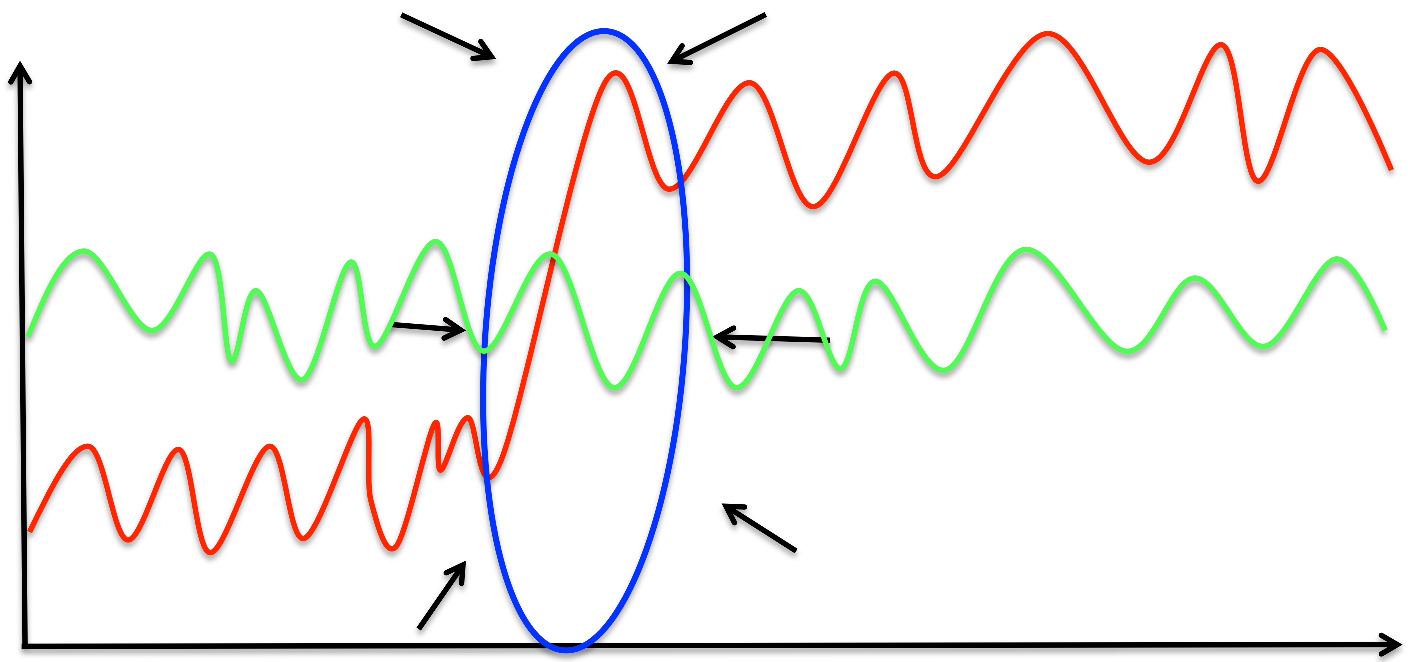
VARIATIONAL BIAS CORRECTION FOR RADIOSONDE DATA



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MOTIVATION

- Radiosondes data often used as reference for other data
- Radiosondes data, especially at high altitudes, are not unbiased
- Changes bias due to:
  - Change of radiosonde
  - Change of locations for the same radiosonde
  - Other equipment changes
- Vertically constant wind direction bias in many radiosondes
- Unadjusted biases affect trends and observations usage
- A bias adjustment, which takes into account all these problems, is needed

OUTLINE

- Previous works:
  - Radiosonde adjustment during ERA-INTERIM
- Current approach
  - Variational Bias correction (VarBC)
  - Possible bias models
  - Grouping of data (radiosonde types, elevation angles, …)
- Preliminary results
- Conclusions

