GFSv16 Evaluation

STI SOO GFSv16 Evaluation Team

17 September 2020

MEG STI GFSv16 Evaluation Team

- ***Purpose:*** Help evaluate readiness of GFSv16 for implementation from the perspective of the NWS Regions and Centers
- Team Members

Geoff Manikin (EMC)	Warren Blier (Western Region)
Chris Karstens (SPC)	Mike Fowle (Central Region)
Mark Klein (WPC)	Bill Martin (Eastern Region)
Steverino Silberberg (AWC)	Emily Niebuhr and David Levin (Alaska Region)
Ben Trabing & Brian Zachry (NHC)	Jack Settelmaier (Southern Region)
Bob Ballard (Pacific Region)	

Background

- A major outcome of the National 2015 SOO/DOH Meeting was to have SOOs and DOHs contribute to national and regional projects that support Weather Ready Nation goals
- The STI leadership team oversees these projects/teams and solicits volunteers to join the teams for approved projects (D. Myrick, National SOO)
- The MEG has been invoking SOO/DOH teams to assist with evaluation activities since 2016, as the expertise of forecasters at the local and regional level is invaluable 2020 AMS Presentation
- A team was organized in late spring 2020 to help evaluate GFSv16 and have its members contribute to their Region's/Center's official recommendation on the proposed upgrade

Subjective Assessments

- Each team member was asked to examine GFSv15 and GFSv16 performance for a set of cases relevant to their Region/Center
- Members were asked to assess performance on 2m temperatures, 2m dew points, QPF, instability, synoptic performance, soundings, and overall utility
- The forecasts were split into extended range (days 7-10), medium range (days 4-6), and short range (days 1-3)
- For each item in each forecast range, embers were asked to use a rating system with a range of -3 to +3 (-3 indicating that GFSv15 was clearly better to +3 indicating that GFSv16 was clearly better, with 0 representing no discernible difference)
- In the following tables, we group “as good or better” (0 to +3) together, since in the big picture, it is acceptable for v16 to match the performance of

2m Temperature Ratings

12z Valid Time	Mean Rating -3 to +3	% GFSv16 as good or better than GFSv15	% GFSv16 worse than GFSv15
Extended Range	0.13	71	29
Medium Range	0.23	82	18
Short Range	0.23	95	5
00z Valid Time			
Extended Range	0.29	80	20
Medium Range	0.41	90	10
Short Range	0.36	87	13

- Mean rating shows modest improvements at all time ranges, with slightly larger gains at 00z valid times

- The high percentages of “as good or better” for all three time ranges reflect that there were a lot of ‘0’ ratings

QPF Ratings

	Mean Rating -3 to +3	% GFSv16 as good or better than GFSv15	% GFSv16 worse than GFSv15
Extended Range	0.17	80	20
Medium Range	0.63	90	10
Short Range	0.27	85	15

- Mean rating clearly shows that the biggest improvements were seen in the medium range

- The high percentages of “as good or better” for all three time ranges reflect that there were a lot of ‘0’ ratings in the extended and short ranges

CAPE Ratings

	Mean Rating -3 to +3	% GFSv16 as good or better than GFSv15	% GFSv16 worse than GFSv15
Extended Range	0.04	70	30
Medium Range	0.21	74	26
Short Range	-0.20	75	25

- Lowest overall ratings were for this parameter

- The only negative mean rating for any parameter is CAPE in the short range; the still high percentage for "as good or better" in the short range is driven by a significant number of '0' ratings with several '-2', '-3', and "+1" ratings

Synoptic Ratings

	Mean Rating -3 to +3	% GFSv16 as good or better than GFSv15	% GFSv16 worse than GFSv15
Extended Range	0.35	78	22
Medium Range	0.59	83	17
Short Range	0.07	85	15

- Mean rating clearly shows that the biggest improvements were seen in the medium range

- The high percentages of “as good or better” for all three time ranges reflect that there were a lot of ‘0’ ratings in the extended range and especially in the short range (with a higher number of positive medium range ratings)

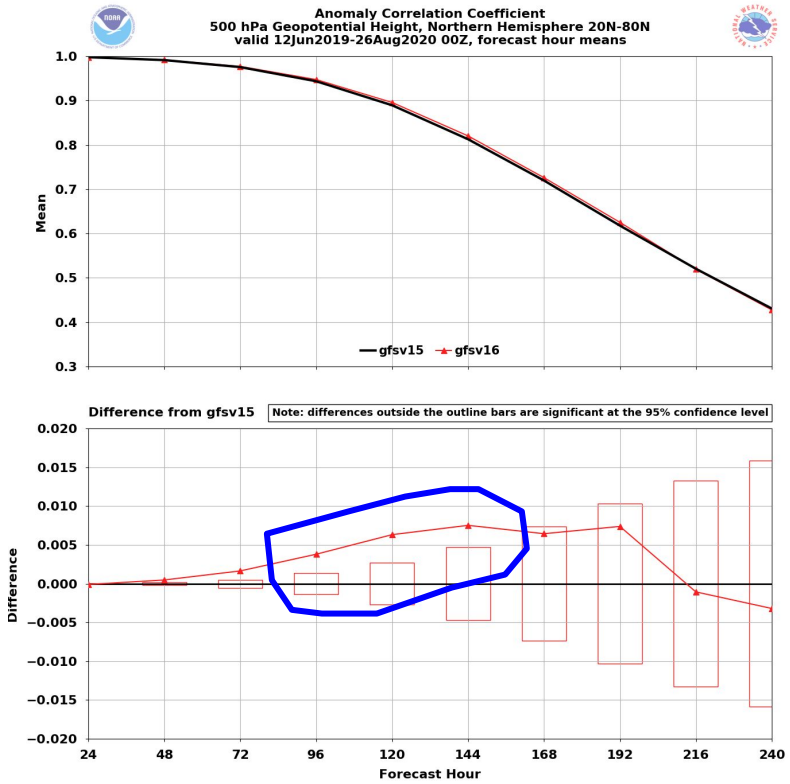
Ratings for Overall Utility

	Mean Rating -3 to +3	% GFSv16 as good or better than GFSv15	% GFSv16 worse than GFSv15
Extended Range	0.34	79	21
Medium Range	0.57	85	15
Short Range	0.26	85	15

- Mean rating clearly shows that the biggest improvements were seen in the medium range, although there is some utility at all ranges

- The high percentages of “as good or better” for all three time ranges reflect that there were a lot of ‘0’ ratings in the extended range and short ranges (with more positive medium range ratings)

Better Medium Range Scores Consistent with Stats



500 hPa ACC scores show statistically significant improvement in GFSv16 over v15 in the medium range, and the subjective ratings show that it this statistical improvement is manifested in the forecast maps the most during this time range

Mark Klein

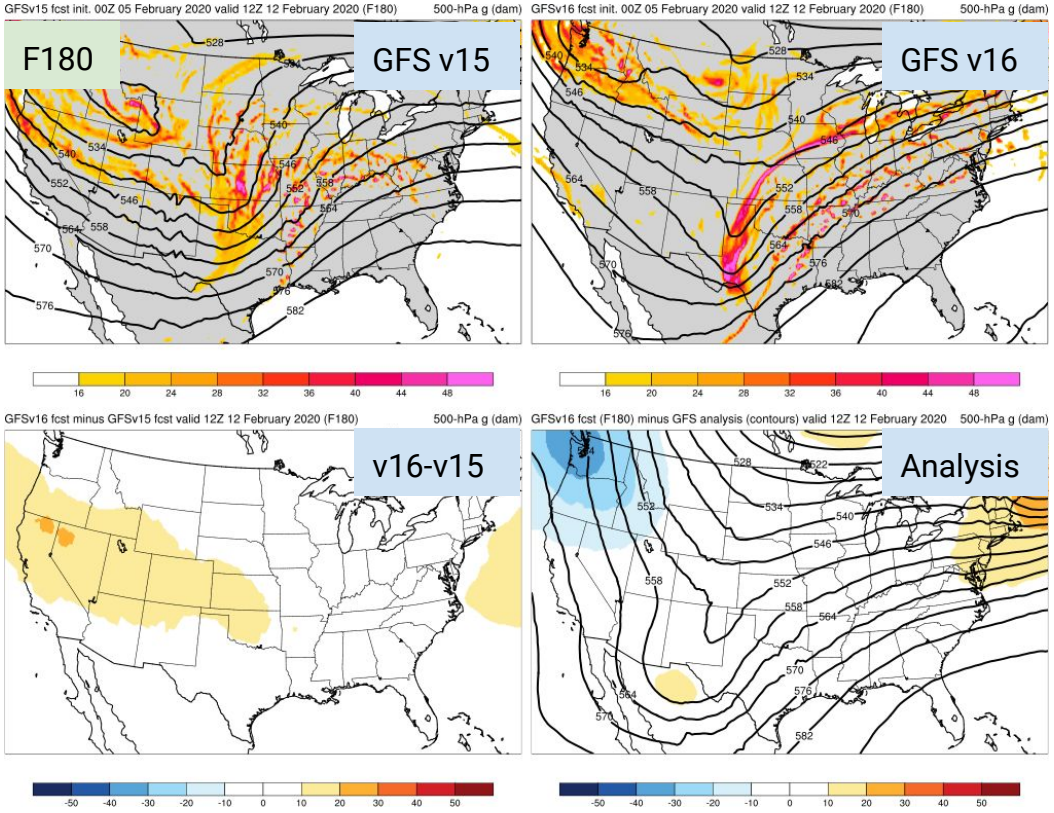
Weather Prediction Center

Focus → heavy precipitation events/medium-range forecasting

Main Findings

- Synoptic-scale pattern better handled in v16, particularly in the medium range
- The progressive bias in v15 seems less prevalent in v16
- For the majority of forecast cycles in each case, v16 QPF was an improvement over v15, both with areal coverage and magnitudes.
- Precipitation type forecasts suggest there may be a stronger warm nose in warm advection events (?)

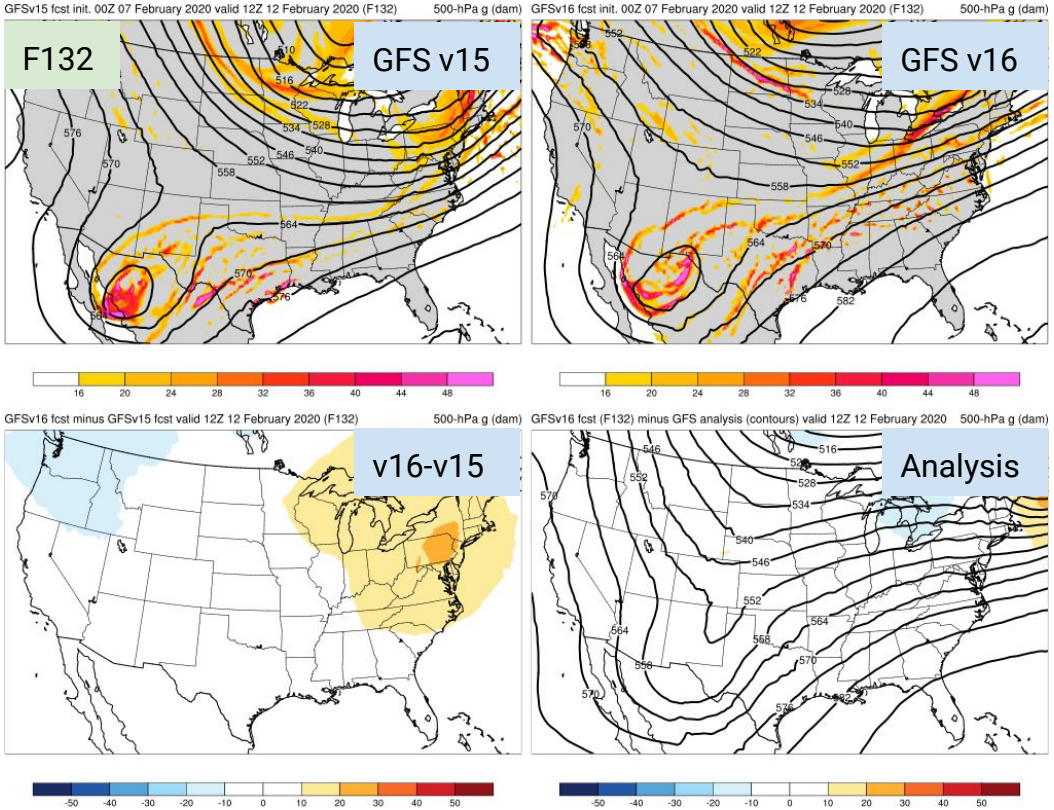
Southeastern U.S. Heavy Rain (Feb 2020)



180-hour forecast from 00Z Feb 5 valid at 12Z Feb 12.

- GFSv16 had an excellent Day 7 forecast
- GFSv15 was too progressive

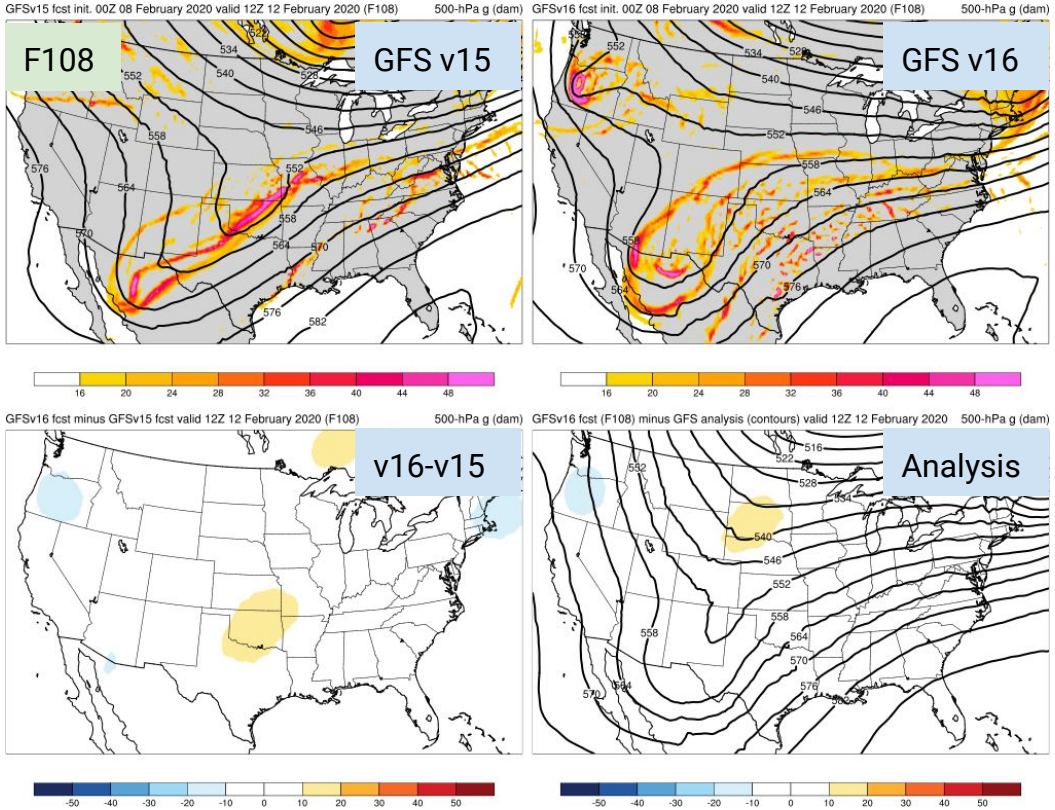
Southeastern U.S. Heavy Rain (Feb 2020)



132-hour forecast from 00Z Feb 7 valid at 12Z Feb 12.

- Similar trough strength and position, though GFSv16 better handling the northern stream pattern

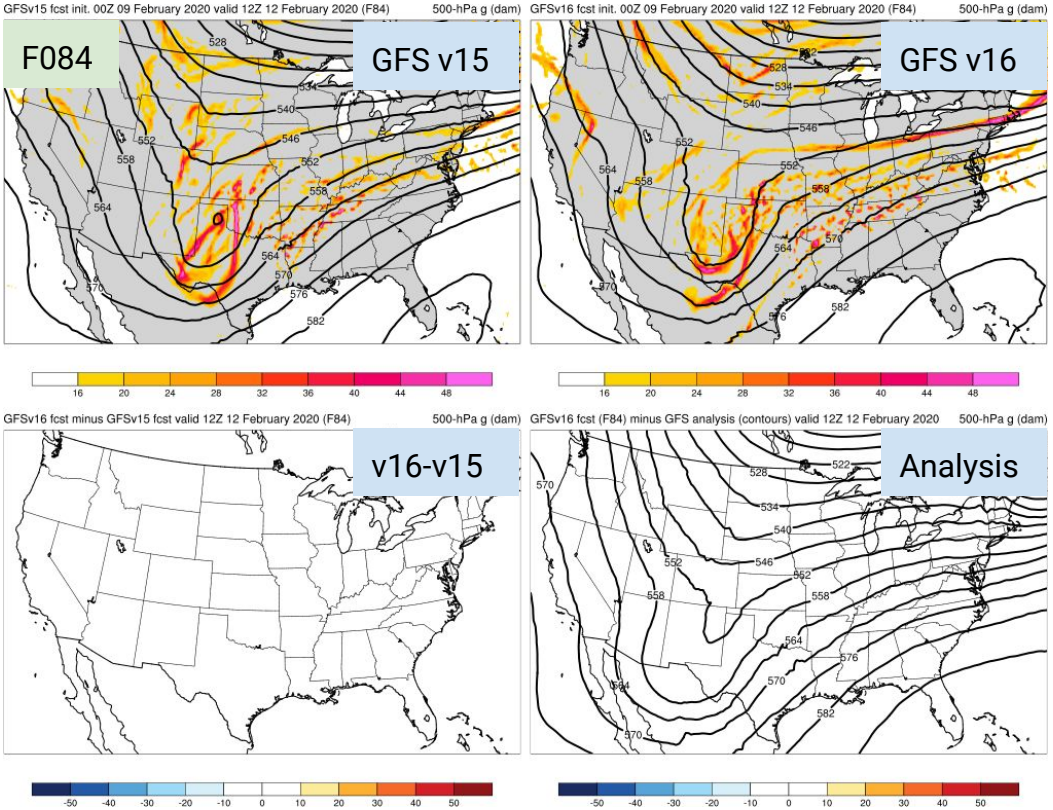
Southeastern U.S. Heavy Rain (Feb 2020)



108-hour forecast from 00Z Feb 8 valid at 12Z Feb 12.

- GFSv16 correctly had a more consolidated southern stream feature and accurate timing

Southeastern U.S. Heavy Rain (Feb 2020)

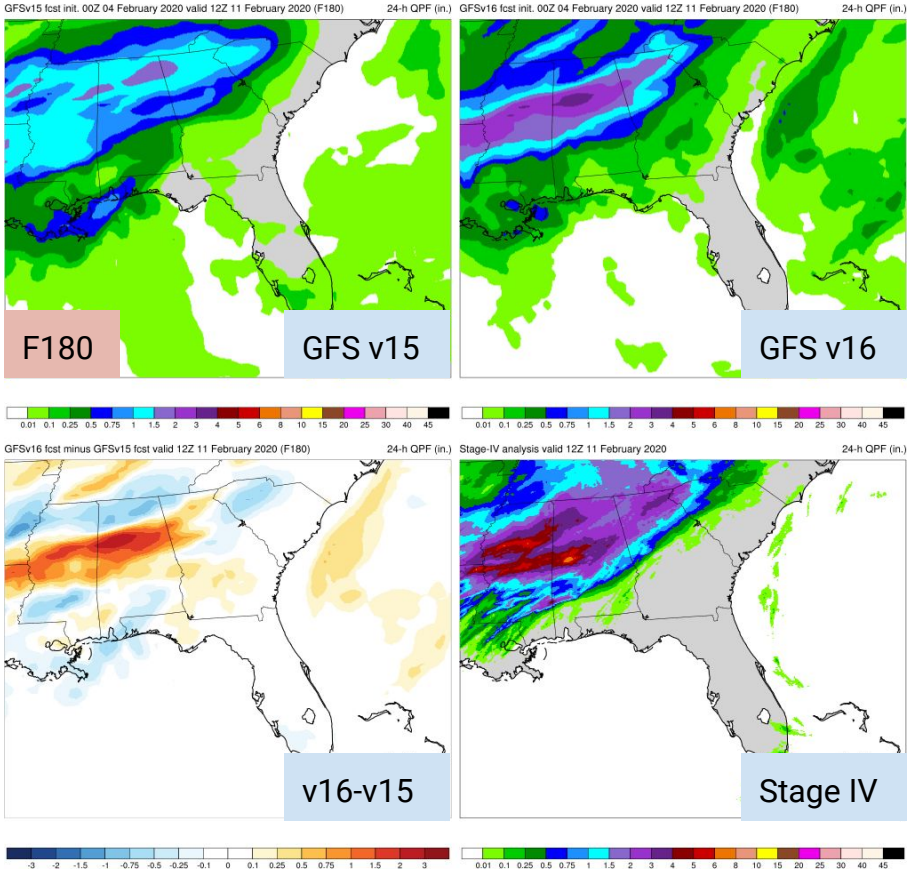


84-hour forecast from 00Z Feb 9 valid at 12Z Feb 12.

GFSv16 -- better and more consistent forecasts of the overall synoptic pattern

Most cycles showed a less progressive bias in GFSv16

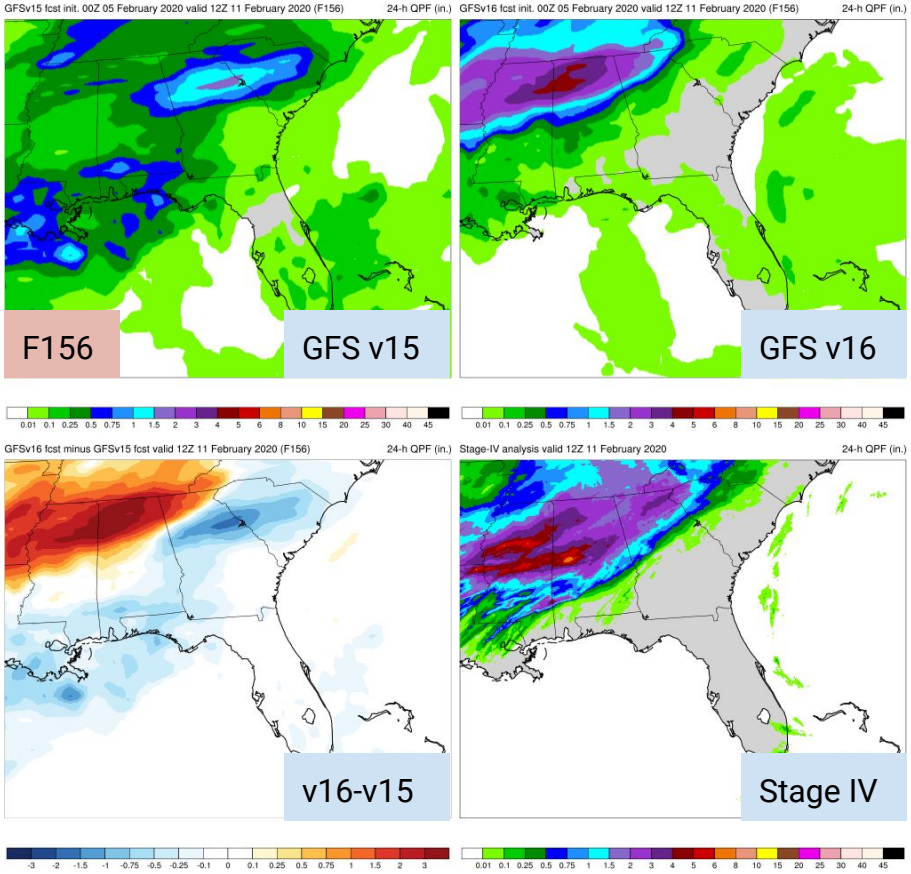
Southeastern U.S. Heavy Rain (Feb 2020)



180-hour forecast from 00Z Feb 4 valid at 12Z Feb 11.

- Both captured the heavy rainfall potential at Day 7, but GFSv16 was almost spot-on with the axis

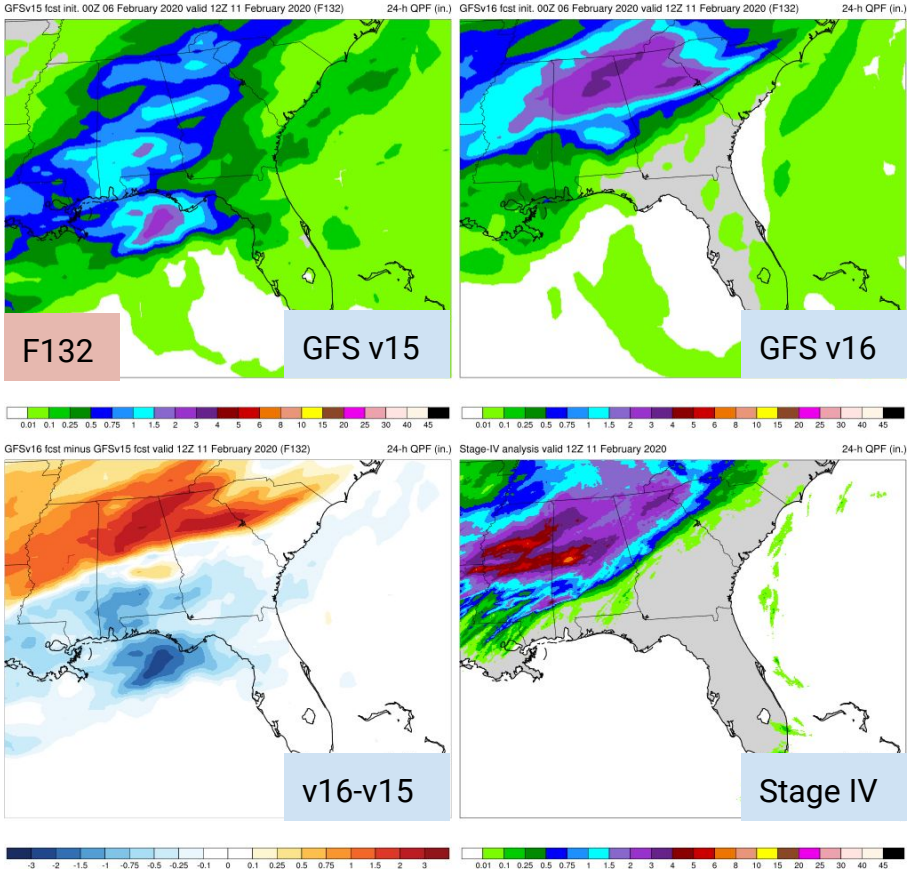
Southeastern U.S. Heavy Rain (Feb 2020)



156-hour forecast from 00Z Feb 5 valid at 12Z Feb 11.

- On Day 6, GFSv16 maintained excellent continuity, while GFSv15 showed a much more disorganized rainfall pattern along the front

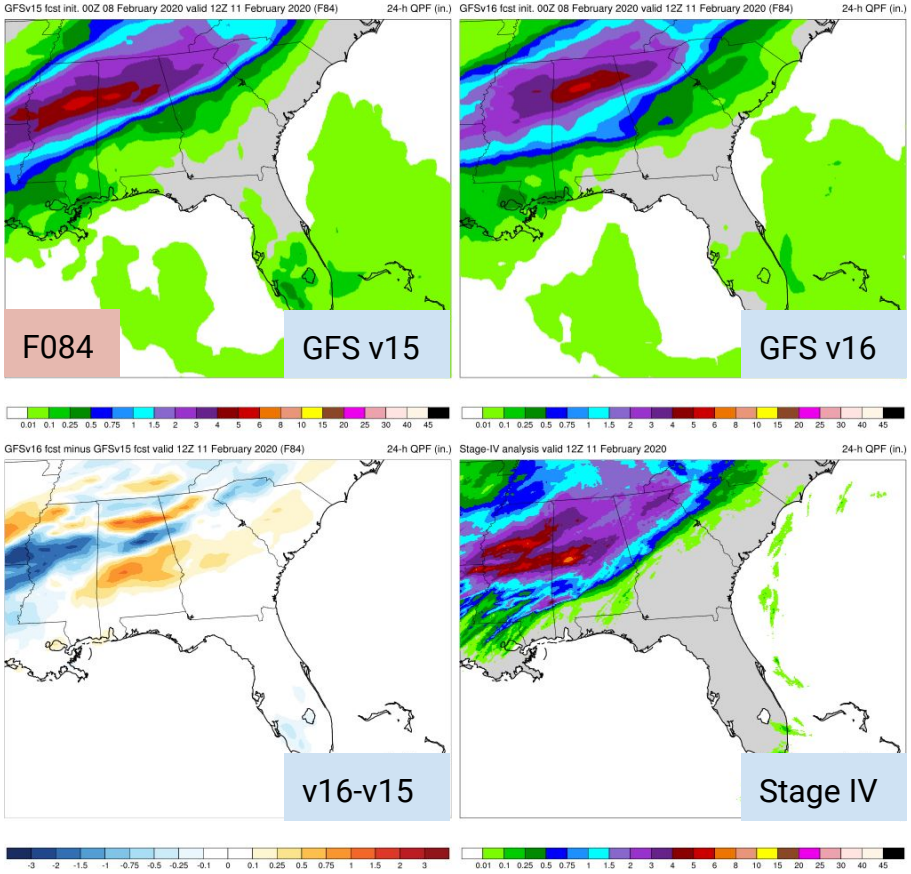
Southeastern U.S. Heavy Rain (Feb 2020)



132-hour forecast from 00Z Feb 6 valid at 12Z Feb 11.

- Similar story for Day 5; great continuity in GFSv16 and an unfocused QPF pattern in GFSv15

Southeastern U.S. Heavy Rain (Feb 2020)



84-hour forecast from 00Z Feb 8 valid at 12Z Feb 11.

GFSv16 captured the heavy rainfall potential at F216, earlier than GFSv15

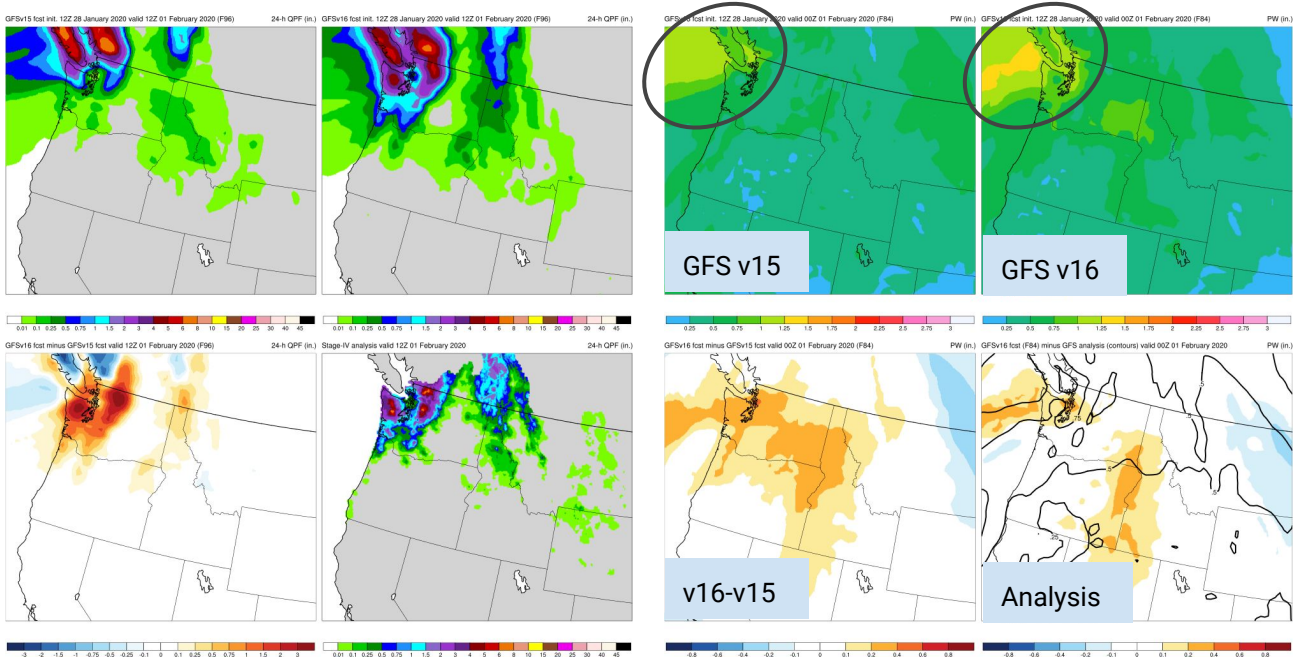
GFSv16 showed excellent run to run consistency

Tended to be too far north with the precipitation axis in the short to early medium range period

Pac NW Atmospheric River - Jan/Feb 2020

96-hour forecast from 12Z Jan 28
24-hour QPF valid 12Z 2/1

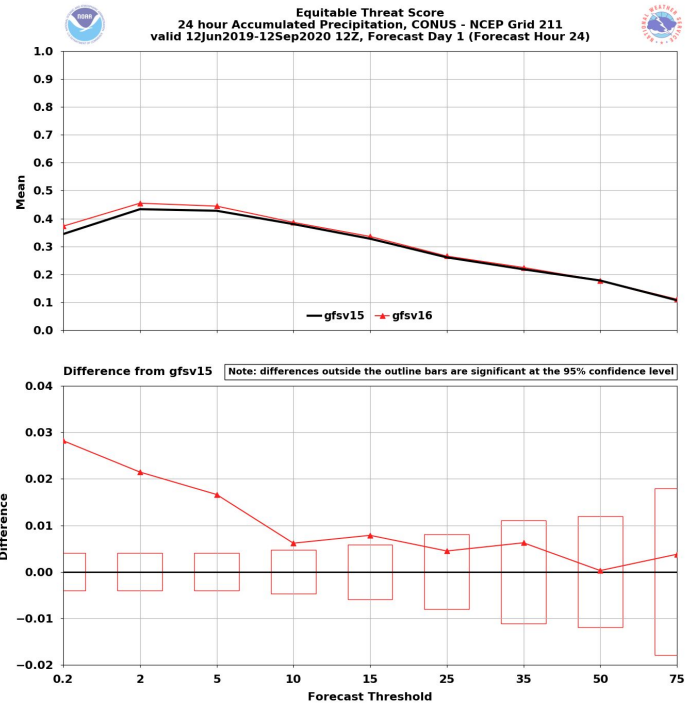
84-hour PW forecast from 12Z Jan 28



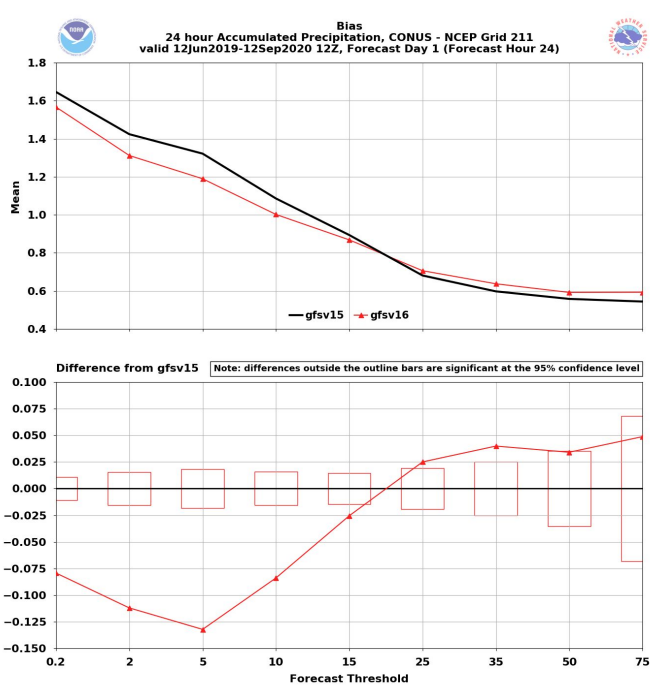
Just one example, but for nearly all short and medium range cycles of this case, GFSv16 produced significantly better QPF, in part due to higher PWs in the atmospheric river

QPF Verification Statistics

ETS Jun 12 2019 - Sep 12 2020



Bias Jun 12 2019 - Sep 12 2020

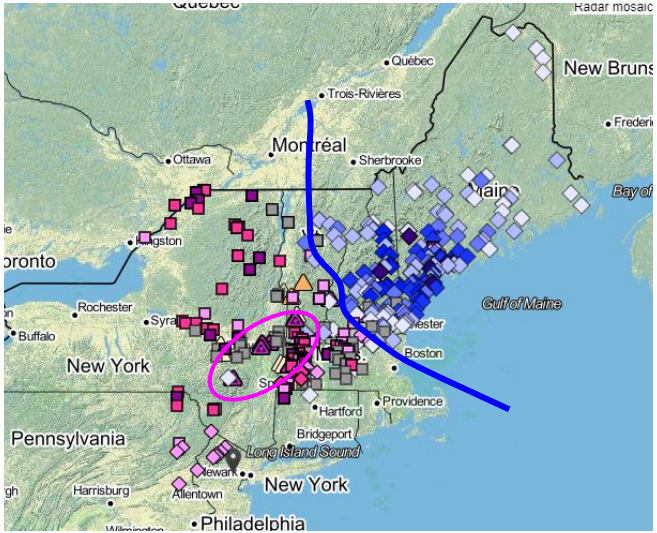


Higher threat scores at low thresholds

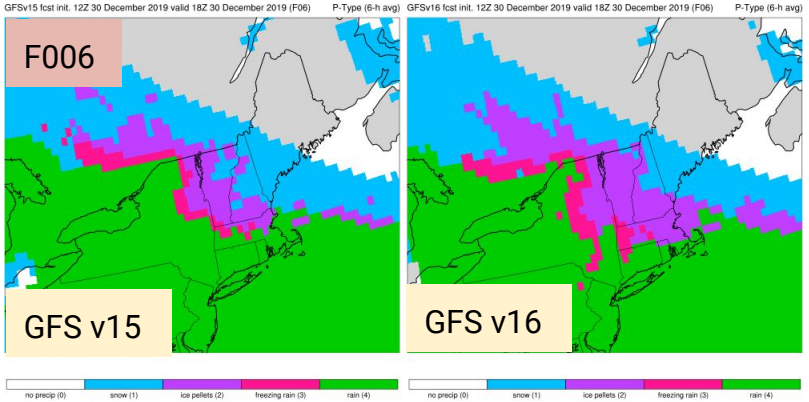
Improved lower bias for light amounts and slightly better bias for heavier thresholds

New England Ice/Snow - December 2019

Snow (blue diamonds), sleet (purple triangles), and freezing rain (red squares) for the 12Z 12/30 - 12Z 12/31 period



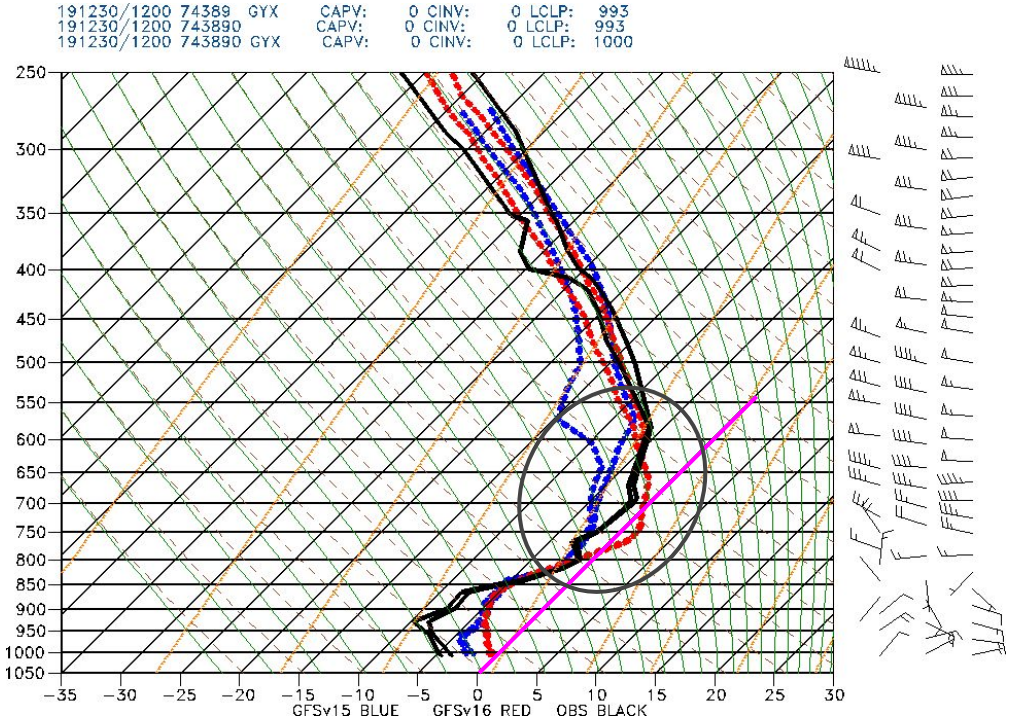
Forecasts valid 18Z Dec 30, 2019



GFSv16 caught onto this event about 36 hours ahead of GFSv15

GFSv16 seemed to overforecast sleet coverage

New England Ice/Snow - December 2019



84-hour forecast valid 12Z 12/30.

Note the warm nose in v16 that resulted in the sleet sounding

Bill Martin

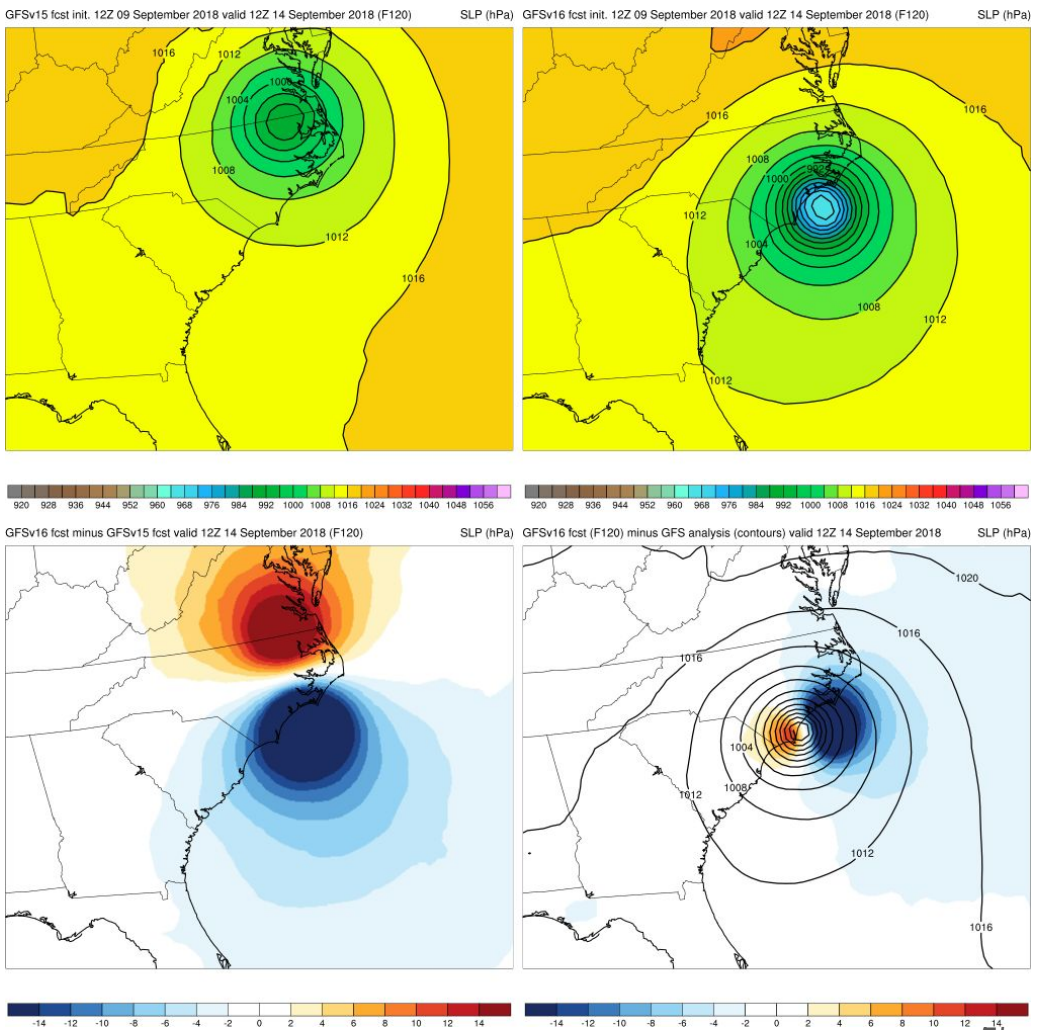
NWS Eastern Region
SOO, WFO Greenville/Spartanburg, SC

- **On balance, GFSv16 is an improvement over GFSv15, but the improvement is not huge.**
- **In some cases, GFSv16 is much better**
- **In some cases, GFSv15 is better**

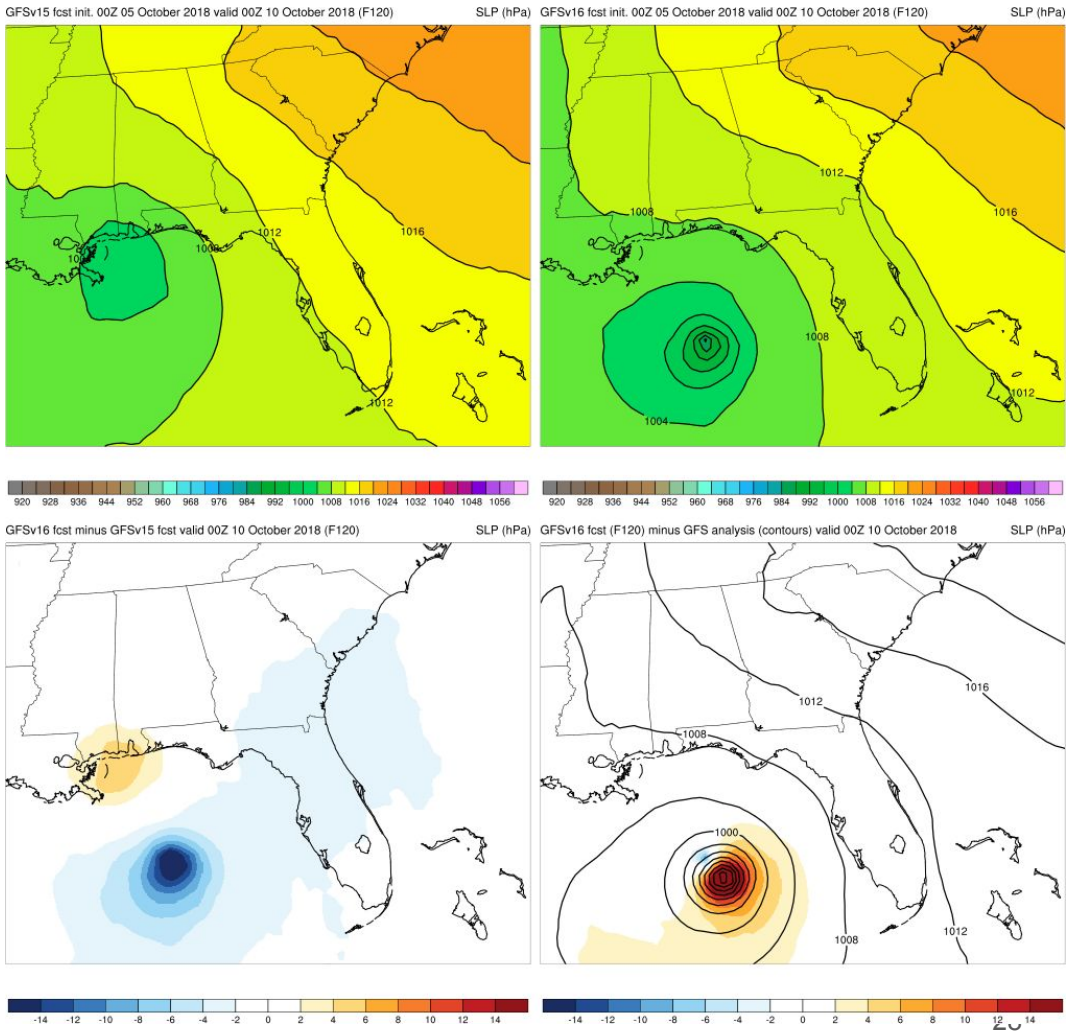
Some examples from 120 hour forecasts of 500mb heights, MSLP, and surface T2m. 120 hours is chosen as that is close to the point where skill begins to rapidly drop off in forecast models.

