Comparison of tropospheric humidity products provided by MWIR and Radio Occultation on Metop-A

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Outline

- Background
- Data sets
- Data preparation
- Results
- Conclusions

Background

- As part of ESA WV_cci project
  - ***Mapping differences between ROM SAF RO and RAL IMS humidity profiles in the troposphere***

water vapour cci

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UNIVERSITY OF TORONTO
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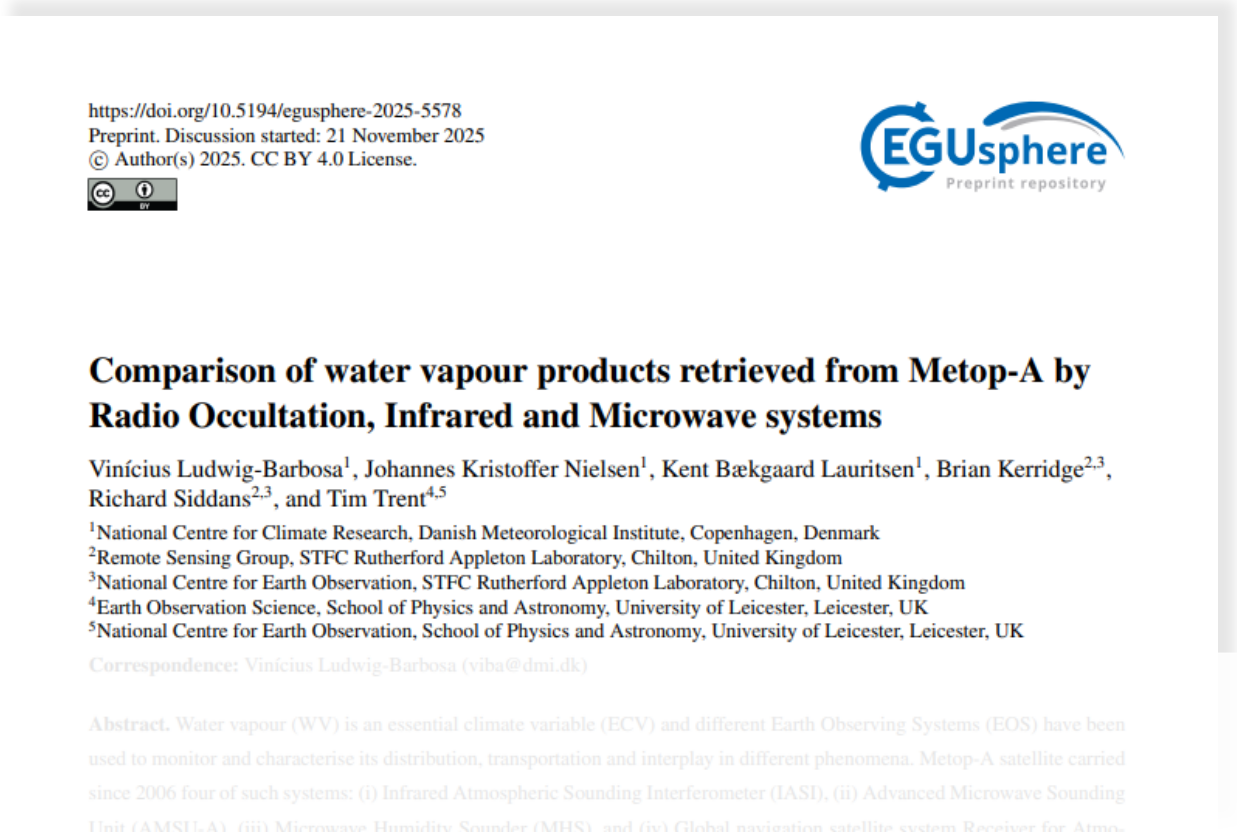
CCI: Climate Change Initiative
CDR: Climate Data Record
RO: Radio Occultation
ROM SAF: Radio Occultation Meteorology Satellite Application Facility
RAL IMS: Rutherford Appleton Lab Infrared Microwave Sounder

Background

- Manuscript under review: https://doi.org/10.5194/egusphere-2025-5578



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EGUsphere
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Comparison of water vapour products retrieved from Metop-A by Radio Occultation, Infrared and Microwave systems

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Abstract. Water vapour (WV) is an essential climate variable (ECV) and different Earth Observing Systems (EOS) have been used to monitor and characterise its distribution, transportation and interplay in different phenomena. Metop-A satellite carried since 2006 four of such systems: (i) Infrared Atmospheric Sounding Interferometer (IASI), (ii) Advanced Microwave Sounding Unit (AMSU-A), (iii) Microwave Humidity Sounder (MHS), and (iv) Global navigation satellite system Receiver for Atmo-

