Constraining the sources and transport history of atmospheric water in models

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EGU Leonardo conference
Ourense, Spain
25-27 October 2016

BJERKNES CENTRE
for Climate Research

Atmospheric life time of water vapour

Total water volume: 12.7 x 10^3 km^3 yr^{-1}

Global average rain rate: 500 km^3 yr^{-1} = 1.37 mm day^{-1}

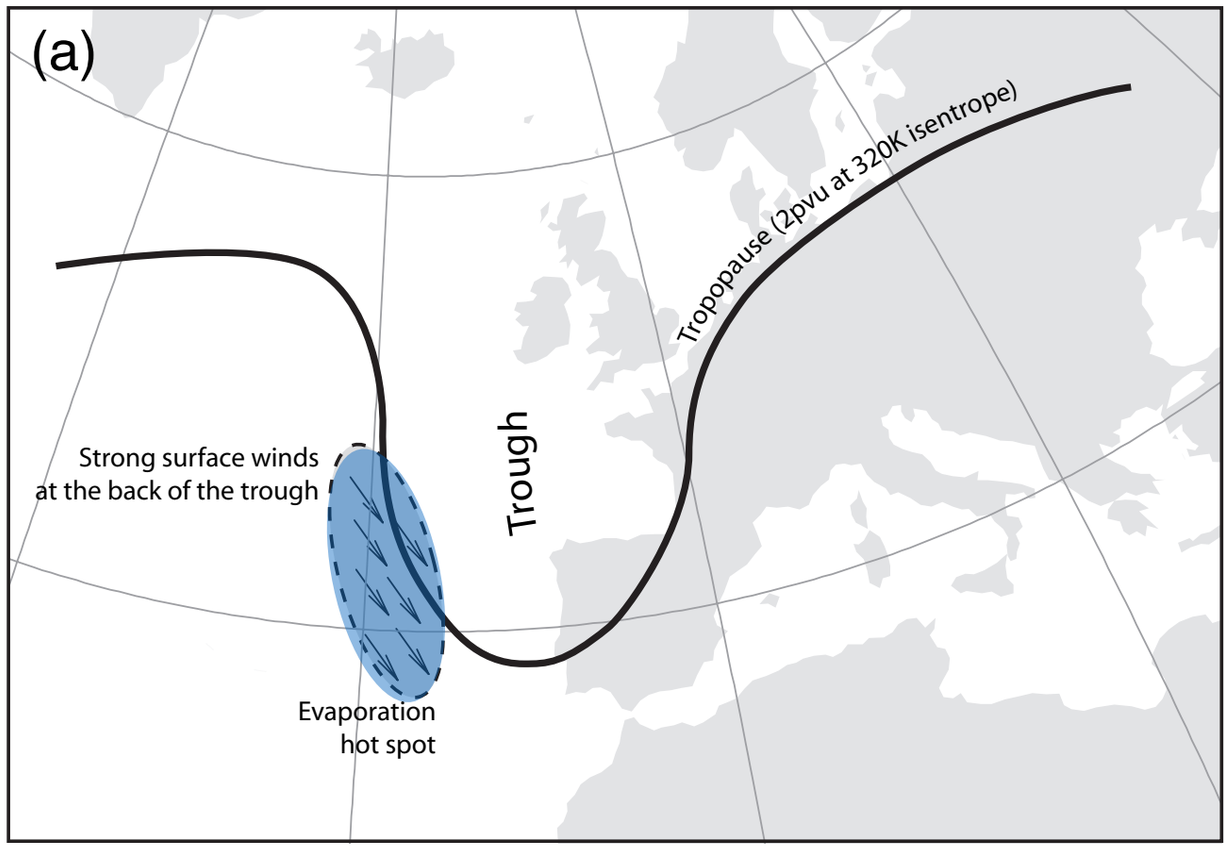
Global average residence time: 9.3 days (8-10 days)

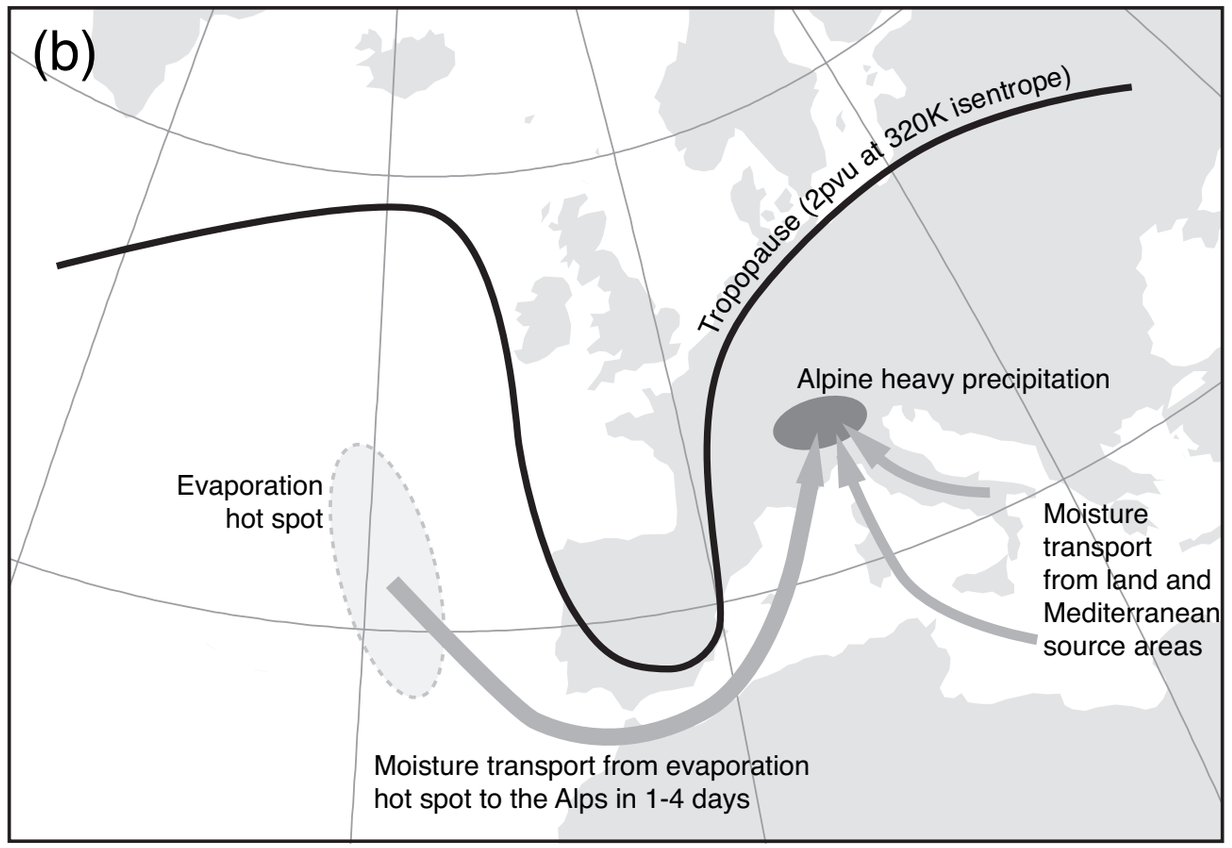
$$\tau \equiv \lambda^{-1} = \frac{w}{P}$$

The depletion time constant is an estimate for the residence time, assuming that precipitation is described adequately by a stationary, random decay process.

Is the depletion time constant an accurate measure for the atmospheric water cycle?

