Relative roles of deep convection, shallow convection and large-scale condensation parameterizations using water isotopic measurements

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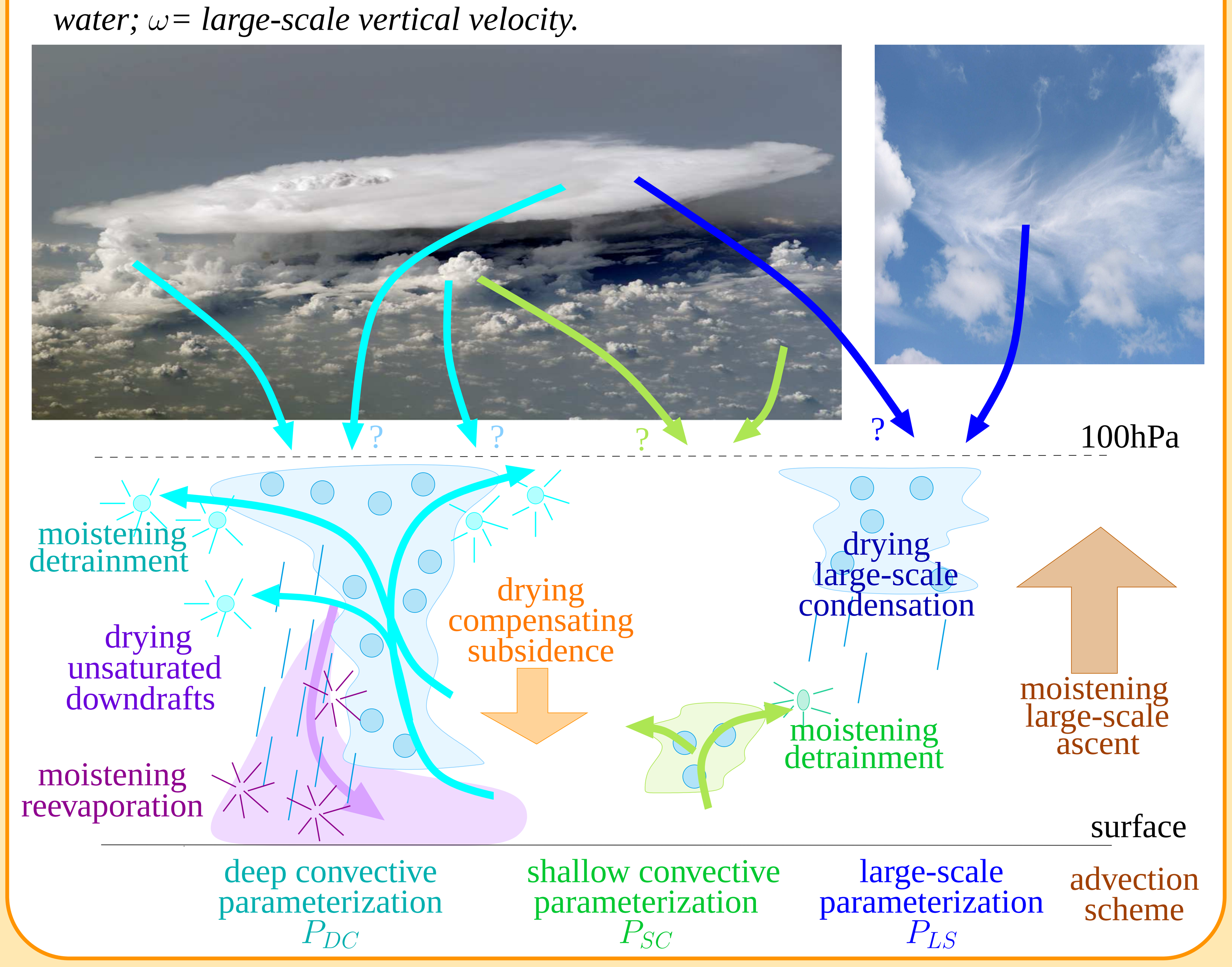
Introduction

Precipitation and clouds in GCMs can be produced by deep convection (DC), shallow convection (SC) and large-scale condensation (LS) parameterizations (fig 1). The relative importance of these 3 parameterizations is arbitrary and model-dependent. However, it has a strong impact on latent heating profiles and on the tropospheric water budget. We explore the possibility of using water vapor isotopic measurements to better evaluate the relative role of DC, SC and LS parameterizations, using the LMDZ GCM enabled with isotopes ([5]).

