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

NATIONAL WEATHER SERVICE

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Atmospheric Composition

Infrastructure

Coupled Model Evaluation

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 (¼ tripolar) - Ice (¼ tripolar) - Wave (¼ 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

GFS v16

Atm: C364, L127
GFSv16 physics including

- Land: NOAH
- GFDL microphysics
- NSST

Ocean: N/A
Ice: N/A
Wave: 9-25km
Aerosols: N/A

GDAS DA

HR1

Atm: C768, L127
Updated physics including

- Land: NOAH-MP
- Thompson microphysics
- NSST

Ocean: ¼ tripolar
Ice: ¼ tripolar
Wave: ¼ tripolar
Aerosols: Not invoked

no DA

GFSv17

Atm: C768, L127
Updated physics including

- Land: NOAH-MP
- Thompson microphysics
- NSST

Ocean: ¼ tripolar
Ice: ¼ tripolar
Wave: unstructured
Aerosols: In GDAS deterministic forecast only and no aerosol-radiation interaction

GDAS DA (Weakly Coupled)

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)

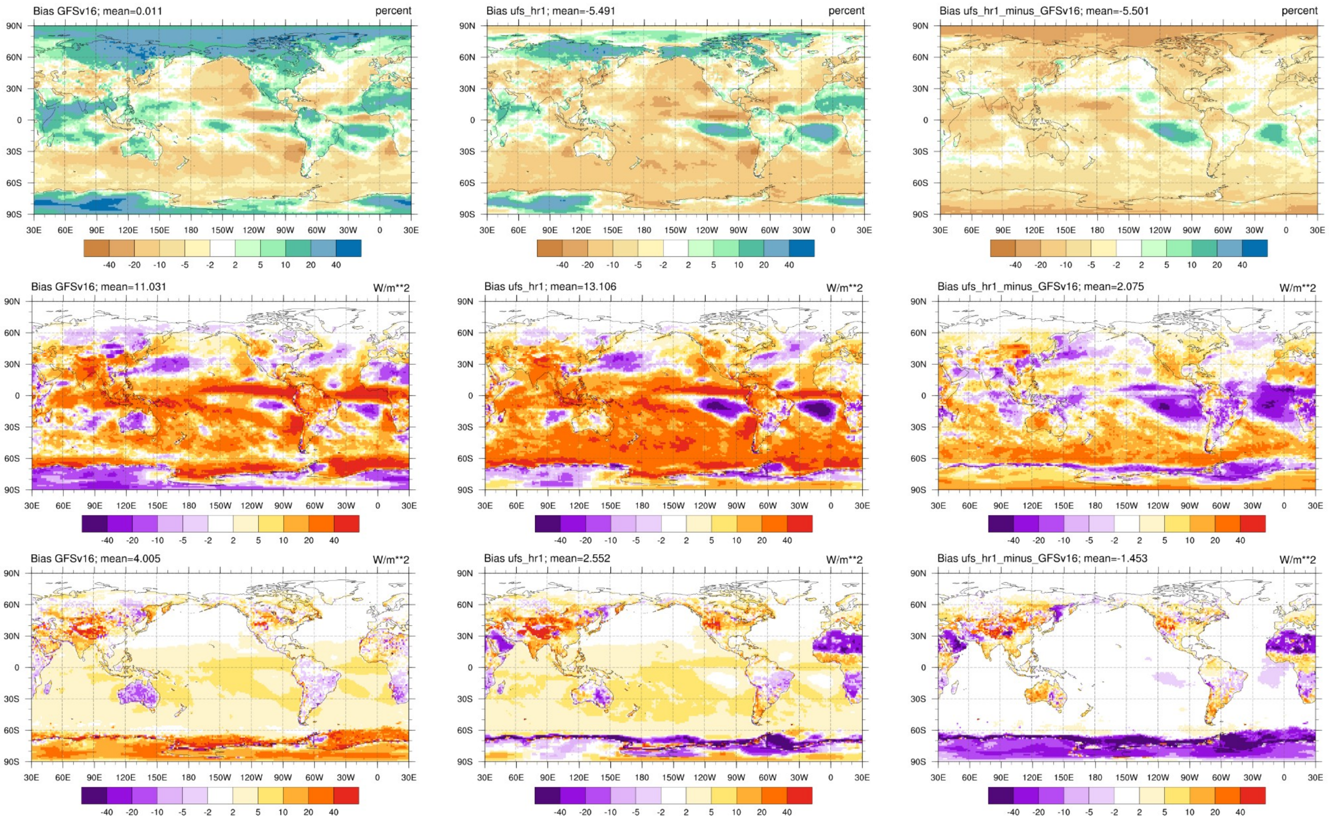
Total Clouds, SFC Downward Shortwave, Upward longwave: Bias (DJF)

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

Clouds

SW down

SW up

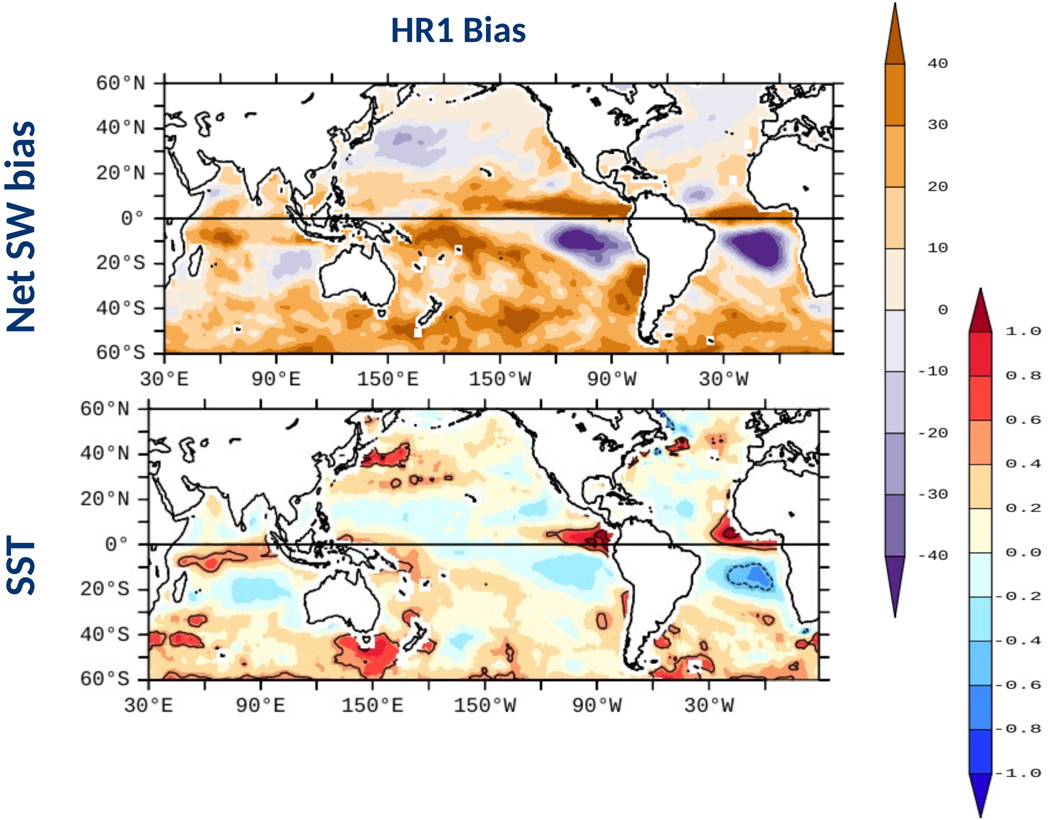


Total clouds generally reduced, but increased south of equator in the eastern tropical Pacific and Atlantic. The reduction is an improvement over Indian Ocean and high latitudes

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

SW and SST bias in HR1 (DJF)



