

What can we learn from
water isotopes in the vapor
about processes controlling
tropical tropospheric humidity?
Analysis using water tagging experiments
with the LMDZ-iso GCM

Camille Risi

University of Colorado, Boulder

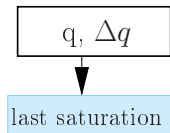
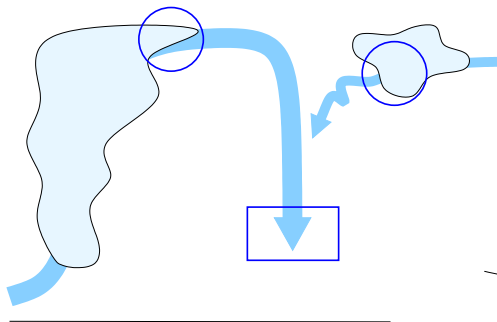
Contributors: David Noone, Sandrine Bony, Christian Frankenberg, John Worden,
Jeonghoon Lee, Derek Brown

30 April 2010

Humidity controls

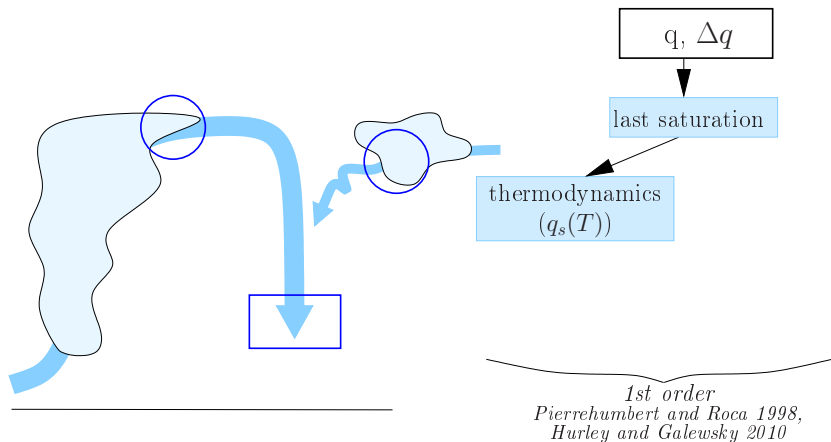
$q, \Delta q$

Humidity controls

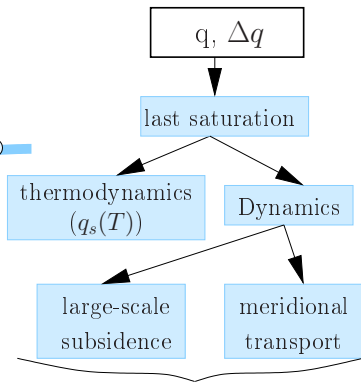
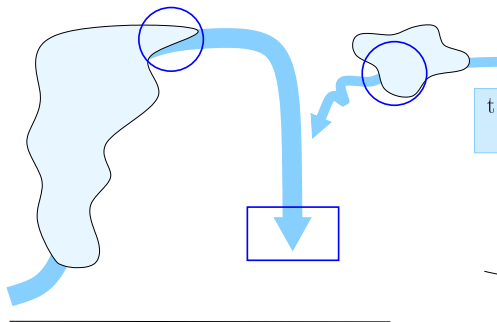


1st order
Pierrehumbert and Roca 1998,
Hurley and Galewsky 2010

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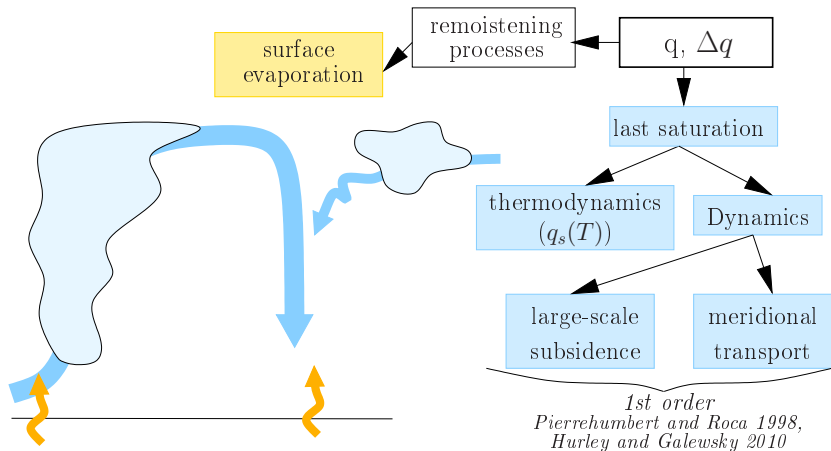
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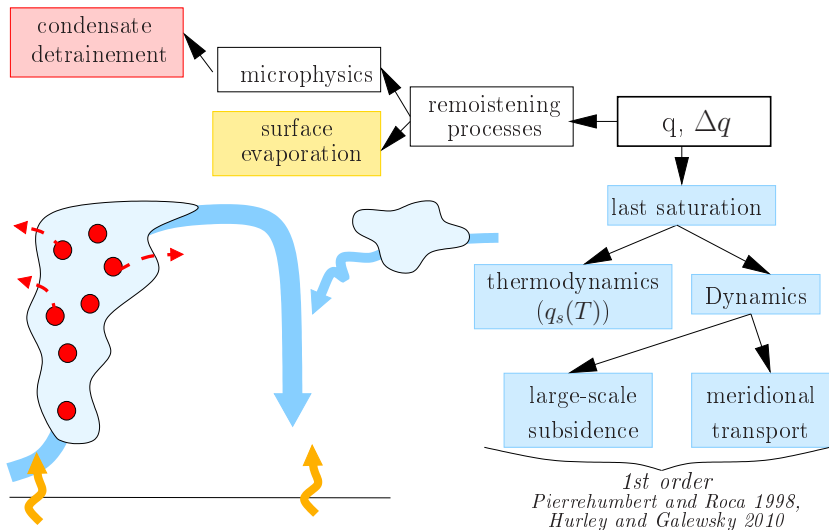
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*Pierrehumbert and Roca 1998,
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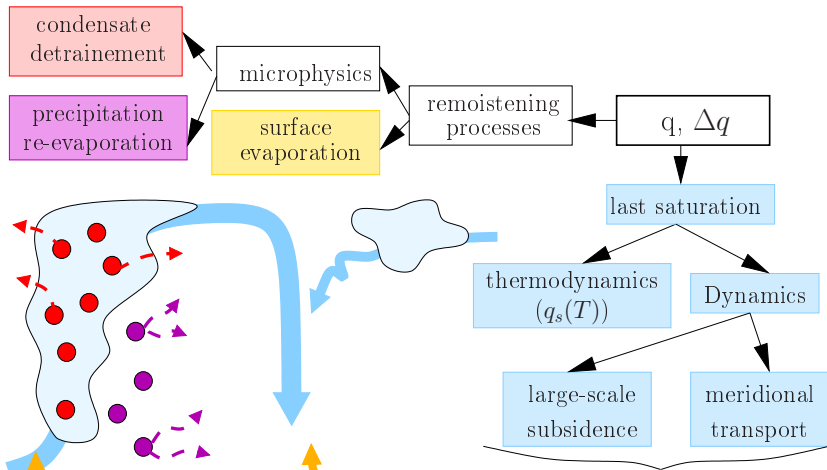
Humidity controls



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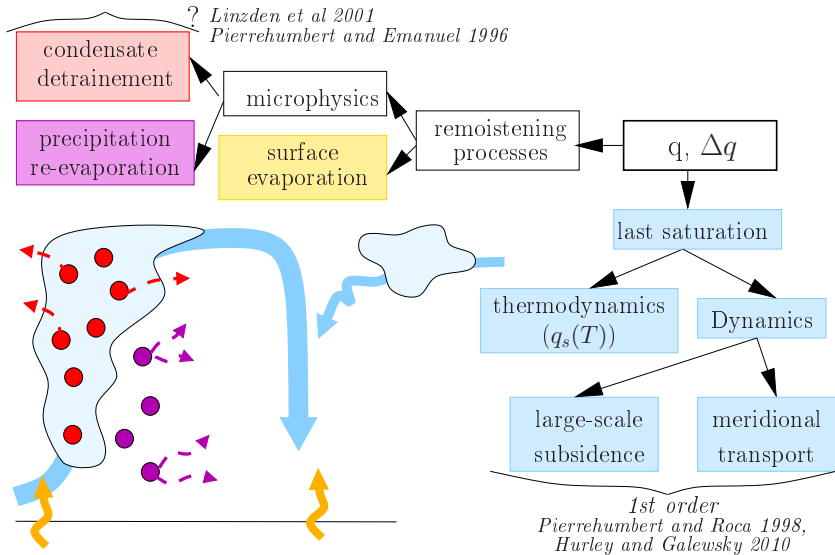


Humidity controls

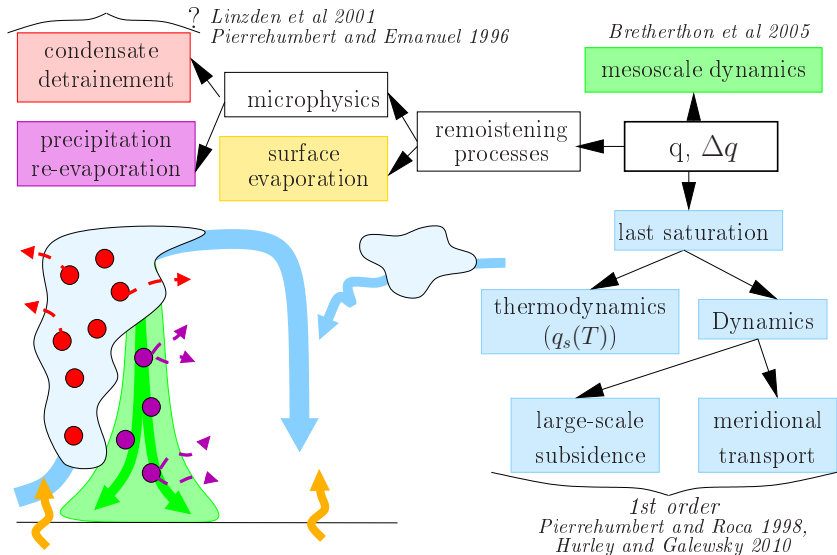


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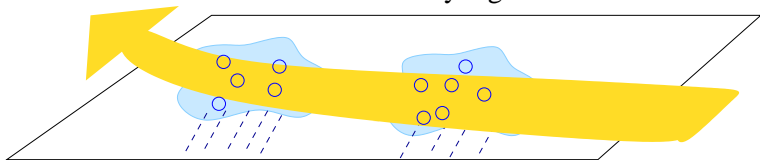


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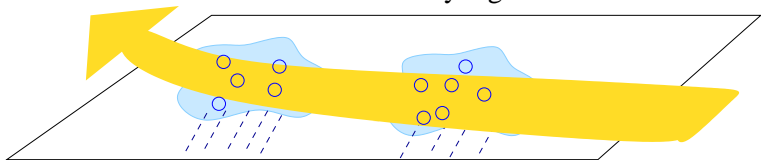
Isotopic controls

Traditional view: Rayleigh distillation

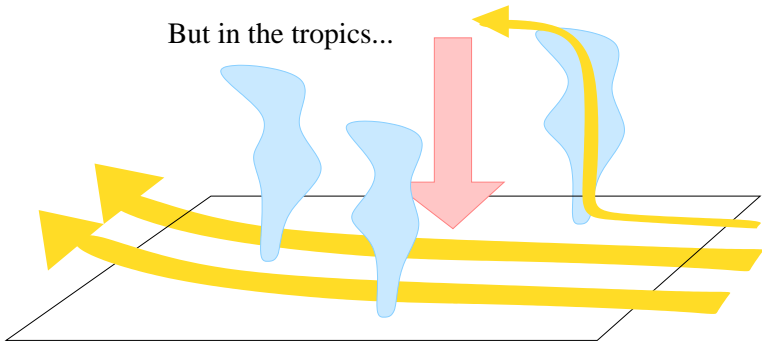


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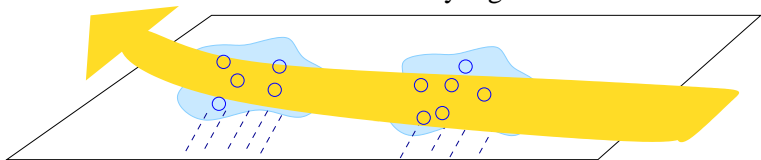


But in the tropics...

