COMPOUND DROUGHT AND HEATWAVES OVER SOUTH AMERICA UNDER PRESENT AND FUTURE CLIMATE CHANGE CONDITIONS:

HISTORICAL EVOLUTION, ATMOSPHERIC DYNAMICS AND LAND–ATMOSPHERE FEEDBACKS

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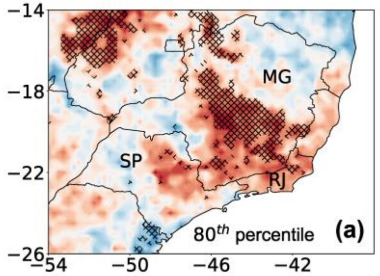
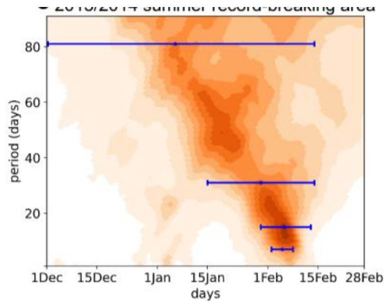
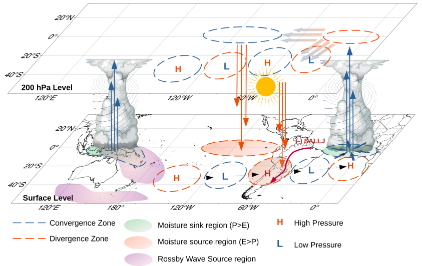
OUTLINE

1. **Compound Drought and Heatwaves**
   - Historical Characterization
   - Casy-studies: the summer seasons of 2013/2014 and 2014/2015

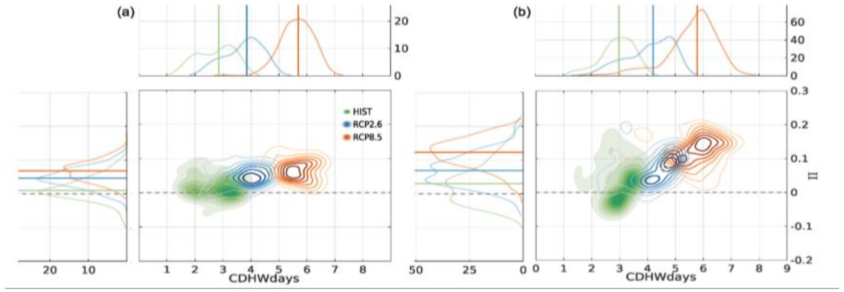




2. **The record-breaking 2013/2014 hot summer**
   - The exceptionality of the drought and heatwave conditions.
   - Influence of mesoscale meteorological drivers and soil moisture–temperature coupling on temperature escalation
3. **Combined large-scale tropical and subtropical forcing on severe droughts**
   - The joint role of internal variability and climate change on severe soil dessication
   - Flash droughts triggered by a coupled tropical and subtropical forcing



4. **Future influence of soil moisture–temperature coupling on compound hot and dry conditions**
   - Impact of climate change on the occurrence of compound hot and dry events through changes in the soil moisture–temperature coupling dynamics.



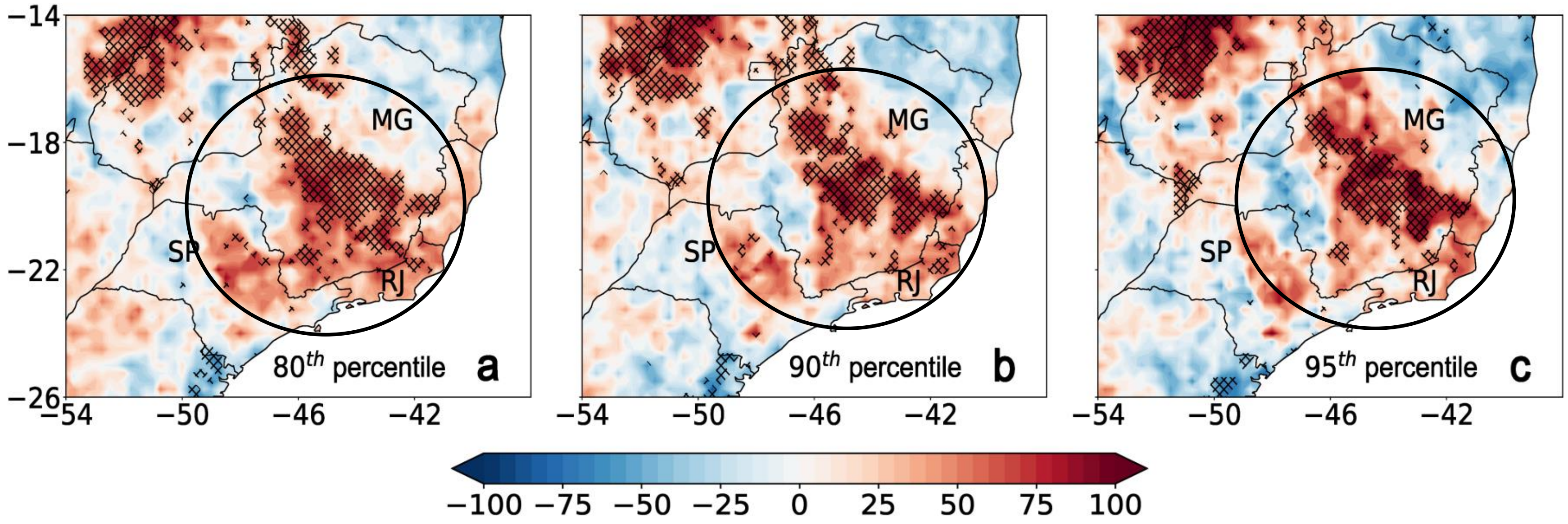
COMPOUND DROUGH AND HEATWAVES

HISTORICAL CHARACTERIZATION OVER SOUTHEAST BRAZIL

Period of analysis: Summer seasons (DJF) between 1980-2018.

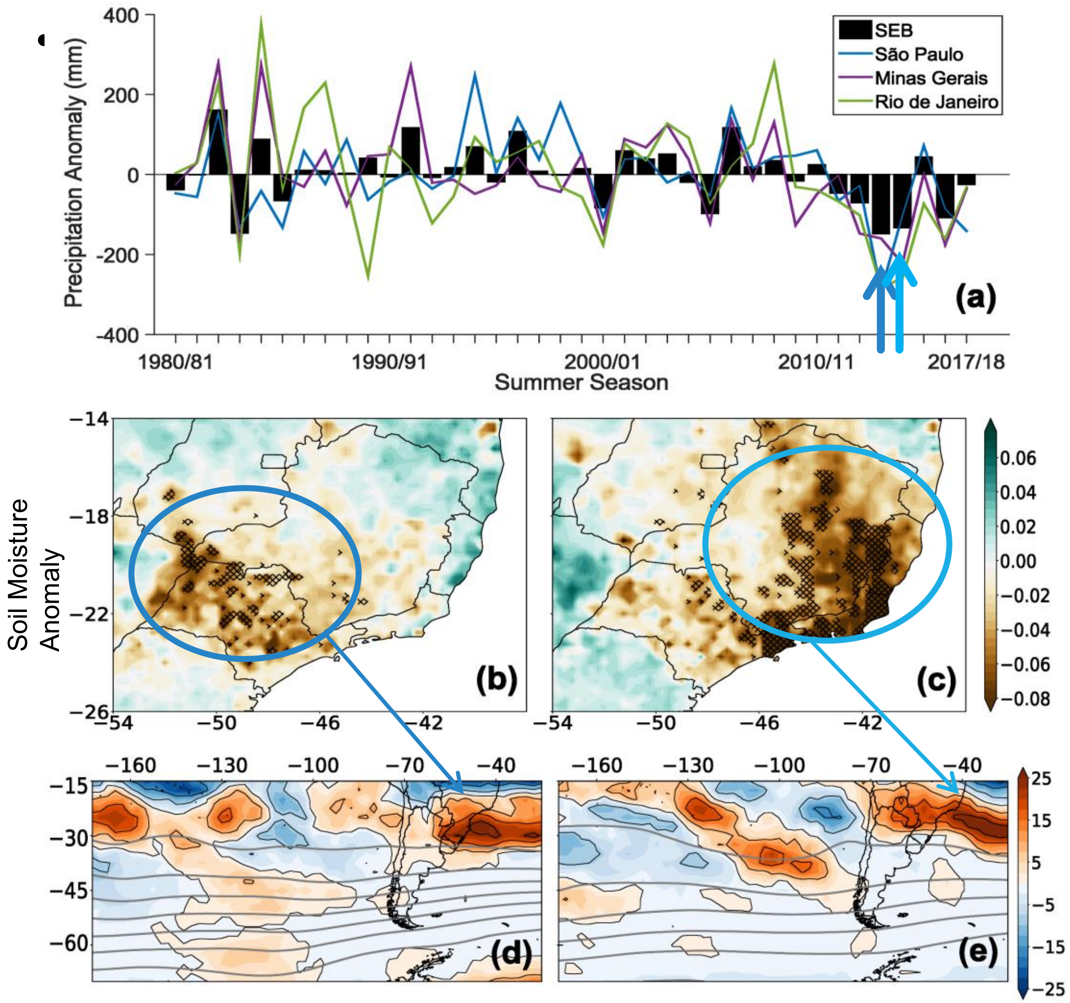
- **1st sub-period:** 1980/81 – 1998/1999 summer seasons;
- **2nd sub-period:** 1999/00 – 2017/2018 summer seasons;

$$Percent\ change\ (\%) = \frac{N^{o}.of\ compound\ events(\mathbf{2nd\ sub{-}period}) - N^{o}\ of\ compound\ events\ (\mathbf{1st\ sub{-}period})}{N^{o}\ of\ concurrent\ events\ (\mathbf{total\ analysis\ period})} \times 100$$

