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

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Paradigm of the least squares optimal estimation

To estimate:

$$\mathcal{T} = \mathcal{T}_{\text{total}} - \mathcal{T}_{\text{clim}}, \qquad \langle T \rangle = 0.$$

Input:

$$\mathcal{T}^o = H\mathcal{T} + \varepsilon^o, \qquad \langle \varepsilon^o \rangle = 0.$$

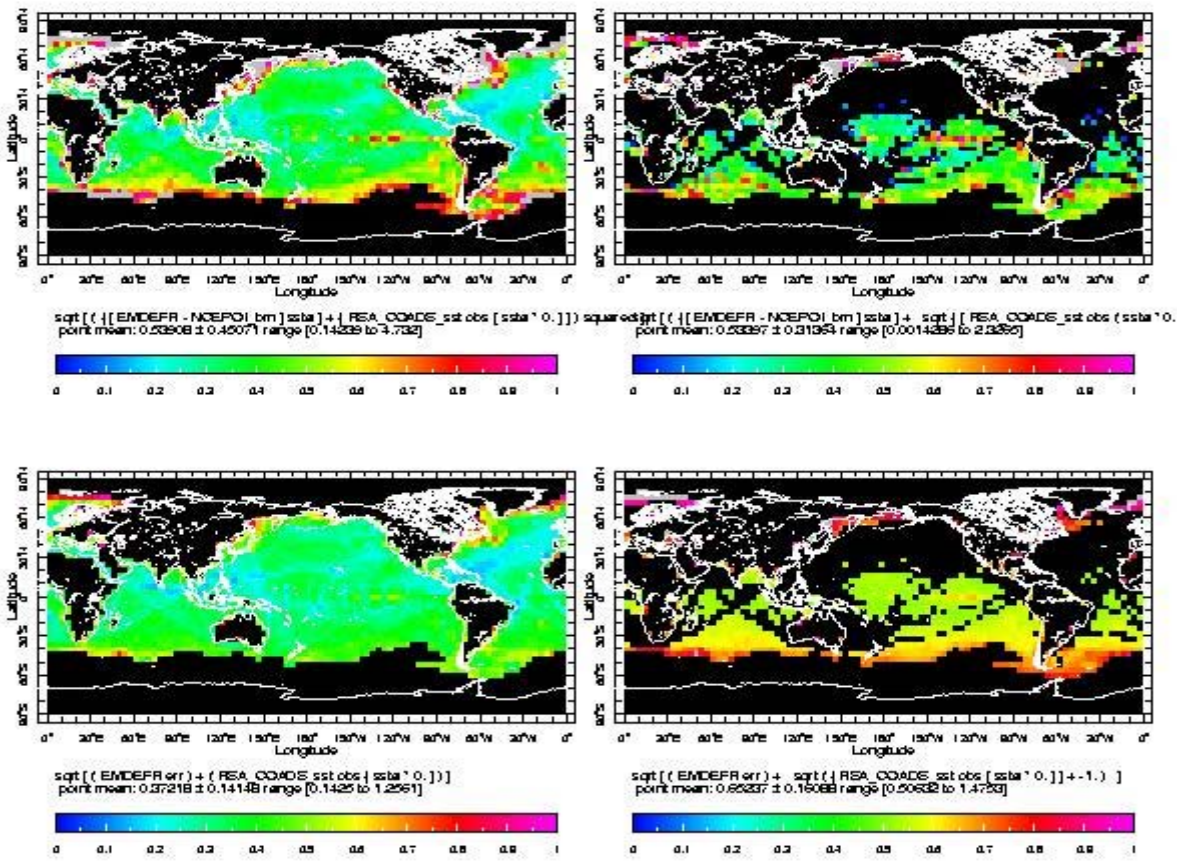
A priori information:

$$\langle \varepsilon^o \varepsilon^{oT} \rangle = R,$$
$$\langle \mathcal{T}\mathcal{T}^T \rangle = C.$$

