Lamont-Doherty Earth Observatory of Columbia University

# SMALL-SCALE VARIABILITY IN SEA SURFACE HEIGHTS AND SURFACE WINDS: IMPLICATIONS FOR ERRORS IN OCEAN MODELS AND OBSERVATIONS


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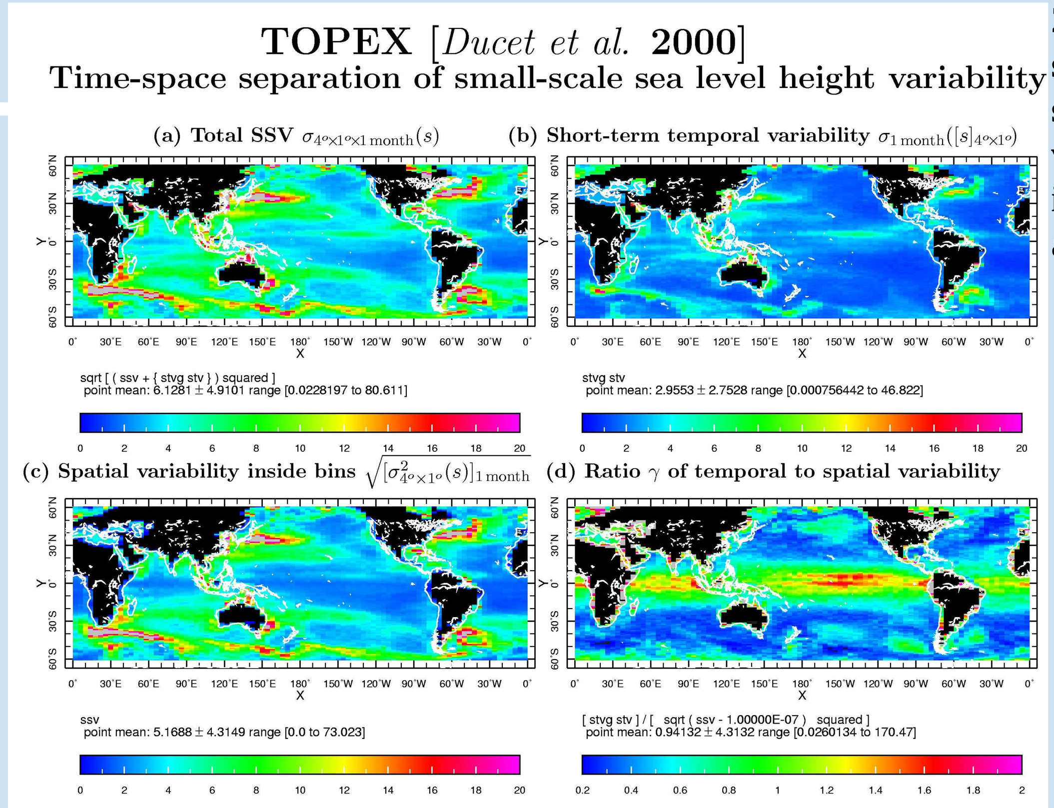
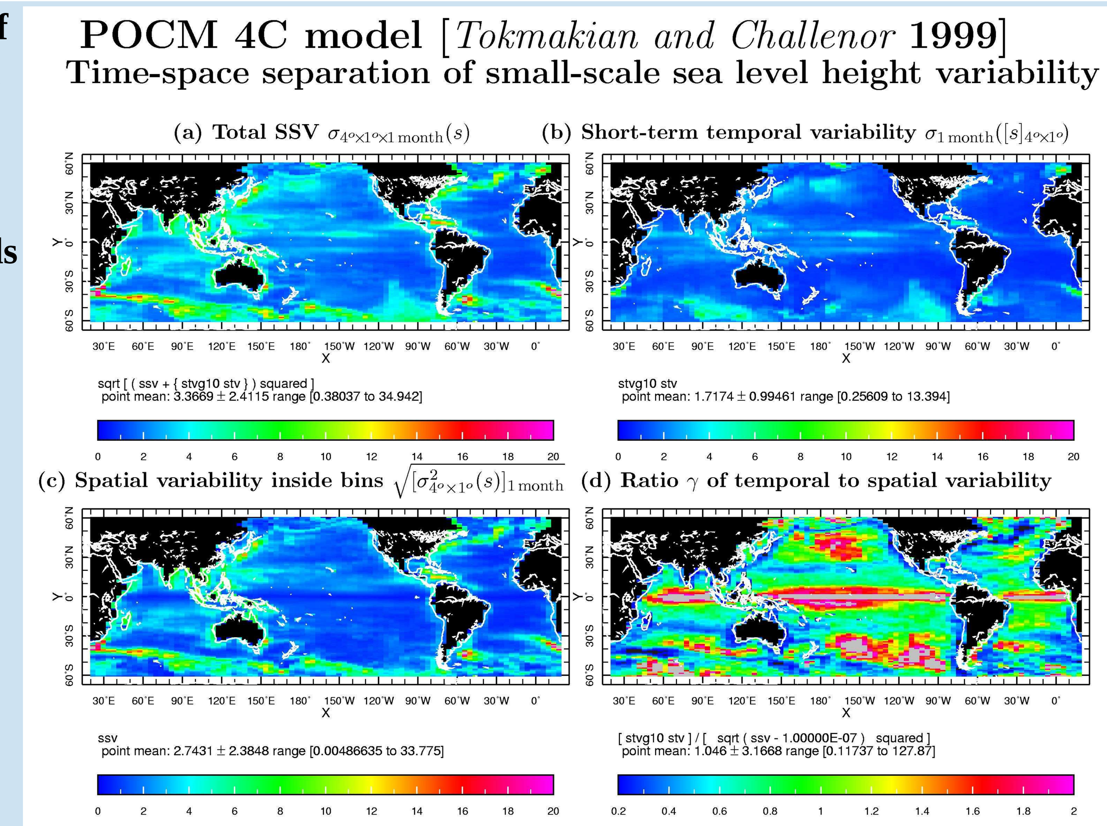
## 1. INTRODUCTION

