GRAS SAF CDOP VISITING SCIENTIST REPORT

Concern:	Visiting scientist at ECMWF within the GRAS/SAF project GRAS SAF CDOP-1 VS10
Title:	Impact of GPS-RO on the variational bias correction of radiosonde temperature measurements
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Date:	11 June 2013

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1 Introduction

Radiosonde observations have been a valuable dataset to represent the atmospheric upper air conditions since the late 1950s. Even with the introduction of satellite data in the 1970s there was still the advantage of the high vertical resolution in the radiosonde observations. During the history of radiosonde observations the quality of the used instrument types changed. Up to this day there are different instrument types used and intercomparison experiments as well as comparisons to reanalysis data sets have shown that some instrument types have systematic biases especially observing temperature in the stratosphere (see Haimberger, 2007). Systematic biases in radiosonde observations also exist due to technical problems and due to the station setup.

With the introduction of the GPS radio occultation (GPS-RO) dataset in the early 2000s a high quality dataset with a high vertical resolution became available. This allows to introduce an effort of setting up a variational bias correction (VarBC, Dee and Uppala, 2009) scheme for radiosonde data since the GPS-RO data could replace the radiosonde data as a model anchor due to their high quality and high vertical resolution.

A VarBC for radiosonde data would not only be useful to handle systematic biases due to instrument types in the current forecasting system but would also be a useful tool for bias correction within the new reanalysis effort ERA-Clim carried out at the European Centre for Medium-range Weather Forecasts (ECMWF).

The proposal is to study the impact of GPS-RO measurements on the variational bias correction of radiosonde temperature measurements.

2 Aim of work

The objectives behind this work are an investigation whether GPS-RO measurements can "anchor" the variational correction of radiosonde temperature measurements and compare with the impact of aircraft measurements.

The aim of the visits at the ECMWF funded by the GRAS/SAF project was to progress the development of a variational bias correction scheme for radiosonde data.

Such a system will allow to adjust systematic biases within the 4D-Var assimilation system. The chosen parameters for bias correction were:

- Wind direction bias: A constant bias throughout a radiosonde profile. This was choosen as first parameter since it is a constant bias for each radiosonde profile and there is evidence that such a bias exists due to technical issues (e.g. a wrong north alignment of a radiosonde station). The existence of this type of bias could be shown by comparing radiosonde station data to background data from a reanalysis data set (see Gruber and Haimberger, 2008) especially when constrained by GPS-RO data.

- Temperature bias: Due to the development in temperature sensors a bias dependent on the instrument type used at each radiosonde station can be detected comparing different radiosonde types with each other as well as through comparison with reanalysis data. This bias is a vertically non-constant bias and depends on the vertical height of the observation, with larger biases found in higher levels.

To estimate the quality of different radiosonde instrument types an intercomparison to GPS-RO data will be used (see for example Rennie, 2010). These intercomparisons are a nice tool since the GPS-RO dataset is a reference dataset that covers the whole globe. The same high quality observations can be compared to different sonde types currently in use in different countries.

Once the system is set up there will be experiments to show the benefits of such a system as well as to discuss the anchoring of the model. This is so far done using (mainly high quality) radiosonde observations. Subjecting all radiosonde observations to a variational bias correction will not make them suitable as an anchor for the model anymore. GPS-RO data should be able to replace the radiosonde observations regarding the anchoring of the model since they are a high quality dataset with high vertical resolution. Additionally a VarBC scheme for aircraft temperature observations was developed at ECMWF and implemented in cycle 37r3. With this running GPS-RO information will be the main source of information to anchor the model so it's performance will be very valuable for the analysis and forecast of the atmospheric fields.

3 Progress during the Visits at ECMWF

There were two visits at ECMWF as a visiting scientist for a period of two weeks each funded by the GRAS/SAF project. These were mainly used to set up the variational bias correction system for radiosonde data and to discuss possible experiments to show the outcome. Especially for initial coding and the experiment setup it was necessary to be at the ECMWF to draw advice of the experts on VarBC in the data division.

