Unraveling the Drivers of the Drought over São Paulo (Brazil) using HadAM3

Presented by

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Outline

- Characterization of São Paulo droughts 2013/14 and 2014/15
- Limited analysis of possible causes using HadCM3 simulations
- Limited analysis of future repeatability of the events in a warming climate

Empty Reservoirs

Drought-Stricken Southeast Brazil Has Lost 15 Trillion Gallons of Water Per Year Since 2012

By **Mark Leberfinger**, AccuWeather.com Staff Writer
November 12, 2015; 6:23 PM ET

The ongoing drought in southeast Brazil has cost the region 15 trillion gallons National Aeronautics and Space Administration (NASA).

WORLD BRAZIL

A Megacity Without Water: São Paulo's Drought

Jon Gerberg @Jongerberg | Oct. 13, 2015

Drought and bad management mean São Paulo is running out of water

World / Brazil

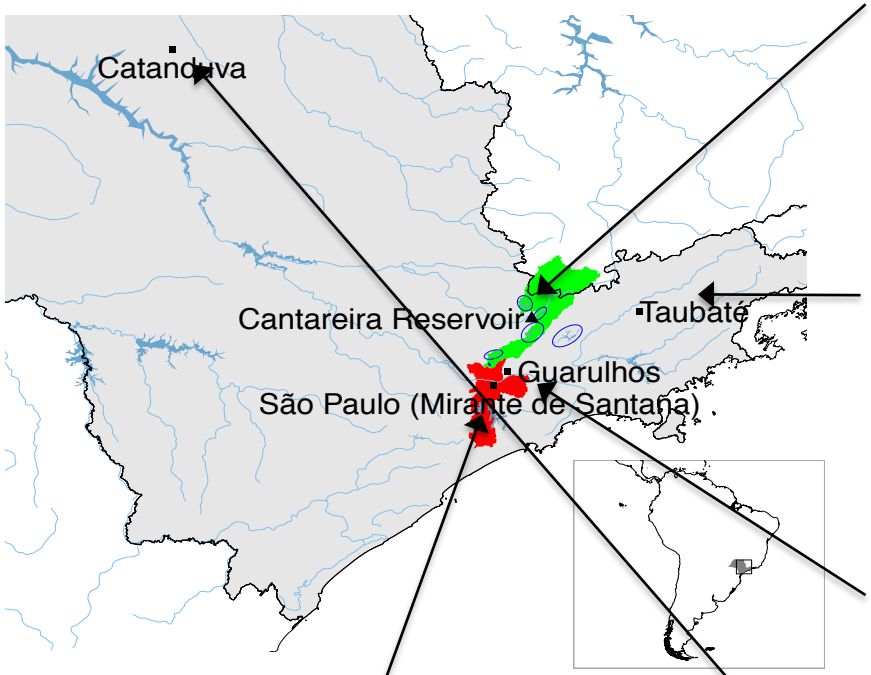
Drought drives water shortage to critical stage in Sao Paulo, Brazil

By **Claire Rigby**

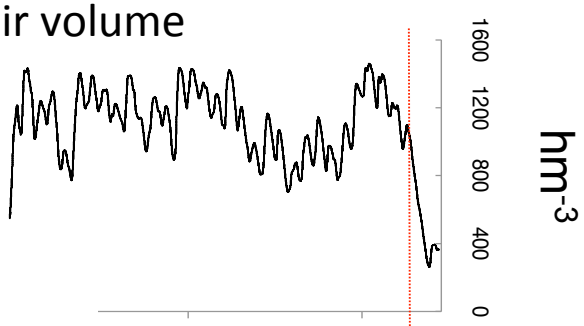
AUGUST 19, 2015, 5:49 PM | REPORTING FROM SAO PAULO, BRAZIL

Officials in Sao Paulo state have announced that the water shortage in the city of the same name is now "critical," with multimillion-dollar emergency construction projects so far failing to ease the situation.

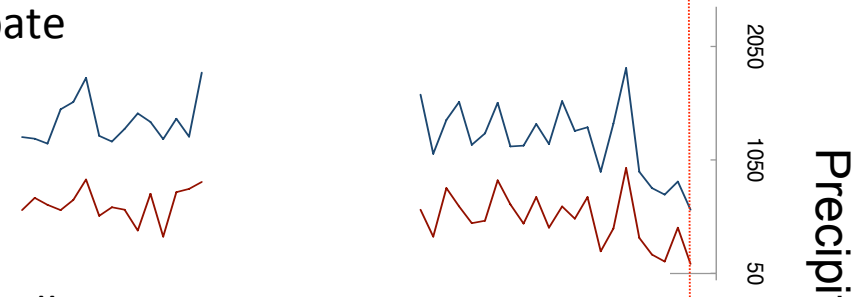
Precipitation records – Cantareira Catchment



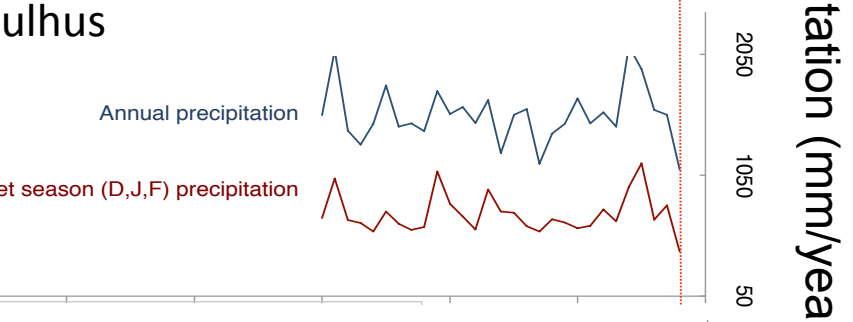
Cantareira reservoir volume



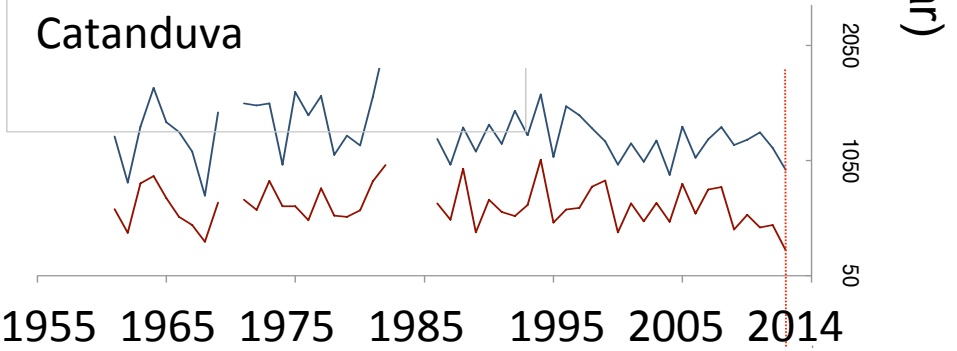
Taubate



Guarulhus

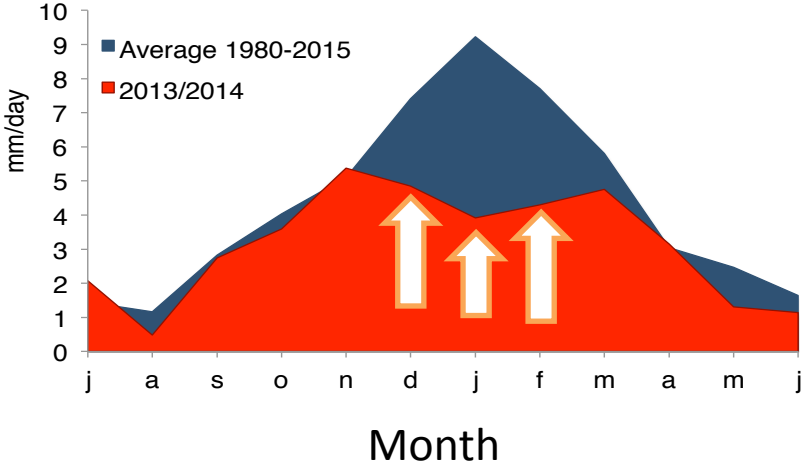


Catanduva

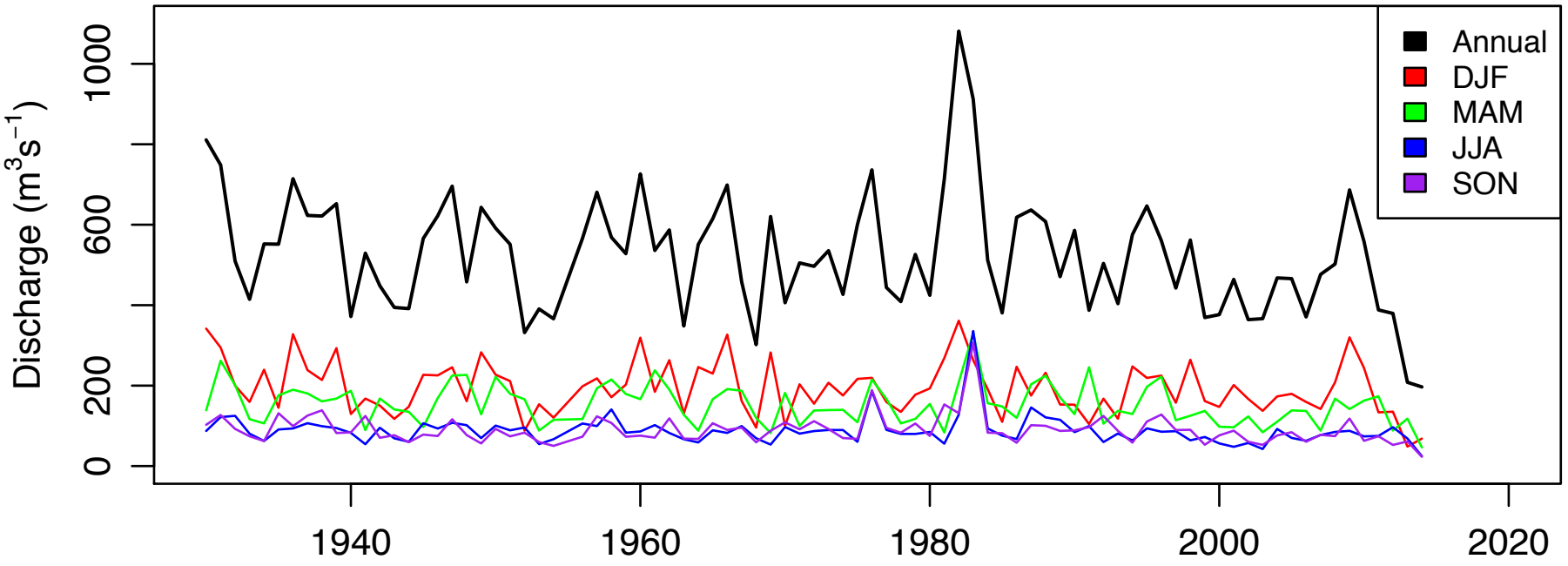


Precipitation (mm/year)