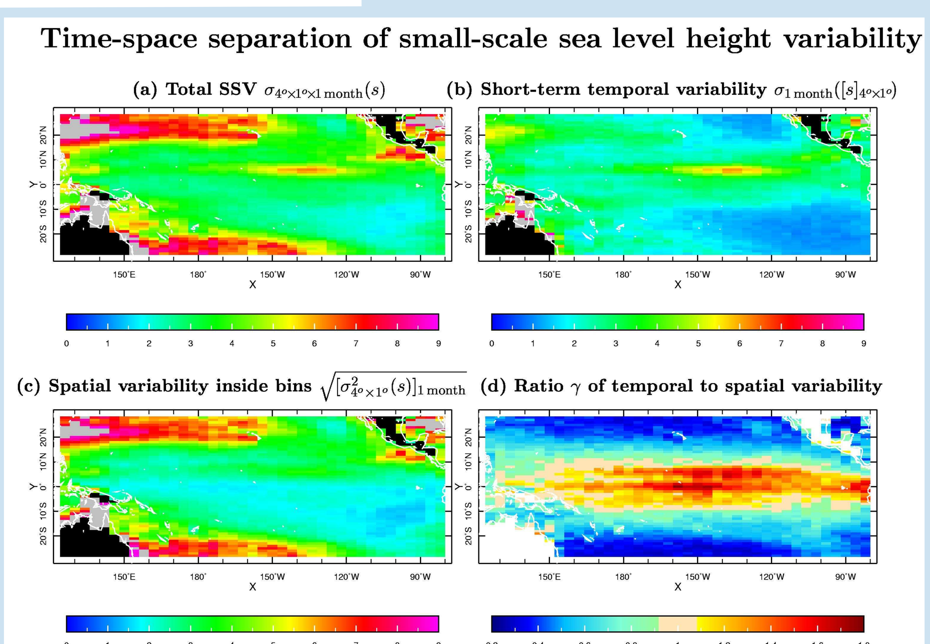
Variability in nature exists on all spatial and temporal scales, including those smaller than the resolution of model and observational data sets. Imperfect parameterization of the small-scale variability (SSV) in models and incomplete sampling of it by observational systems creates model and observational error on the resolved scales of variability. The SSV in sea surface height plays a major role in defining the error pattern of wind-forced ocean simulation and satellite altimetry assimilation products. The statistical modeling of the SSV in sea surface height suggests that in the tropical Pacific the major portion of this variability can be explained as a dynamical ocean model response to the SSV (and error) in the wind. Areas of high error which are not associated with local wind SSV are those of high shear and current instabilities in the ocean. Most GCMs underestimate the wind-driven sea surface height SSV even if driven by wind forcing with well-represented SSV and, as a result, underestimate variability on signal scales as well. Not only magnitude, but also decorrelation scales of the wind error are crucial for determining the error in the ocean response. Data assimilation procedures usually interpret observed data as if they could be expressed in terms of the averages over model grid box areas despite in reality the observations are either pointwise values (for in situ data) or averages over certain footprints (for remote sensing data). Therefore the difference between observations and model values ought to reflect the influence of the small-scale variability (SSV) of the observed physical field, because this variability is getting averaged differently by the model grid and by the observational system. The statistical details of the SSV, e.g. its standard deviations and temporal-to-spatial SSV ratios, helps model data error.

