University of Vienna
Department of Meteorology
and Geophysics

Marie Curie Fellowships

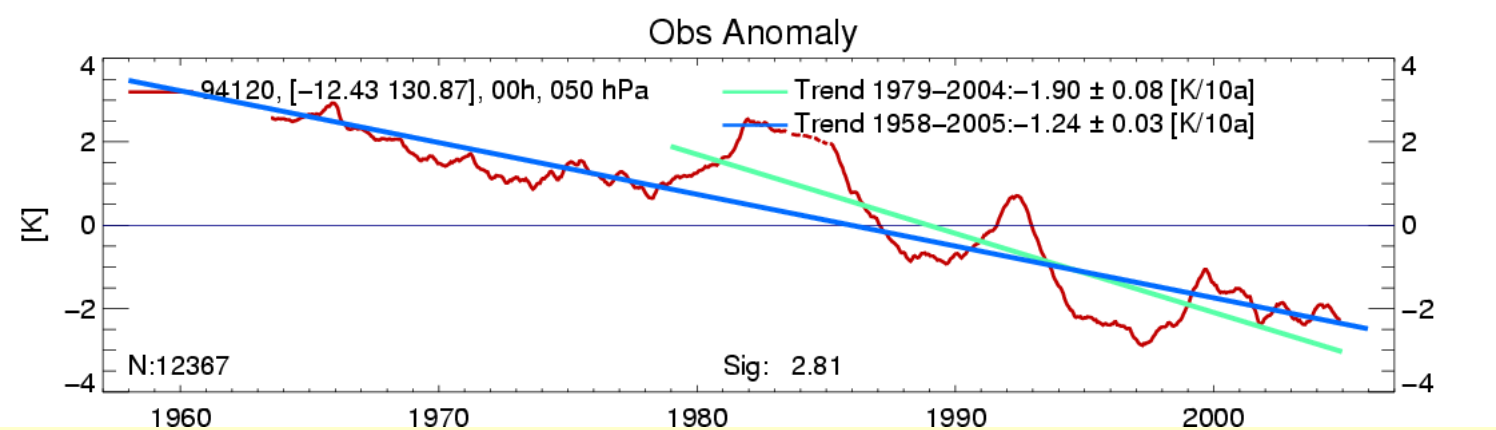
FWF

ECMWF

Homogenization of radiosonde data

Leopold Haimberger
University of Vienna

Credits to Christine Gruber, Stefan Sperka, Christina Tavolato

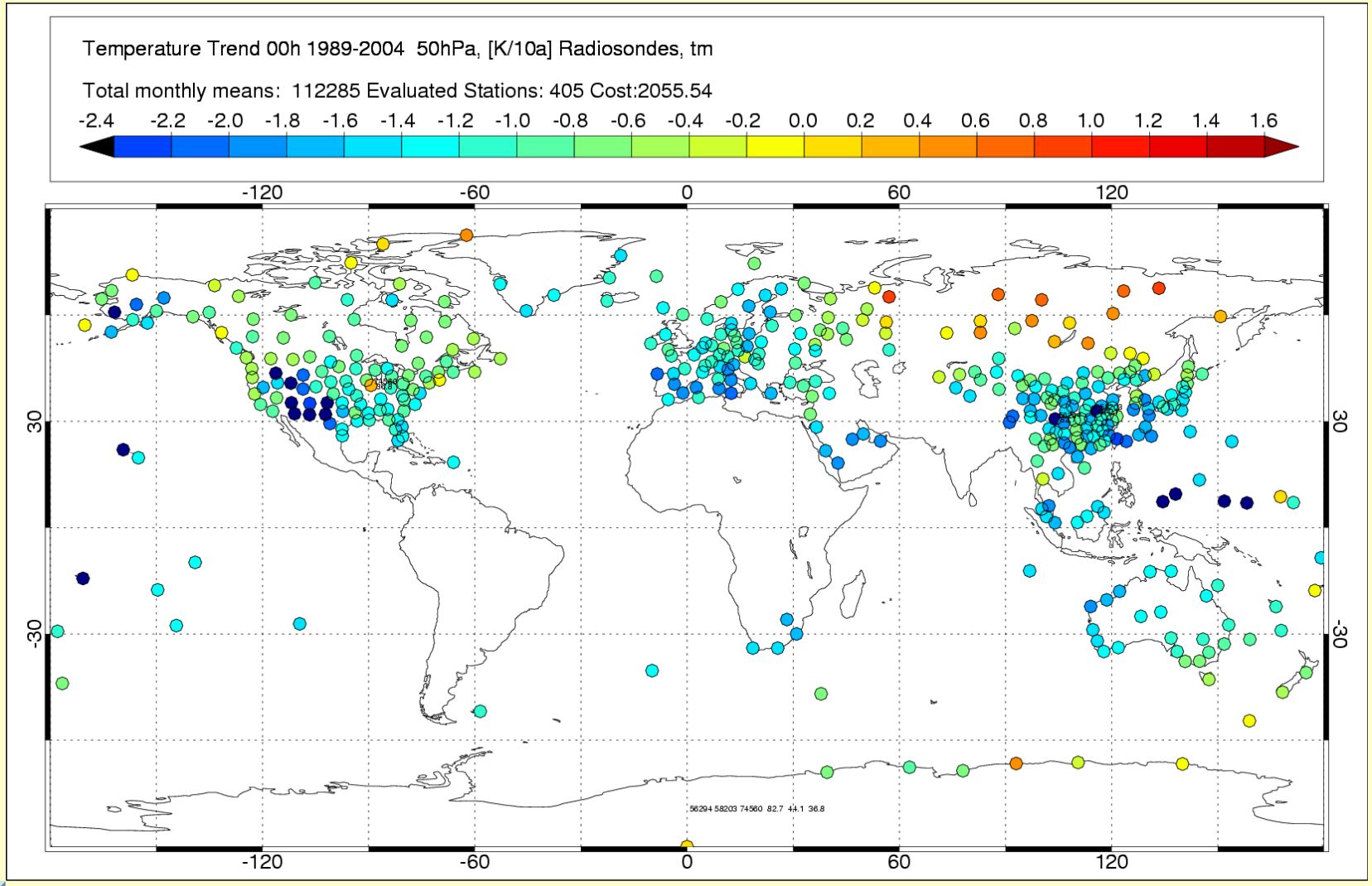


EC-Fellowship -MEIF-CT-2003-503976
FWF-Project P18120-N10

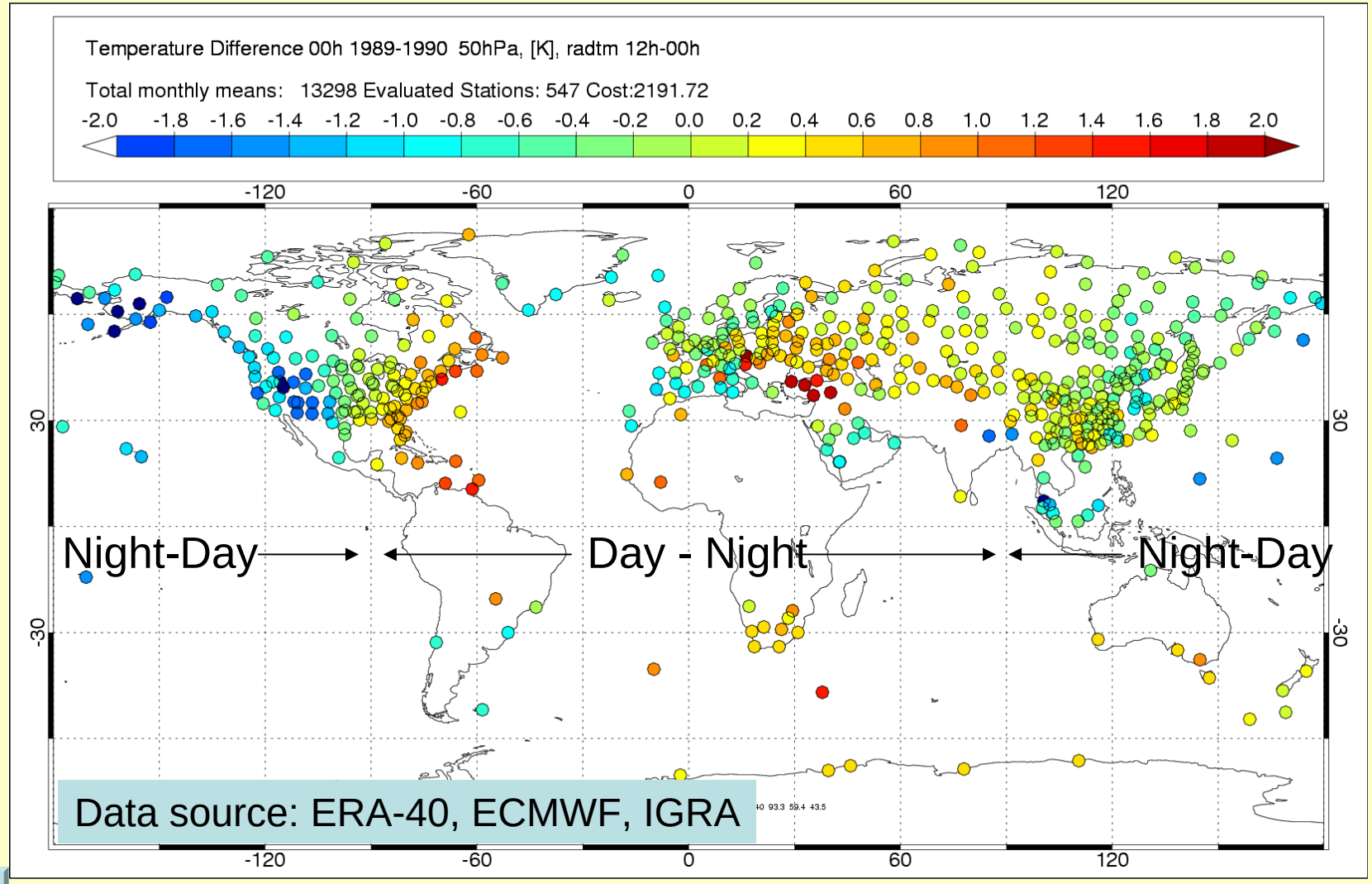
Outline

- Focus on temperature biases, bit of wind
- Examples of inconsistencies
- Needs of reanalyses
- Homogenization based on time series of background departures (RAOBCORE)
- Results
- Trend comparison 1979-2004
- Outlook/Recommendations

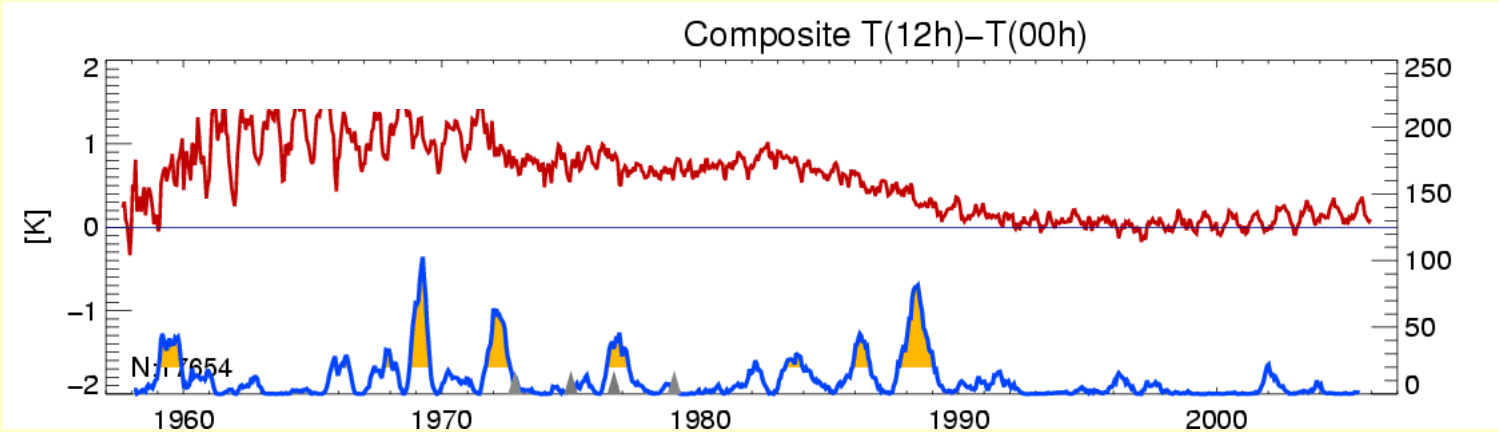
Temperature Trends, 00h, 50hPa, 1989-2004



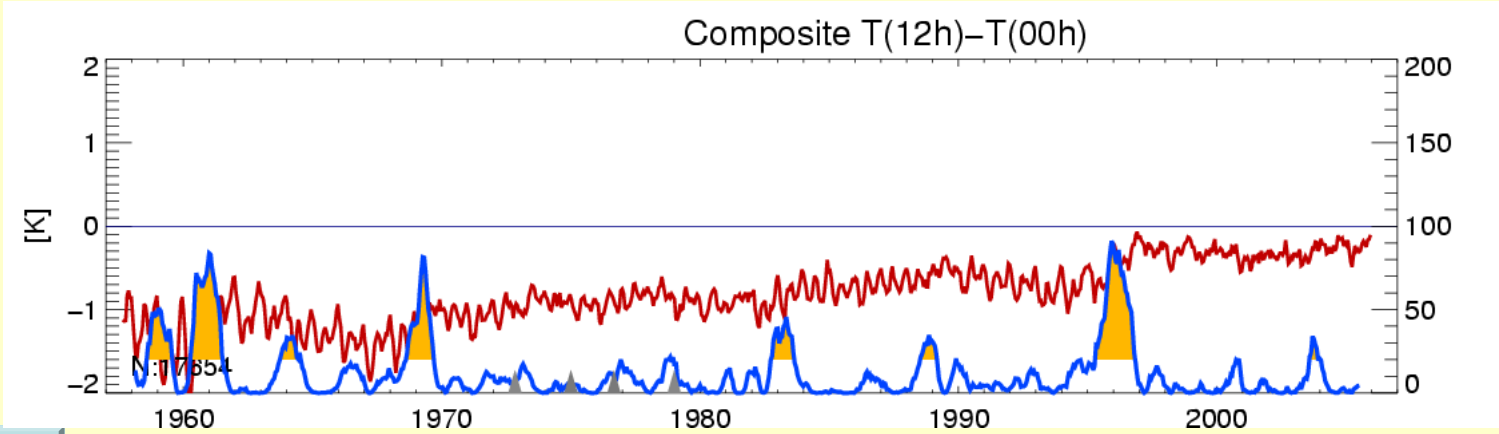
12GMT-00GMT T-Difference 50 hPa, 1989-1990



Composite Mean 12GMT-00GMT T-Differences, 50 hPa

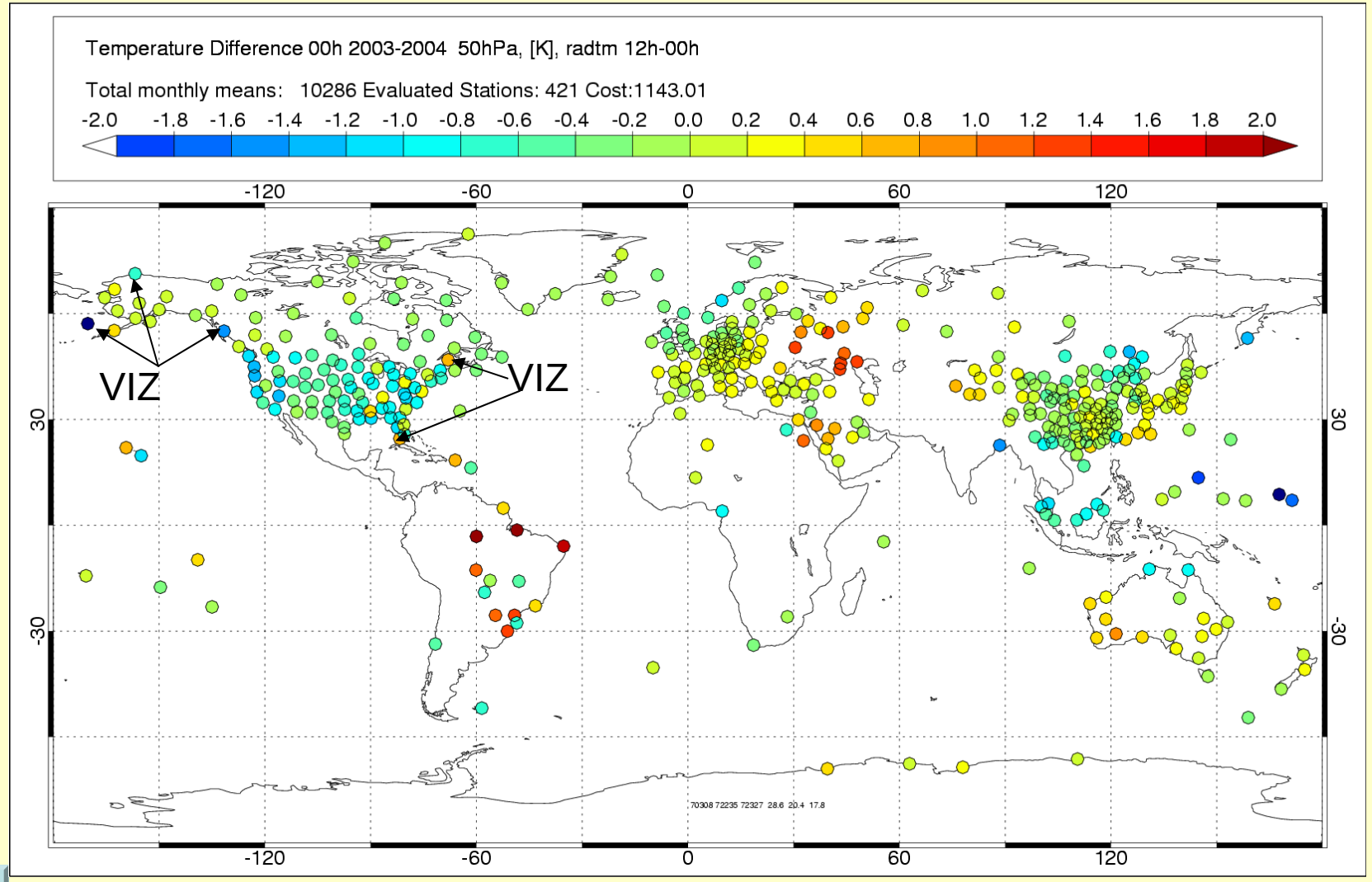


Composite 30W-40E Europe/ Africa



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

12h-00h T-Difference 2003/04

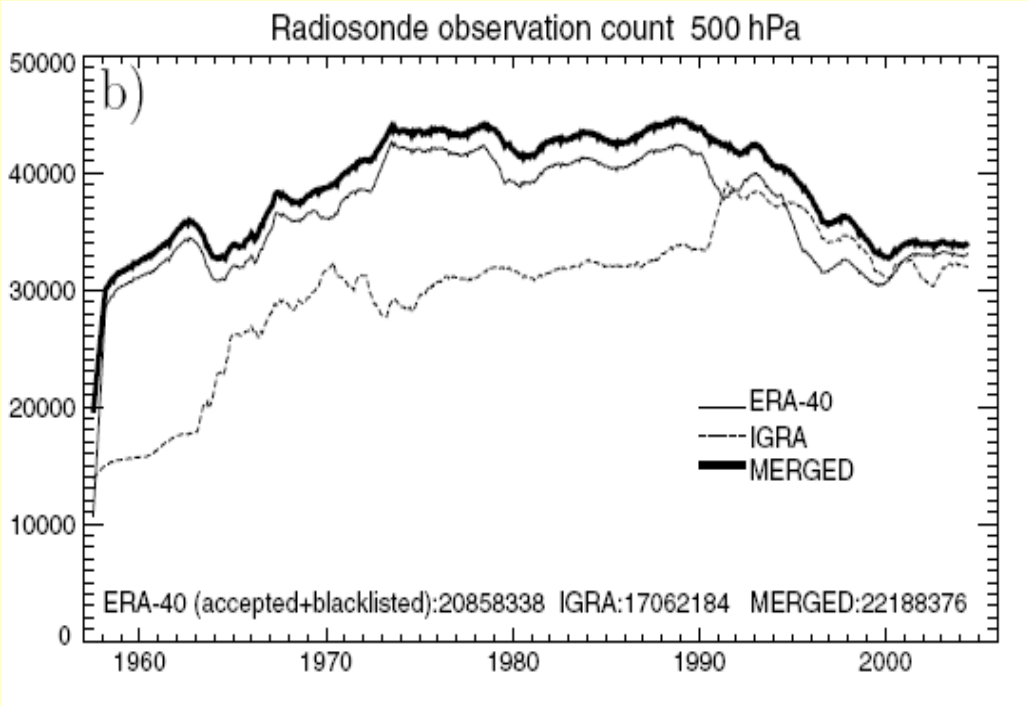


Radiosonde bias corrections for reanalyses

- Adjustment of breaks in input time series
- Adjustment of anomalies not sufficient, climatologies must be adjusted as well
- Complete radiosonde dataset needs to be adjusted
- No available radiosonde dataset (HadAT, RATPAC) to date fulfils all requirements
- Create one specifically for needs of reanalyses

Observation input

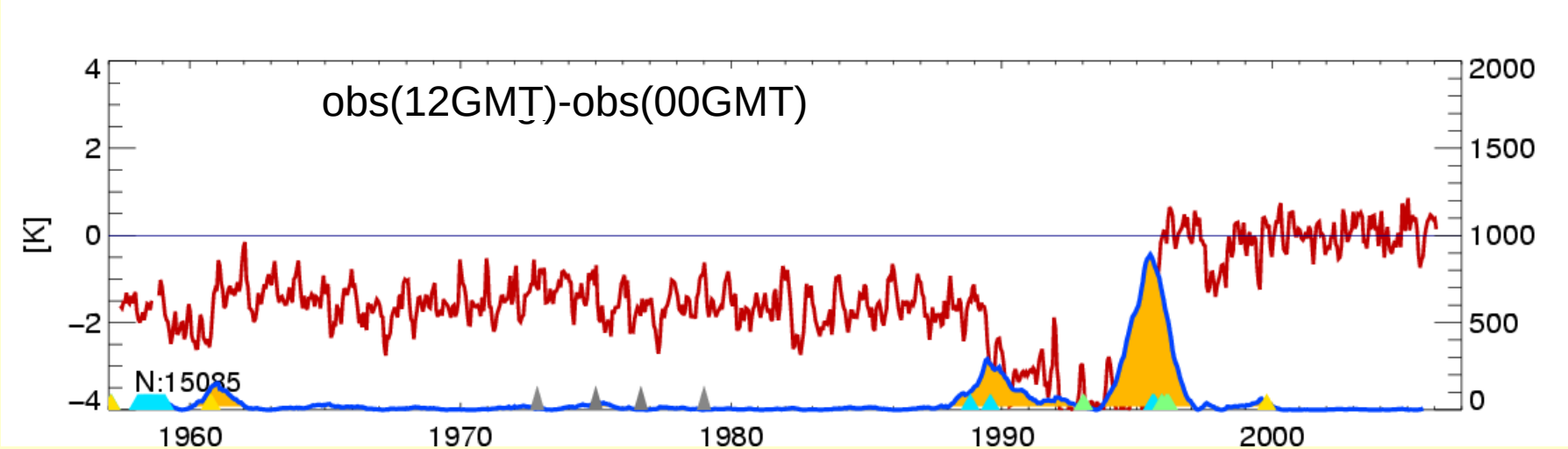
- ERA-40 AF (-2001)
  - obs-bg
  - QC-flags
  - metadata (RS-type)
- ECMWF AF (2001-)
  - obs-bg, QC, metadata
- IGRA
  - obs-bg (interpolated)
- CARDS
  - only metadata (RS-type, radiation correction)



RAOBCORE

- RAdiosonde OBservation COrrection for REanalyses
- Raw radiosonde records (obs) are homogenized station by station. Method is fully automatic
- Time series of background (bg) forecasts from a DA-system (ERA-40/ECMWF) used as reference
- obs-bg differences available for each radiosonde observation
- Time series of obs-bg are analysed to detect and adjust breaks in obs record
- Hypothesis: Bg independent and homogeneous enough for this purpose

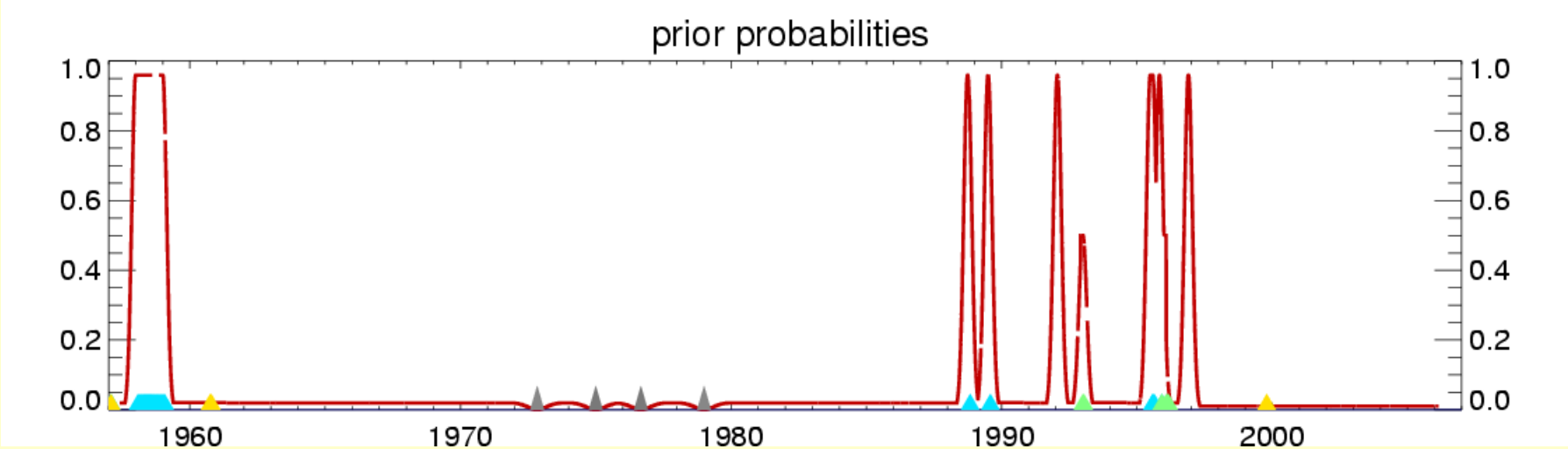
Difference series
Bethel Alaska, 50 hPa



Difference series: obs(12GMT)-obs(00GMT)
obs-bg stratosphere at 00GMT, 12GMT
obs-bg troposphere at 00GMT, 12GMT

Blue curve = Standard normal homogeneity test statistic
(shaded if significant)

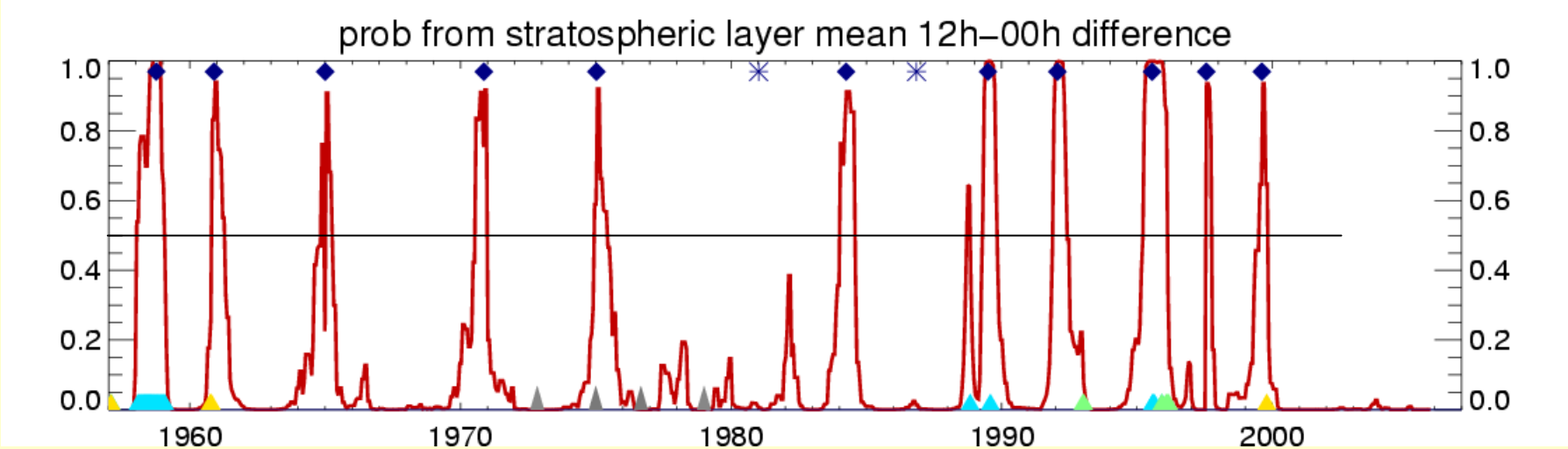
Metadata information



Radiosonde type changes (6000 from CARDS, 2000 from GTS/BUFR)
Radiation correction changes (3000 from CARDS)

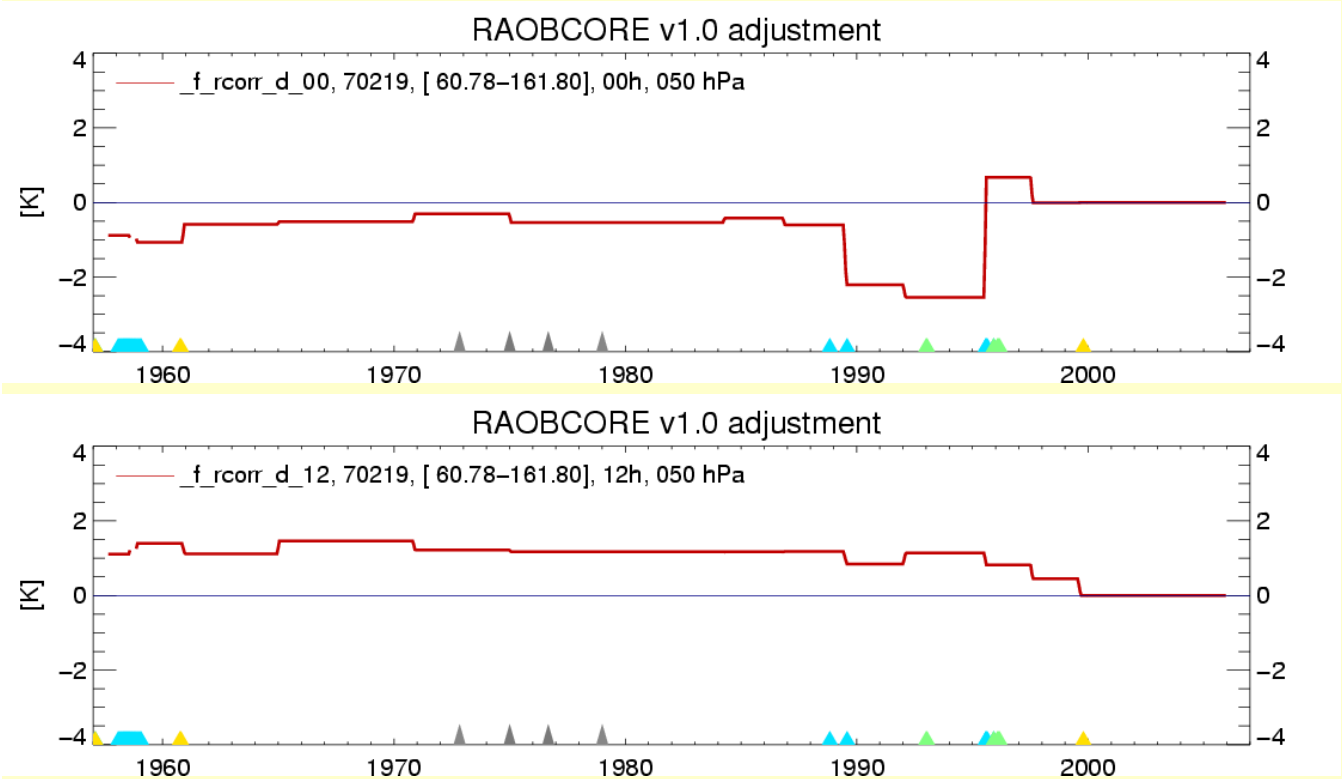
With metadata: Break can be 40% smaller than normal to be detected

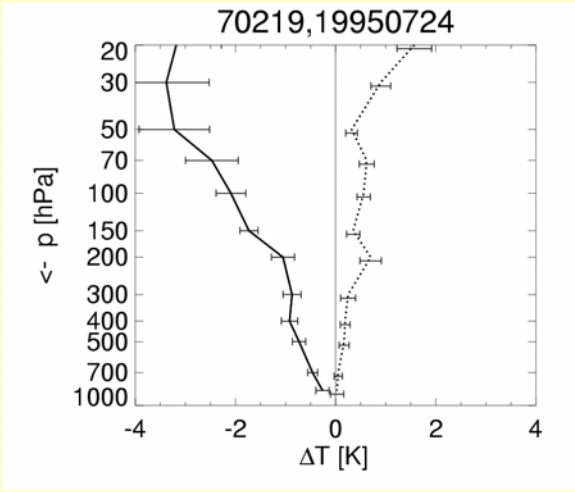
Posterior „probability“



6500 breaks detected, 10 breaks per station not unusual

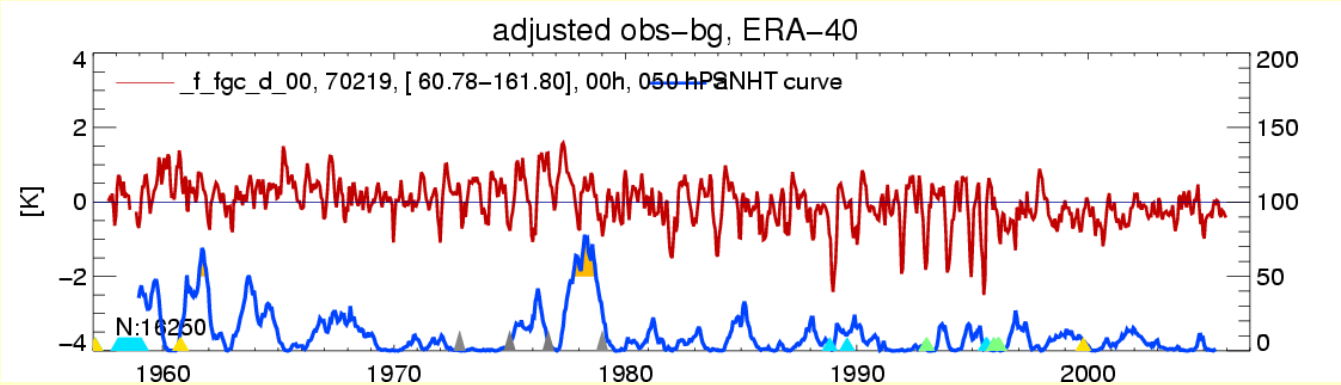
Homogenization



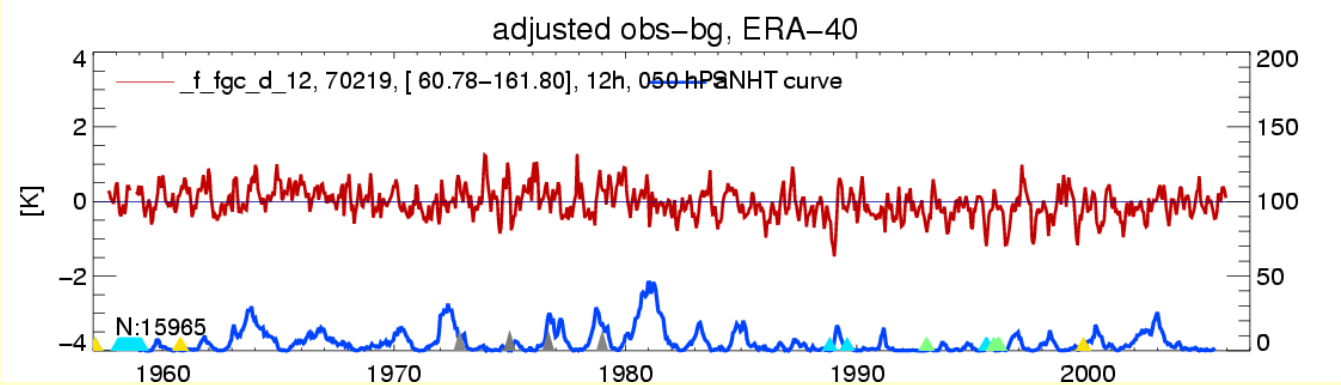


Break profile is calculated at 00GMT, 12GMT at breakpoints.
Adjustment only if 90% significant and larger than 0.3K at two p-levels at least
Data to estimate adjustment: 1-8 years, depending on interval between breaks

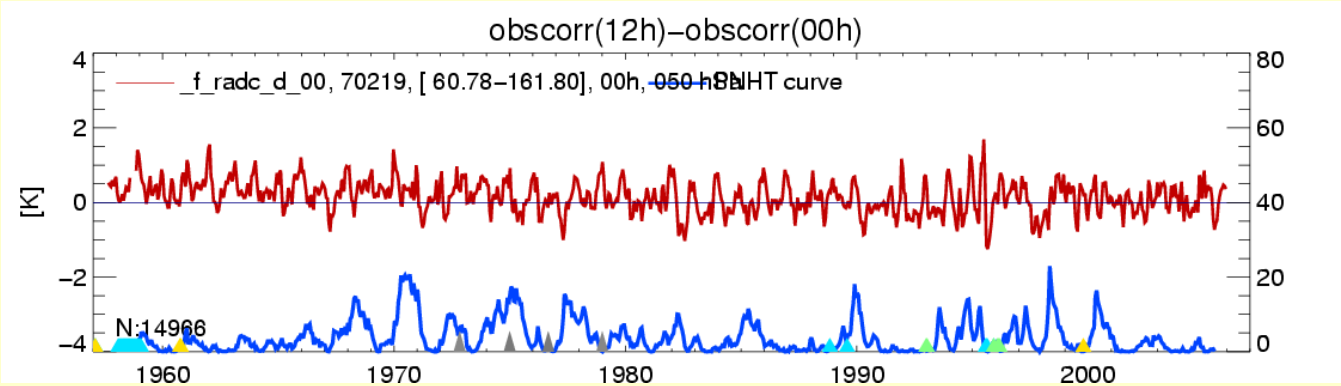
Homogenized time series



00GMT

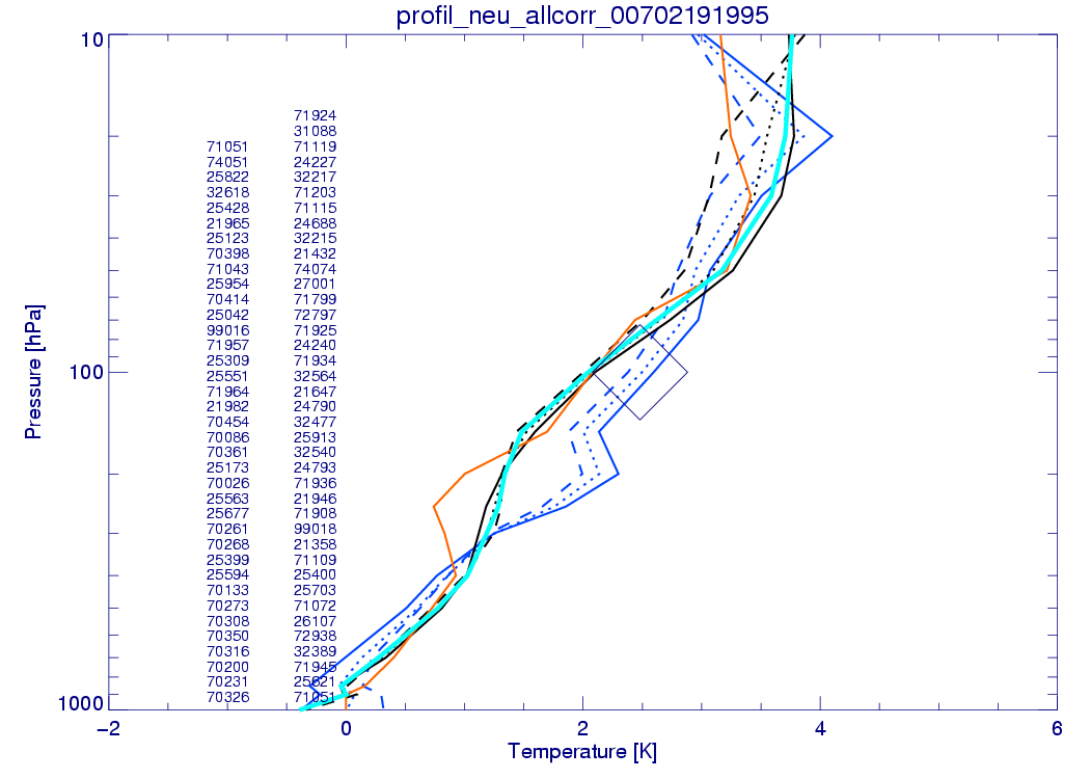


12GMT



12GMT-00GMT

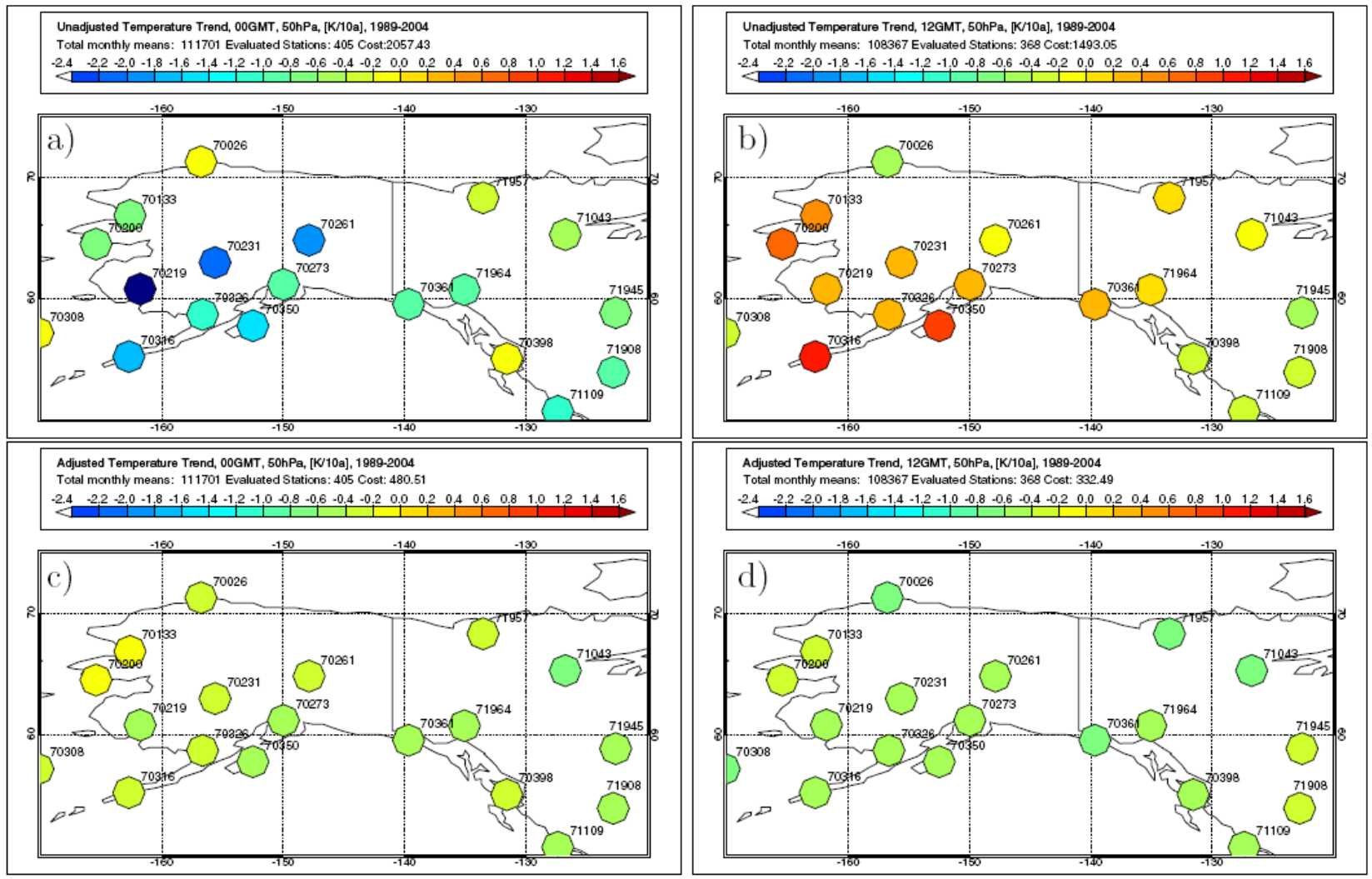
Break profile verification



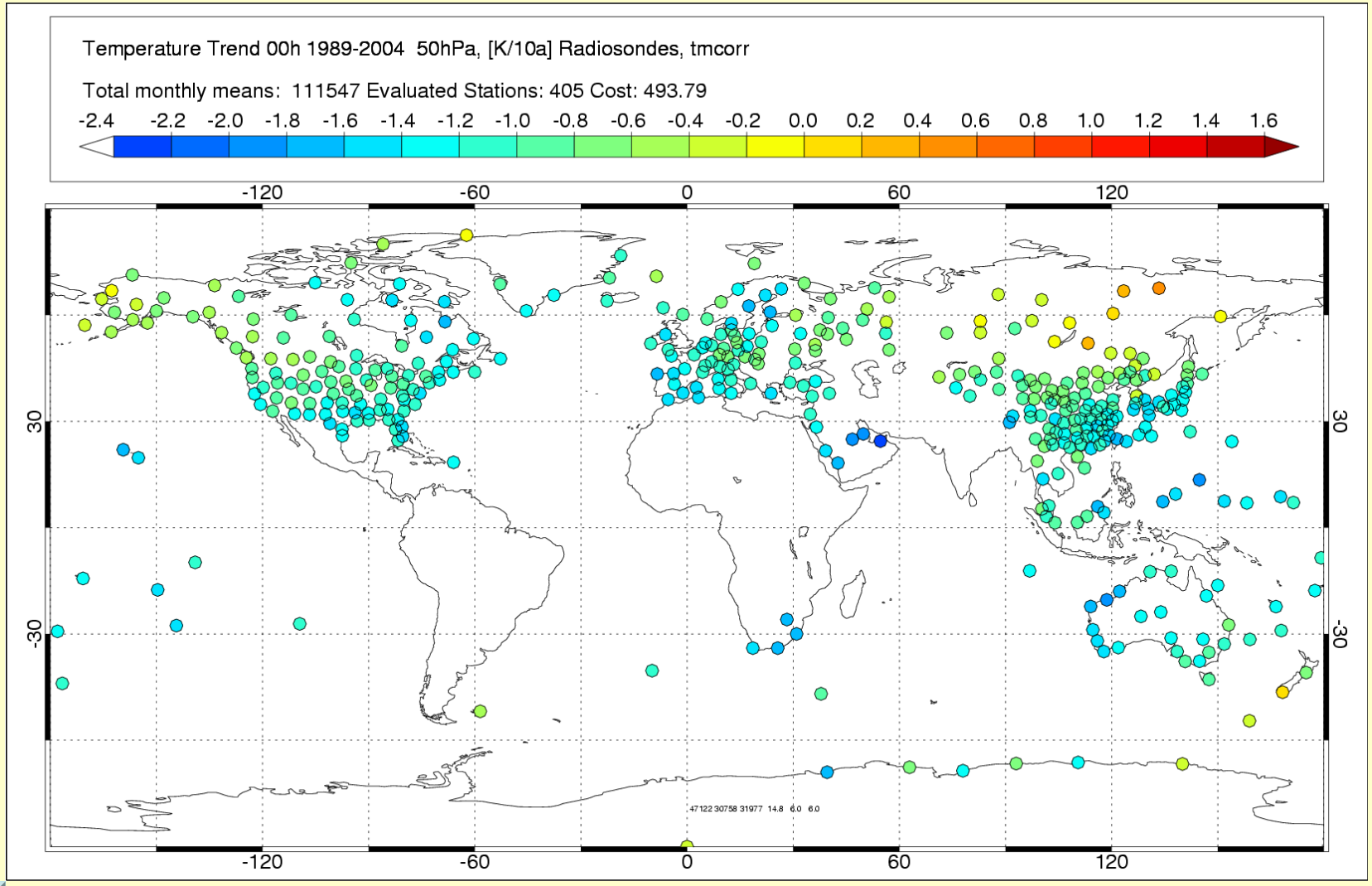
- Red=RAOBCORE
- Black = obs-bg Composites
- Dark blue = obs anomaly composite
- Square=MSU TLS

Alaska 1989-2004, 50 hPa

00GMT 12GMT



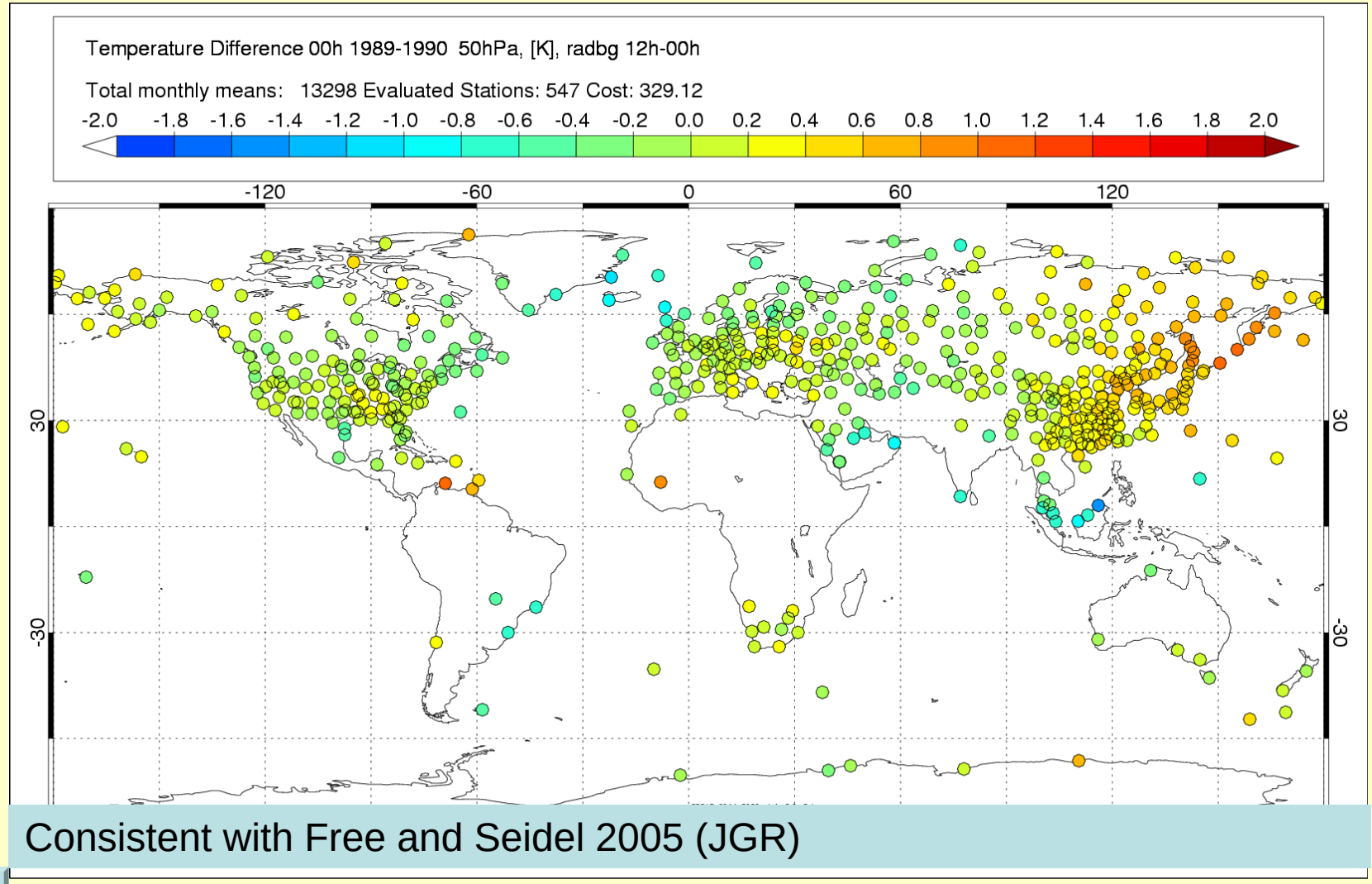
Adjusted T-trends, 00h, 50hPa, 1989-2004



Properties of ERA/ECMWF bg

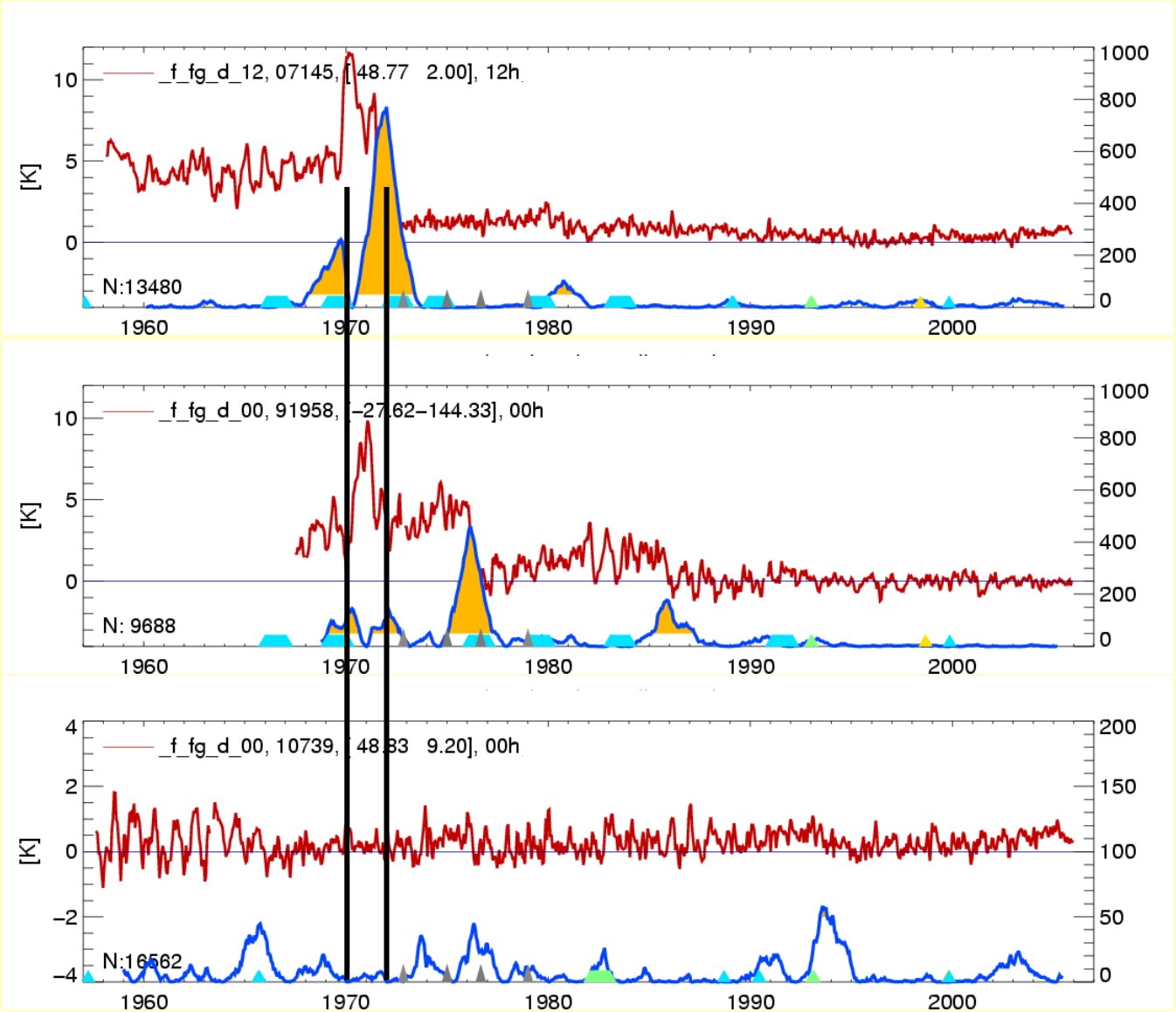
- Spatially smooth, realistic spatial autocorrelations
- Available for every radiosonde 1958-
- Independence of records to be tested
  - Autocorrelation of obs-bg is weak, except at remote stations at high levels
  - Compare similar RS changes in different regions
- Temporal homogeneity of bg?

12h-00h Difference ERA-40 bg 1989-90



Consistent with Free and Seidel 2005 (JGR)

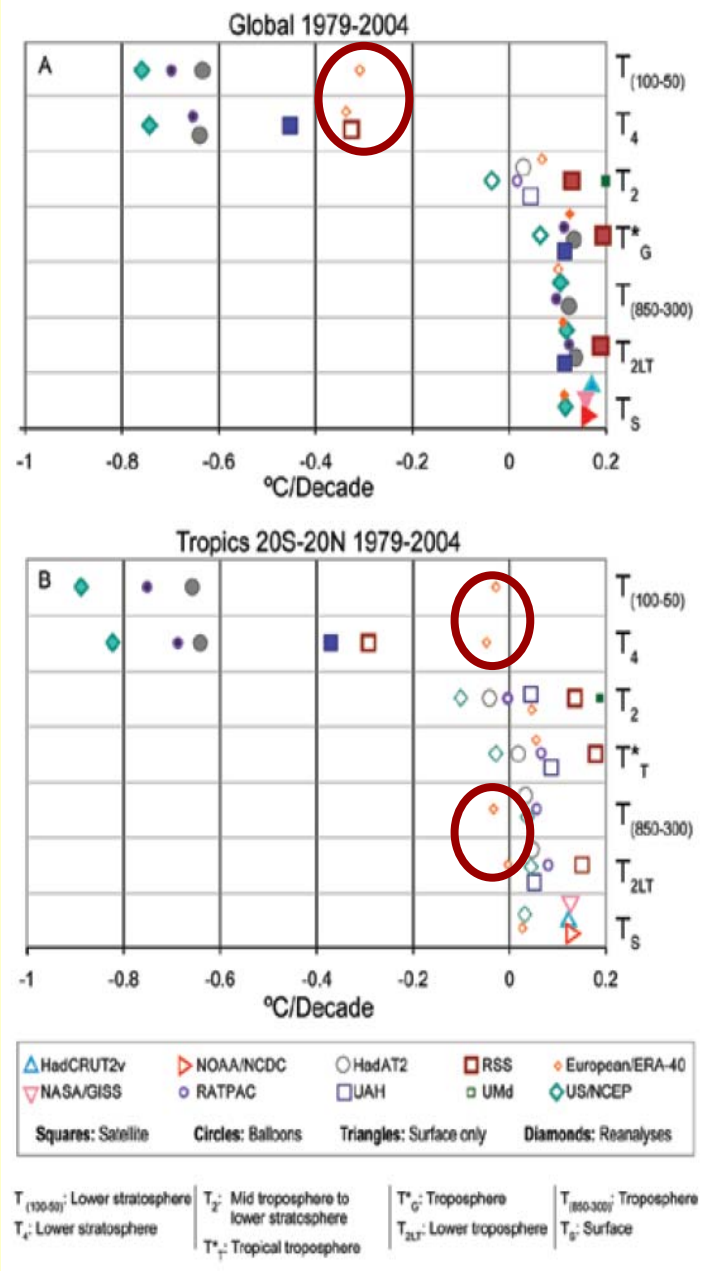
Independence of bg



Trappes
(France) 12GMT

Rapa
(South Pacific)
00GMT

Stuttgart 00 GMT
No sign of
break in bg

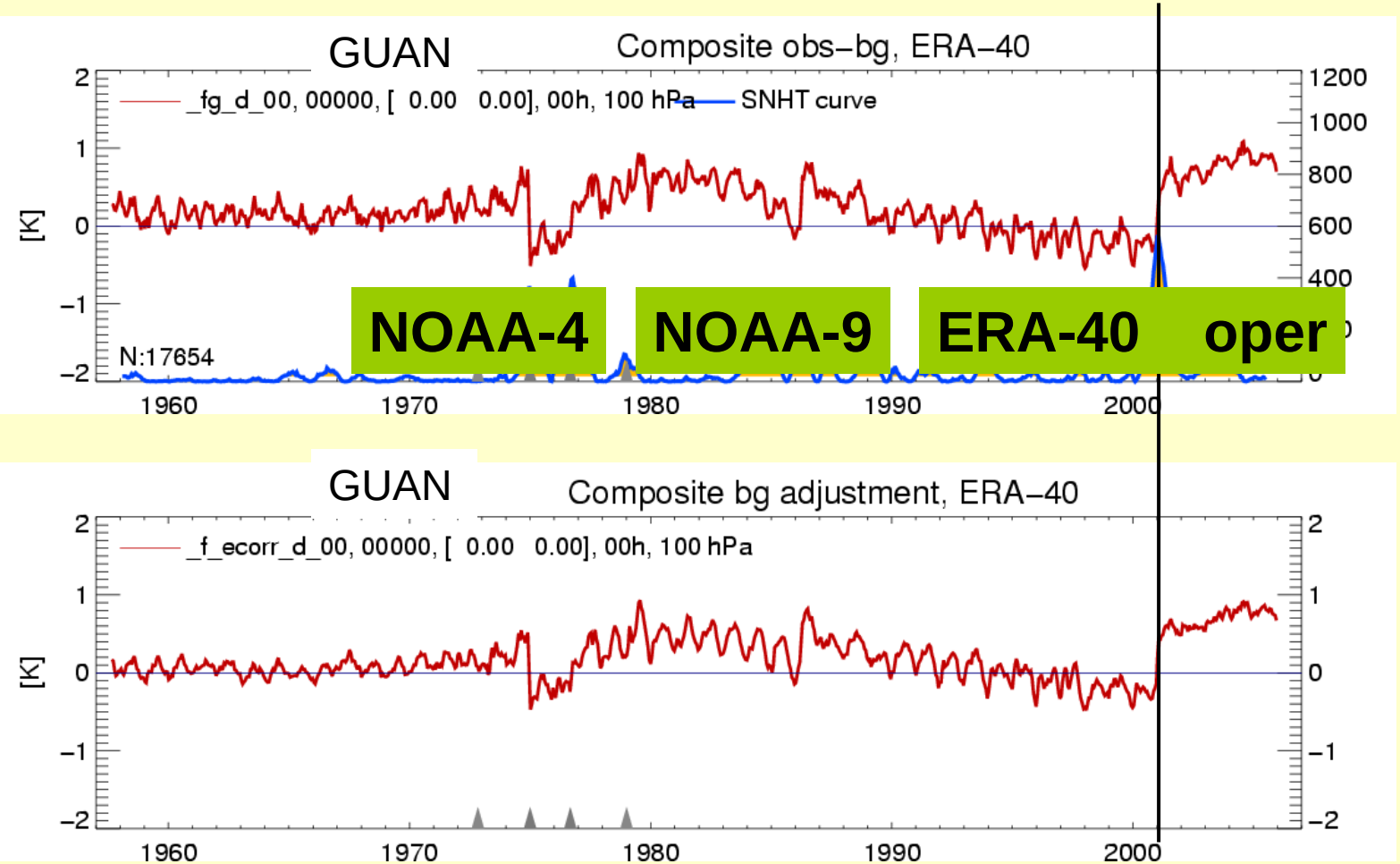


Global Linear Trend profiles 1979-2004, K/10a

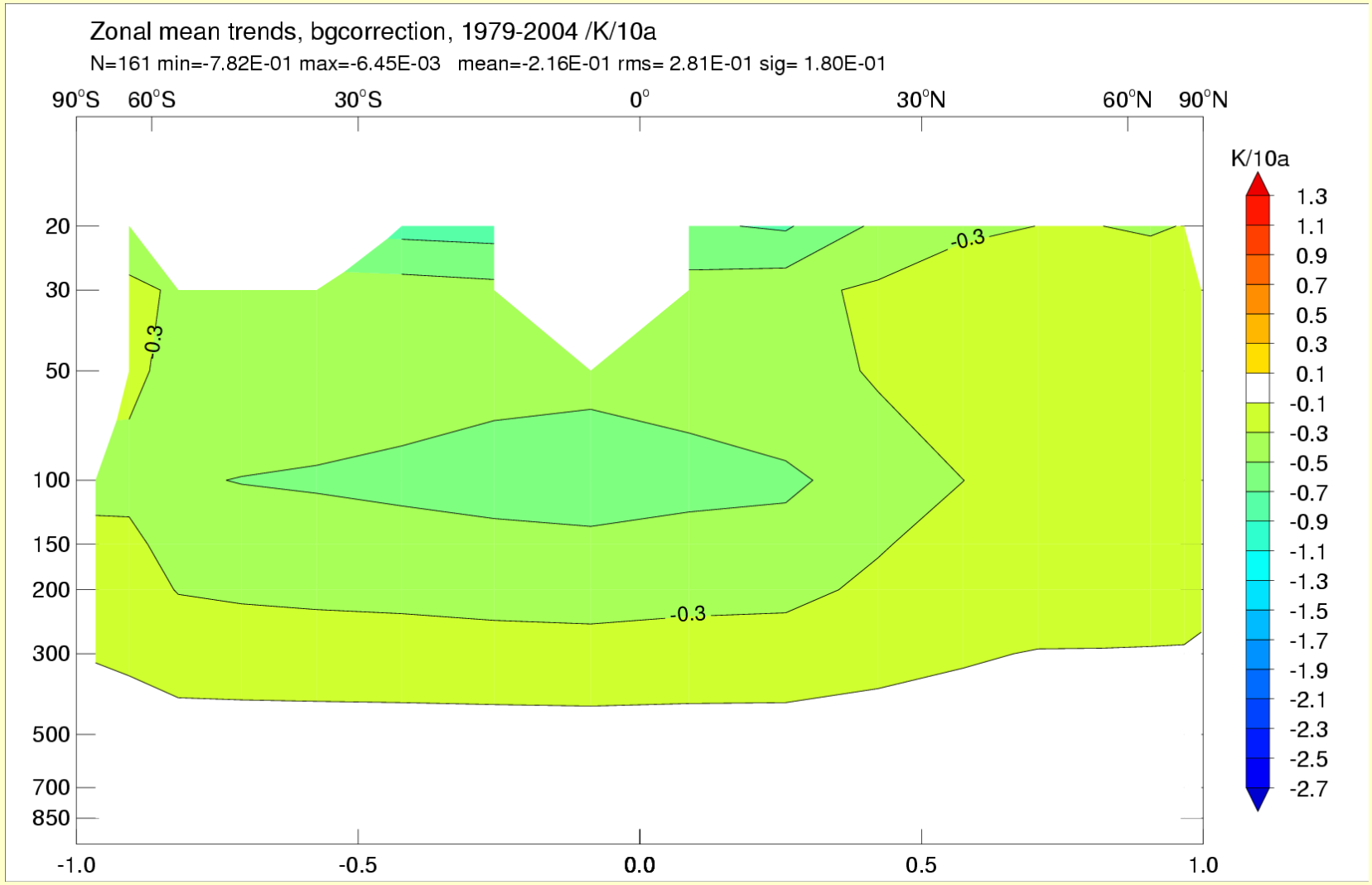
Fig. 3.4, US CCSP Report (Karl et al. 2006)

ERA-40/ECMWF trend leans towards warming, especially in the lower stratosphere, compared to available homogenized radiosonde and MSU temperature datasets

Homogeneity of bg time series



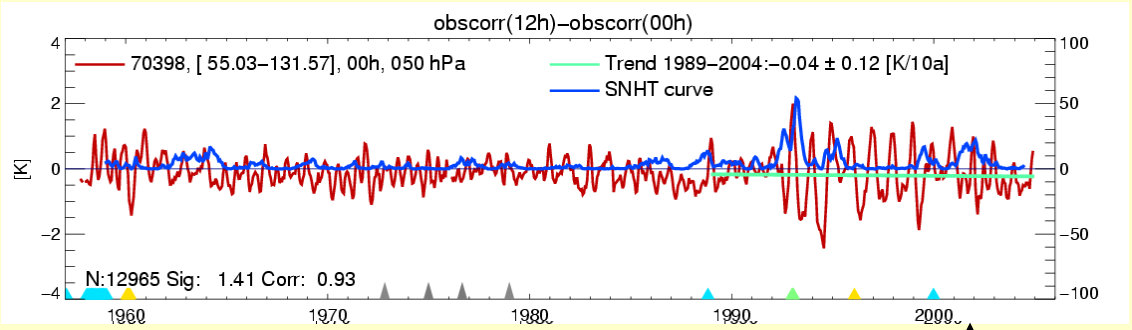
Effect of bg adjustment on bg trends 1979-2004

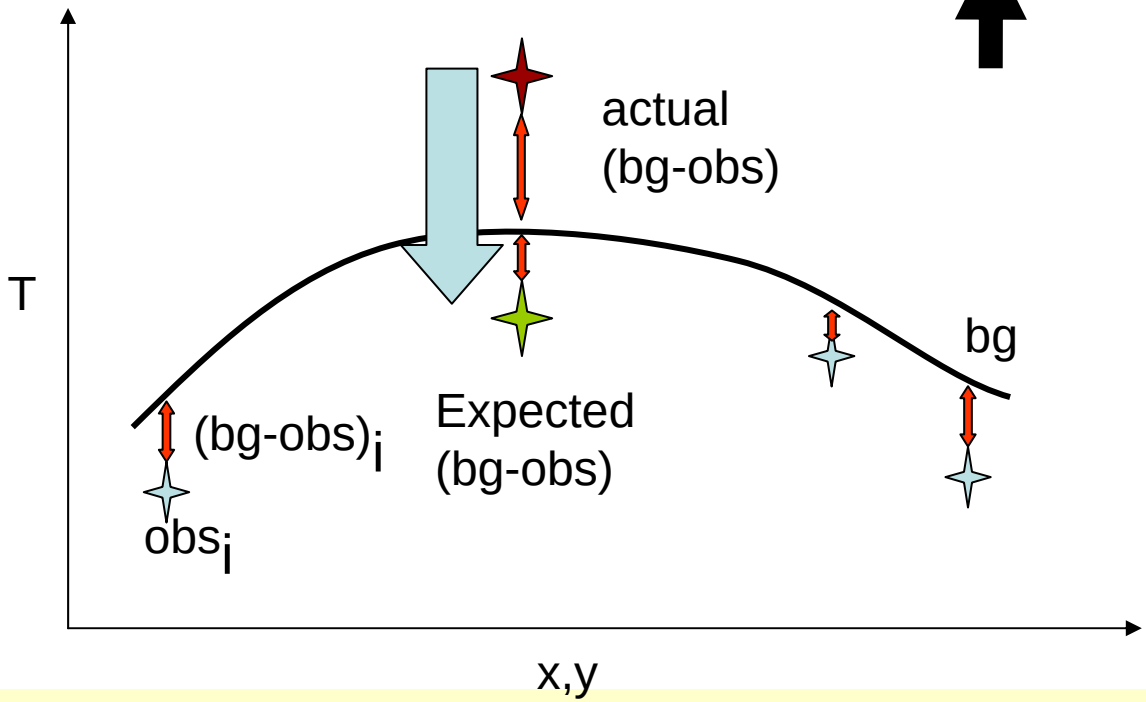


Bias adjustments beyond homogenization

- Adjustment of station climatologies
  - Some records biased even in most recent part
  - Data gaps
  - Some records end early (e.g. weather ships)
- Adjustment of seasonally varying radiation errors
  - Polar regions, near 90W/90E
  - RAOBCORE cannot capture seasonally varying biases - must be estimated by different method
  - Similar to radiation error correction used in ERA-40

Station climatology adjustment



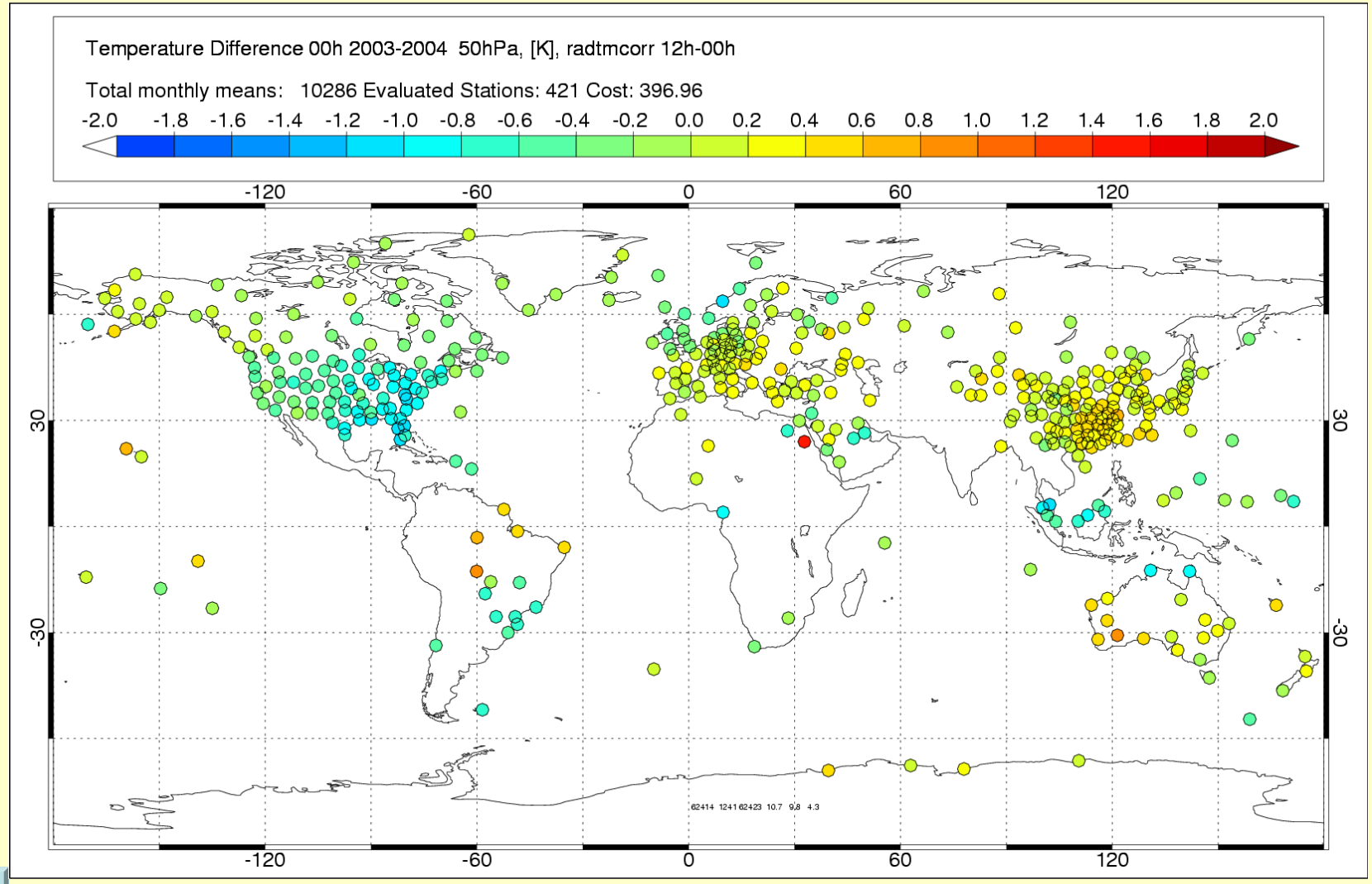


Mean T of neighbouring homogenized „reliable“ series

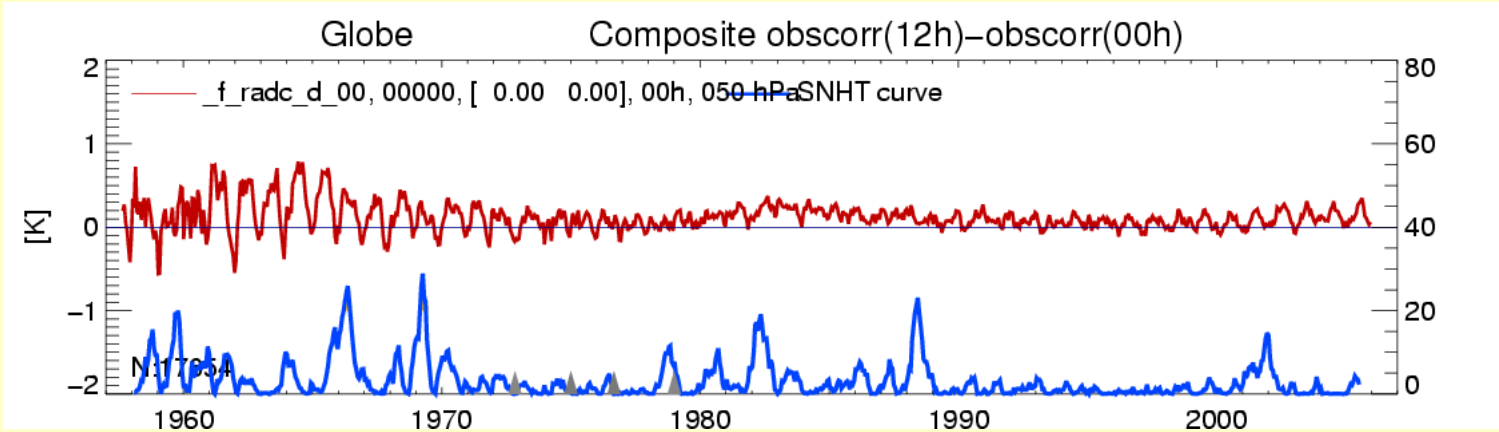
Mean T of most recent part of tested series

Bg used for interpolation

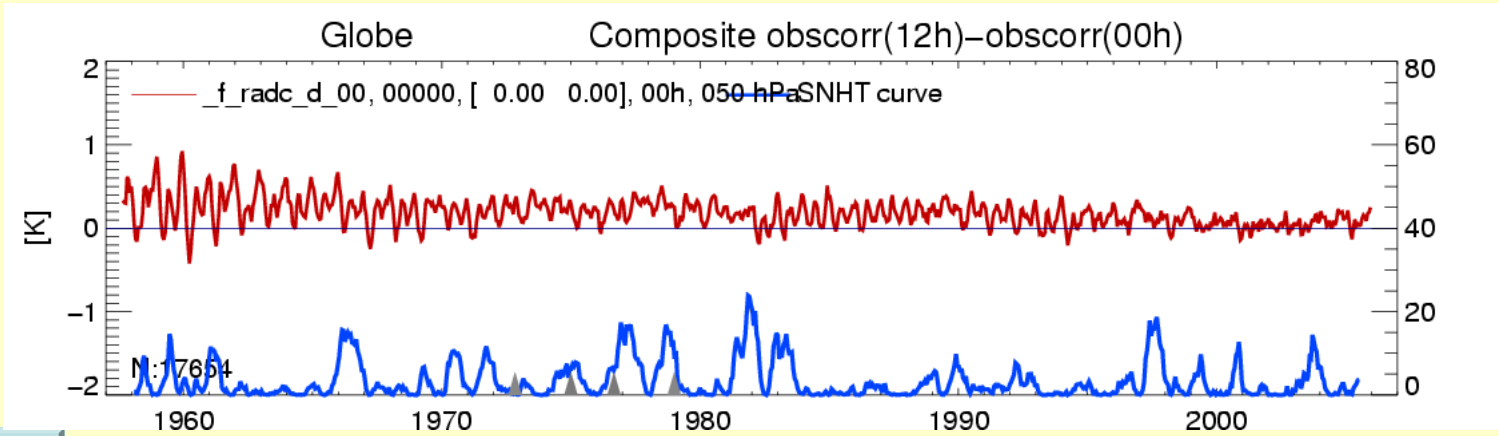
Adj. 12h-00h T-Difference 2003/04



Adjusted 12h-00h T-Difference, 50 hPa

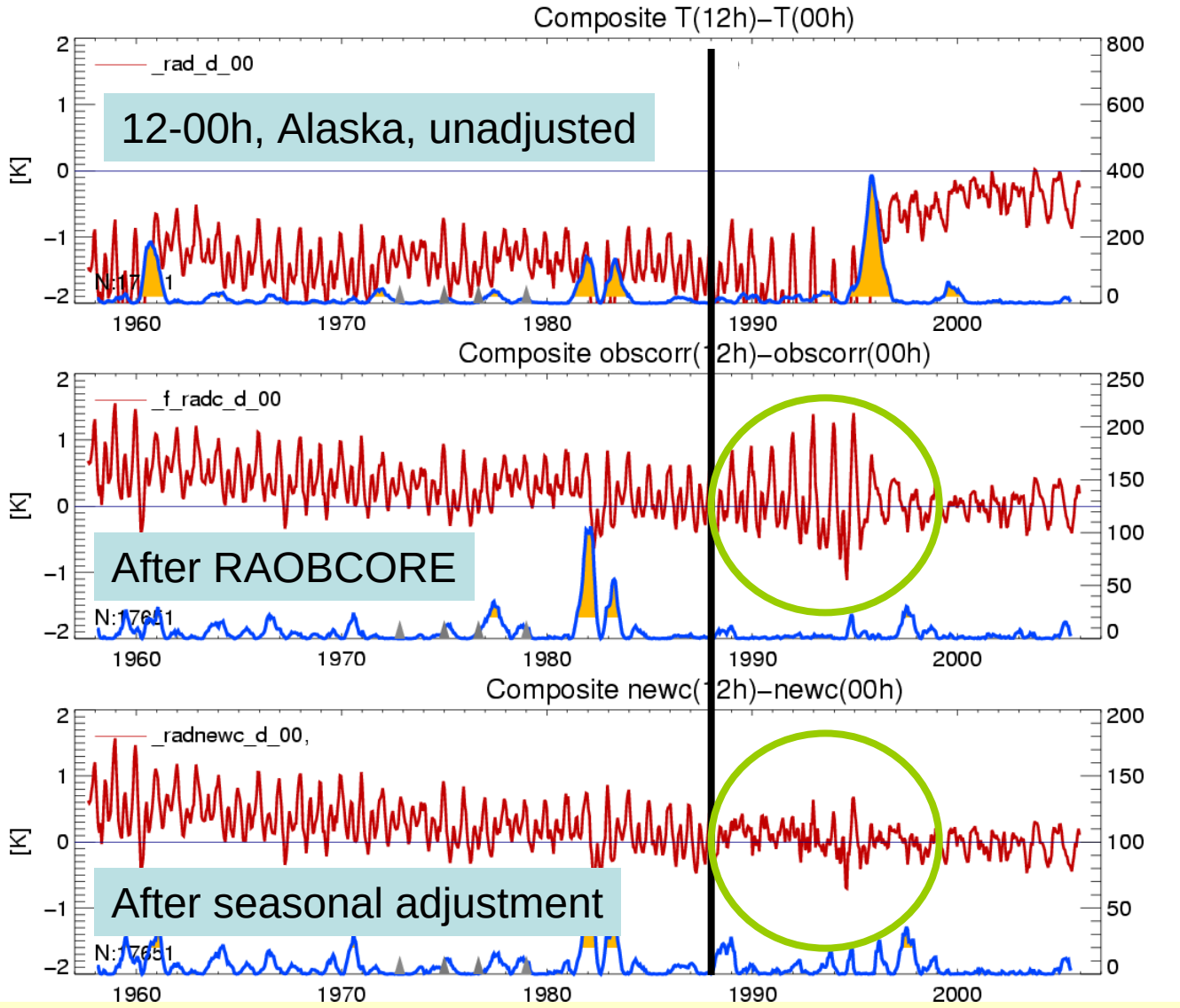


Composite 30W-40E Europe/ Africa



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

Seasonal variation of radiation error



Work with Ulf Andrae

•Obs-bg as function of solar elevation

•Calculated for composites, e.g. Alaska

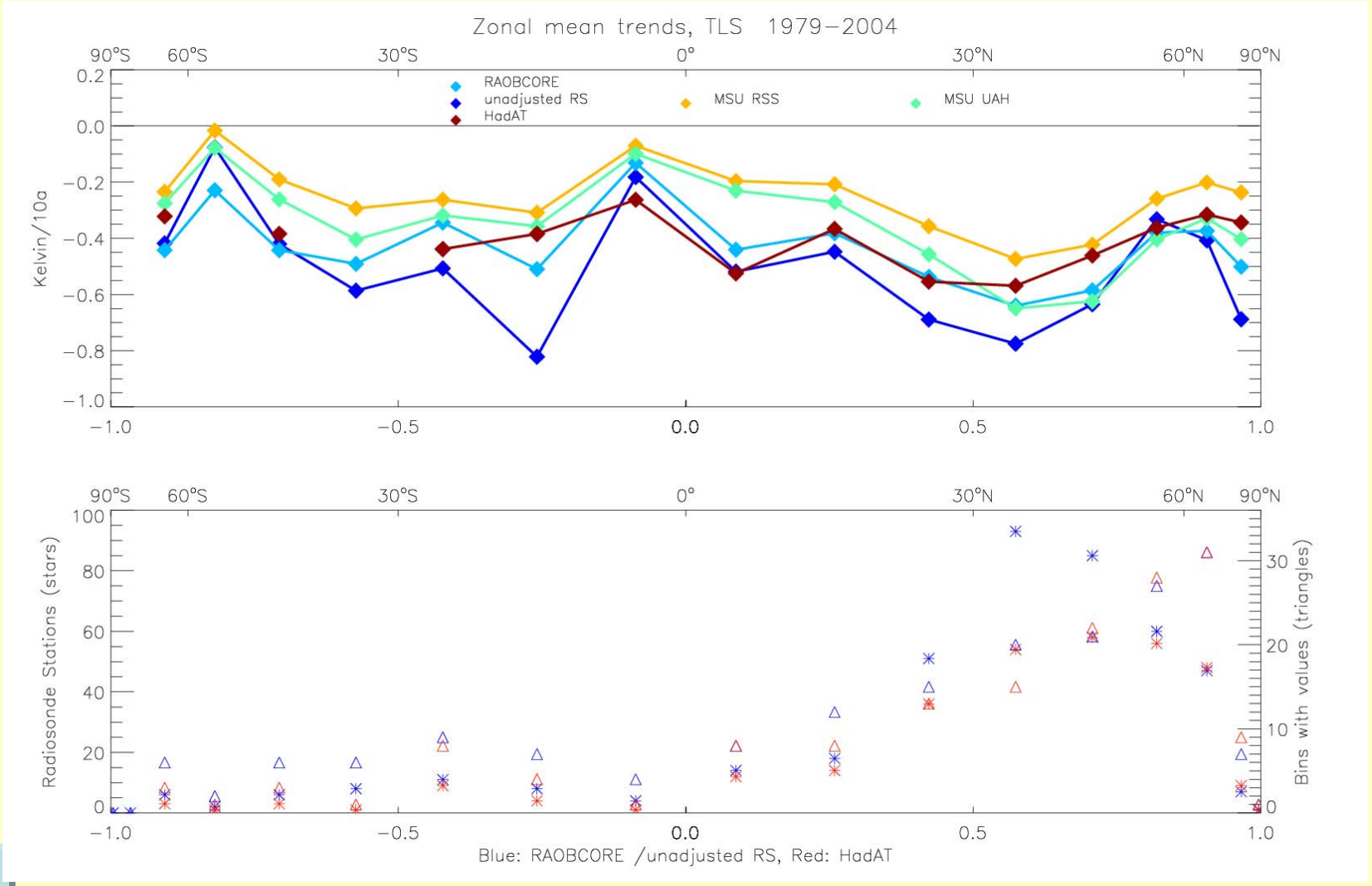
•Calculated separately at 00GMT and 12 GMT

• Seasonal cycle of obs-bg is attributed to obs bias and is removed

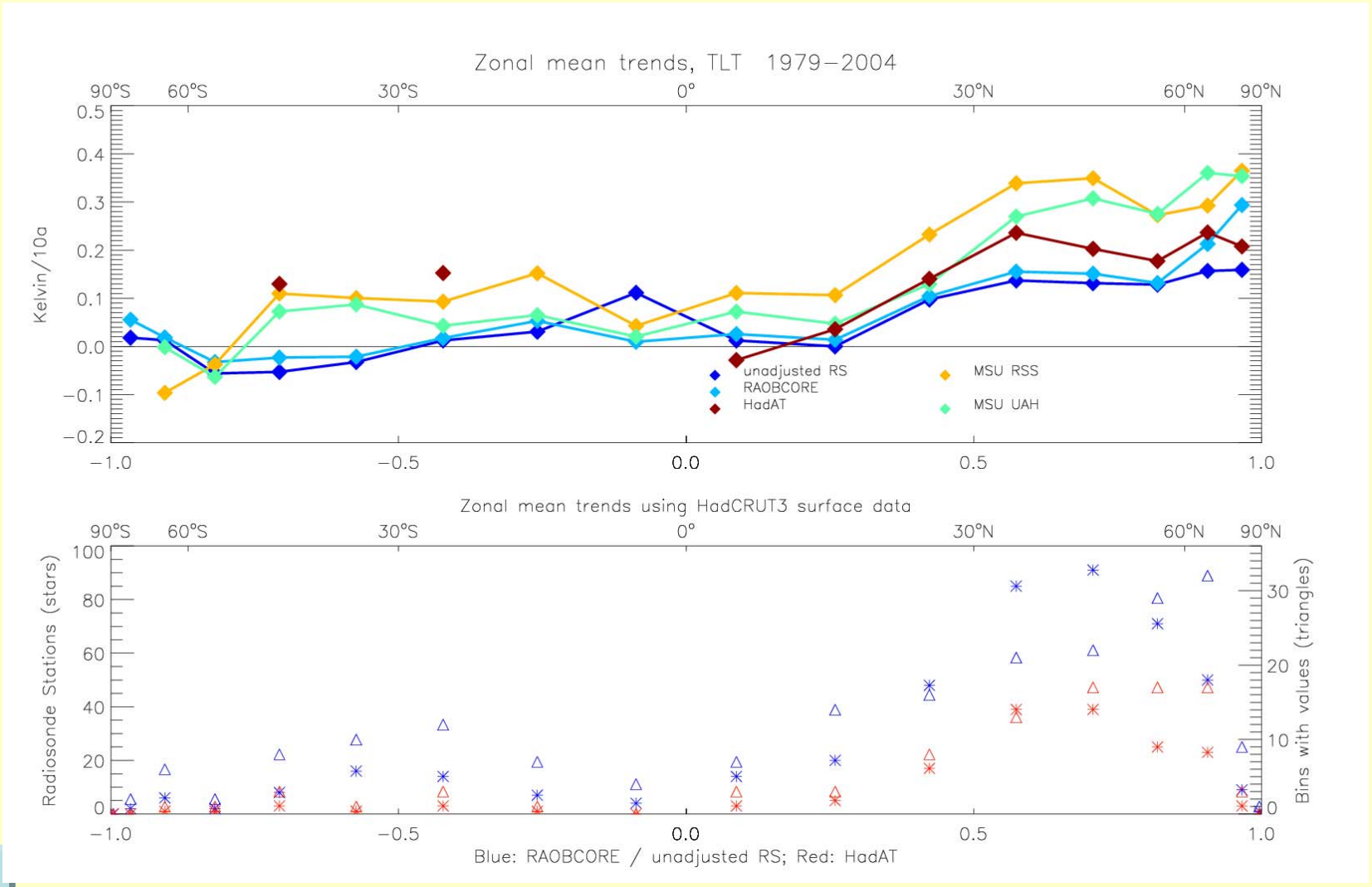
•Seasonal cycle of bg assumed correct

•At most stations only subtle adjustment, does not change mean

MSU Lower Stratosphere 1979-2004



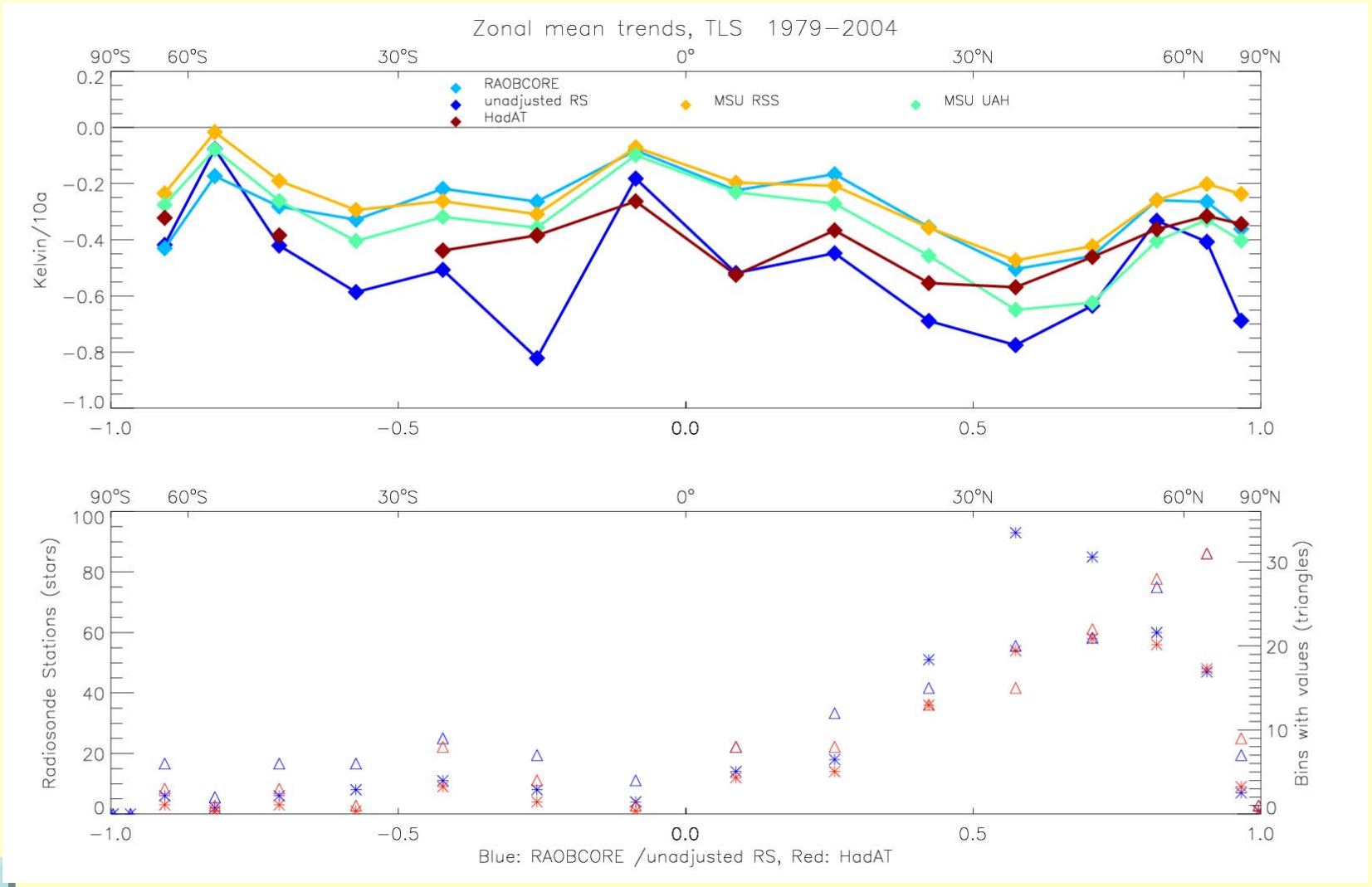
MSU Lower-Troposphere 1979-2004



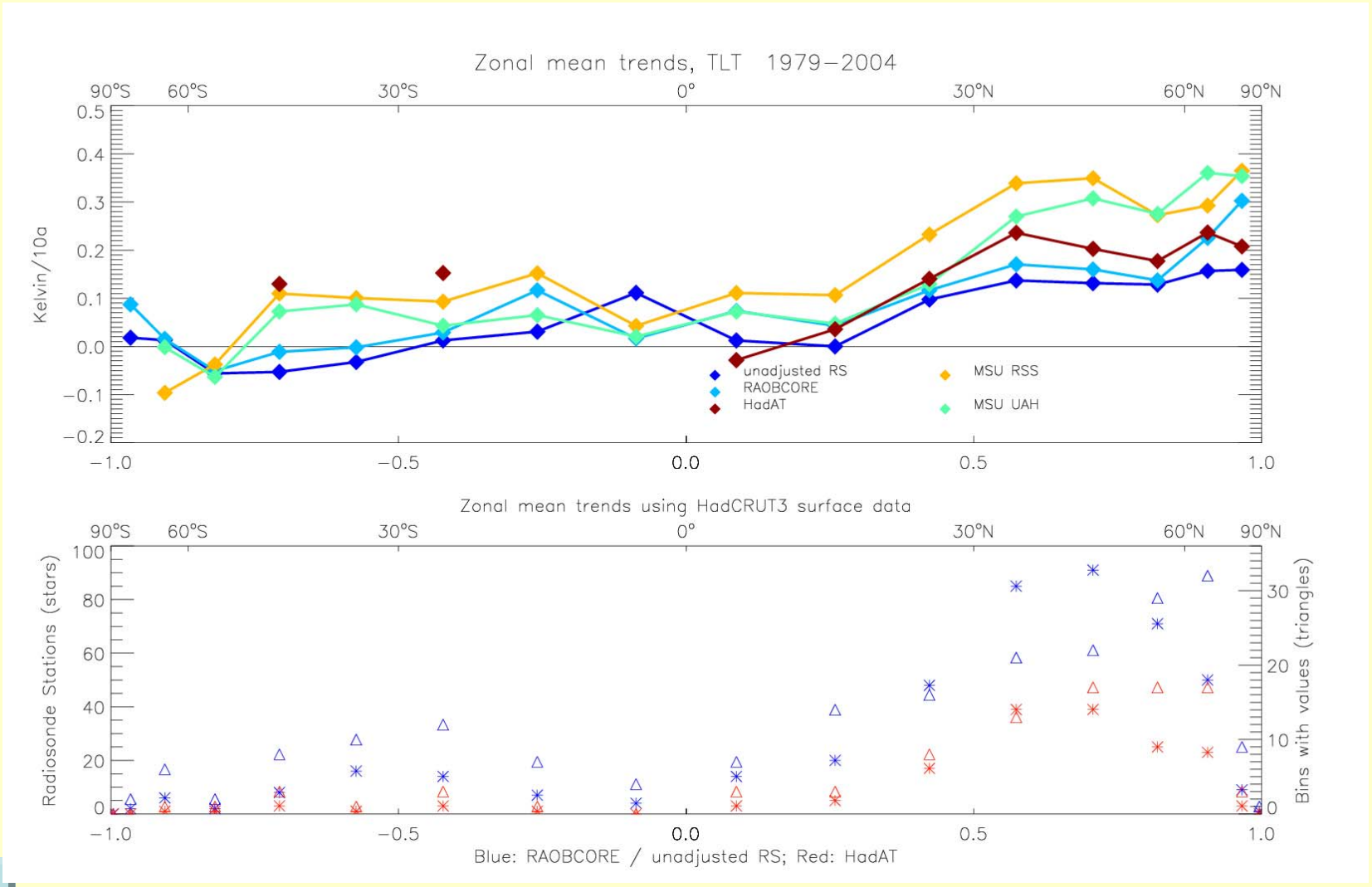
Sensitivity to bg adjustment

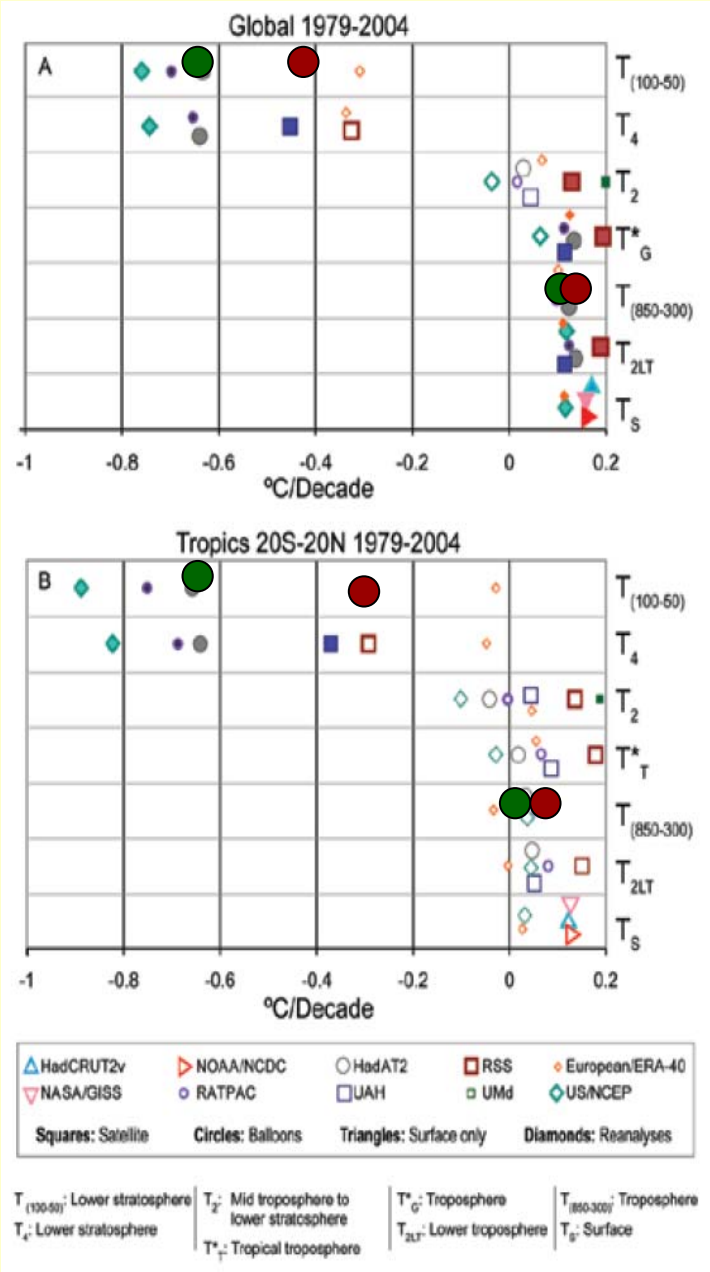
- Adjustment of bg reasonable but with high uncertainty.
- What happens, if we do not adjust the bg?

Lower Stratosphere, bg unadjusted



Lower Troposphere, bg unadjusted





Global Linear Trend profiles 1979-2004, K/10a

Fig. 3.4, US CCSP Report (Karl et al. 2006)

Acronym	Description	50-100 hPa Trend	300-850 hPa Trend	Cost 50 hPa Trend	Cost 50 hPa 12- 00	Break Count
BG	Unadjusted bg(except shift at 2001) ERA-40 + ECMWF bg temperatures	-0.05(0.11)	0.15(0.02)	139	360	
BGADJ	Adjusted bg	-0.39(-0.34)	0.11(-0.03)	134	356	
UADJ	Unadjusted radiosondes	-0.83(-0.94)	0.09(-0.01)	564	3401	
RAOBCORE	RAOBCORE best estimate (Control run)	-0.68(-0.69)	0.1(0.02)	169	625	6505
NOMETA	No Metadata, constant prior probability 0.02	-0.65(-0.65)	0.11(0.00)	187	696	6448
ONLYMETA	Adjustments only at documented changes	-0.69(-0.73)	0.13(0.03)	477	1594	2745
NOBGC	No adjustment of bg before RAOBCORE	-0.42(-0.31)	0.15(0.06)	175	600	6367
STRICT	ΔT of 0.5 K required at 2 places in break profile	-0.65(-0.64)	0.12(0.02)	286	922	4346

Sensitivity tests

Haimberger 2006, J. Climate (accepted)

General summary

- „Complete“ radiosonde dataset has been homogenized (breaks at 1184 stations)
- ~6500 breakpoints detected and adjusted
- Metadata helpful, especially those from GTS
- Adjustment of climatologies and of seasonally dependent errors has been applied
- Trends agree with other RS datasets, uncertainties remain due to bg inhomogeneities.
- It appears unlikely that RS-trend uncertainties can be reduced to level needed for climate model validation – in view of the number of breaks

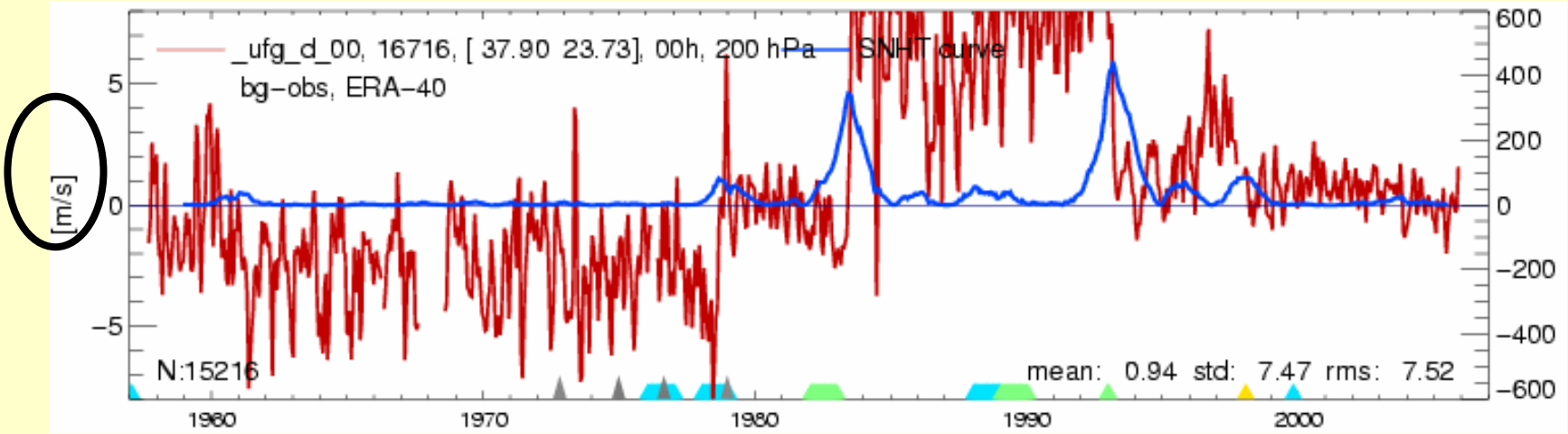
Implications for reanalyses

- Obs-bg is an important reanalysis product that helps improving input observations
- Improved consistency of RS dataset allows to assimilate also short series without harming homogeneity of reanalysis
- More stringent QC possible?
- It may easier to apply variational bias correction to an internally consistent radiosonde dataset
- RAOBCORE adjustments can be read into IFS

- Next goals:
  - Radiosonde data before 1957 (Bronnimann, …) need to be assimilated before ERA-70
  - Detailed comparisons with satellite data and other radiosonde data (e.g. HadAT)
  - Assimilation experiments with ERA-40 interim
  - Develop adjustment method based on neighbour composites of obs-bg differences
- More infos und plots:
  - http://www.univie.ac.at/theoret-met/research/RAOBCORE/
  - Look at detected breaks – please verify/falsify!

Wind inhomogeneities – the same story once again?

- U-departures at station 16716 (Athens)
- Problems in ERA with wind homogeneity as well
- **Do not forget:** It is the ERA-40 feedback that lets us see this in this clarity
- Apply RAOBCORE to wind data



Consistency of RS-wind trends