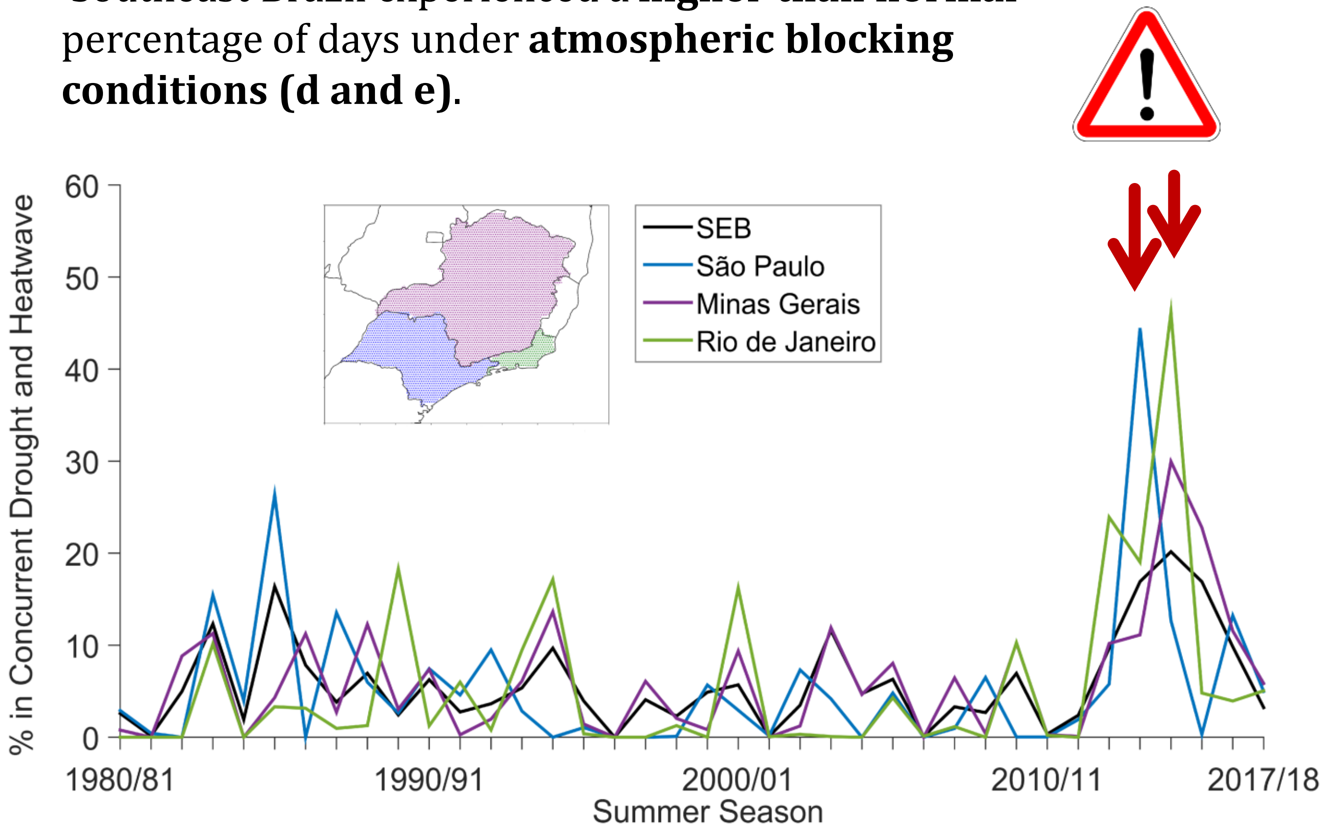


COMPOUND DROUGH AND HEATWAVE EVENTS

THE SUMMER SEASONS OF 2013/2014 AND 2014/2015

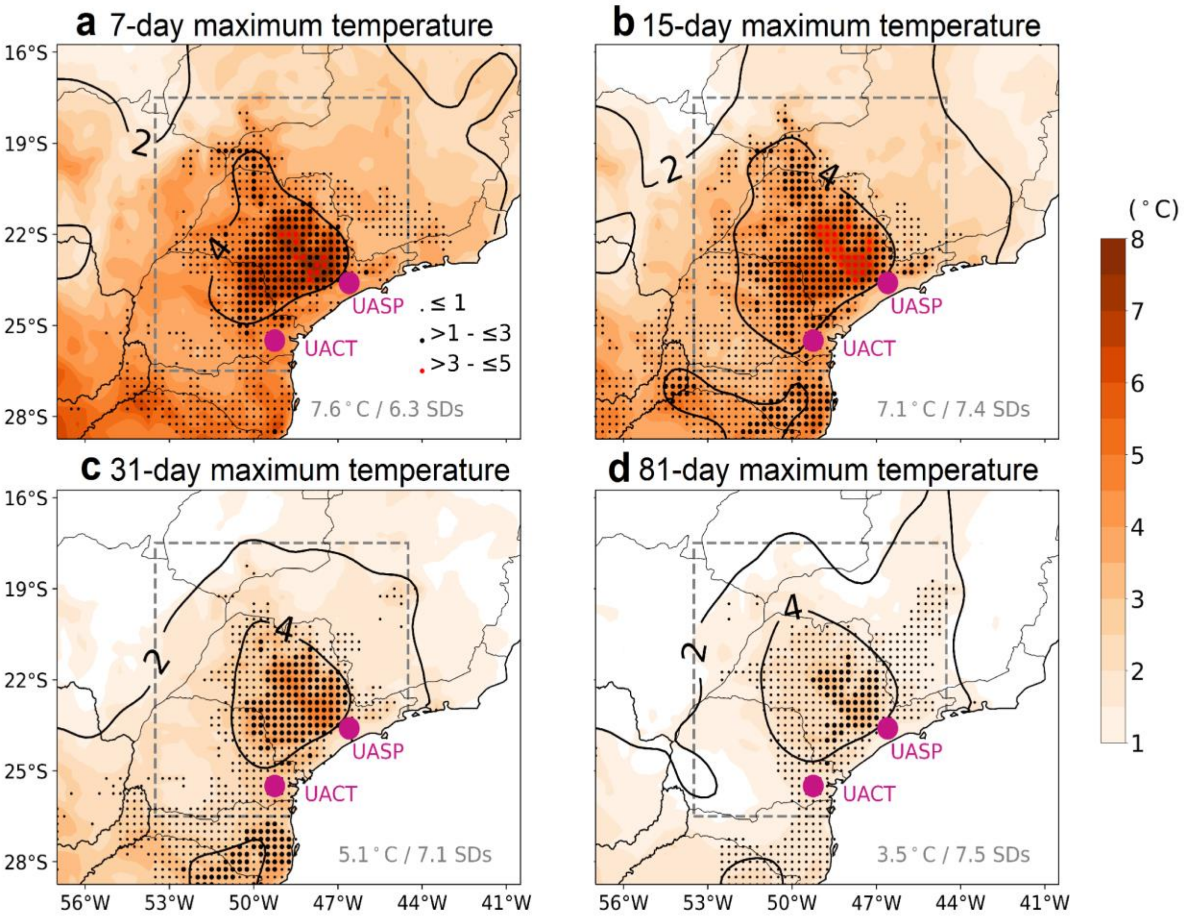


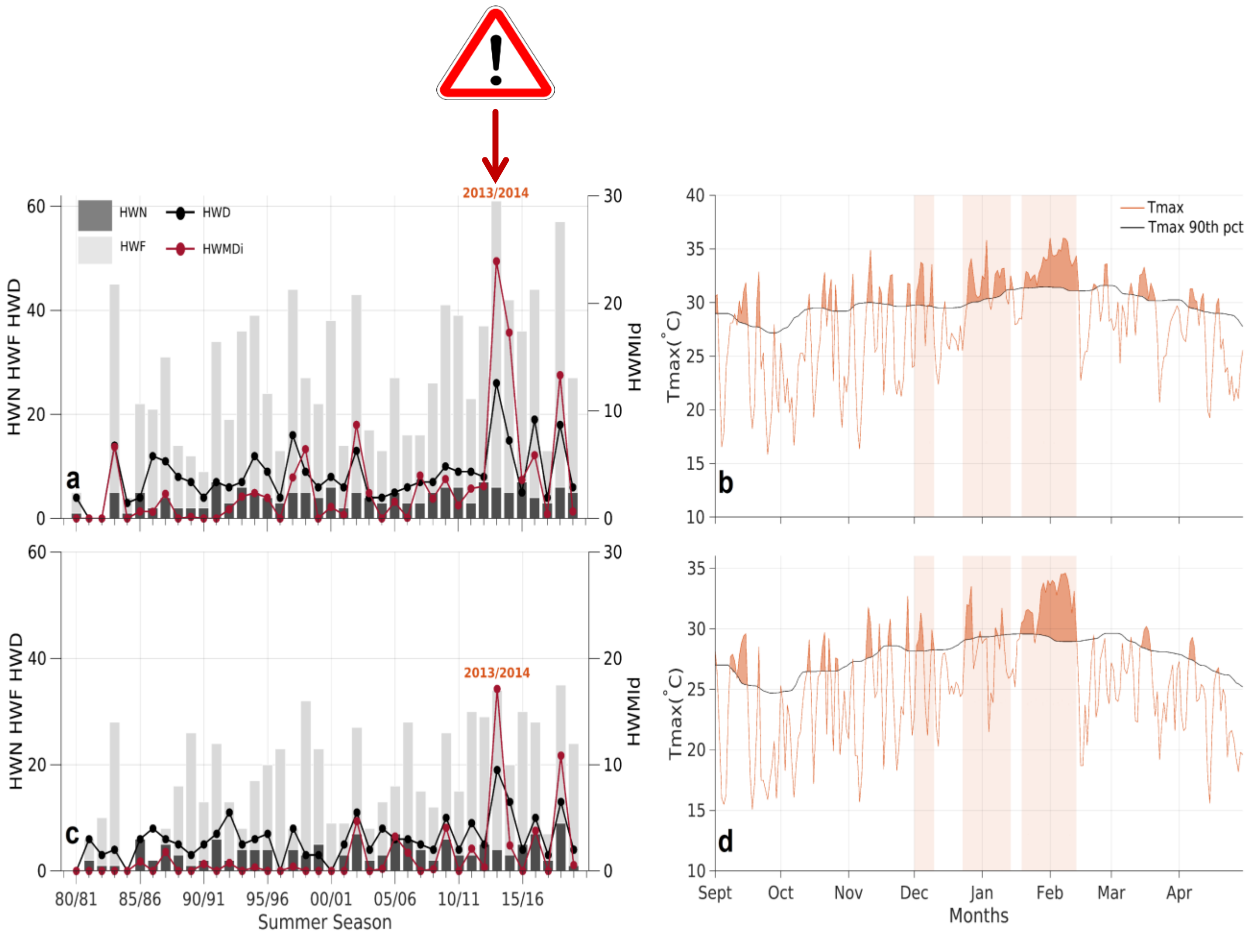
- Clear skies conditions were promoted by **persistent anticyclonic circulation patterns**.
- Southeast Brazil experienced a **higher than normal** percentage of days under **atmospheric blocking conditions (d and e)**.

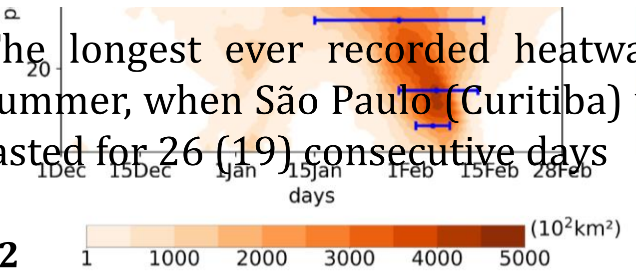


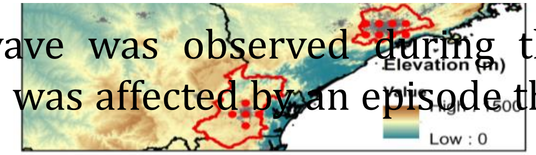
