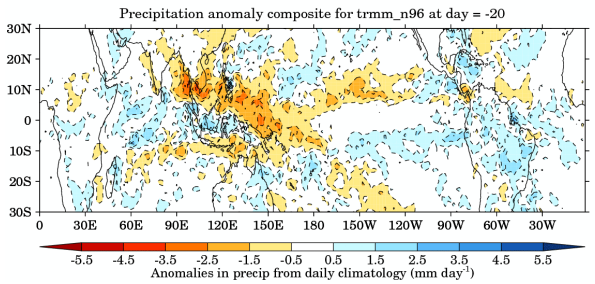
MJO impacts on South America monsoon season and their modulation by ENSO in MetUM-GOML3 model

Laís G. Fernandes, Alice M. Grimm and Nicholas P. Klingaman



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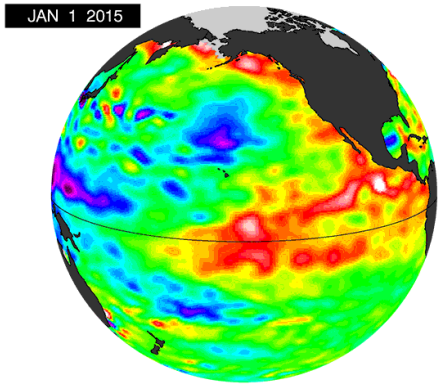
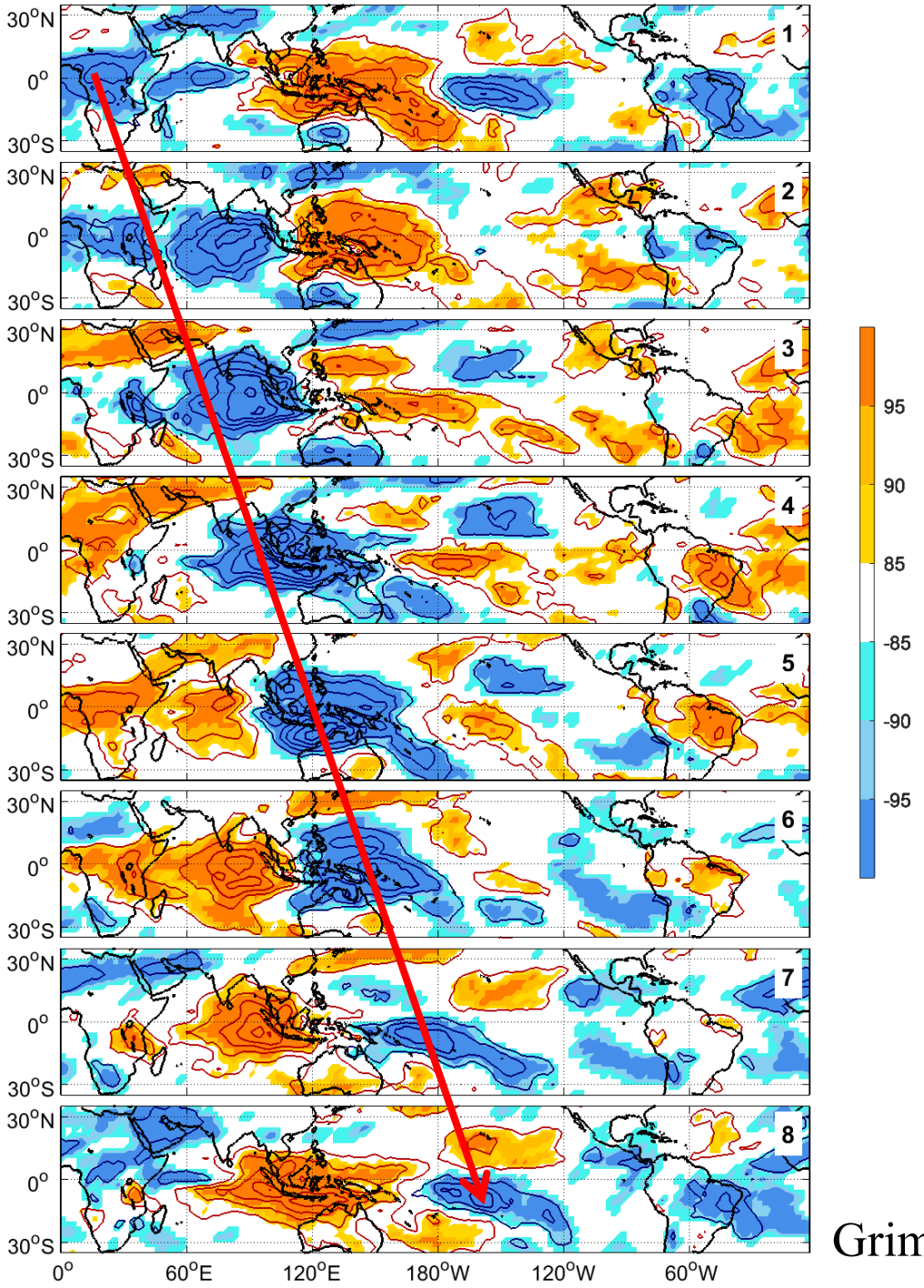


6th WGNE Workshop, ECMWF, 2022

Reading, 2nd November 2022.

The Madden-Julian Oscillation (MJO)

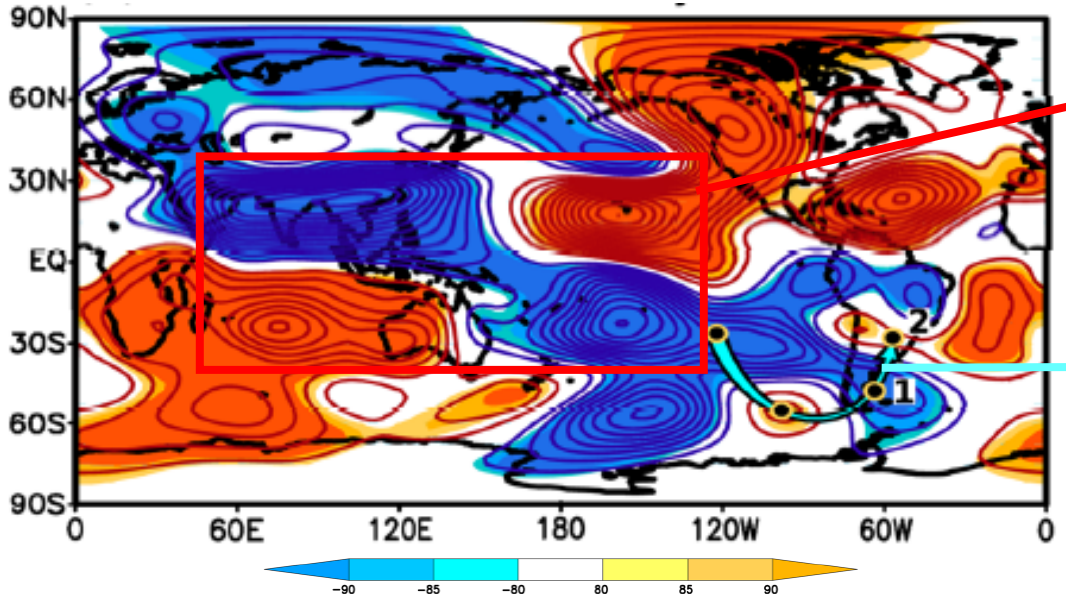


MJO OLR anomalies (Wm^{-2}). The color bar indicates confidence levels for OLR anomalies, with signs indicating positive or negative anomalies.

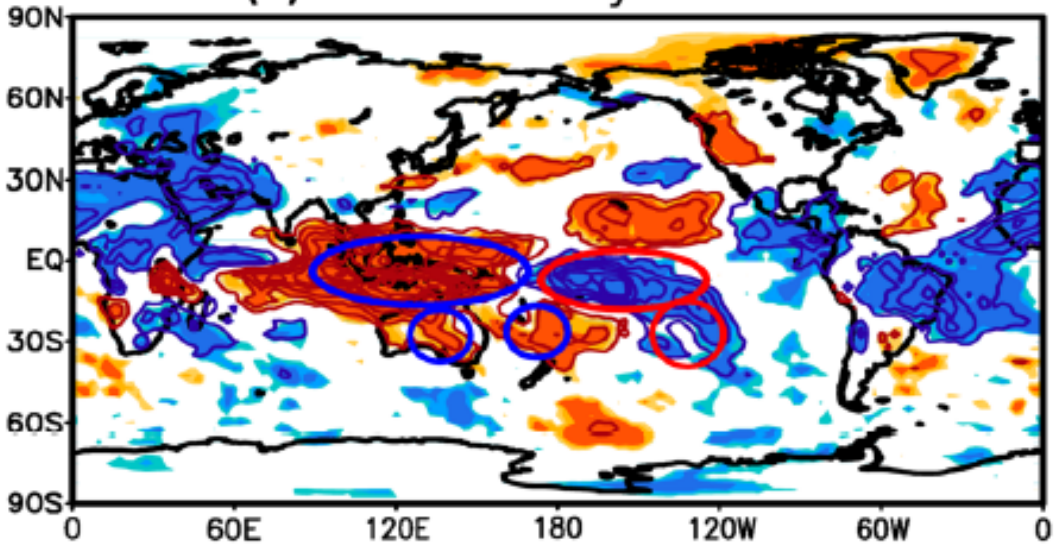
Grimm (2019)

MJO impacts on SA rainfall

Streamfunction anomalies (200 hPa) ($m^2 s^{-1}$) Phases 8+1. (Grimm, 2019)



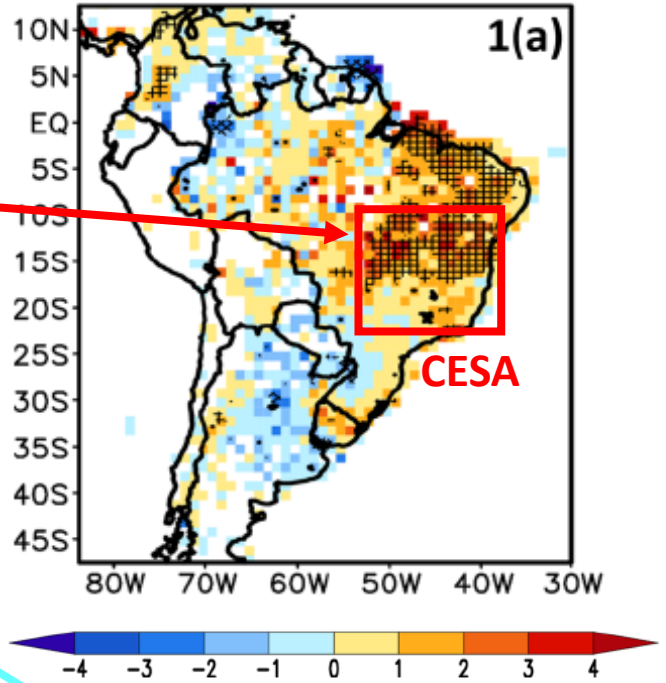
(a) OLR anomaly - Phase 8

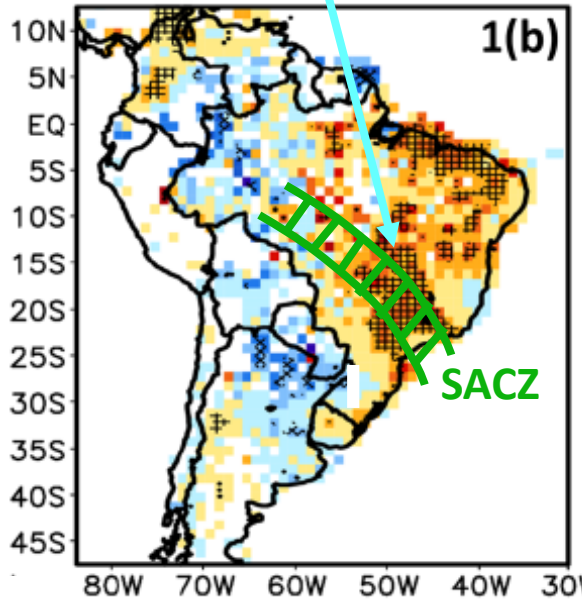


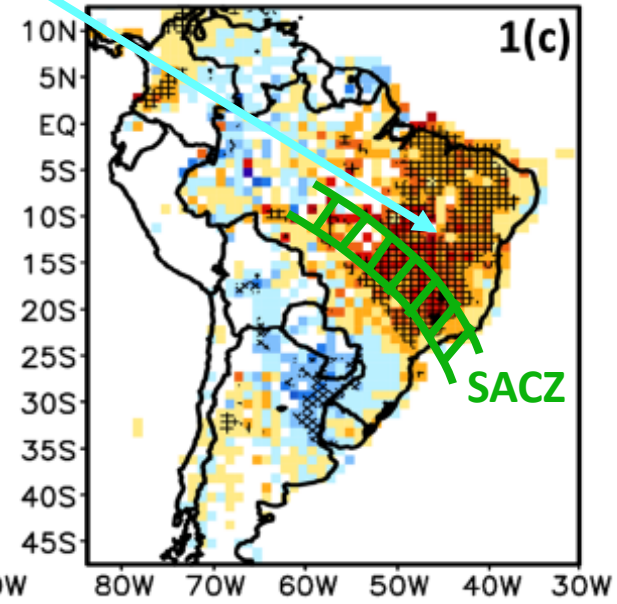
Quadrupole (Rossby and Kelvin equatorial waves)

