GRAS SAF CDOP VS4 Report

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(Michael Gorbunov visit at DMI 16 Nov - 6 Dec 2008)

RO data processing Occ package: updates and enhancements

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1. Purpose:

The purpose of the visit consisted in updating RO data processing package Occ, including Occ and Invert programs, in order to reduce biases in O-B/B stat for CHAMP and GRAS observational data.

2. Overall Summary:

We investigated the overall program design to establish possible leaks, inaccuracies and inconsistencies. Also, an attention was paid to the enhancement of the options set in order to give more possibilities in controlling the data processing chain parameters.

3. Updated Code:

Updated programs Occ (version 16.3.350, 04 Dec 2008) and Invert (version 2.3.027, 04 Dec 2008) have been supplied. The following updates of the code were made:

3.1. Enhanced accuracy in the Abel integral for the computation of background bending angles from background refractivity profile.

3.2. Enhanced overall consistency of the data processing chain. The background refraction angle profile is computed up to a height of 150 km and merged with the measured refraction angles. The overall merged profile is then consecutively used in the program. This allows for the reduction of the initialization errors at large heights.

3.3. The format of inf-files was updated, which now include the complete set of active options.

3.4. Option –fit=hmin,hmax was added. This option allows the direct specification of the height interval for fitting background refractivity profiles when using MSIS for the initialization.

3.5. Option –earth=sphere|ellips|geoid was added. This option allows the choice of the Earth's (mean sea level surface) shape (spherical, ellipsoidal or geoidal). The former two options are most convenient for numerical simulations. The latter option is most important for the comparisons of NWP data with observations.

3.6. Option –so=olc|lcso,sigma was added. This option allows the choice of the statistical optimization mode (optimal linear combination or linear combination + statistical optimization). Sigma is the square root of the neutral refractivity variance. This parameter can be chosen to be positive or negative. In the former case it directly specifies the the square root of the neutral refractivity variance, in the latter case the neutral refractivity variance is computed automatically in the framework of the OLC algorithm.

3.7. Small bug corrections.

4. Investigations

In the statistical optimization the optimal solution for the bending angle is obtained as follows:

$$\varepsilon_N = \varepsilon_{BG} + \frac{\sigma^S}{\sigma^S + \sigma^N}\left(\varepsilon_{LC} - \varepsilon_{BG}\right), \quad (1)$$

where ε_N is the neutral atmospheric refraction angle, ε_{BG} is the background profile, ε_{LC} is the noisy linear combination of L1 and L2 refraction angles, σ^S is the estimated variance of $\varepsilon_N - \varepsilon_{BG}$, and σ^N is the variance of the ionospheric noise estimated from the upper parts of refraction angle profiles at heights above 50 km.

Figures 1–4 show examples of the weighting function $\sigma^S / \left(\sigma^S + \sigma^N\right)$ versus height for different choices of σ^S and the relative deviation O-B/B of the retrieved refractivity from the background refractivity profile (which was taken from ECMWF fields). The RO event 0077, March 01, 2004 (UTC 08:09, 79.3°N 126.7°W) was analyzed.