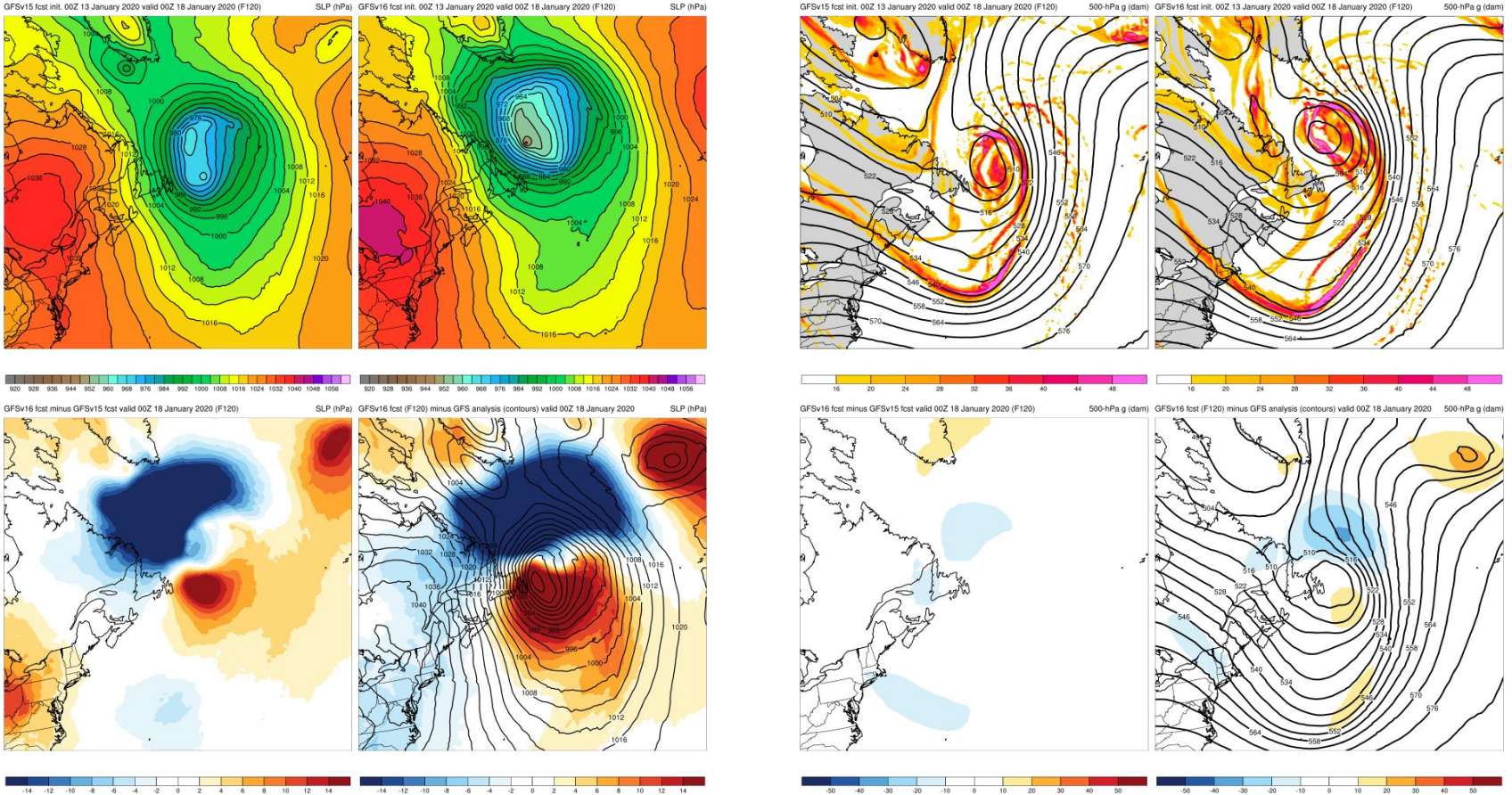
Hurricane Florence, Sept. 2018

A fairly dramatic win for v16 at F120.



GFSv16 also caught on to Hurricane Michael (Oct. 2018) earlier than GFSv15 in the 5 day forecast.



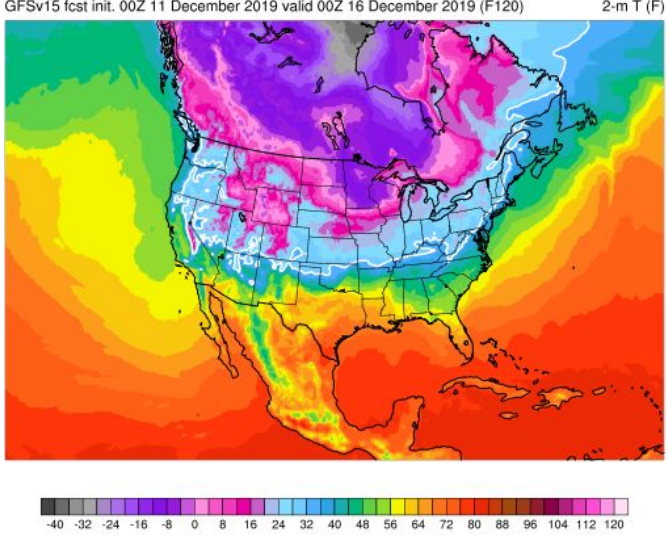


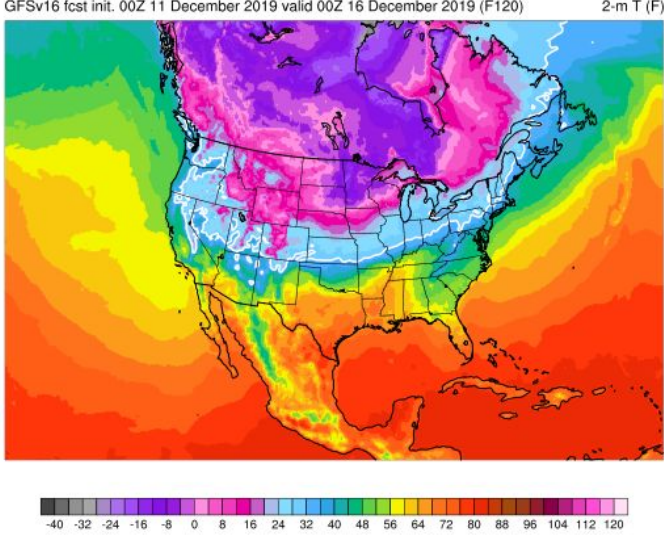
Newfoundland Cyclone Jan 2020. F120 valid 00z Jan 2020. Minimum contour is 504 dam for v15, 498 for v16, and 504 for verification. V15 somewhat better for this case, with V16 too strong and too far north.

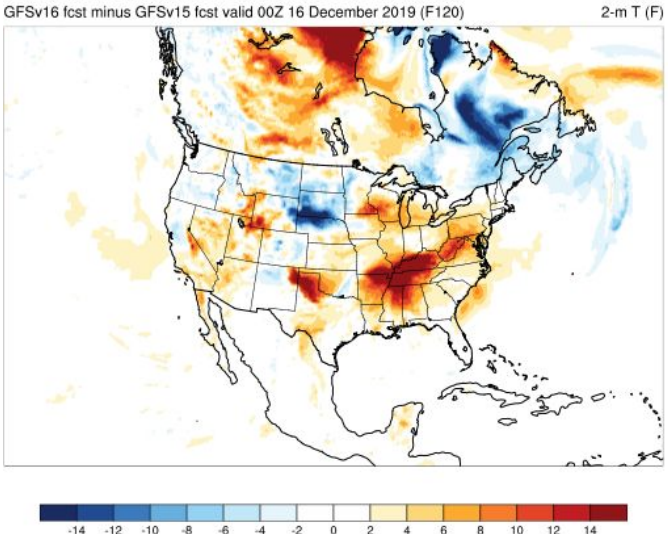
Dec. 2019 N. American "Bomb" T2m.

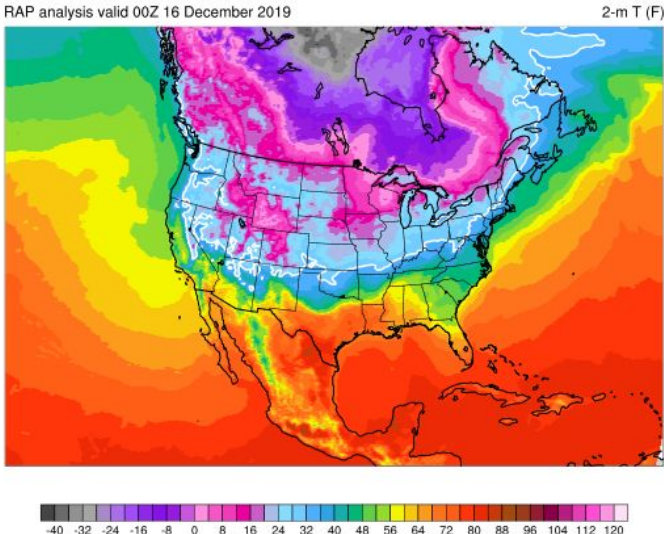
Note that T2m in v16 tends to have a sharper, more realistic gradient over the ocean.

This leads to better temperatures in eastern coastal areas for these events.



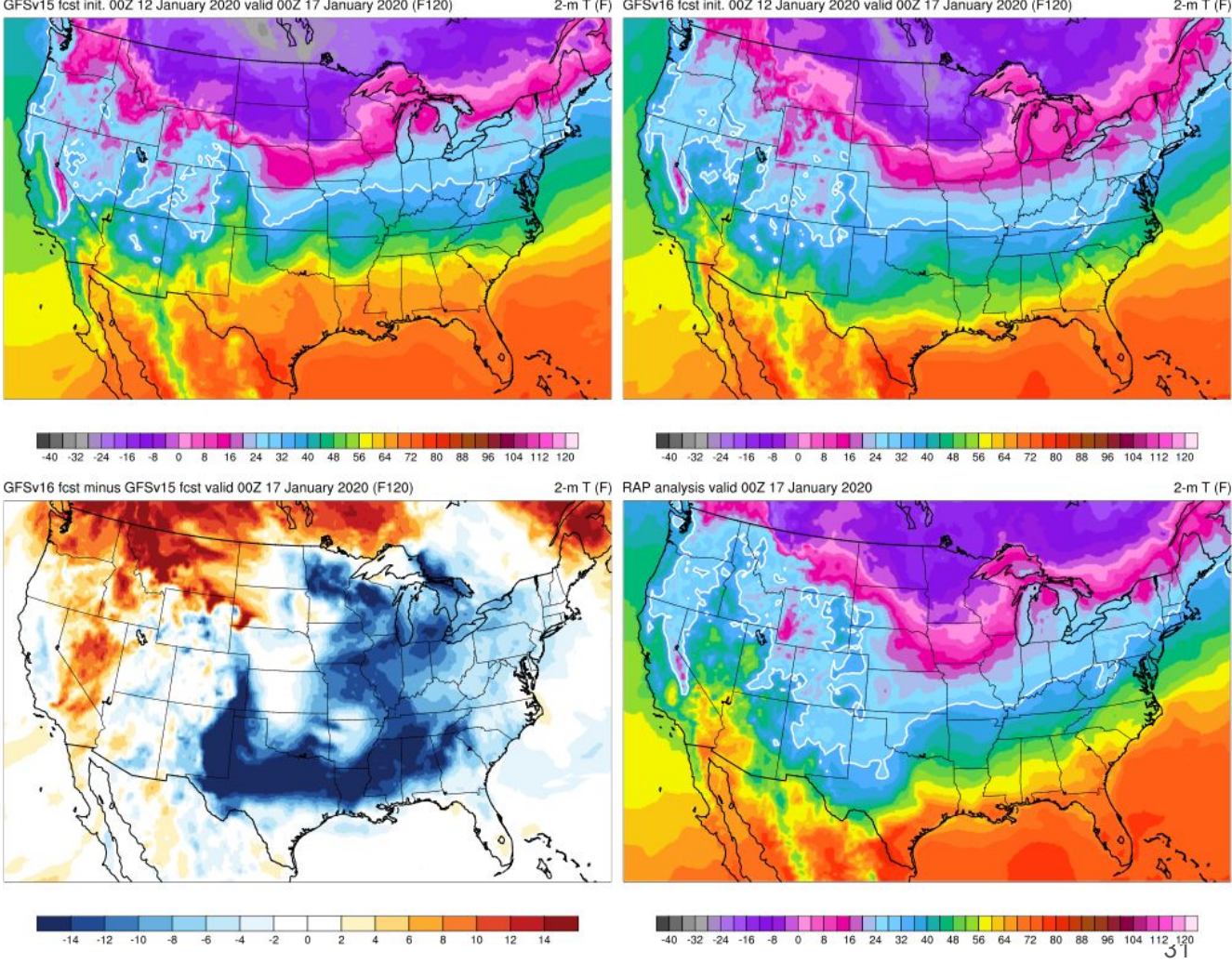






Another cold case, this one F120 for Jan. 2020 with cold front all the way to the southern tier of states.

V16 has the front further, but with a better temperature gradient along the front. This is partly good, but makes things too cold just behind the front as it is too progressive.



SUMMARY

Generally prefer v16 over v15 as it improved things more than it hurt them, though it is not difficult to find cases where v15 is better in some way.

V15 and V16 are different enough that having both of them sometimes provided a limited multi-model ensemble with decent dispersion and verification somewhere between the two.

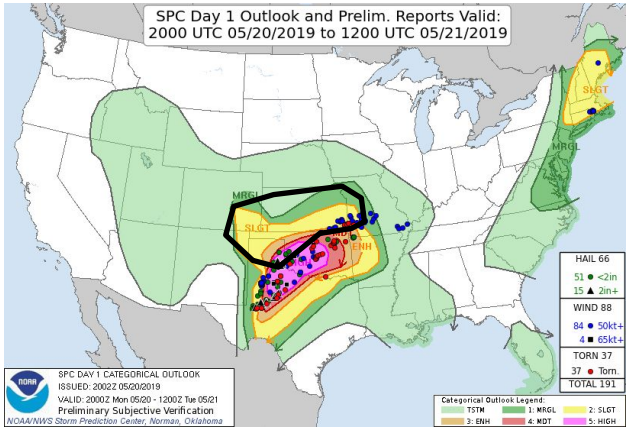
Chris Karstens

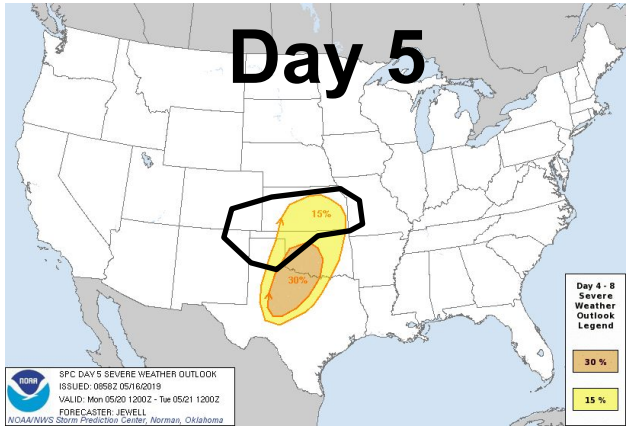
Storm Prediction Center

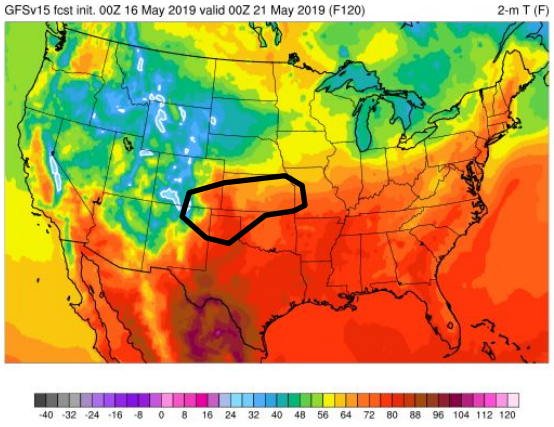
Summary

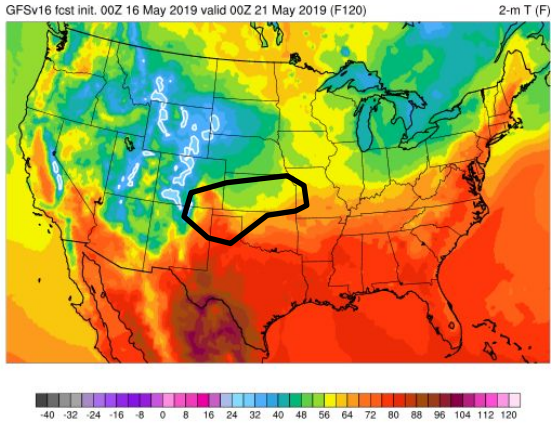
- **Focused on Day 3-8 forecasts**
- **Improvements in the short- and mid-range forecasts, mostly in low-level fields.**
  - Better handling of baroclinic zones, particularly warm front positioning, but tendency in deep toughing to pull warm sector too far north in both versions in extended range (*limited sample)
  - Smaller values of SBCAPE in the warm sector, and spatial coverage of warm sector appears smaller/refined.
  - May result in improvements/refinements of our extended outlook probability delineations on Days 4/5, and perhaps on Days 3 and 6.
- **Similar synoptic evolution between versions**
  - Cold season event too progressive, warm season events not progressive enough.
  - v16 randomly captures features quite well in medium/extended range.

