Intra-seasonal Impacts of the (Extra-)Tropics on Extreme Rainfall Events

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EARTH INSTITUTE | COLUMBIA UNIVERSITY

Subseasonal-to-Seasonal S2S Prediction Project

Outline

1. Extreme rainfall events
2. Some large- and regional-scale mechanisms
3. Concrete examples
   I. Southeastern South America (SE SA)
   II. The Ohio River Basin (NE US)
4. Summary

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Extreme Rainfall Events

Characteristics

+ High impact
+ Extreme events are in general difficult to forecast!
+ Diverse physical mechanisms
  - Mesoscale convective complexes (MCCs)
  - Extratropical cyclones (baroclinic fronts)
  - Heat and moisture advection (e.g., by low-level jets)
  - Atmospheric rivers

Basic ingredients

+ Condensation rate, *c*, required to maintain water vapor content of the rising air near saturation (vertical velocity, changes in the saturation of specific humidity, saturation equivalent potential temperature).
+ Latent heat release balances adiabatic cooling in updrafts.
+ Intensity of precipitation, P_e, is proportional to mass-weighted integral over troposphere of upward velocity, moist-adiabatic derivative of saturation specific humidity at given temperature.

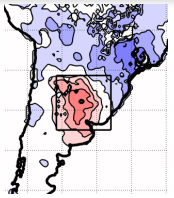
$$c = -\omega \left.\frac{dq_s}{dp}\right|_{\theta^*}, \qquad P_e \sim -\left\{ \omega_e \left.\frac{dq_s}{dp}\right|_{\theta^*, T_e} \right\}.$$

Muñoz et al., 2015 (J. Clim), O'Gorman and Schneider, 2009 (PNAS)

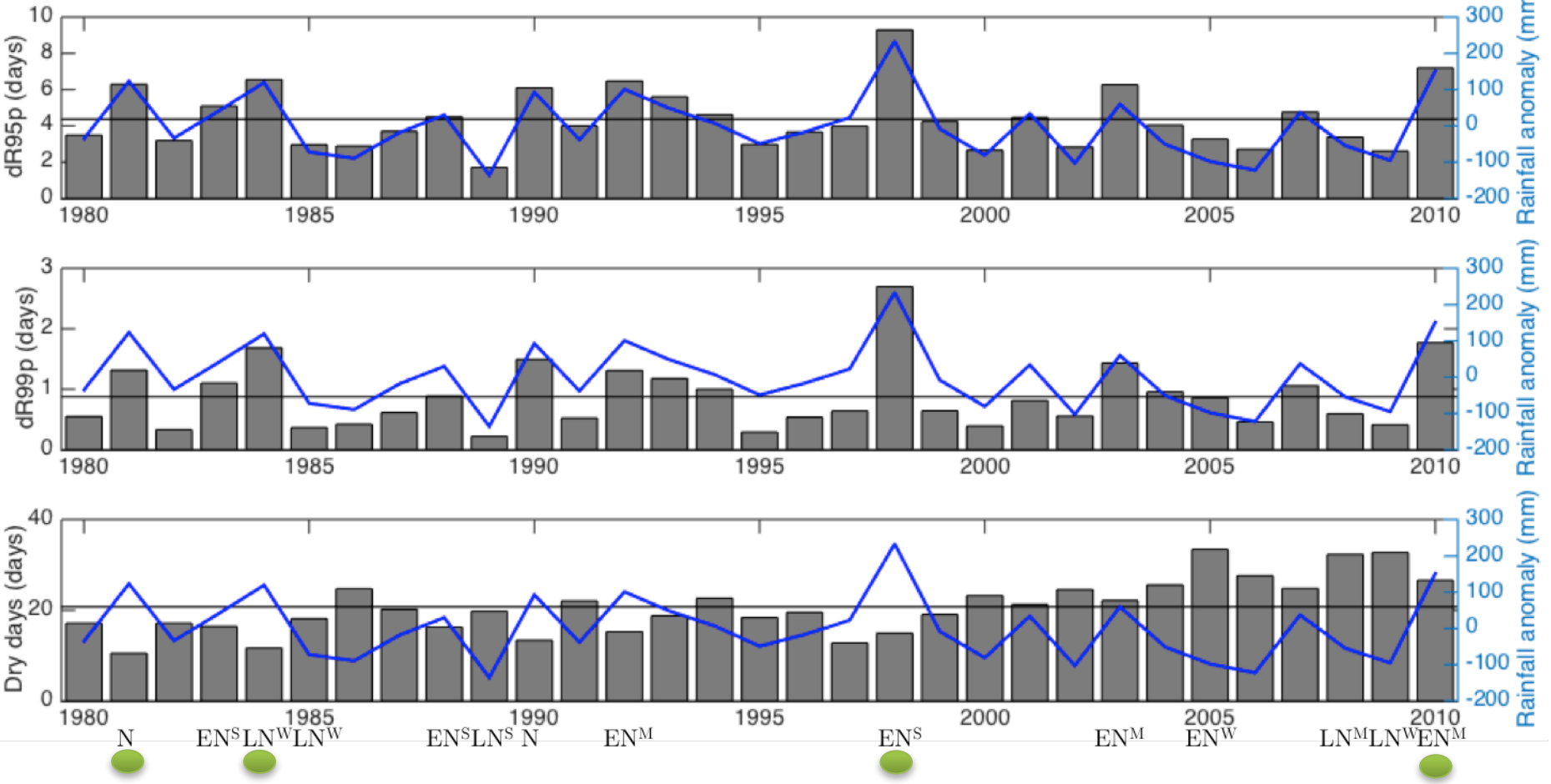
Extreme Rainfall in SE South America

Dataset: NOAA-NCEP-CPC-Unified Precipitation (Chen *et al.*, 2008)
f_{ij}: *number of days* above/below threshold for gridbox i and year j.
N: number of gridboxes.
F_j: overall extreme event frequency for year j

$$F_j = \frac{1}{N}\sum_i f_{ij}$$



DJF 1980-2010



Muñoz et al., 2015 (J. Clim)

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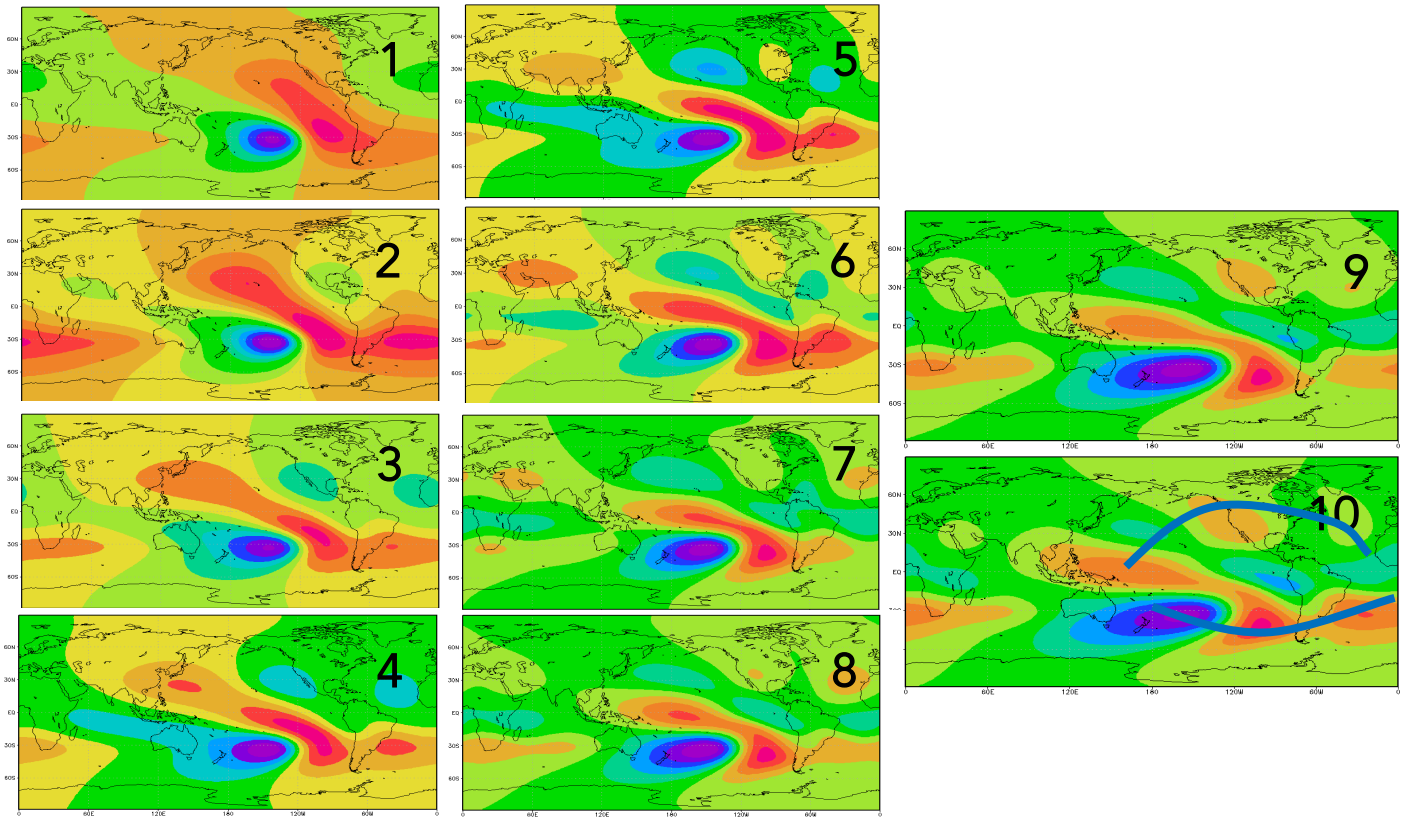
Extreme Rainfall and mechanisms

