THE EMC MODEL EVALUATION GROUP
ASSESSMENT of GFSv15

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Strategic Implementation Plan Coordination Meeting
14 May 2019

Additional materials provided by Fanglin Yang, Vijay Tallapragada, Mark Klein, Ying Lin, and Avichal Mehra
EMC’s Model Evaluation Group

- Established in 2012; now part of EMC’s Verification, Post Processing, & Product Generation Branch
  www.emc.ncep.noaa.gov/users/meg/home
- OUTREACH – the MEG serves as the “customer service” function of EMC with webinars, direct communication, and visits to WFOs
- Supplements the center’s statistical verification/validation efforts by assessing model performance from the perspective of the forecasting community
- Organized evaluation of EMC parallels and experiments
- Provides critical feedback to modelers and management and keeps customers “in the loop” regarding model changes, verification, and forecast issues
- Provides streamlined feedback to outside users with model concerns – EMC is listening to customer/stakeholder feedback
- Conducts weekly-ish webinars, open to the field
The Evaluation of the FV3GFS (GFSv15)
An Unprecedented Evaluation of an NCEP Upgrade
in Terms of Scope and Transparency

• Comprehensive central web site
• Retrospective runs covering 3 cold and 3 warm seasons
• Full statistics covering all retro and real-time periods
• **13 MEG webinars featuring 18 separate presentations covering the evaluation period and 3 more webinars on recent issues with cold bias**
• 2D, plume, and soundings graphics generated on web sites for real-time parallel
• The MEG generated graphics on web site for 32 high-impact retrospective cases covering tropical cyclones, winter storms, QPF, wind storms, excessive heat, atmospheric rivers, severe weather, and cold air outbreaks
• Vlab forum for feedback and general discussion
Official Evaluation Website

http://www.emc.ncep.noaa.gov/users/meg/fv3gfs

<table>
<thead>
<tr>
<th>TIMELINE</th>
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<td>FV3GFS Code Frozen</td>
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SUMMARY

FV3GFS Model Evaluation Summary - Presented by Geoff Mandrake (9/25/18 MEC Meeting)
FV3GFS Model Evaluation Summary - Presented by Fengdi Yang (9/16/18 CCM Meeting)
FV3GFS NCEP/NCAR Model Evaluation Summary - Presented by Logan Dawson (8/27/18 MEC Meeting)

INFORMATION

FV3GFS Educational Overview - Presented by Geoff Mandrake (9/25/18 MEC Meeting)
FV3GFS SST Improvement - Presented by Geoff Mandrake (5/24/18 MEC Meeting)
FV3GFS Over-Simplified Meteorology, Reflectivity, Visibility - Presented by Geoff Mandrake (5/31/18 MEC Meeting)
FV3GFS Operational Update - Presented by Logan Dawson (8/14/18 MEC Meeting)
FV3GFS East Coast Winter Storm Retrospective - Presented by Tracey Dorian, Alissa Bentley (8/18/18 MEC Meeting)
FV3GFS Tropical Cyclone Shut-Down Update - Presented by Troy Talley (6/15/16 NCEP/NCAR Meeting)
FV3GFS North Atlantic/East Pacific TC Retrospection - Presented by Geoff Mandrake (6/23/18 MEC Meeting)
FV3GFS Western U.S. Retrospection - Presented by Alissa Bentley (6/3/18 MEC Meeting)
FV3GFS Alaska Rains Retrospection - Presented by Tracey Dorian, Alissa Bentley (7/10/18 MEC Meeting)
FV3GFS Cold SST Concern c.k Alaskan Cool Shit - Presented by Logan Dawson (6/9/18 MEC Meeting)
FV3GFS Products Update - Presented by Logan Dawson (6/10/18 MEC Meeting)
FV3GFS AIR Update - Presented by Tracey Dorian (9/11/18 MEC Meeting)
FV3GFS GFS Retrospection - Presented by Alissa Bentley (9/13/18 MEC Meeting)

