MARCDAT-III May 2011 Frascati, Italy

A new historical SST analysis: COBE2-SST

Shoji Hirahara*, Yoshikazu Fukuda

Global Environment and Marine Department
Japan Meteorological Agency

Masayoshi Ishii

Meteorological Research Institute / JAMSTEC

COBE
Centennial in-situ Observation-Based Estimates Of variability of SST and marine meteorological variables

気象庁
Japan Meteorological Agency

気象研究所

JAMSTEC
海洋研究開発機構
Japan Agency for Marine-Earth Science and Technology

Outline

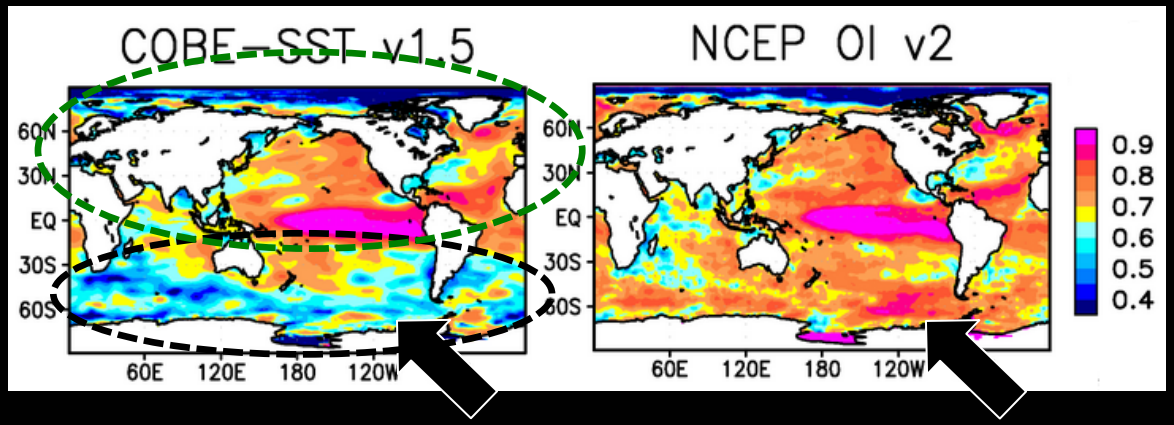
1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

Outline

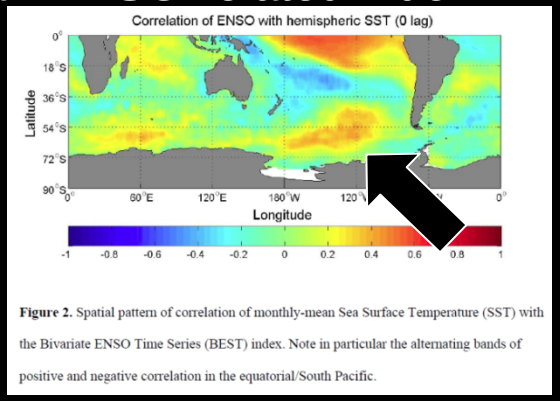
1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

Motivation

1-Month Autocorrelation (1982-2006)



Regression coefficients on an ENSO-related index



Meredith et al. (2008)

- El Nino drives long-lasting (~2yr) positive SST anomaly at the south-eastern part of the South Pacific through the "Atmospheric Bridge".
- Also, ice edge retreat associated with this warm SST has been observed (Kwok and Comiso 2002)
- COBE1-SST has much less persistence when compared with satellite-based SST datasets (here, NCEP OI v2).

- Need to introduce satellite observations/EOF reconstruction technique to improve reproducibility of SST persistence and variation in the Southern hemisphere

Basic Spec. of COBE2-SST

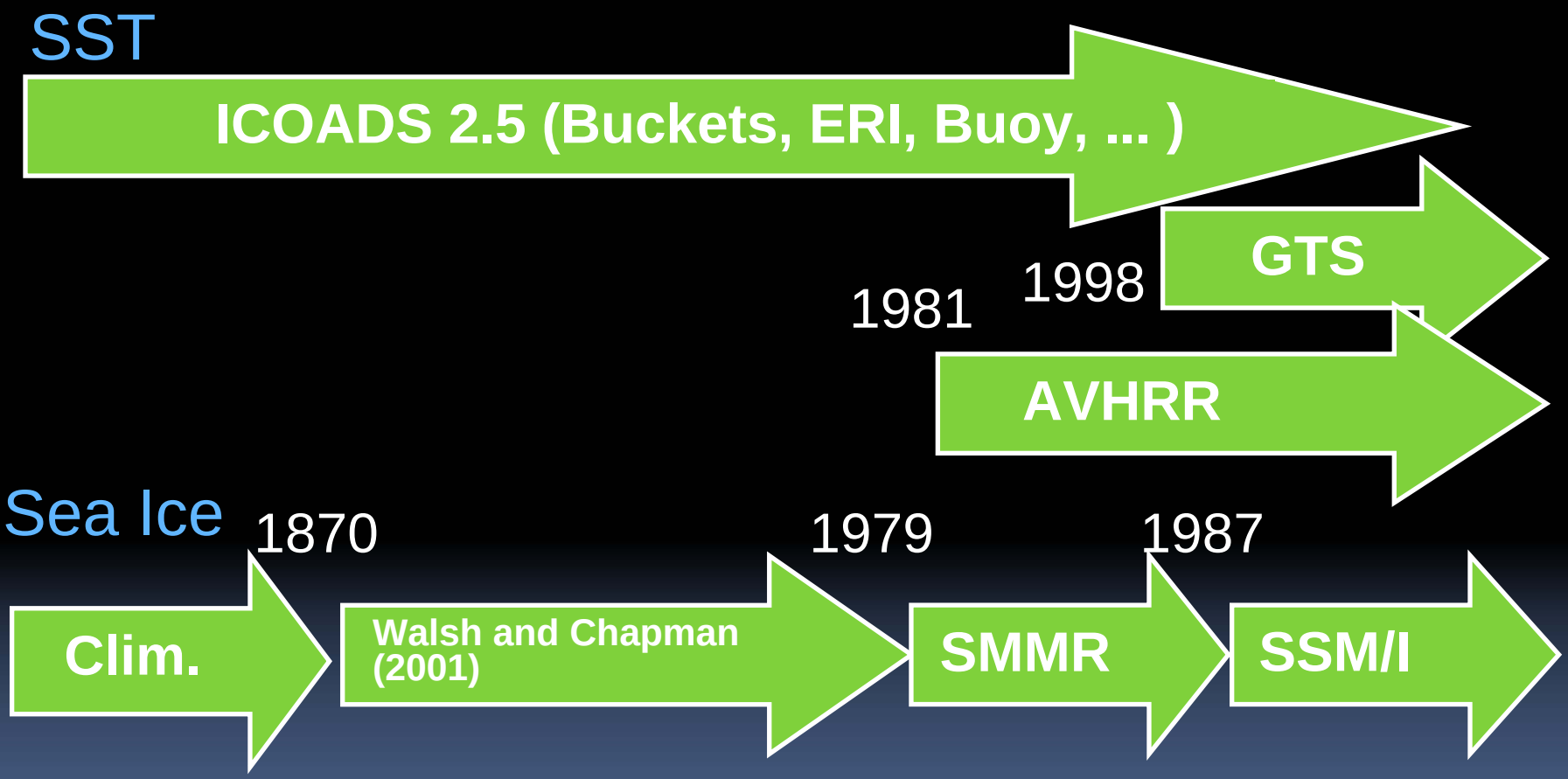
Version	Observation	Analysis Method	Others
COBE1 (Ishii et al. 2005)	❑ In-situ SST ▪ ICOADS 2.0*1 ▪ Kobe Collection*2 ❑ Satellite Sea Ice ▪ SSMR (NASA team Algorithm*3) ▪ SSM/I (NASA team Algorithm)	❑ Optimal Interpolation (OI)	❑ Buckets Bias Correction (Folland and Parker 1995)
COBE2 (Dev. Ver.)	❑ In-situ SST ***Updated!*** ▪ ICOADS 2.5*4 ❑ Satellite SST ***New!*** ▪ AVHRR pathfinder*5 ❑ Satellite Sea Ice ▪ SSMR (NASA team algorithm) ▪ SSM/I (Bootstrap Algorithm*6 ***New!***)	❑ Multiple timescale estimates (MTE) with OI and EOF reconstruction ***New!***	❑ AMIP2-type reference climatology*7 ***New!*** ❑ Salinity-dependent ICE-SST transformation ***New!*** ❑ Buckets Bias Correction for the period after the WW-II ***To Be Done!***)

1. Worley et al. (2005) 2. Manabe et al. (1999) 3. Cavalieri et al. (1984) 4.Woodruff et al.(2011)
5. NODC 6.Comiso (1986) 7.Taylor (2000)

Outline

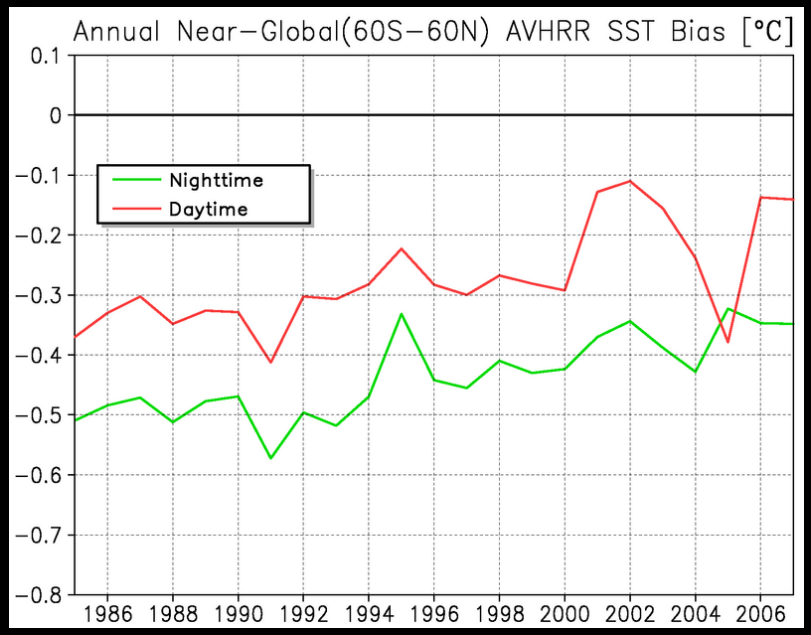
1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

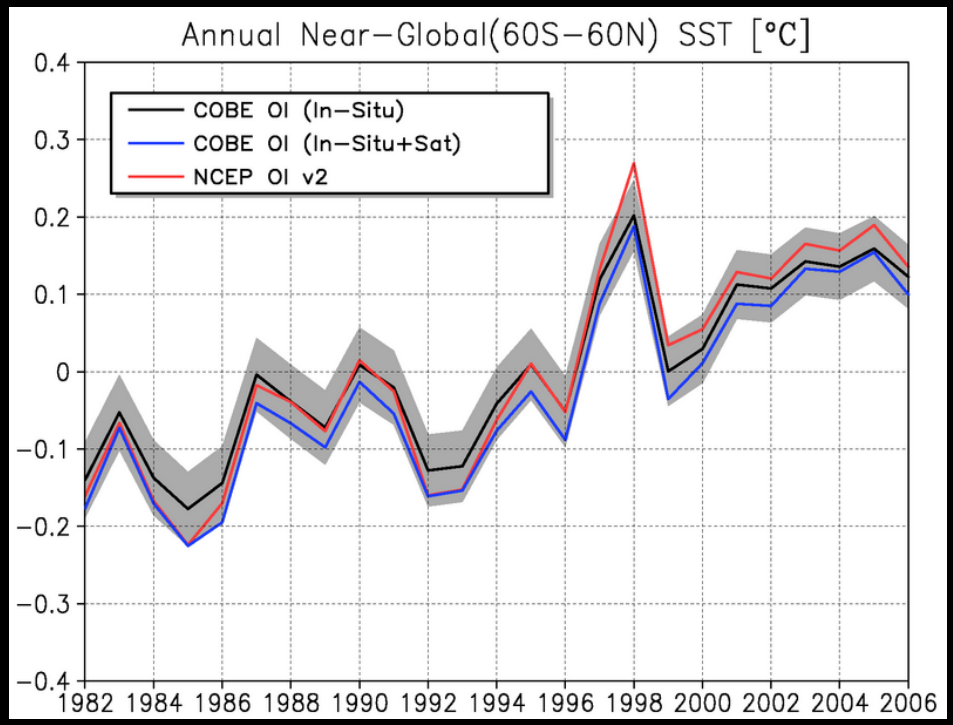
Observational Data Sources To be Used



- Various types of observation are all mixed up together
- Bias corrections for various measurement methods are inevitable for creating a historically consistent product