Shallow water barotropic GFDL model (T85). Executed for 70 days (spin-up in ~58 days) without local perturbations in geopotential height, but with ITCZ present. Sea-surface temperature perturbation induced at (140W, 28S) on day 71, shown here as day 1. Streamflow anomaly for 10 days (initial state and zonal mean subtracted). Streamflow anomaly for 10 days (initial state and zonal mean subtracted).



Simulation by Á.G. Muñoz (Princeton U.)

Meridionally-propagating Rossby waves

Extreme Rainfall and mechanisms

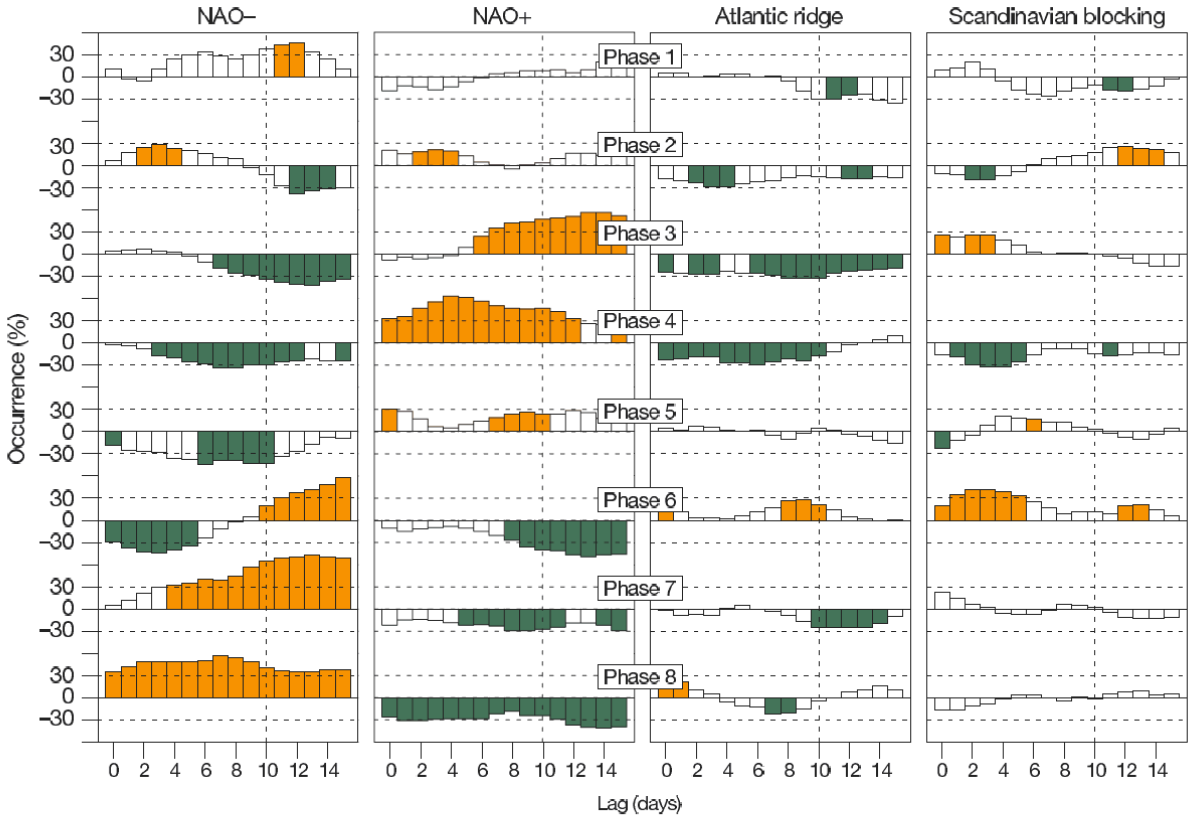


Figure 3 | Lagged relationships between the eight phases of the MJO and the four North Atlantic weather regimes. Table of contingency between the MJO phases (rows) and the North Atlantic weather regimes (columns). For each MJO phase, I plot the anomalous percentage occurrence of a given regime as a function of lag in days (with regimes lagging MJO phases). The 0% value means that the MJO phase is not discriminative for the regime whose occurrence is climatological. A 100% value would mean that this regime occurs twice as frequently as its climatological mean; −100% means no occurrence of this regime. The presence of a slope as a function of lag is suggestive of the MJO forcing. For white bars, either the change in the distribution between the four regimes is not significant on the basis of χ^2 statistics at the 99% significance level, or the individual anomalous frequency of occurrence is lower than the minimum significant threshold tested at 95% using a Gaussian distribution (approximation for binomial distribution because of the sufficiently large sampling). For orange and green bars, the regimes occur significantly more or, respectively, less frequently than their climatological occurrences.

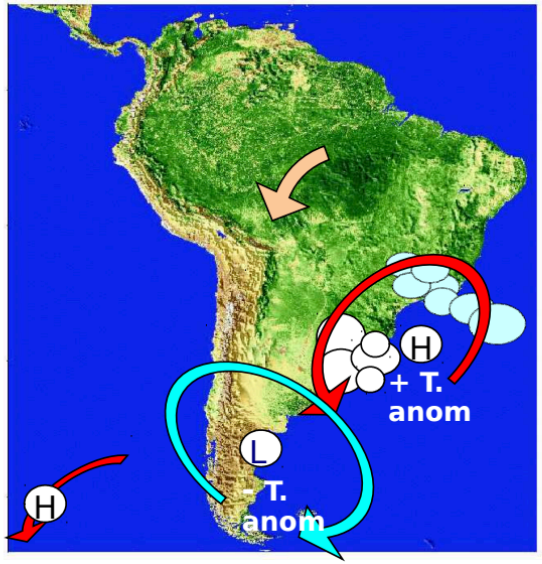
Changes in atmospheric regimes occurrence

Cassou, 2008 (Nature)

Extreme Rainfall and mechanisms

Weakened SACZ

Intensified SALLJ poleward progression



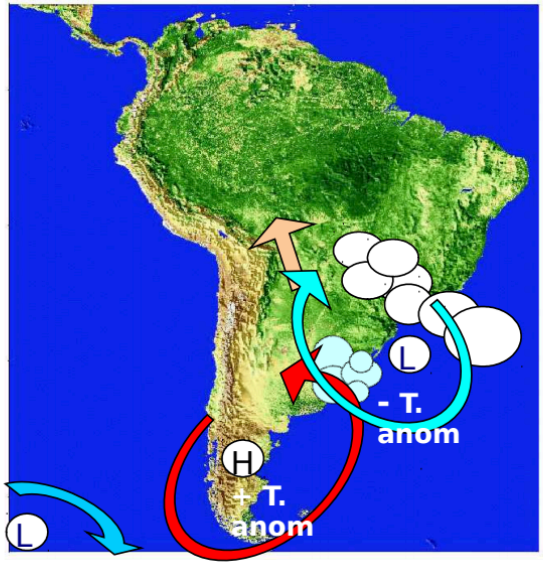
Higher frequency of **extreme daily rainfall events at the subtropics**

(Liebmann, Kiladis, Vera and Saulo, 2004)

(Gonzalez,, Vera, Liebmann Kiladis 2007)