Monthly precipitation over Sao Paulo



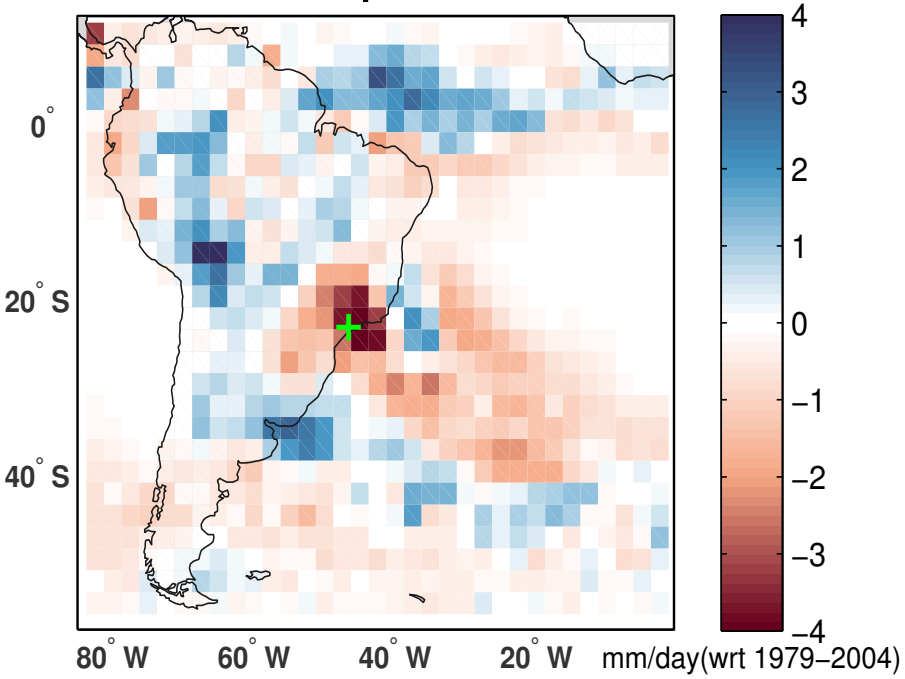
Discharge of rivers feeding the Cantareira Reservoirs



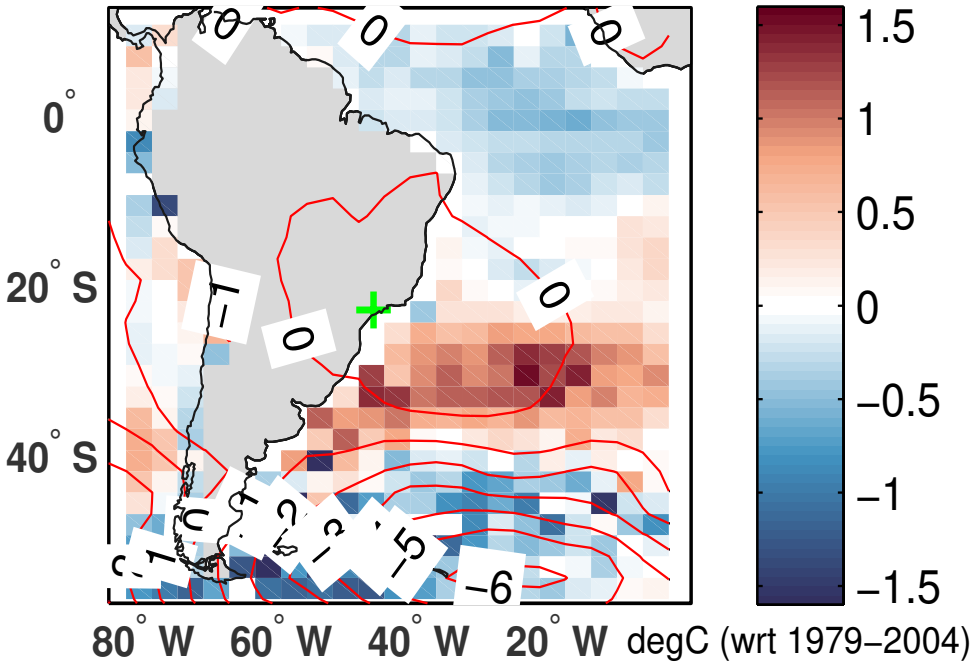
- Inflow has been much lower in 2013/14 and 2014/15 compared to earlier years

Large scale Climate patterns – DJF 2013/14 anomalies

GPCP Precipitation



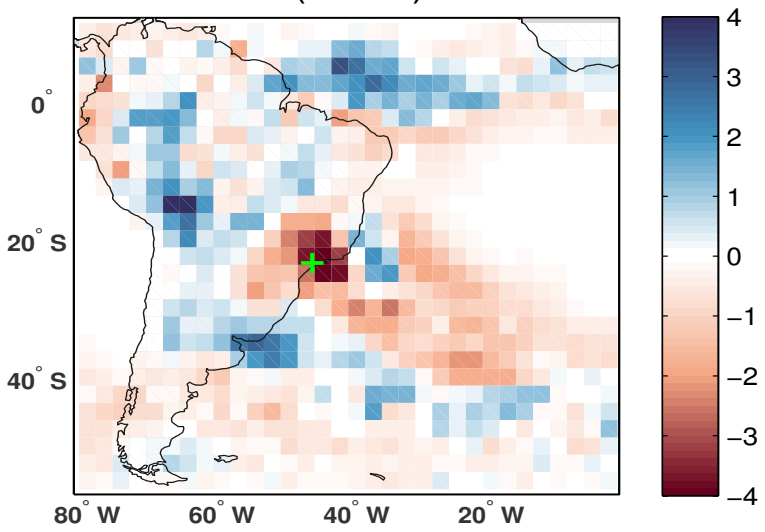
ERA-Interim SST and SLP



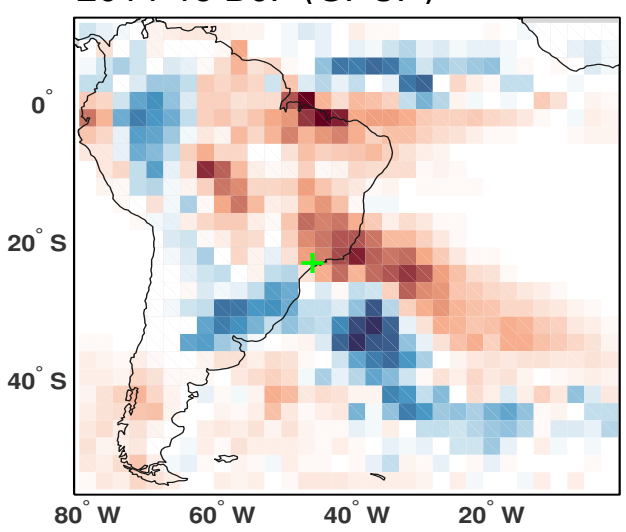
Comparison 2013/14 and 2014/15

Precipitation Anomaly (mm/day)

2013-14 DJF (GPCP)

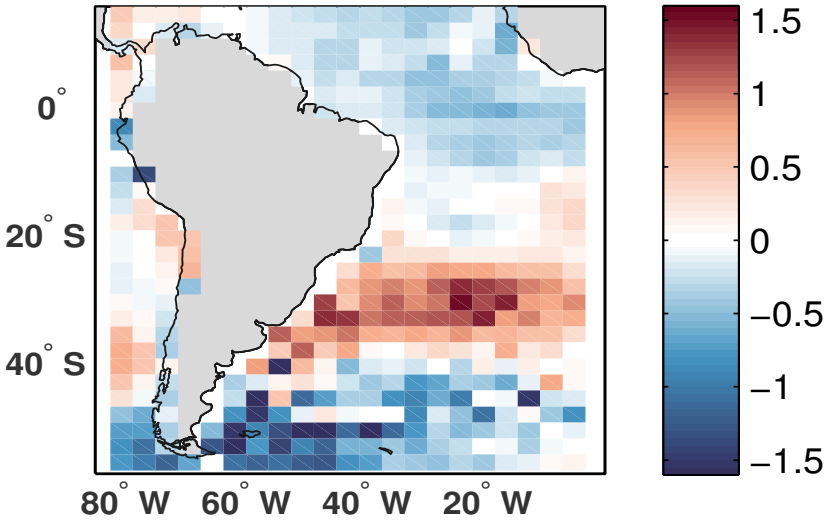


2014-15 DJF (GPCP)

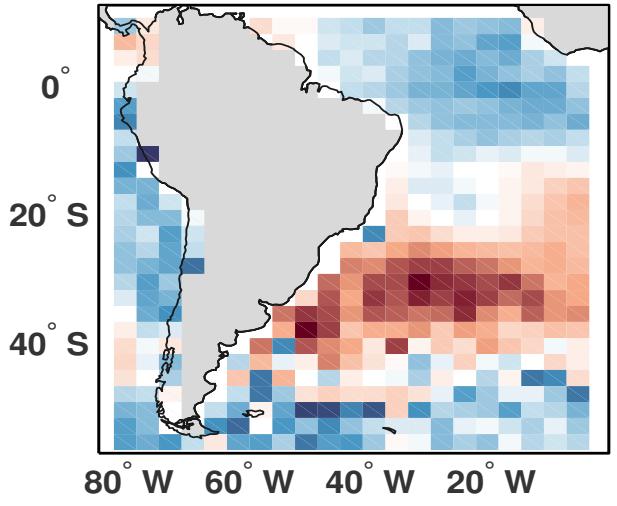


SST Anomaly (deg C)

2013-14 DJF (ERA Interim)

