Impactos de variações climáticas sobre a chuva e seus extremos no Sul do Brasil: ENOS Central e Leste e outras oscilações

Alice M. Grimm
Universidade Federal do Paraná, Curitiba, Brazil

grimm@fisica.ufpr.br

Sumário

1) Influência da variabilidade associada a ENOS sobre a frequência de precipitação extrema e sobre a distribuição de precipitação diária: clima presente (observado e simulado) e clima futuro (A2)

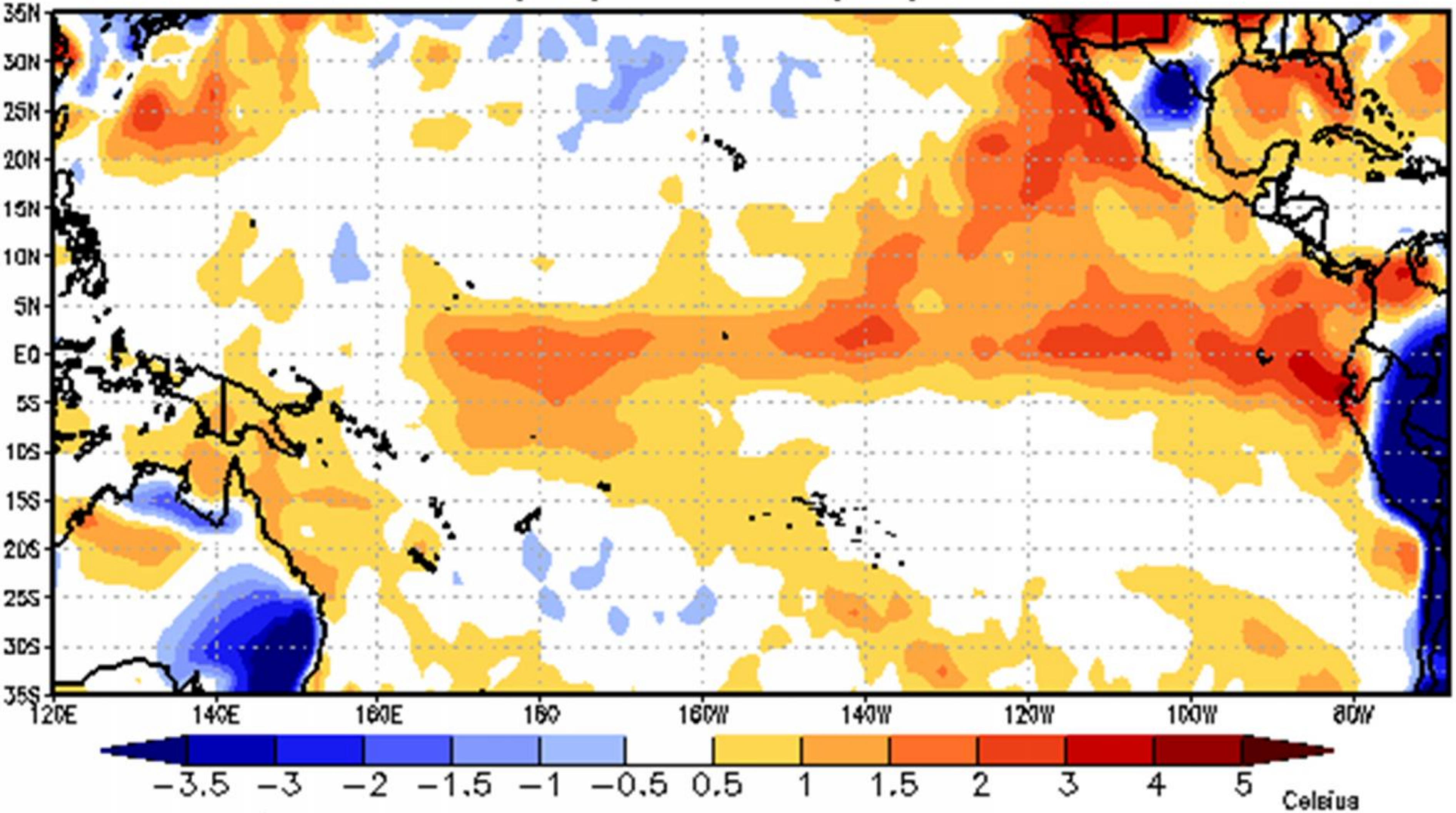
2) Influência de ENOS no Pacífico Central e Pacífico Leste sobre a frequência de eventos extremos de precipitação

3) Variações intrassazonais

4) Variações interdecadais

El Niño / La Niña

Anomalia de Temperatura da Superficie do Mar
06/05/2015 a 13/05/2015



Fonte de dados: NCEP/NOAA - EUA
Elaboracao: CPTEC/INPE

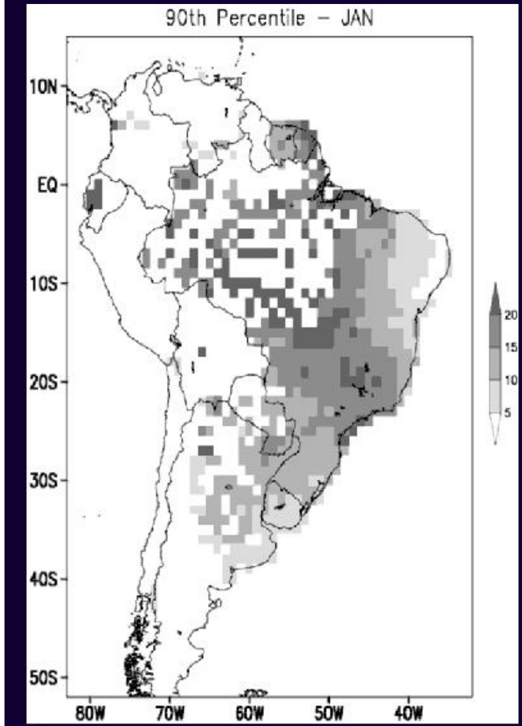
Motivation

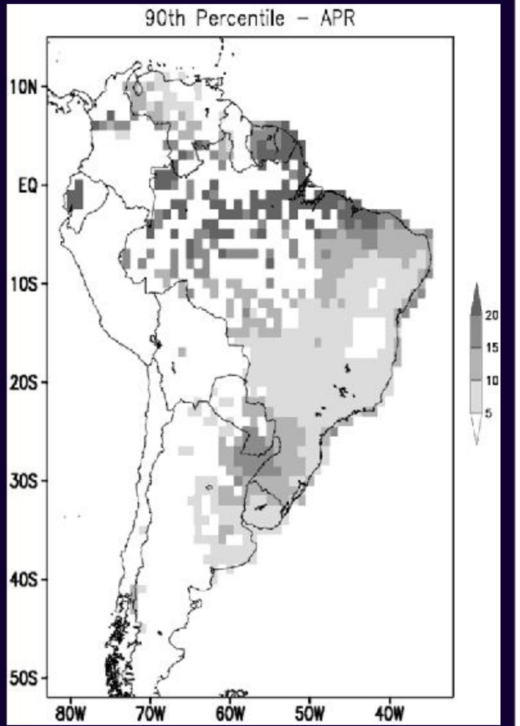
- There are significant impacts on seasonal and monthly precipitation amounts in several regions of South America during the different phases of the El Niño – Southern Oscillation (ENSO).
- As monthly to seasonal precipitation amounts depend on the frequency of extreme precipitation events, it is reasonable to expect the frequency of extreme rainfall events to be also modulated by ENSO.
- However, this does not mean that regions with ENSO-sensitive monthly and seasonal precipitation are necessarily regions with ENSO-sensitive frequency and intensity of extreme events, and vice-versa.
- As some of the most dramatic consequences of climate variability manifest through extreme events, the present study is focused on the impact of EN and LN episodes on the frequency and intensity of extreme precipitation events, with monthly resolution throughout the entire ENSO cycle.
- This information is useful to refine climate prediction and enhance preparedness for natural disasters, such as floods and landslides, which have been observed more frequently in association with EN and LN episodes in certain regions of South America.

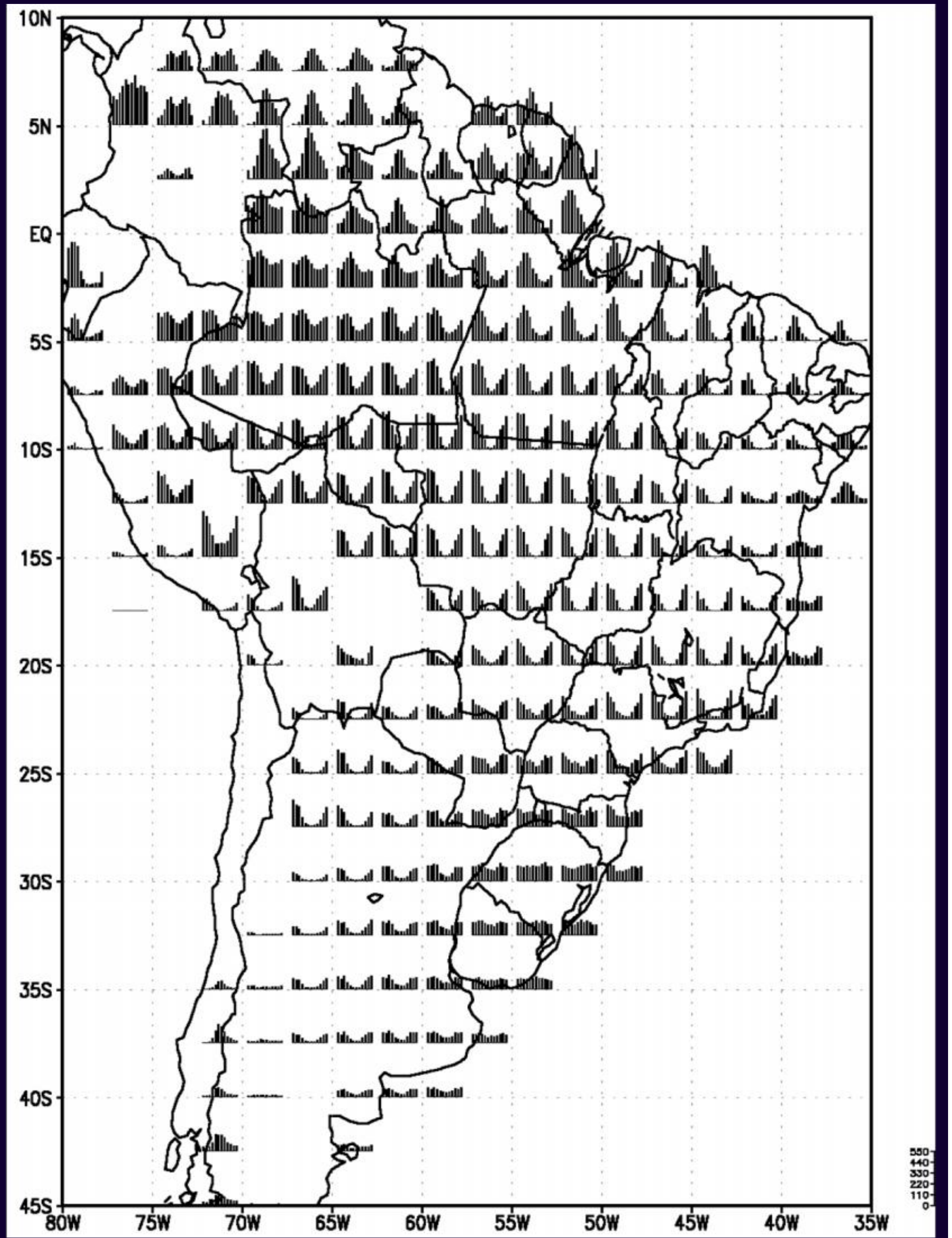
Data / Methods

- Daily precipitation totals in the period 1956-2002, from more than 10,000 stations in SA, went through procedures for elimination of spurious data, with incorrect order of magnitude or zeros in place of missing data. The data are gridded to 1.0º. Also used is daily precipitation output of the coupled model ECHAM5-OM for the periods 1960-2000 and 2060-2100 (scenario A2).
- Three-day running means of precipitation are computed and the values attributed to the central days. Gamma distributions are fitted to these means, one distribution for each day of the year. Extreme events are those with a three-day mean above the 90th percentile.
- The number of extreme events are computed for each month of each year.
- Years are classified as EN, LN, and neutral years, and the mean frequency of extreme events for each month, within each category of year, is computed. EN (LN) episode must have at least 6 consecutive values of five months running mean of Niño 3 SST anomaly above (below) 0.5ºC (- 0.5ºC).
- Differences (and their statistical significance) between the mean frequencies for EN and normal years, and for LN and normal years are computed.
- These differences are also calculated for the average daily rainfall during extreme events.
- The daily rainfall frequency distributions are calculated separately for EN, LN, and NN years for some regions.
- Composites of anomalous atmospheric daily fields are computed for extreme events in affected regions, and compared with ENSO-related atmospheric perturbations.

How much precipitation corresponds to the 90th percentile?

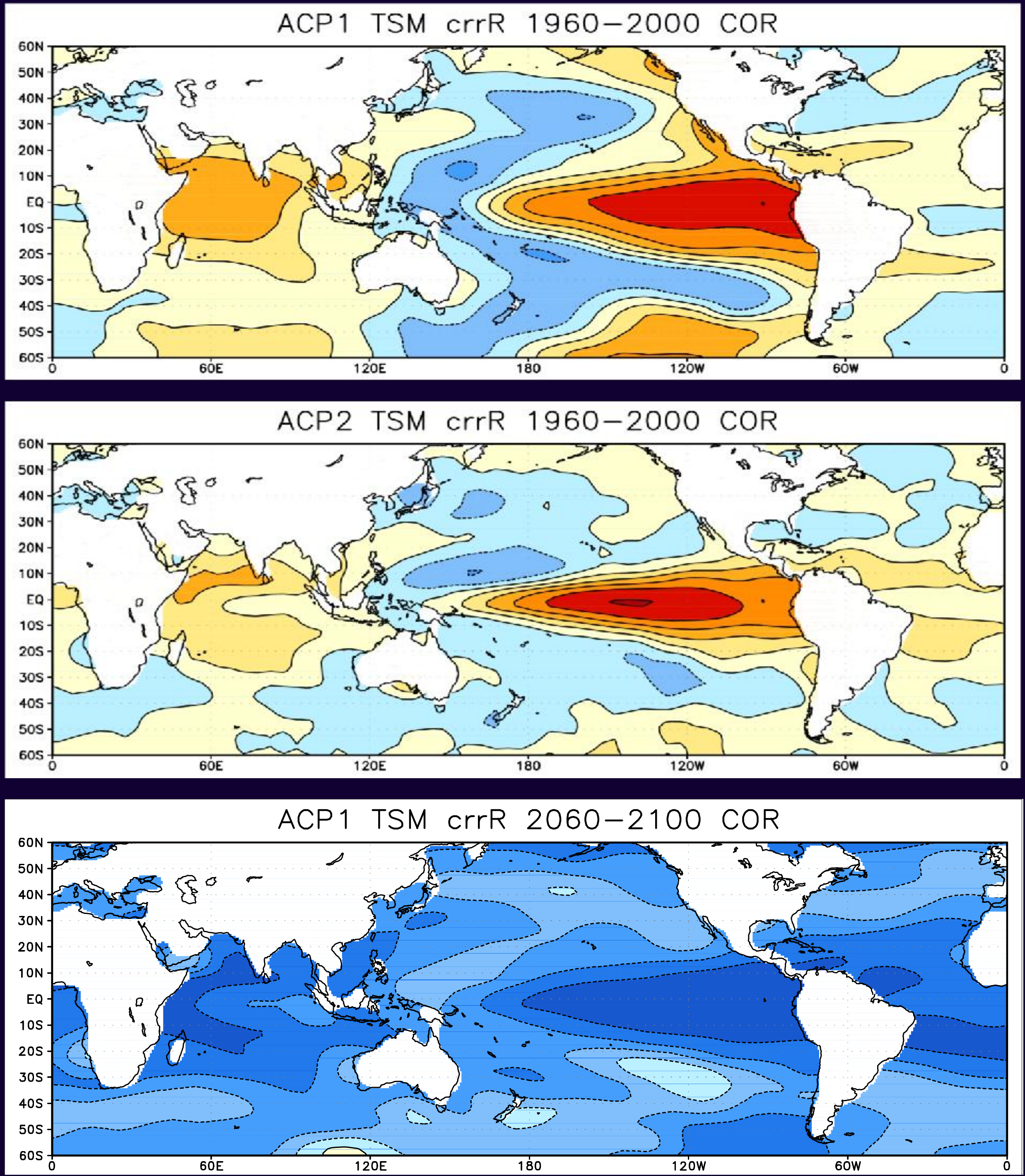






Ciclos anuais de precipitação (Grimm, 2011)