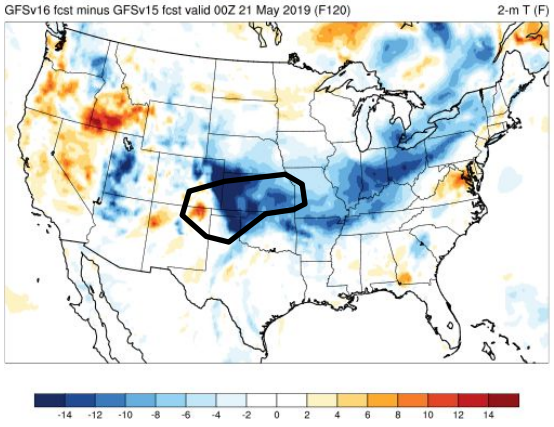
20 May 2019: High Risk/Southern Plains

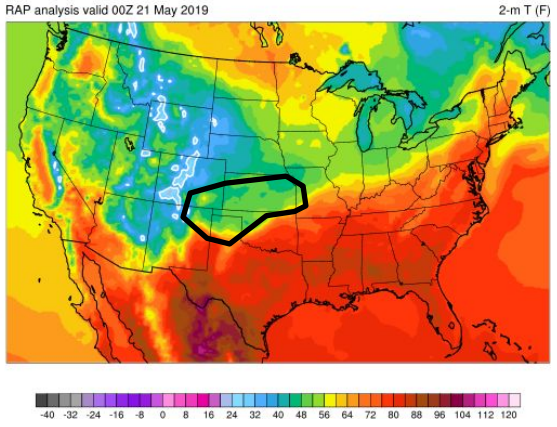




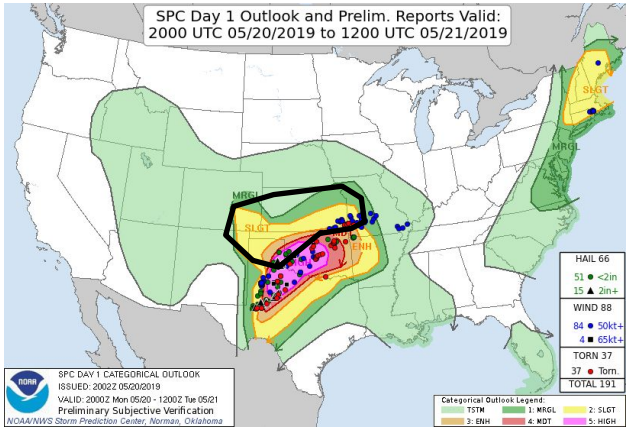


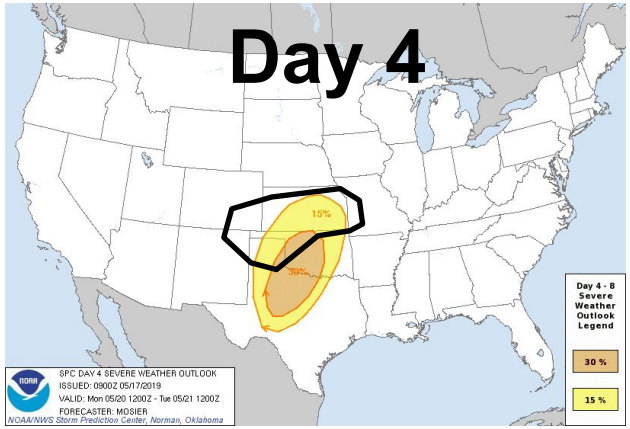


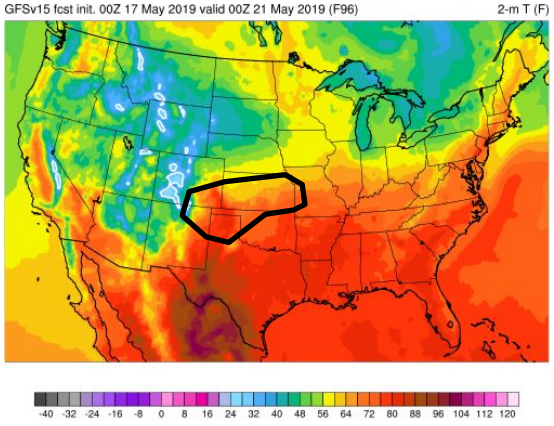


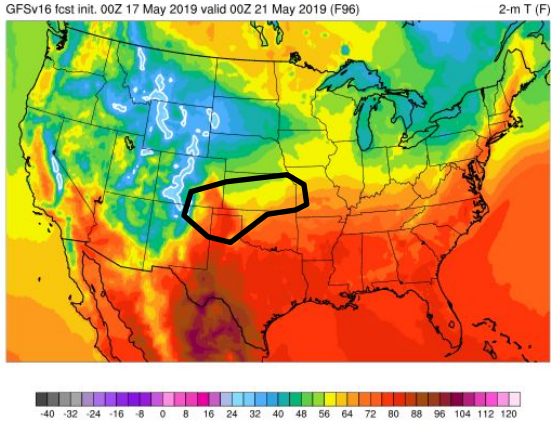


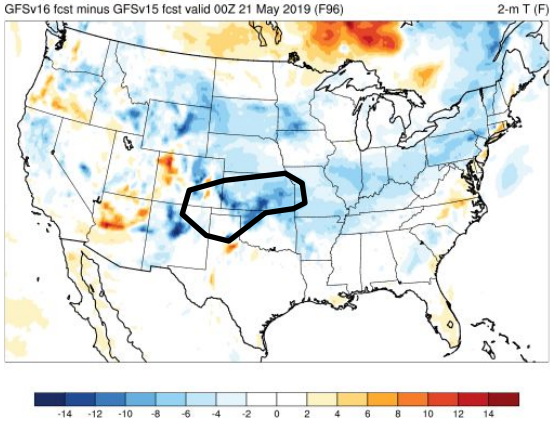
20 May 2019: High Risk/Southern Plains

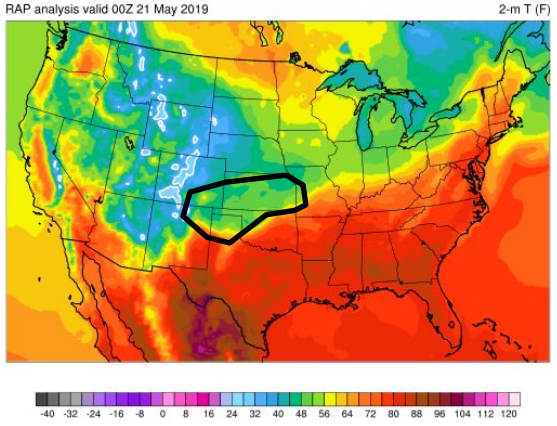




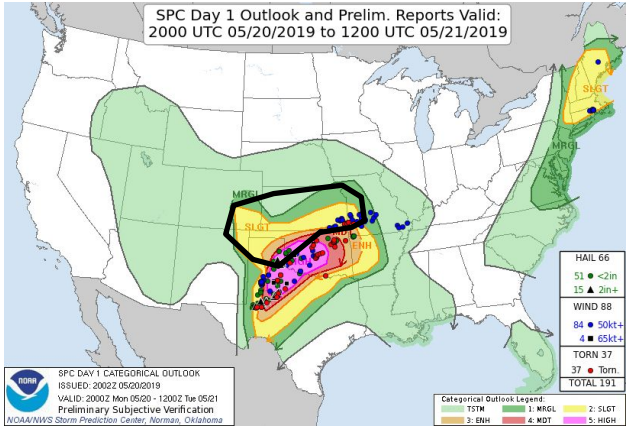


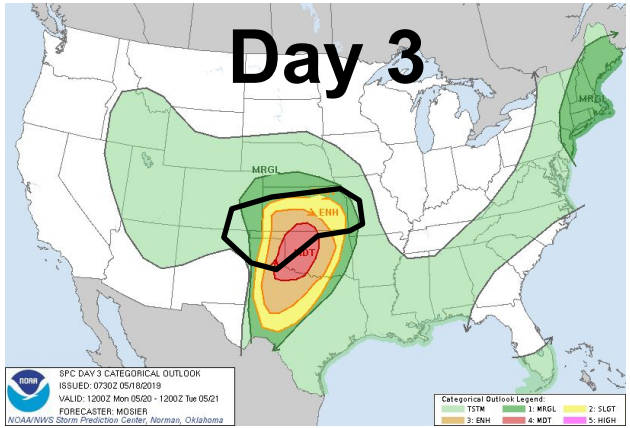


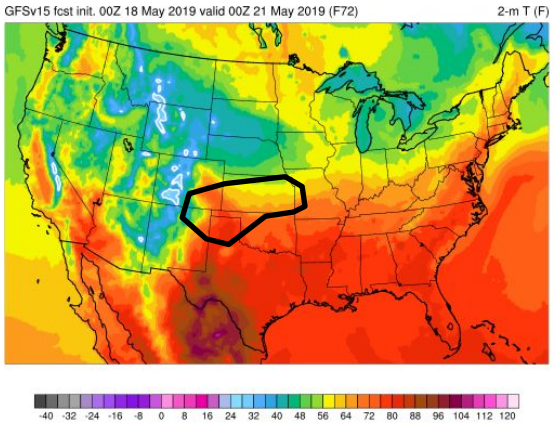


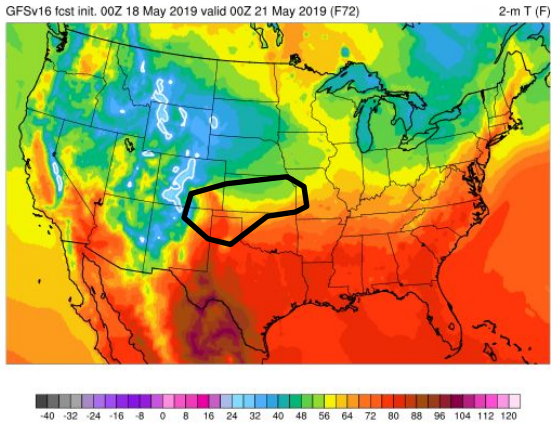


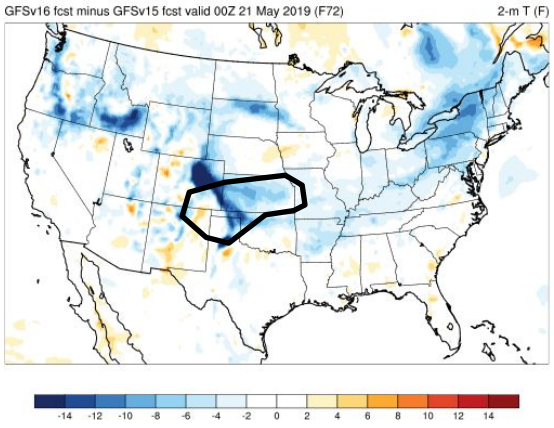
20 May 2019: High Risk/Southern Plains

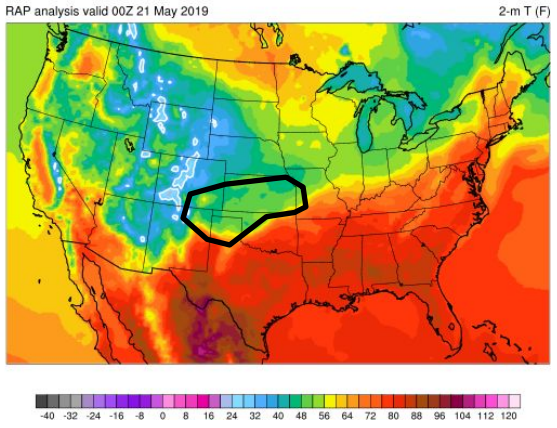




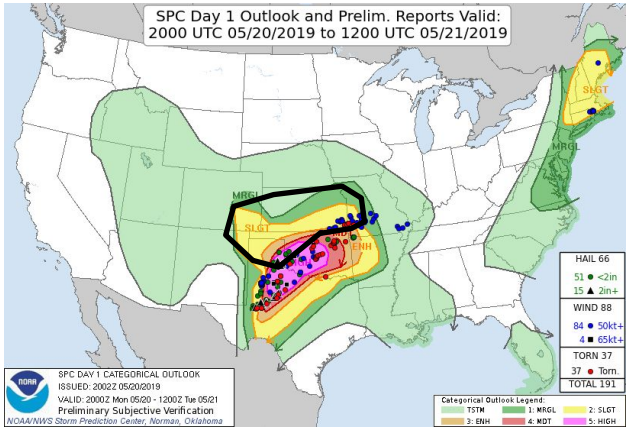


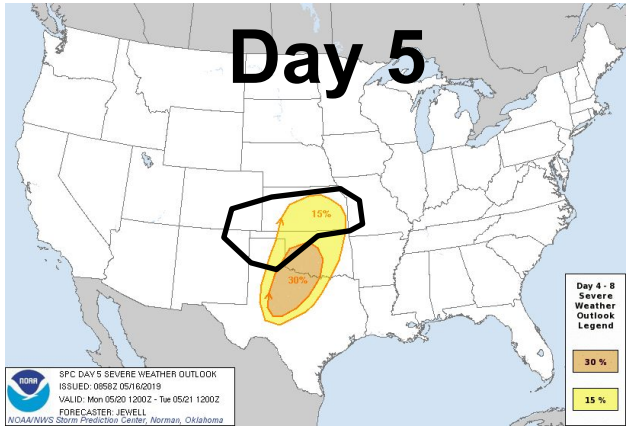


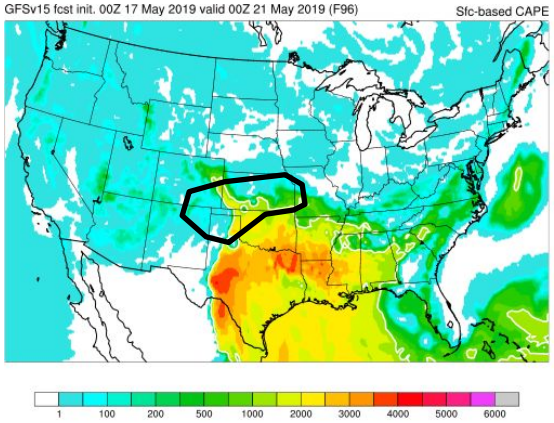


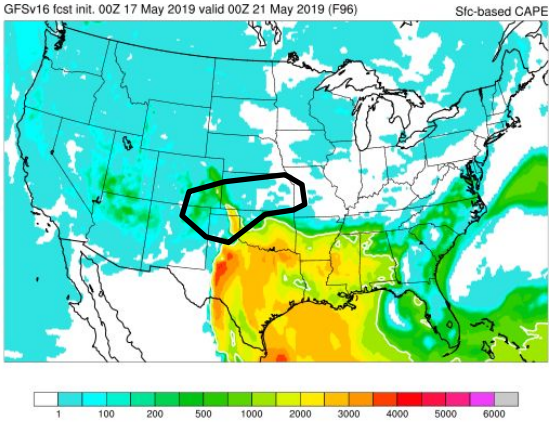


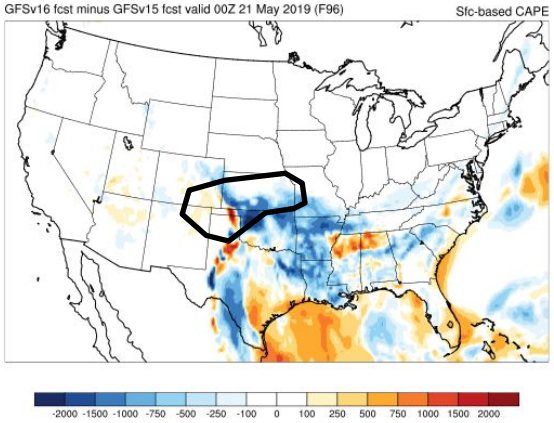
20 May 2019: High Risk/Southern Plains

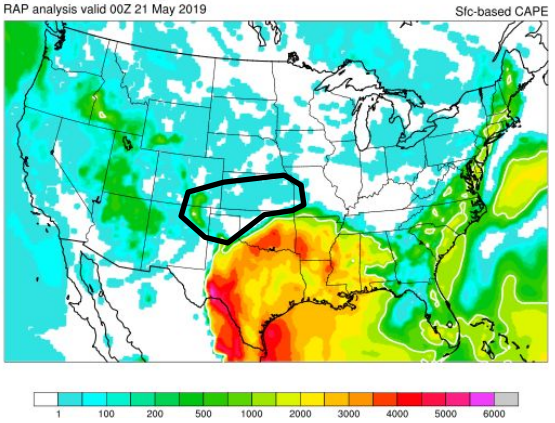




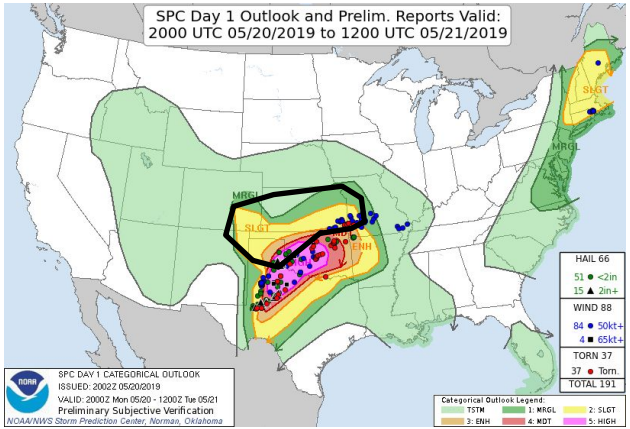


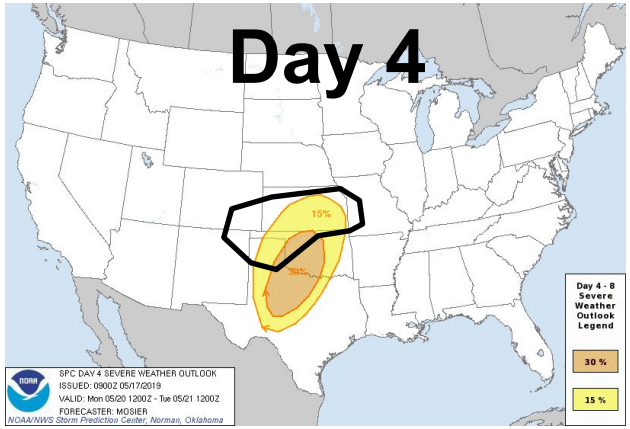


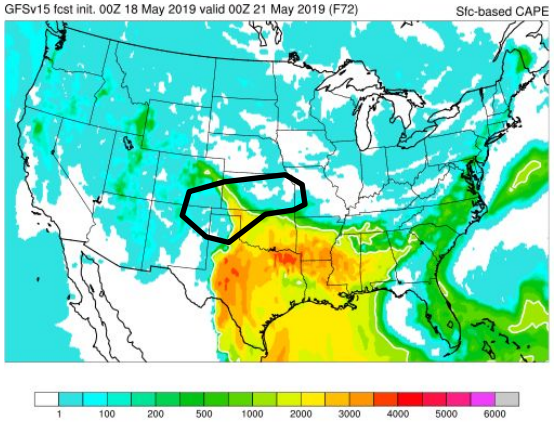


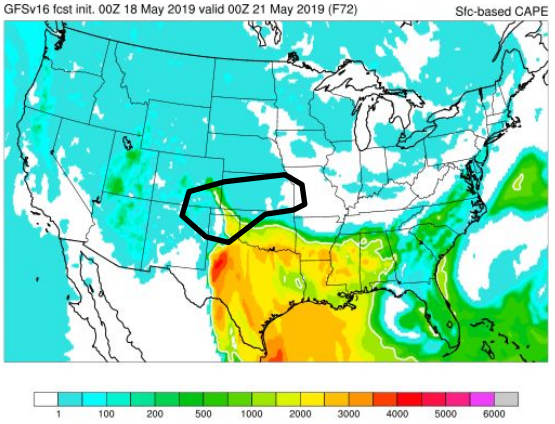


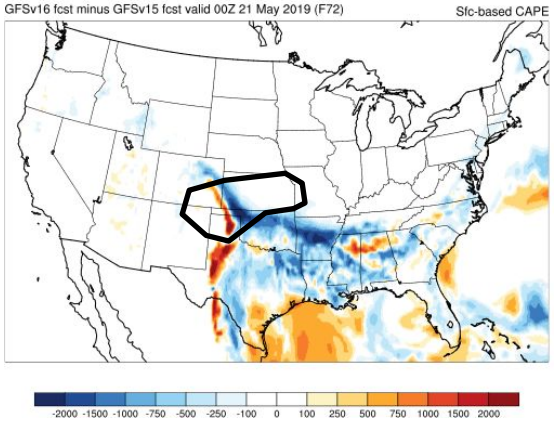
20 May 2019: High Risk/Southern Plains

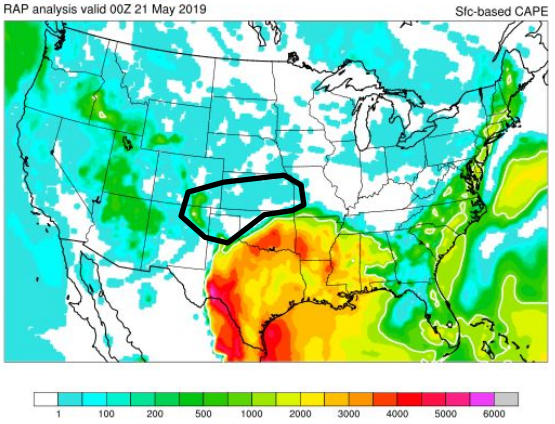




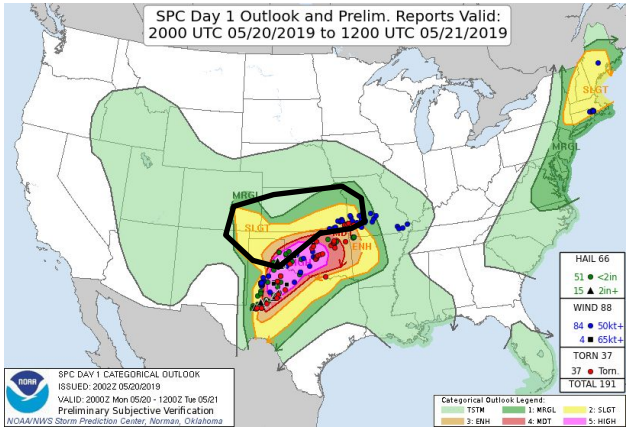


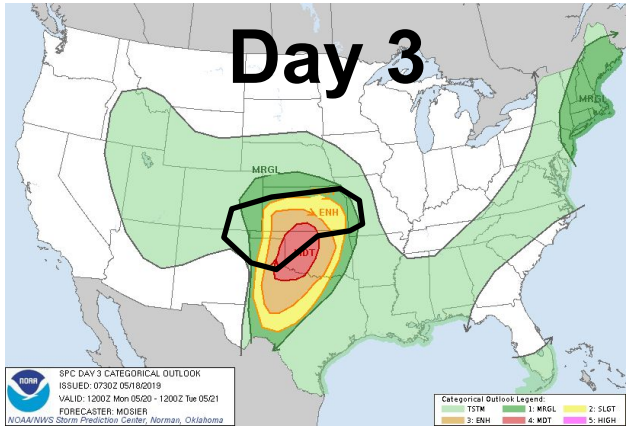


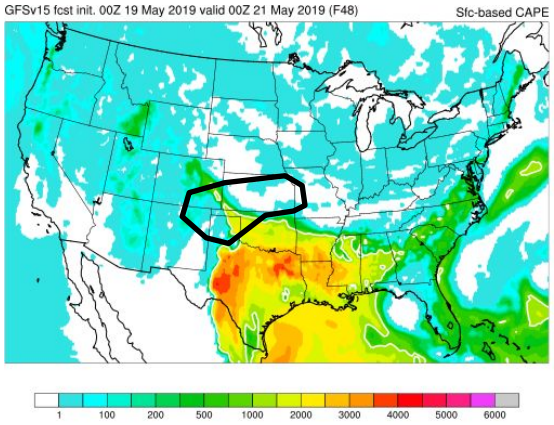


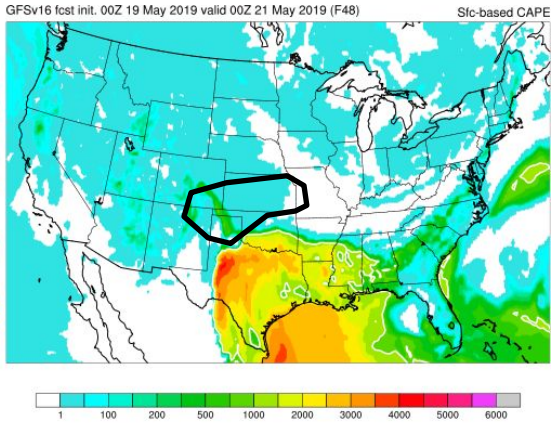


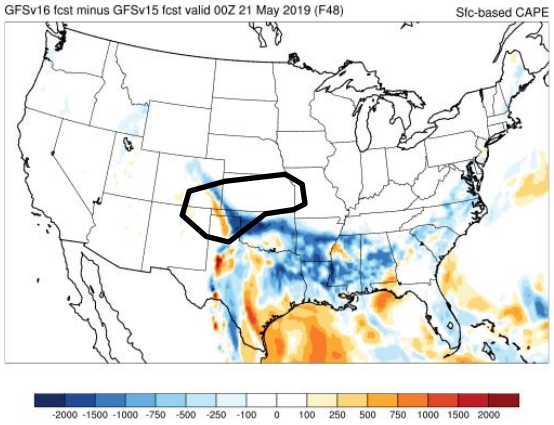
20 May 2019: High Risk/Southern Plains

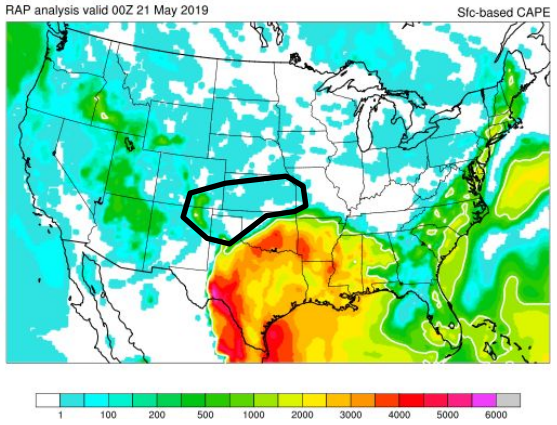




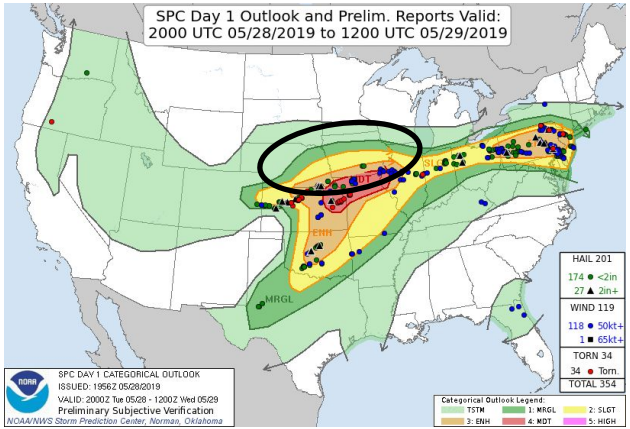


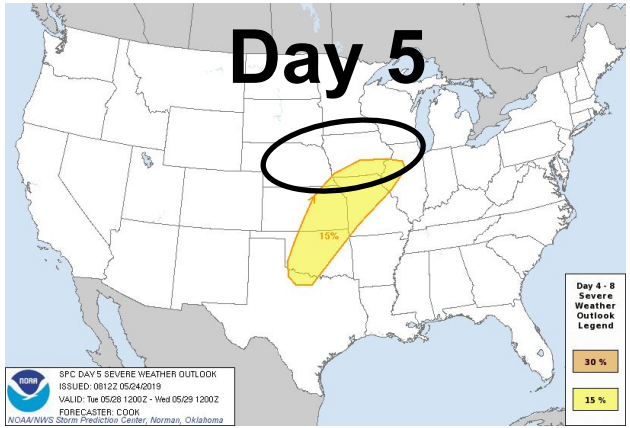


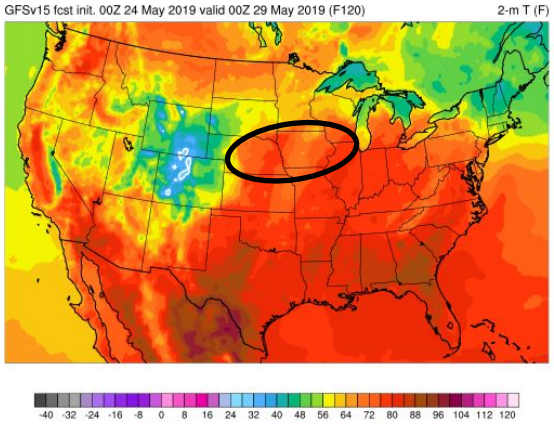


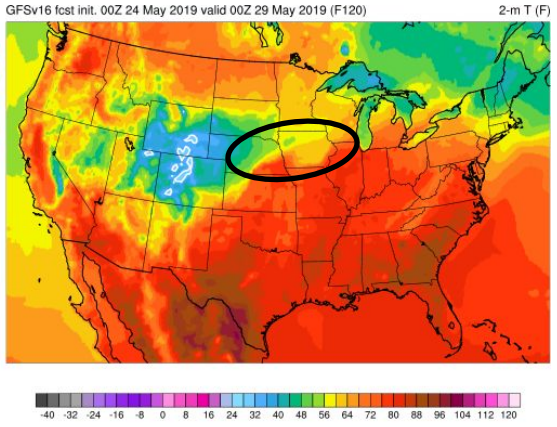


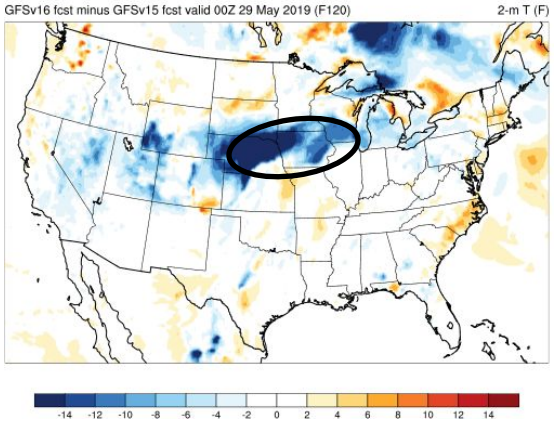
28 May 2019: Northern Missouri

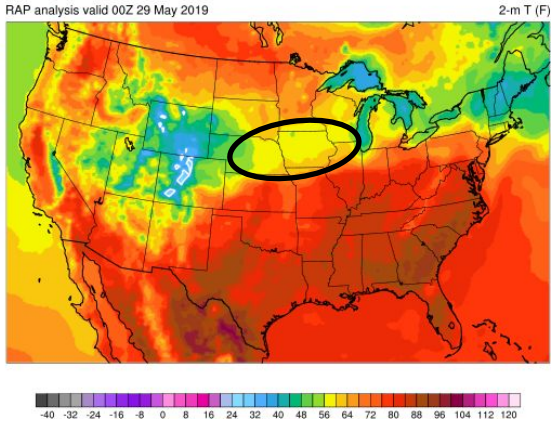




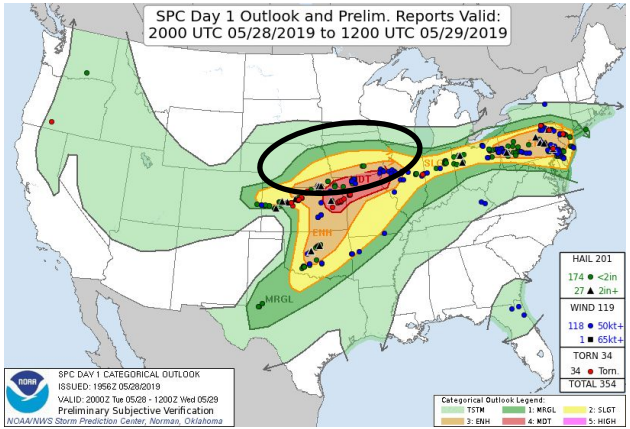


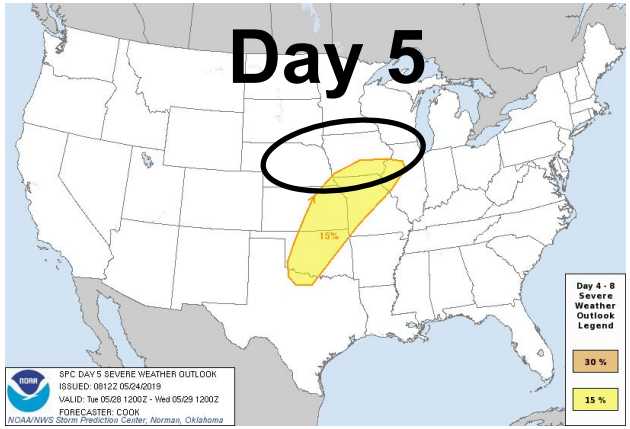


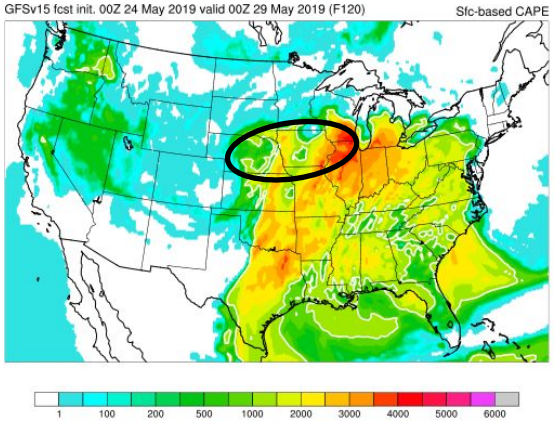


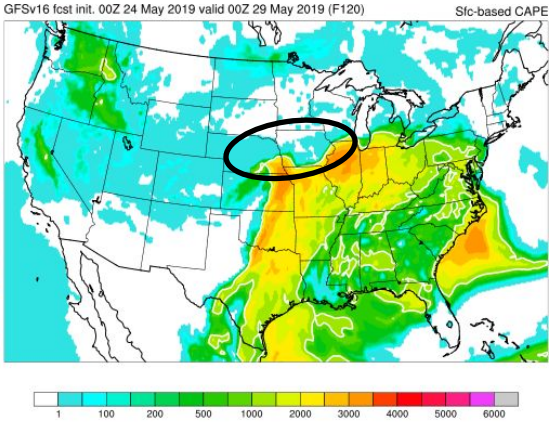


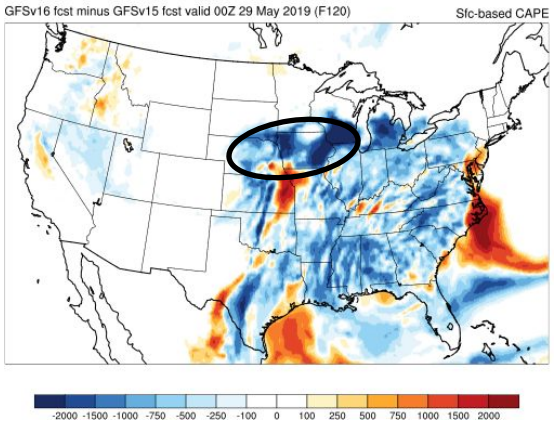
28 May 2019: Northern Missouri

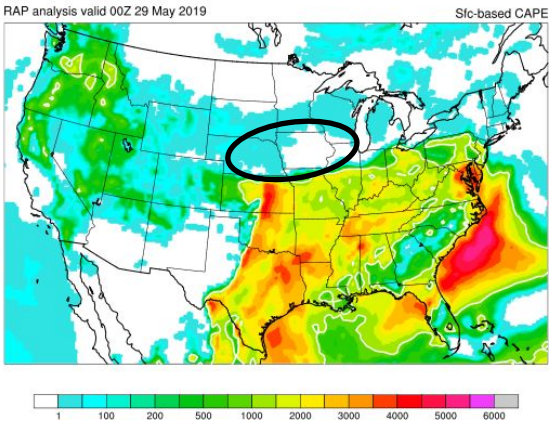




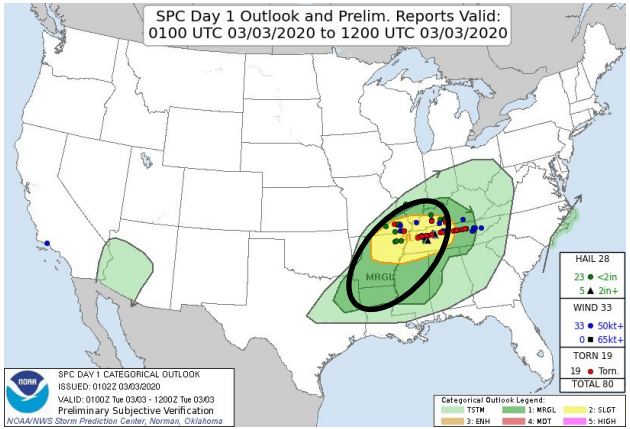


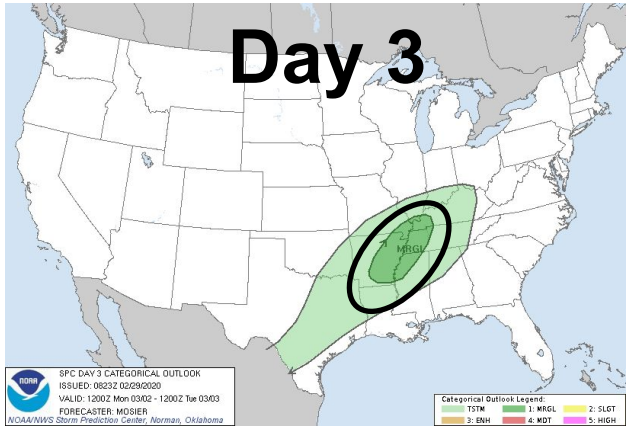


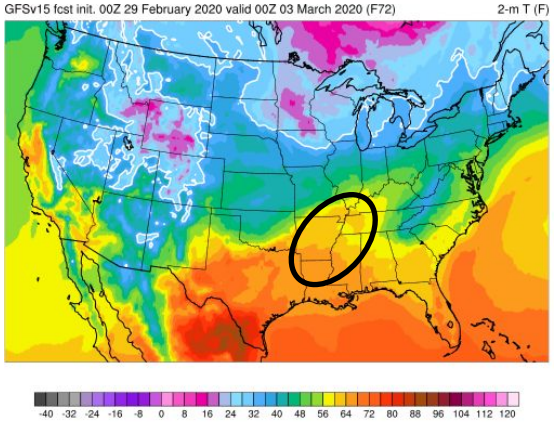


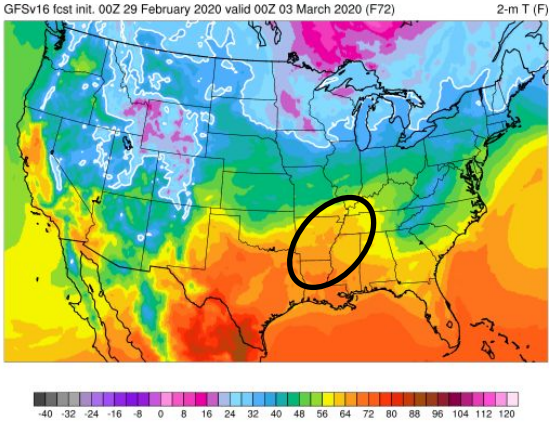


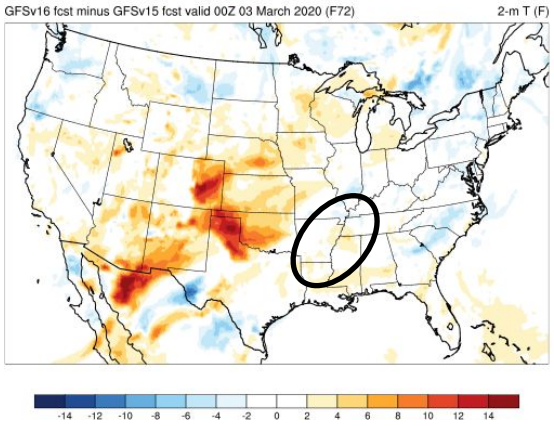
2 March 2020: Tennessee Tornadoes

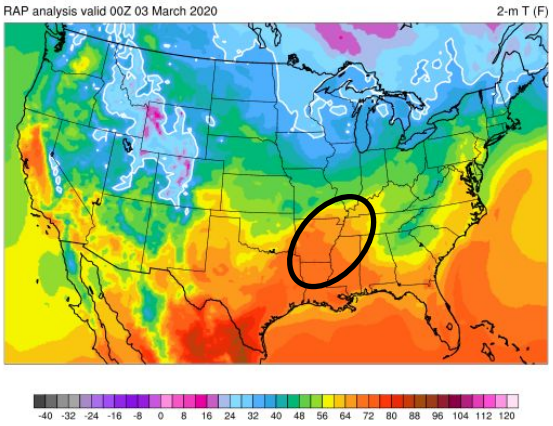




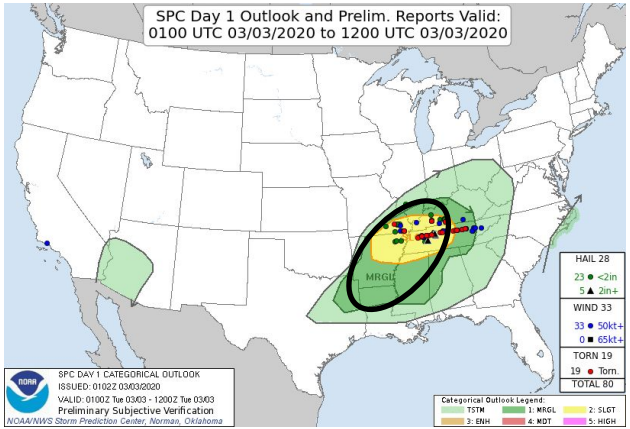


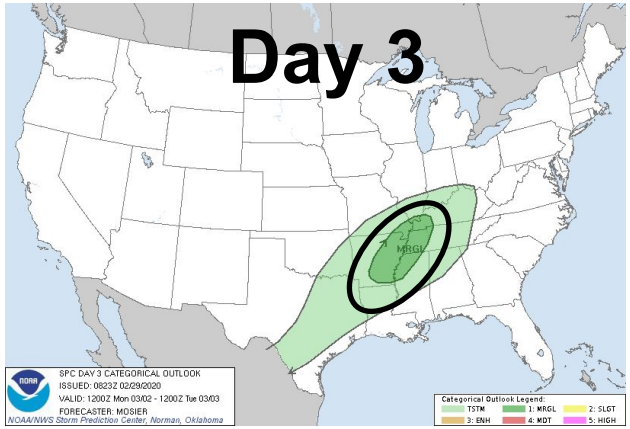


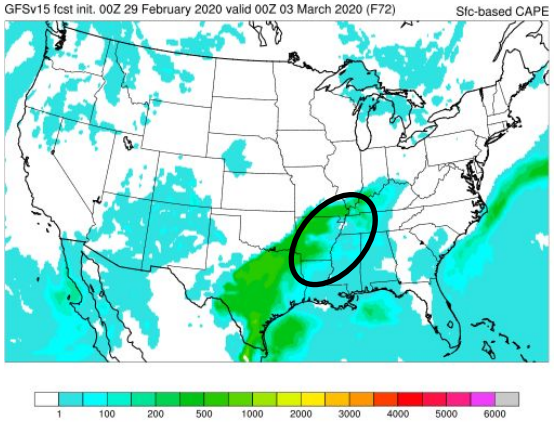


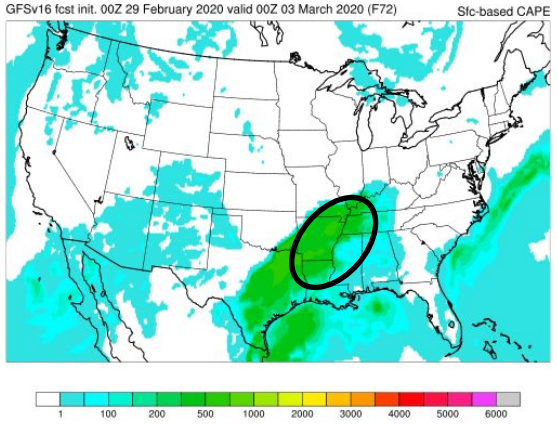


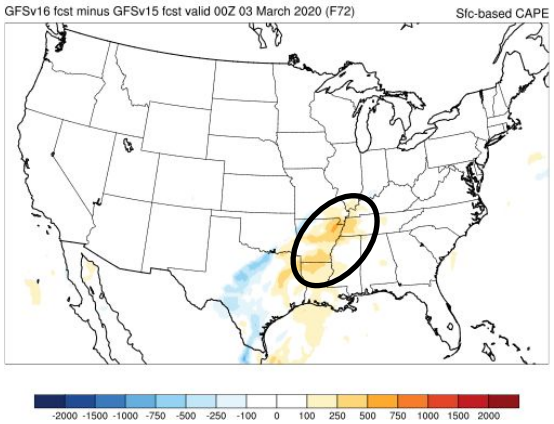
2 March 2020: Tennessee Tornadoes

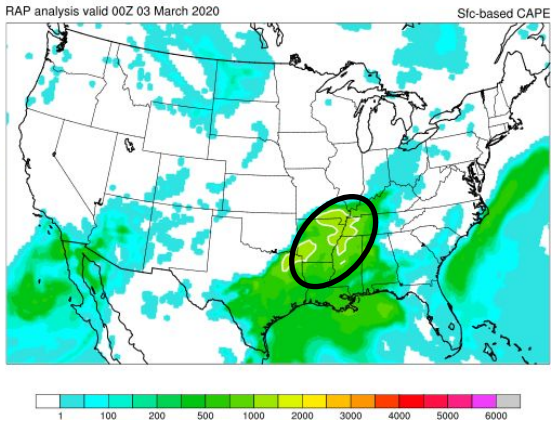






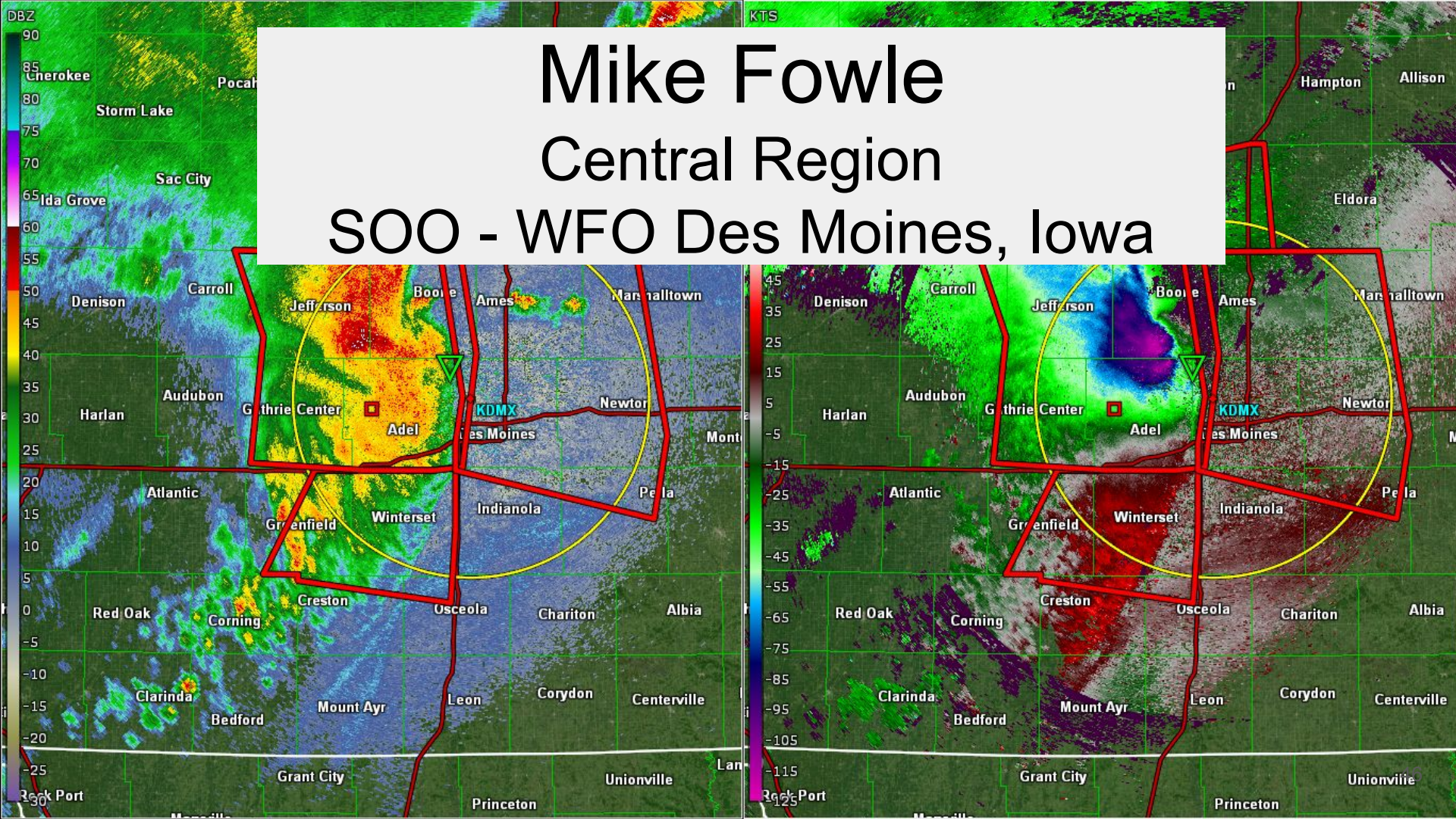






Summary

- **Focused on Day 3-8 forecasts**
- **Improvements in the short- and mid-range forecasts, mostly in low-level fields.**
  - Better handling of baroclinic zones, particularly warm front positioning, but tendency in deep toughing to pull warm sector too far north in both versions in extended range (*limited sample)
  - Smaller values of SBCAPE in the warm sector, and spatial coverage of warm sector appears smaller/refined.
  - May result in improvements/refinements of our extended outlook probability delineations on Days 4/5, and perhaps on Days 3 and 6.
- **Similar synoptic evolution between versions**
  - Cold season event too progressive, warm season events not progressive enough.
  - v16 randomly captures features quite well in medium/extended range.


DBZ
KTS
Mike Fowle
Central Region
SOO - WFO Des Moines, Iowa
Cherokee
Storm Lake
Sac City
Ida Grove
Denison
Carroll
Audubon
Harlan
Guthrie Center
Adel
KDMX
Des Moines
Ames
Newton
Marshalltown
Eldora
Hampton
Allison
Atlantic
Greenfield
Winterset
Indianola
Creston
Osceola
Red Oak
Corning
Chariton
Albia
Clarinda
Bedford
Mount Ayr
Leon
Corydon
Centerville
Grant City
Unionville
Princeton

Bottom Line Up Front...

Synoptic:

- V16 - *modest to significant improvements* in the synoptic wave pattern - most notable in events in the medium/extended range (D3-D6)
- Improved position surface features, better thermal/moisture profile, QPF, snow forecasts

2M T/Td:

- 2M T: V16 skill was similar (heat) or *slight improvements* (cold/dynamic)
- 2M Td: V16 similar (cold/dynamic) or *slight degradation* dry bias (heat)

Soundings (eyeball test):

- V16 - improved thermal/moisture structure in “most” locations (winter)
- V16 - dry bias/overmixed PBL (summer) and included odd sfc inversion at 00UTC

23 January 2020 - Forecast Hour - F120

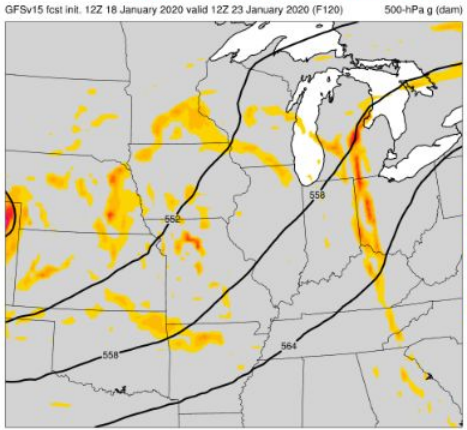
GFSv16 Retrospectives

- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››

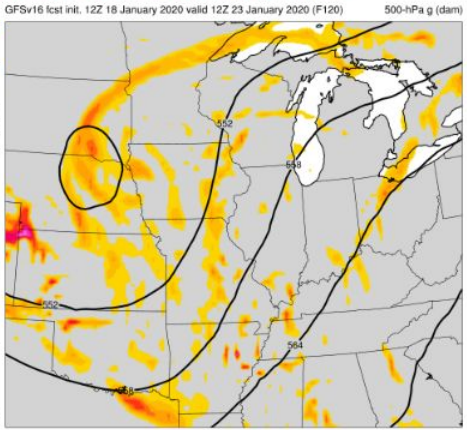
Variable: 500-hPa Geo. Height | Initialized: 12Z Sat 1/18/20 | Valid: 12Z Thu 1/23/20 (120 h) | Domain: Midwest U.S.

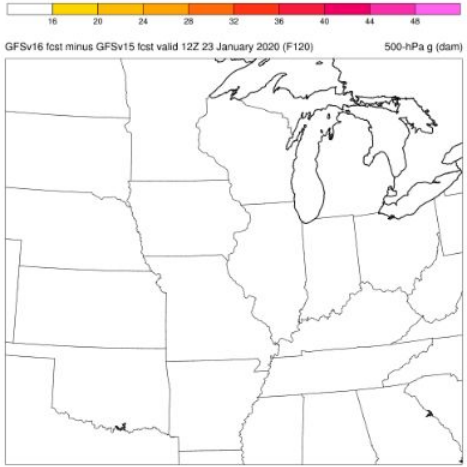
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

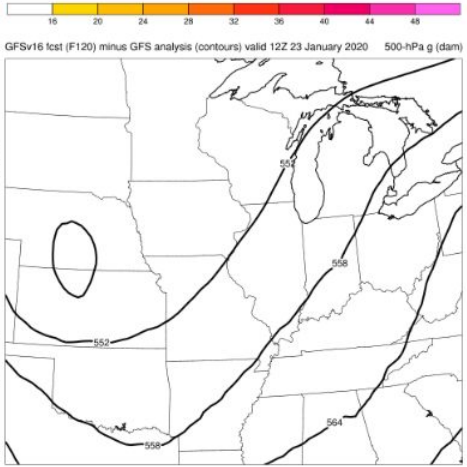
GFSv15



GFSv16







Analysis

GFSv16 better prediction of the position and amplitude of the 500mb trough.

23 January 2020 - Forecast Hour - F120

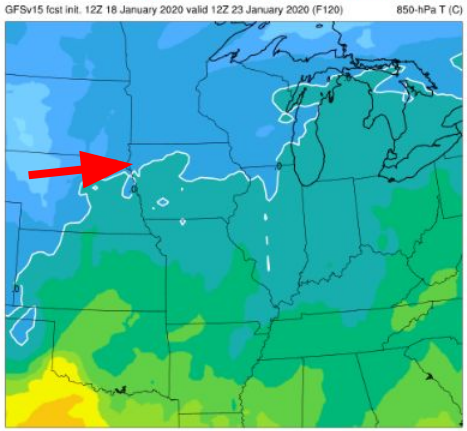
GFSv16 Retrospectives

- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››

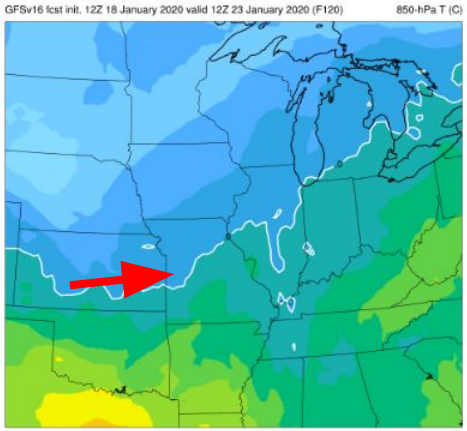
Variable: 850-hPa Temperature | Initialized: 12Z Sat 1/18/20 | Valid: 12Z Thu 1/23/20 (120 h) | Domain: Midwest U.S.

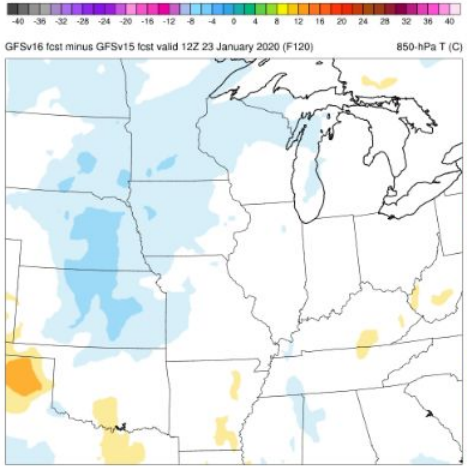
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

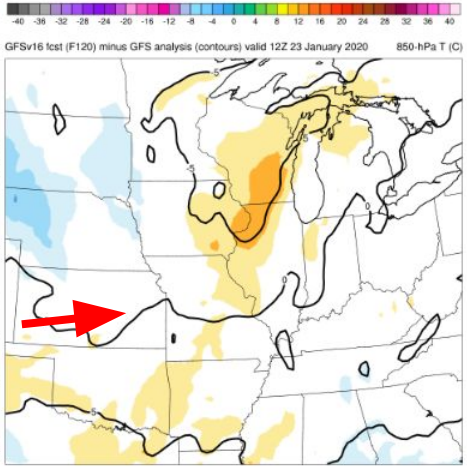
GFSv15



GFSv16







Analysis

GFSv16 better prediction of 850mb thermal structure - important for rain/snow.

27 November 2019 - Forecast Hour - F120

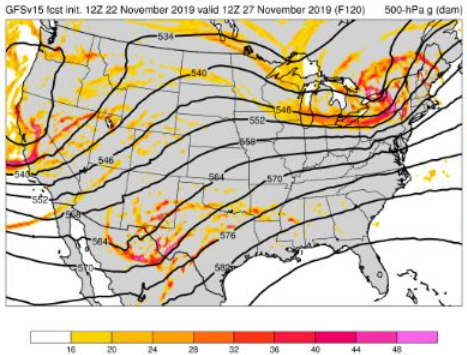
GFSv16 Retrospectives

- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››

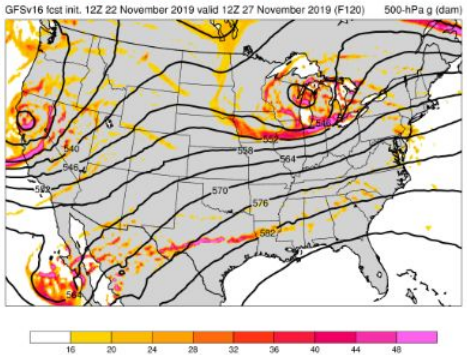
Variable: 500-hPa Geo. Height | Initialized: 12Z Fri 11/22/19 | Valid: 12Z Wed 11/27/19 (120 h) | Domain: CONUS

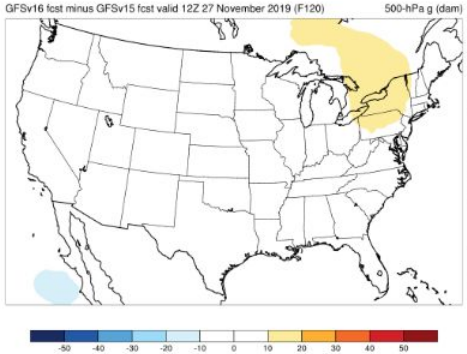
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

GFSv15

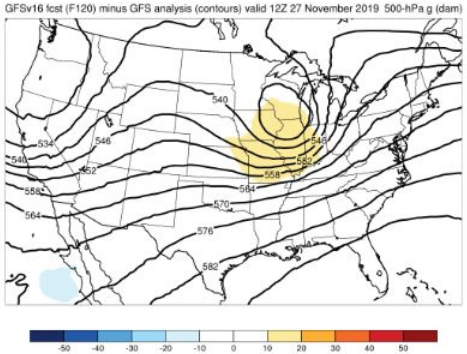


GFSv16





Analysis



GFSv16 better prediction of the position and amplitude of the 500mb trough over the Great Lakes region.

27 November 2019 - Forecast Hour - F120

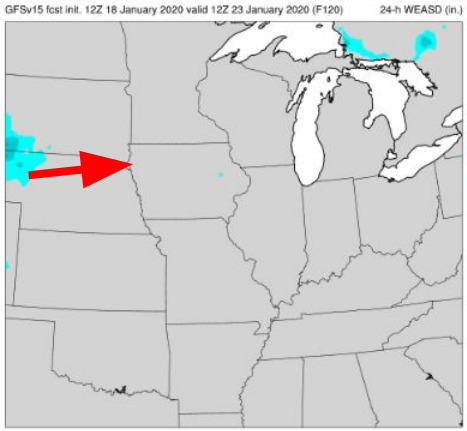
GFSv16 Retrospectives

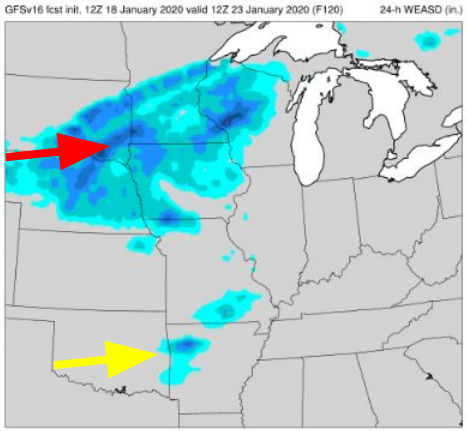
- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››

Variable: 24-h Snowfall (WEASD) | Initialized: 12Z Sat 1/18/20 | Valid: 12Z Thu 1/23/20 (120 h) | Domain: Midwest U.S.

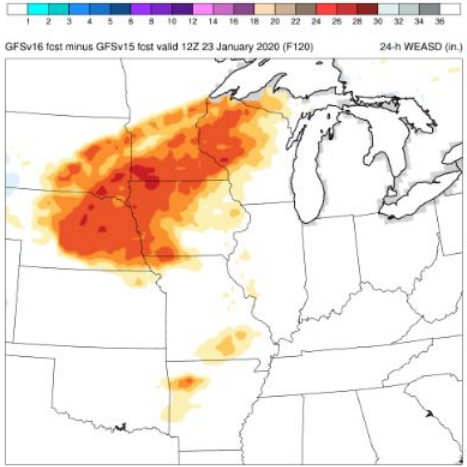
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

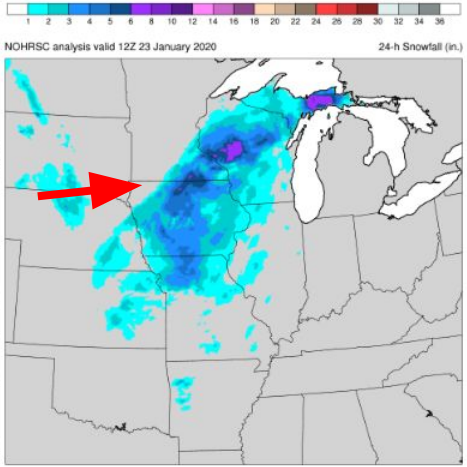
GFSv15





GFSv16





Analysis

GFSv16 better prediction of the resultant snowfall forecast.

16 January 2020 - Forecast Hour - F144

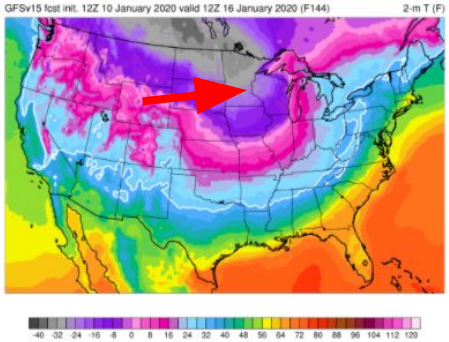
GFSv16 Retrospectives

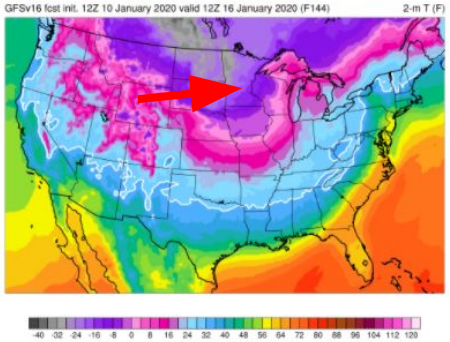
- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››
- GFSv16 Retrospective

Variable: 2-m Temperature | Initialized: 12Z Fri 1/10/20 | Valid: 12Z Thu 1/16/20 (144 h) | Domain: CONUS

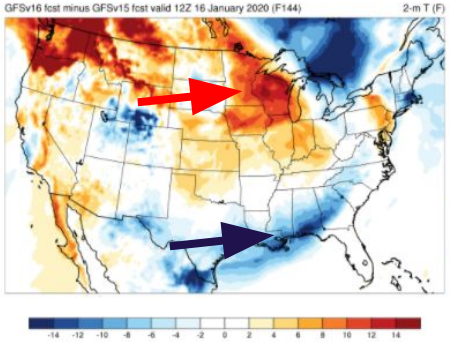
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

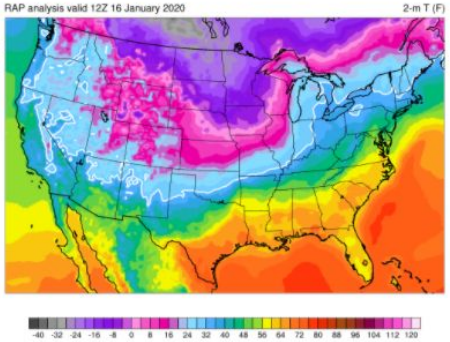
GFSv15





GFSv16





Analysis

GFSv16 better prediction of the 2m temps over the upper Midwest (reduced cold bias) but too cold over the Gulf Coast states.

20 July 2019 - Forecast Hour - F120

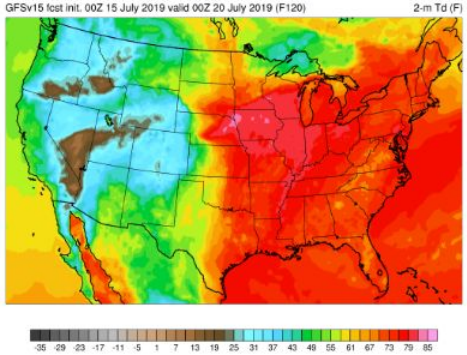
GFSv16 Retrospectives

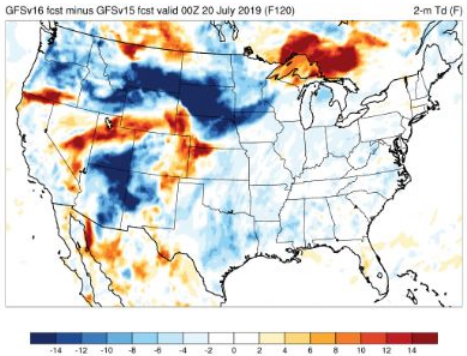
- Home
- Winter Storms ››
- Tropical Cyclones ››
- Excessive QPF ››
- Severe Weather ››
- Extreme Heat/Cold ››

Variable: 2-m Dew Point | Initialized: 00Z Mon 7/15/19 | Valid: 00Z Sat 7/20/19 (120 h) | Domain: CONUS

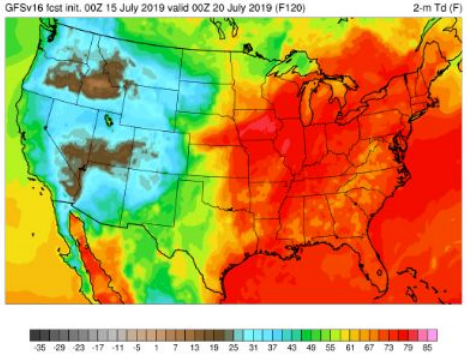
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time

GFSv15

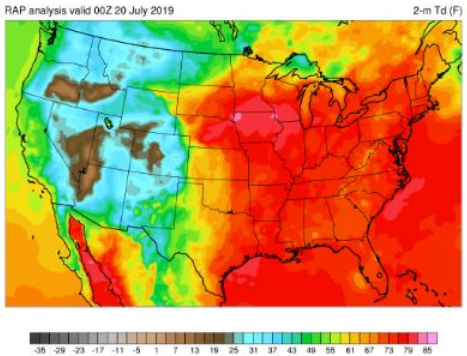




GFSv16



Analysis



GFSv16 not as skillful with 2m dewpoint temps - especially over the Corn Belt (dry bias).

