Effect of Sea Level Variability on Estimation of Mean Sea Surface Gradients

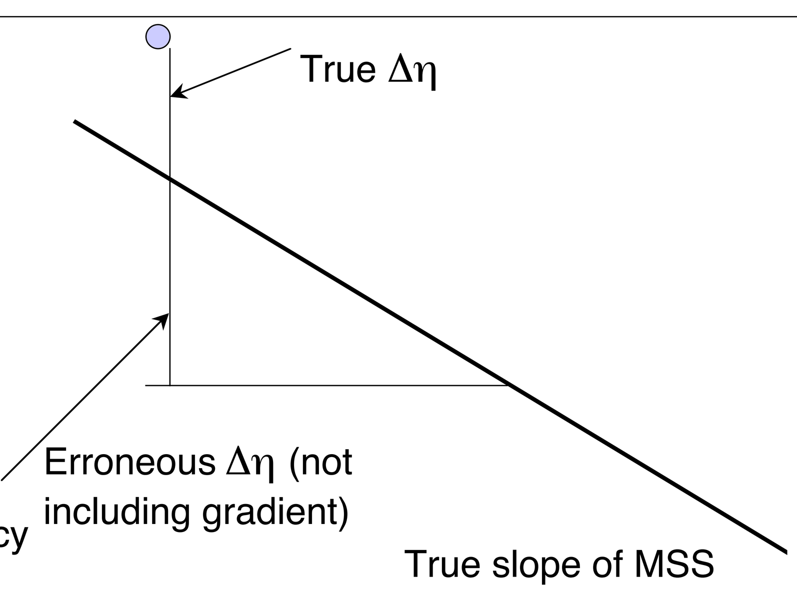
Don P. Chambers
The University of Texas, Center for Space Research
chambers@csr.utexas.edu

1. Introduction

- In order to observe accurate sea level variations, mean sea surface (MSS) gradients must be removed
- If only an average value in a region is used, sampling of constant gradients could imply unrealistic sea level variability ($\Delta\eta$)
- One method to model gradients is to estimate parameters of a plane over 1-sec bins from altimetry data [Chambers et al., Marine Geodesy, 1998]

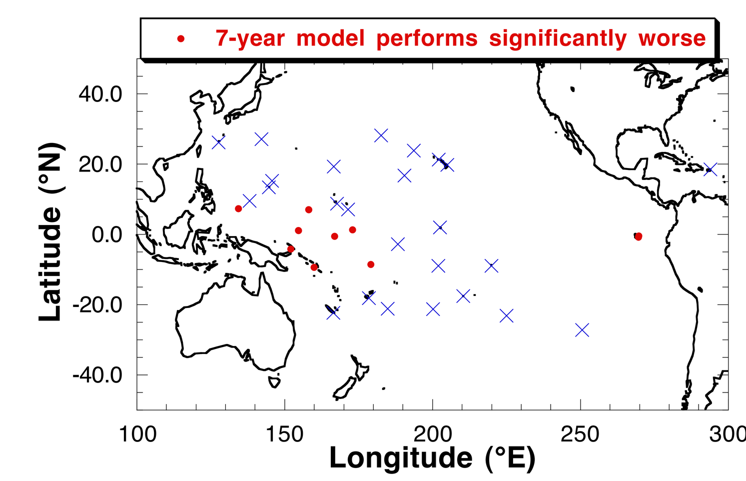
  >> Include model for secular, annual frequency, and semi-annual frequency