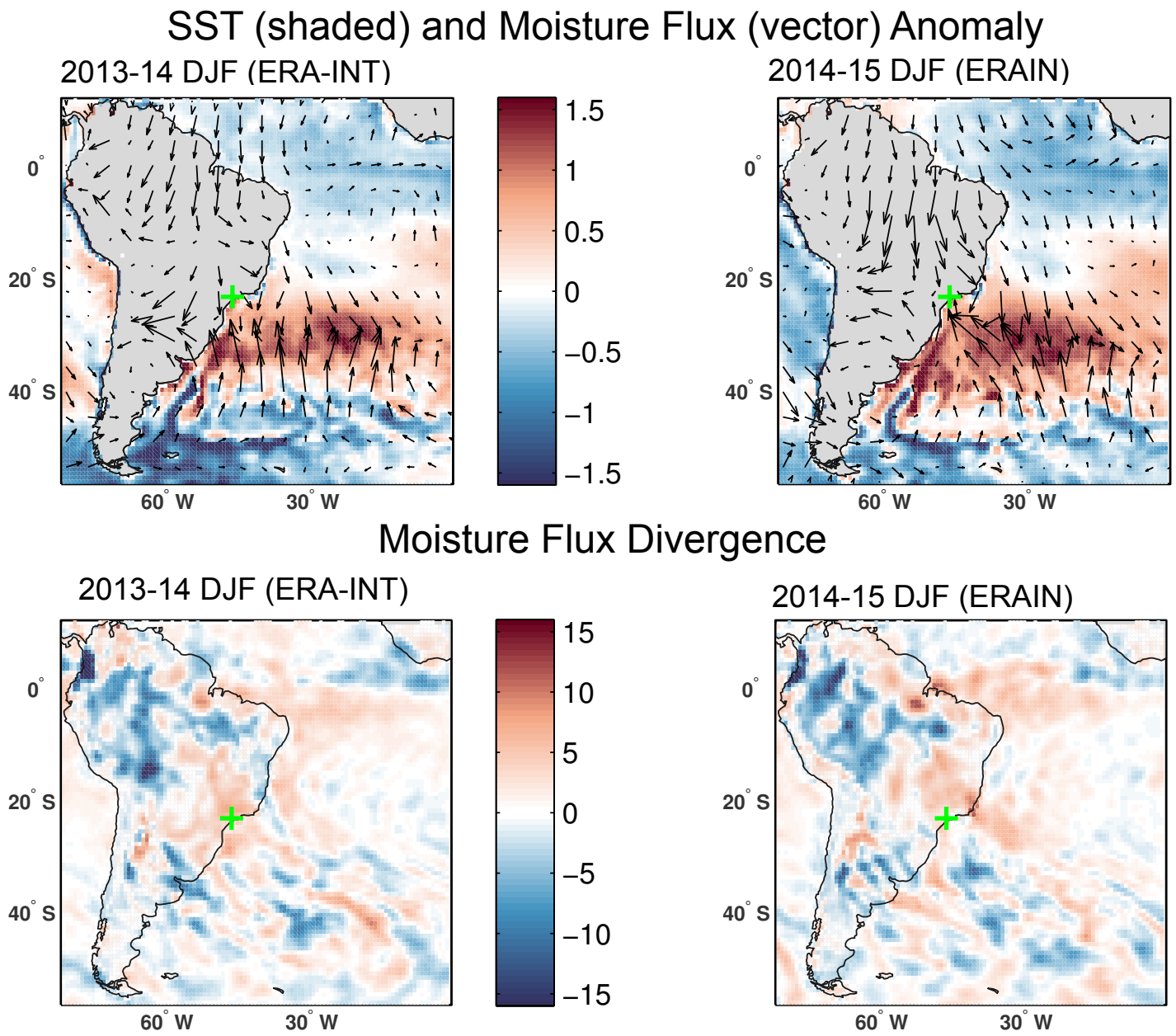


2014-15 DJF (ERA Interim)



Large scale pattern of anomalies are very similar

Water vapour transport anomalies



What could be the causes ?

- Natural climate variation
- Amazon deforestation
- Global warming

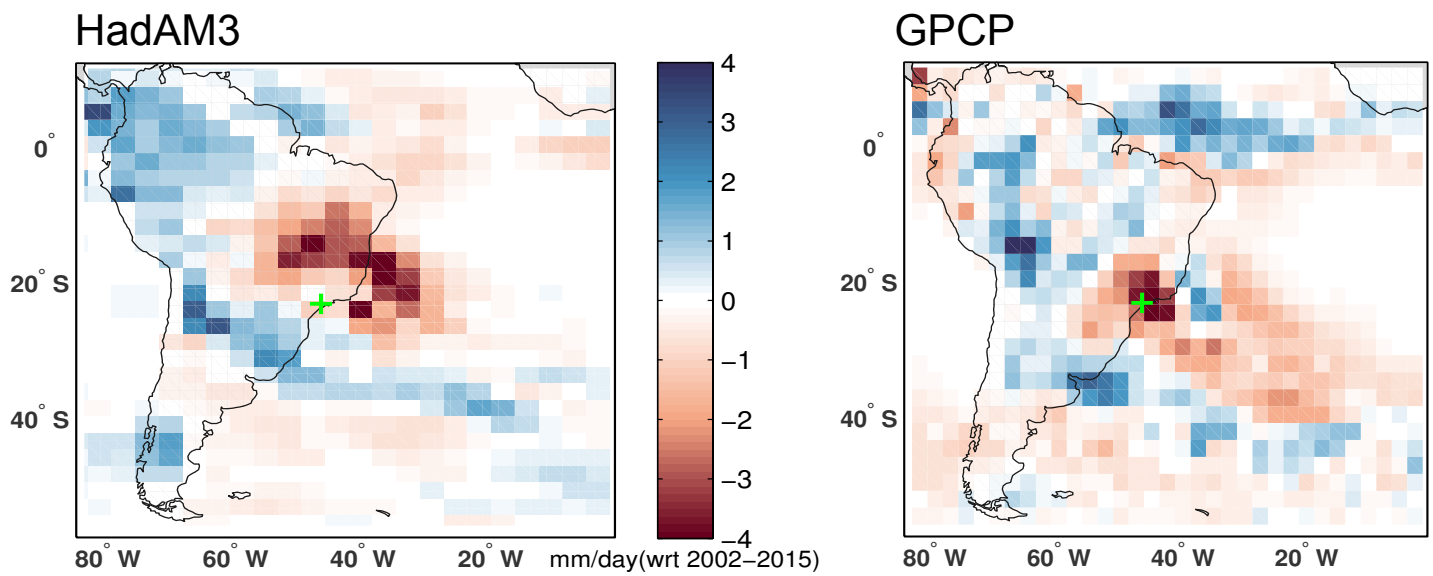
Should we expect more such events in the future ?

Limited investigation of effect of deforestation using HadAM3 simulations

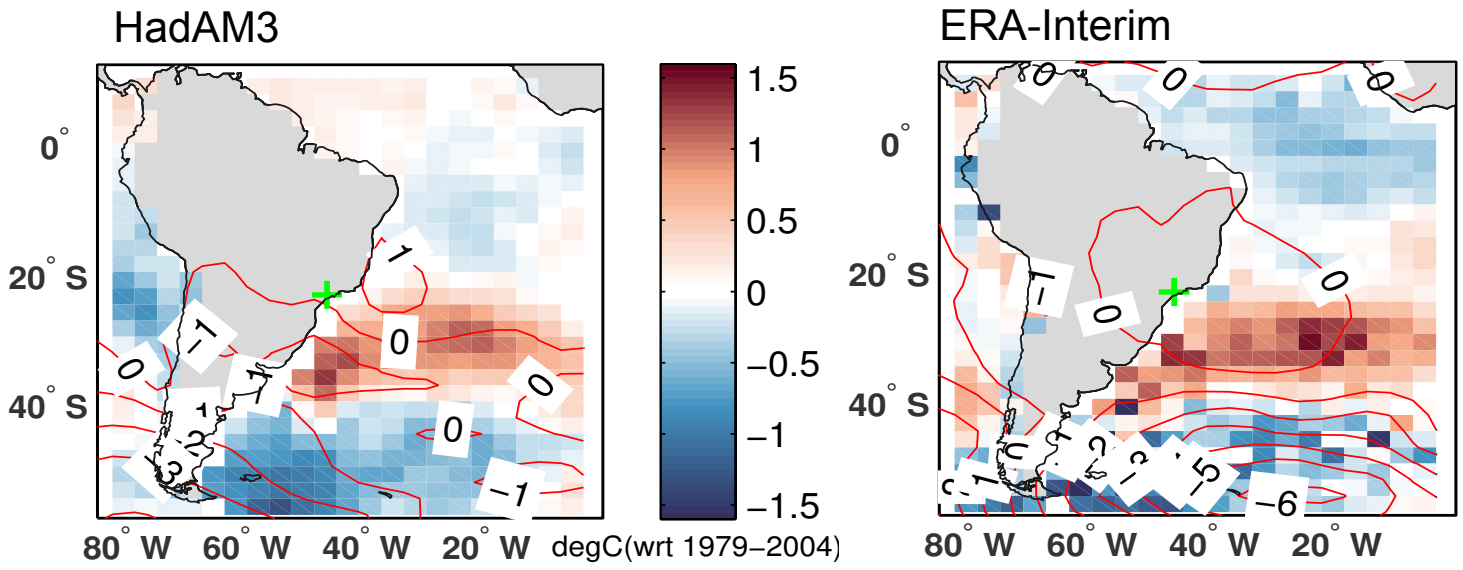
HadAM3 (atmospheric component of HadCM3)

- Simulation period 1861-2014
- Prescribed observed SST's
- No deforestation
- No greenhouse gases added (i.e. constant greenhouse gas radiative forcing)

Comparison Simulation results and Observations: 2013/14 DJF Precipitation Anomaly



2013/14 DJF SST (shaded) and MSLP(contour) Anomaly

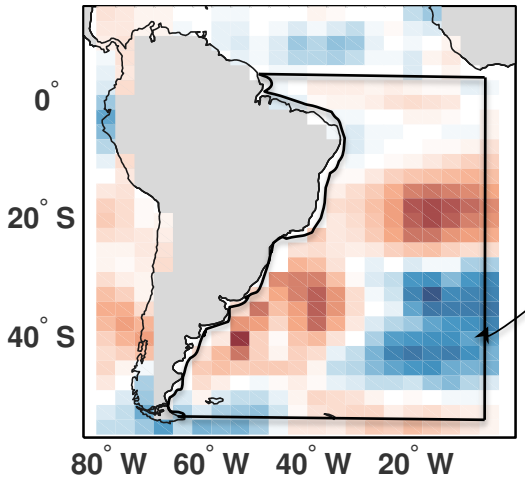


The simulation without Amazon deforestation still leads to deficient rainfall over Sao Paulo region in 2013/14. Thus deforestation may be the reason for such dry event.

How unique is the climate anomaly?

