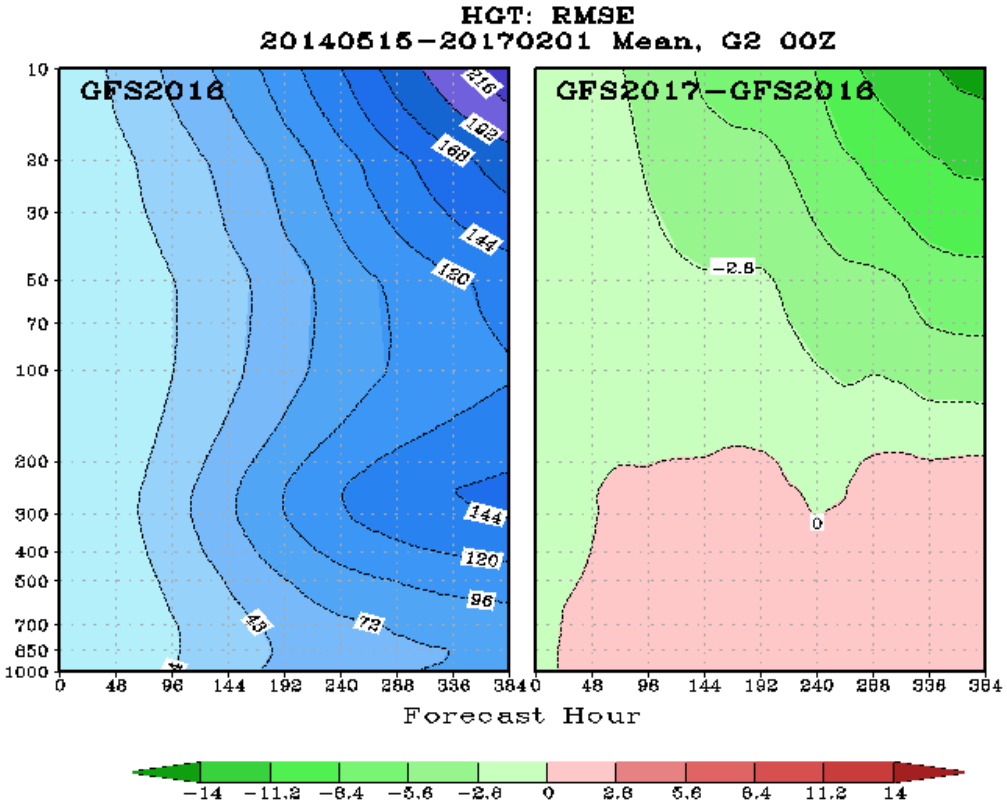
Same AC
Essentially no statistically significant differences at any forecast hour

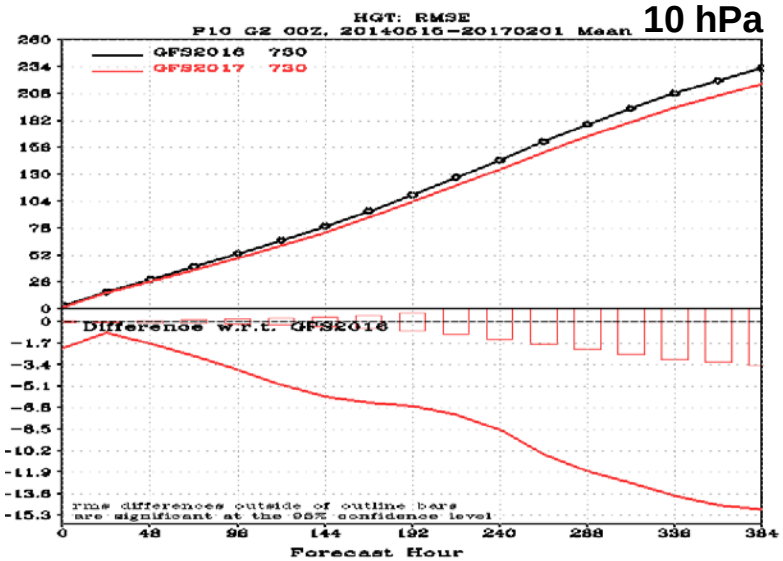
AC Frequency for Day-5 500 hPa Heights: Northern and Southern Hemispheres

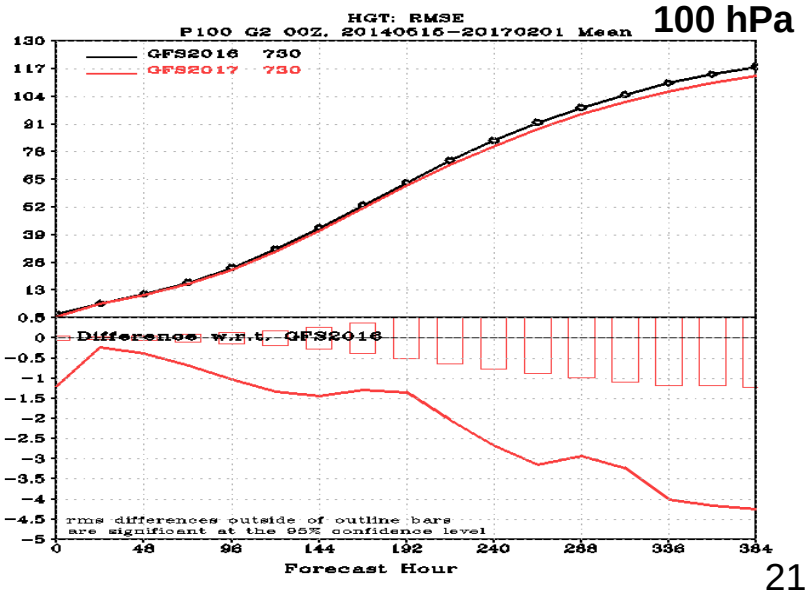




RMSE for Heights: Global

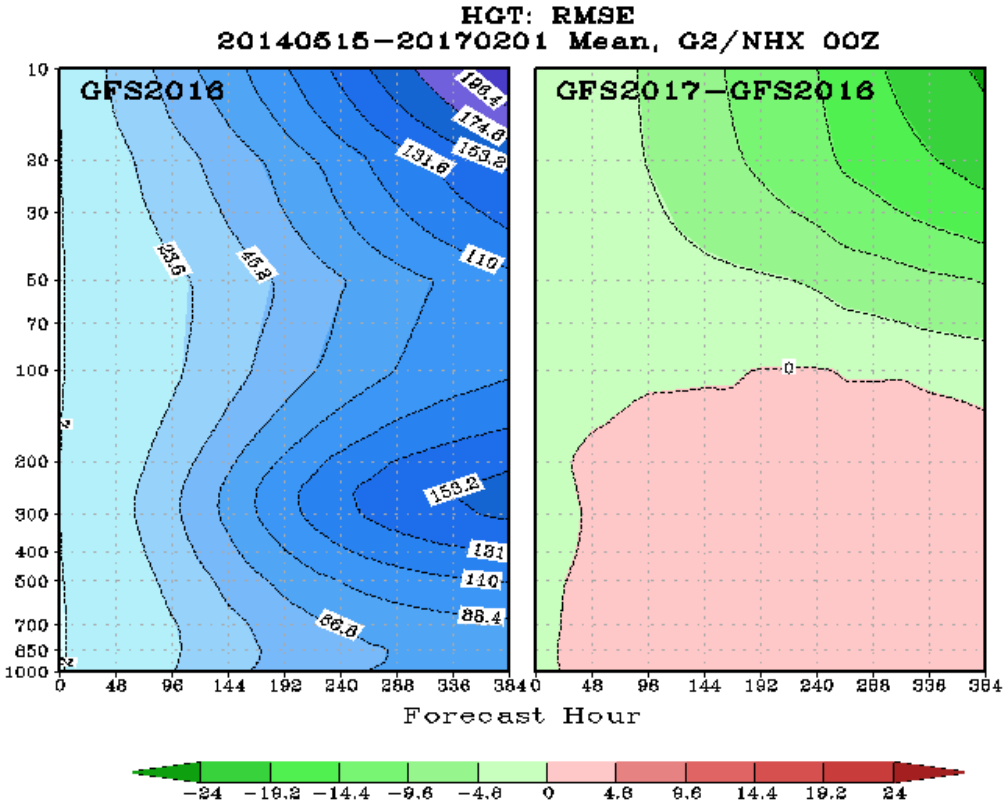


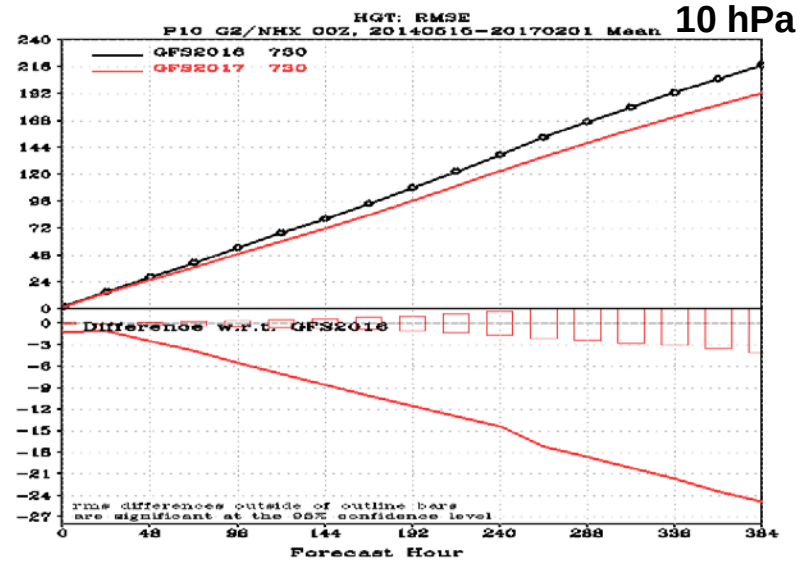


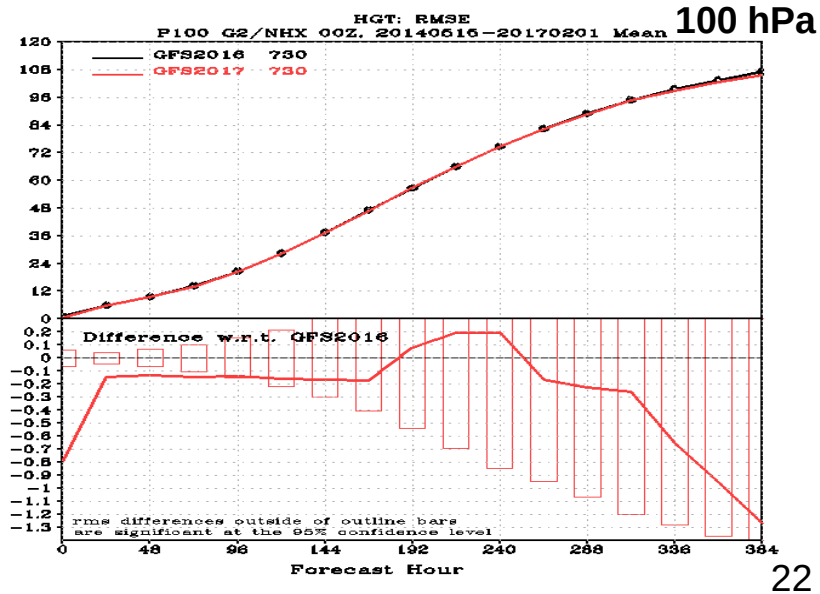


Statistically significant improvement of RMSE in stratosphere/upper troposphere at all forecast hours

RMSE for Heights: Northern Hemisphere



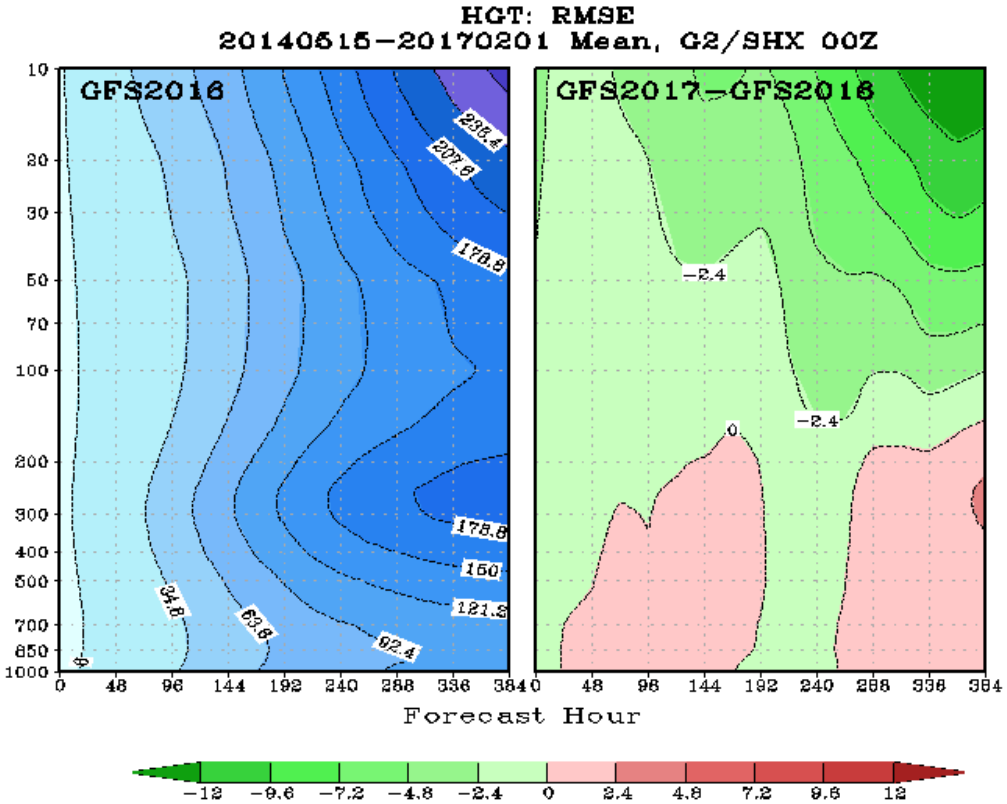


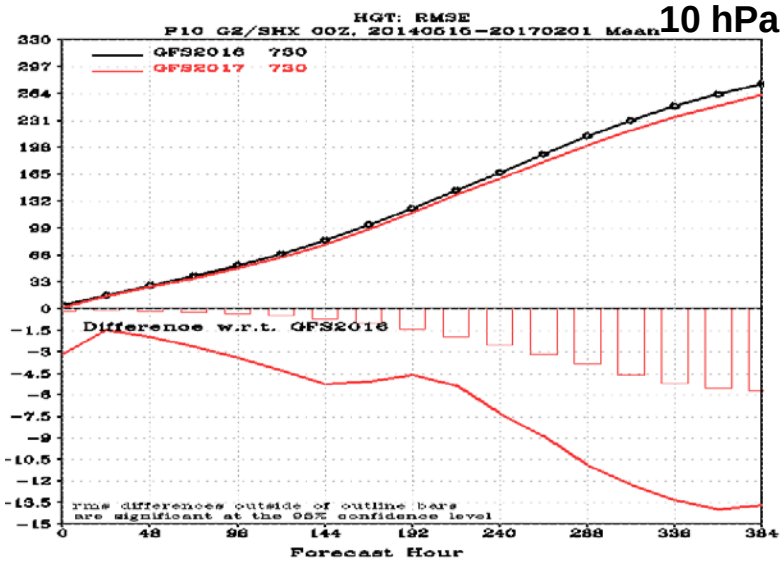


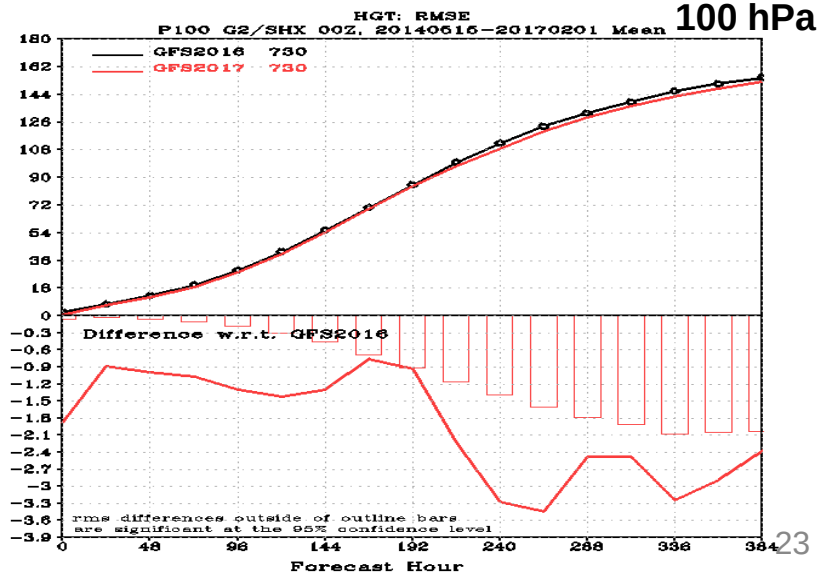
Statistically significant improvement of RMSE in at 10 hPa at all forecast hours

Statistically significant improvement of RMSE at early forecast hours at 100 hPa

RMSE for Heights: Southern Hemisphere

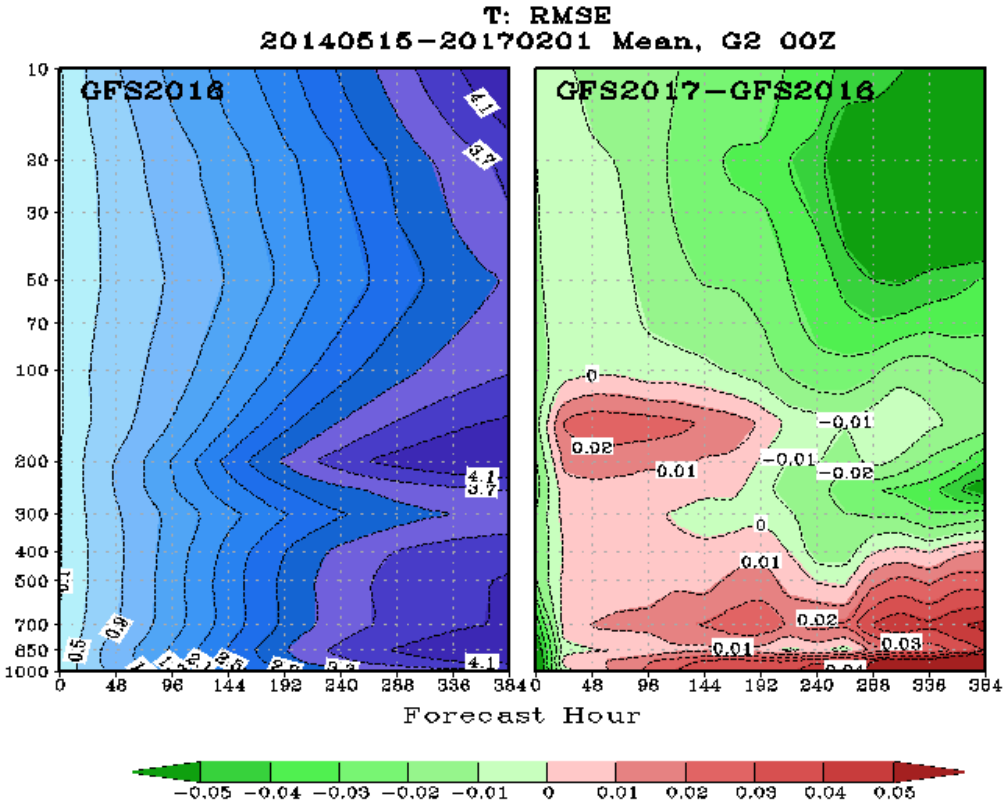


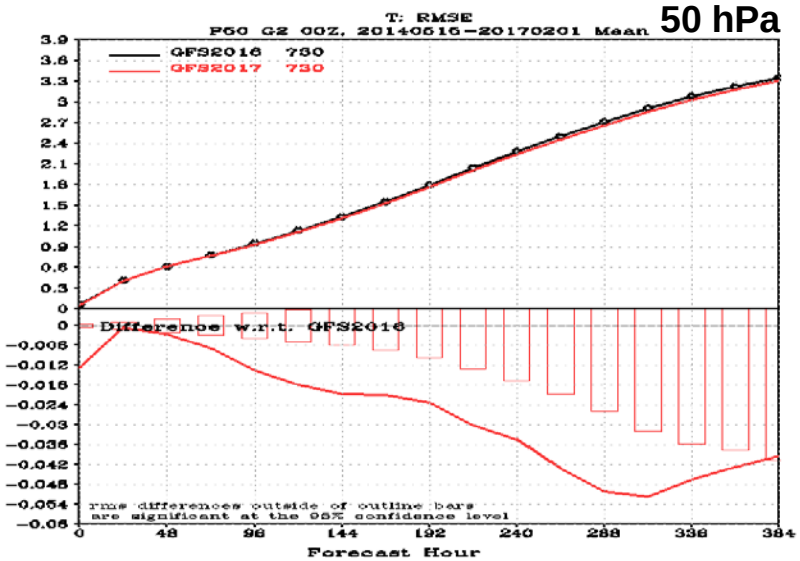


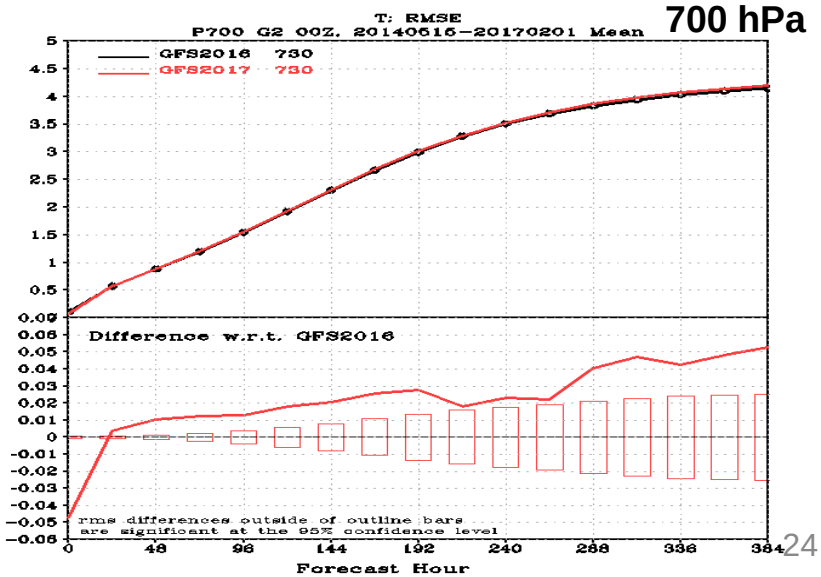


Statistically significant improved RMSE in stratosphere/upper troposphere at all forecast hours

