Bias correction for radiosonde observations

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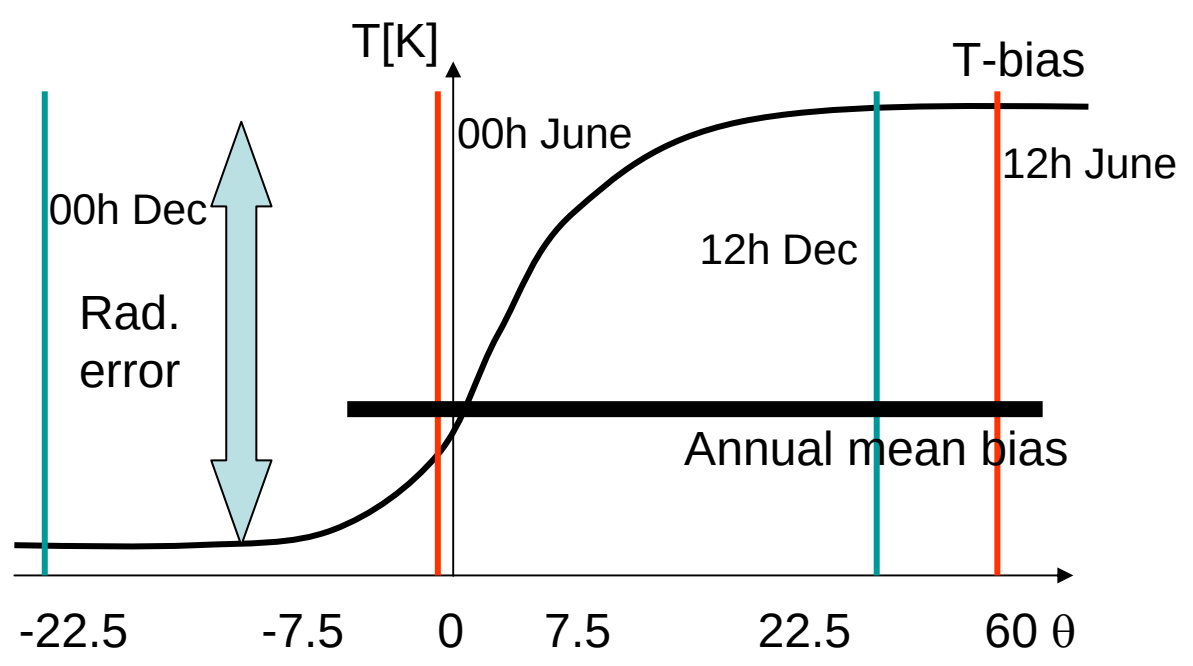
Outline

- Focus on radiosonde temperature biases
- Some examples of RS-biases
- Bias correction for operations/climatology
  - Focus on reanalysis/climatology
- A bias adjustment method based on time series of analysis feedback data (RAOBCORE)
- Results and validation strategy
- Outlook/Recommendations

Nature of radiosonde T-biases



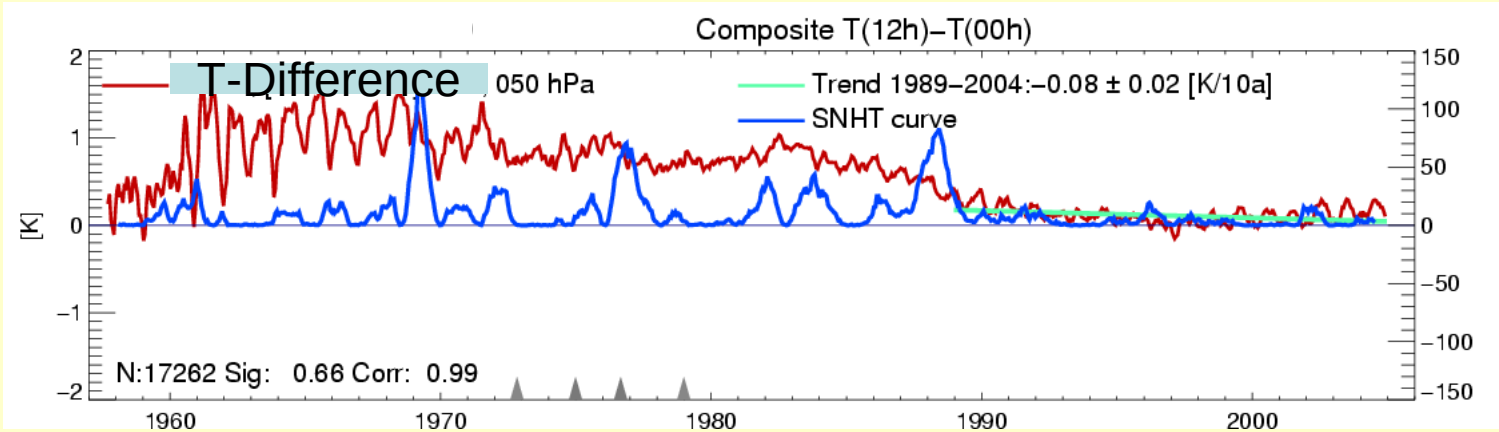
T-bias mainly a function of Solar elevation angle θ, pressure, RS-type

θ depends on
Latitude,longitude
Time of day, time of year

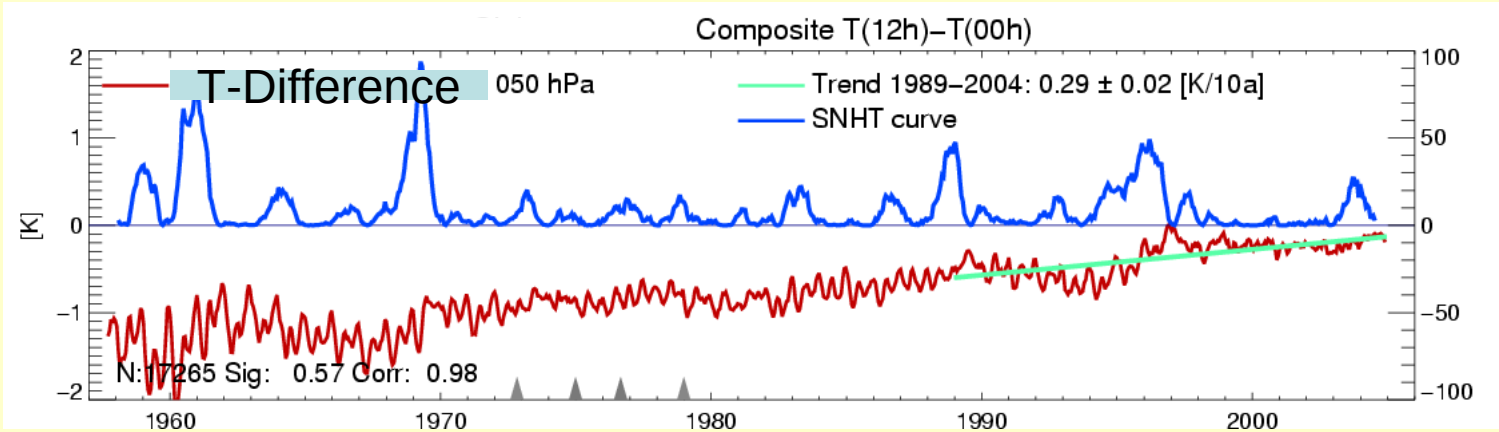
12h-00h difference is crude estimate of radiation error, independent of bg

Radiation error may be estimated from obs-bg difference
4 classes of solar elevation angles (<-7.5°; -7.5°-7.5°, -7.5°-22.5°, >22.5°)

The problem:
12h-00h T-Differences, 50 hPa

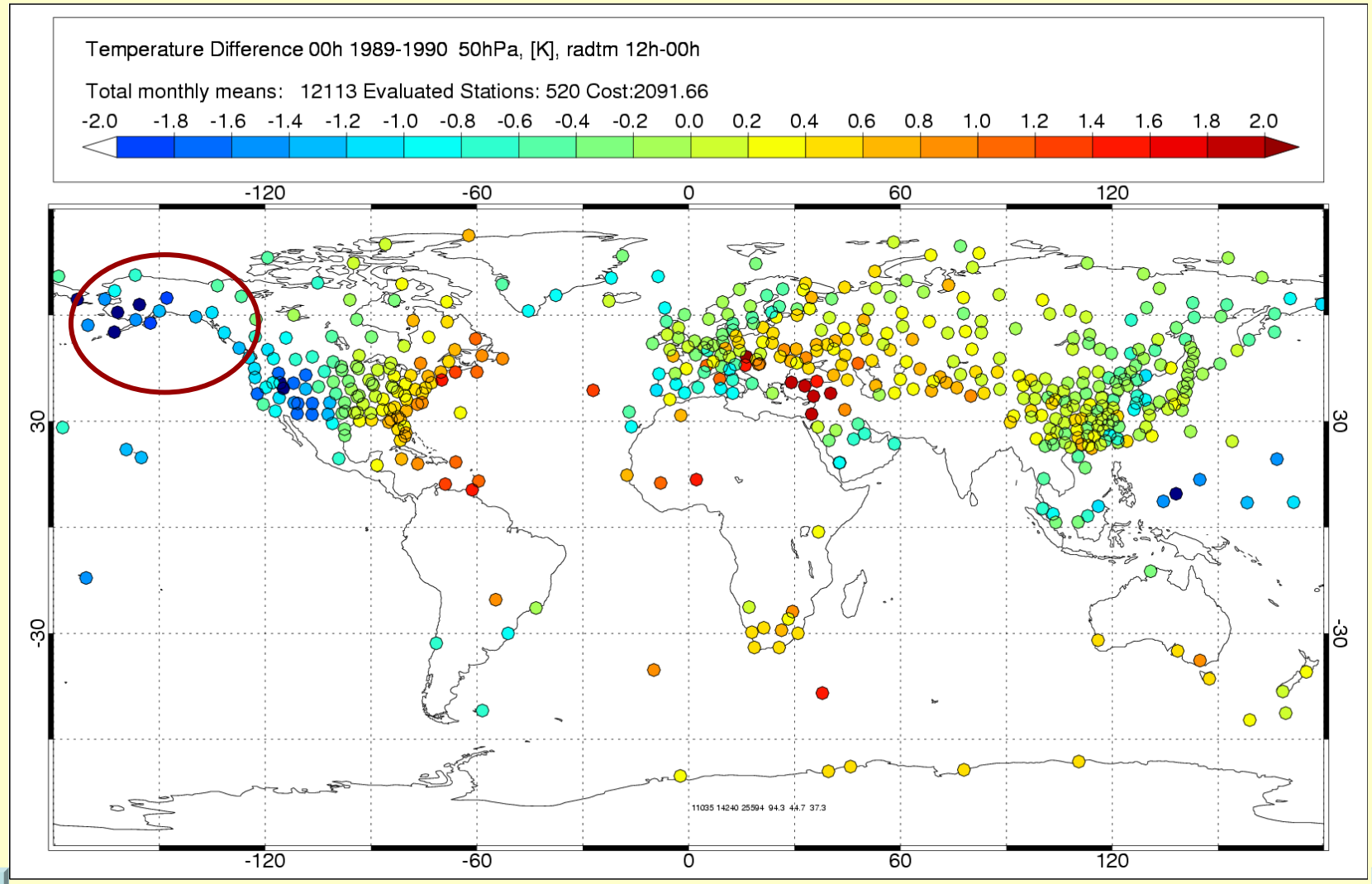


Composite
30W-40E
Europe/
Africa

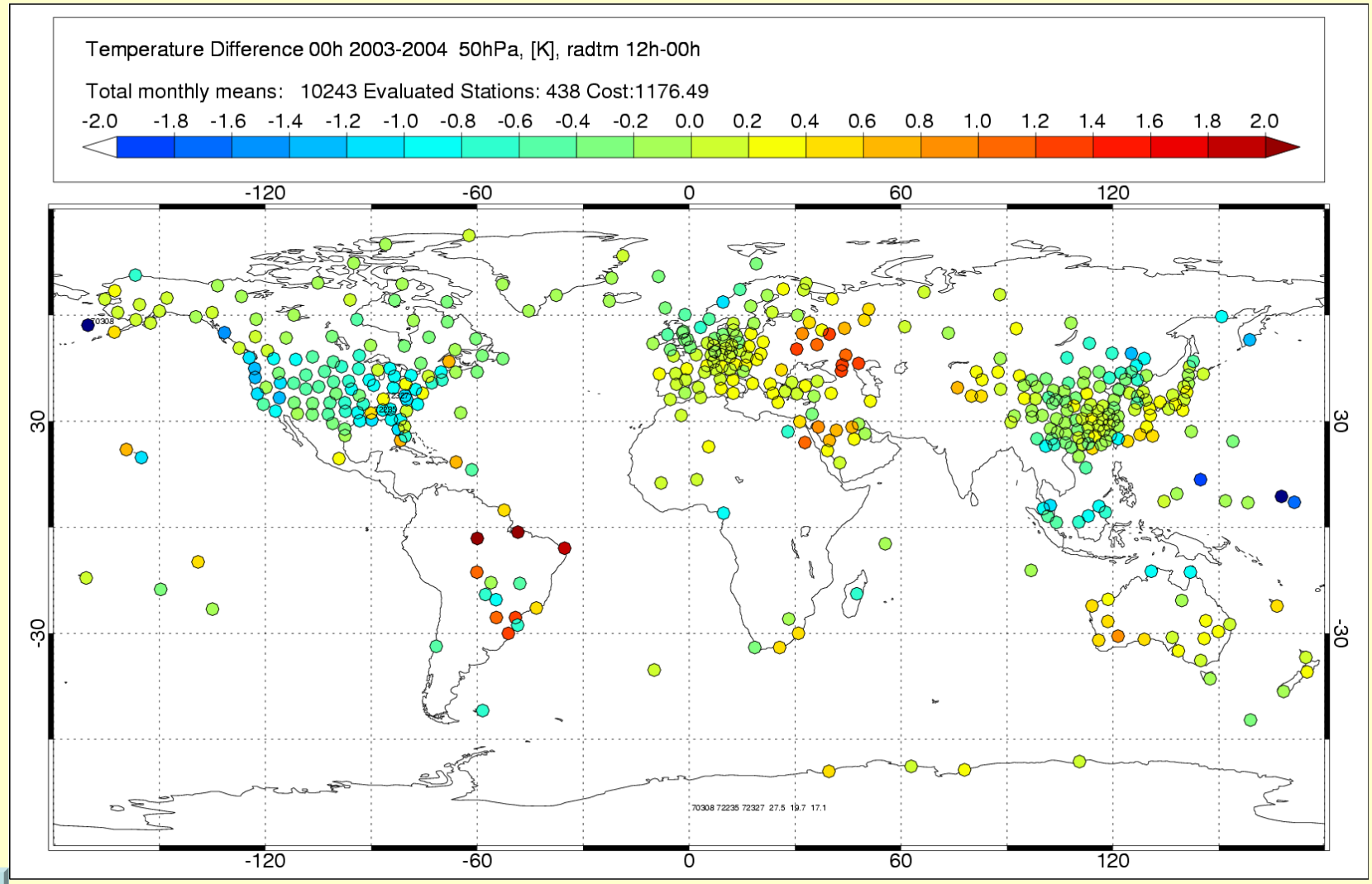


Composite
120E-120W
Far East/
Pacific/Alaska

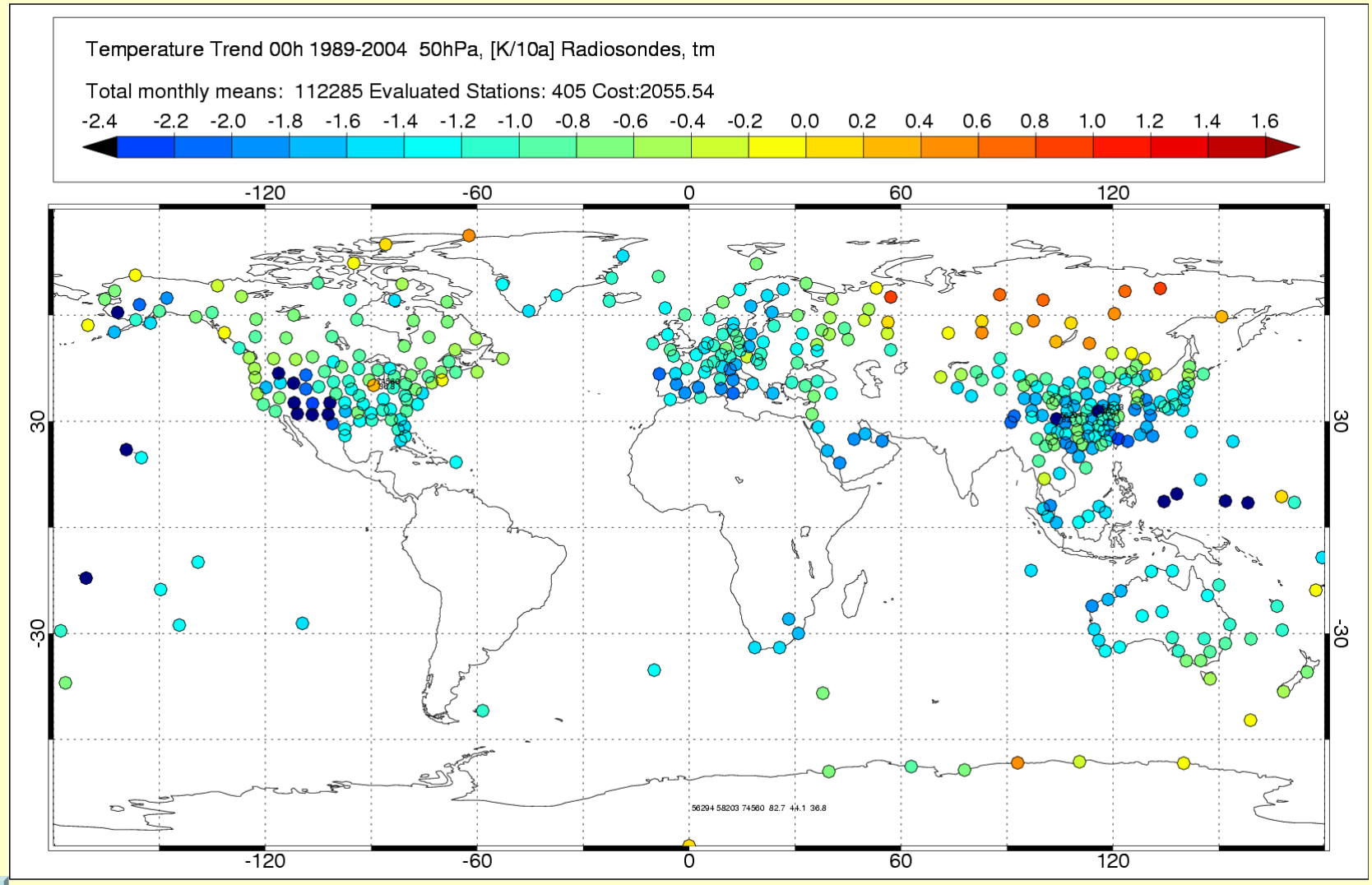
12h-00h T-Difference 50 hPa, 1989-1990



12h-00h T-difference 2003/04



Temperature trends, 00h, 50hPa, 1989-2004



Requirements for bias corrections

- For operations
  - Bias estimates for all current radiosondes
  - Short lead time for bias estimation desirable
  - Temporal shifts of adjusted biases acceptable

- For Climatology/Reanalysis
  - Result of bc must be temporally homogeneous time series
  - At least for climatology subset of stations sufficient
  - Adjustments for past radiosonde types needed

Present status

- Operational radiosonde temperature bias adjustments
  - Based on RS-vendor information, tables need to be updated
  - Only radiation error correction in most cases
  - Adjustments based on analysis feedback information (U. Andrae)

- Bias correction for climatology/reanalyses
  - **Error-prone and tedious due to lack of transfer standards**
  - **Manual adjustments of monthly temperature anomalies:**
    - Lanzante et al 2003 (83 stations, 1958-)
    - Thorne et al. 2005 (676 stations, 1958-), monthly means
    - Main purpose: Temporal homogeneity (for climate trend assessment)
  - **ERA-40** (Andrae et al. 2004) – uses analysis feedback data, all radiosondes, **only radiation error**
  - Feedback-based approach using time series analysis (Haimberger, 2005) – all available radiosondes, **adjustment of annual mean bias**

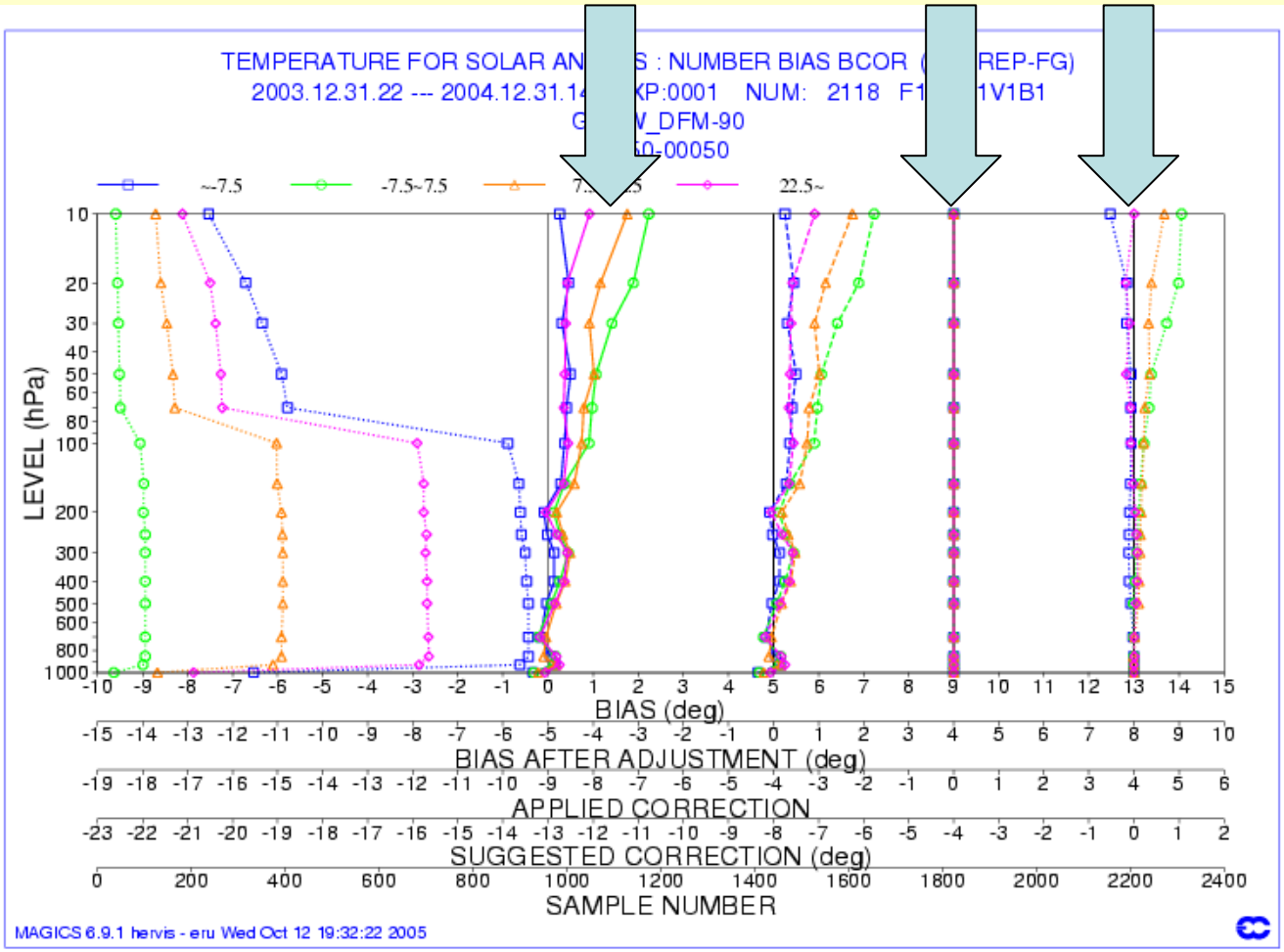
- **No method to date addresses all aspects of radiosonde T-bias!**