Extratropical Rossby waves

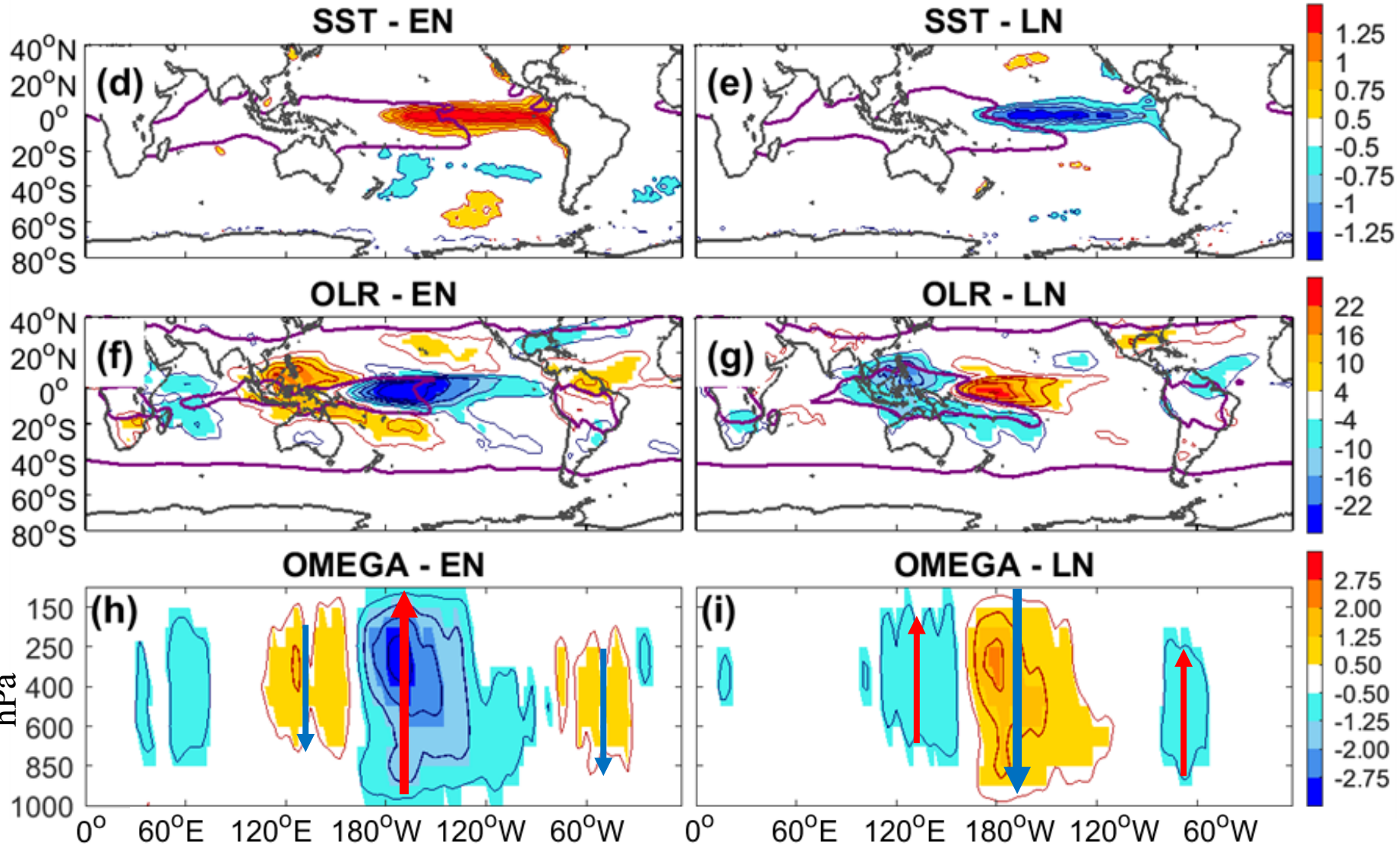
Precipitation anomalies ($mm\ day^{-1}$).

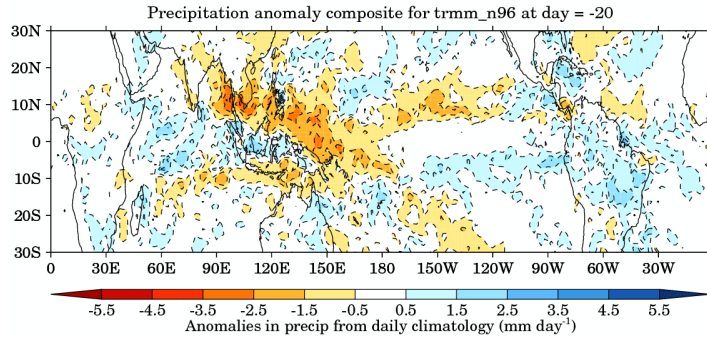






The El Niño-Southern Oscillation (ENSO) background state





Precipitation anomalies associated with the MJO.

Changes in SST (°C), OLR (Wm^{-2}), and vertical motion (averaged over 0-15°S) ($Pa\ s^{-1}$) produced by El Niño and La Niña.

Hypothesis

The ENSO phenomenon alters the MJO impacts on SA rainfall on intraseasonal timescales.

Main objective

To identify the ENSO influence on the MJO impacts on SA through the ENSO modulation of the MJO structure, propagation and teleconnections.

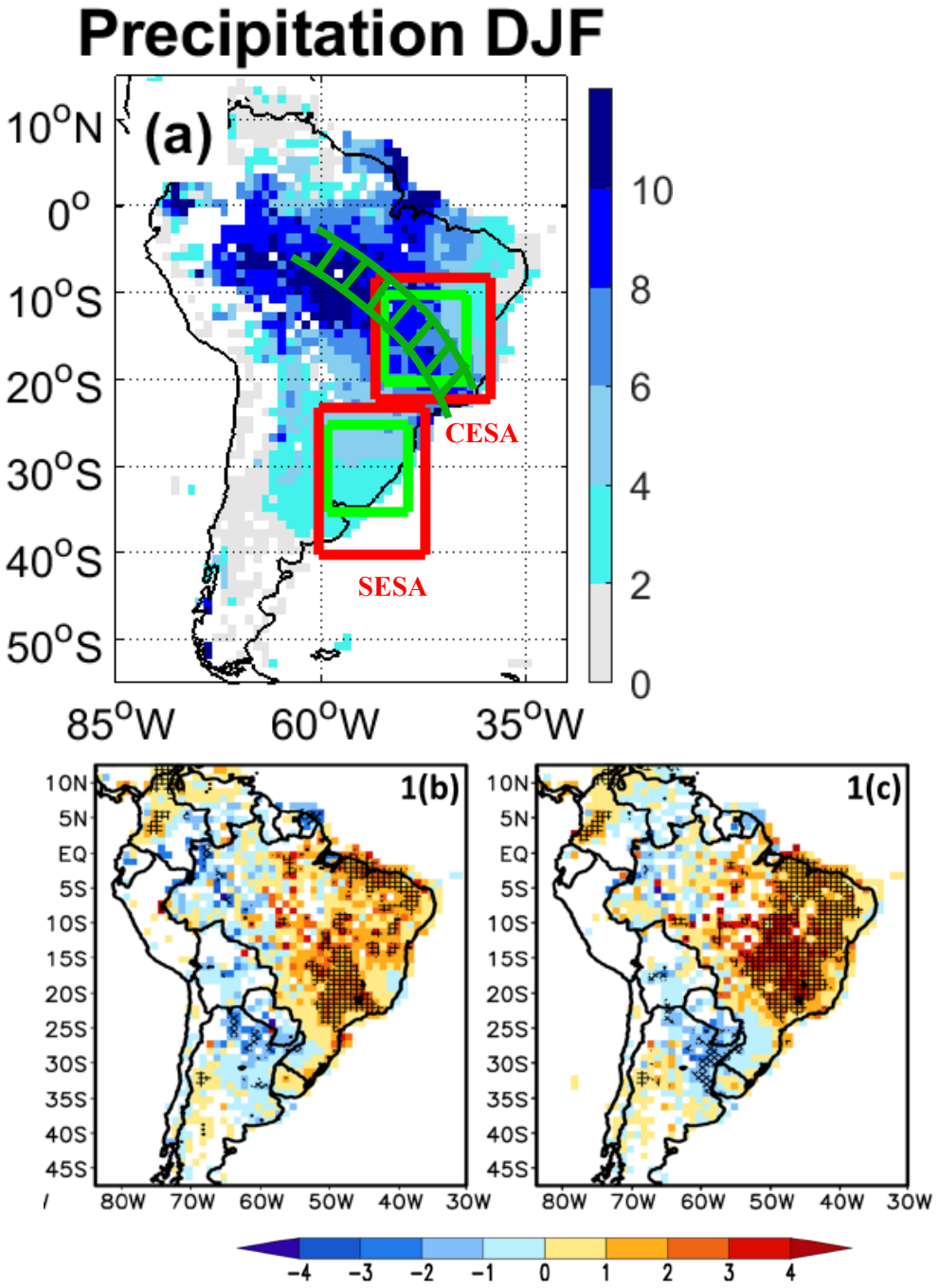
- ❑ Observational datasets;

- ❑ Simulations with the latest version of the coupled model Met Office Global Ocean Mixed Layer (MetUM-GOML3, Hirons et al., 2015);

- We chose to analyze the ENSO modulation of the MJO impacts on South America during December-February (DJF) between 1979-2009.
- How did we isolate the ENSO anomalies (deviations from long-term averages) from the modulation that ENSO exerts on the MJO precipitation anomalies?

We compute daily anomalies of precipitation and atmospheric circulation for MJO phases in the three different ENSO states.

Then, we submit these anomalies to a filter with 20-90 day band that retains only the variability signal associated with the MJO.

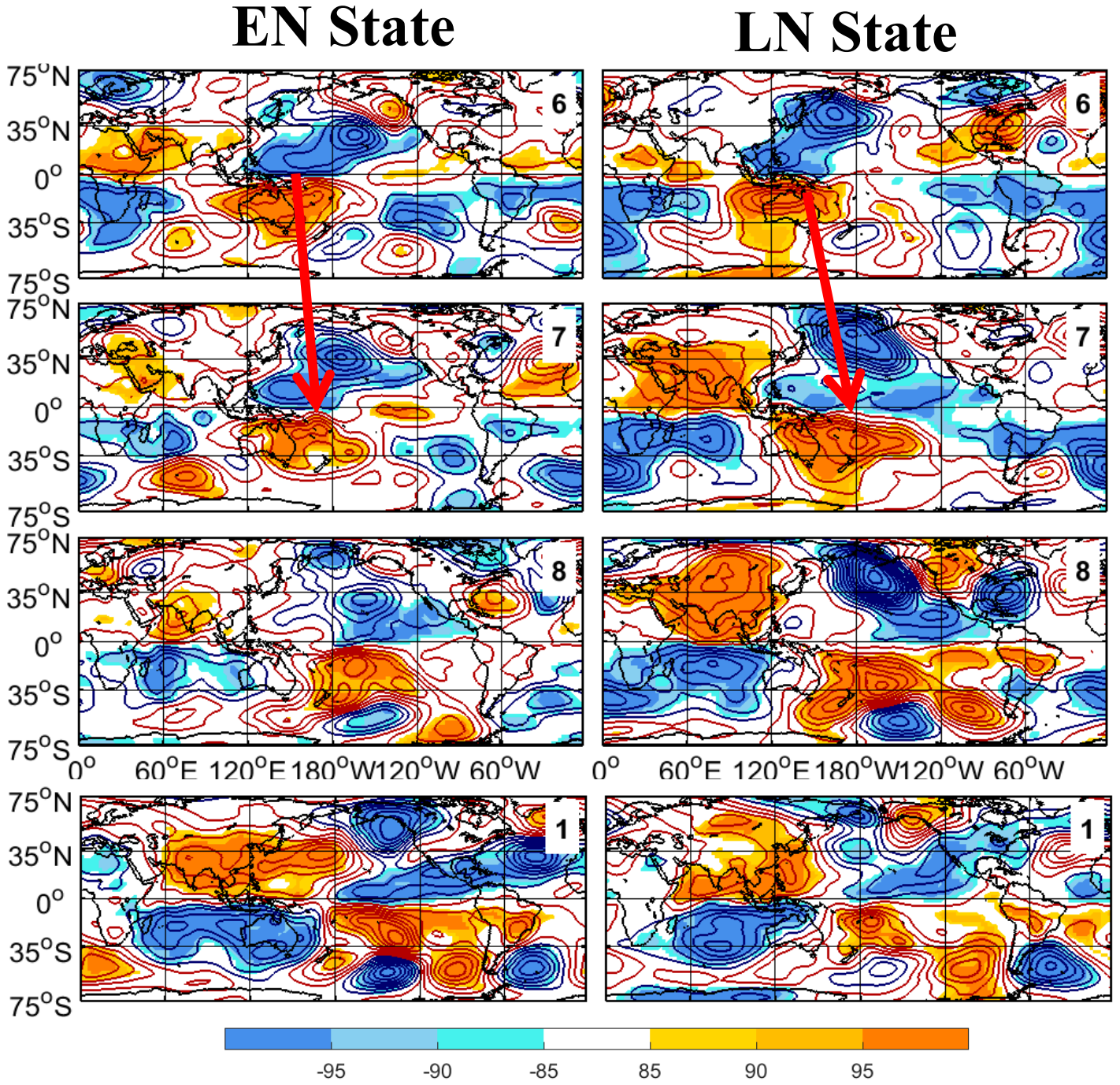


ENSO modulation of global MJO and its impacts on South America

Laís G. Fernandes and Alice M. Grimm

(Submitted in Journal of Climate)

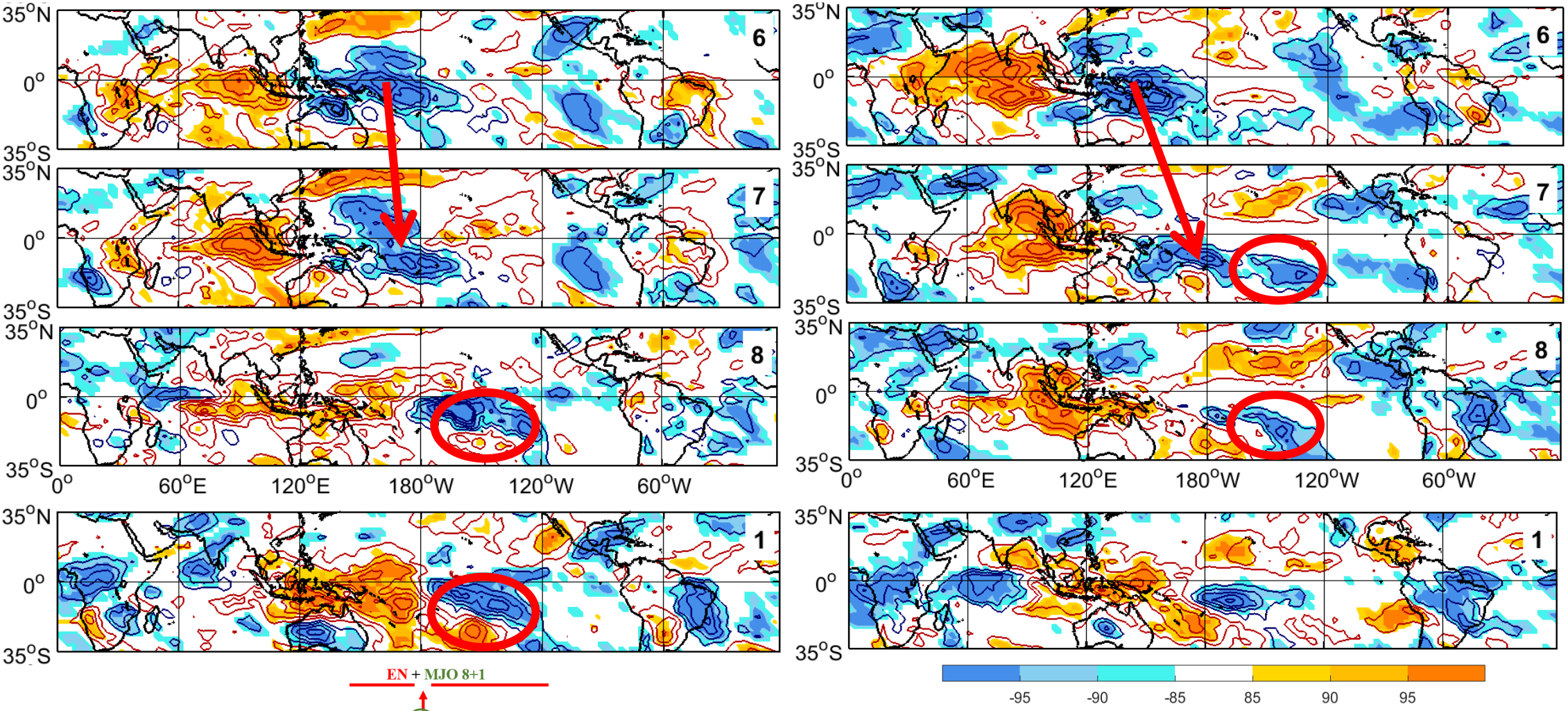
MJO phases 6, 7, 8, 1

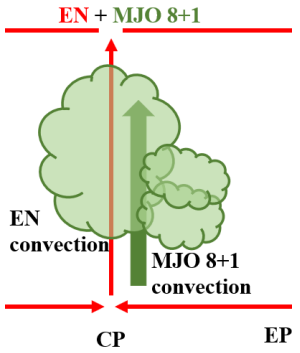


Streamfunction anomalies (850 hPa) ($m^2 s^{-1}$). The color bar indicates confidence levels for the streamfunction anomalies, with signs indicating positive or negative anomalies.

