On the decadal trend of global mean sea level and its implication on ocean heat content change

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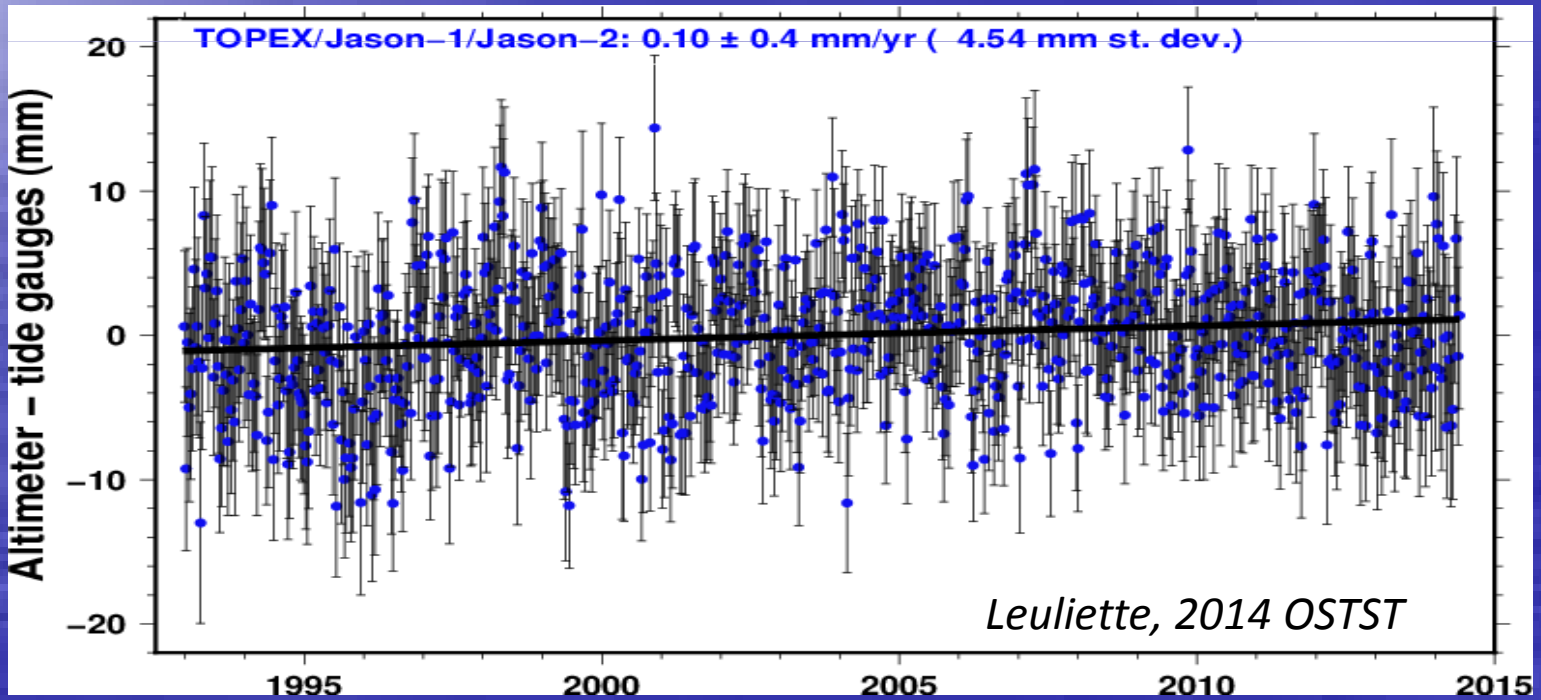
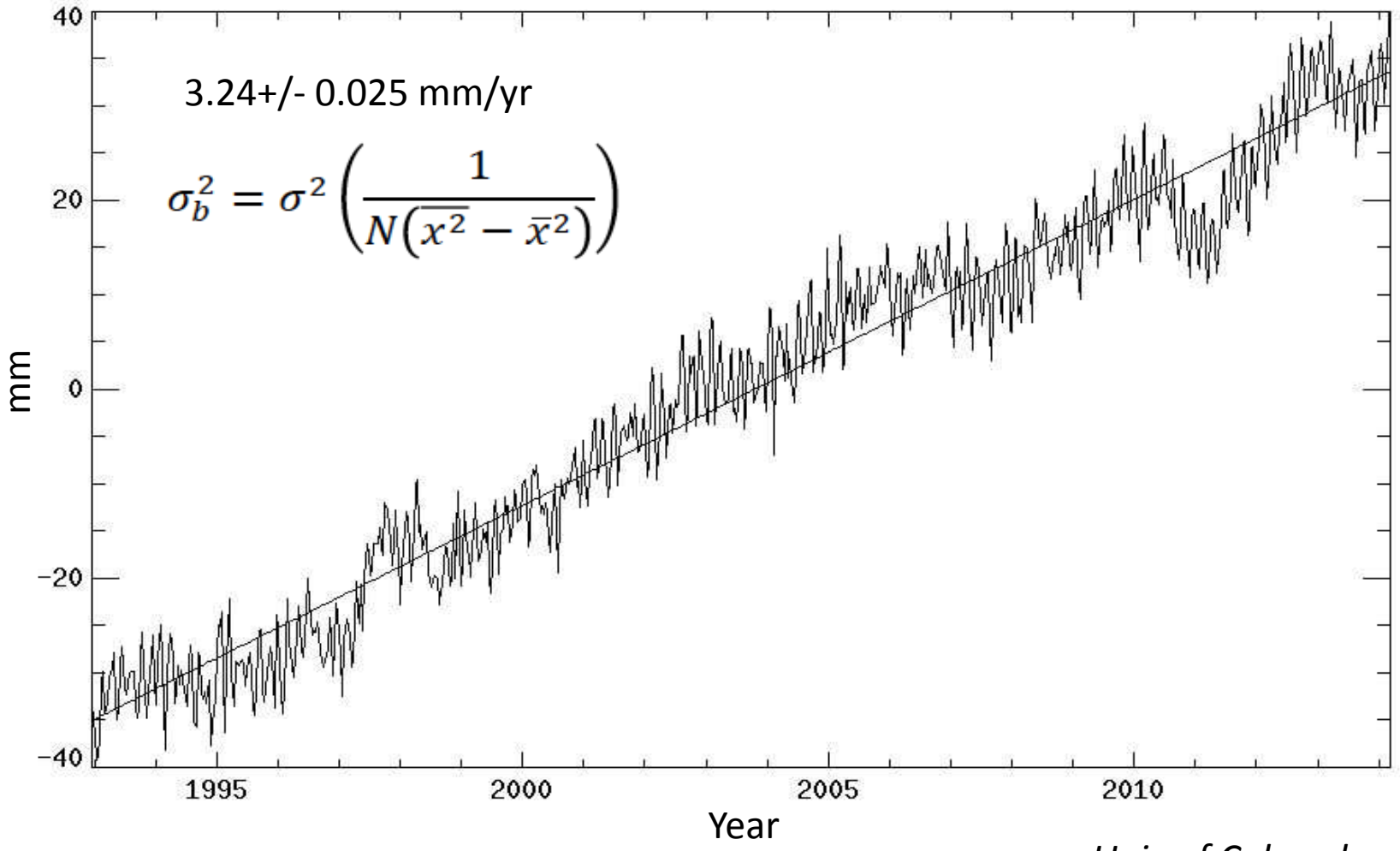
- What is the dominant uncertainty in the decadal trend of the GMSL? The formal fit error? Or some unknown systematic errors?
- The uncertainty in the bias drift calibration is essentially random.
- Based on the rms difference of 4.54 mm and the 730 repeat cycles of the 20 year record, the formal fit error is ~ 0.03 mm/yr.
- The quoted 0.4 mm/yr is probably a systematic error associated with the large-scale land motion errors that have time scales longer than a decade. In fact, this estimate has been steady since Mitchum (2000).