  >> Use real observations, iterate until changes in parameters are small

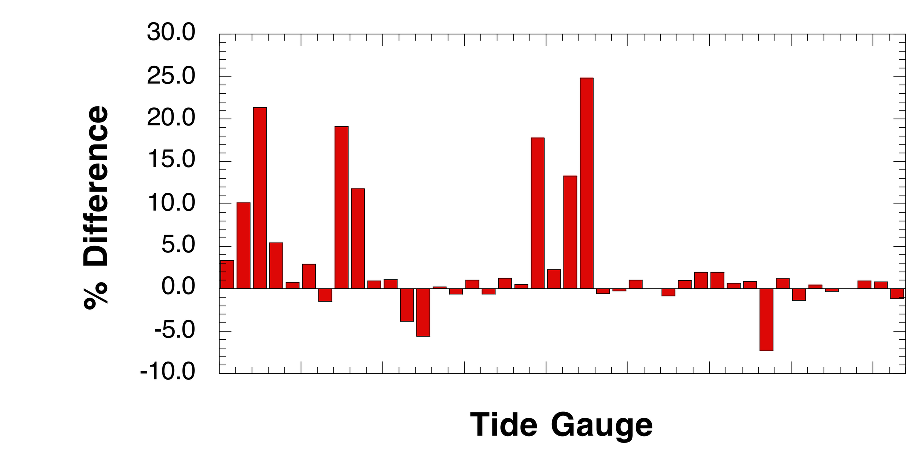


2. Initial Update of MSS Model

- Original MSS model used data from 1993-1996 (4-yr)
- Updated MSS model to use data from 1993-1999 (7-yr)
- One test for improvement is to see if statistics with tide gauges improve



Locations of tide gauges. Red dots indicate where 7-yr MSS produces worse residuals than 4-yr MSS

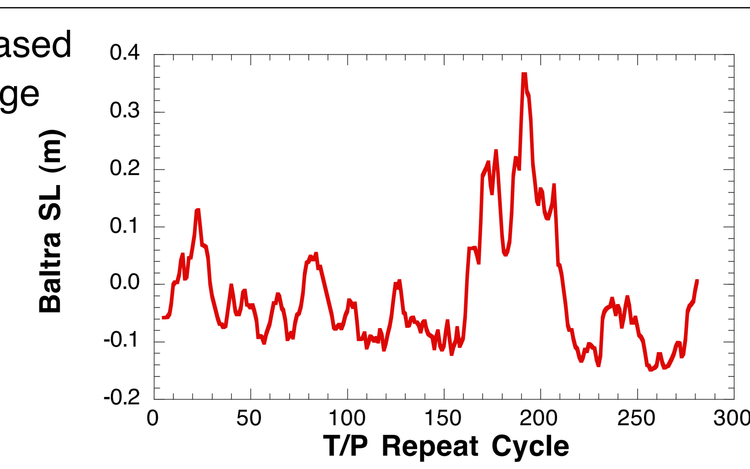


This shows the % difference change in in the tide gauge residuals, where σ is std. dev. of sea level residual (T/P - tide gauge), and + values indicate $\sigma_{7yr} > \sigma_{4yr}$

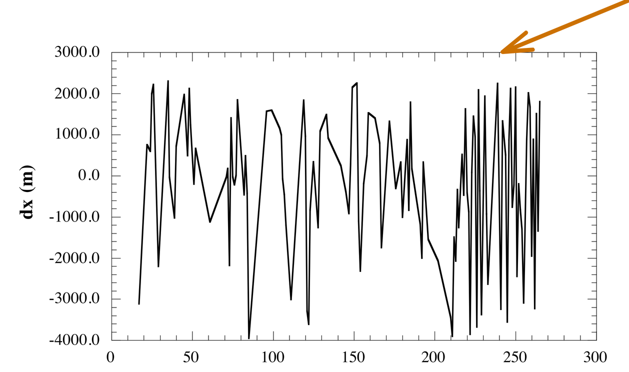
$$\%\ Diff = 100 \times \frac{\sigma_{7yr} - \sigma_{4yr}}{\sigma_{4yr}}$$