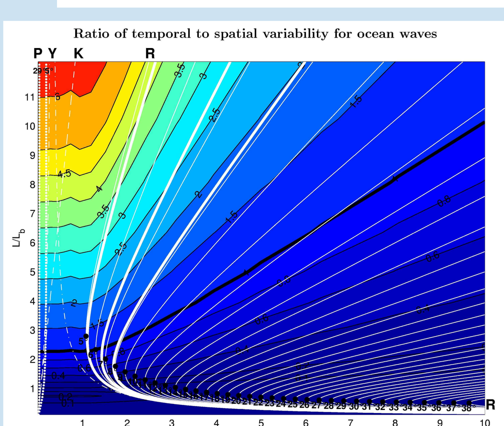
## 2. Separation of small-scale and short-term variability in altimetry and model fields

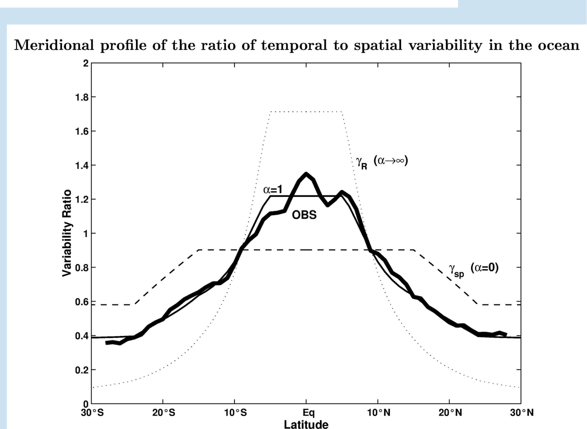


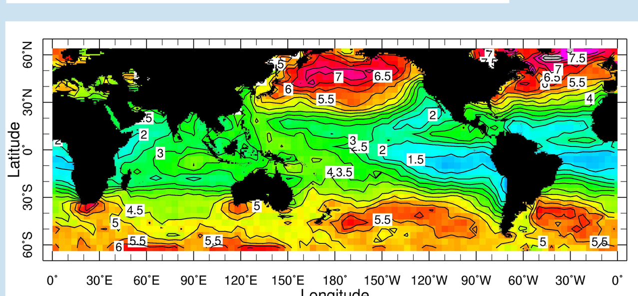

## 3. Case of Tropical Pacific and theoretical interpretation of SSV ratio based on dispersion relationship of planetary waves