Moisture transport and moisture residence time

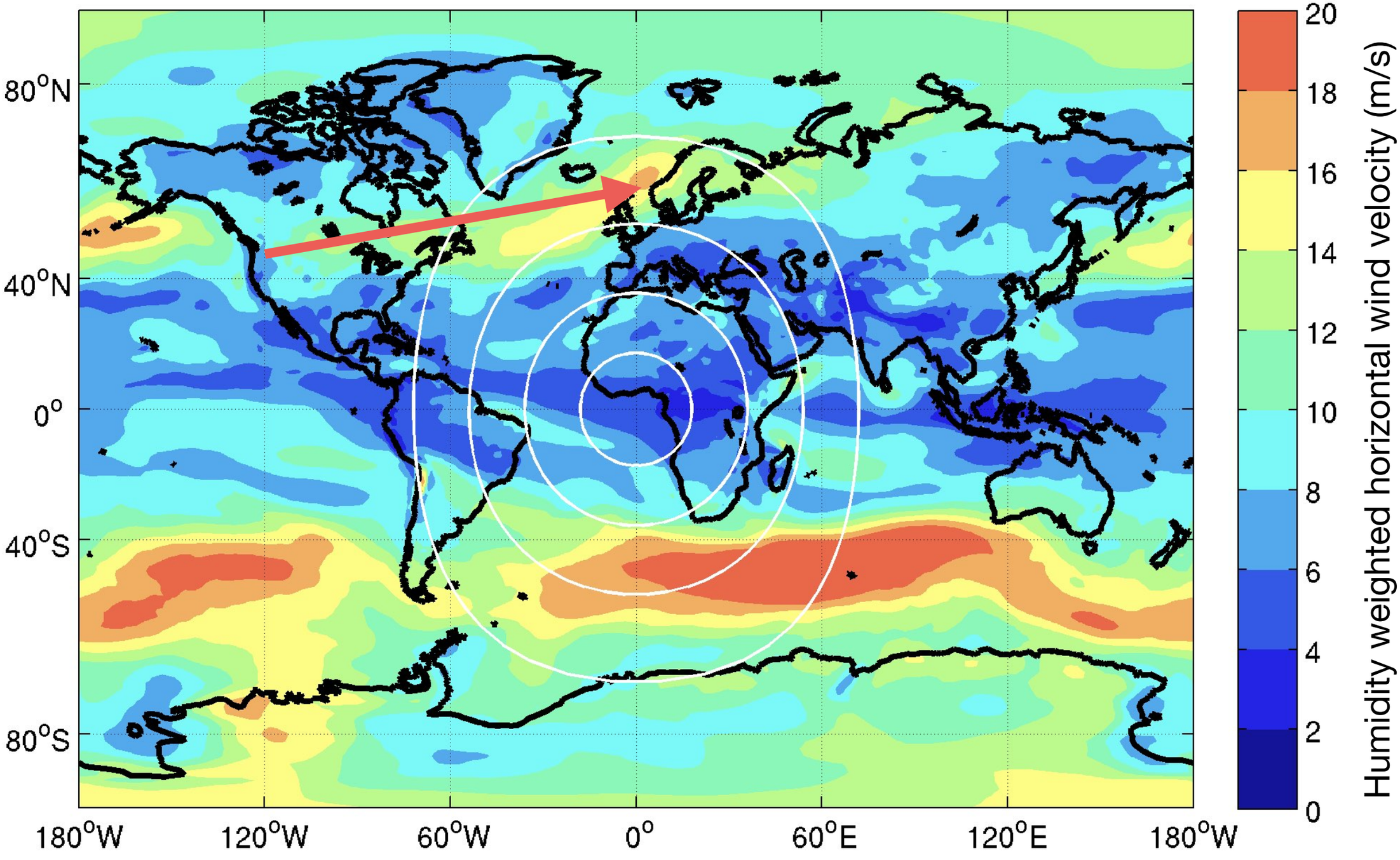




Evaporation hot spot
$E>250\ W\ m^{-2}$

Winschall et al.,QJ, 2012

Column-average humidity-weighted wind velocity

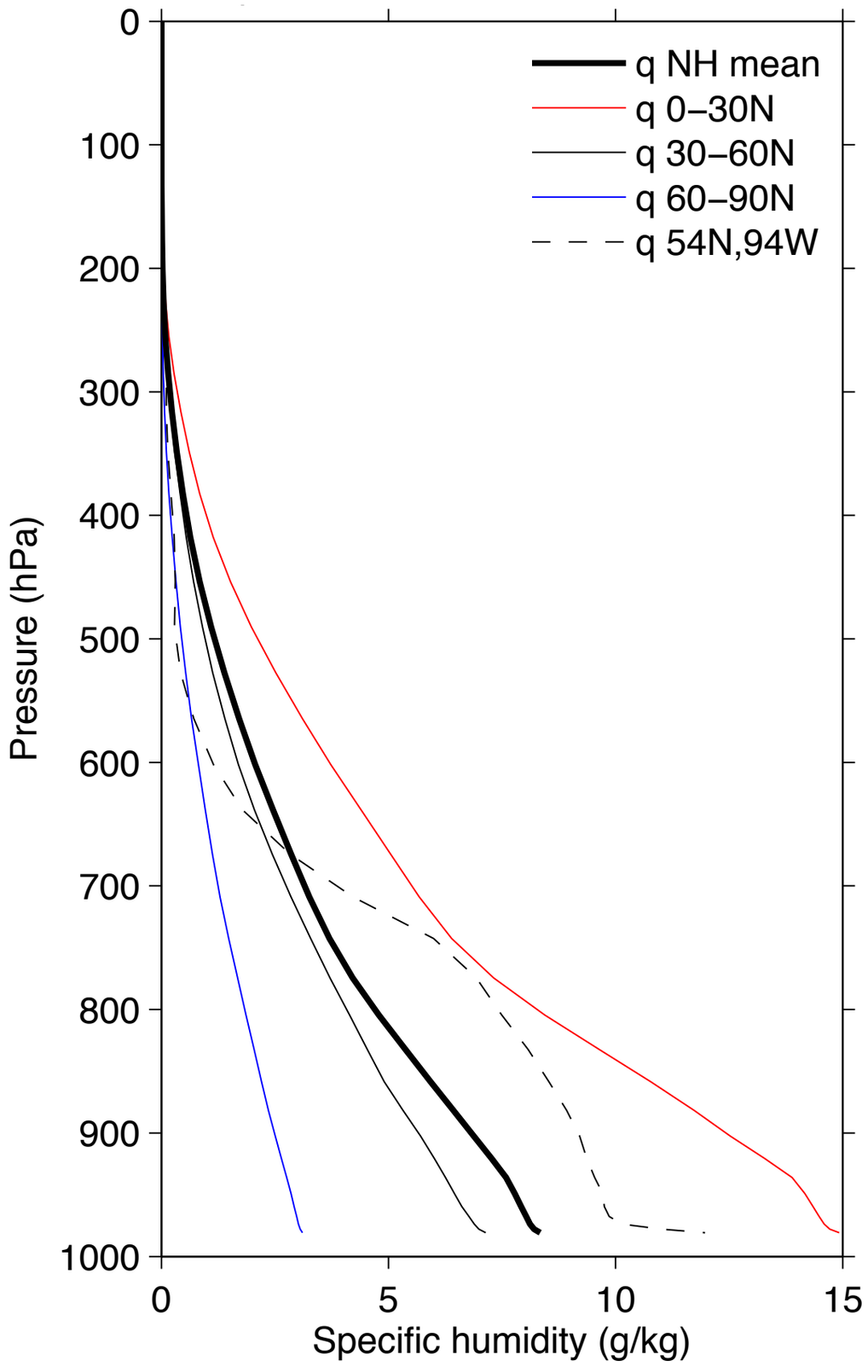


15 m/s: 11000 km in 9 days

5 m/s: 3800 km in 9 days

ERA-Interim, Sep 2010

Atmospheric vertical stratification



Total column water:

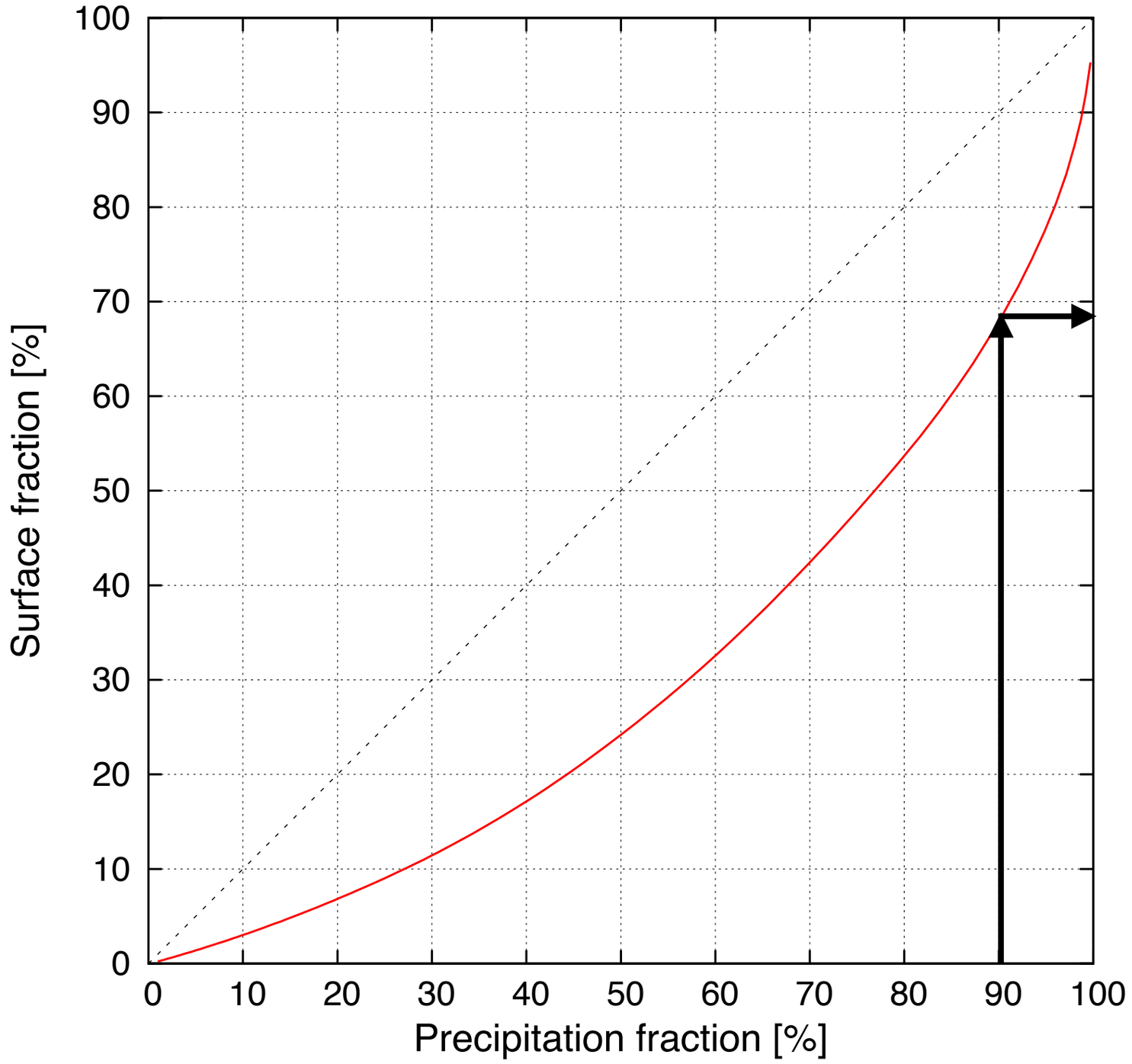
40% below 900 hPa

66% below 780 hPa

90% below 600 hPa

Does rainfall on average deplete the entire column?

Spatial inhomogeneity of precipitation

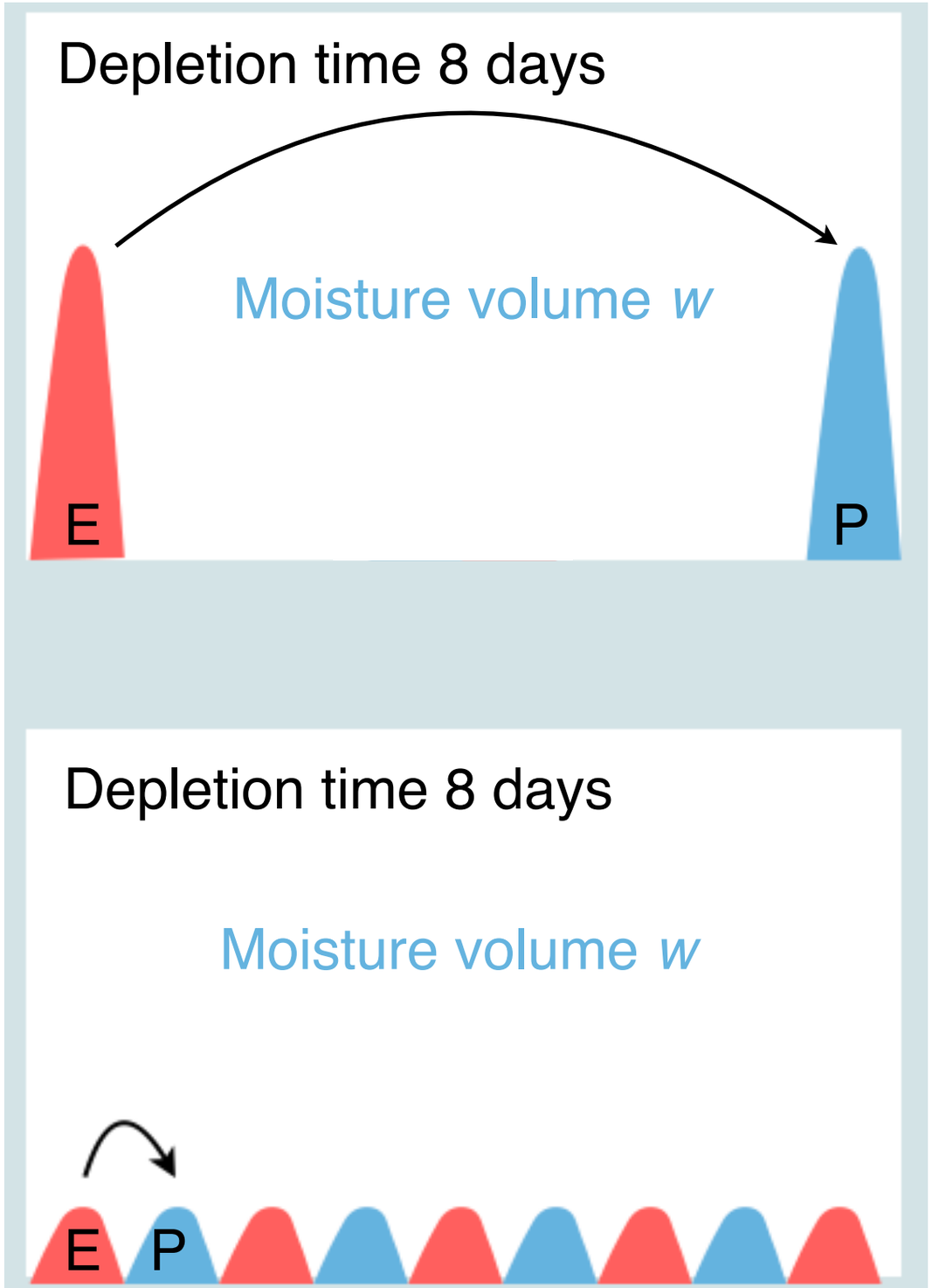


90% of precipitation fall on
70% of land surface

Which global average
rain rate should be used?