EN State

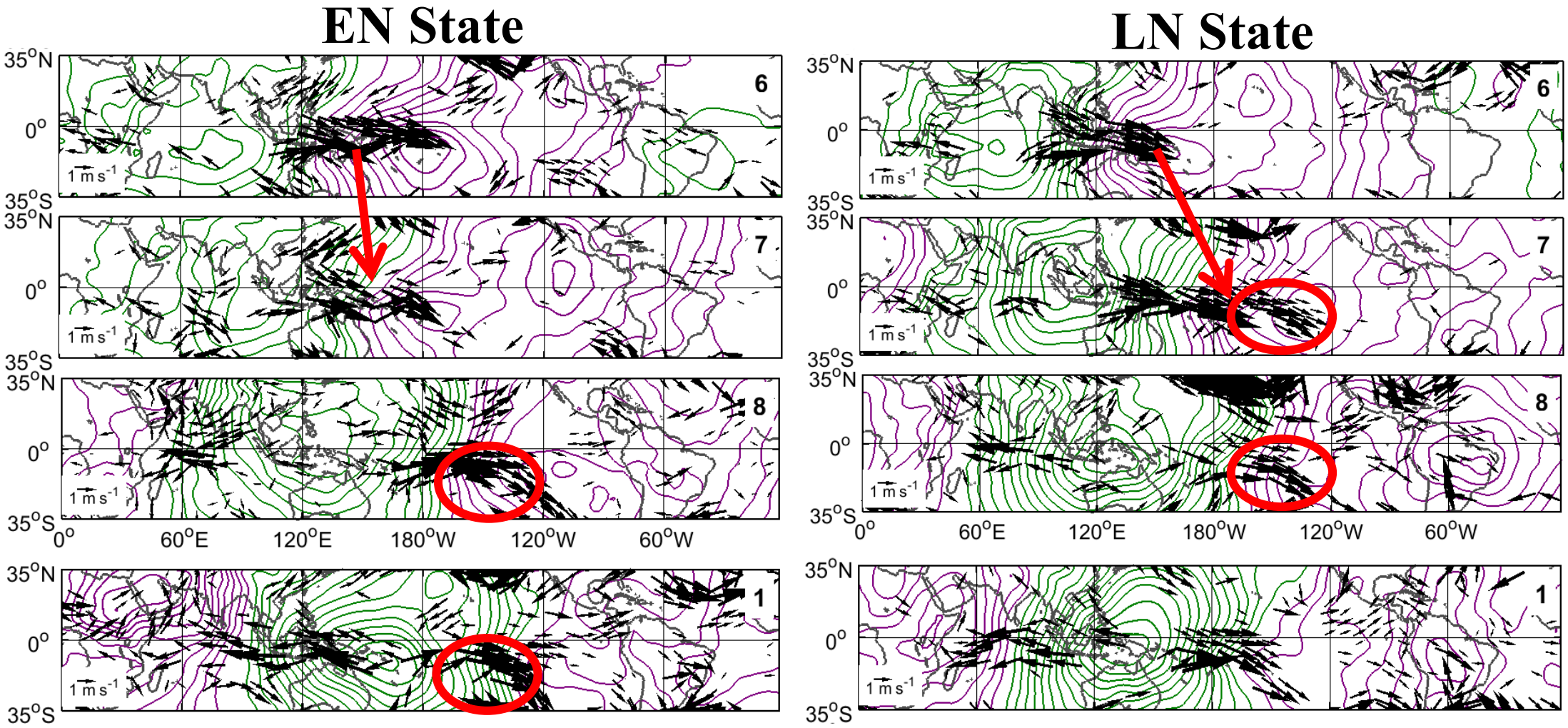
LN State





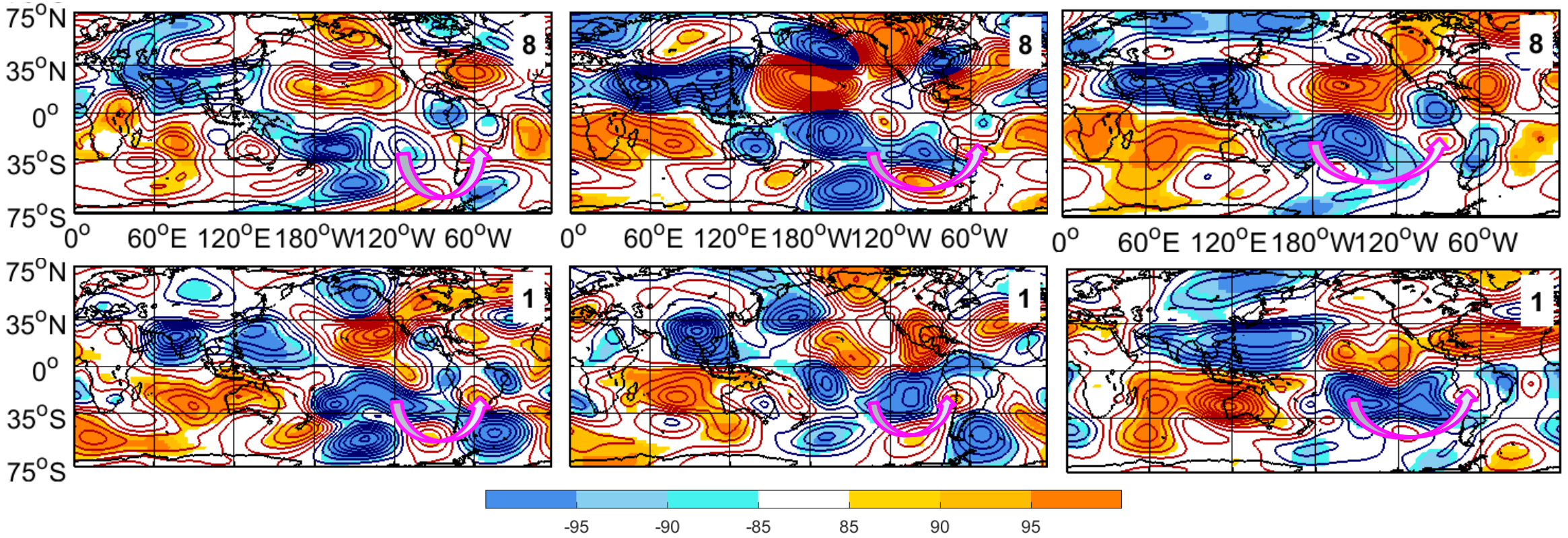
MJO phases 6, 7, 8, 1

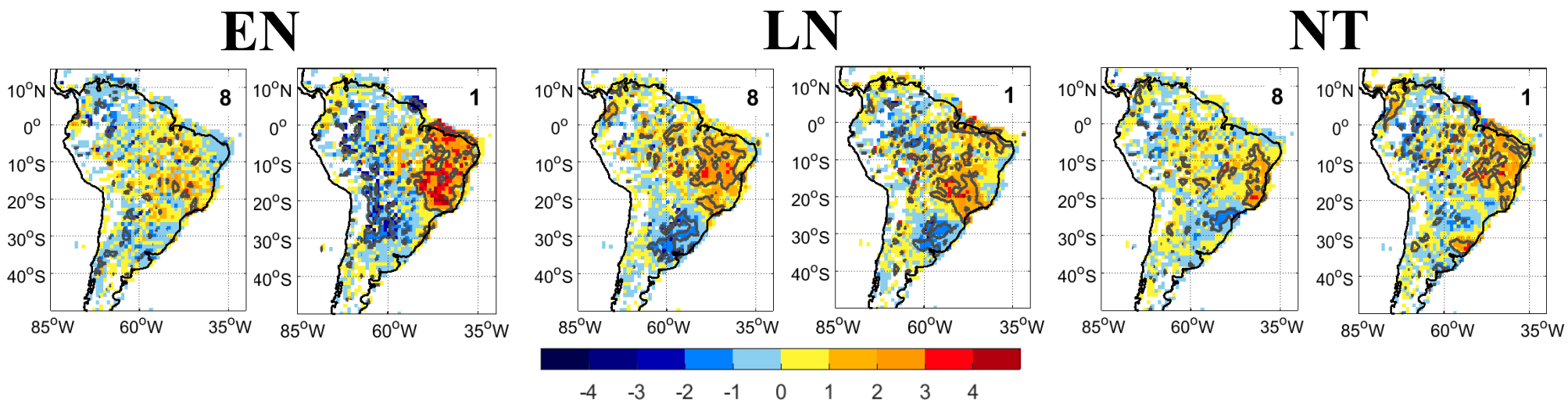
OLR anomalies (Wm^{-2}) .



MJO phases 6, 7, 8, 1

Low-level velocity potential ($m^2 s^{-1}$) and wind (ms^{-1}) .

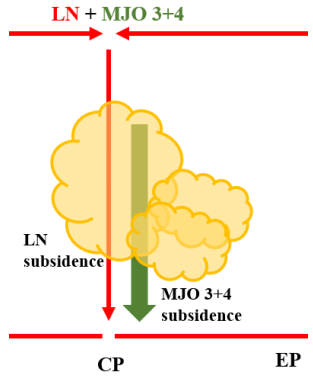




Streamfunction (200 hPa) ($m^2 s^{-1}$) and precipitation anomalies ($mm\ day^{-1}$).

MJO phases 8 and 1

MJO
phase 4

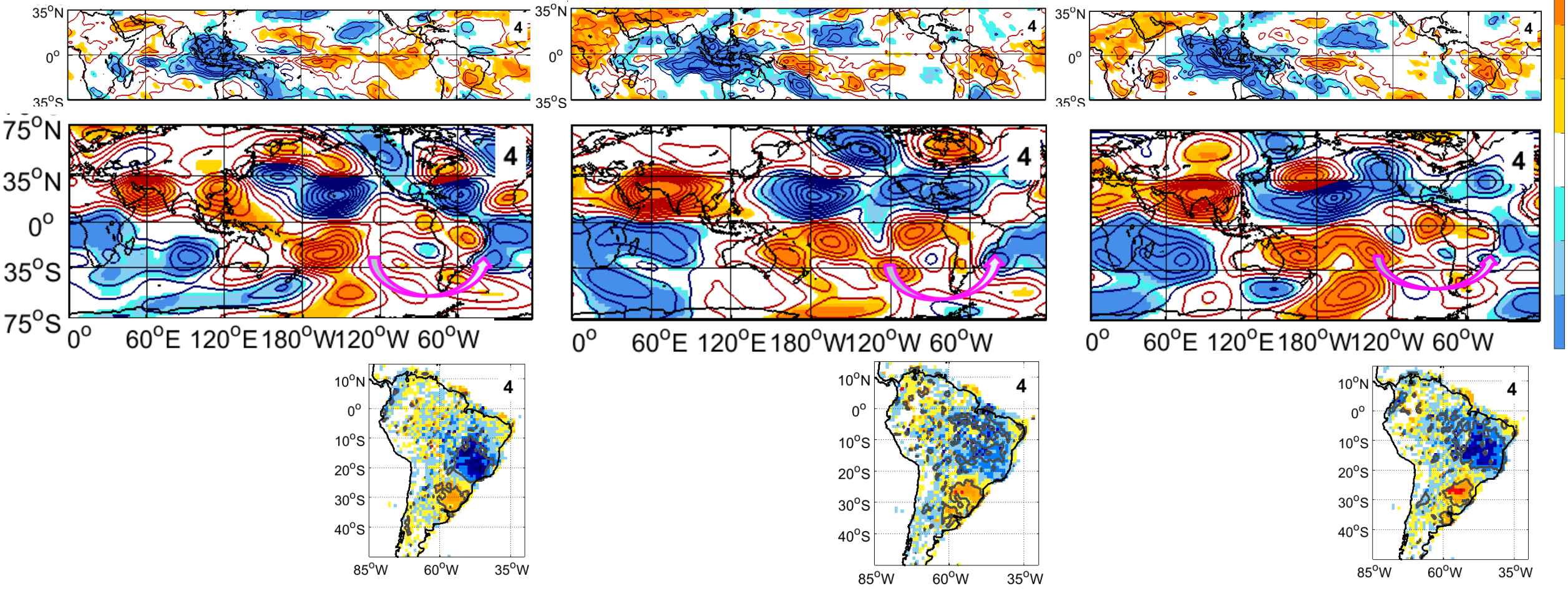


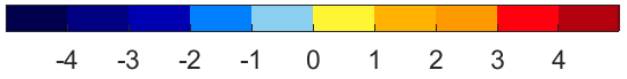
OLR (Wm^{-2})
Streamfunction (200 hPa) (m^2s^{-1}) and precipitation anomalies ($mm\ day^{-1}$).

