

Water vapour in the Central Arctic: How well do Satellite Products, Reanalyses and Reference Observations from MOSAiC agree?

Andreas Walbröl¹, Janna E. Rückert², Gunnar Spreen², Susanne Crewell¹, Kerstin Ebell¹

¹Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany, ²Institute of Environmental Physics, University of Bremen, Bremen, Germany



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I: Motivation

- Water vapour is the strongest greenhouse gas and results in a positive climate feedback loop: **Water vapour feedback**^[1-2]
- Observations indicate moistening of Arctic for certain regions and seasons, but uncertainties among reanalyses and satellite products are large^[3-5]
- Vertical water vapour distribution affects downward thermal-infrared radiation^[6]
- We need high-quality water vapour observations from field campaigns with high spatial and temporal resolution
- How well do satellite products and reanalyses agree with reference observations from MOSAiC?
- How well are Arctic humidity profiles represented by reanalyses and satellite products?

II: Reference observations from MOSAiC:

- Vaisala RS41 radiosondes: Temperature & humidity profiles, Integrated Water Vapour (IWV)
- Microwave radiometers (MWRs) **HATPRO** and **MiRAC-P** (Fig. 1): Measure radiances emitted from atmospheric gases and hydrometeors (see PAMTRA^[7] simulations in Fig. 2)
 - Supervised machine learning** (Neural Network) algorithm combining both MWRs for improved temperature and humidity profiling, and IWV estimates compared to single-instrument retrievals^[8]



Fig. 1: Microwave radiometers HATPRO (left) and MiRAC-P (right).