Idealised thought experiment

A



B

Residence time: A > B

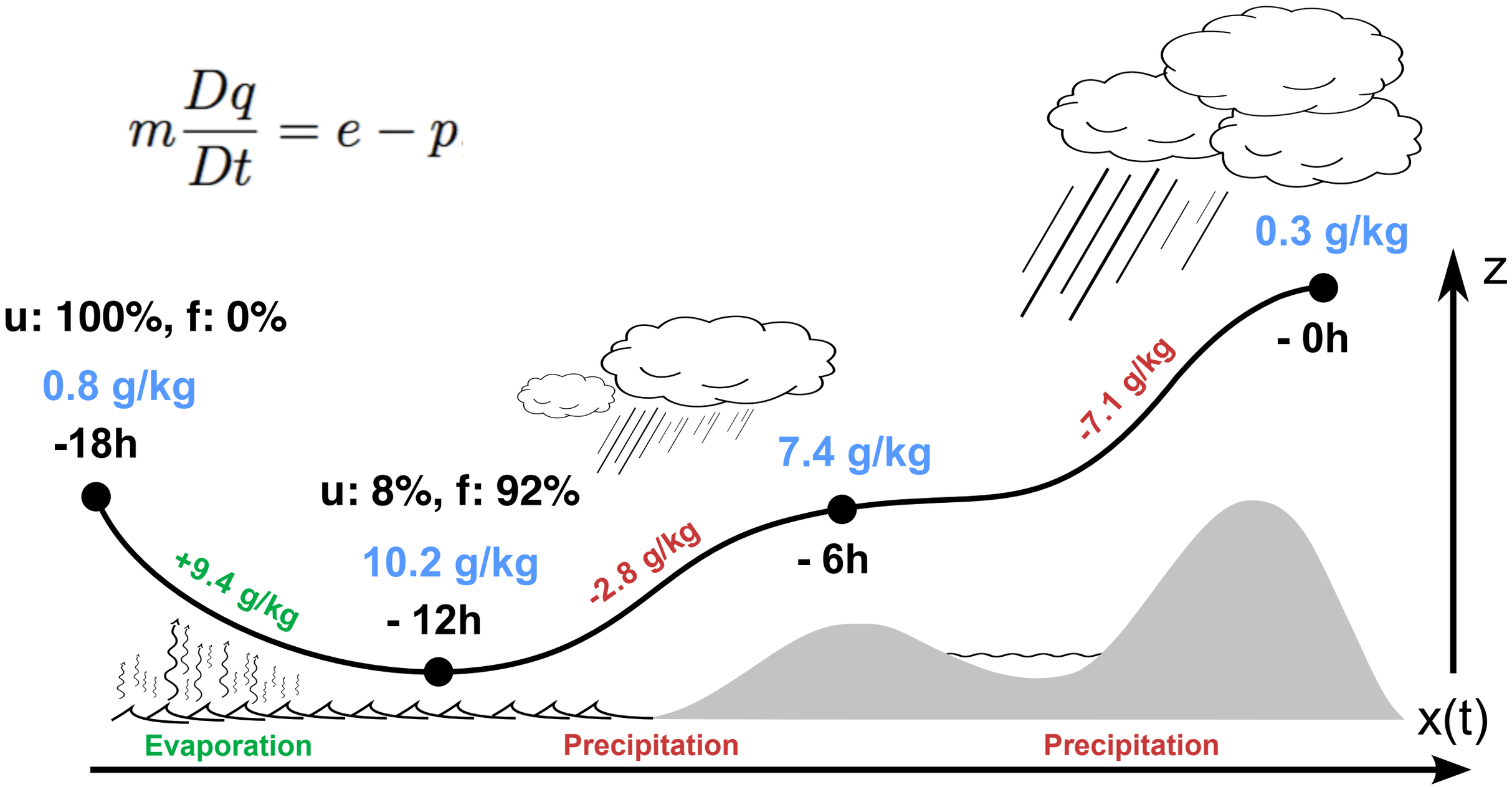
Depletion time: A = B

If the assumptions are violated, depletion times do not provide an esimtate of the atmospheric residence time of water vapour