Progress during the first visit in May 2010 The coding work on the newly built VarBC module for radiosonde wind direction bias correction was started. We started with the wind direction correction since it is a constant bias throughout a whole radiosonde profile. The grouping of the data was discussed as this is a critical thing when setting up a VarBC system. Different technical problems were solved with the help of the staff at ECMWF. Next to the coding investigations on the bias behavior of different radiosonde types compared to GPS-RO data started.

Progress during the second visit in May 2011 The coding for the VarBC module on wind direction was further developed after solving some technical issues within the adjoint and tangent linear code. There were ongoing discussions about the parameter settings within the VarBC and discussions on the possible grouping of the data for the radiosonde temperature bias correction. An old grouping scheme was revised that uses the country code of each observation as well as the information about the instrument type to group the data. The instrument type seemed useful information especially for the temperature since comparisons of different radiosonde types to GPS-RO observations are available to allow a better understanding of the quality of the different radiosonde types.

Further progress after the visits at ECMWF Testing on the VarBC module for radiosonde wind direction started and different experiments were carried out to show the impact of certain parameter settings. Large artificial wind direction biases were introduced to selected stations and will be used for case studies.

Work on the VarBC module for radiosonde temperature is ongoing with the challange of dealing with a vertical non-constant bias ahead. This work will now be carried out within the ERA-Clim project by Marco Milan from the University of Vienna.

Currently a lot of work is put into the upgrading to the current model version cy38r2 which uses a new observation database.

4 Results

4.1 Experiment setup

First experiments were carried out using the VarBC scheme for wind direction. The experiments used different setups. One option was to only apply VarBC on non Vaisala RS92 (a high quality radiosonde instrument type) radiosondes only. There were also experiments with/without aircraft VarBC and the usage of GPS-RO data was turned on and off.

4.2 First results

First results are shown as comparison plots to a control run which used the same model version and settings, only the VarBC for radiosonde data was turned off. The plots all show the standard deviation and the bias of the analysis and background departures for wind direction in a vertical profile.

The plots show statistics for a 10 day period from 1 December 2012 to the 10 December 2012 and show all radiosonde wind data used in the assimilation system. During this time periode there was not a big influence of the radiosonde VarBC for wind direction eith the standard deviation of analysis and background departures almost equal and some changes in the bias on a global scale (Fig. 5.3 and Fig. 5.4).

If the GPS-RO data is excluded from the experimental run there seems to be a bigger influence of the bias correction on the wind direction bias. This is best visible looking at higher vertical levels. Figures 5.1 and 5.2 show the same statistics as Figures 5.3 and 5.4 but a clearer difference between the control run (which is identical for both experiments) and the experimental run is visible when looking at the bias profiles.

5 Conclusions and further outlook

The aims of the VS activity were to implement and test a bias model for Varbc of radiosonde temperatures within the Integrated Forecast System (IFS) at ECMWF. This task is not finished so far. There has been a lot of progress on the Varbc radiosonde system for wind direction and further work on the Varbc for radiosonde temperature is done within the reanalysis project. The second task was to test, with a series of observing system experiments, the Varbc of a part, or of the complete radiosonde temperature observing system. The experiments will be performed with/without GPS-RO and aircraft data. Experiments have been carried out for radiosonde wind Varbc but so far not for radiosonde temperature Varbc since this is still under construction. Once finished the plan is to publish the results of different experiments.

Follow up work is done within reanalysis projects to assess the possibility to use variational bias correction of radiosondes in a reanalysis context, prior to the availability of GPS-RO measurements.

Upcoming results should lead to interesting findings which will be published with a reference to GRAS/SAF.

