Evaluation of hydrostatic option in UFS for community-based seasonal modeling

Benjamin W. Green*,[1,2], Sina Khani[1,2], and Shan Sun[1]
*ben.green@noaa.gov; [1]NOAA/GSL, Boulder, CO; [2]CIRES, CU Boulder, Boulder, CO

Introduction

NOAA is in the process of developing a UFS-based coupled (atmosphere/ocean/sea-ice/wave) model system for seasonal predictions; for operations, this will be realized as the Seasonal Forecast System (SFS). SFS will have an atmospheric resolution of ~50km horizontally. However, for the wider UFS community, this configuration may be too expensive computationally, and lower horizontal resolution may be sufficient for research and development purposes. This work uses a coarser horizontal resolution (~100km) to demonstrate the impact of switching the atmospheric dynamics from non-hydrostatic to hydrostatic. Because the operational SFS will be hydrostatic (an option only recently implemented in UFS), it is important to understand its impact at coarser resolutions as well. For seasonal time scales (9+ months), evaluation focuses on mean-state biases.

Experimental Configuration

Atmosphere: 100km horizontal; L127; hydrostatic
Ocean: 1° horizontal; 75 vertical layers
ICs: May 21, Nov 1 of 2000 through 2022 (**23 years**)
Integration length: 284 days (9 full months)

Results

• Hydrostatic has larger SST biases than non-hydrostatic

Hydrostatic worsens existing warm bias; **still need to address the root causes!**

A primary driver of SST bias at seasonal timescales is surface downward shortwave bias. We look at that later in the poster.

