OPSv5.6 – An Improved Version of the Wegener Center Radio Occultation Processing System and its Recent Reprocessing

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Introduction

At the WEGC we developed an improved version of our occultation processing system, OPSv5.6, and performed a reprocessing over 2001 to 2016 and beyond from data of several RO missions, including CHAMP, SAC-C, GRACE, C/NOFS, FORMOSAT-3/COSMIC, and METOP-A/B. The data record provides a varying number of retrieved high-quality profiles per day, starting from about 100 to 150 profiles in the CHAMP-only era, reaching up to 3000 profiles in the COSMIC era, then decreasing again to about 1500 profiles per day in 2016.

In Figure 1 the basic steps of the OPSv5.6 retrieval processing system are outlined.

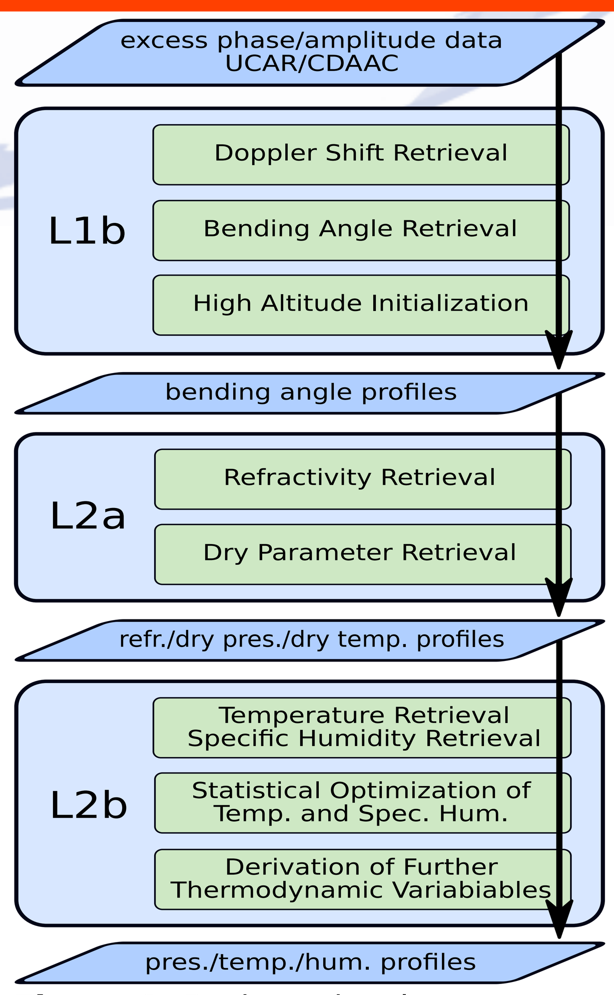

Figure 1: Basic retrieval steps.

Raw Quality Control (QC)

Raw QC - Geometric Optics (GO) + Wave Optics (WO):
- straight-line-tangent-point (SLTA) range: 65 km < SLTA-range < 20 km
- 10 ray average at 20 km, 45 km, and 65 km -> rejected if difference between average and phases are too large

WO only QC:
cut off data at bottom of measurement if:
- amplitude of Coarse/acquisition code (CA)-signal is lower than 10 % of max ampl.
- smoothed GO bending angle (BA) (3 points) exceeds 0.05 rad
- smoothed impact parameter (3 points) below 0 m
- SLTA < -250 km

GO only - BA based QC:
cut off data below 15 km impact height if gradient is too large.
comparison to MSIS-90 climatology; reject measurement if:
- BA < 0 rad below 50 km
- bias relative to MSIS-90 > 10^{-5} rad
- std. dev. relative to MSIS-90 > $5*10^{-5}$ rad

