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Atmospheric Trace Gases and Remote Sensing

Investigating moisture pathways by comparing ICON-ART-Iso simulations with MetOP/IASI satellite data

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Introduction

During the last decade, investigating stable isotopologues of atmospheric water vapor has been shown to be a promising tool for analyzing processes in the hydrological cycle, because the distributions of {H_2O, δD} pairs depends on moisture pathways and sources. δD is the standardized ratio between the heavy isotopologue HDO, where one hydrogen atom is substituted with the heavy isotope deuterium, and H_2O.
In this work, we present ICON-ART-Iso, the isotopologue enabled version of ICON, and discuss a method for adequately evaluating the modeled {H_2O, δD} pair distributions with remote sensing data obtained from the satellite nadir sensor IASI (*Infrared Atmospheric Sounding Interferometer*).

ICON

- NWP physics [1]
- two-way-nesting
- included water tracer types: q_v, q_s, q_r, q_i, q_c, q_g, q_h

- tendencies (S) for non-fractionating processes of heavy (h) isotopologues:

$$S^h = S^l \cdot \frac{q_x^{h,\,\mathrm{source}}}{q_x^{l,\,\mathrm{source}}}$$

ART

- flexible tracer infra-structure by using XML tables [3]
- non-fractionating two-moment microphysics scheme, extended for cloud-aerosol interactions

Iso

- calculation of diagnostic passive water tracers [2]
  - heavy water isotopologues
  - process- and region-based tagging tracers
- fractionation: change in the ratio of the isotopologues due to different equilibrium fractionation factors α and diffusion constants *D*
- fractionating processes:
  - surface evaporation
  - parametrized microphysics
  - saturation adjustment
  - convection

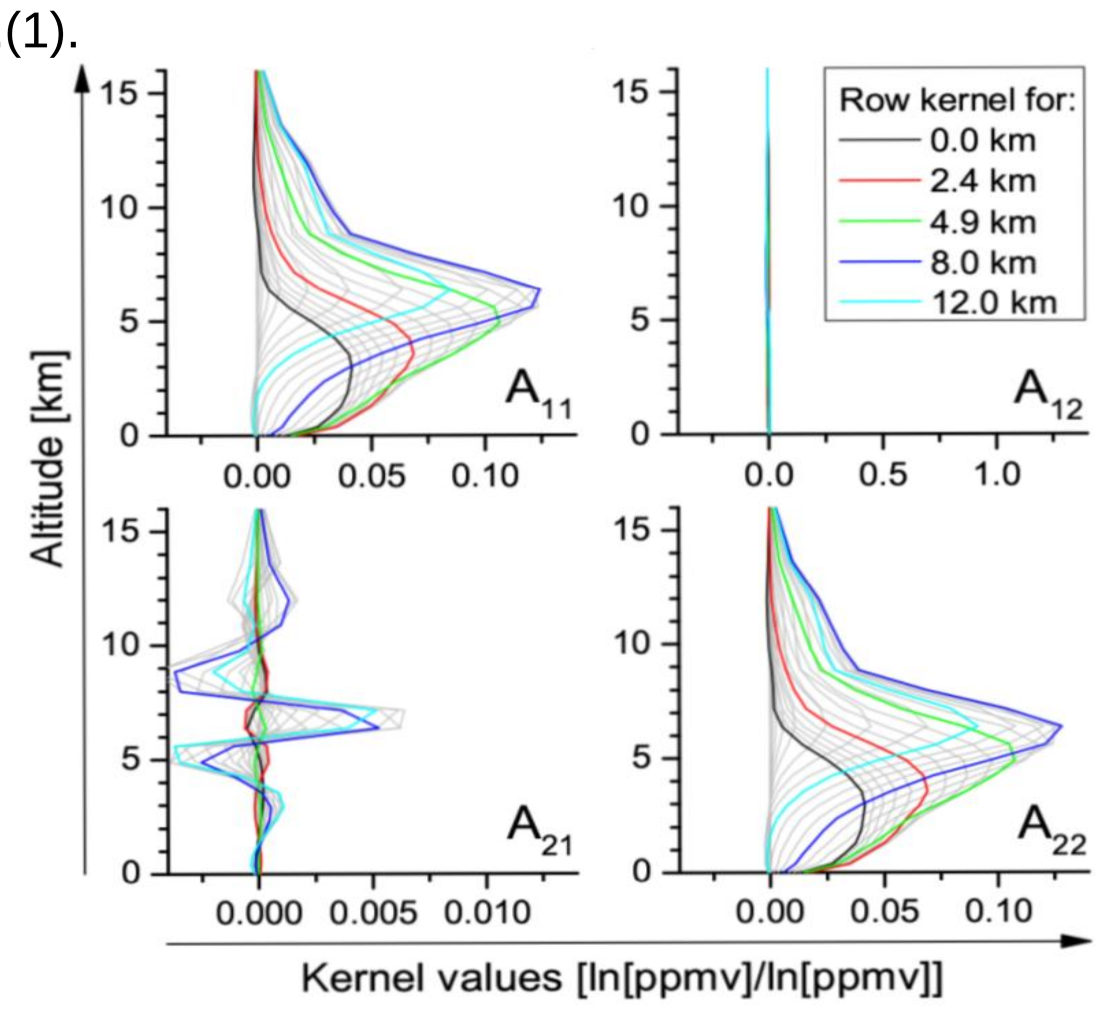
Postprocessing with the Retrieval Simulator

Remote sensing data ($\hat{x}$) have a limited vertical resolution and sensitivity which can be related to the real atm. state (x) and the a priori state (x_a) by:

$$\hat{x} = A(x - x_a) + x_a \qquad (1)$$

This weighting needs to be considered for comparisons between model and remote sensing data [4]:

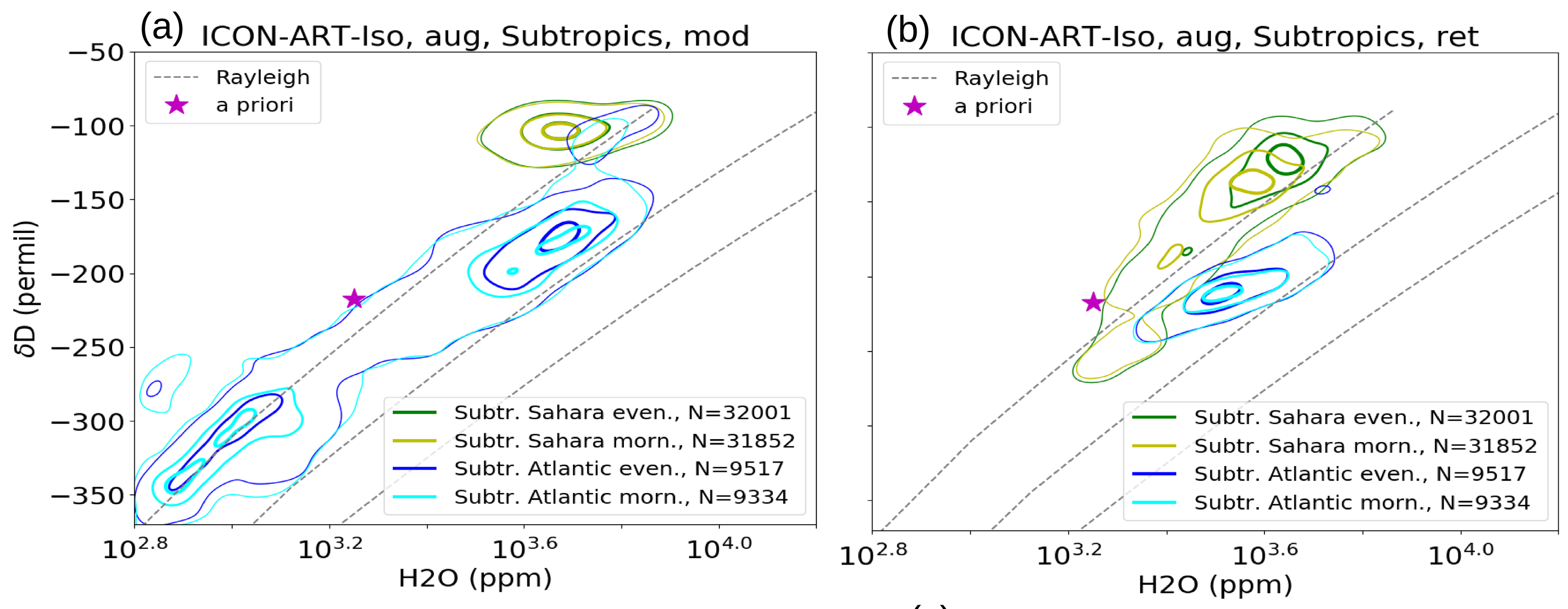
1. The averaging kernel matrix A corresponding to a modeled atmosphere x is calculated by the retrieval simulator, based on a simple radiative transfer model.
2. The model atmosphere as observable by the remote sensor is calculated according to eq.(1).
3. This processed model output $\hat{x}$ can then be compared to the remote sensing data.



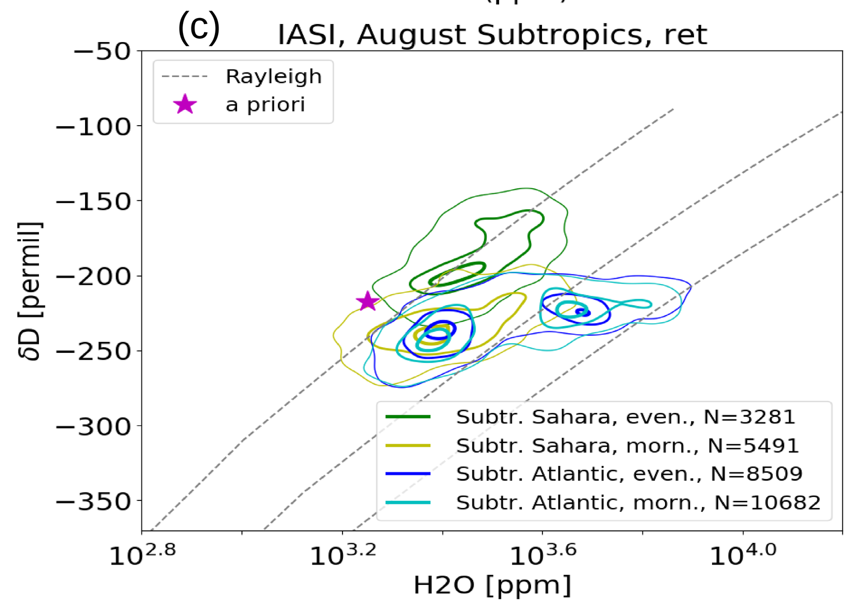
Entries of the matrix A, *describing the sensitivities with respect to H_2O and δD (A_{11} and A_{22}) and their cross-responses (A_{12} and A_{21}). The curves indicate the weighting functions for the different altitude regions.*

ICON-ART-Iso compared to IASI data

The sensor IASI is carried by the polar-orbiting sun-synchronous satellite MetOp and measures at approx. 09:30 and 21:30 local time. Its spectra are processed by the MUSICA retrieval processor [5]. The model data are sampled and processed for morning and evening IASI overpasses over chosen regions.
The raw ICON-ART-Iso output at 5km (a) and the model data processed by the retrieval simulator (b) are shown. In this first comparison between the IASI pairs (c) and the post-processed model state (b) results in an overall good qualitative agreement. However, the model underestimates the daily cycle over the Sahara.



Pair distributions of {H_2O, δD}, *shown by isolines of the relative normalized frequency distributions (0.2, 0.6 and 0.9). The datasets for region Sahara (Atlantic) are sampled for land (ocean) points. Data are chosen for the period 12. – 18.08.2014.*



Conclusion

- successful implementation of water isotopologues with ICON
- simulation of averaging kernels is needed for comparing model and satellite data
- first comparison of IASI and ICON-ART-Iso provides promising results

Outlook

- detailed studies of moisture pathways during the West African Monsoon in nested domains, as part of the DFG-project MOTIV
- further model development of ICON-ART-Iso
- improvement of the radiative transfer model of the retrieval simulator

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