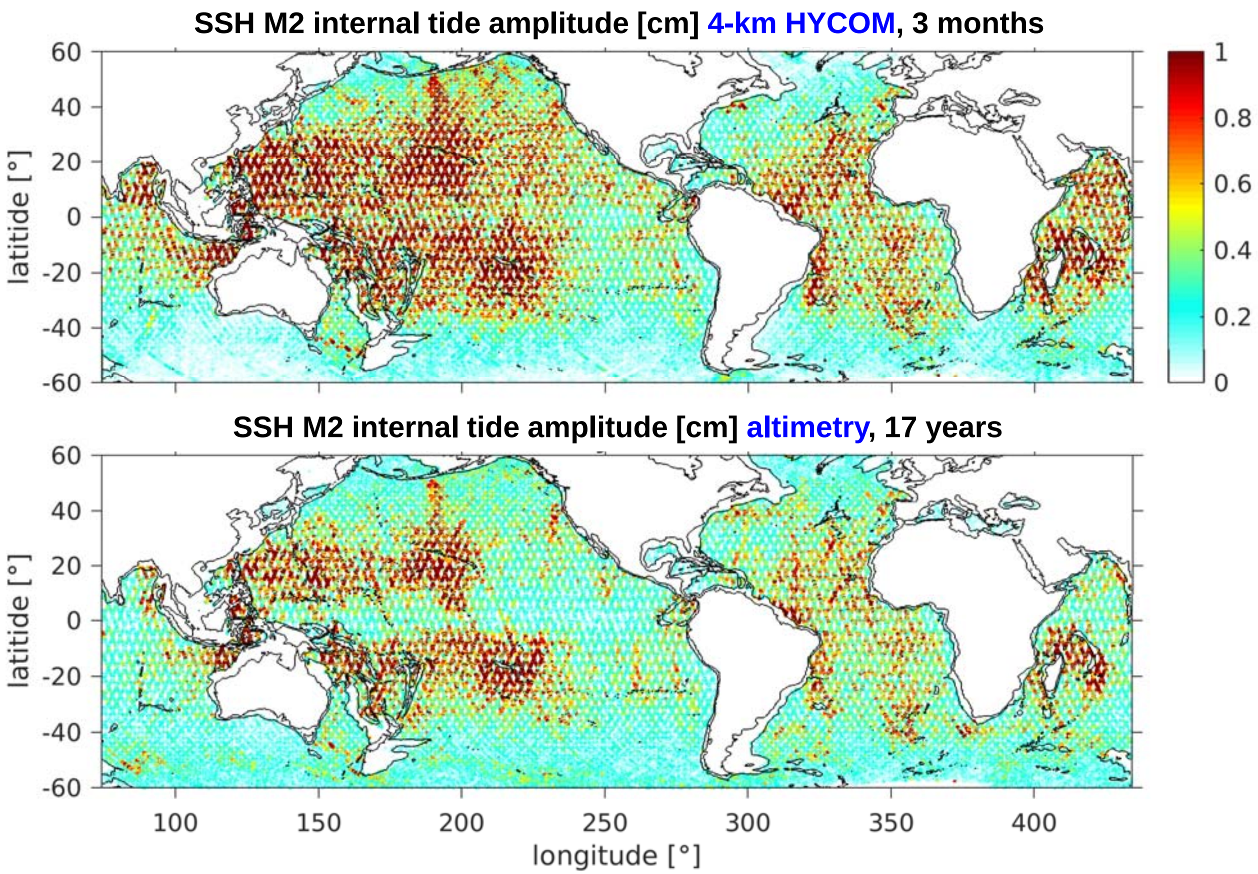
A Correction Factor for Internal Tide Variance in Models



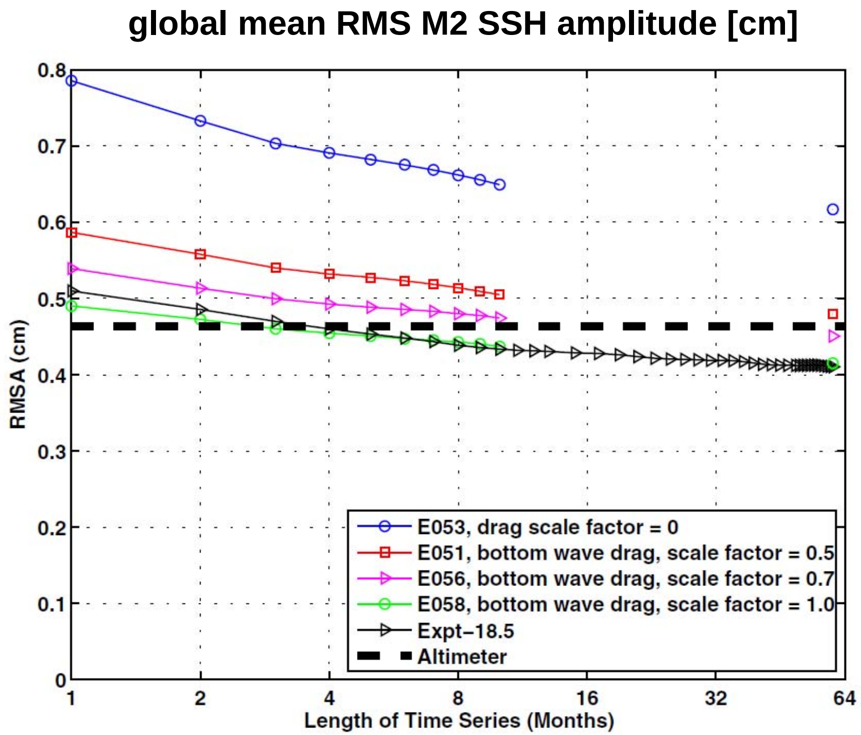
Why is the M_2 internal tide SSH amplitude of a short HYCOM record larger than the amplitude extracted from altimetry?

Objectives

- The internal tide M_2 SSH amplitude decreases as a function of time series duration due to refraction/reflection/ducting by mesoscale background flow

- We will compute the SSH variance decay for each horizontal grid cell for a 6-year long HYCOM simulation

- We will use this decay relation to compute a spatially varying correction factor



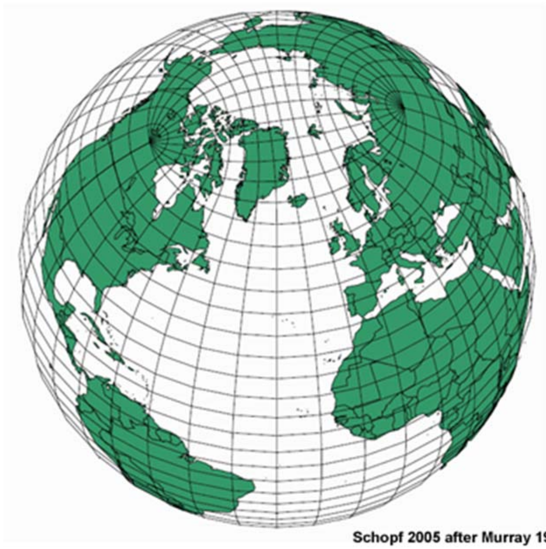
Ansong et al. (2015)

- The correction factor can be applied to shorter duration simulations to ensure an “apples to apples” comparison to altimetry

Methodology

- We analyze the **HY**brid **C**oordinate **O**cean **M**odel (HYCOM) simulation Expt_185:
  - Forward simulation
  - 8-km horizontal resolution and 32 layers
  - atmospheric forcing from FNMOC NOGAPS
  - forced with M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1 tidal constituents and SAL correction
  - 6-year simulation; data output every hour

