Modeling observational error of bin-averaged in situ climate data

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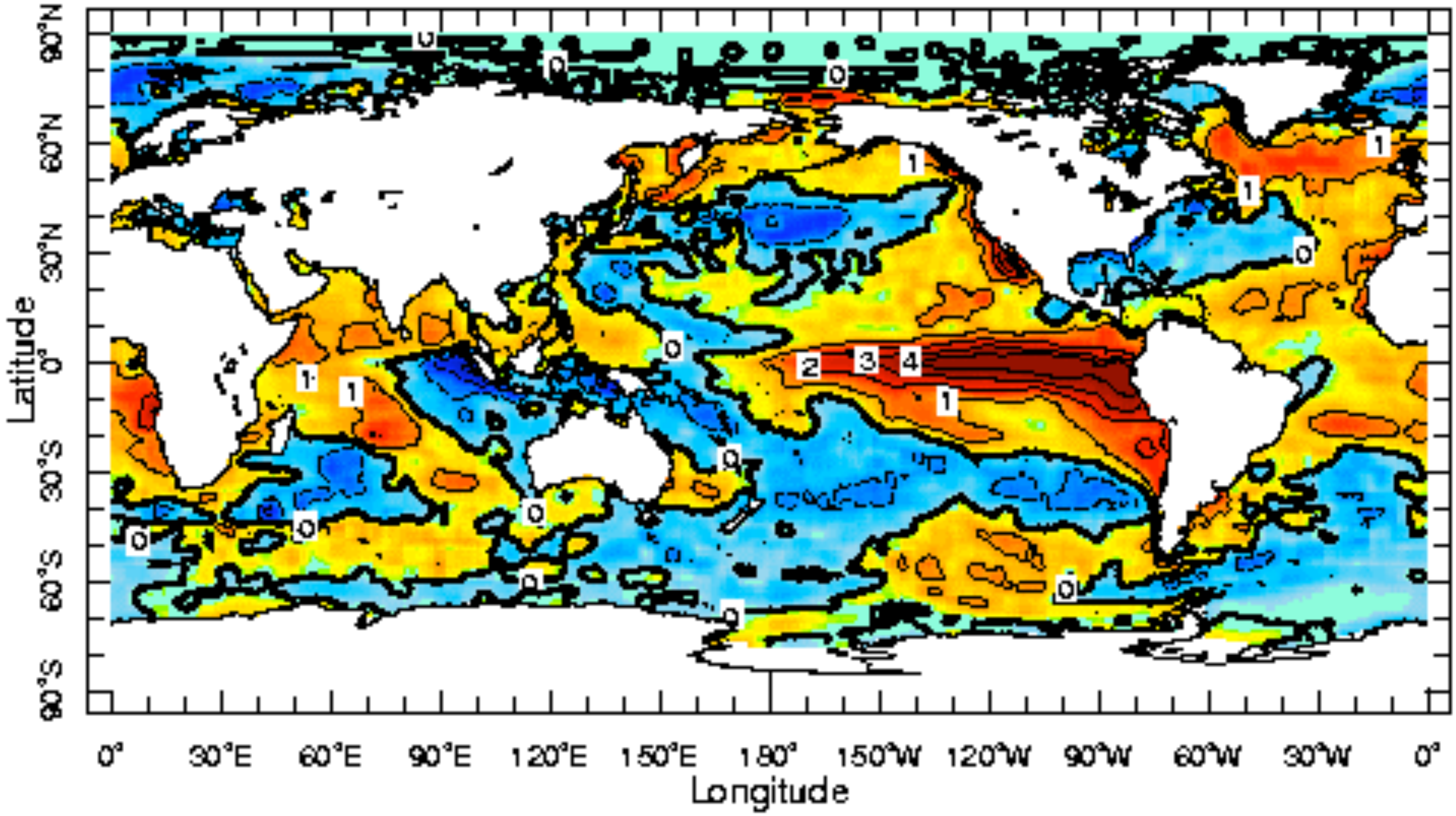
OUTLINE

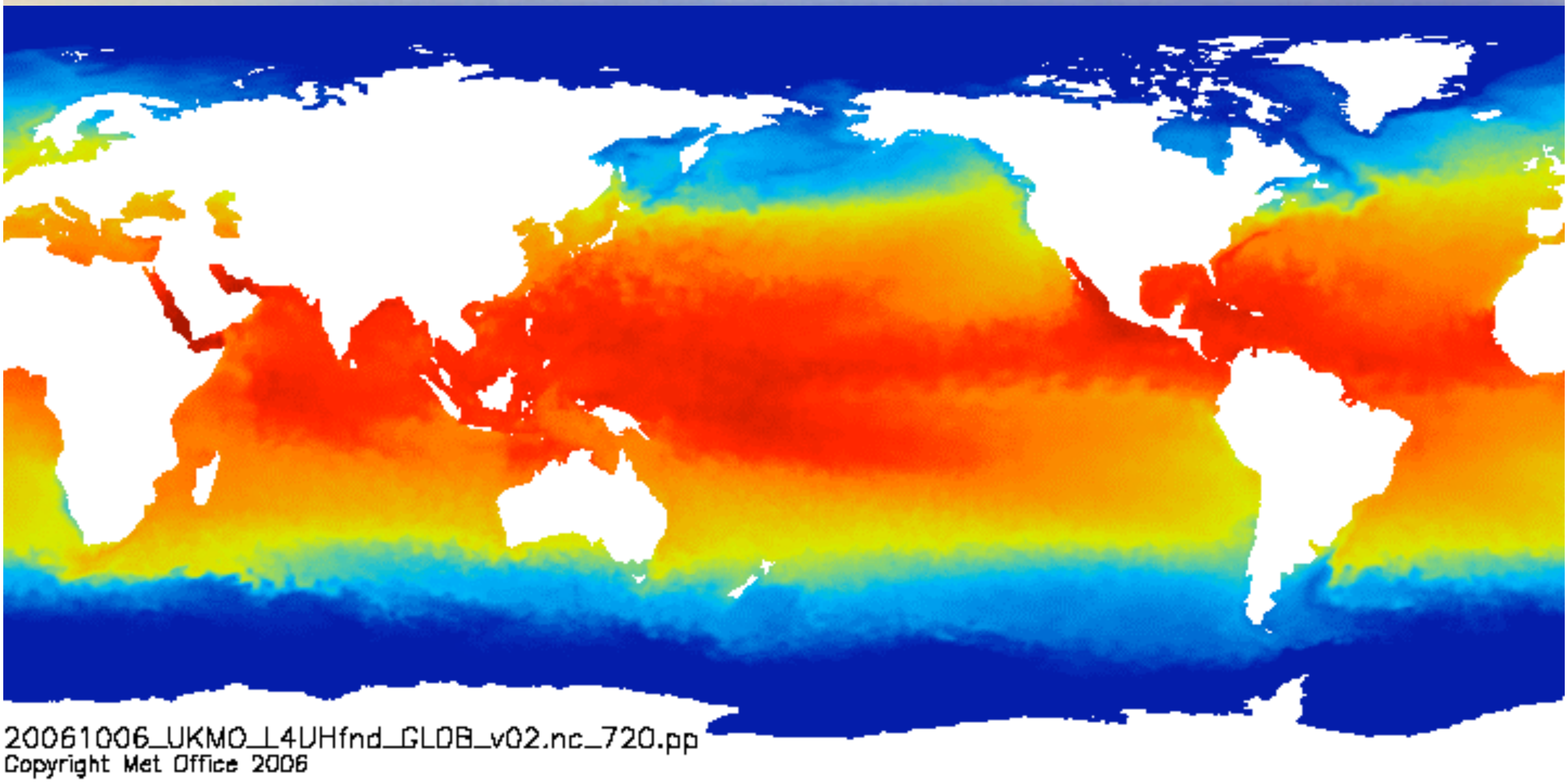
- Small-scale and short-term variability in physical fields → sampling error in their gridded representations from data
- Importance of knowing this error (for SST data)
- Estimating subgrid variability from satellite data
- Using it to model in situ error in SST