Analysis feedback data

- Analysis feedback data contain:
  - obs (e.g. Radiosonde temperatures)
  - obs-bg (=innovations $\mathbf{y}$-H($\mathbf{x}$)), obs-an
  - Quality control flags
- Valuable by-product of data assimilation
- Uniform format (BUFR)

- ERA-40: 1958-2002, 6h-3D-VAR DA-System
- Operational AF (4D-VAR) used 2001-
- AF for new RS data (IGRA) may be calculated “offline”

Solar-elevation dependent bias correction for station groups (Andrae et al. 2004)



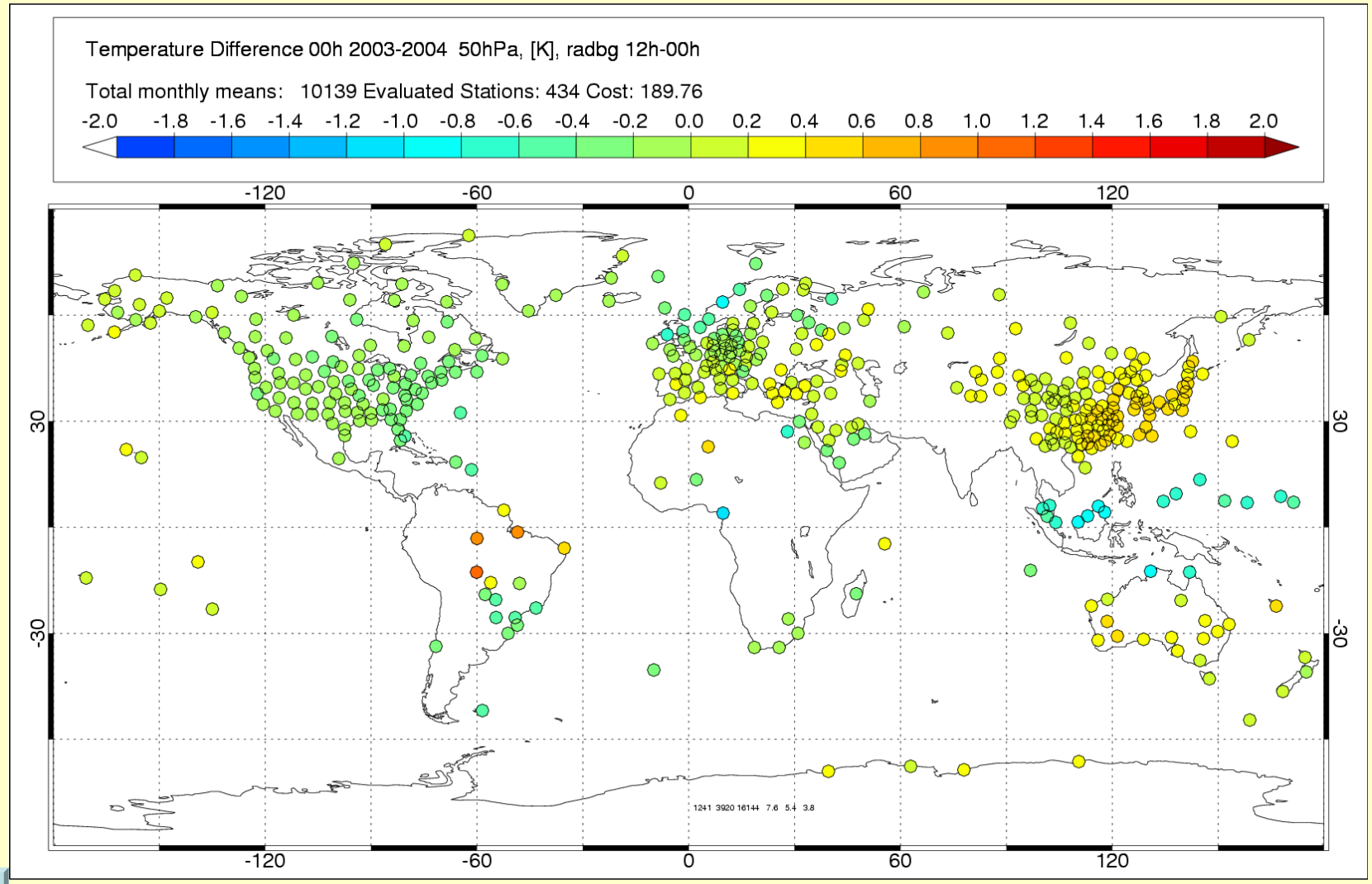
Uses composites

4 classes of solar elevation angles

Main Assumption:

Diurnal T-variation of Background Forecast realistic

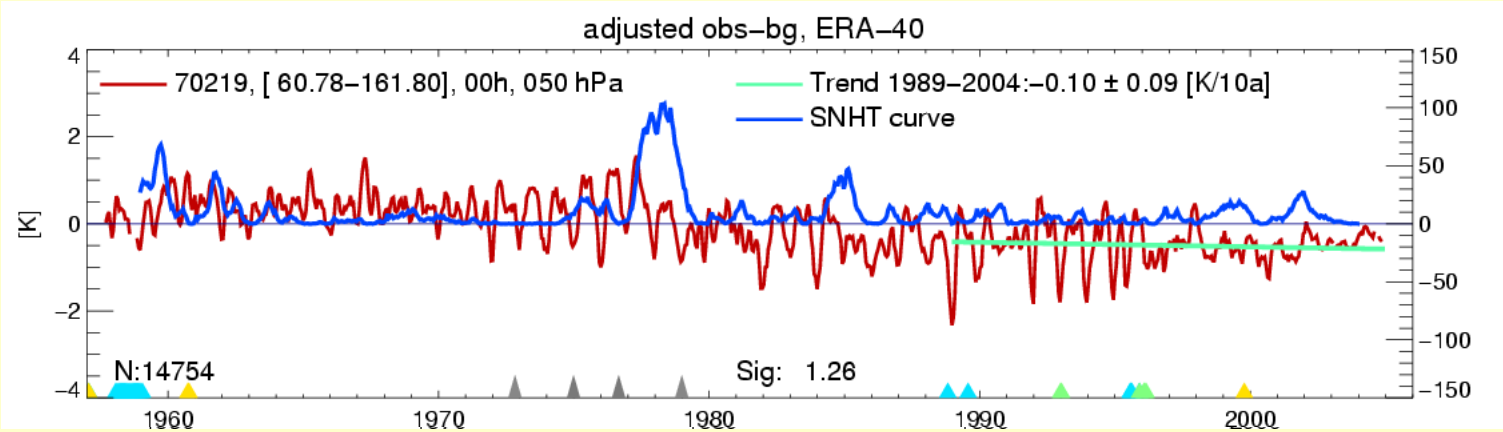
12h-00h T-Difference ERA-40 bg



Consistent with Free and Seidel 2005 (JGR)

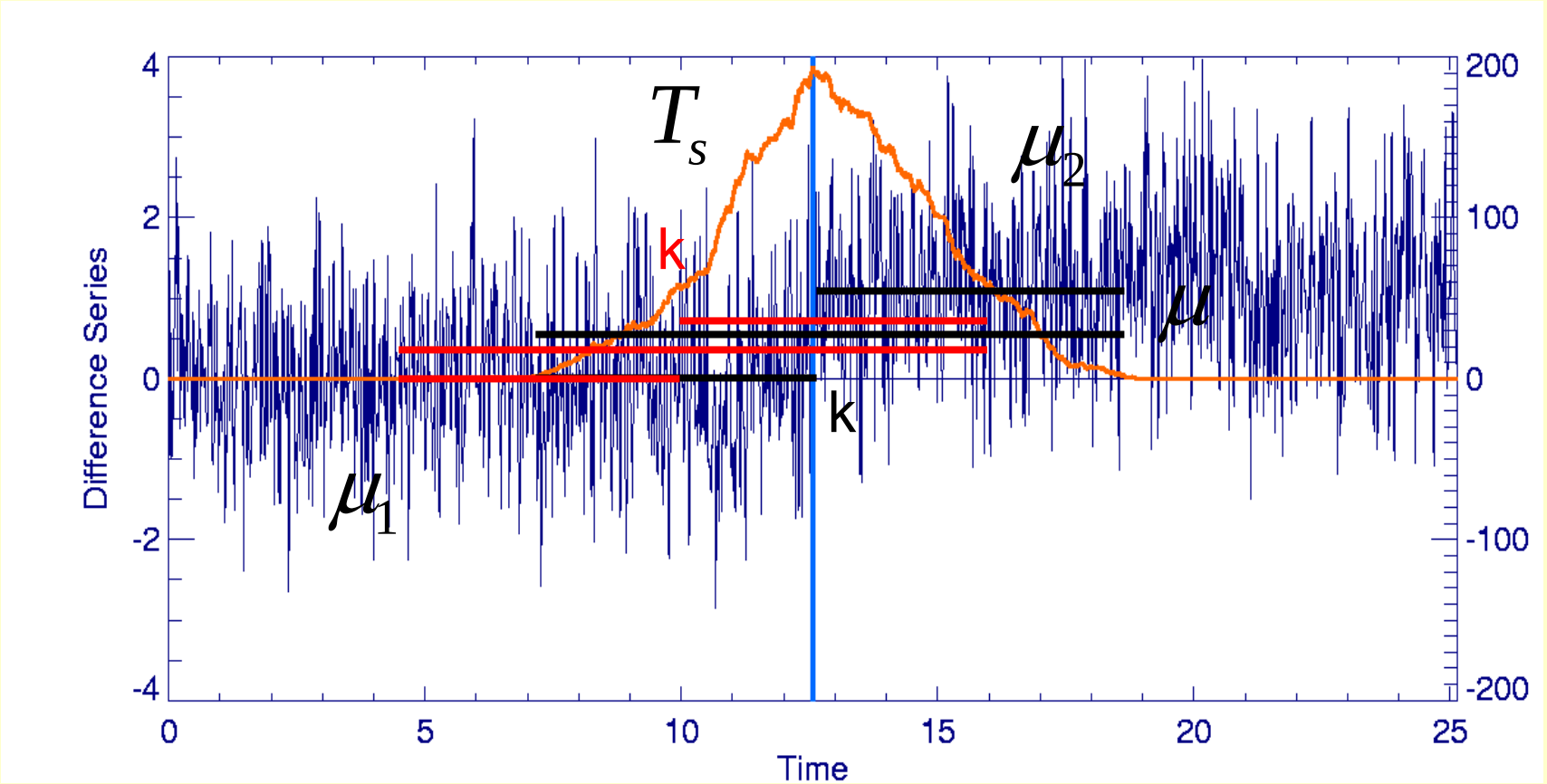
RAOBCORE

- RAdiosonde OBservation COrrection for REanalyses
- Homogeneity adjustment method
- Uses time series of obs-bg for adjustment
- bg used as reference time series



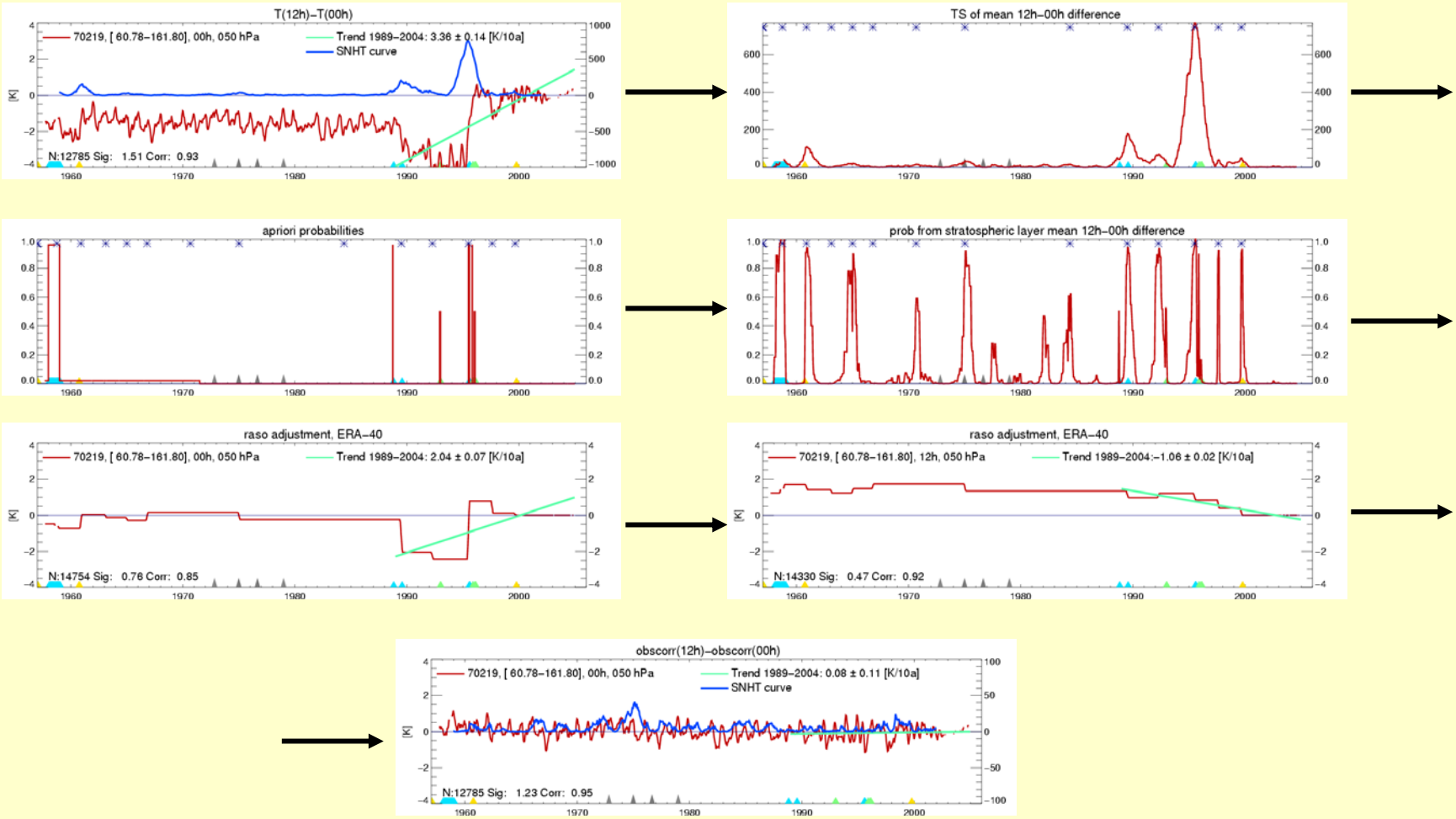
- Works on individual radiosondes
- 12h and 00h launches adjusted separately
- Can use metadata for break detection

Standard Normal Homogeneity Test

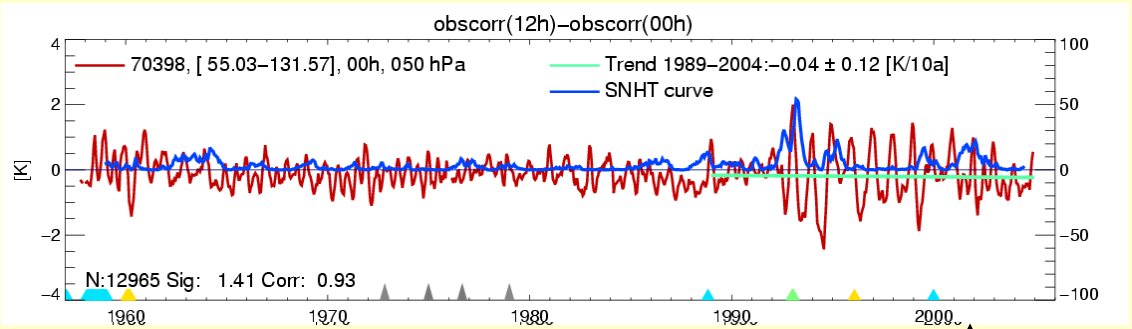


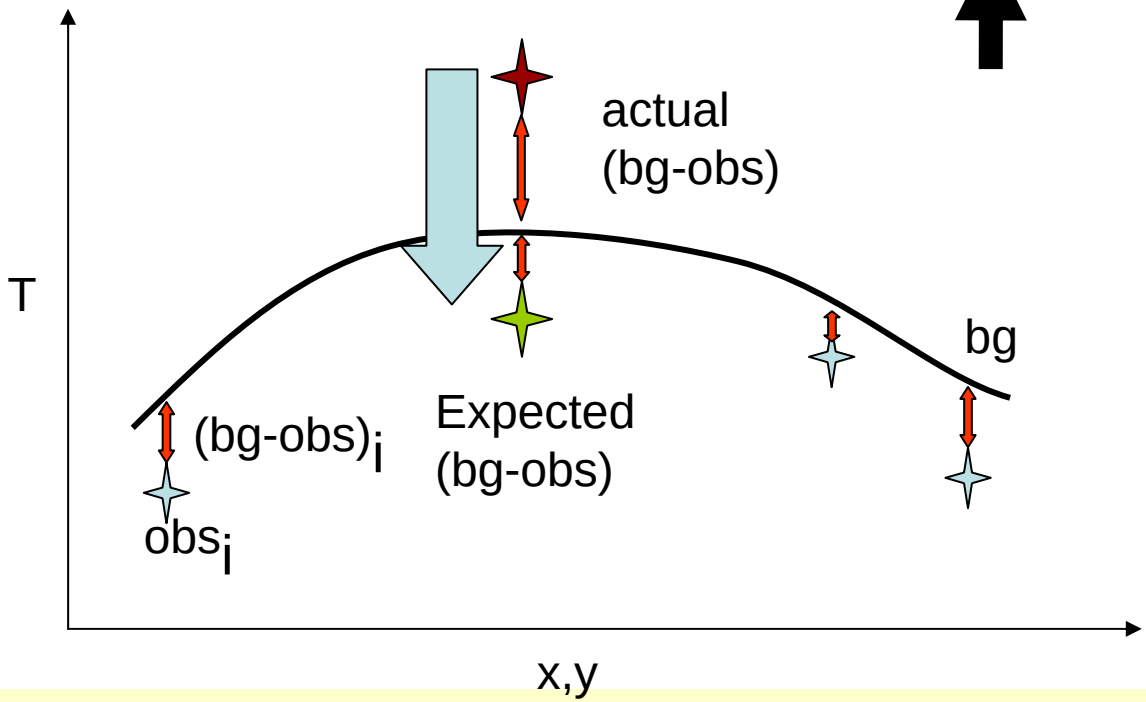
$$T_k^s = [(N/2)(\mu_{1,k} - \mu_k)^2 + (N/2)(\mu_{2,k} - \mu_k)^2] / \sigma_k$$

RAOBCORE break detection



Bias adjustment of most recent part





Mean T of neighbouring homogenized „reliable“ series

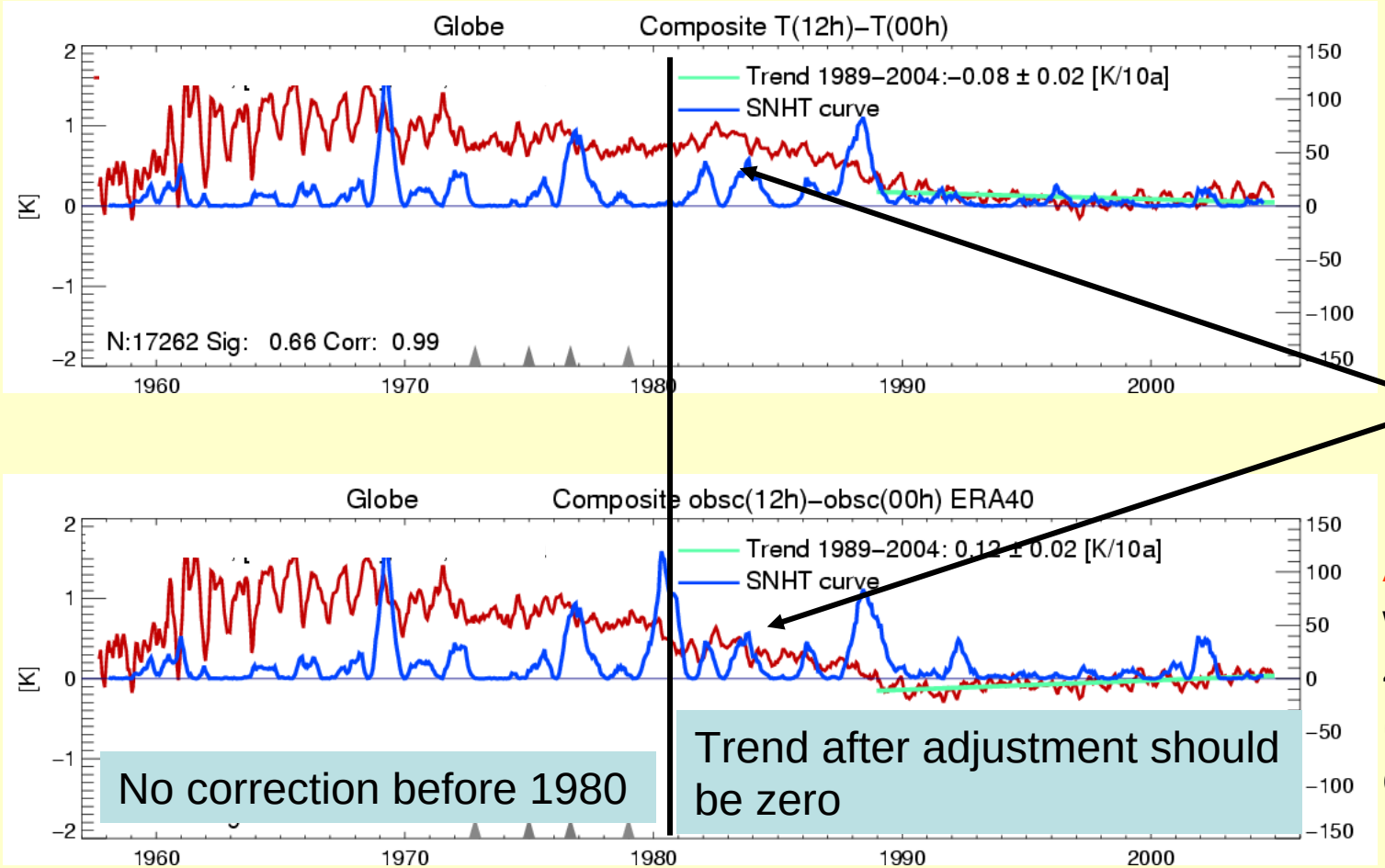
Mean T of most recent part of tested series

Bg used for interpolation

Adjustment results for 1958-2004

- Radiation error correction in ERA-40
- RAOBCORE correction
- Updated solar angle dependent correction for interim reanalysis