Pattern recognition algorithm

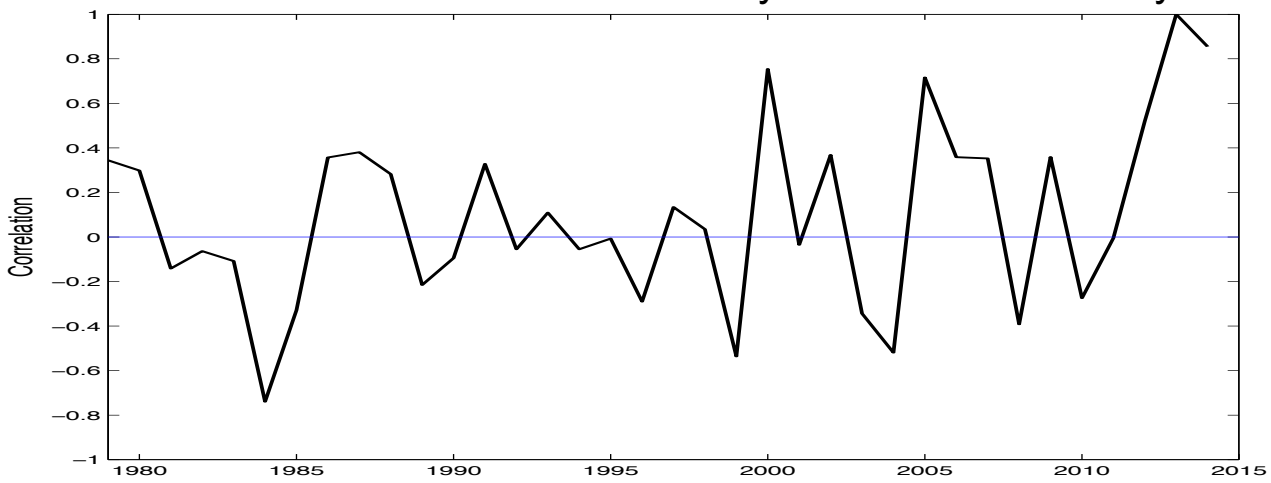
Order SST anomaly in box into a vector



$$\Delta SST_{2013/14}$$

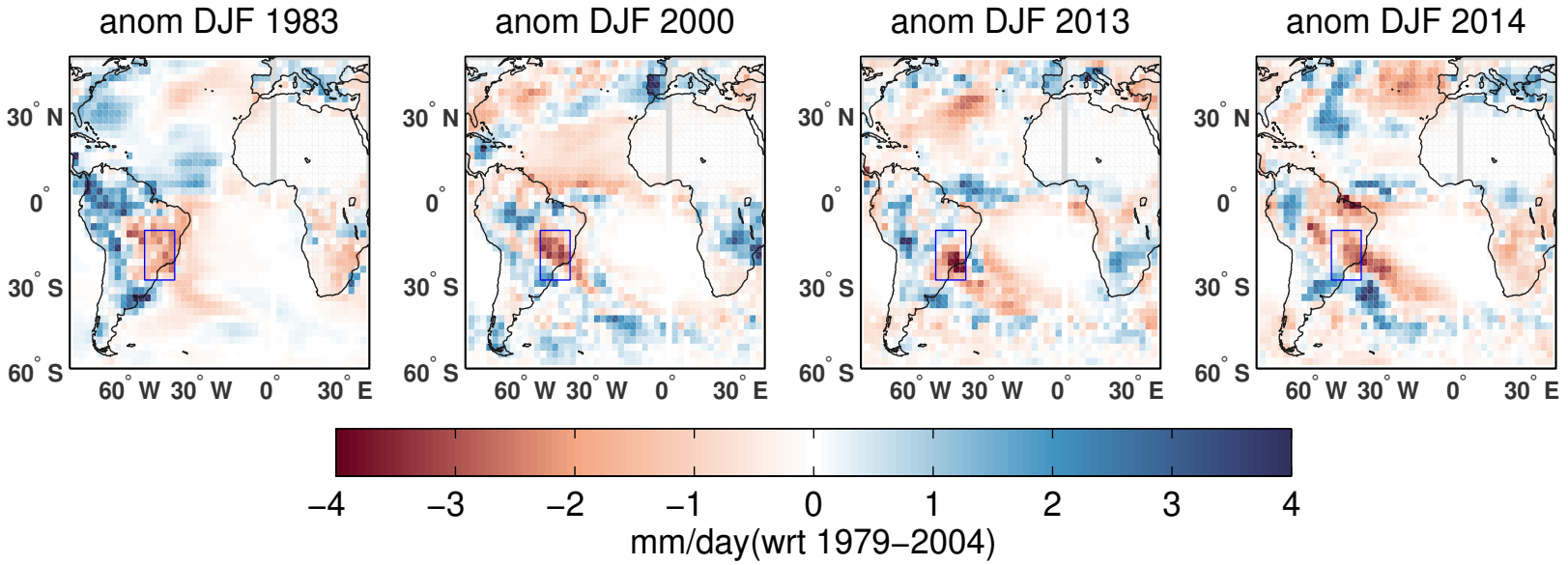
do the same for each other year and calculate correlation coefficient between the two

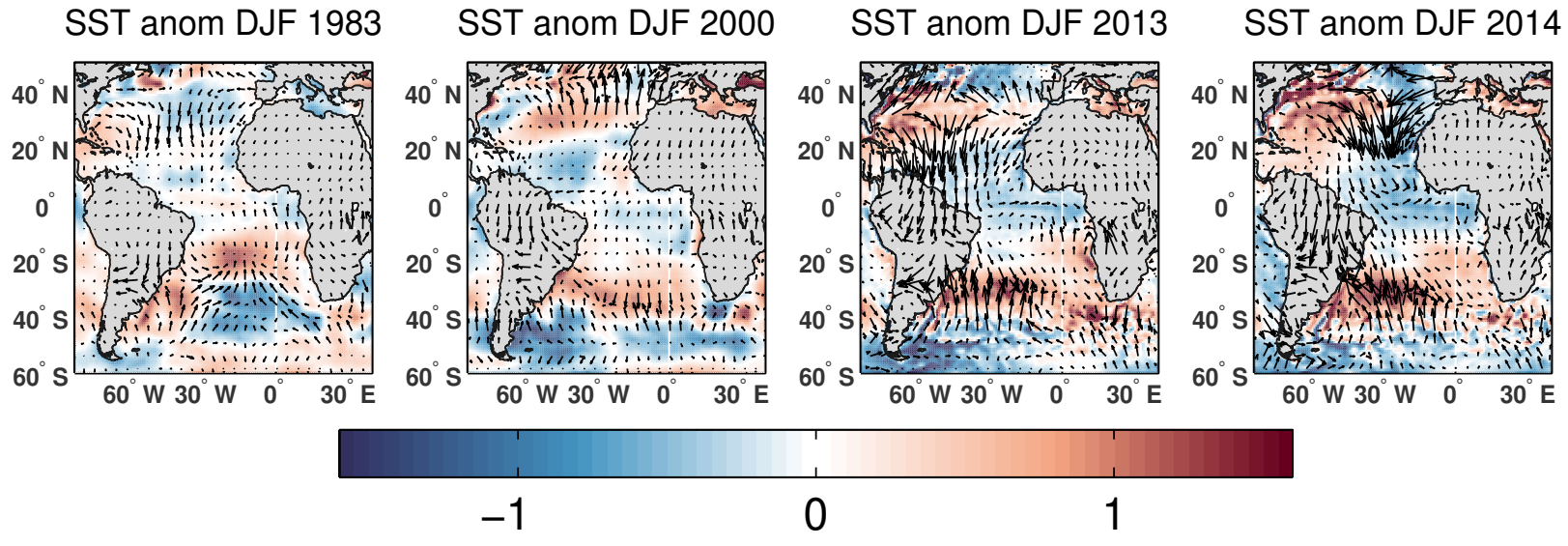
Pattern Correlation of SST anomaly 2013/14 with other years



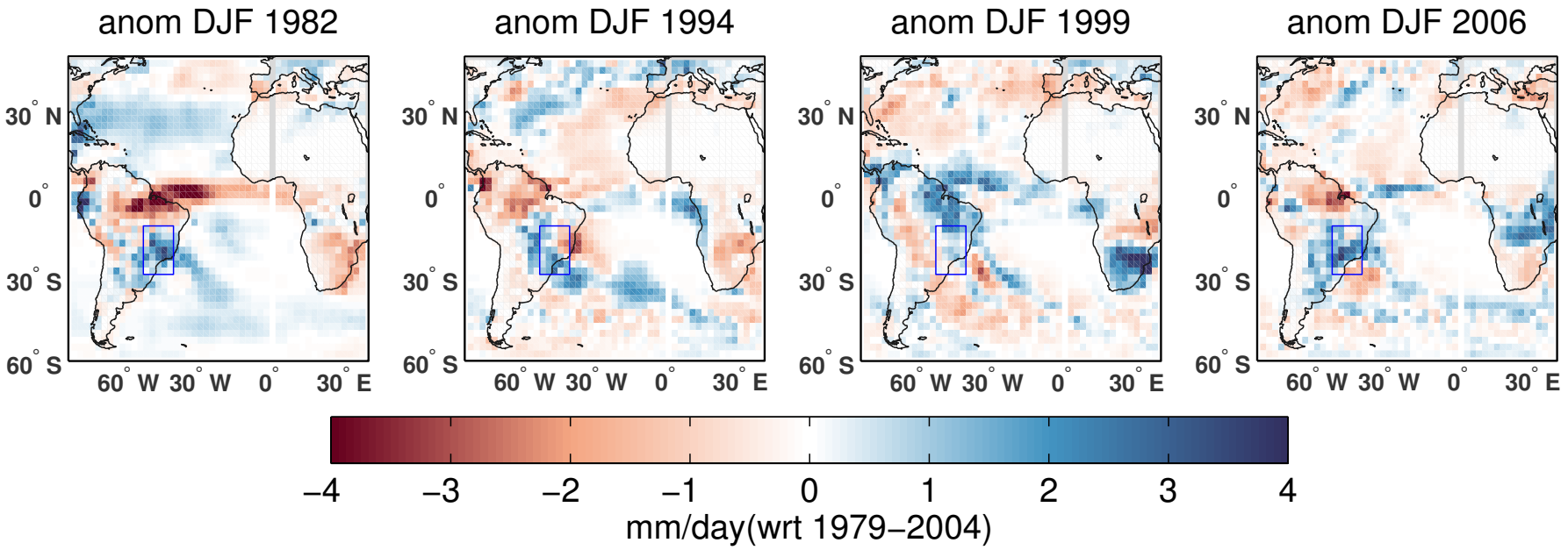
Testing the Pattern Recognition Algorithm