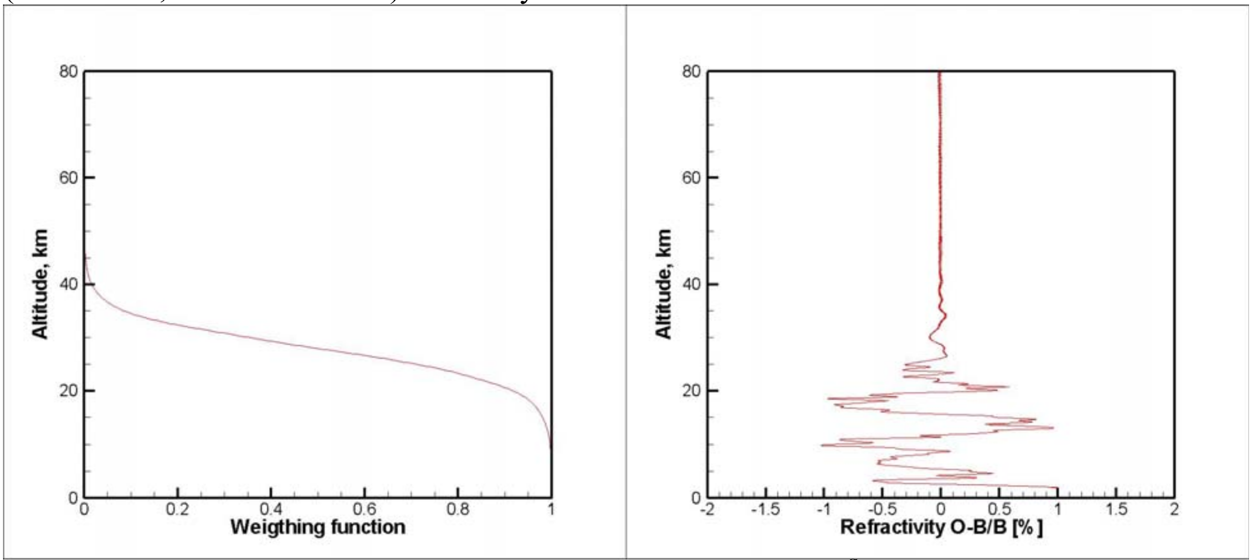

Figure 1. Weighting function of the statistical optimization with $\sigma^S = 0.01$.

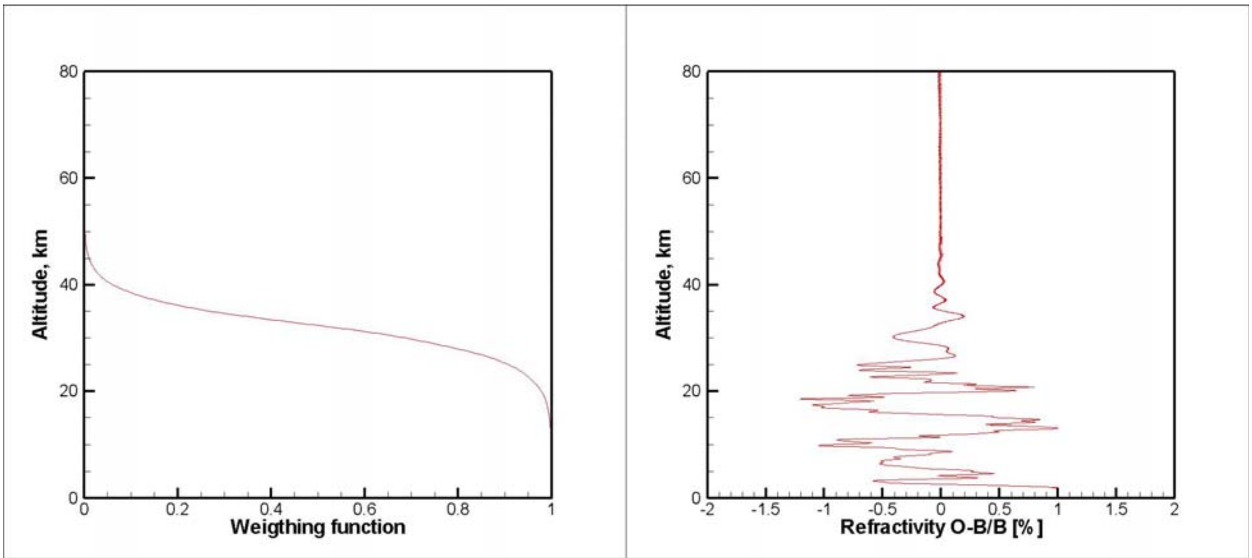

Figure 2. Weighting function of the statistical optimization with $\sigma^S = 0.02$.

