Tropospheric Biases in Metop-A RO Water Vapour Product: Comparison to IASI, AMSU and MHS Data

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Abstract: Since 2006, the Metop-A satellite has orbited the Earth and collected atmospheric data provided by different instruments onboard. Among them, GRAS receiver providing GNSS Radio Occultation (GNSS-RO) data, Infrared Atmospheric Sounding Interferometer (IASI), Advanced Microwave Sounding Unit (AMSU) and Microwave Humidity Sounder (MHS).
Given the independence in the data acquisition, in regards to techniques and geometries, we present an assessment of tropospheric statistics in the RO water vapour (WV) product processed by Radio Occultation Meteorology Satellite Application Facility (ROM SAF) and the Rutherford Appleton Laboratory (RAL) Infrared Microwave Sounding (IMS) data set, which is composed by WV profiles jointly retrieved from IASI, AMSU and MHS measurements. Profiles are collocated in time and space, and are grouped in latitude bands.
This cross-validation exercise is the first RO contribution to the ESA Water Vapour Climate Change Initiative (ESA WV_cci) project, and should lead to a better understanding of the differences between RO and IMS WV product and their uncertainties.

1. Introduction

Water vapour (WV) is the most important greenhouse gas and it is an essential climate variable (ECV), according to the Global Climate Observing System (GCOS), since it shapes the global environment and provides the conditions needed to a livable planet **[1]**. Understanding the redistribution of WV via processes such as cloud formation and precipitation, on global and regional scales, is key. Also, being able to detect changes in these physical processes is mandatory to protect life as we known.
This is only possible with trustworthy atmospheric models and climate date records (CDRs) provided by different sorts of Earth Observing Systems (EOS). However, data provided by distinct EOS differ regarding the representativeness due to the fact they are acquired in different geometries. Additionally, the data contain inherent bias from the "truth", and uncertainties depending on their instruments accuracy and their retrieval schemes.
In order to assess empirically the uncertainties of the WV product in different data sets using, for example, an method such as Three Cornered Hat (3CH) **[2]**, one must start this task by creating a subset of collocated and independent measurements **[3, 4]**.
In the context of this study, the GRAS-RO WV product processed by ROM SAF during reprocessing campaign 1 **[5]** is collocated to the Rutherford Appleton Lab (RAL) Infrared Microwave Sounding (IMS) data set, which is based on retrievals combining Infrared Atmospheric Sounding Interferometer (IASI), Advanced Microwave Sounding Unit (AMSU) and Microwave Humidity Sounder (MHS) through an Optimized Estimation Method (OEM) scheme, which includes a forward model (RTTOV) **[6,7]**.
RAL IMS data set was developed as a climate data record (CDR) package of the ESA WV Climate Change Initiative (CCI) project**.** As part of its validation and fully characterization of uncertainties to be used in climate studies, RAL IMS is compared to GRAS-RO WV product from Metop-A occultations.
In this poster, the data sets are described in Section 2, the methodology is presented in Section 3, and the preliminary results of the tropospheric statistics for a representative month are presented in Section 4. Remarks and next steps are addressed in Section 5.

2. Data

Two data sets are assessed in this study, which covers the period from June, 2007 to December, 2016 (9,5 years). ERA-Interim analysis profiles are assumed as the reference in the comparison. ERA-Interim assimilated AMSU, MHS and Metop-A RO during this period.

2.1. GRAS-RO, Metop-A (observation)

The data corresponds to ROM SAF Level 2B product. The WV profiles are obtained via ROPP 1D-Var retrieval assuming ERA-Interim forecasted profiles as the background, and are disseminated at 60 pressure levels (not fixed) **[5]**.

2.2. RAL IMS v2.1, nadir-view, Metop-A (observation)

The Infrared Microwave Sounding (IMS) data set is the result of a joint retrieval scheme using optimal estimation method (OEM) to obtain water vapour, temperature, and stratospheric ozone. The retrieval combines Infrared Atmospheric Sounding Interferometer (IASI), Advanced Microwave Sounding Unit (AMSU), Microwave Humidity Sounder (MHS) measurements to surface spectral emissivity and cloud parameters. WV profiles are disseminated at 101 pressure levels (fixed). The RAL IMS data set v2.1 was produced during phase 1 of ESA Water Vapour (WV) Climate Change Initiative (CCI) and spans from June, 2007 to December, 2016 **[6,7]**.