Fig 1: Roles of DC, SC and LS on the tropospheric water budget in tropical regions of large-scale ascent, as represented by GCM parameterizations.

q = specific humidity; δD= HDO concentration in ‰ anomalies relatively to sea water; ω= large-scale vertical velocity.



Controls on tropical water vapor δD

The different moistening processes (fig 1) don't have the same effects on δD (figs 2,3). Convective detrainment is strongly enriching ([3]), vertical advection is moderately enriching, rain reevaporation is enriching or depleting ([7, 4]). Same for the different drying processes: large-scale condensation is more depleting than the compensating subsidence of convection (*[2]*, figs 2,3).

Fig 2: q tendencies and δD signature from different processes , simulated by LMDZ.

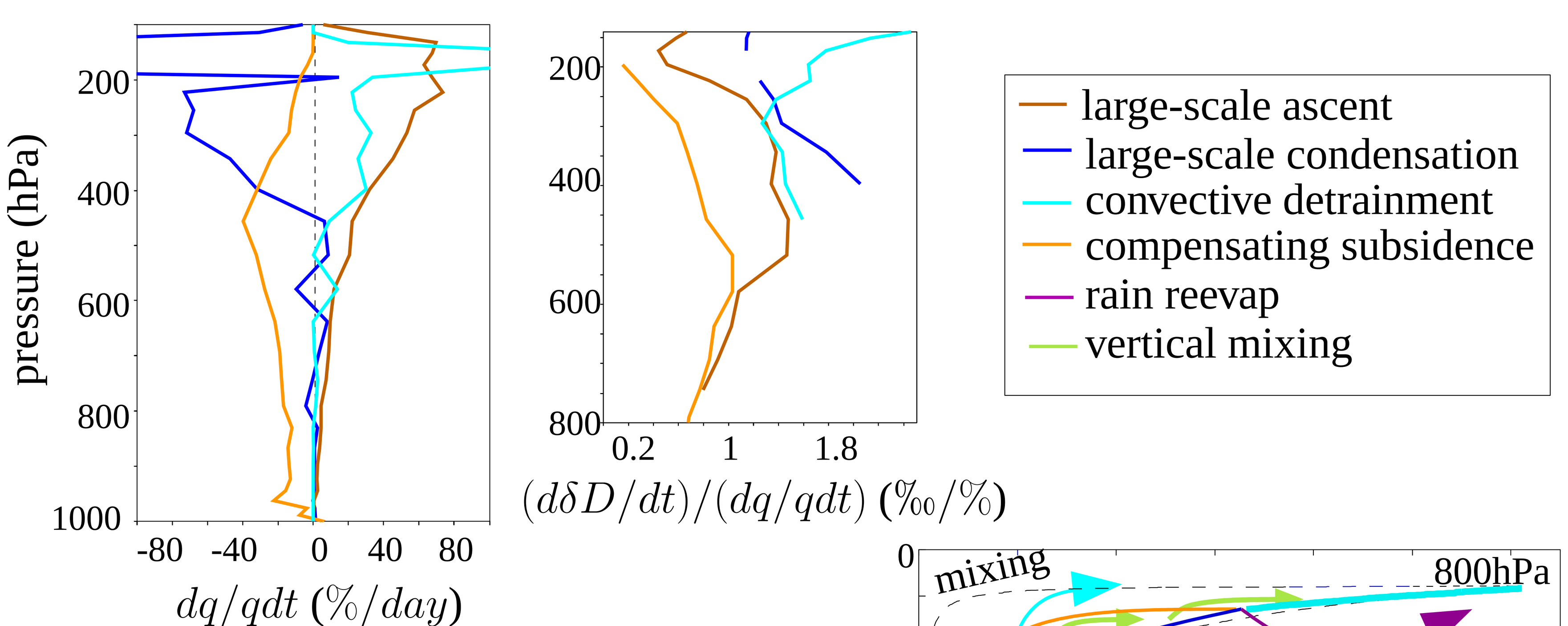
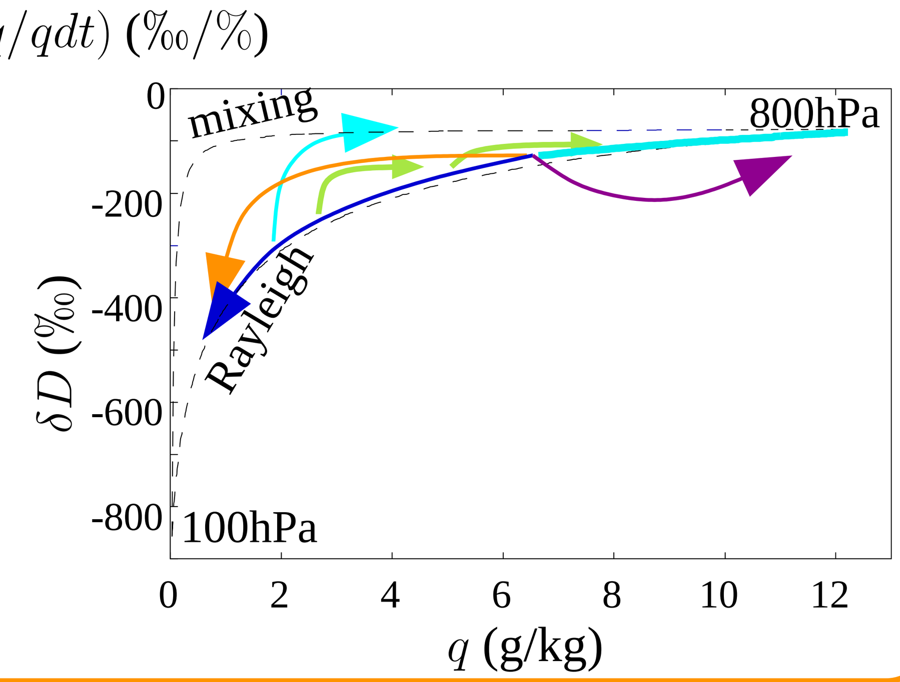


