Reconstructing the past to understand the present: inferring Amazon climate from tree ring oxygen isotopes

Jess Baker

Contributors : Manuel Gloor, Dominick Spracklen, Steve Arnold, Arnoud Boom, Julia Tindall, Santiago Clerici, Melanie Leng and Roel Brienen

NERC
SCIENCE OF THE ENVIRONMENT

@JessTreeBaker

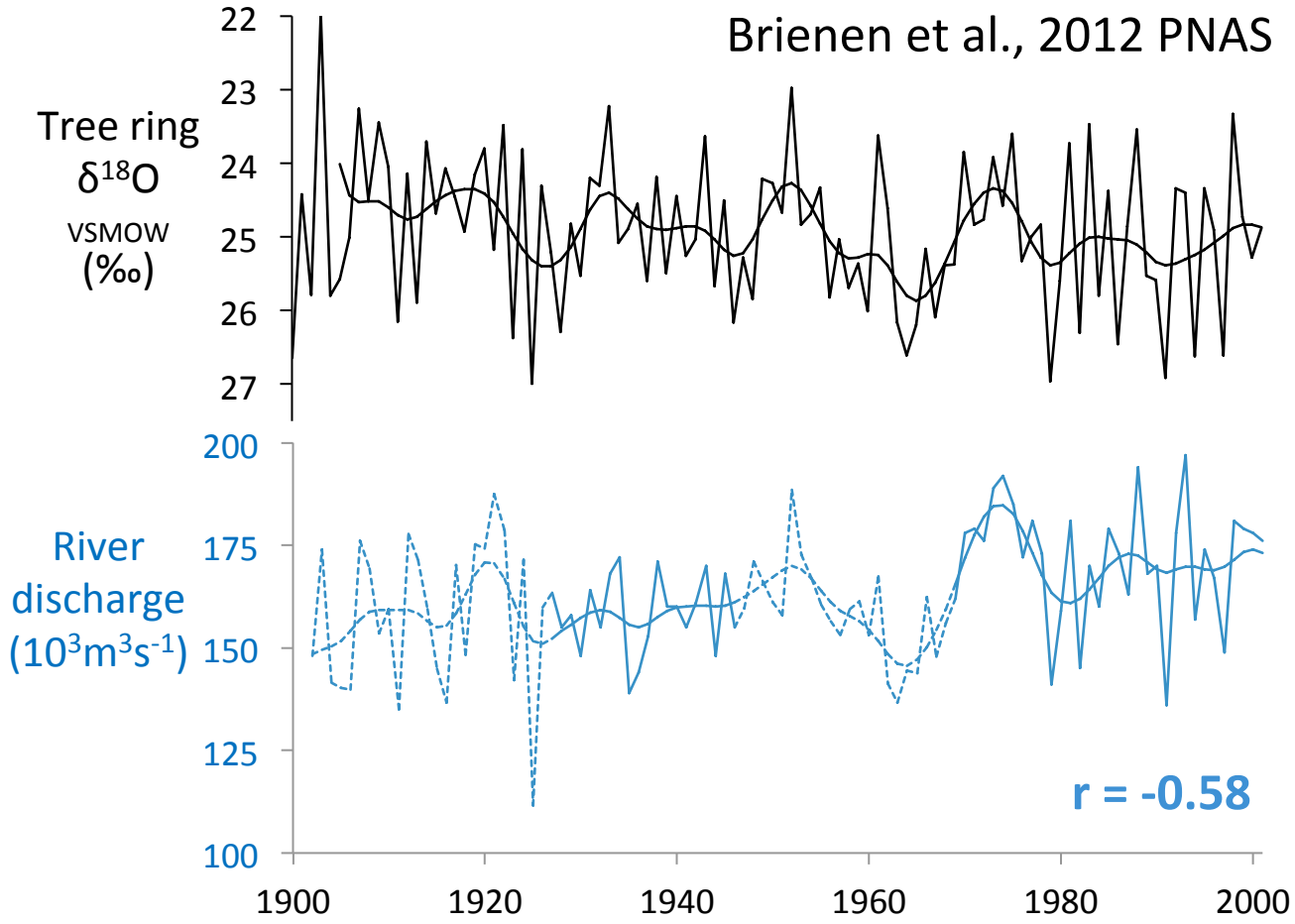
UNIVERSITY OF LEEDS

Introduction to tree rings

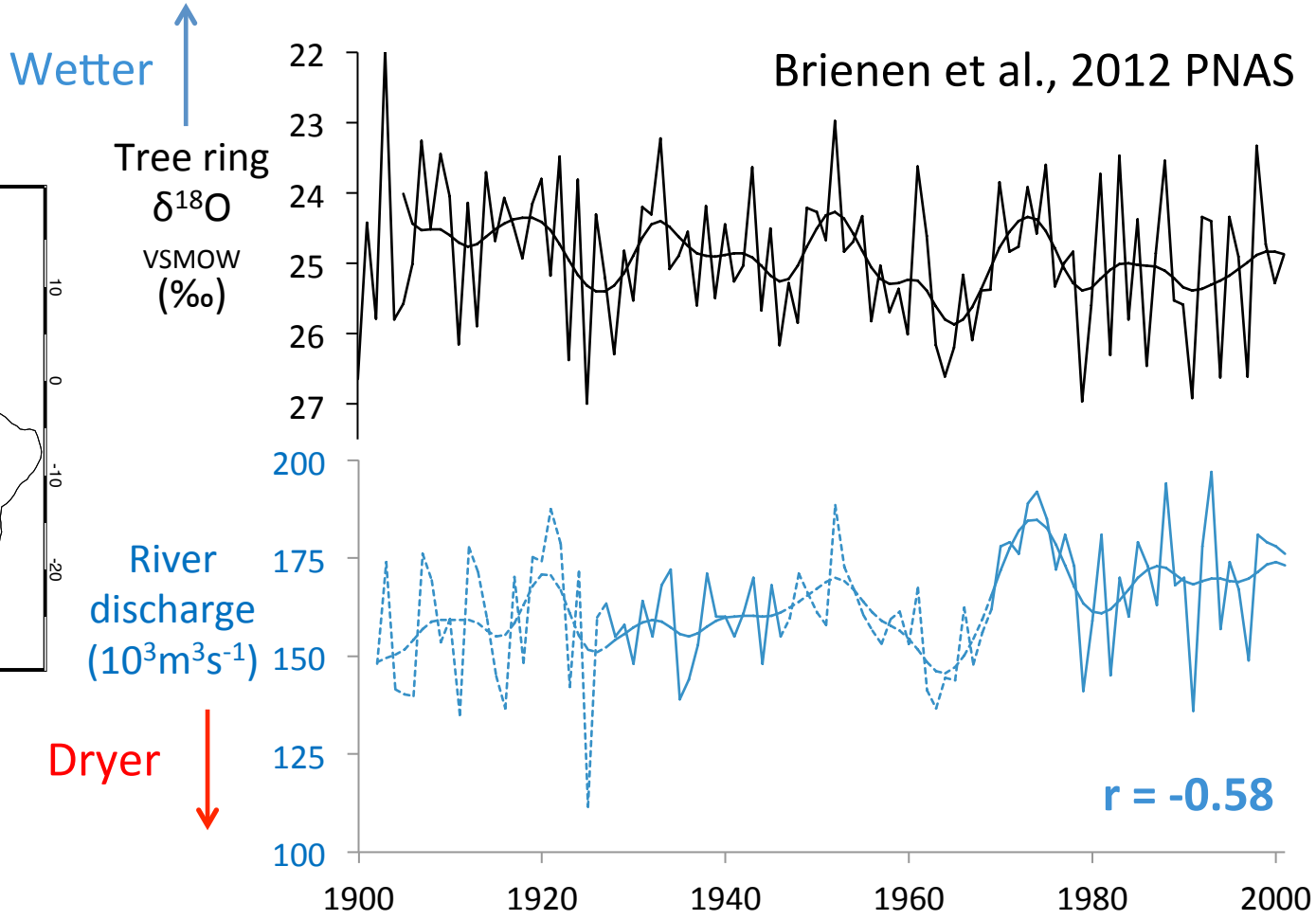
- Tree rings are a natural climate record
- Annual ring formation now confirmed in 230 tropical tree species (Brienen et al., 2016)
- Various tree ring characteristics can contain information about climate

Tree ring oxygen isotopes ($\delta^{18}O_{TR}$) in the Amazon

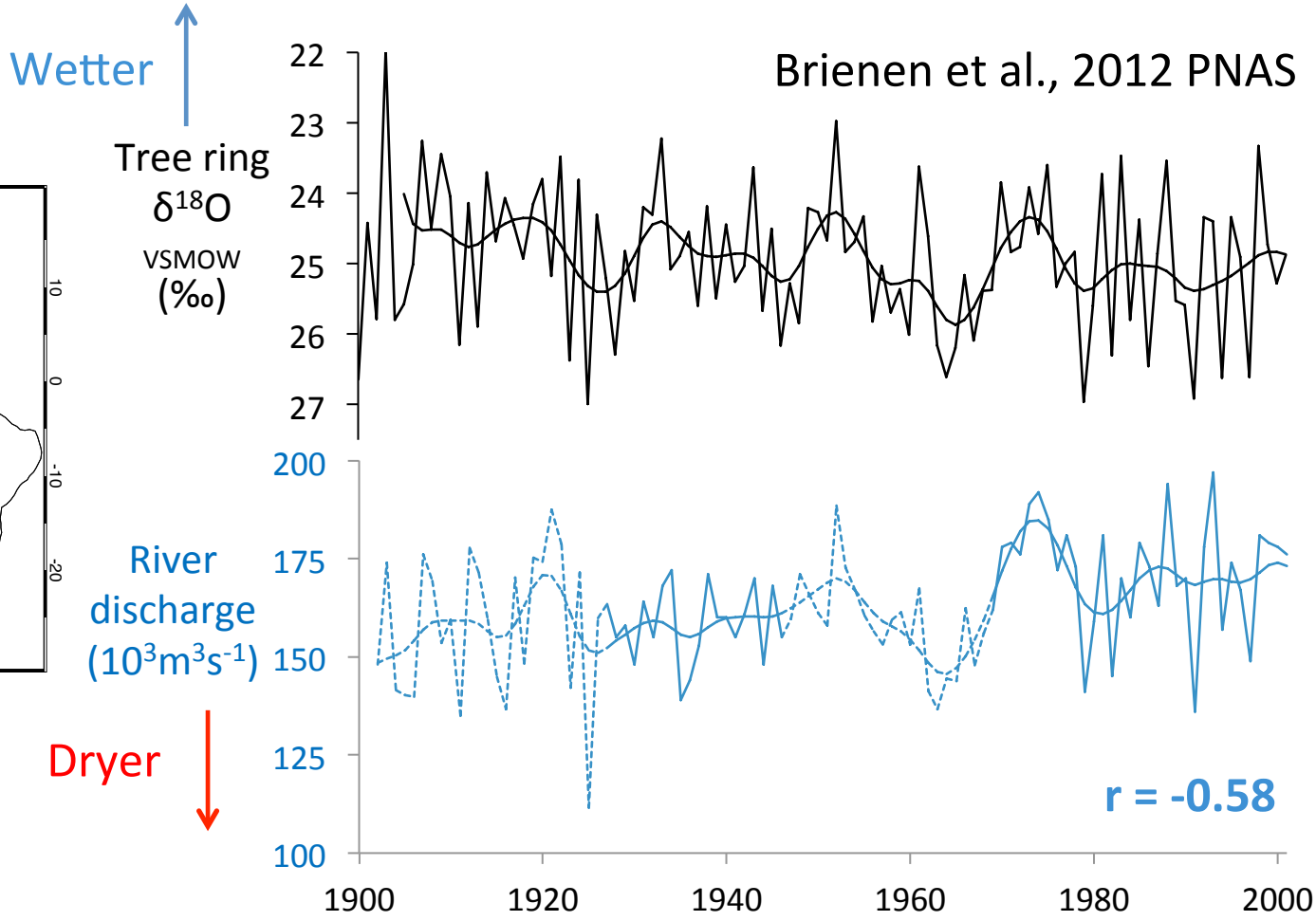
Tree ring oxygen isotopes ($\delta^{18}O_{TR}$) in the Amazon