Sea Surface Temperature Anomaly from Reynolds and Smith's NCEP OI v.2: AVHRR and in situ SST blend



9-15 Nov 1997

Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA), from U.K. Met Office and GHRSST, blend of many satellite data streams



Optimal Interpolation

$$T = T_B + e_B$$

$$HT = T_o + e_o$$

$$\langle e_B \rangle = \langle e_o \rangle = \langle e_B e_o^T \rangle = 0$$

$$\langle e_B e_B^T \rangle = C$$

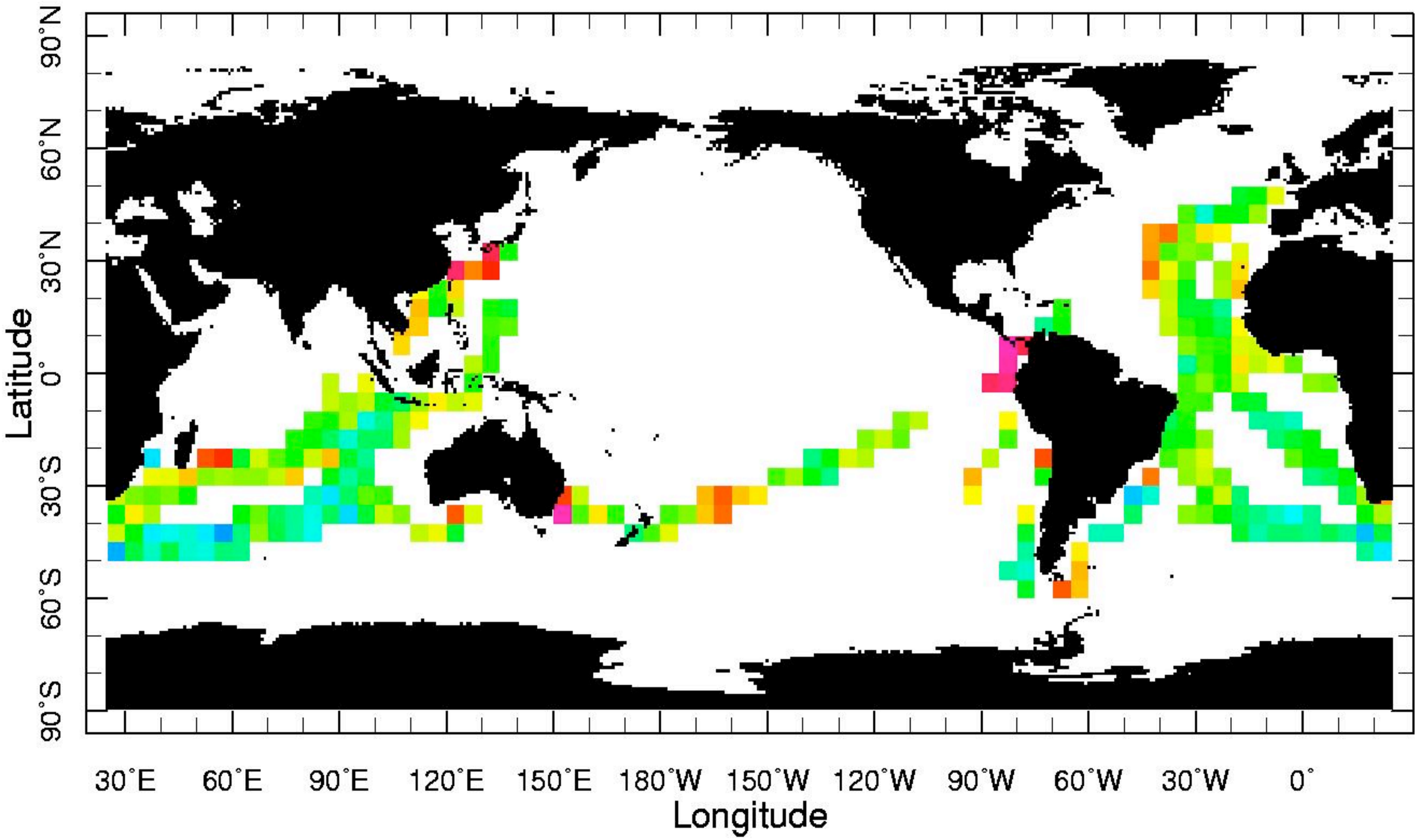
$$\langle e_o e_o^T \rangle = R \leftarrow \text{obs error covariance}$$

Solution minimizes the cost function

$$S[T] = (HT - T_o)^T R^{-1} (HT - T_o) + (T - T_B)^T C^{-1} (T - T_B)$$

$$\boxed{T = (H^T R^{-1} H + C^{-1})^{-1} (H^T R^{-1} T_o + C^{-1} T_B)}$$

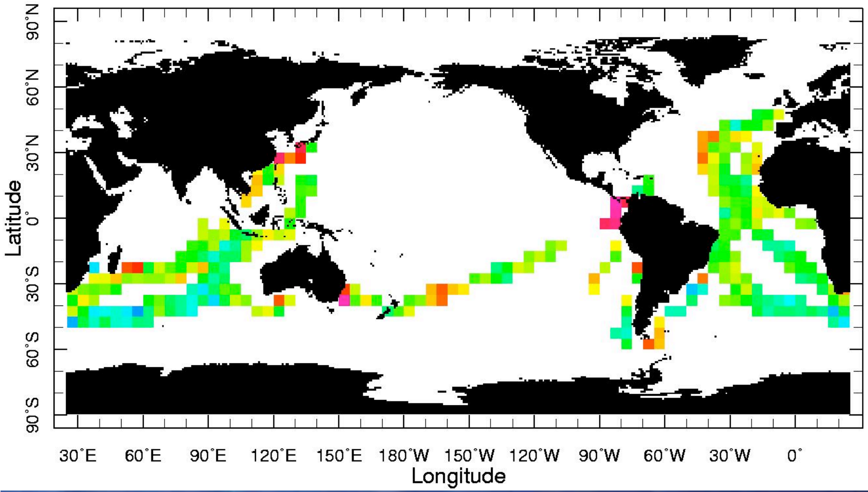
Dec 1868: Available observations



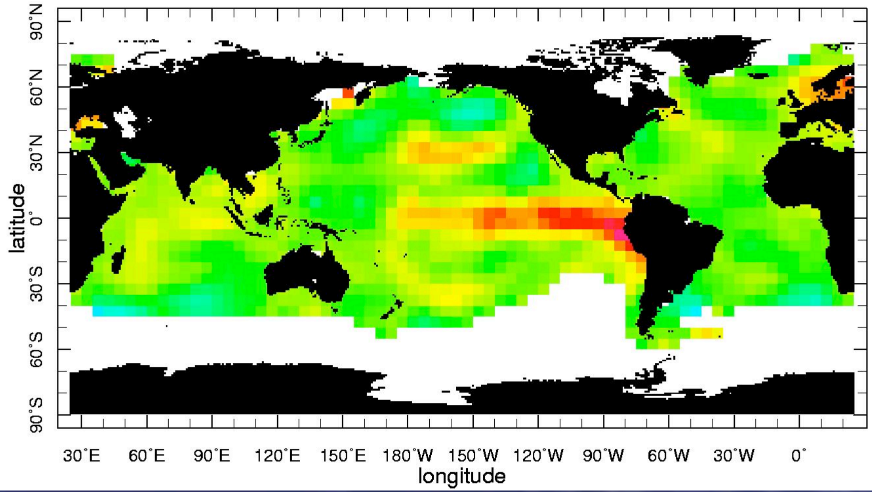
Dec 1868

Ability to attribute accurate observational error to historical ship data is especially important

