

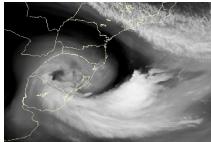
# **RegCM4: results and challenges**



**Michelle S. Reboita - UNIFEI**  
Rosmeri P. da Rocha - USP  
Marta Llopart - UNESP  
Vitor Hugo Marrafon – UNIFEI  
Brazil

# Outline

**Results:** with CMIP5 global model outputs driving RegCM4

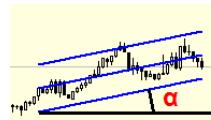


Precipitation associated with extratropical cyclones in the future climate

**Challenges:** to evaluate the RegCM4 performance in order to find a good configuration to CORDEX phase II



Annual Cycle of Precipitation in LPB



Daily Rainfall Extreme Events in LPB



South American Monsoon



Severe droughts in South America

# Precipitation associated with cyclones

## In this study

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of Climatology



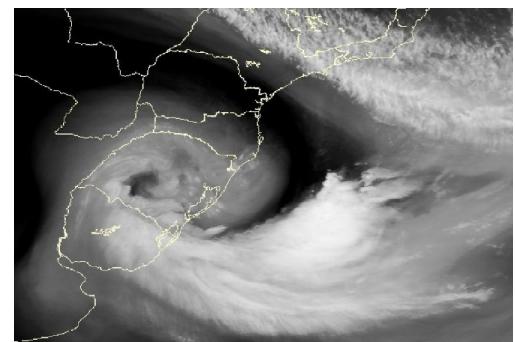
## RESEARCH ARTICLE

## Extratropical cyclones over the southwestern South Atlantic Ocean: HadGEM2-ES and RegCM4 projections

Michelle S. Reboita<sup>1</sup> | Rosmeri P. da Rocha<sup>2</sup> | Marcelo R. de Souza<sup>1,2</sup> | Marta Llopert<sup>3,4</sup>

one of the goals were to evaluate the precipitation associated with extratropical cyclones over the South Atlantic Ocean

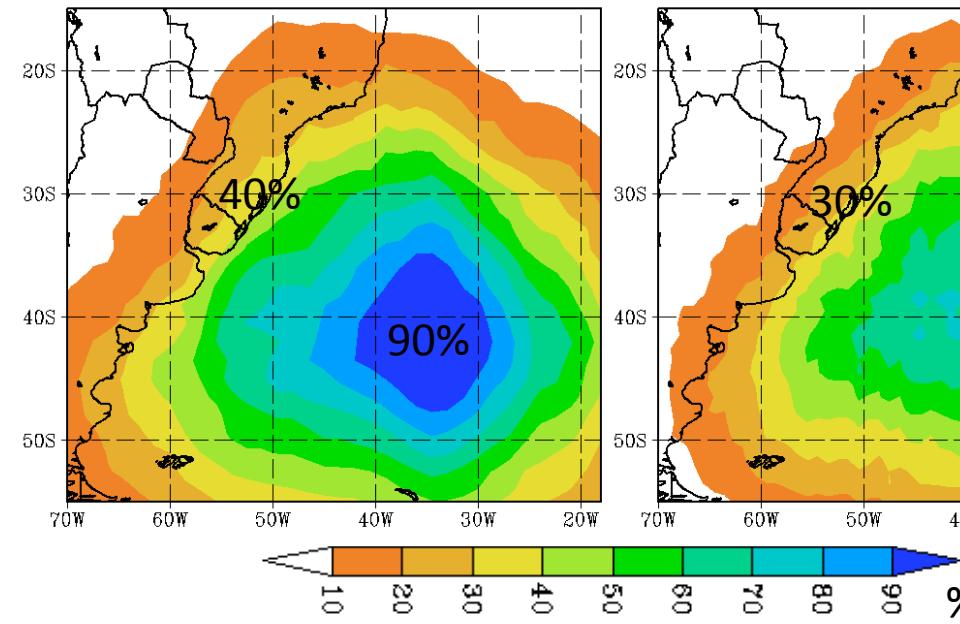
- Periods: 1997-2005 and 2070-2098
- RegCM4 nested in HadGEM2-ES
- RCP8.5
- South America CORDEX domain



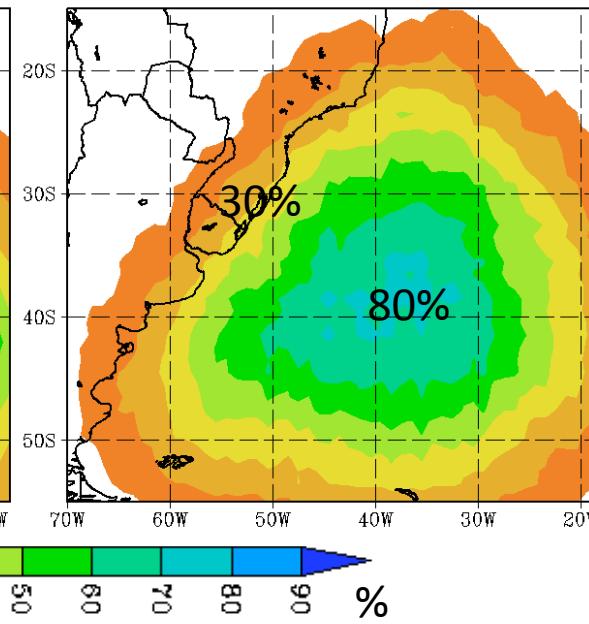
# Porcentage of the annual precipitation associated with cyclones Present Climate

We identified only cyclones initiating over the ocean.

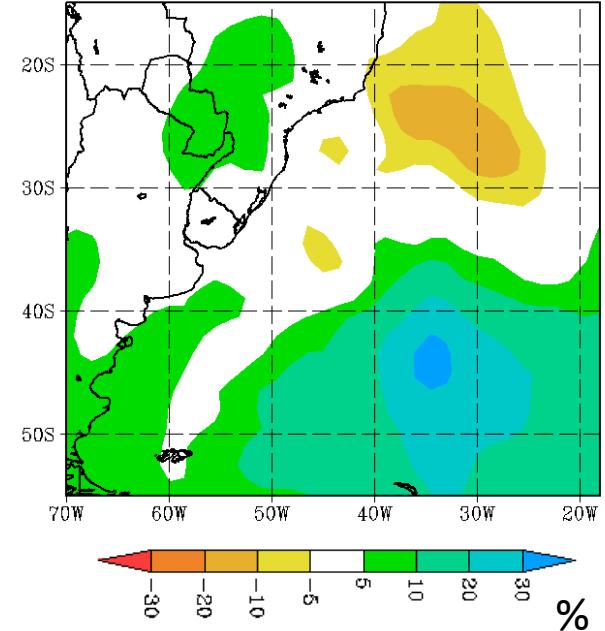
RegCM4 (1997-2005)



GPCP (1997-2005)



RegCM4 - GPCP



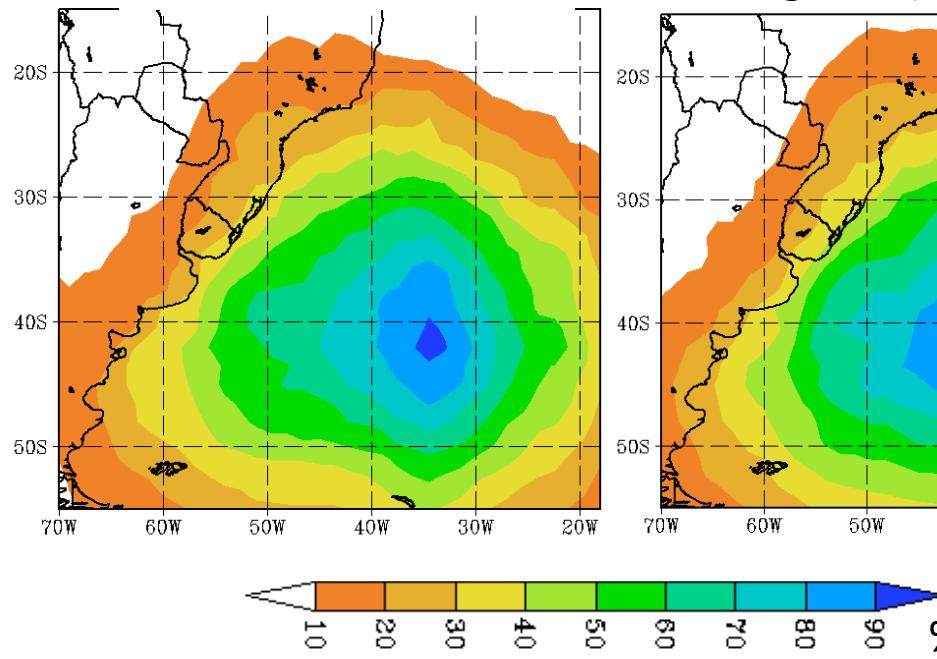
RegCM4 overestimates the precipitation associated with the cyclones.

One reason: model simulates higher number of cyclones in the central part of the ocean

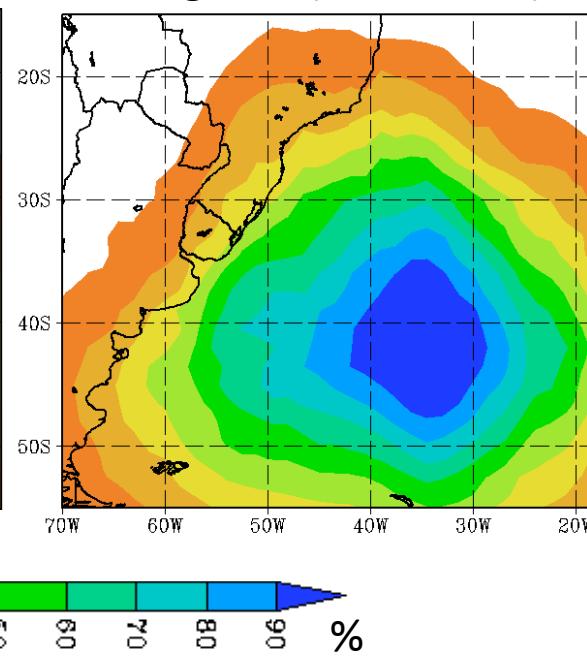
# Percentage of annual precipitation associated with the cyclones

## Future Climate – RCP8.5 scenario

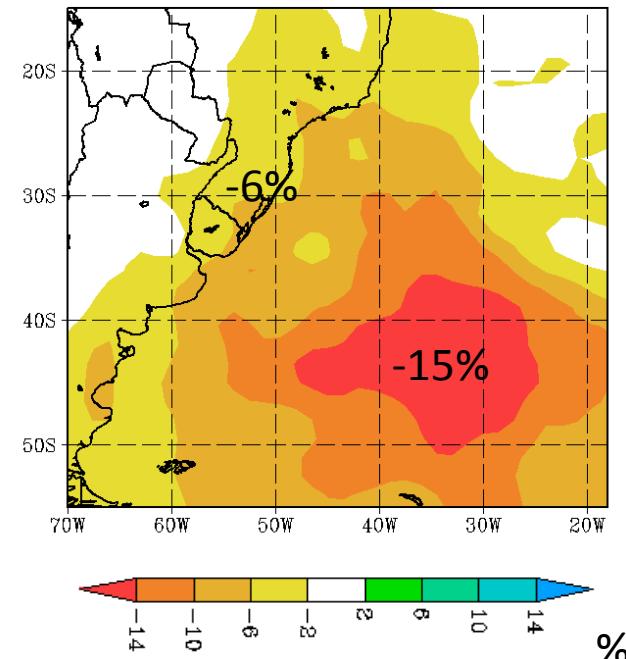
RegCM4 (2070-2098)



RegCM4 (1997-2005)



Far Future - Present

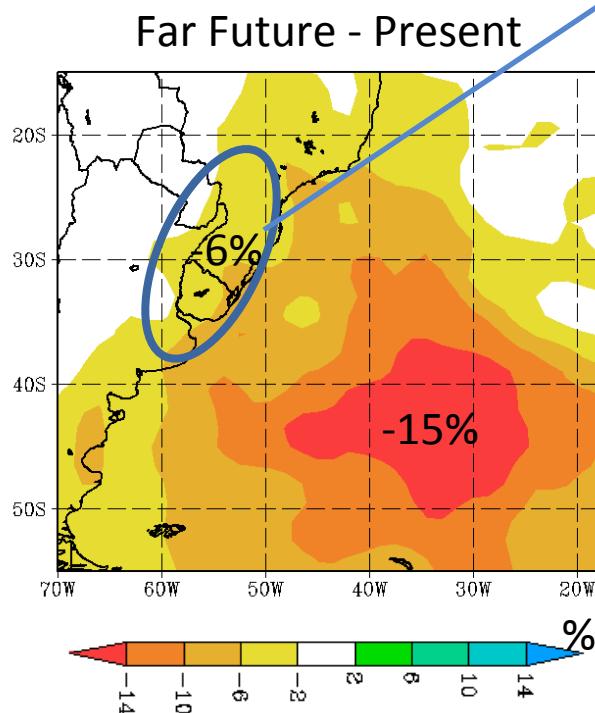


The precipitation associated with cyclones is projected decreasing in the future and it can be associated with the lower number of cyclones projected in the future (see Reboita et al. 2018).

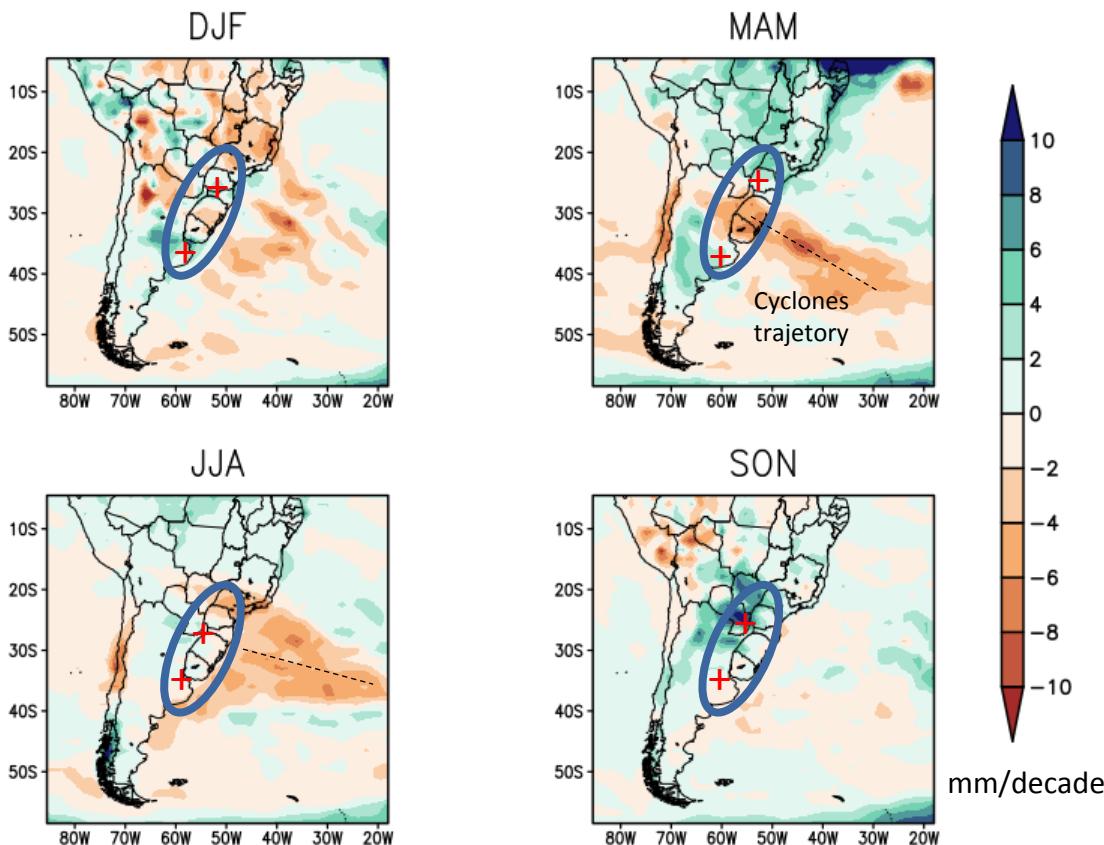
This continental area shows a decrease of precipitation (in the cyclones analysis).

