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Towards the Use of HYCOM in Coupled ENSO Prediction: Assessment of ENSO Skill in Forced Global HYCOM

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LONG-TERM GOALS

Coupled ocean/atmosphere variability in the tropical Pacific, through El Niño/Southern Oscillation (ENSO), is a major contributor to fluctuations in North American and global rainfall and temperature, including tropical cyclones, extreme rainfall events, and droughts. Prediction of ENSO beyond the few months between the occurrence of westerly wind events in the western Pacific and the equatorial warming that triggers the Bjerknes feedback has been a major challenge. The long-term goal of this project is to contribute to the development and testing of a global fully coupled prediction system for the operational US Navy. The target time scales of this system will be seasonal through interannual; an essential capability of this system will be to forecast ENSO conditions with a reasonable degree of certainty.

OBJECTIVES

The project objective is to assess the skill of forced global Hybrid Coordinate Ocean Model (HYCOM) in reproducing ENSO events. In order for coupled prediction to be successful, both the ocean and atmospheric components must first show skill in the uncoupled mode.

APPROACH

To address this goal, we are assessing the skill of a suite of forced coupled HYCOM/CICE (sea ice) simulations: two are configured on a global 0.72° grid that telescopes at the equator to roughly 0.5° and are forced with different atmospheric reanalysis fluxes, while the third is configured on a global fine-resolution (0.08°) grid. The latter is forced with the same atmospheric fluxes as those used in one

of the low-resolution cases allowing us to assess the impact of eddy-resolving resolution in the tropics on the depiction of ENSO events.

We are currently running a global coupled 0.72° HYCOM/CICE simulation that is forced with Coordinated Ocean-Ice Experiment 2 (CORE2) interannually varying fluxes (IAF) for 1948-2009. These CORE2 fluxes of momentum, heat, and freshwater and their components are available globally from 1948-2009; the input data is based on 6-hourly National Centers for Environmental Prediction (NCEP) analysis only for the near-surface vector wind, temperature, specific humidity and temperature, and on a variety of satellite based radiation, sea surface temperature, sea-ice concentration, and precipitation products. All fluxes are computed from 1984 onwards, but radiation prior to 1984 and precipitation before 1979 are given only as climatological mean annual cycles (Large and Yeager, 2009). A. Bozec (FSU) and A. Wallcraft (NRLSSC) supplied this version of the HYCOM/CICE code to us. The existing companion simulation (supplied by A. Wallcraft) is a global 0.72° HYCOM/CICE simulation for 2003-2012 forced with Navy Operational Global Atmospheric Prediction System (NOGAPS). Consistent NOGAPS forcing is not available before 2003. NOGAPS is run on a 0.5° horizontal resolution grid, whereas CORE2 is on a T62 (roughly equivalent to 2°x2° degrees) grid. The use of the two different forcing products will provide a measure of the robustness of the representation of the characteristics of the ENSO events produced by HYCOM.

To understand how the explicit resolution of mesoscale eddies in the tropics and mid-latitudes together with narrow, fast mean flows changes the representation of ENSO events in HYCOM, we are analyzing a forced fine-resolution (0.08°) global HYCOM/CICE simulation provided to us by Wallcraft (NRLSSC) for 2003-2012. This simulation also uses NOGAPS forcing allowing us to consistently compare ENSO events in the high and low-resolution simulations.

We have started our analysis phase by evaluating the mean state of the tropical Pacific by comparing the simulations with available observations. The TAO/TRITON mooring array, consisting of 70 moorings deployed across the entire Pacific basin in 11 meridional sections that span the equatorial waveguide, has provided unparalleled temporal and spatial coverage of the evolution and structure of ENSO events since the 1990s. Primarily temperature and salinity together with meteorological measurements are available. Sea surface height anomalies from altimetry are also available since 1994. Meridional sections of upper ocean zonal currents, collected at ten longitudes across the equatorial current system (Johnson et al, 2002), can be used to gauge the strength and position of the equatorial currents. ARGO temperature and salinities collected since about the year 2000 over the upper 2000m provide a valuable means of assessing the validity of the upper water column hydrographic structures.