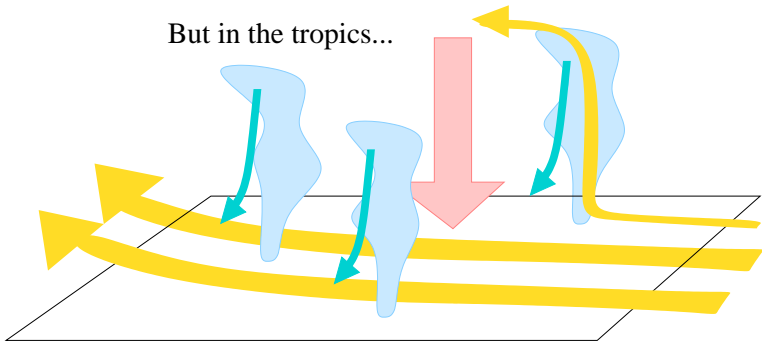


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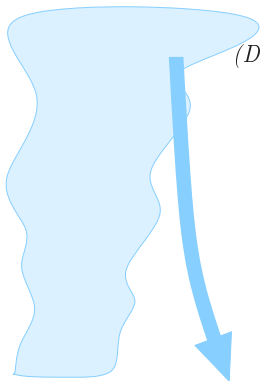
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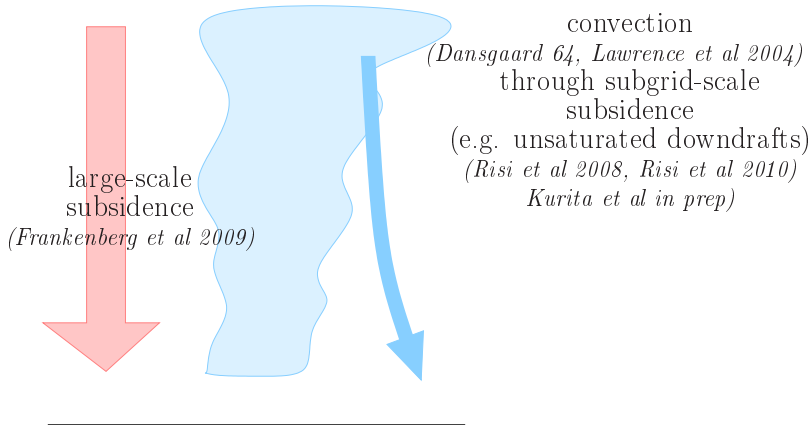


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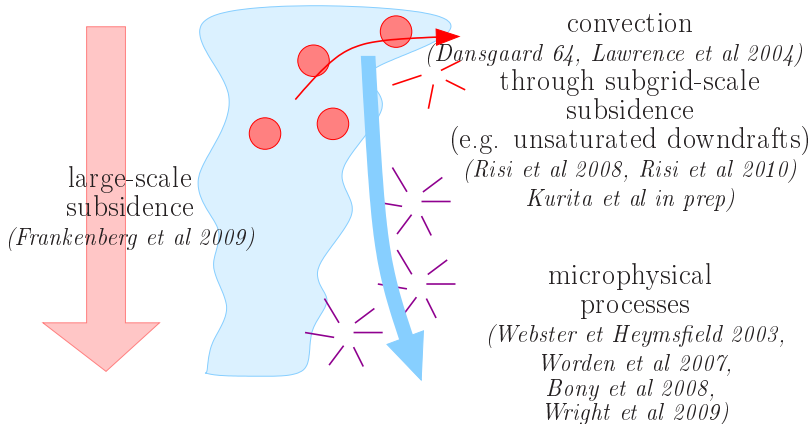


convection
(*Dansgaard 64, Lawrence et al 2004*)
through subgrid-scale
subsidence
(e.g. unsaturated downdrafts)
(*Risi et al 2008, Risi et al 2010*)
Kurita et al in prep)

Isotopic controls



Isotopic controls

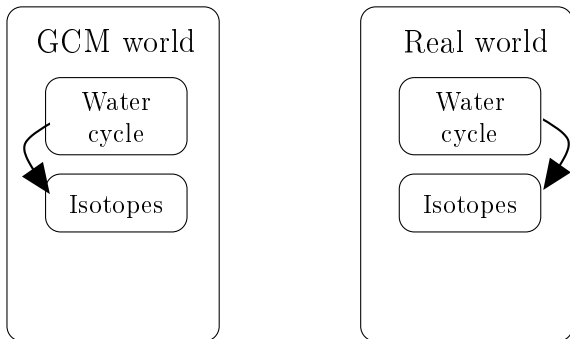


Strategy overview

- ▶ goal: quantify this potential, using an isotopic GCM

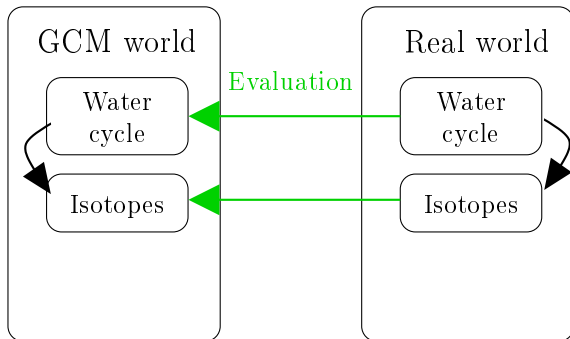
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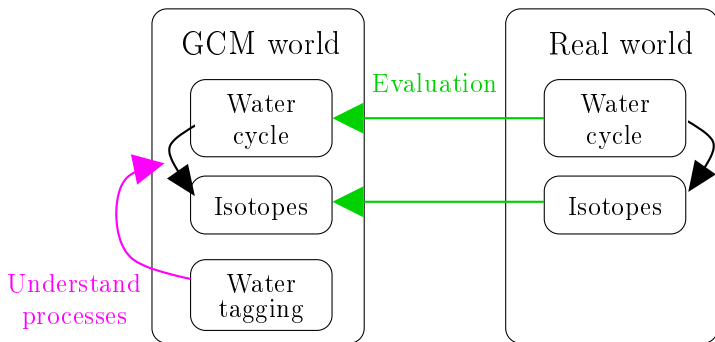
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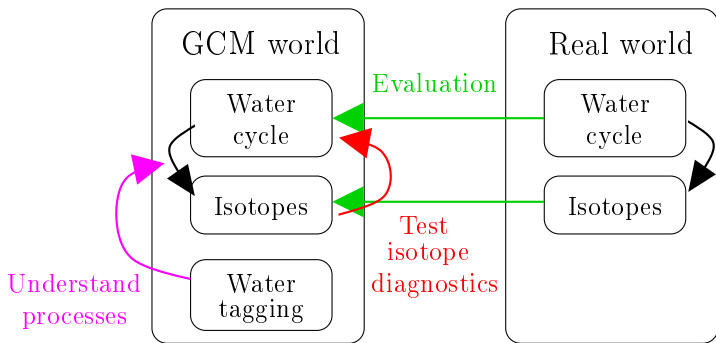
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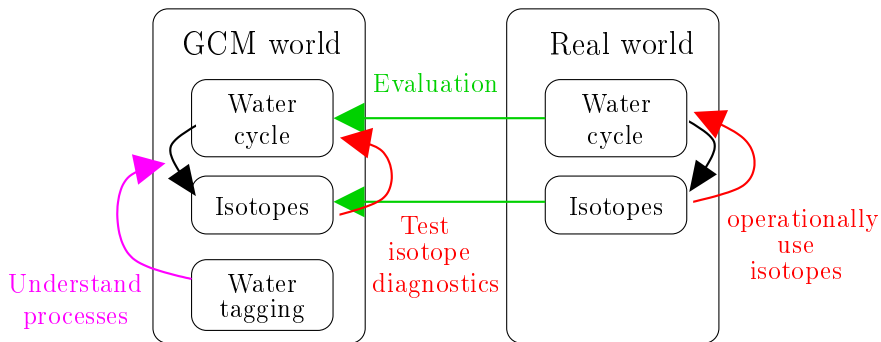
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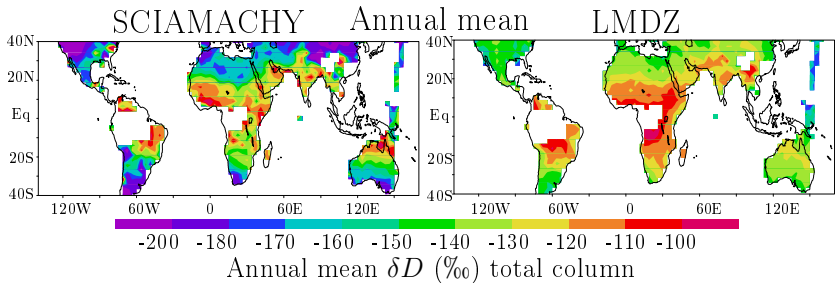
The LMDZ GCM

- ▶ Atmospheric component of the IPSL model used for IPCC
- ▶ Emanuel convection scheme: detailed entrainment/detrainment, precipitation evaporation, unsaturated downdrafts (*Emanuel 1991*)
- ▶ Large-scale condensation scheme based on a statistical cloud scheme (*Bony and Emanuel 2001*)
- ▶ Possibility to nudge by reanalyses winds (here: ECMWF)
- ▶ Water stable isotopes: detailed precipitation evaporation, evaluation at the synoptic to paleo time scales (*Risi et al in press*)
- ▶ Water tagging (*Risi et al in prep*)

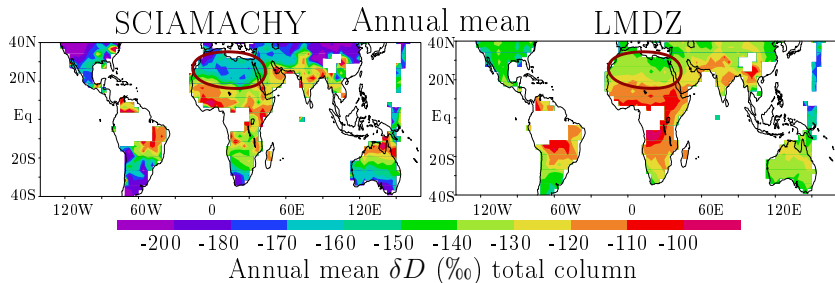
LMDZ-iso evaluation by satellites

instrument	SCIAMACHY <i>(Frankenberg et al 2009)</i>	TES <i>(Worden et al 2007)</i>
altitude	total column	800-500hPa here: 600hPa
years	2003-3005	2004-2008
quality selection	cloud fraction < 10% +prw within 10% from ECMWF	° freedom > 0.5
collocation	co-located in day not collocated in time of day: error < 20‰ over tropical continents	
model to satellite approach	none	monthly mean kernels + possibility to remove the 10% cloudiest scenes in LMDZ

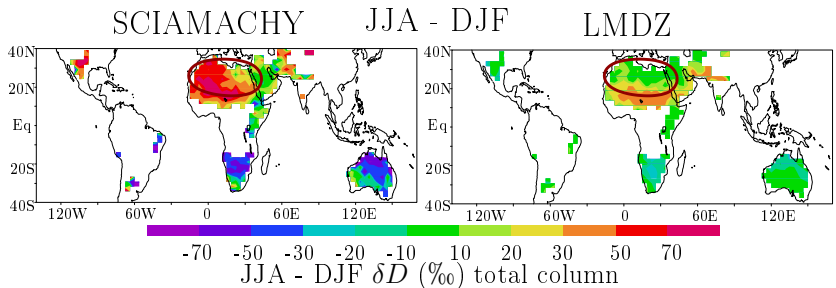
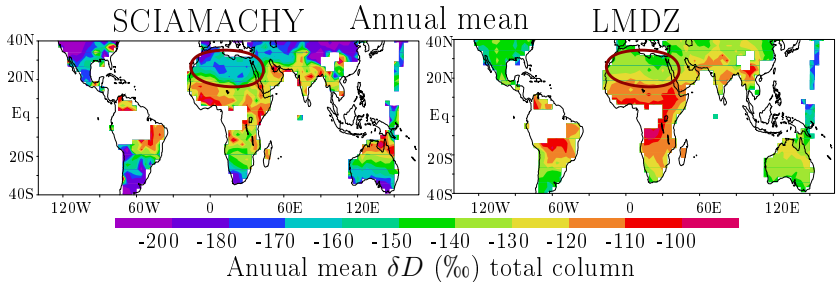
Evaluation with SCIAMACHY



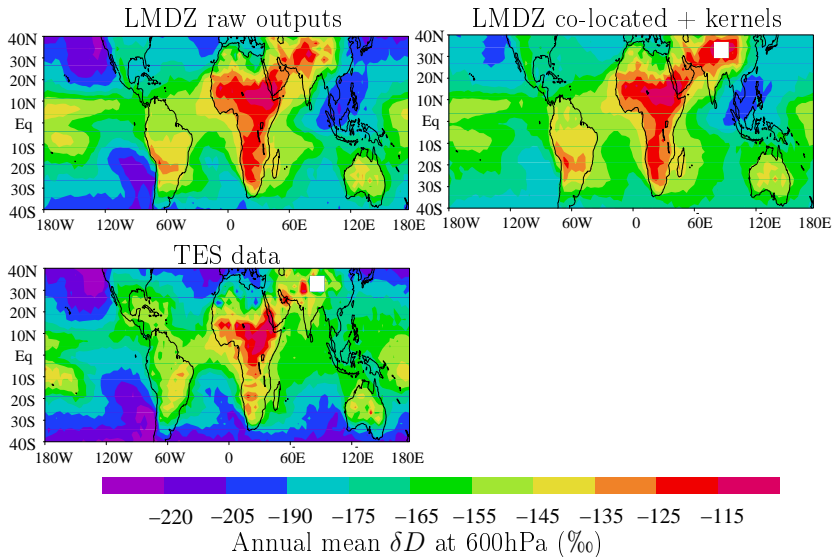
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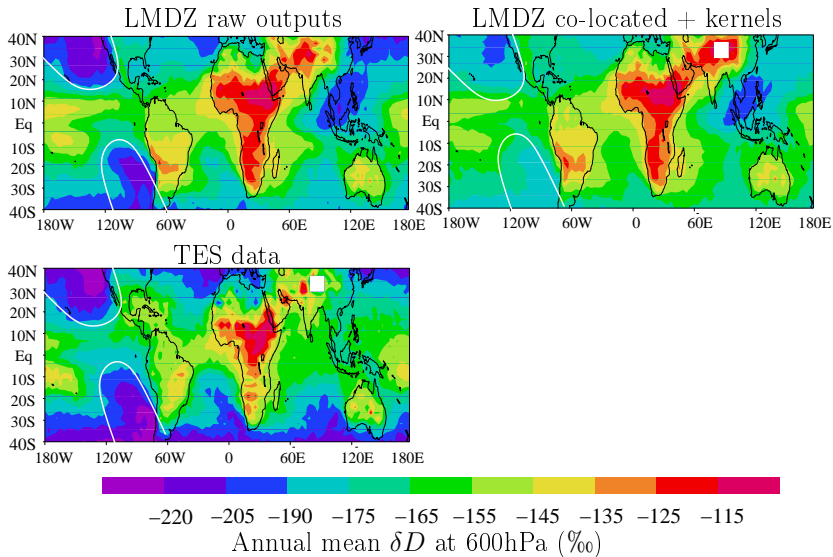
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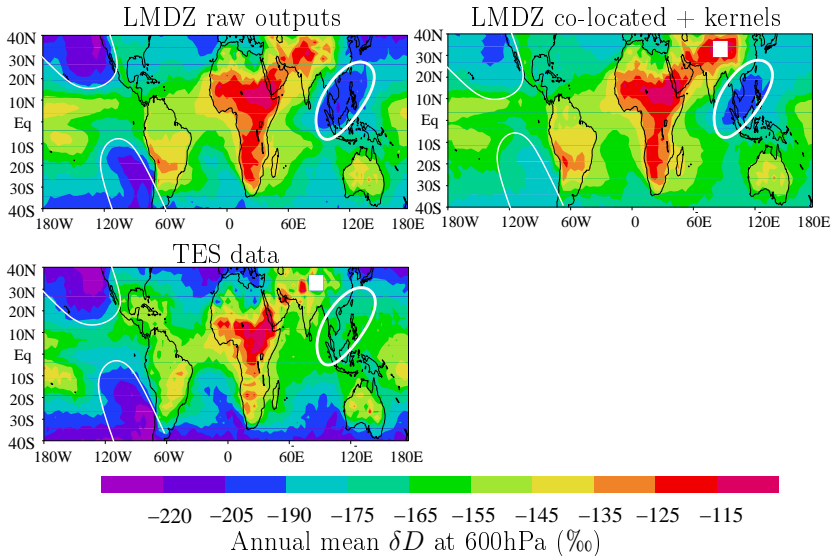
Annual mean in TES