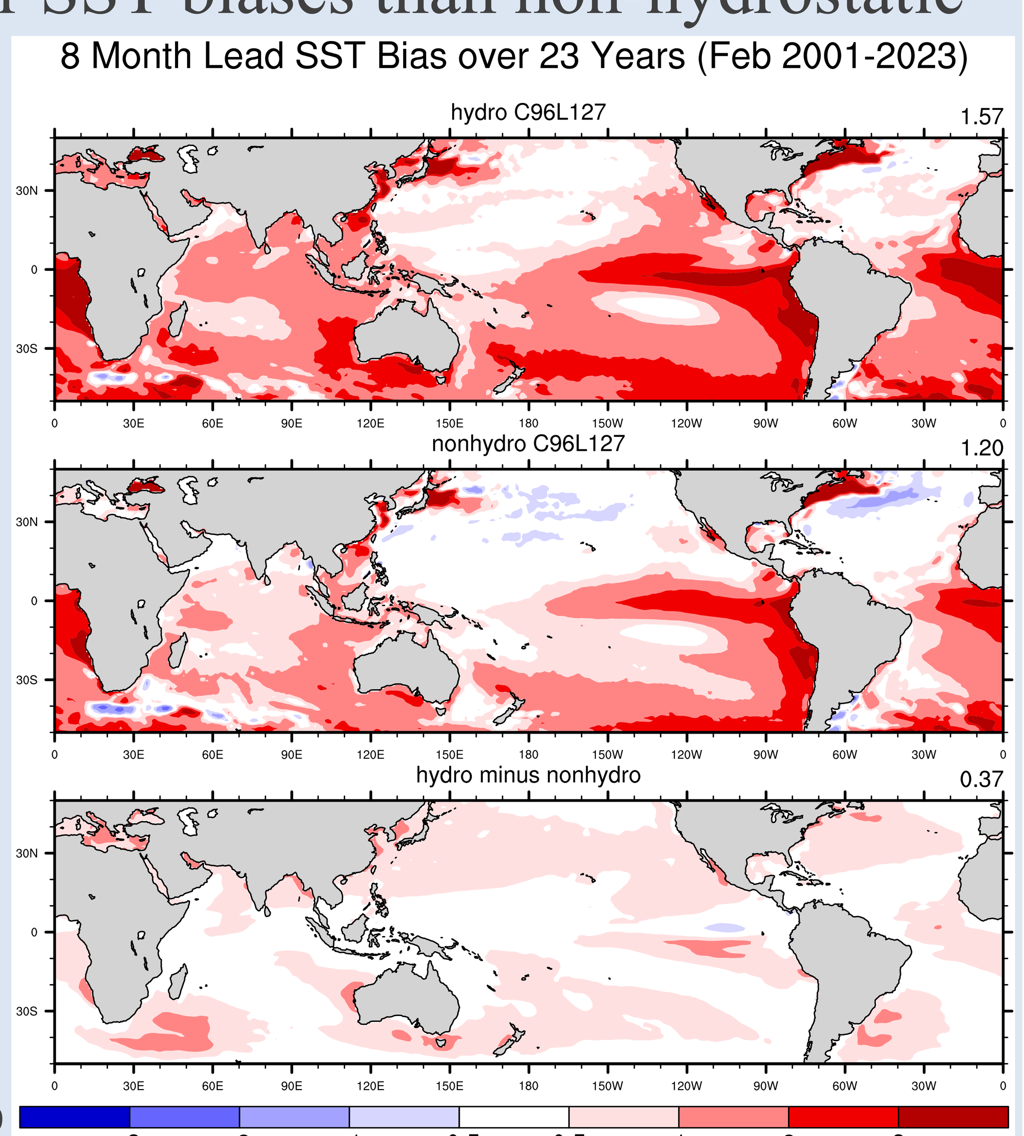

Figure 1: SST bias verified against OISST for (top) hydrostatic and (middle) non-hydrostatic at Lead 8 (February) from May ICs. Bottom: SST **difference**, hydrostatic minus nonhydro

Fluxes

• Both sets of UFS runs have too much DSW at the surface; hydrostatic exacerbates the problem

• But, regional patterns of DSW and SST are different, so there must be other factors:

- Sensible/latent heat flux
- Advection
- Error bars on verifying datasets?