Tree ring oxygen isotopes ($\delta^{18}O_{TR}$) in the Amazon

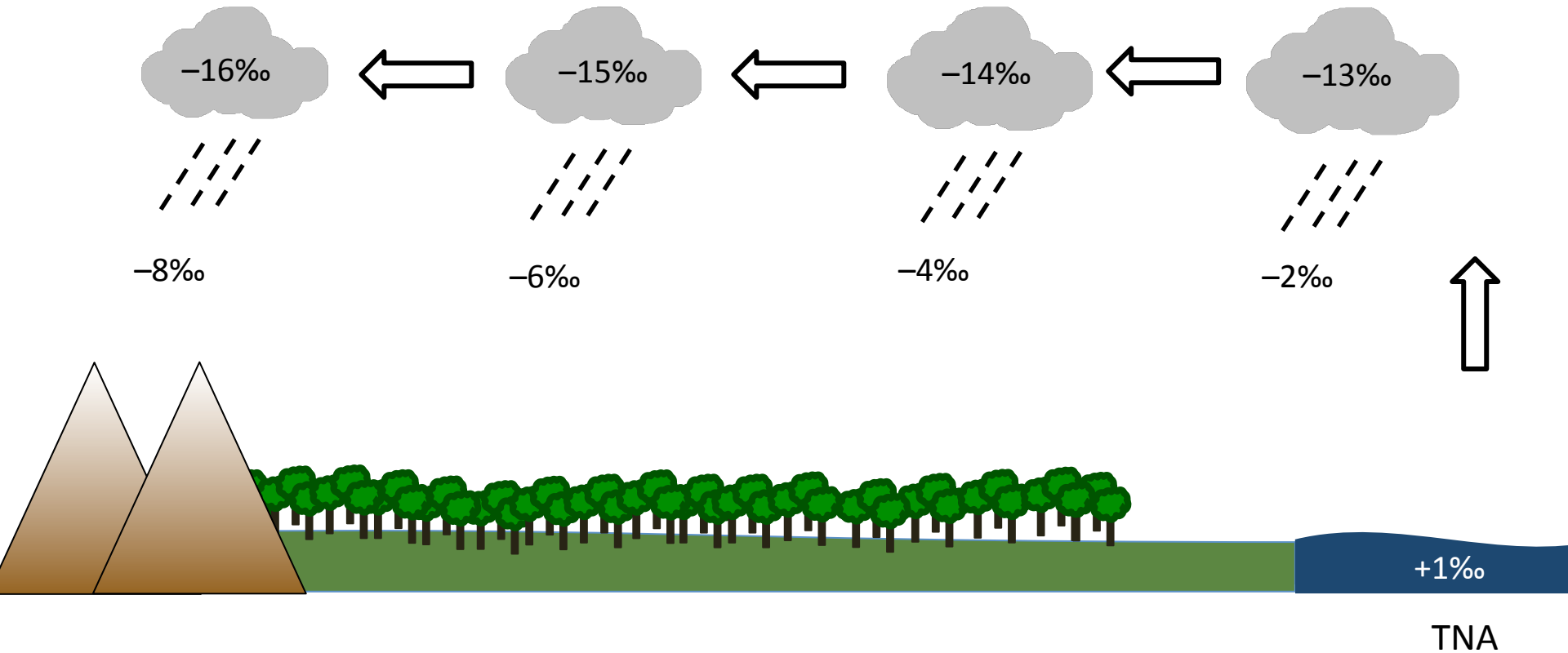


Tree ring oxygen isotopes ($\delta^{18}O_{TR}$) in the Amazon

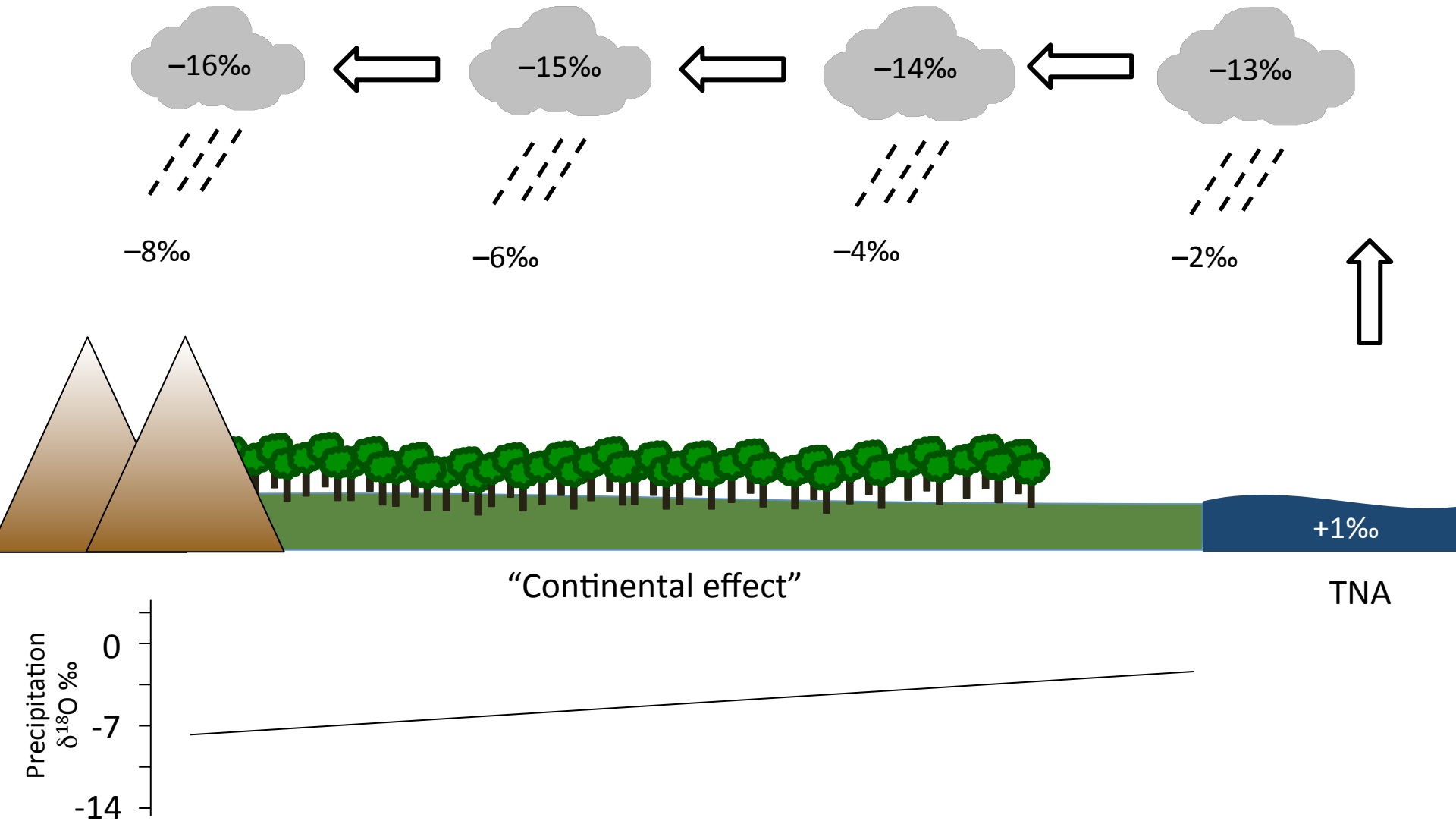


Why is $\delta^{18}O_{TR}$ a proxy for precipitation over such a large area?

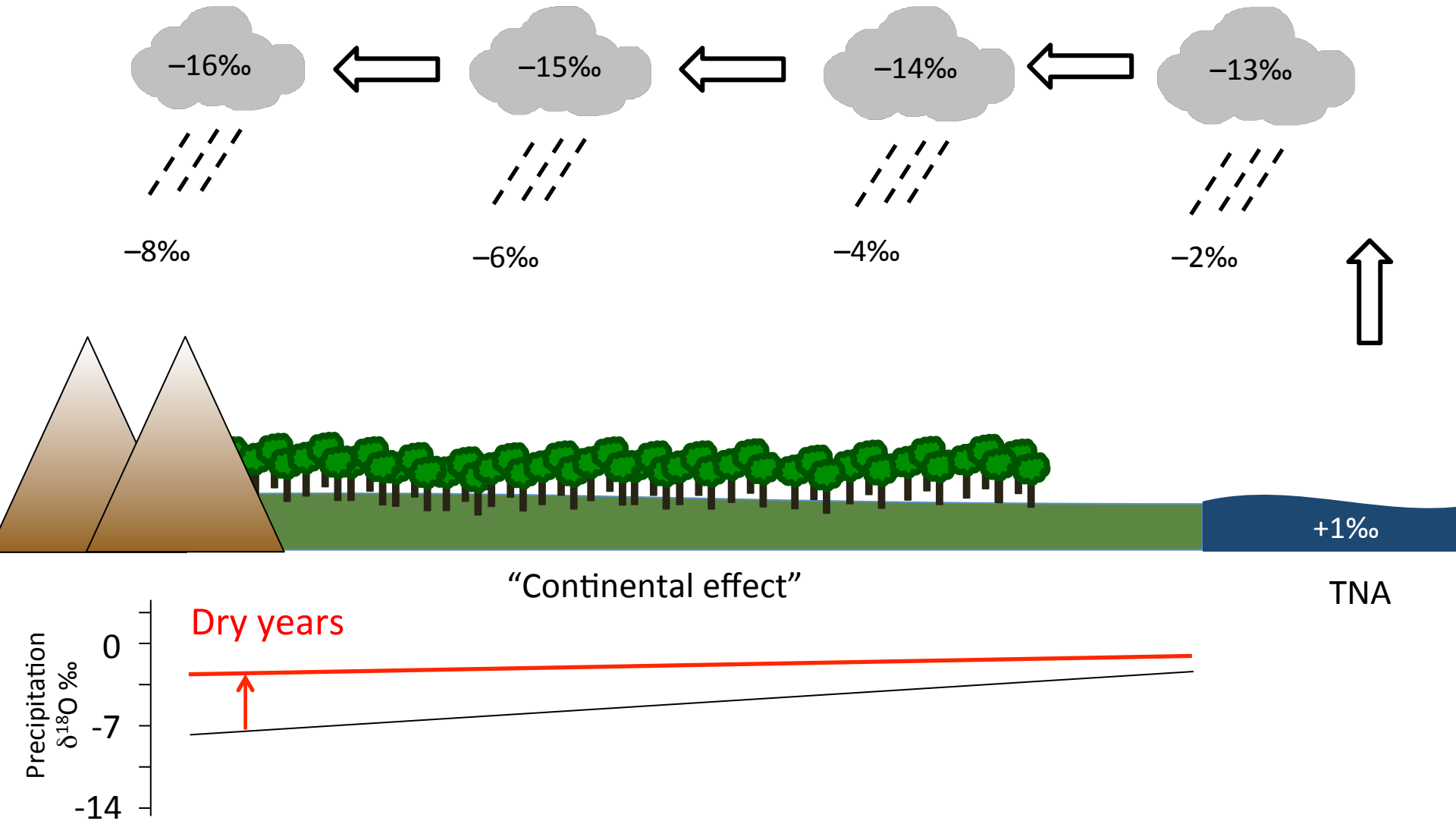
Isotopes in the Amazon hydrological cycle



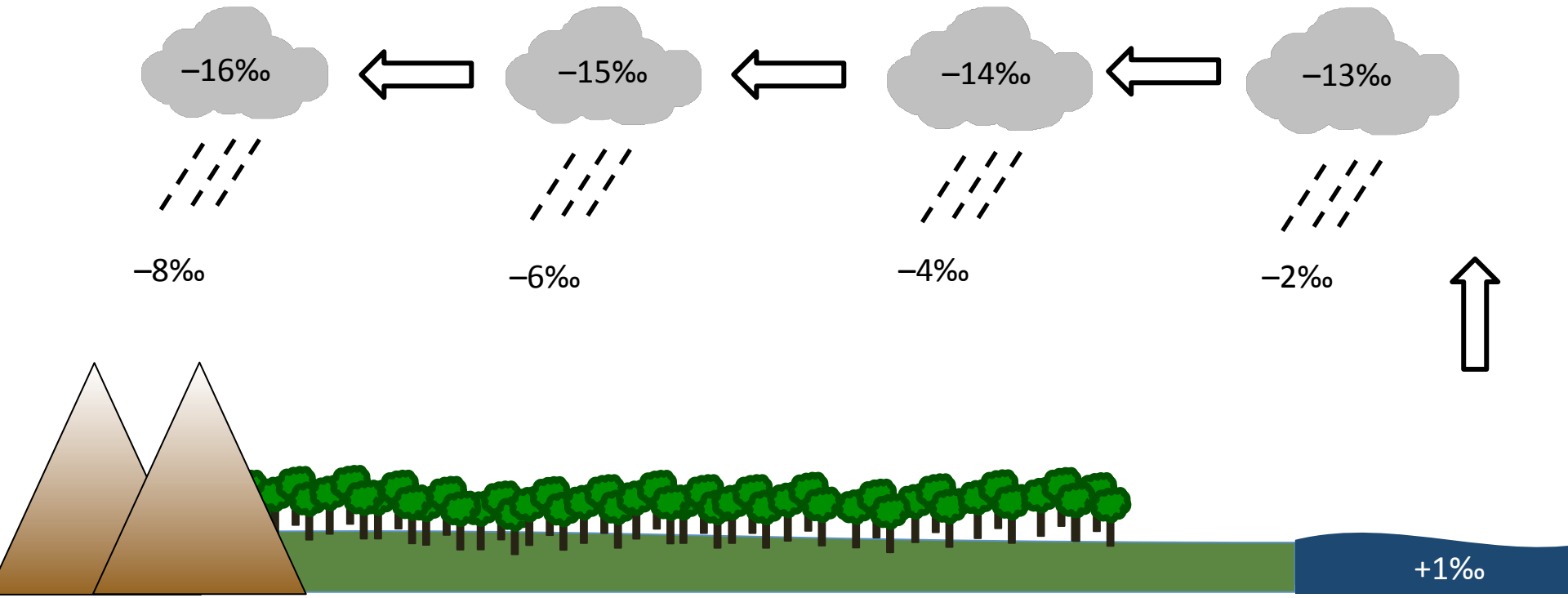
Isotopes in the Amazon hydrological cycle



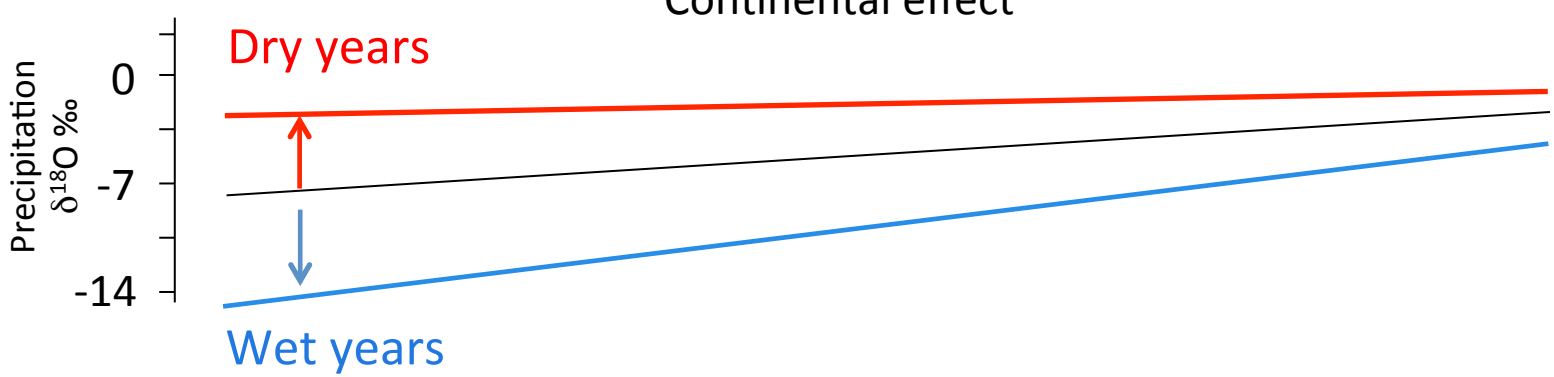
Isotopes in the Amazon hydrological cycle



