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Historical land surface temperature reconstruction with observations over land and oceans

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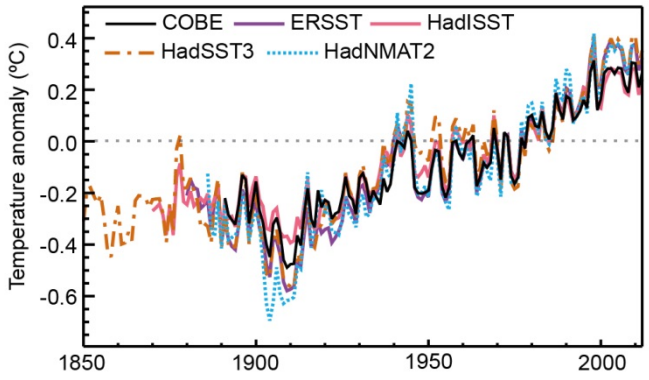
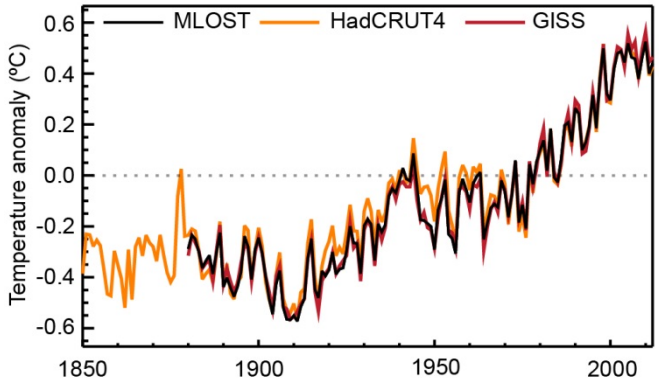
Motivation

Global average SST



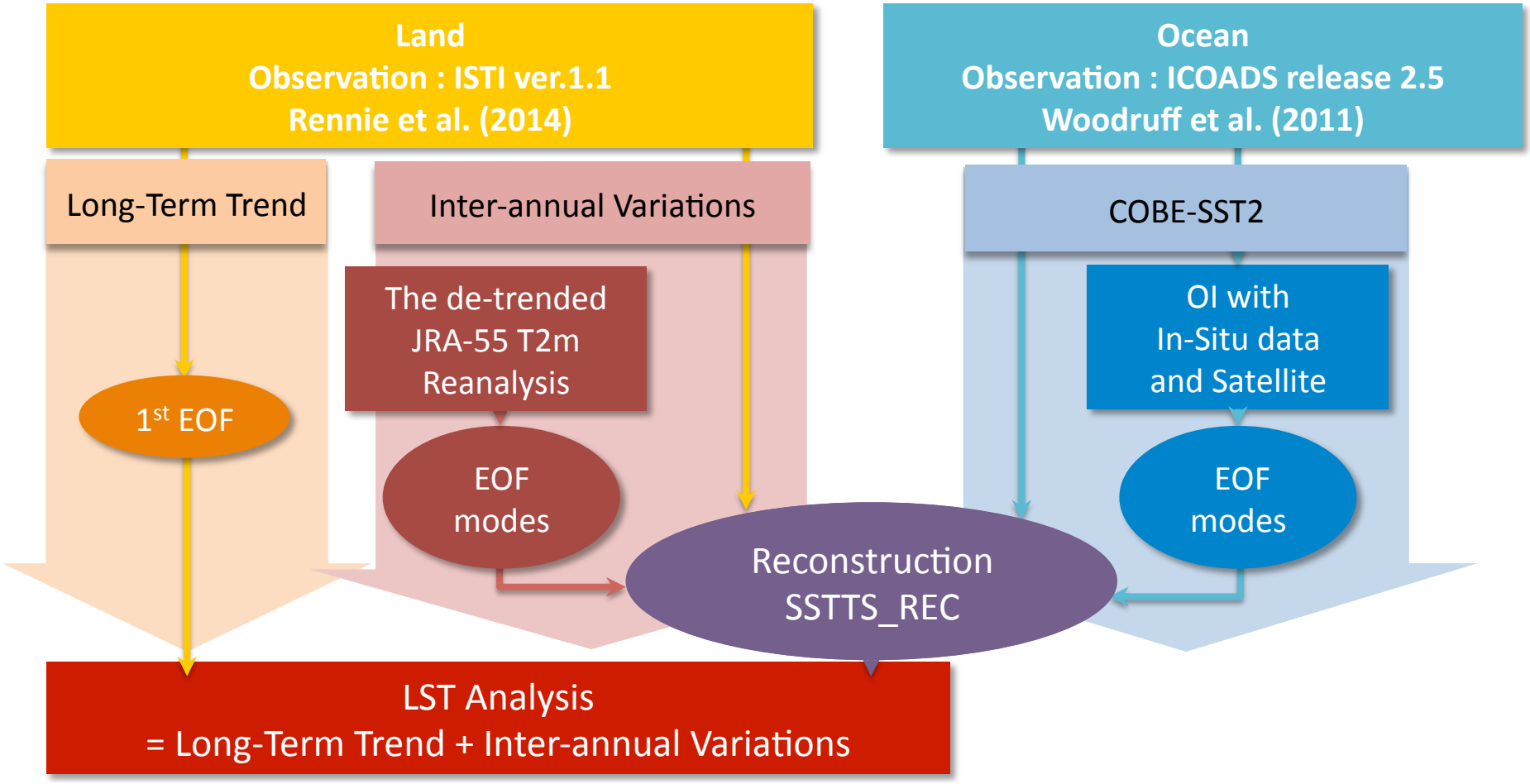
Global mean surface temperature



- We conducted a simultaneous analysis of monthly land surface temperature (LST) and sea surface temperature (SST) by using in situ observations over land and ocean.
- The purpose is to improve both LST and SST analyses with high accuracy in space and time.
- We applied the reconstruction method of COBE-SST2 (Hirahara et al. 2014) to LST analysis using ISTI.