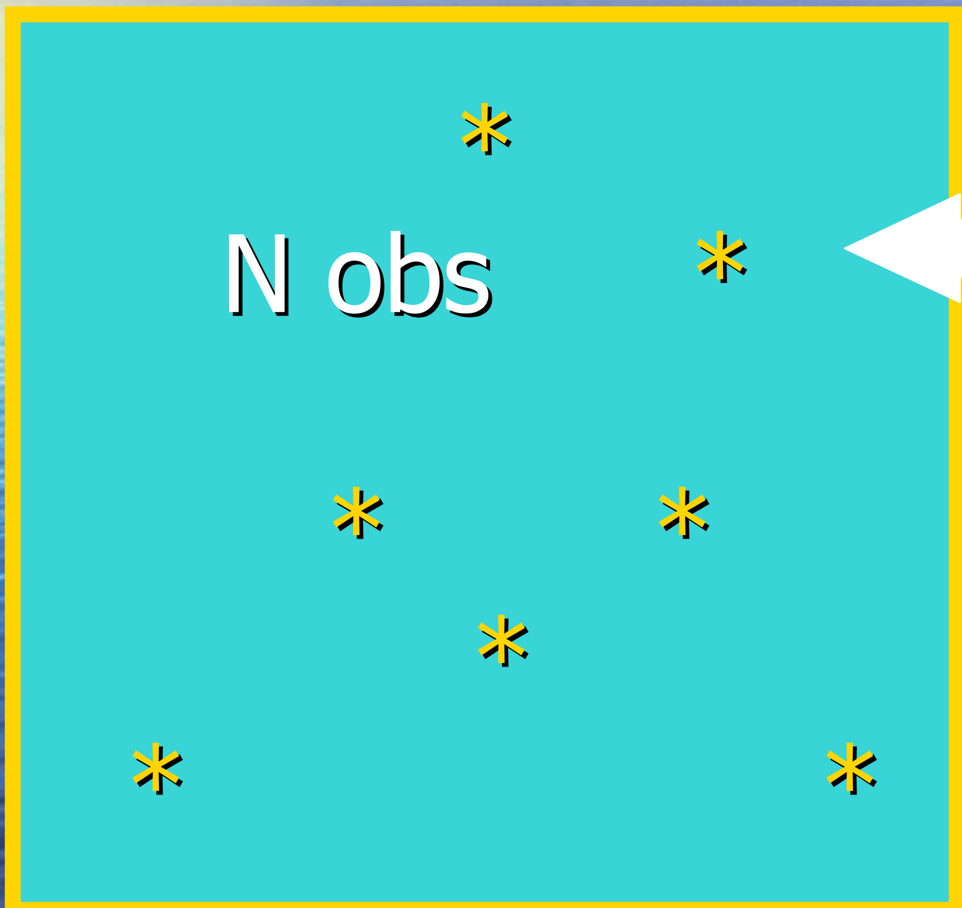
Dec 1868: Available observations



Dec 1868: Reconstruction



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

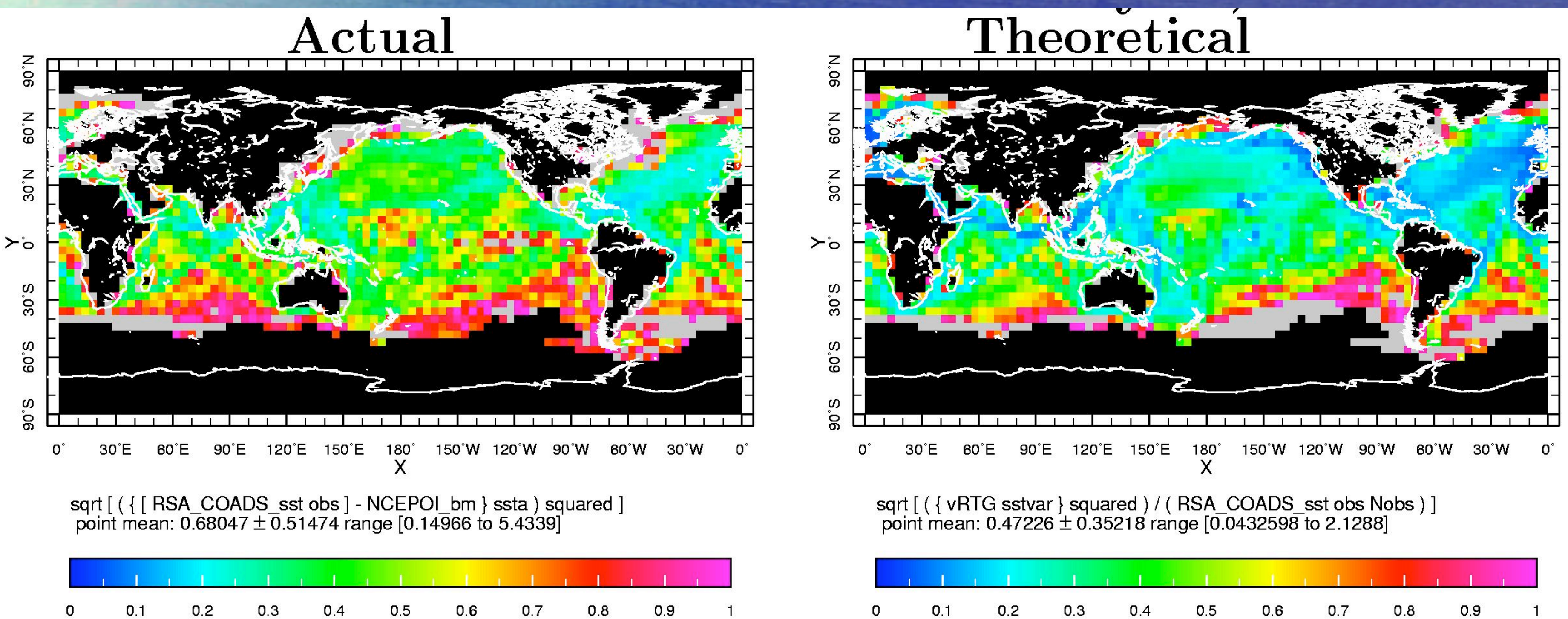
Will this formula work?

Can observations be viewed as randomly sampled?

Can we estimate σ from a reasonably well-sampled ICOADS period, will that be good enough?