Next, we wish to understand how well HYCOM depicts the diversity of ENSO events over an extended period. A recent study has shown that most of the El Niño events in the 21st Century: 2002/03, 2004/05, and 2009/10 had their largest anomalies in the central Pacific (CP) (Yu and Kim, 2013). We wish to understand how well HYCOM depicts the three strong eastern Pacific (EP) events in 1972/3, 1982/83, and 1997/98, as well as the CP events. CP events also occurred in 1968/69, 1977/78, and 1994/95 (Yu and Kim, 2013). We will compare the structures (geographic and modal) and evolution of the major events as well as ENSO spectral characteristics with observational counterparts. Particularly, we will compare and contrast the structure and evolution of CP and EP events. Does forced HYCOM faithfully reproduce the two types of events or does it preferentially

reproduce one type? If the latter is found, what aspects of the atmospheric forcing or ocean conditions produce this bias?

WORK COMPLETED

Since the start of this project in July 2014, we have made progress towards meeting our primary goal by carrying out the CORE-forced global 0.72° HYCOM/CICE simulation that is near completion, and by analyzing the 0.08° global HYCOM/CICE simulation. In addition, we worked with A. Bozec (FSU) to convert HYCOM from its native grid onto a standard set of *z*-levels as part of the model run and have started to convert the Community Earth System Model (CESM) ocean model diagnostics package to accept HYCOM output. This tool will provide a systematic approach to skill assessment and includes comparisons of temperature and velocity sections across the tropical Pacific with the Johnson et al. (2002) observations.

RESULTS

Our preliminary skill assessment of the mean state of the tropical Pacific includes comparisons of mean temperature and salinity from ARGO with those from 0.08° global HYCOM/CICE. In Fig. 1 we show potential temperature from ARGO and 0.08° global HYCOM/CICE at 100m for 2003-2012. Between 10°S and 10°N, warm biases of up to 2°C are seen in the west and and cold biases largely around 1°C are seen in the east. The amplitude and phase of the annual cycle of sea surface height and temperature (SST) from the 0.08° model have been compared with those from observations. The simulated SST amplitude pattern is in good agreement with that from observations (Reynolds et al. 2007), however the simulated amplitude is lower than that of the observations in the eastern boundary region (See Fig. 2). Phasing of the simulated annual cycle generally agrees with that from observations.

Figs. 3 and 4 show the Niño 1.2, 3, 3.4, and 4 regions and Niño indices for 2003-2012, respectively, from NCEP observations and 0.08° HYCOM/CICE. In the central Pacific (Niño 4, 3.4, and 3) anomalies are strongest during the 2009/10 event, while in the eastern Pacific (Niño 1.2) anomalies are strongest during 2011 and 2012 events. HYCOM anomalies track with the observations for the 2009/10 and 2011 events, but in 2012 the HYCOM anomalies are weaker than those observed.

IMPACT/APPLICATIONS

Improved realism of ENSO events in the Navy's operational coupled ocean/sea-ice prediction system should reduce uncertainty in predictions and provide increased confidence in projections for decision making.

RELATED PROJECTS

"Optimized Infrastructure for the Earth System Prediction Capability"; Celicia DeLuca (PI). A goal of this project is to incorporate HYCOM into CESM. As a first step, A. Wallcraft (NRLSSC), A. Bozec (FSU), and E. Chassignet (FSU) have modified HYCOM so that it can be forced stand-alone with CORE2 fluxes, the data atmosphere used in CESM. We are using their code in our project.

