# The added value of tropospheric water vapor isotopic measurements for process-oriented evaluation of convective, cloud and transport processes in climate models

Camille Risi*, Sandrine Bony, Gaelle Benoit
*LMD/IPSL, Paris (France)*, *contact: crlmd@lmd.jussieu.fr

## Introduction

Differences between model representations of convective and cloud processes remain the dominant source of inter-model dispersion in climate change projections for a given grenhouse gas scenario. Evaluating the representation of the water cycle in climate models remain a challenge. Because of fractionation during phase changes, the water vapor isotopic composition reflects the history of phase changes during the water cycle. The development and availability of a growing number of remote sensing retrievals of isotopic composition provides an opportunity to explore the added value of tropospheric water vapor isotopic measurements for process oriented evaluation of climate models. This is investigated here using the LMDZ GCM enabled with isotopes ([6]).

*$q$ = specific humidity; $\delta D$= concentration in HDO in ‰ anomalies relatively to sea water; SWING2=isotopic GCM inter-comparison project*

## Role of convective detrainment in the upper tropospheric moisture budget

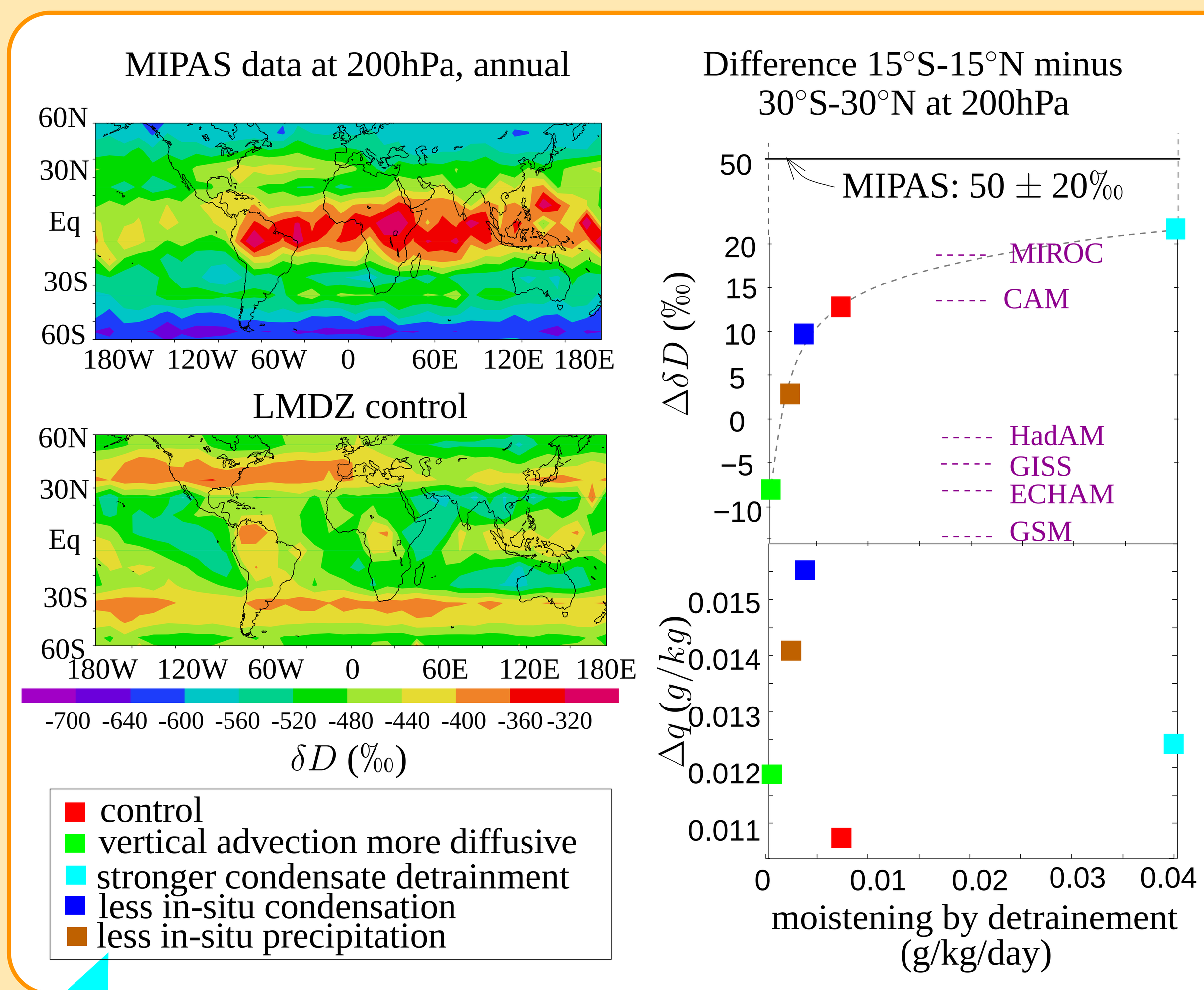
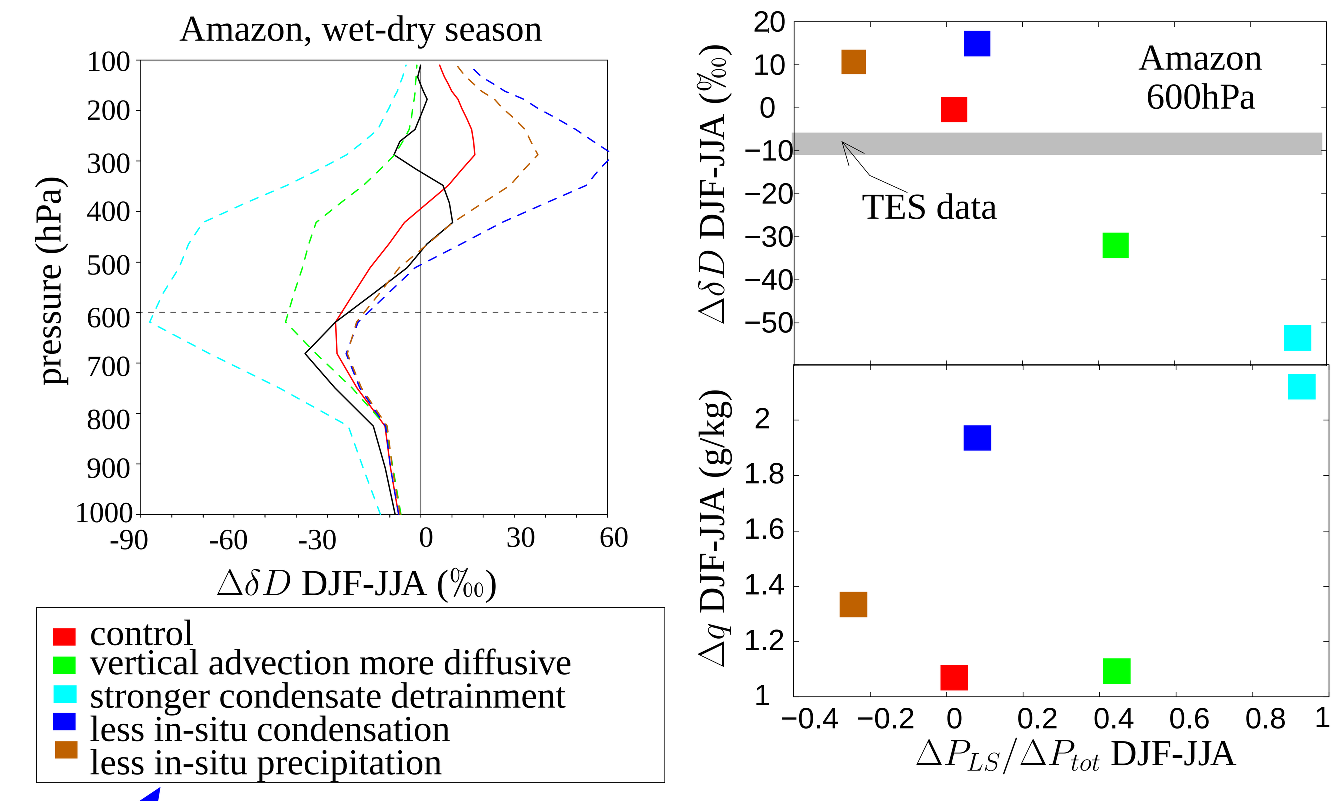



*Fig: The MIPAS data shows maximum enrichment in the upper troposphere. LMDZ has trouble reproducing this latitudinal gradient. Sensitivity tests show that the larger the moistening tendency by convective detrainment, the sharpest the latitudinal gradient. This effect is not detected in $q$. No test and none of the SWING2 models can capture the $\delta D$ gradient. Data or model issue?*