RMSE for Temperature: Globe



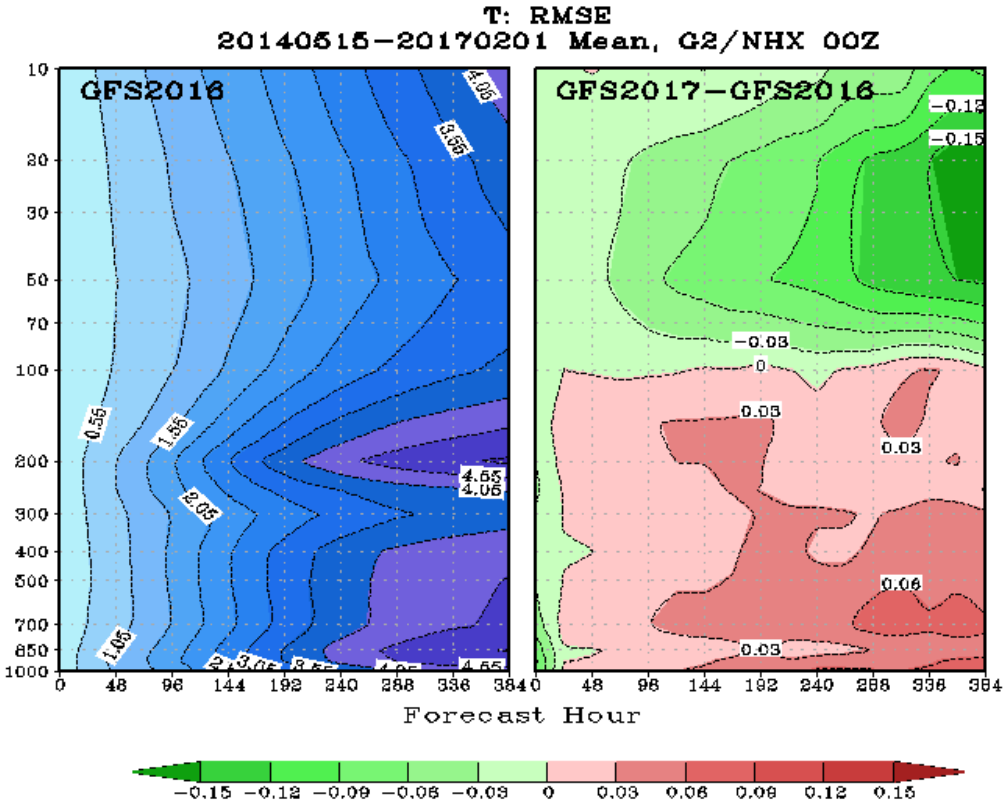


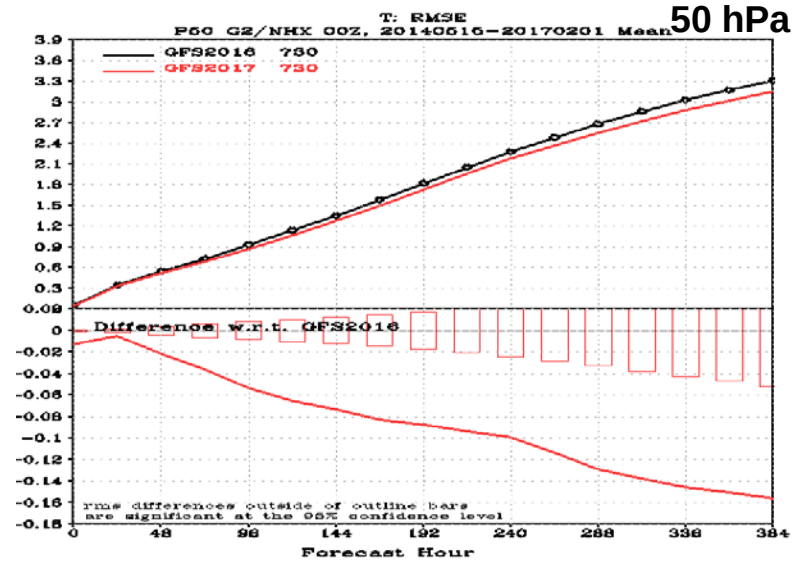


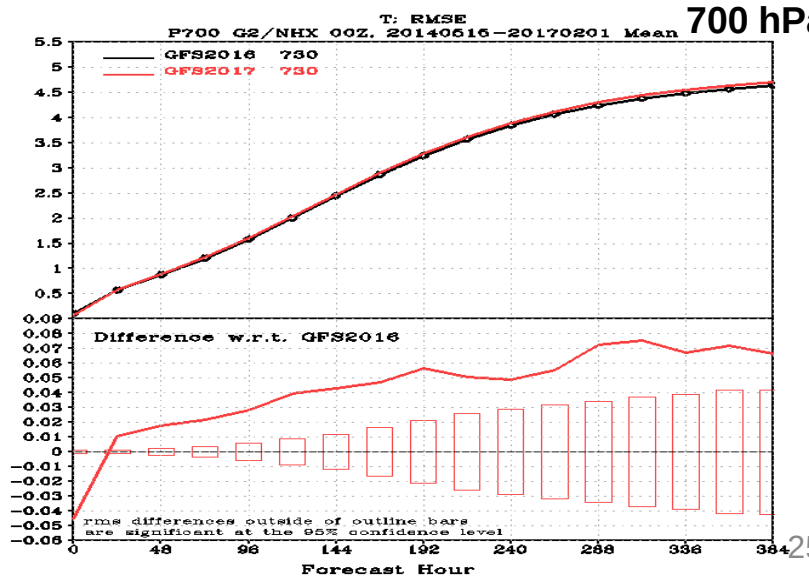
Statistically significant improvement RMSE in stratosphere/upper troposphere at all forecast hours

Increase in RMSE below 500 hPa past forecast hour ~24

RMSE for Temperature: Northern Hemisphere



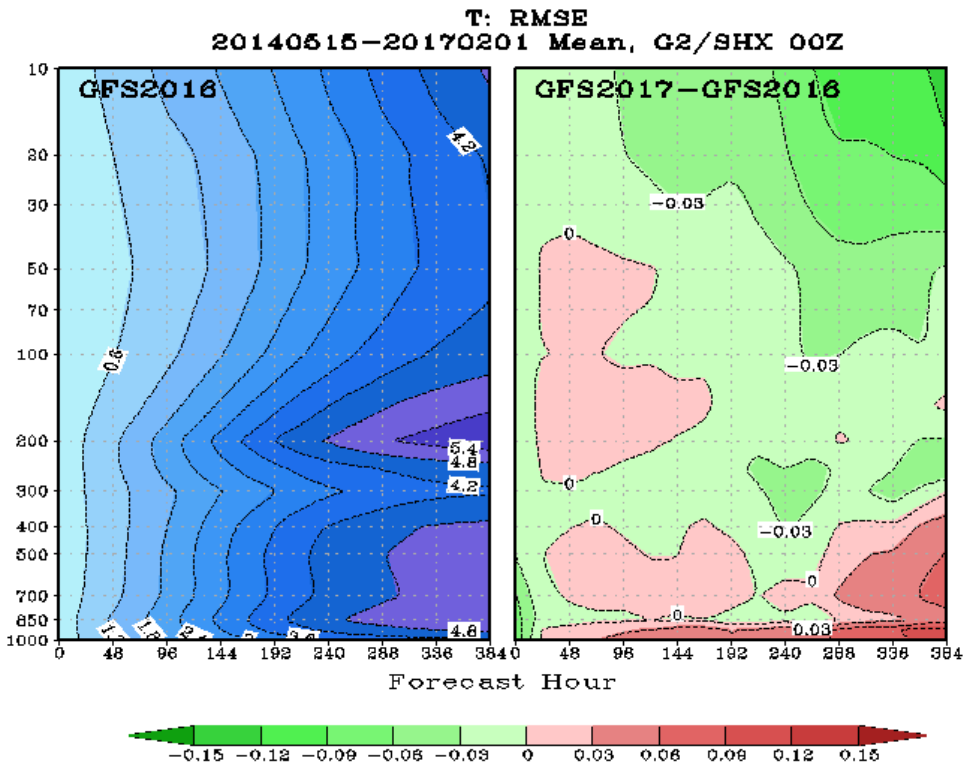




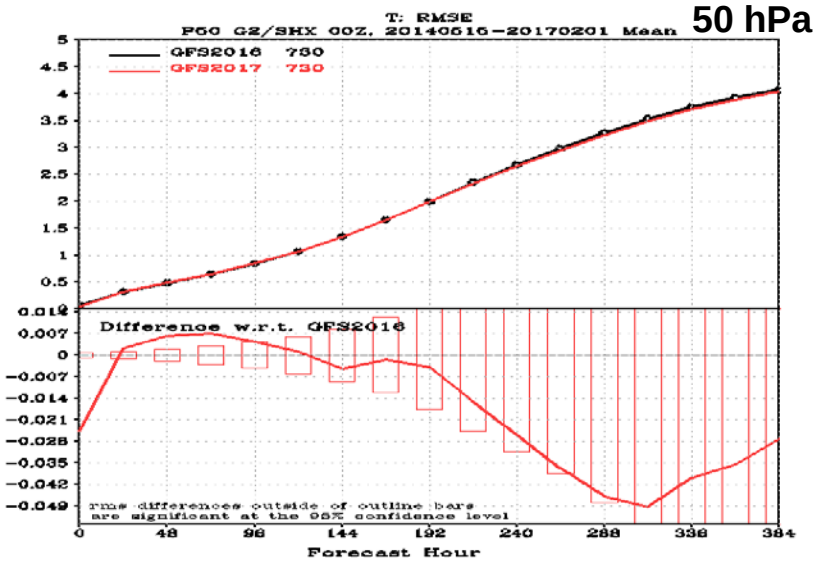
Statistically significant improved RMSE in stratosphere/upper troposphere at all forecast hours

Statistically significant increased RMSE in below 100 hPa past forecast hour ~24

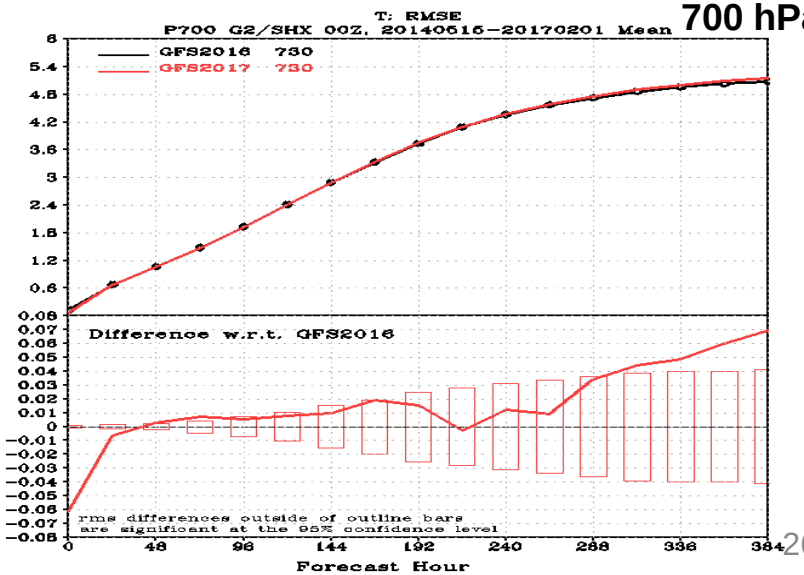
RMSE for Temperature: Southern Hemisphere



50 hPa



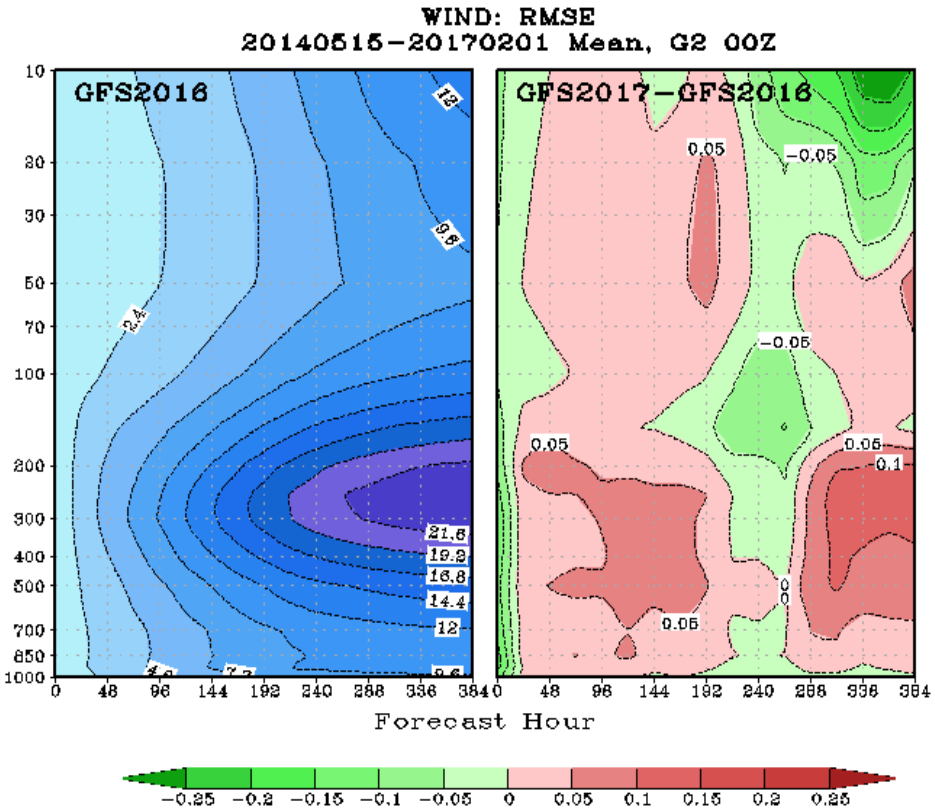
700 hPa

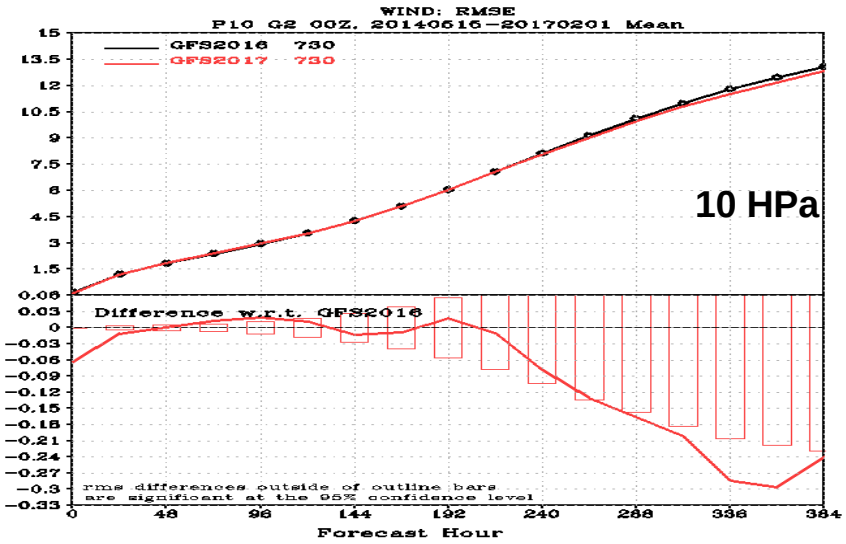


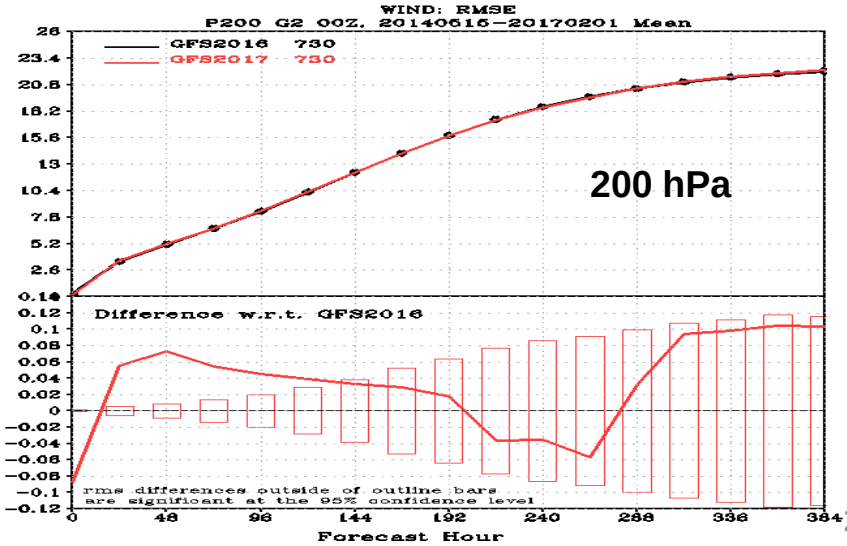
Improved RMSE in stratosphere/upper troposphere past forecast hour 240

Increased RMSE in below 100 hPa past forecast hour 288

RMSE for Wind: Globe



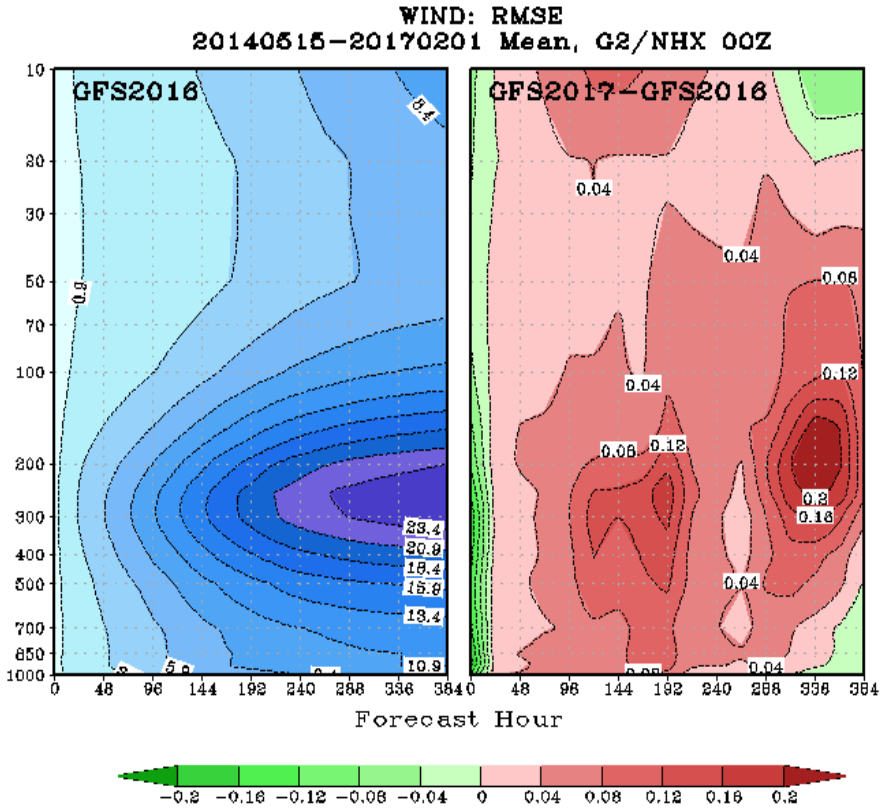


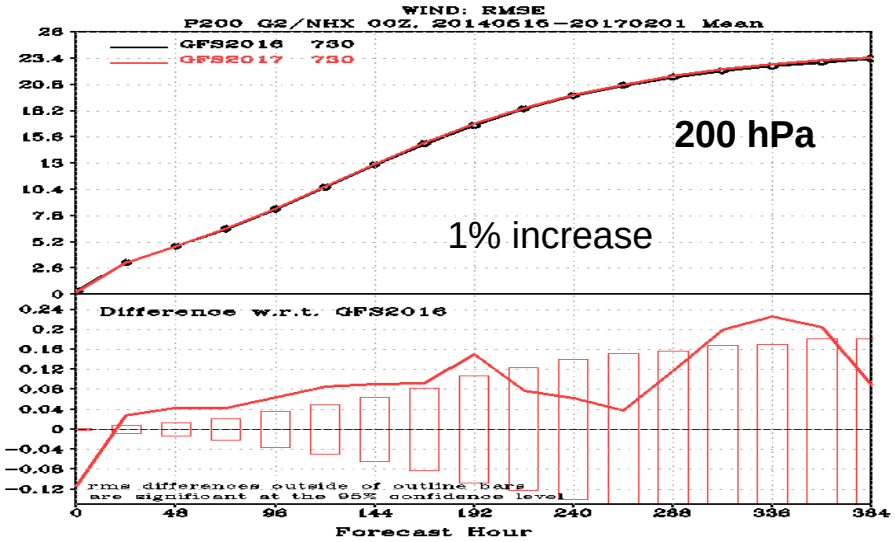


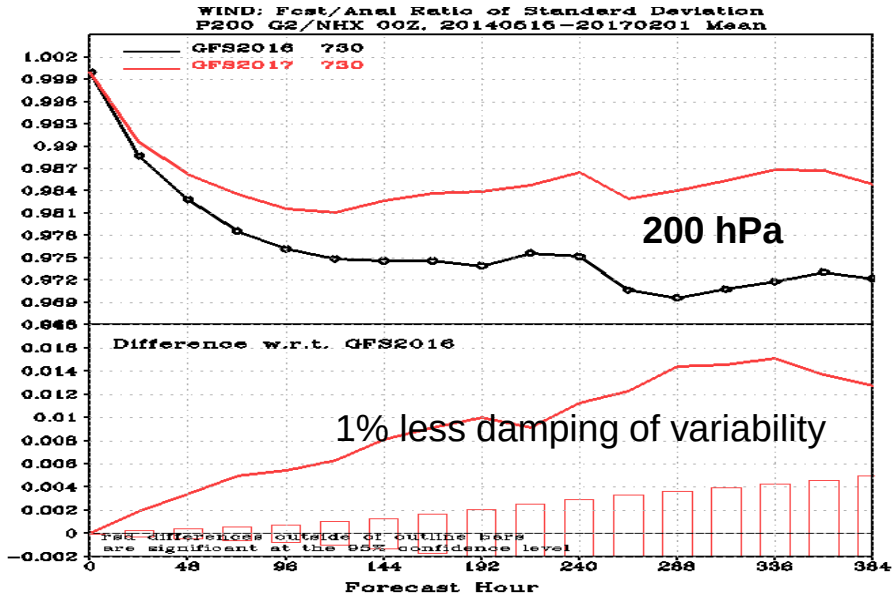
RMSE reduced in upper stratosphere beyond day 10