Intensified SACZ

Inhibited SALLJ poleward progression

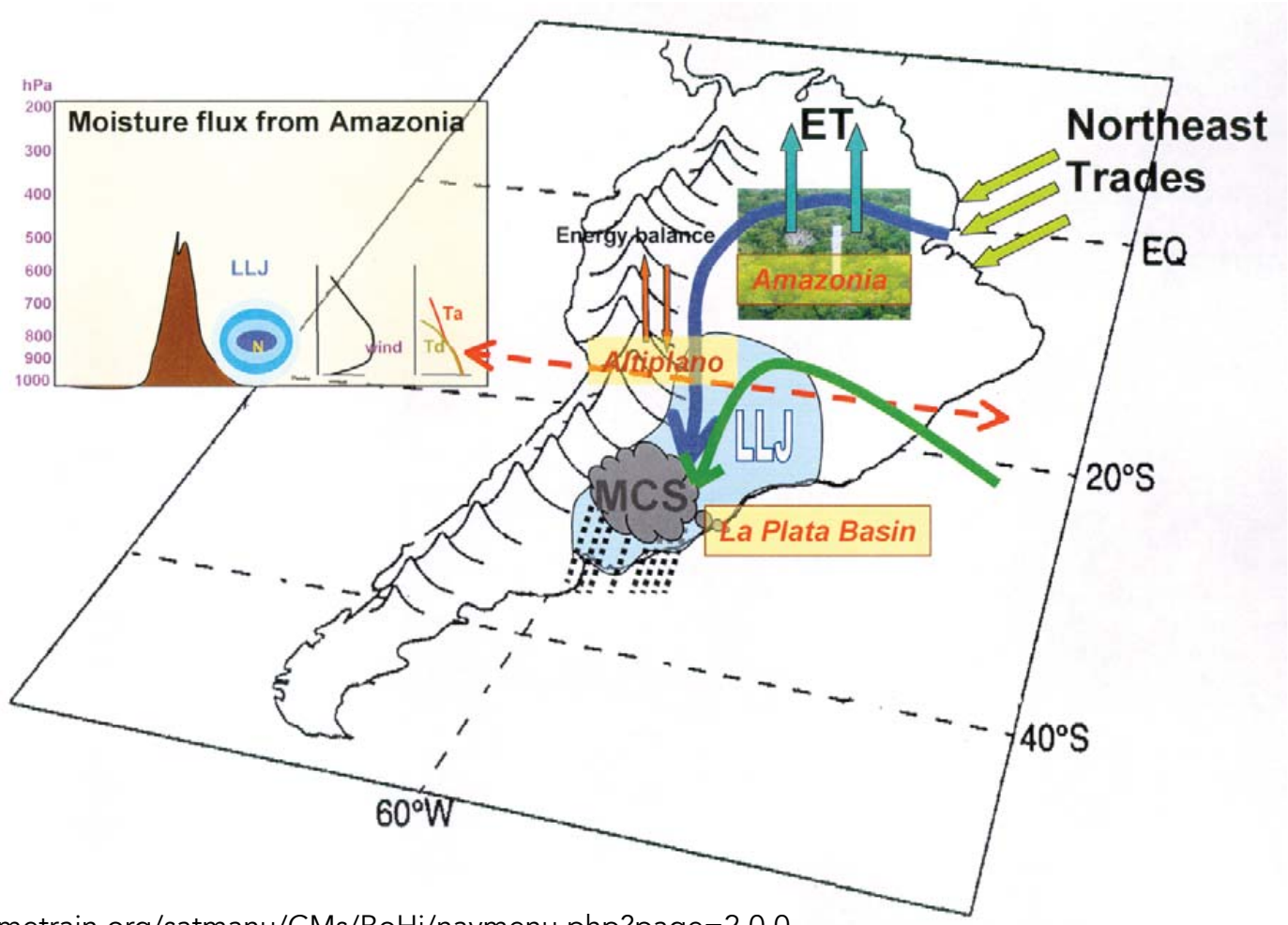


Higher frequency of **heat waves** and extreme daily temperature events **at the subtropics**

(Cerne and Vera, 2011)

South Atlantic Convergence Zone

Extreme Rainfall and mechanisms



http://www.eumetrain.org/satmanu/CMs/BoHi/navmenu.php?page=2.0.0

South American Low-Level Jet(s)

Extreme Rainfall and mechanisms

Synoptic Control

Changes in circulation patterns (location, frequency of occurrence, intensity, ⋯) can produce suitable conditions conducive to extreme rainfall events.

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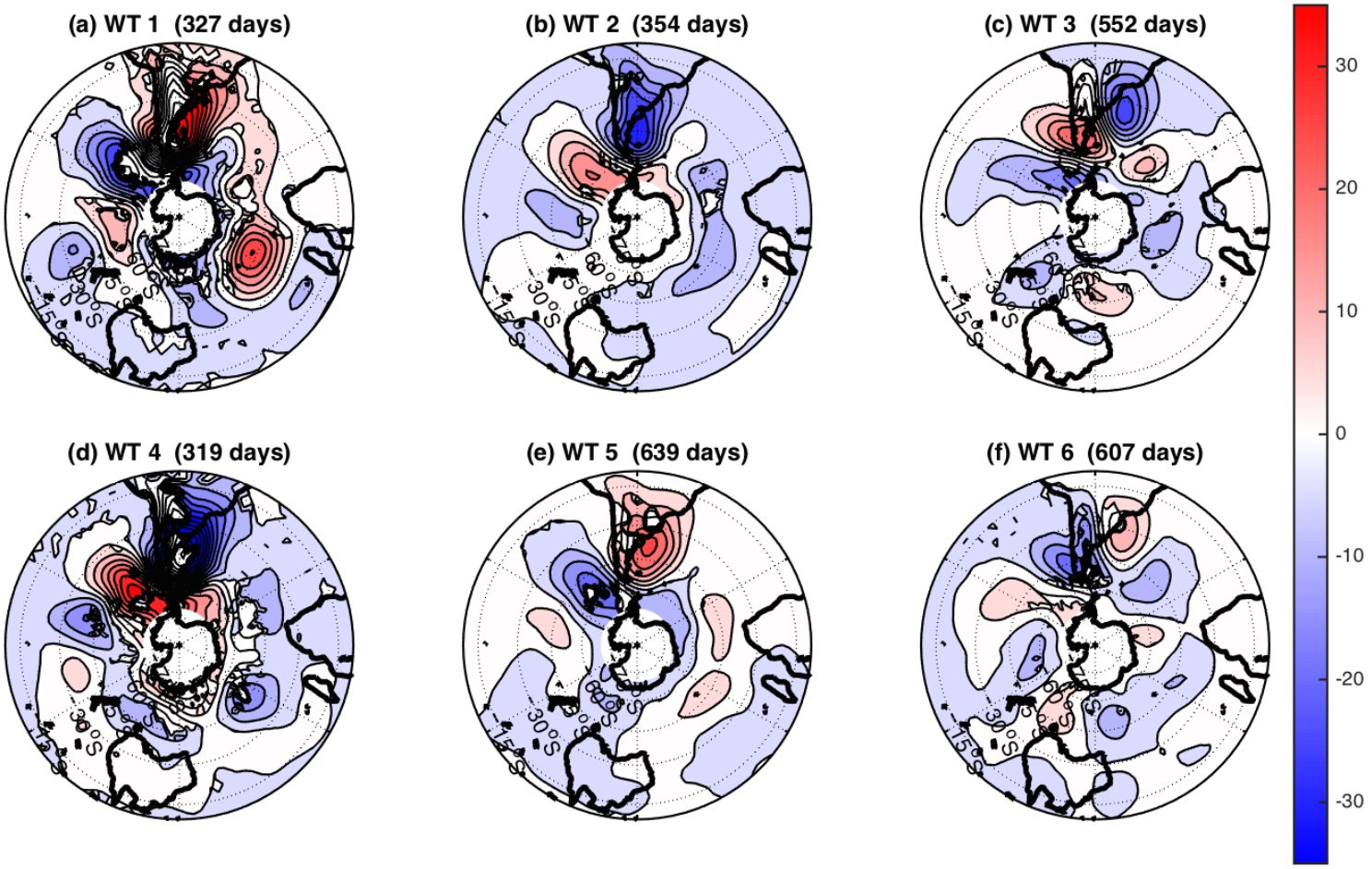
Extreme Rainfall in SE South America