References

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Rennie, M.P., 2010: Investigation into the consistency of radiosonde and GPSRO observations and their application in NWP at the MetOffice. *Forecasting R&D Technical Report No. 541*

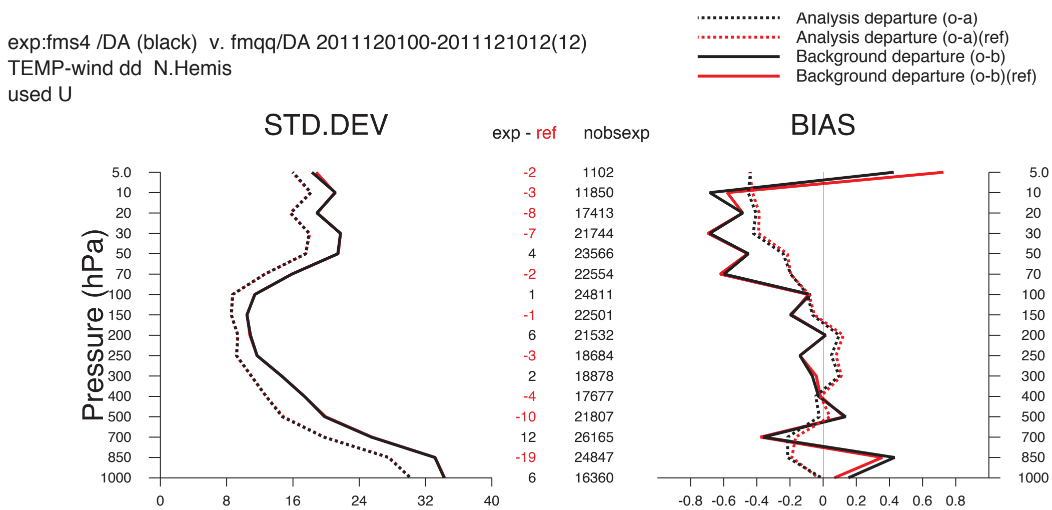

Figure 5.1: Comparison of the standard deviation (left) and the bias (right) for an experimental run with radiosonde VarBC and no GPS-RO data (black) agains a control run (red) over the Northern Hemisphere.

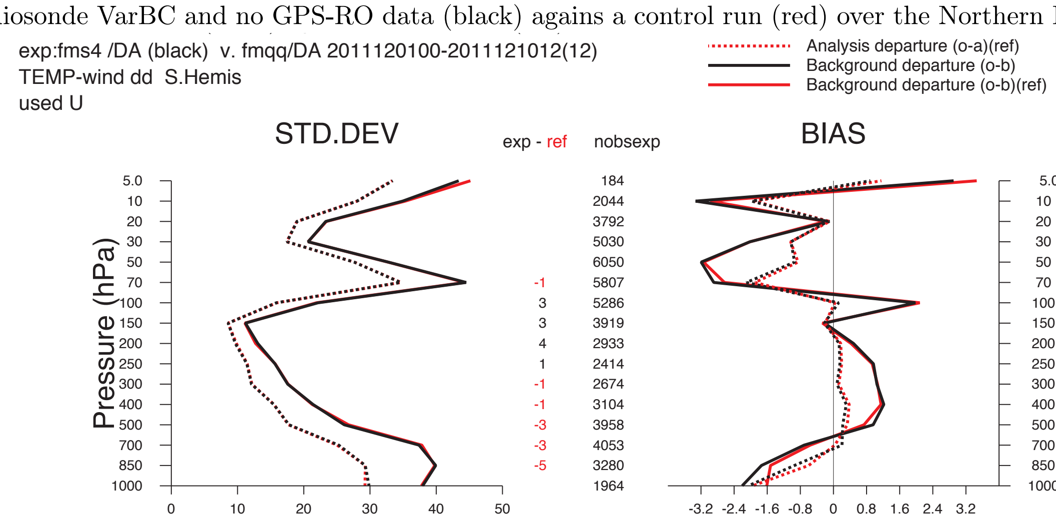

Figure 5.2: Comparison of the standard deviation (left) and the bias (right) for an experimental run with radiosonde VarBC and no GPS-RO data (black) agains a control run (red) over the Southern Hemisphere.

