Reducing systematic errors in GFS sensible weather forecasts

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\textsuperscript{1} EMC/NCEP/NWS/NOAA/DOC
\textsuperscript{2} IMSG at NOAA/NCEP/EMC
\textsuperscript{3} SRG at NOAA/NCEP/
\textsuperscript{4} SPC/NCEP/NWS/NOAA/DOC

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--Not just 500 hPa height anymore
--GFS sensible weather forecasts used and scrutinized (“They complain, but they use it”.)
--EMC developers respond to forecaster complaints, modifying GFS physics
--Model Evaluation Group found many problems and heard about many others
--New implementation procedure increased forecaster-developer interaction
Includes link to precipitation verification

Verification of near surface fields over continental US.

Posters:

Yihua Wu—land surface parameterization
Tracey Dorian-GFS mode verification
Glenn White-systematic errors
Annual Mean 500-hPa HGT Day-5 Anomaly Correlation

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

Fanglin Yang
588. EMC’s Model Evaluation Group

Geoffrey Mankin¹, Glenn White¹, Tracey Dorian¹,², Corey Guastini¹,²
¹EMC/NCEP/NWS/NOAA/DOC  ²IMSG

MEG presents weekly synoptic model evaluations to
1) Improve NOAA forecast systems
2) Improve communications between model developers and model users.

Recent West Coast Storms

MEG’s Role in New Implementation Process
Work with forecasters to find model problems, present to developers
Developers address problems,
MEG examines tests of model fixes
Initial briefings from developers on upgrades
Alert field on what to look for before evaluation begins
Longer scientific evaluation before, separate from 30 day IT test
Greater forecaster involvement
Set up and maintain web pages for each implementation
Review cases and stats
Must find effective way to get parallel data to the field
Bring in visitors to evaluate tests with developers
New process improved GFS 2016 implementation

Greater involvement with NWS regions, forecast offices

MEG involved in Science Technology Integration teams with NWS SOOs
Global: Involved in GFSX evaluation effort, providing recommendations on global model development
Hi-Res Ensemble: Evaluating hi-res guidance to provide recommendations on construction of future convection-permitting ensemble
Communication/Dissimination: Working on better ways to get model data to forecast offices

MEG Visiting scientist program
MEG personnel visited 5 WFOs last fall
Plans for WFO forecasters to visit EMC

Questions
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glenn.white@noaa.gov(tracey.dorian@noaa.gov)
corey.guastini@noaa.gov

Winter storm Jan. 7, 8, 2017 Individual pies show how many GFS ensemble members forecast that category

The MEG meets each Thursday 11:30 AM EST NCWCP
ALL ARE WELCOME TO ATTEND
Webinar access available, presentations recorded

Contact mary.hart@noaa.gov for MEG announcements/agendas
evaluations are held. The group noted a late afternoon moist bias in the GFS (especially over the mid west US); an associated cold bias became evident as summer arrived since the problem was most evident in hot air masses. EMC was aware of issue by the time forecasters noticed it and were able to implement a correction in early September.

GFS soundings for Davenport, Iowa 07 July 23, 2012

G. Manikin
09/05/2012 12Z: GFS Minor Change. A look-up table used in the land surface scheme to control Minimum Canopy Resistance and Root Depth Number was updated to reduce excessive evaporation to mitigate GFS cold and moist biases in late afternoon over the central US when drought conditions existed in summer of 2012.

Physics “Whack-a-mole” or “wheel of pain”
GFS 2016 implementation

http://www.emc.ncep.noaa.gov/gmb/noor/4dGFS/synergy%20announcementjan08.htm
Complaints

- We received many complaints about the GFS being too warm and too dry from the field offices particularly over the Great Plains in the summer of 2015.

12h FCSTs vs OBS for Aberdeen, SD
Solutions

Evaporation is too low and sensible heat flux is too high after the new soil moisture climatology (GLDAS/CFS) is used in the operational GFS since January 2015.

Factors include:
• Thermal roughness and momentum roughness
• Canopy resistance
• Soil moisture

We proposed the following parameter refinements in pr4devb:

• rsmin (veg resistance coefficient) for grassland from 45 to 20
• rsmin for cropland from 45 to 20
• roughness length for cropland from 3.5cm to 12.5cm (used to address too strong surface winds)
Improvements
focus on the summer period of pr4devb (from July 8 to August 31, 2015)

18z latent heat flux averaged over 20150708-20150831
gdasx=pr4devb

Compared to NLDAS (quasi observation) and NDAS, the operational GFS produces too little evaporation. The parallel GFS has increased the evaporation.
• For 2015, the low frequency bias of SBCAPE is improved at all instability thresholds in the GFSp, but still very low compared to observations.
The observed sounding at Lamont, OK is hot and very moist in the low levels with steep lapse rates, resulting in very unstable conditions with SBCAPE ~6000 J/kg.

