Reduced SST forecast error in UFS-P8 by turning off interactive aerosols and waves models

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1. Introduction

Systematic error in sea surface temperature (SST) forecasts has plagued several generations of coupled general circulation models for decades and is one of the major sources of errors in subseasonal-to-seasonal (S2S) predictions. We present a comparative study of the performance of SST forecast in the Unified Forecasts System Prototype-8 (UFS-P8) with and without interactive aerosol and wave models. Also, we attempt to examine uncertainty of ocean initial conditions (OICs) and its possible impact on SST forecast error in S2S time scales using the 6-month ensemble reforecasts by UFS-P8 conducted at COLA/GMU.

2. Experimentation with UFS-P8 Configurations

- *UFS-P8 configurations* : Atmosphere – FV3 dynamic core, GFSv17 physics, Noah-MP LSM, C384 (~25km), 127 vertical levels; Ocean – MOM6, hybrid-coordinate with tri-polar grid (~0.25º) and 75 vertical levels; Sea Ice – CICE6, same tripolar grid as MOM6 with 5 thickness categories; Waves – WAVEWATCHIII, 0.5º; Aerosols – GOCART at the atmospheric model resolution; CMEPS mediator
- *Running UFS-P8 on Frontera and Initial Conditions (ICs)* : The UFS-P8 model was compiled with configuration files generated to run both with and without waves and aerosols components on Frontera at Texas Advanced Computing Center. All ICs used in this study were originally generated at NOAA, for use in their 35-day hindcasts of UFS-P8 (April 2011~March 2018). Two different ocean analyses were used for OICs, which came from the NOAA CPC 3D-Var analysis and the ECMWF Ocean Reanalysis System 5 (ORAS5).
- ***EXP–I*** : (1) **Control** – Fully coupled UFS-P8 with ORAS5 OICs, (2) **No aerosol/wave** – Same as Control but for no interactive aerosols and waves components. 28-day ensemble (6 members) reforecasts initialized on October 1, 2016 were analyzed. Verification data is 0.05º × 0.05º OSTIA SST.
- ***EXP–II*** : (1) **CPC 3D-Var** – Fully coupled UFS-P8 with CPC 3D-Var OICs, (2) **ORAS5** – Fully coupled UFS-P8 with ORAS5 OICs. 6-month ensemble (10 members) reforecasts initialized on October 1, 2015 and 2016 were analyzed. 0.25º-degree OISSTv2 and 1º-degree OSTIA data are used for verification.

5. Summary and Discussion

- Our preliminary analysis indicates that the current coupling of interactive aerosols and waves models to the other UFS-P8 components can exacerbate a systematic SST error even though it requires more computational resources.
- Therefore, we need to pay more attention in future development to coupling processes and/or tuning of respective components.
- With a limited set of UFS-P8 (C384) seasonal hindcasts initialized with two different OICs, the prediction of SST is sensitivity to the uncertainty of ocean initial states and, overall, ORAS5 OICs perform better than CPC 3D-Var OICs except for the overestimated 2015/16 El Niño intensity.
- Increased numbers of seasonal hindcast cases are required to investigate the uncertainty of ICs and its impact on S2S prediction.

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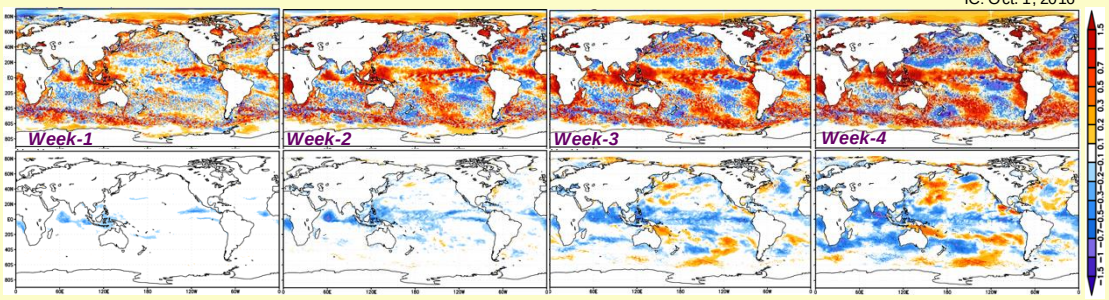
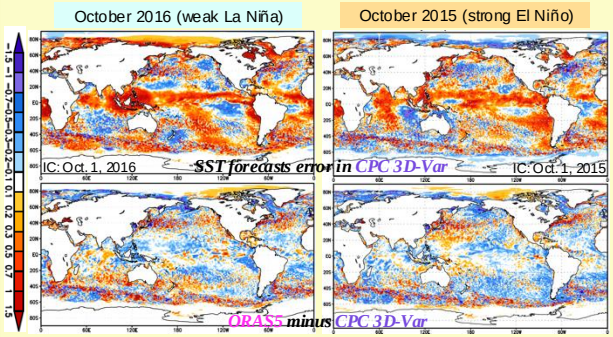
3. Results of the experiment with and without aerosols and waves models (*EXP–I*)



(top panels) Error of ensemble mean SST forecasts in Control, (bottom panels) Comparison of SST forecasts between No aerosol/wave and Control

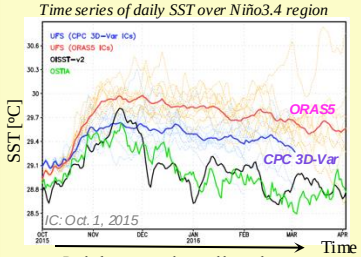
- A basin-wide warm SST error in the tropics over all the three basins is well established in week-2 and continuously grows until week-4 (top panels). However, **this warm SST error tends to be reduced by turning off the interactive aerosol/wave models**, especially in the tropical Indian Ocean up to about 1.5ºC for week-4 (bottom panels).
- For week-4, a respective reduction of cold and warm SST forecast error in the subtropics is also noticeable in No aerosol/wave while reduction and growth of SST error in mid-latitudes seem to be blended (bottom panels).
- On average, **the computational cost of No aerosol/wave is about 29.3% less than that of Control**.
- No attempt was made to re-tune the atmospheric physics parameterizations in No aerosol/wave.

4. Results of the experiment initialized with two different OICs (*EXP –II*)



- For 0-month lead (October) in both weak La Niña and strong El Niño years, a warm SST error in CPC 3D-Var tends to be reduced, in particular over the Warm Pool, in the subtropical central and southeastern Pacific and the southern Atlantic Oceans.
- While a warm SST error in the north of 60ºN is diminished in ORAS5 especially in 2016, a coldish SST error in the NH winter storm tracks in 2015 seems to be decreased to some extent in ORAS5.

Time series of daily SST over Niño3.4 region



Dashed curves : each ensemble member
Solid curves : 10-member ensemble mean

- Different OICs seem to affect a growth rate of the 2015/16 El Niño intensity until mid November. After its peak, both ORAS5 and CPC 3D-Var decay slower than observations with a very similar rate, implying that the model drift becomes dominant (left panel).
- A cold SST forecast error for DJF in the subtropics and mid-latitudes of NH in CPC 3D-Var is apparently decreased in ORAS5 (right panel).
- In the subtropics and mid-latitudes of SH, ORAS5 shows a mixed reduction and growth of SST error, compared to CPC 3D-Var (right panel).

Ensemble mean SST forecast in 2-month lead (DJF)