ERA-Interim adjustment

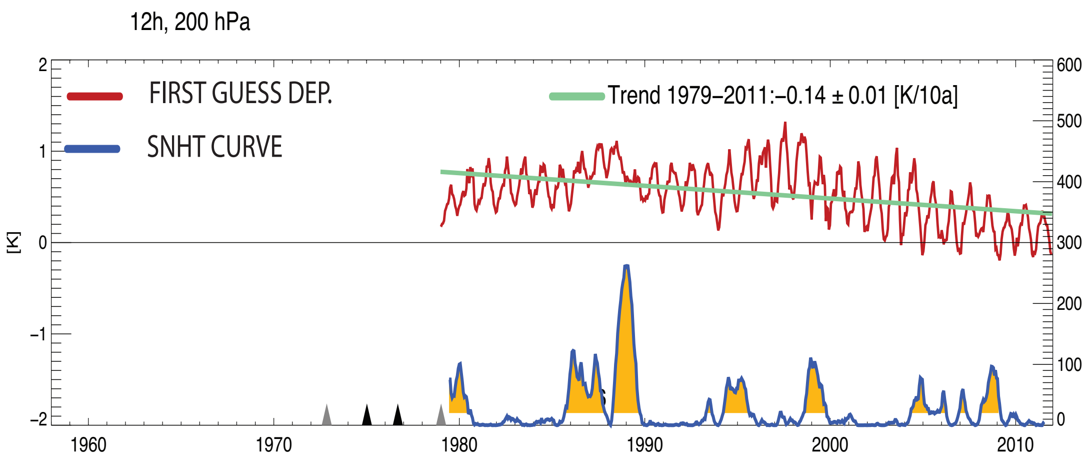
Wind

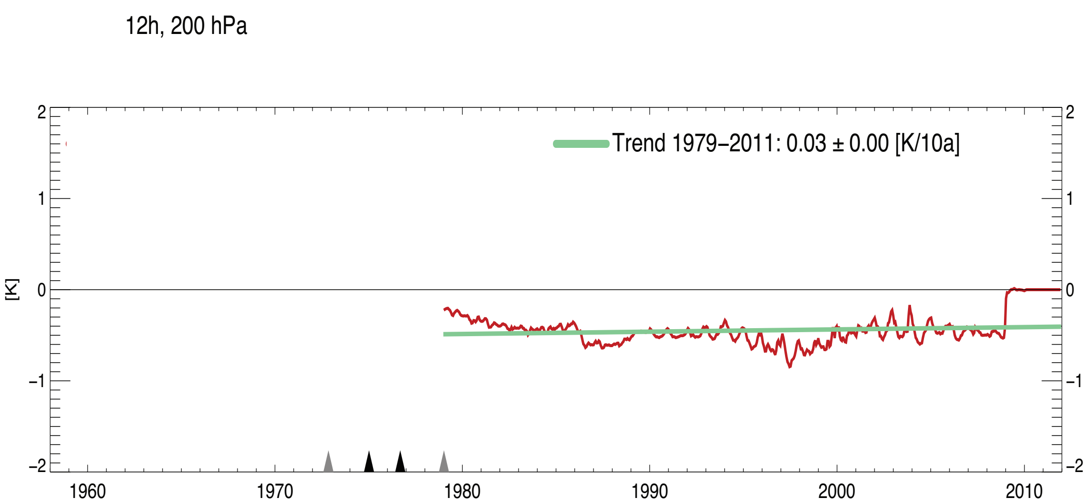
- No adjustment is done for radiosonde winds

Temperature

- Adjustment of annual mean bias
  - Use of RAOBCORE (*Haimberger et al. 2007, 2008*)
  - Based on time series of individual stations
  - Detection of shifts in background departure
  - Adjustments can change temperature trends
- Adjustment of daily/seasonal bias
  - Method based on solar elevation adjustment (*Andrae et al. 2004*)
  - Based on station groups
  - Four classes of solar elevation
  - Adjustments calculated from the statistics of background departures over the previous 12 months

ERA-Interim adjustment





- Russian radiosonde, 12 UTC, 200hPa
- Start from 1979, when satellite data are available
- First guess departure, using uncorrected radiosondes
- Bias correction to apply
- Bias correction only until 2008, not applied any more
- After 2008 less departure but still existing, a bias adjustment is needed
- Limited departure probably due to changes on radiosondes dataset in the Russian federation

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 β^b a priori estimations of model state and bias control parameters
- A large $\mathbf{B}_\beta$ allows the parameter estimates to respond more quickly to the latest observation.
- The adjustment of the radiosondes depends on the resulting fit of the analysis to all other OBS, given the background from the model.

Variational Bias correction

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

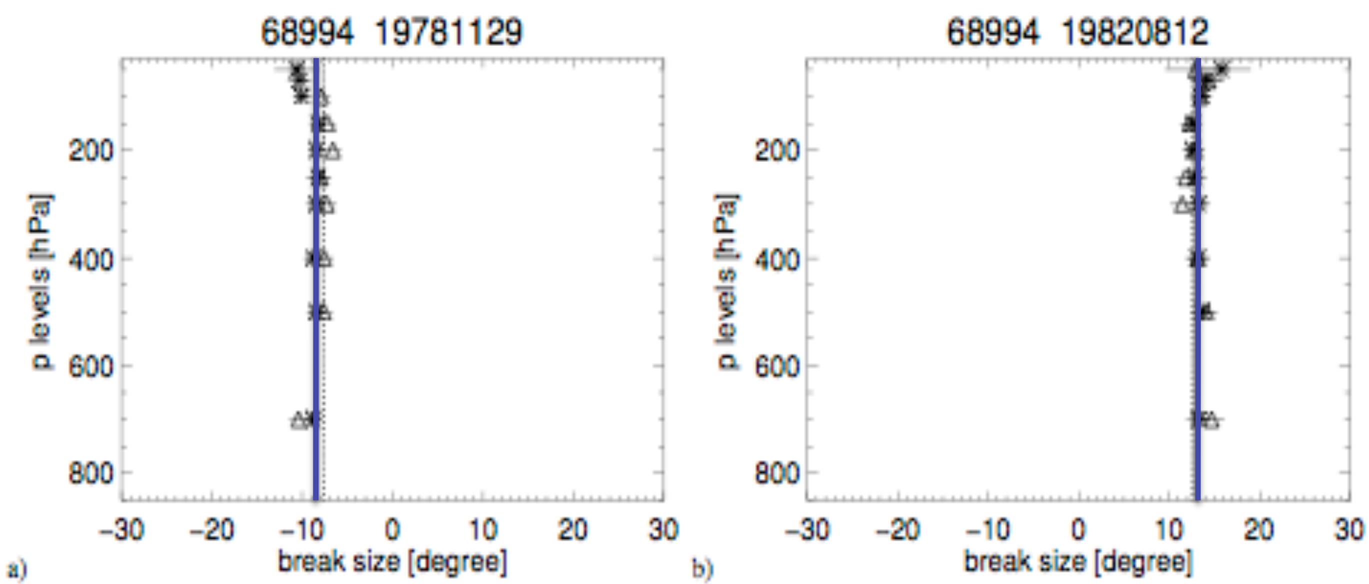
$$b(x,\beta) = \beta_0 + \sum_i \beta_i p_i(x)$$

Must be chosen according to observations and physical origins of the bias.