Isotopes in the Amazon hydrological cycle

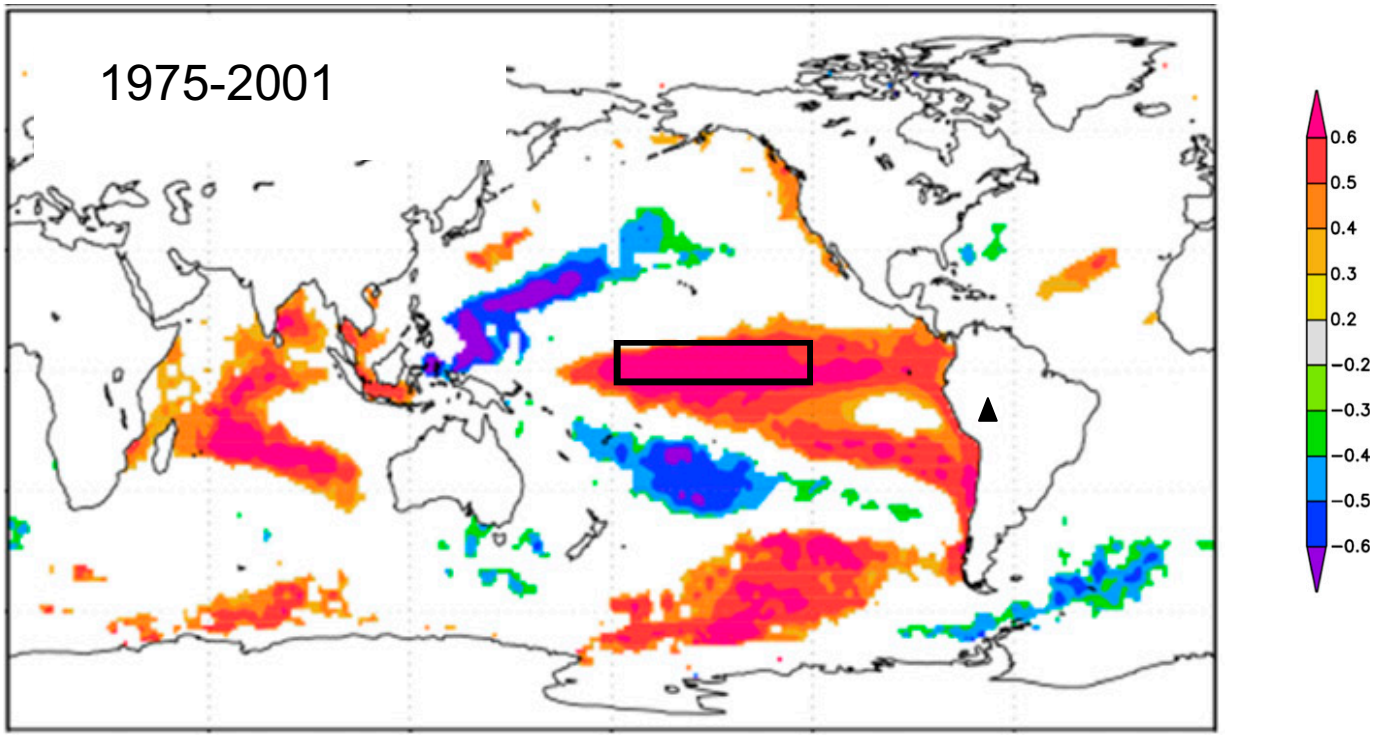


"Continental effect"

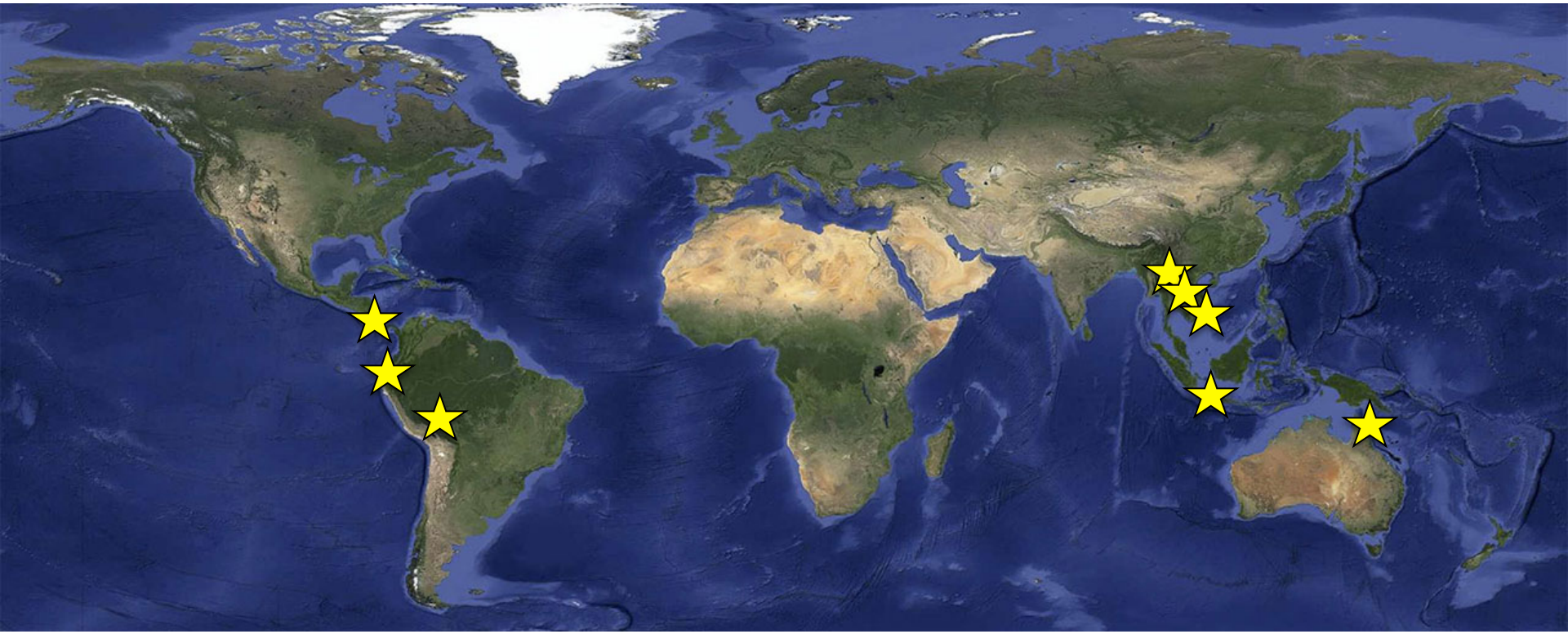


But $\delta^{18}O_{TR}$ also correlates strongly with SSTs and the El Niño Southern Oscillation

Brienen et al., 2012 PNAS

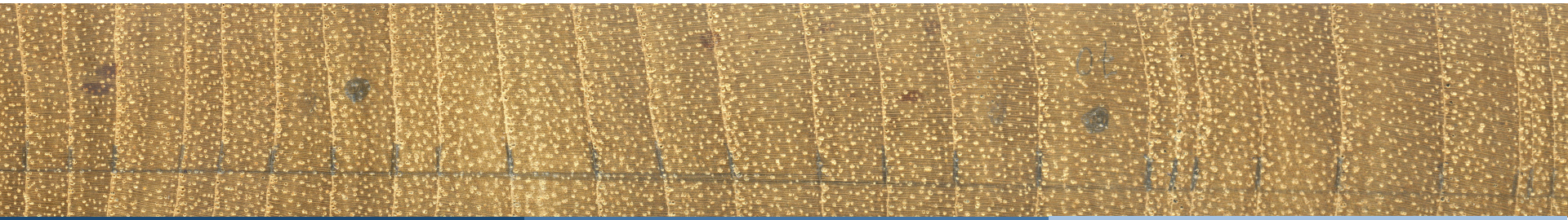


Studies which found a relationship between $\delta^{18}O_{TR}$ and ENSO

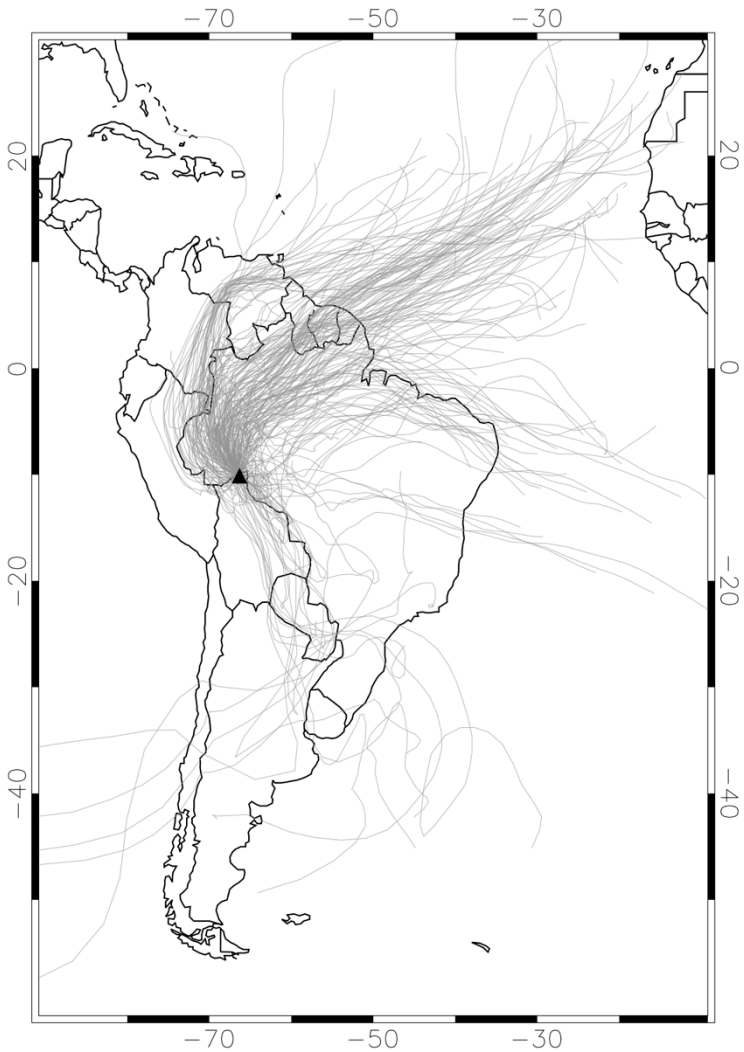


Is the $\delta^{18}O_{TR}$ signal pantropical and therefore not a direct reflection of Amazon climate?

What drives interannual variation in $\delta^{18}O_{TR}$ in the Amazon?

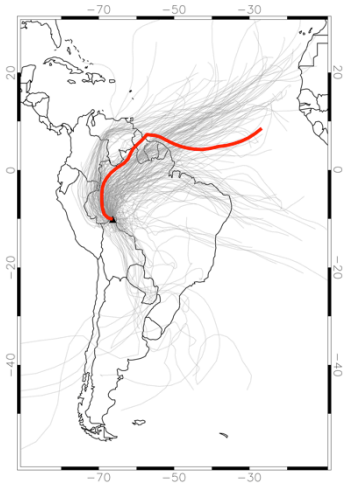


Approach 1: Back trajectory analysis

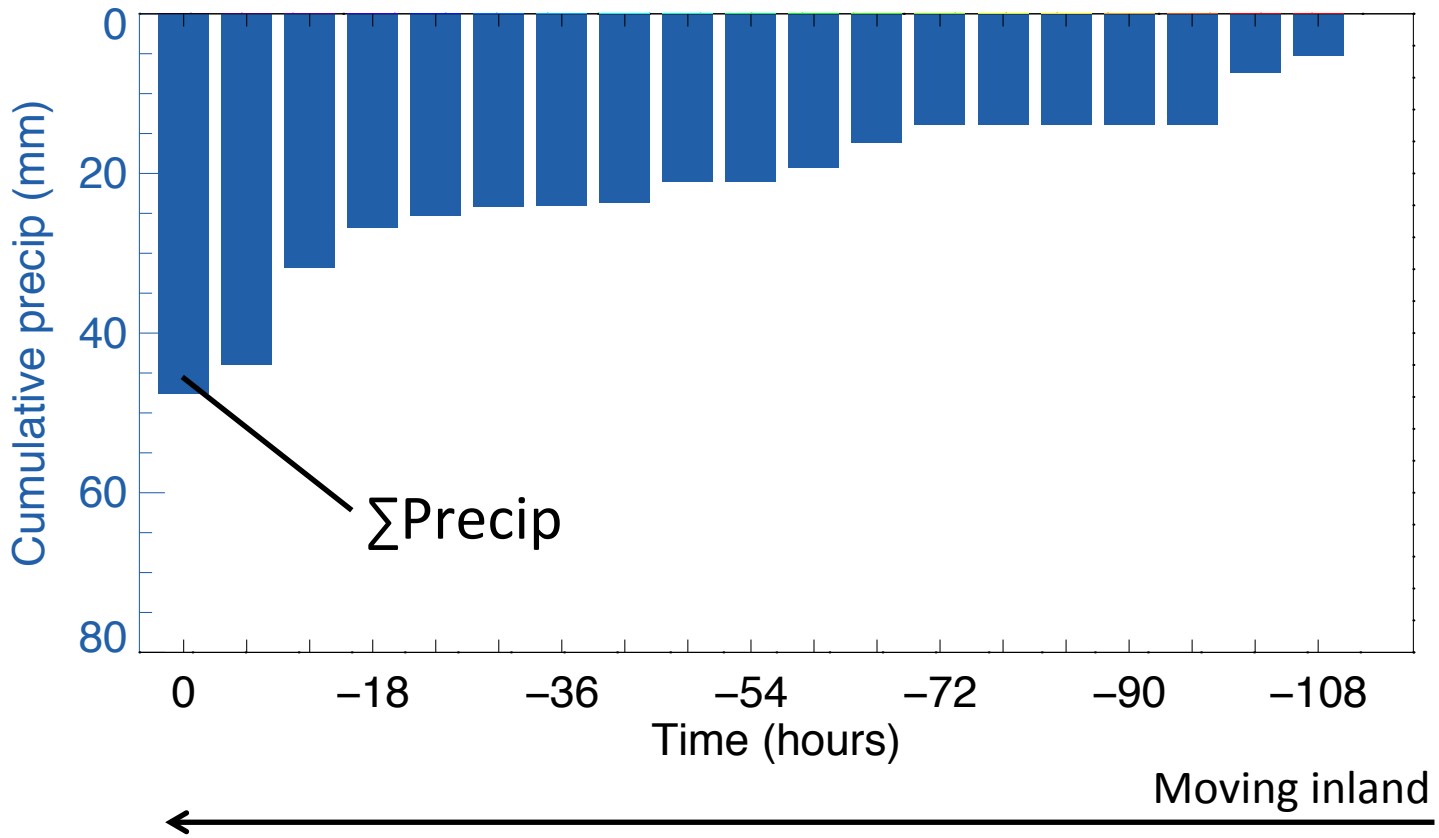


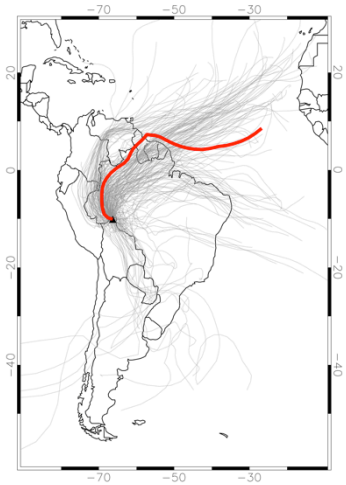
2010 wet season trajectories

- ROTRAJ trajectory model (Methven, 1997)
- ECMWF ERA-Interim reanalysis wind data
- Calculate daily 10-day back trajectories for 1998-2011
- Gridded TRMM precipitation data
- Accumulate precip (∑P) along each trajectory during its time over land
- Relate $\delta^{18}O_{TR}$ to ∑P