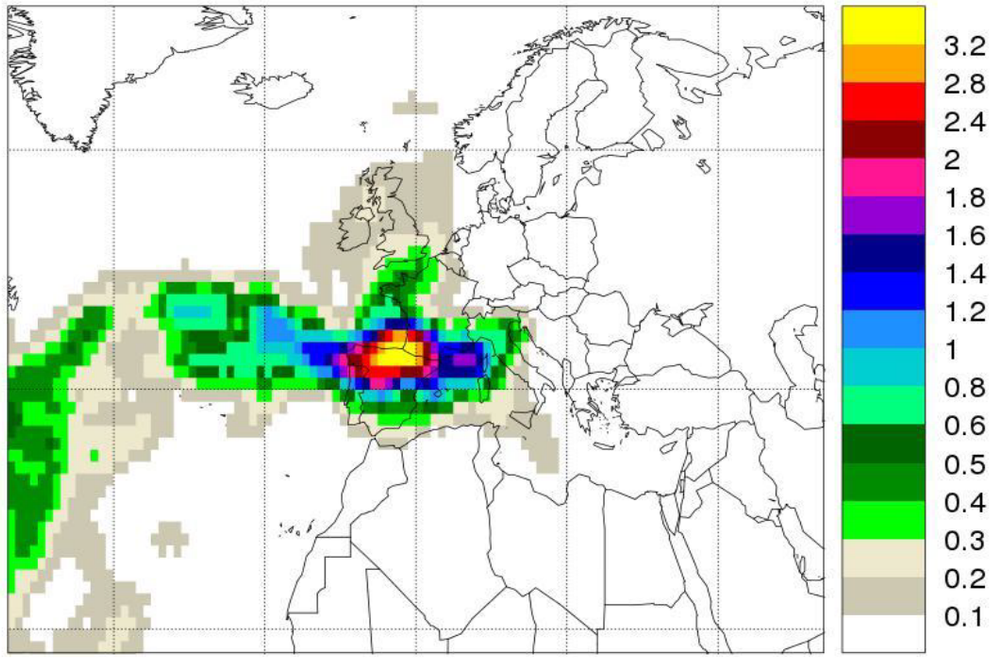
Lagrangian moisture source diagnostic

Läderach and Sodemann, GRL, 2016
Sodemann et al., JGR, 2008

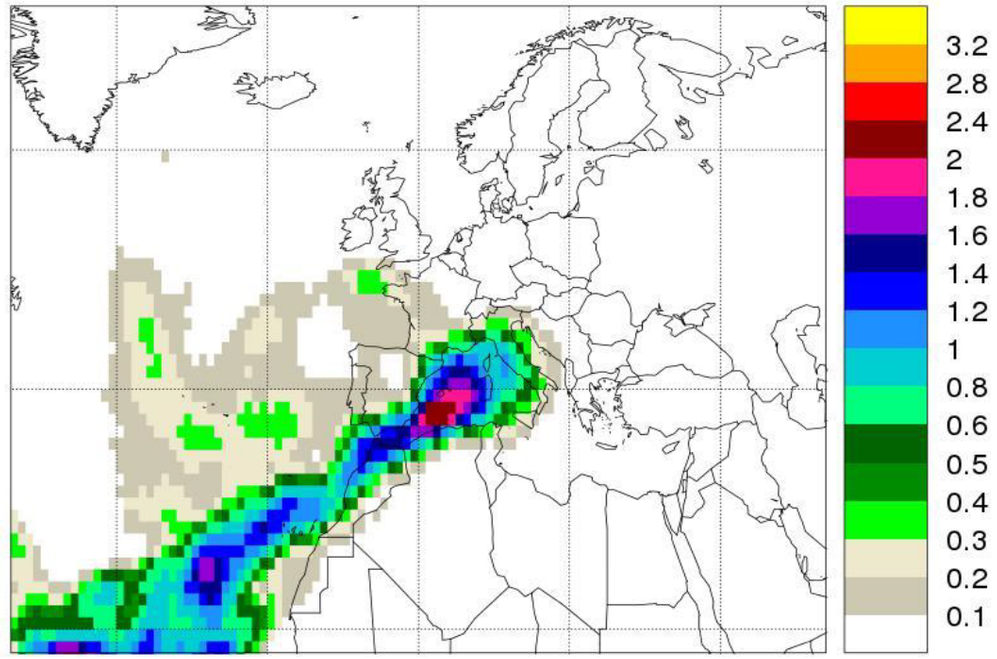
$$m\frac{Dq}{Dt} = e - p$$



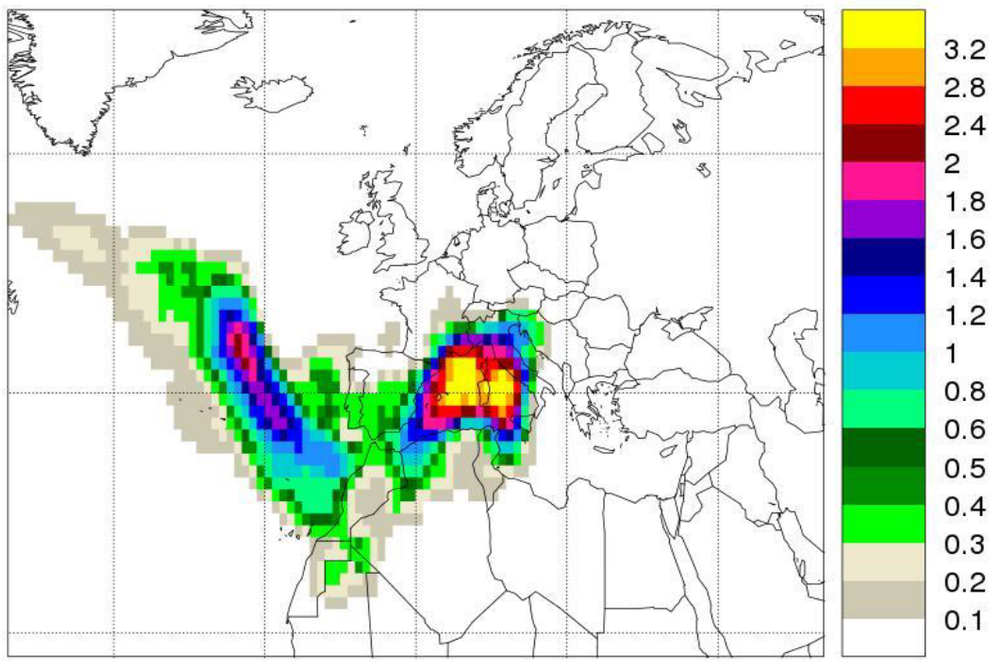
Moisture source variability



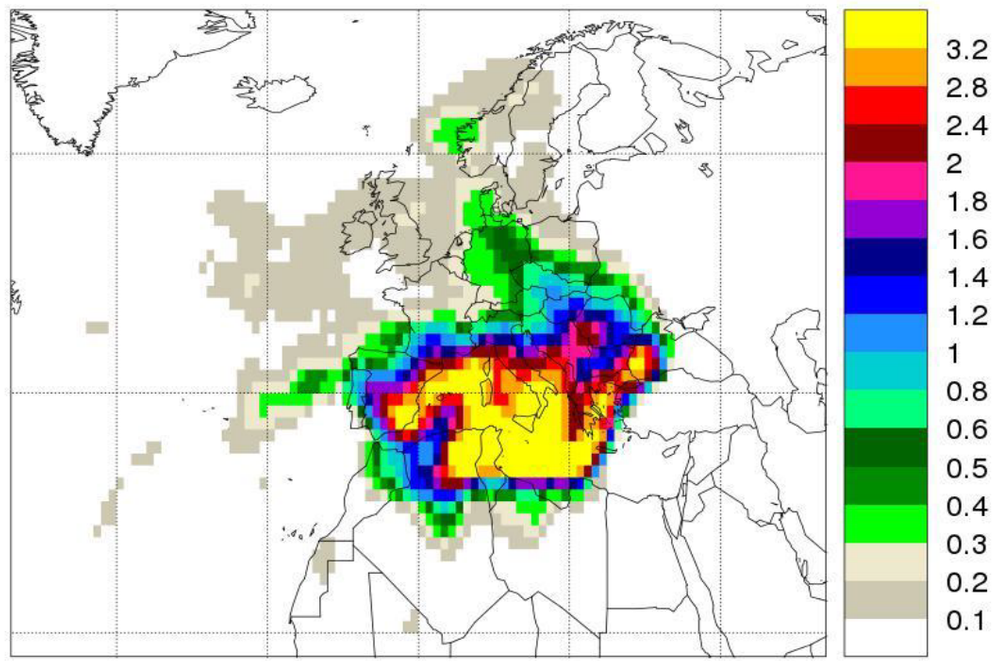
(a) 07 June 1991



(b) 19 December 1996



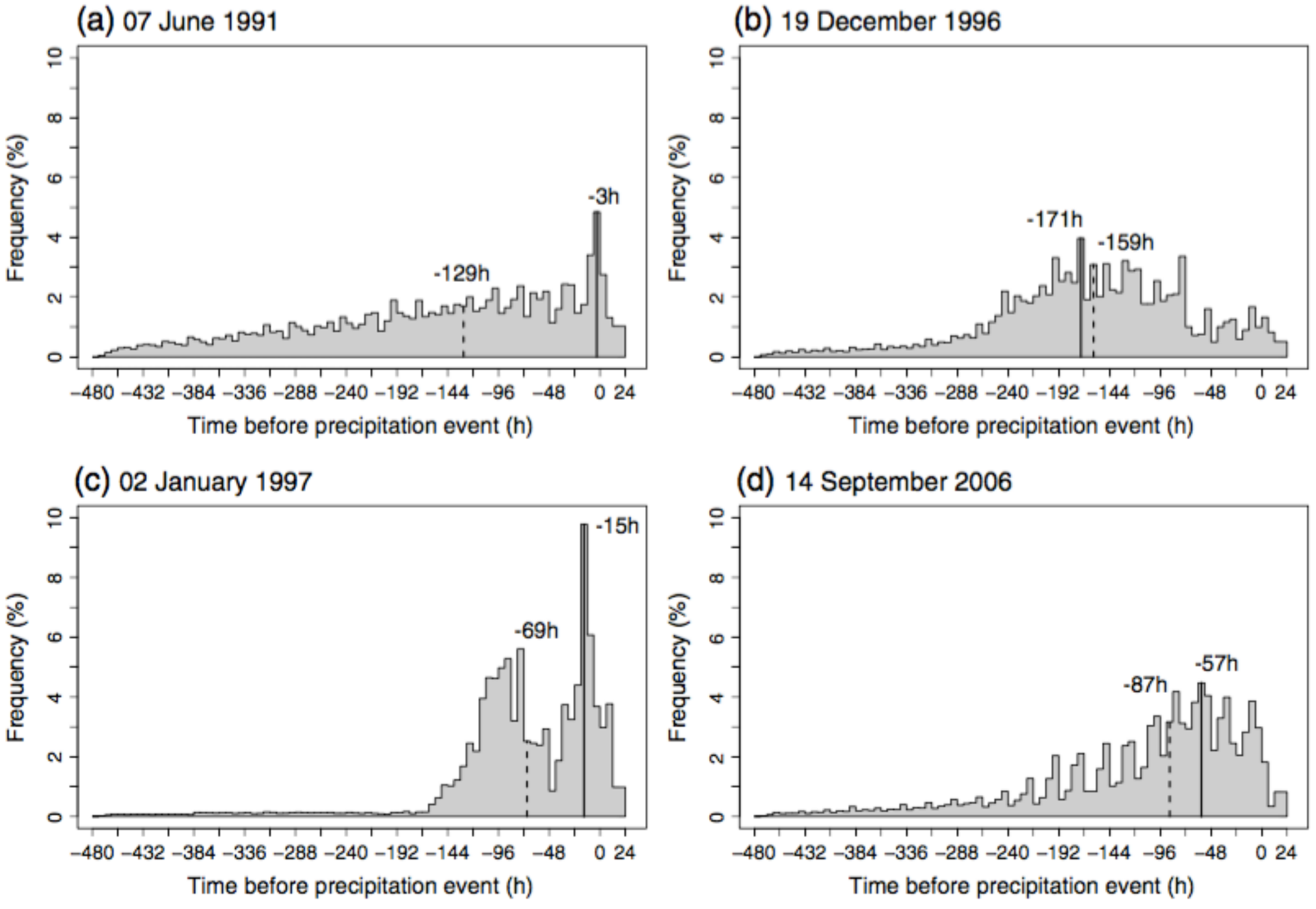