AVHRR Bias Adjustment





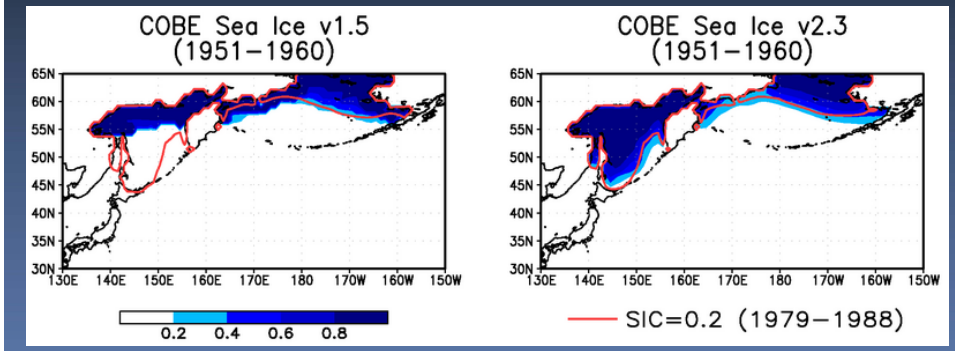
- To adjust AVHRR satellite bias, matchup data against in-situ observations (ships and buoys) are generated seperately for ascending(daytime) data and descending(nighttime) data.
- Matchup data are analyzed with OI to make a gridded bias field

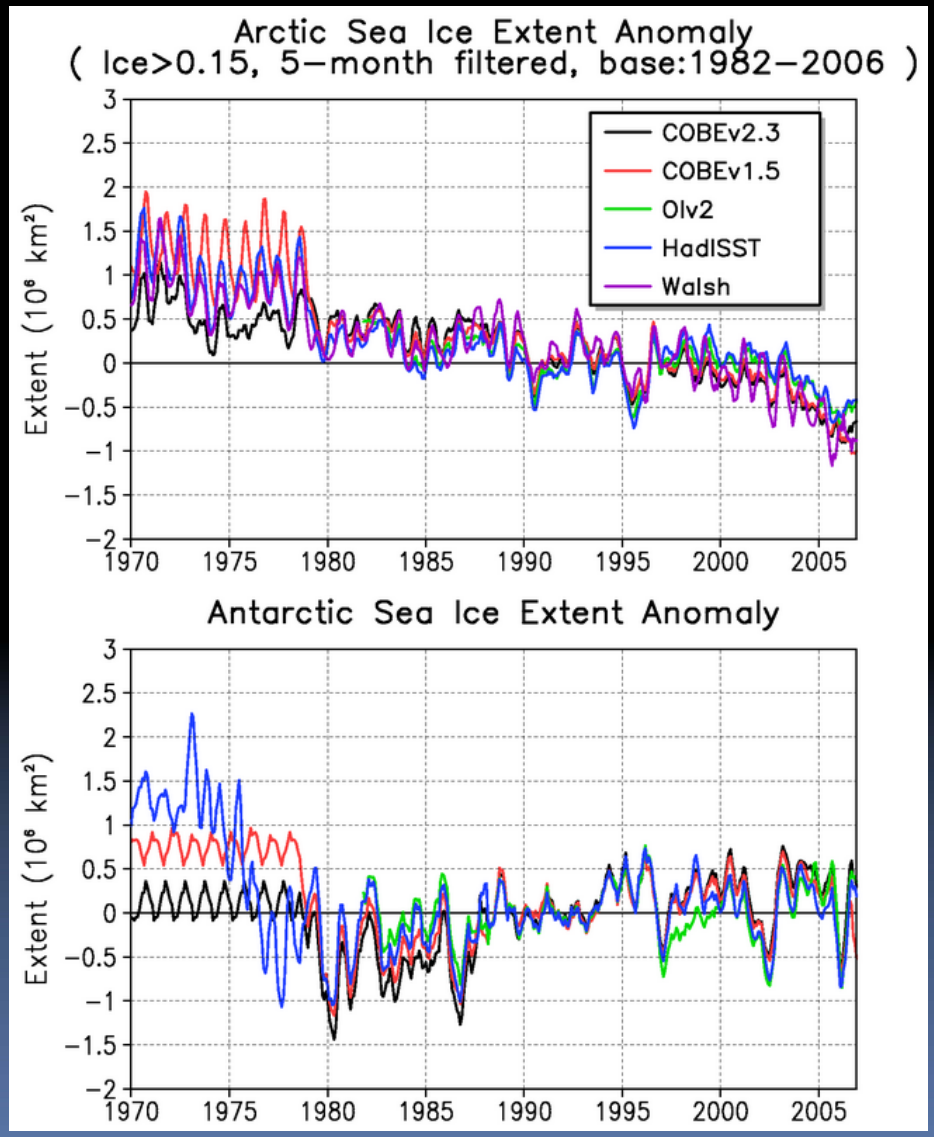
⇨

- AVHRR biases are estimated to be 0.1~0.4 for daytime data, and 0.3~0.6 for nighttime data
- Introduction of satellite observation affects global mean SST little, as long as its biases are properly removed.

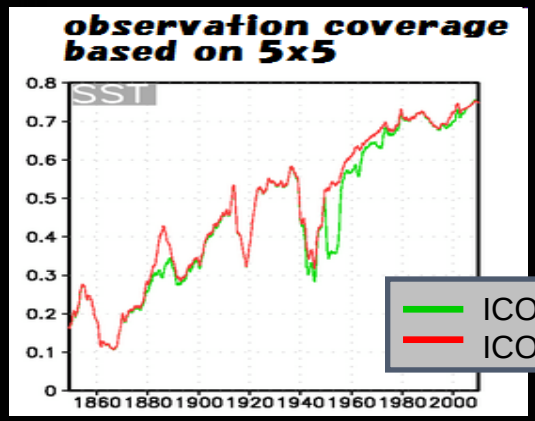
Connecting satellite-derived Sea Ice to WC01

- SMMR(1979-1987) is adjusted to the level of SSM/I (1988-)
- Walsh and Chapman(2001) is a SIC dataset for the Arctic, which blends land/sea observations or handwritten charts
- A sudden decrease of sea ice in 1979 is corrected by adding a mean difference between before/after 1979.



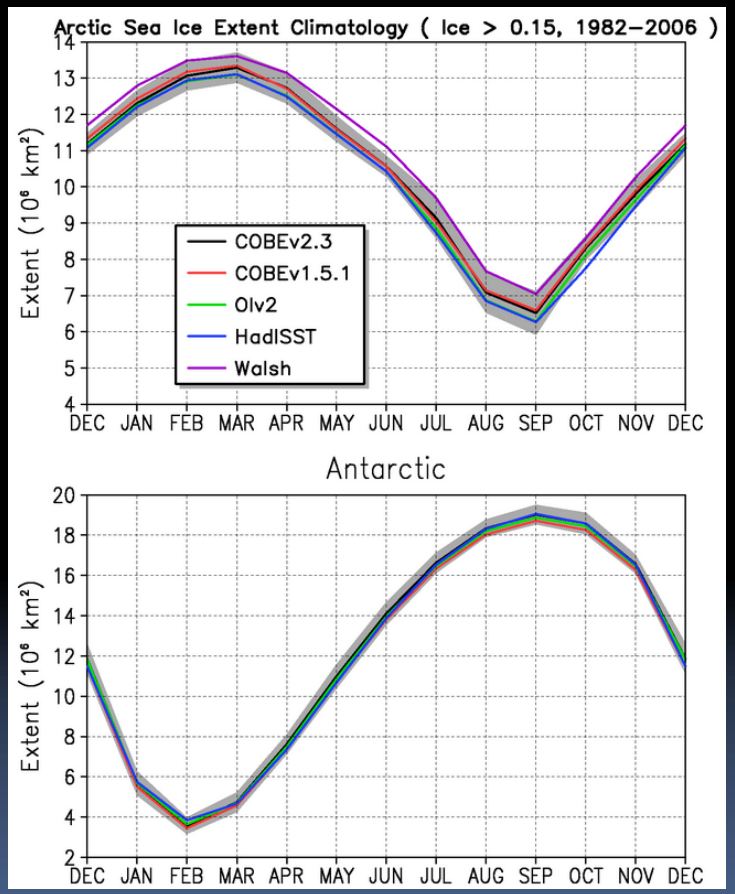


Other modifications



Improved observation coverage

Introduction of Bootstrap Algorithm to SSM/I sea ice concentration



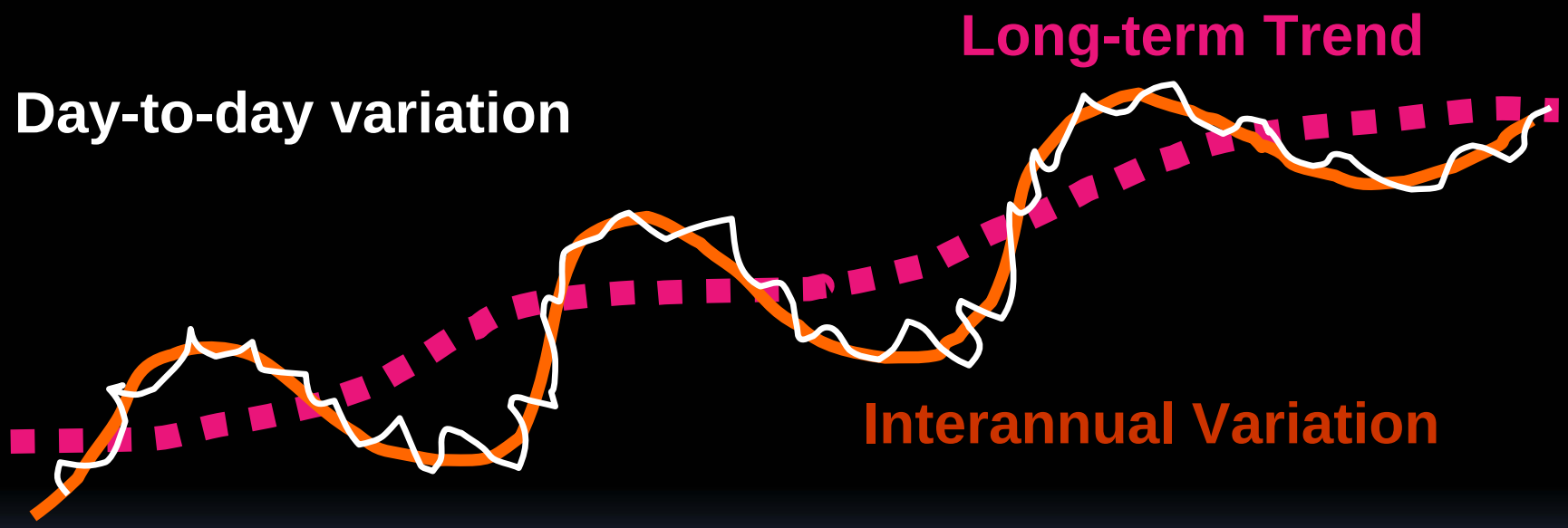
Boosted seasonal cycle for a refference SST climatology (Taylor et al. 2001)

Outline

1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

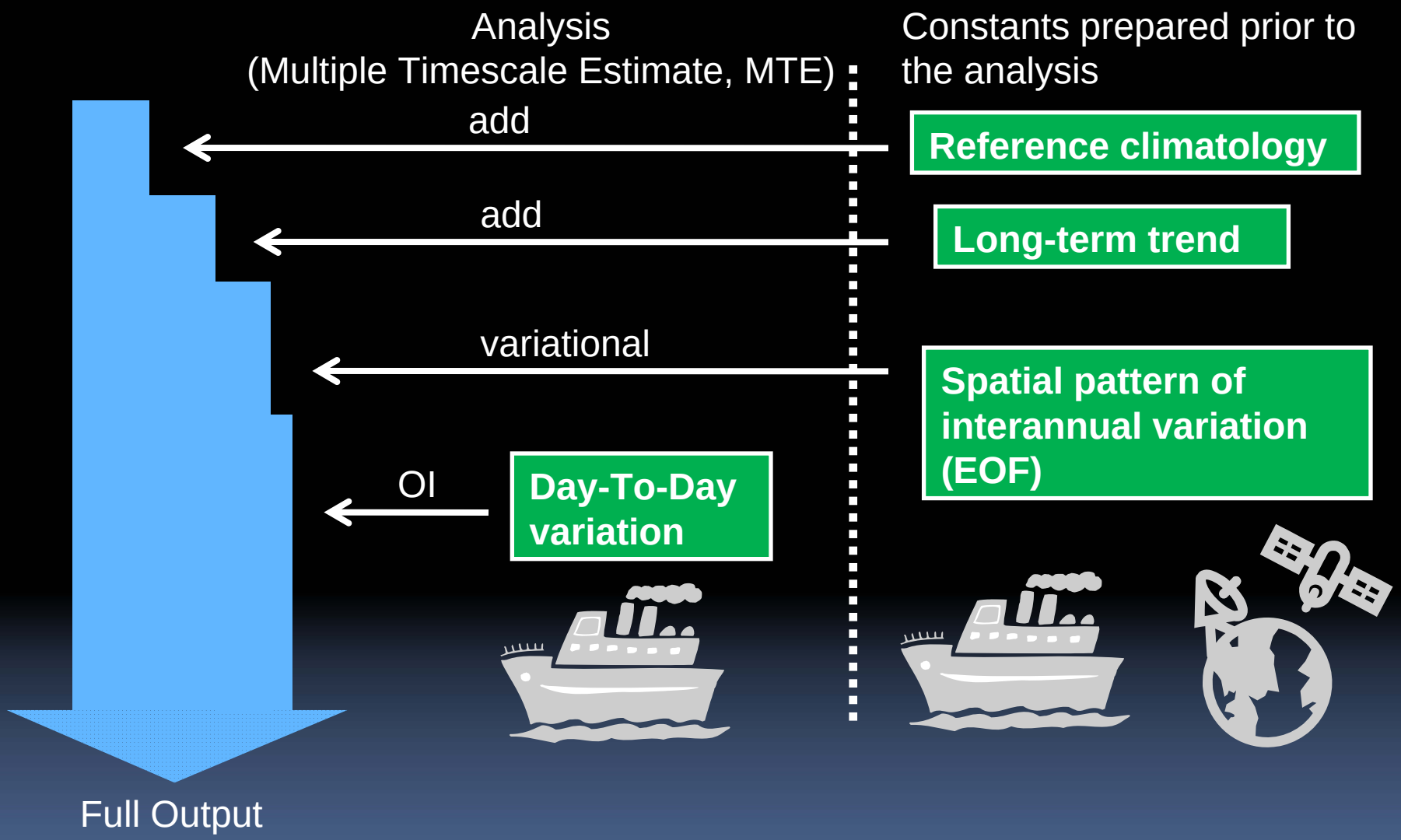
Multiple Time Scale Estimates with OI and EOF Reconstruction

$$T_a(n) = T_c(n) + \delta T_c(n) + \delta T_a^{rec}(n) + \delta T_a^{day}(n)$$



- Long-Term Trend : 1st EOF mode on 5x5 SST anomaly fields (δT_c)
- Interannual Variation : 1x1 EOFs calculated with both in-situ and satellite observations, 1961-2005, explains 90% of residual variance (δT_a^{rec})
- Day-To-Day Variation : Defined as an increment from previous day, analyzed by the Opimal Interpolation Method, 10% of residual variance (δT_a^{day})
- With an Analysis Error Estimation