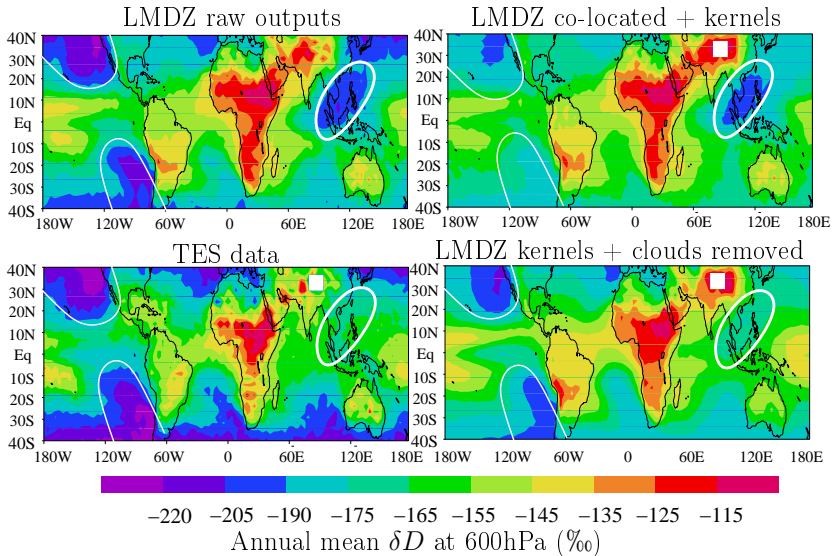
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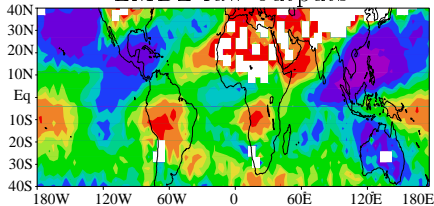


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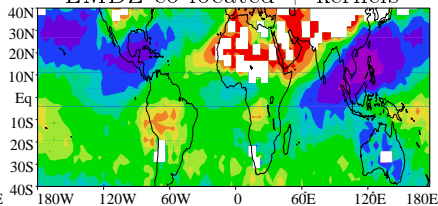


Seasonal variations in TES

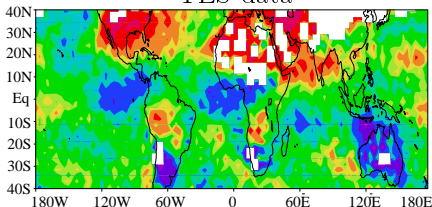
LMDZ raw outputs



LMDZ co-located + kernels



TES data

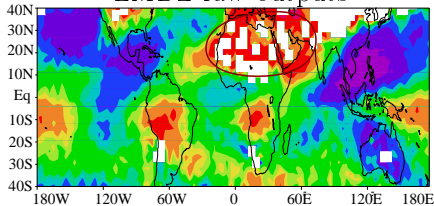


-70 -40 -24 -16 -8 8 16 24 40 70

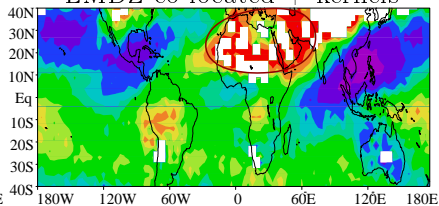
JJA - DJF δD (‰)

Seasonal variations in TES

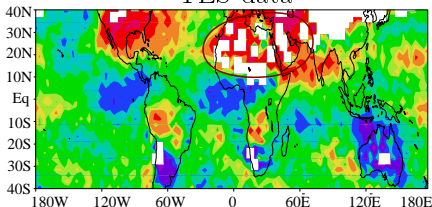
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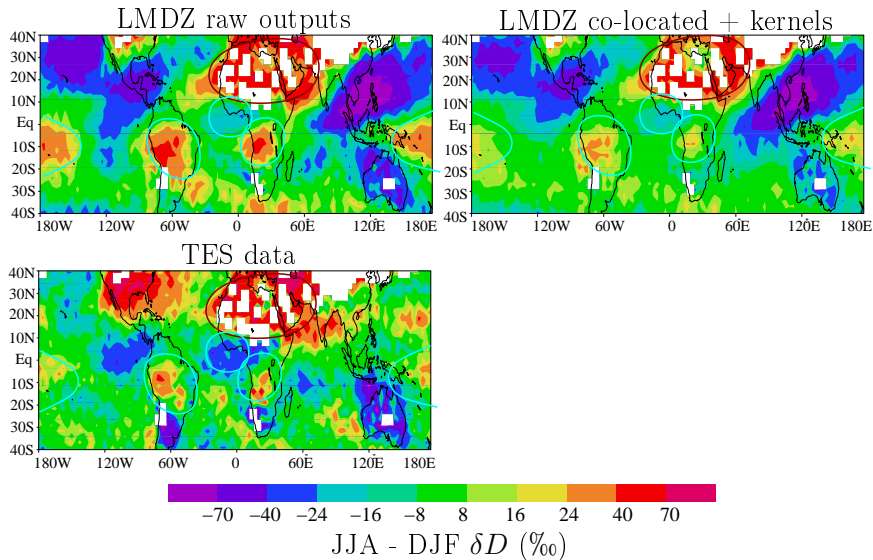
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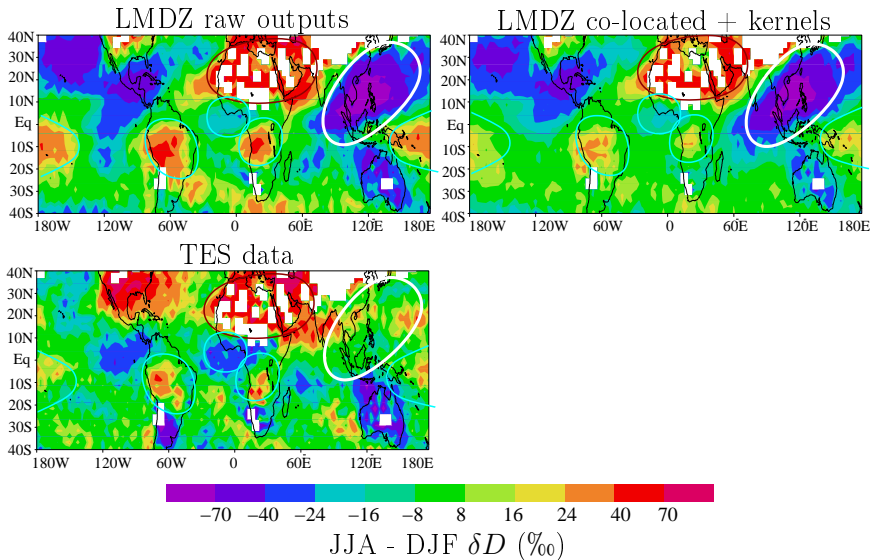
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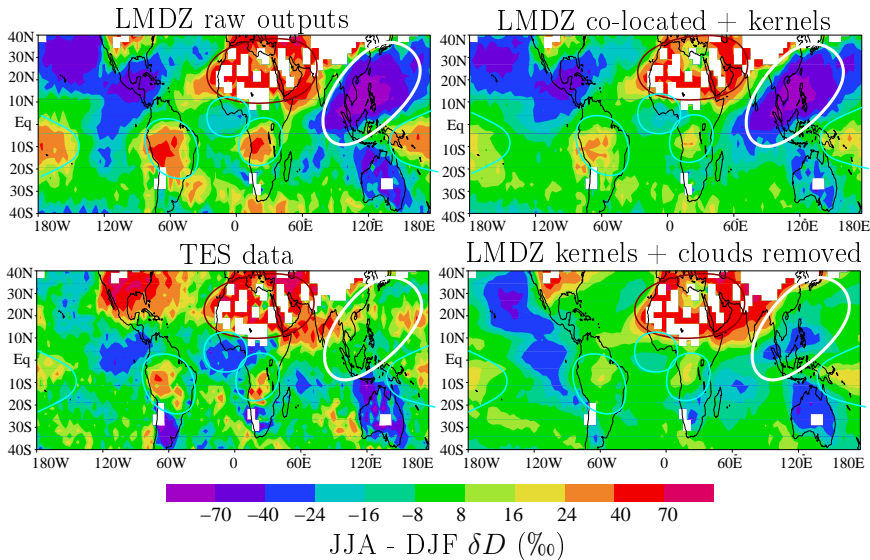
Seasonal variations in TES



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Summary on LMDZ-iso evaluation

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- ▶ Subsidence effect too weak in dry regions?
- ▶ Convective effect too strong over ocean, too weak over land?

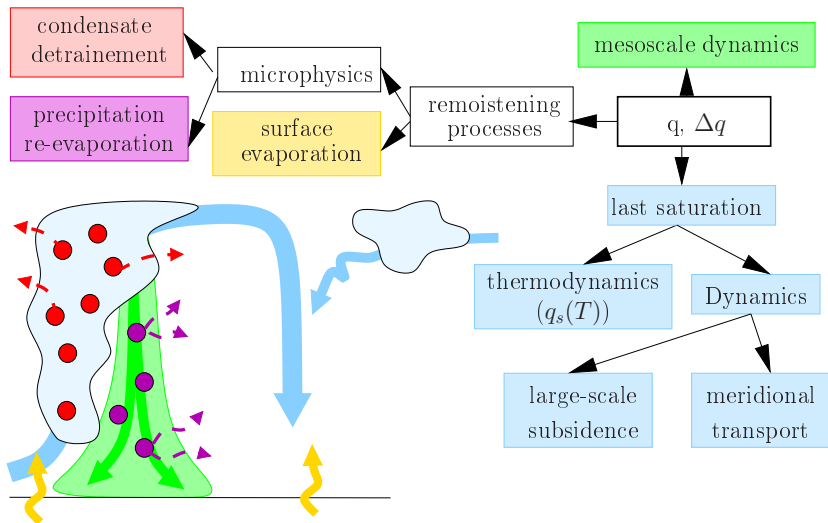
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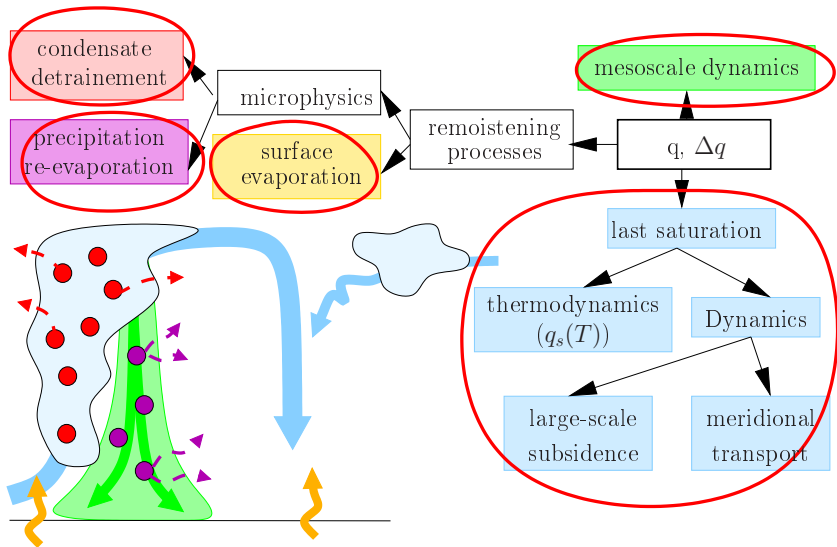
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 - ▶ GCM simulator

Tagging experiments

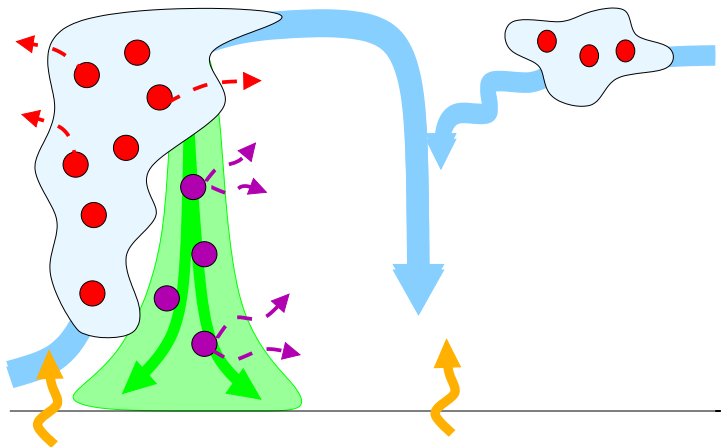


Tagging experiments



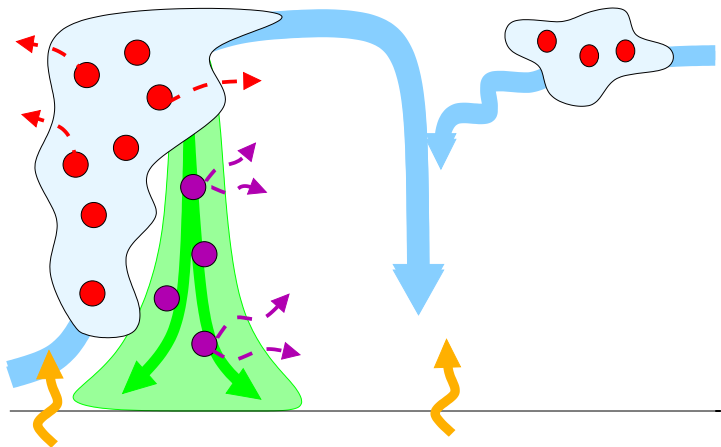
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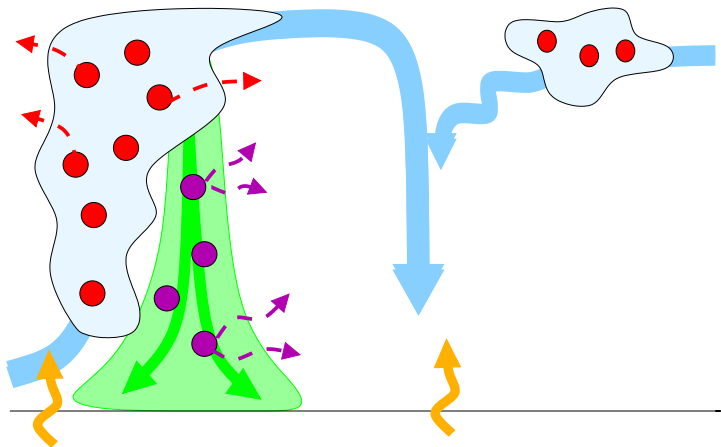
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Galewsky et al 2005

