Water vapor isotope measurements from space and ground to evaluate processes controlling tropical and subtropical free tropospheric relative humidity in general circulation models

Camille Risi

CIRES, Boulder

Thanks to: D Noone, S Bony,
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ground-based FTIR: M Schneider, D Wunch, P Wennberg, V Sherlock
in-situ data: R Uemura
SWING2: C Sturm

Aura meeting, 29 September 2010

Uncertainties in humidity change projections

- tropical and subtropical free tropospheric relative humidity strongly impacts
  - water vapor feedback (*Soden et al 2008*)
  - clouds feedbacks (*Sherwood et al 2010*)
  - deep convection (*Derbyshire 2004*)

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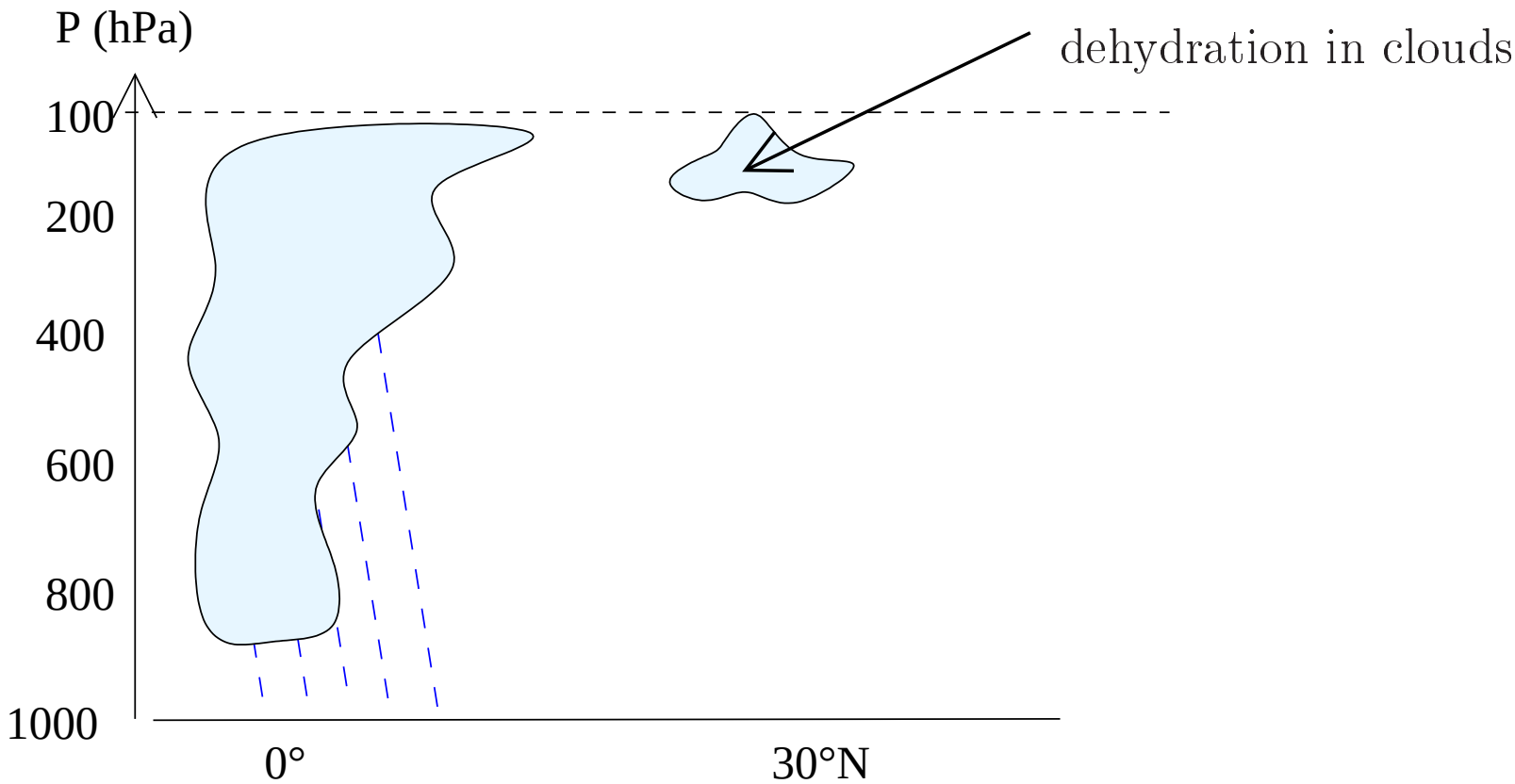
$\Longrightarrow$ What confidence do we have in processes controlling relative humidity in climate models?
$\Longrightarrow$ Goal: design observable diagnostics to evaluate processes controlling relative humidity, detect and understand biases?

Processes controlling relative humidity



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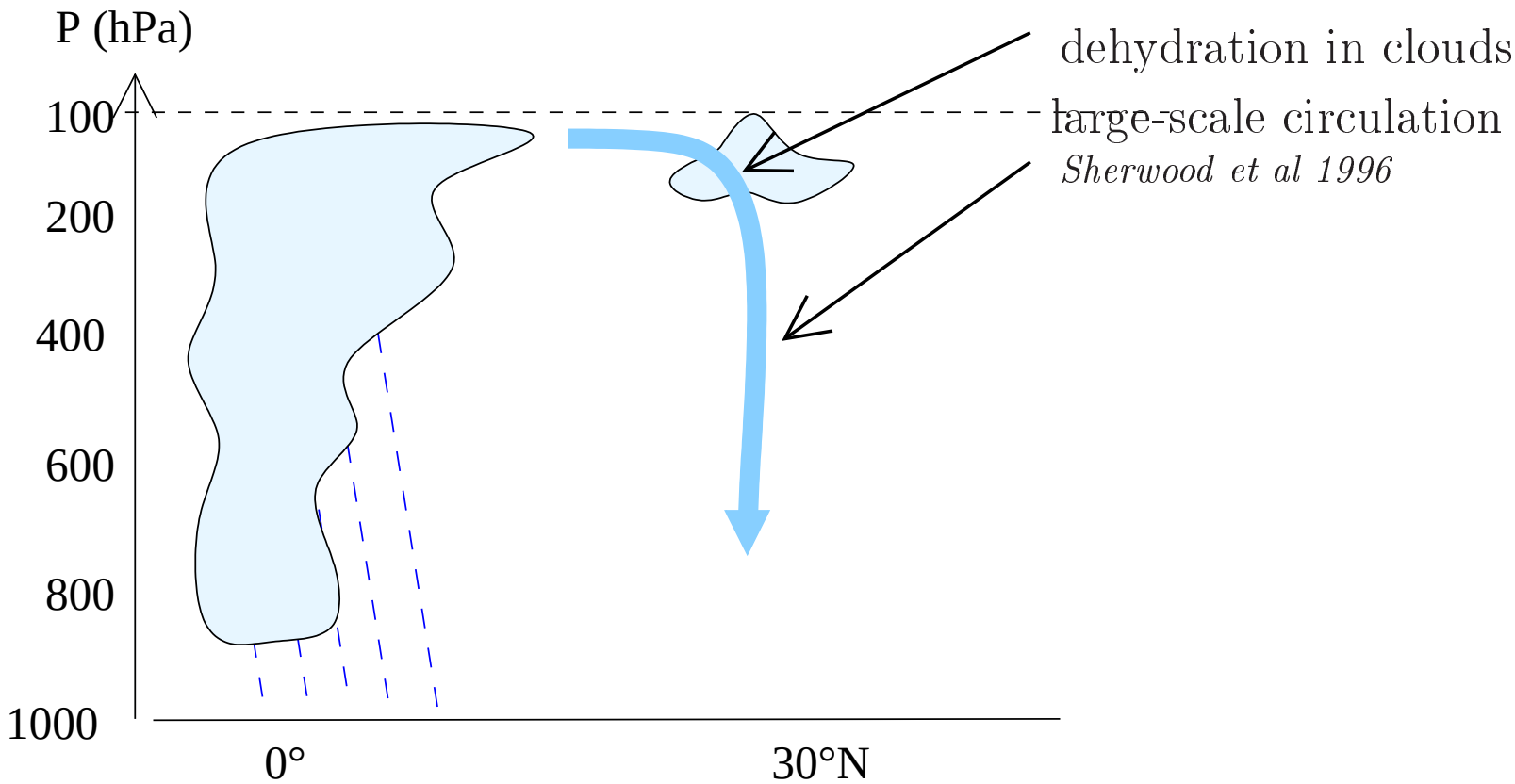

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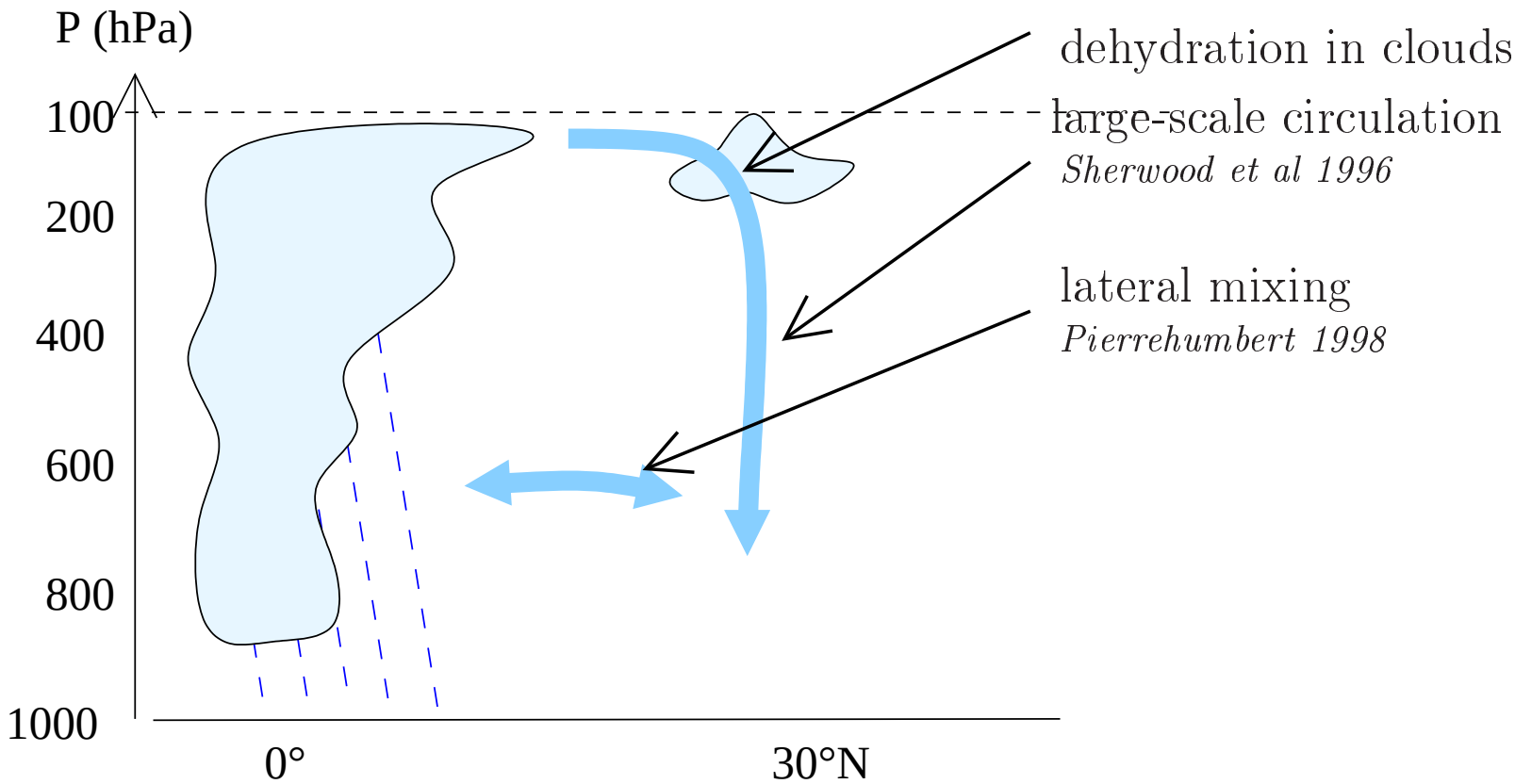

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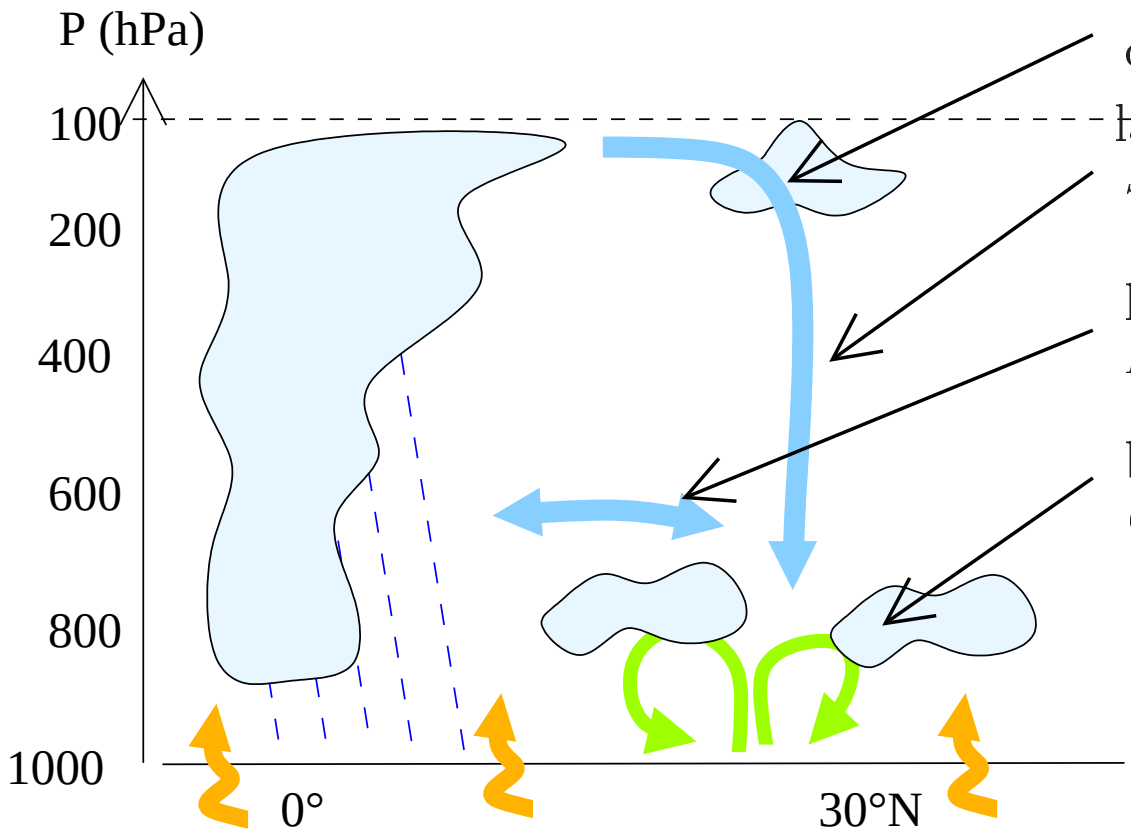

dehydration in clouds

large-scale circulation
Sherwood et al 1996

lateral mixing
Pierrehumbert 1998

boundary layer mixing
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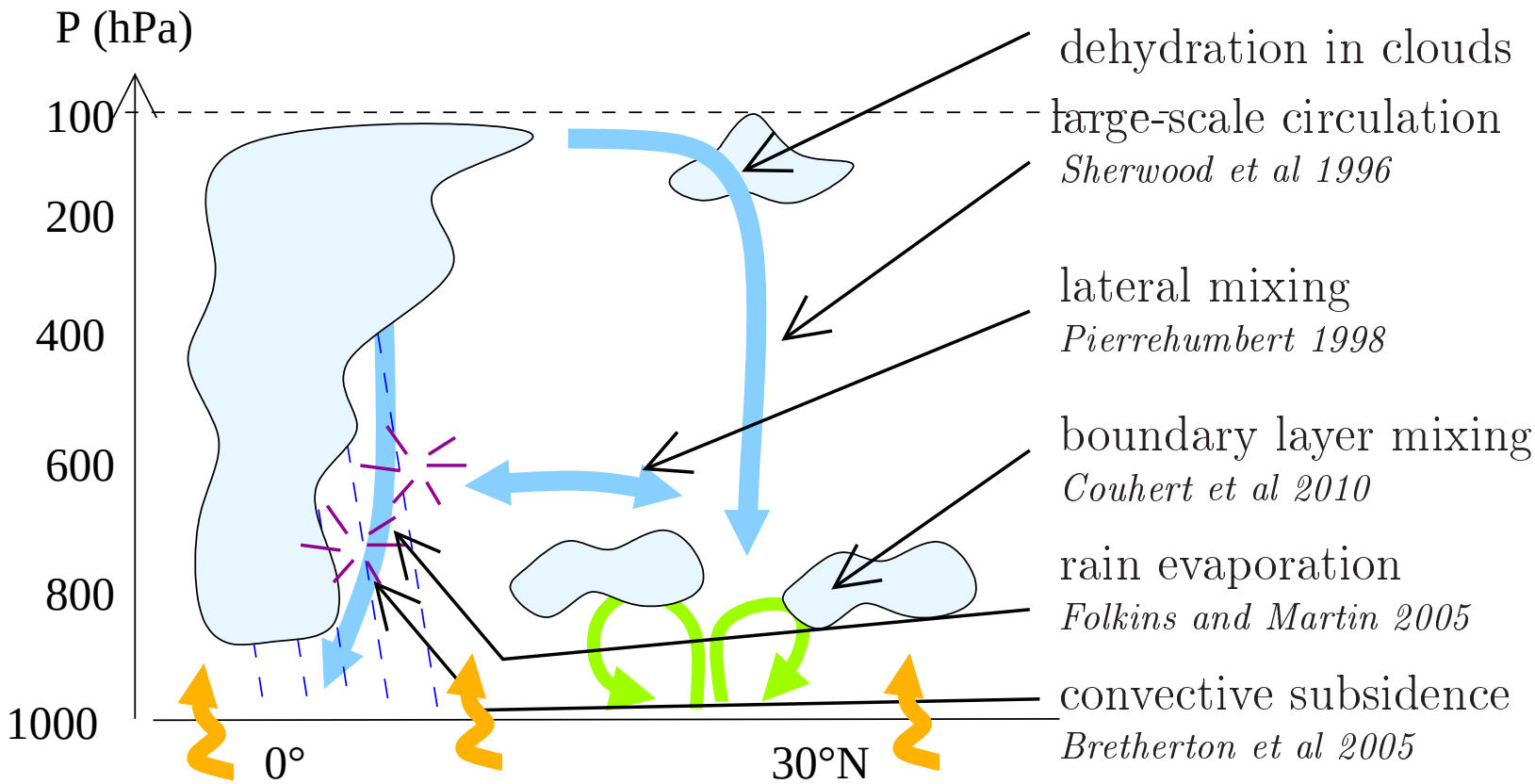
Processes controlling relative humidity



