Modeling observational error of bin-averaged in situ climate data

Alexey Kaplan
*Lamont-Doherty Earth Observatory of Columbia University*

in collaboration with:
Mark A. Cane
*Lamont-Doherty Earth Observatory of Columbia University*
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
Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA), from U.K. Met Office and GHRSSST, blend of many satellite data streams
Optimal Interpolation

\[ T = T_B + e_B \]
\[ H^T T_o + e_o \]
\[ <e_B> = <e_o> = <e_B e_o^T> = 0 \]
\[ <e_B e_B^T> = C \]
\[ <e_o e_o^T> = R \]  \( \Rightarrow \) obs error covariance

Solution minimizes the cost function

\[ S[T] = (H^T T_0)^T R^{-1} (H^T T_0) + (T - T_B)^T C^{-1} (T - T_B) \]

\[ T = (H^T R^{-1} H + C^{-1})^{-1} (H^T R^{-1} T_0 + C^{-1} T_B) \]
Dec 1868: Available observations
Ability to attribute accurate observational error to historical ship data is especially important.
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

\[ \sigma^2/N \]
Will this formula work?

Can observations be viewed as randomly sampled?

Can we estimate $\sigma$ 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)?

Error variance for the mean of N observ is \( \sigma^2/N \)
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 $1^\circ \times 1^\circ$ bins
Measurement error (or very small-scale variability) has to be taken into account.
Combining the two estimates to obtain $\sigma$:

Sampling error estimates for a single observation $\text{STD}[\text{SST}]$ in $1^\circ \times 1^\circ$ monthly bins with the addition of KC2006 estimate.
Does left look like right?

Modeling in situ data error for $1^\circ$ bins
Modeled as $\langle \sigma / \sqrt{n_{obs}} \rangle$

Actual MODIS–ICOADS STD
Single observation SST sampling + measurement error, °C, inside 5° × 5° monthly bins

Modeling in situ data error for 5° bins
Modeled as $\left\langle \sigma / \sqrt{n_{\text{obs}}} \right\rangle$
Actual MODIS–ICOADS STD
What we have learned:
1. We can use variability estimates from satellite data to model sampling error.
2. In 1x1x1 month bins measurement error is not-negligible in comparison with natural SST variability. Individual in situ observations can be viewed as randomly distributed.
3. In 5x5x1 month boxes the opposite is true for the measurement error and probably for the obs distribution as well.

Supported by NASA MODIS Science Team and NOAA CCDD and JCSDA grants