But considering all precipitation, will it decrease or increase?

Precipitation associated with cyclones



Annual Precipitation Trend (2070-2098)  
RegCM4 nested in HadGEM2-ES



In a global view, there is + trend of precipitation over the region.  
Over the ocean, there is - trend in the path of the cyclones.

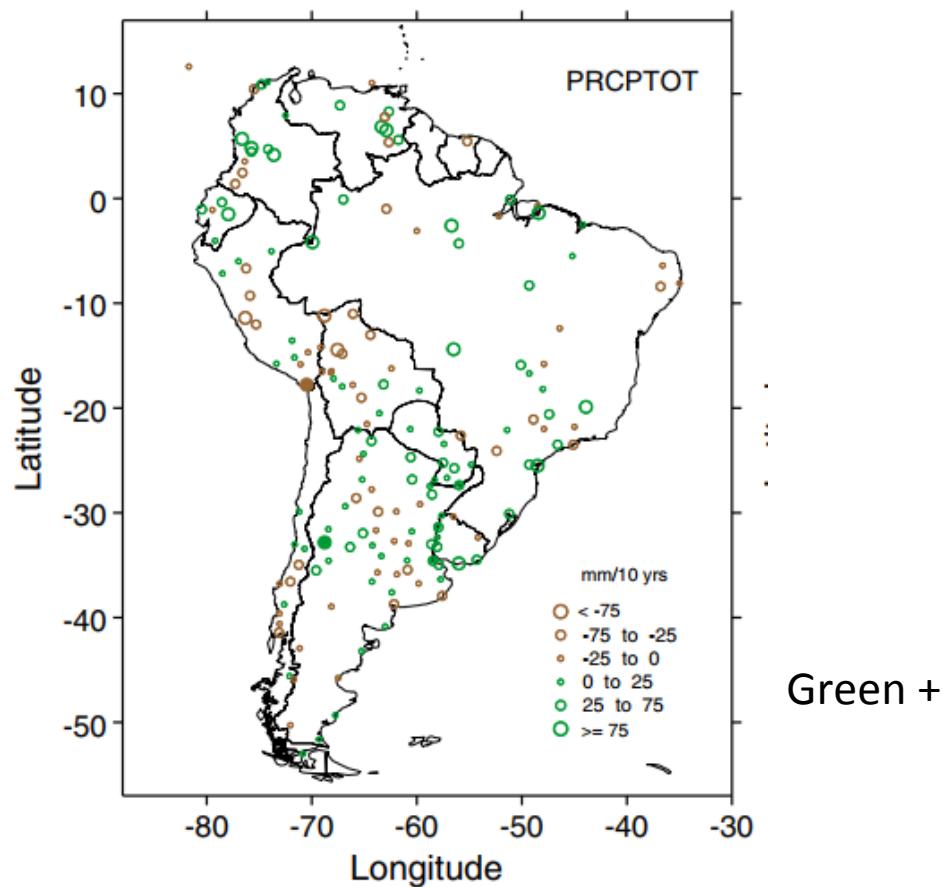
Total precipitation trend  
1960-2000

Haylock et al. 2006



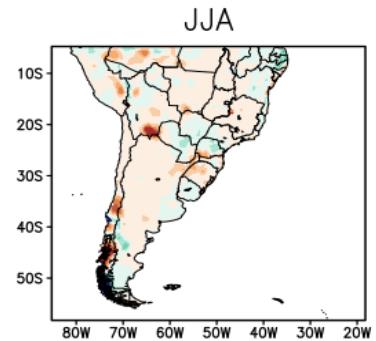
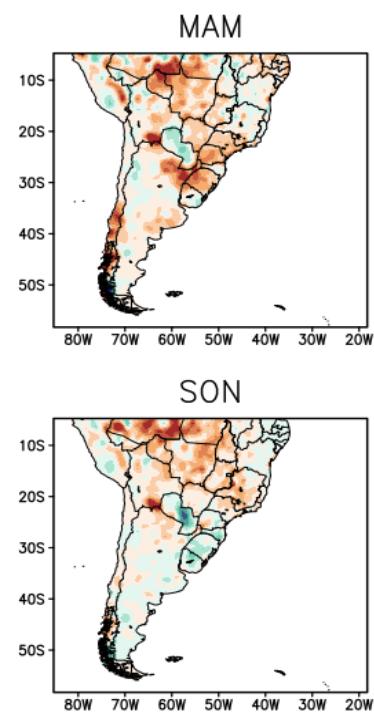
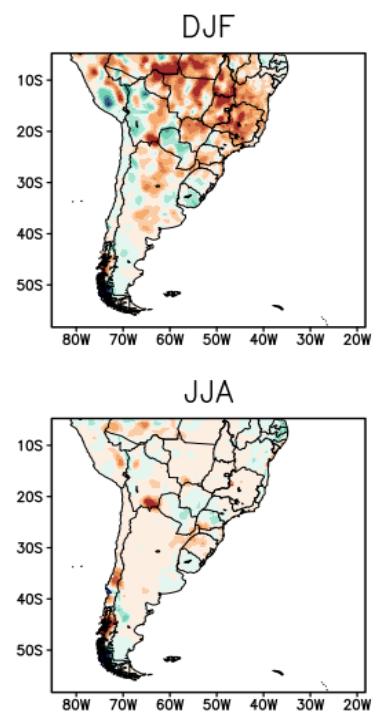
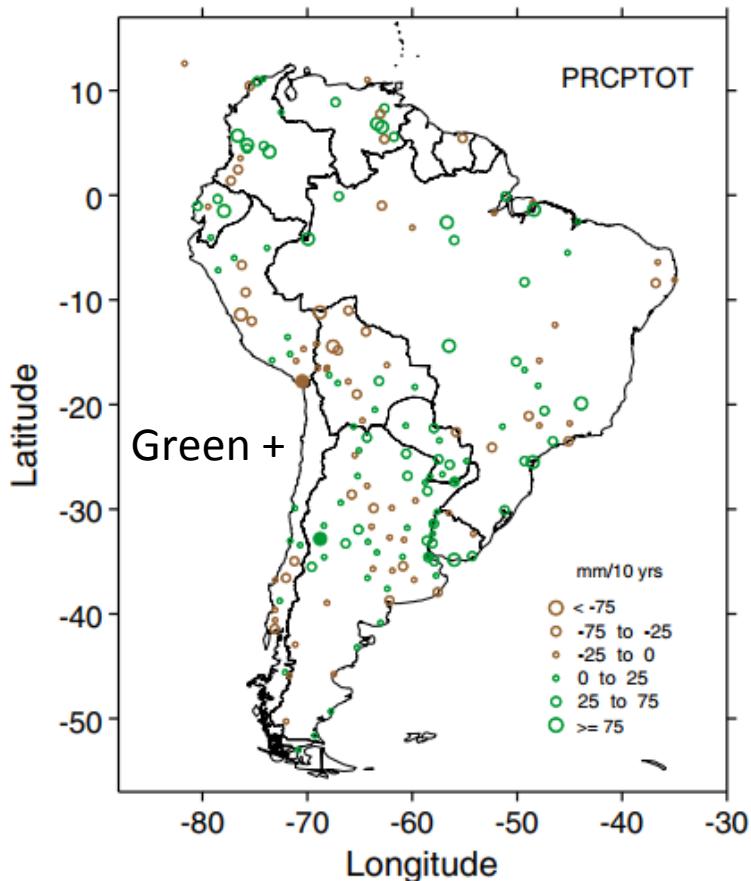
Total precipitation trend  
1969-2009

Skansi et al. 2013



# Total precipitation trend 1969-2009

Skansi et al. 2013



CPC 1979-2014

mm/decade



# Precipitation Trends

Soares et al. 2016

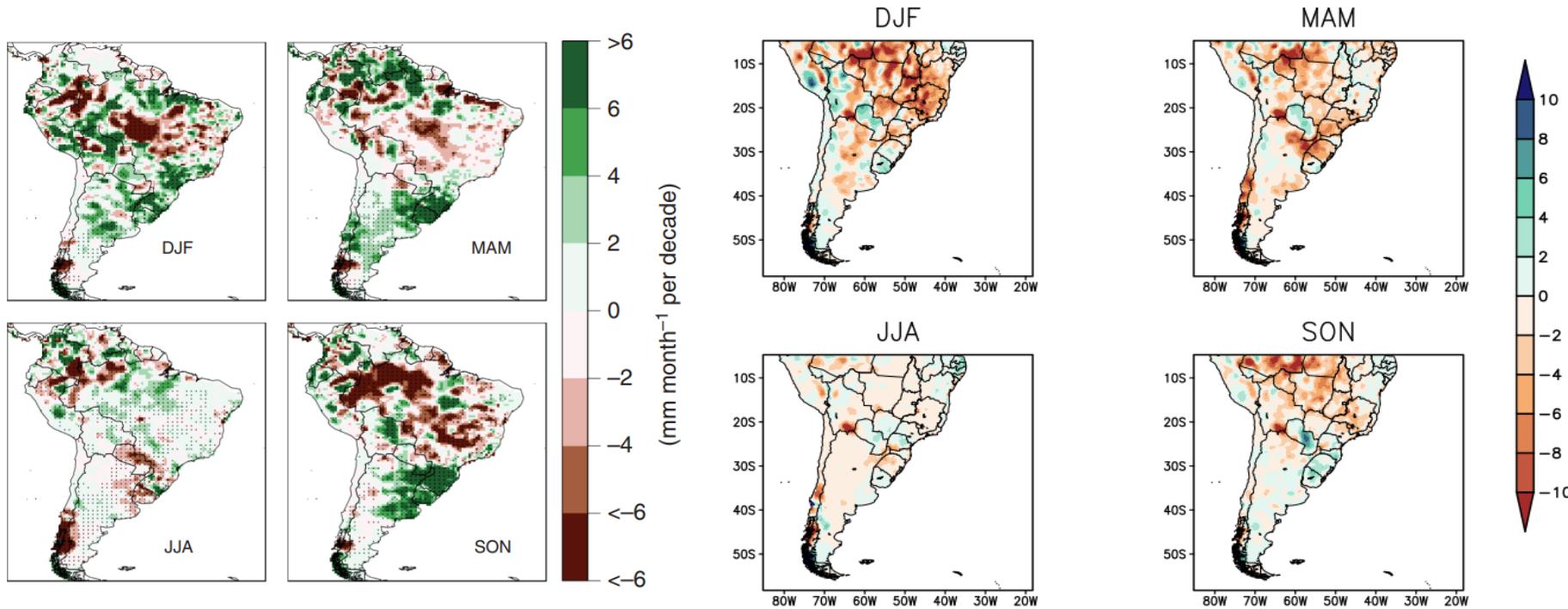


Figure 9. Seasonal mean GPCC precipitation trends ( $\text{mm month}^{-1}$  per decade) over South America for the period 1955–2004. The dots indicate regions where the trends are significant.

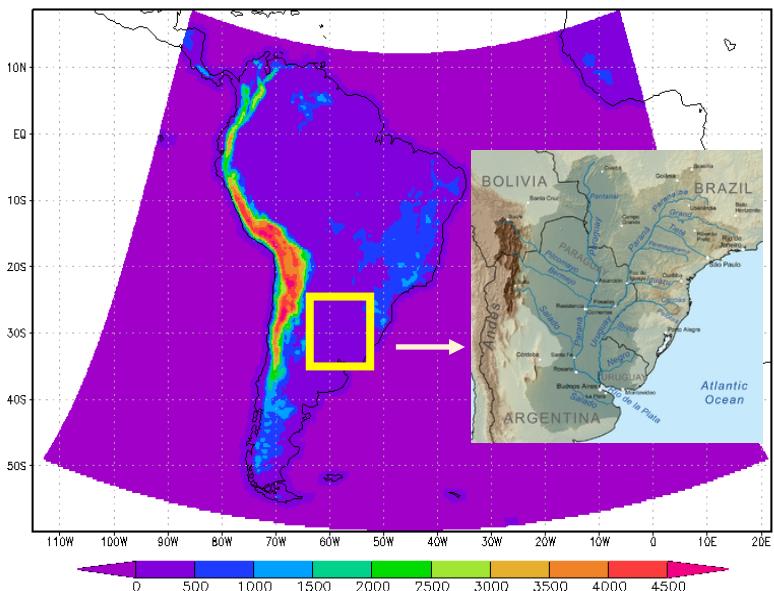
CPC 1979-2014

mm/decade

GPCC 1955-2004

# Evaluating RegCM4.6.1 and RegCM4.7

## Focus on La Plata Basin



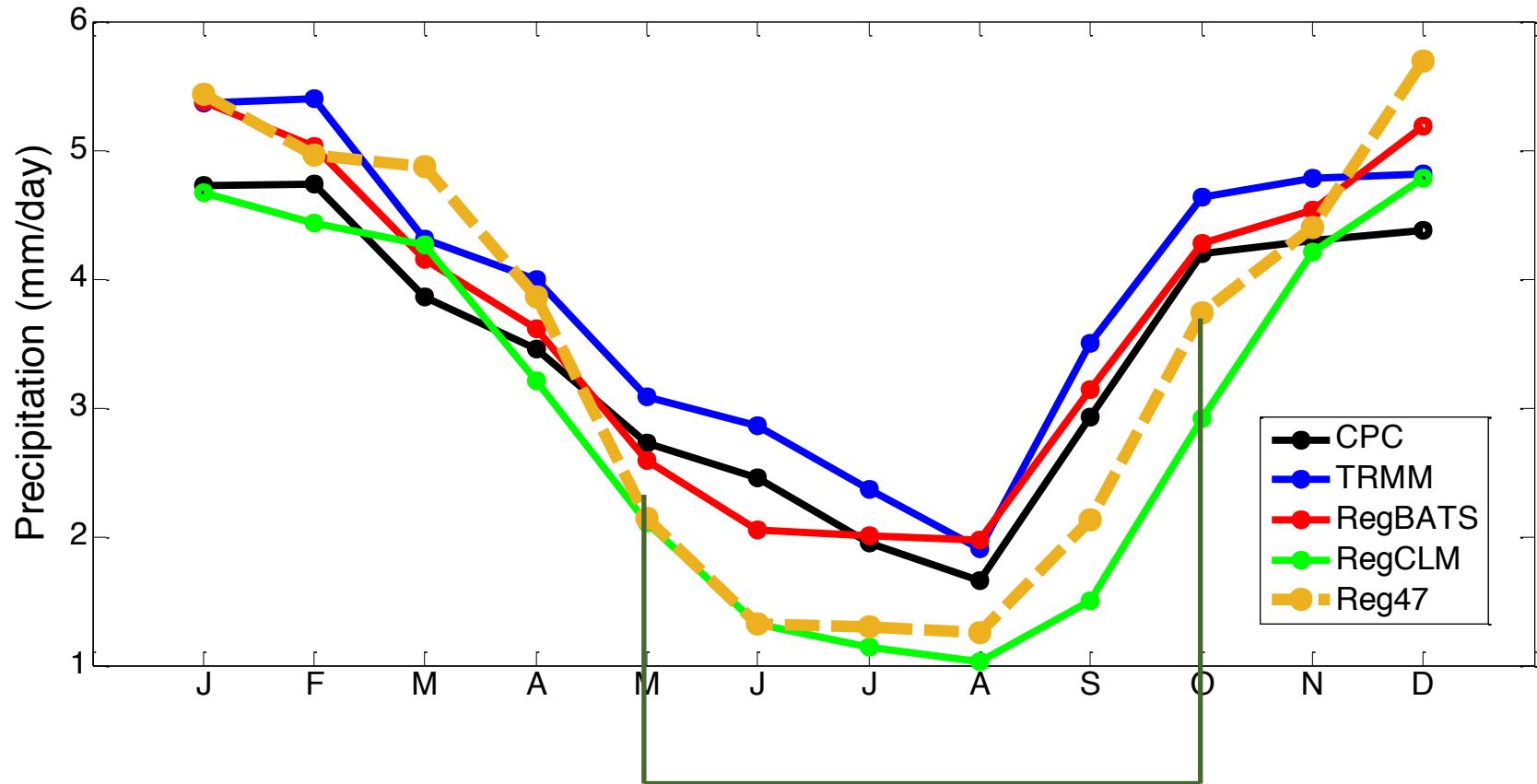
South America domain used with RegCM4.6.1, topography and location of the box indicating the La Plata Basin (LPB.)