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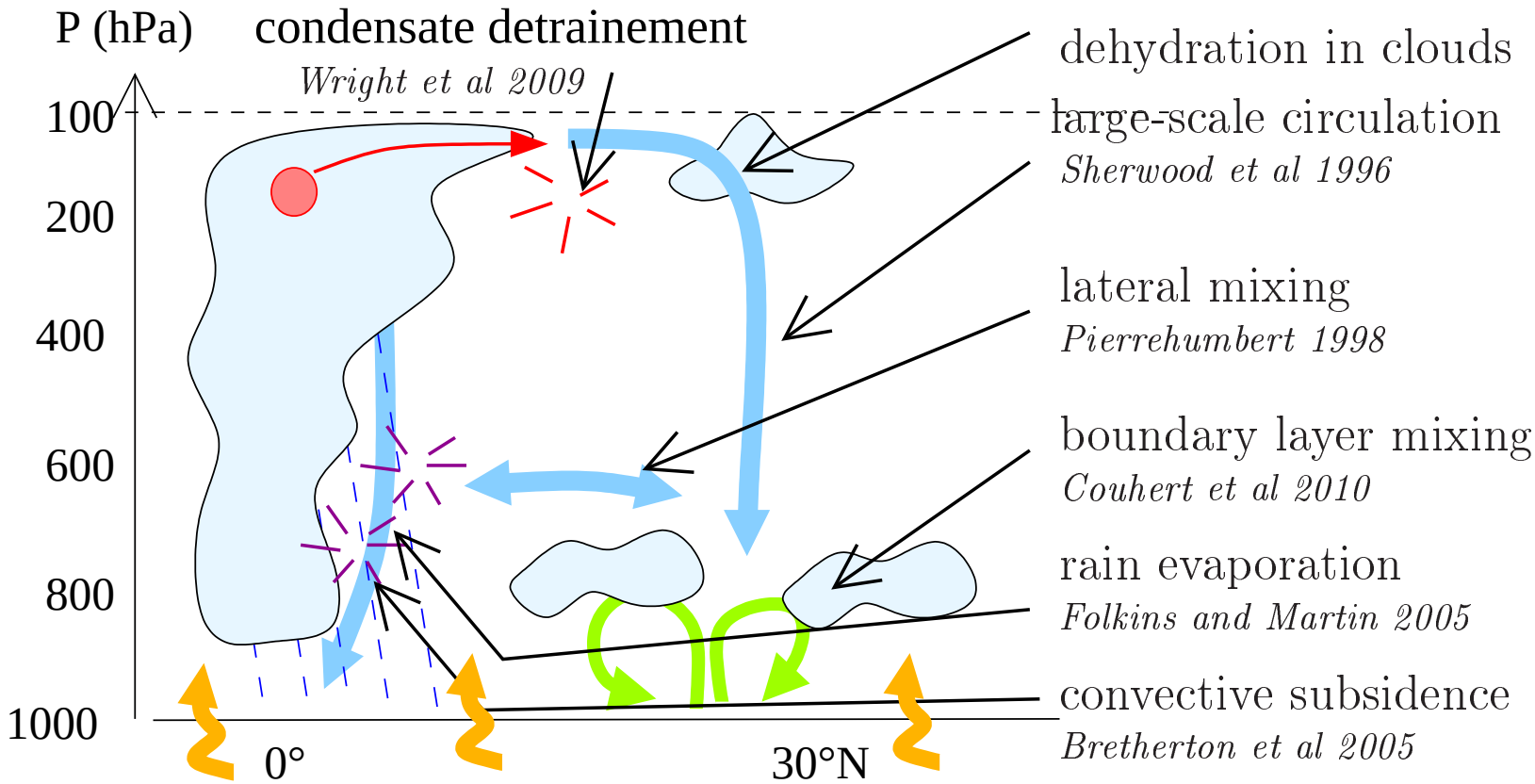

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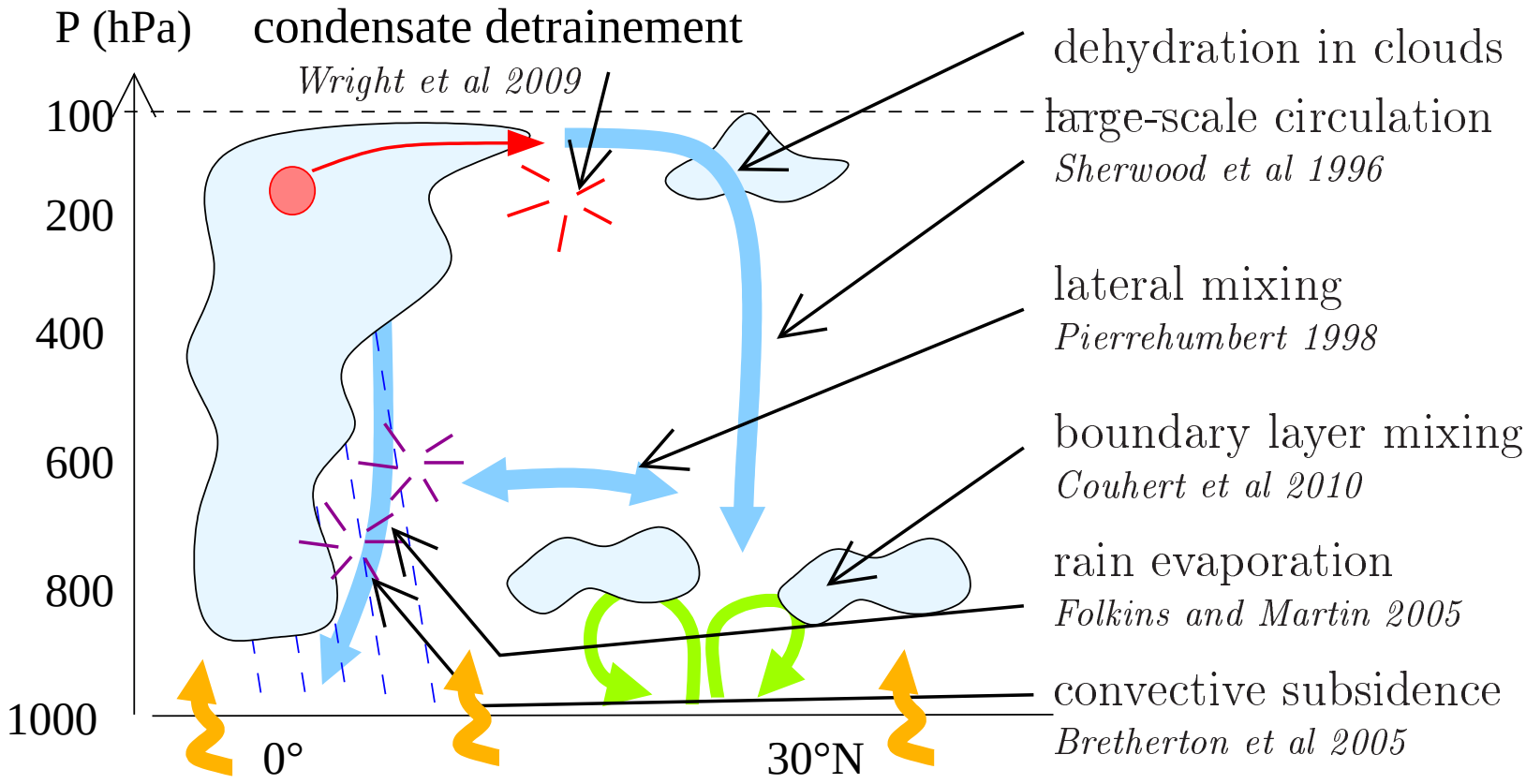
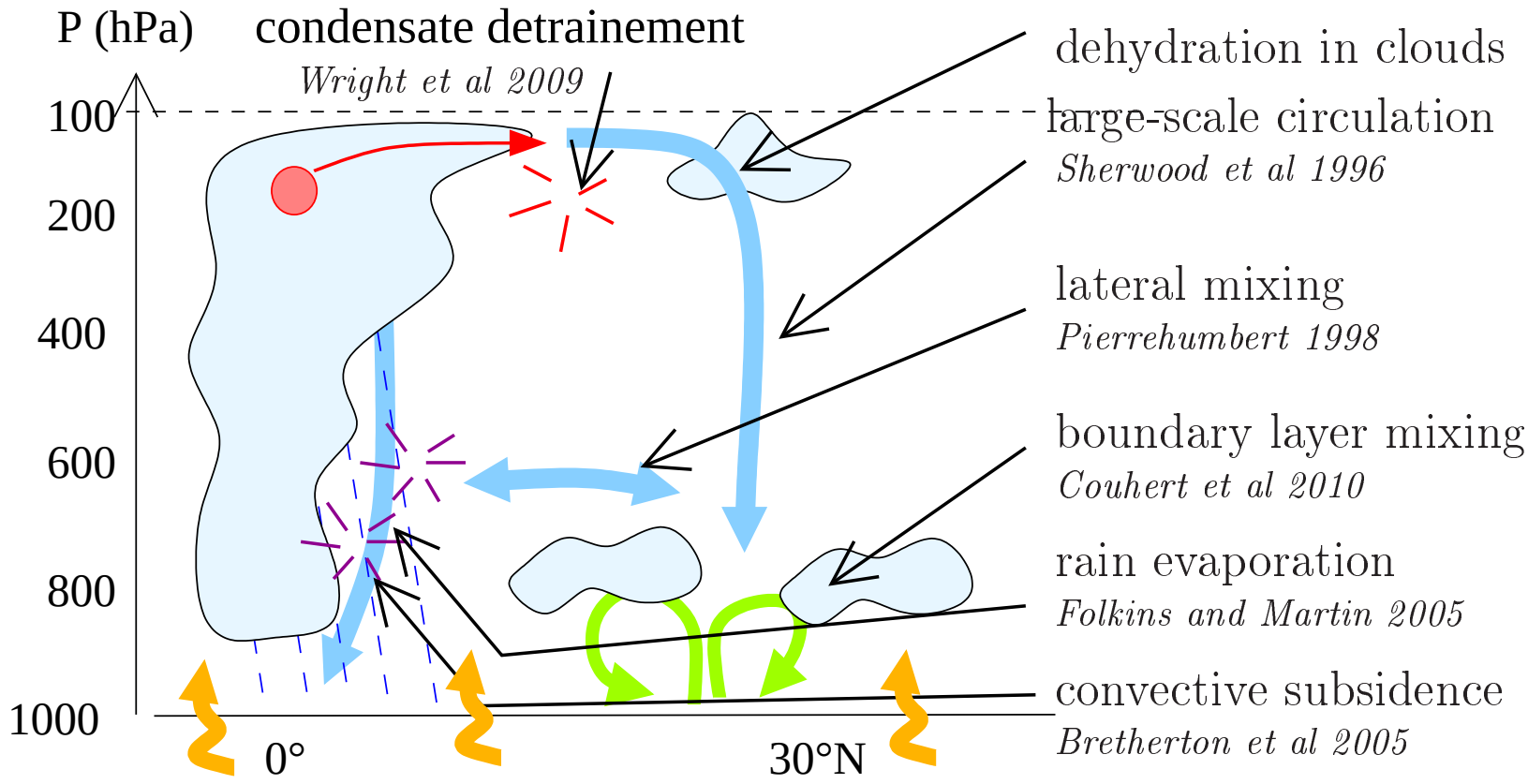


⇒need complementary evaluation tools

Processes controlling relative humidity



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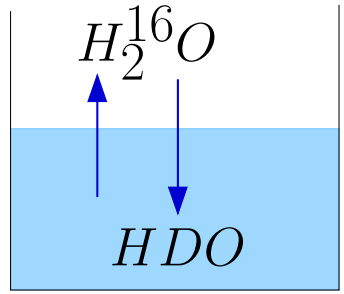

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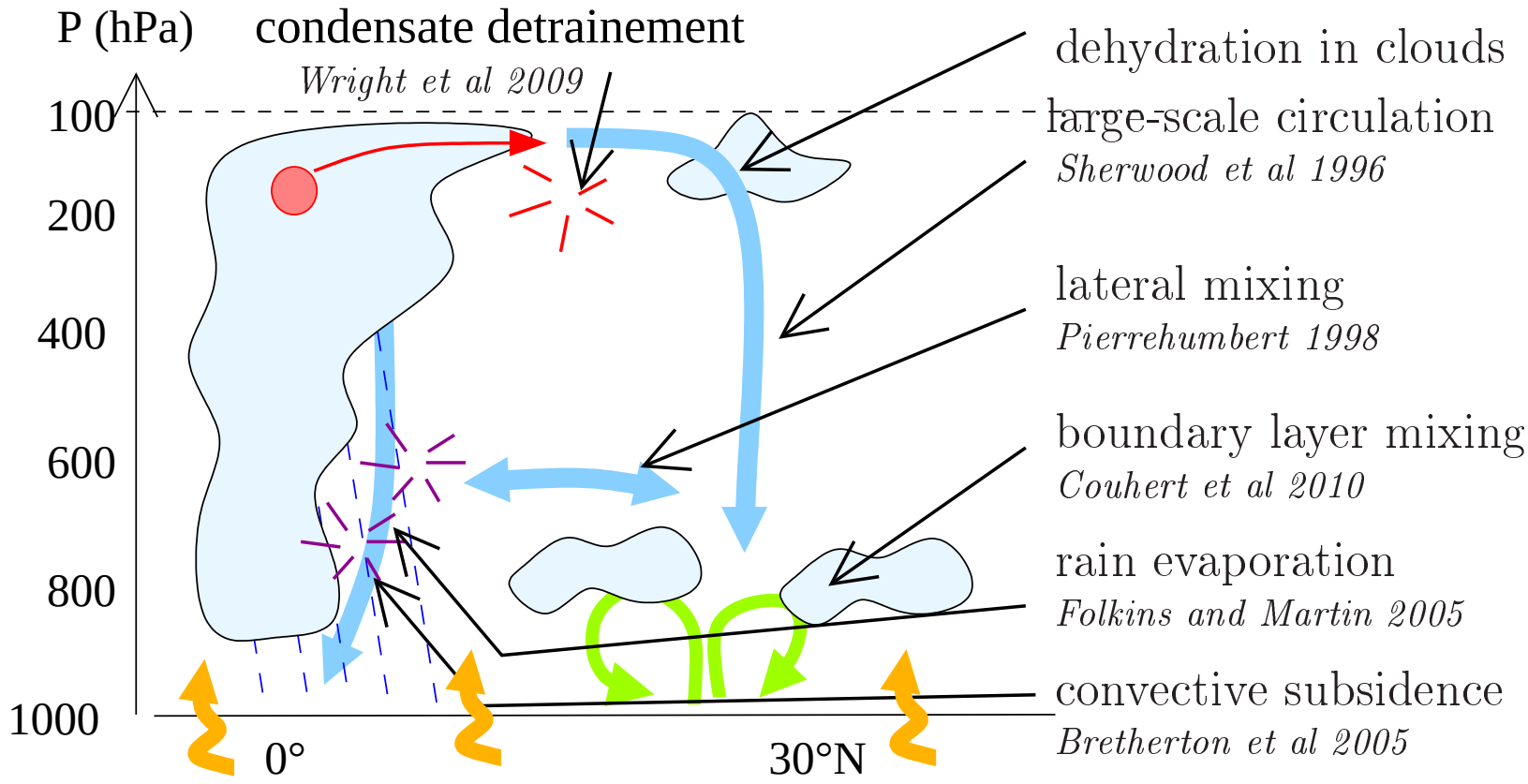

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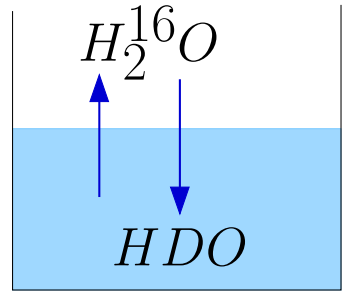
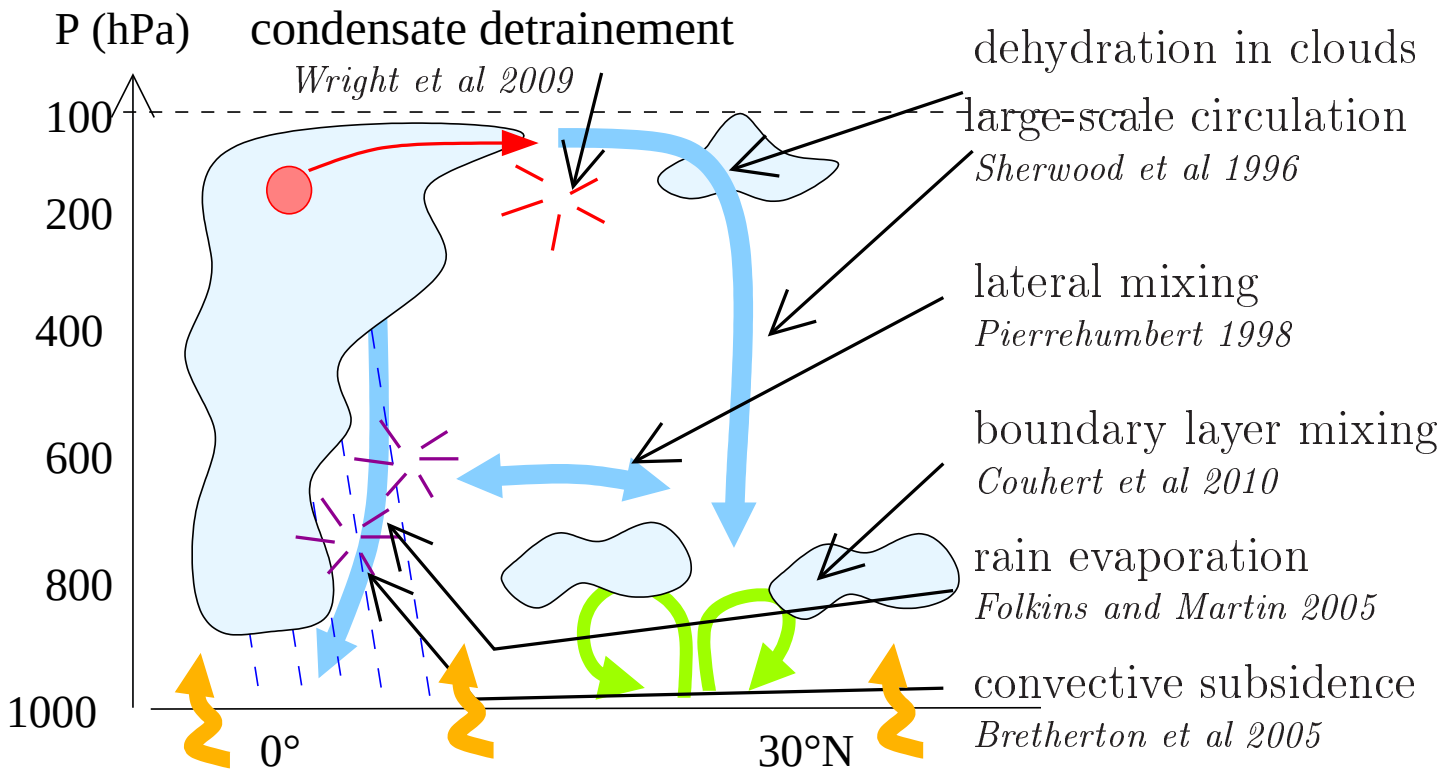
⇒ water isotopes to evaluate humidity processes in models?



