The added value of water isotopic measurements to evaluate land surface processes in climate models

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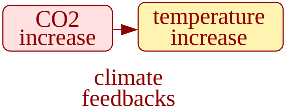
with the contribution of: T. Bariac, S. Bony, C. Frankenberg, D. Noone, J. Ogée, N. Raz-Yaseef, J. Welker, J. Worden, L. Wingate

NEON, 22 April 2011

Uncertainties in hydrological projections



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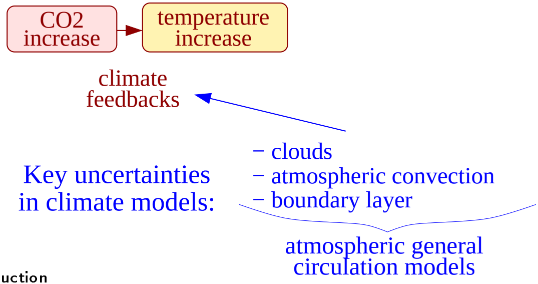

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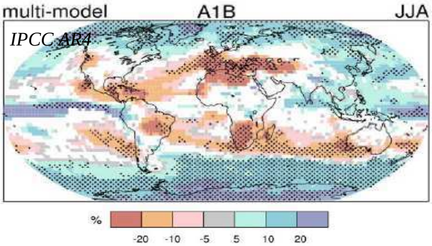


precipitation change by 2100 (%)

☐ <2/3 agree on sign

CO_2 increase → temperature increase → regional precipitation changes

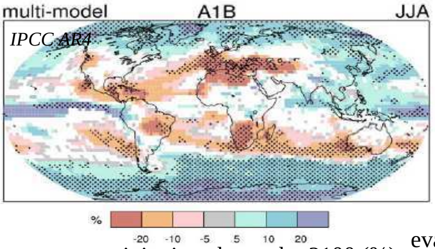
climate feedbacks

Key uncertainties in climate models:

− clouds
− atmospheric convection
− boundary layer

atmospheric general circulation models

Uncertainties in hydrological projections



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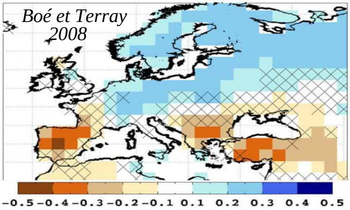

evapo−transpiration change by 2100 (mm/d)
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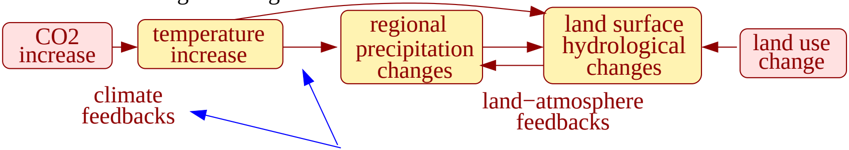

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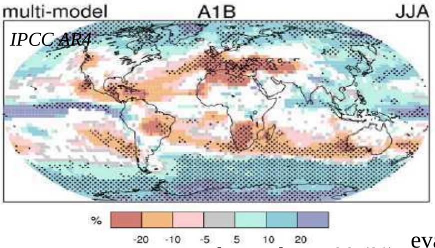

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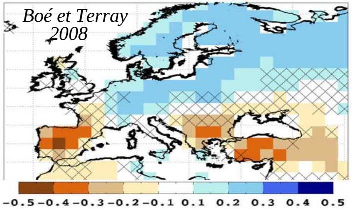

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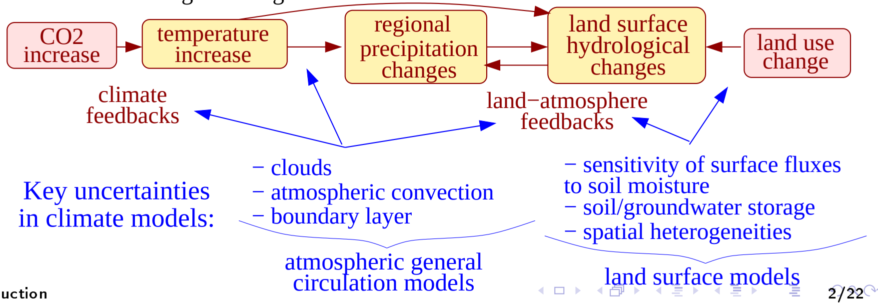
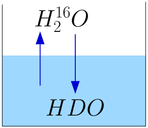


Water stable isotopes

- $H_2^{16}O$, HDO, $H_2^{18}O$, $H_2^{17}O$, fractionation
- records phase changes



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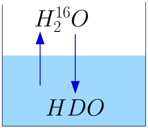
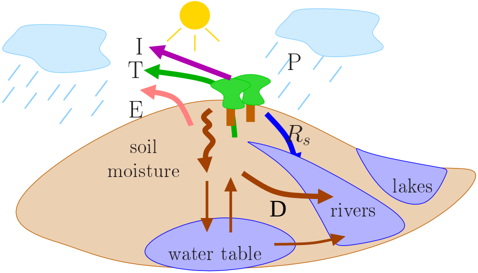


- isotopes to estimate budgets and study processes in nature



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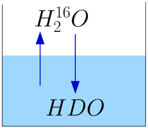
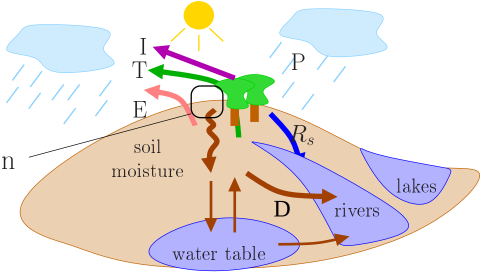


- isotopes to estimate budgets and study processes in nature

local partitioning
of evapo-transpiration
e.g. Moreira et al 1997



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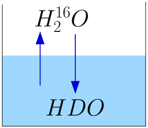

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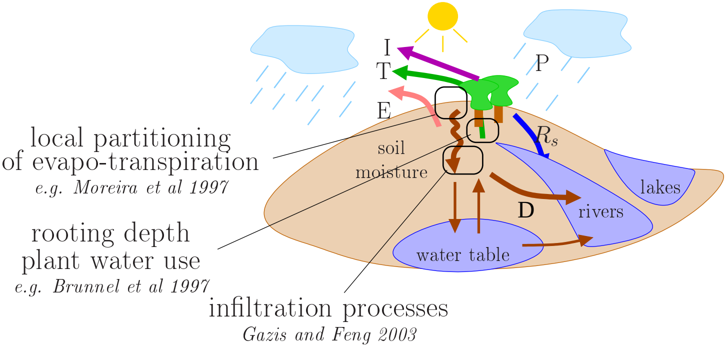

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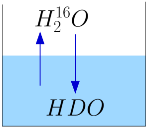

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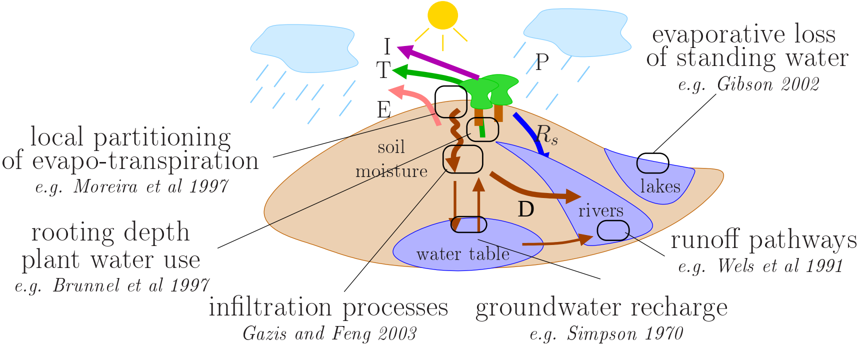

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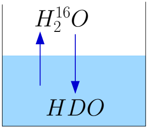

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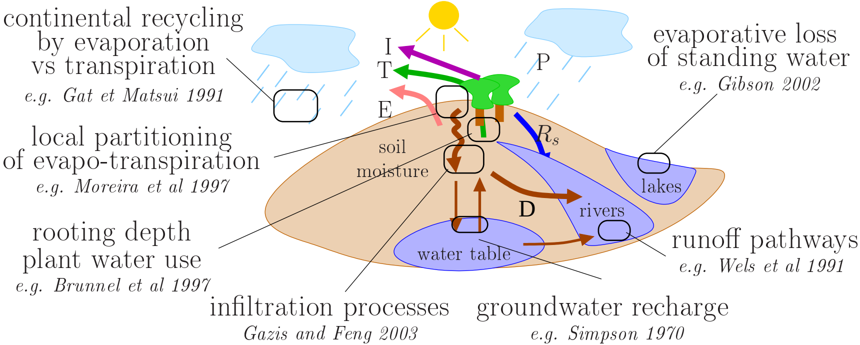