Sounding Analysis

V16 Improvements:

1. Better P-type forecast
2. Improvement in cold bias

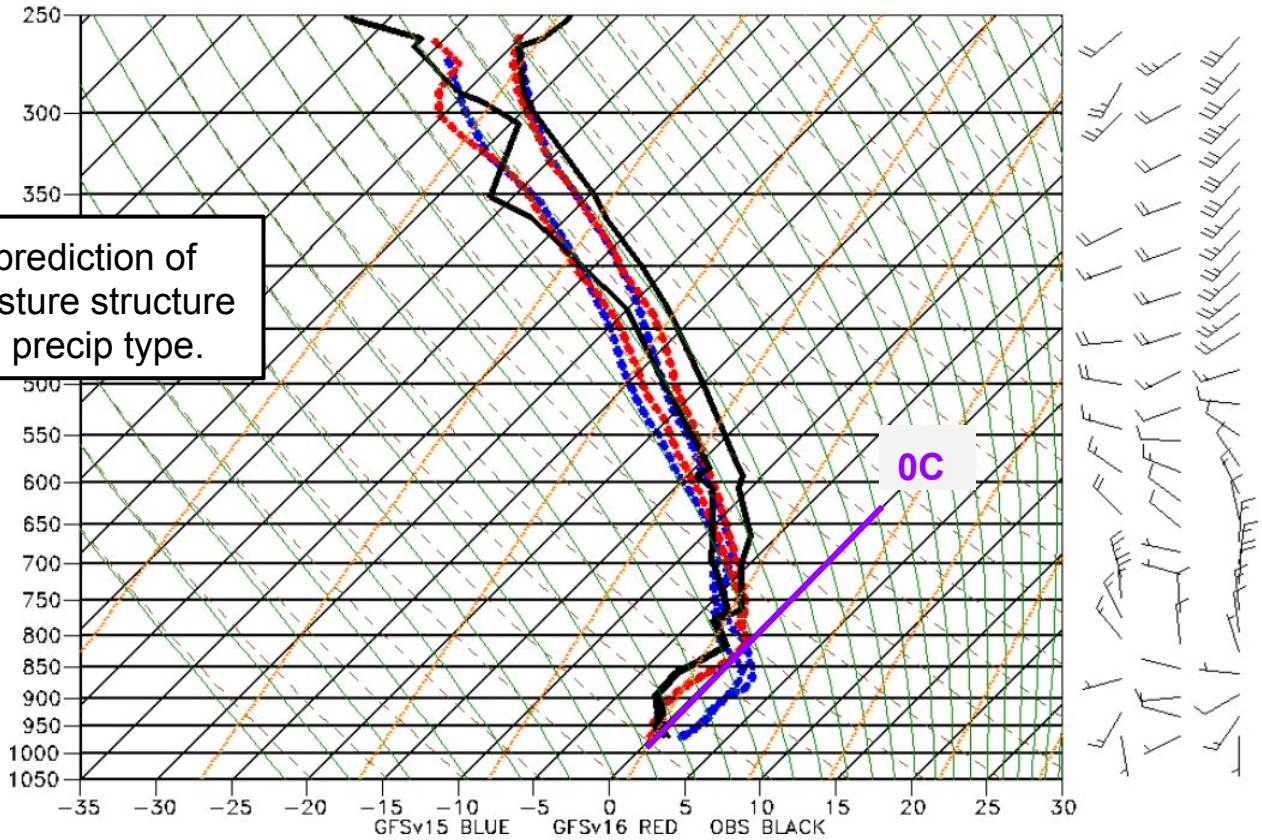
V16 Potential Issues:

1. Overmixing PBL, dry bias
2. Strange 00UTC inversion development

Initialized: 12Z Mon 1/20/20 Valid: 00Z Thu 1/23/20 (60 h) Sounding Location: OAX - OMAHA, NE (725580)

KOAX- 23 January 2020 - Forecast Hour - F60

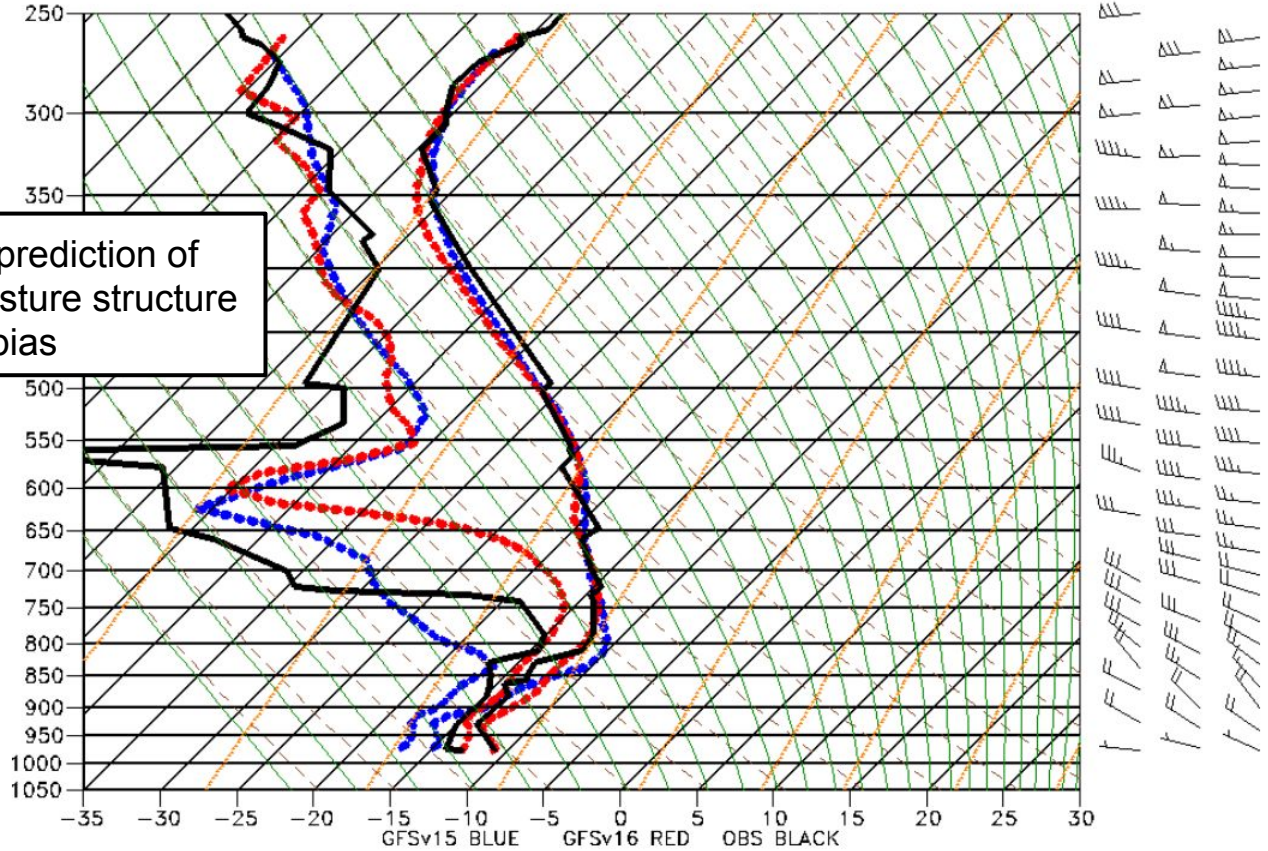
GFSv16 better prediction of the thermal/moisture structure - more accurate precip type.



Initialized: 00Z Mon 1/13/20 Valid: 00Z Wed 1/15/20 (48 h) Sounding Location: INL - INTERNATIONAL FALLS, MN (727470)

KINL- 15 January 2020 - Forecast Hour - F48

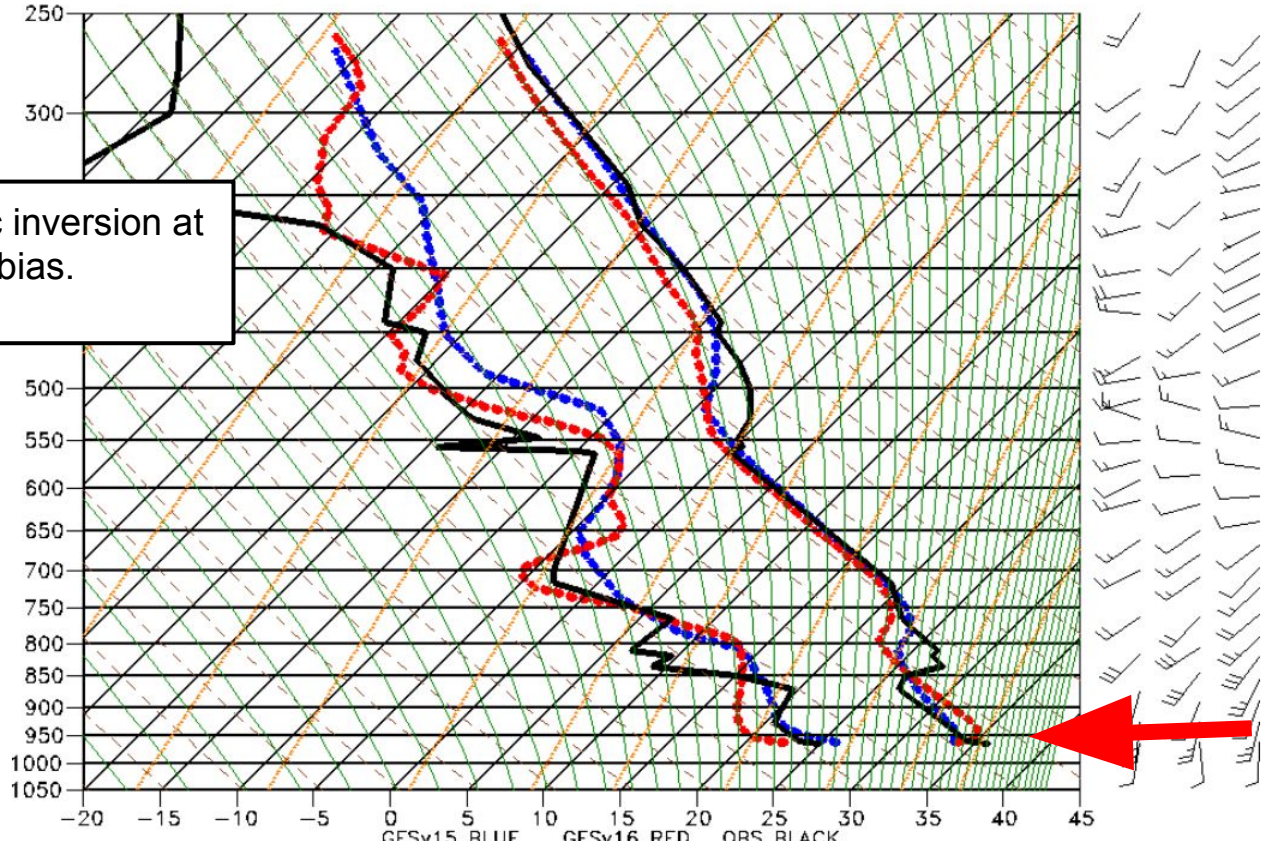
GFSv16 better prediction of the thermal/moisture structure - reduced cold bias



Initialized: 00Z Wed 7/17/19 Valid: 00Z Sat 7/20/19 (72 h) Sounding Location: OAX - OMAHA, NE (725580)

KOAX- 20 July 2019 - Forecast Hour - F72

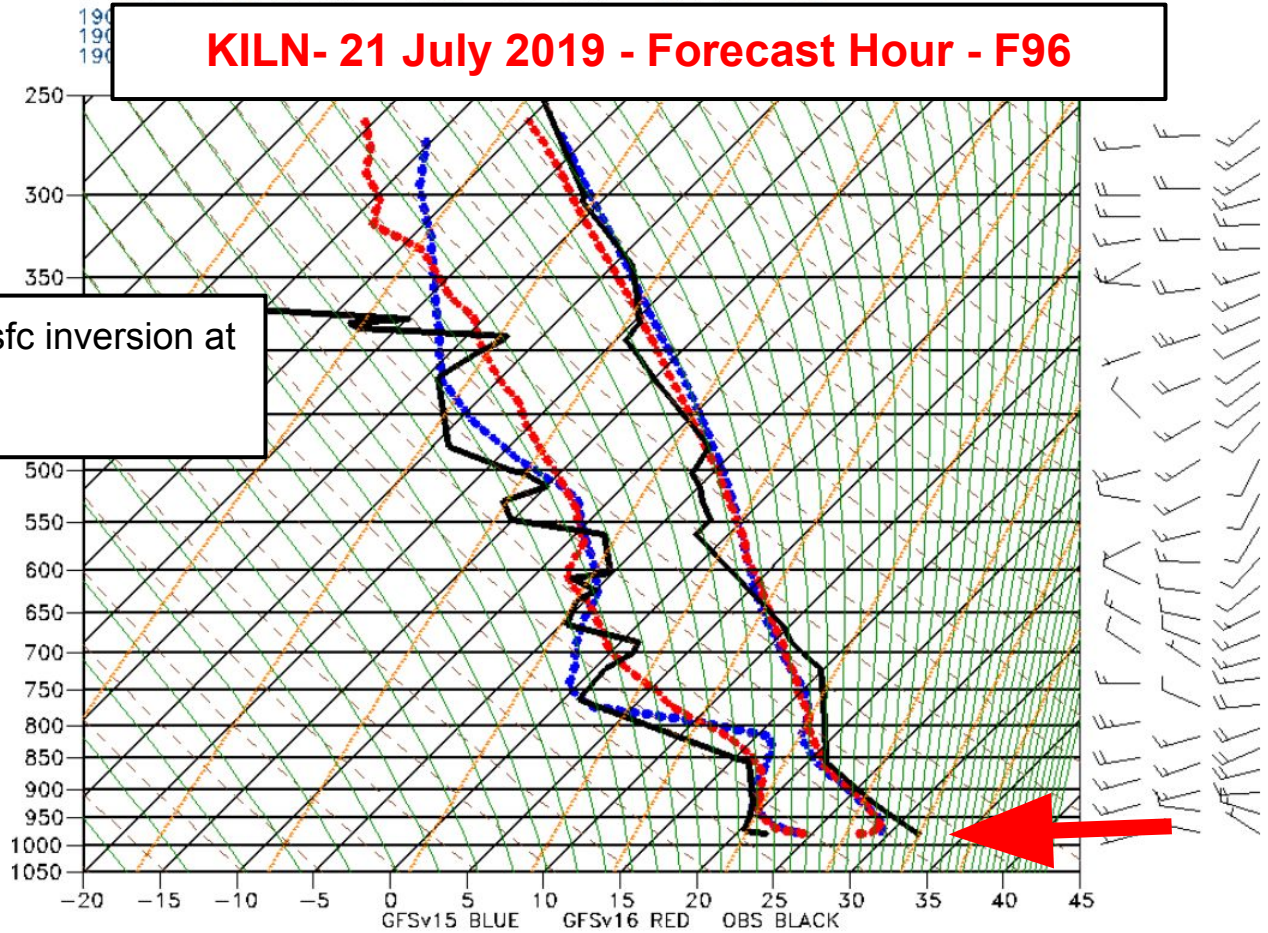
GFSv16 “odd” sfc inversion at 00UTC - and dry bias.



Initialized: 00Z Wed 7/17/19 Valid: 00Z Sun 7/21/19 (96 hr) Sounding Location: ILN - WILMINGTON, OH (724260)

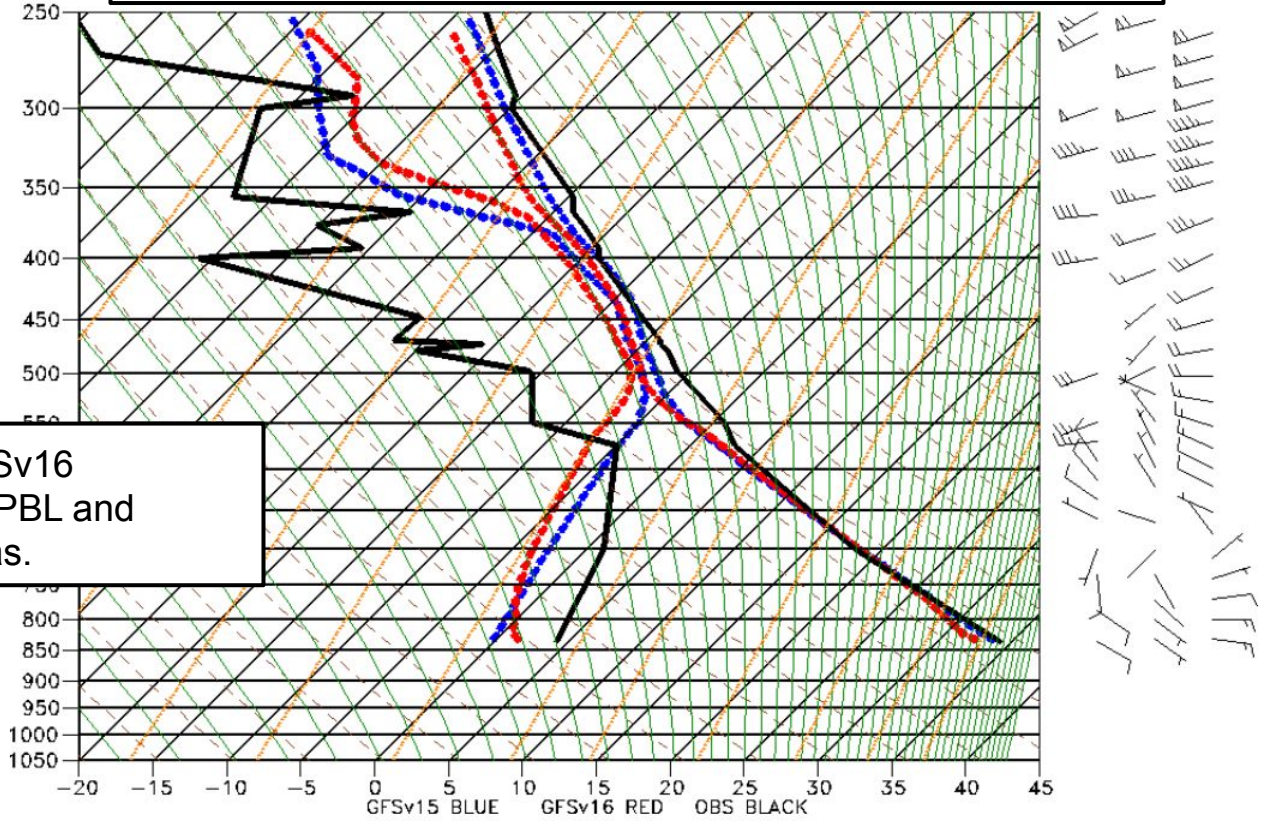
Press F11 to exit full screen

Up/Down arrow keys = Change sounding location | Left/Right arrow keys = Change valid time



GFSv16 “odd” sfc inversion at 00UTC.

KDNR- 18 July 2019 - Forecast Hour - F24



Example of GFSv16 overmixing the PBL and resulting dry bias.

Final Thoughts...

- Purely “observational” - eyeball test
- Others computing “statistical metrics”
- Regional view - local details matter!!

Final Scoring:

- **Overall - V16 an improvement over V15 in a composite sense**
  - Better over more spatial areas, more fields, more run cycles
- “Nudged” the needle forward
- A few issues remain - need to be addressed

Western Region Cases: GFSv16 vs GFSv15

Cases Examined

<u>California Spring Storm (May 2019)</u>

San Francisco Heat (June 2019)

Hurricane Lorena (Sep 2019)

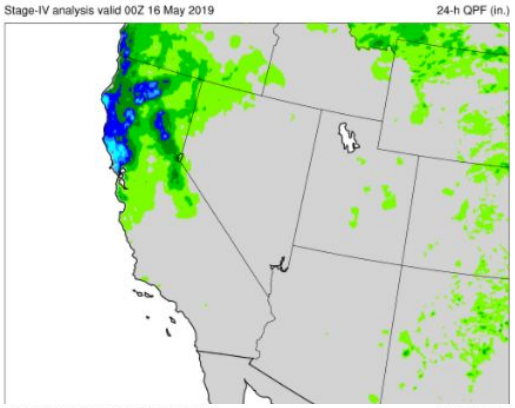
West Coast Bomb Cyclone (Nov 2019)

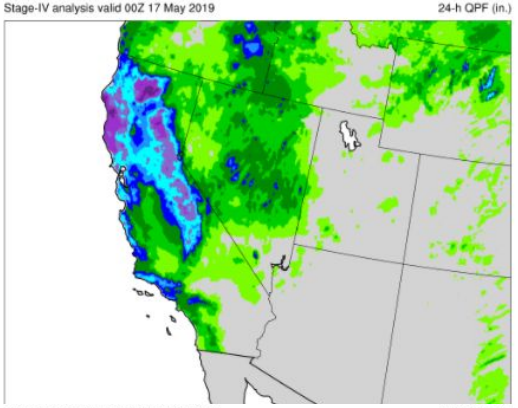
Warren Blier
SOO, WFO MTR (San Francisco/Monterey)

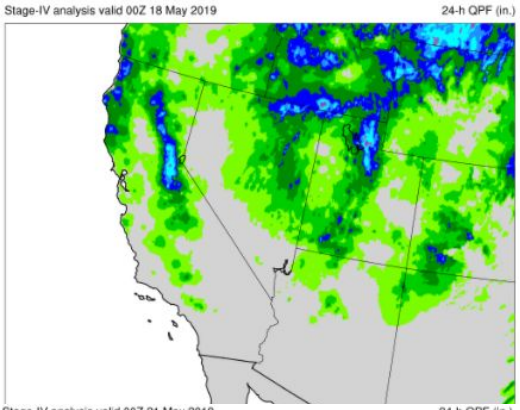
<u>Takeaway</u>: Overall very similar performance, aside perhaps from v16 performing a bit poorer than v15 in the extended range and slightly better than v15 in the medium range. Basically a toss up, given the limited and subjective nature of this evaluation (uncertainty larger than magnitude of findings).

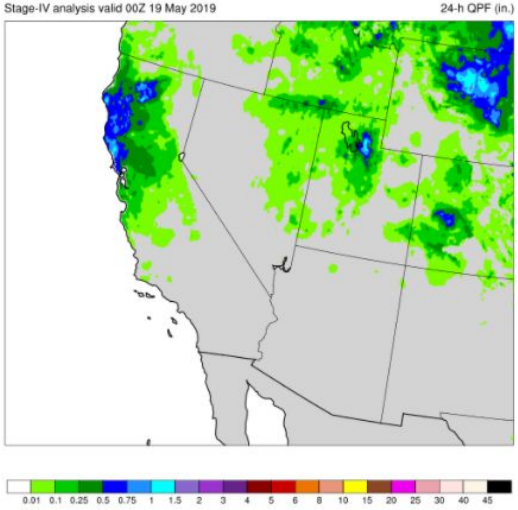
California Spring Storm (May 2019): Late season heavy precip event

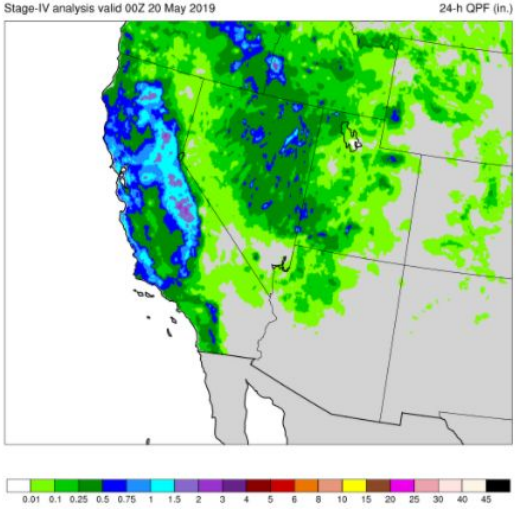
24-hr totals, 2 separate rounds of heavy precip

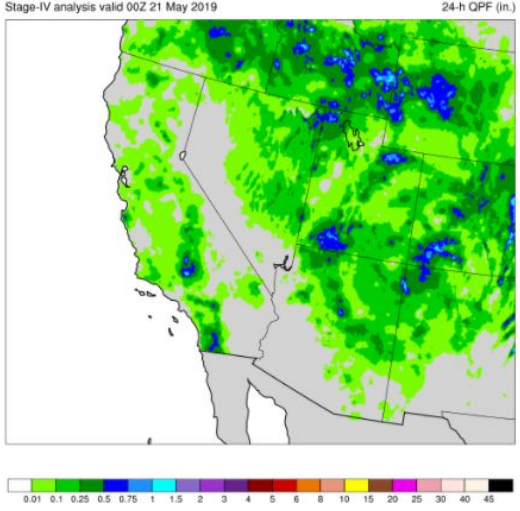




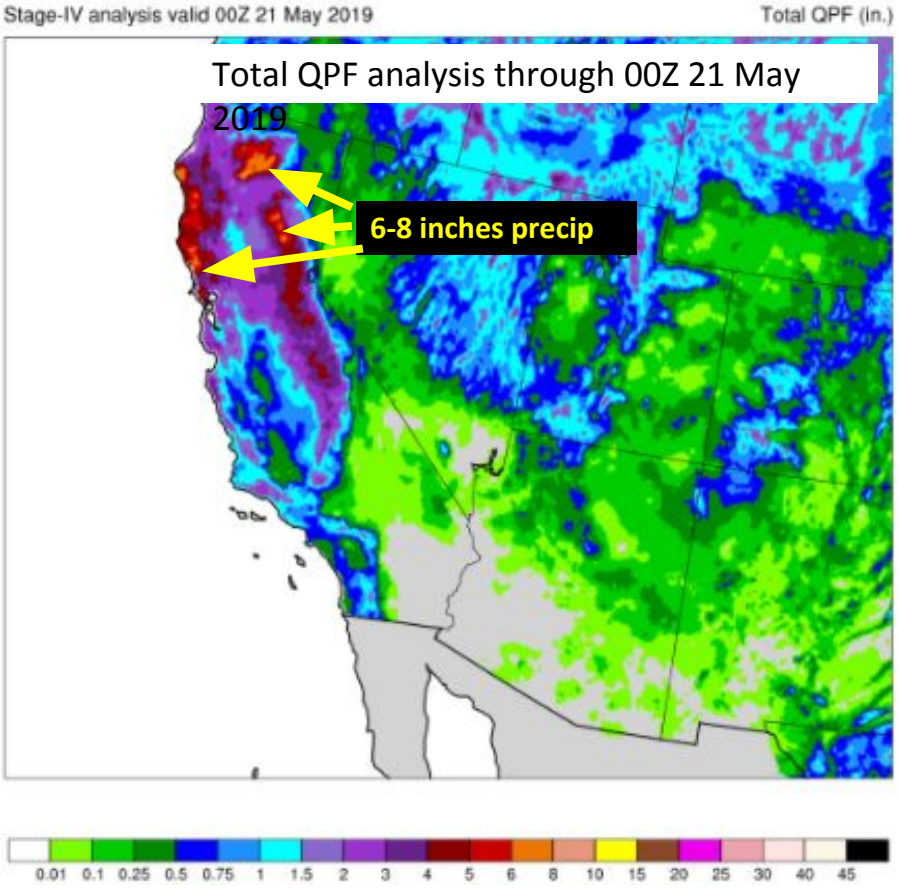


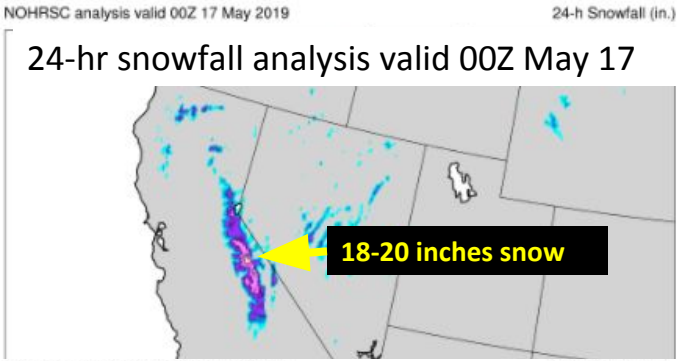


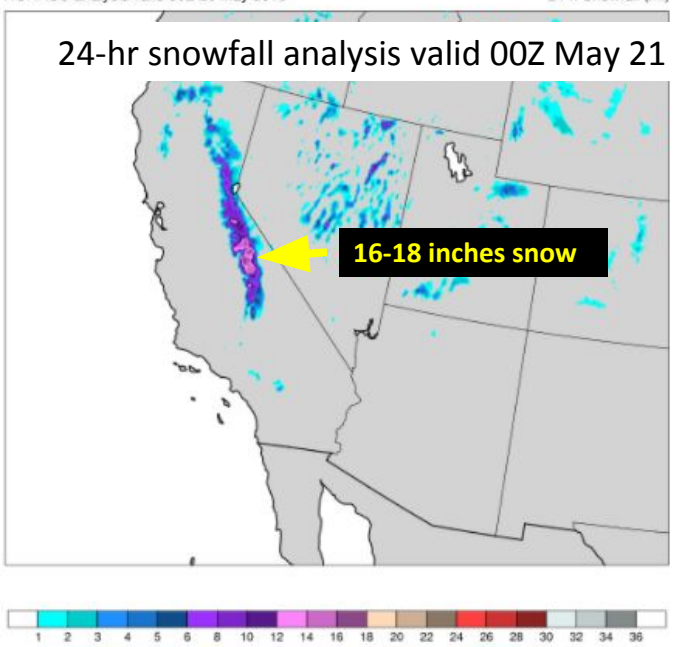




California Spring Storm (May 2019)







California Spring Storm (May 2019): GFSv15 vs GFSv16 Results

Forecast Parameter	Extended Range	Medium Range	Short Range
500 mb Height	0	+1	0
QPF	+1	+1	+1
Snowfall	X	X	X
KOAK short-range soundings	N/E	N/E	0
Overall Utility	+0.5	+1	+0.5

GFS **v15** much better

-3	-2	-1	0	+1	+2	+3

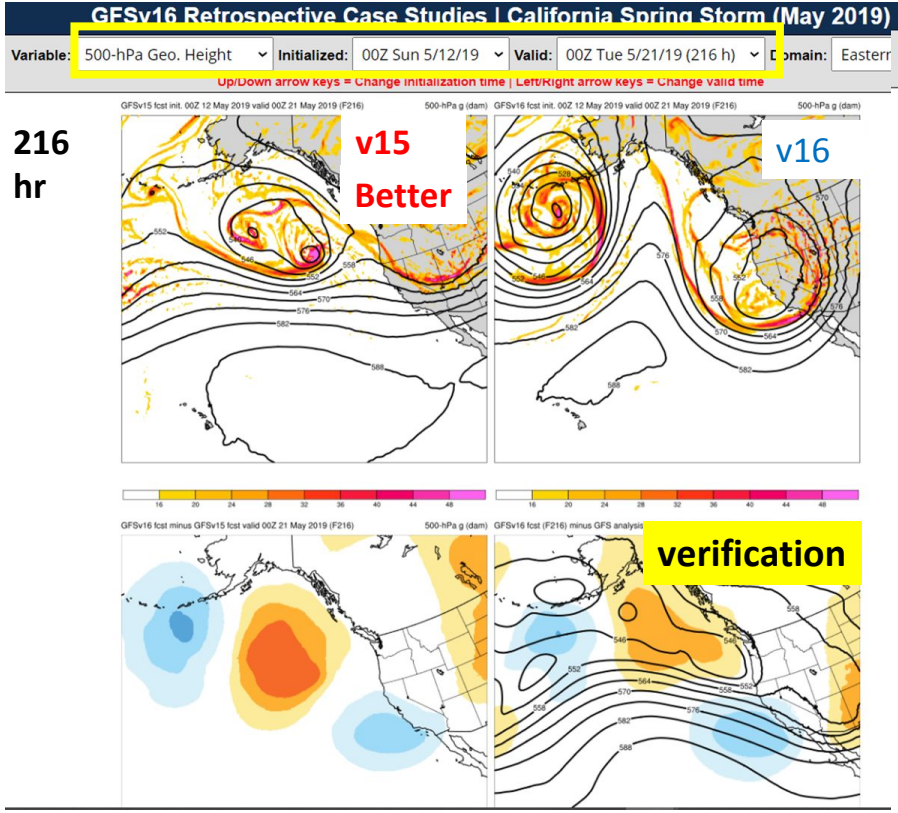
GFS **v16** much better

N/E = Not Examined

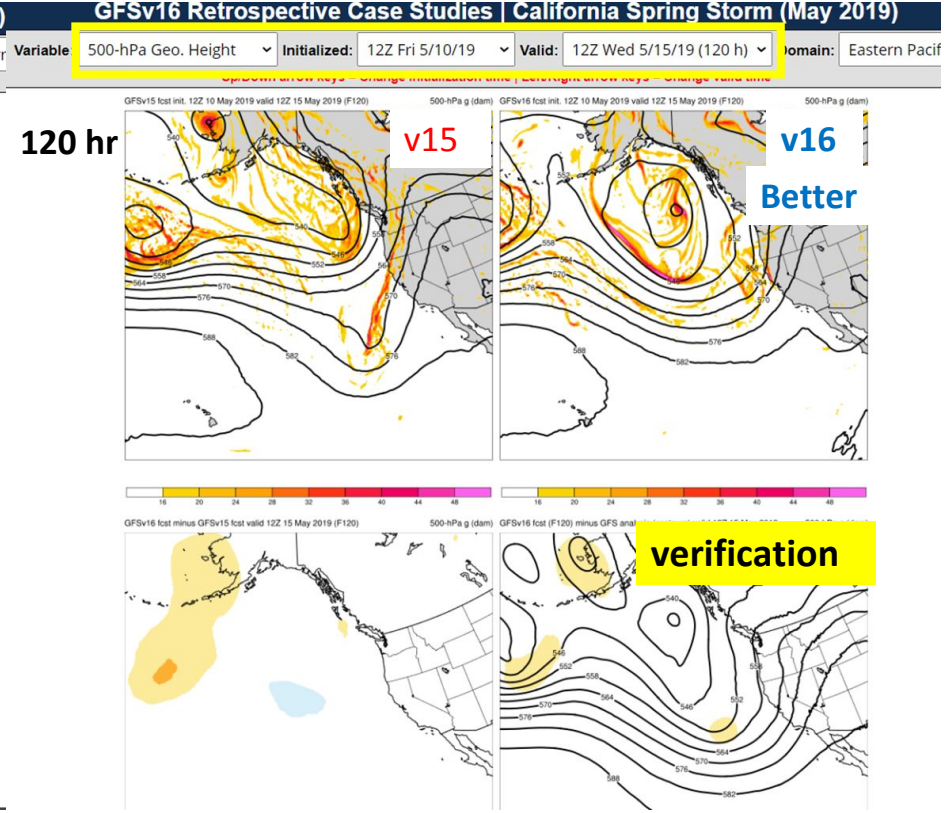
X = Retrospective Case Studies web site malfunctioned

California Spring Storm (May 2019): GFSv15 vs GFSv16 Examples – 500 mb Z

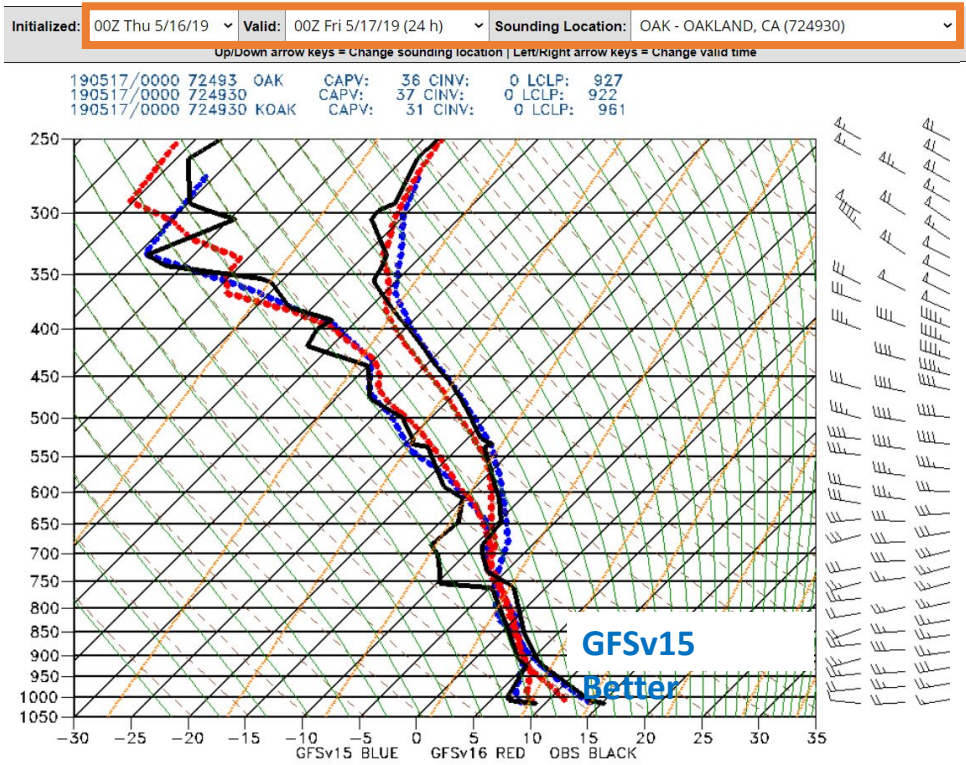
Extended Range

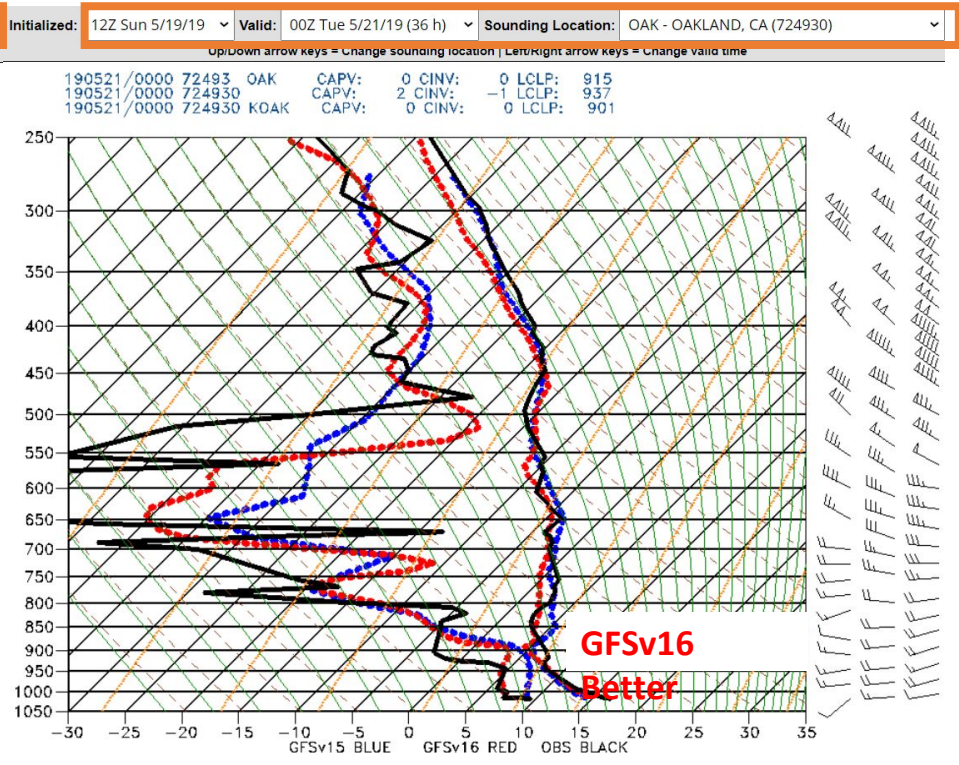


Medium Range



California Spring Storm (May 2019): GFSv15 vs GFSv16 Examples - Soundings





Western Region Cases: GFSv16 vs GFSv15

Cases Examined

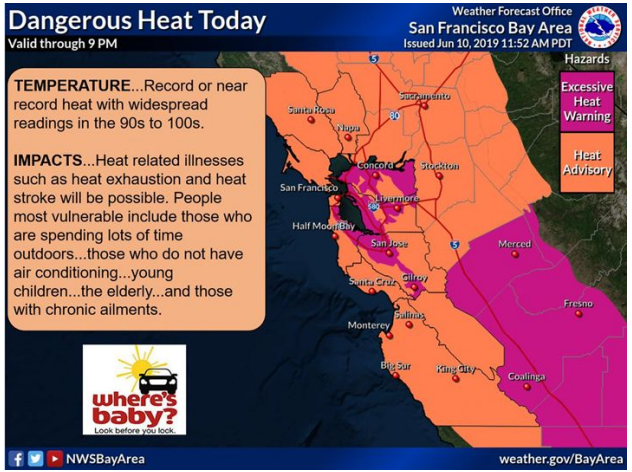
California Spring Storm (May 2019)

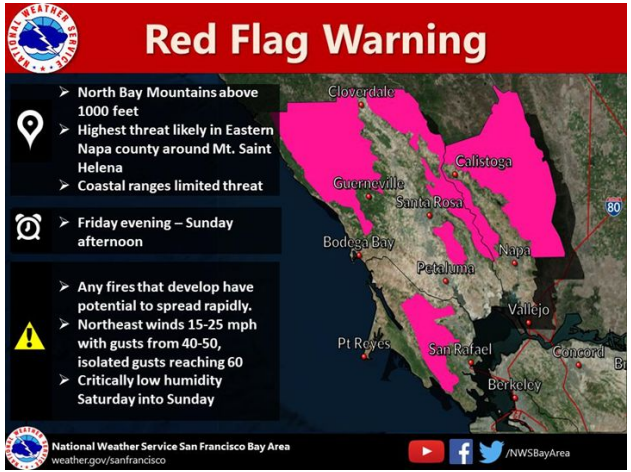
San Francisco Heat (June 2019)

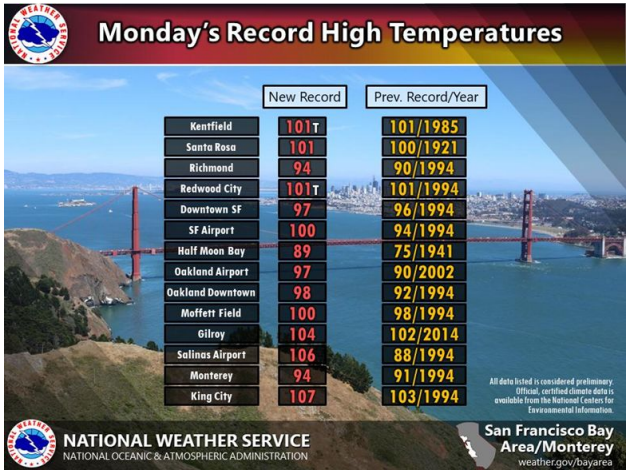
Hurricane Lorena (Sep 2019)

West Coast Bomb Cyclone (Nov 2019)

San Francisco Heat (June 2019)







Key factor was strong low-level offshore flow (500 mb heights and 850 mb Temps were unremarkable).