Features	Simulation Details		
	RegBATS v4.6.1	RegCLM v4.6.1	RegCM4.7
Domain	slightly larger than CORDEX (fig)	slightly larger than CORDEX (fig)	CORDEX
Boundaries	ERA-Interim*	ERA-Interim*	ERA-Interim*
Horizontal resolution (km)	25	25	25
Period	Dec 2004 to Dec 2015	Dec 2004 to Dec 2015	1979-2014
Surface Scheme	BATS	CLM4.5	CLM4.5
Cumulus Scheme	Emanuel	Emanuel	Tiedtke (land)/Kain-Fritsch (ocean)

$$\text{ERA-Interim} = 0.75^\circ \times 0.75^\circ$$

# Annual Cycle of Precipitation in LPB 2005-2014

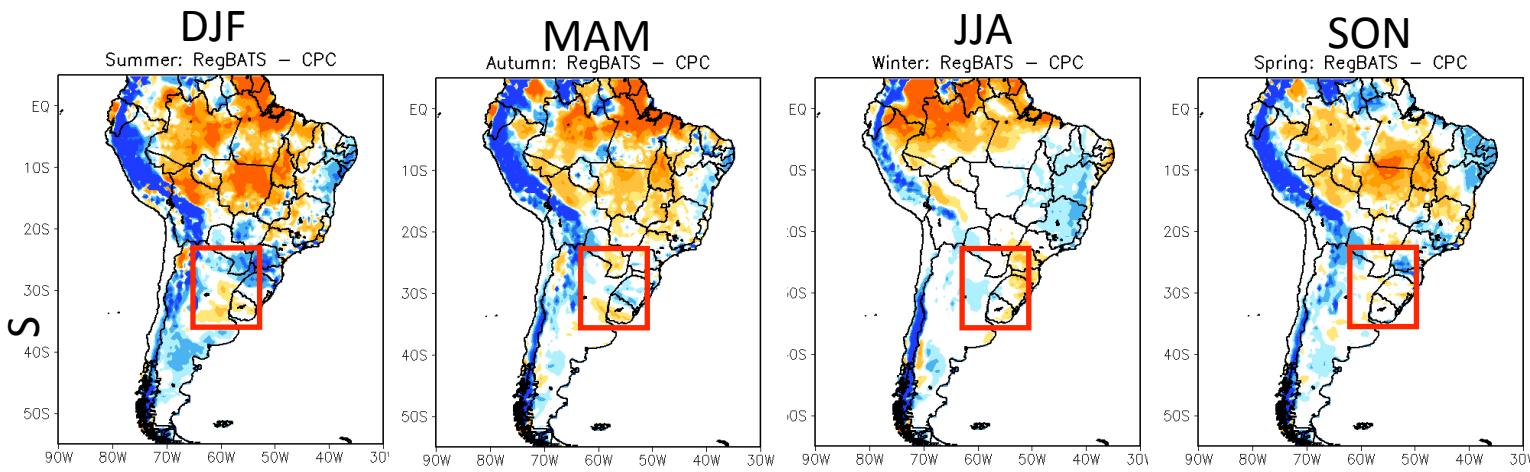
LPB (2005-2014)



RegCM4.7 underestimates the precipitation from May to October  
RegCM4.7 is slightly better than RegCLM  
RegBATS = better performance

# Seasonal Bias of Precipitation (RegCM-CPC)

RegBAT



# Daily Rainfall Extreme Events in LPB

## 2005-2014

Thereshold (mm/day) for daily precipitation using the 95% percentile.

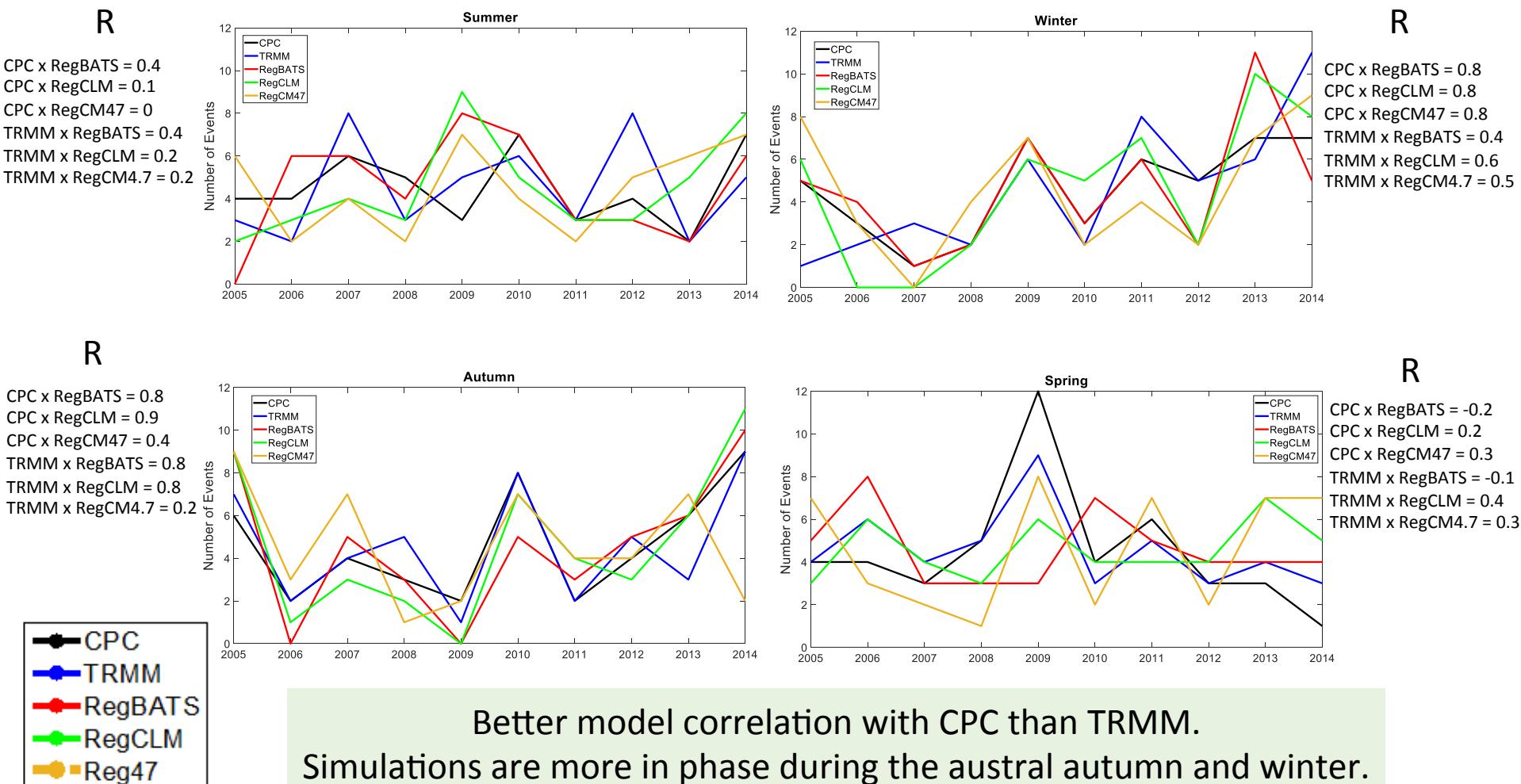
Data	Summer	Autumn	Winter	Spring
CPC	12.661	11.682	8.8264	12.414
TRMM	14.121	13.355	9.82	15.764
RegBATS	11.238	10.371	7.2019	12.081
RegCLM	10.061	10.359	5.1409	10.176
RegCM4.7	13.069	11.863	5.634	12.671

For each season, the number of events that overtakes the thereshold is presented in the next slide.

# Daily Rainfall Extreme Events in LPB

## 2005-2014

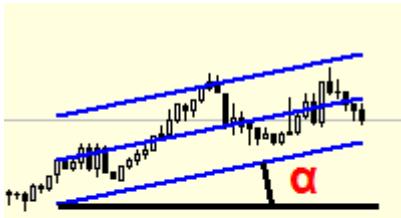
Daily extreme events occur when the daily total precipitation is higher than the percentile of 95%.  
 Percentiles were computed by season.



# Daily Rainfall Extreme Events in LPB

## 2005-2014

### TRENDS



ANGLE OF TREND

Using Mann-Kendall test, the angle of trend is known by Sen's slope.

Sen's slope

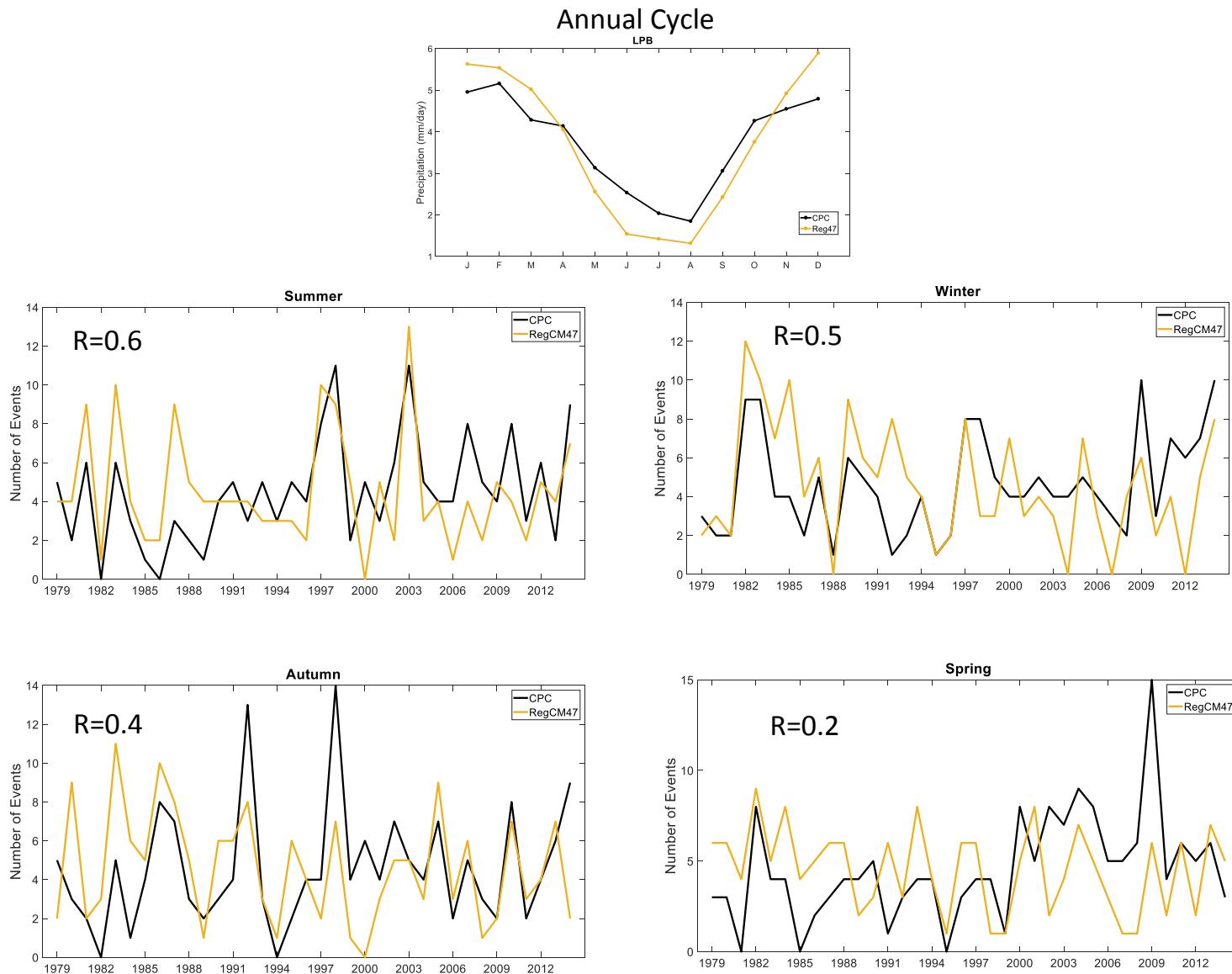
Data	DJF	MMA	JJA	SON
CPC	0	0.33	0.5	-0.16
TRMM	0	0.20	<b>1.0</b>	-0.20
RegBATS	-0.40	0.6	0.4	0
RegCLM	0.33	0.5	1.0	0.15
RegCM4.7	0.33	-0.12	0.4	0

Observations  
Trend + MMA and JJA  
Trend - SON

Bold: significant values with 95% of confidence

# Rainfall Extreme Events in LPB

## 1979-2014



R=correlation

# Daily Rainfall Extreme Events in LPB 1979-2014

## TRENDS

Sen-slope

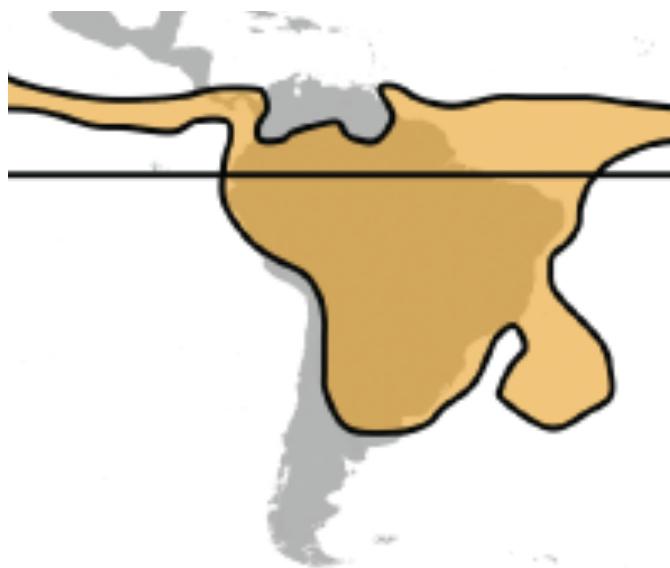
Data	DJF	MMA	JJA	SON
CPC	<b>0.1</b>	0.06	0.05	<b>0.1</b>
RegCM4.7	0	-0.05	-0.08	-0.05

Bold: significant values with 95% of confidence

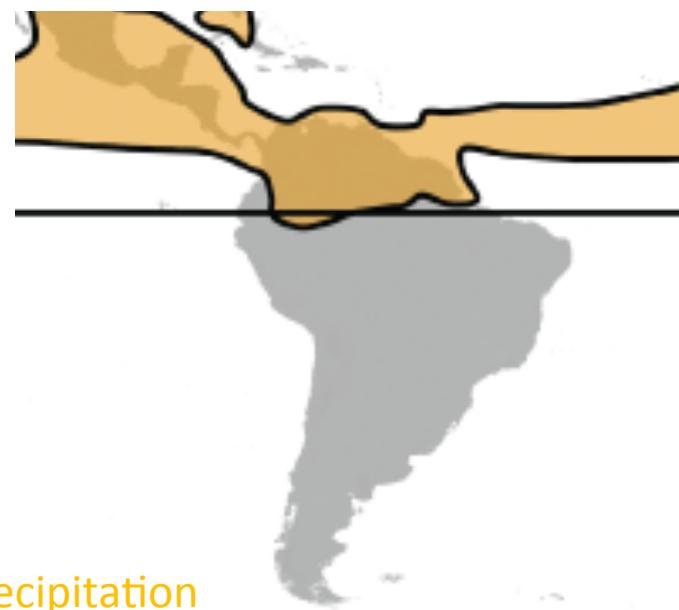
Observation: trend +  
Model does not  
simulate the trend  
signal