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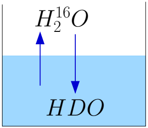

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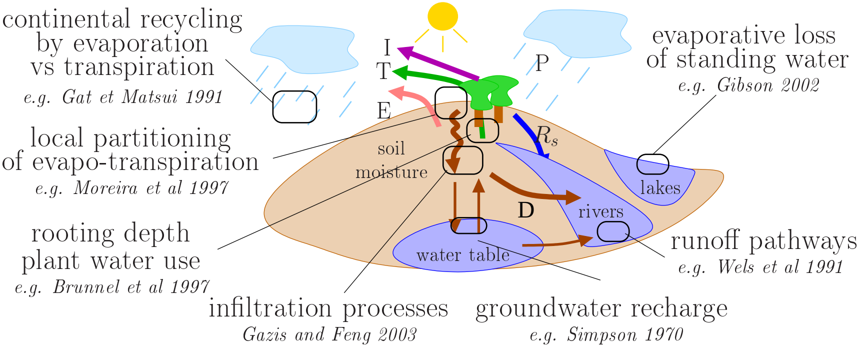
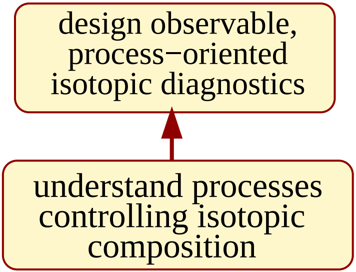


- to evaluate land surface models? *(e.g. Henderson-Sellers et al 2006)*

General strategy

understand processes controlling isotopic composition

General strategy



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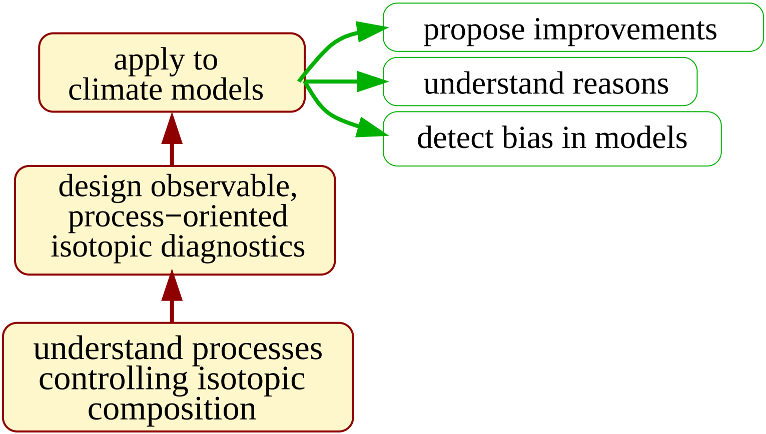

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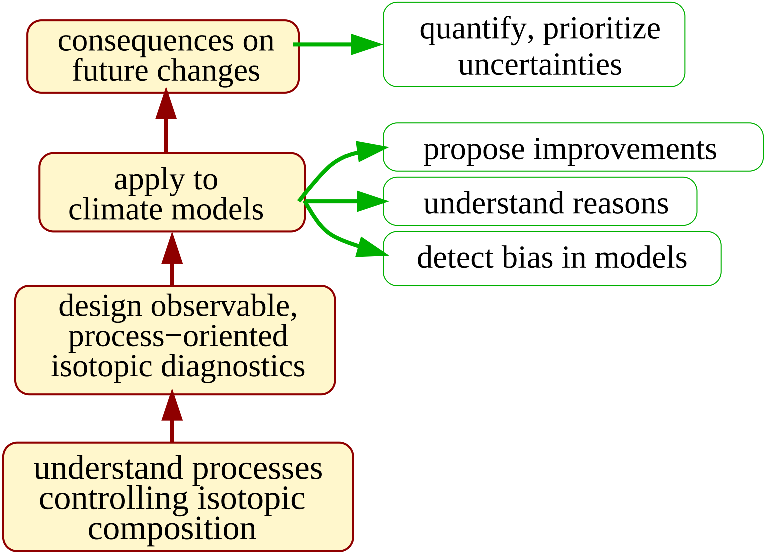
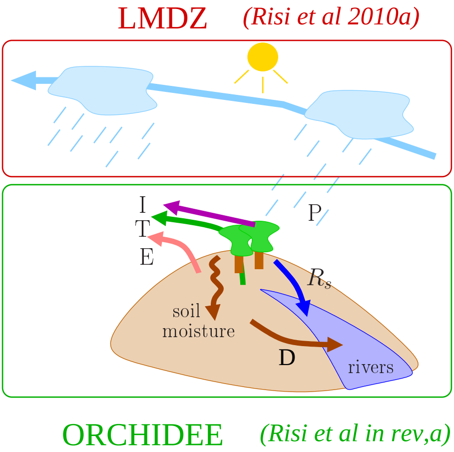


Isotopic models



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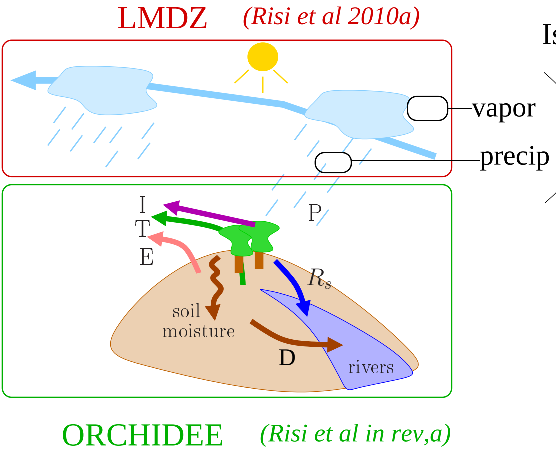
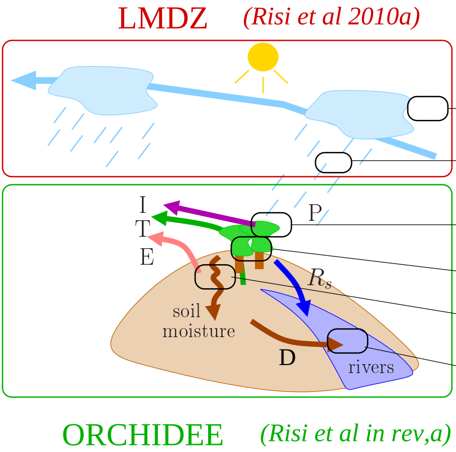


Isotopic data needed:

to evaluate LMDZ
or force ORCHIDEE

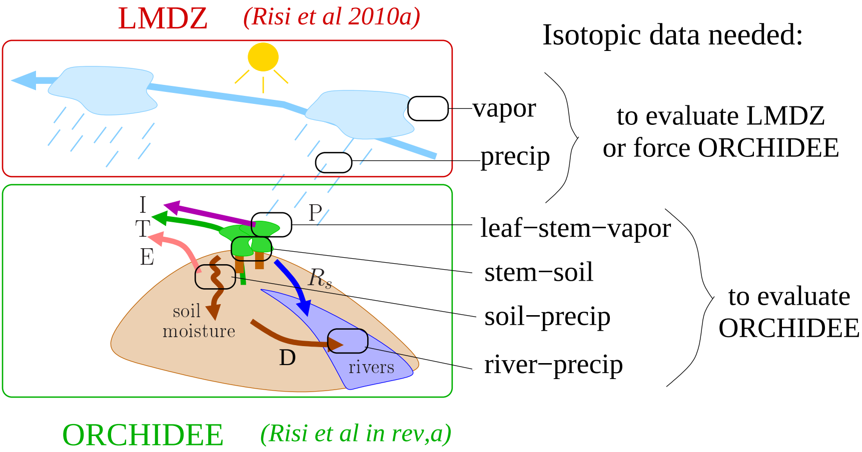
Isotopic models



Isotopic data needed:

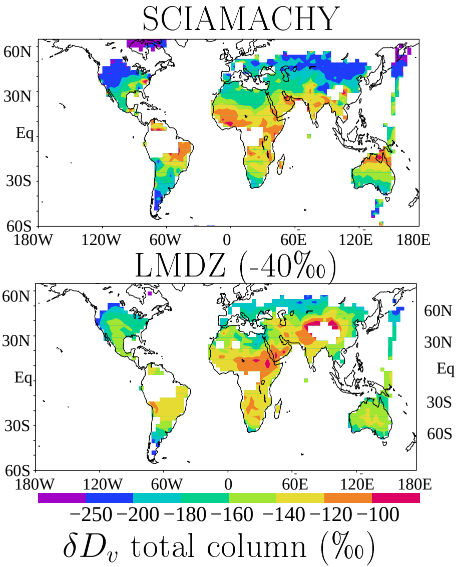
- vapor, precip: to evaluate LMDZ or force ORCHIDEE
- leaf−stem−vapor, stem−soil, soil−precip, river−precip: to evaluate ORCHIDEE

