Isotopic composition of rain collected in the Niamey region: what information on cloud convection and water cycle?

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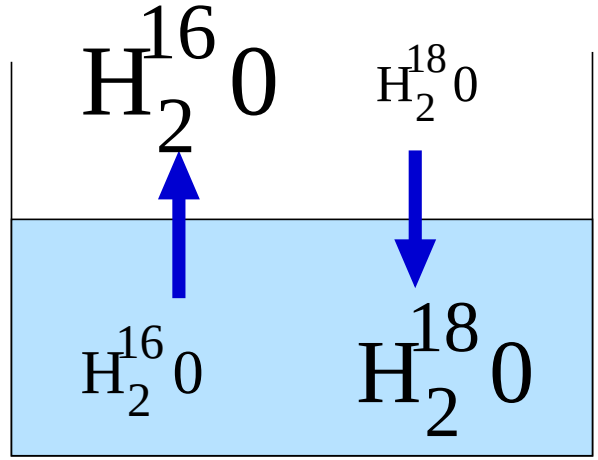
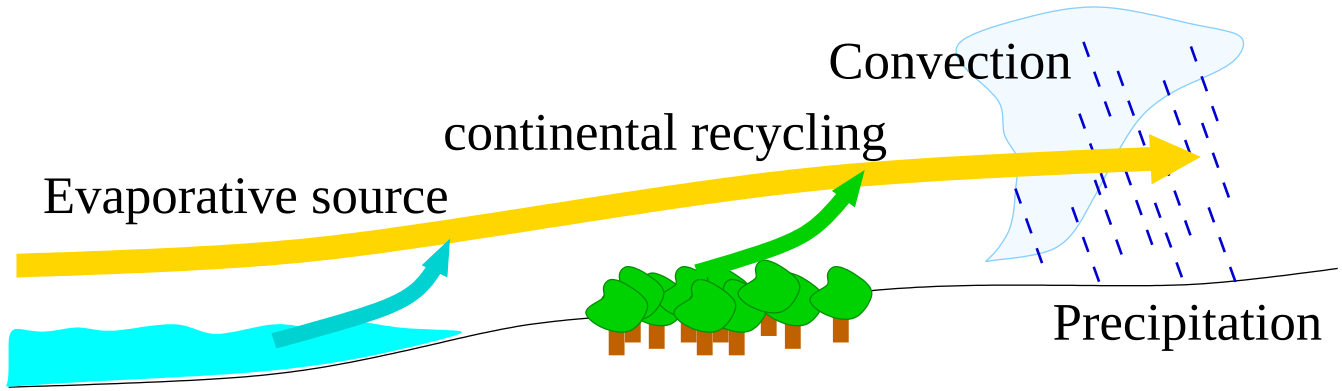
Why studying water isotopes?

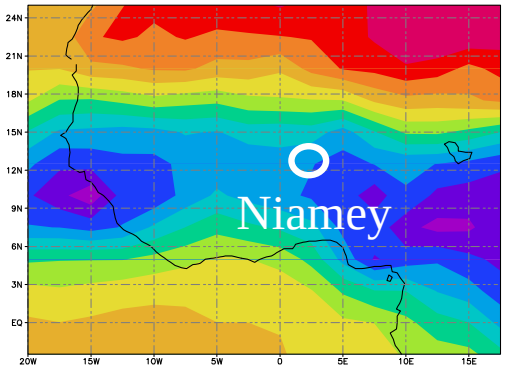
- water=light molecules ($H_2^{16}O$) + heavy ($H_2^{18}O$, HDO)
- isotopic fractionation
- $\delta^{18}O$ = abundance in $H_2^{18}O$ in water expressed in ‰
- δD = abundance in HDO
- d-excess $= \delta D - 8 \cdot \delta^{18}O$

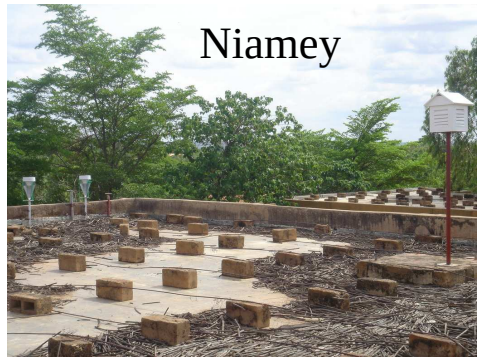


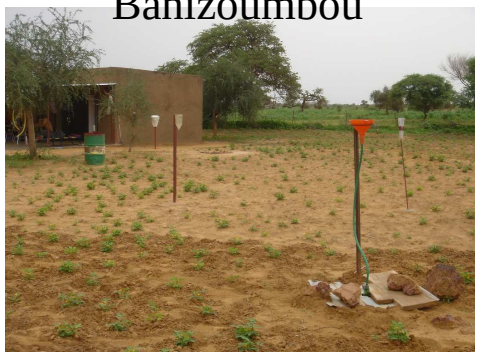


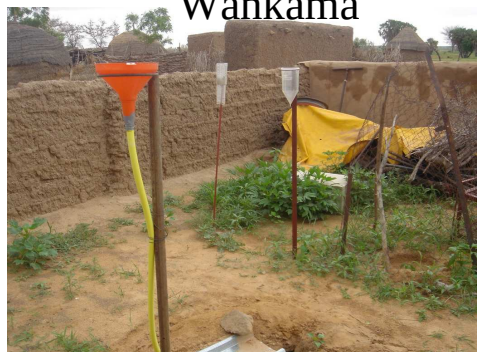
Goals during the AMMA campaign

- What controls the isotopic composition of Sahelian precipitation?
- What information on
  - convection processes?
  - water cycle?
- $\Rightarrow$ collection at the end of each event, during the entire 2006 monsoon season, on 3 sites around Niamey