# South American Monsoon

DJF



JJA

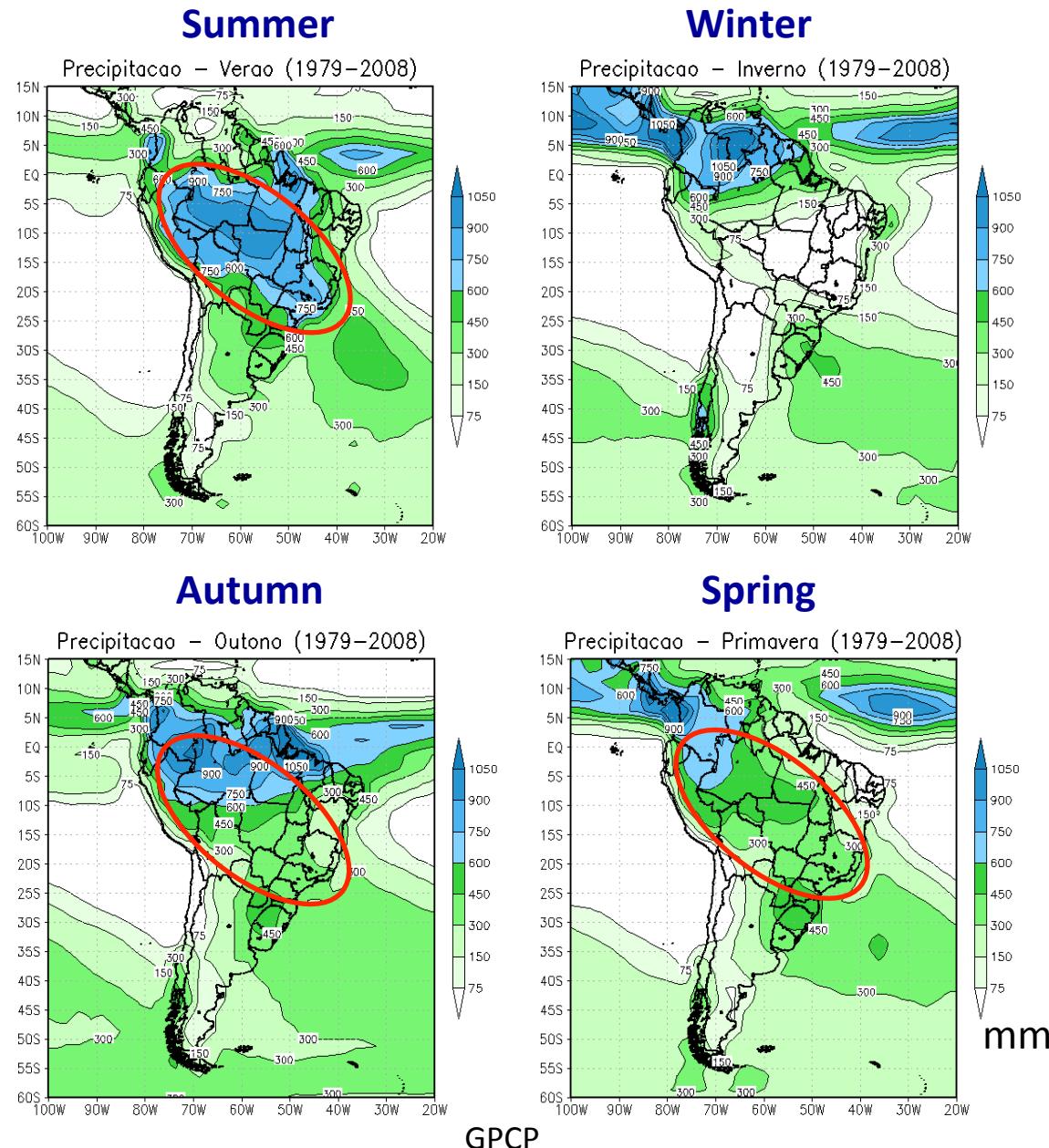


Great values of precipitation

# South America Monsoon: onset, demise and duration

Most part of the SA precipitation occurs in summer

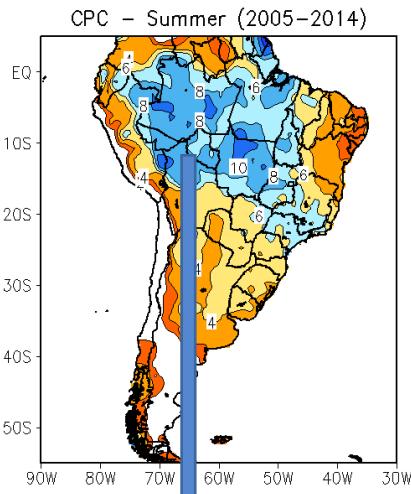
in the region known as SACZ.



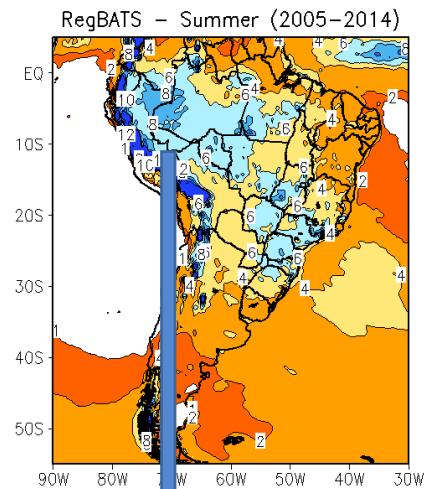
Reboita et al. (2012)

## DJF Precipitation (2005-2014)

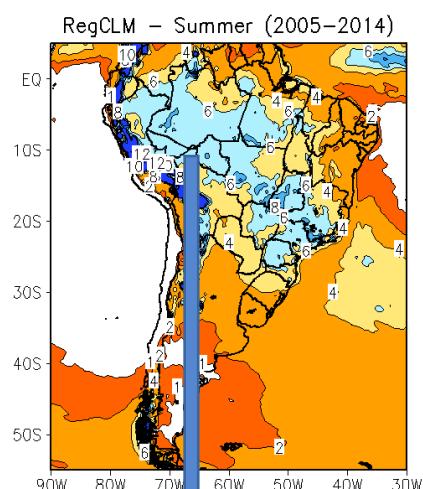
CPC



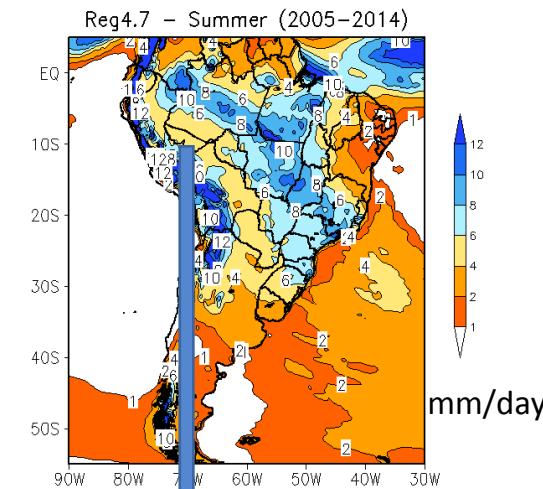
RegBATS



RegCLM

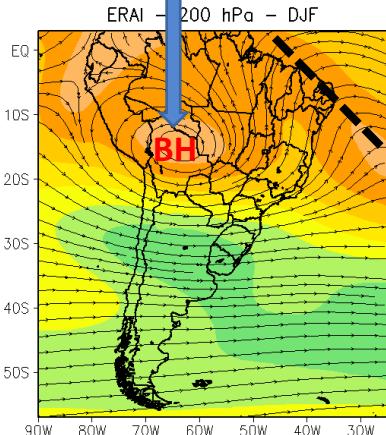


RegCM4.7



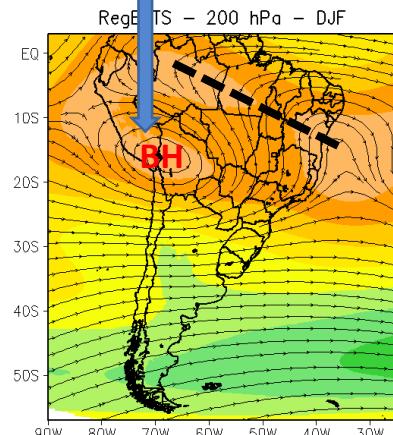
According to Lerner and Cook (1997), the Amazon convection develops the Bolivian High.

ERA1

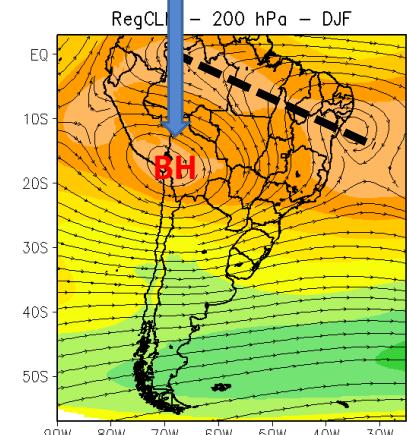


DJF 200 hPa Circulation

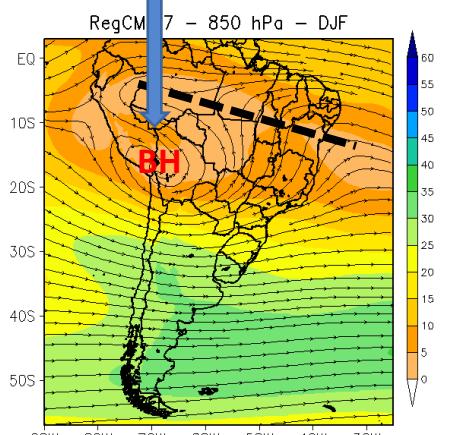
2005-2014)



RegCLM – 200 hPa – DJF



RegCM4.7 – 850 hPa – DJF



Simulations displace BH westward and show the trough crossing the continent.

n/s

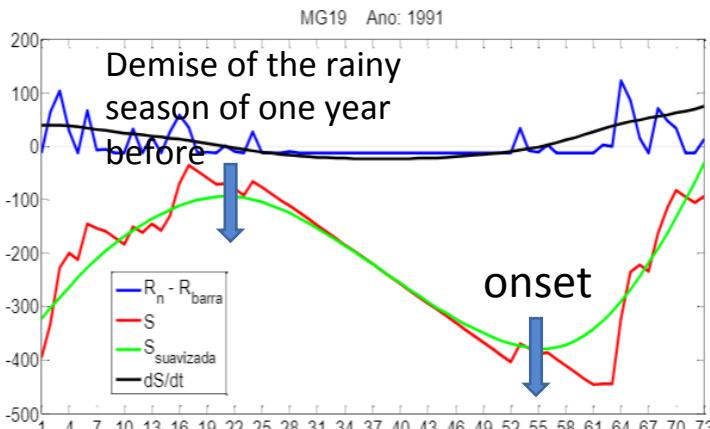
# South America Monsoon: onset, demise and duration

We computed the onset, demise and duration of the South America Monsoon (**SAM**)

from 2005 to 2014

following Bombardi and Carvalho (2008)

- Pentads are computed (73 for each year)
- Use a derivate to find the onset and demise (green line)



Silva and Reboita (2013)

Pentad numbers and corresponding calendar dates.

Pentad	Dates	Pentad	Dates
1	1–5 January	38	5–9 July
2	6–10 January	39	10–14 July
3	11–15 January	40	15–19 July
4	16–19 January	41	20–24 July
5	20–24 January	42	25–29 July
6	25–29 January	43	30 July - 3 August
7	30 Jan. - 4 Feb.	44	4–8 August
8	5–9 February	45	9–13 August
9	10–14 February	46	14–18 August
10	15–19 February	47	19–23 August
11	20–24 February	48	24–28 August
12	25 Feb. - 1 Mar.	49	29 Aug. - 2 Sep.
13	2–6 March	50	3–7 September
14	7–11 March	51	8–12 September
15	12–16 March	52	13–17 September
16	17–21 March	53	18–22 September
17	22–26 March	54	23–27 September
18	27–31 March	55	28 Sep. - 2 Oct.
19	1–5 April	56	3–7 October
20	5–10 April	57	8–12 October
21	11–15 April	58	13–17 October
22	16–20 April	59	18–22 October
23	21–25 April	60	23–27 October
24	26–30 April	61	28 Oct. - 1 Nov.
25	1–5 May	62	2–6 November
26	6–10 May	63	7–11 November
27	11–15 May	64	12–16 November
28	16–20 May	65	17–21 November
29	21–25 May	66	22–26 November
30	26–30 May	67	27 Nov. - 1 Dec.
31	31 May – 4 June	68	2–6 December
32	5–9 June	69	7–11 December
33	10–14 June	70	12–16 December
34	15–19 June	71	17–21 December
35	20–24 June	72	22–26 December
36	25–29 June	73	27–31 December
37	30 June - 4 July		

Kousky (1988)

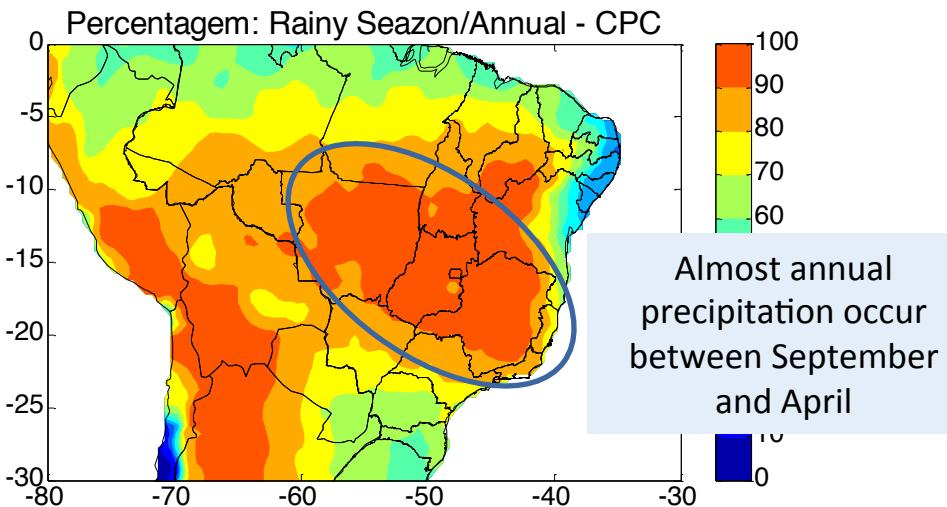
# Percentage of Precipitation

SAM onset and demise will be presented only to the sectors that have **60% or more** of the precipitation between the pentads **53** and **21**.