EN State

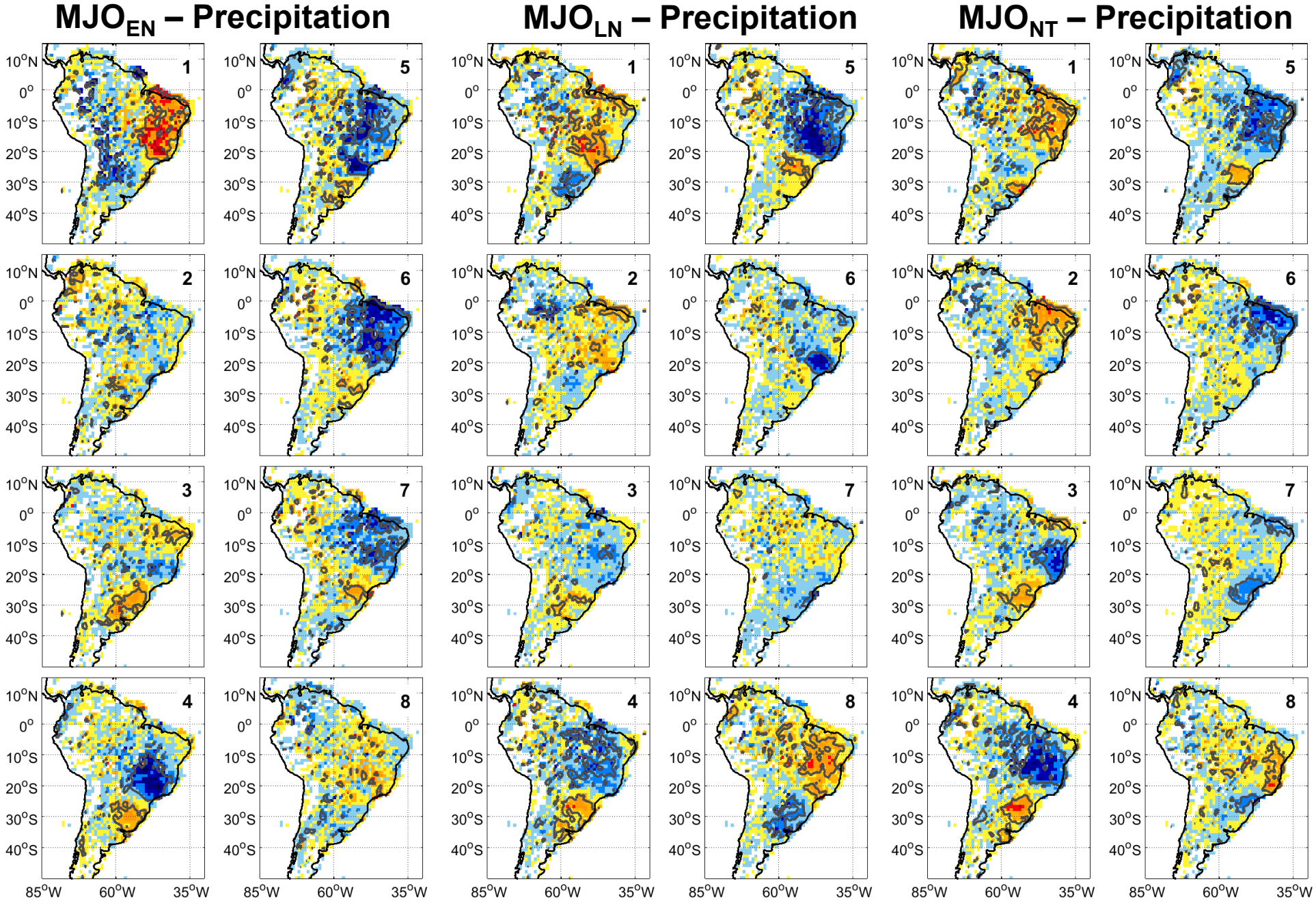
LN State

NT State

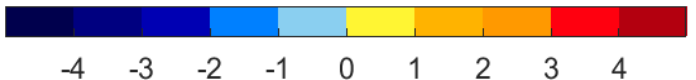


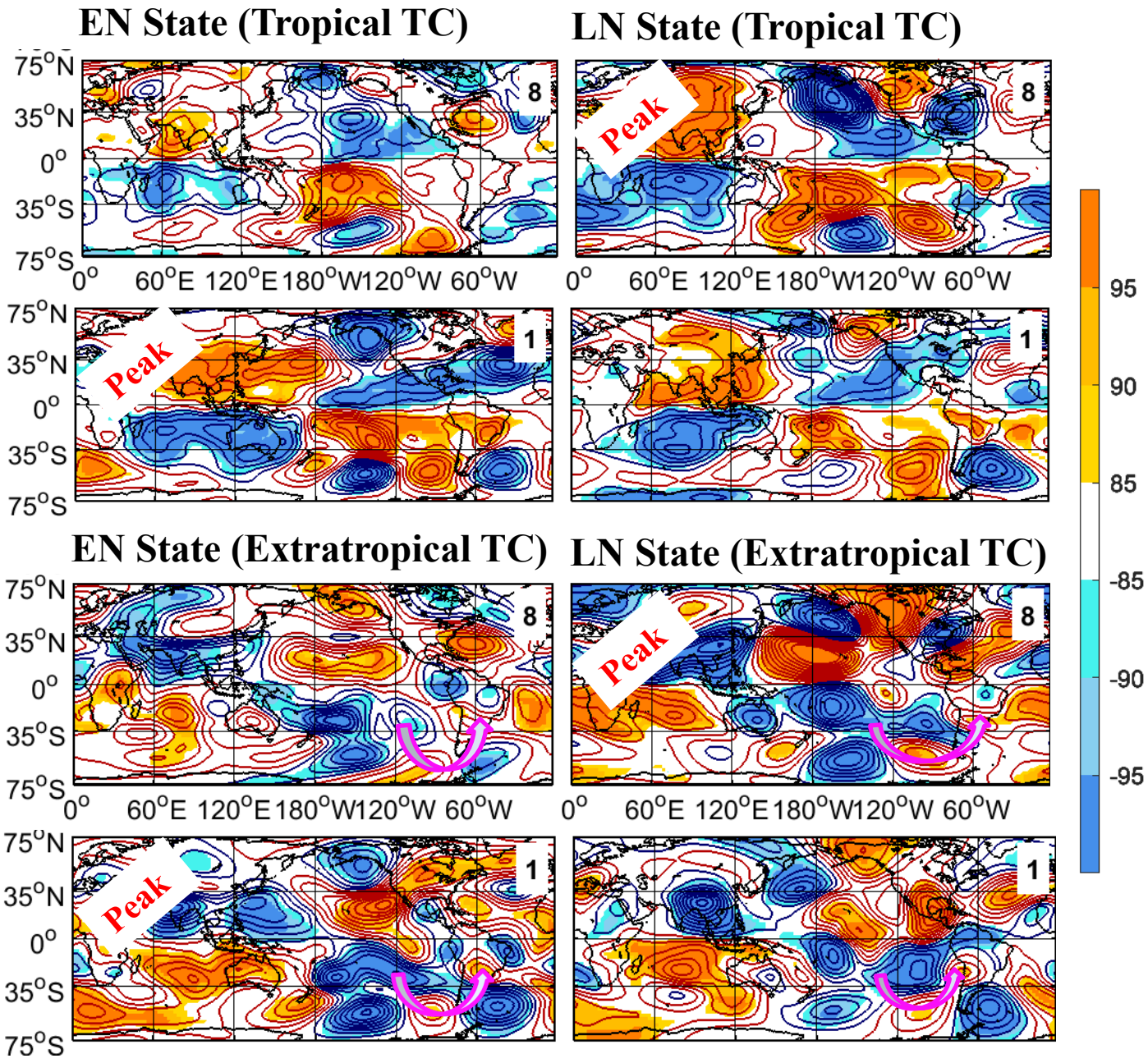


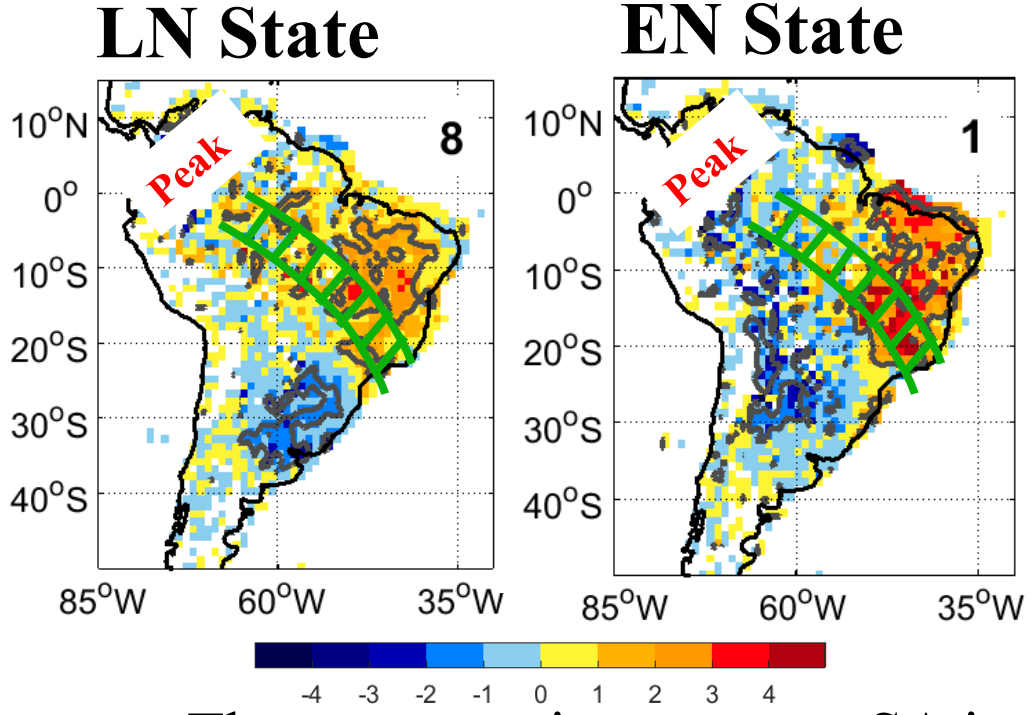
The ENSO driven-modulation can produce significant changes in the MJO impacts over SA;



Precipitation anomalies ($mm\ day^{-1}$).







The strongest impact over SA is advanced by one phase in LN with respect to EN, since both, the tropics-tropics and the tropics-extratropics teleconnections that connect the MJO to SA are established one phase before in LN;

“The ENSO seems to modulate the MJO teleconnections to SA in complex ways due to its widespread influence on both the basic state and the MJO convective anomalies.”

- To go further in the investigations, how does the MetUM-GOML3 model represent the MJO impacts on SA and their ENSO modulations?

MJO impacts on South America and their modulation by ENSO in MetUM-GOML3 model

Laís G. Fernandes, Alice M. Grimm and Nicholas Klingaman

Model

- Coupled model Met Office Global Ocean Mixed Layer (MetUM-GOML3);
- MetUM atmospheric model coupled to a simplified one-dimensional ocean model, the Multi-Column K Profile Parameterization boundary-layer model (MC-KPP, based on Large et al., 1994);

Geosci. Model Dev., 8, 363–379, 2015
www.geosci-model-dev.net/8/363/2015/
doi:10.5194/gmd-8-363-2015
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Geoscientific Model Development
Open Access

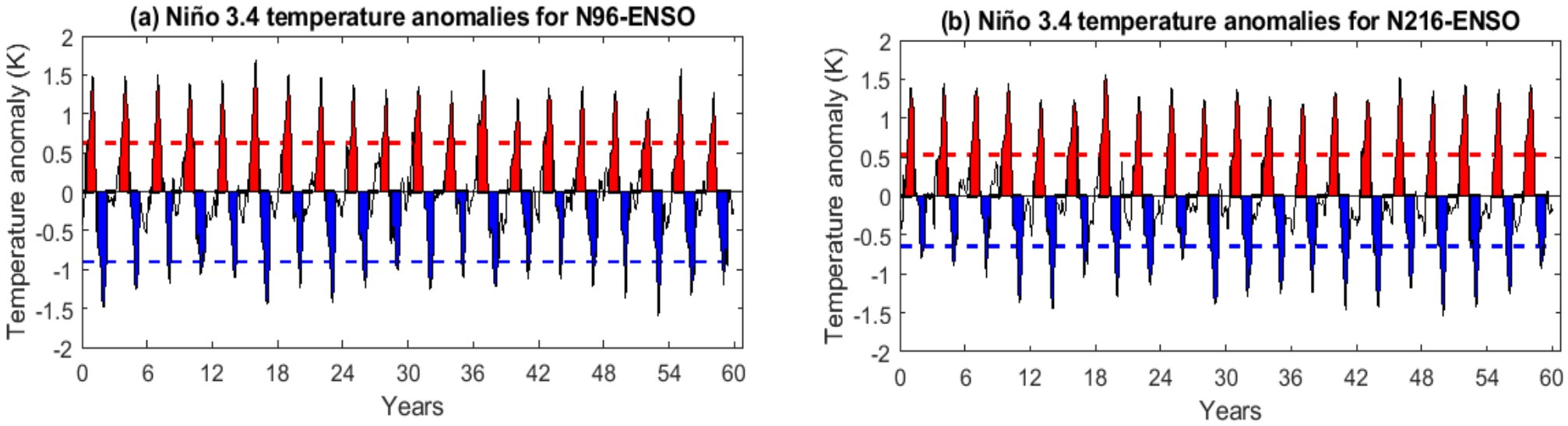
MetUM-GOML1: a near-globally coupled atmosphere–ocean-mixed-layer model

L. C. Hirons, N. P. Klingaman, and S. J. Woolnough

National Centre for Atmospheric Science-Climate and Department of Meteorology, University of Reading, P.O. Box 243, Reading, Berkshire, RG6 6BB, UK