THE RECORD-BREAKING 2013/2014 SUMMER

HISTORICAL UNPRECEDENT WARM CONDITIONS









- The longest ever recorded heatwave was observed during this summer, when São Paulo (Curitiba) was affected by an episode that lasted for 26 (19) consecutive days

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THE RECORD-BREAKING 2013/2014 SUMMER

THE INFLUENCE OF SOIL DRY-OUT ON TEMPERATURE ESCALATION

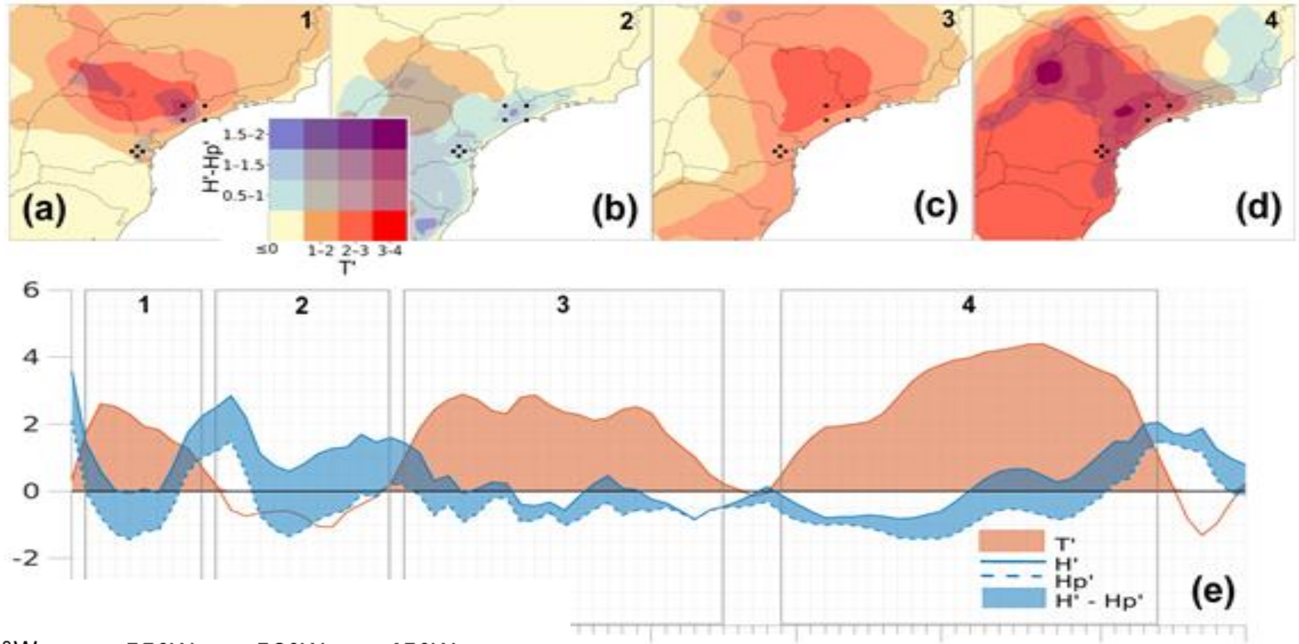
- Soil moisture–atmosphere coupling metric (π):