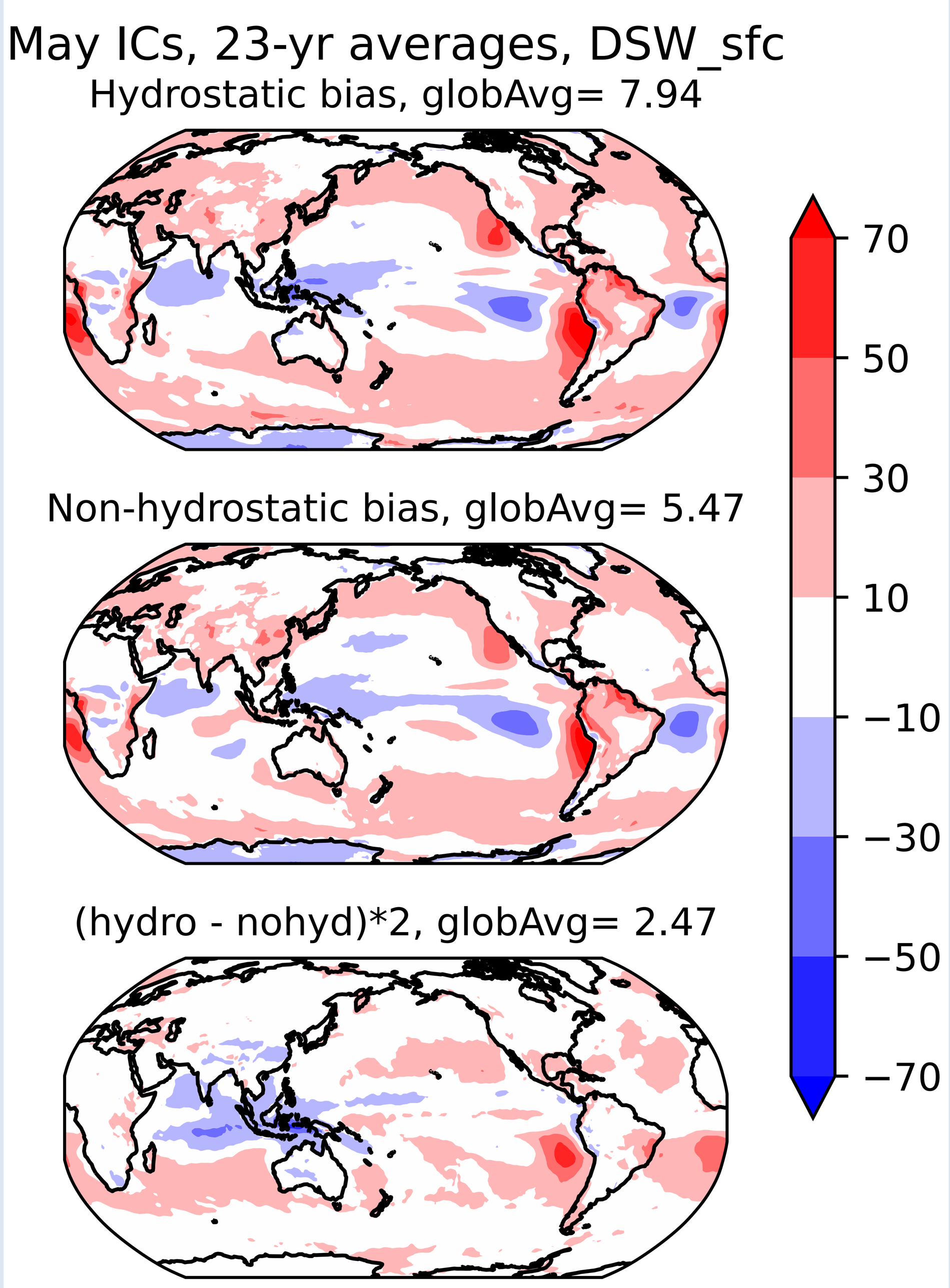

Figure 2: Bias in downward SW radiation (vs. CERES) for (top) hydrostatic and (middle) non-hydrostatic. Bottom: DSW **difference** (multiplied by 2 in the map)

Globally-averaged fluxes over time

• Biggest differences from CERES are ULW_sfc (consistent with higher SST), DSW_sfc, and USW_toa

