Sea Surface Salinity Variability from Simulations and Observations: Preparing for Aquarius

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1. Introduction

Oceanic fresh water transport has been shown to play an important role in the global hydrological cycle. Sea surface salinity (SSS) is representative of the surface fresh water fluxes and the upcoming Aquarius mission scheduled to be launched in December 2010 will provide excellent spatial and temporal SSS coverage to better estimate the net exchange. In most ocean general circulation models, SSS is relaxed to climatology to prevent model drift. While SST remains a well observed variable, relaxing to SST reduces the range of SSS variability in the simulations (Fig.1). The main objective of the present study is to simulate surface tracers using a primitive equation ocean model for multiple forcing data sets to identify and establish a baseline SSS variability. The simulated variability scales are compared to those from near-surface argo salinity measurements.

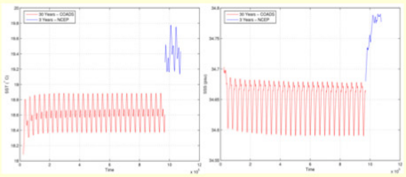

Figure 1: Evolution of mean SST and SSS in a global model. The higher mean surface temperature of the NCEP high frequency forcing causes the domain averaged temperatures to be higher.

2. Background

Mechanisms controlling SSS

- E-P
- Vertical Mixing
- Advection/ Diffusion

E and P Variability

- E-P standard deviation of ~500 mm/yr
- Precipitation variability of over 250 mm/yr over Indian and Equatorial Pacific
- Evaporation in North Atlantic ~250 mm/yr

Upper Ocean Mixing

- Measured and simulated quantities based on different hypothesis are used to compute entrainment mixing.

3. Objectives

Investigate SST and SSS Variability – Provide SST and SSS for use in Aquarius forward model and retrieval algorithm development

For different forcing climatologies and boundary conditions:

- Adjusted COADS (Da Silva et al.)
- CORE Forcing (Large and Yeager 2004, available from GFDL
- OMIP Forcing (Röske 2006)

For Multiple Mixing Schemes:

- Gaspar (1988)
- Price, Weller and Pinkel (1986)
- K Profile Parameterization (Large et al. 1994)
- Mellor and Yamada (1972; 1998)
- GISS Level-2 turbulence closure (Canuto et al. 2001,2002)

Simulations from 2004 to 2009:

- Varibility of SST and SSS
- Realistic Forcing
- Averaged to a 1° Grid
- Seasonal Cycle

Observations from 2004 to 2009:

- Near-surface argo SST and SSS (top 20m)
- Averaged to a 5° Grid
- Seasonal Cycle

4. Model Configuration and Simulations

A fully global Hybrid Coordinate Ocean Model (HYCOM) is configured at 0.72° resolution at the equator. There are 26 layers/ levels in the vertical with a minimum spacing of 3 *m* and a maximum spacing of 5 *m*.

- Initial conditions derived from Levitus climatology
- Monthly forcing fields from COADS, CORE and OMIP are used including precipitation.
- Evaporation is calculated using bulk formula from state variables.
- Monthly river runoff from the global river data set
- Model spin-up for 30 years for multiple boundary conditions with and without relaxation.
- Additional five year simulations with no relaxation for multiple boundary conditions.
- Simulations with NCEP forcing from 1994 to 2009 from a CORE forced 30 year spin-up.
  - Relaxed to NCEP surface temperature
  - KPP mixing scheme
  - SST and SSS from 2004 to 2009 analyzed

5. Results: Forcing Experiments

Evolution of domain averaged temperature and salinity for different boundary conditions and forcing data sets indicate that the COADS forcing needs SSS to be relaxes for the drift to be small wheras the CORE and OMIP forcing data sets make the model drift less with no relaxation.

For all the three forcing datasets, when SSS is relaxed, the amplitude of annual cycle in the SST increases. Significant freshening occurs in the model for COADS forcing when the SST is relaxed although no surface relaxation boundary condition recovers the SSS annual cycle magnitude better. The drifts in SSS and SST are much smaller in both CORE and OMIP forced cases, however, similar to Figure 1, when SST is relaxed the magnitude of SSS annual cycle is reduced.