Analysis Procedure



➢Satellite SST observation is not used for historical analysis but it's used only for creating temporally constant variables

EOF Reconstruction and Analysis Errors

Background error covariance:

$$\mathbf{P}^f = \mathbf{F}\mathbf{L}\mathbf{F}^T$$

Minimize the following cost:

$$J = \mathbf{x}^T \left(\mathbf{P}^f\right)^{-1}\mathbf{x} + \left(\mathbf{y}-\mathbf{H}\mathbf{x}\right)^T \mathbf{R}^{-1}\left(\mathbf{y}-\mathbf{H}\mathbf{x}\right)$$

Analysis error :

$$\mathbf{P}^a = (\mathbf{I}-\mathbf{K}\mathbf{H})\mathbf{P}^f$$

$\mathbf{P}^a$	Analysis Error Covariance Matrix
$\mathbf{P}^f$	Background Error Covariance Matrix
$\mathbf{R}$	Observation Error Covariance Matrix
$\mathbf{I}$	Unit Matrix
$\mathbf{K}$	Optimal Weight matrix
$\mathbf{H}$	Observation Operator matrix
$\mathbf{L}$	Eigenvalue matrix
$\mathbf{F}$	Eigenvector matrix
$\mathbf{x}$	Optimal solution vector

$$\mathbf{K} = \left\{\left(\mathbf{P}^f\right)^{-1} + \mathbf{H}^T\mathbf{R}^{-1}\mathbf{H}\right\}^{-1}\mathbf{H}^T\mathbf{R}^{-1}$$

Rewritten as :

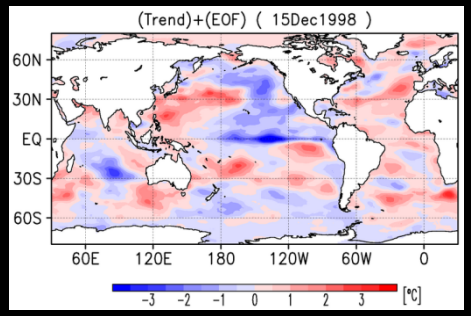
$$\mathbf{P}^a = \mathbf{F}(\mathbf{L}^{-1}+\mathbf{B})\mathbf{F}^T$$

where

$$\mathbf{B} = \mathbf{F}^T\mathbf{H}^T\mathbf{R}^{-1}\mathbf{H}\mathbf{F}$$

A snapshot of a Daily Output

(Dec. 15, 1998)

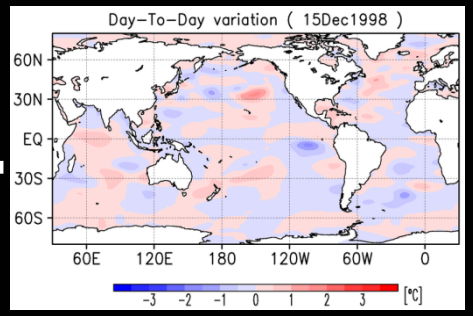


(Long-Term Trend)

+

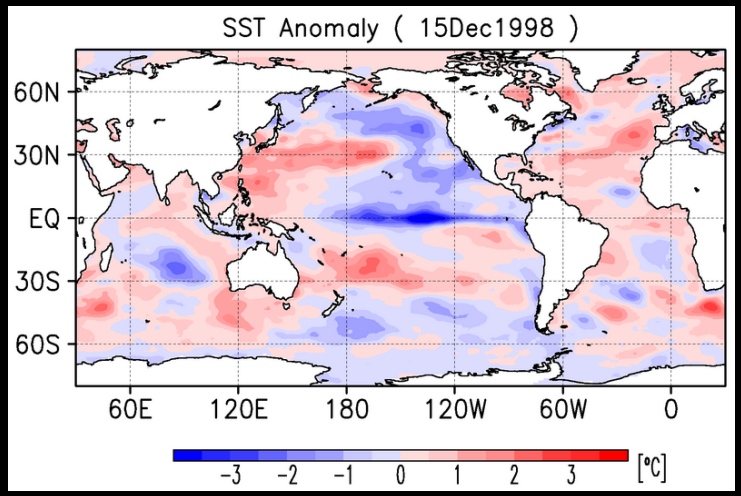
(Reconstructed 31-day mean field centered at the analysis date)

+

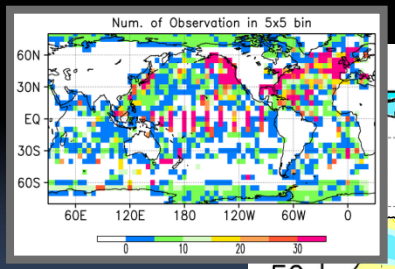


(Day-To-Day Variation)

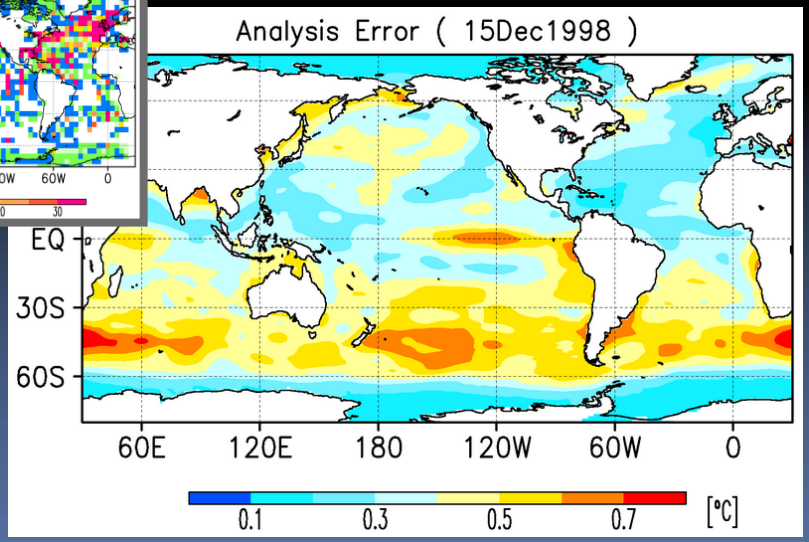
=



(Full Daily Output)



(Observation)



(Analysis Error)

Outline

1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

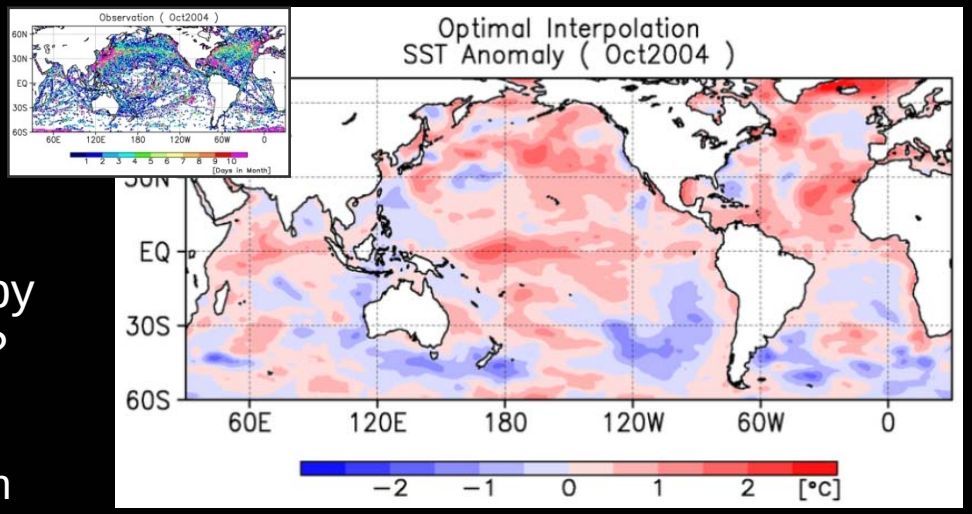
Strategy for Evaluating the new analysis scheme

EOF reconstruction yields substantial variances even in data-sparse areas, but almost zero anomalies in OI.

How much is our product affected by changes in observation distribution?

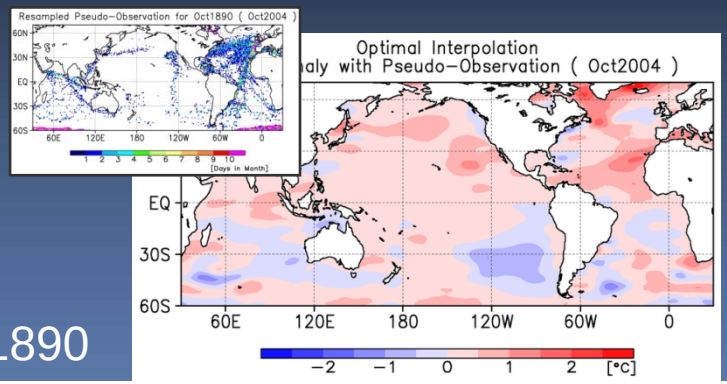
To emulate the observational network in 1890, we extract samples at the nearest position in time and space from 2004

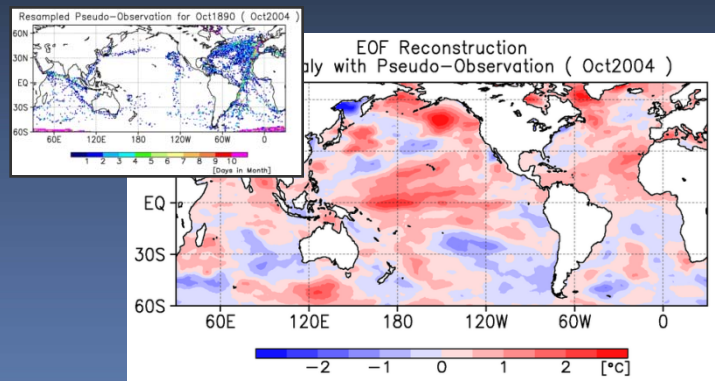
"True" SST anomaly analyzed with OI (Oct. 2004)



Previous analysis method (OI)

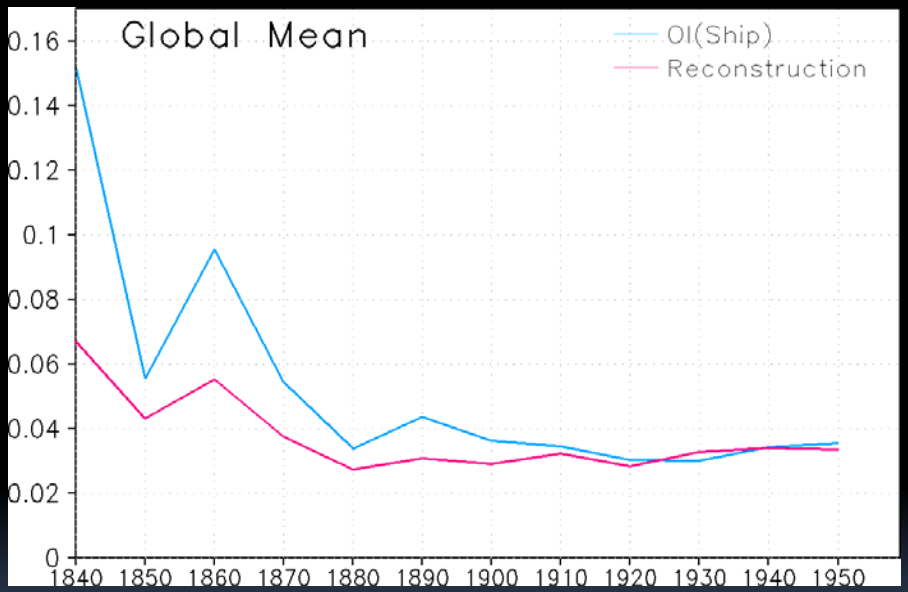
New Method (MTE)