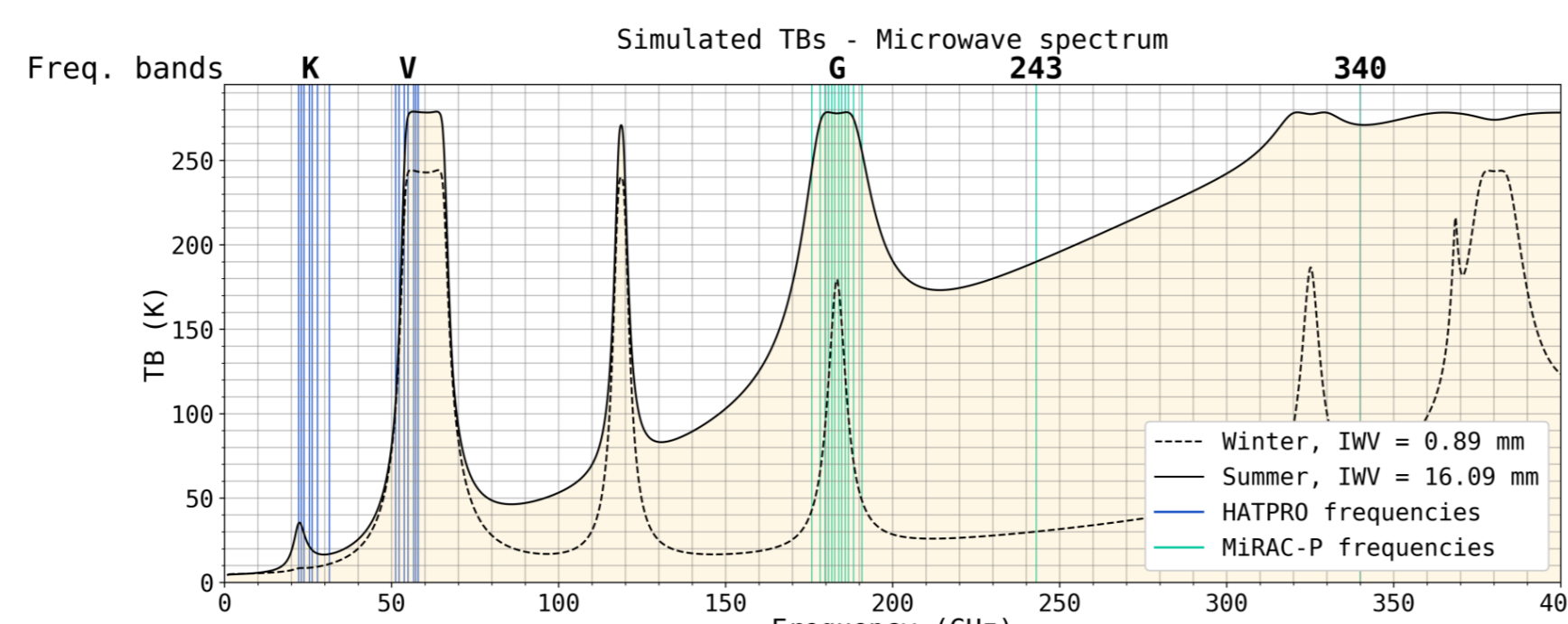


Fig. 2: Simulated radiances for low and high IWV conditions. Vertical lines indicate the measurement frequencies of HATPRO and MiRAC-P.

III: Water vapour error reduction: Synergy vs single radiometer

We evaluate single-instrument and synergetic retrievals with MOSAiC radiosondes for IWV (Fig. 3) and specific humidity profiles (Fig. 4).