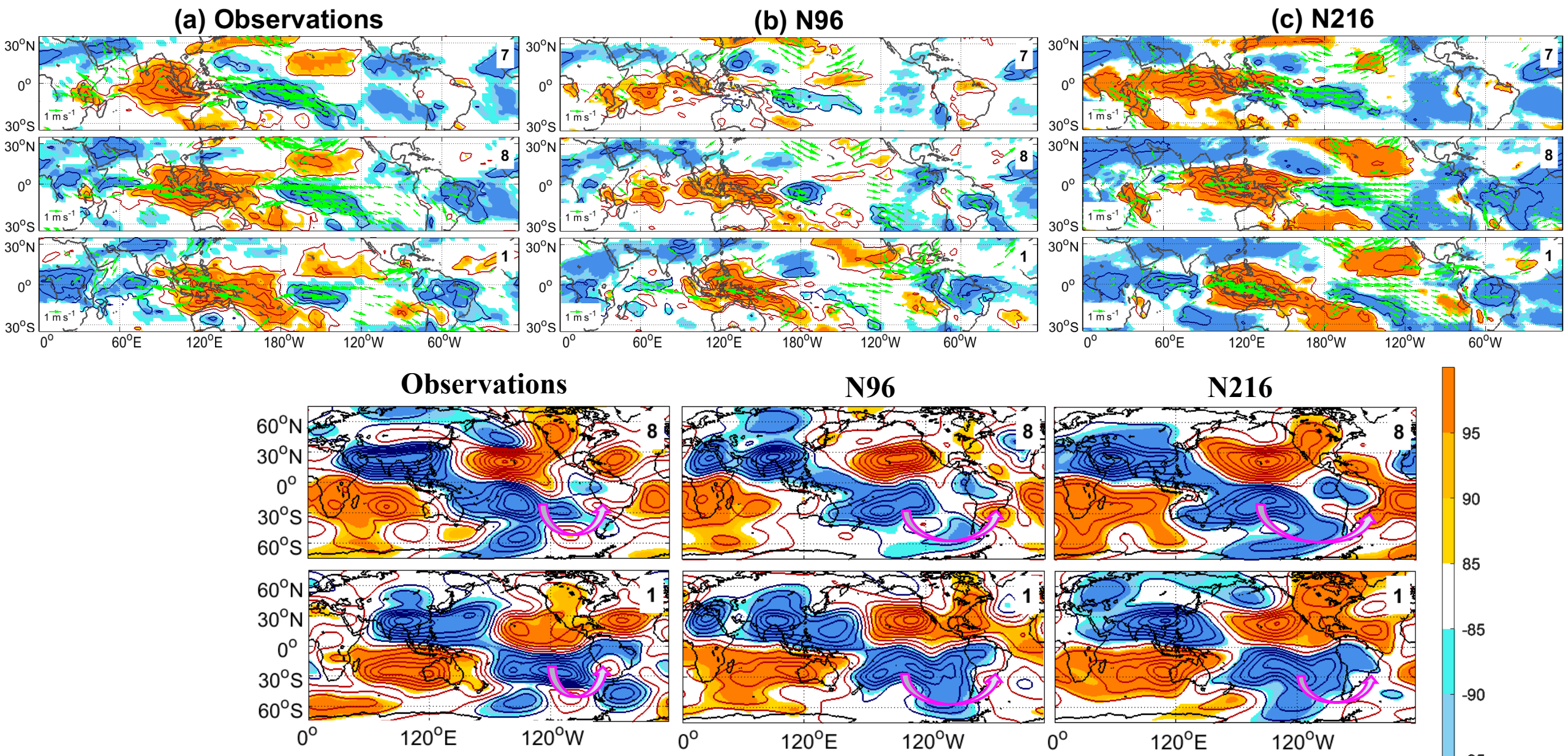
Simulations

Name	Grid	Length	Target ocean state
N96	200 km	30 years	Smith and Murphy (2007)
N216	90 km	60 years	Smith and Murphy (2007)
N96-ENSO	200 km	60 years	3-year ENSO cycle
N216-ENSO	90 km	60 years	3-year ENSO cycle



1.5 meter temperature anomalies (K) in the Niño 3.4 region in simulations with ENSO cycles.

The simulated MJO impacts on SA

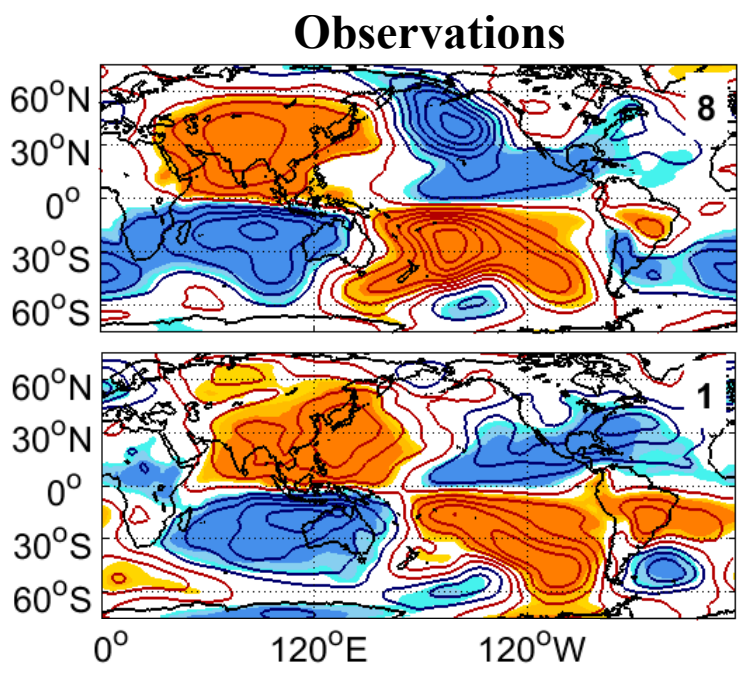


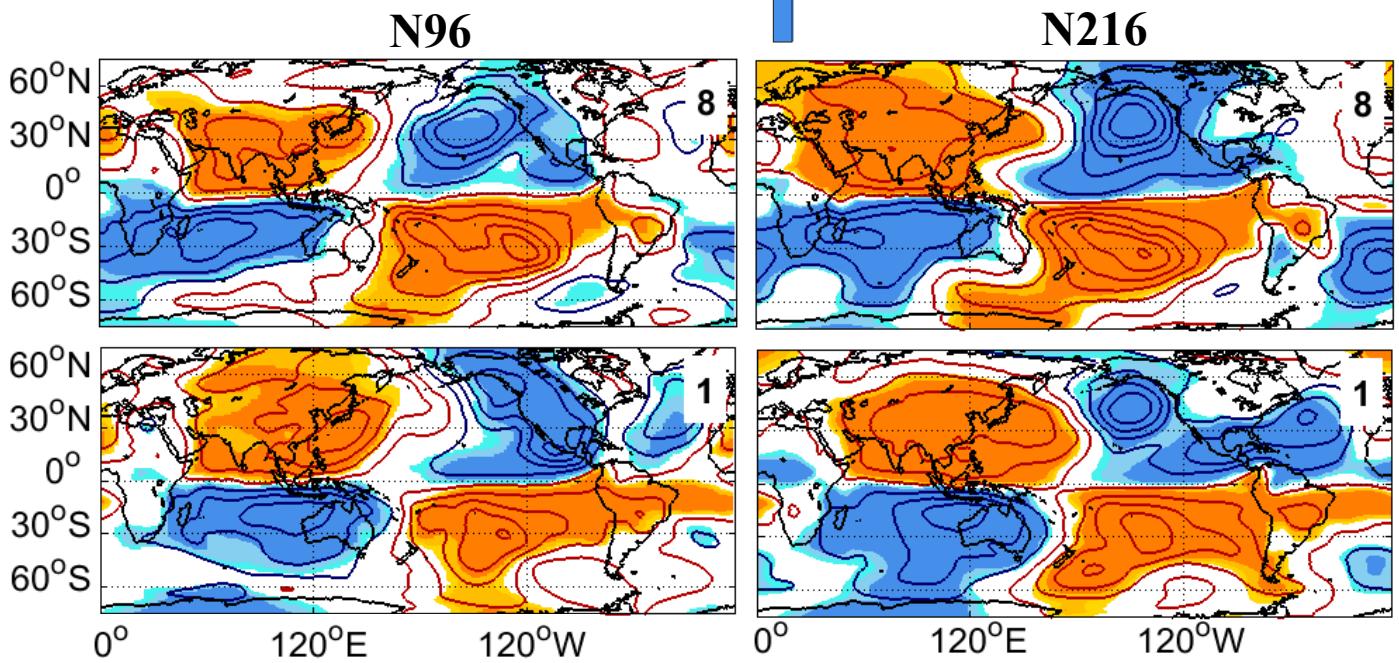
OLR (Wm^{-2}), low-level wind (ms^{-1}) (top), and streamfunction anomalies (200 hPa) (m^2s^{-1}) (bottom) in observations and simulations.

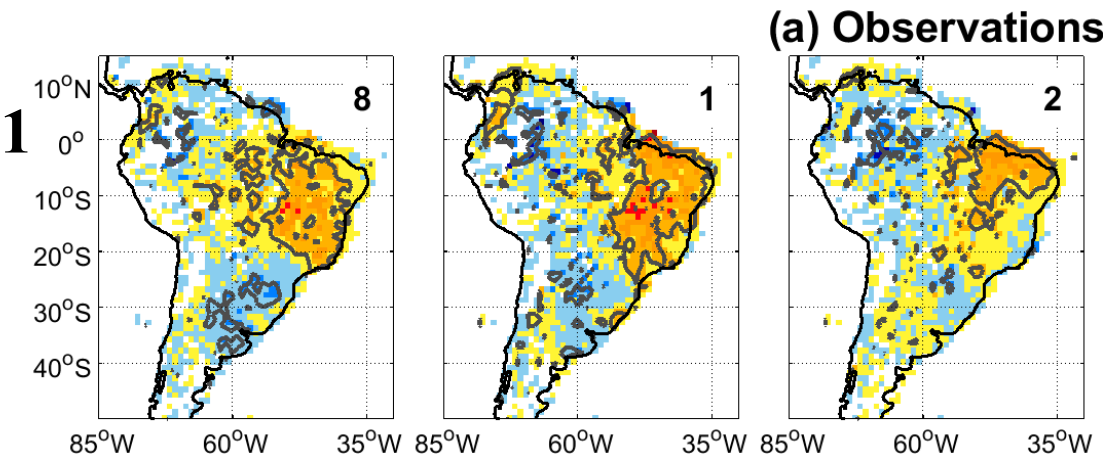
MJO phases 7, 8, 1

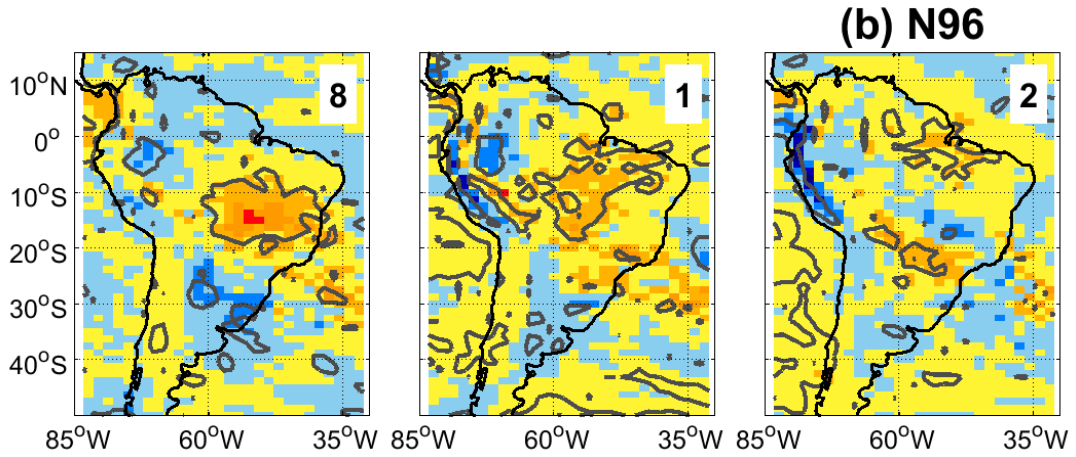
MJO phases 8 and 1

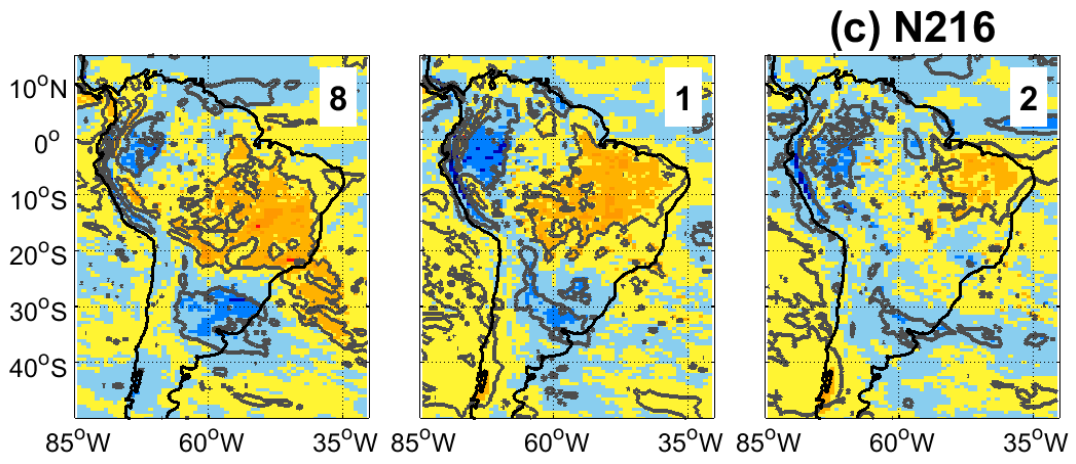
Streamfunction (850 hPa) (left) ($m^2 s^{-1}$) and precipitation (right) anomalies ($mm\ day^{-1}$) in observations and simulations.