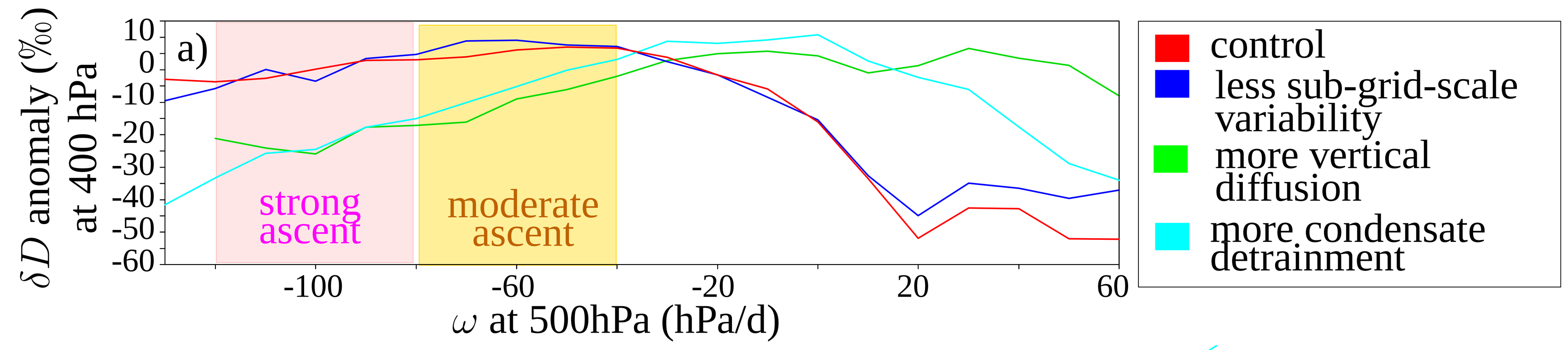
Fig 3: Rayleigh distillation (progressive drying by condensation) has a log shape while mixing has a hyperbolic shape ([7]). This explains why large-scale condensation is more depleting than compensating subsidence for a given drying.