Data sets

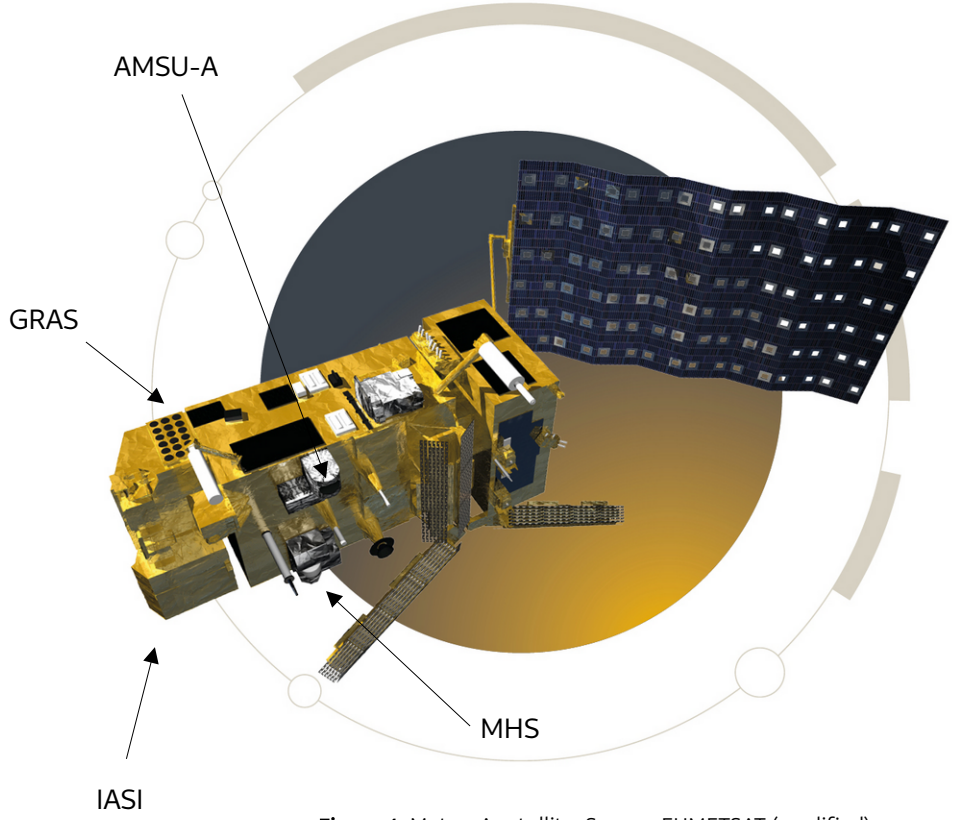

Figure 1: Metop-A satellite. Source: EUMETSAT (modified).

- All instruments on board Metop-A
- Period: June 2007 to December 2016
- Limb-view: GRAS-RO
  - Horizontal resolution: ~300 km
  - Vertical resolution: ~100 m
- Nadir view: IASI, AMSU-A, MHS
  - Swaths: ~2000 km
  - Horizontal resolutions: ~25 km to 48 km
  - Vertical resolution: 1-2 km

GRAS: GNSS Receiver for Atmospheric Sounding
IASI: Infrared Atmospheric Sounding Interferometer
AMSU-A: Advanced Microwave Sounding, Unit A
MHS: Microwave Humidity Sounder
IR: Infrared
MW: Microwave

Data sets

- [1]ROM SAF CDR, v1.0
  - 1D-Var specific humidity profiles
  - Background: ERA-I forecast
- [2]RAL IMS, v2.1
  - Optimal Estimation Method (OEM) scheme
  - WV profiles combining MW/IR measurements
  - Background: zonal mean climatology
- [3]GRUAN, RS92
  - Relative humidity profiles
  - Resolution: 5-10 m
  - Limited coverage

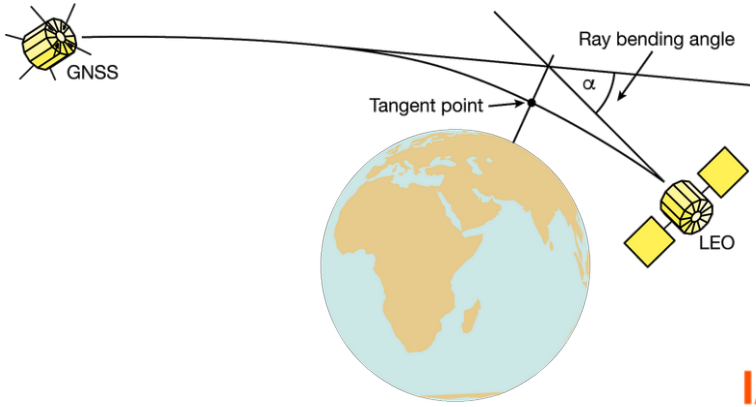

Figure 2: Radio Occultation geometry.

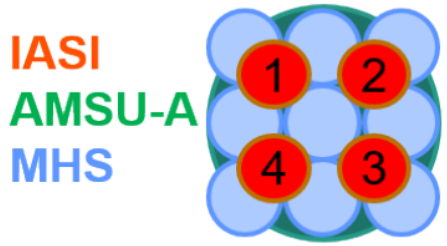

Figure 3: MW/IR instant field of view. AMSU-A (48 km), IASI (12 km), and MHS (16km).