Model simulations

- LMDZ-iso (*Risi et al 2010*), control simulation= AR4 version
- 3 possible reasons for moist bias in mid and upper troposphere:



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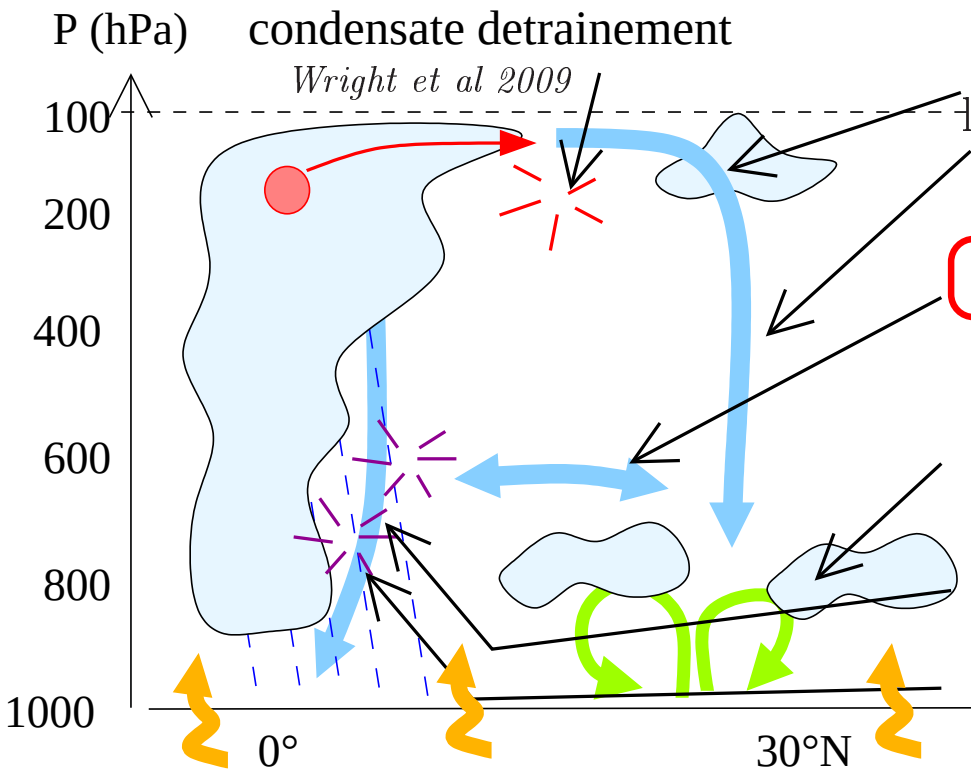

condensate detrainement
Wright et al 2009

dehydration in clouds

large-scale circulation
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lateral mixing
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advection scheme more diffusive -> +15%

boundary layer mixing
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rain evaporation
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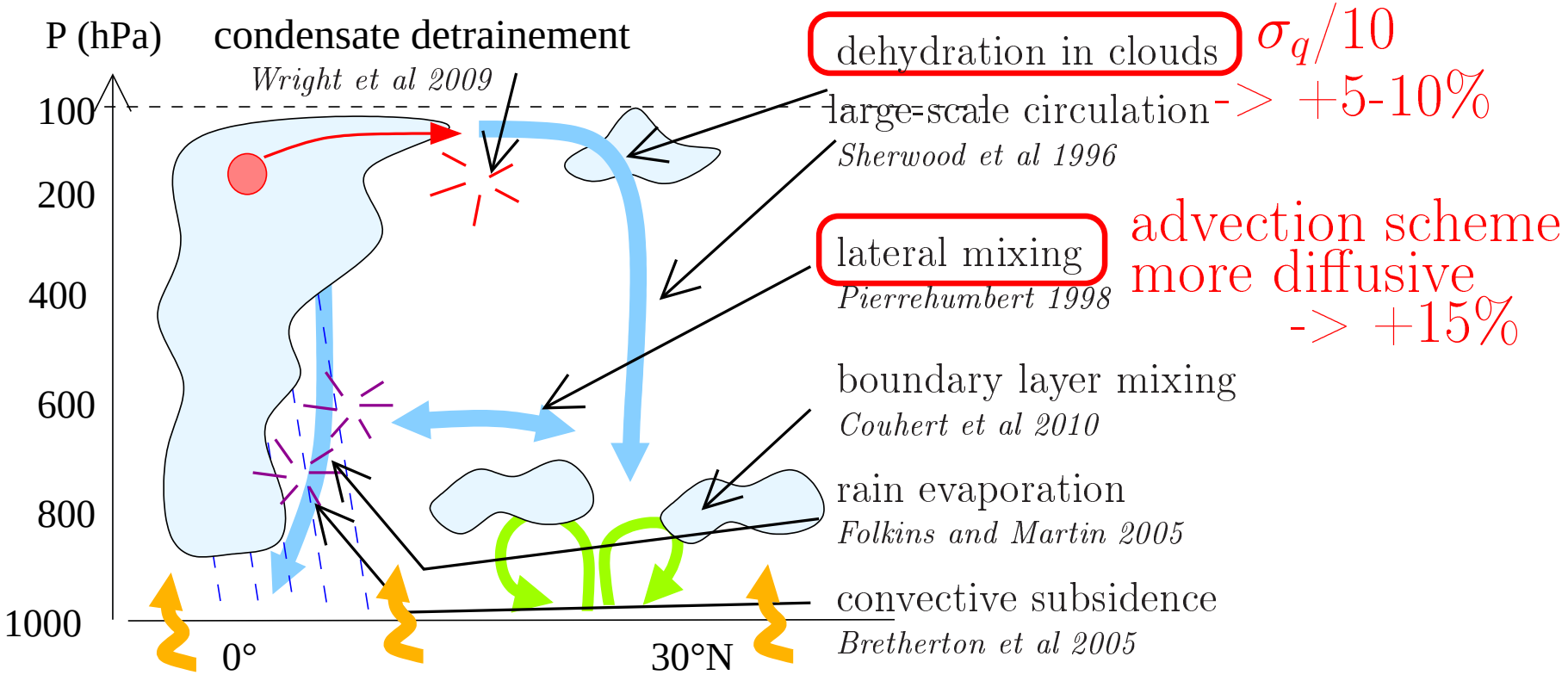

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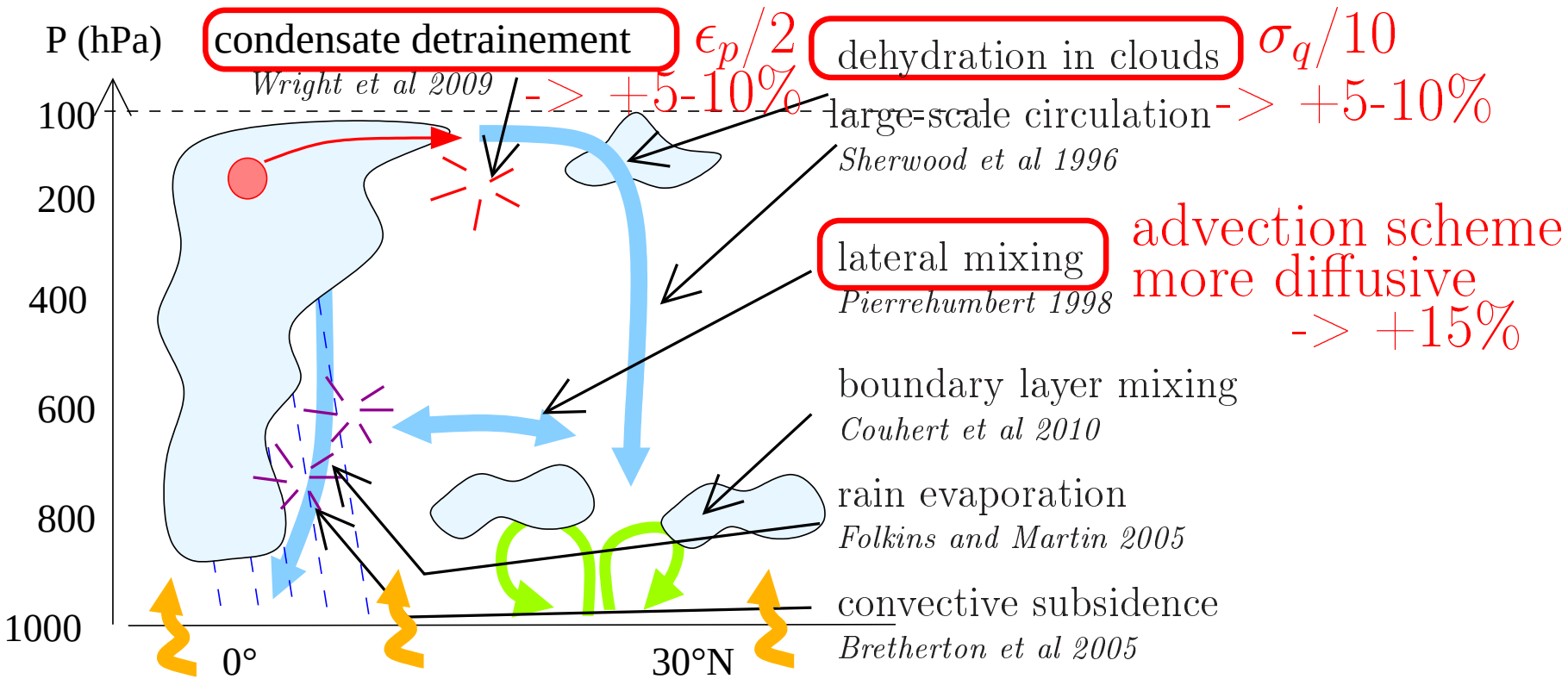

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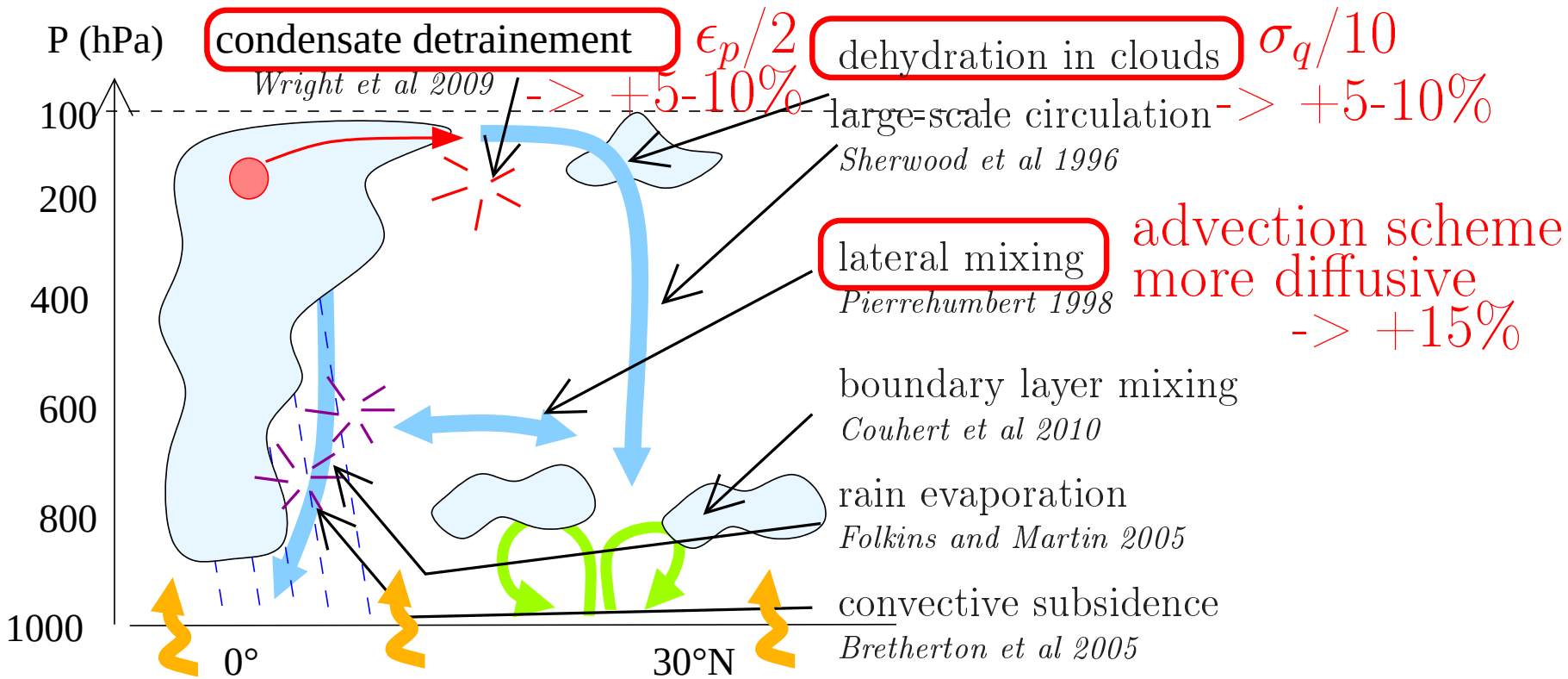
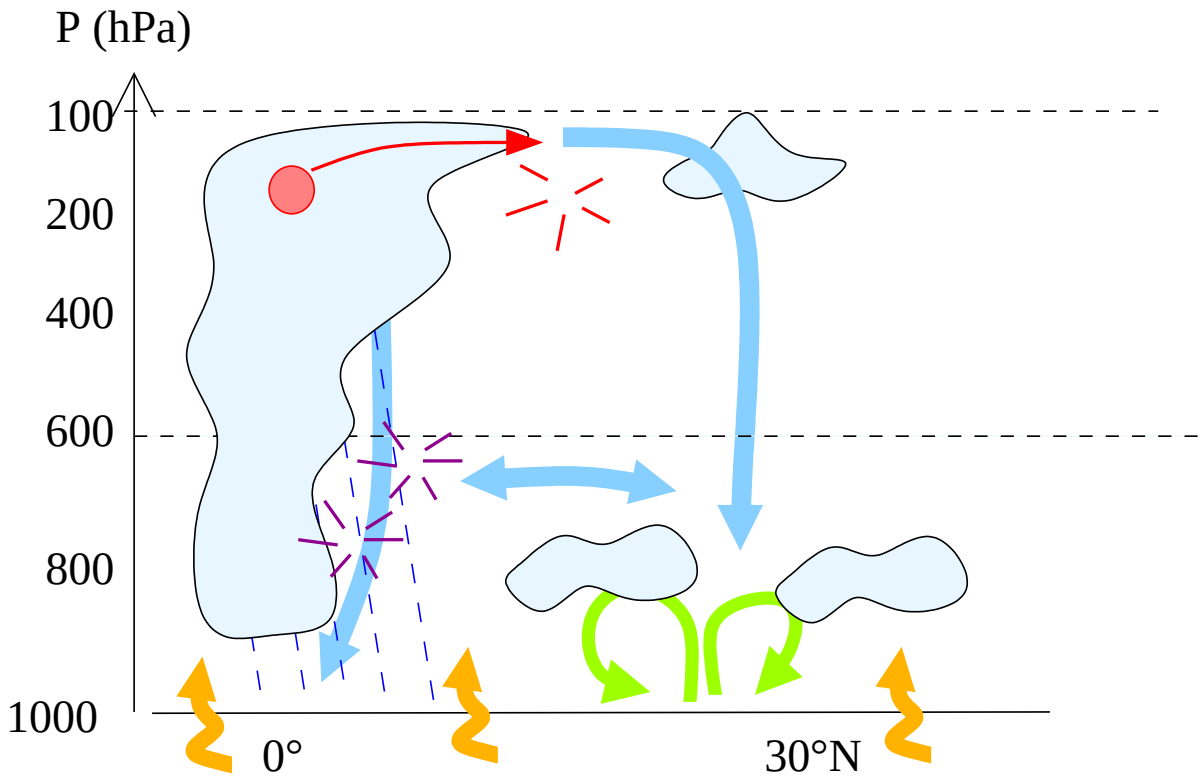


⇒ water isotopes to detect these different reasons for moist bias?

3D isotope measurements



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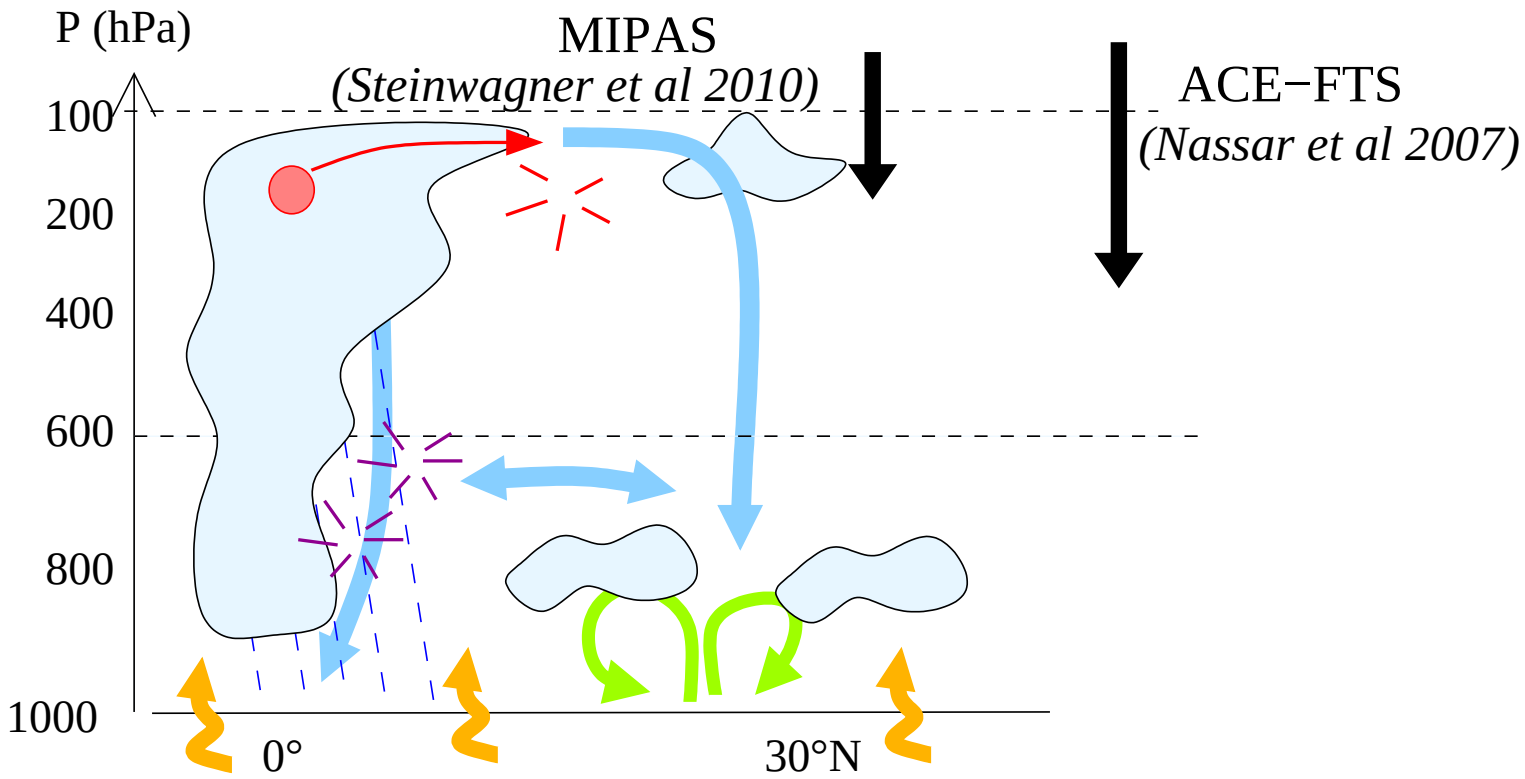