Two types of analyses

1. TS_REC : Based on EOFs defined from JRA55 T2m, Inter-annual variations is reconstructed by using observations on land only.
2. SSTTS_REC : Based on EOFs defined from both JRA-55 T2m and COBE-SST2, Inter-annual variations is reconstructed by using observations over land and oceans.



QC

Climatology of station data adjusted to JRA-55

- If in situ data are available for more than 15 years.
- Otherwise, the station climatology is constructed by comparing temperature observations at nearby stations.

➔ The most of the ISTI data (99.7%) is usable for the LST analysis.

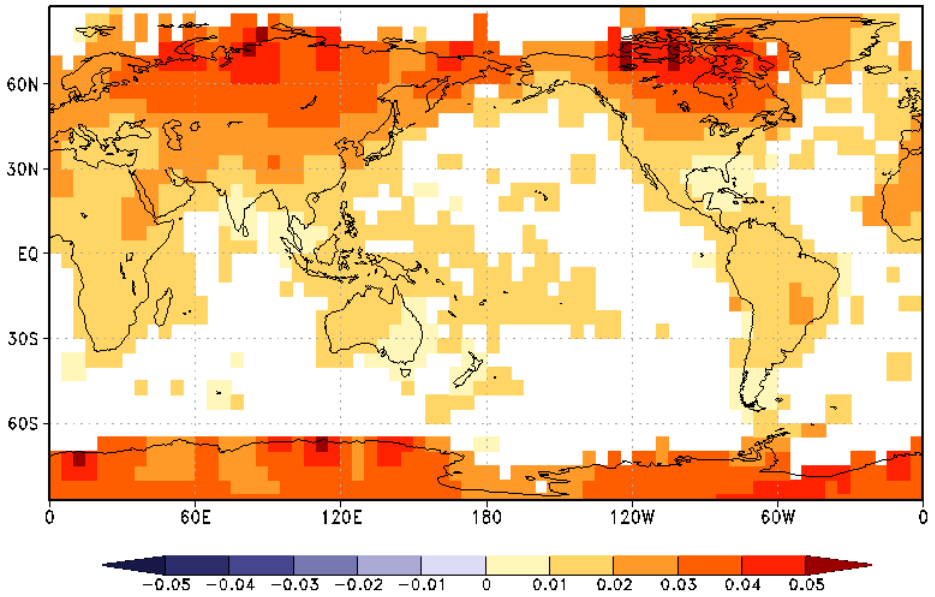
Offline and Online QC

- Hirahara et al. (2014) & Ishii et al. (2003, 2005)

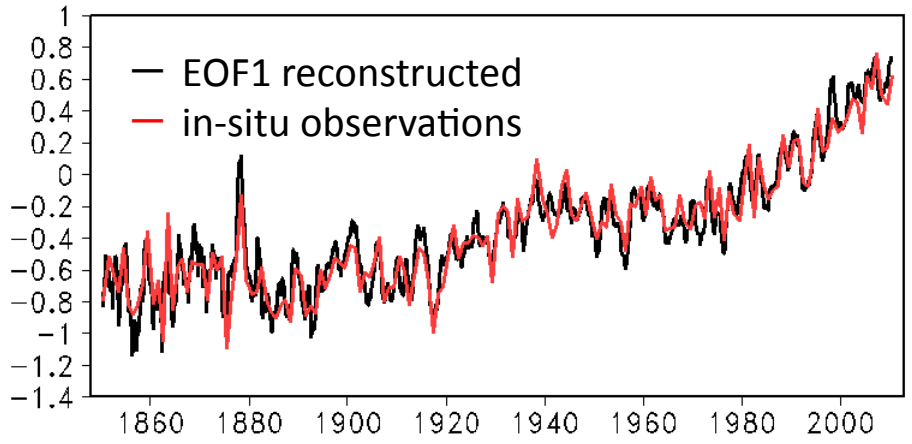
Long-Term Trend

- Estimated in the same way as COBE-SST2
- The trend is the 1st EOF of annual mean LST anomalies of in situ observations averaged in 5x5 boxes from 1850 to 2010.
- Time series of global mean LST reconstructed only from 1st EOF explains the most part of the observed trend (Red line) as seen in COBE-SST2.
- Contribution : 54.7%