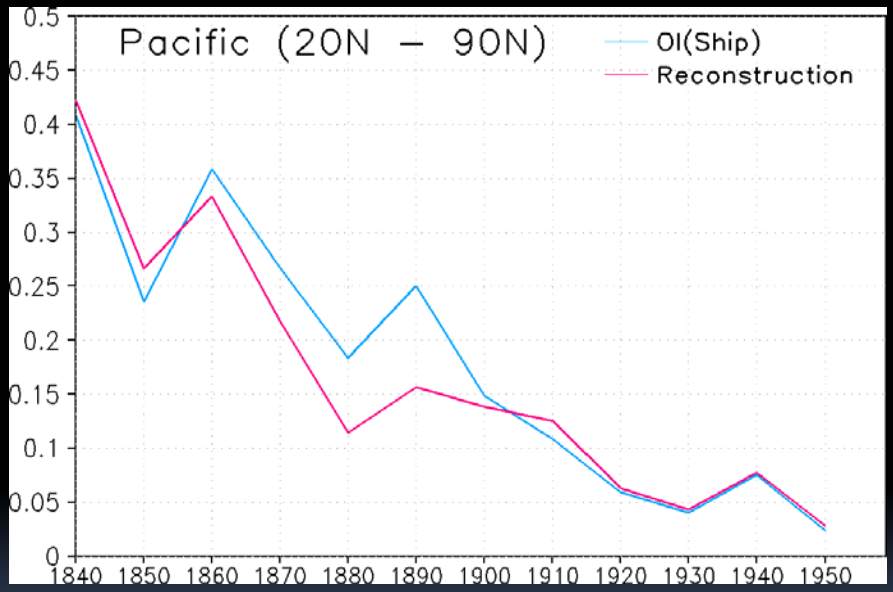




Oct.1890

Cross Varidated Performance for the newly introduced analysis method



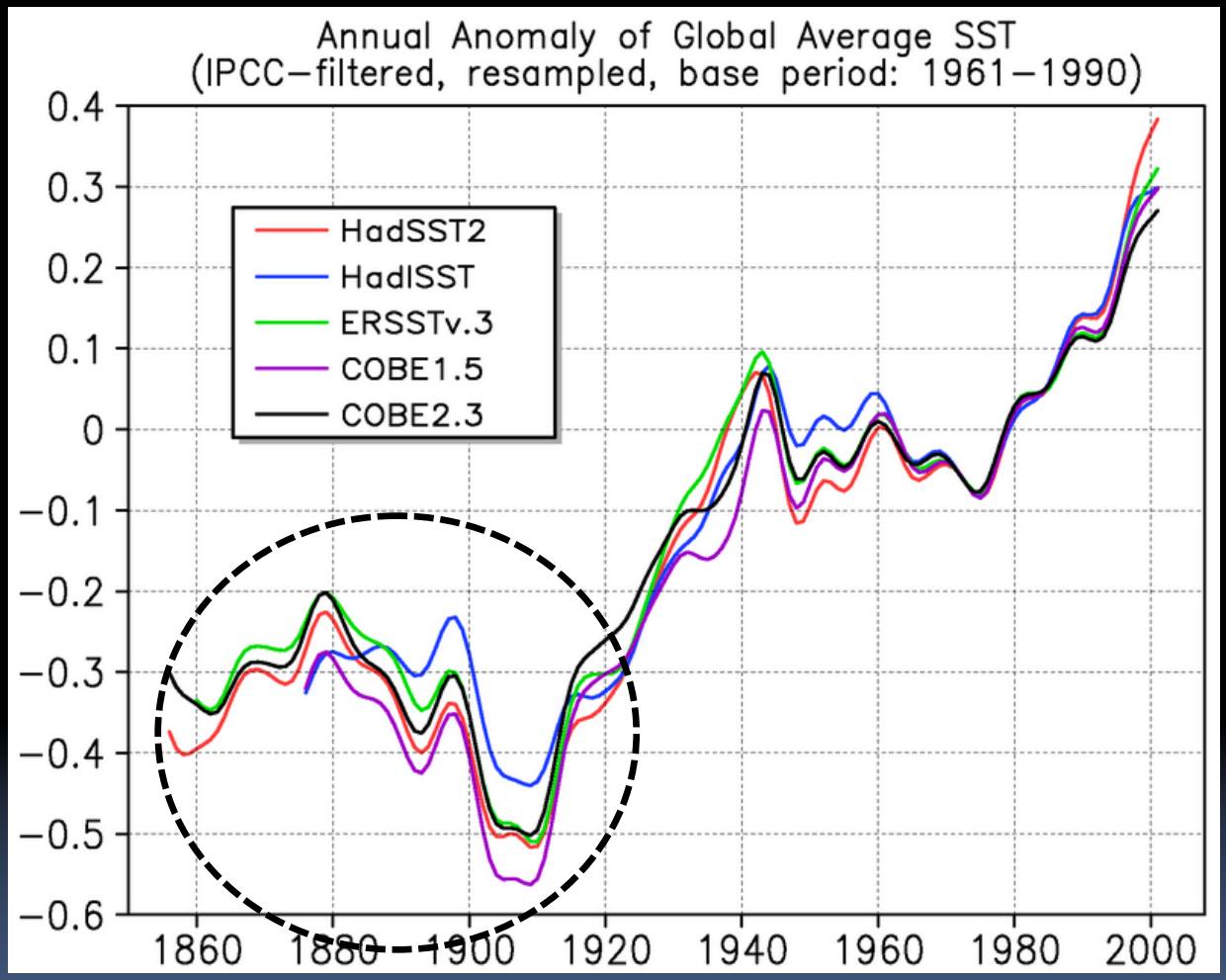


- Global means are shown to be better in MTE than in OI
- Also, MTE raises reliability of regional average over the North Pacific, where observation is relatively rich in number

Outline

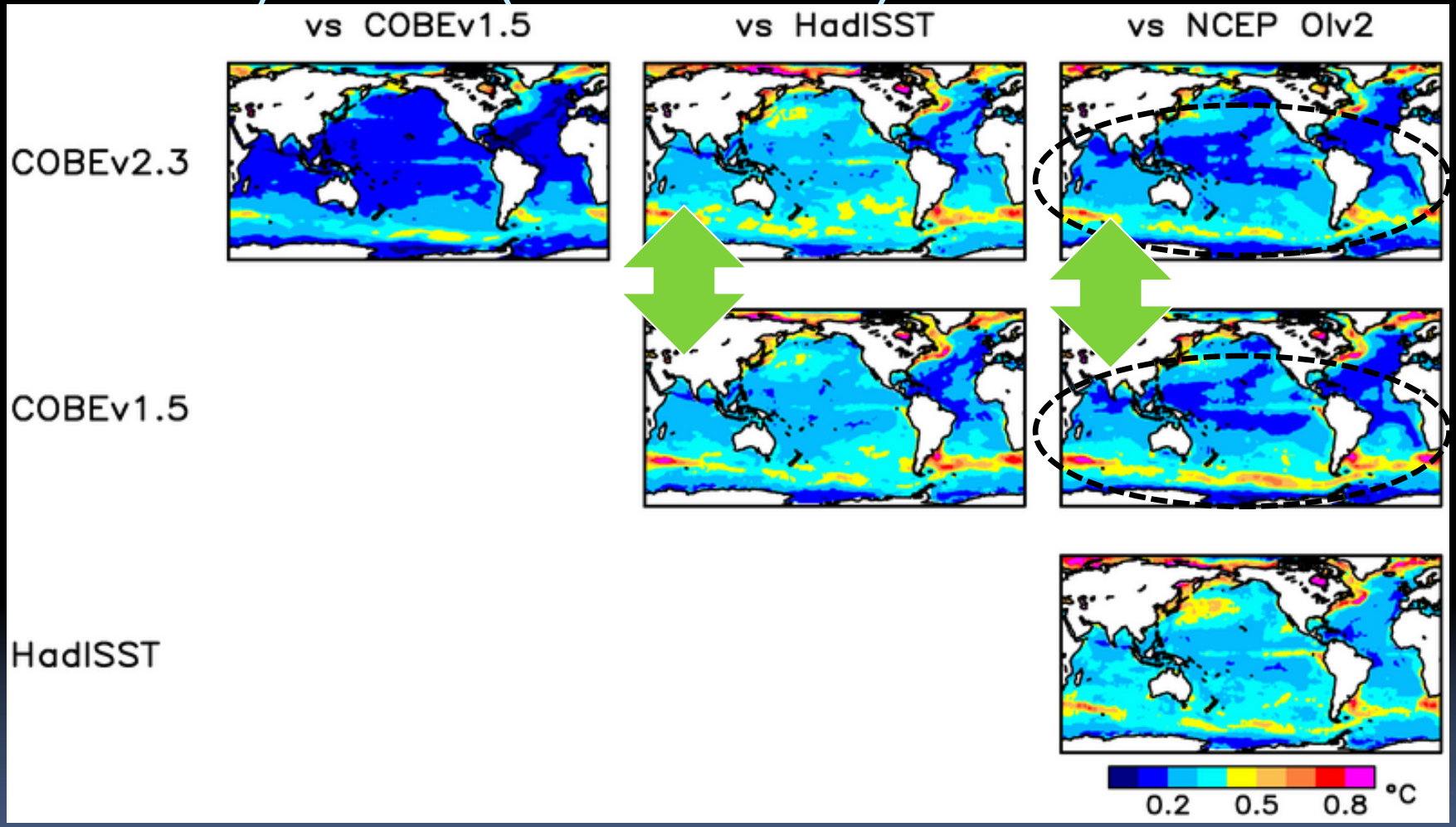
1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

Global Average SST



- Better agreement with HadISST and ERSSTv3
  - A slight decrease in analysis uncertainty

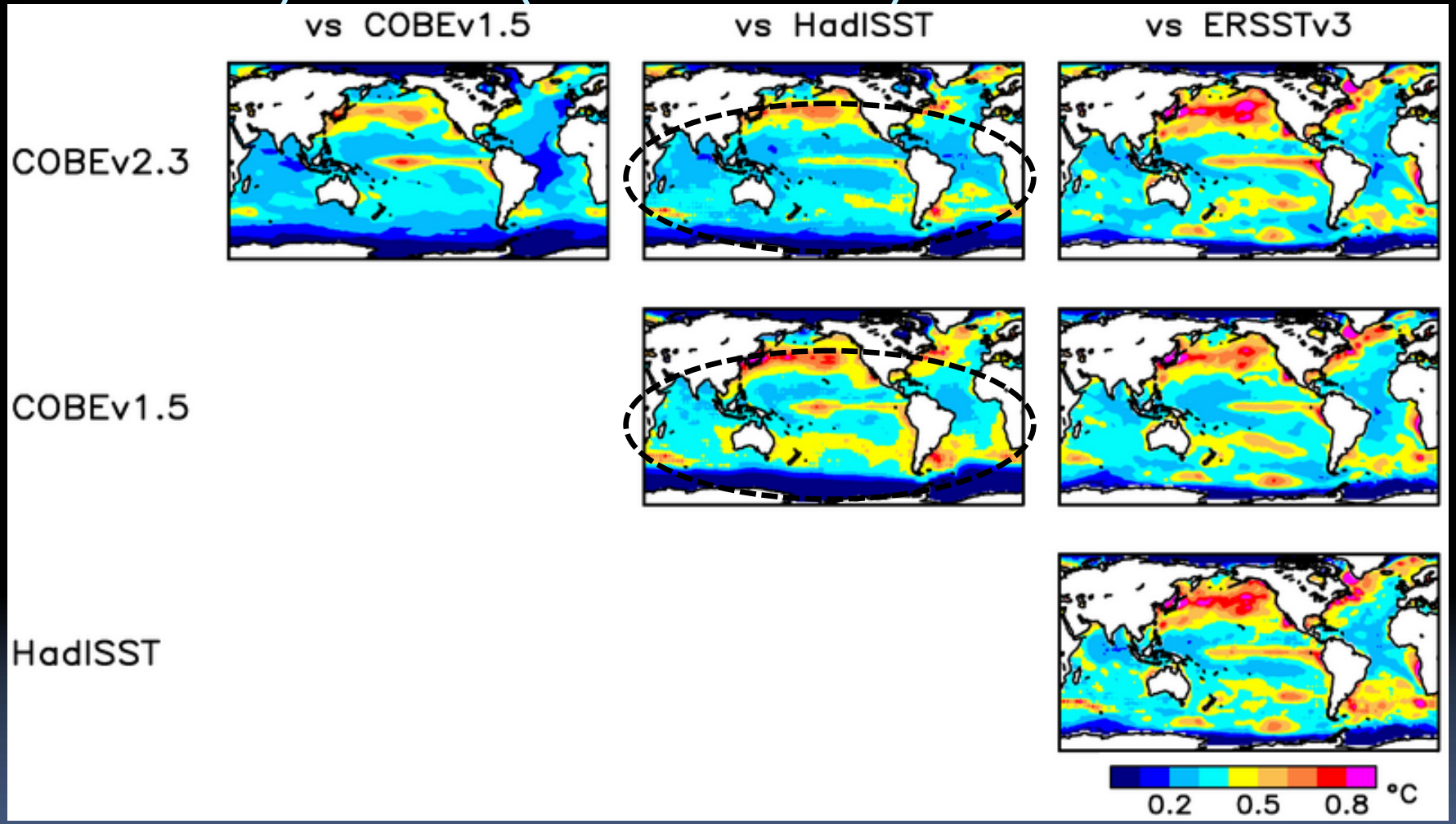
Root Mean Square Differences between the monthly SSTs (1982-2006)



Root mean square differences of monthly SST anomaly between the every pair of SST datasets

- Better agreement of the interannual variation with the other datasets, particularly with NCEP OIv2.