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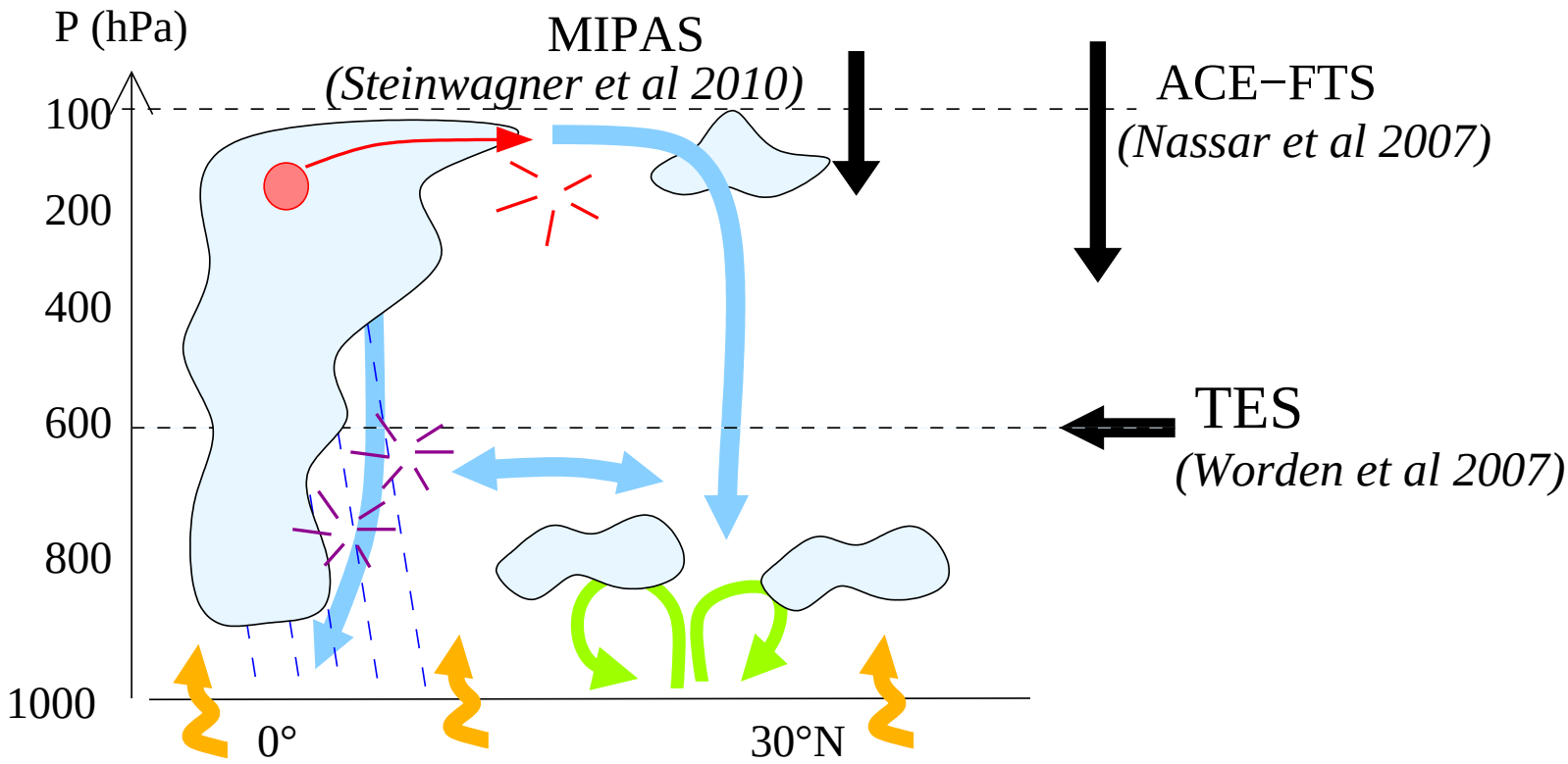

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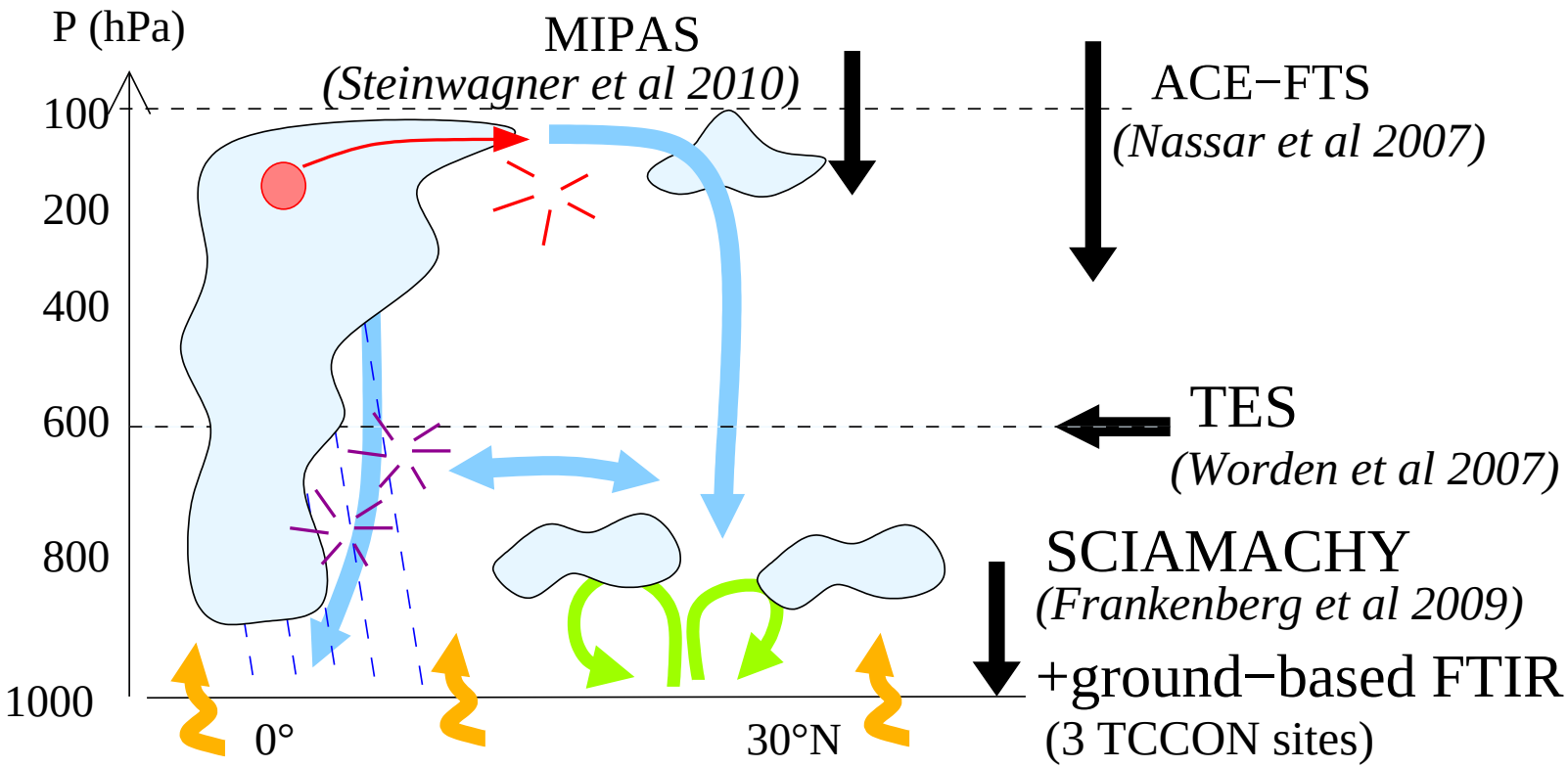

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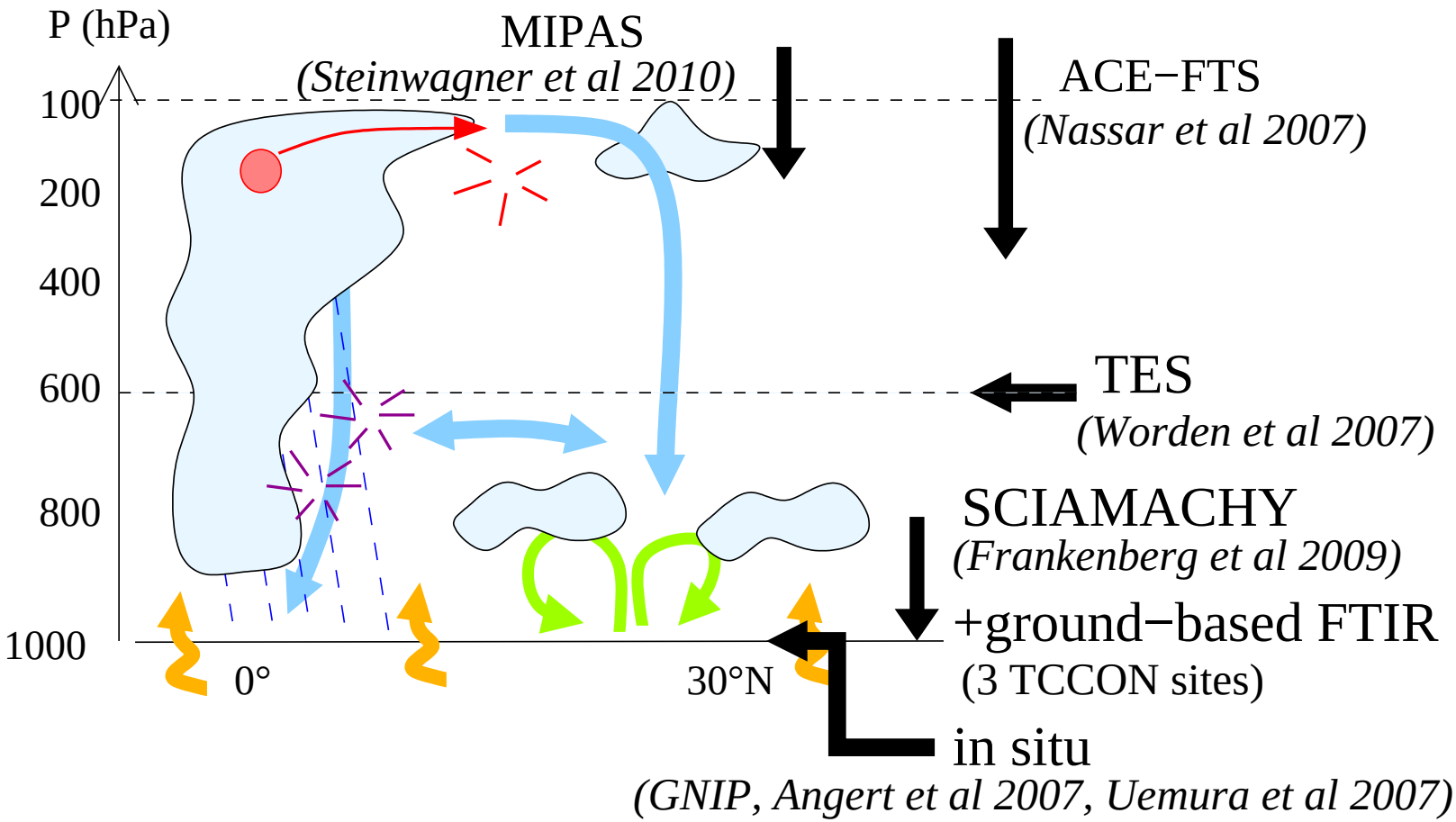

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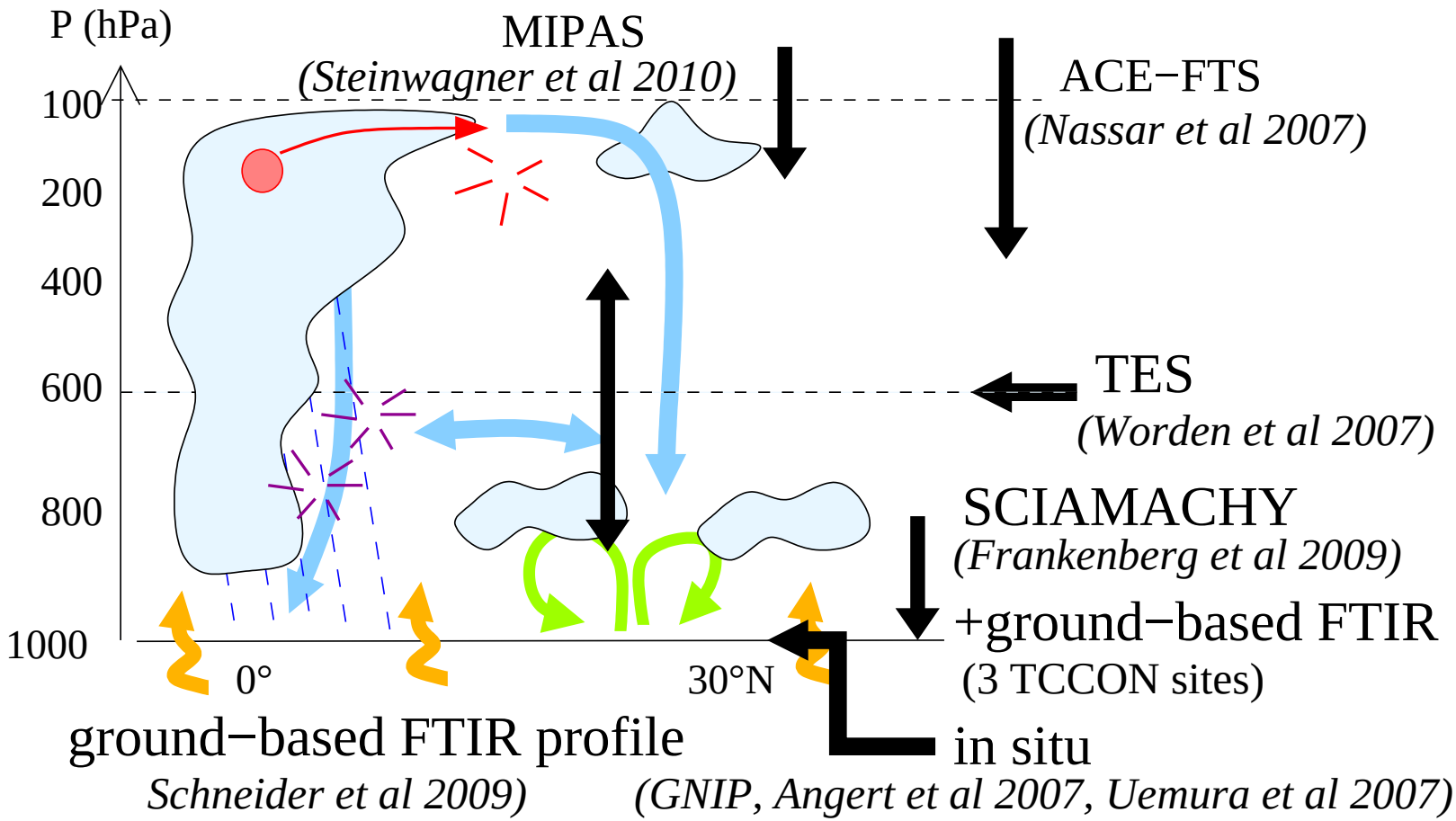

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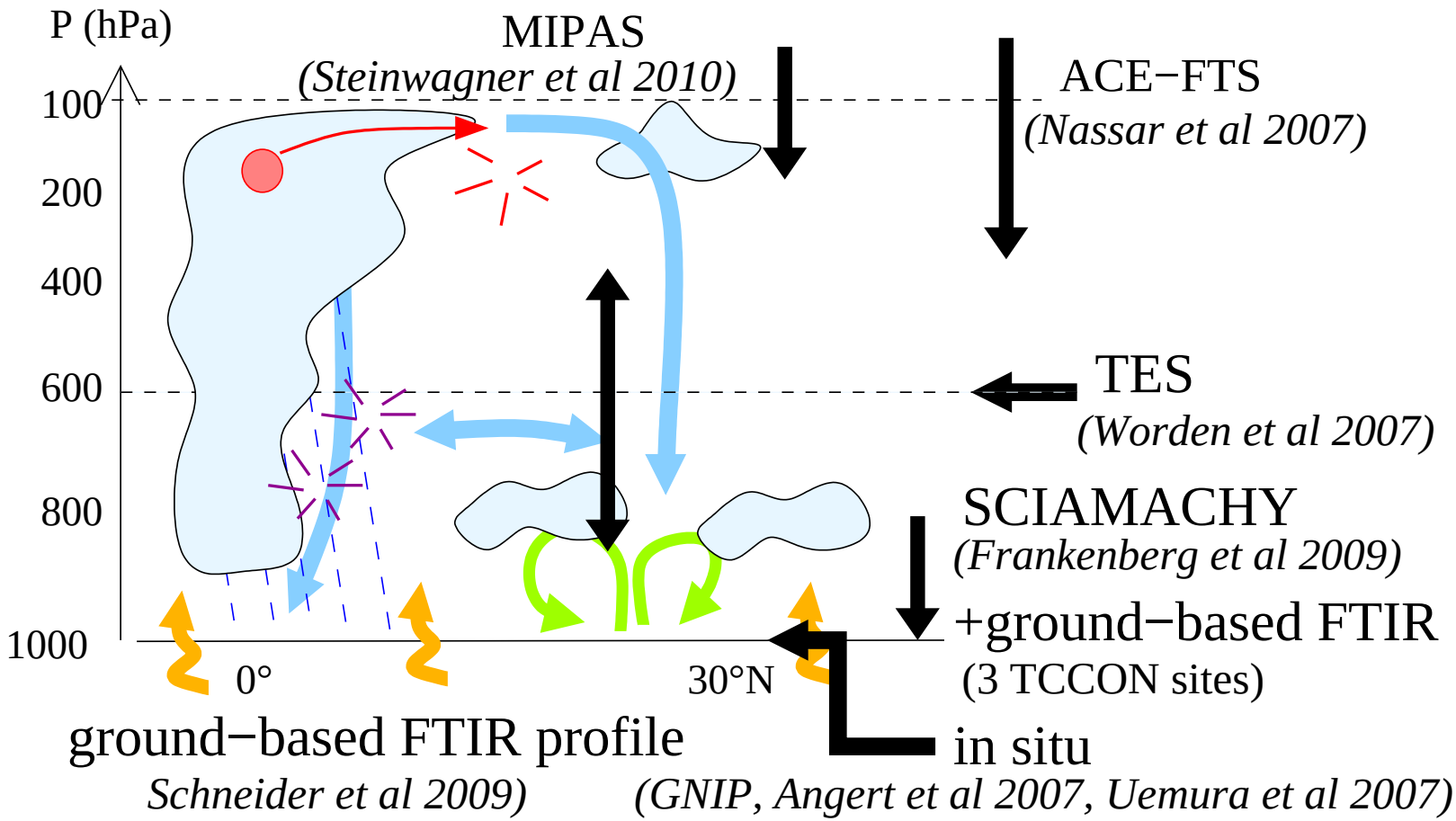
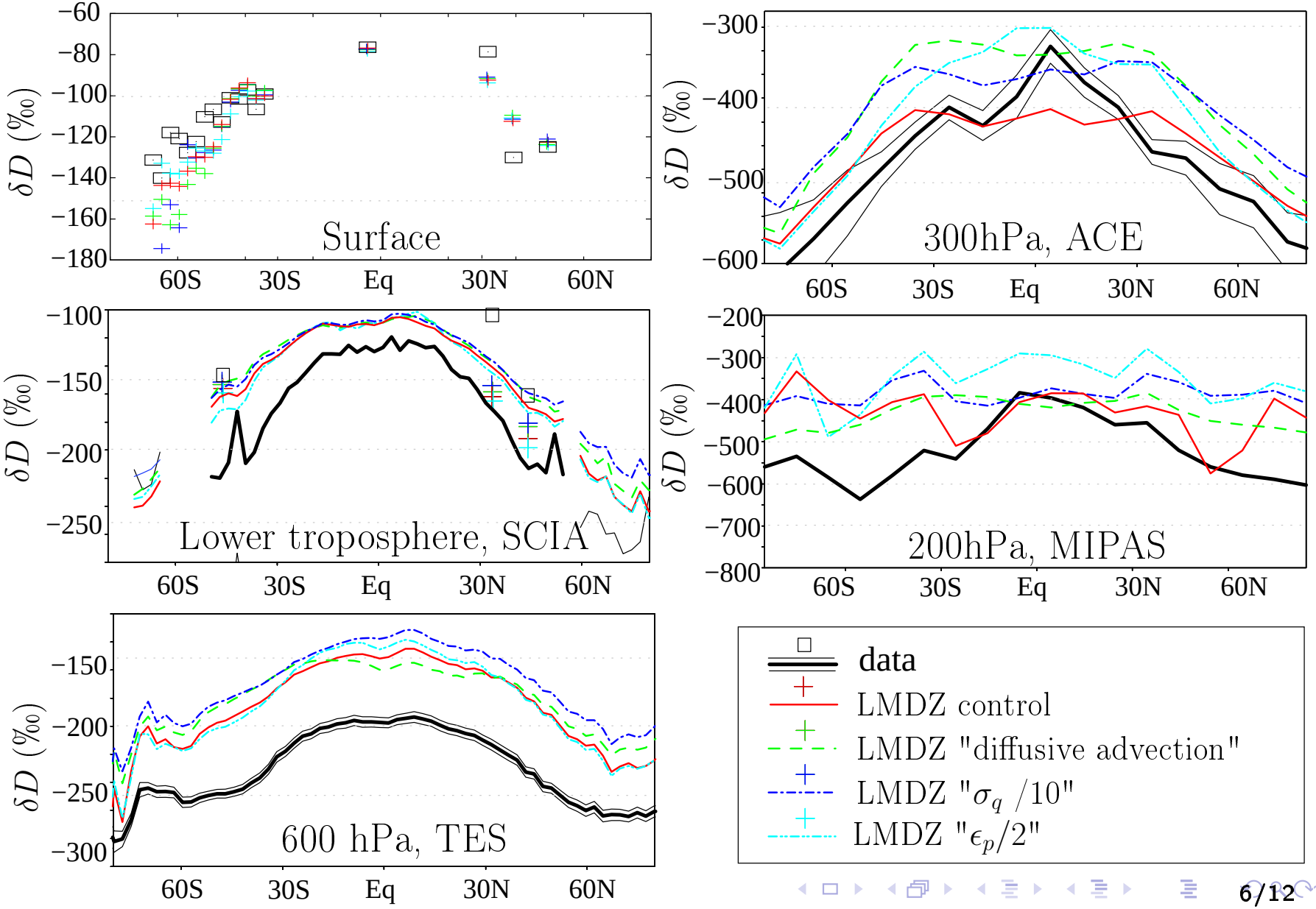
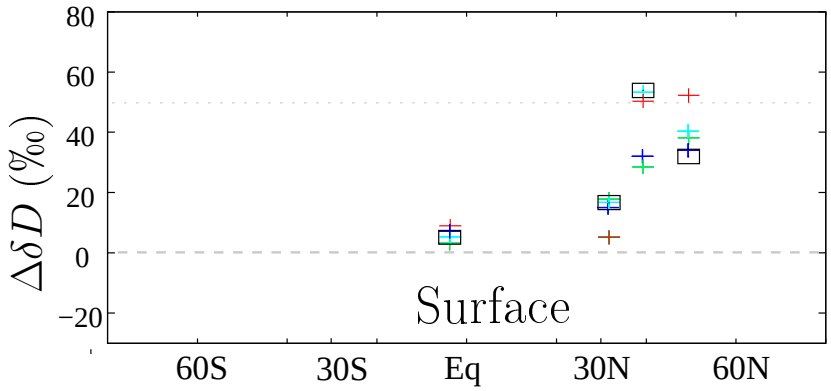


