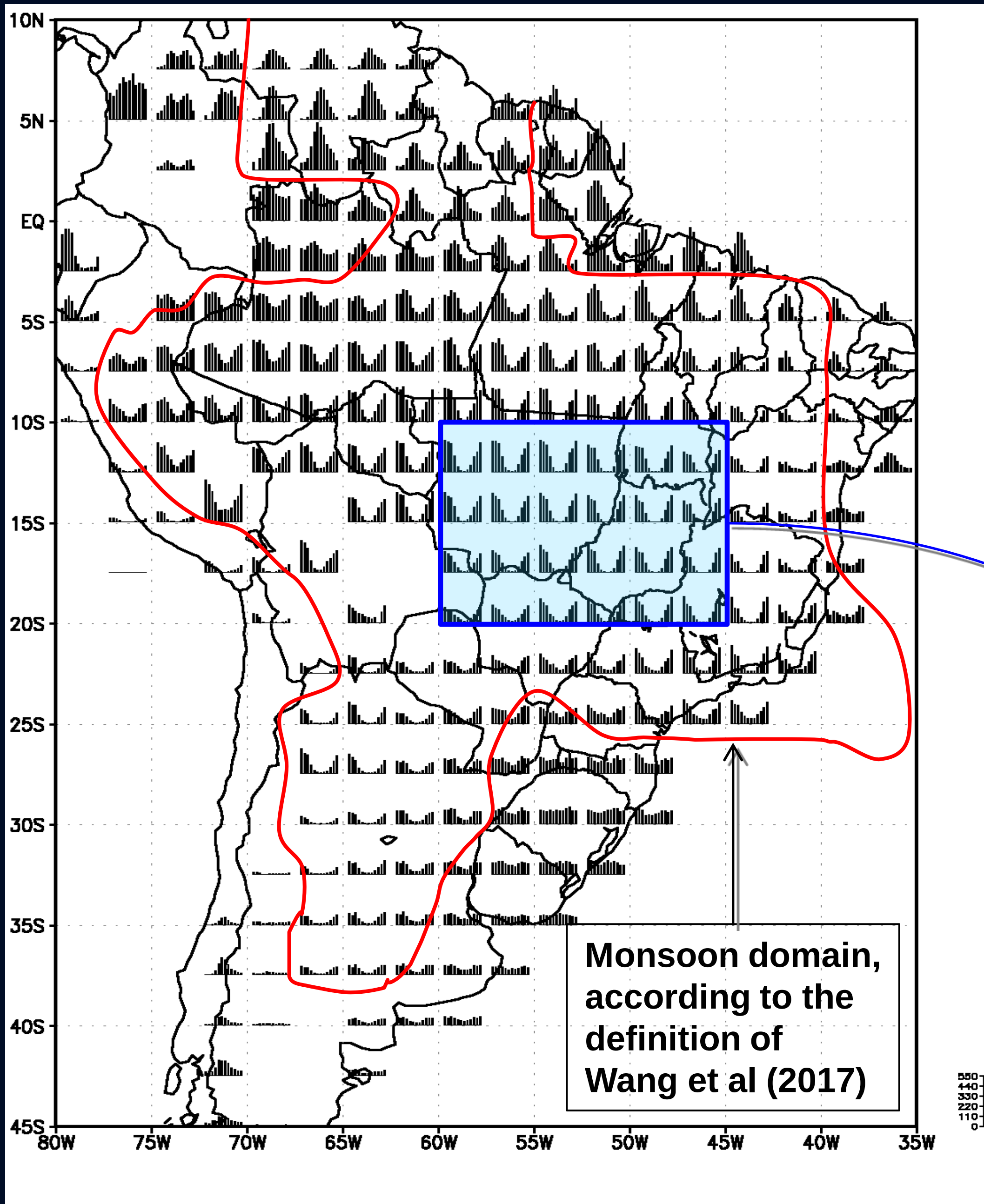
Interannual and intraseasonal variability of the South American monsoon: the MJO modulation by ENSO

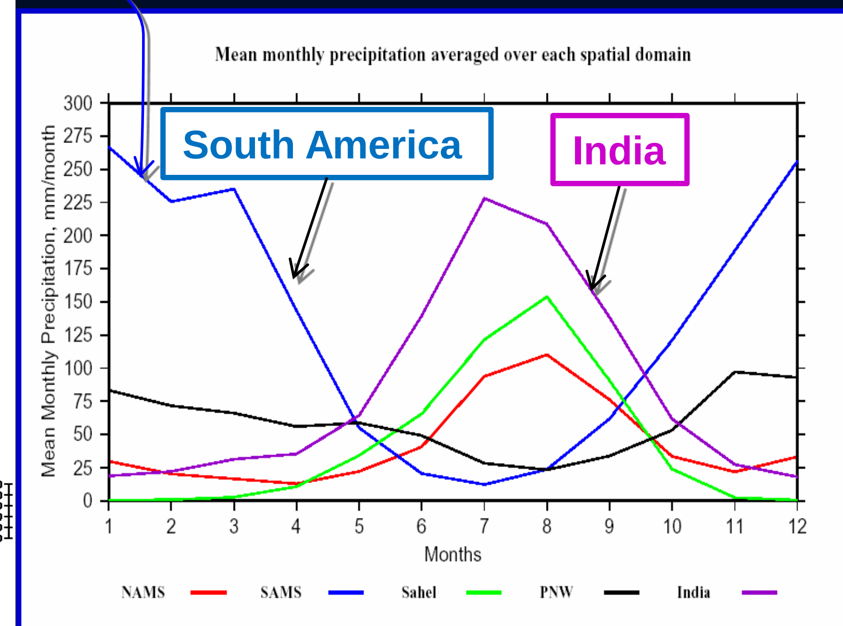
Alice M. Grimm
Department of Physics, Federal University of Paraná, Curitiba, Paraná, Brazil
grimm@fisica.ufpr.br

AMS Annual Meeting

Annual cycles of precipitation



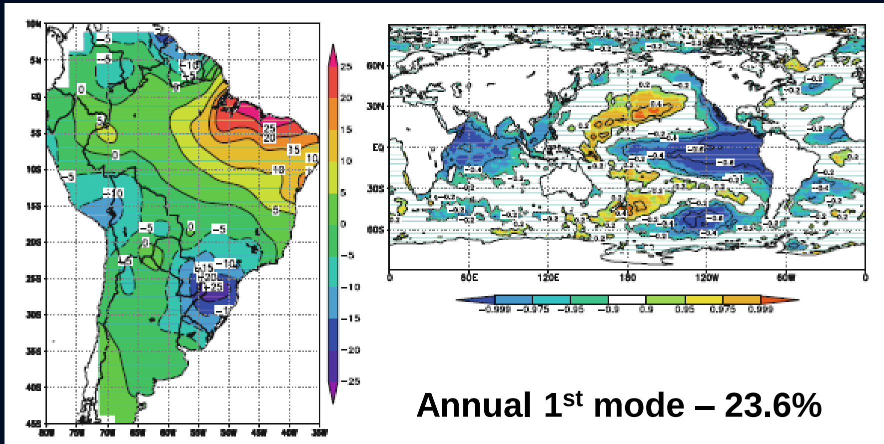
(Grimm 2011)



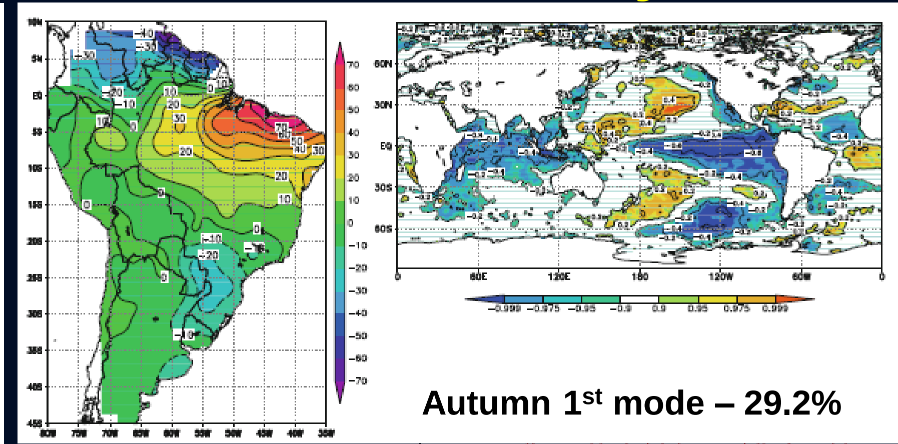
(Vera et al. 2006)

Interannual variability in SA:
the importance of ENSO

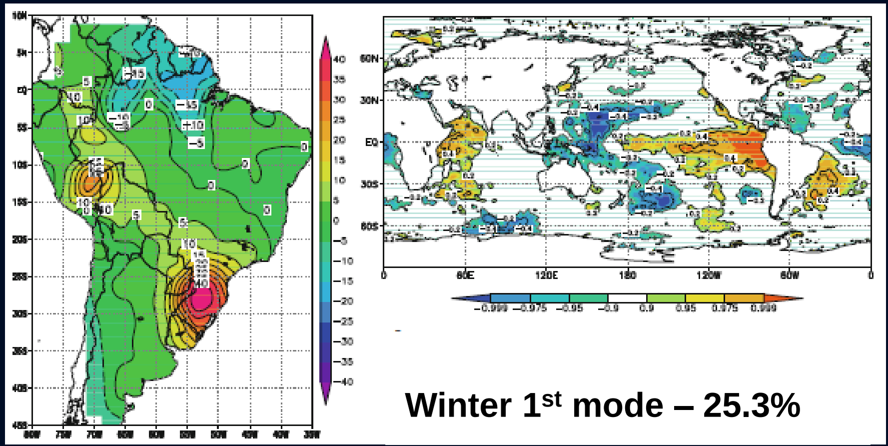
Continental modes of interannual variability (Grimm 2011)



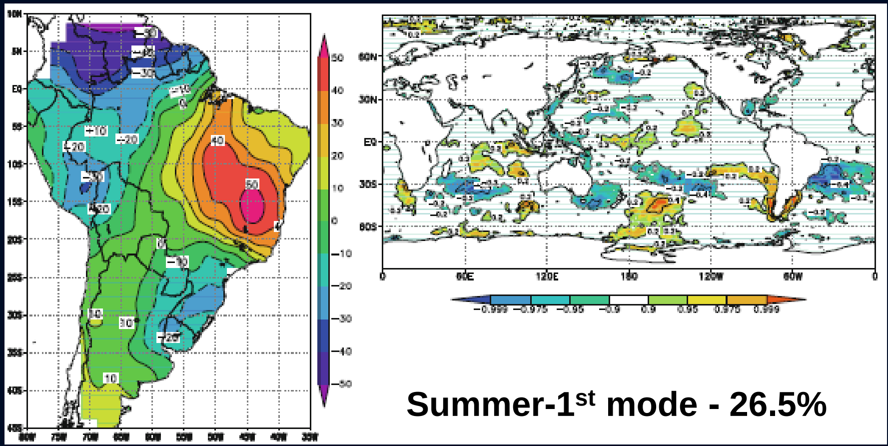
Annual 1st mode – 23.6%



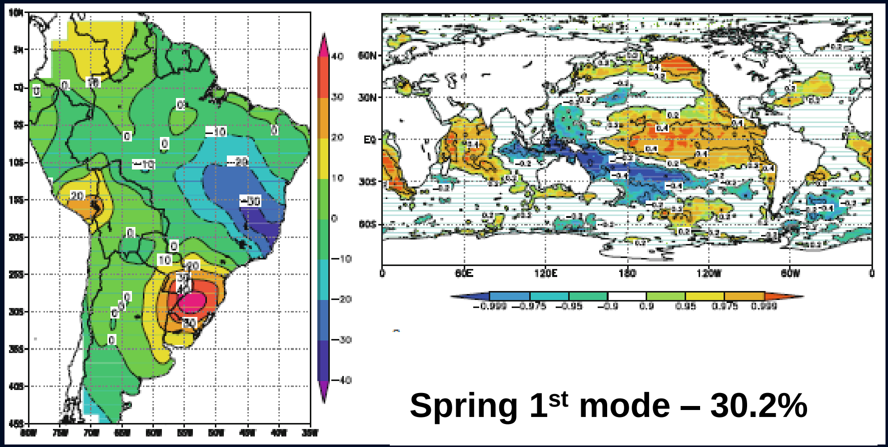
Autumn 1st mode – 29.2%



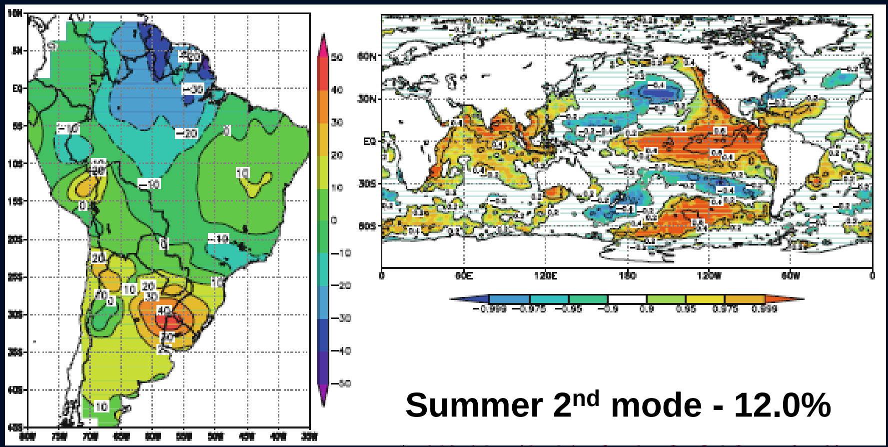
Winter 1st mode – 25.3%



Summer-1st mode - 26.5%



Spring 1st mode – 30.2%



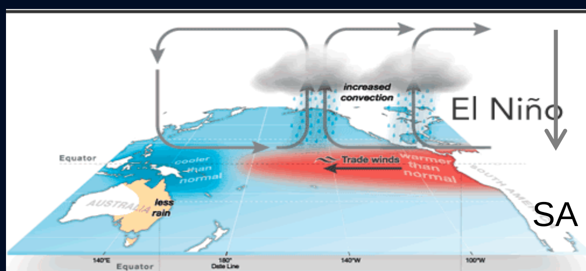
Summer 2nd mode - 12.0%

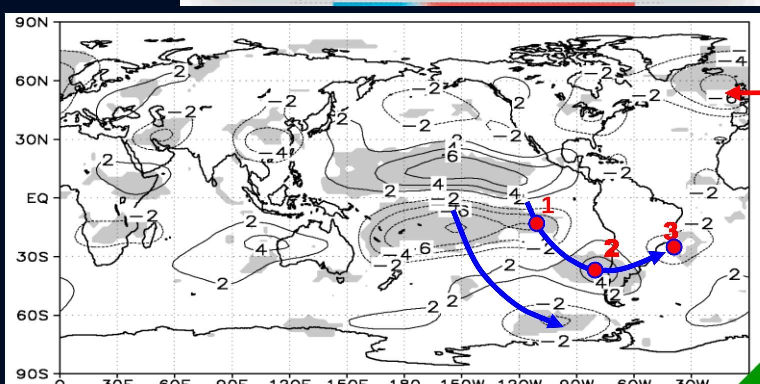
Mechanisms for ENSO impact on South America