Level 1b Processing

- combined GO/WO retrieval
- WO retrieval using (CT)-2 method (c.f. Gorbunov and Lauritsen 2004[1])
- combination of GO and WO BA's using a Gaussian transition with transition width of 4.5 km and variable center height (7 km - 13 km)
- ionospheric correction: linear combination of BAs; extrapolation of the correction with constant L1 – L2 BA below 15 km
- statistical optimization of the BAs above 30 km using a short-term forecast of ECMWF
- as measurement error the std. dev. compared to the MSIS-90 climatology is used
- the background error is set to 15 % of the modeled BA

Figure 2a+b show the retrieval-to-apriori-error ratio (RAER) for Jan. 2006 (CHAMP only) and Jan. 2014 (METOP A/B and COSMIC dominated) to illustrate the increasing height where the measurements are dominating.
Figure 3 shows the comparison of the OPSv5.6 temperatures compared to temperatures from the SABER instrument for the whole data record to illustrate the changing impact of the ECMWF background over time.

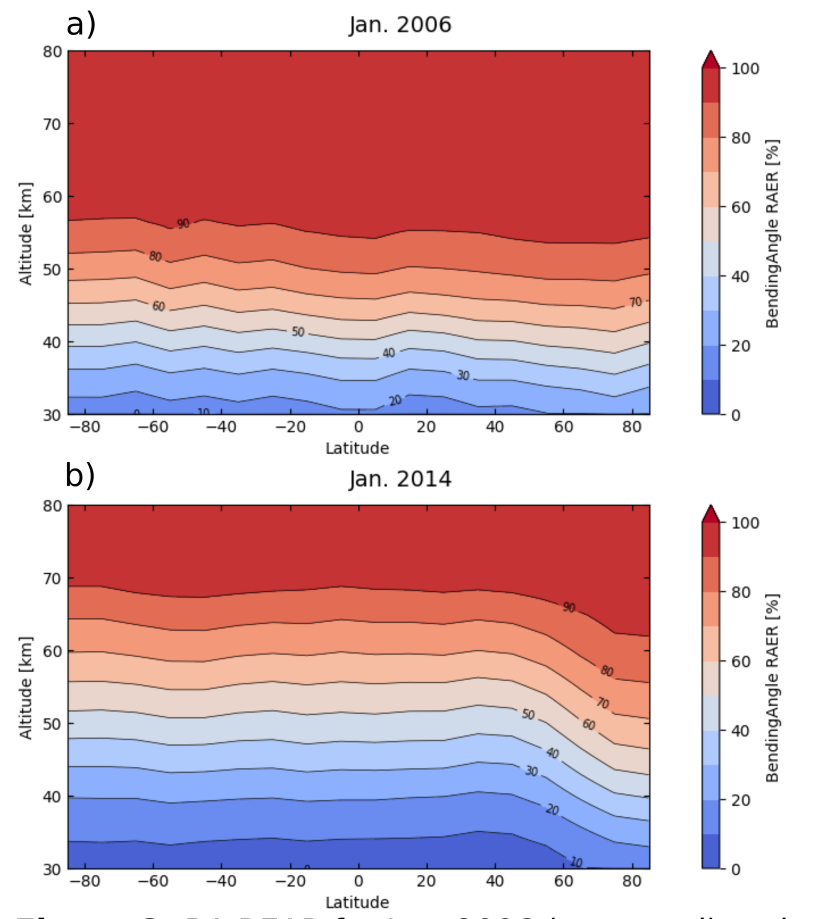

Figure 2: BA REAR for Jan. 2006 (top panel) and Jan. 2014 (bottom panel).