## Relative contribution of convective and large-scale precipitation

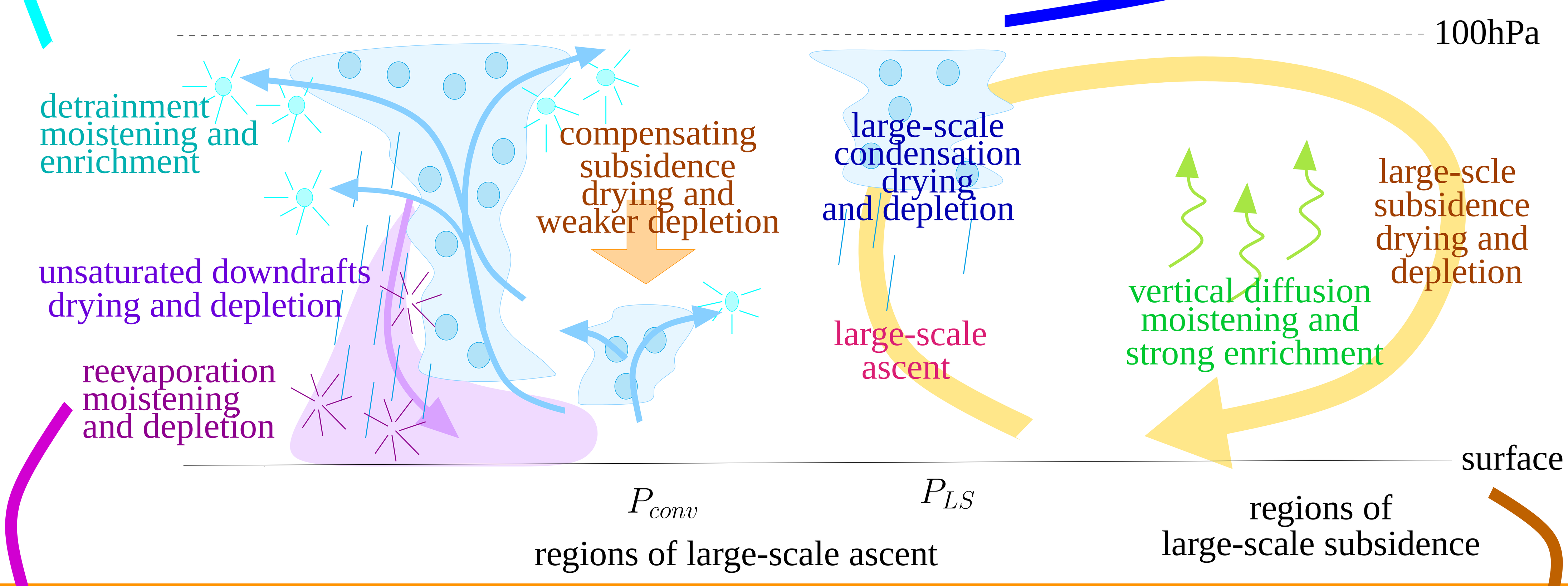
In GCMs, precipitation can be produced by the convective or large-scale schemes. The physical meaning of these 2 schemes is model-dependent. Their relative contribution is arbitrary, but has a strong impact on diabatic heating profiles and tracer transport. Water isotopes can provide an additional constraint: the balance between compensating subsidence and convective detrainment (associated with convective precip $P_{conv}$) leads to more enriched $\delta D$ than the balance between large-scale ascent and large-scale condensation (associated with large-scale precip $P_{LS}$) for a given $q$.

*Fig: Example over the Amazon. In the TES data, during the wet season, the water vapor is more depleted in the lower troposphere and slightly more enriched in the upper troposphere. LMDZ reproduces this feature. Sensitivity tests show that the larger the contribution of large-scale precipitation to the precipitation seasonal variation, the larger the mid-tropospheric depletion during the wet season. This effect is not detected in $q$.*



