Investigation of Moisture Recycling over Amazon Basin: A Modelling Approach using HadCM3

Presented by

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Contributors

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Objectives

Main objectives of this study are

- How land cover changes change hydrological cycle, primarily net precipitation change and spatial distribution of $\delta^{18}O$ change over Amazon Basin
- Quantify the contribution due to recycling changes
- How this is reflected in $\delta^{18}O$ (precipitation)

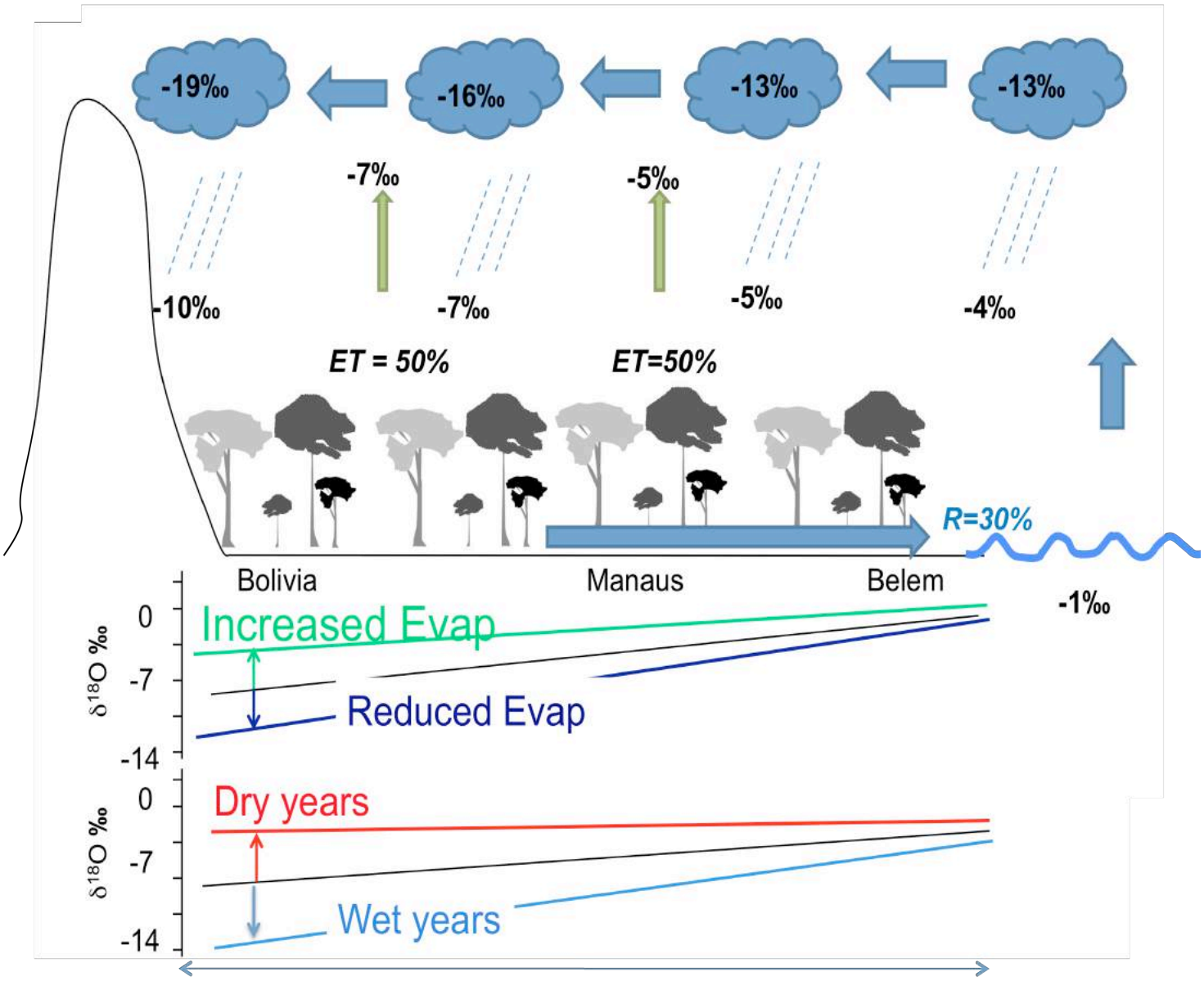
Background

- Amazon river discharges approximately 17 % of all freshwater to the oceans (Callede *et al.*2010)
- The Amazon forests have indeed been reduced in size substantially by deforestation
- Changes in vegetation cover effects the amount of water recirculating to the atmosphere, also the hydrological cycle of the basin (Nobre et al. 1991).

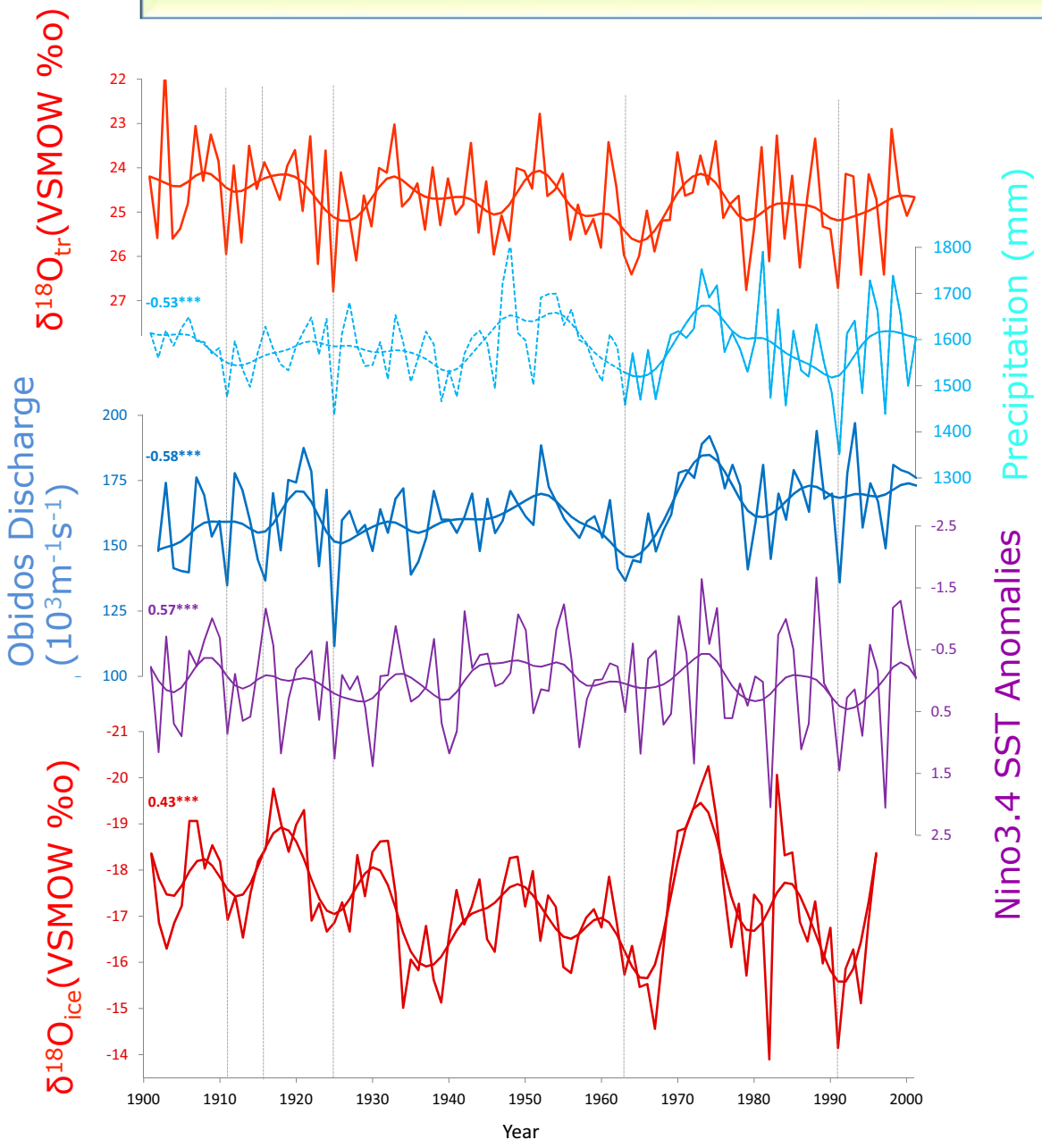
Stable water isotope ($\delta^{18}O$)

- Stable water isotope can be used as good proxy for precipitation
- It is a better tool to study convective processes and hydrological cycle
- Stable isotopes of water in hydrology are helpful to
  - identify the moisture source for precipitation
  - study spatio-temporal variation for moisture in the atmosphere
  - understand the post-precipitation evaporation
  - investigate ground water discharge
  - the effects of evaporation on the ground water systems

Simplified schematic of controls of Amazon basin precipitation $\delta^{18}O$



Changes of precipitation and $\delta^{18}O$ over Amazon basin



- Strong correlation between $\delta^{18}O$ recorded in eight trees at a Bolivian Amazon site and Amazon river discharge at Obidos
- One conclusion is that tree rings in this species are accurate recorders of $\delta^{18}O$ in precipitation.

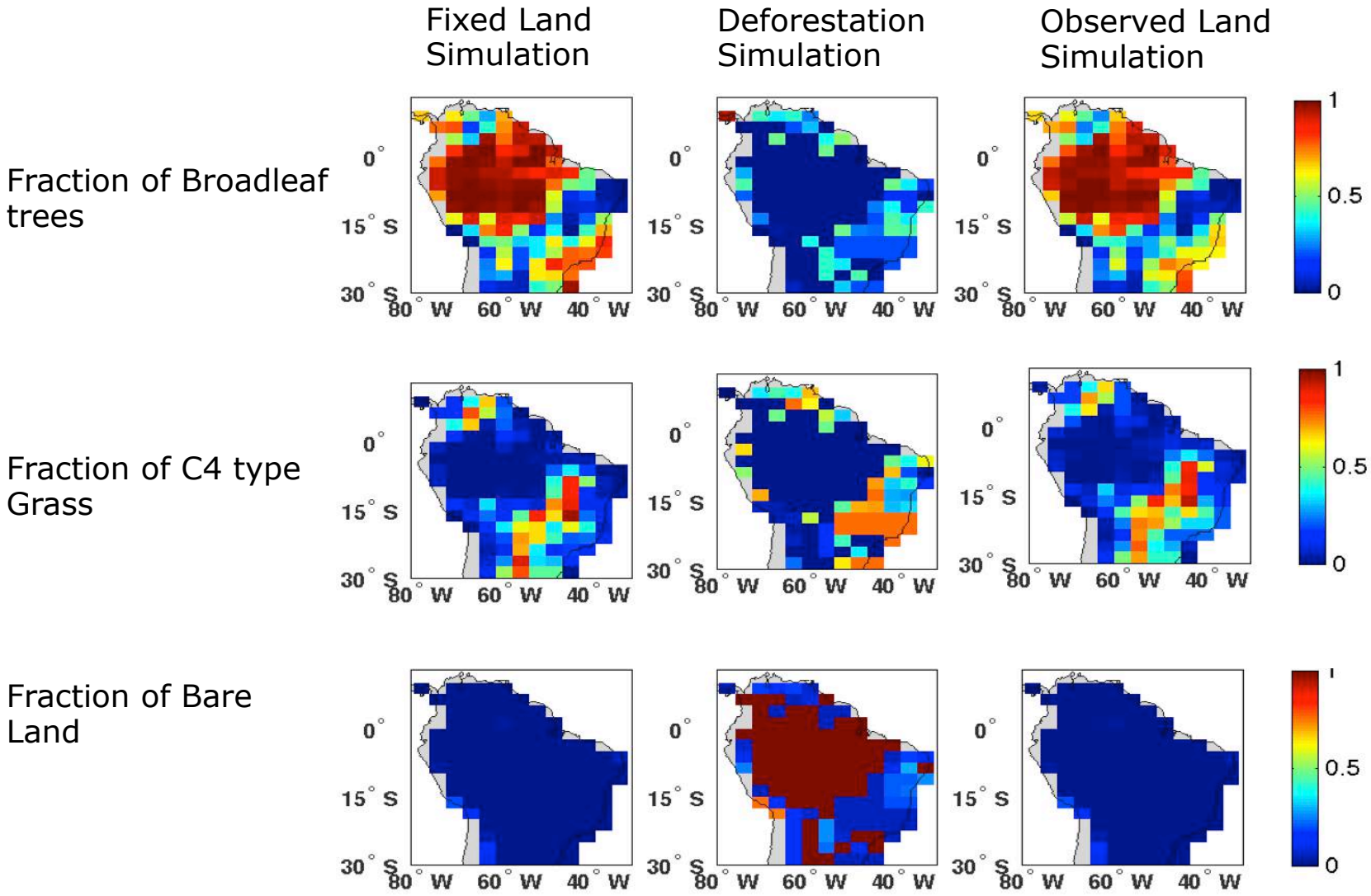
Brienen et al. PNAS 2012

Simulations

This is a modeling analysis which attempts to give us a better understanding the relation between isotope signatures and changes of the hydrological cycle

Simulations	Greenhouse Gas	Land Use and Land Cover	Simulation Period
1. Fixed land Simulation	Fixed at Pre-industrial (280 ppm)	Land cover fixed at 1870	1870 - 1900
2. Deforestation Simulation	Fixed at Pre-industrial (280 ppm)	Broad leaf trees replaced with bare land	1870 - 1900
3. Observed land Simulation	Observed Greenhouse Gas Concentrations	Time varying land cover *(Meiyappan and Jain 2012*)	1870 - 2016

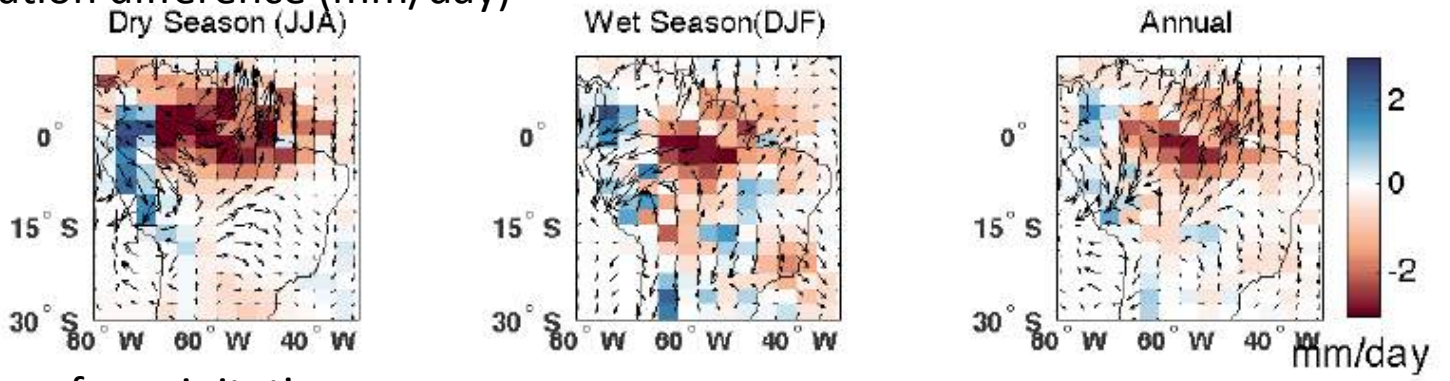
Land cover fractions prescribed in three simulations



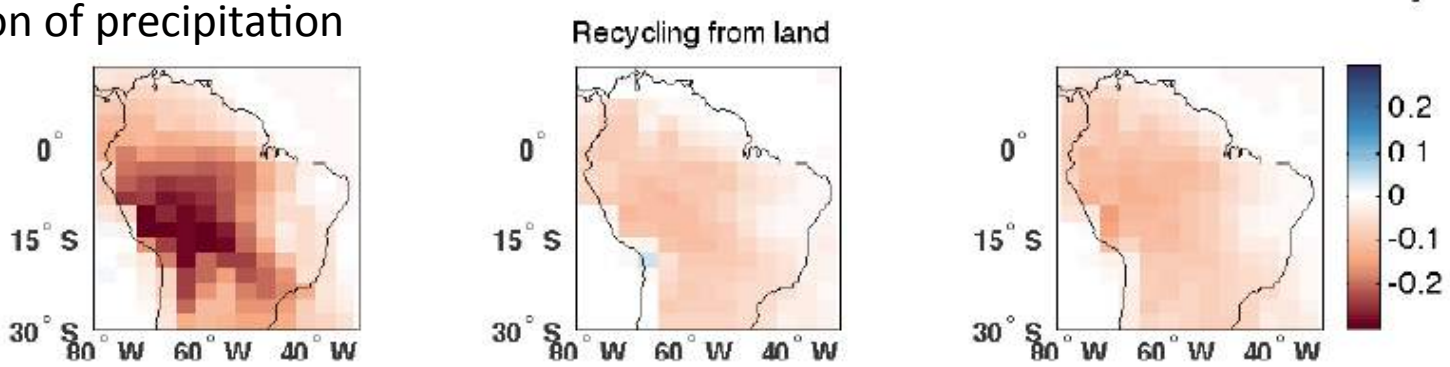
Results

Deforestation – Fixed land Simulation (1870 – 1900)