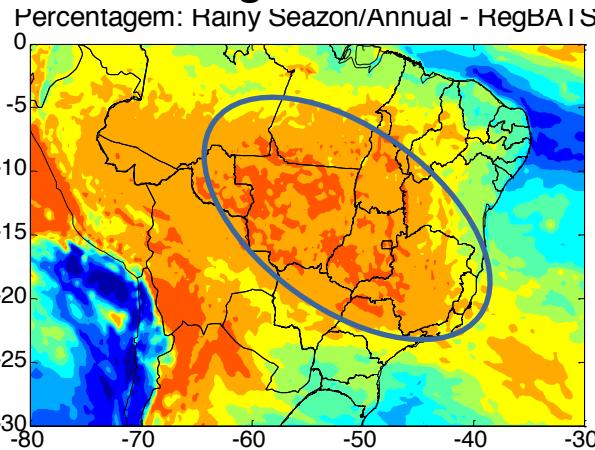
Pentad 53 = 18 to 22 September

Pentad 21 = 11 to 15 April

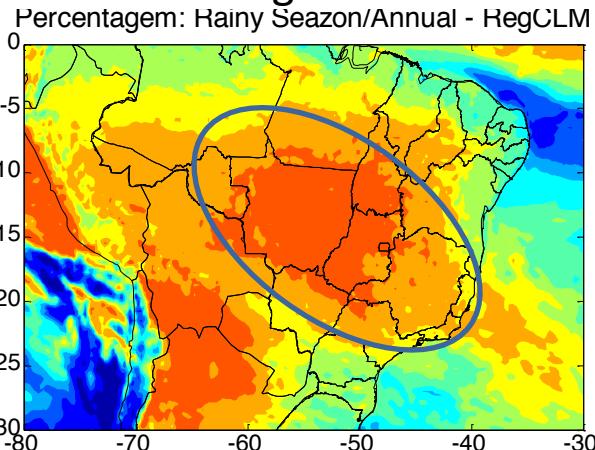
CPC 2005-2014



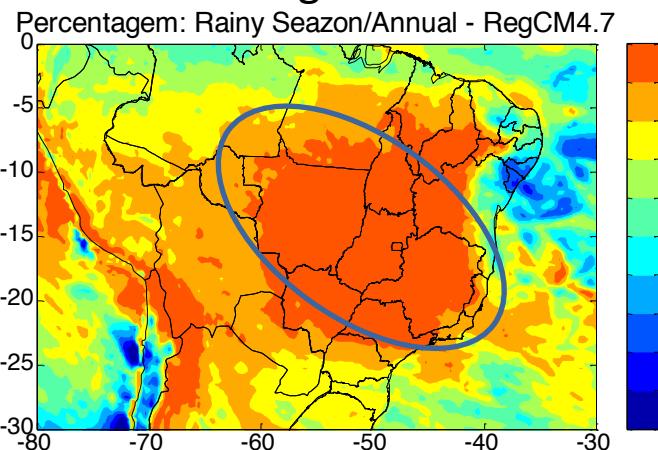
RegBATS



RegCLM



RegCM4.7

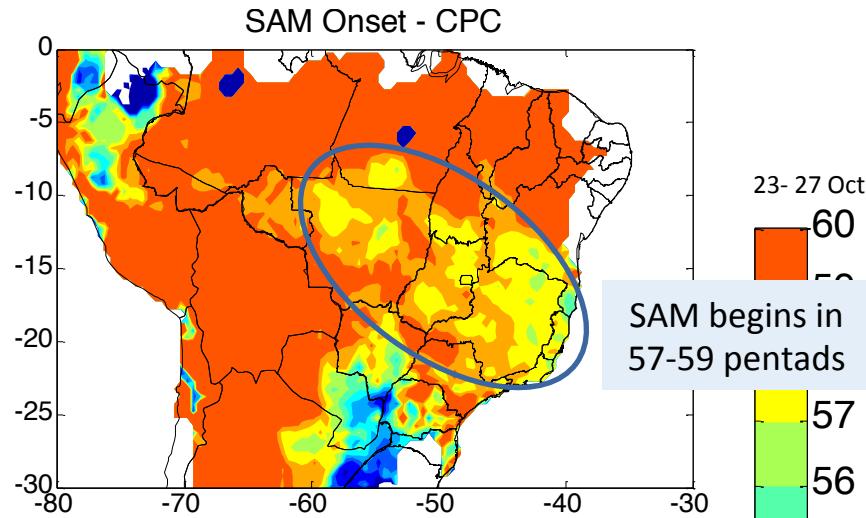


Better representation in RegCM4.7

# SAM ONSET

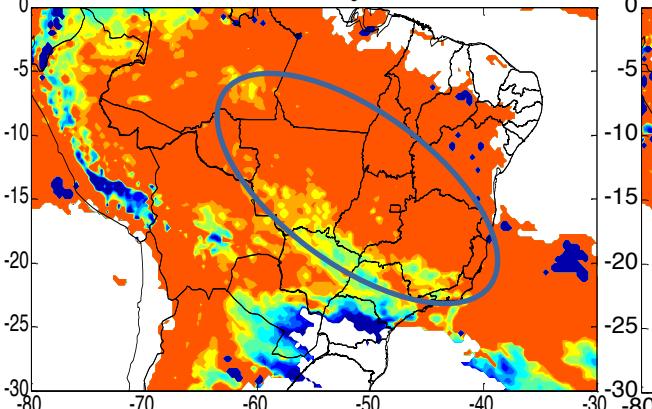
- Simulations delay the SAM onset
- RegCM4.7 shows the more different spatial pattern compared to CPC

CPC 2005-2014



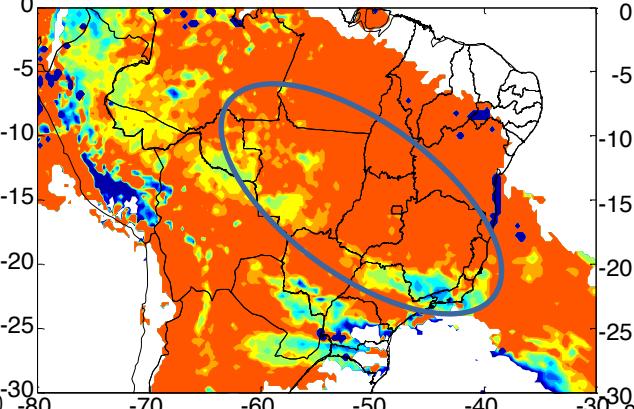
RegBATS

SAM Onset - RegBATS



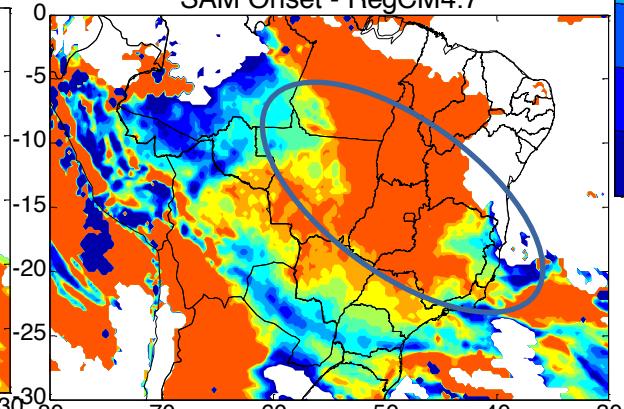
RegCLM

SAM Onset - RegCLM



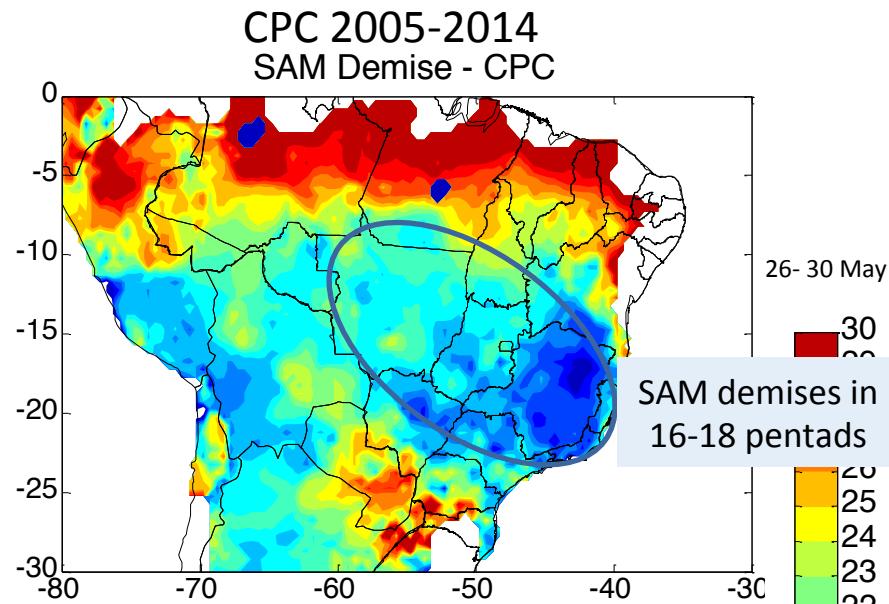
RegCM4.7

SAM Onset - RegCM4.7



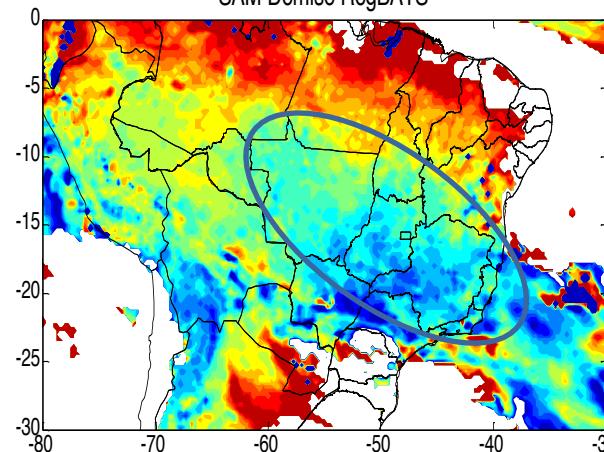
# SAM DEMISE

- Simulations delay the SAM demise
  - Better skill of RegBATS in representing the spatial pattern of the SAM demise.



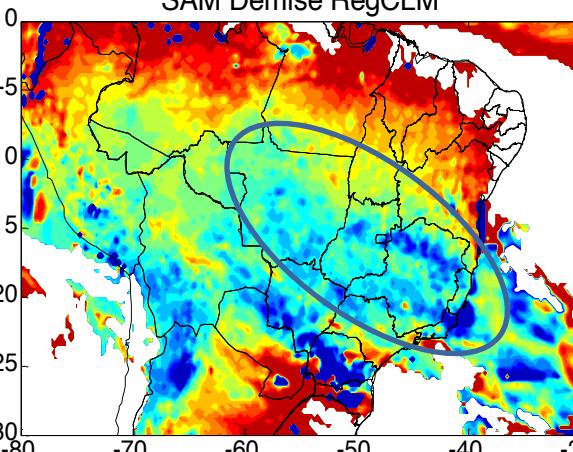
RegBATS

SAM Demise RegBATS



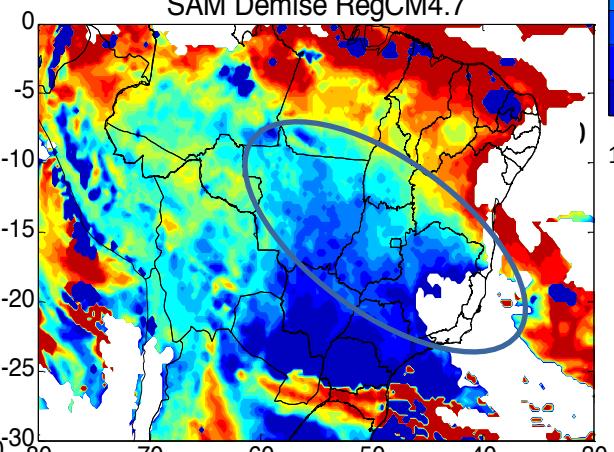
RegCLM

SAM Demise RegCLM



RegCM4.7

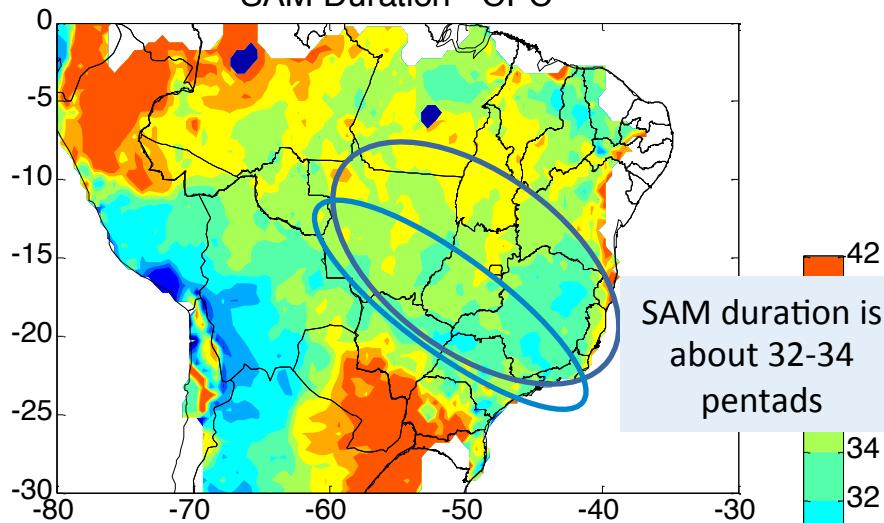
SAM Demise RegCM4.7



# SAM DURATION

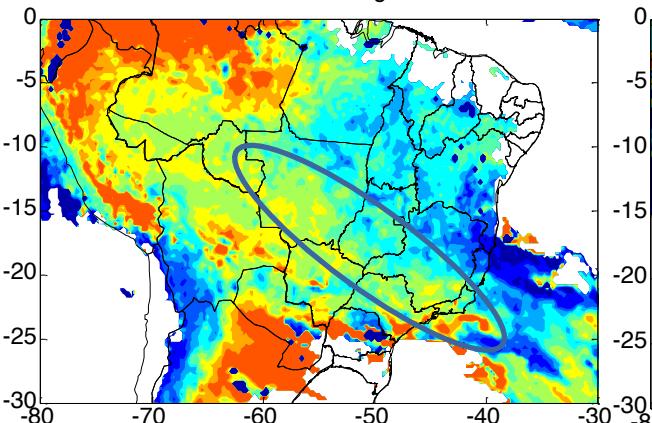
- As the simulations delay the SAM onset and demise, they show, in some areas, values near to CPC.
- It occurs in a narrow band, in RegBATS and RegCLM.
- Low performance of RegCM4.7

CPC 2005-2014  
SAM Duration - CPC



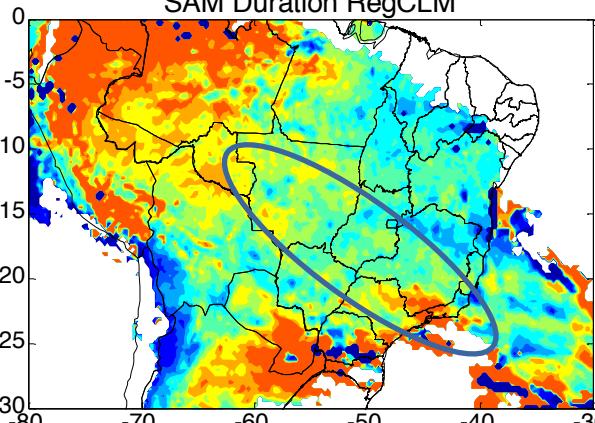
RegBATS

SAM Duration RegBATS



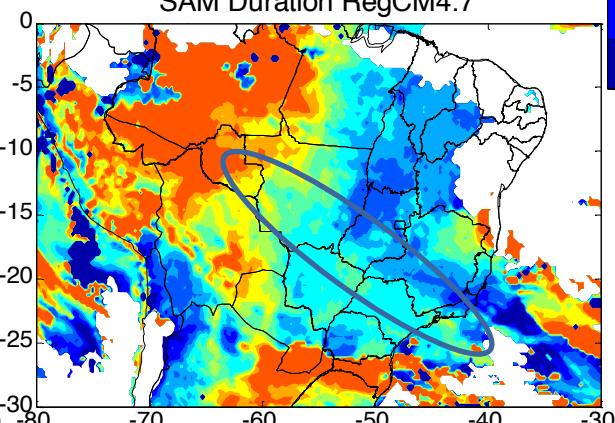
RegCLM

SAM Duration RegCLM



RegCM4.7

SAM Duration RegCM4.7



## Observations: 1979-2014

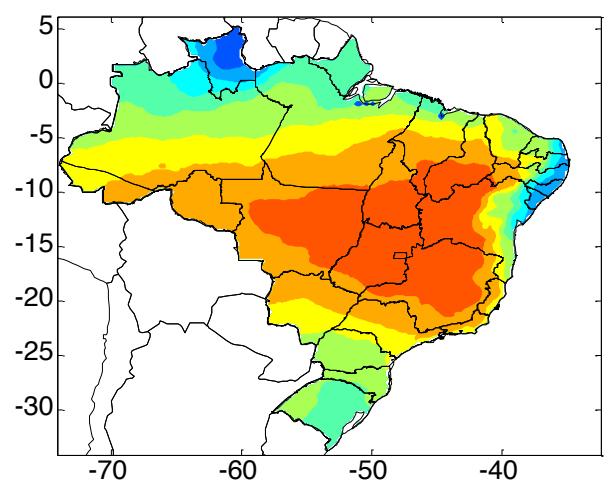
### Percentagem of Precipitation

The results will be present only to the sectors that have **60% or more** of the precipitation between the pentads **53** and **21**.