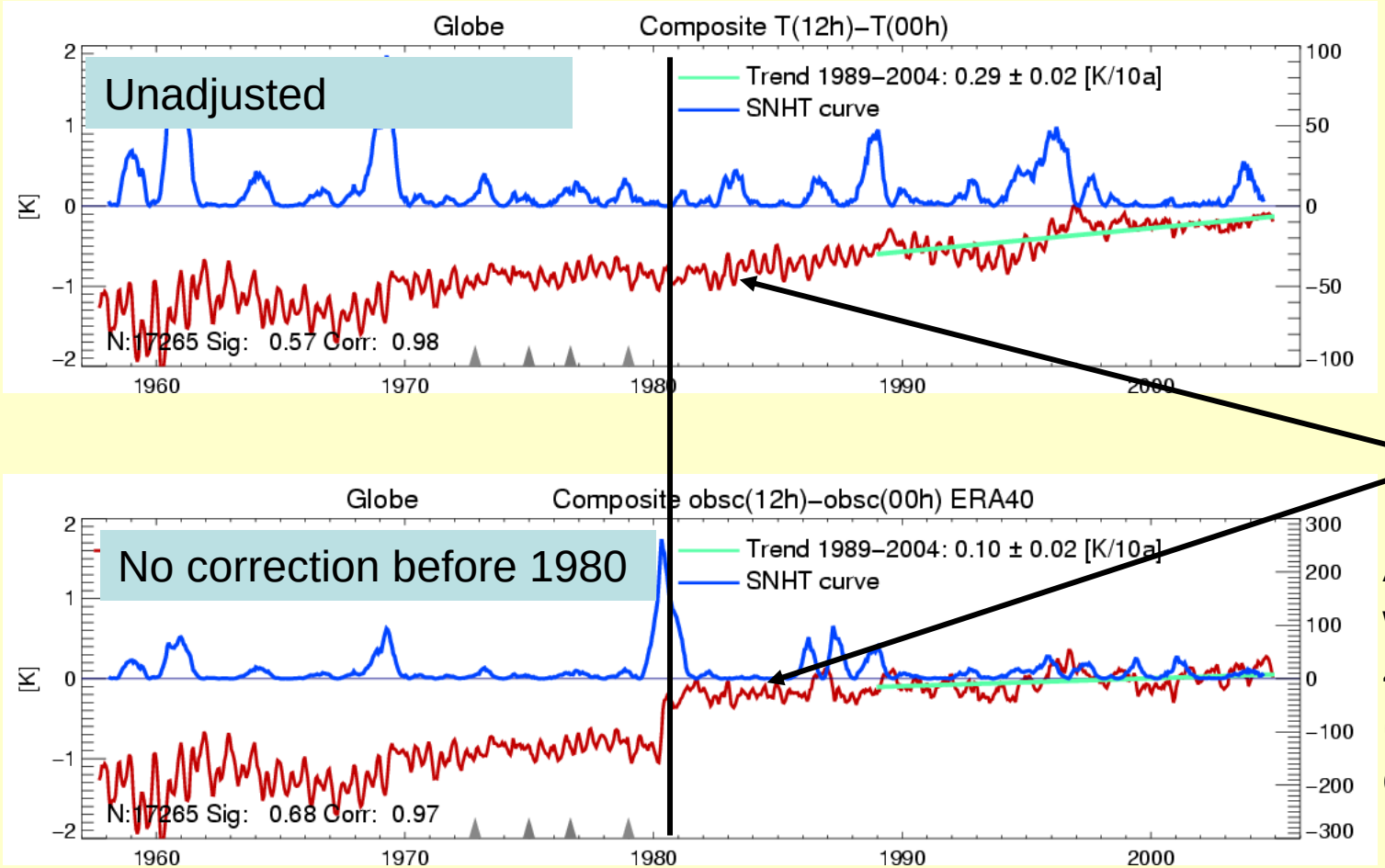
12h-00h, ERA-40 bc, Europe/Africa



12h-00h, 50hPa, Europe, unadjusted

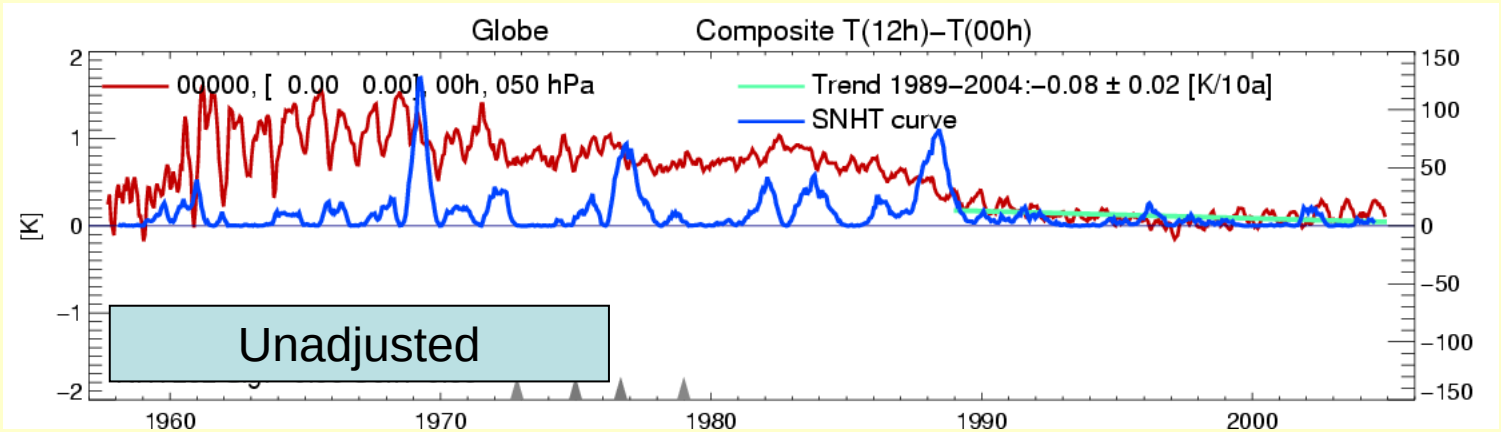
Adjusted with ERA-40 bc (1980 onwards)

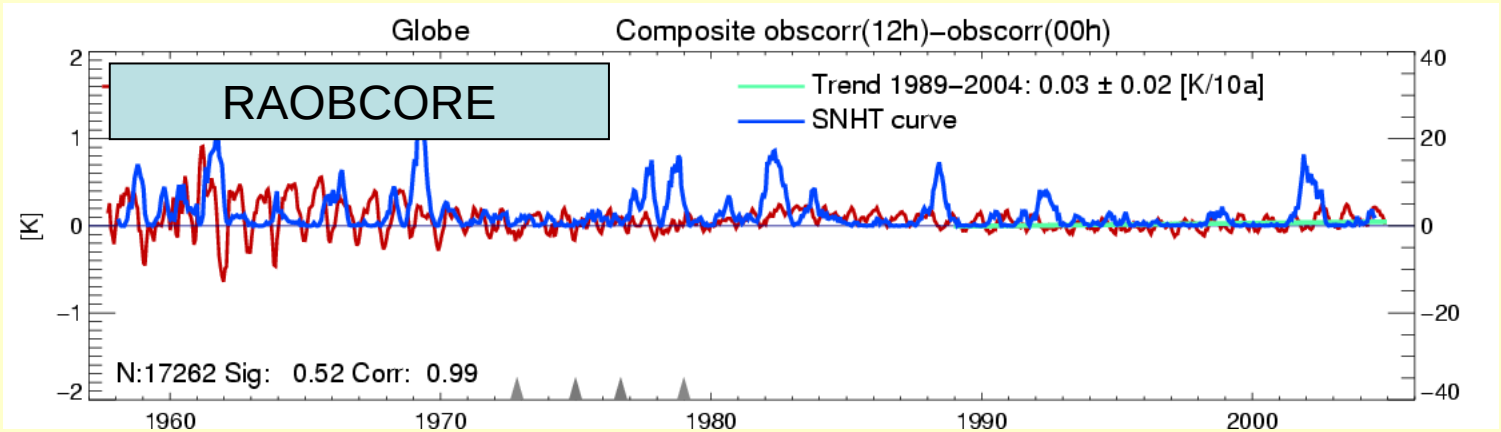
12h-00h of ERA-40 bc, Pacific

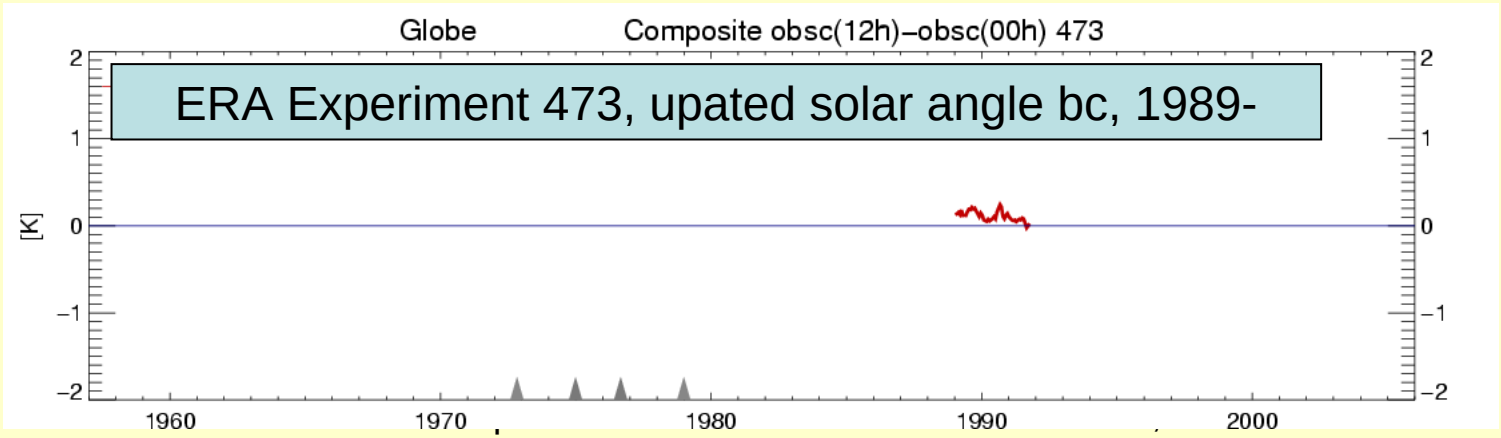


12h-00h, 50hPa, Pacific, unadjusted

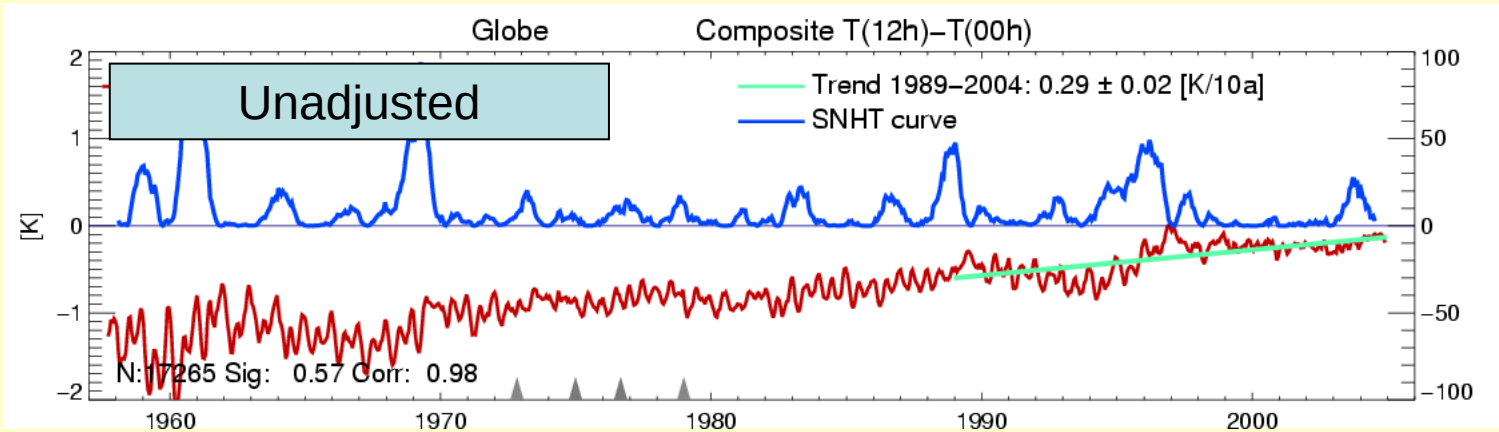
Adjusted with ERA-40 bc (1980 onwards)

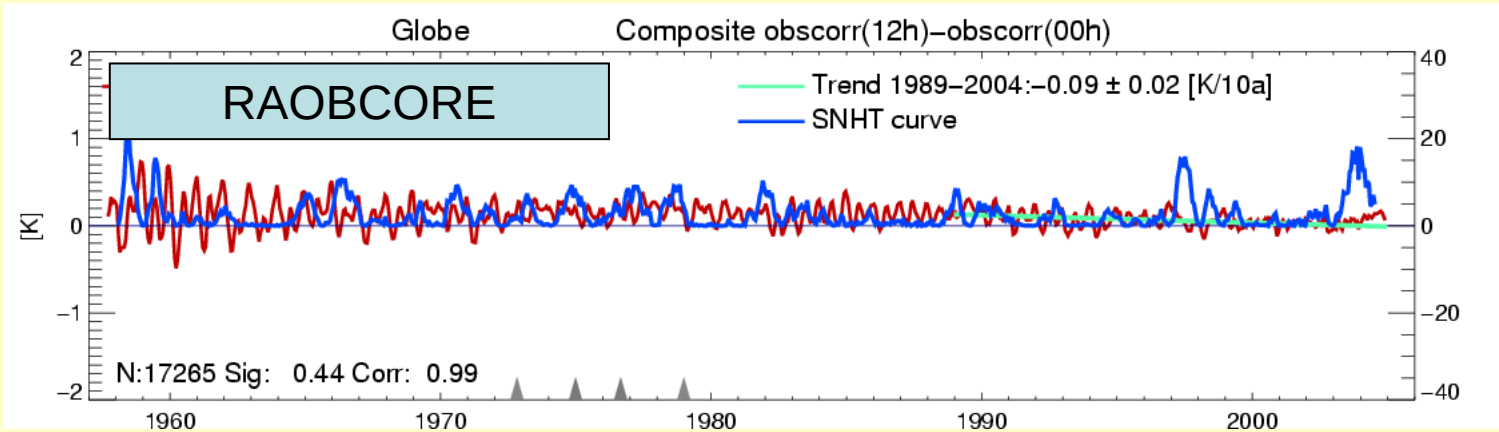


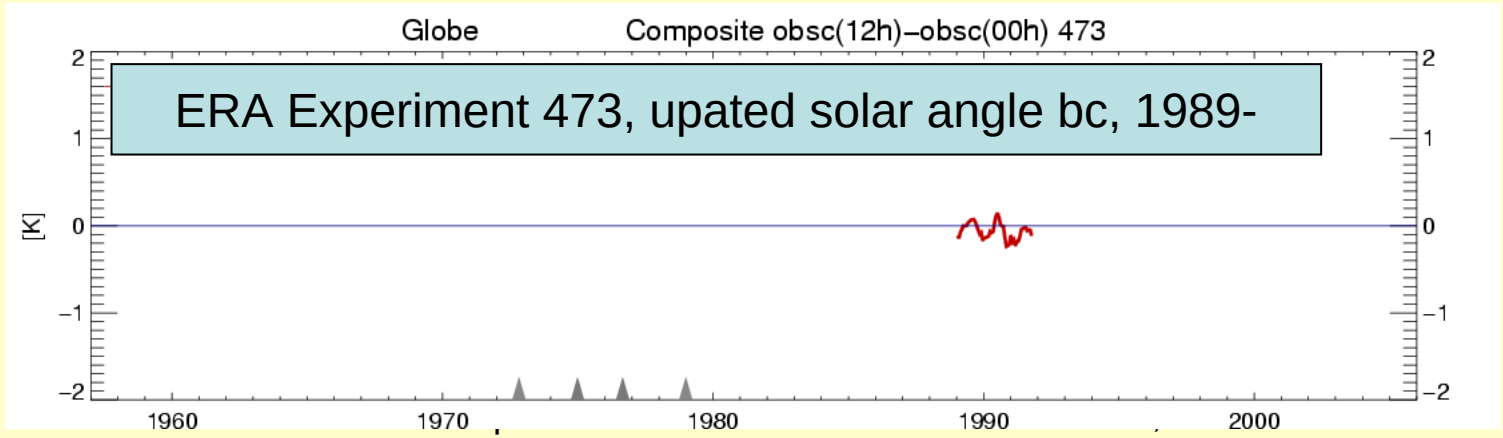




Europe
Africa


Globe
Composite T(12h)–T(00h)
Unadjusted
Trend 1989–2004: 0.29 ± 0.02 [K/10a]
SNHT curve
N:17265 Sig: 0.57 Corr: 0.98
[K]
1960
1970
1980
1990
2000

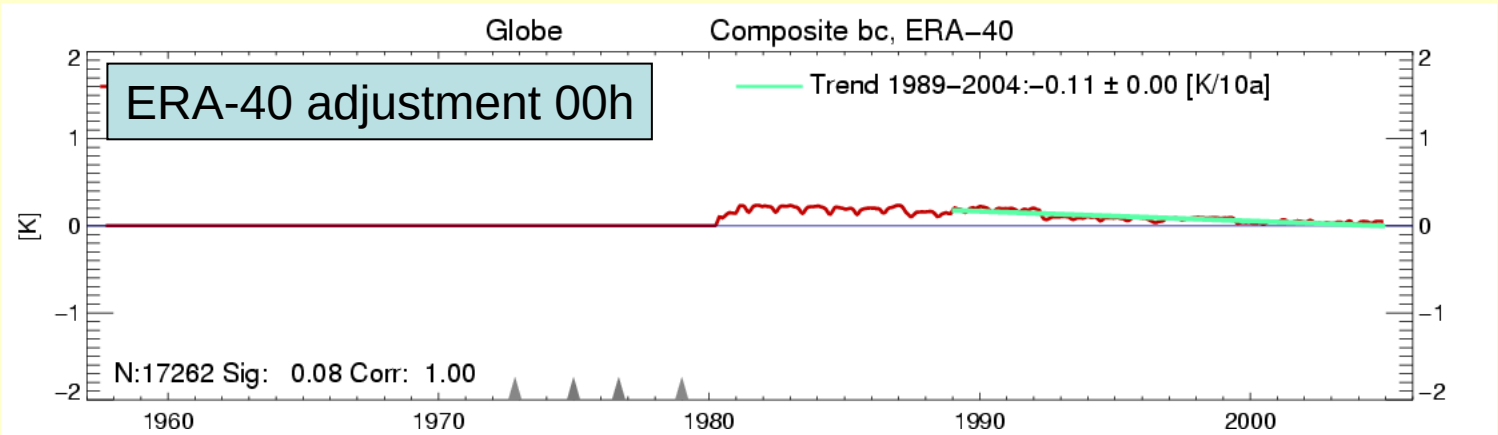

Globe
Composite obscorr(12h)–obscorr(00h)
RAOBCORE
Trend 1989–2004:–0.09 ± 0.02 [K/10a]
SNHT curve
N:17265 Sig: 0.44 Corr: 0.99
[K]
1960
1970
1980
1990
2000

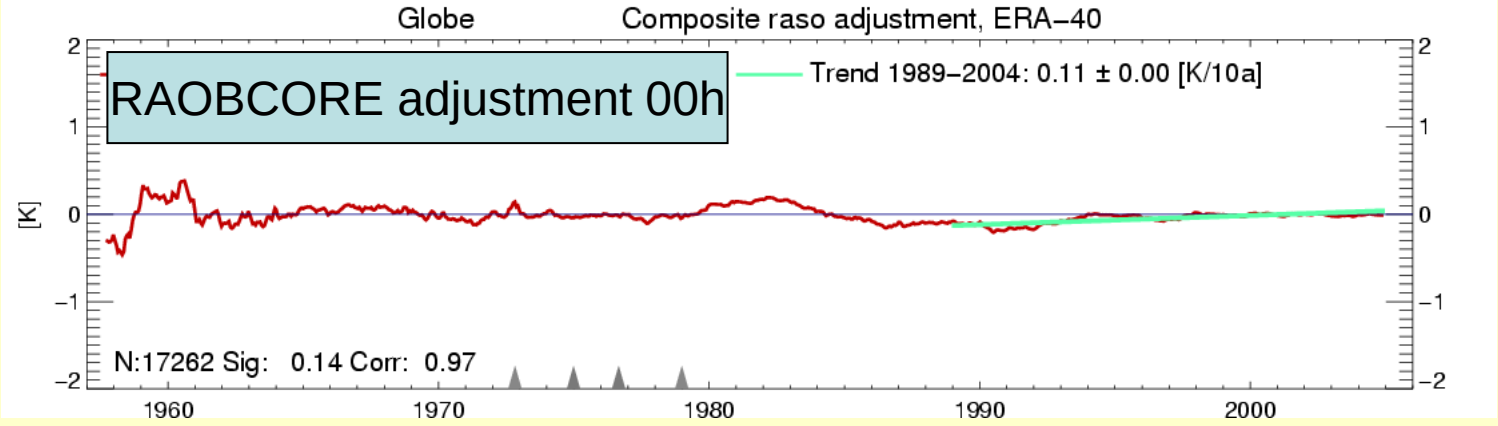

Globe
Composite obsc(12h)–obsc(00h) 473
ERA Experiment 473, upated solar angle bc, 1989-
[K]
1960
1970
1980
1990
2000

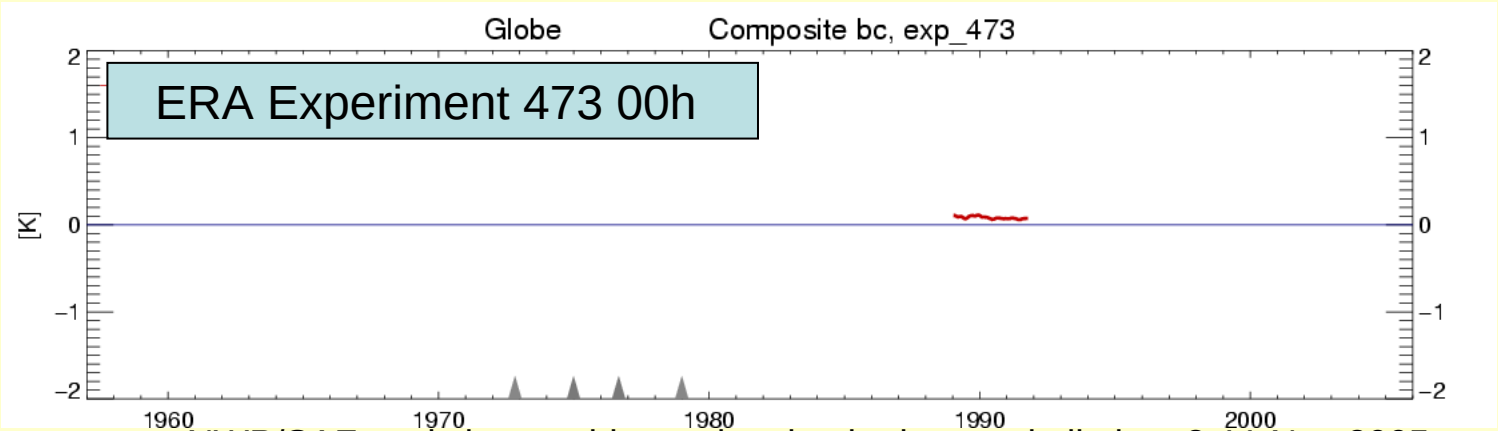
Pacific

12h-00h T-difference only a consistency check

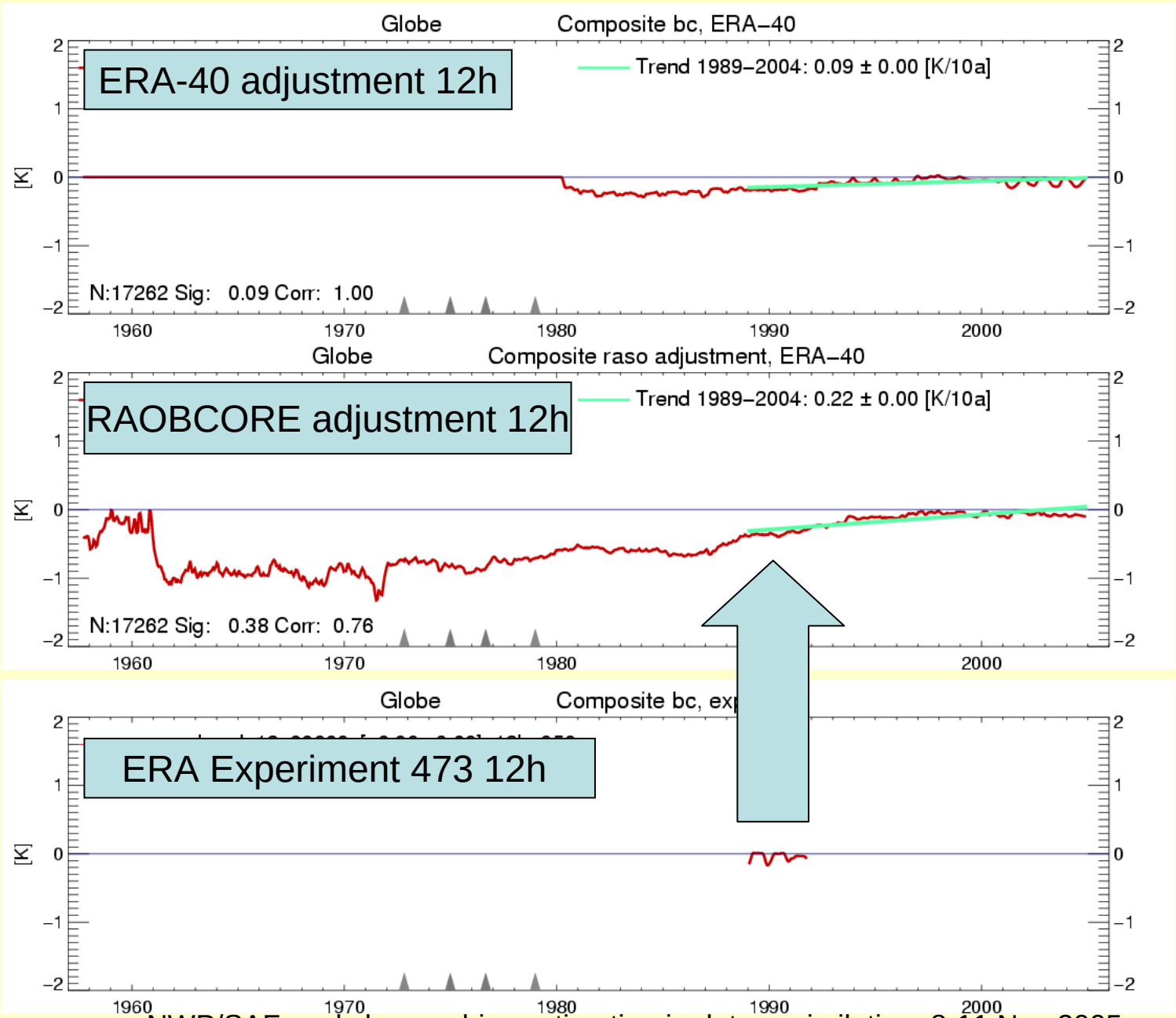
- There may still be daily mean biases
- -> Look at 00h and 12h adjustments separately







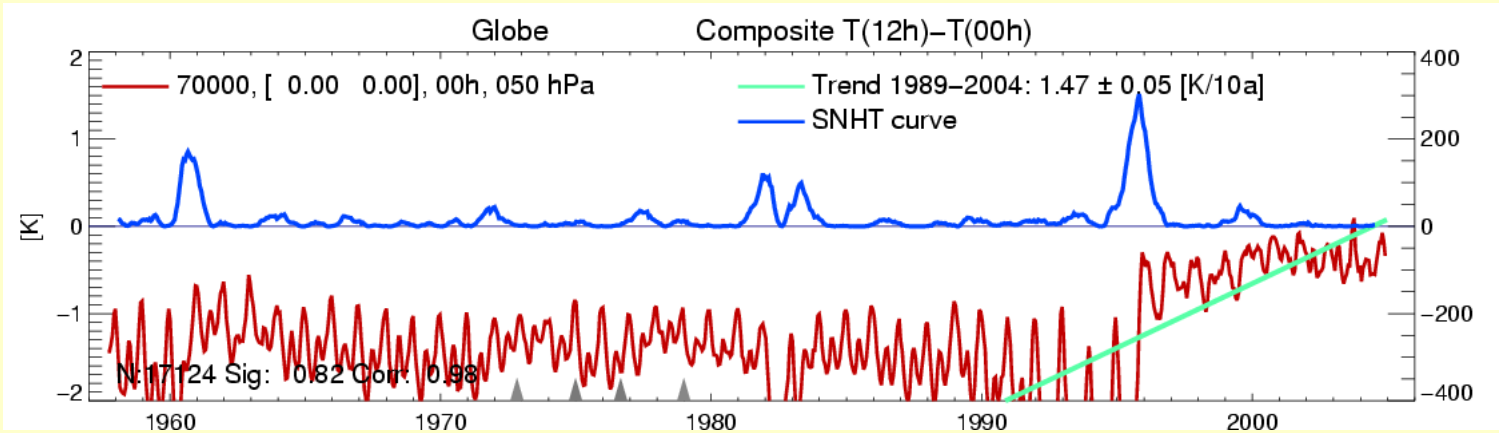
Adjustments
30W-40E
50hPa
00h

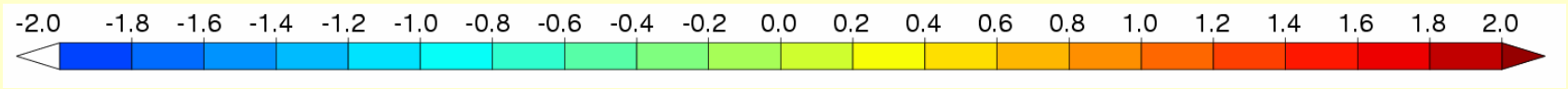


Adjustments
30W-40E
50hPa
12h

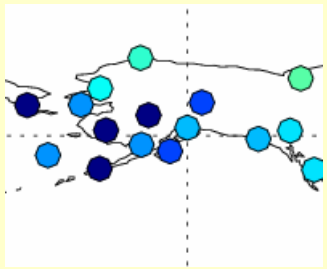
How to assess validity of adjustments?

- „Case Study“ Alaska

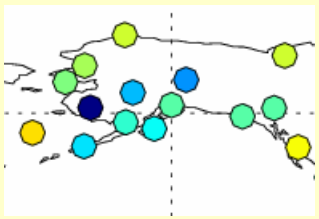




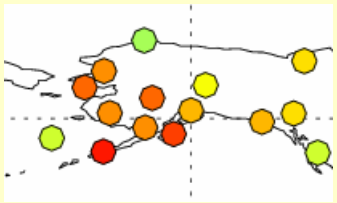
12h-00h
1989/90



Trend 00h
1989-2004



Trend 12h
1989-2004

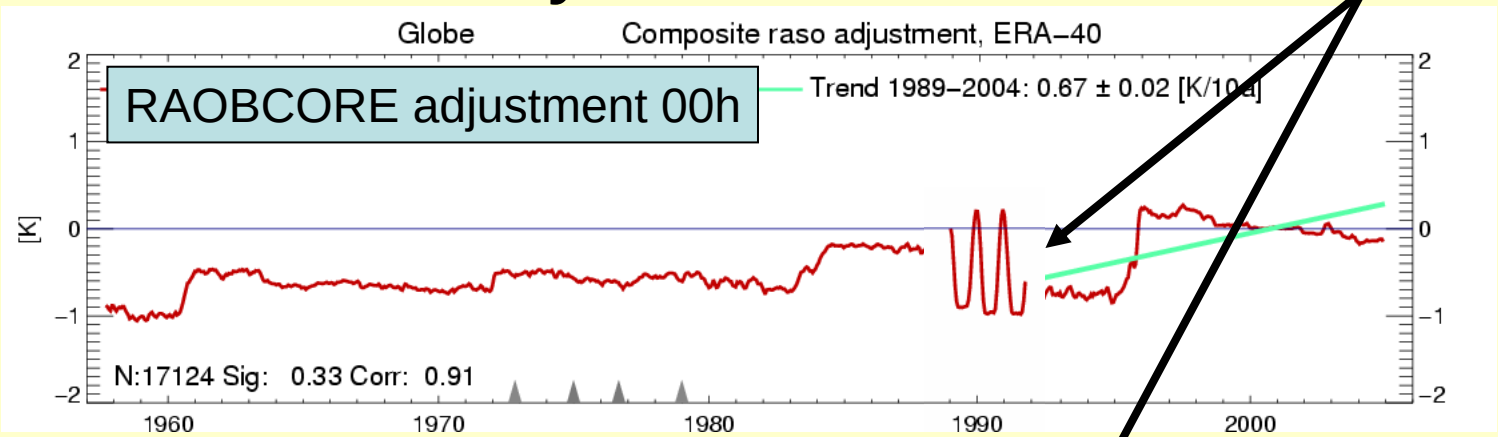


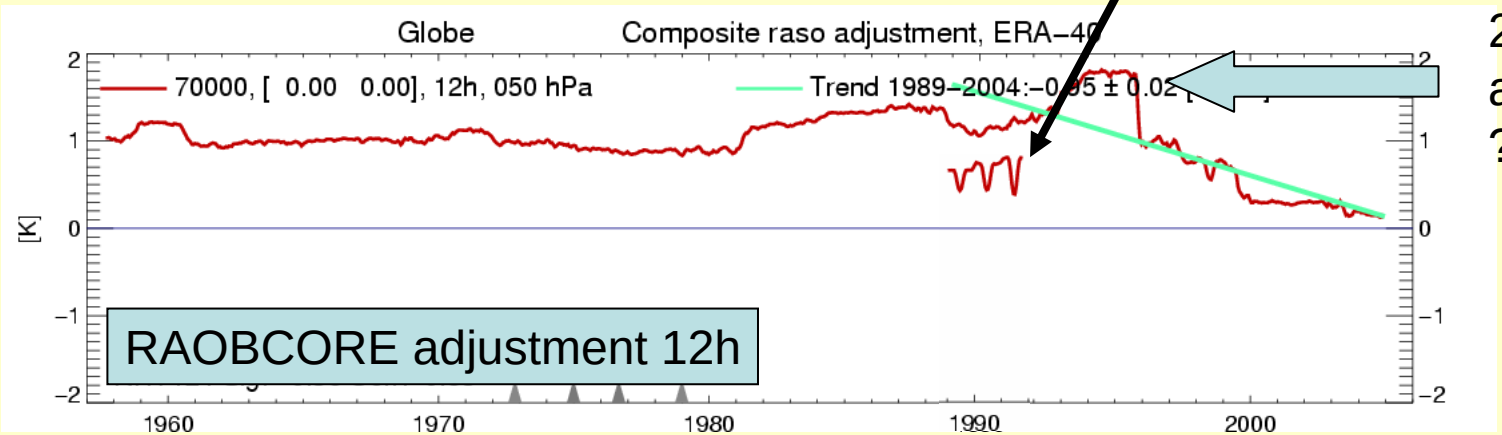
Unadjusted

How to assess validity of adjustments?

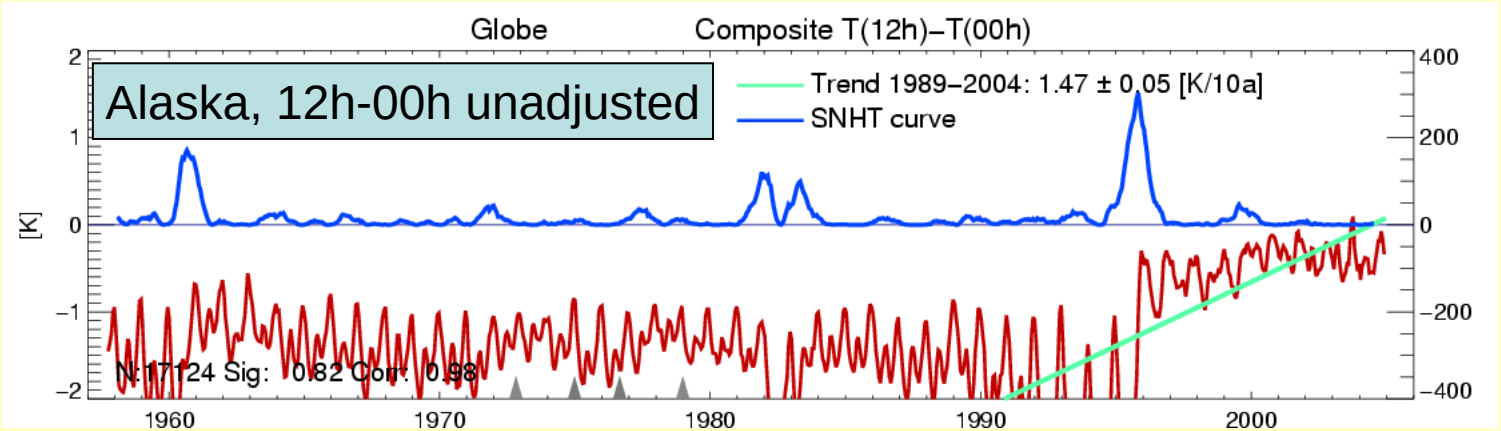
- „Case Study“ Alaska

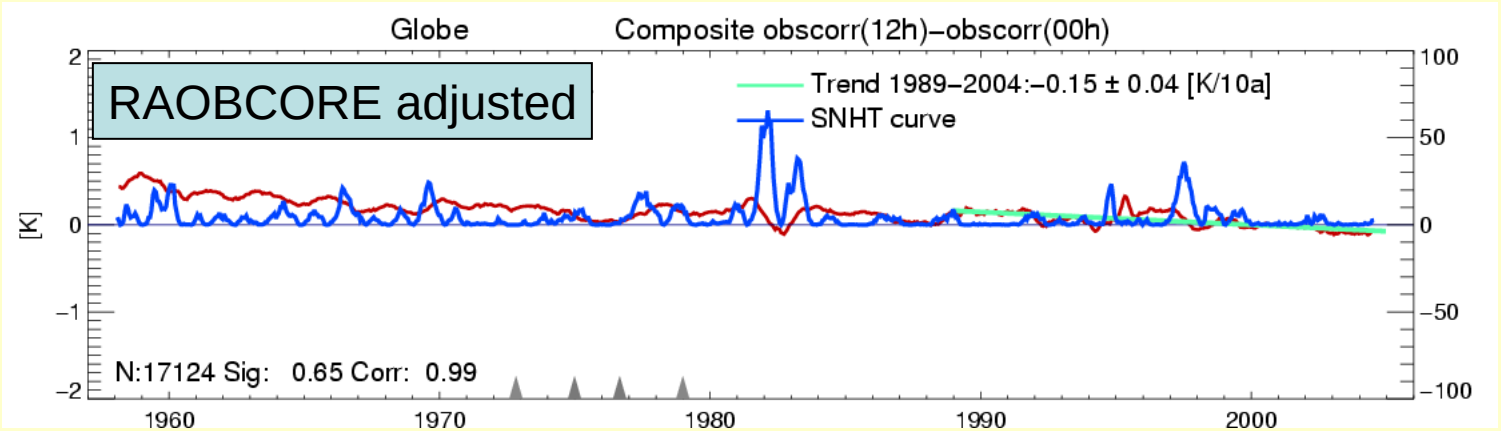
updated solar angle bc

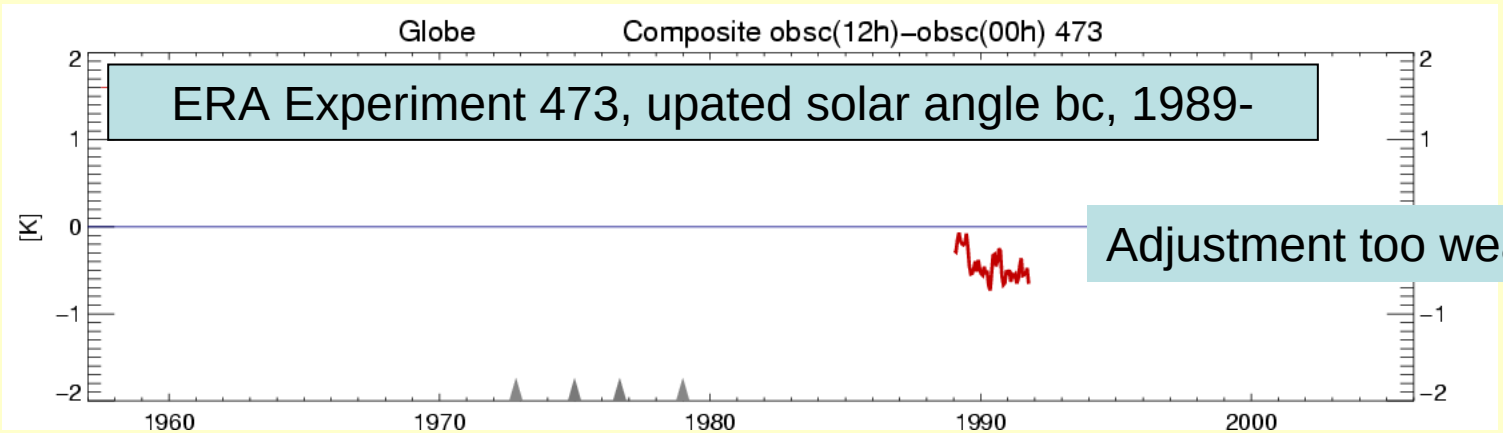




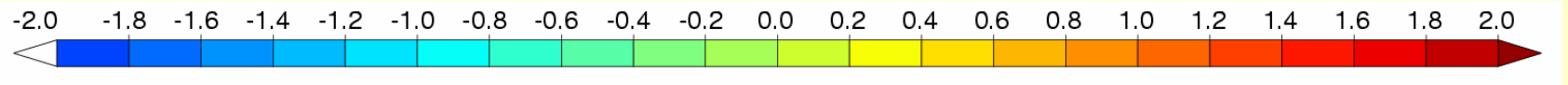
2K adjustment at nighttime ??


Globe
Composite T(12h)–T(00h)
Alaska, 12h-00h unadjusted
Trend 1989–2004: 1.47 ± 0.05 [K/10a]
SNHT curve
[K]
N:17124 Sig: 0.82 Corr: 0.98
1960
1970
1980
1990
2000


Globe
Composite obscorr(12h)–obscorr(00h)
RAOBCORE adjusted
Trend 1989–2004:–0.15 ± 0.04 [K/10a]
SNHT curve
[K]
N:17124 Sig: 0.65 Corr: 0.99
1960
1970
1980
1990
2000


Globe
Composite obsc(12h)–obsc(00h) 473
ERA Experiment 473, upated solar angle bc, 1989-
Adjustment too weak?
[K]
1960
1970
1980
1990
2000