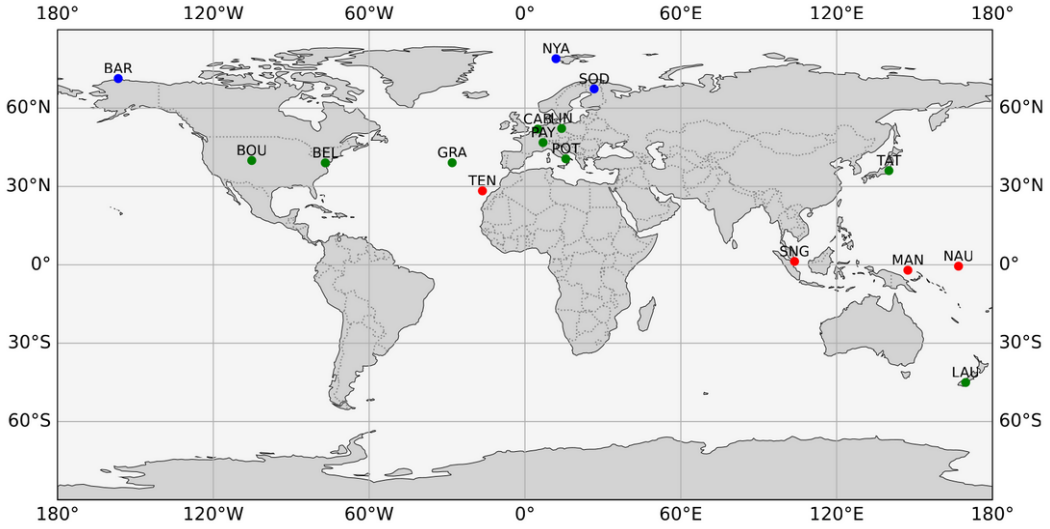

Figure 4: Location of GRUAN's stations considered in the study.

[1]EUMETSAT ROM SAF Radio Occultation Climate Data Record (v1.0, 2019), GRM-29-R1, DOI:10.15770/EUM_SAF_GRM_0002, https://doi.org/10.15770/EUM_SAF_GRM_0002

[2]Siddans, R.; Walker, J.; Latter, B.; Kerridge, B.; Gerber, D.; Knappett, D. (2018): RAL Infrared Microwave Sounder (IMS) temperature, water vapour, ozone and surface spectral emissivity. Centre for Environmental Data Analysis, 28 June 2018. DOI:10.5285/489e9b2a0abd43a491d5afdd0d97c1a4. https://dx.doi.org/10.5285/489e9b2a0abd43a491d5afdd0d97c1a4

[3]Sommer, M.; Dirksen, R.; Immler, F. (2012): RS92 GRUAN Data Product Version 2 (RS92-GDP.2). GRUAN Lead Centre (DWD), https://doi.org/10.5676/GRUAN/RS92-GDP.2

Data preparation

- Collocation
  - 300 km, 3 hours
  - Lowest altitudes with difference of up 10 hPA (~100 meters)
- Interpolation to common fixed pressure grid (IMS 101-pressure levels)
  - RO (ERA-I): extrapolated from 60 non-fixed pressure levels
  - GRUAN: downsampled from ~10-m resolution
- Unit conversions to volume mixing ratio (ppmv)
  - RO (ERA-I): converted from specific humidity (g/kg)
  - GRUAN: converted from relative humidity (%)
- Quality control
  - RO: nominal profiles (ROM SAF PCD flag)
  - IMS: nominal profiles, cloud filtering (cfrac $\leq$ 80%), uncertainty < 50%

Data preparation

- Filtering using IMS averaging kernels (AKs)