SST during ENSO episodes



SST ENSO mode

Observed SST 1960-2000

Model SST 1960-2000

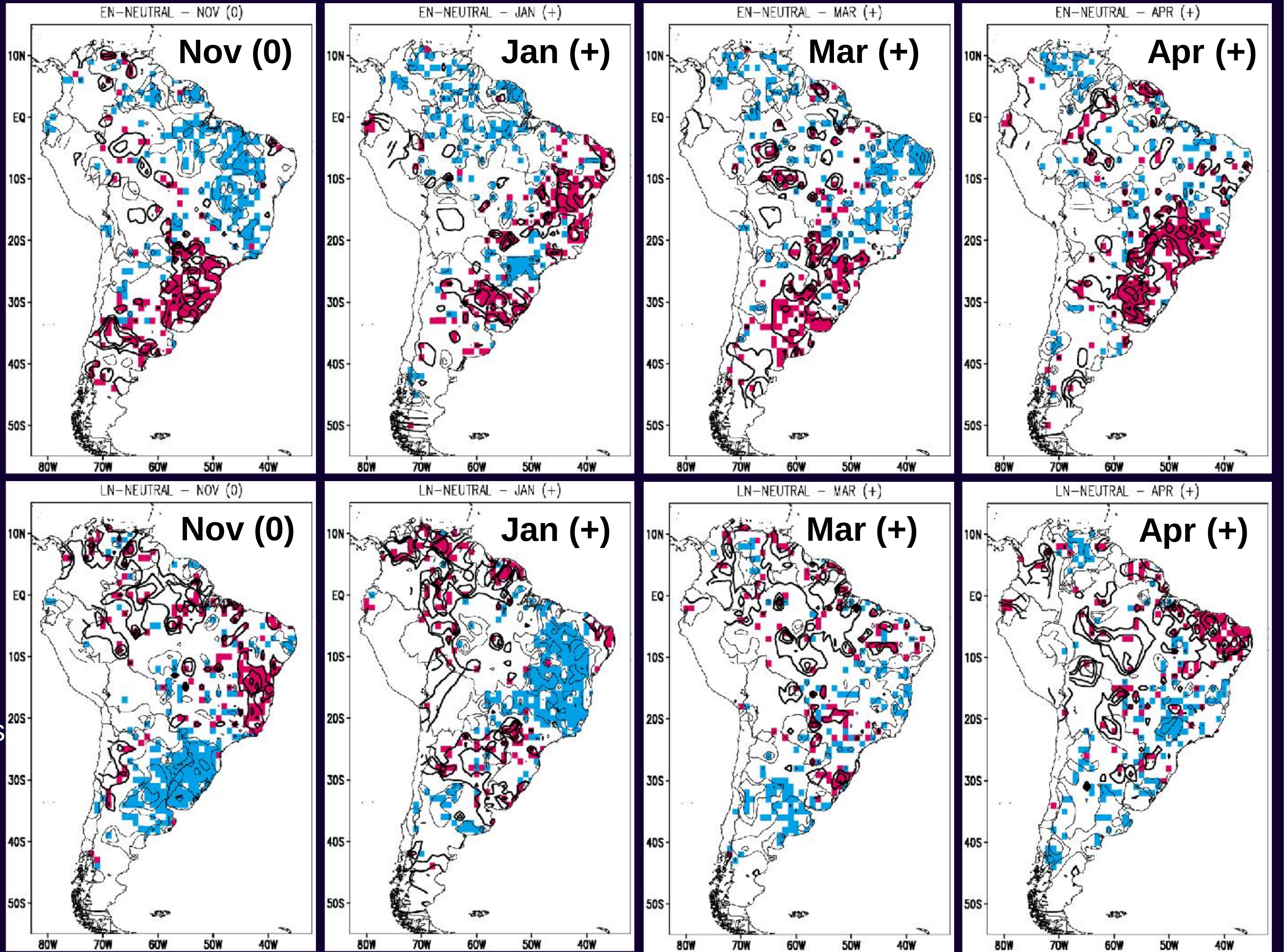
Model SST 2060-2100 (A2)
(Cavalcanti et al., 2015)

ENSO Impact on the frequency of extreme events

Observations 1956-2002

El Niño

La Niña



Areas with significant variation in frequency of extreme events

- Increase
- Decrease

(Grimm and Tedeschi, 2009 J. Climate)

Variations in the frequency X variations in the intensity of extreme events

Frequency El Niño

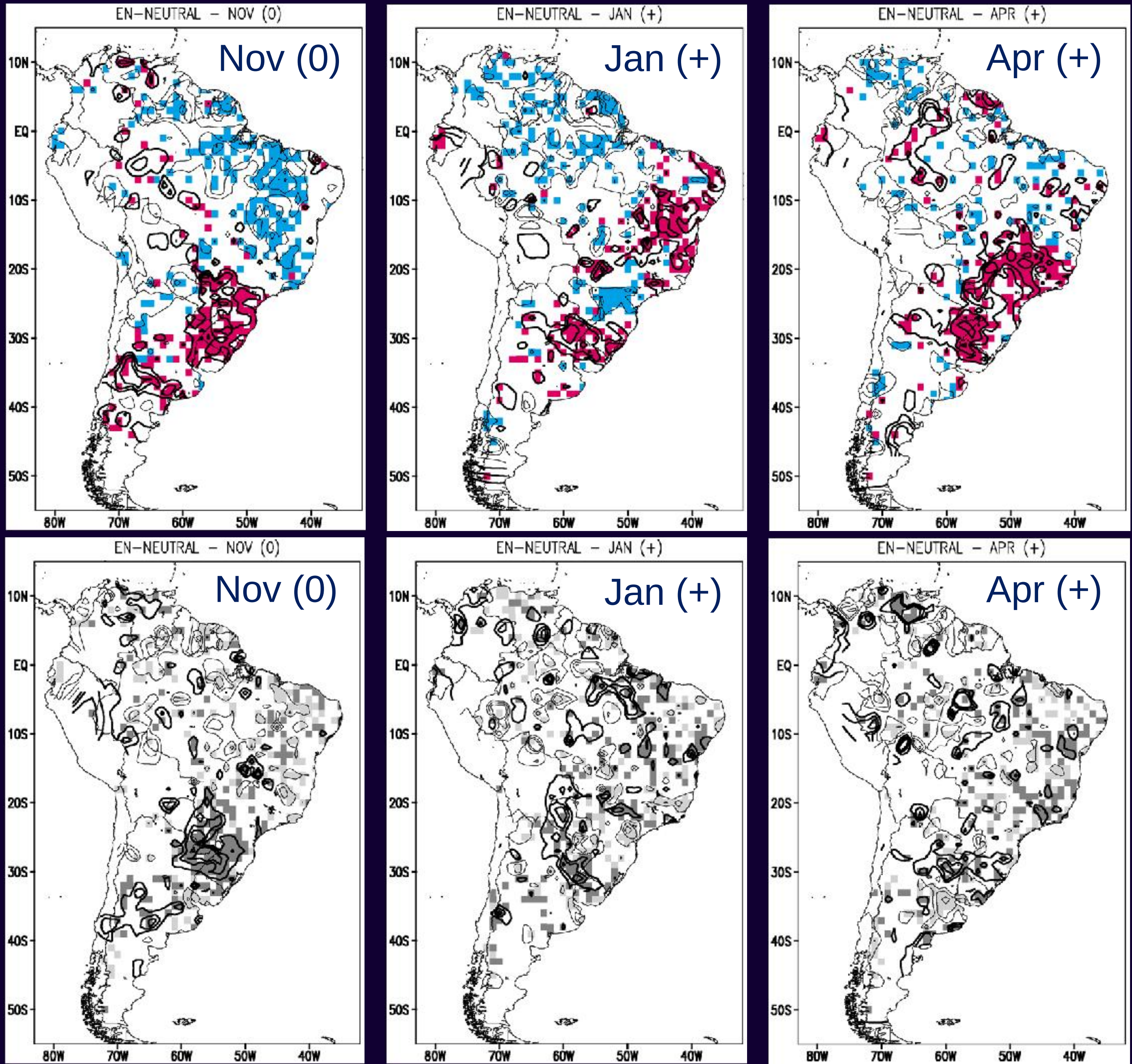
Areas with significant variation in the frequency of extreme events:

- Increase
- Decrease

Intensity El Niño

Areas with significant variation in the intensity of extreme events:

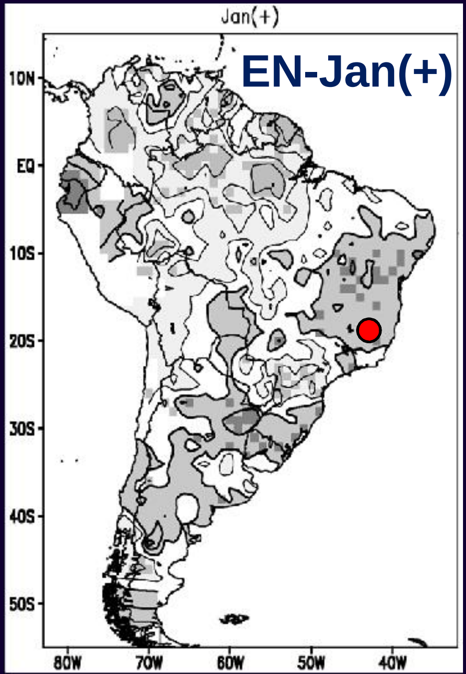
- Increase
- Decrease

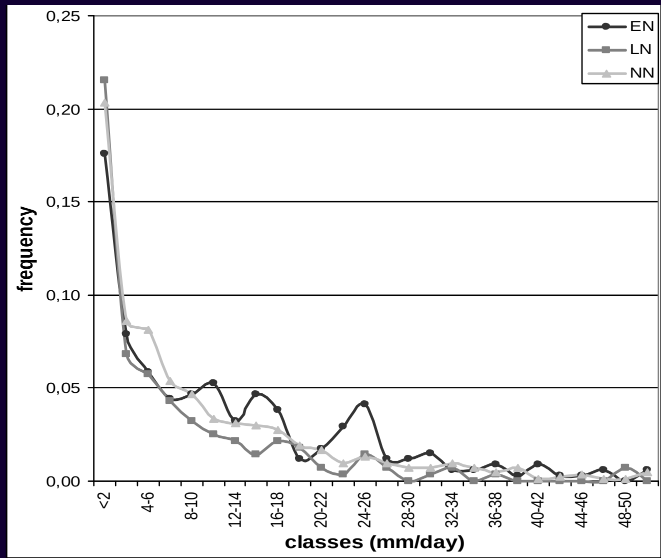


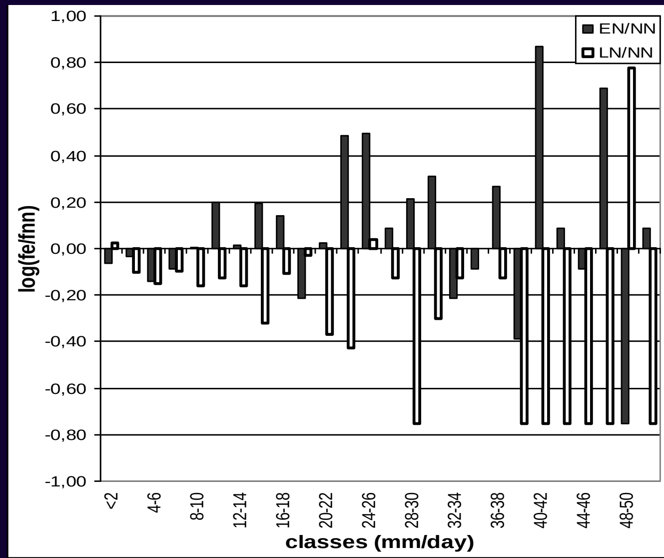
(Grimm and Tedeschi, 2009)

Variations in the monthly rainfall X
Variations in the frequency of extreme events

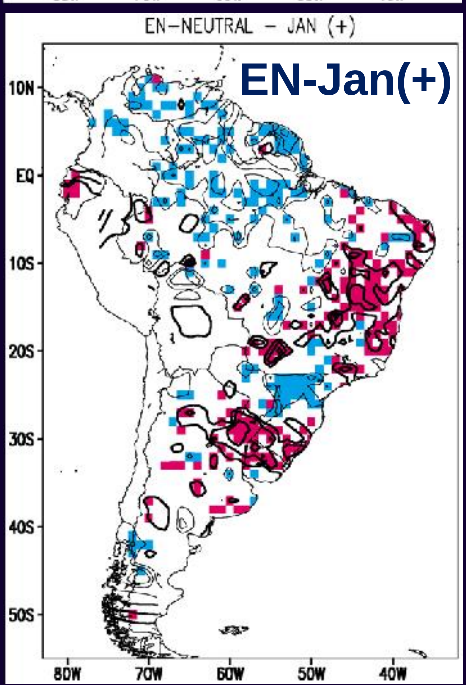
Monthly rainfall







Frequency of extreme events

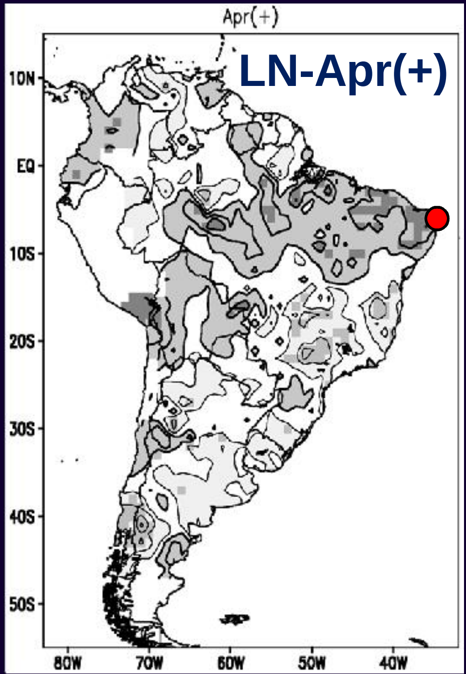


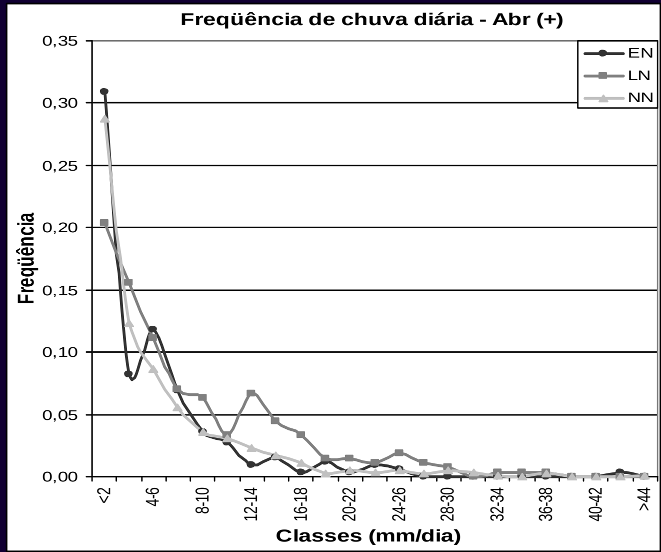
(Left panel) “Scaled” histograms of daily rainfall in a grid box in the SACZ region, for January (+) of El Niño (EN) episodes, La Niña (LN) episodes, and neutral (NN) years; (right panel) logarithm of the frequency ratio EN/NN (black bars) and LN/NN (white bars). When ratio is infinite (no occurrences in one category), the value plotted is ± 0.75.

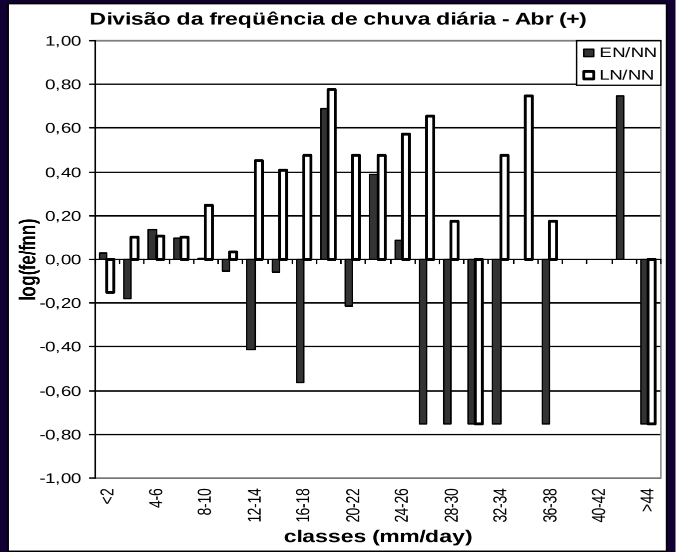
(Grimm and Tedeschi 2009, J. Climate)

Variations in the monthly rainfall X
Variations in the frequency of extreme events

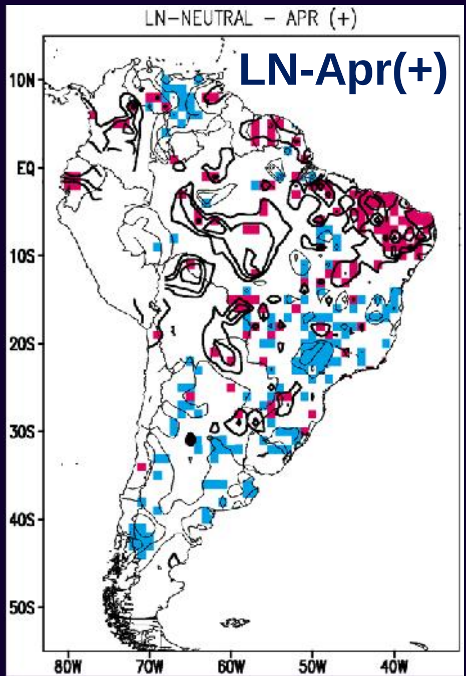
Monthly rainfall







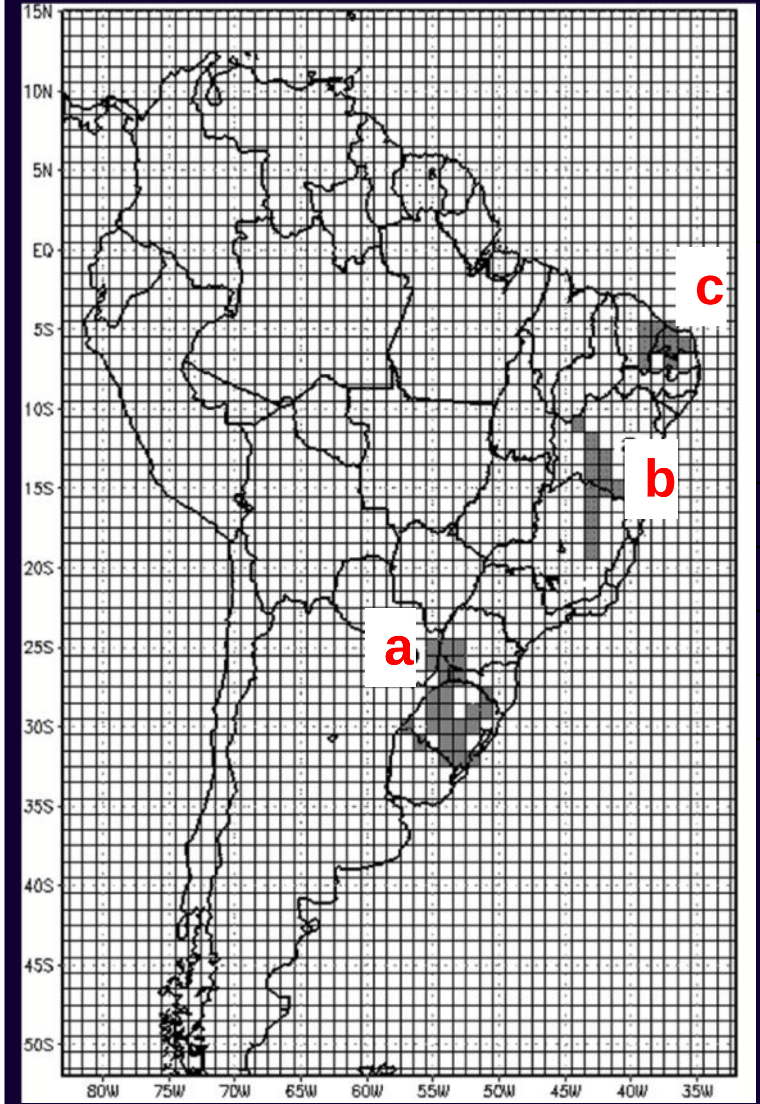
Frequency of extreme events



(Left panel) “Scaled” histograms of daily rainfall in a grid box in Northeast Brazil, for April (+) of El Niño (EN) episodes, La Niña (LN) episodes, and neutral (NN) years; (right panel) logarithm of the frequency ratio EN/NN (black bars) and LN/NN (white bars). When ratio is infinite (no occurrences in one category), the value plotted is ± 0.75.