Tripolar Grid



Schopf 2005 after Murray 1996

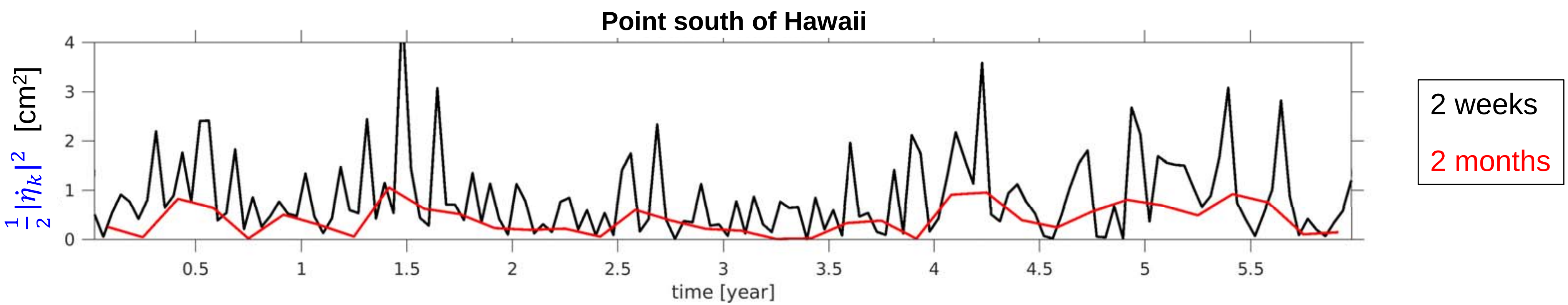
- Steric SSH time series are split into time series with durations of 2 weeks, 1, 2, 3, 4, 6, 9, 12 months, 2, 3, 4, 6 years

  $\Rightarrow$ 2-week series has 144 members, 1 month has 72, etc.

- A least squares-harmonic analysis is applied to each member k to extract complex M_2 internal tide amplitude $\dot{\eta}_k = a_k + ib_k$

Total and stationary M_2 tide

- Complex amplitude $\dot{\eta}_k = a_k + ib_k$
- The mean <u>total</u> variance over all members (6 years): $\overline{\frac{1}{2}|\dot{\eta}_k|^2} = \frac{1}{M}\sum_{k=1}^{M}\frac{1}{2}|\dot{\eta}_k|^2$
- The mean <u>stationary</u> variance over all members: $\frac{1}{2}|\overline{\dot{\eta}_k}|^2$
- Non-stationary fraction: $\frac{\overline{|\dot{\eta}_k|^2} - |\overline{\dot{\eta}_k}|^2}{\overline{|\dot{\eta}_k|^2}}$
- M_2 tidal variance decreases with time series duration:

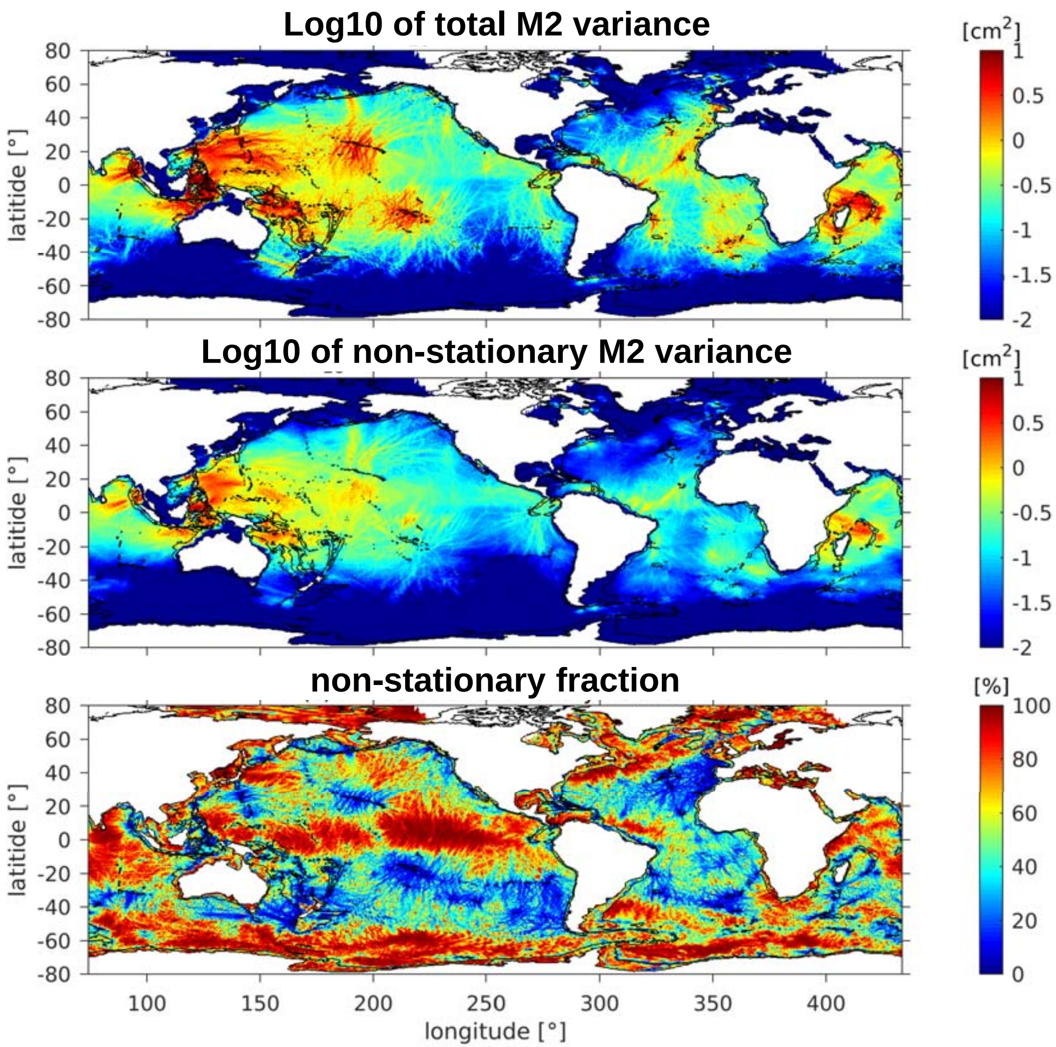


Variance for bi-weekly series

$$\overline{\frac{1}{2}|\dot{\eta}_k|^2}$$

$$\frac{1}{2}\left(\overline{|\dot{\eta}_k|^2} - |\overline{\dot{\eta}_k}|^2\right)$$

$$\frac{\overline{|\dot{\eta}_k|^2} - |\overline{\dot{\eta}_k}|^2}{\overline{|\dot{\eta}_k|^2}}$$

