Radiosonde bias adjustments for ERA5

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Overview

- Two midterm aims in ERA-CLIM2:
- A variational radiosonde temperature bias correction scheme
  - Bias regression model developed in ERA-CLIM
  - Bias model tested ‚offline' with ERA-Interim bg departures
  - Implemented in IFS by Hans Hersbach
- Updated radiosonde temperature adjustment dataset calculated „offline"
  - RAOBCORE/RICH data set, used in ERA-Interim, MERRA, JRA55
  - Detects and adjusts breaks through analysis of time series of background departures, Current version 1.5
  - Combine it with Solar elevation dependent adjustment
- Decision for ERA5 reanalysis production
  - Rationale

VARIATIONAL BIAS CORRECTION

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

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

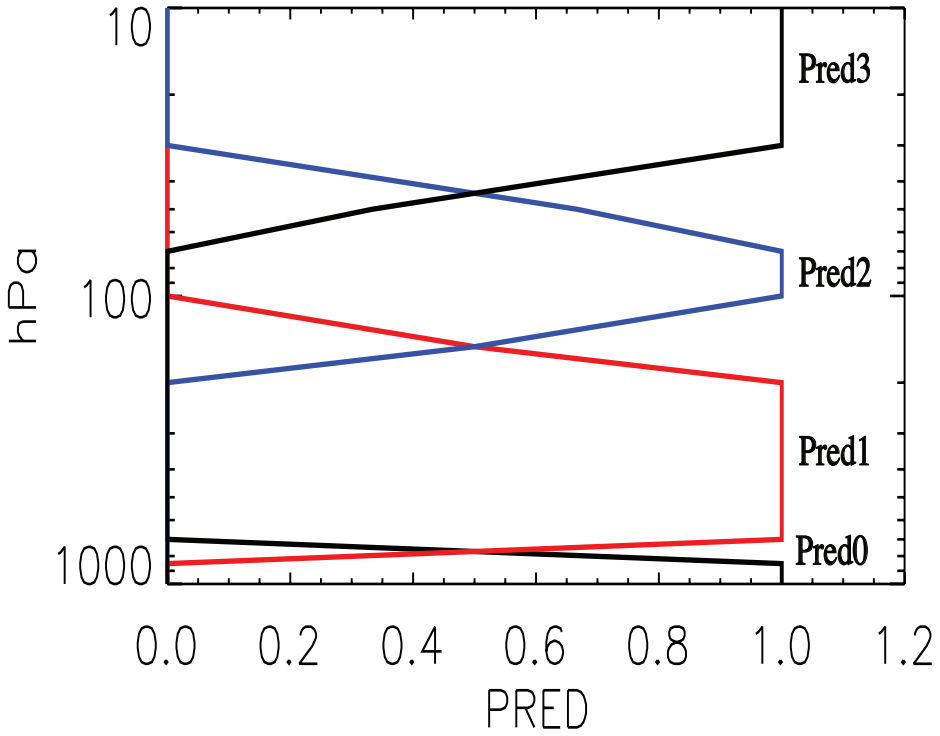
- Introduction of a "bias term" in the variational cost function

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

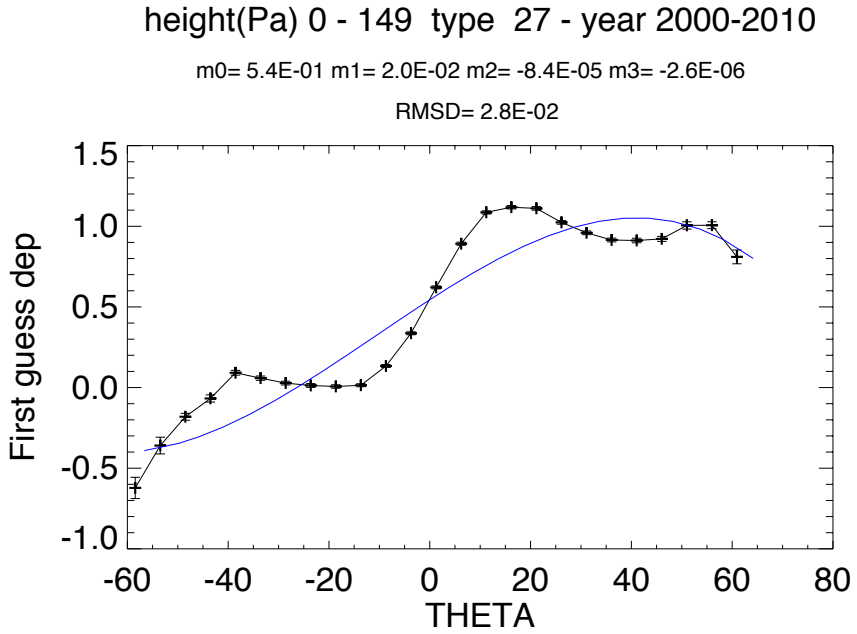
- With x^b and b^b a priori estimations of model state and bias control parameters
- A large $\mathbf{B}_b$ allows the parameter estimates to respond more quickly to the latest observation, a sensitivity test is needed.
- The adjustments depend on the resulting fit of the analysis to all other OBS, given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

PREDICTORS

Pressure



Solar Elevation



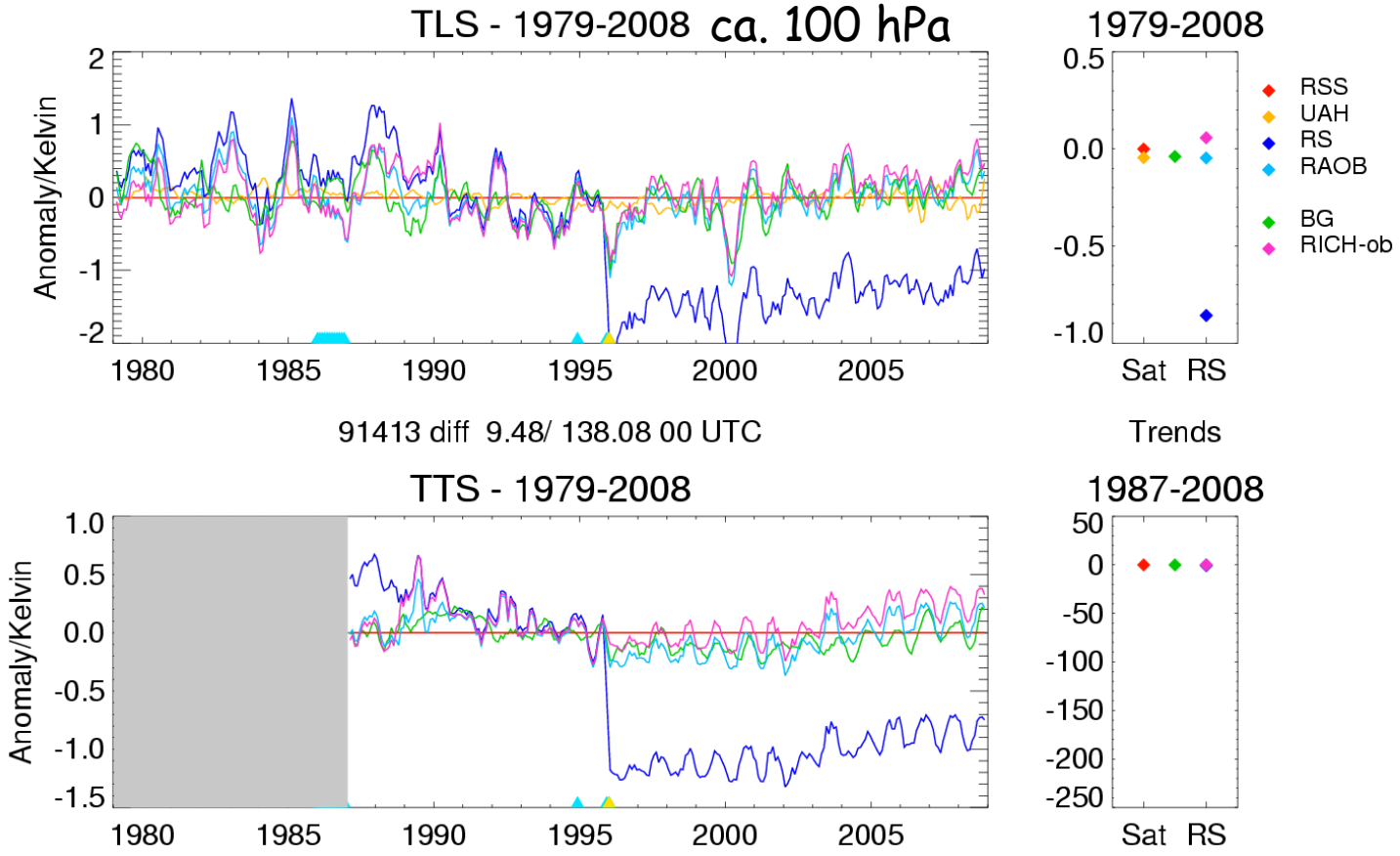
Third „predictor" is radiosonde type – used to group radiosondes together