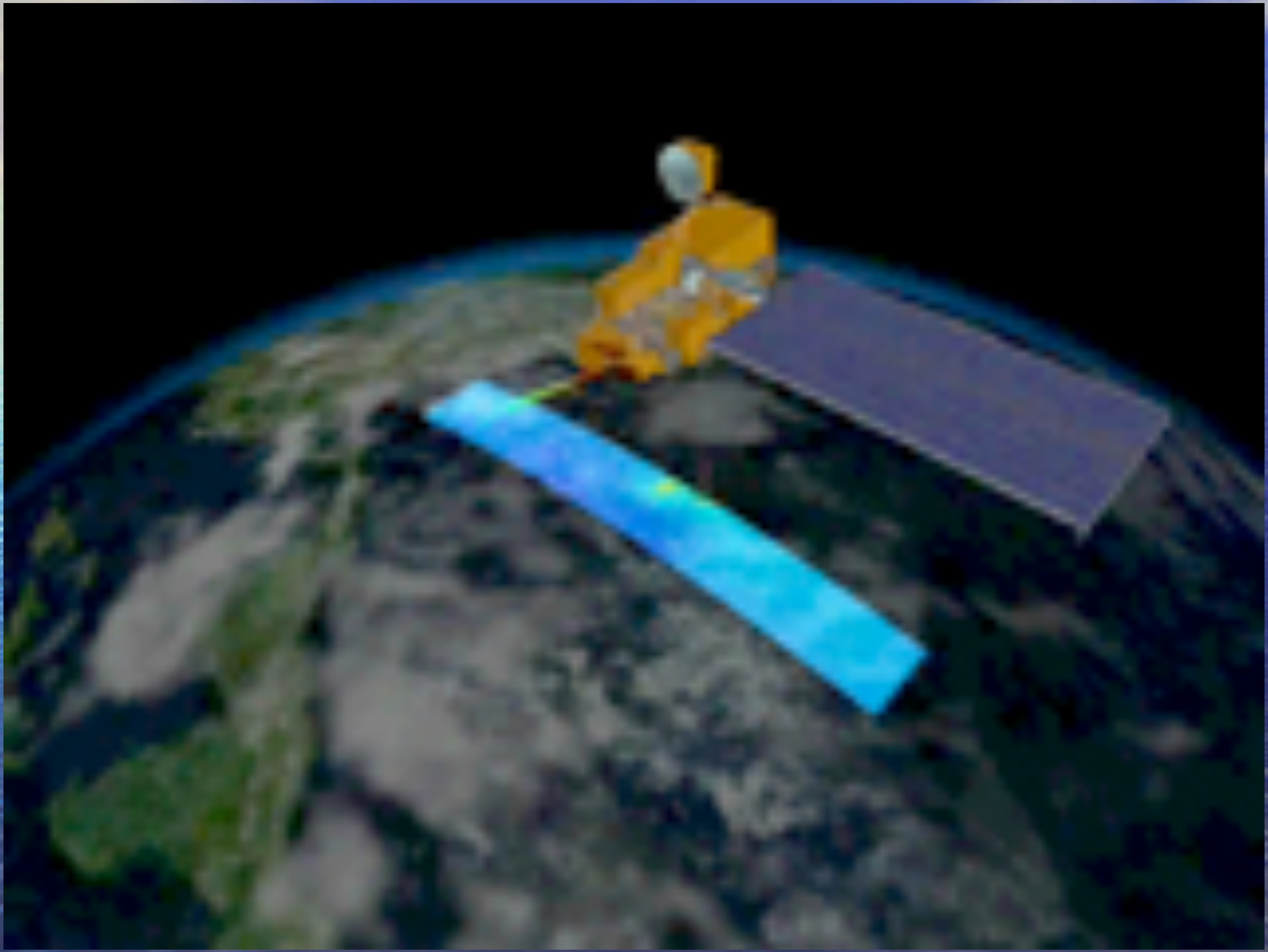
Error in 4 degree ICOADS bins (NCEP OI analysis is used as "truth"): Actual and theoretical error variance differ by a factor of two

[my talk at MARCDAT-1, Boulder,CO, Jan 2002]

