



# Comparison Between GNSS Radio Occultation and RAL IMS Water Vapour Profiles

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# Outline

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- Methodology
  - Parsing data sets
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# Background

- Cross-validation activity part of CDR-4 in ESA WV\_cci project
  - Vertically resolved WV profiles in the troposphere
    - ♦ **Mapping differences between ROM SAF RO and RAL IMS WV product**
    - ♦ Estimating random uncertainties and performing cross-validation

RO: Radio Occultation

ROM SAF: Radio Occultation Meteorology Satellite Application Facility, <https://rom-saf.eumetsat.int/>

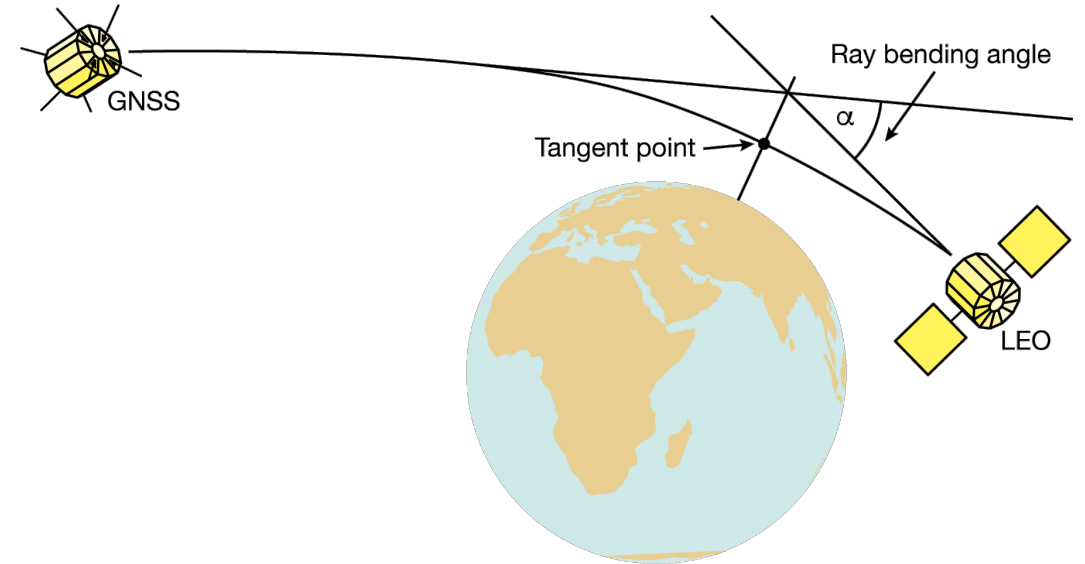
RAL: Rutherford Appleton Laboratory

IMS: Infrared, Microwave Sounder data set, <https://dx.doi.org/10.5285/489e9b2a0abd43a491d5afdd0d97c1a4>



# GNSS-RO intro

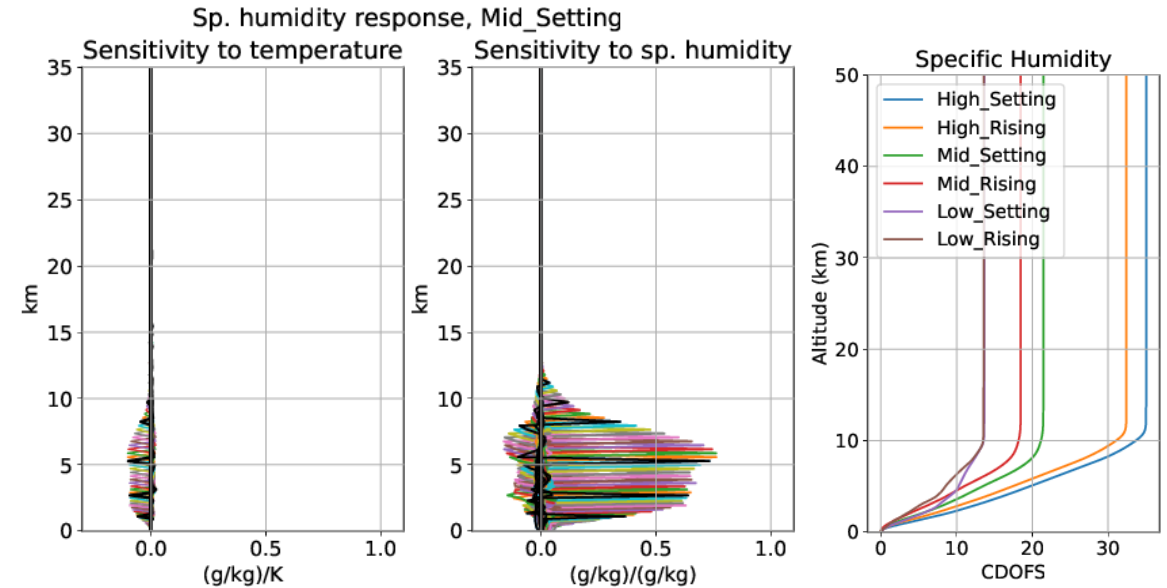
- Occultation events (setting and rising)
  - amplitude, phase, satellites' positions and velocities
- Features
  - High vertical resolution (~hundreds of meters)
  - All-weather operation
  - Global coverage
  - Long-term stability
- Limitations
  - Low horizontal resolution (~300 km)
  - Known negative bias in humidity product
  - Some level of instability in RO humidity product due to background model used in the 1D-Var retrieval