Milan and Haimberger, 2015, JGR

Combination strategy

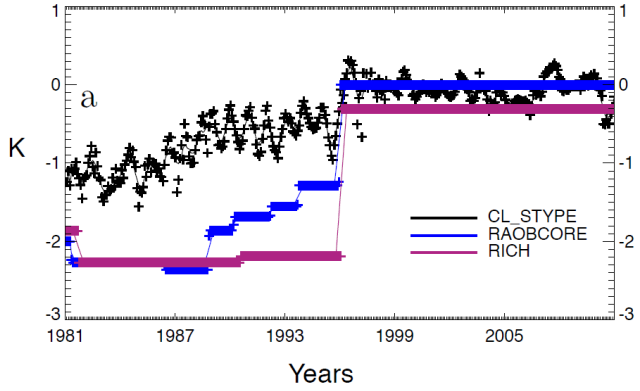
- 3 Methods:
  - STYPE:
    - Combine stations with same sonde type
  - CL-STYPE:
    - Combine stations with same sonde type and additionally cluster those sonde types with similar estimated bias profiles
  - CL-STATID:
    - Combine stations with similar estimated bias profiles, regardless of sonde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

T-anomaly differences at Yap

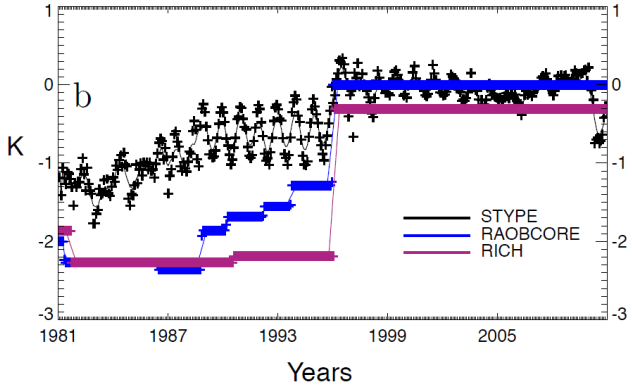


Adjustments at Yap, 100 hPa

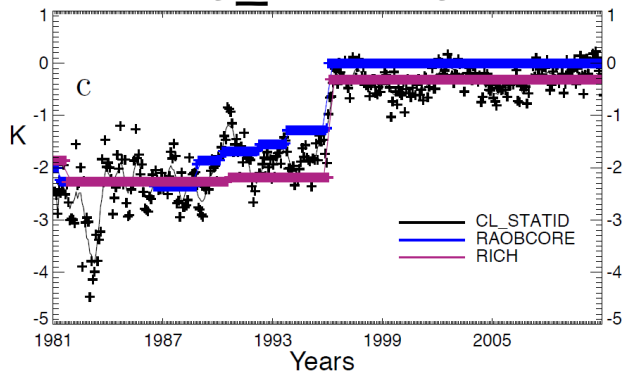
CL_STYPE



STYPE



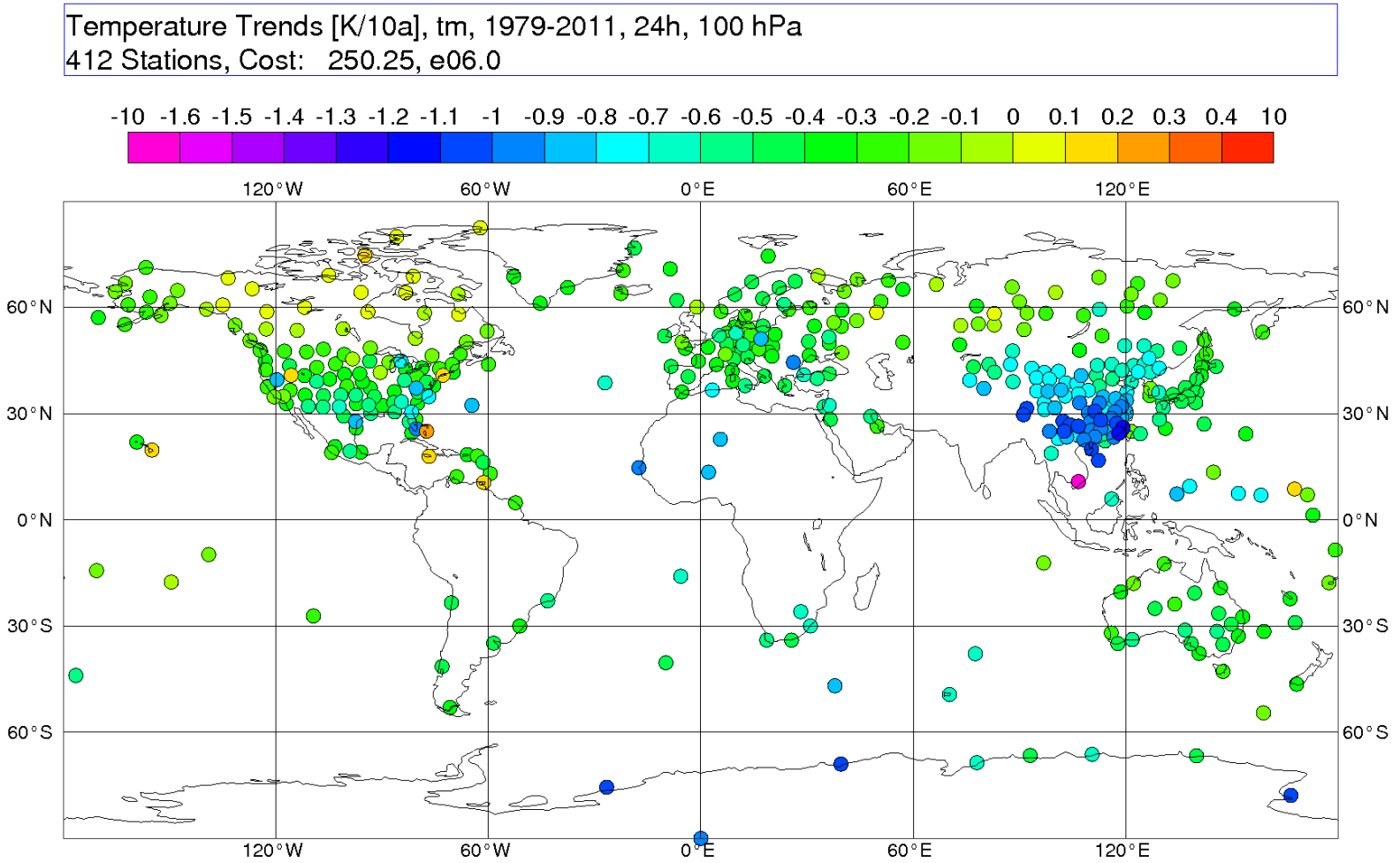
CL_STATID



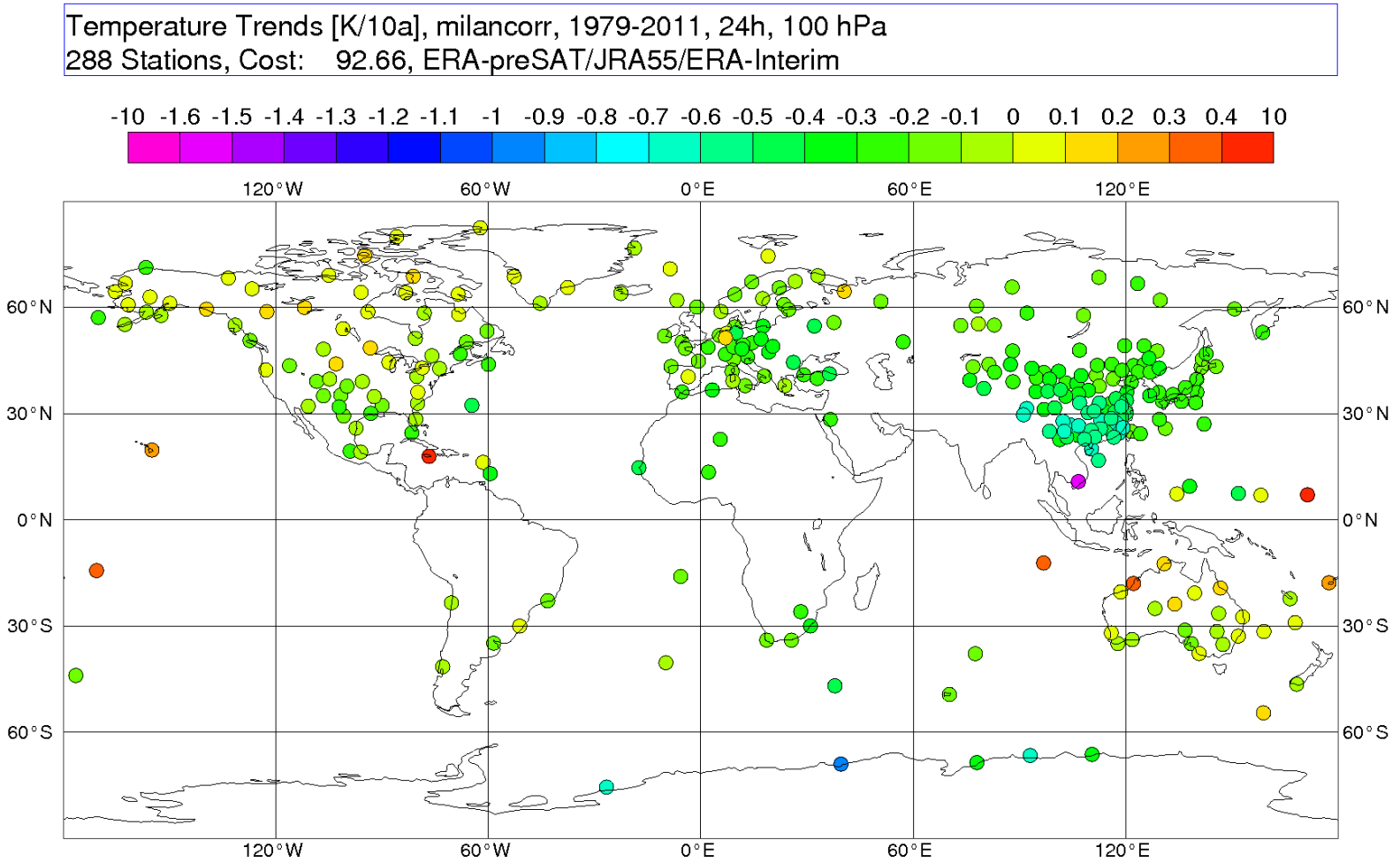
Adjustment estimates
for each month, calculated offline