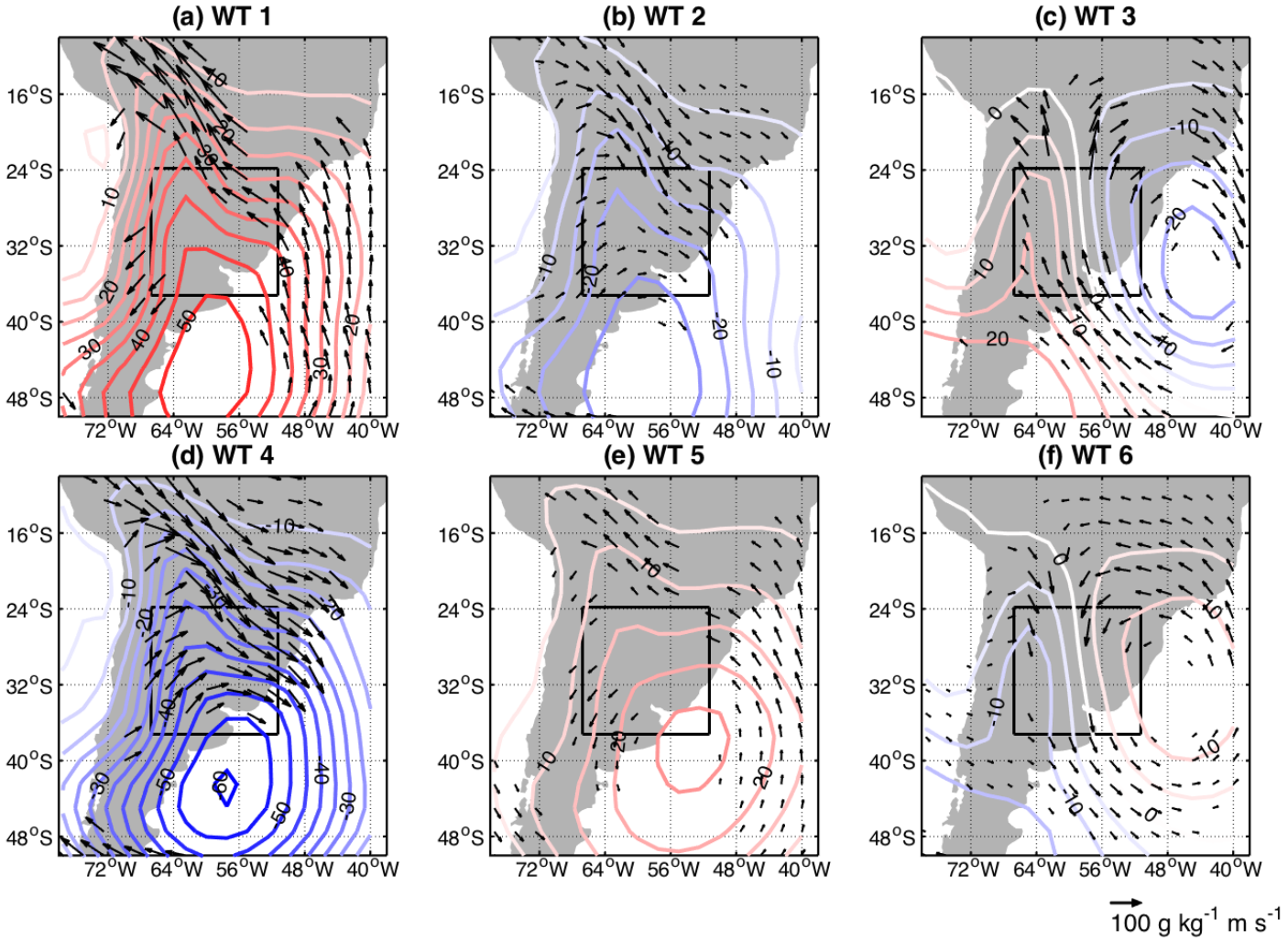
Daily circulation types (DJF)



Muñoz et al., 2015 (J. Clim)

Extreme Rainfall in SE South America

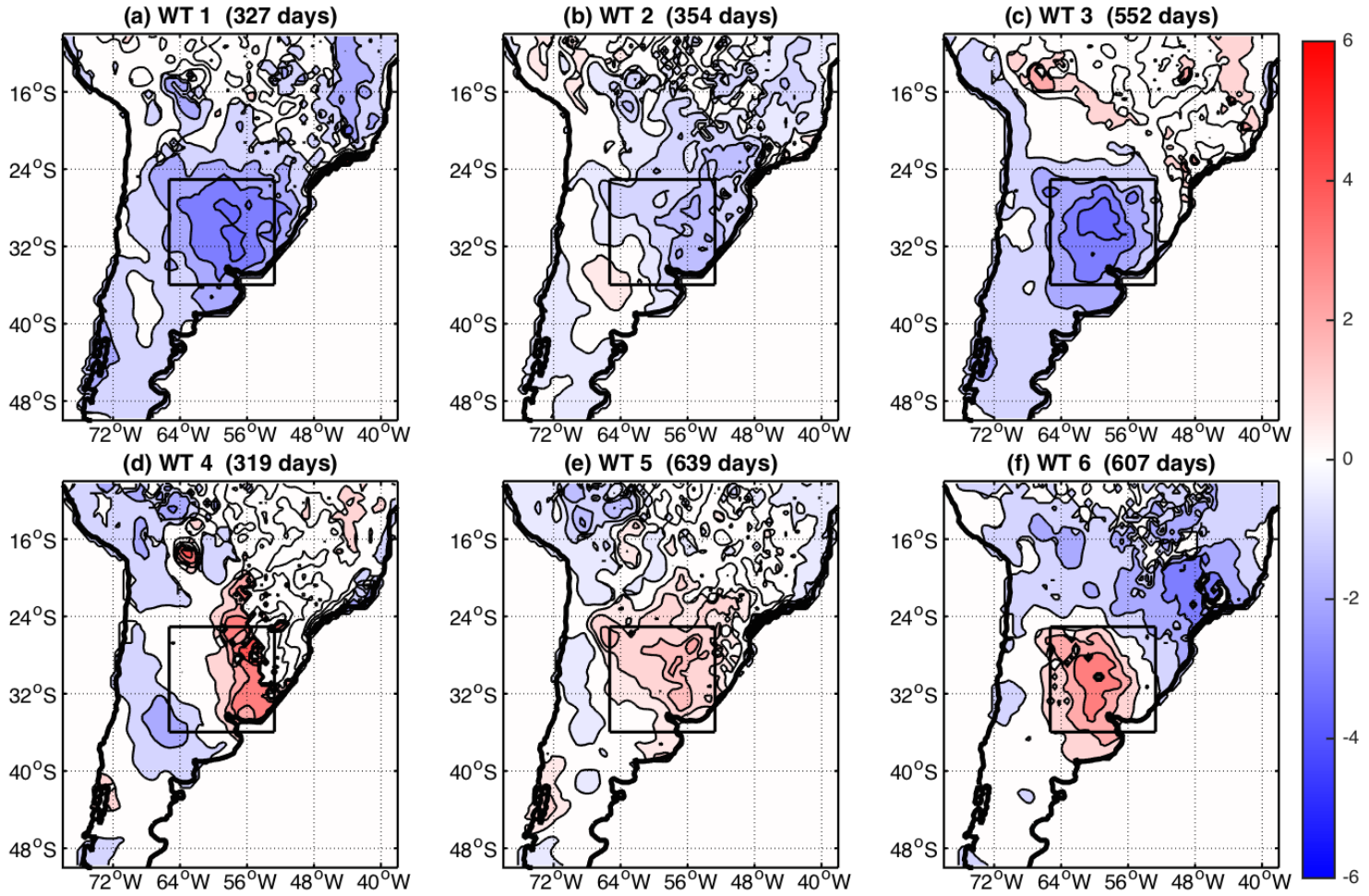
Daily circulation types (DJF)



Muñoz et al., 2015 (J. Clim)