- **Local forcing** (as in western tropical South America)
- **Atmospheric teleconnections**

♣ **Tropical pathway**⟶ Equatorial Kelvin and Rossby waves change the Walker circulation (as in eastern equatorial SA)

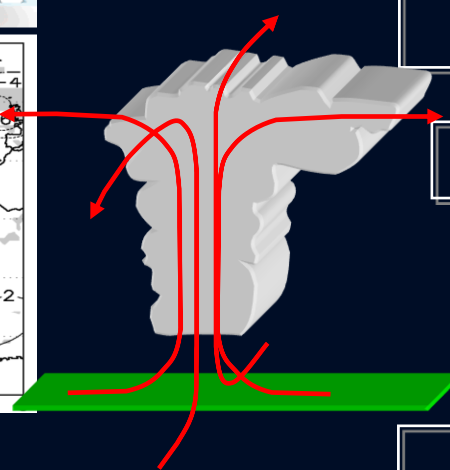
♣ **Extratropical pathway**⟶ Rossby wave trains produced by Pacific tropical convection change subtropical/extratropical circulation (as in SESA)





Upper-level streamfuntion anomalies during the austral spring in El Niño

(Grimm and Ambrizzi 2009)



Rossby waves

↑

Upper-level divergence

↑

Expansion of the air column

↑

Release of latent heat

↑

Convection

↑

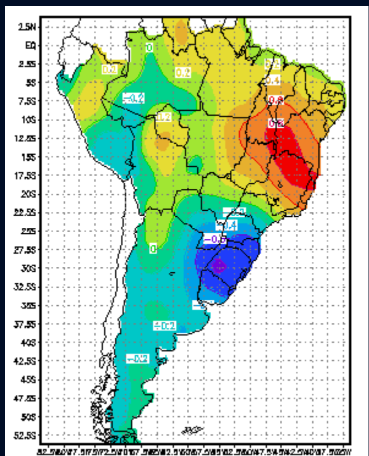
Low-level convergence

Surface-Atmosphere Interactions

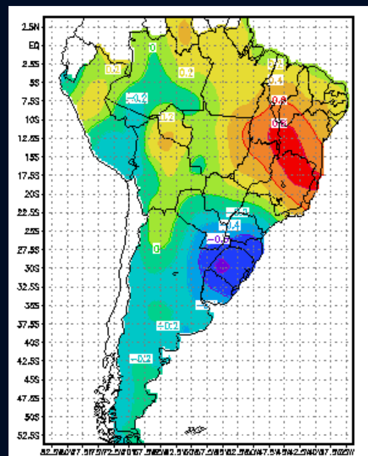
Relationship between precipitation in spring and summer

Spring

EOF1

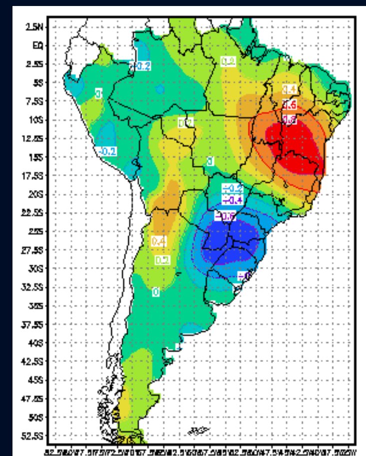


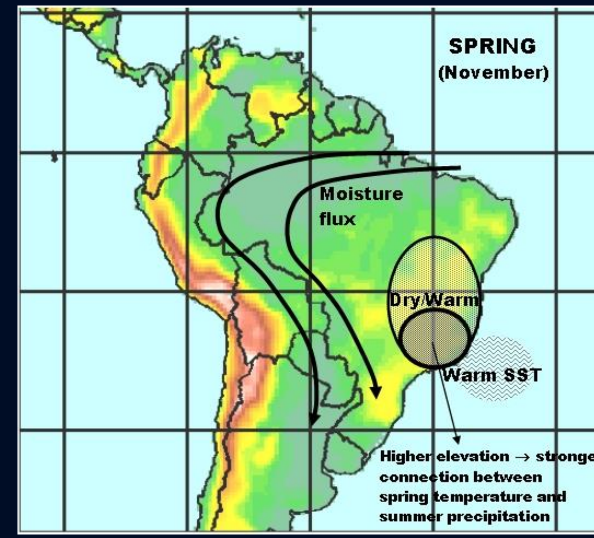
EOF1



November

REOF1





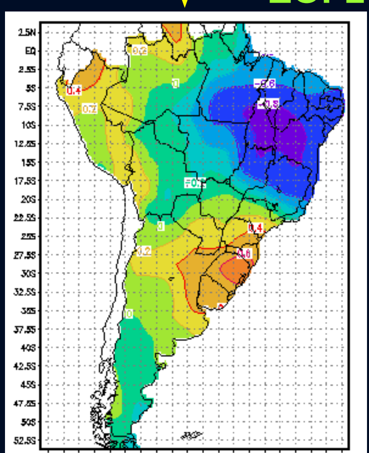
r=0.24

r=-0.31

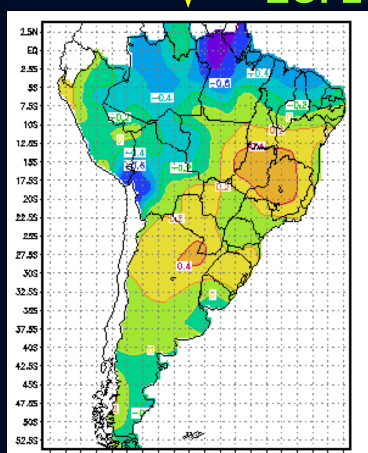
r=-0.33

Summer

EOF1

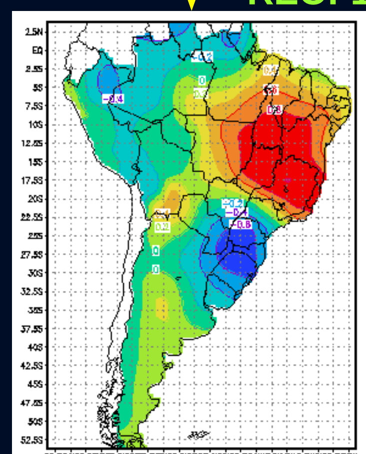


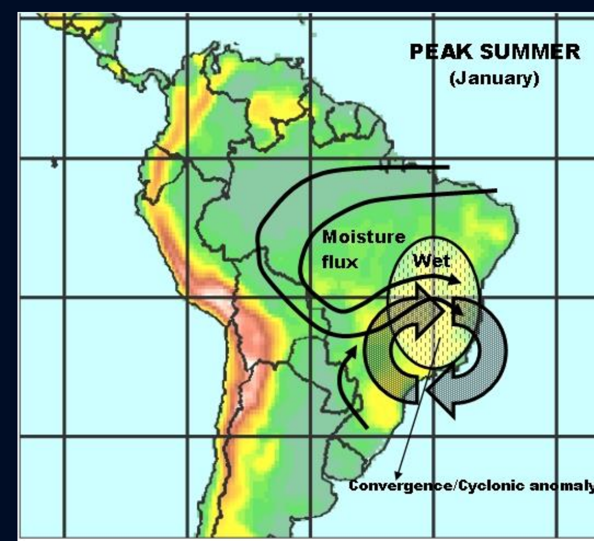
EOF2



January

REOF1

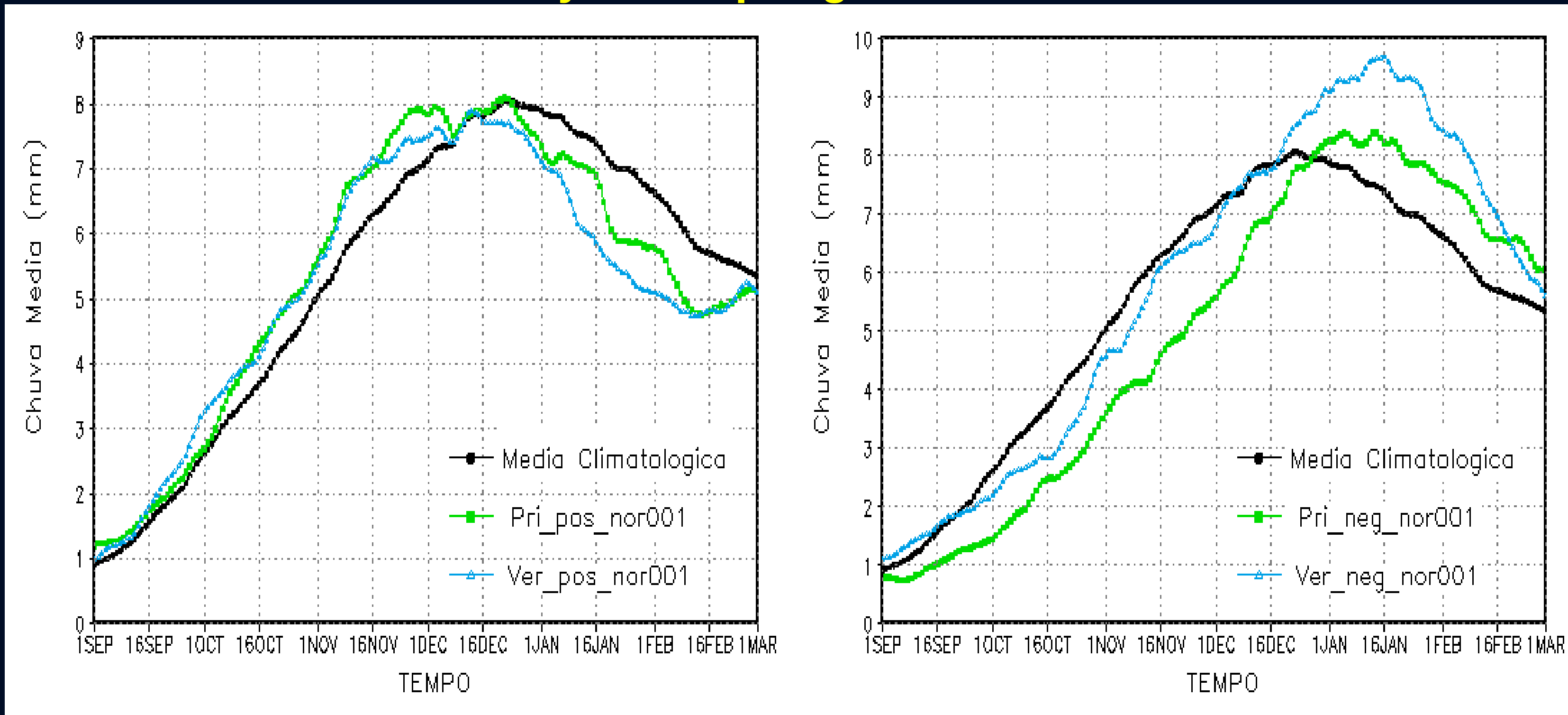




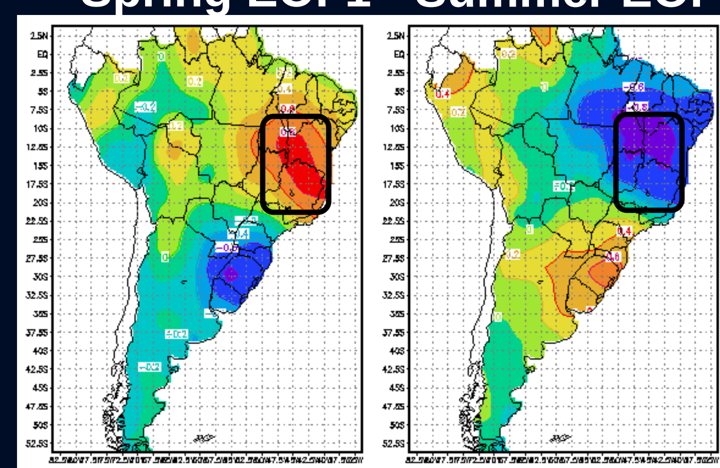
(Grimm et al. 2007; Grimm and Zilli 2009 - *J. Climate*)

Evolution of the precipitation in Central-East Brazil

keyed to Spring and Summer PC1.