**Figure:** Simplified RO geometry (courtesy of Sean Healy, ECMWF).

# GNSS-RO intro

- ROM SAF RO data product
  - Level 1B: Bending angle
  - Level 2A: Refractivity
  - **Level 2B: 1D-Var product**
    - ♦ Temperature
    - ♦ **WV profiles (< 10-15 km)**
  - Level 3: Monthly mean climatologies
- Reprocessing #1, 2018
  - ERA-I forecast background, 2018 reprocessing
  - Large humidity sensitivity
    - Upcoming reprocessing #2
    - Empirical error covariance estimation



**Figure:** Temperature and specific humidity average kernels (AK) in mid latitudes, and cumulative degrees of freedom (CDOFS) for RO WV product in different latitudes and directions (setting/rising).

*Check Johannes' presentation at **12:15!***

# Methodology

- Develop code to parse data sets, including QC flags
- Collocate RO and IMS observations
- Perform required interpolations to have a common vertical grid
- Statistical analysis
  - Map spatial and temporal differences between IMS and RO WV profiles
  - Mean, median, median absolute deviation (MAD)

# Methodology: Parsing data sets

- **Radio occultation data**

- Earth's limb sounding
- GRAS receiver onboard Metop-A satellite
- Water vapour product processed by ROM SAF (1D-Var)
- Variables
  - ♦ Specific humidity profiles
  - ♦ Pressure (60 variable levels)
  - ♦ Occultation direction
  - ♦ Latitude, longitude
  - ♦ Time
  - ♦ Cost function value (convergence)

# Methodology: Parsing data sets

- **RAL IMS data set, v2.1**

- OEM retrieval: IASI + AMSU-A + MHS
- Temporal range: 06/2007 to 12/2016
- Nadir sounders, across track scanning
- Resolution: 1-2 km
- Variables
  - ♦ Water vapour,  $\ln(\text{ppmv})$
  - ♦ Pressure (fixed 101 levels)
  - ♦ Scenes latitude, longitude
  - ♦ Scenes time
  - ♦ WV retrieval error/uncertainty
  - ♦ WV averaging kernels
  - ♦ Cloud fraction



# Methodology: Parsing data sets

- **Reference**

- ERA-Interim analysis fields (ECMWF MARS archive)
- Time and spatial resolution
  - ♦ 3 hours
  - ♦ 1x1 degree grid
- Variables
  - ♦ Specific humidity profiles
  - ♦ Pressure (60 variable levels)
- RO, AMSU and MHS assimilated into ERA-Interim analysis