Extreme Rainfall in SE South America

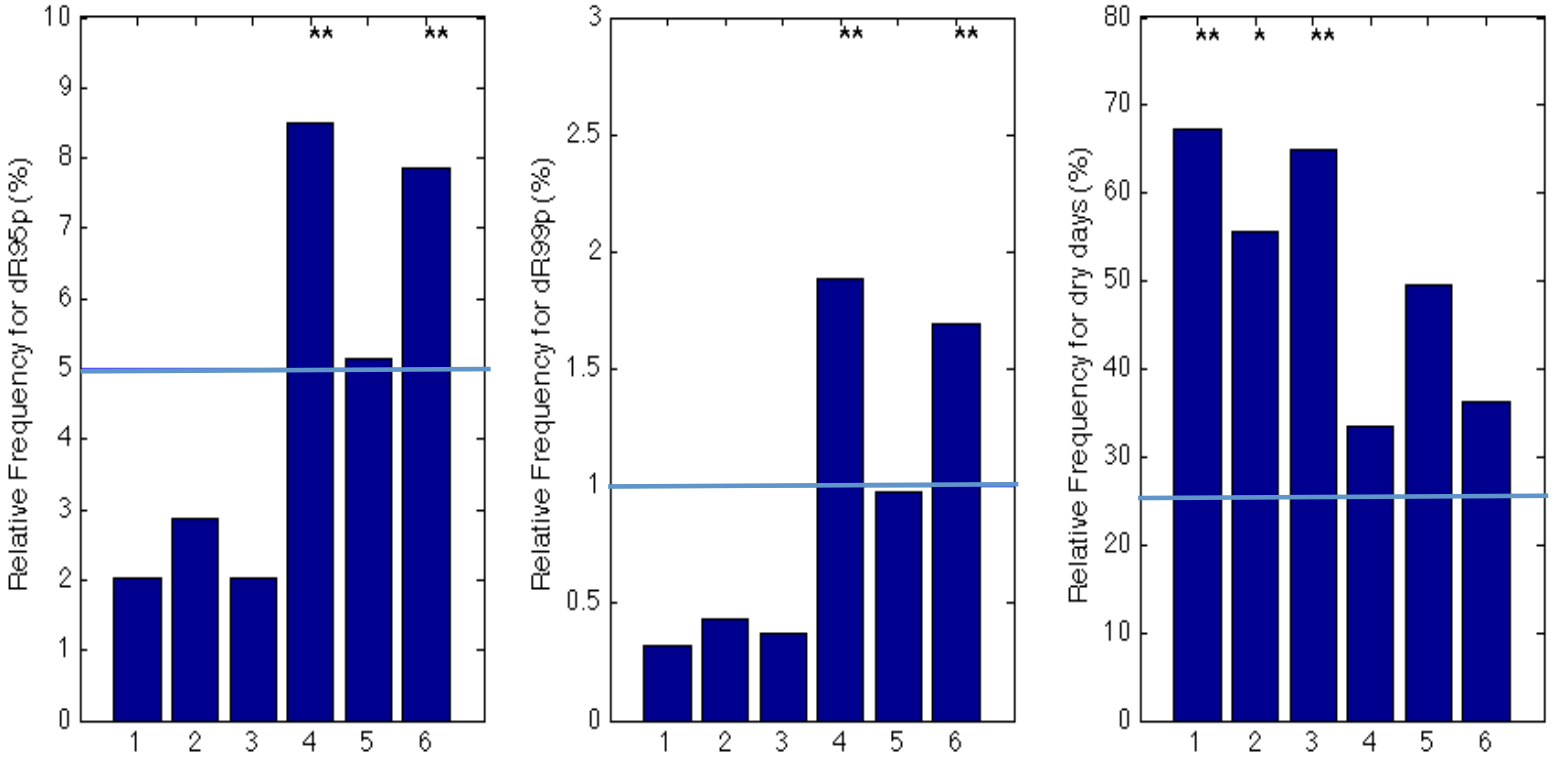
Associated Rainfall patterns (DJF)



Muñoz et al., 2015 (J. Clim)

Extreme Rainfall in SE South America

Which circulation pattern is associated with extreme rainfall events?



Muñoz et al., 2015 (J. Clim)

Extreme Rainfall: Paraguay River Basin


04 de Diciembre, 2015 | Nacionales

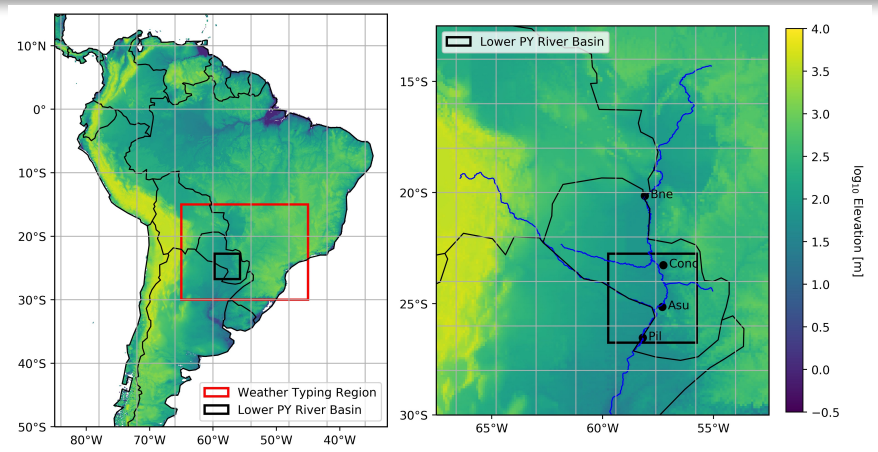
La tormenta más grande de los últimos 18 años

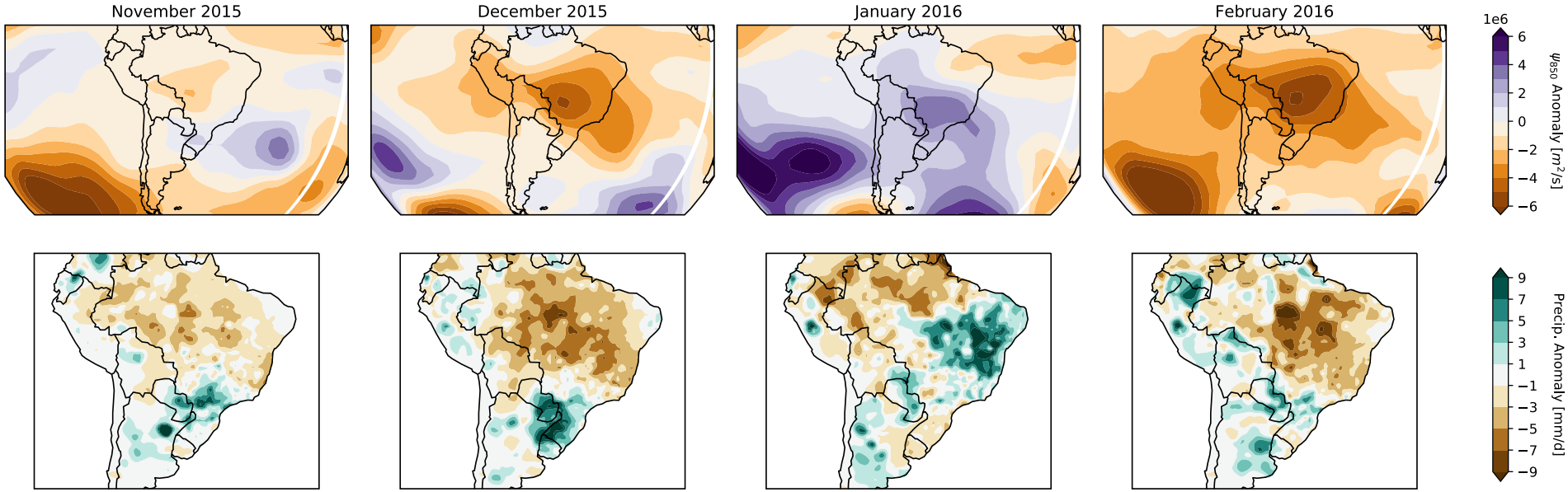
La tormenta que azotó la Capital y alrededores este viernes fue una de las más grandes de los últimos 18 años. Dejó dos muertos, los servicios de agua potable y energía eléctrica colapsados y se declaró emergencia vial.