DATA

FV3GFS Data - Available on Parse Framework
List of New (Old) Descriptors - Maintained by He-tsi Chang

REAL-TIME GRAPHICS/OUTPUT

FV3GFS and Guidance Notes: GFS + FV3GFS - Maintained by NCEP/NOAA
GFS vs. FV3GFS Comparison: Maintained by Geoff Mandrake
GFS vs. FV3GFS Comparison: Maintained by Tracey Dorian
GFS vs. FV3GFS Comparison: Maintained by Tracey Dorian
NCEP vs. FV3GFS Comparison: Maintained by Eric Reagan
NCEP vs. GFS/MOS Comparison: Maintained by NOAA/Warcer

VERIFICATION

NCEP/NCAR Model Evaluation Group (MEG) - Maintained by Geoff Mandrake
NCEP/NCAR MEG Past Presentation - Available to NOAA email address only
NCEP/NCAR MEG Verification Search for FV3GFS - Maintained by Ying Lin
NCEP/NCAR Data Verification: Verification-FoldTest for FV3GFS - Maintained by Stonerable Smith and Jack Medlin

NCEP/NCAR Global Model Experimental Forecast Performance Statistics (Real Data) - Maintained by FV3GFS Parallel Execution Group
Retrospective Forecast Performance Statistics (Full Period Run): December 2013 to September 2016
Retrospective Forecast Performance Statistics (December 2017 - May 2016)
Retrospective Forecast Performance Statistics (May 2016 - November 2016)
Retrospective Forecast Performance Statistics (June 2016 - November 2016)
Retrospective Forecast Performance Statistics (November 2016 - December 2016)
Retrospective Forecast Performance Statistics (December 2016 - May 2017)

RETORETICIVES

FV3GFS Retrospective Case Studies - Images by NCEP/NCAR MEG
MRC Evaluation of FV3GFS Retrospection - Presented by Logan Dawson (7/11/18 MEC Meeting)
FV3GFS East Coast Winter Storm Retrospection - Presented by Tracey Dorian, Alissa Bentley (7/18/18 MEC Meeting)
FV3GFS South Atlantic/East Pacific TC Retrospection - Presented by Geoff Mandrake (6/23/18 MEC Meeting)
FV3GFS Western U.S. Retrospection - Presented by Alissa Bentley (6/3/18 MEC Meeting)
FV3GFS Alaska Rains Retrospection - Presented by Tracey Dorian (9/11/18 MEC Meeting)
FV3GFS GFS Retrospection - Presented by Alissa Bentley (9/13/18 MEC Meeting)

FEEDBACK

VLAB: FV3GFS Feedback Forum - Maintained by NCEP/NCAR MEG

Update:
1. If you email FV3GFS Feedback Forum, a post will appear in the Forum and forum subscribers will get an email from VLAB Feedback Forum.
2. If you reply to the email from VLAB Feedback Forum, forum subscribers will get an email and your response will appear in the Forum.
3. If you write to the Forum from a non-VLAB member, please identify yourself in your email.
4. Non-VLAB members who email the forum will be identified as Anonymous. If you write to the Forum as a non-VLAB member, please identify yourself in your email.
THE IMPROVEMENTS SEEN IN GFSv15
SYNOPTIC STATS
RETROSPECTIVES DAY 5  500 mb AC SCORES

Anomaly Correl: HGT P500 G2/NHX 00Z, fh120

Anomaly Correl: HGT P700 G2/SHX 00Z, fh120

Anomaly Correl: HGT P500 G2/TRO 00Z, fh120

Anomaly Correl: HGT P500 G2 00Z, fh120

NH

SH

TROPICS

GLOBE
FV3GFS IMPROVEMENT OVER GFS is SIGNIFICANT OUT TO:

- DAY 10.5 for WAVES 0-3
- DAY 8.5 for WAVES 4-9
- DAY 9 for WAVES 10-20
CONUS Precip ETS and BIAS SCORES
00Z Cycle, verified against gauge data, 20150601~20180912