3. Methodology

The methodology of this study is separated in three parts, namely (i) the collocation of GRAS-RO and IMS WV profiles, (ii) quality control, and (ii) interpolation and statistical analysis.

3.1. Collocation

The triplets are defined as spatial and temporal collocated when satisfying the following criteria **[3]**,

$$\sqrt{(\lambda_{IMS}-\lambda_{RO})^2\cos^2\theta_{RO}+(\theta_{IMS}-\theta_{RO})^2}<\frac{\Delta d}{R_E}\,, \quad (1)$$

$$|t_{IMS}-t_{RO}|<\Delta t, \quad (2)$$

where λ, θ correspond to the IMS scene and RO reference longitudes and latitudes in radians, and R_E is the Earth's radius in the Equator. The time and space thresholds assumed in this analysis were $\Delta t = 3\mathrm{h}$ and $\Delta d = 300\,\mathrm{km}$, respectively.
This relaxed collocation criteria maximizes the number of match-ups and creates the possibility of future analysis using narrower spatial and temporal bounds to assess their influence in the statistics.
Given the geometry of the techniques (limb- and nadir-view) and the fact they are onboard the same platform (Metop-A), their collocations occur in two moments: (i) ± 8 minutes (same orbit) and (ii) ± 100 minutes (adjacent orbit) **[4].** Therefore, the temporal collocation (2) is checked first, since it reduces significantly the amount of possible match-ups.

3.2. Quality control

Next, **(i)** non-nominal RO profiles, according to the overall quality flag (PCD) used in the ROM SAF processing chain, and **(ii)** profiles containing negative values -- an artifact present in the ROM SAF reprocessing I -- are discarded from the analysis. Regarding IMS profiles, **(i)** retrievals not satisfying quality standards in the RTTOV retrieval (cost function and convergence), **(ii)** without averaging kernels, and **(iii)** with cloud coverage > 80% were also discarded. Further, levels in which the IMS profiles uncertainties are > 50% were not considered in the analysis **[7].**

3.3. Interpolation and Statistical analysis

RO and ERA-Interim QC-ed profiles were interpolated to RTTOV 101-pressure-level grid using spline method. Finally, the subset of collocated triplets were subject to the statistical analyses, which consisted of RO and IMS mean differences to ERA-Interim analysis profiles (reference), their median difference to the reference and their median absolute deviation (MAD),

$$\hat{b} = \mathrm{median}(o-r), \quad (3)$$

$$\mathrm{MAD} = \mathrm{median}(|(o-r)-\hat{b}|). \quad (4)$$

4. Results

A total of 18 million IMS profiles and 2 million RO profiles compose the data set of collocations. **Fig. 4.1-3** show the statistics in low, mid and high latitudes for a representative month (June, 2014), and the breakdown of setting and rising occultations.

