Modeling Altimetry Data Error for Ocean Data Assimilation

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Data Assimilation

Merging observations from different systems, each with its own error characteristics.

What is the error of each observation with regards to the model grid values? It has to be specified for the assimilation procedures.

This error can be split into two components:

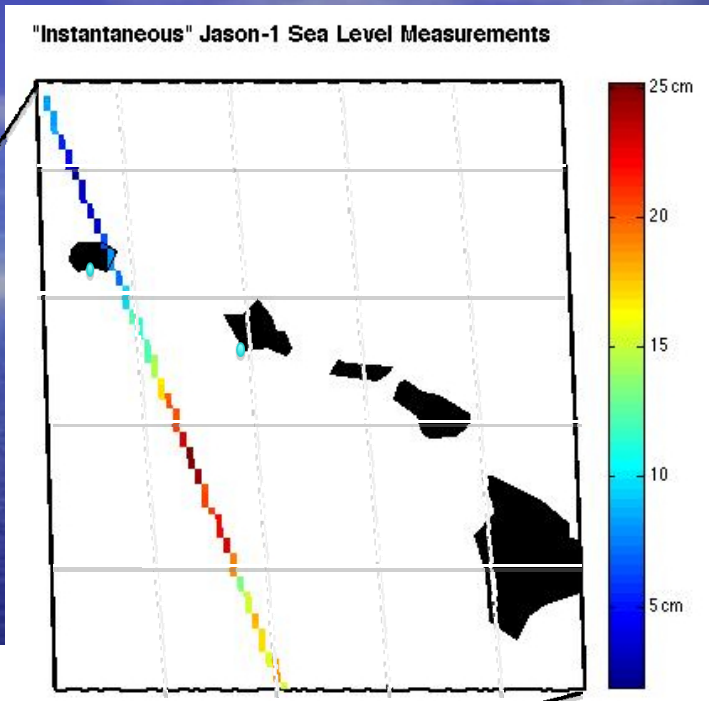
- **Instrument error, i.e. uncertainty associated with each measurement.**

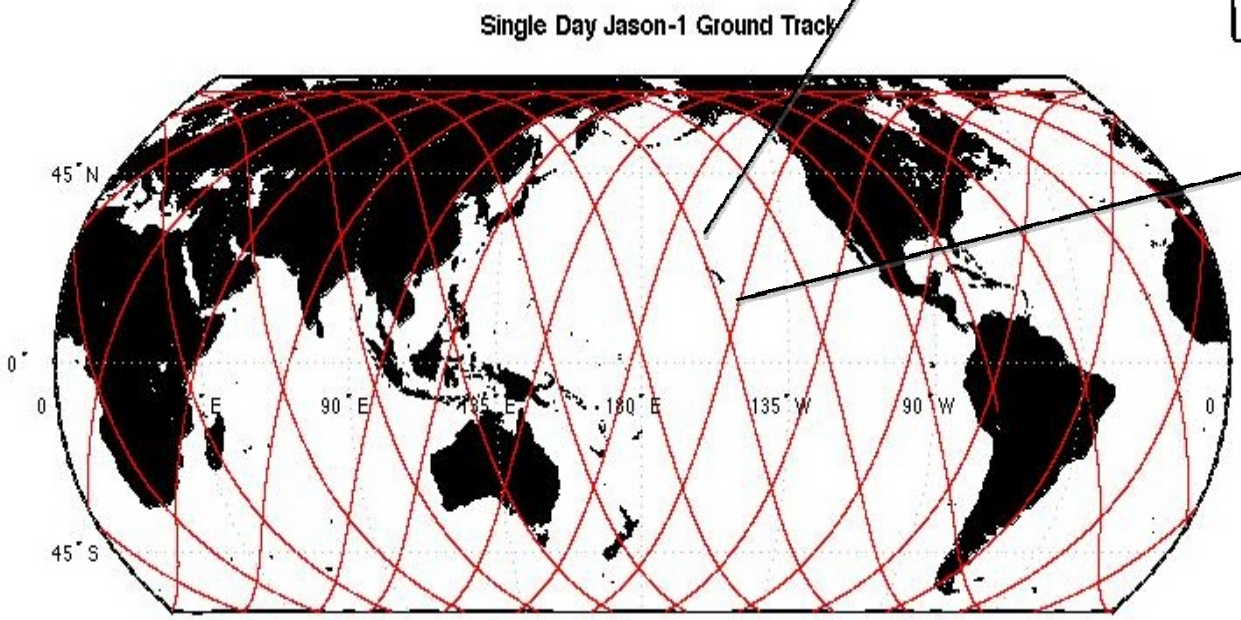
- **Representation error that is due to the difference in averaging of the physical field by the model and by various types of observing systems.**

A typical situation in global or basin-wide ocean modeling:

Model: typical grid resolution – 30km x 60km

Data:
Sea surface height altimetry – 6km footprint;
SST – 1-4-25km averages, depending on the product;
In situ observations – local.





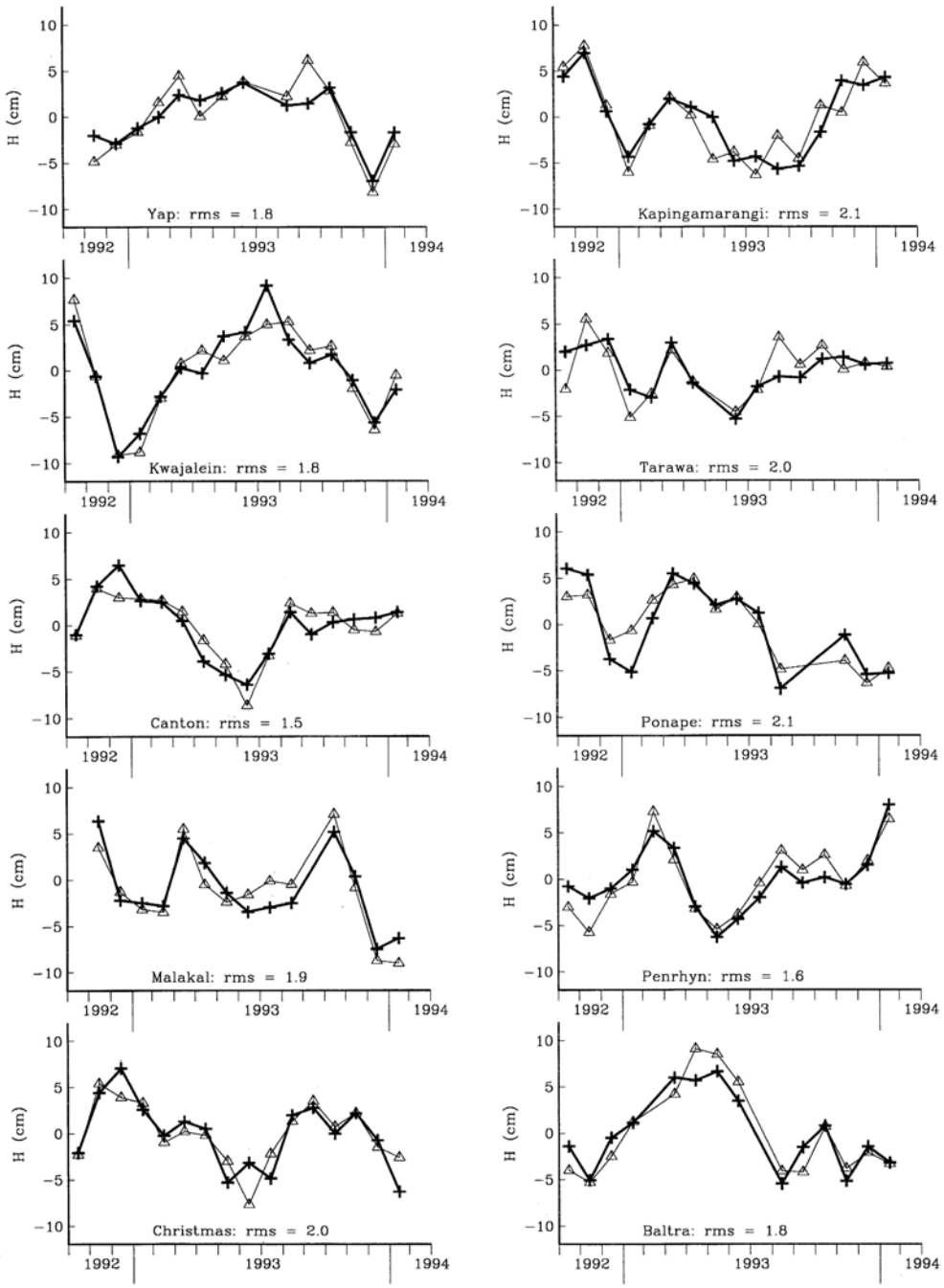
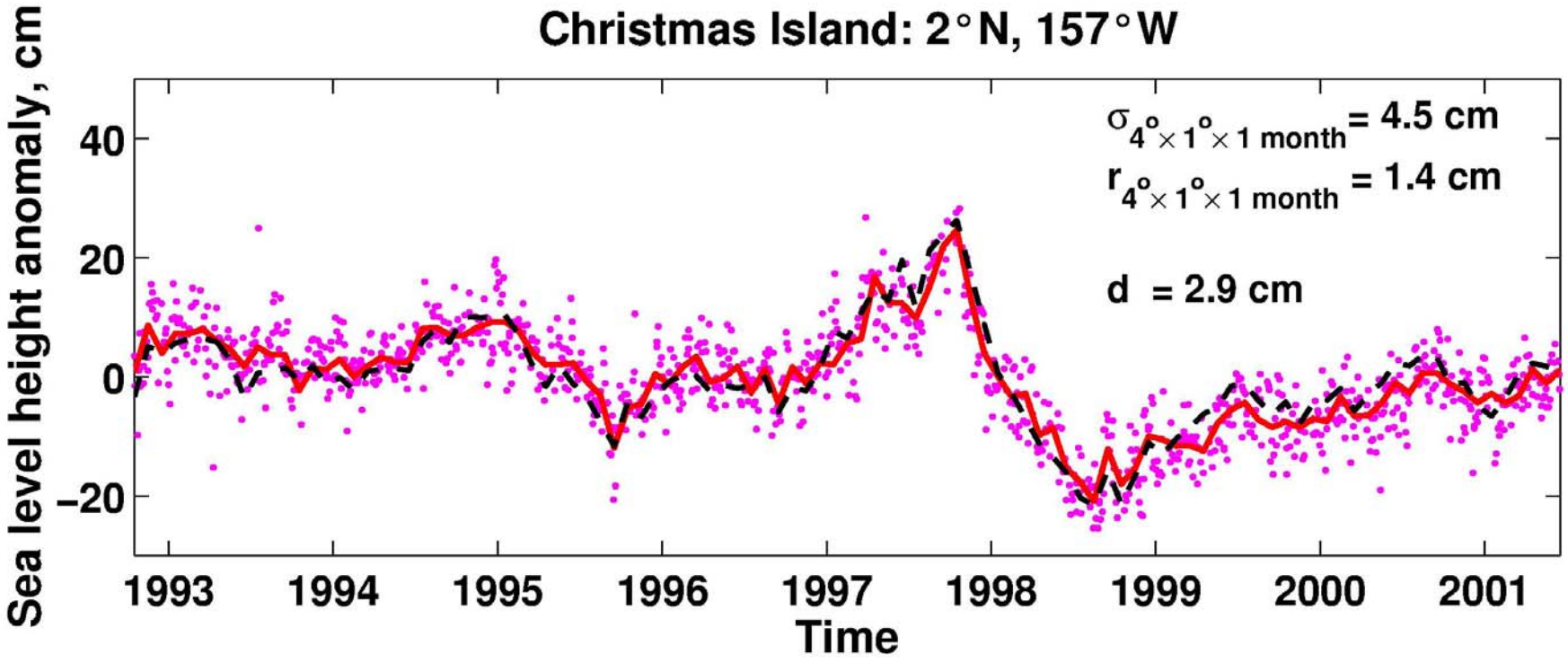
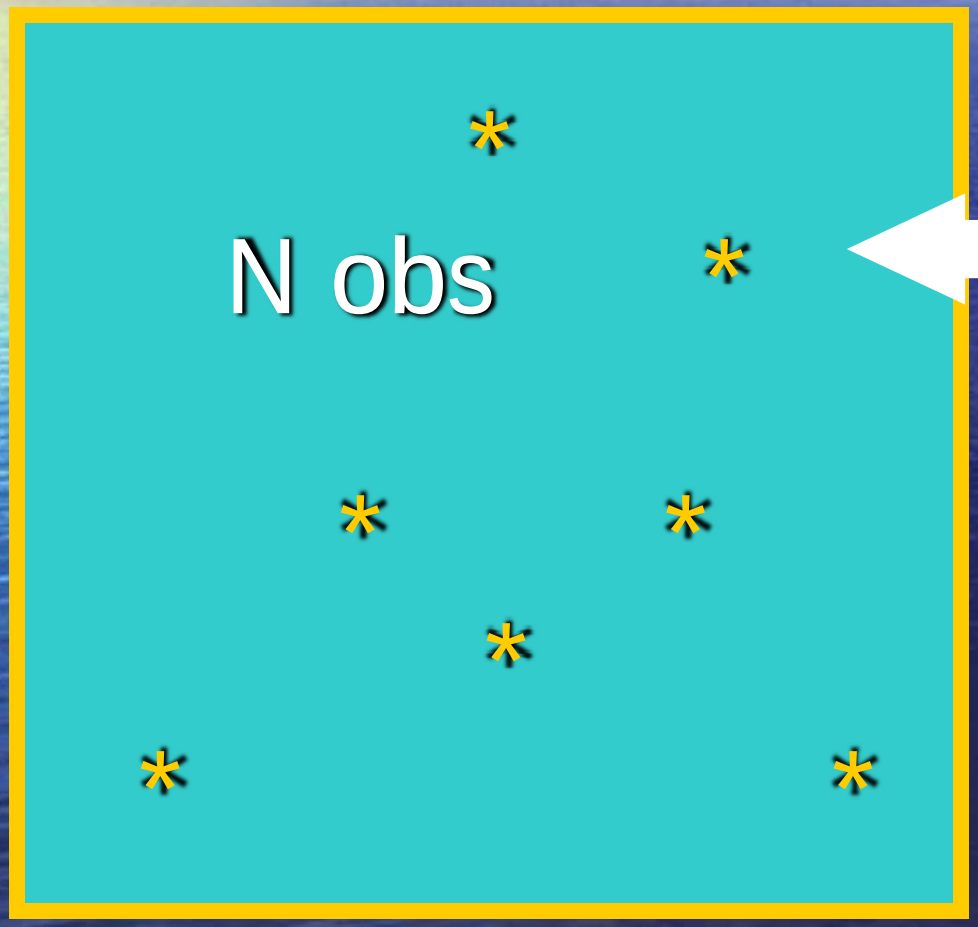