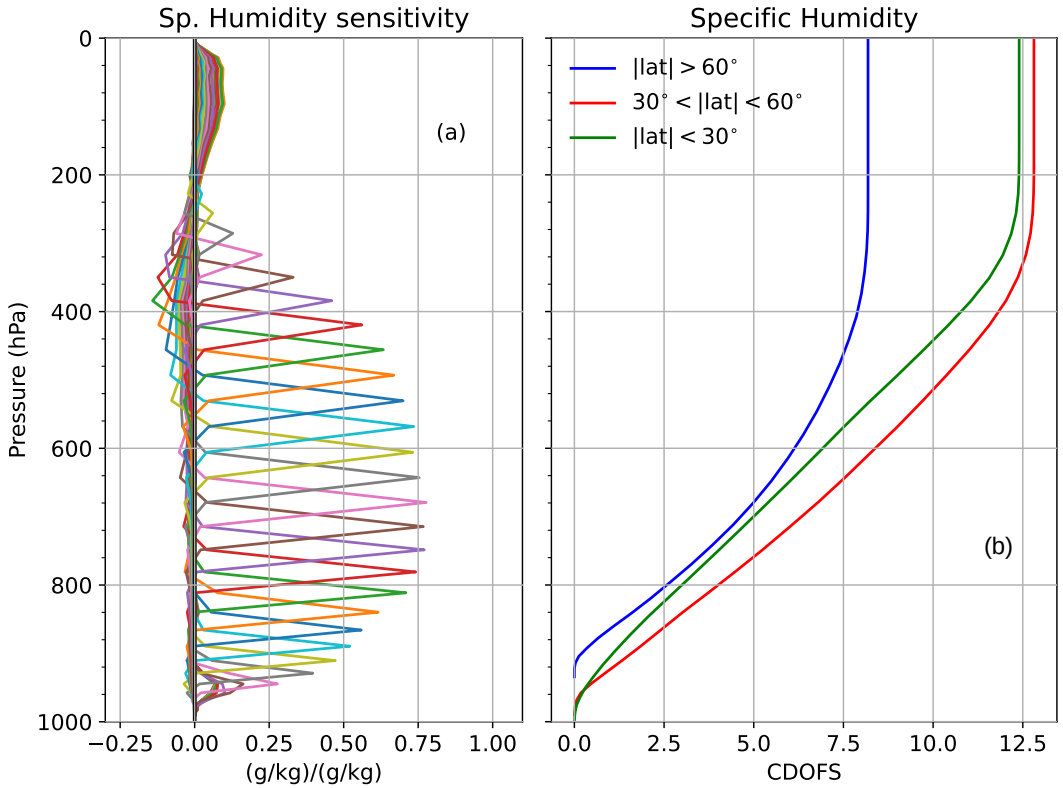

Figure 5: Performance indicators of the ROM SAF CDR v1.0, 1D-Var, calculated as means over Metop-A profiles from 1 October 2007. From the left: (a) Averaging Kernels (AKs) for specific humidity at mid latitudes, (b) cumulative degrees of freedom in the signal (CDOFS) for specific humidity in different latitude bands (12-13 CDOFS in low and mids, 8-9 CDOFS in high latitudes.

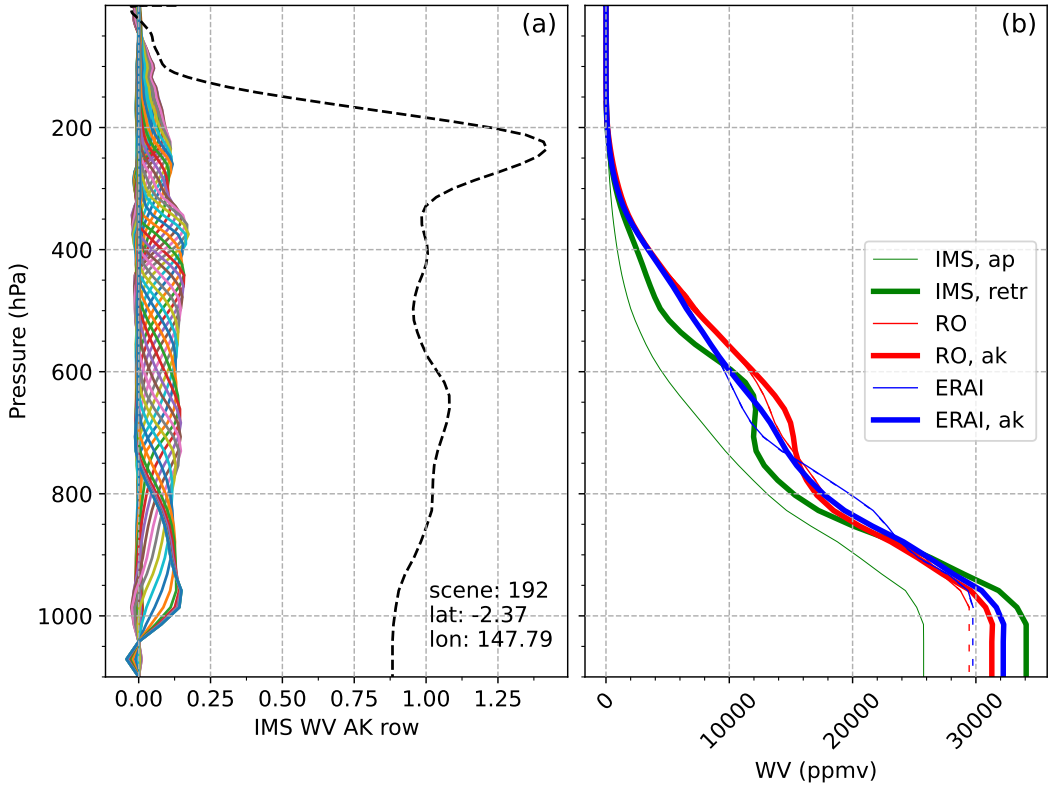

Figure 6: Averaging kernel filtering. Panel (a) shows the rows of one RAL IMS WV AK matrix, where each curve corresponds to the sensitivity at a specific level, and the dashed curve shows the sum of AK matrix rows. Panel (b) shows a comparison between the original and AK-smoothed profiles.