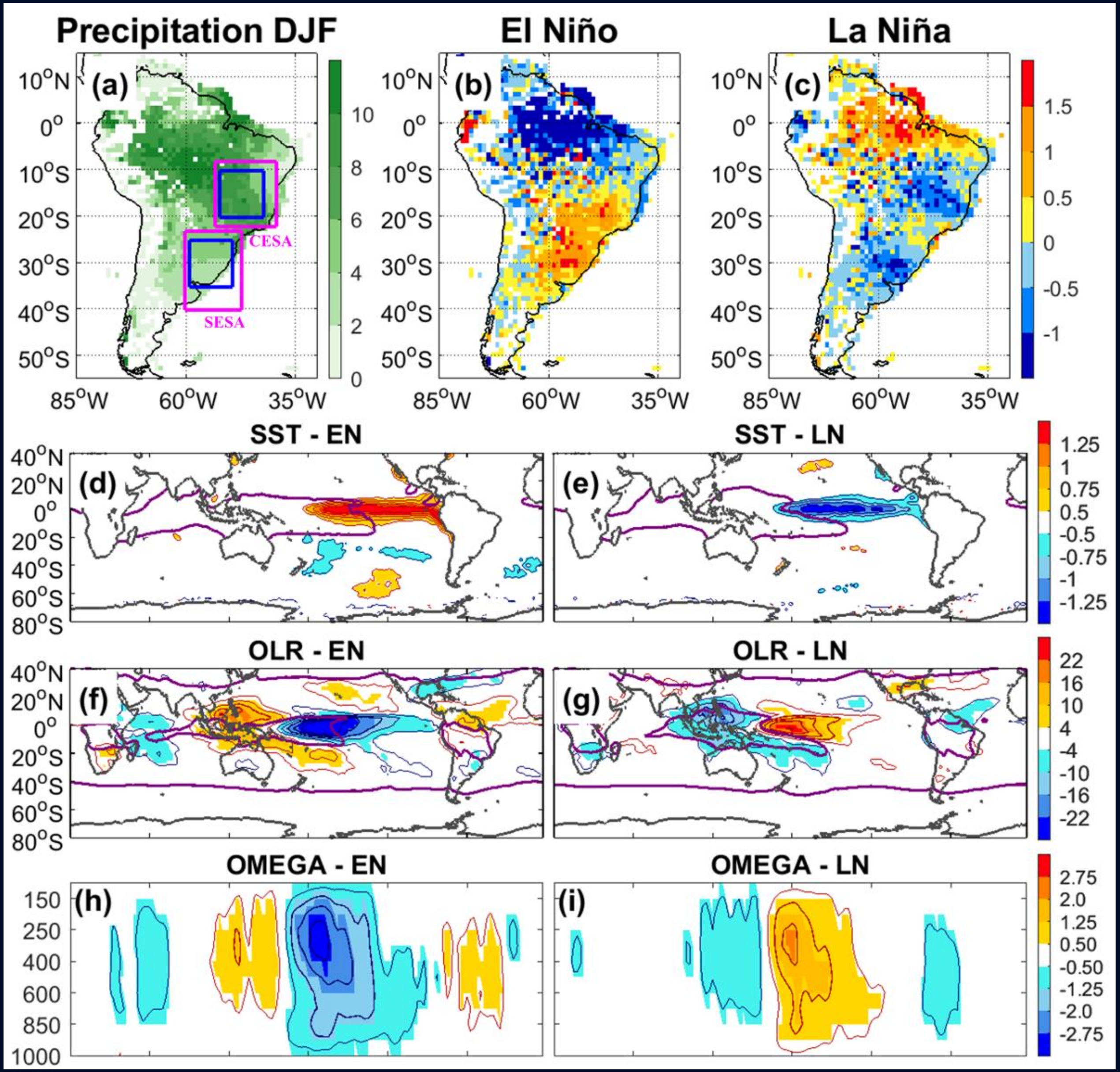
Spring EOF1 Summer EOF1



Composite evolution of the 30-day running mean precipitation (mm day-1), averaged over Central-East Brazil for all years (black line) and (left) for years in which spring (summer) PC1 is above 0.5 standard deviation (green (blue) line) or (right) for years in which spring (summer) PC1 is below -0.5 standard deviation (green (blue) line).

(Grimm and Zilli 2009)

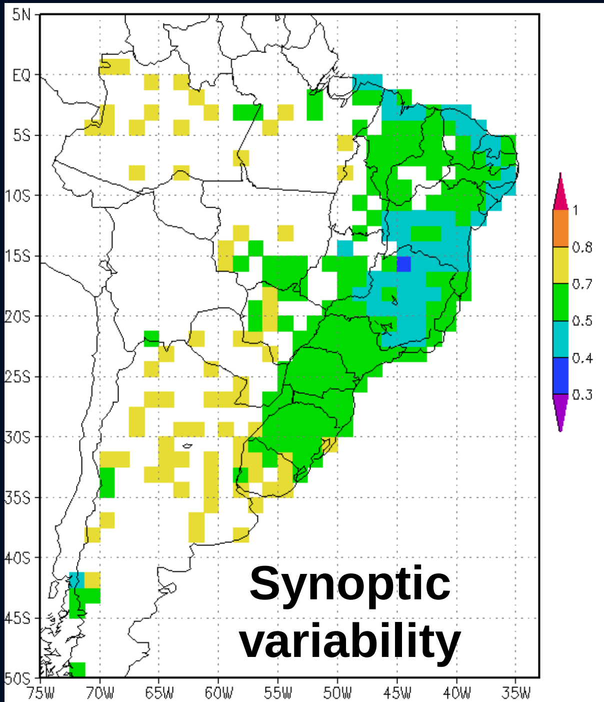
ENSO-related anomalies in austral summer (DJF)

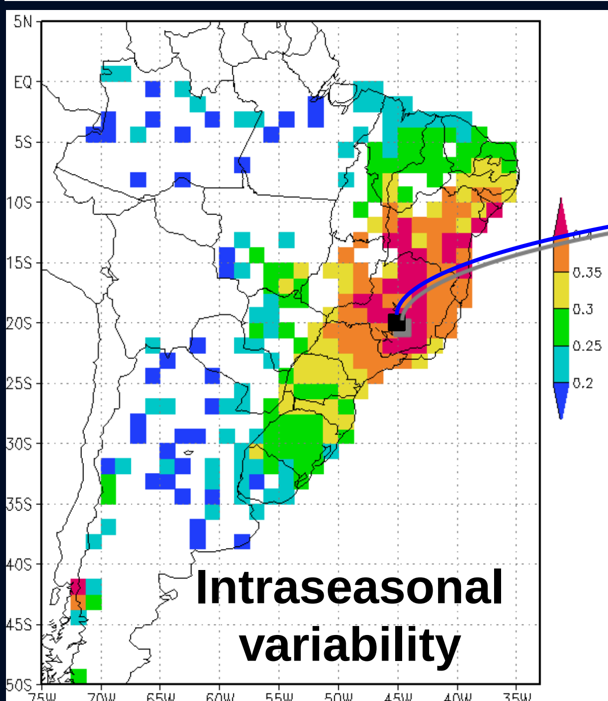


Intraseasonal variability in SA:

the importance of MJO

(Ferraz and Grimm 2004)



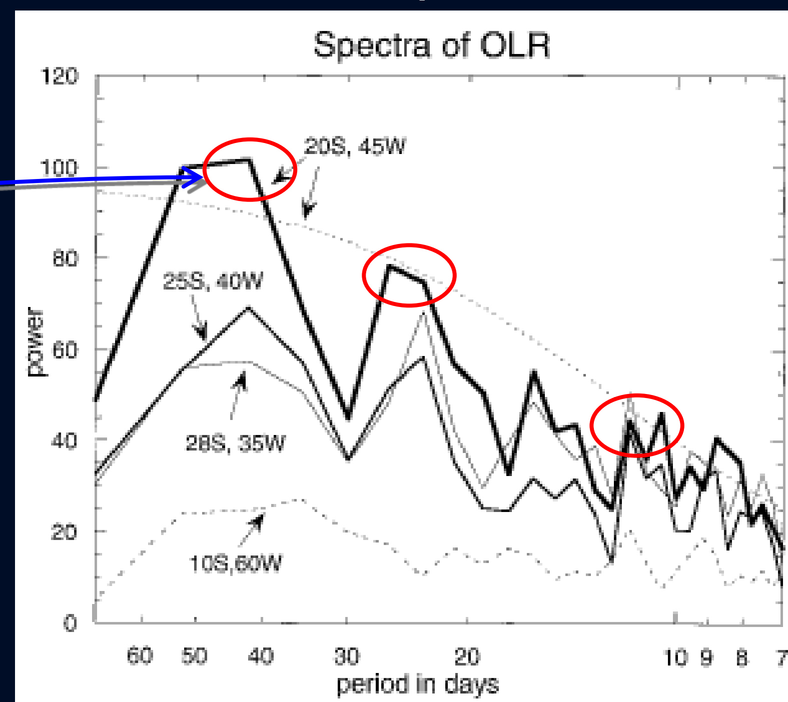


Contribution of synoptic and intraseasonal timescales to total variance of summer rainfall in SA

Intraseasonal variability bands:

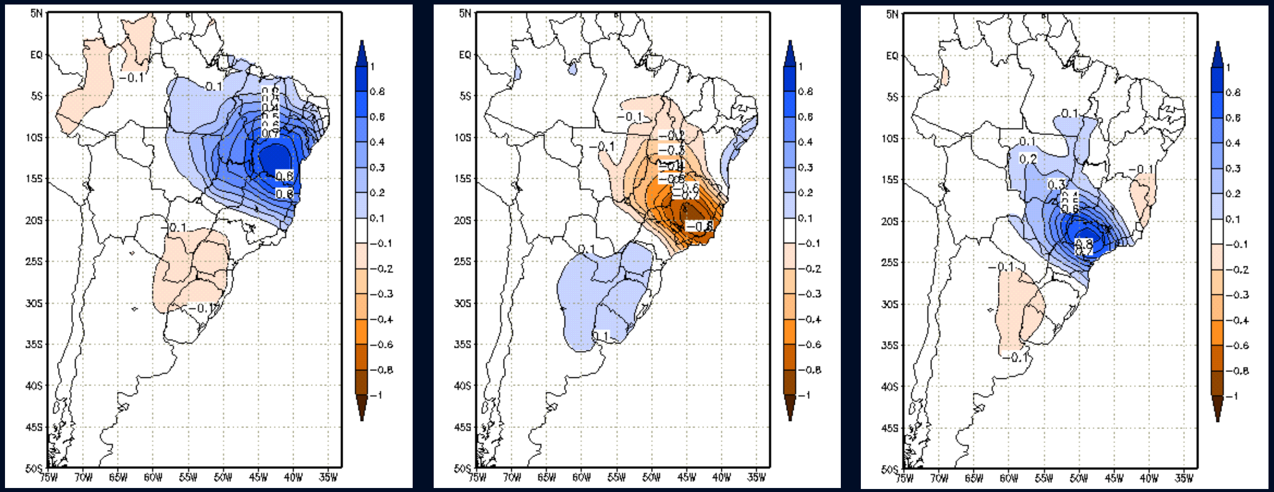
- 10-20 days
- 20-30 days
- 30-70 days

(Liebmann et al. 1999)



Intraseasonal Variability in South America

(10-100 day band - DJF)

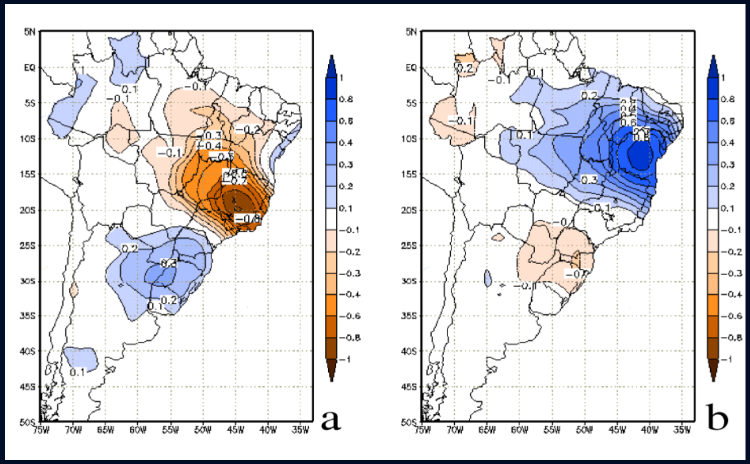


First, second, and third rotated EOFs, which explain 22.9 % of the intraseasonal variance. These are always among the first three in the different intraseasonal bands

Variance explained by the three rotated modes presented above, in the 10-20, 20-30, 30-70 and 10-100 day bands.				
Mode	10/20 dias	20/30 dias	30/70 dias	10/100 dias
REOF1	**7,80%**	**11,45%**	10,28%	9,98%
REOF2	6,33%	9,57%	**10,60%**	7,26%
REOF3	3,87%	6,13%	5,82%	5,67%
Accumulated	18.10%	27.15%	26.7%	27,66%