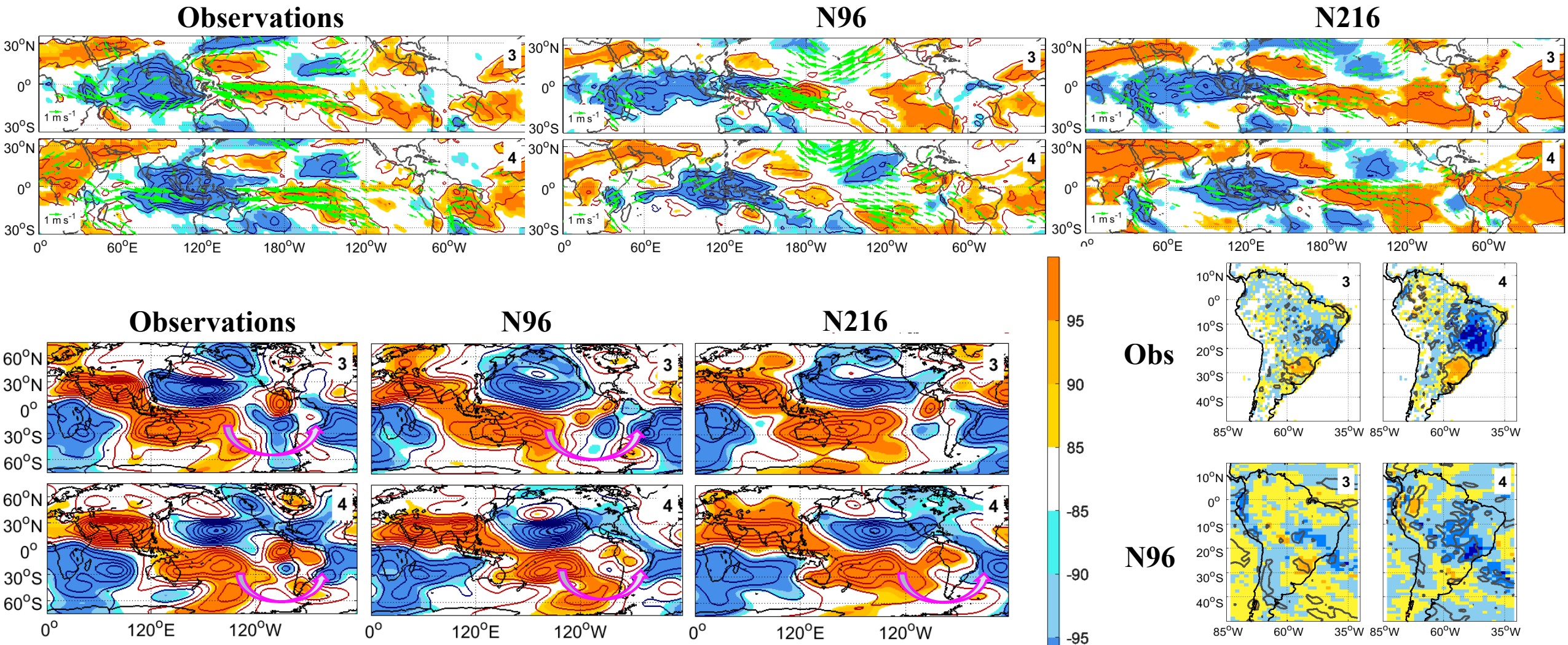








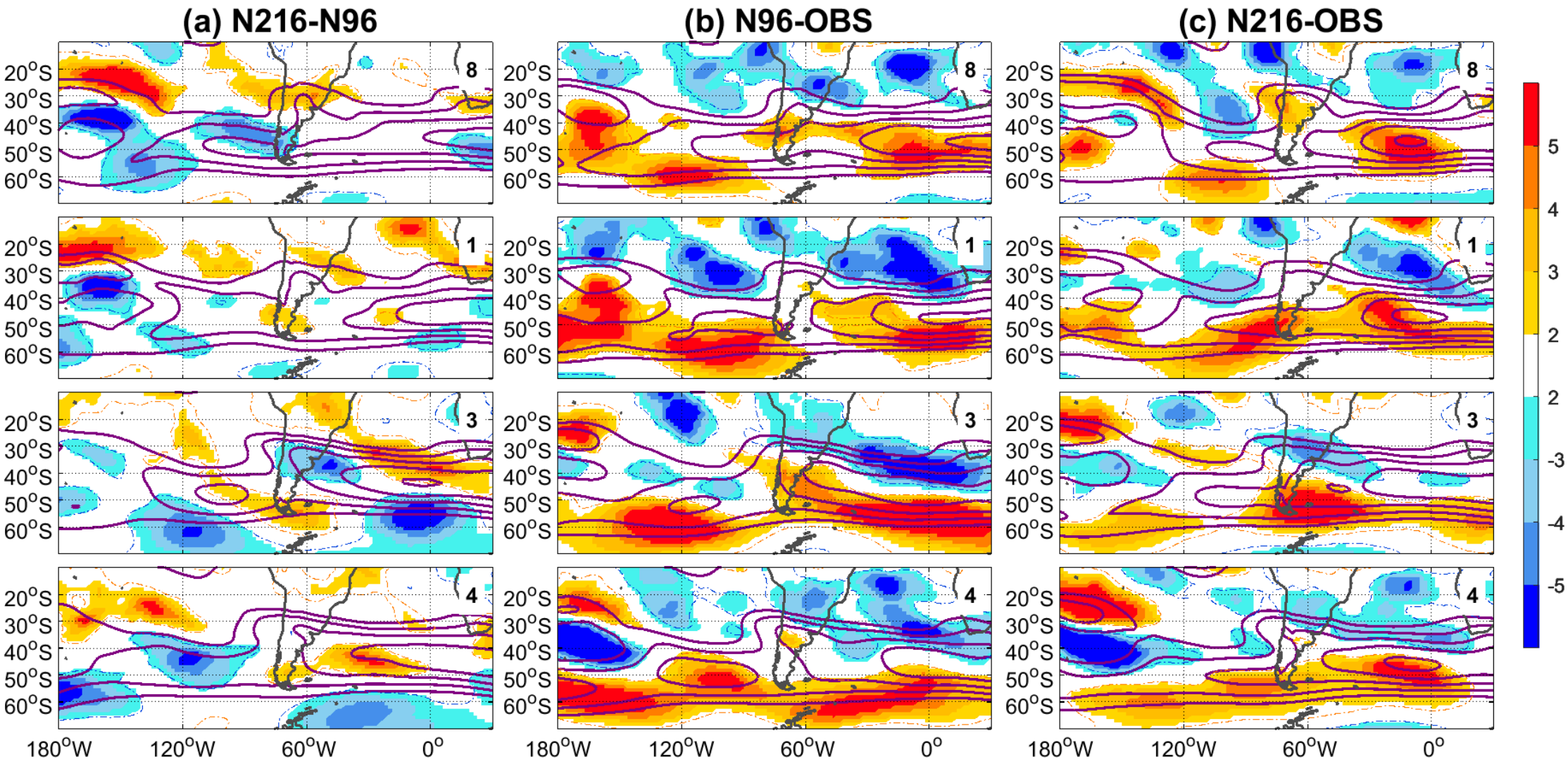




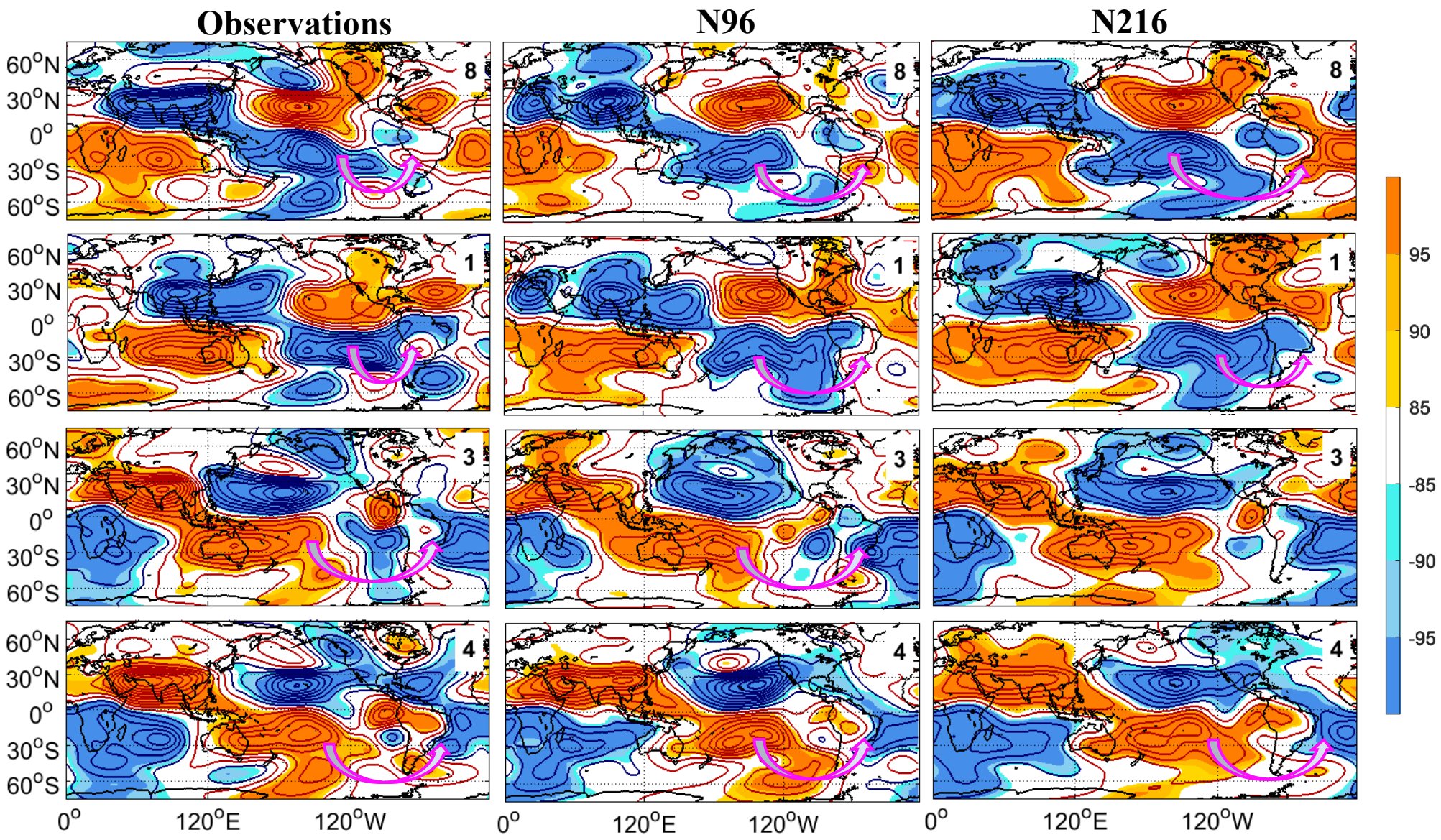
MJO phases 3 and 4

OLR (Wm^{-2}), low-level wind (ms^{-1}) (top), streamfunction (200 hPa) (m^2s^{-1}) (bottom left) and precipitation (bottom right) ($mm\ day^{-1}$) anomalies in observations and simulations.

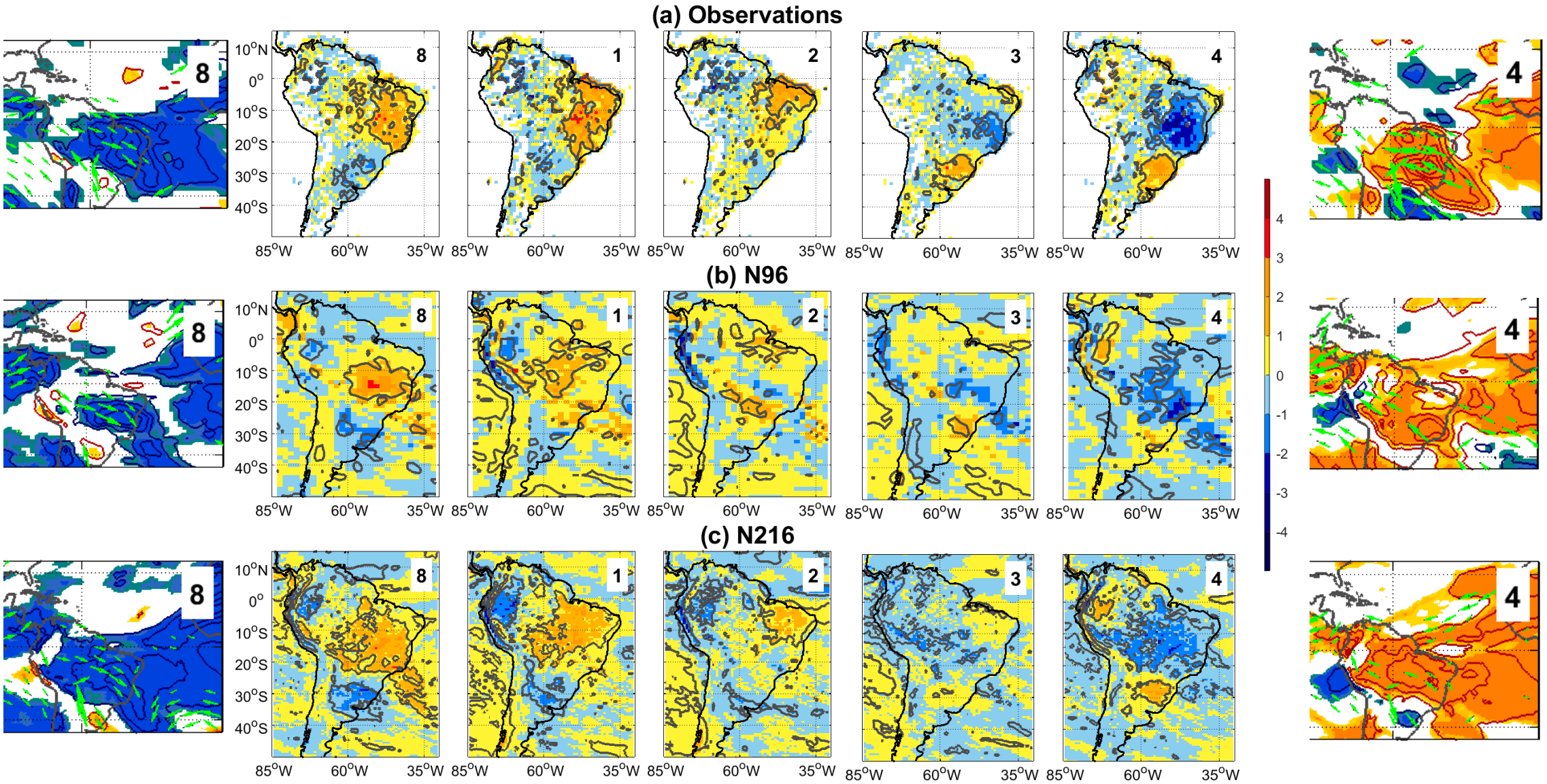
Effect of horizontal resolution on MJO impacts



Zonal wind at 200 hPa (contour interval: 5 ms^{-1} starting from 20 ms^{-1}) in MJO phases 8, 1, 3, 4 in DJF in (a) observations, (b) N96, and (c) N216. Shading denotes (a) N216-N96, (b) N96-OBS, and (c) N216-OBS differences.