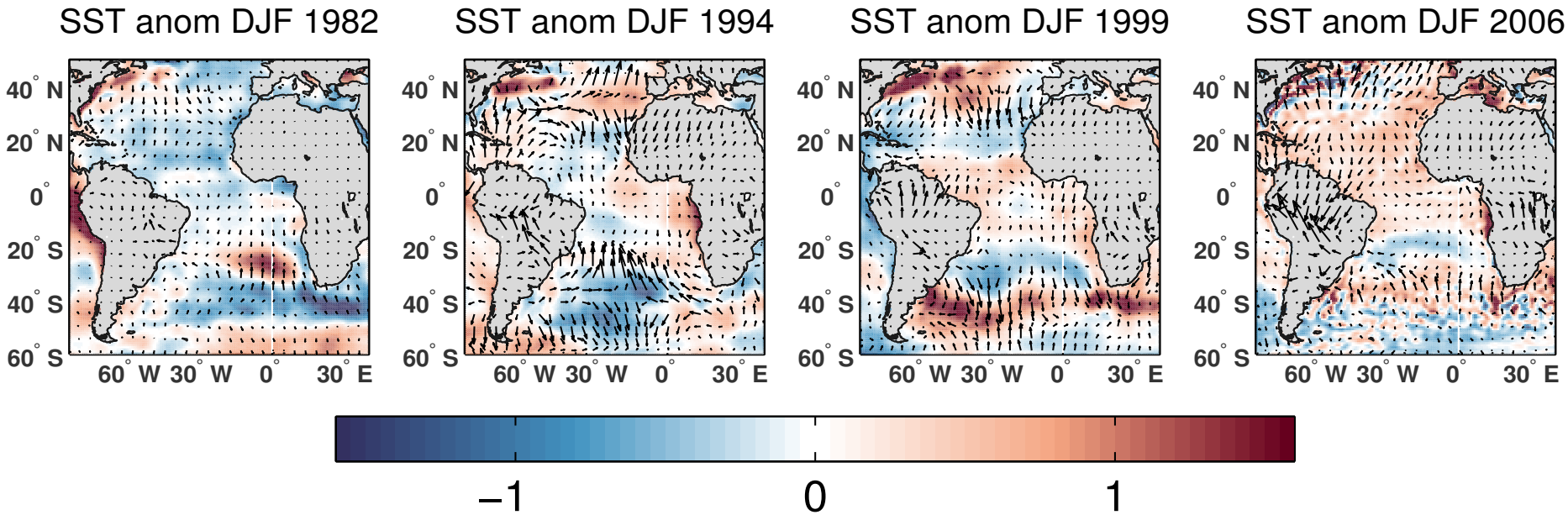
Highest Correlated Years



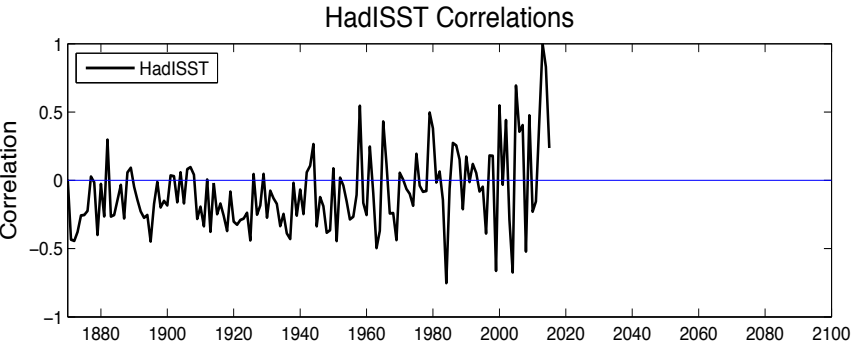


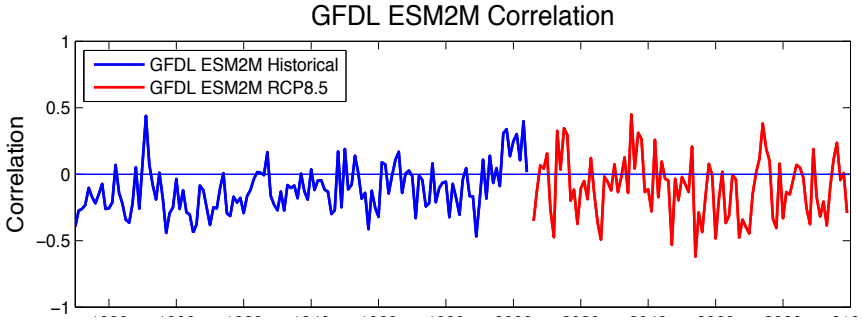
Least Correlated Years

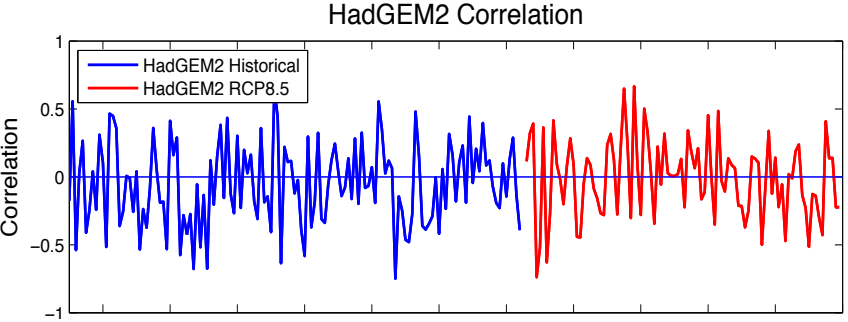


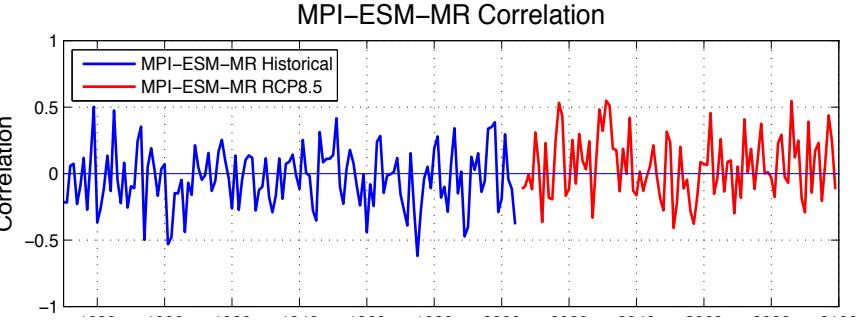


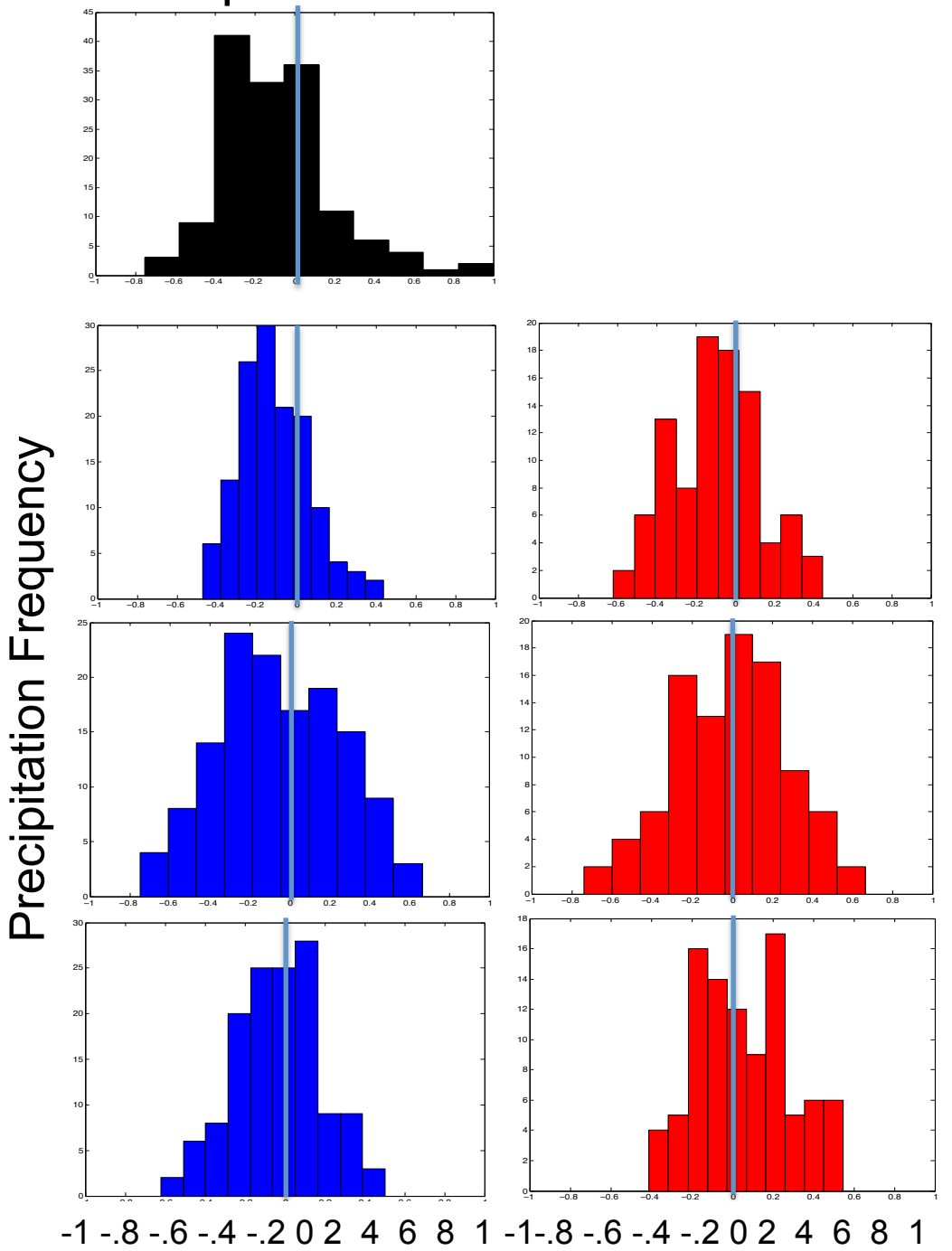
Frequency of such events in the past and future











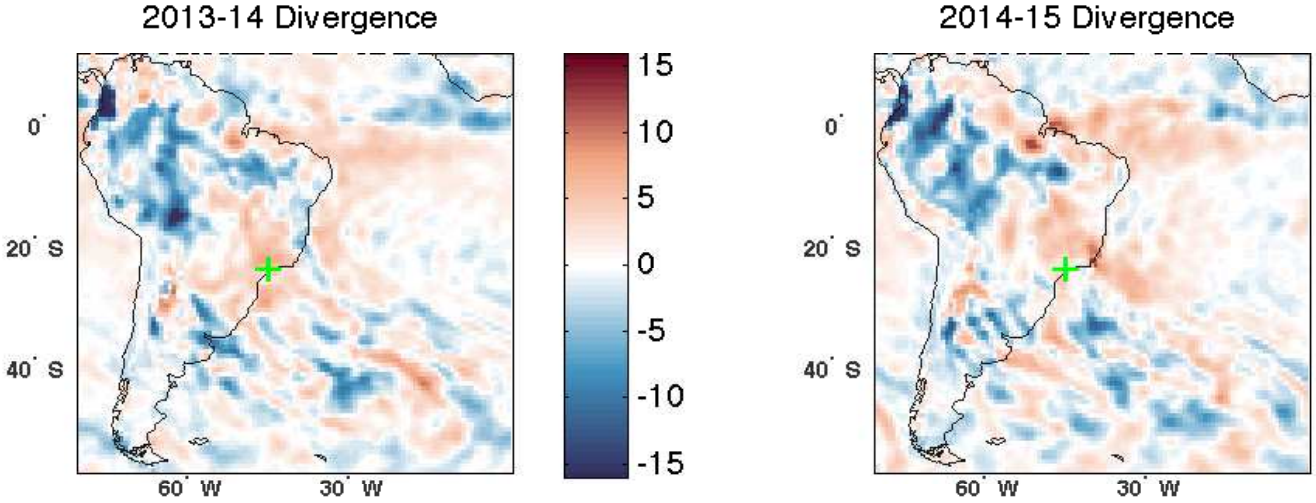
Conclusions

- The wet season 2013/14 and 2014/15 were anomalously dry and unprecedented in the historical record
- Positive SST anomalies and moisture convergence towards south of Sao Paulo causes the shifting of rainfall pattern to the south.
- Our limited analysis using a Climate model forced with observed SST suggests defore-station not the cause
- In the future there will likely be similar meteorological conditions but it seems there will be no increase in frequency

