Evaluation of the interplay between deep convective parameterization and large-scale condensation using measurements of water isotopic composition profiles

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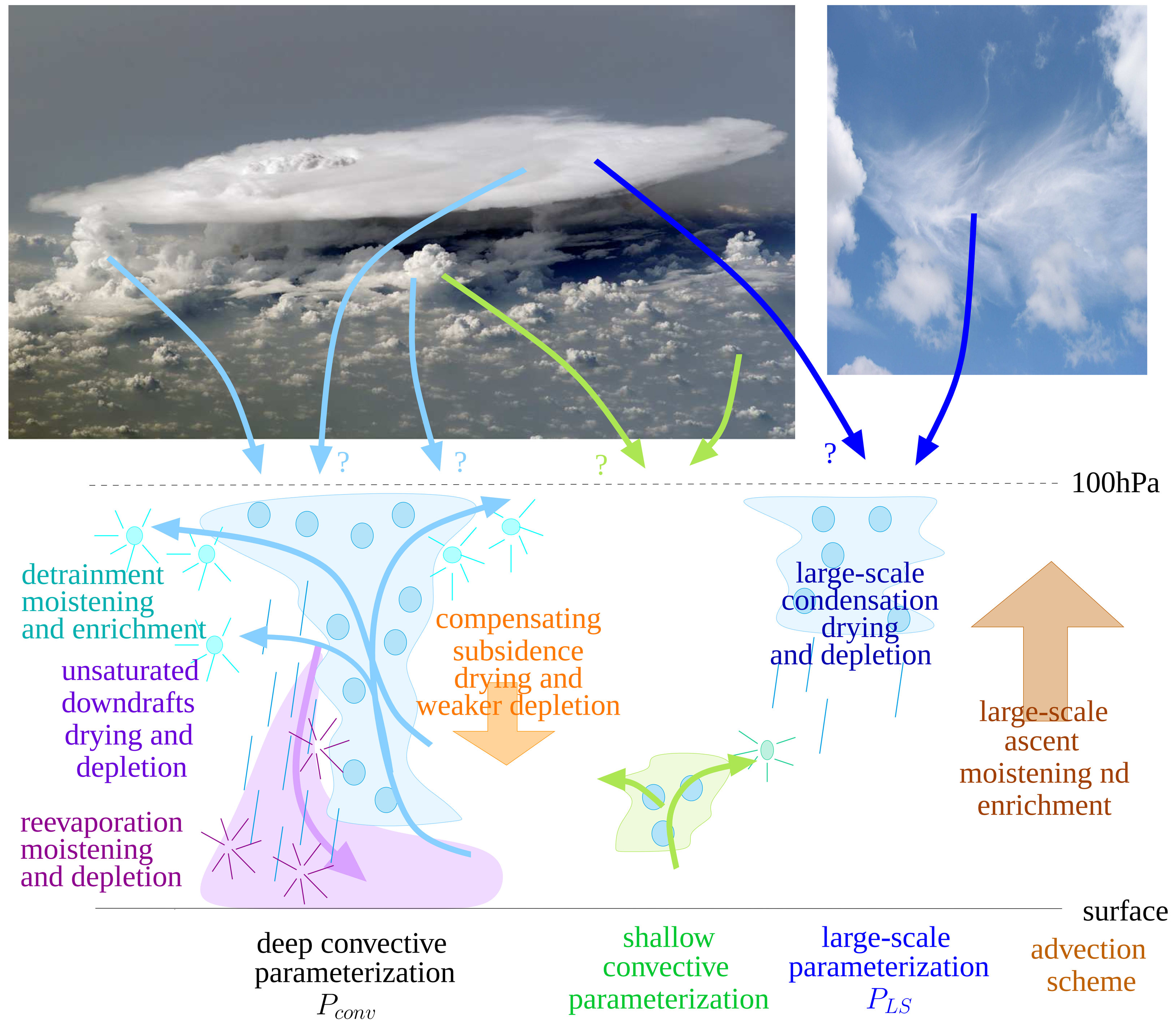
Introduction

A major purpose of a deep convective parameterization in a GCM is to simulate the effect of deep convection on large-scale environmental properties (e.g. temperature, humidity, chemical tracers). How convection affects the environment depends on the deep convective parameterization itself, but also on the interplay with other parameterizations (e.g. shallow convection, large-scale condensation). The proportion of the precipitation produced by the different parameterizations is arbitrary, but has important consequences on heating/moistening profiles and chemical tracer transport. Here we explore the possibility of using profile measurements of water isotopic composition to add some constrain on the interplay between convective parameterization and large-scale condensation, using the LMDZ GCM enabled with isotopes ([8]).