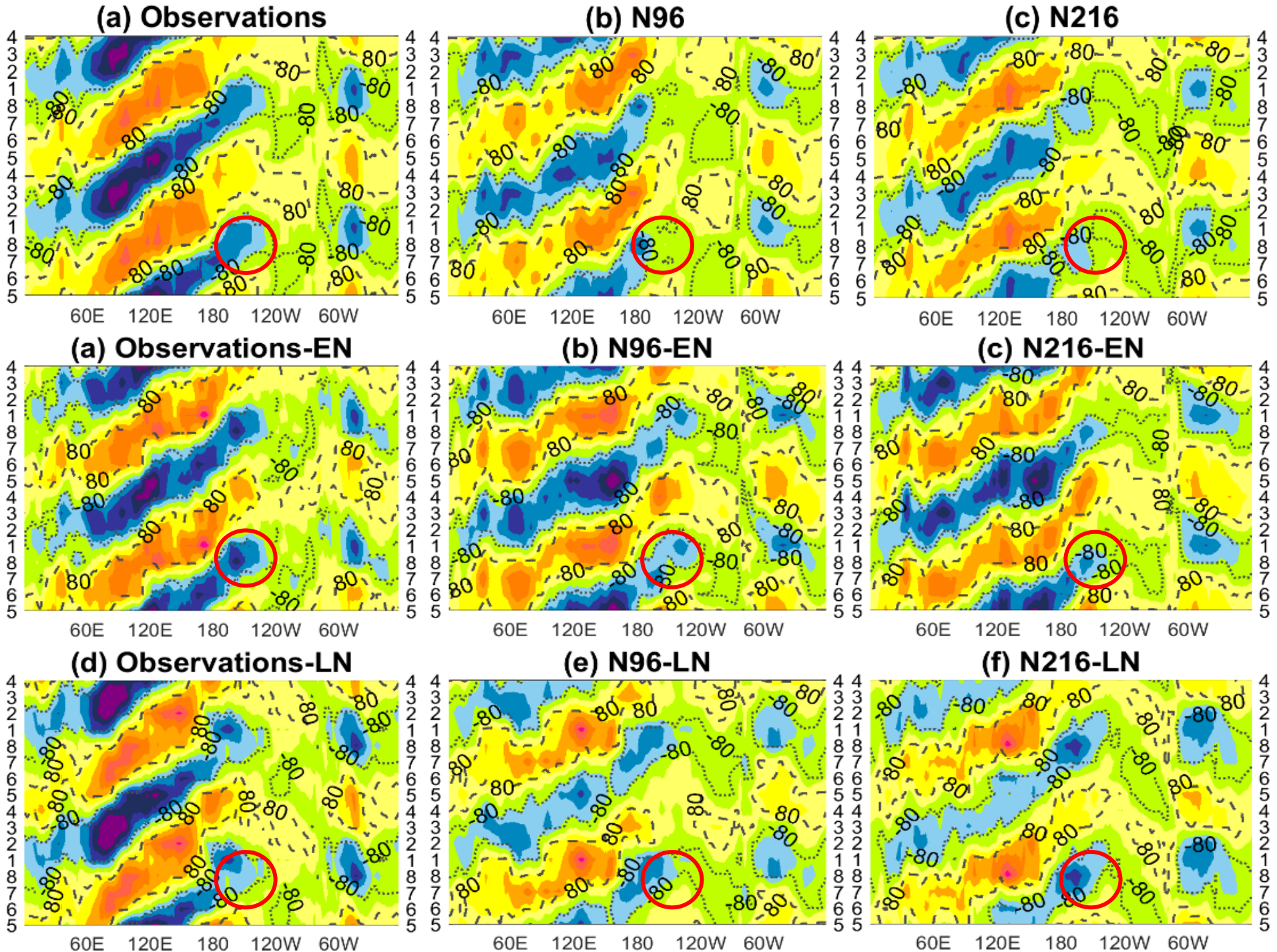


Streamfunction (200 hPa) ($m^2 s^{-1}$) anomalies in observations and simulations.

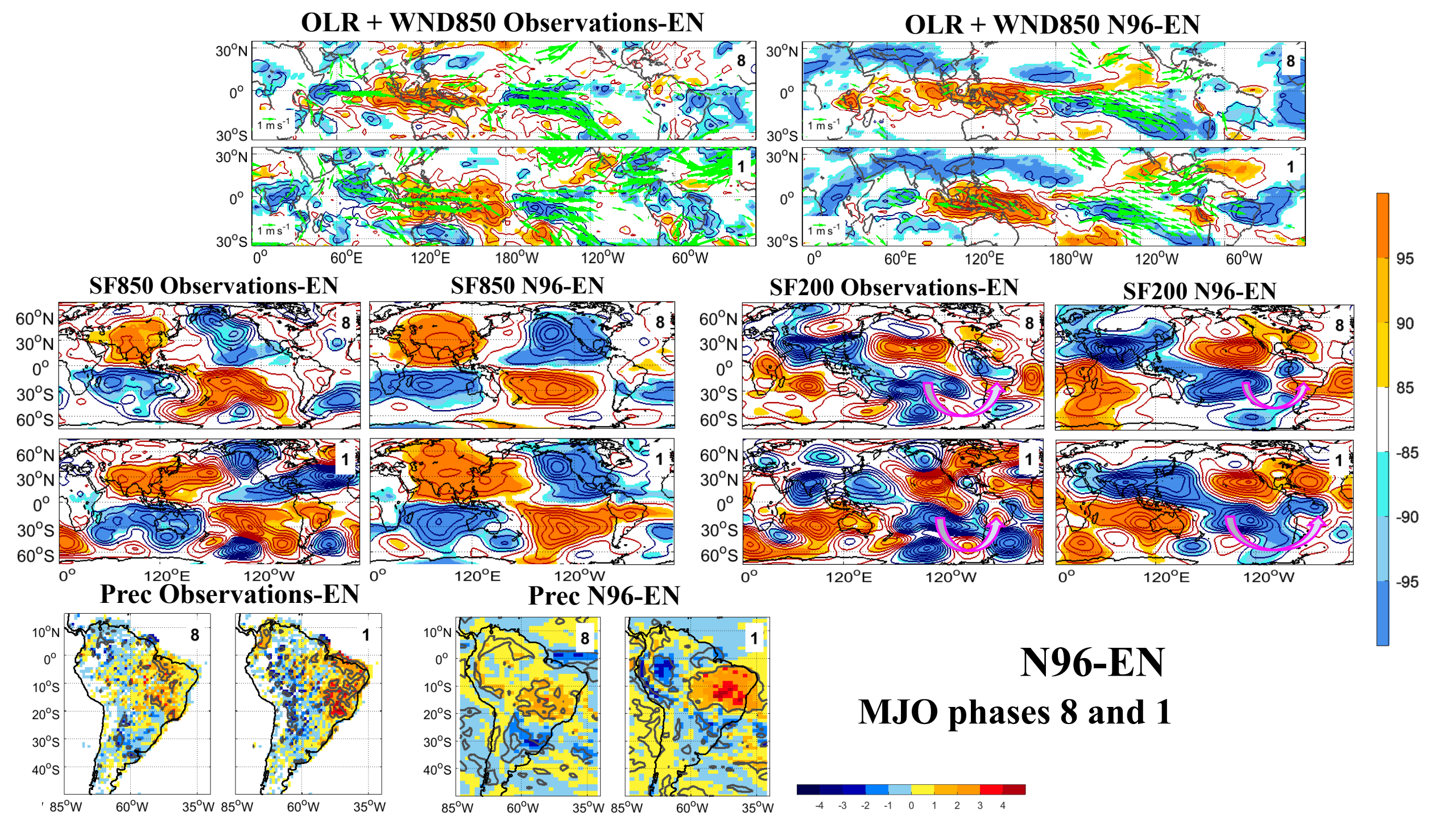


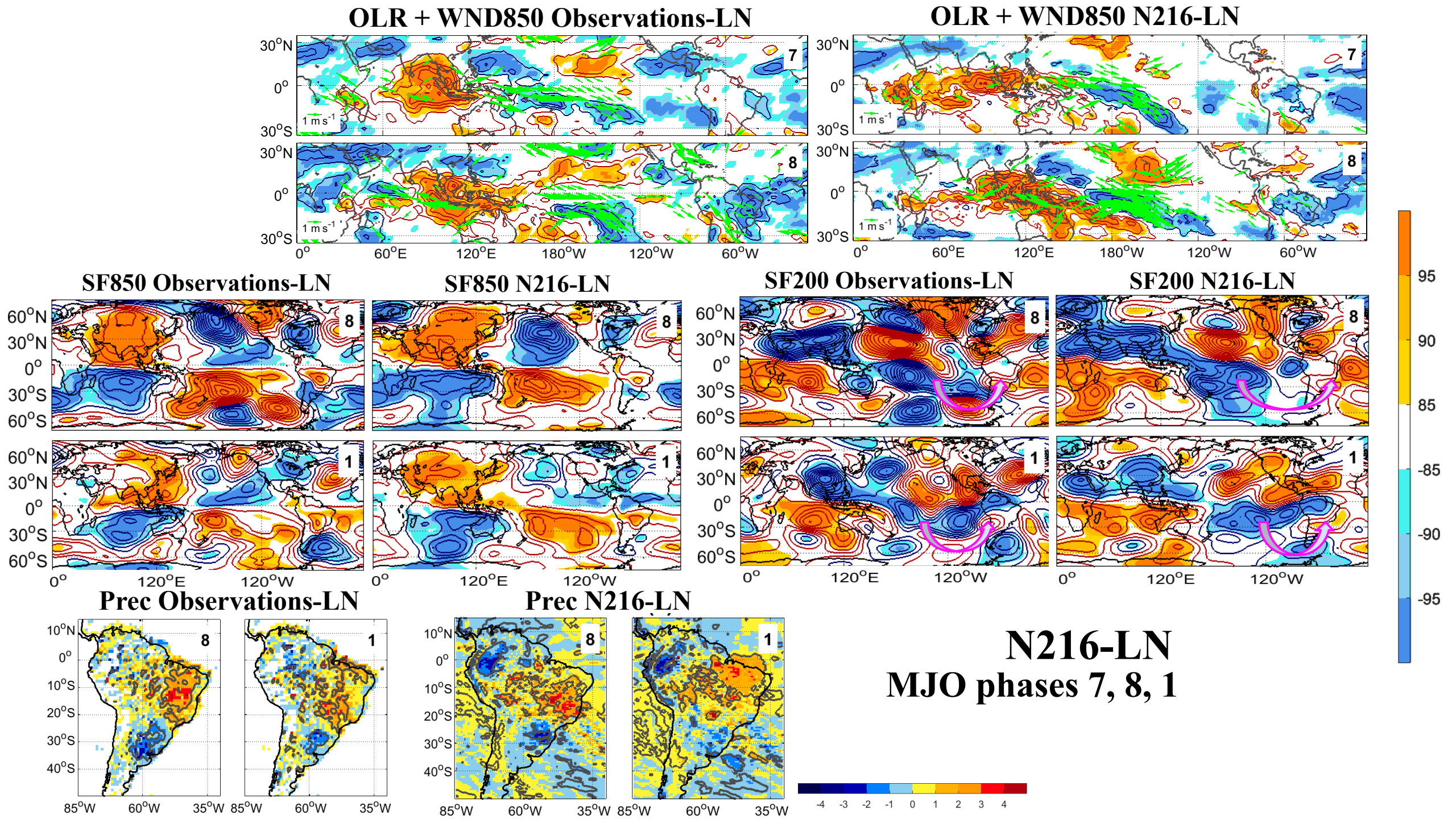
OLR anomalies (Wm^{-2}) and low-level winds (ms^{-1}), and precipitation anomalies ($mm\ day^{-1}$) in observations and simulations.

The simulated MJO impacts on SA in ENSO years



MJO Hovmoller diagrams of 0°-15°S averaged OLR anomalies (Wm^{-2}).


OLR + WND850 Observations-EN
OLR + WND850 N96-EN
SF850 Observations-EN
SF850 N96-EN
SF200 Observations-EN
SF200 N96-EN
Prec Observations-EN
Prec N96-EN
8
1
1 m s-1
95
90
85
-85
-90
-95
-4 -3 -2 -1 0 1 2 3 4
N96-EN
MJO phases 8 and 1