Spatial structure similar to low-res P8

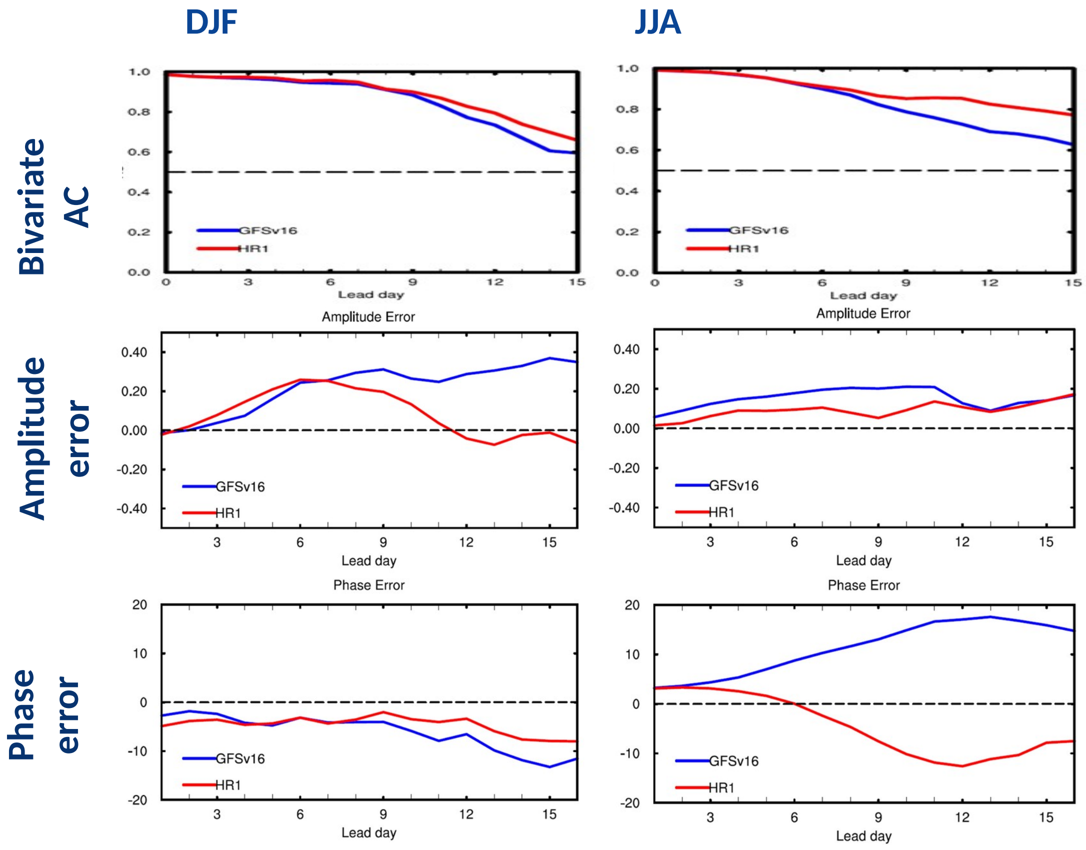
Net SW bias is generally positive, except south of the equator in the eastern tropical Pacific and Atlantic, where HR1 has increased cloud amounts and exacerbated negative downward SW bias

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.

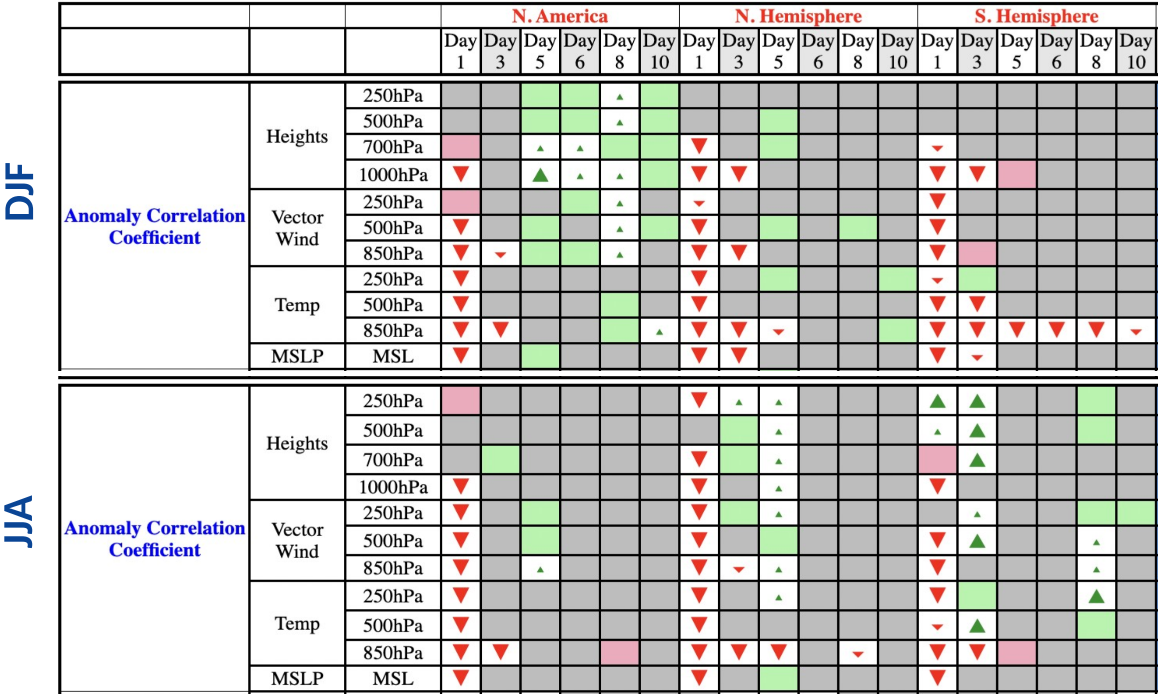
For both GFSv16 and HR1, larger amplitude bias in strong MJOs; larger propagation bias in weak MJOs.

ACC scorecard

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

HR1 is worse than GFSv16 at the 99.9% significance level
HR1 is worse than GFSv16 at the 99% significance level
HR1 is worse than GFSv16 at the 95% significance level

HR1 is better than GFSv16 at the 99.9% significance level
HR1 is better than GFSv16 at the 99% significance level
HR1 is better than GFSv16 at the 95% significance level
No statistically significant difference between HR1 and GFSv16



Day 1

ACC scores for HR1 worse than GFSv16 (initialization shock)

Days 3-10

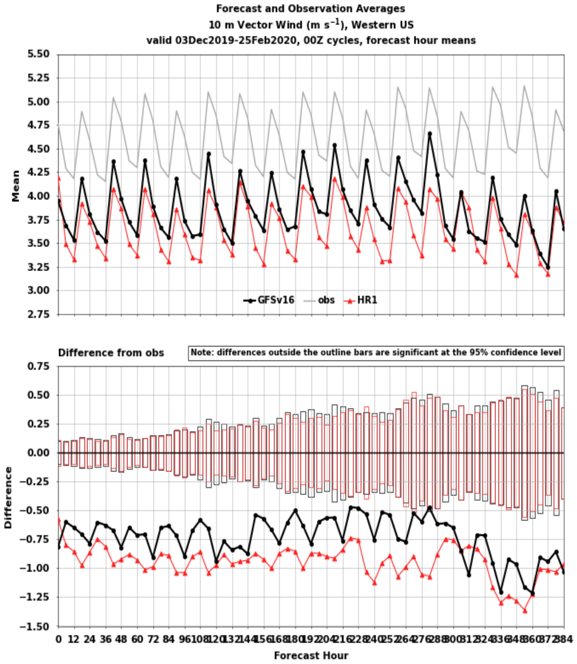
- Improvement: tropics and winter hemisphere – heights, wind speed, upper tropospheric temperature
- Worsening: low level temperatures

Mean Bias: 10m Wind Speed (DJF)