Global Mean Sea Level (GMSL) Record from Altimetry



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Linear regression as an optimal estimation problem

$$a + bt + n(t) = y(t)$$

$$\boldsymbol{D}\,\boldsymbol{a} + \boldsymbol{n} = \boldsymbol{y}$$

Where

$$\boldsymbol{D} = \begin{Bmatrix} 1 & t_1 \\ 1 & t_2 \\ . & \\ . & \\ 1 & t_m \end{Bmatrix}, \quad \boldsymbol{a} = \begin{bmatrix} a \\ b \end{bmatrix}, \quad \mathbf{y} = \begin{bmatrix} y(t_1) \\ y(t_2) \\ . \\ . \\ y(t_m) \end{bmatrix},$$

and $n(t)$ is the noise vector. Let the m x m autocovariance matrix of $\boldsymbol{y}$ be noted by $\boldsymbol{R}$, then the optimal solution for x is expressed as follows

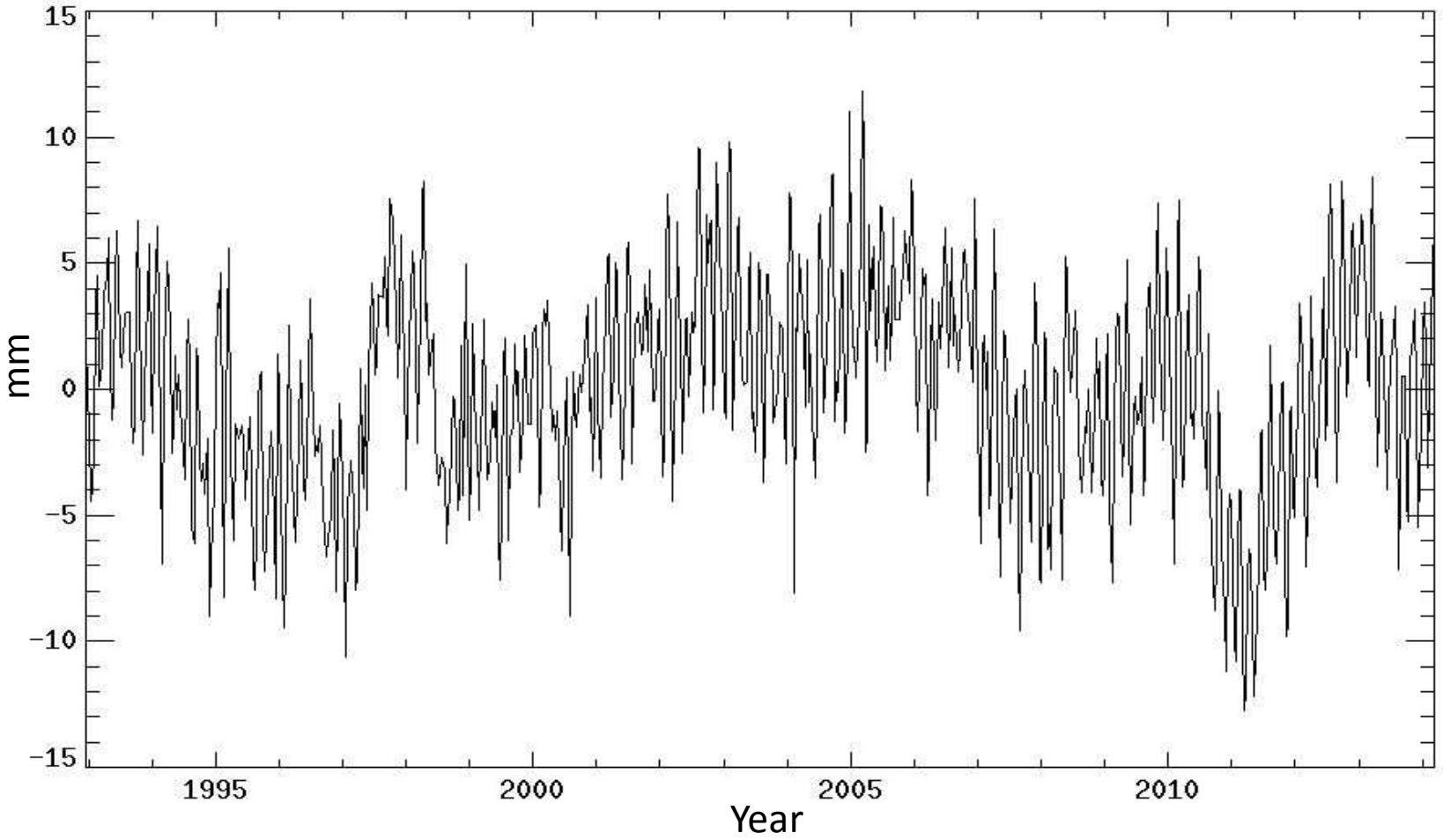
$$\tilde{\boldsymbol{a}} = \begin{bmatrix} \tilde{a} \\ \tilde{b} \end{bmatrix} = [\boldsymbol{D}^T\boldsymbol{R}^{-1}\boldsymbol{D}]^{-1}\,\boldsymbol{D}^T\,\boldsymbol{R}^{-1}\,\mathbf{y}$$