- We assume the model unbiased, the presence of model bias attributes a wrong bias to the observations where there are not enough observations to correct the analysis

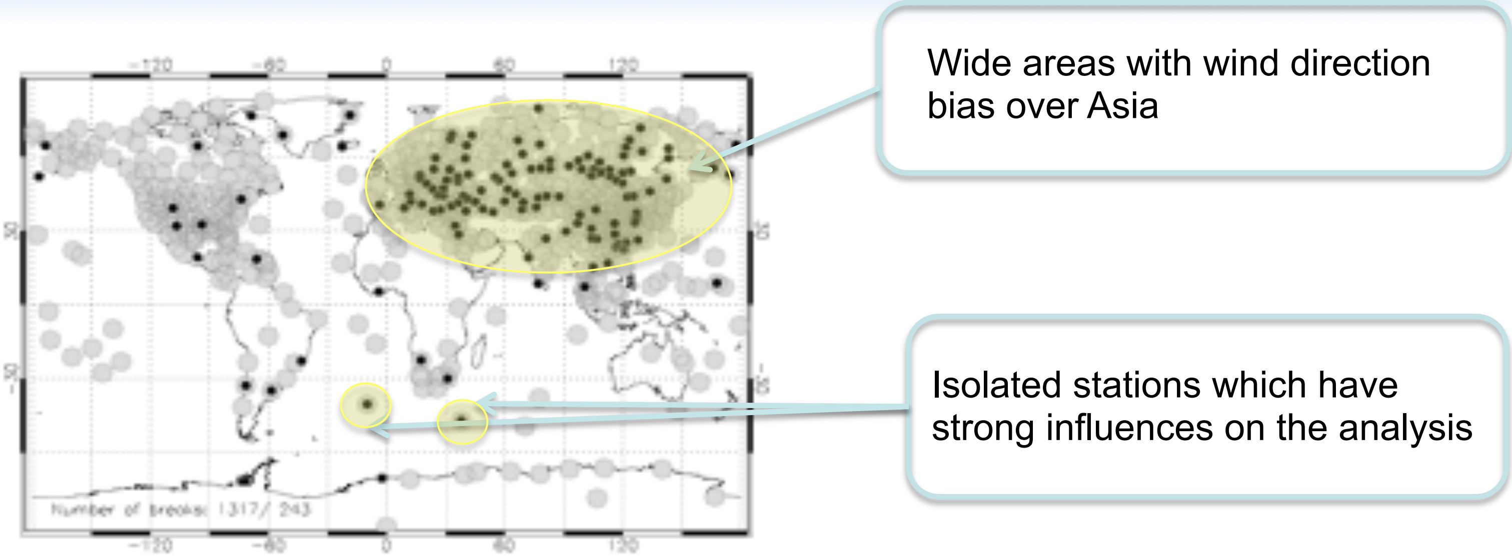
Wind direction bias

- Marion Island – Indian Ocean (extreme bias)
  - FG-departure wind direction compared to ERA-40
  - 1978, 1982: Wind direction change throughout the whole profile



Gruber and Haimberger, 2008

Wind direction bias



Gruber and Haimberger, 2008

- Due to constant vertical bias only a constant bias parameter is needed

$$\mathbf{b}_j(\beta) = \beta_0$$

- Constant wind direction bias parameter for the whole profile of each station

Wind direction bias

- One constant predictor
- Problem:
  - Model: u,v
  - Control variable in cost function: wind direction
- Transformation:

  From u,v

  → Wind direction

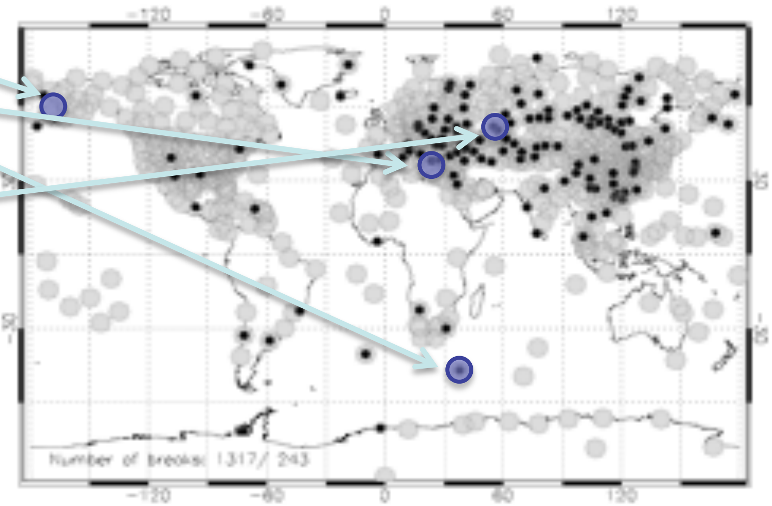
  → Bias model

  → Bias back to u,v

Wind test for bias correction

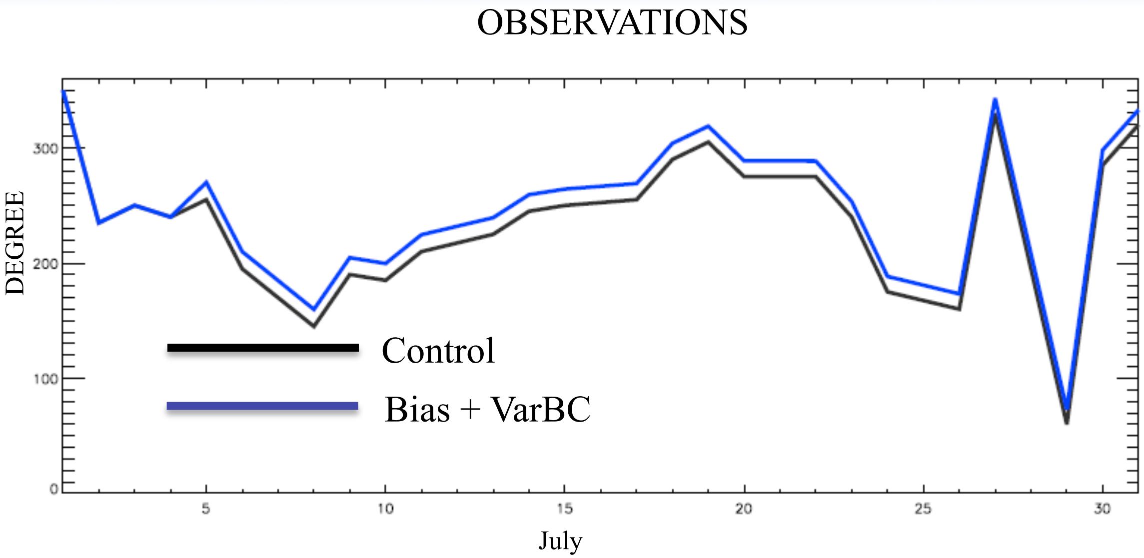
- Test setup:
  - 15 degree wind direction bias added to 4 radiosonde stations from day 4 onwards:

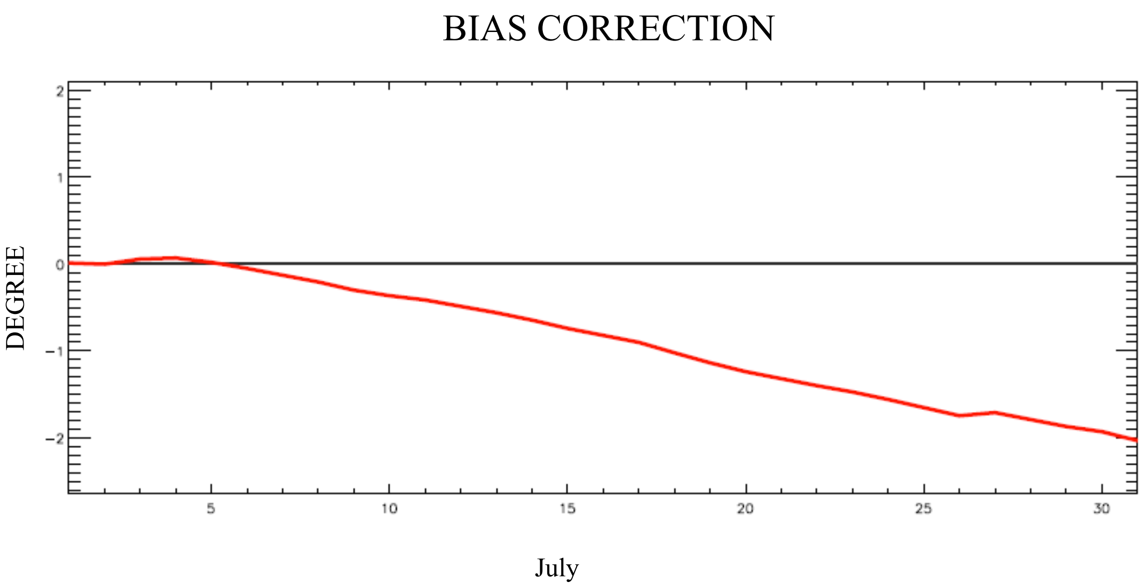
- Bethel, Alaska - 70219
- Athens, Greece - 16716
- Marion Island, Indian Ocean - 68994
- Aktynbinsk, Russia – 35229