Isotopic models



⇒ need collocated measurements in different reservoirs at each site

Vapor and precipitation isotopes



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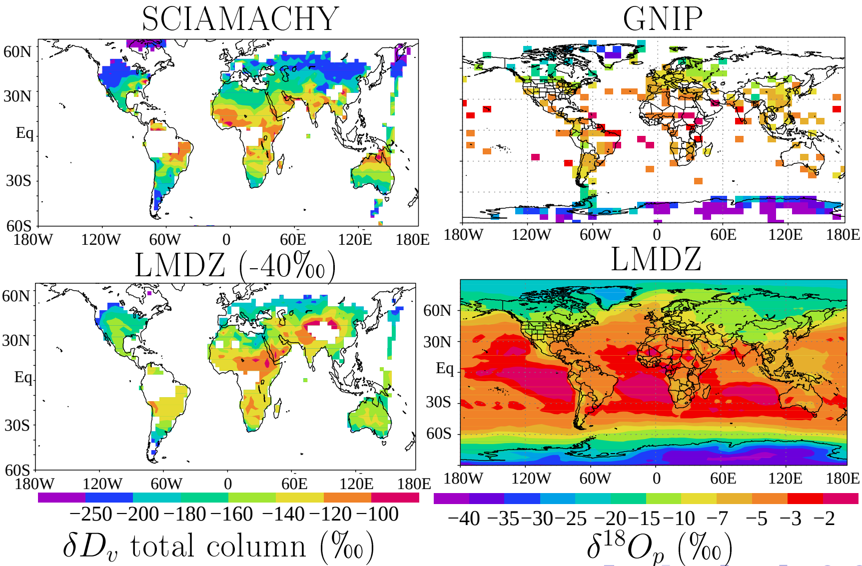
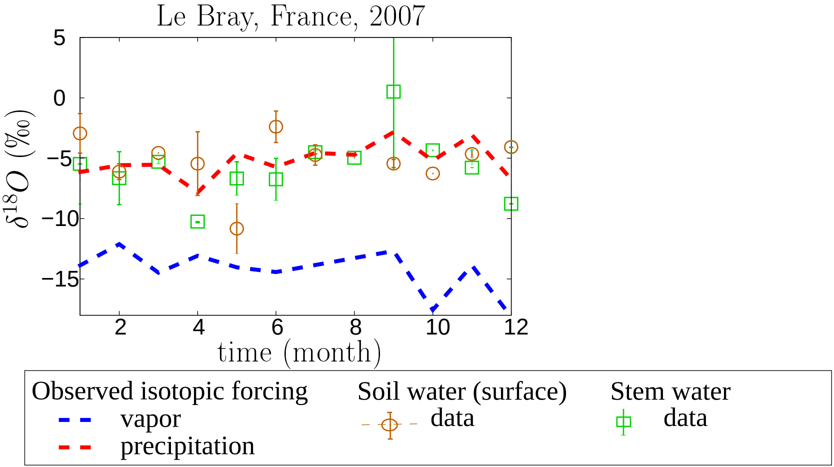


Soil water and biosphere isotopes

- 2 MIBA sites: Yatir (Israel, *Raz-Yaseef et al 2009*) and Le Bray (France, *Wingate et al 2009*, shown here)



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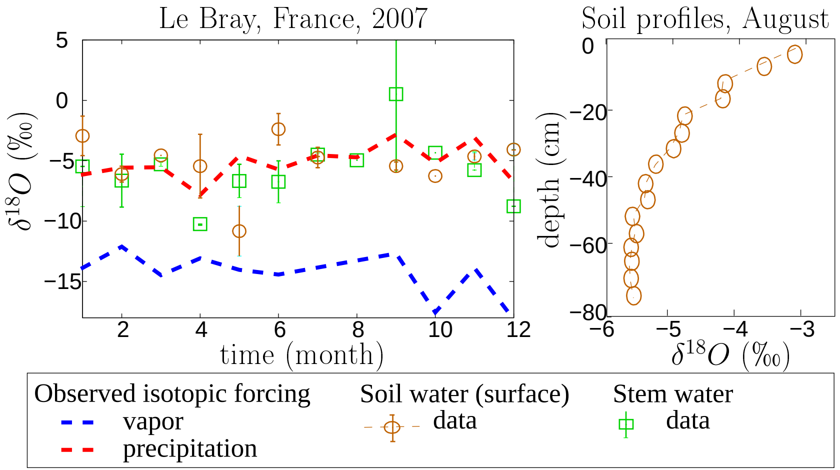

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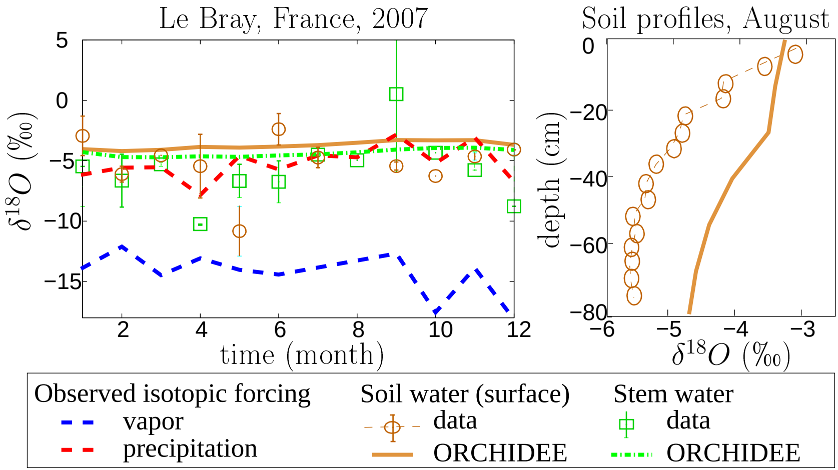

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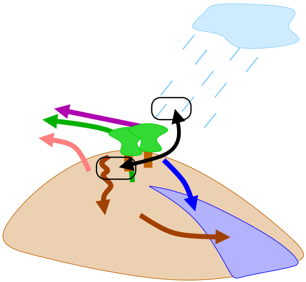
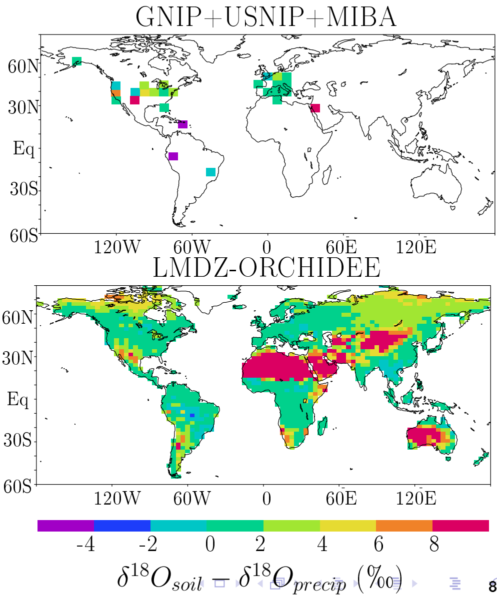
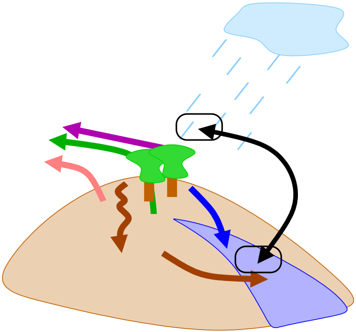
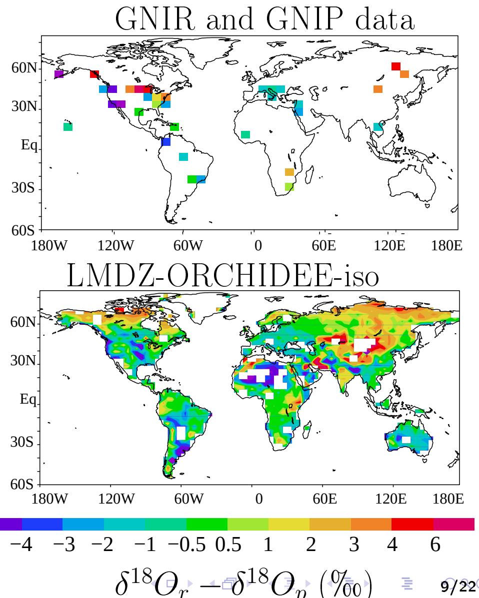




River water isotopes





Summary on evaluation

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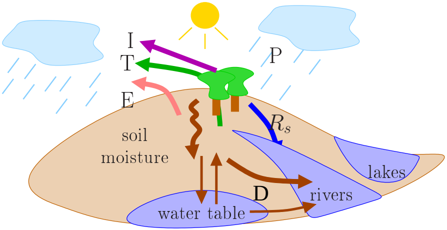