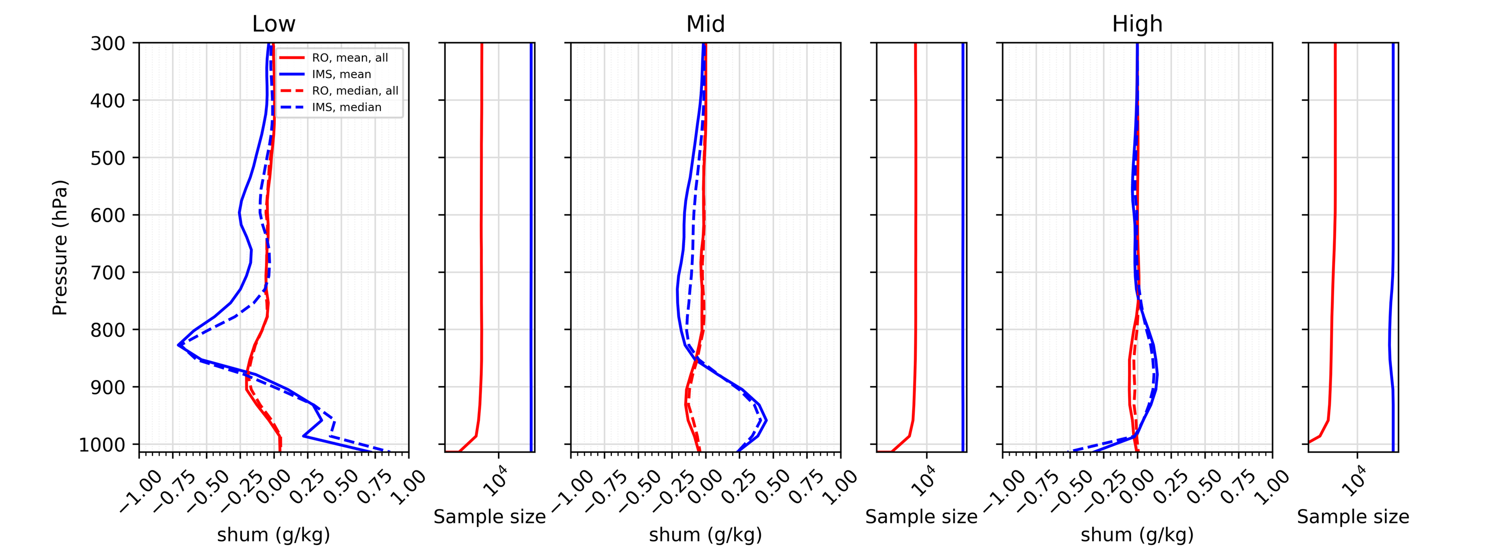

Fig. 4.1: Mean (solid) and median (dashed) differences of RO (red) and IMS (blue) specific humidity collocated profiles (in g/kg) to ERA-Interim analysis profiles in low, mid and high latitudes.

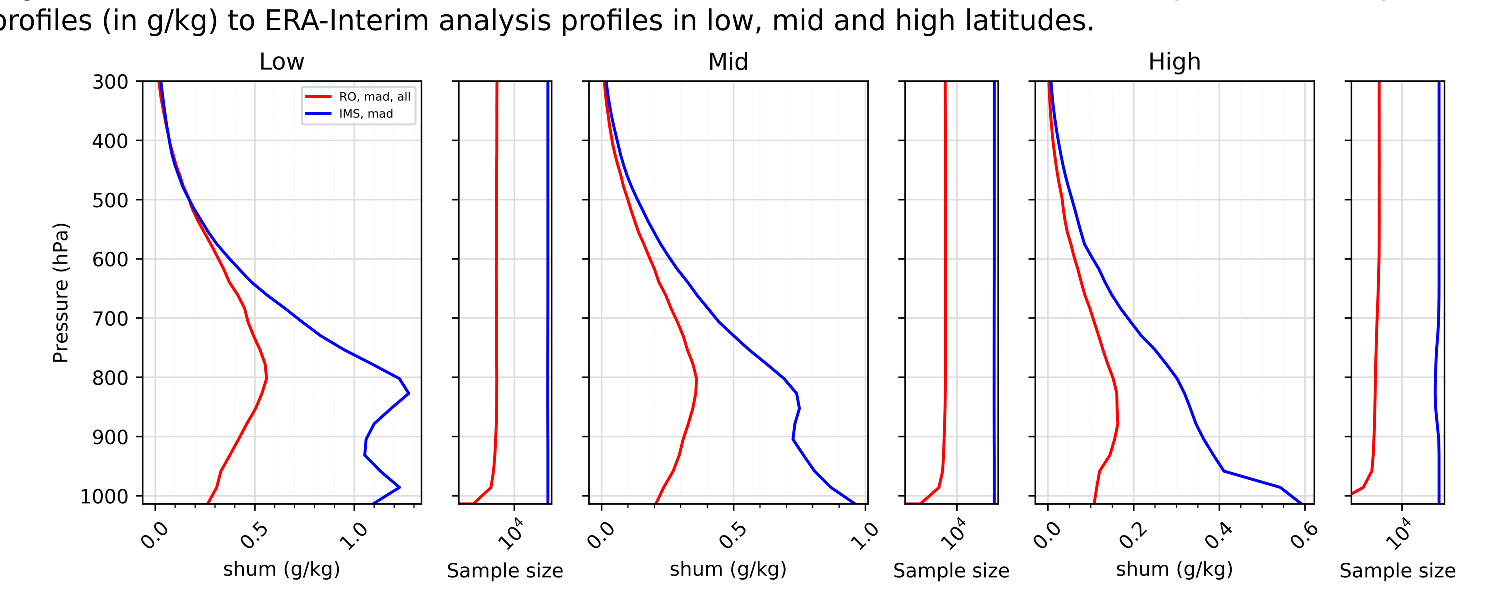

Fig. 4.2: Median absolute deviation (MAD) of RO (red) and IMS specific humidity (blue) in low, mid and high latitudes.