- Evaluation of first experimental runs July and December 2011

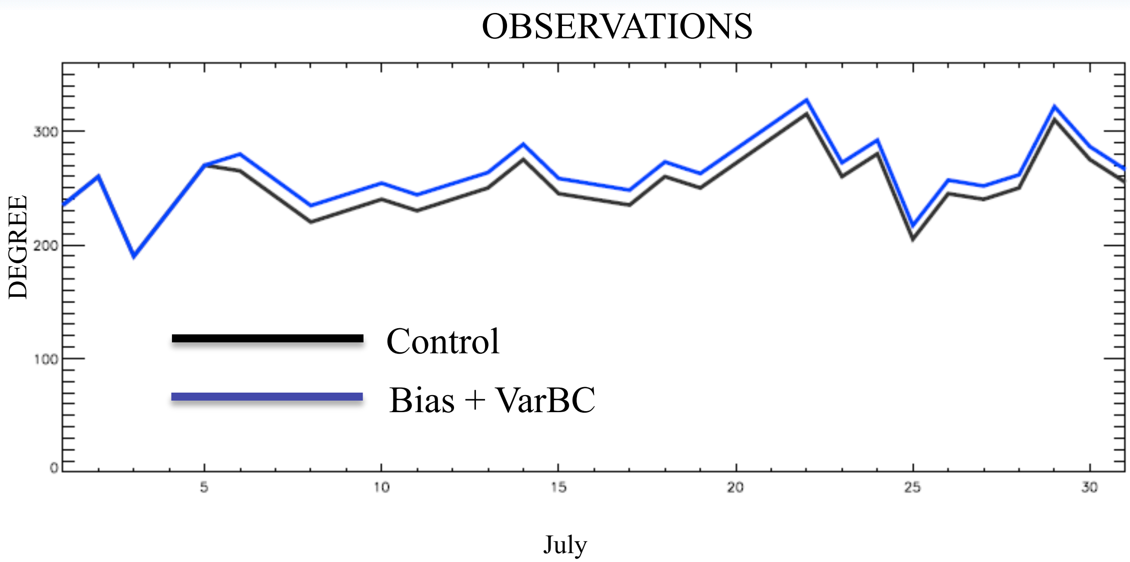
Wind July 2011
Bethel, 70219

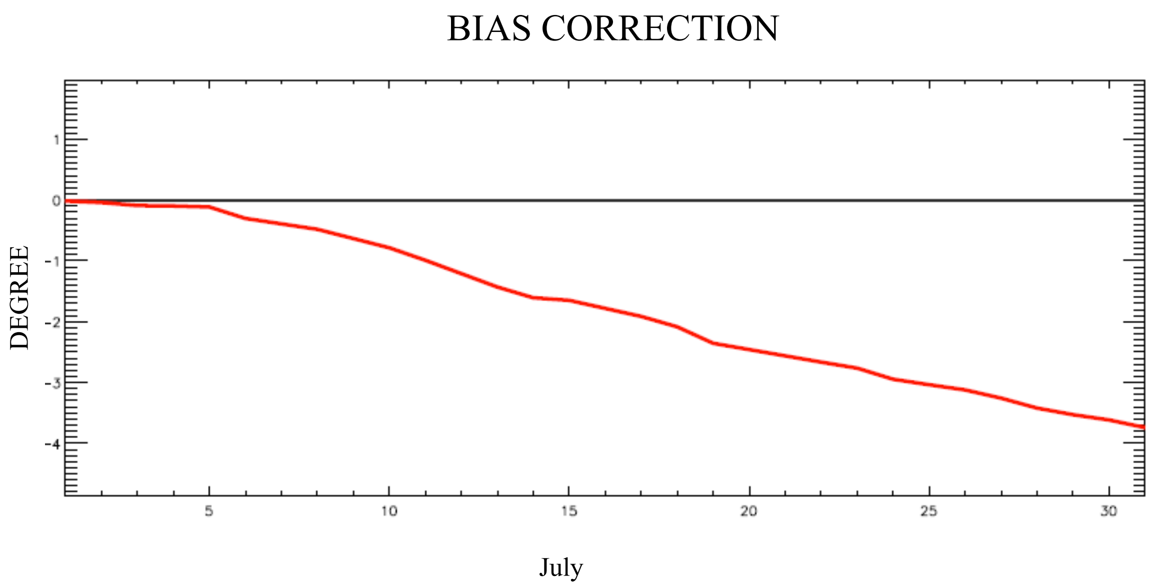




- 500 hPa but same bias over the whole profile
- To correct 15 degree
- Bias correction around 2 degree after 31 days
- The bias correction is in the “right” direction but the amount is too low

Wind July 2011
Marion Island, 68994

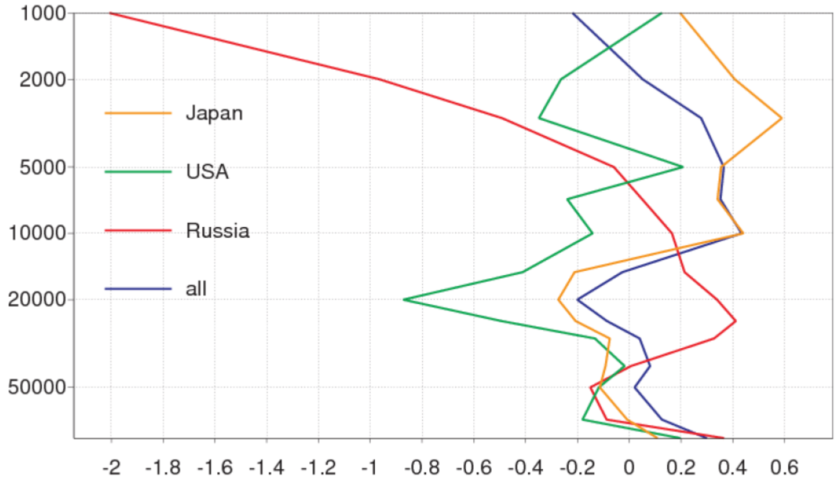




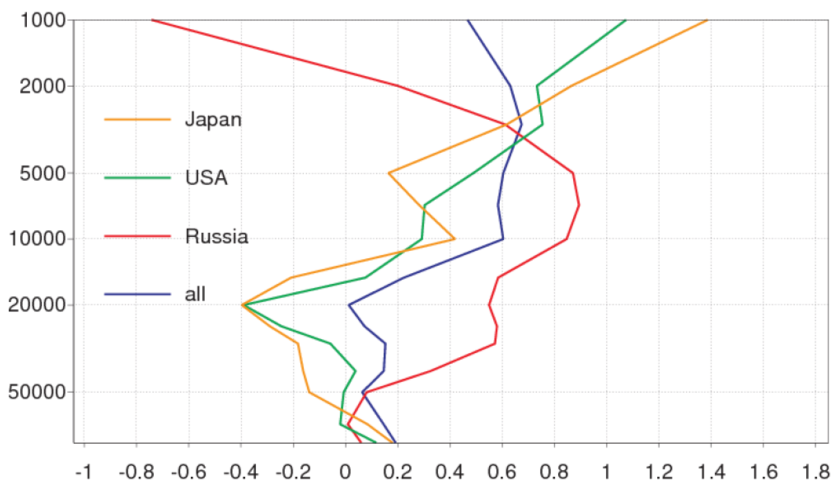
- 500 hPa but same bias over the whole profile
- To correct 15 degree
- Bias correction around 4 degree after 31 days
- The bias correction is in the “right” direction but the amount is too low
- In this case the correction is larger

First guess departure T

Night Θ < -7.5°



Θ > 22.5°



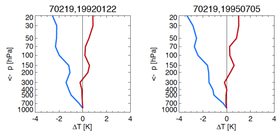
- Analysis of July 2011
- Average of first guess departure
- Results divided by station type
- Large differences between different station types (necessity of grouping)
- Different behaviour between stations at night and at large solar elevations
  - Russian stations near 50 hPa positive departure for large solar angles, around 0 during the night
  - Japanese and USA stations different path, positive departure in the upper levels
- Height dependencies are visible
- Bias depends on RS-type, pressure and solar angle

Radiosonde temperature bias correction

1. Bias model

$$\mathbf{b}_j(\beta) = \beta_{0,j} + \beta_{1,j} logp/p_s + \beta_{2,j} log(p/p_s) f(\theta)$$
$$f(\theta) = 0.5 * (1 + tanh(a\theta + b))$$