RAOBCORE/RICH adjustments
for comparison

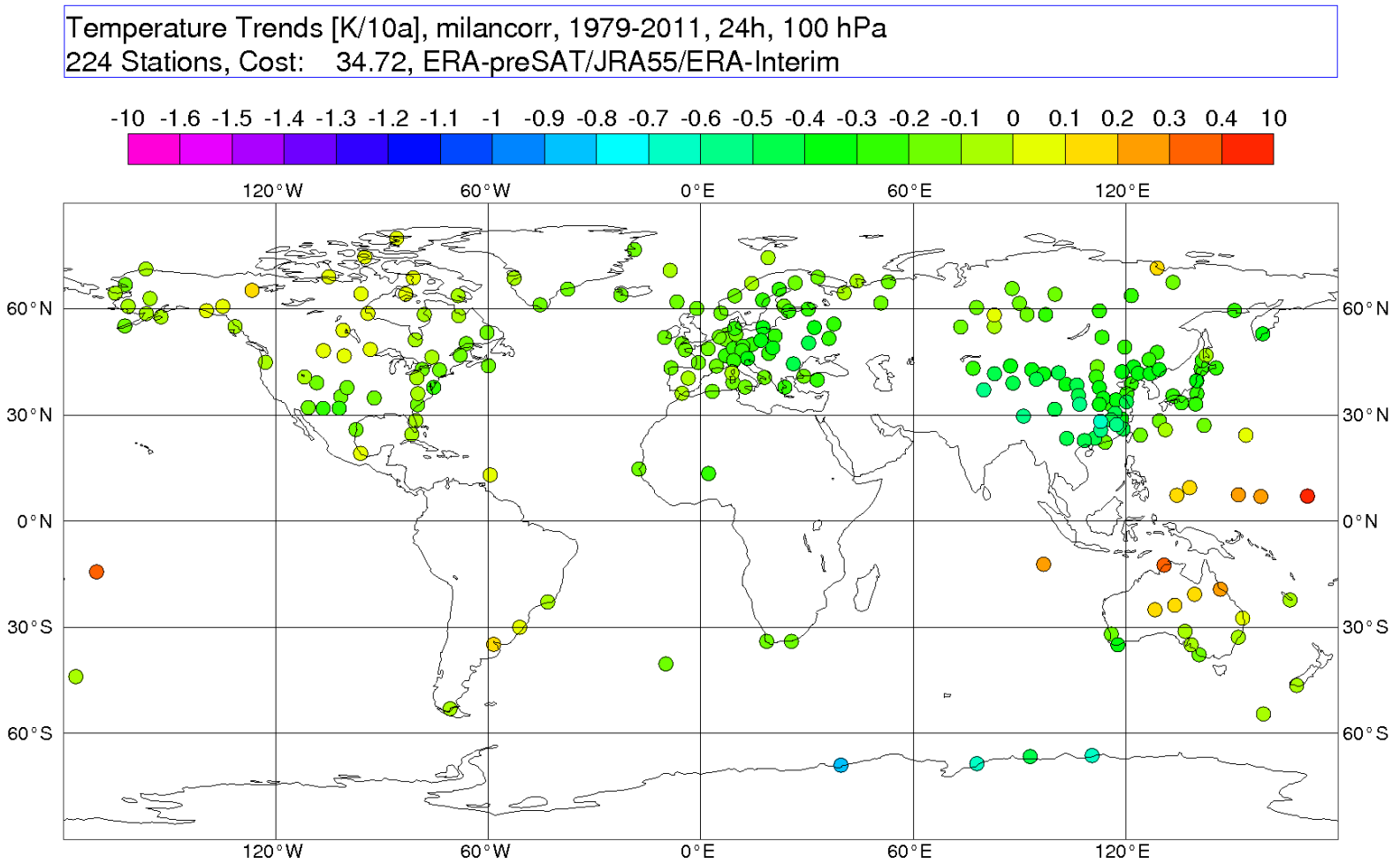
Unadjusted Trends, 100 hPa



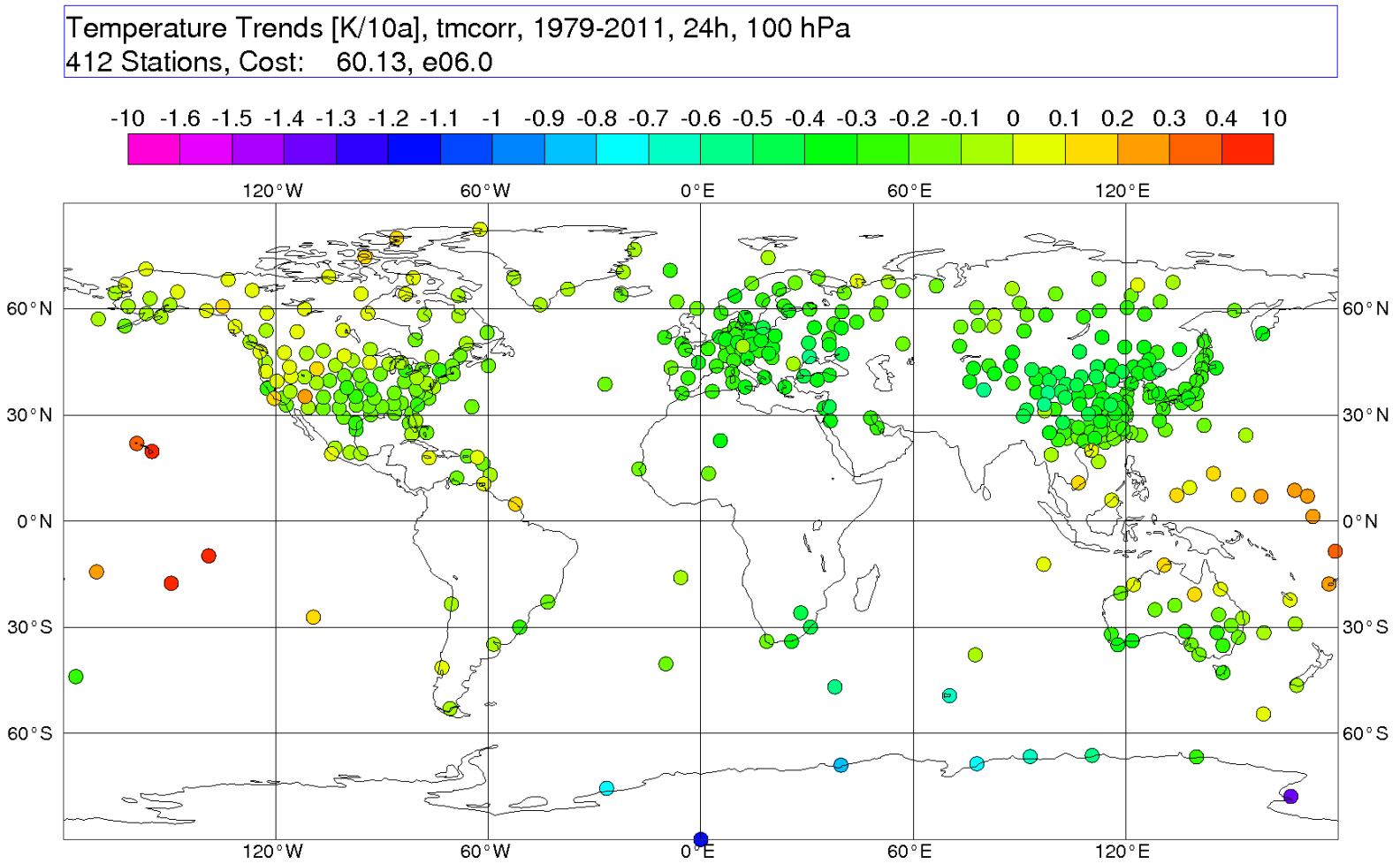
CL_STYPE (similar type)