San Francisco Heat (June 2019)

Forecast Parameter	Extended Range	Medium Range	Short Range
00Z Temp (4 pm PST/5 pm PDT)	-2	+1	0
12Z Temp (4 am PST/5 am PDT)	-2	+1	0
2m Dew Point	0	0	0
Synoptic scale details	-2	0	0
KOAK short-range soundings	N/E	N/E	+0.5
KVBG short-range soundings	N/E	N/E	-0.5
Overall Utility	**-1.5**	**+0.5**	**0**

GFS **v15** much better

-3	-2	-1	0	+1	+2	+3

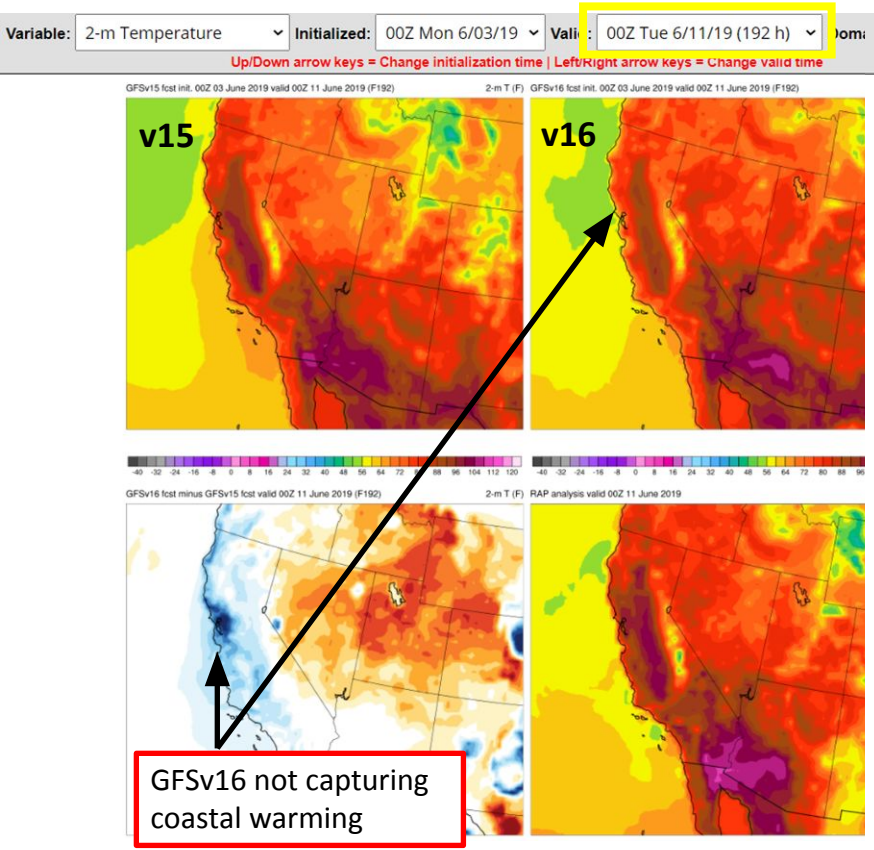
GFS **v16** much better

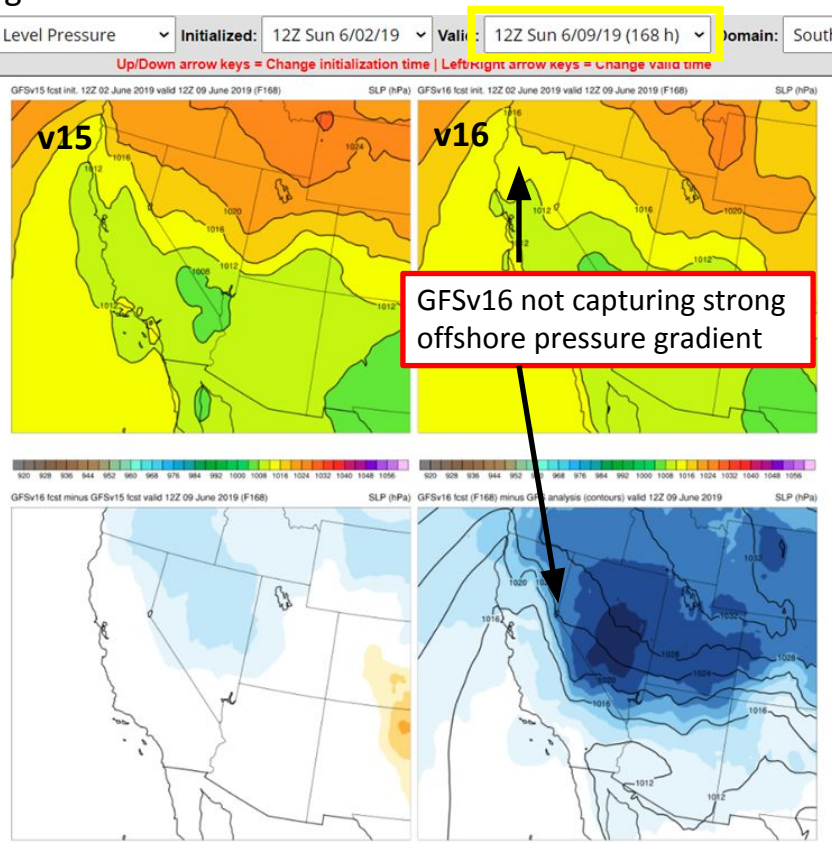
N/E = Not Examined

X = Retrospective Case Studies web site malfunctioned

San Francisco Heat (June 2019)

Extended Range





Western Region Cases: GFSv16 vs GFSv15

Cases Examined

California Spring Storm (May 2019)

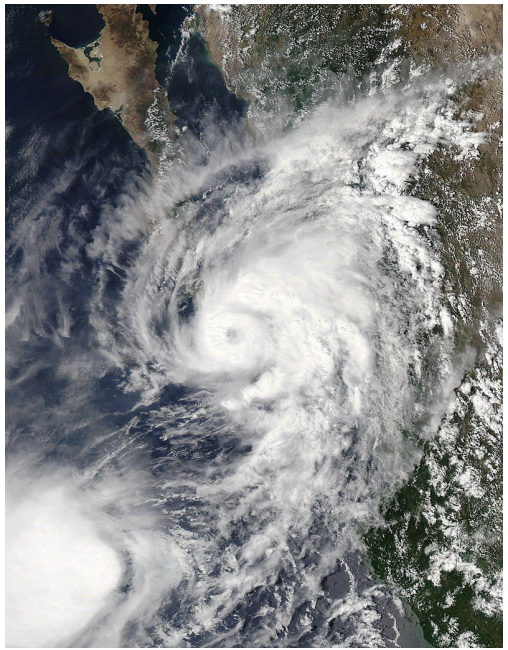
San Francisco Heat (June 2019)

Hurricane Lorena (Sep 2019)

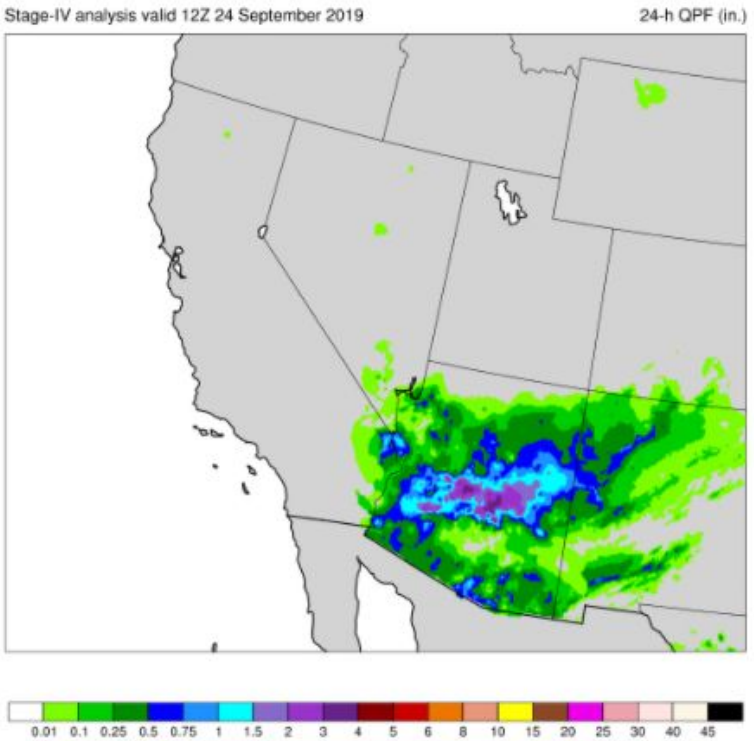
West Coast Bomb Cyclone (Nov 2019)

Hurricane Lorena (Sep 2019)

2019-09-20_2010Z



The remnants of Hurricane Lorena brought locally heavy rain to parts of Arizona on September 22–24. Precipitation peaked at 4 to 6 in (100 to 150 mm) near Phoenix



On September 23, a supercell thunderstorm produced a brief EF0 tornado in New River in Maricopa County.

Hurricane Lorena (Sep 2019)

Forecast Parameter	Extended Range	Medium Range	Short Range
QPF	-2	+1	0
Surface CAPE	-2	0	0
Synoptic Scale Details	X	X	X
KPHX short-range soundings	N/A	N/A	N/A
Overall Utility	-2	+0.5	0

GFS **v15** much better

-3	-2	-1	0	+1	+2	+3

GFS **v16** much better

N/E = Not Examined
X = Retrospective Case Studies web site malfunctioned

Western Region Cases: GFSv16 vs GFSv15

Cases Examined

California Spring Storm (May 2019)

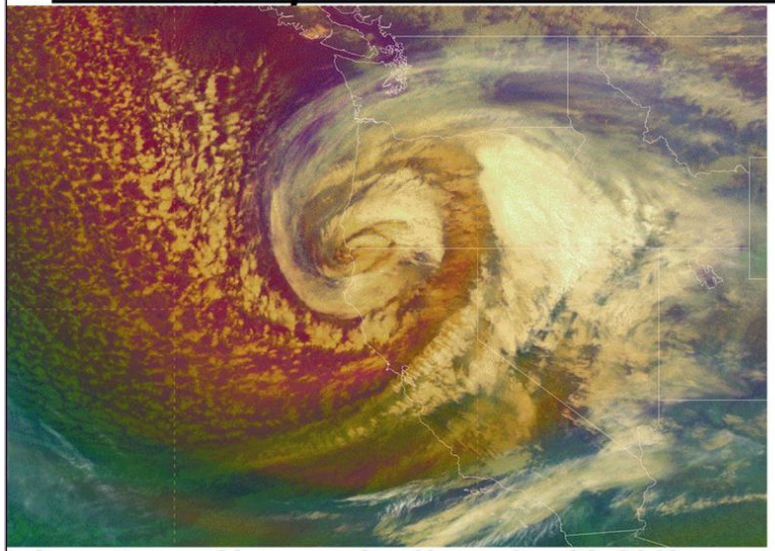
San Francisco Heat (June 2019)

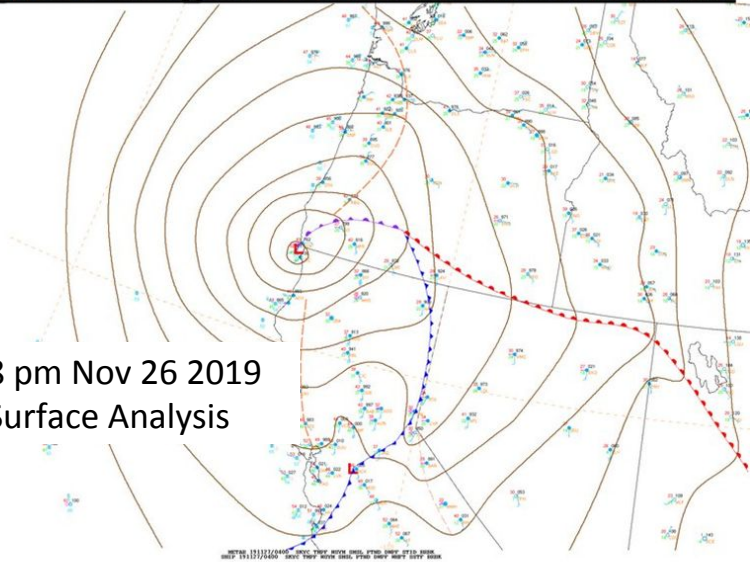
Hurricane Lorena (Sep 2019)

West Coast Bomb Cyclone (Nov 2019)

West Coast Bomb Cyclone (Nov 2019)

Historic, unprecedented storm in southwest Oregon & northwest California





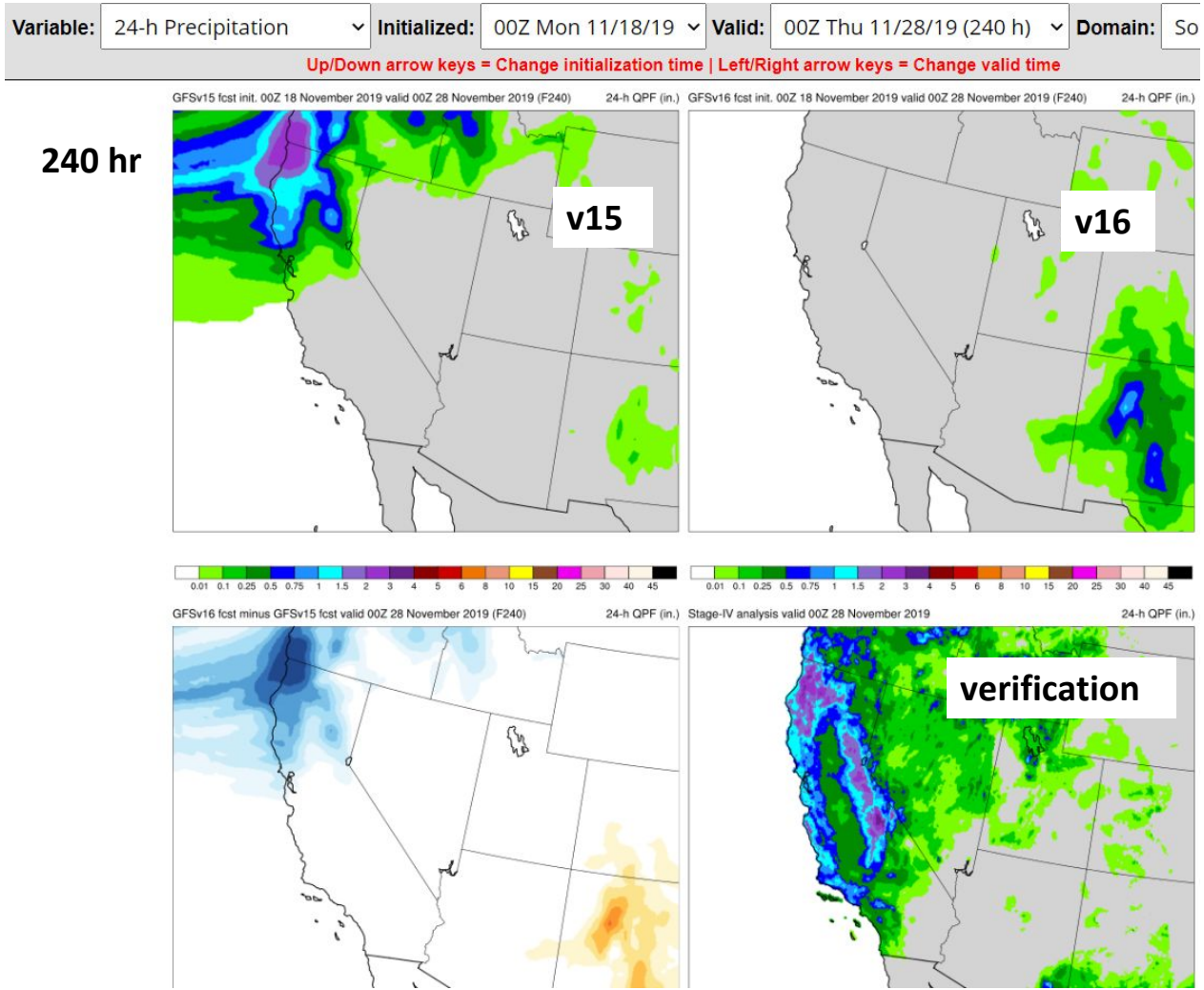
8 pm Nov 26 2019
Surface Analysis

- Impacts as of late evening November 26, 2019

-Sustained winds of 85 mph with gusts to 106 mph at Cape Blanco, OR @ 1:15 pm
-Wind gust to 69 mph at Crescent City, CA
-Whiteout conditions reported due to wind and snow from LaPine to Lakeview OR
-High seas (up to 34 foot seas so far)
-Heavy coastal rain/inland and mountain snowfall across southwest OR & northern/central CA (parts of I-5 closed)
-November low pressure records set at Medford OR (981.4 hPa/28.98") & Eureka CA (984.8 hPa/29.08")
-Lowest pressure in Oregon: 974.6 hPa/28.78" @ 6:35 pm at Gold Beach Airport
-All-time low pressure record preliminarily set for the state of California (~973.6 hPa/28.75" at Crescent City)

West Coast Bomb Cyclone (Nov 2019)

Forecast Parameter	Extended Range	Medium Range	Short Range
00Z Temp (4 pm PST/5 pm PDT)	-1	+1	0
12Z Temp (4 am PST/5 am PDT)	-1	0	0
2m Dew Point	0	0	0
Surface CAPE	-2	-1	-1
QPF	-3	0	0
Synoptic Scale Details	0	+2	0
KOAK soundings	N/E	N/E	0
Overall Utility	-1.5	+0.5	0


Variable: 24-h Precipitation
Initialized: 00Z Mon 11/18/19
Valid: 00Z Thu 11/28/19 (240 h)
Domain: So
Up/Down arrow keys = Change initialization time | Left/Right arrow keys = Change valid time
240 hr
GFSv15 fcst init. 00Z 18 November 2019 valid 00Z 28 November 2019 (F240)
24-h QPF (in.)
v15
GFSv16 fcst init. 00Z 18 November 2019 valid 00Z 28 November 2019 (F240)
24-h QPF (in.)
v16
0.01 0.1 0.25 0.5 0.75 1 1.5 2 3 4 5 6 8 10 15 20 25 30 40 45
0.01 0.1 0.25 0.5 0.75 1 1.5 2 3 4 5 6 8 10 15 20 25 30 40 45
GFSv16 fcst minus GFSv15 fcst valid 00Z 28 November 2019 (F240)
24-h QPF (in.)
Stage-IV analysis valid 00Z 28 November 2019
24-h QPF (in.)
verification

Overall Utility Summary from these four WR Cases

Case	Extended Range	Medium Range	Short Range
California Spring Storm (May 2019)	+0.5	+1	+0.5
San Francisco Heat (June 2019)	-1.5	+0.5	0
Hurricane Lorena (Sept 2019)	-2	+0.5	0
West Coast Bomb Cyclone (Nov 2019)	-1.5	+0.5	0
OVERALL	**-1**	**+0.5**	**0**

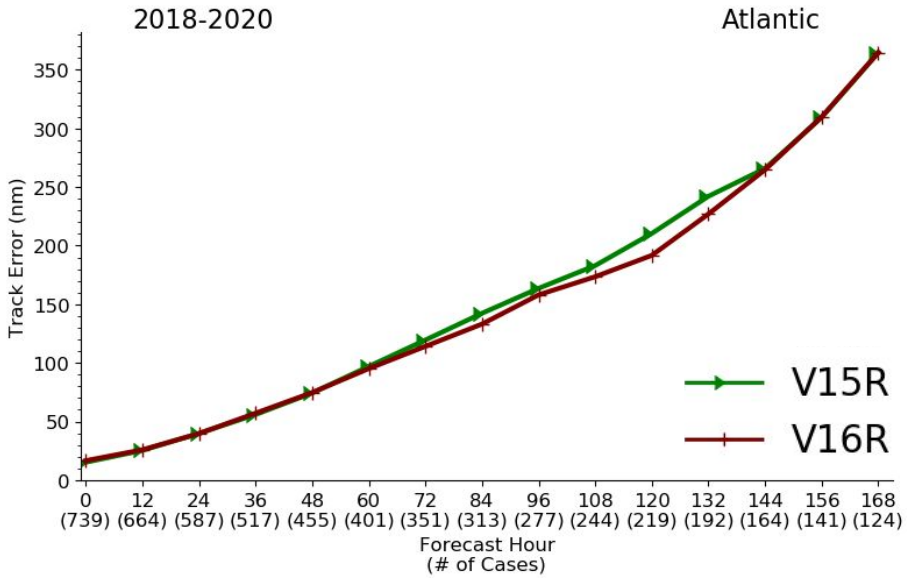
Overall Short Range Soundings: **0**

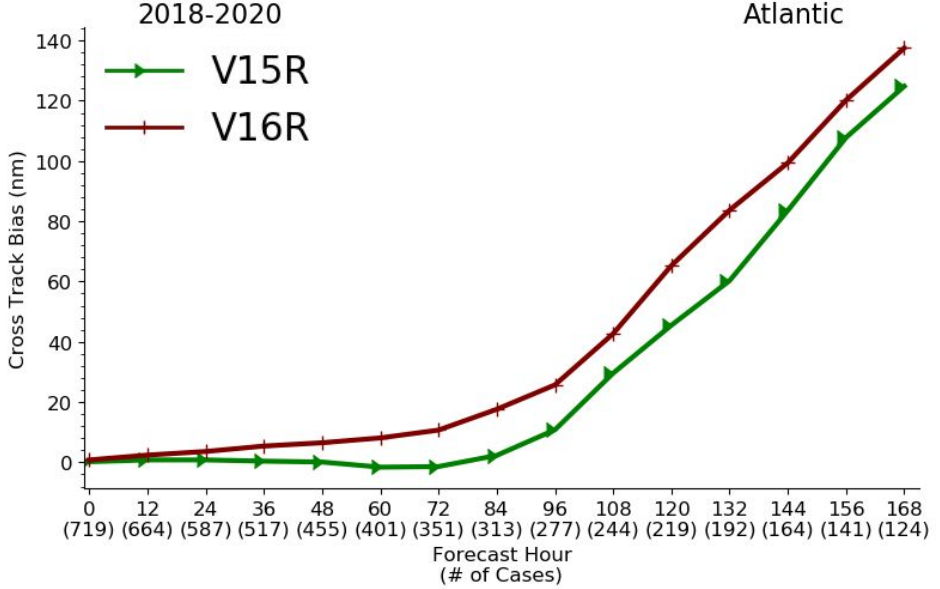
<u>Takeaway</u>: Overall very similar performance, aside perhaps from v16 performing a bit poorer than v15 in the extended range and slightly better than v15 in the medium range. Basically a toss up, given the limited and subjective nature of this evaluation (uncertainty larger than magnitude of findings).

Ben Trabing

National Hurricane Center

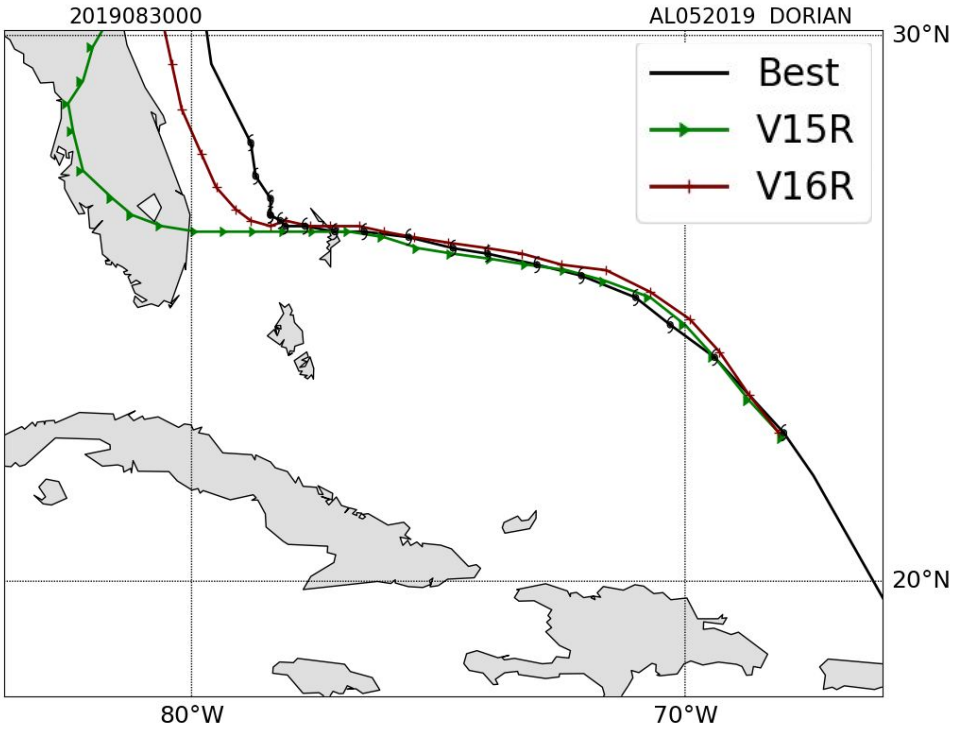
Slightly Improved Tracks with Right of Track Bias



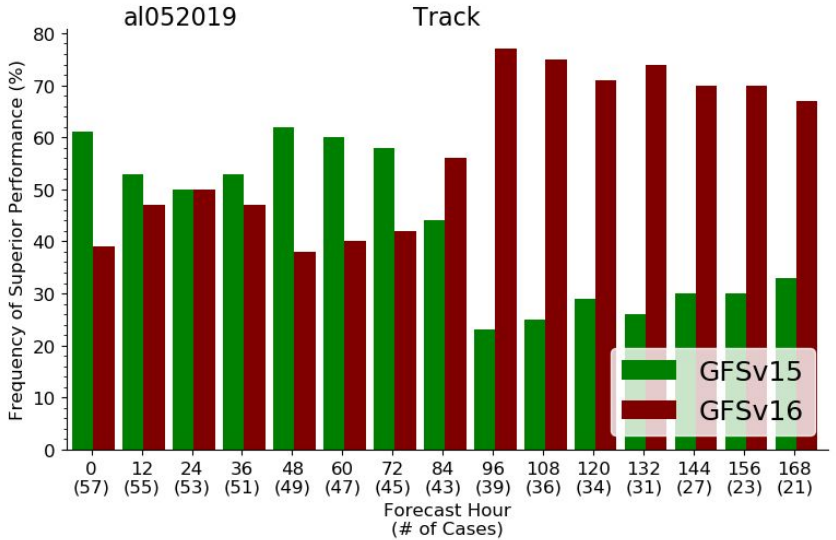


GFSv16 had slightly improved track forecasts for days 3-6 but a stronger right of track bias at all forecast times compared to GFSv15.

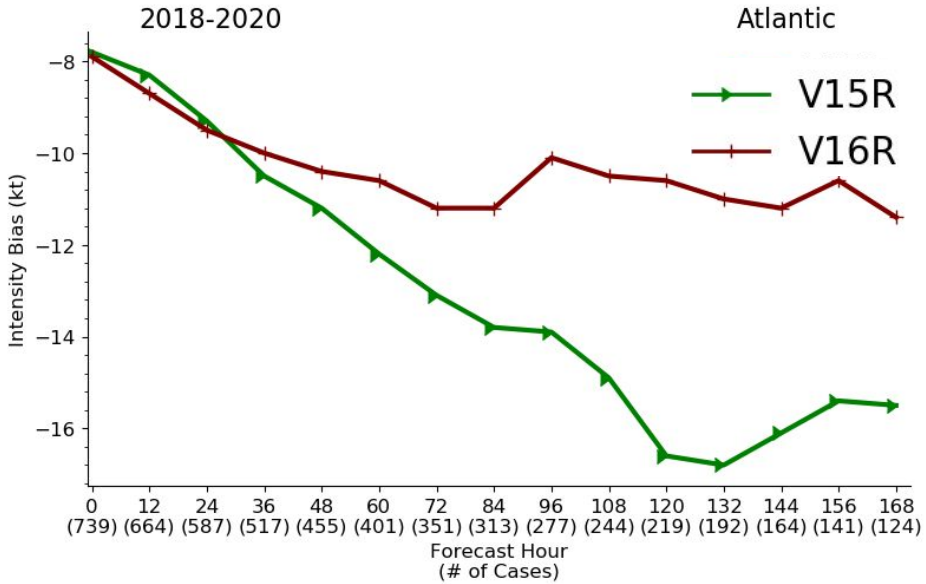
Hurricane Dorian (2019)

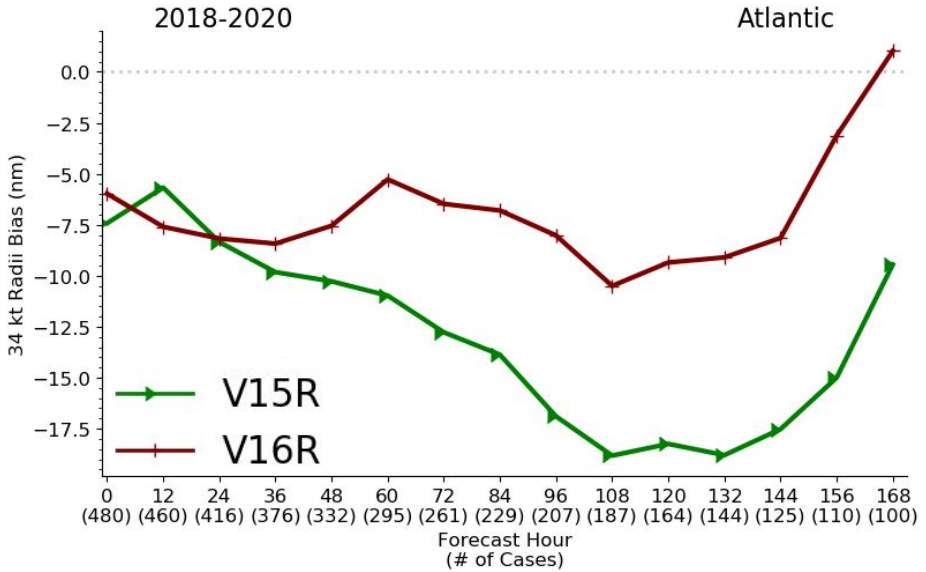


GFSv15 did better with Dorian's short term track forecasts, but GFSv16 had better 4-7 day forecasts and did a better job forecasting recurvature.



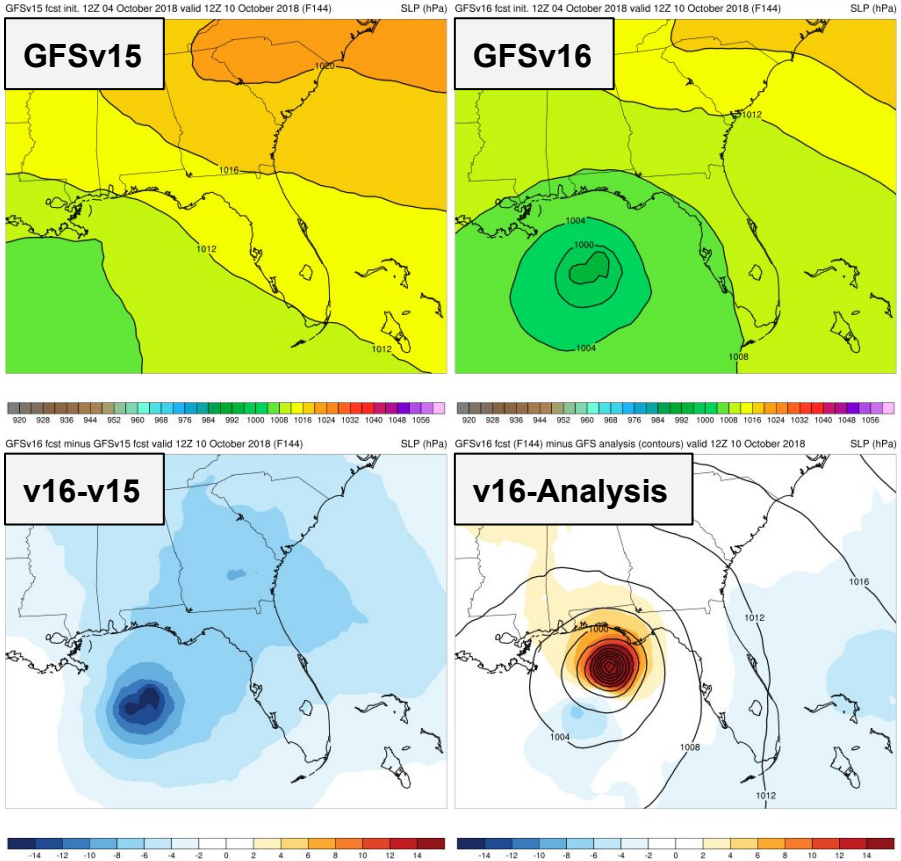
Bigger and More Intense Hurricanes





GFSv16 reduced a negative intensity bias and a negative bias in the radii of 34-kt winds beyond day 2. GFSv16 creates more intense and larger hurricanes compared to GFSv15.

Hurricane Michael (2018)

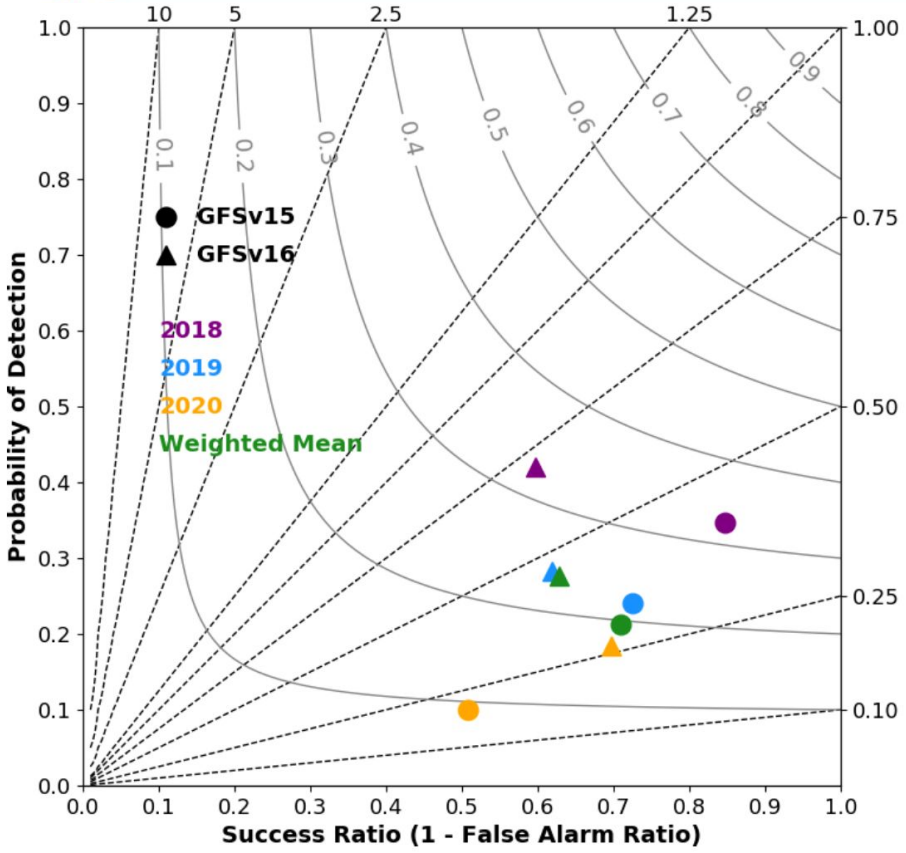


MSLP (hPa)
Forecast Hour: 144 h
Valid: 12Z Oct 10

GFSv16 consistently outperformed GFSv15 in forecasting Michael at long lead times.

GFSv16 would have given multiple days of added lead time on Hurricane Michael being a strong hurricane near landfall due to better intensity estimates.

2018-2020 Genesis Verification



All values would be 1 for a perfect model

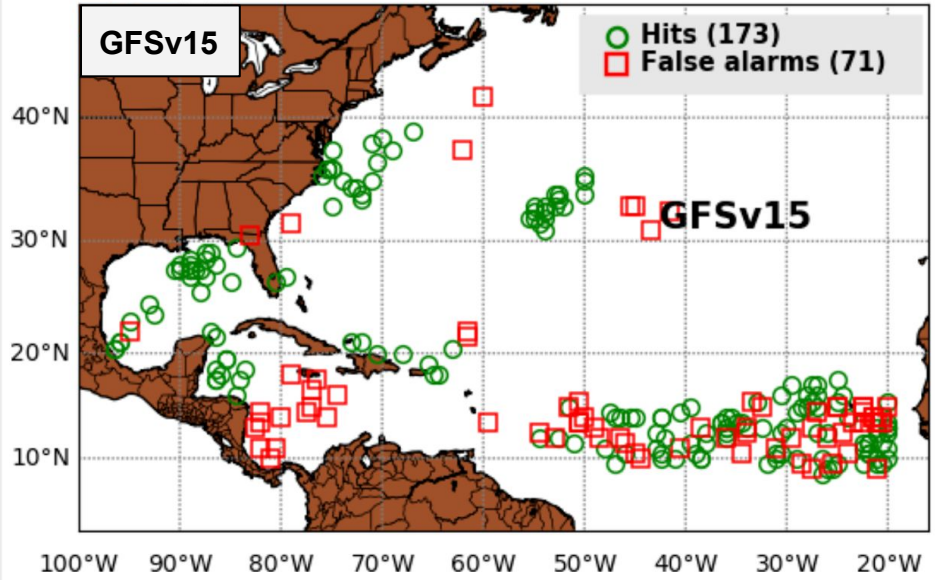
Compared to GFSv15, GFSv16 has:

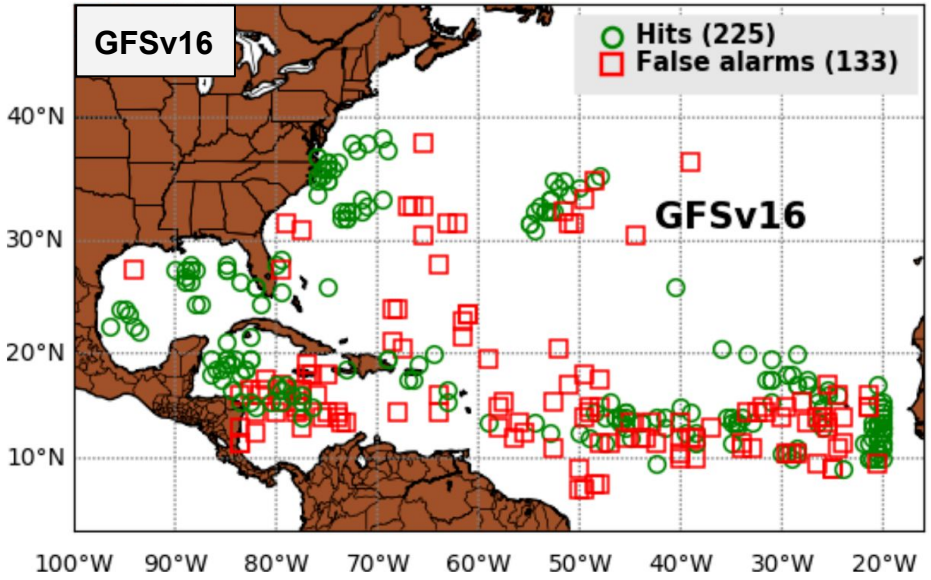
- **higher probability of detection**
- **larger critical success index**
- **lower success ratio**

Similar in East Pacific Basin

Courtesy of Dan Halperin

2018-2020 Genesis Verification





GFSv16 creates more tropical cyclones overall leading to more hits but also more false alarms compared to v15.

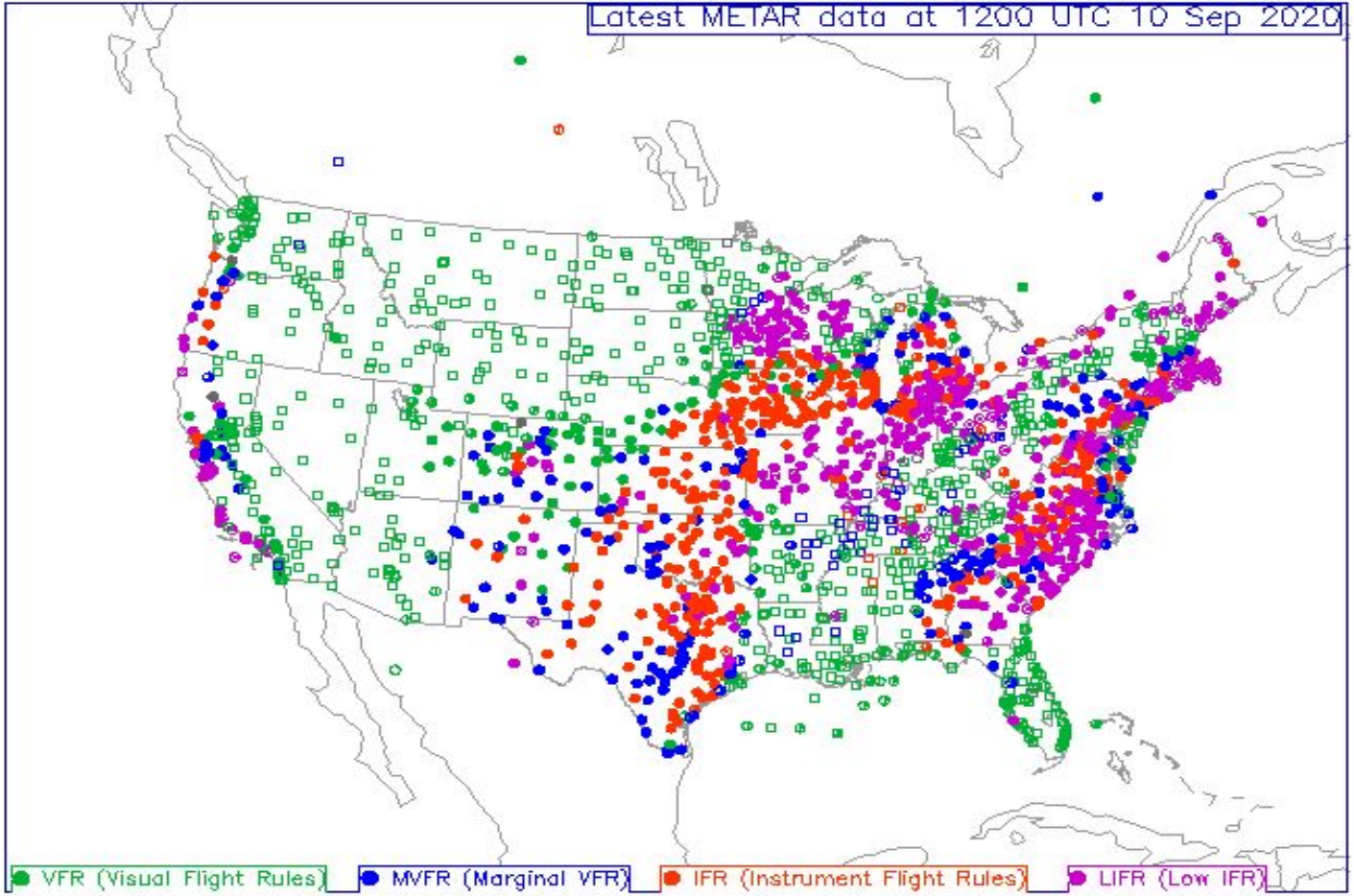
Courtesy of Dan Halperin

Steverino Silberberg

Aviation Weather Center

FOCUS

- Ceiling, Visibility, Cloud Cover
- Turbulence
- Icing



3000’ 5sm

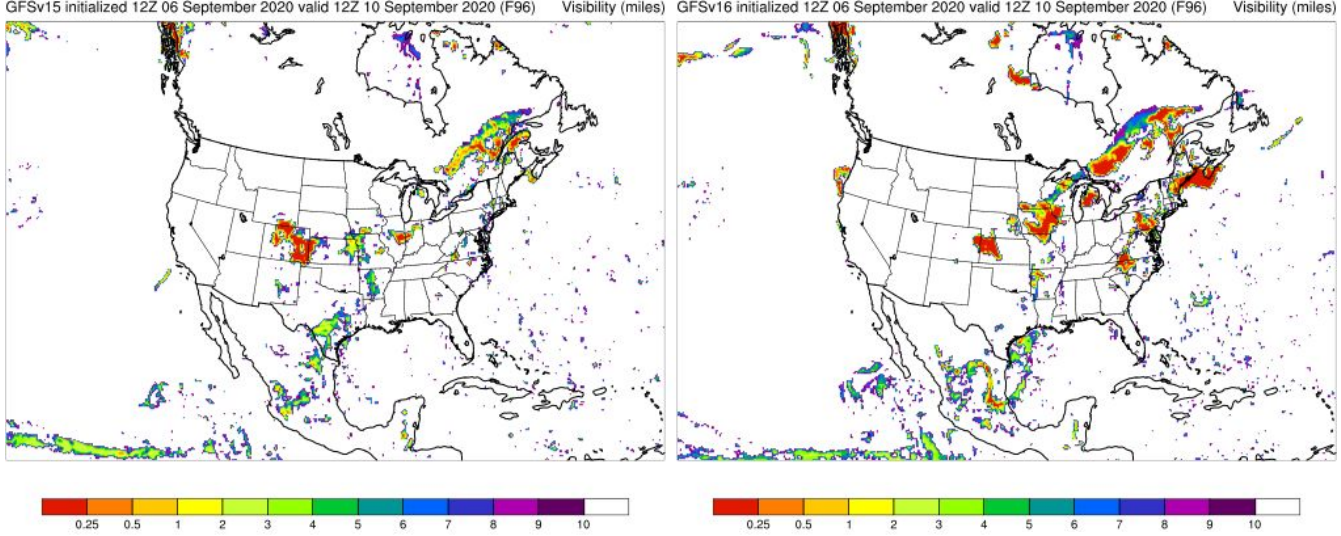
1000’ 3sm

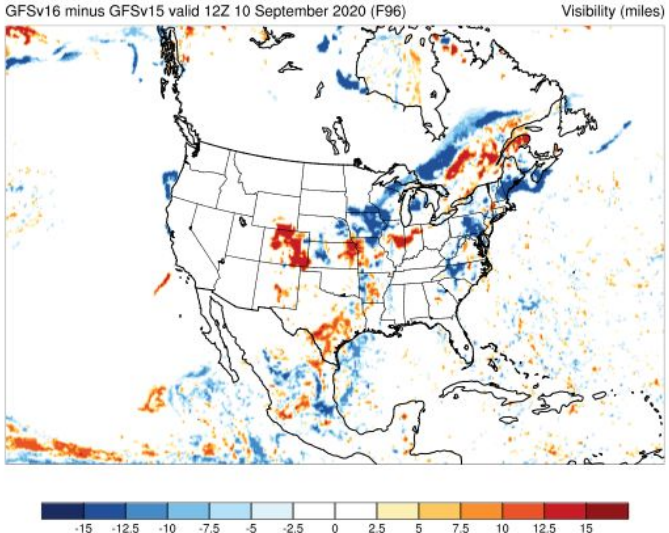
500’ 1sm

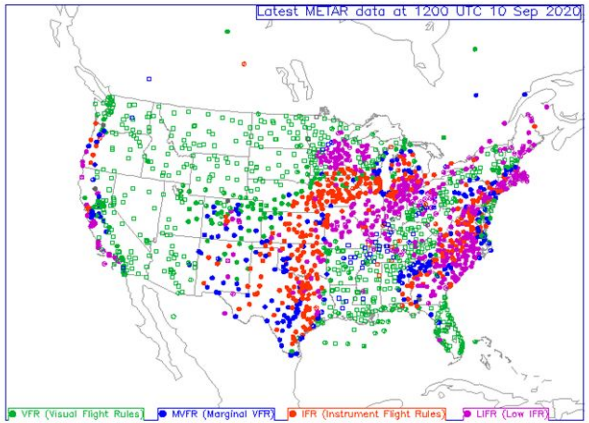
v15

v16

F96

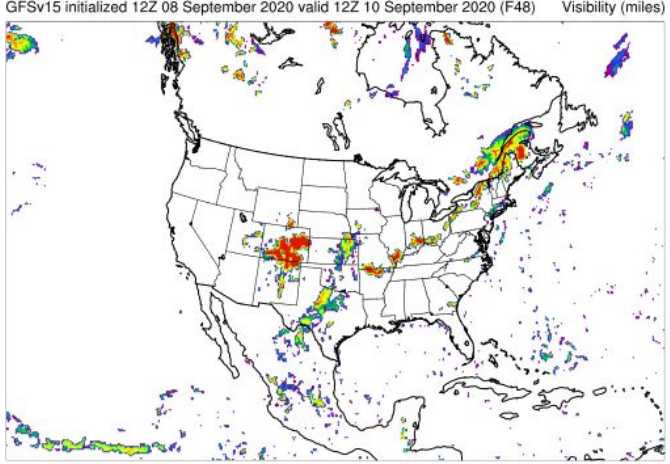

GFSv15 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96) Visibility (miles)
GFSv16 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96) Visibility (miles)
0.25 0.5 1 2 3 4 5 6 7 8 9 10
0.25 0.5 1 2 3 4 5 6 7 8 9 10