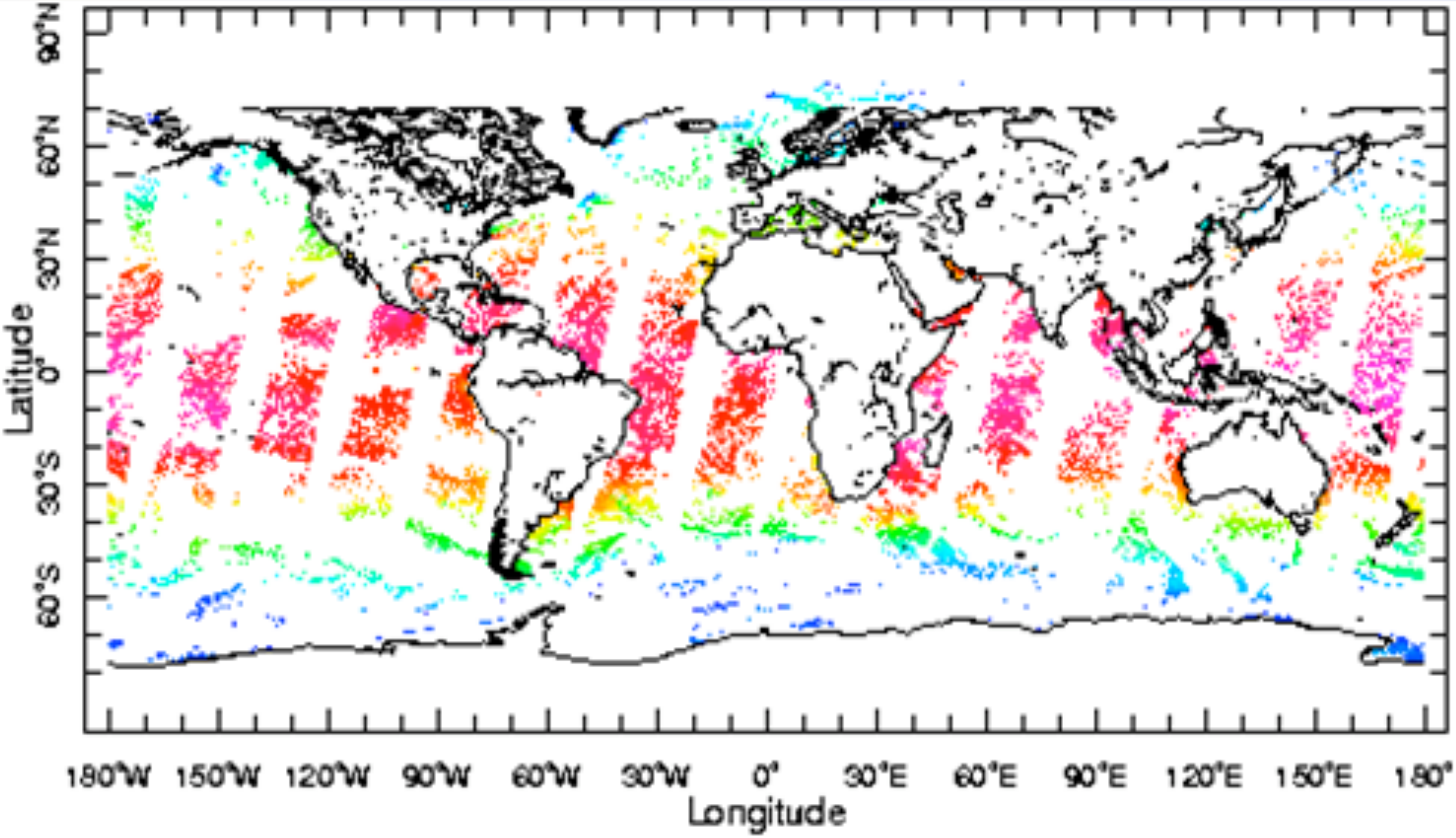


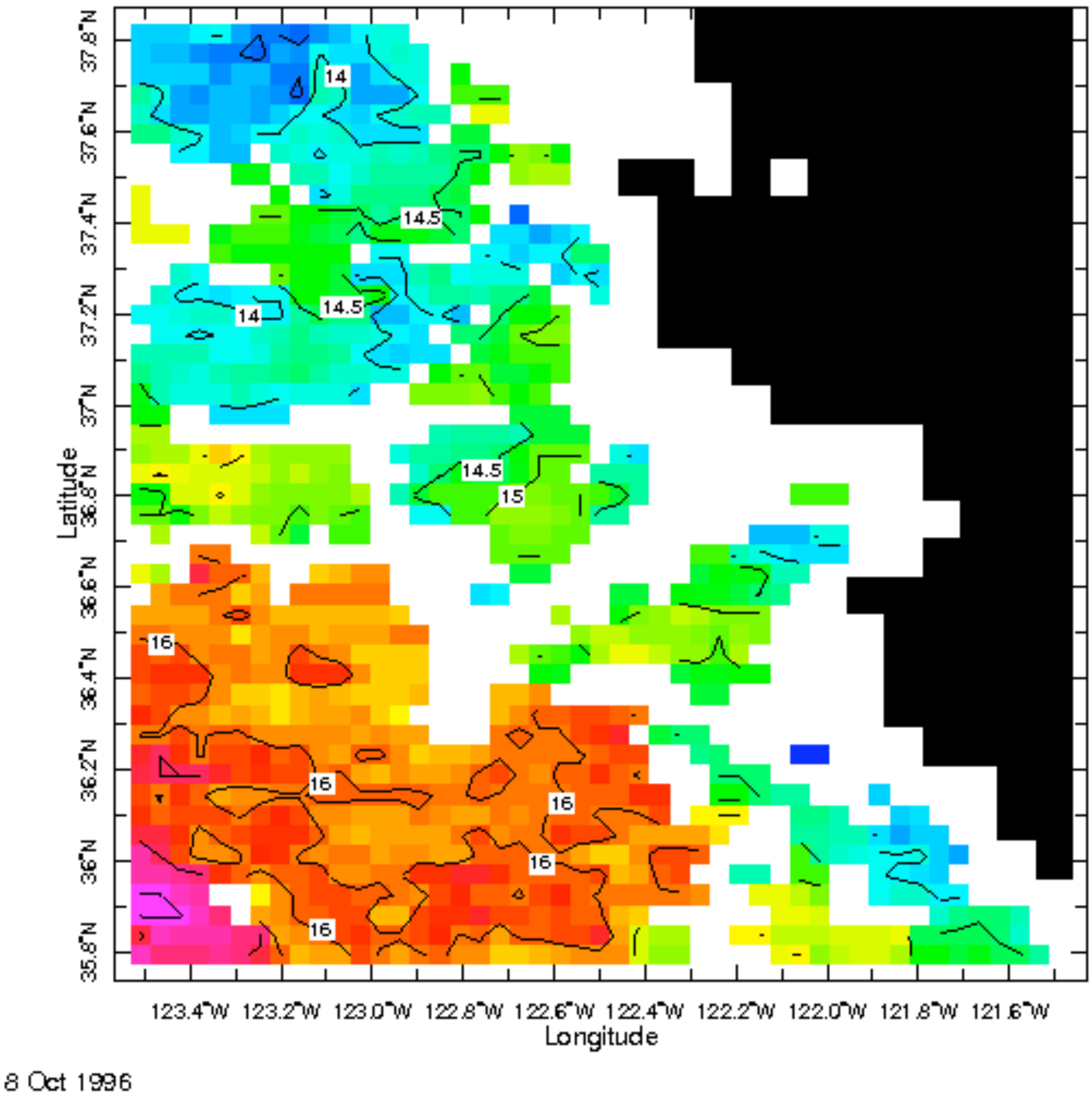
High-resolution brought in by satellite data can help pinpoint natural SST variability

MODIS Scanning Swath



Satellite Sea Surface Temperature Measurements for one day

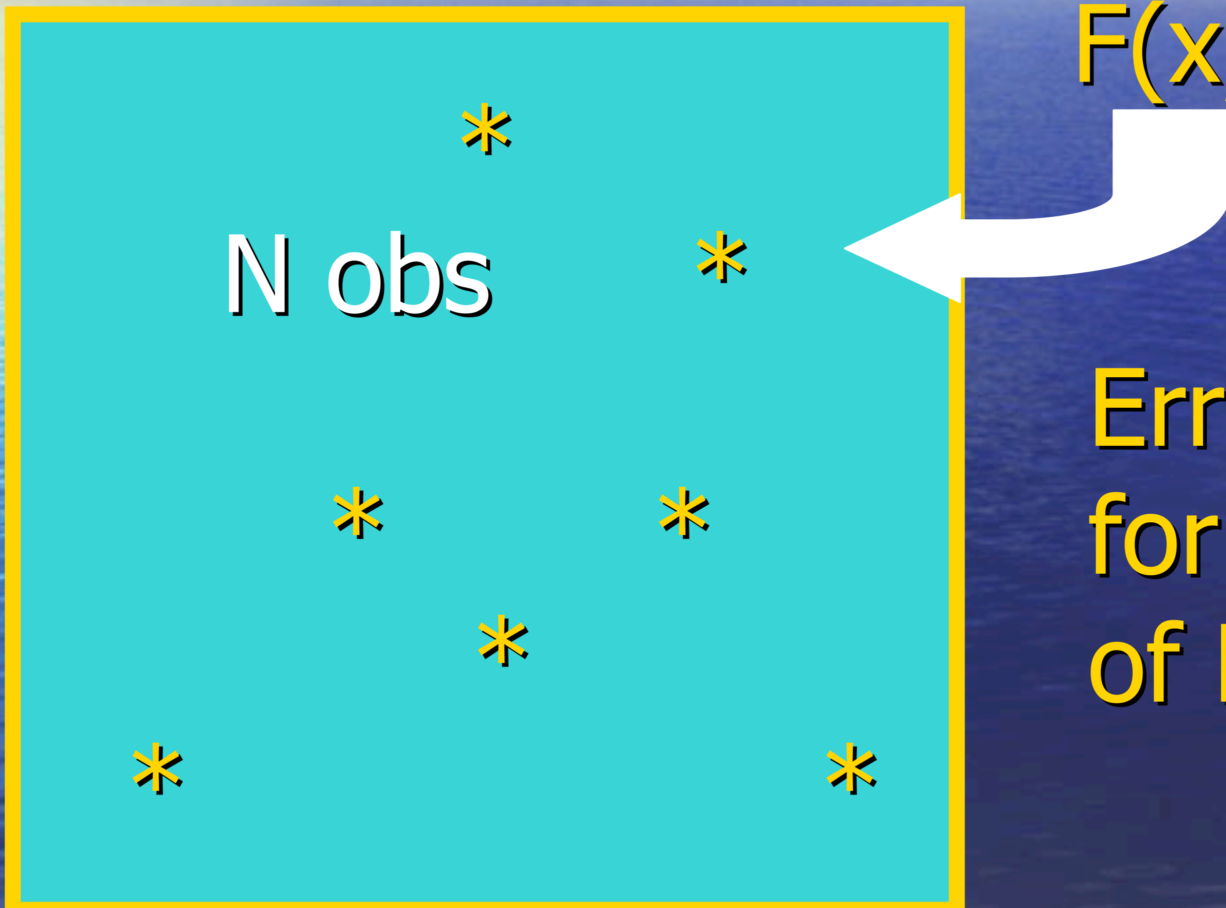




Pathfinder SST: Monterey Bay, Oct 8, 1996 4km resolution

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)]