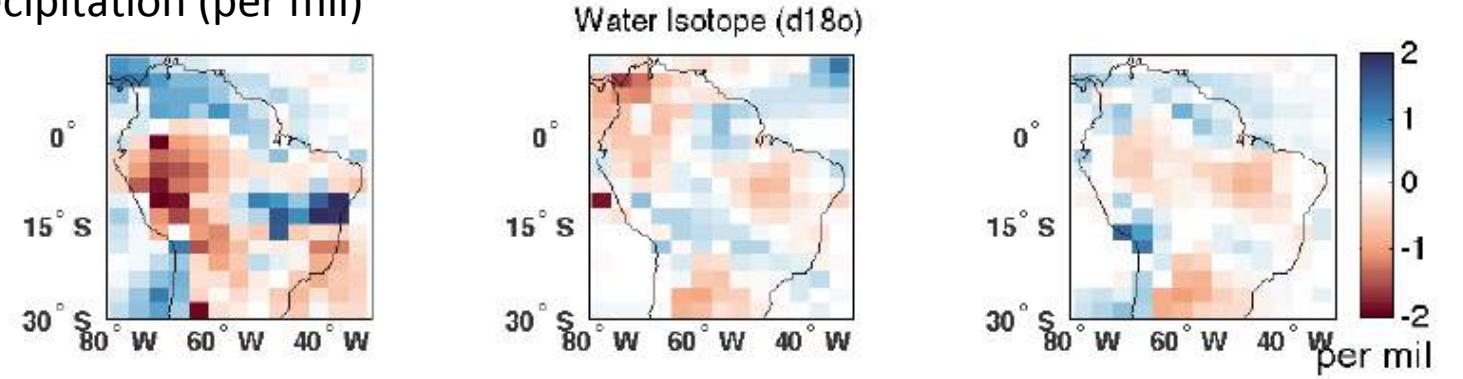
Precipitation difference (mm/day)



Land fraction of precipitation

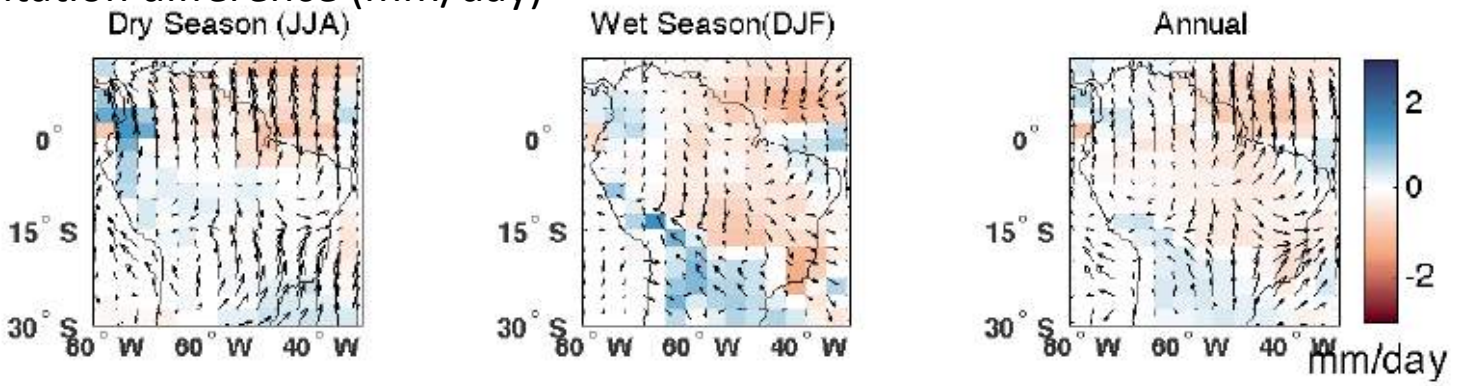


$\delta^{18}O$ in precipitation (per mil)

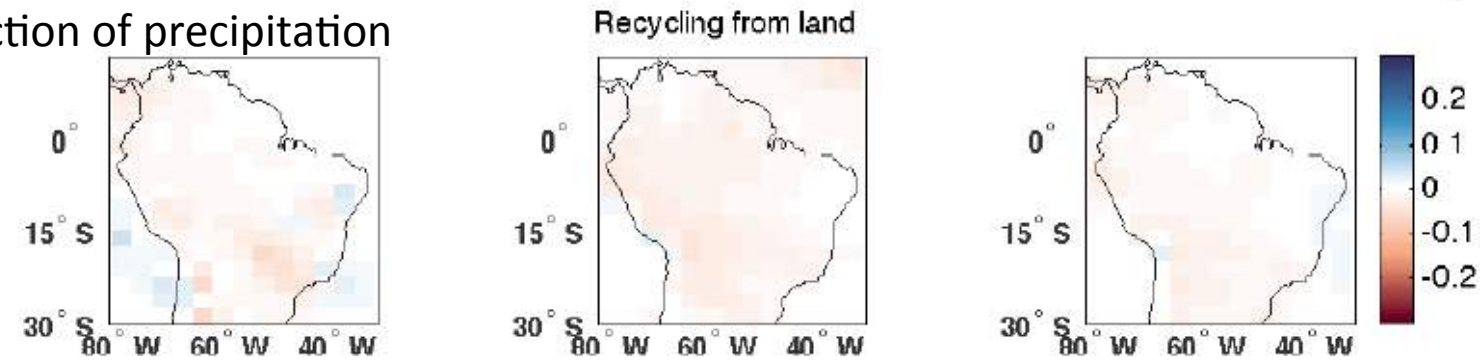


Observed land – Fixed land Simulation (1870 – 2015)

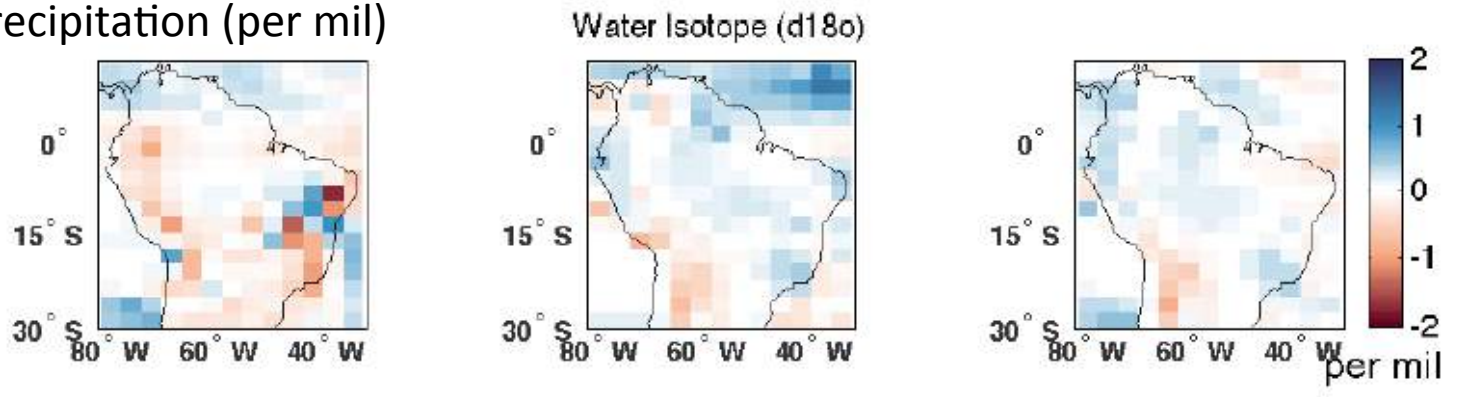
Precipitation difference (mm/day)



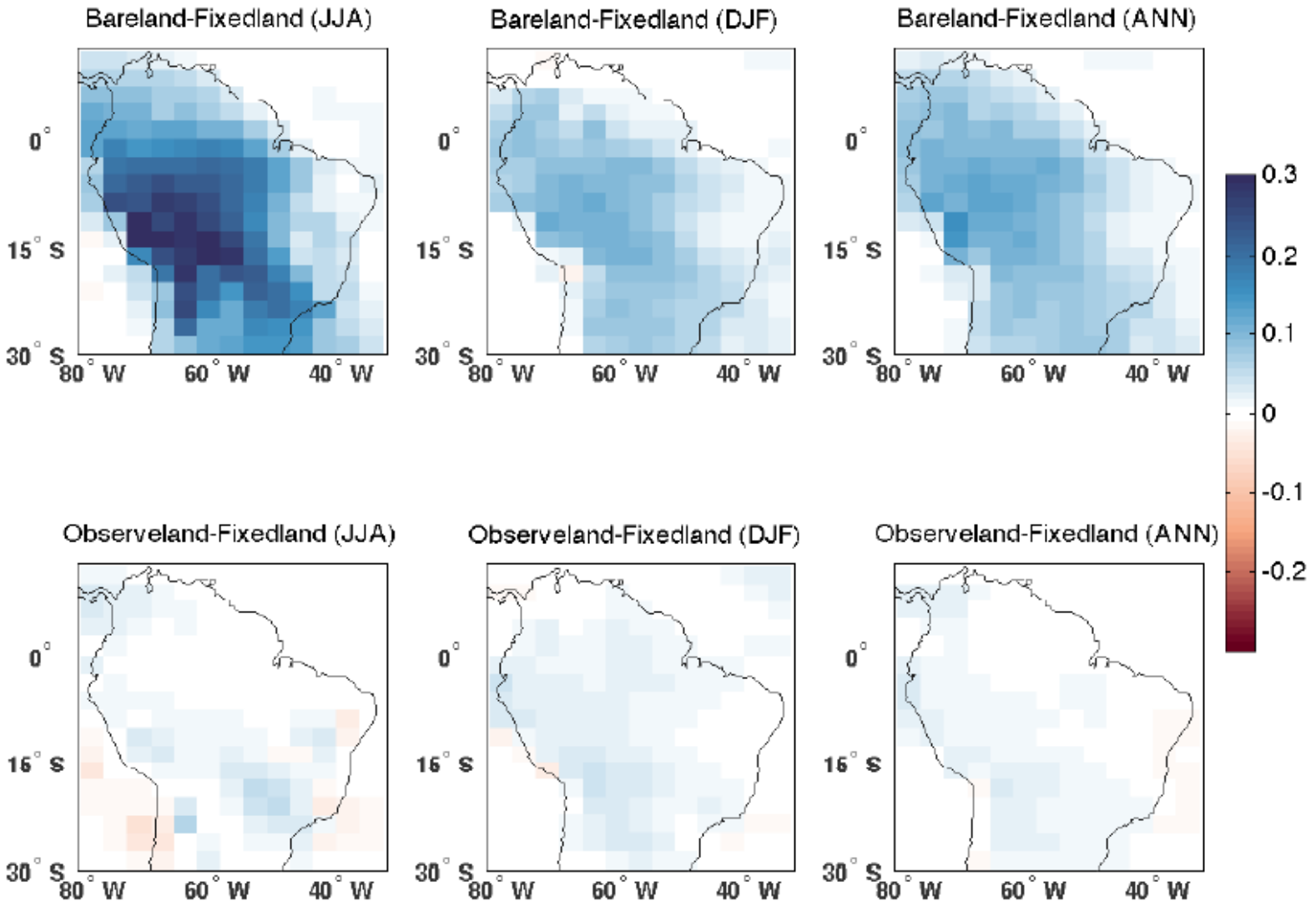
Land fraction of precipitation



$\delta^{18}O$ in precipitation (per mil)



Oceanic fraction of precipitation

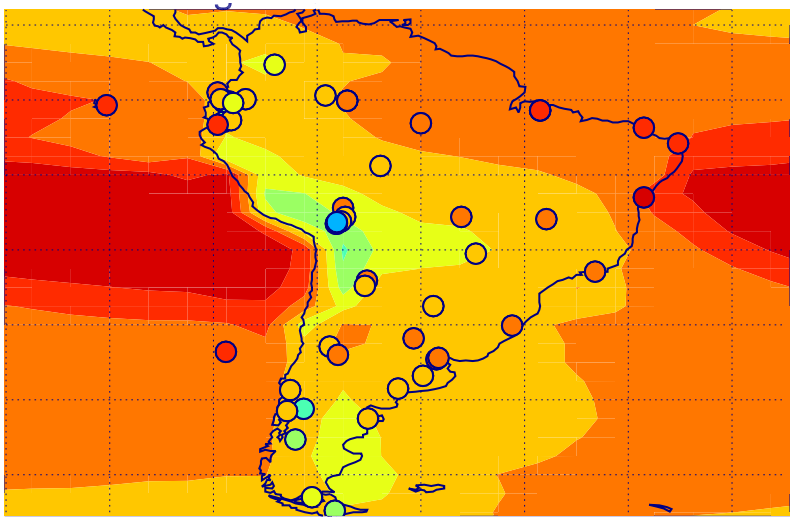


Summary

- In the deforestation simulation, the precipitation reduced and low level circulation got weaken over Amazon.
- Effects of changes of land surface on hydrological cycle
- The general patterns of fields in Deforestation – Fixed and Observed – Fixed are similar but magnitude much larger.
- The effect of deforestation is higher in the dry season than in the wet season. The moisture recycling from the land has reduced by about 20%.
- Moisture recycling tracer proofs helpful to understand the patterns in isotopes


Thank You

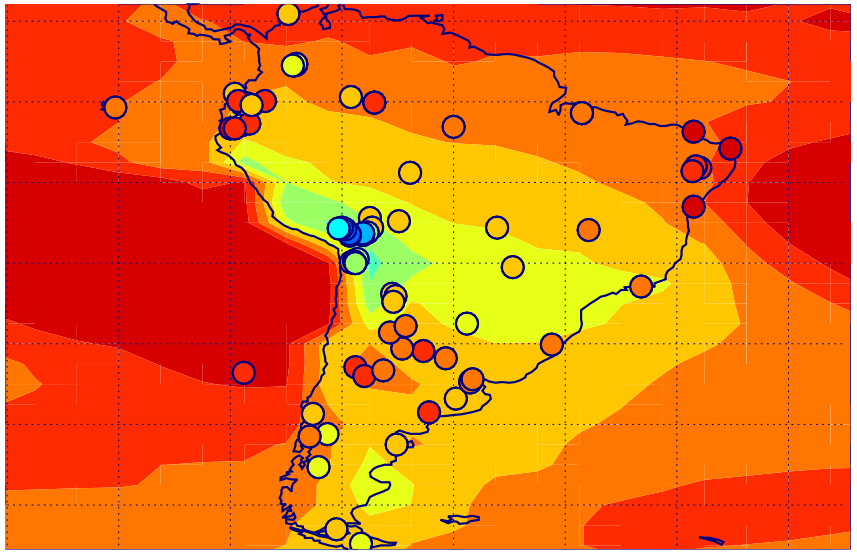
Annual $\delta^{18}O$



‰

-30 -18 -16 -14 -12 -10 -8. -6. -4. -2. 5.0

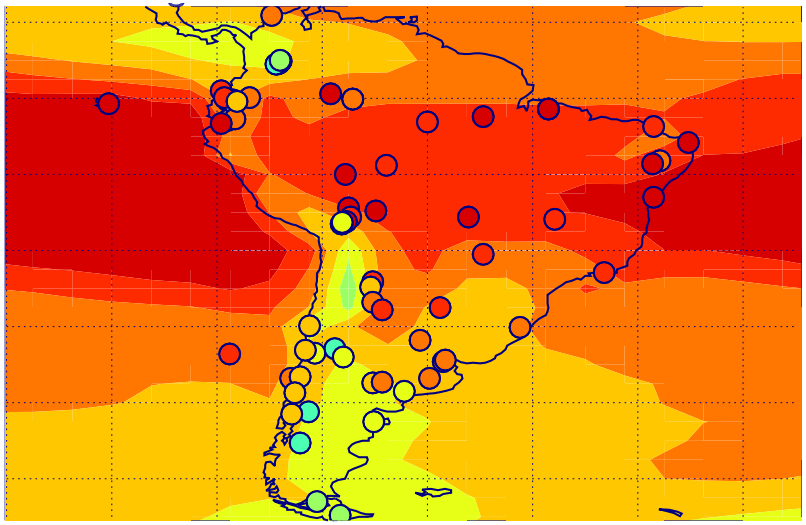
Wet Season $\delta^{18}O$ (DJF)