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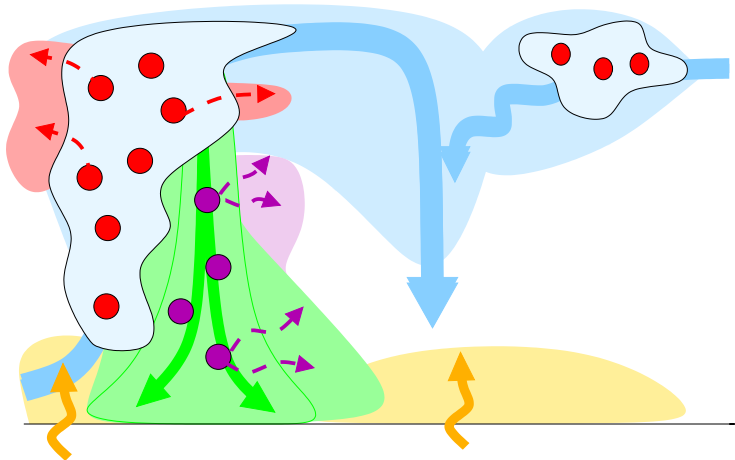
- 5 tags + possibility to tag q_s



Galewsky et al 2005

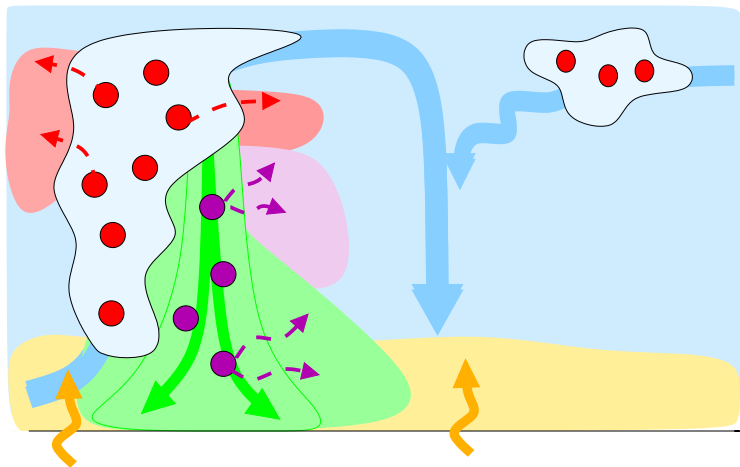
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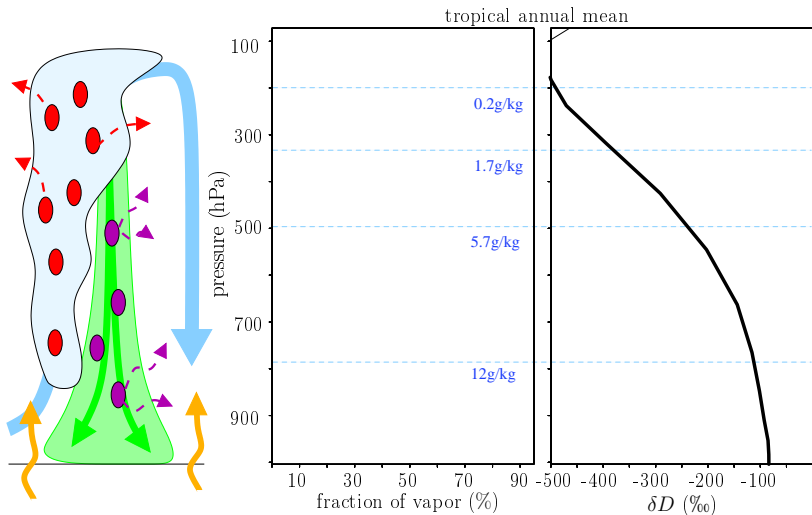


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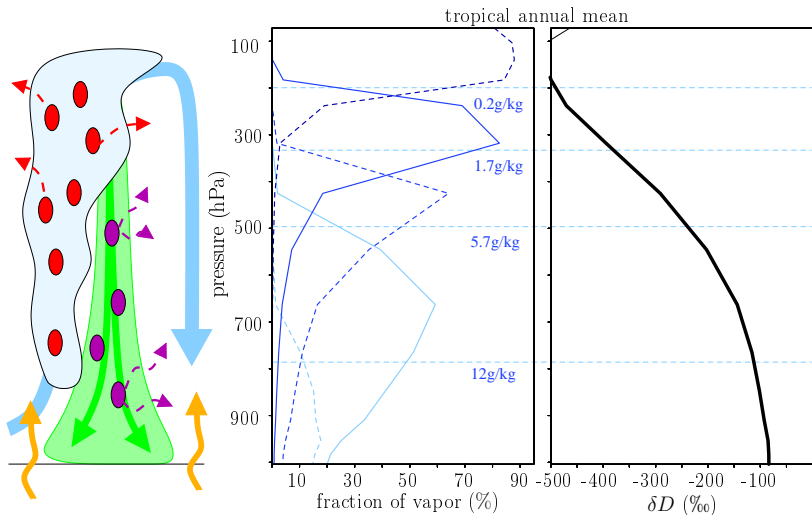
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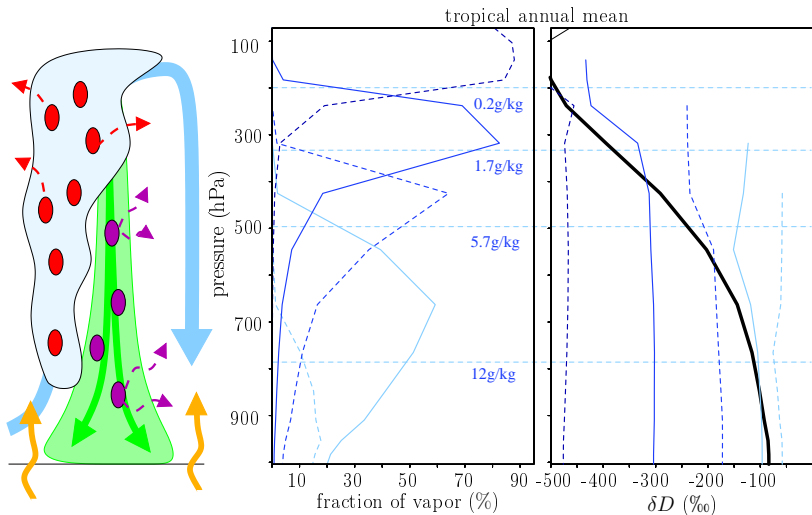
Interpreting the vertical isotopic distribution



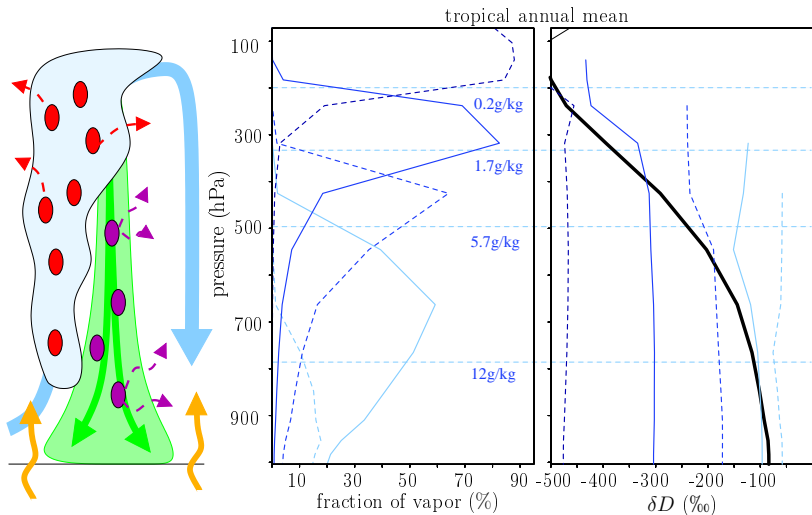
Interpreting the vertical isotopic distribution



Interpreting the vertical isotopic distribution



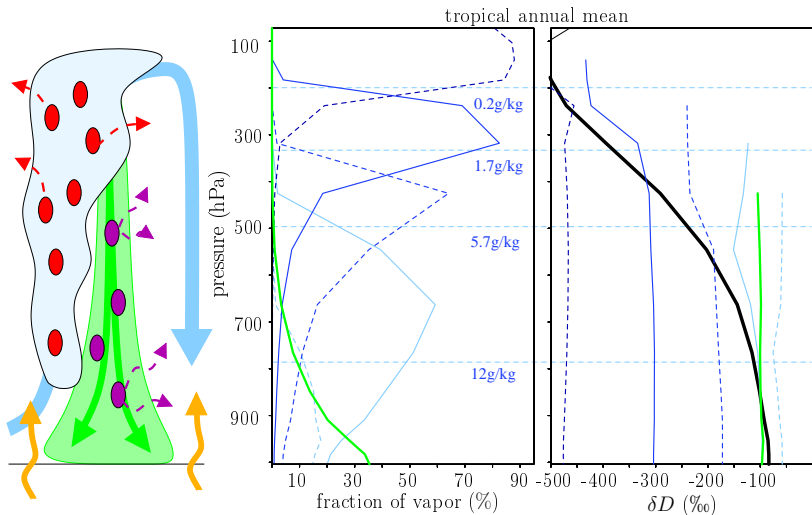
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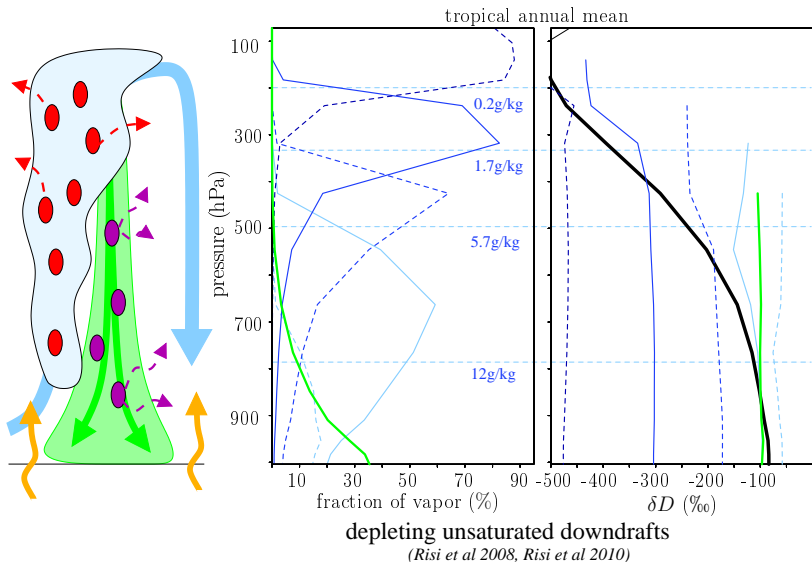
Depleting subsidence

(Frankenberg et al 2009)

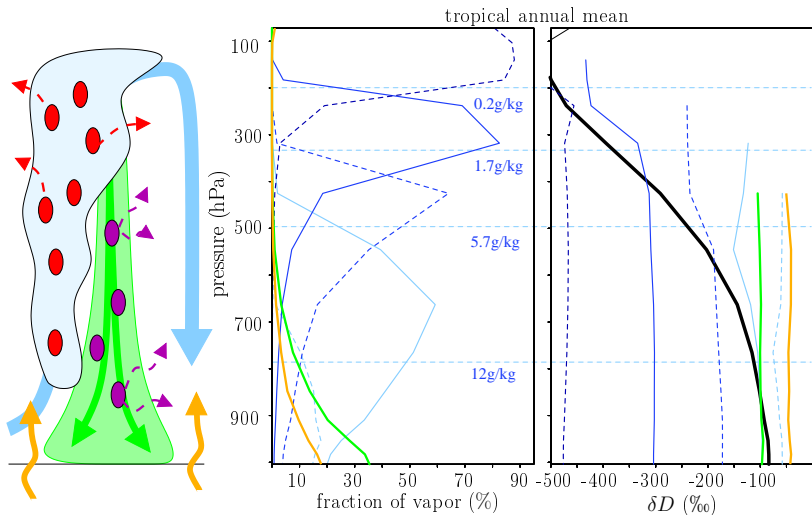
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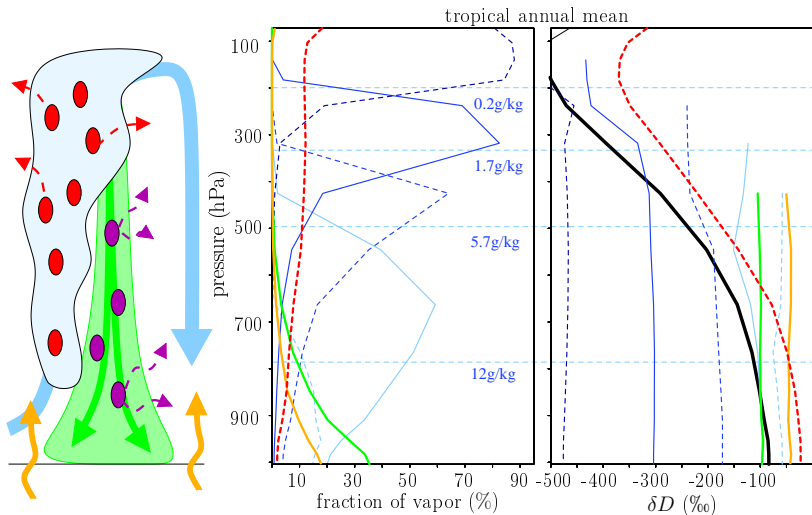
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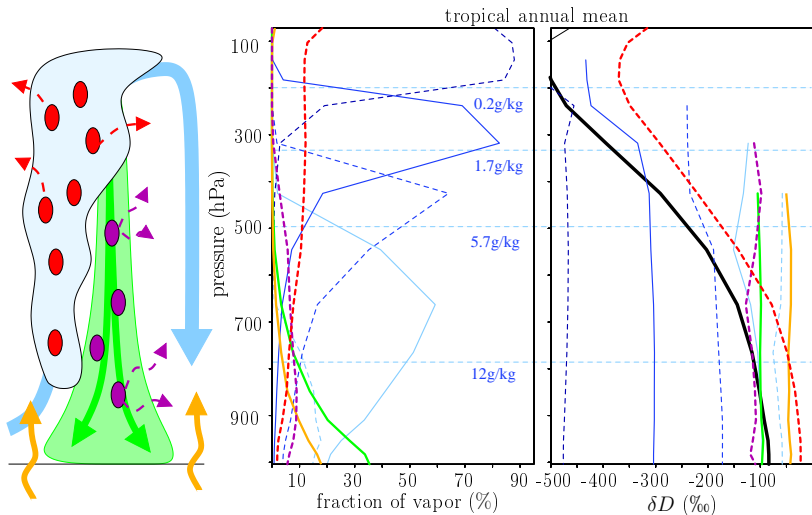
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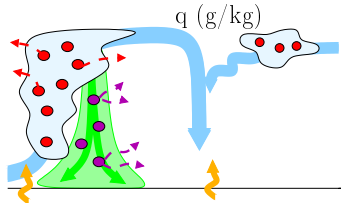
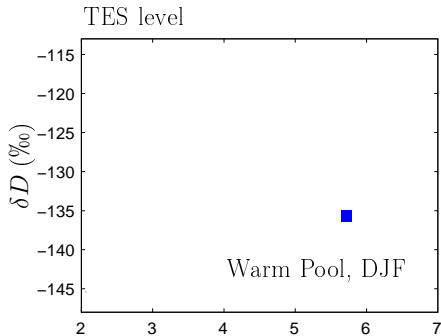