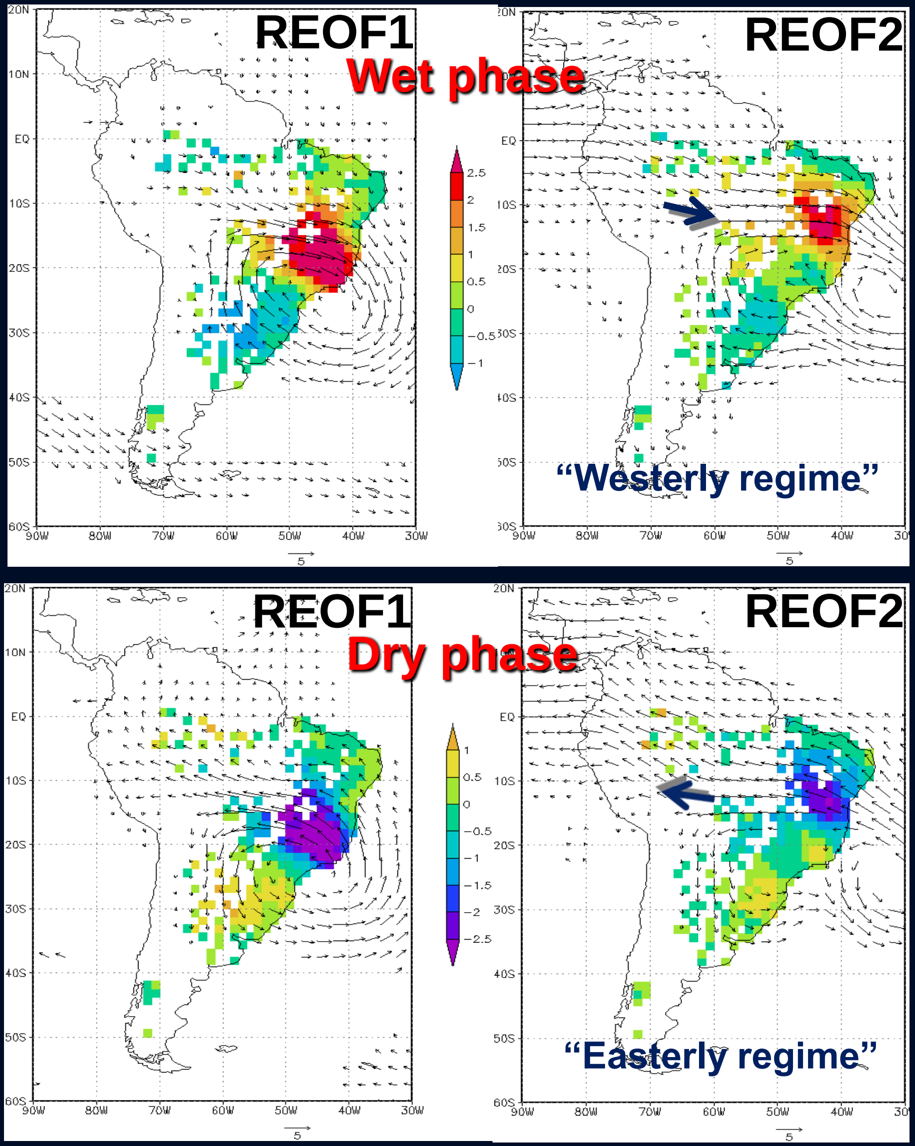
(Ferraz 2004)

Intraseasonal Variability in South America
(30-70 day band - DJF)



REOF1 REOF2

(Left) First two rotated modes of DJF intraseasonal variability in the 30-70 day band (10.6% and 10.3% of the variance). (Right) Composites of rainfall anomalies and vertically integrated moisture flux for wet and dry phases of these modes. Only significant anomalies are represented by arrows.

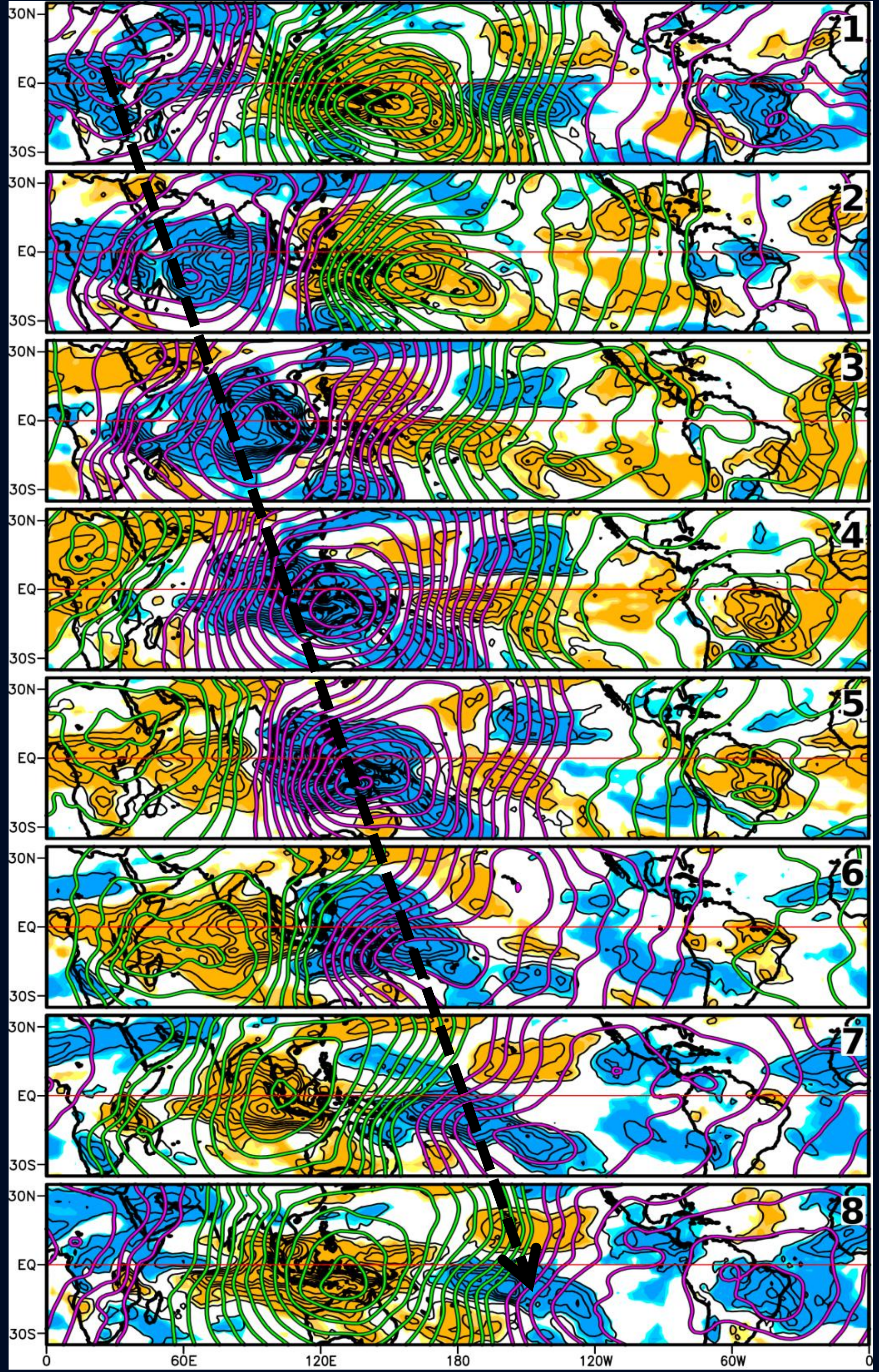


REOF1 REOF2

(Ferraz 2004; Grimm and Ambrizzi 2009)

Average MJO impact in summer

(Grimm 2019)



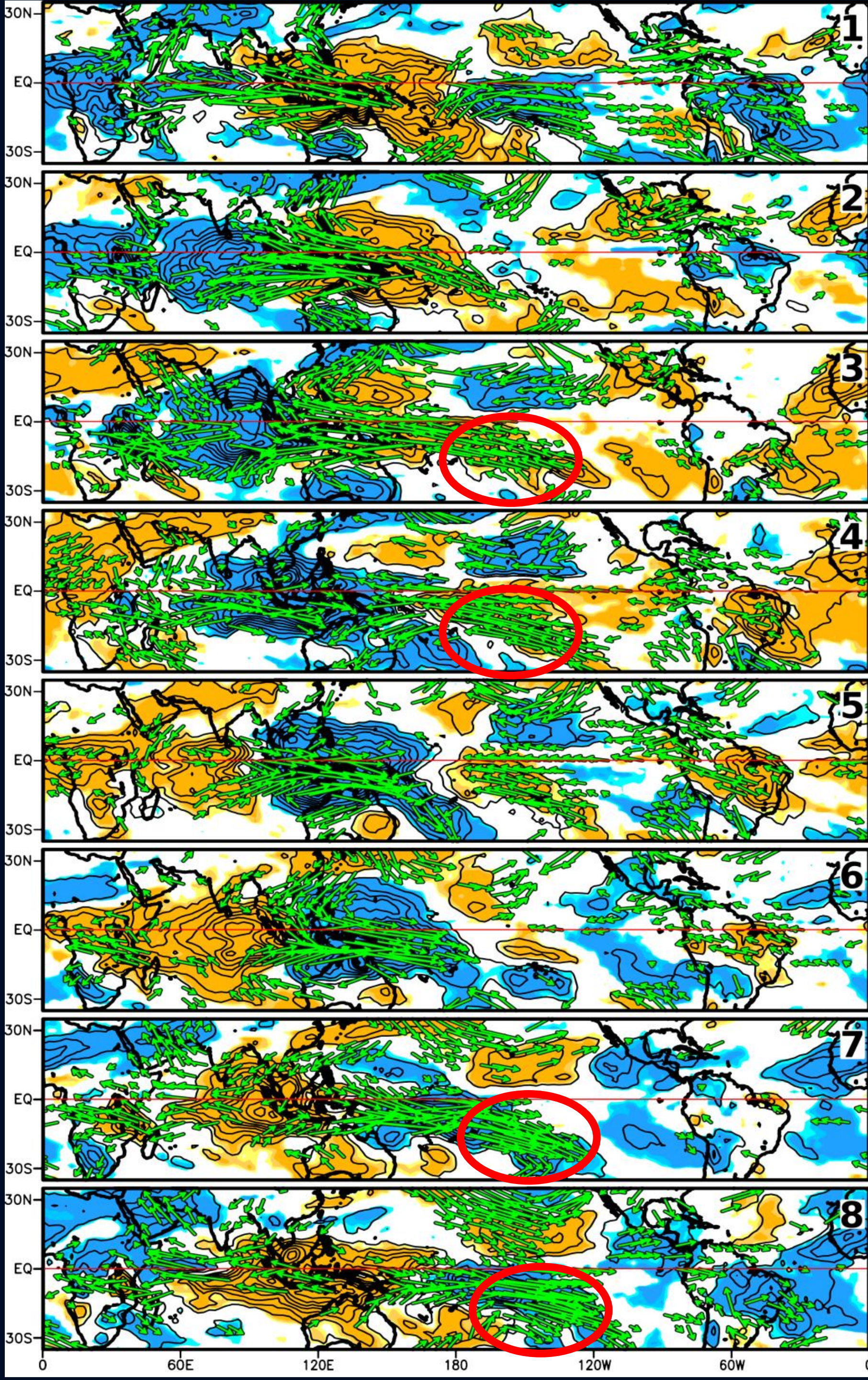
(Grimm 2019)

Austral summer MJO OLR and X_{850} anomalies

7

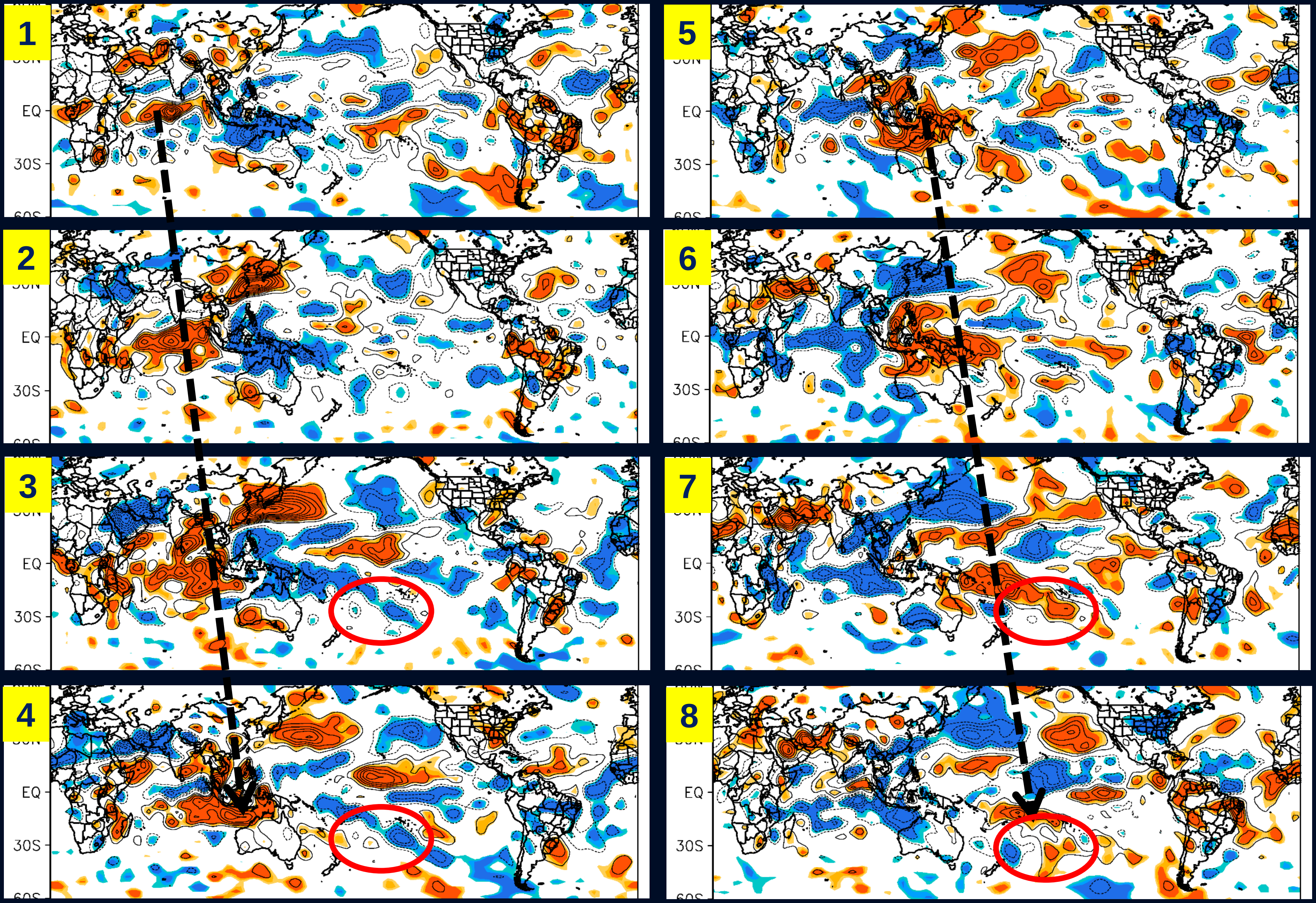
(Grimm 2019)