‰

-30 -18 -16 -14 -12 -10 -8. -6. -4. -2. 5.0

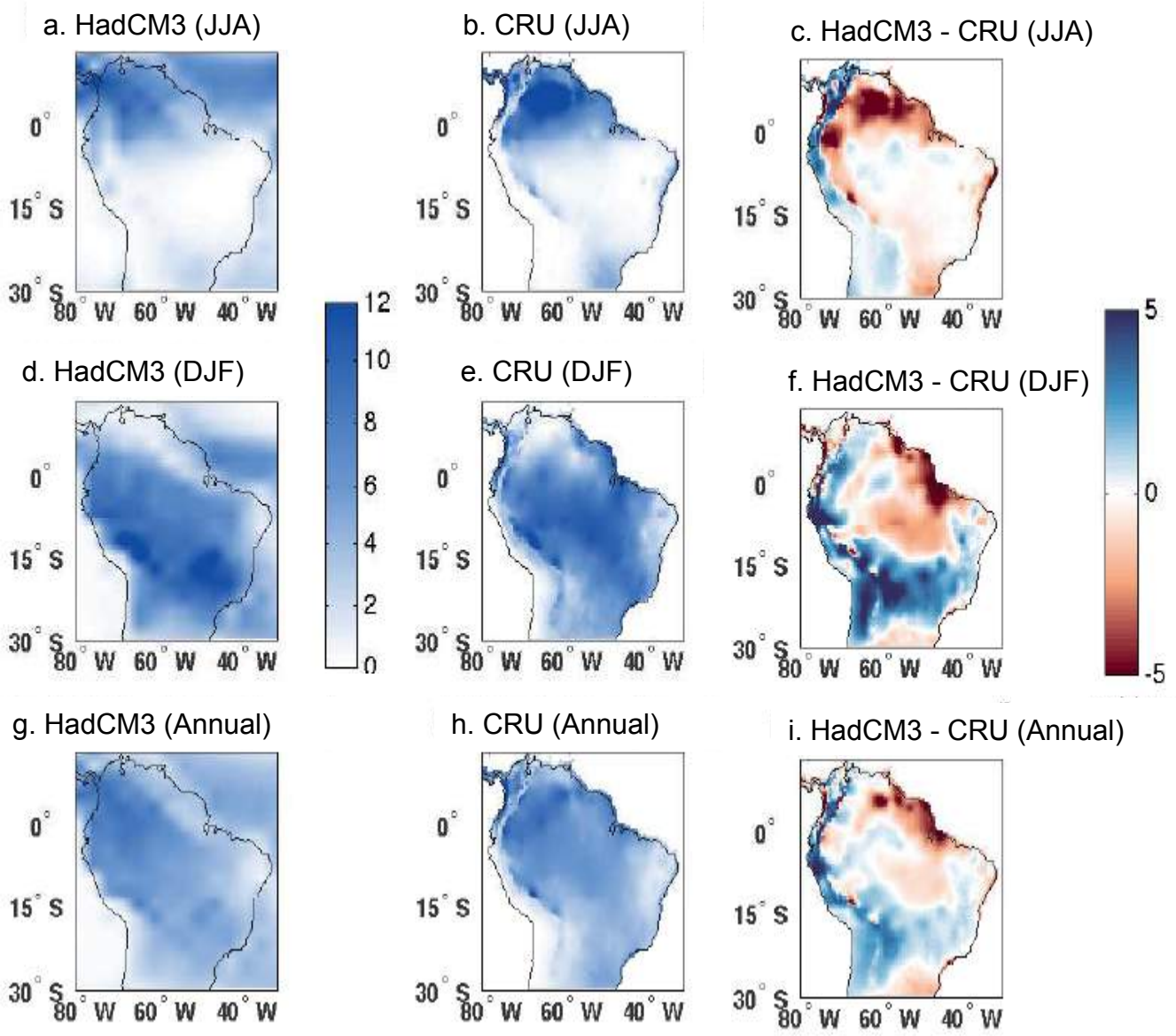
Dry Season $\delta^{18}O$ (JJA)

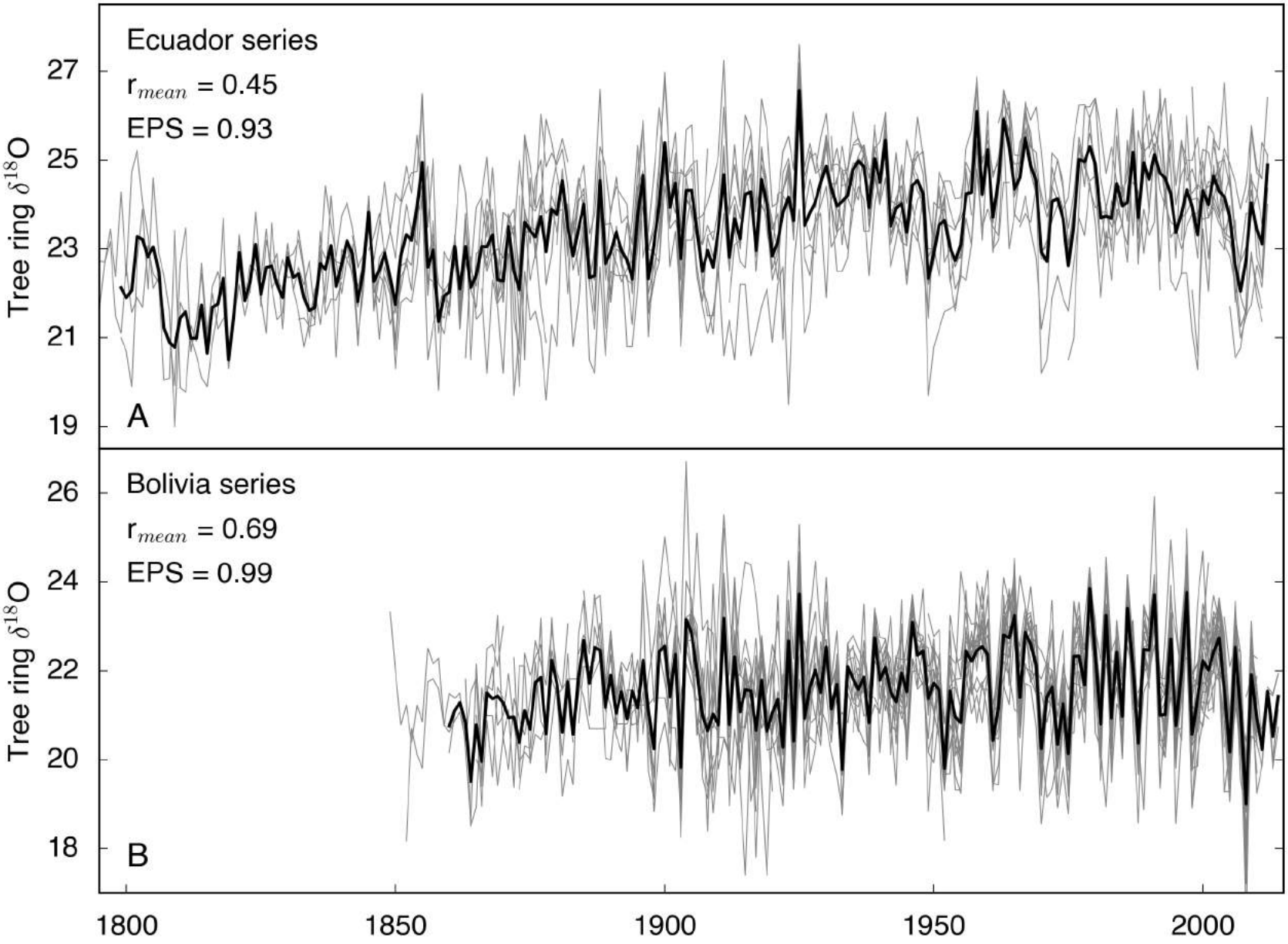


‰

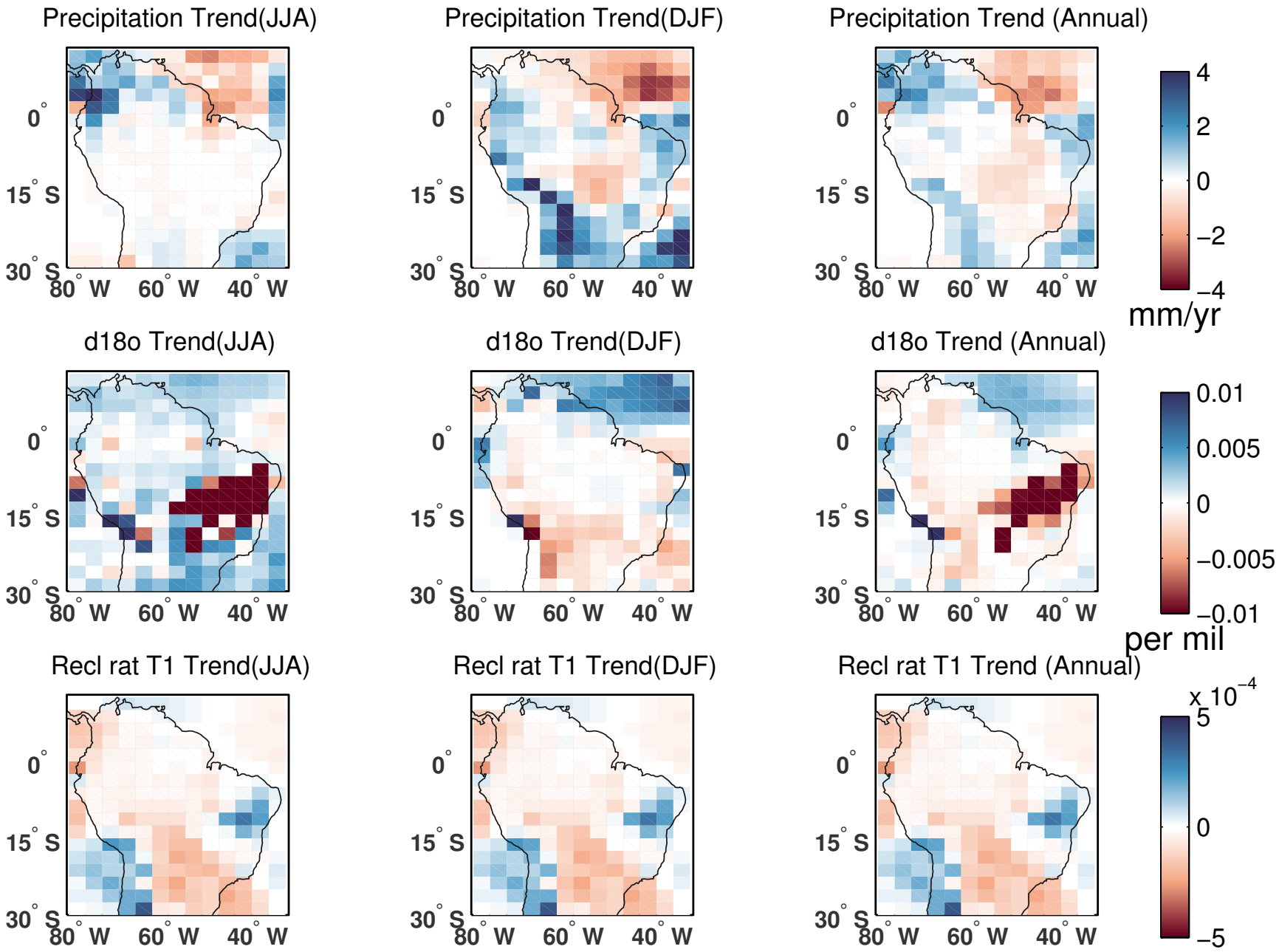
- The $\delta^{18}O$ simulated from observed land cover simulation have been validated against GNIP data. … you may need to explain a tiny bit
- Global Network of Isotopes in Precipitation (GNIP) observational database

Observed Land Simulation vs CRU Precipitation (1975 – 2012)




Ecuador series
r$_{mean}$ = 0.45
EPS = 0.93
A
Tree ring δ^{18}O
27
25
23
21
19
Bolivia series
r$_{mean}$ = 0.69
EPS = 0.99
B
Tree ring δ^{18}O
26
24
22
20
18
1800
1850
1900
1950
2000