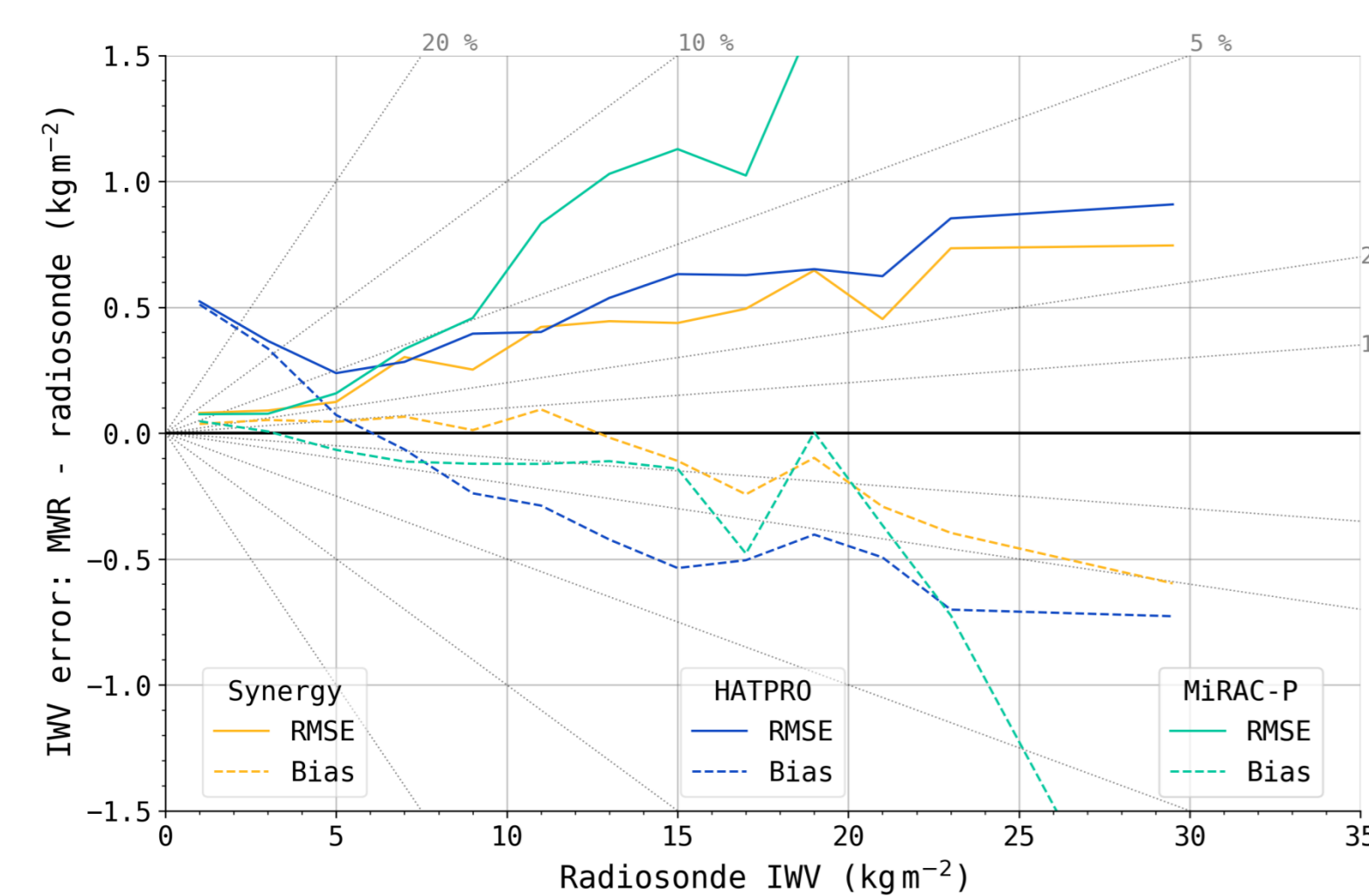
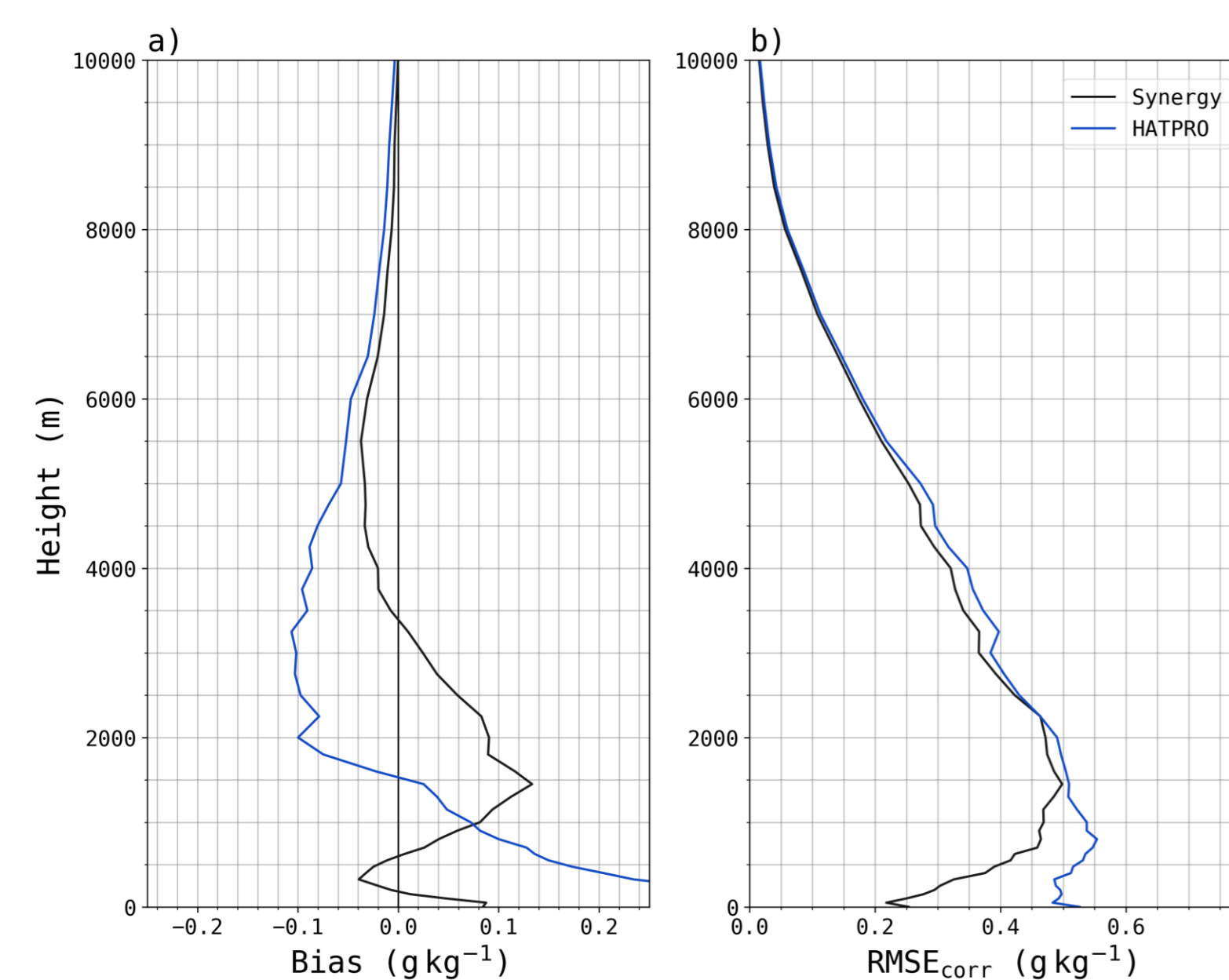