(Grimm and Tedeschi 2009, J. Climate)

ENSO Impact on the frequency of extreme events



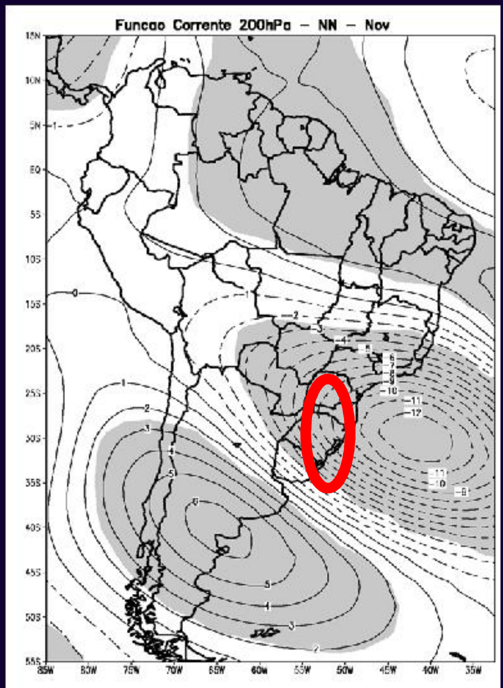
Region	Month	Average number of extreme rainfall events (1956-2002)	
		EN (11)	LN (9)
a	NOV (0)	6.3	1.2
b	NOV (0)	2.5	6.2
b	JAN (+)	6.6	1.1
c	APR (+)	3.4	7.4

Why does El Niño increase extremes in South Brazil?

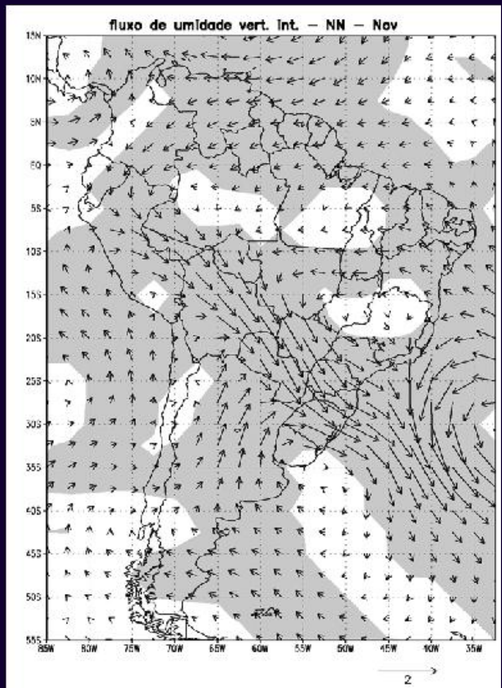
Average daily anomalies during November extreme events in SESA

Average monthly anomalies during November of El Niño years

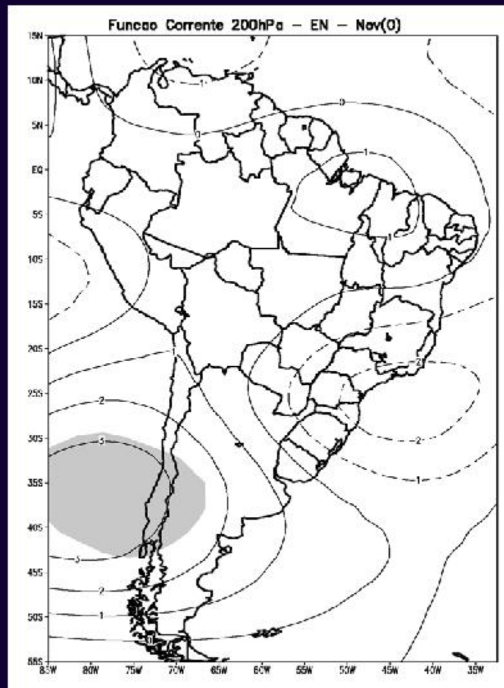
200 hPa streamfunction



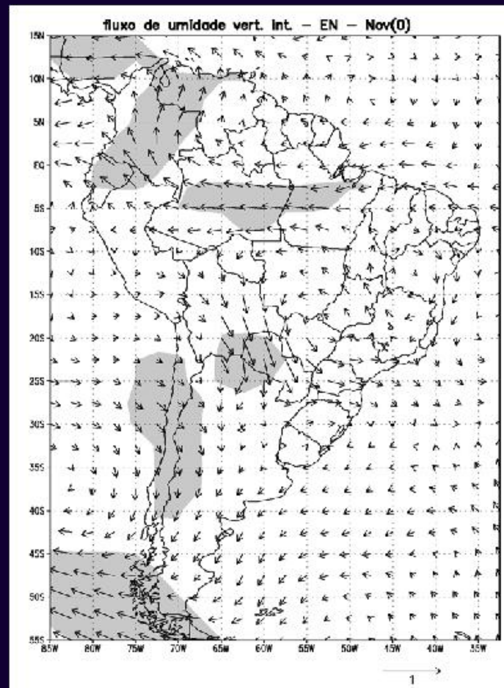
Moisture flux



200 hPa streamfunction

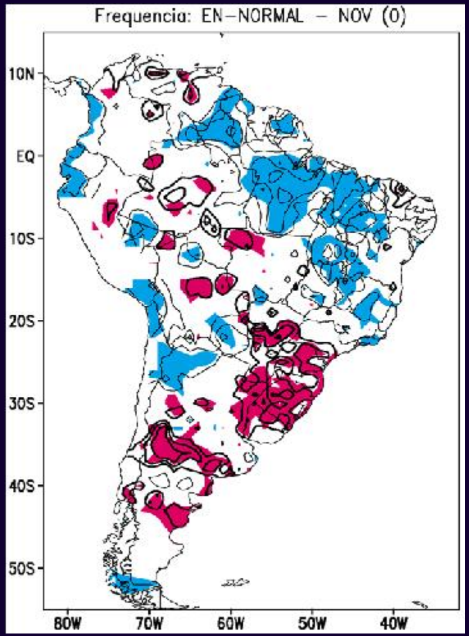


Moisture flux

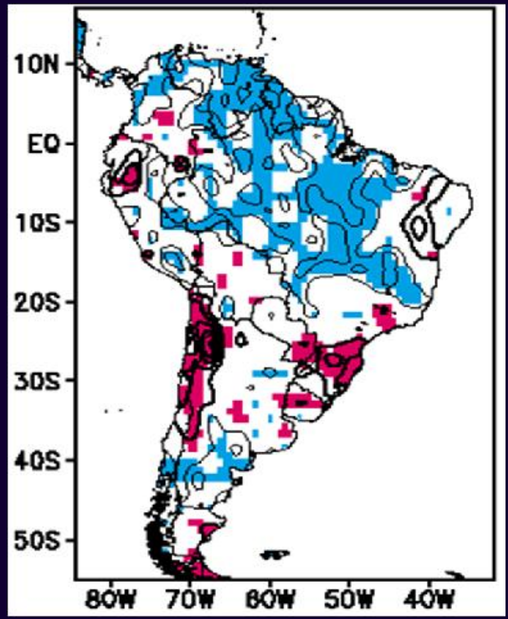


(Grimm and Tedeschi 2009, J. Climate)

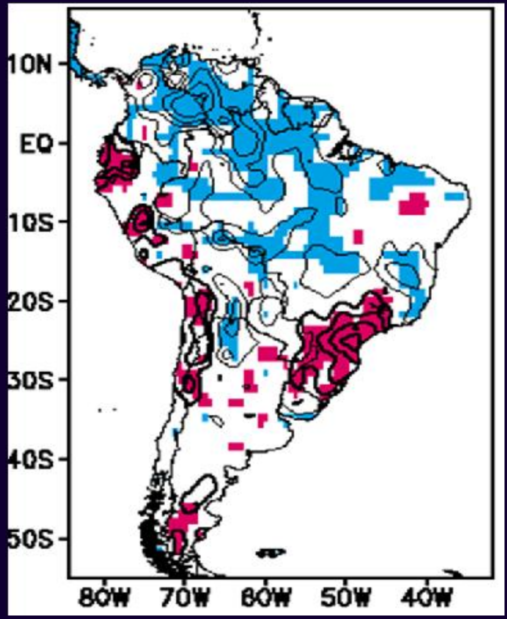
November: El Niño – Neutral (different scenarios)



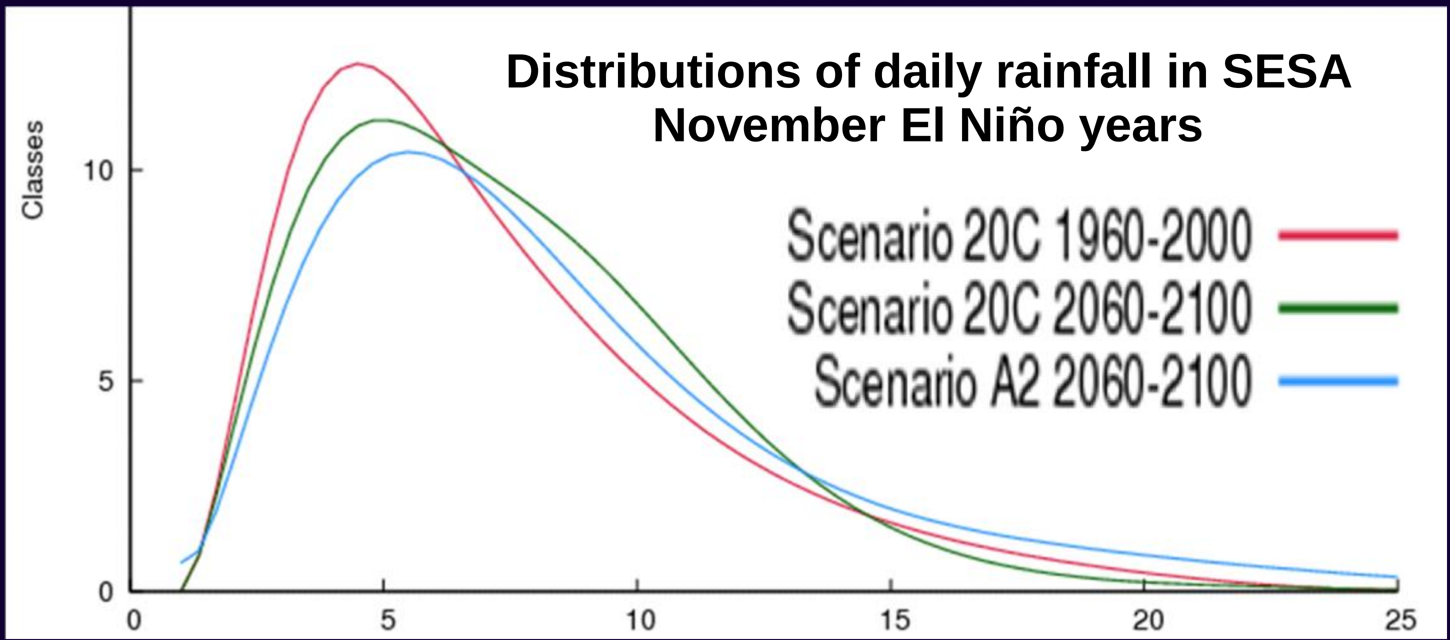
Observations
1960-2000



20C
1960-2000

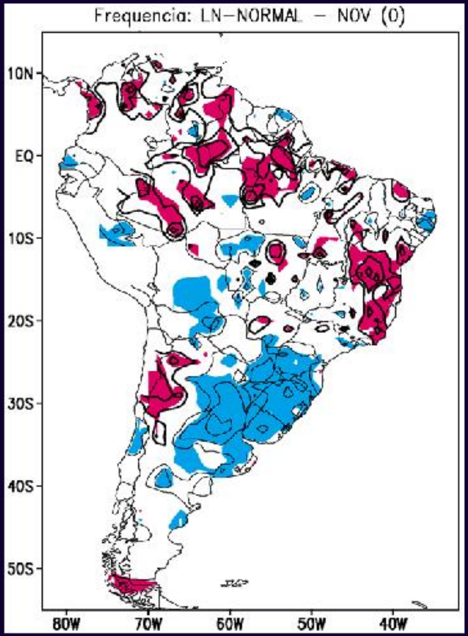


A2
2060-2100

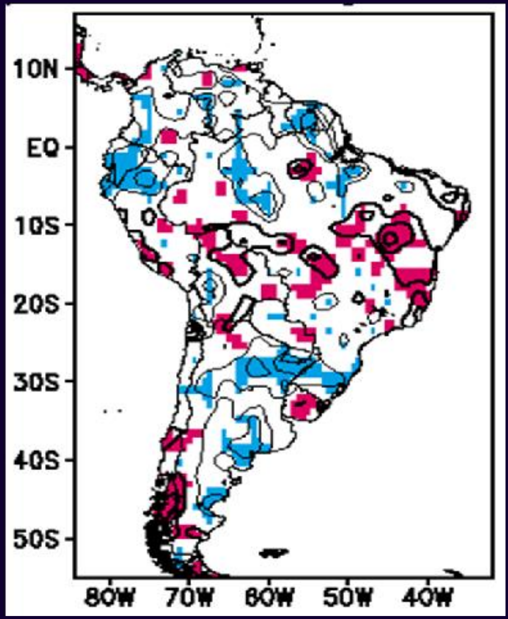


(Cavalcanti et al., 2015)

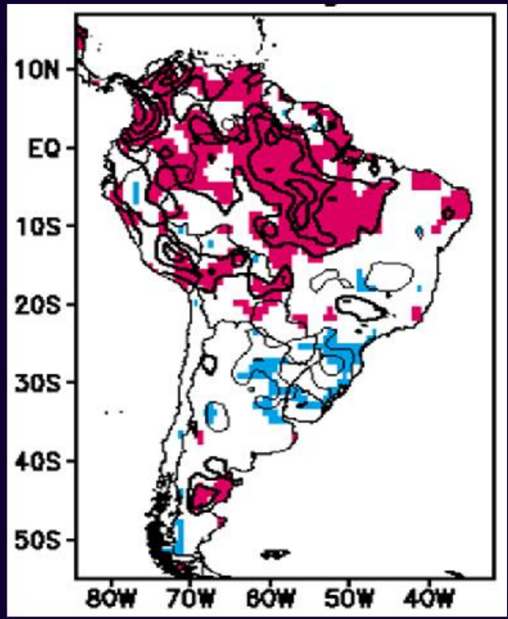
November: La Niña – Neutral (different scenarios)



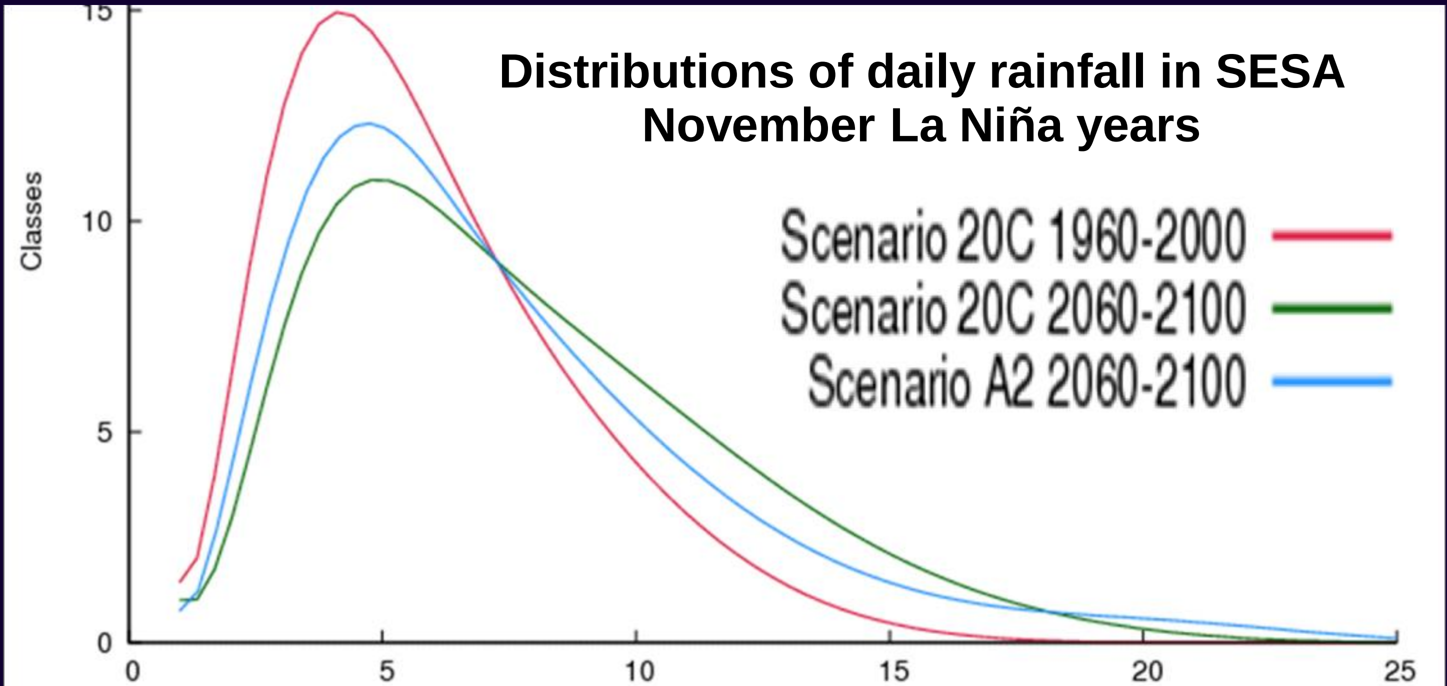
Observations
1960-2000



20C
1960-2000



A2
2060-2100



(Cavalcanti et al., 2015)

Conclusions

• EN and LN episodes influence significantly the frequency of extreme precipitation events in several regions of South America during certain periods of the ENSO cycle. Most of the impact occurs during the rainy season.