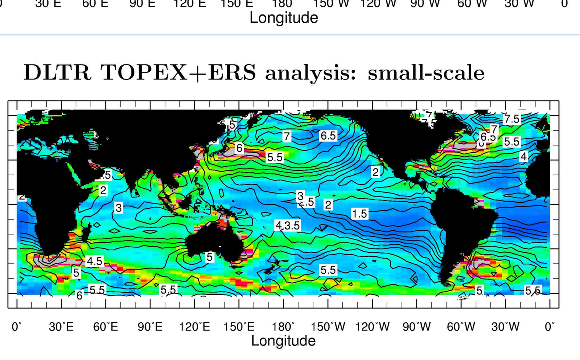



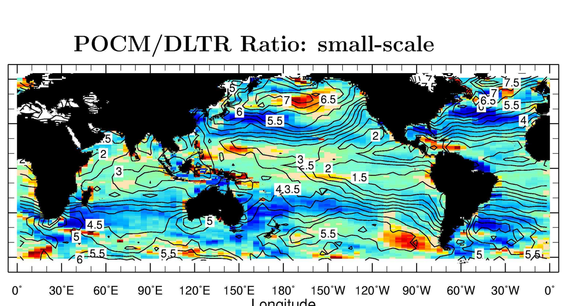

## 4. Small-scale variability in surface winds and sea surface heights



SSV in winds (colors and contours)

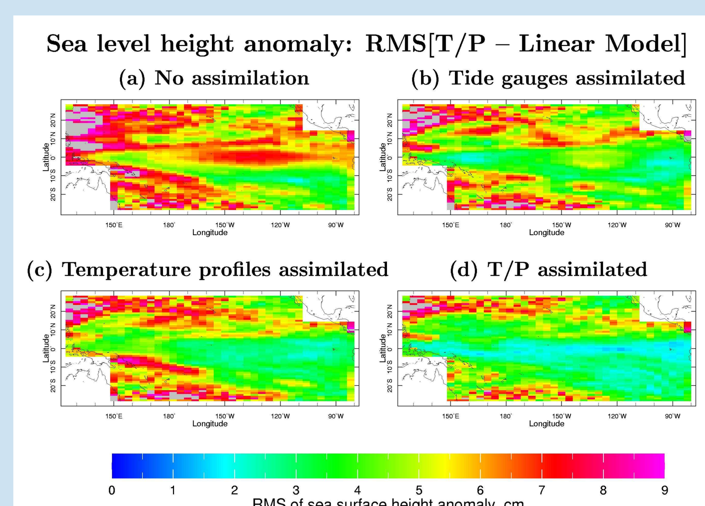


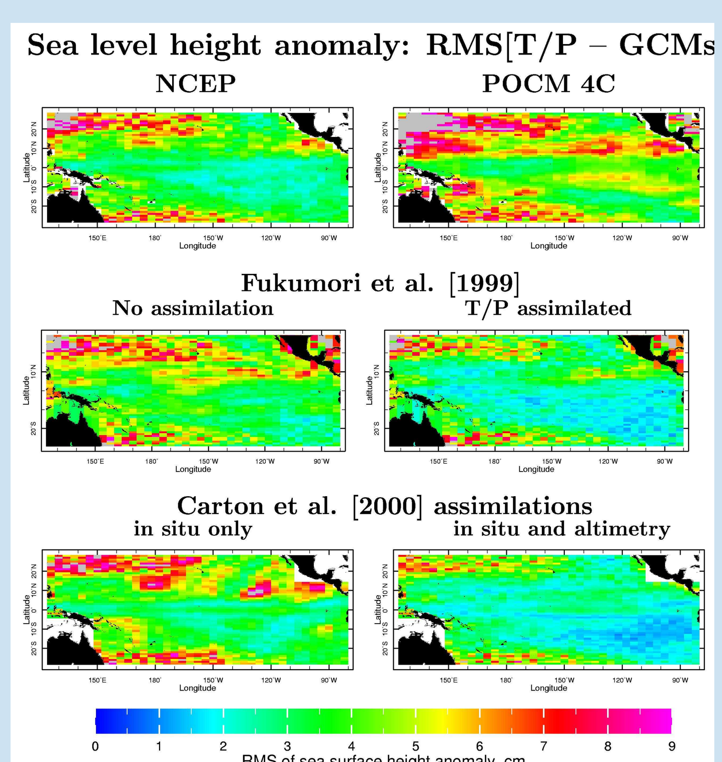

SSV in sea surface height (colors) and SSV in winds (contours)

