Evaluation of High Resolution Prototypes for the Next Global Forecast System GFSv17

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U. Mich.: Christiane Jablonowski
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Outline

High-resolution prototypes: HR1
  • Specification of HR1
  • Modeling system differences between GFSv16, HR1, and planned GFSv17

HR1 evaluation
  • Evaluation targets
  • Results

Summary
High Resolution Prototypes: HR1

Starting point: P8 (deterministic, lower resolution, all system components in)
High-Resolution Prototypes: **HR1 (completed)**, HR2 (in progress), HR3 (planned), ...
End point: GFSv17

Details of HR1

- **Model**
  - Coupled Model: Atm (C768) - Ocean (√₄ tripolar) - Ice (√₄ tripolar) - Wave (¾ tripolar)

- **Time periods**
  - Summer: June 1– Aug. 30, 2020, cold start forecasts at 00Z cycle every 3 days, 16 day forecast
  - Winter: Dec. 03, 2019 – Feb. 26, 2020, cold start forecasts at 00Z cycle every 3 days, 16 day forecast
  - Hurricane: July 20, 2020 – Nov 20th, 2020, cold start forecasts at 00Z cycle everyday, 7 day forecast

- **Initial conditions**
  - Atm: GFSv16
  - Land: New spin up
  - Wave: New spin-up forced from GFSv16 (Winter), interpolated from GFSv16 for (Summer, Hurricane)
  - Ocn/Ice: Replay
## Differences between GFSv16, HR1, and GFSv17

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<tr>
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<th>GFS v16</th>
<th>HR1</th>
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Evaluation targets

Comparison between HR1 with GFSv16 for

- Global distribution of biases
- MJO
- AC score card – geopotential heights, winds, temperature
- CONUS 10-m wind biases
- CONUS 2-m temperature biases
- CAPE magnitude
- TC track and intensity

Tools

- Non-METplus-based scripts, as in prior prototype evaluations
- METplus-based EMC_verif-global package (https://github.com/NOAA-EMC/EMC_verif-global.git)
Total clouds generally reduced, but increased south of equator in the eastern tropical Pacific and Atlantic. The reduction is an improvement over Indian Ocean and high latitudes.

SFC downward SW underestimation exacerbated in eastern tropical Pacific and Atlantic.

SFC upward SW shows negative bias over deserts and sea ice. Result of lower desert albedoes and lower ice concentrations.
Spatial structure similar to low-res P8

Net SW bias is generally positive, except south of the equator in the eastern tropical Pacific and Atlantic, where HR1 has increased cloud amounts and exacerbated negative downward SW bias.

Warm SST bias in the eastern equatorial Pacific and Atlantic. Cold bias south of there.

Close correspondence between net SW bias and SST bias; any discrepancies are largely from the ICs.

Biases growing with lead time (not shown).
**MJO**

**AC**
- Improved AC in HR1 for both seasons

**Amplitude error**
- Reduced amplitude error in HR1 for both seasons.

**Phase error**
- Reduced phase error
  - Still too slow in DJF
  - Switched from too fast to too slow in JJA.

For both GFSv16 and HR1, larger amplitude bias in strong MJOs; larger propagation bias in weak MJOs.
ACC scorecard

Computed with EMC_verif-global package
https://github.com/NOAA-EMC/EMC_verif-global.git

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Day 1
ACC scores for HR1 worse than GFSv16 (initialization shock)

Days 3-10
- **Improvement**: tropics and winter hemisphere – heights, wind speed, upper tropospheric temperature
- **Worsening**: low level temperatures
Mean Bias: 10m Wind Speed (DJF)

Sign of biases same as in GFSv16. Wind speeds on average lower in HR1 than GFSv16

- Exacerbated underestimation in Western CONUS
- Reduced overestimation in Eastern CONUS

(The shifts are in the same direction for JJA)
Mean Bias: T2m (West Conus)

**JJA**
- Reduced daytime warm bias, improved diurnal cycle shape
- Reduced diurnal range

**DJF**
- Exacerbated nighttime cold bias
- Improved diurnal cycle shape

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**Forecast and Observation Averages**

- Mean and Error plots for T2m (2 m Temperature) in the Western US for JJA and DJF.
- Comparison between GFSv16, HR1, and OBS datasets.
- Key points:
  - Reduced daytime warm bias in JJA.
  - Reduced diurnal range in JJA.
  - Exacerbated nighttime cold bias in DJF.
  - Improved diurnal cycle shape in DJF.
Larger CAPE in HR1 compared to in GFSv16

This is a move in the right direction but the magnitude of increase is insufficient.
TC intensity and track error

