# Closing the sea level budget on regional scales in the tropical North Pacific

**Josh Willis**
Joshua.K.Willis@jpl.nasa.gov
*Jet Propulsion Laboratory, California Institute of Technology*

**Don Chambers**
chambers@csr.utexas.edu
*Center for Space Research, University of Texas at Austin*

## Introduction

Using temperature and salinity data from the Argo array and gravity variations from GRACE, total sea surface height (SSH) observed by satellite altimetry can be decomposed into steric and mass-related parts. In addition to providing a more complete dynamical description of observed variability, this should allow for closure of the sea level budget within the accuracy of each measurement system and serves as an important validation of the observing system as a whole.

## Components of Sea Level

Total sea level from altimeter data averaged over the study region, along with the steric and mass components.

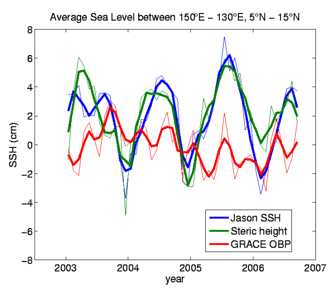


**Figure 2. SSHl from Jason, 0/900 m steric height from Argo, and GRACE bottom pressure averaged over the study region. Thin lines are monthly estimates, thick lines are the 3 month running average.**

## Steric Sea Level from Argo

Data from about 40 Argo floats exist in the region of study between 2003 and the present, providing approximately 1300 temperature and salinity profiles. None of the recently discovered floats with pressure problems (SOLO floats with FSI sensors) occupied the study region.

| Variance of 0/900 m steric height from profile data (cm) | |
|---|---|
| Thermosteric | 8.2 |
| Halosteric | 1.6 |
| Steric | 7.8 |

Inclusion of salinity, *reduces* variability. It also improves agreement with SSH.

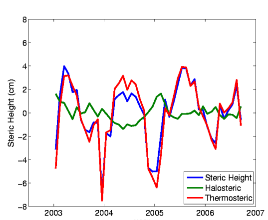


**Figure 3. Time series of 0/900 m thermosteric, halosteric and total steric sea level from Argo data.**

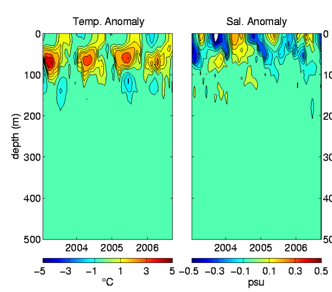


**Figure 4. Time series of temperature and salinity anomaly in the region of study.**

## Region of Study

We consider the sea level budget in a 20° x 10° box in the tropical N. Pacific centered around 140°W and 10°N. This encom passes a large part of the equatorial current system in the N. Pacific and was shown by Chambers et al. (JGR, 1998) to be a region where total and thermosteric sea level variability have significant differences.

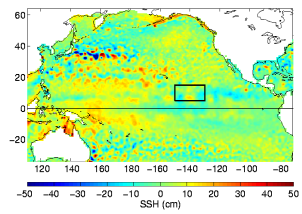


**Figure 1. Snapshot of SSH from Jan., 4, 2006 illustrating the region of study.**

Note region of significant difference between altimeter and temperature data

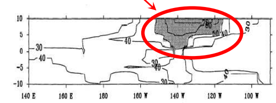

Figure 8. Annual amplitude of difference between TOPEX and TAO measurements. The contour interval is 10 x 10⁷ J m⁻², and values larger than 50 x 10⁷ J m⁻² are shaded gray. The grid has been interpolated as in Figure 2.

From Chambers et al. (*JGR*, 1998)

## Sampling

Although Argo drastically improves in situ sampling, it does not provide sufficient coverage to resolve the mesoscale eddy field. Fortunately, much of the eddy variability is common to both the steric data and the altimeter data. Using high resolution altimeter maps from AVISO, sampling error can be reduced by interpolating SSH to profile locations and subtracting *prior* to averaging over the region.

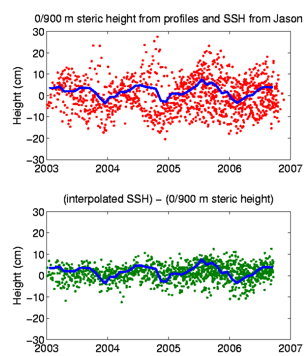


**Figure 5. Time series of average SSH in the study region from Jason (blue curves), 0/900 m steric height from Argo (top panel, red dots), and difference between interpolated AVISO SSH and 0/900 m steric height (bottom panel, green dots).**

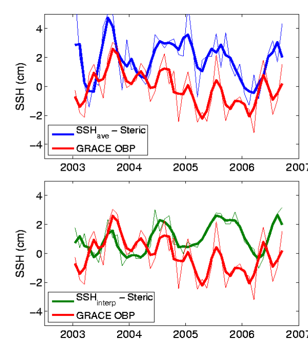


**Figure 6. Ocean bottom pressure in the study region from GRACE (red curves), (SSH – steric height) computed by differencing box-averages (blue curve, top panel), and computed by averaging over interpolated (SSH – steric height) (green curve, bottom panel).**

## Comparison with Simulated Bottom Pressure

Bottom pressure from the ECCO model is compared with the inferred bottom pressure estimate based on (SSH – steric height) and observed bottom pressure from GRACE. Since total ocean mass is not allowed to vary in the ECCO model, the global ocean mass signal from GRACE has been subtracted from the two observational estimates.

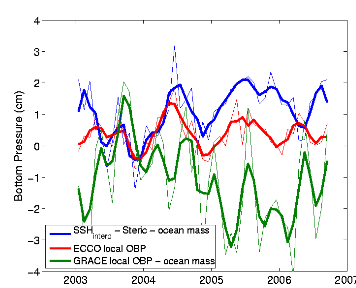


**Figure 7. Ocean bottom pressure in the region of study from the ECCO model (red), "regional" bottom pressure computed from total SSH minus steric height (blue), and GRACE in the study region. Both GRACE and the (SSH – steric curves) have had globally averaged ocean bottom pressure from GRACE removed.**

## Conclusions

At least some of the disagreement between altimeter and XBT data observed by Chambers et al. (JGR, 1998) was likely due to salinity variability in the upper ocean, as inclusion of salinity reduces the variance of steric height and improves agreement with altimeter data. Although the time period is short, low frequency variability, or "trends" remain a concern for closing regional sea level budgets such as this. While global averages of GRACE data over the oceans appear to be robust (Chambers, *GRL*, 2004), GRACE data from this region remain somewhat noisy. Higher latitude regions where barotropic signals are stronger may provide a better means of validating GRACE, Argo and altimeter data.