EGU General Assembly 2021

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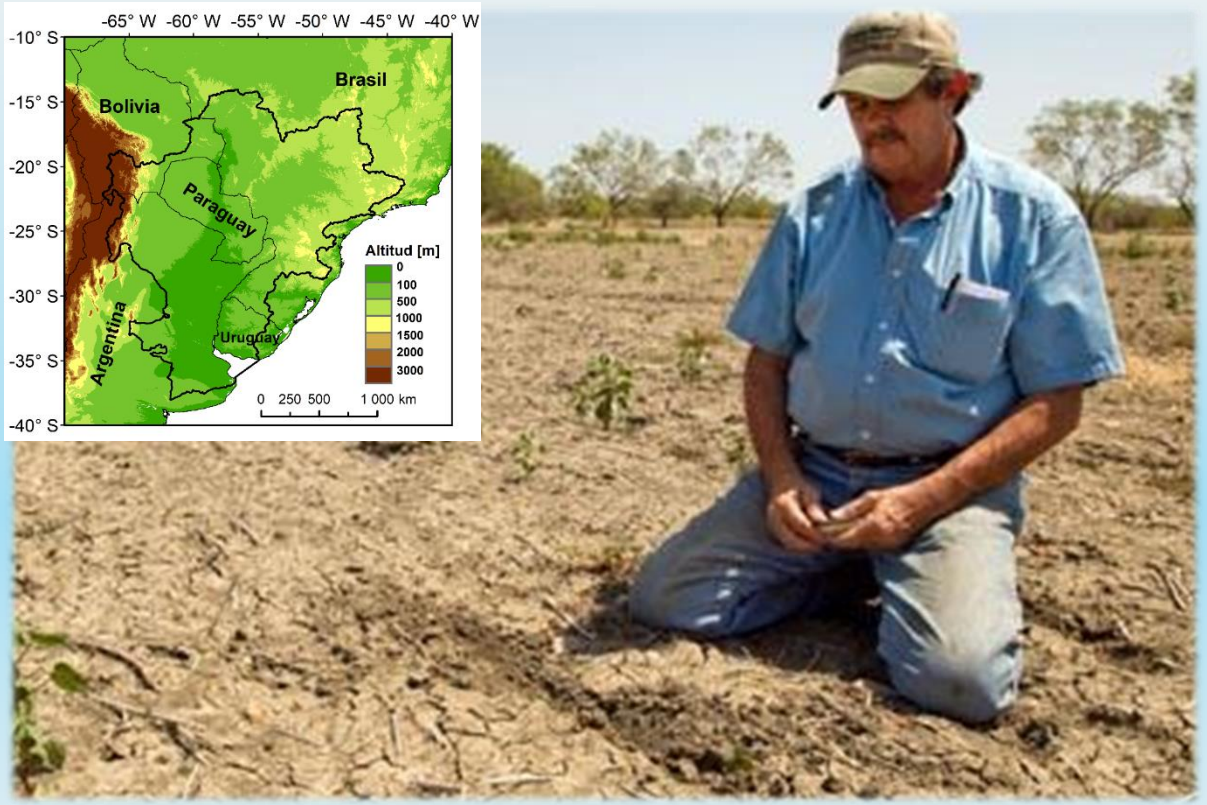
Flash droughts in southern South America as captured by ERA5 reanalysis data