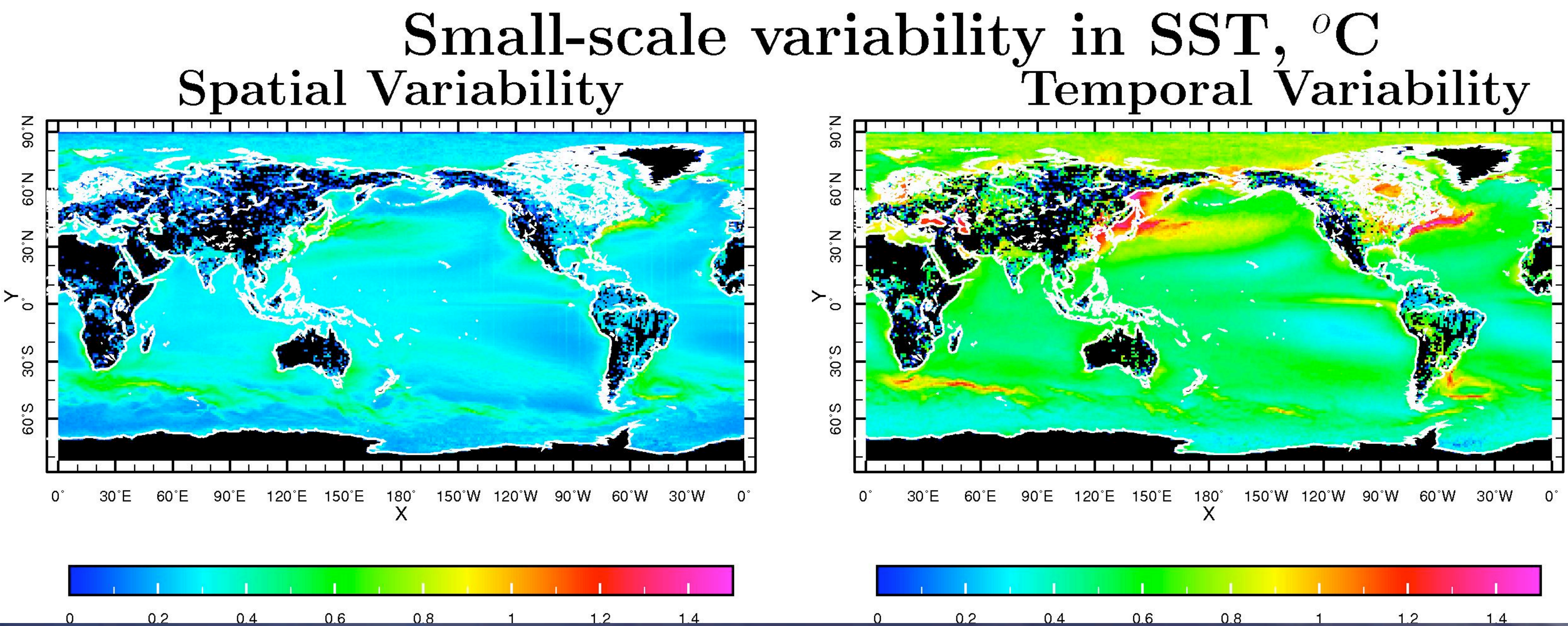
Error variance for the mean of N observ is

σ^2/N

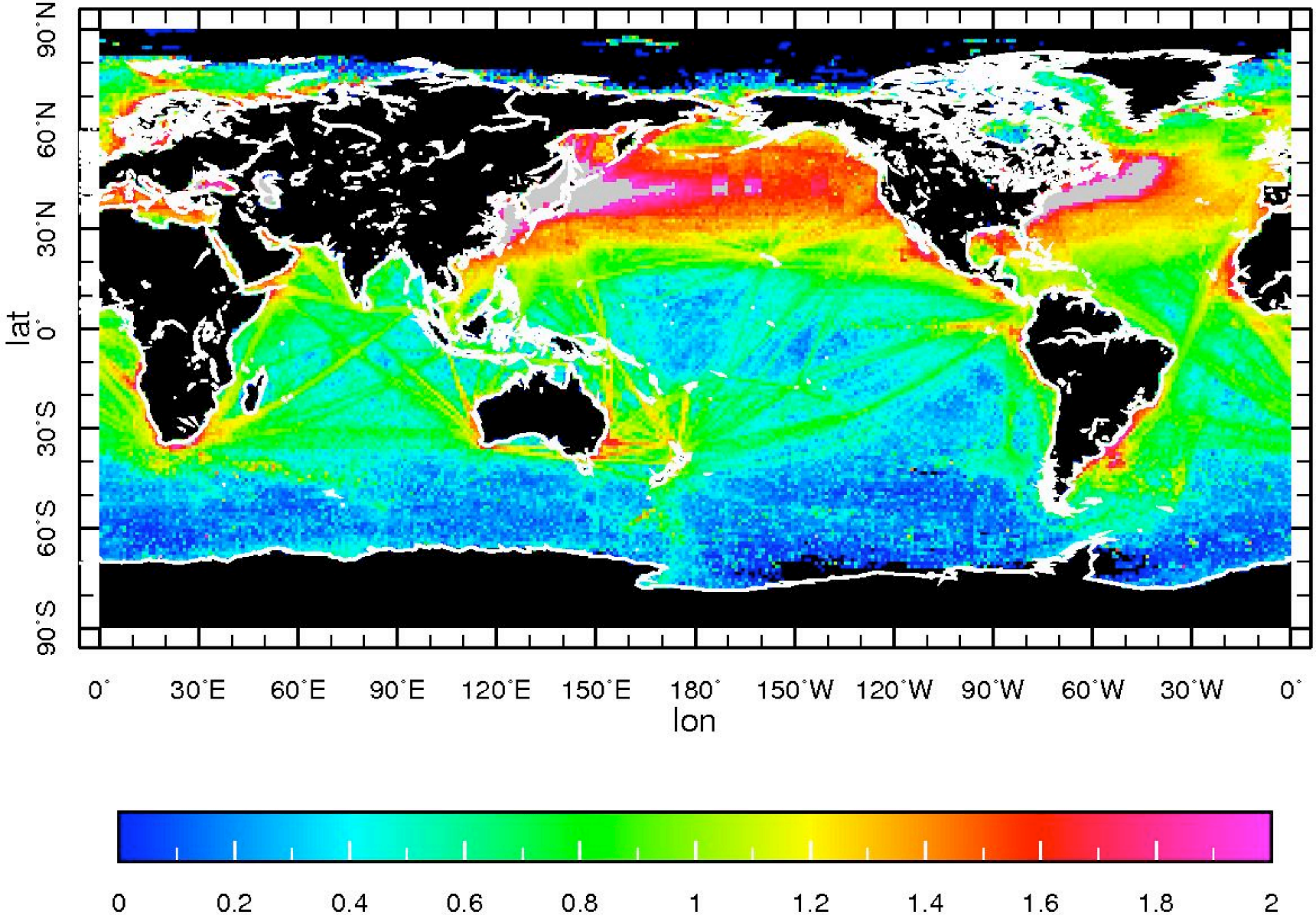
High spatial and temporal resolution of satellite data can help pinpoint natural SST variability on small scales (below 1 deg) and short terms (within 1 month).

A few weeks of background processing of 20 years of daily 4km maps of Pathfinder SST gave us the SST variability inside 1x1 monthly boxes estimated.