Results

- Global statistics and in different latitude bands
- Influence of cloud contamination
- Difference between matchups over land and sea
- Difference between matchups during day- and nighttime (GRUAN, reference)

Results

- Global statistics and in different latitude bands compared to ERA-I analysis

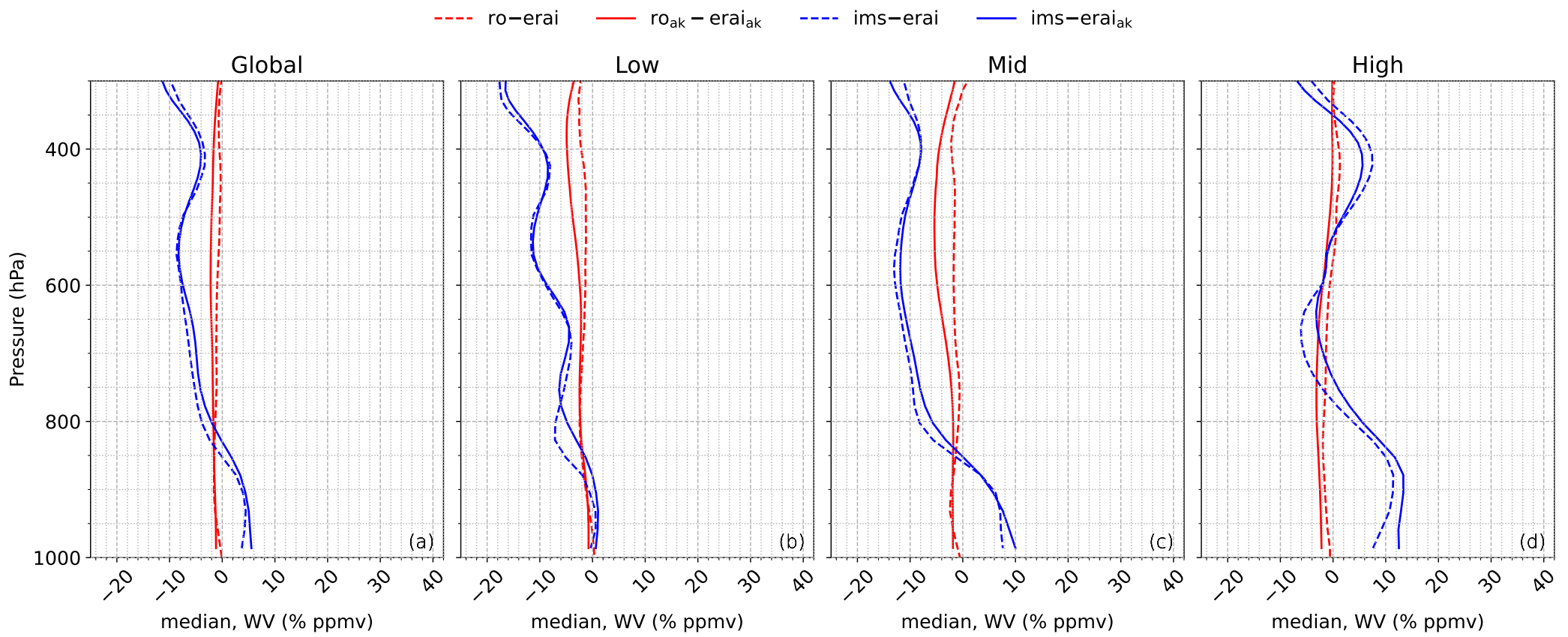

Figure 7: Median differences of RO and IMS profiles to ERA-Interim analysis WV profiles in (a) global, (b) low-, (c) mid- and (d) high-latitude statistics. Dashed lines represent statistics based on original RO and ERA-I profiles, and solid lines represent statistics for profiles convoluted by RAL IMS AKs. RO AK-smoothed profiles were subject to the same truncation as their RAL IMS matchups. Only RAL IMS profiles with cloud fraction up to 80% (baseline) are considered.