Figure 5. Time series from 10 island gauges (thin line) within 10° of the equator at which particularly good agreement was found with T/P data (heavy line). The existence of so many examples such as this argues that T/P is achieving accuracies at the 2-cm level for monthly mean heights in 4 × 1 cells, without orbit adjustment.

Comparison of 4x1 degree T/P altimetry averages with tide gauge data (from Cheney et al 1994)


Christmas Island: 2°N, 157°W
Sea level height anomaly, cm
40
20
0
−20
1993
1994
1995
1996
1997
1998
1999
2000
2001
Time
σ4°×1°×1 month = 4.5 cm
r4°×1°×1 month = 1.4 cm
d = 2.9 cm

What is the error in the binned obs mean (as estimates of the "true" bin area average)?



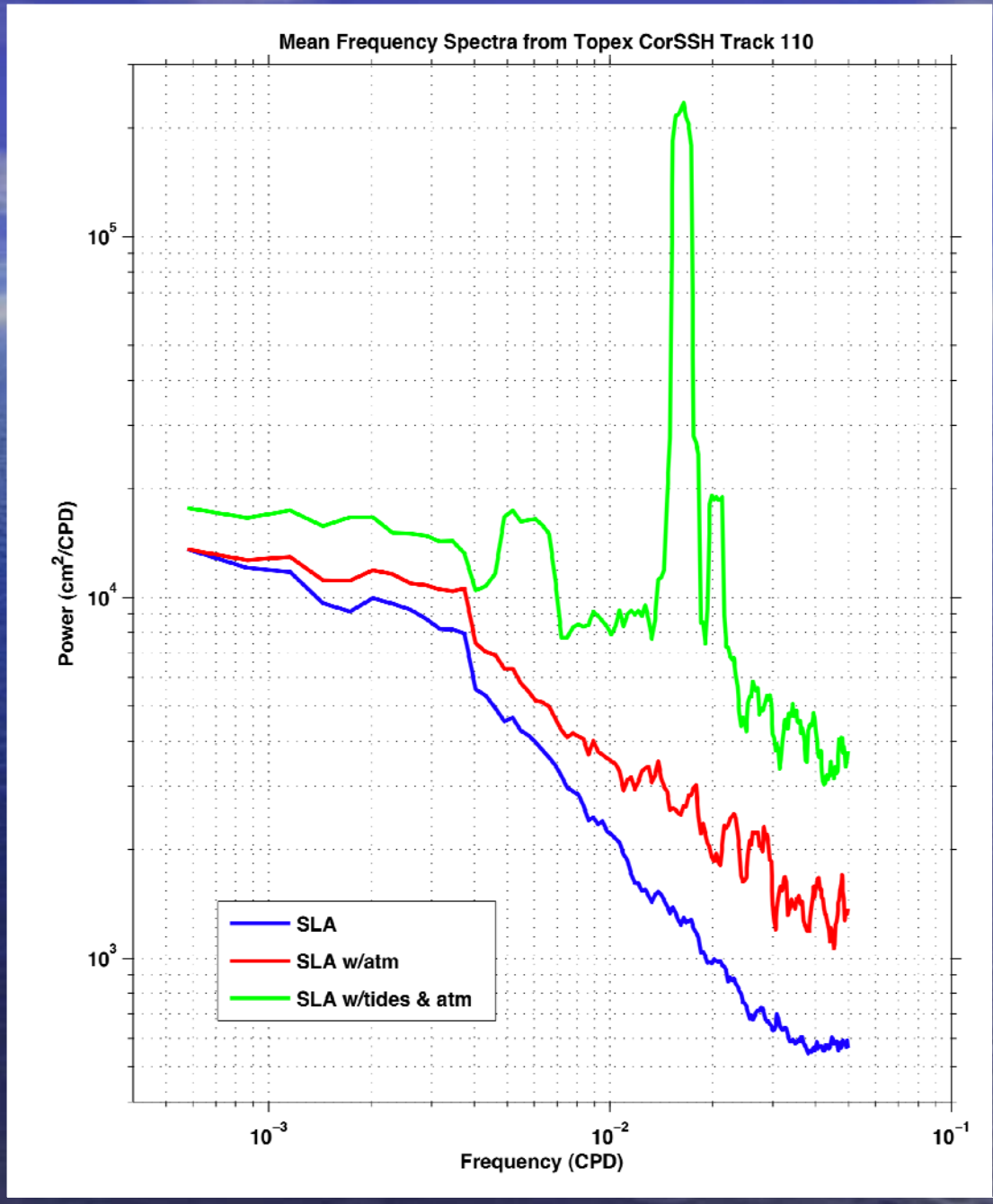
F(x,y) [or F(x,y,t)]