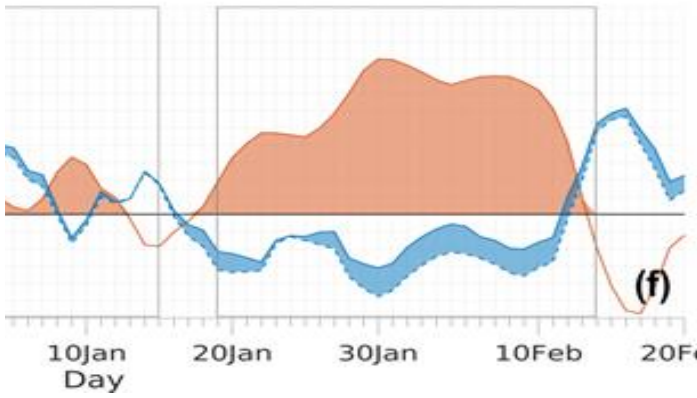
Temperature Term

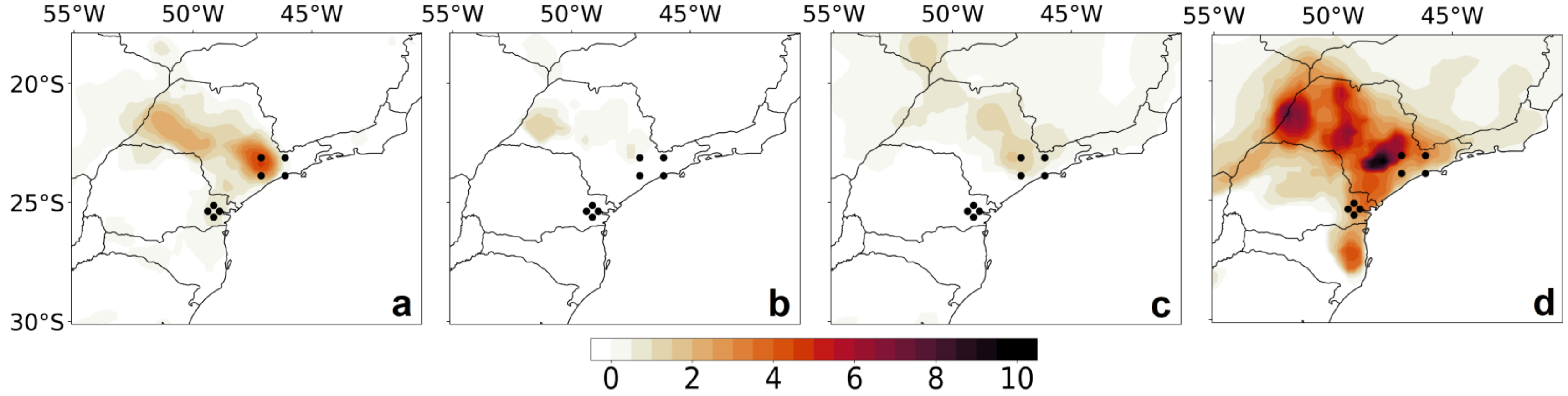
$$\pi = \underbrace{(H' - H'_p)}_{\text{Energy Term}}\,T'$$