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CENTRO DE ESTUDIOS DE VARIABILIDAD Y CAMBIO CLIMÁTICO

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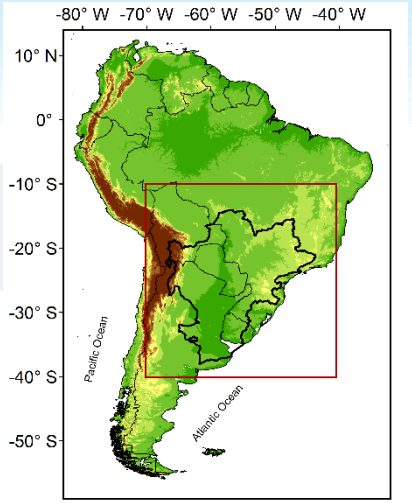
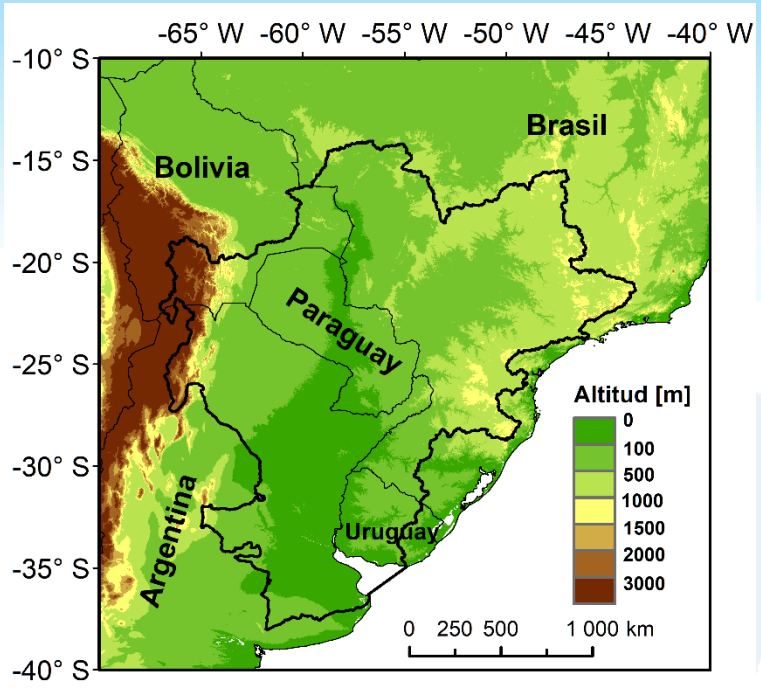
Southern South America





- Concentrates most of the economic activities and the population of the region.
- Has high vulnerability to climate extremes of precipitation and temperature

OBJECTIVE

✓ This study investigates the frequency of occurrence, the persistency and observed trends of two types of flash droughts in southern South America: heatwave flash droughts (HWFD) and precipitation deficit flash droughts (PDFD).

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ERA5 reanalysis

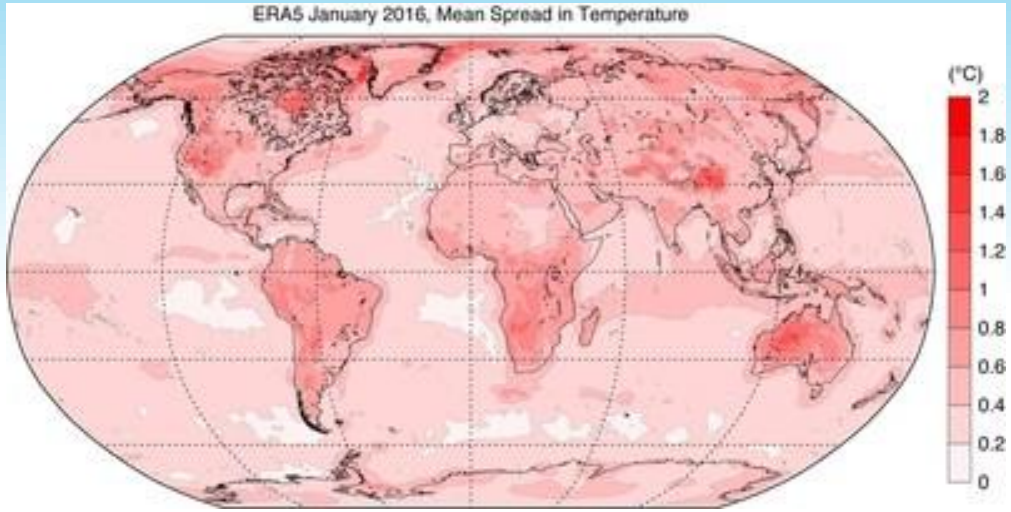
Original hourly data : 1979 onwards

Back extension: 1950-1978 period

Daily Data

regular lat-lon grid of 0.25 degrees
Study period: 1950-2020

- Temperature (T)
- Evapotranspiration (EVT)
- Precipitation (P)
- Root-zone Soil Moisture (top meter of soil) (SM)



- We computed pentads (5 day means) for each variable

- Anomalies are defined as departures from the climatology during the 1950-2020 base period

- We computed percentiles for SM and P

Approach

Following Mo and Lettenmaier (2015, 2016): Two types of flash droughts originated from different physical mechanisms. Multiple variables forcing drought's occurrence.