# Methodology: Collocating measurements

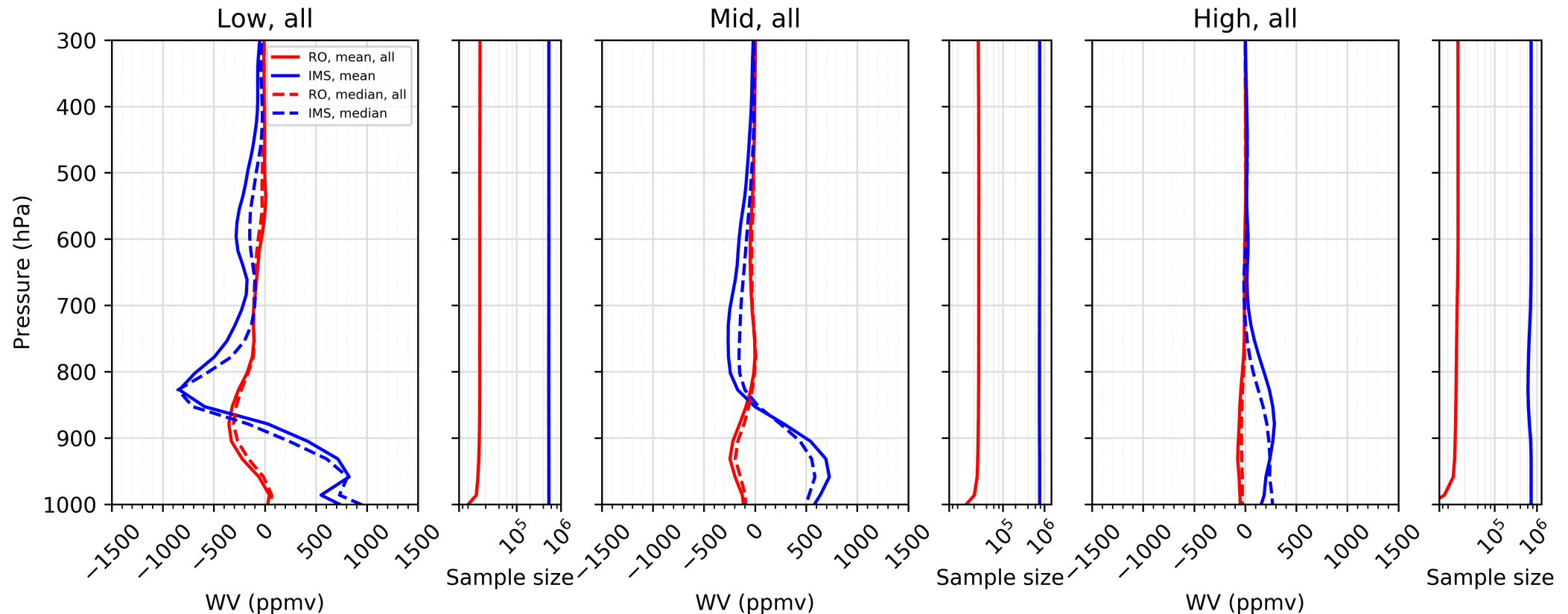
- Temporal collocation criterion: < 3 hours
- Spatial collocation criterion: < 100 km, 300 km
- Given the RO limb sounding geometry ...
  - Collocation interval #1: 5-15 minutes
  - Collocation interval #2: 80-125 minutes
- Generation of daily netCDF files containing triplets profiles and auxiliary data
  - 100-km: 55k (RO), 2M (IMS)
  - 300-km: 1.6M (RO), 18M (IMS)

# Methodology: Data Quality Filter

- RO data QC
  - Overall quality flag (PCD), ROM SAF processing
  - Missing points (discontinuities) in specific humidity profiles
- IMS data QC
  - Convergence flag
  - Cloud fraction/cover, < 80%\*
  - IMS WV uncertainty (profile and levels basis), < 50%\*
- RO and ERA-I interpolated into IMS 101 pressure levels (spline)
- (Ongoing) Average kernel (AK) filtering of RO and ERA-I profiles