Results

- Influence of cloud contamination compared to ERA-I analysis

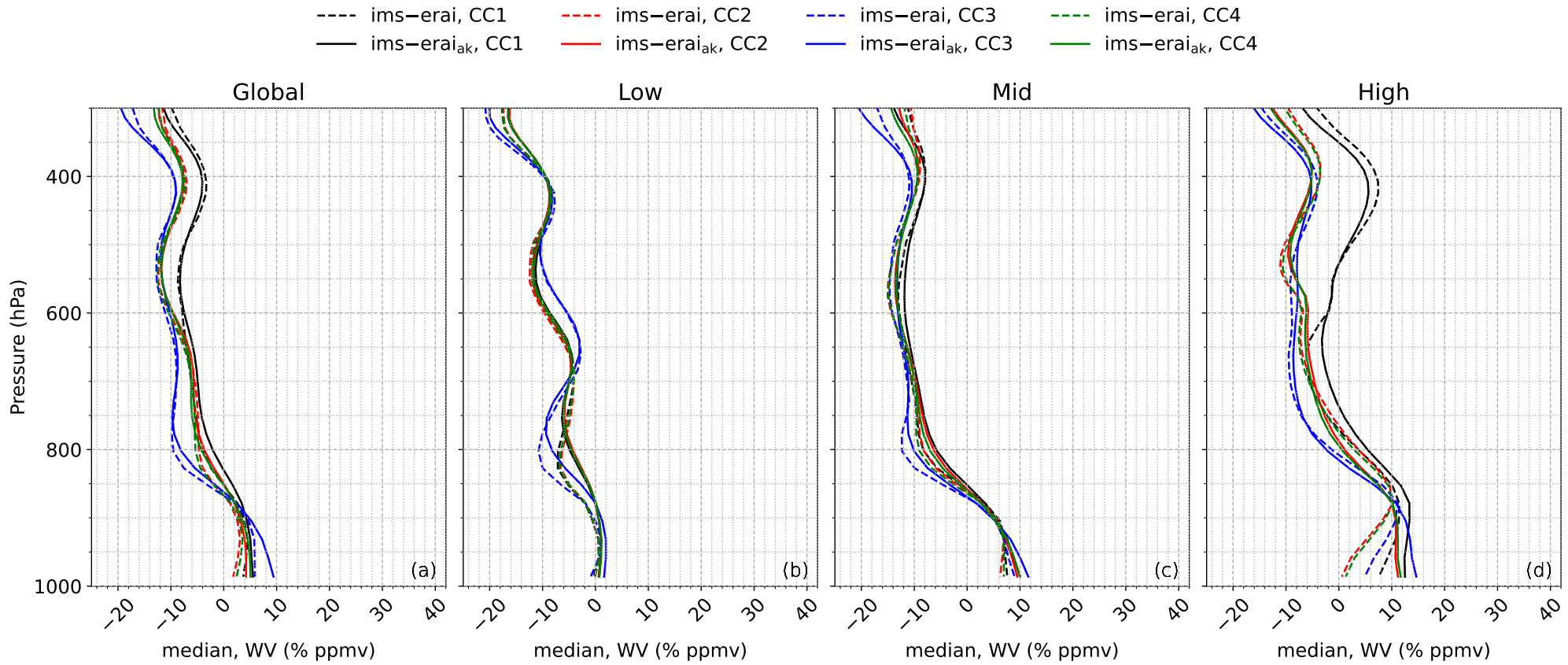

Figure 8: Median differences of RAL IMS profiles to ERA-Interim analysis WV profiles in (a) global, (b) low-, (c) mid- and (d) high-latitude statistics. Dashed lines represent statistics assuming original ERA-I profiles, and solid lines assume their AK-smoothed profiles as the reference. Black curves represent the statistics assuming the baseline cloud criterion (CC1, cfrac≤80%), red curves are related to CC2 (clear-sky, cfrac≤5%), blue to CC3 (cfrac≤30% and cloud top height up to 3 km), and green to CC4 (CC2 or CC3 satisfied).