Fig. 3: IWV root mean squared error (RMSE) and bias with respect to MOSAiC radiosondes for single-instrument and synergetic retrievals.



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C41C-1527, a.walbroel@uni-koeln.de

IVa: Integrated water vapour comparison

- Reanalyses: ERA5, MERRA2
 - Satellite products: IASI Combined Sounding Products – Metop, AMSR-E/2 IWV retrieval^[9]
- With the IWV from the synergetic retrieval as reference, errors of each dataset are computed.

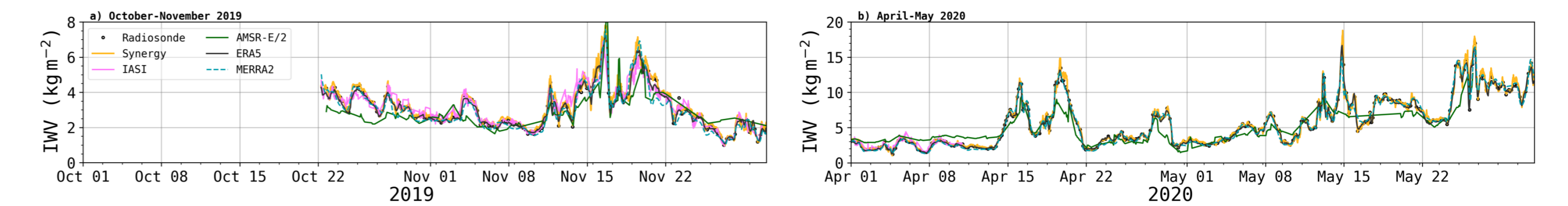


Fig. 6: IWV time series for parts of MOSAiC from radiosondes, MWR, reanalyses and satellite products.