Trend for the period 1870-2015



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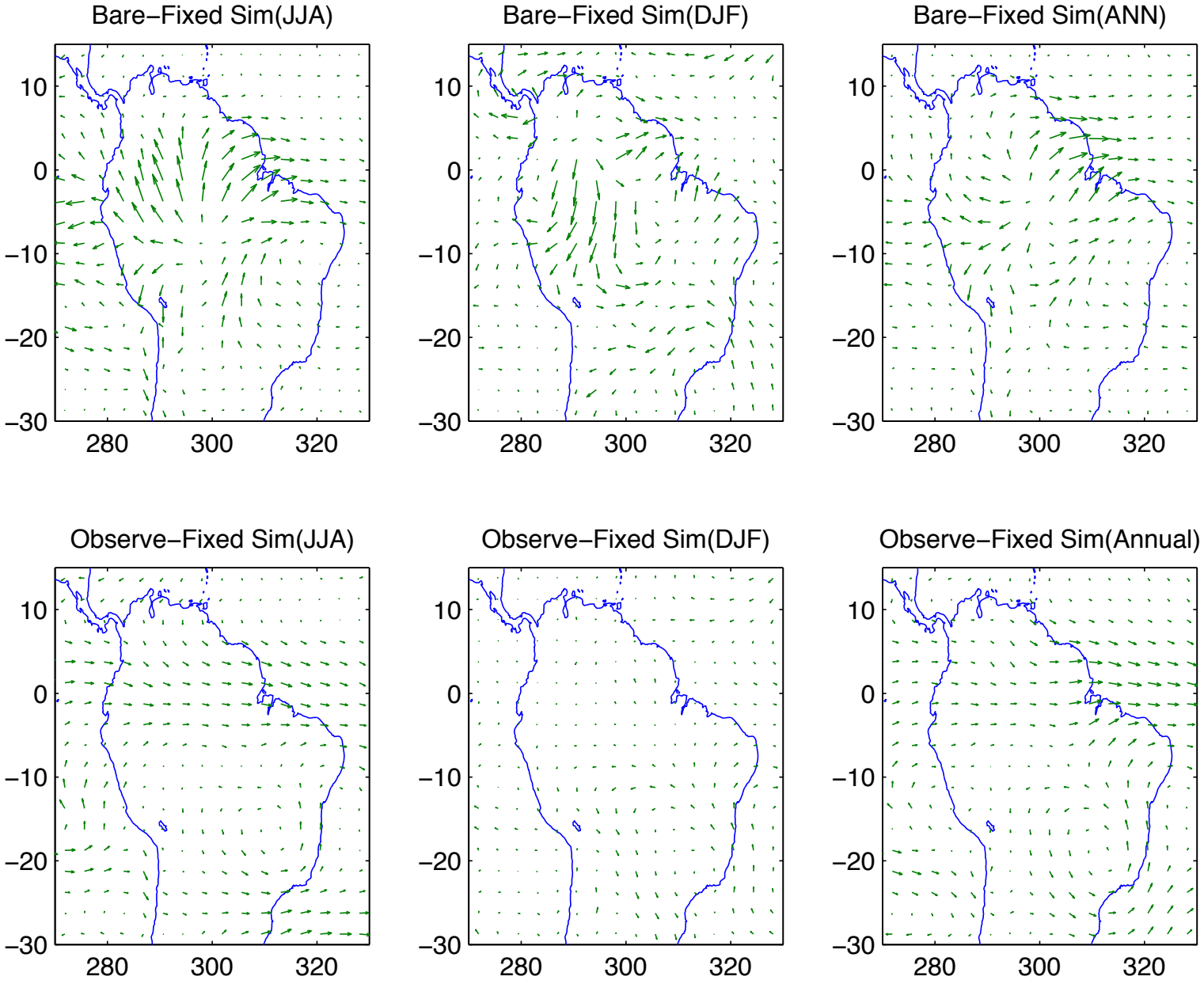
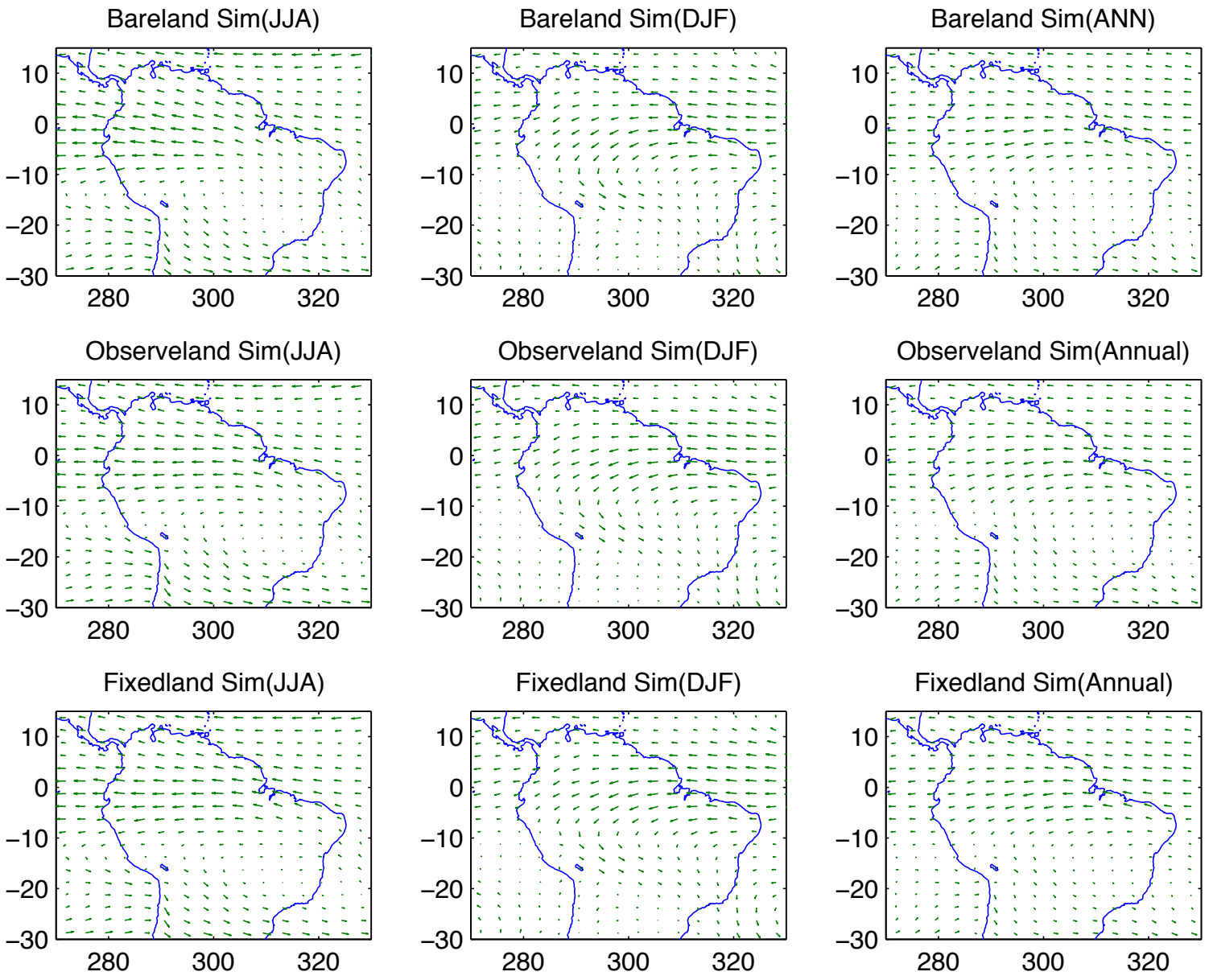
  - investigate ground water discharge
  - the effects of evaporation on the ground water systems

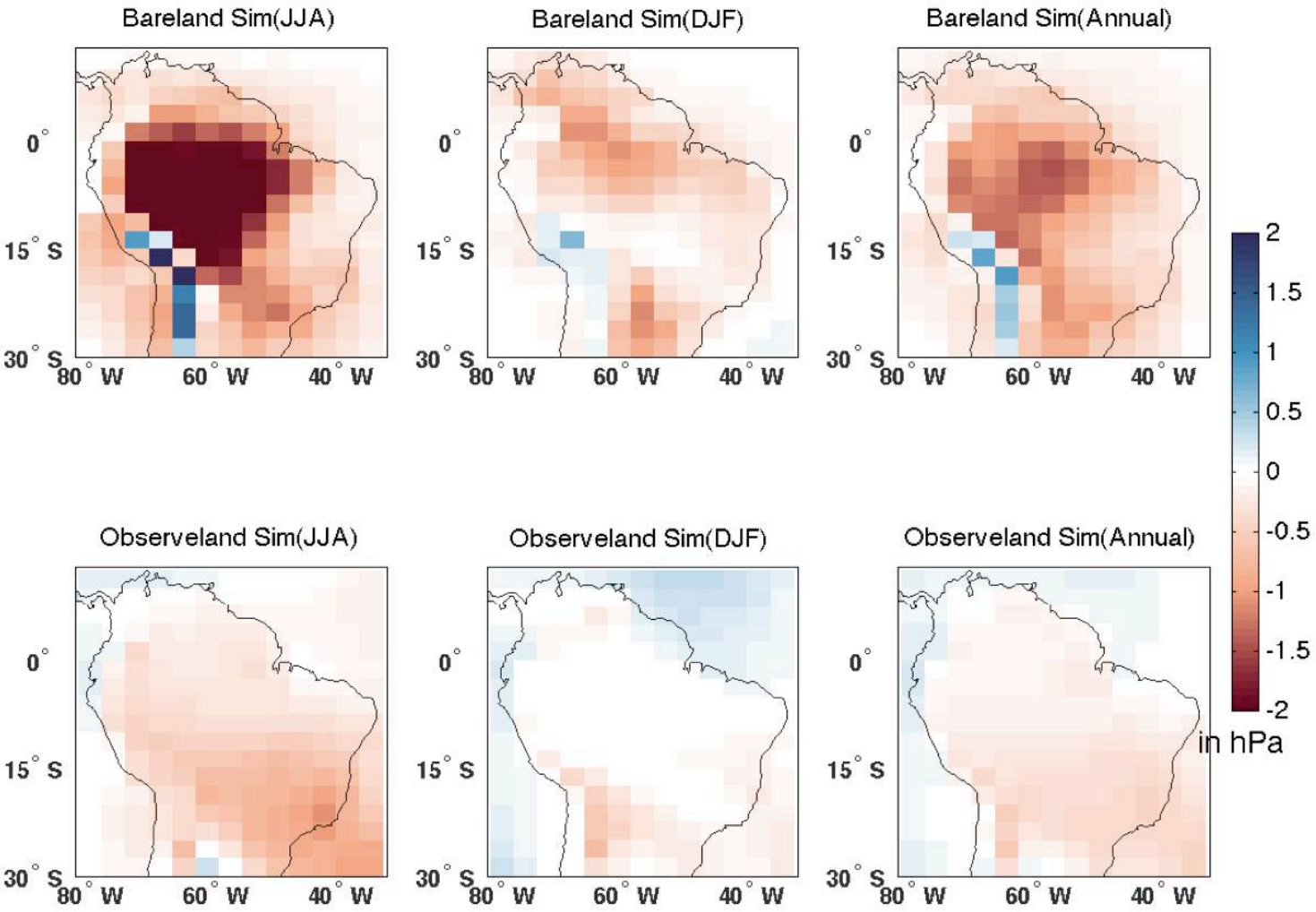
Wind@850 difference w.r.t. Fixed land simulation



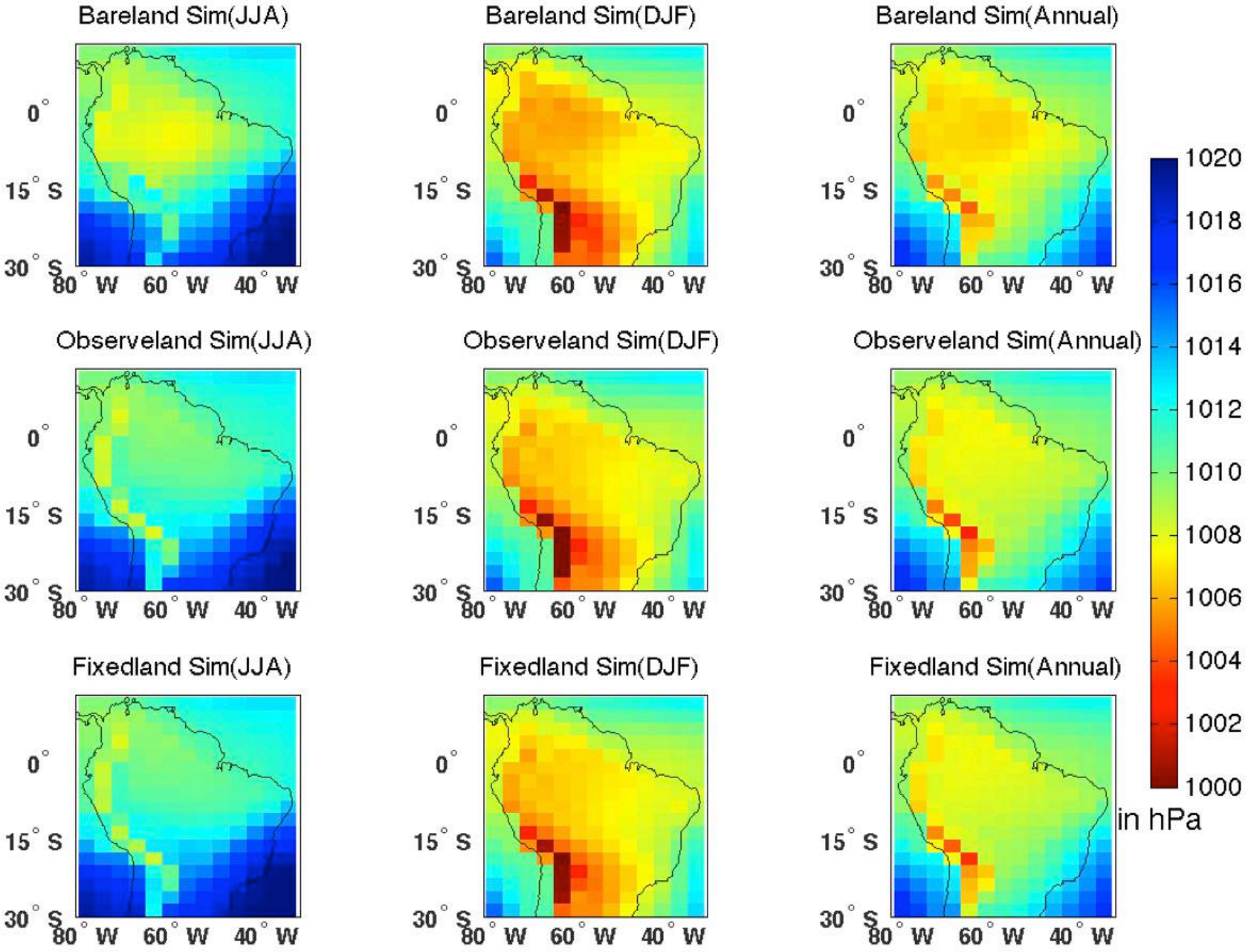
Mean Wind@850 hPa from All Three Simulations