Results

- Difference between matchups over land and sea compared to ERA-I analysis

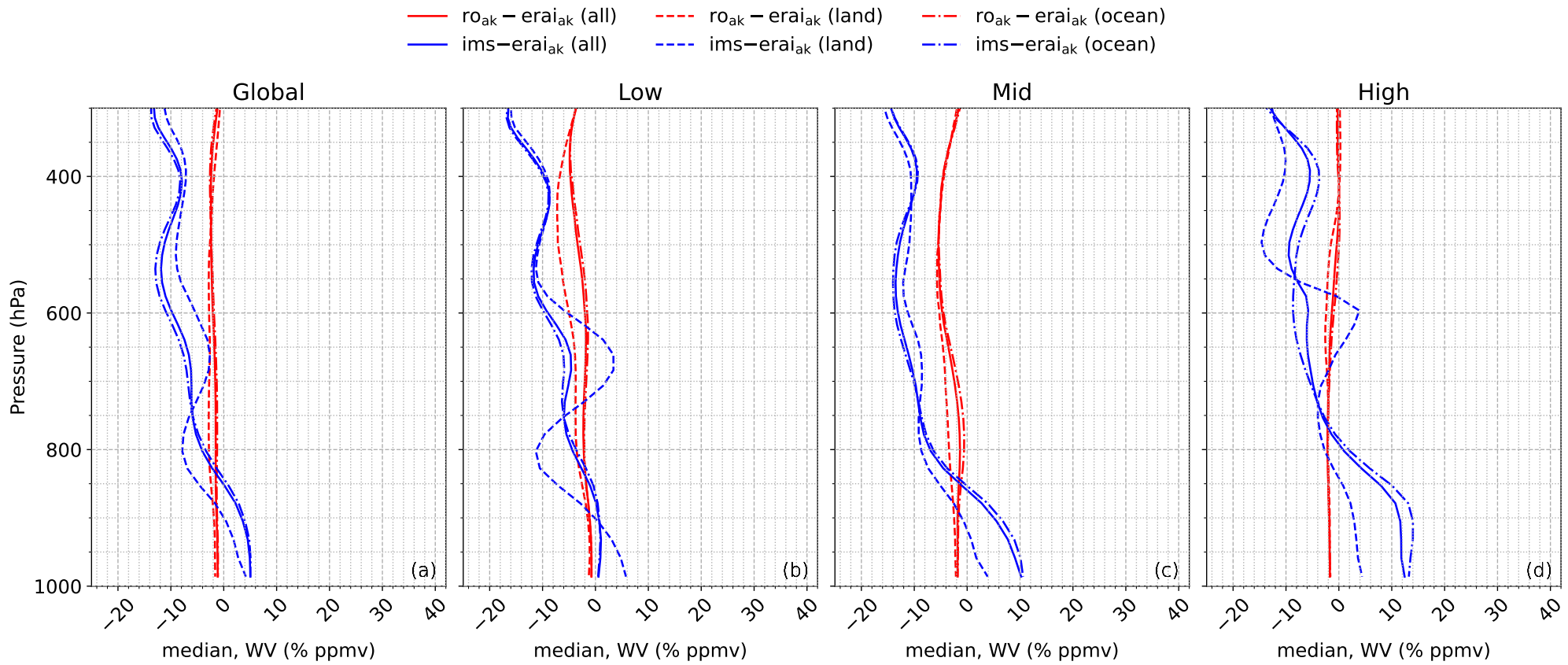

Figure 8: Median differences of RO and IMS to ERA-Interim analysis humidity profiles over land and water. (a) Global, (b) low-, (c) mid-, and (d) high-latitude statistics. Solid lines correspond to combined statistics (land+water), dashed lines represent statistics over land, and dash-dotted lines represent statistics over water. RO and ERA-I profiles are AK-smoothed, and matchups follow CC4 criteria.

Results

- Global statistics and in different latitude bands (GRUAN, reference)

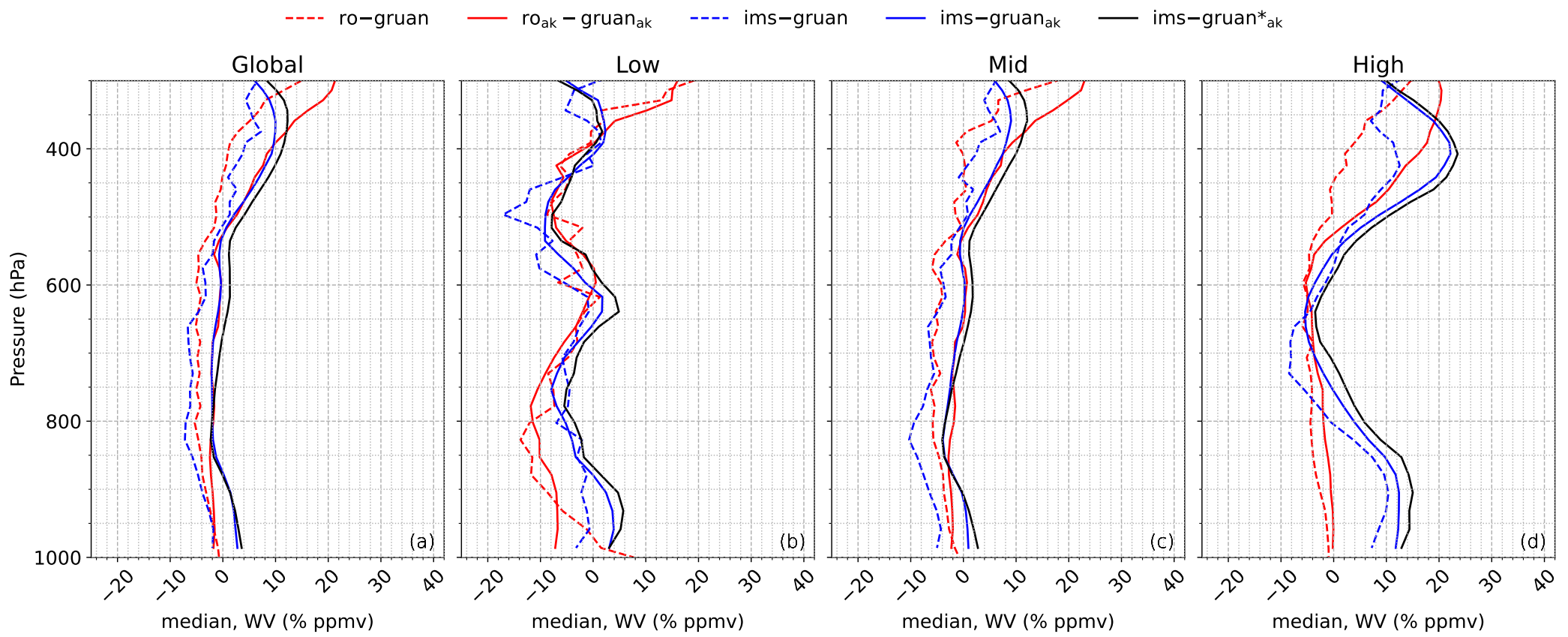

Figure 9: Median differences of RO and IMS to GRUAN humidity profiles. (a) Global, (b) low-, (c) mid-, and (d) high-latitude statistics. Dashed lines represent statistics based on original RO profiles, and solid lines represent their profiles convoluted by IMS AKs. AK-smoothed profiles were subject to the same truncation as their IMS matchups. Statistics based on IMS scenes with cfrac ≤80%. Black curves labelled "ims-gruan*, ak" show the statistics for collocations up to 100 km apart.