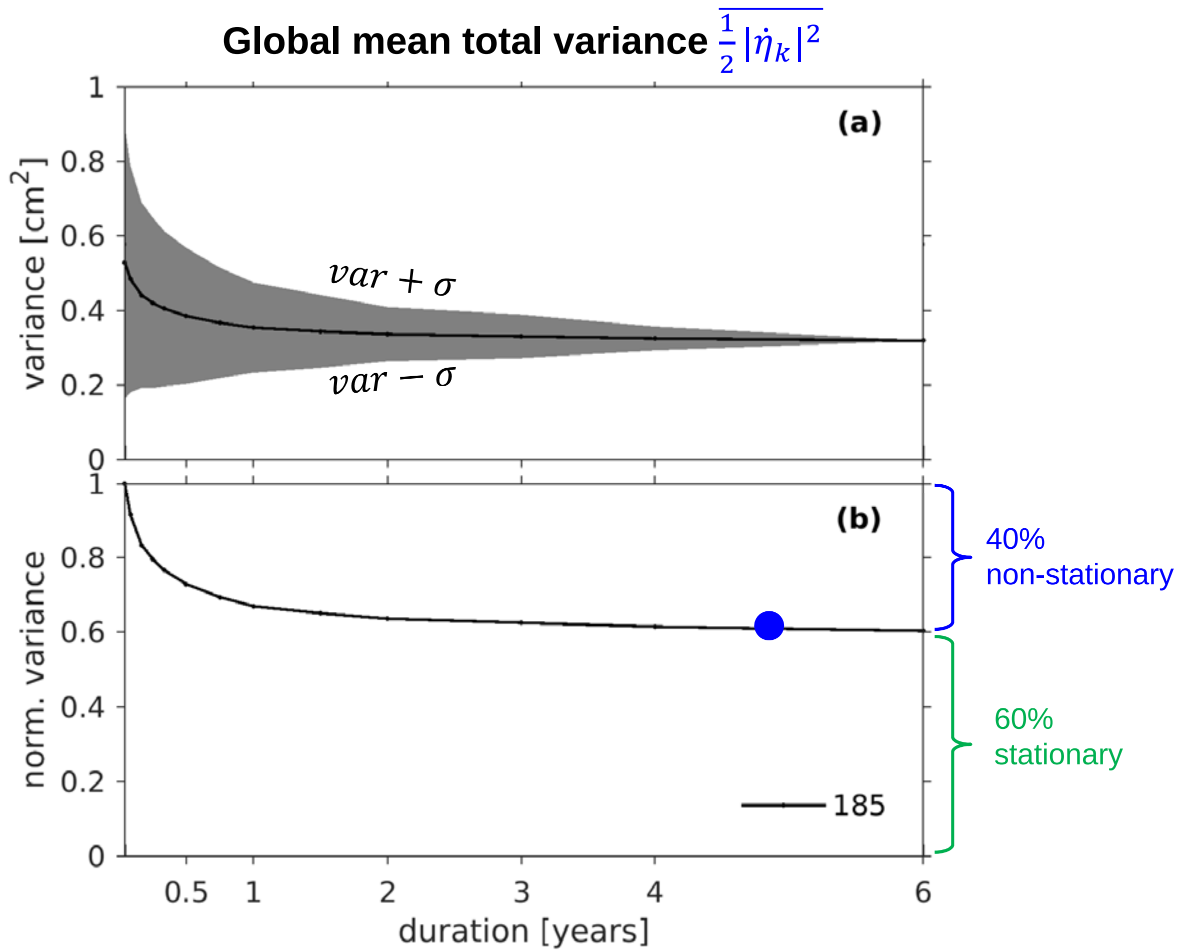


Variance as a function of duration

- Total M_2 variance decreases with duration

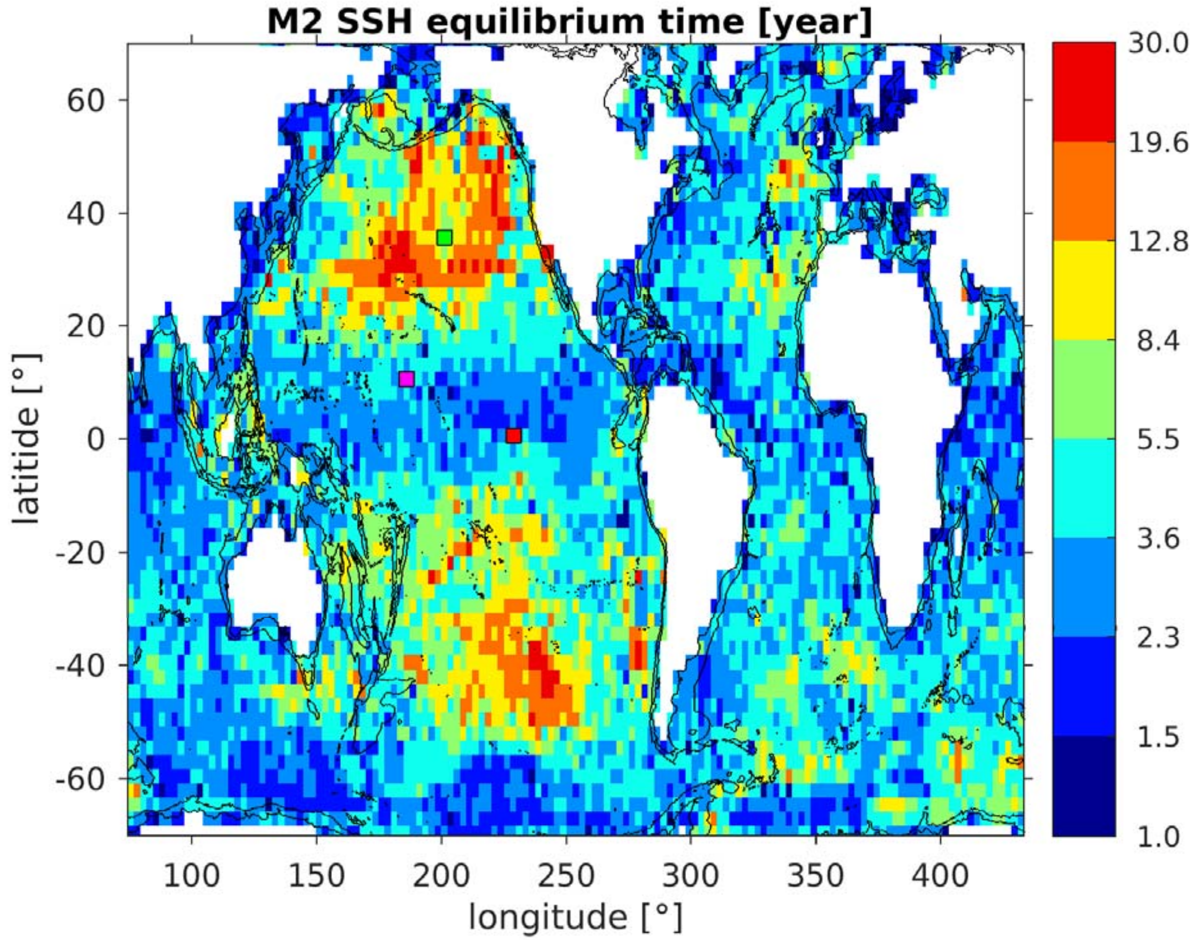
- Equilibrium time (●) is the time at which the decay rate has dropped below a "threshold" value