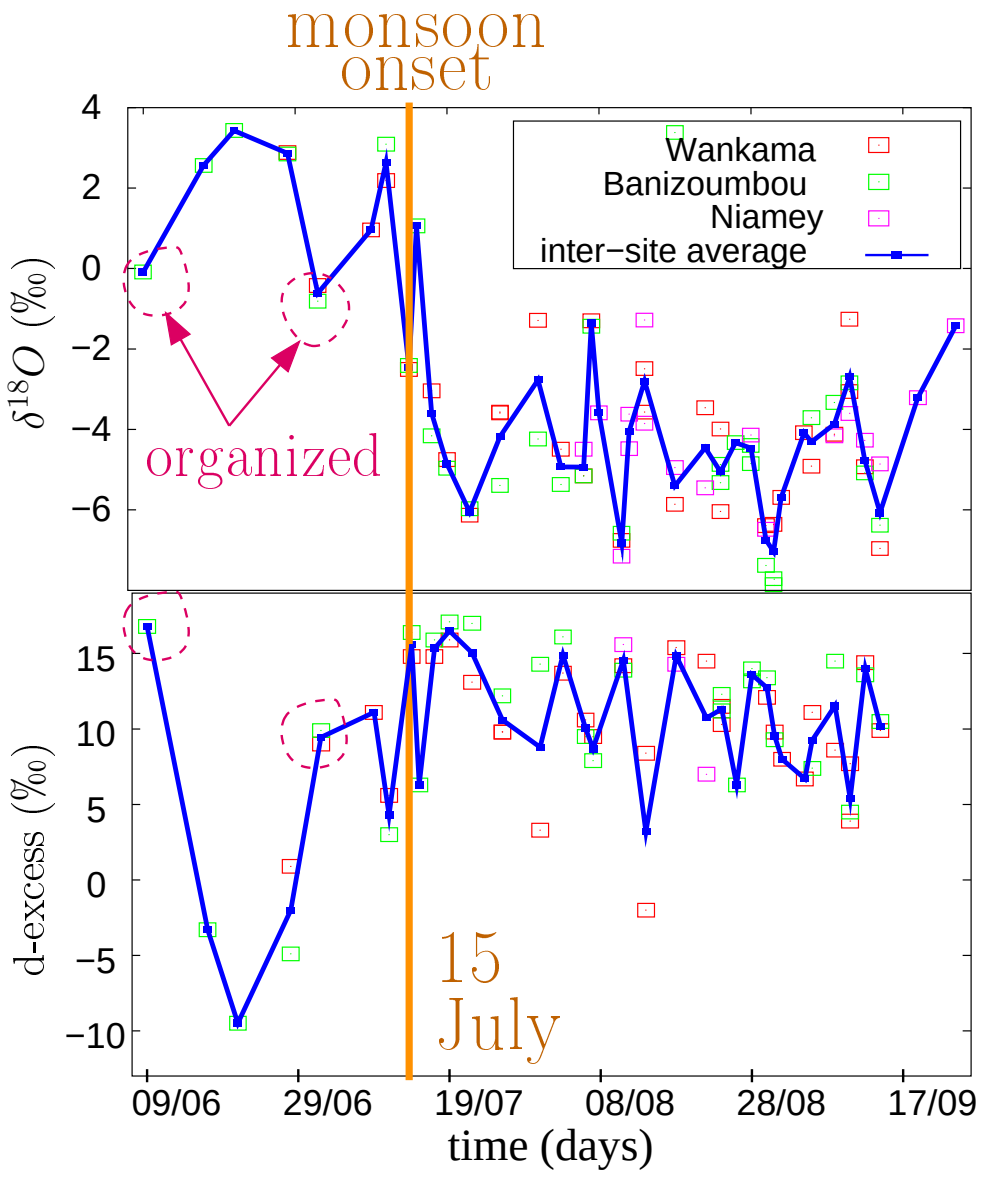






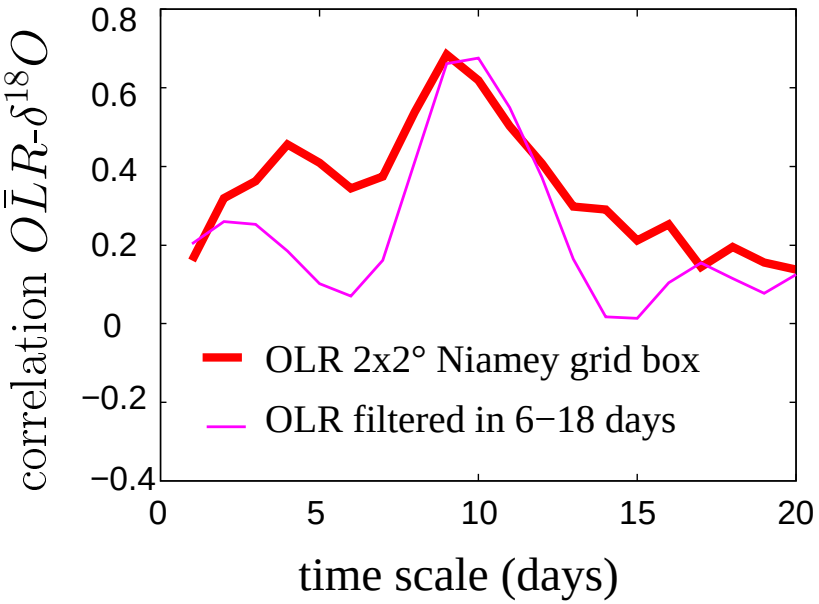


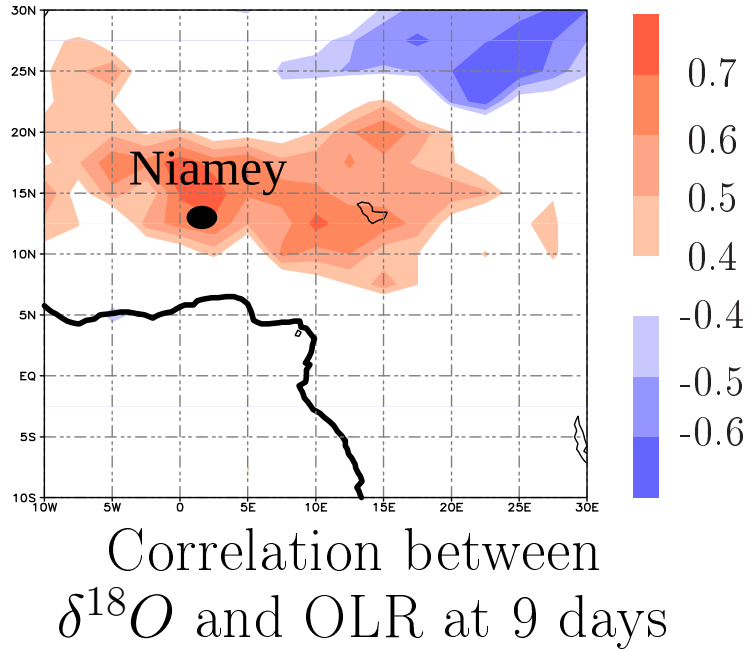
Isotopic evolution during the season



- isotopes record variations in convective activity:
  - the monsoon onset
  - before the onset: organization and intensity of individual systems