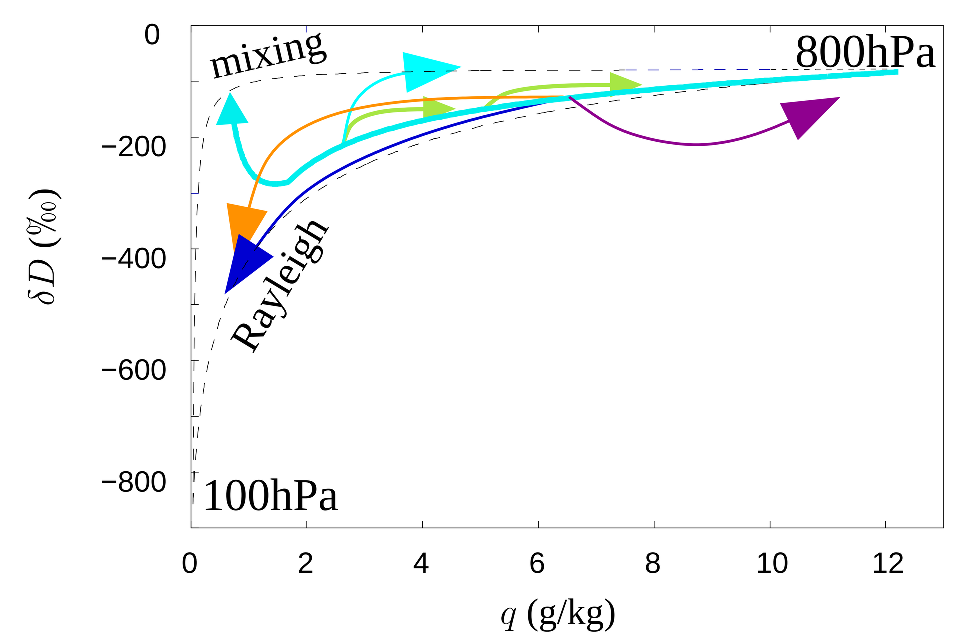

## Factors controling tropical water vapor $\delta D$

*Fig: Observational and modeling studies have suggested or evidenced the enriching role of convective detrainment ([3]) and the depleting role of unsaturated downdrafts ([4, 5]), rain reevaporation ([9]), large-scale condensation ([2]) and large-scale subsidence ([1]) on the water vapor.*



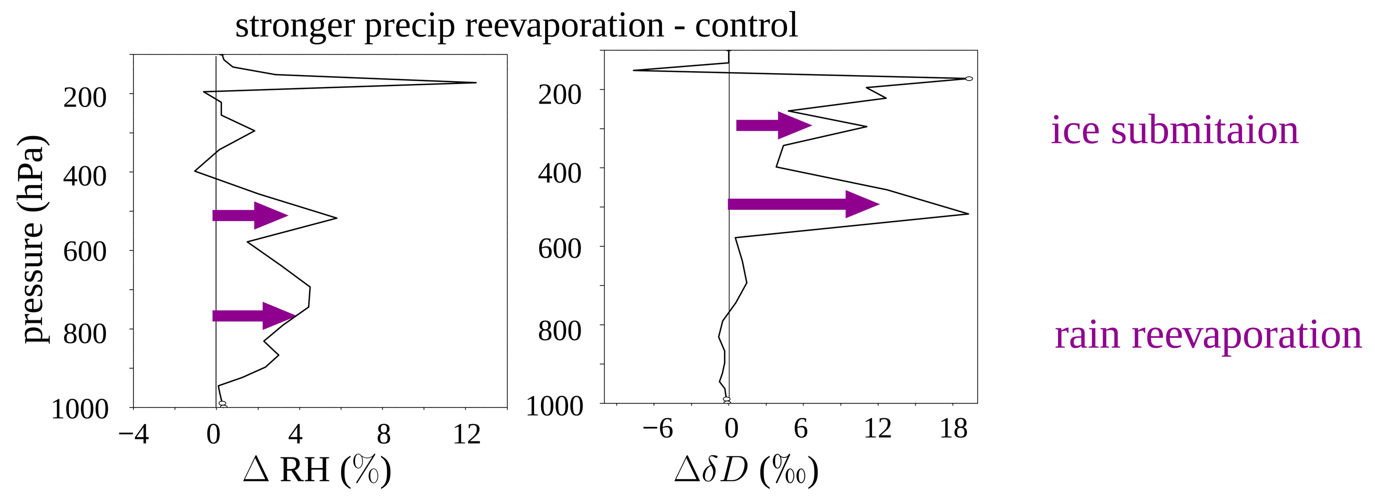

## Complementarity $q$- $\delta D$

*Fig: Rayleigh distillation (resulting from progressive dehydration by condensation) has a log shape while mixing has a hyperbolic shape ([9]). This explains why $\delta D$ of an air mass depends on the previous dehydrating and moistening processes. In addition, there is fractionation during rain reevaporation.*