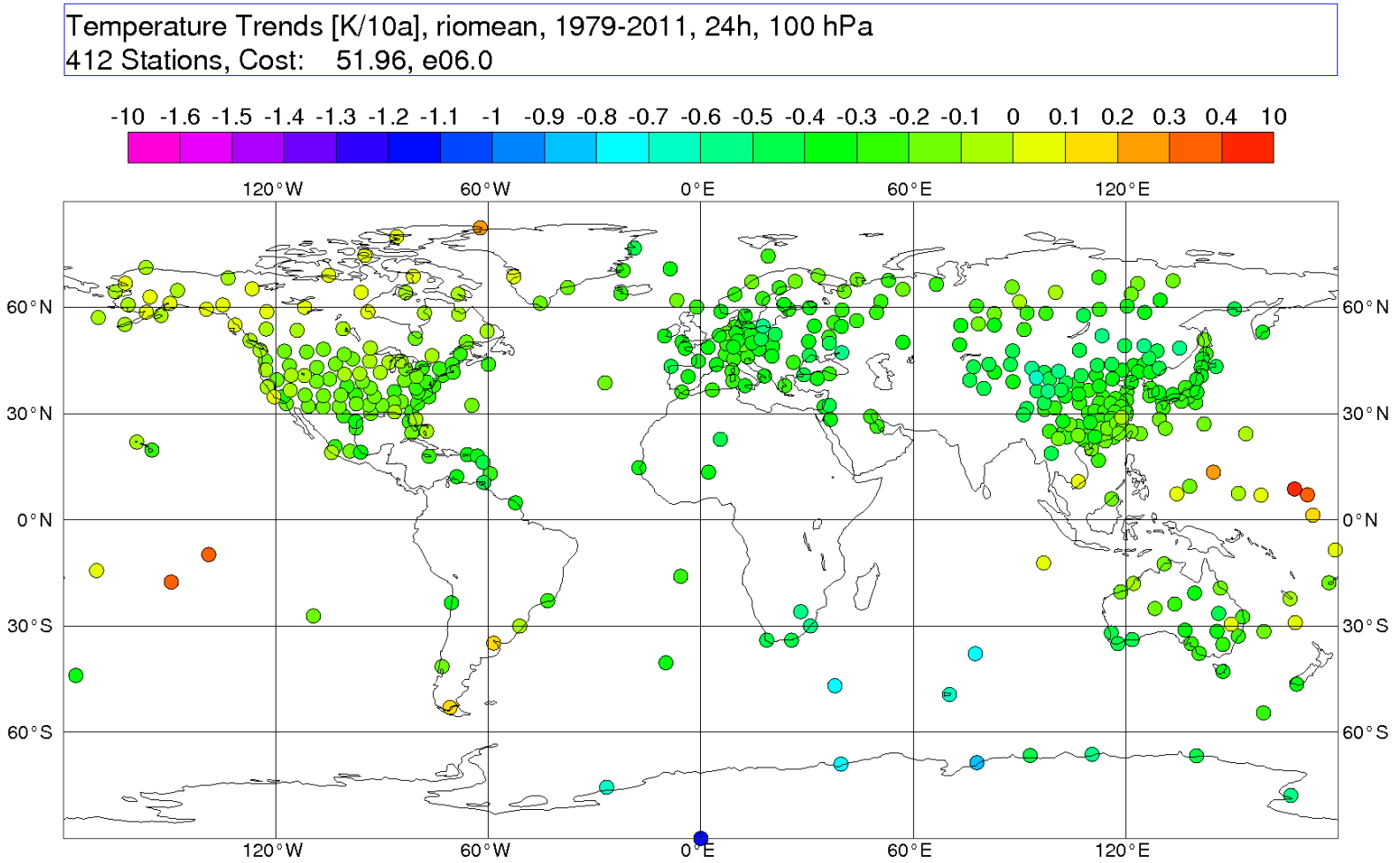
Cluster statid (similar biases)



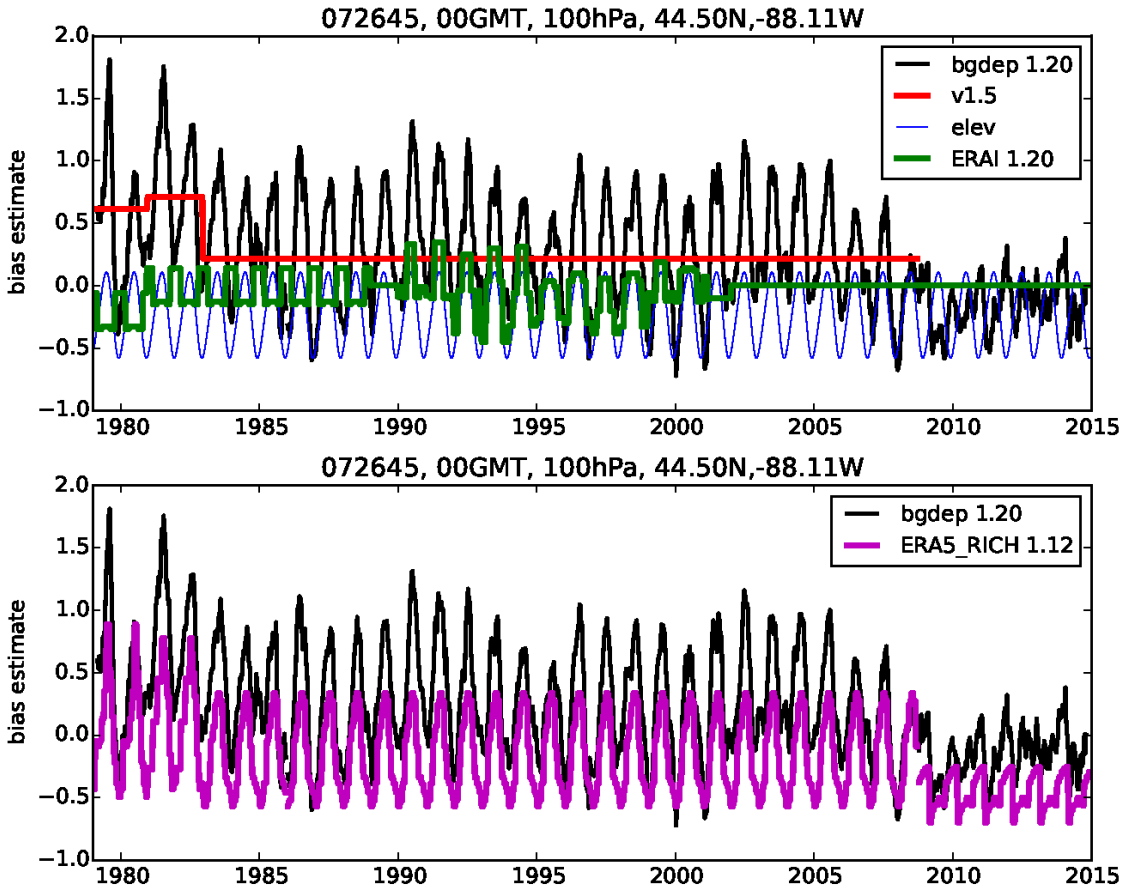
RAOBCORE v1.5



RICH ensemble mean v1.5



RICH with solar elevation dependence (RISE)



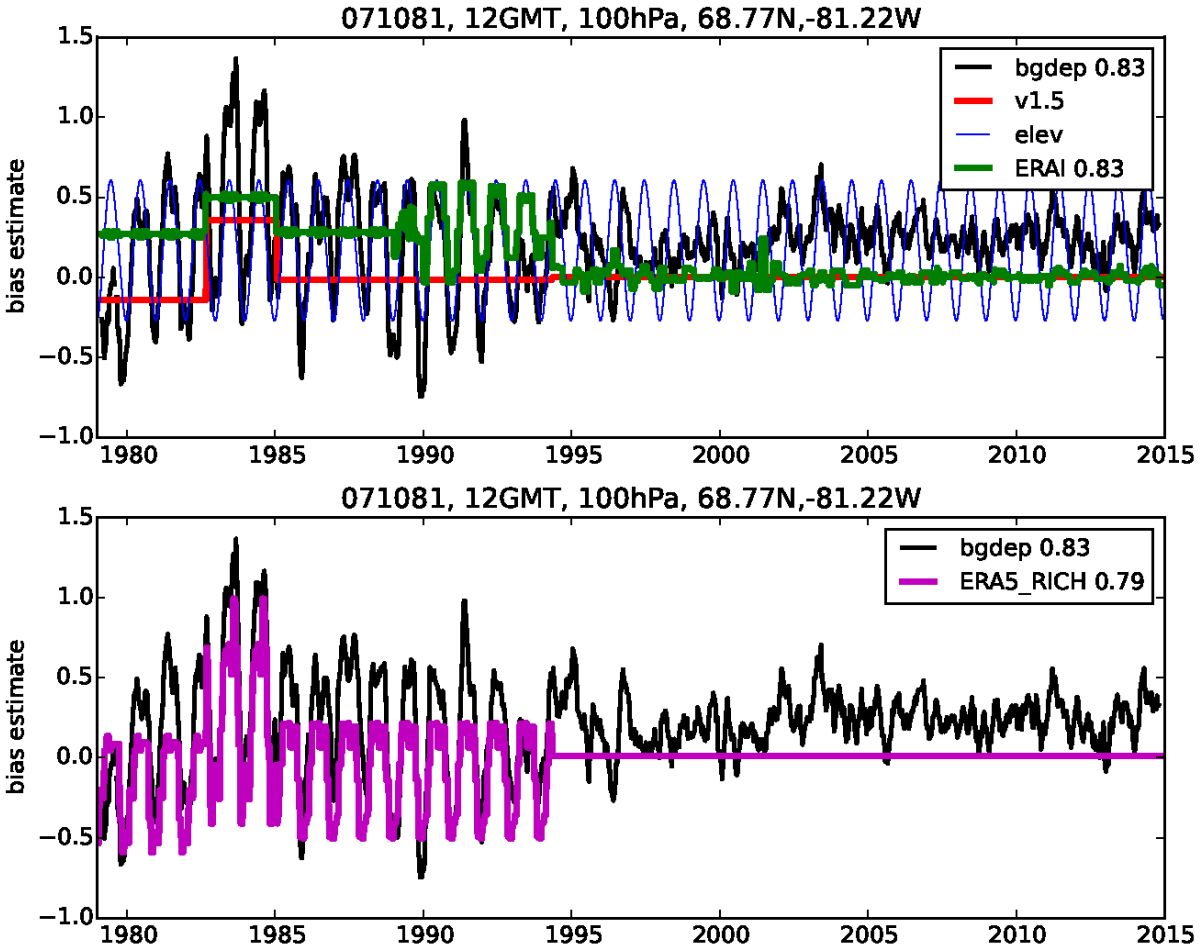
Bias adjustment in ERA-Interim (green) too weak