Energy Term

$$(H' - H'_p) = (R_n - \lambda E)' - (R_n - \lambda E_p)'$$

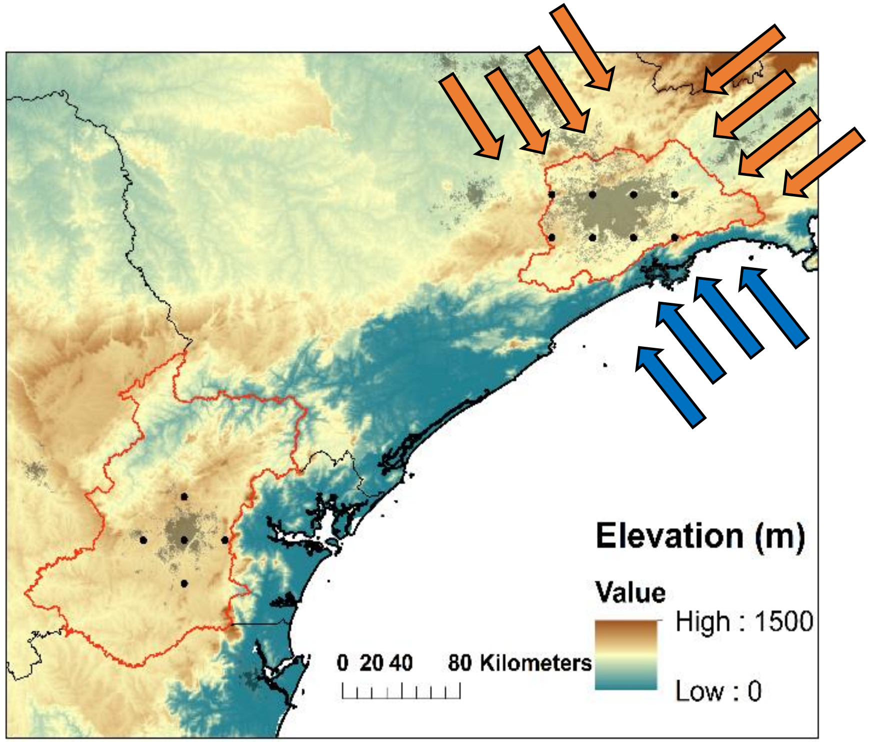


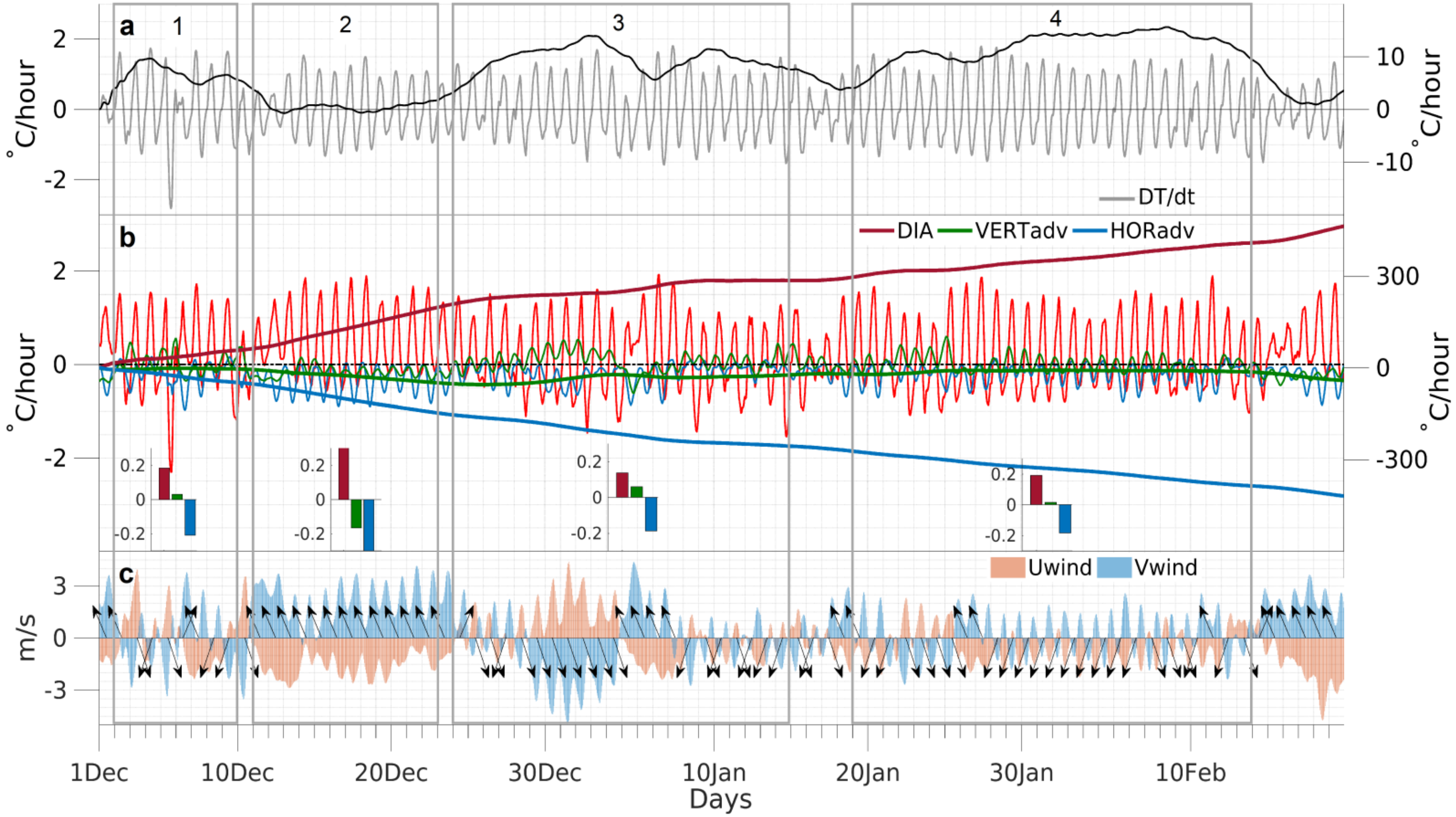




THE RECORD-BREAKING 2013/2014 SUMMER

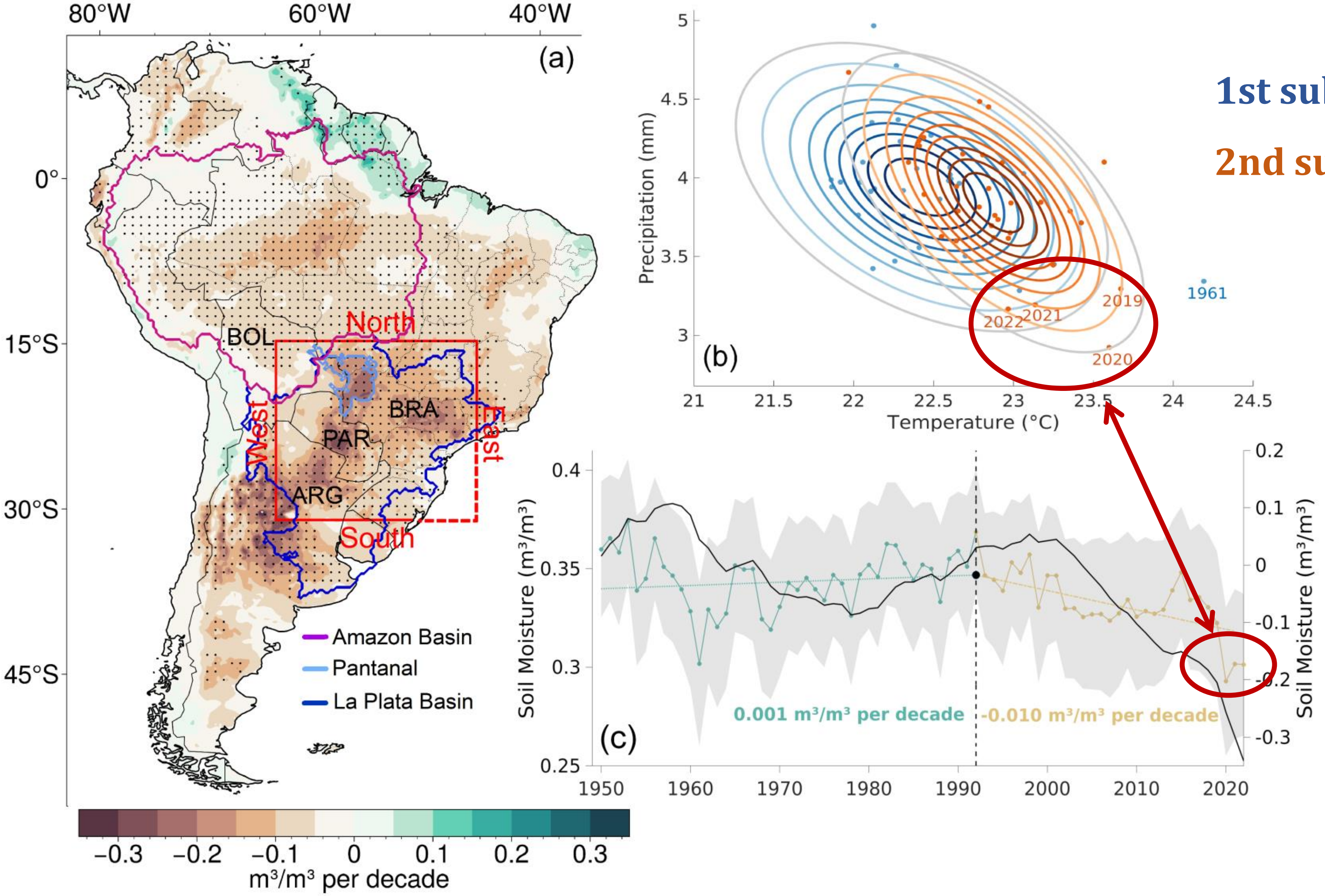
MESOSCALE METEOROLOGICAL DRIVERS





Combined large-scale tropical and subtropical forcing on severe droughts

A LONG-TERM HISTORICAL PERSPECTIVE OF SEVERE DROUGHT CONDITIONS IN SOUTH AMERICA



1st sub-period: 1959-1989

2nd sub-period: 1990-2022

$0,001\, m^3/m^3\ per\ decade$

vs

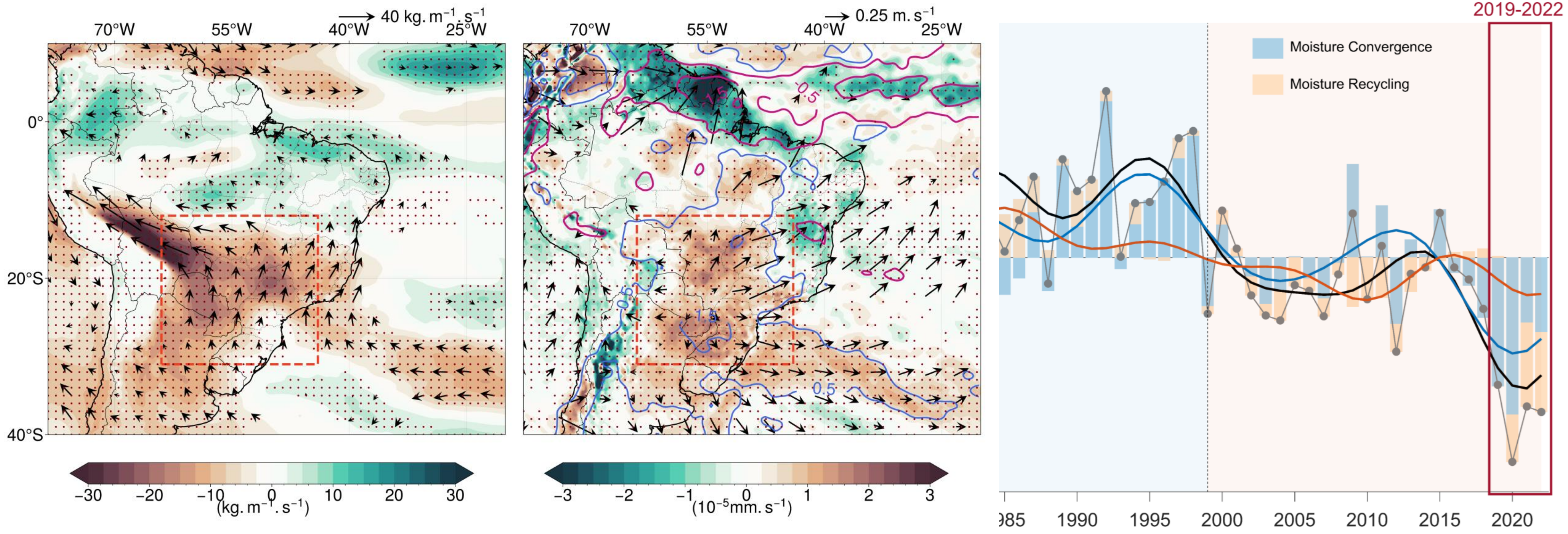
$-0,010\, m^3/m^3\ per\ decade$

Combined large-scale tropical and subtropical forcing on severe droughts

A LONG-TERM HISTORICAL PERSPECTIVE OF SEVERE DROUGHT CONDITIONS IN SOUTH AMERICA

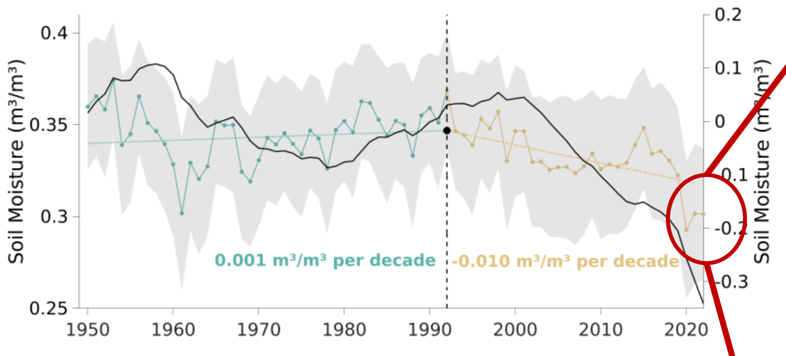
$$R\left(Prec.Anomaly_{Total}, Prec.Anomaly_{Moisture\ Convergence}\right) = 0{,}94$$

$$R\left(Prec.Anomaly_{Total}, Prec.Anomaly_{Moisture\ Recycling}\right) = 0{,}56$$