Spatial Pattern of 1st EOF Land Mode

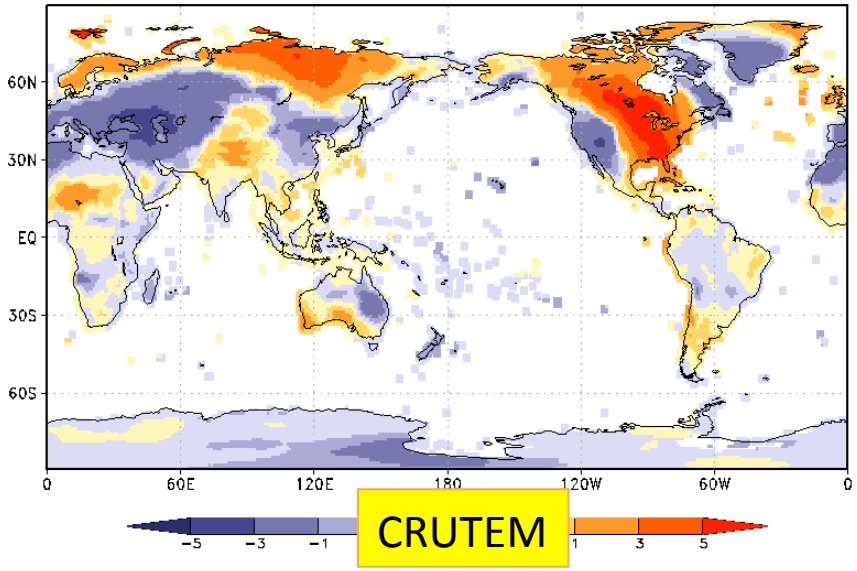


Time Series of 1st EOF Component

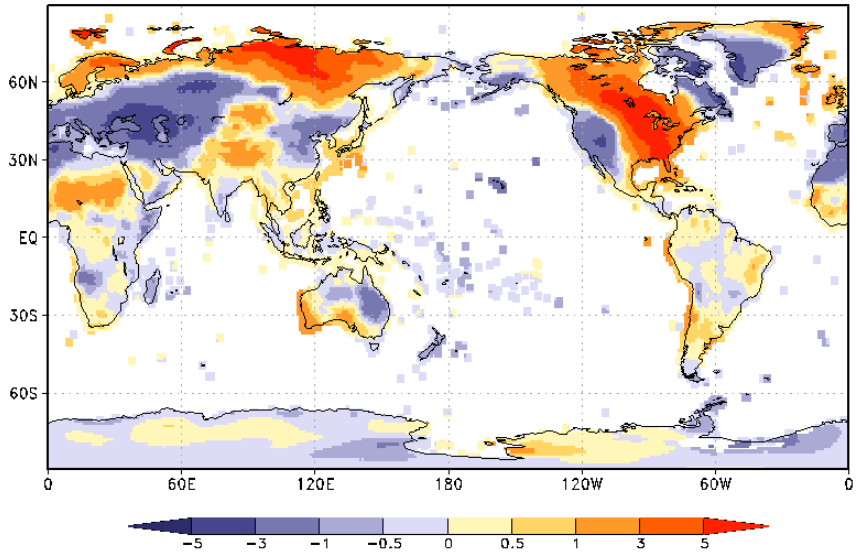


Distribution of Surface Temperature Anomalies (ex. Dec 1931)