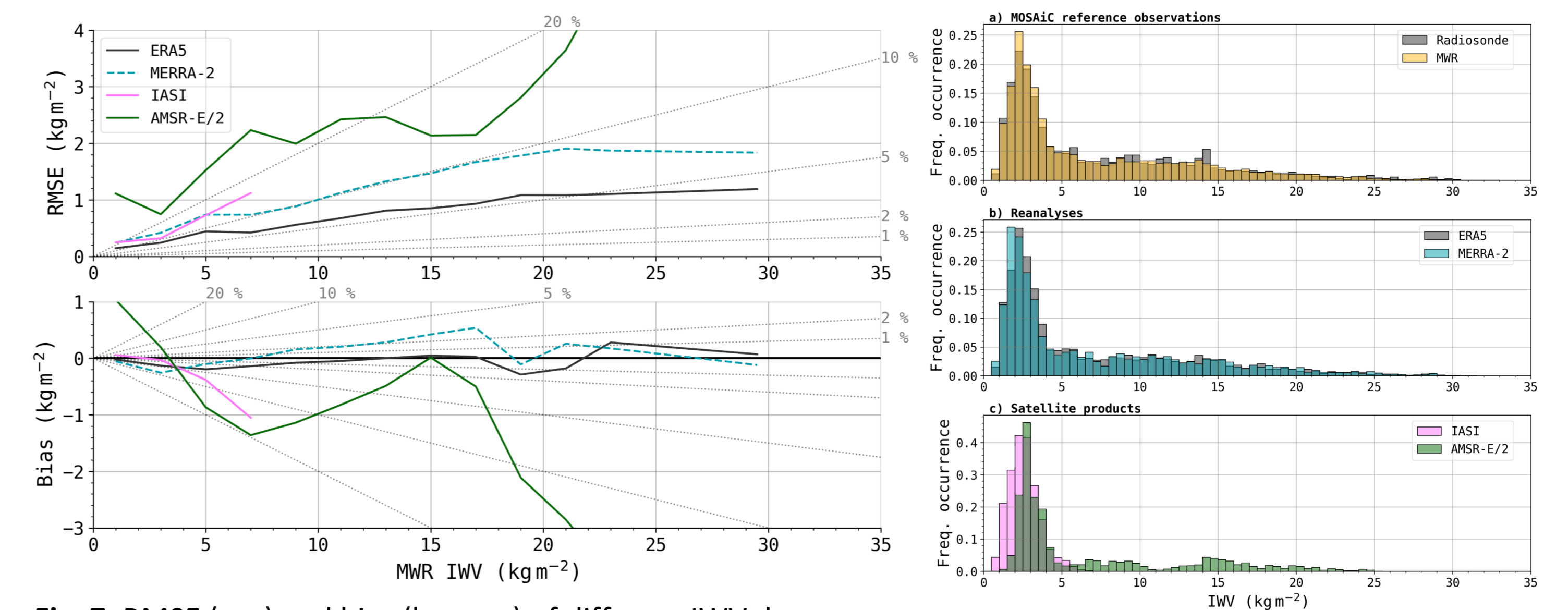


Fig. 7: RMSE (top) and bias (bottom) of different IWV datasets from reanalyses and satellites.