Error variance for the mean of N observ is

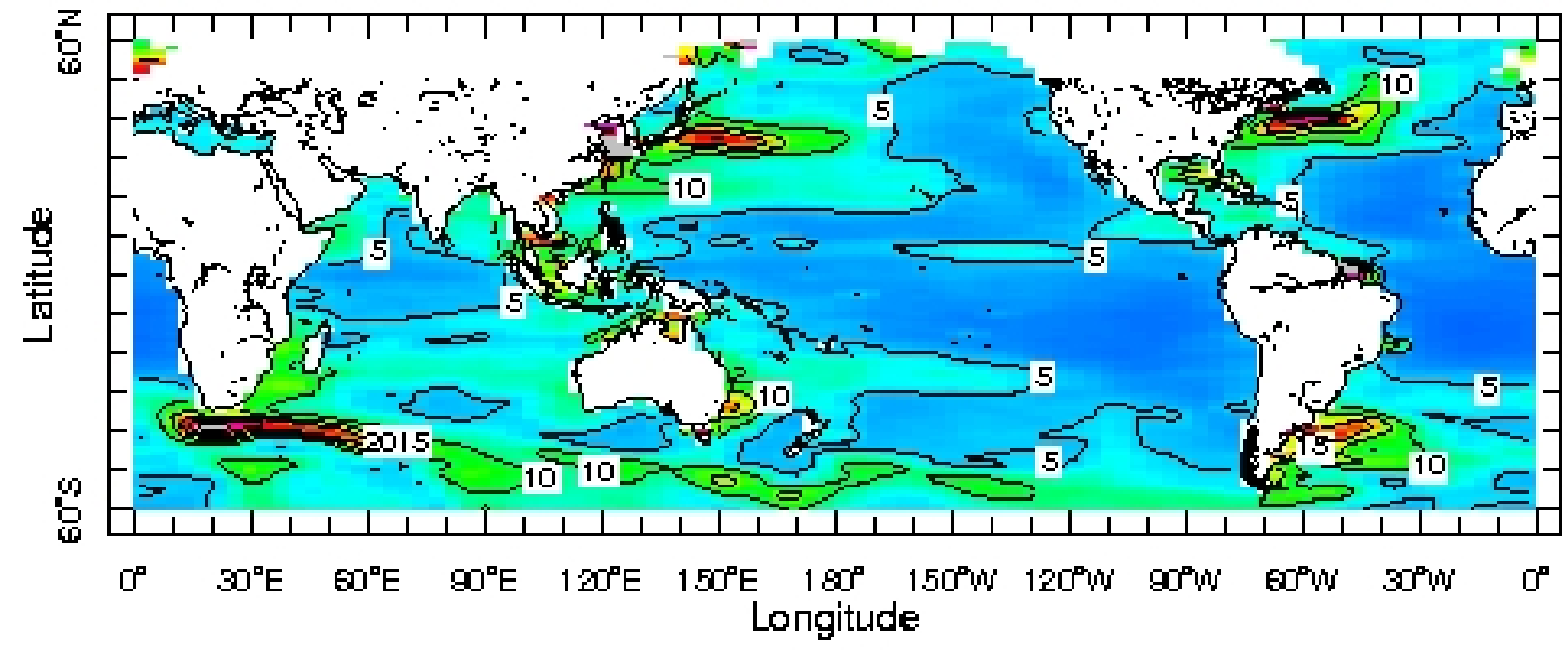
σ^2/N

Altimetry Corrections

- Tidal signal removed by FES2004 tidal model
- AVISO Dynamic Atmospheric Correction:
  - Static "Inverted Barometer" response to pressure removed using ECMWF pressure field
  - Dynamic response to wind and pressure simulated by Mog2D FE barotropic model



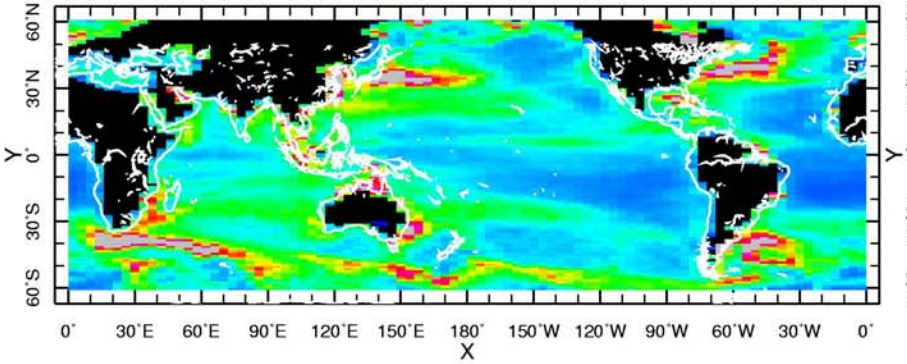
Total SS and ST variability in T/P inside 4x1xmonth bins



TOPEX [*Ducet et al.* 2000]

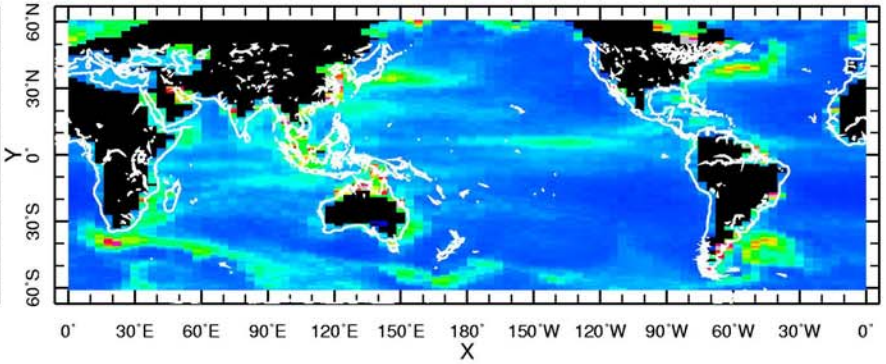
Time-space separation of small-scale sea level height variability

(a) Total SSV $\sigma_{4^o\times1^o\times1\,\mathrm{month}}(s)$

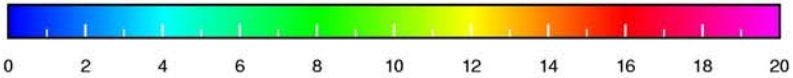


sqrt [(ssv + { stvg stv }) squared]
point mean: 6.1281 ± 4.9101 range [0.0228197 to 80.611]

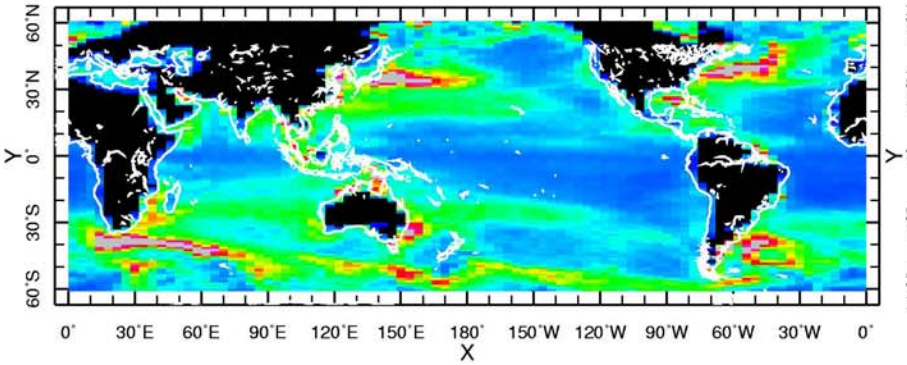
(b) Short-term temporal variability $\sigma_{1\,\mathrm{month}}([s]_{4^o\times1^o})$



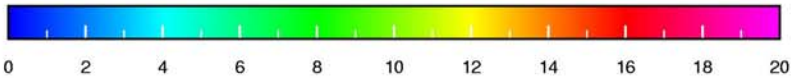
stvg stv
point mean: 2.9553 ± 2.7528 range [0.000756442 to 46.822]



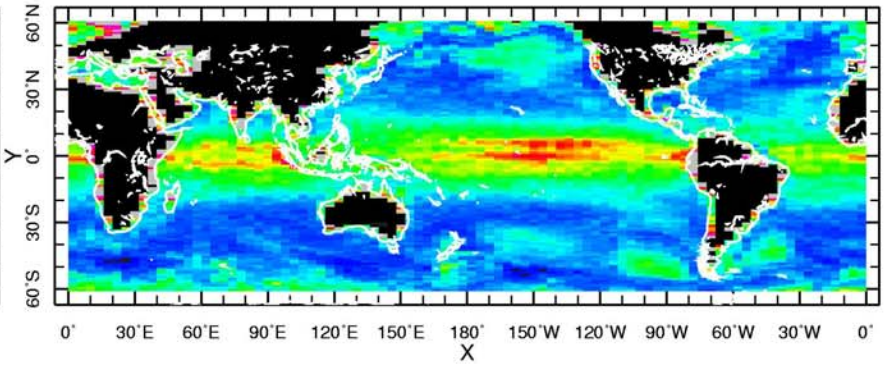
(c) Spatial variability inside bins $\sqrt{[\sigma^2_{4^o\times1^o}(s)]_{1\,\mathrm{month}}}$



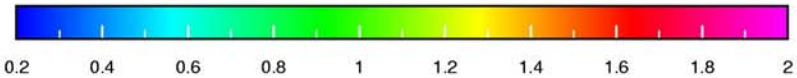
ssv
point mean: 5.1688 ± 4.3149 range [0.0 to 73.023]