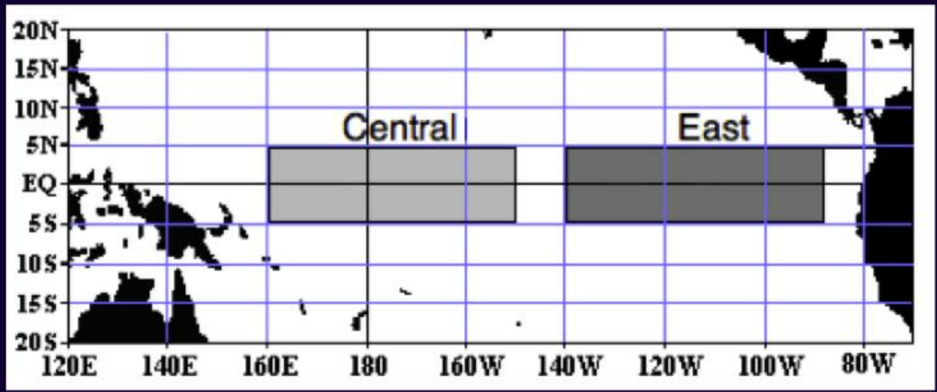
•The impact of ENSO on extreme events is more significant and extensive than on monthly or seasonal precipitation totals. There is more sensitivity to ENSO in the extreme ranges of daily rainfall.

• The frequency of extreme events increases (decreases) when the large-scale perturbations associated with ENSO favor (hamper) the circulation anomalies associated with extreme events in the affected regions. This happens frequently during ENSO events.

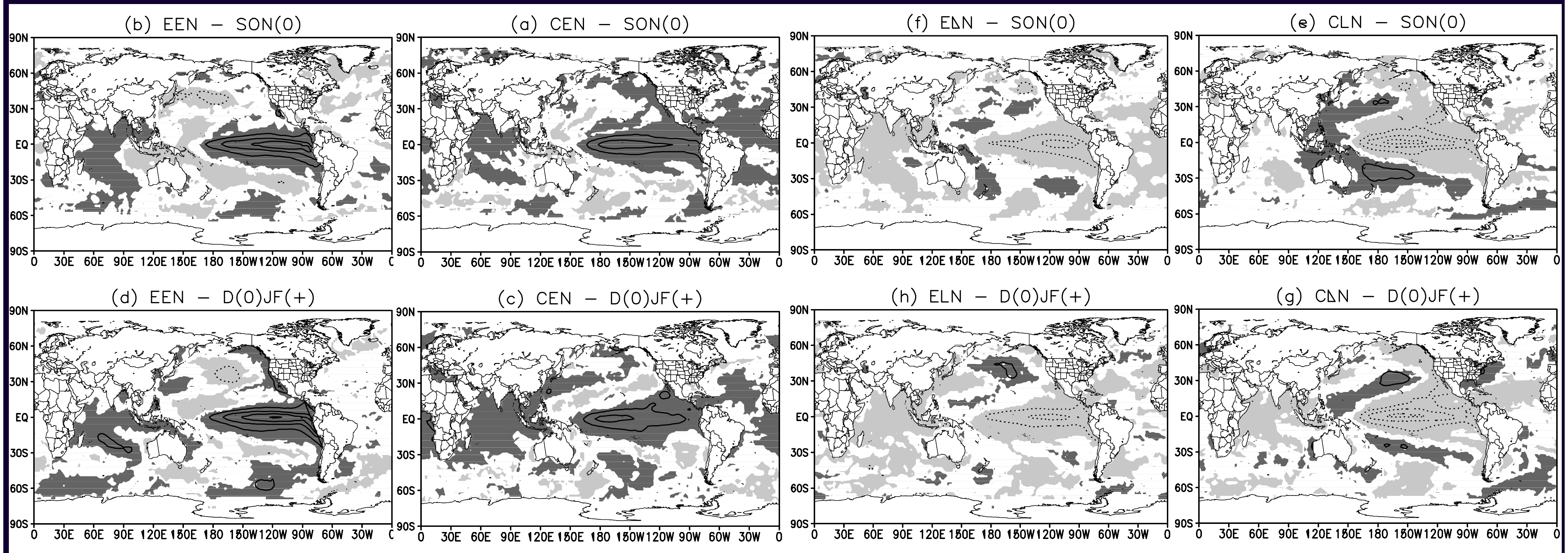
• ECHAM5-OM reproduces reasonably the impact of ENSO on extreme events during spring. The future scenario A2 shows enhancement of extreme events in the Basin with respect to the present impact of El Niño.

•The histograms of daily rainfall in November in La Plata Basin show reduction (increase) of frequency of light (heavy) rainfall from the present to future climate, especially during La Niña years, which reduces the ENSO impact on the region.

Eastern and Central ENSO



EEN **CEN** **ELN** **CLN**



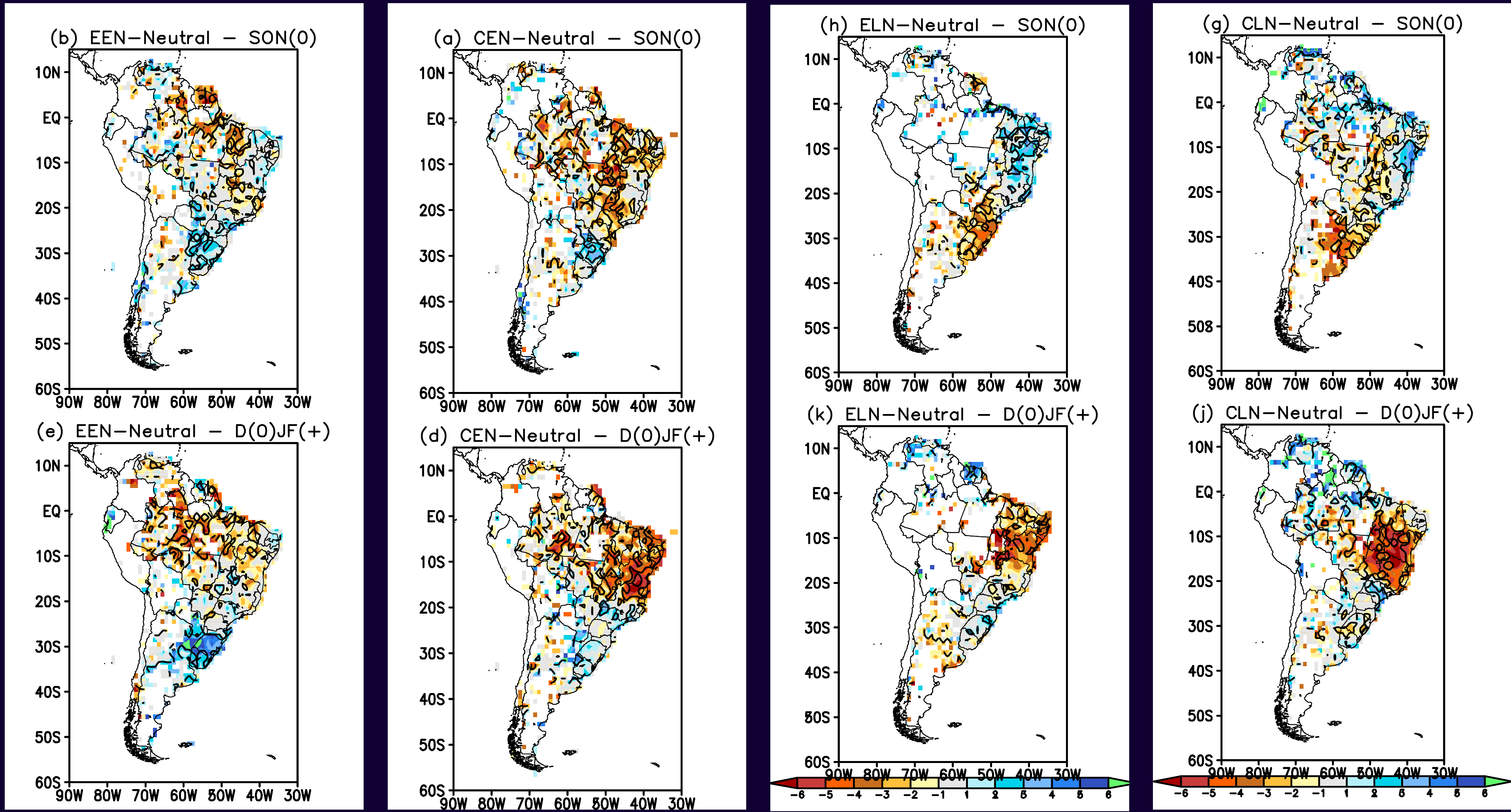
(Tedeschi, Grimm and Cavalcanti, 2014, Int. J. Climatology)

Impact of Eastern and Central ENSO on the seasonal frequency of extreme events

EEN CEN ELN CLN

SON(0)

DJF(+)



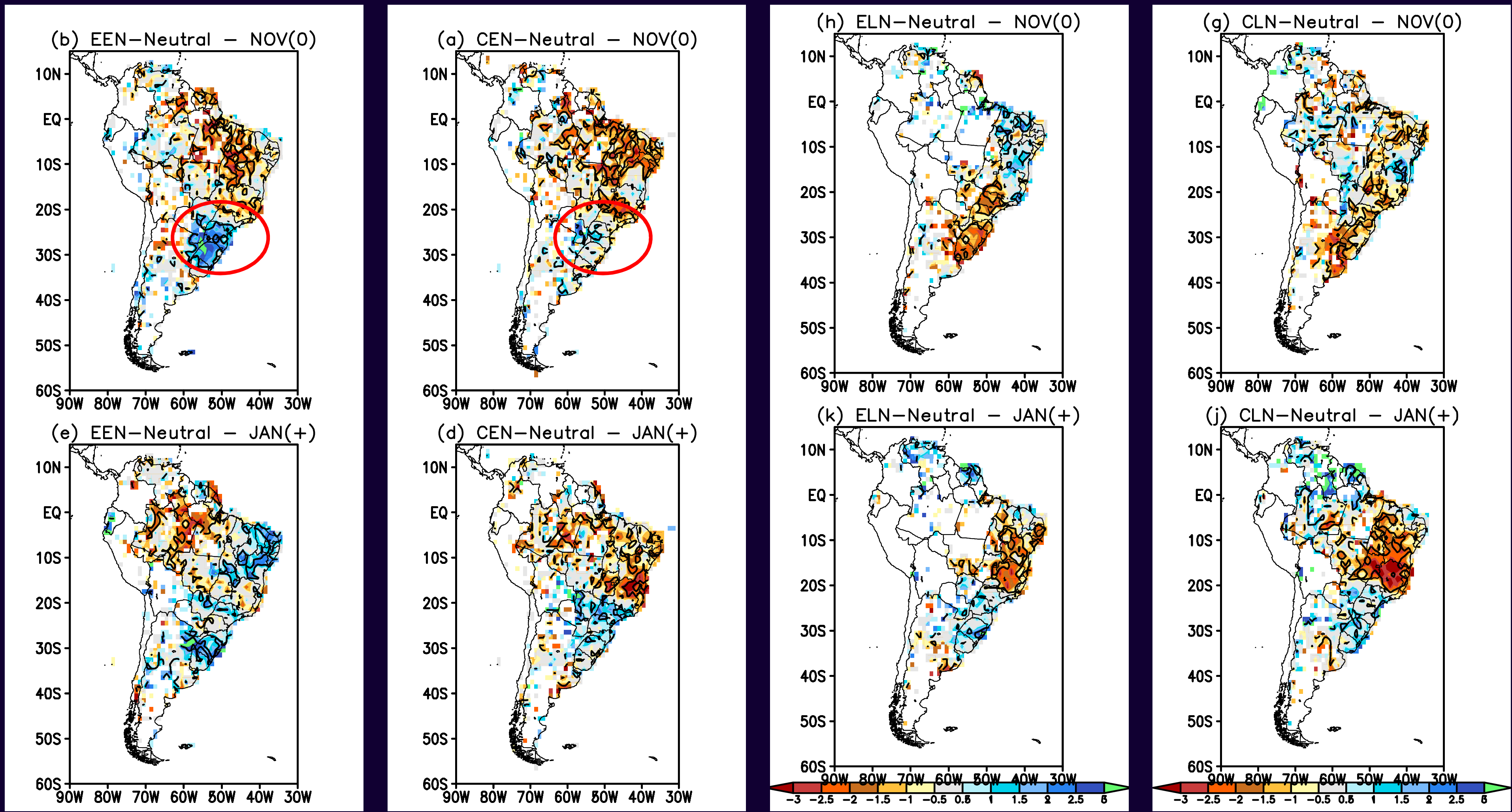
(Tedeschi, Grimm and Cavalcanti, 2014)

Impact of Central and Eastern ENSO on the monthly frequency of extreme events

	EEN	CEN	ELN	CLN

Nov(0)

Jan(+)



(Tedeschi, Grimm and Cavalcanti, 2014)

Conclusões

Pode haver significativas e grandes diferenças nos impactos de episódios ENOS Leste e Central sobre os eventos extremos de precipitação na América do Sul em certos períodos do ciclo ENOS e em certas regiões, embora haja relativamente pouca diferença na maior parte do ciclo e das regiões.

Interdecadal variability during the monsoon season in South America

Alice M. Grimm
João Paulo J. Saboia

Federal University of Parana
Curitiba, Parana, Brazil
grimm@fisica.ufpr.br

(Grimm e Saboia, 2015, Journal of Climate)

MOTIVATION

- ❑ Interdecadal/decadal climate variations control water availability, affect ecosystems, influence farming practices, and modulate higher-frequency variability and extreme events (floods and droughts).

- ❑This is useful information for hydropower generation, since the distribution networks are interconnected in Brazil, and some countries in the continent share hydropower generation plants that depend on rainfall over large basins. Thus, knowledge of the temporal and spatial patterns of interdecadal precipitation variability is useful in medium-long range planning of hydropower generation and distribution.

- ❑ Therefore, they need to be well characterized and understood, even in order to achieve more reliable detection of anthropogenic climate change.

- ❑ They have been reported in some regions of South America, but a comprehensive assessment of interdecadal climate variability in the continent and its connection with global-scale oceanic and atmospheric oscillations has not been carried out so far.

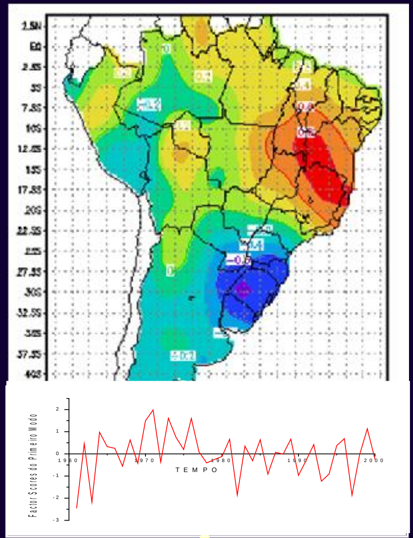
- ❑ Why focus on the summer monsoon season? It is the rainy season over most of South America.

Is this relationship modulated by interdecadal variability?