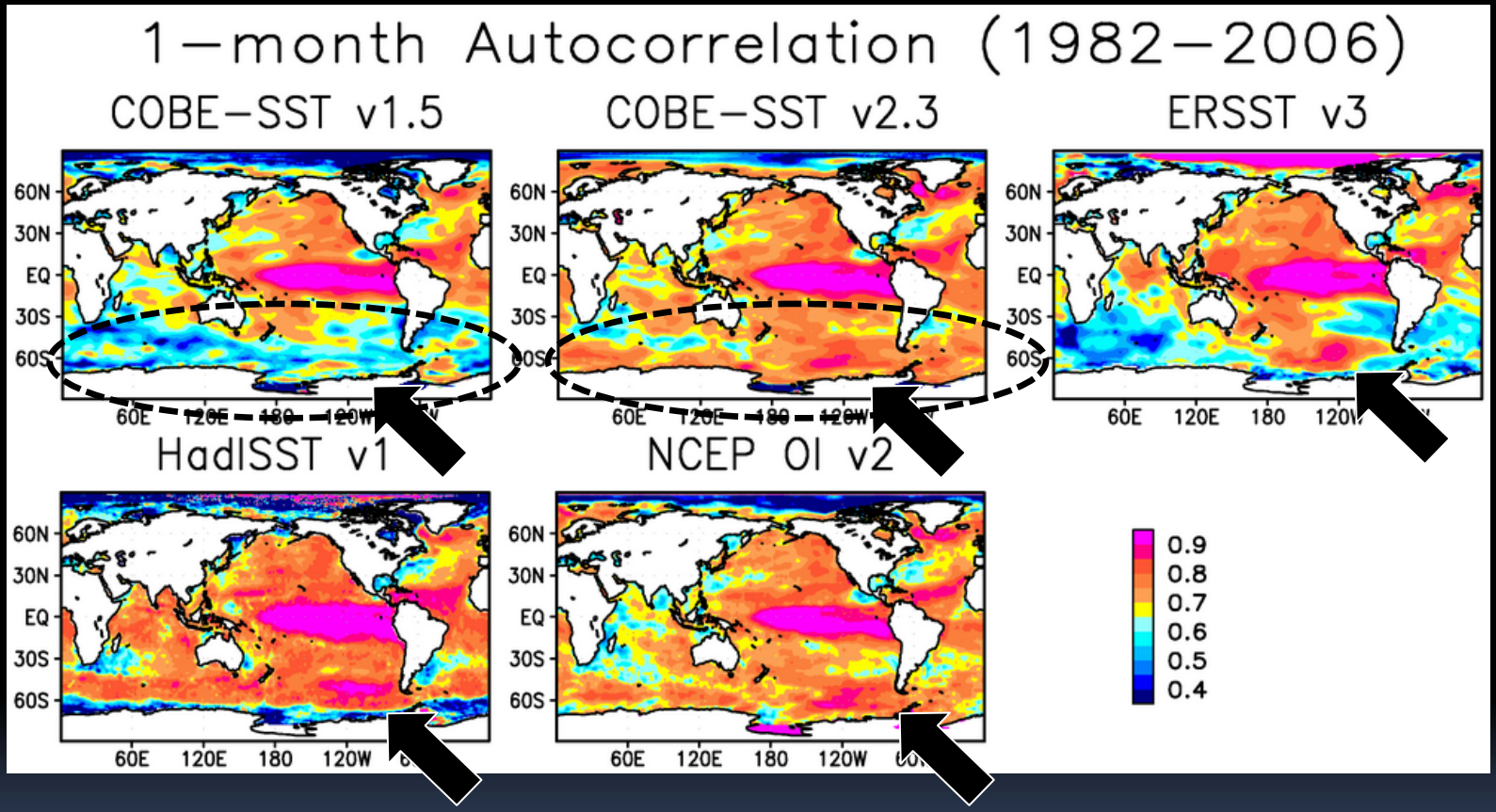
Root Mean Square Differences between the monthly SSTs (1871-1900)



Root mean square differences of monthly SST anomaly between the every pair of SST datasets

➢Better agreement of the interannual variation with the other datasets, particularly with HadISST

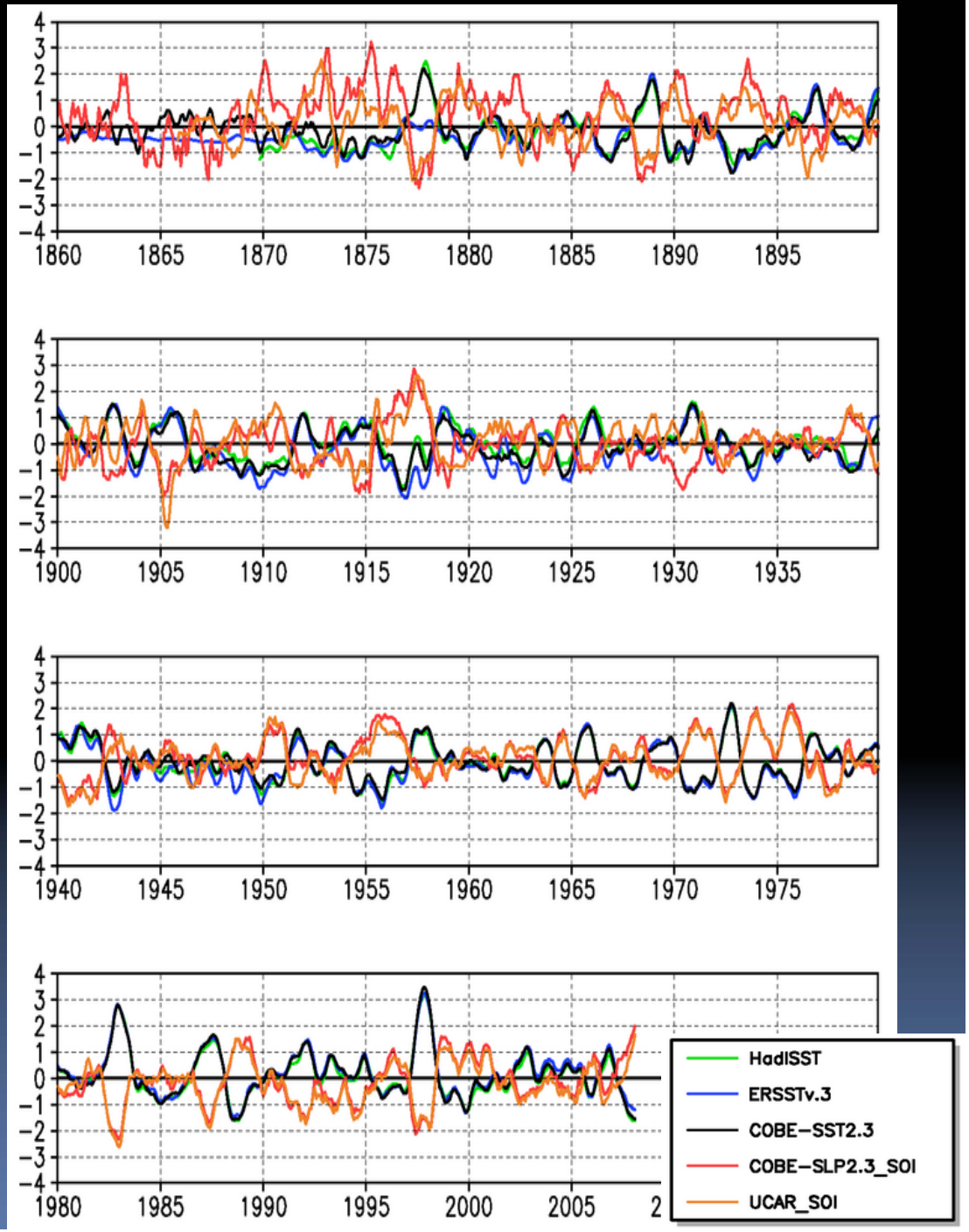
SST Anomaly Persistence



- Thanks to satellite observations, the new analysis scheme produces South Pacific SSTs with large persistence.
- One-month autocorrelation coefficients of the new analysis are in good agreement with those of the other SSTs

COBE2-SLP

- There are practically little differences among three NINO.3 SST time series
- COBE2-SLP is the historical SLP analysis processed in the same fashion as COBE2-SST
- SOIs based on ship observations are similar to those of land observations.
- Signals of seesaw-like covariation between NINO.3 SST and SOI would be detectable from 1870s



Outline

1. Basic Spec. of COBE2-SST
2. Data and Analysis Methods
3. Performance
4. Comparison with other datasets
5. Summary

Summary

COBE-SST has updated :

- Observational data sources
- Analysis method

And these updates have :

- Raised reliability of global mean SST
- Decreased differences against the other datasets

Future Plan

- Introduction of SST Analysis Ensemble (fluctuating raw observations, analysis parameters etc.)
- Bias adjustment for recent drifters (Kennedy et al. 2008@ CLIMAR-III)
- Metadata Inference for better bias adjustment

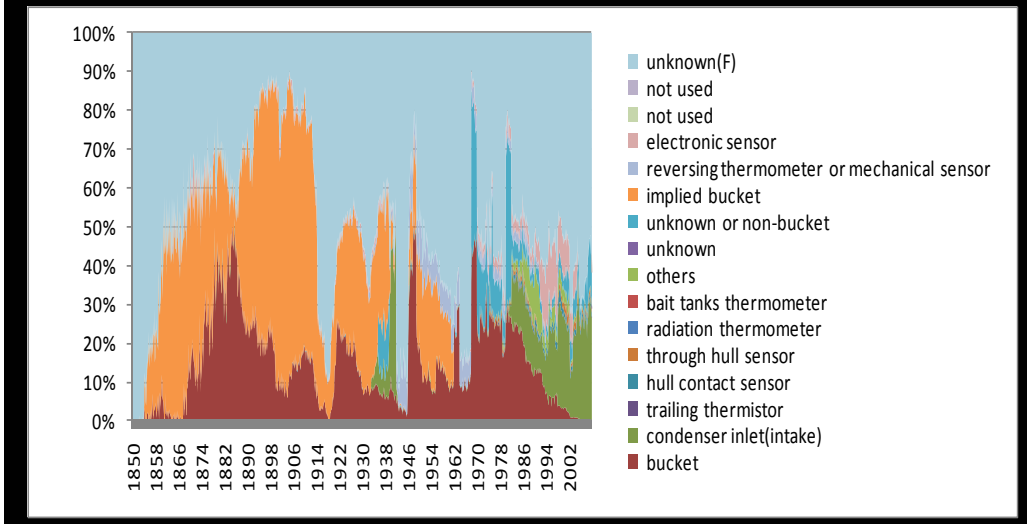
Thank You very much for your kind attention !

- ICOADS 2.1
  - Worley, S.J., S.D. Woodruff, R.W. Reynolds, S.J. Lubker, and N. Lott, 2005: ICOADS Release 2.1 data and products. Int. J. Climatol., 25, 823-842
- ICOADS 2.5
  - Woodruff, S. D., Worley, S. J., Lubker, S. J., Ji, Z., Eric Freeman, J., Berry, D. I., Brohan, P., Kent, E. C., Reynolds, R. W., Smith, S. R. and Wilkinson, C., 2011: ICOADS Release 2.5: extensions and enhancements to the surface marine meteorological archive. International Journal of Climatology, 31: n/a. doi: 10.1002/joc.2103
- Buckets Bias Correction
  - C. K. Folland and D. E. Parker, 1995: Correction of Instrumental Biases in Historical Sea Surface Temperature Data, Q.J.R. Meteorolol. Soc. 121, 319-367
  - Smith, Thomas M., Richard W. Reynolds, 2002: Bias Corrections for Historical Sea Surface Temperatures Based on Marine Air Temperatures. J. Climate, 15, 73–87.
- NASA Team Algorithm
  - Cavalieri, D.J, P. Gloersen, & W. J. Cambell, 1984: Determination of sea ice parameters with the NIMBUS 7 SMMR. Journal of Geophysical Research 89(D4), 5355-5369.
- Bootstrap Algorithm
  - Comiso, J.C., 1986: Characteristics of arctic winter sea ice from satellite multispectral microwave observations. Journal of Geophysical Research 91(C1), 975-994.
- Walsh and Chapman Northern Hemisphere Sea Ice
  - Walsh J. E. and W. L. Chapman, 2001: Twentieth-century sea ice variations from observational data. Ann. Glaciology, 33, 444-448.
- AVHRR Pathfinder dataset v.5
  - Referrence not found ...
  - available at http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/
- Salinity from WOA05
  - Antonov, J. I., R. A. Locarnini, T. P. Boyer, A. V. Mishonov, and H. E. Garcia, 2006: *World Ocean Atlas 2005, Volume 2: Salinity.* S. Levitus, Ed. NOAA Atlas NESDIS 62, U.S. Government Printing Office, Washington, D.C., 182 pp.