Small increase in RMSE in troposphere

RMSE for Wind: Northern Hemisphere

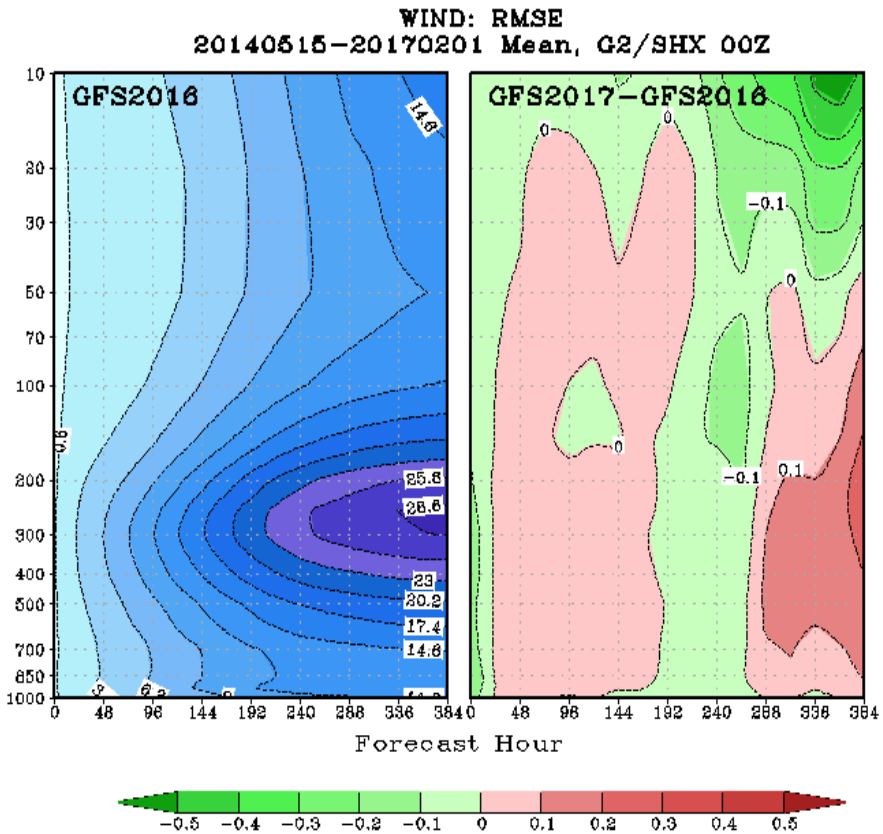


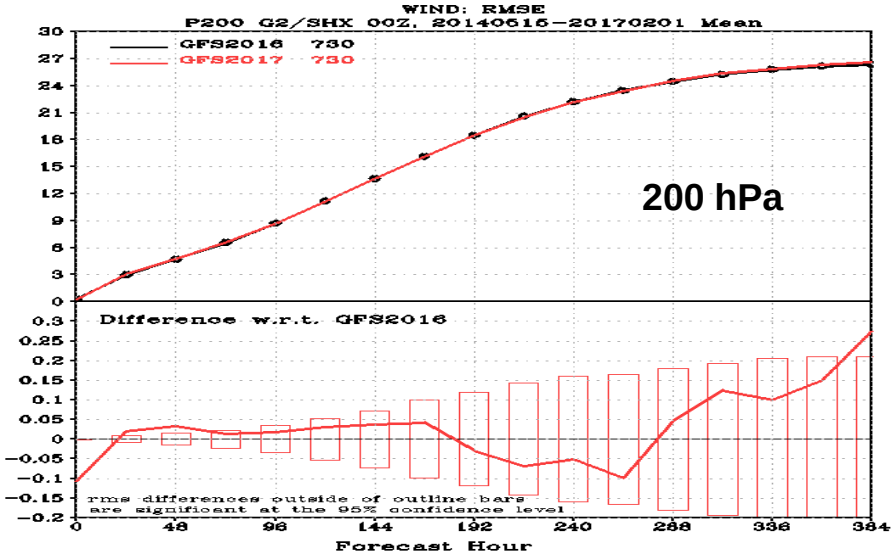


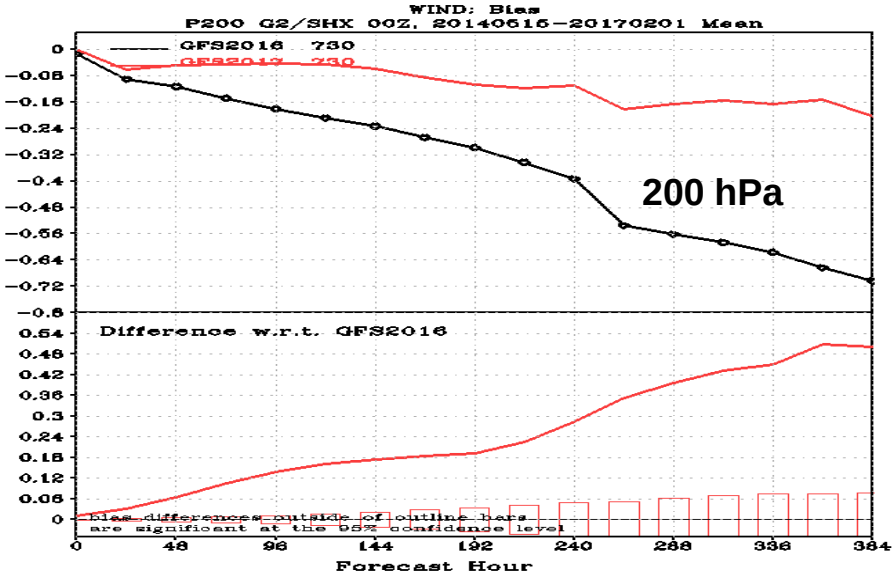


Small increase in rms error, less damping
Of variability in wind in forecasts

RMSE for Wind: Southern Hemisphere



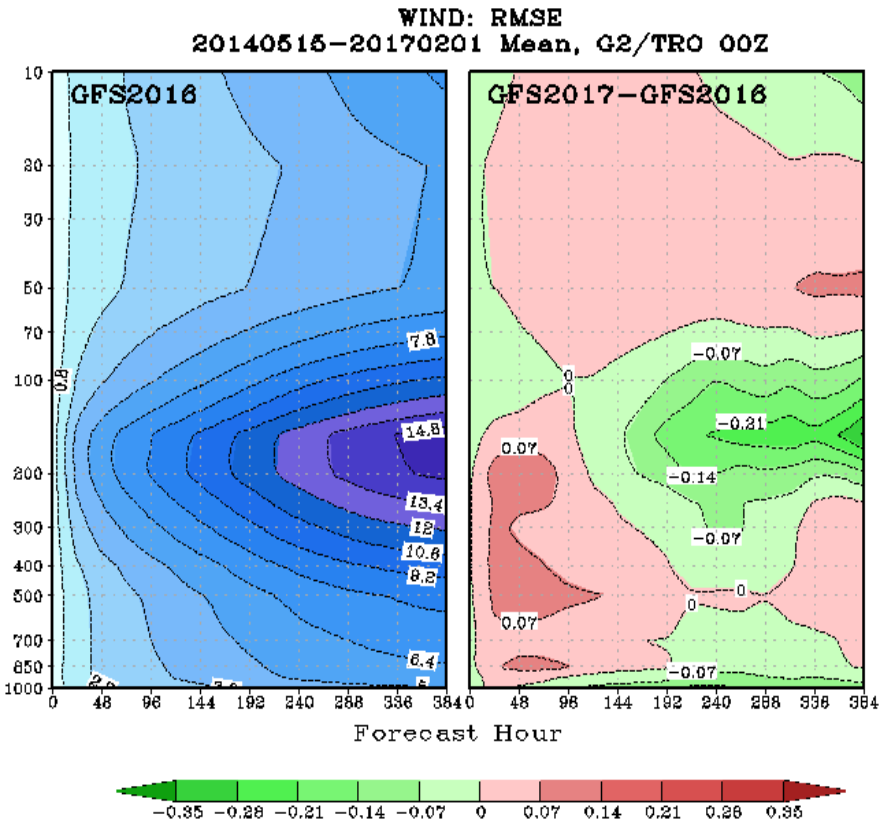


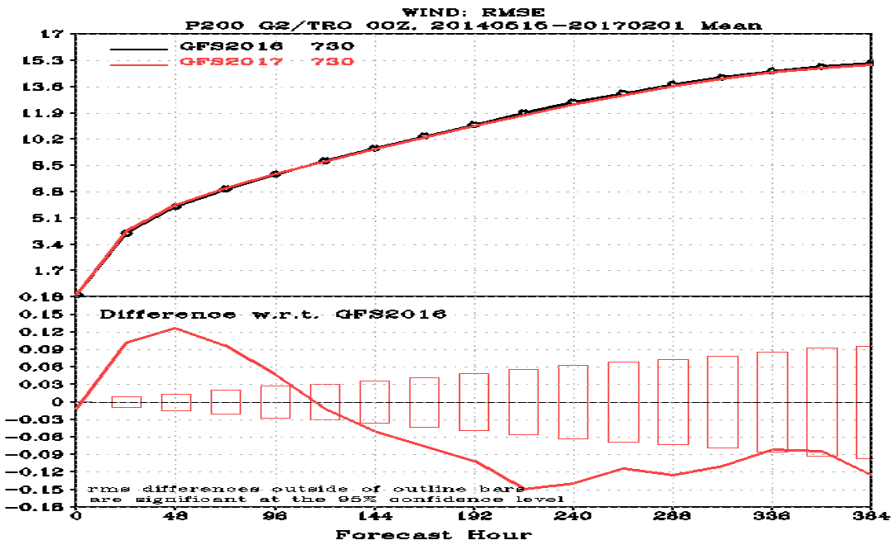


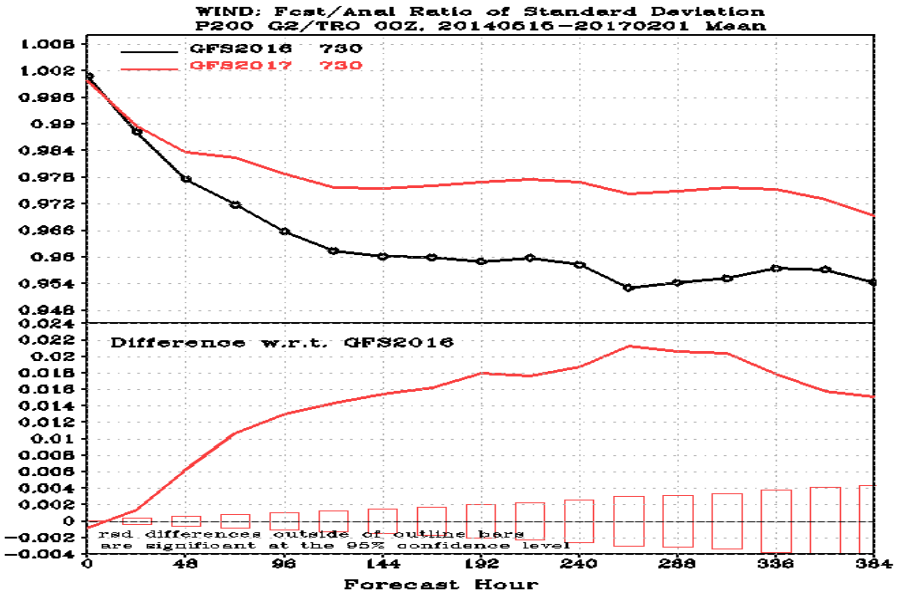
Improved RMSE in upper stratosphere past forecast hour 240

Reduction in negative bias in wind

RMSE for Wind: Tropics





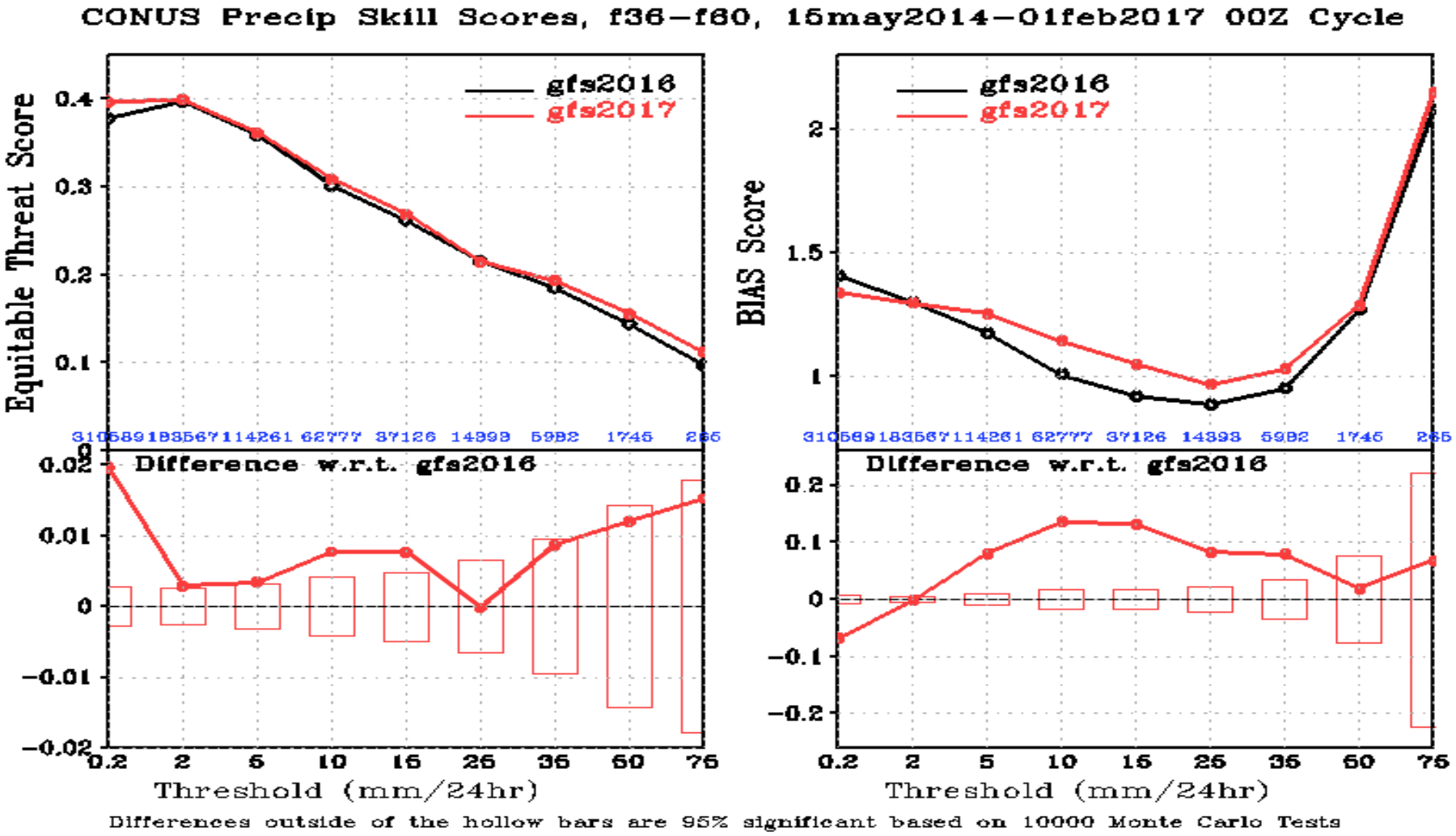


Improved RMSE at 150 hPa past forecast hour 96

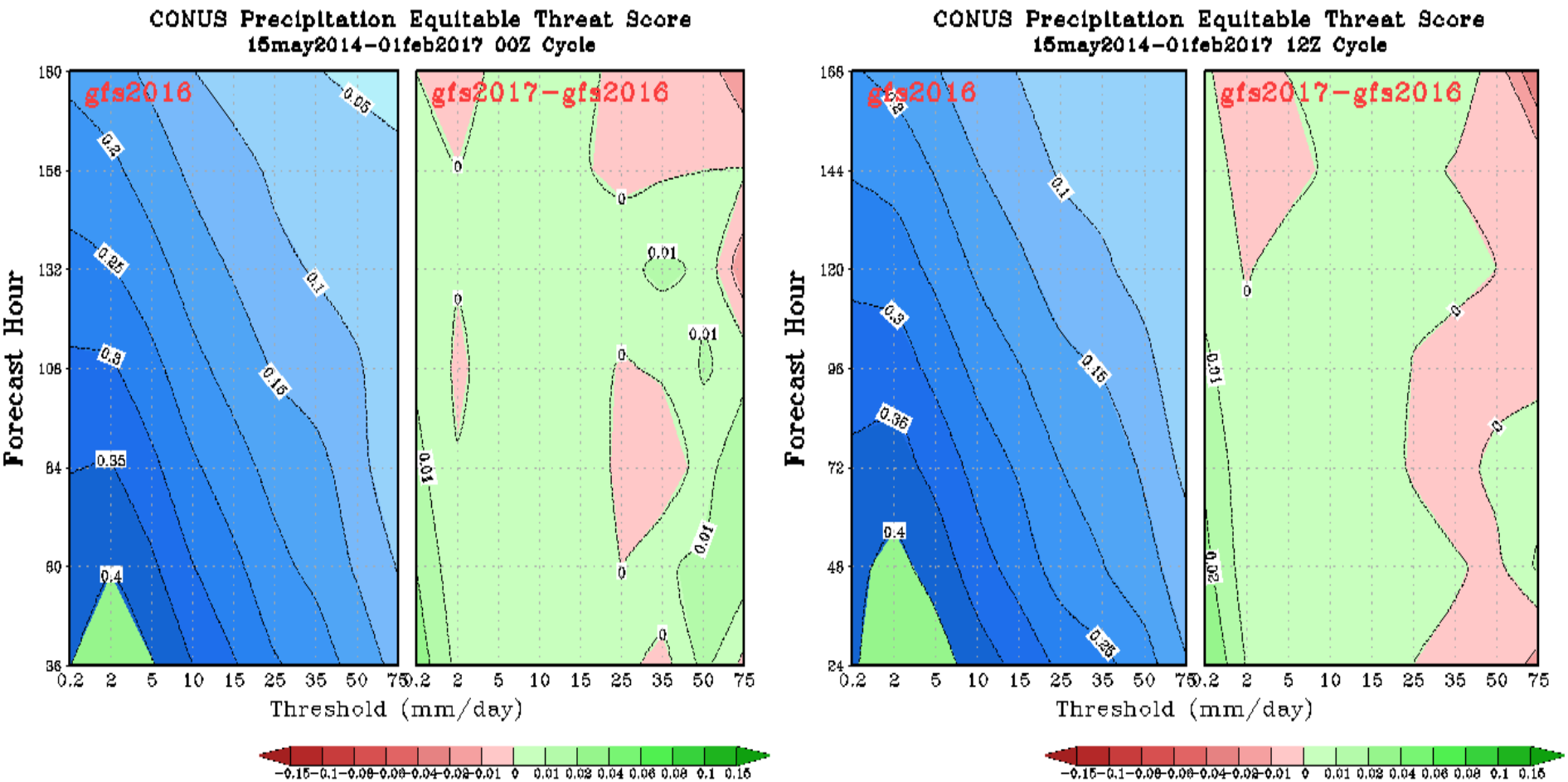
Increased RMSE in troposphere in short range forecasts, less damping of wind

Tropical analyses more uncertain

CONUS Precip Skill Scores



CONUS Precip ETS (00Z & 12Z)



Improved ETS for smaller thresholds for both 00Z and 12Z

Decreased ETS for larger thresholds at 12Z at all forecast hours and for 00Z at past 156 hours

Equitable threat score (Threshold mm/24h)
15 May 2014-01 Feb 2017 CONUS

Fcst Hr	0.2	2	5	10	15	25	35	50	75
0-24h	+	+	+	+	+				
12-36	+	+	+	+	+				
24-48	+	+		+	+				
36-60	+	+	+	+	+				
48-72	+	+	+						
60-84	+			+	+				
72-96	+		+	+	+				
84-108	+								
96-120	+								
108-132	+						+		
120-144	+								
132-156									