Austral summer MJO OLR and V_{850} anomalies

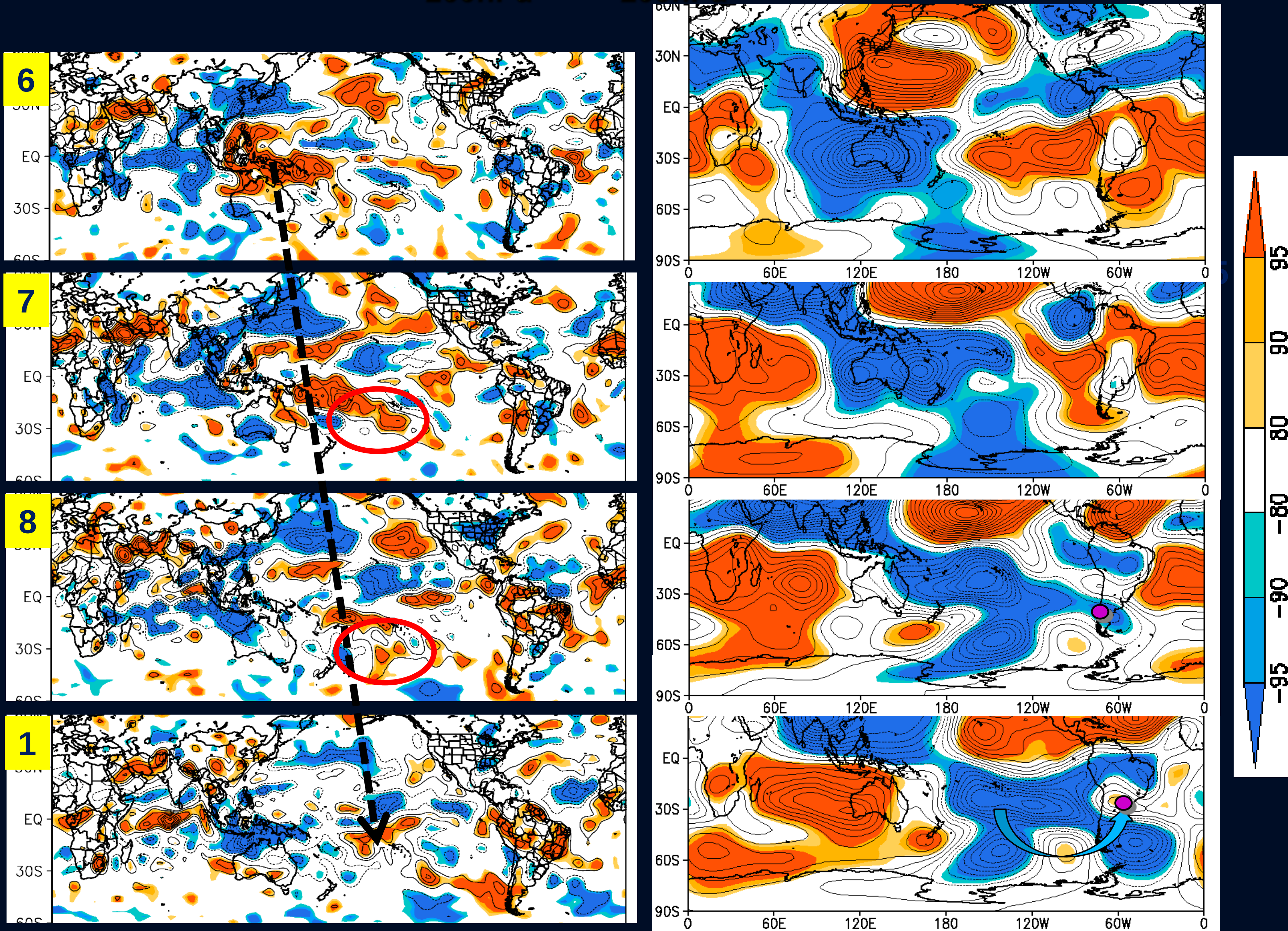


7

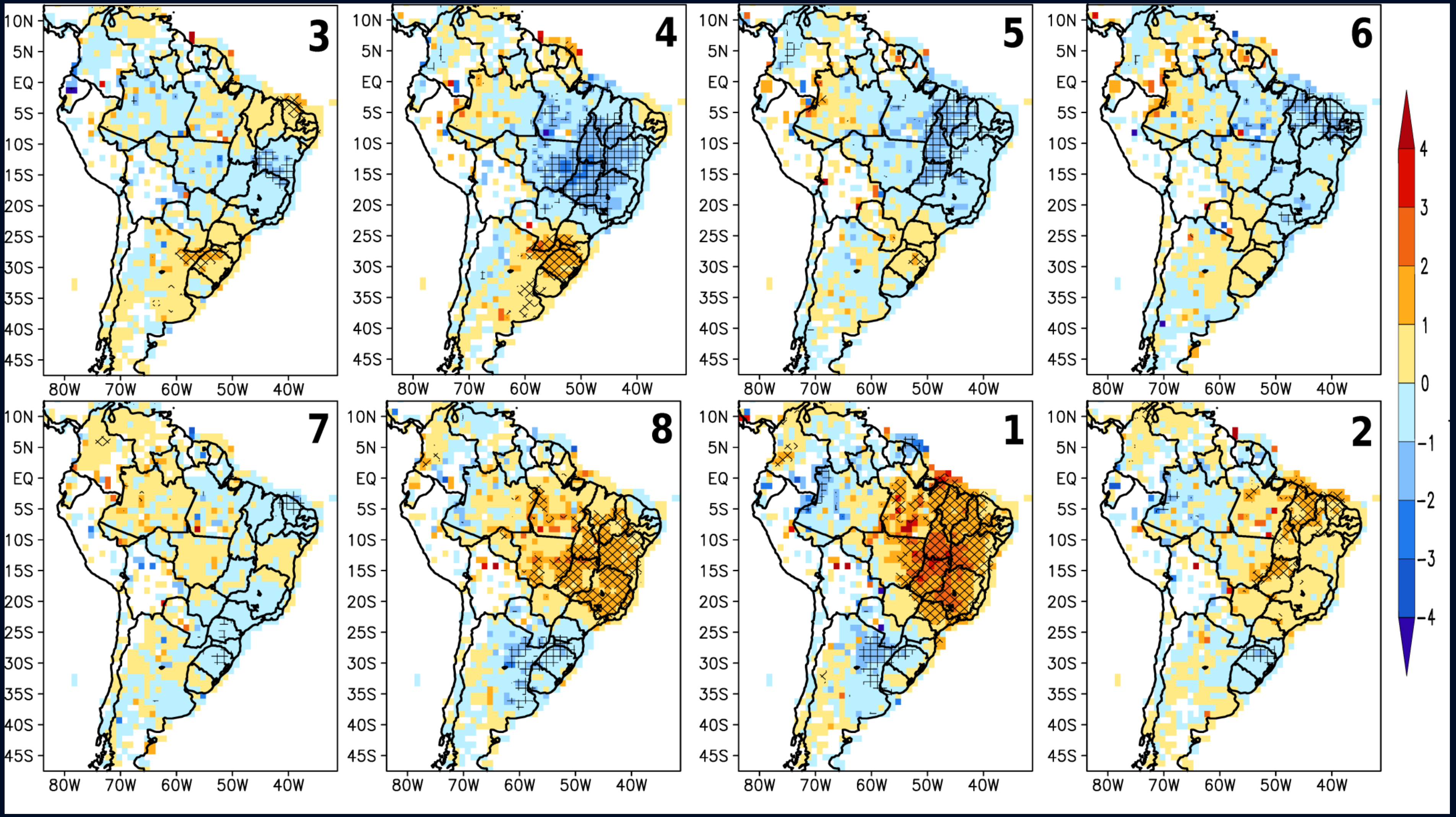
Austral Summer MJO Div_{200hPa} anomalies



Anomalies Div_{200hPa} e Ψ_{200hPa} – MJO – SH Summer



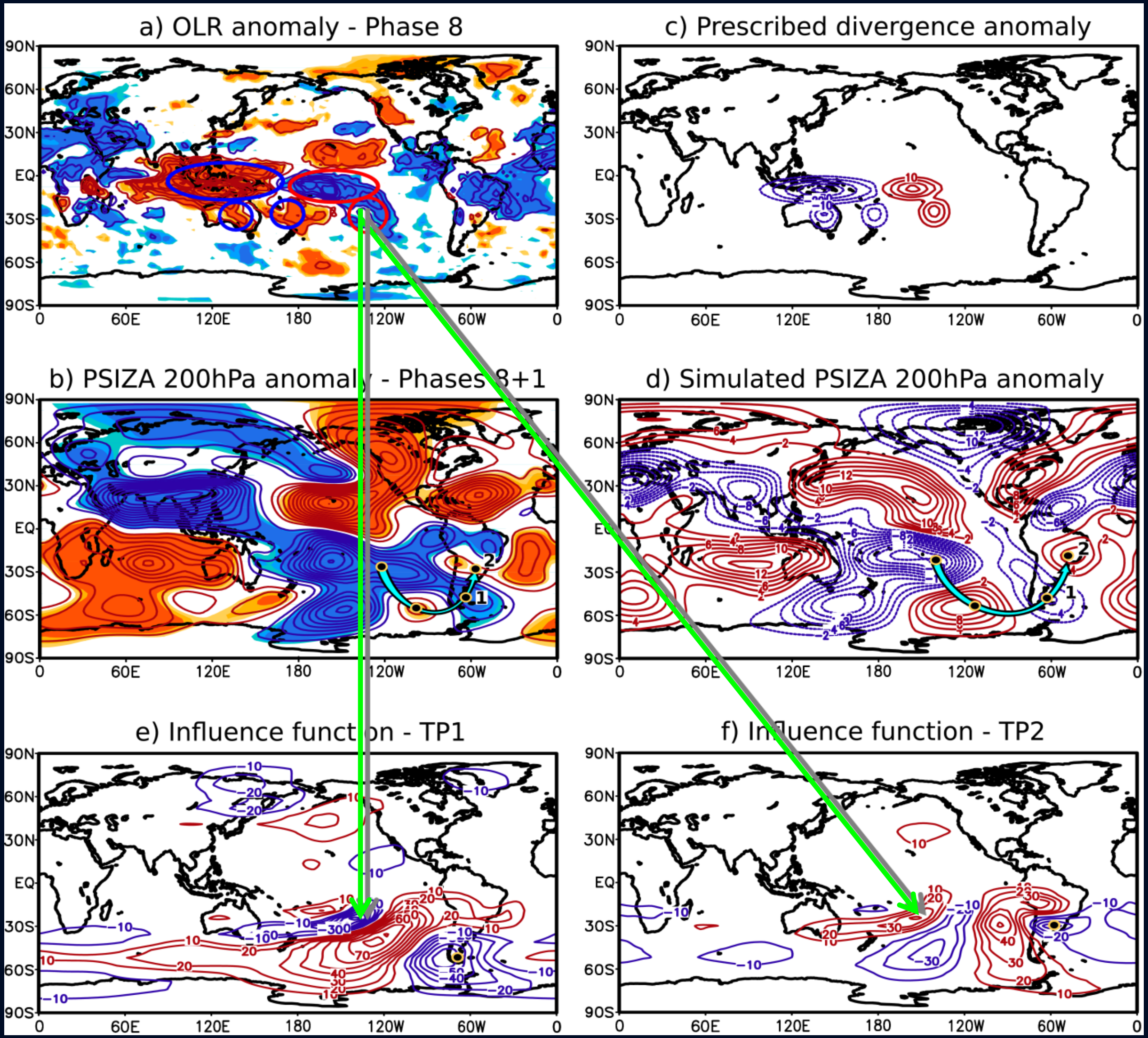
South America summer
MJO daily precipitation anomalies



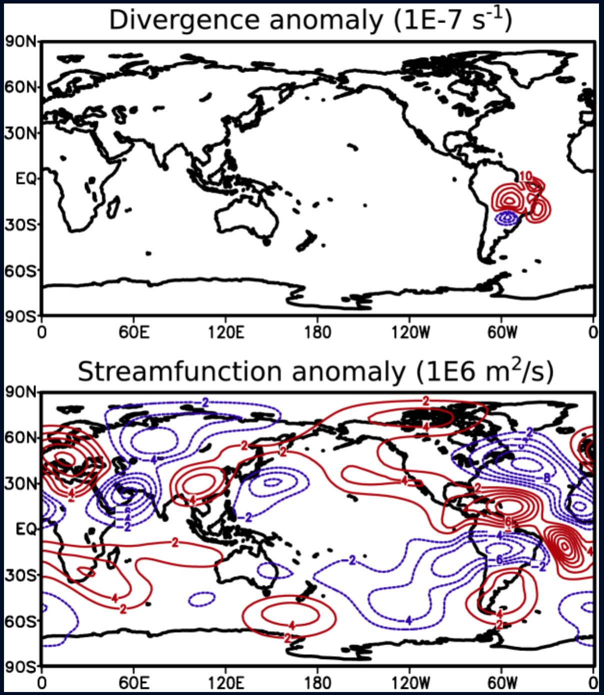
In central-east South America the daily precipitation increases more than 4 mm (~35% of climatology) in MJO phase 1, and extreme events more than double.