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

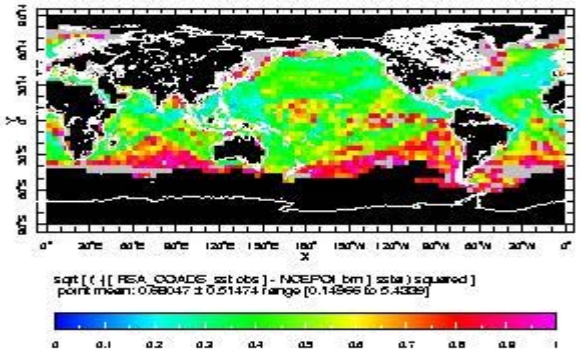
Actual error
(cf NCEP OI)

Theoretical error

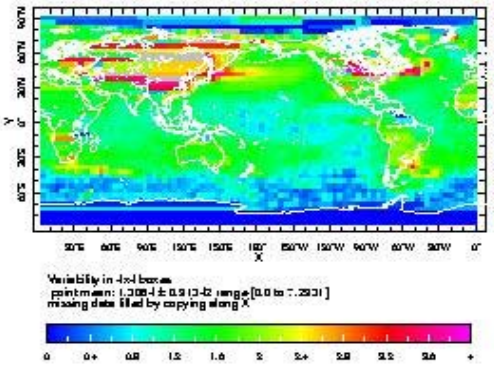


Available COADS Missing COADS

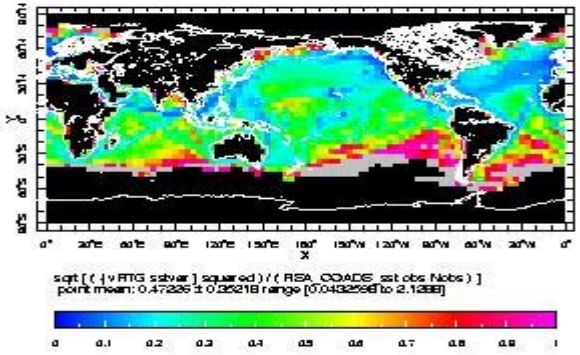
RMS(COADS-NCEPOI)



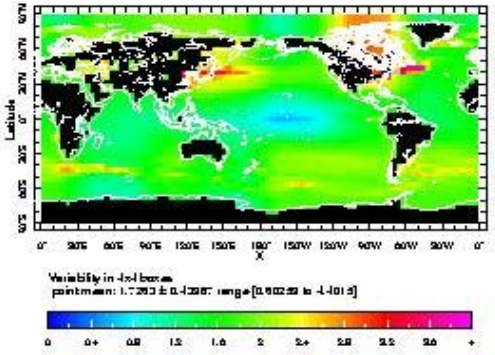
SSV from COADS



SSV/Nobs

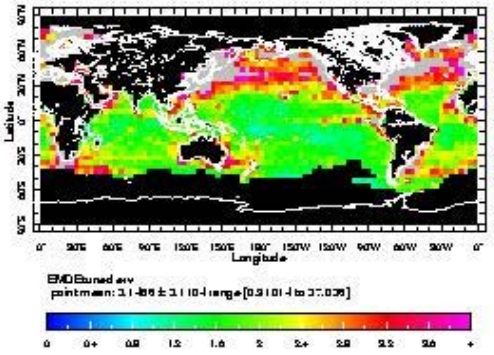


SSV from L.Kent-RTG+NCEPOI



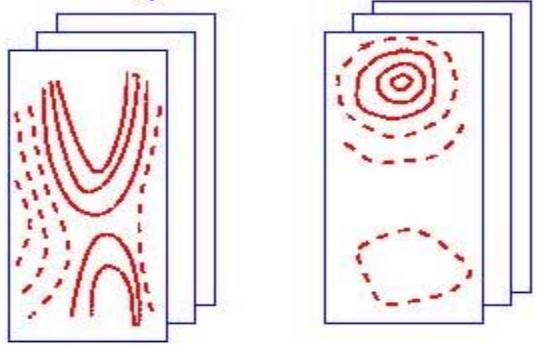
Theoretical obs error

Needed SSV! ;-(



APPROXIMATING COVARIANCE

$$C = E\Lambda E^{T} + E'\Lambda' E'^{T}$$



Reduced space optimal analysis

Successive corrections; Kriging

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...