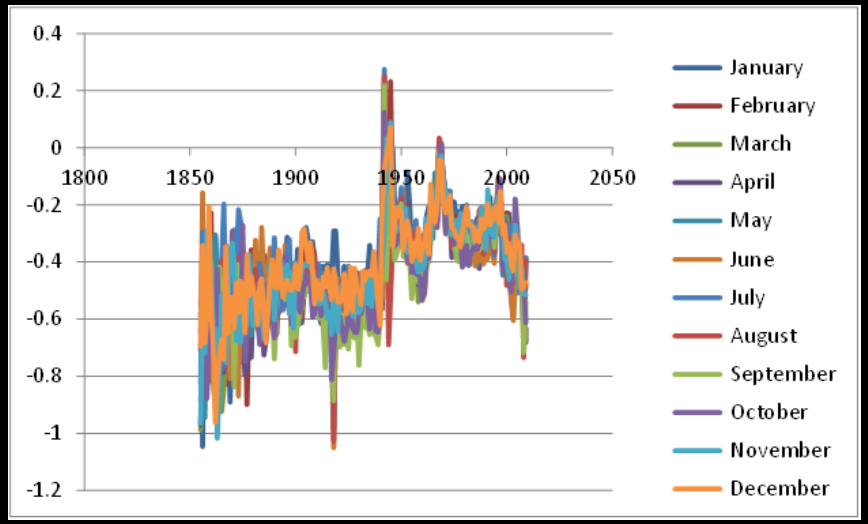
- HadSST2
  - Rayner, N.A., P.Brohan, D.E.Parker, C.K.Folland, J.J.Kennedy, M.Vanicek, T.Ansell and S.F.B.Tett, 2006: Improved analyses of changes and uncertainties in sea surface temperature measured in situ since the mid-nineteenth century: the HadSST2 data set. Journal of Climate. 19(3), 446-469.
- HadISST
  - Rayner, N. A., Parker, D. E., Horton, E. B., Folland, C. K., Alexander, L. V., Rowell, D. P., Kent, E. C. and Kaplan, A., 2003: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century, J. Geophys. Res., 108, No. D14, 4407 10.1029/2002JD002670
- ERSST v3
  - Smith, T.M., R.W. Reynolds, Thomas C. Peterson, and Jay Lawrimore, 2008: Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880-2006). Journal of Climate,21, 2283-2296.
- NCEP OI v.2
  - Reynolds, R.W., N.A. Rayner, T.M. Smith, D.C. Stokes, and W. Wang, 2002: An improved in situ and satellite SST analysis for climate. J. Climate, 15, 1609-1625.
- COBE1-SST
  - Ishii, M., A. Shouji, S. Sugimoto, and T. Matsumoto, 2005: Objective analyses of SST and marine meteorological variables for the 20th century using ICOADS and the Kobe ollection. Int. J. Climatol., 25, 865-879.
  - Manabe, T., 1999: The digitized Kobe Collection, Phase I: Historical surface marine meteorological observations in the archive of the Japan Meteorological Agency. Bull. Amer. Meteor. Soc., 80, 2703–2715.

- Meredith et al. 2008
  - Meredith, Michael P.; Murphy, Eugene J.; Hawker, Elizabeth J.; King, John C.; Wallace, Margaret I.. 2008 On the interannual variability of ocean temperatures around South Georgia, Southern Ocean: forcing by El Niño/Southern Oscillation and the Southern Annular Mode. Deep Sea Research II, 55 (18-19). 2007-2022. 10.1016/j.dsr2.2008.05.020
- NAT Bias Correction
  - Bottomley, M., et al., 1990: Global Ocean Surface Temperature Atlas “GOSTA”. HMSO, London, 20 pp.+iv, 313 plates.
- Boosted SST climatology
  - Taylor, K.E., D. Williamson, and F. Zwiers, 2000: The sea surface temperature and sea-ice concentration boundary conditions for AMIP II simulations, PCMDI Report No. 60, Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, California, 25 pp

Bias Adustment for In-situ Observations



Historical transition of SST observation methods



Global average “Engine room intake” SST bias against nighttime marine air temperature

- There are several choices (ex. Smith and Reynolds 2002) to adjust biases on
  - Drifters in recent decades
  - Buckets observations before/after WW-II

- Issues we need to tackle here are:
  - Sudden changes of major observation method in history
  - A large amount of “Method-Unknown" observations

Salinity-Dep. ICE-SST Equations

Empirical Relationship between SST and Sea Ice Concentration :

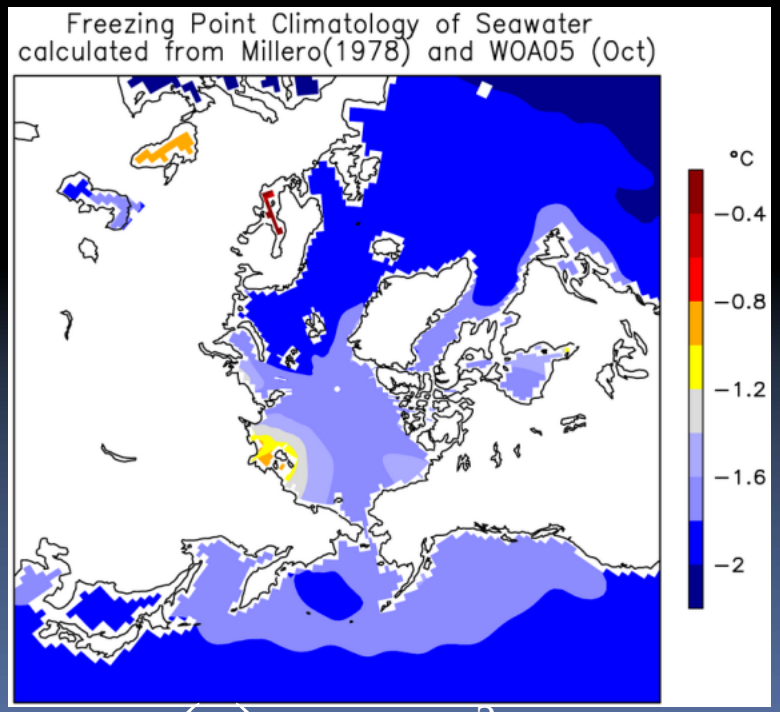
$$T_{Pseudo} = aI^2 + bI + c$$

where

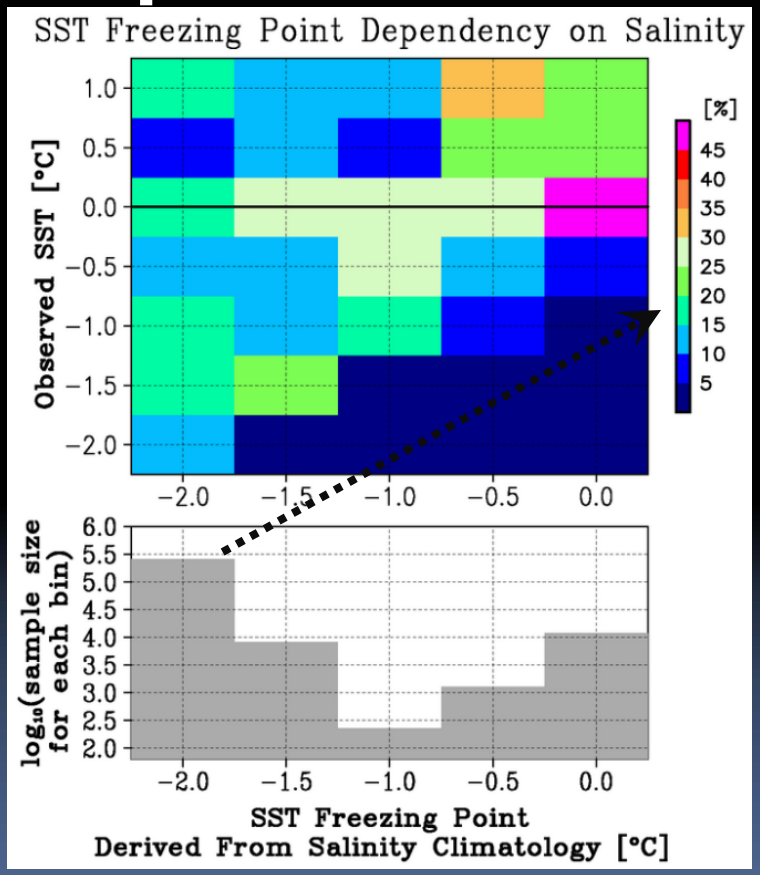
T_{Pseudo} : Pseudo SST Observation Derived From Sea Ice data

I : Sea Ice Concentration [0~1]

Coefficients a and b are estimated by the method of least squares under a constraint, and they vary in space and seasonally, corresponding to monthly salinity climatology of WOA05

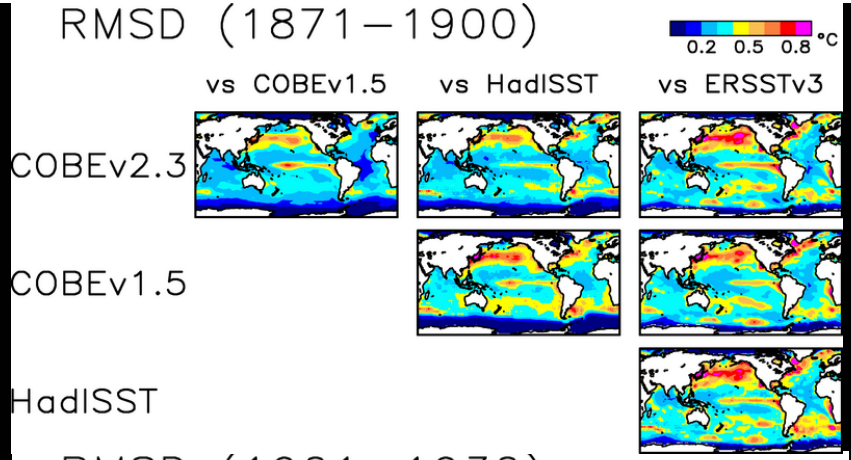


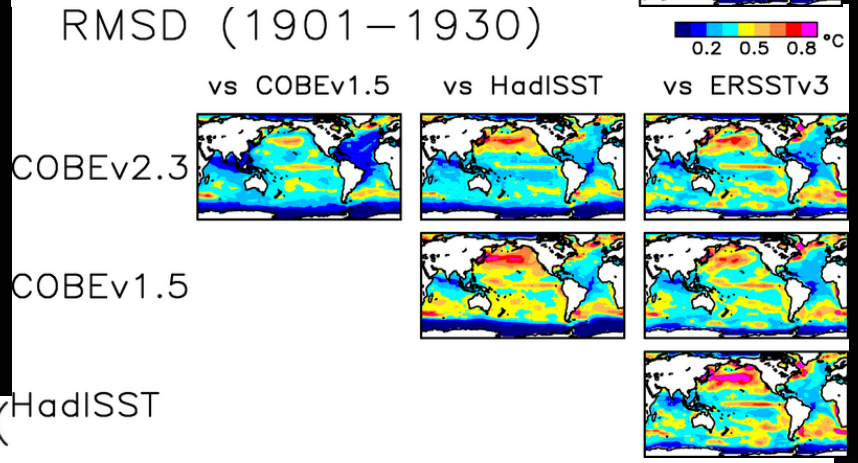
$$T_{freezing}(S) = aI_{MAX}^2 + bI_{MAX} + c$$

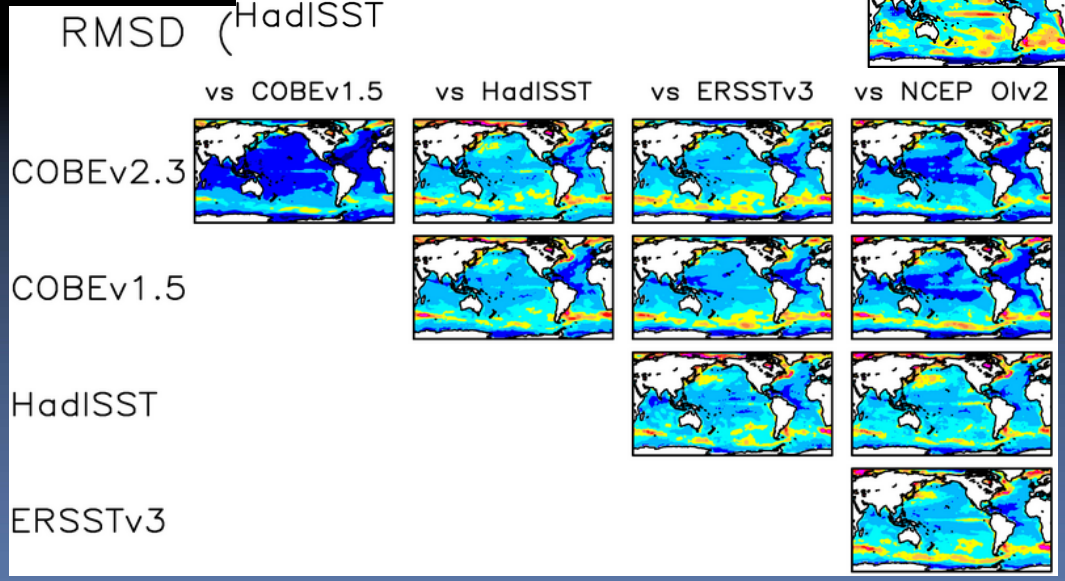


Frequency distribution of In-situ SST versus climatological SST derived from salinity. Samples are taken at grids where SIC is greater than 0.9