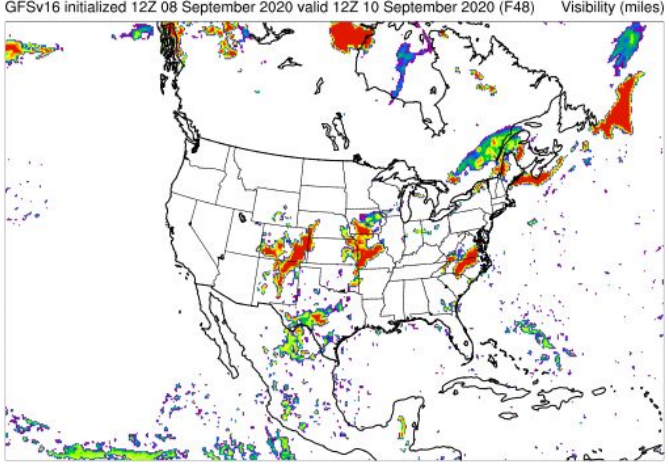

GFSv16 minus GFSv15 valid 12Z 10 September 2020 (F96) Visibility (miles)
-15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15


Latest METAR data at 1200 UTC 10 Sep 2020
VFR (Visual Flight Rules)
MVFR (Marginal VFR)
IFR (Instrument Flight Rules)
LIFR (Low IFR)

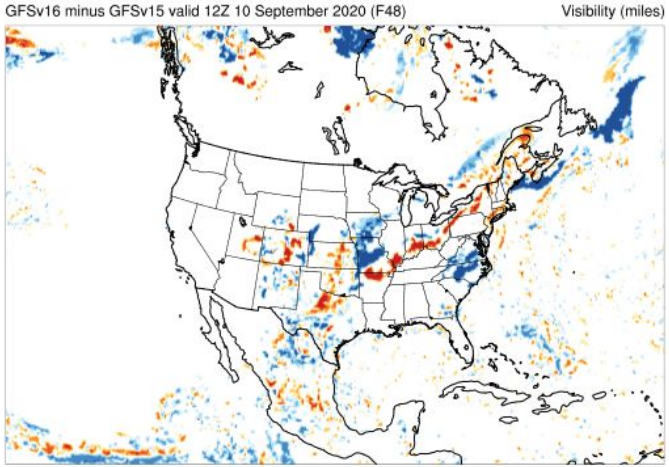
v15

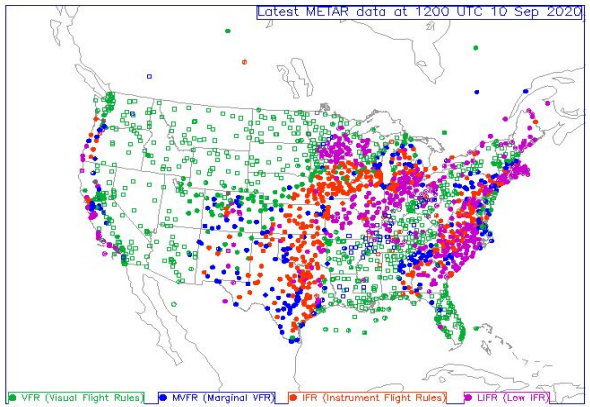
F48





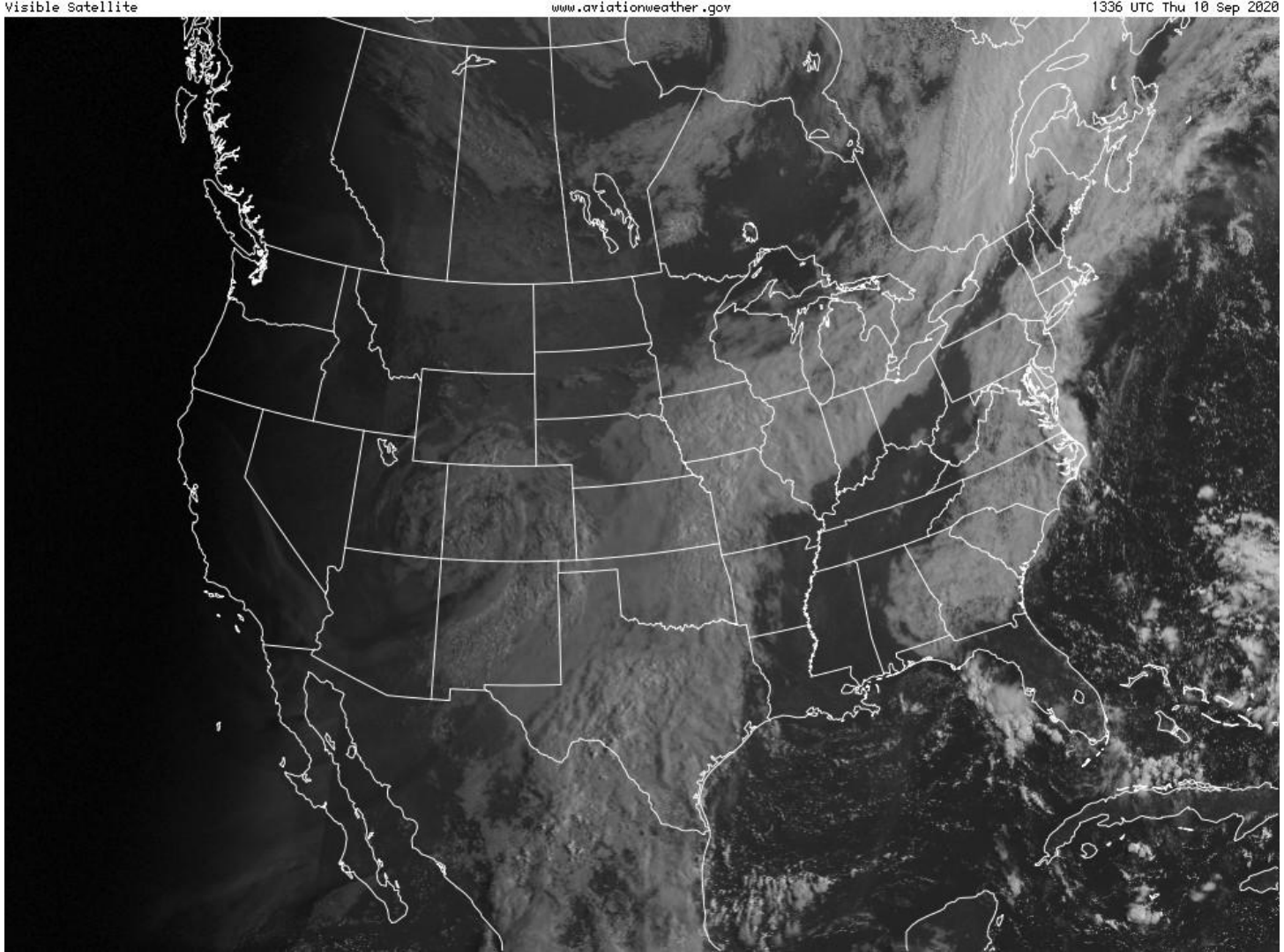
v16





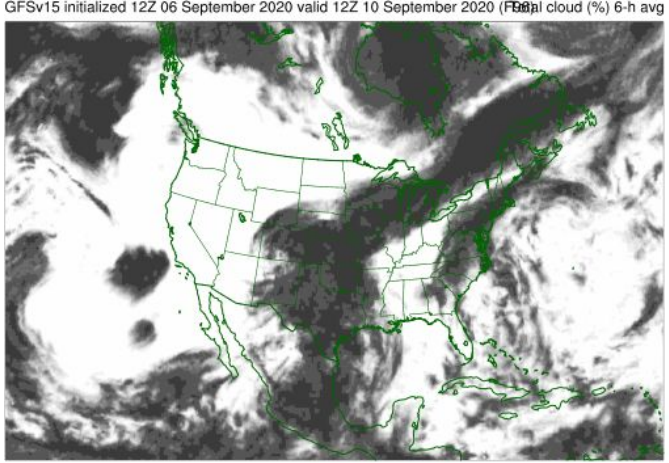
Created by ADDS

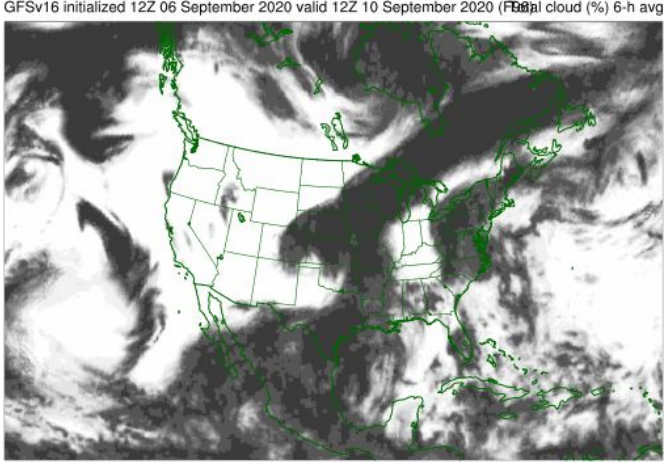
VIS
1336Z
10
Sep
2020



v15

F96

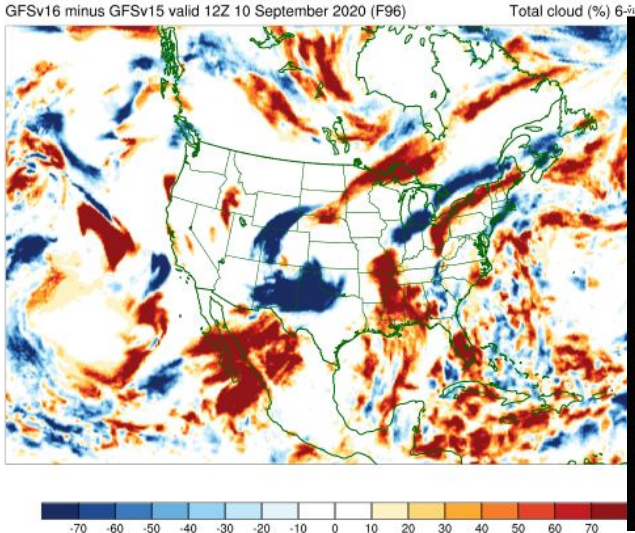

GFSv15 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96)
Total cloud (%) 6-h avg

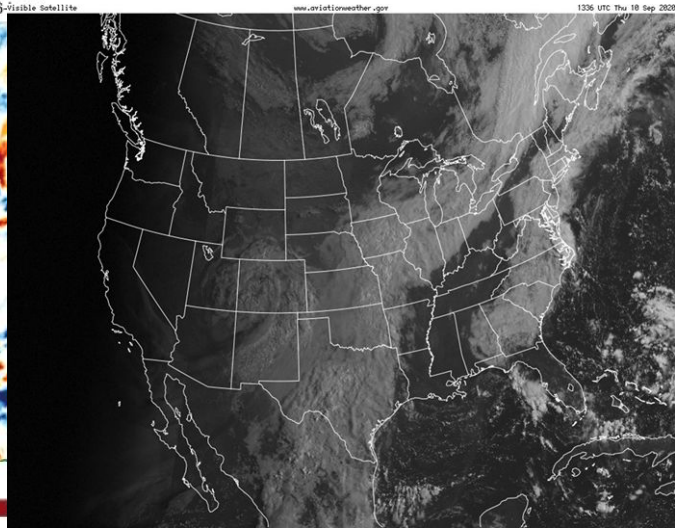

GFSv16 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96)
Total cloud (%) 6-h avg

v16


10 20 30 40 50 60 70 80 90 100

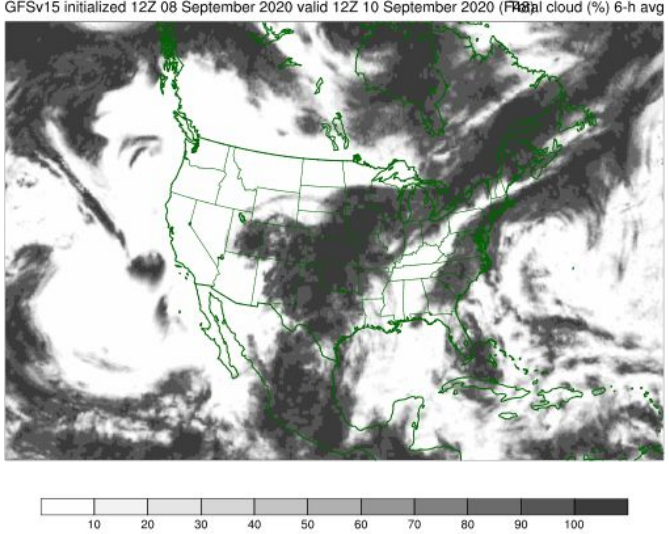

10 20 30 40 50 60 70 80 90 100

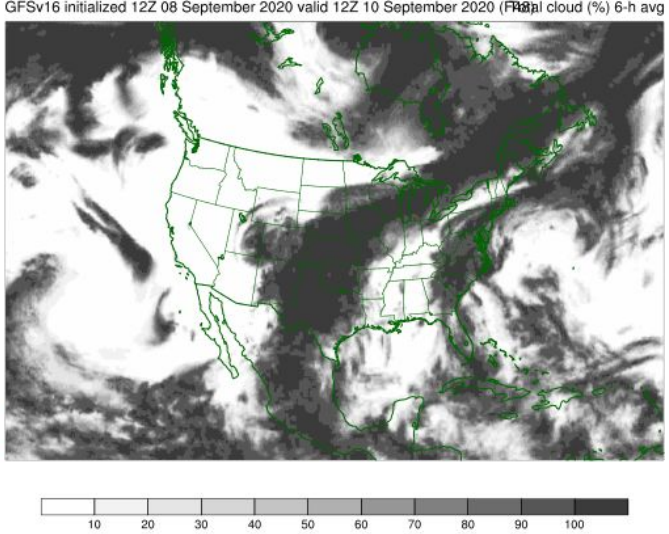

GFSv16 minus GFSv15 valid 12Z 10 September 2020 (F96)
Total cloud (%) 6-
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70


Visible Satellite
www.aviationweather.gov
1336 UTC Thu 10 Sep 2020

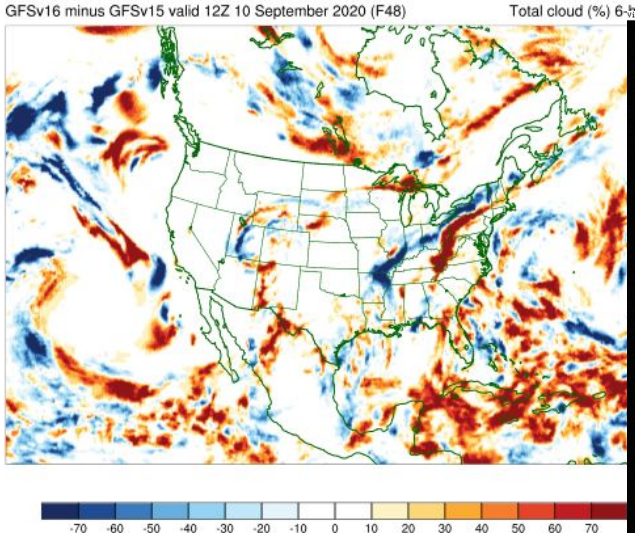
v15

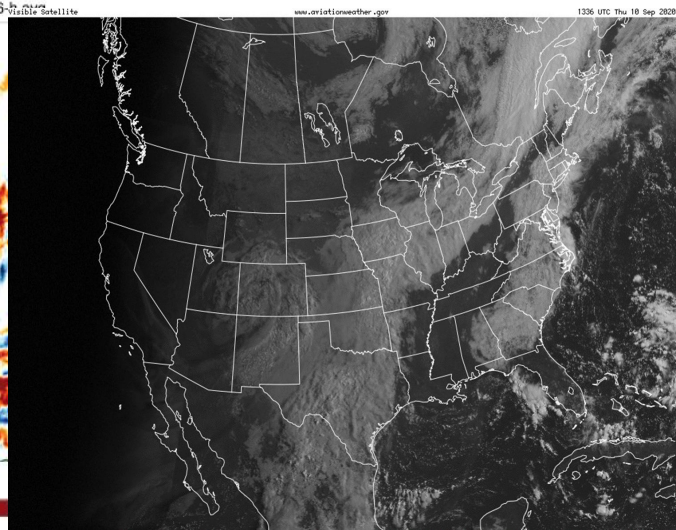
F48


GFSv15 initialized 12Z 08 September 2020 valid 12Z 10 September 2020 (F48)
Total cloud (%) 6-h avg
10 20 30 40 50 60 70 80 90 100


GFSv16 initialized 12Z 08 September 2020 valid 12Z 10 September 2020 (F48)
Total cloud (%) 6-h avg
10 20 30 40 50 60 70 80 90 100

V16

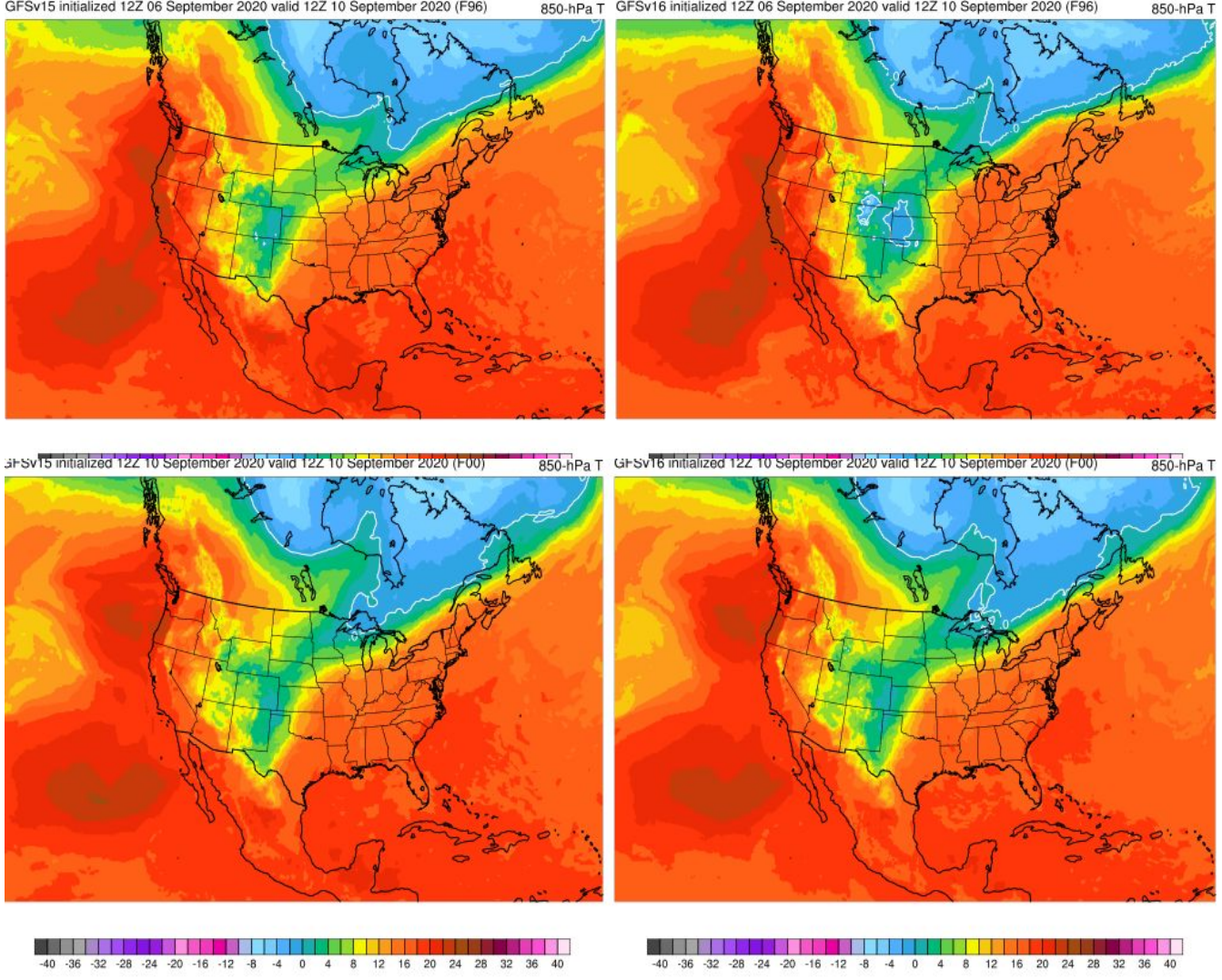

GFSv16 minus GFSv15 valid 12Z 10 September 2020 (F48)
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70


Visible Satellite
www.aviationweather.gov
1336 UTC Thu 10 Sep 2020

v15

F96

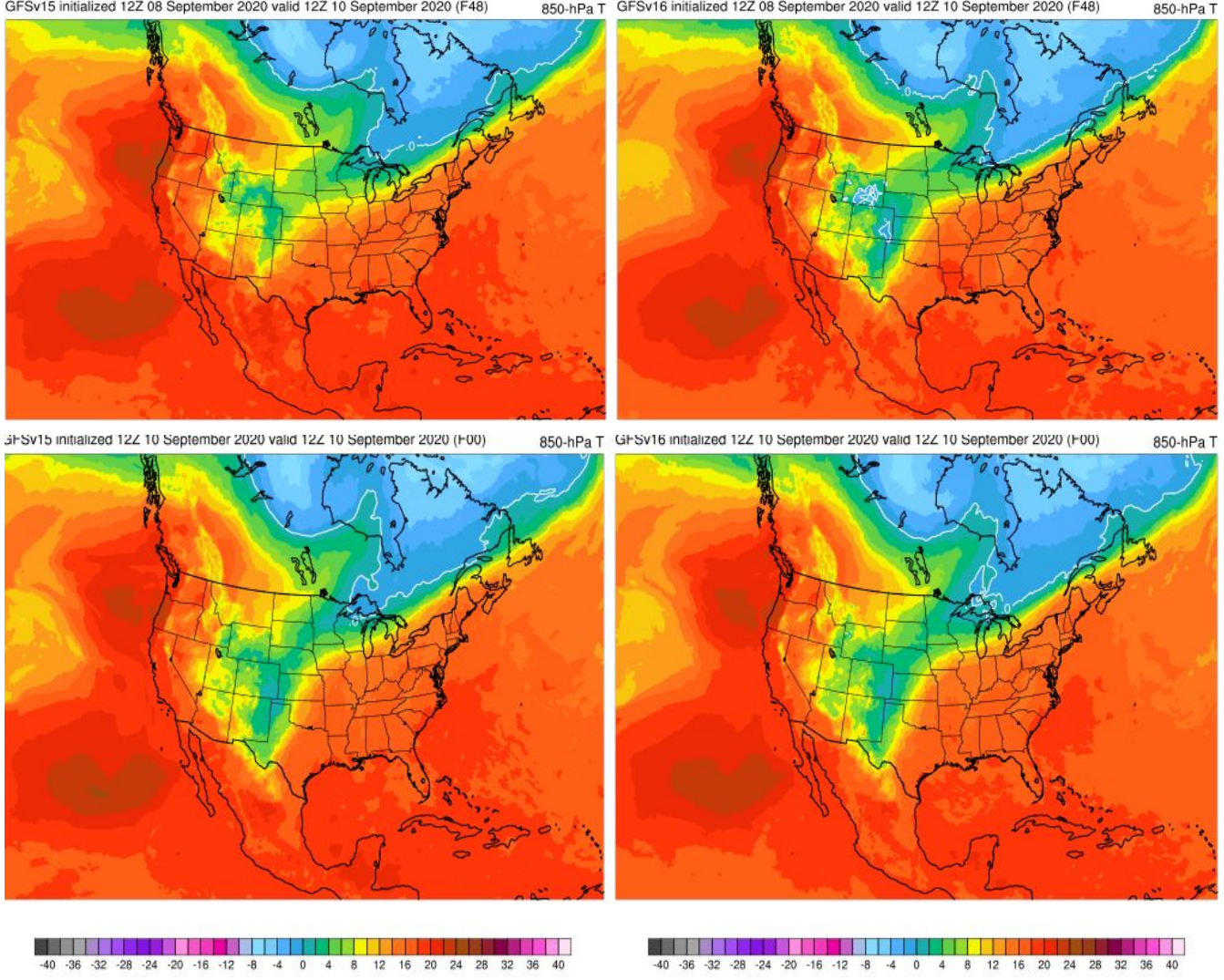
v16


GFSv15 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96)
850-hPa T
GFSv16 initialized 12Z 06 September 2020 valid 12Z 10 September 2020 (F96)
850-hPa T
GFSv15 initialized 12Z 10 September 2020 valid 12Z 10 September 2020 (F00)
850-hPa T
GFSv16 initialized 12Z 10 September 2020 valid 12Z 10 September 2020 (F00)
850-hPa T
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40

v15

F48

V16


GFSv15 initialized 12Z 08 September 2020 valid 12Z 10 September 2020 (F48)
850-hPa T
GFSv16 initialized 12Z 08 September 2020 valid 12Z 10 September 2020 (F48)
850-hPa T
GFSv15 initialized 12Z 10 September 2020 valid 12Z 10 September 2020 (F00)
850-hPa T
GFSv16 initialized 12Z 10 September 2020 valid 12Z 10 September 2020 (F00)
850-hPa T
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40

SUMMARY

- Visibility
  - GFSv16 better: CO, Midwest, Southeast
  - Radiation/Advection coastal fog issue over Southeast, Northeast
  - Missing West Coast marine layer – all forecast times – v15 & v16
- Total Cloud
  - v16 better
- Turbulence
  - v16 better with jet speed, VWS, horizontal shear wrt PIREPS
- Icing (850 T)
  - v16 better with cold air over and east of Rockies

Jack Settelmaier

Southern Region

GEFSv12 Eval alum

GFSv16 Case Studies: Severe Weather

Southern Region (**unique**) assigned cases

Tennessee Tornadoes (Mar 2020)
Easter Sunday Severe (Apr 2020)
Southeast Severe (Apr 2020)
Southern Plains ENH (May 2020)
Southern U.S. QPF (Feb 2020)
Memorial Day Heat (May 2019)
Imelda (2019)
Dorian (2019)
Michael (2018)
Florence (2018)

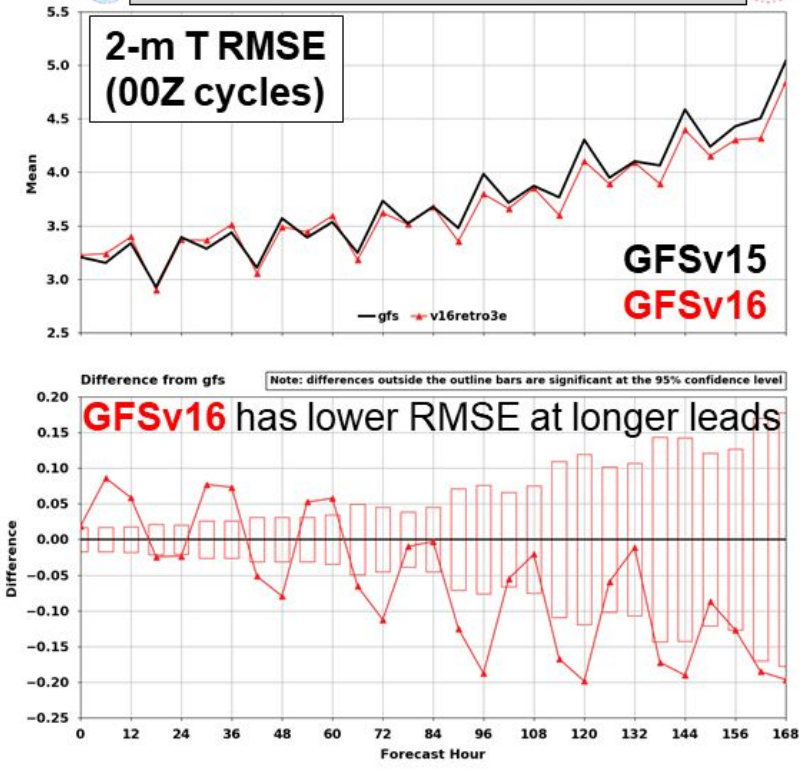
https://www.emc.ncep.noaa.gov/users/meg/gfsv16/retros/

Overall GFSv16 Eval Summary

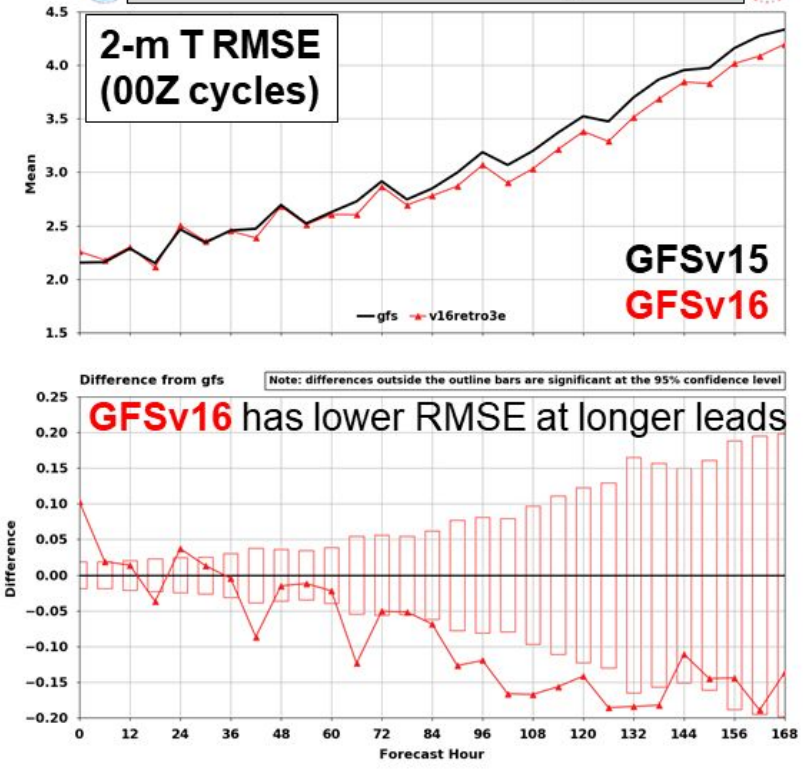
- For examined retro cases, GFSv16 appears to:
  - exhibit **slightly superior skill** at early-identification, location, and intensity of features
  - This superiority appears more often than not across all run/projection times, but is **most evident** at longer lead times (>132hrs)
- Additional output fields, domain views, soundings made available for the retro cases, as well as the real-time parallel views and improved d(prog)/dt functionality, all **GREATLY** enhanced the ability to assess and feedback.
- Kudos to Geoff and the larger MEG group for these evaluation improvements! Tremendous UFS/EPIC V&V foundation.

GFSv16 2-m Temperature RMSE: Winter/Spr. 2020

Western US – Winter/Spr. 2020

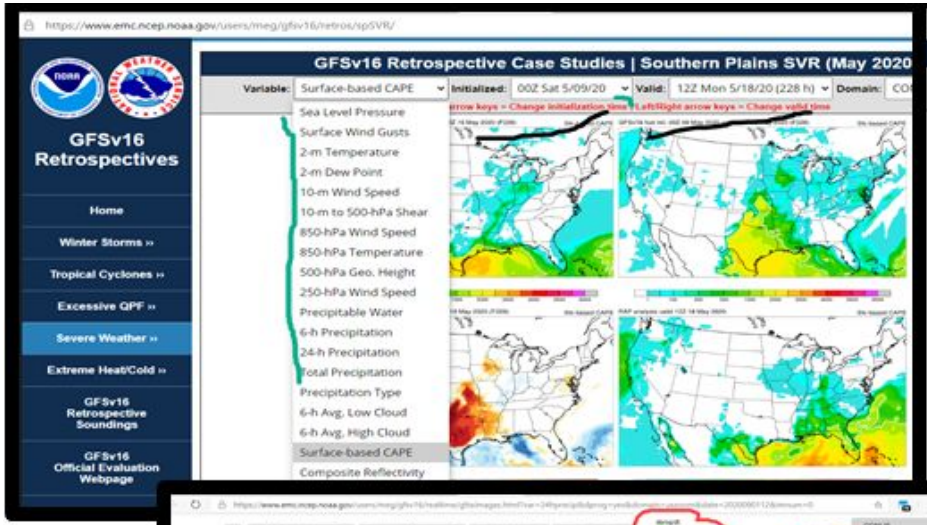


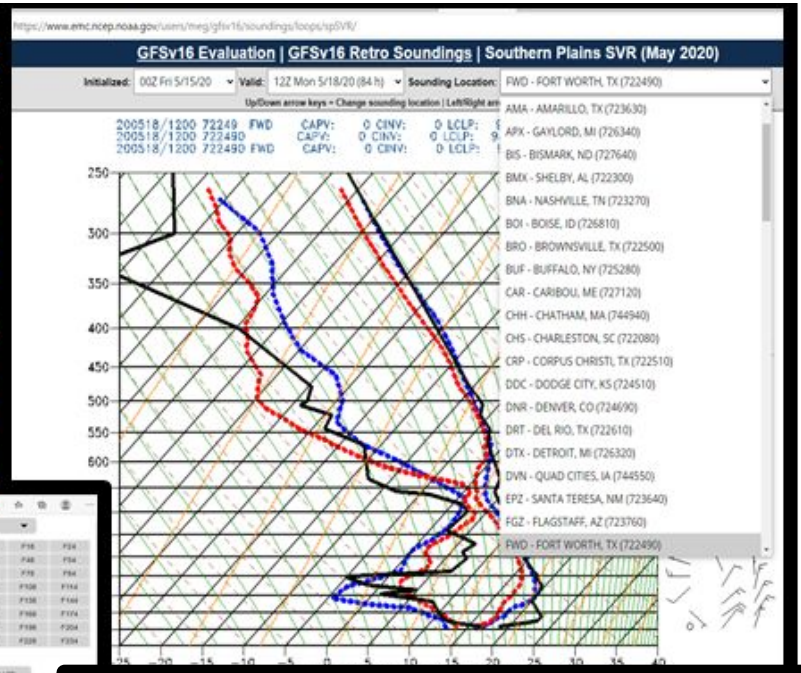
Eastern US – Winter/Spr. 2020

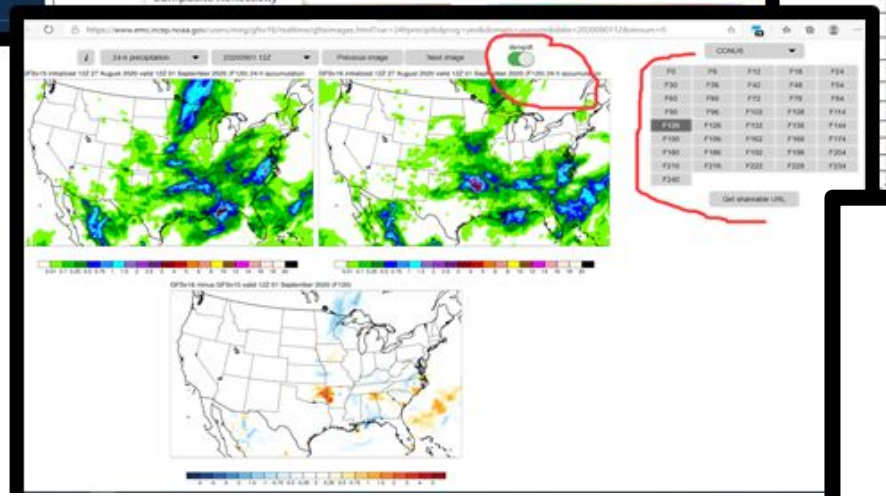


Overall GFSv16 Eval Summary

- For examined retro cases, GFSv16 appears to:
  - exhibit **slightly superior skill** at early-identification, location, and intensity of features
  - This superiority appears more often than not across all run/projection times, but is **most evident** at longer lead times (>132hrs)
- Additional output fields, domain views, soundings made available for the retro cases, as well as the real-time parallel views and improved d(prog)/dt functionality, all **GREATLY** enhanced the ability to assess and feedback.
- Kudos to Geoff and the larger MEG group for these evaluation improvements! Tremendous UFS/EPIC V&V foundation.







Changes to products:

- Addition of additional vertical levels in the station time series BUFR data
- New levels for the pressure level output (0.01, 0.02, 0.04, 0.07, 0.1, 0.2, and 0.7 hPa)
- New parameters, including 1 and 4 km simulated radar reflectivity, cloud ceiling height, and instantaneous cloud fractions
- Isobar specific humidity records moved from pgrb2 to pgrb2b files
- Replacement of filtered Shuell sea level pressure with unfiltered sea level pressure
- Movement of turbulence and icing severity products to a new separate file

Dorian--2019

Summary

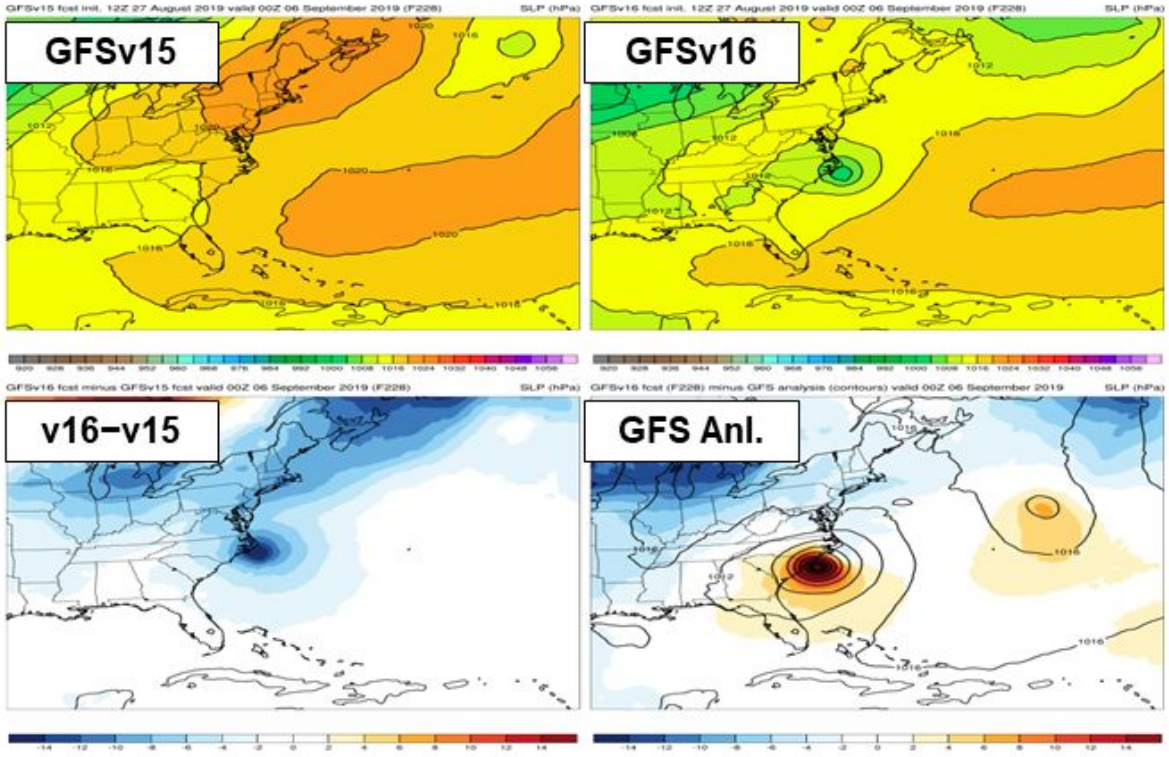
- GFSv16 exhibited earlier identification (fhr=228 and 192), but not in between.
- Better intensity at fhr=144, but worse location.
- No sig differences between v16 and v15 for fhr=132 to 0
- (Barely) early v16 jump on heavy rain swath location, then alike
- CONUS US vs Bahamian landfall