Separating large and small scales

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

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

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

OI problem for small scale corrections:

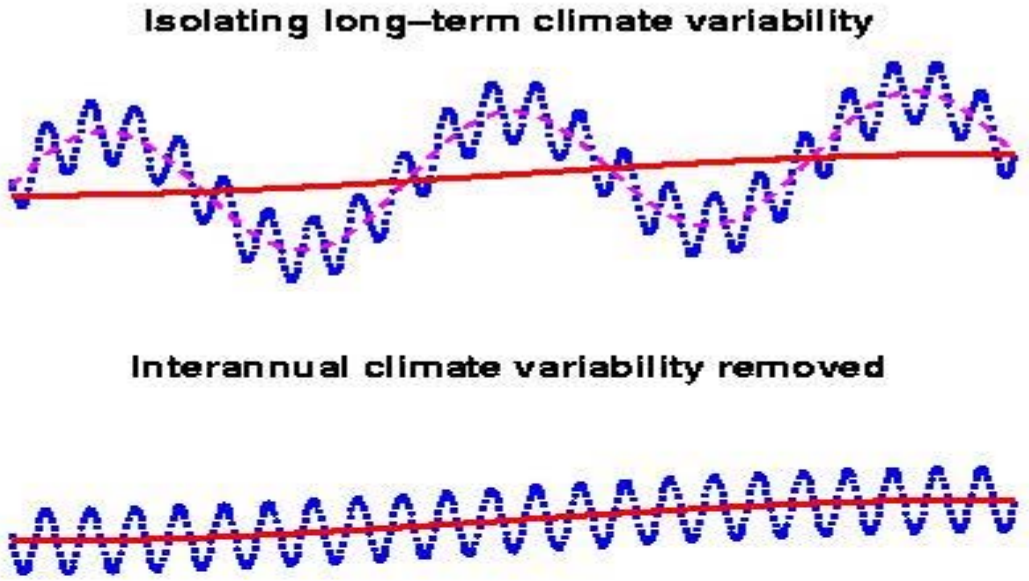
$$H\Delta\mathcal{T} = \Delta\mathcal{T}^o + \varepsilon^o,$$
$$\langle \Delta\mathcal{T} \Delta\mathcal{T}^T \rangle = C', \qquad \langle \varepsilon^o \varepsilon^{o\,T} \rangle = R$$

Solution:

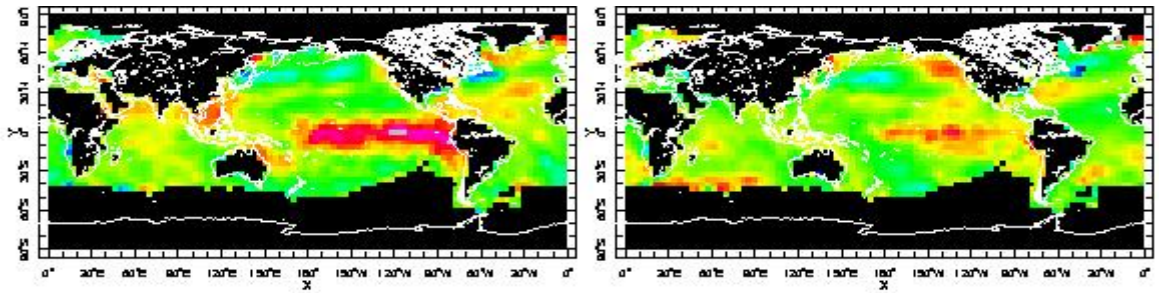
$$\Delta\mathcal{T} = C' H^T (HC' H^T + R)^{-1} \Delta\mathcal{T}^o$$