Relationship between first interannual PCs

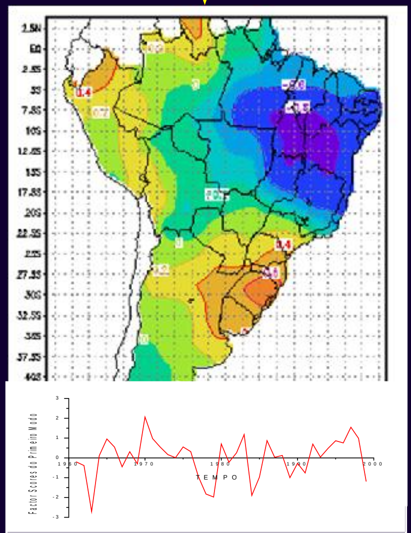
Spring X Summer

Spring **EOF1**



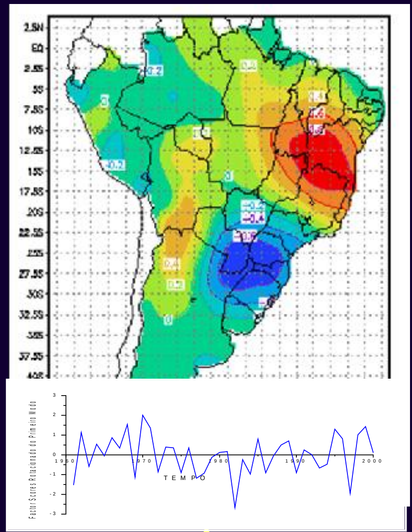
r=0.24

Summer **EOF1**



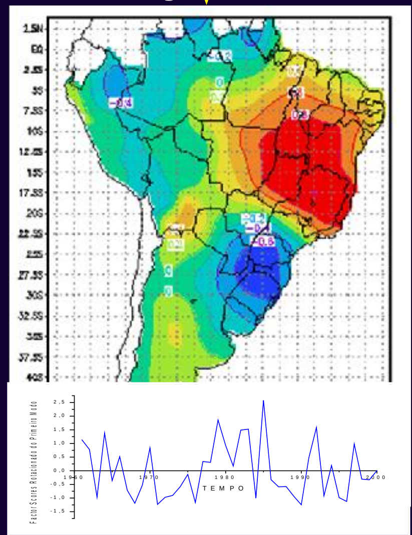
(Grimm and Zilli, 2009)

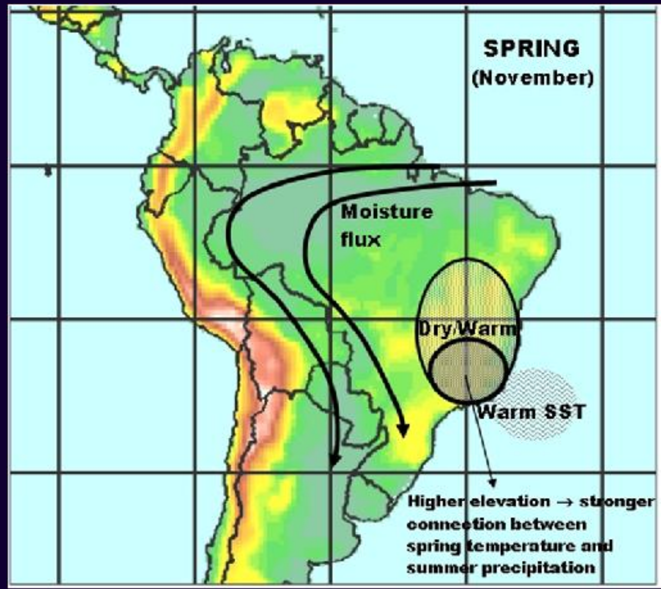
November **REOF1**



r=-0.32

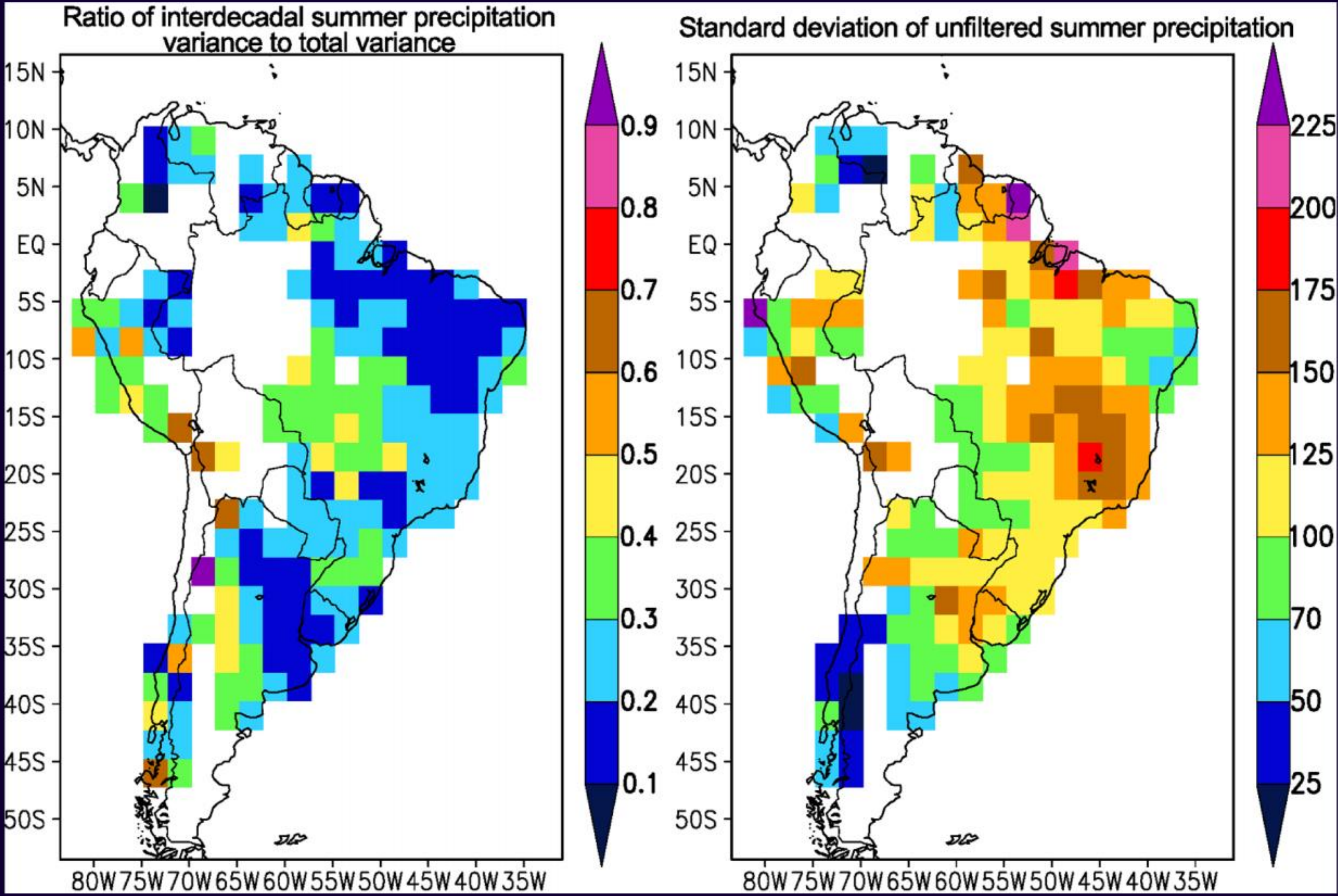
January **REOF1**





(Grimm et al., 2007)

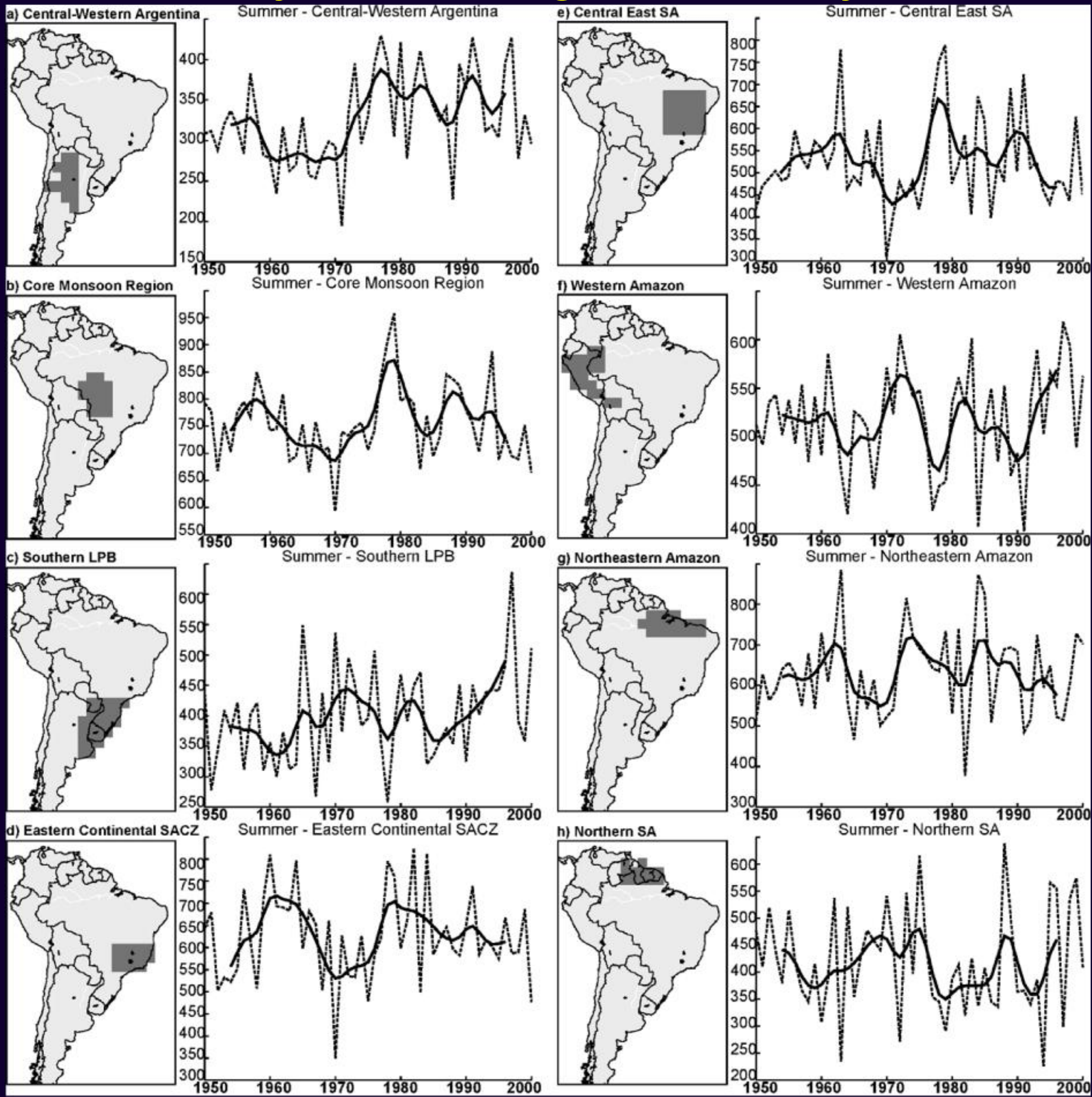
Contribution of interdecadal variability



(Grimm and Saboia, 2015)

It amounts to more than 30% of the total summer precipitation variance in extensive regions for which summer is the rainy season and winter is very dry.

Further motivation for a continental-scale analysis is provided by the inspection and comparison of filtered series of summer precipitation in regions chosen for great contribution of interdecadal variability to total variability and/or high variability in summer



(Grimm and Saboia, 2015)

OBJECTIVES

- ❑ To characterize the large-scale interdecadal oscillations of rainfall in South America during the summer monsoon season (spring + summer), on the basis of relatively long data series with good spatial coverage.

- ❑ To verify their relationships between spring and summer;

- ❑ To verify their statistical connections to sea surface temperature (SST) anomalies and known climatic indices.

- ❑ To assess their impact on precipitation regimes.

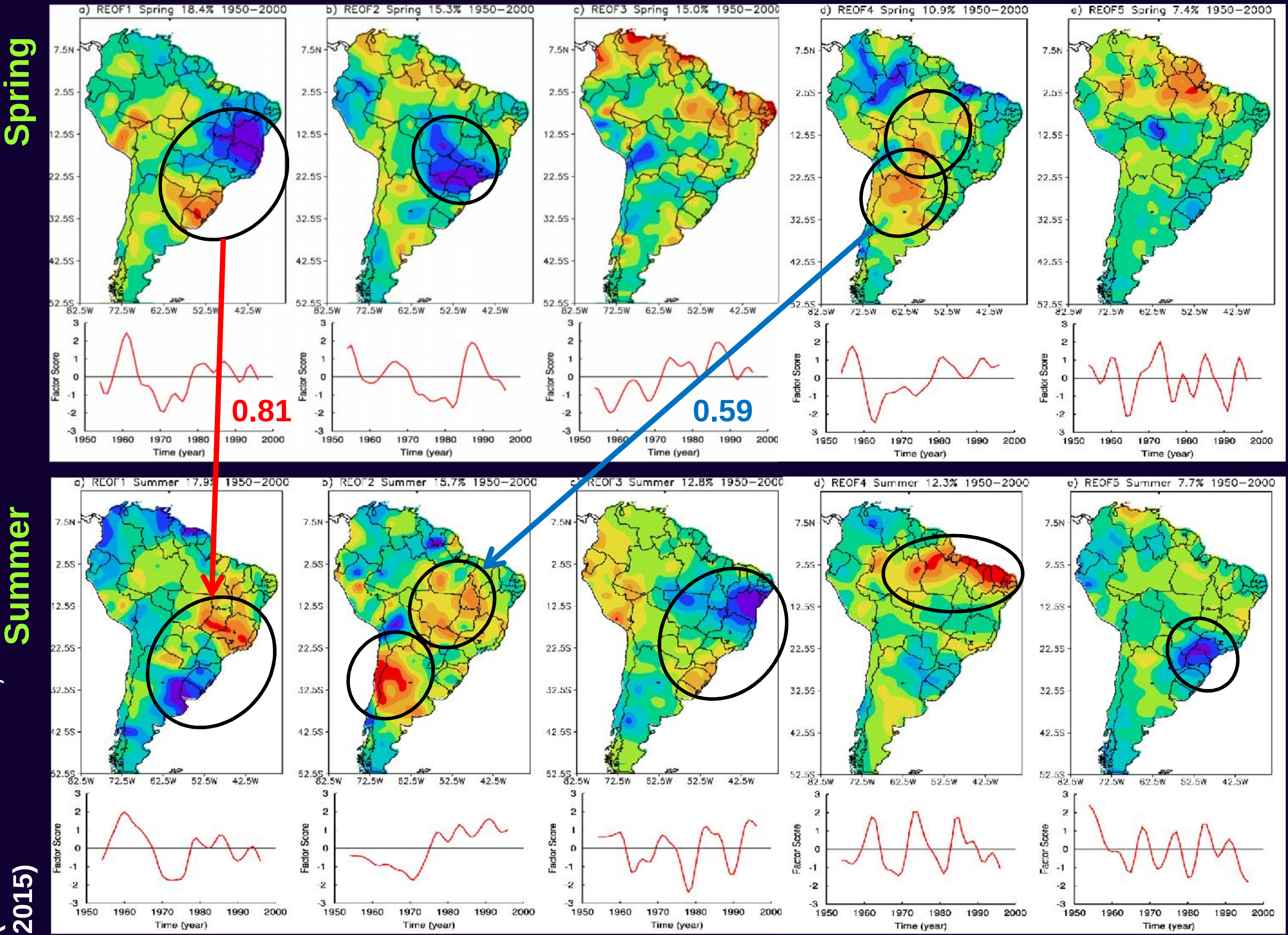
DATA

- **Precipitation:**
  Monthly totals from more than 10,000 stations over most of South America, gridded to 2.5îò2.5î lat-long (1950-2000).
- **Missing data:**
  Filled, when possible, from regression onto data of neighbor stations.
- **Sea Surface Temperature:**
  HadISST1.

METHODS

- Gaussian filter (retains $T \geq 8$ years).
- EOF analysis, with rotation. Verification with different periods of analysis and different domains.
- Correlation analysis (significance by Monte Carlo approach).