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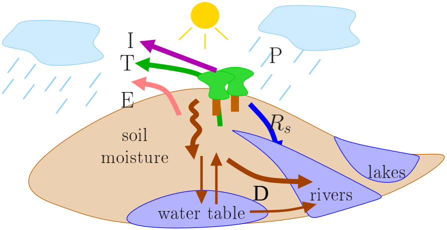

$\Rightarrow$ 4 potential isotopic diagnostics

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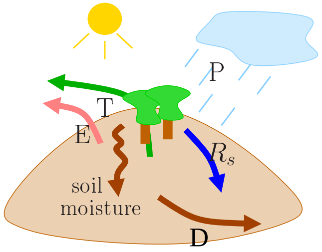

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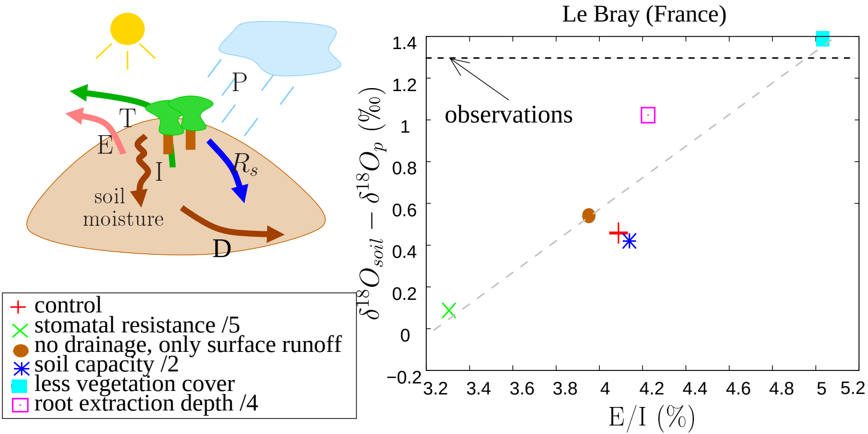

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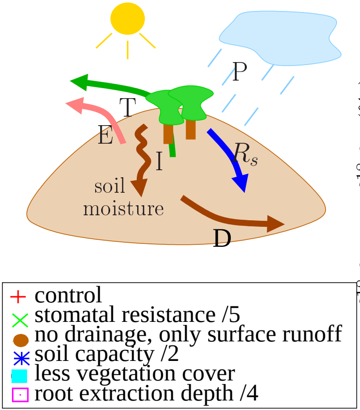

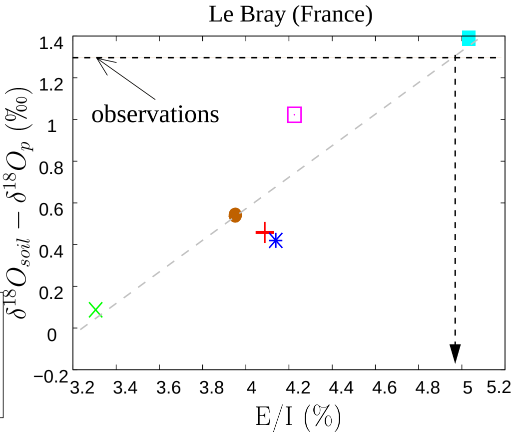

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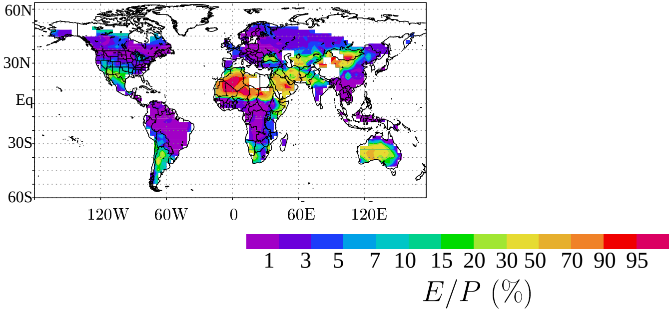
Estimating bare soil evaporation ratio

$\delta^{18}O_{soil} - \delta^{18}O_p$
$\delta^{18}O_v$
RH, T

estimated from simulated isotopic "measurements"



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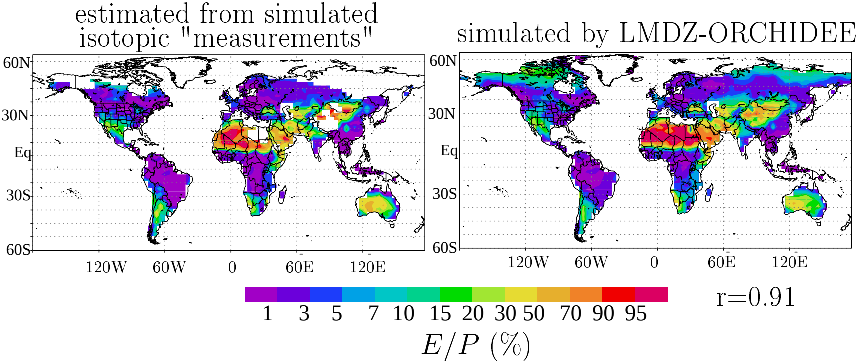
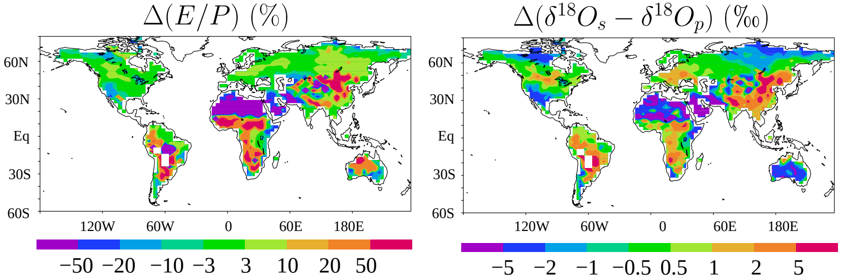


Detecting changes in surface water budget

Deforestation experiment:



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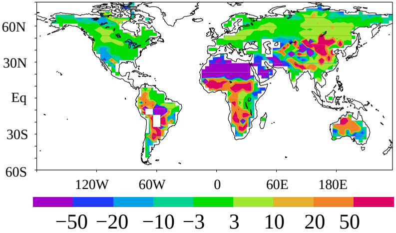
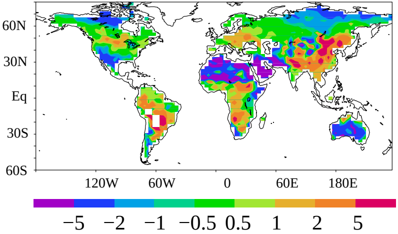
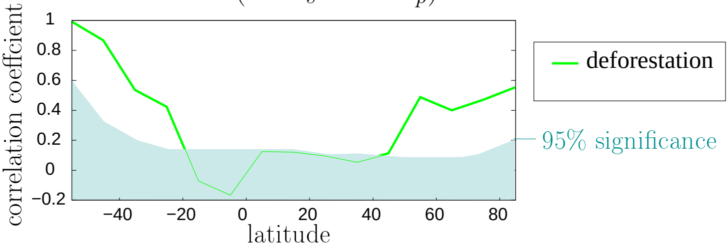




Spatial correlation between $\Delta(E/P)$ and $\Delta(\delta^{18}O_s - \delta^{18}O_p)$



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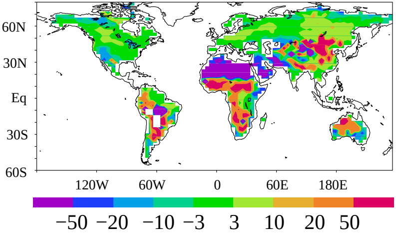
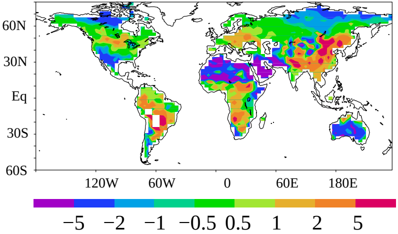


$\Delta(\delta^{18}O_s - \delta^{18}O_p)$ (‰)



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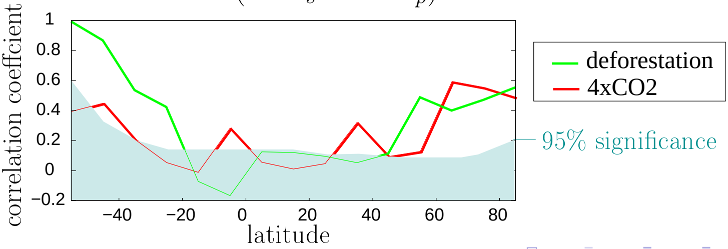