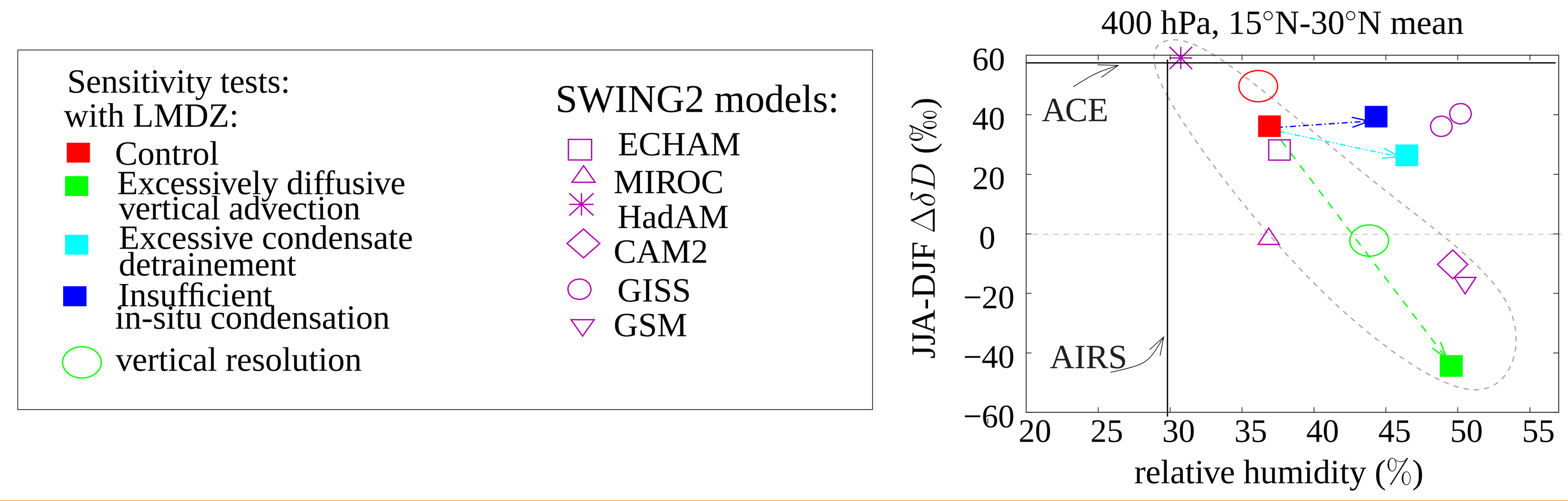

## Effect of precipitation reevaporation

*Fig: 1D simulations are run in radiative-convective equilibrium. In a sensitivity test, precipitation reevaporation is doubled and the troposphere is moistened. Ice sublimation doesn't fractionate and enriches the upper troposphere. Rain reevaporation fractionates and its effect depends on the reevaporated fraction: depleting (enriching) effect for small (large) reevaporated fractions.*




## Understanding the upper-tropospheric moist bias in GCMs

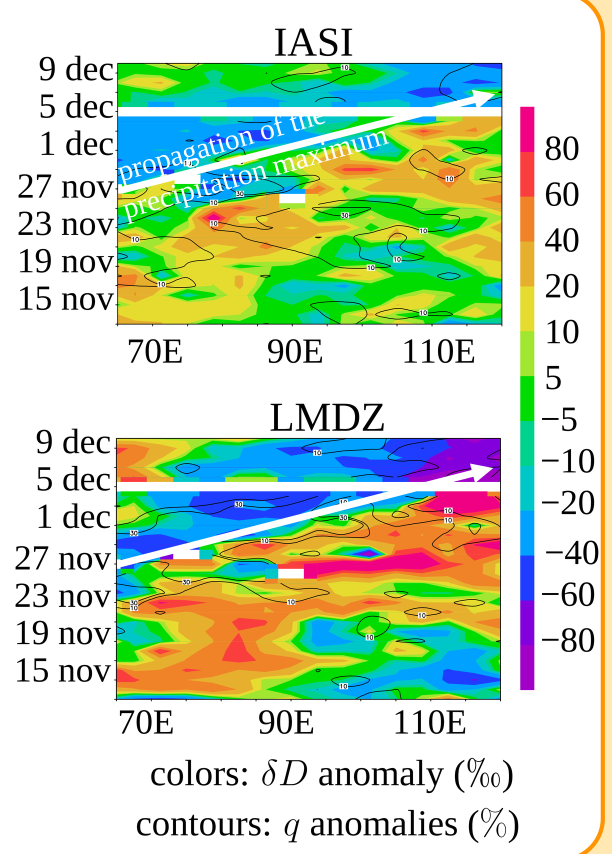
*Fig: GCMs often feature a moist bias in the upper troposphere. To understand the cause of this bias, we perform sensitivity tests in which it is amplified. Only an excessive vertical diffusion leads to a reversed $\delta D$ seasonality compared to observations. Comparing with 7 SWING2 models suggests that the moist bias frequently results from an excessive diffusion ([7, 8]).*