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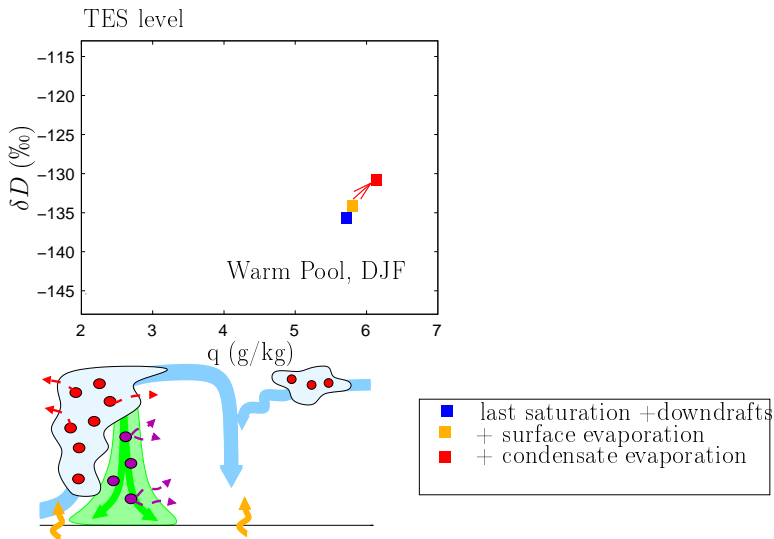
depleting reevaporation
(Worden et al 2007, Wright et al 2009)

Effect of remoistening processes

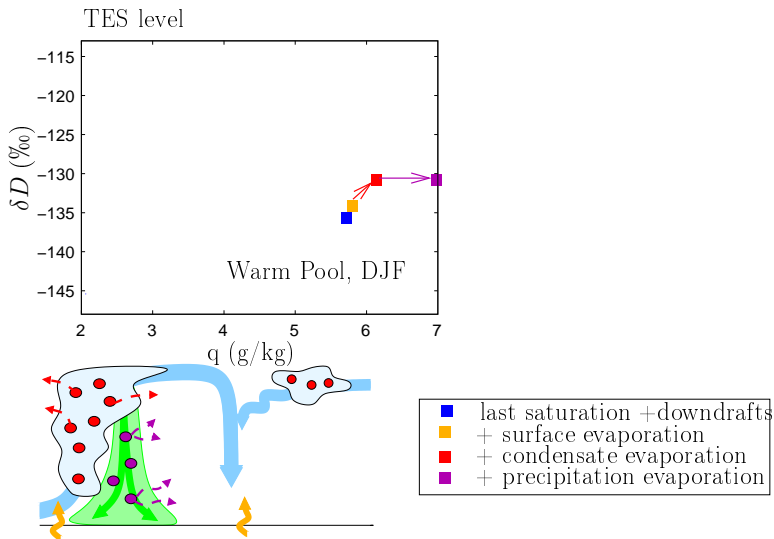


■ last saturation + downdrafts

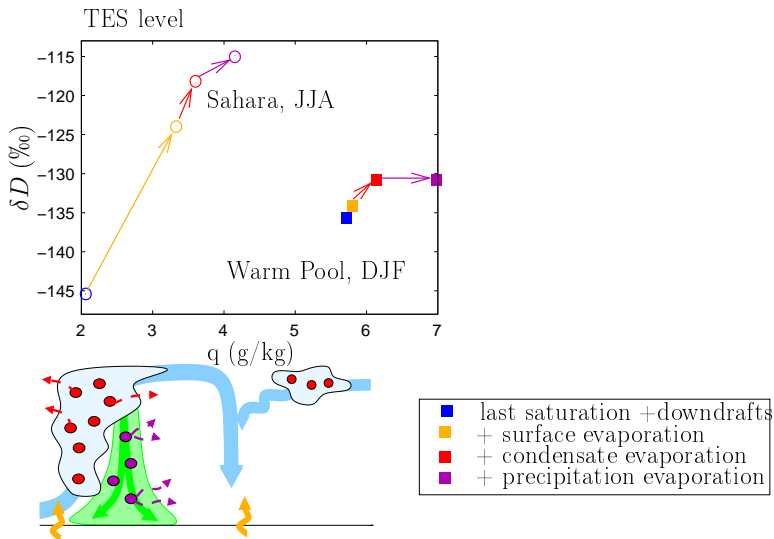
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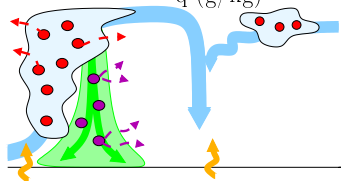
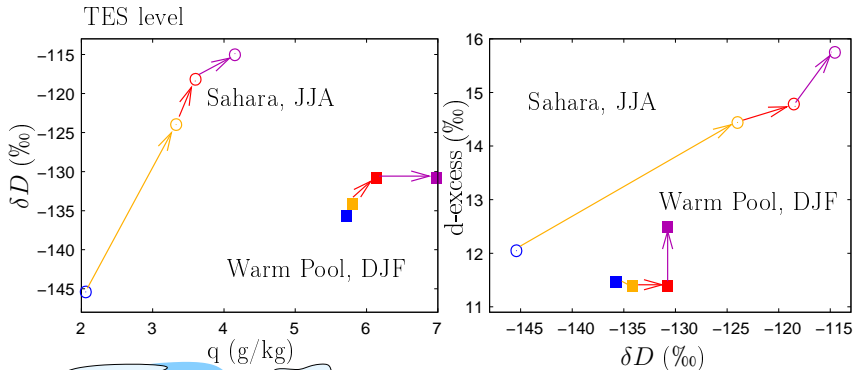
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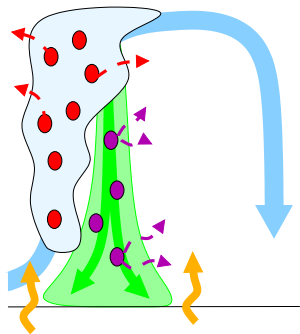
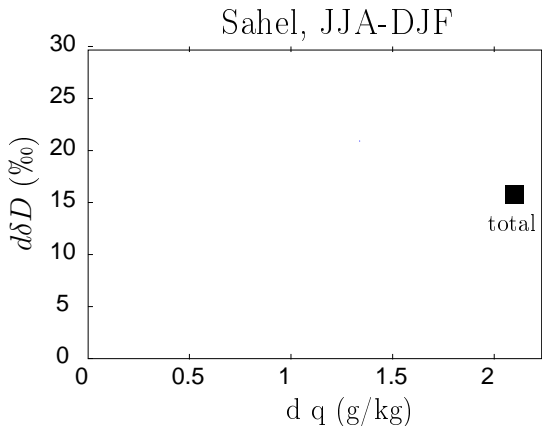


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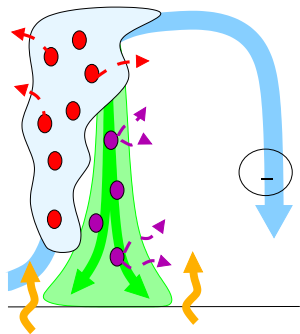
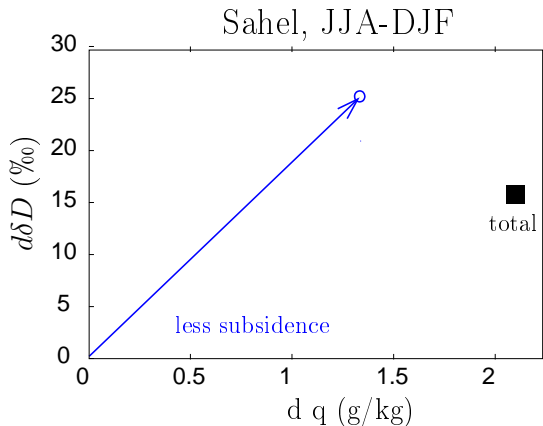


- last saturation only
- + surface evaporation
- + condensate evaporation
- + precipitation evaporation

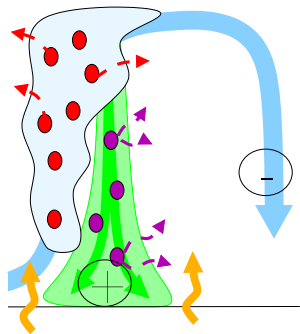
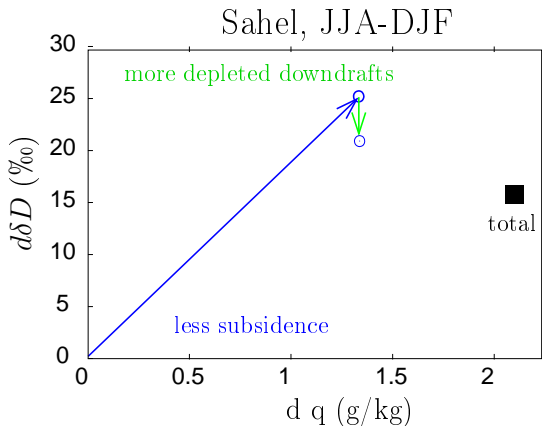
Interpreting seasonal isotopic variations



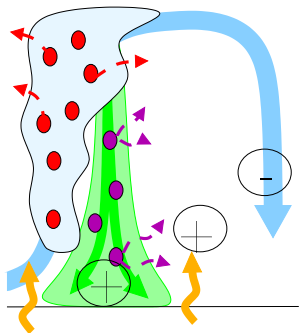
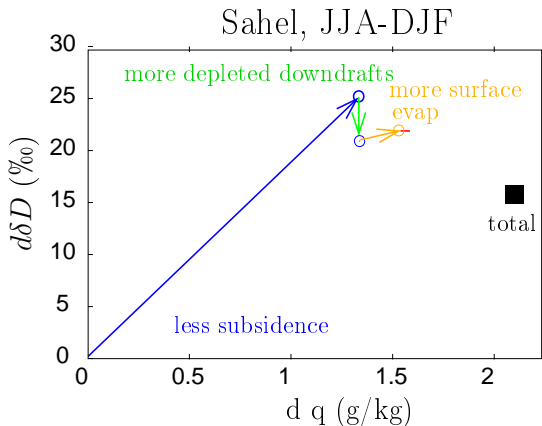
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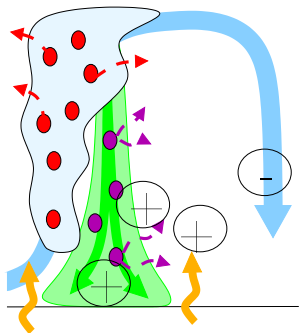
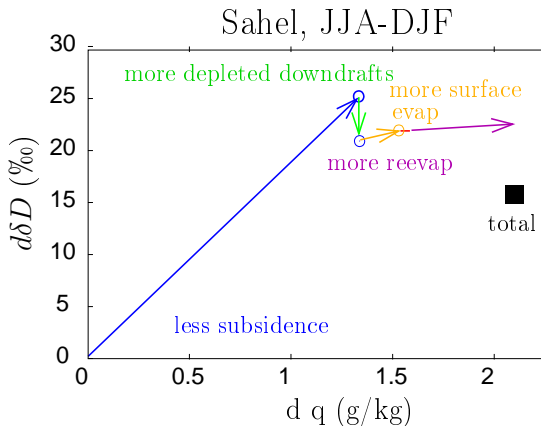
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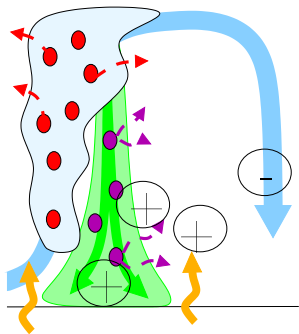
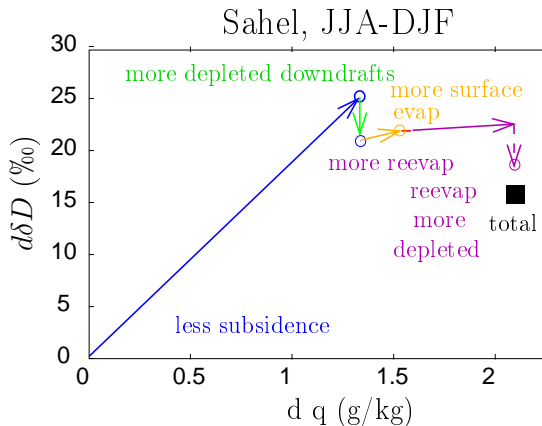
Interpreting seasonal isotopic variations



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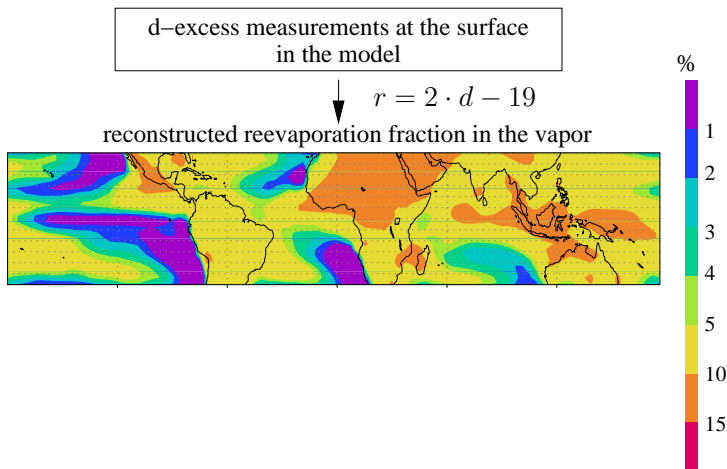
Interpreting seasonal isotopic variations