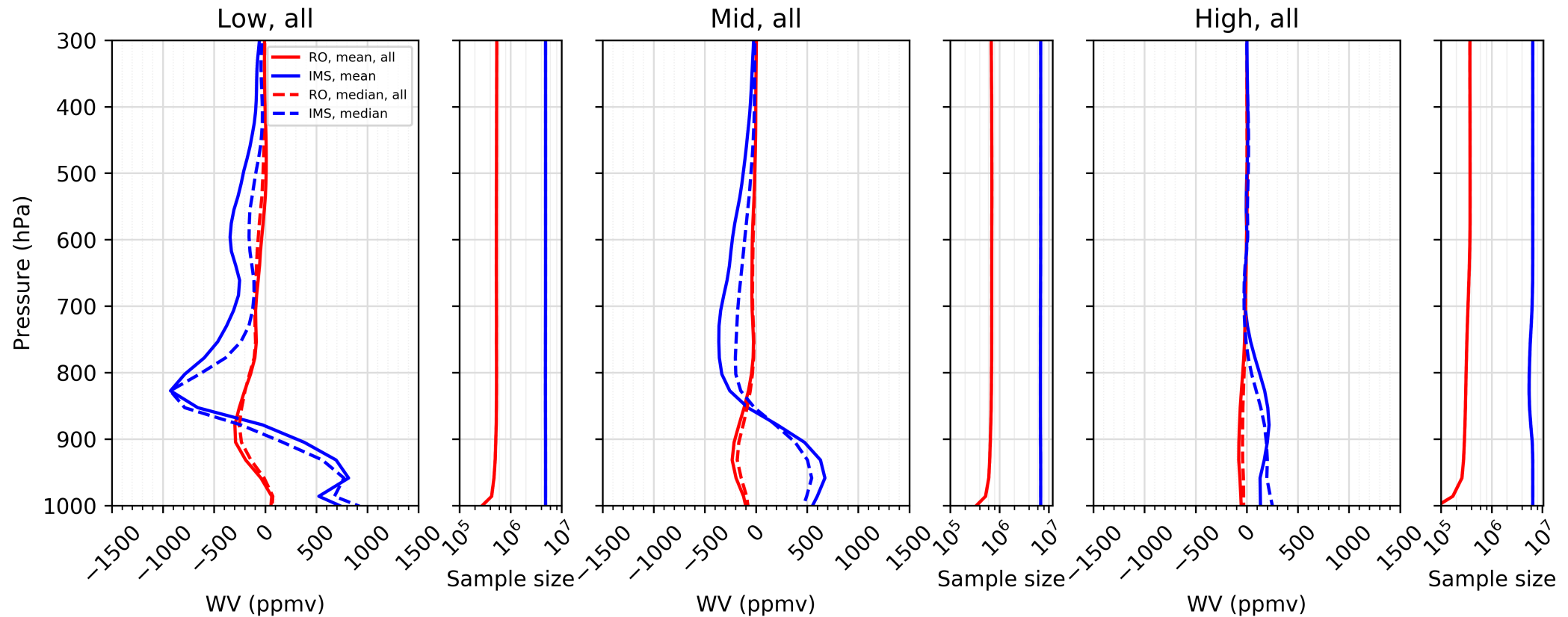
\*Trent, T., Siddans, R., Kerridge, B., Schröder, M., Scott, N. A., and Remedios, J.: *Evaluation of tropospheric water vapour and temperature profiles retrieved from MetOp-A by the Infrared and Microwave Sounding scheme*, Atmos. Meas. Tech., 16, 1503–1526, <https://doi.org/10.5194/amt-16-1503-2023>, 2023.

# Results: mean/median diffs. (100 km)



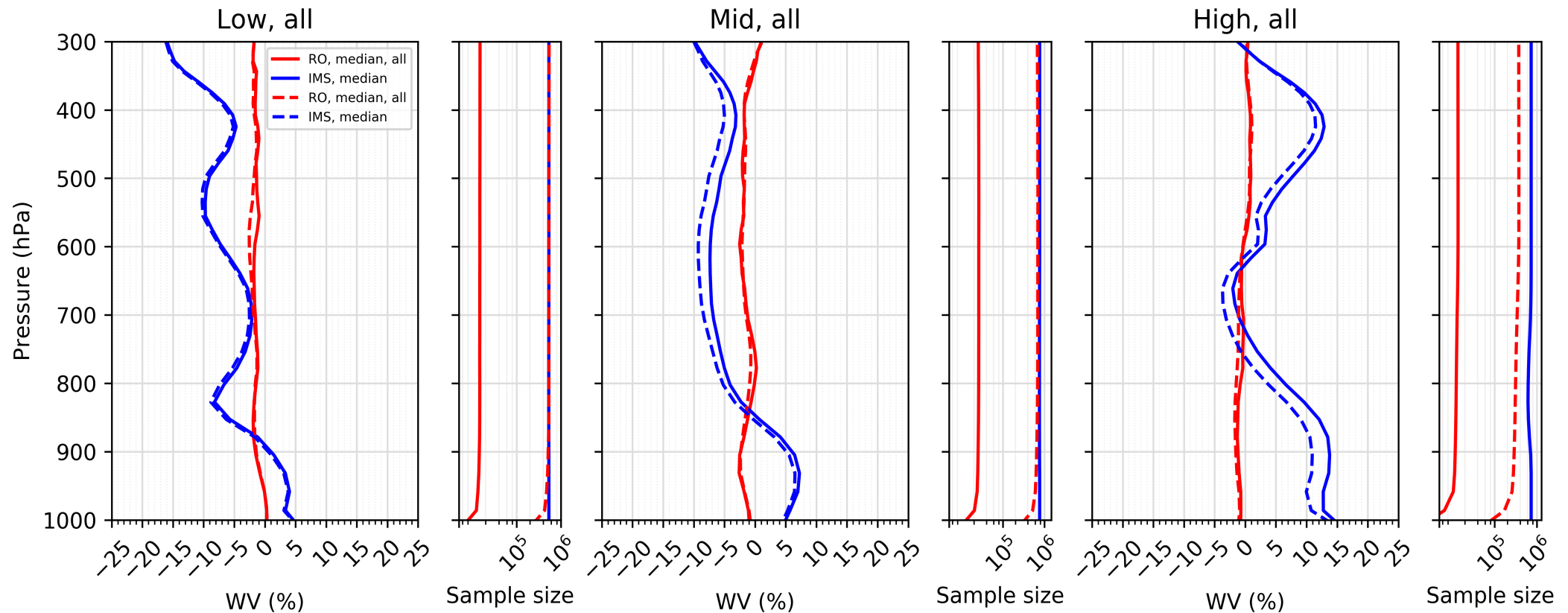
**Figure:** Mean (solid) and median (dashed) difference of RO (red) and IMS (blue) to ERA-Interim analysis profiles. RO and ERA-I profiles are only interpolated to IMS pressure levels. Spatial collocation criterion, 100 km.

