Karlsruhe Institute of Technology

Institute of Meteorology and Climate Research
Troposphere Research (IMK-TRO)

Modeling of stable water isotopes in Central Europe with COSMOiso

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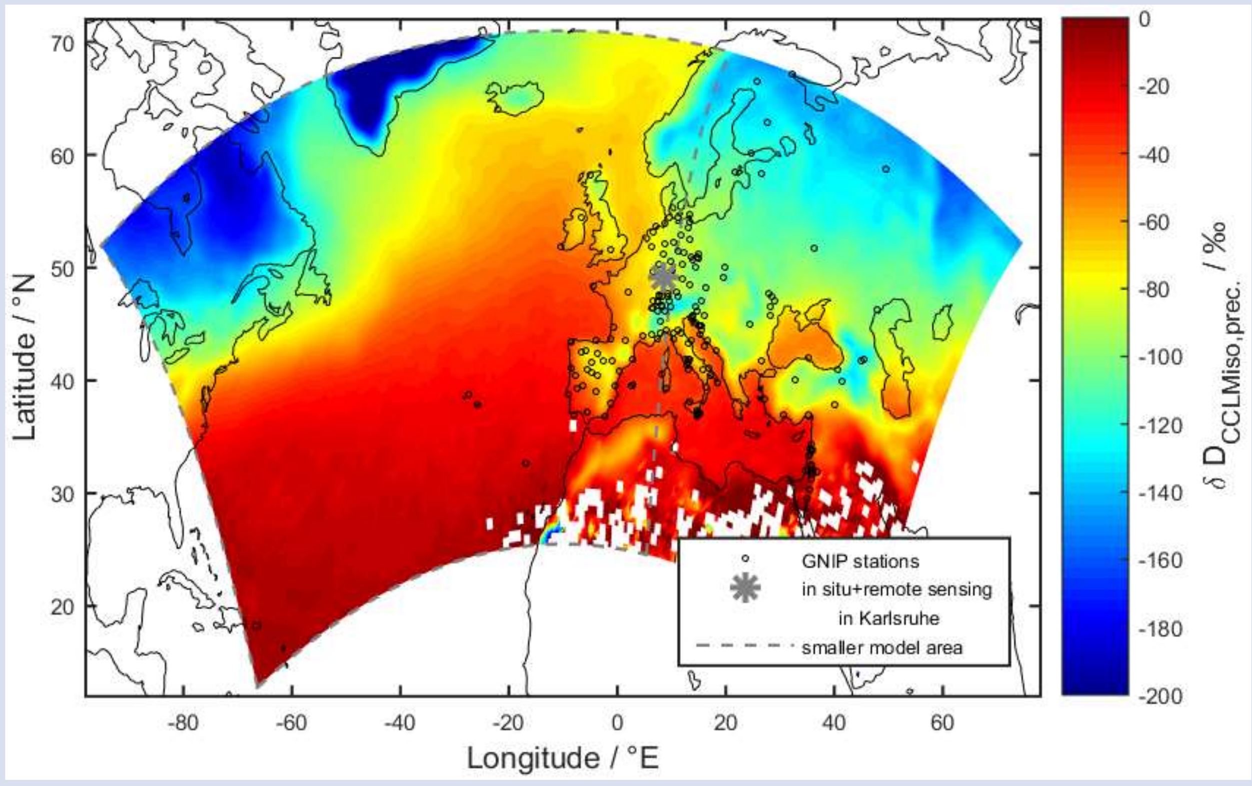
The stable water isotopes $HH^{16}O$ and $HD^{16}O$ are fractionated during phase transitions in consequence of slightly different vapor pressures and constants of diffusion of the different water isotopes. For this reason, the concentration ratios $R_D=[HD^{16}O]/[HH^{16}O]$ of atmospheric water vapor or precipitation reflect the condensation and evaporation history of air masses. Concentration ratios are given as $\delta D=R_D/R_{D,VSMOW}-1$, whereby $R_{D,VSMOW}=0.00031152$ is the concentration ratio of the Vienna Standard Mean Ocean Water.

(1) We validate δD simulations of the isotope-enabled limited-area model COSMOiso (Pfahl et al., 2012) in CLimate Mode (CCLMiso) by comparing 15 years of modeled δD ratios from Central Europe (2000-2014) with δD observations (precipitation, in situ, and remote sensing).

Model configuration:

- horizontal resolution of 0.5° x 0.5°
- fifty vertical levels
- lateral boundary data from ECHAMwiso 5.4 (Werner et al. 2011) simulations, which were nudged to observations.

(2) We identify the most important processes with respect to δD in Central Europe by means of four sensitivity runs and assess the suitability of the different types of observations for validation of the respective processes in the model.



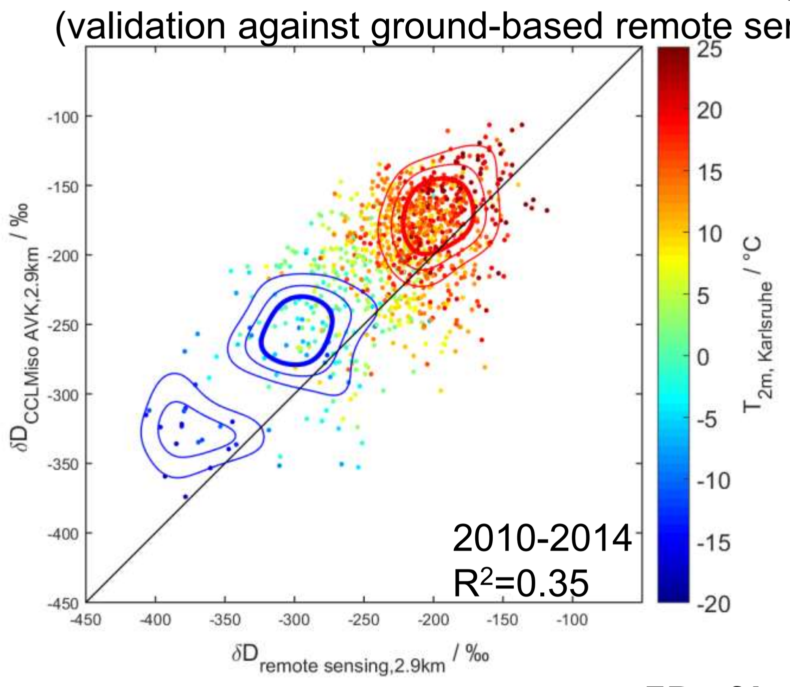
CCLMiso simulation of δD in precipitation in winters (DJF) from 2000 to 2014.

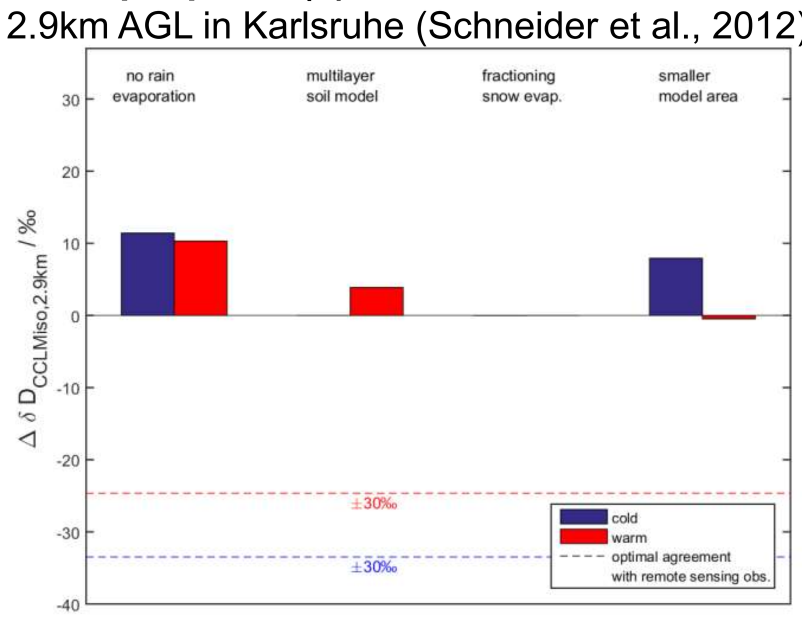
Model-data comparisons

Sensitivity study

δD of water vapor in the free troposphere (F)

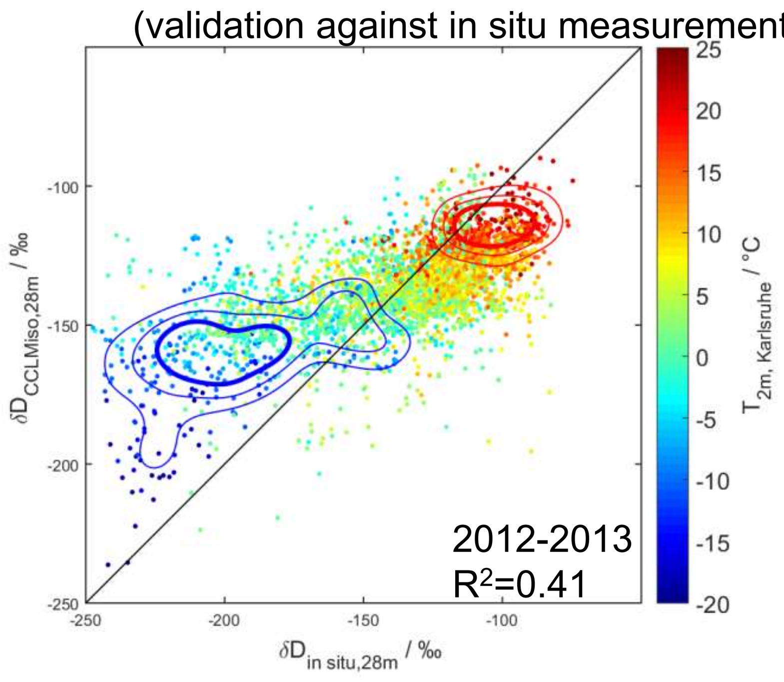
(validation against ground-based remote sensing of δD 2.9km AGL in Karlsruhe (Schneider et al., 2012))

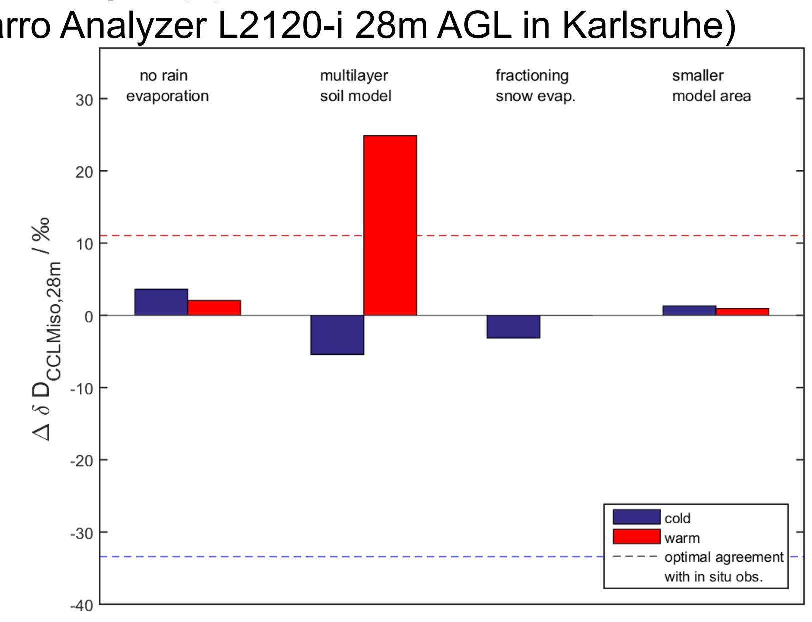




δD of low-level water vapor (L)

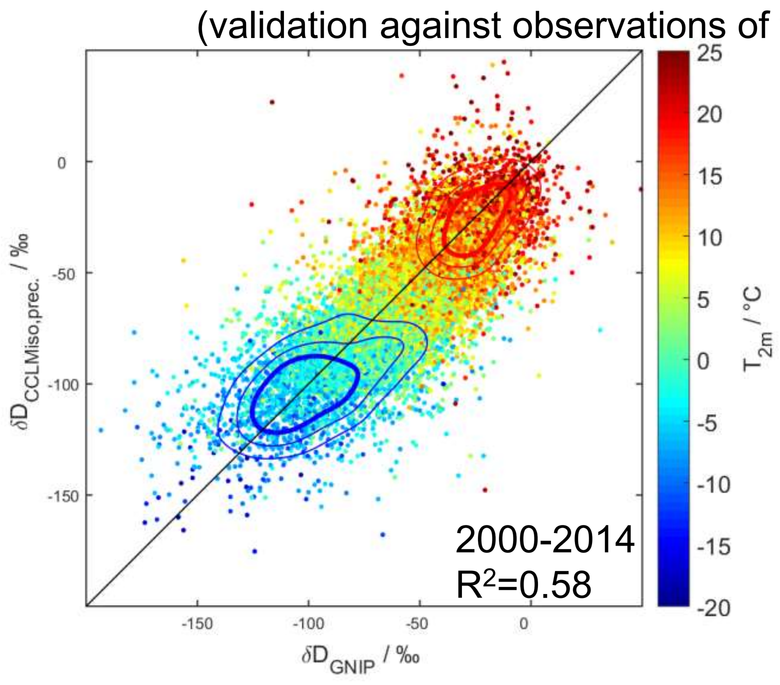
(validation against in situ measurements with Picarro Analyzer L2120-i 28m AGL in Karlsruhe)

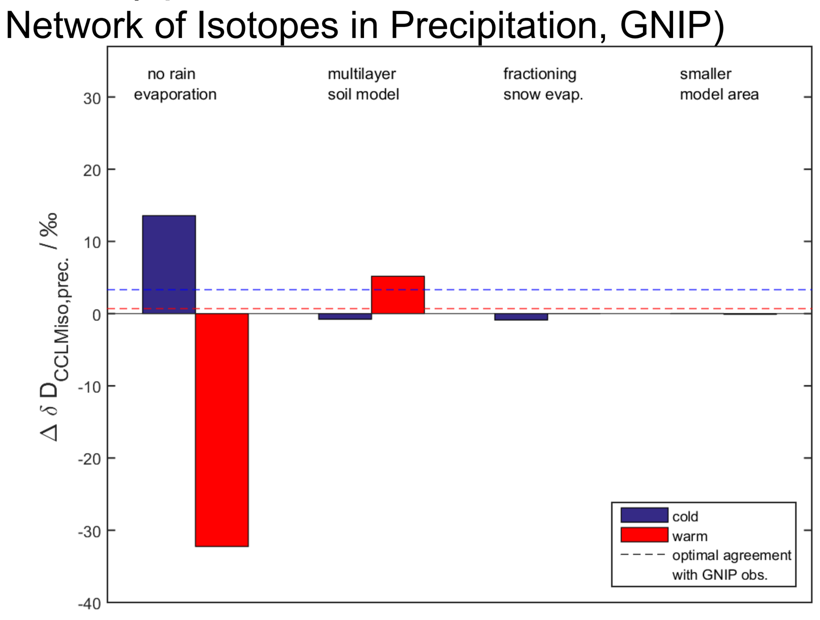




δD in precipitation (P)

(validation against observations of the Global Network of Isotopes in Precipitation, GNIP)

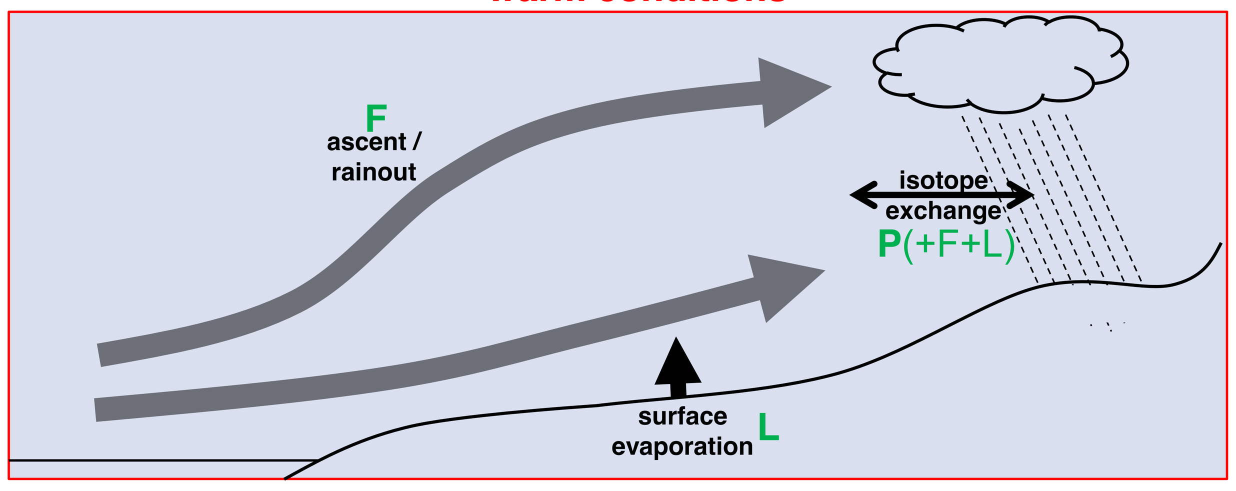


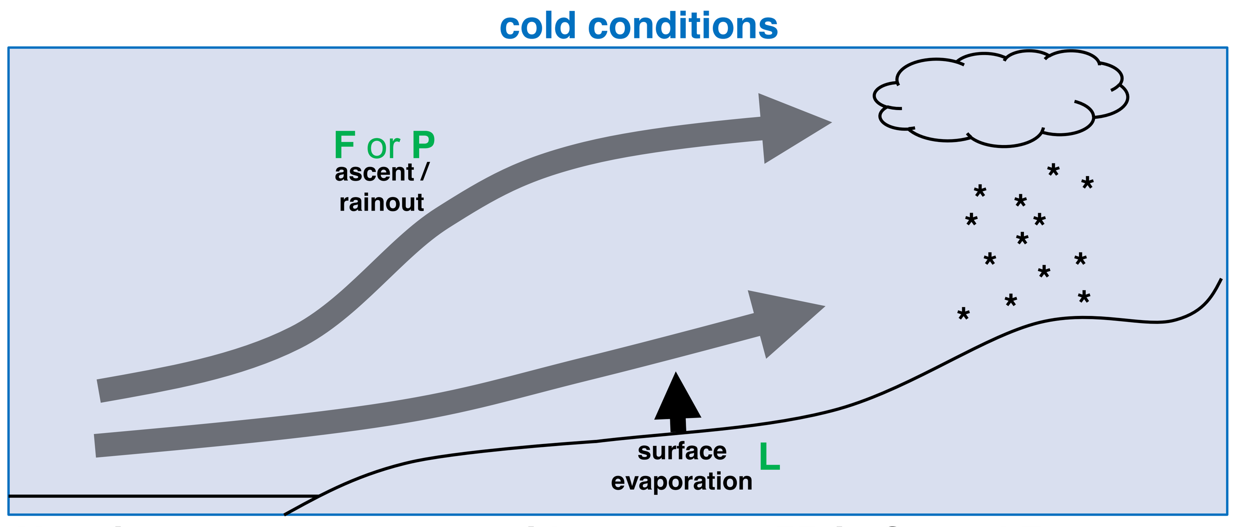


Contour lines: Two-dimensional probability distributions of modeled and observed δD, which correspond to the lowest(<-4°C) / highest(>17°C) decile of modeled T_{2m} at the sampling locations. Lines indicate probabilities of occurrence of **0.7**, 0.5, and 0.3 (normalized to 1 at the maximum).
AVK: Averaging kernels applied.

Sensitivity of the modeled δD on assumptions of CCLMiso, calculated for the lowest / highest decile of modeled T_{2m} at the sampling locations.

Suitability of different types of observations for model validation





Most important processes with respect to δD in Central Europe.
Types of observations which are suited for validation of the respective processes – P (δD in precipitation), **L** (δD of low-level water vapor), **F** (remote sensing of δD in the free troposphere).

Conclusions for warm conditions in Central Europe:

- The modeled δD in precipitation is highly sensitive to the strength of rain evaporation and isotope exchange. Therefore, the accuracy of modeled δD of water vapor in the free troposphere as well as the accuracy of modeled δD of low-level water vapor are difficult to assess from comparisons with GNIP data.
- The modeled δD of water vapor in the free troposphere agrees with remote sensing observations (max. sensitivity at 2.9km AGL) within the range of uncertainty of the observations. This implies a robust representation of isotope microphysics with respect to the formation of precipitation in the model.
- δD in low-level water vapor is suited for validation of isotope microphysics with respect to surface evaporation. The δD in low-level water vapor is simulated best if applying an isotope-enabled multilayer soil model.

Conclusions for cold conditions in Central Europe:

- The modeled δD in precipitation agrees with observations of the GNIP. Since isotope exchange can be ignored in the case of solid precipitation, the GNIP data allows to validate the modeled δD of water vapor at higher altitudes (condensation level). The accuracy of modeled δD of low-level water vapor is difficult to assess from a comparison with GNIP data.
- Consistent with the findings from δD in precipitation, modeled δD in the free troposphere agrees with remote sensing observations within the range of uncertainty of the observations.
- The modeled δD ratios in low-level water vapor are on average 33‰ higher than the observed ratios. The main reason is the underestimation of easterly moisture transport in the CCLMiso simulations of winter 2012/2013. Spectral nudging of horizontal wind fields to the ECHAMwiso simulations reduces the mean difference between modeled and observed δD ratios to 5‰ (in the model run with isotope-enabled multilayer soil model).

References:
Pfahl et al. (2012), Atmos. Chem. Phys., 12, 1629–1648, 2012
Schneider et al. (2012), Atmos. Meas. Tech., 5, 3007–3027, 2012
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