(c) 02 January 1997



(d) 14 September 2006

Winschall et al., 2014

Moisture residence time variability

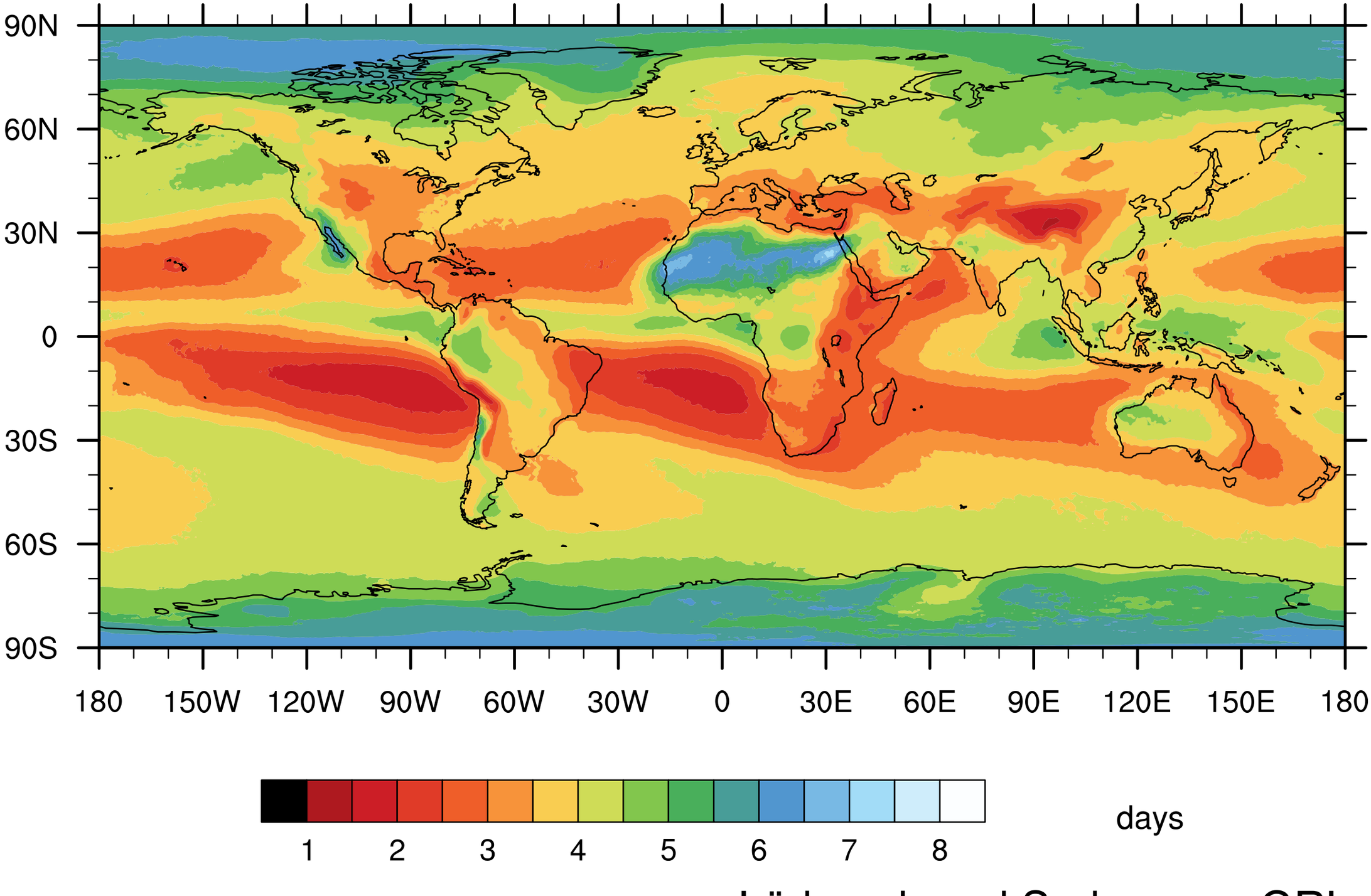


Winschall et al., 2014

Lagrangian moisture residence time

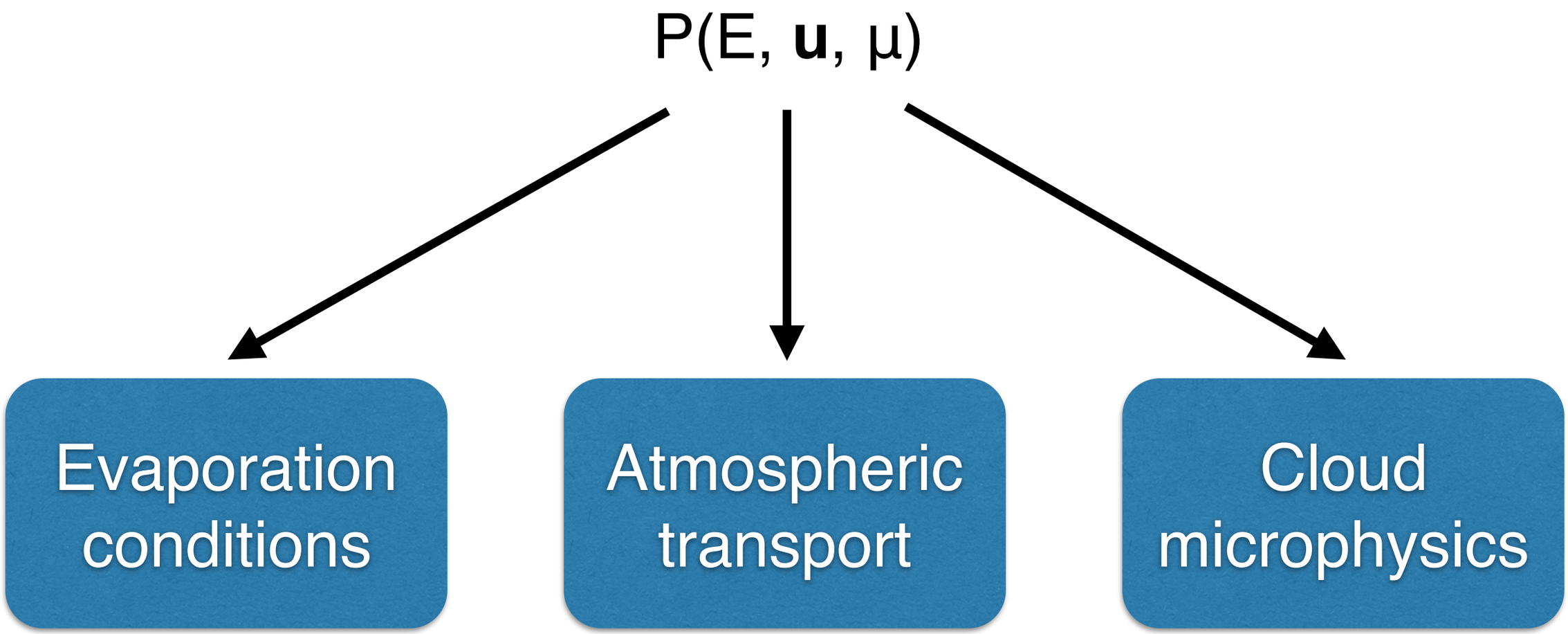
Global mean moisture residence time: 4-5 days

Global mean depletion time: 8-10 days



Läderach and Sodemann, GRL, 2016

How to observe and validate the model water cycle?