RAOBCORE/RICH constant

Calculate climatology of Background departues between breaks

Subtract climatology (mean zero)

Adjustments for launches at dawn/dusk



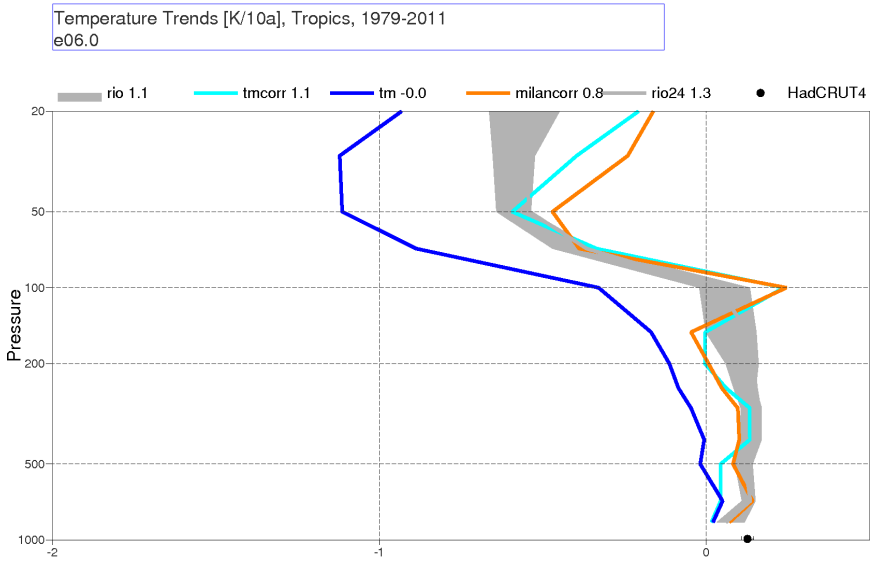
Abrupt stop of annual cycle of departures after Introduction of Vaisala RS80

Annual cycle adjusted only if it is not negligible

Robust, proposed for ERA5

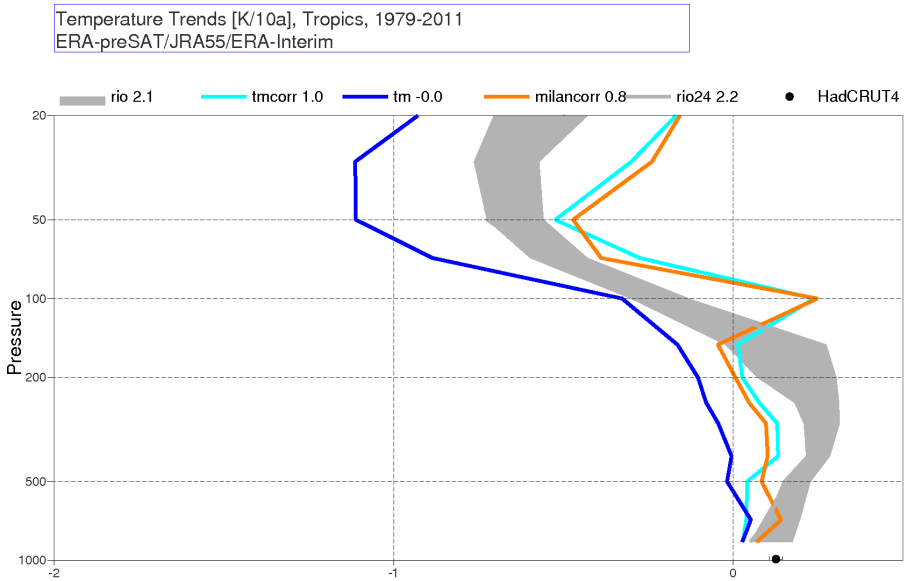
Tropical belt mean trends

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

Future work

- Start of ERA5 in the next few weeks using RISE adjustments
- Further improve RS-T bias correction for satellite era
- Make variational adjustment scheme more robust
- Offline RS-T bias correction for <1978
  - Use ERA-preSAT, JRA55 bg departures
  - Cross-validation much more difficult
- Wind bias correction much more important for <1978
- Demonstrate beneficial impact of RS bias correction in ERA5

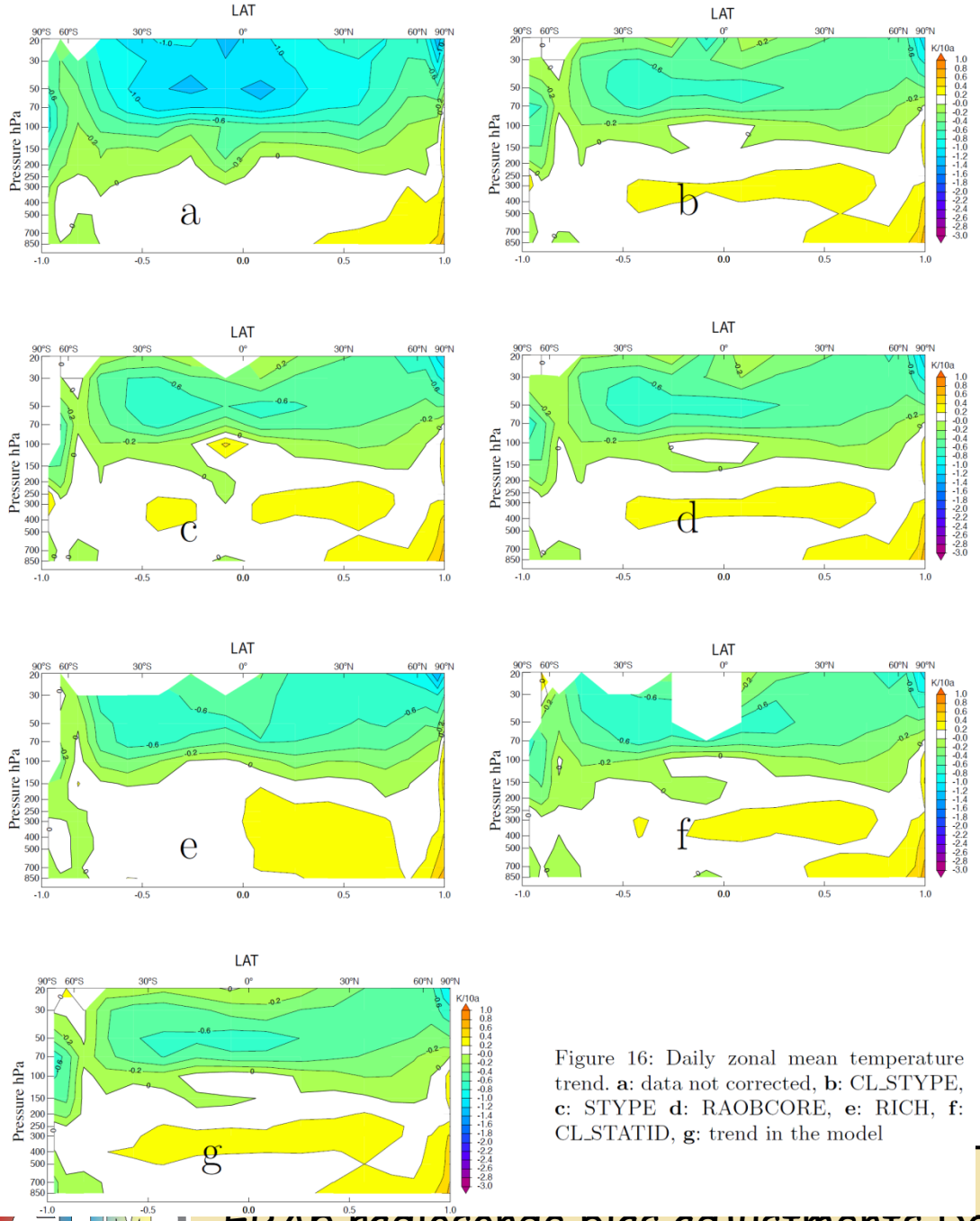
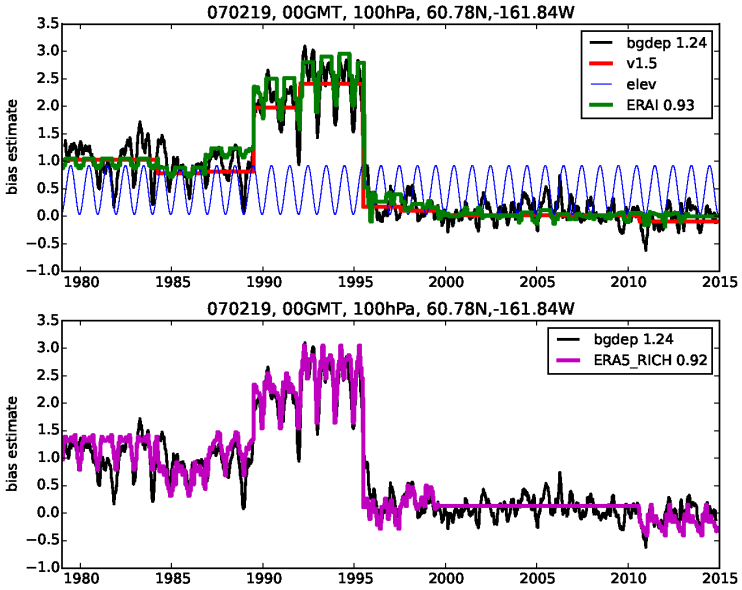
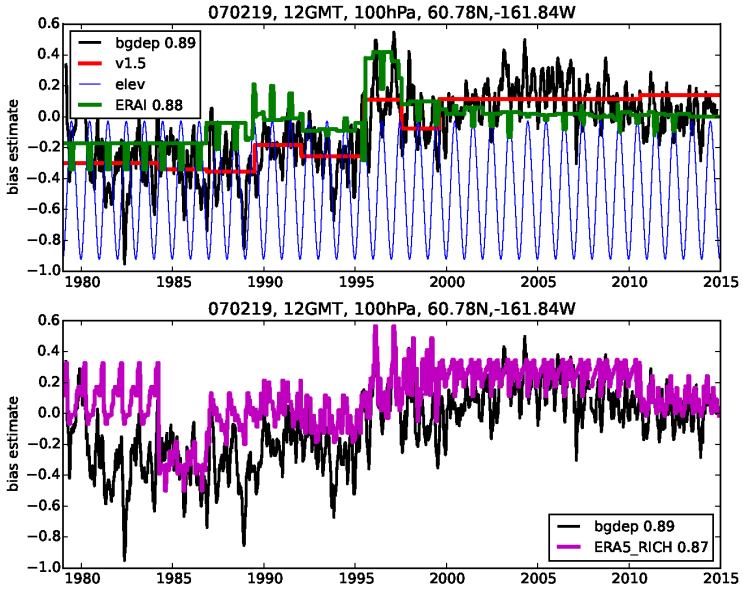