Challenges

Dorian--2019

17

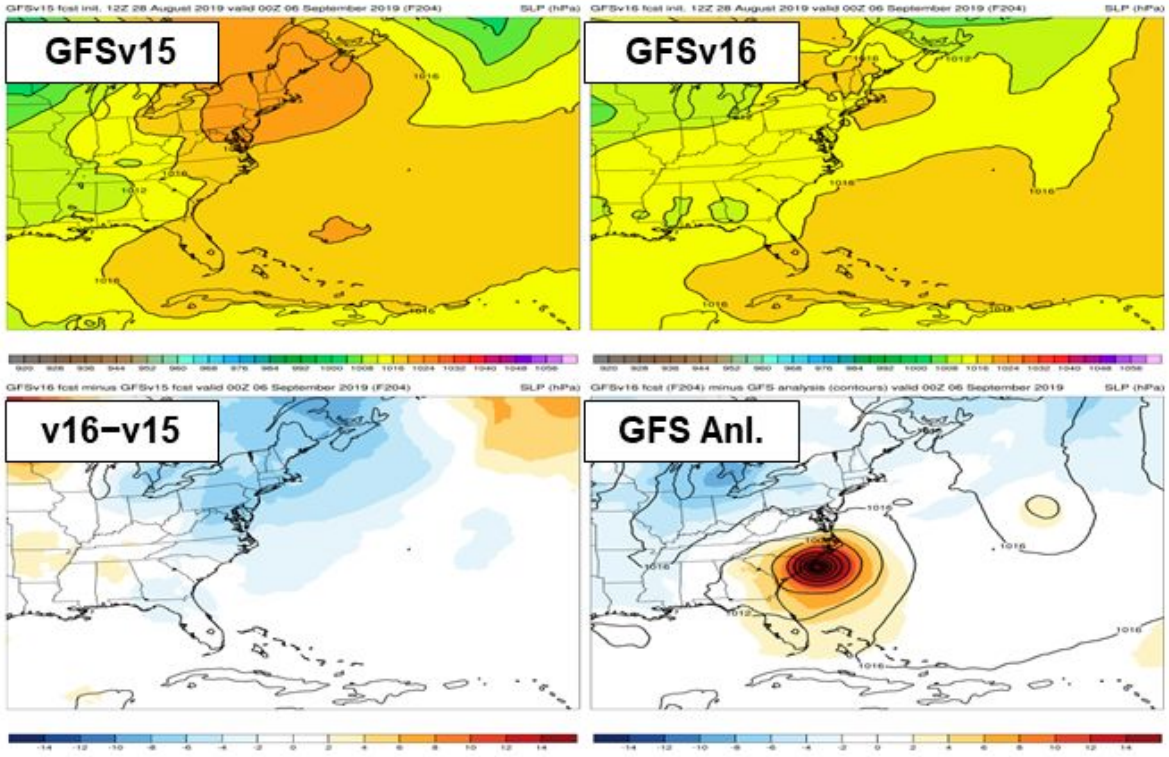
Dorian--2019: MSLP



Dorian--2019 (F228)
Valid: 00Z 09/06/19

- v16 had early identification AND location of Dorian; v15 did not

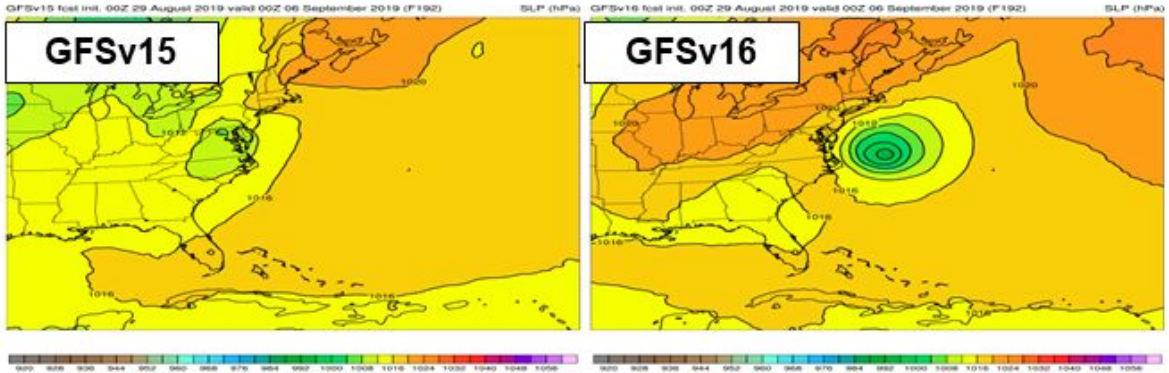
Dorian--2019: MSLP



Dorian--2019 (F204)
Valid: 00Z 09/06/19

- However, 24hrs later, neither version showed Dorian

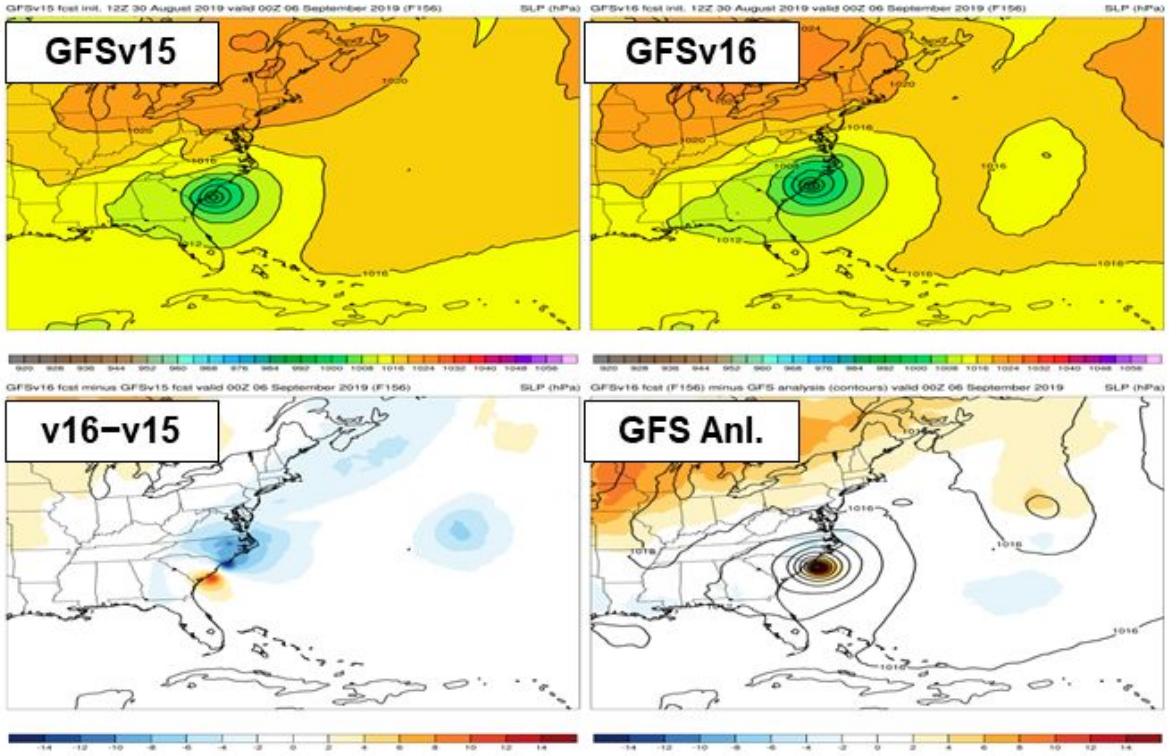
Dorian--2019: MSLP



Dorian--2019 (F192)
Valid: 00Z 09/06/19

- Now, 12hrs later, v16 returns to show a Dorian-like system, v15 does still does not

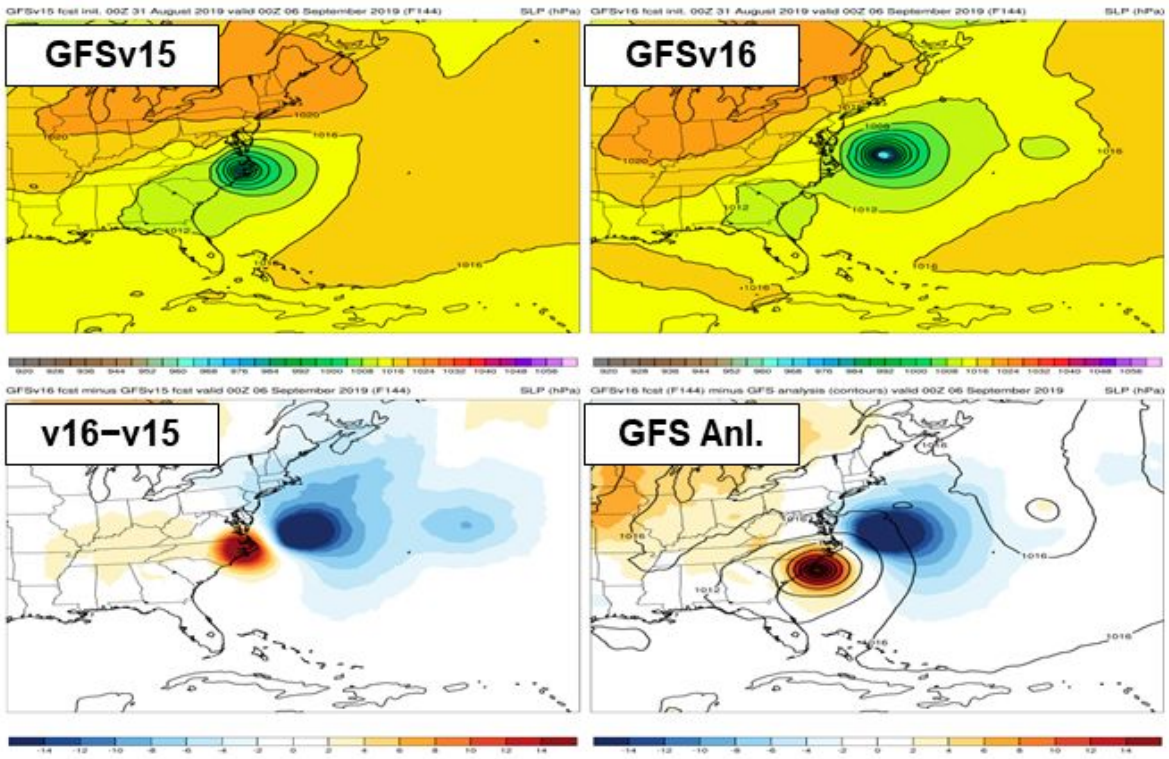
Dorian--2019: MSLP



Dorian--2019 (F156)
Valid: 00Z 09/06/19

- At this projection, v15 first begins to show Dorian along with v16.
- v16 has slightly better location/intensity

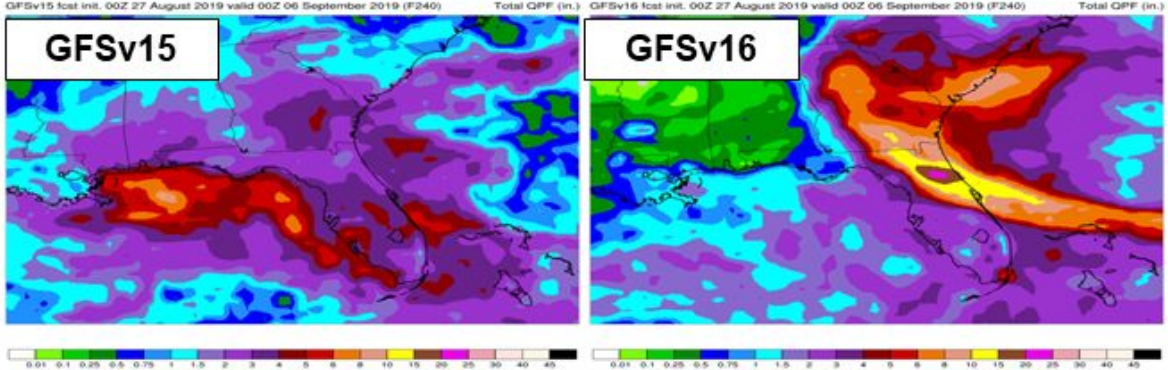
Dorian--2019: MSLP

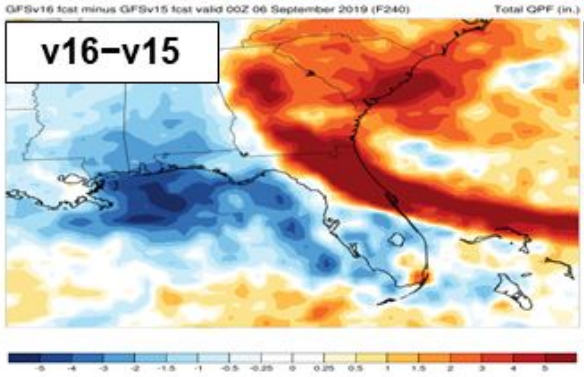


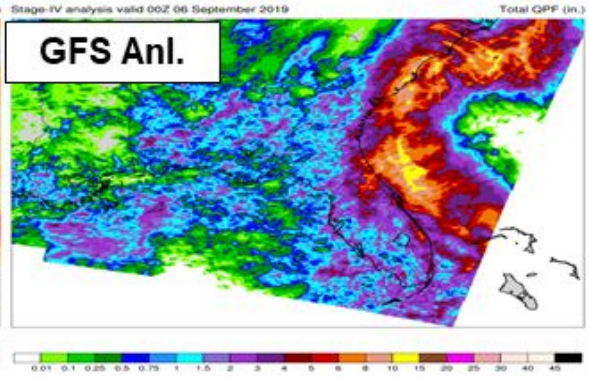
Dorian--2019 (F144)
Valid: 00Z 09/06/19

- v16 has a better intensity match, but worse location
- Little noticeable differences from FcstHr=132 to 0 (not shown).

Dorian--2019: Total Rainfall







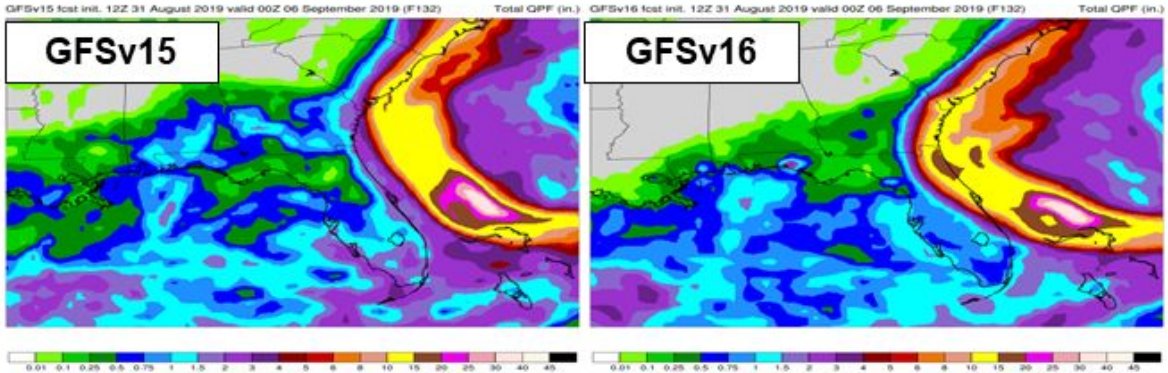
Dorian--2019 (F240)
Valid: 00Z 09/06/19

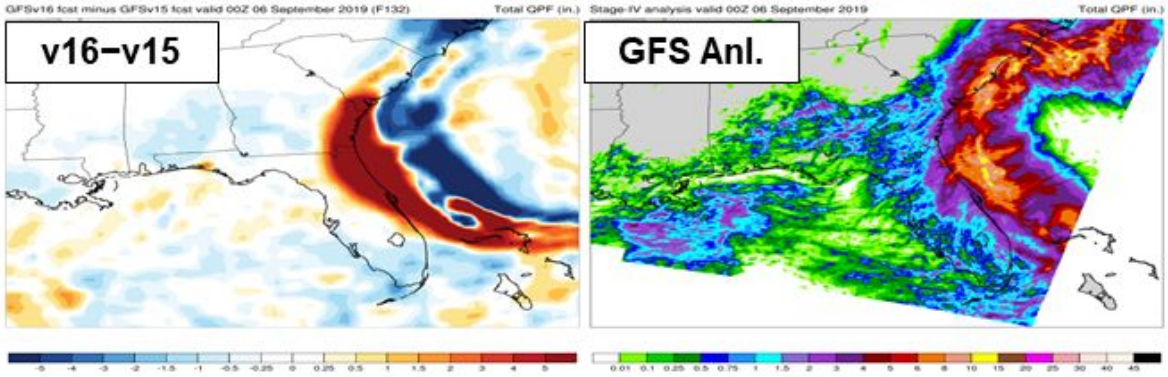
- v16 better at indicating observed higher (yellow=10”) amounts, albeit wrong location, and had storm move into N. FL in this run

Dorian--2019

24

Dorian--2019: Total Rainfall

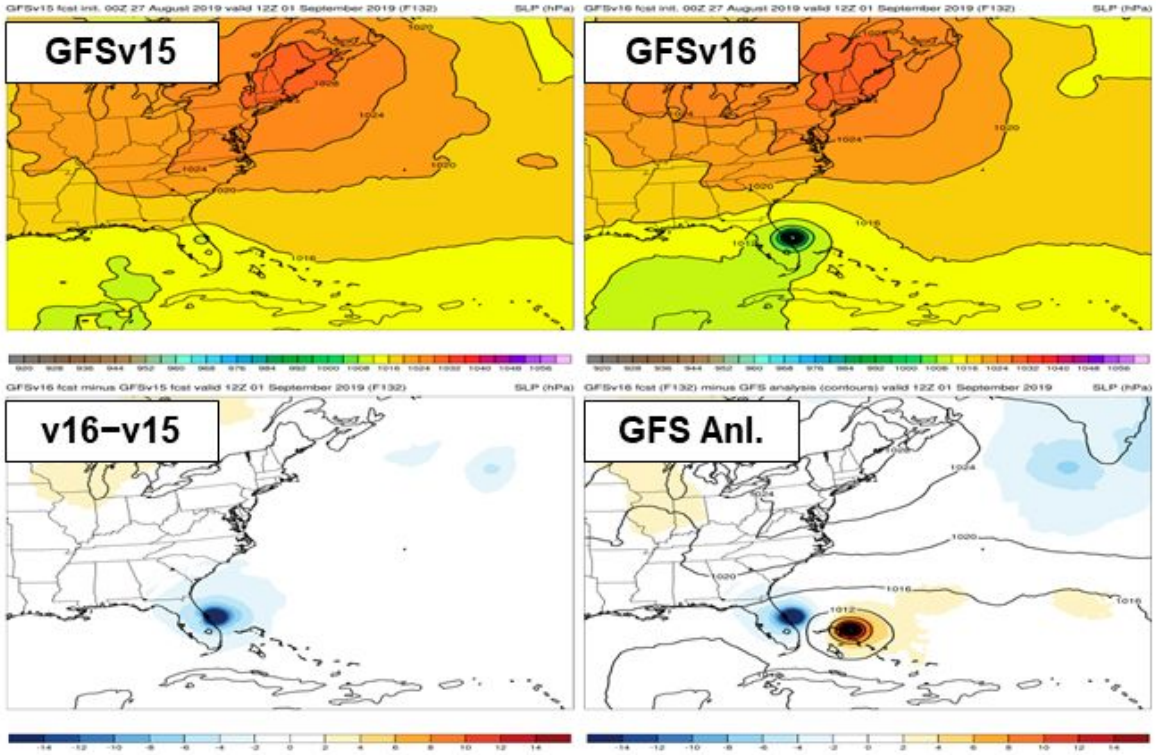




Dorian--2019 (F132)
Valid: 00Z 09/06/19

- By this projection, and closer to event, very similar heavy rainfall swaths, though v16 had more, along N. FL coast, which was observed

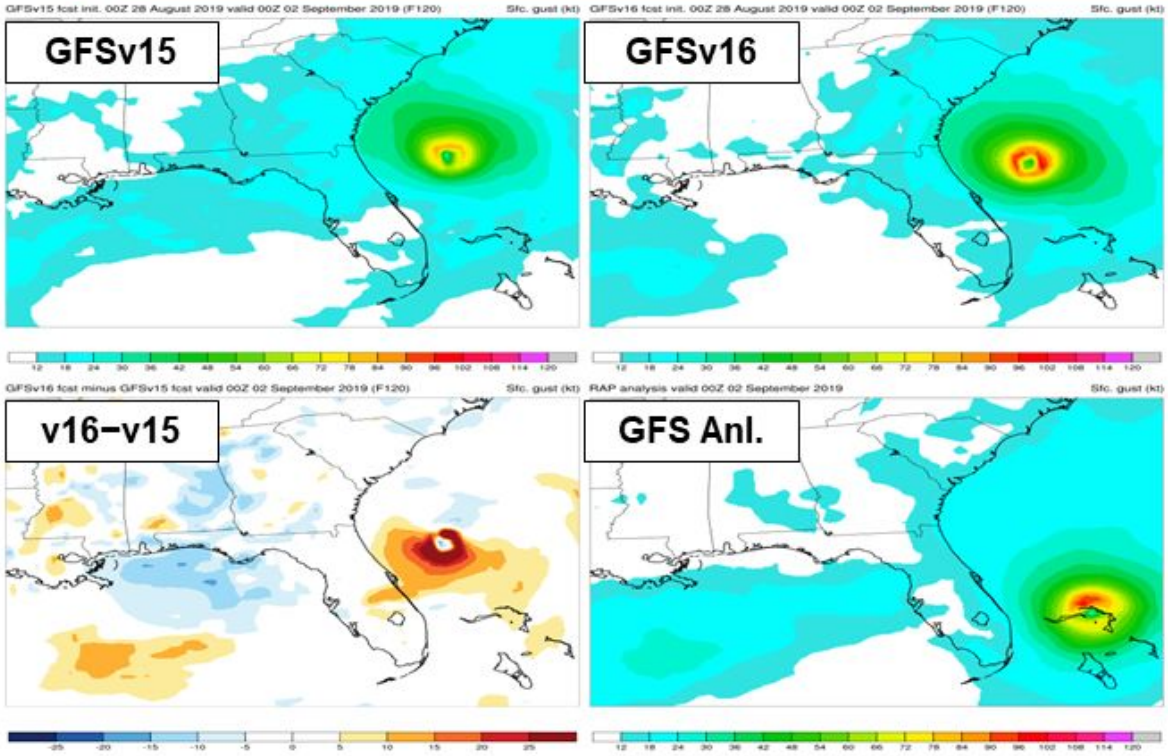
Dorian (Bahamian Landfall)--2019: MSLP



Dorian--2019 (F132)
Valid: 12Z 09/01/19

- 5 days earlier than US landfall
- v16 had earlier indication of intense cyclone near western Bahamas, close to observed

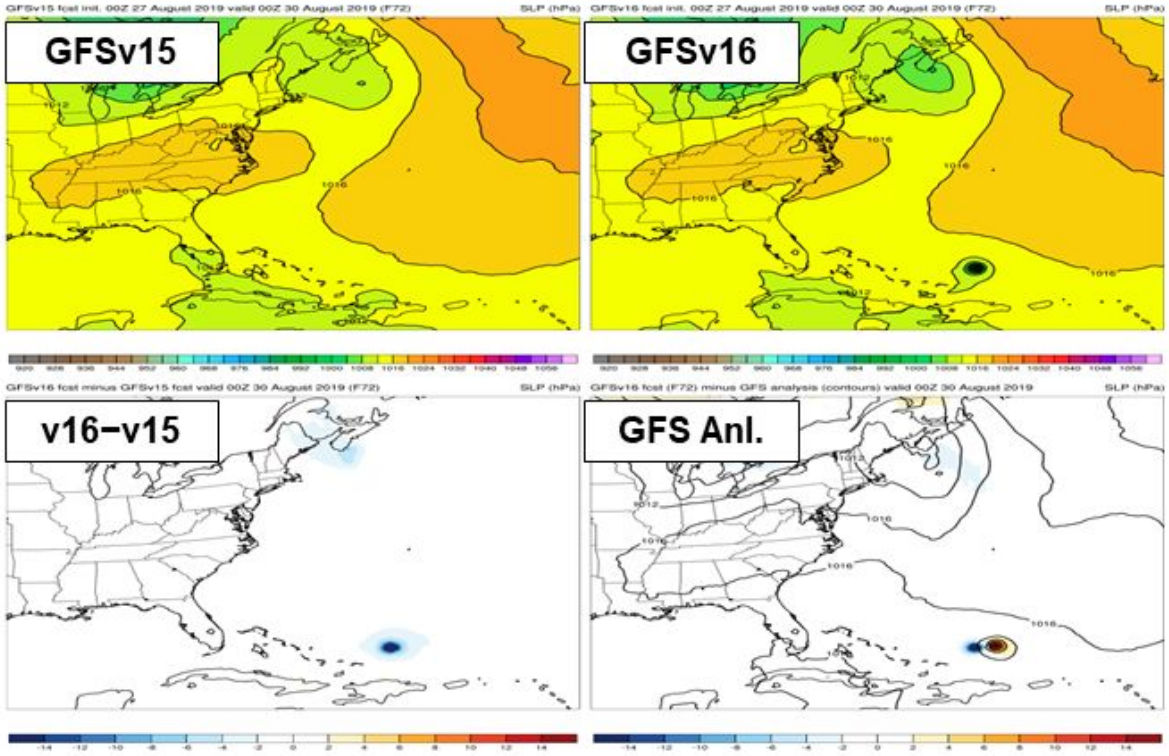
Dorian (Bahamian Landfall)--2019: Sfc Wind Gusts



Dorian--2019 (F120)
Valid: 00Z 09/02/19

- Though both positionally similar, v16 better, more intense sfc wind gusts forecast

Dorian (Bahamian Landfall)--2019: MSLP



Dorian--2019 (F072)
Valid: 00Z 08/30/19

- 4 days before NW Bahamian landfall, v16 had earlier detection of Dorian

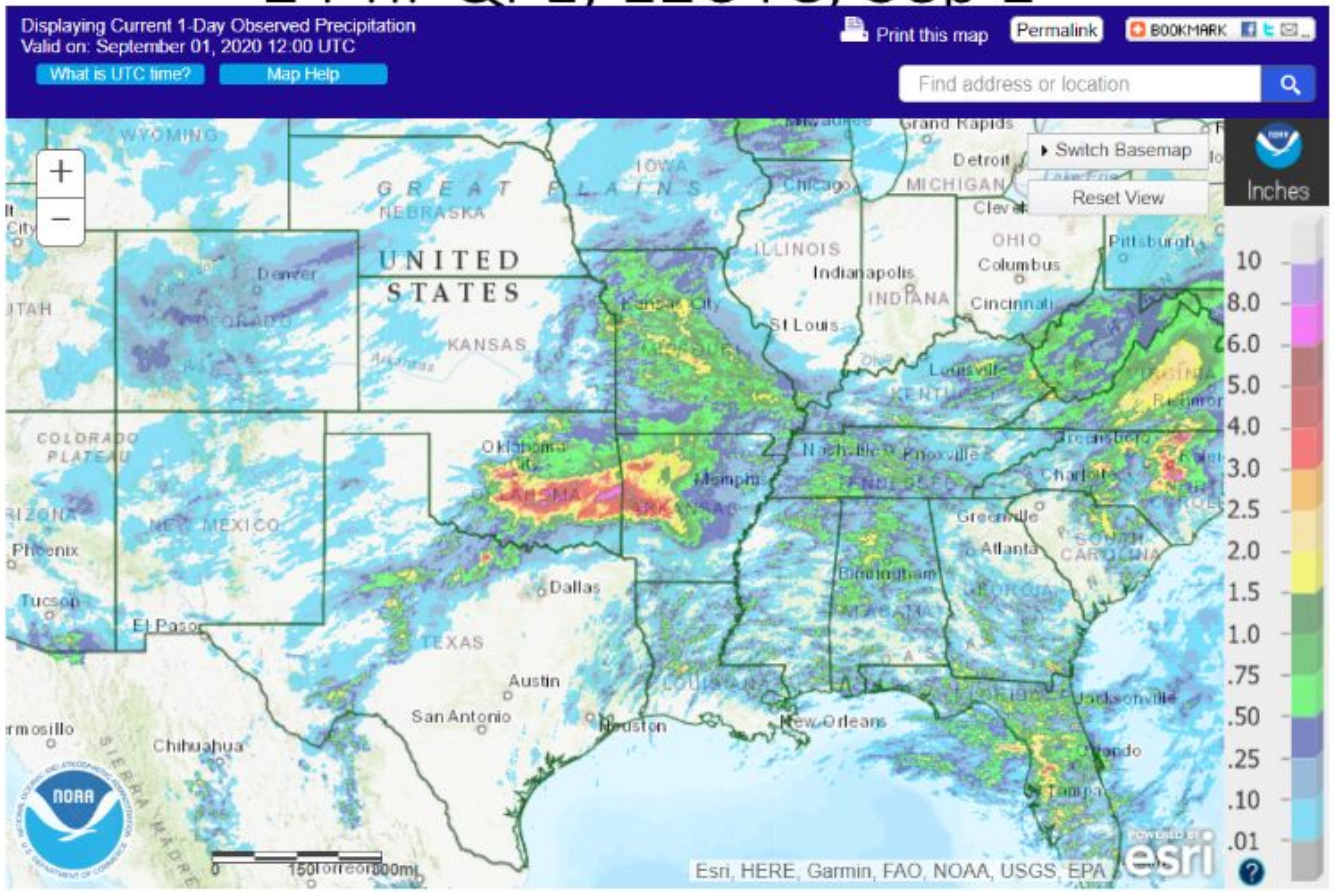
Flash Flood Emergency—Sep 1, 2020

Summary

- Shady Point, OK, just southwest of Fort Smith, AR received 6”+ of rainfall in 24hrs

- As could be seen in helpful d(prog)/dt interface, v16 in general had better location and rainfall intensity performance, at a majority of forecast time steps.

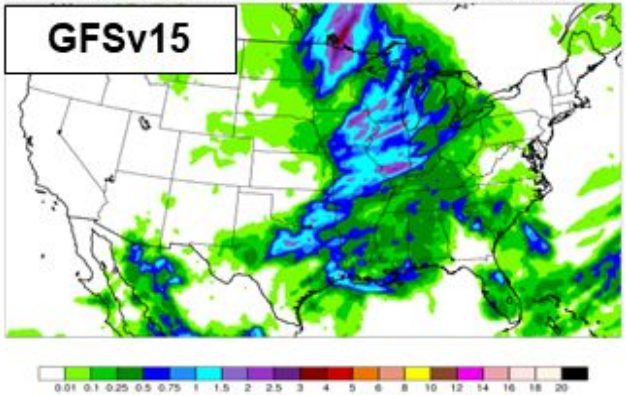
24-hr QPE, 12UTC, Sep 1



Flash Flood Emergency—Sep 1, 2020

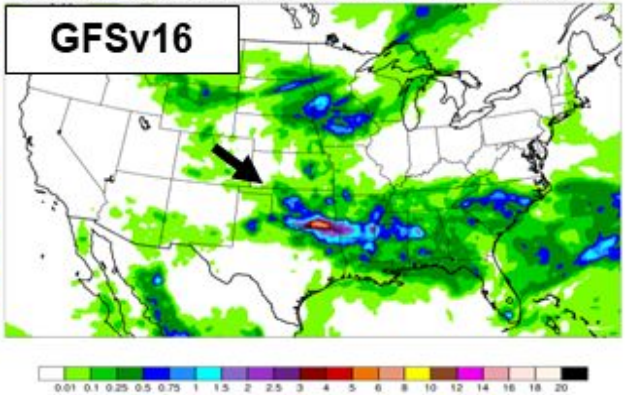
GFSv15 initialized 06Z 25 August 2020 valid 12Z 01 September 2020 (F174) 24-h accumulation

GFSv15



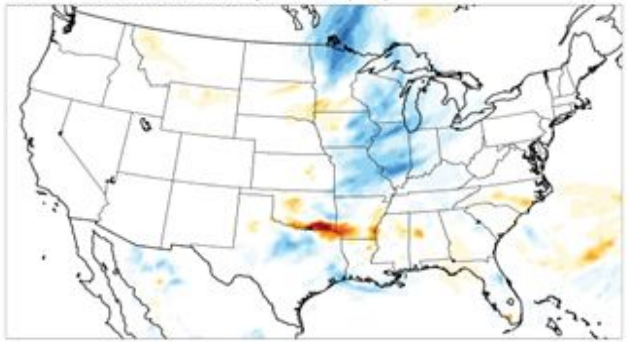
GFSv16 initialized 06Z 25 August 2020 valid 12Z 01 September 2020 (F174) 24-h accumulation

GFSv16



v16−v15

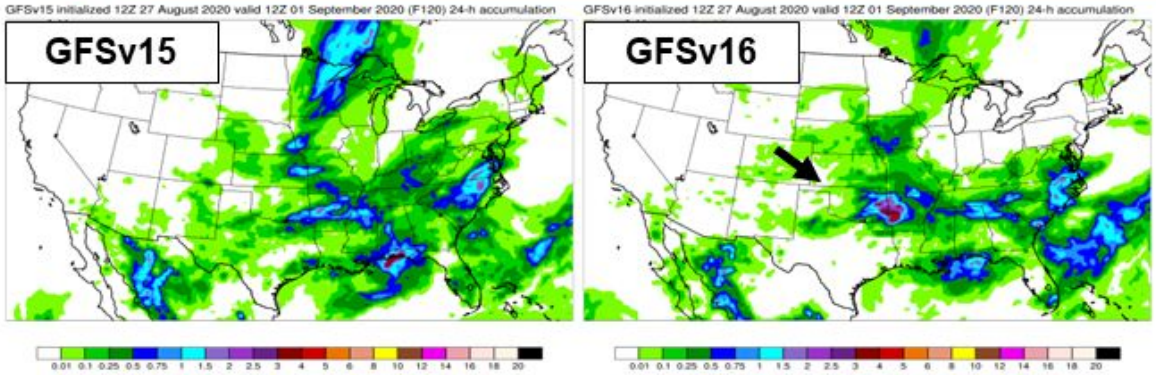
GFSv16 minus GFSv15 valid 12Z 01 September 2020 (F174)

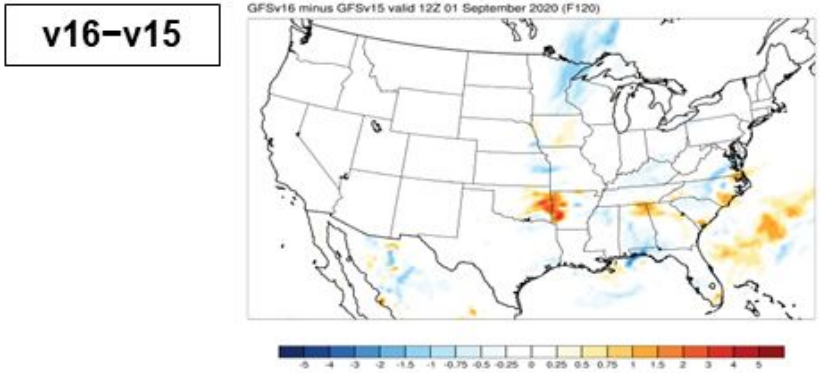


Flash Flood (F174)
Valid: 12Z 09/01/20

- v16 better (higher amounts, early indication) of the rainfall amounts
- d(prog)/dt loop options

Flash Flood Emergency—Sep 1, 2020

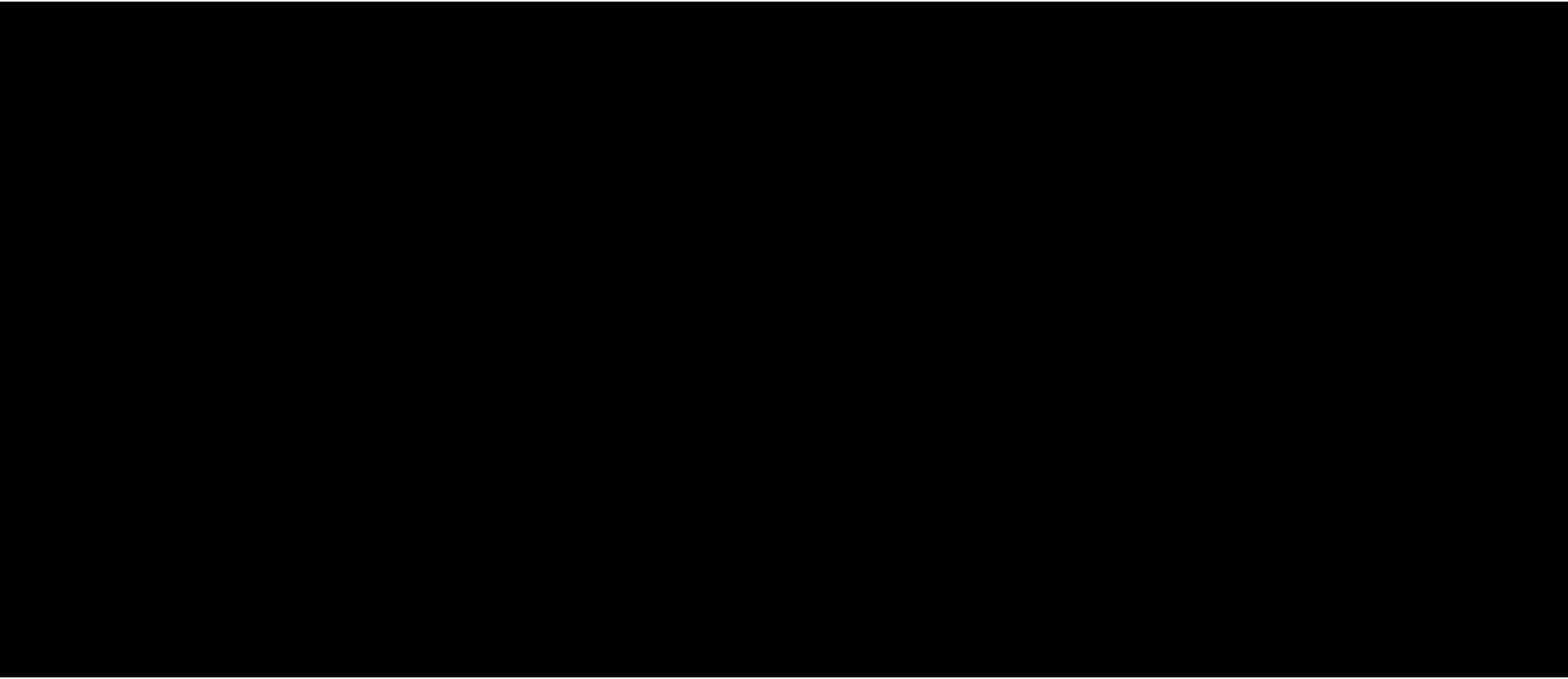




Flash Flood (F120)
Valid: 12Z 09/01/20

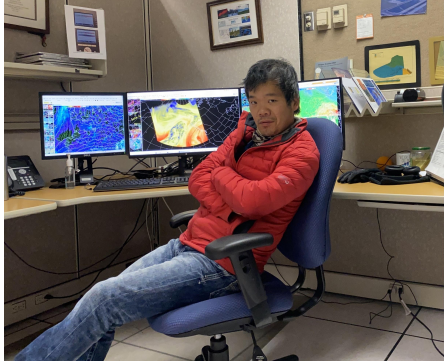
- v16 again higher amounts in eastern OK

Flash Flood Emergency—Sep 1, 2020



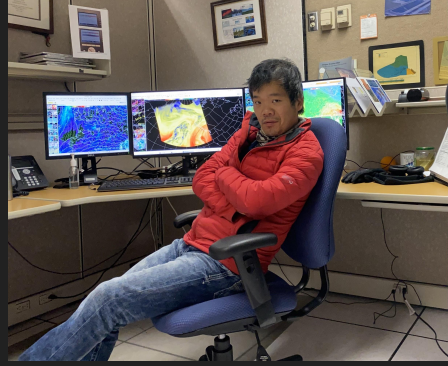
Overall GFSv16 Eval Summary

- For examined retro cases, GFSv16 appears to:
  - exhibit **slightly superior skill** at early-identification, location, and intensity of features
  - This superiority appears more often than not across all run/projection times, but is **most evident** at longer lead times (>132hrs)
- Additional output fields, domain views, soundings made available for the retro cases, as well as the real-time parallel views and improved d(prog)/dt functionality, all GREATLY enhanced the ability to assess and feedback.
- Kudos to Geoff and the larger MEG group for these evaluation improvements! Tremendous UFS/EPIC V&V foundation.



Emily Niebuhr
David Levin
Jason Ahsenmacher
Alaska Region

Real-time Analysis: Lead Forecaster inputs from Fairbanks WFO - Jason Ahsenmacher

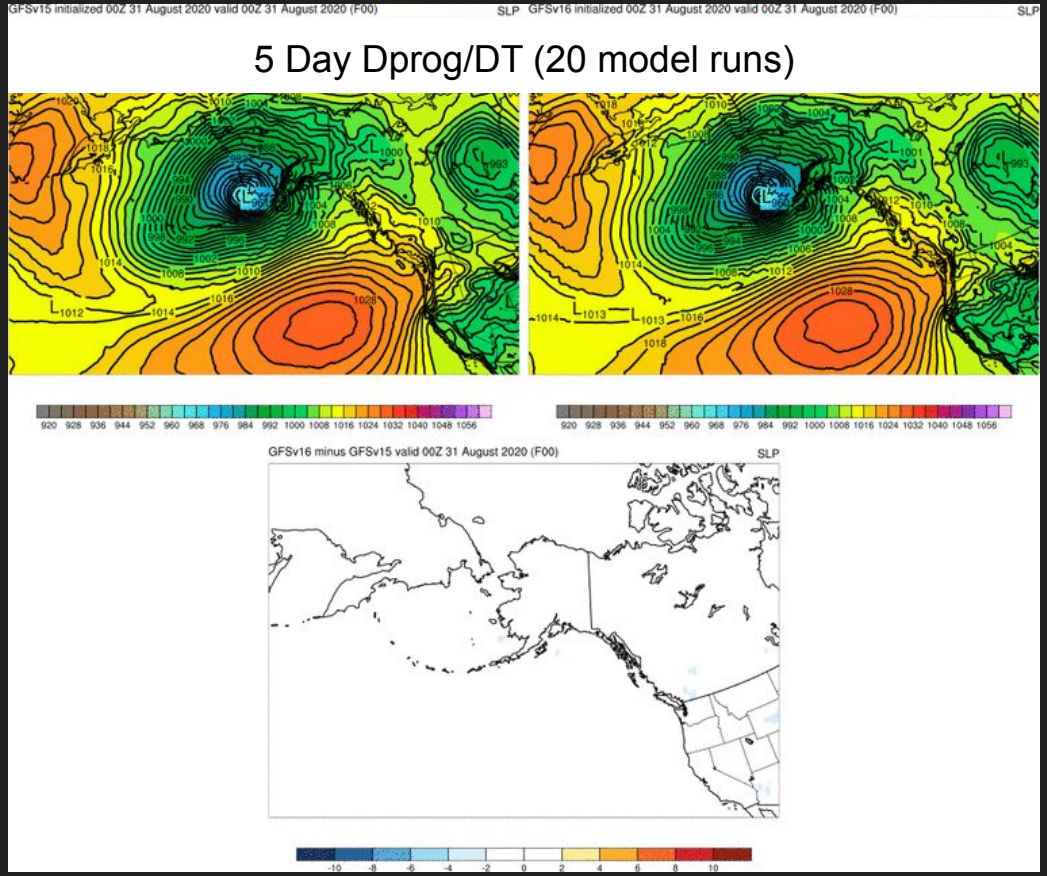


think the best example is by far the remnants of Bavi,

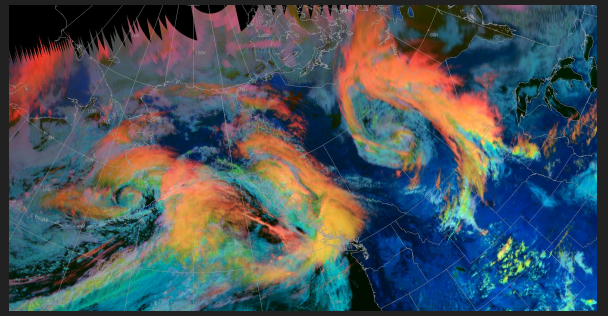
- Remnants of typhoons and subtropical diabatic anomalies play a very large role in fall across the Bering Sea and Alaska mainland.
- A recurving typhoon over Japan can be in the Bering Sea waters by day 3, and have large downstream impacts over the Mainland shortly thereafter.
- Historically, this was a large forecast problem for the GFS15 and previous versions of the GFS for Alaska. Oftentimes, these recurving typhoons and/or strong diabatic anomalies (usually some sort of MJO wave) do not result in huge hurricane force lows, but are much more typically a phasing event with the "northern stream" polar flow. Over water phasing events are *extremely* challenging for numerical weather models to simulate,

MSLP: Operational GFS vs GFSv16

- GFSv16 was consistent with a track much closer to reality from about F120 onward
- Operational GFS trended much to far south then had to correct at the last minute
- GFSv16 was much less “jumpy” overall with the low position and strength
- Resulted in coastal flooding in Bristol Bay and hurricane force winds along Dutch Harbor



Improvements

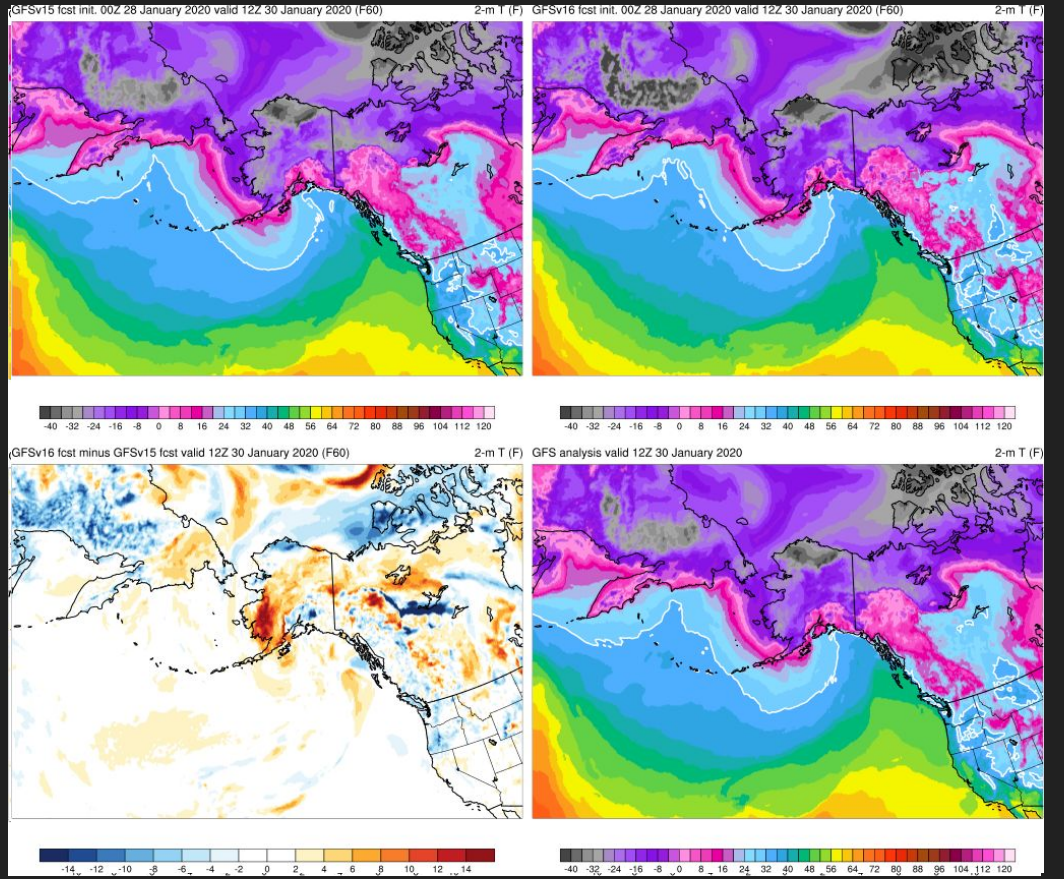


- The old version 15 GFS showed what has often been a significant issue with the GFS (and other models, as well), and that is "flip-flopping" back and forth, which results in poor confidence and *hard to develop forecast messaging.*

- In this case, what made the performance of the new version 16 FV3 particularly impressive was the amazingly stable dprog/dt, which, for 120 hours (20 model runs) properly simulated a Bristol Bay landfall instead of a Gulf of Alaska low.
- While this may sound trite given how close they are, this is a common model error (as seen in the version 15 GFS), as the terrain along the Alaska Peninsula dramatically influences triple point low development given the high arc of volcanic mountains in excess of 5000-9000 feet.
- In zonal flow, models have historically suffered large errors in low tracks as they historically have struggled with simulating whether a low moves into Bristol Bay (less common) or form a triple point along/south of the Alaska Peninsula and reform a low in the Gulf of Alaska (much more common).