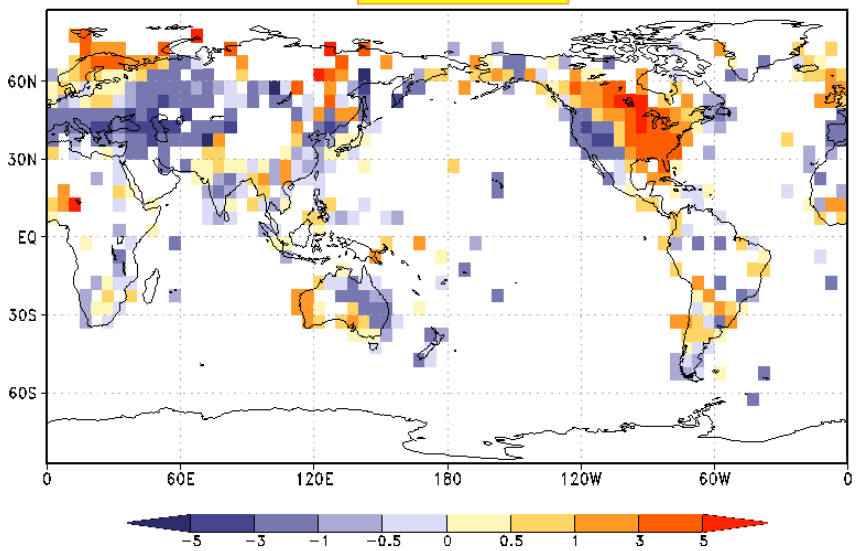
TS_REC



SSTTS_REC

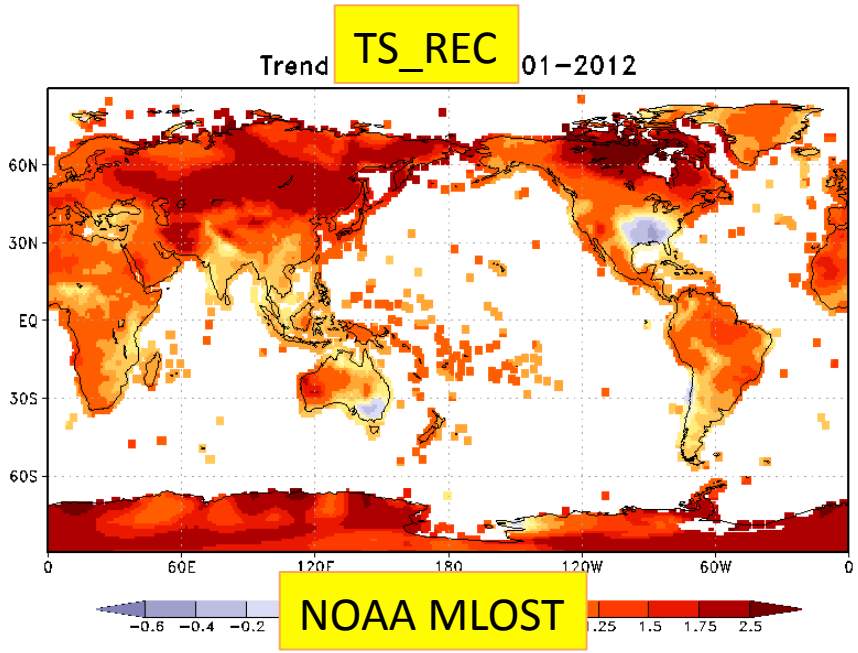


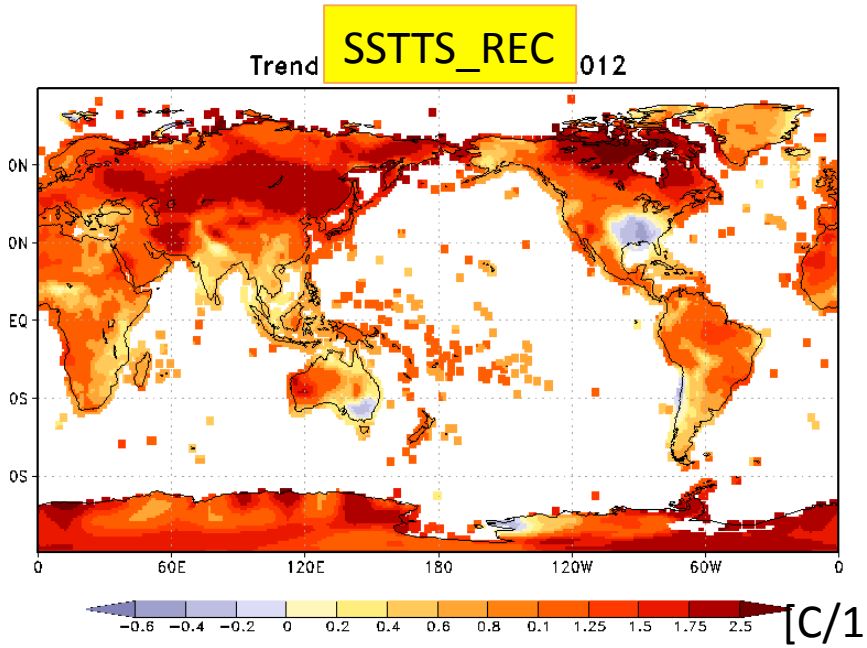
CRUTEM



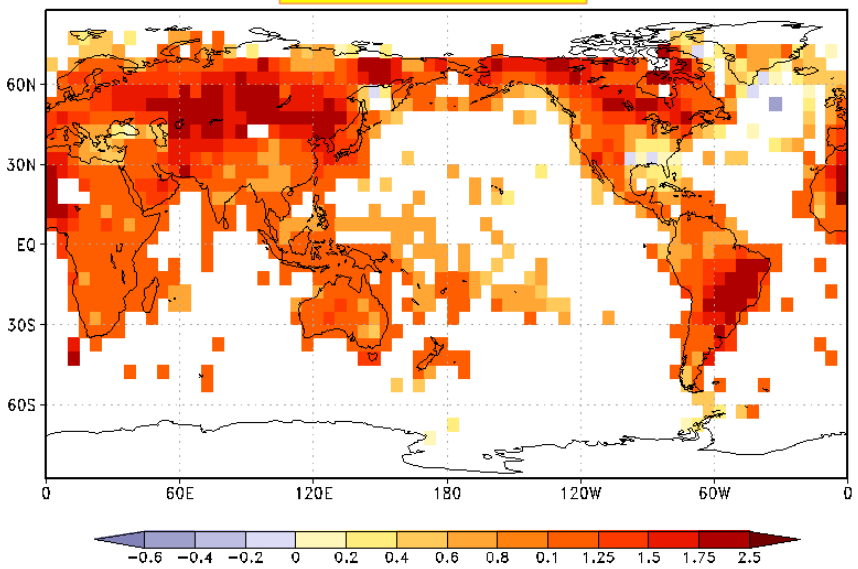
- Smooth spatial patterns can be estimated even if some observation values in ISTI are noisy.
- LST variation can be generated in areas devoid of observations.
- Some differences between TS_REC and SSTTS_REC

Trend Map
1901-2012 (annual)





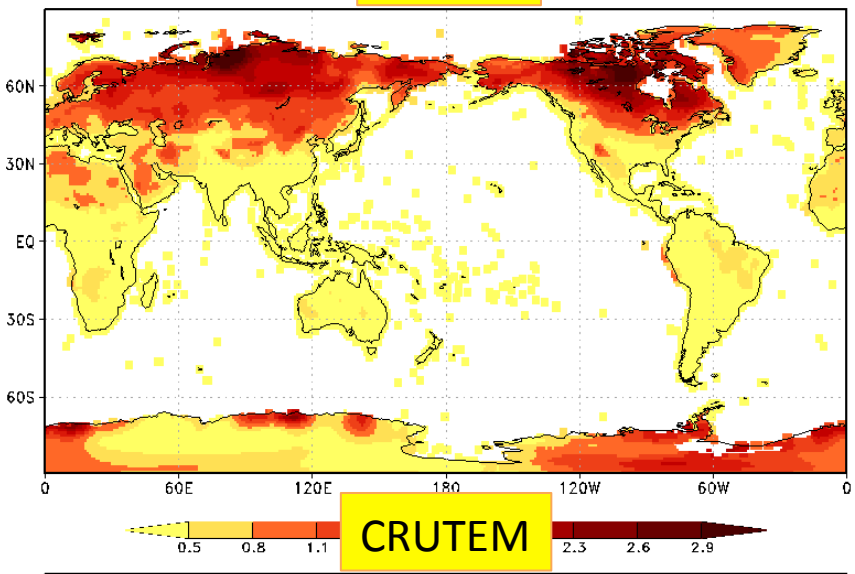
[C/122yr]



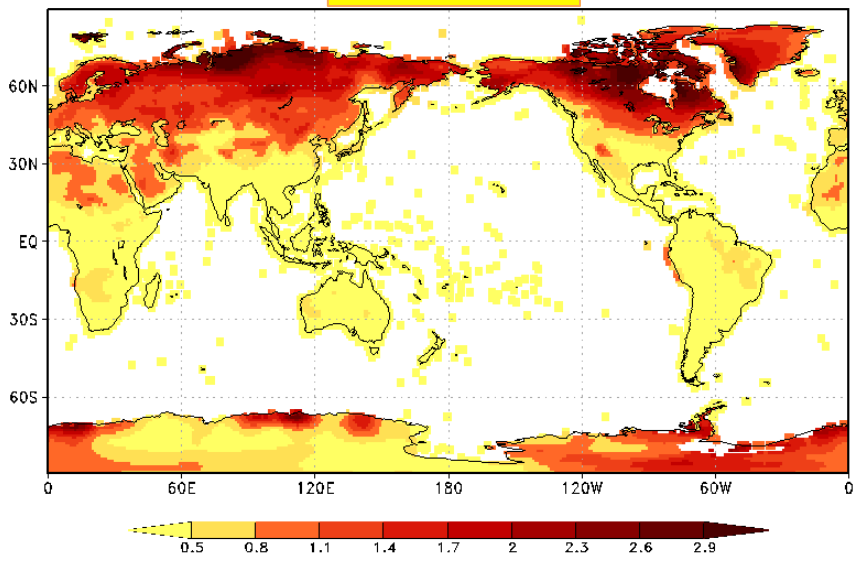
- Good agreement of trends with MLOST globally.
- Three analyses also agree very well over the multi-decadal periods. (1911-1940, 1951-1980, 1981-2012, not shown)

Standard Deviation Map
1981-2012 (annual)