Could we infer the moistening effect of precipitation evaporation from isotope data?

d-excess measurements at the surface
in the model

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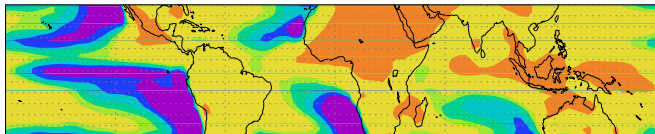


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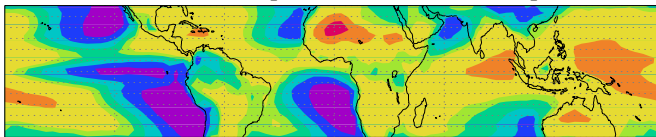
d-excess measurements at the surface
in the model

$$r = 2 \cdot d - 19$$

reconstructed reevaporation fraction in the vapor



simulated reevaporation fraction in the vapor



%

1

2

3

4

5

10

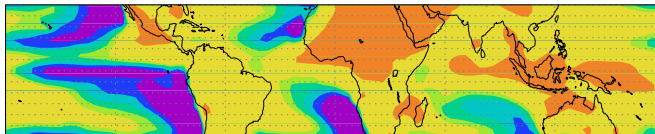
15

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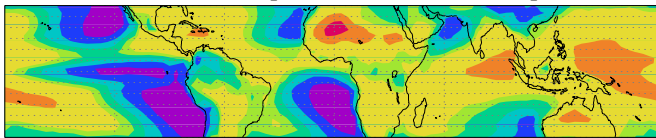
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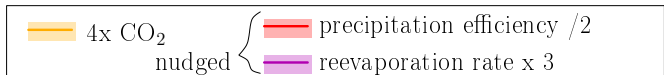


simulated reevaporation fraction in the vapor

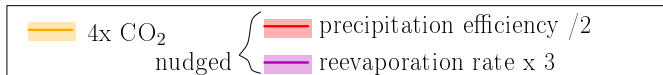
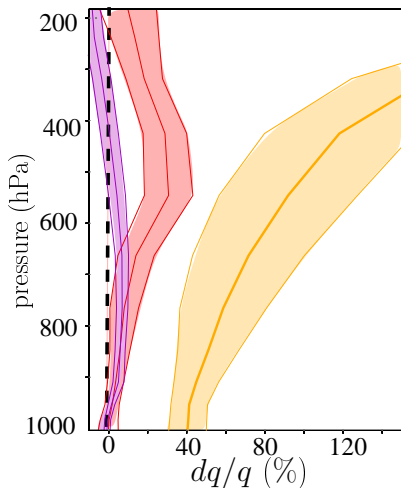


RMS = 3% of spatial standard deviation
1 ‰ error in d-excess \rightarrow 2 % error in fraction

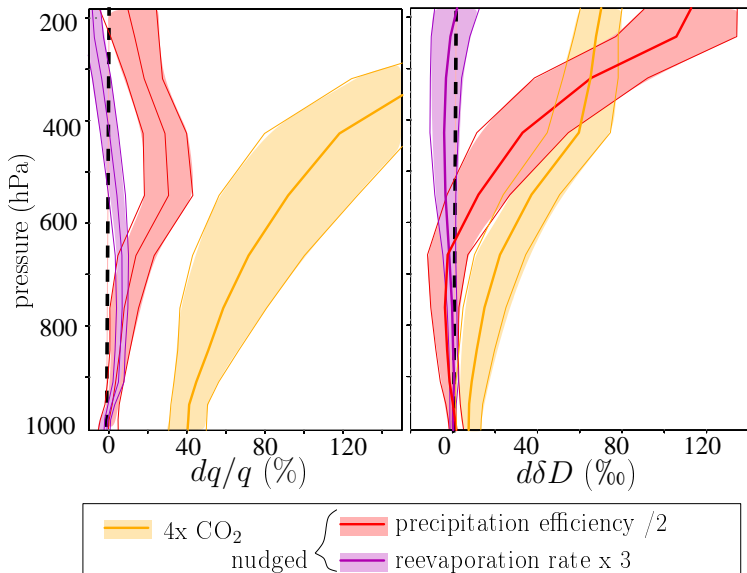
Long term monitoring of isotopes?



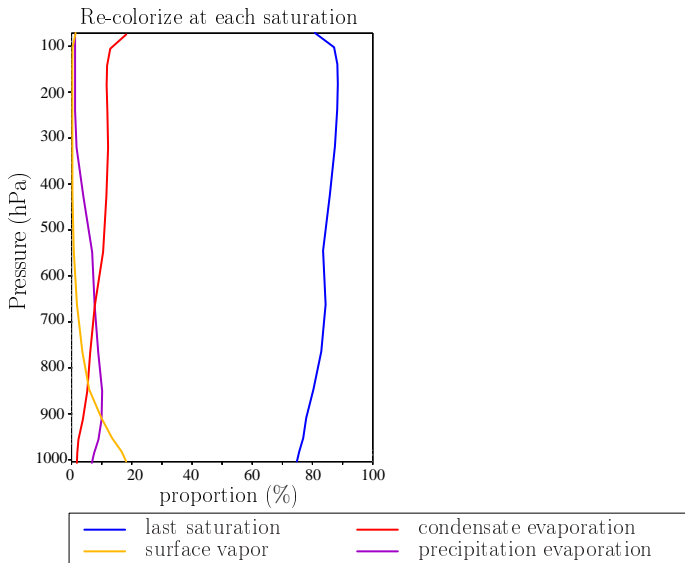
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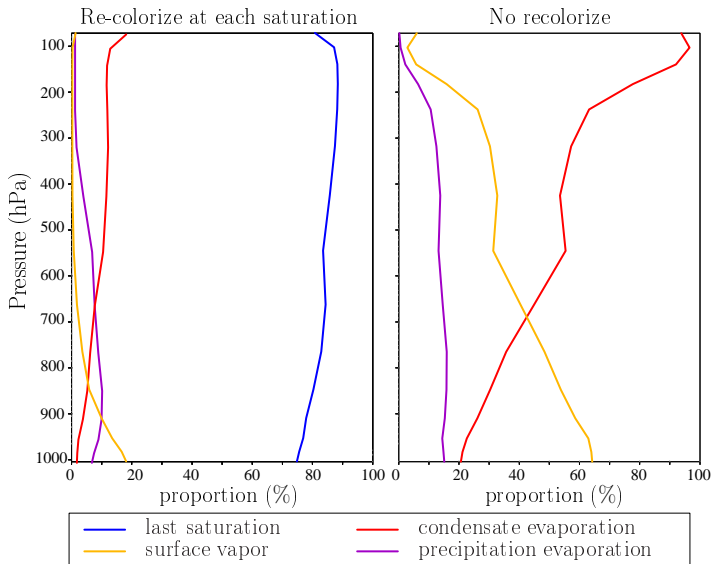
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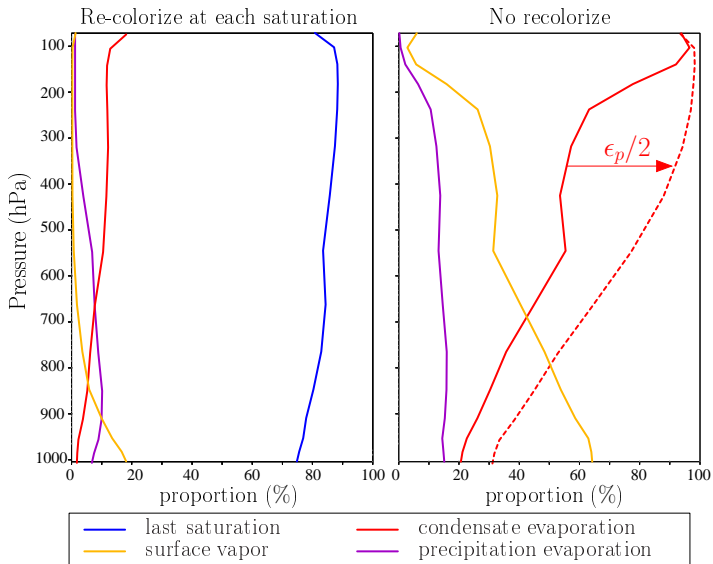
Last saturation paradigm vs microphysics



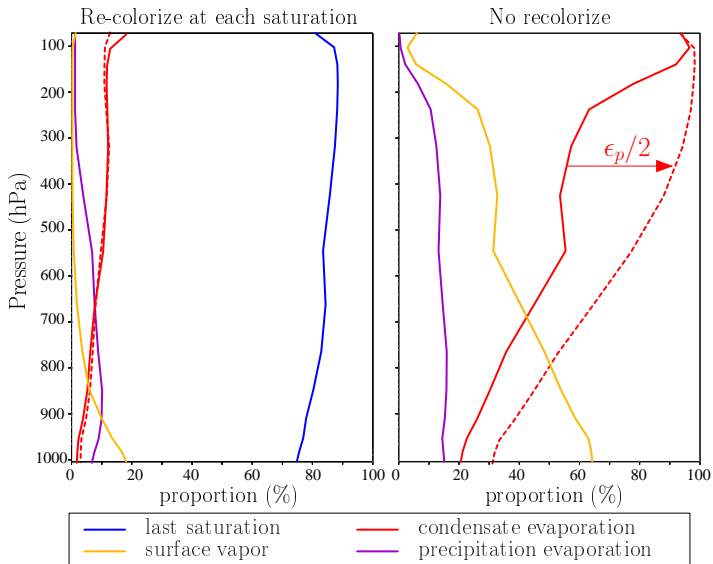
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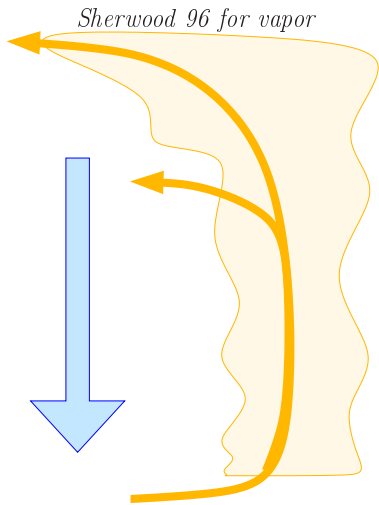
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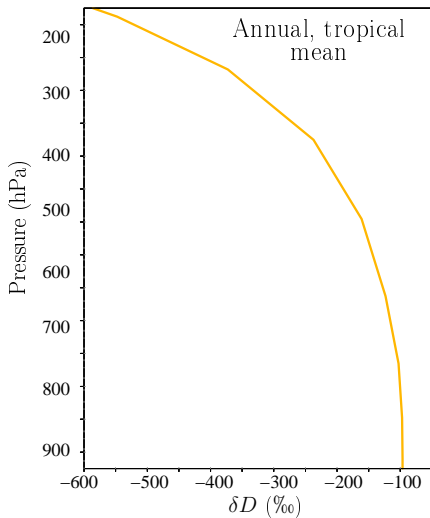
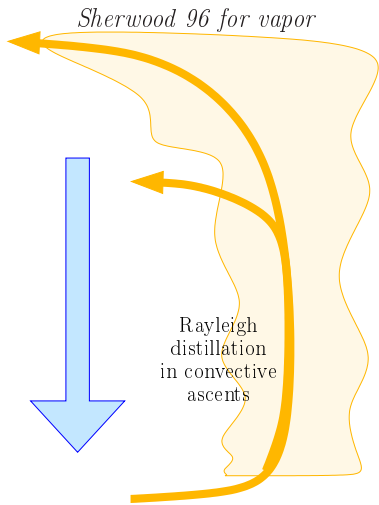
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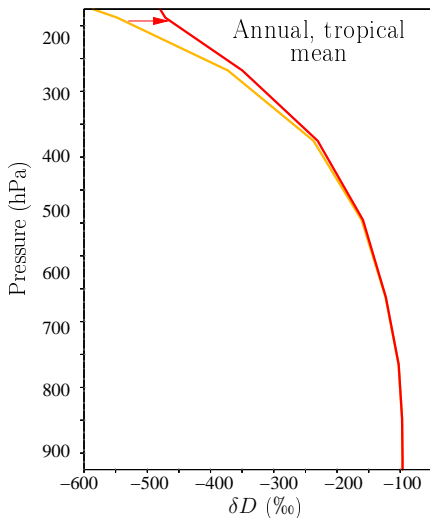
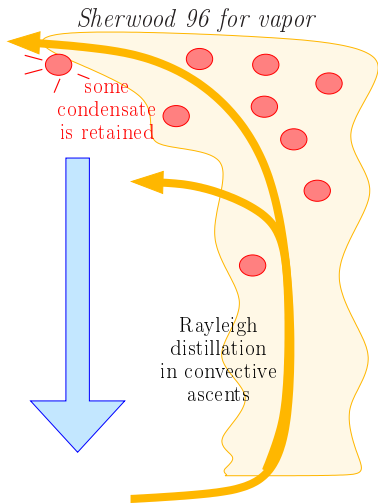
A last saturation model for isotopes