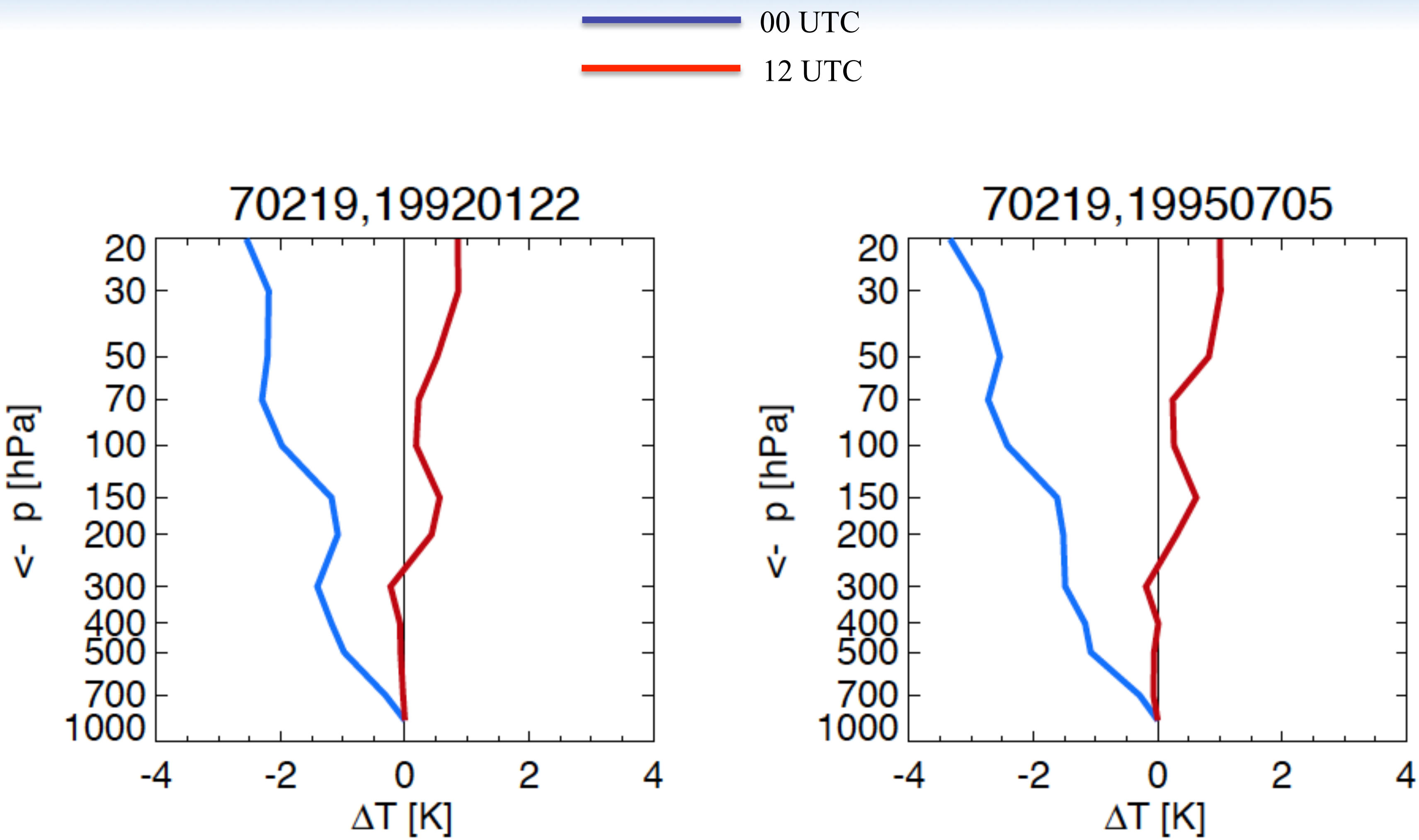
   - First approach, seems suitable for US and Japanese radiosondes at some periods



   - Not suitable for vertically nonlinear bias profiles

2. No functional relationships, instead estimate bias parameters for pressure layers, solar elevations and station groups
   - More bias parameters need to be estimated
3. First results (test) using only a vertically constant bias parameter valid for all solar elevations

$$\mathbf{b}_j(\beta) = \beta_0$$


00 UTC
12 UTC
70219,19920122
70219,19950705
<- p [hPa]
20
30
50
70
100
150
200
300
400
500
700
1000
-4
-2
0
2
4
ΔT [K]

Radiosonde temperature bias correction

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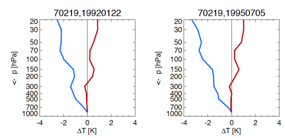

   – Not suitable for vertically nonlinear bias profiles

2. No functional relationships, instead estimate β_0 for different pressure layers, solar elevations and station groups
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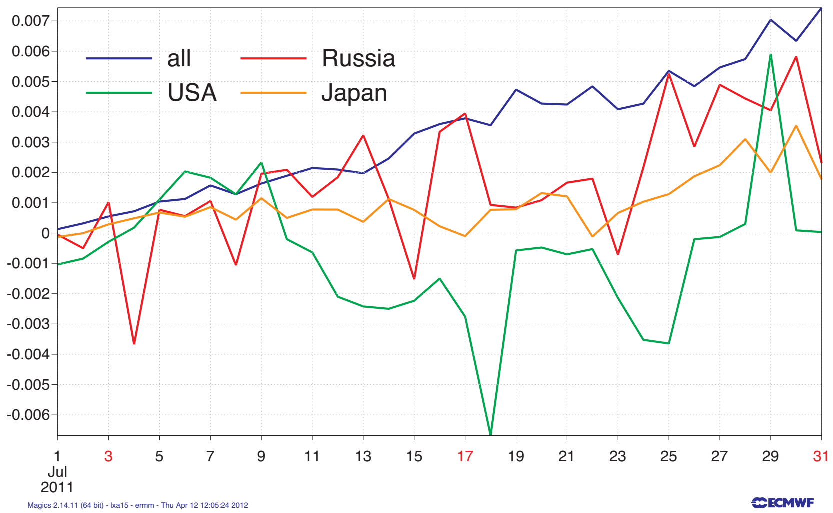
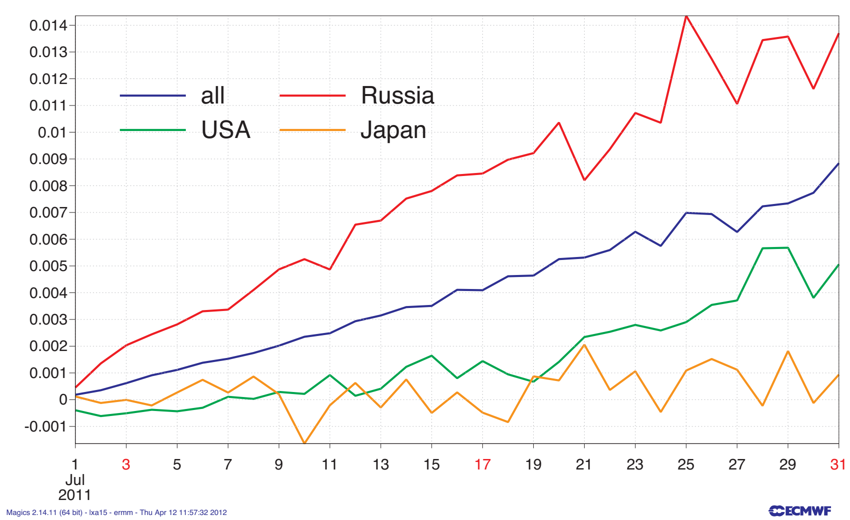
Bias adjustment