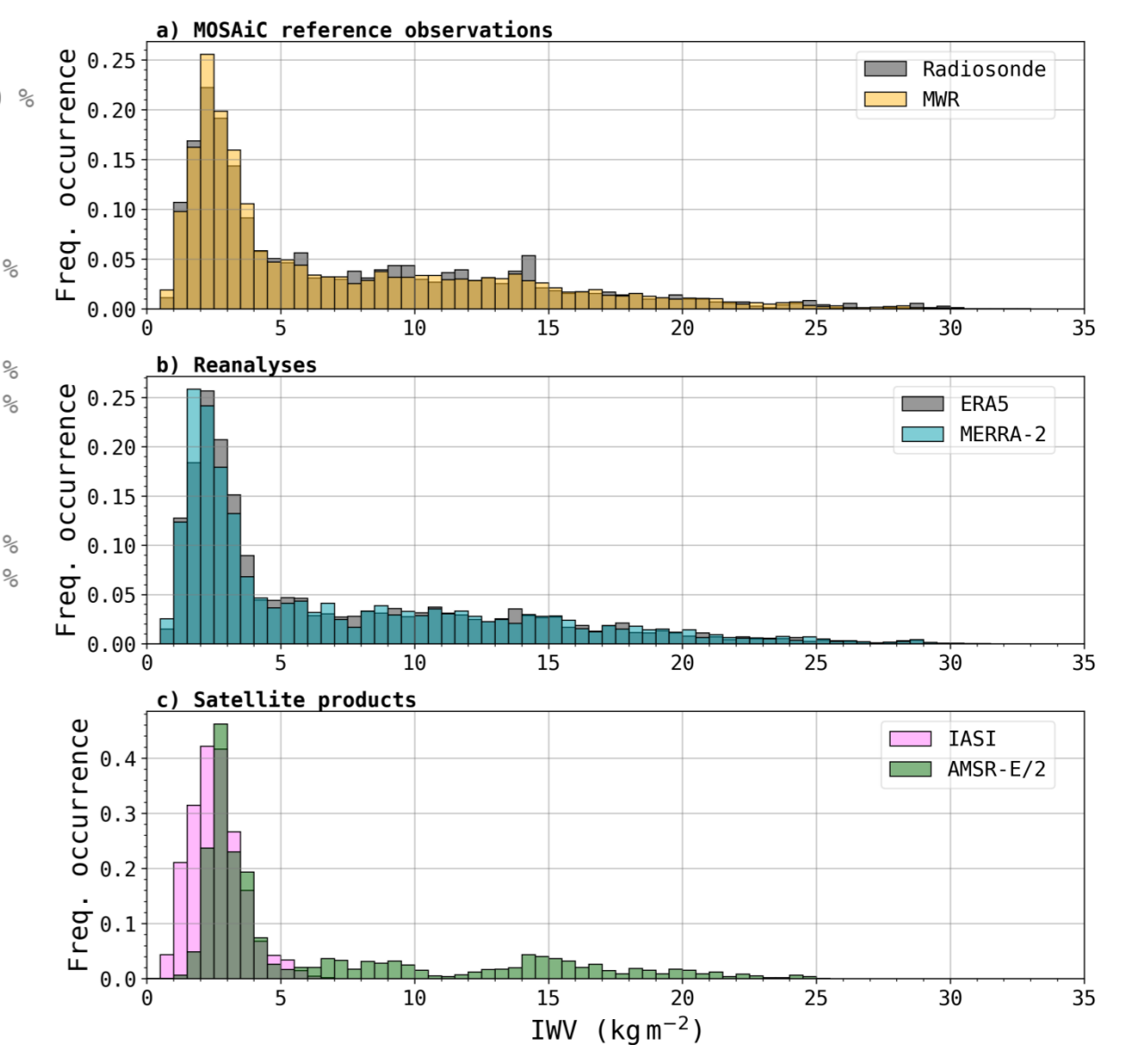


Fig. 8: IWV histograms from MOSAiC reference observations (a), reanalyses (b) and satellite products (c).

- Apart from slight biases (5 %), ERA5 agrees very well with MOSAiC observations for IWV and humidity profiles (but radiosondes have been assimilated)
- MERRA2 shows negative biases for low IWV, positive bias for high IWV
- The satellite products IASI & AMSR-E/2 have biases > 10 % in low IWV conditions

IVb: Humidity profile comparison

Case study of a developing humidity inversion on 20 November 2019. Here, the AMSR-E/2 is excluded because it contains IWV only (Fig. 9 and 10). ERA5 captures the inversion best compared to the reference observations.