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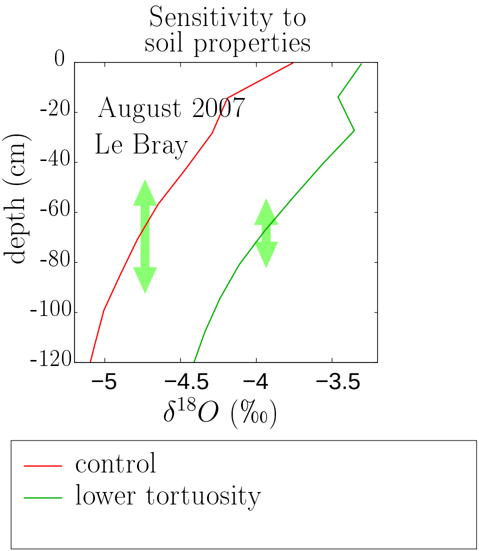

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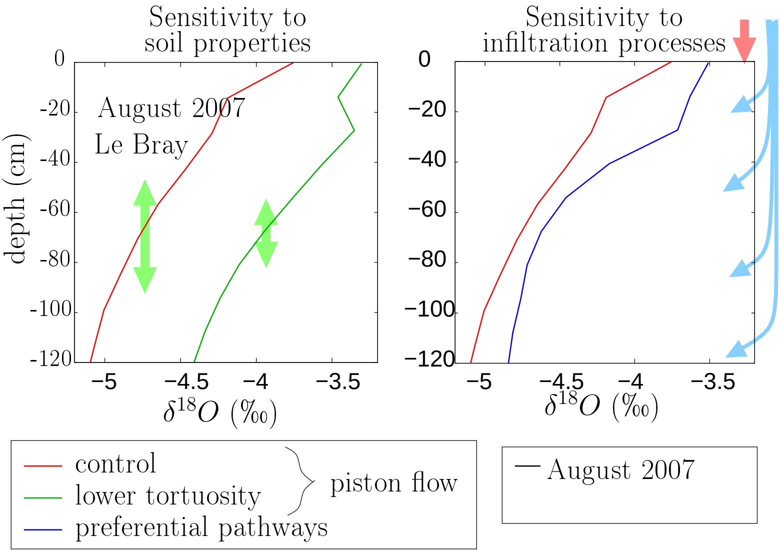

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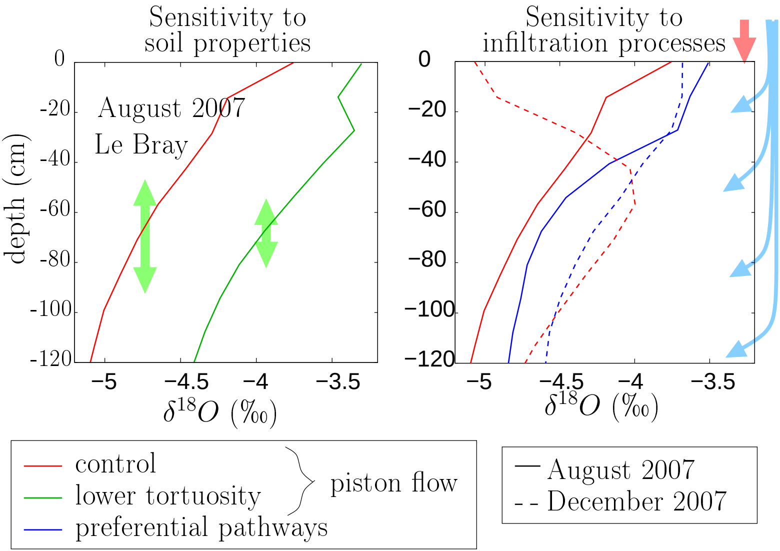

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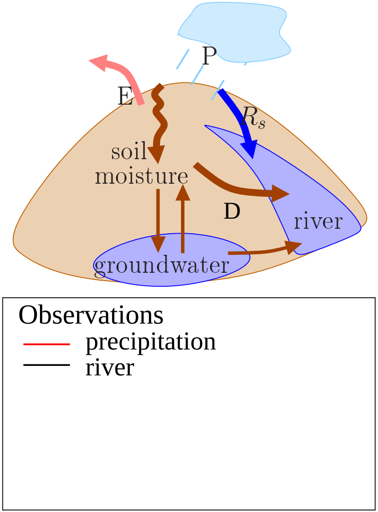

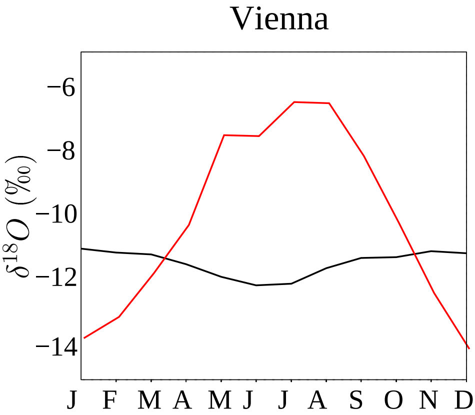

Risi et al in rev,a

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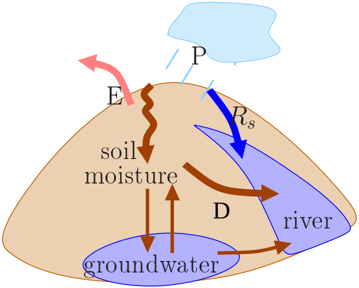
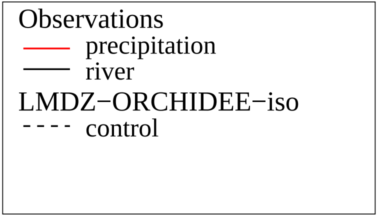
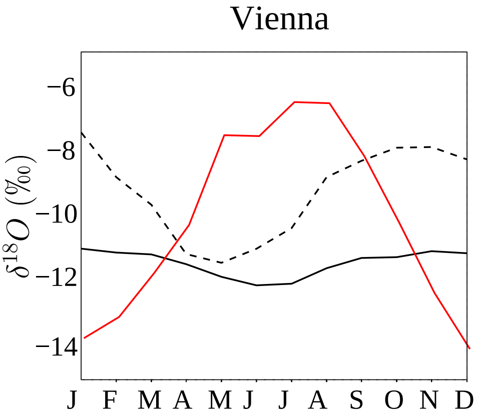
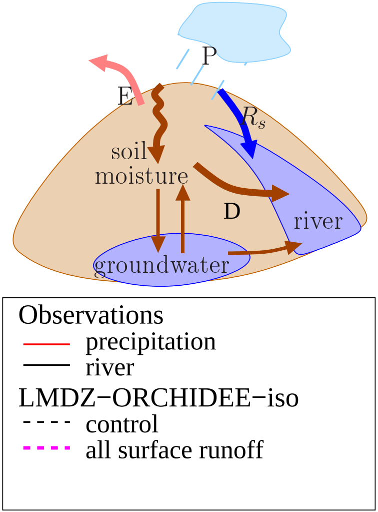


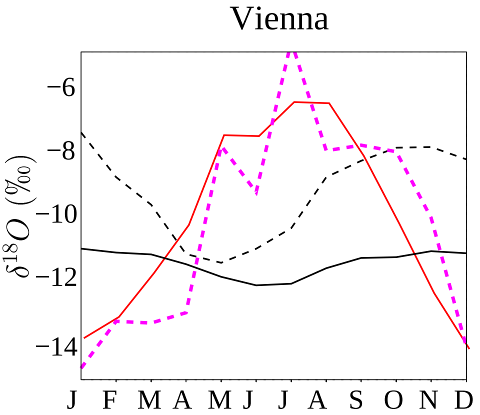




Risi et al in rev,a

3) Pathways from precipitation to rivers





Risi et al in rev,a

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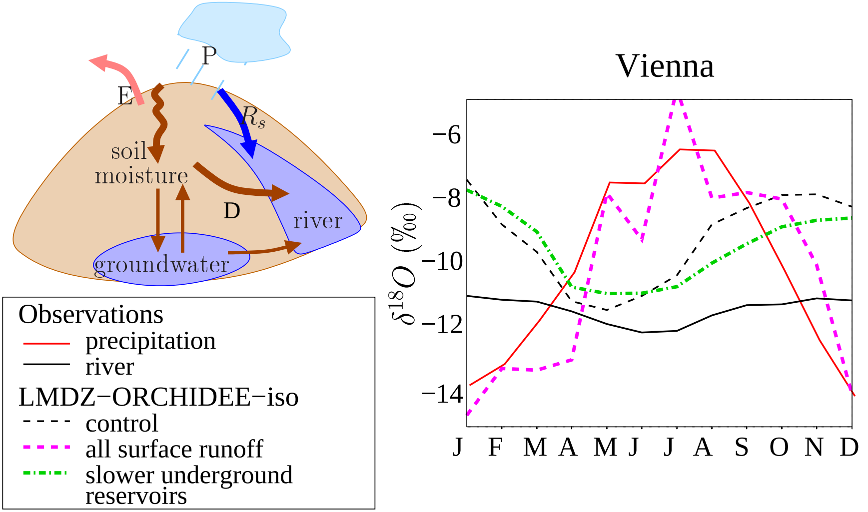
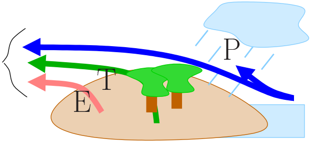