  $\Rightarrow$ the variance no longer decays beyond T_{eq}

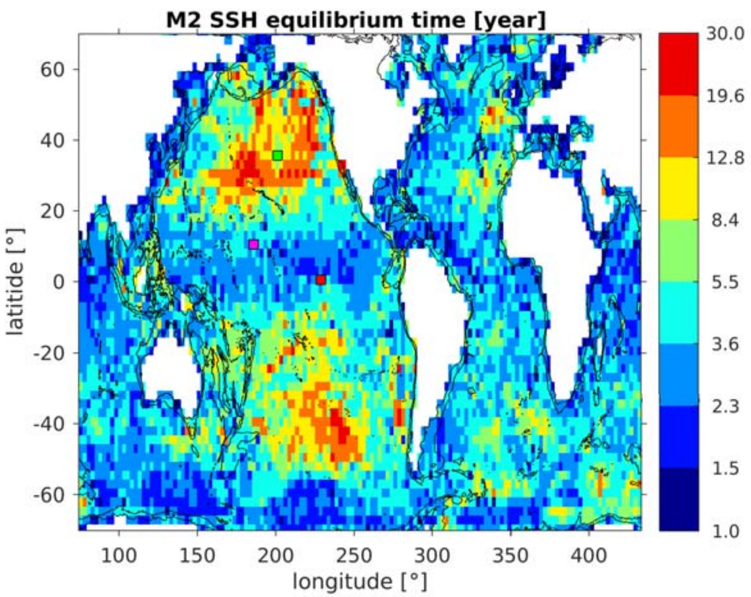


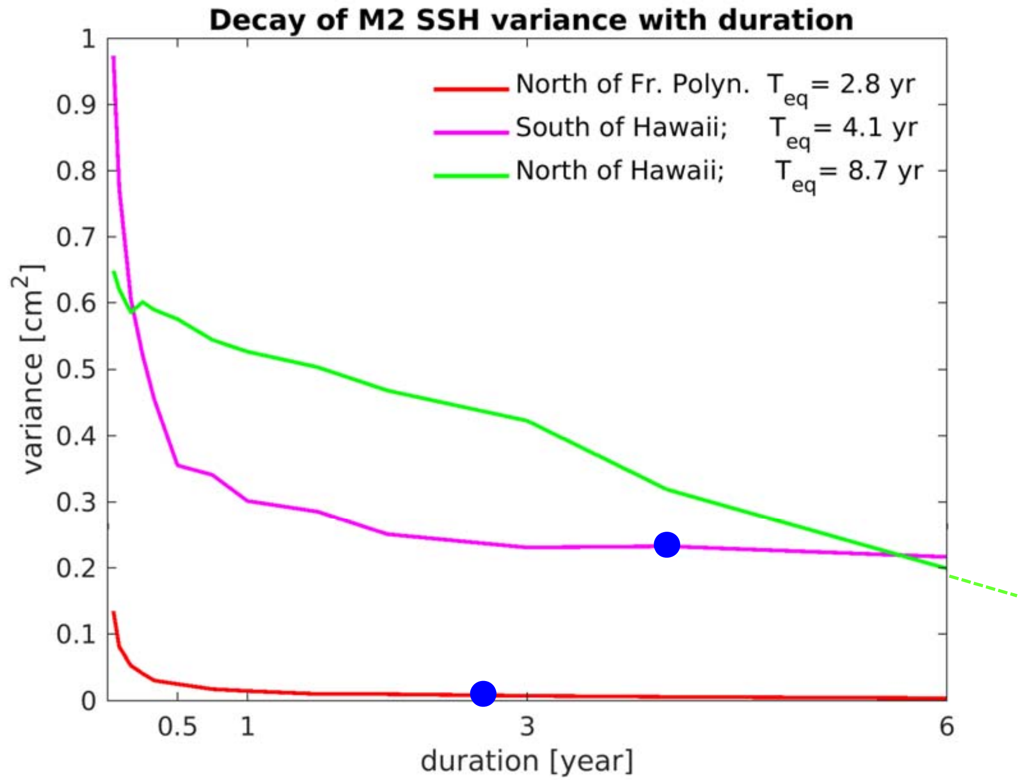
Equilibrium time T_{eq}

- Variance is averaged to 2.5° bins
- $T_{eq} < 6$ years in tropics and Western Boundary currents
- $T_{eq} > 6$ years in subtropical gyres



Variance decay in 3 Locations

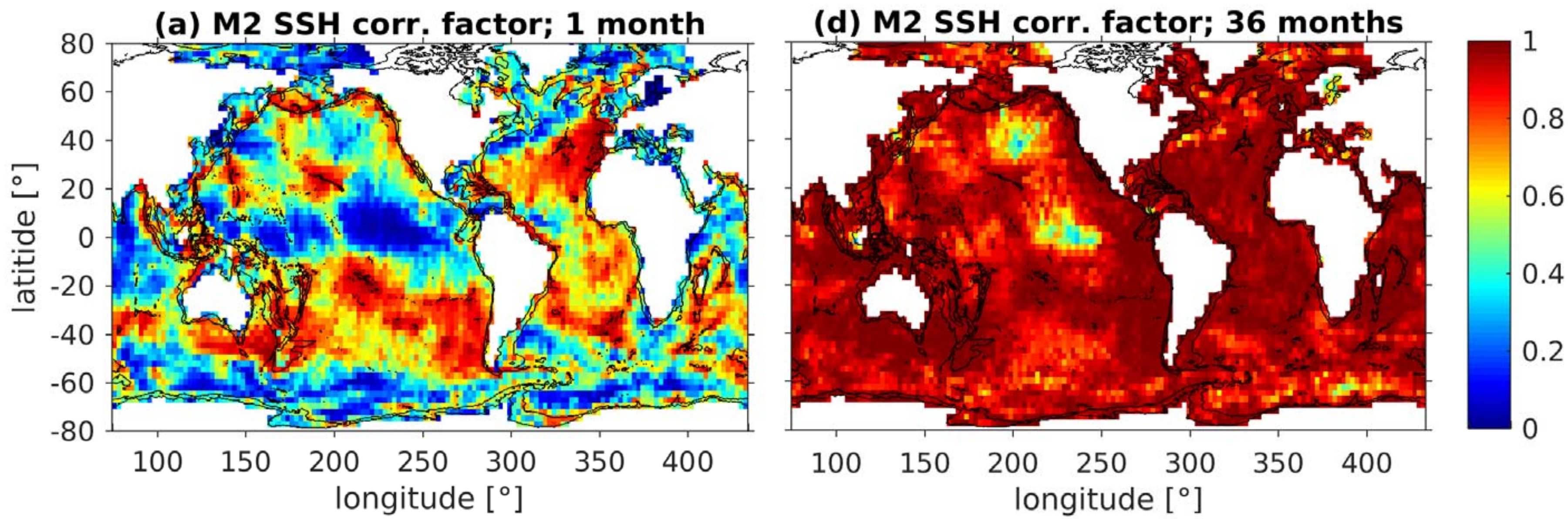




- Variance in tropics equilibrates quickly
- Gyres do not appear to equilibrate in HYCOM!!

Correction factor $\frac{var_{eq}}{var_{dur}}$

- We can use the decay relations for expt_185 to compute a spatially varying correction factor
- The correction factor is a function of duration
- Relatively short-duration simulations can be corrected in order to compare them with altimetry

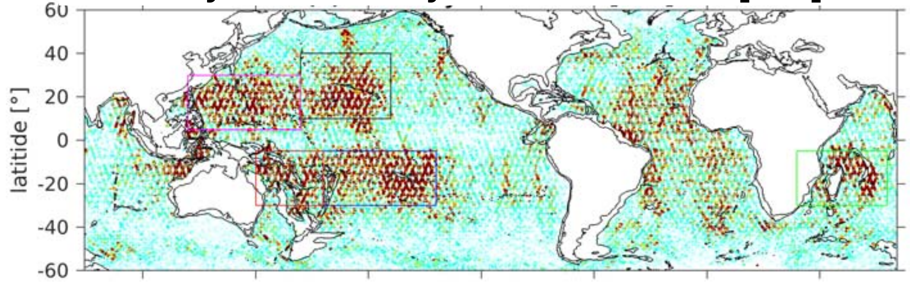


Correction of expt_221

- Correction is applied to 4-km HYCOM expt_221
  - Harmonic analysis based on 3 months
  - Harmonic analysis based on 12 months

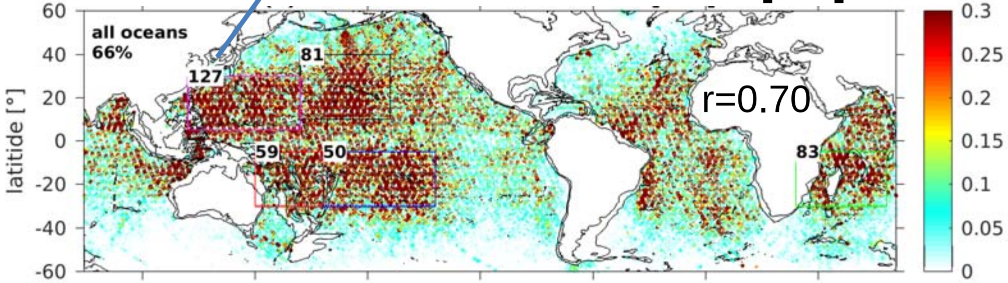
numbers are % difference with altimetry

17 years altimetry M2 SSH variance [cm^2]