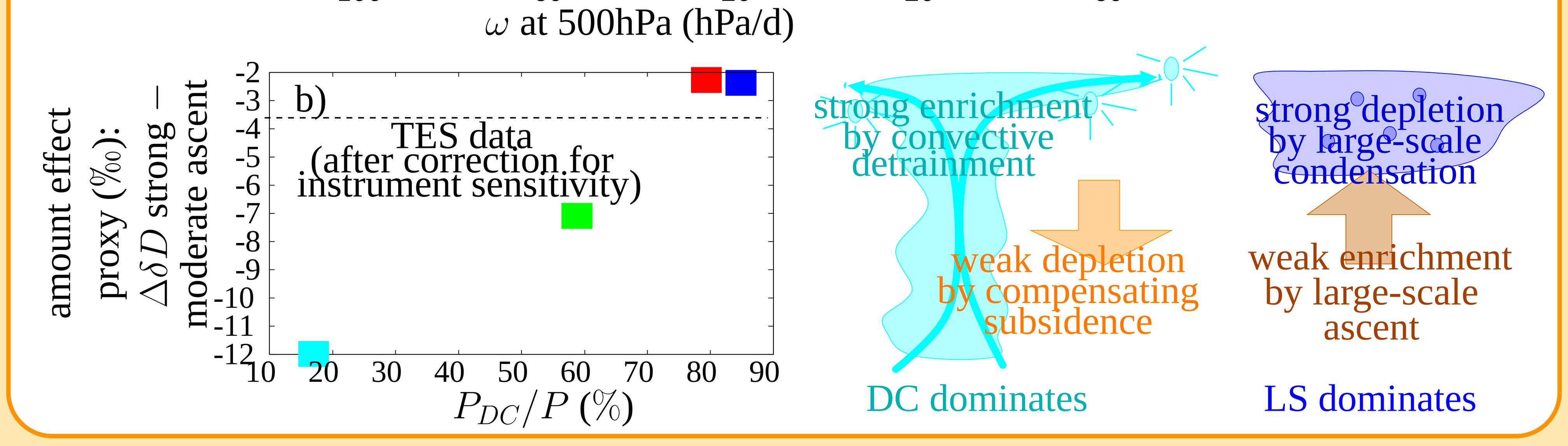


1) Deep convection vs LS condensation

In the mid/upper troposphere, the amount effect (quantified here as the δD decrease from regimes of moderate to strong ascent) is steeper when the precipitation is simulated more by LS vs DC (fig 4a). TES observations ([7]) may help constrain P_{DC}/P (fig 4b).

Fig 4a: δD at 400 hPa as a function of monthly ω at 500hPa, for all tropical ocean grid boxes, in different LMDZ sensitivity tests ([6]). b: amount effect proxy as a function of P_{DC}/P.