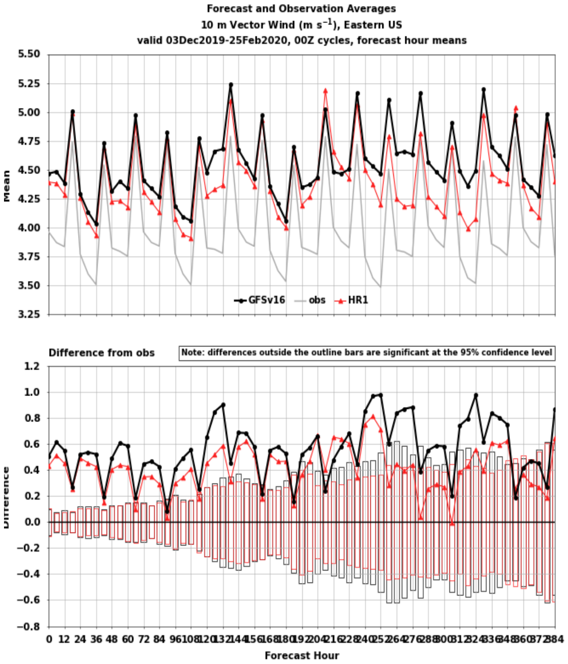
Mean

Error

West CONUS



East CONUS



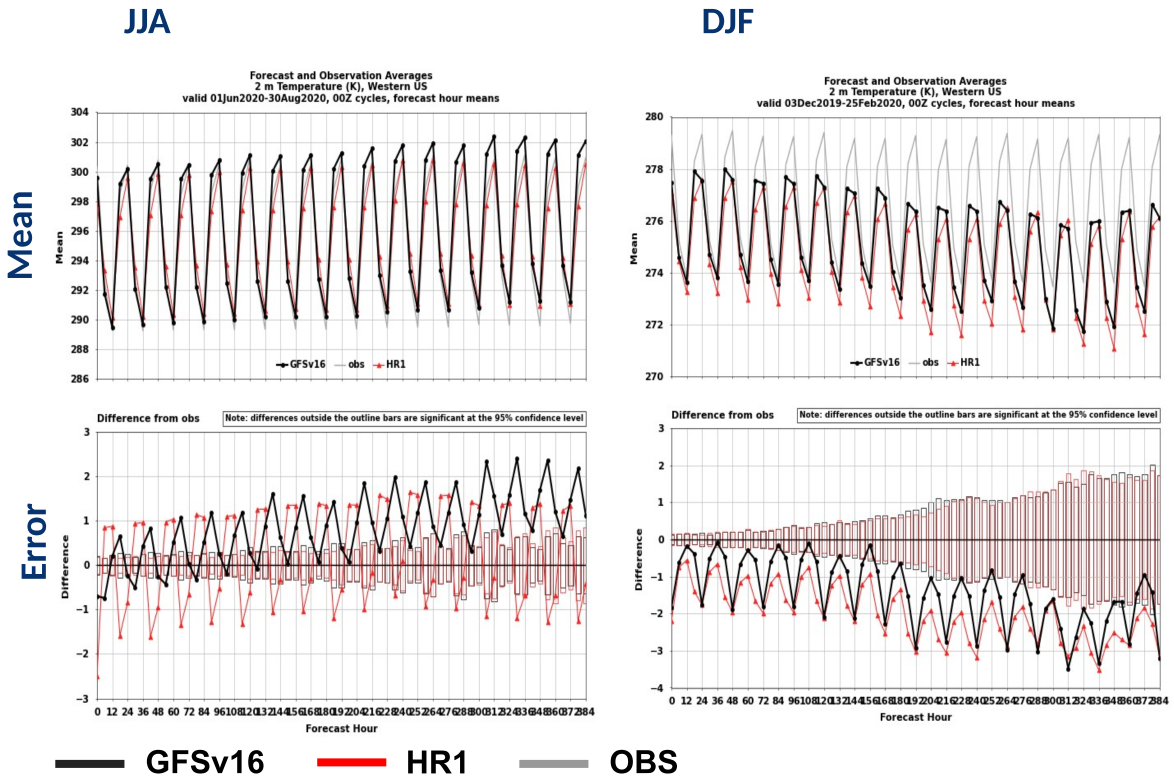
GFSv16 HR1 OBS

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

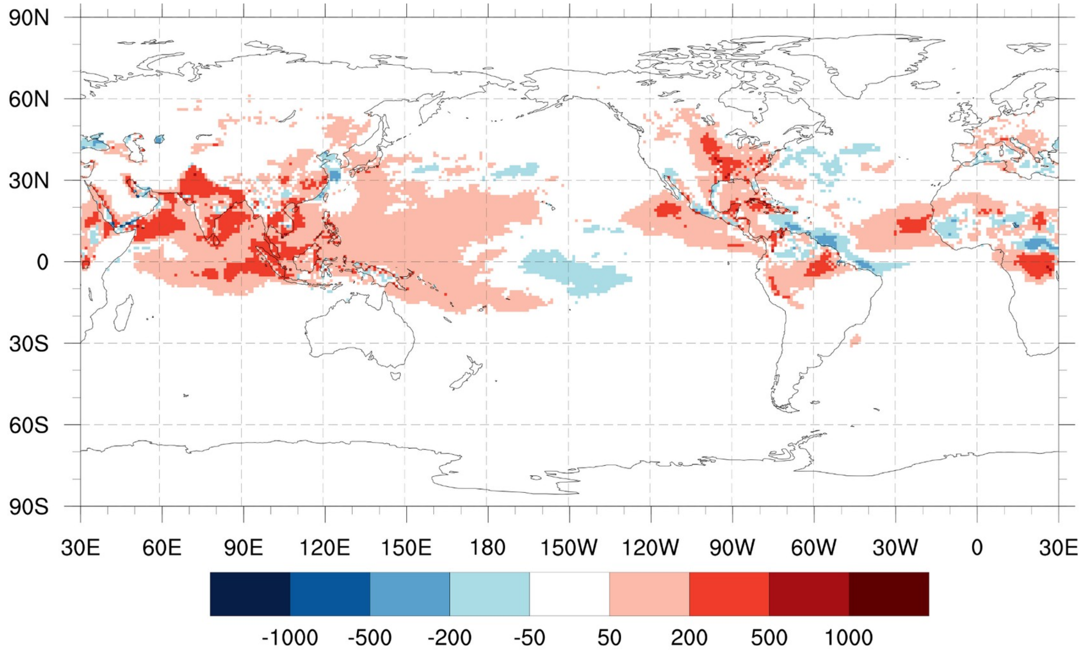
- Reduced daytime warm bias, improved diurnal cycle shape
- Reduced diurnal range

DJF

- Exacerbated nighttime cold bias
- Improved diurnal cycle shape

CAPE

HR1 minus GFSv16, JJA 2020



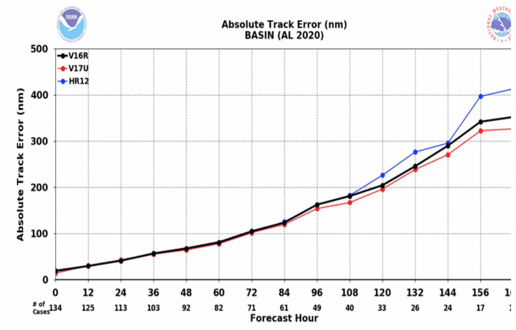
Larger CAPE in HR1 compared to in GFSv16

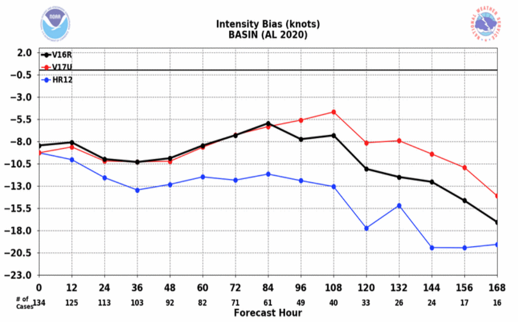
This is a move in the right direction but the magnitude of increase is insufficient.

TC intensity and track error

TC track error | **TC Intensity error**

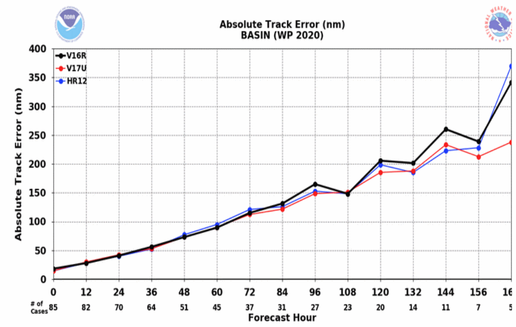
N. Atl

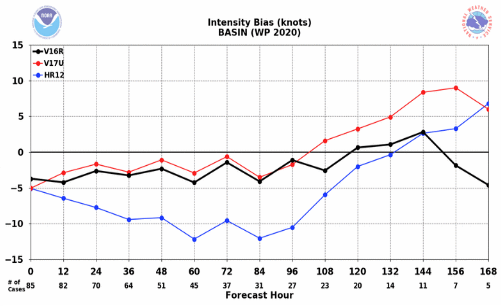




HR1 Uncoupled HR GFSv16

W. Pac





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

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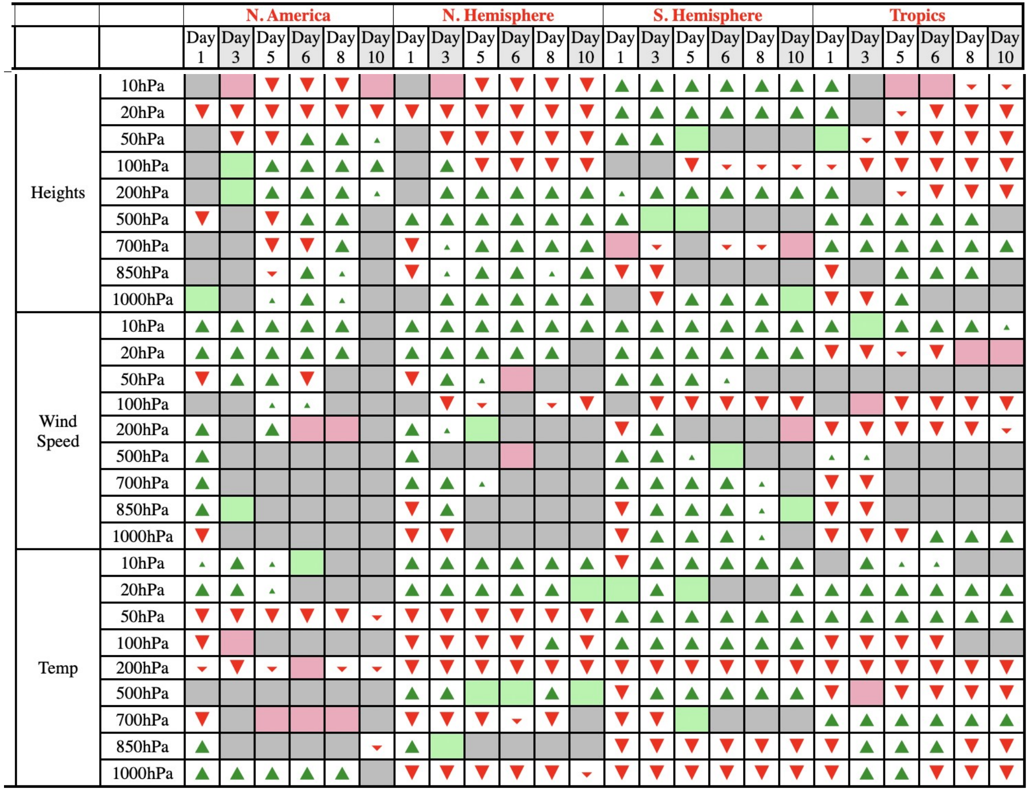
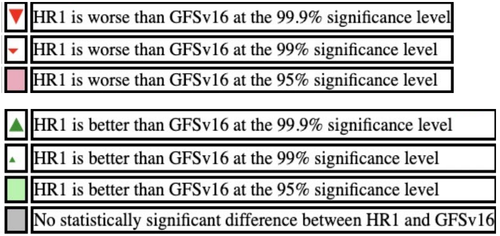
BACK-UP SLIDES