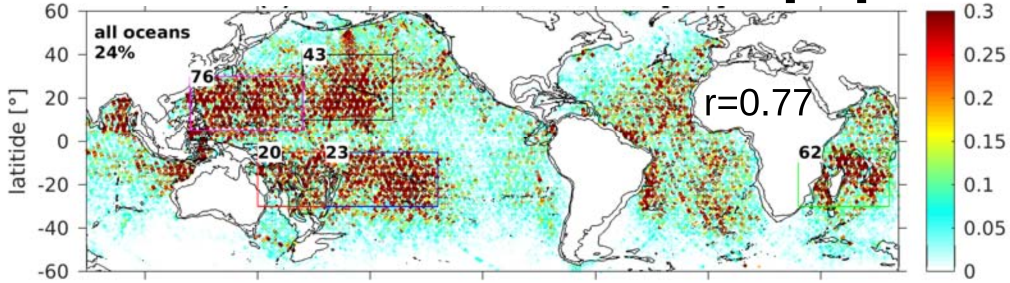


R. Ray

3 months uncorrected M2 SSH variance [cm^2]



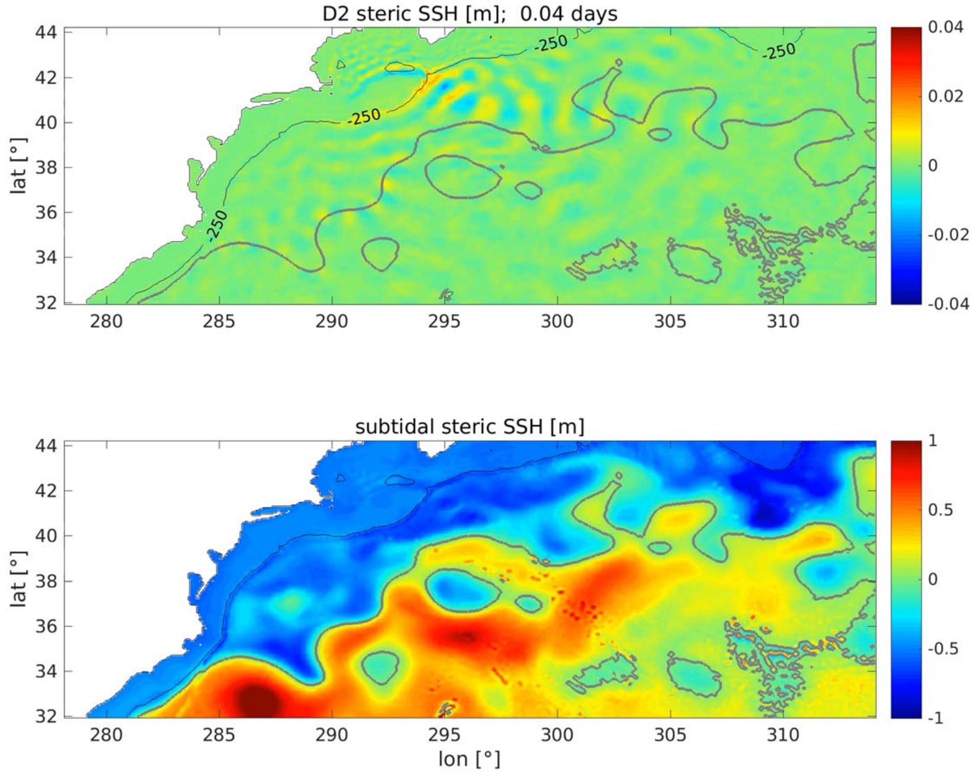
12 months uncorrected M2 SSH variance [cm^2]



Conclusions

- Internal tides become non-stationary in the tropics and western boundary currents
- The tidal variance decay and equilibrium times are spatially variable
- The variance decay can be used to correct SSH variance of shorter simulations

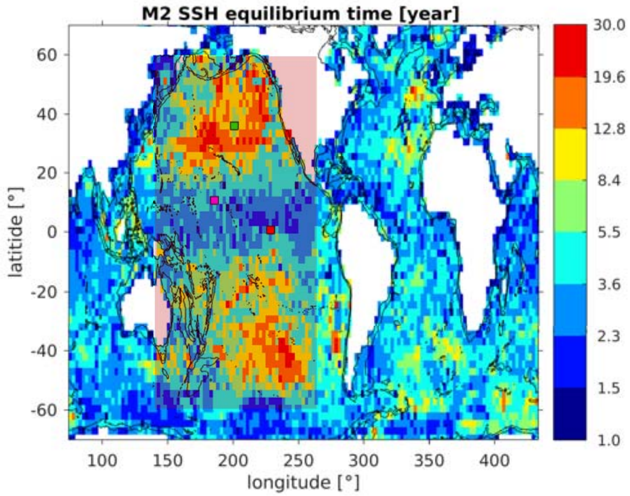
M_2 internal tides from Georges Bank



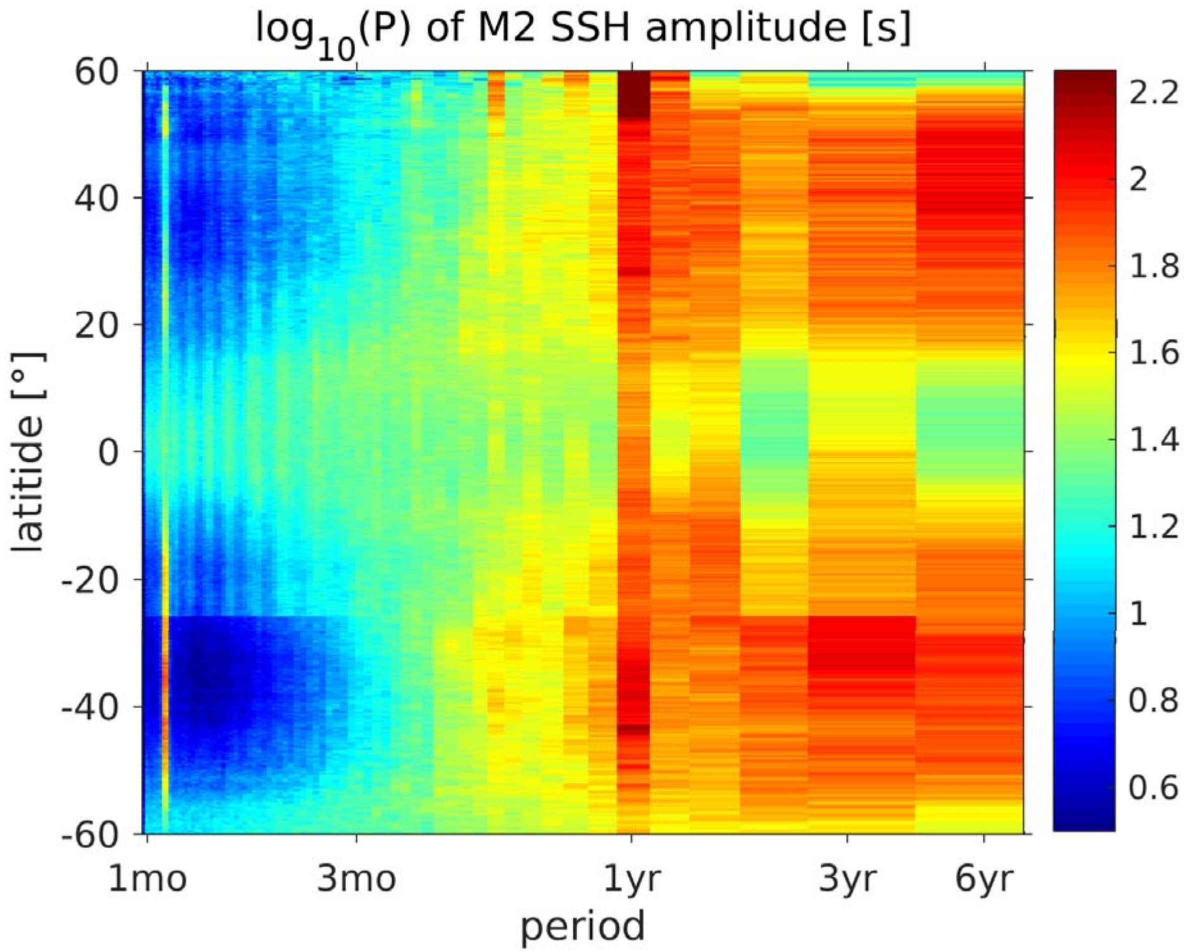
Future work:

- Update the altimetry data for this analysis
- Perform a complex modulation on the altimetry data to verify variance decay in the gyres
- Extend the 1-year 4-km simulation to 6 years

Why no equilibrium in the gyres?

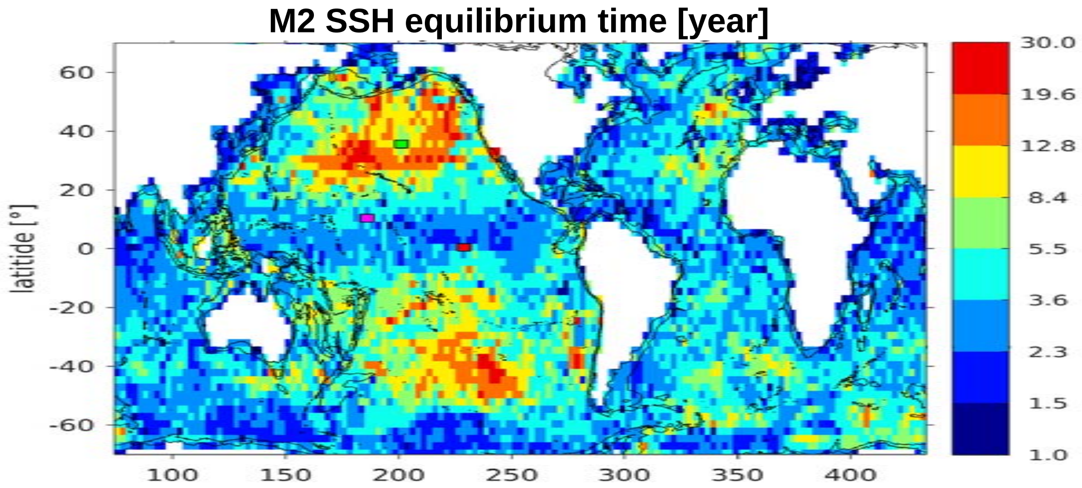


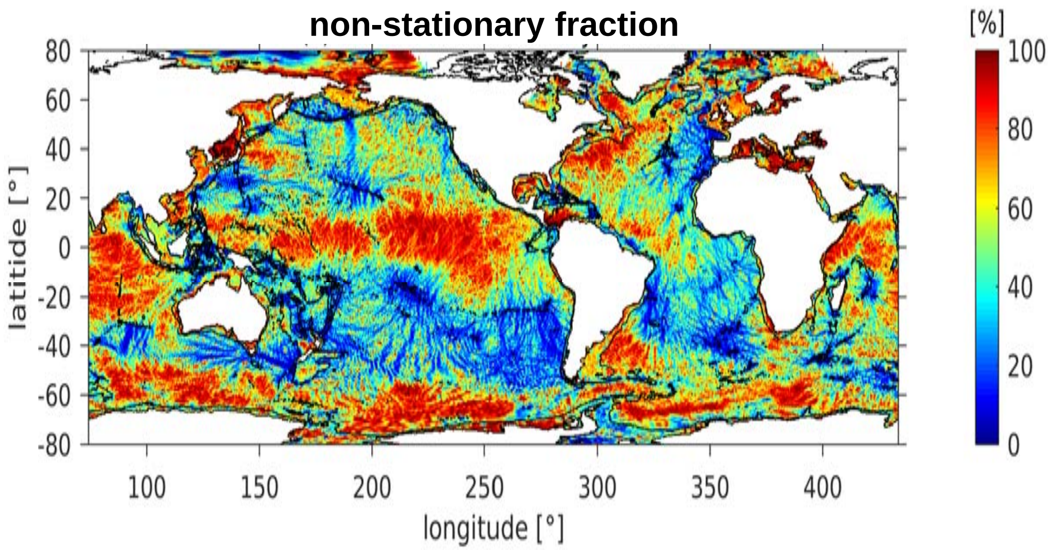
- Compute FFT for the normalized amplitude of the bi-weekly time series with 144 members
- In gyres, modulation periods longer than 1 yr have much energy



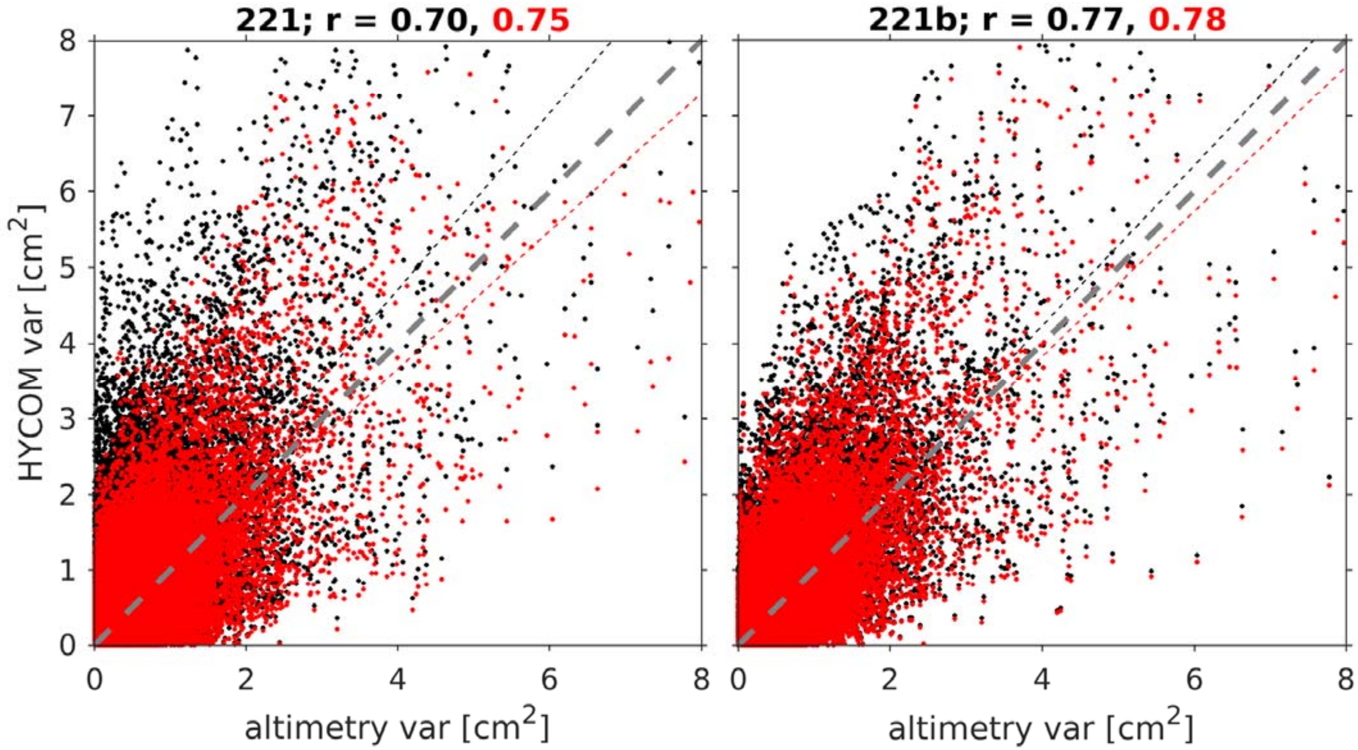
Equilibrium time T_{eq}

- Variance is averaged to 2.5° bins
- $T_{eq} < 6$ years in tropics and Western Boundary currents
- $T_{eq} > 6$ years in subtropical gyres
- The smaller T_{eq}, the larger the non-stationary fraction