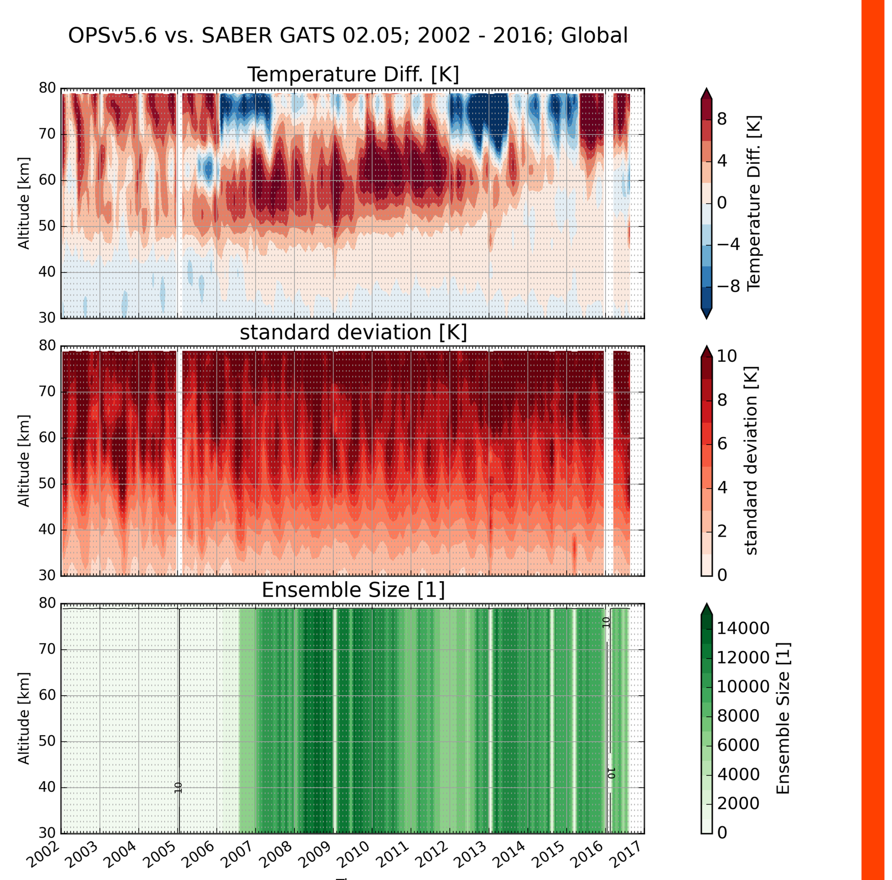

Figure 3: Mean sys. diff., std.dev. and number of measurements for a OPSv5.6 vs. SABER validation.

Level 2a+b Processing

Dry Parameter Retrieval:
- Upper boundary condition for Abel Integral is based on an exponential fit of the topmost 10 km
- Blackman filtering of refractivity
- hydrostatic integral for dry pressure is initialized with background pressure at 120 km
- dry temperature is calculated using the two term Smith-Weintraub formula (K1 = 0.776 K/Pa; K2 = 3730 K^2/Pa)

Physical Parameter Retrieval:
- above 16 km: calculation of physical temp. and pres. using a first order approximation for the ratio between pres. and dry pres.
- below 14 km:
  * retrieval of T and p using a fixed background q
  * retrieval of q and p using a fixed background T
  * stat. opt. of T and q from previous step with T and q from ECMWF short-term forecast fields; background errors from ROPP and measurement errors obtained from Scherllin-Pirscher et al. 2011[2]
- between 14 km and 16 km: sinusoidal transition