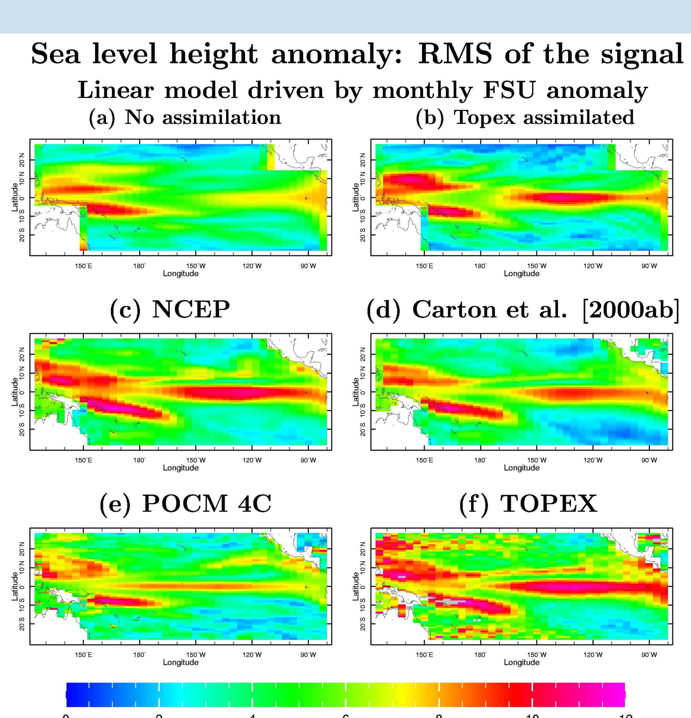



SSV ratio for altimetry and POCM model (colors) and SSV in winds (contours)