3. Why Didn't 7-Yr Model Do Better?

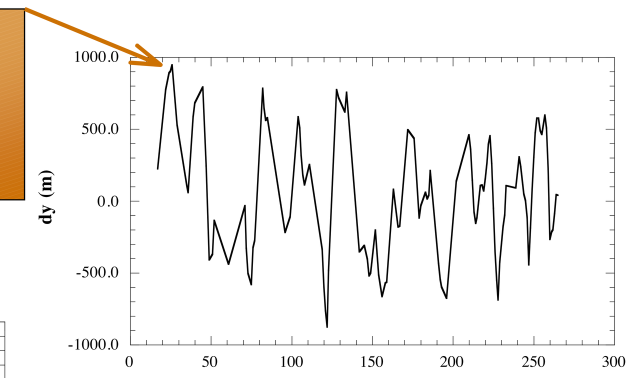
- Locations of tide gauges where σ increased with new MSS model are in areas of large El Niño variability
- No significant El Niño during 4-year model period
- Very large El Niño during 7-year model period

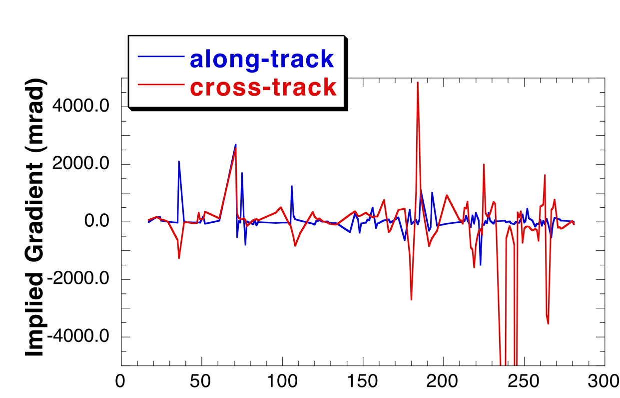


An example of real sea level variability (measured by a tide gauge) in eastern Pacific.



Real along-track (dx) and cross-track (dy) deviations of TOPEX subsatellite point in a bin at the equator.





False gradients implied by real variability (found by dividing real $\Delta\eta$ by dx or dy). In order to estimate true gradients in the presence of this, the averages must be nearly zero. In fact, they are about 60 μrad for along-track and 144 μrad for the cross-track. For comparison, the estimates from the 4-year model for the absolute gradients are -27 and 7 μrad, respectively, for this bin.

4. Reducing Errors

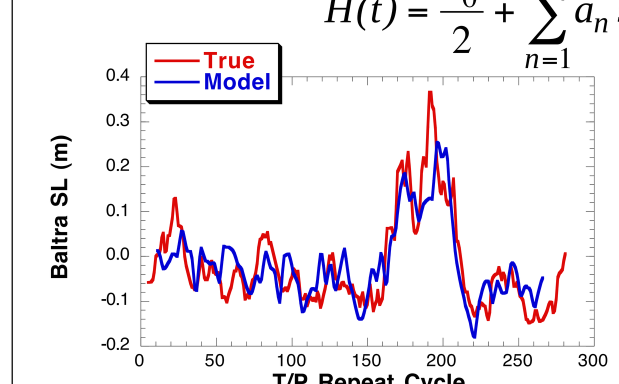
- To correct model, want to try to parameterize variability other than trends, annual, and semi-annual in order to better remove "true" sea level variability
- As an example, use Fourier series (I(t)) of Southern Oscillation Index (SOI) and Pacific Decadal Oscillation Index (PDOI) and Hilbert transform of indices (H(t)) to parameterize variability
- Hilbert transform allows for phase shifts of variable signal

$$I(t) = \frac{a_0}{2} + \sum_{n=1}^{N} a_n \cos(\omega_n t) + b_n \sin(\omega_n t)$$

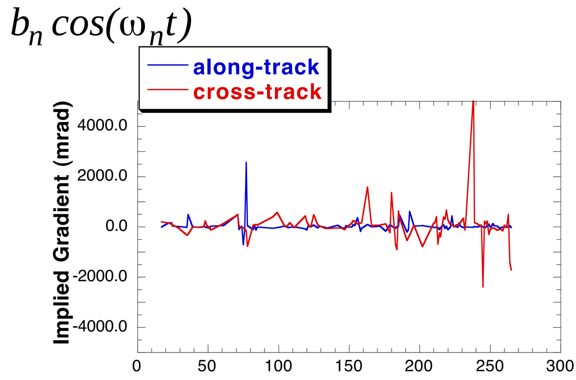
$$\omega_n = \frac{n\pi}{L},\ 2L = time - interval$$

$$H(t) = \frac{a_0}{2} + \sum_{n=1}^{N} a_n \cos(\omega_n t - \frac{\pi}{2}) + b_n \sin(\omega_n t - \frac{\pi}{2})$$

$$H(t) = \frac{a_0}{2} + \sum_{n=1}^{N} a_n \sin(\omega_n t) - b_n \cos(\omega_n t)$$