with error

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



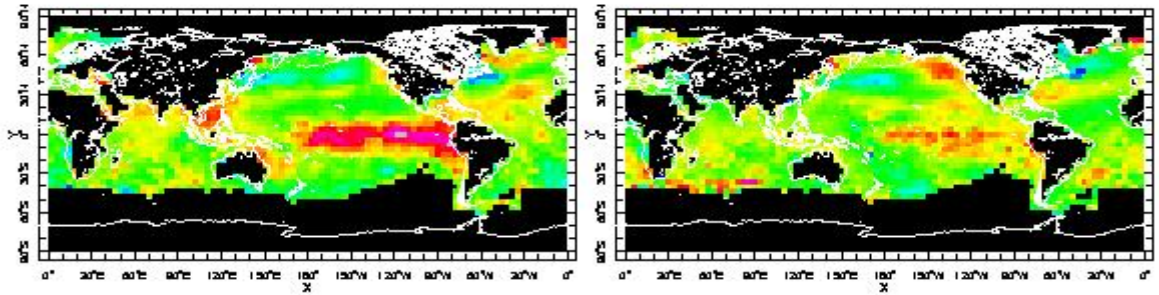
Residual data consists of error, physical small-scale variability and long-term variability (trends)



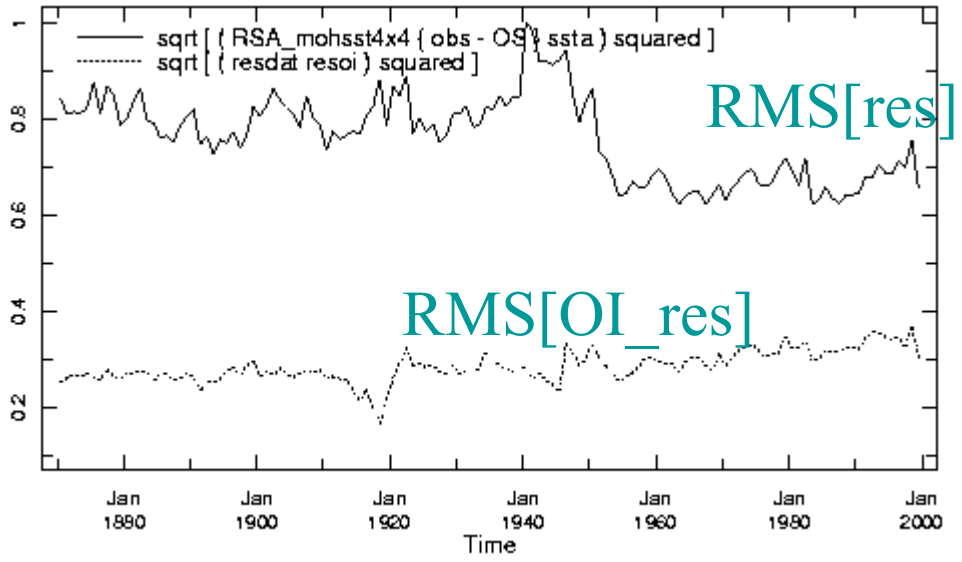
Dec 1877

Dec 1986

OS



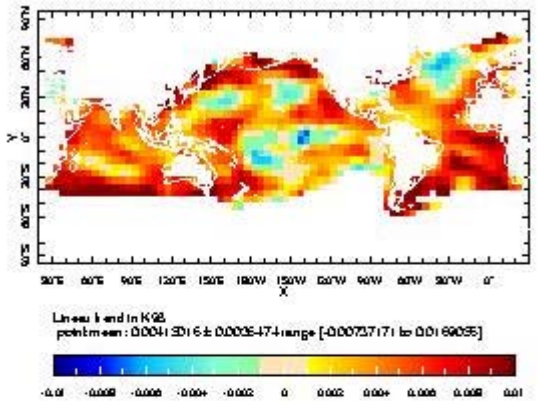
OS + OI_res



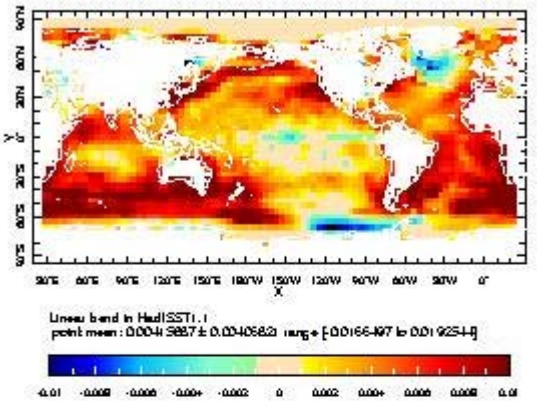
Reestimation of sliding climatology and window covariance is possible at this stage!