Tropics-extratropics teleconnection

To South America

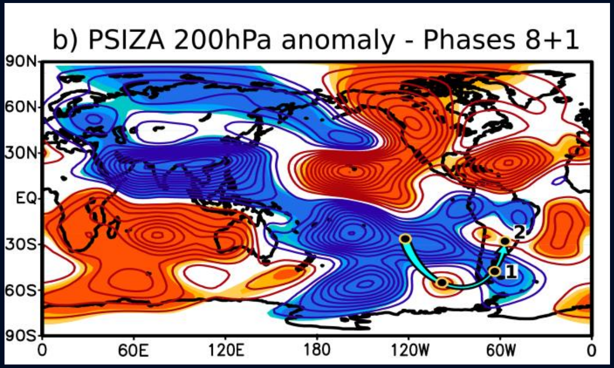


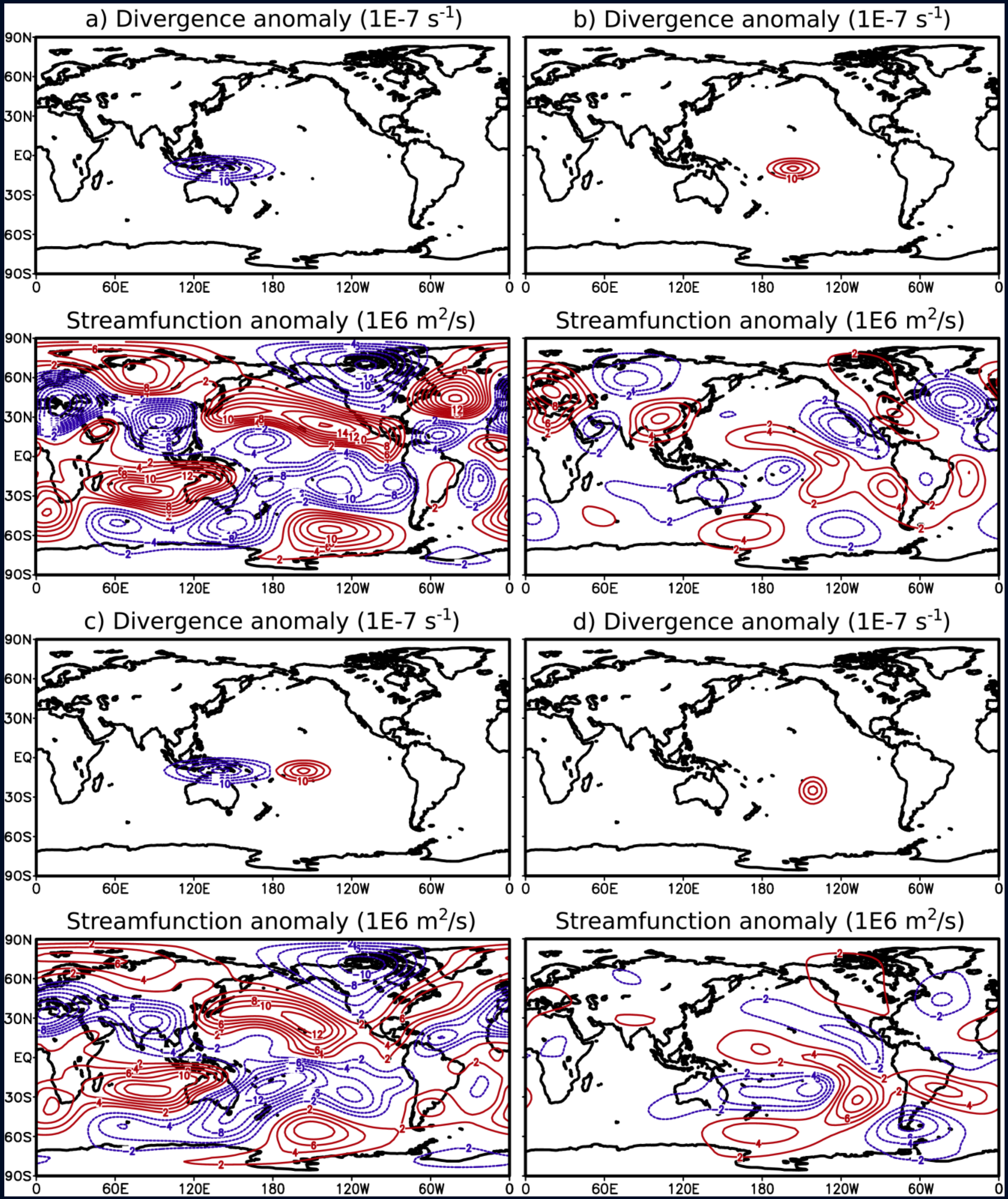
From South America



(Grimm 2019)

Tests of the tropics-extratropics teleconnection to South America



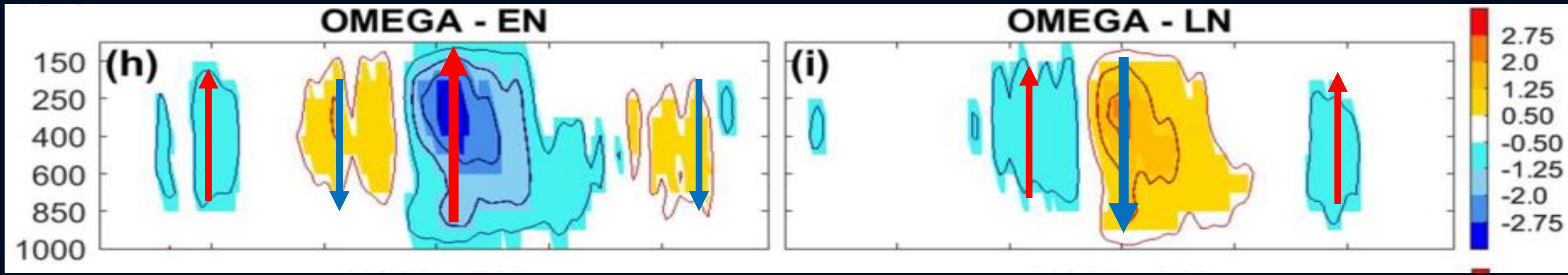


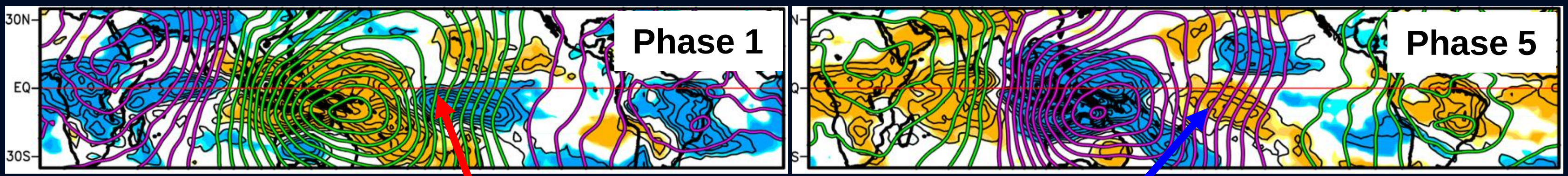
(Grimm 2019)

MJO modulation by ENSO in austral summer

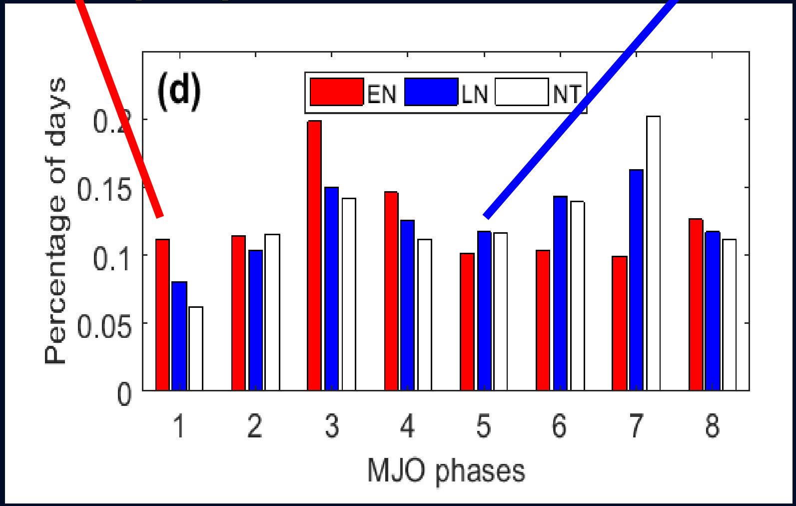
(Fernandes and Grimm 2022, submitted)

ENSO states and frequency of MJO phases

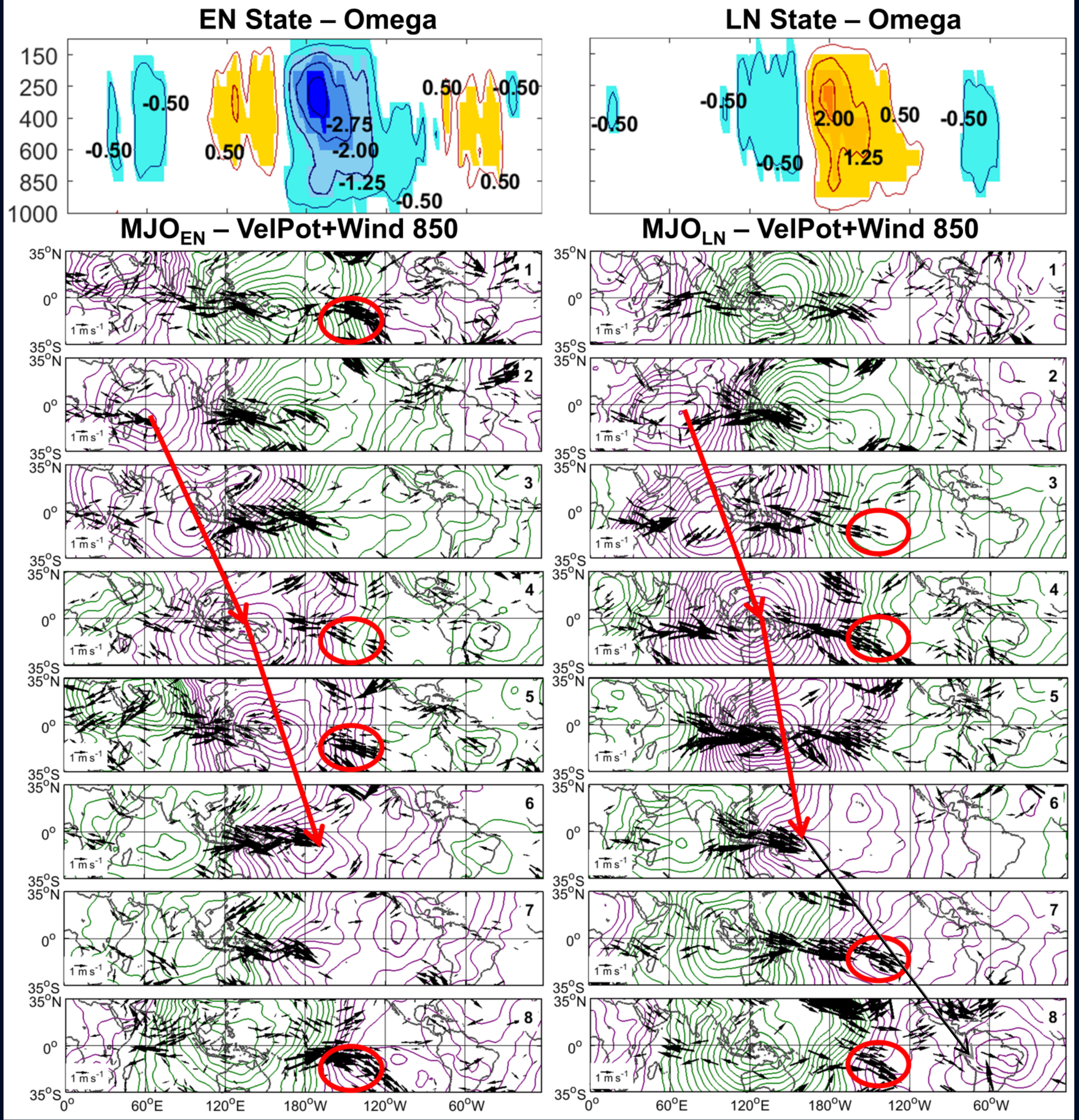




Frequency of active MJO phases (DJF) for each ENSO state.