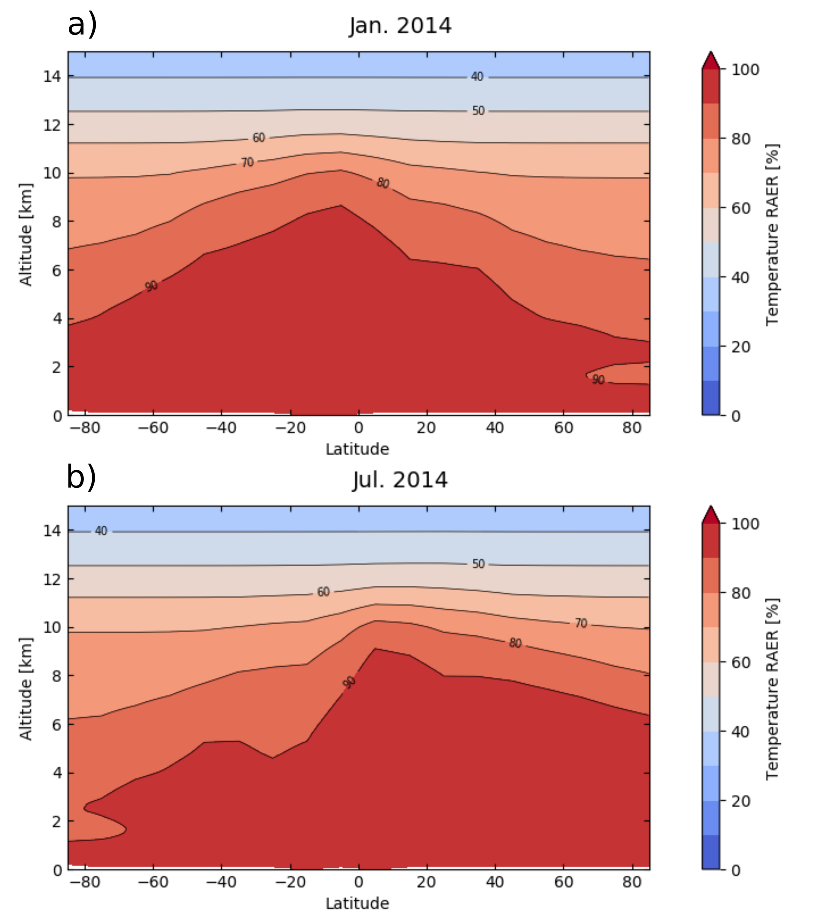

Figure 4: Temperature REAR for Jan. 2014 (top panel) and July 2014 (bottom panel).

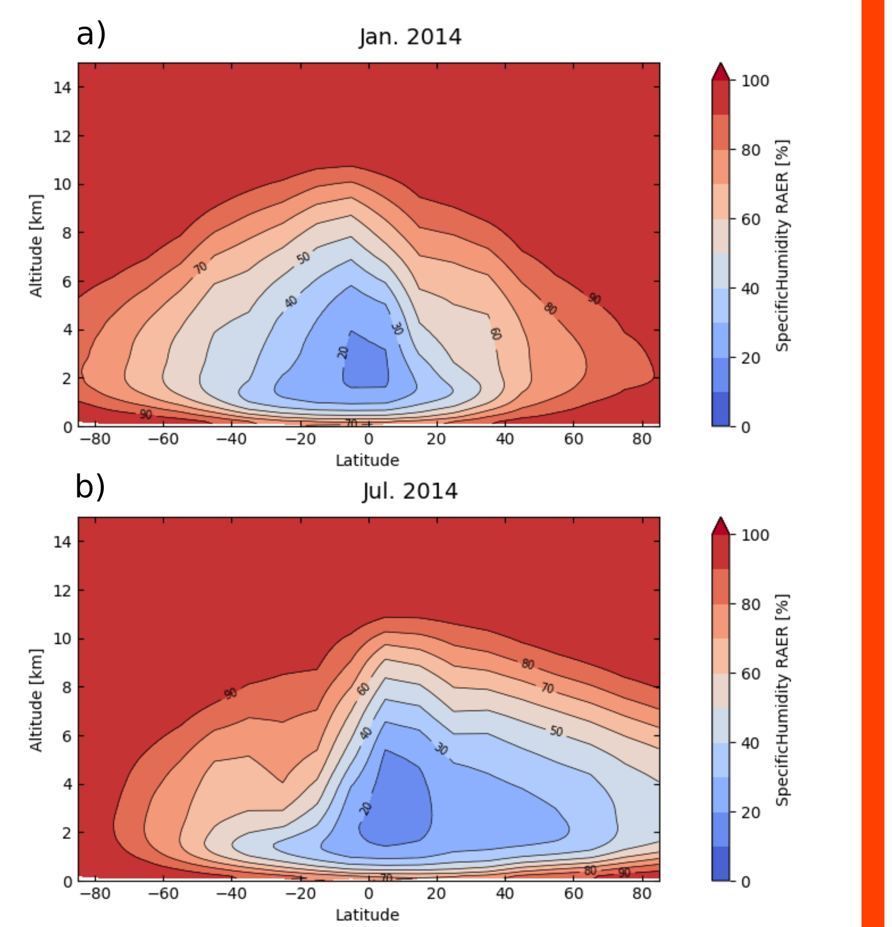

Figure 5: Spec.hum. REAR for Jan. 2014 (top panel) and July 2014 (bottom panel).