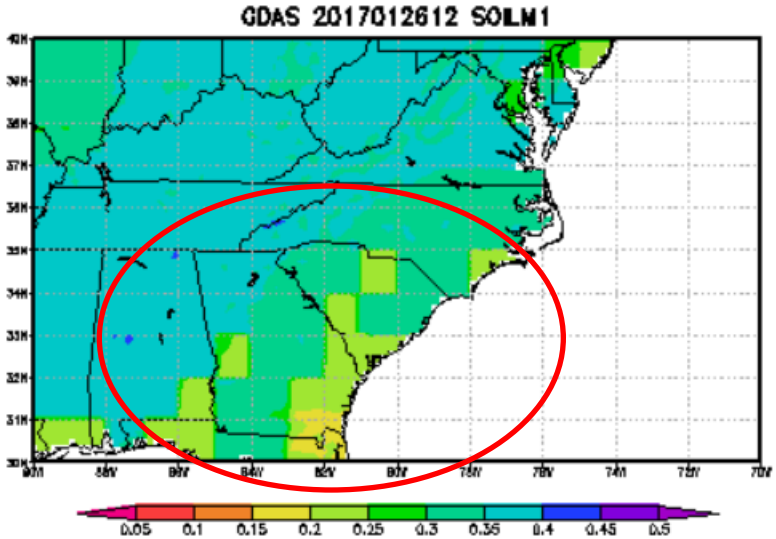
+ GFSX significantly better than GFS

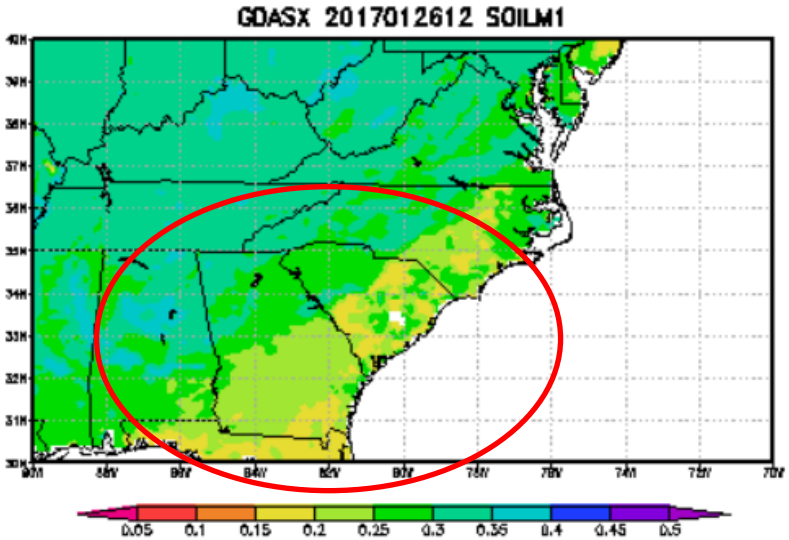
GFSX significantly worse than GFS

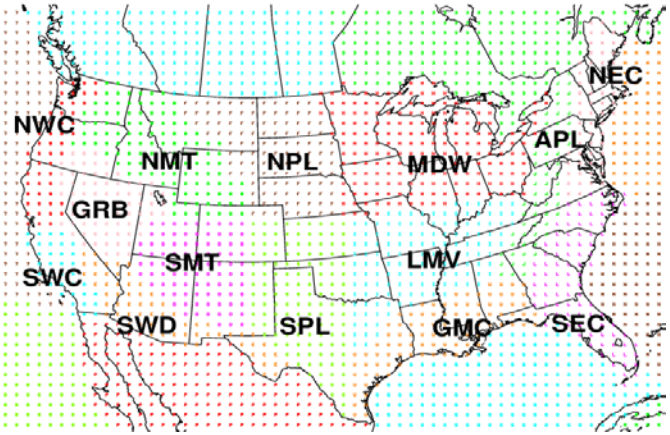
- Reduced drizzle
- Increased bias light to medium amounts
- Significant improvements in skill for thresholds of 0.2 to 15 mm/day forecast lengths 0-24 to 72-96 hrs
- AWC, WPC noted improvements in tropical convection

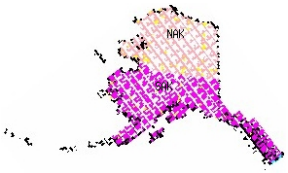
Improved LSM, T2m & Td2m

The issue of tiling or blockiness due to the coarse LSC data was solved







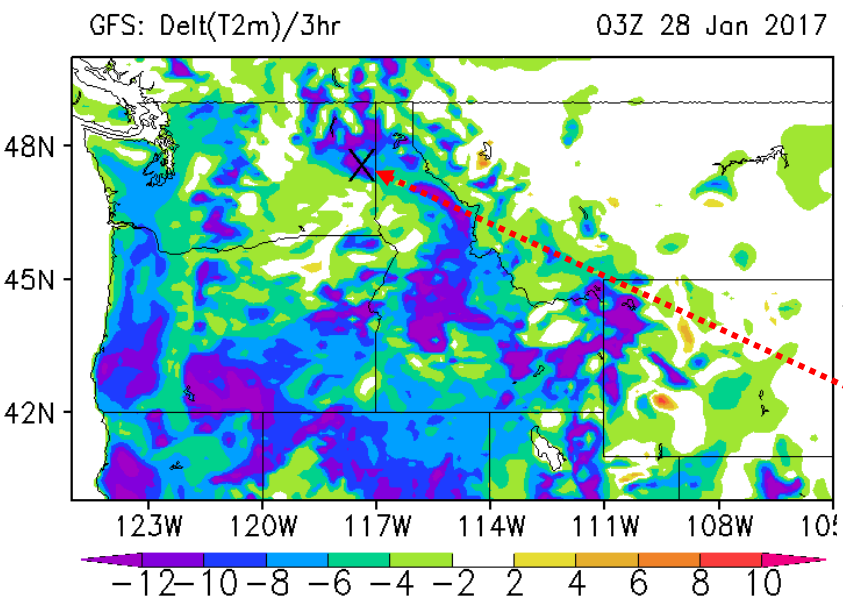


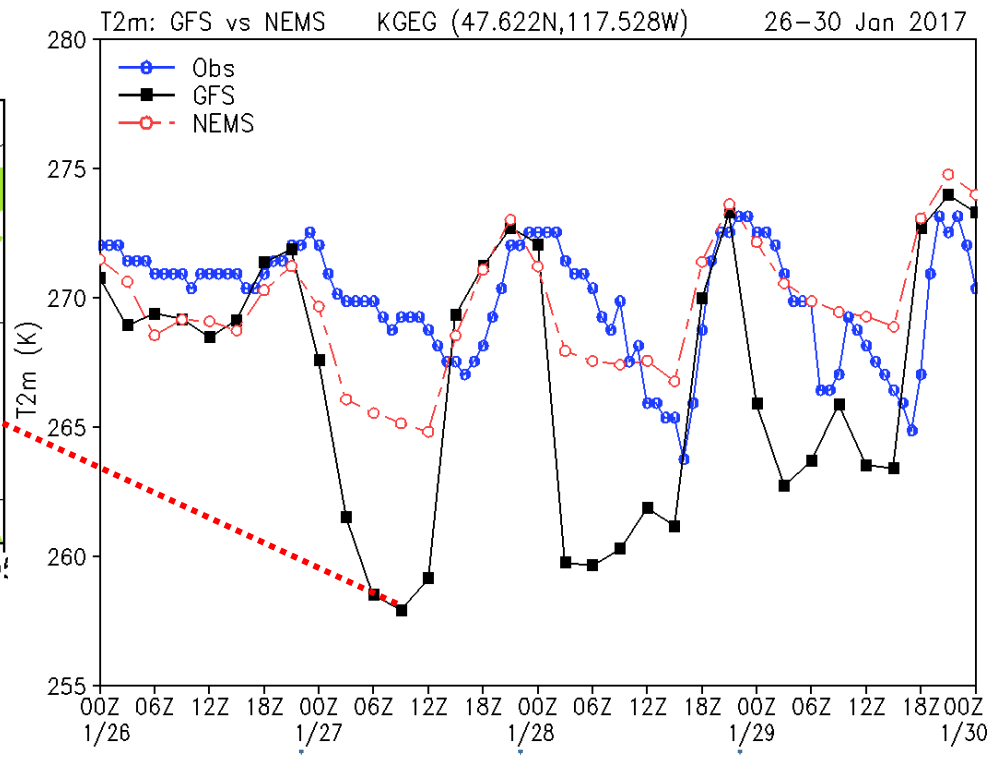
16 regions

2m T	000GMT	0600GMT	1200GMT	1800GMT
May-Oct. 16	10/16	9/16	7/16	10/16
May-Dec. 15	10/16	8/16	8/16	6/16
Dec15-May 16	15/16	12/16	9/16	14/16
2m Td	**000GMT**	**0600GMT**	**1200GMT**	**1800GMT**
May-Oct. 16	10/16	15/16	15/16	13/16
May-Dec. 15	9/16	16/16	15/16	12/16
Dec15-May 16	13/16	8/16	8/16	9/16

GFS/NEMS T2m @ GEG Spokane Airport, WA

Ronald Miller pointed out this case

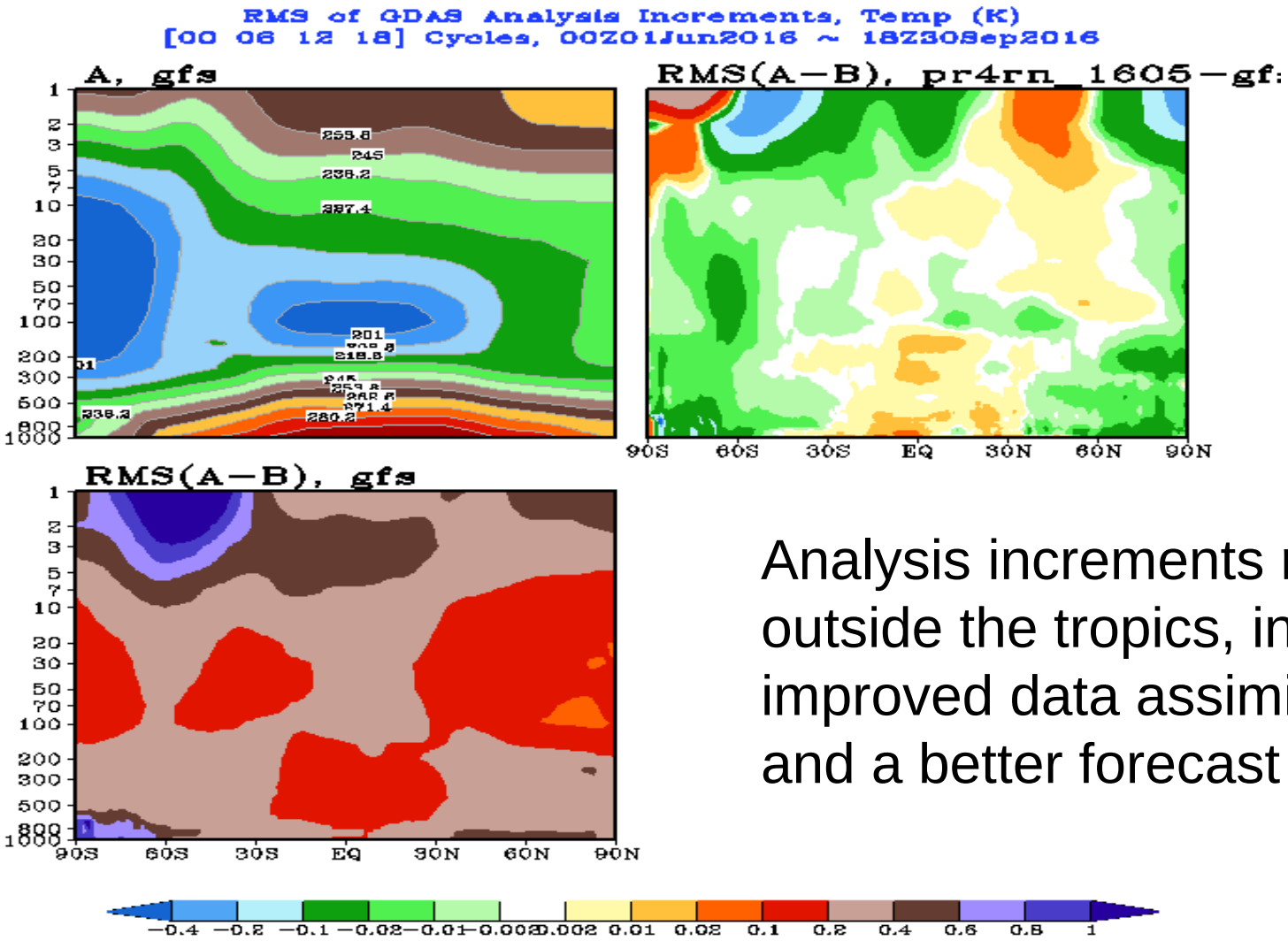




GFS: **T2m forecast > 12 C temperature drop in 3 hours.**

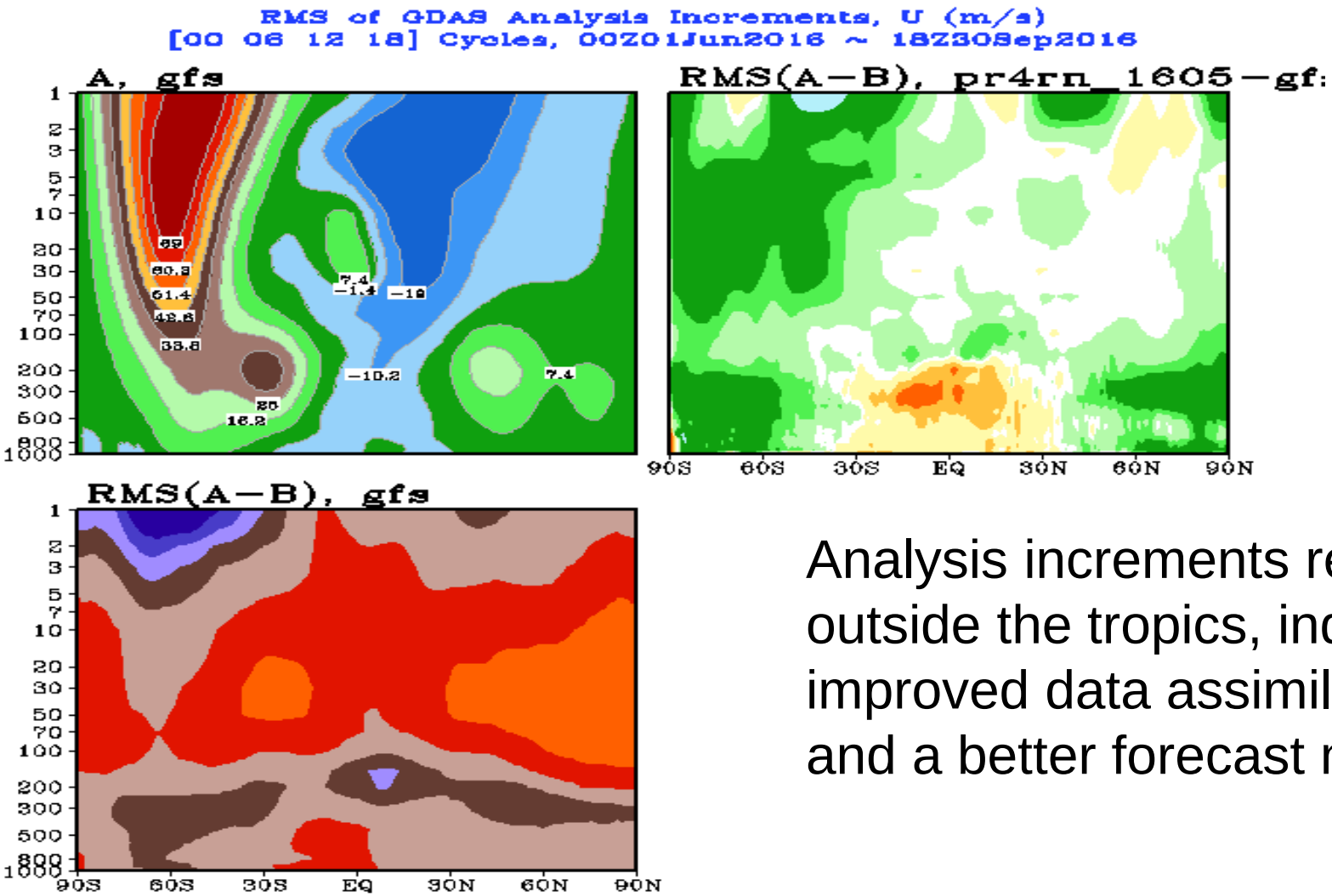
GFS: Rapidly cooling more than 12 °C during 3hr;
NEMS: Substantially improved around sunset.

Improved Data Assimilation: Temperature Analysis Increments



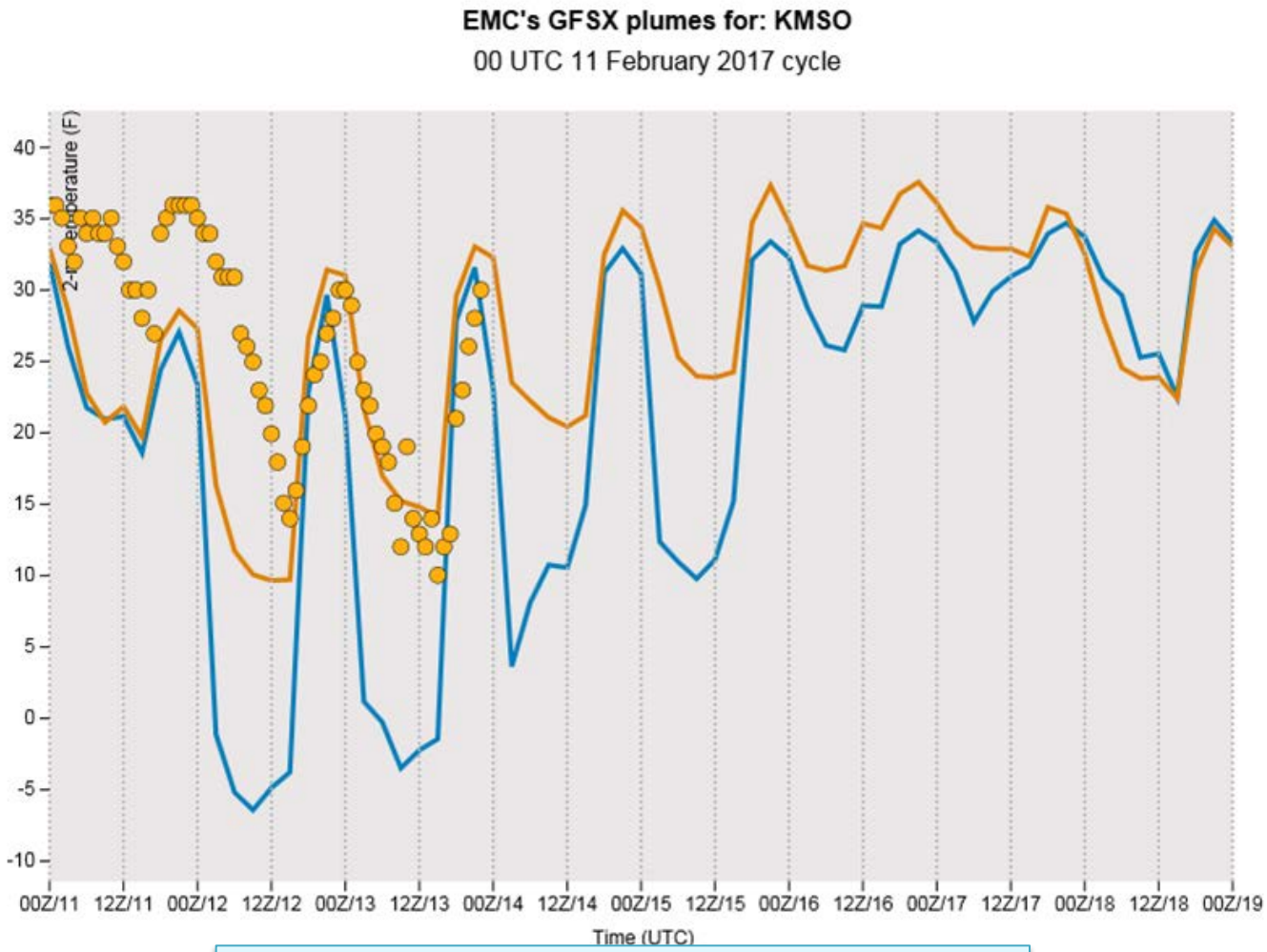
Analysis increments reduced outside the tropics, indicating improved data assimilation and a better forecast model

Improved Data Assimilation: Wind Analysis Increments



Analysis increments reduced outside the tropics, indicating improved data assimilation and a better forecast model

GFSX plumes provided in real-time



Missoula International Airport, Montana

Evaluation of Fit to Obs (radiosondes and aircraft observations)

Differences in fits to radiosondes small

Analyses, 6 hr forecast better agreement with radiosondes

Winds: mixed results
Slightly positive Jan-May 2016 for GFSX; Some tendency for winds to be stronger in GFSX, especially SH and tropics

Temperatures tend to be warmer in GFSX Slightly better fit in GFSX

Moisture slightly better fit near surface in GFSX, slightly worse mid-troposphere

Fits to global aircraft observations over three retrospectives:

--mixed for winds, more positive than negative for temperatures
--winds, temperatures biases mostly decreased in GFSX

Fits to North American ACARS

--GFSX more likely to improve fits, reduce biases

Change in RMS fit to station observations May 1, 2015-Dec. 28, 2016; 96 hr forecasts

T 2m	0000GMT	0600GMT	1200GMT	1800GMT	AVERAGE
west	-6.9%	-3.6%	+1.1%	-1.8%	-2.8%
east	-8.6%	-1.6%	+2.3%	-1.2%	-2.2%
Td 2m	0000GMT	0600GMT	1200GMT	1800GMT	AVERAGE
west	-4.3%	-4.4%	-3.8%	-5.2%	-4.4%
east	-2.1%	-3.4%	-1.3%	-2.4%	-2.0%
Winds 10m	0000GMT	0600GMT	1200GMT	1800GMT	AVERAGE
west	+0.1%	+0.8%	+0.1%	+0.1%	+0.3%
east	-1.2%	-1.8%	-1.5%	-1.1%	-1.4%

RMS fit to obs decreased in GFS2017
RMS fit to obs increased in GFS2017

Case studies and evaluation/analysis by MEG/EMC

Case Studies	Case Studies
Louisiana flooding case study	Christmas Day 2016 Northern Plains Blizzard
January 23, 2016 East Coast Blizzard	January 22-23, 2017 California precipitation event
Hurricane Matthew	Portland heavy snow Jan. 10-11, 2017
Hurricane Joaquin	Long-range predictability of high-impact west coast atmospheric river
February 7-8, 2016 explosive cyclone	West Virginia flooding case
MODE Jet Verification	MODE Precipitation Verification
Minnesota Blizzard November 18-19, 2016	MODE CAPE Verification
Weather Prediction Center case studies	
Central Region case studies	
Hurricane Joaquin precipitation	
California precipitation January 9-10, 2017	

Subjective evaluation of Case studies by MEG/EMC

GFSp	Subjective score	Objective Score (MMI >= 15mm)	Objective Score (MMI >= 20mm)	Objective Score (MMI >= 25mm)
Case	**Subjective score**	**Objective Score (MMI >= 15mm)**	**Objective Score (MMI >= 20mm)**	**Objective Score (MMI >= 25mm)**
Louisiana flooding August 12, 2016	2 out of 14	7 out of 14	N/A	N/A
10 individual forecasts	4 out of 10	8 out of 10	N/A	N/A
February 2016 cyclone	4 out of 10	N/A	N/A	N/A
January 2016 Blizzard	3 out of 7	4 out of 7	N/A	N/A
Central Region case studies	14 out of 32	17 out of 32	N/A	N/A
California heavy precipitation	6 out of 14	7 out of 14	8 out of 14	8 out of 14
Joaquin precipitation	9 out of 28	15 out of 28	17 out of 28	12 out of 28
West Virginia flooding	3 out of 7	6 out of 7	3 out of 7	3 out of 7
Total:	**45 out of 122**	**64 out of 112**	**28 out of 49**	**23 out of 49**