### TC track error

**N. Atl**
- **HR1**
- **Uncoupled HR**
- **GFSv16**

**W. Pac**

### TC Intensity error

#### Track error
- Slightly increased for N. Atl, little change for W. Pac

#### Intensity error
- Both GFSv16 and HR1 underestimate intensity
- The intensity underestimation is clearly exacerbated in HR1. A not-surprising impact of coupling

### Steps to improve for HR2
Summary

Benefits of HR1

• Improved MJO AC, amplitude, propagation speed (but propagation too slow)
• Improved ACC for heights, winds, upper tropospheric temperature in winter hemisphere and tropics
• Reduced West CONUS T2m warm bias in summer, improved diurnal cycle shape
• Reduced East CONUS 10m wind speed overestimation (but still positive bias)
• Increased CAPE (although insufficient)

Deficiencies of HR1

• Overestimation of total cloud cover in eastern tropical Pacific/Atlantic south of the equator and consequent underestimation of downward shortwave, leading to cold SST biases
• Warm SST biases along the equator in eastern Pacific/Atlantic
• Reduced ACC for temperatures at low atmospheric levels
• Exacerbated West CONUS 10m wind speed underestimation
• Exacerbated West CONUS T2m nighttime cold bias
• Exacerbated TC intensity underestimation

Steps to correct these deficiencies are planned for HR2

Contact: Lydia.B.Stefanova@noaa.gov
BACK-UP SLIDES
## Bias scorecard: DJF

<table>
<thead>
<tr>
<th>Height</th>
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<th>N. Hemisphere</th>
<th>S. Hemisphere</th>
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### Bias scorecard: JJA

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- ▼ indicates HR1 is worse than GFSv16 at the 99.9% significance level
- ▼ indicates HR1 is worse than GFSv16 at the 99% significance level
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- ▼ indicates HR1 is better than GFSv16 at the 99.9% significance level
- ▼ indicates HR1 is better than GFSv16 at the 99% significance level
- ▼ indicates HR1 is better than GFSv16 at the 95% significance level
- ▼ indicates No statistically significant difference between HR1 and GFSv16
APPARENT IMPROVEMENT IN 500MB HEIGHTS IN NH/SH/TROPICS, STARTING AROUND DAY 3-5, ALTHOUGH NOT CONSISTENTLY STATISTICALLY SIGNIFICANT.
Statistically significant degradation for 850 mb Temperature, particularly in the summer hemisphere (SH in DJF, NH in JJA), and in the Tropics.
T2max, T2min (JJA)

GFSv16 Bias  HR1 Bias  HR1 minus GFSv16

Mostly lower Tmax
Mostly higher Tmin
T2max, T2min (DJF)

- GFSv16 Bias
- HR1 Bias
- HR1 minus GFSv16

Mostly higher Tmax
Mostly lower Tmin
Ice concentration (and thickness) differences between HR1 and GFSv16 are notable in both SH and NH, but particularly prominent in SH.

- This is a known issue from the Replay ICs for ice, its solution is being implemented by PSL.
GFSv16 overestimates the total cloud cover over high latitudes, Indian ocean, Western equatorial Pacific, and south of the equator in the eastern tropical Pacific and Atlantic, as well as over Northern Africa. Cloud cover is underestimated over the remainder of oceans.

HR1 has less clouds than GFSv16, except for the eastern tropical Pacific and Atlantic, where it is cloudier.
OLR, bias wrt NOAA-CDR

- OLR reduced (bias improved) along the equator (SH in DJF, NH in JJA). OLR increased (bias improved) in Indian Ocean.
Precip increased where OLR reduced, and vice versa
Most prominent differences between GFSv16 and HR1: Sahara, Arabian Peninsula (deserts) and Antarctic/Greenland (permanent ice/snow), suggesting lower albedoes in HR1.

For the desert regions, this is an exacerbation of negative bias, while for the ice/snow regions it is an amelioration of positive bias.
- Upward longwave radiation at the surface: increased positive bias notable over Sahara, Arabian Peninsula (deserts), and in the Southern ocean in JJA – reflecting warmer biases in these regions.
- The warmer biases over the Southern ocean in JJA stem from reduced ice extent (attributed to Replay initialization)
Deserts: Tmax is warmer (consistent with lower albedo)

- Winter: slight reduction of cold bias in the eastern US, but still cool bias
- Summer: reduced warm bias in central US, cool bias elsewhere (and most of Eurasia)
- Deserts: Tmin is cooler (consistent with reduced cloudiness)
- CONUS
  - Winter Tmin: slight reduction of the warm bias (increased cold bias to the north)
  - Summer Tmin: slight increase in warm bias, except for the west coast
Warm bias enhanced in summer hemisphere. Bias increases from week 1 to 2
Warm bias (Kuroshio and south of Australia) and too cold bias in south tropical Atlantic in winter
Overall, spatial structure similar to low-res prototype 8; differences largely due to ICs