Me gusta 33 Twittear G+1 0

El derrumbe de este muro causó la muerte de un adolescente. Foto: Última Hora

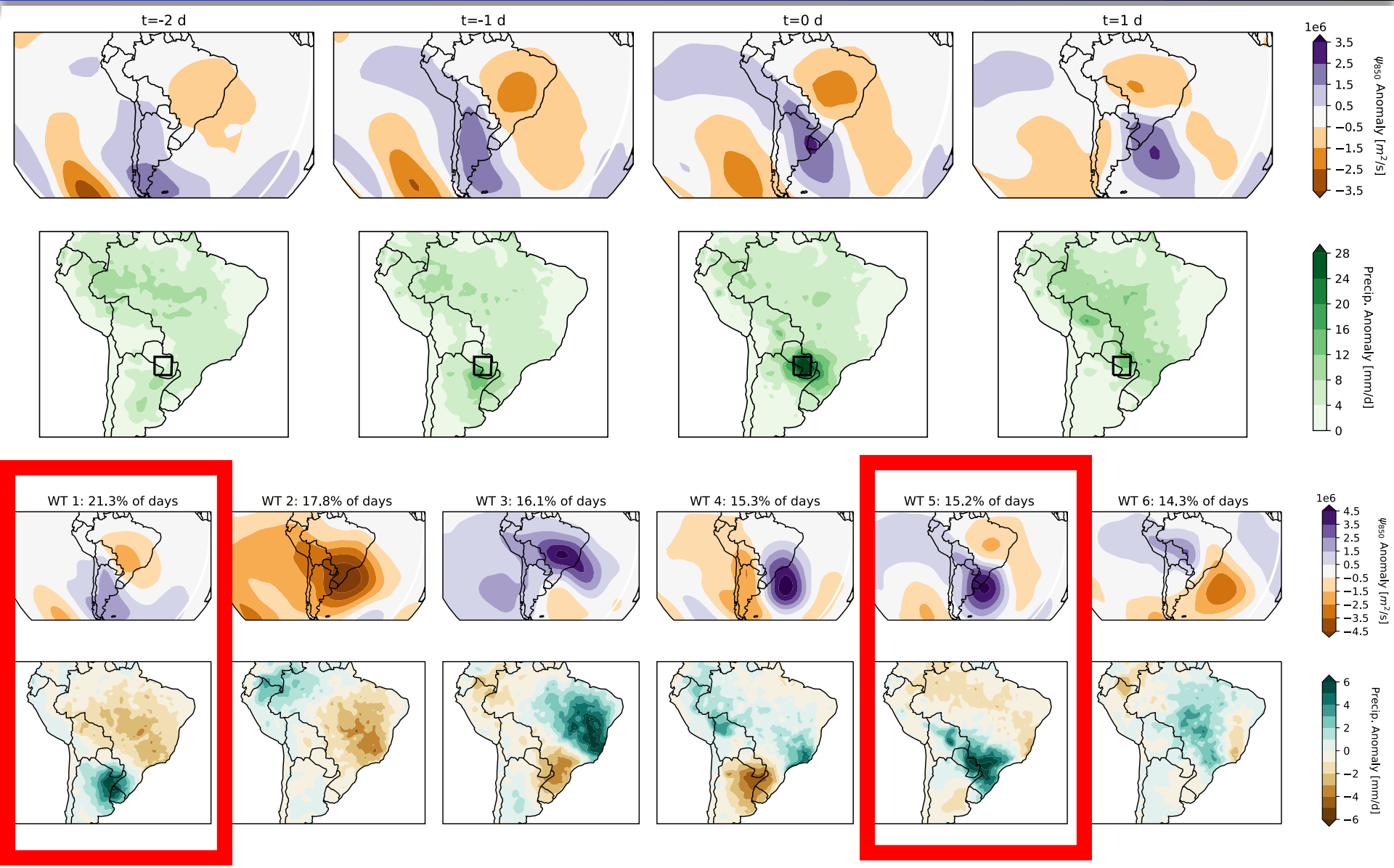
Julián Báez, director de la Dirección de Meteorología, afirmó que el temporal que afectó principalmente a la Capital del país y el Área Metropolitana fue el más grande de los últimos 18 años.





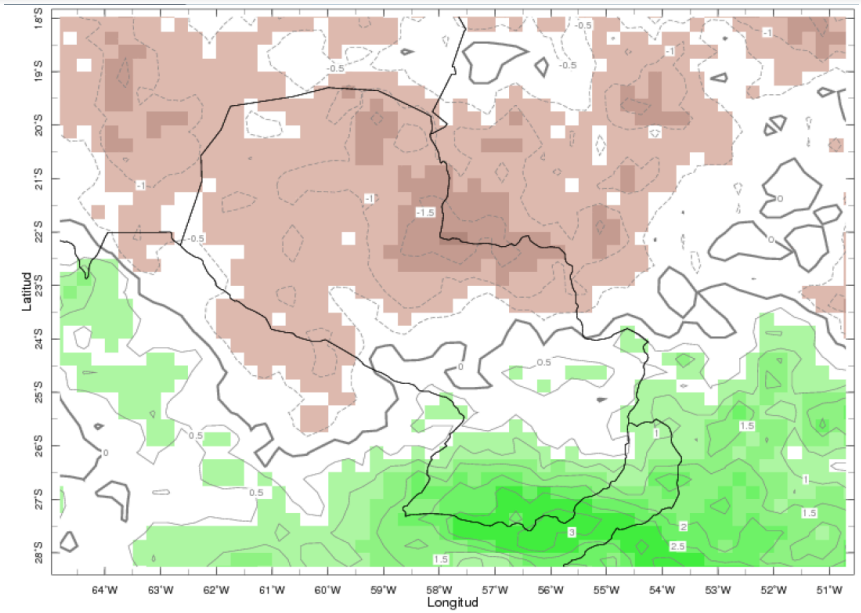
Doss-Gollin et al. (2016; to be submitted)

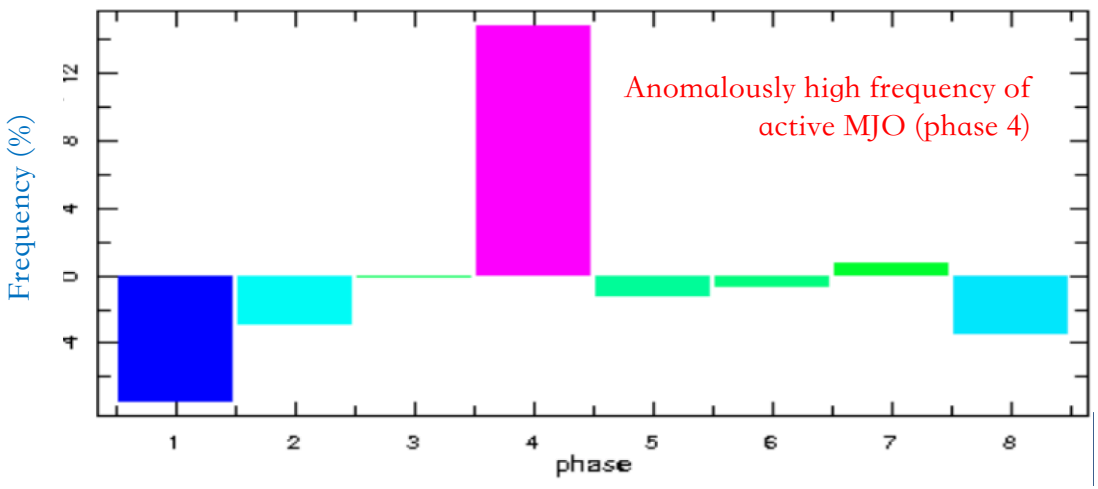
Extreme Rainfall: Paraguay River Basin



Extreme Rainfall: Paraguay River Basin

MJO rainfall composite (phase 4)



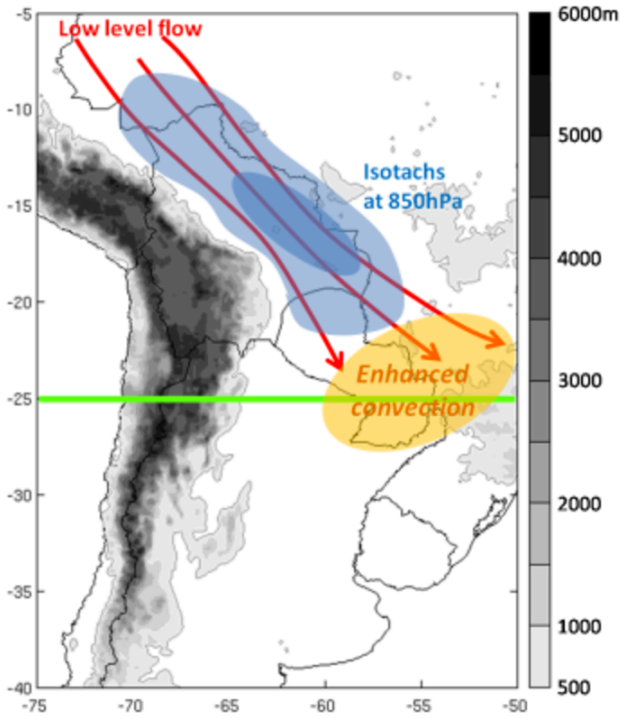


Doss-Gollin et al. (2016; to be submitted)

ENSO+MJO

Schematics of the circulation in low levels under NCJE event

http://www.eumetrain.org/satmanu/CMs/BoHi/navmenu.php?page=2.0.0



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Extreme Rainfall in NE US

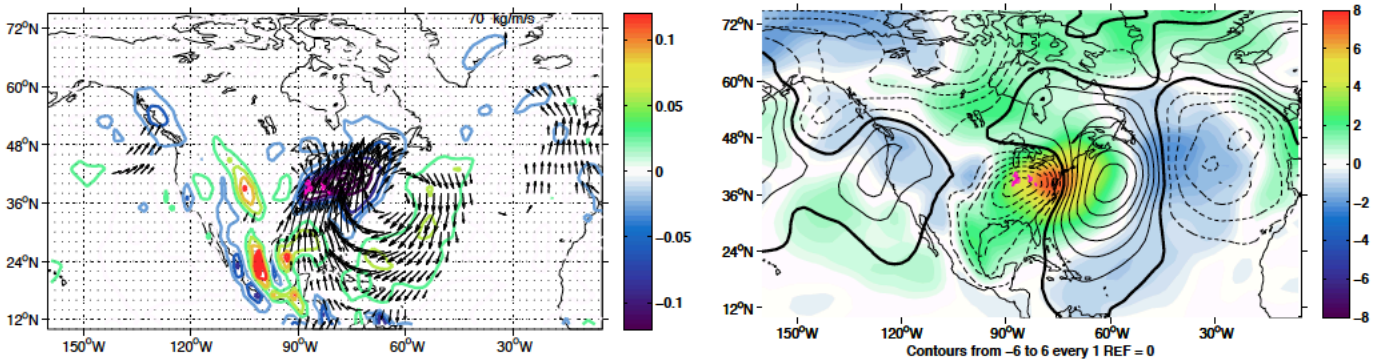


Figure 2. (a) Vertically integrated 600 hPa - surface moisture flux in $kg\ m\ s^{-1}$ (strongest 20 percent of values shown as arrows) and moisture divergence in $g\ m^{-2}\ s^{-1}$ (contours) (b) 850 hPa temperature (colors, °C) and mean sea level pressure (contours, hPa) Composite of 20 extreme flood events (1901–2008) observed in large drainage basins (size $> \ 10^3\ km^2$) within the Ohio Valley (basin outlines in hot pink) one day prior to start of 10-year flood [Nakamura et al., 2012].