- Improved ETS scores for almost all thresholds and at all forecast length
- Reduced wet bias for light rains
- Slightly worsened dry bias for moderate rain categories
SIGNIFICANTLY IMPROVED WIND-PRESSURE RELATIONSHIP WITH TROPICAL CYCLONES LEADING TO IMPROVED INTENSITY FORECASTS
Much improved W-P relationship with GFSv15 (hord=5) compared to operational GFS and older runs of GFSv15 (hord=6)
**IRMA**

00z 9/8/17  F54

**KEY:**
- Blue = GFSv15 is stronger (lower MSLP)
- Red = GFSv15 is weaker (higher MSLP)
FLORENCE
00z 9/11/18   F72

KEY:
Blue = GFSv15 is stronger (lower MSLP)
Red = GFSv15 is weaker (higher MSLP)
TYPHOON NORU
00z 7/31/17   F120

KEY:
Blue = GFSv15 is stronger (lower MSLP)
Red = GFSv15 is weaker (higher MSLP)
IMPROVED TROPICAL CYCLONE FORECAST TRACKS (THROUGH DAY 5)
STATS FOR FULL SET OF RETRO CASES COMPARING GFSv14 to GFSv15
IMPROVEMENT with WARM SEASON
DIURNAL PRECIP CYCLE
Clear FV3GFS improvement, especially overnight
MULTIPLE TROPICAL CYCLONE CENTERS
(FOR SINGLE STORM)
GENERATED BY OPS GFS NOT SEEN IN
GFSv15 FORECASTS OR ANALYSES
OPS GFS FORECASTS FOR HURRICANE NATE (OCTOBER 2017)
GFSv15 – GFSv14 SLP DIFFERENCE PLOT:

GFSv14 HAD PROBLEMS WITH DOUBLE LOW STRUCTURE THAT WERE MUCH LESS PREVALENT IN v15

But also note a position difference that we’ll revisit later
GFSv14
MSLP and 10-m winds (kt) | Int: 1800 UTC 27 Jun 2018 | Fhr: 0

GFSv15
MSLP and 10-m winds (kt) | Int: 1800 UTC 27 Jun 2018 | Fhr: 0
ADDITION of SIMULATED COMPOSITE REFLECTIVITY PARAMETER
ABILITY TO GENERATE
MODEST SURFACE COLD POOLS
FROM SIGNIFICANT CONVECTION
QPF Evaluation - Positives

Reduces the operational run’s northward precipitation bias

GFS 60-hr forecast

GFS-FV3 60-hr forecast

Precip focused on outflow boundary

24-hour Stage IV QPE valid 12Z 9/9/2018
Other GFSv15 Improvements

- General improvement in HWRF & HMON runs
- Improved ozone and water vapor physics and products
- GFSv15, running with the advanced GFDL MP, provides better initial and boundary conditions for driving the stand-alone regional FV3, and for running downstream models that use advanced MP
- FV3-based GEFSv12 showed significant improvements when initialized with GFSv15
CONCERNS WITH GFSv15
A LOW-LEVEL COLD BIAS GROWS WITH FORECAST LENGTH
From the MEG evaluation report last fall:

The increasing bias with time was a concern, but the magnitude was fairly small.
MAGNITUDE INCREASED SIGNIFICANTLY THIS WINTER

Day-10 500-hPa winter geopotential height bias
(2015–2016) -4.5 m
(2016–2017) -5.0 m
(2017–2018) -3.2 m
(2018–2019) -14.4 m

Day-10 850-hPa winter temperature bias
(2015–2016) -0.27°C
(2016–2017) -0.35°C
(2017–2018) -0.23°C
(2018–2019) -0.77°C

GFSv14
GFSv15

500 mb
Height Bias

850 mb
Temp Bias
GFSv15 change @ 18z 9-17-18 to correct radiation error

Temperature bias trends more negative (cooler with respect to observations) after change
Mitigation of the cold bias

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

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

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

GFDL is acknowledged for their contribution to the implementation of the improved cloud-radiation interaction scheme in the new configuration.
Example: Arctic Blast of Late January 2019

- **New Configuration** is warmer than the Real-time Parallel over the Great Lakes and Upper-Midwest.