Heat wave FD → T driven

Conditions:

- **Tair anom > 1 standard deviation**
- **EVT anomaly > 0**
- **Percentile SM < 40%**

P-deficit FD → P driven

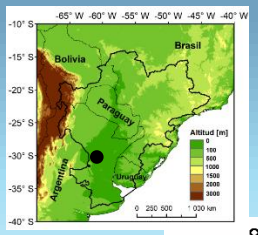
Conditions:

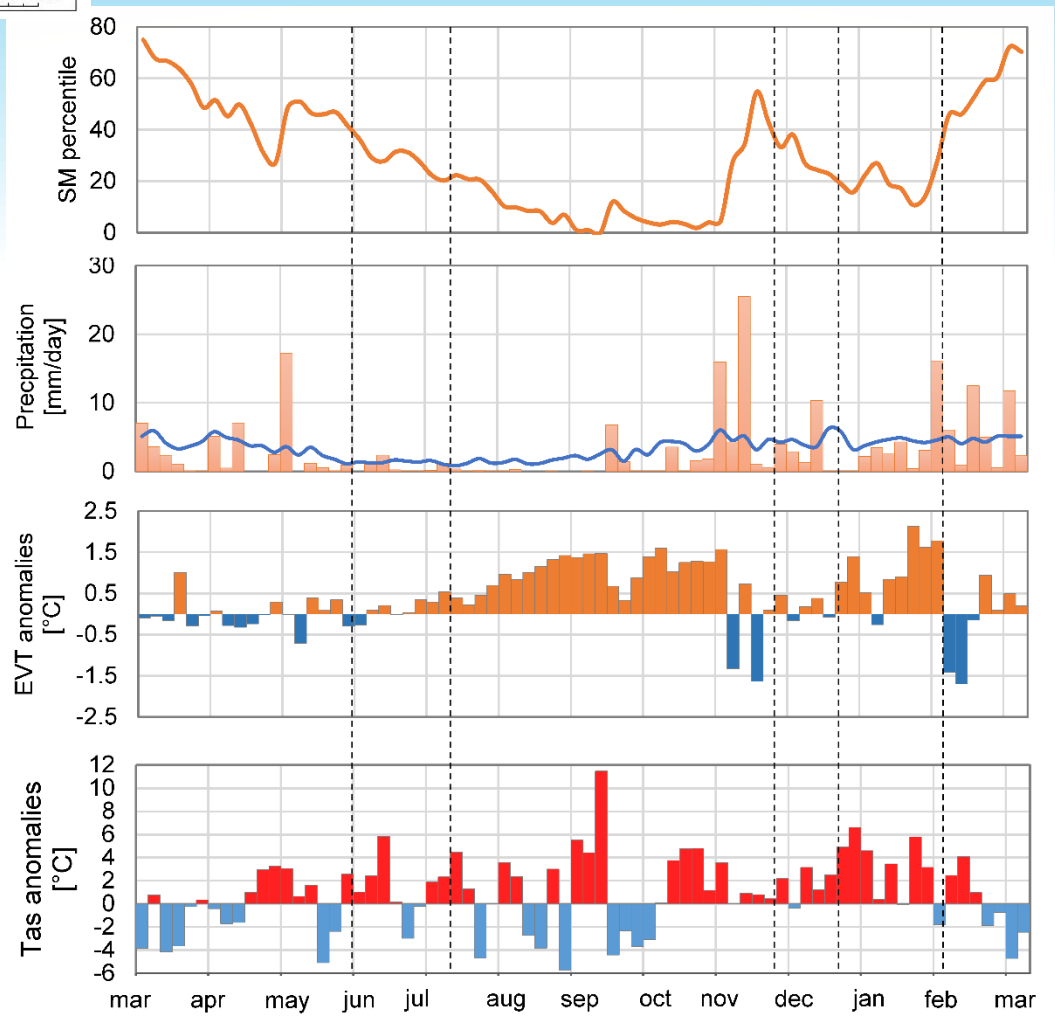
- **Percentile P < 40%**
- **EVT anomaly < 0**
- **Tair anom > 1 standard deviation**

We also included (following Liu et al., 2020)

- **P anomaly < 0**
- **Percentile SM < 40%**

Example: advantages and disadvantages of the method





Time series of pentads for **march 2013 – march 2014** at a grid cell centered on **30S, 61W (in the center of the Pampas plain)** of (a) soil moisture percentiles, (b) precipitation and its climatological cycle (blue line), (c) evapotranspiration anomalies, and (d) mean temperature anomalies.

Pros

- Treatment of drought as a compound extreme event, using multiple variables.

- It is based on supported physical mechanisms.

Cons

- The definitions do not account for changes in soil moisture with time (rapid intensification), nor is the threshold dry enough to actually be considered drought (Otkin et al., 2018; Osman et al., 2021).

- It identifies very short periods (one or two pentads) as flash drought, too short to cause impacts.

Methodology

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Frequency of occurrence (FOC)

1- We computed the number of pentads (N) under HWFD o PDFD

2- We estimated the percentage over the total number of pentads (Nt)

$$\mathrm{FOC} = \frac{N}{N_{\mathrm{total}}}(100\%).$$

Persistency

- We counted the percentage of events that persist for 1, 2, 3 or more consecutive pentads.