Combined large-scale tropical and subtropical forcing on severe droughts

A CLOSER INSIGHT INTO THE SEVERE 2019-2022 DROUGHT: EVOLUTION, EXCEPTIONALITY AND SPATIAL EXTENT

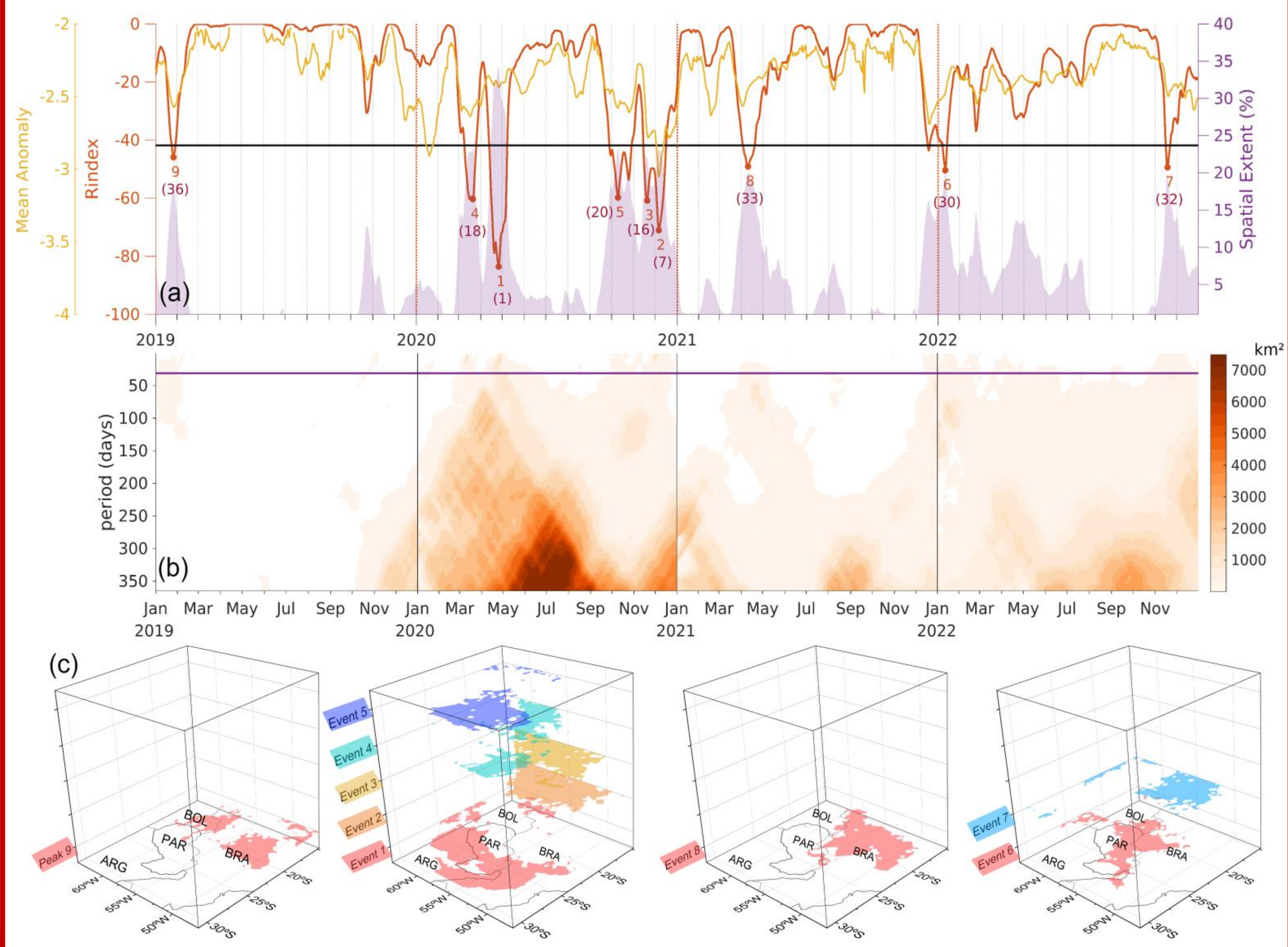


$$R_{index} = S_1 \times S_2$$

S_1 = mean standardized anomaly of soil moisture (*)

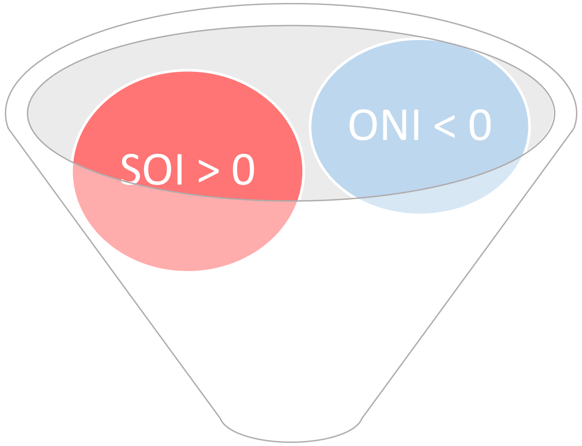
S_2 = percentage of SE South America with soil moisture anomalies < 2std

(*) only considering the grid-points where soil moisture anomaly < 2std.



Combined large-scale tropical and subtropical forcing on severe droughts

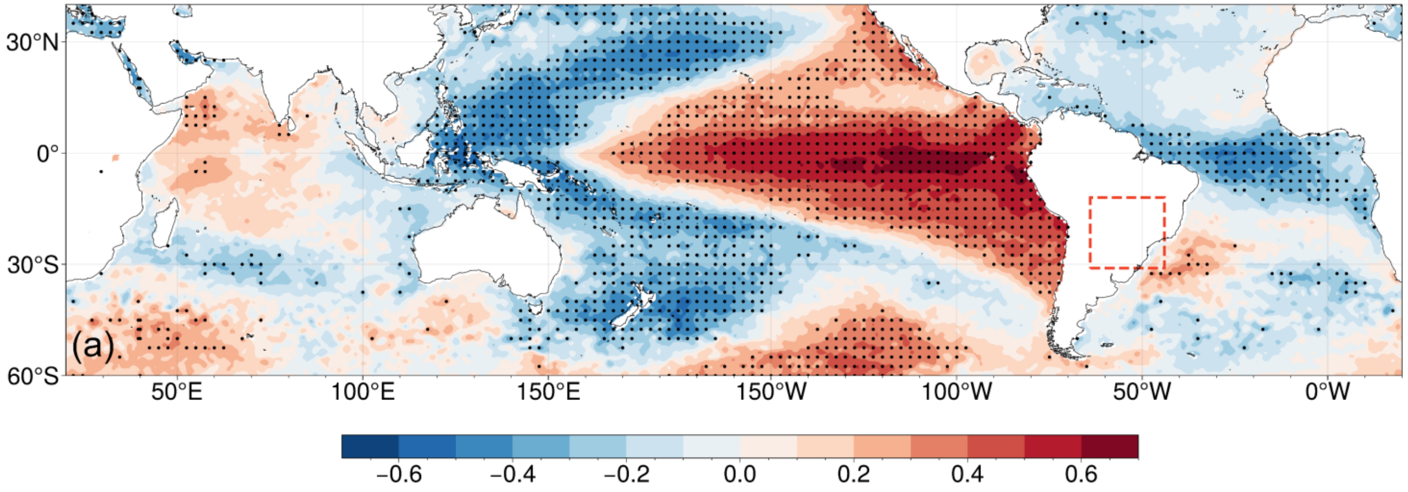
THE INFLUENCE OF LARGE SCALE TROPICAL FORCING ON DROUGHT CONTIDIONS OVER SOUTH AMERICA