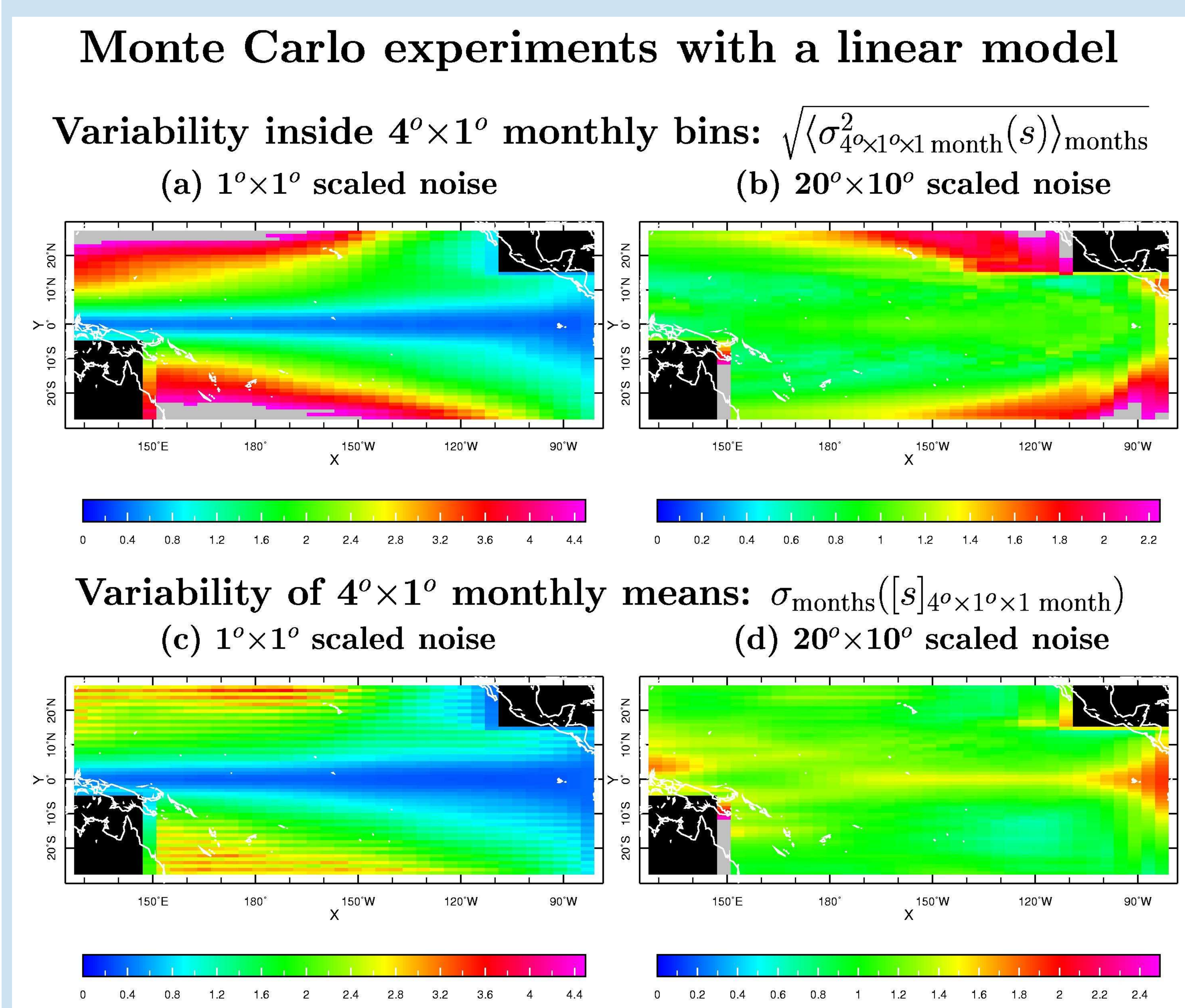
## 5. Tropical Pacific assimilation, error and signal fields