MSLP difference w.r.t. Fixed land simulation

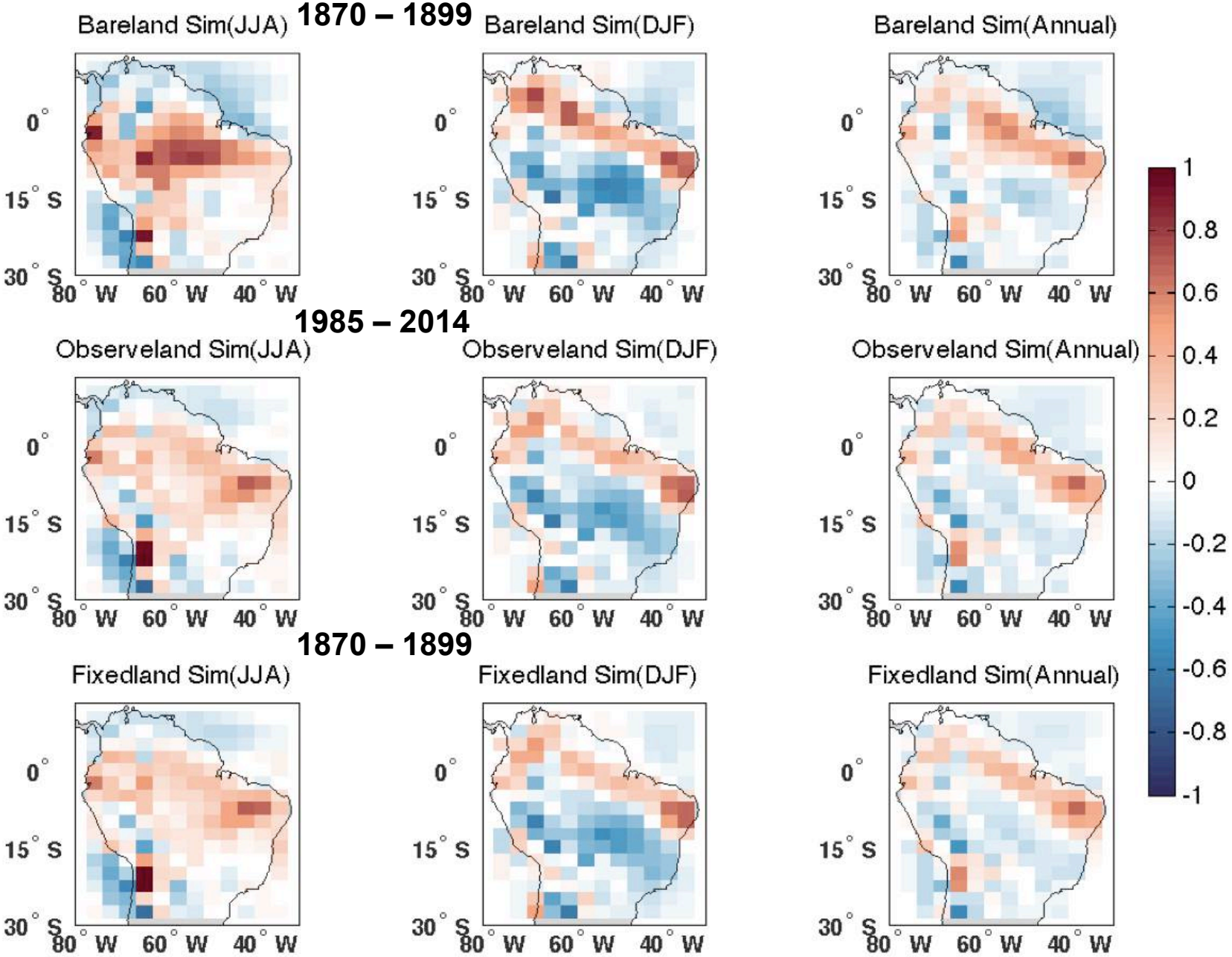


MSLP in all Simulation



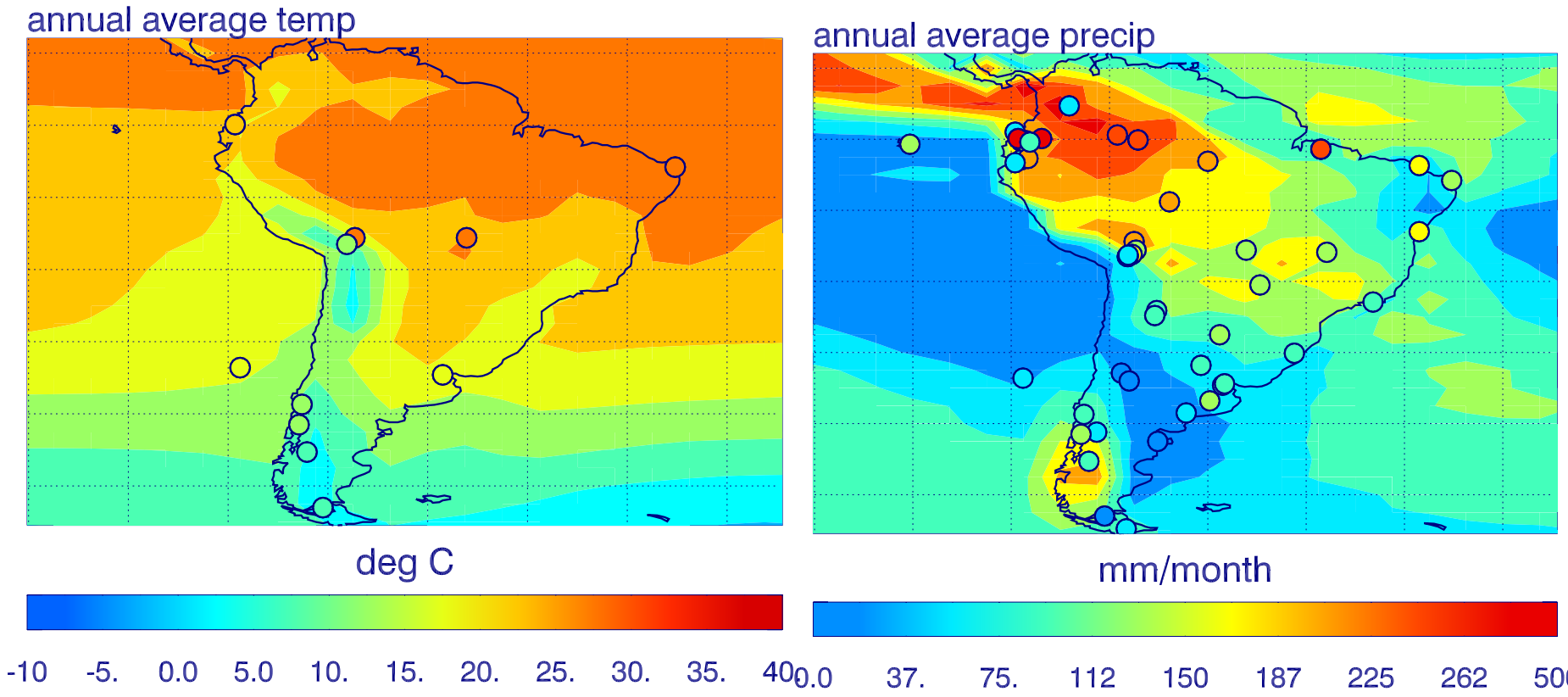
Divergence from All three Simulations

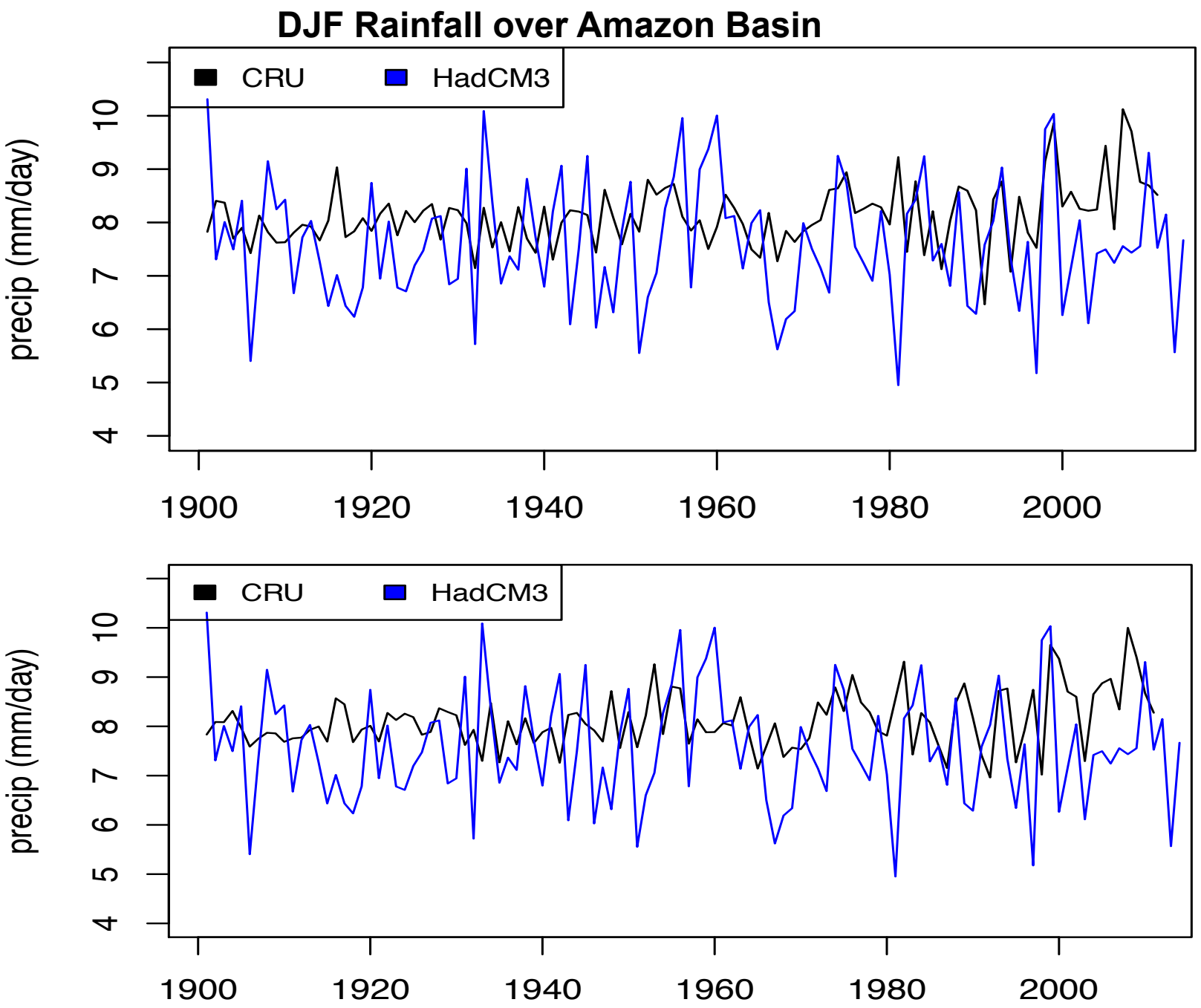
1870 – 1899

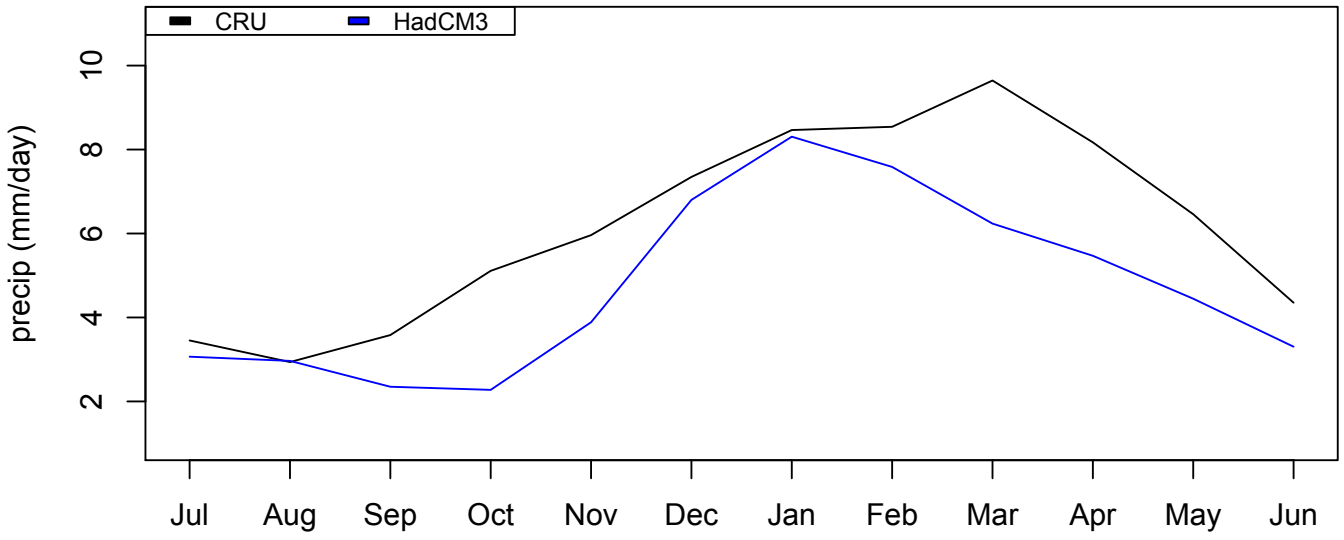


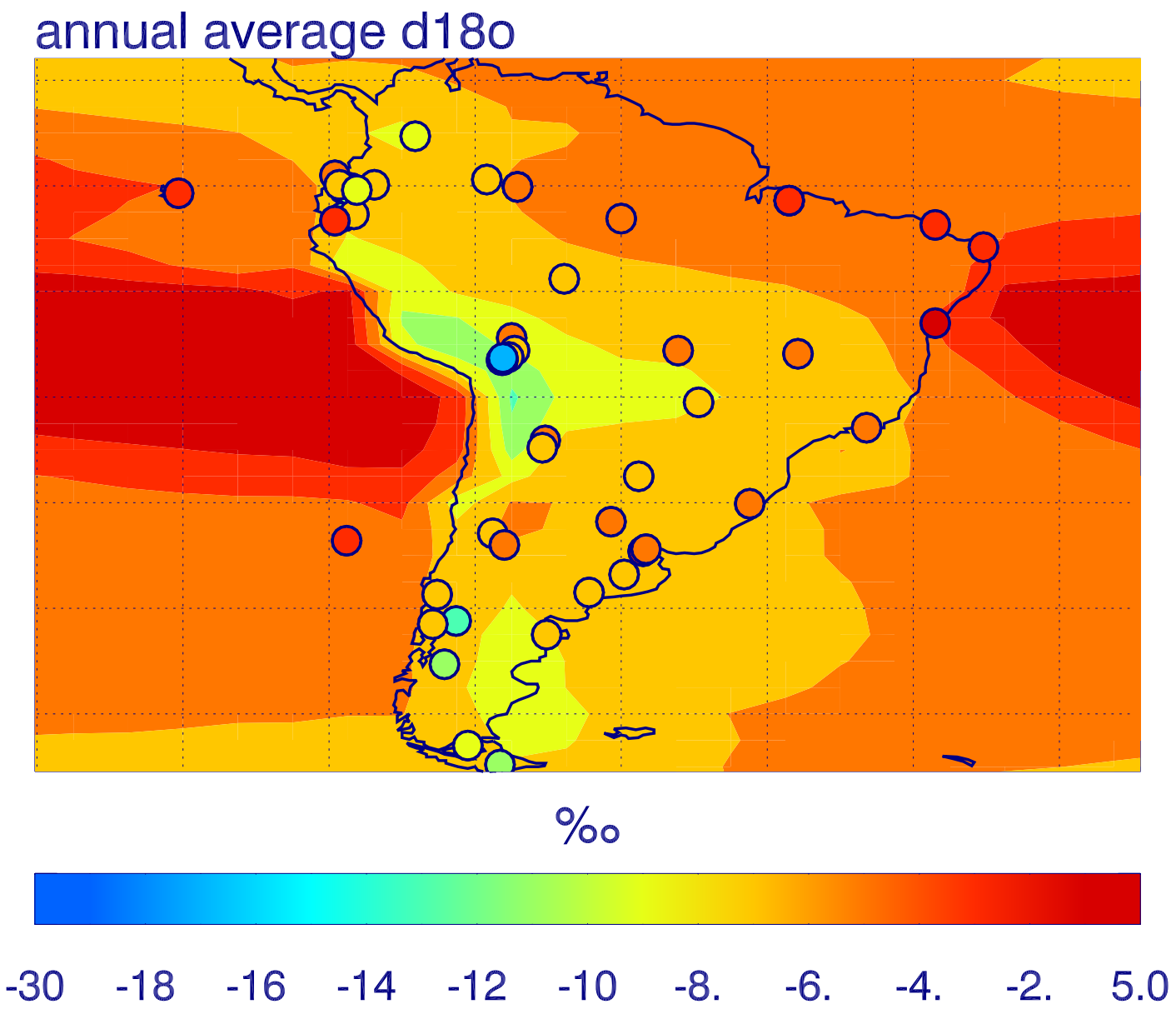
Conclusions

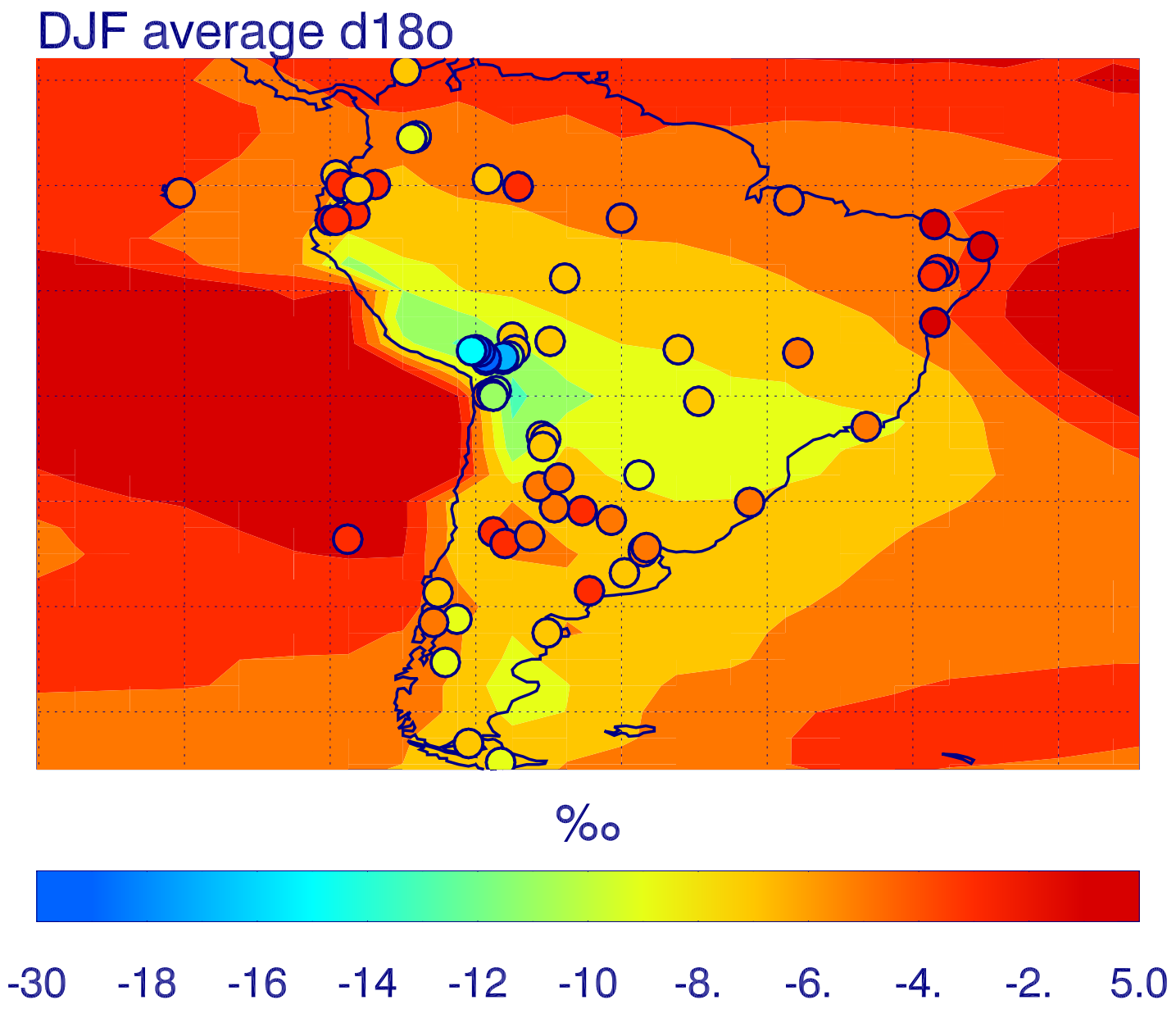
- The

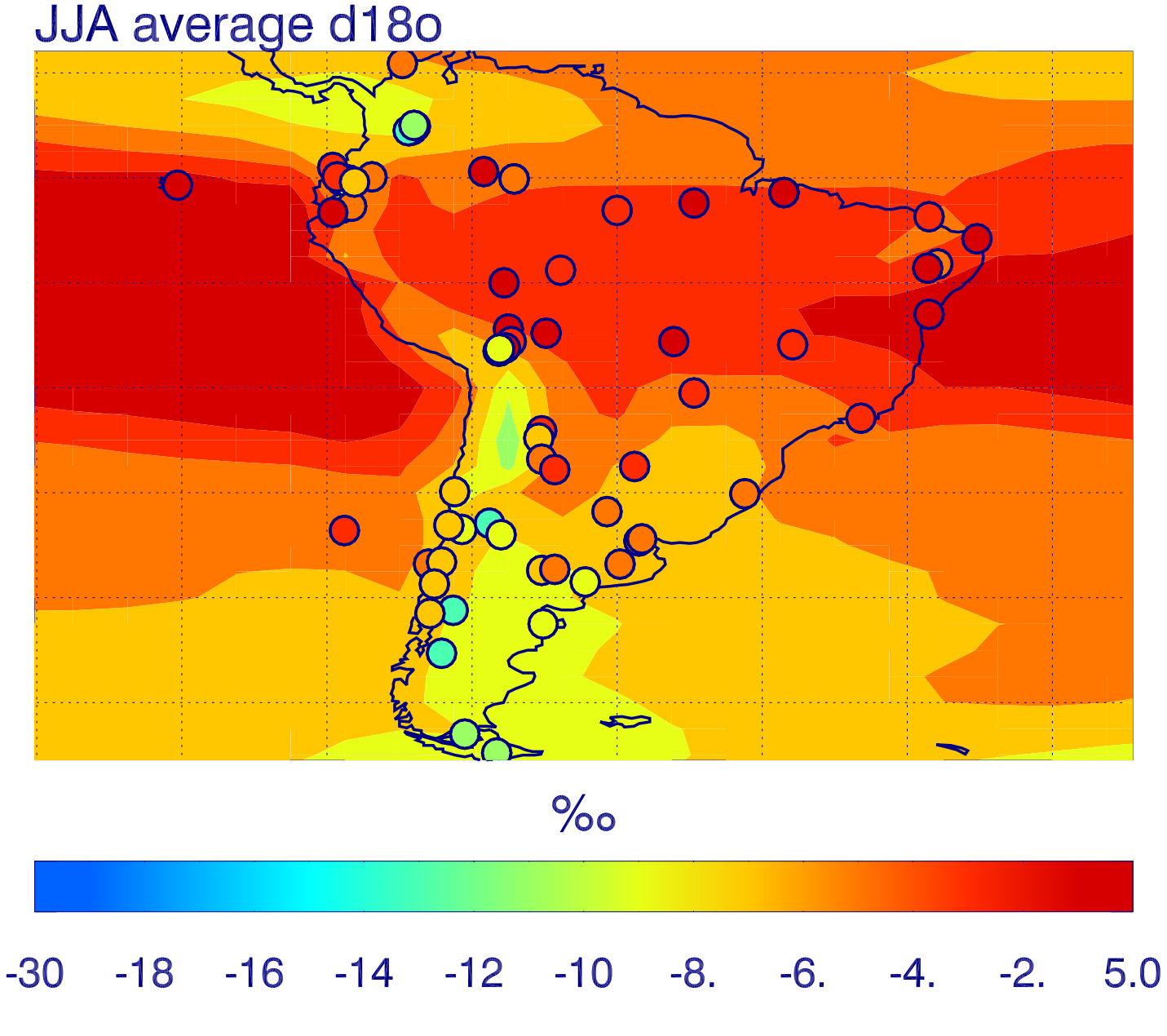

annual average temp