After the onset, $\delta^{18}O$ integrates convection

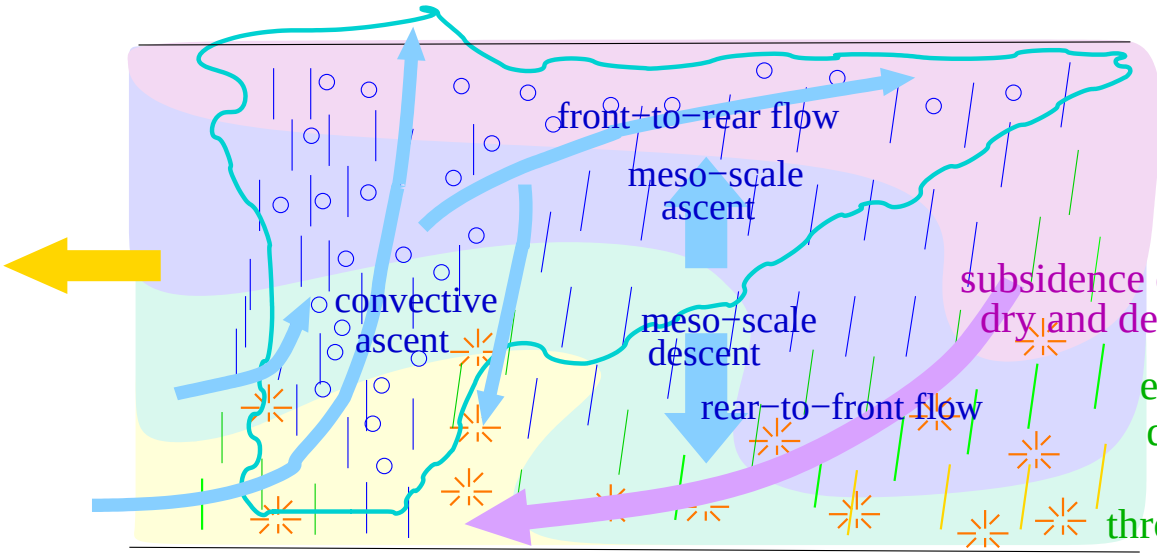


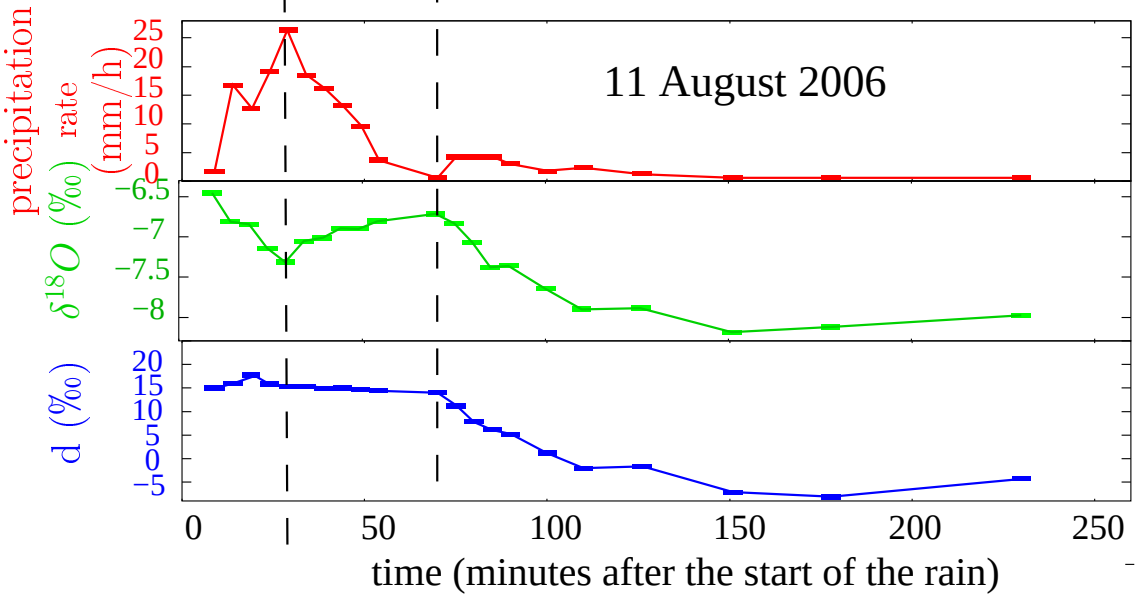


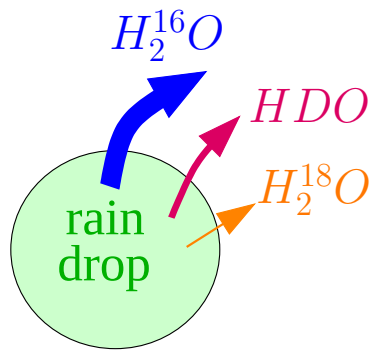
Correlation between $\delta^{18}O$ and OLR at 9 days

- temporal integration of convection
- record of large-scale signal of intra-seasonal variability