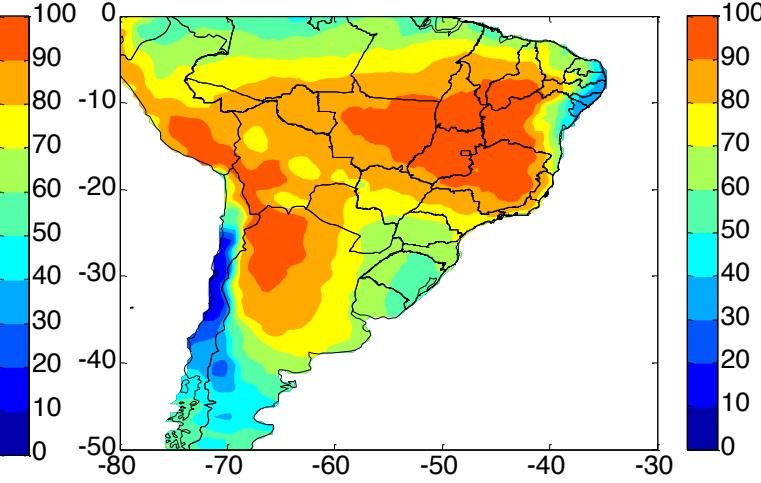
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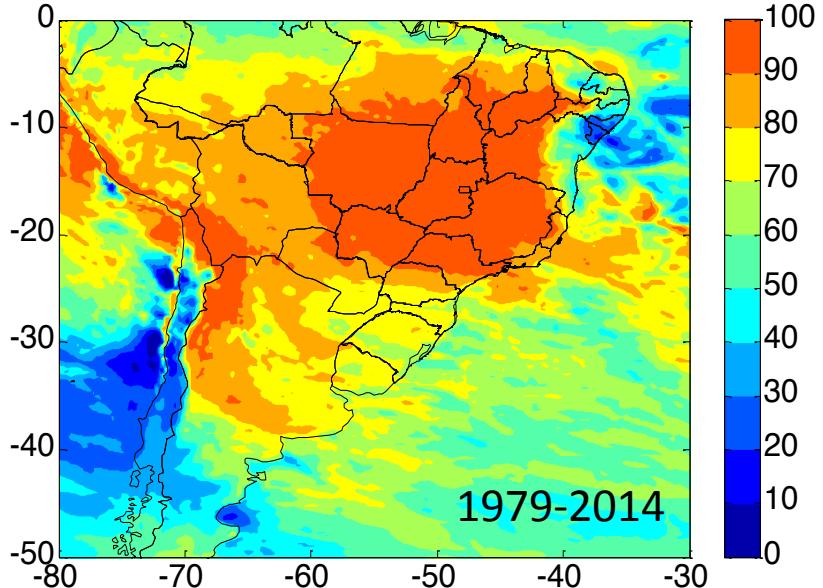
Percentagem: Rainy Season/Annual - Xavier Dataset



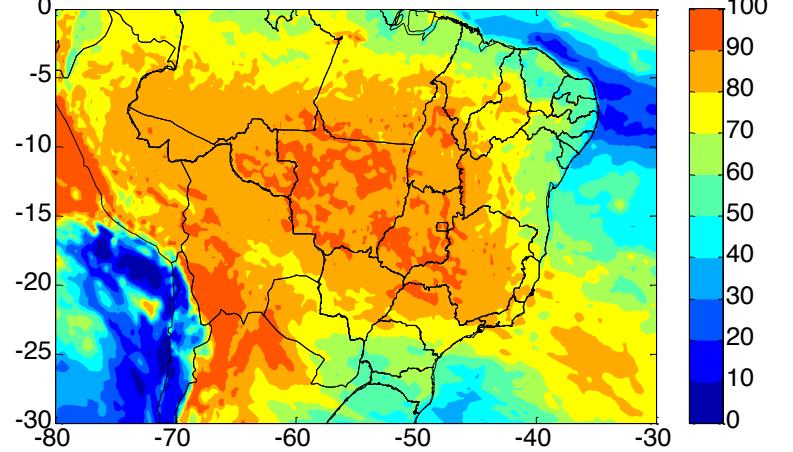
Percentagem: Rainy Season/Annual - CPC



Percentagem: Rainy Season/Annual - RegCM4.7



Percentagem: Rainy Season/Annual - RegBAMIS

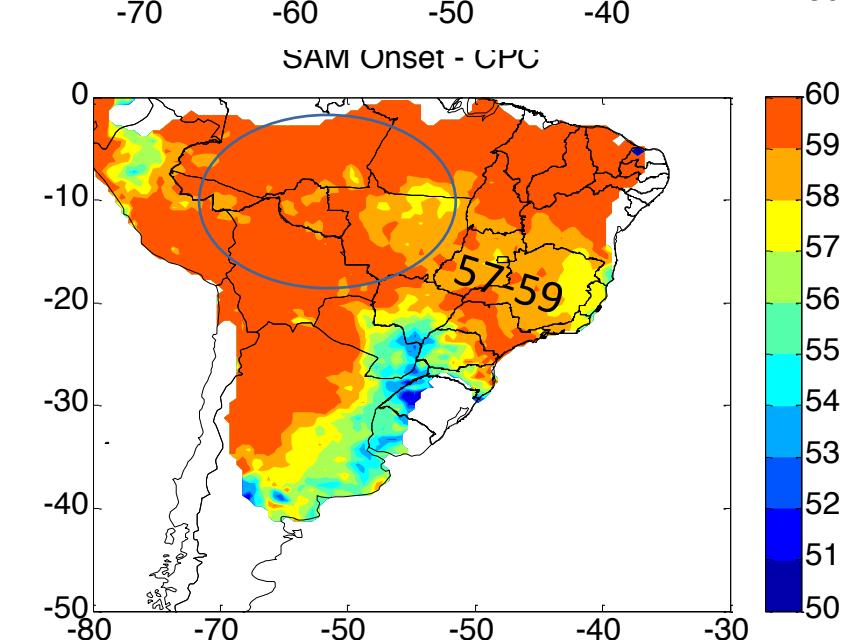
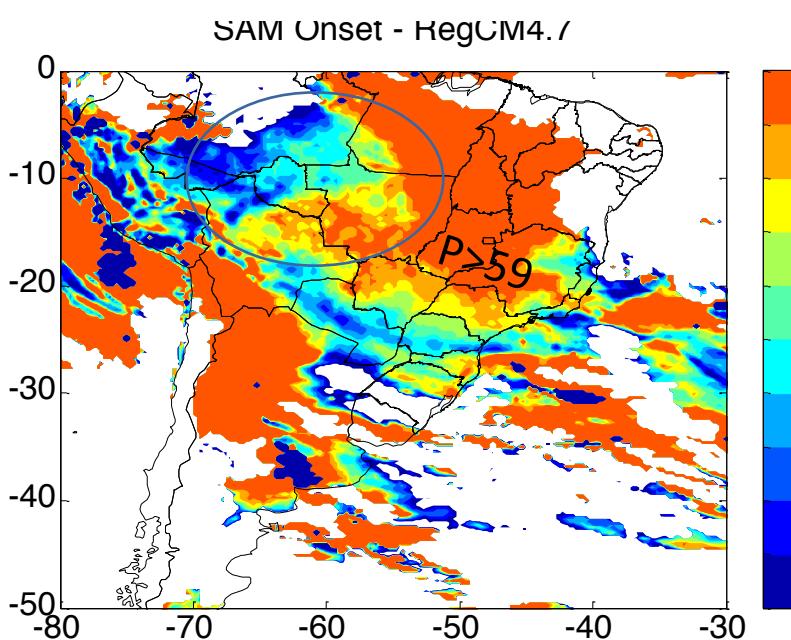
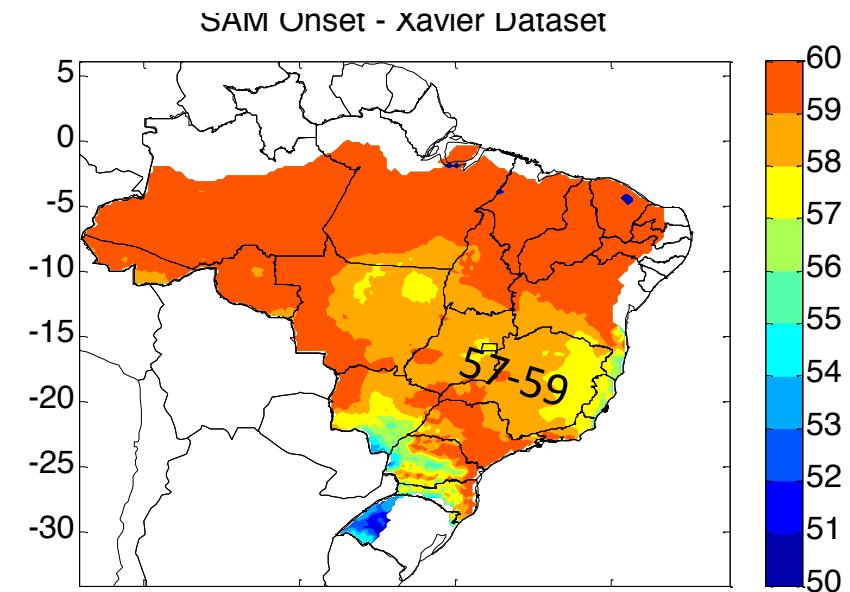
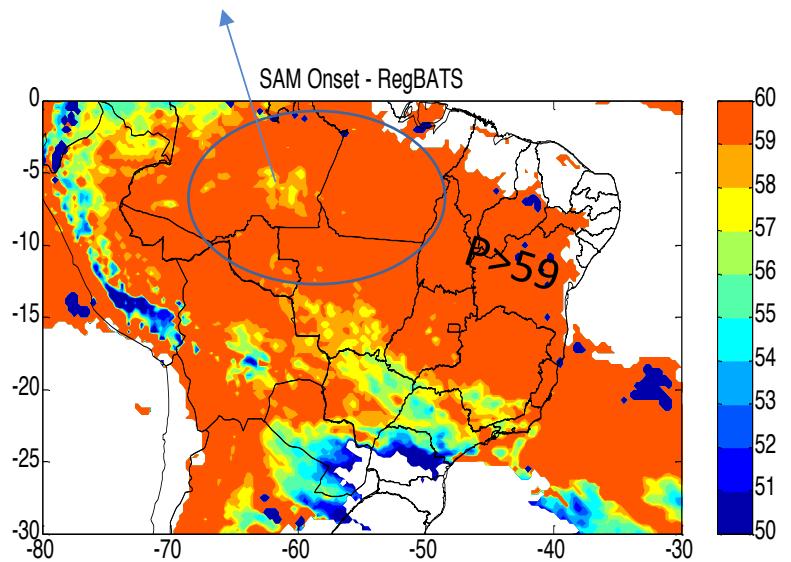


1979-2014

2005-2014

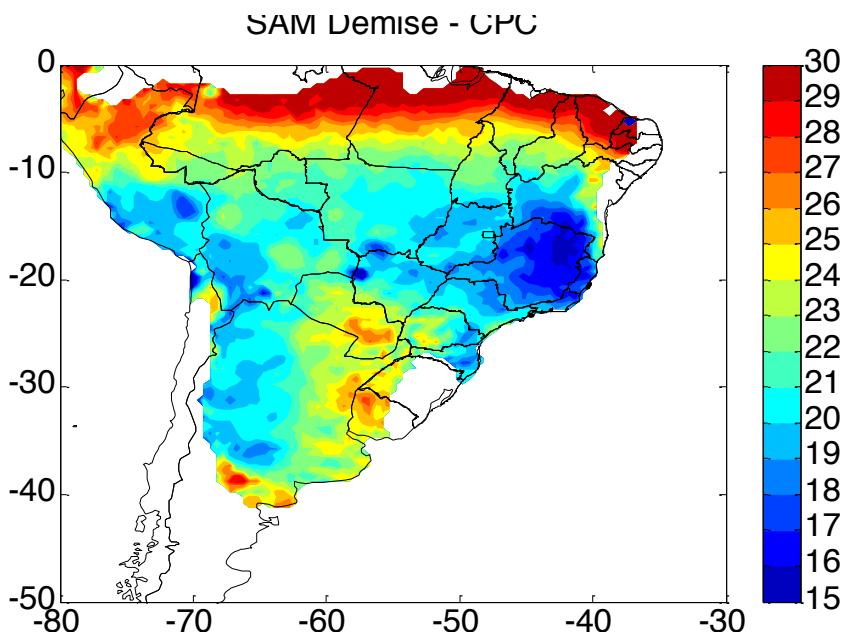
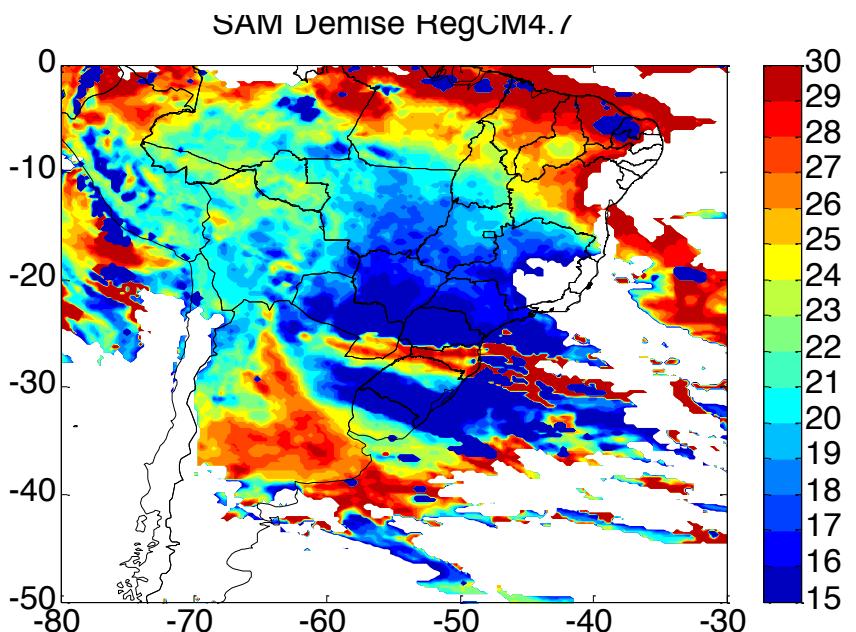
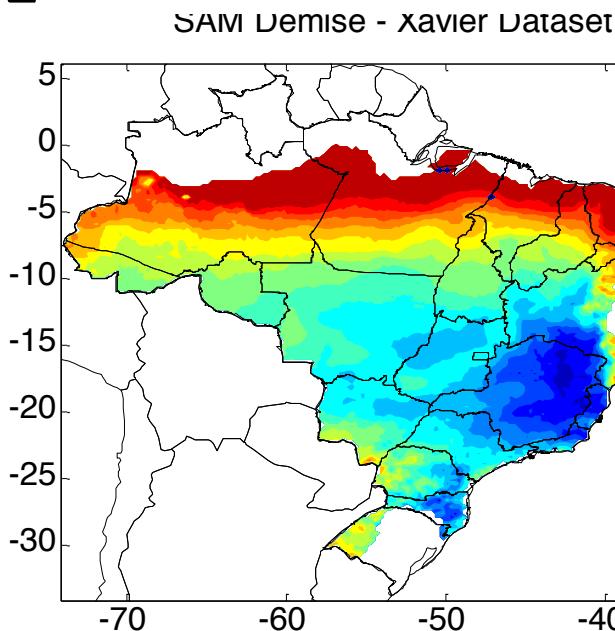
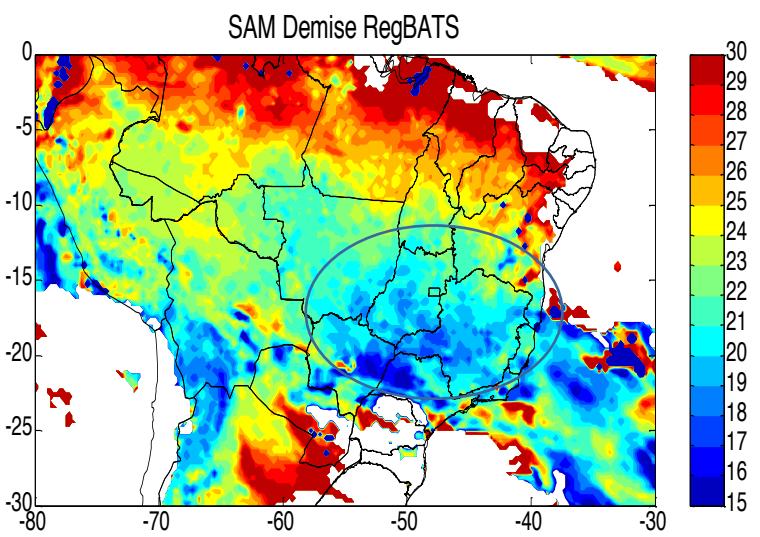
# SAM ONSET