Figure 16: Daily zonal mean temperature trend. **a**: data not corrected, **b**: CL_STYPE, **c**: STYPE **d**: RAOBCORE, **e**: RICH, **f**: CL_STATID, **g**: trend in the model

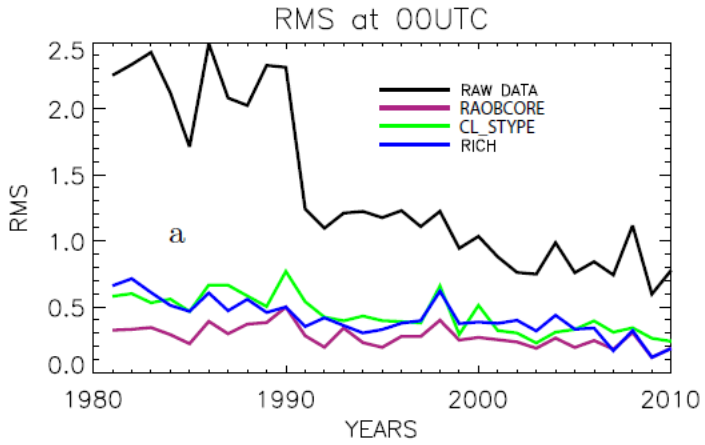
Zonal mean trends 1981-2010

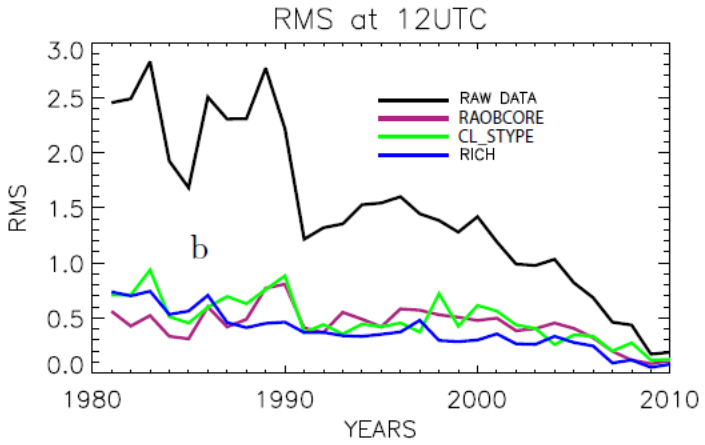


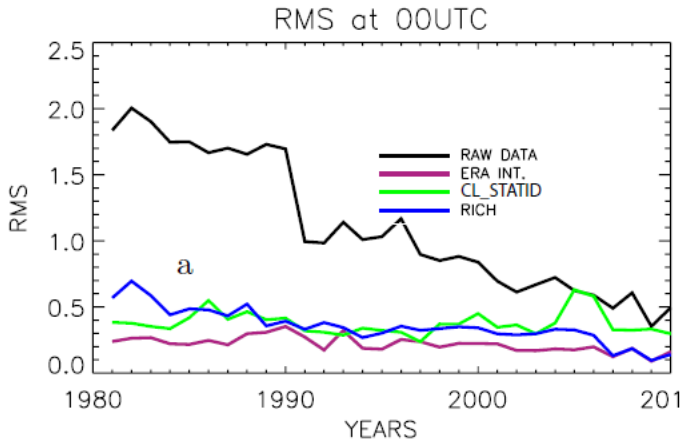


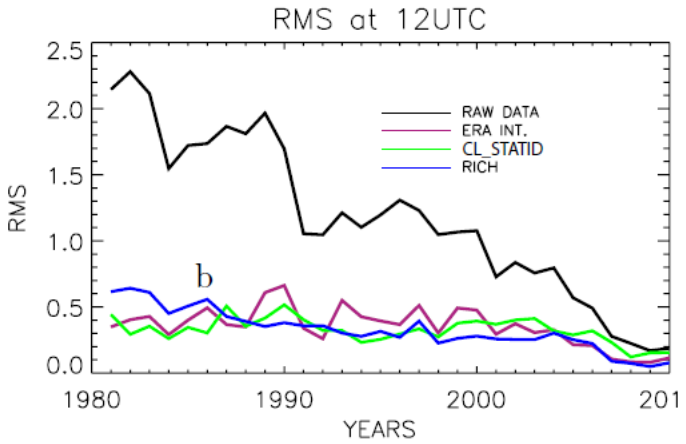
ERA5 radiosonde bias adjustments Dec 10, 2015

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









Comparison summary

Varbc

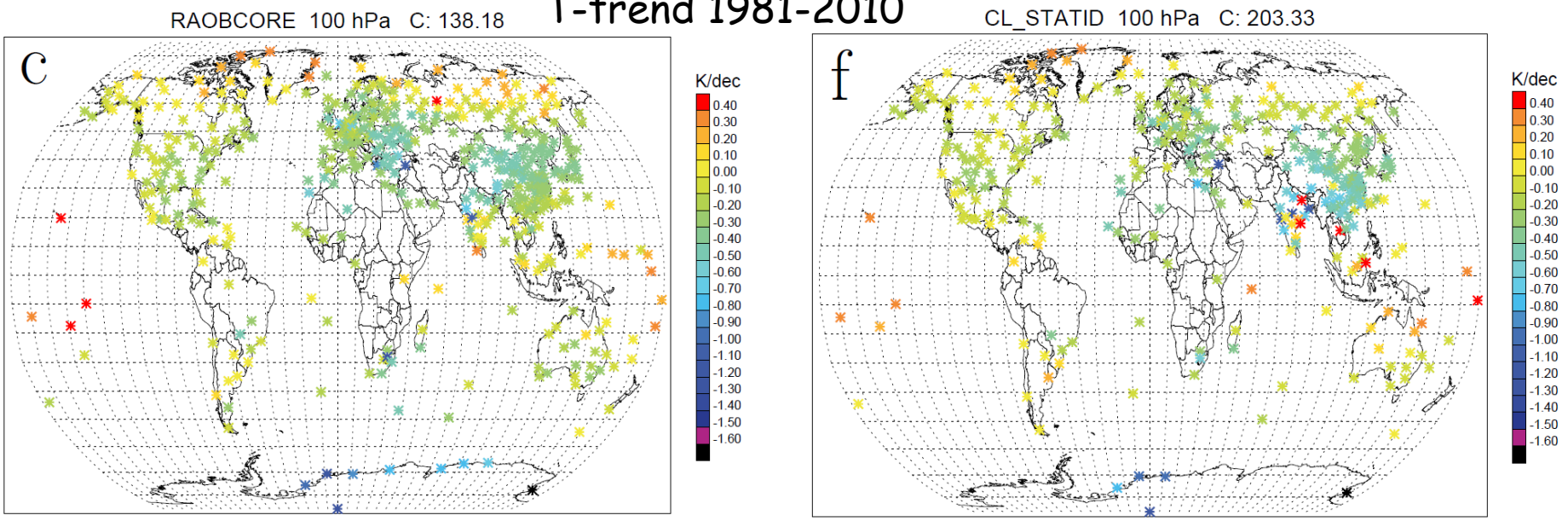
- Varbc implemented, tested „offline“
- RS-type information too inaccurate for station grouping
- Adjusts many stations but less than RICH/ RAOBCORE
- Yearly „jumps“
- Radiosondes no longer „anchors“

RAOBCORE/RICH

- Tested offline, reading is implemented
- Well tested for satellite era
- RAOBCORE adjustments too strongly dependent on background, better use RICH
- Adjustments constant between breaks

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)