The variance of the uncertainty of the estimate $\tilde{\boldsymbol{a}}$ about its mean is

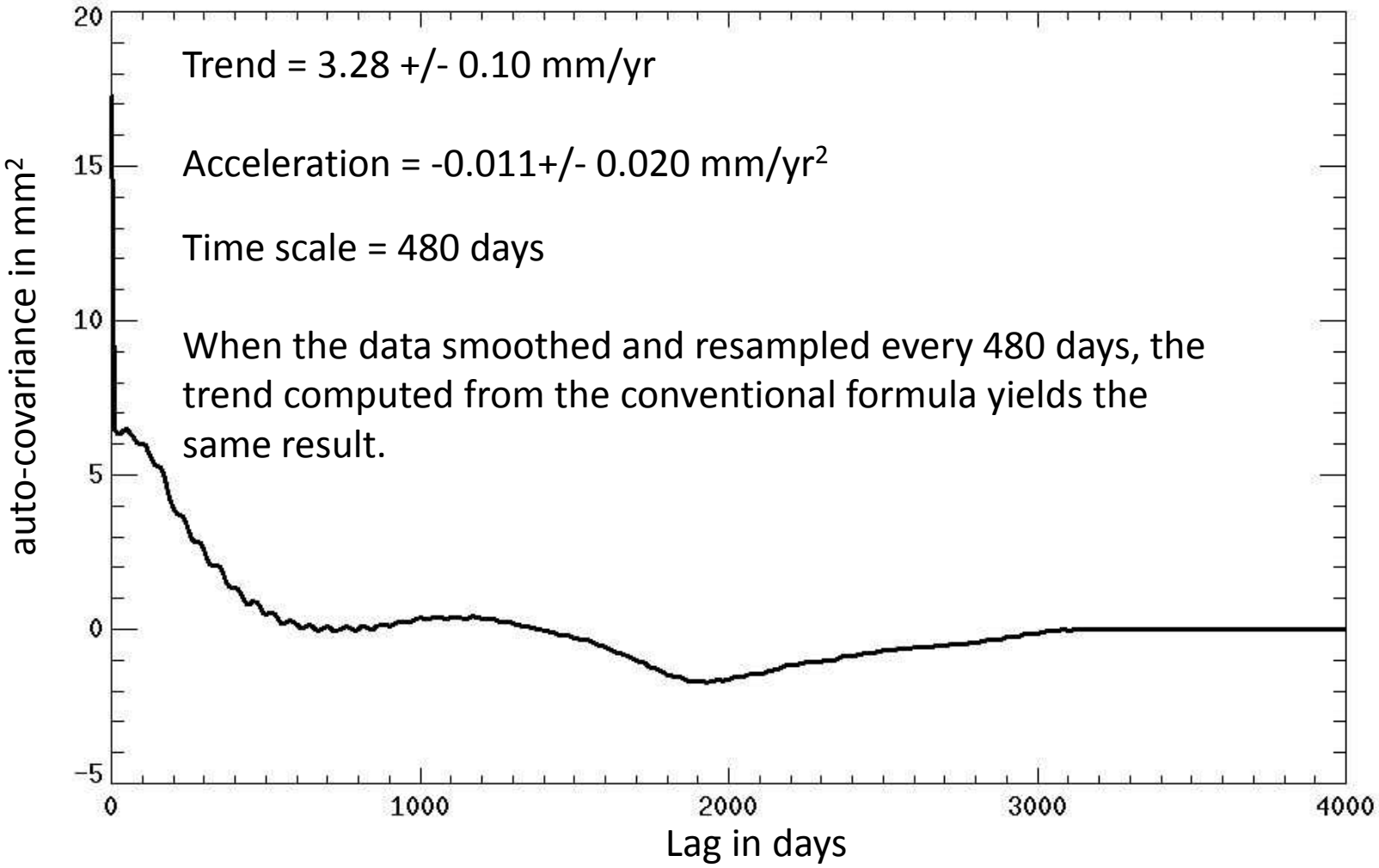
$$\boldsymbol{P} = \langle (\tilde{\boldsymbol{a}} - \boldsymbol{a})^2 \rangle = [\boldsymbol{D}^T\boldsymbol{R}^{-1}\boldsymbol{D}]^{-1}$$