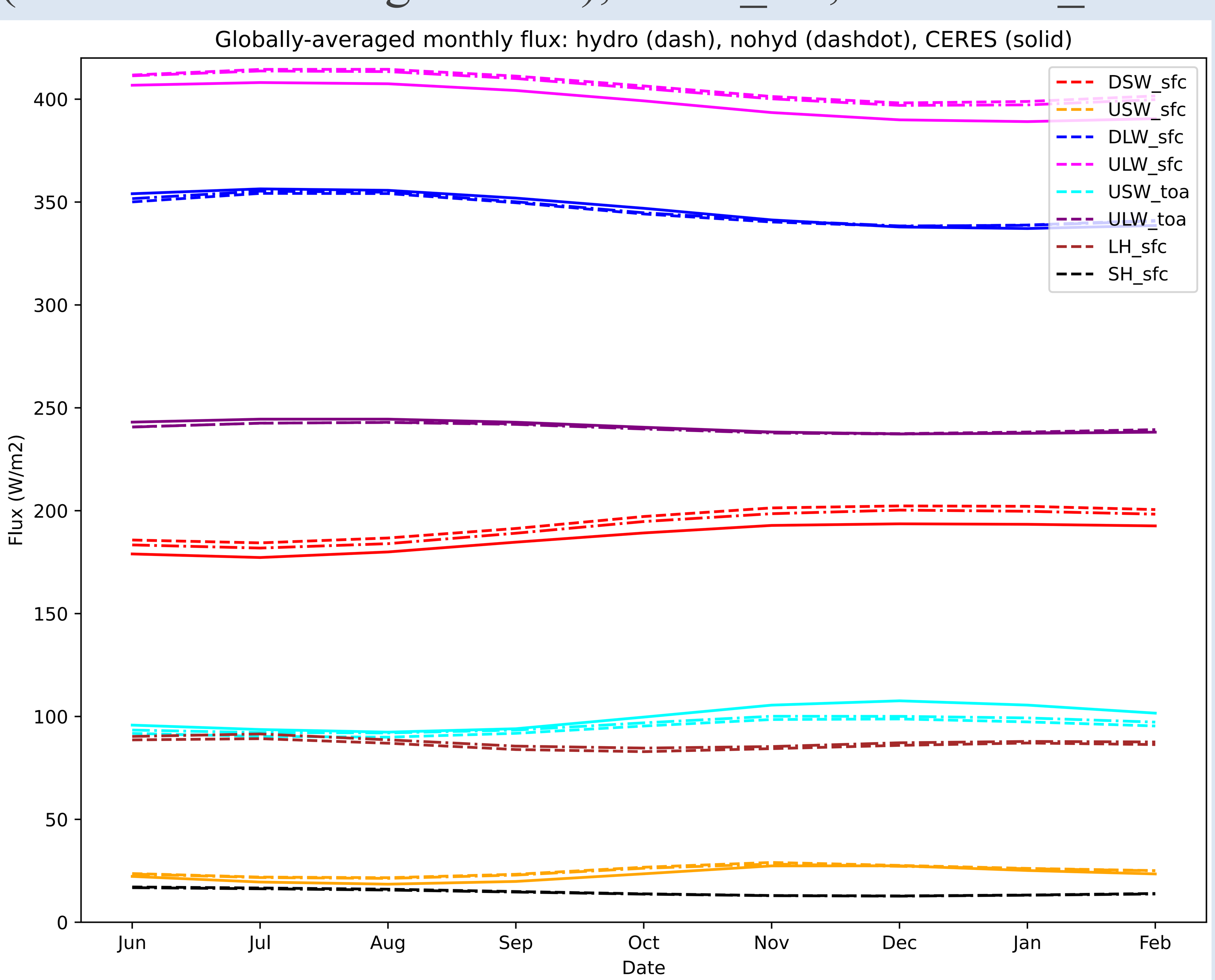

Figure 3: Global average (as a function of lead month over all 23 years) of surface and TOA radiative flux components for both hydrostatic and non-hydrostatic experiments, compared with CERES; surface sensible and latent heat fluxes are also shown for UFS runs (no "truth" shown)

Net TOA flux

TOA spatial bias patterns are consistent across years (not shown). Breaking down by component (not shown), net biases are primarily from upward SW. OLR biases have opposite sign as well as smaller magnitude. Differences between hydrostatic and non-hydro are small, but do mimic the patterns of DSW_sfc differences, which is not surprising because TOA & surface radiative fluxes are both impacted by clouds.

