Collocating GRAS with AMSU onboard of Metop:
An assessment for instrument and climate monitoring

F. Ladstädter (1,2), H. Gleisner (2), K. Kinch (2), K.B. Lauritsen (2), U. Foelsche (1), T. Rieckh (1), C. Marquardt (3), J. Ackermann (3), and A. von Engeln (3)

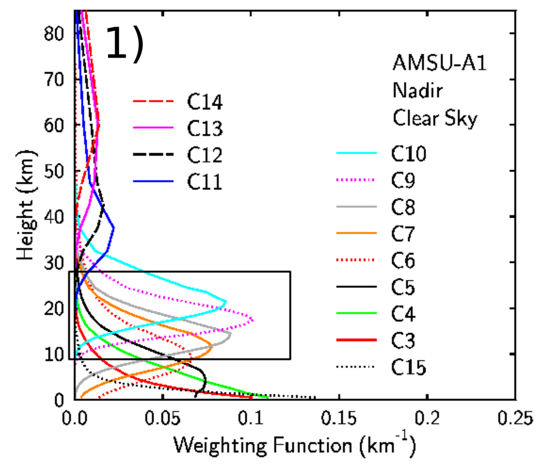
(1) Wegener Center for Climate and Global Change (WegCenter) and Institute for Geophysics, Astrophysics, and Meteorology/Inst. of Physics (IGAM/IP), University of Graz, Graz, Austria
(2) ROM-SAF, Danish Meteorological Institute (DMI), Copenhagen, Denmark
(3) EUMETSAT, Darmstadt, Germany

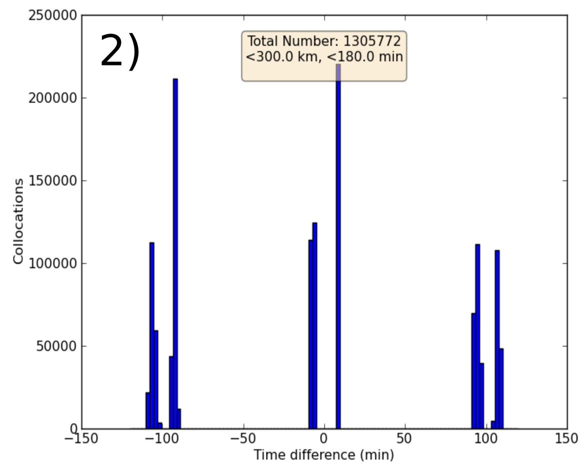
1 Introduction

Knowledge about upper-air temperature trends is still limited as the MSU and AMSU instruments have been the only source for long-term temperature measurements with global coverage for the last several decades. The calibration of time series containing data from only one source is a demanding task and error-prone. Thus trend signals can easily be masked by spurious time-varying biases in climate studies. It is therefore obvious that new, independent datasets are needed to reduce the structural uncertainties involved. In this context, the series of Metop satellites provide unique opportunities to both meteorological and climatological applications. Metop hosts several instruments that are sensitive to the atmospheric temperature profile, including the nadir sounder AMSU and the limb sounding radio occultation (RO) instrument GRAS. This opens the possibility to compare data from different types of instruments with a high rate of collocations while avoiding uncertainties stemming from different sampling characteristics. A number of studies have shown that RO measurements are essentially bias-free. With their inherent low systematic error, RO observations thus provide a unique opportunity for validation and calibration of AMSU data and may also improve the contribution of AMSU to weather forecasting and climate monitoring.

2 Data and Method

The RO technique uses electromagnetic signals transmitted by GPS satellites, which are delayed and refracted by the atmosphere. The measured phase changes of the signals are processed and yield atmospheric profiles. GRAS provides more than 600 occultation soundings per day. AMSU is a 15-channel radiometer and measures layer-average brightness temperatures with a coarse vertical resolution. It covers a swath of ±1026 km width by cross-track scanning. Each scan samples 30 Earth views.
In this study, data of Oct. 2007 are used. The GRAS RO data consist of dry temperature output of ROPP as well as 1D-var physical temperatures. To compute synthetic layer-average brightness temperatures, the RTTOV model is used. The corresponding AMSU data consist of brightness temperatures for the AMSU channels 8, 9 and 10 (upper troposphere/lower stratosphere) (Fig. 1). Collocated ECMWF data are used for reference.