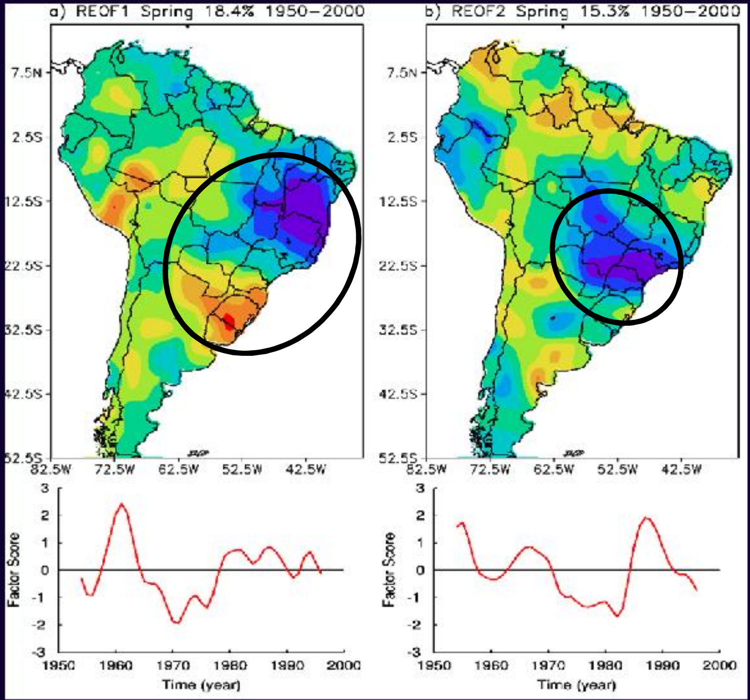
Interdecadal Variability Spring- Summer

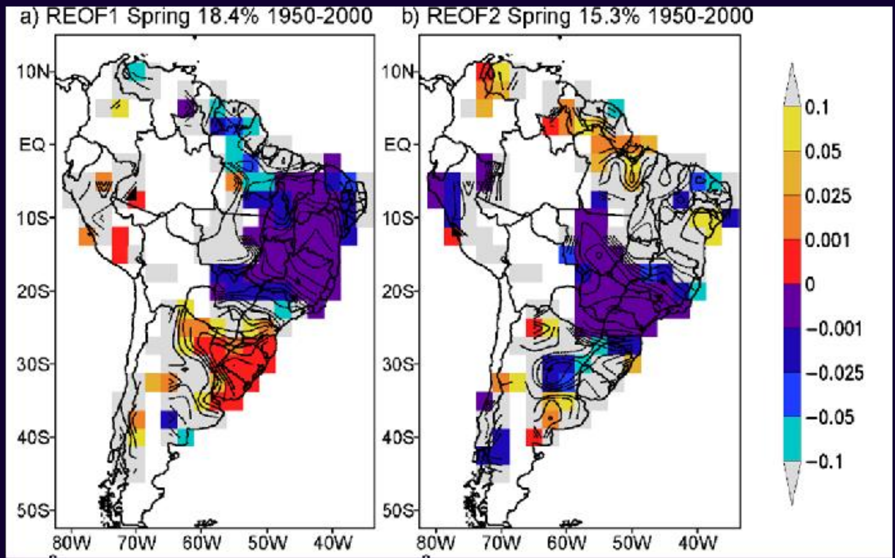


(Grimm and Saboia, 2015)

Interdecadal Variability Spring

Spring



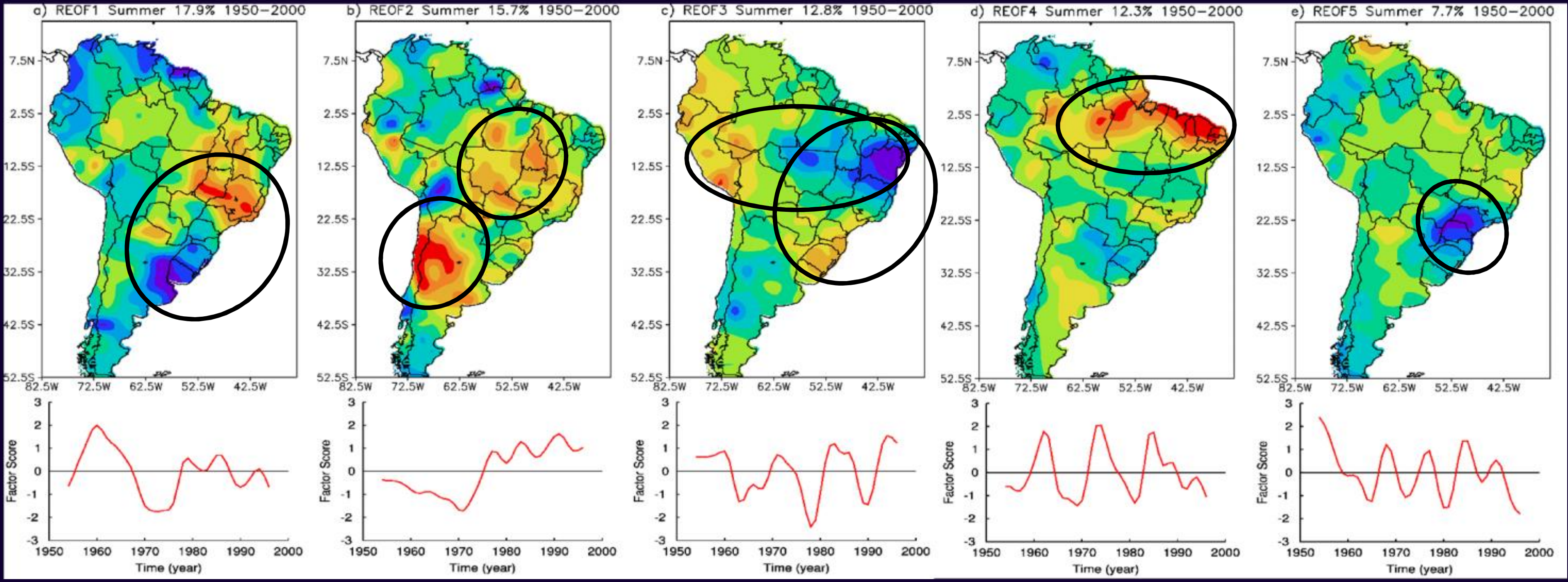


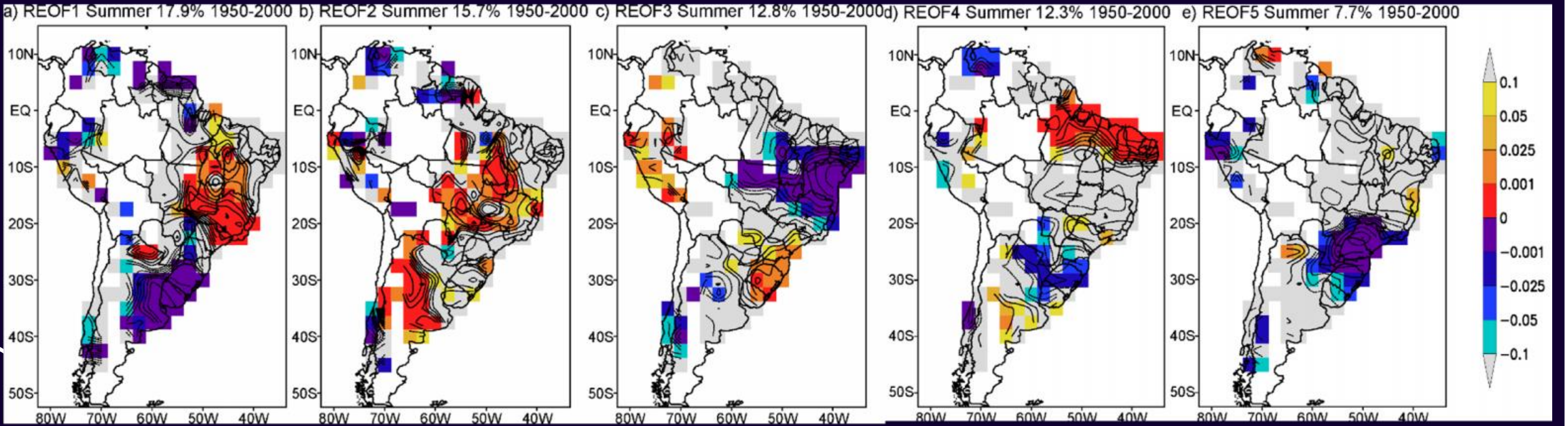
(Grimm and Saboia, 2015)

Correlation coefficients between the spring first two REOFs factor scores and precipitation data. The isolines interval is 0.1, and the zero isoline is omitted. Colours indicate levels of significance, with signs indicating positive or negative correlation coefficients. Areas with data, but significance level worse than 0.10, are shaded in grey.

Interdecadal Variability Summer

Summer

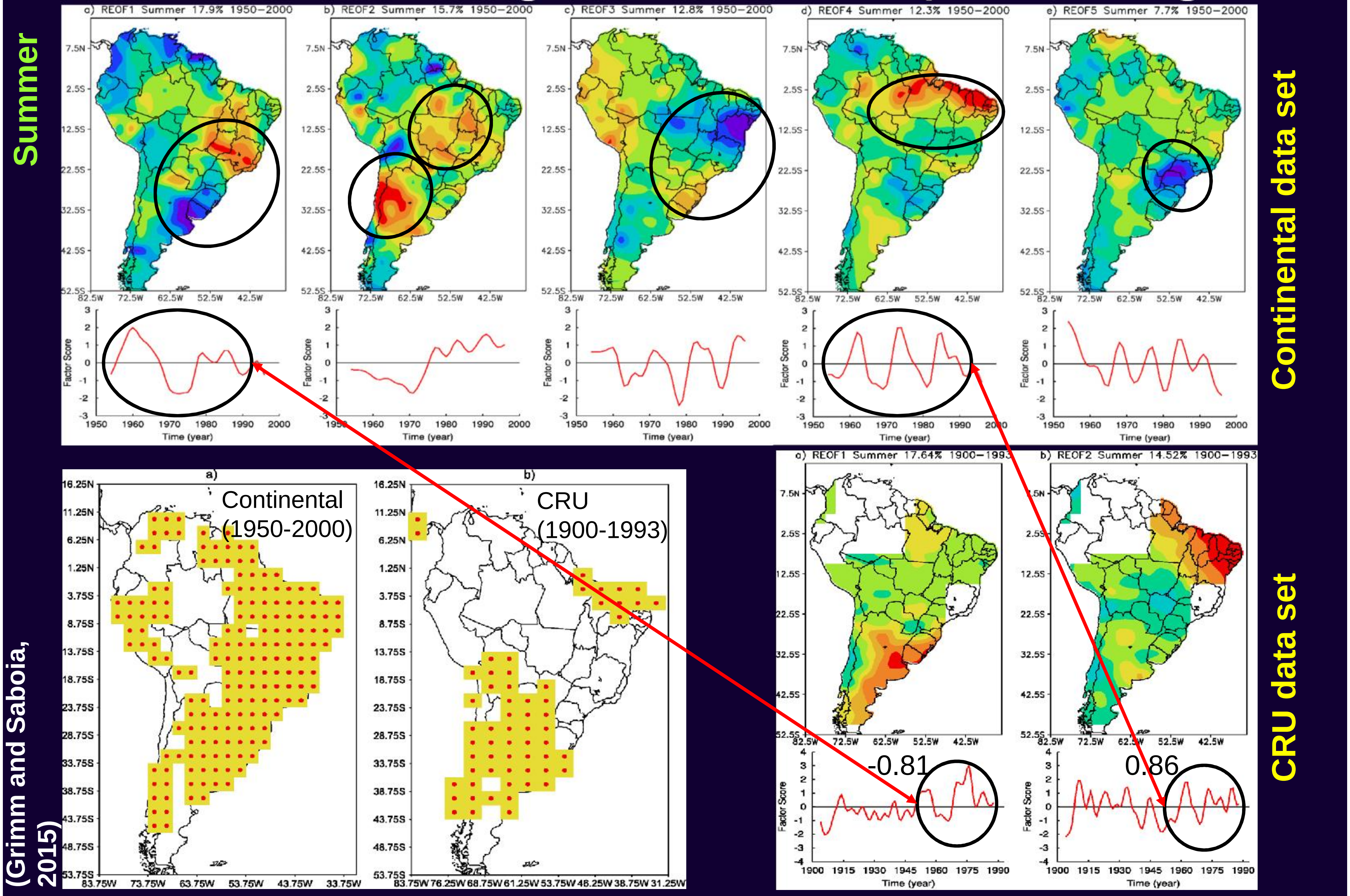




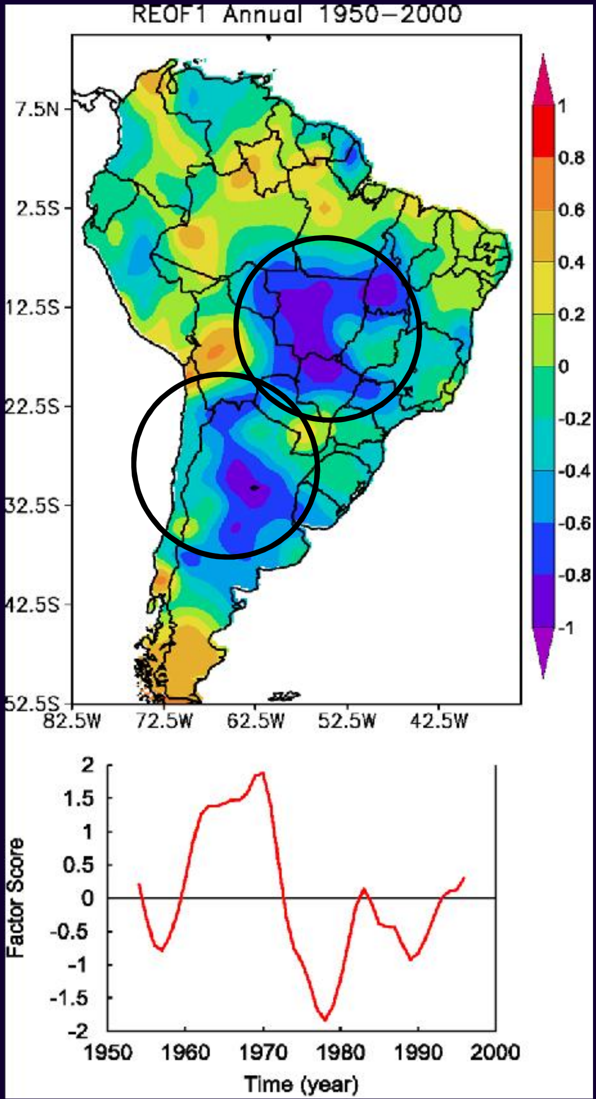
(Grimm and Saboia, 2015)

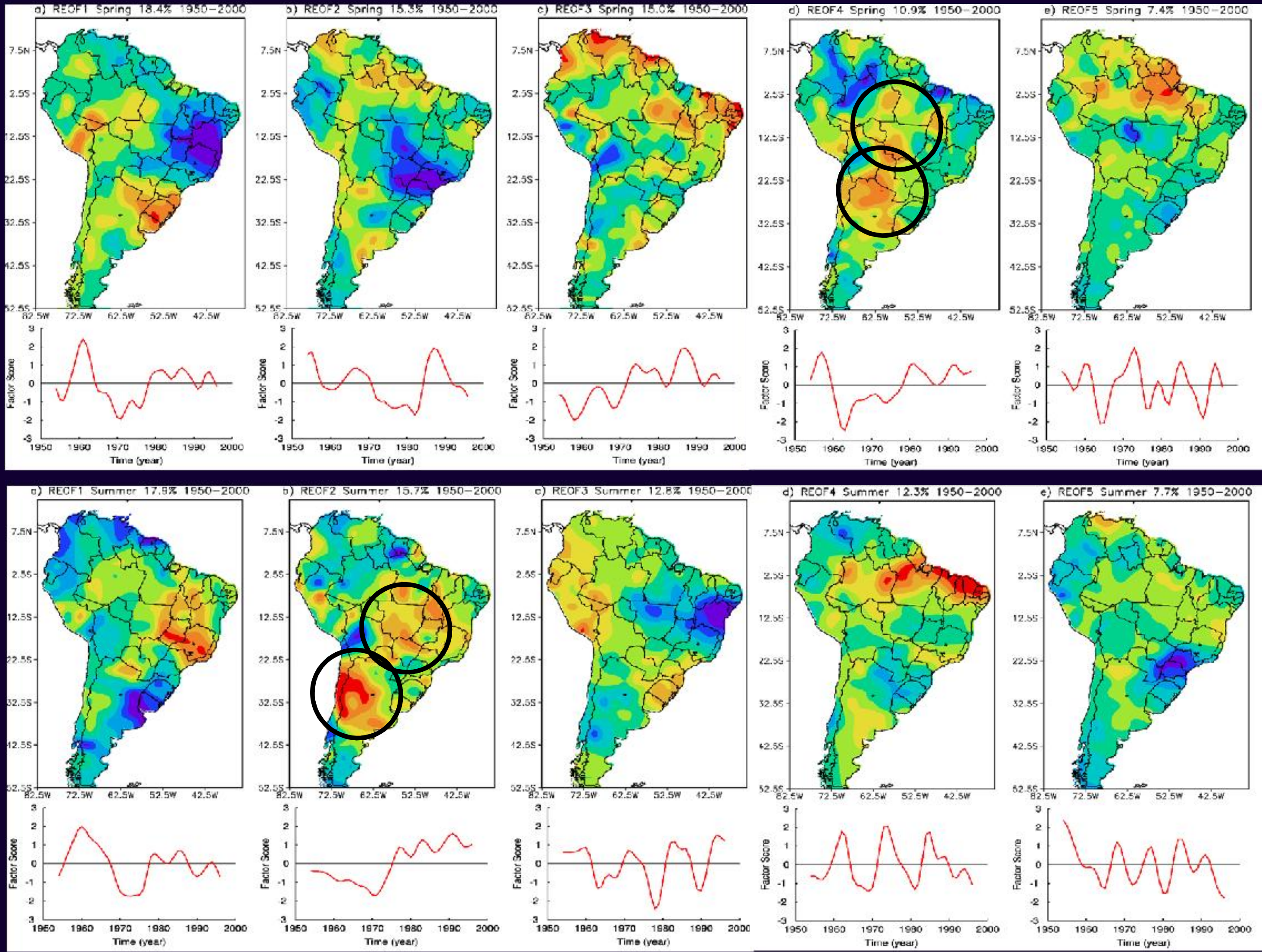
Interdecadal Variability Spring-Summer:

Verification with longer series, but less spatial coverage



Interdecadal Variability Spring-Summer: contribution to anual precipitation variability