Wunsch (1996)

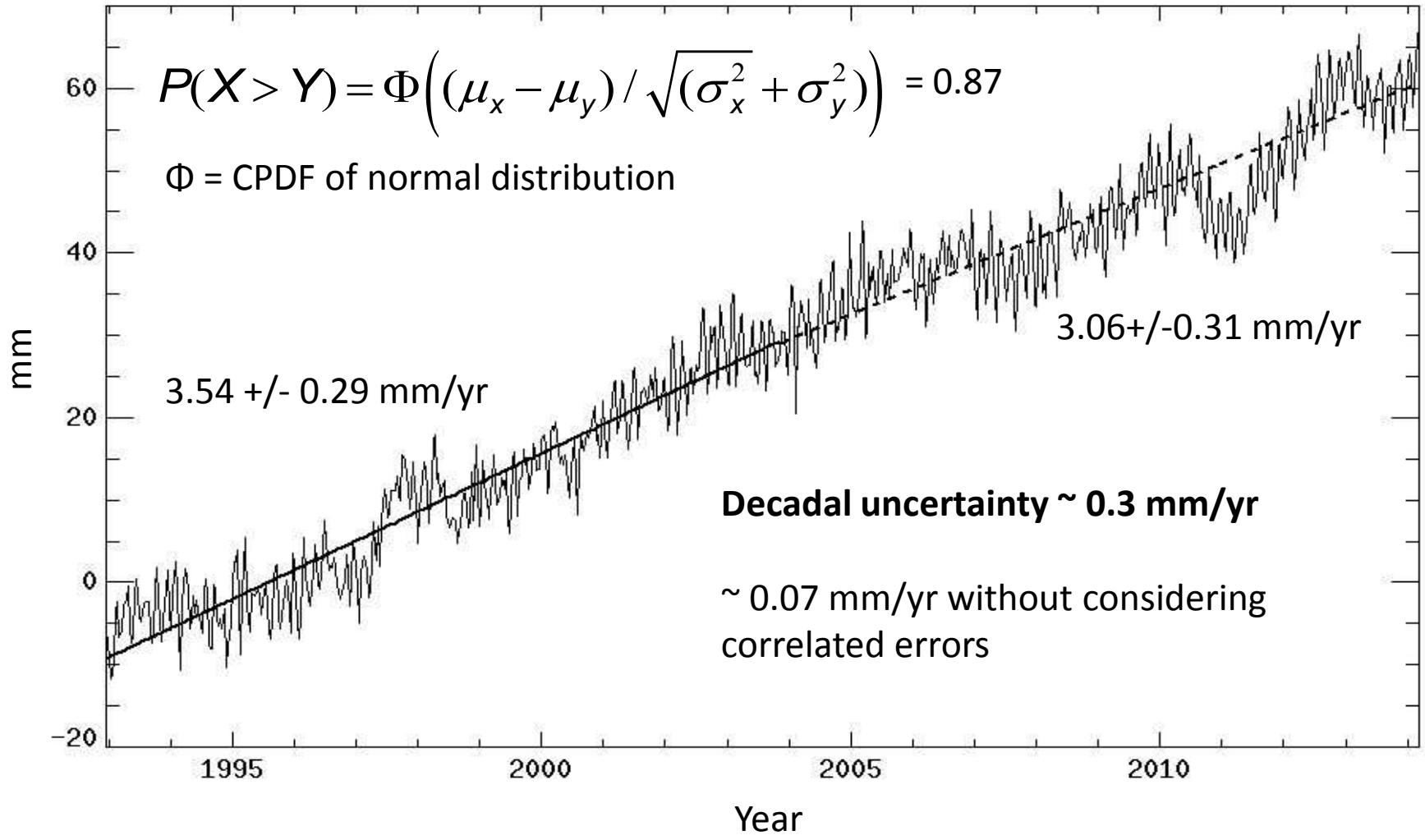
De-trended GMSL



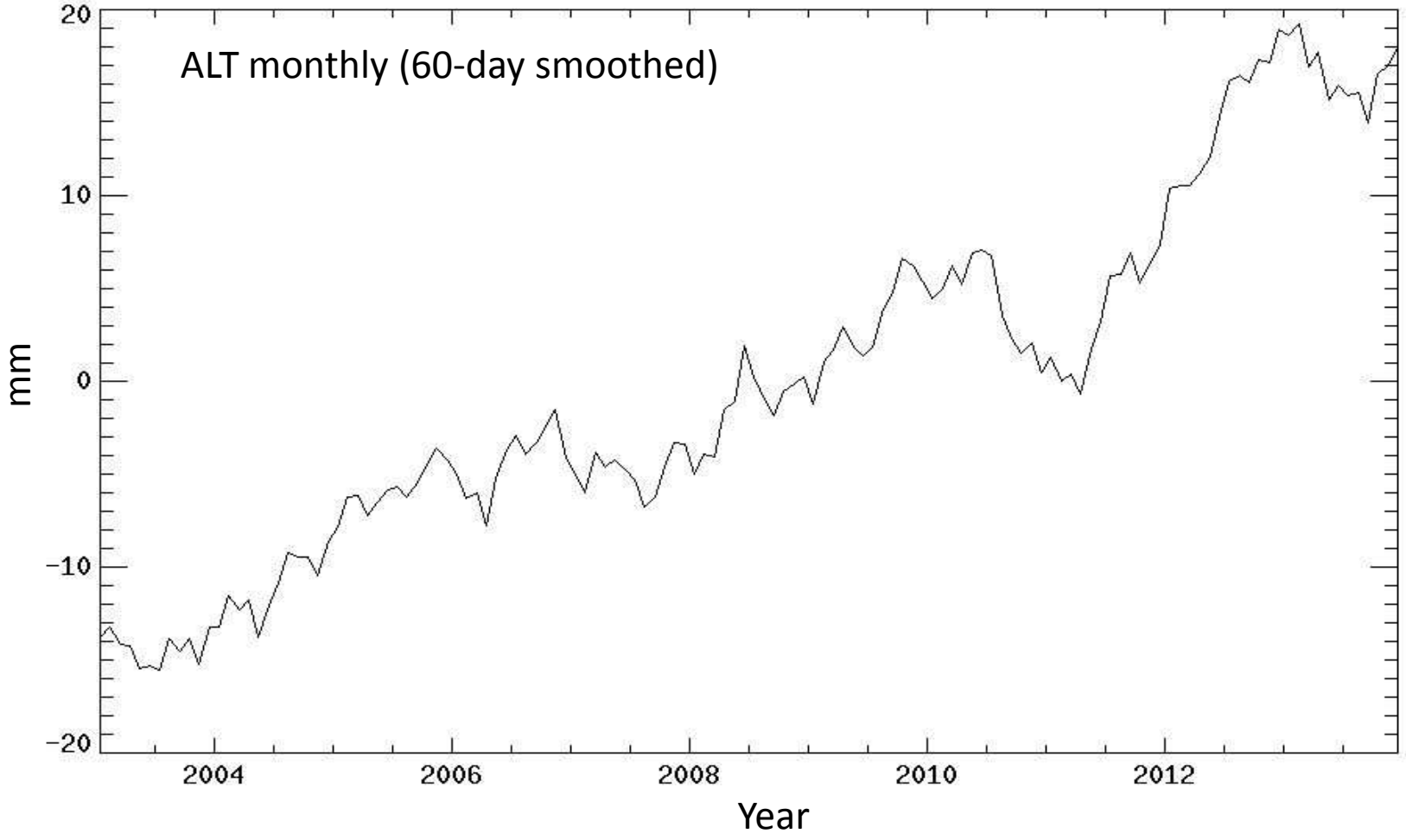
Auto-covariance of GMSL



Decadal Trend Variation



Comparison to GRACE measurement of ocean mass



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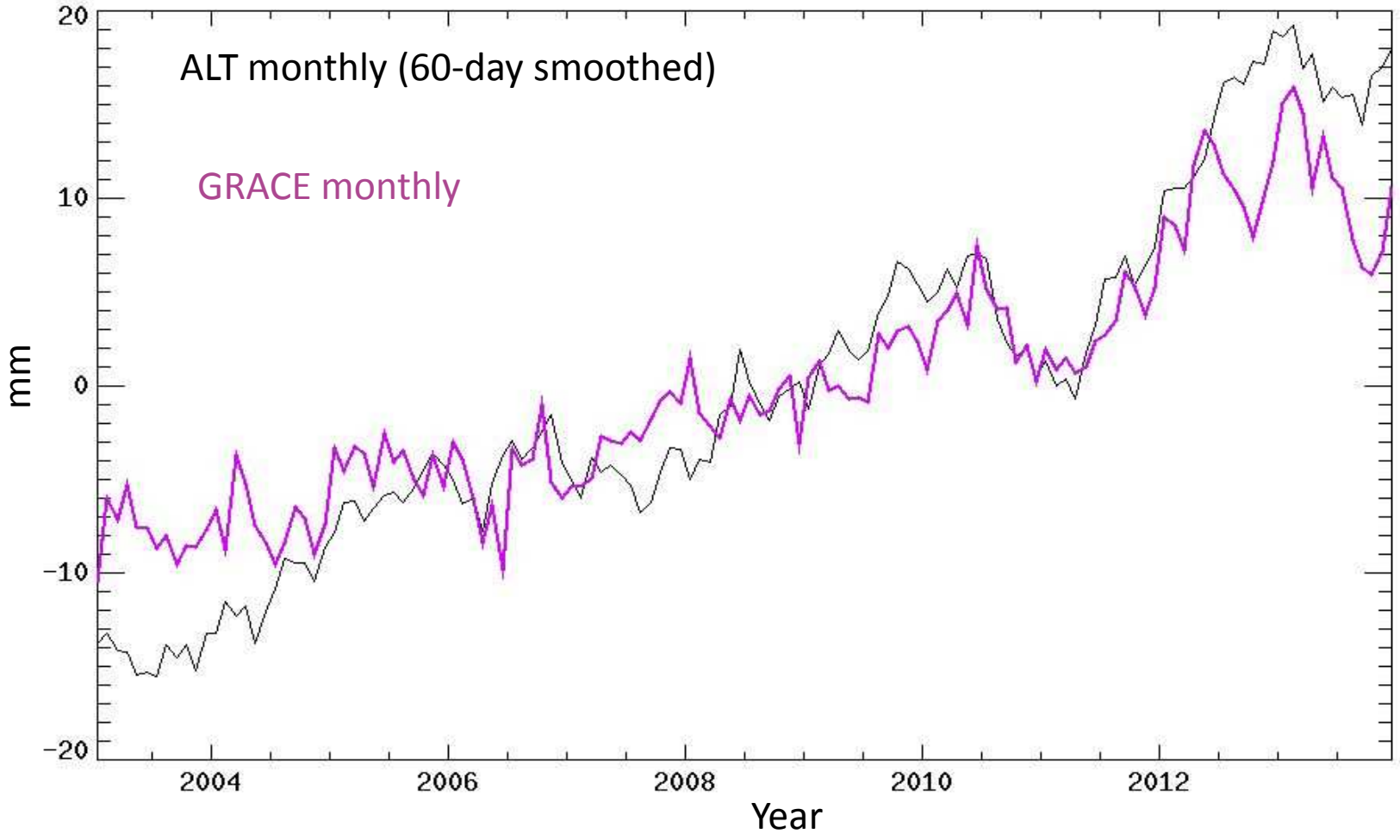