Risi et al in rev,a

4) Continental recycling

Water tagging:



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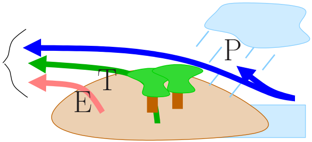

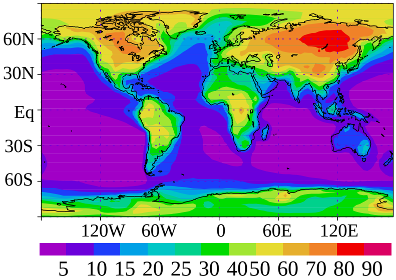

% vapor from continental evapo-transpiration (r_{con})

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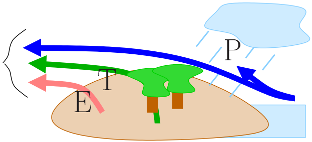

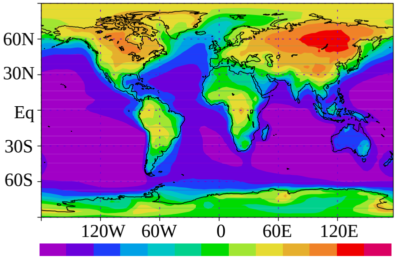

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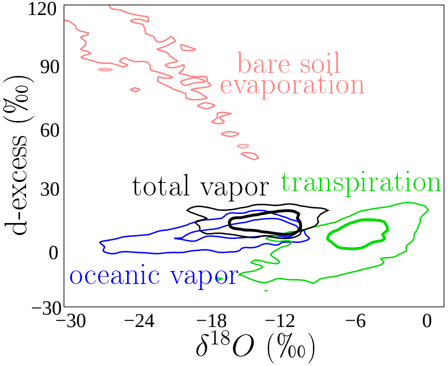
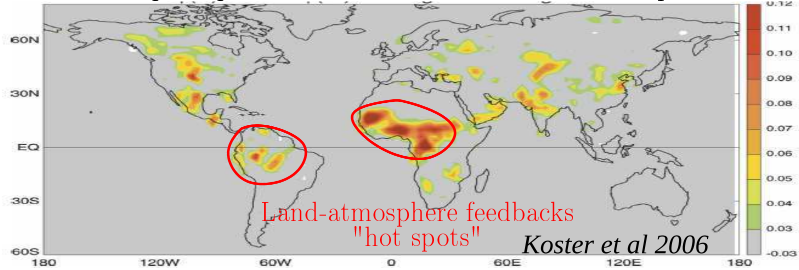
PDF of vapor composition monthly, all tropical land points



Water isotopes and continental recycling

decrease in precip variance when soil moisture is prescribed



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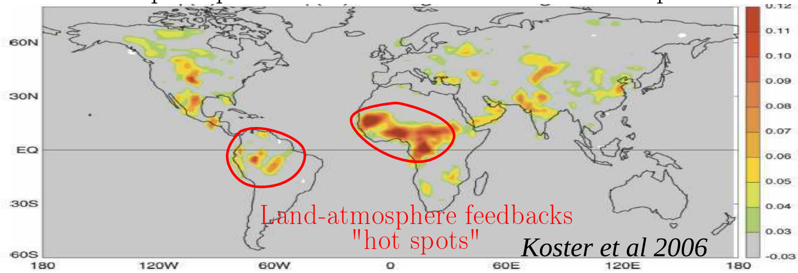
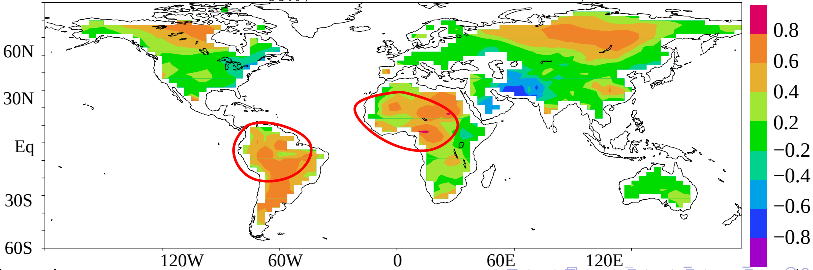
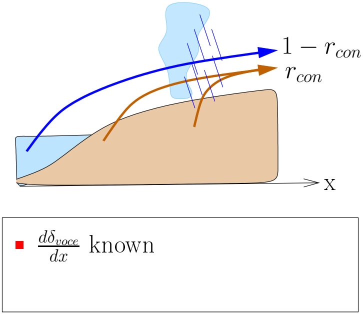
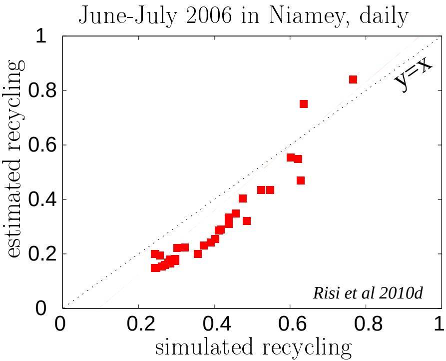


correlation $\delta^{18}O$ - r_{con}, intra-seasonal scale, annual mean



Estimating continental recycling





$$d\left(\frac{r_{con}}{1 - r_{con}}\right)/dx = \frac{d\delta_v/dx - d\delta_{voce}/dx}{\delta_p - \delta_v}$$

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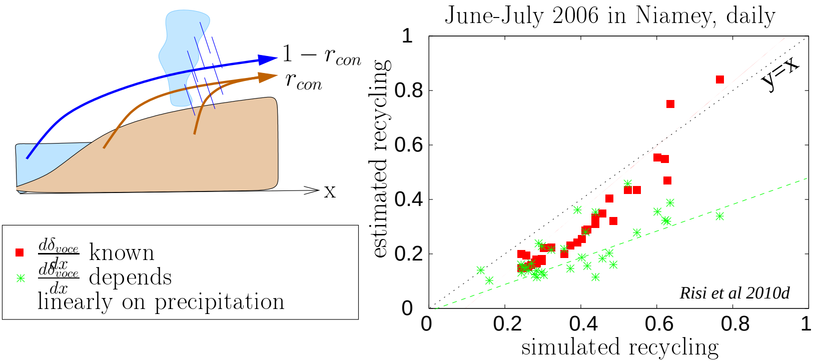

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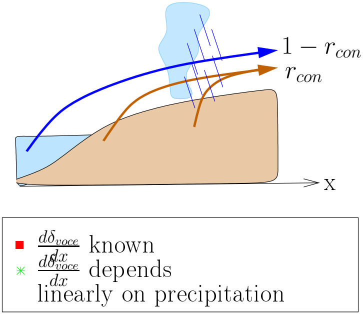

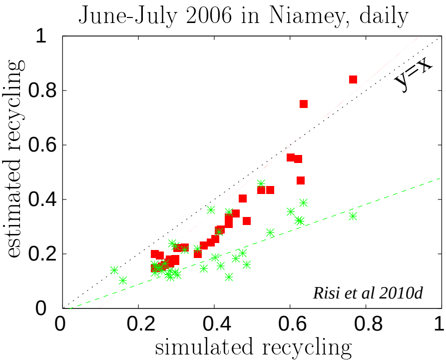

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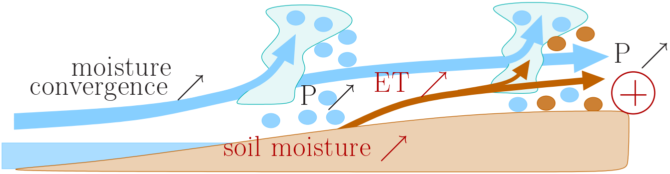
- Main limitation in using vapor isotopic measurements for continental recycling: understanding atmospheric controls

Isotopic signature of land-atmosphere feedbacks



strong precipitation composite minus seasonal average:

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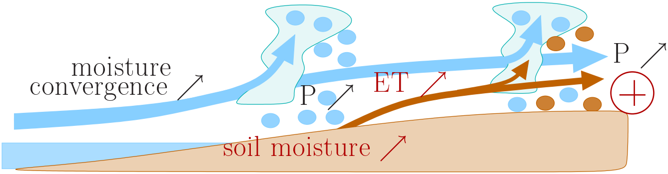