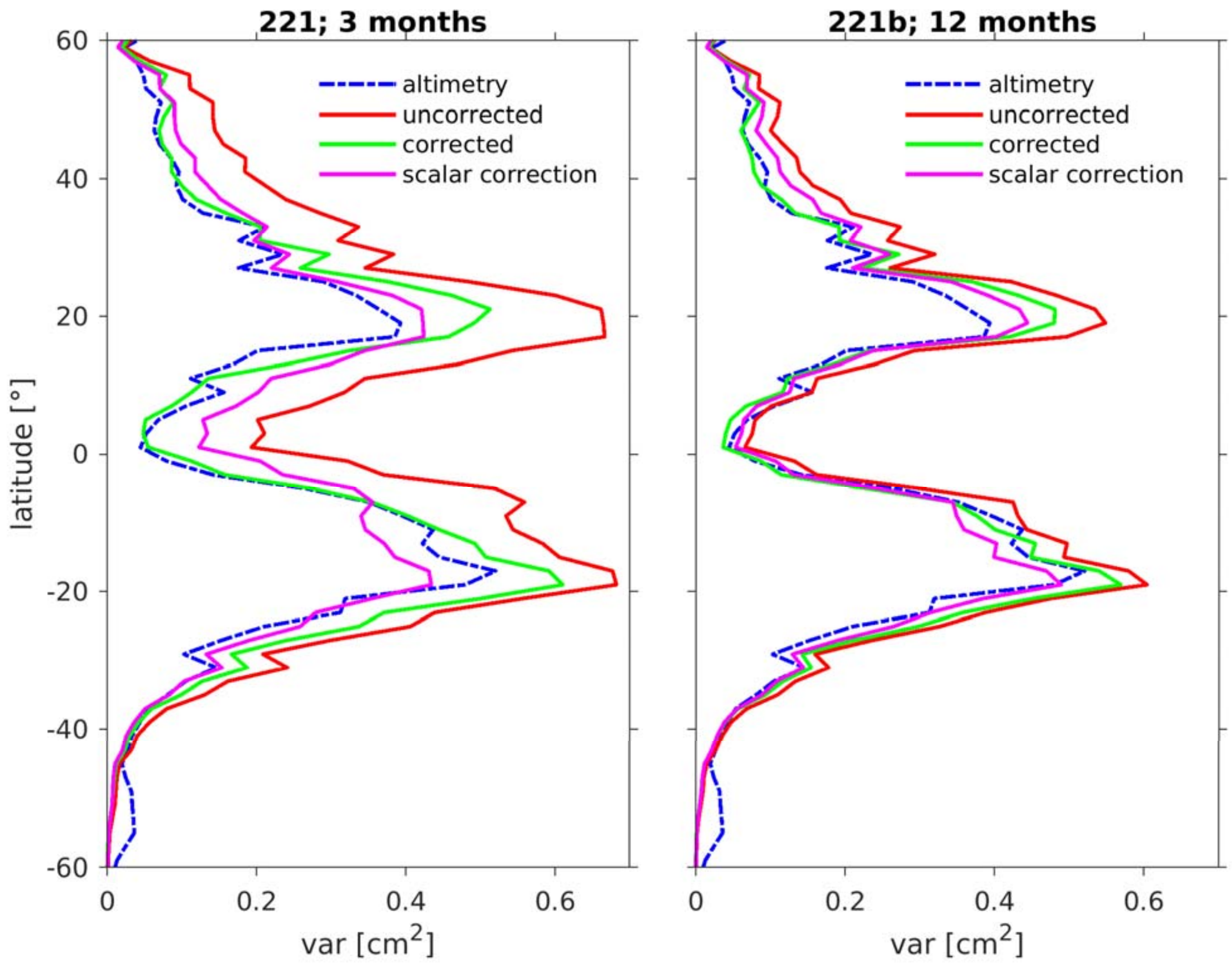
Scatter plot



Meridional Transect Across Pacific

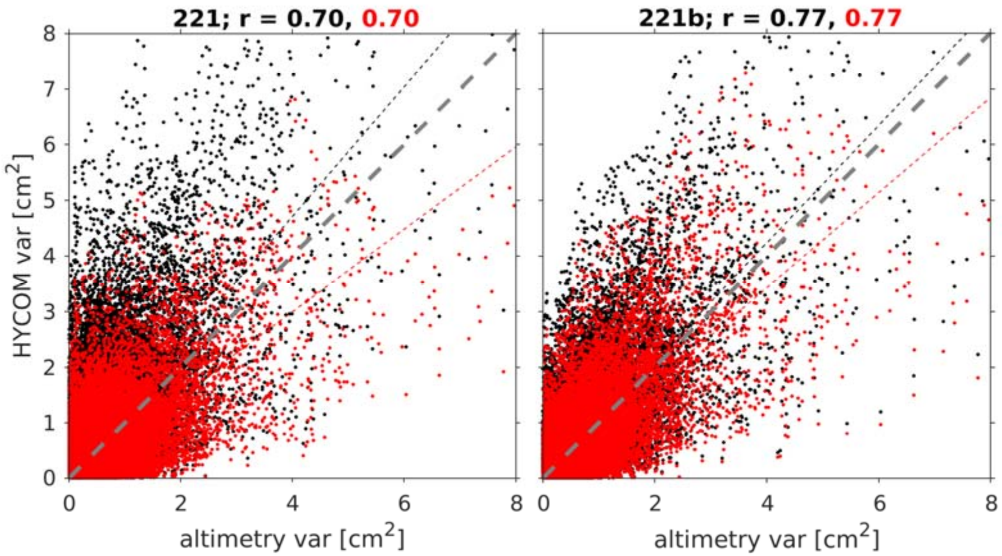
- Global-mean scalar correction
  - 3 months: 0.63
  - 12 months: 0.8

- Scalar correction
  - reduces variance closer to altimetry
  - But yields a weaker spatial correlation