annual average precip
deg C
mm/month
-10 -5. 0.0 5.0 10. 15. 20. 25. 30. 35. 40
0.0 37. 75. 112 150 187 225 262 500

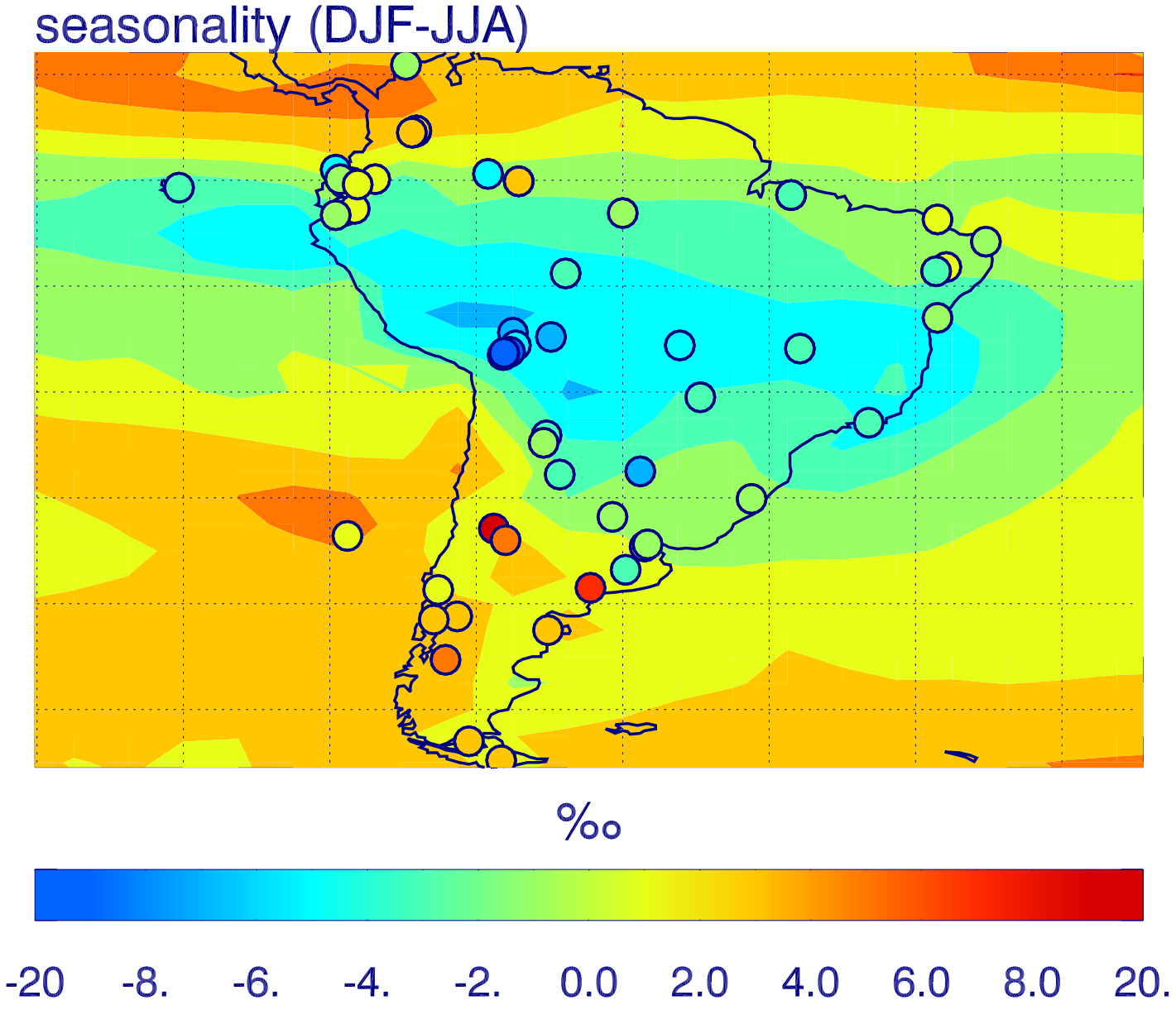

DJF Rainfall over Amazon Basin
CRU
HadCM3
precip (mm/day)
4
5
6
7
8
9
10
1900
1920
1940
1960
1980
2000
CRU
HadCM3
precip (mm/day)
4
5
6
7
8
9
10
1900
1920
1940
1960
1980
2000

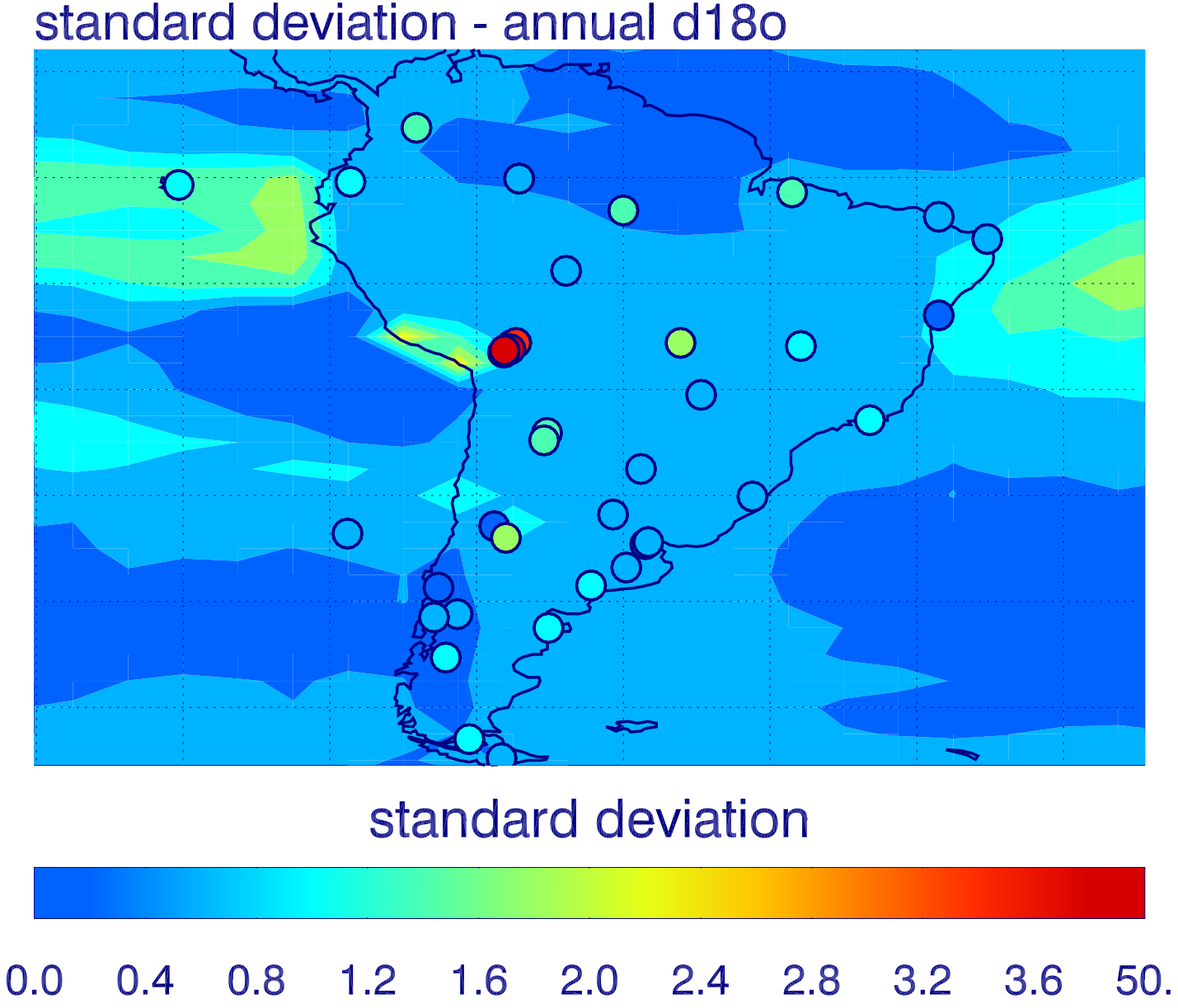

CRU
HadCM3
precip (mm/day)
2
4
6
8
10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun

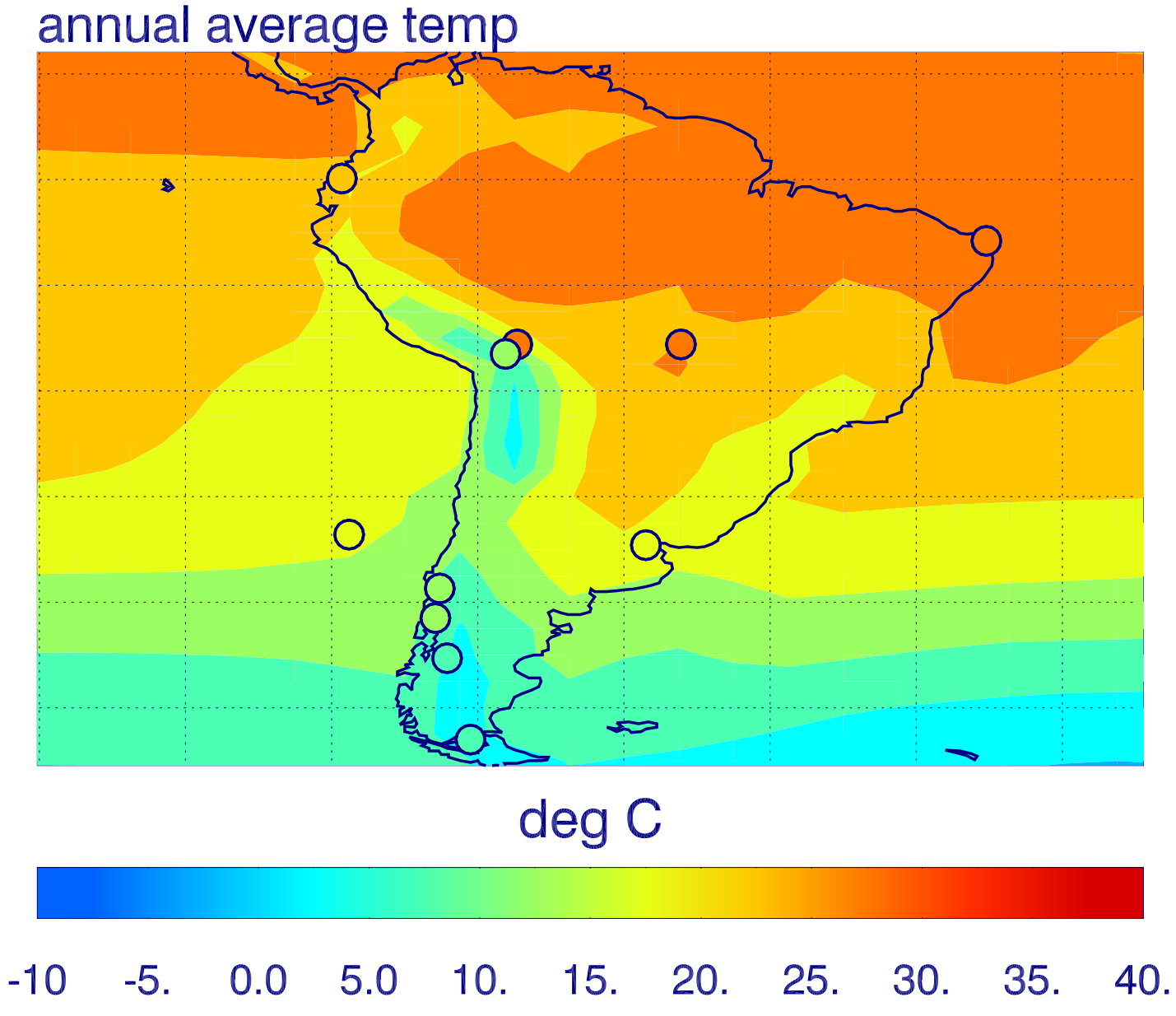

annual average d18o
‰
-30
-18
-16
-14
-12
-10
-8.
-6.
-4.
-2.
5.0

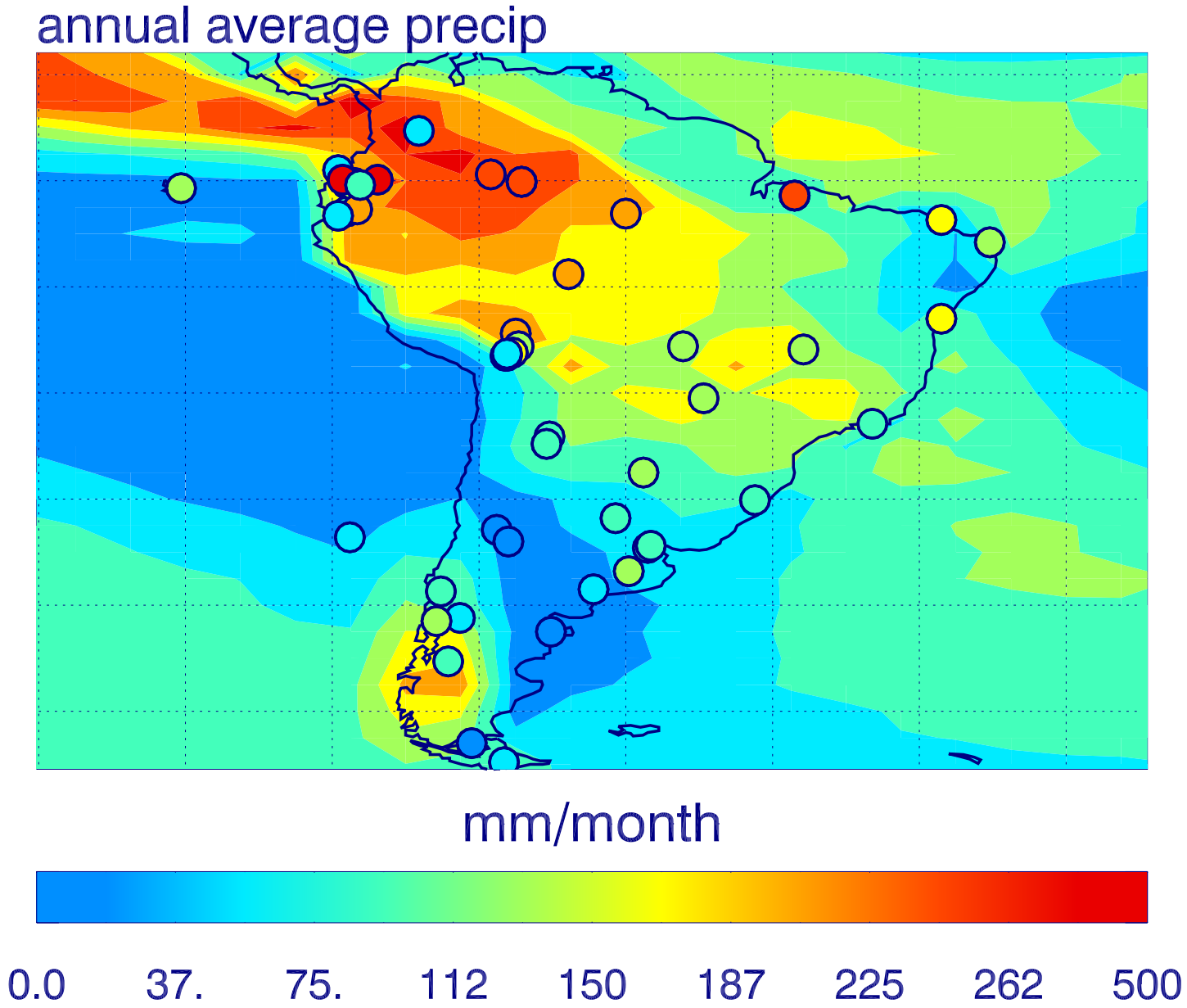

DJF average d18o
‰
-30
-18
-16
-14
-12
-10
-8.
-6.
-4.
-2.
5.0

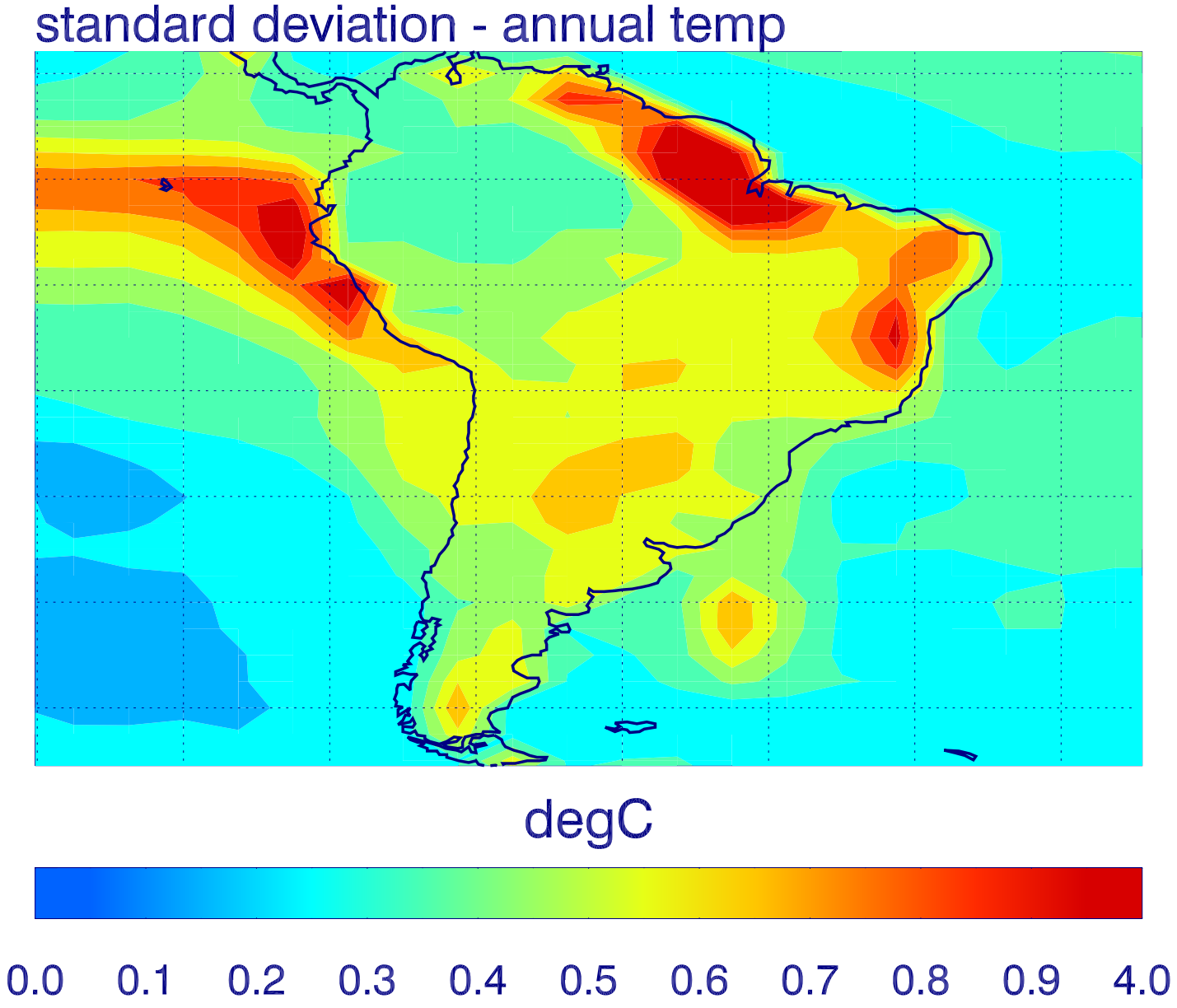

JJA average d18o
‰
-30
-18
-16
-14
-12
-10
-8.
-6.
-4.
-2.
5.0

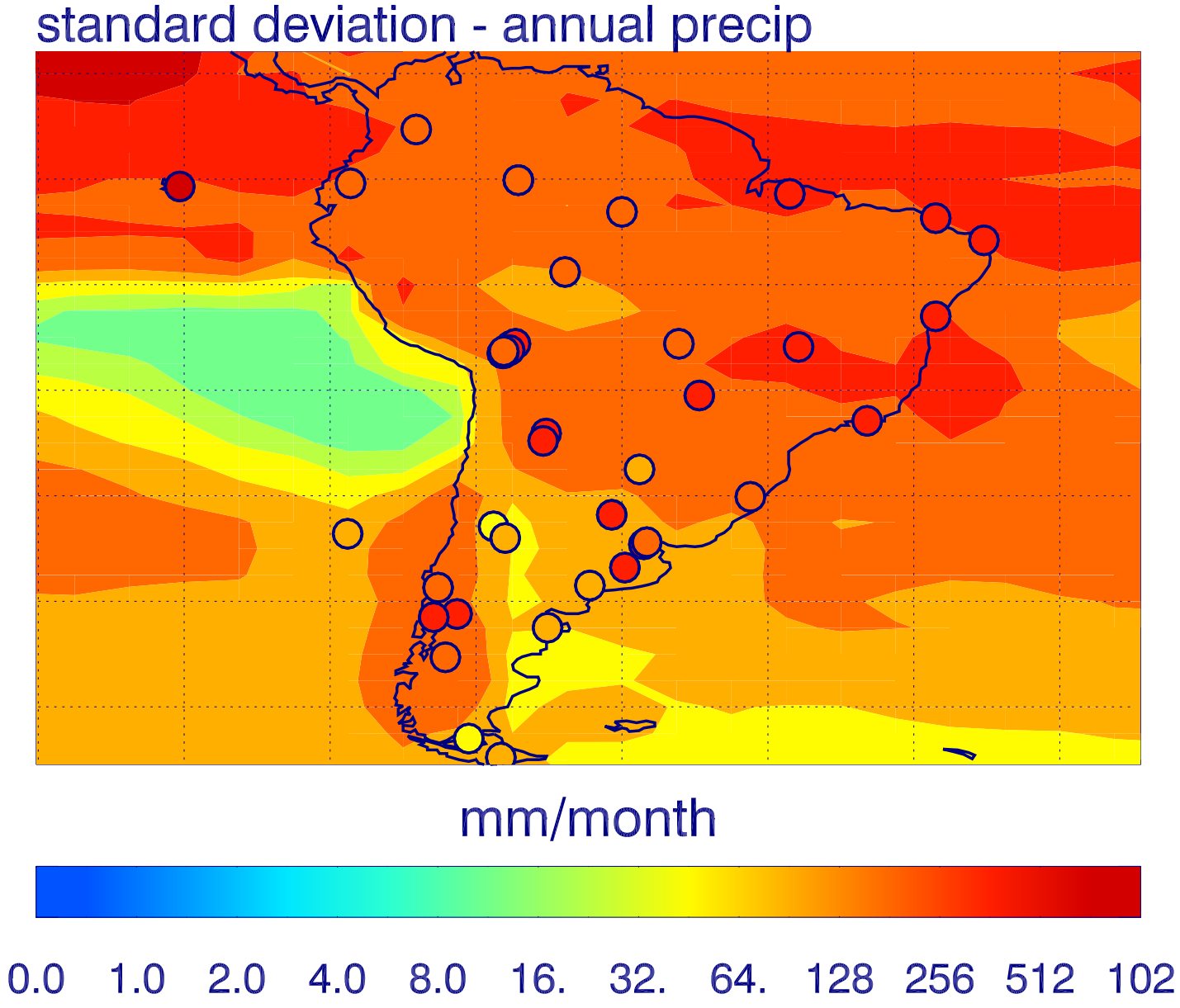

seasonality (DJF-JJA)
‰
-20
-8.
-6.
-4.
-2.
0.0
2.0
4.0
6.0
8.0
20.


standard deviation - annual d18o
standard deviation
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
50.

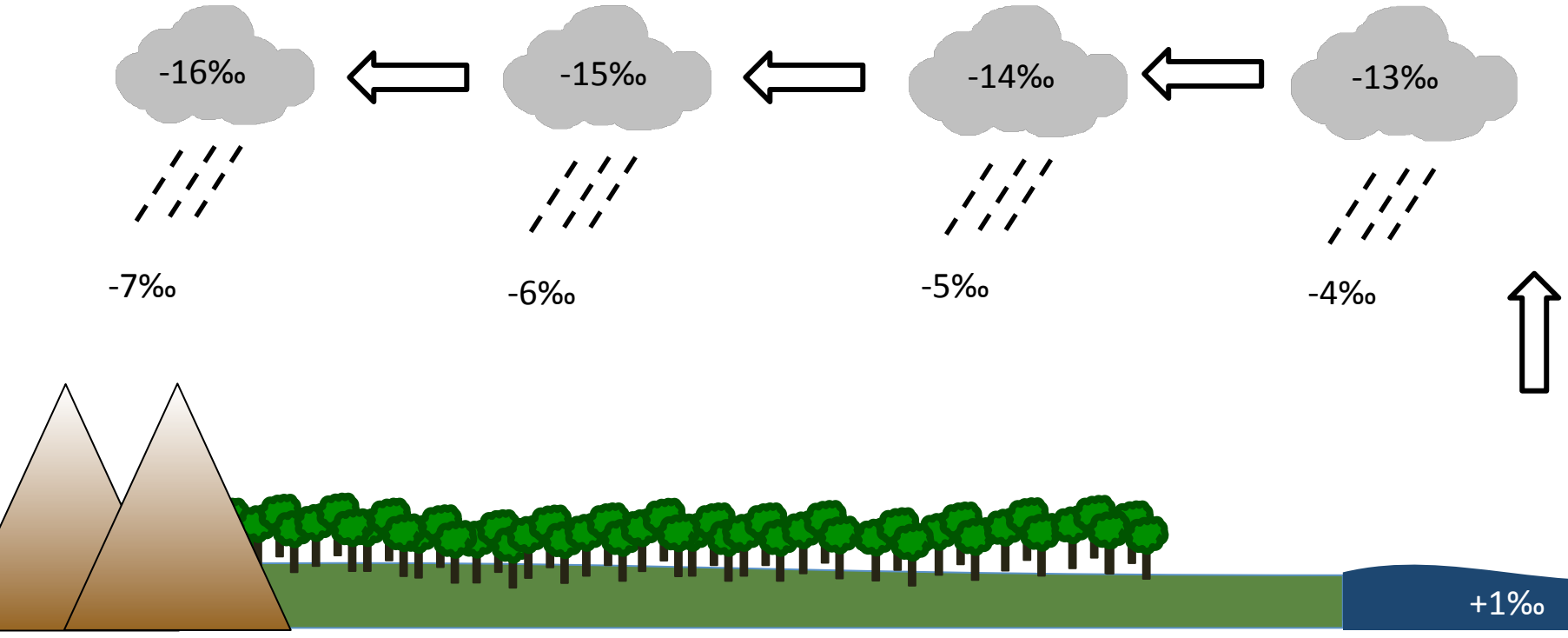

annual average temp
deg C
-10
-5.
0.0
5.0
10.
15.
20.
25.
30.
35.
40.


annual average precip
mm/month
0.0
37.
75.
112
150
187
225
262
500


standard deviation - annual temp
degC
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
4.0

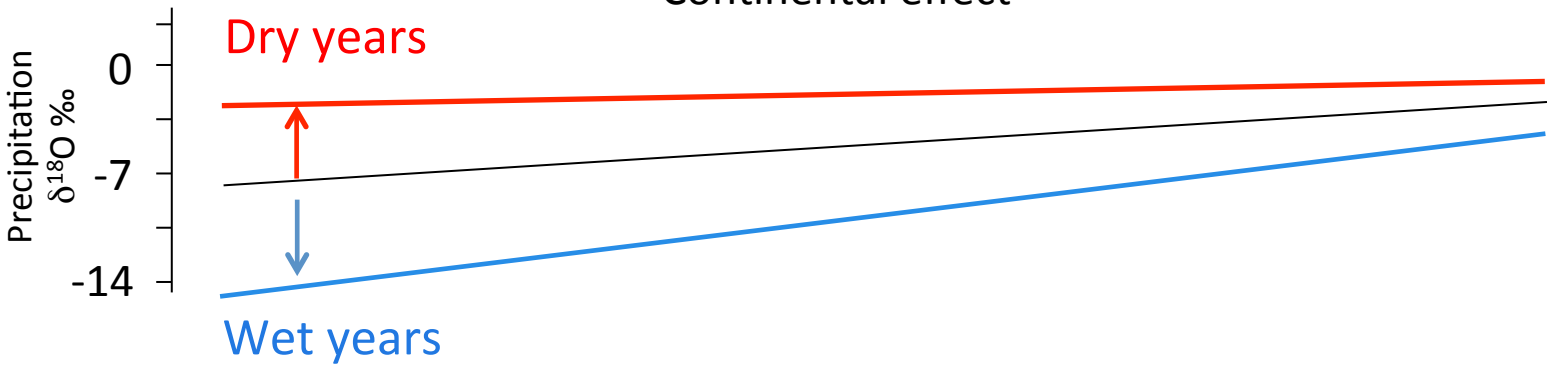

standard deviation - annual precip
mm/month
0.0 1.0 2.0 4.0 8.0 16. 32. 64. 128 256 512 102