Isotopic processes in a squall line



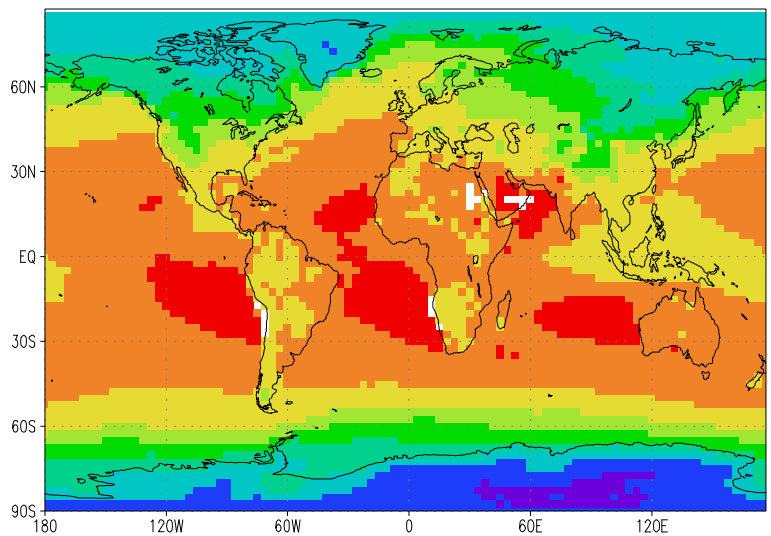




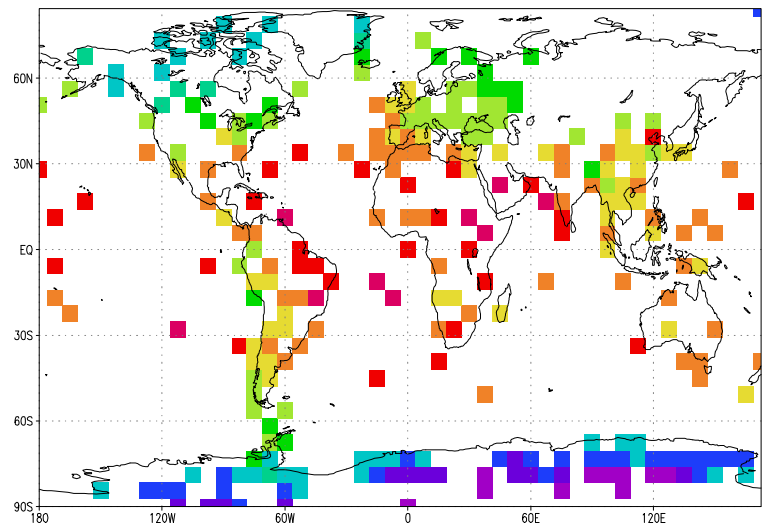
Use of LMDZ GCM simulations

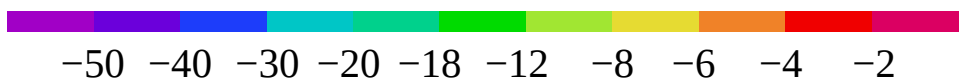
- LMDZ4 GCM, AR4 physics
- 2.5°x3.75° horizontal resolution, 19 vertical levels
- nudged by NCEP 3D horizontal winds
- includes water isotopes:
  - advected like water
  - fractionation at phase changes, except evaporation from land