OLR + WND850 Observations-LN
OLR + WND850 N216-LN
SF850 Observations-LN
SF850 N216-LN
SF200 Observations-LN
SF200 N216-LN
Prec Observations-LN
Prec N216-LN
N216-LN
MJO phases 7, 8, 1
1 m s-1
7
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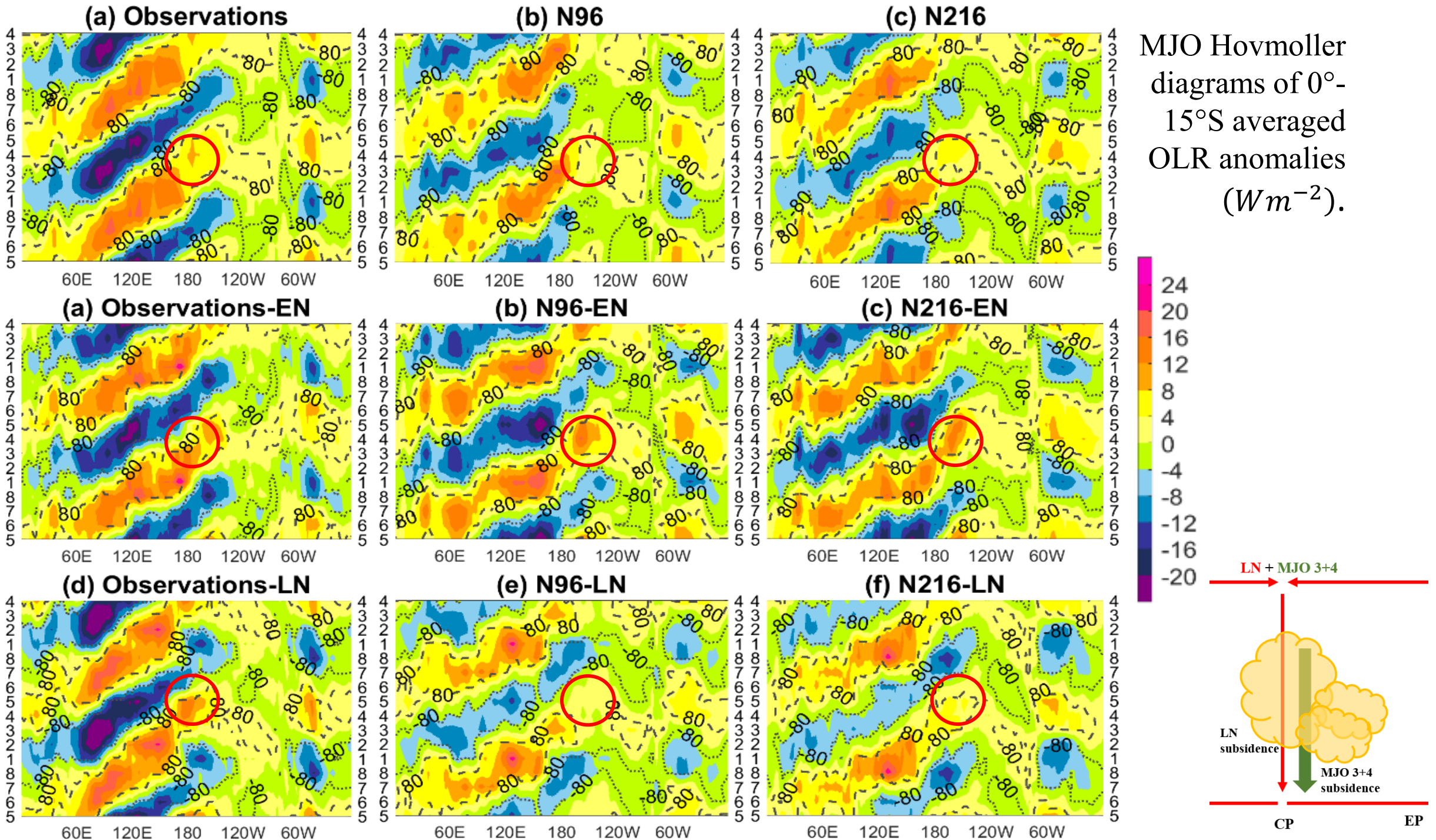
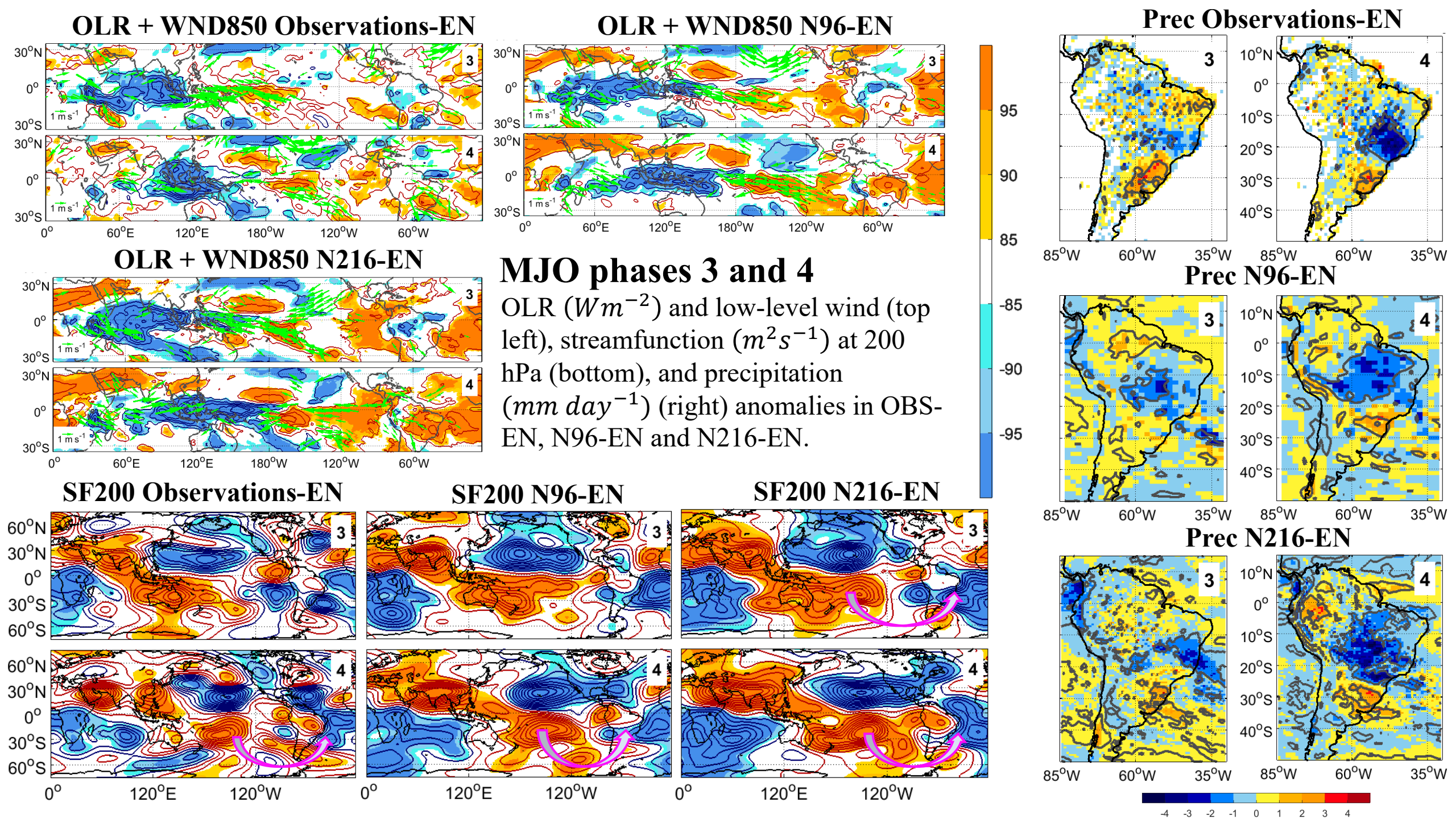
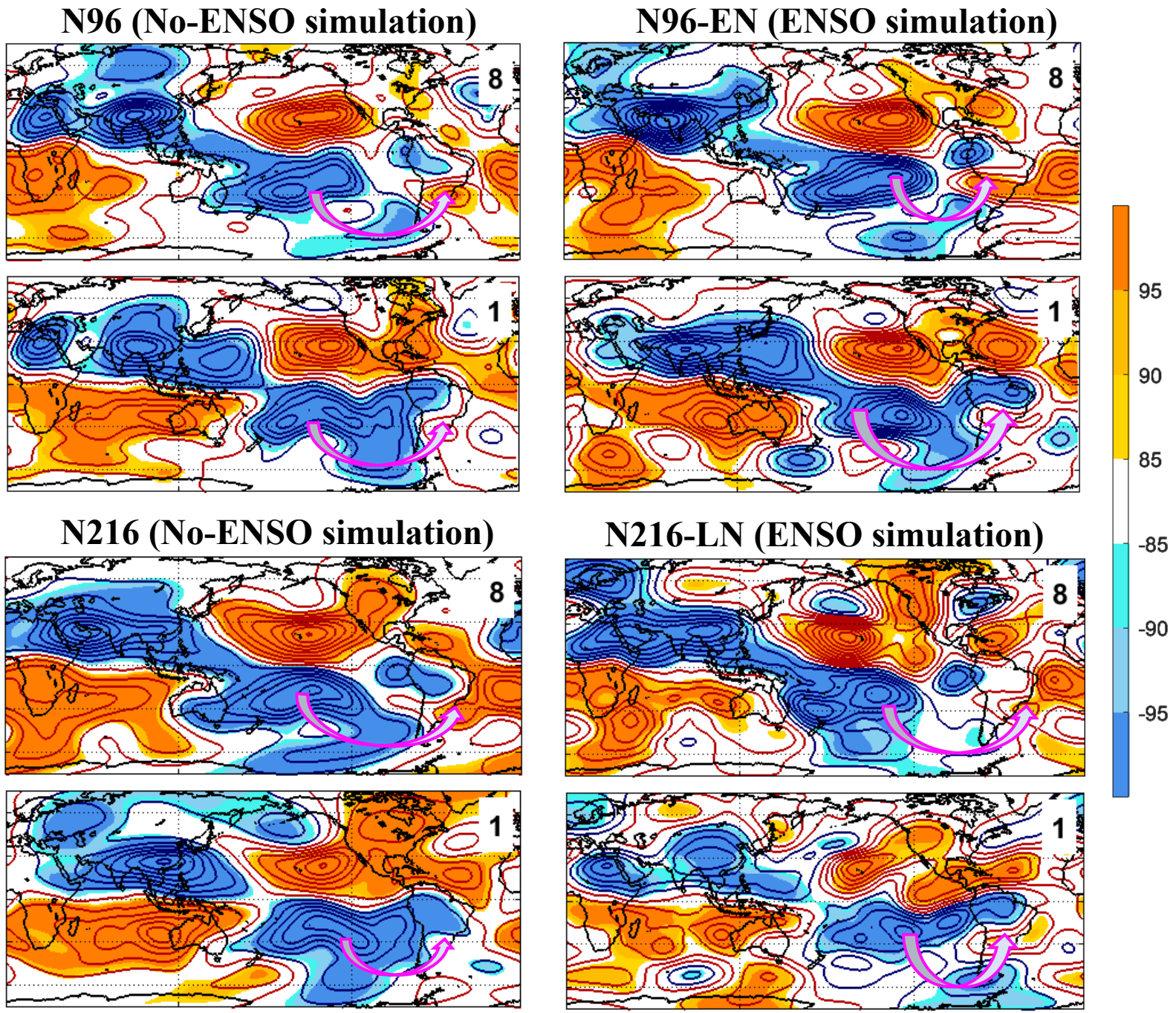
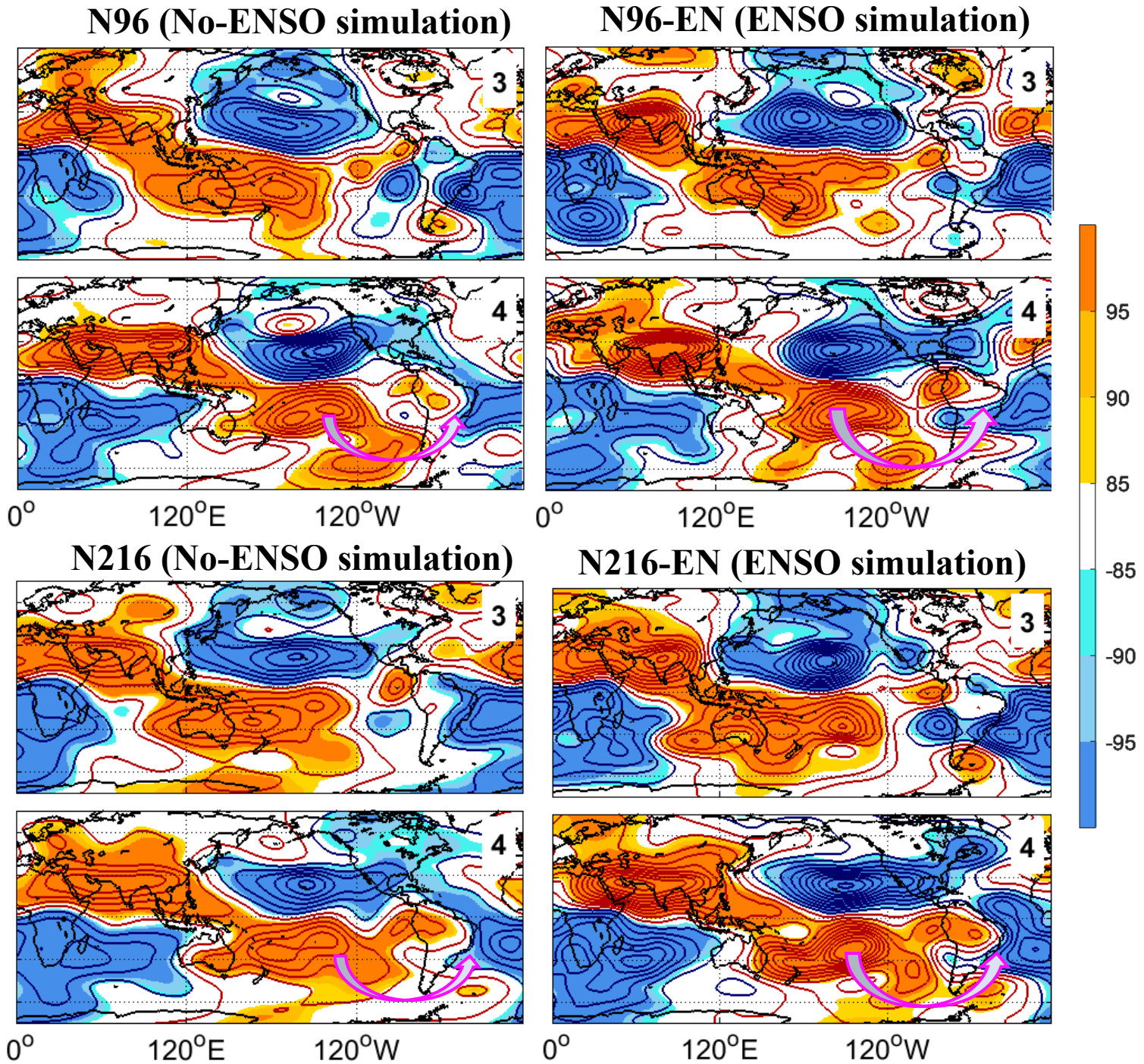
1
95
90
85
-85
-90
-95
-4 -3 -2 -1 0 1 2 3 4



MJO Hovmoller diagrams of 0°-15°S averaged OLR anomalies (Wm^{-2}).


OLR + WND850 Observations-EN
OLR + WND850 N96-EN
OLR + WND850 N216-EN
Prec Observations-EN
Prec N96-EN
Prec N216-EN
SF200 Observations-EN
SF200 N96-EN
SF200 N216-EN
MJO phases 3 and 4
OLR (Wm^{-2}) and low-level wind (top left), streamfunction (m^2s^{-1}) at 200 hPa (bottom), and precipitation ($mm\ day^{-1}$) (right) anomalies in OBS-EN, N96-EN and N216-EN.
1 ms-1
95
90
85
-85
-90
-95
-4 -3 -2 -1 0 1 2 3 4


N96 (No-ENSO simulation)
N96-EN (ENSO simulation)
N216 (No-ENSO simulation)
N216-LN (ENSO simulation)
8
1
95
90
85
-85
-90
-95


N96 (No-ENSO simulation)
N96-EN (ENSO simulation)
N216 (No-ENSO simulation)
N216-EN (ENSO simulation)
3
4
95
90
85
-85
-90
-95
0°
120°E
120°W

Summary (for N96 and N216)

- The model reproduces the most substantial MJO impacts on SA earlier (phase 8) than in observations (phase 1) → earlier establishment of MJO teleconnections;

- Increased horizontal resolution enhances the MJO convection and the anomalous circulation-precipitation dipole over SA. However, the extratropical teleconnections at upper levels are slightly shifted east at higher resolution due to an enhanced SA westerly jet with respect to the lower resolution;

Summary (N96-ENSO and N216-ENSO)

- EN and LN background states in the model influence the MJO eastward propagation, the position and intensity of the convection, teleconnections, and impacts on SA rainfall;

- Not all observed ENSO effects are well simulated by the model;

Summary (N96-ENSO and N216-ENSO)

- Notwithstanding, the agreement between MetUM-GOML3 and observations on many aspects validates the physical mechanisms proposed for ENSO modulation of the MJO impacts on observations;

- Both ENSO states in the model generate forcing in the source region that more efficiently triggers stronger extratropical teleconnections than in simulations without ENSO, indicating nonlinear ENSO effects on MJO-related anomalies over the subtropical SA;

- When MetUM-GOML3 correctly simulates MJO teleconnections, the magnitude and spatial distribution of the precipitation anomalies over SA improve;

- As the MJO and its teleconnections improve during EN, other CGCMs may reproduce these features, and S2S predictions to SA may be better when EN and MJO peak in DJF.

Thank you!
Obrigada!

https://www.climate.gov/news-features/blogs/enso/catch-wave-how-waves-mjo-and-enso-impact-us-rainfall