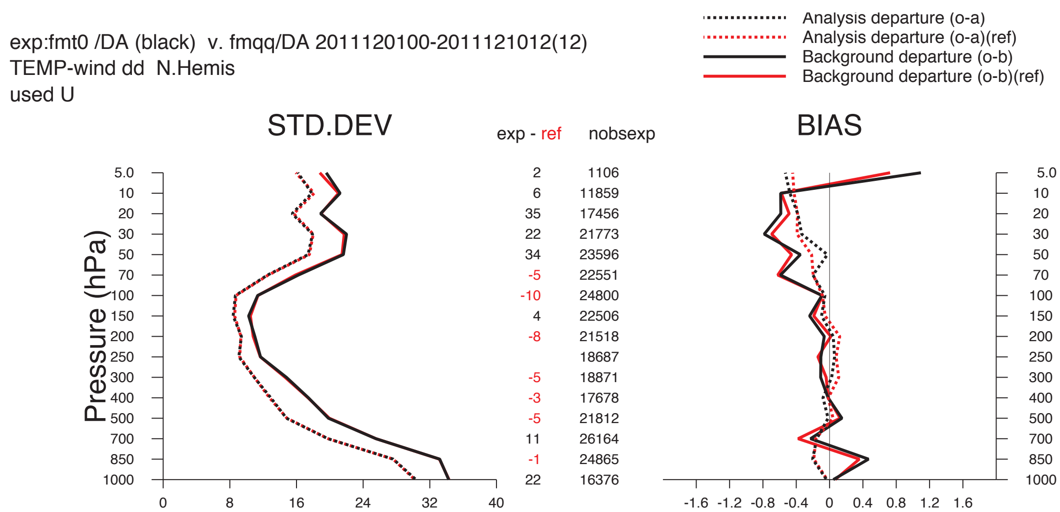

Figure 5.3: Comparison of the standard deviation (left) and the bias (right) for an experimental run with radiosonde VarBC (black) agains a control run (red) over the Northern Hemisphere.

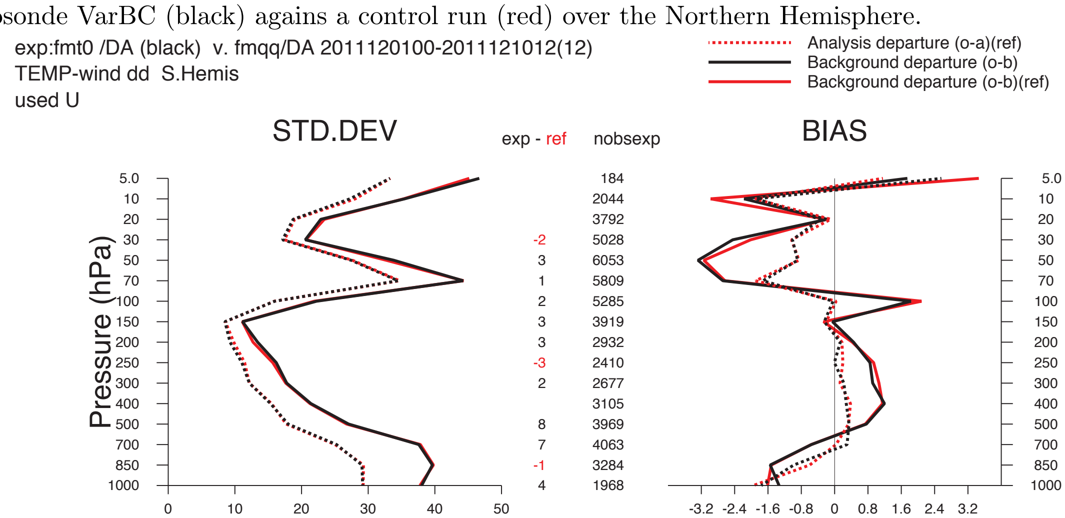

Figure 5.4: Comparison of the standard deviation (left) and the bias (right) for an experimental run with radiosonde VarBC (black) agains a control run (red) over the Southern Hemisphere.