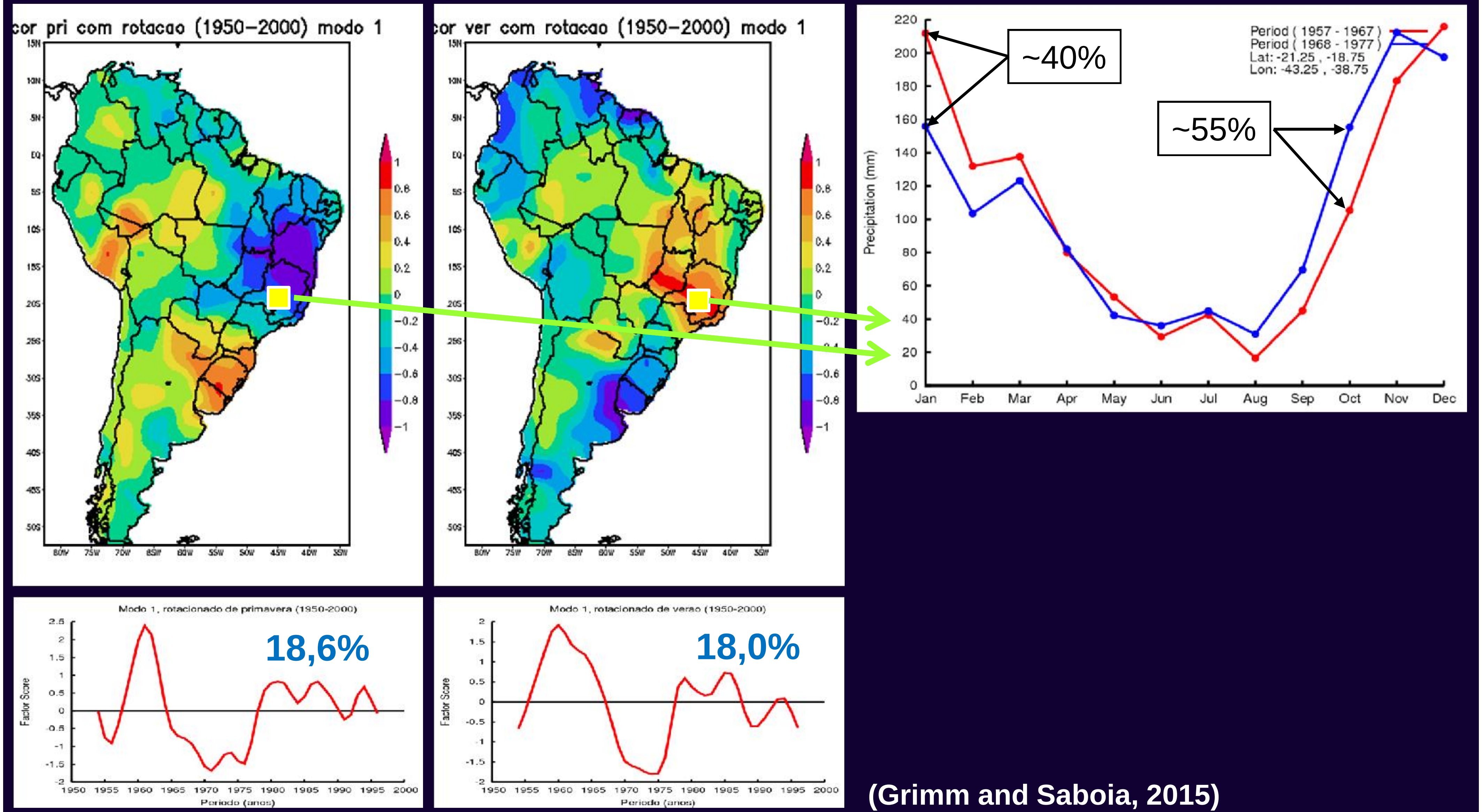
(Grimm and Saboia, 2015)

Interdecadal Variability – Spring-Summer

Impact on precipitation regimes

Spring - REOF 1

Summer - REOF 1

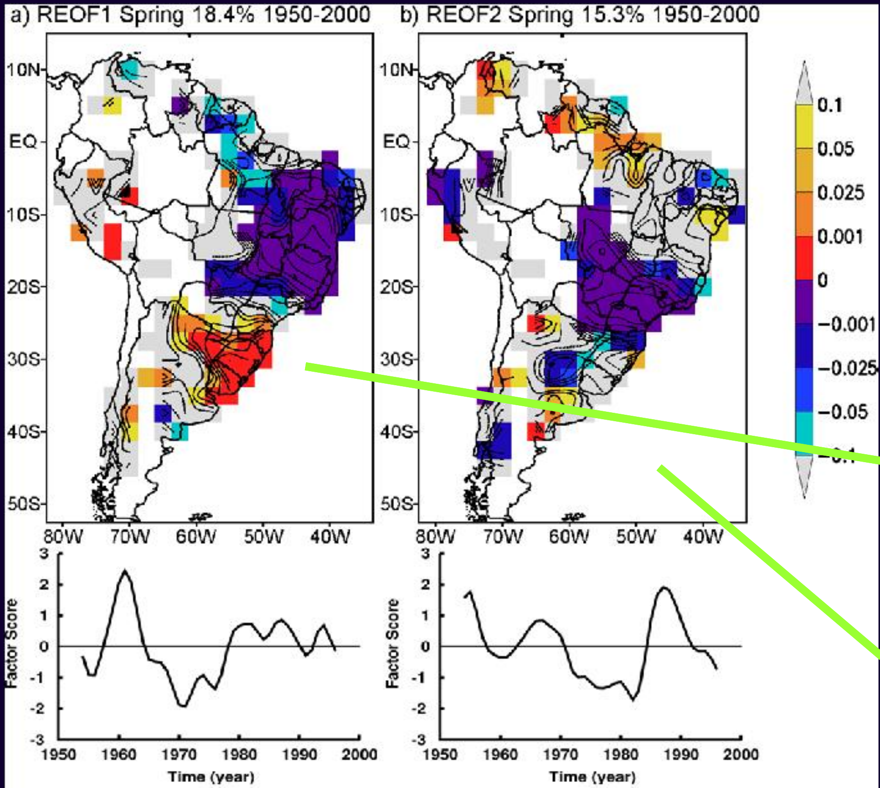


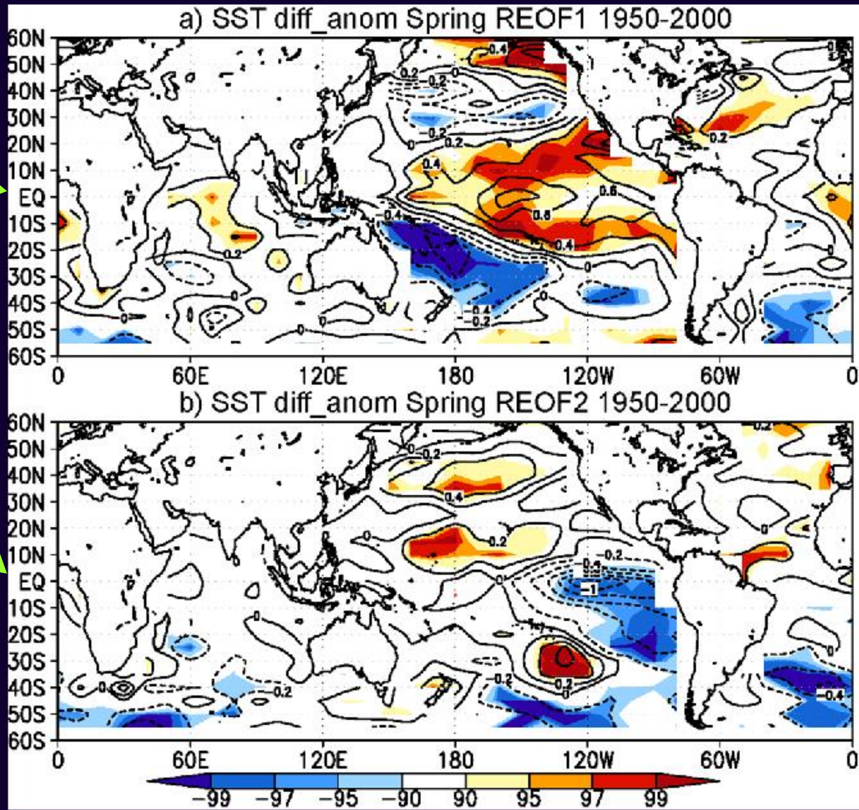
(Grimm and Saboia, 2015)

Correlation: 0.81

Interdecadal Variability
Spring

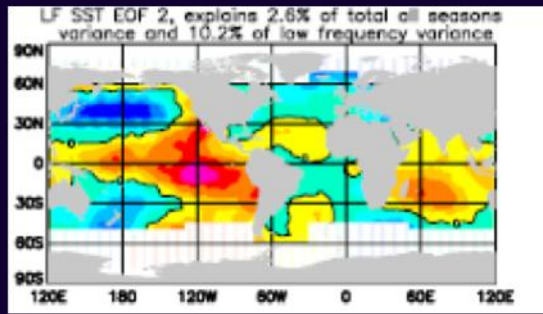
Relationships with SST and climatic indices



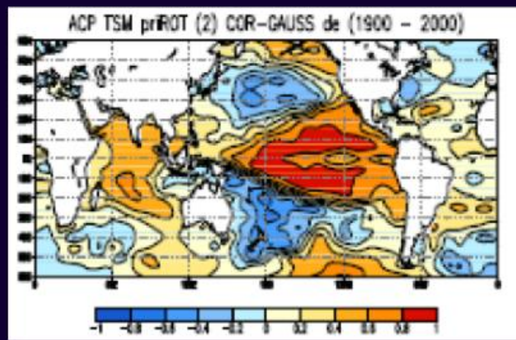


Spring	Precipitation modes	
Indices	REOF1	REOF2
AMO_70	**0.43 (0.00)**	**0.39 (0.01)**
AMO_60	0.23 (0.13)	**0.37 (0.01)**
NAO	0.13 (0.41)	-0.14 (0.39)
IPO	0.24 (0.12)	-0.28 (0.07)
PDO	0.16 (0.31)	-0.19 (0.22)
TSA	0.21 (0.18)	-0.04 (0.80)
TNA	0.25 (0.11)	**0.42 (0.01)**
SAM	0.29 (0.06)	-0.26 (0.10)
NAM	-0.20 (0.21)	0.22 (0.16)

This IPO index does not reflect very faithfully the IPO SST mode that is acting on this mode.



Power et al.´ s (2007) IPO

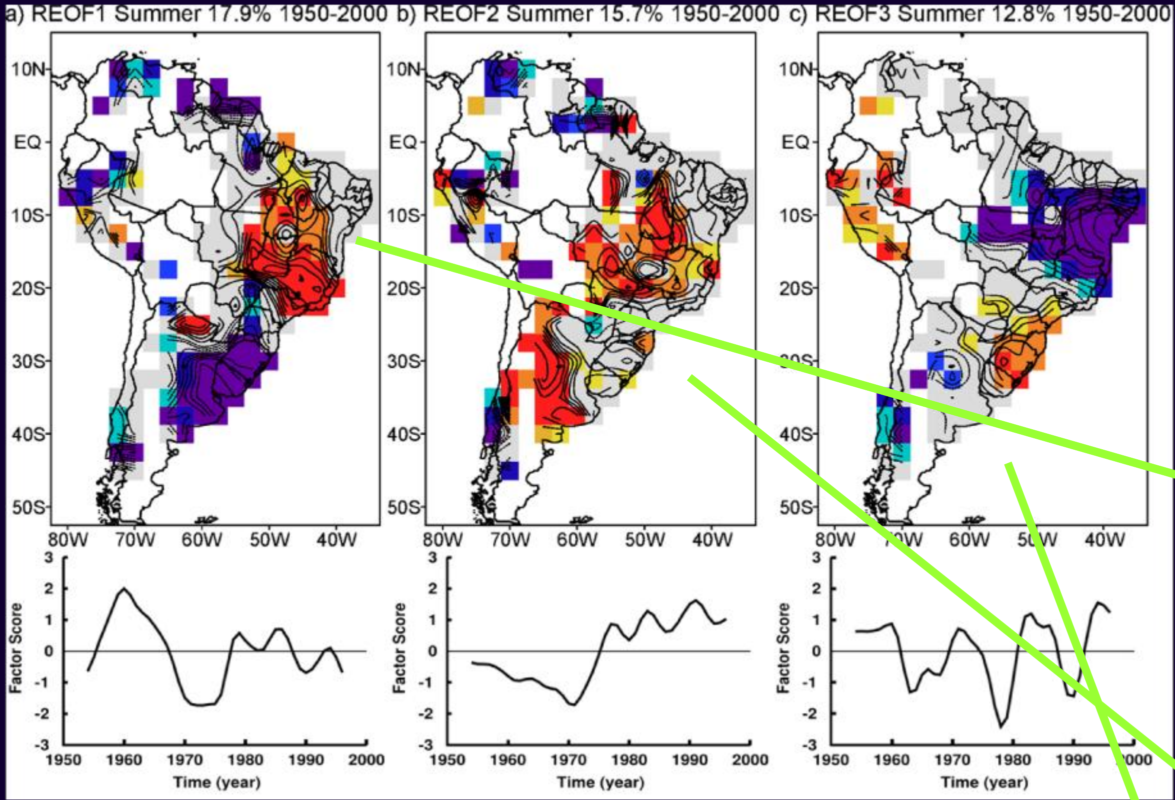


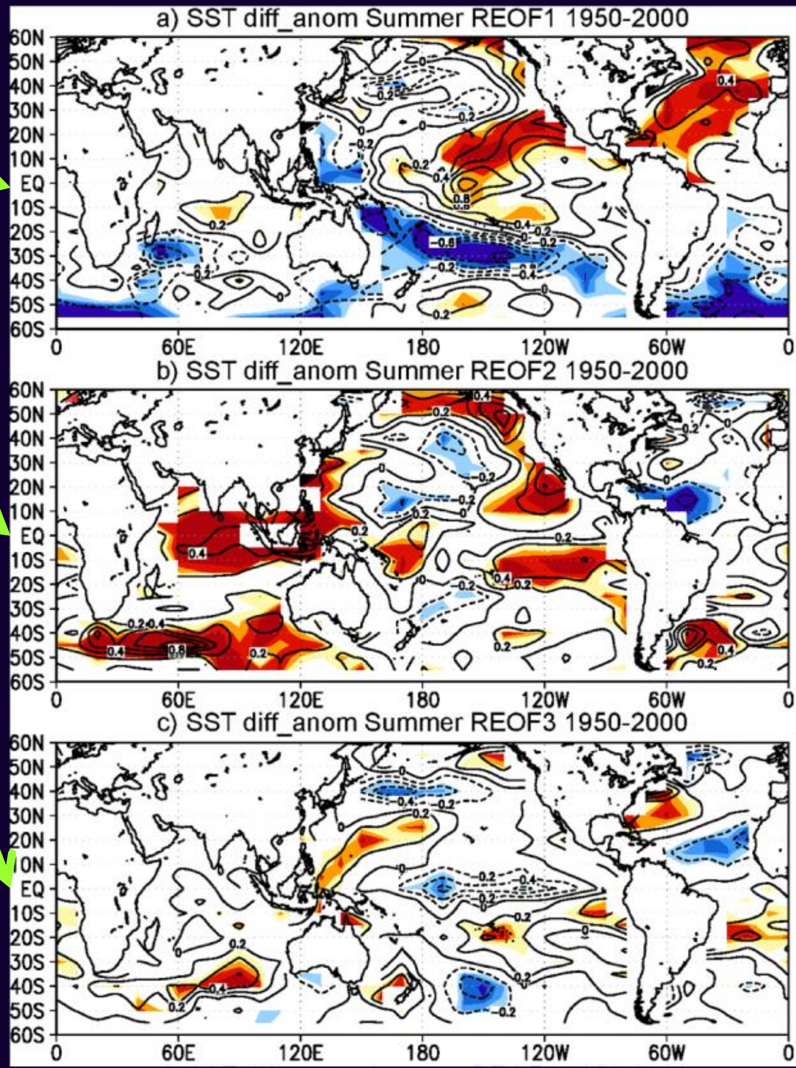
Our IPO

(Grimm and Saboia, 2015)

Interdecadal Variability
Summer

Relationships with SST and climatic indices





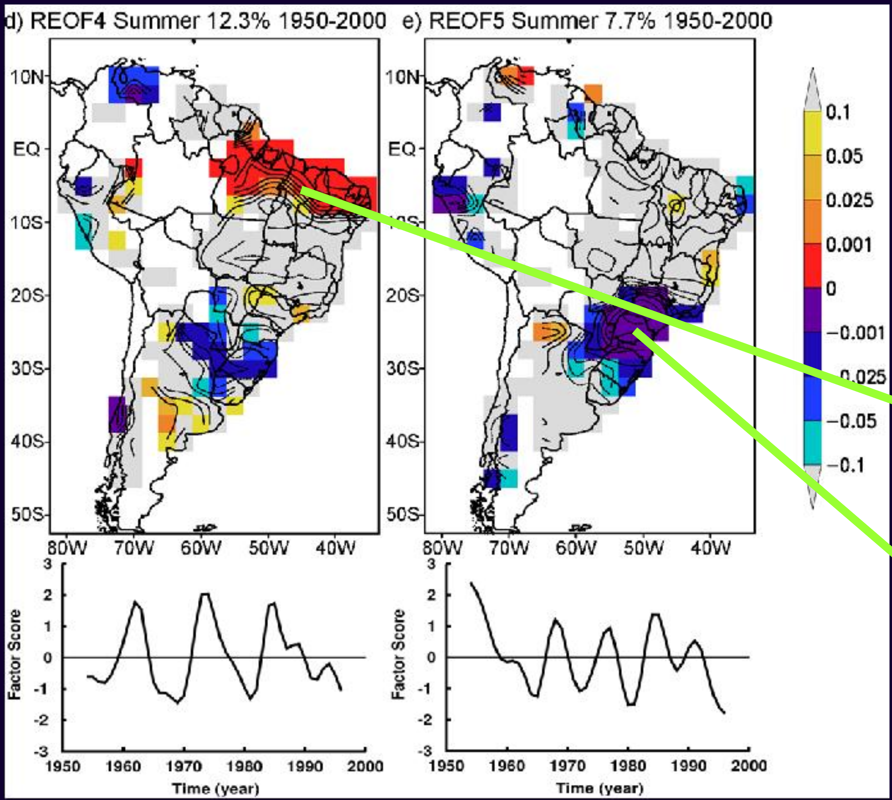
Summer	Precipitation modes				
Indices	REOF1	REOF2	REOF3	REOF4	REOF5
AMO_70	**0.71 (0.00)**	-0.24 (0.12)	0.14 (0.37)	**-0.31 (0.05)**	0.15 (0.36)
AMO_60	**0.45 (0.00)**	**-0.50 (0.00)**	0.02 (0.89)	-0.23 (0.12)	0.15 (0.36)
NAO	**-0.35 (0.02)**	**0.65 (0.00)**	**0.34 (0.03)**	-0.01(0.94)	-0.21 (0.17)
IPO	**0.34 (0.02)**	**0.70 (0.00)**	-0.05 (0.76)	**-0.32 (0.04)**	-0.20 (0.21)
PDO	**0.30 (0.05)**	**0.68 (0.00)**	0.22 (0.15)	0.06 (0.72)	-0.10 (0.53)
TSA	-0.08 (0.61)	0.25 (0.11)	**0.34 (0.03)**	**0.30 (0.05)**	**-0.37 (0.02)**
TNA	**0.43 (0.01)**	**-0.32 (0.04)**	-0.18 (0.25)	**-0.56 (0.00)**	-0.08 (0.61)
SAM	0.28 (0.08)	**0.40 (0.01)**	0.27 (0.08)	0.16 (0.32)	**-0.48 (0.00)**
NAM	**-0.42 (0.01)**	**0.49 (0.00)**	0.12 (0.42)	0.11 (0.46)	-0.26 (0.10)