$\delta^{18}O$ (‰) LMDZ

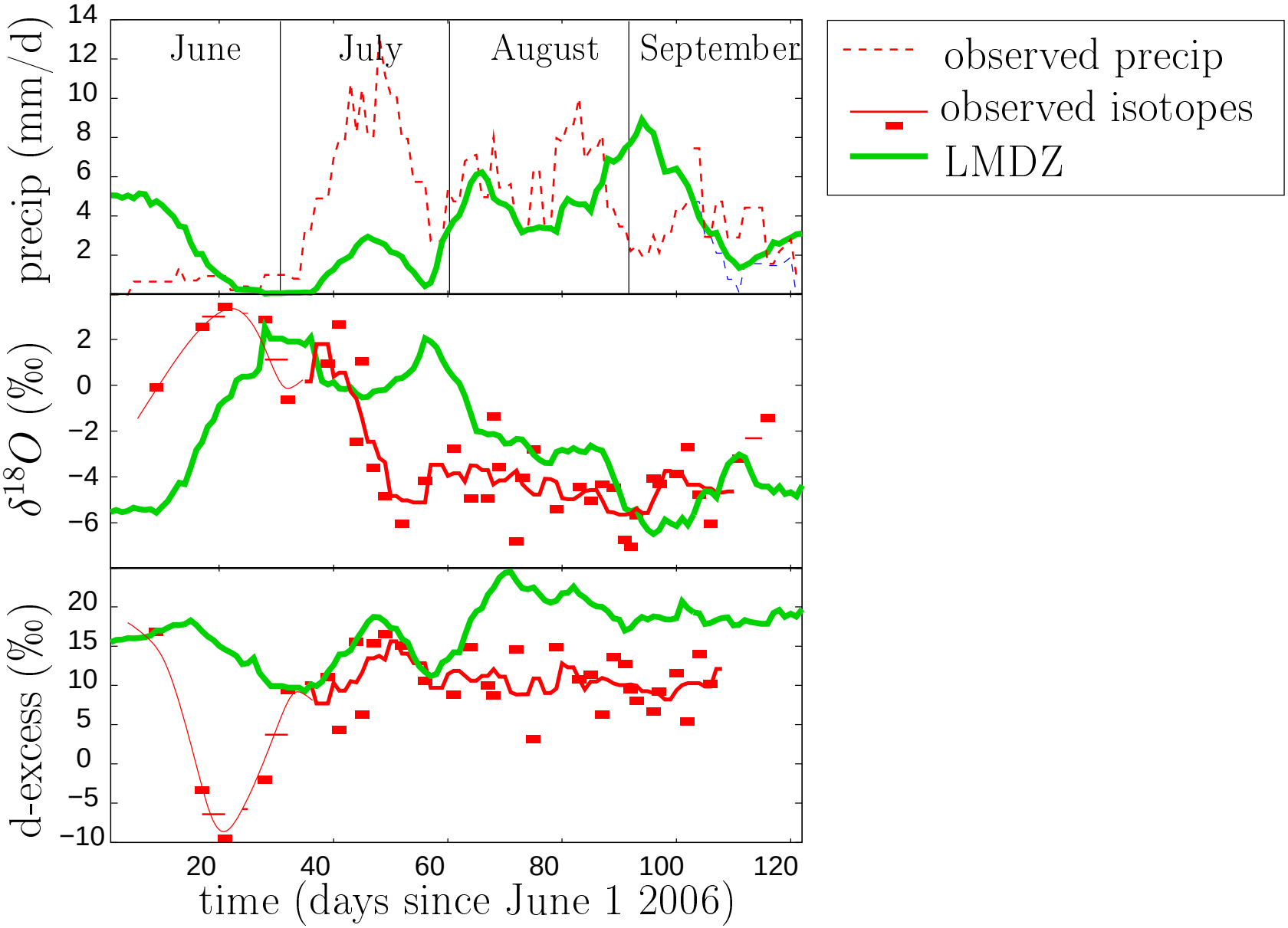


$\delta^{18}O$ (‰) observations





LMDZ-iso over Niamey



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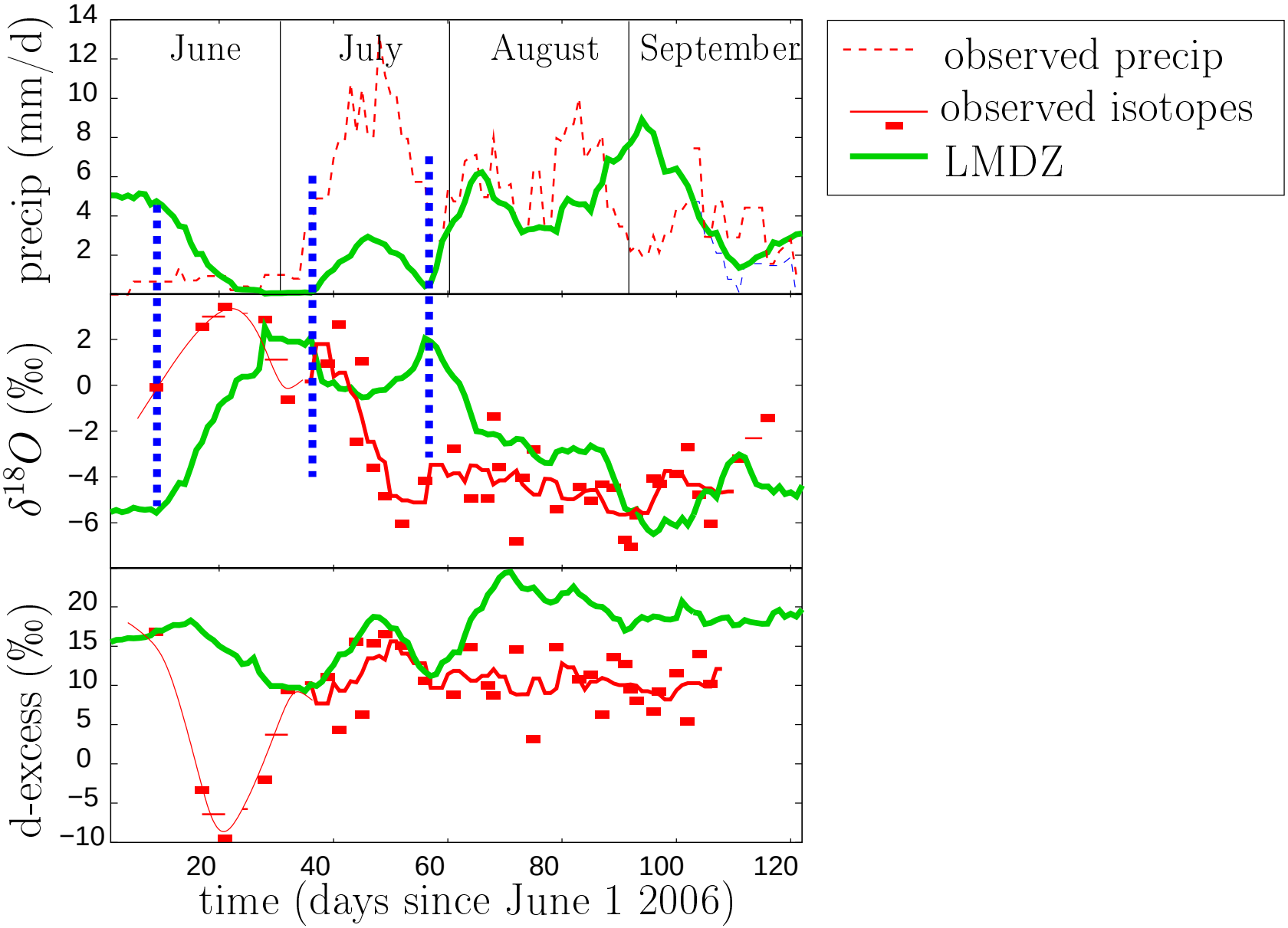