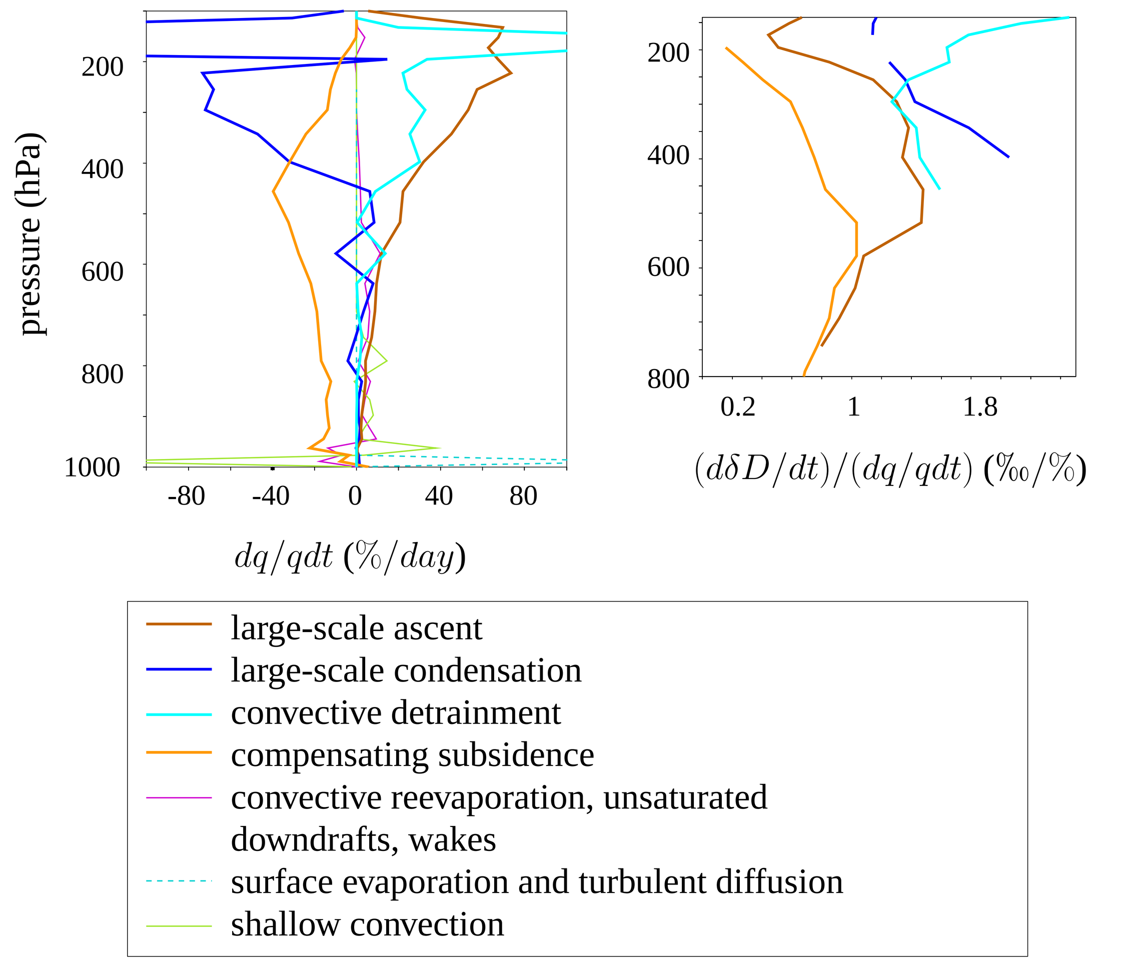
q = specific humidity; δD= concentration in HDO in ‰ anomalies relatively to sea water

