Effect of Higher Resolution and Advanced Atmospheric Physics Package on Week 3&4 Equatorial Thermocline Forecasts

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1. Introduction

In recent configurations, NCEP/EMC Unified Forecast System (UFS) coupled prototypes for subseasonal to seasonal forecasts introduced an advanced atmospheric physics package and increased the atmospheric resolution from L64 to L128. This affects forecasts of upper and lower level winds which in turn influences the upper ocean in regions of strong ocean-atmosphere coupled interaction, in particular the equatorial oceans. The zonal slope and depth of equatorial thermocline (D20) changes if (i) there is a net increase/decrease in heat uptake by the ocean, (ii) a strengthening/weakening of equatorial zonal wind stress (τ_x), and/or (iii) changes in near-equatorial wind stress curl that enhances/diminishes the equatorial Ekman upwelling and poleward Sverdrup transport. In this study we validate the changes in week 3&4 forecasts of D20 between coupled UFS Prototype 5 (P5) and Prototype 6 (P6) (Stefanova et al., 2022), and quantify processes that could drive the changes. The atmospheric components of P5 and P6 use the FV3 dynamical core, but the physics package and vertical levels in P5 (GFSv15.2, L64) are updated in P6 (GFSv16, L128). GFSv16 includes updates in PBL/turbulence scheme, the solar radiation absorption by water clouds, the microphysics scheme for computing ice cloud effective radius, and added parameterization of subgrid scale nonstationary gravity wave drag. The ocean (MOM6), ice (CICE6) and wave (WAVEWATCH III) components remain unchanged between P5 and P6. In the following section we present results of forecasts of week 3&4 average, for the period April, 2011-March, 2018. Although the wind stress from ERA5, and radiation flux from CERES-flux are daily fields for validation, D20 from ECMWF-ORAS5 is monthly. Thus, the bias in standard deviation (σ) in D20 is subject to a minimal error on comparing a bimonthly to a monthly time series.

2. Results

Pacific Ocean

Strong easterly τ_x with a larger σ in the west and a strong east-west sloping D20 with its largest σ in the east remain unchanged in P6 (Fig 1, 2). In general, a deepening of D20 in P6 is associated with a decrease in easterlies, but a negative heat uptake from P5→ P6 into the ocean. The systematic underestimation of τ_x variability around the dateline, especially in OND – the season of strong winds – indicates a deficiency in capturing the intra-seasonal wind variations (particularly related to ENSO anomalies). This under-represents the D20 variability (in OND) between 150°W-120°W, in spite of having minimal depth bias (Fig 1). Seasonally, the mean τ_x bias varies between the prototypes, with P5 showing less bias in OND, and P6 in MJJ - indicating seasonally dependent improvement in τ_x. Weakening of mean equatorial easterlies in P6 in OND do not drive changes in D20 entirely. Instead further eastward an enhanced shallow bias (Fig 1) is likely associated with strengthening of off-equatorial wind stress curl (for December ICs only), which strengthens the Ekman upwelling and shoals the equatorial D20 in P6.

Indian Ocean (IO)

The mean slope of equatorial D20 is flatter compared to the Pacific, and is dominated by westerly τ_x. Seasonally, P6 captures better the strengthened westerlies in OND, and the zonal τ_x pattern in MJJ. An increase in τ_x strength and an improved σ (particularly in the east in MJJ, and west in OND) reduces the τ_x bias P6. This likely drives the overall decrease in D20 bias, particularly in the east, in absence of any increase in radiative heating of the ocean. The small σ in D20 is similar to ORAS5 and remains almost unchanged in P6. However, the shallow D20 bias in the east is largely reduced in P6 (mostly in MJJ). A possible mechanism could be the strengthening of low level westerlies and upper level easterlies from P5 → P6, which strengthens the Walker circulation. Although that improves the D20 in the east, it does little to change the bias in the west, which requires further investigations.

Atlantic Ocean

The D20 variability is too large and τ_x variability is too weak in both P5 and P6. The seasonal strengthening of easterlies (particularly in MJJ) is also not captured. Although the mean τ_x bias decreases in the east and increases in the west in P6, it does not seem to drive the mean bias in D20, which deepens basinwide in P6. Instead, an increase in net radiative heat uptake by the ocean seems consistent with D20 deepening in P6.

3. Summary

In summary, we find regionally and seasonally dependent improvements in equatorial D20 forecasts in P6. Although the bias improves slightly in the central equatorial Pacific, it increases in the eastern equatorial regions. In IO, the bias is reduced in the east, with no clear improvement in the west. In the Atlantic, however, the forecast remains unchanged, except for a deeper D20 in the west. In both the IO and Pacific changes in bias are related to changes in τ_x and wind stress curl bias, however, changes in net radiative heat uptake seem to dominate the Atlantic.