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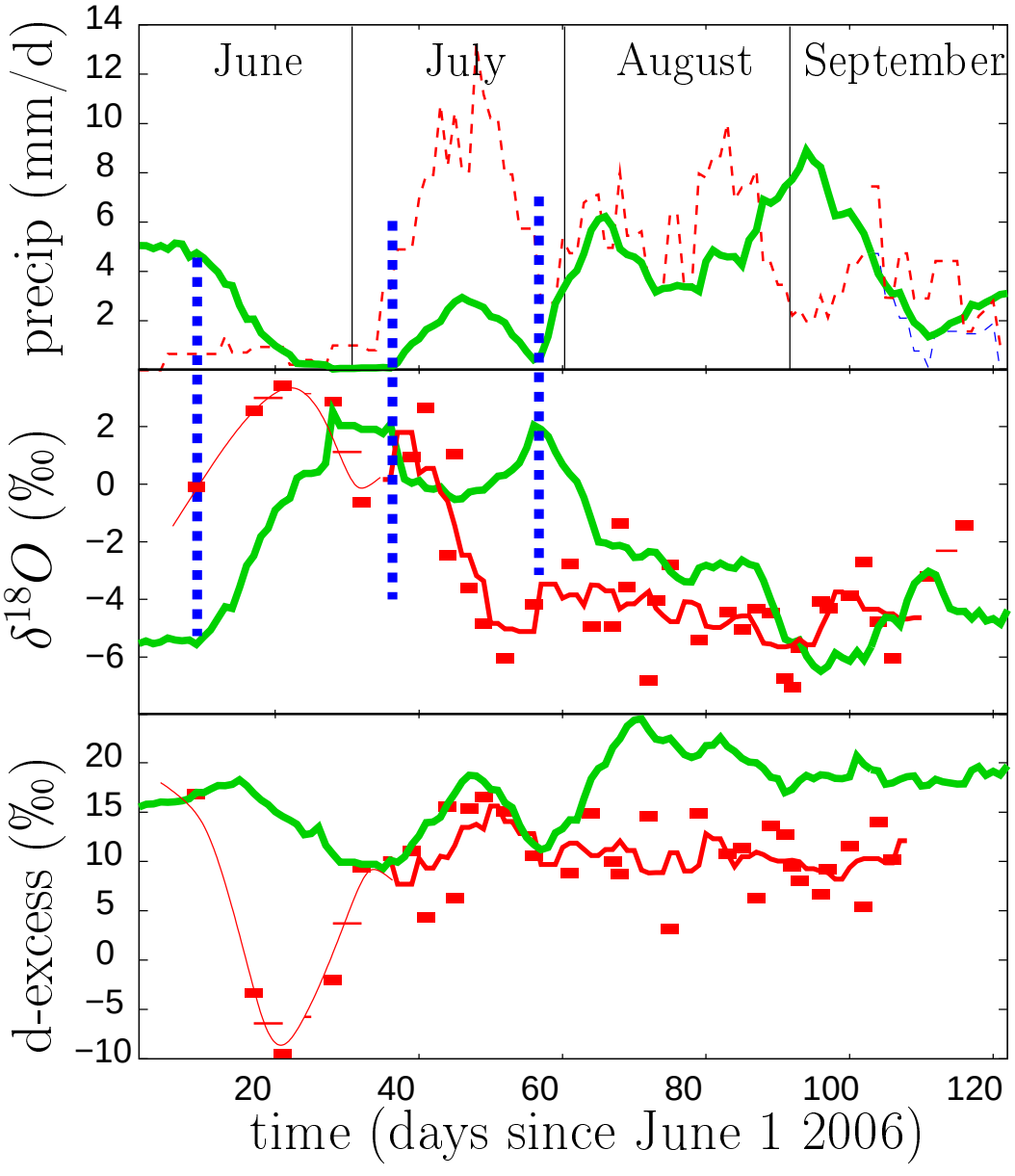
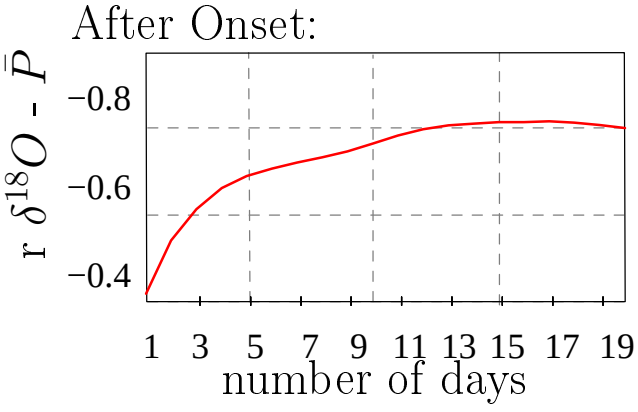
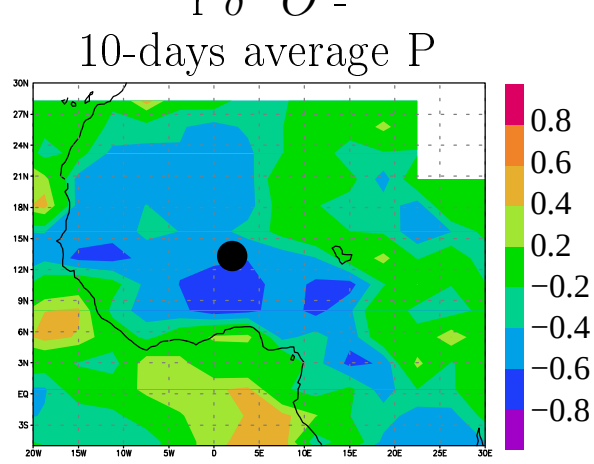
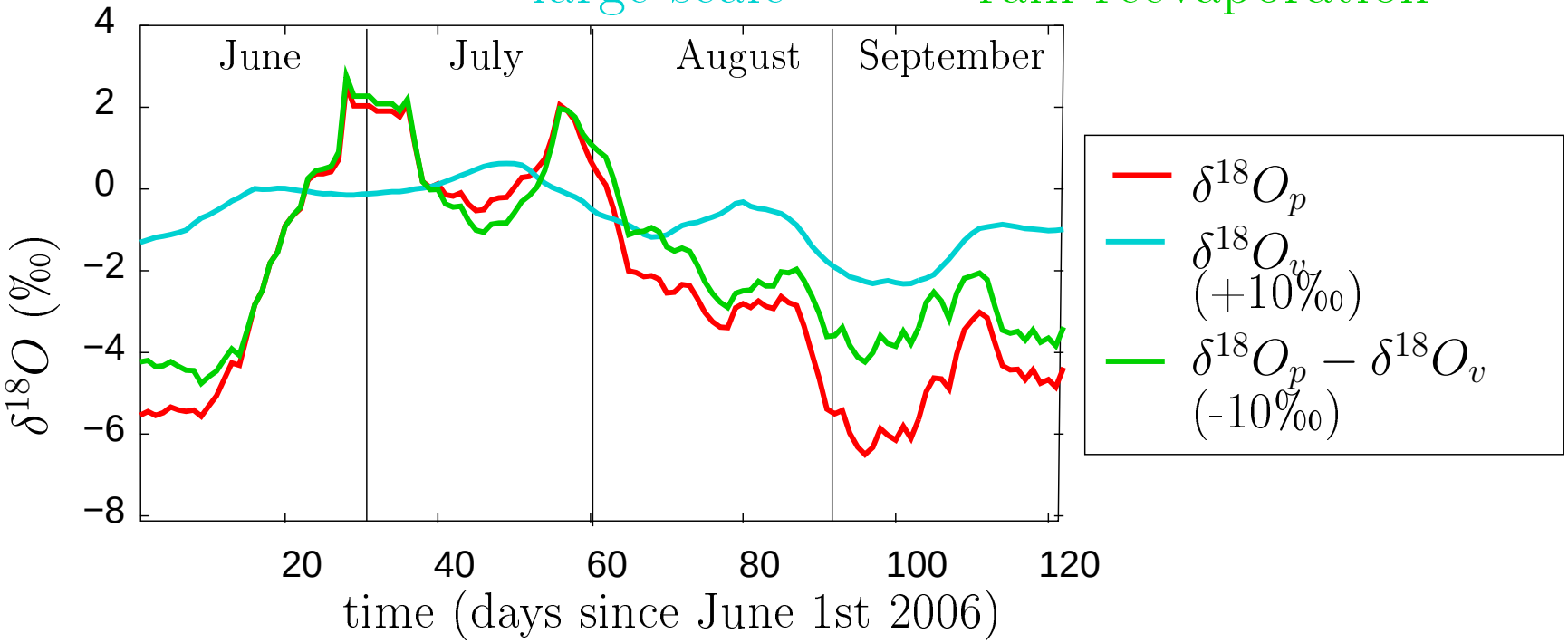






$\delta^{18}O$ intra-seasonal variability in LMDZ

$$\delta^{18}O_p = \underbrace{\delta^{18}O_v}_{\text{large-scale}} + \underbrace{\delta^{18}O_p - \delta^{18}O_v}_{\text{rain reevaporation}}$$