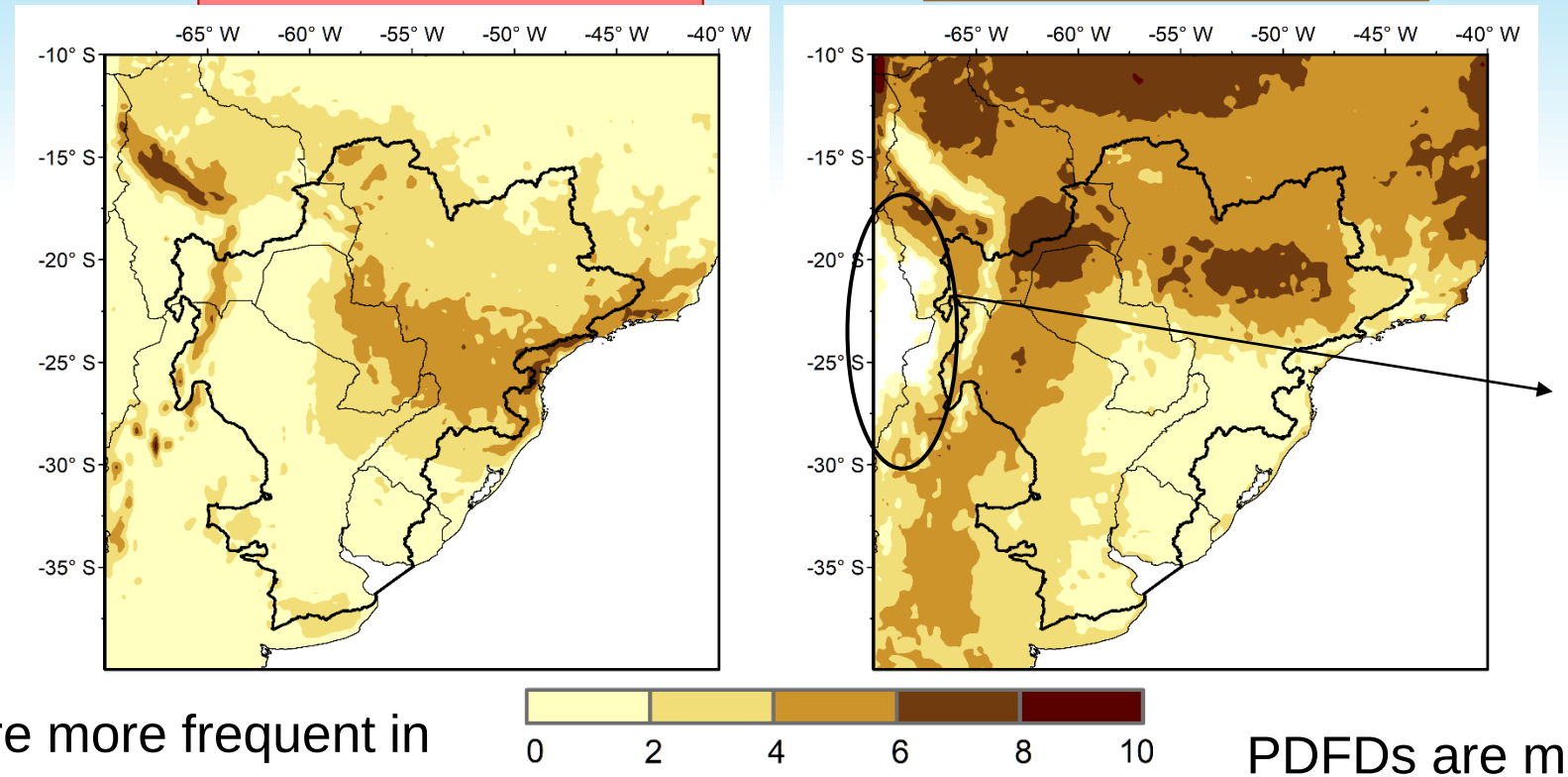
Trends

- We estimated linear trends by least squares fit in the total number of pentads under FD conditions and in the number of events per consecutive pentads.
- We calculated the significance at the 95% confidence level with the Mann-Kendall test.