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

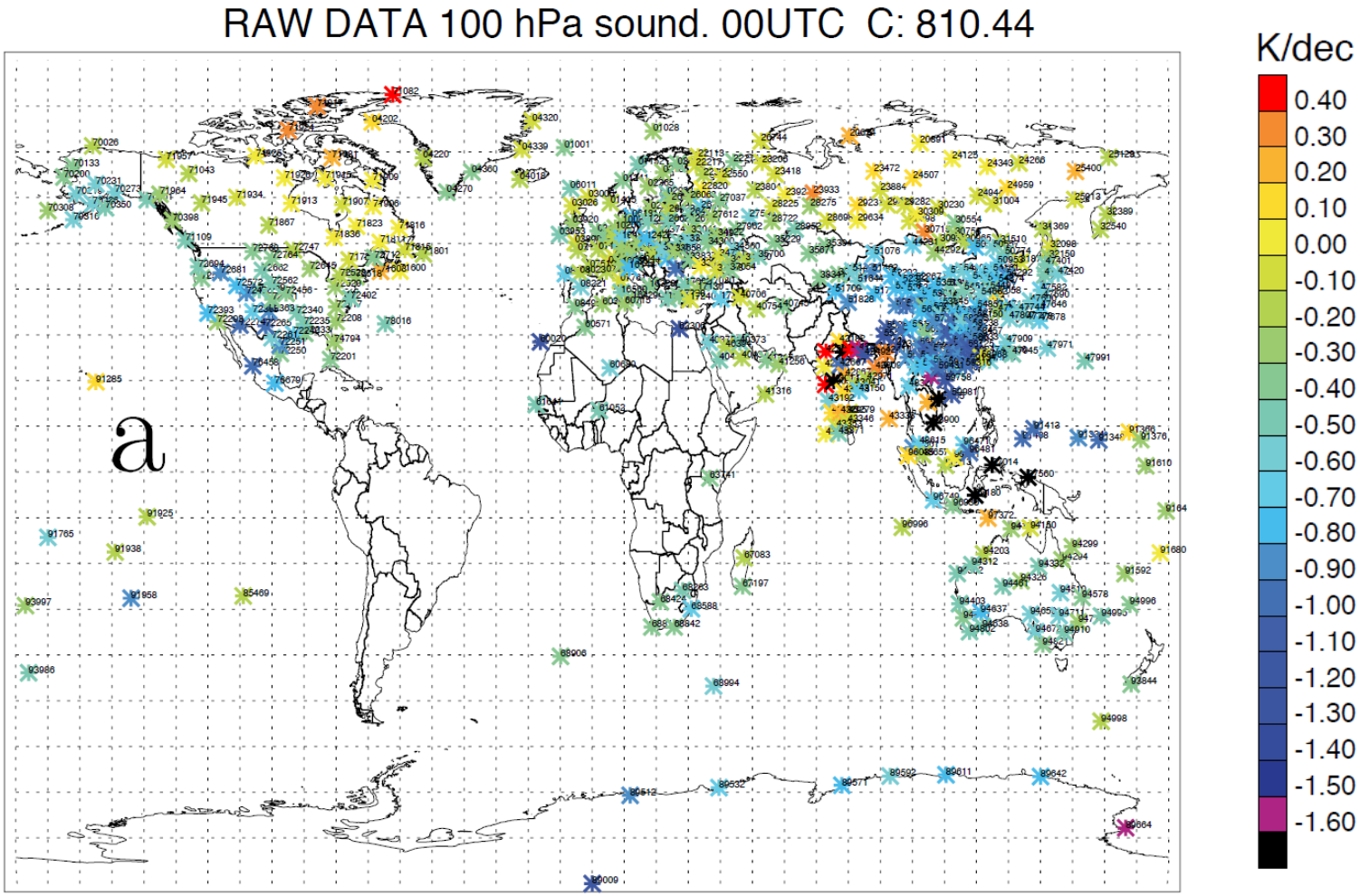
- LINEAR + SOLAR ELEVATION + LOG

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

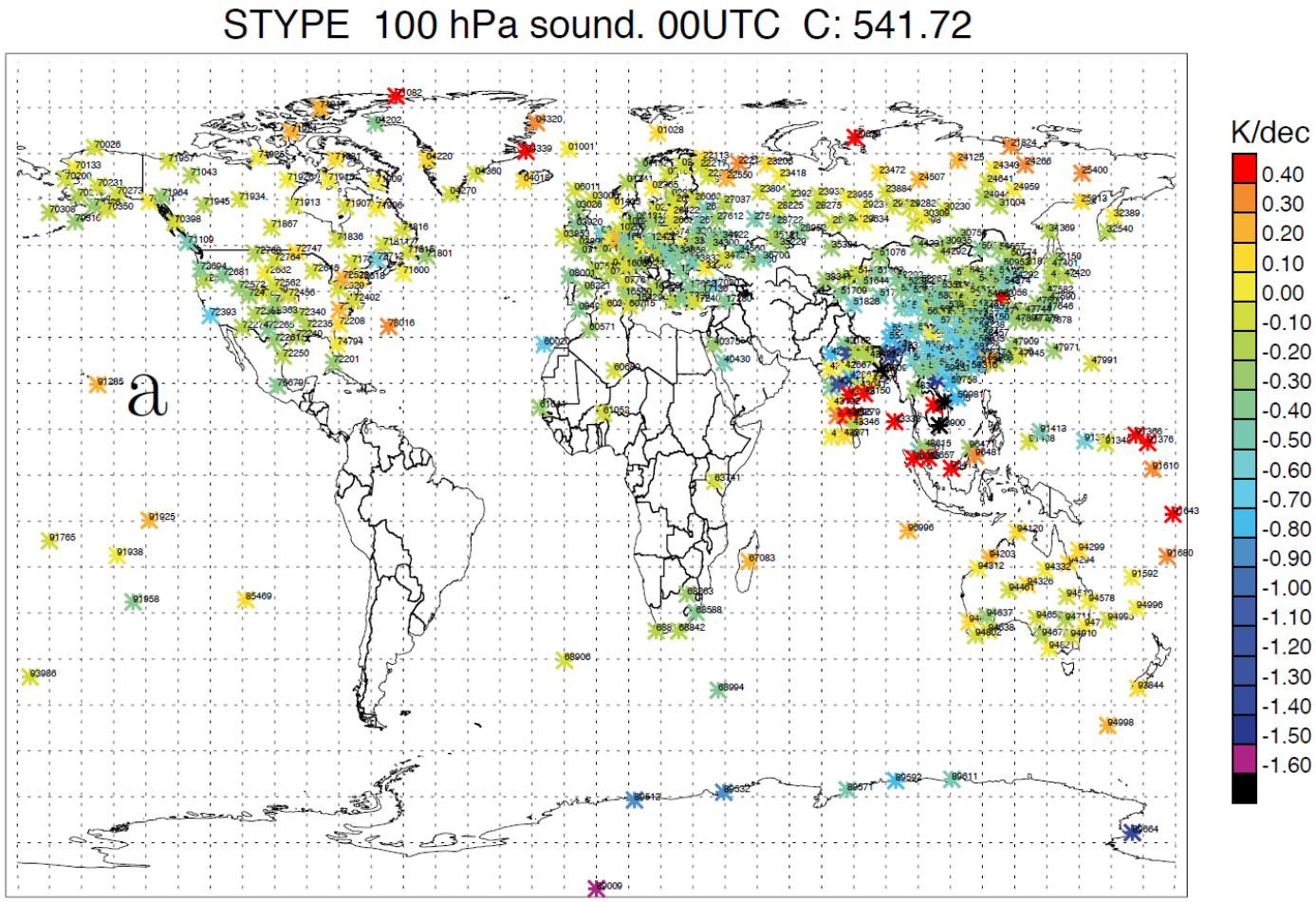
- LINEAR + SOLAR ELEVATION + LOG. STRAT.