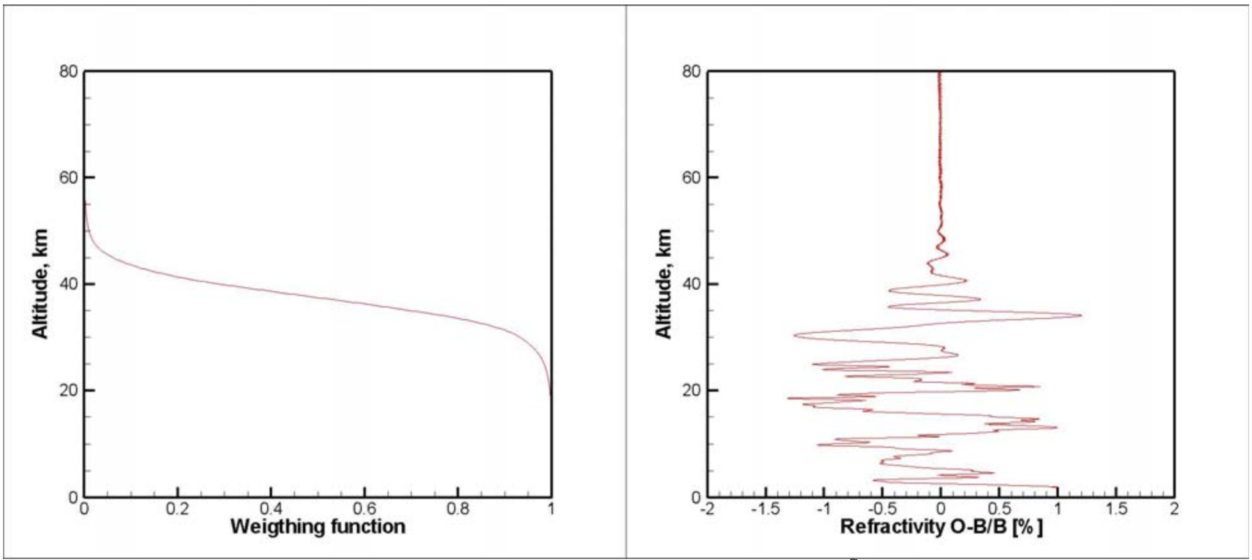

Figure 3. Weighting function of the statistical optimization with $\sigma^S = 0.05$.

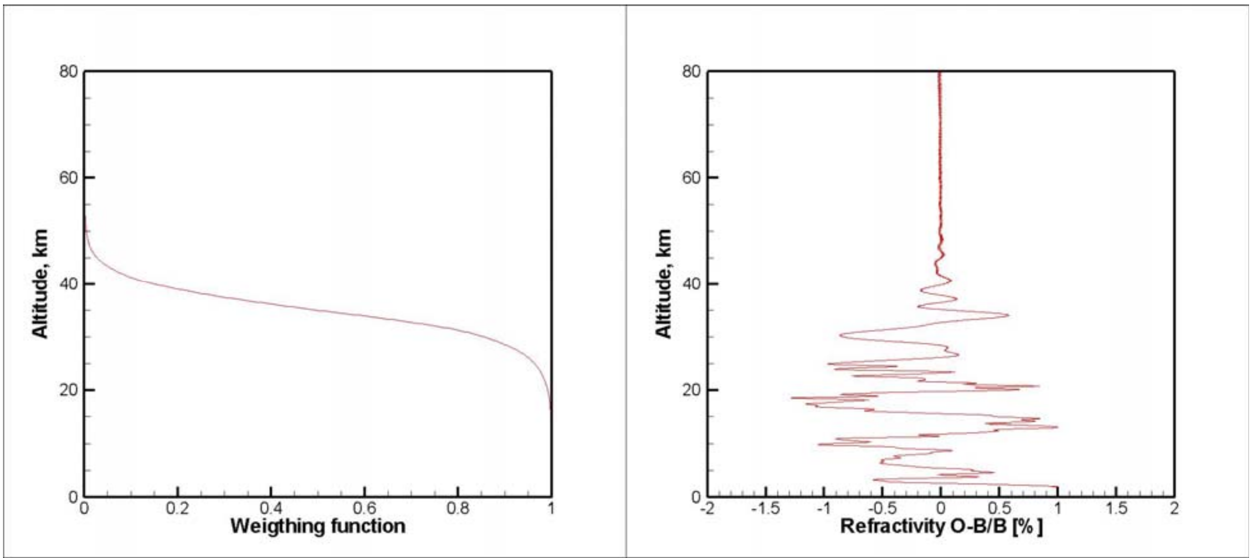

Figure 4. Weighting function of the statistical optimization with automatic choice of σ^S.