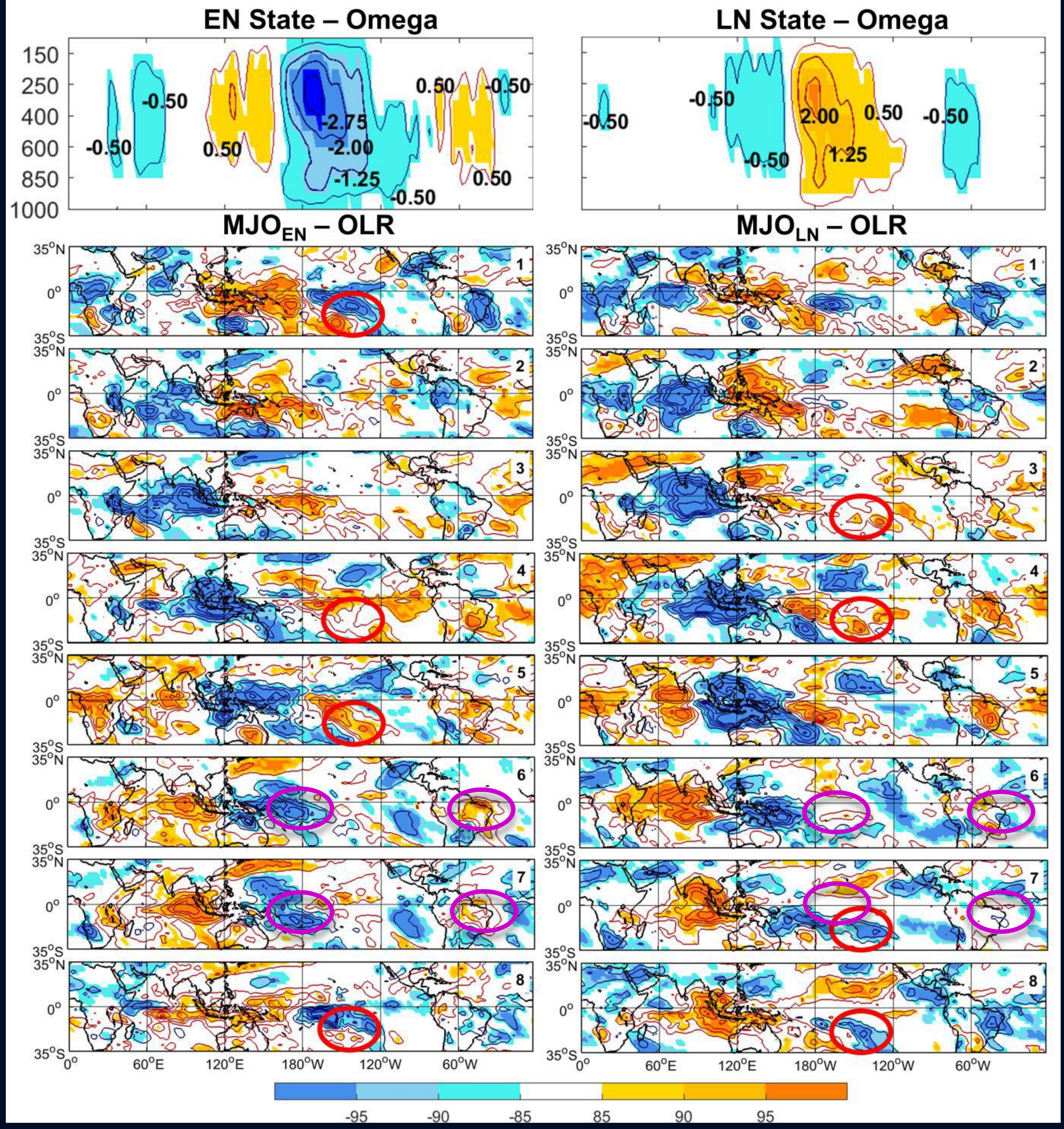
It seems that the background ENSO-related anomalies influence the relative occurrence of MJO phases with similar patterns of circulation / convection anomalies



ENSO states and MJO propagation

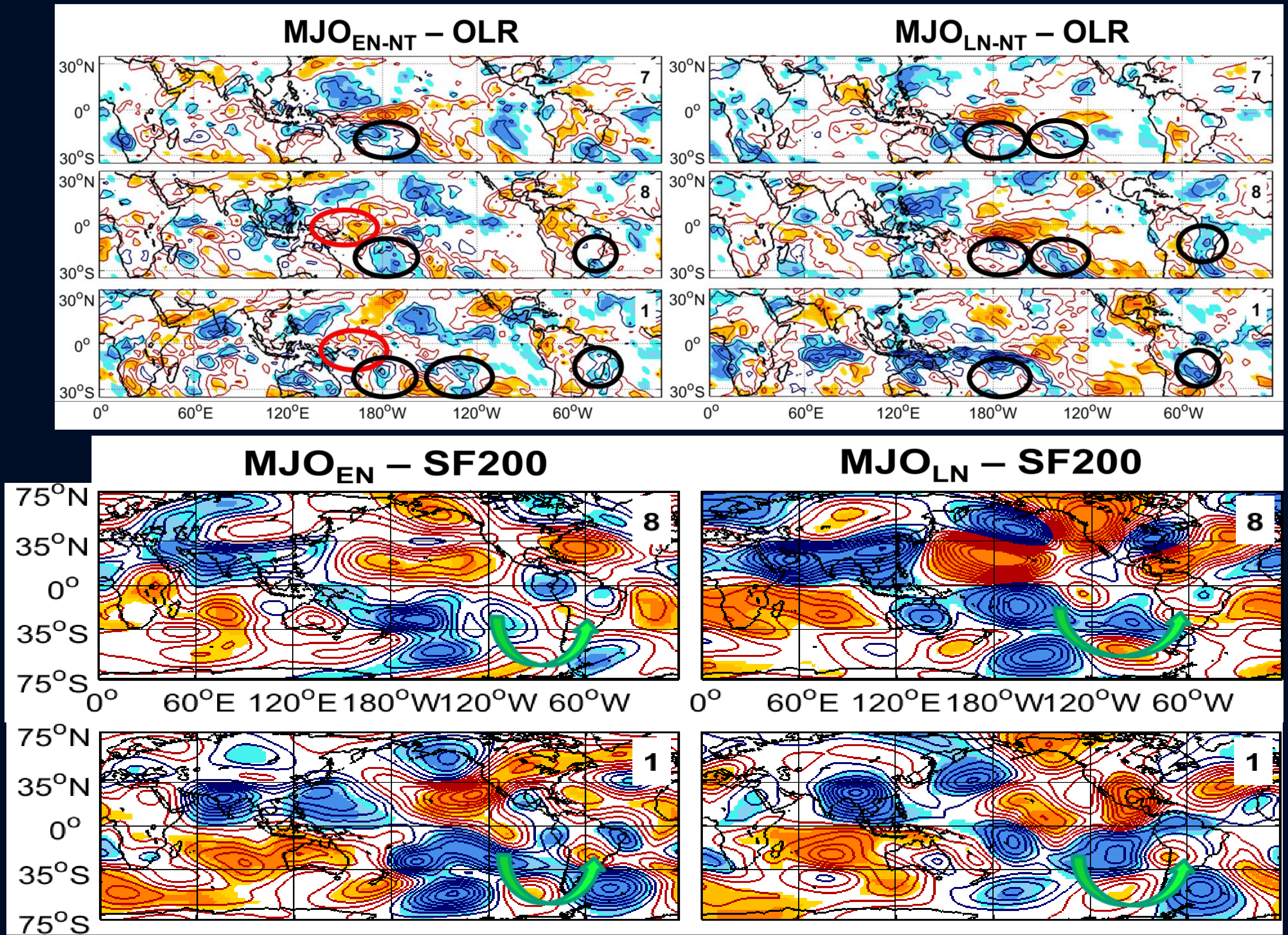
Quicker (slower) propagation is expected for weaker (stronger) convection. During LN, the stronger convection over the Maritime Continent (MC) is consistent with slower eastward propagation, and the great weakening of the convection when it moves from the MC to the western Pacific is consistent with the MC barrier effect. During EN, the anomalous convection over the MC is weaker and does not reduce much as it moves to the western Pacific Ocean with higher speed, and extends further eastward over the equatorial warm pool. Yet during LN zonal wind anomalies propagate quicker over the colder east Pacific, and anomalous convection is earlier established over SA than during EN.

ENSO states and MJO anomalous convection



(Fernandes and Grimm 2022, submitted)

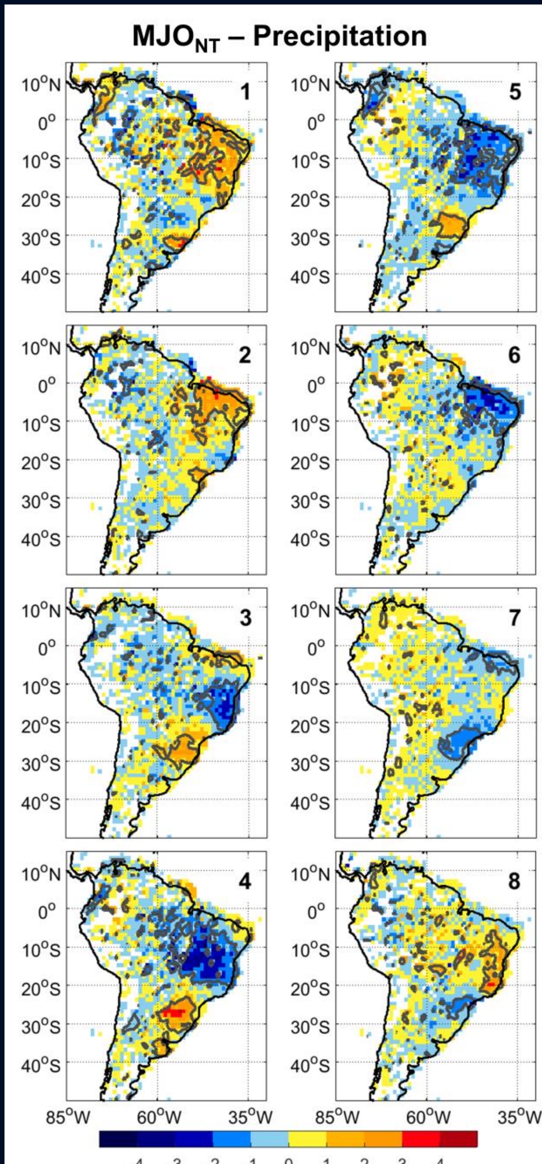
ENSO states and MJO anomalous convection and circulation

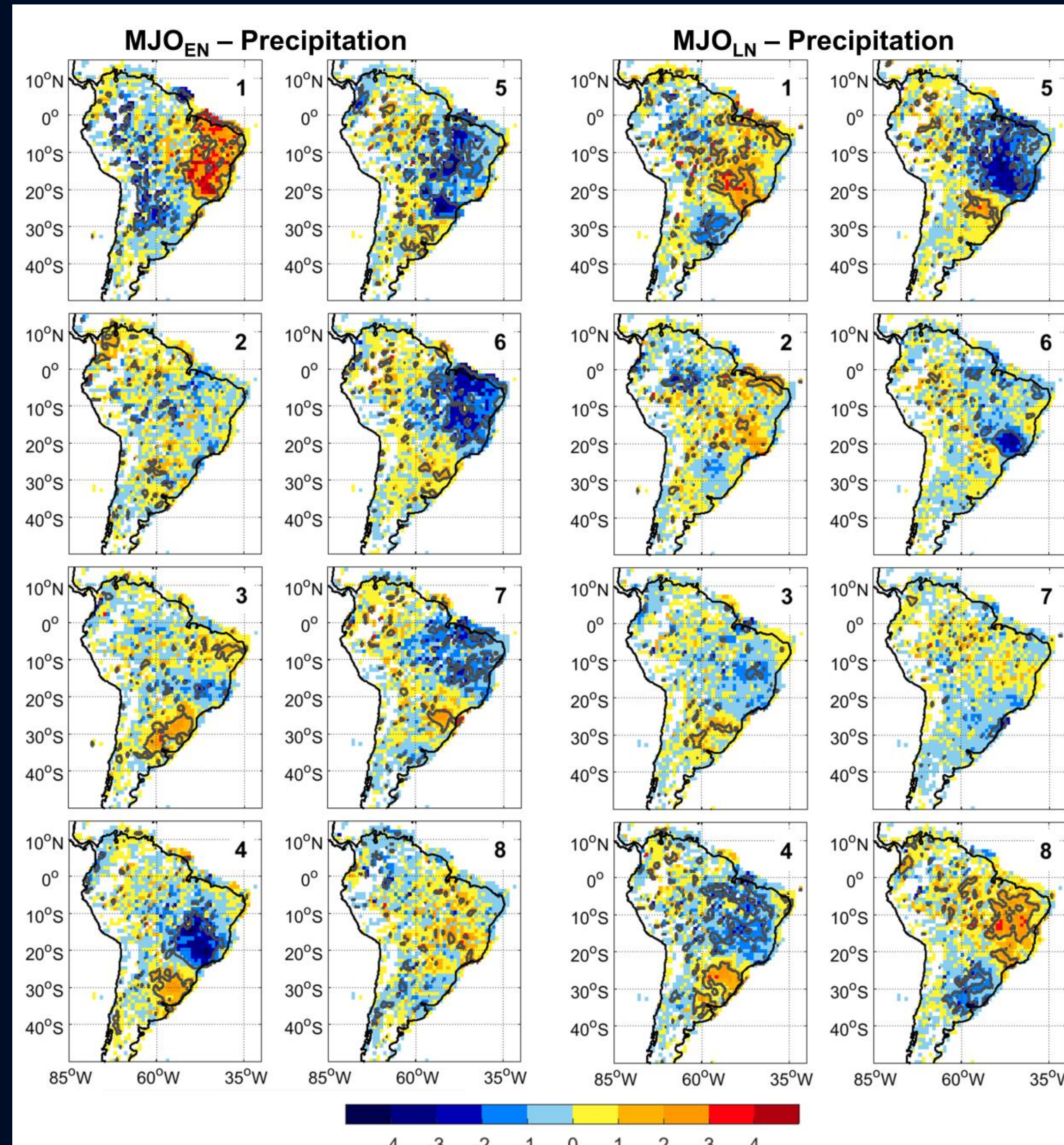


(Fernandes and Grimm 2022, submitted)