Verification with External Datasets and ECMWF

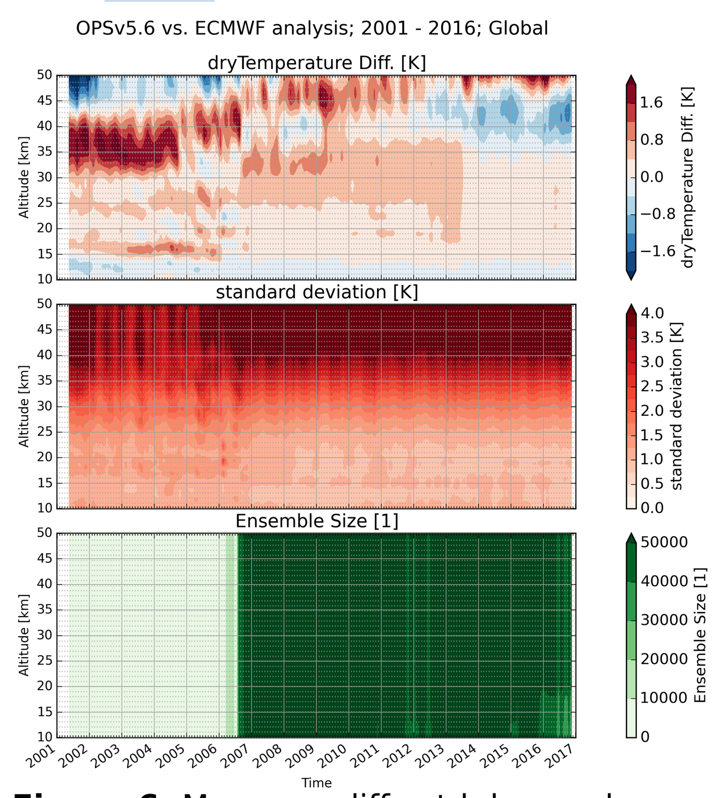

Figure 6: Mean sys.diff., std.dev. and number of measurements for dry temperature between OPSv5.6 and operational ECMWF analysis data.

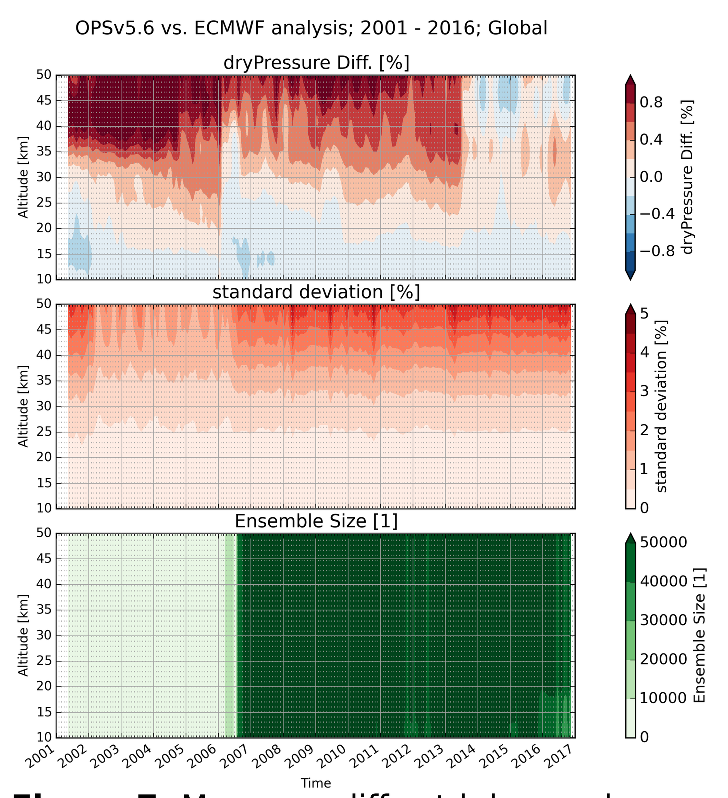

Figure 7: Mean sys.diff., std.dev. and number of measurements for dry pressure between OPSv5.6 and operational ECMWF analysis data.