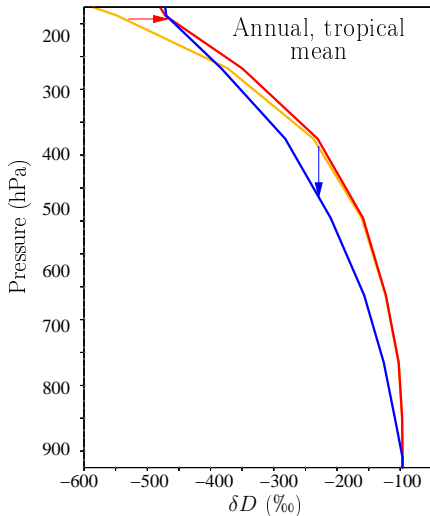
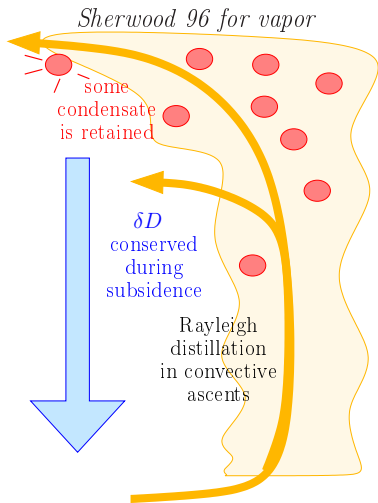
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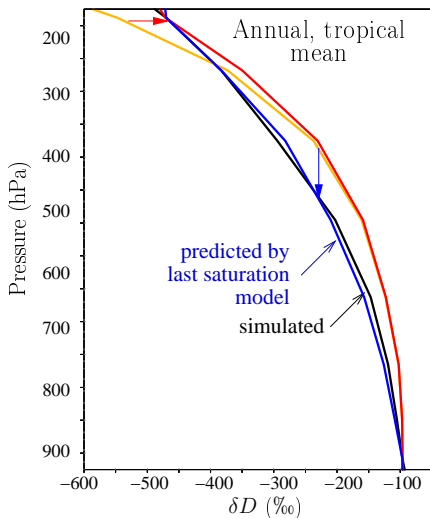
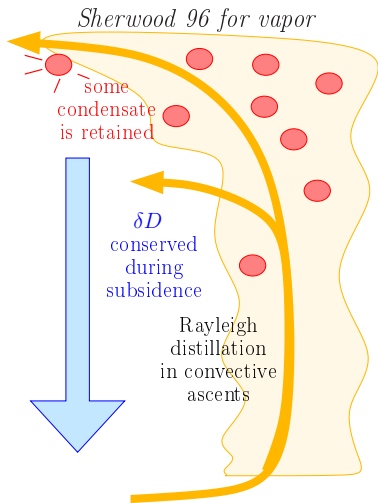
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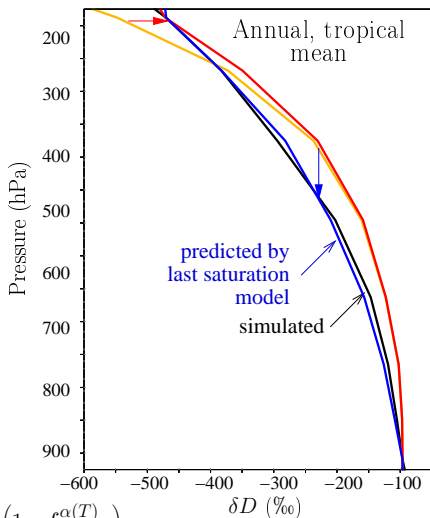
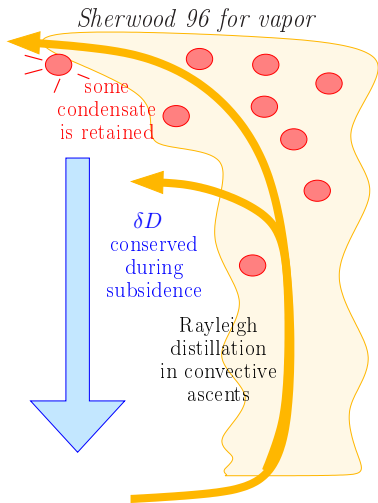
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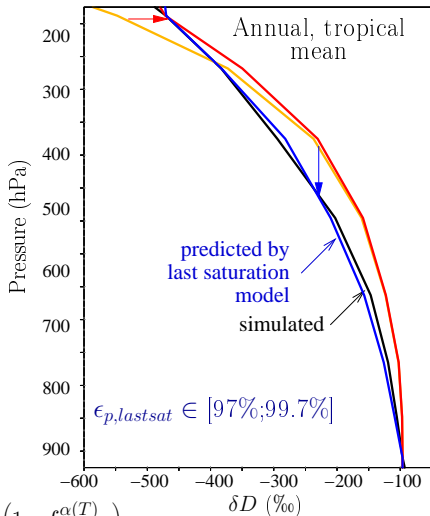
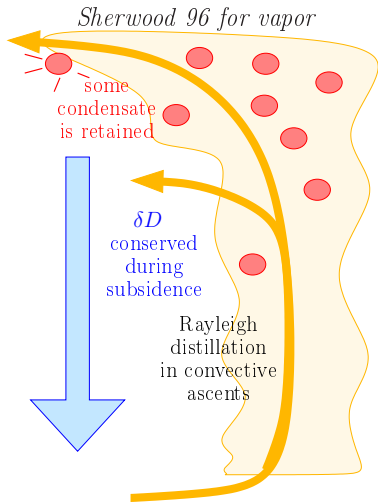


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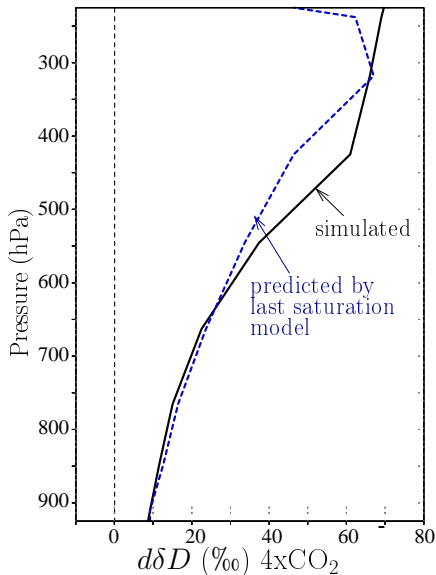
$$R_v(T, h, \epsilon_p) = R_{v0} \cdot \frac{1 - \epsilon_{p, \text{lastsat}} \cdot (1 - f_{\text{lastsat}}^{\alpha(T)})}{1 - \epsilon_{p, \text{lastsat}} \cdot (1 - f_{\text{lastsat}})} \quad \text{with} \quad f_{\text{lastsat}}(T, h) = h \cdot \frac{q_s(T)}{q_0}$$

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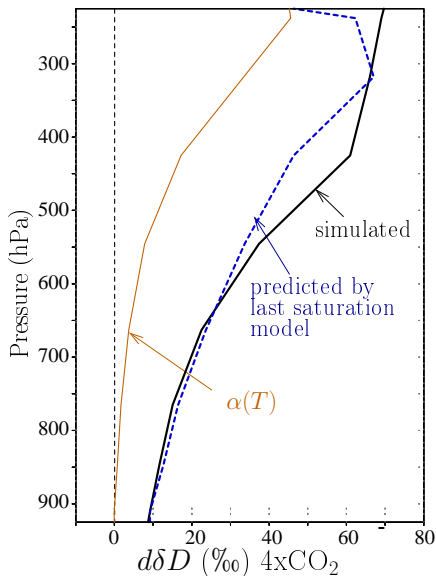


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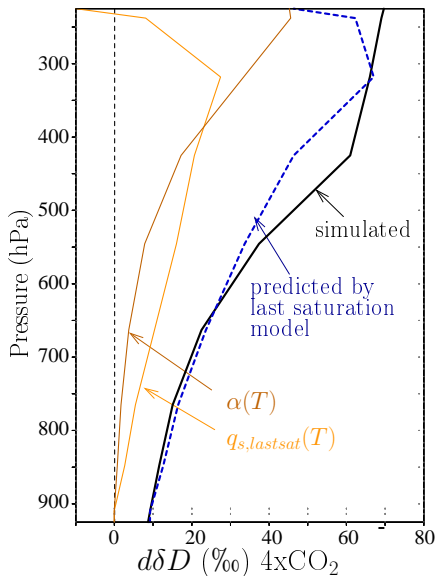
Disentangling isotopic changes



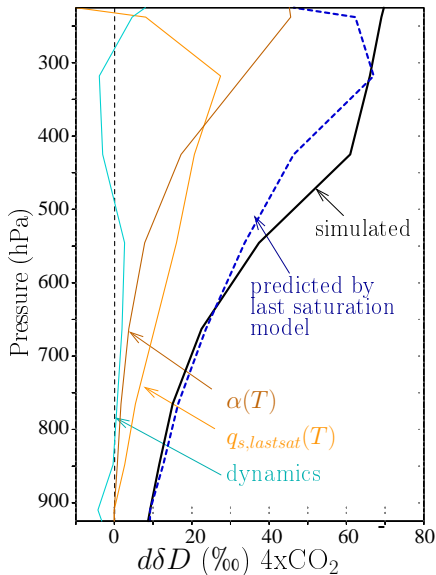
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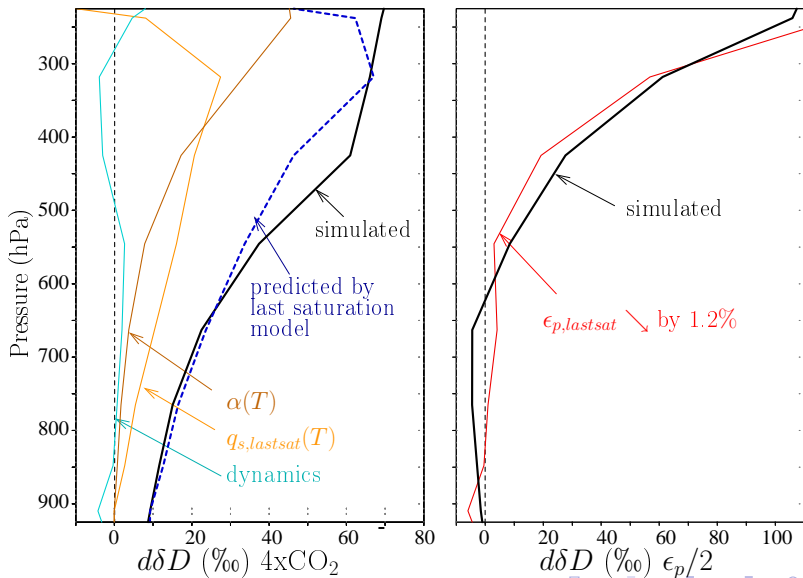
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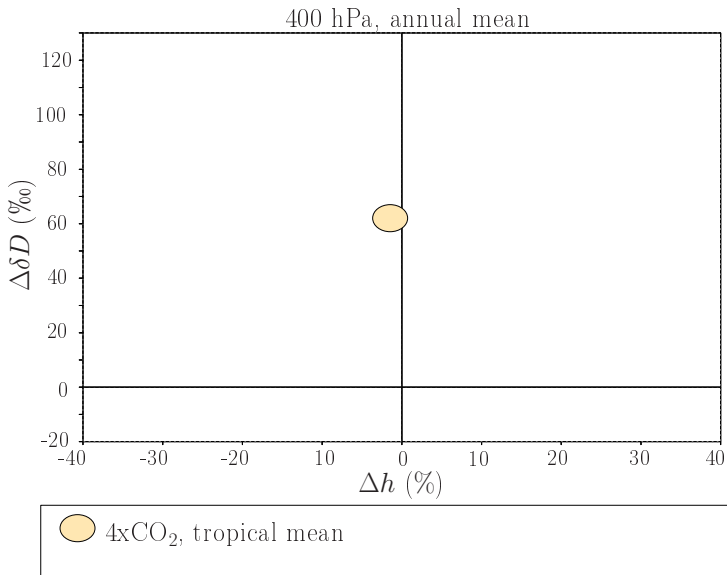
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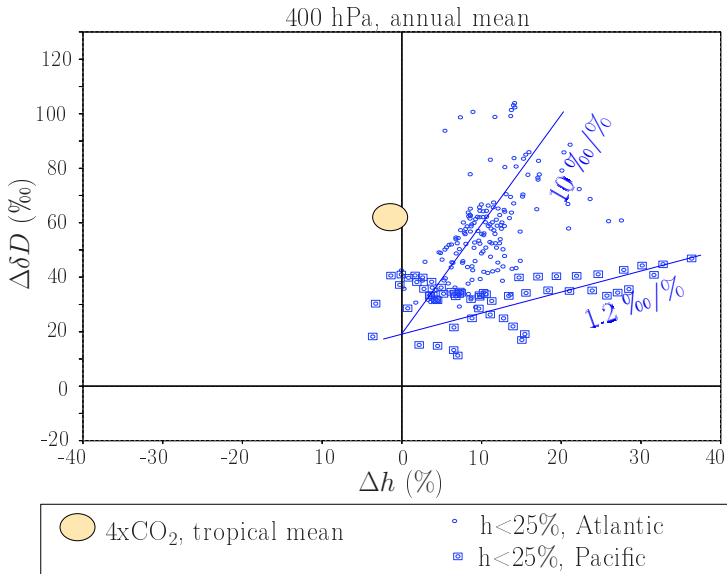
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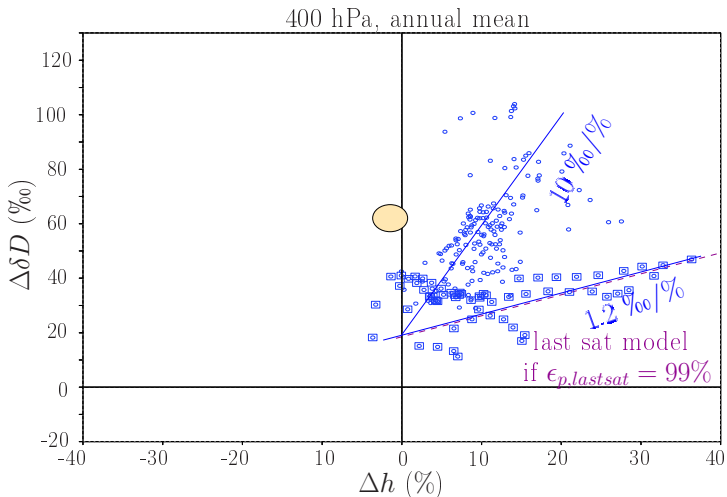
Spatial heterogeneities in humidity changes