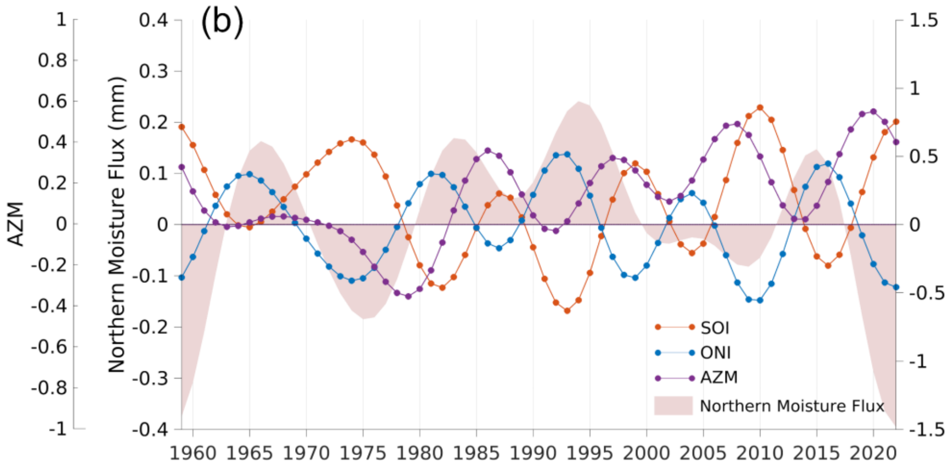


La Niña

Northward Moisture Advection towards CESA

Precipitation in CESA

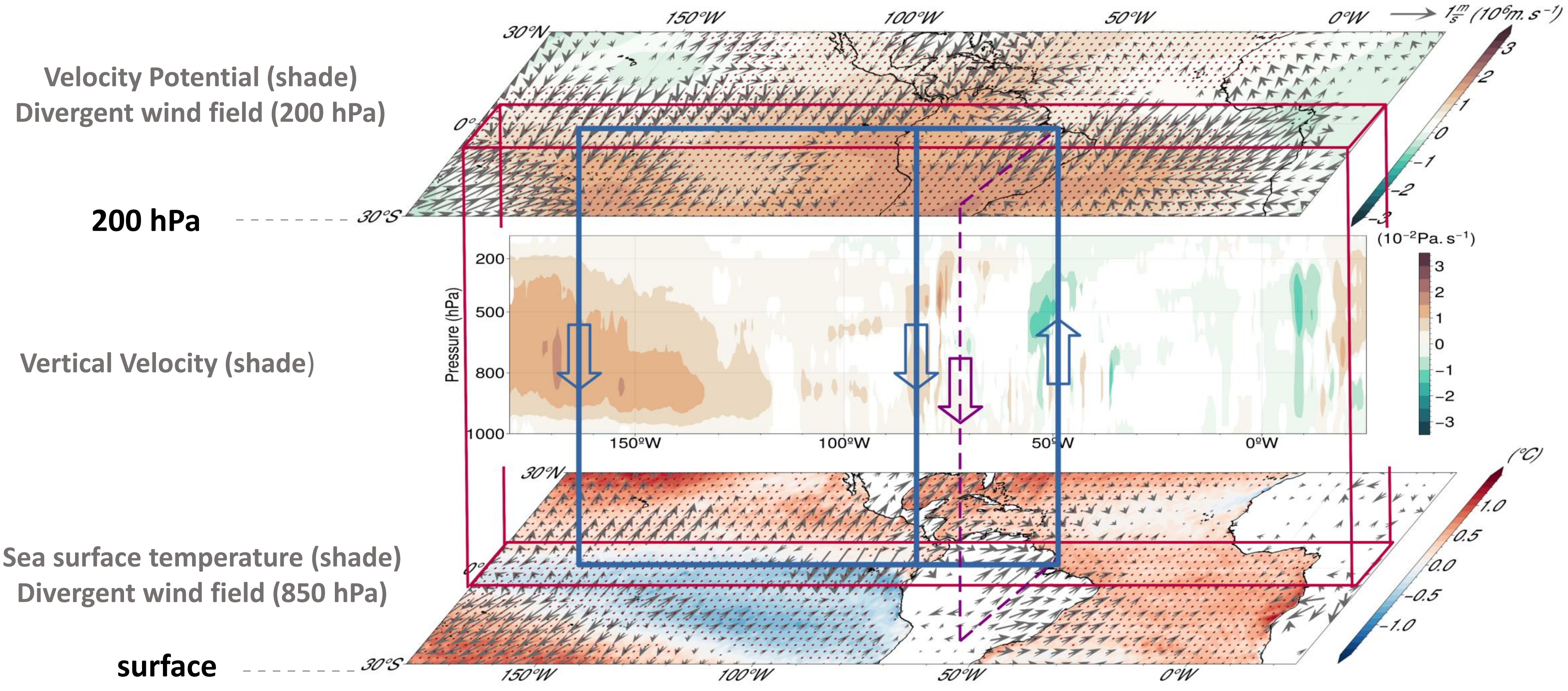




	r SOI	*r* ONI	*r* AZM
JAN	-0.18	0.24	-0.02
FEB	-0.15	0.22	0.05
MAR	-0.04	0.00	0.16
APR	**-0.33**	**0.29**	-0.10
MAY	**-0.29**	**0.51**	**-0.37**
JUN	**-0.41**	**0.30**	**-0.41**
JUL	**-0.50**	**0.41**	**-0.37**
AUG	-0.24	**0.30**	-0.15
SEP	**-0.36**	**0.42**	-0.12
OCT	-0.19	0.12	0.10
NOV	**-0.24**	**0.38**	-0.15
DEC	**-0.35**	**0.34**	-0.22
ANNUAL	**-0.56**	**0.56**	**-0.36**
ANNUAL (10-yr Filtered)	**-0.73**	**0.67**	-0.19

Combined large-scale tropical and subtropical forcing on severe droughts

THE INFLUENCE OF LARGE-SCALE TROPICAL FORCING ON DROUGHT CONDITIONS OVER SOUTH AMERICA



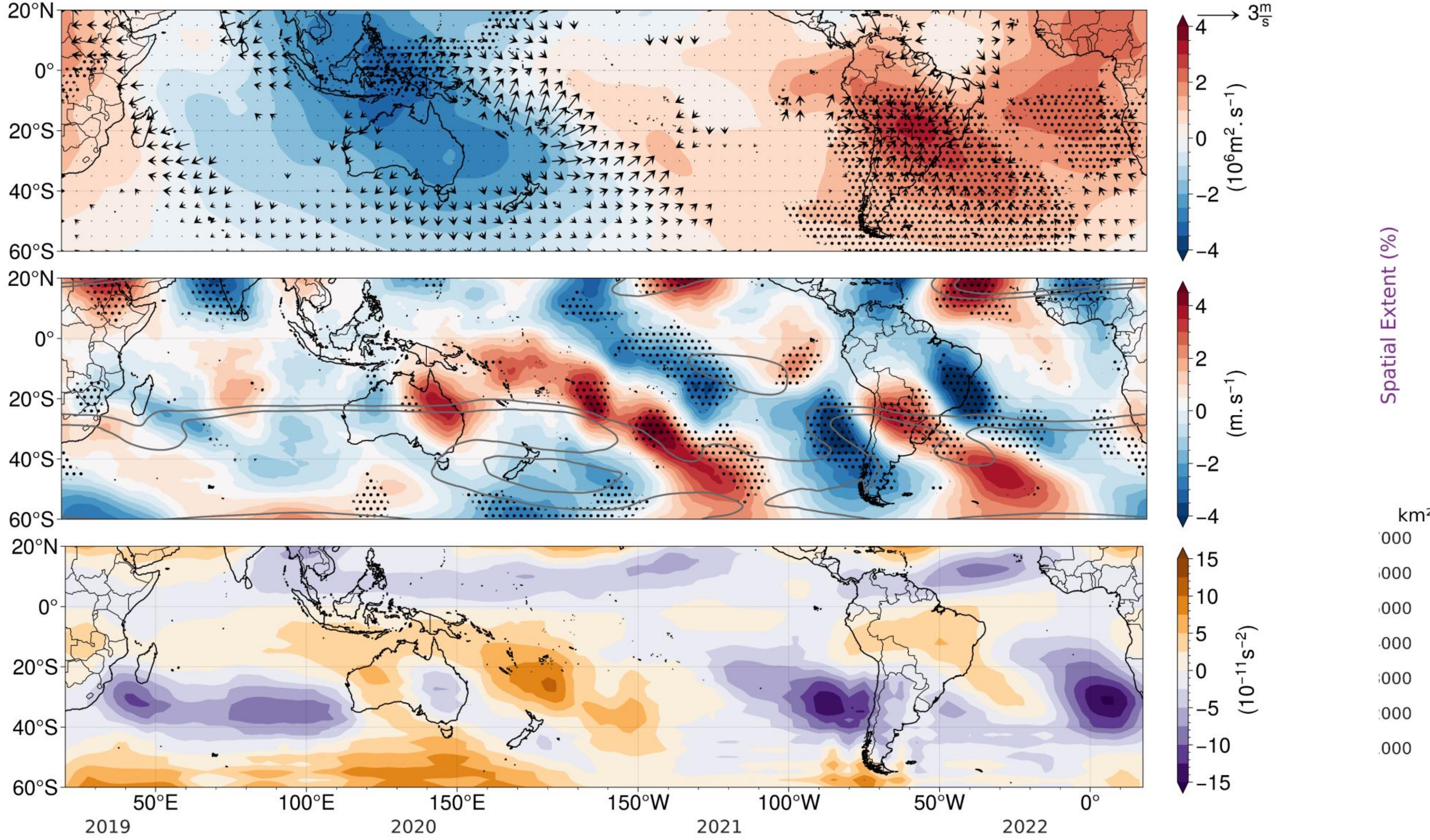
Combined large-scale tropical and subtropical forcing on severe droughts

THE INFLUENCE OF LARGE-SCALE SUBTROPICAL FORCING ON DROUGHT CONDITIONS OVER SOUTH AMERICA

200 hPa Velocity Potential (shade)
200 hPa Divergent wind field (vectors)

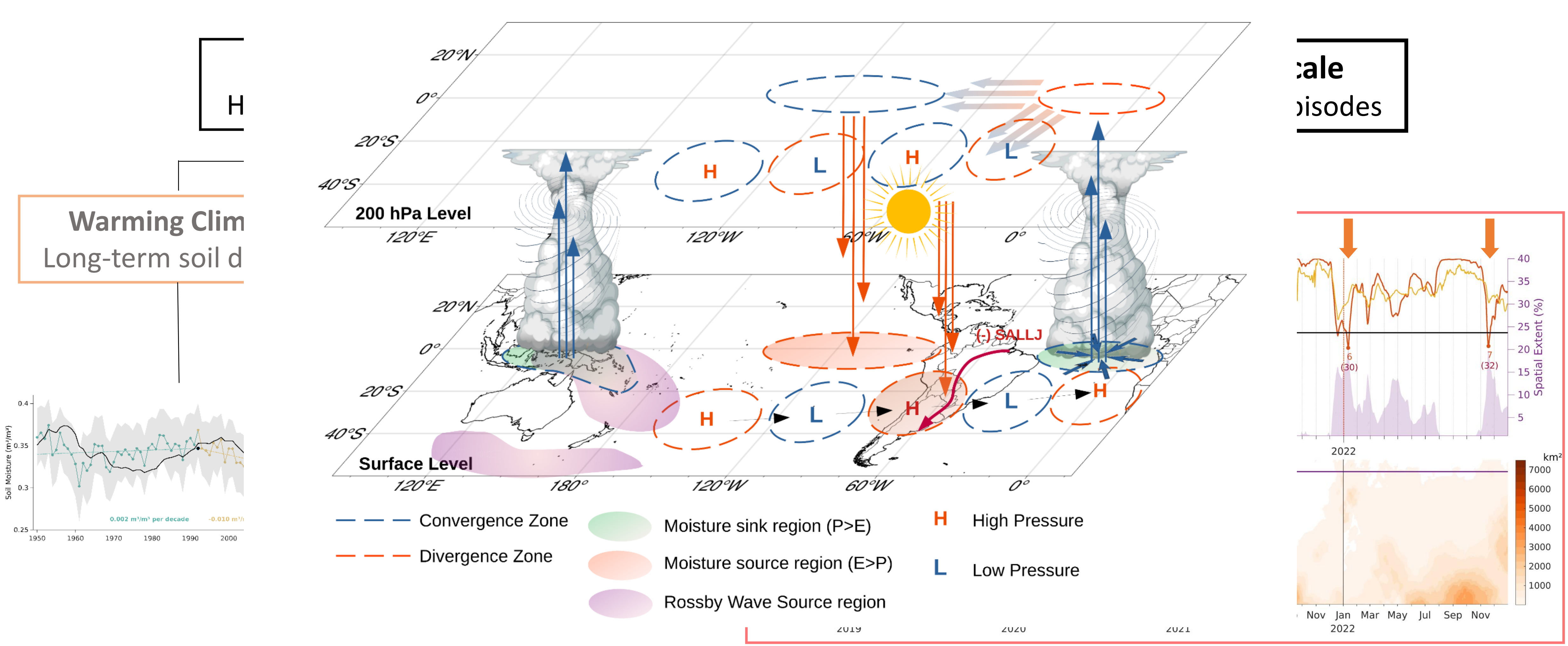
200hpa Meridional Wind (shade)