TS_REC



SSTTS_REC



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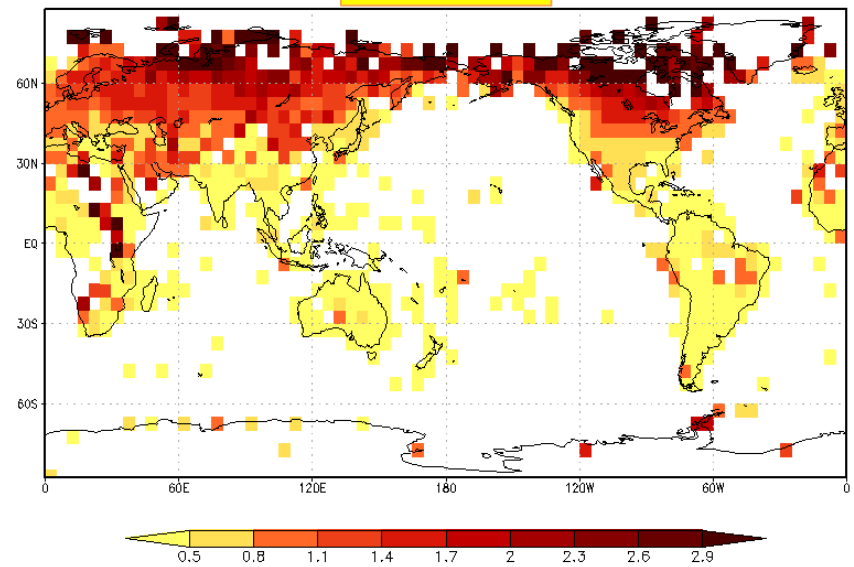
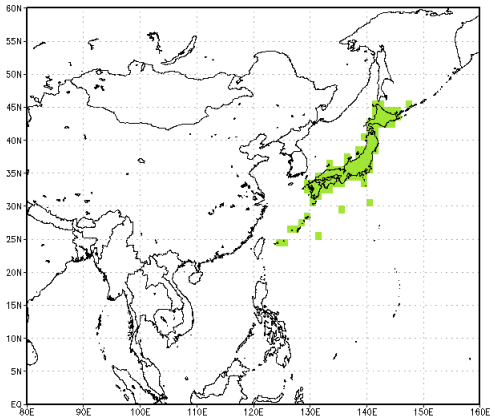
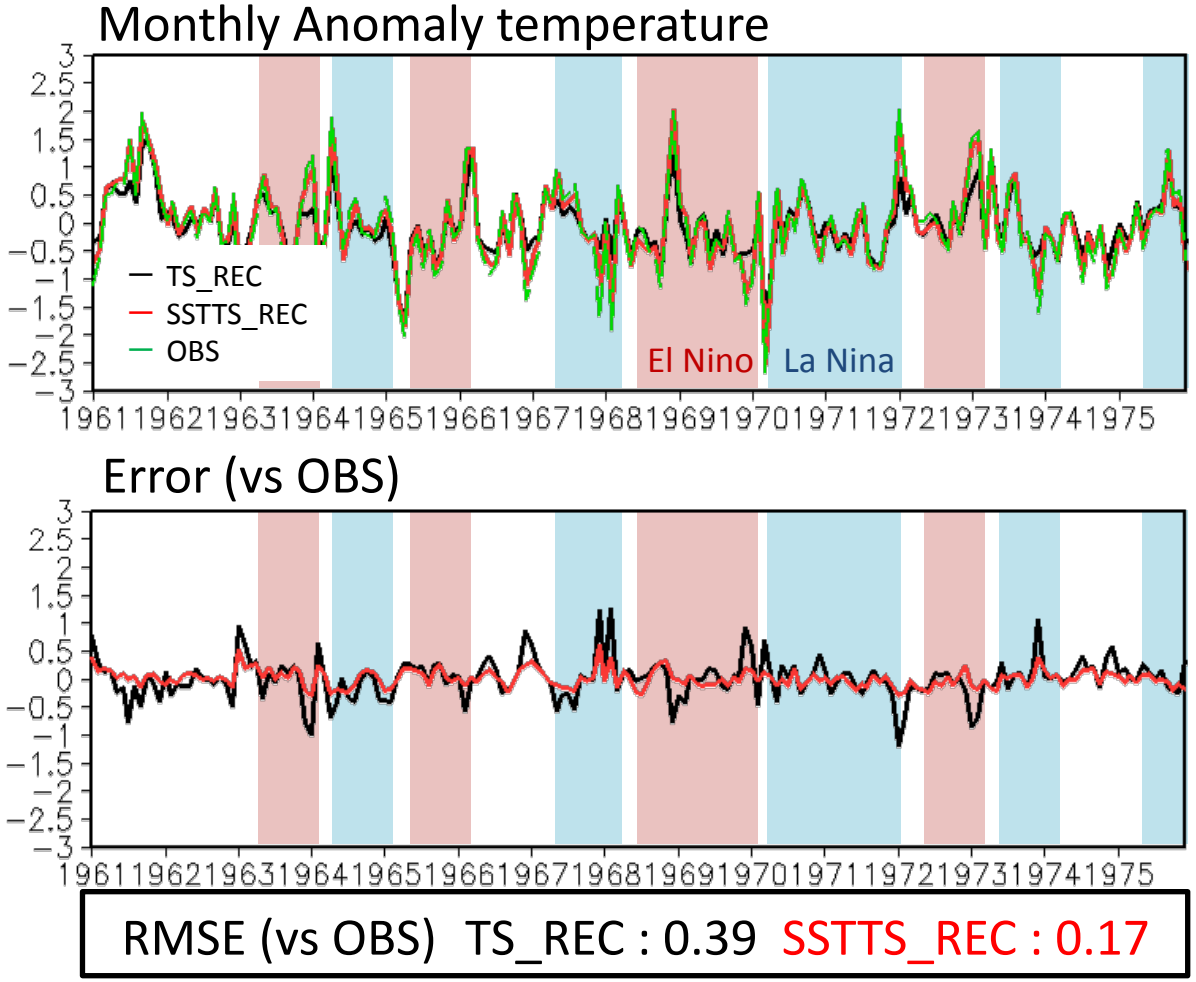


- Regional variations for both TS_REC and SSTTS_REC can be estimated well for recent data-rich decades. (1951-1980, 1981-2012).
- Before these periods, LST variations reconstructed in areas devoid of observations tend to be underestimated (1891-1920, not shown).