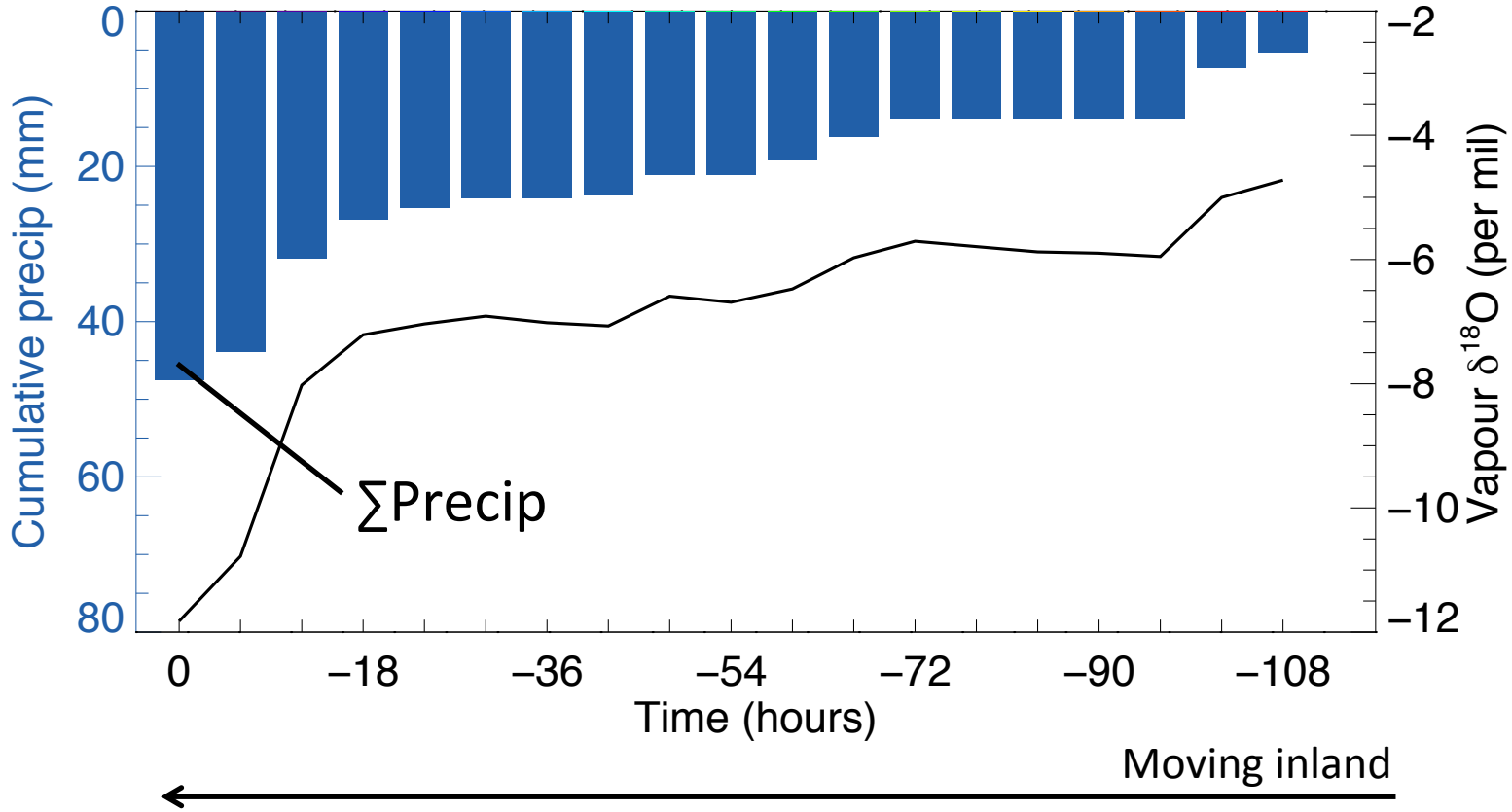


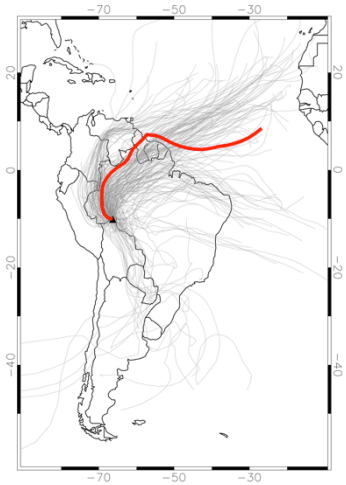
Precipitation along a sample back trajectory



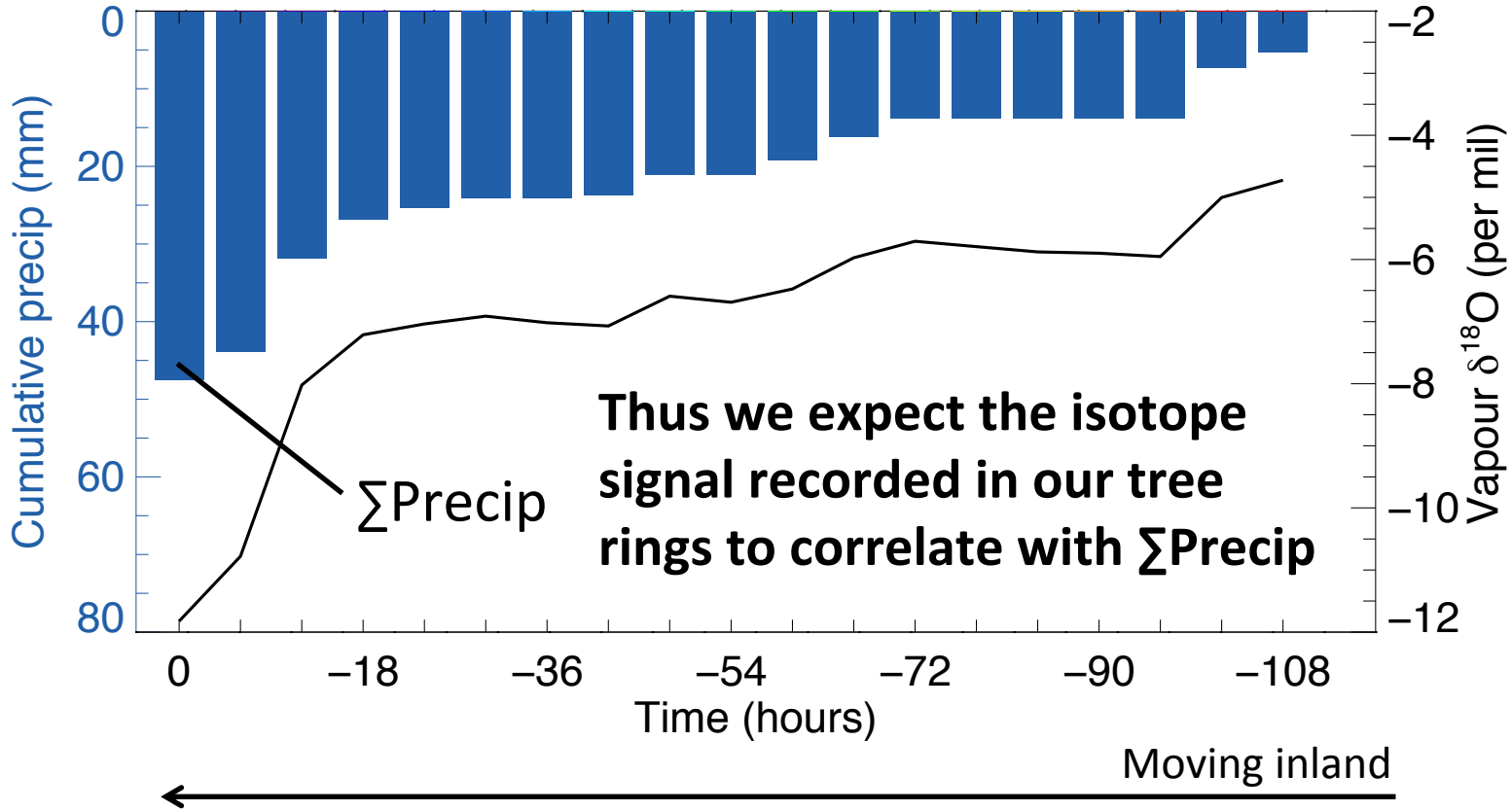


Precipitation along a sample back trajectory

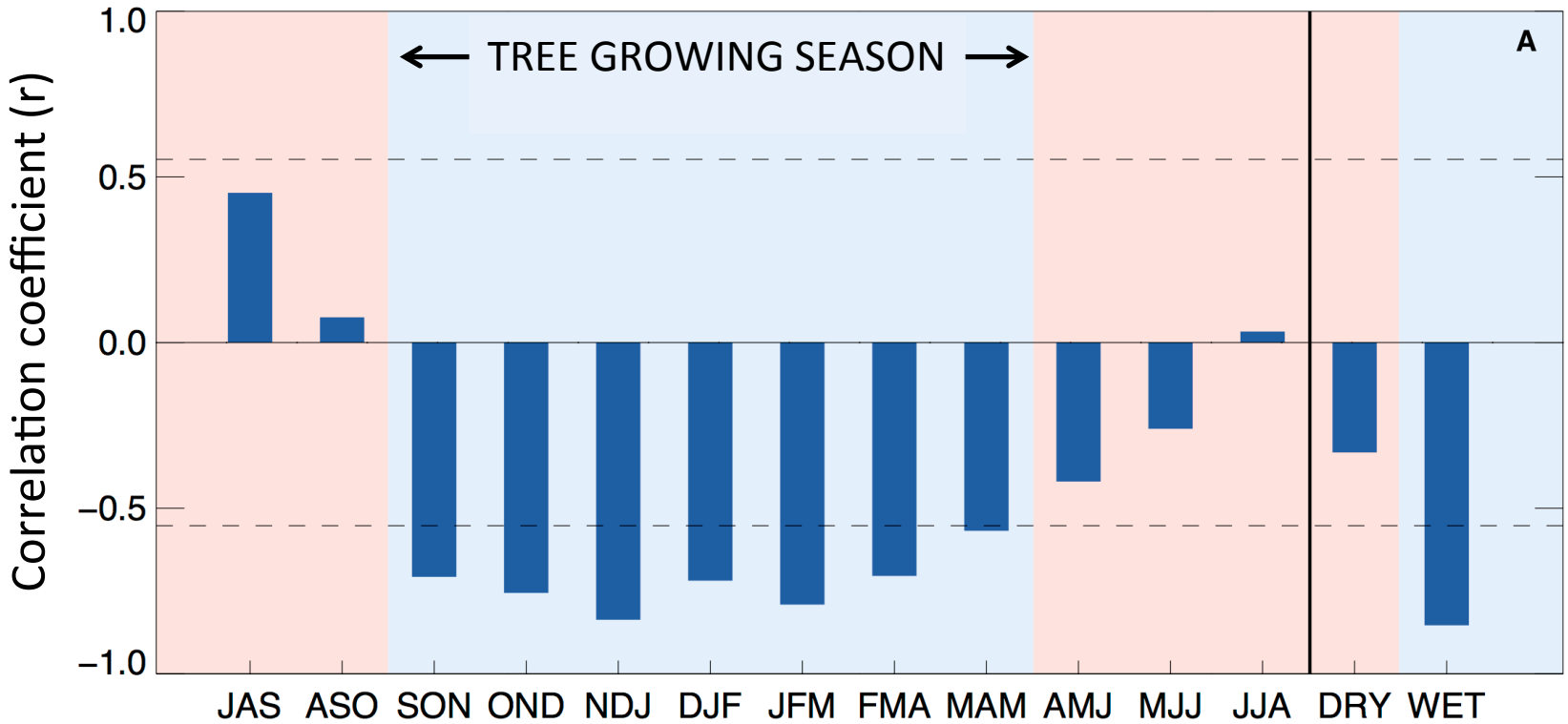




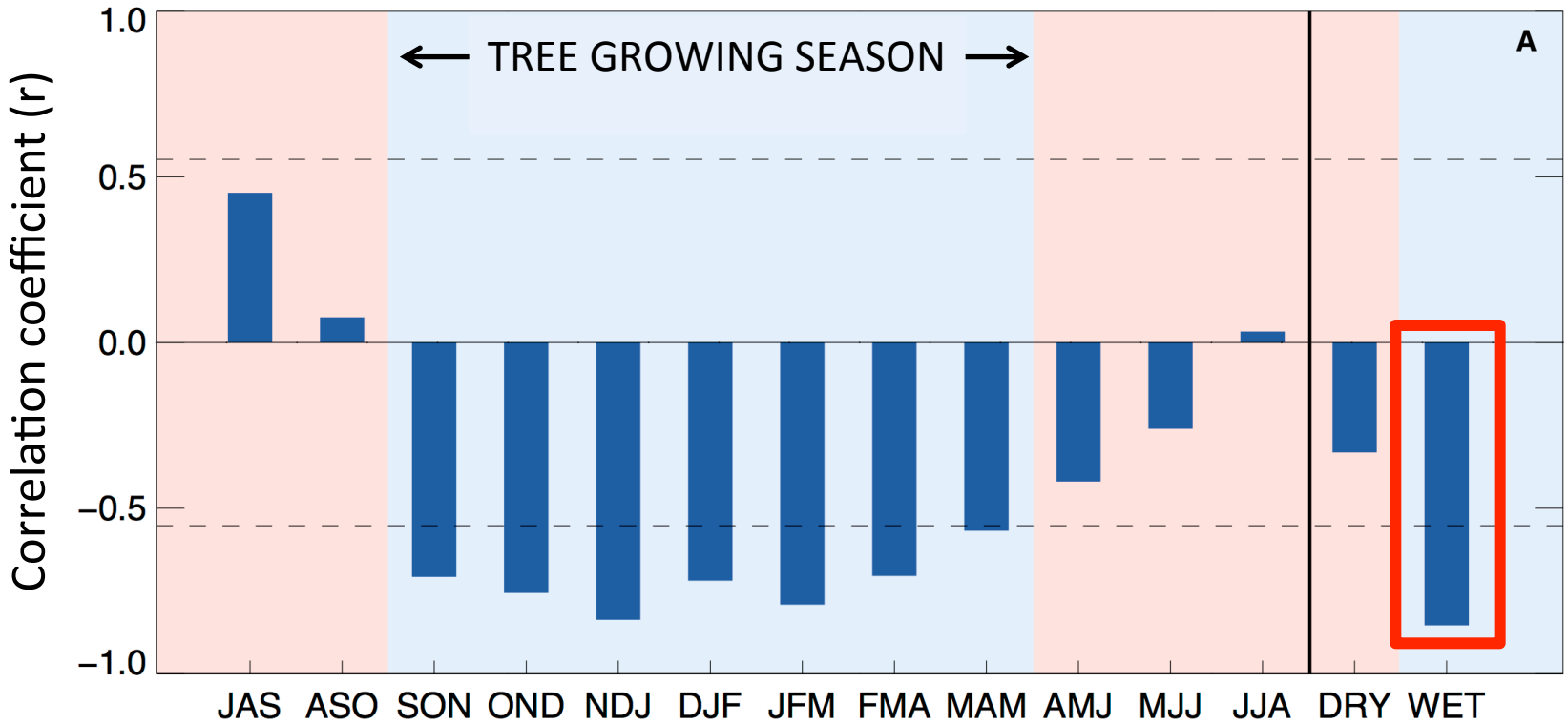
Precipitation along a sample back trajectory