Linear trends
1900-1991

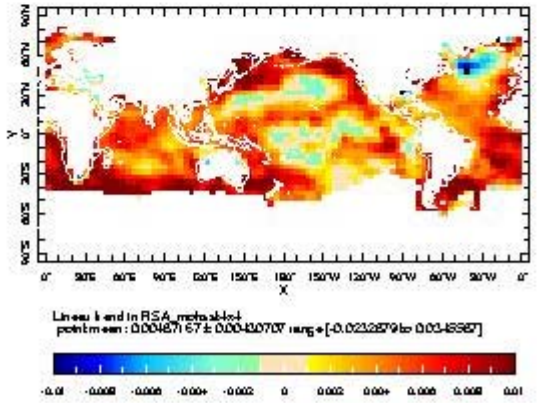
K98



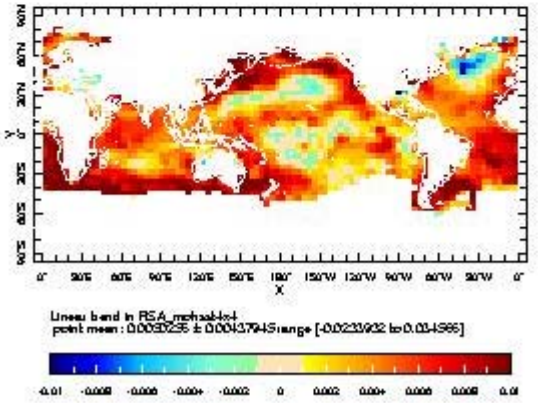
HadISST1.1



OS

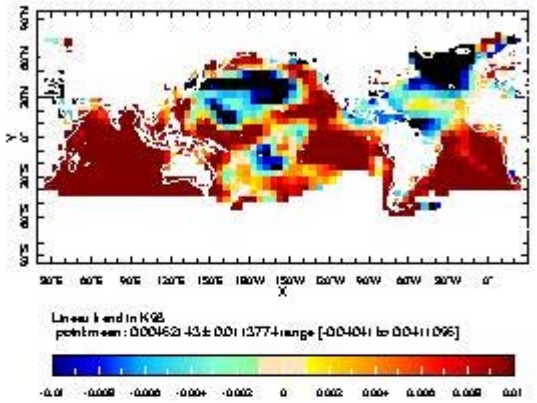


OS+OI_res

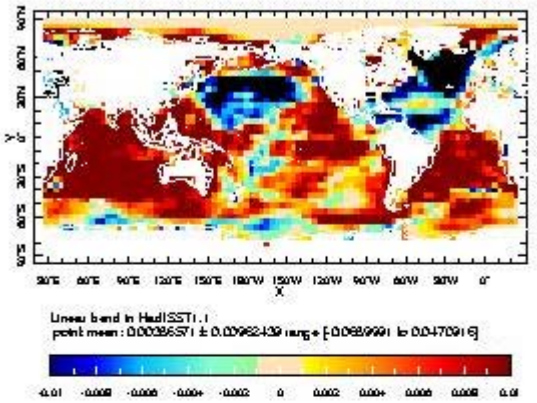


Linear trends
1951-1991

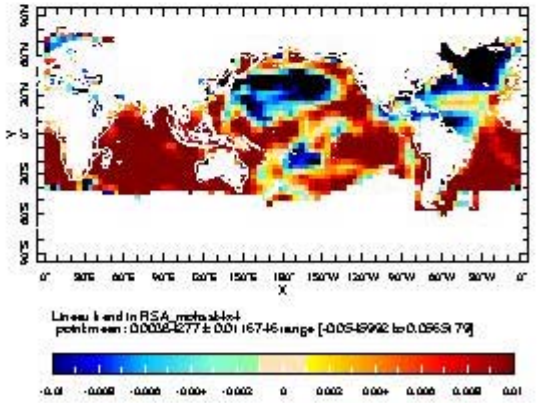
K98



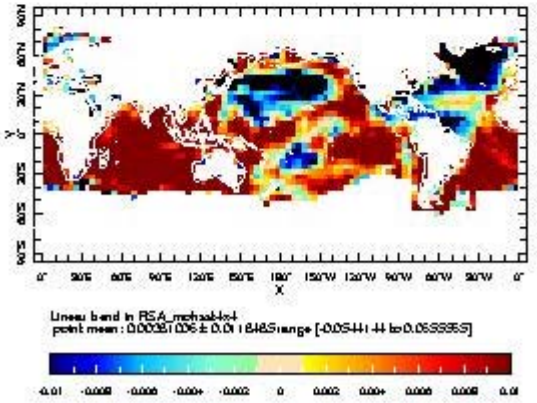