# Results: mean/median diffs. (300 km)



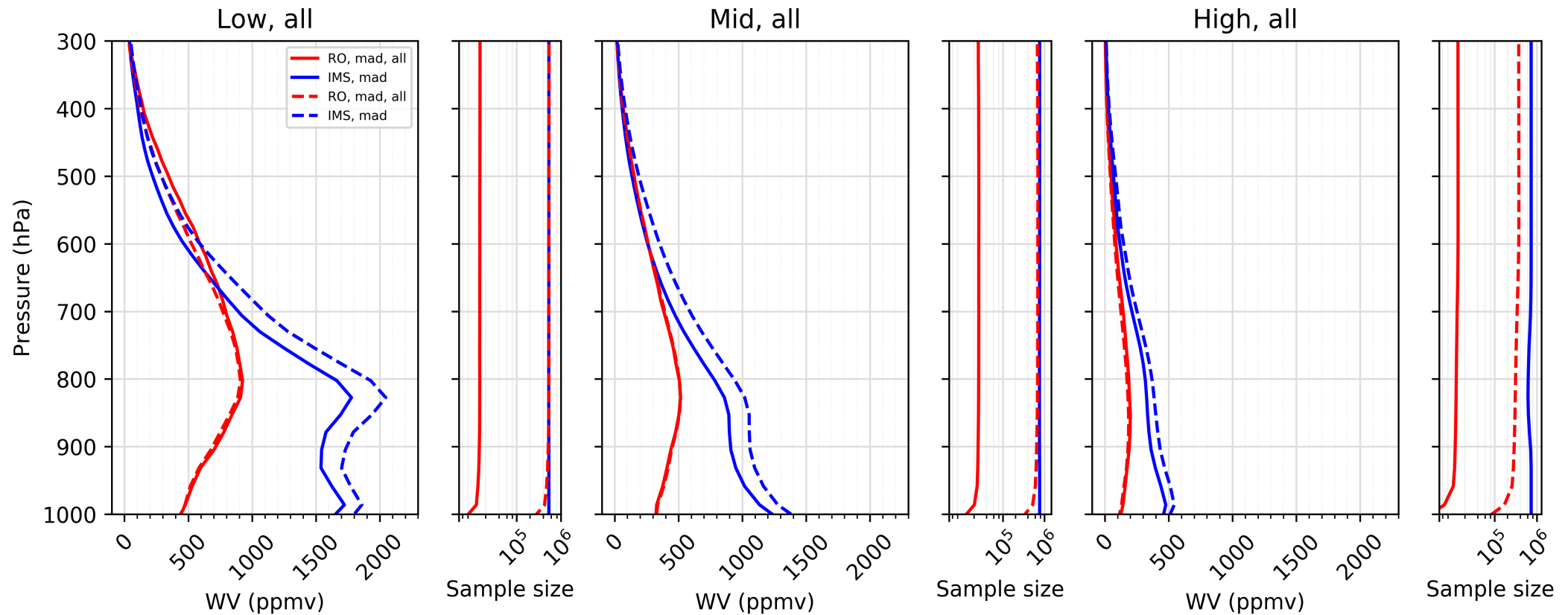
**Figure:** Mean (solid) and median (dashed) difference of RO (red) and IMS (blue) to ERA-Interim analysis profiles. RO and ERA-I profiles are only interpolated to IMS pressure levels. Spatial collocation criterion, 300 km.