RegBATS has better performance



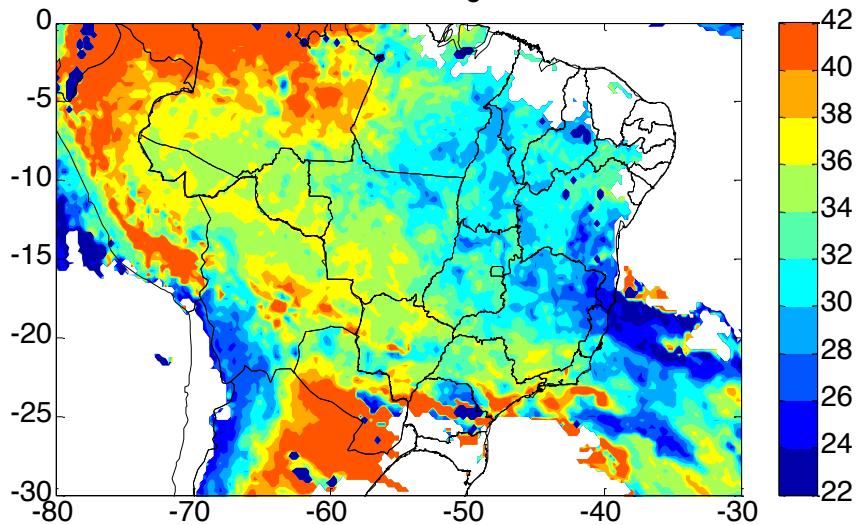
Delays the onset but ends  
later the SAM

# SAM DEMISE

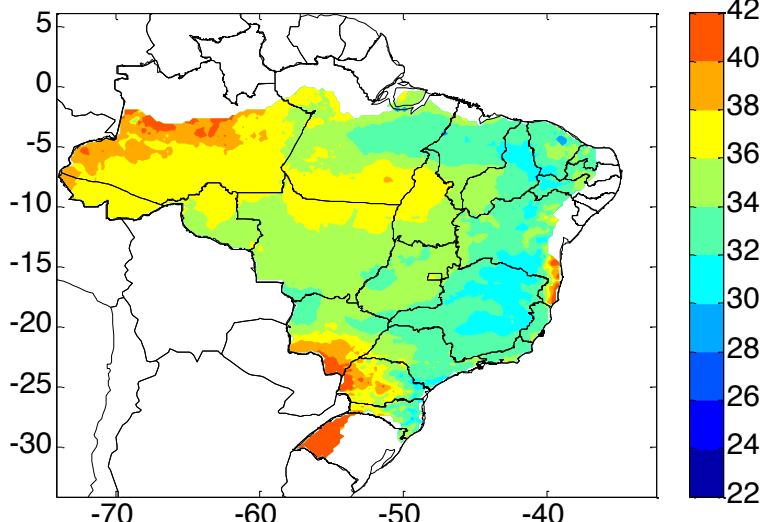


# SAM DURATION

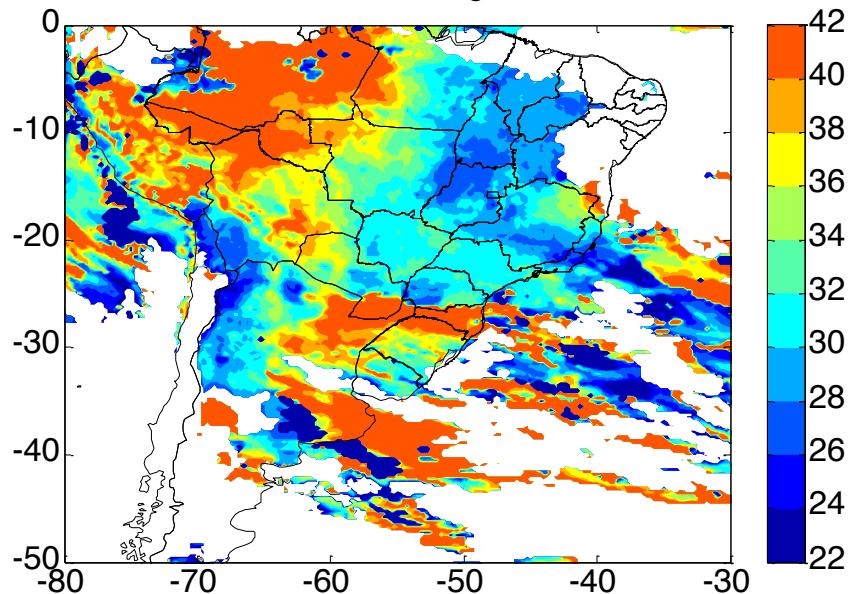
SAM Duration RegBATS



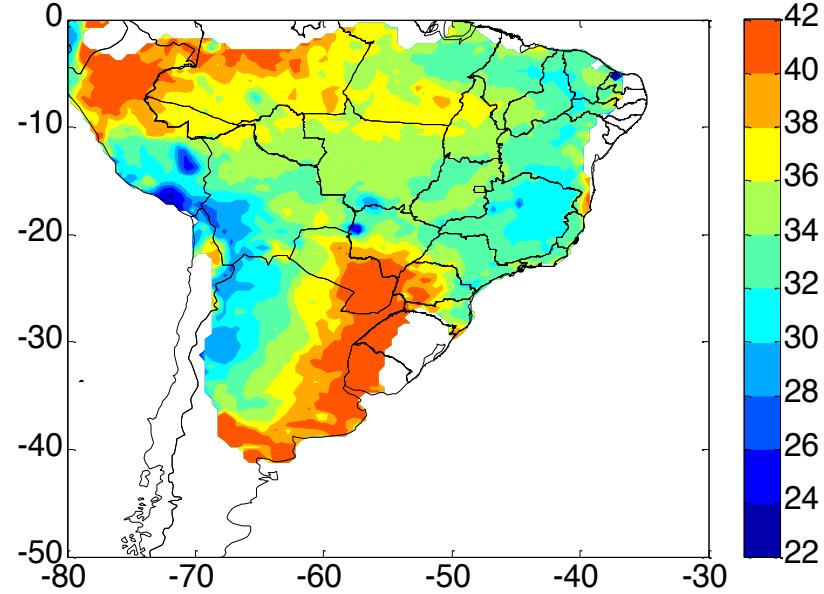
SAM Duration - Xavier Dataset



SAM Duration RegCM4.7



SAM Duration - CPC



# Droughts in South America



<https://www.worldwildlife.org/climatico/climate-change-impacts-in-latin-america>

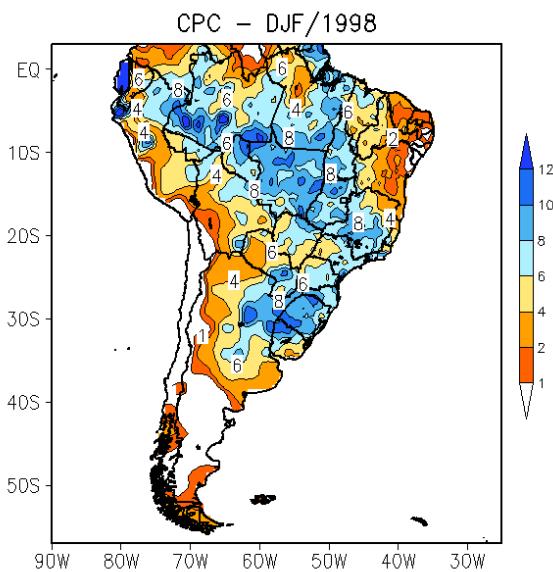
# Droughts in South America

**Goal:** to verify if the simulations of RegCM represent the atmospheric circulation pattern during the most impacting drought events in SA

Place	Period (studied here)	Reason	Reference
Amazon	DJF/1998	El Niño	Marengo et al. (2007) Tomasella et al. (2010)
Amazon	JF/2005	warming of the tropical North Atlantic	Marengo et al. (2007) Zeng et al. (2008)
Amazon	JFM/2010	started in early austral summer during El Niño and then was intensified as a consequence of the warming of the tropical North Atlantic	Zeng et al. (2008) Marengo et al. (2011)
Southeast Brazil	JFM/2014	Warm anomalies over the north Australia impact the atmospheric circulation	Coelho et al. (2015)

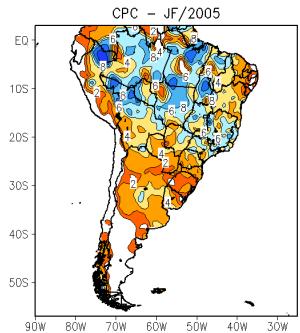
# Precipitation DJF/1998

CPC



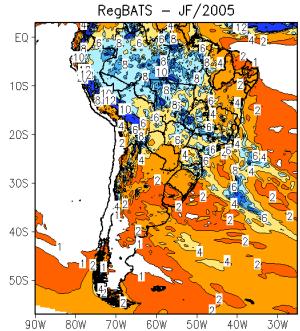
## Average JF/2005

CPC

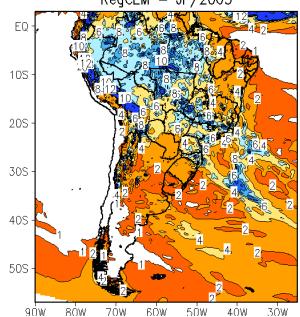


## Average – Climatology

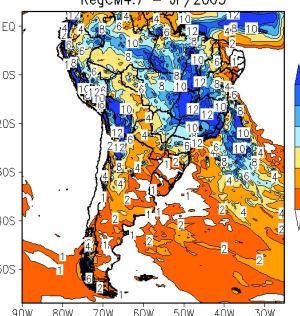
RegBATS



RegCLM



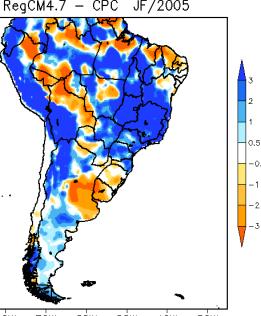
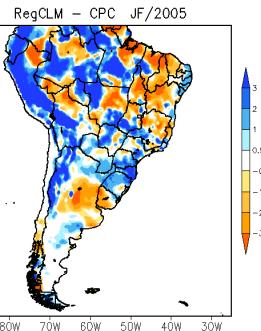
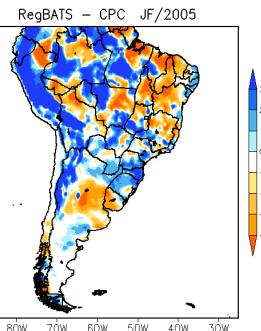
RegCM4.7



## Precipitation JF/2005

The drought occurred in the whole Amazon.

## Simulations - CPC



Simulations present great bias compared to CPC

Only RegCM4.7 shows a drought signal.

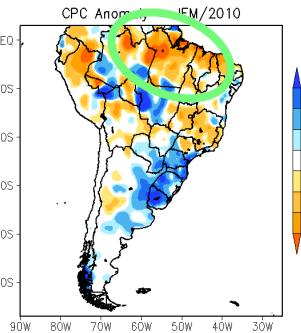
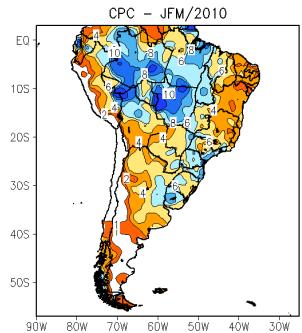
mm/day

Average JFM/2010

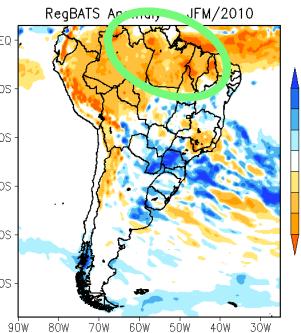
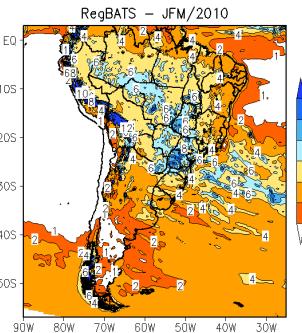
Average – Climatology

# Precipitation JFM/2010

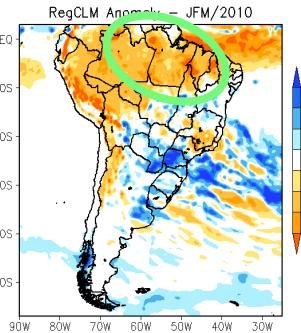
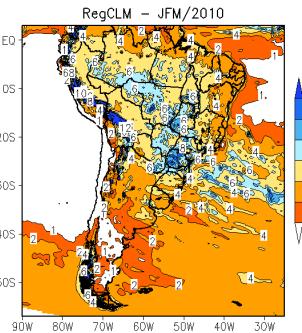
CPC



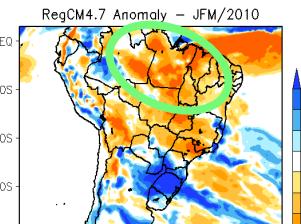
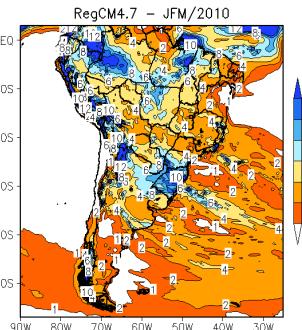
RegBATS



RegCLM



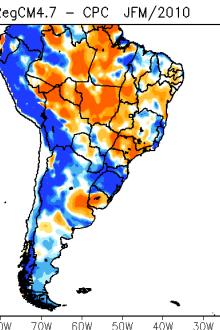
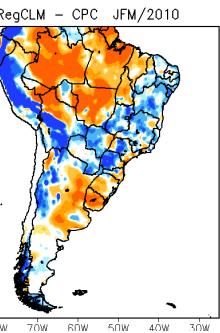
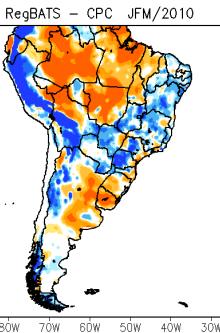
RegCM4.7



Simulations showed large area of drought compared to CPC.

The drought occurred in the northeastern Amazon.

## Simulations - CPC



Simulations are dryer than CPC over the Amazon.

mm/day

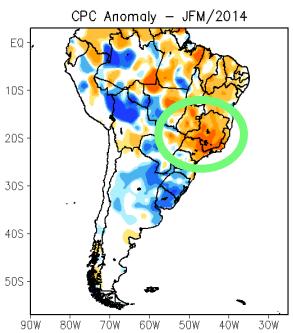
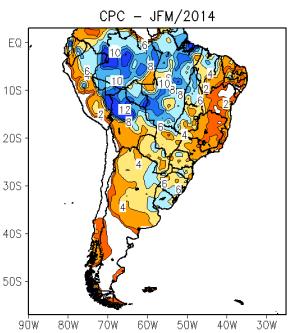
Average JFM/2014

Average – Climatology

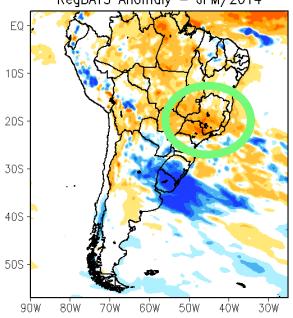
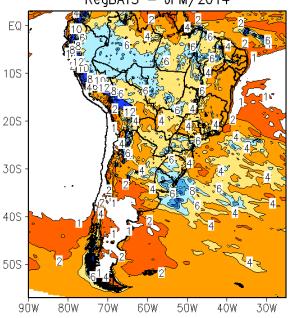
# Precipitation JFM/2014

The drought was more intense in the southeastern Brazil.