NIGHT

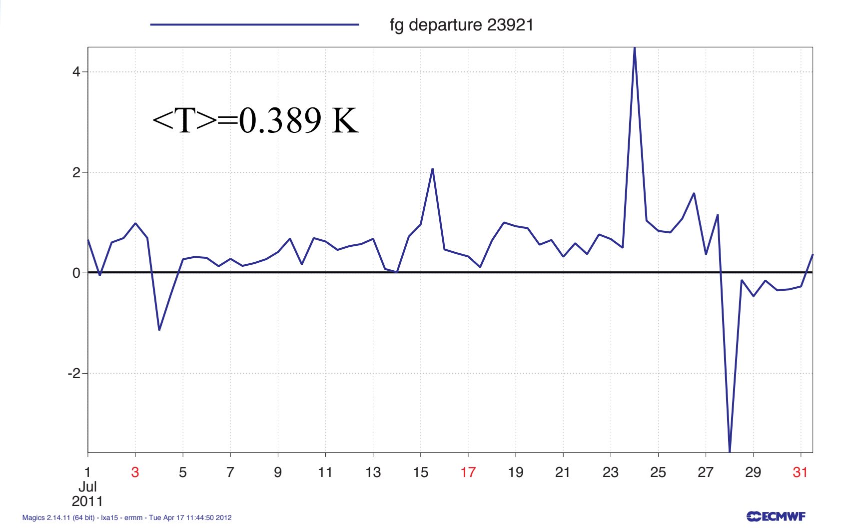


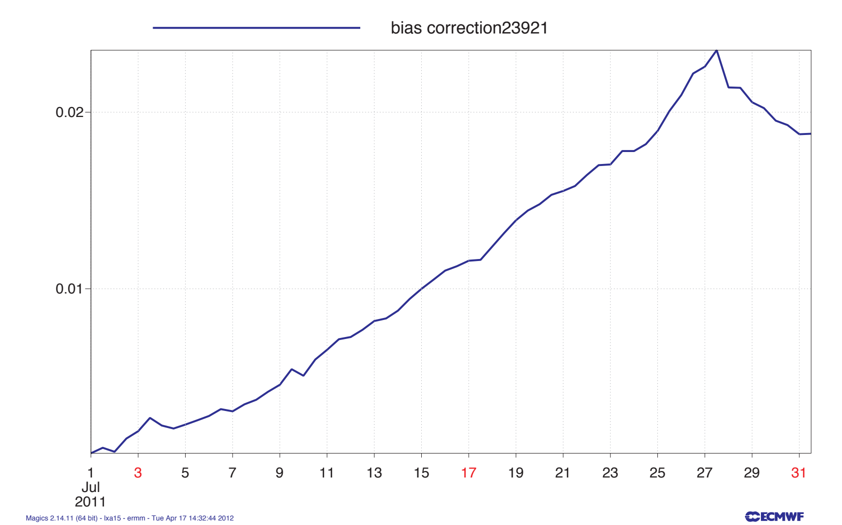
SOLAR ELEVATION > 22.5°



- Time series for vertical mean bias correction
- Generally very small bias corrections
- For higher solar elevations larger bias corrections
- Radiosonde types with larger first-guess departure (Russia) have also the higher bias corrections
- The bias corrections are in the “right” direction but the amount is too low

First-guess departure T bias correction





- Station 23921, Russia
- Vertically averaged first guess departure positive at most times
- We expect a bias correction which converges to a positive value of about 0.4K
- The bias correction for this station increases until a value around 0.02K and then decreases (negative fg-departure)
- The bias correction is in the “right” direction but the amount is too low
- **B** too small?
- This is just a start, much development still needed

CONCLUSIONS AND OUTLOOK

- Variational bias correction for temperature for radiosondes is far away from a final solution. For wind a constant parameter could be sufficient
- A different approach as in ERA-INTERIM
- First results: too small bias corrections but in the right directions
- VarBC can be applied where RAOBCORE detects the shifts
- Anchoring using “trusted” radiosondes and nowadays GPS data

Temperature

- Use of a “physical approach” (function of predictors) taking into account grouping of radiosondes
- Different predictors and functions for different groups have to be tested (work in progress)

Wind

- The Bias is normally quite constant over the whole profile
- Larger B_β in order to have faster adjustments

THANK YOU FOR YOUR ATTENTION

QUESTIONS

- Definition of the matrix B_β
- RMS
- Examples Temp

DEFINITION OF B_b

- We do not know the actual error covariances of β (B_β)
- We use B_b to control the adaptivity of the bias parameters:
  - Increase B_b for faster bias adjustments; decrease for slower adjustments
- We take diagonal B_β related to the diagonal of R:

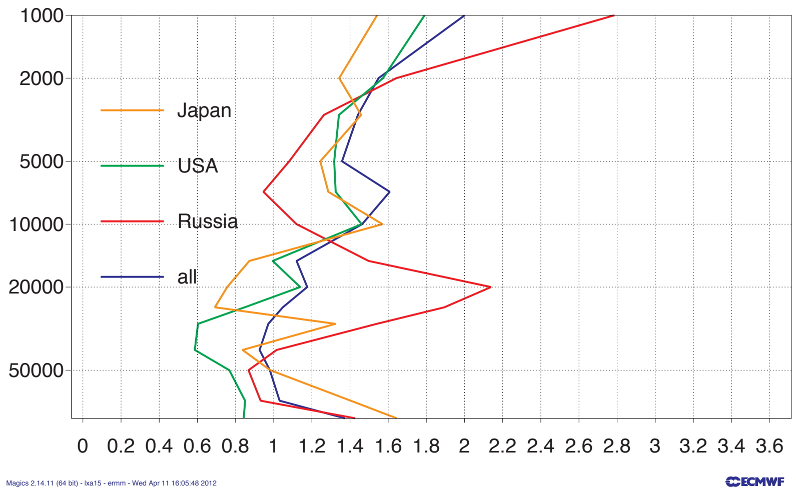
$$\sigma^2_{\beta_i^j} = \frac{\sigma^2_{o^j}}{M^j}$$

for i=1,…,N^j number of predictors for the variable j

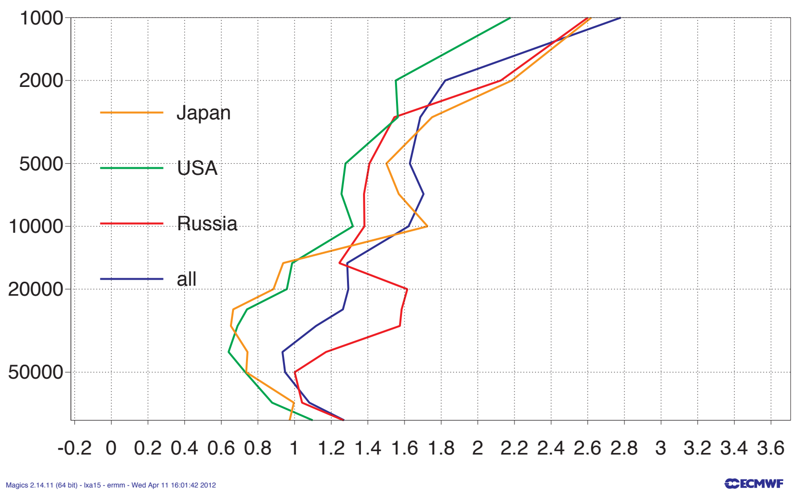
- In this way the part in the cost function related to the bias parameter background constraint for the variable j has the same weight as M^j new observations.

RMS first guess departure T

Night Θ < -7.5°



Θ > 22.5°

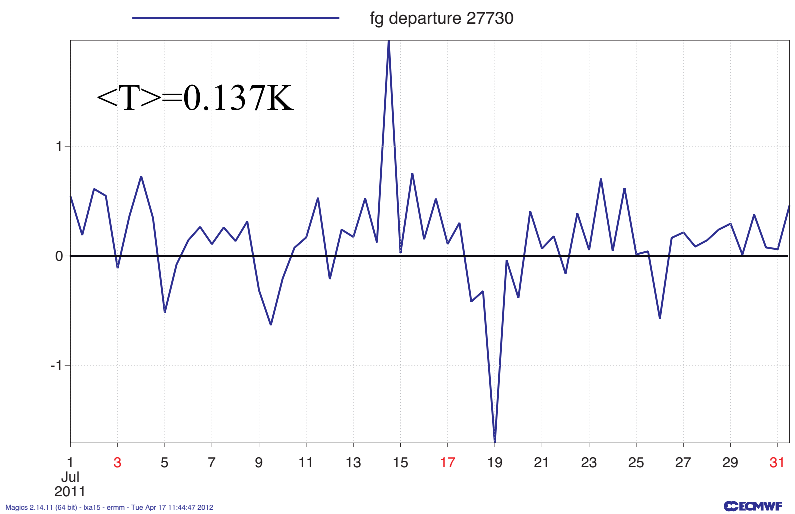


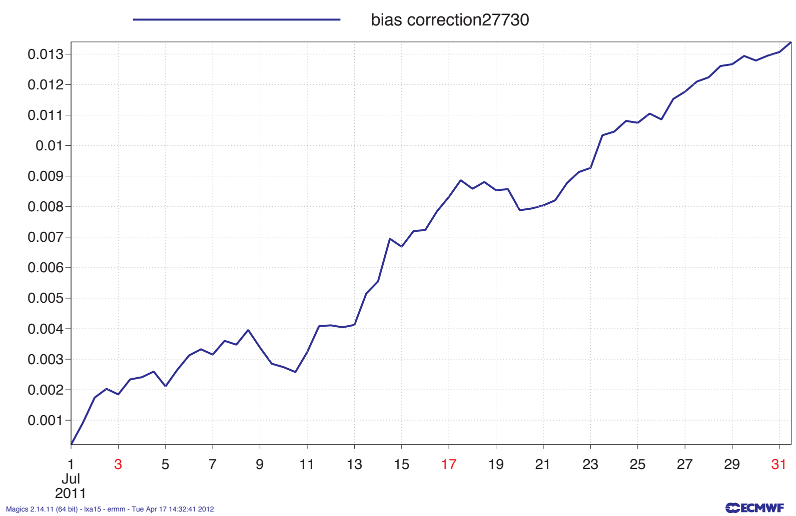
- The negative departures do not counteract the positive departures

$$RMS = \sqrt{\frac{1}{N}\sum_{i}^{N} x_i^2}$$

- RMS give more weight to the larger first guess departure
- The Russian stations has larger RMS in the upper levels and near 200 hPa
- Japanese's stations RMS in the upper levels larger for higher solar angles
- USA stations better than Russian's and Japanese's for Θ > 22.5°
- Groups for different stations are desirable

First-guess departure bias correction





- Station 27730, Russia
- Vertical averaged first guess departure change from positive to negative
- The negative bias corrections could counteract the positive
- The bias corrections could be too slow