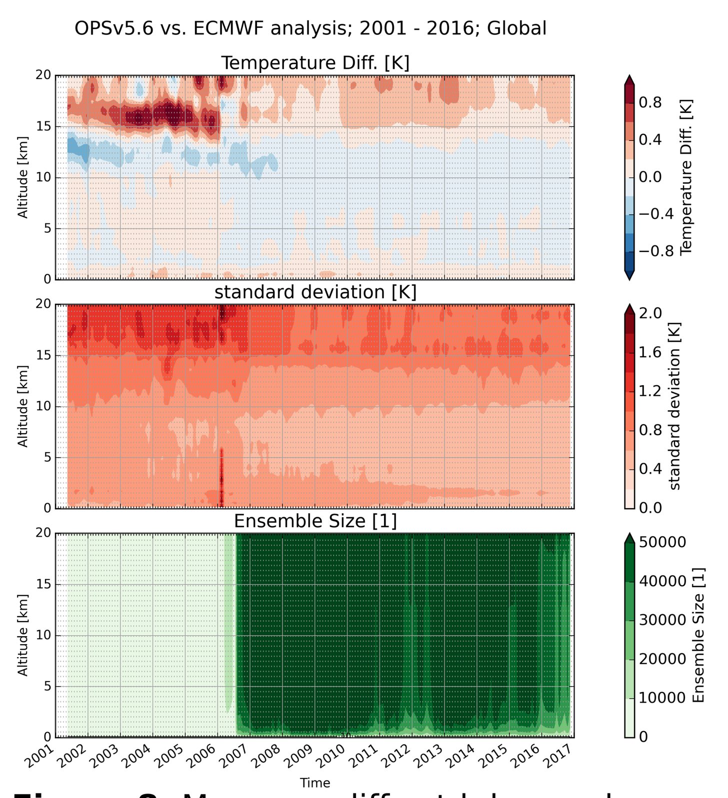

Figure 8: Mean sys.diff., std.dev. and number of measurements for physical temperature between OPSv5.6 and operational ECMWF analysis data.