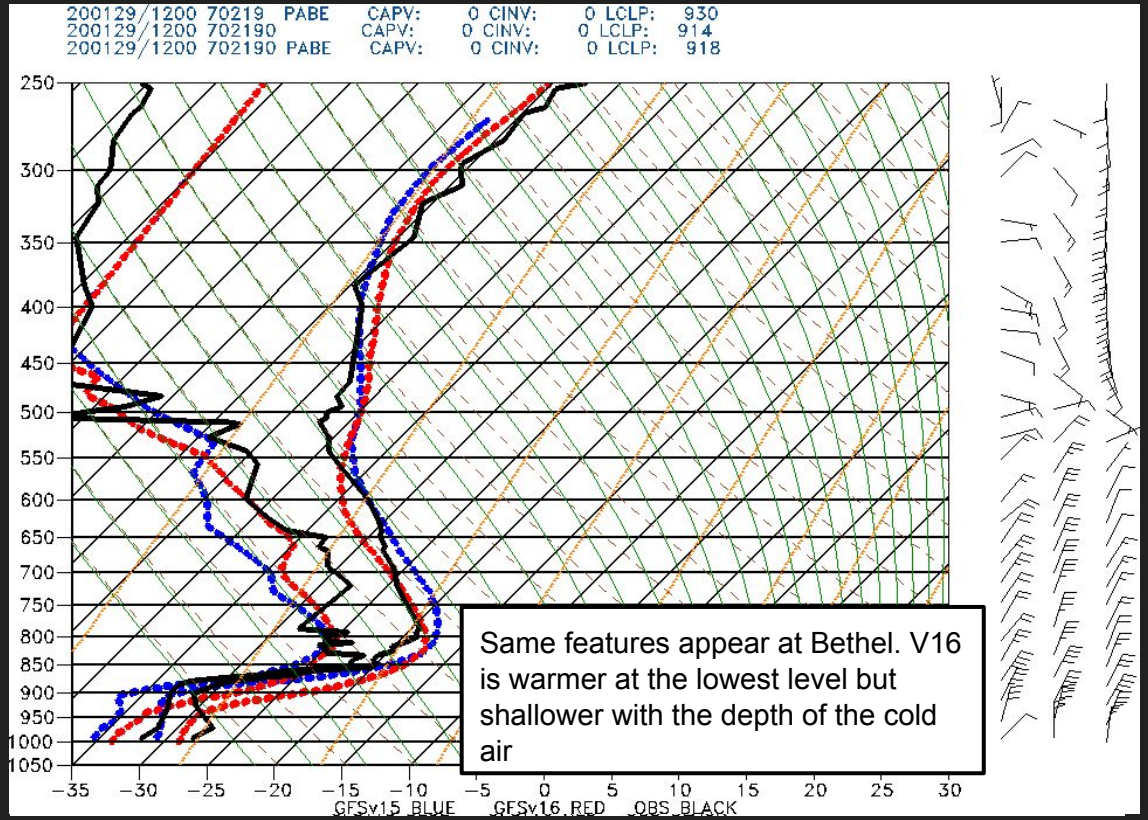
Temperatures: Operational GFS vs GFSv16

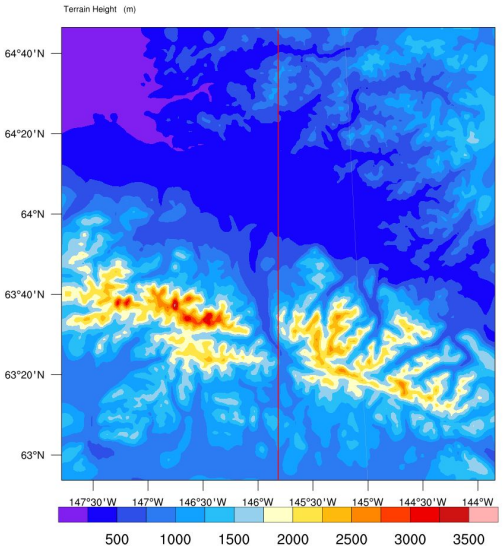
- GFSv16 was consistently warmer than the operational GFS from 850mb and below over the interior of the state and also in SW Alaska west of the Alaska Range.
- However when you look at upstream soundings from Bethel and King Salmon...

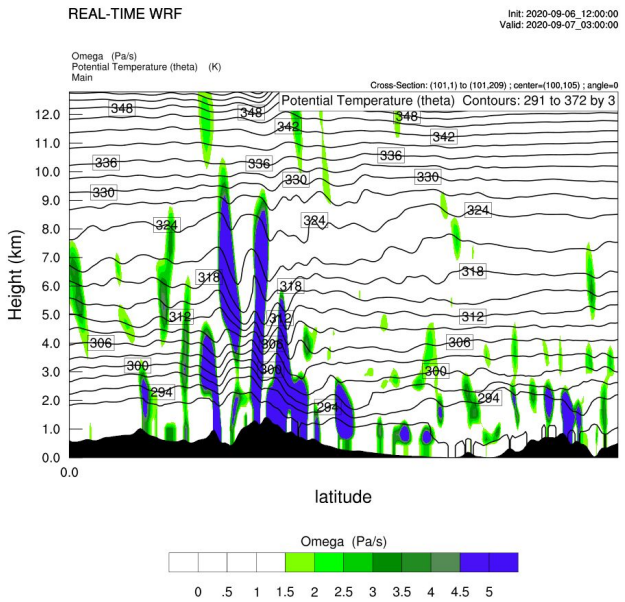


Soundings: Operational GFS vs GFSv16

- V16 seems to be handling the boundary layer temperatures better overall than the operational GFS
- The operational GFS better captures the depth of the cold airmass under the upper trough to the west.
- It's possible that the deeper colder airmass in the operational GFS contributed to the broader and more expansive northern stream trough and the more suppressed southern stream storm track

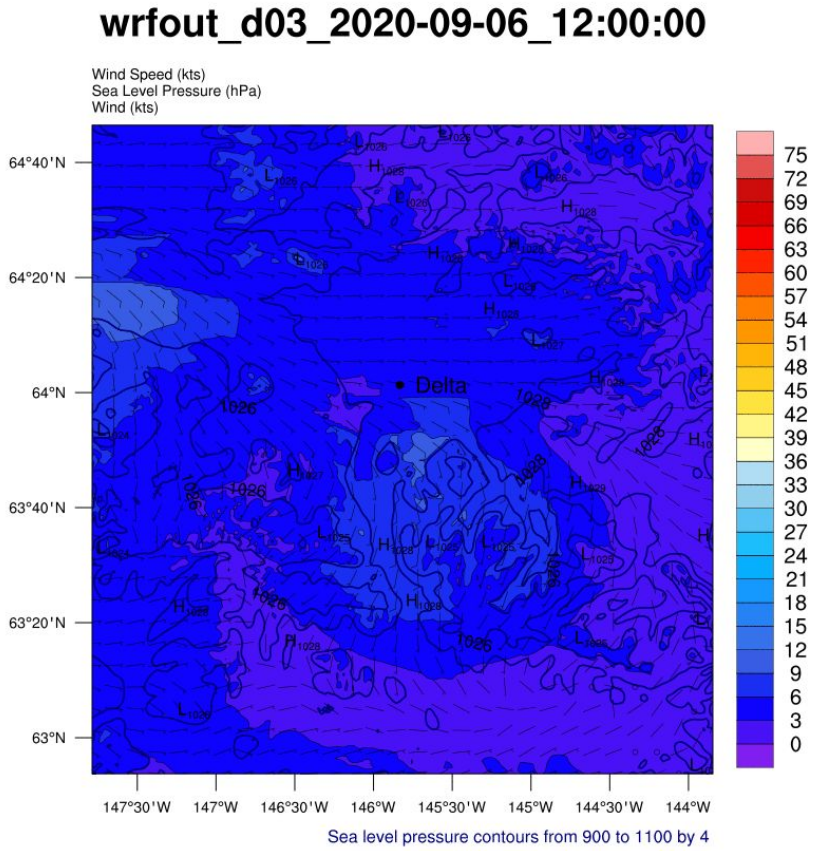


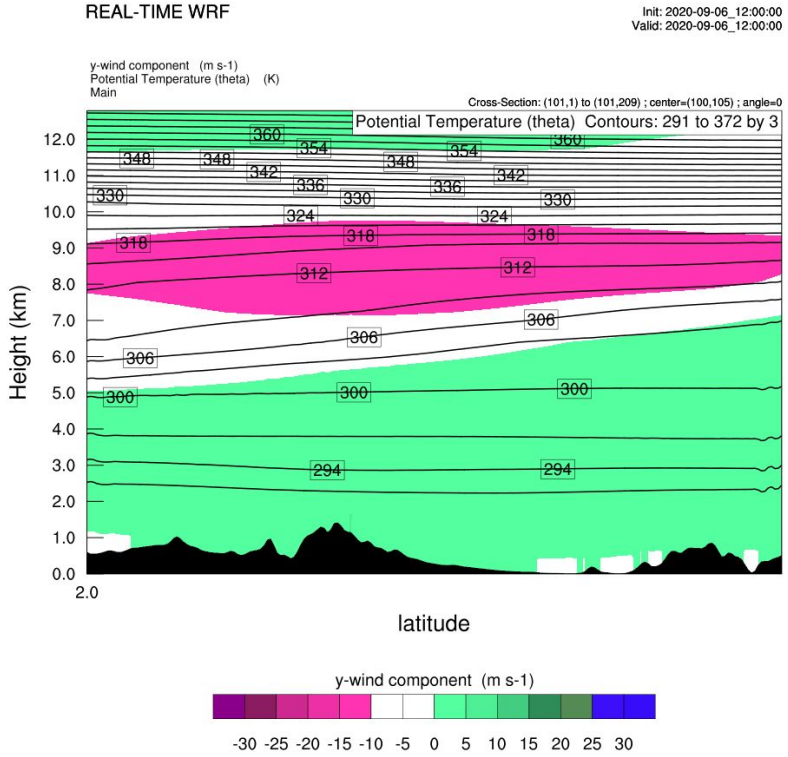




Delta Junction Wind Storm

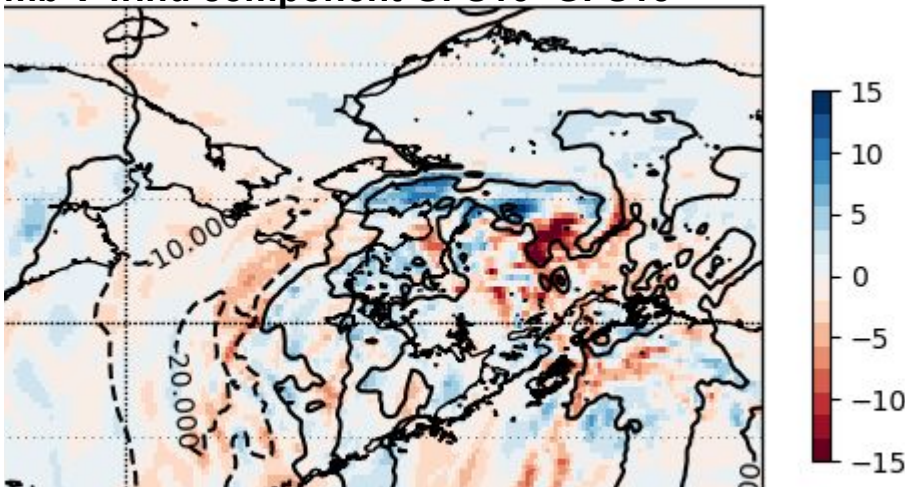
Fairbanks Forecast Office 2020 Sept 7



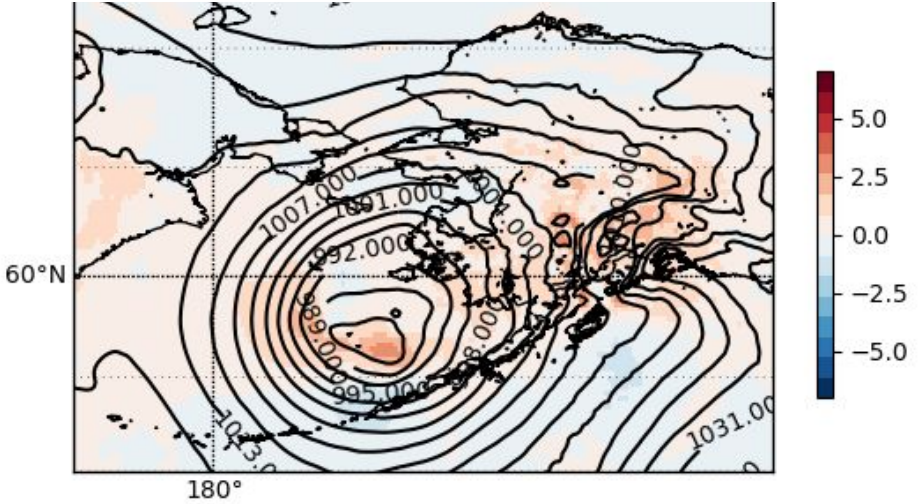


1 km WRF Run to capture gap flow- how does GFS16 capture mountain wave dynamics?

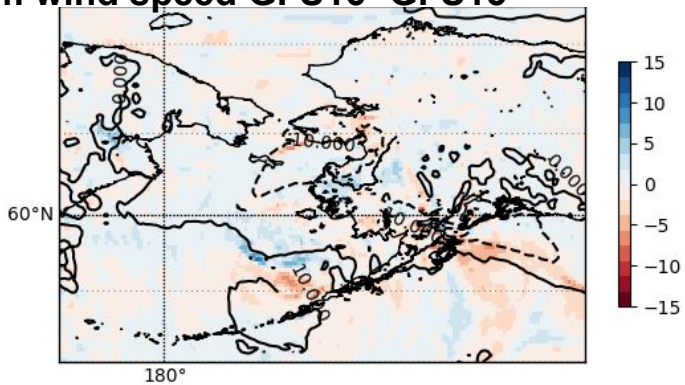
700mb V wind component GFS16- GFS15

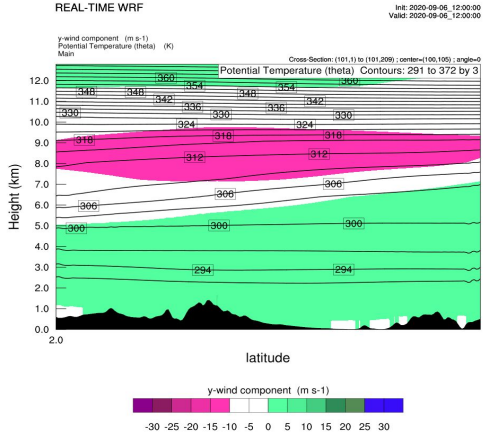


SLP GFS16- GFS15 - contours GFS16

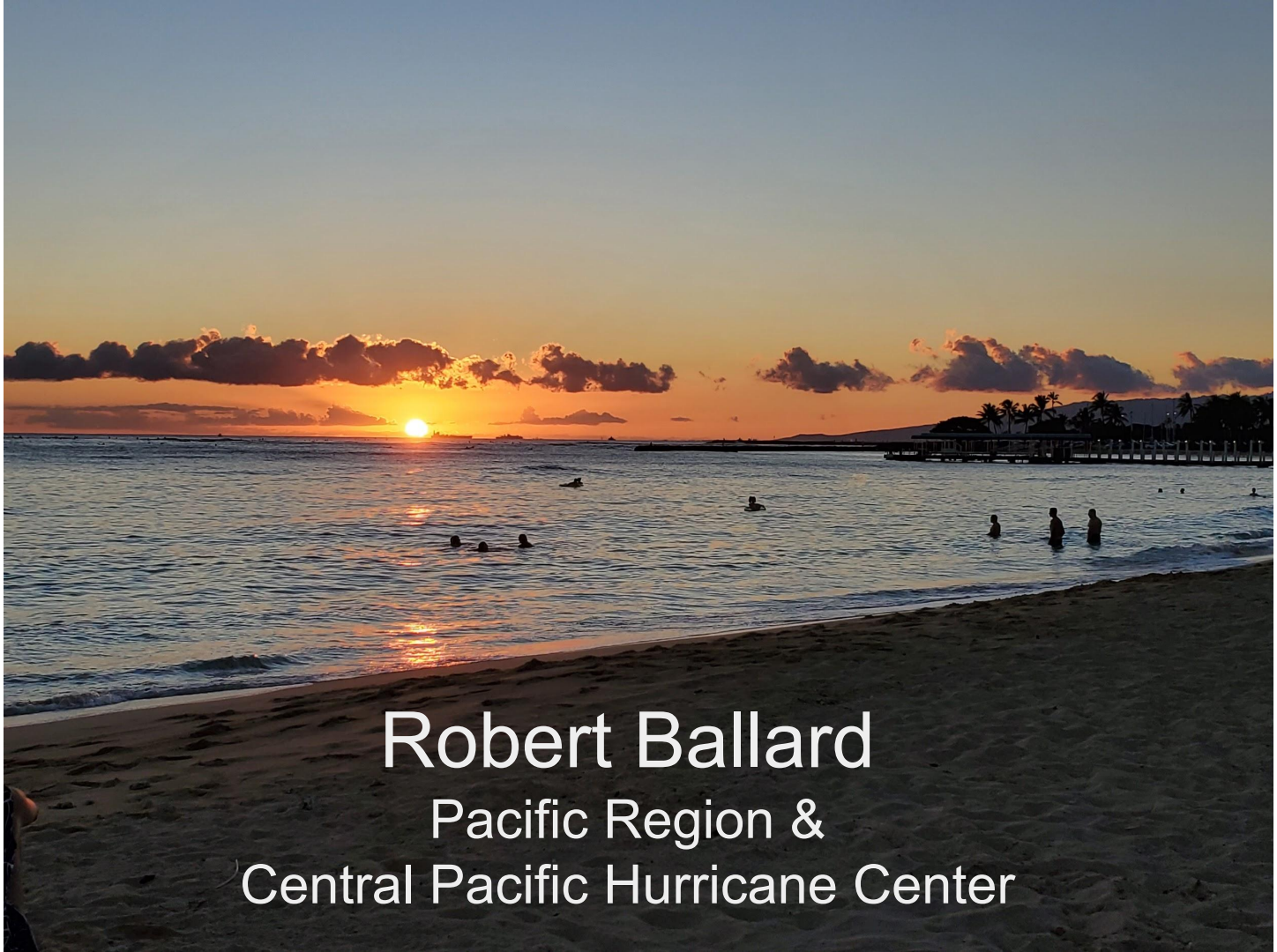


10m wind speed GFS16- GFS15

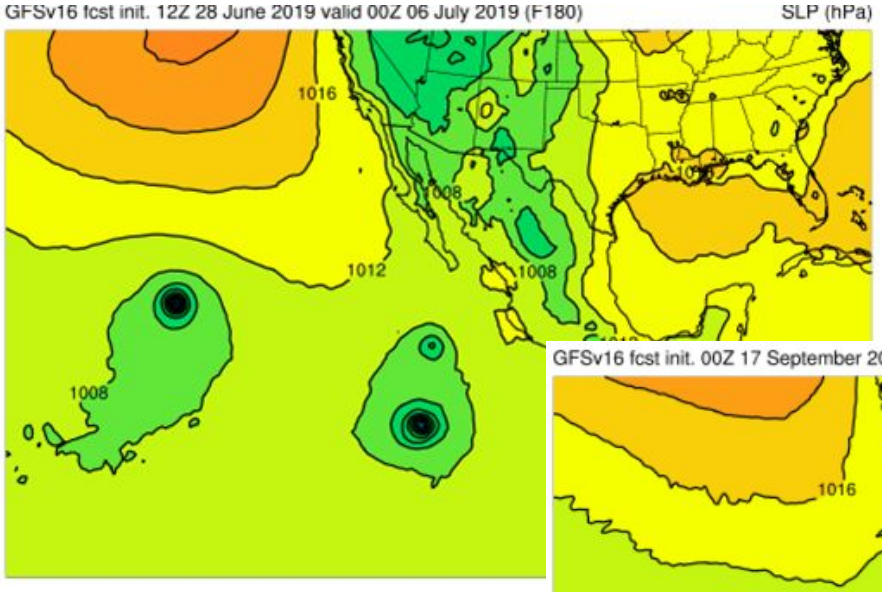




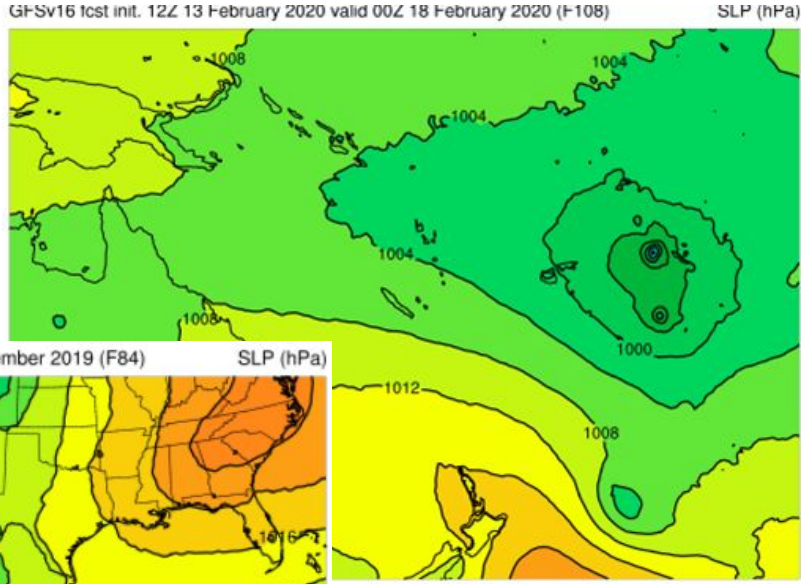
Red color - wind more northerly in GFS16. Blue indicates winds are more southerly than current GFS.


Robert Ballard
Pacific Region &
Central Pacific Hurricane Center

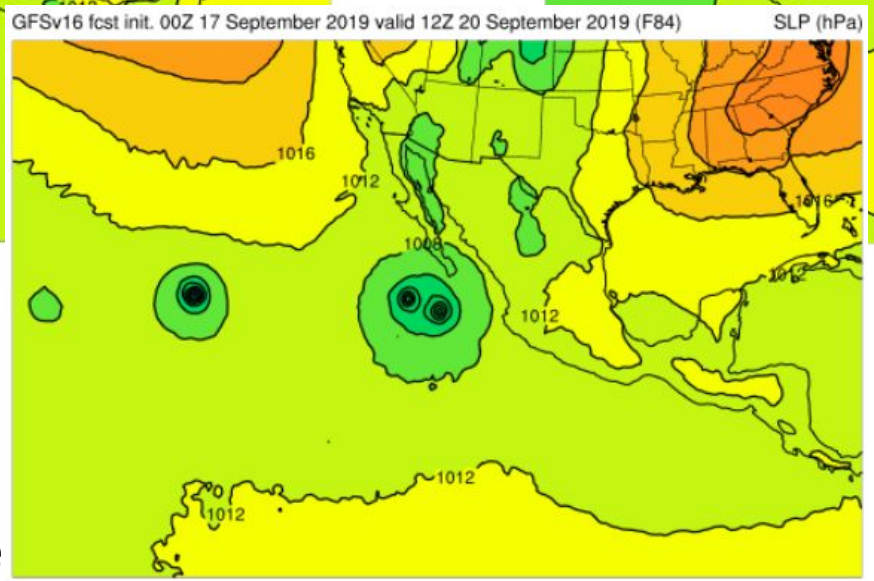
Fujiwhara Effect/Binary Interactions



Barbara (2019) case



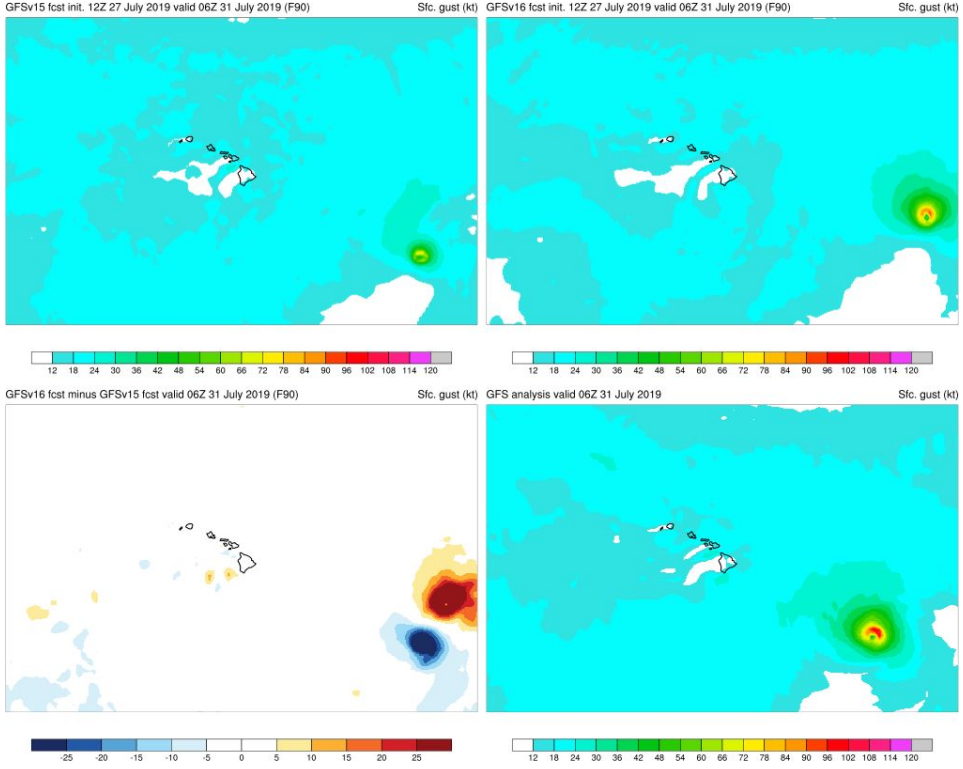
Vicky (2020) case

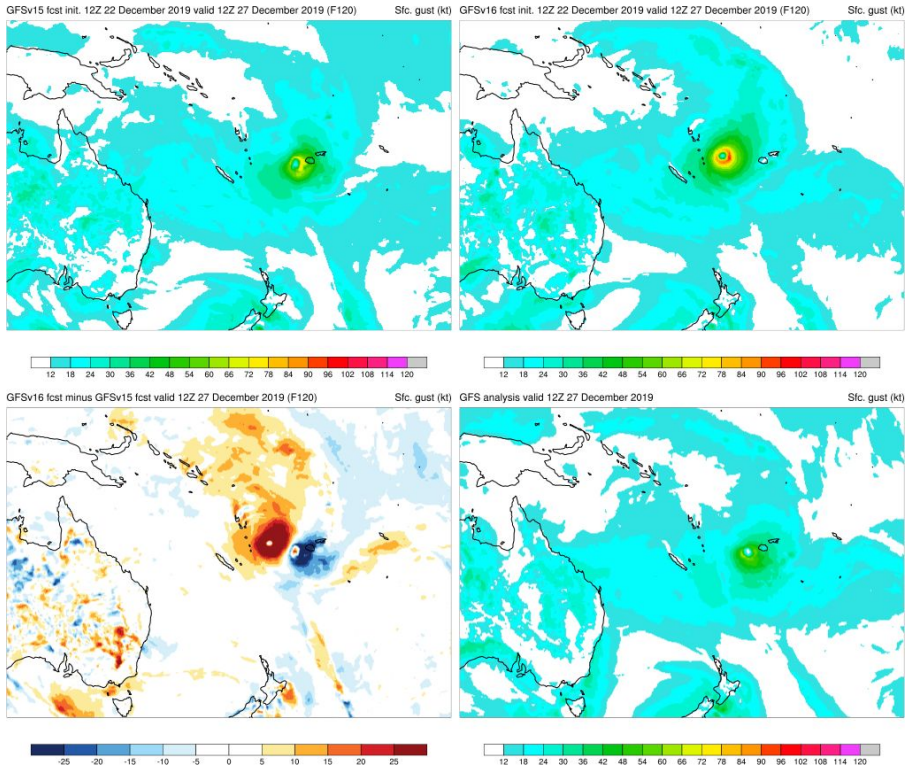


Lorena (2019) case

3 situations where binary interaction was not definitively observed, nor depicted similarly in GFSv15

Right-of-track tendency

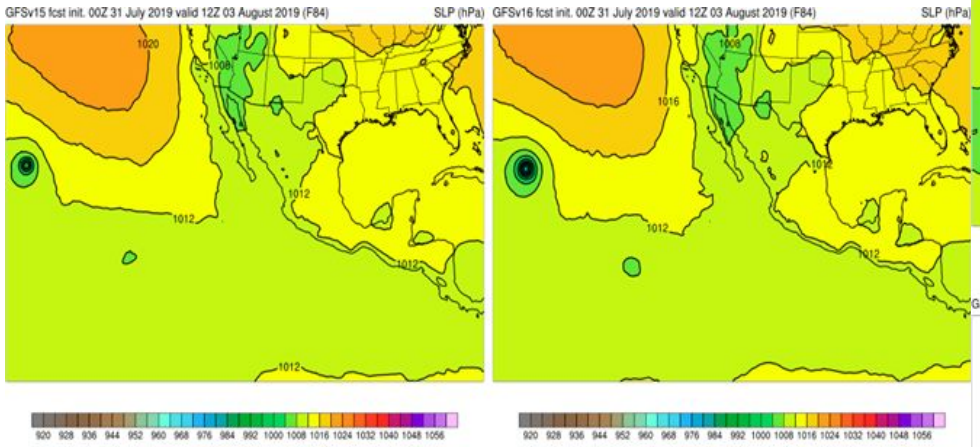


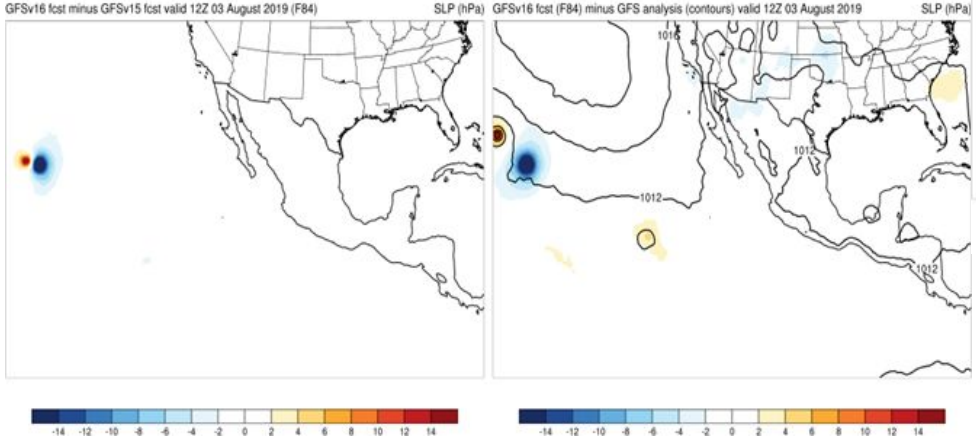


TC Erick (F90)

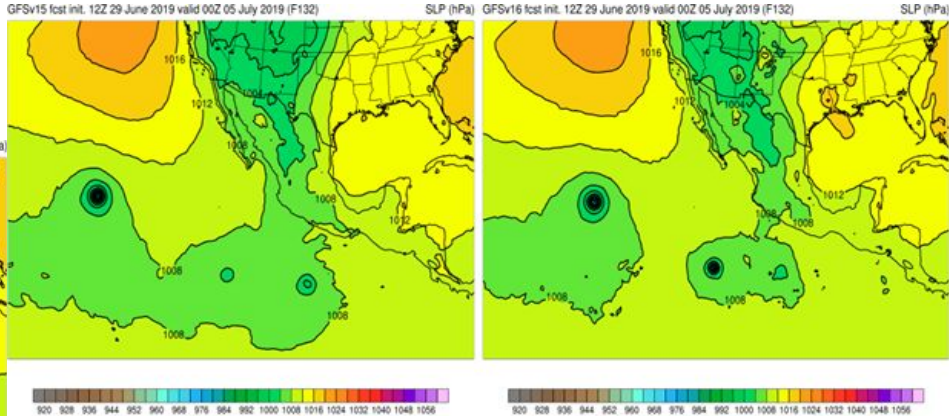
TC Sarai (F120)

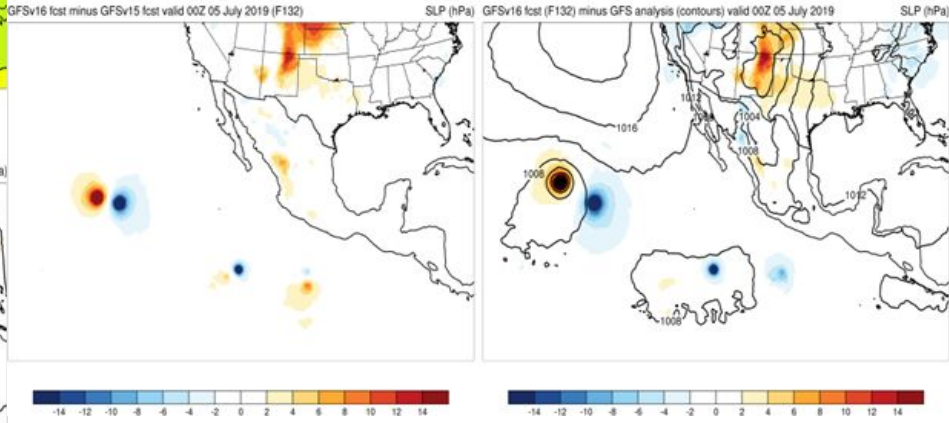
Slow forward speed tendency





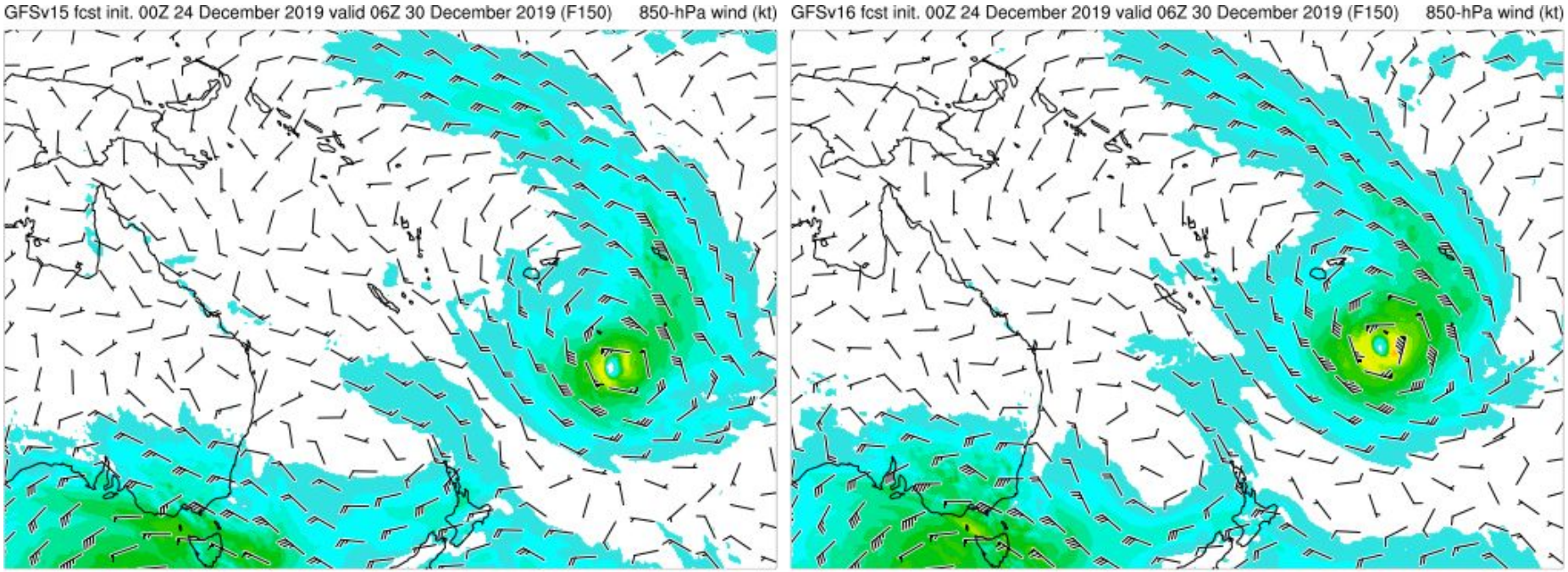
Erick (F84)



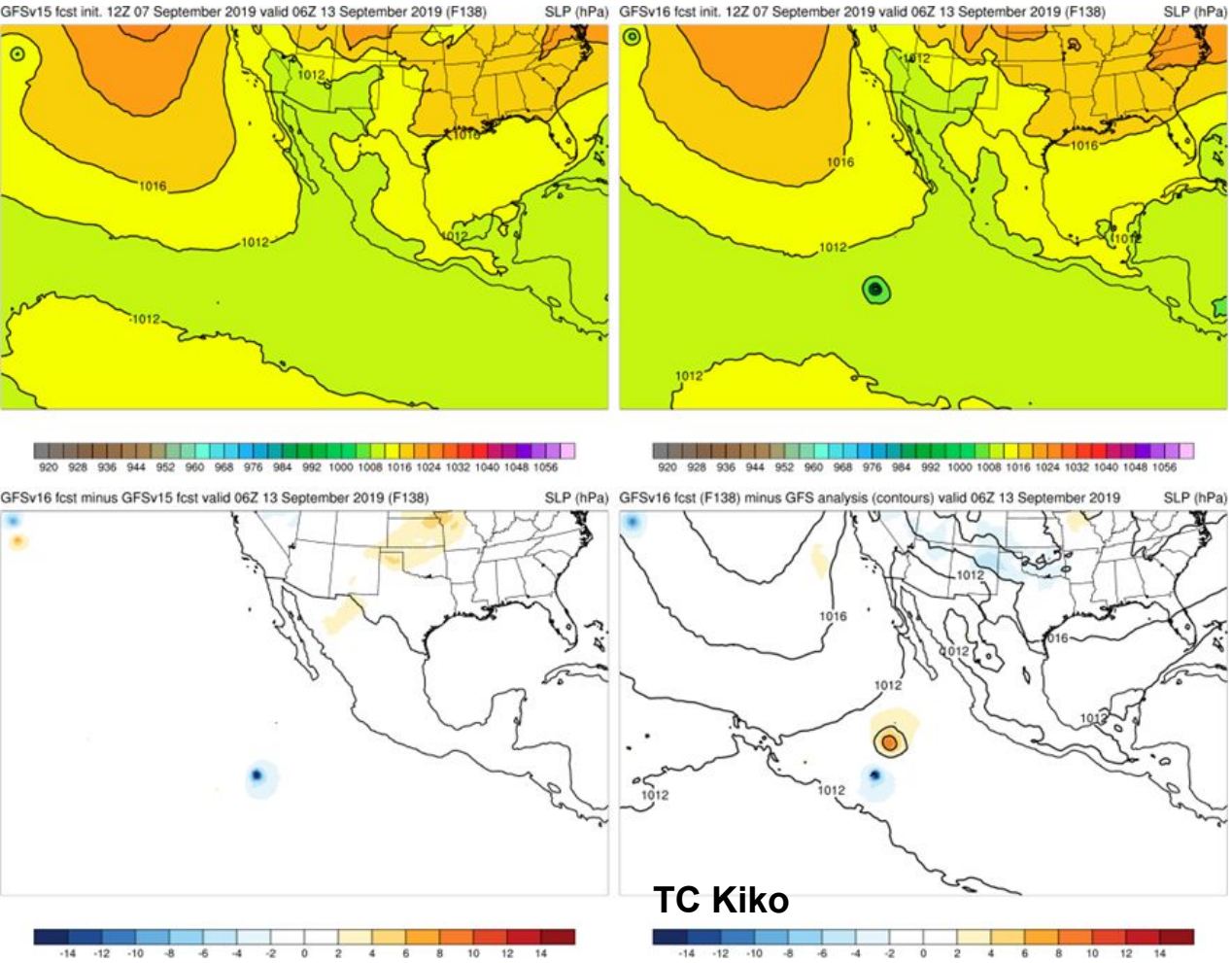


Barbara (F132)

Larger radii & more intense TC tendency
(likely related to other artifacts?)



TC Sarai (F150)



TC Genesis

GFSv16 wins!

- Kiko, Flossie, Douglas, Wasi, Bavi

GFSv15 wins

- Barbara, Erick, Juliette

Tie

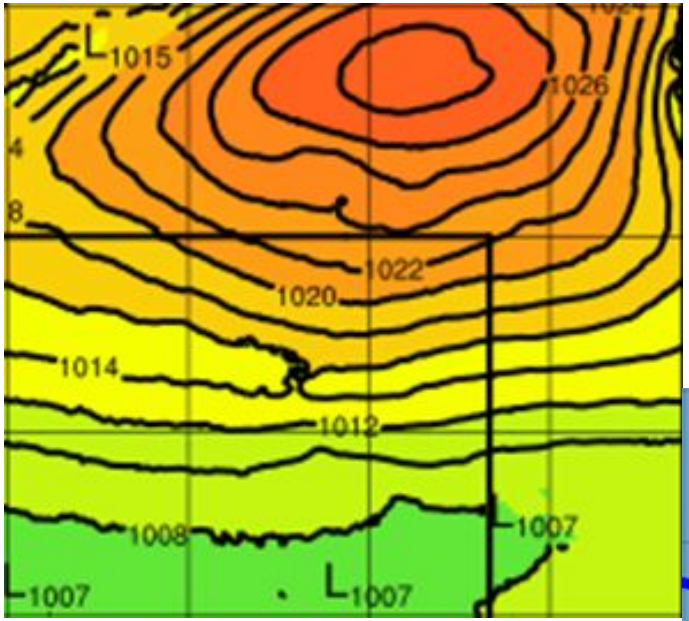
- Lorena, Haishen, Sarai, Maysak

Unknown

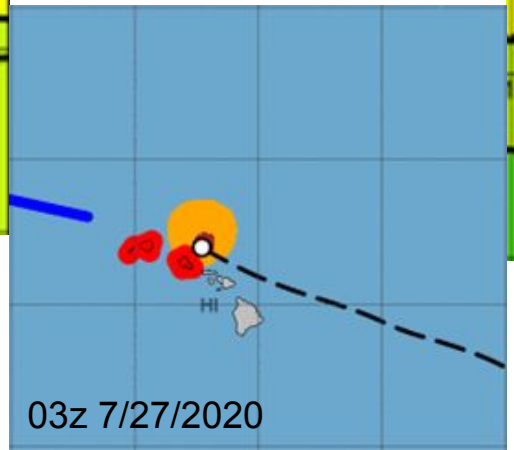
- Vicky

Hurricane Douglas

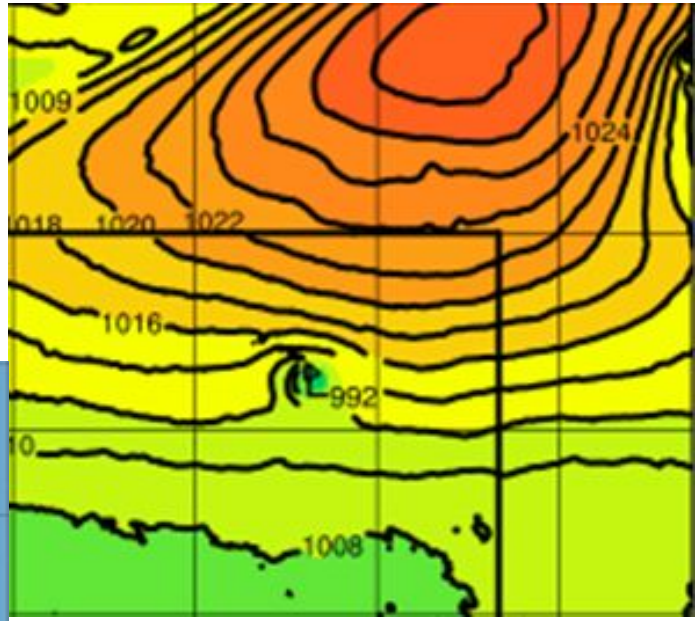
GFSv15



init 00z 7/20/2020
vt 00z 7/27/2020 (F168)



GFSv16



At times the GFSv16 was about two days ahead of the trend in GFSv15.

TC Sarai 240 hour forecast

Amazing guidance for a S Pac tropical cyclone!