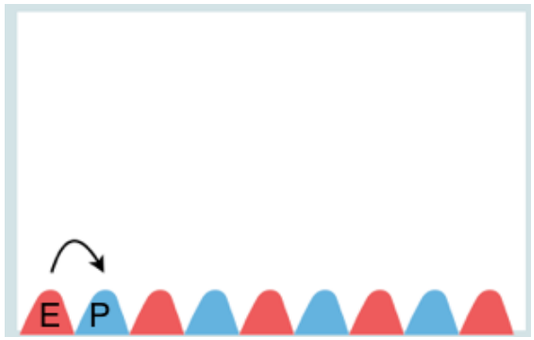
Stable water isotopes are a natural tracer, influenced during phase changes, dependent on temperature, integrating in time

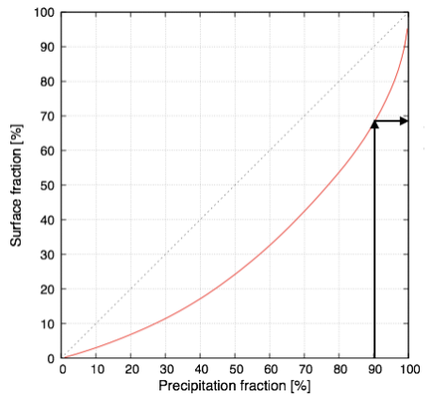
HDO **$H_2{}^{18}O$** **d-excess**

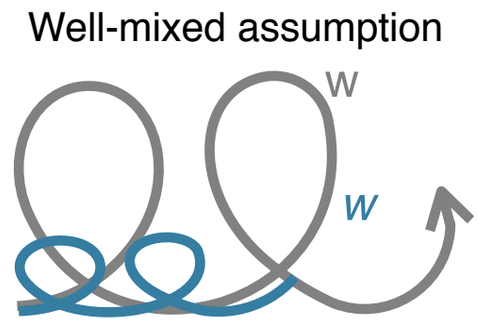
$$\text{d-excess} = \delta D - 8 \cdot \delta^{18} O$$

Summary and Conclusions

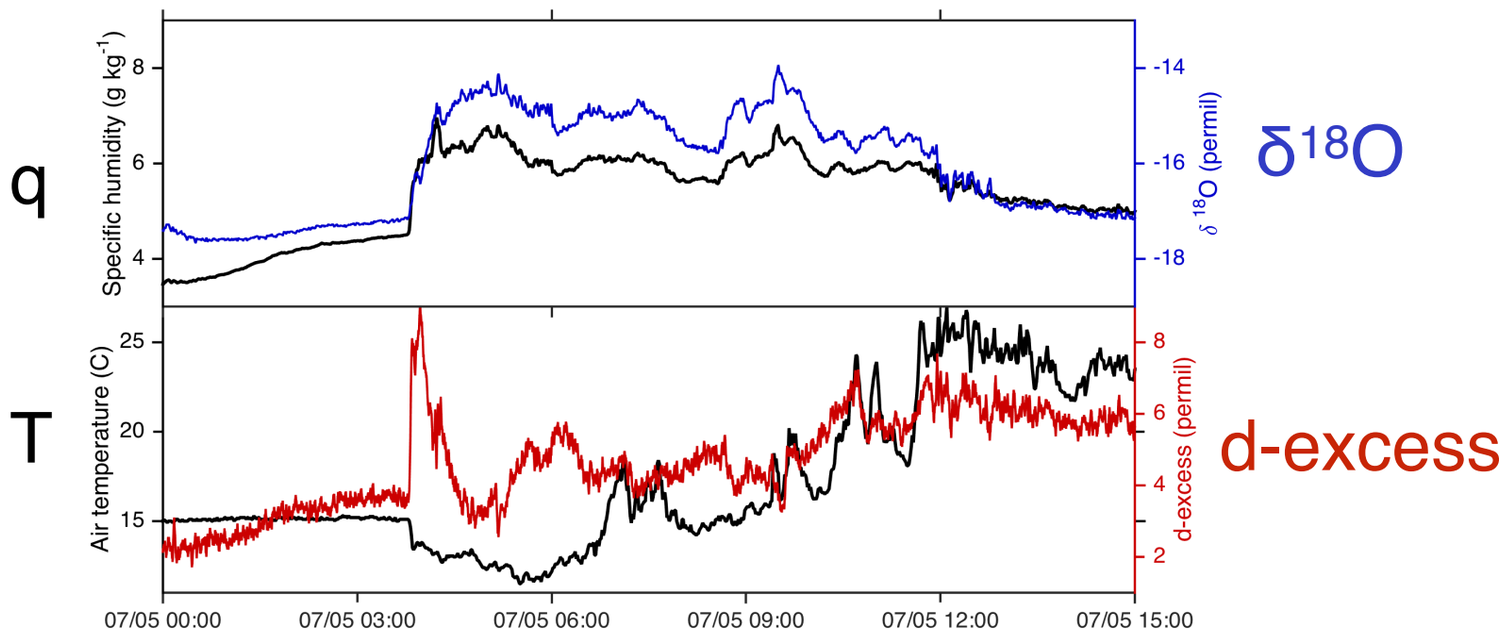
Residence time of water vapour is a key figure
Considering the uncertainties, what is the observational benchmark?