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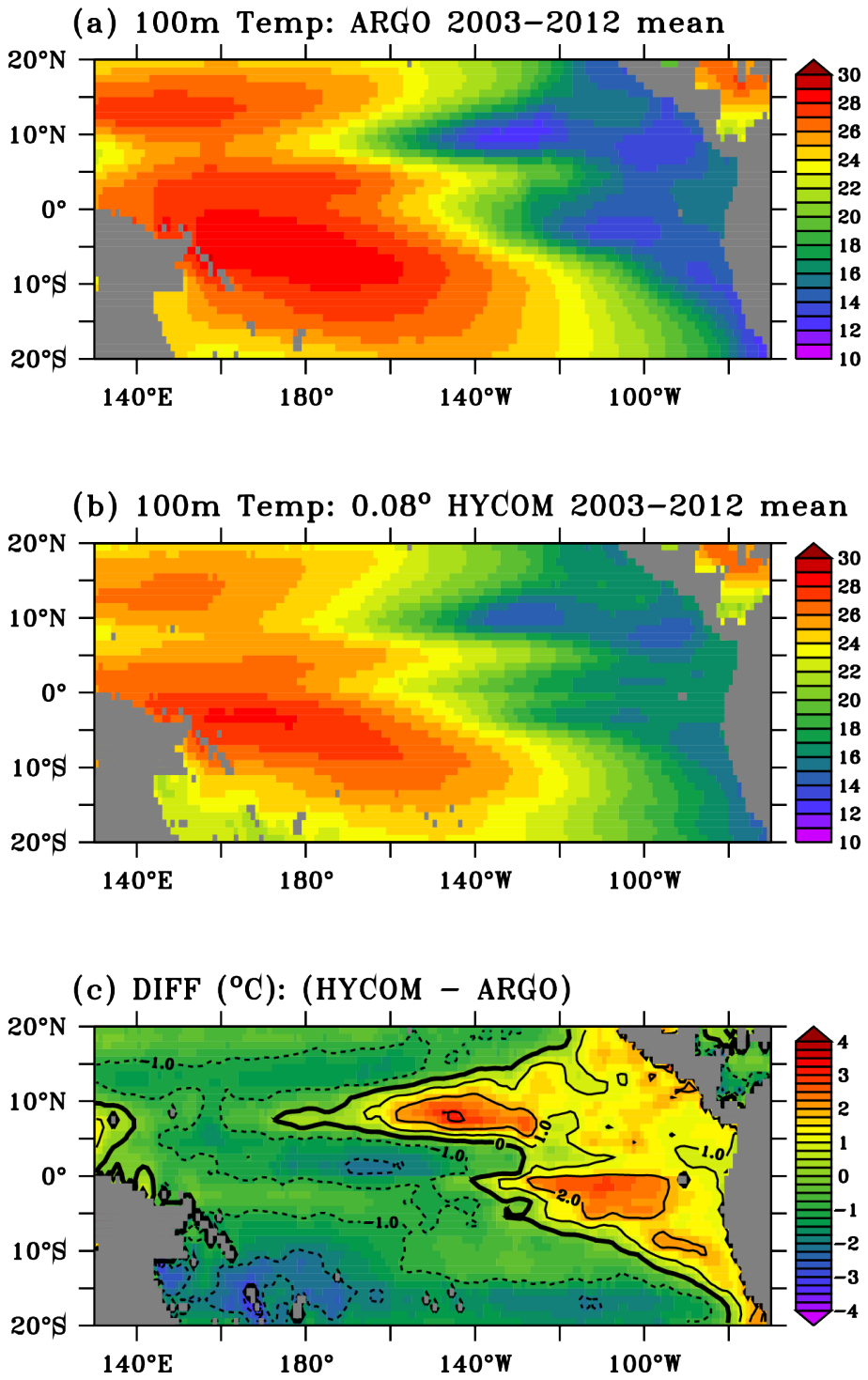

Fig. 1. Potential temperature from (a) ARGO, (b) 0.08° global HYCOM/CICE, and (c) their difference at 100m for 2003-2012.