FREQUENCY OF OCCURRENCE (FOC)

Heat wave FD

P-deficit FD

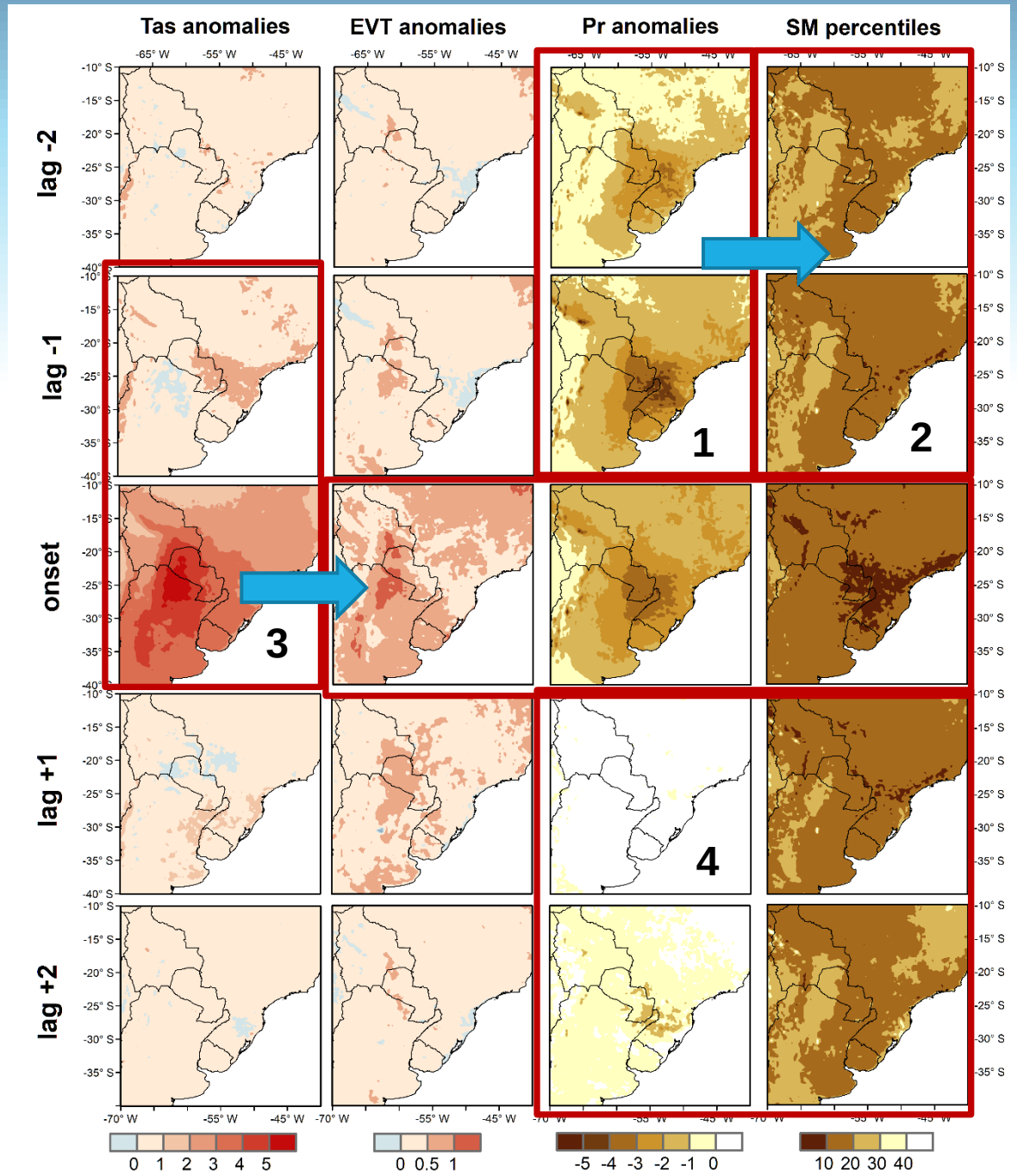


No PDFDs on the Atacama desert region

HWFDs are more frequent in southern Brazil, Paraguay, and central Bolivia (4-6%)

PDFDs are more frequent in the arid west and in the central-east of Brazil (6-8%)