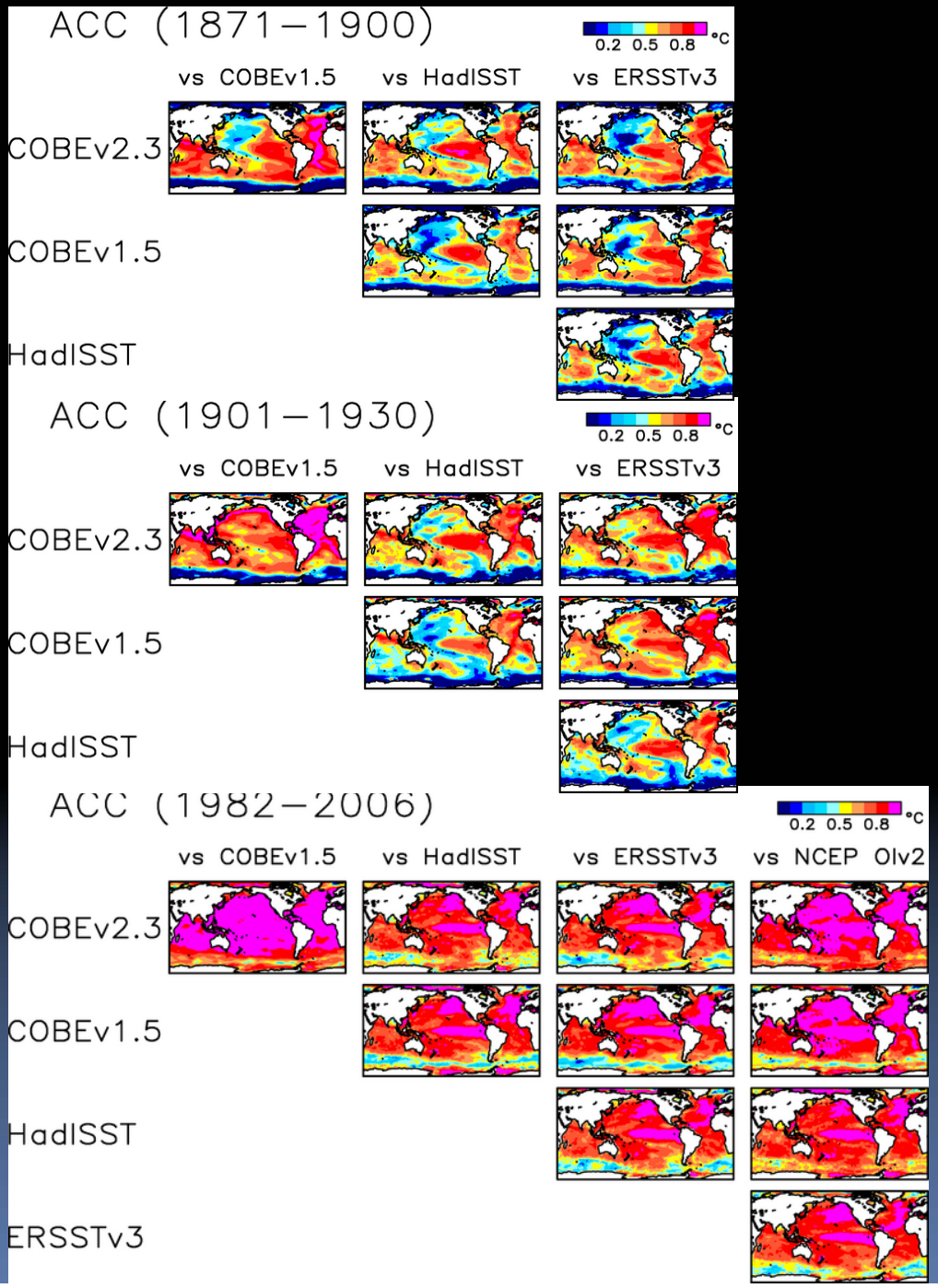
Anomaly Correlation



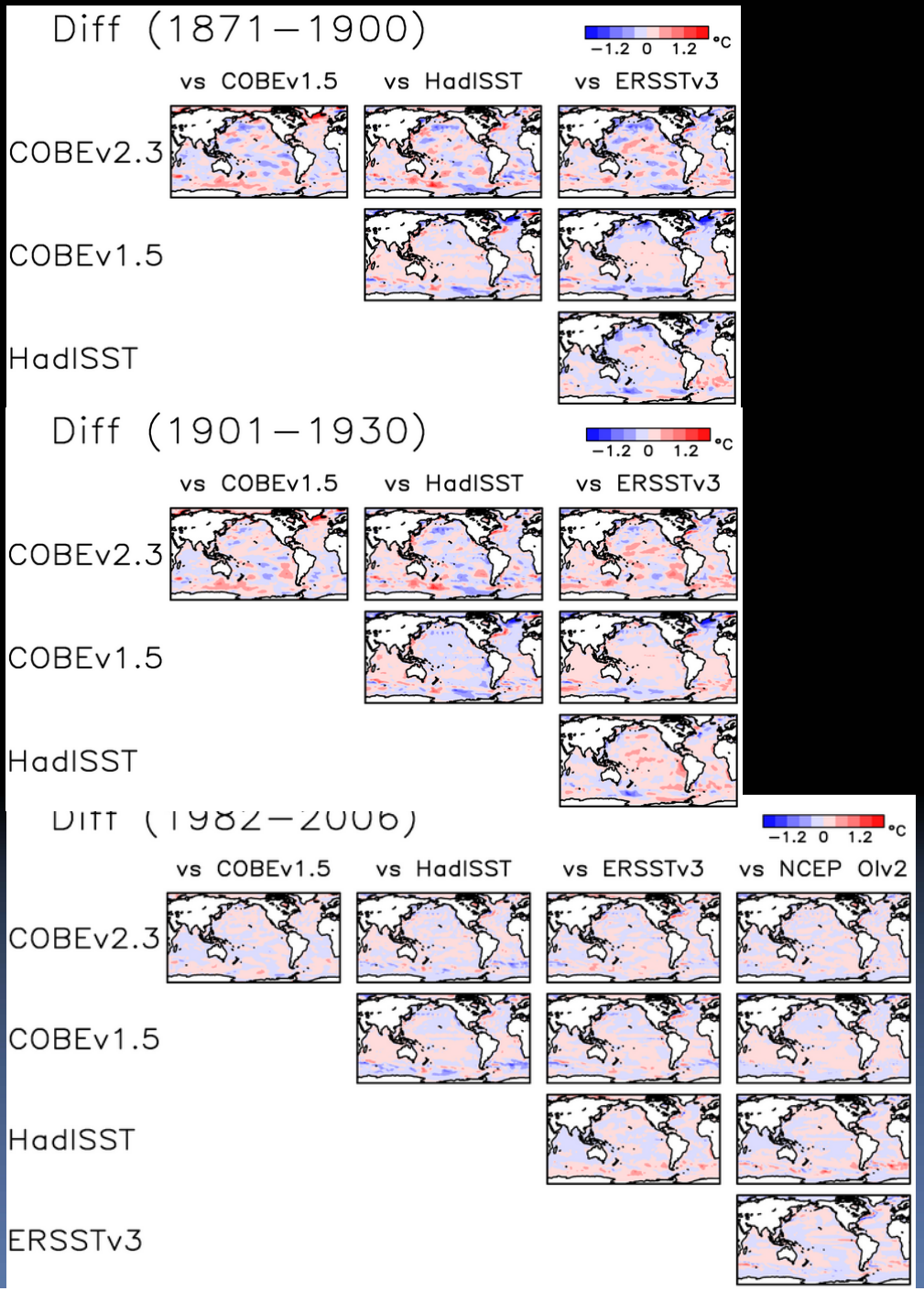


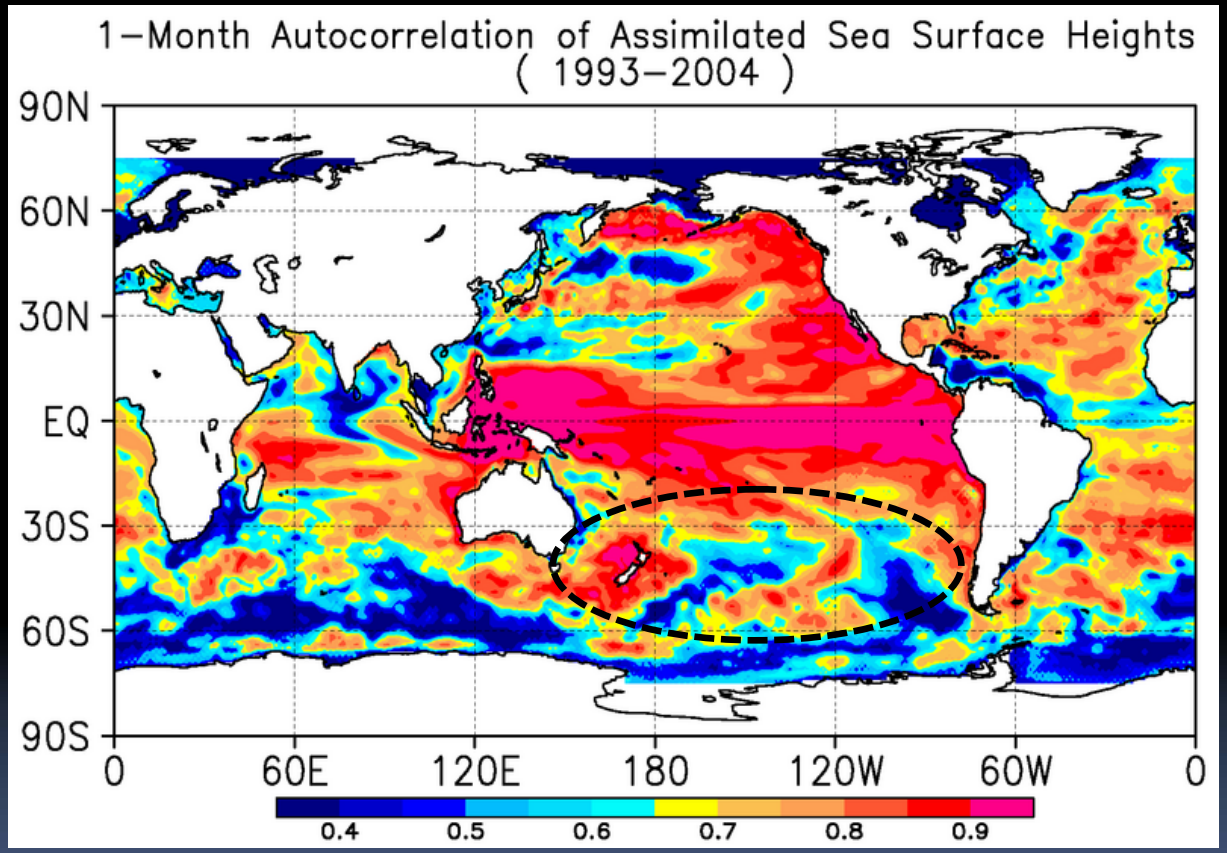


Anomaly Correlation

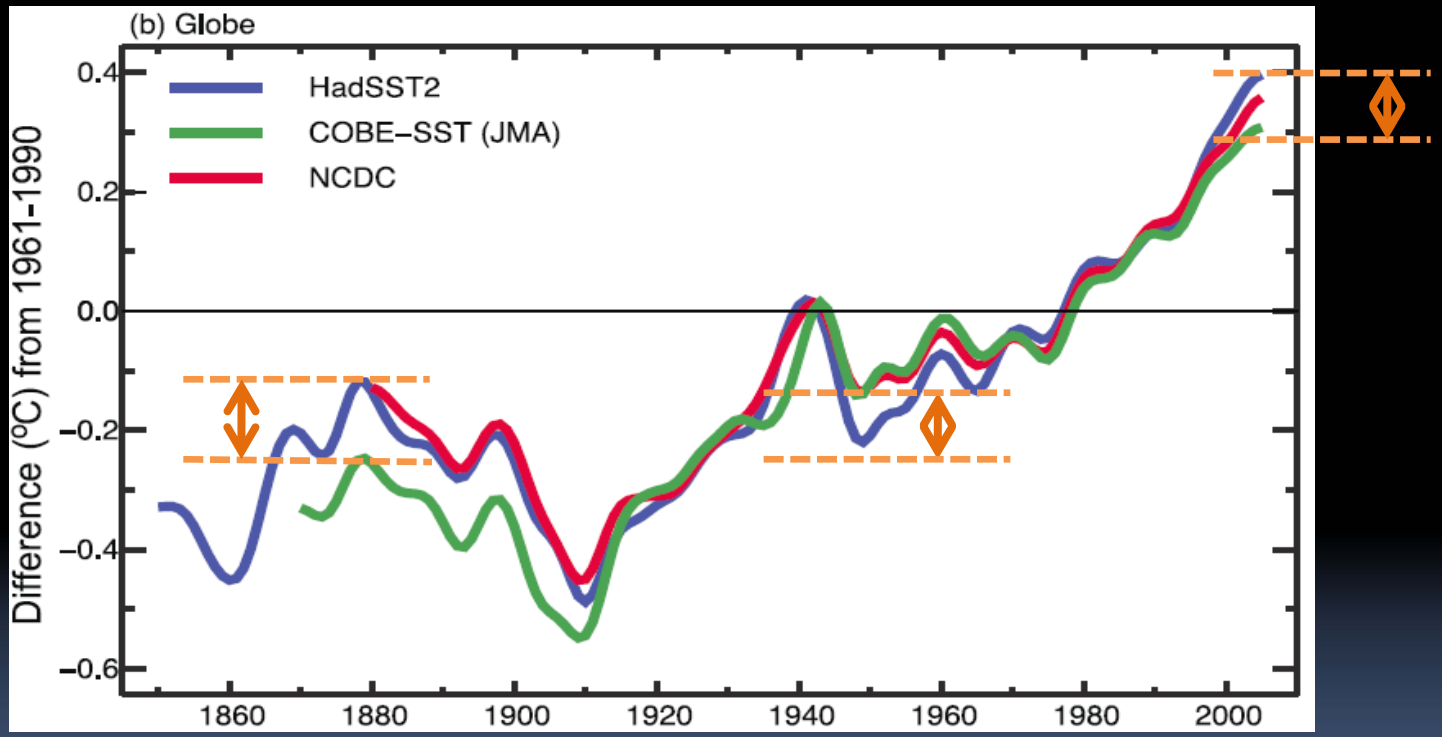


Mean Difference

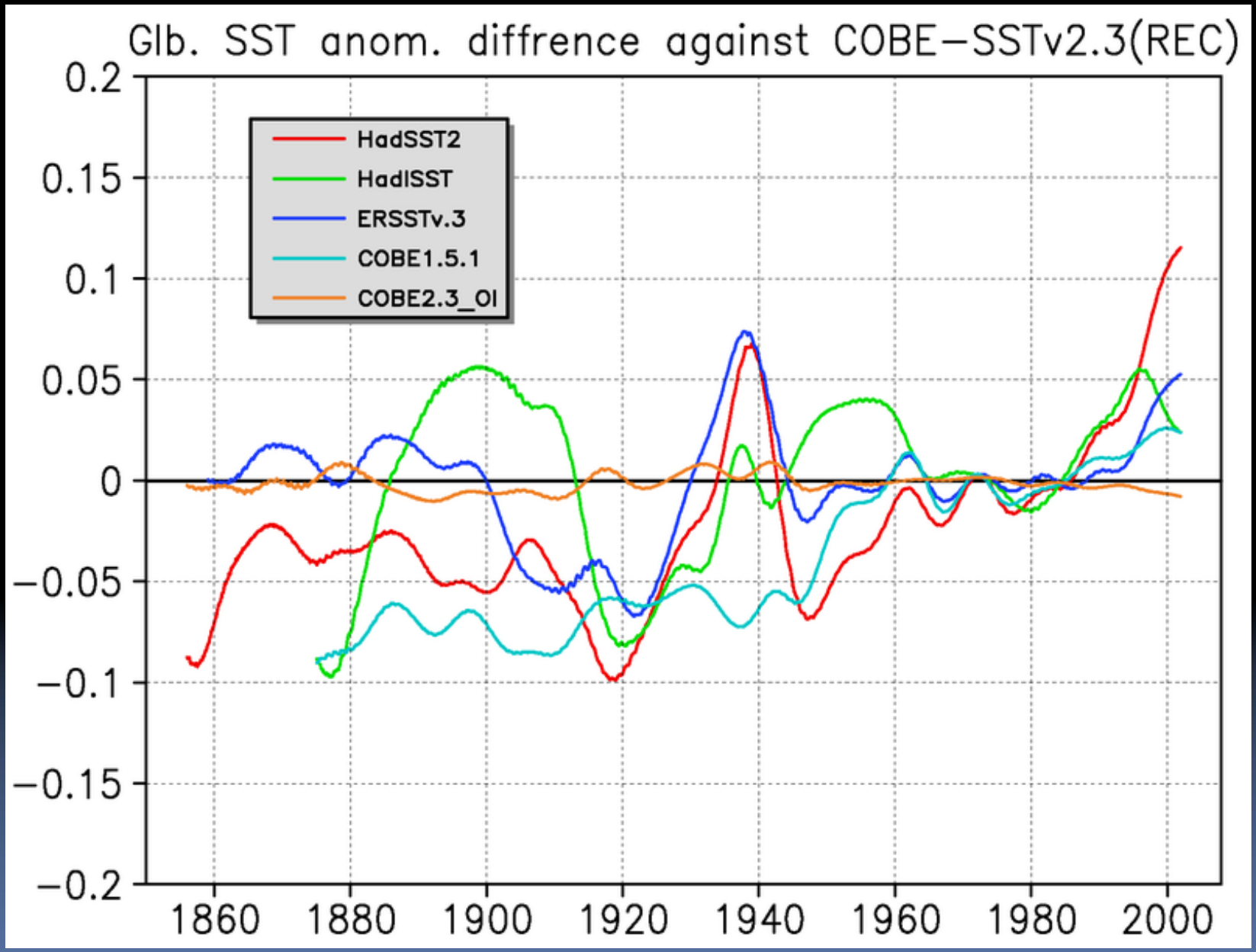



1−Month Autocorrelation of Assimilated Sea Surface Heights
(1993−2004)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
0.4
0.5
0.6
0.7
0.8
0.9

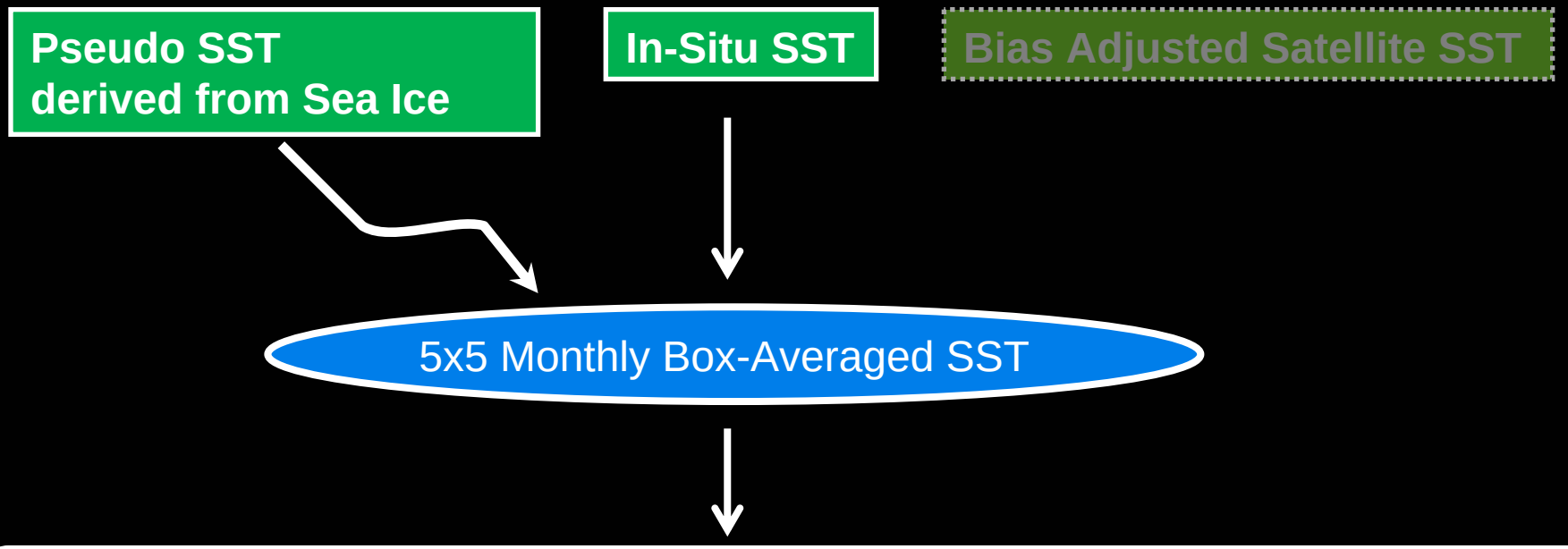
IPCC AR4