Regional average temperature over Japan 1961-1976



OBS is calculated from temperatures at 15 local stations in Japan. Notice that these station data are not independent of ISTI.



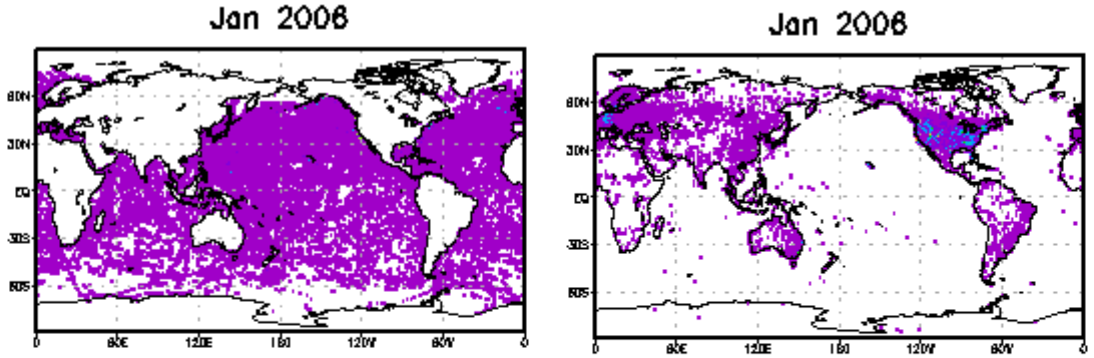
RMSE (vs OBS) TS_REC : 0.39 SSTTS_REC : 0.17

The Inter-annual variations are underestimated in TS_REC. The variations of LST over Japan are estimated better in SSTTS_REC by using SST observations than TS_REC.

Analysis procedure of estimating sampling errors

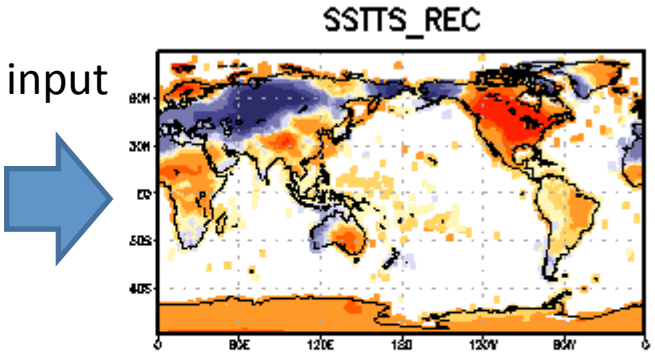
The quality of the analysis depends on the spatiotemporal distribution of the observations. The uncertainty caused by sampling errors is investigated by a cross validation technique.

Original dataset (Jan 2006)



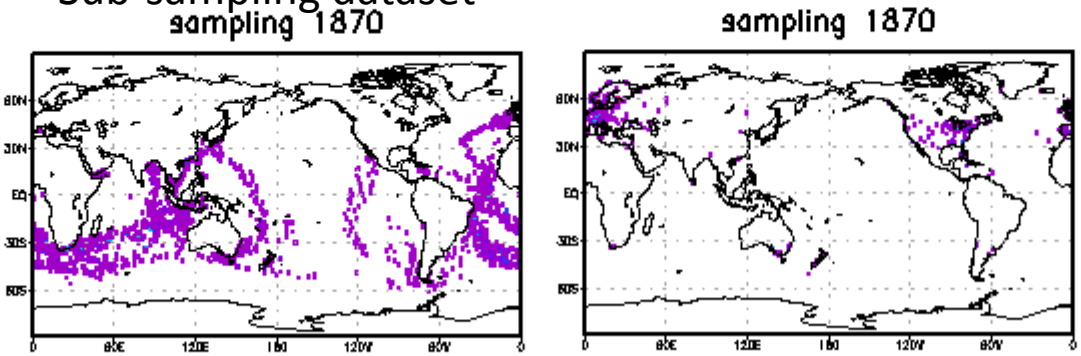
SSTTS_REC with full OBS
Jan 2006

input



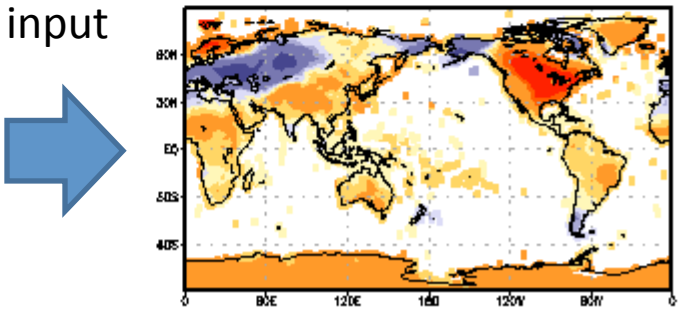
We make a sub-sampling observational dataset whose distributions are similar to those of the past (ex, 1870)

Sub-sampling dataset



SSTTS_REC with Pseudo OBS
Jan 2006

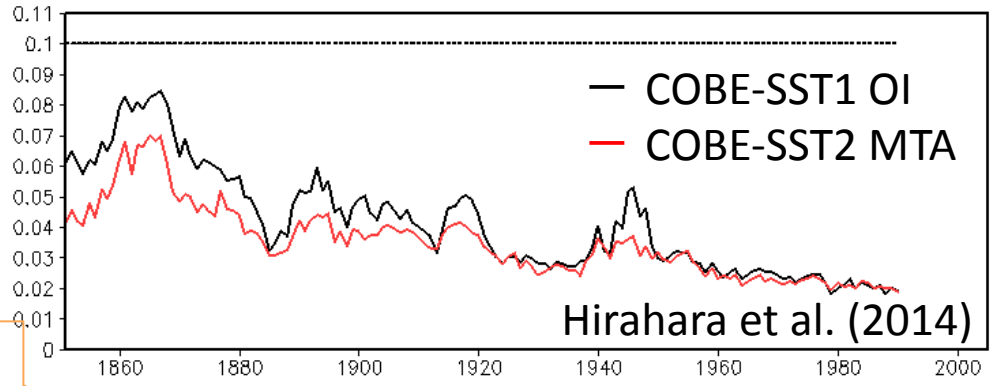
input



How much is two analyses affected by changes in sub-sampling observation?