PDFDs are more frequent than HWFDs



EVOLUTION OF A TYPICAL HWFD

Composite of each variable in lags (-2; +2) and onset

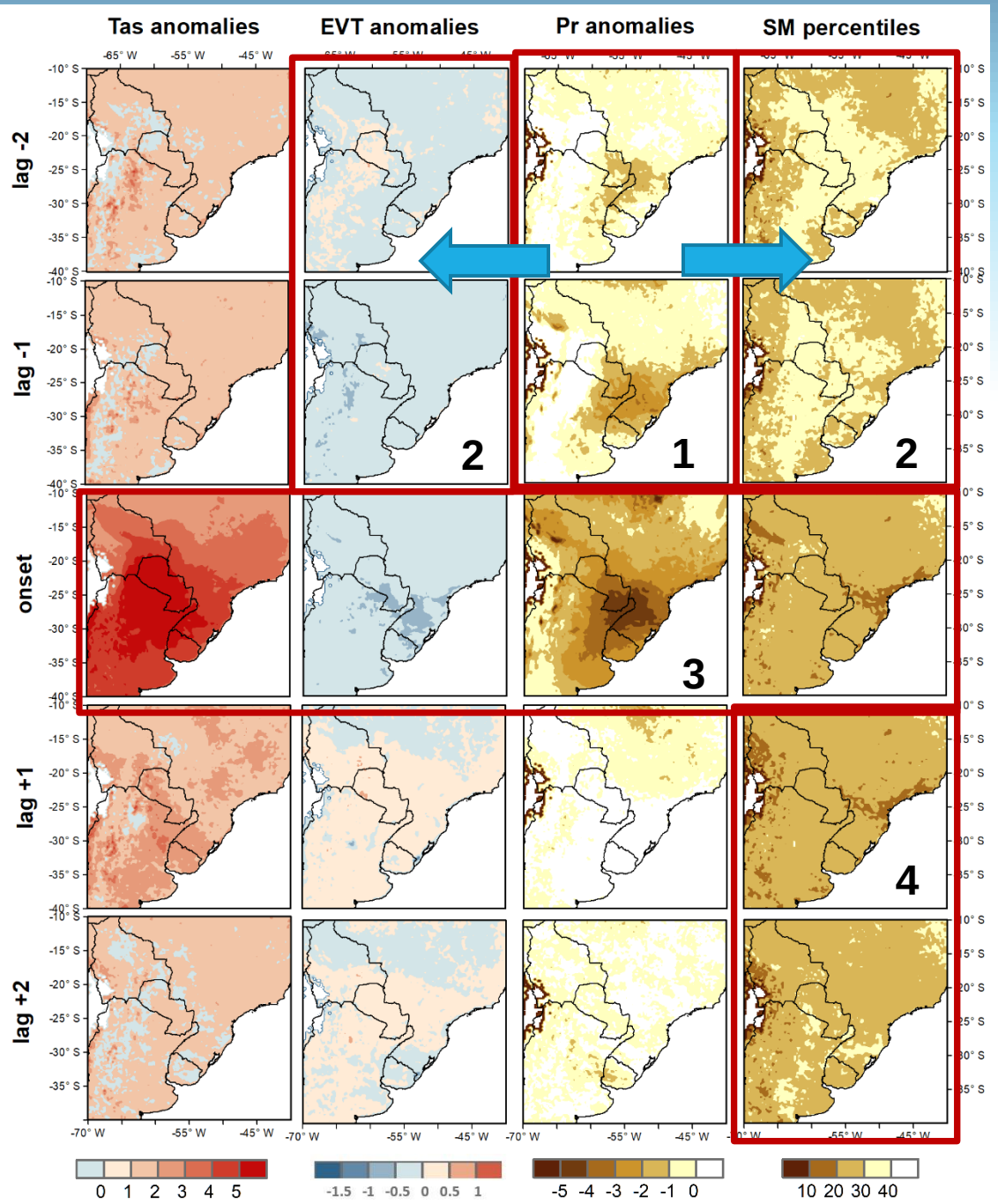
1- HWFD starts by T rise, but Panom <0 is needed prior to onset

2 - Panom <0 causes SM% <40

3 - T increases rapidly in the onset, produces an increase in EVT and greater SM deficits

4 - SM% <40 persists for more than two pentads, but not Panom <0

P role: to create favorable conditions for HWFD. It does not produce the increase in temperature or the increase in ET.