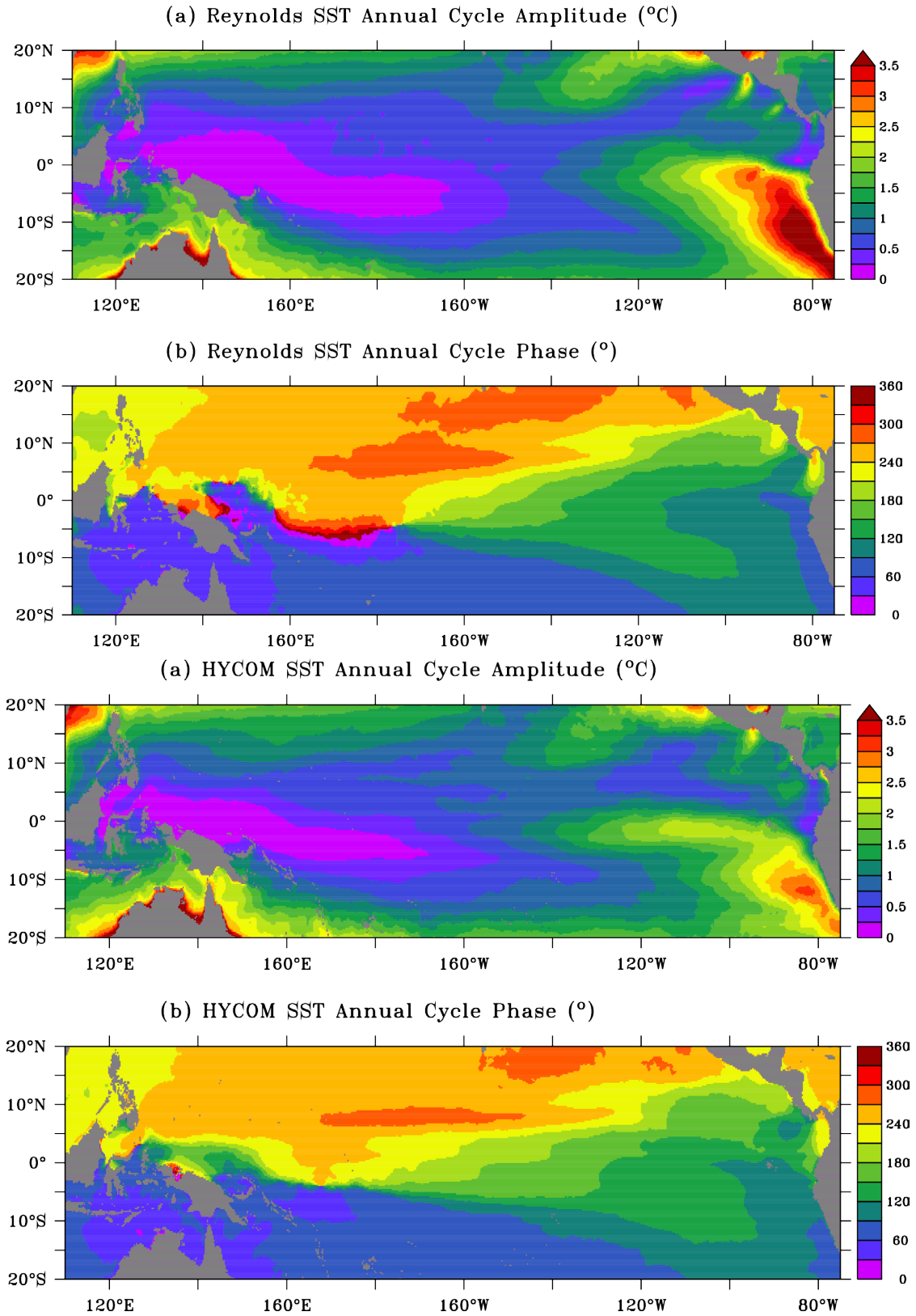

Fig. 2: Amplitude (cm) and phase (°) of the annual cycle of sea surface temperature from Reynolds et al. (2007) observations (upper two panels) and 0.08°HYCOM/CICE (lower panels) for 2003-2012.