ENSO states and the MJO daily precipitation anomalies

Neutral (NT) | **El Niño (EN)** | **La Niña (LN)**

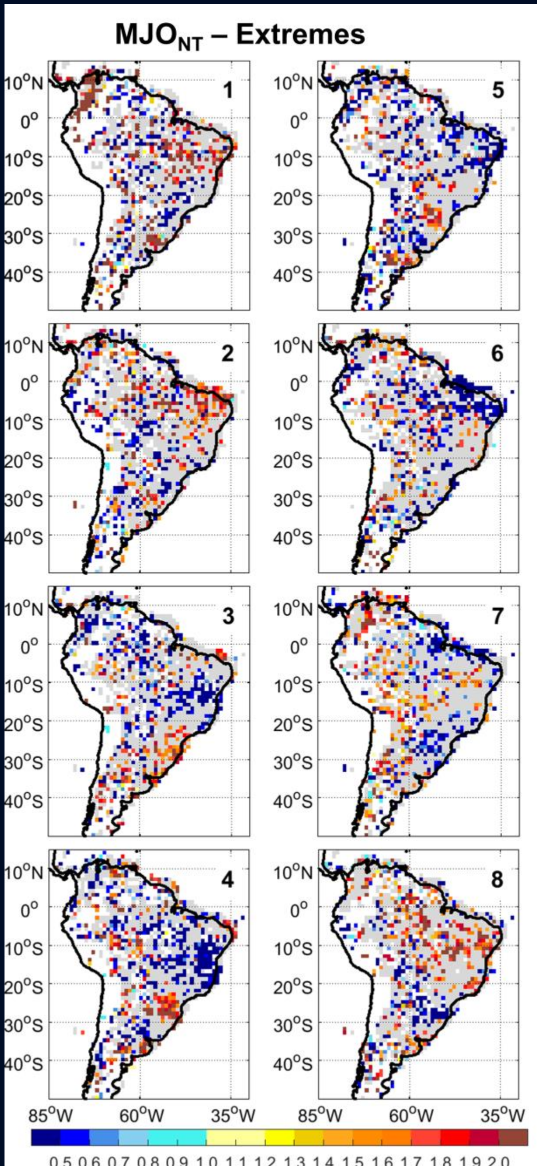




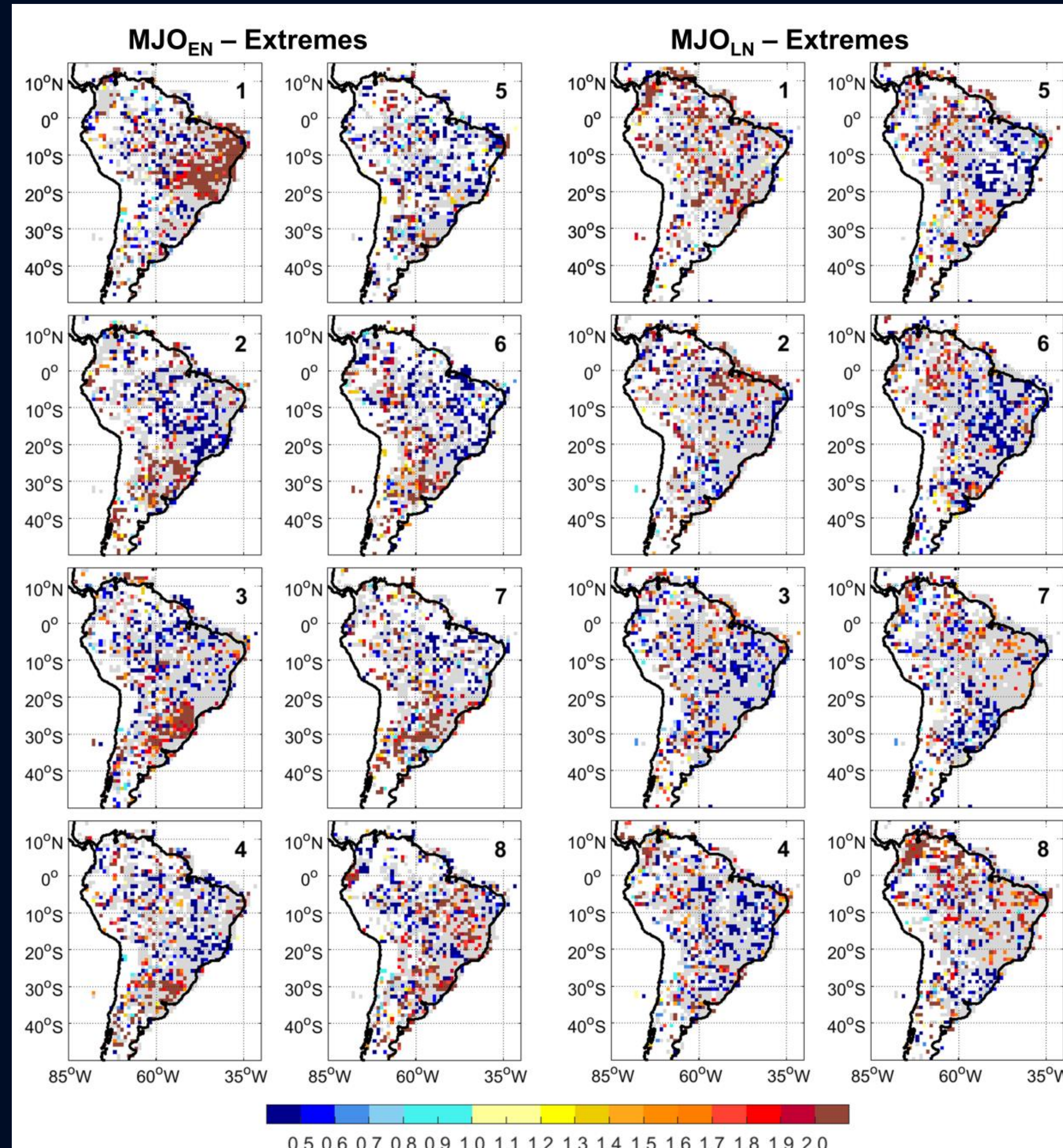
(Fernandes and Grimm 2022, submitted)

ENSO states and the MJO daily precipitation anomalies

Neutral (NT)

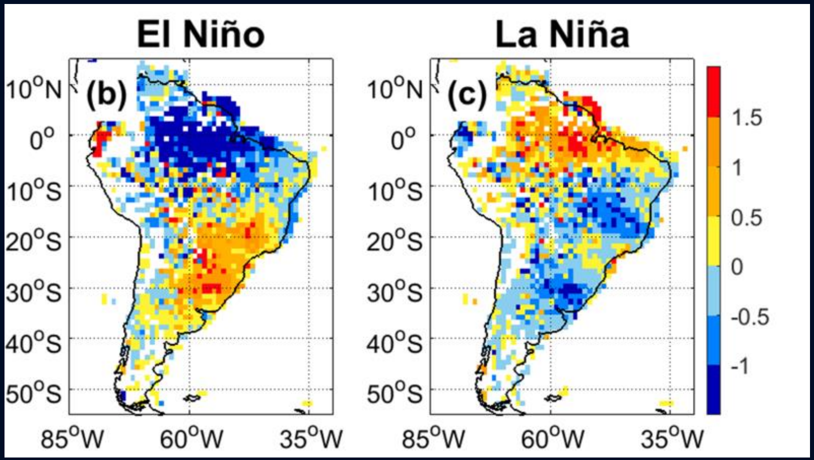


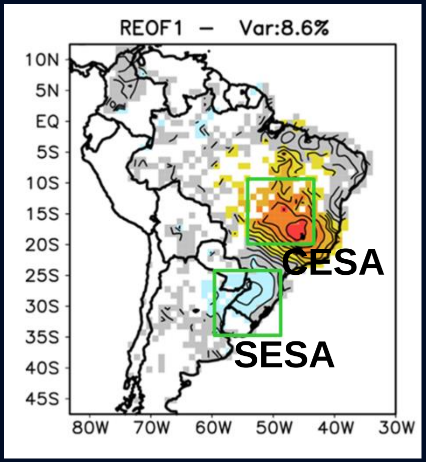
El Niño (EN) **La Niña (LN)**

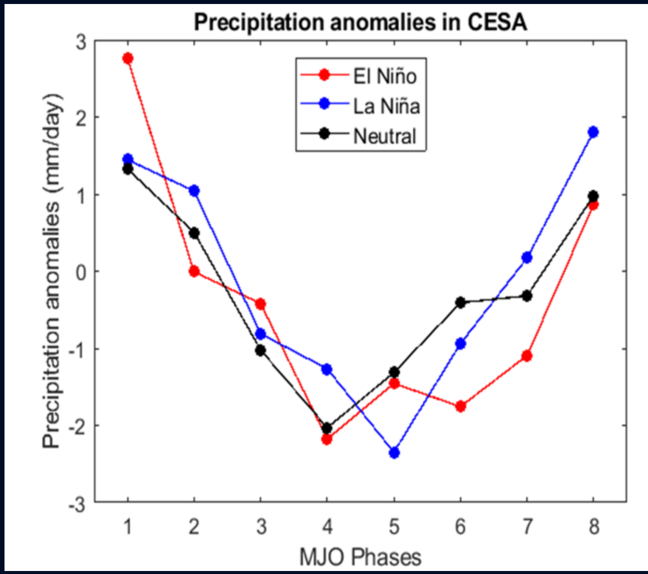


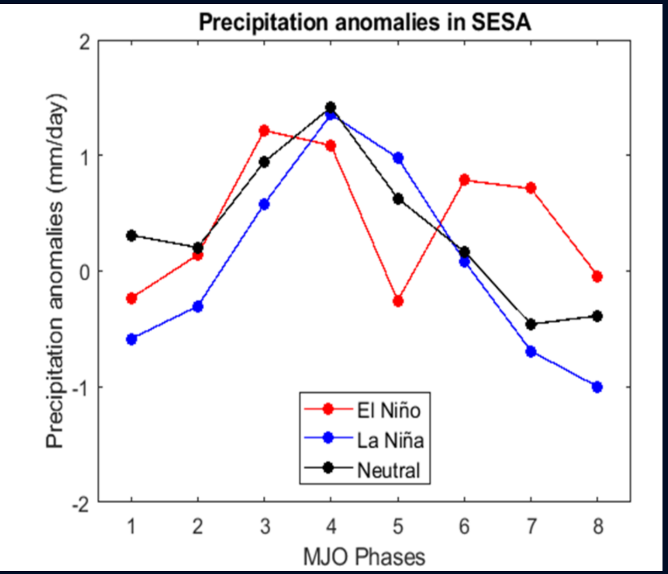
Ratio between the probability of extreme precipitation events in each MJO phase and the mean probability

ENSO states and the MJO impact on the first intraseasonal precipitation variability mode in SA









(Fernandes and Grimm 2022, submitted)

Considering the strongest Walker circulation and tropical convection anomalies associated with ENSO and MJO, the MJO phases that most project on the ENSO states in DJF are MJO_{8+1} (onto EN state) and MJO_{4+5} (onto LN state). Therefore, we expect the anomalous convection in MJO_{EN}phases8+1 and MJO_{LN}phases4+5 to be reinforced in EN and LN, respectively. As there is a lag between forcing and precipitation response, strongest enhancement is expected in MJO_{EN}phase1 and MJO_{LN}phase5, as is confirmed in the figure. On the other hand, anomalies in CESA are expected to weaken in MJO_{EN}phase5 and MJO_{LN}phase1, with respect to the opposite ENSO state.

Conclusions (1)

The background ENSO-related anomalies influence several aspects of MJO (relative occurrence of phases, propagation, convection and teleconnections), and therefore modify the MJO impacts on South America (SA), such as precipitation anomalies and their temporal distribution throughout the MJO cycle. Changes include:

- **a delay in the peak of the teleconnections between central-eastern Pacific and SA, from MJOphase8 in LN to MJOphase1 in EN;**
- **enhanced MJO convection in the central-east subtropical South Pacific in MJO_{LN}phases7+8 and a little further east in MJOENphases8+1, in a region efficient in generating tropics-extratropics teleconnections to SA, producing rainfall anomalies over Central-East SA (CESA), especially the South Atlantic Convergence Zone (SACZ), strongest one phase earlier in LN (MJO_{LN}phase8) than in EN (MJO_{EN}phase1), and a little shifted east in the latter than in the former;**
- **predominant increase (or reduction) in the frequency of extreme events over densely populated SA regions where both ENSO and MJO contribute in the same direction, with the greatest increase over CESA (including SACZ) during EN, in MJO_{EN}phase1, and over Southeast SA (SESA), in MJO_{EN}phase3;**

Conclusions (2)

- enhanced amplitude in both states, EN and LN, of the first continental intraseasonal dipole-like mode of precipitation variability between CESA and SESA, with maximum opposite anomalies in CESA, the center with largest amplitude, in phases 1 and 4 for EN, and phases 8 and 5 for LN;
- change of MJO-related anomalous patterns due to the influence of ENSO background state opposite or similar to MJO anomalies. For instance, over northeast SA, the MJO-related anomalous subsidence and dryness that occurs mainly in phases 5 and 6 is enhanced during EN and extended to phase 7, because the EN background anomalies of Walker circulation enhance the anomalous convection in central Pacific and subsidence over northeast SA. During the LN state, the opposite occurs.