EVOLUTION OF A TYPICAL PDFD

Composite of each variable in lags (-2; +2) and onset

1- Panom < 0 before the onset and gain strength towards onset

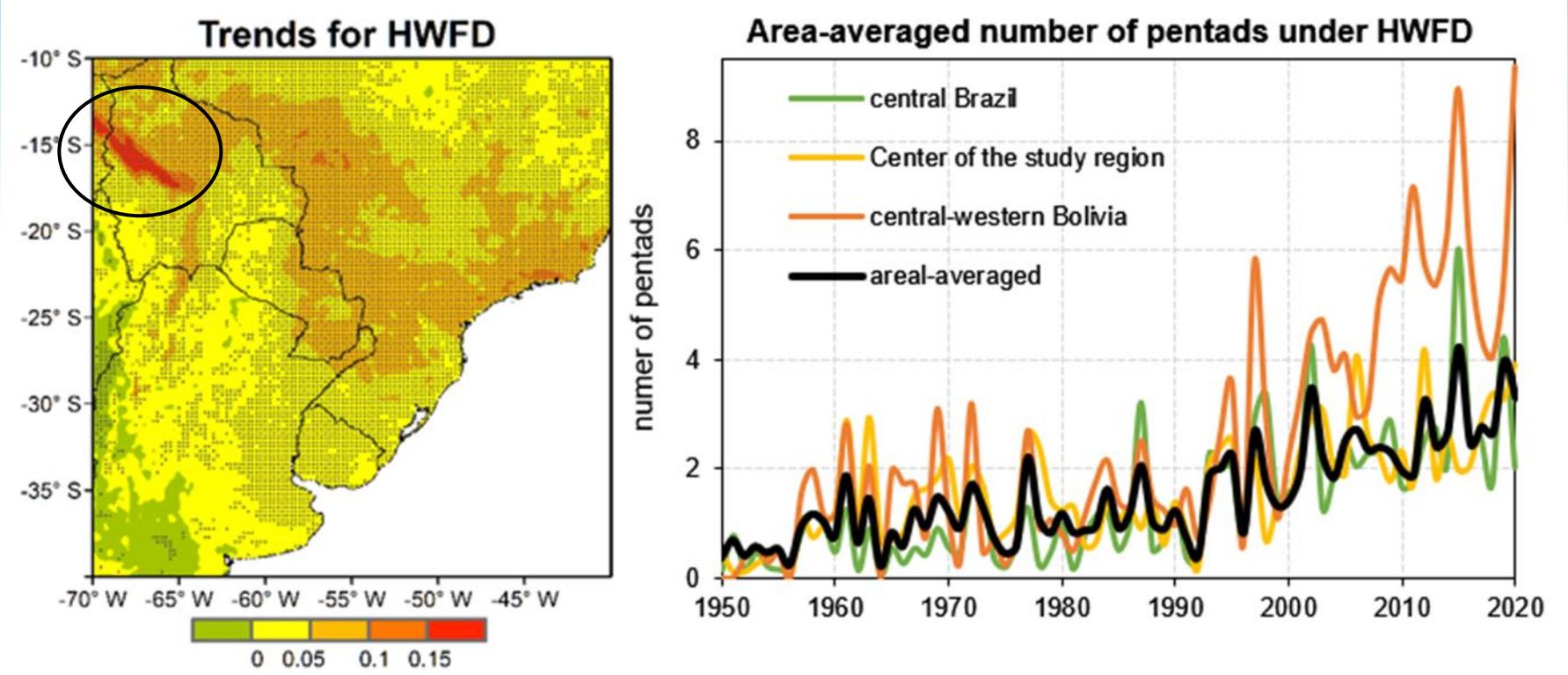
2 - Panom <0 causes SM% < 40 and ET decreases in response to SM

3 - In onset Panom reaches the minimum and produces a decrease in SM (EVT and T respond)

4 - SM% < 40 persists for more than two pentads

P role: generate the PDFD. The increase in temperature is consistent with the decrease in ET.