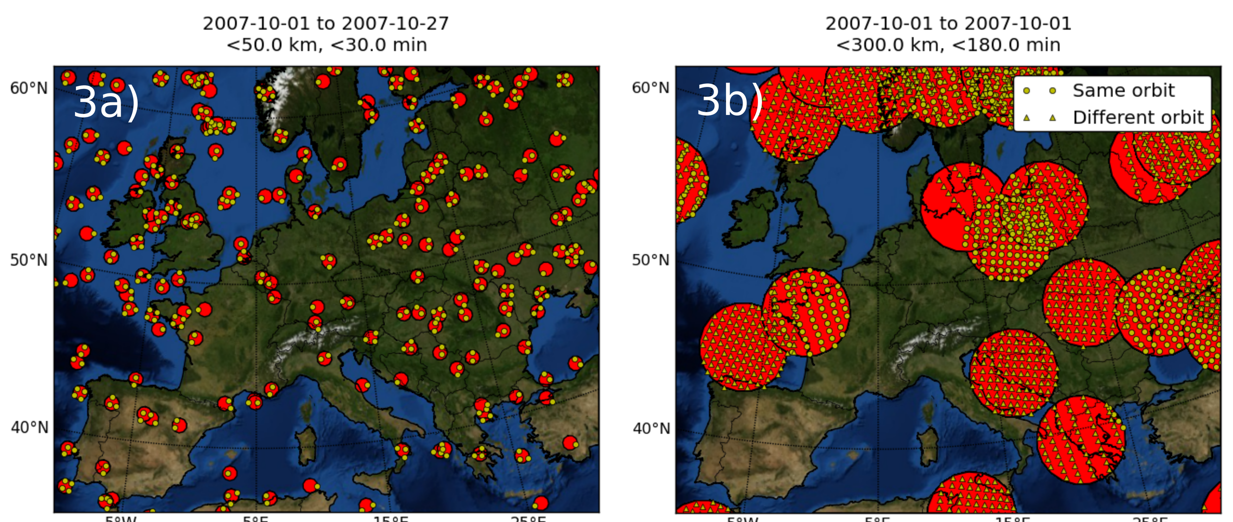


Fig. 3: Collocations over Europe for the whole study time period for the criteria ≤50 km, ≤30 min (a); for one day for the criteria ≤300 km, ≤180 min (b)

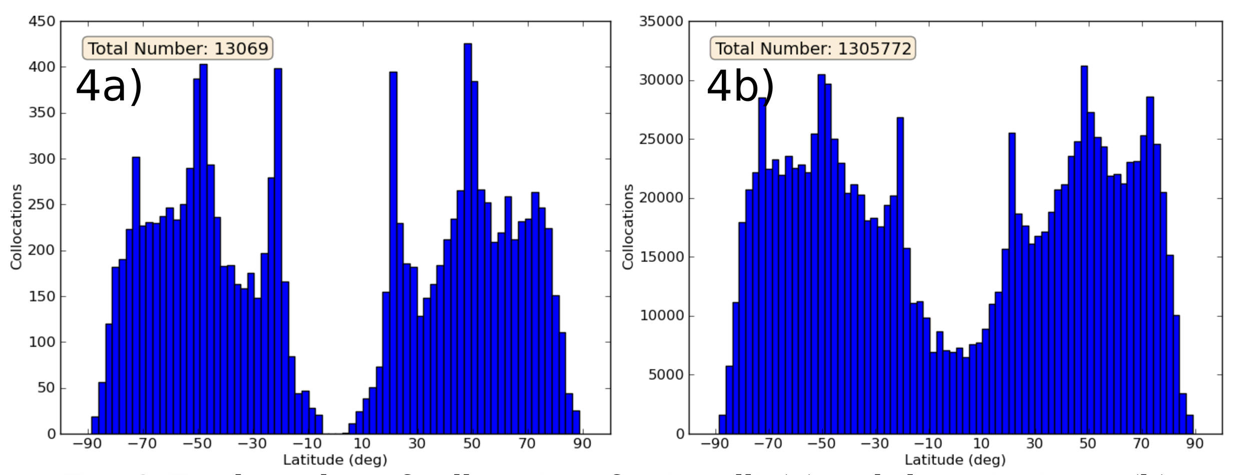


Fig. 4: Total number of collocations for "small" (a) and "large" criteria (b)