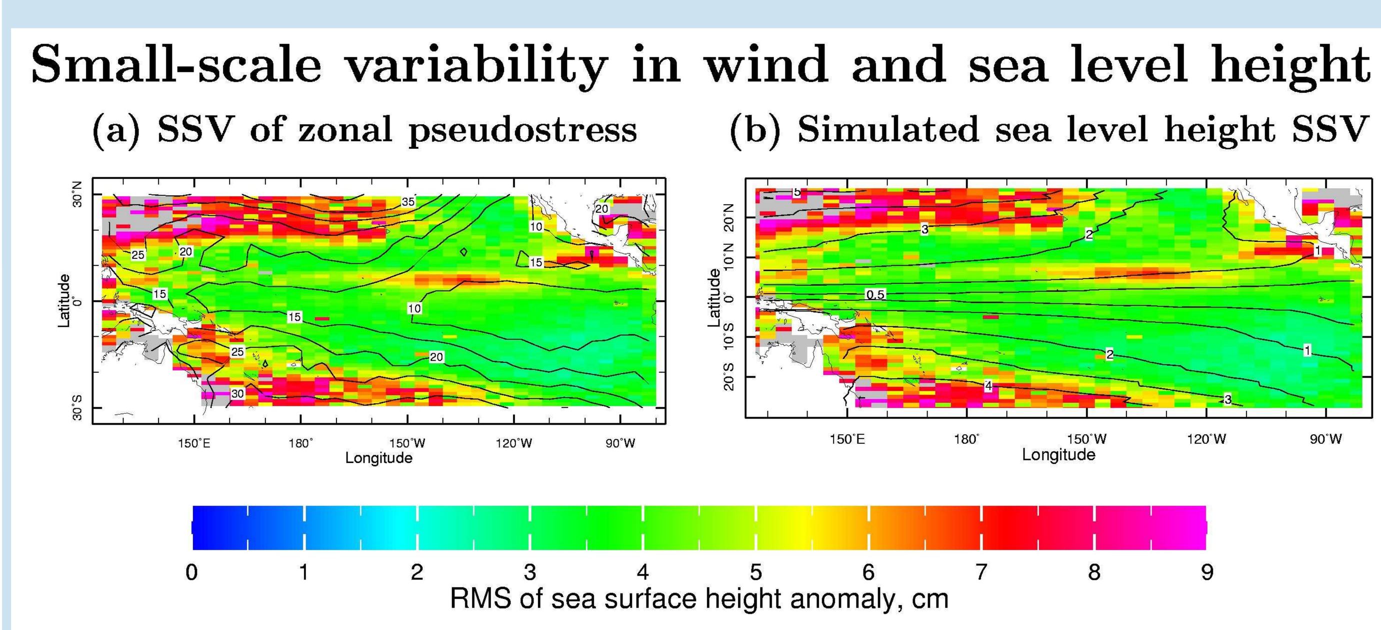



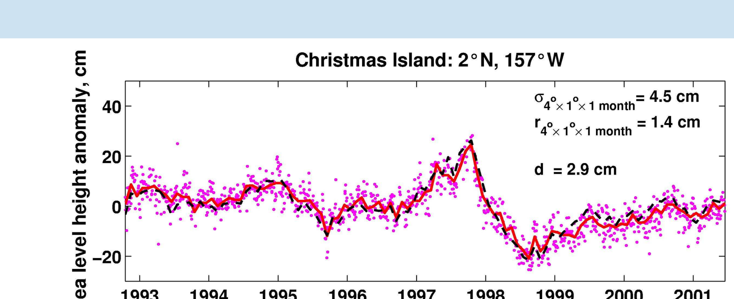

## 6. Dependence of sea surface height variability on noise decorrelation scales

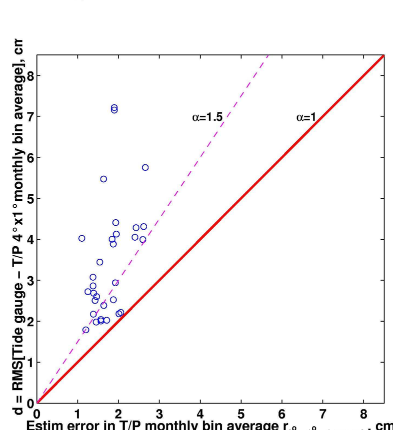


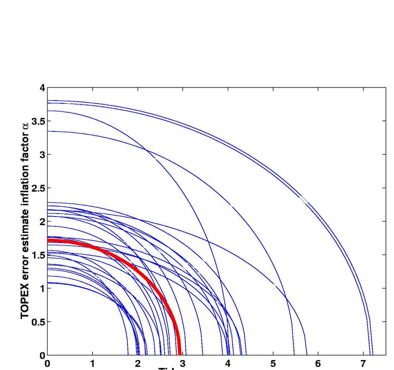

## 7. Monte Carlo simulation of observed small-scale variability of sea surface height




## 8. ERROR MODELS FOR ALTIMETRY AND TIDE GAUGES





Validation of T/P error estimates by comparison with the tide gauge records, October 1992 -- March 2001. The top panel compares monthly tide gauge sea level height anomalies at Christmas Island (dashes) with altimetric measurements from the corresponding gridbox (centered at 2N and 158W) of *Cheney et al.* [1994] T/P product. Dots show values from individual altimetry passes, and the solid line shows their monthly averages for this gridbox. Temporal RMS values of the intrabox variability sigma inside the gridbox, the sampling error estimate r for the gridbox mean, and the RMS difference between the gridbox and tide gauge monthly means d are indicated as well. In the lower left panel, circles are differences between 31 tide gauges and T/P bins. Differences would fall along the solid line if the only errors were the ``optimistic'' estimate of T/P errors. The dashed line inflates these optimistic estimates by a factor of 1.5. In the lower right panel, thin lines show constraints on the inflation factor alpha and tide gauge error r for individual tide gauges. The thick line shows the median constraint.

## 9.MODELING TIDE GAUGE ERROR