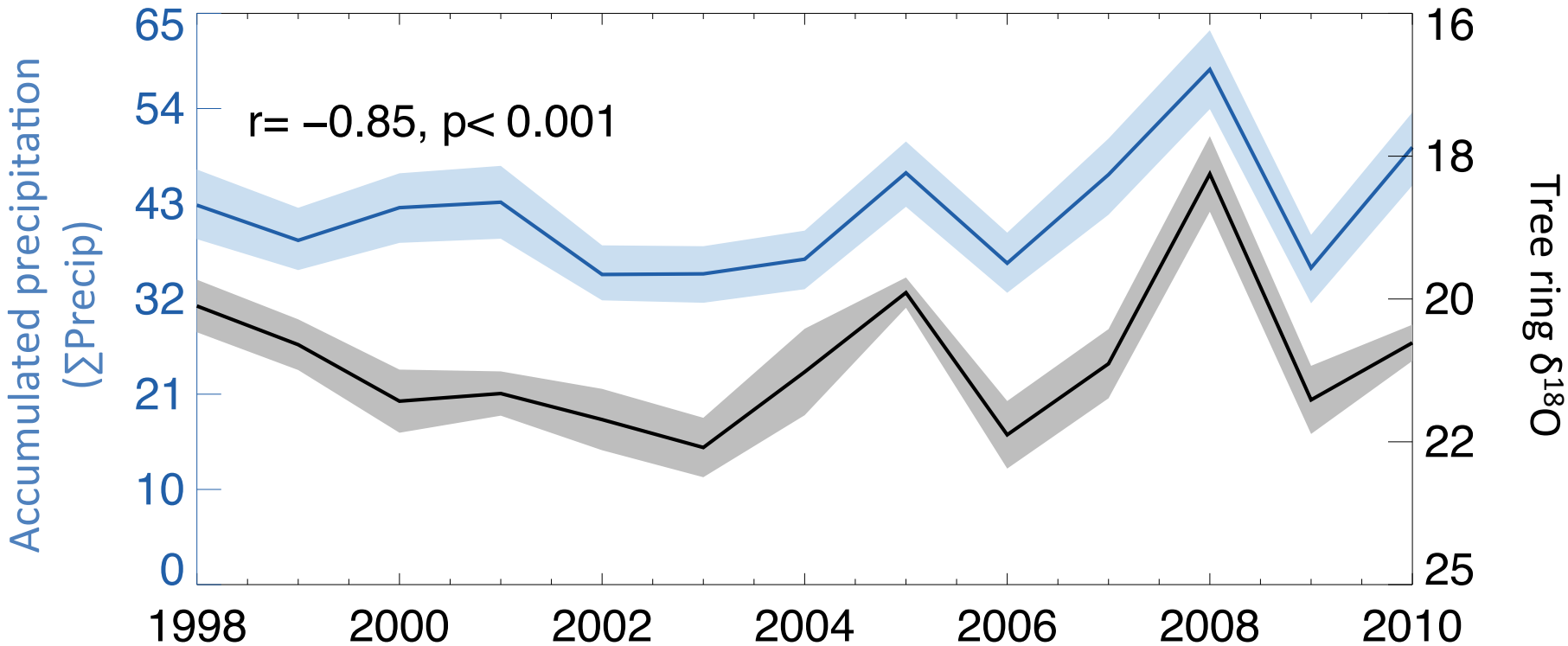
Correlations between $\delta^{18}O_{TR}$ and ∑Precip



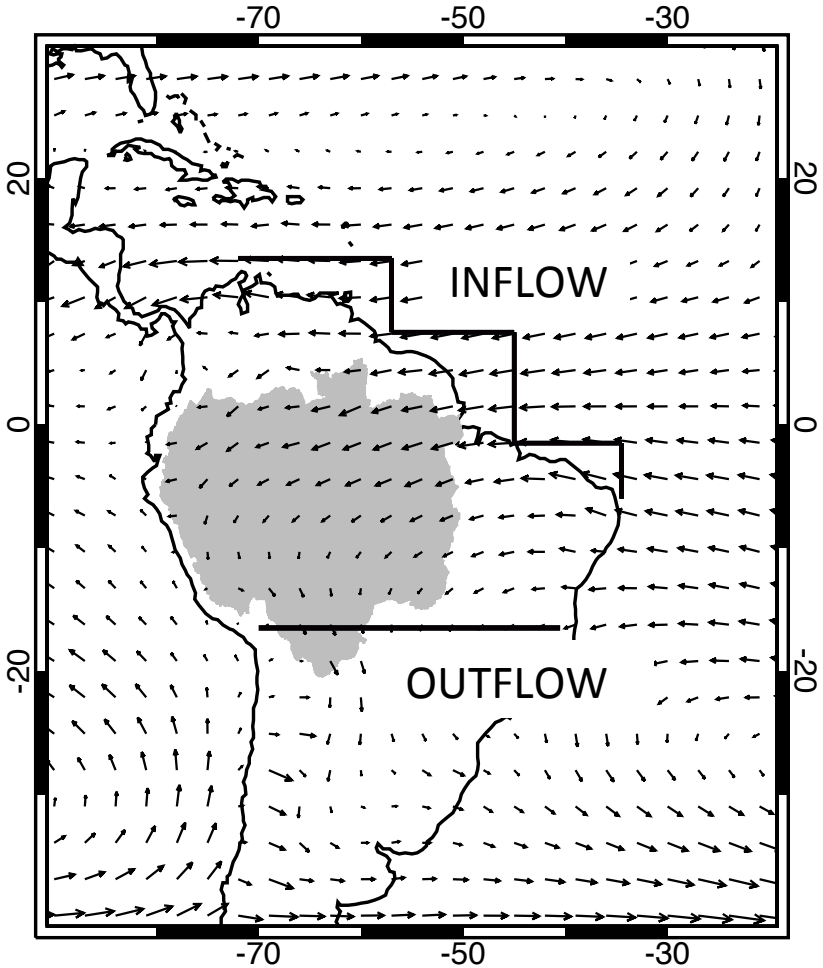
Correlations between $\delta^{18}O_{TR}$ and ∑Precip



How does air parcel history relate to $\delta^{18}O_{TR}$?

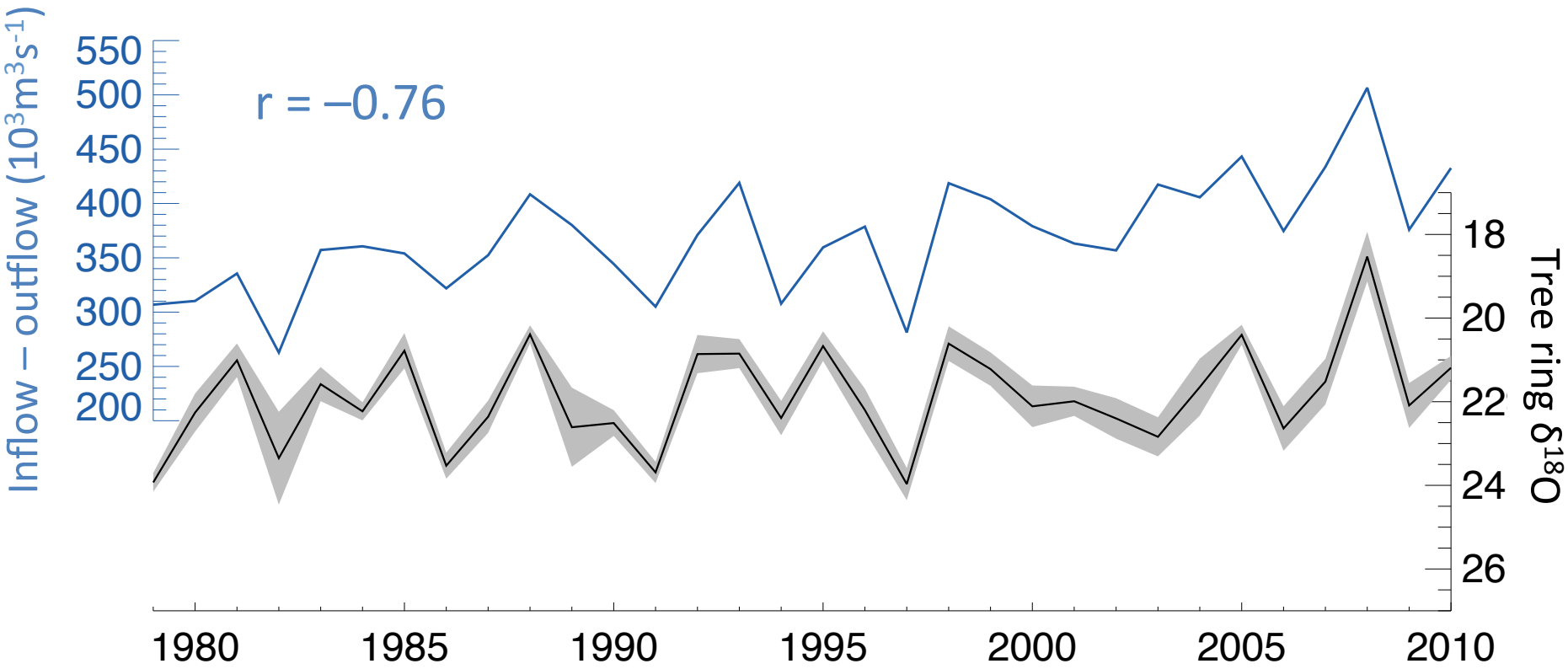


Approach 2: Water vapour transport analysis

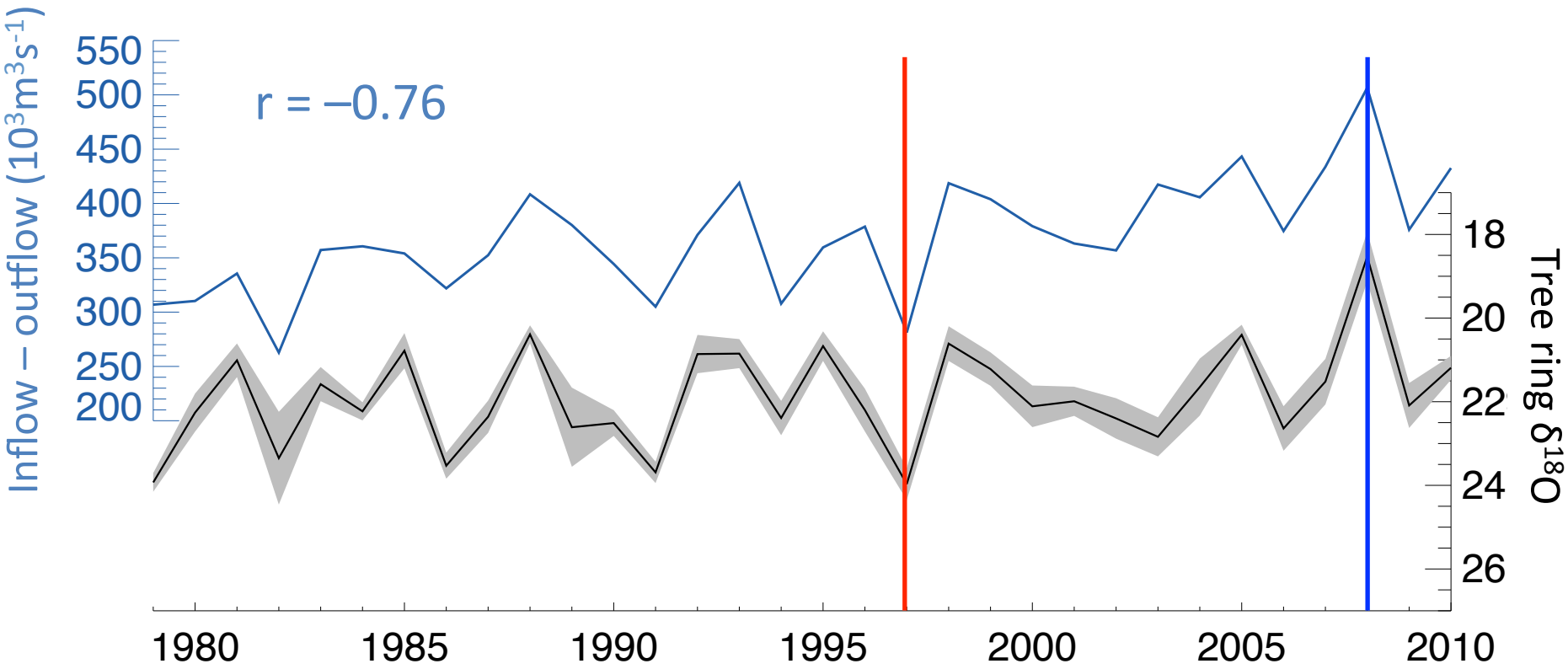


- Wind fields and column-integrated water vapour flux fields from ERA-Interim
- Calculate wet season moisture transport into and out of Amazon basin 1979-2010