GRAS observes the horizon in limb sounding view and most of the occultations are on the AMSU nadir swath. This gives a high number of collocated measurements with a time offset of approx. ±8 min (same orbit) and ±100 min (adjacent orbits, related to the orbit period) (Fig. 2). Approx. 36 % of all RO profiles have collocated AMSU data for the criteria of 30 min, 50 km (Fig. 3a); approx. 92 % of all RO profiles are matched for the criteria of 180 min, 300 km (adjacent orbits also within reach) (Fig. 3b). Due to the occultation geometry, the number of collocations is latitude-dependent and there are no collocations at all near the equator (Fig. 4a). When using the "large" criteria, the equatorial gap vanishes (Fig. 4b). Only results for the "small" criteria are shown in the following.

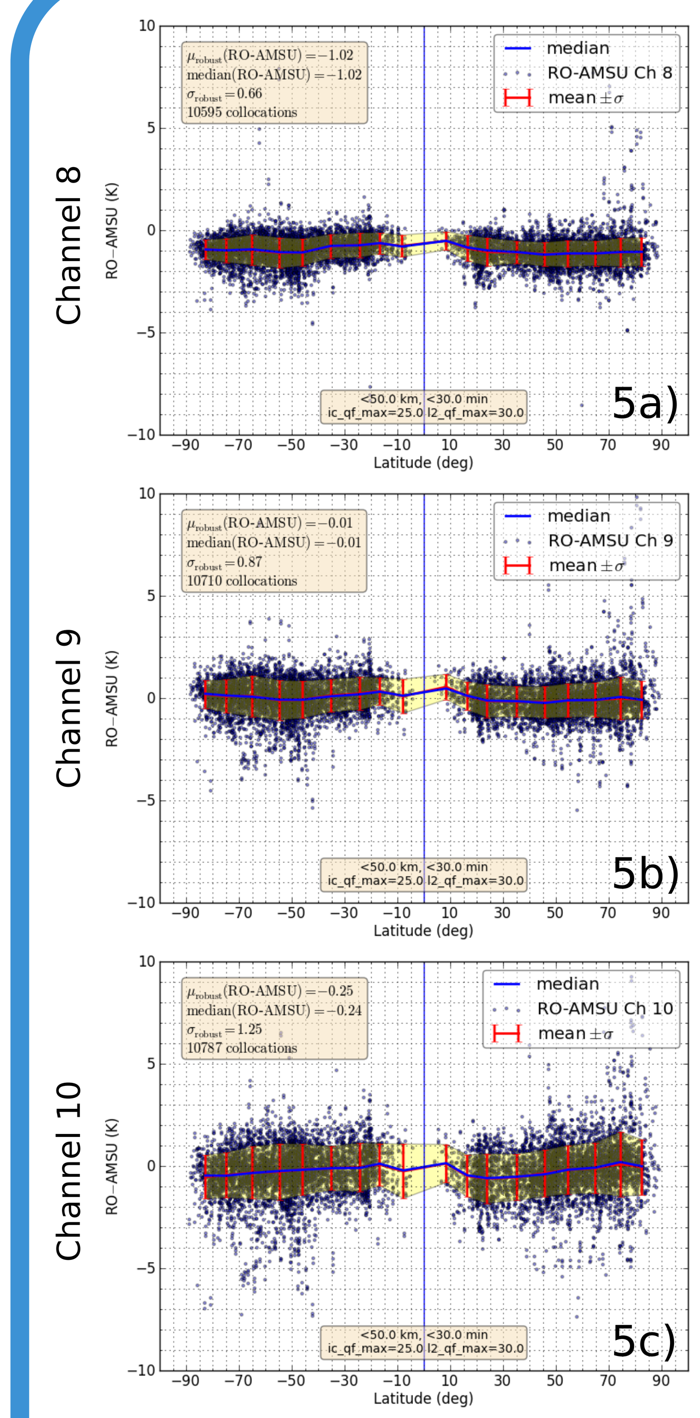


Fig. 5: Differences of RO−AMSU for different channels

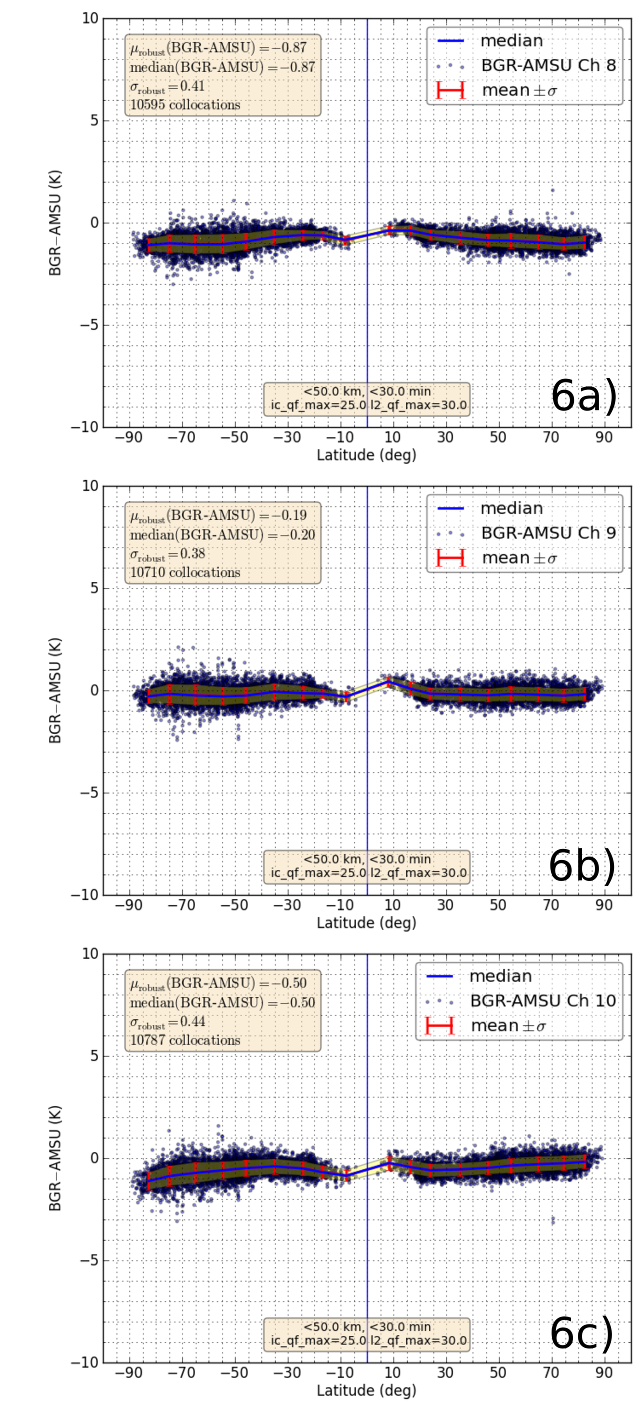


Fig. 6: Differences of ECMWF−AMSU for different channels

[AMSU] The scan range of AMSU is ±48° with respect to nadir. Using tightly collocated RO measurements allows to monitor the bias of AMSU for different pixels (nadir to swath edges). When limiting the maximum zenith angle to ±15°, a bias of about 0.2 K appears while the standard deviation remains mostly unaffected (Fig. 7d).
When checking on a possible asymmetry in scanning in one direction (Fig. 8a) vs. the other direction (Fig. 8b) with regard to nadir, a bias of approx. 0.2 K is found.