Bias scorecard: DJF

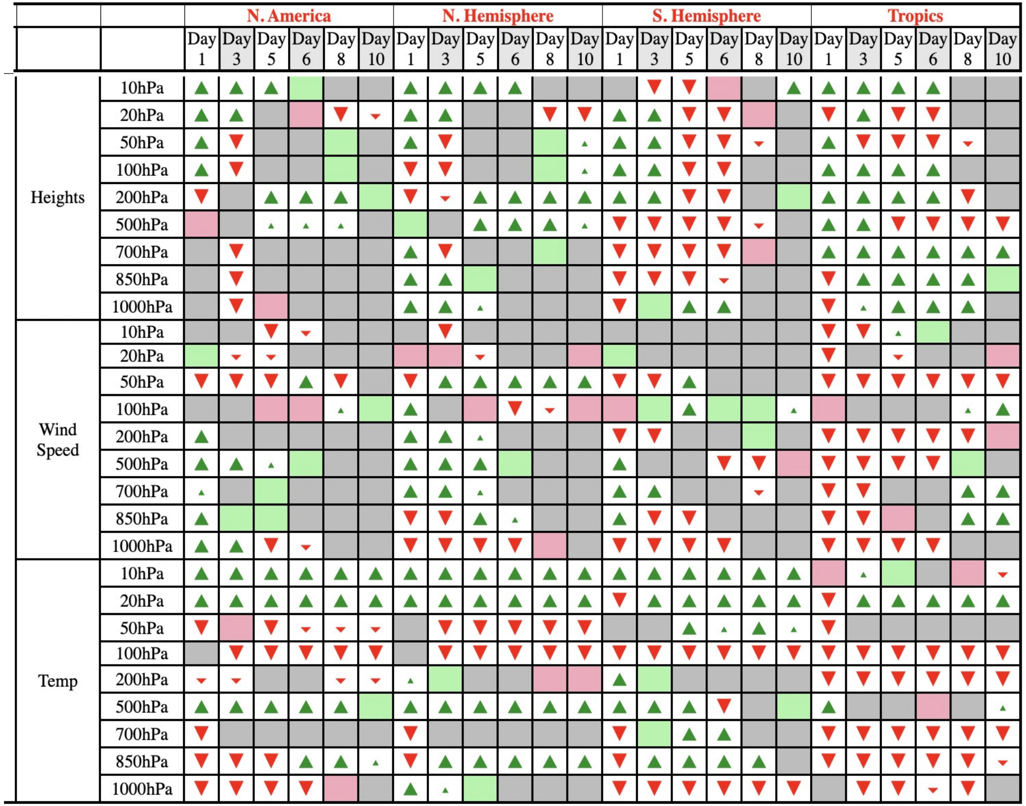
DJF

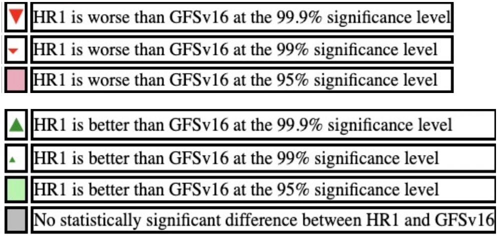




Bias scorecard: JJA

JJA



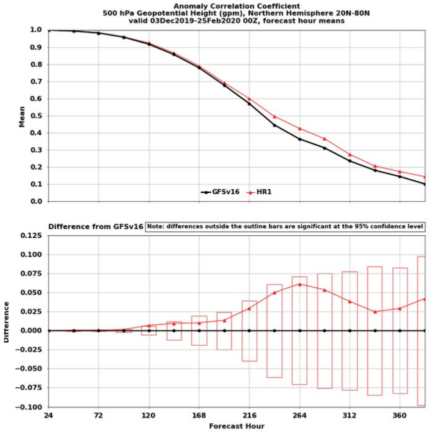


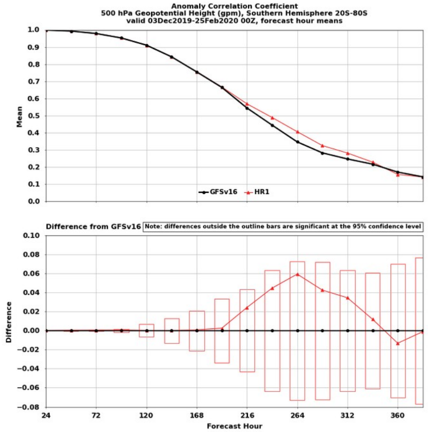
ACC: 500mb Geopotential Height

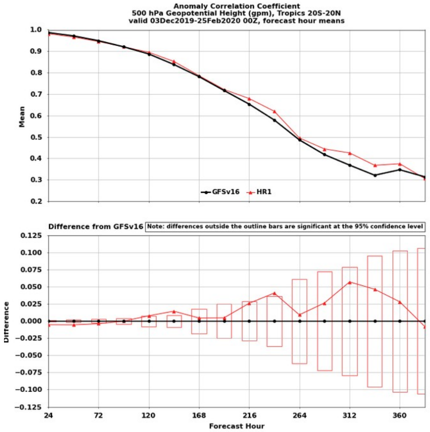
GFSv16

HR1

DJF





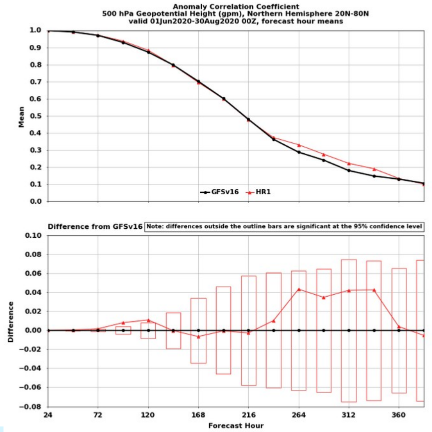


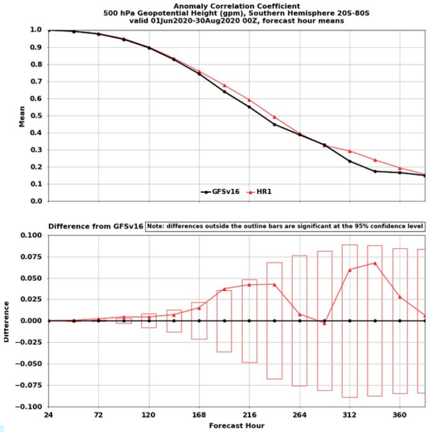
Northern Hemisphere

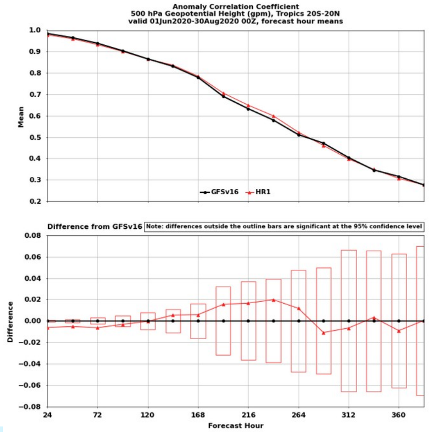
Southern Hemisphere

Tropics

JJA







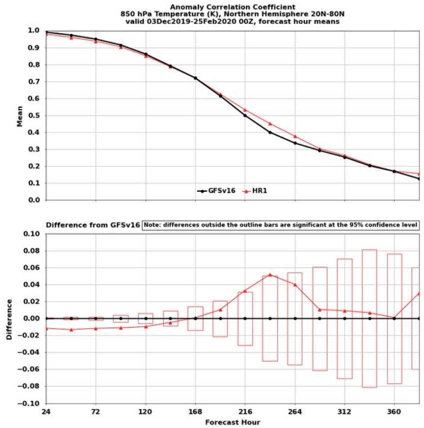
Apparent **improvement** in 500mb heights in NH/SH/Tropics, starting around day 3-5, although not consistently statistically significant