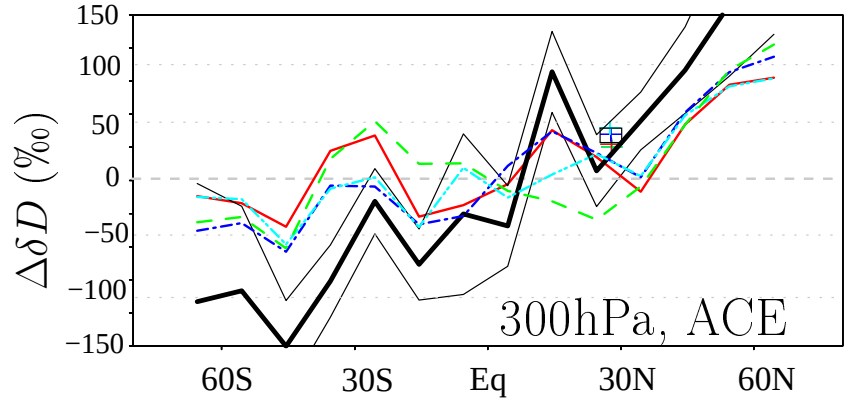
- model-data comparison: collocation; simulations nudged by ECMWF; averaging kernels

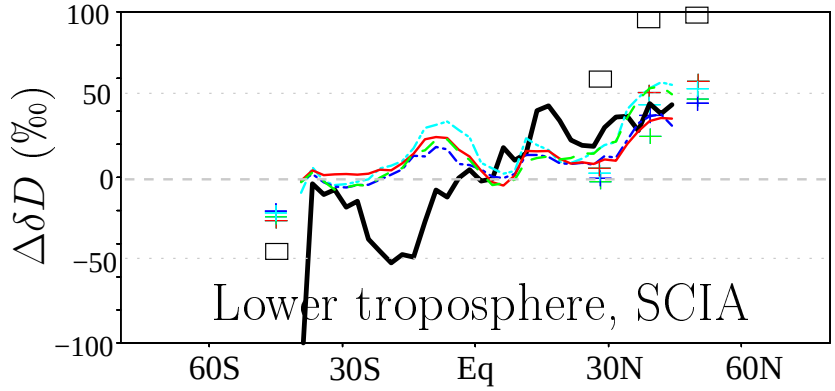
Multidataset evaluation: annual mean

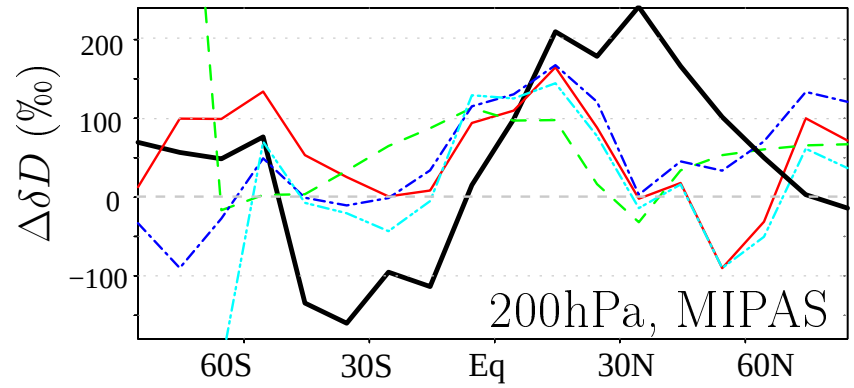


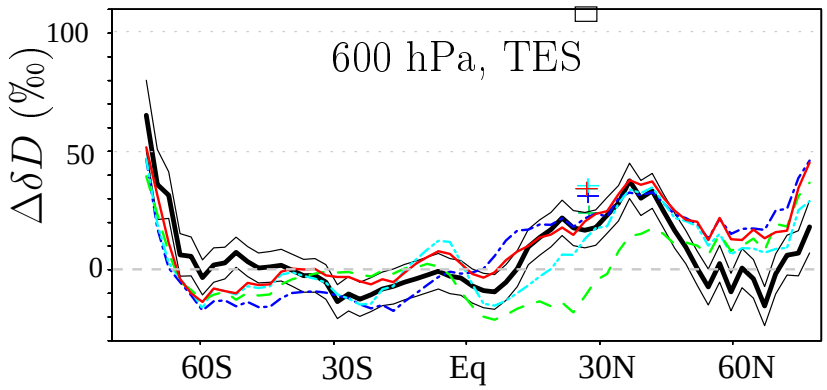
Multidataset evaluation: seasonal (JJA-DJF)

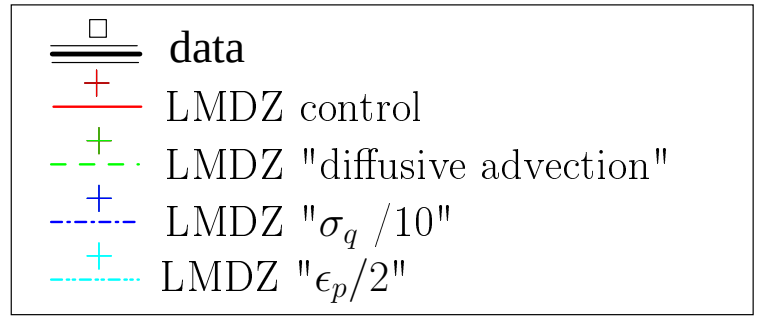




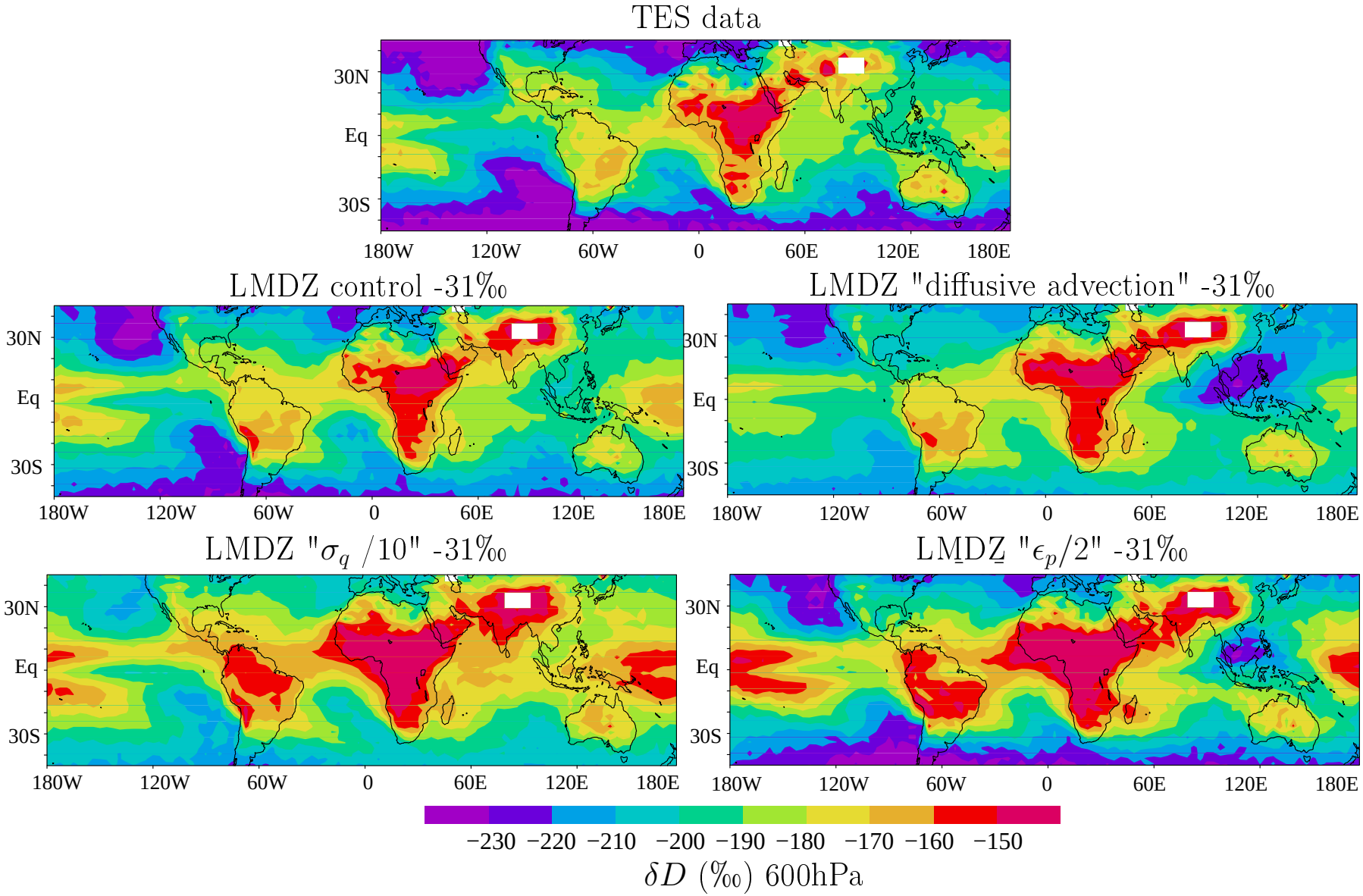








Annual mean δD in TES at 600hPa



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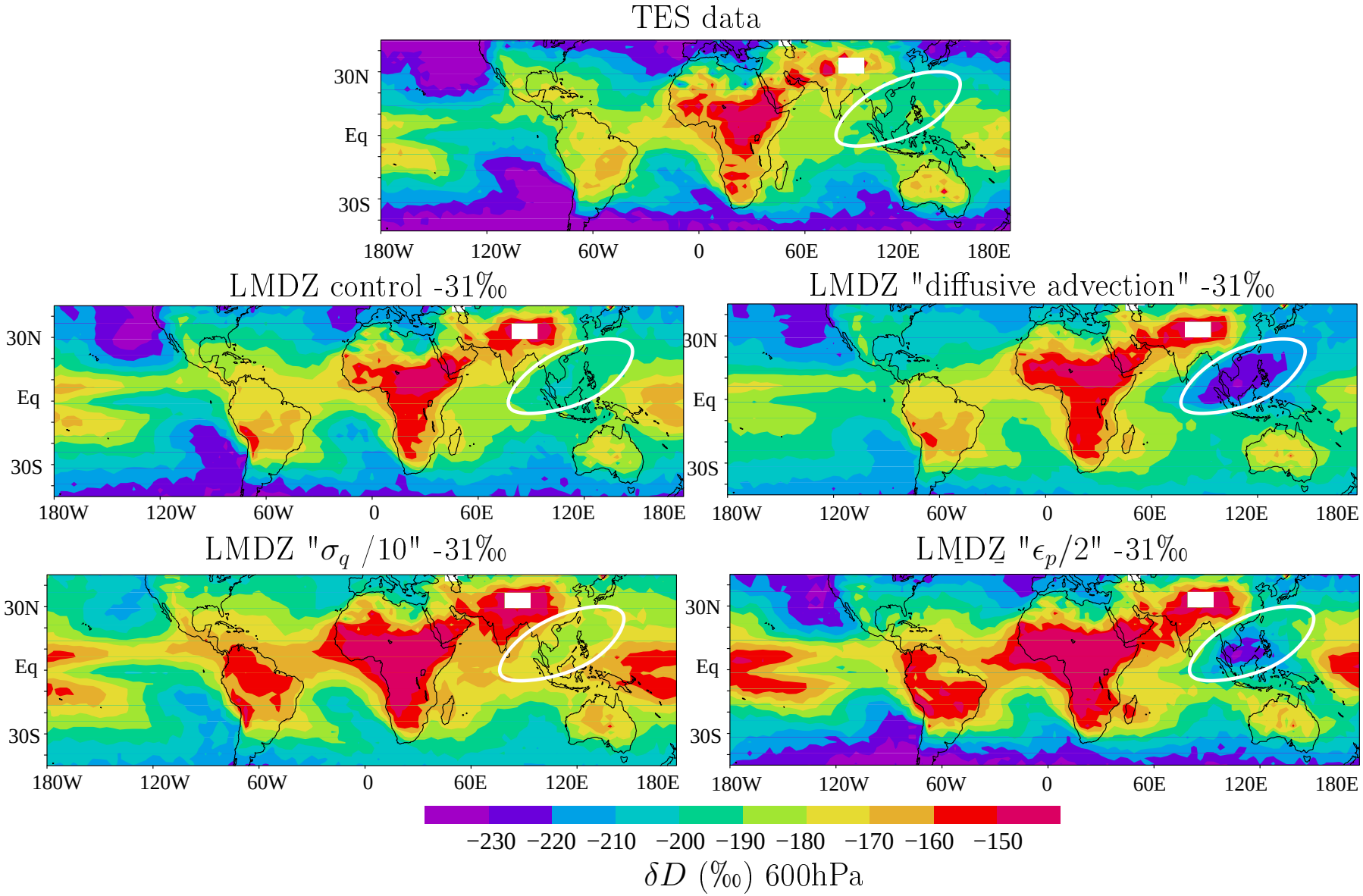

Summary: isotope diagnostics for moist bias

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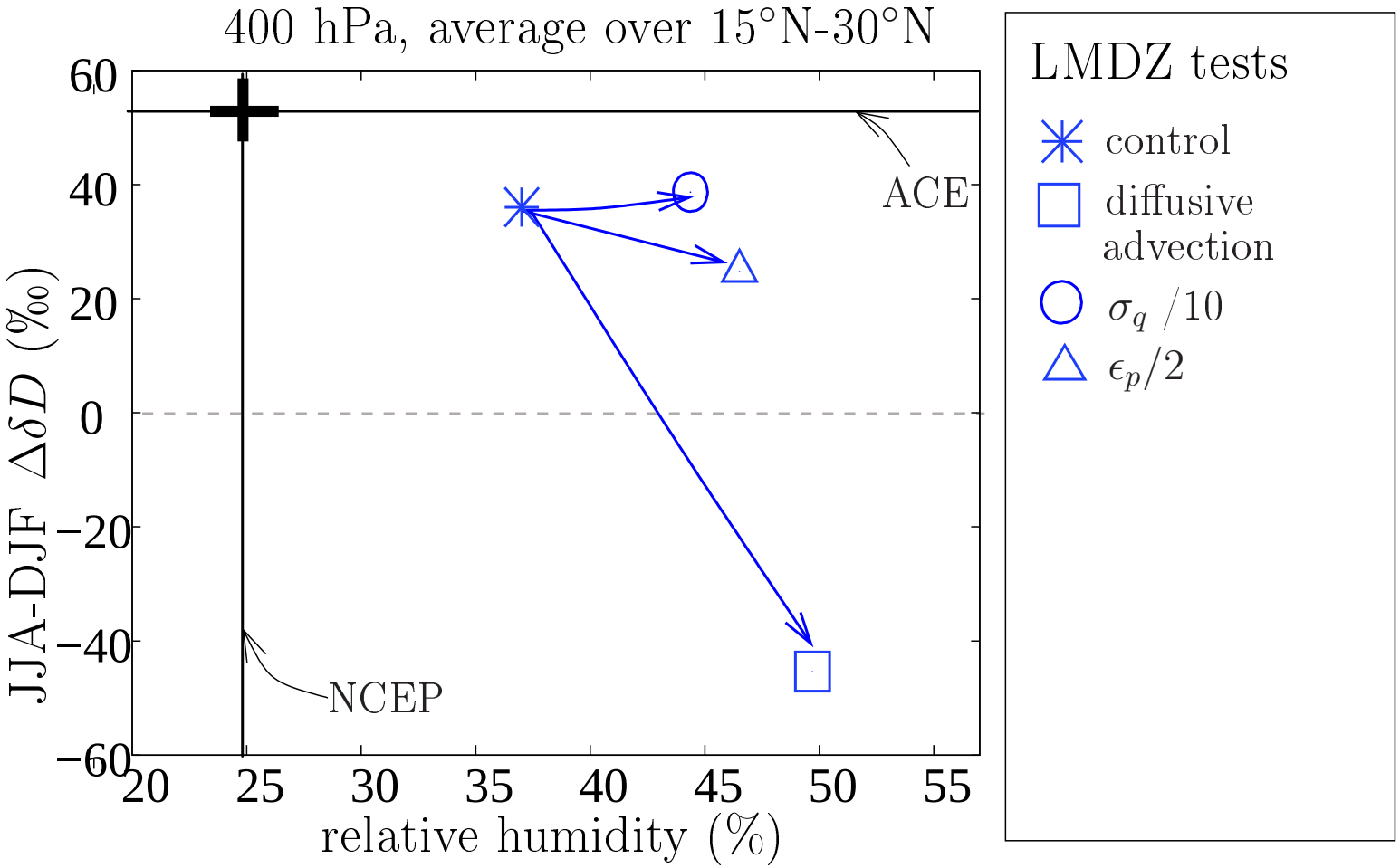
δD intra-seasonal variability in subtropics too low	subgrid-scale water vapor variability too low
δD is too high in upper troposphere	condensate detrainement too strong

What causes the moist bias in models?