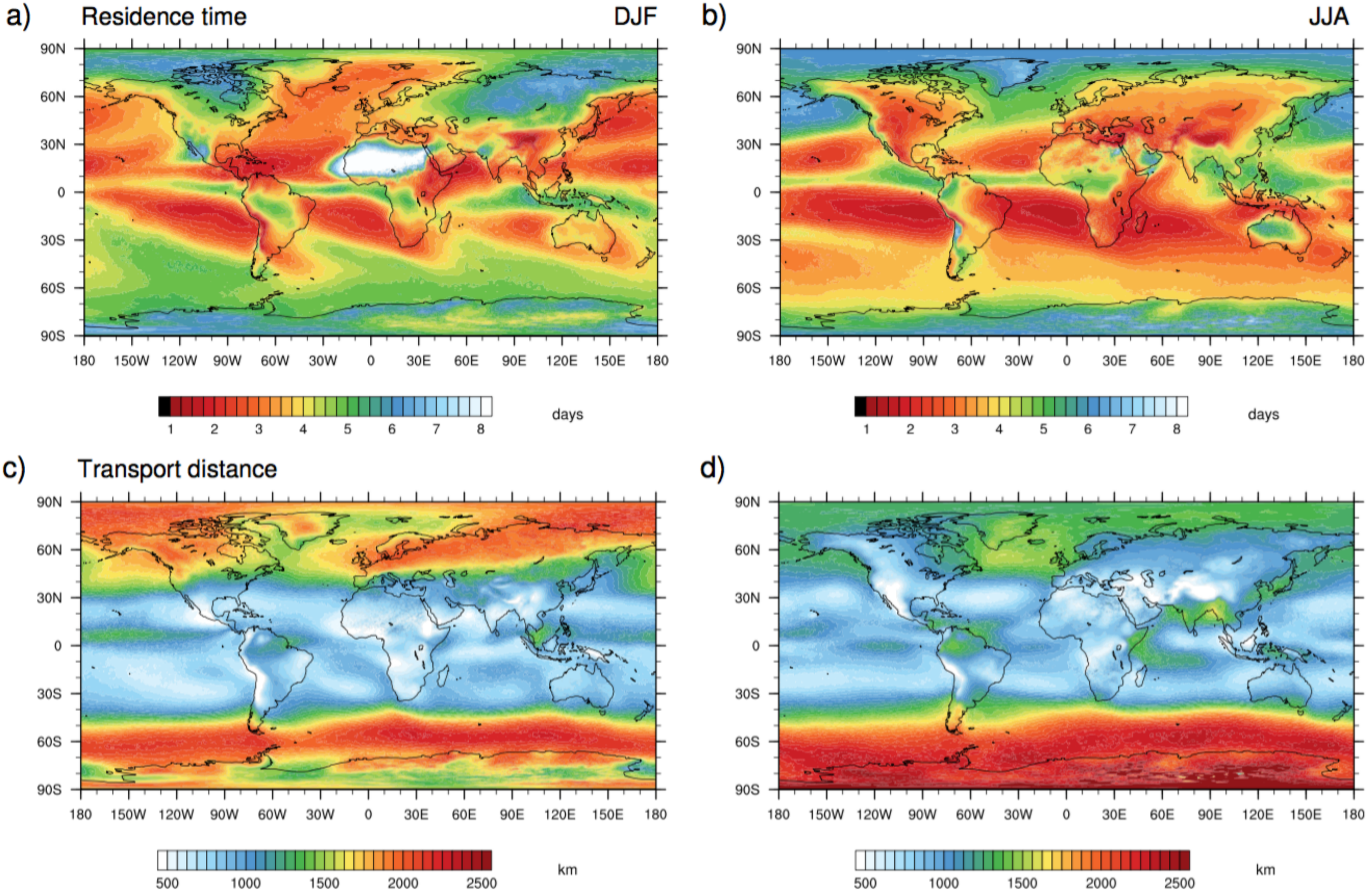




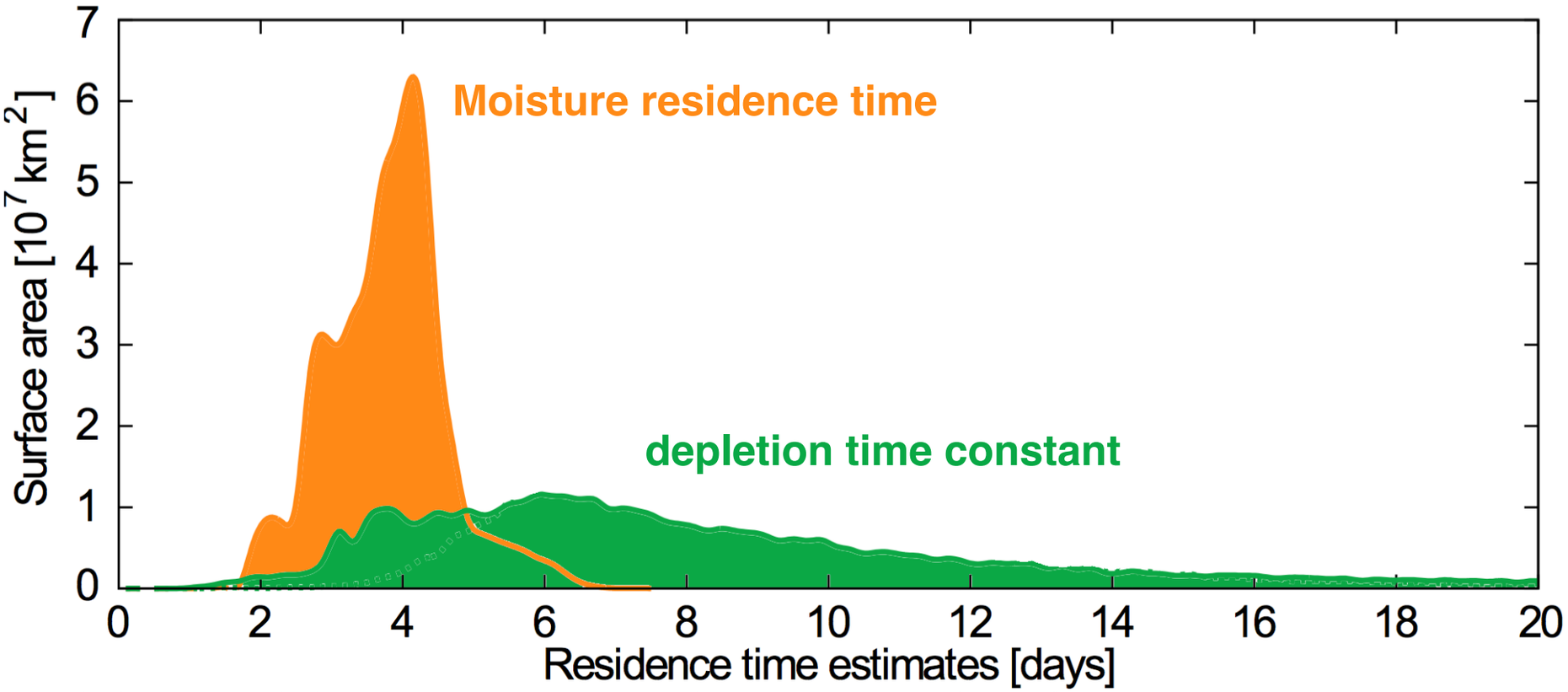
Lagrangian moisture source diagnostics test the model world. Water vapour tracers are an additional means of model-based diagnostics. In addition, stable water isotopes can provide observational constraints.



Seasonality of residence time and transport distance



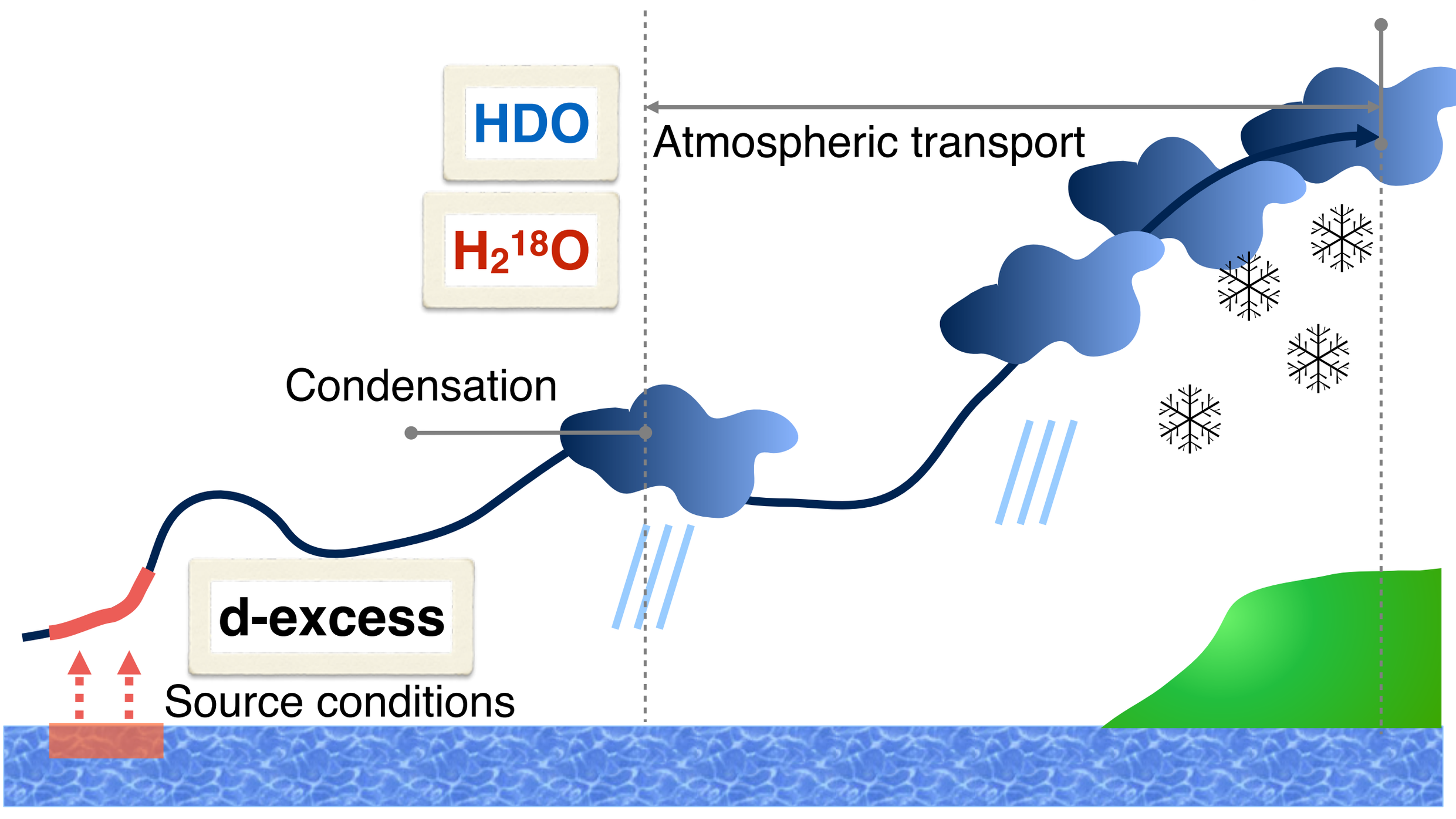
Spatial annual-mean histogram



Contributions to stable isotope fractionation

Combined source and transport signal ("transport history")

Temperature is the principal driver of fractionation



Sodemann et al., JGR, 2008