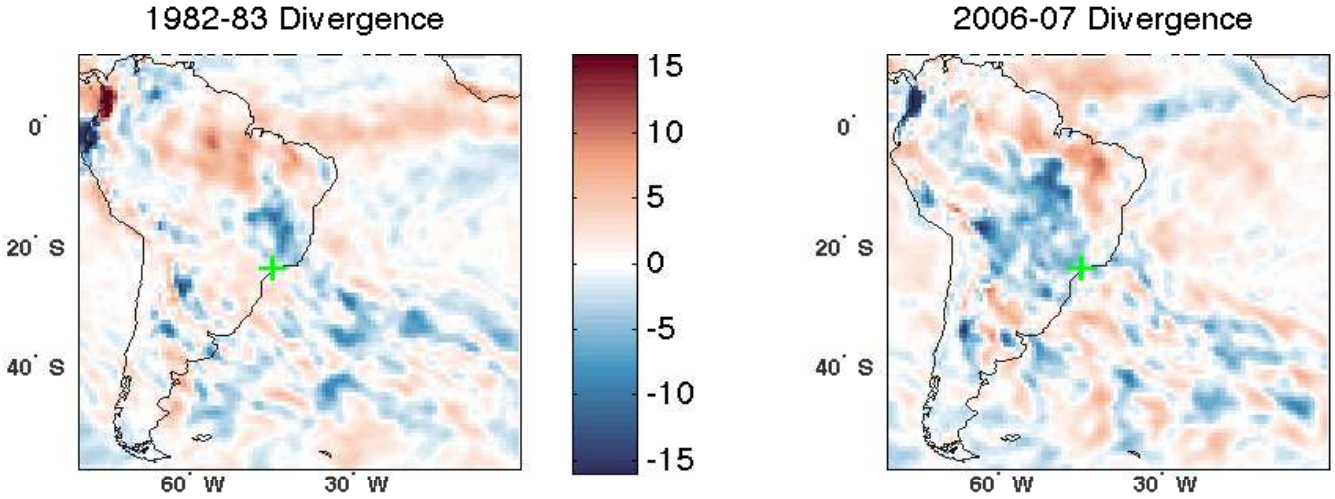
THANK YOU

Moisture Divergence

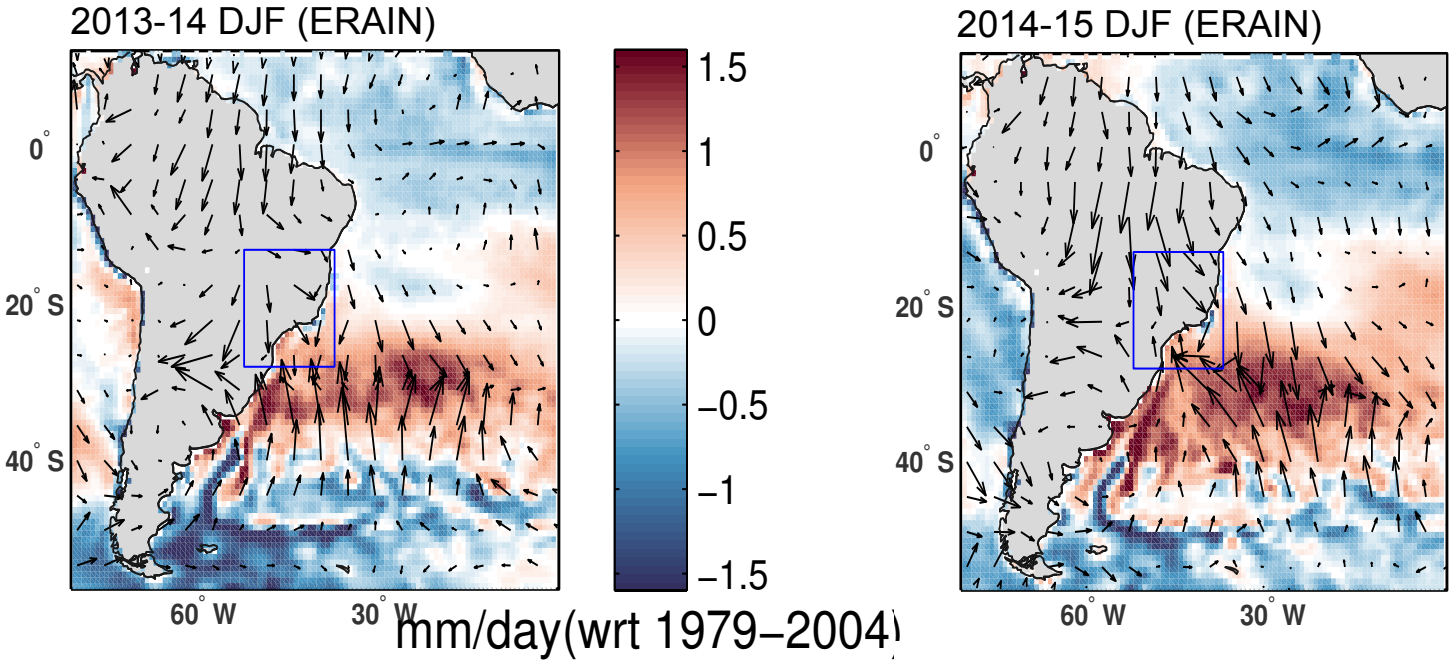
Deficit Rainfall Years



Excess Rainfall Years

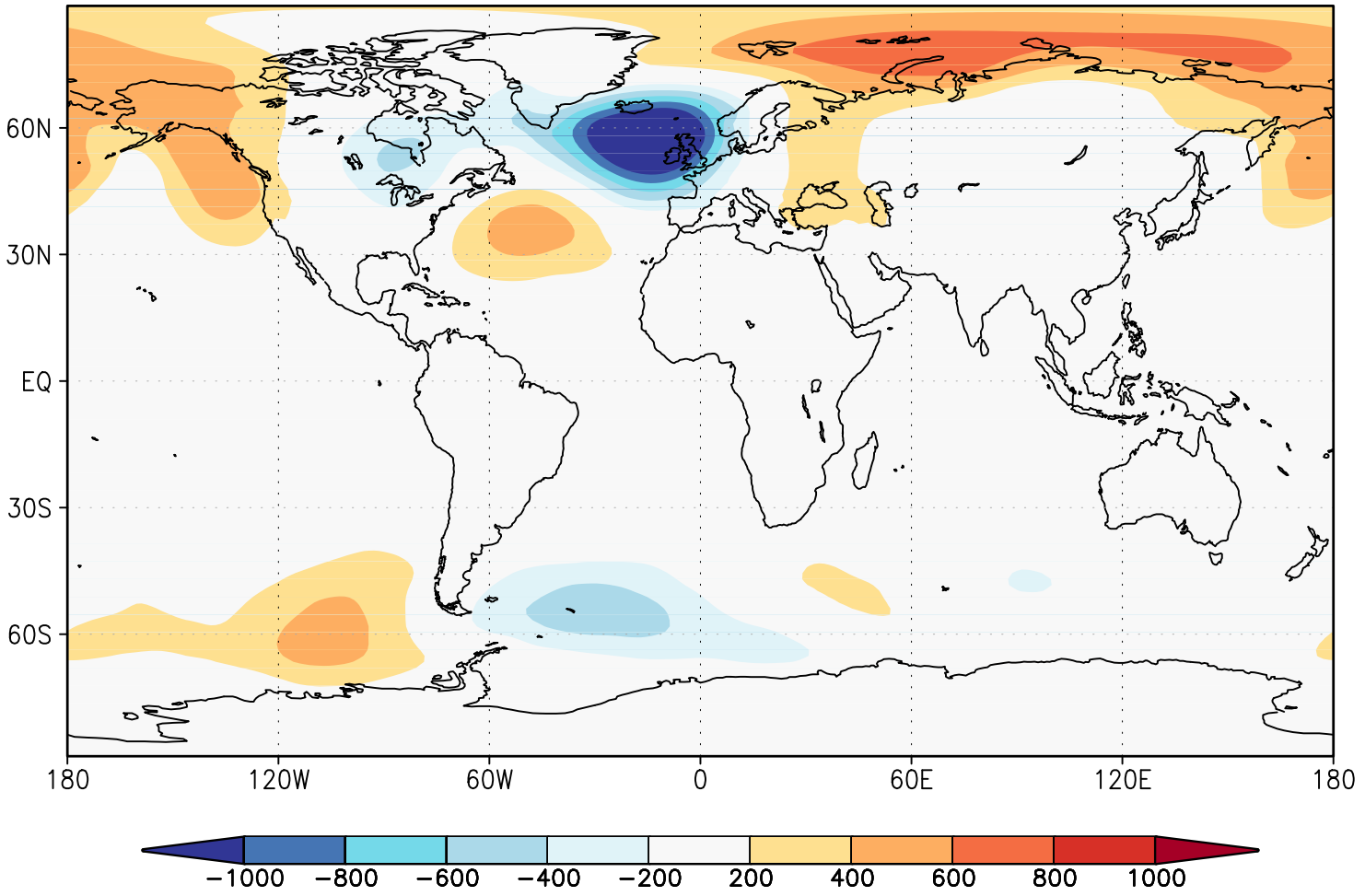


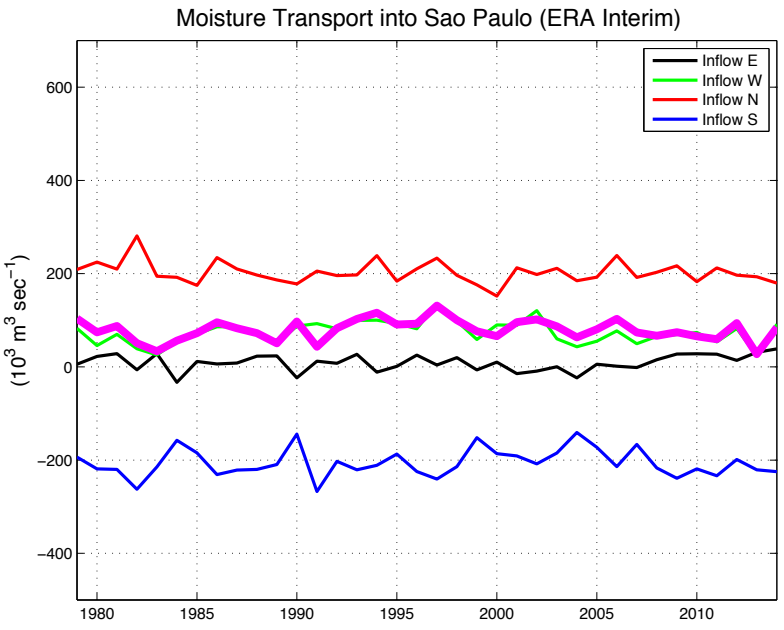
SST (shaded) and Moisture Flux (vector) Anomaly