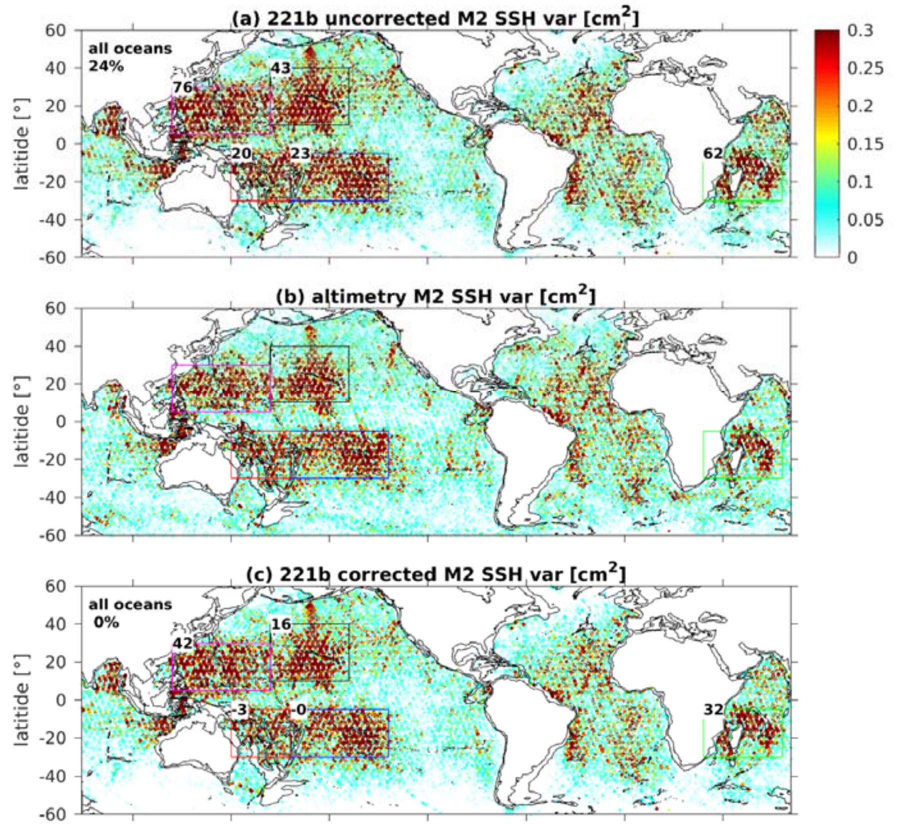


Scalar correction

3 months 12 months



12 months

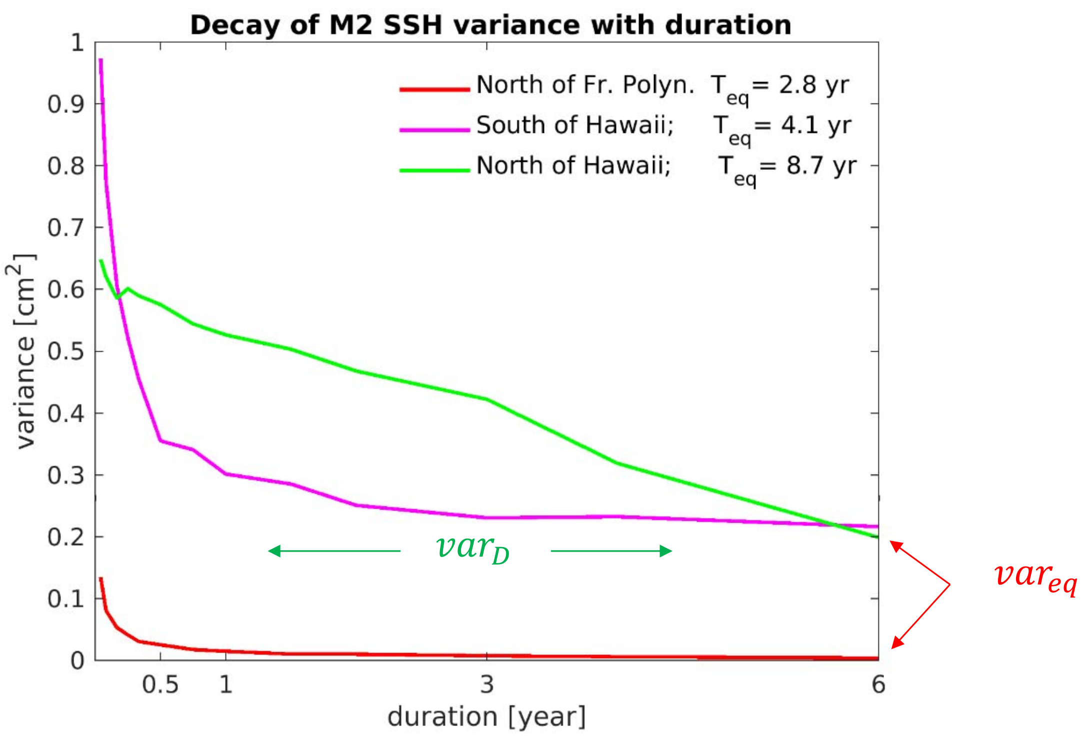


Compute Correction

- How can we compare HYCOM with satellite altimetry?
- We assume
  - equilibrium variance values are reached by 6 years in HYCOM
  - decay process in HYCOM is realistic
- Equilibrium variance of a data set:

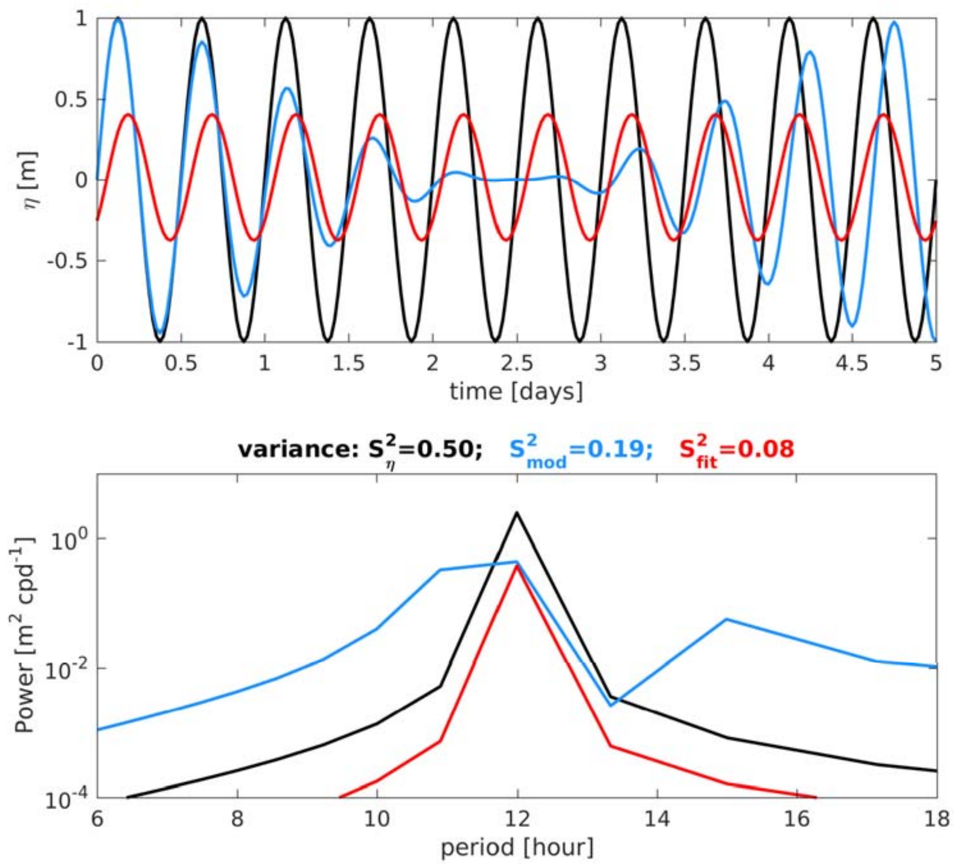
$$var_{eq,data} = \frac{var_{eq}}{var_D} var_{D,data}$$

  - Variance of data set: $var_{D,data}$ with duration *D*
  - Variance of HYCOM for duration *D:* var_D
  - Equilibrium variance in HYCOM: var_{eq}
- $var_{eq,data}$ can be compared with altimetry variance



Non-stationarity affects variance

- Internal tides are modulated by the time variability of the background flow
- The stronger the modulation, the smaller the variance of the least-squares fit



Show “decay rate”