GFS	Subjective score	Objective Score (MMI>=15mm)	Objective Score (MMI>=20mm)	Objective Score (MMI>=25mm)
Case	**Subjective score**	**Objective Score (MMI >= 15mm)**	**Objective Score (MMI >= 20mm)**	**Objective Score (MMI >= 25mm)**
Louisiana flooding August 12, 2016	3 out of 14	7 out of 14	N/A	N/A
10 individual forecasts	2 out of 10	2 out of 10	N/A	N/A
February 2016 cyclone	3 out of 10	N/A	N/A	N/A
January 2016 Blizzard	3 out of 7	3 out of 7	N/A	N/A
Central Region case studies	4 out of 32	15 out of 32	N/A	N/A
California heavy precipitation	2 out of 14	7 out of 14	6 out of 14	6 out of 14
Joaquin precipitation	9 out of 28	13 out of 28	11 out of 28	16 out of 28
West Virginia flooding	2 out of 7	1 out of 7	4 out of 7	4 out of 7
Total:	**28 out of 122**	**48 out of 112**	**21 out of 49**	**26 out of 49**

Tie	Subjective scores		
Case	**Subjective score**	**Case**	**Subjective score**
Louisiana flooding August 12, 2016	9 out of 14	Central Region case studies	14 out of 32
10 individual forecasts	4 out of 10	California heavy precipitation	6 out of 14
February 2016 cyclone	3 out of 10	Joaquin precipitation	10 out of 28
January 2016 Blizzard	1 out of 7	West Virginia flooding	2 out of 7
	Total:	**49 out of 122**	

Summary of MEG evaluations of Case Studies

Evaluation	Remarks
MODE jet verification	Jet Streams: Small differences overall between the GFS and GFSX. Tied or GFSX slightly better in Summer 2015, but operational GFS looked slightly better in Winter 2015-2016. Biggest differences were seen with the meridional component of the jets and differences were larger in the summer than the winter. -*Tie*
Louisiana flooding case	GFSX better for 2/14, GFS better for 3/14, tied for 9/14 , slight edge to GFS - *GFS*
Jan 23 Blizzard	GFSX better for 3/7, GFS better for 3/7, tied for 1/7 - *Tie*
WPC Case studies	GFSX did better for 4/10, GFS better for 2/10, tied for 4/10, GFSX had higher MMI score 8/10, GFS 2/10 – *GFSX*
Minnesota blizzard	GFSX looked slightly better since it was at times shifted SE relative to operational GFS – *GFSX*
Christmas Day 2016 Northern Plains Blizzard	GFSX performed worse 8 and 7 days out but better 6 and 5 days out. Storm was well forecast by both the GFS and GFSX. GFSX was more skillful 5–6 days out - *GFSX*
Portland snow Jan. 10-11, 2017	GFS underforecasted, GFSX had even lower amounts - *GFS*
West Virginia flooding case	GFSX 84-hour forecast was too far north, but the parallel GFS had heavier precipitation over WV for the 36-60 hour forecasts. Slight edge to GFSX overall based on subjective and objective evaluation - *GFSX*

Summary of MEG evaluations of Case Studies

Evaluation	Remarks
Central Region case studies	GFSX did slightly better overall, had higher MMI values for 8/10 -*GFSX*
CA heavy QPF	Both versions were similar - *Tie*
Hurricane Matthew	GFSX slightly better with track further west closer to FL, but GFS handled NE movement slightly better - *Tie*
Hurricane Joaquin	GFSX better SE low forecasts and forecasted a track out to sea earlier than the operational - *GFSX*
Hurricane Joaquin QPF	Both versions looked similar for many cycles, no clear winner- *Tie*
Feb 7-8, '16 explosive cyclone	Both versions generally similar, no clear winner - *Tie*
January 22-23, 2017 California precipitation event	The GFSX also performed better 5 and 6 days out but not 7 and 8 days out. Little difference between models in the short range. Most differences concerned amount of shadowing in the valleys. GFS captured large-scale pattern 7 and 8 days out - *Tie*
West Coast AR event predictability	A tie or call the GFSX slightly worse. 500mb fields - GFSX was slightly weaker with the flow into CA on 12/31, but in the bigger picture, both versions picked up on the changing pattern about the same time. Both GFS version captured the threat about 7 days out. – *GFS or tie*
MODE precipitation/CAPE verification	The GFSX precipitation looked better in summer 2015 overall, about the same or slightly worse in winter 2015-2016. Bigger differences were seen in the summer season. CAPE also looked better overall in the parallel GFS for summer 2015. -*GFSX*

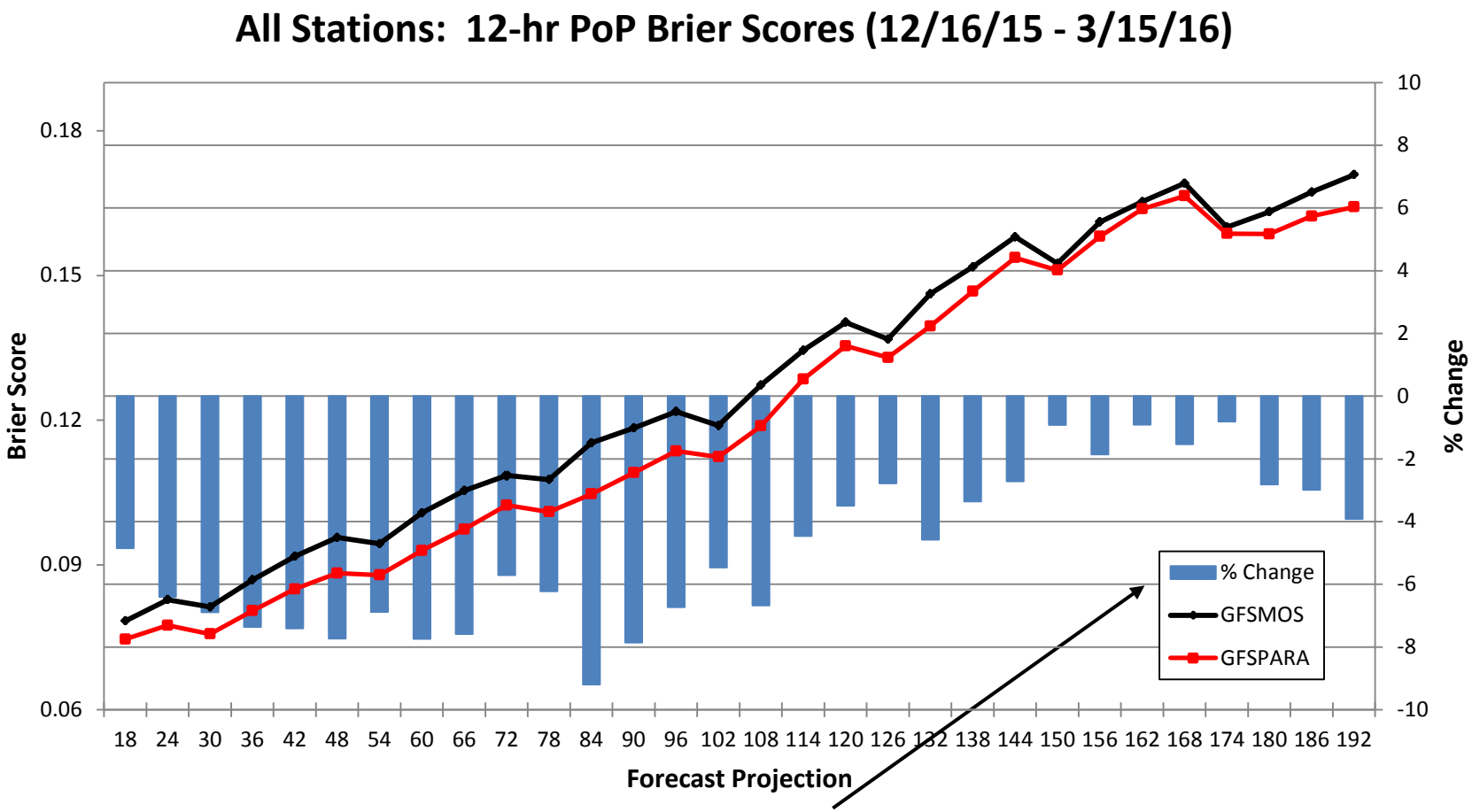
WPC Case Studies Evaluated by EMC

WPC Case Studies	Remarks
36-h forecast valid 12Z 5/26/15: Rain displaced well to the north	GFSX better southern extent of rainfall
60-h forecast valid 12Z 12/14/15: Days 2 and 3 GFS forecasts were too fast and too far to the north with their QPF	GFS and GFSX similar, Tie
36-h forecast valid 12Z 12/17/15: Southeastern US dry bias	GFSX looked slightly better, heavier QPF and fewer gaps
60-h forecast valid 12Z 1/22/16: Gulf coast dry bias	GFSX better southern extent rainfall
36-h forecast valid 12Z 4/18/16:GFS was too dry across southeast TX and too wet across the central plains	GFSX looks better, heavier precipitation in Texas and correctly lighter in central plains
36-h forecast valid 12Z 5/21/16: The GFS was too wet across AL/GA	GFS and GFSX looked similar, Tie
36-h forecast valid 12Z 6/24/16: *West Virginia flooding case*	GFSX looked slightly better, heavier in West Virginia
48-h forecast 12Z 8/12/16: Beginning of LA heavy rainfall case, GFS too dry	GFS looked better, correctly heavier in Louisiana
48-h forecast valid 12Z 8/13/16: Louisiana flooding case	GFS looked better, correctly heavier in Louisiana
24-h forecast valid 12Z 9/29/16:Mid-Atlantic heavy rainfall (NC), popcorn convection in West	GFS looked slightly better over DC and Maryland region, heavier

Central Region Case Studies Evaluated by EMC

Central Region Case Studies	Remarks
February 2, 2016: Ground Hog's Day Blizzard that affected much of the central plains in Minnesota and Wisconsin. Days 3-4 showed no snow for much of northwestern Iowa and southern Minnesota.	The GFSX did better overall both based on subjective and objective evaluation
November 20, 2015: Banded snowfall event across southern South Dakota into northern Iowa. This band was forecast to be along the Missouri River into central Iowa and was much closer to I-90. Up to 18'' of snow fell with this system.	Overall a tie
June 14, 2014: Heavy rain event and flooding in southeastern South Dakota and southwestern Minnesota	GFSX slightly better since it was heavier for some runs
June 16, 2014: Heavy rain event in southeastern South Dakota and northwestern Iowa. This was also the Pilger, NE tornado as well and there was severe weather in northern Iowa and southern South Dakota.	GFSX looked better, heavier for some runs
March 23, 2016: Colorado Front Range Blizzard	GFS GFSX similar, tie

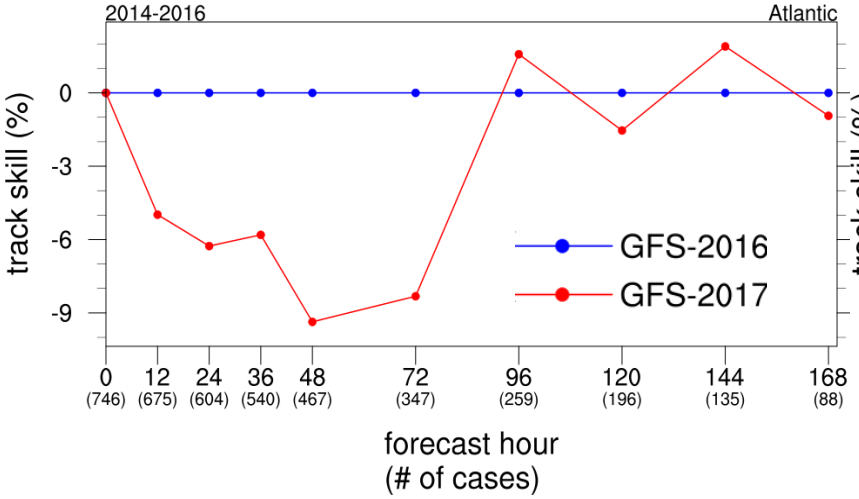
Evaluation from MDL

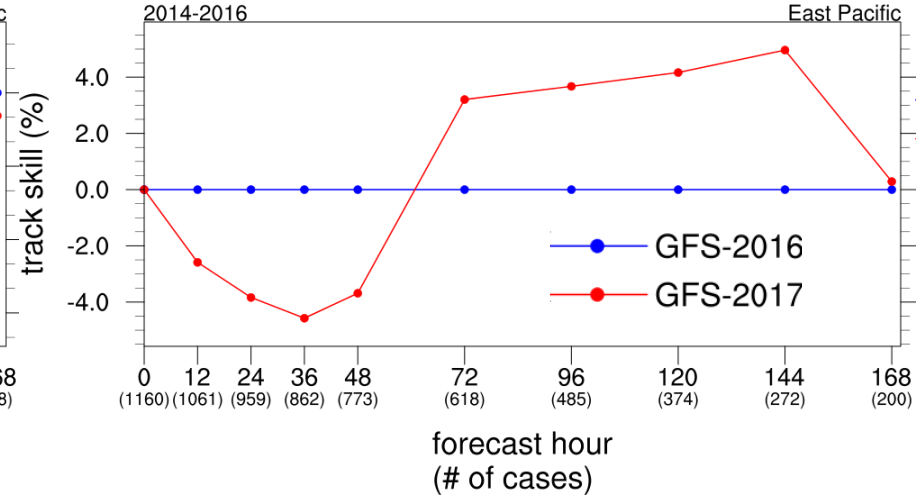


Brier Scores…remember, smaller is better!

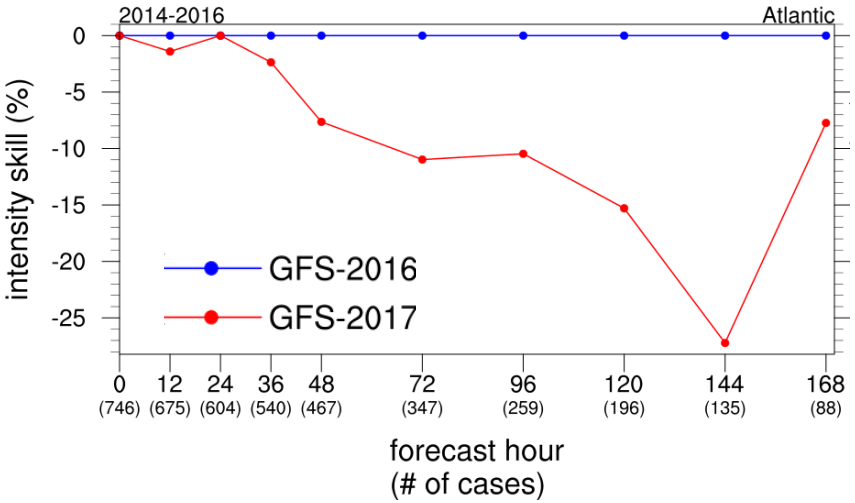
NHC Evaluation of Hurricane Forecasts

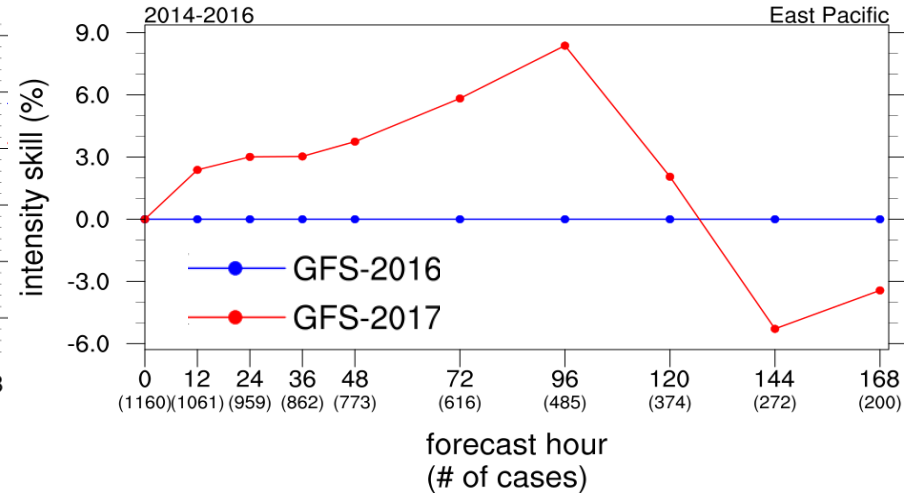
Skill relative to GFS-2016





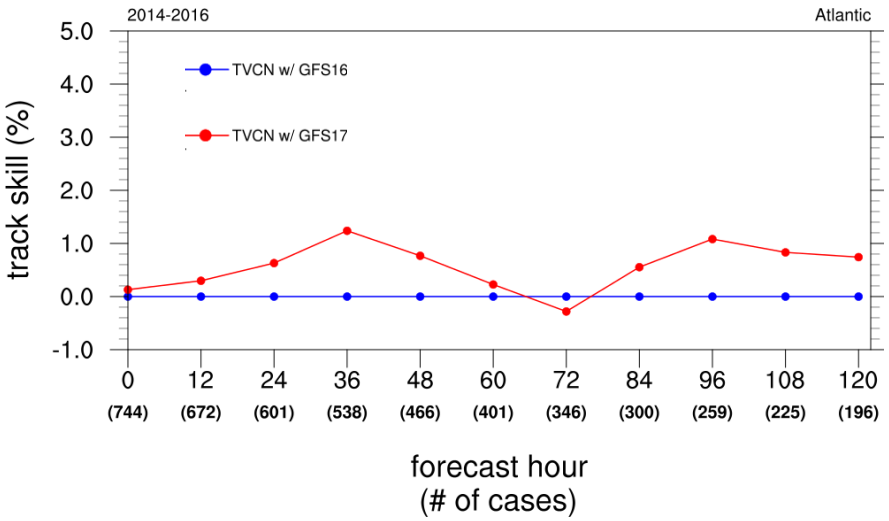
About 9-10% degradation in the Atlantic (48-72 hrs) & about 4% degradation in the East Pacific (24-48 hrs)