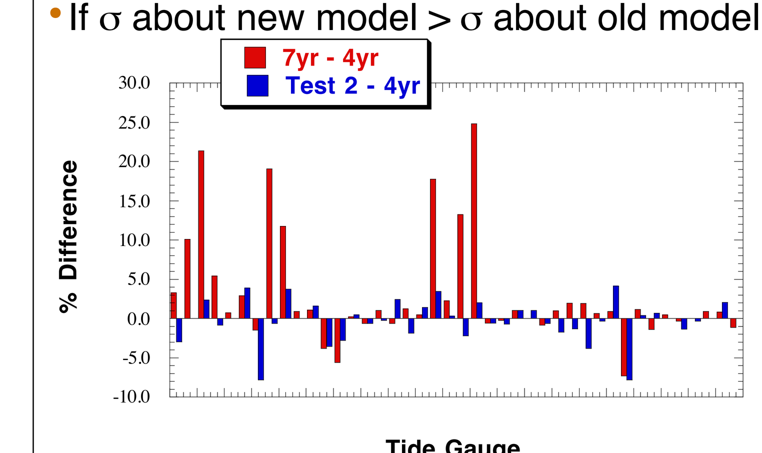
Real sea level variability and model based on SOI and PDOI



Residual gradients implied by real variability after removing model of variability. Means are now 4 μrad for along-track and 22 μrad for the cross-track, after removing bins where residual exceeds 3-σ. Compare with initial plot in Section 3 .

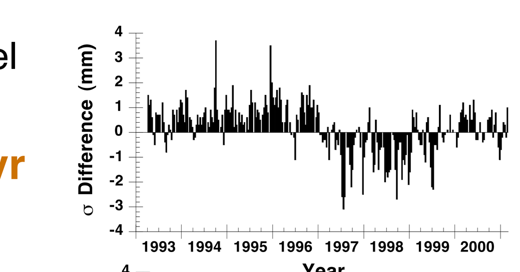
5. Results of Application

- If interannual variability model does not reduce σ in a bin by more than 20%, use only annual model
- If σ about new model > σ about old model in a bin, keep old model

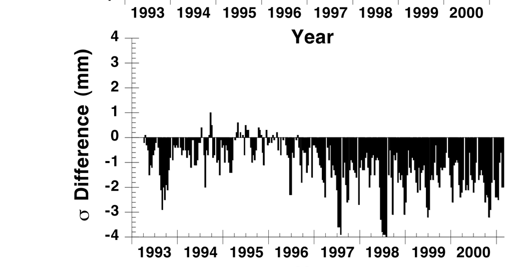


% difference change in the tide gauge residuals for the old 7yr model (red) and the new 7yr model (blue). Now, no comparison is significantly worse when 7 years of data are used than when 4 years are used.

Old 7yr - 4yr



New 7yr - 4yr



Difference in global standard deviation of TOPEX sea level anomalies relative to MSS models. Previously, the 7yr model only decreased σ for a few cycles. Now, σ is decreased for most cycles.

6. Conclusions

- Adding more data will not necessarily improve MSS models because large, real sea level variations may be interpreted as MSS gradients

  >> Using more data may actually degrade gradients because interannual signals may not "average out"
- Demonstrated one way to model interannual variations

  >> Probably not the best method

  >> With enough data, should probably edit out times with large real SL variations
- Still does not account for even larger signals such as mesoscale eddies or coastal tides
- A paper with more details is currently in press at Marine Geodesy.