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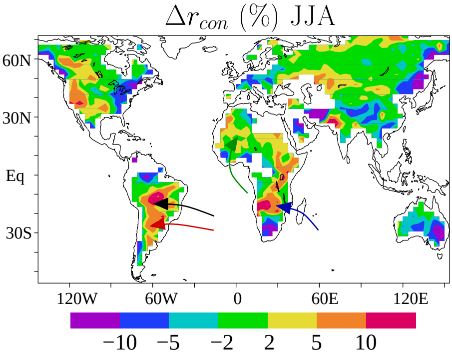

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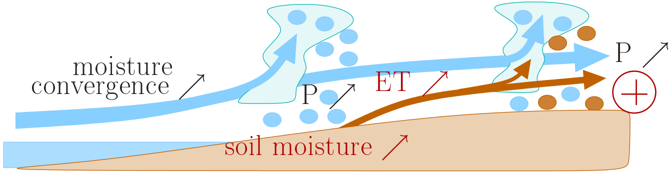

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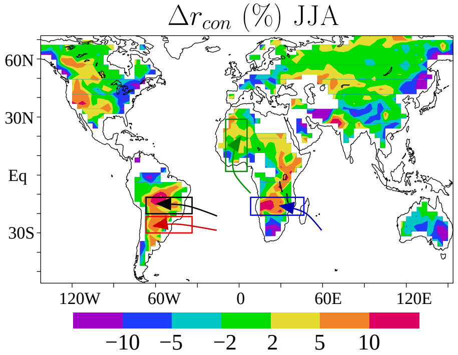
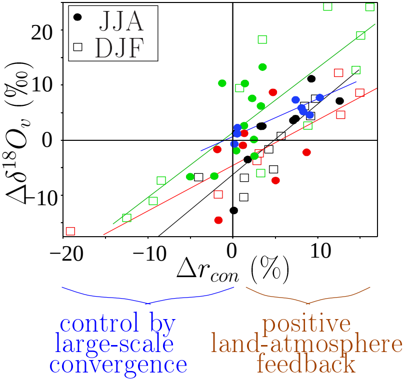
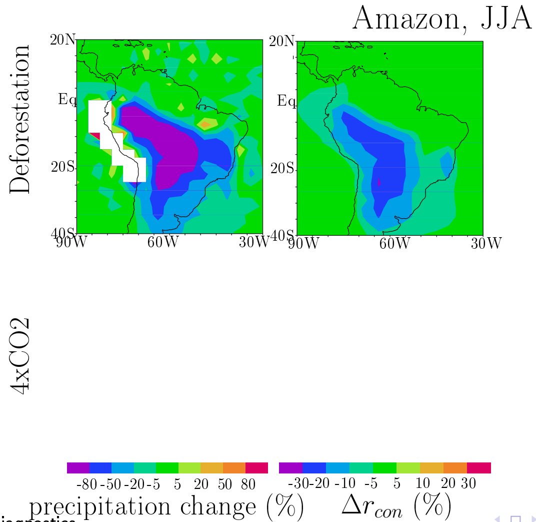




Monitoring land-atmosphere feedbacks related to land use change or global warming



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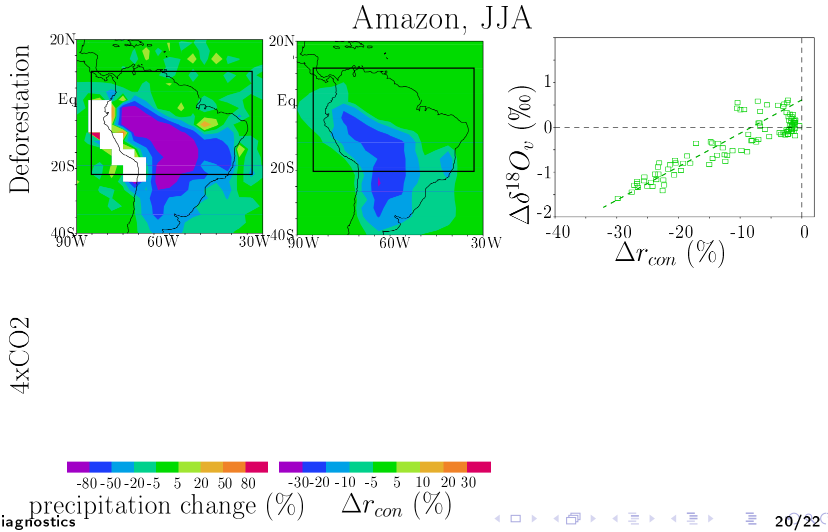

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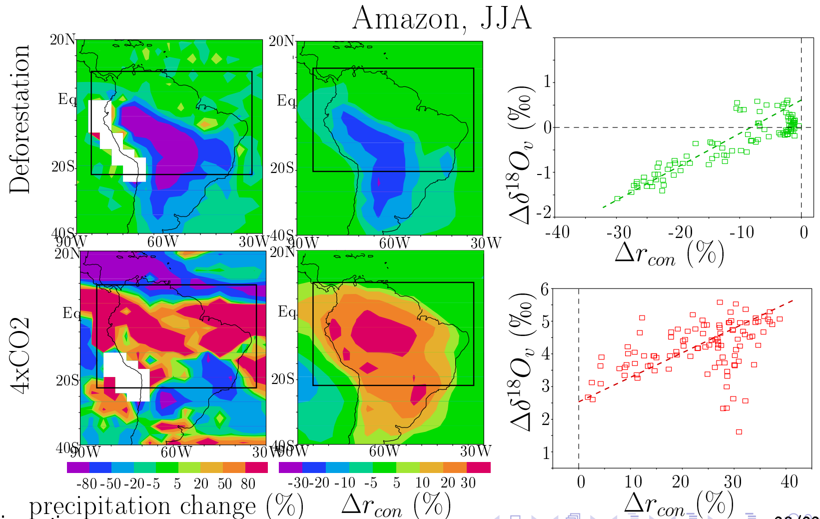
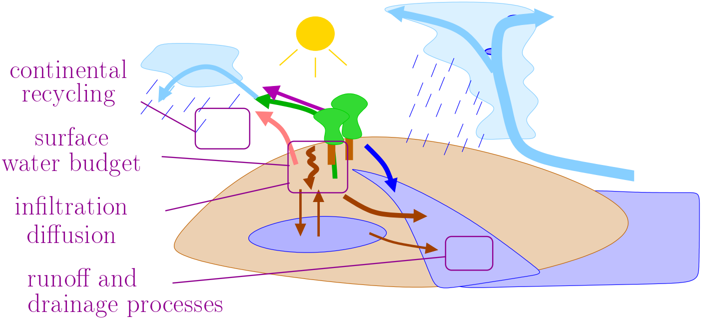


Conclusion

- Potential of isotopic measurements to evaluate a broad range of processes in land surface models



Perspectives

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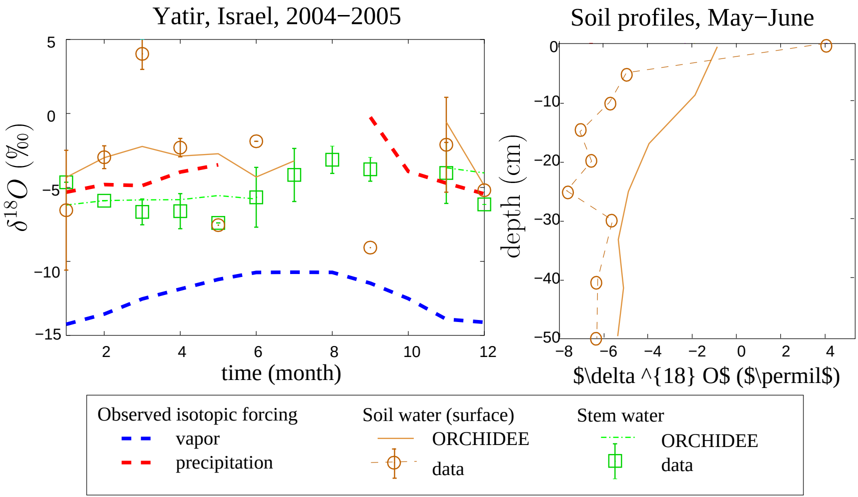
  - model inter-comparisons:
    - ORCHIDEE, isoLSM, soon CLM and ORCHIDEE-multi-layer
    - SWING2, AR4 CMIP3

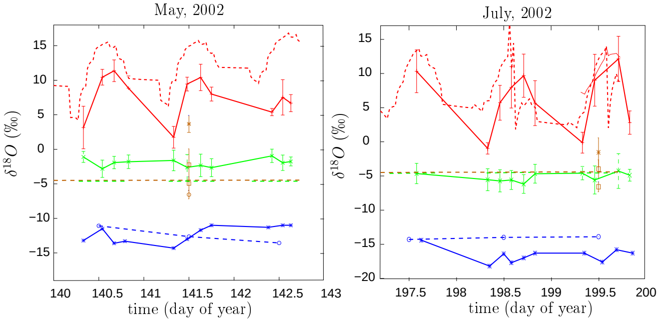
Suppl material

Evaluation of soil and biosphere isotopes

- 2 MIBA sites: Le Bray (France) and Yatir (Israel, shown here)