- While still too cold relative to the RTMA analysis, the **New Configuration** shows a clear improvement.

* Init: 1200 UTC 26 Jan 2019
  Val: 1200 UTC 30 Jan 2019
Excessive 24-h Snowfall Totals at Day 5 (Valid: 12Z 2/20/19)

NOHRSC Analysis

Real-time Parallel

New Configuration

Operational GFS

• New Configuration has correct areal coverage of snowfall, and coverage of higher amounts is significantly reduced from the real-time parallel run but are still too high.
Mitigation of Cold Bias

- **Winter 2018/2019**
  - Ops GFS
  - New Configuration
  - Real-time Parallel

- **Winter 2017/2018**
  - Ops GFS
  - FV3GFS Retro

- **Fall 2018**
  - Ops GFS
  - New Configuration
  - Real-time Parallel

- **Fall 2017**
  - Ops GFS
  - FV3GFS Retro

850 hPa Temp Bias
What is the Cause of This Cold Bias?

A possible clue from early testing of the global system with the FV3 core.

The runs with the Zhao-Carr microphysics don’t display the increasing cold bias; the introduction of the GFDL microphysics seems to introduce the bias.

Baseline GFSv14
FV3 test with GFDL MP
FV3 with old MP

FV3 test with GFDL MP
500-hPa Geopotential Height Bias from the Physics Suites Testing

**KEY POINTS:**

- Suites 1 and 2 (with GFDL MP) have a nearly identical low bias that increases with forecast lead time.

- Suite 3 (Morrison-Gettleman MP) has a high bias that increases with forecast lead time.

- Suite 4 (Thompson MP) has the smallest average 500-hPa height bias at almost all forecast hours.
850-hPa Temperature Bias

KEY POINTS:
- Suites 1 and 2 (GFDL MP) have a cold bias that increases with lead time.
- The suites without GFDL microphysics do not show a cold bias increasing with time.
SYNOPTIC PROGRESSIVENESS WITH CUTOFF UPPER LOWS RAPIDLY RE-ENTERING THE MIDLATITUDE FLOW
**MAIN POINTS:**

- GFSv14 shifts AR west before GFSv15

- GFSv15 is more progressive with AR than GFS

**KEY:**

- Blue = GFSv15 is drier (lower PW)

- Red = GFSv14 is wetter (higher PW)

Black lines denote analyzed AR axis
BLIZZARD of 2016

00z 1/2/16 cycle F144

GFSv14

GFSv15

ANL, v15 – v14

FV3GFS is ONE DAY FAST
v15 – v14  500mb
BLIZZARD of 2016

Blue = v15 has lower heights

Red = v15 has higher heights

CLEARLY TOO PROGRESSIVE in MEDIUM RANGE; DIFFS GET SMALLER CLOSER to VERIFYING TIME
TROUGH HAS LIFTED OUT

APR 2016 SVR OUTBREAK

GFSv14

GFSv15

FV3GFS-GFS

GFS ANL
WARM SEASON DRY BIAS
GFS vs. FV3GFS (Forecasts: 18Z 25 May to 18Z 10 September 2018)

![Graph showing GFSv14 and GFSV15 comparison](image-url)
QPF Evaluation - Concerns

Low bias for higher QPF thresholds

24-hour QPF from the 00Z Sep 14 runs valid 12Z Sep 16 (F060)
SPEED OF NORTHWARD MOVING HURRICANES
For all 2015-2018 Atlantic TCs (left), modest improvement in track forecasts through Day 5

Clear degradation by Day 6 with significant degradation at Day 7

For all 2015-2018 Atlantic hurricanes (right), track forecasts were degraded at all lead times
GFSv15 FASTER and TOO FAR EAST WITH TRACK
Example: TC Michael (2018)