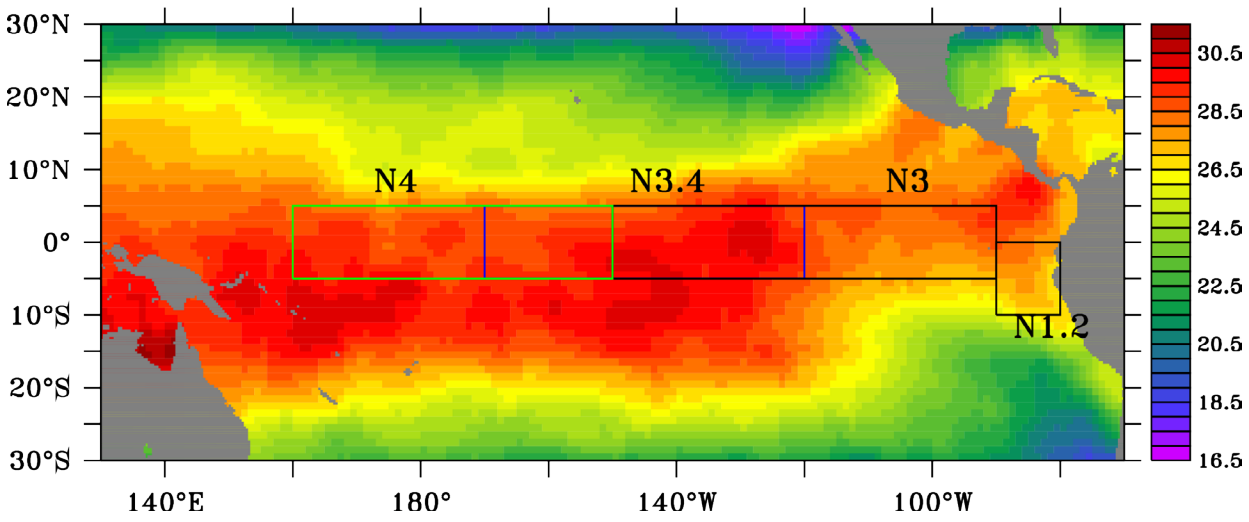

Fig. 3: Observed SST (Reynolds and Smith, 1994) for January 1983 overlaid with geographic regions representing the Niño 1.2, 3, 3.4, and 4 indices. Black thick line = Nino1.2 (0 - 10°S, 80°W-90°W); Black thin line = Nino 3 (5°N-5°S, 90°W - 150°W); Blue thick line = Nino3.4 (5°N-5°S 120°W - 170°W); Green thin line = Nino 4 (5°N -5 °S, 160°E - 150°W).

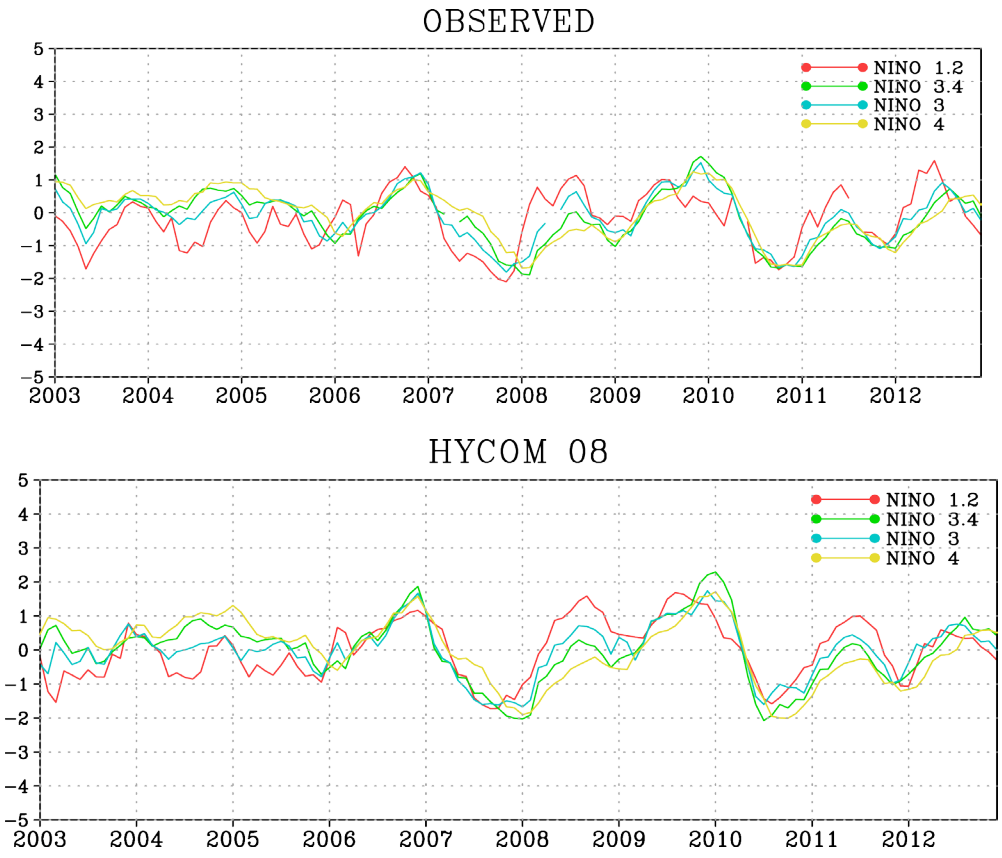

Fig. 4: Time series of Niño indices for 2003-2012. Indices from NCEP: ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/sstoi.indices (upper) and 0.08° HYCOM/CICE (lower).