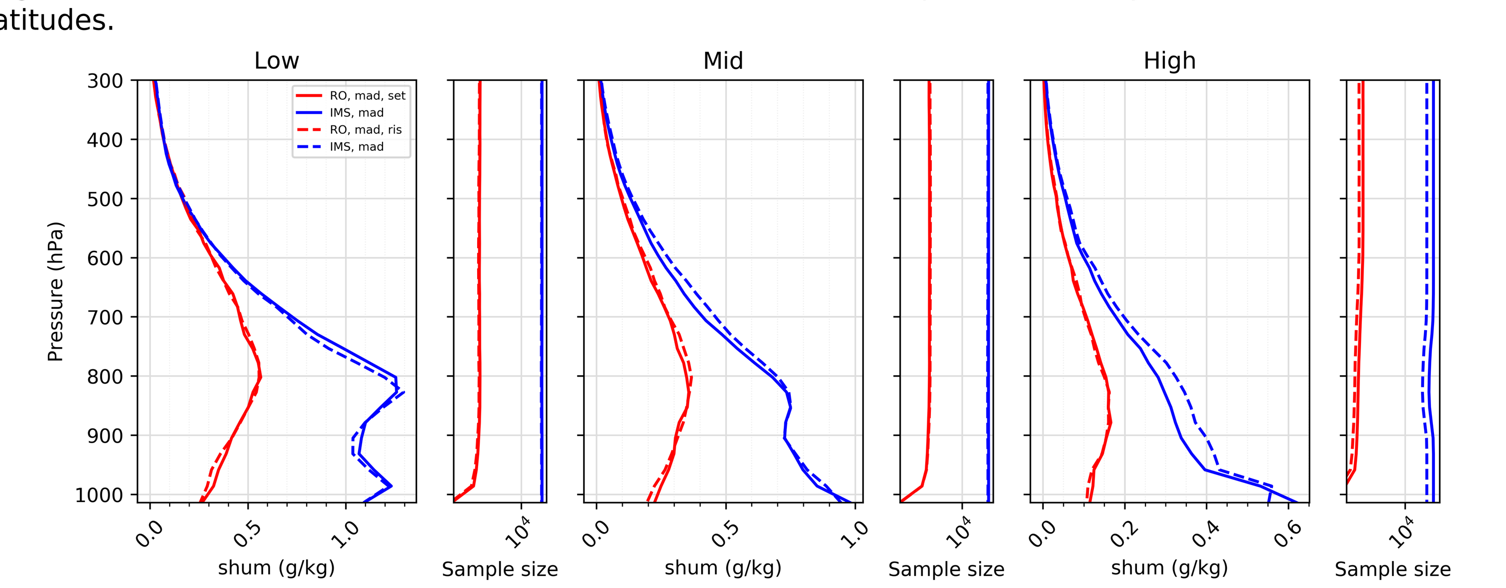

Fig. 4.3: Median absolute deviation (MAD) of RO (red; solid, setting; dashed, rising) and IMS specific humidity (blue) in low, mid and high latitudes.

5. Conclusions & Outlook

- RO WV medians tend to be drier than ERA-I analysis (ref) at all pressure levels up to the tropopause; around (max.: ~0.25 g/kg) at the tropics and more similar towards high latitudes.
- In general, IMS is wetter than ERA-I and RO at low pressure levels, up to around 800 hPa at high latitudes and ~900 hPa in the tropics. Above these pressure levels, IMS tends to be drier than ERA-I and RO.
- RO WV data shows lower MAD than IMS WV in all pressure levels and in all regions.
- Profiles from setting and rising occultatoins show similar statistics.
- The analysis will be extended to the entire period covered by RAL IMS data set v2.1 and the data sets will have their uncertainties estimated using 3CH method.

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