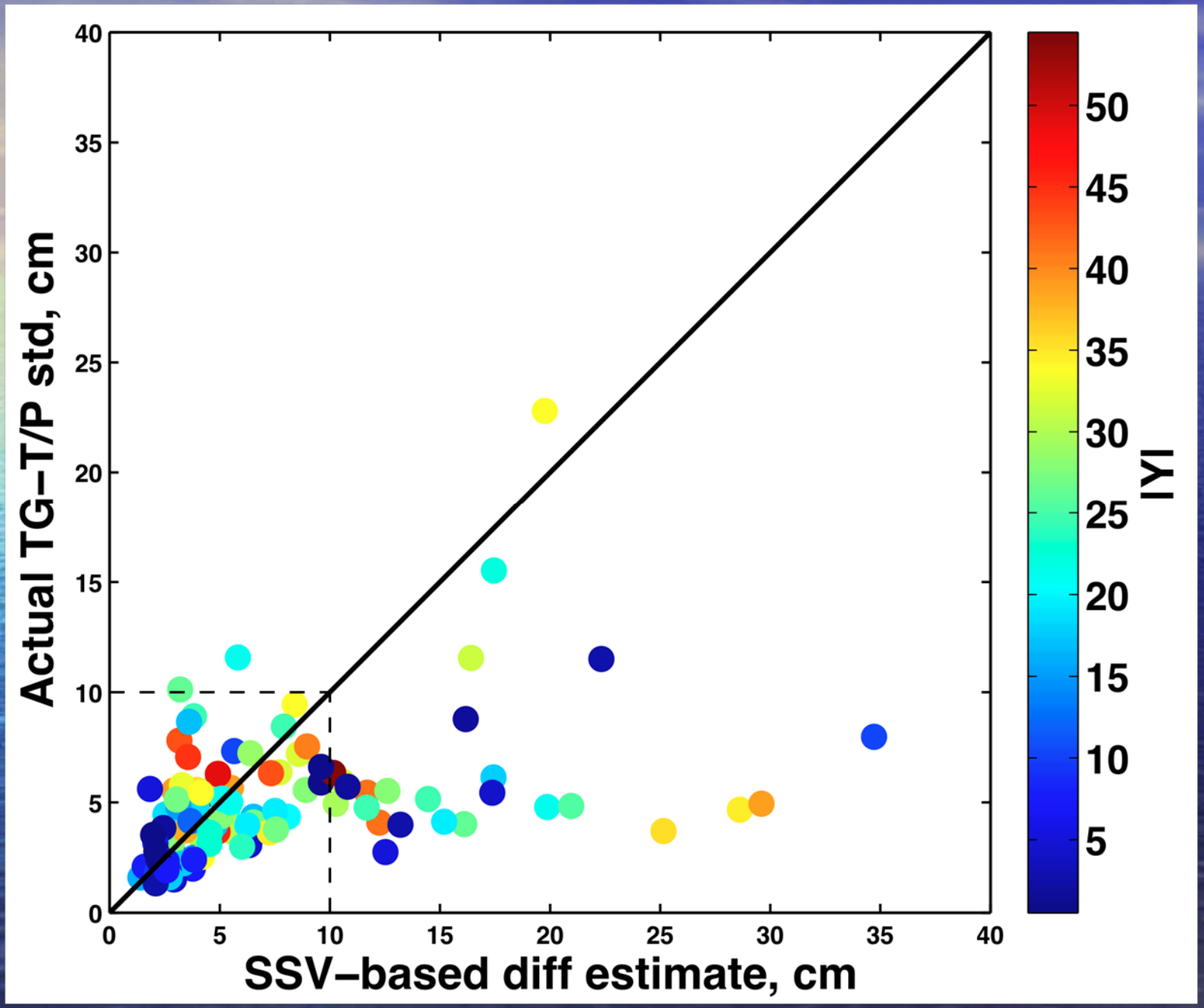


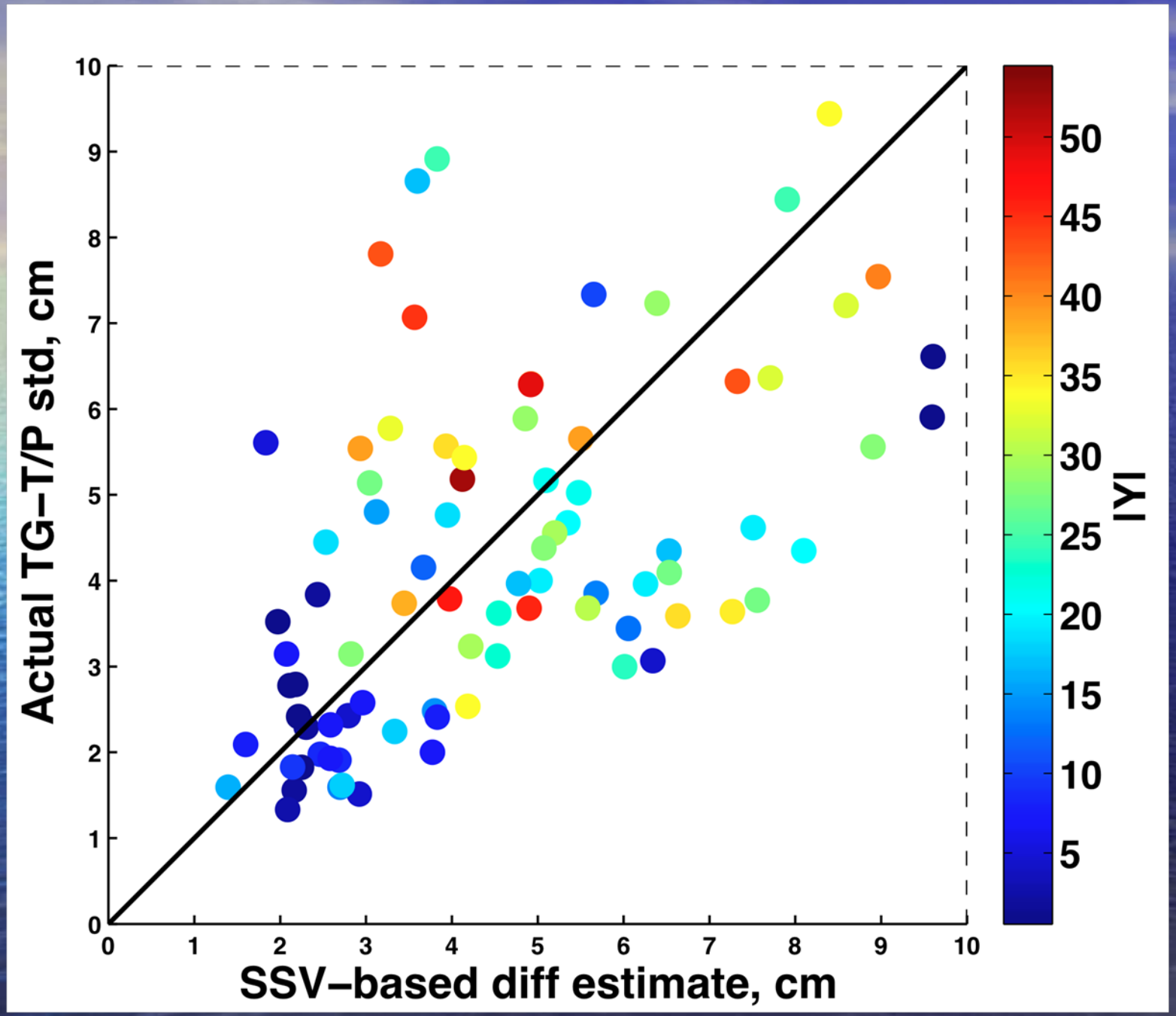
(d) Ratio γ of temporal to spatial variability

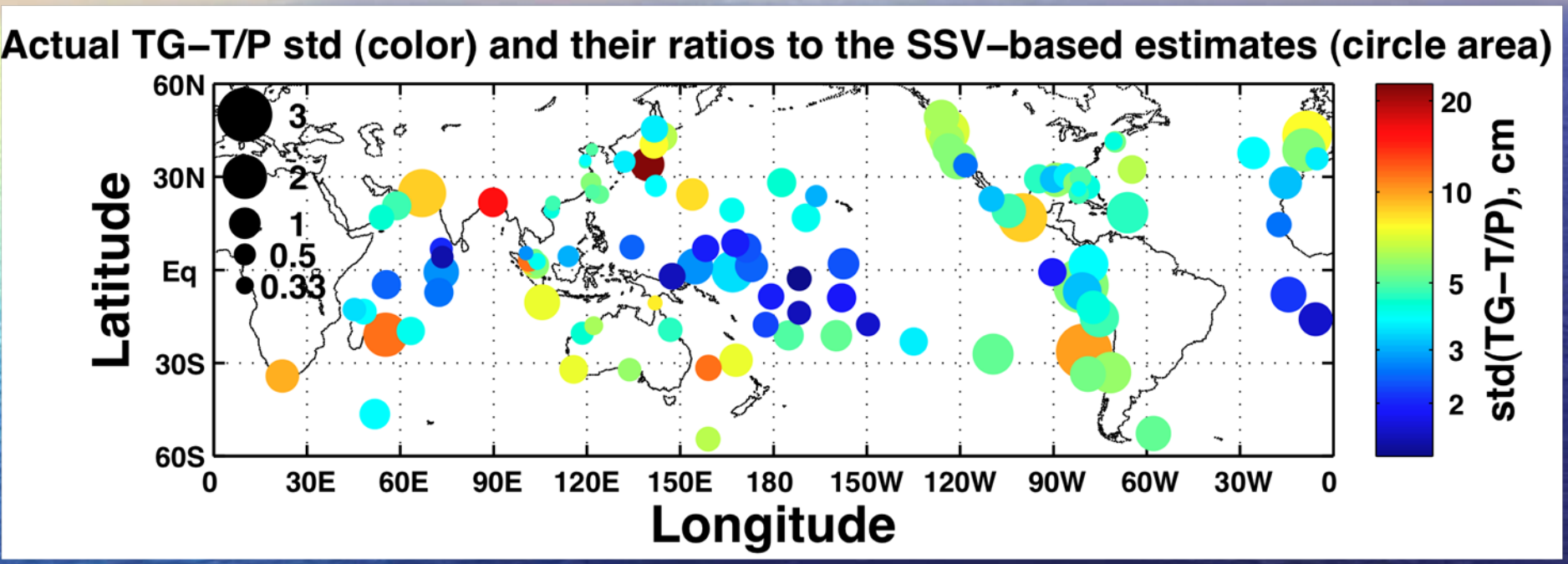


[stvg stv] / [sqrt (ssv - 1.00000E-07) squared]
point mean: 0.94132 ± 4.3132 range [0.0260134 to 170.47]




Actual TG–T/P std, cm
SSV–based diff estimate, cm
|Y|
0
5
10
15
20
25
30
35
40
45
50