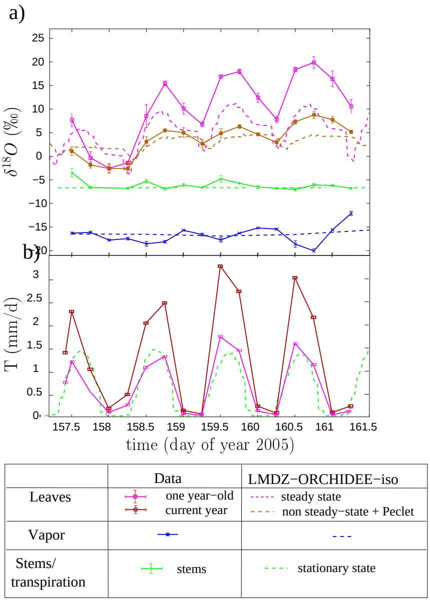


Diurnal cycles in leaves: Kansas

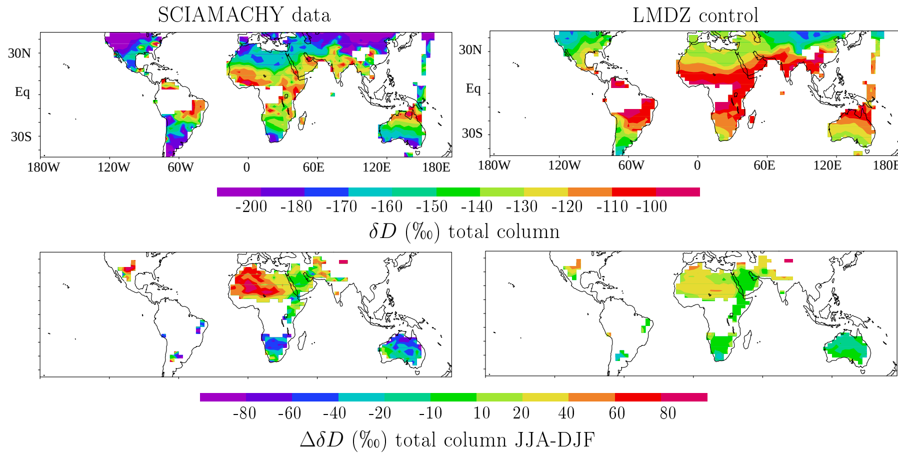


	Data	LMDZ−ORCHIDEE−iso
Leaves		stationary state
Vapor		
Soil	0cm 10cm 20cm 30cm	
Stems/ transpiration	stems	stationary state

Diurnal cycles in leaves: Germany

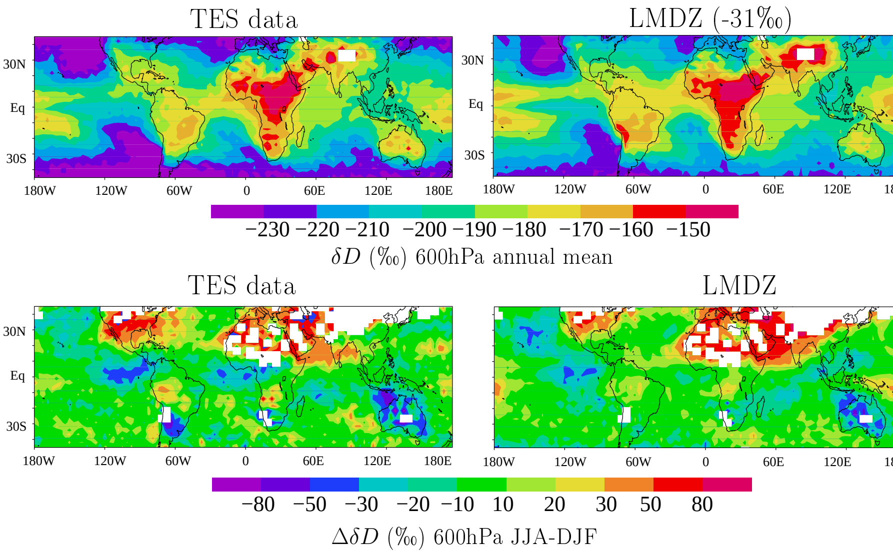


Evaluation against SCIAMACHY

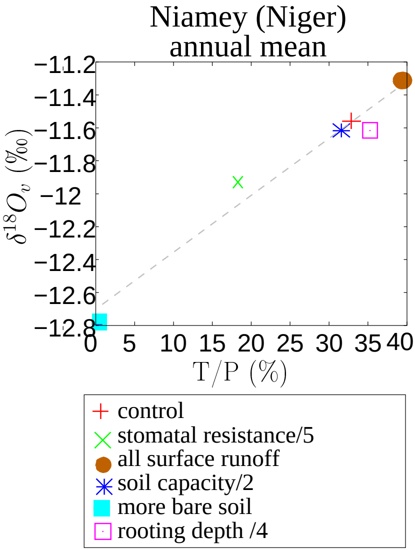


Risi et al in rev,b

Evaluation against TES



Continental recycling



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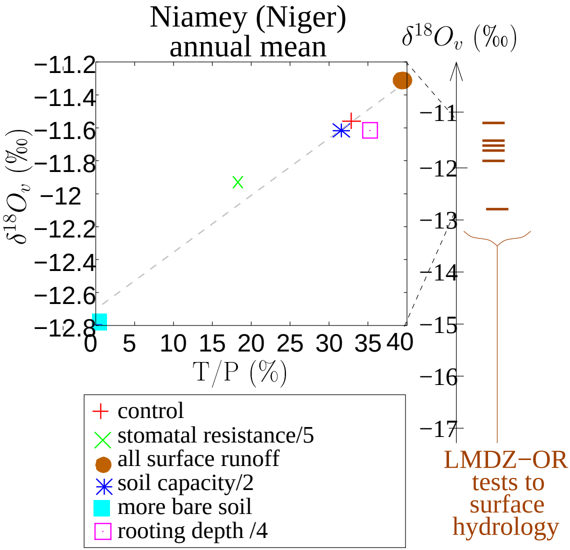

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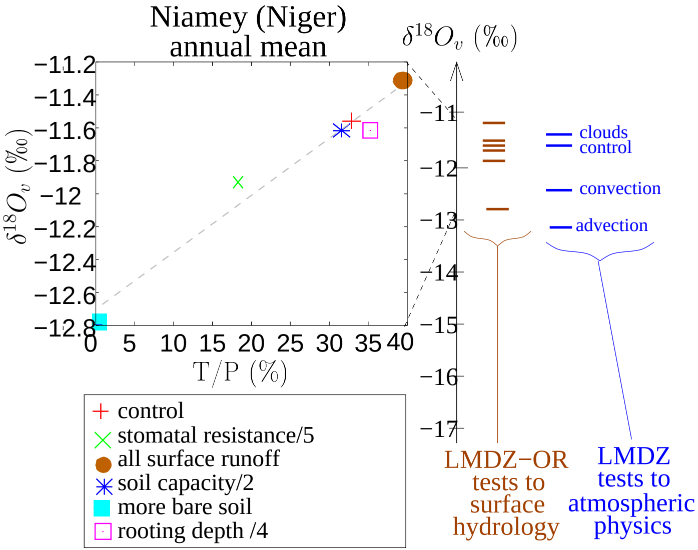

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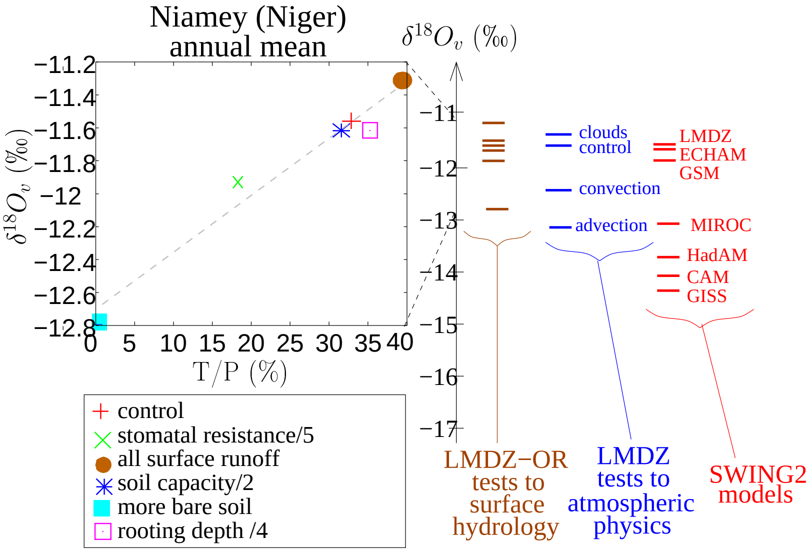

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