72-h Forecast | Init: 0000 UTC 7 Oct 2018 | Valid: 0000 UTC 10 Oct 2018

New Configuration is slower than Real-time Parallel (still too fast) and has a better (i.e., lower) central pressure
CONCERNS WITH THE GFS THAT EXISTED PRIOR TO V15
STRUGGLES WITH INVERSIONS
MAJOR IMPACTS on EARLY MORNING 2m TEMPS

OPS GFS has 6h 2-m temp errors exceeding 15F
MOST COMMON INVERSION FINDING: Suite 4 handles inversions the best, Suite 1 struggles the most, Suite 2 offers some level of improvement over 1, and Suite 3 sometimes offers modest improvement over 1.
MOST COMMON INVERSION FINDING: Suite 4 handles inversions the best, Suite 1 struggles the most, Suite 2 offers some level of improvement over 1, and Suite 3 sometimes offers modest improvement over 1.
12-hr FCST SOUNDINGS for PHILADELPHIA, PA VALID 12z SUNDAY

BAL-PHL-NYC Corridor 1/22/15 Ice Event
GFS OFTEN HAS TOO LITTLE PRECIP on the NORTHWEST SIDE OF EAST COAST CYCLONES
STRUGGLES WITH INSTABILITY
The drier and deeper GFS PBL also contributes to very weak lapse rates and we’ve long documented that the GFS underdoes instability due to poor lapse rates and overmixing of the PBL. The drier and deeper GFS PBL also contributes to low cape.
18 May 2017 High Risk
6-h SBCAPE Forecasts Valid 18Z

Sfc-Based Cape

GFSv14

GFSv15

FV3GFS - GFS

RAP Analysis

Sfc Cape Regional Mean - TROPICS
There are many significant positives from GFSv15, highlighted by improved synoptic scores, a much-improved TC wind-pressure relationship, and a better diurnal cycle for precipitation.

The most pressing new issue is the low-level cold bias that increases with time.

The issue with northward-moving TCs (possibly a major contributor to worse hurricane tracks) also requires attention.

The long-standing struggle with low-level inversions is the most critical long-standing issue and likely stands in the way of turning off the NAM (and SREF); physics suite testing shows some progress.

Other long-term issues include underdoing instability (tied to lapse rates?) and precip on northwest side of east-coast winter storms (tied to weaker low-level jet?)

FINAL THOUGHTS
EXTRA SLIDES
Fall 2018 Tropical Cyclone Mean Track Errors With New Config

NH Hurricane Season (8/27/18–10/31/18)

**North Atlantic**

Neutral Impact

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

**East Pacific**

Improved

**West Pacific**

Improved
CPC FV3GFS Evaluation: Stratospheric Prediction

Specific Humidity Comparison:

- Unrealistically high values
- Values agree more with climatology

SSW Detection:

- Both GFS and FV3 capture warming @192 and @240 hours and show similar correlation and RMS scores

Zonal Mean Temperature Comparison (GFS-FV3):

- FV3 is warmer (colder) in upper stratosphere at most latitudes (winter polar region)

Key Results:

- FV3GFS temps are similar to operational GFS in middle/lower stratosphere but warmer in upper stratosphere.
- FV3GFS temperature forecasts in winter hem upper strat high lats are colder.
- Polar jet winds differences reflect greater temp gradient in winter hem.
- Ozone mixing ratio analyses and fcsts are similar at most locations
  - FV3GFS has slightly higher values in winter polar region.
- FV3GFS total ozone fcsts are slightly better outside polar regions.
  - Both forecast too high ozone in ozone hole region.
- FV3GFS Specific Humidity is much more realistic.
- FV3GFS is similar to GFS forecasting the 2018 SSW.
QPF Evaluation - Positives

Improved handling of convective cold pools

6-hour QPFs valid from 06Z-18Z June 7, 2018

GFSv14

GFSv15

MRMS

F006

F012

F018
QPF Evaluation - Positives

Improved handling of convective cold pools

Boundary layer moisture convergence and 2-m dew point

F006

F012

RALA 06Z (top) and 12Z (bottom)