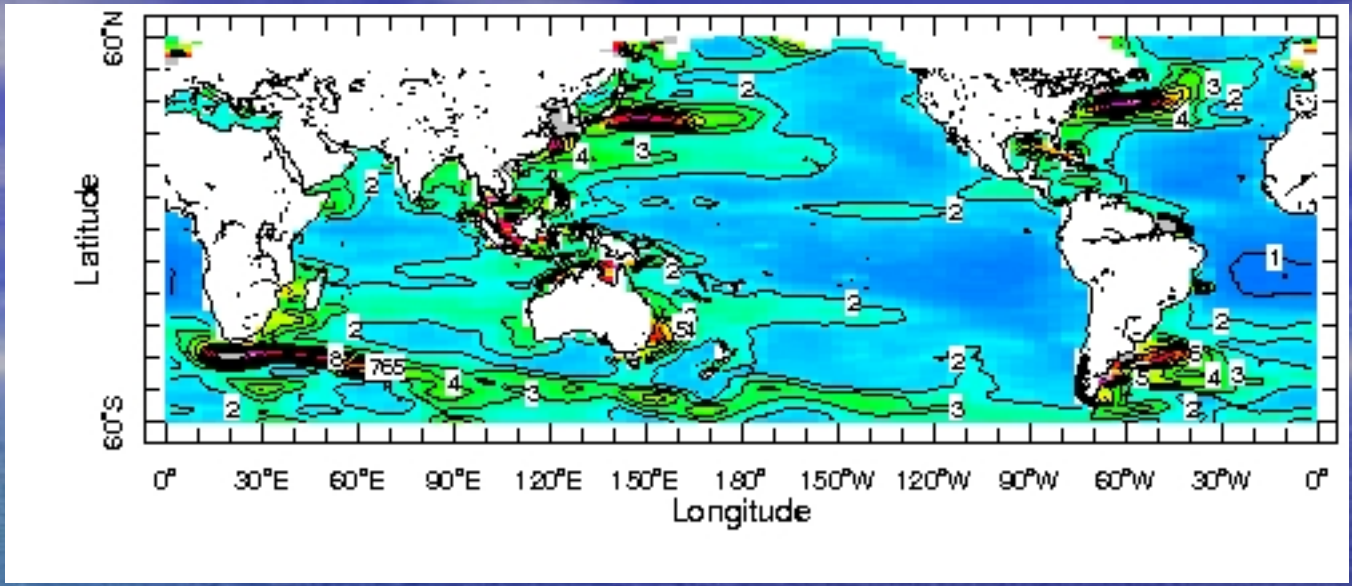

Actual TG–T/P std, cm
SSV–based diff estimate, cm
|Y|
0
1
2
3
4
5
6
7
8
9
10
5
10
15
20
25
30
35
40
45
50

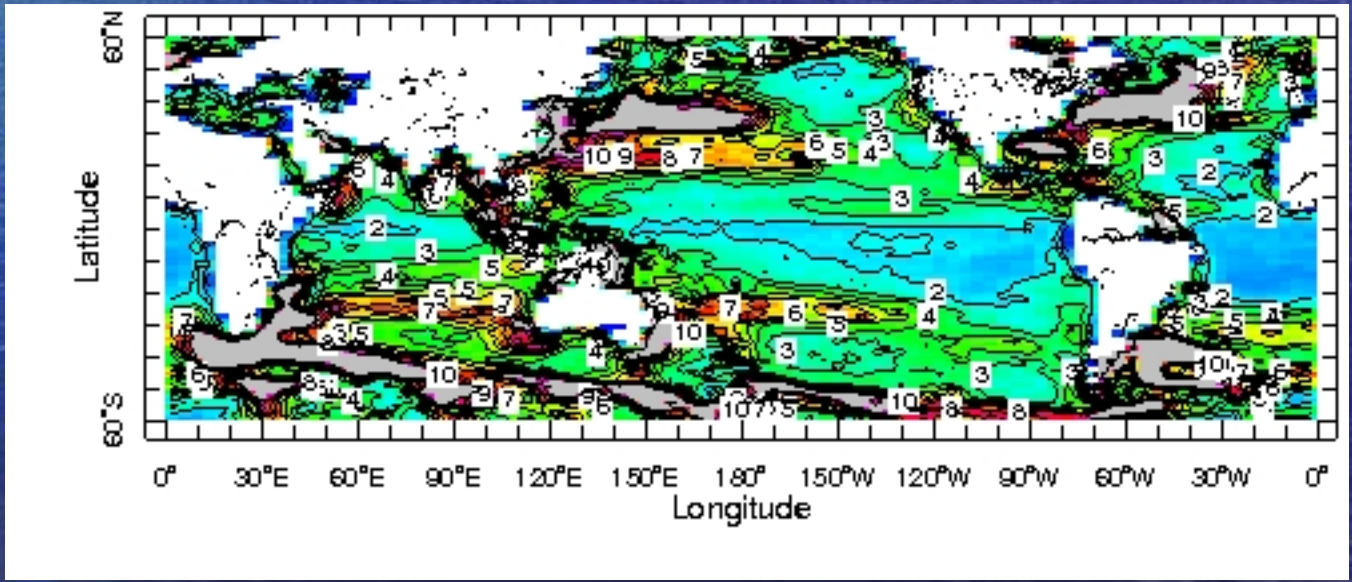

Actual TG–T/P std (color) and their ratios to the SSV–based estimates (circle area)
Latitude
60N
30N
Eq
30S
60S
3
2
1
0.5
0.33
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
Longitude
20
10
5
3
2
std(TG–T/P), cm

4x1 mon values:

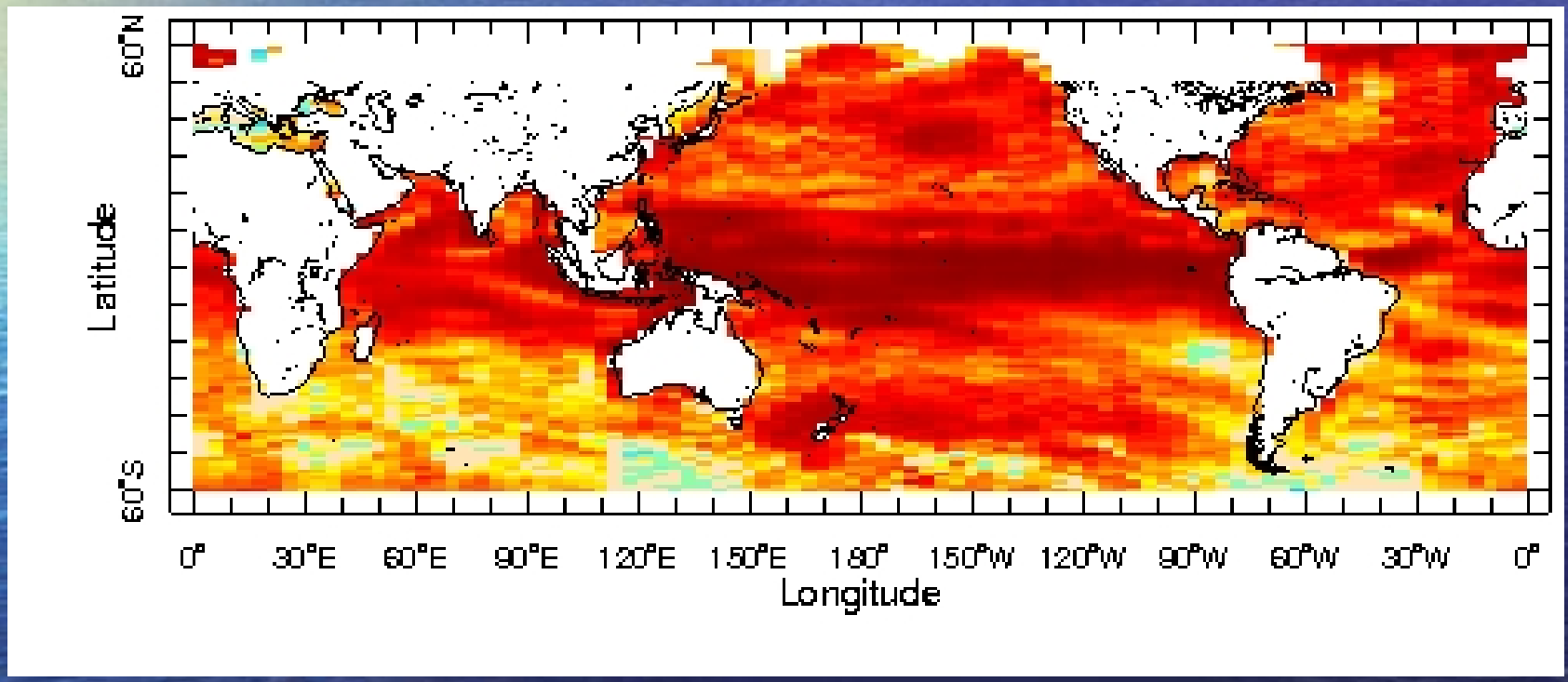
T/P

TG

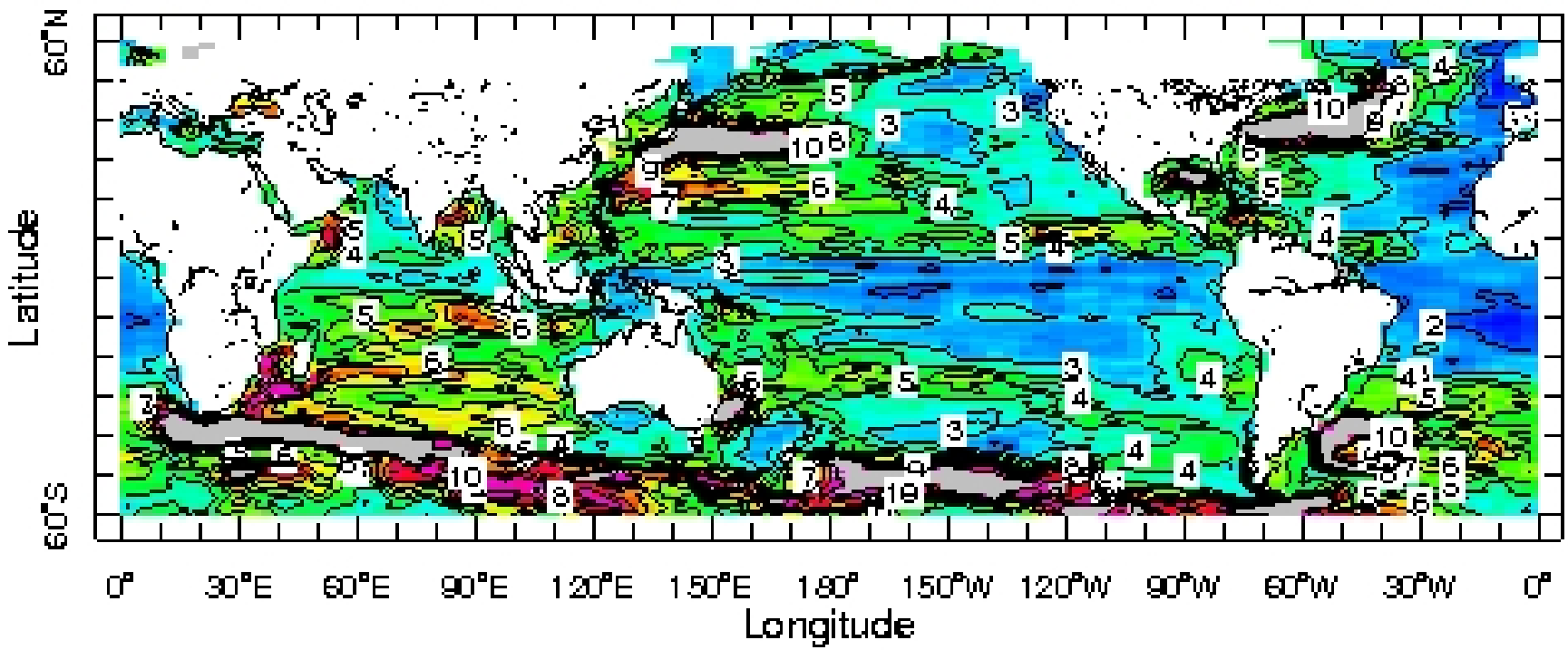




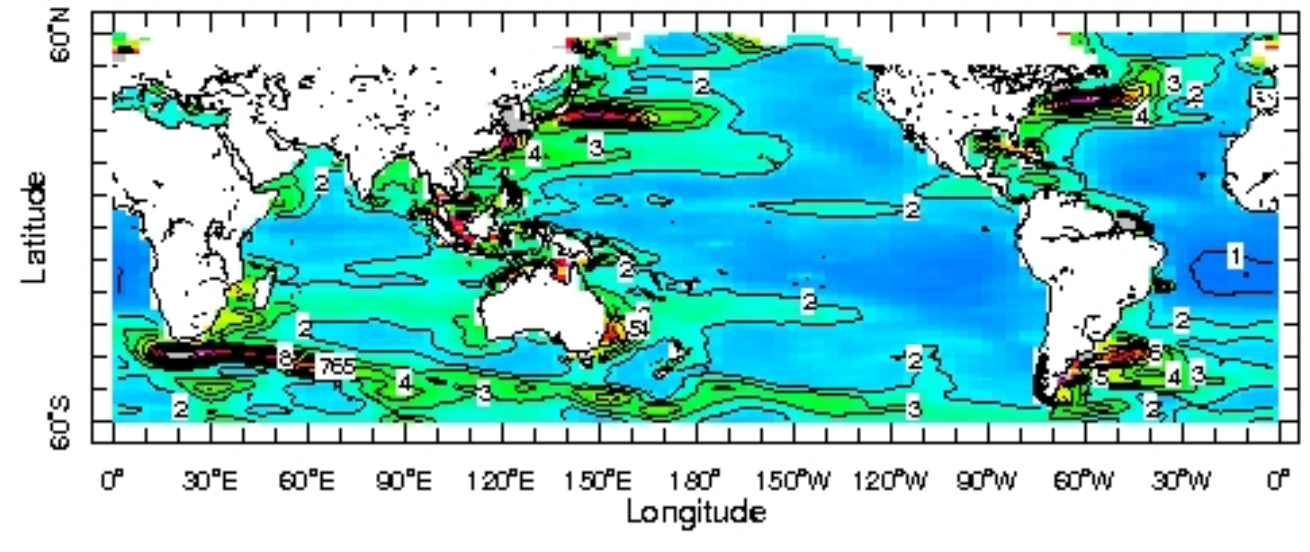
Monthly correlation coefficient: GODAS SSH (D. Behringer et al) and AVISO altimetry map



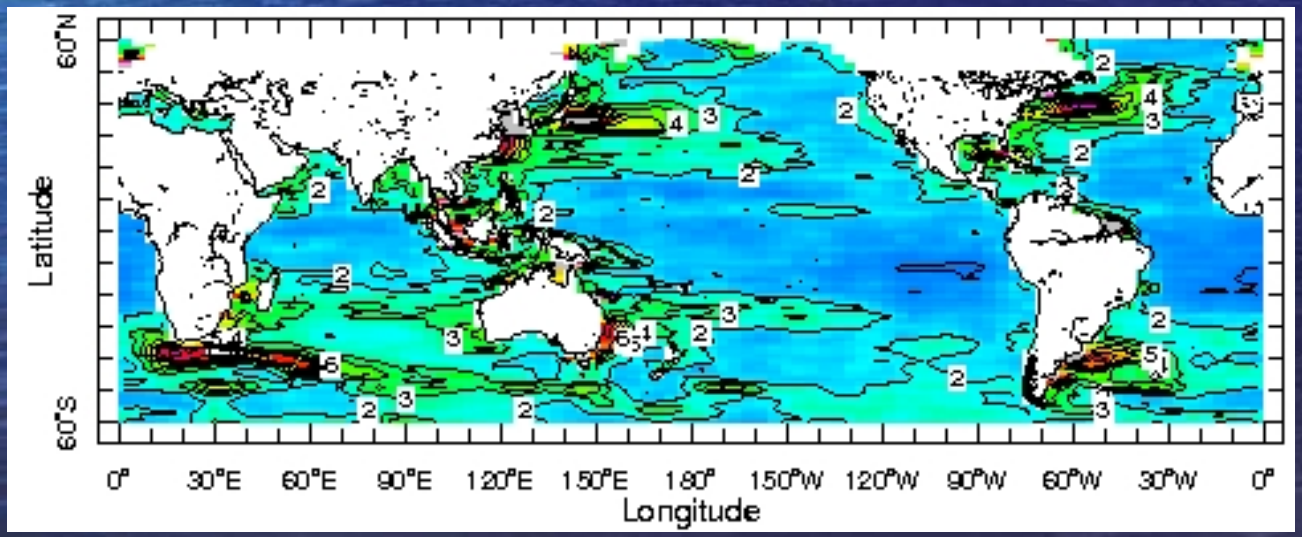
Monthly anom diff std, cm: GODAS SSH (D. Behringer et al) and AVISO altimetry map

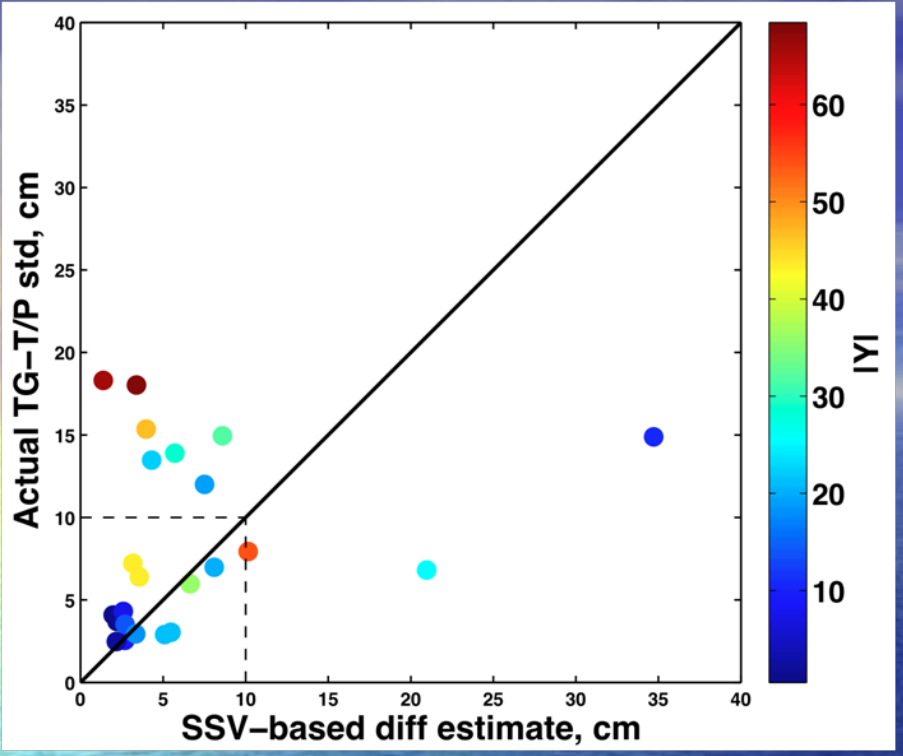


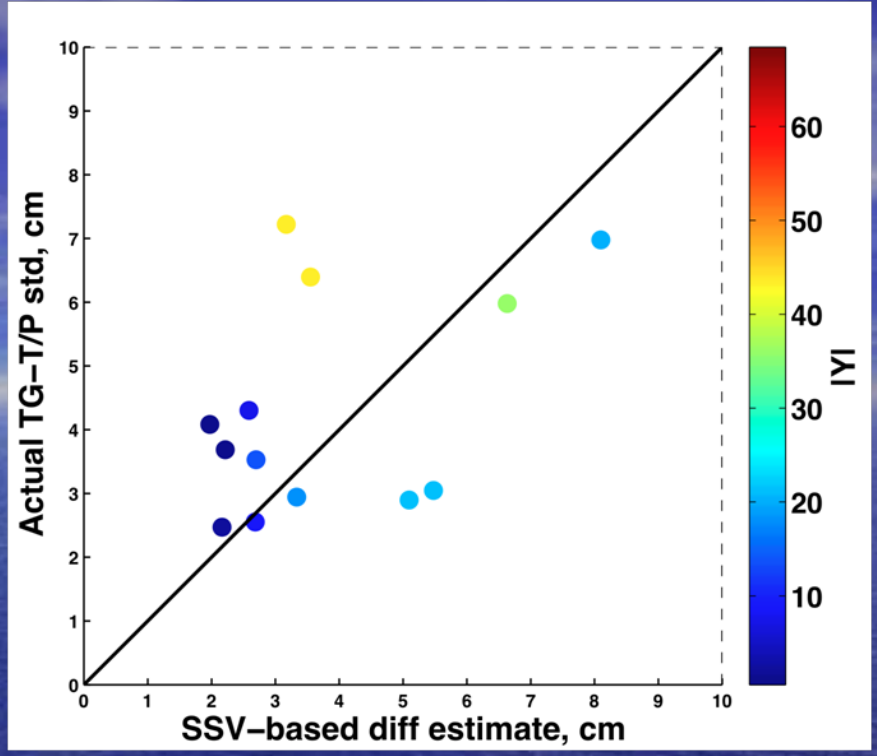
T/P error in representing bin 4x1x1mon means