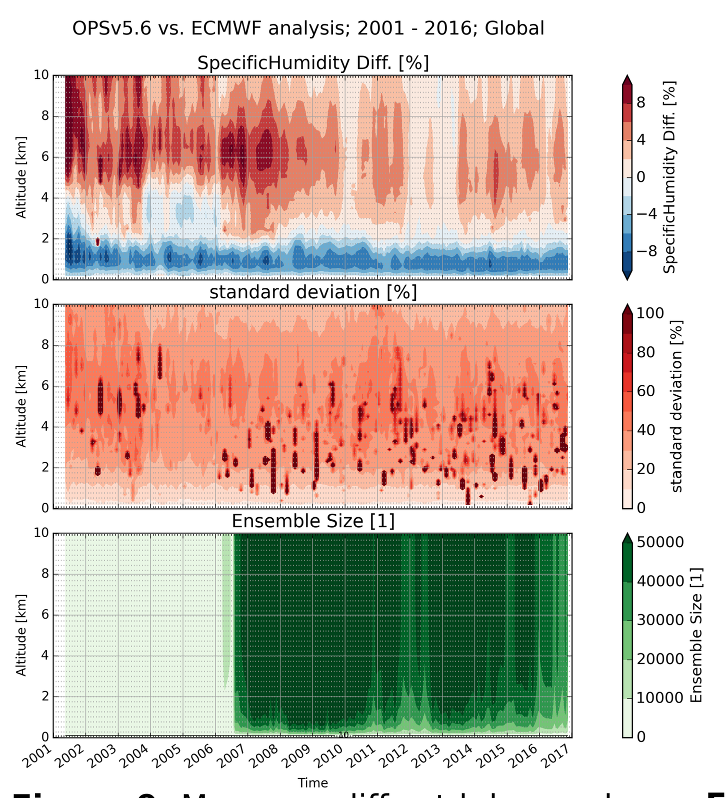

Figure 9: Mean sys.diff., std.dev. and number of measurements for specific humidity between OPSv5.6 and operational ECMWF analysis data.

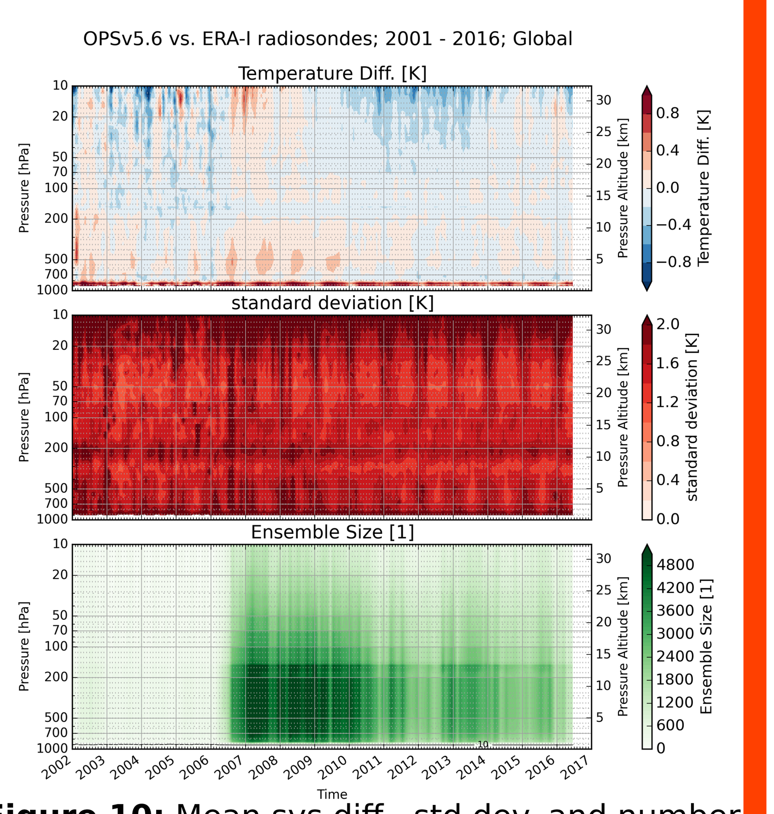

Figure 10: Mean sys.diff., std.dev. and number of measurements for temperature between OPSv5.6 and collocated Vaisala radiosonde meas. from the ERA-Interim archive (ECMWF).

Acknowledgements

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References

[1] Gorbunov, M. E., and K. B. Lauritsen (2004), Analysis of wave fields by Fourier integral operators and their application for radio occultations, Radio Sci., 39, RS4010, doi:10.1029/2003RS002971.
[2] B. Scherllin-Pirscher et al. "Empirical analysis and modeling of errors of atmospheric profiles from GPS radio occultation". In: Atmos. Meas. Tech. 4 (2011), pp. 1875–1890. doi: 10.5194/amt-4-1875-2011 (cit. on pp. 21, 39, 64).

Summary

The OPSv5.6 record is serving as input for a large number of studies regarding the investigation of atmospheric and climate processes, the analysis of atmospheric variability and the detection of climate trends as well as long-term validation of other atmospheric satellite data products such as from the Envisat satellite of ESA.
The OPSv5.6 data, both profiles and climatologies, are currently (Sept.2016) available on request (see e-mail in header); as of 2018 they will become available on-line via a web portal.