VARIATIONAL BIAS CORRECTION FOR RADIOSONDE DATA

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Radiosondes data are often used as reference for other data.

Radiosondes data, especially at high altitudes, are not unbiased due to changes in:
- Change of radiosonde
- Change of locations for the same radiosonde
- Other equipment changes

Vertically constant wind direction bias exists in many radiosondes.

Unadjusted biases affect trends and observations usage.

A bias adjustment is needed to account for all these problems.
• 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
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
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

\[ J(x, \beta) = (x^b - x)^T B_x^{-1}(x^b - x) + (\beta^b - \beta)^T B_\beta^{-1}(\beta^b - \beta) + [y - h(x, \beta)]^T R^{-1}[y - h(x, \beta)] \]

- With \( x^b \) and \( \beta^b \) a priori estimations of model state and bias control parameters
- A large \( B_\beta \) 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.
• 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

Wide areas with wind direction bias over Asia

Isolated stations which have strong influences on the analysis

Gruber and Haimberger, 2008

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

\[ b_j(\beta) = \beta_0 \]

- Constant wind direction bias parameter for the whole profile of each station
- One constant predictor
- Problem:
  - Model: $u,v$
  - Control variable in cost function: wind direction
- Transformation:
  From $u,v$
  $\rightarrow$ Wind direction
  $\rightarrow$ Bias model
  $\rightarrow$ Bias back to $u,v$
• 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
• 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
INFLUENCE OF THE ANGULAR MOMENTUM ON THE WIND

- 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 $T$

- 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
1. Bias model

\[ b_j(\beta) = \beta_{0,j} + \beta_{1,j} \log(p/p_s) + \beta_{2,j} \log(p/p_s) f(\theta) \]

\[ f(\theta) = 0.5 \times (1 + \tanh(a\theta + b)) \]

- 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

\[ b_j(\beta) = \beta_0 \]
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2. No functional relationships, instead estimate \( \beta_0 \) for different pressure layers, solar elevations and station groups
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3. First results (test) using only a vertically constant bias parameter valid for all solar elevations

\[ b_j(\beta) = \beta_0 \]
Bias adjustment

- 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
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 $B_\beta$ in order to have faster adjustments
THANK YOU FOR YOUR ATTENTION
• Definition of the matrix $B_\beta$
• RMS
• Examples Temp
DEFINITION OF $B_b$

- We do not know the actual error covariances of $\beta$ ($B_\beta$)
- 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 $B_\beta$ related to the diagonal of $R$:
  \[
  \sigma^2_{\beta^j_i} = \frac{\sigma^2_{o^j}}{M^j}
  \]
  for $i=1,\ldots,N^j$ 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.
The negative departures do not counteract the positive departures.

RMS give more weight to the larger first guess departure.

The Russian stations have 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 $\Theta > 22.5^\circ$.

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

\[ <T> = 0.137 \text{K} \]