The updated version of the package was used for processing one day of CHAMP radio occultation data. As the background we used ECMWF fields. The ECMWF data are given up to a height of about 50 km. Above the upper height of the model data we added MSIS refractivity profiles multiplied with a fitting coefficient. The coefficient was chosen such that the integration of the hydrostatic equation starting at a height of 150 km would result in correct ECMWF temperatures. We performed forward simulations with ECMWF data using the wave optics simulator and the orbit data of the CHAMP radio occultations. We compared local dry temperatures retrieved from CHAMP data with those retrieved from simulated data, bending angles retrieved from CHAMP data with those retrieved from simulated data, and refractivities retrieved from CHAMP data with local ECMWF refractivity profiles. The outliers removal was based on the badness score obtained from the radio holographic analysis of L2 signals and their comparison with L1. The results are presented in Figure 5.

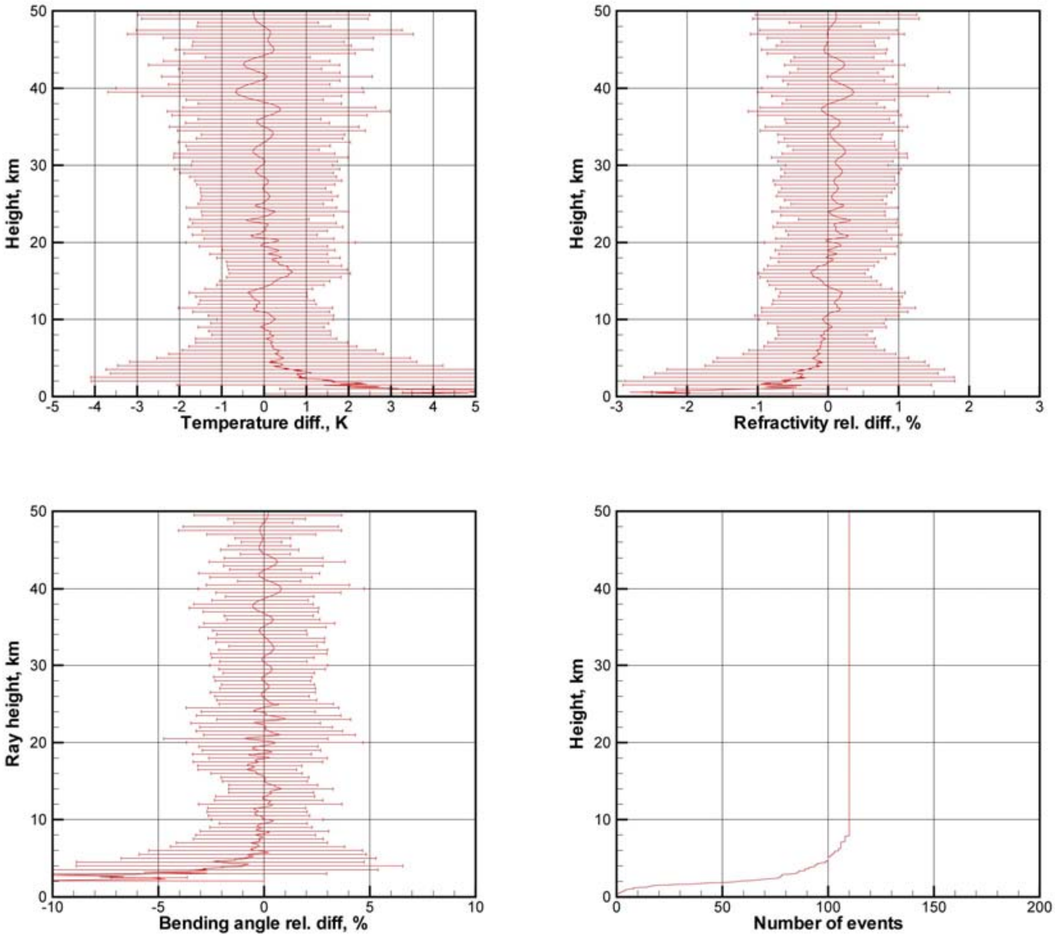

Figure 5. Statistical comparison of CHAMP and ECMWF data for March 01, 2004.