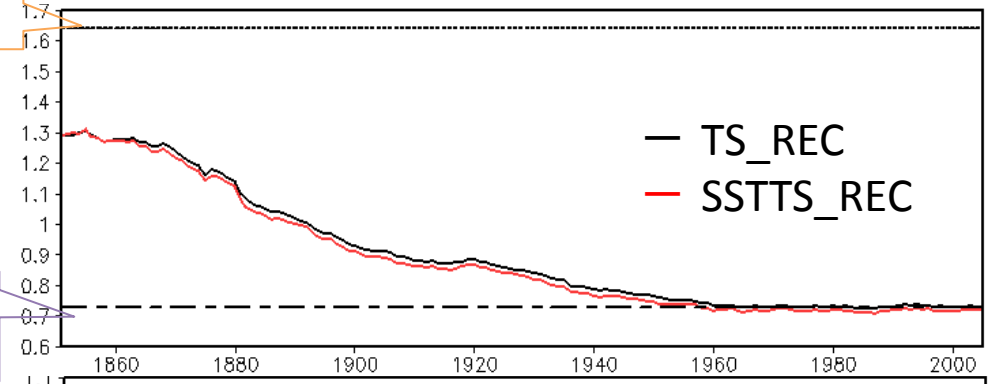
Sampling errors estimate

SST analysis
Global mean RMSE
(vs in situ and satellite)



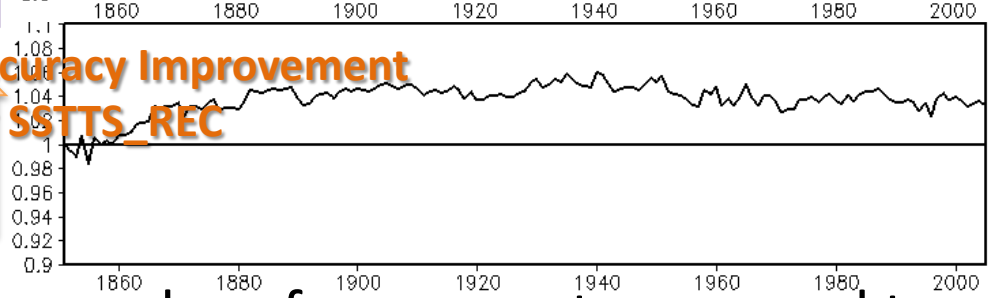
Inter-annual SD
(1961-1990 reanalysis)

LST analysis
Global mean RMSE
(vs reanalysis)



Global mean RMSE (full analysis vs reanalysis)

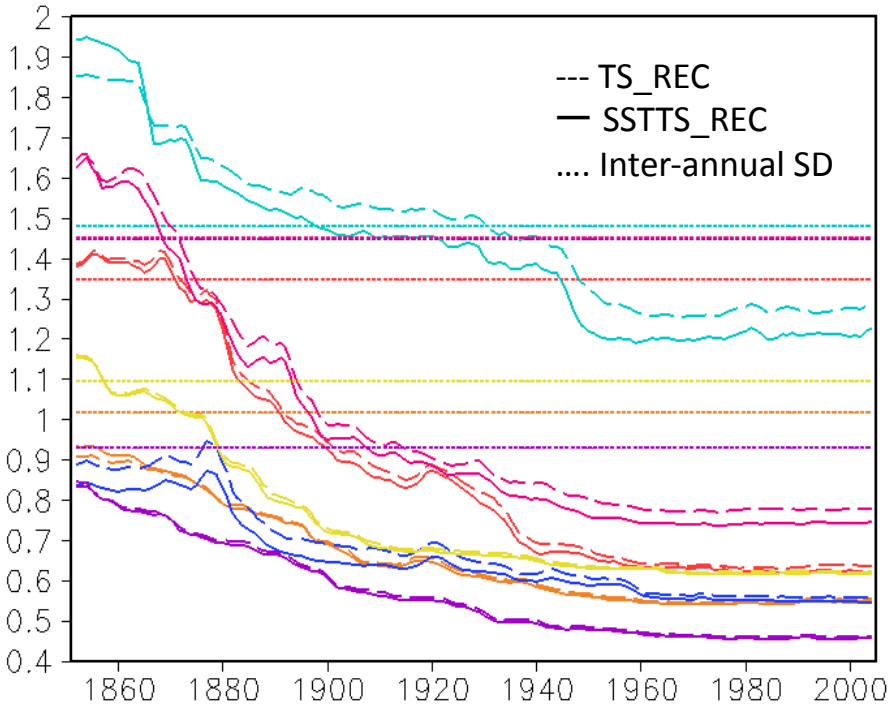
The ratio SSTTS_REC : TS_REC



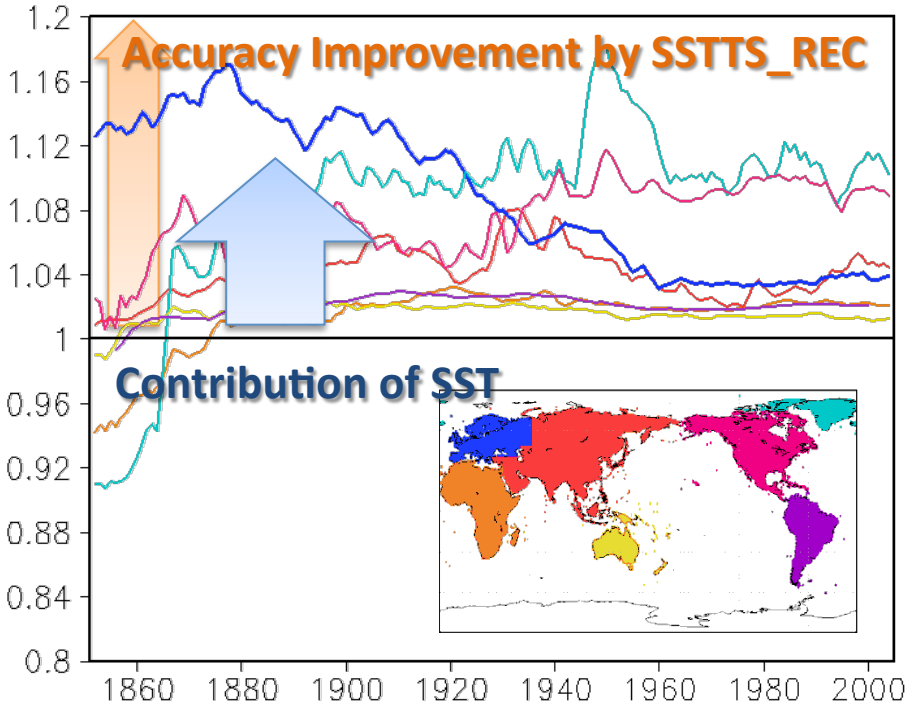
SSTTS_REC improves LST accuracy by a few percent compared to TS_REC. This suggests that LST analysis with SST observations is likely to produced more accurate.