## Perspectives

- collocate $q$, $\delta D$ and cloud data: e.g. A-train (TES+CALIPSO/Cloudsat), IASI, ARM sites.
- spatial structure around convective systems, evolution during convective life cycles and during MJO events using IASI data
- build a theroretical framework to interpret joint $q$, $\delta D$ and cloud distribution
- actually use isotopic data for model evaluation
- combine water isotopic tracers with air tracers (CO, $O_3$, Be)?

*Fig: Observed (IASI) and simulated $\delta D$ during the November 2011 CINDY-DYNAMO campaign case at 500hPa averaged over 10S-10N.*




**Acknowledgments** Thanks to J Worden for the TES data, G Stiller for the MIPAS data, K Walker for the ACE data, J-L Lacour for the IASI data, D Noone for supervising my post-doc in 2010-2011.

## References

[1] J. Galewsky and J. V. Hurley. An advection-condensation model for subtropical water vapor isotopic ratios. *J. Geophys. Res.*, 115 (D16):D16115 , doi:10.1029/2009JD013651, 2010.

[2] J.-E. Lee, R. Pierrehumbert, A. Swann, and B. R. Lintner. Sensitivity of stable water isotopic values to convective parameterization schemes. *Geophy. Res. Lett.*, 36:doi:10.1029/2009GL040880, 2009.

[3] E. J. Moyer, F. W. Irion, Y. L. Yung, and M. R. Gunson. ATMOS stratospheric deuterated water and implications for troposphere-stratosphere transport. *Geophys. Res. Lett.*, 23:2385–2388, 1996.

[4] C. Risi, S. Bony, F. Vimeux, M. Chong, and L. Descroix. Evolution of the water stable isotopic composition of the rain sampled along Sahelian squall lines. *Quart. J. Roy. Meteor. Soc.*, 136 (S1):227 – 242, 2010.

[5] C. Risi, S. Bony, F. Vimeux, C. Frankenberg, and D. Noone. Understanding the Sahelian water budget through the isotopic composition of water vapor and precipitation. *J. Geophys. Res*, 115, D24110:doi:10.1029/2010JD014690, 2010.

[6] C. Risi, S. Bony, F. Vimeux, and J. Jouzel. Water stable isotopes in the LMDZ4 General Circulation Model: model evaluation for present day and past climates and applications to climatic interpretation of tropical isotopic records. *J. Geophys. Res.*, 115, D12118:doi:10.1029/2009JD013255, 2010.

[7] C. Risi, D. Noone, J. Worden, C. Frankenberg, G. Stiller, M. Kiefer, B. Funke, K. Walker, P. Bernath, M. Schneider, D. Wunch, V. Sherlock, N. Deutscher, D. Griffith, P. Wernberg, S. Bony, D. B. Jeonghoon Lee, R. Uemura, and C. Sturm. Process-evaluation of tropical and subtropical tropospheric humidity simulated by general circulation models using water vapor isotopic observations. Part 1: model-data intercomparison. *J. Geophy. Res.*, 117:D05303, 2012.

[8] C. Risi, D. Noone, J. Worden, C. Frankenberg, G. Stiller, M. Kiefer, B. Funke, K. Walker, P. Bernath, M. Schneider, D. Wunch, V. Sherlock, N. Deutscher, D. Griffith, P. Wernberg, S. Bony, J. Lee, D. Brown, R. Uemura, and C. Sturm. Process-evaluation of tropical and subtropical tropospheric humidity simulated by general circulation models using water vapor isotopic observations. Part 2: an isotopic diagnostic of the mid and upper tropospheric moist bias. *J. Geophy. Res.*, 117:D05304, 2012.

[9] J. Worden, D. Noone, and K. Bowman. Importance of rain evaporation and continental convection in the tropical water cycle. *Nature*, 445:528–532, 2007.