Tree ring $\delta^{18}O$ reflects Amazon basin moisture balance



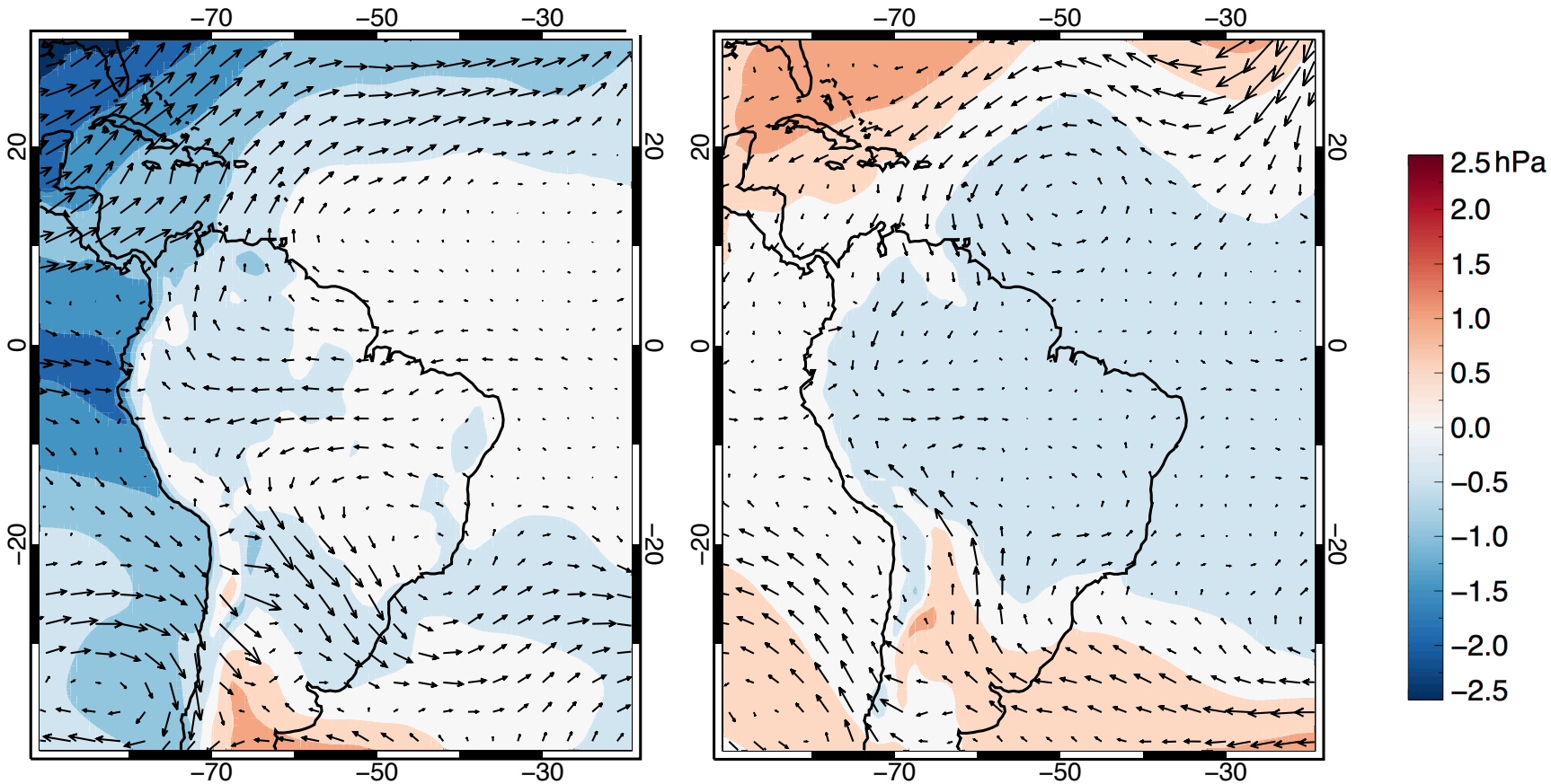
Tree ring $\delta^{18}O$ reflects Amazon basin moisture balance



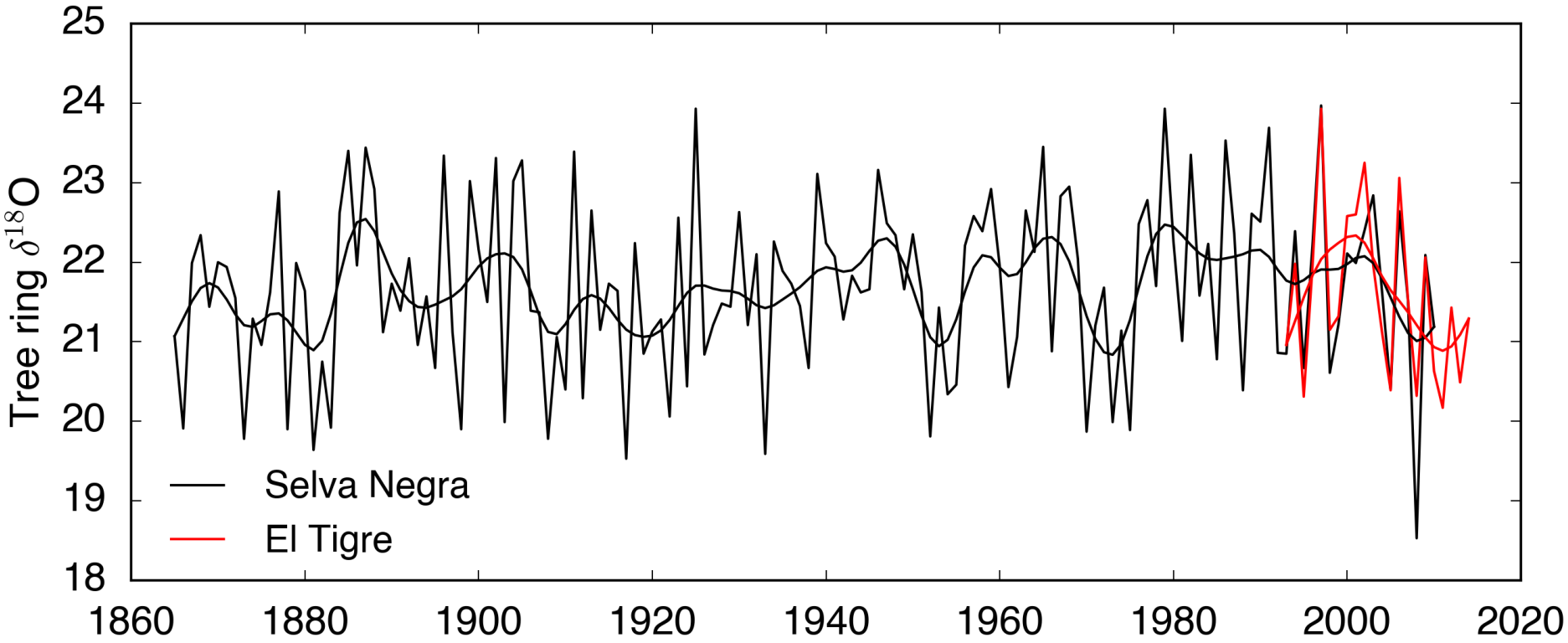
Wind and sea level pressure anomalies

1997/98 – High $\delta^{18}O_{TR}$

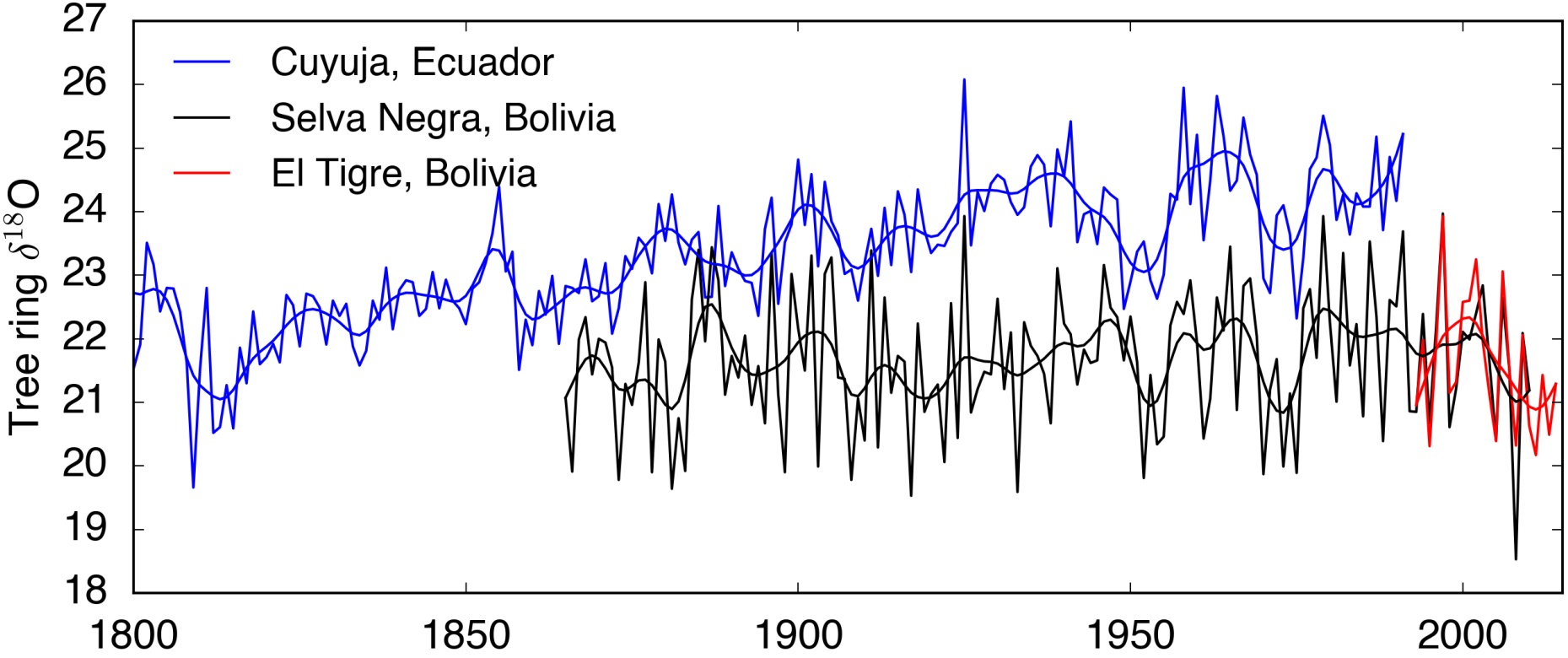
2008/09– Low $\delta^{18}O_{TR}$



Northern Bolivia $\delta^{18}O_{TR}$ record: 1865-2014

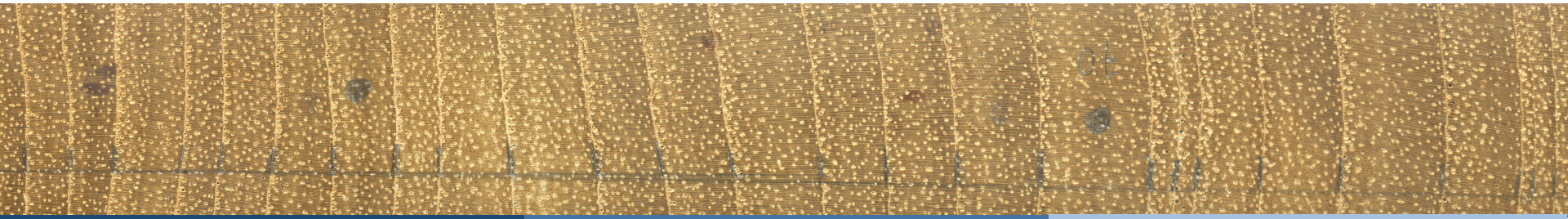


New record from Ecuador



Conclusions

- Variation in $\delta^{18}O_{TR}$ is controlled by basin-intrinsic processes
- Rainout during transport over the basin is the most important factor affecting $\delta^{18}O_{TR}$
- This suggests $\delta^{18}O_{TR}$ can be reliably used to reconstruct Amazon basin precipitation
- Extending such proxy records backwards in time can help us to understand recent shifts in Amazon hydrology