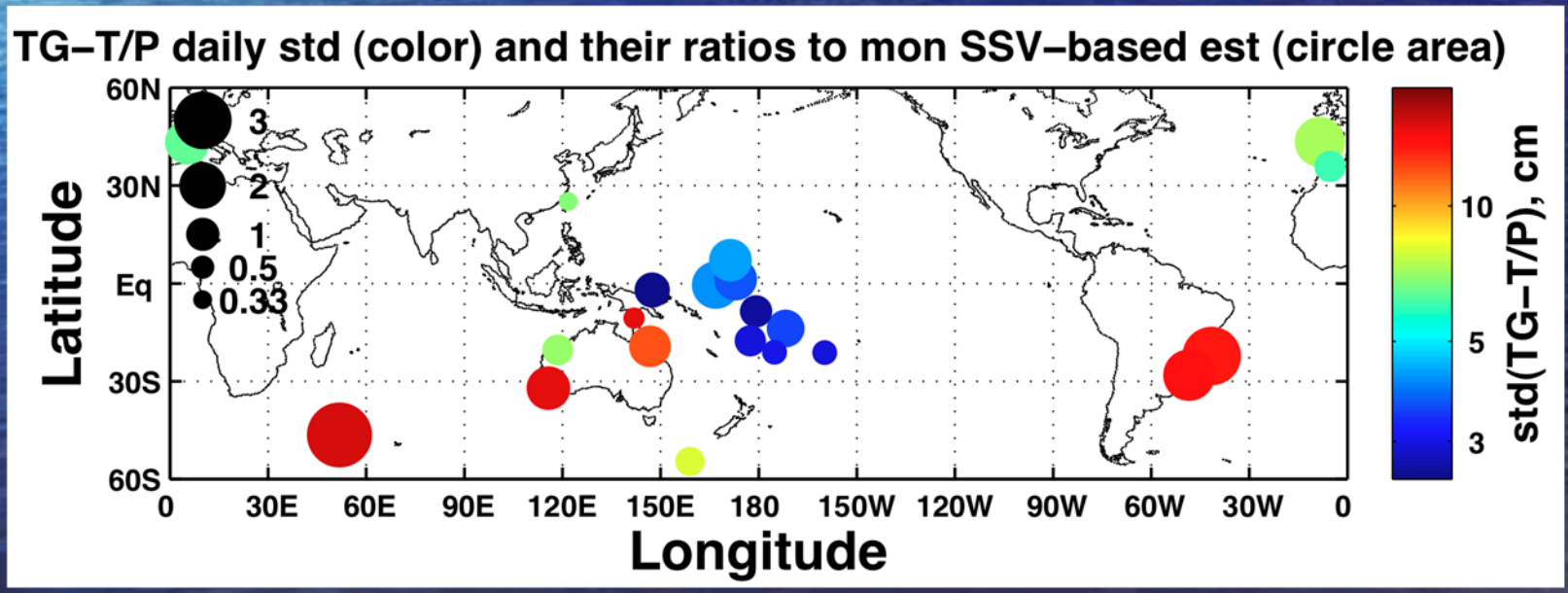


T/P – (T/P+ERS1,2) [Ducet et al, 2000]

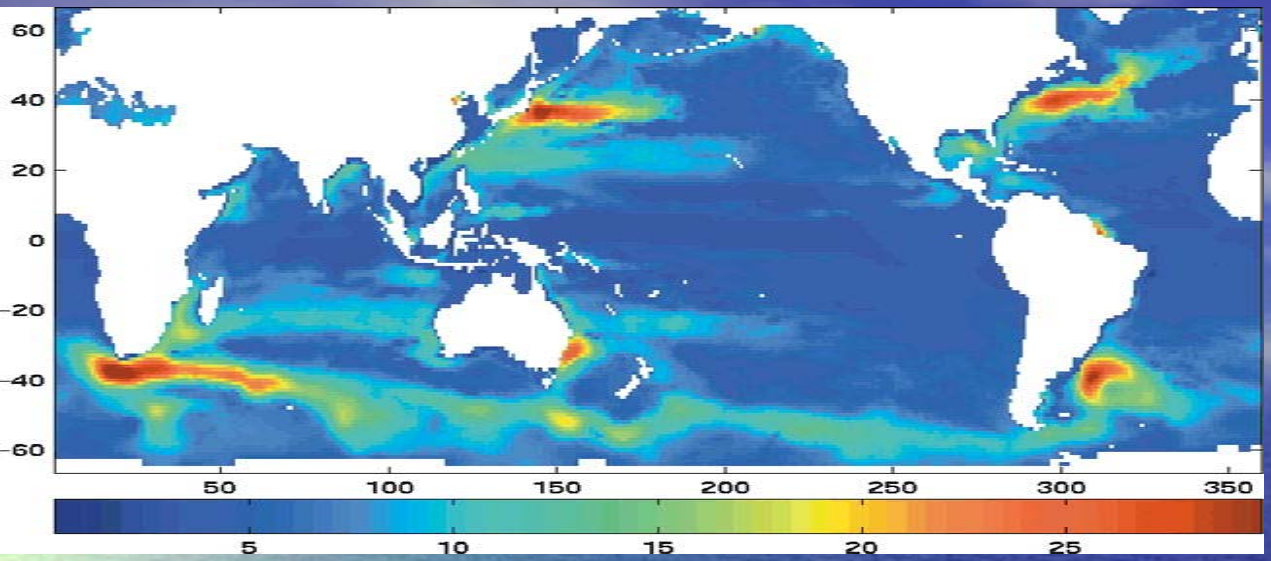


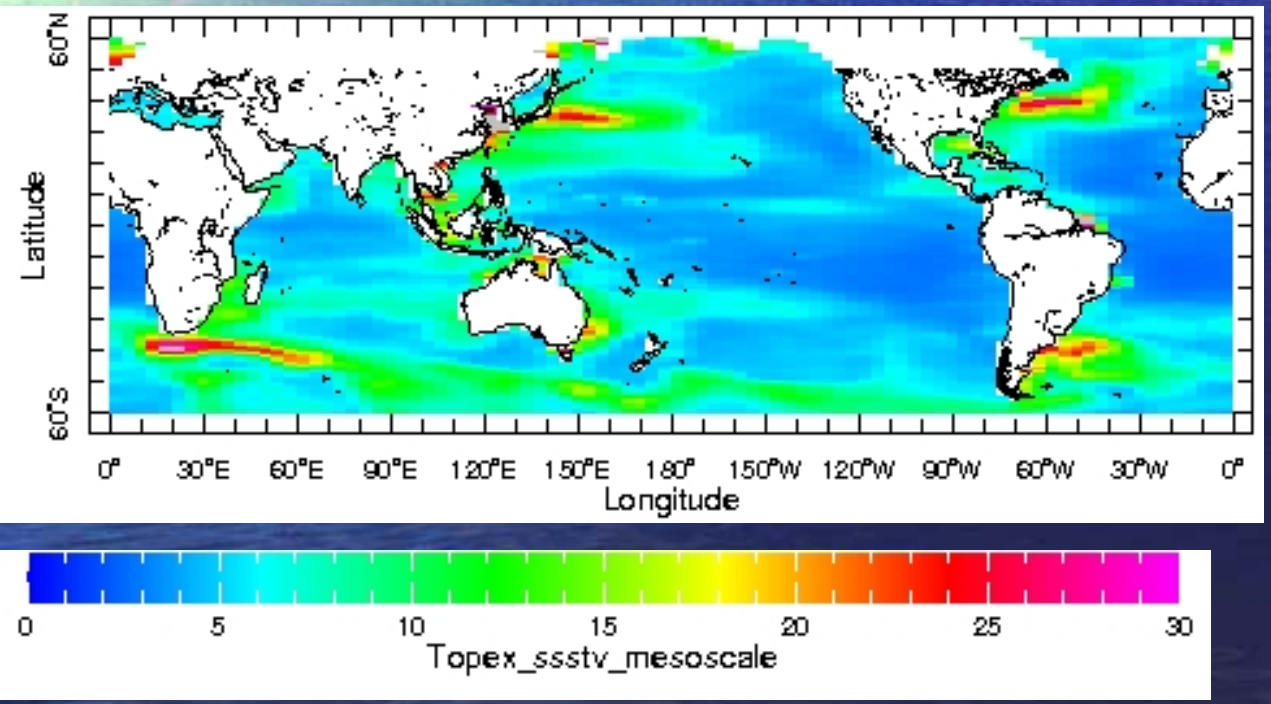

Actual TG–T/P std, cm
SSV–based diff estimate, cm
|Y|


Actual TG–T/P std, cm
SSV–based diff estimate, cm
|Y|


TG–T/P daily std (color) and their ratios to mon SSV–based est (circle area)
Latitude
Longitude
std(TG–T/P), cm

Altimetry error by Ponte et al [2007]