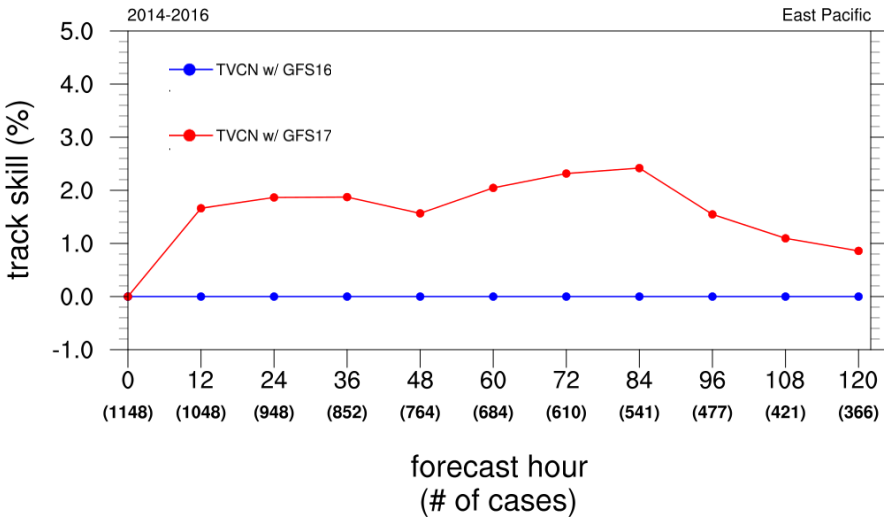


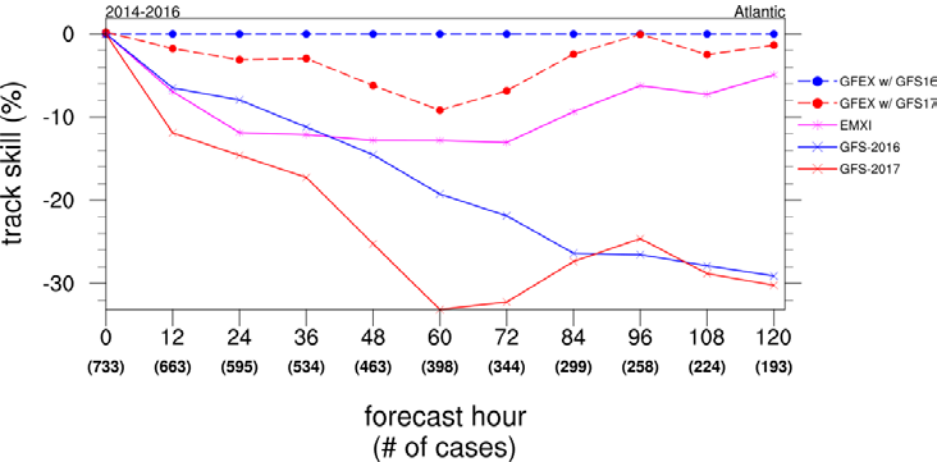


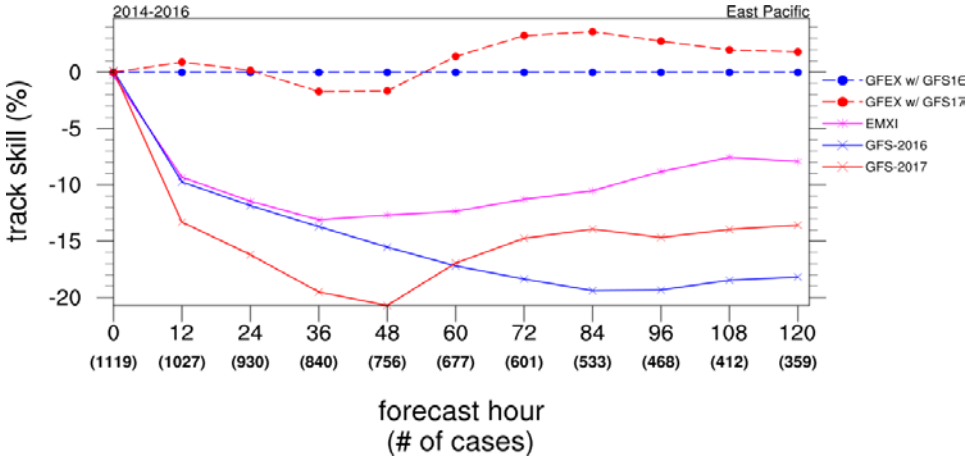
NHC Evaluation of Hurricane Forecasts

Skill relative to TVCN & GFEX



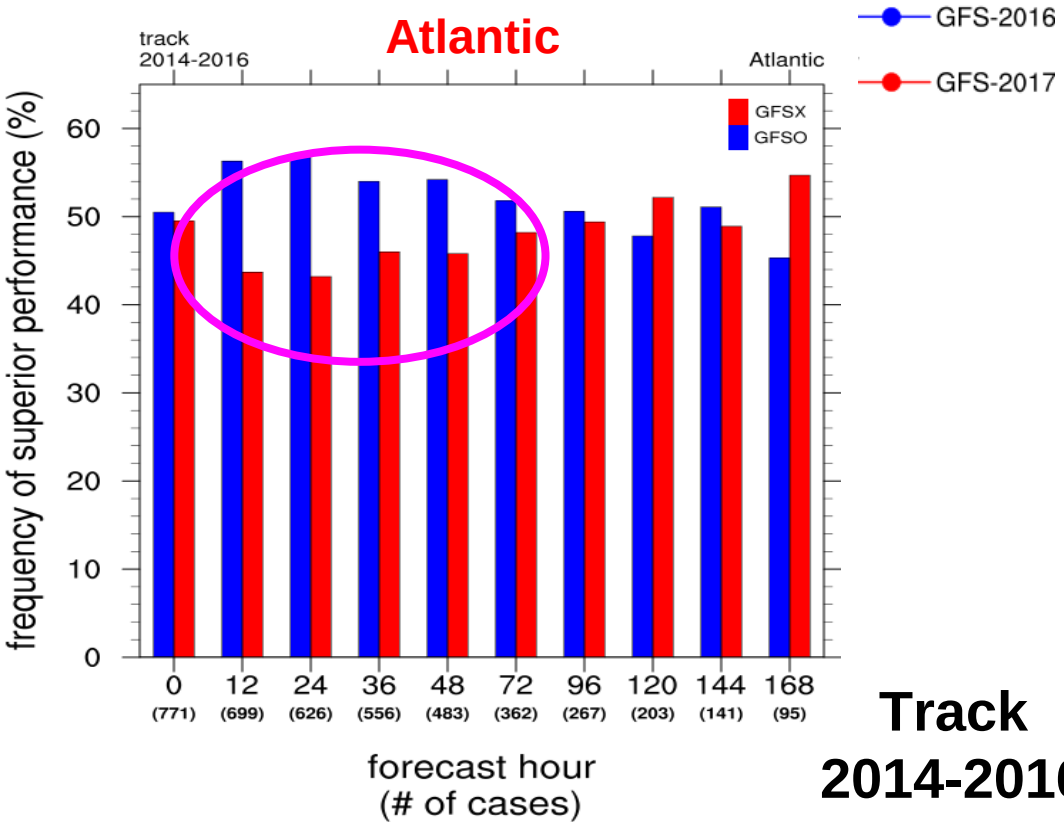




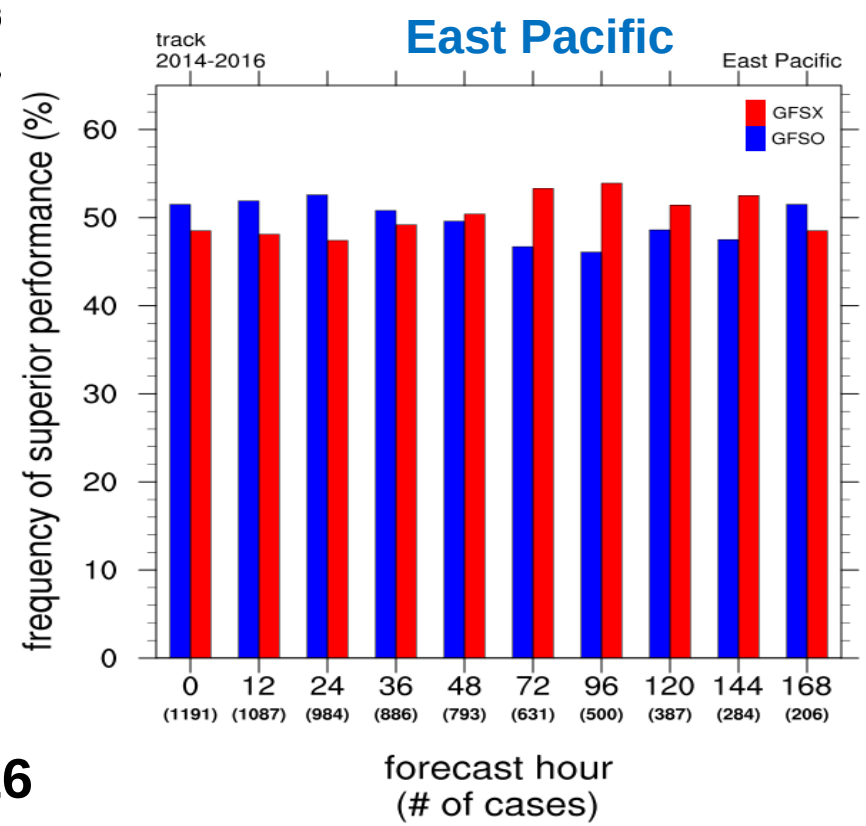


Improved skill w/TVCN, degraded with GFEX in ATL. Improved in EPAC

Frequency of Superior Performance

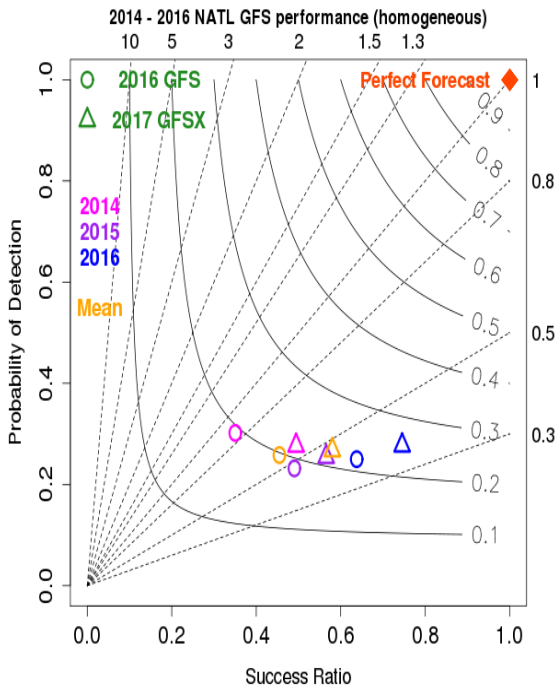


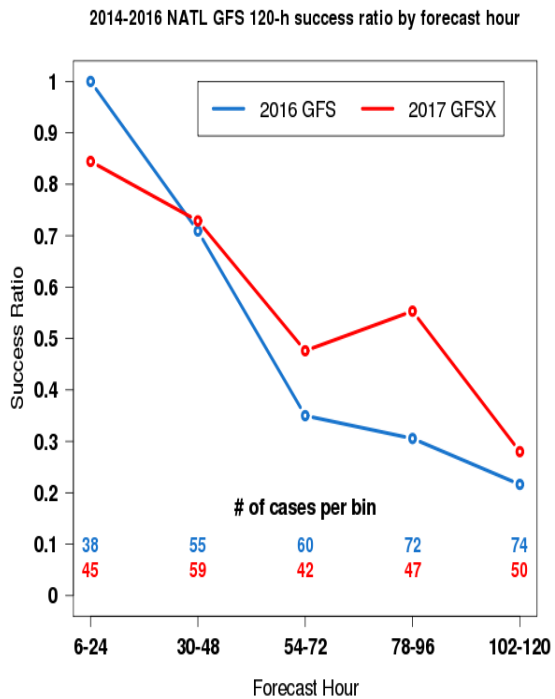
Track 2014-2016

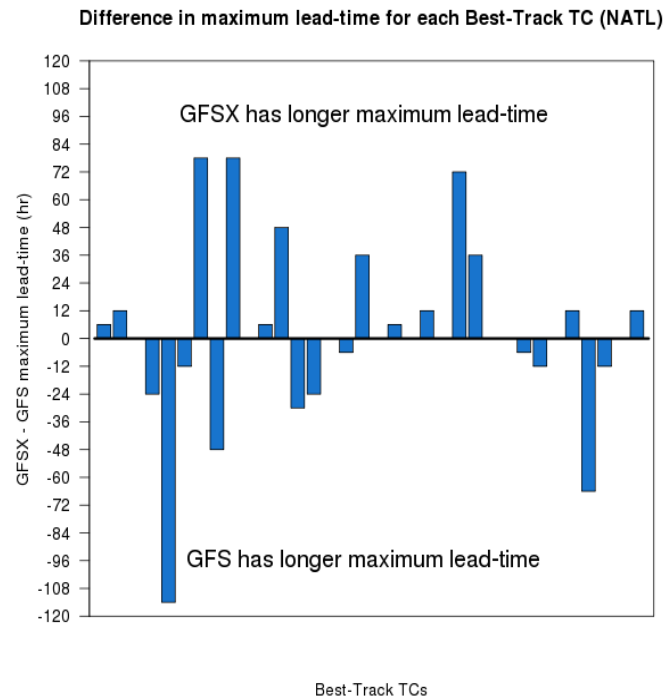


The loss of short- to medium-range TC track and intensity forecast skill for the Atlantic basin in the proposed 2017 GFS is unacceptable to the National Hurricane Center. We are also concerned about the lack of testing of the downstream impact of the 2017 GFS on the regional hurricane models. Therefore, we oppose this implementation.

Tropical Cyclone Genesis Verification: Atlantic



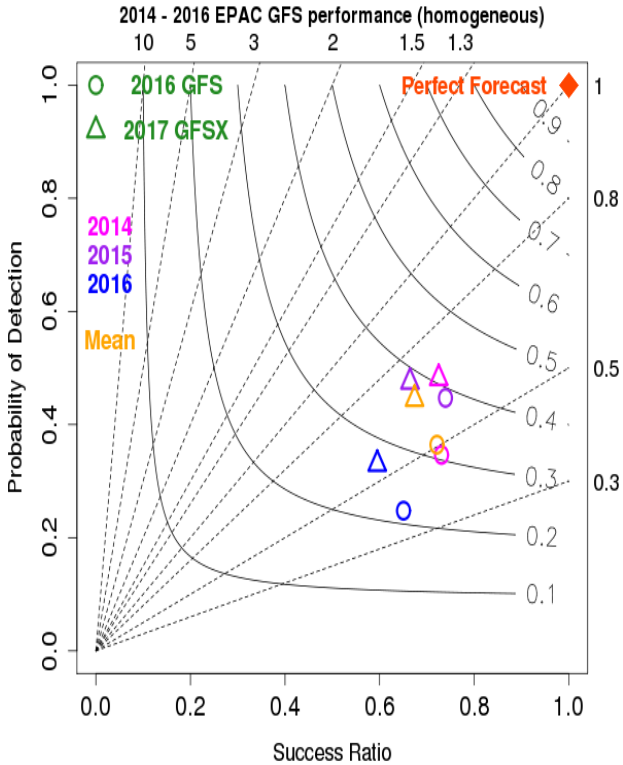


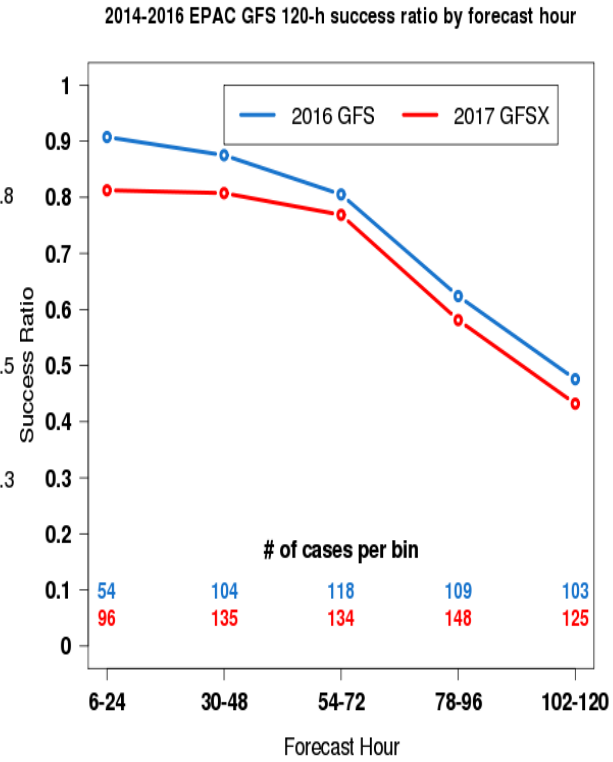


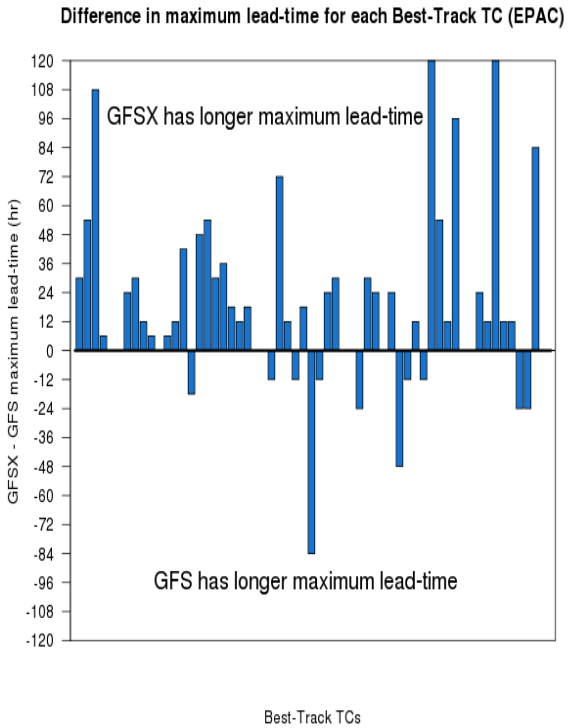
Improved TC Genesis in the NATL for both POD and Success Ratio

Significant gains in lead time for TC Genesis

Tropical Cyclone Genesis Verification: Atlantic







Improved TC Genesis in the EPAC for POD, neutral for Success Ratio

Significant gains in lead time for TC Genesis

EMC Perspective on evaluation of Hurricanes

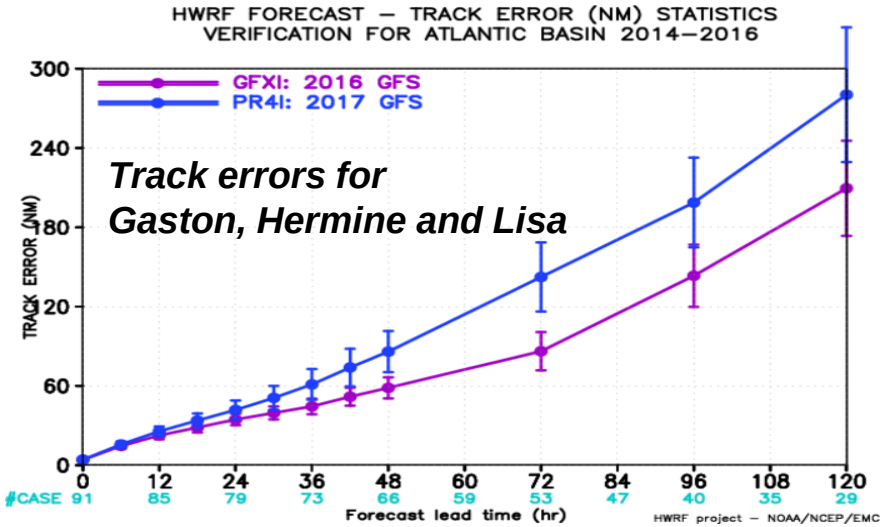
Evaluation report from NHC indicating opposition to the implementation. Key points raised are:

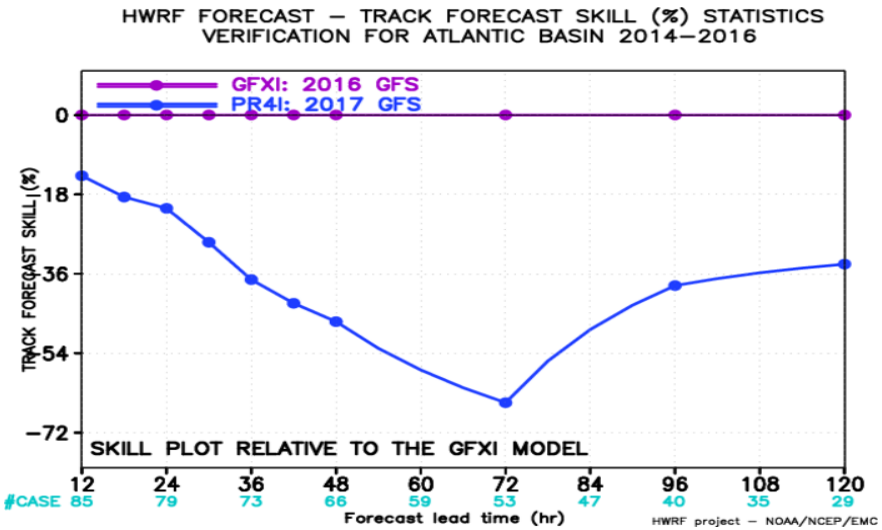
- **Negatives**:
  - –Short-term track forecast degradation in the Atlantic (48-72 hr) by about 9-10%
  - –Short-term track forecast degradation in the East Pacific (24-48 hr) by about 4-5%
  - –Loss if intensity skill from GFS2017 (potentially degrade SHIPS forecasts)
  - –Two member GFS+ECMWF ensemble degraded by about 8% in the Atlantic (48-72 hr)

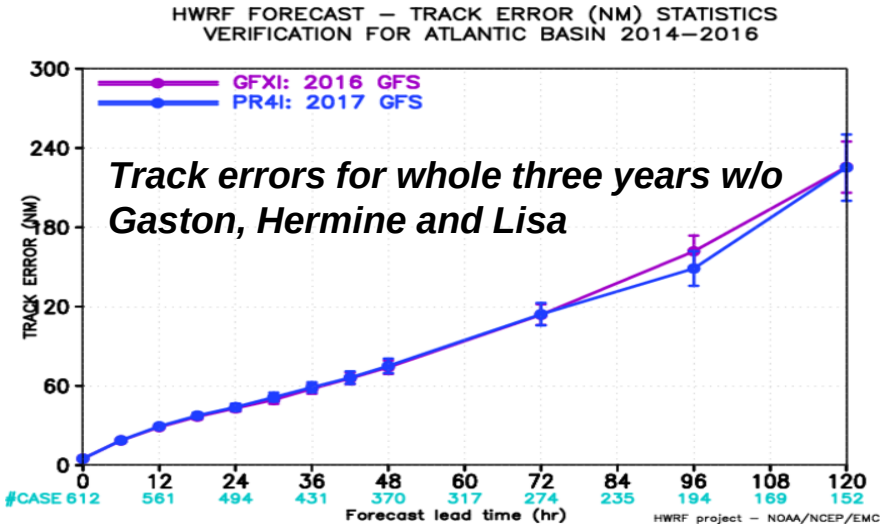
- **Positives**:
  - –East Pacific track forecasts improved beyond 48 hrs
  - –TVCN Consensus forecasts improved slightly for both ATL and EPAC
  - –Genesis forecasts both in Atlantic and East Pac significantly improved
  - –Lead time for Atlantic genesis forecasts gained by almost a day

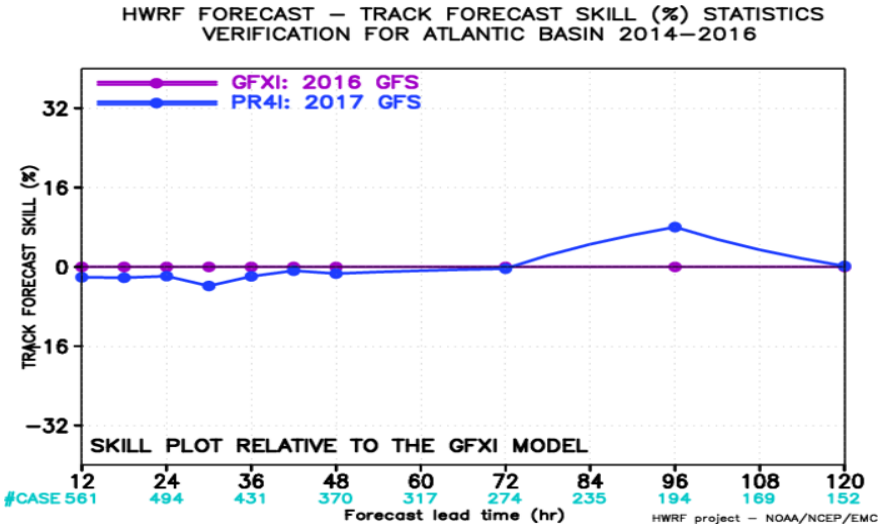
Further analysis of Hurricane Track performance in the Atlantic:

The three worst storms from 2016: Gaston, Hermine and Lisa

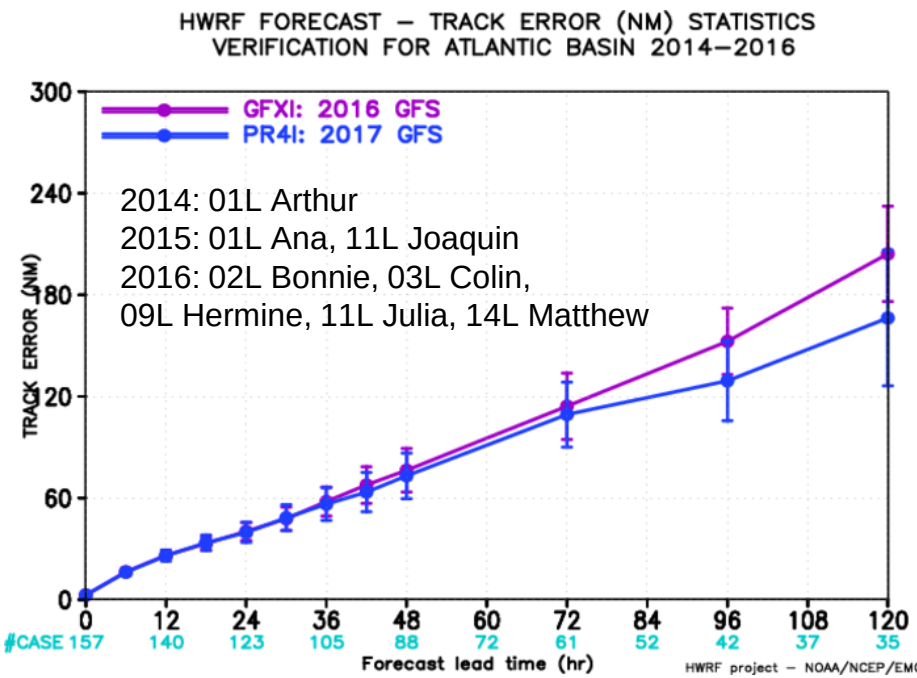


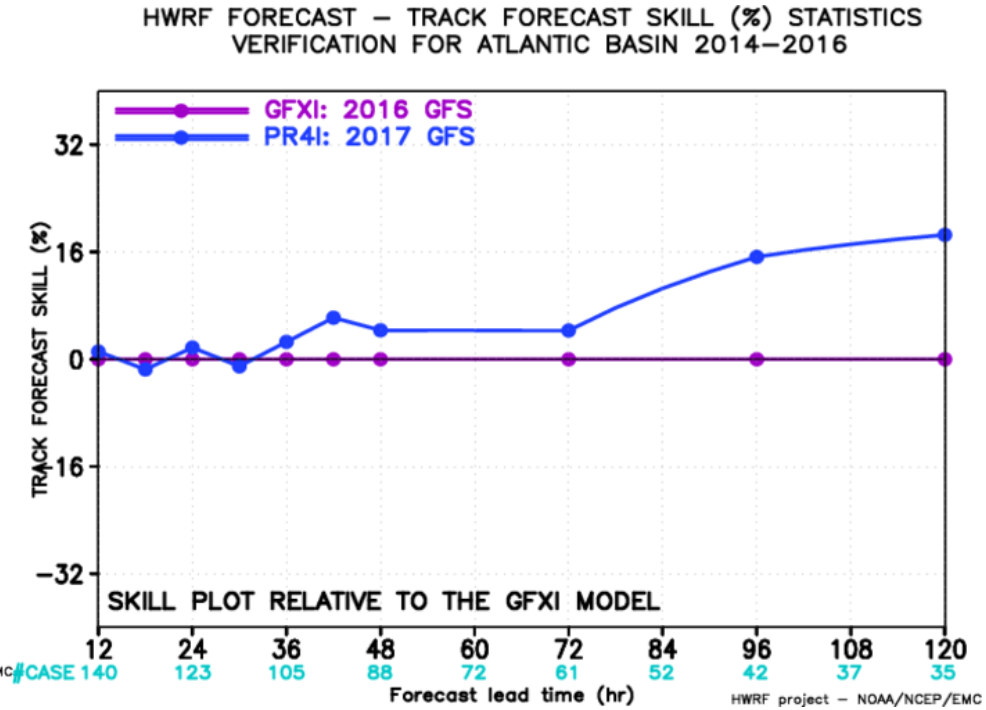






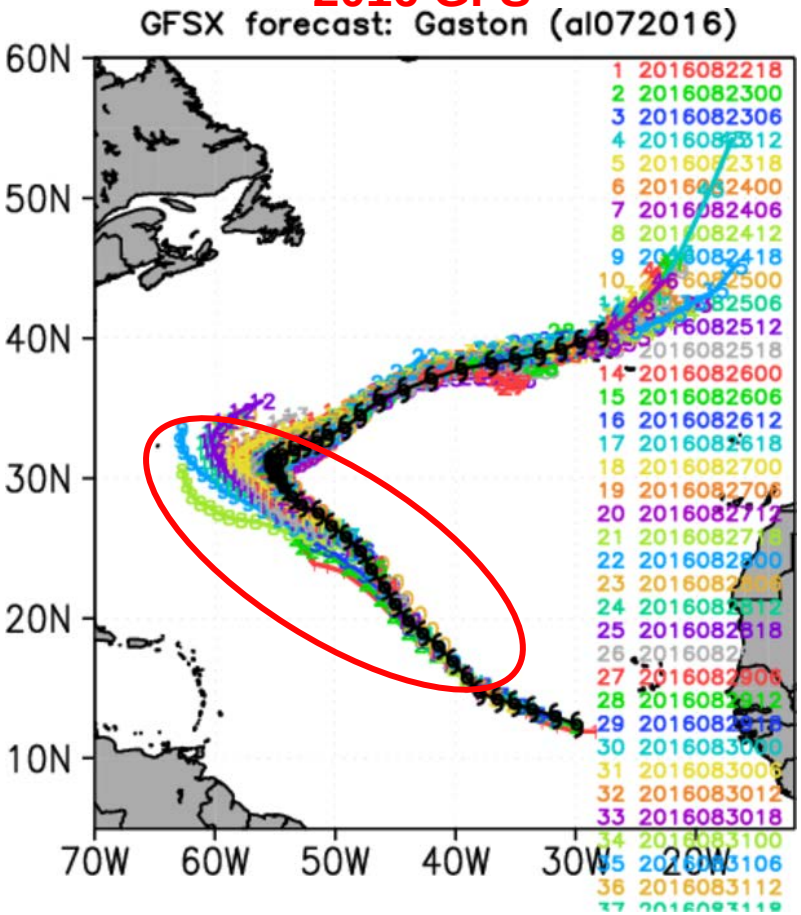
Track errors for US Landfalling Storms (including Joaquin), 2014-2016 ATL