Extreme Rainfall in NE US

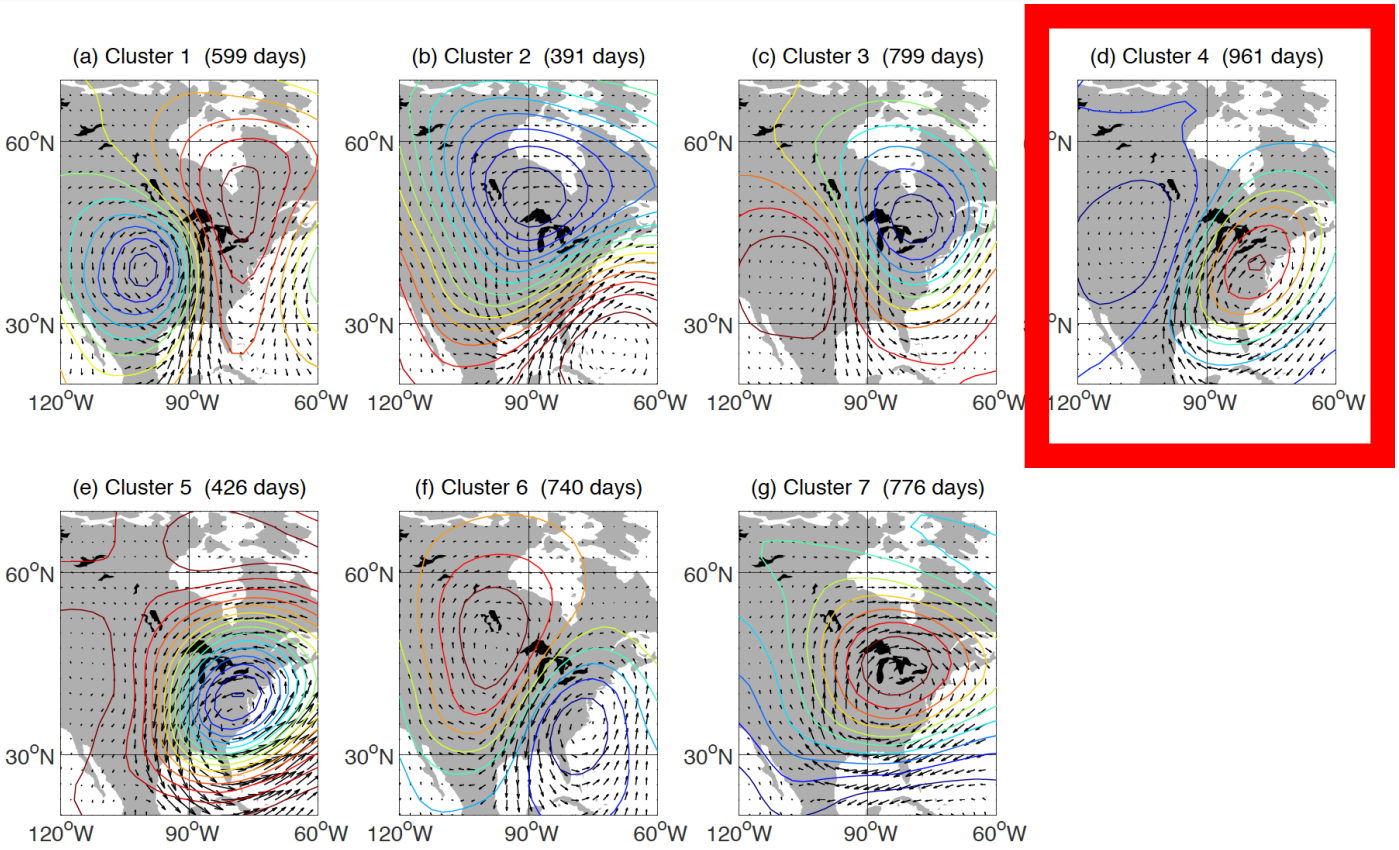
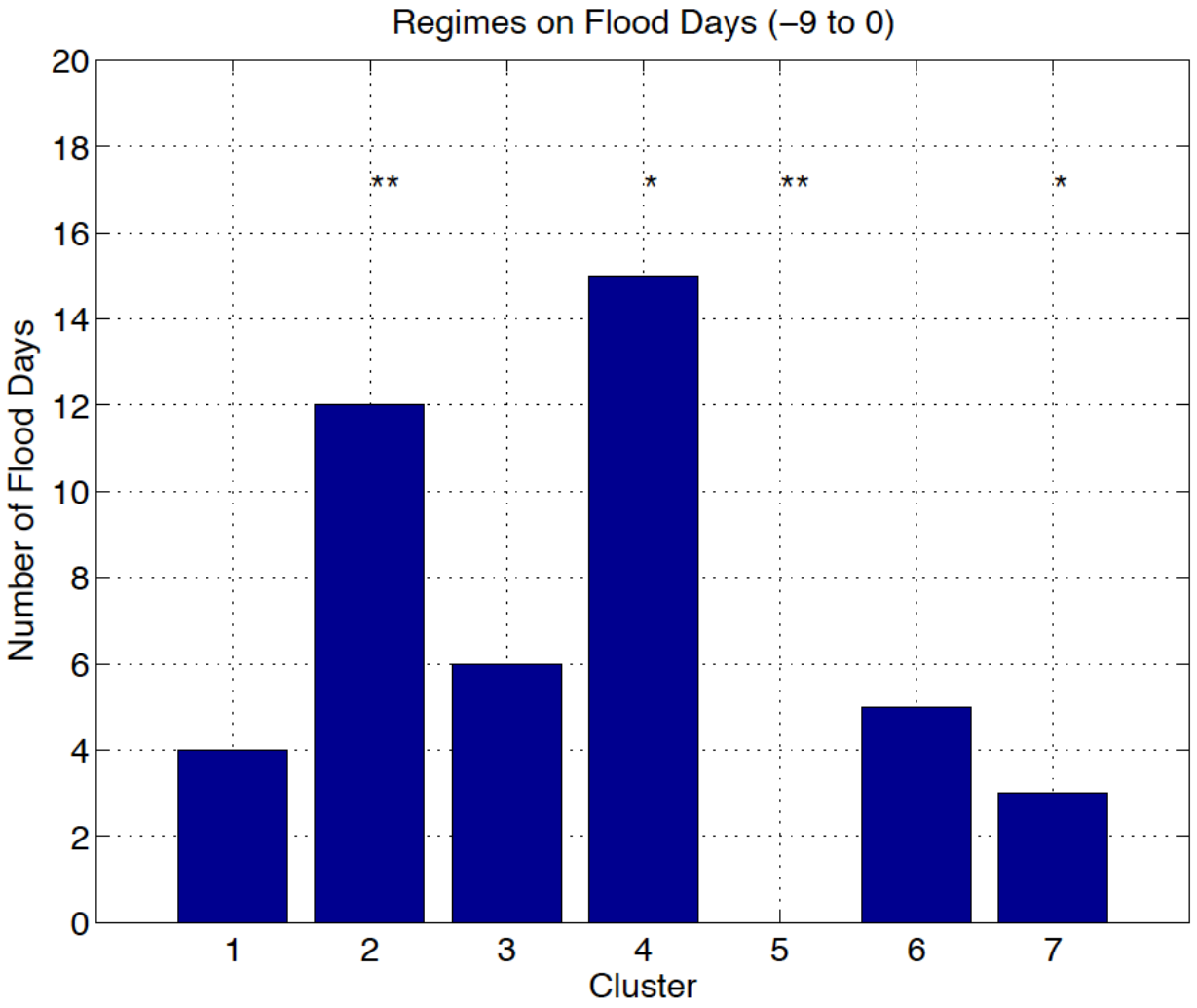


Figure 4. Seven-cluster K-means solution, showing 700hPa geopotential height anomalies (CI: 20 gpm), together with anomaly composites of vertically integrated moisture fluxes (arrows). Panel titles give the number of MAM days assigned to each cluster.