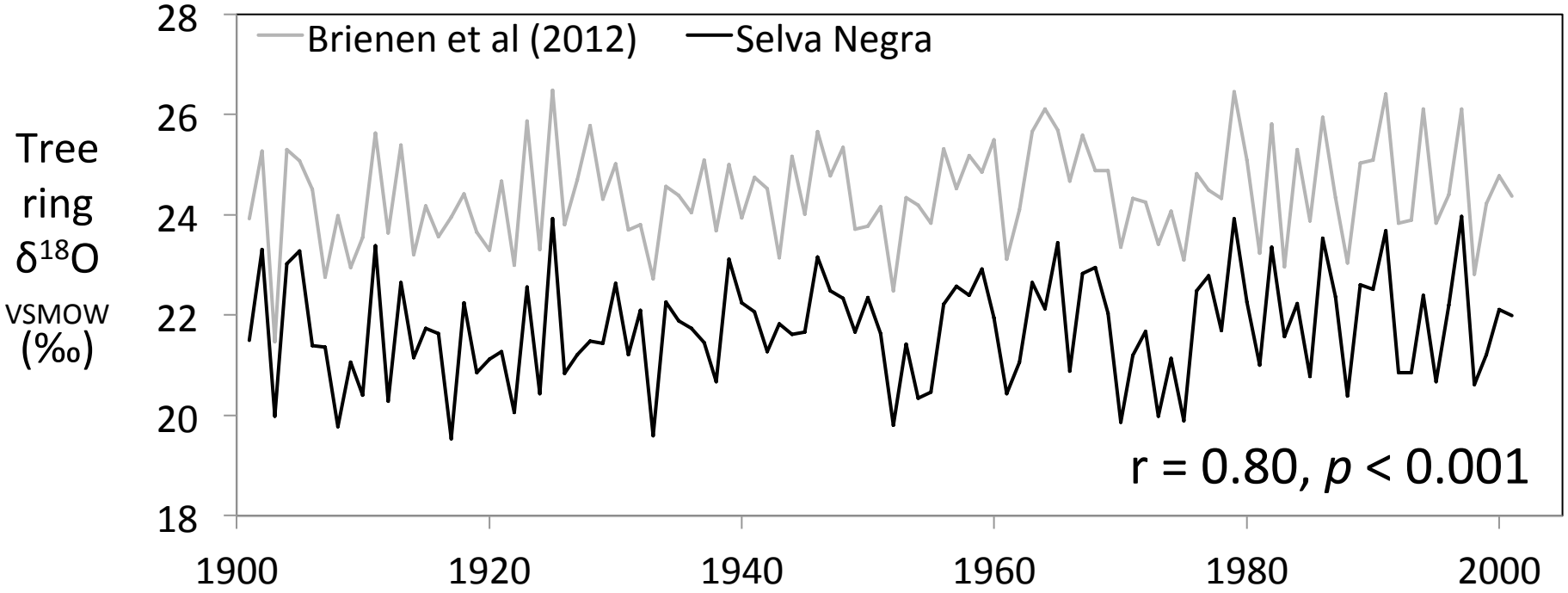


Many thanks for your attention

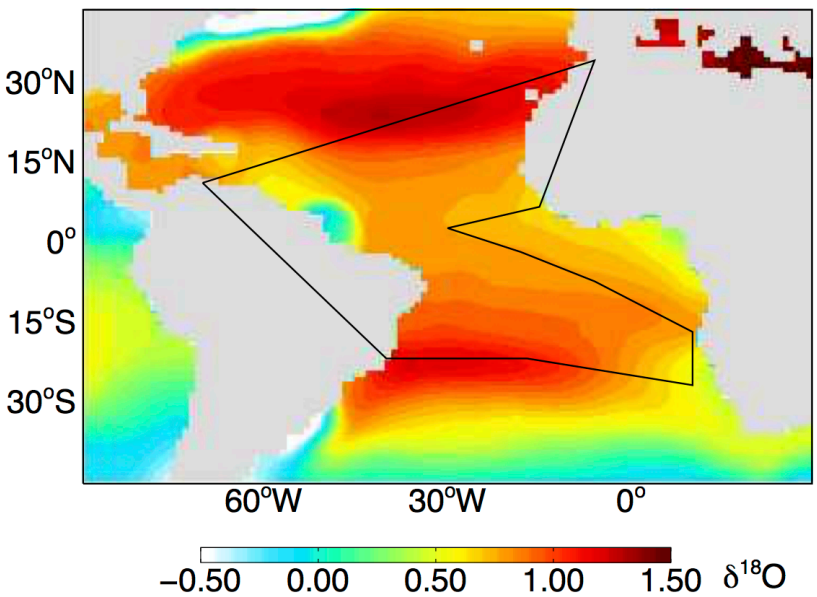
With thanks to:
John Methven
Rob Newton
Simon Bottrell
Timothy Heaton
and
Sarah Hunt

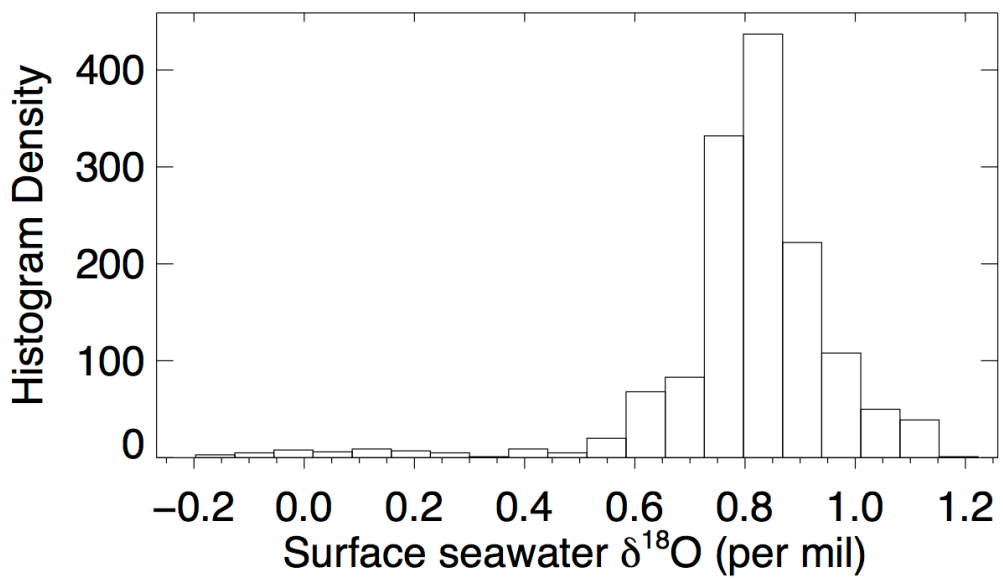
Further evidence for large-scale controls on tree ring oxygen isotopes

Baker et al., 2015
Global and Planetary Change

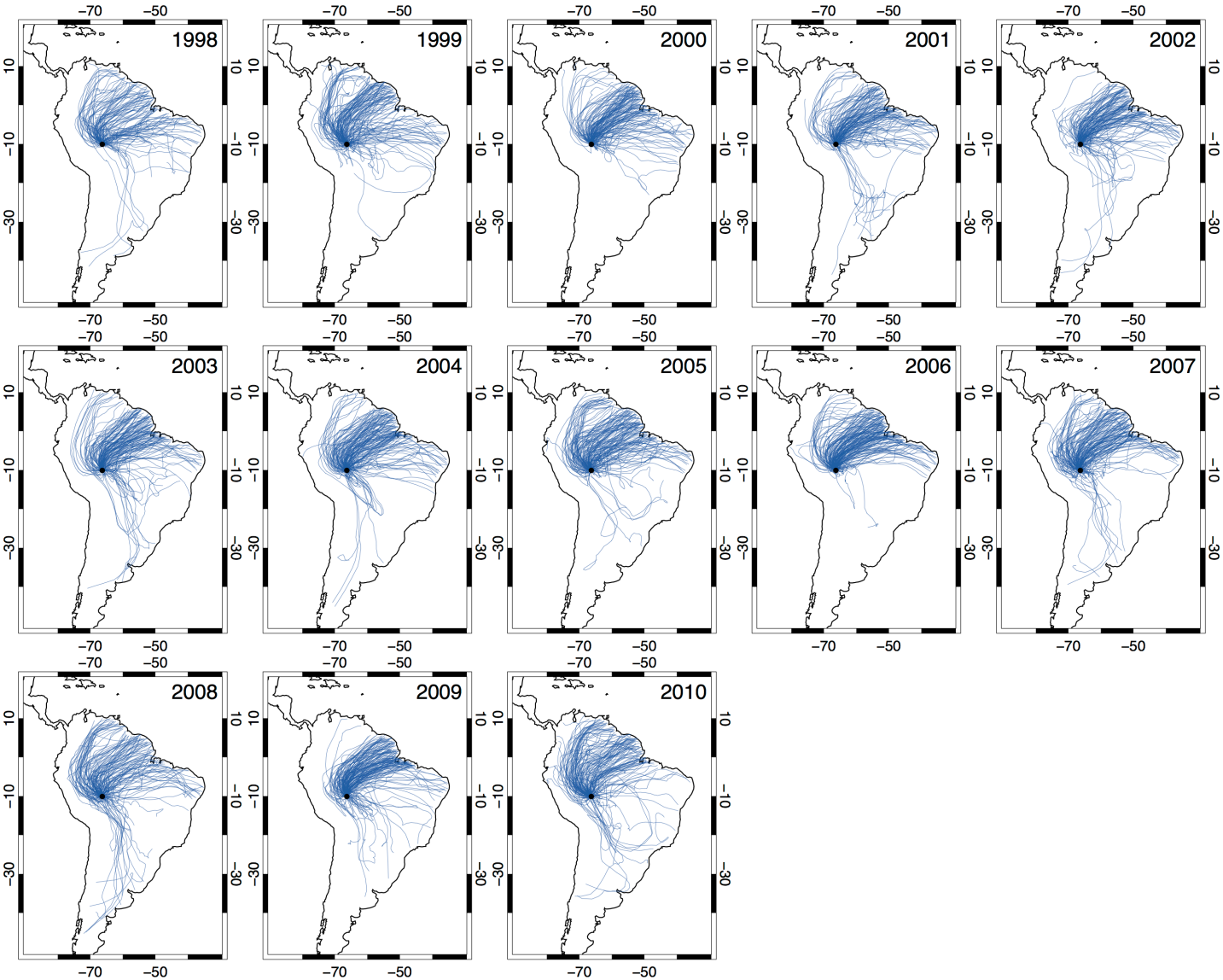


Variation in source water $\delta^{18}O$





Trajectories 1998-2010/11



What controls interannual variation in ∑Precip?

What controls interannual variation in ∑Precip?

Two sources of interannual variation:

1. Climate
2. Trajectory pathway

What controls interannual variation in ∑Precip?

Two sources of interannual variation:

1. Climate
2. Trajectory pathway

Experiment description	**Correlation between ∑Precip and $\delta^{18}O_{TR}$**
Control (normal trajectories and climate)	-0.85 (p<0.001)
Experiment 1: remove interannual variation in climate	
Experiment 2: remove interannual variation in transport pathway	

What controls interannual variation in ∑Precip?

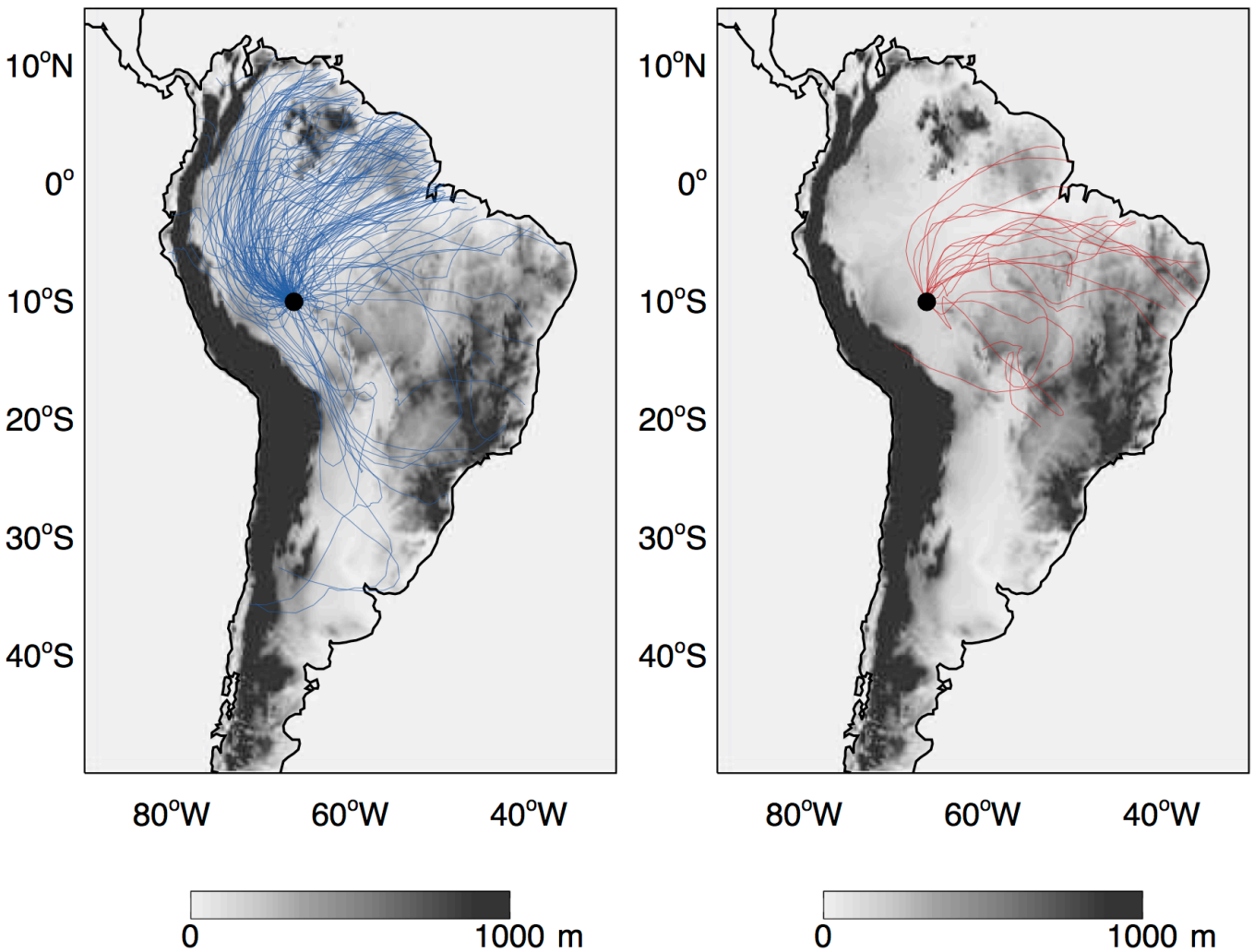
Two sources of interannual variation:

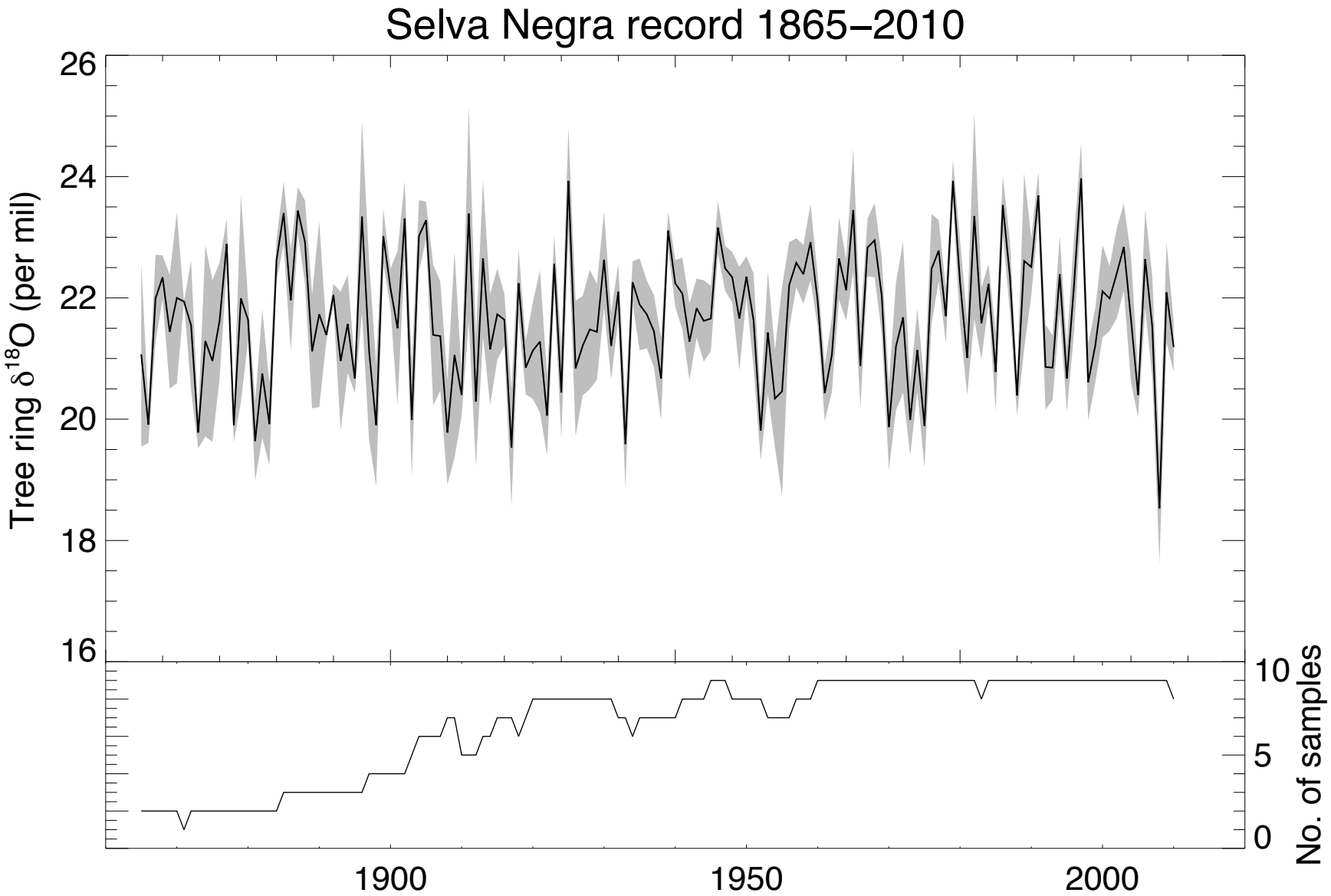
1. Climate
2. Trajectory pathway

Experiment description	**Correlation between ∑Precip and $\delta^{18}O_{TR}$**
Control (normal trajectories and climate)	-0.85 (p<0.001)
Experiment 1: remove interannual variation in climate	-0.83 (p<0.001)
Experiment 2: remove interannual variation in transport pathway	-0.75 (p<0.01)

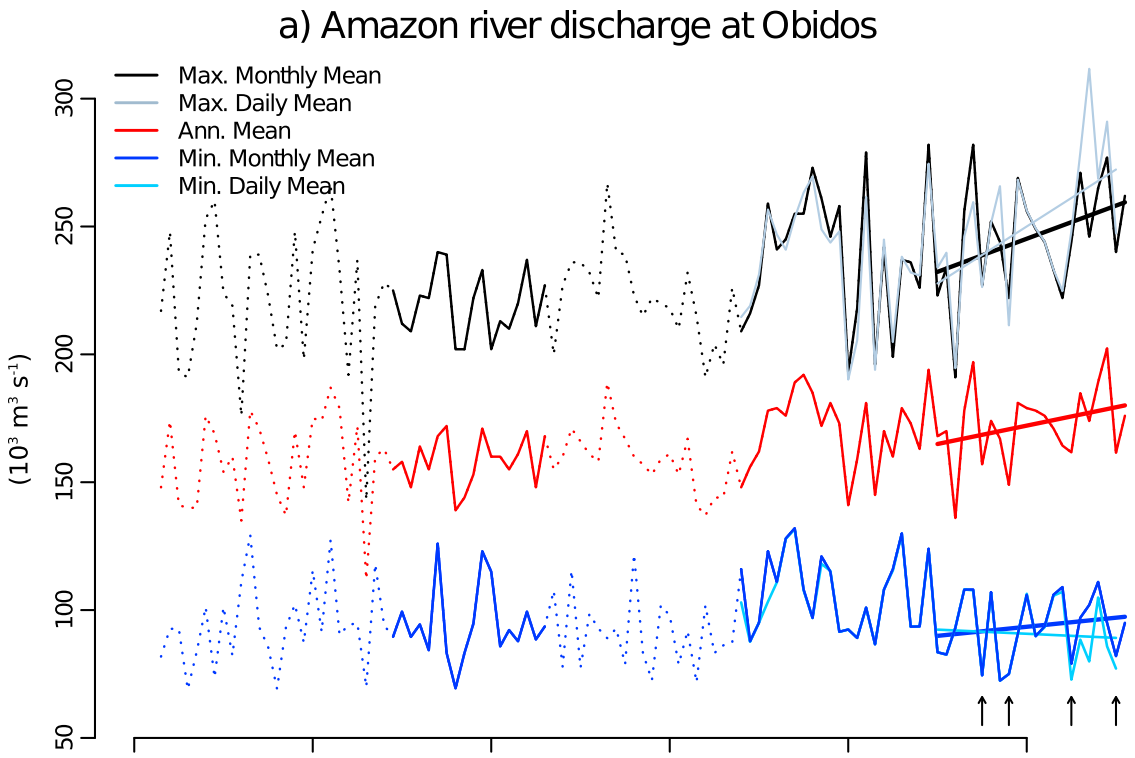
Confirms the importance of within-basin processes

Wet season (Oct-Apr) and dry season (May-June) trajectories




Selva Negra record 1865–2010
Tree ring δ18O (per mil)
26
24
22
20
18
16
No. of samples
10
5
0
1900
1950
2000

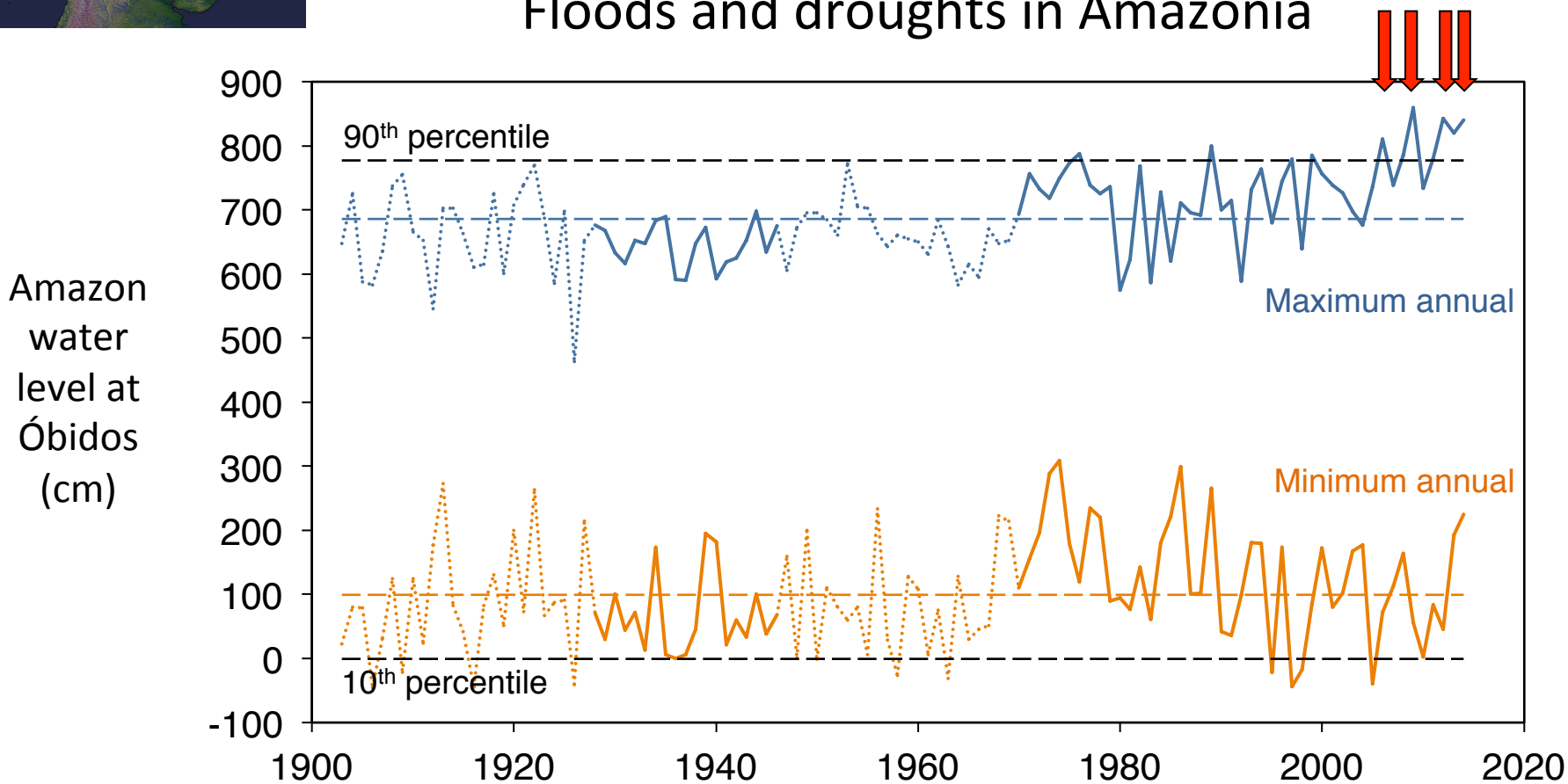
Changes in Amazon hydrology 1990 – 2010



Gloor et al., 2013 GRL

Why study Amazon hydrology?

Floods and droughts in Amazonia



6 May 2009

UK world politics sport football opinion culture business lifestyle fashion environ

home › world › americas asia australia africa middle east cities development europe

South America

Brazil floods leave 186,000 homeless

At least 19 people die after months of heavy rains

Associated Press

Wednesday 6 May 2009
16.20 BST

Shares
0

Save for later

A firefighter helps residents to salvage belongings in Teresina, northern Brazil. Photograph: Efrem Ribeiro/AFP/Getty Images EFREM RIBEIRO/AFP/Getty Images

28 February 2012

117,000 affected by floods in NE Brazil

Flooding of the Acre River has caused extensive damage in Cobija, Pando department, northern Bolivia, on the border with Brazil.

Approximately 117,000 people have been affected by the floods in the Brazilian state of Acre, according to the Bolivian National Defense Ministry.

Tue Feb 28, 2012 1:6AM

0 0

29 January 2014

BBC Sign in News Sport Weather

NEWS

Home UK World Business Politics Tech Science Health

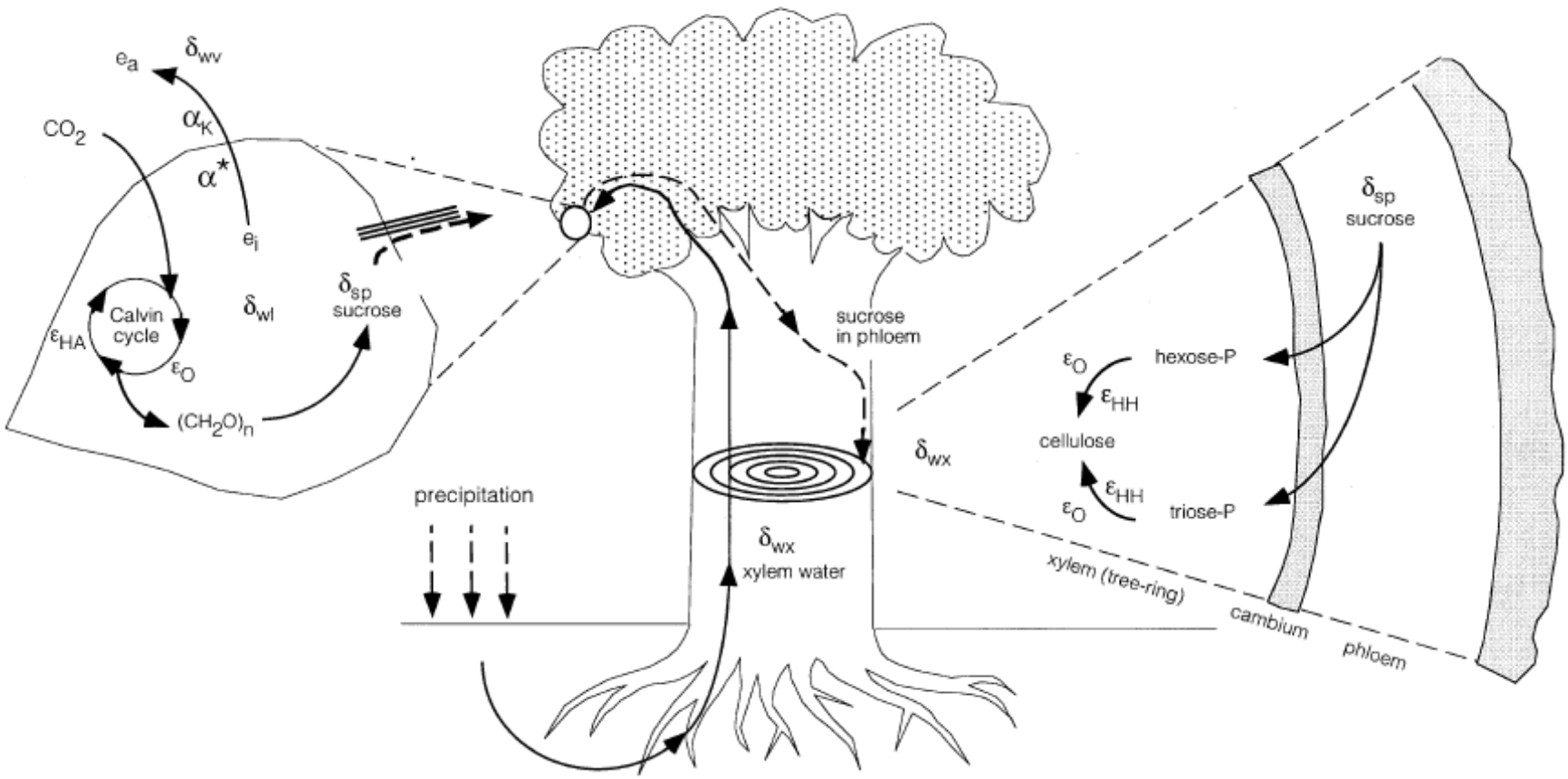
World Africa Asia Australia Europe Latin America Middle

Bolivia floods: State of emergency declared

29 January 2014 Last updated at 01:47 GMT

Oxygen isotopes in tree rings

Model for hydrogen and oxygen isotope ratios in tree-ring cellulose



Roden et al., 2000

$\delta^{18}O_{TR}$ enriched by ~27‰ relative to water present during synthesis