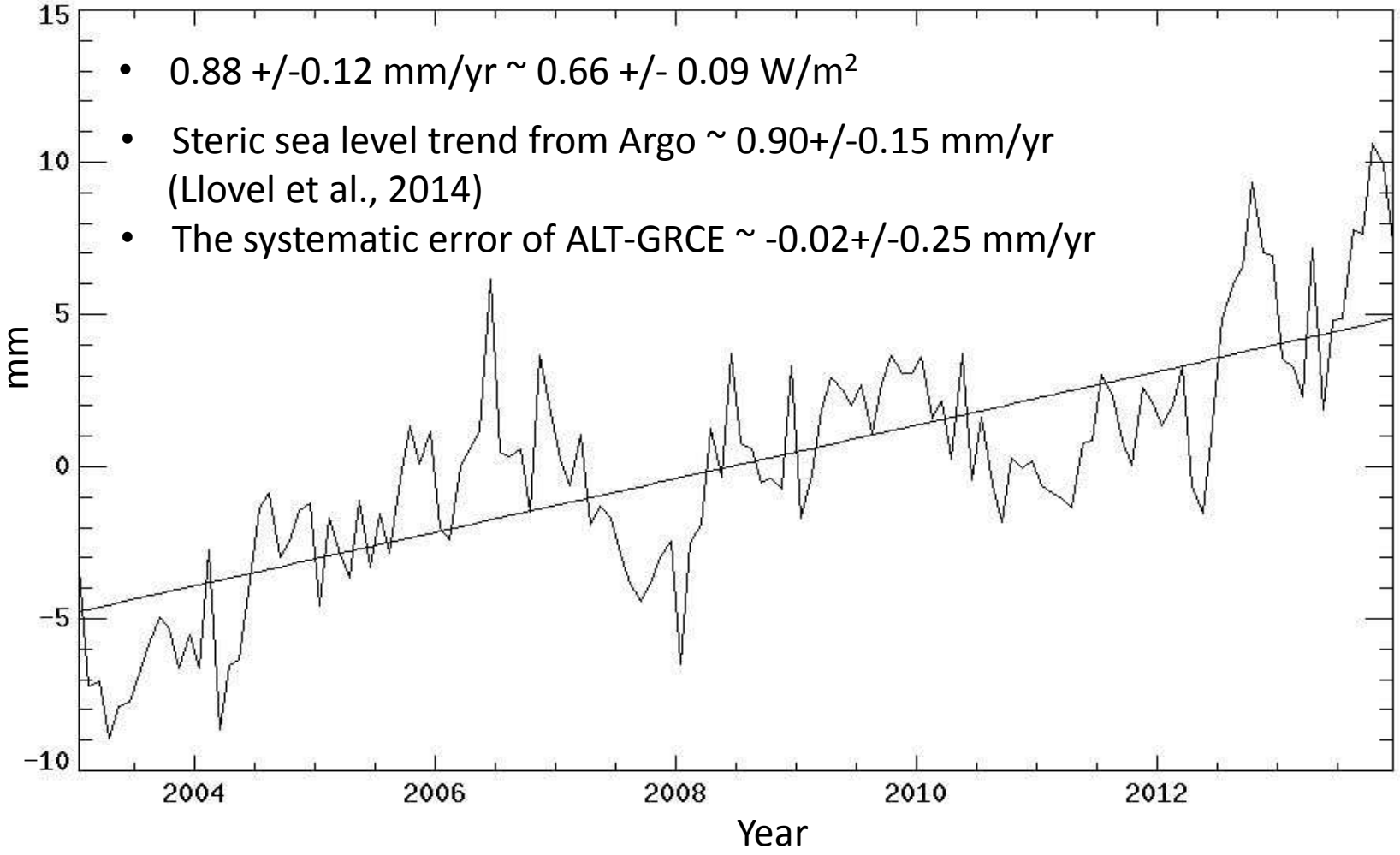


Steric sea level

ALT - GRACE



- 0.88 +/-0.12 mm/yr ~ 0.66 +/- 0.09 W/m^2
- Steric sea level trend from Argo ~ 0.90+/-0.15 mm/yr (Llovel et al., 2014)
- The systematic error of ALT-GRCE ~ -0.02+/-0.25 mm/yr

Conclusions

- Sea level trend is treated as an optimal estimation problem.
- On decadal scales, the uncertainty of the global mean sea level trend is ~ 0.3 mm/yr, associated with the interannual variability.
- The uncertainty of the decadal trend of steric sea level is ~ 0.12 mm/yr, equivalent to the rate of ocean heat content change of 0.1 W/m^2, about 20% of the oceanic heat uptake.
- The consistency among altimetry, GRACE, and Argo observations indicates that the systematic errors in altimetry and GRACE, if not anti-correlated, are bounded by 0.02 +/- 0.25 mm/yr.