High resolution objective analysis of historical SSTs: small-scale, long-term, and sea-ice aspects

Alexey Kaplan LDEO of Columbia University Paradigm of the least squares optimal estimation



An educative example: reconstructing SSTs from COADS data for the NCEP OI period: Nov 1981 - 2001. No space reduction!

Actual error (cf NCEP OI)





({[EMDEFR - NCEPOI bm]sta]+} RSA_COADS_stabs [sta*0.]]) squared grt (({[EMDEFR - NCEPOI bm]sta]+ sqt {[RSA_COADS_stabs (sta*0. mean: 0.53808 ± 0.45071 nange [0.14338 to 3.732] point mean: 0.53897 ± 0.31353 nange [0.0014386 to 2.3385]

Theoretical error



אלהב אלנים אלהם אלהבו אלהבו למו כלהבו כלהם כלנים כלהב בטנוקרים ב ď

sqt[(EMDEFR err)+(RSA_COADS_sstots|ssta*0.])] point mean: 0.37218 ± 0.14148 range [0.1425 to 1.2561]



אלוב אלנם אלום אלובן אלובן לבון שלובן שלובן שלוב שלום שלום באלוב אלום אלום אלובן אלובן לבון שלובן שלובן שלוב a*

sqt[(EMDEFRer)+ sqt([RSA_COADS_stobs[sstat'0.]]+-1.)] pontmean:0.65237 ± 0.16088 range [0.50632 to 1.4733]

47

48

4.5

Available COADS Missing COADS

4.7

48

RMS(COADS-NCEPOI)





Theoretical obs error



SSV from COAD



SSV from L.Kent-**RTG+NCEPOI**

305 40% 90% ISOK ISOK IBO" ISOW ISOW 90W 40W 20W

Yeriebiliy in 4x4 box as pointmann: 1,7200 ± 0,42007, range (0,50230 to 4,4013)

SSV/Nobs

60





APPROXIMATING COVARIANCE



Separating large and small scales

$$\mathcal{T} = (H^T R^{-1} H + C^{-1})^{-1} H^T R^{-1} \mathcal{T}^o = C H^T (R + H C H^T)^{-1} \mathcal{T}^o = C H^T (R + H C H$$

$$= E\Lambda E^{T}H^{T}(HE\Lambda E^{T}H^{T} + HE'\Lambda'E'^{T}H^{T} + R)^{-1}\mathcal{T}^{o} +$$

$$E'\Lambda'E'^{T}H^{T}(HE\Lambda E^{T}H^{T} + HE'\Lambda'E'^{T}H^{T} + R)^{-1}\mathcal{T}^{o} =$$

$$= E\alpha + C'H^{T}(HE\Lambda E^{T}H^{T} + HC'H^{T} + R)^{-1}\mathcal{T}^{o} =$$

$$E\alpha + C'H^{T}(HC'H^{T} + R)^{-1}\Delta\mathcal{T}^{o} = E\alpha + \Delta\mathcal{T}$$

Introduce $\Delta \mathcal{T}^o = \mathcal{T}^o - HE\alpha$ and $\Delta \mathcal{T} = \mathcal{T} - HE\alpha$.

OI problem for small scale corrections:

$$\begin{split} H\Delta \mathcal{T} &= \Delta \mathcal{T}^{o} + \varepsilon^{o}, \\ \langle \Delta \mathcal{T} \Delta \mathcal{T}^{T} \rangle &= C', \qquad \langle \varepsilon^{o} \varepsilon^{o} \rangle^{T} \rangle = R \end{split}$$

Solution:

$$\Delta \mathcal{T} = C' H^T (HC' H^T + R)^{-1} \Delta \mathcal{T}^{\circ}$$

with error

$$P = C' - C'H^{T}(HC'H^{T} + R)^{-1}HC'.$$

Small-scale variability in the signal and data error can be separated from the large-scale signal variability that presumably can be estimated in a more robust way... Isolating long-term climate variability



Interannual climate variability removed

Residual data consists of error, physical small-scale variability and long-term variability (trends)



K98

HadISST1.1



Linear trends 1900-1991

OS

5075 ISOTE IBOT ISOTA 1207A 907A 807A 207A

Linear & end in RSA_moto_skie4 continueses: 0.00487167±0.00480707 rang+[-0.0232879to_0.0348587]

-0.00 -0.000 -0.000

a



0. 2012 9012 9012 12012 2012 1201 12014 12014 9014 9014 9014 1 X

Unear band in RSA_mohaa4444 point mean : 0003025 ± 000437945:range [-0.0233932 to 0.034566]

K98

HadISST1.1



-0002

-0.000 -0.000+

0 0002 000+ 0.000 0.000



Linear band in Had(SST).1 point mean: 000326371 ± 0.03962439 rang+ [:00689991 to 00470916]

0.000 0.0

Linear trends 1951-1991

OS

-0.002 0



-0.000 -0.00+ -0.002 . 0.002 000+

K98

HadISST1.1



Linear trends 1900-1950

OS

+000 -0000 0 -0000 +0000





OS+OI res

CONCLUSIONS

1. In order to obtain reliable error estimate we need to have better knowledge of small-scale variability in signal and data error.

- 2. Scale separation approach allows to work towards conceptually uniform globally-complete high-resolution objective analyses of SST according to the following scheme:
- (a) start from the reduced-space analysis (with an assumption of stationary mean and covariance);
- (b) small-scale analysis of observational residuals;
- (c) recomputing non-stationary mean and covariance;

(d)adding high-resolution corrections, globalization patches, and sea-ice analyzed fields by the same scheme: large-scale prediction from the SST fields + local-scale corrections.