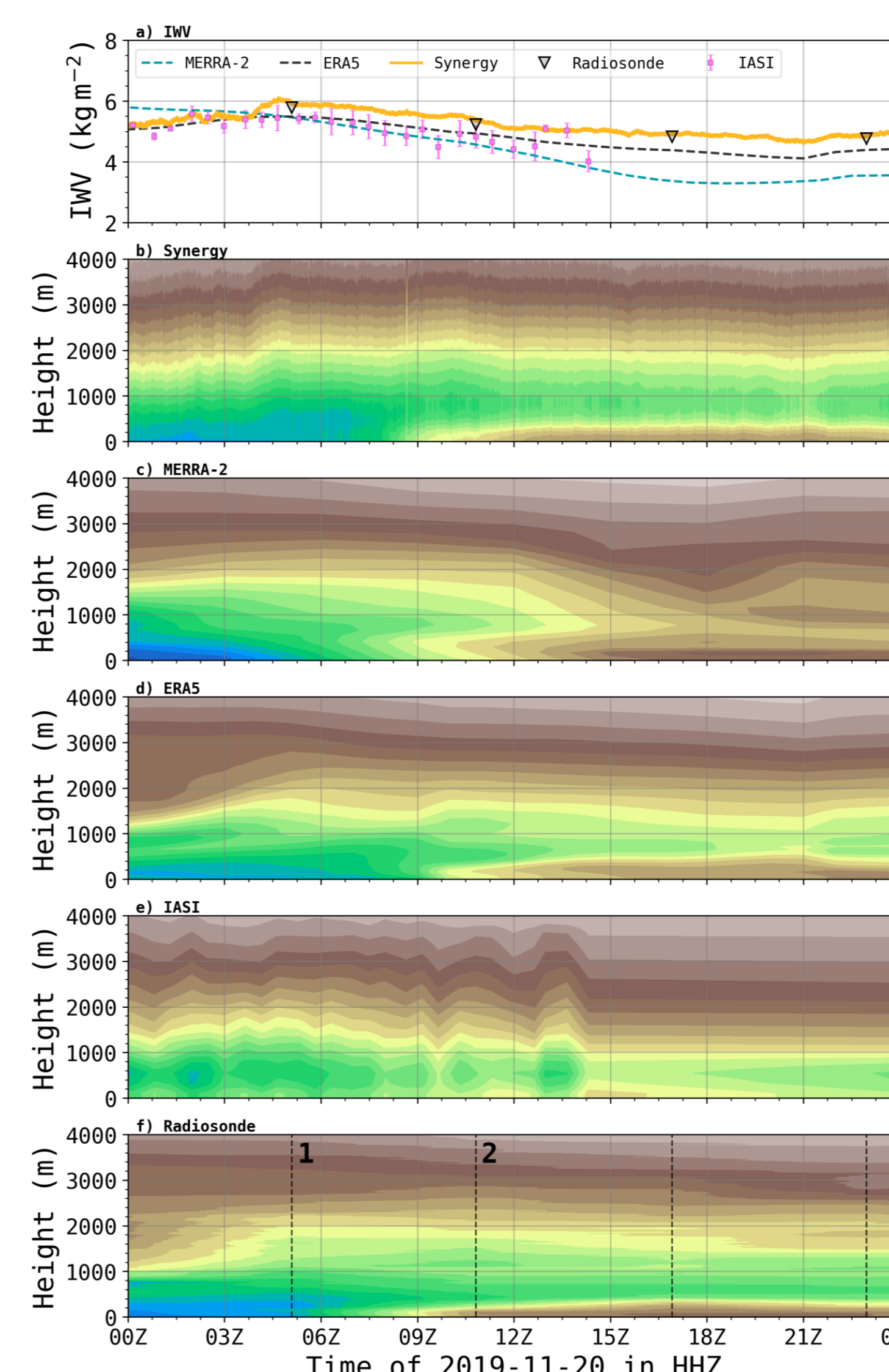


Fig. 9: (a) IWV and (b) – (f) specific humidity time-height cross sections from reanalyses, satellite products and MOSAiC reference observations.