- The GFS is too hot and much too dry near the surface, while the GFSp is an improvement. However, it is still too low by ~2200 J/kg compared to observed sounding.
CONUS Precip Skill Scores, f36-f30, 01may2013–28feb2016 00Z Cycle

Equitable Threat Score

BIAS Score

Difference w.r.t. gfs2015

Threshold (mm/24hr)

Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests
GFS17 implementation

Major science issues addressed in Q3FY17 GFS Upgrades

Surface Parameters (Land Surface Upgrades):
- Cold temperature bias over snow
  - Alaska, NW, NE
- Stable boundary
- Land-Atmosphere Decoupling
- Snow albedo too large

Precipitation (Convection Scheme Upgrades):
- “socialist” rain (too much drizzle)
- “popcorn” precip in western US
- Convective fraction consistent w/resolution

SST (Replace RTGSST with new NSST):
- Oceanic vertical temperature structure near surface due to the diurnal warming and sub-layer cooling physics processes

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

- Scale/aerosol-aware, parameterization
- Decreased rain conversion rate above freezing level.
- Update convective adjustment time in deep convection
- Update cloud base mass flux in shallow convection scheme
- Additional trigger based on CIN
- Enhanced convective cloudiness
Improving the Stable Surface Layer in GFS

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

\[ \frac{z}{L} < \frac{z}{L}_M = \frac{ln(z/z_0)}{[2\alpha*(1-z_0/z)]} \]

Here \( z \) is the height, \( L \) is the Obukhov length, \( z_0 \) is the momentum roughness length, and \( \alpha = 5 \).

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

T2m @ MRB Martinsburg RGNL, WV

**CTL:** Rapidly cooling more than 15 °C during 3hr;

**EXP:** Substantially improved
<table>
<thead>
<tr>
<th></th>
<th>0000GMT</th>
<th>0600GMT</th>
<th>1200GMT</th>
<th>1800GMT</th>
<th>AVERAGE</th>
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<tbody>
<tr>
<td>T 2m</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>west</td>
<td>-6.9%</td>
<td>-3.6%</td>
<td>+1.1%</td>
<td>-1.8%</td>
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<td>-1.6%</td>
<td>+2.3%</td>
<td>-1.2%</td>
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<tr>
<td>T_d 2m</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>west</td>
<td>-4.3%</td>
<td>-4.4%</td>
<td>-3.8%</td>
<td>-5.2%</td>
<td>-4.4%</td>
</tr>
<tr>
<td>east</td>
<td>-2.1%</td>
<td>-3.4%</td>
<td>-1.3%</td>
<td>-2.4%</td>
<td>-2.0%</td>
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<tr>
<td>Winds 10m</td>
<td></td>
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</tr>
<tr>
<td>west</td>
<td>+0.1%</td>
<td>+0.8%</td>
<td>+0.1%</td>
<td>+0.1%</td>
<td>+0.3%</td>
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<tr>
<td>east</td>
<td>-1.2%</td>
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<td>-1.5%</td>
<td>-1.1%</td>
<td>-1.4%</td>
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RMS fit to obs decreased in GFS2017
RMS fit to obs increased in GFS2017
For 2016, the low frequency bias of 2-m dewpoint is generally improved in the GFSp. The high bias at \( \geq 70^\circ\text{F} \) for forecasts valid at 00Z increases slightly with forecast length.
CONUS Precipitation

Reduced drizzle

Increased bias light to medium amounts

Significant improvements in skill for thresholds of 0.2 to 15 mm/day forecast lengths 0-24 to 72-96 hrs

AWC, WPC improvements in tropical convection
Links to Case studies and evaluation/analysis by MEG/EMC