Results

- Difference in matchups during day- and nighttime (GRUAN, reference)

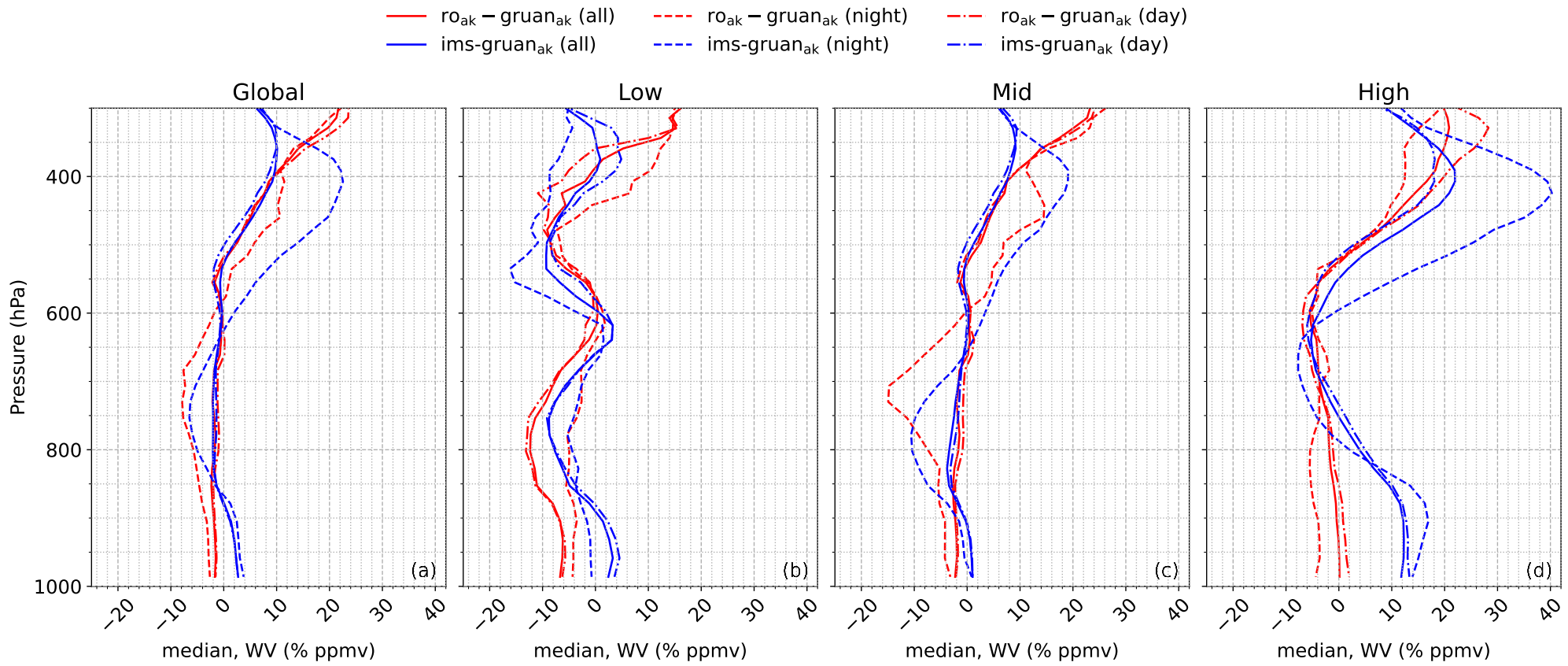

Figure 11: Median differences of RO and IMS to GRUAN humidity profiles during day- and nighttime. (a) Global, (b) low-, (c) mid-, and (d) high-latitude statistics. Solid lines represent the global set combining day and night matchups, dashed lines correspond to nighttime statistics, and dash-dotted lines correspond to daytime. Statistics based on IMS scenes with cfrac ≤80%, and assume AK-smoothed RO and GRUAN profiles.

Conclusions

- In low troposphere, IMS profiles are wetter than GRUAN (up to 3.8% ppmv) and than ERA-I (up to 5.5% ppmv), predominantly in mid latitudes (w.r.t. ERA-I) and high latitudes (w.r.t. ERA-I and GRUAN). Further, these differences are observed more over water than land (w.r.t. ERA-I). The cloud contamination did not explain these differences.
- RO WV data is consistently drier than ERA-I (about 2.2% ppmv at maximum) in all altitudes, and it is also drier than GRUAN (up to 4.6% ppmv) in the lower troposphere.
- In the mid troposphere, IMS is drier than ERA-I (about 11.4% ppmv), mostly in the mid latitudes, with cloud contamination showing a wet contribution in the statistics in high latitudes. IMS is also drier than GRUAN in the lower mid troposphere (850−600 hPa), but moister in the upper mid troposphere (600−400 hPa), by 22.5% ppmv.
- In the upper troposphere, IMS data is on average drier than ERA-I (11.4% ppmv) due to profiles in low and mid latitudes, but it is wetter than GRUAN in mid and high latitudes. RO is also wetter than GRUAN, up to 20% ppmv.
- Filtering with IMS AKs tends to make the smoothed profiles drier than their originals, and equalises their mean difference deviation (MAD) – not shown.
- Potential sinergy in the developments of CDRs between IMS and RO in mid troposphere, given their complementary attributes, i.e., dense spatial sampling and moderate vertical resolution (IMS), and high vertical resolution and sparse spatial sampling (RO).

Thank you

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