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

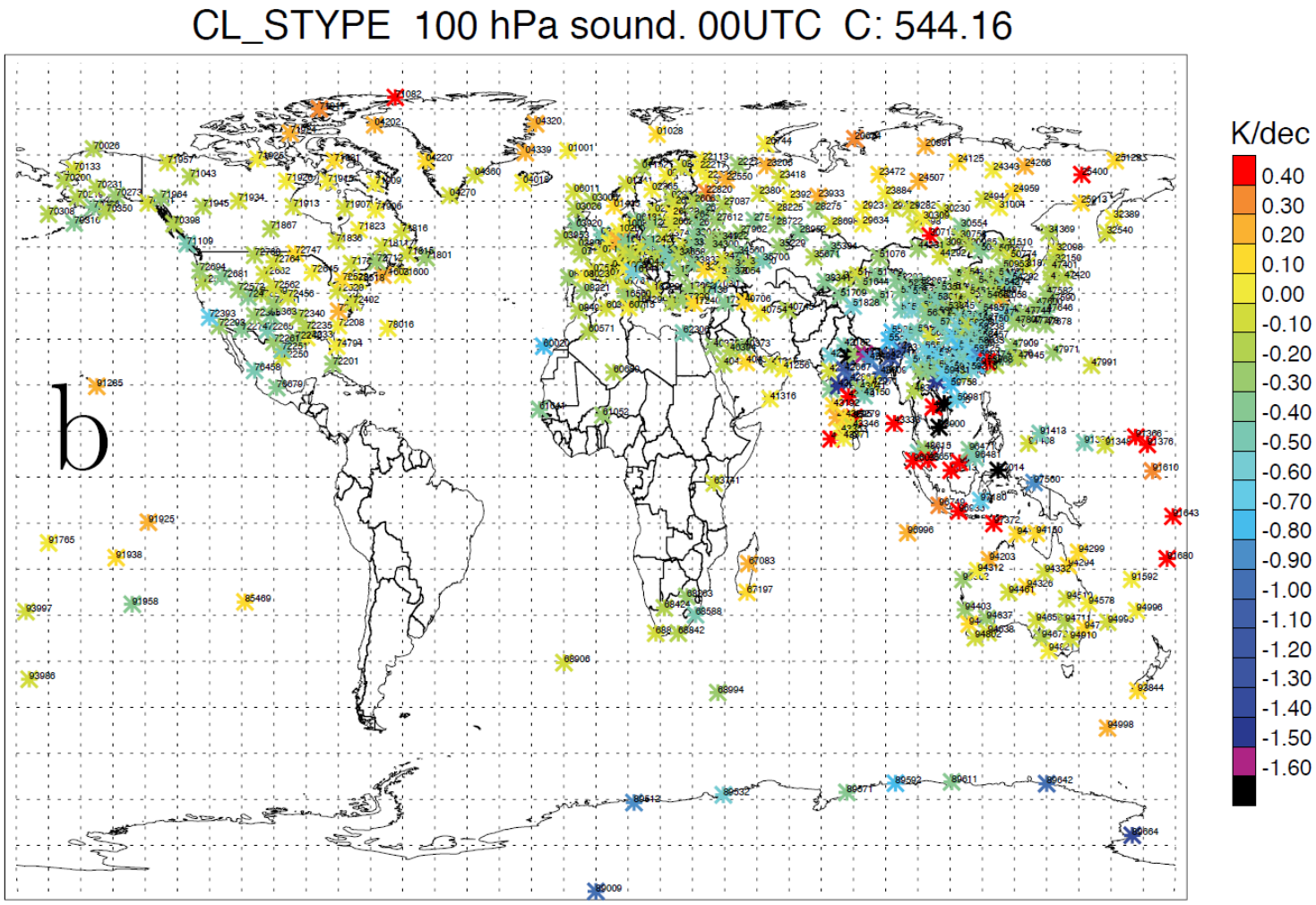
Raw Data, Trend 1981-2010



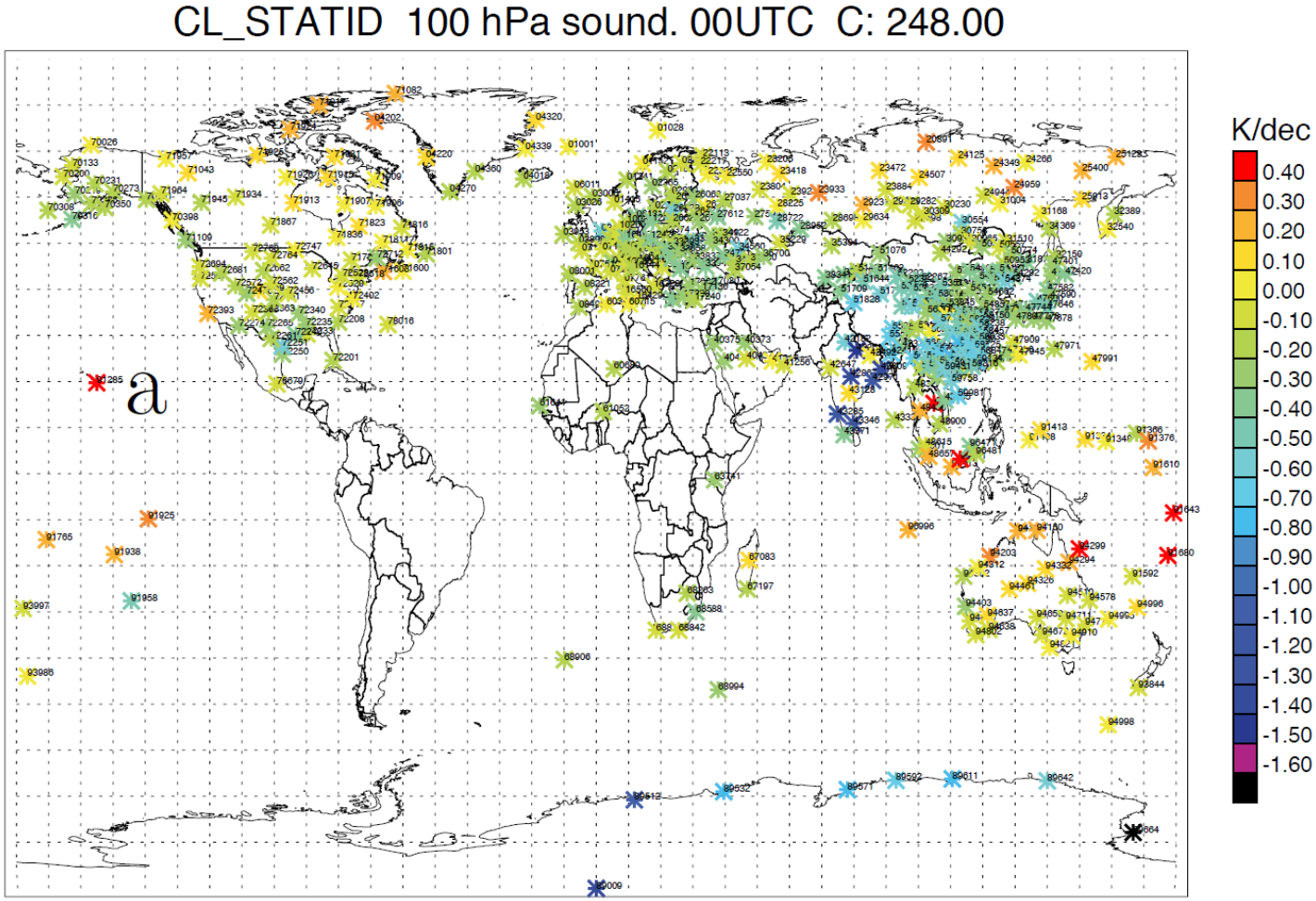
Each sonde type adjusted separately



Similar sonde types clustered together



Stations with similar bias clustered together



VARIATIONAL BIAS CORRECTION

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

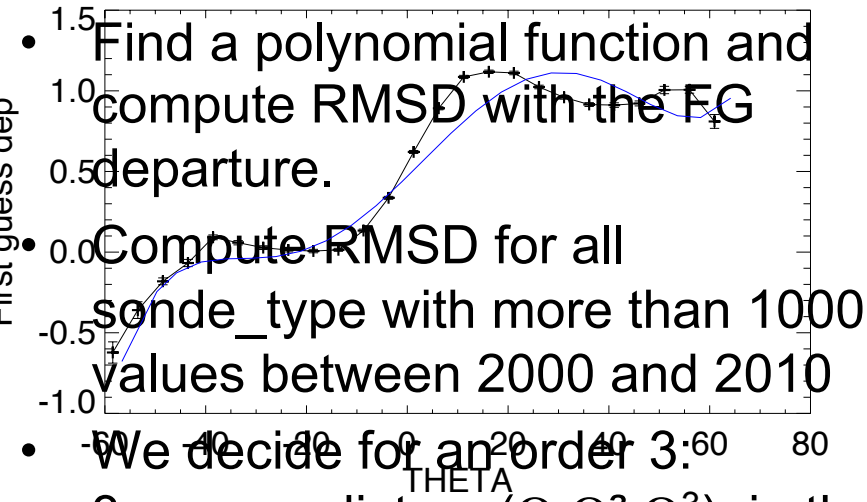
$$b(x,\beta) = \beta_0 + \sum_i \beta_i p_i(x)$$

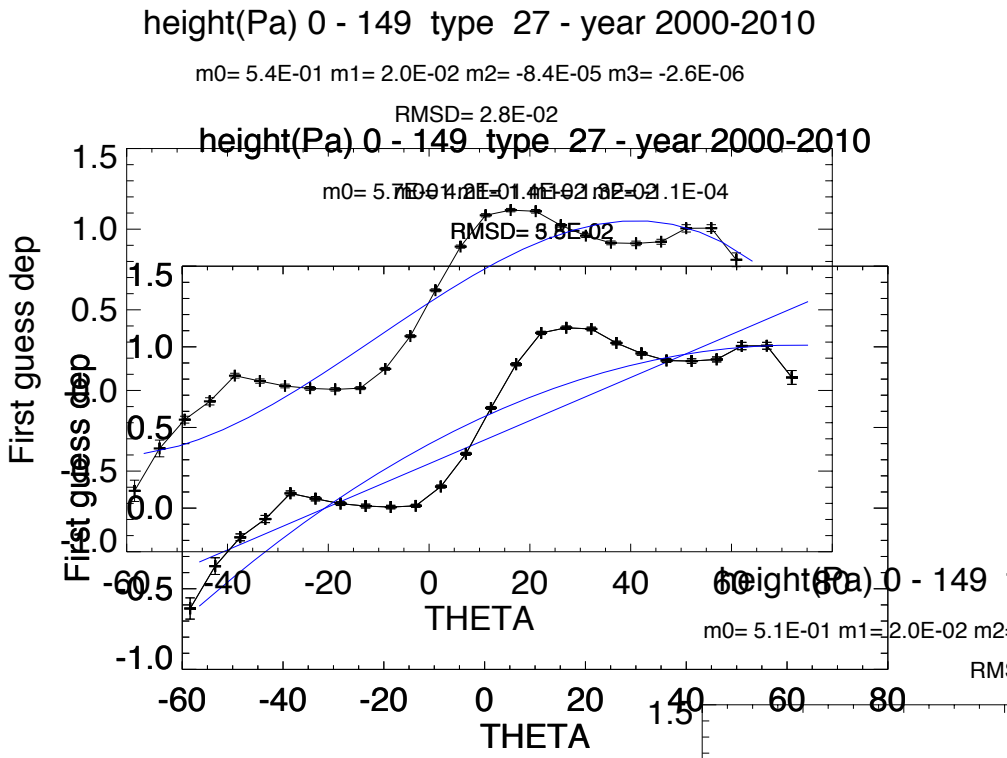
- Predictors:
  - Pressure
  - Solar elevation
  - Radiosonde Type
  - All three do not depend on model state

- 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