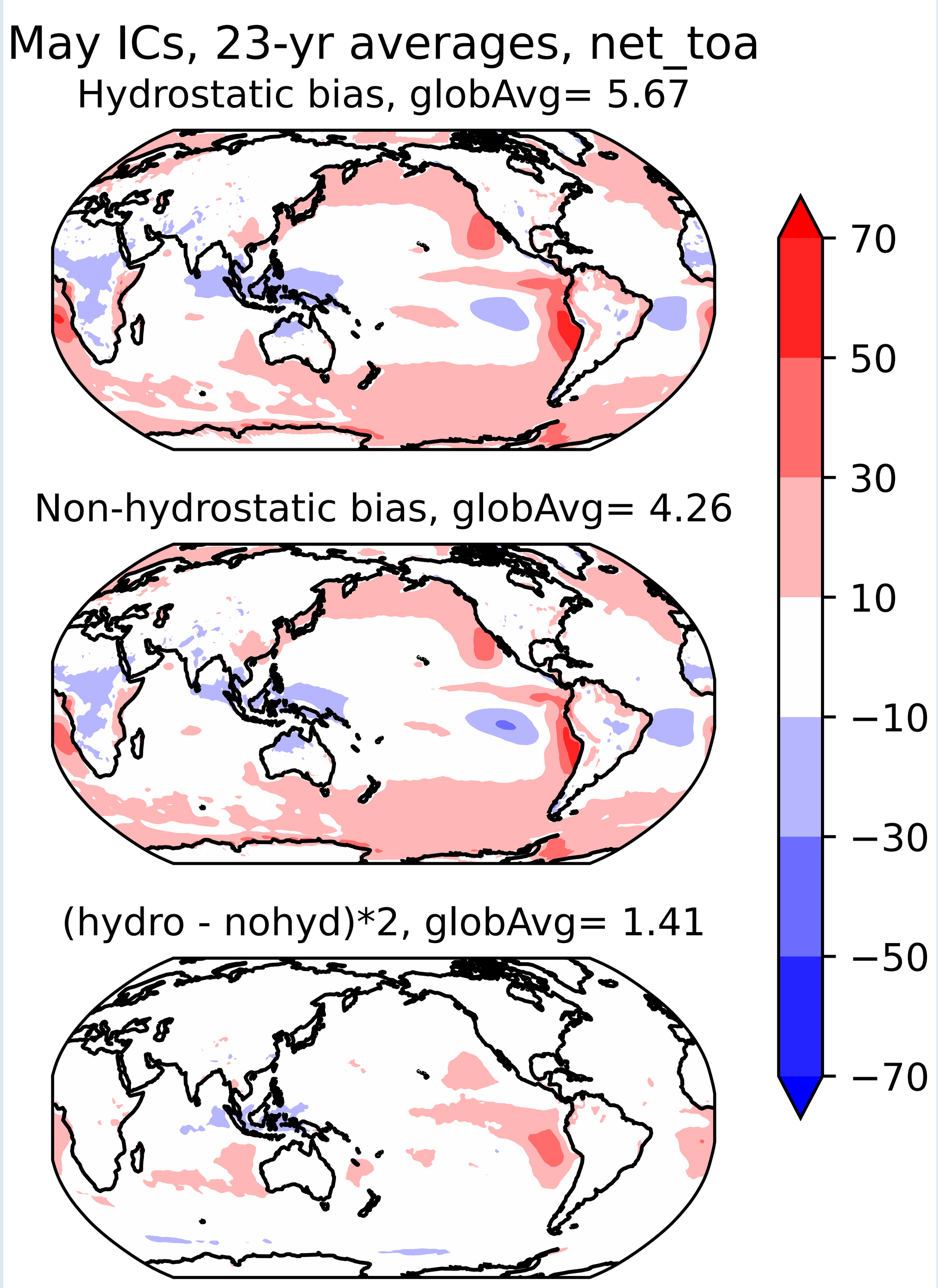

Figure 4: Spatial patterns of net TOA radiation bias for (top) hydrostatic and (bottom) non-hydrostatic runs. Averaged across all 23 years of ICs and all lead times.

Conclusions

• Hydrostatic option at C96 (100km) worsens the warm SST bias seen in non-hydrostatic C96: need to find cause

• Biases in downwelling surface shortwave radiation (sunlight) cannot completely explain SST biases (at least spatially)

• Hydrostatic vs. non-hydrostatic are virtually identical in terms of average TOA radiative fluxes

• There is a strong connection between **difference plots** (hydrostatic minus non-hydrostatic) for TOA radiation and surface downward solar radiation: common impact of clouds

• Cloud fraction is not a useful diagnostic because it does not give any information about thickness or height (not shown)

• Hydrostatic option is usable at C96 (as it should be!), so other processes (e.g., physics) need to be thoroughly investigated to improve model performance (including reducing SST bias)