IPCC AR4 WG-1 (2007) Fig.3.4


Glb. SST anom. diffrence against COBE-SSTv2.3(REC)
HadSST2
HadISST
ERSSTv.3
COBE1.5.1
COBE2.3_OI
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
1860
1880
1900
1920
1940
1960
1980
2000

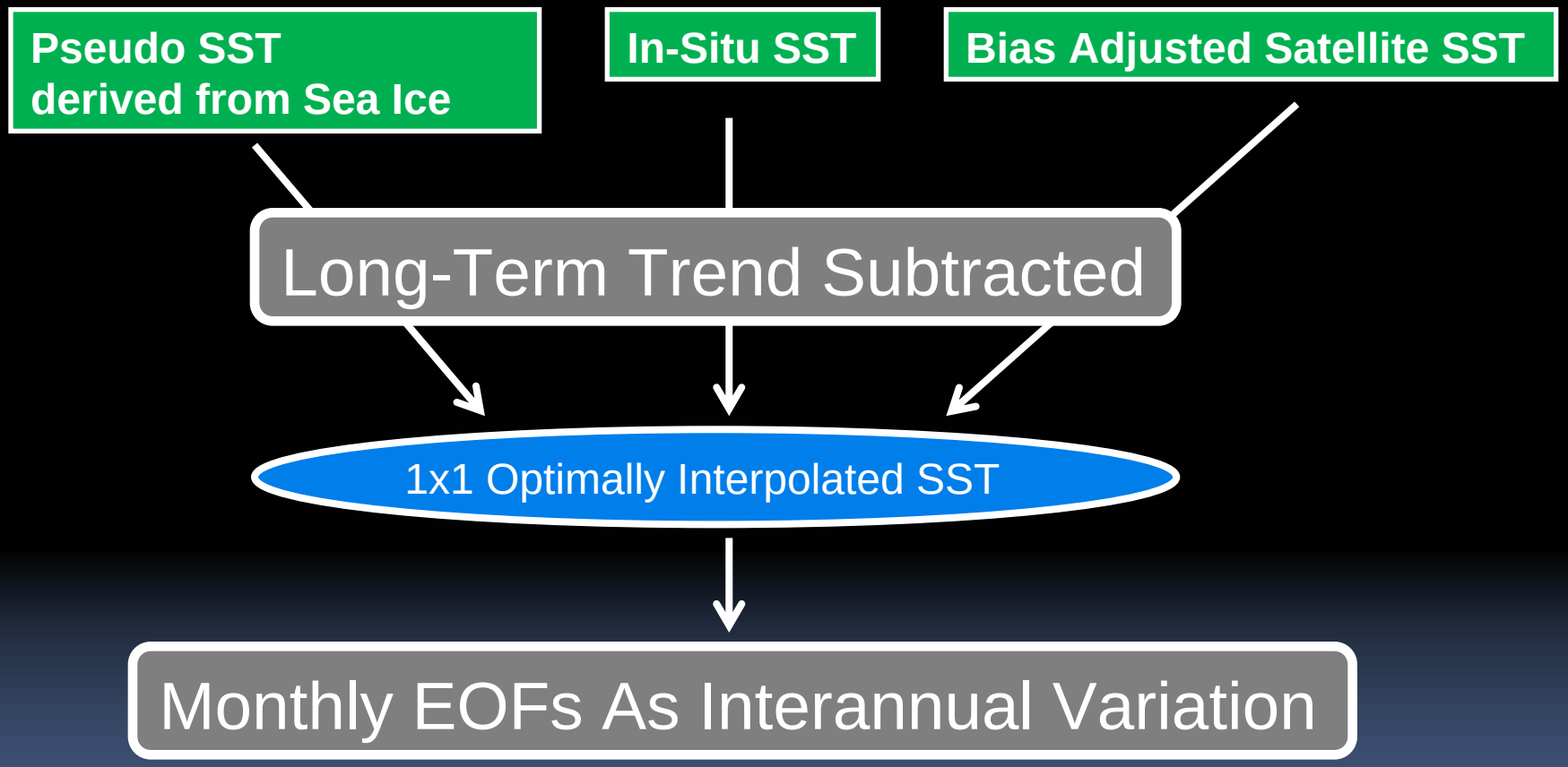
Analysis Flowchart Step 1:



EOF1 As a Long-Term Trend Component

From 1850 onwards

Analysis Flowchart Step 2:



At Recent decades

Only spatial patterns are utilized for following procedures

Analysis Flowchart Final Step: