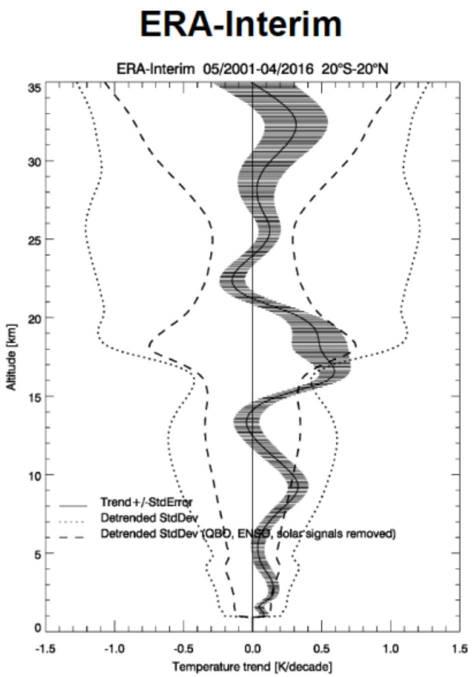
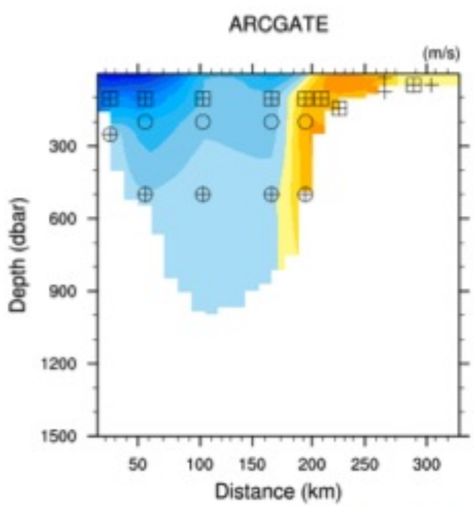
WP4 Estimating and reducing uncertainty of Reanalyses and observations

DWD, ECMWF , FFCUL, RIHMI,
UNIBE, UNIVIE, UVSQ

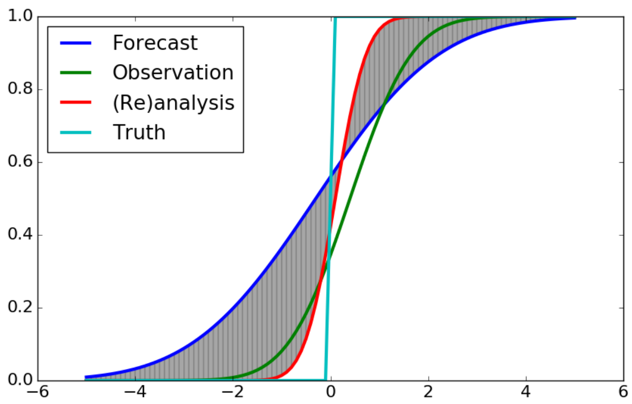
Trend estimation



Flux estimation
Coupled budgets



Observation and analysis uncertainty

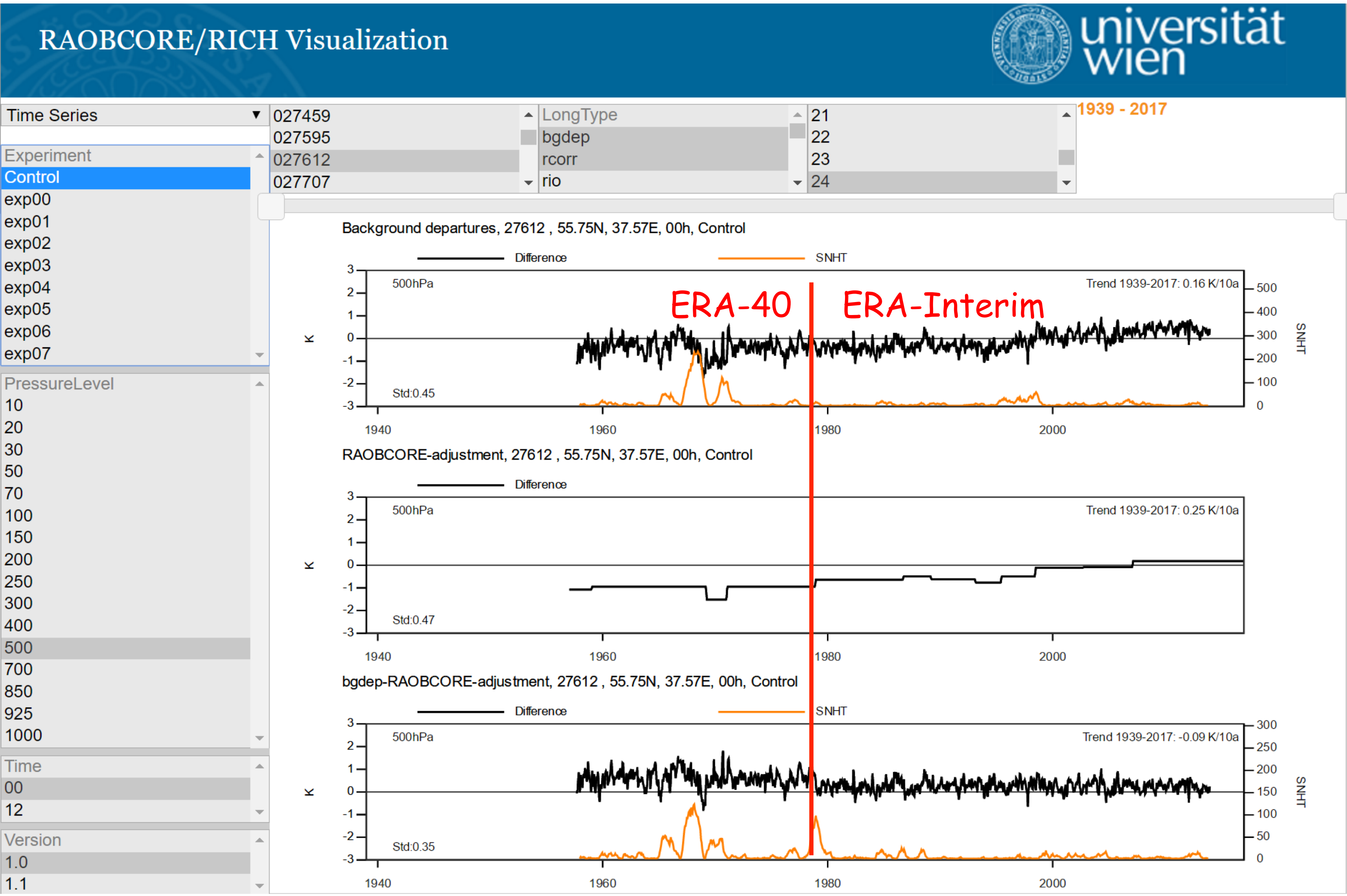


Status of Deliverables

Deliverable number	Deliverable title	Delivery date
D4.1	RS bias adjustments (UNIVIE)	20
D4.2	Updated RS bias adjustments (UNIVIE)	48
D4.3	QC for observations from FFCUL (FFCUL)	48
D4.4	Visualization tool for QC (FFCUL)	12
D4.5	QC for upper-air, surface, and snow obs. (RIHMI)	36
D4.6	Methodology for quantifying obs error (UBERN)	36
D4.7	Verification of precipitation against GPCC (DWD)	48
D4.8	Global energy, water, carbon cycles (ECMWF,UNIVIE, UVSQ)	48
D4.9	Upper air data qc (UBERN, RIHMI)	24
D4.10	Comparison with other reanalyses (UNIVIE; ECMWF)	48
D4.11	Low frequency variability and trends (ALL)	48
D4.12	Uncertainty of input parameters for carbon budget (UVSQ)	20
D4.13	Confidence intervals on carbon fluxes (UVSQ)	48
D4.14	Comparison of CTESSEL, ORCHIDEE flux estimates (ECMWF, UVSQ, UNIVIE)	48

Radiosonde (RS) Temperature Bias Correction Overview

- Variational RS temperature BC scheme
  - Test version implemented in IFS, right now dormant, see Milan and Haimberger (2015), D4.1
- Further development of RAOBCORE/RICH for ERA5 reanalysis production
  - Forward and backward extension using ERA preSAT and CHUAN 2.0 (8' 2015) data. **Merge time series**
  - Use JRA55, ERA preSAT as reference for break detection
  - Assess improvement compared to Haimberger et al. 2012
  - Add solar elevation dependent adjustment 1979-
  - Most recent part of time series consistent with GPS-RO retrievals?


RAOBCORE/RICH Visualization
universität wien
Time Series
Experiment
Control
exp00
exp01
exp02
exp03
exp04
exp05
exp06
exp07
PressureLevel
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
Time
00
12
Version
1.0
1.1
027459
027595
027612
027707
LongType
bgdep
rcorr
rio
21
22
23
24
1939 - 2017
Background departures, 27612 , 55.75N, 37.57E, 00h, Control
Difference
SNHT
500hPa
Trend 1939-2017: 0.16 K/10a
Std:0.45
ERA-40
ERA-Interim
RAOBCORE-adjustment, 27612 , 55.75N, 37.57E, 00h, Control
Difference
500hPa
Trend 1939-2017: 0.25 K/10a
Std:0.47
bgdep-RAOBCORE-adjustment, 27612 , 55.75N, 37.57E, 00h, Control
Difference
SNHT
500hPa
Trend 1939-2017: -0.09 K/10a
Std:0.35
K
SNHT
1940
1960
1980
2000

universität wien

Time Series

	027459	LongType	21
	027595	bgdep	22
	027612	rcorr	23
	027707	rio	24

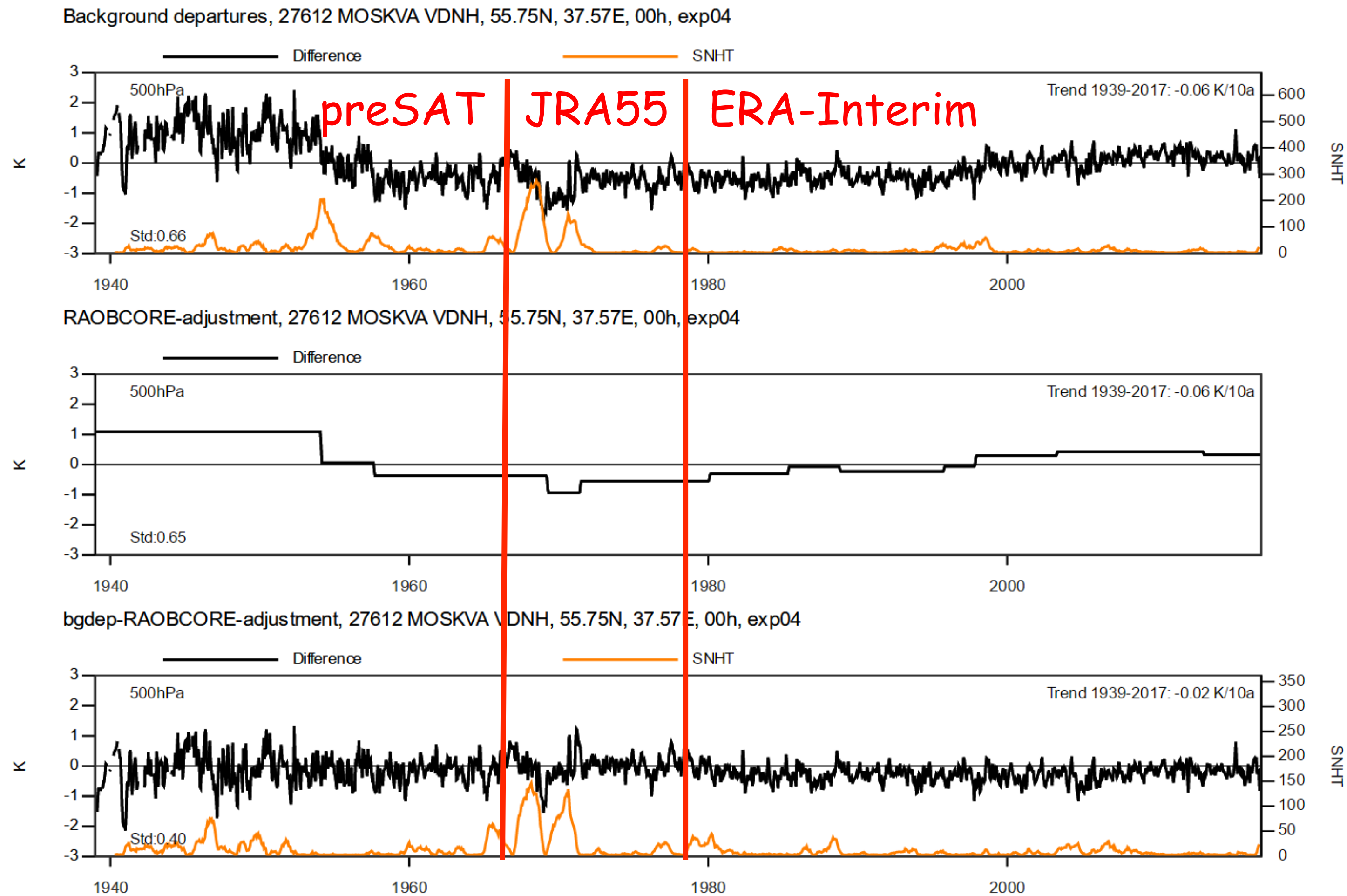
1939 - 2017

Experiment
Control
exp00
exp01
exp02
exp03
exp04
exp05
exp06
exp07

PressureLevel
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000

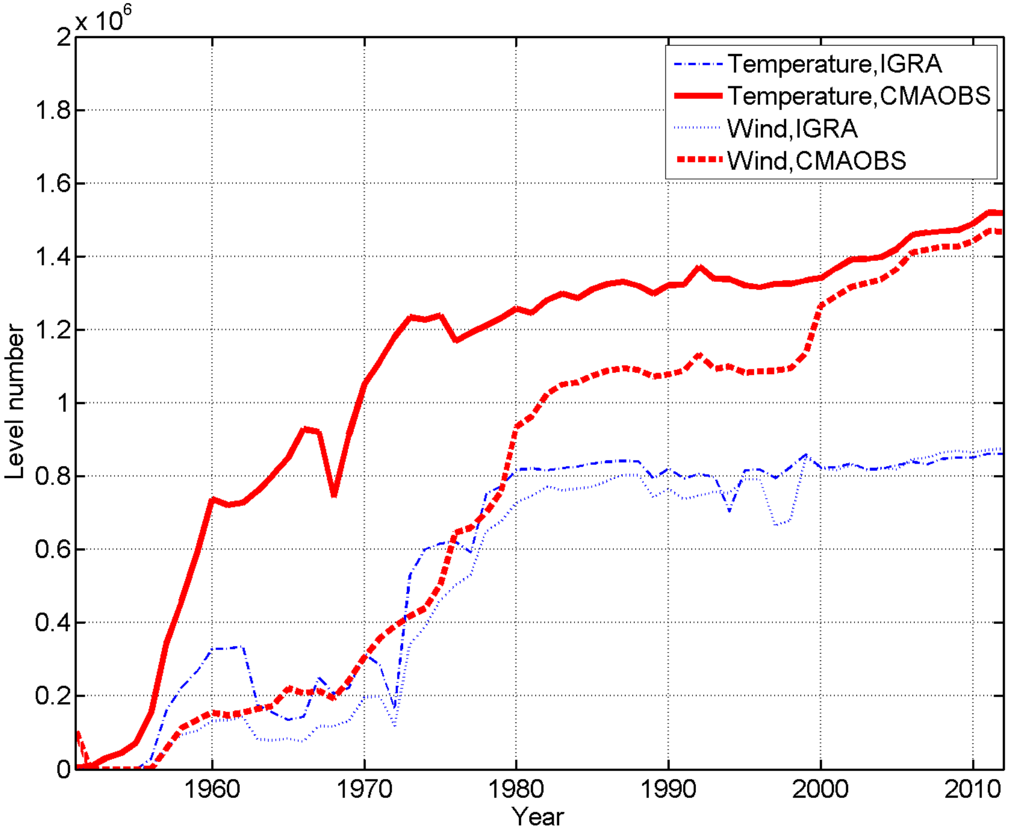
Time
00
12

Version
1.0
1.1



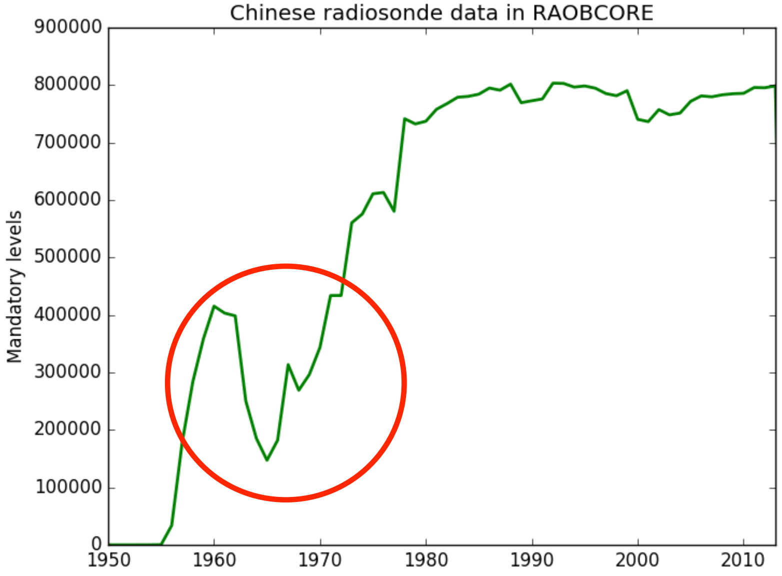
SEVENTH FRAMEWORK PROGRAMME

Are there still unhomogenized UA data out there?

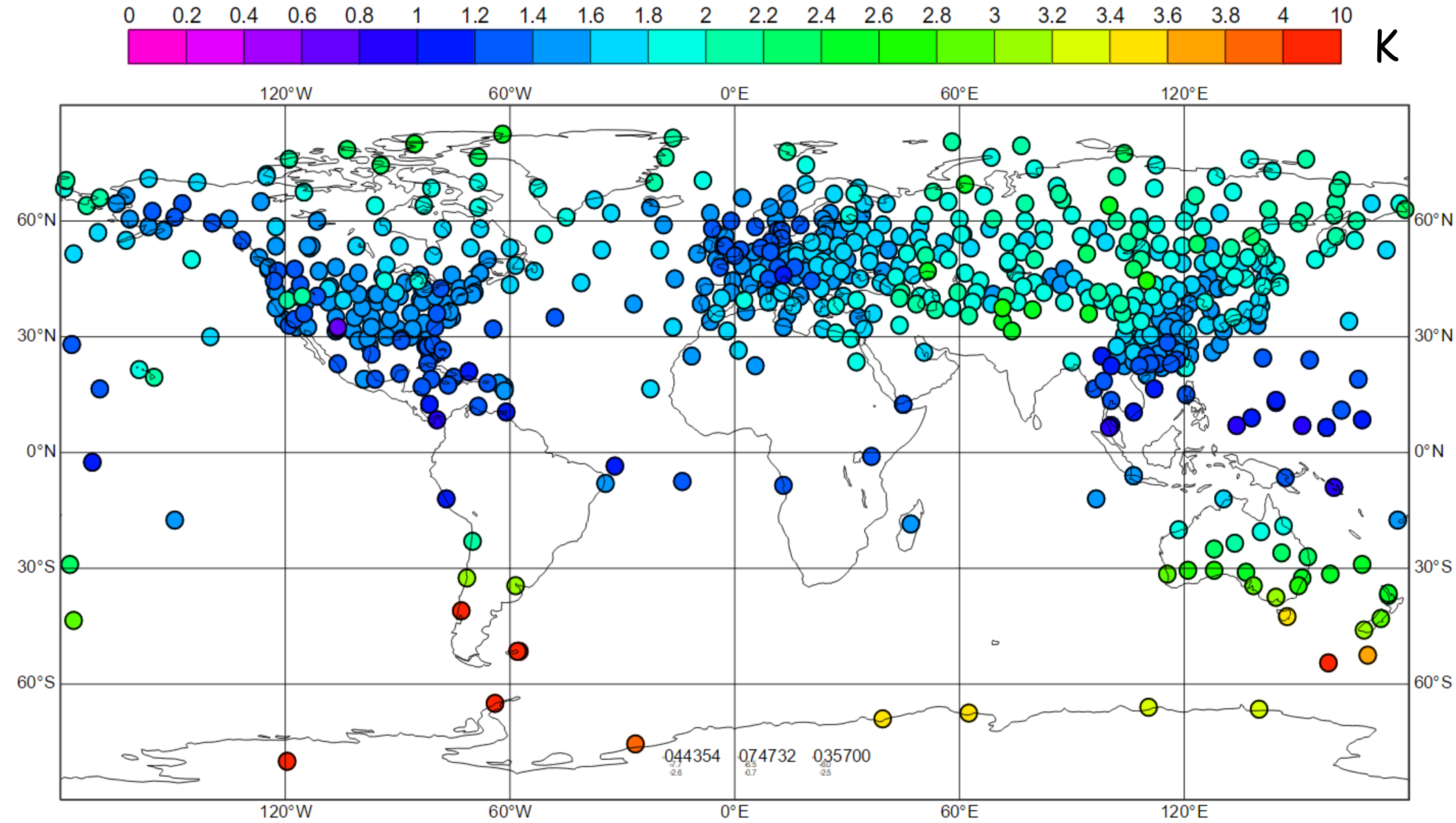


New Meteo-France data!

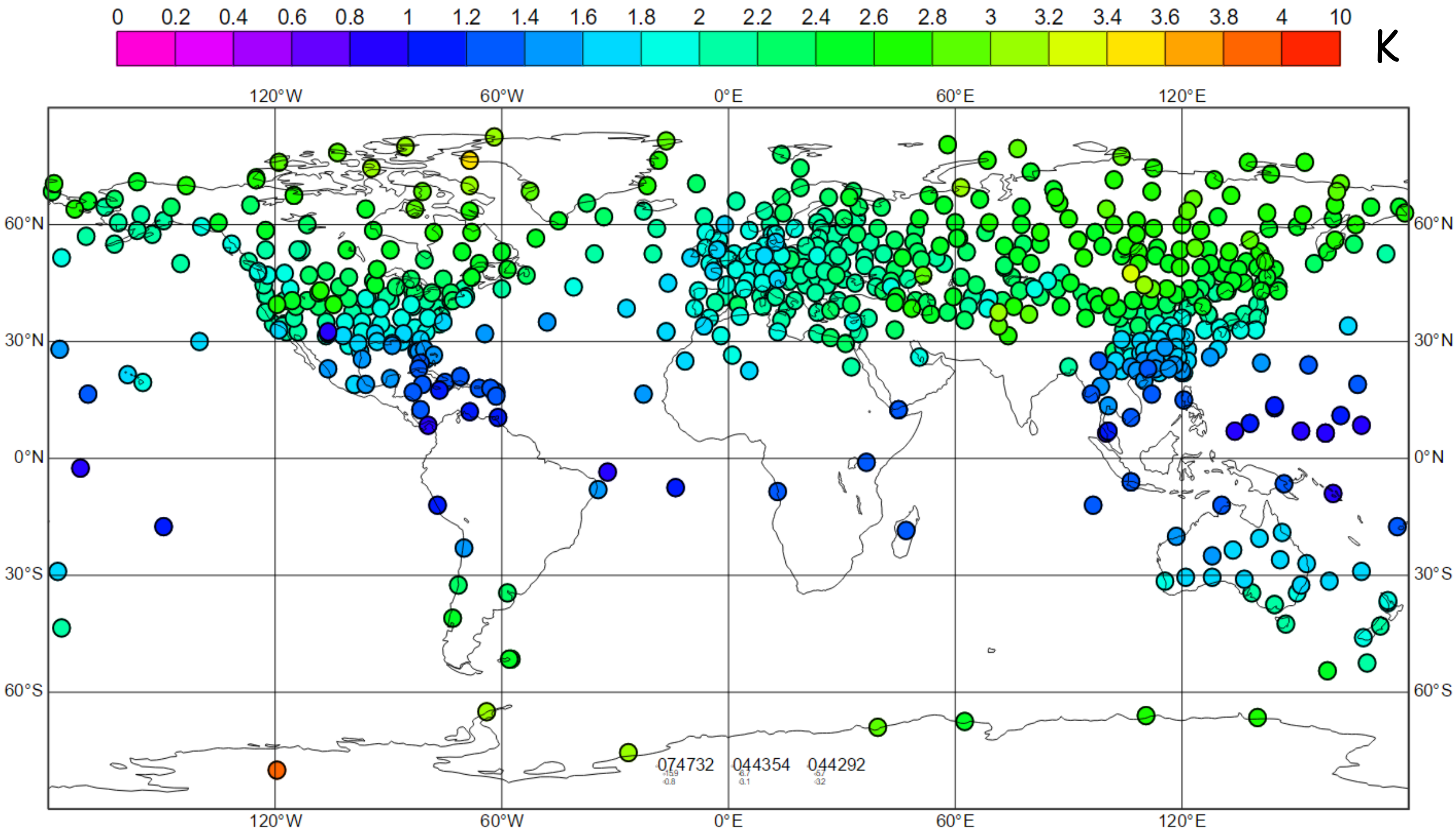
Li Qingxiang, CMA, pers. Comm.



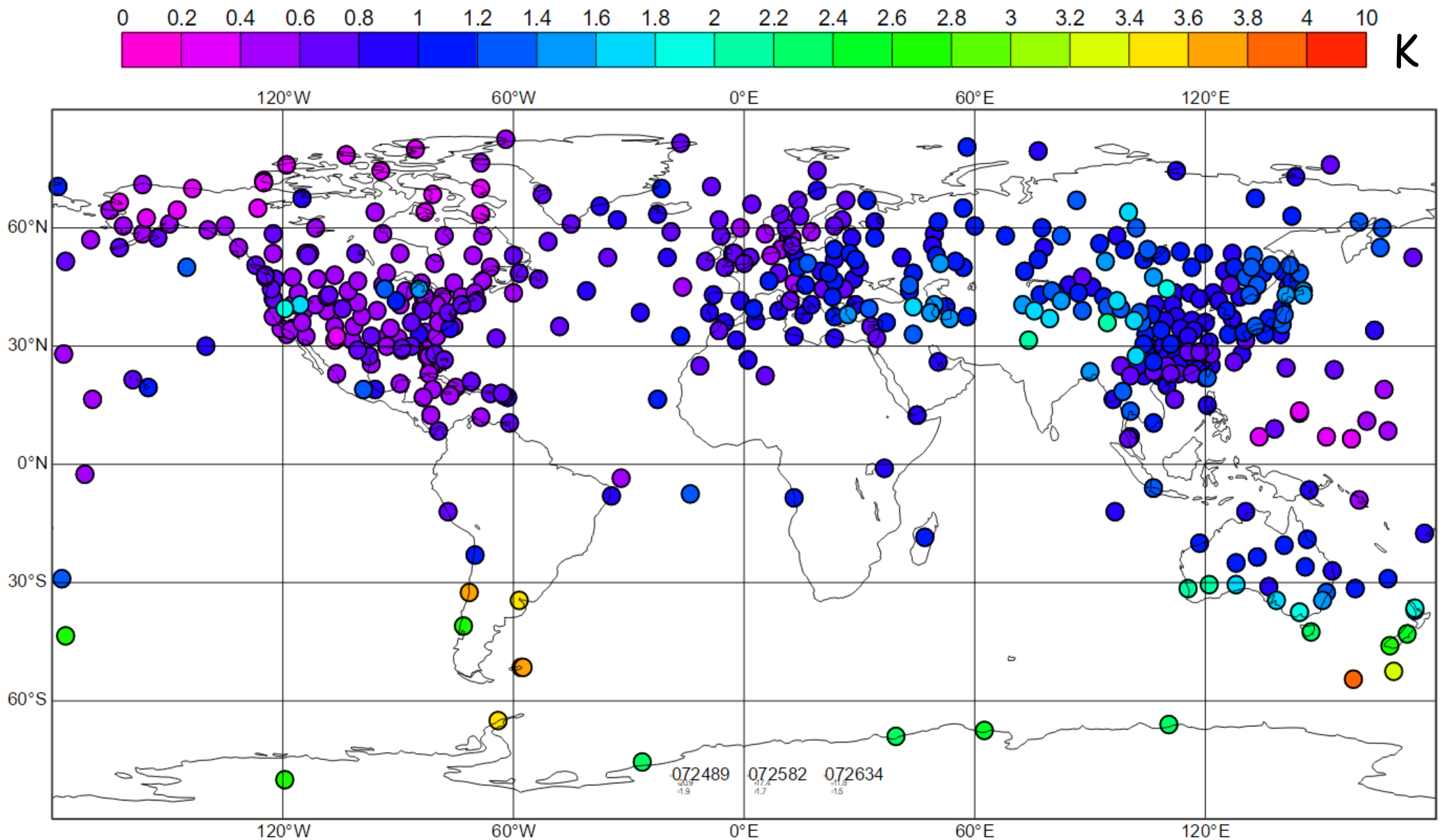
Obs-CERA20C standard dev. 700 hPa 1959/60, from 00h,12h launches



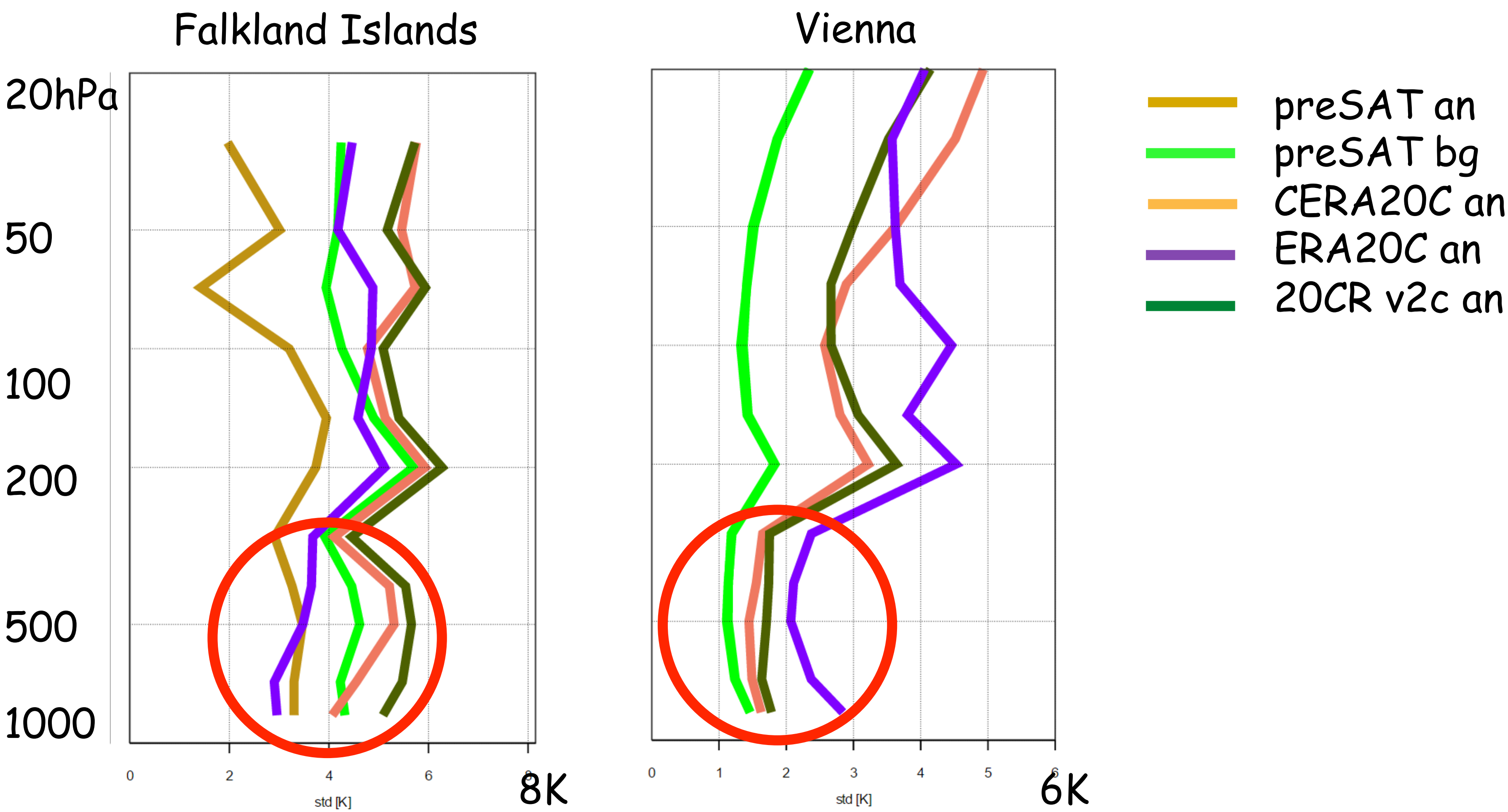
Same for Obs-NOAA 20CR V2c



Same for Obs-ERApreSAT



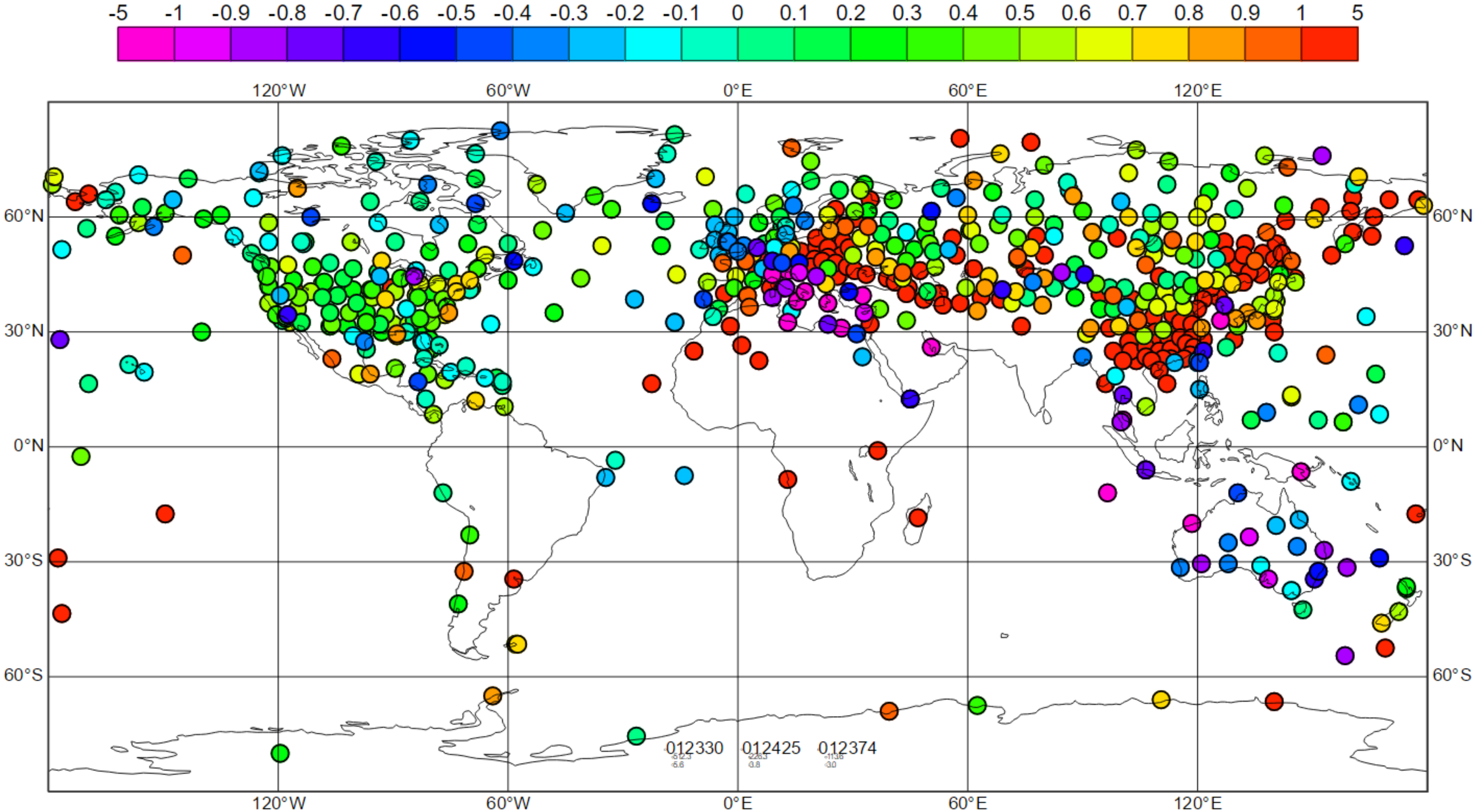
Obs-Reanalysis departure
Standard deviation profiles 1959/60



Biases

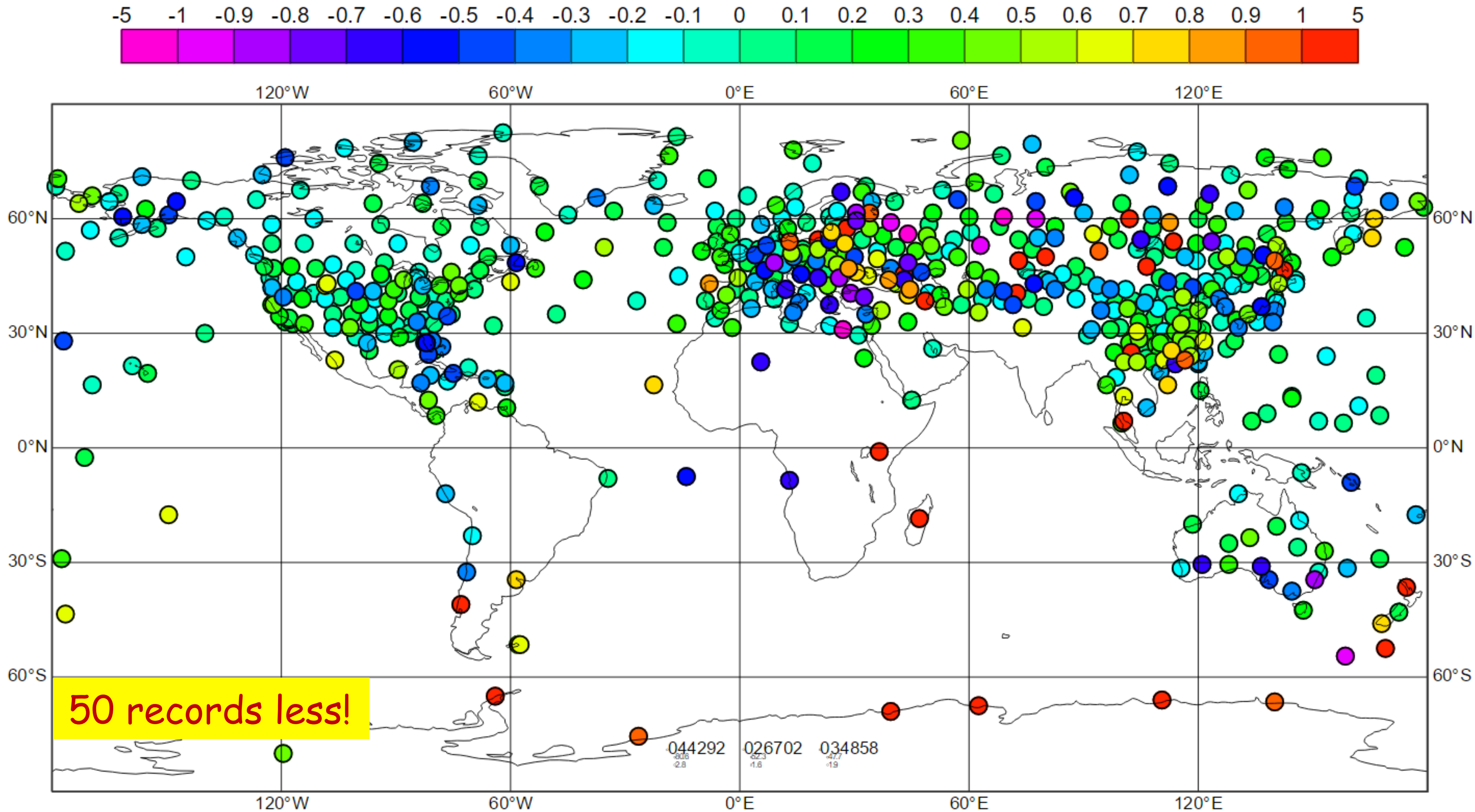
- Check spatial consistency of 2-year mean obs-bg departures
- Consistency harder to achieve than for trends
- Displays also short records

Unadjusted obs-bg, 1959-1960, 300 hPa

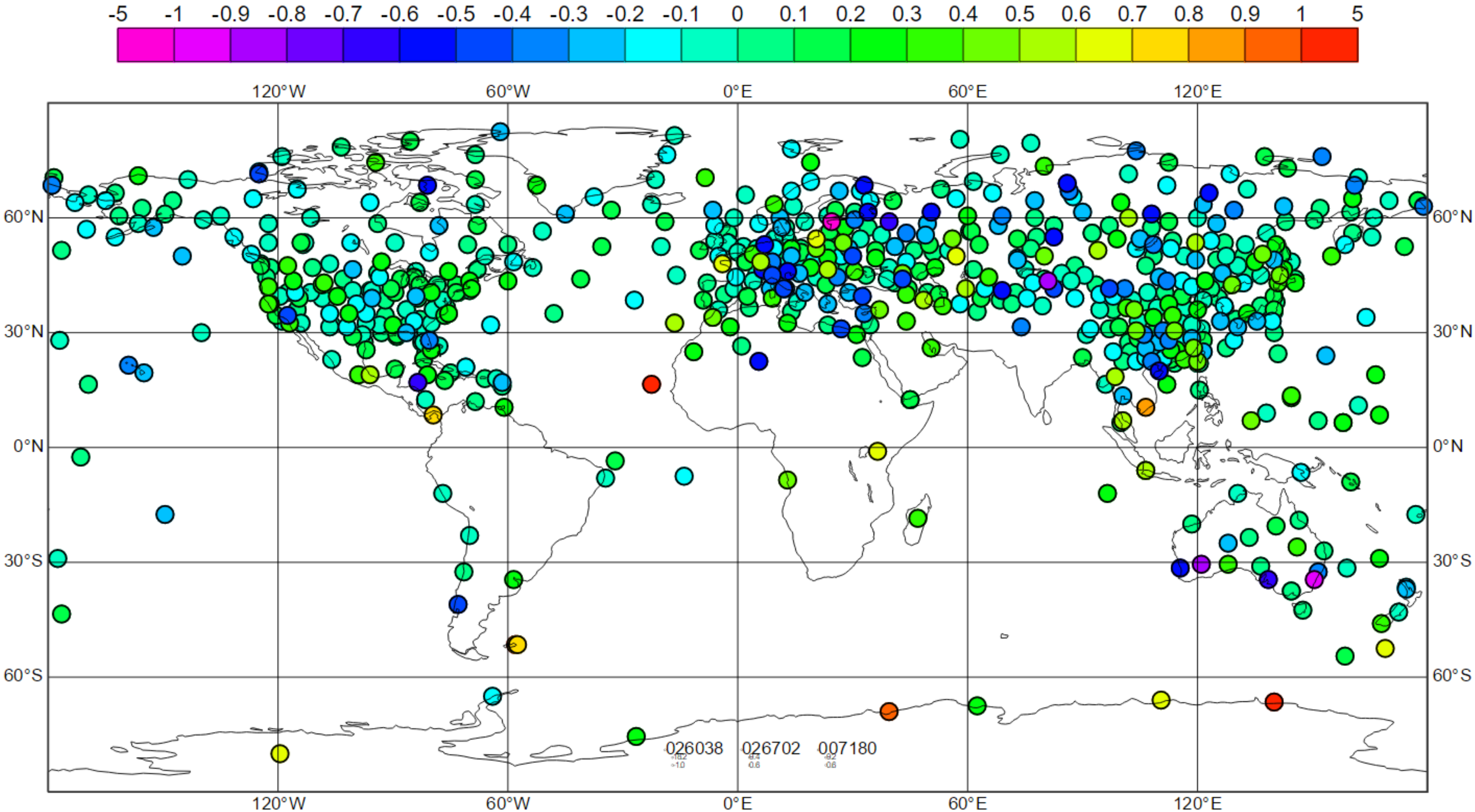


SEVENTH FRAMEWORK PROGRAMME

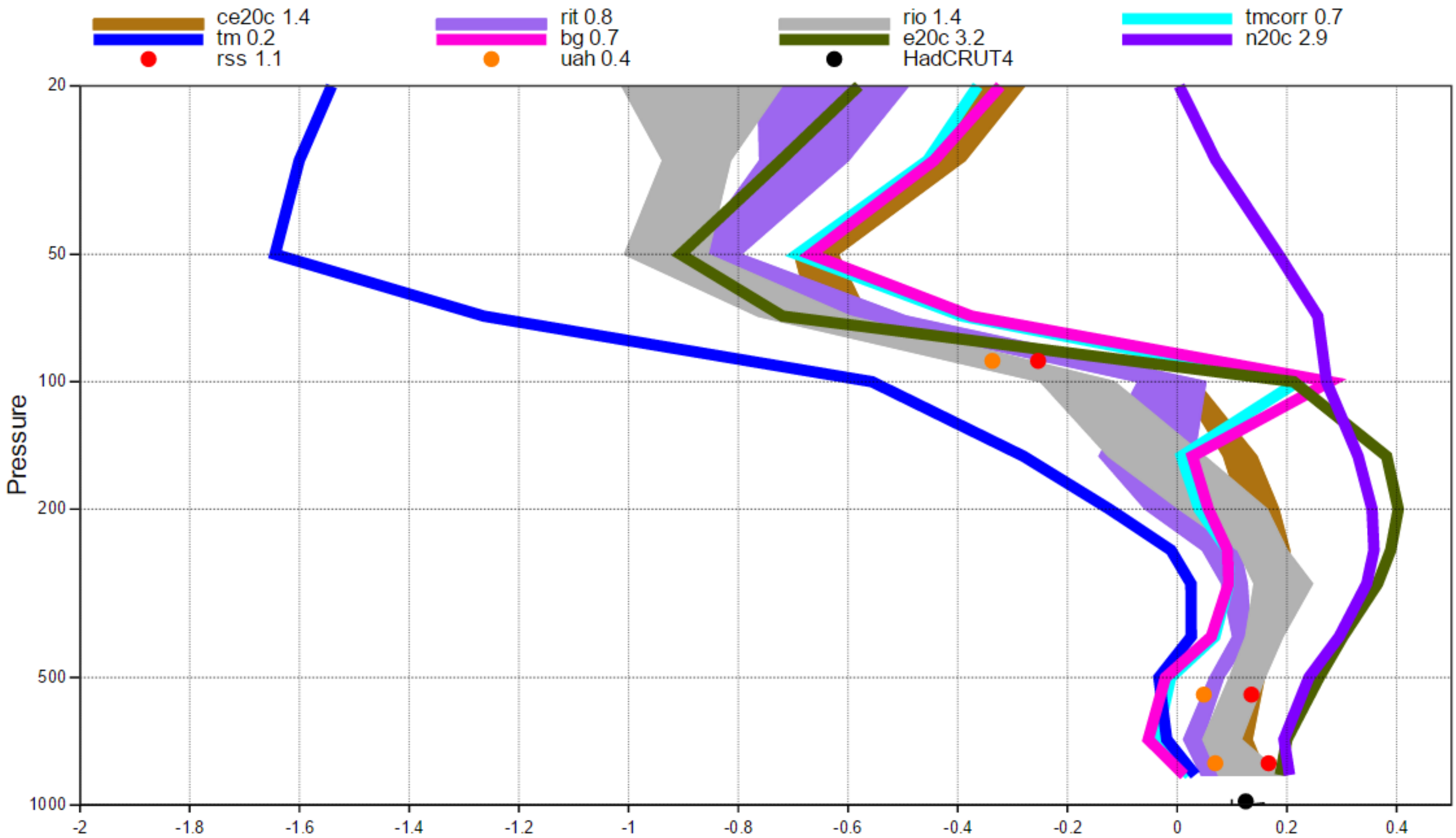
RAOBCORE v1.5 – adjusted obs-bg



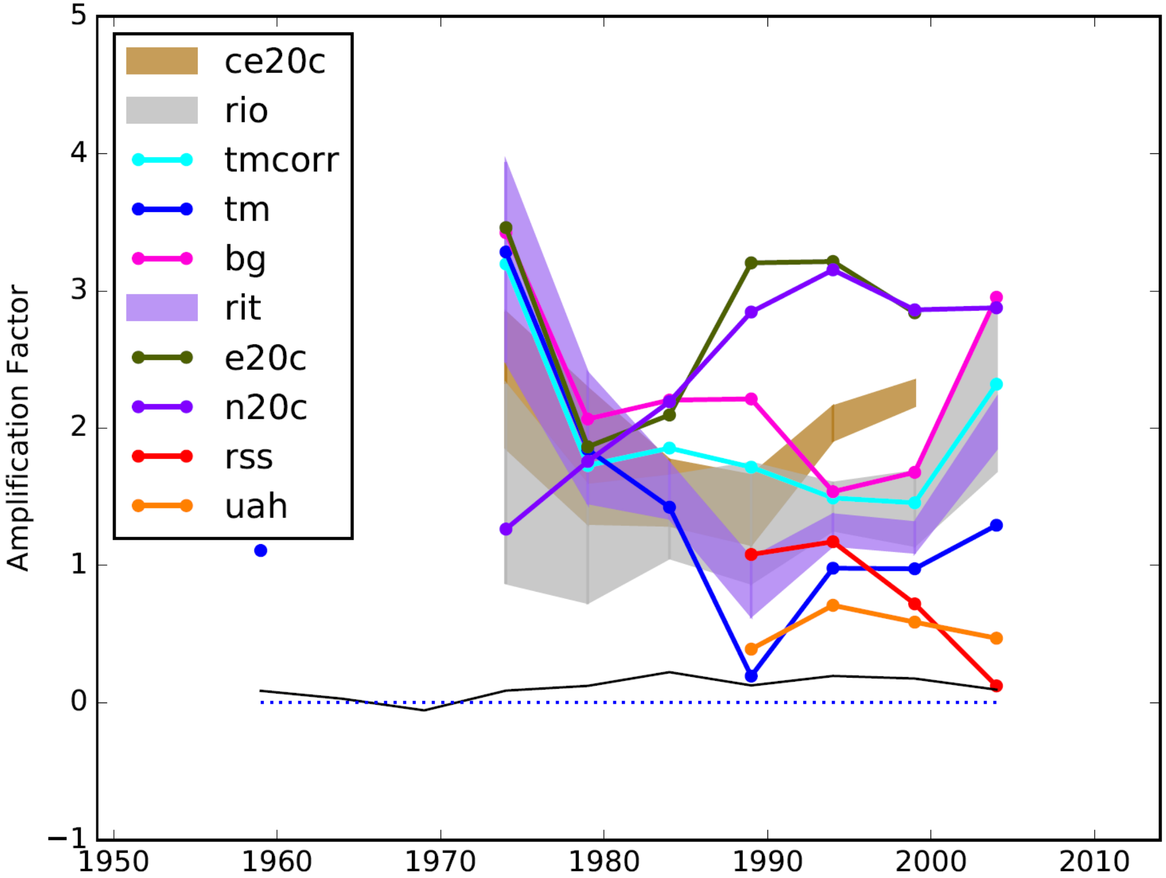
RAOBCORE v1.6 –adjusted obs-bg



Tropical Temperature Trends 1979-1999



20yr Tropical Trend Amplification 20S-20N



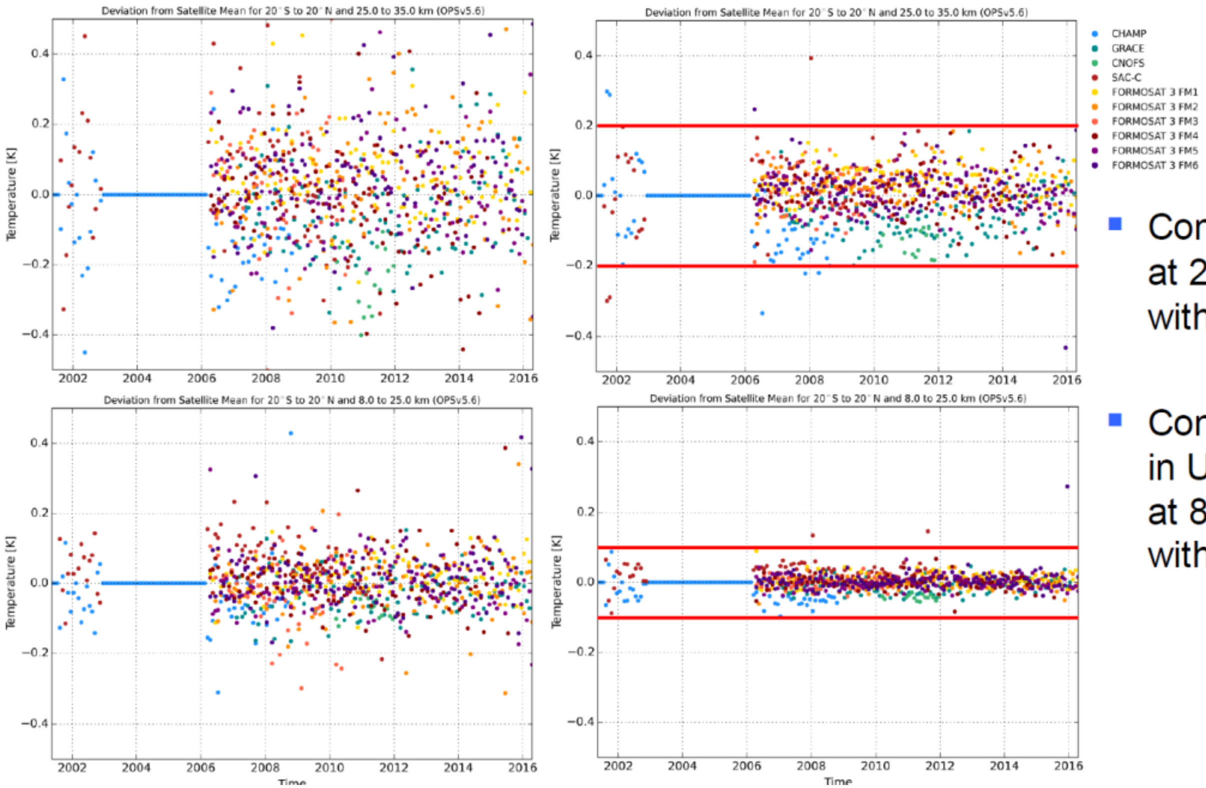
$$\frac{max(\text{UA-Trend})}{\text{SST trend}}$$

- Unrealistic 20CR, ERA-20C
- Strange MSU trends lately
- Stable CERA20C amplification
- Less amplification if SST trend large

GPS-RO temperatures as reference for Stratosphere

Temperature deviation from all-satellite mean for 20°S to 20°N

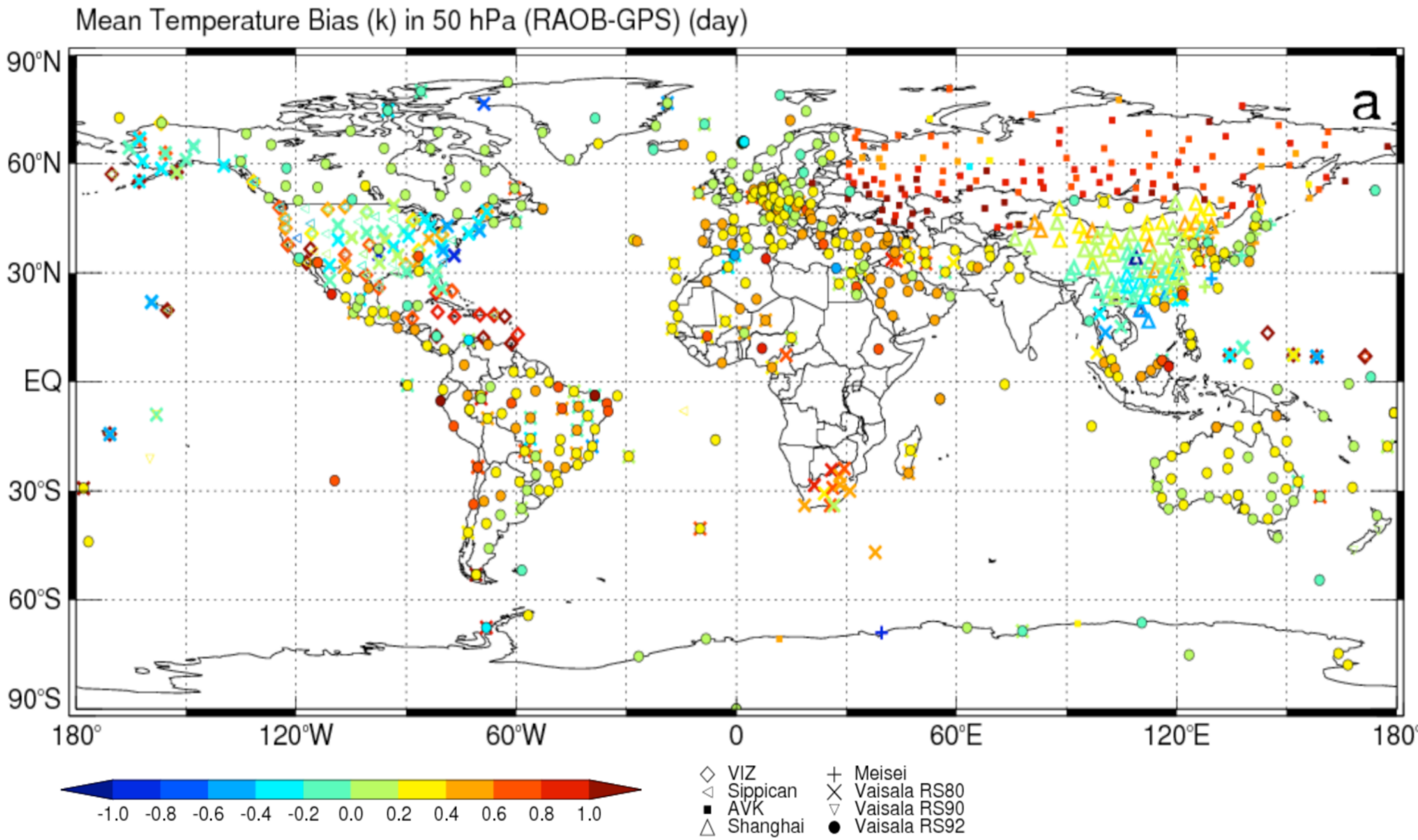
Monthly-mean climatologies | **Sampling error subtracted MMCs**



- Consistency at 25–35 km: within ~0.2 K
- Consistency in UTLS at 8–25 km: within ~0.1 K

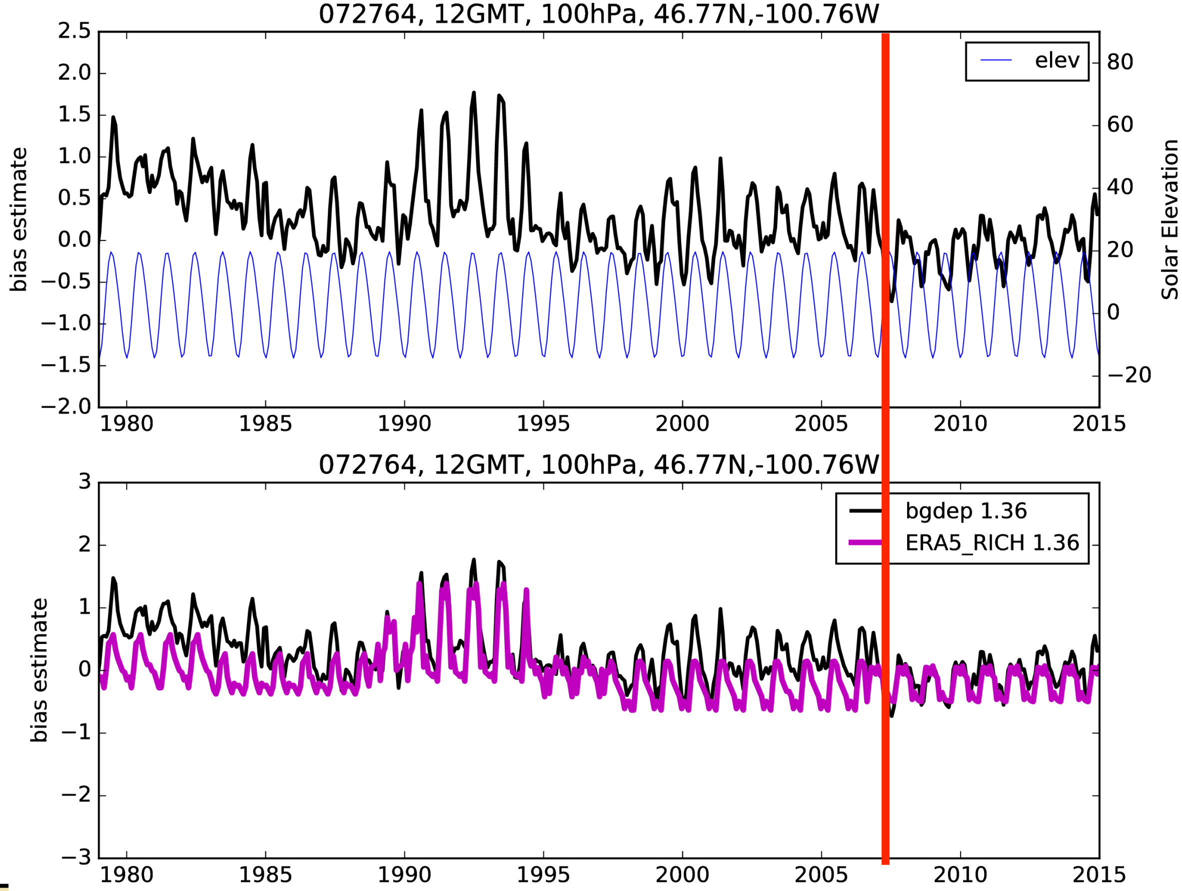
Steiner et al. 2016

Ho et al. 2016 (ACP), RS-GPS, 50 hPa daytime



Annual cycle of observation error

- **At high latitudes, regions around 100W, 80E**
- Estimate variation of radiation error as function of solar



Different radiosonde types have different annual cycles of bias

Mostly in phase with solar elevation.

Web-based Visualization tool

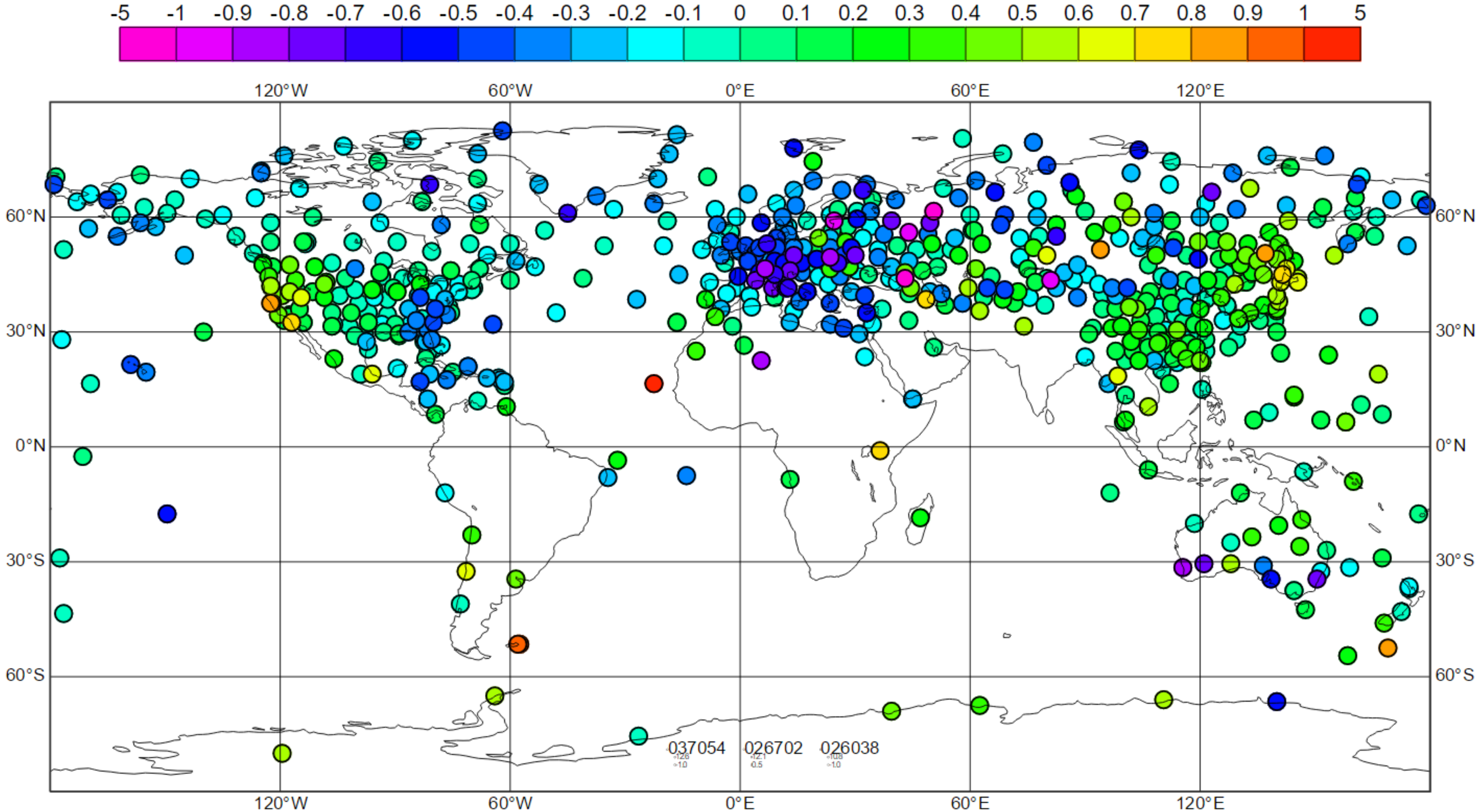
- http://srvx1.img.univie.ac.at/raobvis/
- Test site http://srvx1.img.univie.ac.at:8000/raobvis/

- Please check if you find something strange for stations you know well!

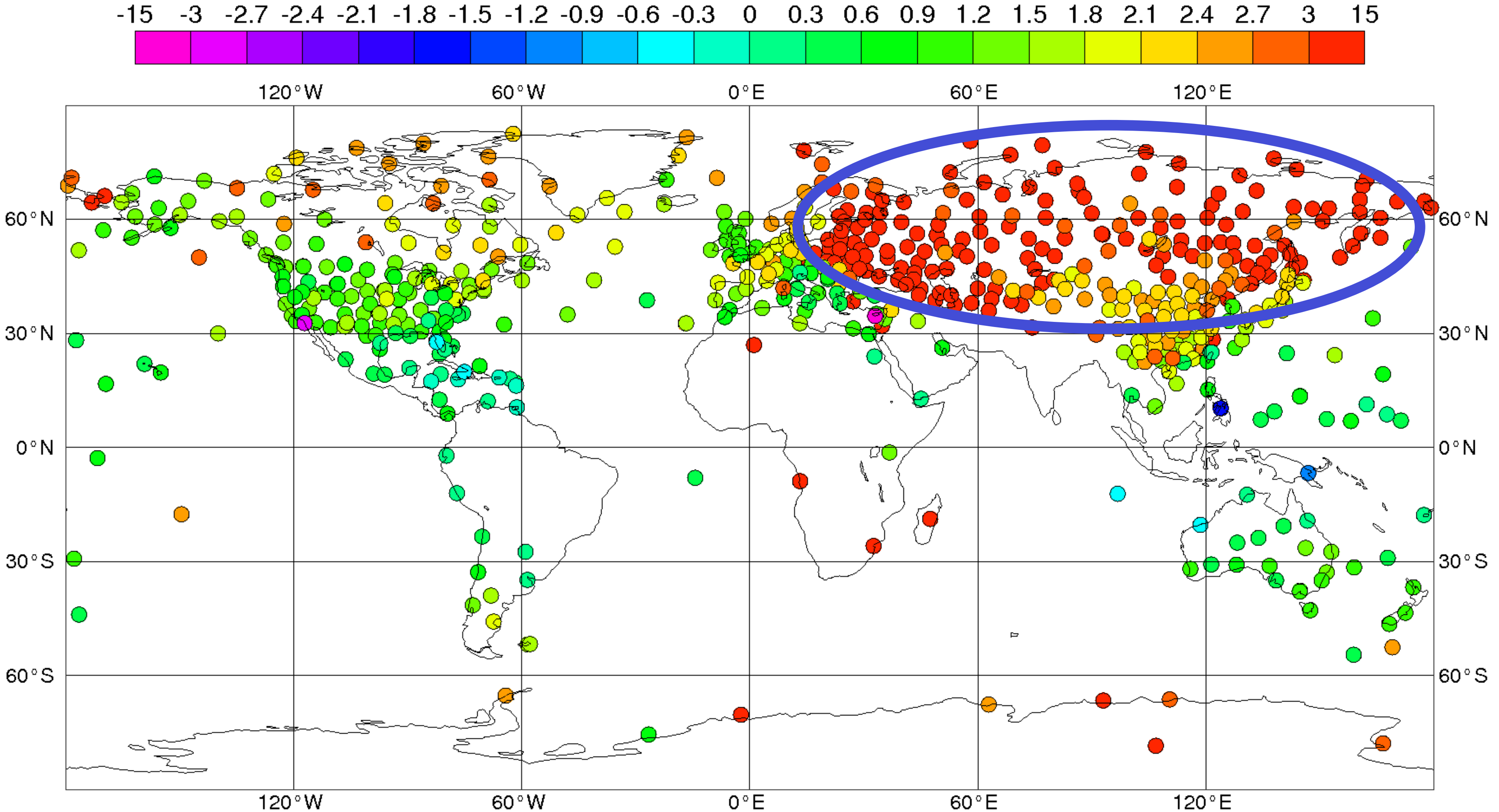
Outlook

- Look into CERA-20C spread-skill relationship
- Publish paper on RS-T adjustment version (D4.1)
- Comprehensive comparison with satellite and reanalysis data
- Ingest latest digitized data (esp. Meteo-France)
- Revisit wind – new PILOT data in early period
- Assist RS bias correction in ERA5
- Write adjustments back to original data
- Try GPSRO for adjustment in recent period

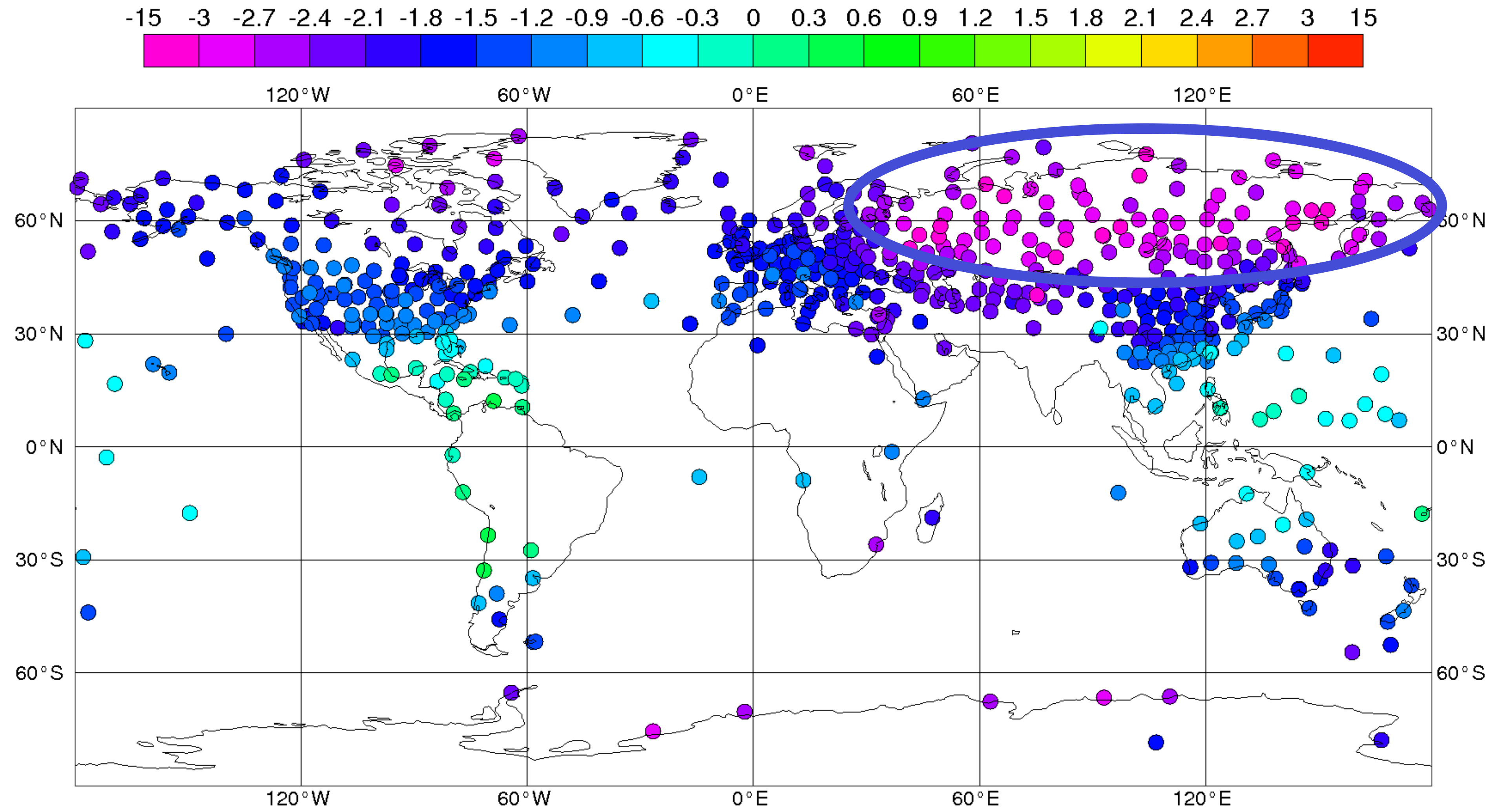
RICH v1.6 adjusted obs-bg



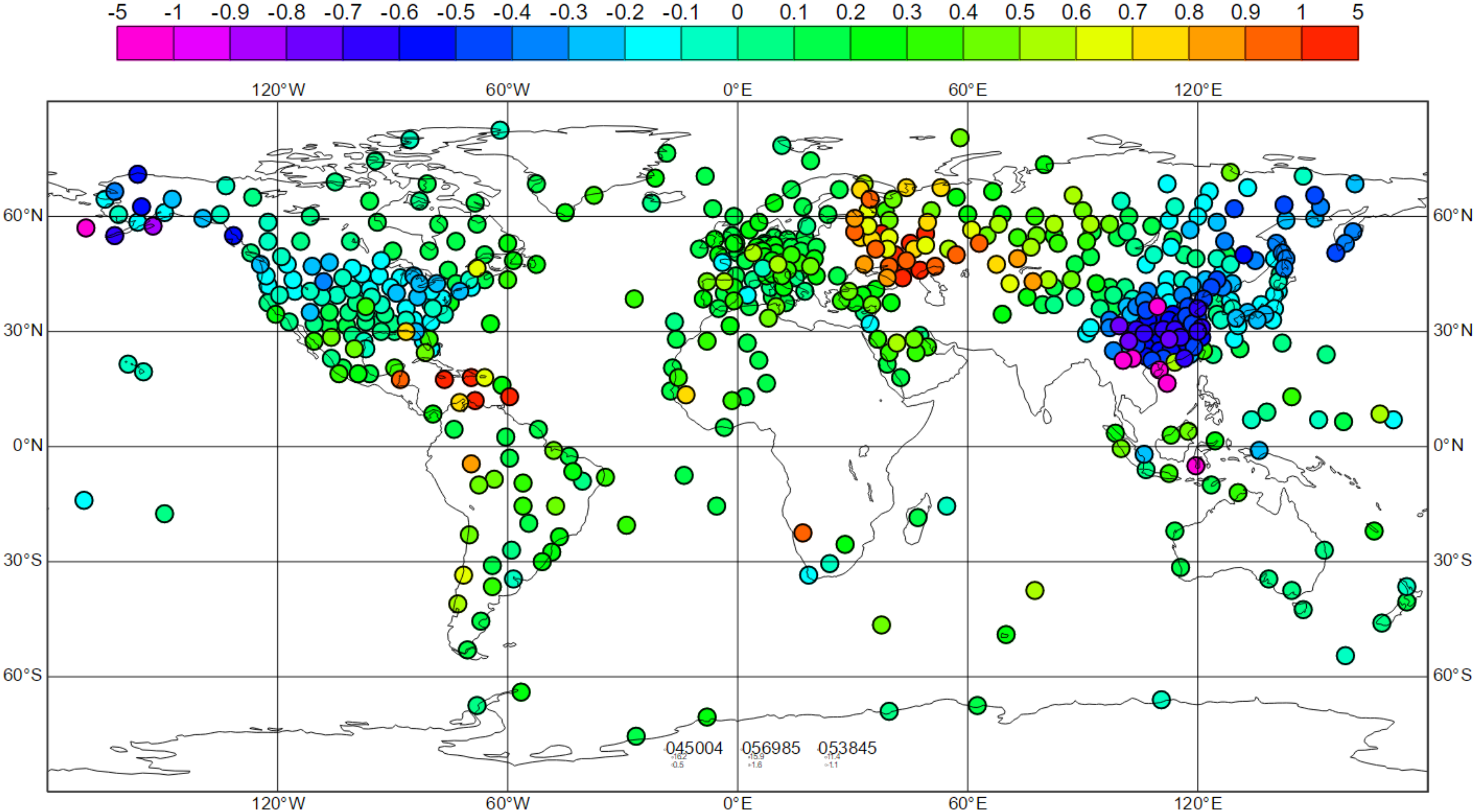
RS-T – CERA-20C, 300hPa, 1958-1959



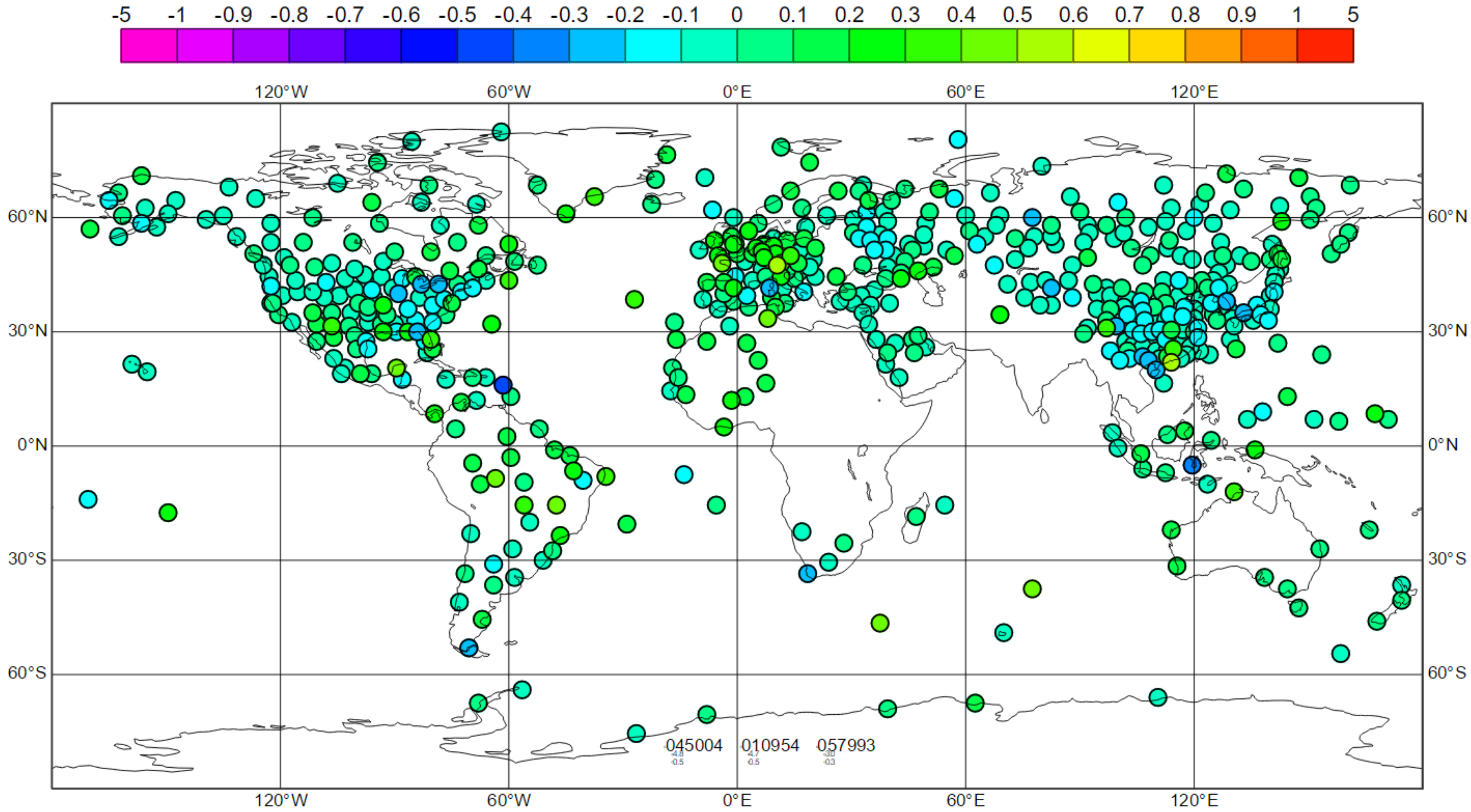
CERA20C- ERApreSAT, 300hPa, 1958-1959



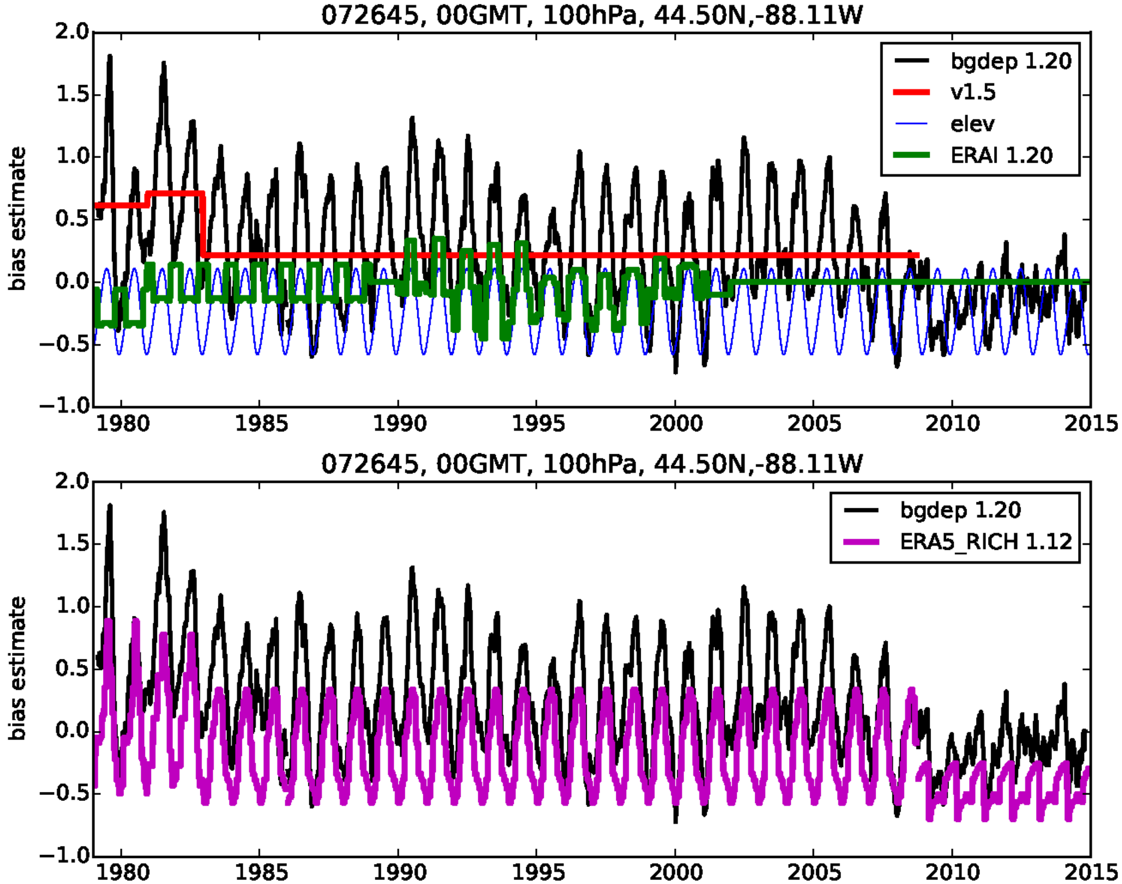
RS-ERA-Interim 12GMT



RAOBCORE adjusts some RS to ERA-Interim



RICH with solar elevation dependence (RISE)



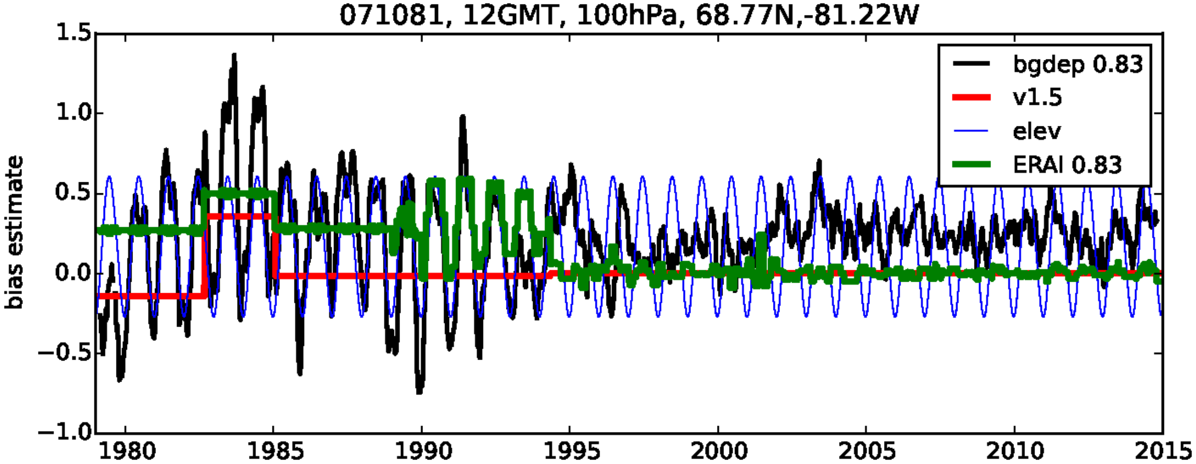
Bias adjustment
in ERA-Interim (green)
too weak

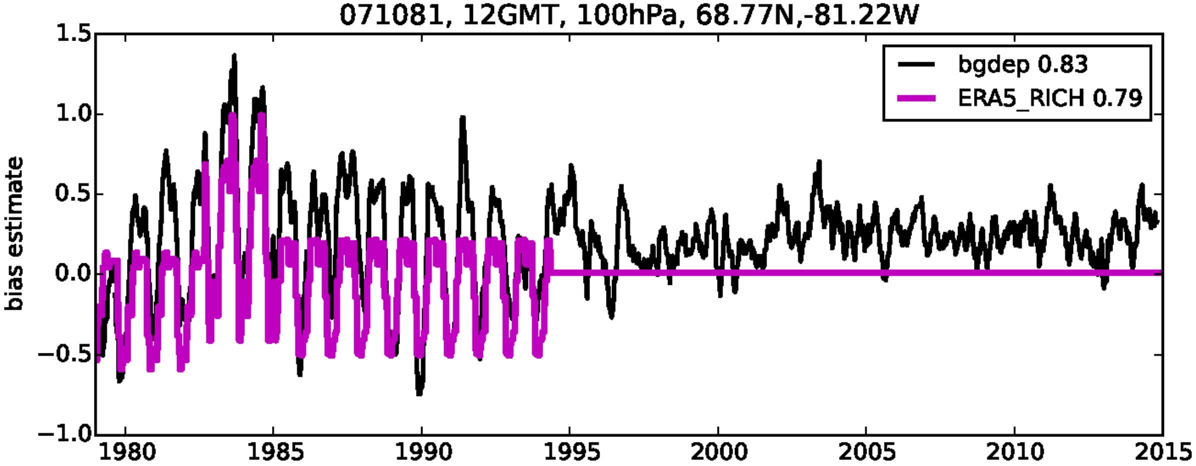
RAOBCORE/RICH
constant

Calculate climatology of
Background departues
between breaks

Subtract climatology
(mean zero)

Adjustments for launches at dawn/dusk





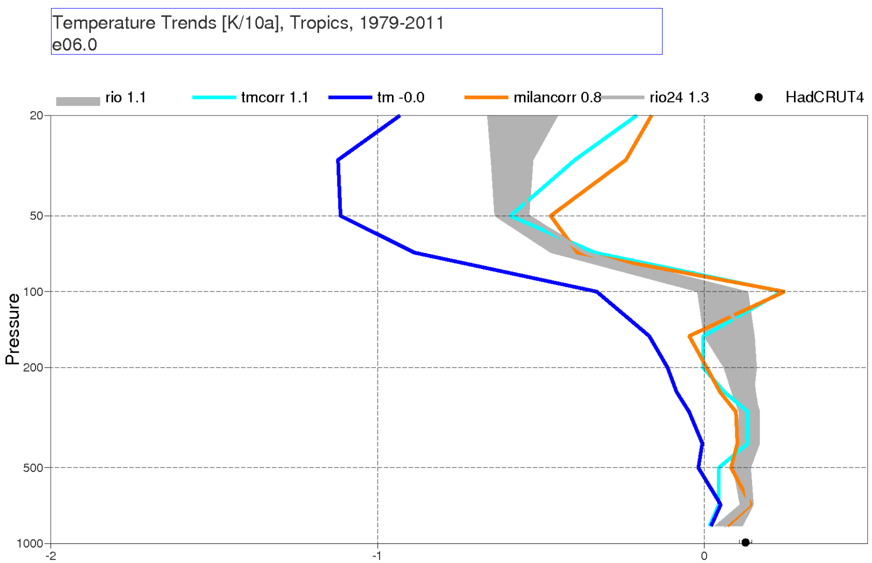
Abrupt stop of annual cycle of departures after Introduction of Vaisala RS80

Annual cycle adjusted only if it is not negligible

Robust, proposed for ERA5

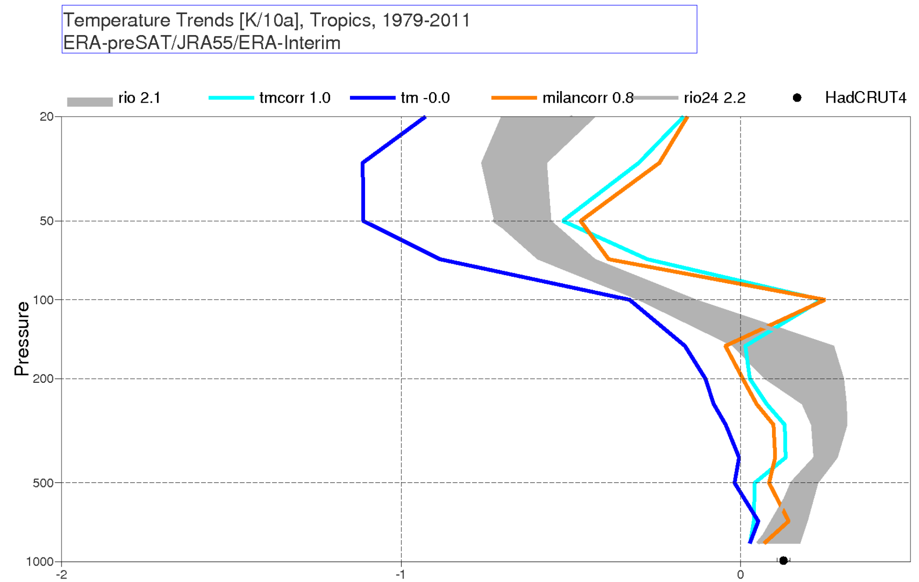
Tropical belt mean trends

RAOBCORE/RICH v1.5



Little tropical amplification in RICH
Weak cooling in stratosphere

RAOBCORE/RICH new test version



Stronger tropical amplification in RICH
Stronger cooling in stratosphere

Zonal mean trends 1981-2010

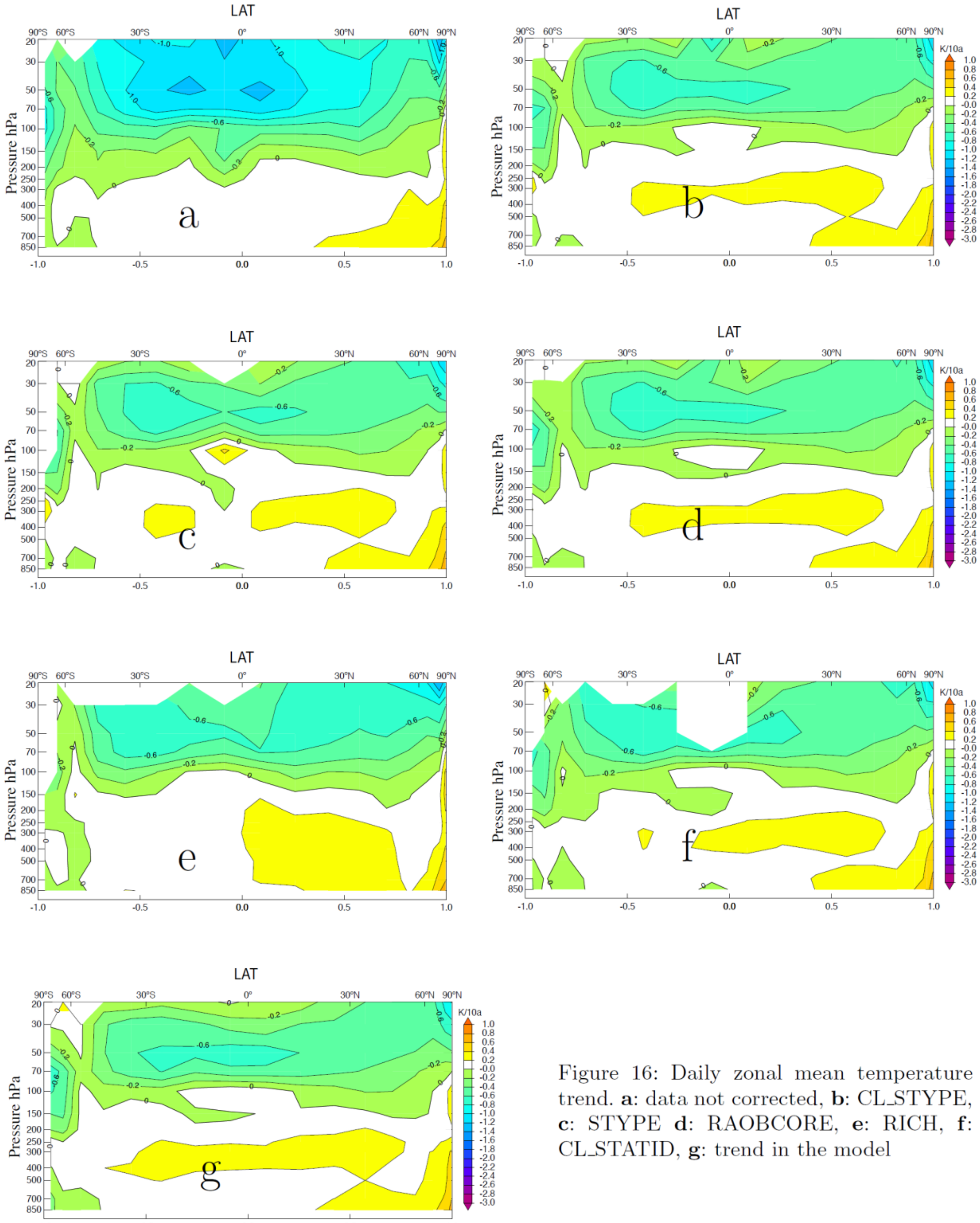
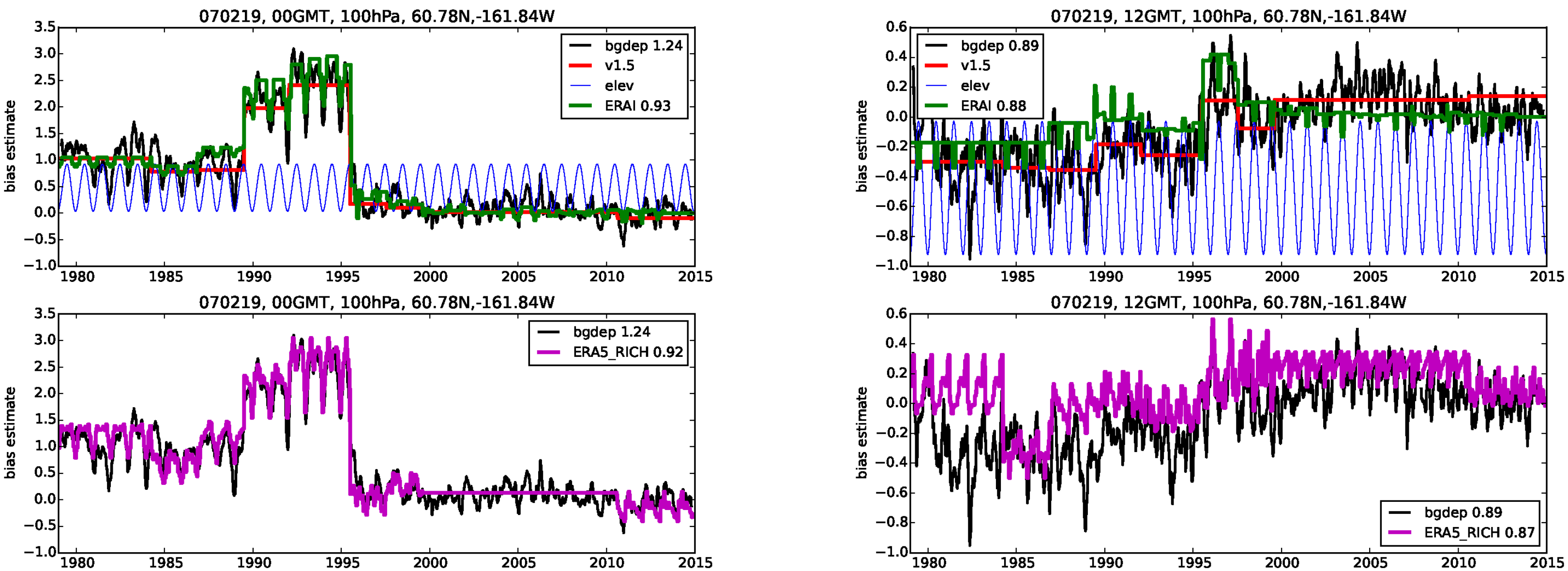
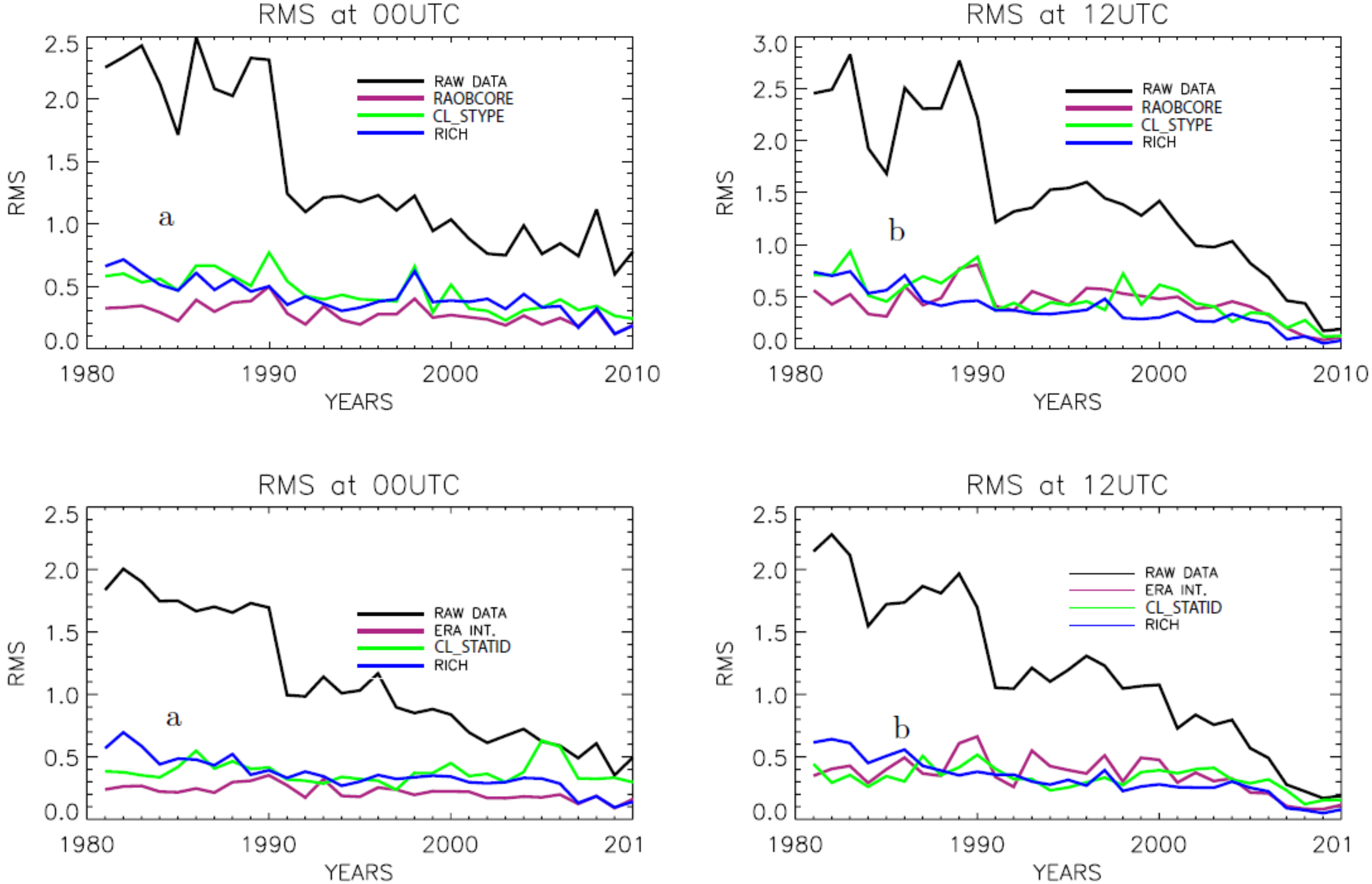


Figure 16: Daily zonal mean temperature trend. **a**: data not corrected, **b**: CL_STYPE, **c**: STYPE **d**: RAOBCORE, **e**: RICH, **f**: CL_STATID, **g**: trend in the model


070219, 00GMT, 100hPa, 60.78N,-161.84W
bias estimate
bgdep 1.24
v1.5
elev
ERAI 0.93
070219, 12GMT, 100hPa, 60.78N,-161.84W
bias estimate
bgdep 0.89
v1.5
elev
ERAI 0.88
070219, 00GMT, 100hPa, 60.78N,-161.84W
bias estimate
bgdep 1.24
ERA5_RICH 0.92
070219, 12GMT, 100hPa, 60.78N,-161.84W
bias estimate
bgdep 0.89
ERA5_RICH 0.87

Evolution of yearly rms mean residual obs-bg after adjustment, averaged over all stations

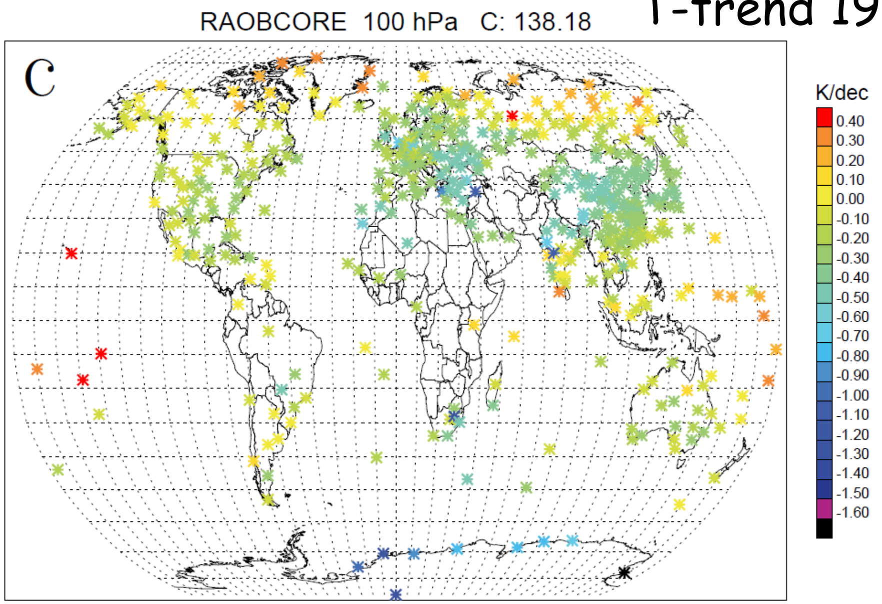


Comparison summary

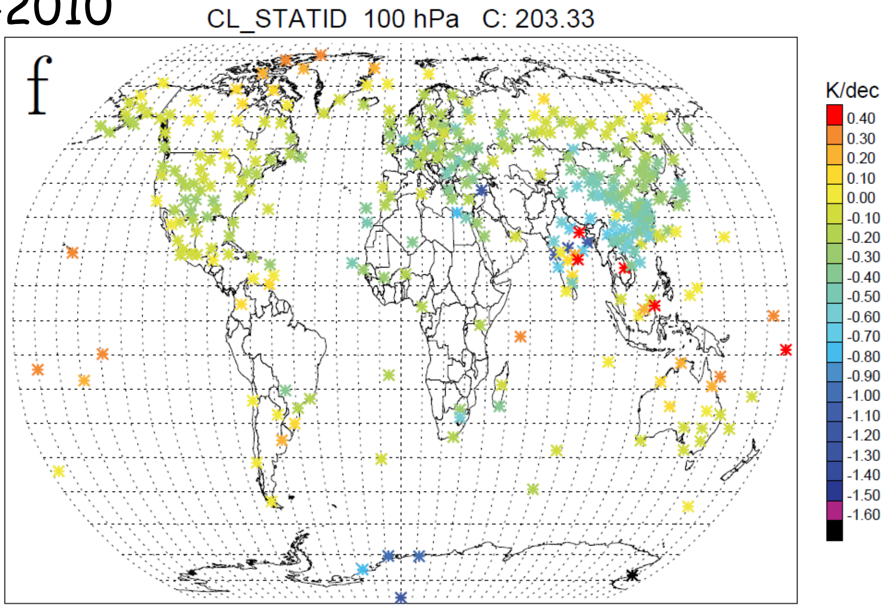
Varbc	RAOBCORE/RICH
• Varbc implemented, tested „offline"	• Tested offline, reading is implemented
• RS-type information too inaccurate for station grouping	• Well tested for satellite era
• Adjusts many stations but less than RICH/ RAOBCORE	• RAOBCORE adjustments too strongly dependent on background, better use RICH
• Yearly „jumps"	• Adjustments constant between breaks
• Radiosondes no longer „anchors"	

Offline vs online bias correction

T-trend 1981-2010



RAOBCORE



with VarBC bias model

Both improve spatial consistency of trend estimates (unadj. 490, background 90)
VarBC bias model not better in this comparison but worth to be tried
Larger errors at 10 hPa

OFFLINE EVALUATION OF PREDICTORS

BIAS MODELS

- LINEAR

$$B = \beta_0 p_0 + \beta_1 p_1 + \beta_2 p_2 + \beta_3 p_3$$

- LINEAR + LOG

$$B = \beta_0 p_0 + \beta_1 p_1 + \beta_2 p_2 + \beta_3 p_3 + \beta_4 \ln(pr / pr_0)$$

- LINEAR + SOLAR ELEVATION (only in the stratosphere)

$$B = \beta_0 p_0 + \beta_1 p_1 + \beta_2 p_2 + \beta_3 p_3 + \beta_4 \theta + \beta_5 \theta^2 + \beta_6 \theta^3$$

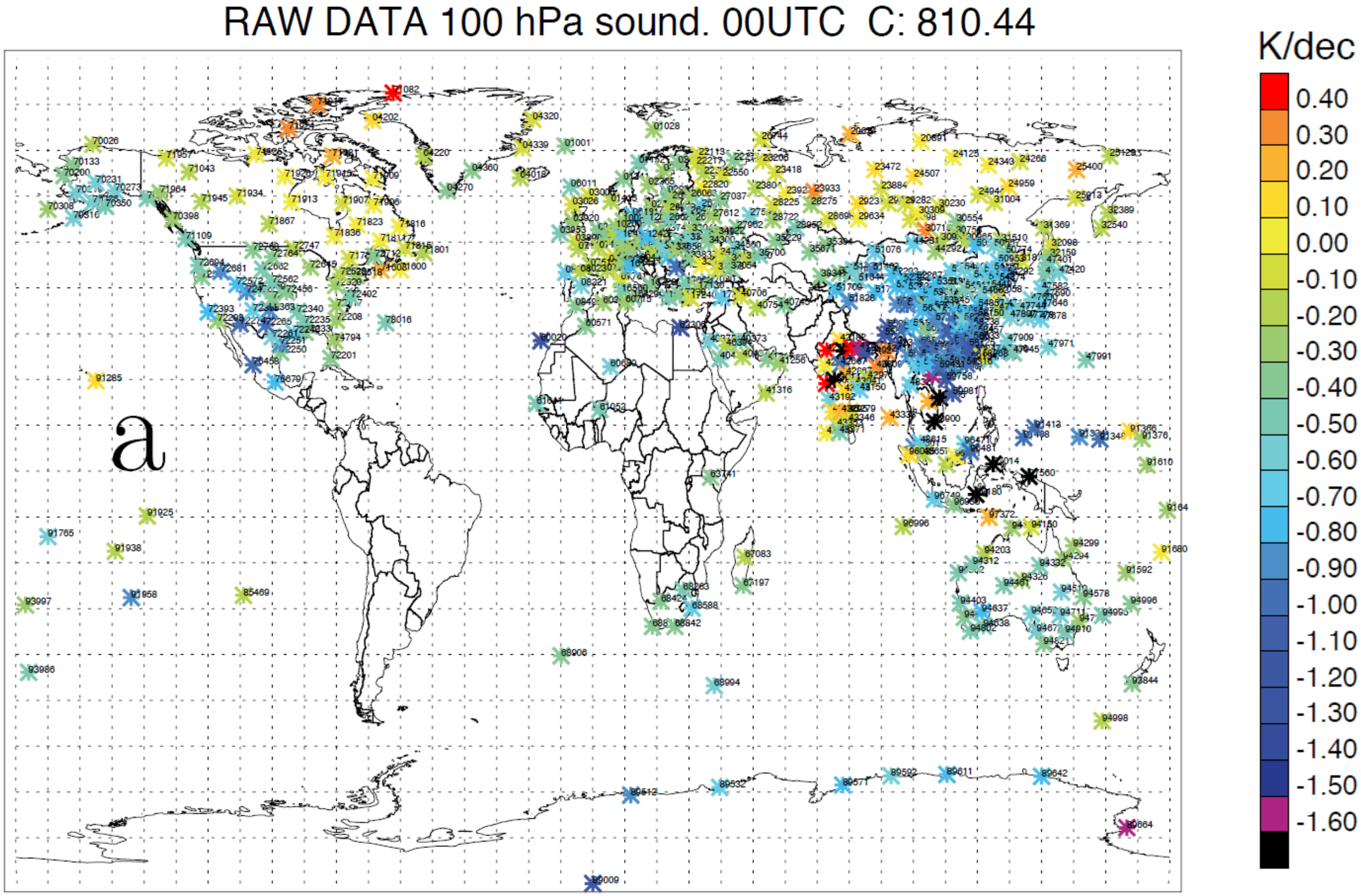
- LINEAR + SOLAR ELEVATION + LOG

$$B = \beta_0 p_0 + \beta_1 p_1 + \beta_2 p_2 + \beta_3 p_3 + \beta_4 \theta + \beta_5 \theta^2 + \beta_6 \theta^3 + \beta_7 \ln(pr / pr_0)$$

- LINEAR + SOLAR ELEVATION + LOG. STRAT.

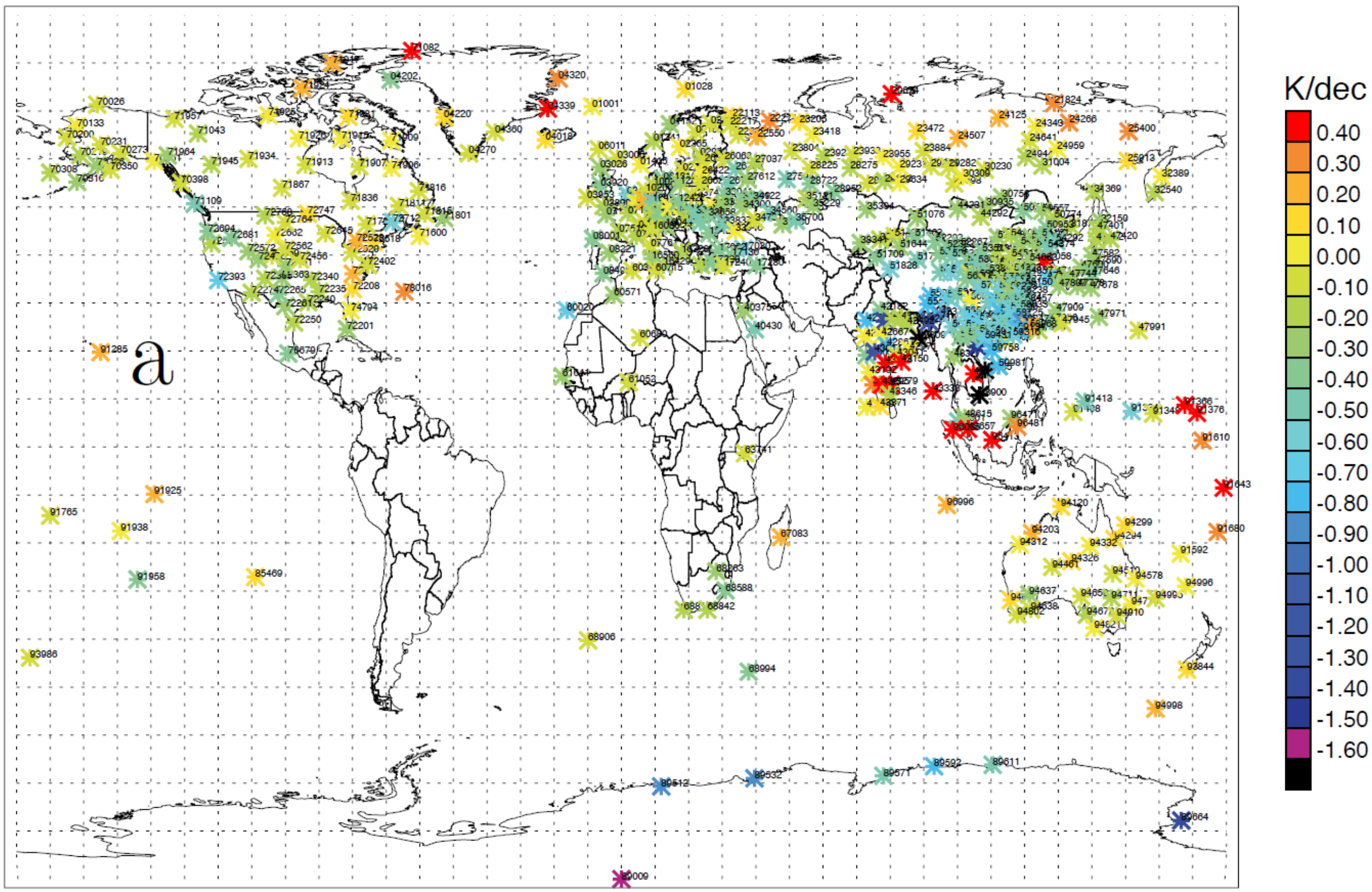
$$B = \beta_0 p_0 + \beta_1 p_1 + \beta_2 p_2 + \beta_3 p_3 + \beta_4 \theta \ln(pr / p_0) + \beta_5 \theta^2 \ln(pr / p_0) + \beta_6 \theta^3 \ln(pr / p_0)$$

Raw Data, Trend 1981-2010

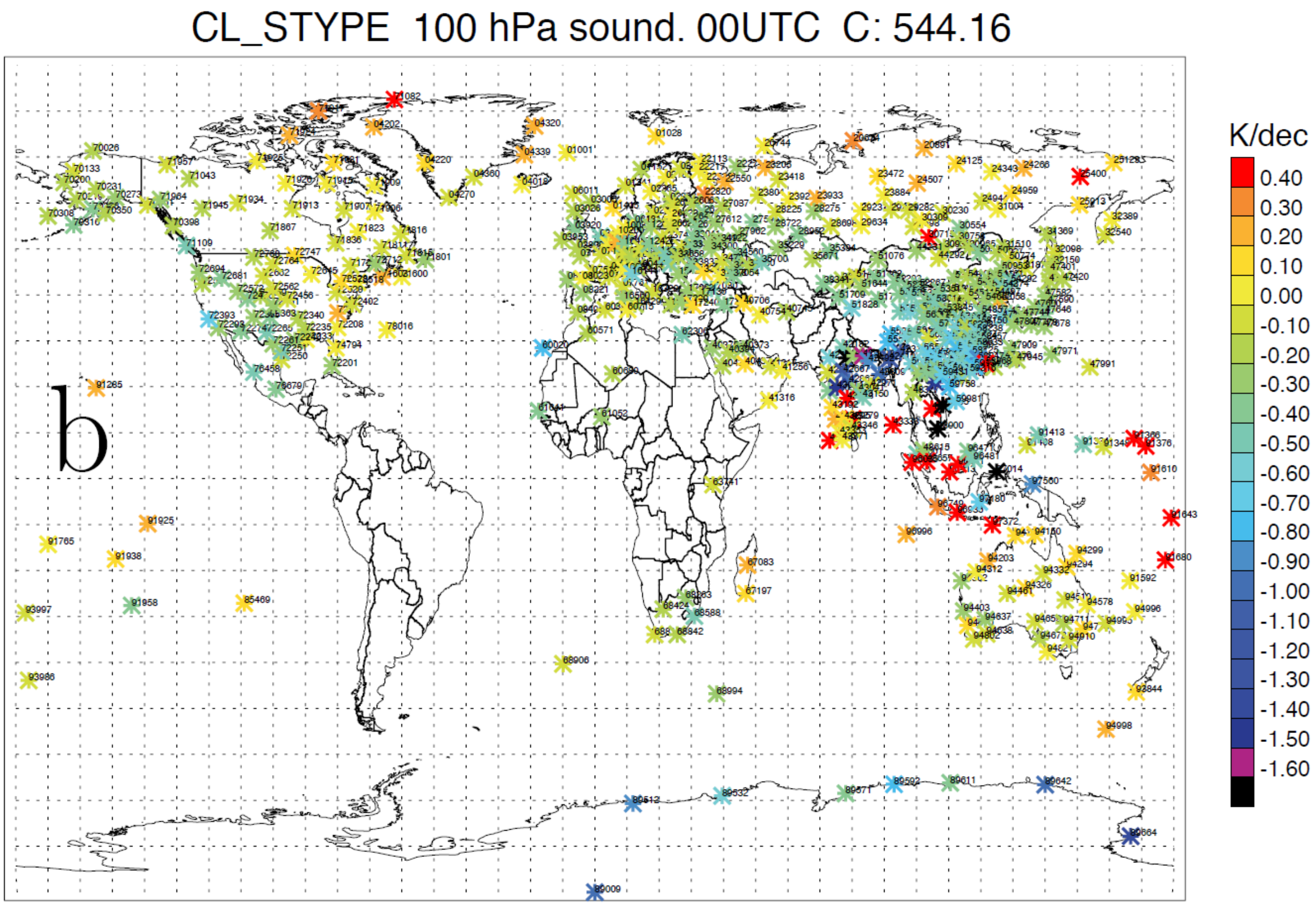


Each sonde type adjusted separately

STYPE 100 hPa sound. 00UTC C: 541.72

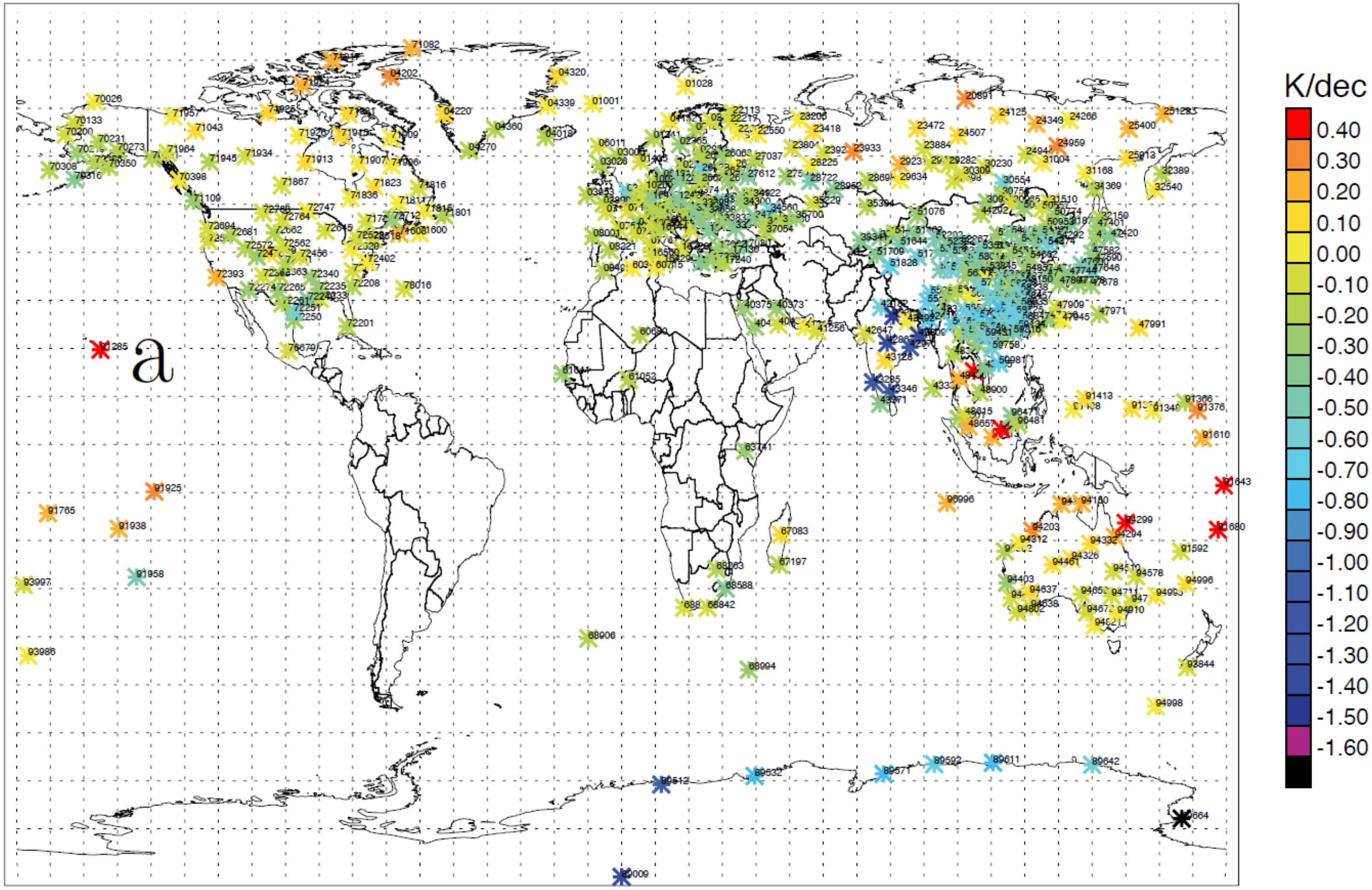


Similar sonde types clustered together



Stations with similar bias clustered together

CL_STATID 100 hPa sound. 00UTC C: 248.00



VARIATIONAL BIAS CORRECTION

- Bias in observations can change during the time
- Seasonal and daily variations in bias exist
- The bias model:

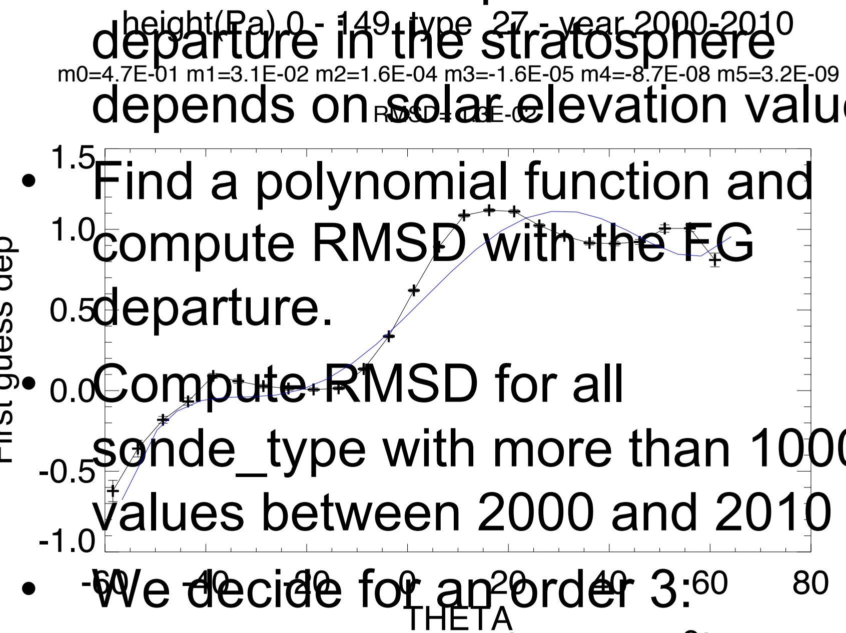
$$b(x,\beta) = \beta_0 + \sum_i \beta_i p_i(x)$$

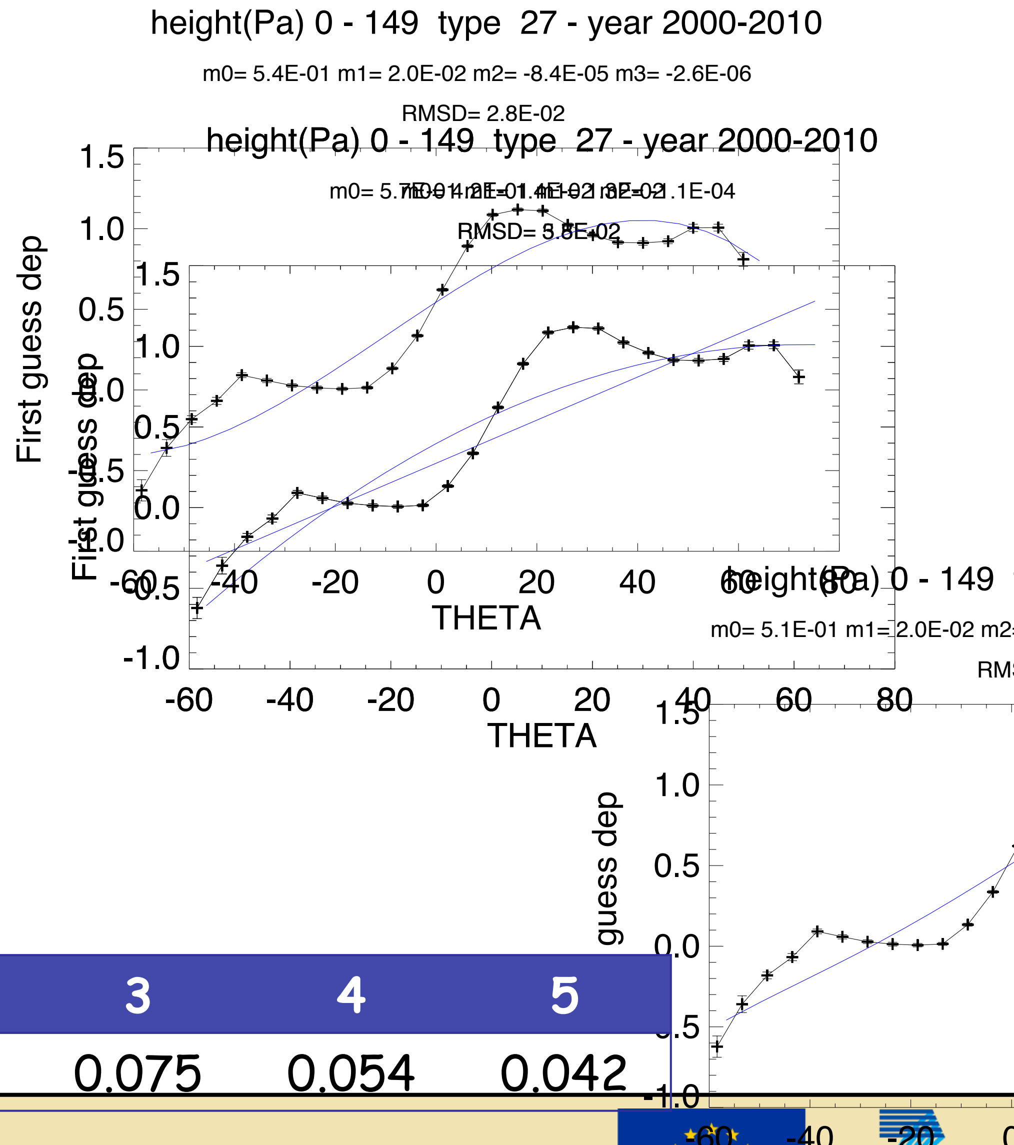
- Predictors:
  - Pressure
  - Solar elevation
  - Radiosonde Type
  - All three do not depend on model state

- Optional clustering of Radiosonde Types with similar clustering to get larger samples

SOLAR ELEVATION DEPENDENT PREDICTORS

- Radiosonde temperature FG departure in the stratosphere depends on solar elevation value.
- Find a polynomial function and compute RMSD with the FG departure.
- Compute RMSD for all sonde_type with more than 10000 values between 2000 and 2010
- We decide for an order 3: 3 new predictors ($\Theta, \Theta^2, \Theta^3$), in the stratosphere.





GRADE	1	2	3	4	5
RMSD	0.12	1.1	0.075	0.054	0.042

VARIATIONAL BIAS CORRECTION

- The observations are considered biased, a linear predictor model is used as observation operator in the 4DVAR equations:

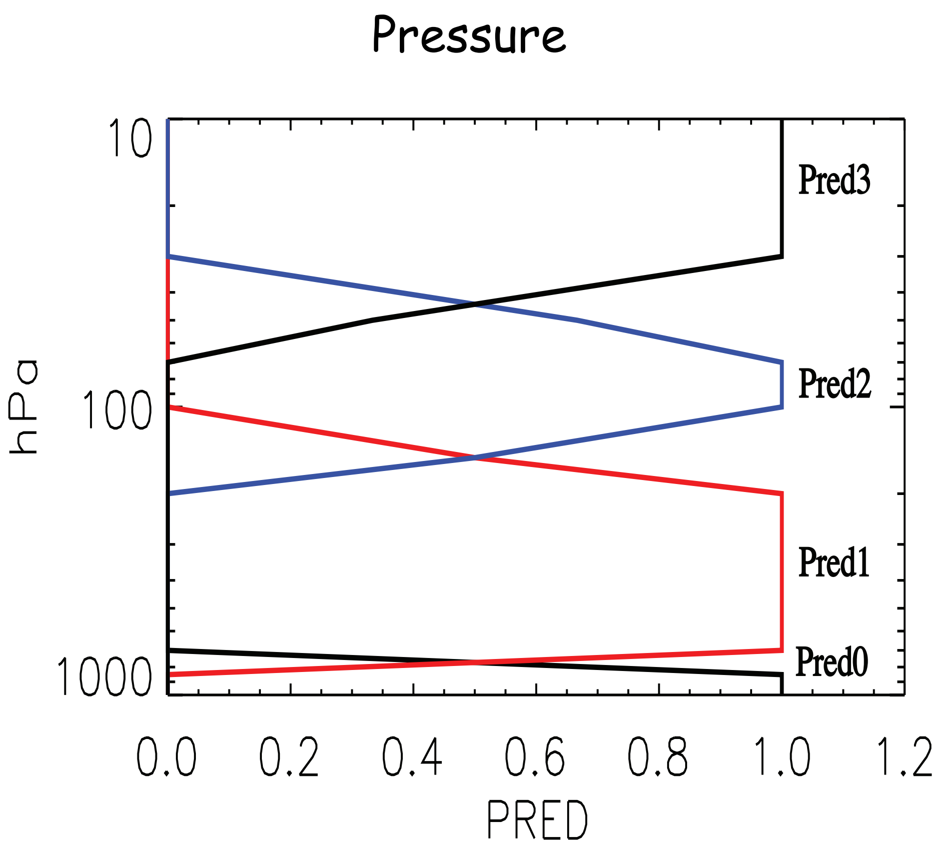
$$h(x,\beta) = h(x) + \sum_{i=0}^{N} \beta_i p_i(x)$$

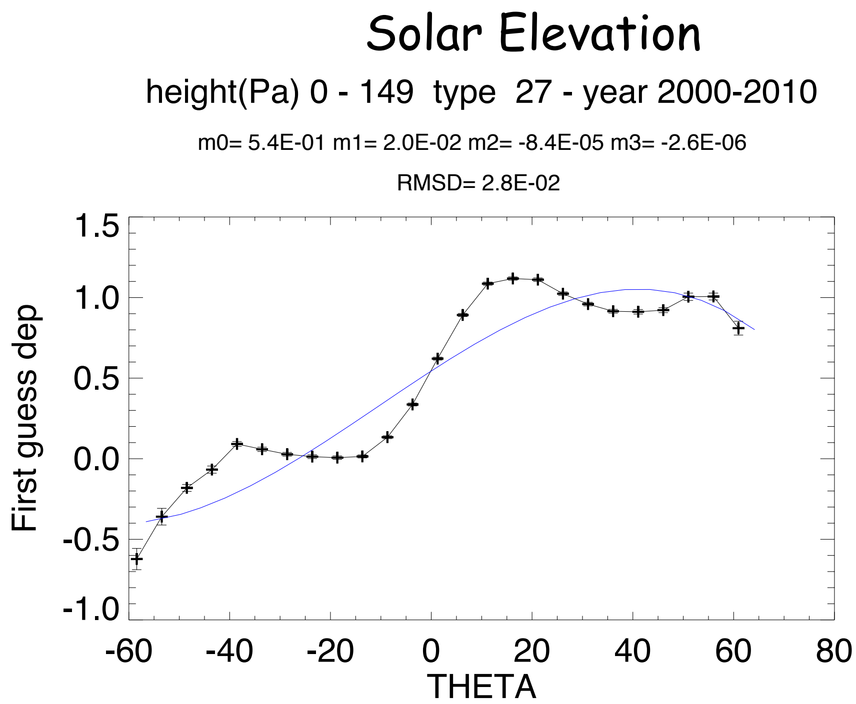
- Introduction of a "bias term" in the variational cost function

$$J(\mathbf{x},\beta) = (\mathbf{x}^b - \mathbf{x})^T \mathbf{B}_{\mathbf{x}}^{-1} (\mathbf{x}^b - \mathbf{x}) + (\beta^b - \beta)^T \mathbf{B}_{\beta}^{-1} (\beta^b - \beta) + [\mathbf{y} - h(\mathbf{x},\beta)]^T R^{-1} [\mathbf{y} - h(\mathbf{x},\beta)]$$

- With x^b and b^b a priori estimations of model state and bias control parameters
- A large $\mathbf{B}_b$ allows the parameter estimates to respond more quickly to the latest observation, a sensitivity test is needed.
- The adjustments depend on the resulting fit of the analysis to all other OBS, given the background from the model.

PREDICTORS





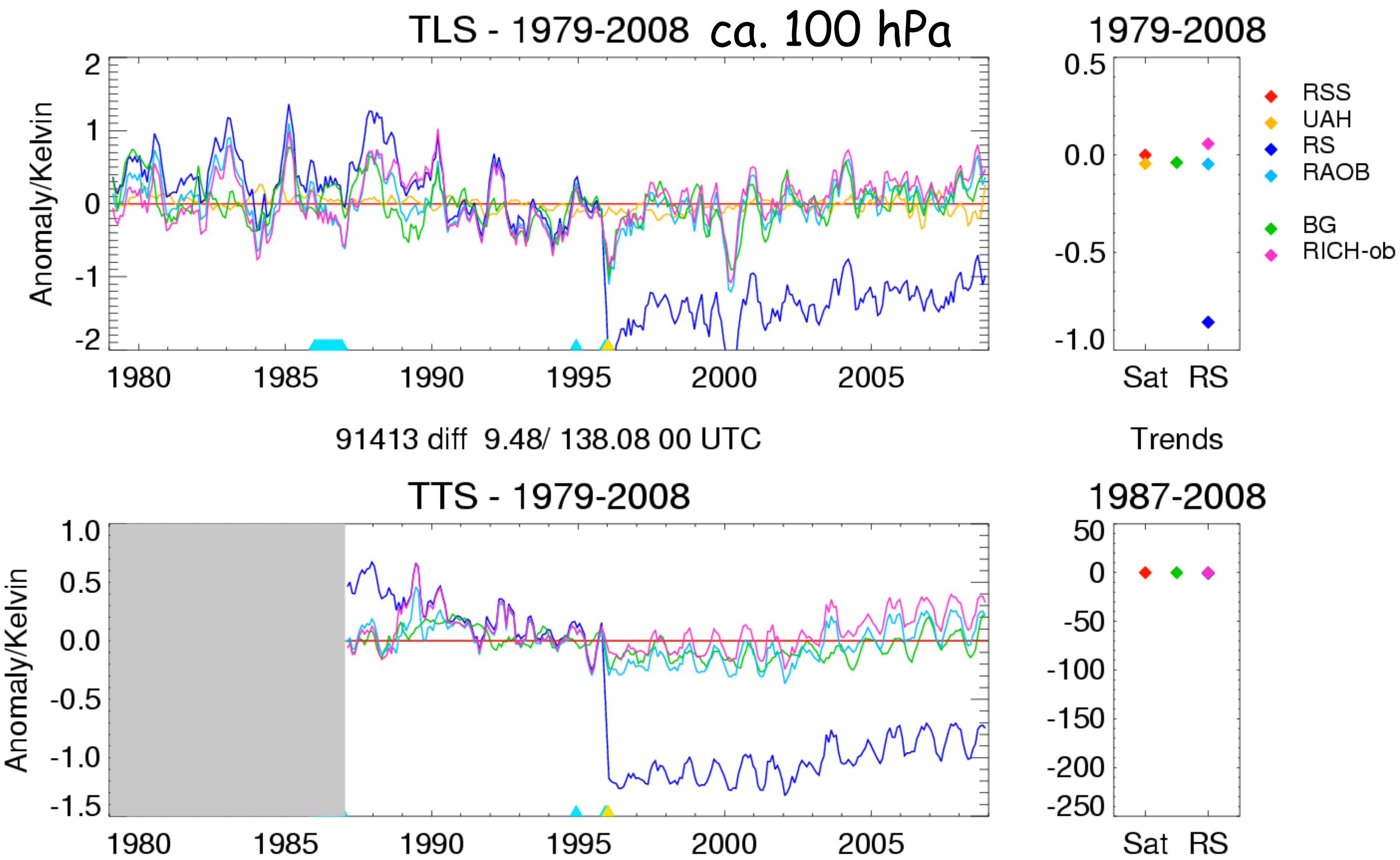
Third „predictor" is radiosonde type – used to group radiosondes together

Milan and Haimberger, 2015, JGR

Combination strategy

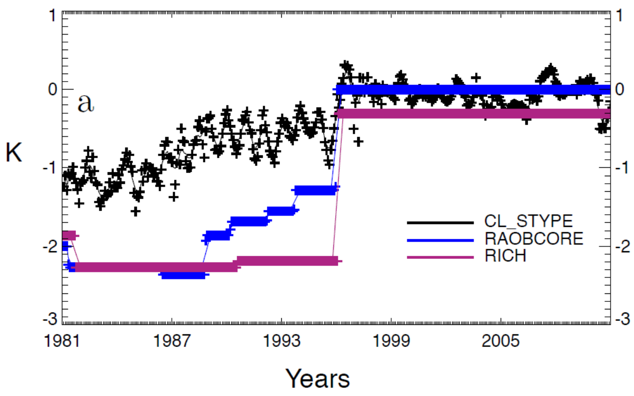
- 3 Methods:
  - STYPE:
    - Combine stations with same sonde type
  - CL-STYPE:
    - Combine stations with same sonde type and additionally cluster those sonde types with similar estimated bias profiles
  - CL-STATID:
    - Combine stations with similar estimated bias profiles, regardless of sonde type

T-anomaly differences at Yap

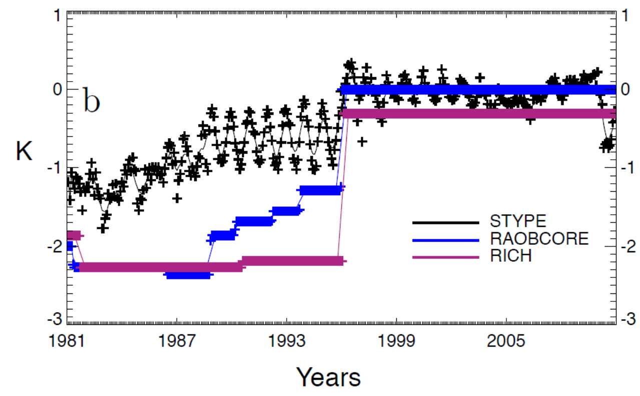


Adjustments at Yap, 100 hPa

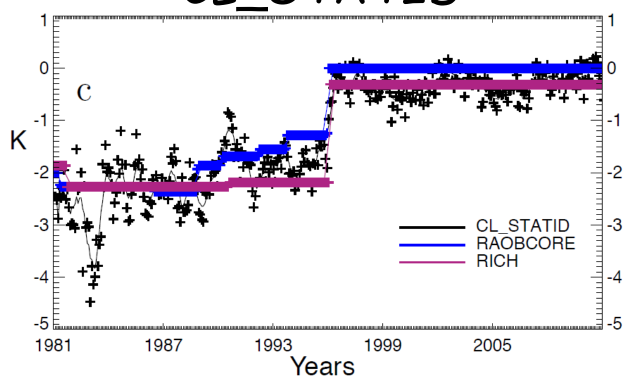
CL_STYPE



STYPE



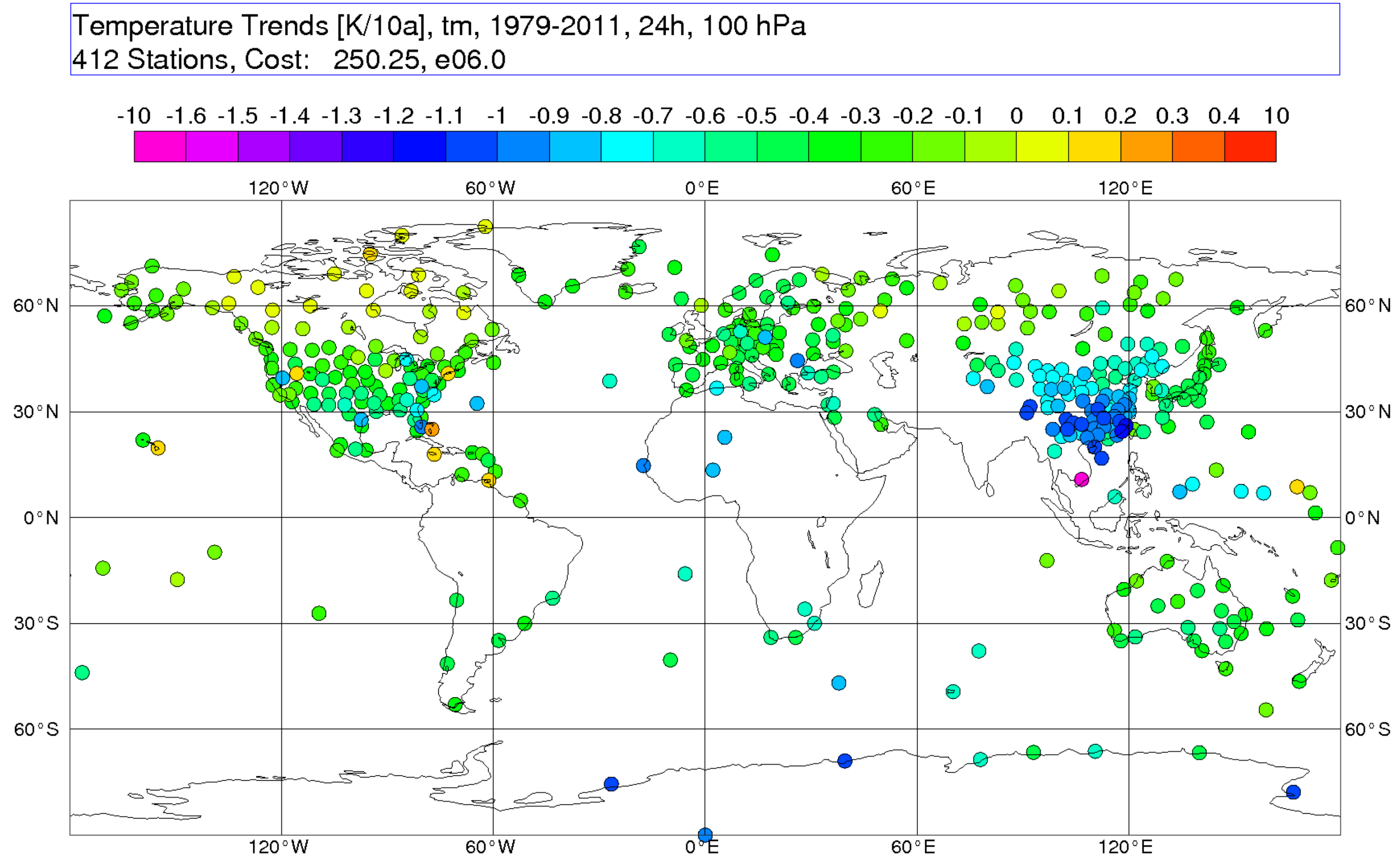
CL_STATID



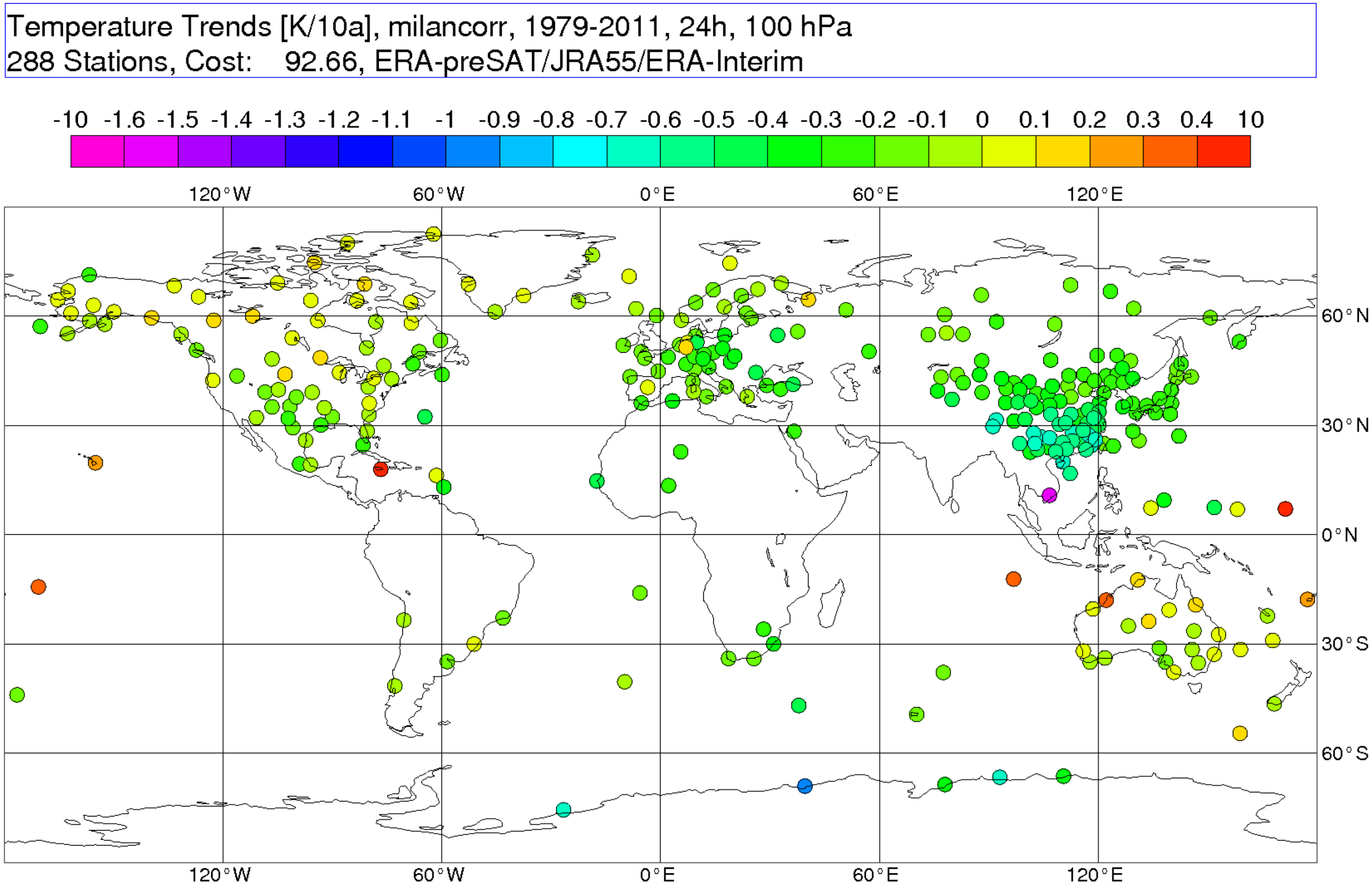
Adjustment estimates
for each month, calculated offline

RAOBCORE/RICH adjustments
for comparison

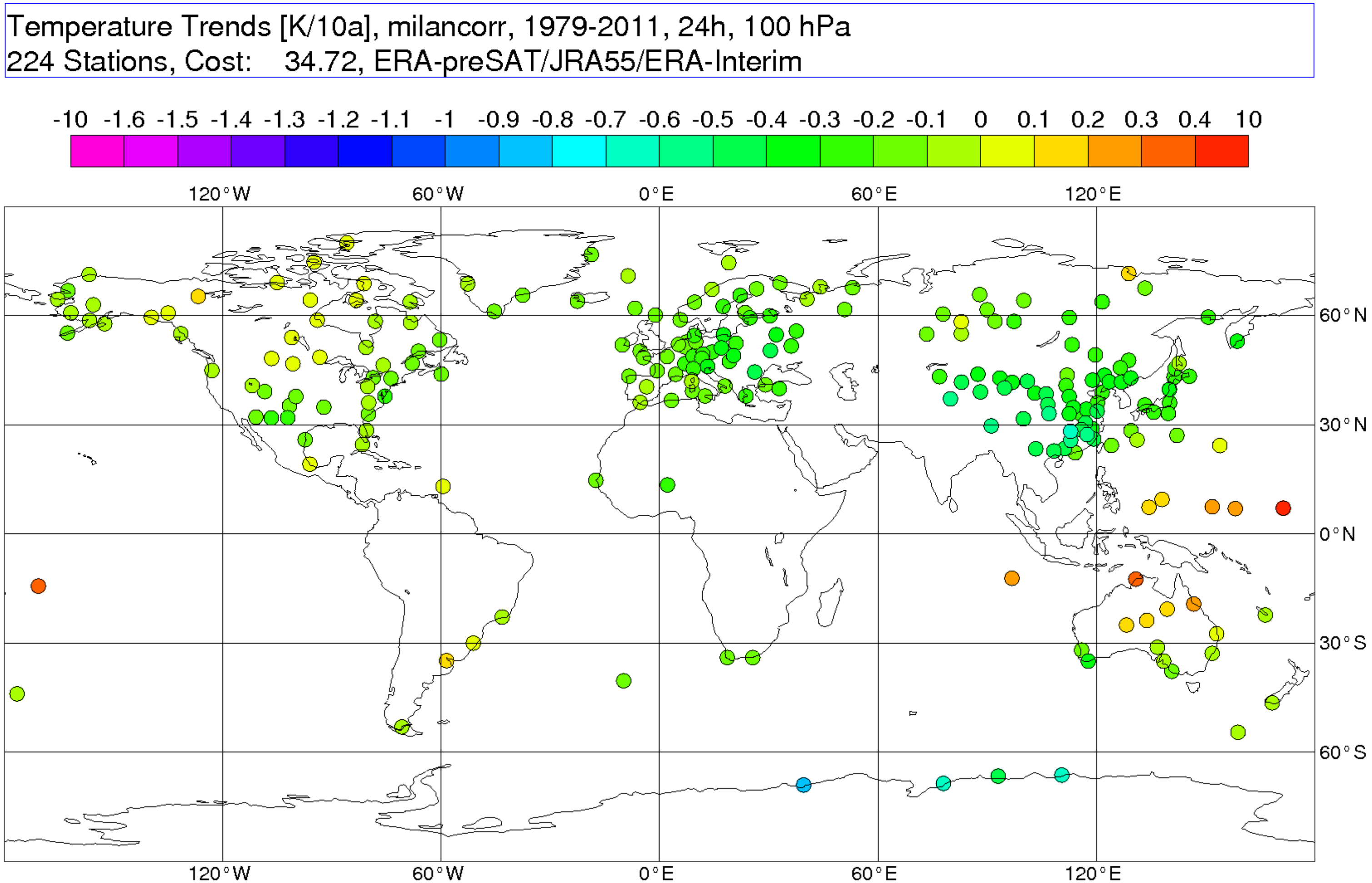
Unadjusted Trends, 100 hPa



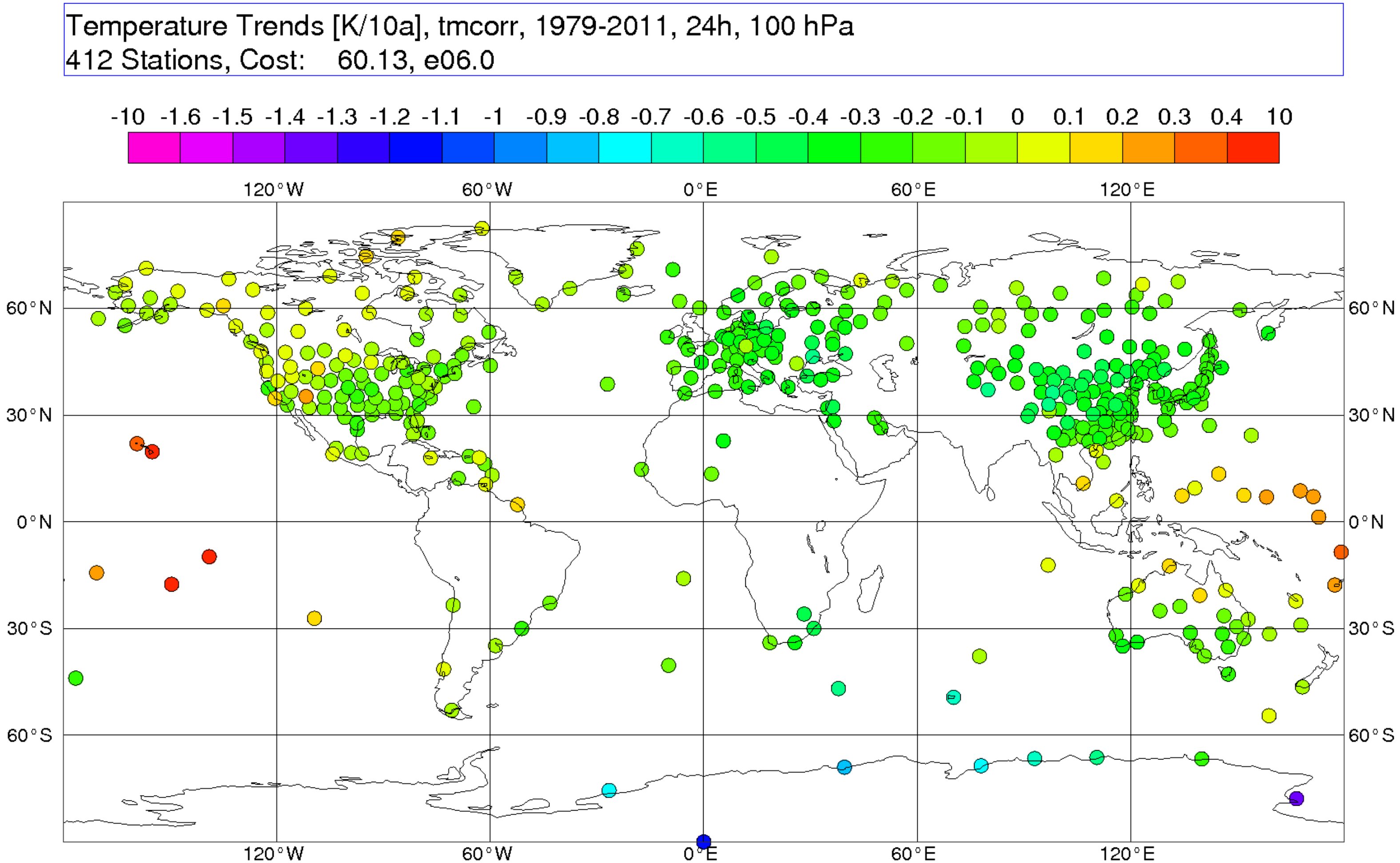
CL_STYPE (similar type)



Cluster statid (similar biases)



RAOBCORE v1.5



RICH ensemble mean v1.5