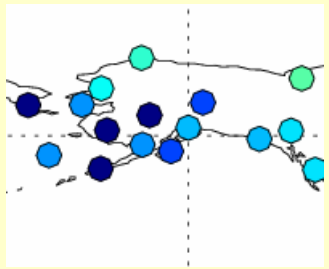
Effect of adjustments in Alaska

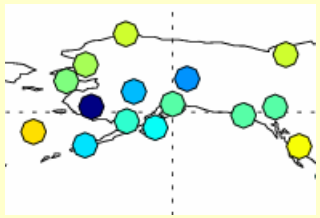


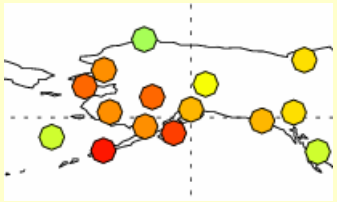
12h-00h
1989/90

Trend 00h
1989-2004

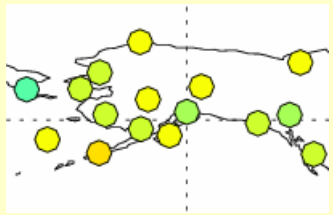
Trend 12h
1989-2004

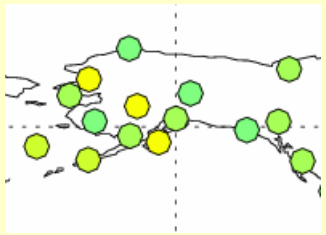


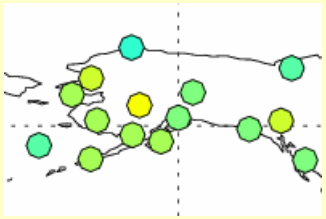




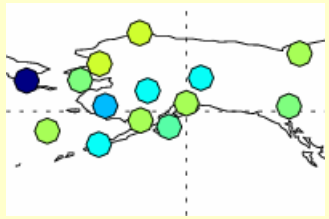
Unadjusted





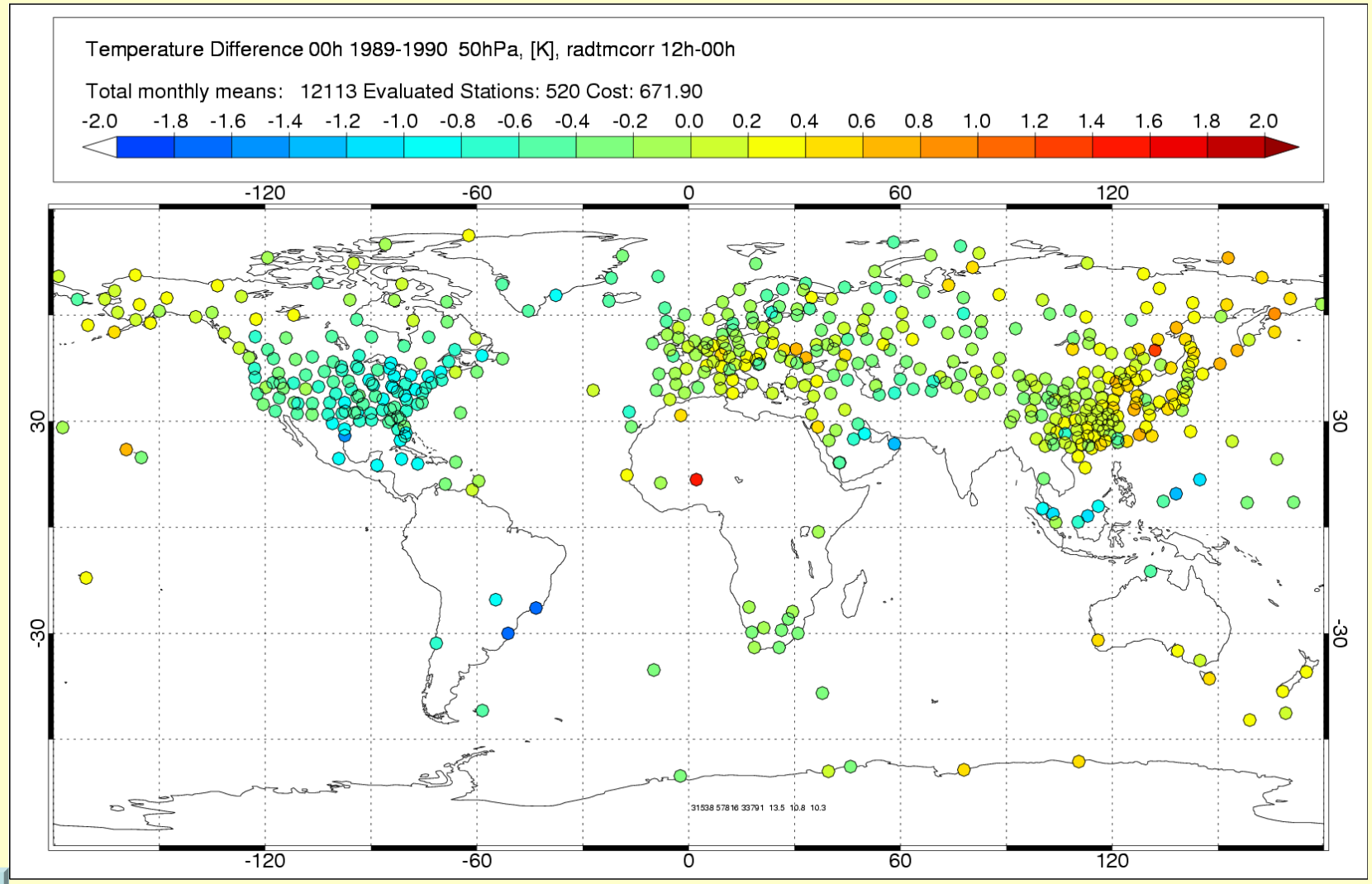


RAOBCORE
adjusted

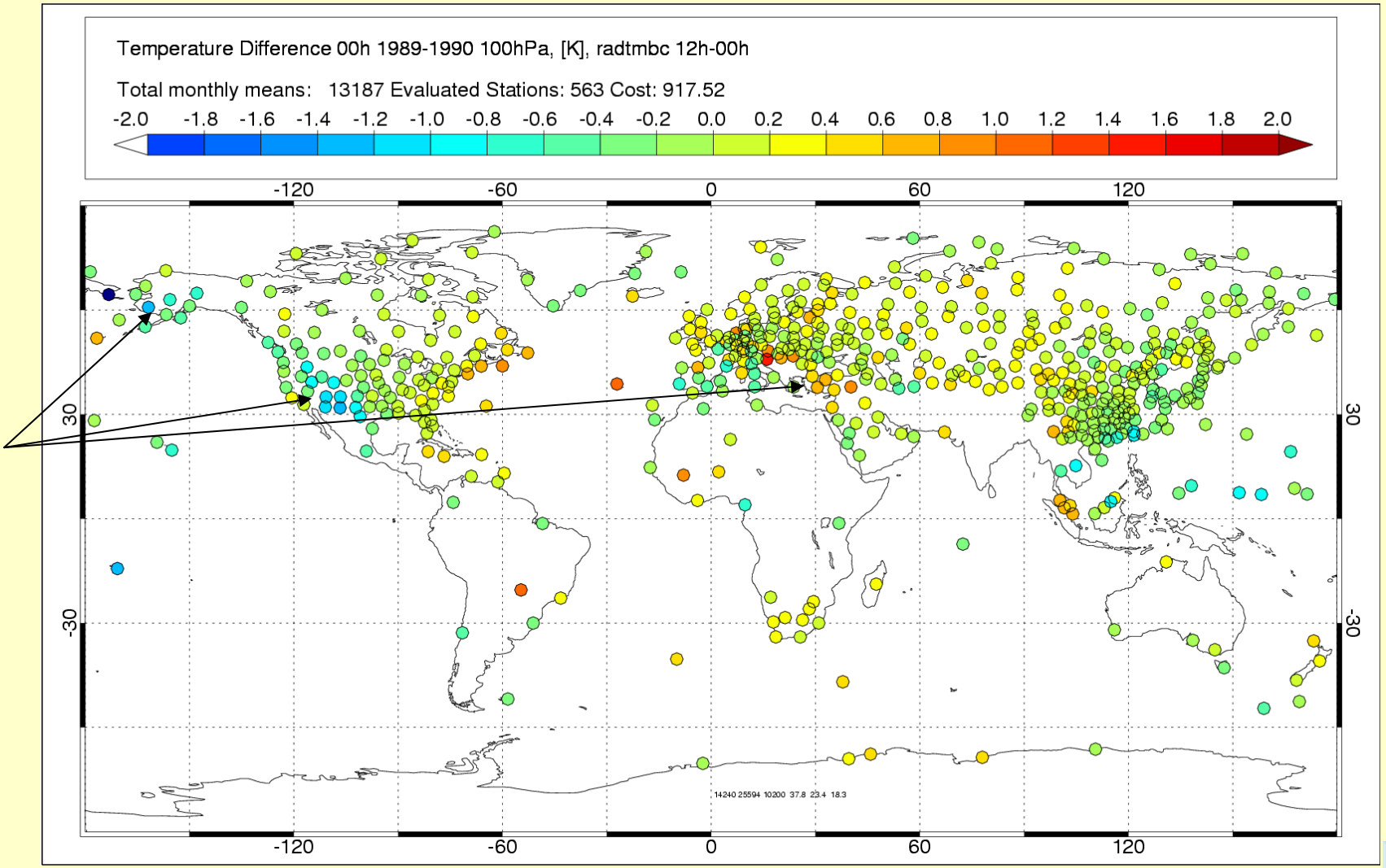


Updated solar angle
dependent adjustment

RAOBCORE,12h-00h 50hPa, 1989-90



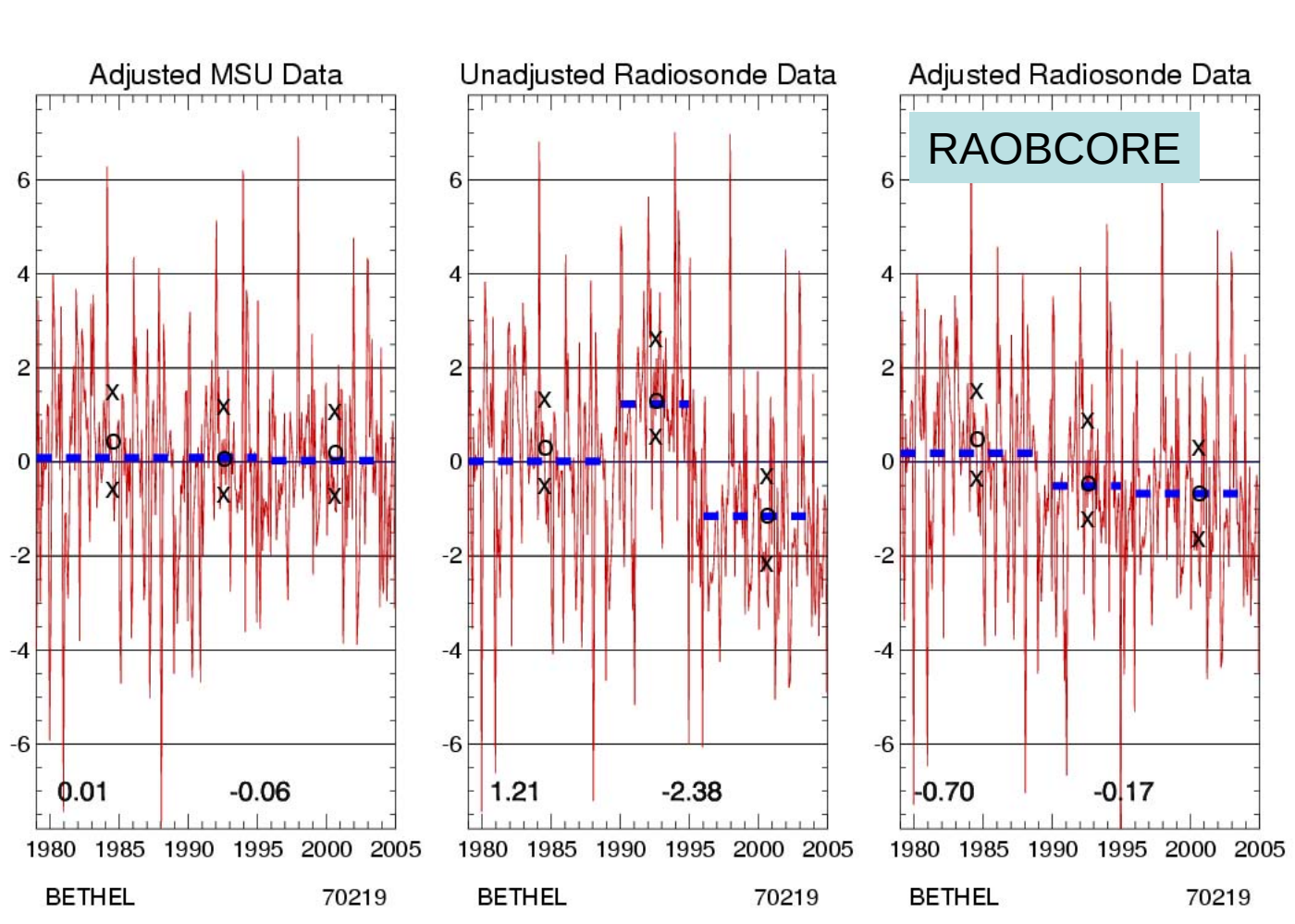
New solar angle bc, 1989-1990



Comparison with other upper air data

- Comparison with MSU-TLS
- Comparison with IRI results

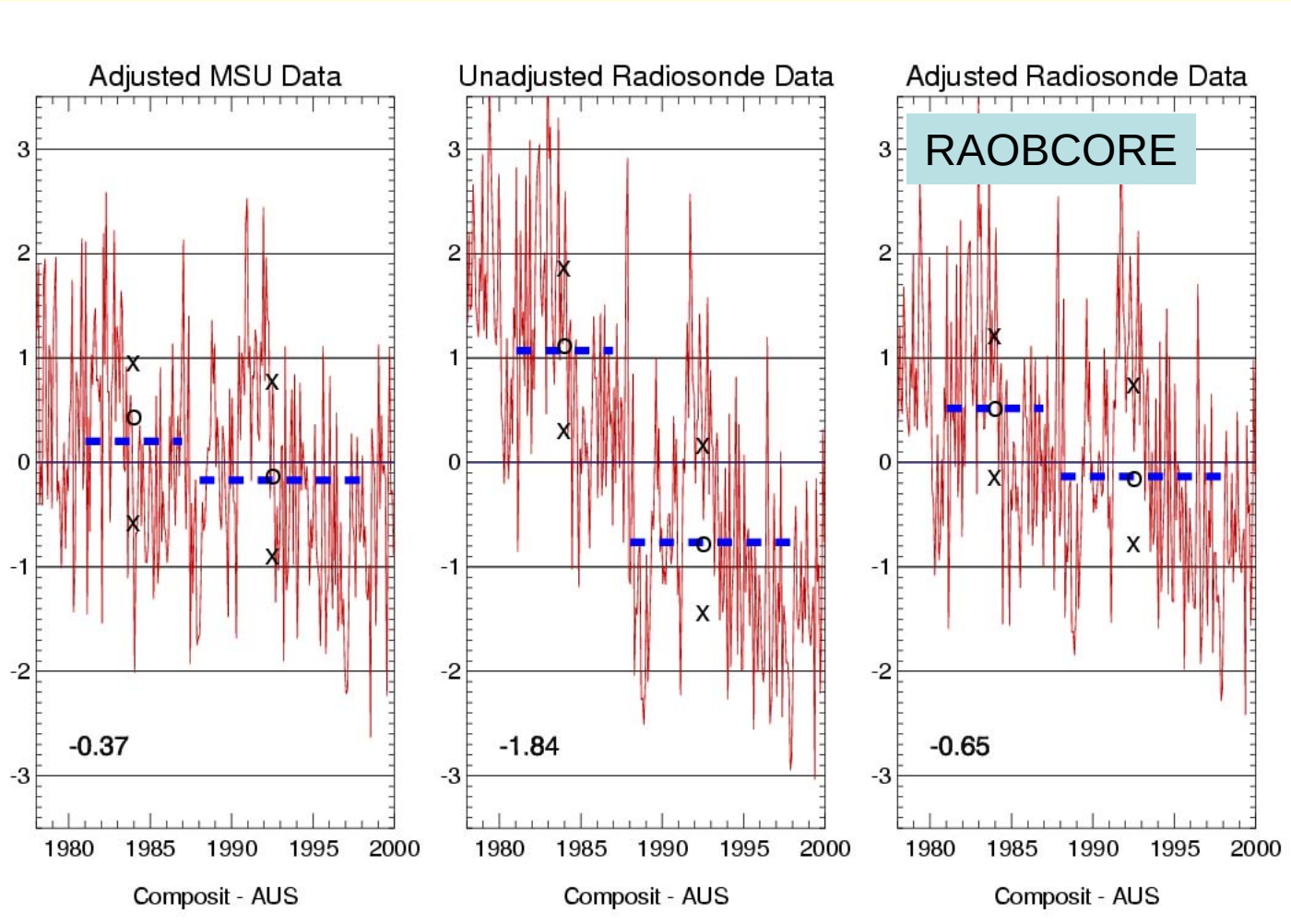
MSU-TLS-Comparison at Alaska



Weighted layer average temperature anomalies

MSU data from Remote Sensing Systems

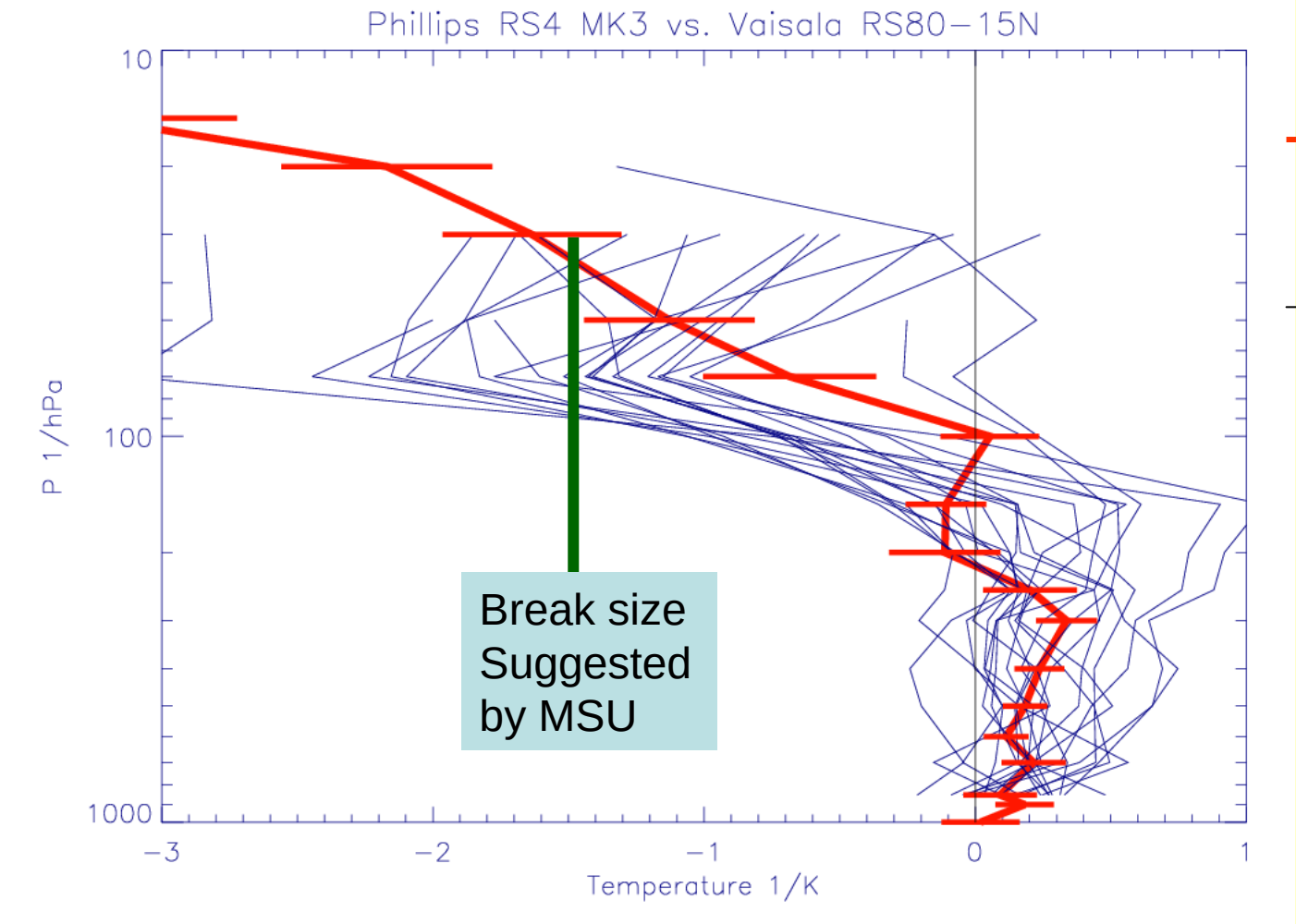
MSU-TLS-Comparison Australia



Adjustments
Still too weak?

MSU data from Remote Sensing Systems

RS- Intercomparison Experiments



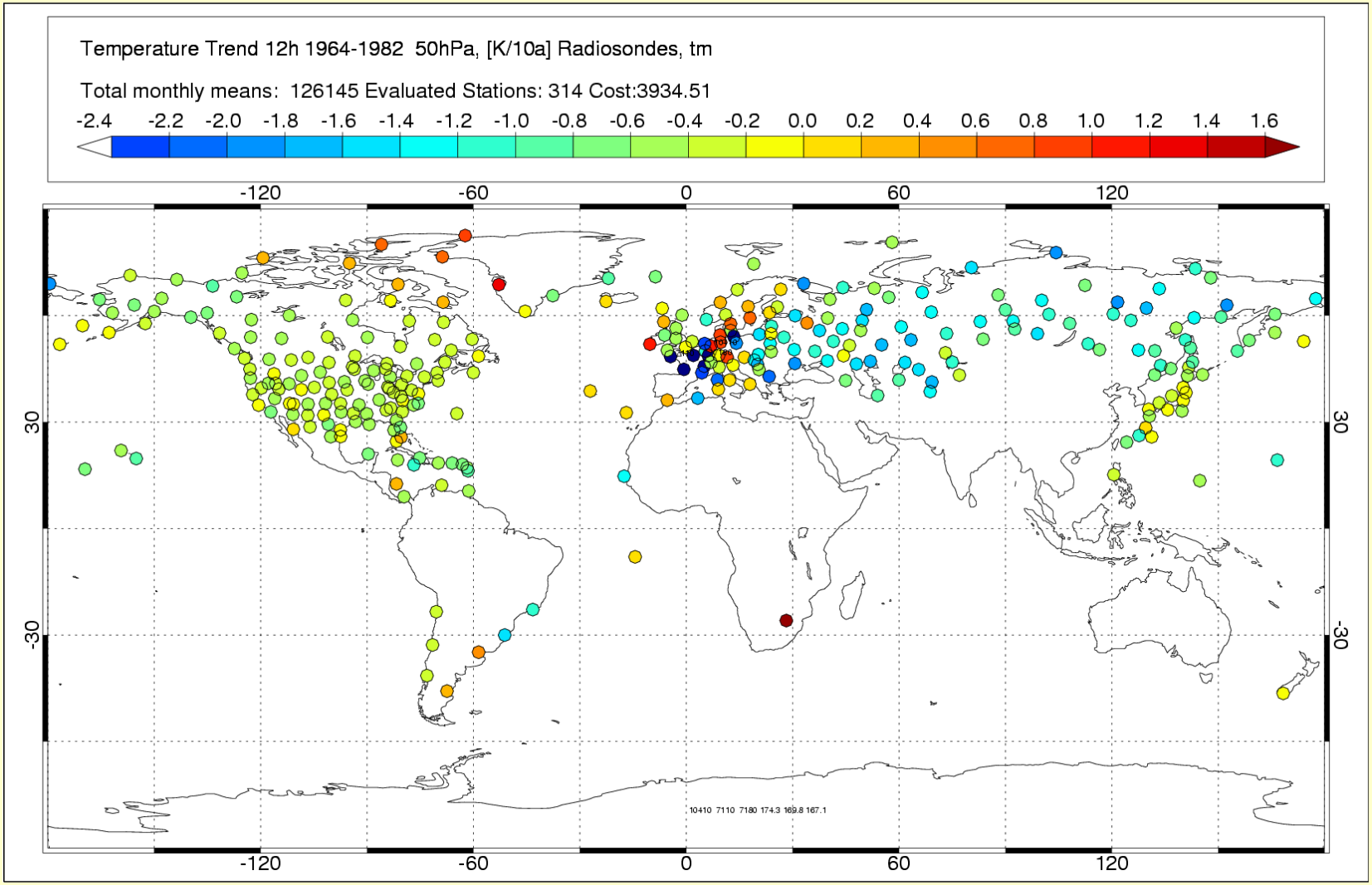
IRI 1987
Wallops Is.