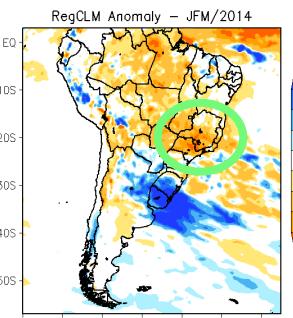
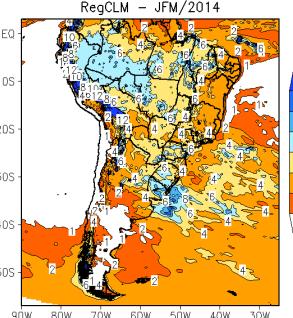
CPC



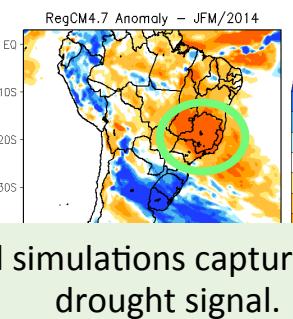
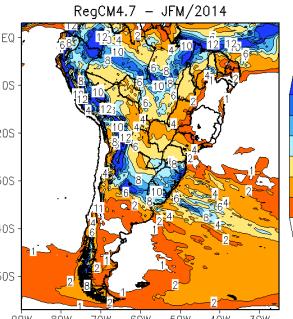
RegBATS



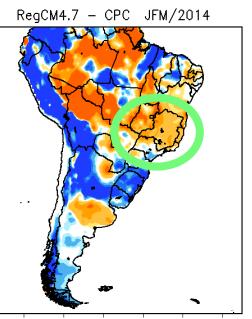
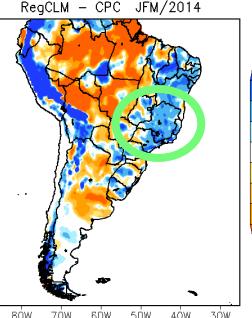
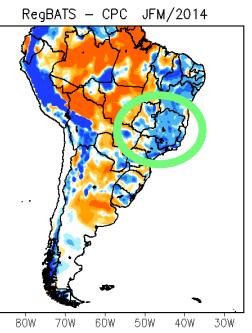
RegCLM



RegCM4.7



## Simulations - CPC



RegBATS and RegCLM overestimate the precipitation over southeastern Brazil compared to CPC, while RegCM4.7 underestimates it.

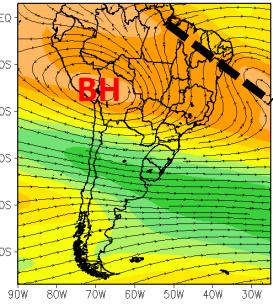
All simulations capture the drought signal.

mm/day

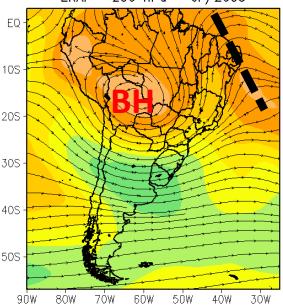
# Atmospheric Circulation at 200 hPa in each drought episode

**ERA-Interim**

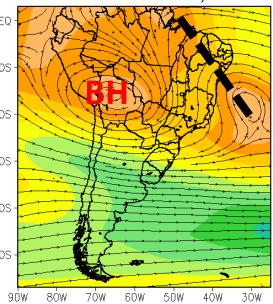
ERAI - 200 hPa - DJF/1998



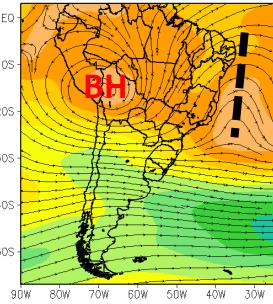
ERAI - 200 hPa - JF/2005



ERAI - 200 hPa - JFM/2010



ERAI - 200 hPa - JFM/2014



**RegBAT**

RegBATS - 200 hPa - JF/2005

**RegCLM**

RegCLM - 200 hPa - JFM/2010

RegCLM - 200 hPa - JFM/2014

**RegCM4.7**

RegCM4.7 - 200 hPa - JF/2005

RegCM4.7 - 200 hPa - JFM/2010

RegCM4.7 - 200 hPa - JFM/2014

**S**

4.6.1

m/s

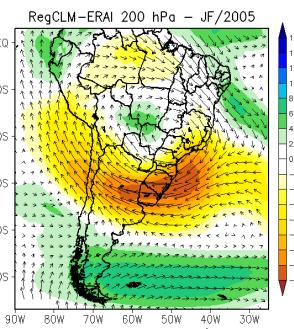
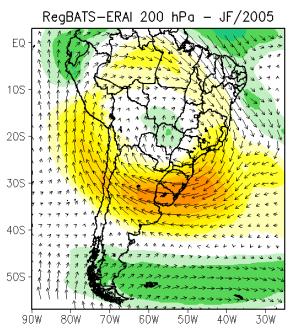
Simulations displace the Bolivian High and the Northeast Trough position compared to ERA-Interim. If the rain does not occur in the correct place, it displaces the BH, that is a response of convection (Lenters and Cook, 1997).

1998

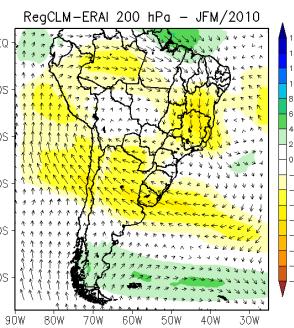
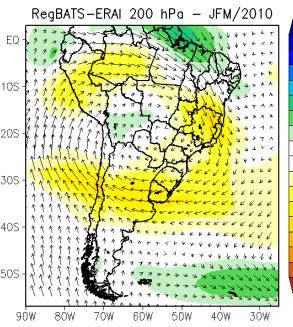
## RegBATS    4.6.1    RegCLM

In general, over Brazil, the winds are weaker in the simulations.

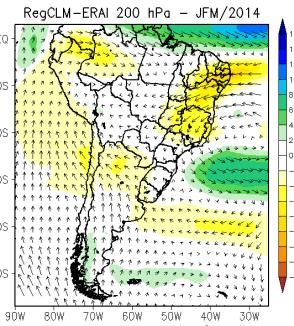
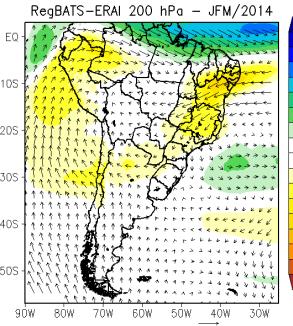
2005



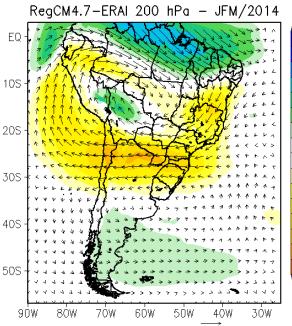
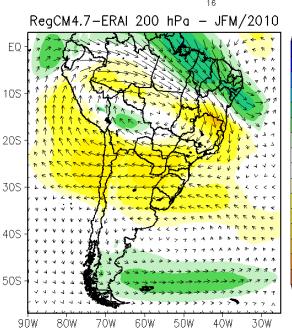
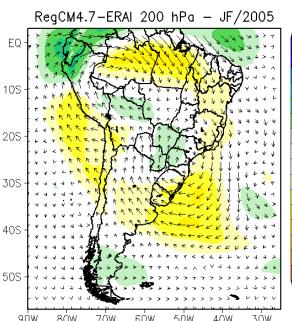
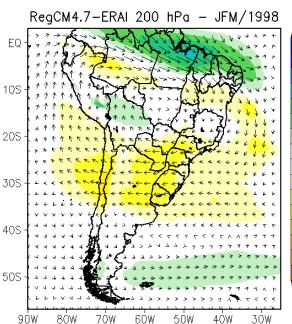
2010



2014



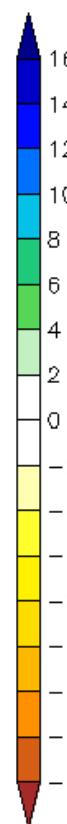
## RegCM4.7



Atmospheric Circulation at 200 hPa in each drought episode

Model - ERAI

stronger

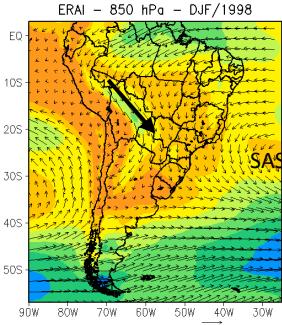


weaker

m/s

# Atmospheric Circulation at 850 hPa in each drought episode

ERA-Interim



1998

RegBATS

4.6.1

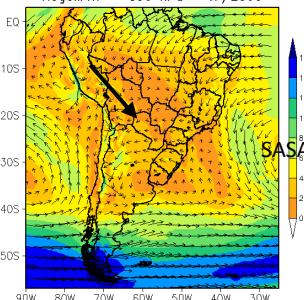
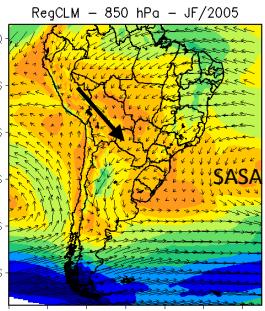
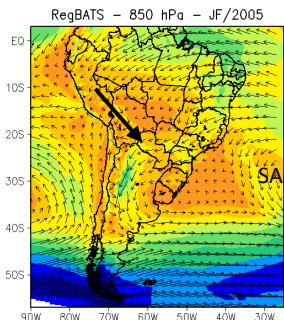
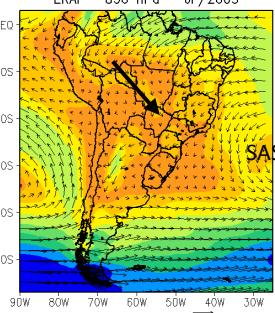
RegCLM

RegCM4.7

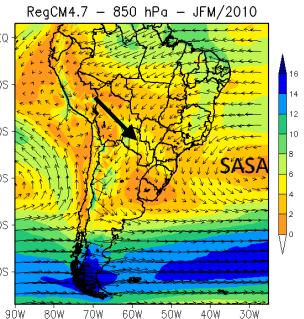
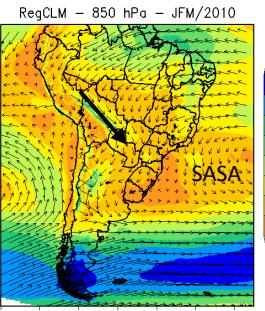
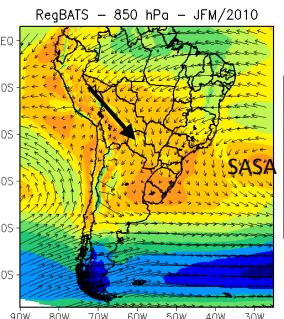
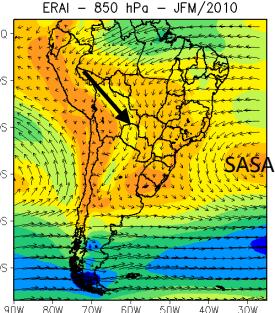


2005 – simulations displace de LLJ to western

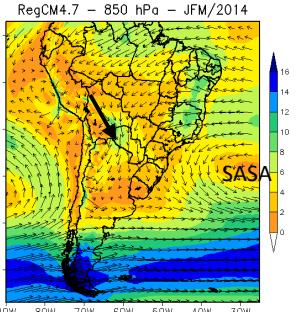
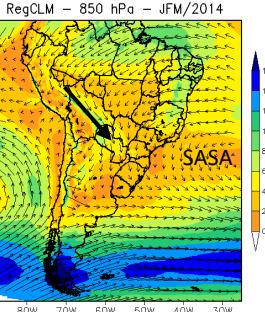
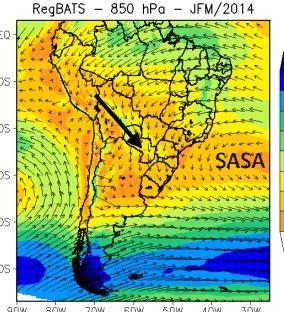
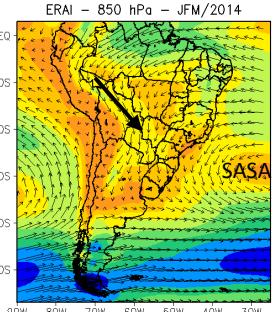
2005



2010



2014



1998

2005

2010

2014

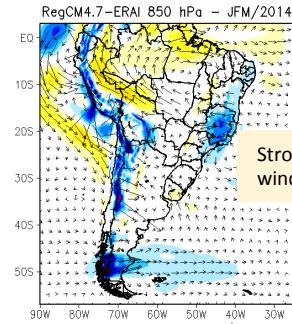
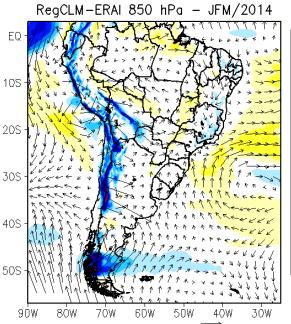
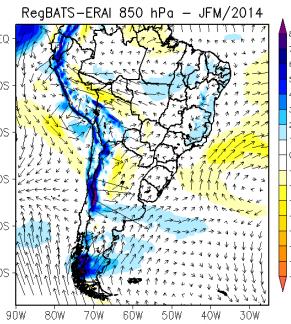
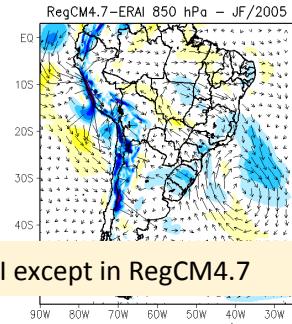
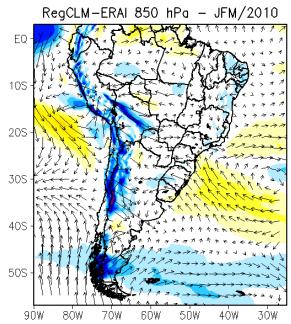
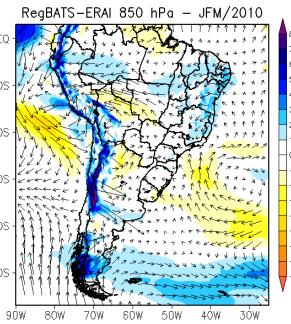
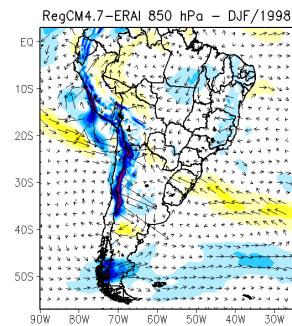
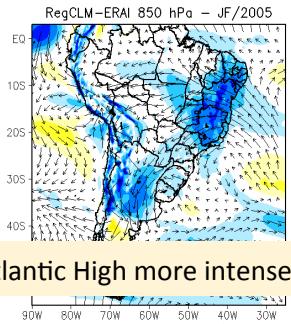
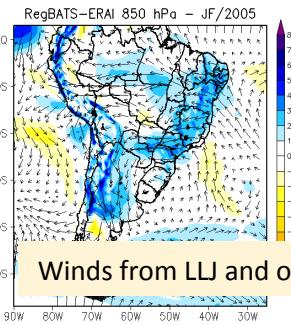
RegBATS

4.6.1

RegCLM

RegCM4.7

Atmospheric  
Circulation at  
850 hPa  
in each drought  
episode  
**Model - ERAI**



stronger

weaker

Stronger  
winds

m/s

# Conclusions

We need to evaluate other configurations.

One suggestion is to run RegCM4.7 with BATS + Emanuel.

Thanks to the ICTP team by RegCM4.7 simulation.

Thanks for the attention!