Sampling errors estimate

RMSE (vs reanalysis)
for each continents



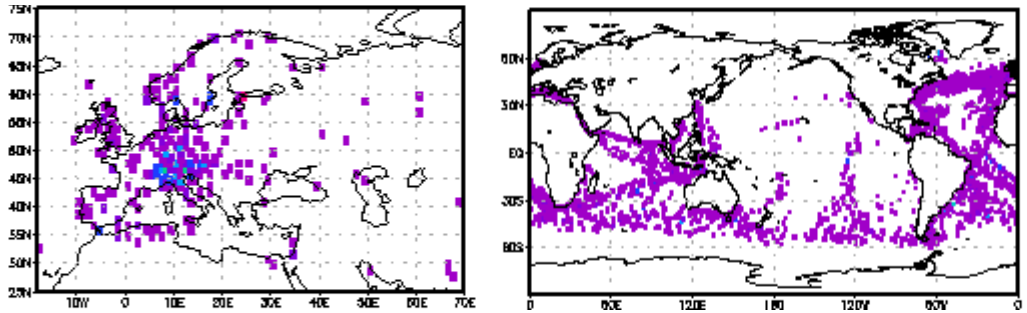
The ratio SSTTS_REC : TS_REC
for each continents



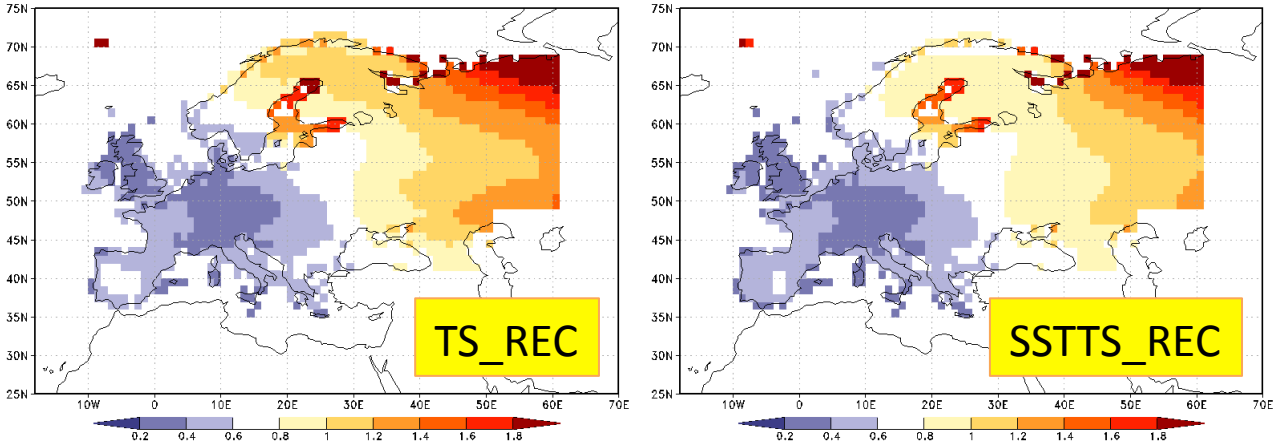
The improvement by the use of SST observations appear from the 1870. SST observations are helpful to produced more accurate in data-sparse periods. For recent decades, the accuracy is mostly dominated by rich observations on land.

Why is the result of Europe better?

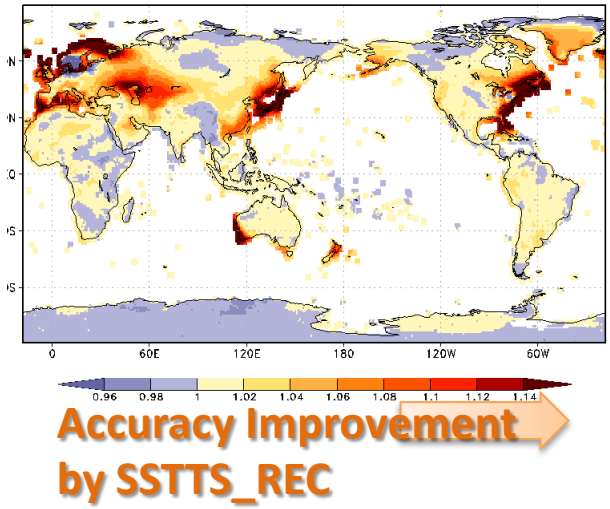
Pseudo analyses with sub-sampling observational dataset
(Similar to distributions in the 1880)



RMSE (vs Reanalysis) for Europe



The ratio SSTTS_REC :
TS_REC (global)



SST observations contribute to accuracy in LST data-sparse area. But it is suggested that SST observations can improves LST accuracy under the conditions where minimum number of LST observation is available.

Summary

- We applied the reconstruction method of COBE-SST2 (Hirahara et al. 2014) to LST analysis with ISTI.
- TS_REC and SSTTS_REC can reproduce the trends and inter-annual variations of LST well mostly over the past 150 years.
- We demonstrated that SSTTS_REC can improves LST accuracy more than TS_REC. Meanwhile it is unclear whether SST analysis of SSTTS_REC becomes better than COBE-SST2 (figures not shown this time).