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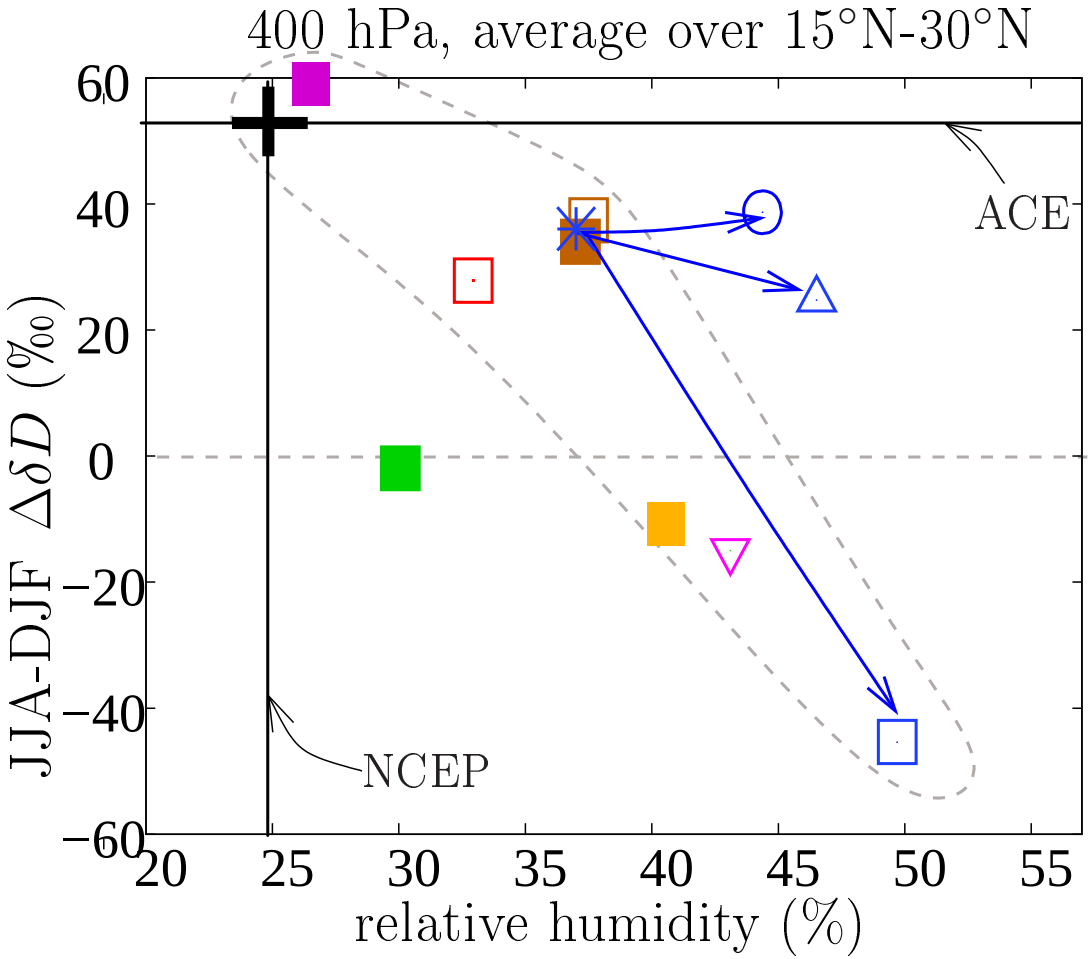

LMDZ tests

- control
- diffusive advection
- σ_q /10
- $\epsilon_p/2$

SWING2 GCMs

- ECHAM
- MIROC
- CAM2
- HadAM
- GSM
- GISS

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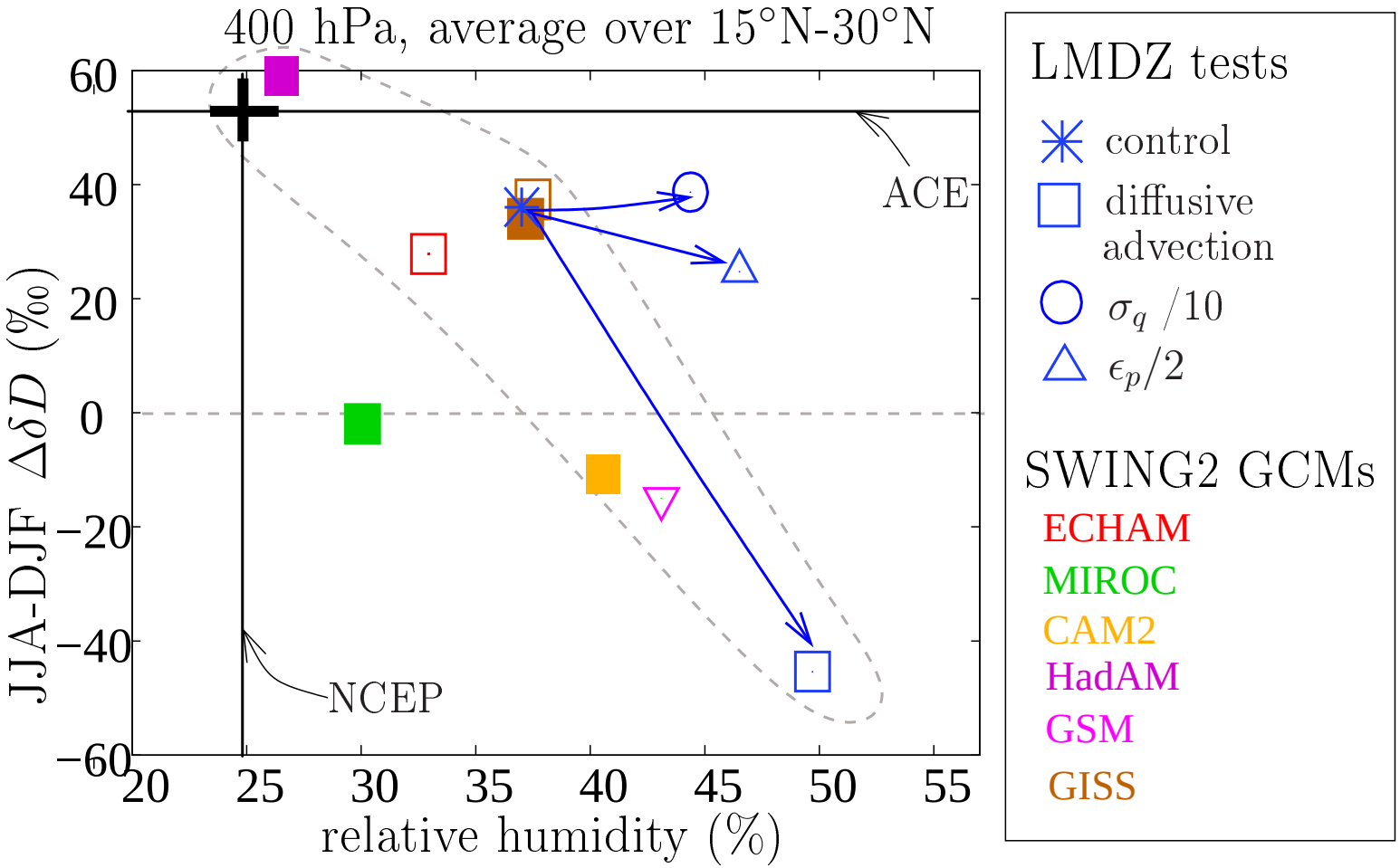
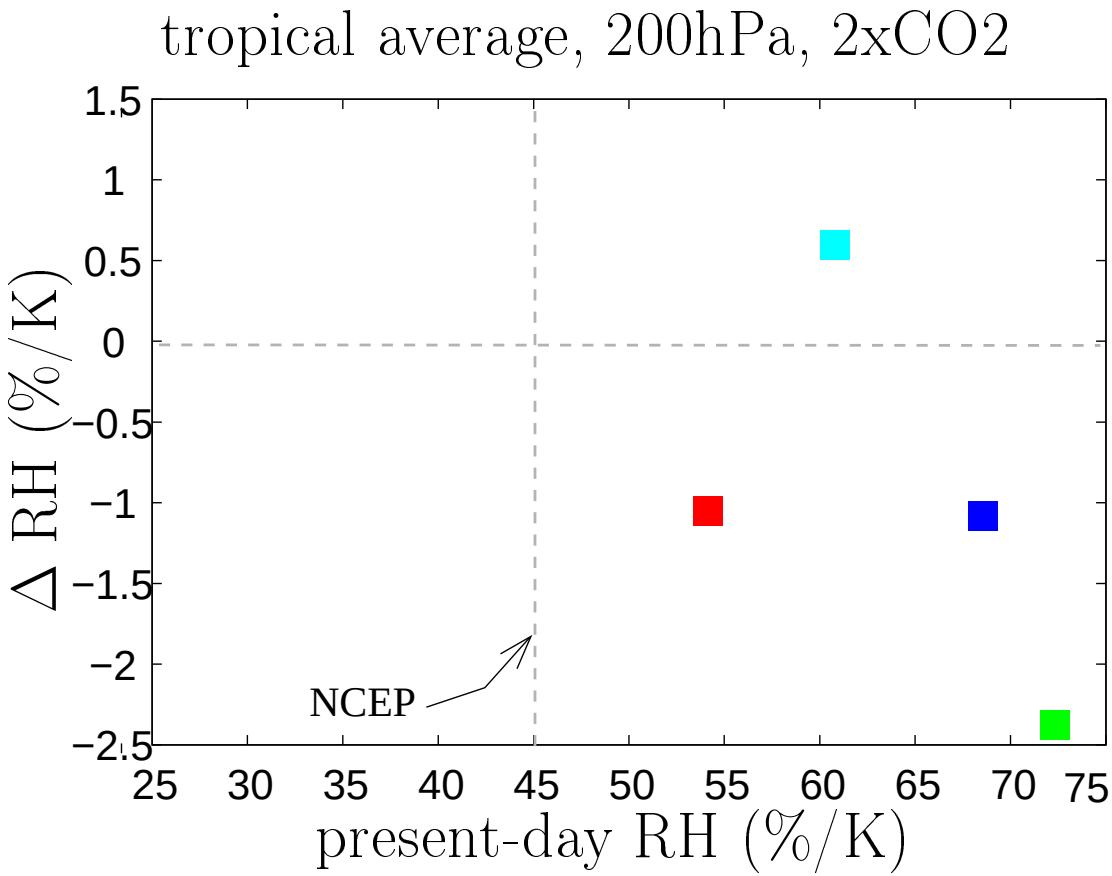


- excessive diffusion during water vapor transport is a widespread cause of moist bias in atmospheric models

What impact on humidity projections?



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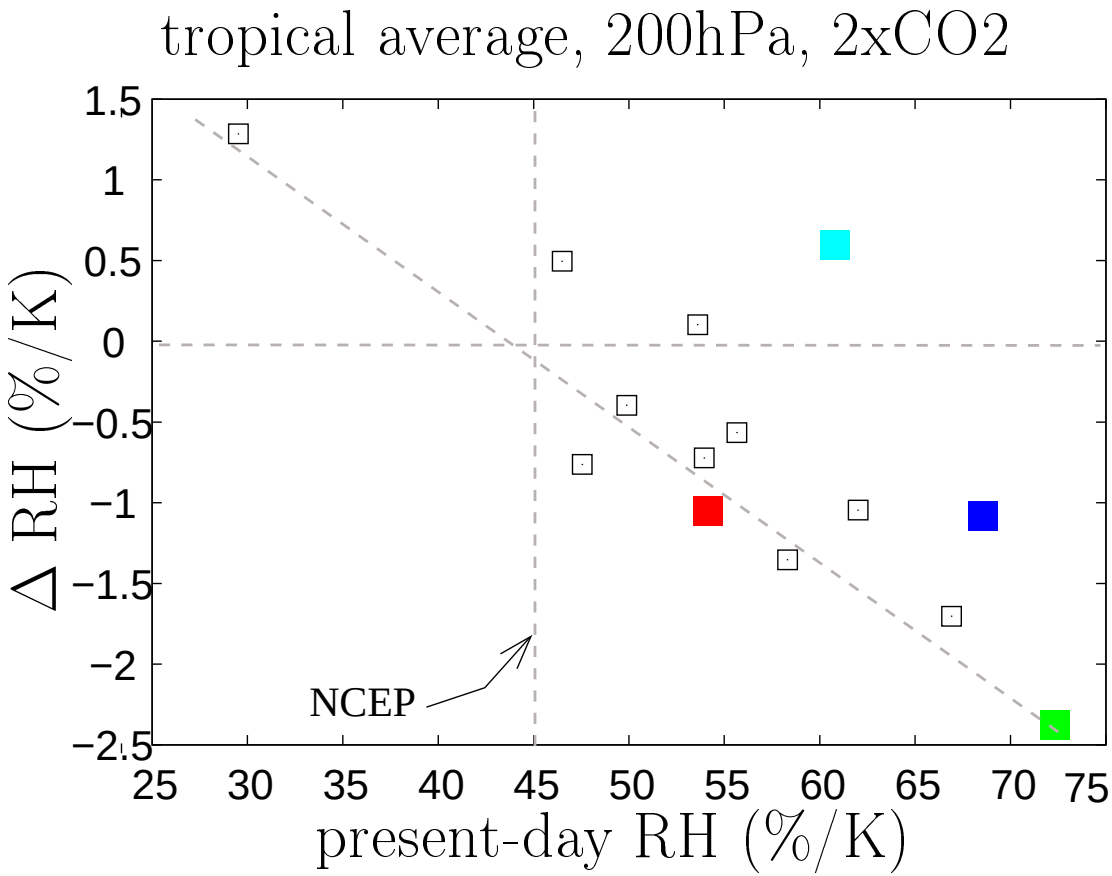

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CMIP3 models

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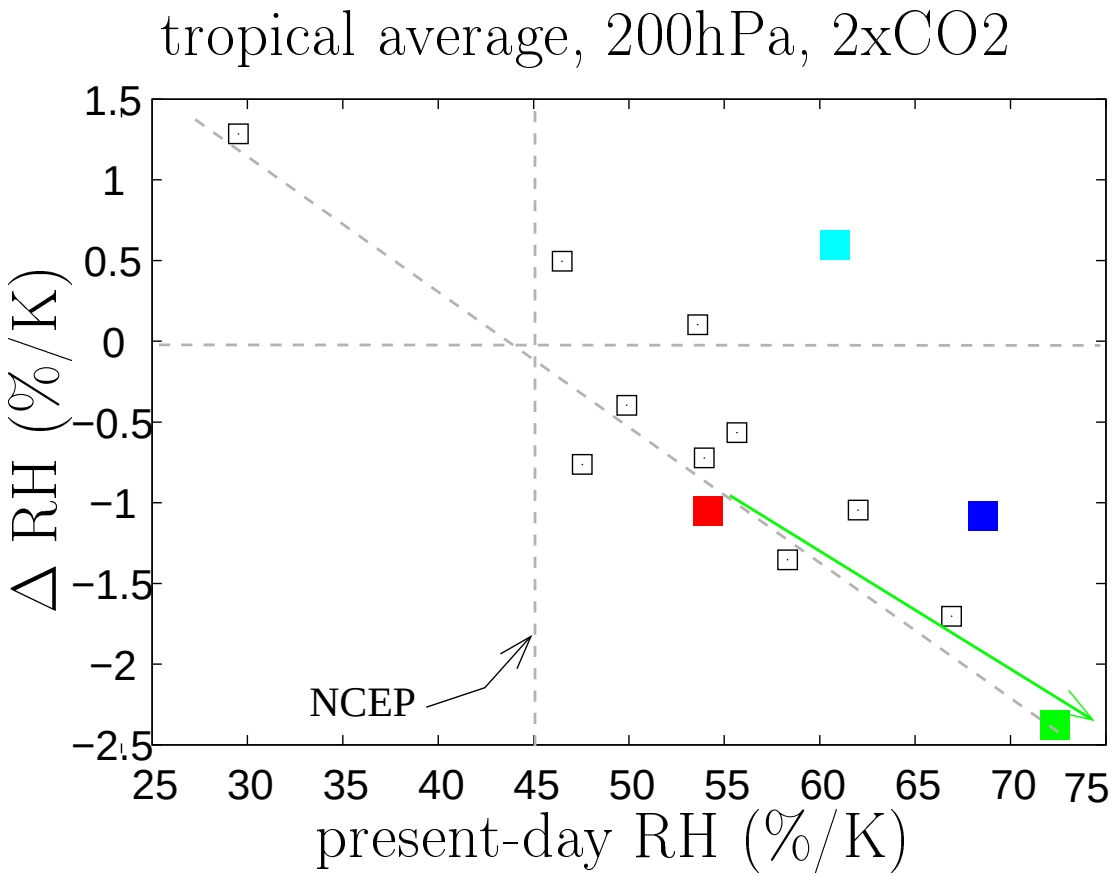

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CMIP3 models

Theoretical framework

diffusion ↗

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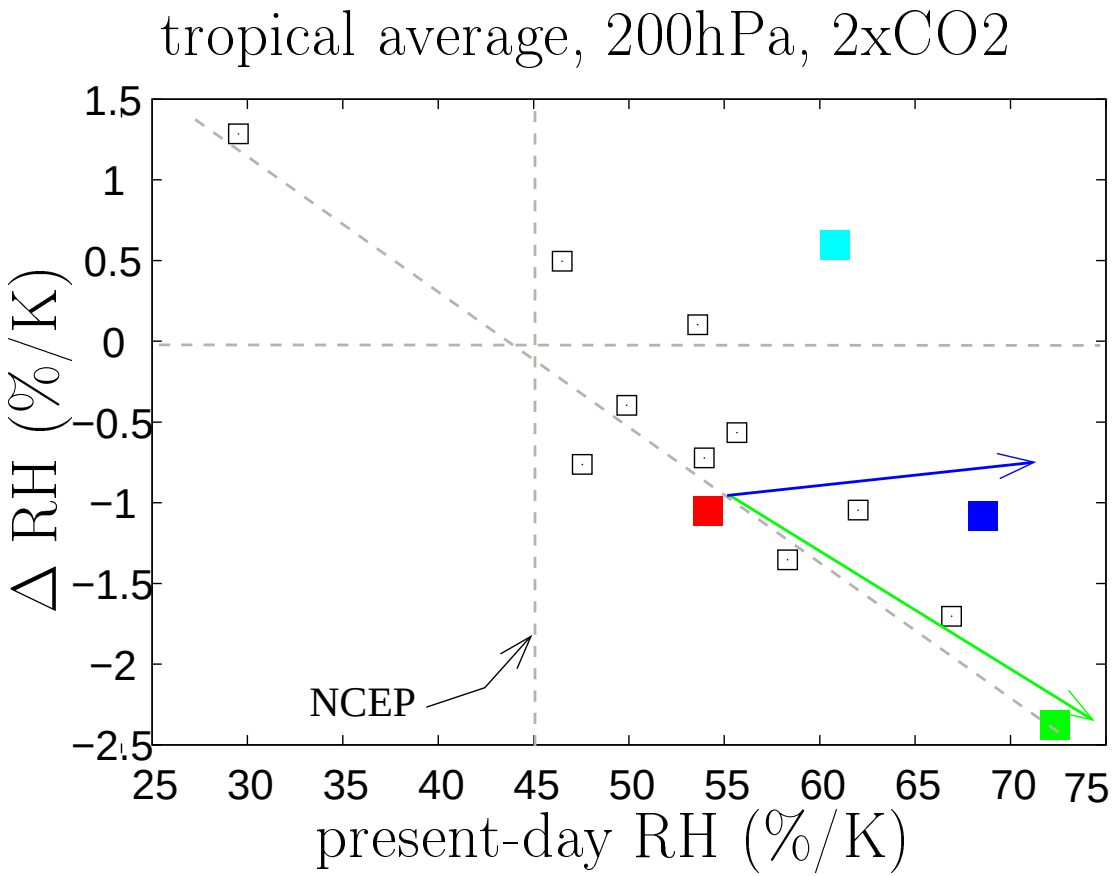