To check for the absence of the bias inherent to the data processing chain (for example, as effect of non-linearity) we performed a numerical simulation, where simulated data were first processed in their original form and then with a realistic ionospheric noise model superimposed. The noise model was generated based on a large number of upper parts of COSMIC radio occultations. The results of this run are present in Figure 6. This figure allows for the conclusion the a random realistic ionospheric noise with zero mean does not result in significant biases.

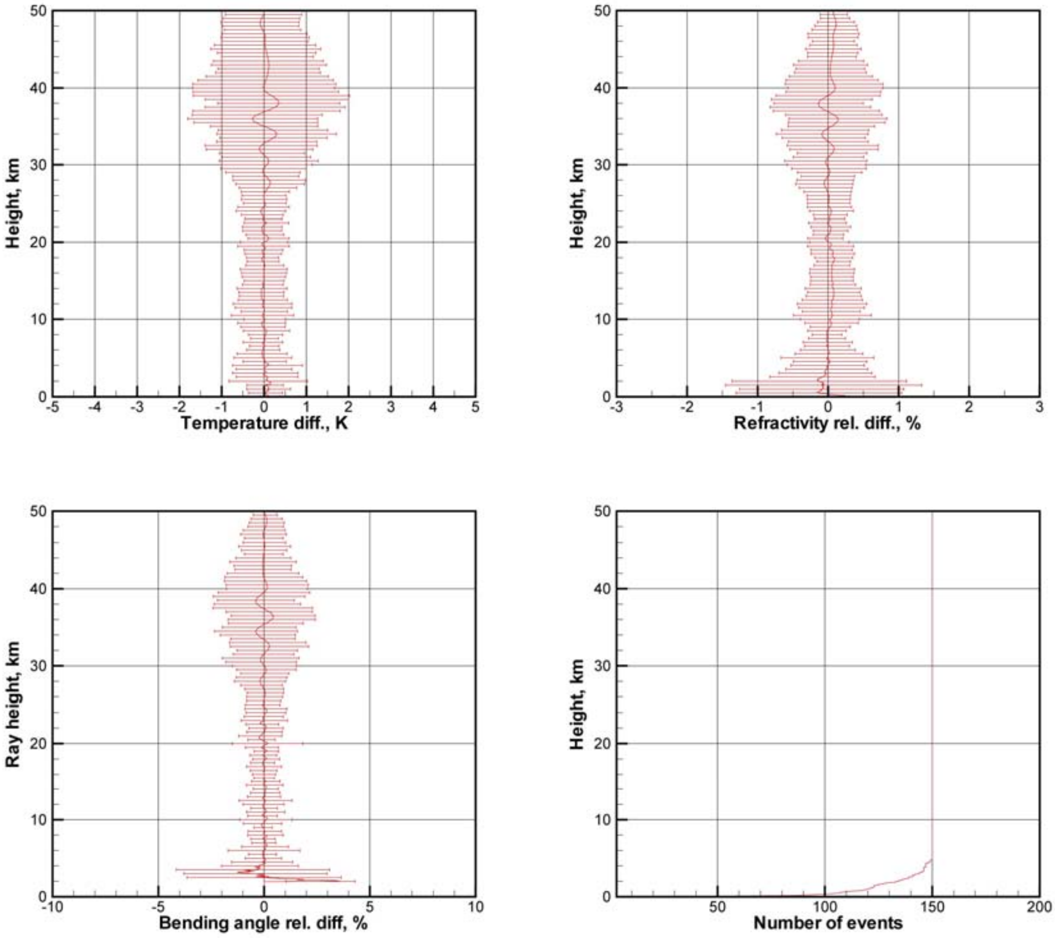

Figure 6. Statistical comparison of simulated RO data for ECMWF (March 01, 2004) with simulated data with a model of ionospheric noise superimposed.

Figure 7 present the results of processing GRAS data for September 06, 2007 with Invert program. The overall design of the computations was the same as that for processing CHAMP data. However, because only bending angles from GRAS can be processed, it was impossible to implement a reliable computation of the badness score. This may explain the larger bias in the refractivity and refraction angles. The accurate outlier removal is included into the plan for the future work.