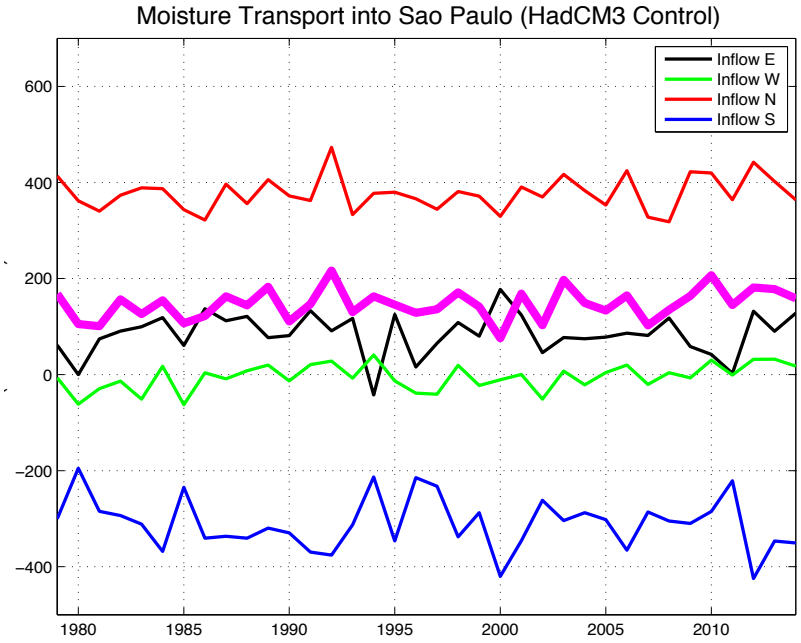


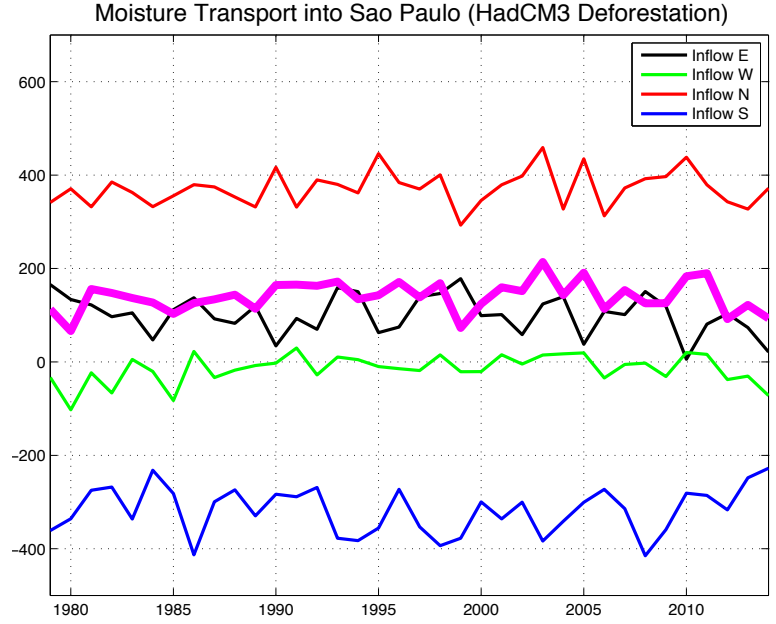
Geopotential Height anomalies

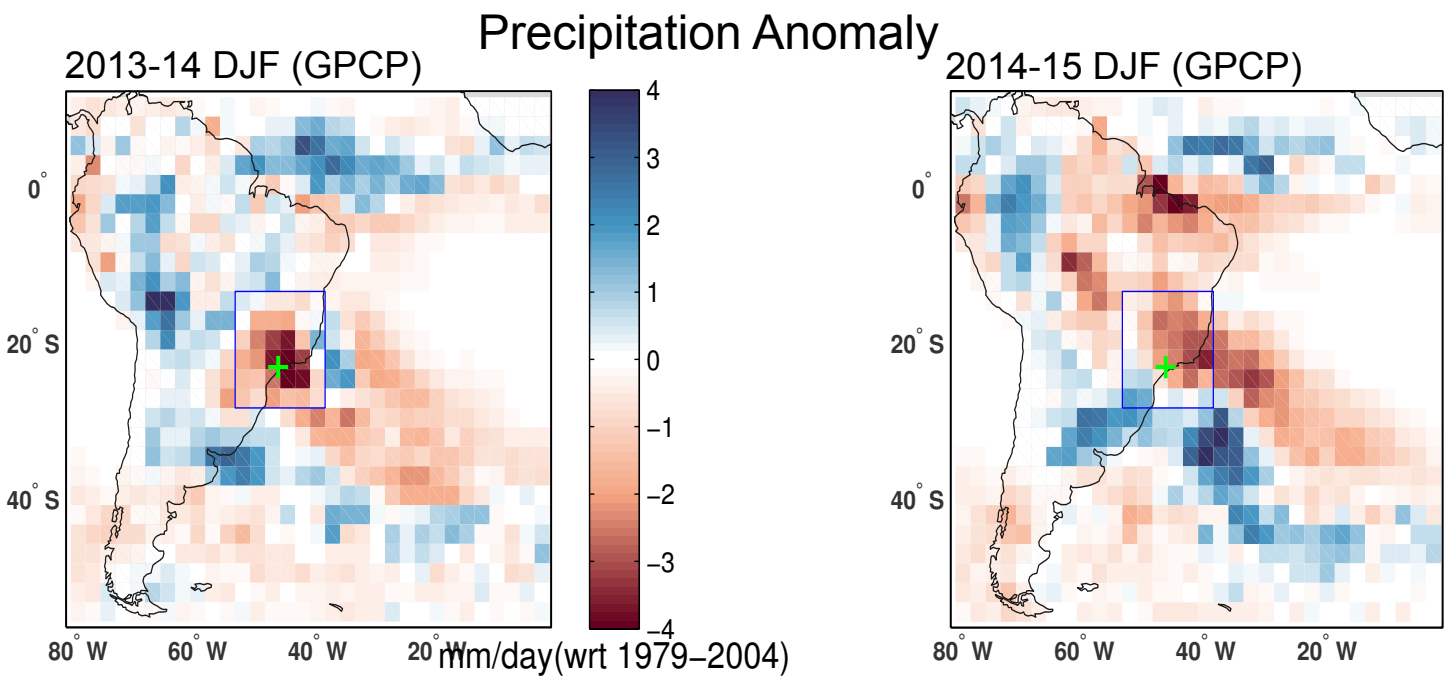
2013/14 DJF Geopotential Anom (w.r.t. 1981-2010) at 850 hPa in ERA Interim

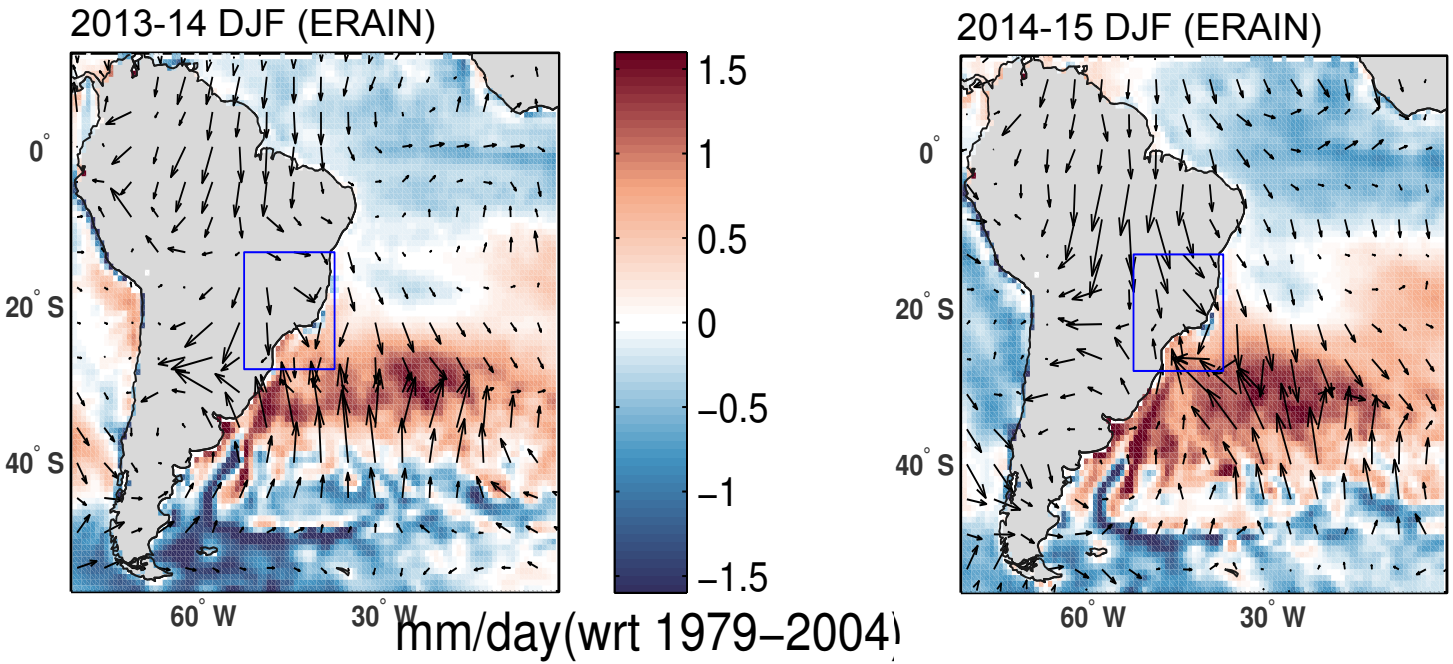



Moisture Transport into Sao Paulo (ERA Interim)
Inflow E
Inflow W
Inflow N
Inflow S
(10^3 m^3 sec^-1)
600
400
200
0
−200
−400
1980
1985
1990
1995
2000
2005
2010


Moisture Transport into Sao Paulo (HadCM3 Control)
Inflow E
Inflow W
Inflow N
Inflow S
600
400
200
0
−200
−400
1980
1985
1990
1995
2000
2005
2010


Moisture Transport into Sao Paulo (HadCM3 Deforestation)
Inflow E
Inflow W
Inflow N
Inflow S
600
400
200
0
−200
−400
1980
1985
1990
1995
2000
2005
2010


Precipitation Anomaly
2013-14 DJF (GPCP)
2014-15 DJF (GPCP)
0°
20° S
40° S
80° W
60° W
40° W
20° W
4
3
2
1
0
−1
−2
−3
−4
mm/day(wrt 1979–2004)