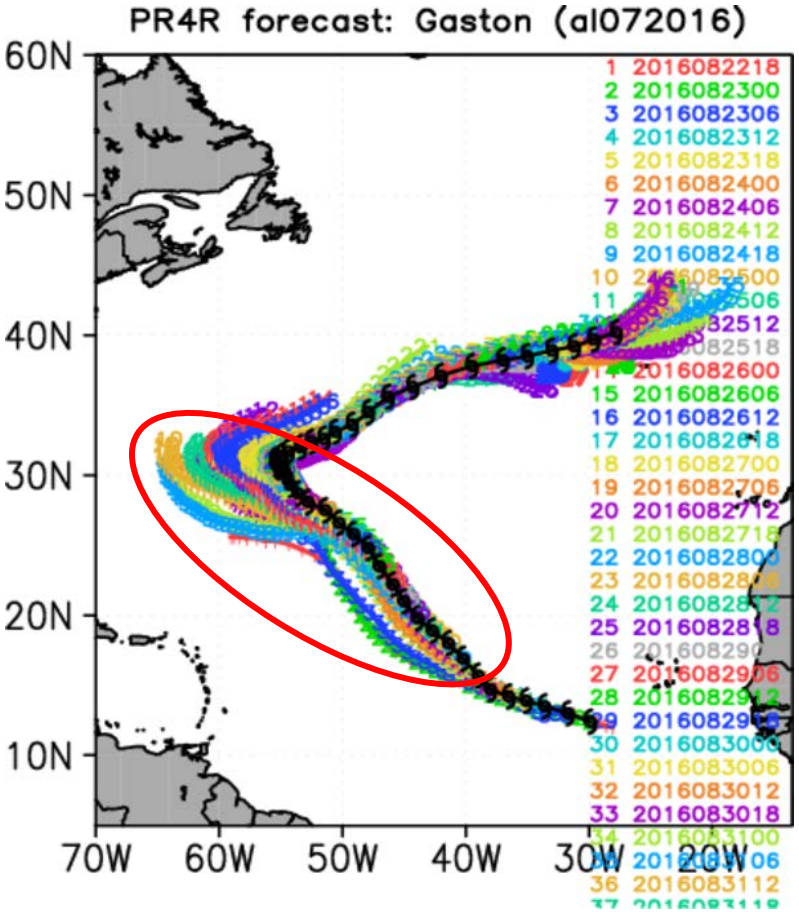


Composite track plots: H. Gaston

2016 GFS

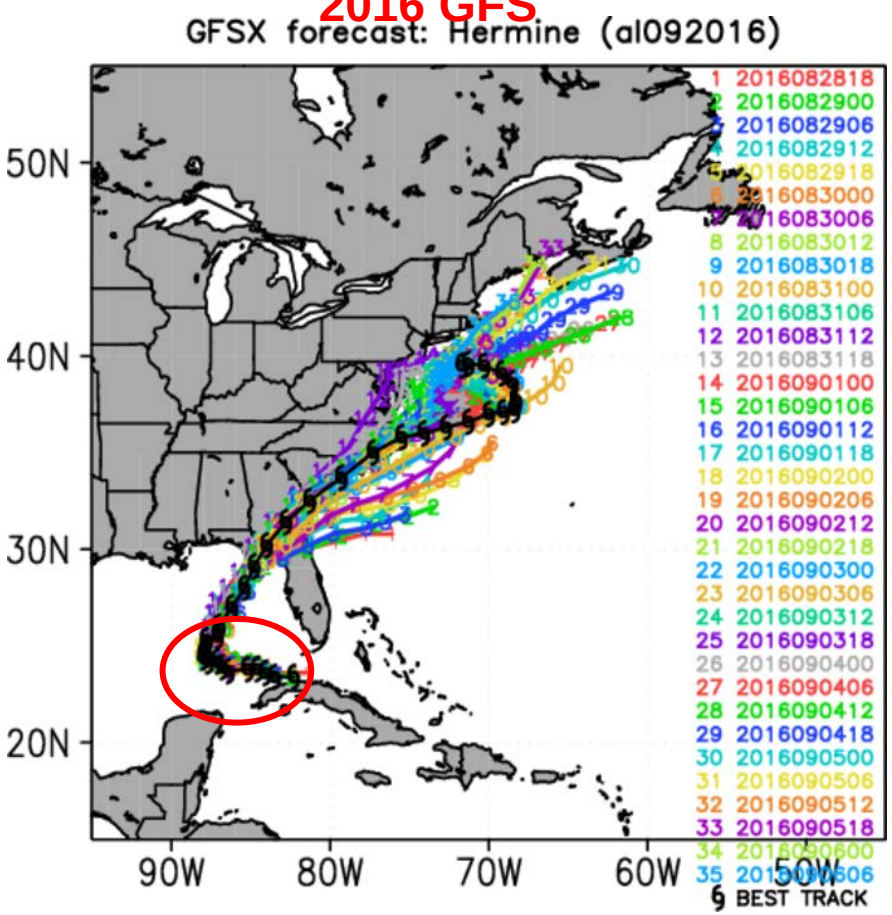


2017 GFS

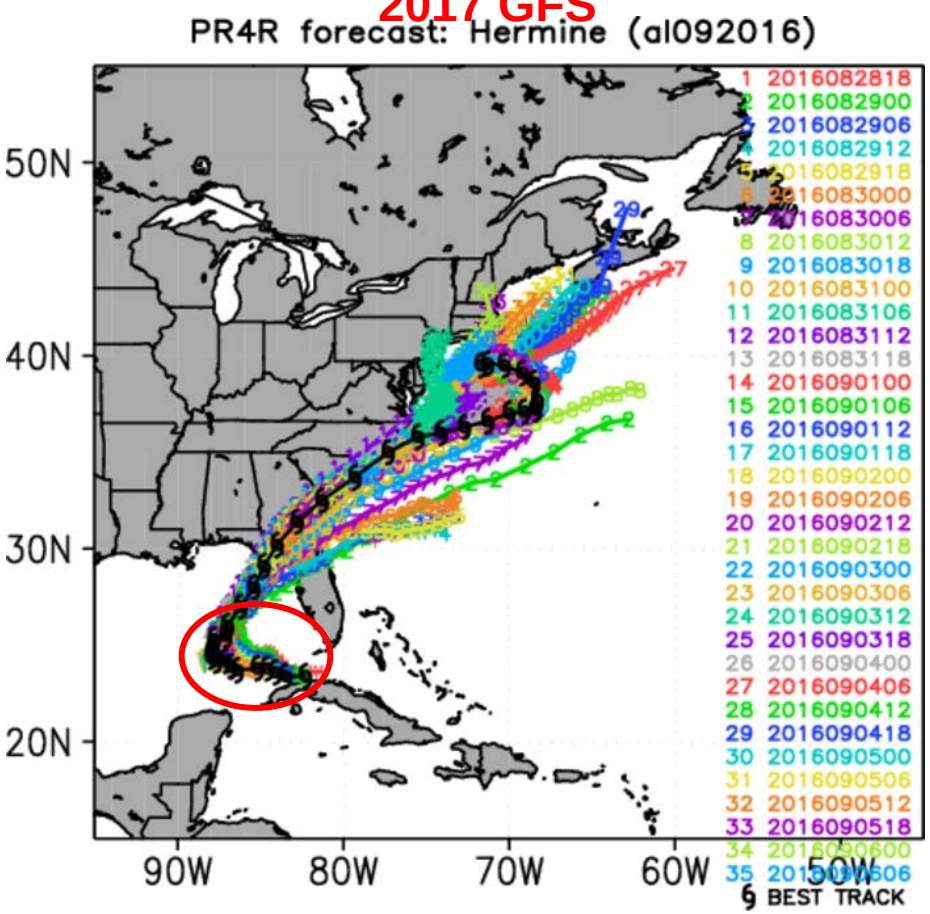


Composite track plots: H. Hermine

2016 GFS

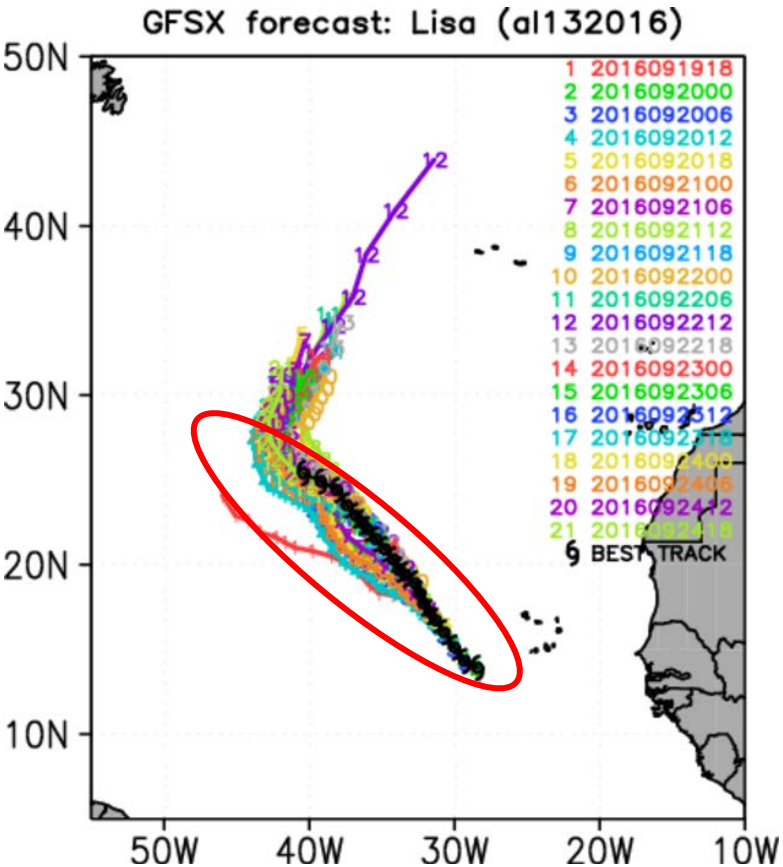


2017 GFS

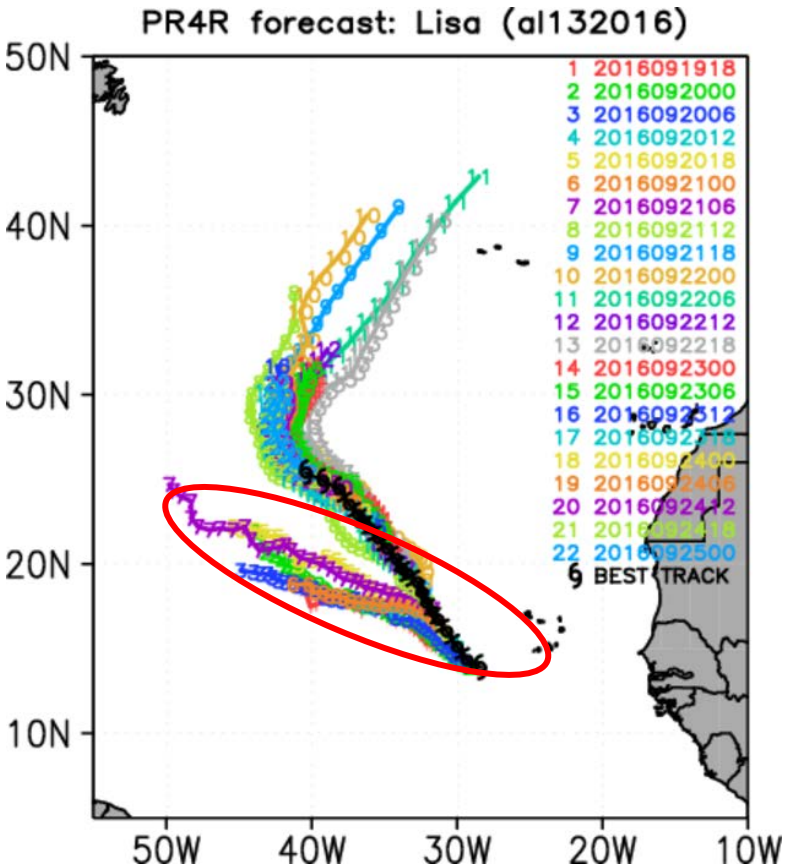


Composite track plots: H. Lisa

2016 GFS

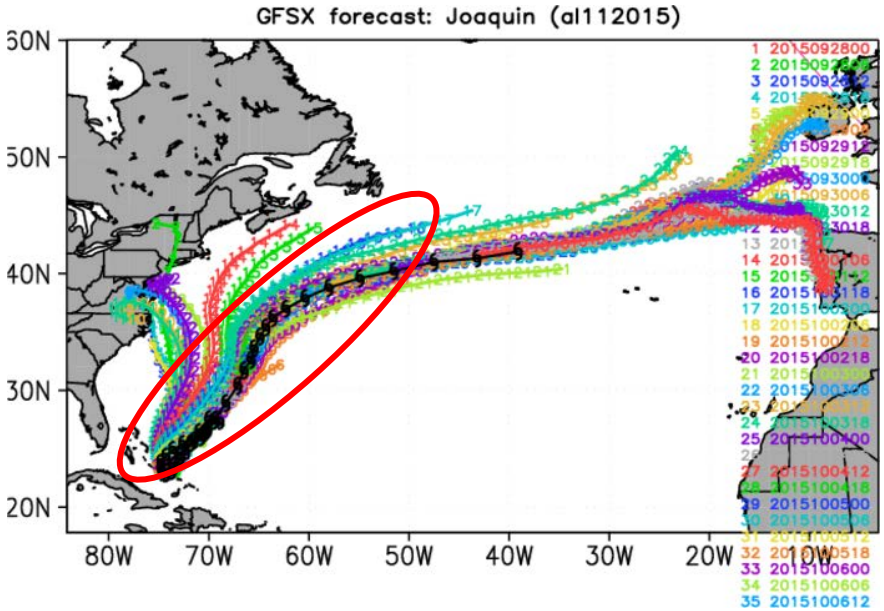


2017 GFS

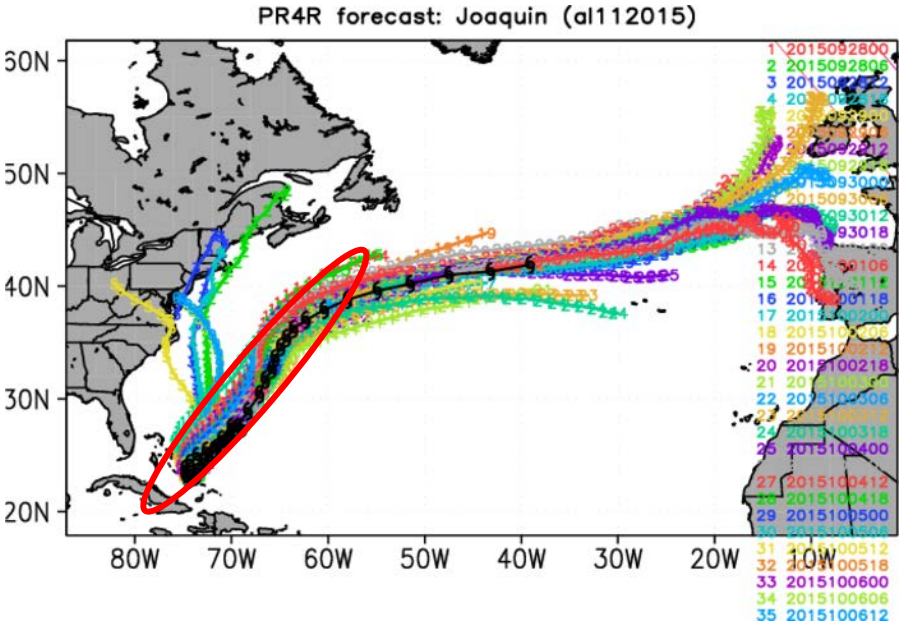


The Good Storms from 2017 GFS: Hurricane Joaquin

2016 GFS

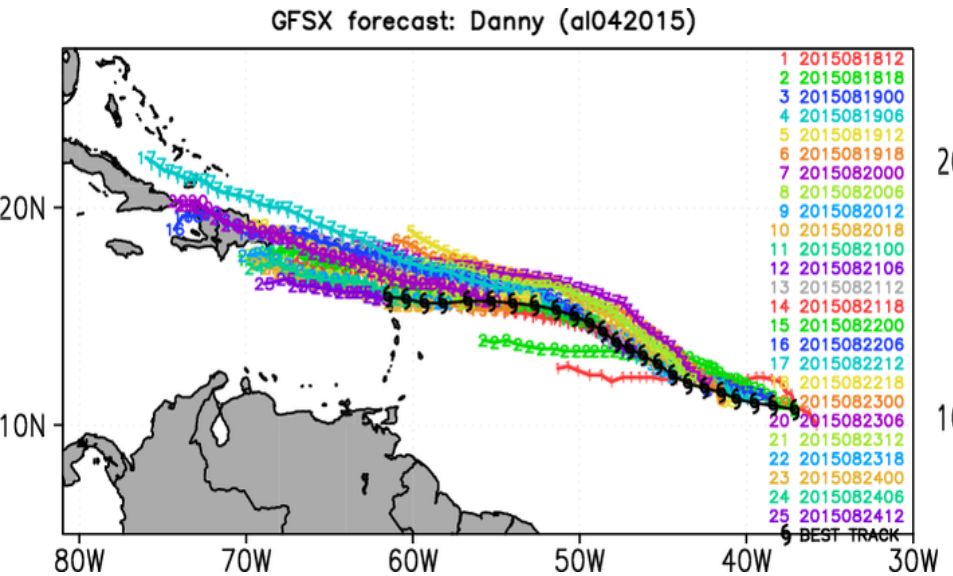


2017 GFS

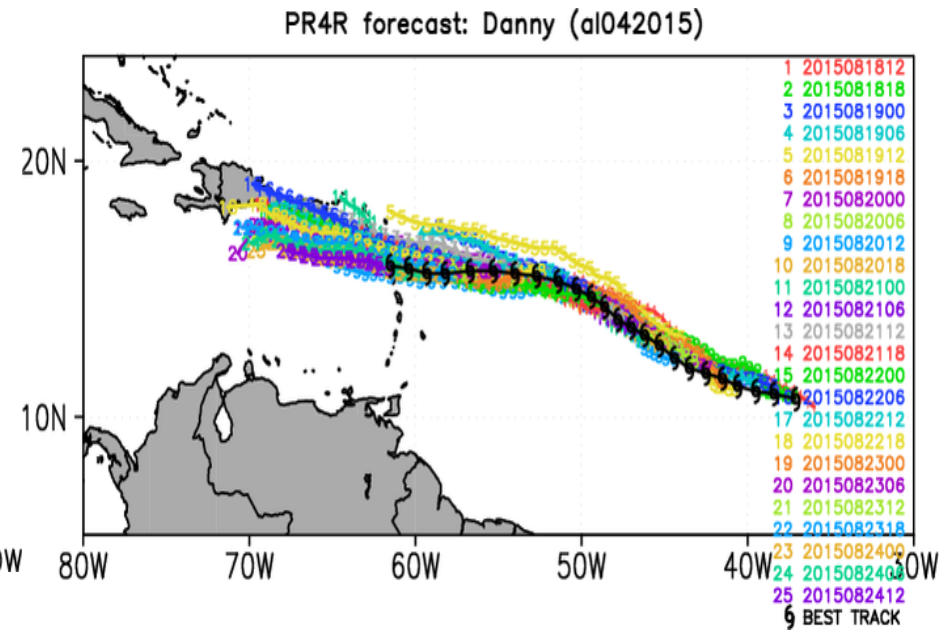


The Good Storms from 2017 GFS: Hurricane Danny

2016 GFS



2017 GFS



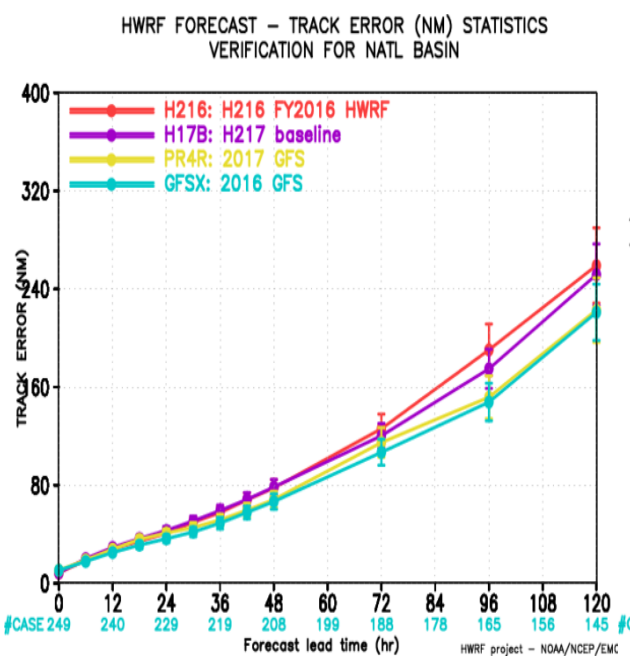
GEFS experiments for NEMS/IO
- Validation for GFS 2017 upgrade (Xiaqiong Zhou)

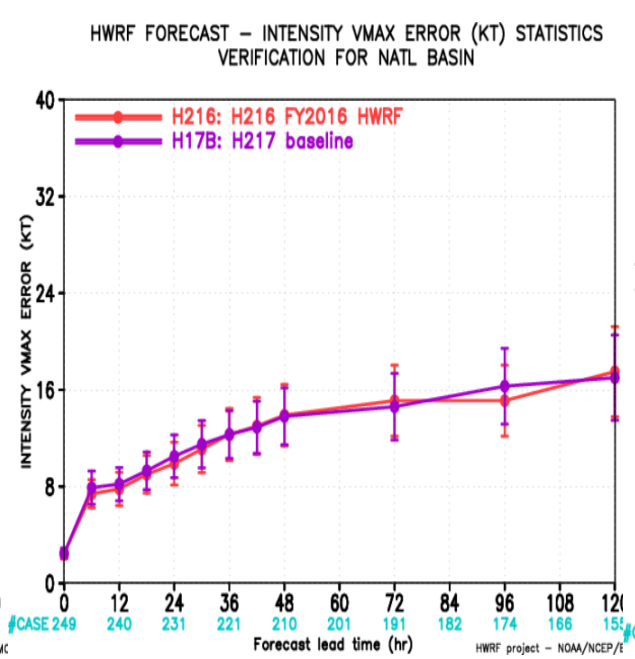
- Period: 20160801 – 20161014 (75 cases)
- GFS para initial analysis/perturbations
- The same GEFS forecast model, but using NEMS/IO
- Experiments run on WCOSS phase II
- Verifications:
  - –Against own analysis; observations
- Results:
  - – Against own analysis
    - •500hPa Z – NH is positive; SH is negative
    - •850hPa T – short-lead is negative; longer-lead in positive
    - •T2m – All short-leads are negative (due to inconsistent analysis)
  - –Against observation
    - •T2m – errors are similar for short lead time, smaller for longer leads, but bias is larger
    - •RH2m – bias is smaller
    - •T-profile (48 hours) – biases are slightly better for 500hPa, 700hPa and 850hPa
  - –Precipitation (CONUS) – neutral
  - –TC track forecasts – neutral

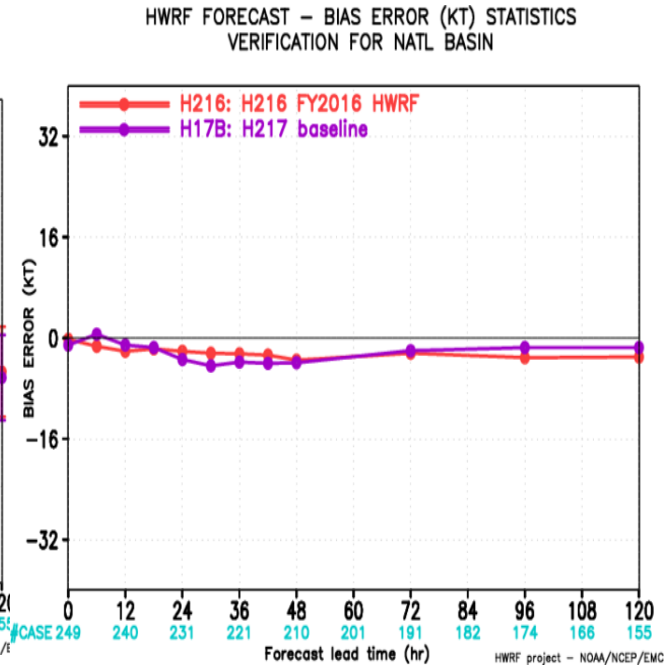
Impact of 2017 GFS upgrade on Global RTOFS v1.0.5

- RTOFS uses GDAS/GFS sflux GRIB2 files, no changes required in pre-processing flux fields
- Results from a few cycles indicate no statistically significant impact on ocean T, S, U, V fields
- Need to assess use of higher resolution GRIB2 files (both temporal and spatial) for the next upgrade

Impact of 2017 GFS upgrade on HWRF (NATL)

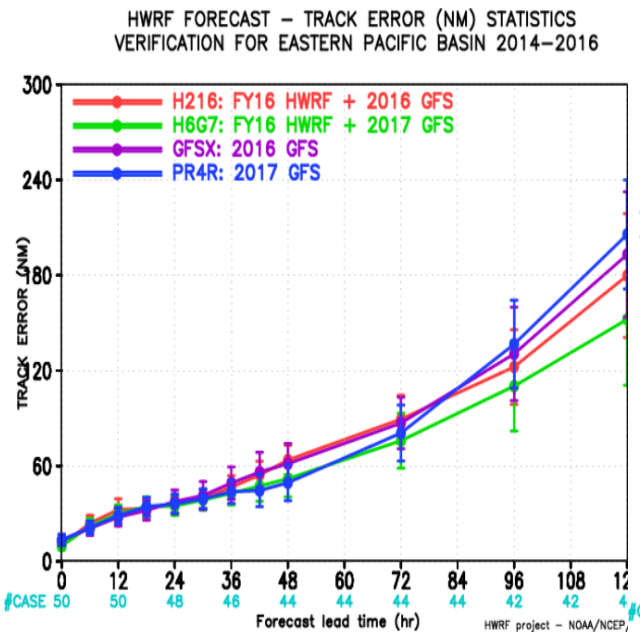


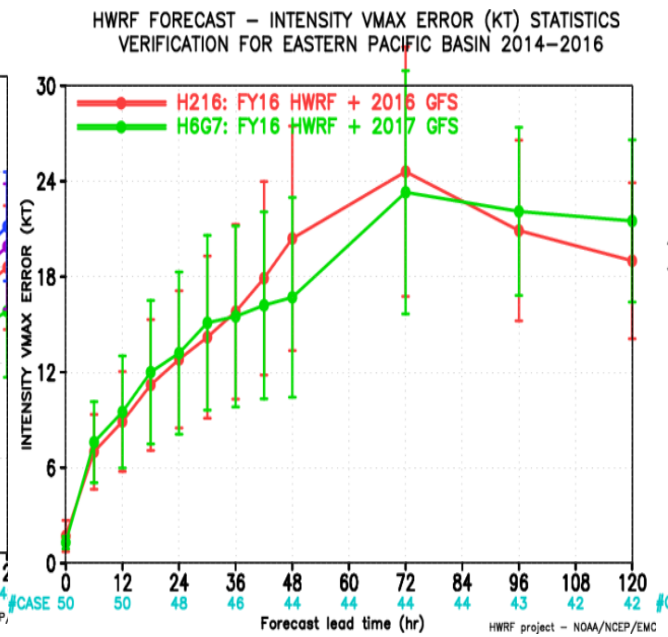


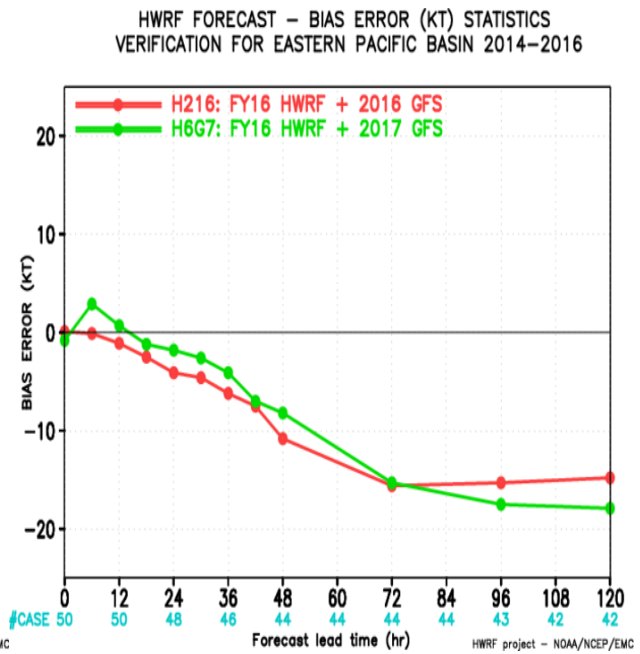


- Compared to H216, H17B track forecasts remain neutral for the first 48hrs, but show improvement after that through day 5.
- Compared to H216, H17B intensity forecast are mostly neutral to slightly negative.
- Intensity bias is improved beyond day 3.
- No statistical significant differences.

Impact of 2017 GFS upgrade on HWRF (EPAC)







- Early results encouraging, sample size too small
- HMON Evaluation is in progress – early results encouraging

Summary of various evaluation metrics

Evaluation	Remarks
Precipitation	**Improved skill and reduced wet bias for rain/norain (reduced drizzle). Significant improvements in skill 0.2 to 15 mm/day, forecast lengths 0-24 to 72-96 h.** *Increased wet bias for light to medium precipitation,* **decreased dry bias for moderate precipitation**
Upward Surface Shortwave Flux	**Reduced high bias in radiative flux due to better surface albedo**
2 m T and T_d	**Bias reduced more than increased in 16 US regions, fit-to-obs T_d RMS improved at all time of days, fit-to-obs T RMS improved at 00UTC (excessive cold bias at sunset reduced)** *worse at 12UTC*
10 m Winds	**Improved over eastern US,** *worse over western US*
MODE Precip Evaluation	**GFSX improved in summer 2015,** about same winter 2015/16.
Tropical precipitation	**Improved convection in tropics-AWC, WPC** **Time-mean precipitation over equatorial west Pacific better maintained in GFSX forecasts**

Summary of various evaluation metrics

Evaluation	Remarks
MODE Jet Stream Verification	*Small differences between GFS and GFSX*
MODE CAPE Verification	**Better overall for GFSX for summer 2015**
Case Studies	**GFSX better in more cases,** often GFS, GFSX very similar
Analysis Increments	**Reduced outside tropics**
500 hPa ACC	**At day 5 NH score decreased .002 over 609 cases**, SH unchanged. **NH 1% decline at day 7, SH 2.2% increase at day 9.**
Wind RMSE & Bias	Against own analyses. **Reduced negative tropospheric wind bias**, but *slight increase RMSE, particularly in NH,* more variability (less smooth) in GFSX, **reduced damping in GFSX forecasts**
Temperature RMSE	**1-2% larger RMSE at low levels in NH.** Smaller differences in SH. More variability in forecasts.

Summary of various evaluation metrics

Evaluation	Remarks
Fit-to-radiosondes	Small differences, winds have mixed results, **temperature slightly better fit in GFSX Winds stronger,** temperatures warmer in GFSX
Fit-to-aircraft (global)	**Wind and temperature biases mostly decreased in GFSX** **Fit of winds mixed results, fit of temperatures improved**
Fit-to-ACARS	**Bias decreased, fit improved**
Hurricane Tracks	*GFSX slightly worse in short range forecasts*
TC Genesis	**GFSX improved overall**
Hurricane Joaquin	**GFS2017 forecast Joaquin to stay out to sea about 42 hours before the GFS2015 and GFS2016 models**
Hurricane Matthew	**GFS2017 did better with track**
HWRF	**Neutral to improved track forecasts**
Multi-Waves	**Improved overall**
GEFS	**Neutral**
Downstream	**Almost ready to digest NEMSIO related changes**

Summary of Fit to observations

Temperatures	
Radiosondes Analyses, 6h	**Improved fit**
Radiosondes 24, 48 h	**Improved fit**, warmer than GFS
Aircraft Biases (global)	**Mostly improved**
Aircraft RMS fit	**Mostly improved**
ACARS Biases (North America)	**Mostly improved**
ACARS RMS fit	**Mostly improved**

Winds	
Radiosondes Analyses, 6h	**Improved fit**
Radiosondes 24, 48 h	**Stronger winds, especially tropics, SH** **Mixed results on fit—summer, fall** **Slightly improved fit --winter, spring**
Aircraft Biases (global)	**Mostly improved**
Aircraft RMS fit	**Mixed results**
ACARS Biases (North America)	**Mostly improved**
ACARS RMS fit	**Mostly improved**

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
Western Region	Implement	GFSX precip lighter in valleys GFSX more jumps 120-180 h fcsts in December
Central Region	Implement	No significant improvements nor detriments
Southern Region	Implement	GFSX slightly better Matthew, worse on Louisiana flooding
Eastern Region	Implement	Some beneficial improvements and upgrades
Pacific Region	No evaluation	
Alaska Region	Implement	Forecast improvements largely neutral
WPC	Implement	Slight improvement, Better tropical convection So. America
NHC genesis	Oppose	9-10% less skill in track forecast at 48-72h in Atlantic Forecasts of tropical storm genesis improved

Endorsements from Stakeholders

Region/Center	Recommendation	Remarks
AWC	Implement	Significant improvements to tropical convection and ceiling and visibility over CONUS
CPC long range stratosphere	Implement	Stratospheric fields improved, slight improvement D+8, week 2
OPC	Implement	Small scale features improved; large scale features similar
SWPC	No evaluation	
MDL	Implement	see little to suggest any dramatic MOS impacts from implementing new GFS
OWP	Implement	Mixed results, extremely limited testing
SPC report	Implement	Slightly improved 2-m dew point and instability bias

Evaluation: Next Steps

- **If approved, GFSX will continue until implementation**
- **Good chance for forecasters to continue to adapt to it**
- **Tracey Dorian and Glenn White plan to examine systematic errors and biases and present MEG briefings on them to prepare forecasters for changes in GFS biases**
- **Will review this evaluation in few weeks**
- **What worked**
- **What could be improved**

Comments Received So Far

- Estimation of statistical significance needs to be re-examined
- Should evaluate tests of individual components more thoroughly
- Need to evaluate GFS, GFSX globally, systematically as well as case studies, statistics
- GFSX availability often lagged GFS by 8-10 hours, should be available within 1-2 hours of GFS
- NAM, GFS evaluations at same time, overburdened evaluators
- GFS NEMS evaluation, FV3 development underway simultaneously
- Hourly data not available from retrospectives
- Need to get more experimental fields to forecasters
  More NH summer review?
- Role of model users in evaluation needs to be re-examined
  --point out problems for EMC to prioritize, address?
  --point out fields for EMC to emphasize in evaluation?
- Assign roles before final testing begins
- More time for evaluation after retrospectives finish?

New Products from 2017 GFS

- **GFSX Bufr data output are now every hour to 120 hours, and then every 3 hours to 240 hours. Original time points were 61, now it is 161.**
- **Despite the labeling of all precipitation data as 3-hourly, the precipitation reflects hourly amounts to 120 hours and then 3-hourly amounts to 240 hours.**
- **Sounding stations are expanded from 1919 to 2021, an increase of 102 stations.**

-1/8th degree files-work begun, suspended for completion of retrospectives

Initially on WCOSS, then on ftp/NOMADS

Will work with OWP, SPC, MDL, WPC

Resource Changes for GFS/GDAS

Compute / runtime changes GFS/GDAS Forecast				
Job Step	**Current Prod nodes/tasks (IBM Phase 2)**	**Current Prod runtime**	**Proposed nodes/tasks (Cray)**	**Proposed runtime**
gfs_fcst_high	90/540 (4 threads)	89.2	**65/260 (6 threads)**	**82.4**
gfs_fcst_low	18/216	14.5	20/80	**13.7**
gdas_fcst_high	43/258	13.4	55/220	**13**

sfc*nc4, flg, nfg, nstanl, sfcgcy, nsnf, nsstbufr, nsnanl, dtfanl, require additional 330GB/cycle disk space

Q3FY17 NEMS/GFS Vertical Structure

https://svnemc.ncep.noaa.gov/projects/gfs/branches/gfs_q3fy17

gdas.v14.1.0

JGDAS_BULLS
JGDAS_EMCSFC_SFC_PREP
JGDAS_VMINMON
JGDAS_VERFRAD
JGDAS_ENKF_POST
JGDAS_ENKF_FCST
JGDAS_ENKF_UPDATE
JGDAS_TROPCY_QC_RELOC
JGDAS_TROPC
JGDAS_ENKF_INFLATE_RECENTER
JGDAS_ANALYSIS_HIGH
JGDAS_ENKF_SELECT_OBS
JGDAS_ENKF_INNOVATE_OBS
JGDAS_MKNAVYBULLS
JGDAS_GEMPAK_META
JGDAS_GEMPAK_NCDC
JGDAS_GEMPAK
JGDAS_FORECAST_HIGH
JGDAS_NCEPPOST

gfs.v14.1.0

JGFS_PRDGEN_MANAGER
JGFS_FBWIND
JGFS_PGRB2_SPEC_GEMPAK
JGFS_PGRB2
JGFS_AWIPS_20KM
JGFS_POST_MANAGER
JGFS_GEMPAK_UPAPGIF
JGFS_EMCSFC_SFC_PREP
JCPC_GET_GFS_6HR
JGFS_AWIPS_1P0DEG
JGFS_TROPCY_QC_RELOC
JGFS_GEMPAK_NCDC
JGFS_PGRB2_SPEC_POST
JGFS_FAX_WAFS
JGFS_VMINMON
JGFS_CYCLONE_TRACKER
JGFS_WAFS_GRIB2
JGFS_WAFS
JGFS_WAFS_BLENDING
JGFS_WAFS_GCIP
JGFS_ANALYSIS
JGFS_NPOESS_PGRB2_0P5DEG
JGFS_GEMPAK_META
JGFS_AWIPS_G2
JGFS_FAX
JGFS_FORECAST_LOW
JGFS_GEMPAK
JGFS_FORECAST_HIGH
JGFS_NCEPPOST
JGFS_POSTSND
JGFS_SMINIT

Included Packages

GSI & ENKF (analysis)
global_fcst (forecast)
ncep_post
emcsfc
tropcy_qc_relo
wafs
gfs_post (downstream)
gempak (downstream)
smartinit
MinMon
RadMon

Points to consider

- This upgrade did not specifically target improving tropical cyclone forecasts
- The differences between 2016 GFS and 2017 GFS are likely very similar to what we would see if we just have to port the current model to a new platform (transitioning from IBM to Cray)
- All downstream models have already adopted to the changes due to NEMS/GFS, HWRF runs have shown non-negative impact on track and intensity forecasts for the Atlantic
- All other centers/regions already endorsed implementation
- No further plans to improve GSM based GFS as we all migrated to FV3 --- THIS IS THE FINAL UPGRADE FOR THE SPECTRAL MODEL
- Not implementing NEMS GSM will require us to run a separate parallel for base-lining FV3GFS in NEMS.

GCWMB requests EMC Director to approve implementation of Q3FY17 NEMS/GFS upgrade package.

Next Steps

- Code Hand-off to NCO: After OD Brief, 02/21/17
- All non-GFS downstream codes submitted to NCO: On track
- Collect Evaluation Reports from the field: Completed
- Final EMC CCB: Today (Completed)
- OD Briefing: 2/21/17 (Scheduled)
- TIN: March (on track)
- 30-day evaluation: April
- Final OD Briefing by NCO: 5/??
- Implementation: 5/??