A comparison of the mean SST and SSS evolution for the three forcing datasets is shown in Figure 2 when the surface is not relaxed. Results indicate that the CORE or OMIP forcing datasets lead to smaller drifts and therefore may be preferable to COADS. Spatial SST and SSS differences at the end of 30 year integration are shown if Figures 3 and 4.

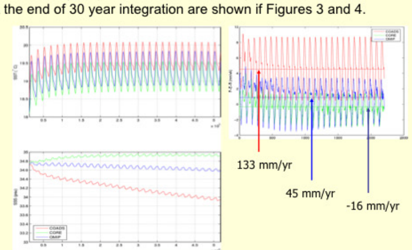

Figure 2: Comparison of mean SST and SSS evolution for the three forcing datasets in the no relaxation case. Clearly, the SST drift stabilizes in all the three cases, however, the SSS evolves much fresher when the COADS forcing is used.

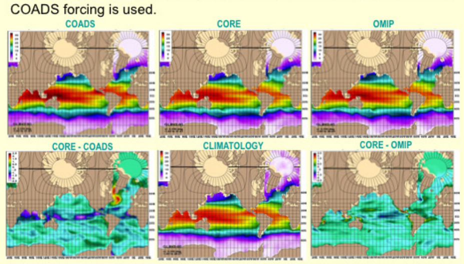

Figure 3: Comparison of annual mean SSTs for year 30. Clearly, due to the divergence during the initial 7 years of integration, large differences are seen in the near-equatorial region between the simulated SSTs for COADS and CORE forcing. The difference between CORE and OMIP is not as large.

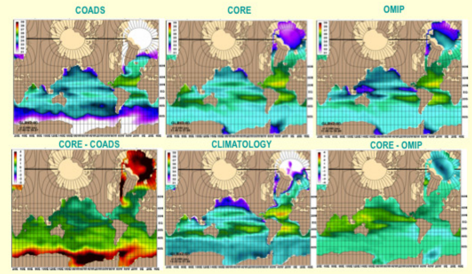

Figure 4: Comparison of annual mean SSSs for year 30. Due to the trends seen in Fig.2, the COADS forced simulation is significantly fresher at the surface than the CORE results. In addition, SSS resulting from COADS forcing is also fresher compared to climatology. CORE results have a higher SSS in the Indian and Pacific Oceans. The differences are significant.

6. Results: Sub-grid scale parameterizations

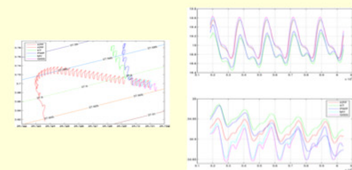

Figure 5: The model is integrated for five more years using four additional sub-grid scale parameterizations. The initial conditions for this five year run is from the CORE forced no relax case. The forcing experiments all used KPP as the sub-grid scale parameterization. The left panel shows the domain averaged temperature and salinity evolution in the domain. Results show that the performance of the three higher order schemes are nearly identical. Although the PWP and KT schemes diverge towards a warmer state the temporal evolution of SST does not show significant drift. However, the mean SSS differences exceed 0.1 psu.

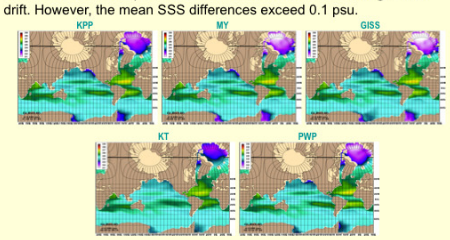

Figure 6: Annual mean SSSs for year 5. The three higher order schemes are nearly identical in simulating the SSS. There are minor differences between the five parameterizations (e.g. Equatorial Atlantic between SST and SSS) as shown in Fig.7. The SSTs (not shown) are also similar, except that the KT scheme has a poor representation of the equatorial cold tongue due to lack of shear induced mixing.