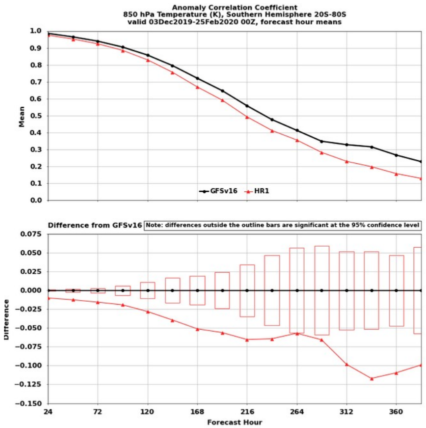
ACC: 850mb Temperature

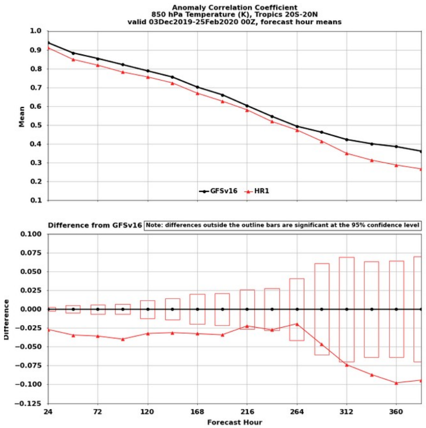
GFSv16

HR1

DJF





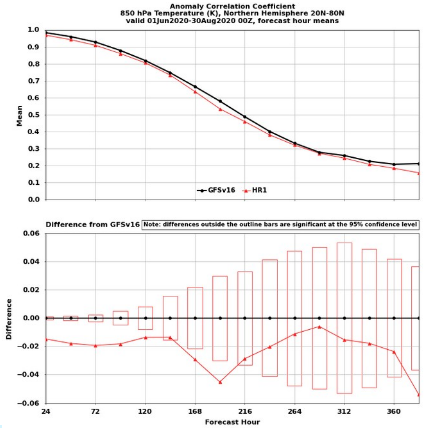


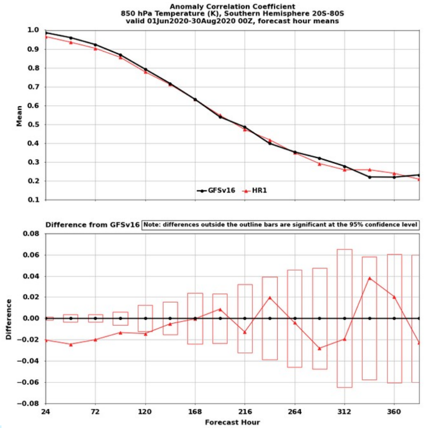
Northern Hemisphere

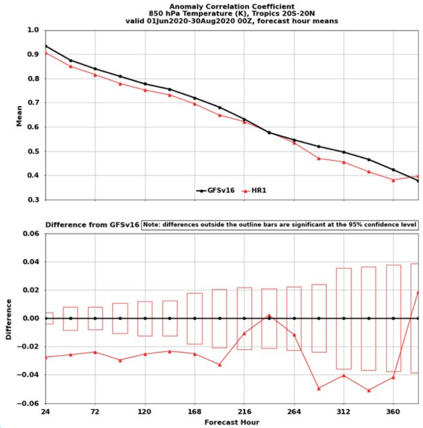
Southern Hemisphere

Tropics

JJA





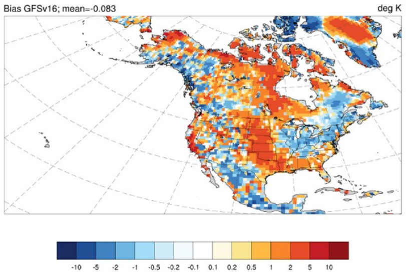


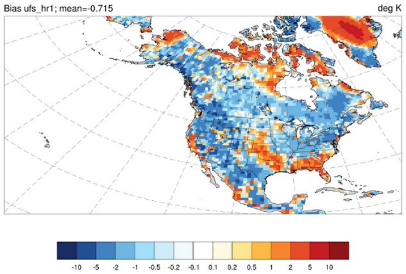
Statistically significant **degradation** for 850 mb Temperature, particularly in the summer hemisphere (SH in DJF, NH in JJA), and in the Tropics

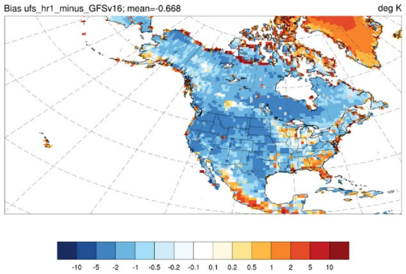
T2max, T2min (JJA)

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

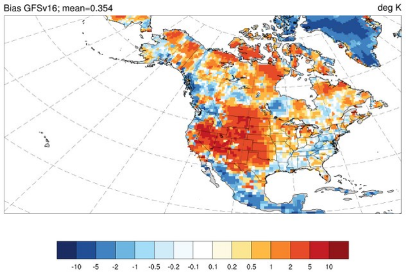
T2max

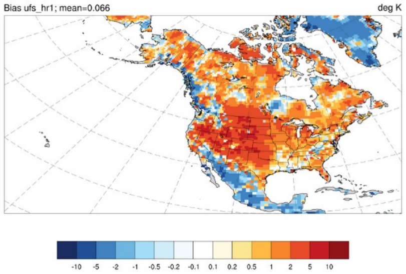


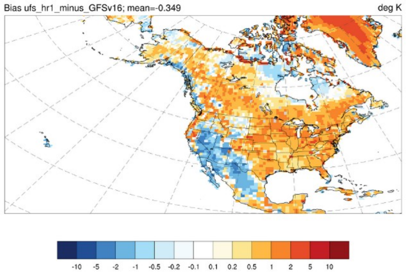




T2min







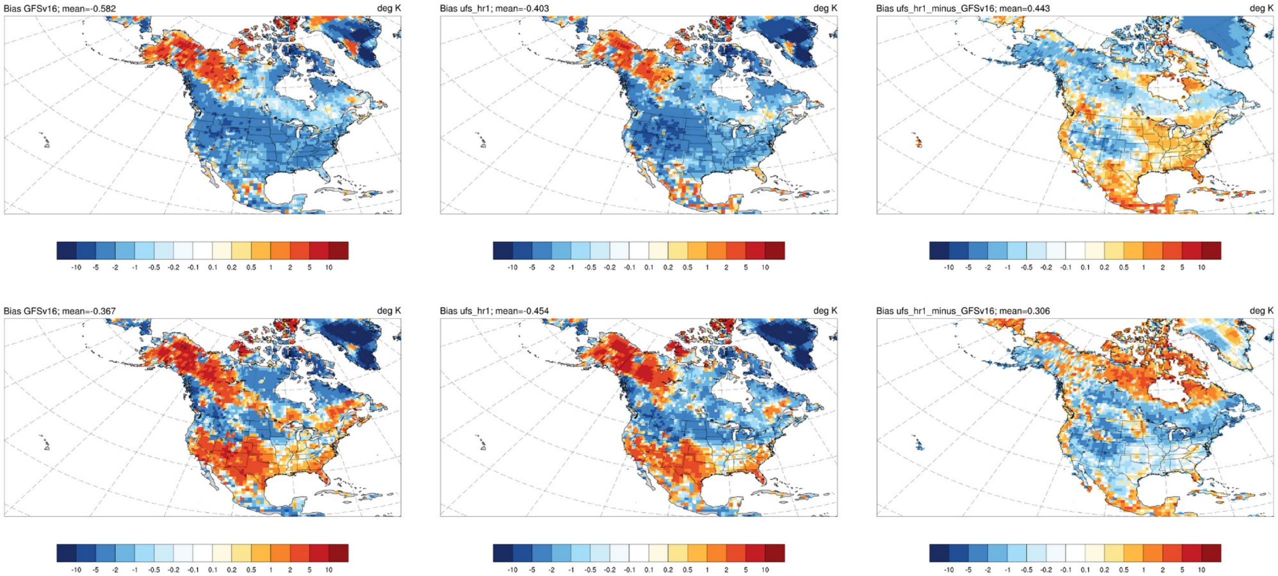
Mostly lower Tmax
Mostly higher Tmin

T2max, T2min (DJF)