Individual
RAOBCORE
adjustments
at Australian
stations
1987/1988

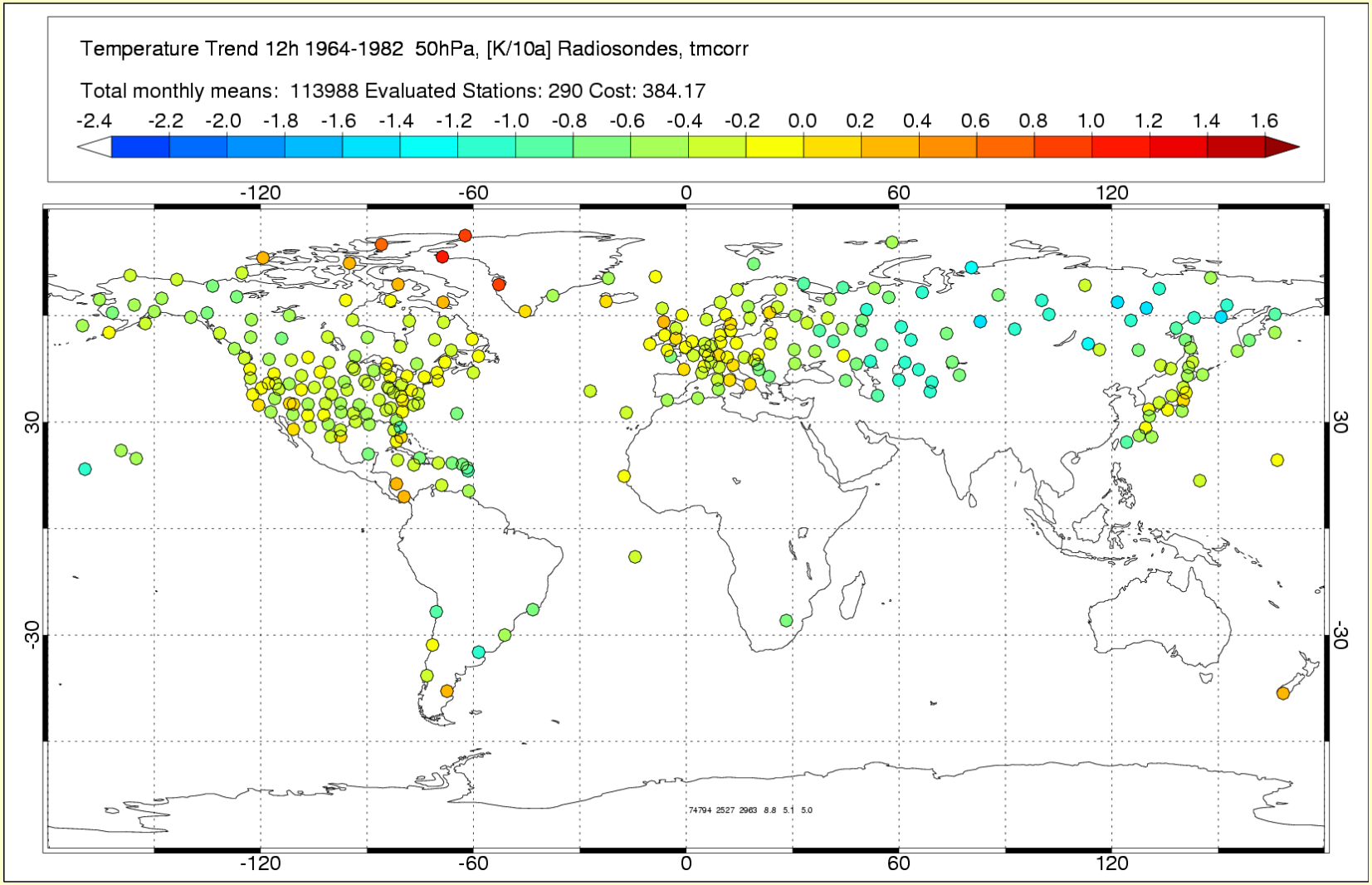
Further results

- Early period (-1980)
- Breaks at low and high atmospheric levels
- Temperature Trends
- Temporal homogeneity of background
- Adjustment of most recent part of time series

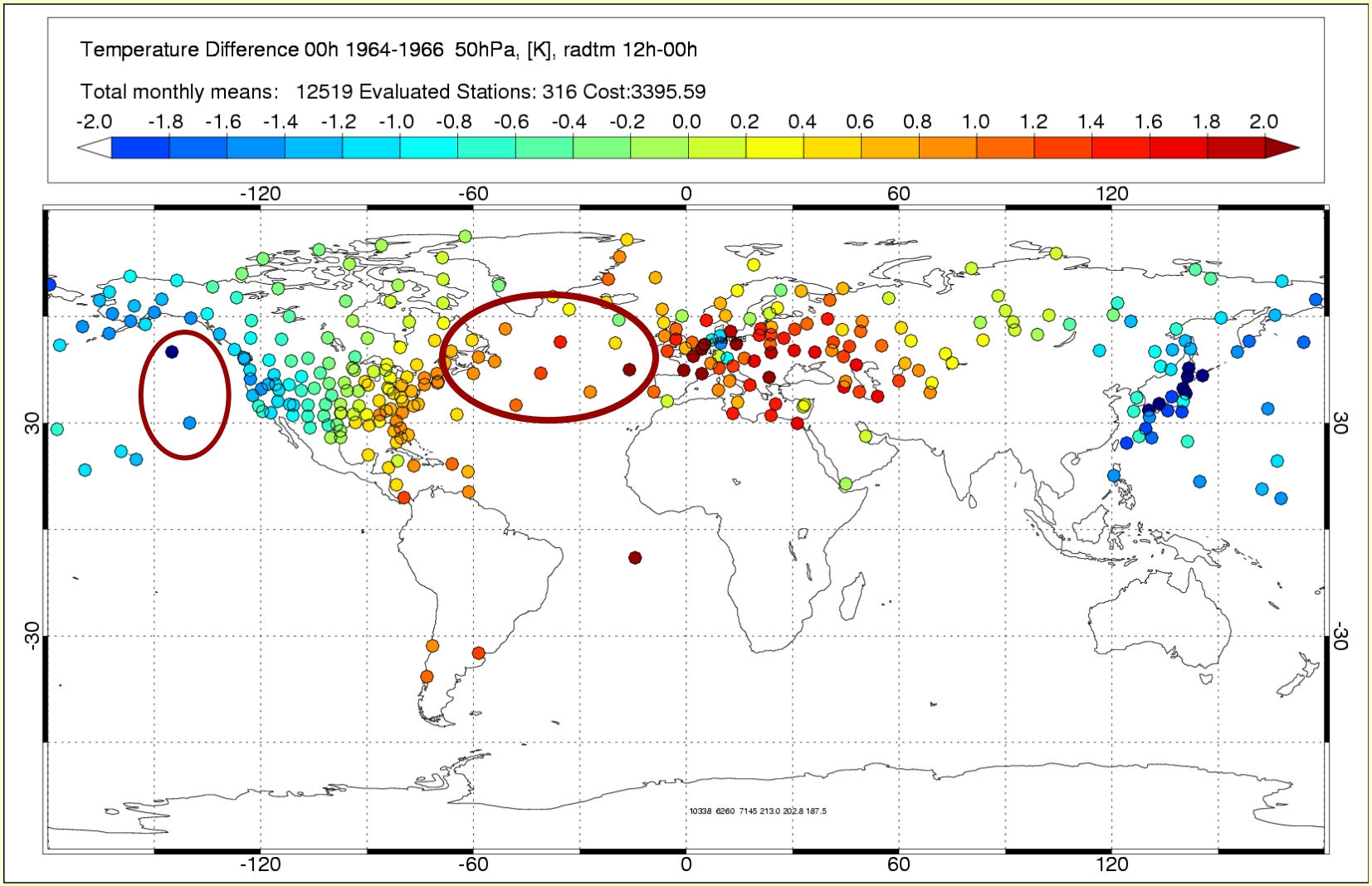
Unadjusted T-trends, 12h, 50hPa, 1964-1982



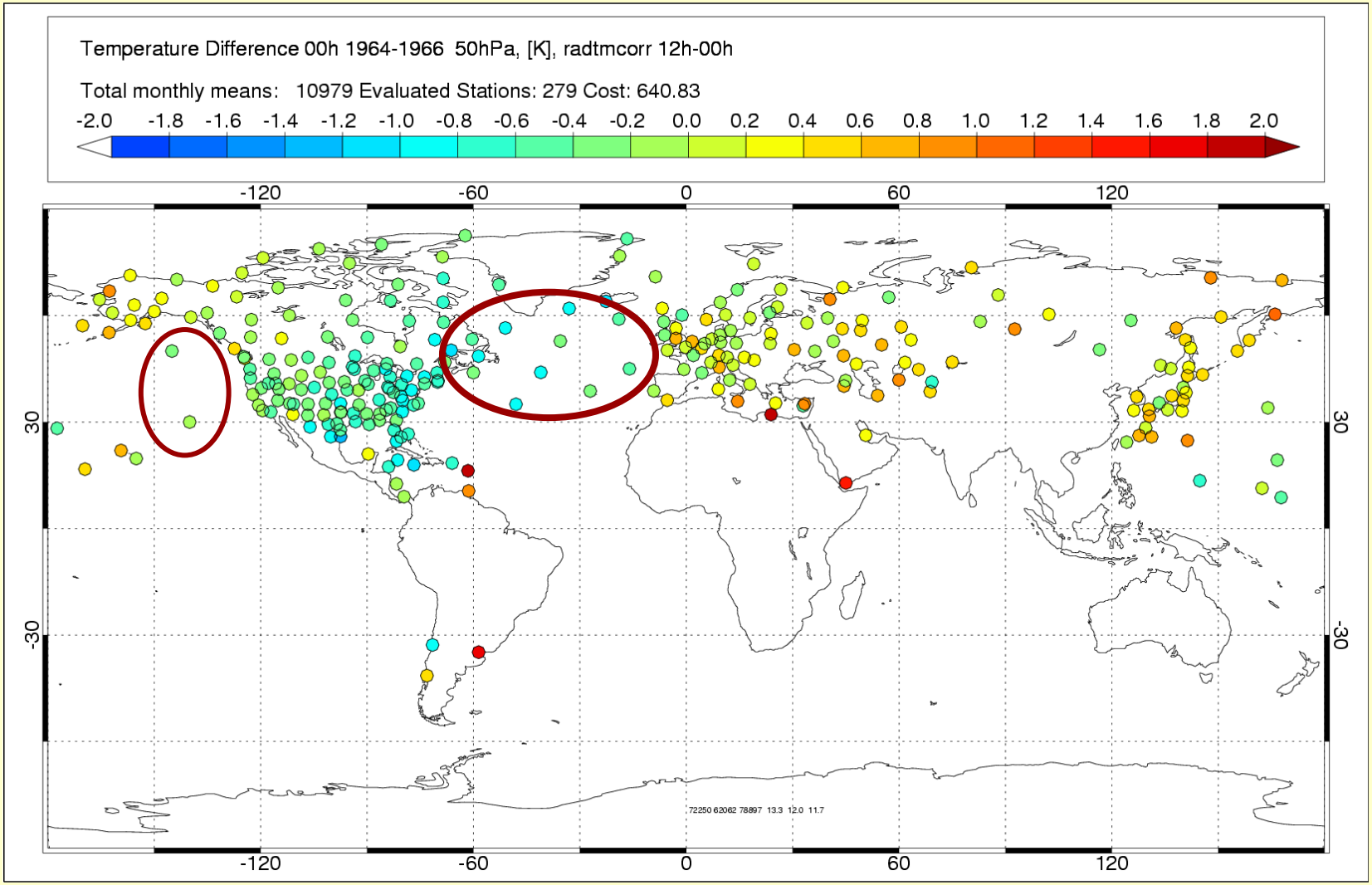
Adjusted T-trends, 12h, 50hPa, 1964-1982