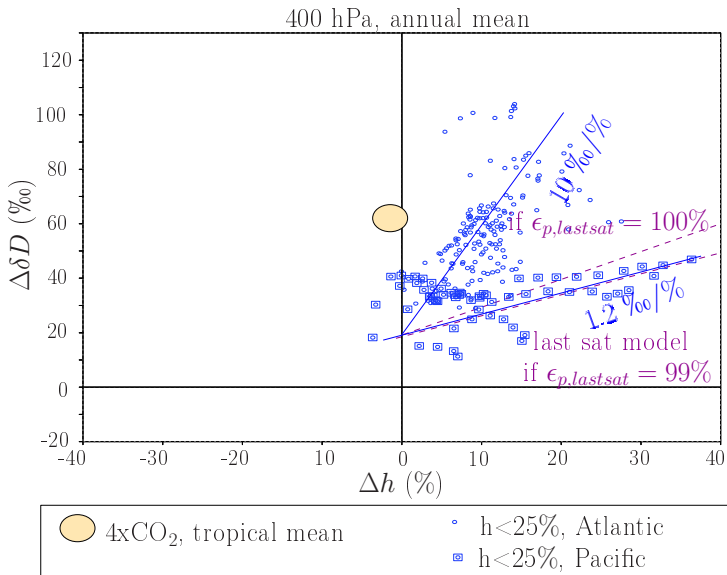
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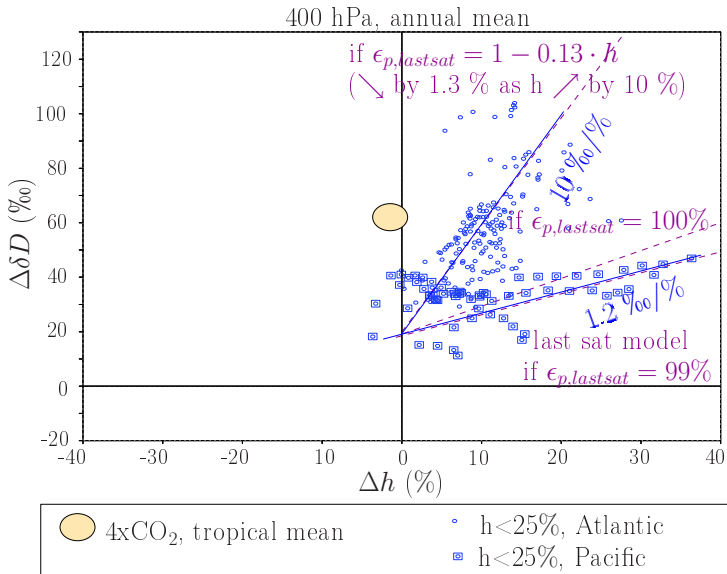
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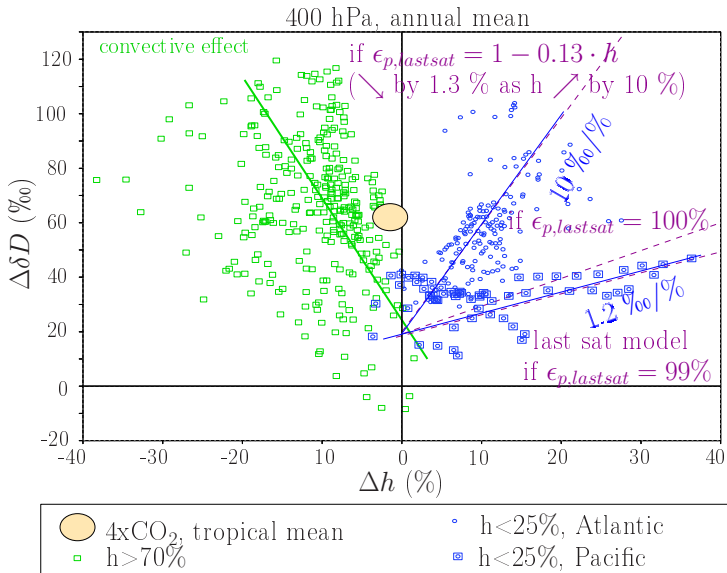
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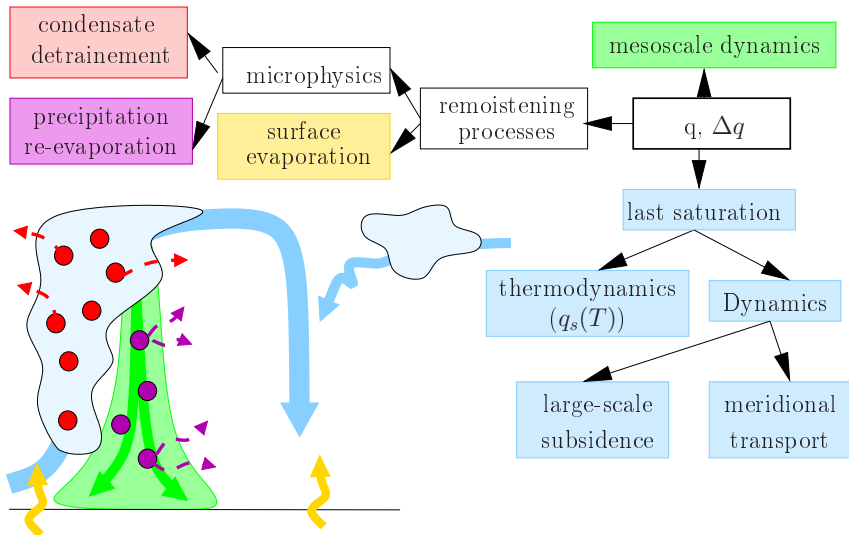
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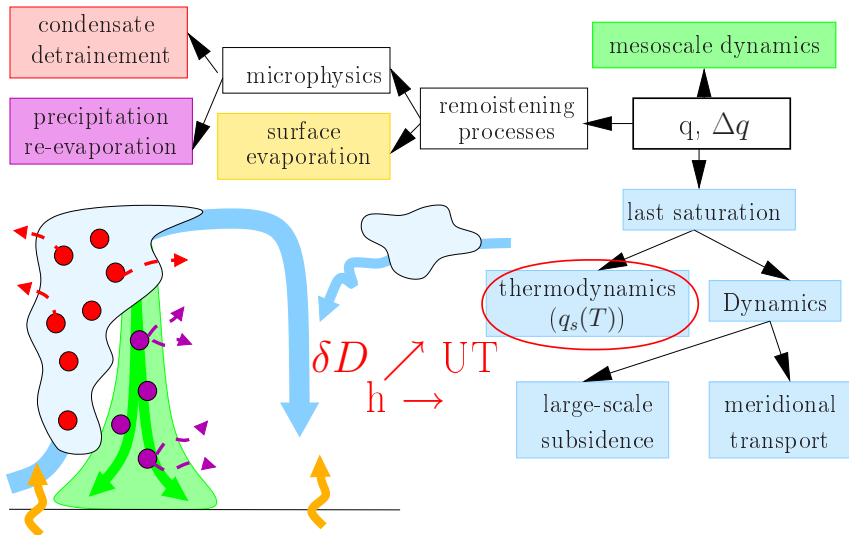
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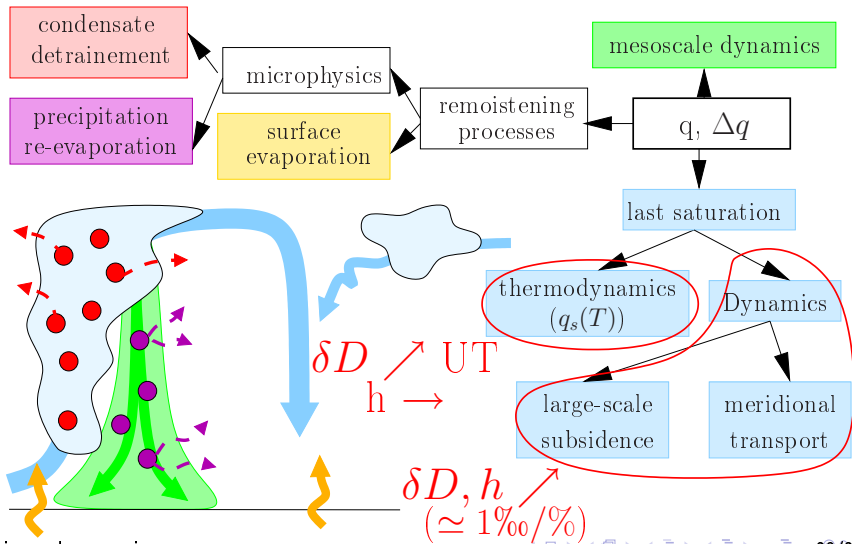
Conclusion: signature of humidity controls?



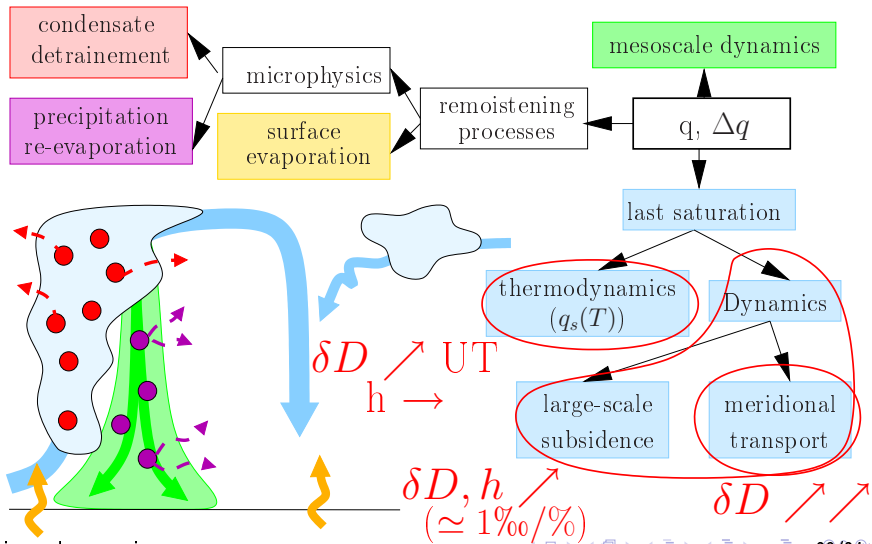
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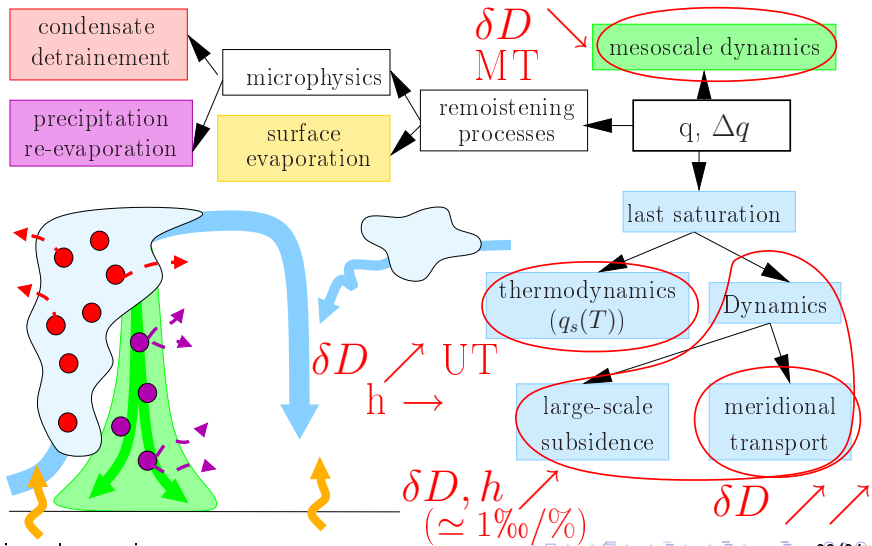
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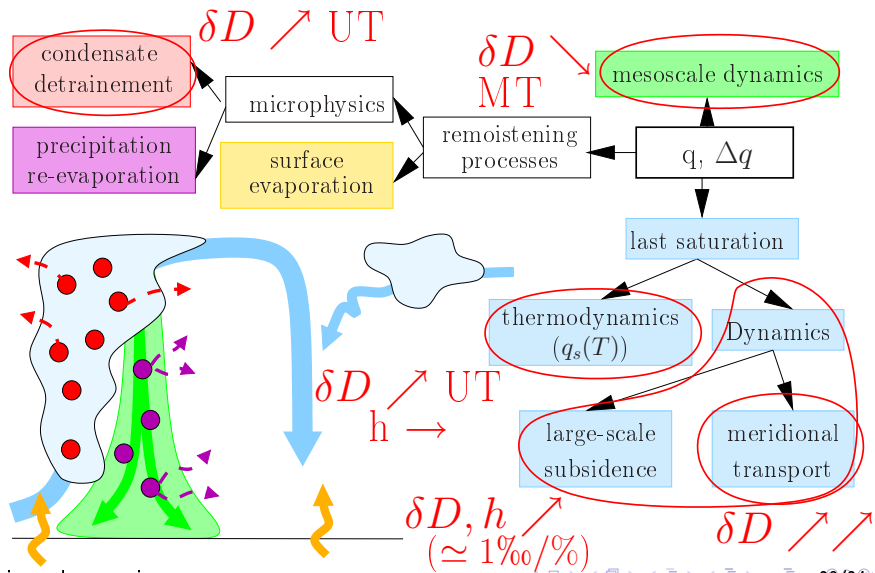
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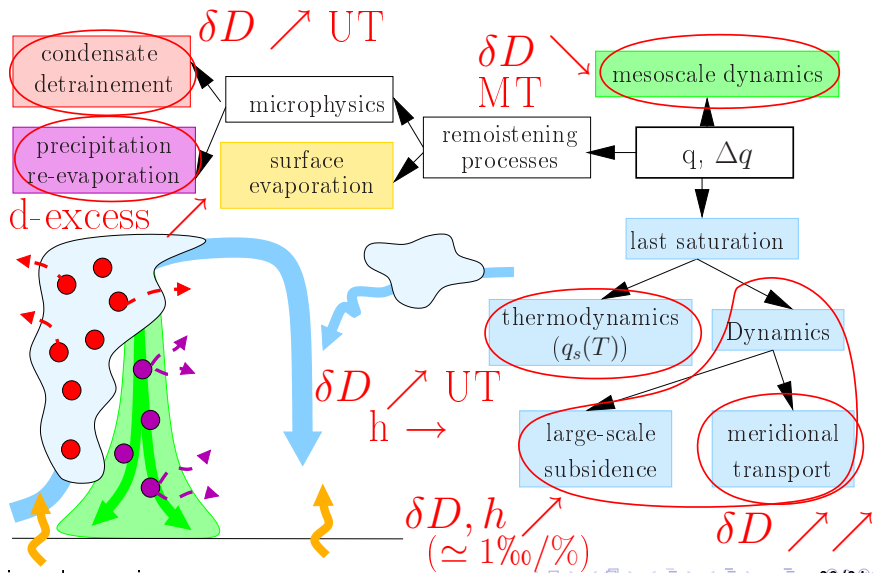
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- ▶ More process-oriented diagnostics to test these isotopic signatures of different processes controlling humidity at intra-seasonal, seasonal, inter-annual time scales using data?
- ▶ In practice, what can we learn quantitatively from isotopes about humidity controls?
 - ▶ test quantitative isotopic diagnostics in the GCM
 - ▶ what measurements would be the most needed and at what accuracy?