Fig: Pictures illustrating a tropical convective region, and how the tropospheric water budget is represented by parametrizations in a GCM. There are two kinds of balances: moistening large-scale ascent compensated by dehydration by large-scale condensation (producing with large-scale precip P_{LS}), and moistening by convective detrainment compensated by dehydration by compensating subsidence (producing with convective precip P_{conv}).
Observational and modeling studies suggest the enriching role of convective detrainment ([4]) and the depleting role of unsaturated downdrafts ([6, 7]), rain reevaporation ([9]) and large-scale condensation ([3]).



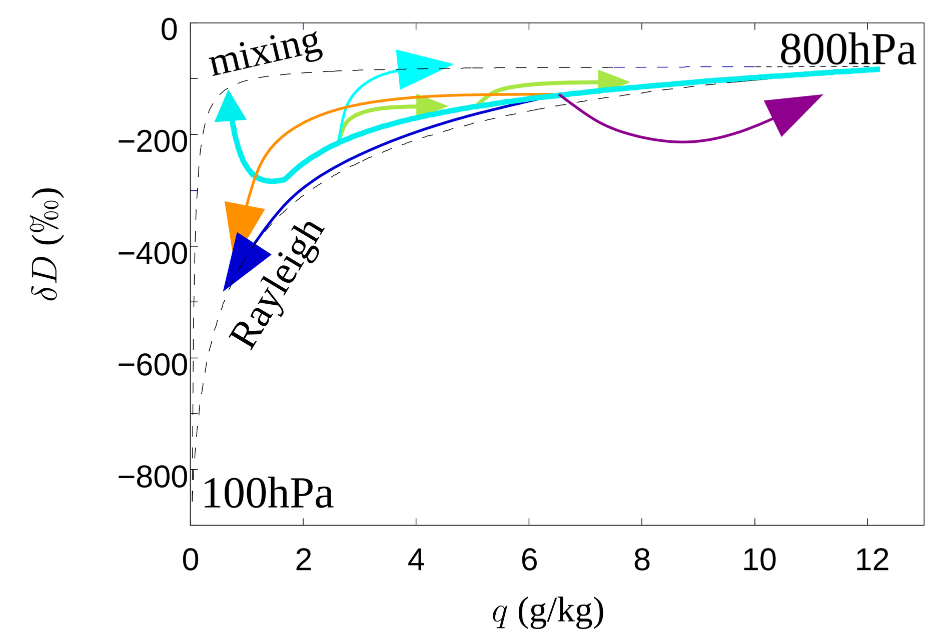
Factors controling tropical water vapor δD

Fig: Humidity tendencies from the different parameterizations, and their δD signature in the free troposphere (example in 1D). Convective detrainment has a stronger enriching effect than large-scale ascent for a given moistening. Large-scale condensation has a stronger depleting effect than compensating subsidence for a given dehydration.