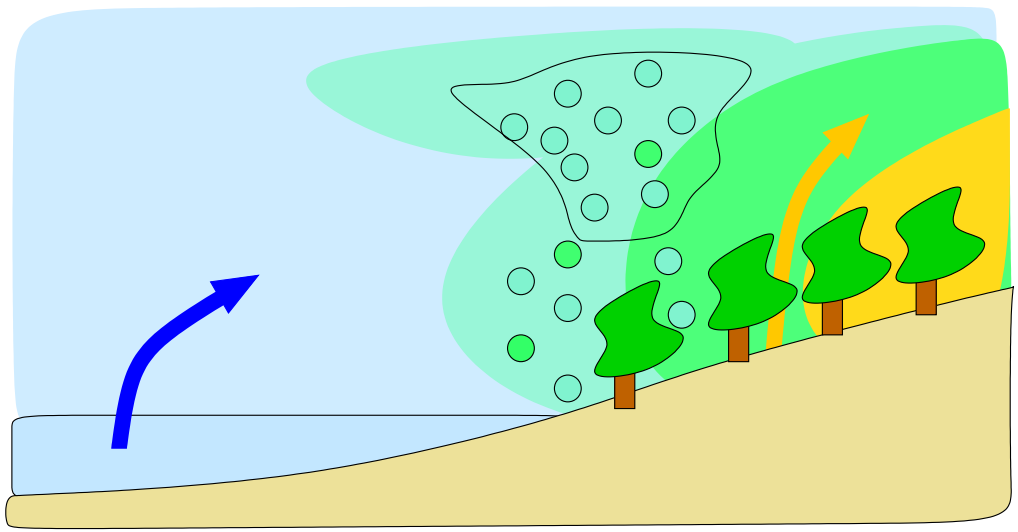


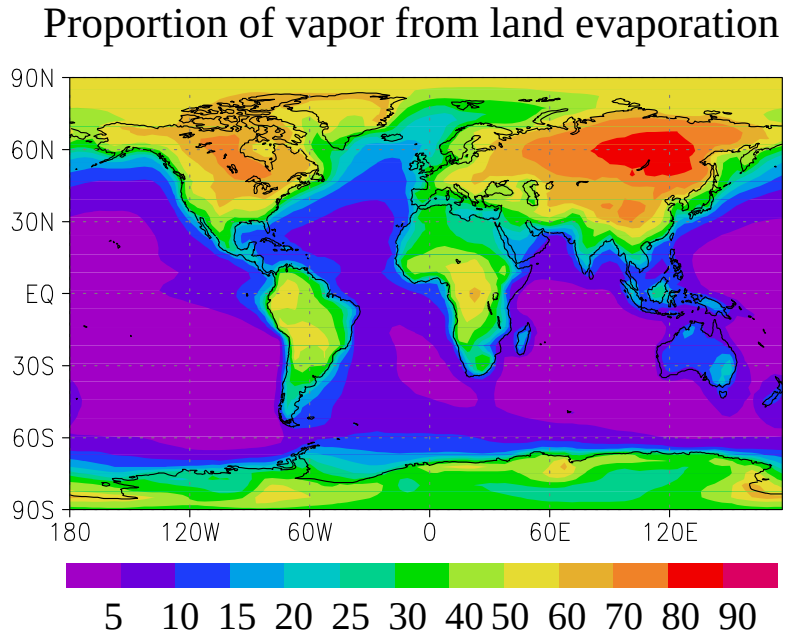
- before onset: instantaneous reponse to convection, through drop evaporation
- after onset: integration of convection, partly through the vapor

Water tagging in LMDZ

- Each water molecule is tagged by a specific color, according to a coloring convention.
- Additional "passive" water species whose sum equals the total "normal" water

example: tag land versus ocean evaporation:





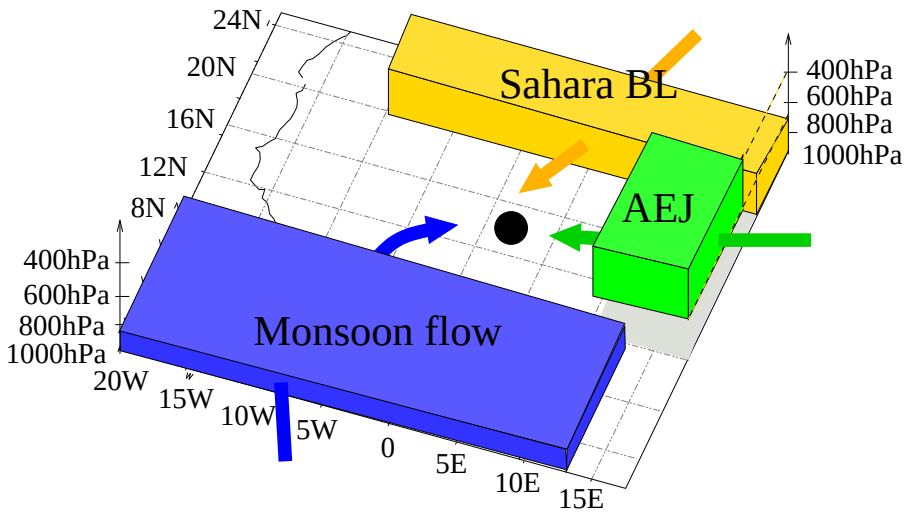
Water tagging on Niamey

% of vapor that has evaporated over:

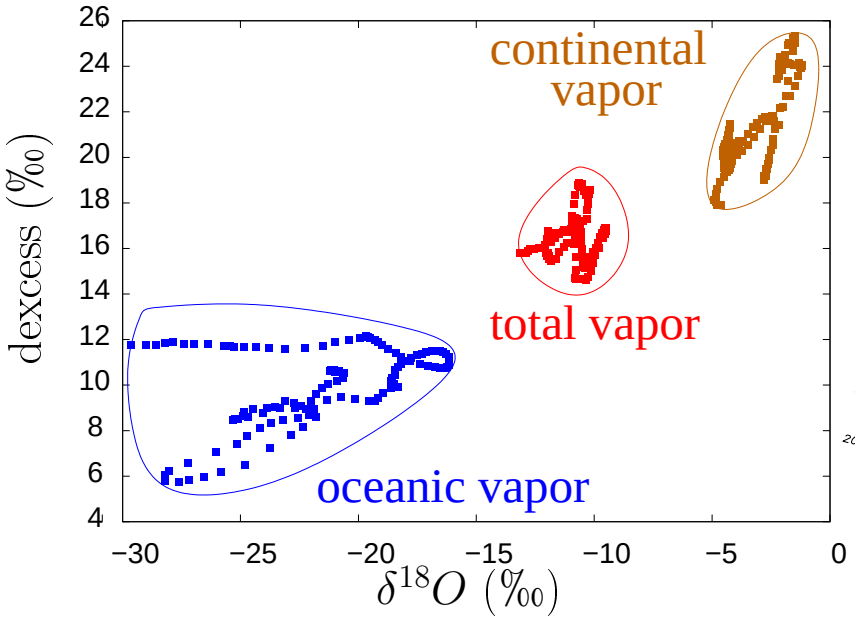
	summer	winter
continent	60%	30%
Atlantic	30%	45%
Mediterranean	2%	10%
Indian Ocean	10%	15%