# Results: Median (%)



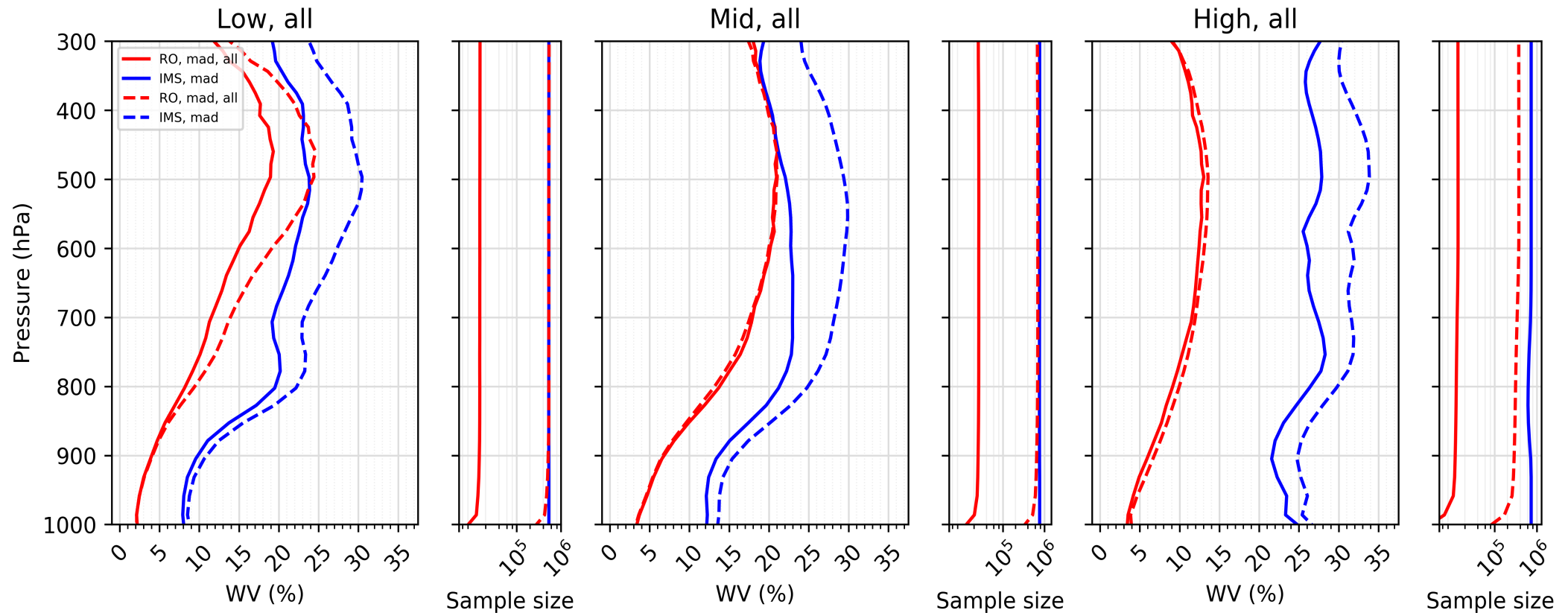
**Figure:** Median difference of RO (red) and IMS (blue) to ERA-Interim analysis profiles. RO and ERA-I profiles are only interpolated to IMS pressure levels. Spatial collocation criteria, 100 km (solid) and 300 km (dashed).

# Results: MAD



**Figure:** Median absolute deviation (MAD) of RO (red) and IMS (blue) to ERA-Interim analysis profiles. RO and ERA-I profiles are only interpolated to IMS pressure levels. Spatial collocation criteria, 100 km (solid) and 300 km (dashed).

# Results: MAD (%)



**Figure:** Median absolute deviation (MAD) of RO (red) and IMS (blue) to ERA-Interim analysis profiles. RO and ERA-I profiles are only interpolated to IMS pressure levels. Spatial collocation criteria, 100 km (solid) and 300 km (dashed).



# Conclusion & Outlook

- Current results indicate...
  - RO tends to be drier than ERA-Interim in all altitudes;
  - IMS is wetter in low altitudes and drier than ERA-Interim above around 800 hPa;
  - IMS median curves in low and mid altitudes tend to be wetter than mean curves;
- Spatial collocation criterion affects mainly MAD figures
- Repeat comparison with RO and ERA-Interim AK-filtered profiles
- Include radiosonde (GRUAN) profiles in the comparison

# Thank you



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