Complementarity q- δD

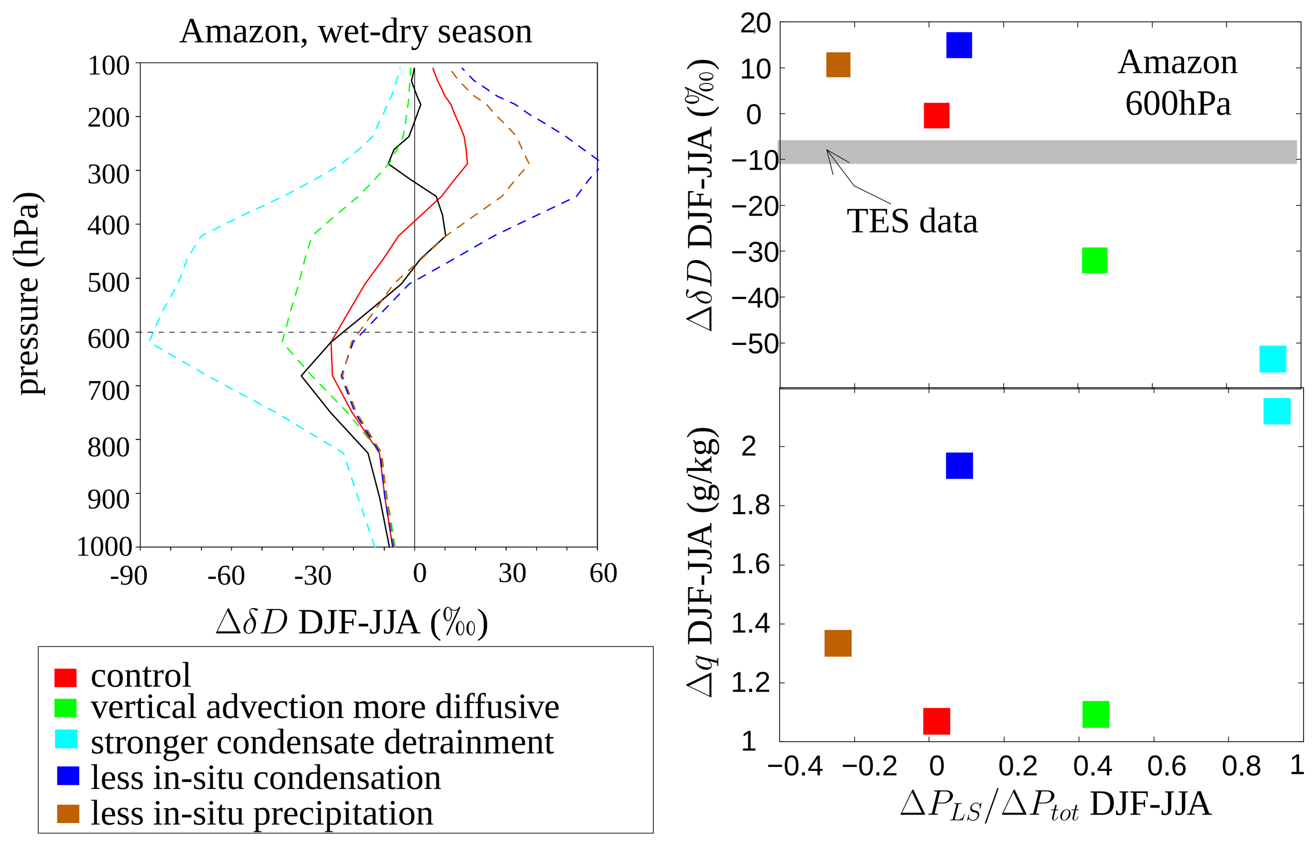
Fig: Rayleigh distillation (resulting from progressive dehydration by condensation) has a log shape while mixing has a hyperbolic shape ([9]). This explains why large-scale condensation is more depleting than compensating subsidence for a given dehydration.