Trends



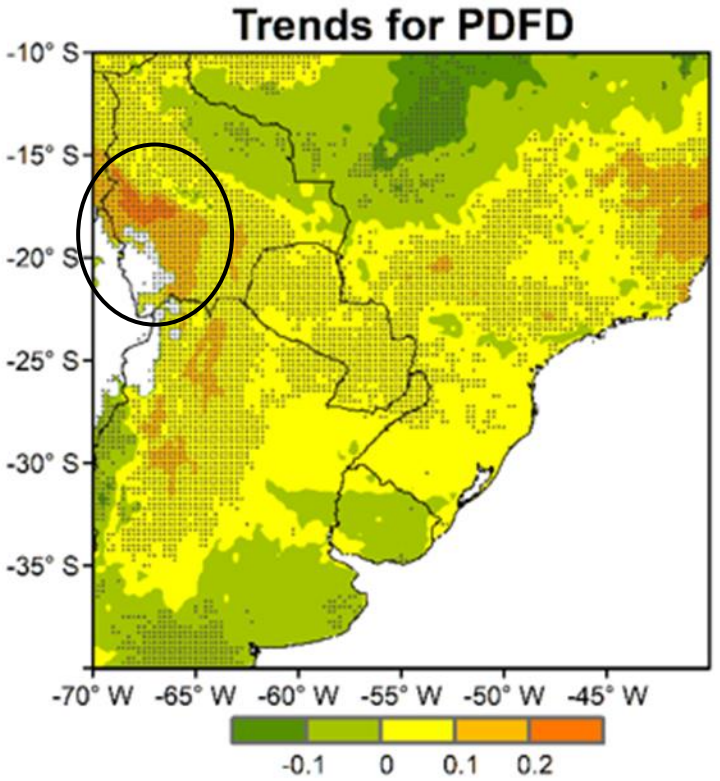
Highest increase in HWFD since 1990

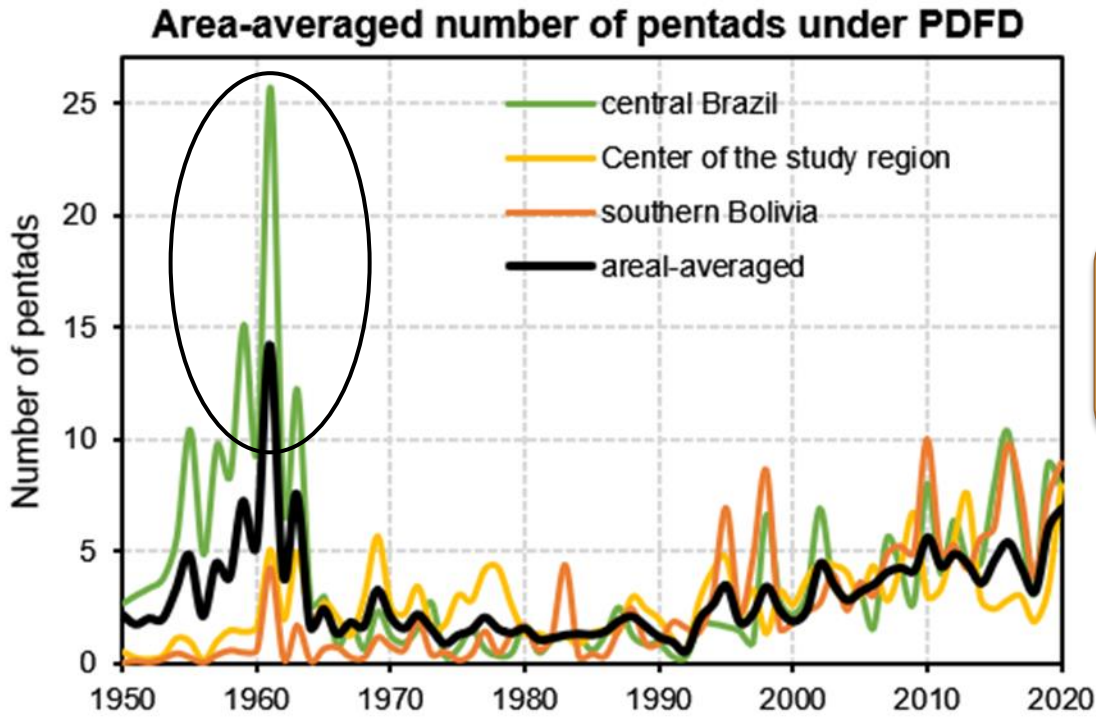
Significant positive trends in almost the entire region

Highest increase in HWFD in the tropical rainy region of Bolivia

Higher positive trends in regions of higher FOC

Trends





Highest increase in PDFD since 1990

Significant positive trends in most of the study region.

Highest increase in PDFD towards southwestern Bolivia (Andean zone)

Particular peak in early 1960s in central Brazil (green line)

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Concluding Remarks

✓ Flash drought conditions were reported in southern South America. PDFDs are more frequent than HWFDs

✓ Flash droughts conditions do not persist for a long time (because Tanom do not persist), although the SM deficit persists for a long period (not shown here)

✓ It was verified that the evolutions of the "typical" HWFD and PDFD respond to the proposed physical mechanisms.

✓ HWFD and PDFD showed significant positive trends

✓ **Given the disadvantages of the method here used, we will analyze other FD definitions that include the rapid depletion of soil moisture.**

Thanks for your attention

References

Liu, Y., Zhu, Y., Ren, L., Otkin, J., Hunt, E. D., Yang, X., Yuan, F., & Jiang, S., 2020. Two Different Methods for Flash Drought Identification: Comparison of Their Strengths and Limitations, Journal of Hydrometeorology, 21(4), 691-704. https://doi.org/10.1175/JHM-D-19-0088.1

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Otkin, J., M. Svoboda, E. D. Hunt, T. W. Ford, M. C. Anderson, C. Hain, and J. B. Basara, 2018. Flash droughts: A review and assessment of the challenges imposed by rapid onset droughts in the United States. Bull. Amer. Meteor. Soc., 99, 911–919, https://doi.org/10.1175/BAMS-D-17-0149.1.