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

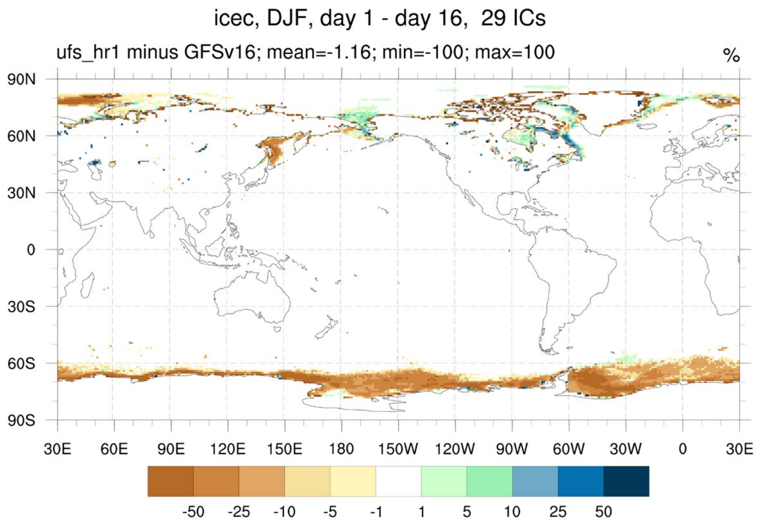
T2max

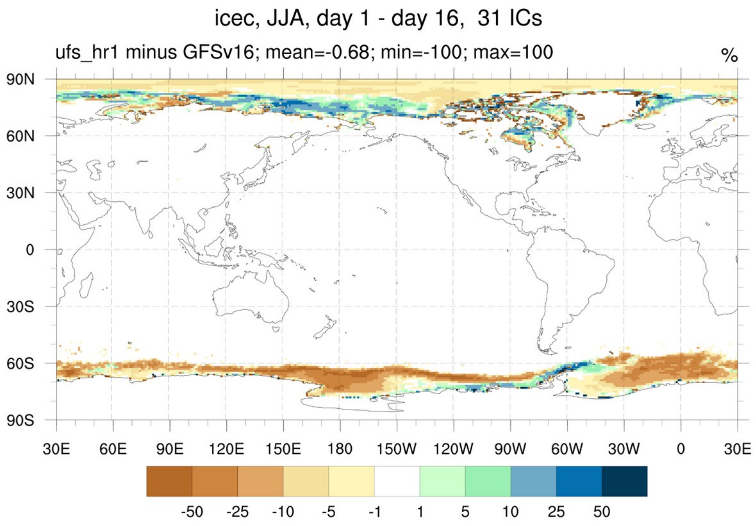
T2min



Mostly higher Tmax
Mostly lower Tmin

Ice Concentration, HR1 minus GFSv16





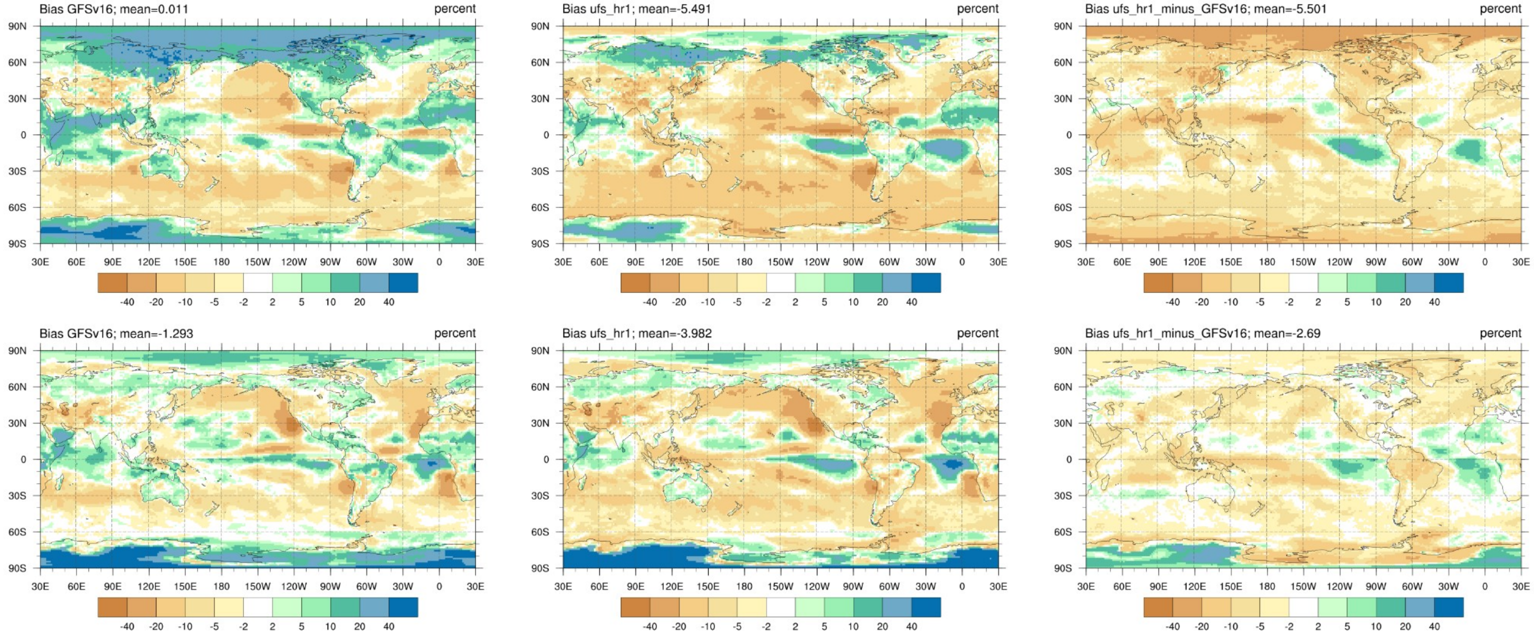
- Ice concentration (and thickness) differences between HR1 and GFSv16 are notable in both SH and NH, but particularly prominent in SH.
- This is a known issue from the Replay ICs for ice, its solution is being implemented by PSL

Total Clouds, bias wrt CERES

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

DJF

JJA



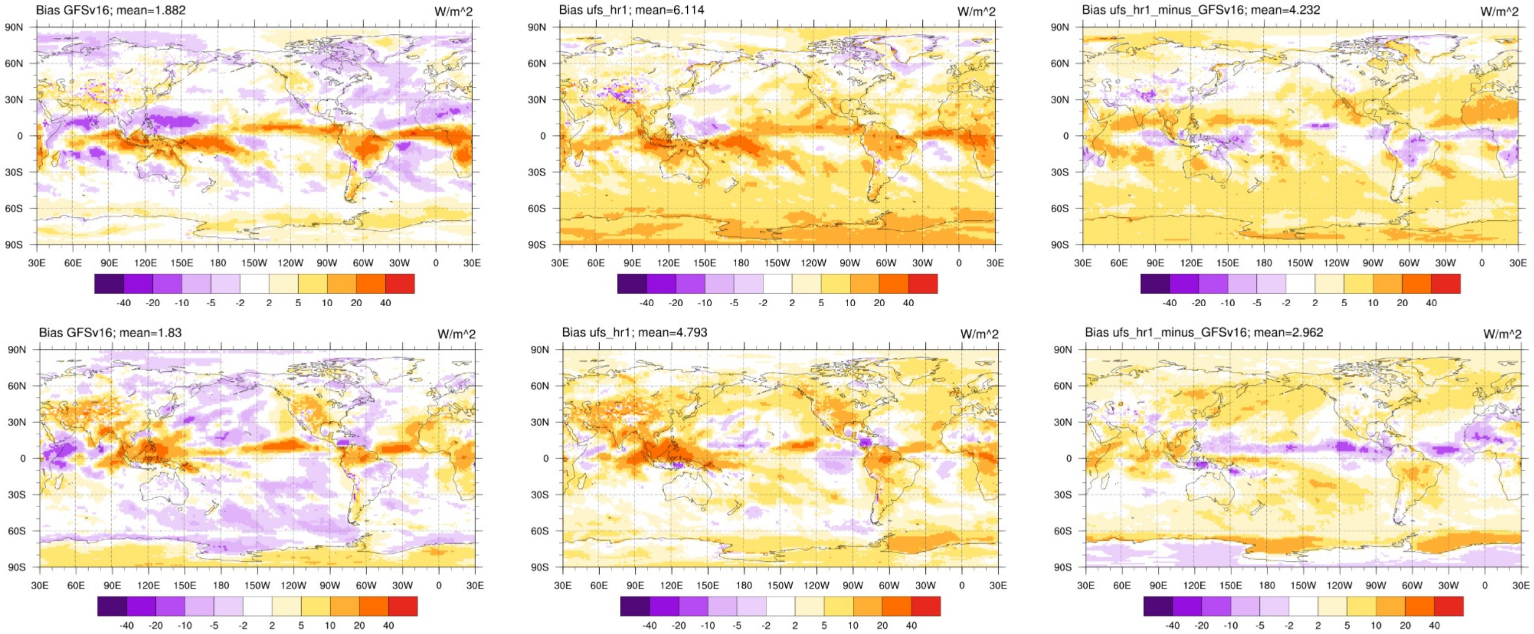
- GFSv16 overestimates the total cloud cover over high latitudes, Indian ocean, Western equatorial Pacific, and south of the equator in the eastern tropical Pacific and Atlantic, as well as over Northern Africa. Cloud cover is underestimated over the remainder of oceans
- HR1 has less clouds than GFSv16, except for the eastern tropical Pacific and Atlantic, where it is cloudier

OLR, bias wrt NOAA-CDR

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

DJF

JJA



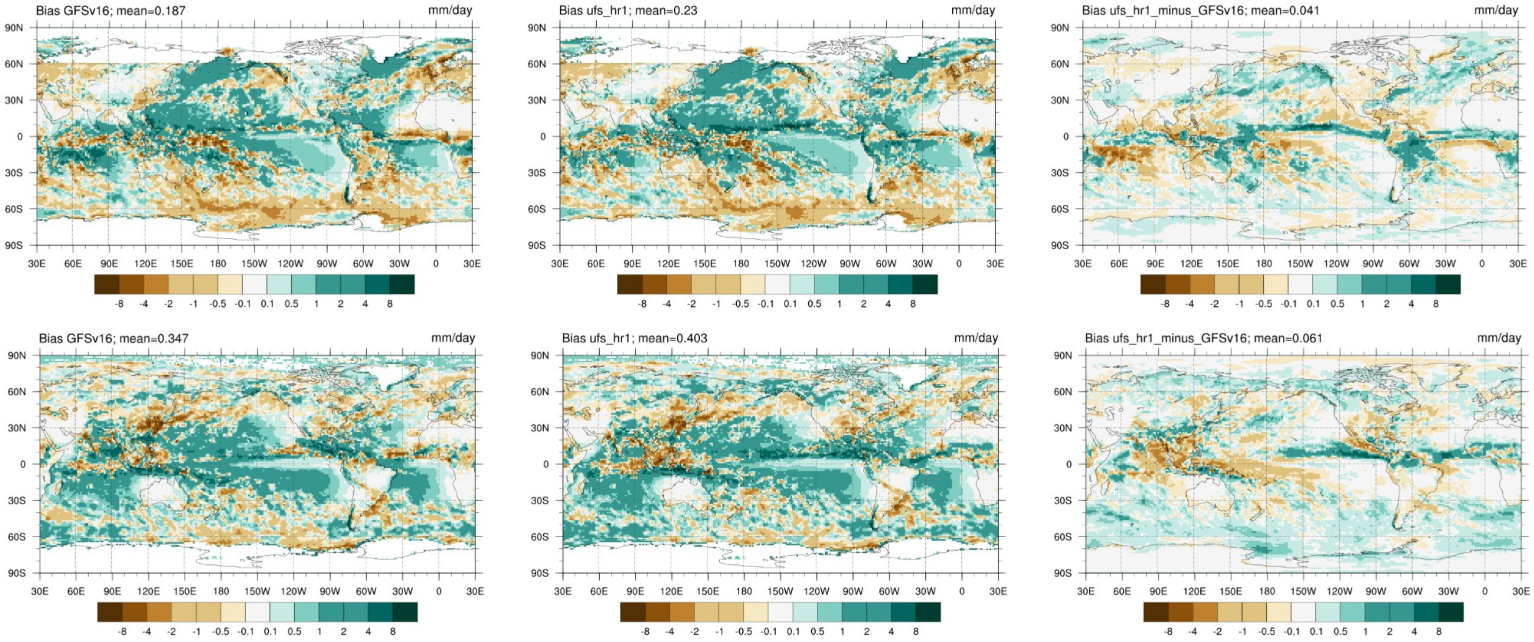
- OLR reduced (bias improved) along the equator (SH in DJF, NH in JJA). OLR increased (bias improved) in Indian Ocean