Tracey Dorian, Geoffrey Manikin, Corey Guastini

<table>
<thead>
<tr>
<th>Case Studies</th>
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<tbody>
<tr>
<td>Louisiana flooding case study</td>
<td>Christmas Day 2016 Northern Plains Blizzard</td>
</tr>
<tr>
<td>January 23, 2016 East Coast Blizzard</td>
<td>January 22-23, 2017 California precipitation event</td>
</tr>
<tr>
<td>Hurricane Matthew</td>
<td>Portland heavy snow Jan. 10-11, 2017</td>
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<tr>
<td>Hurricane Joaquin</td>
<td>Long-range predictability of high-impact west coast atmospheric river</td>
</tr>
<tr>
<td>February 7-8, 2016 explosive cyclone</td>
<td>West Virginia flooding case</td>
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<tr>
<td><strong>MODE Jet Verification</strong></td>
<td><strong>MODE Precipitation Verification</strong></td>
</tr>
<tr>
<td>Minnesota Blizzard November 18-19, 2016</td>
<td><strong>MODE CAPE Verification</strong></td>
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<td>Weather Prediction Center case studies</td>
<td>Hurricanes Joaquin and Matthew</td>
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<td>Central Region case studies</td>
<td>Systematic Biases Summer 2016</td>
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<tr>
<td>Hurricane Joaquin precipitation</td>
<td></td>
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<tr>
<td>California precipitation January 9-10, 2017</td>
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Most requested by other NCEP centers, regional headquarters, forecast offices
## Endorsements from Stakeholders

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

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<tr>
<td><strong>AWC</strong></td>
<td>Implement</td>
<td>Significant improvements to tropical convection and ceiling and visibility over CONUS</td>
</tr>
<tr>
<td><strong>CPC</strong></td>
<td>Implement</td>
<td>Stratospheric fields improved, slight improvement D+8, week 2</td>
</tr>
<tr>
<td><strong>OPC</strong></td>
<td>Implement</td>
<td>Small scale features improved; large scale features similar</td>
</tr>
<tr>
<td><strong>SWPC</strong></td>
<td>No evaluation</td>
<td></td>
</tr>
<tr>
<td><strong>MDL</strong></td>
<td>Implement</td>
<td>see little to suggest any dramatic MOS impacts from implementing new GFS</td>
</tr>
<tr>
<td><strong>OWP</strong></td>
<td>Implement</td>
<td>Mixed results, extremely limited testing</td>
</tr>
<tr>
<td><strong>SPC</strong></td>
<td>Implement</td>
<td>Slightly improved 2-m dew point and instability bias</td>
</tr>
</tbody>
</table>
Interaction with operational forecasters increased

MEG invaluable for finding and highlighting model problems

Model developers responded quickly, effectively to problems

development and implementation of new dynamic core FV3 underway, new physics under development

many areas need more examination

--Alaska

tropics
Extra slides
How I view model evaluation
After 40 years

Statistical verification
Case studies
Systematic errors
NH HGT AC: 500hPa Day5, 3-Mon Mean

Difference w.r.t. GFS

Verification Date

CDAS 0.743
FNO 0.873
CMC 0.884
UKM 0.901
ECM 0.920
GFS 0.891 last 1yr Avg
Major implementation July 27, 2010

Resolution increase: T382 (35 km) -> T574 (27 km) to 192 hrs
T190 192-384 hrs

Tuning--Gravity wave drag one half as strong
Mountain blocking four times stronger (Alpert and Yang)

New mass flux shallow convection (Han and Pan 2010)
New planetary boundary layer
Updated deep convection

Background diffusivity for momentum substantially increased
To 3.0 m²s⁻¹ everywhere to reduce wind forecast errors

Caribbean forecasters complained changes weakened previously realistic trade wind bursts in eastern Caribbean
Note weaker winds at jet level in NH, better fits to radiosondes.

Note weaker winds in tropics. At low levels—Potential Aviation hazard East Caribbean.
Causes

- The evaporation is too low and the sensible heat flux is too high after the new soil moisture climatology (GLDAS/CFS) is used in the operational GFS since January 2015.

From daily land surface monitoring page
http://www.emc.ncep.noaa.gov/mmb/gcp/gfs/soilm

Compared with ndas, both gdas and cdas are warmer, but LH too low (compared to NLDAS)
The warm/dry biases was significantly reduced in the lower troposphere (24/48h fcst over NA).
2m T over North Plains

2m T over South Plains

2m T_{d} over North Plains

2m T_{d} over South Plains
Surface wind. CONUS West and East. 00Z
The instability gradient location is shifted westward in the GFSp. There remains an eastward bias of the unstable warm sector, which still indicates overmixing in the plains.
CONUS Precip Skill Scores

CONUS Precip Skill Scores, f36–f80, 15 May 2014–01 Feb 2017 00Z Cycle

Equitable Threat Score

Bias Score

Differences outside of the hollow bars are 95% significant based on 10,000 Monte Carlo Tests
The frequency bias is lowest at the highest SBCAPE threshold (≥3000 J/kg). Only the forecasts valid at 00Z and 03Z are improved in the GFSp.
Aleksandr Korolokov, Meteorological Center, FOBOS, Moscow—GFS main source for forecasts

extreme short cold waves in GFS forecasts—GFSX better

Year earlier, complaint from Argentina that GFS too hot, dry over pampas

GFS2016 contained partial fix