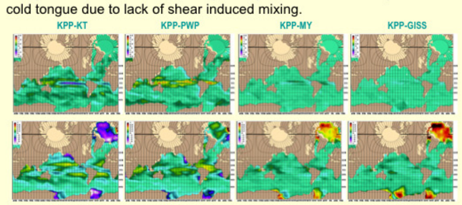

Figure 7: Range of differences between the SSTs (top panels) and SSSs (bottom panels) for different sub-grid scale parameterizations with the KPP solution as the baseline. While considerable differences are seen between KPP and the bulk parameterizations, differences of 0.5°C and 0.2 psu are seen in near equatorial regions between the higher order schemes.

7. Results: 2004-2009 Comparison and Analysis

The spatial and temporal variability of simulated monthly mean SST and SSS from 2004-2009 are compared to those from the near-surface temperature and salinity data from argo profiling floats. While the argo spatial coverage has increased significantly in recent years, there are still regions where the coverage is not optimal. Fields of near-surface monthly mean temperature and salinity at 5° spatial resolution are constructed using quality controlled argo measurements and the annual cycle and its spatial variability are analyzed to quantify the range of observed variability and realism of simulated SST and SSS.

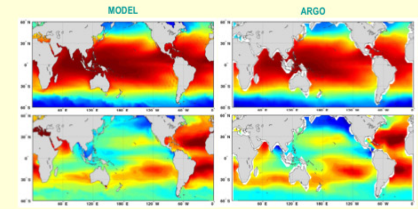

Figure 8: Mean SSTs and SSSs from simulations (left) and observations. Simulated temperatures follow NCEP surface temperatures closely, however, SSS magnitudes are smaller in the simulations.

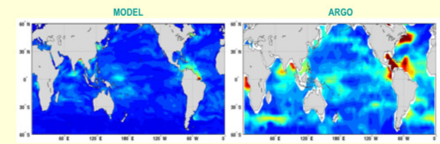

Figure 9: Standard Deviations of the simulated and observed SSS. Although qualitatively the simulated spatial variability patterns match the observations in most of the domain, the model variability is much lower than Argo measurements.

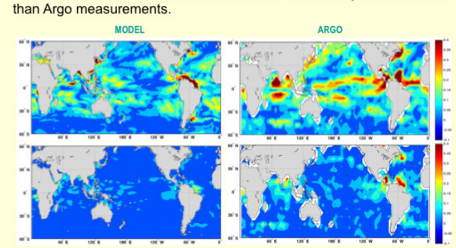

Figure 10: Amplitudes of annual and semi-annual components of SSS decomposed using a harmonic analysis procedure. As mentioned earlier, simulated SSS fields have less spatial variability. Maximum variability occurs in the ITCZ region which has a large amplitude of 0.4 PSU in the observations (top right panel) in the open ocean. Closer to the river discharge regions, the model also produces higher variability. The semi-annual component has maximum amplitudes near the coastal regions, with a clear signal along the ITCZ region as well. The range of values of the annual and semi-annual cycles are higher than what was found from climatology (Boyer and Levitus, 2002). Although, the model variability is less, a similar pattern is also seen in the simulated results.

8. Conclusions

- The global HYCOM ocean simulations show that relaxation to either SST or SSS at the surface will affect the magnitude of annual cycle of the other surface variable.
- The CORE forced solutions without any relaxation at the surface show the least drift among the three forcing datasets considered here closely followed by the OMIP forcing.
- The sub-grid scale parameterizations play a secondary role to the forcing variability as indicated by the differences in mean surface tracers.
- Amplitudes of annual and semi-annual components of SSS from Argo measurements are higher than what was found from climatology. With a minimum SSS resolution of 0.2 PSU, Aquarius measurements will clearly be able to resolve this variability.
- Model simulated SSS has a smaller variability when the surface temperatures are relaxed. Therefore, the model is relaxed to Argo near-surface salinity to provide surface conditions for use in Aquarius forward and retrieval algorithms.

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