OLR, bias wrt NOAA CDR

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

DJF

JJA



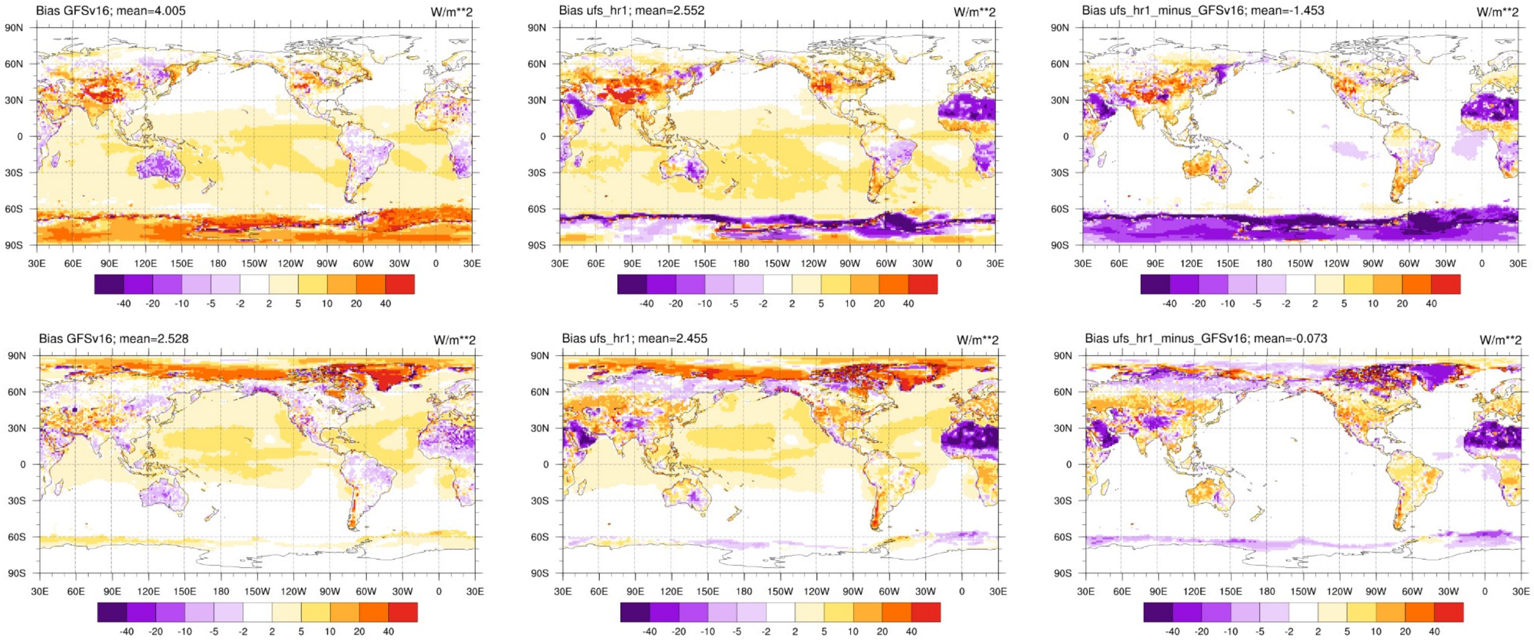
- Precip increased where OLR reduced, and vice versa

Surface upward shortwave radiation, bias wrt CERES

GFSv16 Bias | **HR1 Bias** | **HR1 minus GFSv16**

DJF

JJA



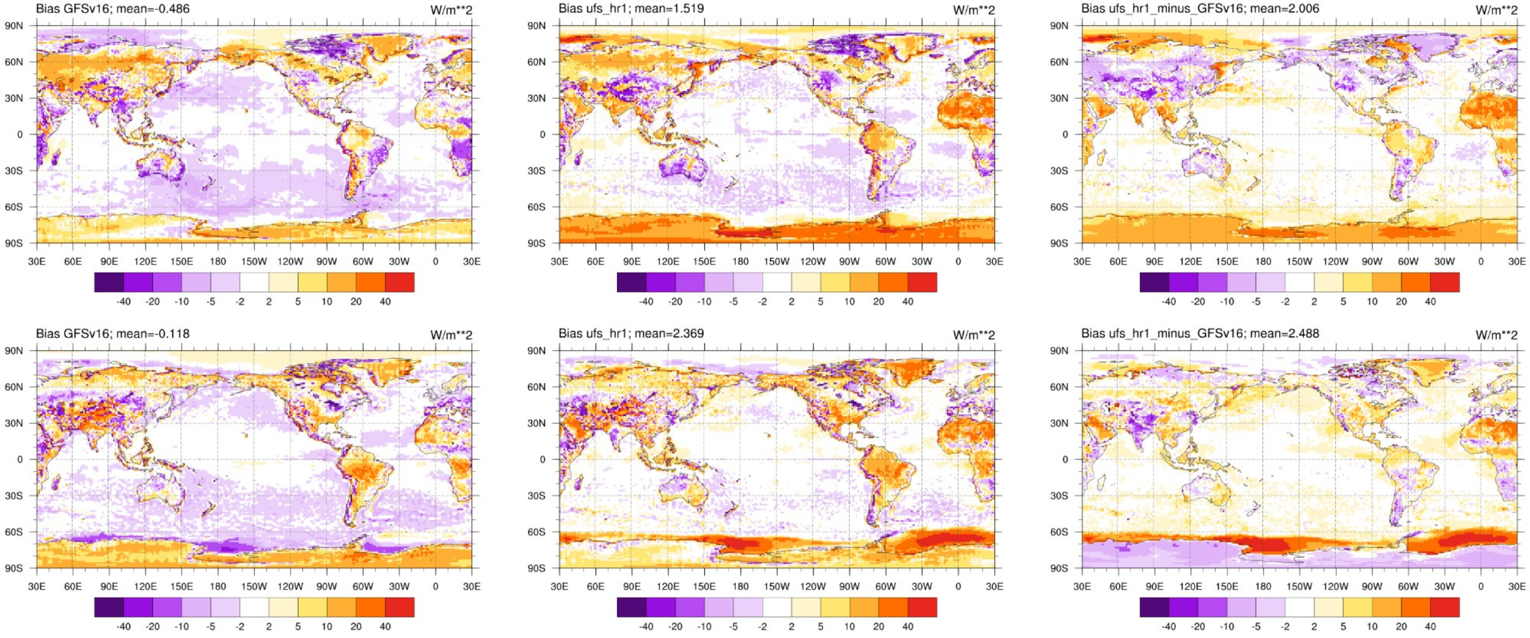
- Most prominent differences between GFSv16 and HR1: Sahara, Arabian Peninsula (deserts) and Antarctic/Greenland (permanent ice/snow), suggesting lower albedoes in HR1
- For the desert regions, this is an exacerbation of negative bias, while for the ice/snow regions it is an amelioration of positive bias