HadISST1.1



OS

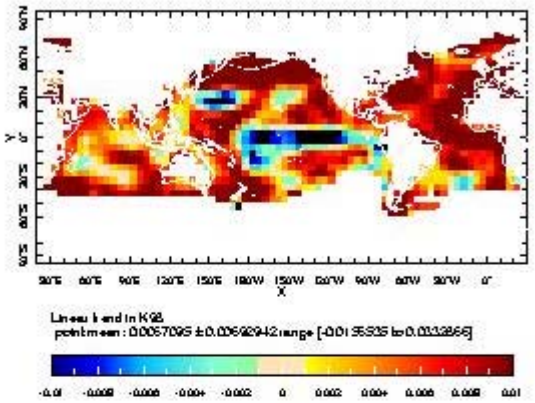


OS+res_OI

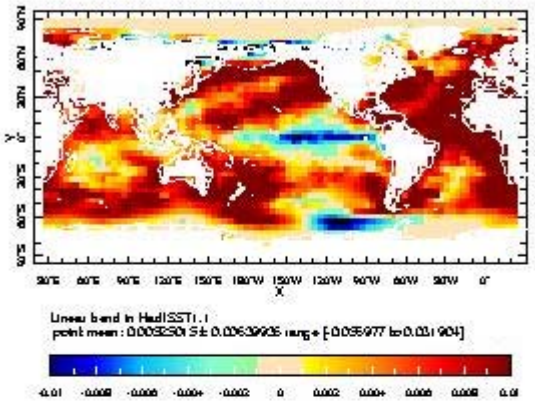


Linear trends
1900-1950

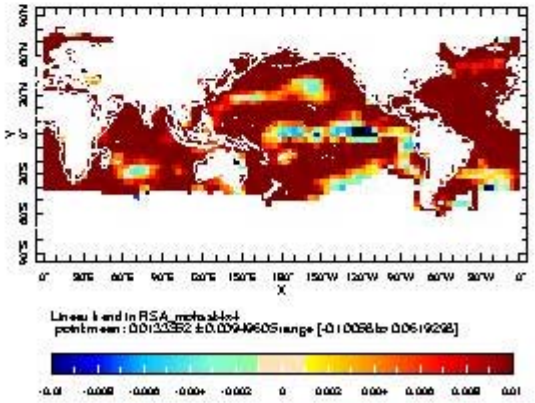
K98



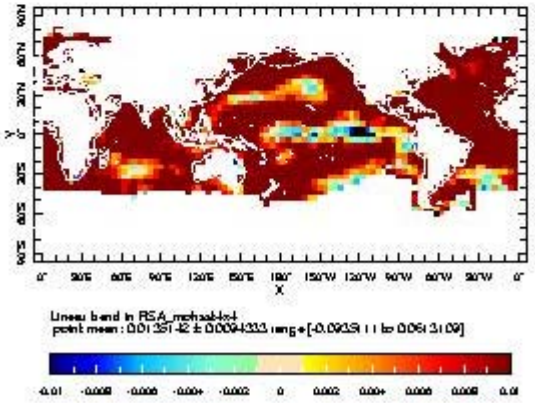
HadISST1.1



OS



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.