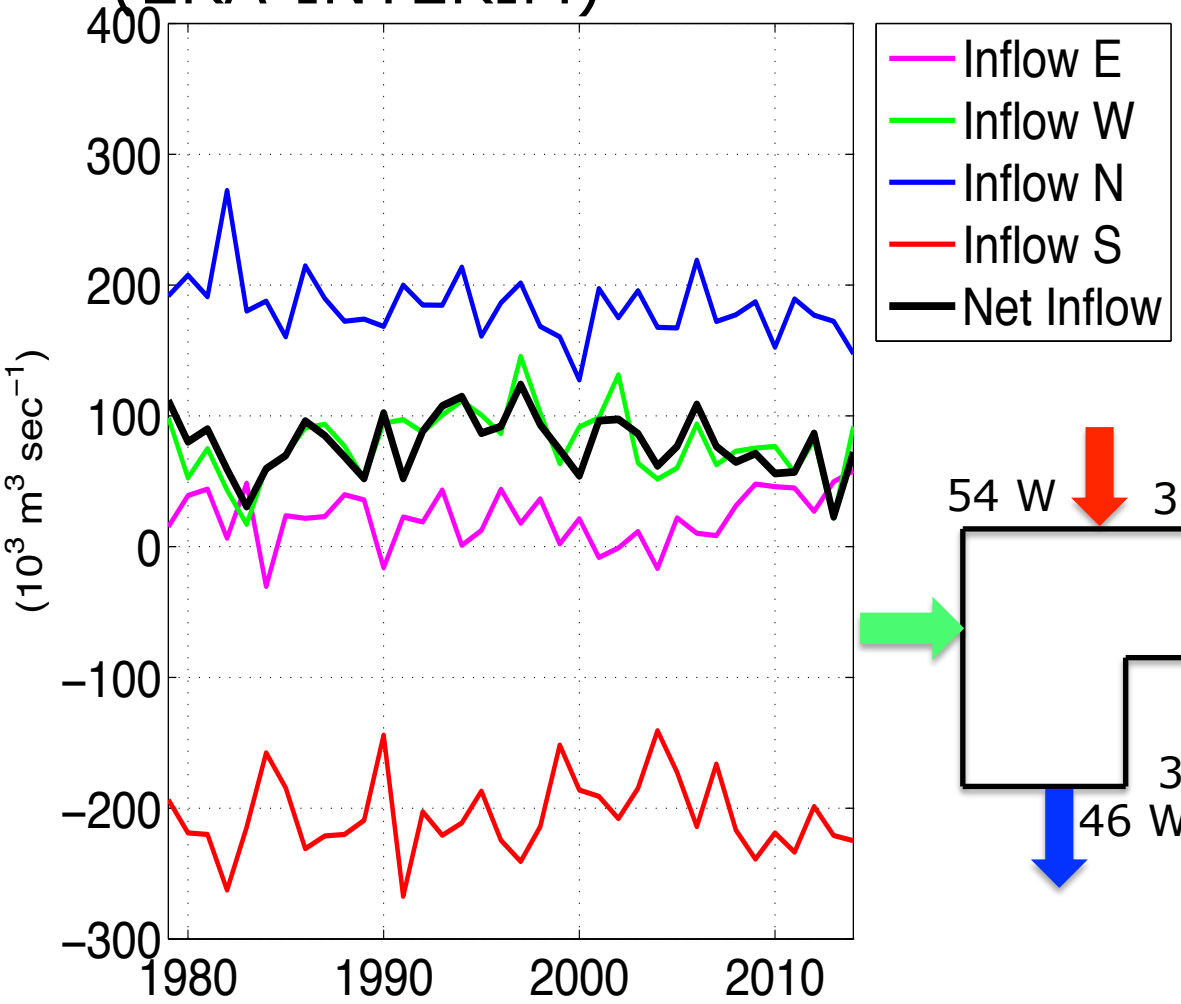

SST (shaded) and Moisture Flux (vector) Anomaly
2013-14 DJF (ERAIN)
2014-15 DJF (ERAIN)
0°
20° S
40° S
60° W
30° W
1.5
1
0.5
0
−0.5
−1
−1.5
mm/day(wrt 1979–2004)

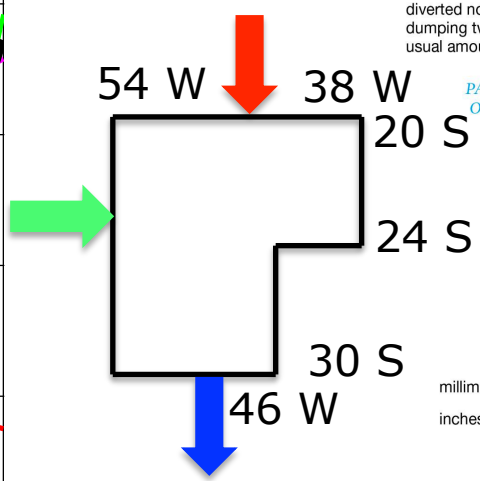
Possible Causes

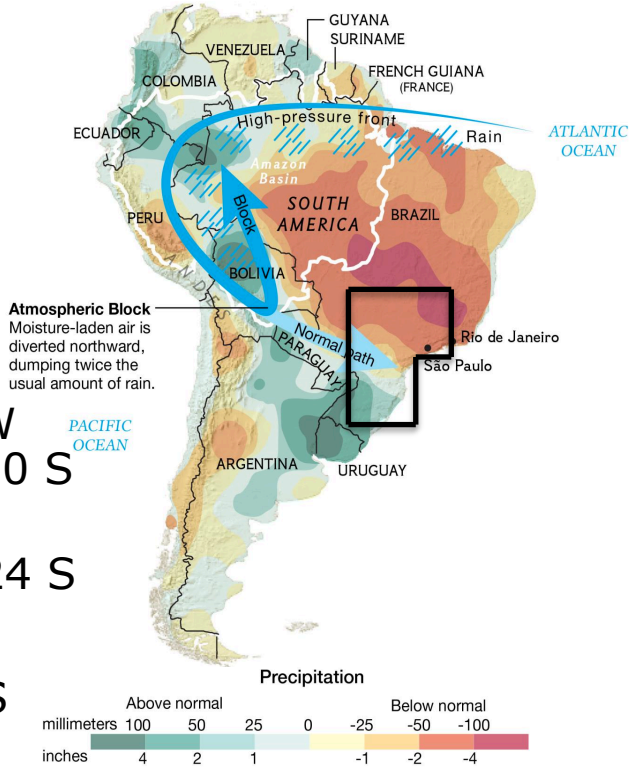
- Climatic
  - rainfall deficit
  - change in moisture transport
- Non- Climatic
  - deforestation
  - population growth and increasing demand

Deforestation - Water vapor transports

Water vapor transports (ERA-INTERIM)



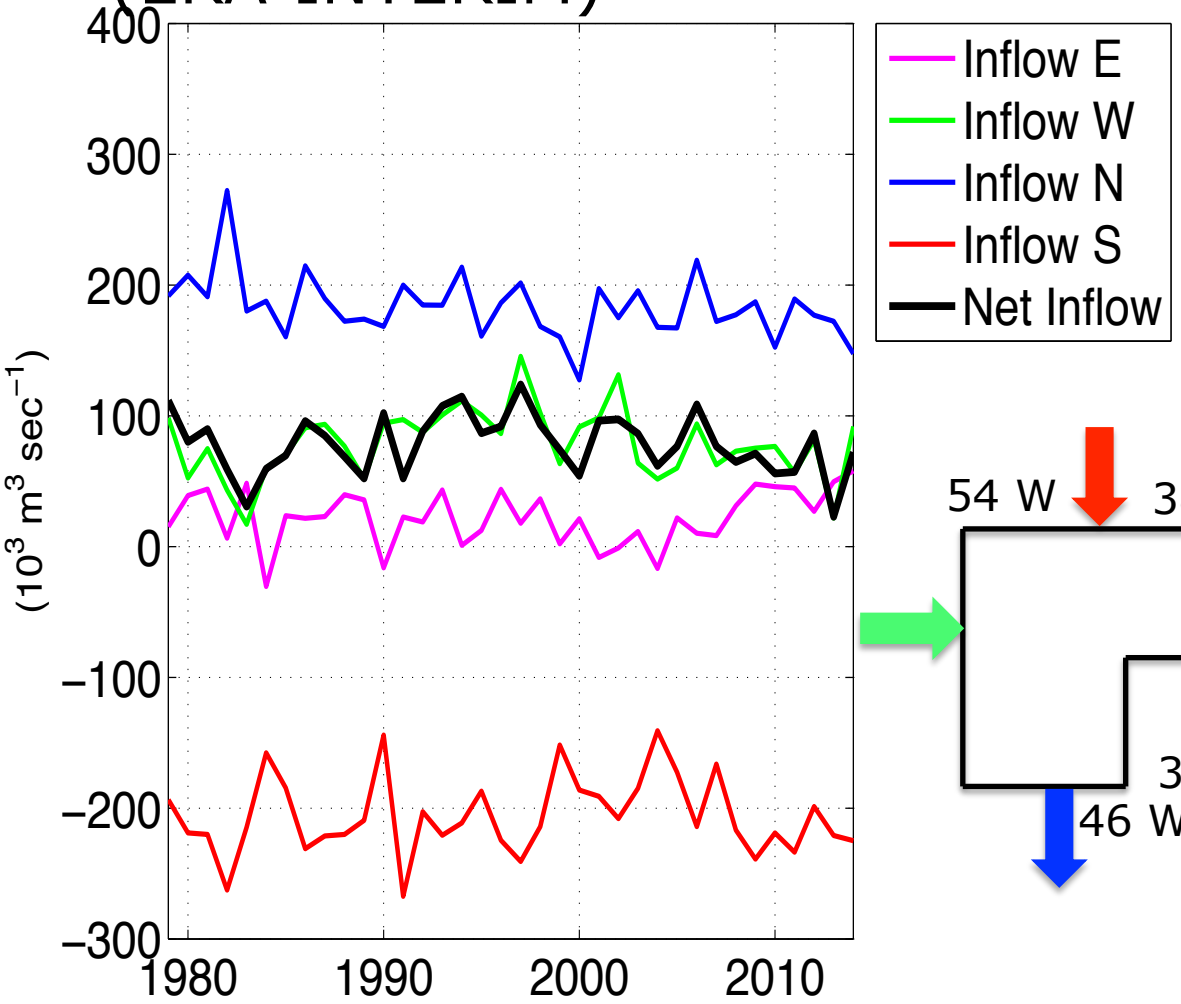


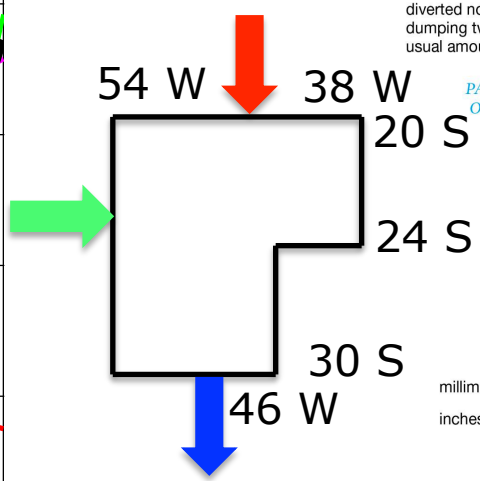


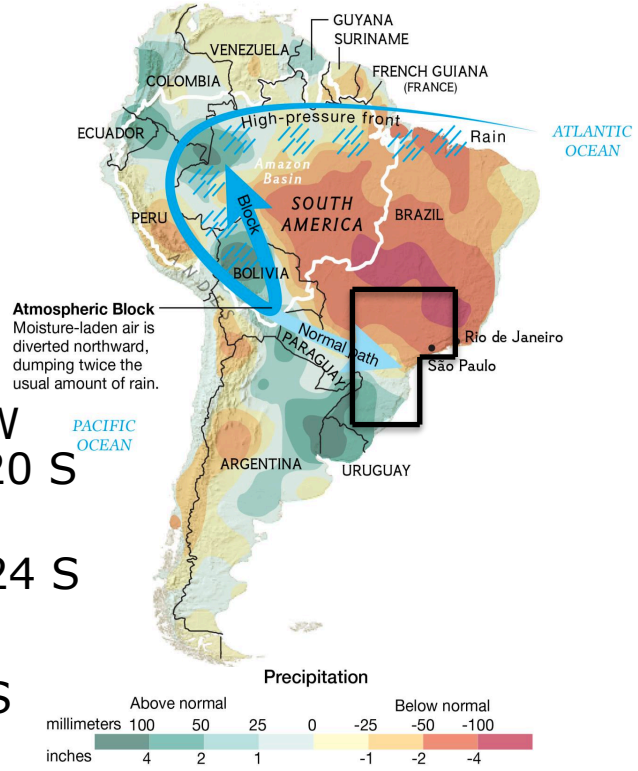
Marengo's hypothesis

Deforestation - Water vapor transports

Water vapor transports (ERA-INTERIM)







- How unusual is the meteorological situation in 2013/14 ?
- Will such situations occur more often in the future?