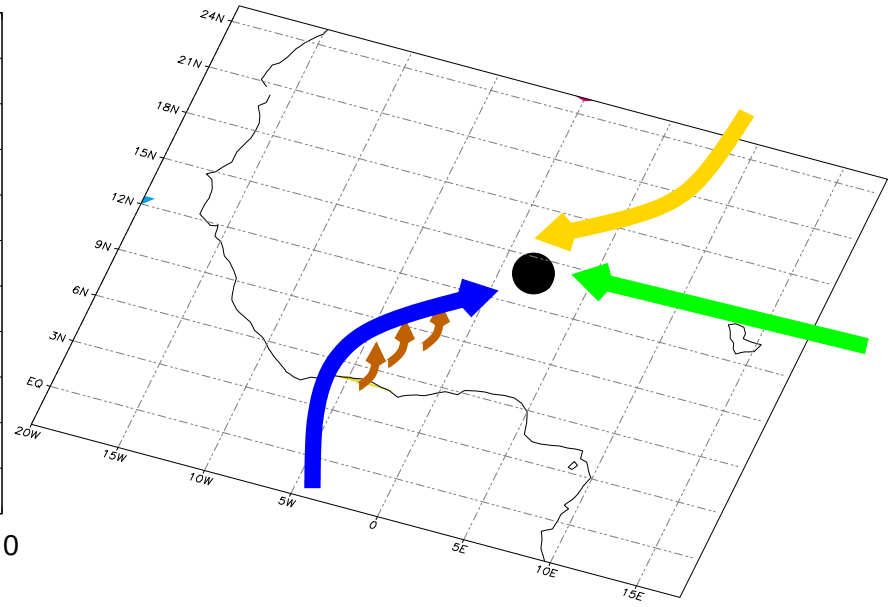
% of vapor that has been through:

	summer	winter
Monsoon flow	32%	20%
AEJ	32%	10%
Sahara BL	8%	60%
unsat. downdraft	70%	50%



Isotopes and origin of vapor





- distinct isotopic properties of continental vapor $\Rightarrow$ potential to evaluate continental recycling?
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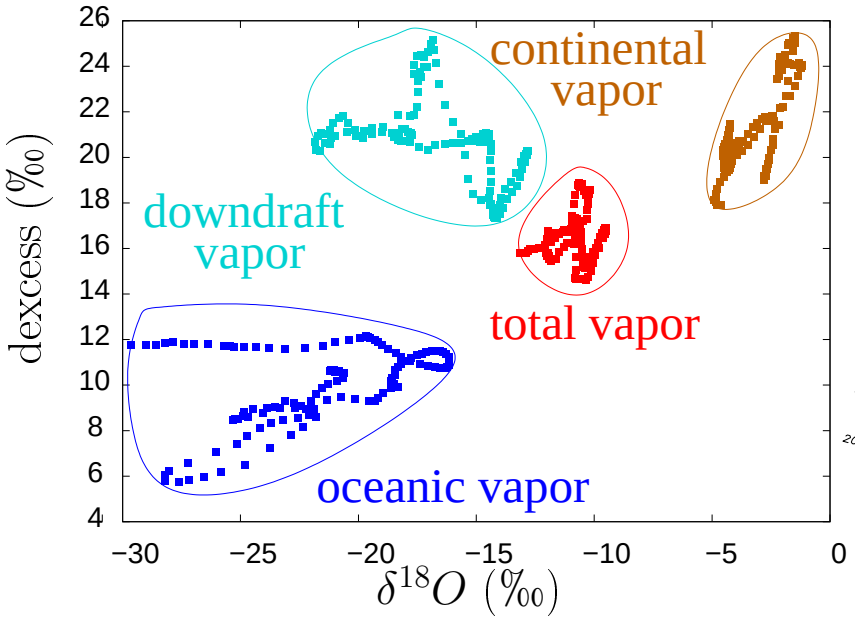
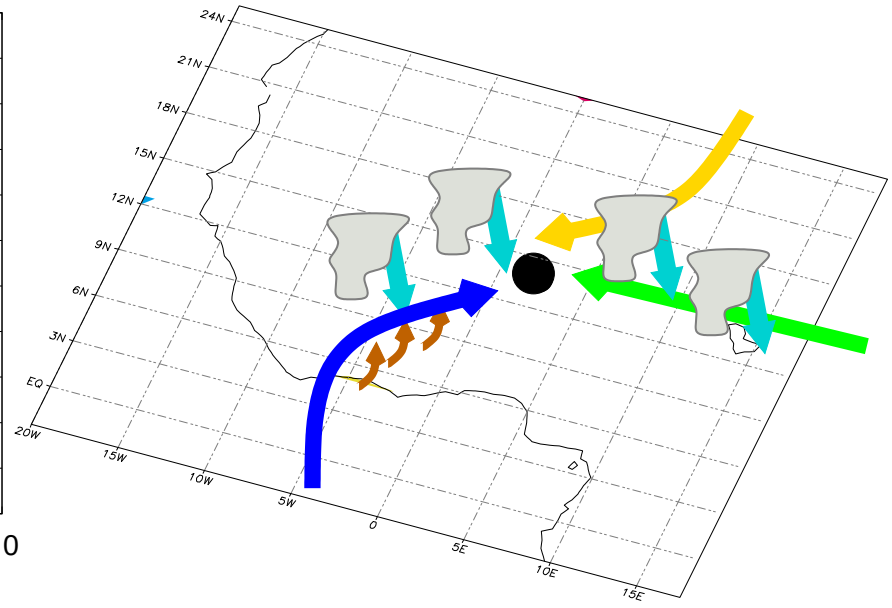
Isotopes and convection





- distinct isotopic properties of continental vapor $\Rightarrow$ potential to evaluate continental recycling?
- depletion of vapor by convective downdrafts
- at intra-seasonal scales: oceanic vapor depleted by convective downdrafts along the monsoon flow

Conclusion

- $\delta^{18}O$ records convective activity
  - records the monsoon onset
  - before the onset, local response to convection by rain drop evaporation
  - after the onset, when convection is stronger, $\delta^{18}O$ integrates convection by progressive depletion of oceanic vapor by convective downdrafts along the monsoon flow
- Water tagging a powerful diagnostic tool to better understand the water cycle and isotopic variability in models

Perspectives

- Evaluation of LMDZ results? Evaluating the vapor composition?
- Advantages of vapor measurments:
  - All year long, during monsoon breaks
  - clearer signal of large-scale processes
  - Constrain representation of isotopic exchanges between vapor and precipitation
  - $\Rightarrow$"Picarro" intsrument to measure vapor isotopes
- Role of land surface processes:
  - LMDZ-ORCHIDEE coupled simulations
- What information can we infer from water isotopes about convection? origin of vapor? Continental recycling? land surface processes?
  - device observational methods based on isotopes to deduce terms of the water budget
  - device observational tests based on isotopes to evaluate models