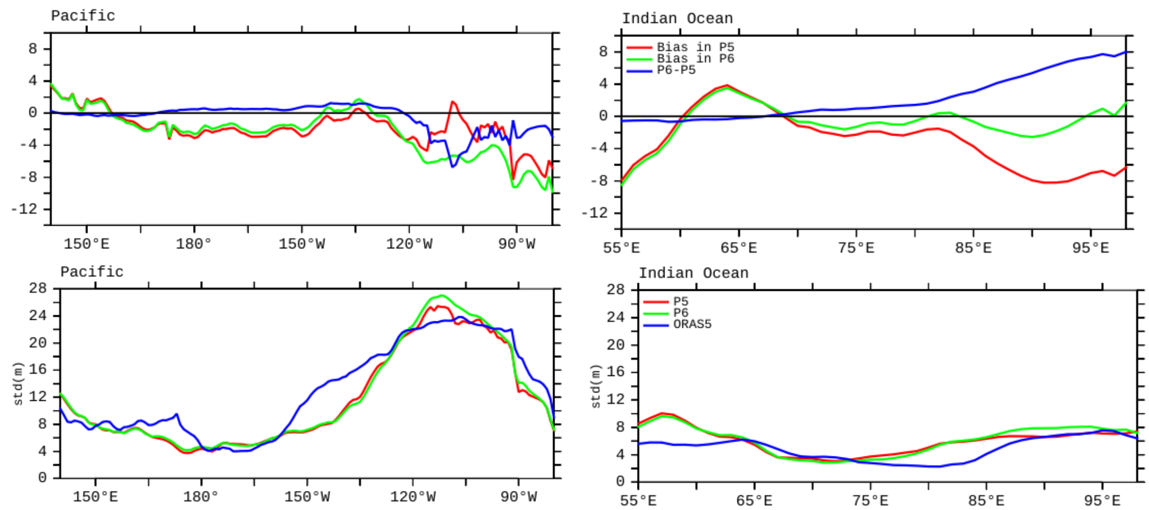

Fig 1. Mean week 3&4 forecast bias in equatorial (2°S-2°N) D20 (top) and σ (bottom) for OND in the Pacific (left) Indian Ocean (right). Bias assessed with ORAS5. Legends provide description of the colored lines.

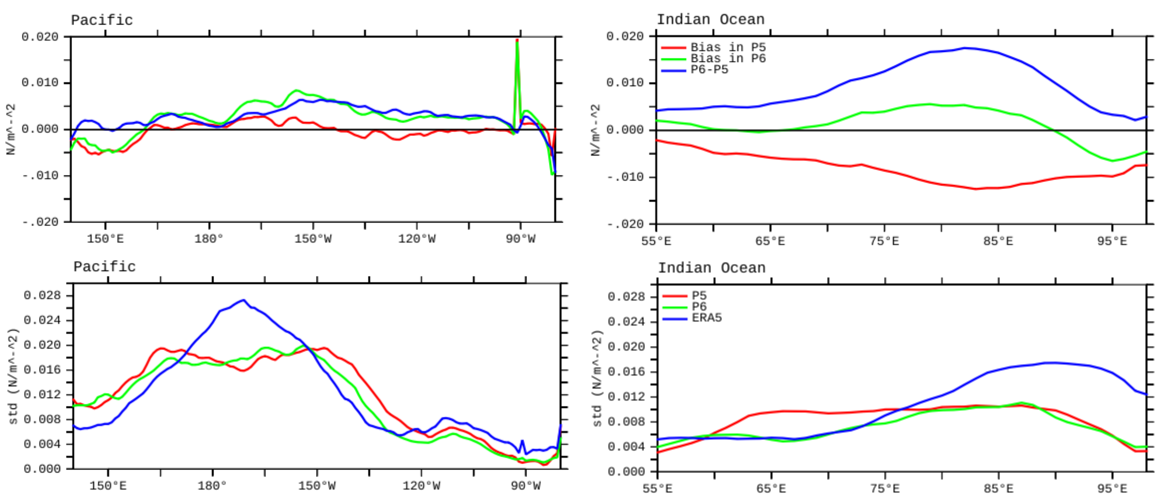

Fig 2. As in Fig 1 but for τ_x. Bias assessed with ERA5.

References

Stefanova, L., et al., 2022: Description and Results from UFS-Coupled Prototypes for future Global, Ensemble and Seasonal Forecasts at NCEP, NCEP Office Notes (In preparation).