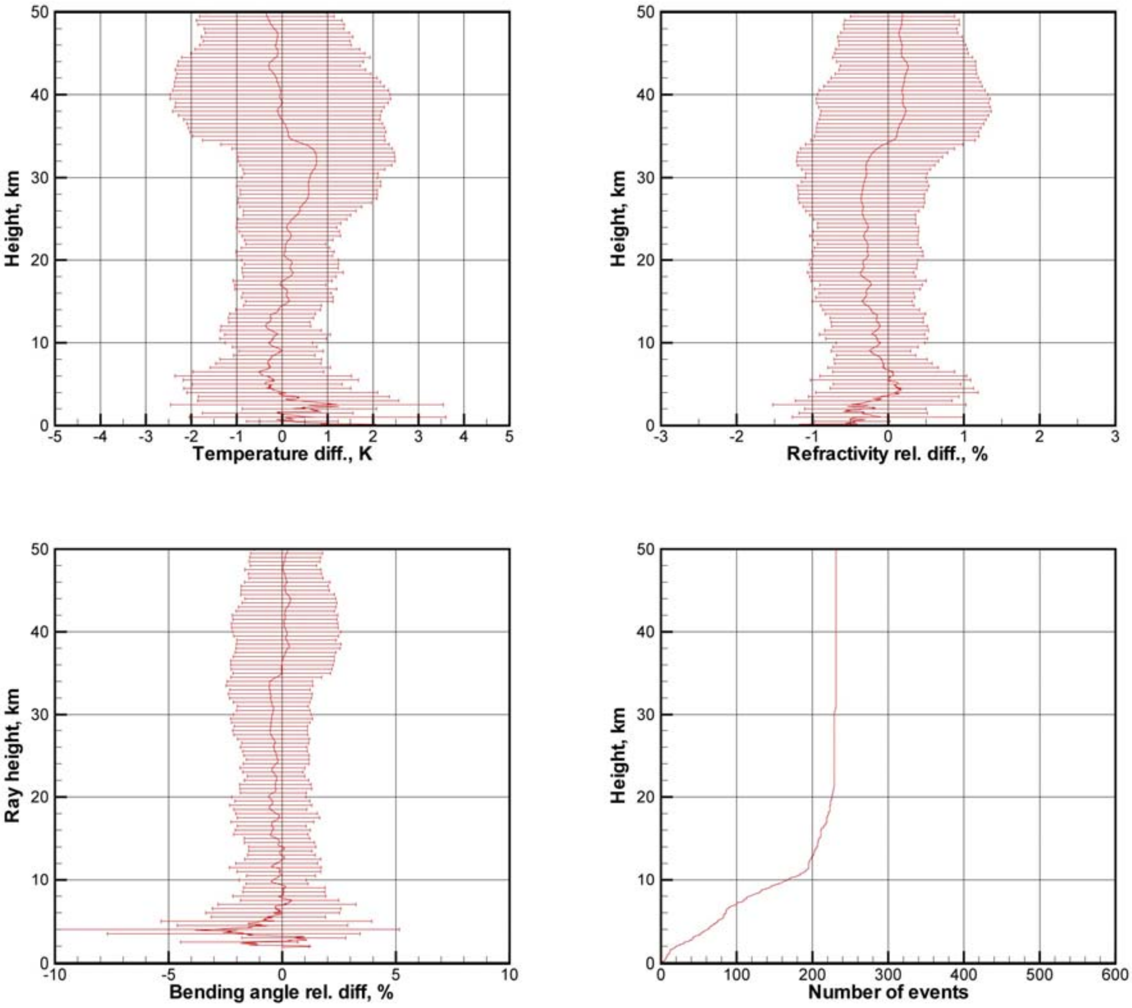

Figure 7. Statistical comparison of GRAS data 06.09.2007 with ECMWF.

5. Future directions:

Following directions are included in the plan for the future work:

- improved logarithmic two-parameter fitting of MSIS background bending angles to enhance the quality of the background;
- generate improved climatology from raw LC data;
- consider obtaining an improved climatology from averaged ECMWF fields;
- statistical comparison of MSIS and ECMWF fields;
- implementation of robust statistical methods.