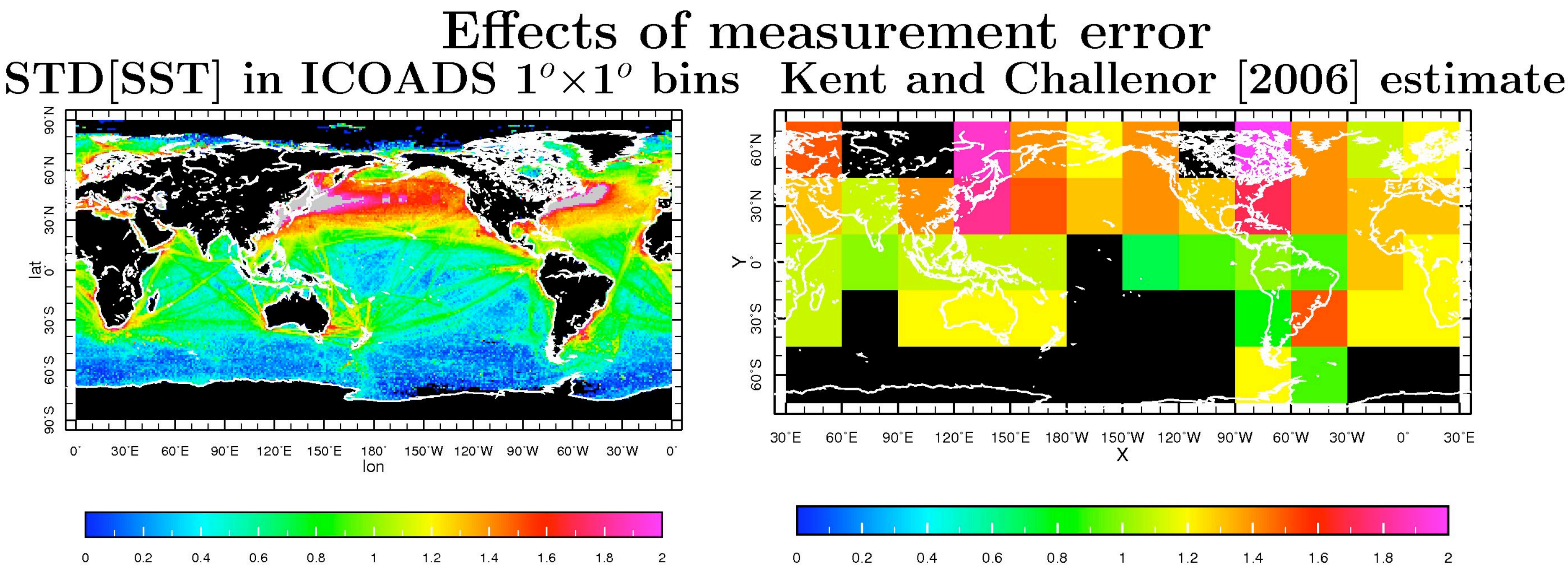
[http://rainbow.ldeo.columbia.edu/~alexeyk/Satellite_SST.html]



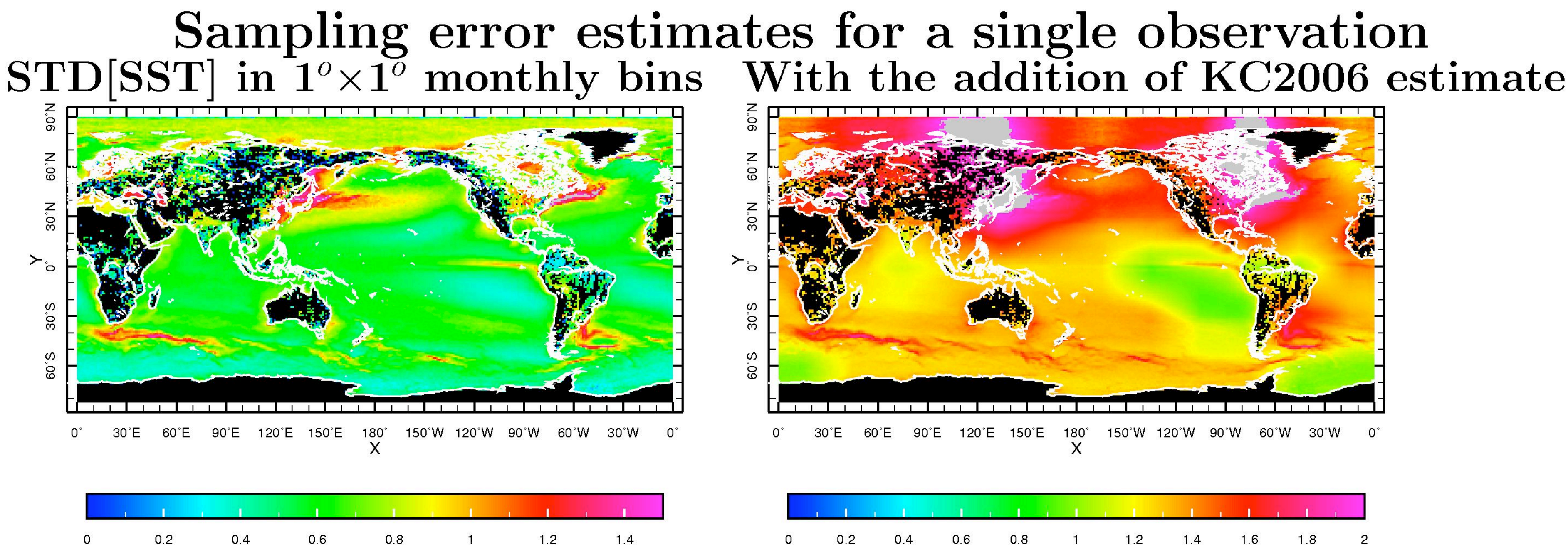
STD[SST] in ICOADS $1^o \times 1^o$ bins