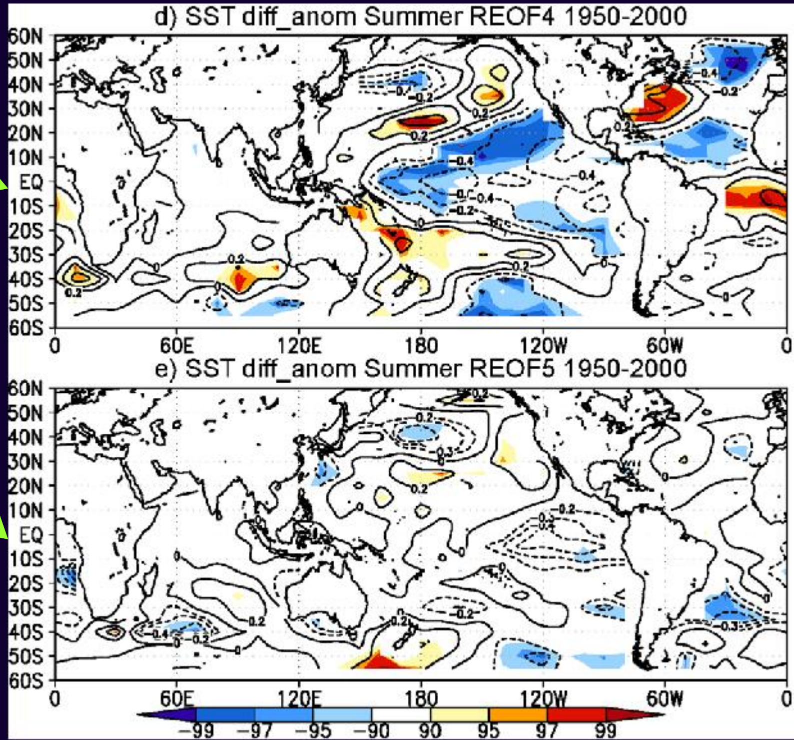
(Grimm and Saboia, 2015)

Interdecadal Variability

Summer

Relationships with SST and climatic indices





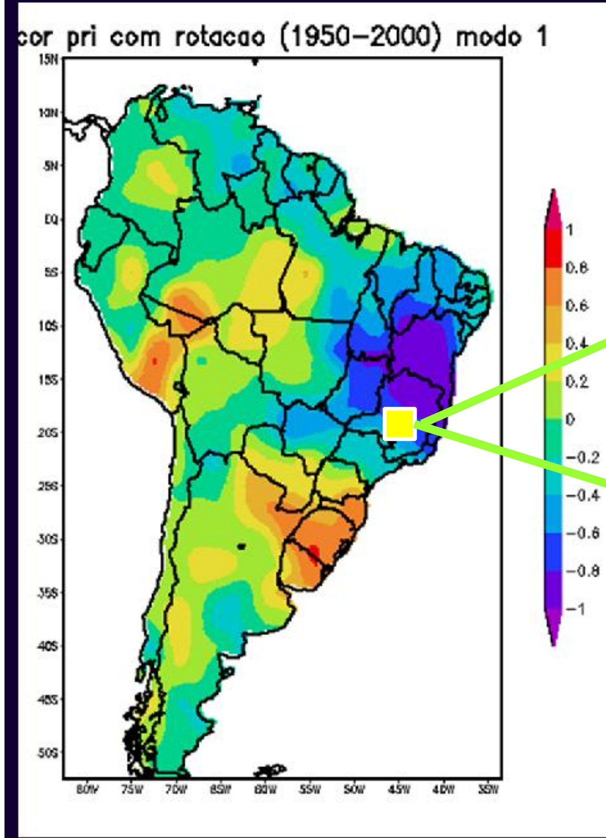
Summer	Precipitation modes				
Indices	REOF1	REOF2	REOF3	REOF4	REOF5
AMO_70	**0.71 (0.00)**	-0.24 (0.12)	0.14 (0.37)	**-0.31 (0.05)**	0.15 (0.36)
AMO_60	**0.45 (0.00)**	**-0.50 (0.00)**	0.02 (0.89)	-0.23 (0.12)	0.15 (0.36)
NAO	**-0.35 (0.02)**	**0.65 (0.00)**	**0.34 (0.03)**	-0.01(0.94)	-0.21 (0.17)
IPO	**0.34 (0.02)**	**0.70 (0.00)**	-0.05 (0.76)	**-0.32 (0.04)**	-0.20 (0.21)
PDO	**0.30 (0.05)**	**0.68 (0.00)**	0.22 (0.15)	0.06 (0.72)	-0.10 (0.53)
TSA	-0.08 (0.61)	0.25 (0.11)	**0.34 (0.03)**	**0.30 (0.05)**	**-0.37 (0.02)**
TNA	**0.43 (0.01)**	**-0.32 (0.04)**	-0.18 (0.25)	**-0.56 (0.00)**	-0.08 (0.61)
SAM	0.28 (0.08)	**0.40 (0.01)**	0.27 (0.08)	0.16 (0.32)	**-0.48 (0.00)**
NAM	**-0.42 (0.01)**	**0.49 (0.00)**	0.12 (0.42)	0.11 (0.46)	-0.26 (0.10)

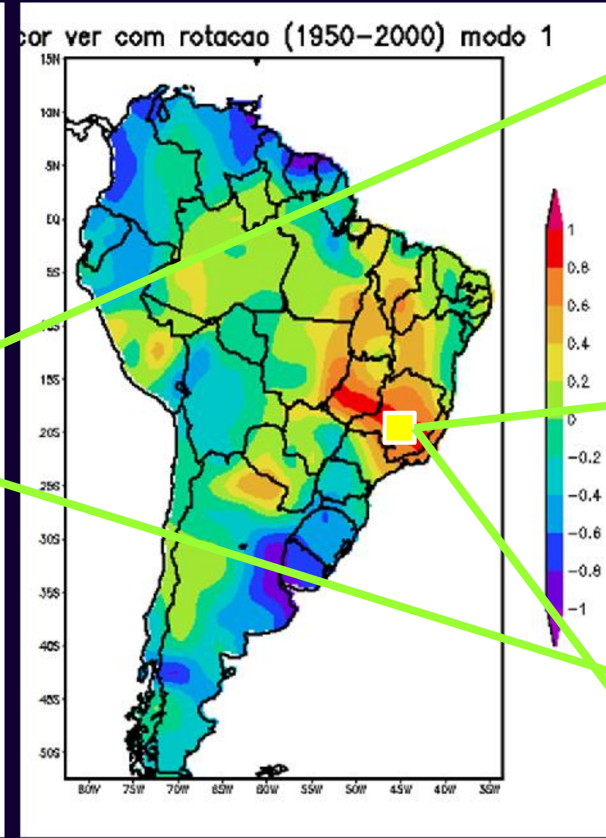
(Grimm and Saboia, 2015)

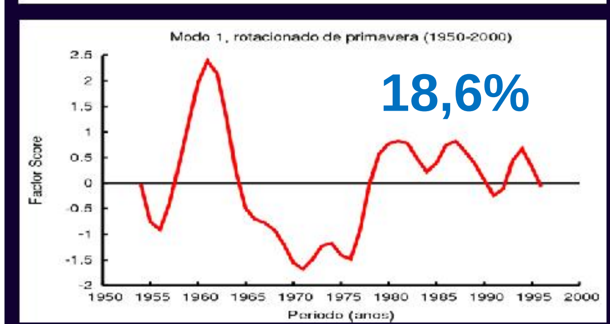
Interdecadal Variability– Spring-Summer

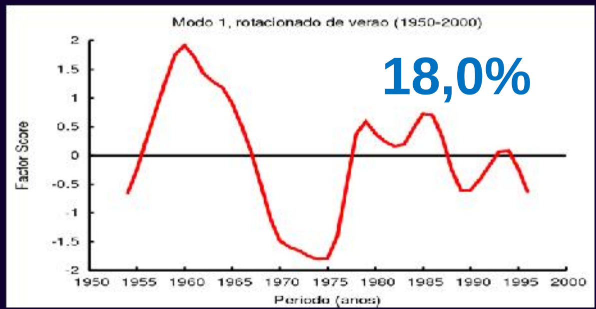
Spring - REOF 1

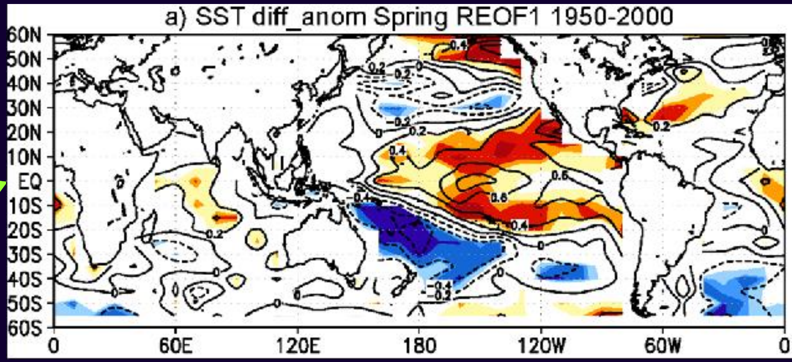
Summer - REOF 1

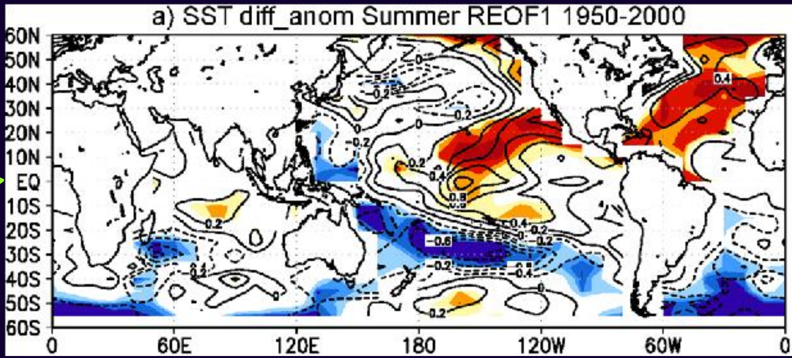


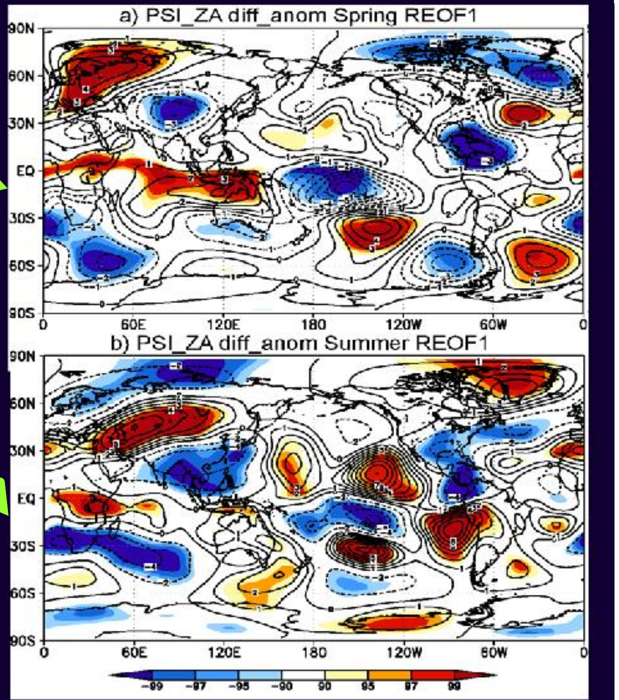








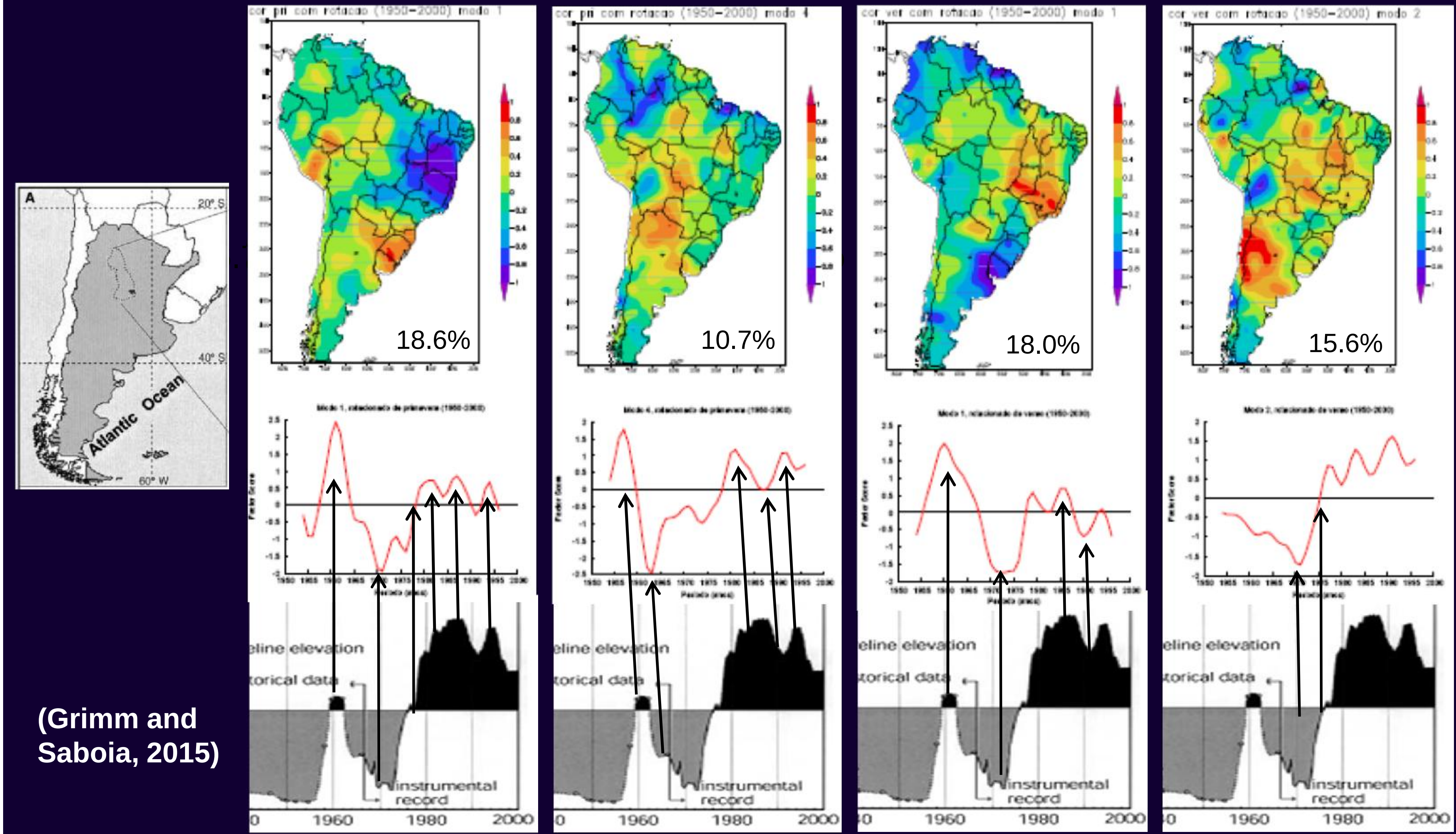




(Grimm and Saboia, 2015)

Correlation: 0.81

Interdecadal Variability - Laguna Mar Chiquita



(Grimm and Saboia, 2015)

Lake-level curve for Laguna Mar Chiquita during the period 1950-2000 (lower row, Piovano et al 2002) and the principal components of the 1st and 4th rotated modes for spring and 1st and 2nd rotated modes for summer.

CONCLUSIONS

- The 1st modes of interdecadal rainfall variability in South America in spring and summer exhibit dipole-like pattern with centers in central-east and southeast South America. This dipole tends to invert polarity from spring to summer, while the SST anomalies associated with these modes tend to persist, except in the SACZ region. These anomalies are mainly distributed in the Pacific and Atlantic oceans (IPO, AMO).

- The 2nd summer mode, which affects the core monsoon region and central/northwestern Argentina, is significantly correlated to the fourth mode in spring, indicating persistence of anomalies from one season to the other. This is why this mode has the largest contribution to the 1st interdecadal mode of annual precipitation.

- Three of the 5 first summer modes show strongest connections with SST-based modes and two have strongest connections with atmospheric modes. The first modes show connections with more than one SST/climatic mode, stressing the importance of combined influence.

- The modes of SST interdecadal variability are associated not only with significant seasonal rainfall variability, but also with significant variations in the frequency of extreme events.

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