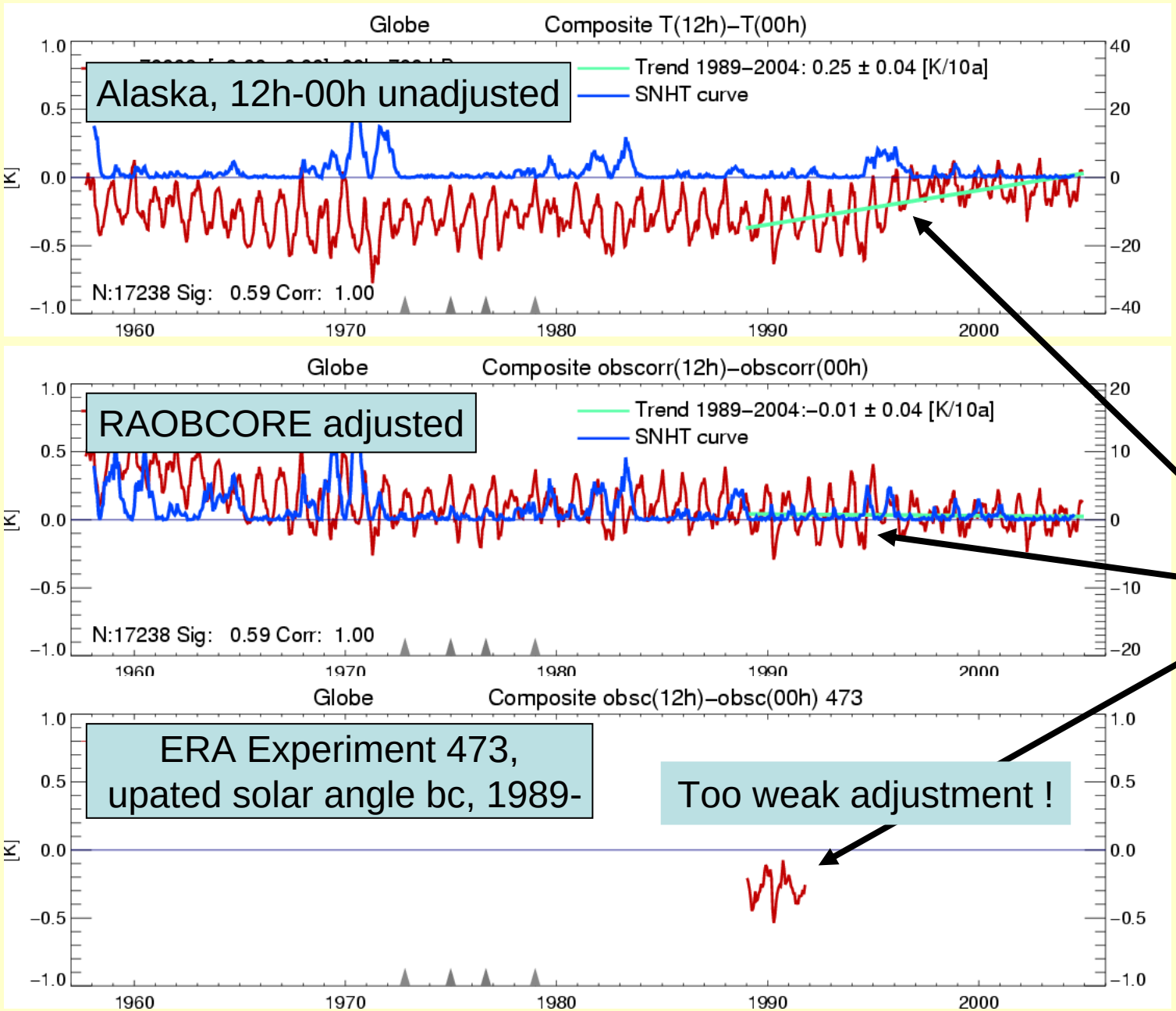


Unadj.12h-00h difference, 1964-1966



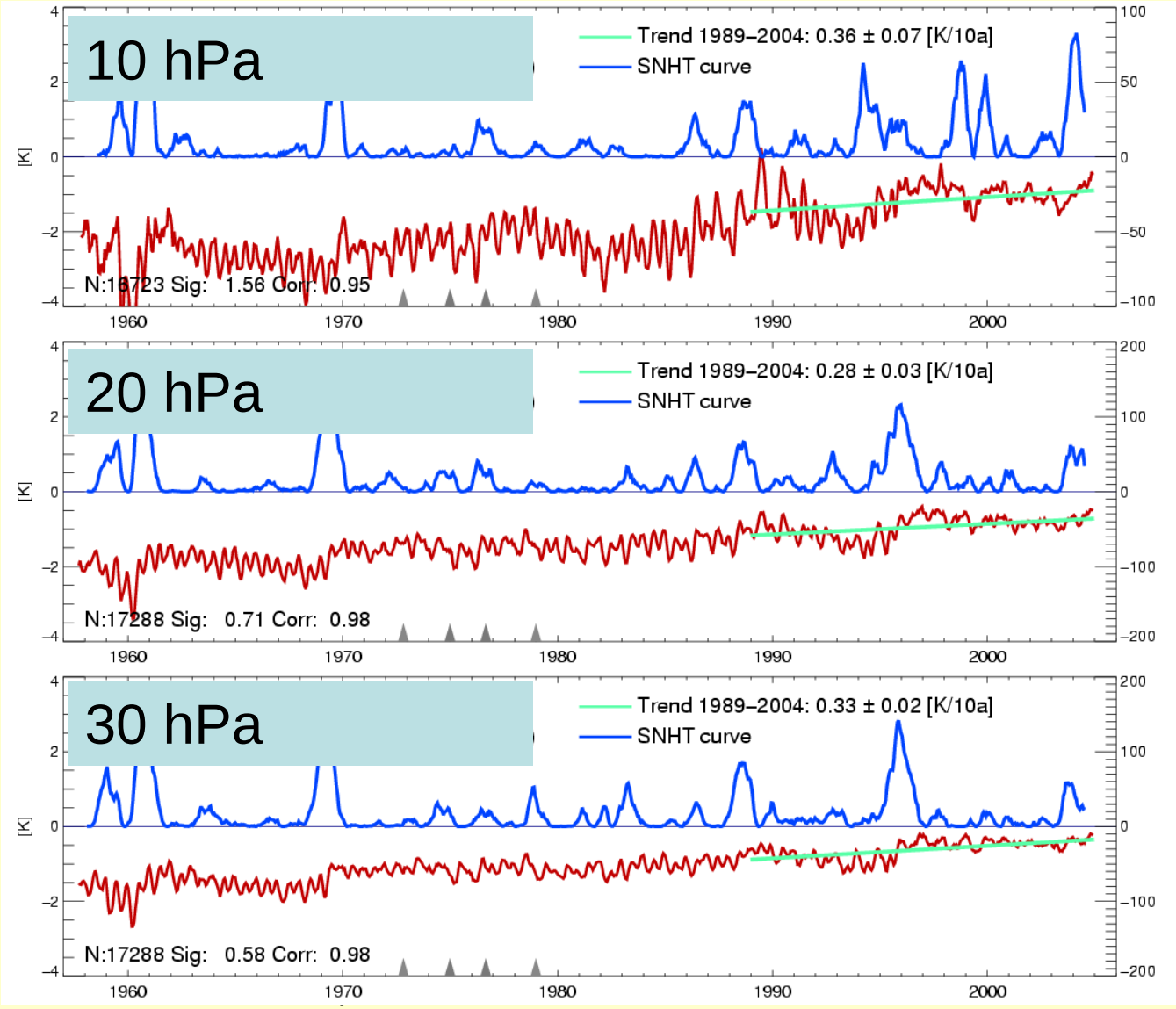
Adj. 12h-00 difference, 1964-1966



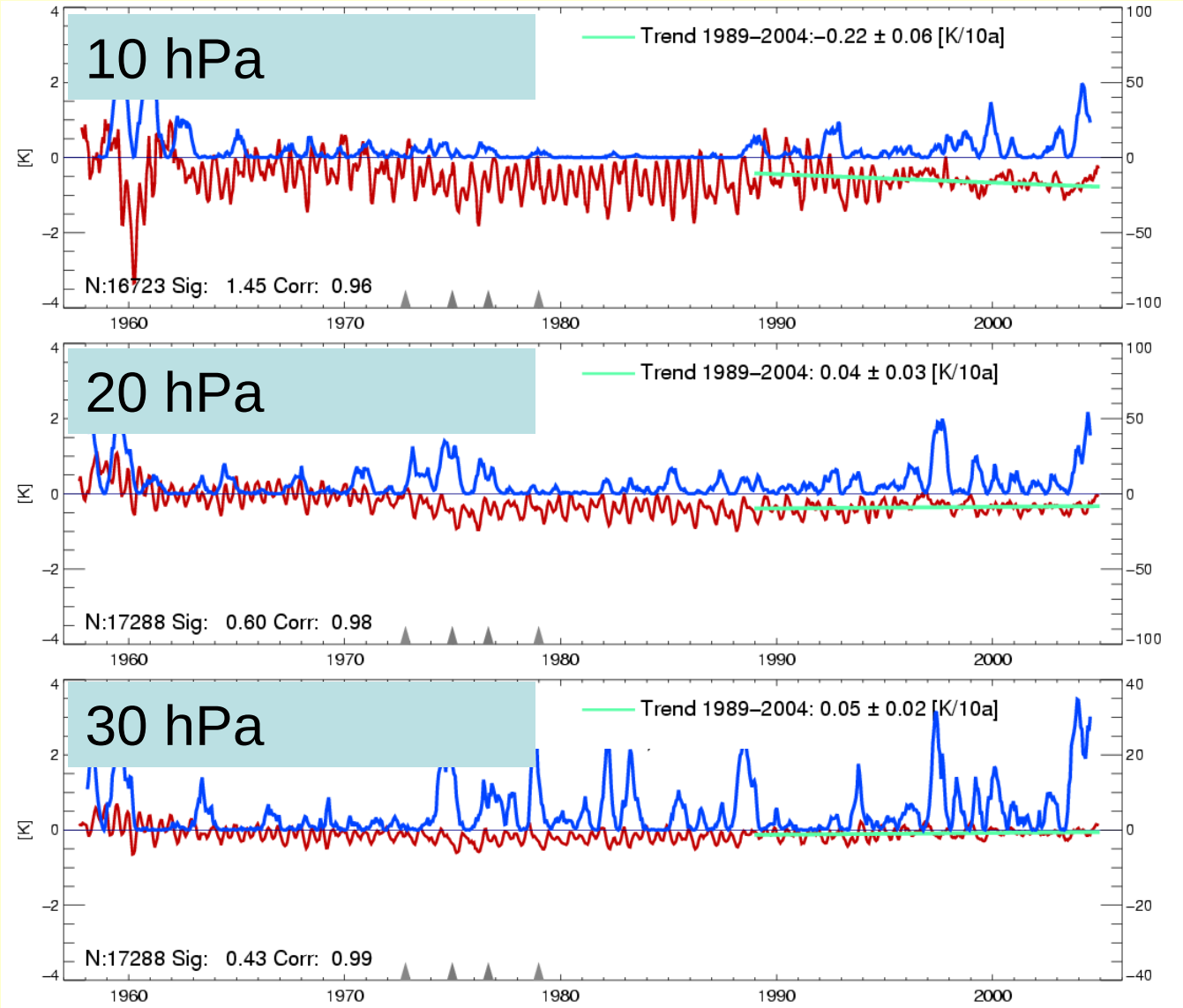


Alaska
700 hPa

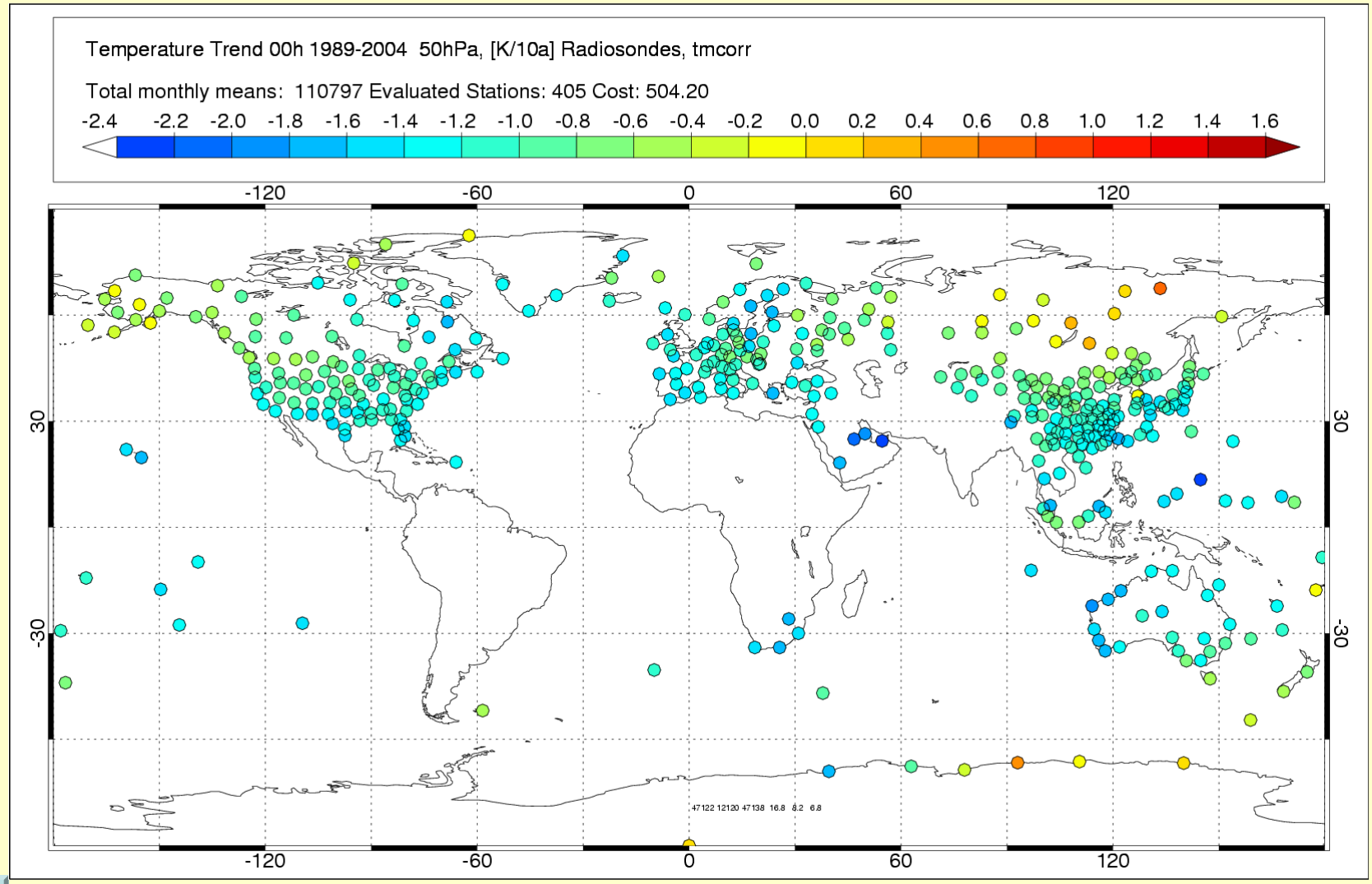
Unadj. 12h-00h, high levels, Pacific



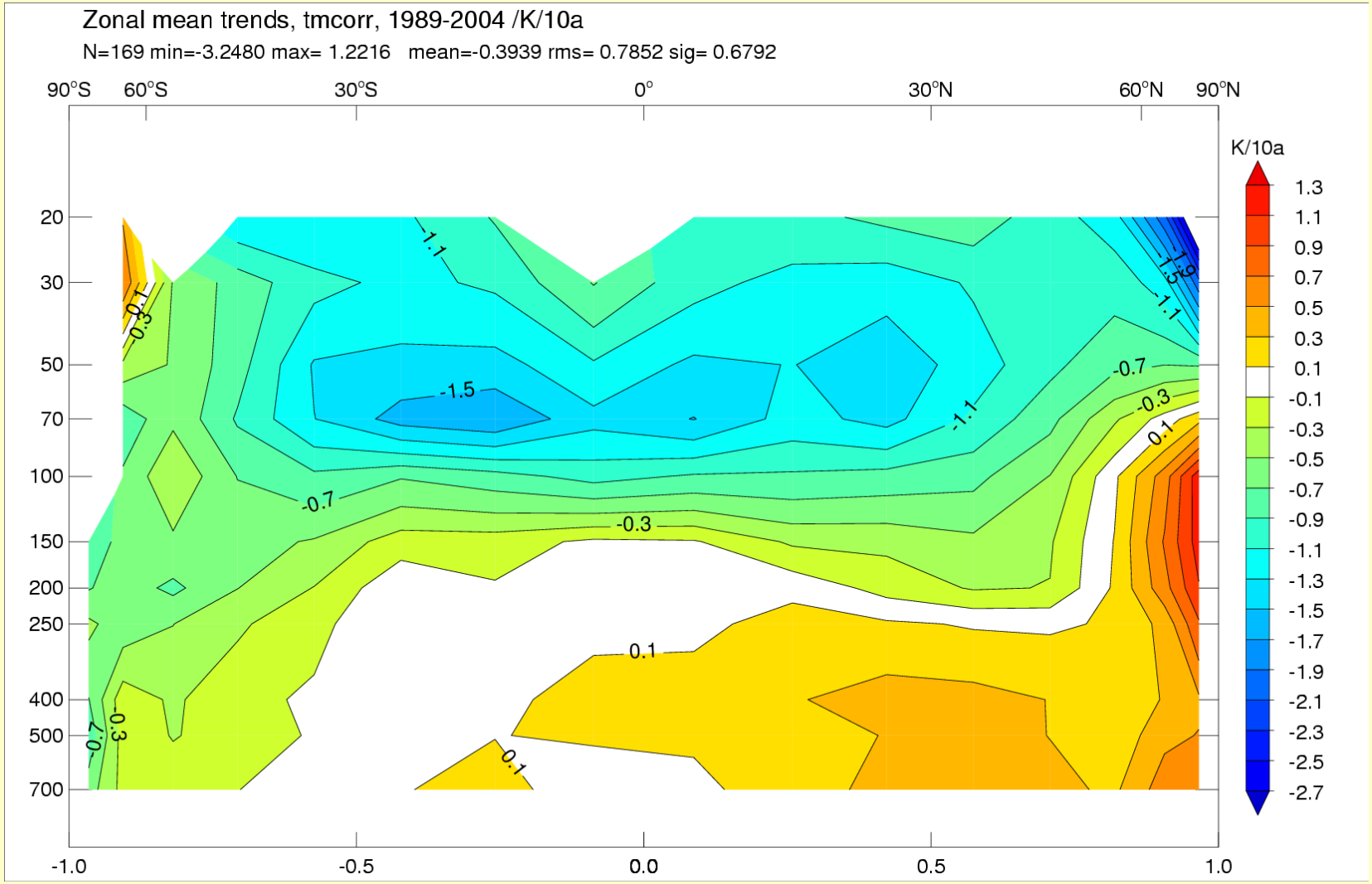
Adj. 12h-00h, high levels, Pacific



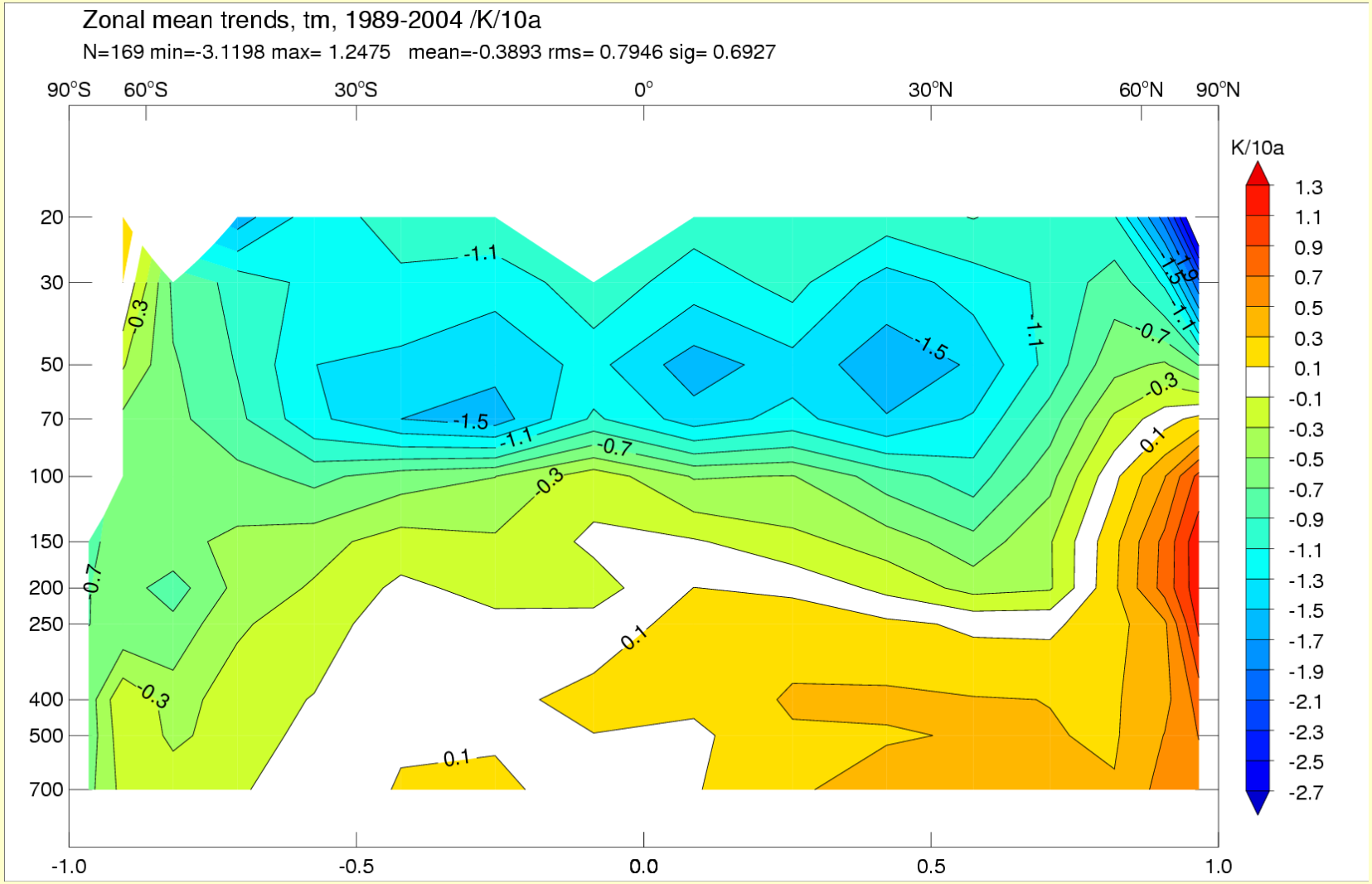
Adjusted T-trends, 00h, 50hPa, 1989-2004



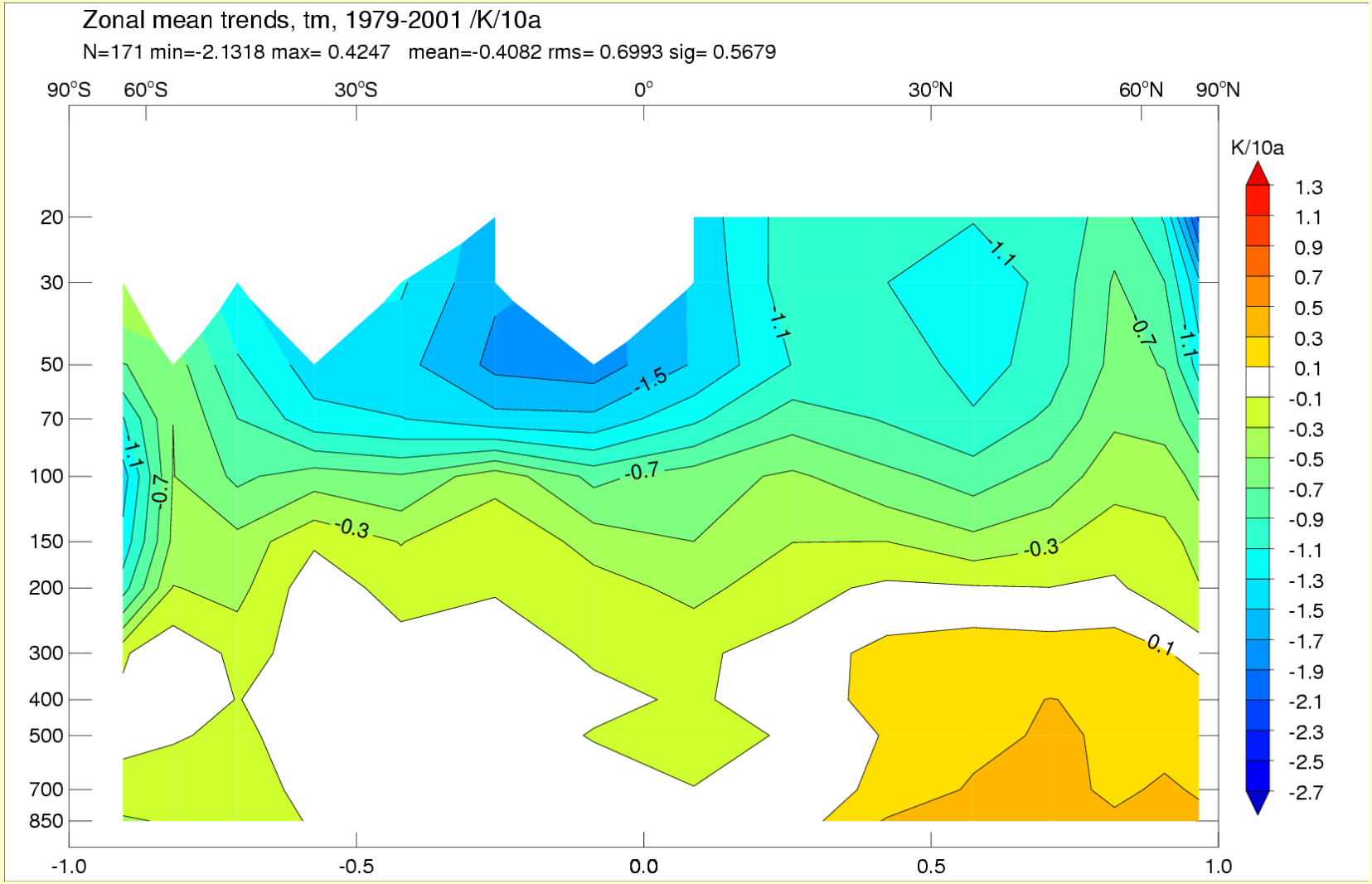
Adjusted T-trends 1989-2004



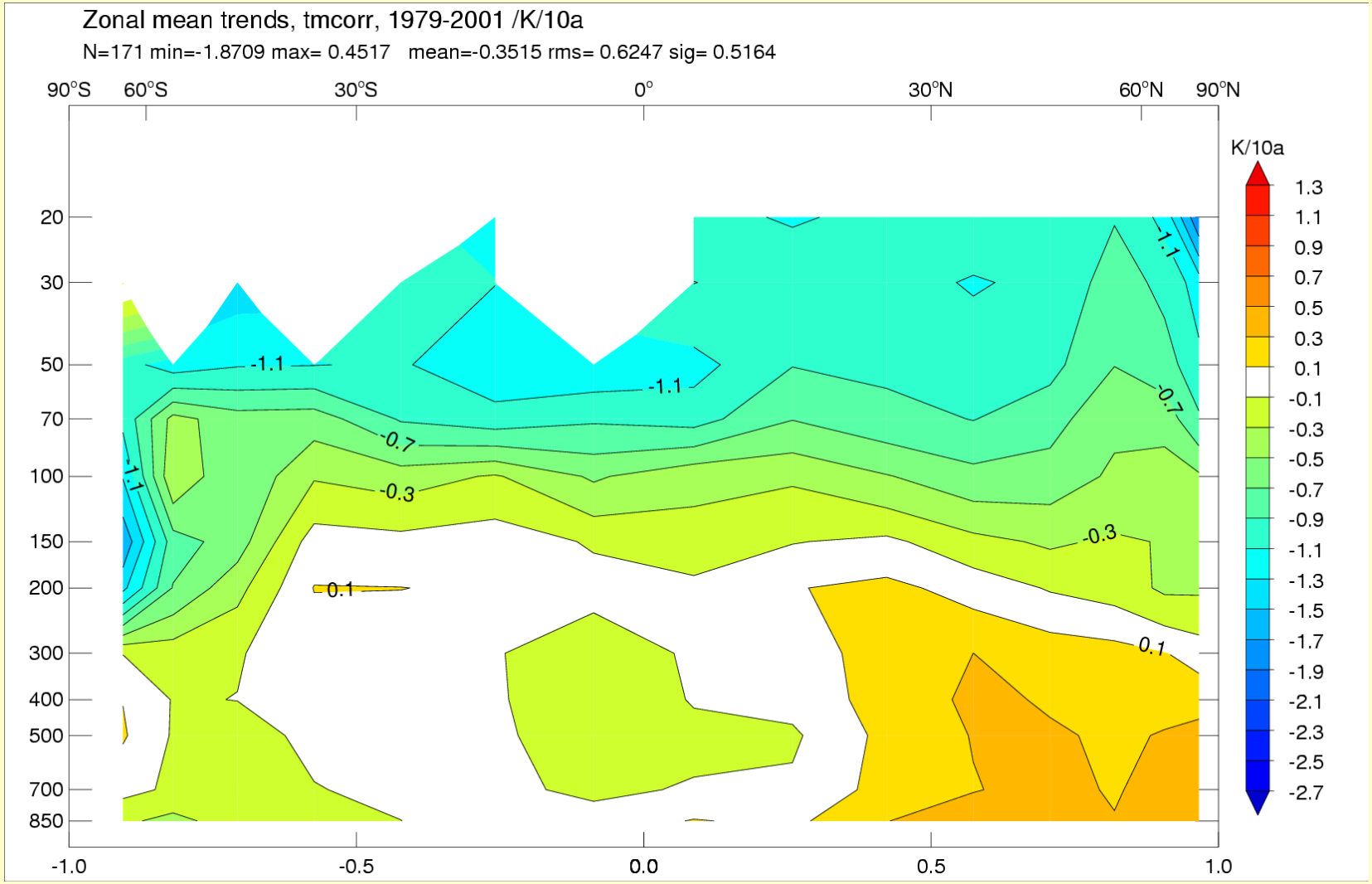
Unadjusted zonal mean T-trends 1989-2004



Unadjusted Trends 1979-2001



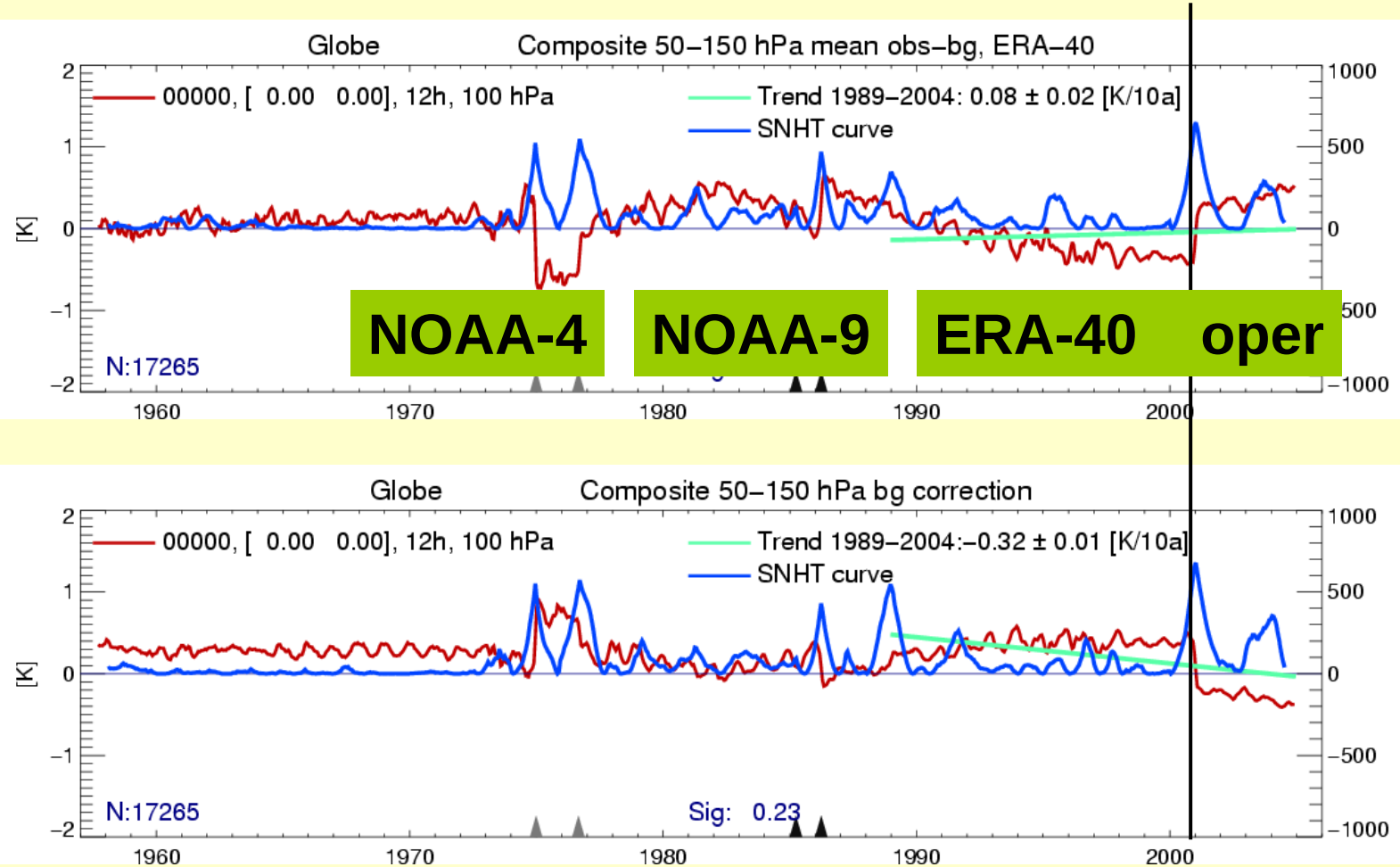
Adjusted Trends 1979-2001



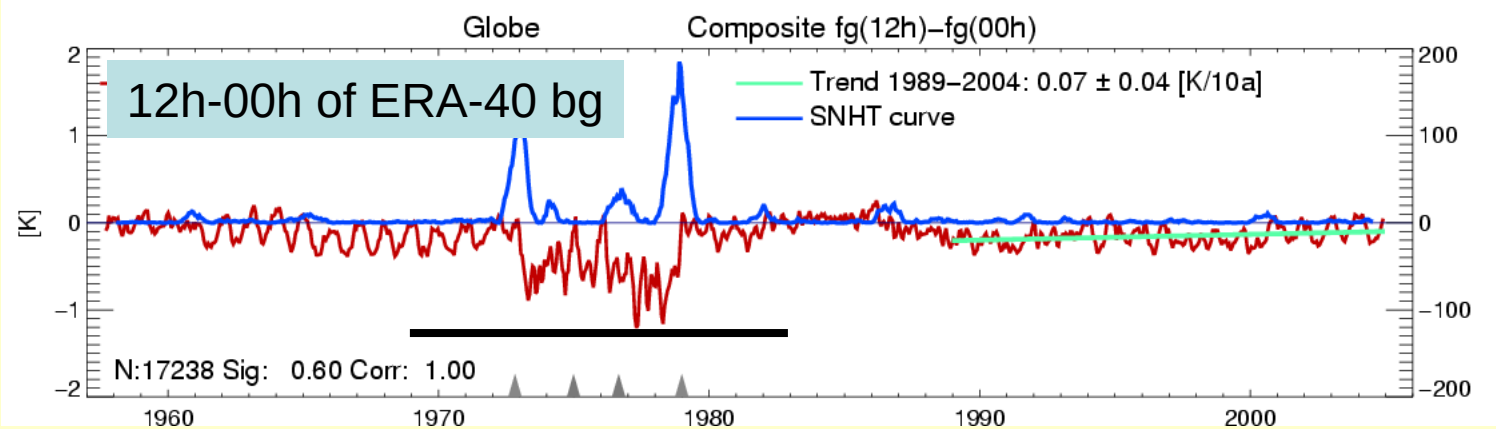
Problems with using bg as reference

- Bg may be inhomogeneous
  - due to changes in the satellite observing system
    - Examples 1973,1975,1976,1979,1986,1995
  - due to changes in the assimilating model
    - Example: difference between ERA and operational bg
  - due to changes in the radiosonde observing system
    - Example: Eastern Russia
- During these periods a more homogeneous reference can be generated with radiosondes only
  - Composite had to be used between 1969,1982