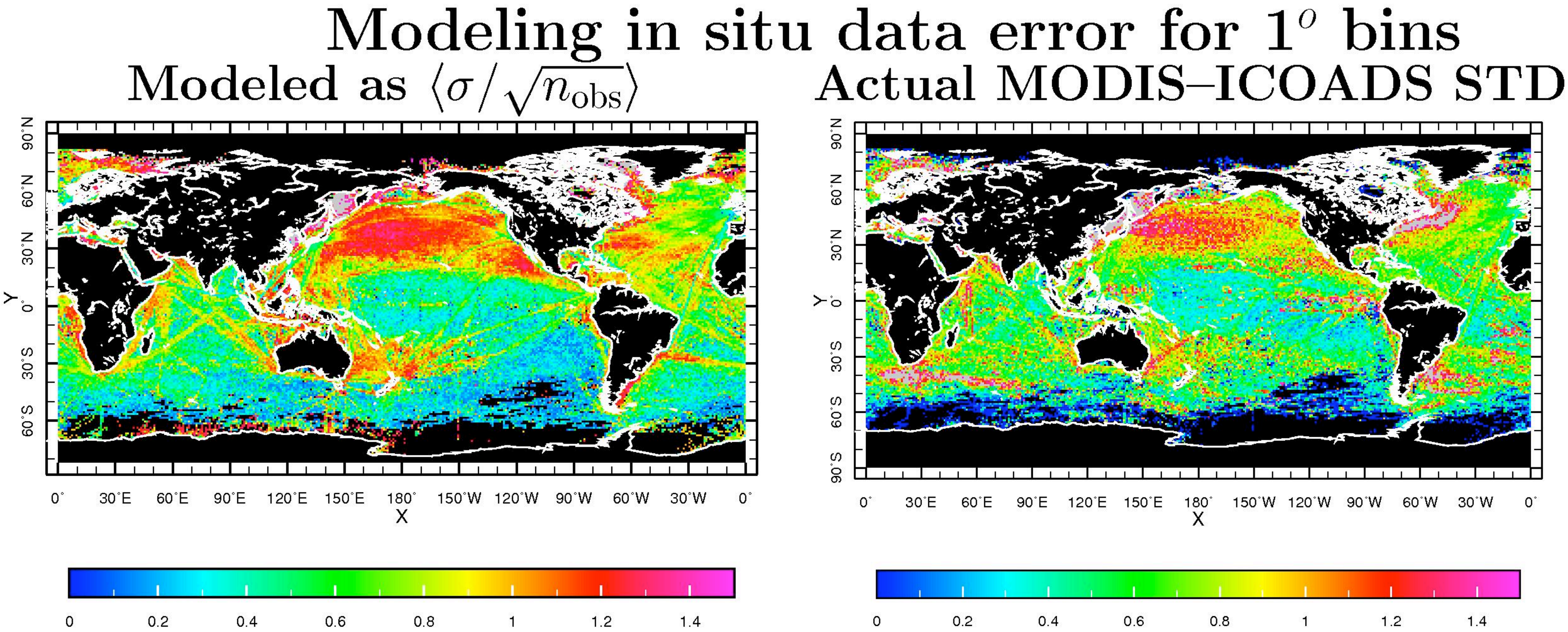
Measurement error (or very small-scale variability) has to be taken into account



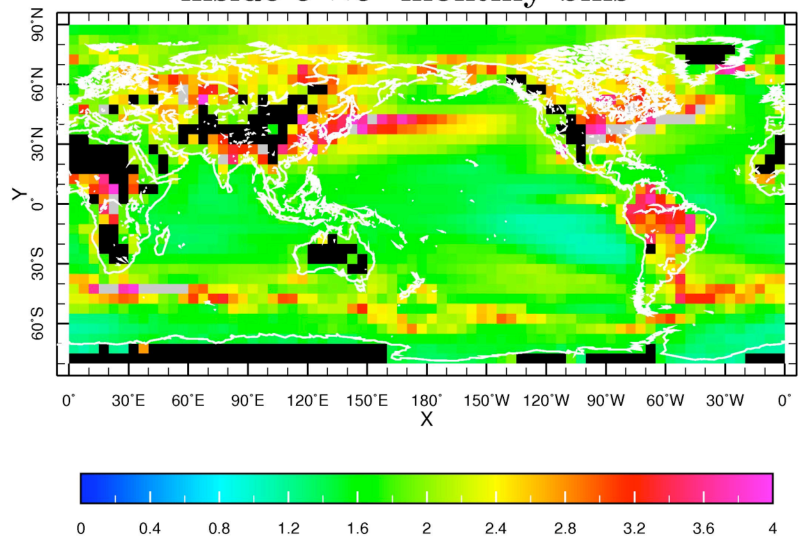
Combining the two estimates to obtain σ:



Does left look like right?

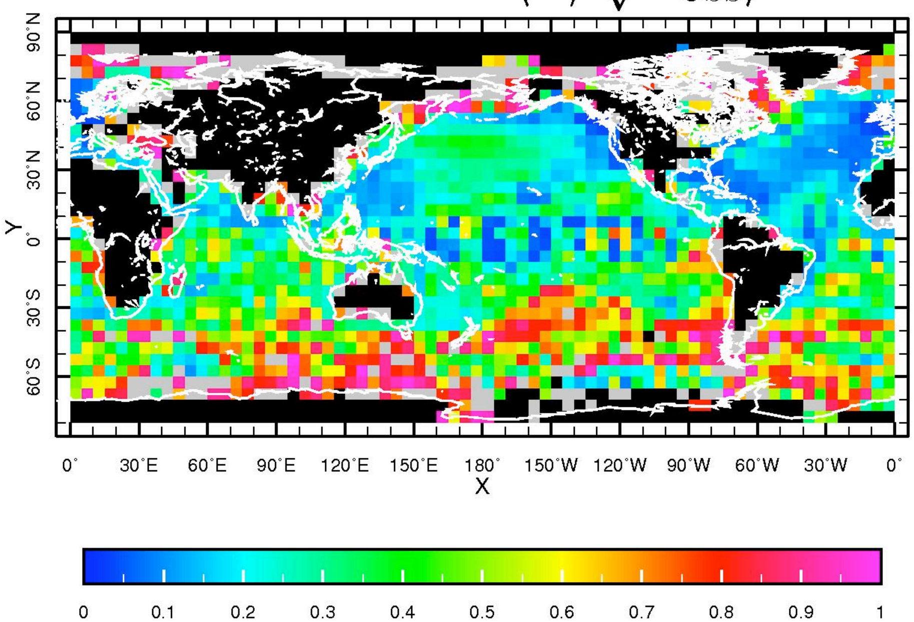


Single observation SST sampling+measurement error, ^{o}C, inside $5^{o}\times5^{o}$ monthly bins

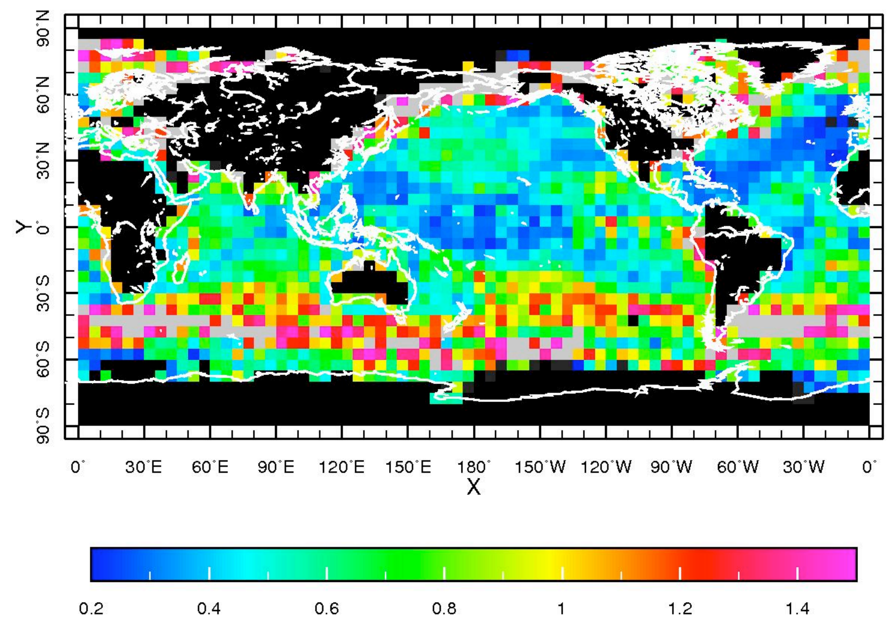


Modeling in situ data error for 5^{o} bins

Modeled as $\langle \sigma/\sqrt{n_{\rm obs}} \rangle$



Actual MODIS–ICOADS STD



What we have learned:

1. We can use variability estimates from satellite data to model sampling error.
2. In 1x1xmonth bins measurement error is not-negligible in comparison with natural SST variability. Individual in situ observations can be viewed as randomly distributed.
3. In 5x5xmonth boxes the opposite is true for the measurement error and probably for the obs distribution as well.

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