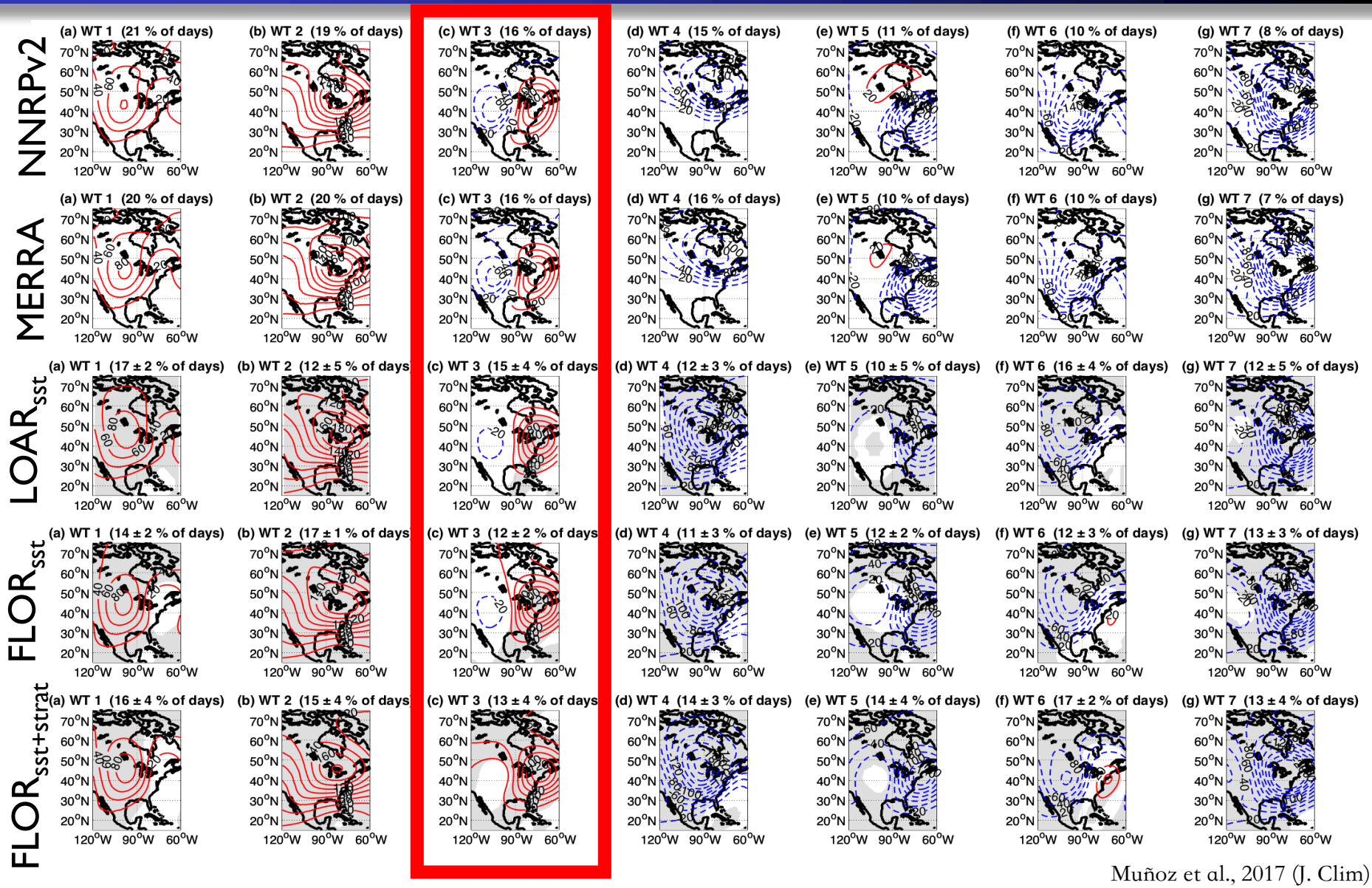
Robertson et al., 2015

Extreme Rainfall in NE US



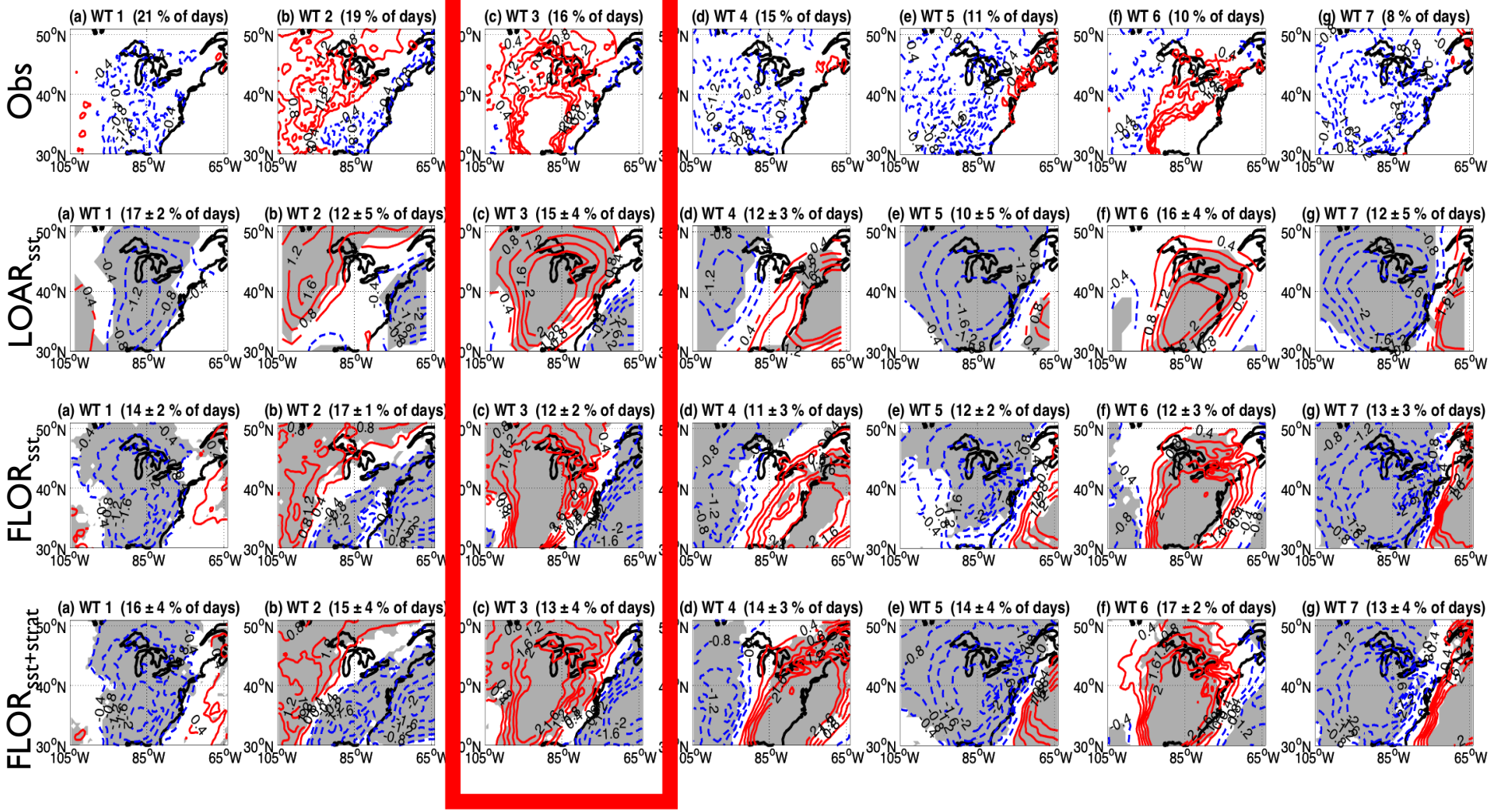
Robertson et al., 2015

Extreme Rainfall in NE US



Muñoz et al., 2017 (J. Clim)

Extreme Rainfall in NE US



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Summary

+ Different mechanisms could be understood in terms of perturbations of circulation pattern characteristics (location, frequency of occurrence, intensity, ⋯)

+ Tropical-extratropical interactions change atmospheric circulation patterns that could be conducive to extreme rainfall events.

+ Multiple spatial and temporal scales.

+ How to link extreme rainfall, climate drivers and circulation patterns?