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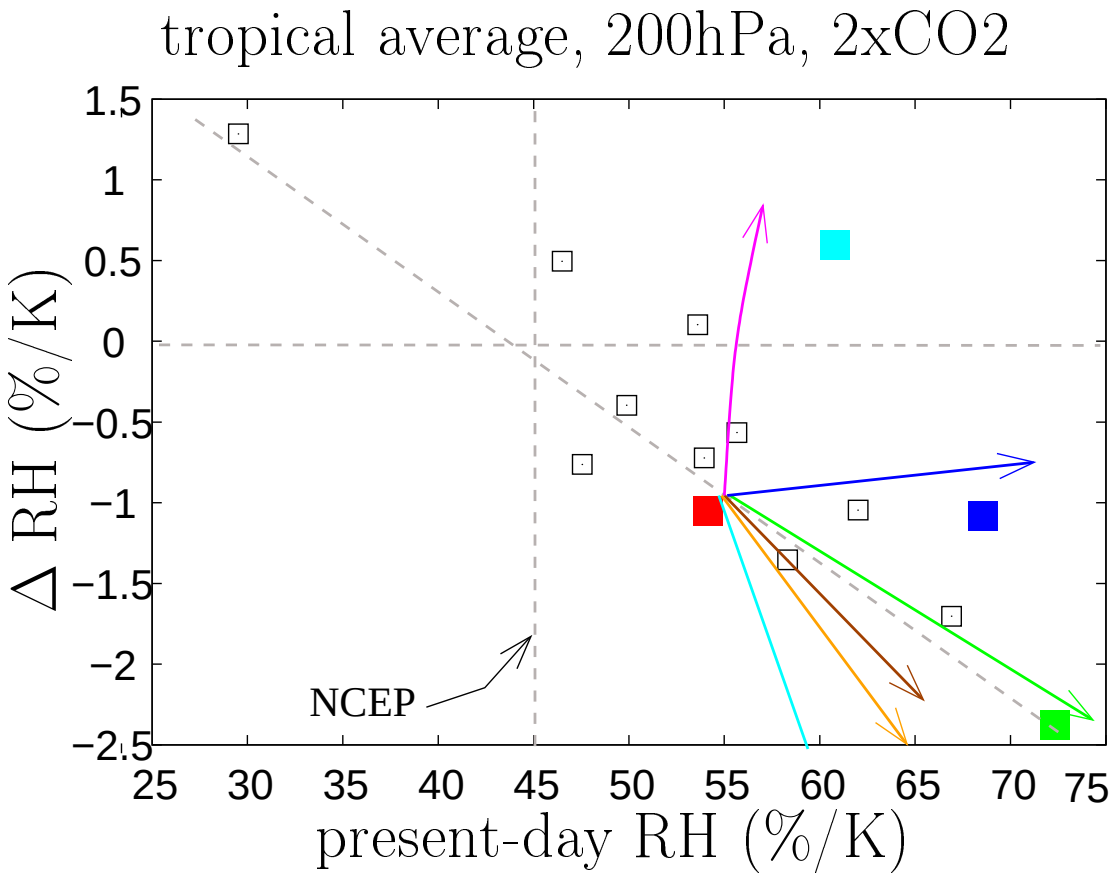

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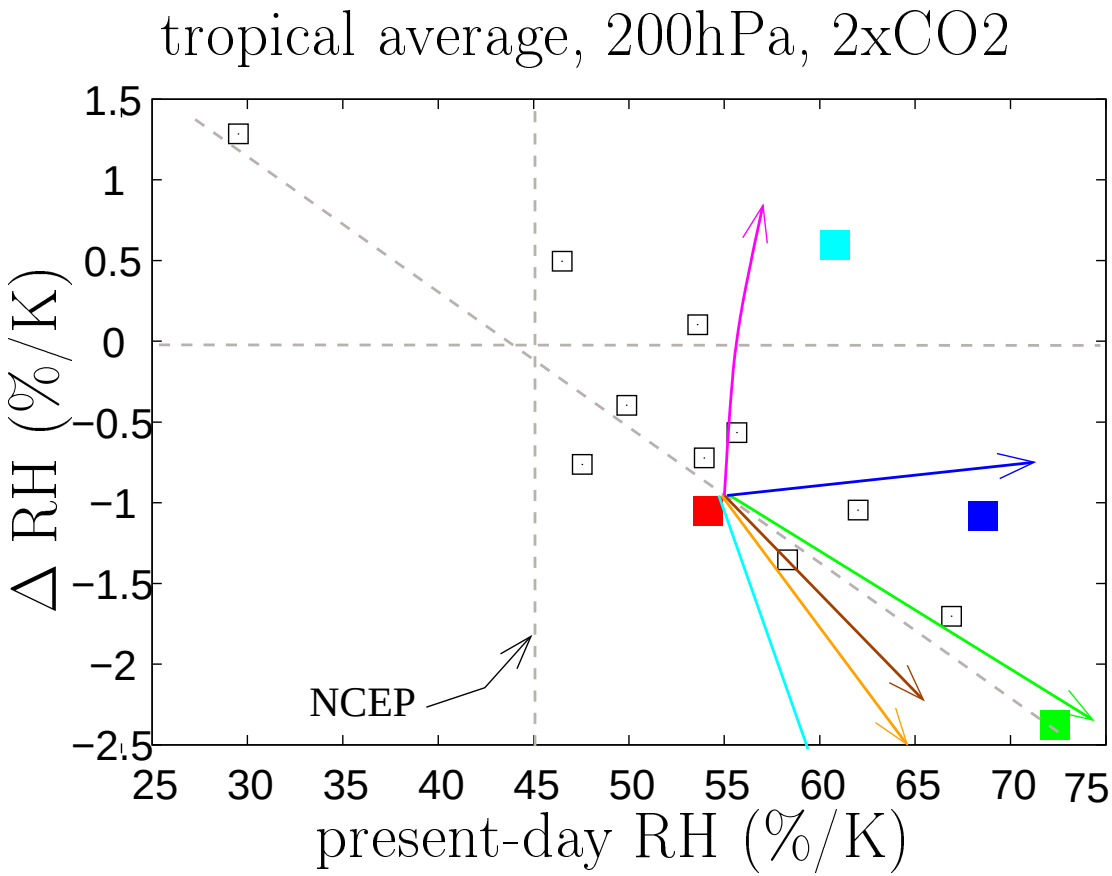

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- How a moist bias affect humidity change projections depends on the reason for the bias

Conclusion and perspectives

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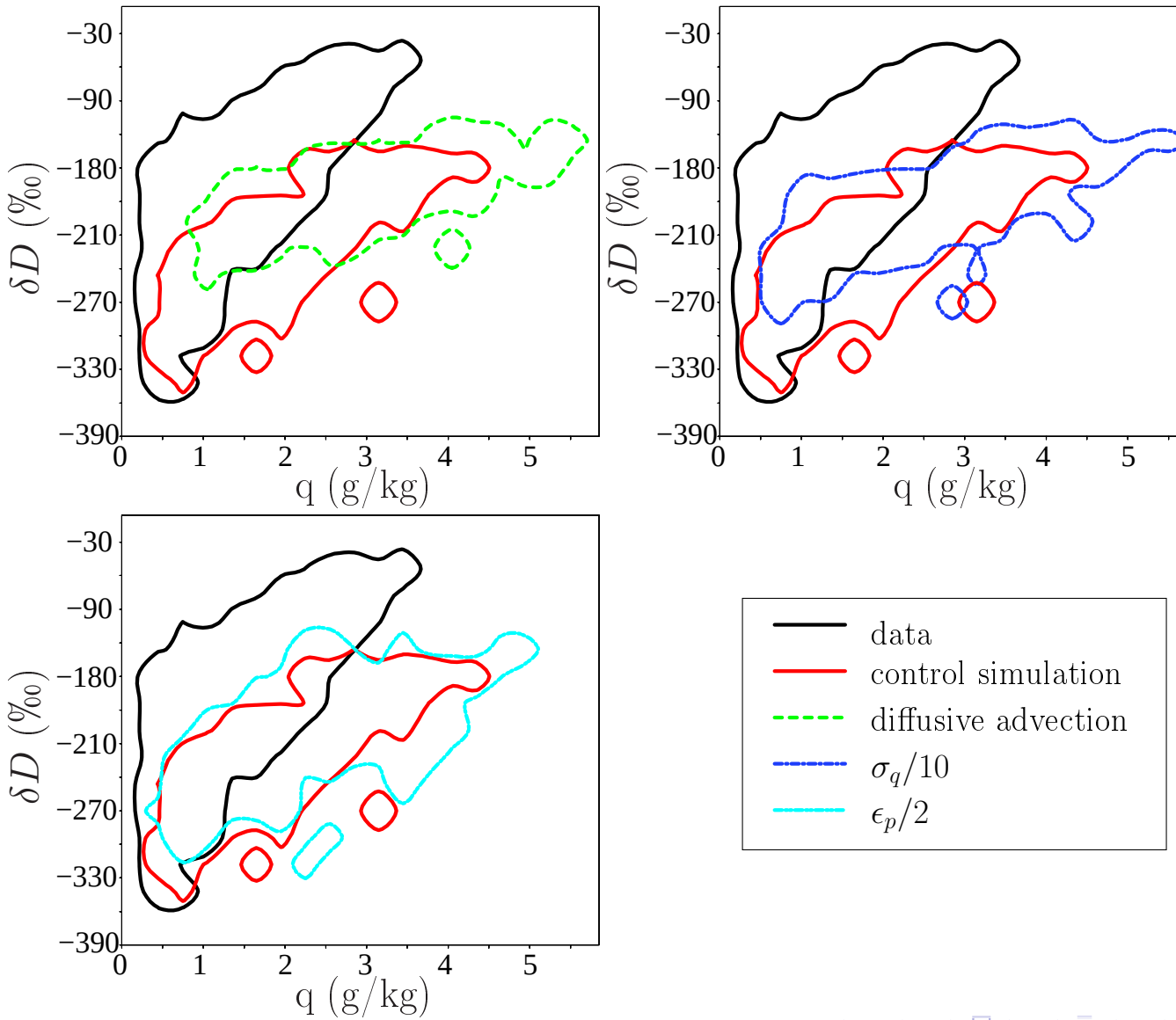
  - Water isotopes in CMIP?

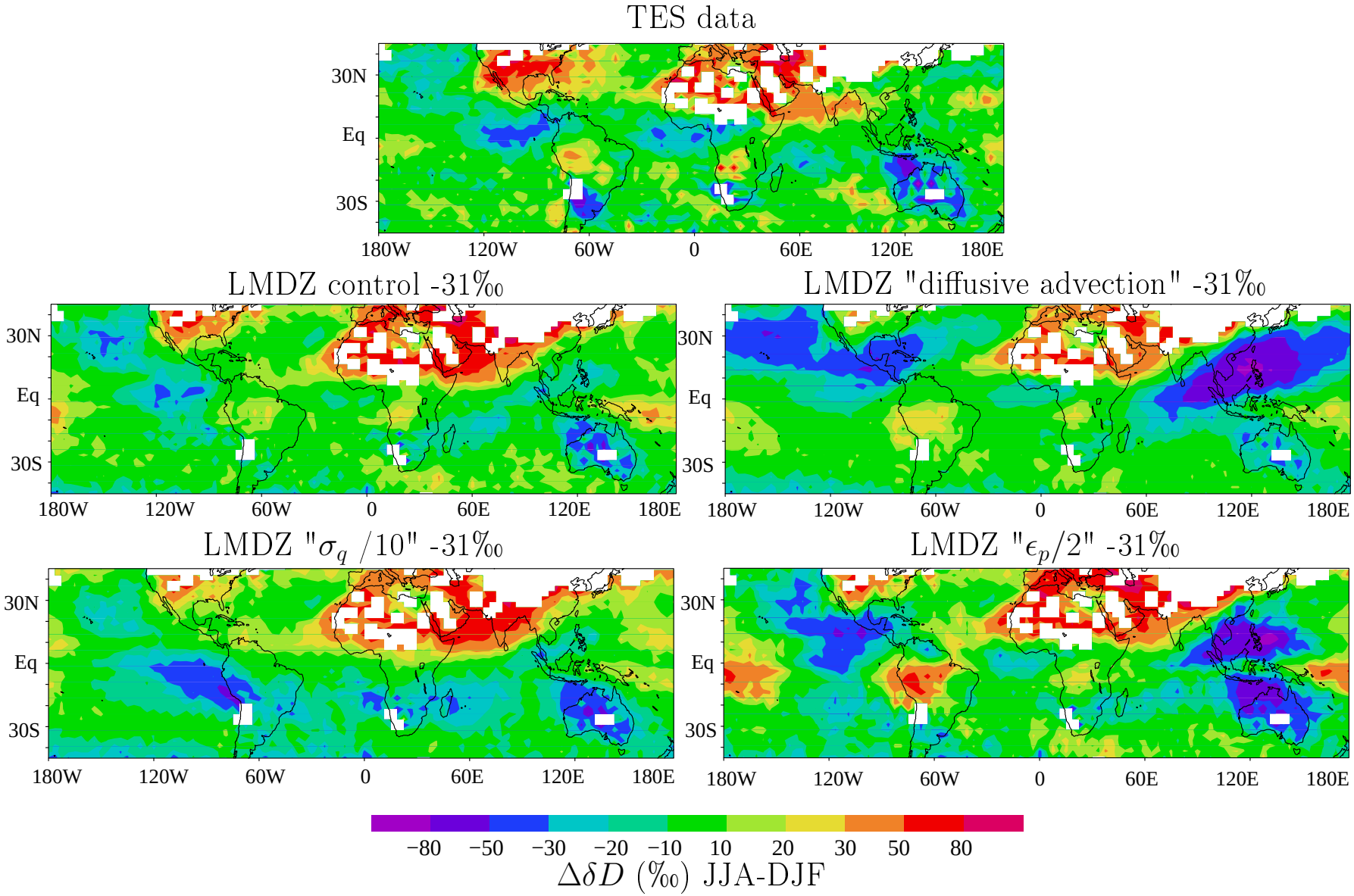
Supplementary material

Dehydration pathways to the subtropics

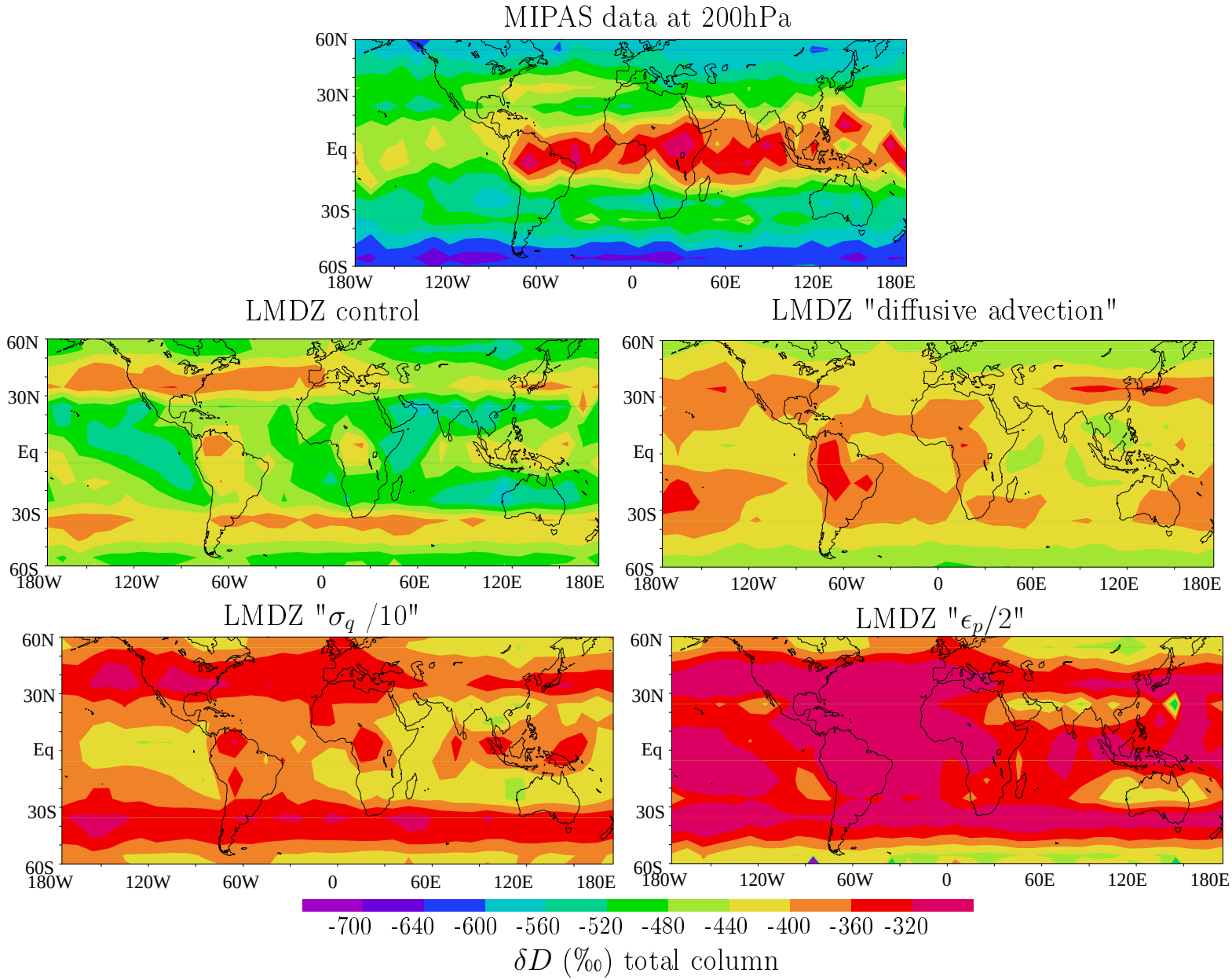
- Daily ground-based FTIR data at Izana at 4.2km over 5 years