3 Results

[BIAS] Comparing collocated RO and AMSU brightness temperatures reveals an overall bias of 1.0 K (Fig. 5a), no bias (Fig. 5b) and -0.25 K (Fig. 5c) for the three different AMSU channels. Collocated long-term stable RO observations can potentially be used to monitor and correct these biases. It is noticeable that the standard deviation increases by about a factor of two when going from the lowest channel 8 to channel 10. Comparing with AMSU and ECMWF differences (Fig. 6a-6c) indicates that this spread stems from increasing RO data noise as an effect of statistical optimization needed to initialize RO profiles at higher altitudes. The small difference between AMSU and ECMWF might be due to the impact of AMSU on ECMWF.
[1D-VAR] Comparing physical temperatures from RO calculated with 1D-var assimilation (using ECMWF forecasts as background) with AMSU (Fig. 7a) reveals a bias of about -0.2 K, while the standard deviation is remarkably small. The differences of 1D-var and ECMWF analyses (Fig. 7b) show very small biases and standard deviation. This agreement is expected due to the large impact of RO data on ECMWF at this height, but should be investigated further.

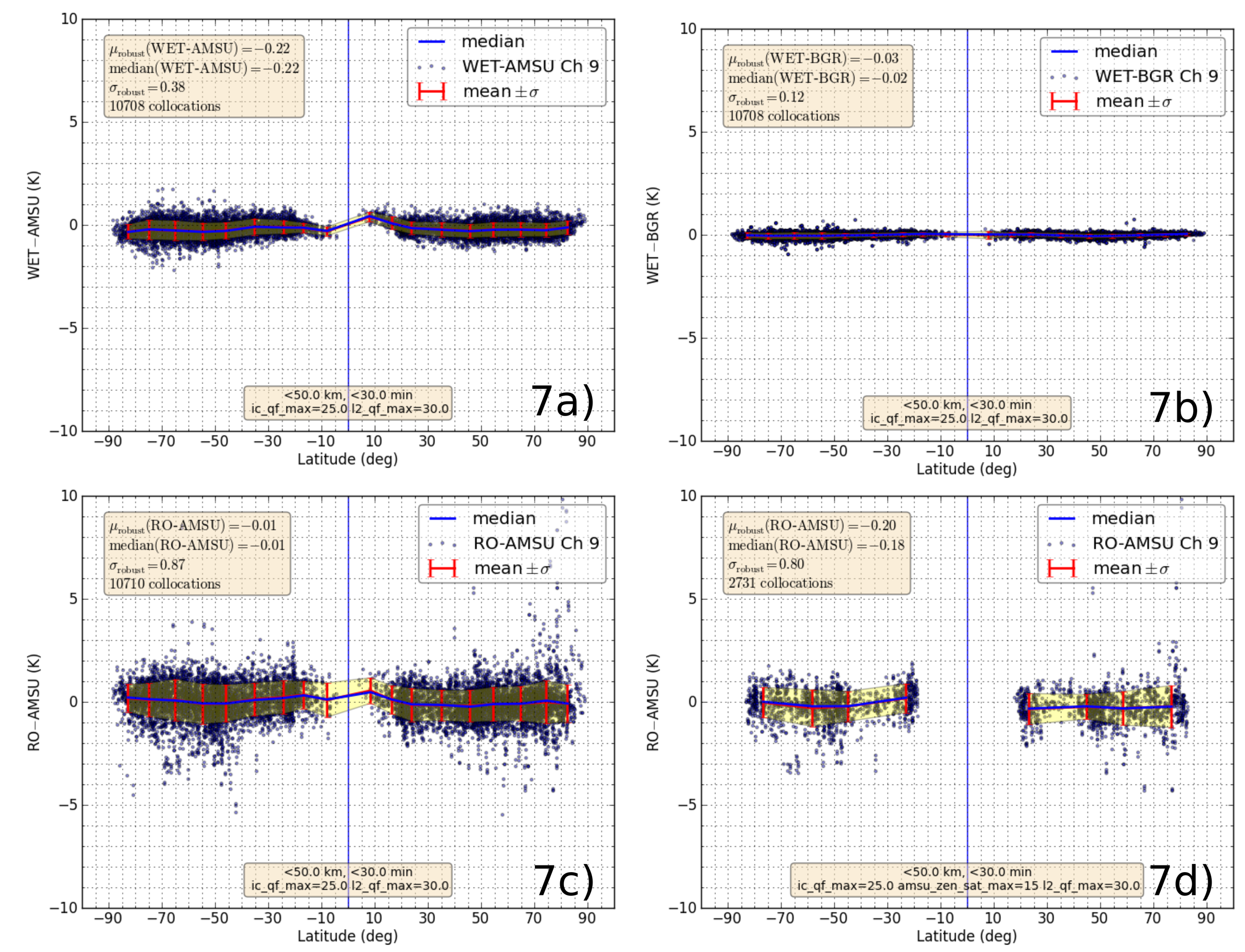


Fig. 7: Channel 9: Differences of 1D-var−AMSU (a); 1D-var−ECMWF (b); RO−AMSU (c); RO−AMSU, zenith angle restricted to 15° (d)

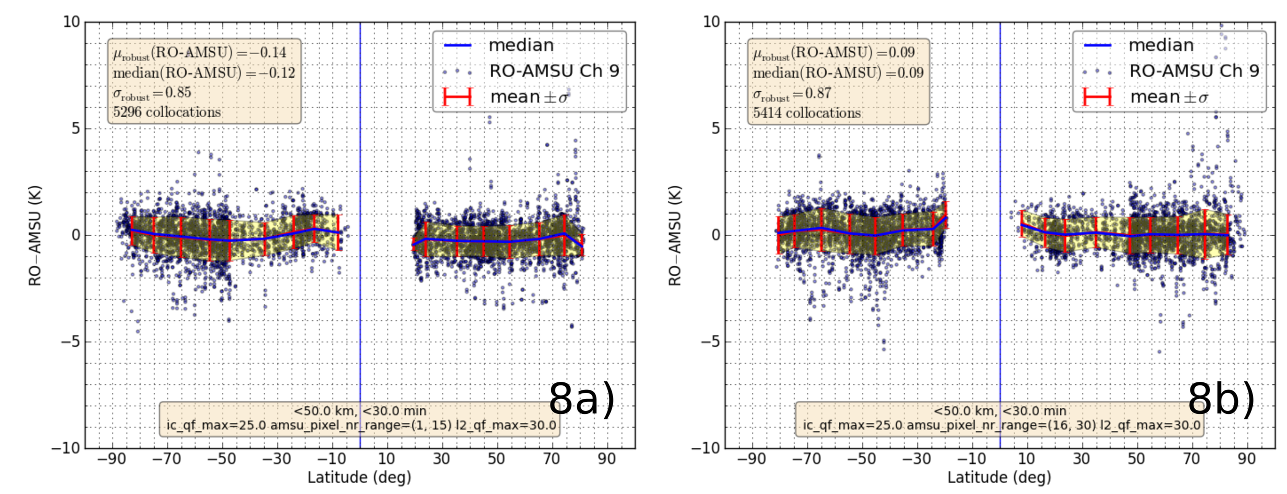


Fig. 8: Channel 9: Comparing scanning directions

4 Conclusions

The inherent absolute RO accuracy can be used to monitor and eventually calibrate other types of atmospheric sounders. Metop provides the opportunity for a large number of collocated measurements of the GRAS RO instrument with onboard nadir sounders. This is especially important for AMSU measurements, which need substantial bias corrections before being used in climate and weather applications. In this initial study, collocated RO and AMSU temperature data for an example month were used to assess these prospects.

Acknowledgments: This study was conducted at the Danish Meteorological Institute (DMI), Copenhagen as part of EUMETSAT's ROM-SAF visiting scientist program, and was partly supported by the Austrian Science Fund (FWF; Project BENCHCLIM - P22293-N21).