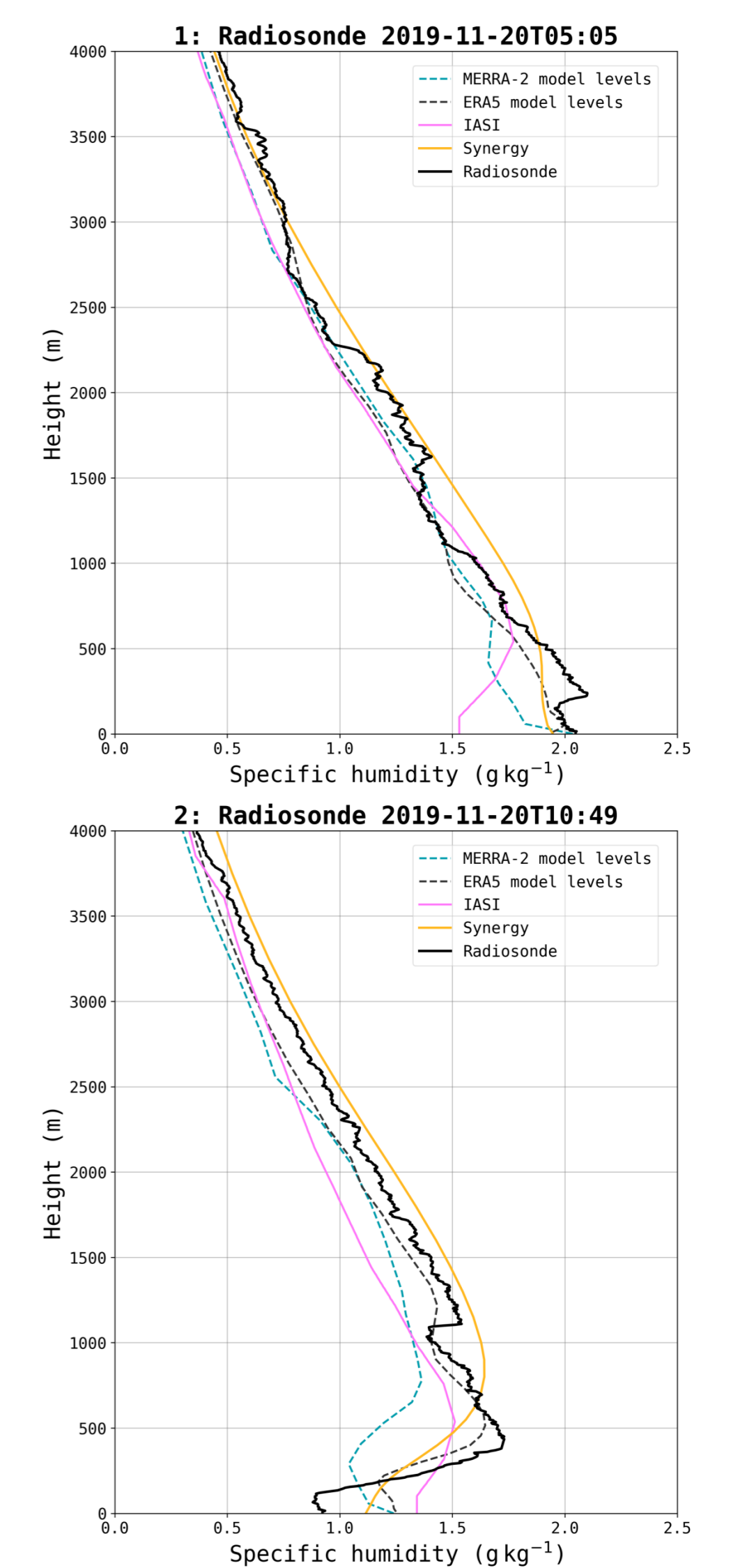


Fig. 10: Specific humidity profile snapshots at 05:05 (top) and 10:49 UTC (bottom) on 2019-11-20.

- The synergetic MWR humidity profile retrieval is able to resolve the inversion and capture its development
- ERA5 agrees well with radiosonde observations, which is expected because they have been assimilated
- IASI and MERRA2 cannot capture the strength and development of the humidity inversion

V: OUTLOOK

- Perform statistical analysis of humidity inversion characteristics
- Investigate influence of humidity profile errors on downward thermal-infrared radiation errors