Sensitivity tests

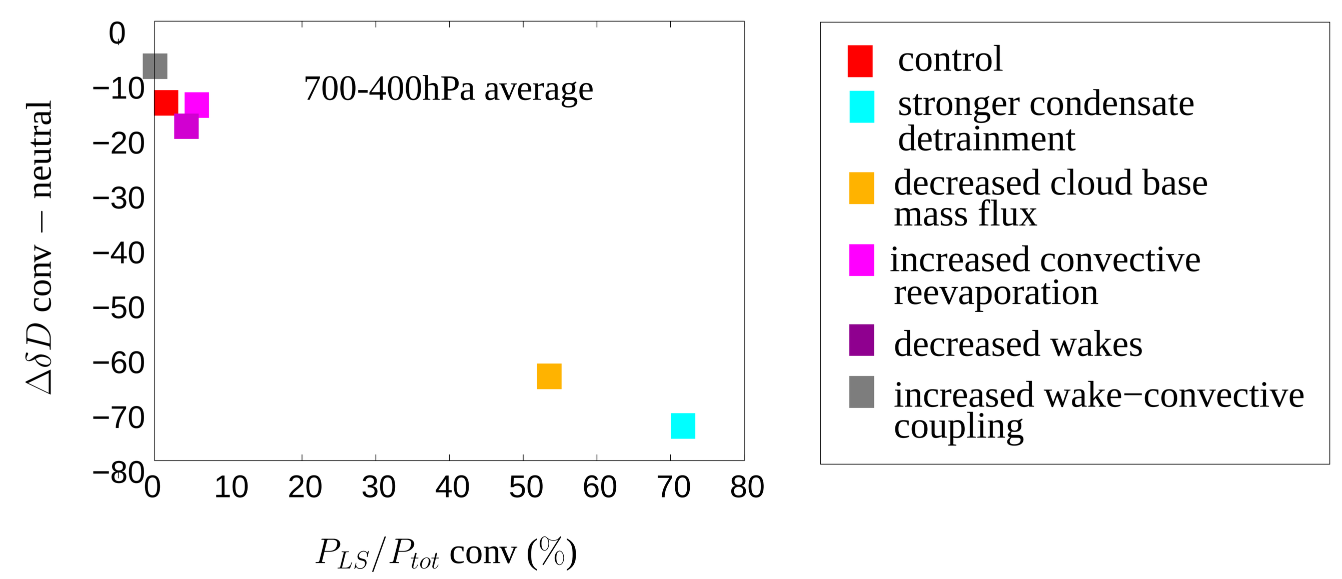
Example in 3D

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.



Example in 1D

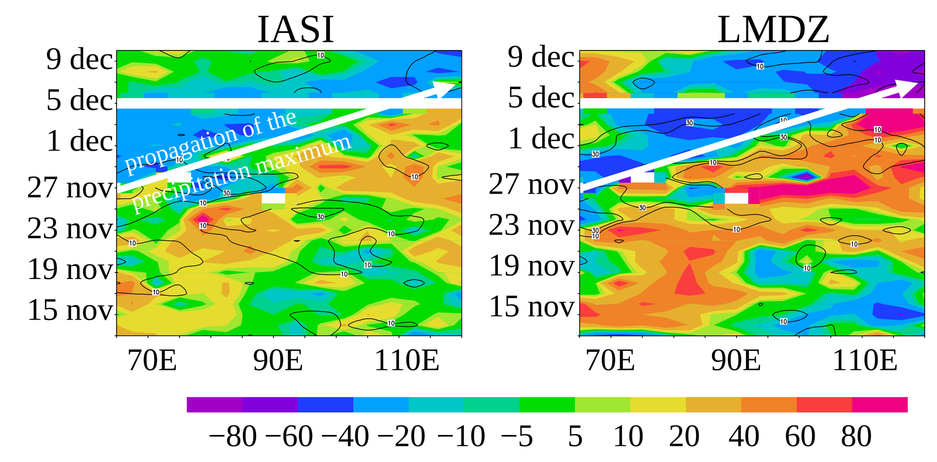
Fig: Example for 1D radiative convective equilibrium. We use the LMDZ new physical package allowing modifications of convection closure ([1]). We compare results for neutral regime (ω = 0hPa/d) and convective regime (ω = −30hPa/d). Again, sensitivity tests with largest P_{LS} contribution lead to the strongest depletion in convective regime. This effect is also confirmed when running 1D campaign cases (e.g. TWP-ice).



Perspectives

- collocate q, δD with cloud data, because q-cloud link helps constrain large-scale condensation ([5]): e.g. A-train (TES+CALIPSO/Cloudsat), IASI, ARM sites.
- improved process understanding: spatial structure around convective systems, evolution during convective life cycles and during MJO events using IASI data
- build a therоretical framework to interpret joint q, δD distribution
- actually use isotopic data for model evaluation
- combine water isotopic tracers with air tracers (CO, O_3, Be)?

Fig: Observed (IASI, [2]) and simulated δD during the November 2011 CINDY-DYNAMO campaign case at 500hPa averaged over 10S-10N.



colors: δD anomaly (‰)
contours: q anomalies (%)

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