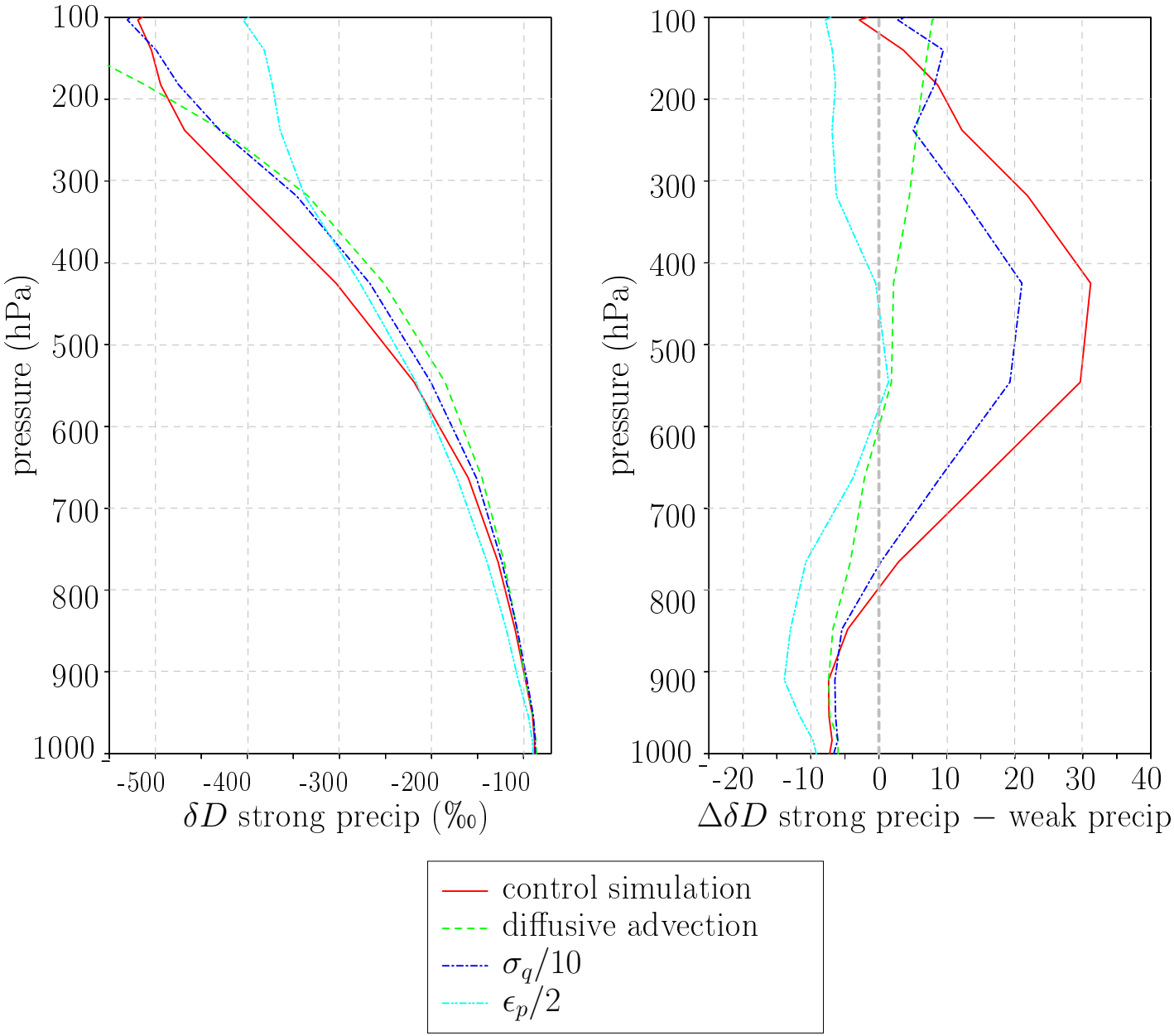
Seasonal variations in TES



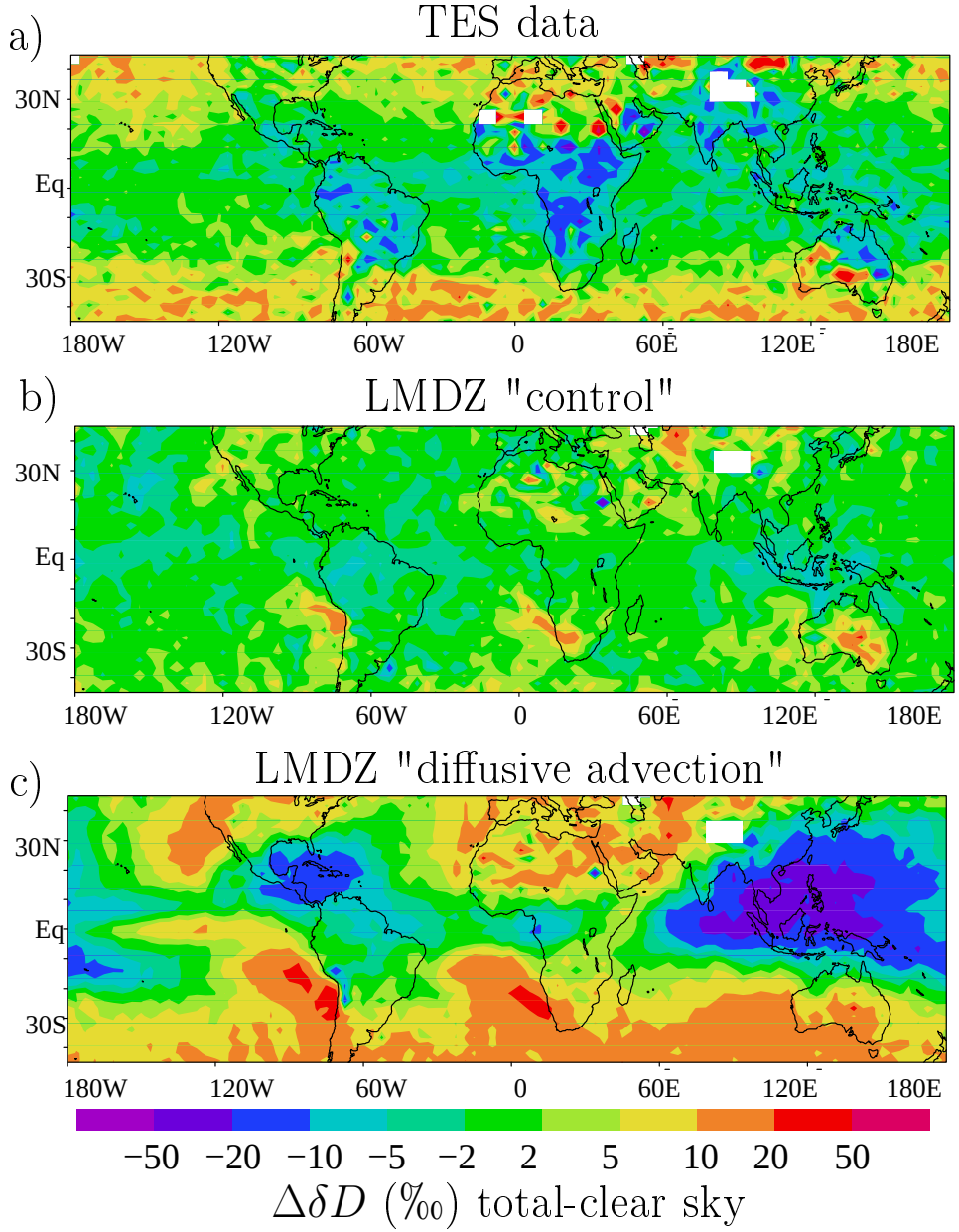
Annual mean in MIPAS



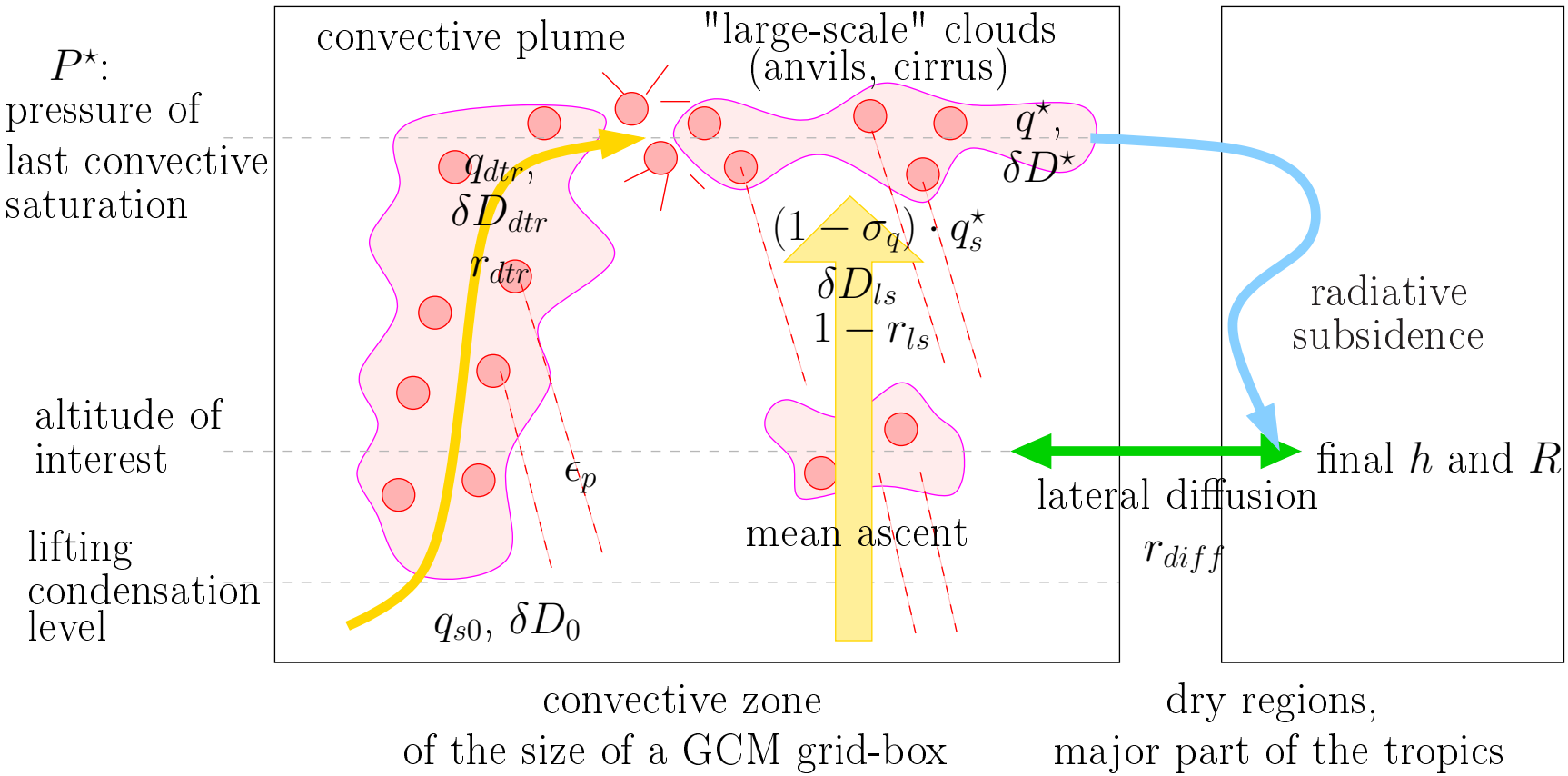
Effect of convection on isotopic profiles



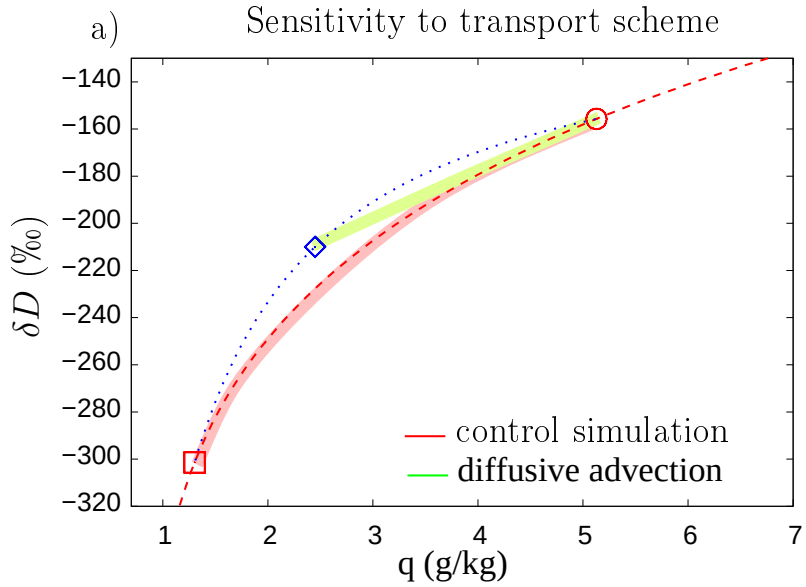
Evaluation of the link δD-cloud cover in TES

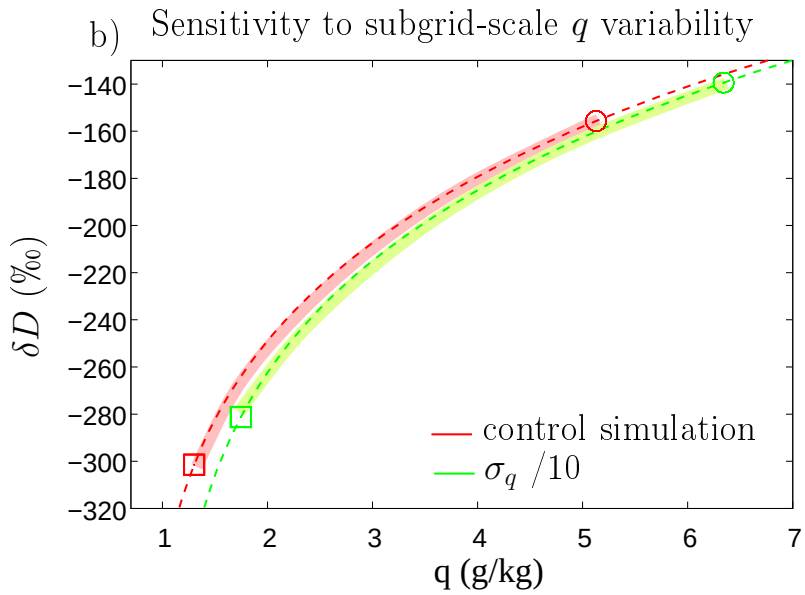


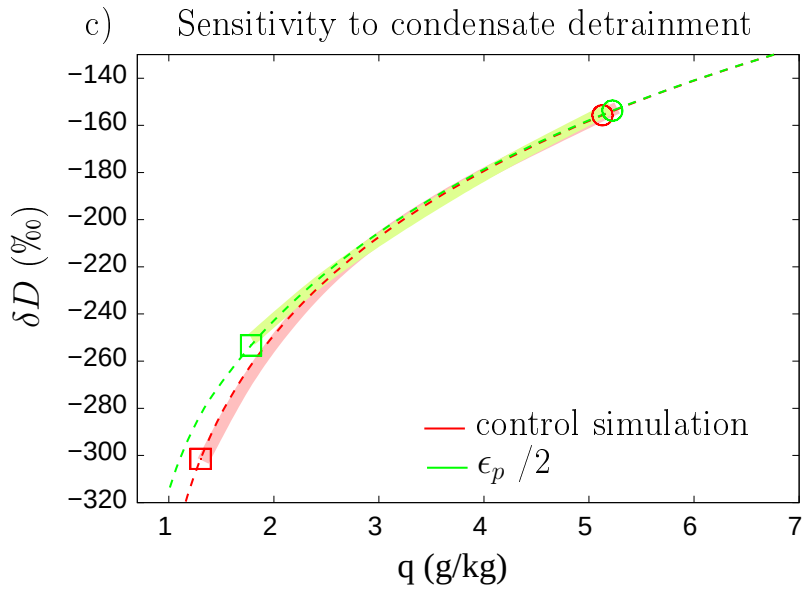
Theoretical framework



Interpretation of the sensitivity tests



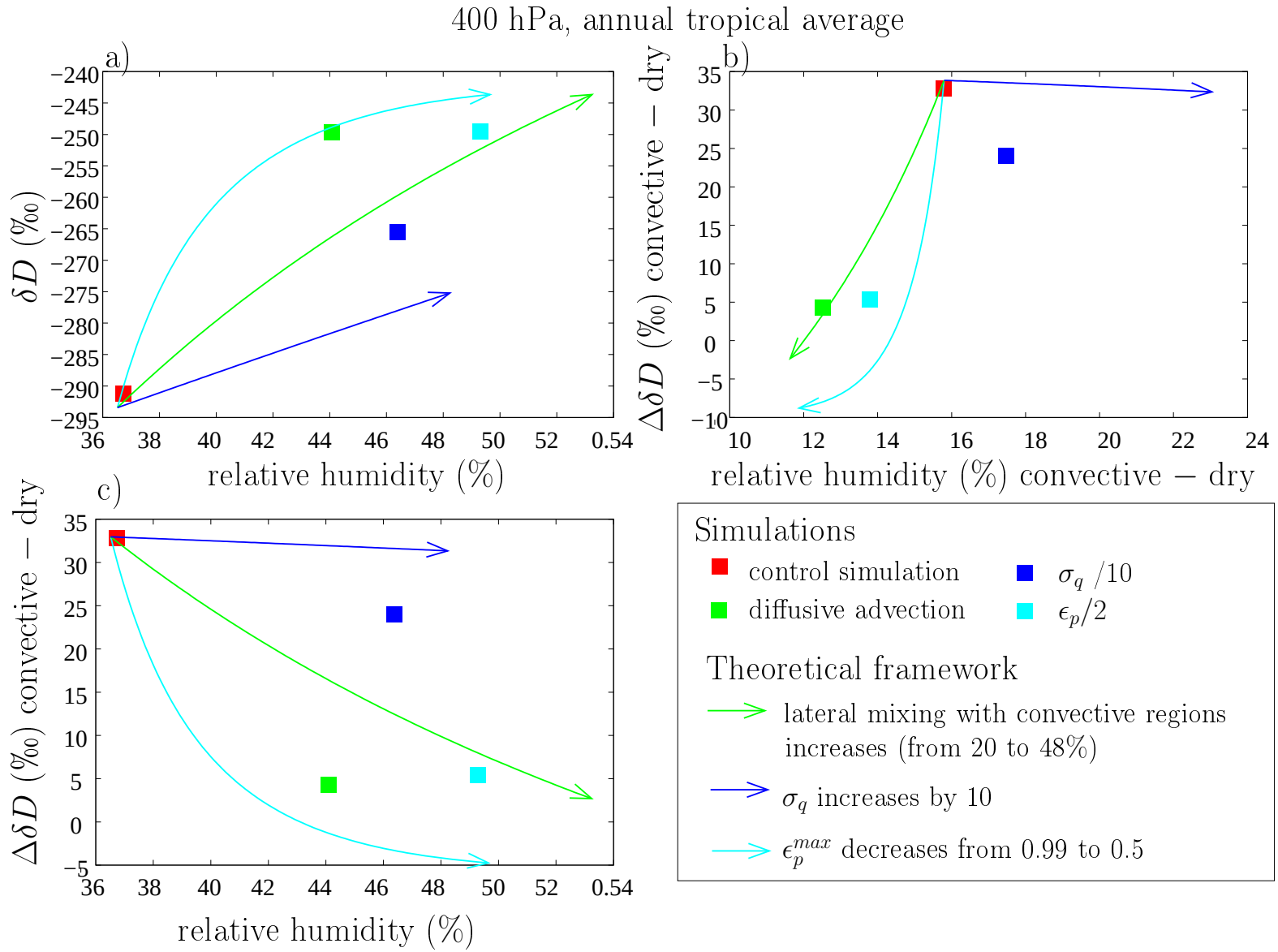




Symbols and line styles:

- convective region at 500hPa
- convective region profile
- air mass having last saturated at 290 hPa
- mixing line representing lateral diffusion
- mixture between dry and convective regions
- range of values at 500hPa across different dynamical contexts

Validation of the theoretical framework



Uncertainty due to parameterizations vs large-scale circulation