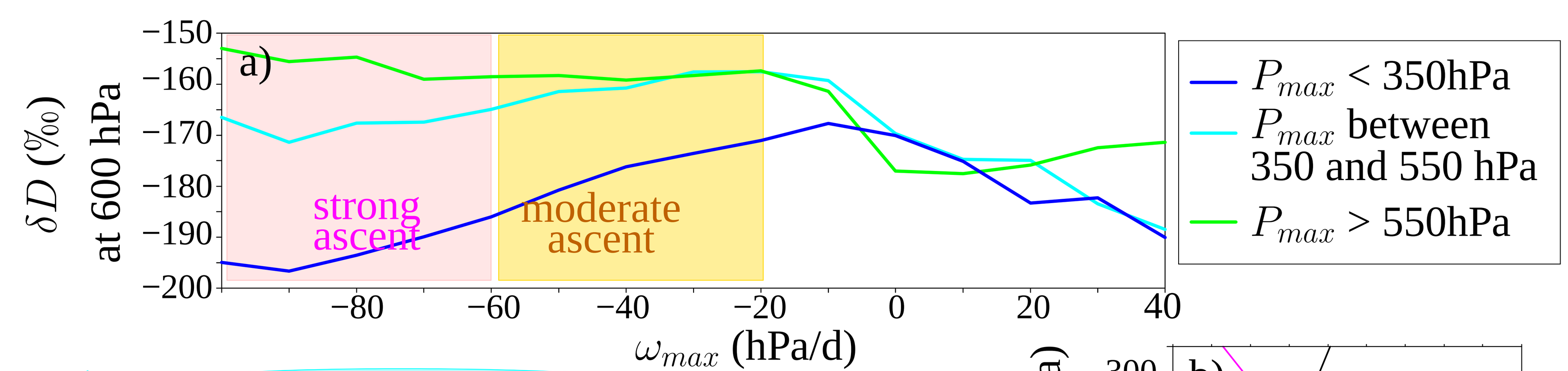


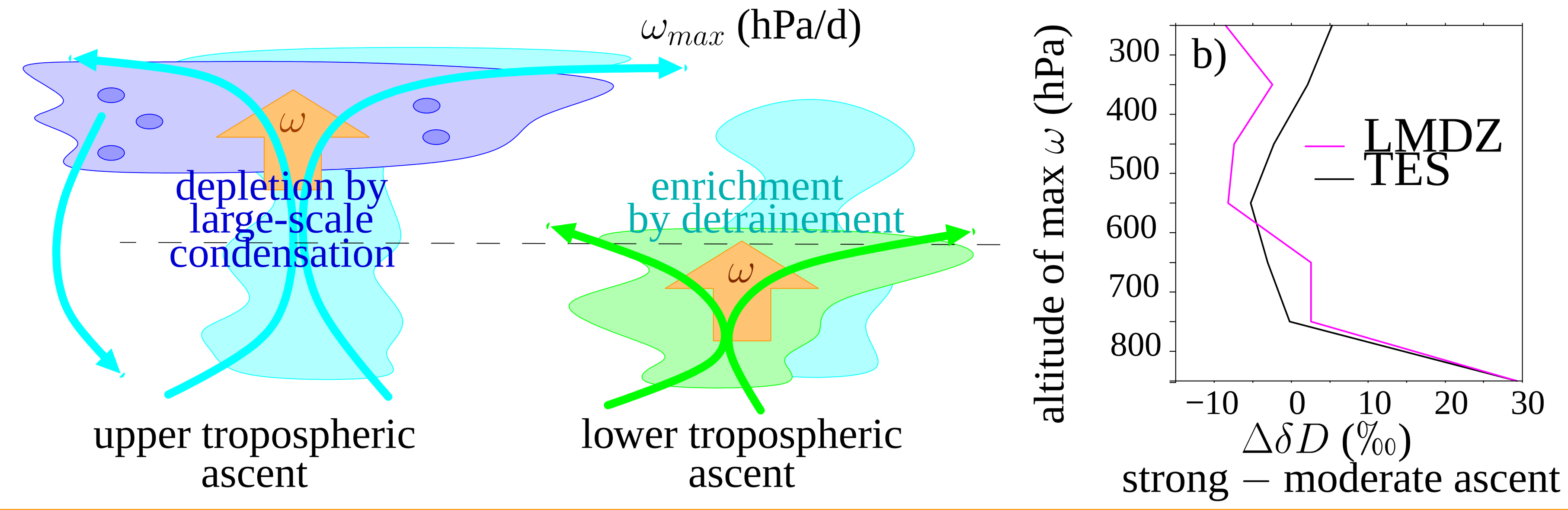


2) Shallow vs deep convection

In the lower troposphere, there is normal amount effect only when ascent is in the upper troposphere. When ascent is in the lower troposphere, δD is more enriched as ascent is stronger (fig 5a), in LMDZ and TES (fig 5b) and IASI observations ([1], not shown). TES or IASI observations could help constrain the shape of ω profiles, and thus the DC/SC partitionning.

Fig 5a: δD at 600 hPa as a function of monthly ω at the altitude where it is maximum (P_{max}), in LMDZ simulations, depending on P_{max}. b: proxy of the amount effect as a function of P_{max} for LMDZ and TES observations.





Perspectives

* Compare with results in 1D (more sensitivity tests, idealized ω forcing, interactive ω)
* Link with latent heat profiles: less arbitrary diagnostic of the DC/SC/LS partitionning.
* Link with degree of organization?
* Combine δD with cloud data and/or with air tracers (CO, O_3, Be)?
* Help from CRMs to better understand processes.

References

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