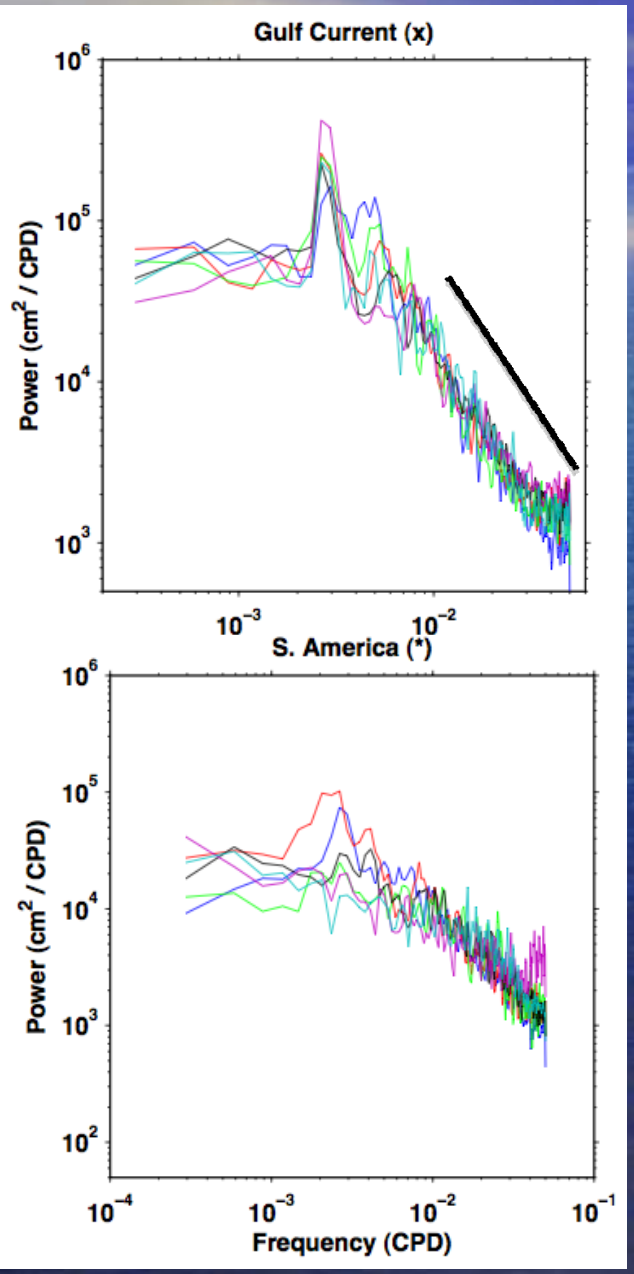


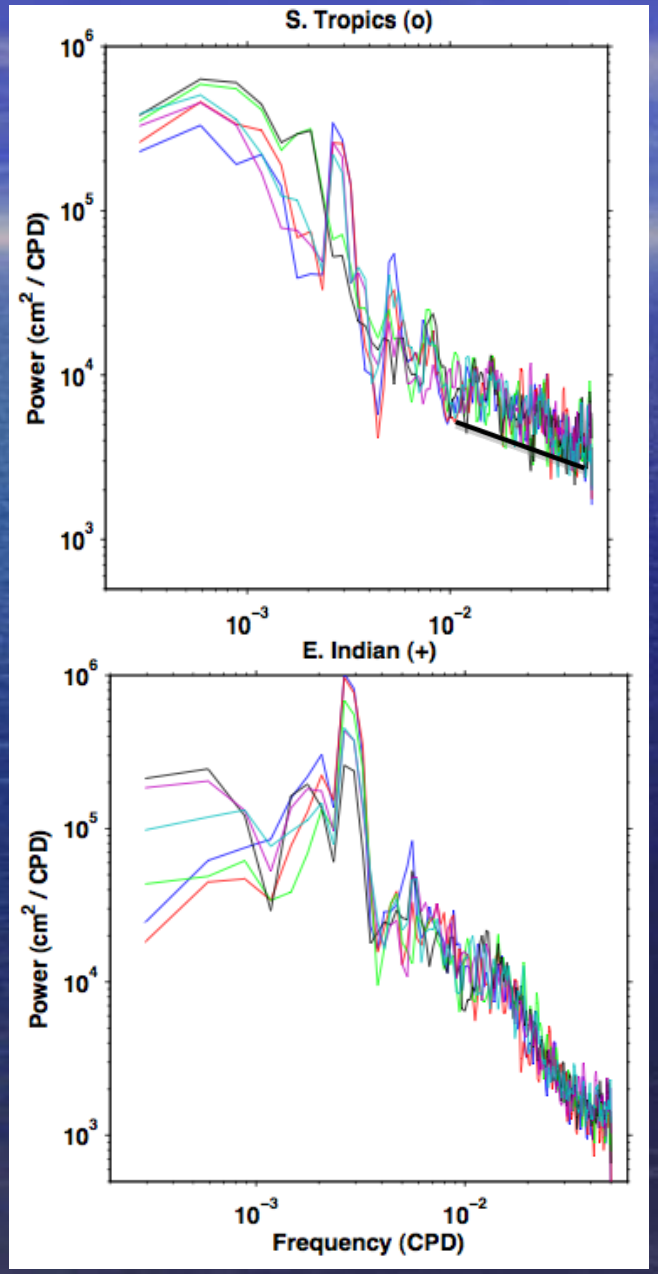


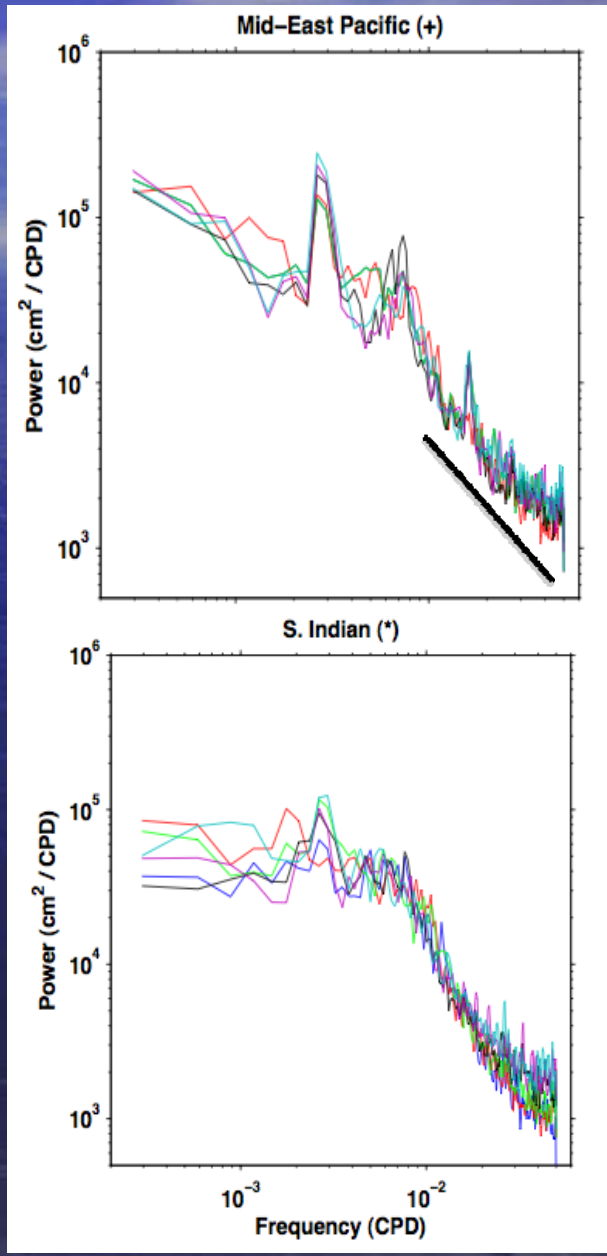
High-Energy

Tropics

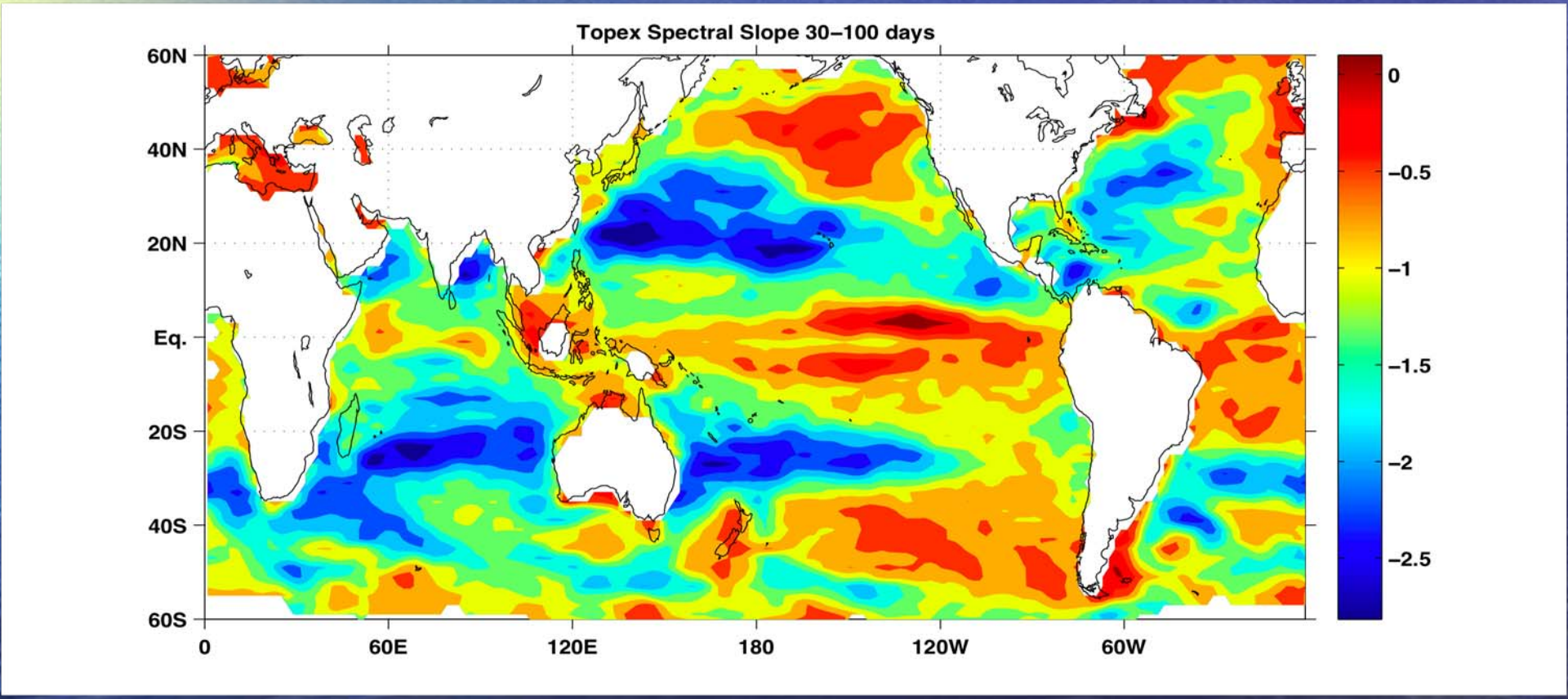
Open Ocean







Global map of SSH spectral slope (30-100 day periods)



Conclusions and Outlook

1. Sea surface height error parameterizations were presented in terms of sampling errors affecting the grid box averages and verified by comparisons with tide gauge records. The method provided the spatial error maps that can be physically interpreted in terms of small-scale and short-term (mesoscale) variability.

2. Error maps for the monthly gridded altimetry fields, for monthly tide gauge values, and for along-track 1° averages of T/P data were presented with regards to the "true" 4° longitude by 1° latitude monthly sea surface height means.

3. Assimilation into state-of-the-art ocean models with resolution below 1° requires similar maps (under development) produced with regards to the true daily values of the model gridbox averages, i.e. based on variance estimates at the scales smaller than those currently resolved by the satellite altimetry; such estimates can be derived from power spectrum parameterizations of sea surface height variability.

Joint Center for Satellite Data Assimilation