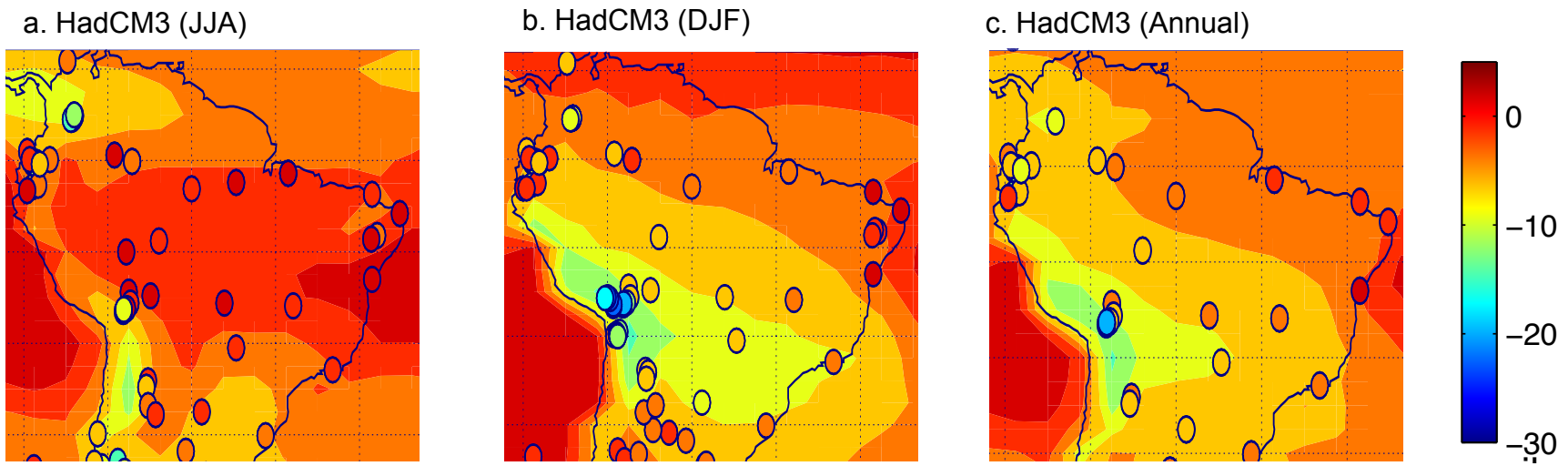
Oxygen isotopes in the Amazon hydrological cycle



"Continental effect"

Tropical North Atlantic



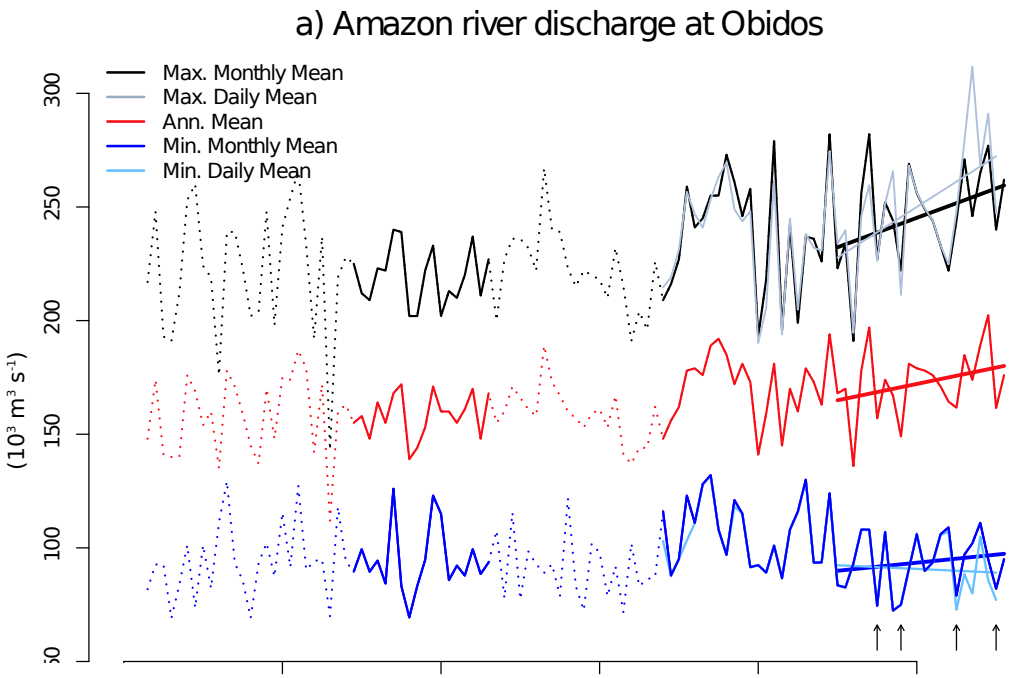

a. HadCM3 (JJA)
b. HadCM3 (DJF)
c. HadCM3 (Annual)
0
−10
−20
−30

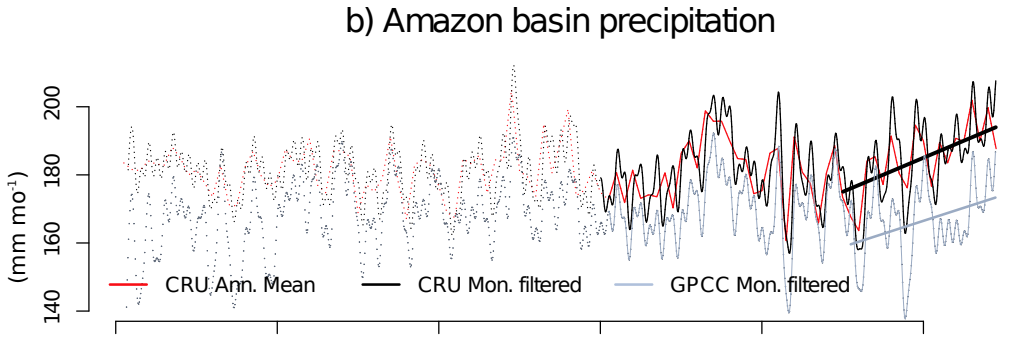
Amazon river discharge at Obidos

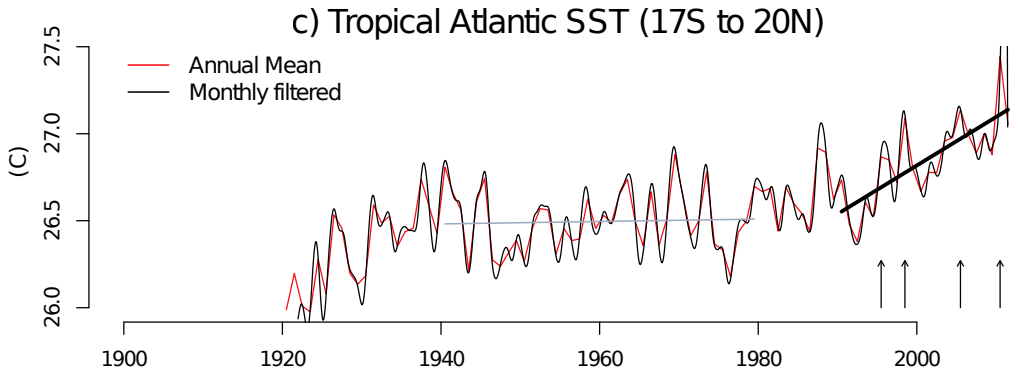
Amazon basin precipitation

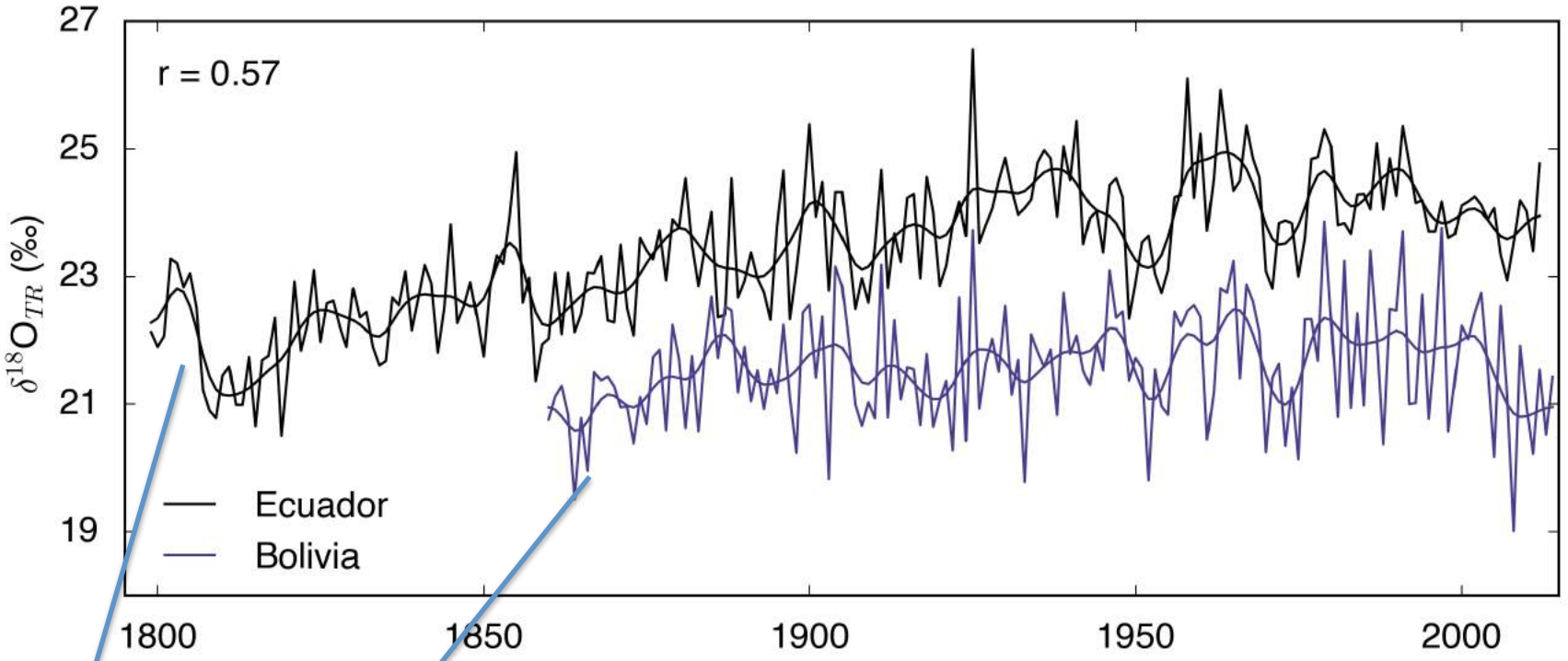
Tropical Atlantic SST (17S to 20N)

Gloor et al. GRL 2013



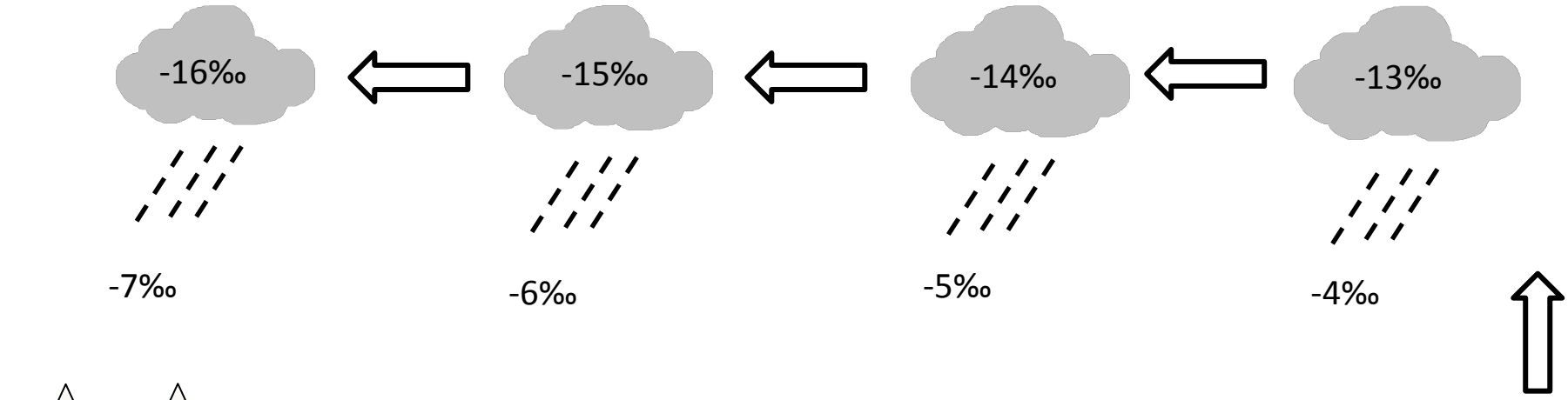




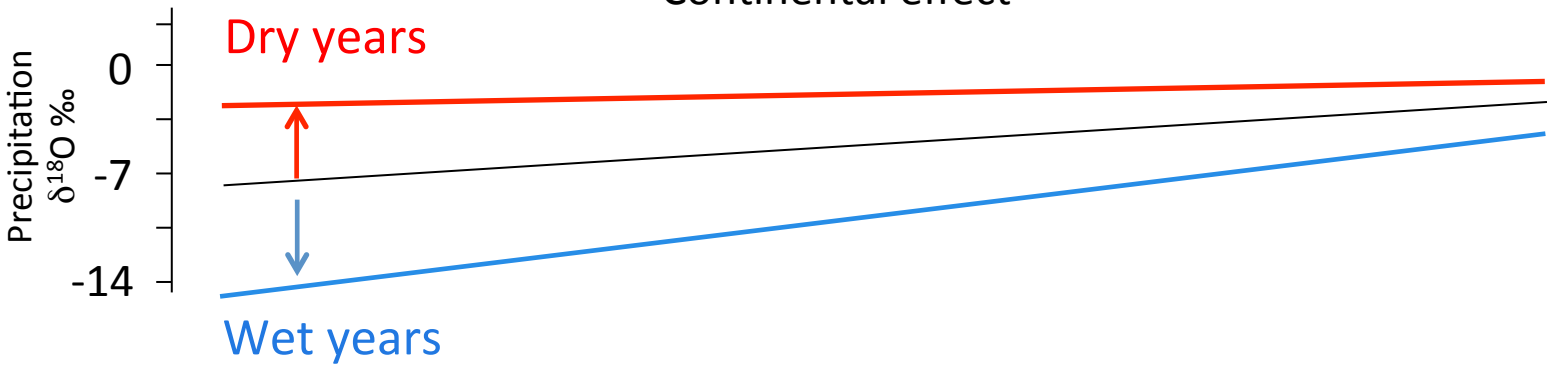

r = 0.57
$\delta^{18}O_{TR}$ (‰)
27
25
23
21
19
1800
1850
1900
1950
2000
Ecuador
Bolivia


10°N
0°
10°S
20°S
80°W
70°W
60°W
50°W
40°W
30°W
CY
SN
ET
P
Ecuador
Bolivia

Oxygen isotopes in the Amazon hydrological cycle



"Continental effect"



Rayleigh Distillation

Isotopic ratio of water isotopes (R)

$$\frac{R(t)}{R(0)} = f^{\alpha-1}$$

f - Fraction of water remaining

$$f = \frac{N(t)}{N(0)}$$

From conservation of momentum,

we can conclude that $\frac{N(t)}{N(0)}$ may change

But cannot say that $N(0)$ changed

Maybe show records of Roel / possibly Jessica

There seem to be long-term patterns

[maybe also one slide with main winds / circulation of the lower troposphere over Amazon − 1991 paper of Nobre ..

Explain possible mechanisms - mention Raleigh distillation
…

Show a map with deforestation in Amazon
1991 paper of Nobre .. [two stable states ???]

This is a modelling analysis which attempts to give us a better understanding the relation between isotope signatures and changes of the hydrological cycle

Simulations and diagnostics

- Use your table
- Need to explain what the recirculation ratio is − Van der Ent paper
  say how implemented − add an additional water vapor tracer − water vapor which is evaporated from the land …

What can water oxygen isotopes tell us about changes in the Amazon Hydrological Cycle?

Presented by

K C Pattnayak

Contributors

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University of Leeds
Leeds, UK

Symposium on "Cloud, Their Properties and Their Climate Feedbacks", 6 – 8 June 2017, NASA GISS, Columbia University, New York, USA