Surface upward longwave radiation, bias wrt CERES

GFSv16 Bias | HR1 Bias | HR1 minus GFSv16

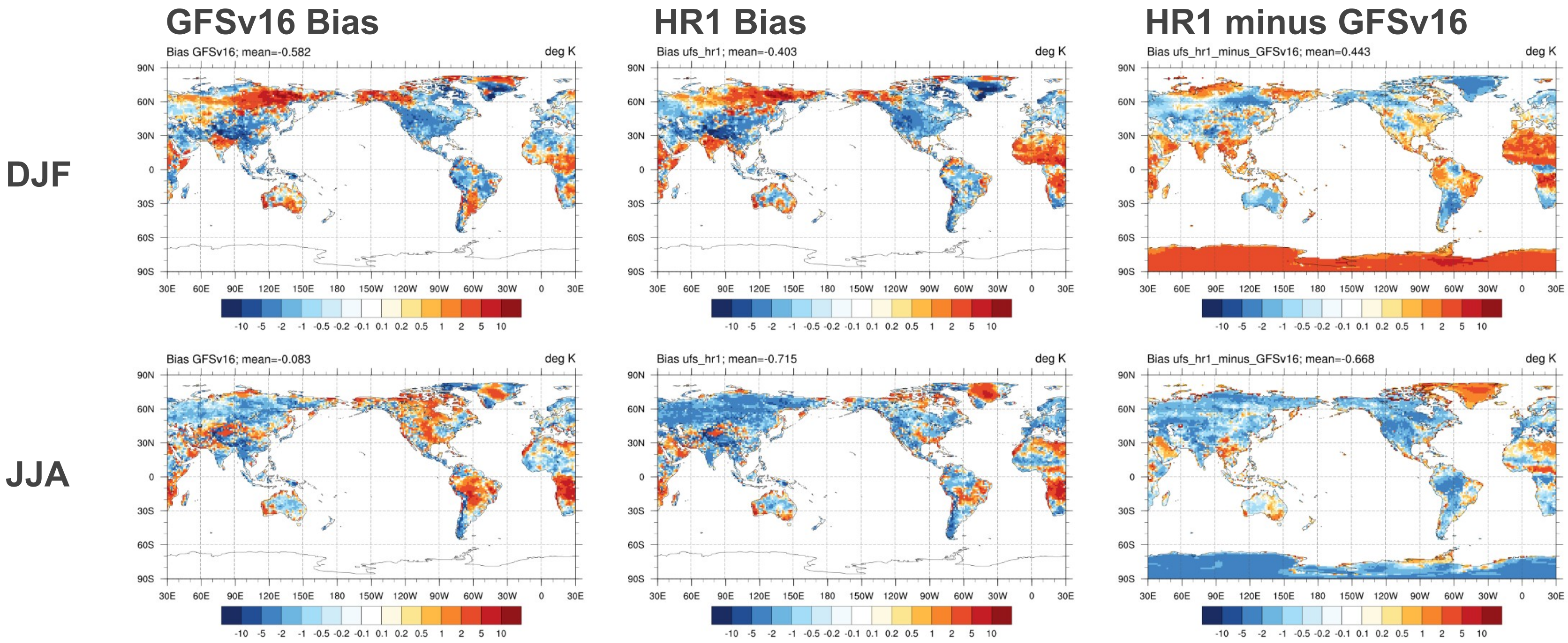
DJF

JJA



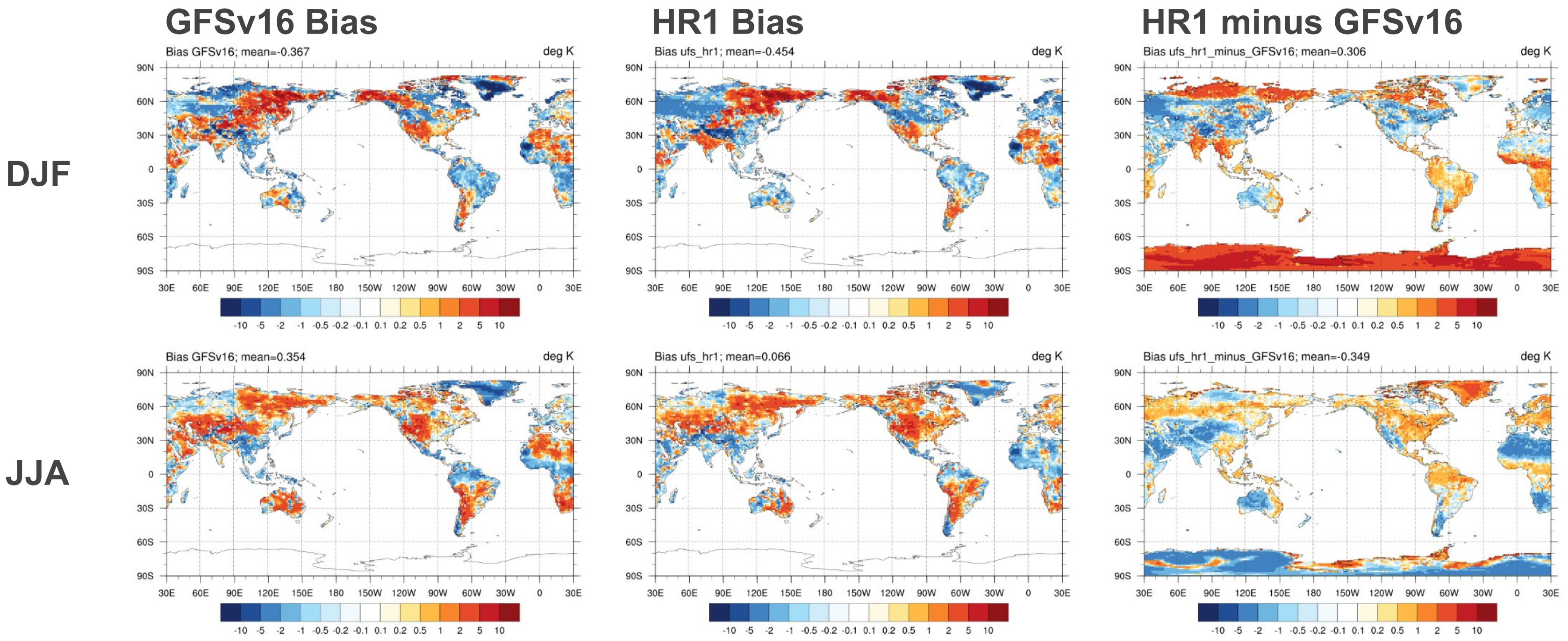
- Upward longwave radiation at the surface: increased positive bias notable over Sahara, Arabian Peninsula (deserts), and in the Southern ocean in JJA – reflecting warmer biases in these regions.
- The warmer biases over the Southern ocean in JJA stem from reduced ice extent (attributed to Replay initialization)

2-m Tmax, bias wrt CPC



- Deserts: Tmax is warmer (consistent with lower albedo)
- CONUS
    - 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)

2-m Tmin, bias wrt CPC



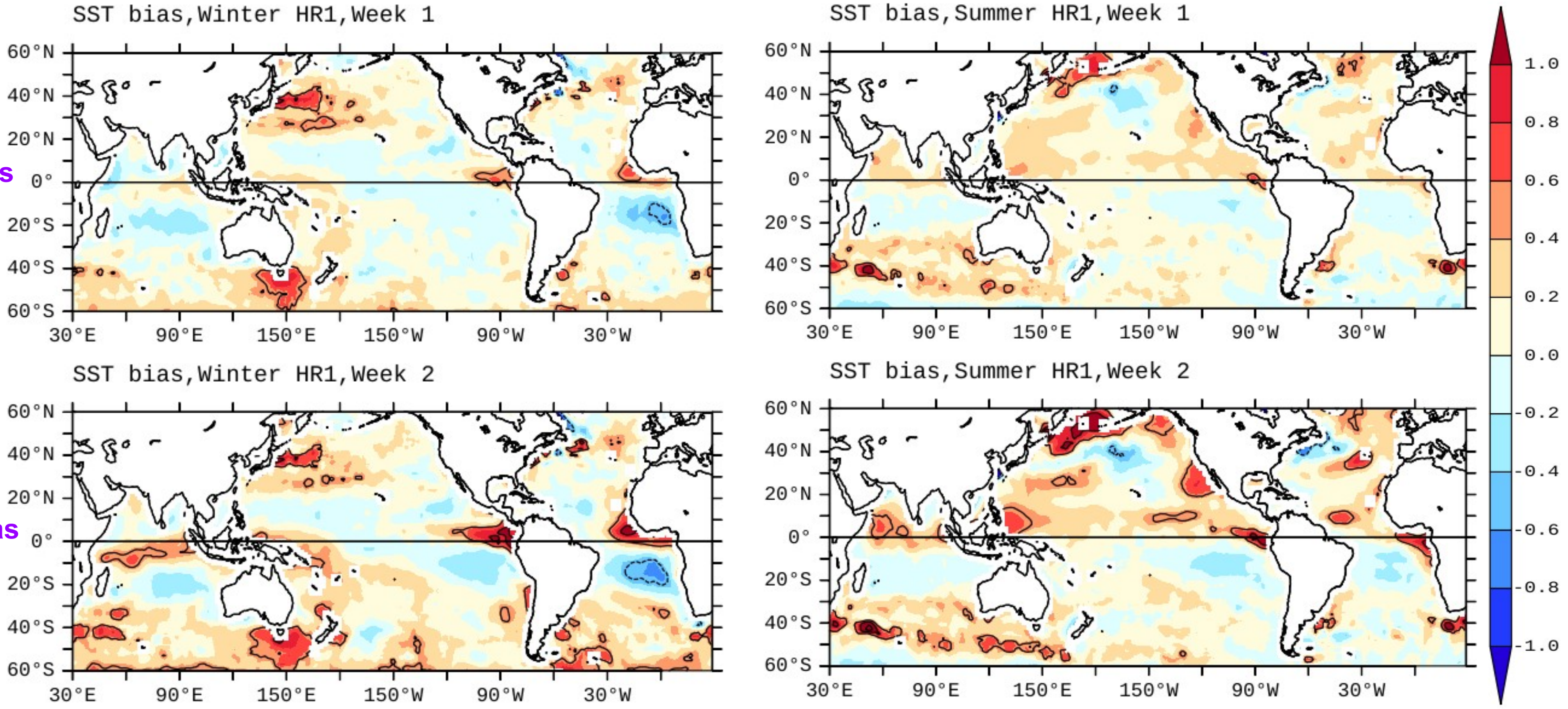
- Deserts: Tmin is cooler (consistent with reduced cloudiness)
- CONUS
    - Winter Tmin: slight reduction of the warm bias (increased cold bias to the north)
    - Summer Tmin: slight increase in warm bias, except for the west coast

SST bias in weekly averaged forecasts of HR1

Winter case | **Summer case**

Week 1 bias

Week 2 bias



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