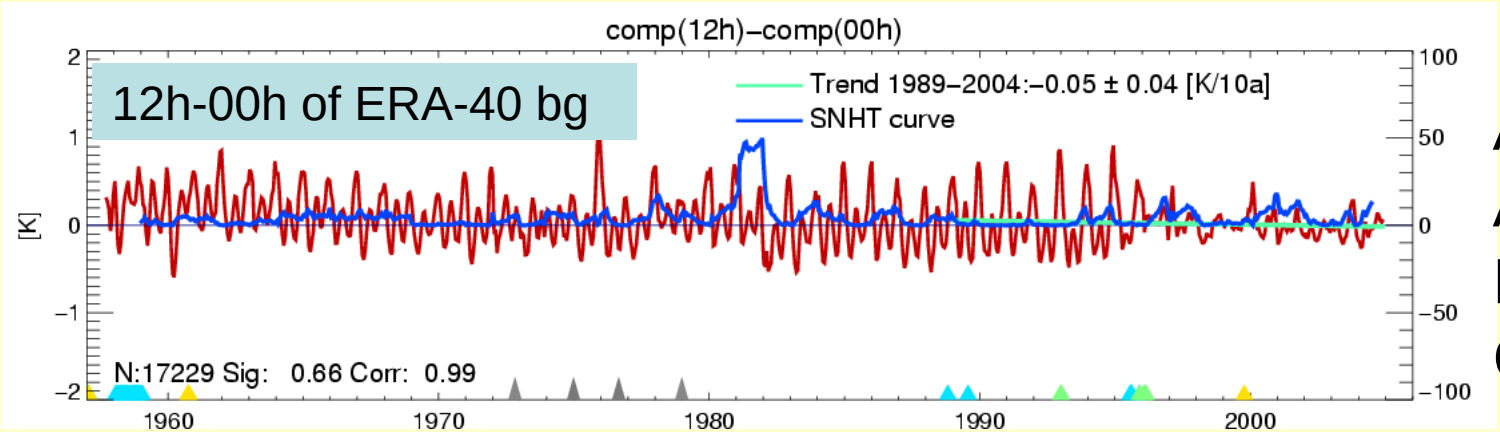
Global mean obs-bg in stratosphere (50-150 hPa)



Spurious bg 12h-00h differences

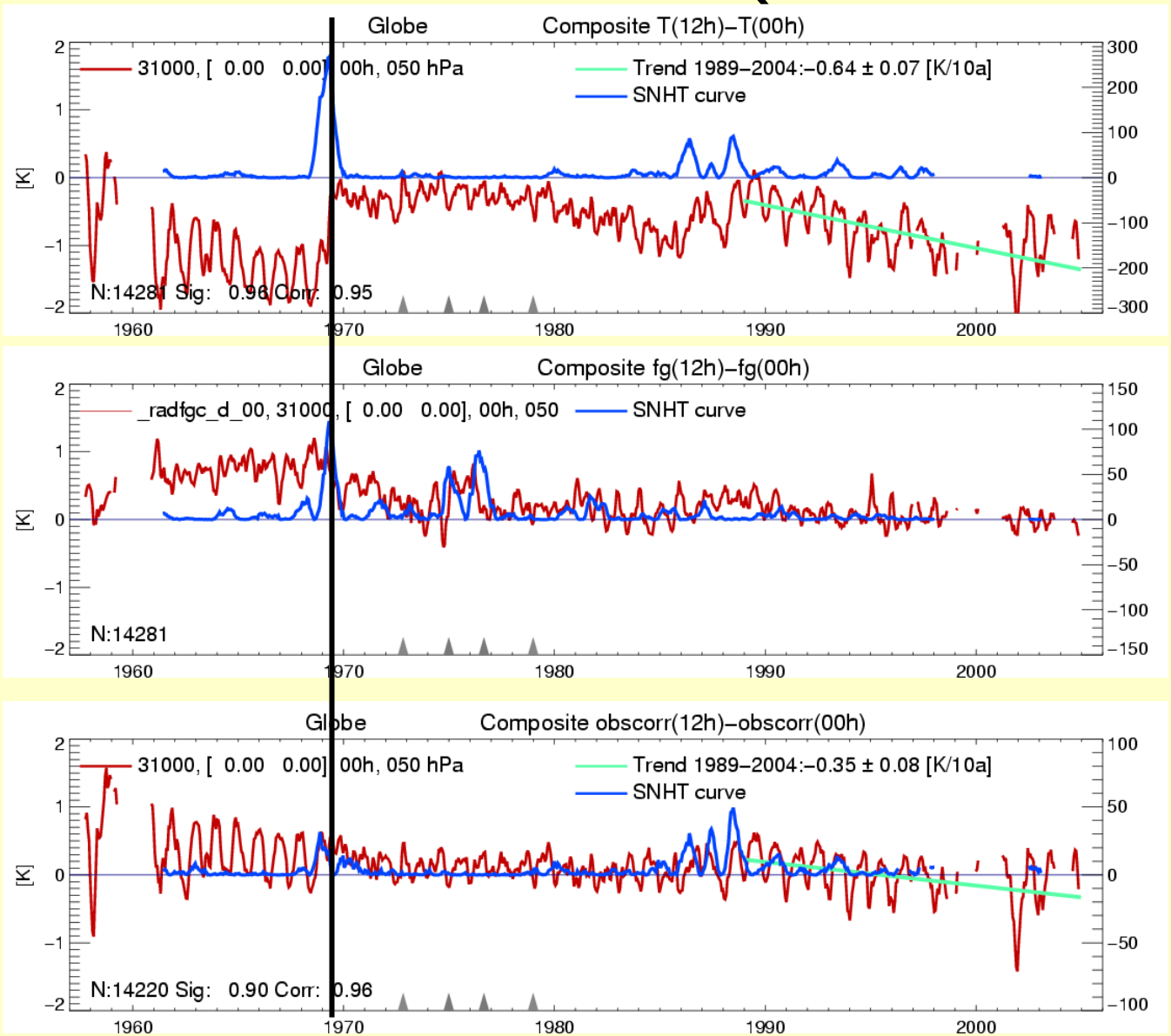


Alaska bg



Alaska Adjusted Radiosonde Composite

Eastern Russia (31000-33000)

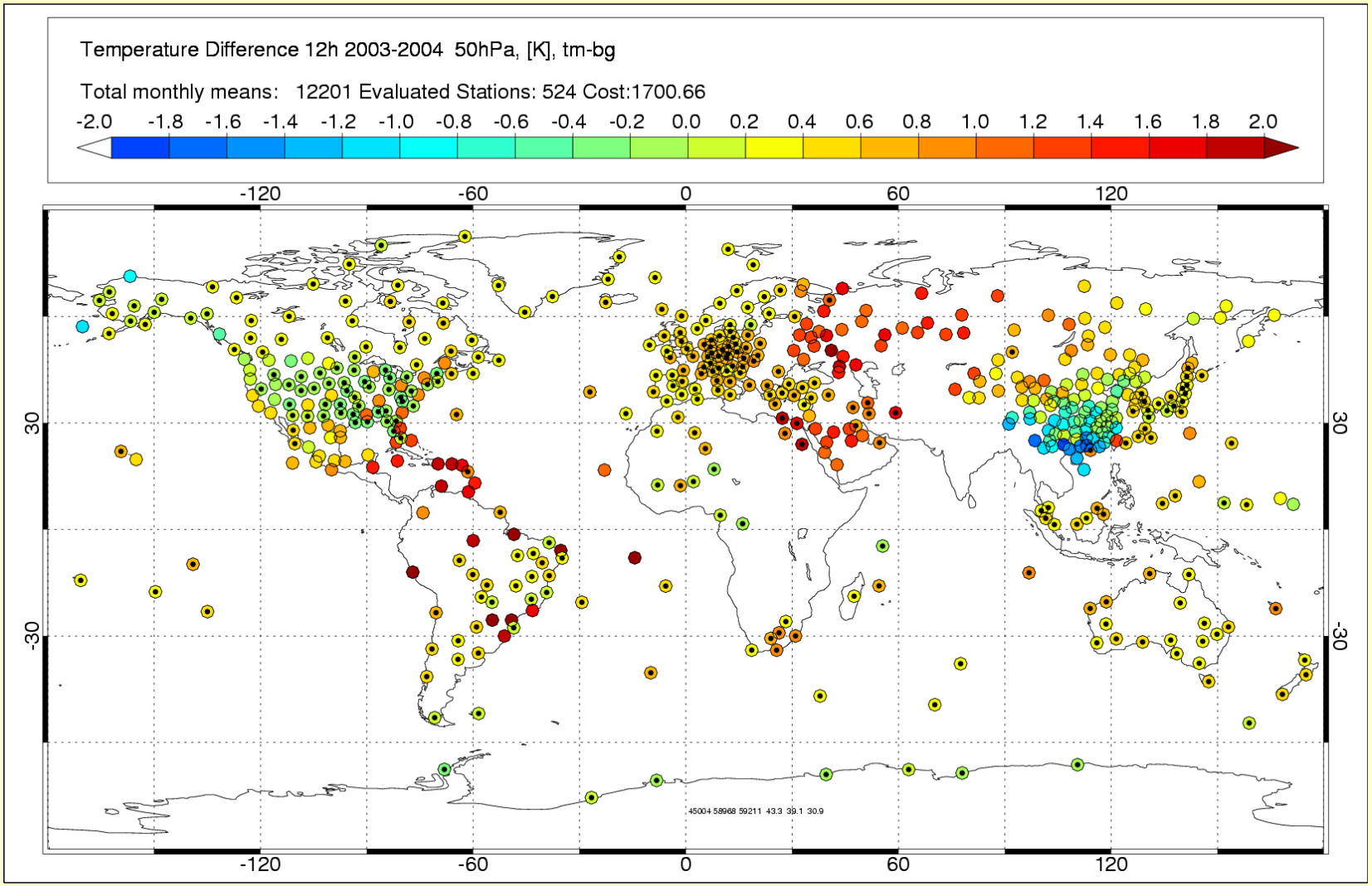


Observations

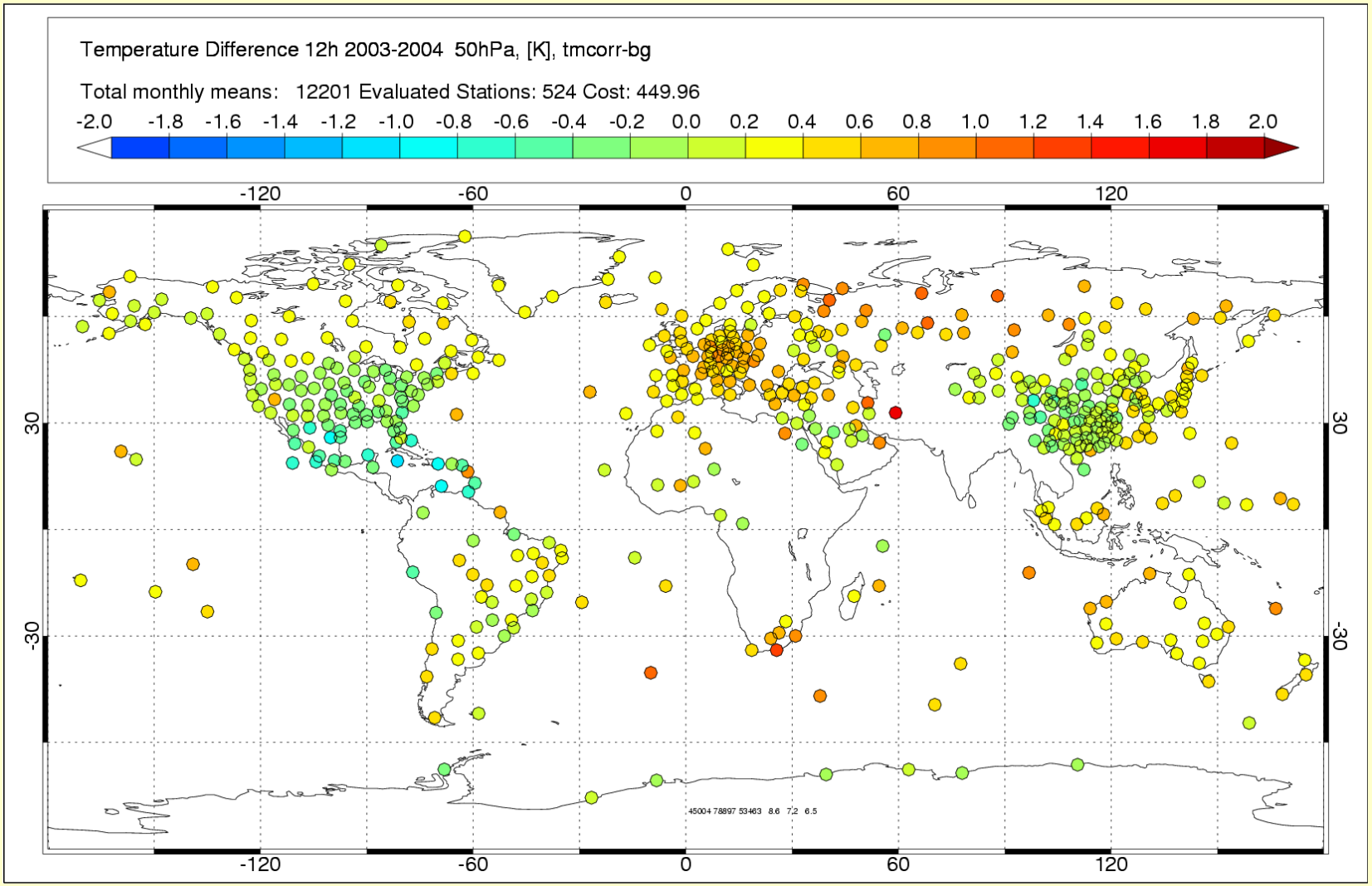
Background (strongly influenced)

Adjusted Observations

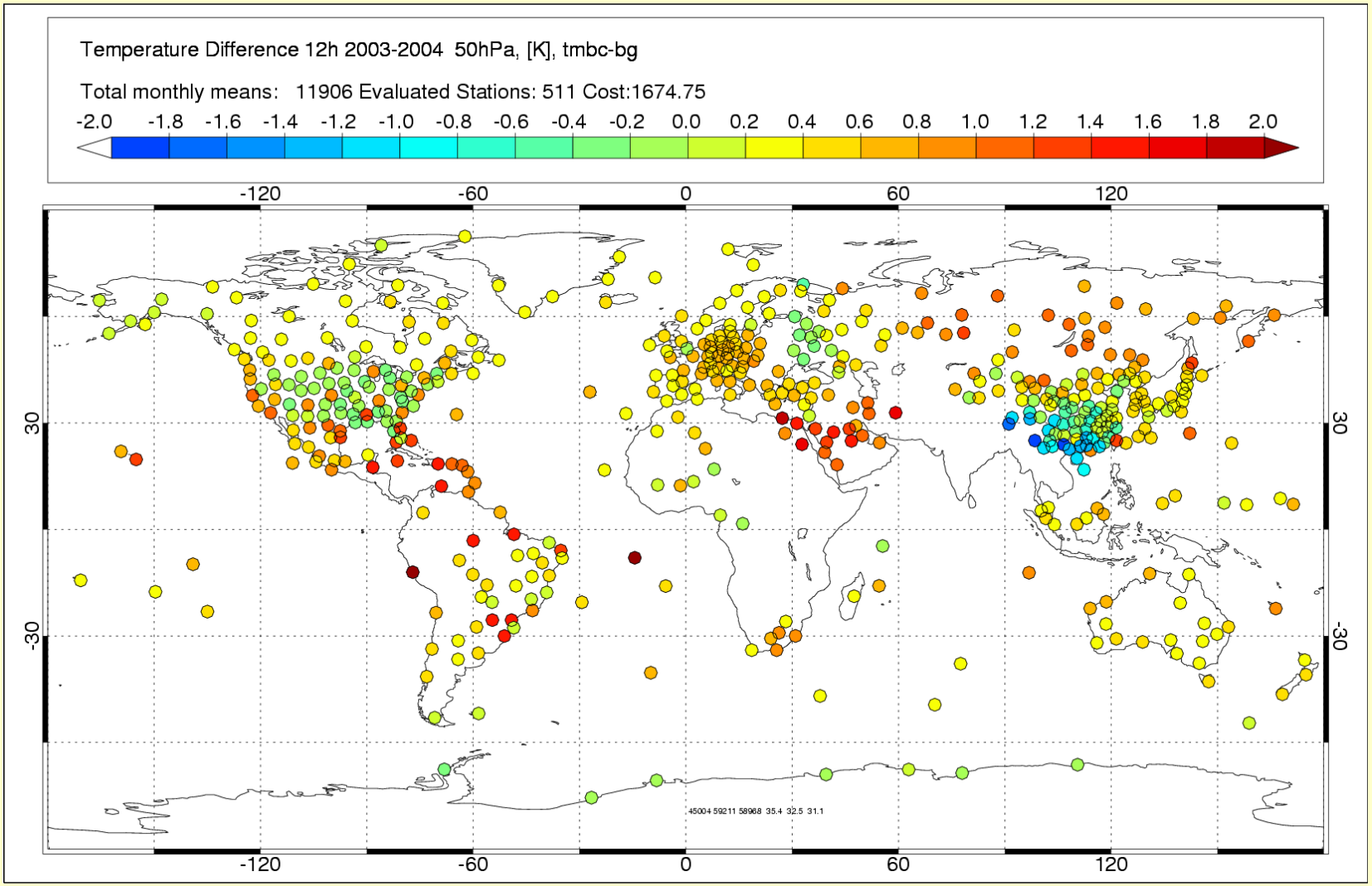
Obs-bg 12h, 50 hPa, 2003/04



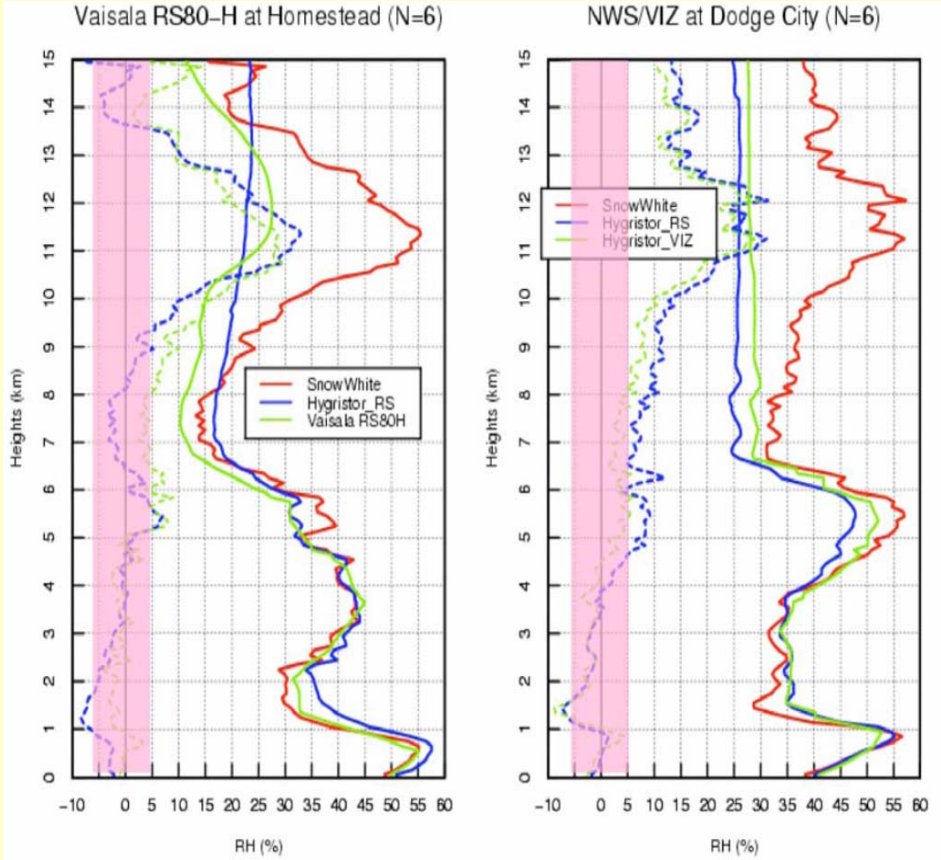
RAOBCORE obs-bg 12h, 50 hPa, 2003/04



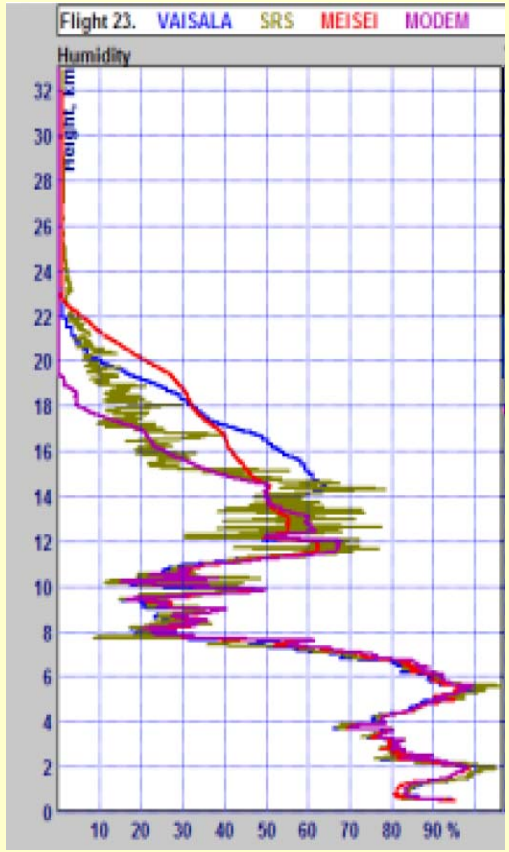
Operational adj. obs-bg 12h 2003/04



RS humidity biases



Wang et al. 2003, RS80, VIZ



Latest IRI, Vacoas

Only latest generation of RS resolves RH-maximum at 12km

Conclusions

- 2 automatic analysis feedback-based RS-bias adjustment methods available
  - Adjustment of radiation error (Andrae et al. 2004)
  - Adjustment of daily mean bias (Haimberger, 2005)
- Adjusted T-trends consistent with other radiosonde-based datasets
- Adjustment of most recent biases can be improved with AF information

- Results suggest more aggressive radiation error correction for some RS-types.
- Radiation error correction should be revised before interim-reanalysis starts.
- Combine RAOBCORE, solar angle dependent adjustment for next reanalysis

- Similar analysis to remove inhomogeneities in RS-wind data in preparation
- RS-biases before 1957: asynoptic times. Feedback needs to be generated
- Adaptive RS-bias correction not attempted yet
  - Ratio data:bias parameters is less favorable than for satellite data
  - For operations highly desirable since static tables tend to be out of date
  - For reanalyses it may be valuable to have one upper-air observing system that does not need to be adaptively bias corrected