Rossby Wave Source (shade)

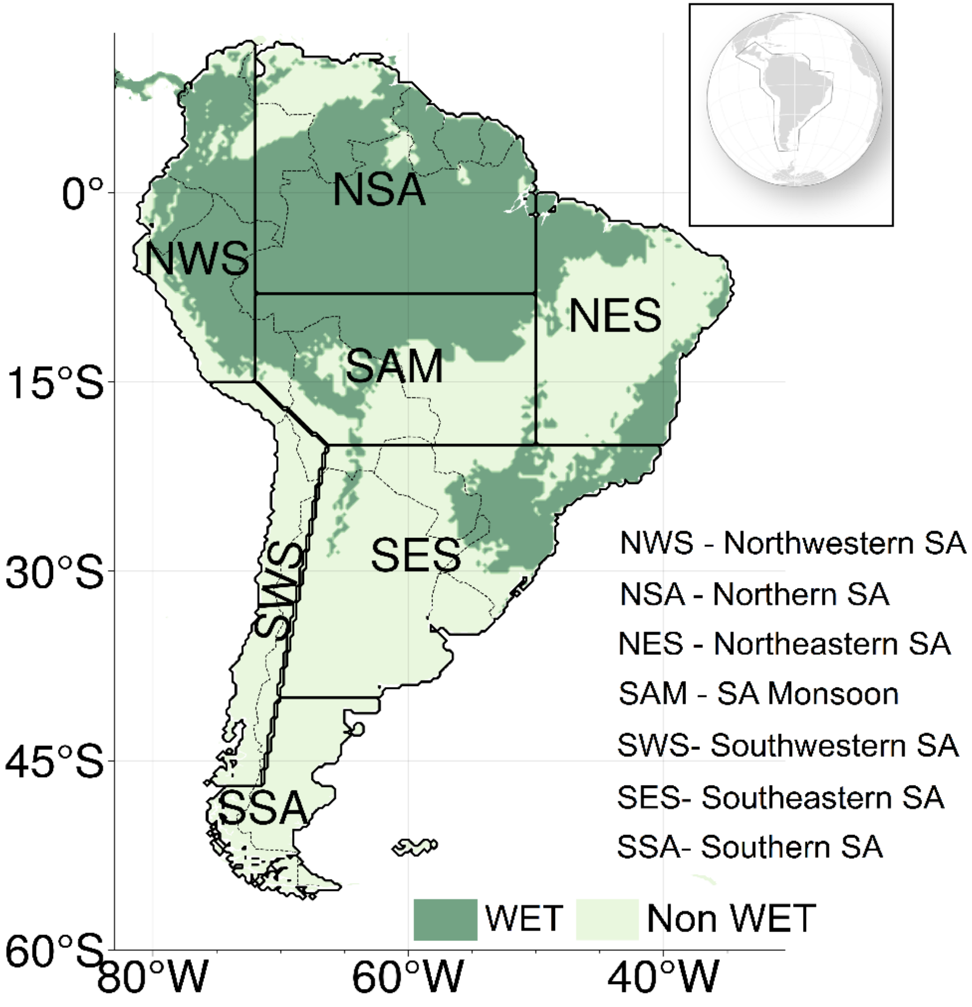


Combined large-scale tropical and subtropical forcing on severe droughts

The 2019–2022 drought



Future influence of soil moisture-temperature coupling on compound hot an dry conditions



	Wet		Non-Wet	
	RCP2.6	RCP8.5	RCP2.6	RCP8.5
NWS	↑ ↓	↑ ↑	↑ -	↑ -
NSA	↑ -	↑ ↑	↑ ↑	↑ ↓
NES	↑ ↑	↑ ↑	↑ ↑	↑ ↑
SAM	↑ ↑	↑ ↑	↑ ↑	↑ ↑
SES	↑ ↑	↓ ↑	↑ -	↓ ↑
SWS	–	–	↑ -	↑ ↑
SSA	–	–	↑ -	↑ ↓

↑strengthening

↓weakening

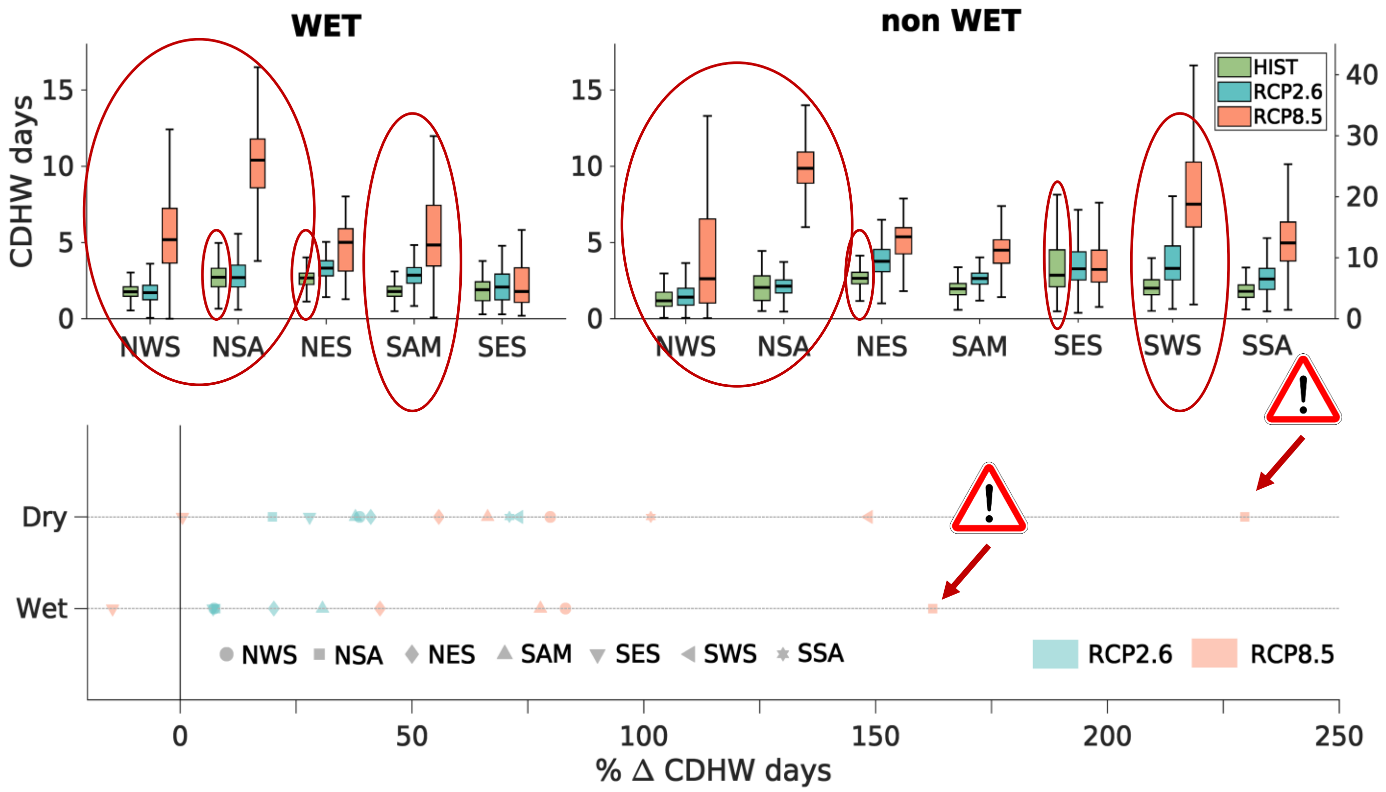
- no change

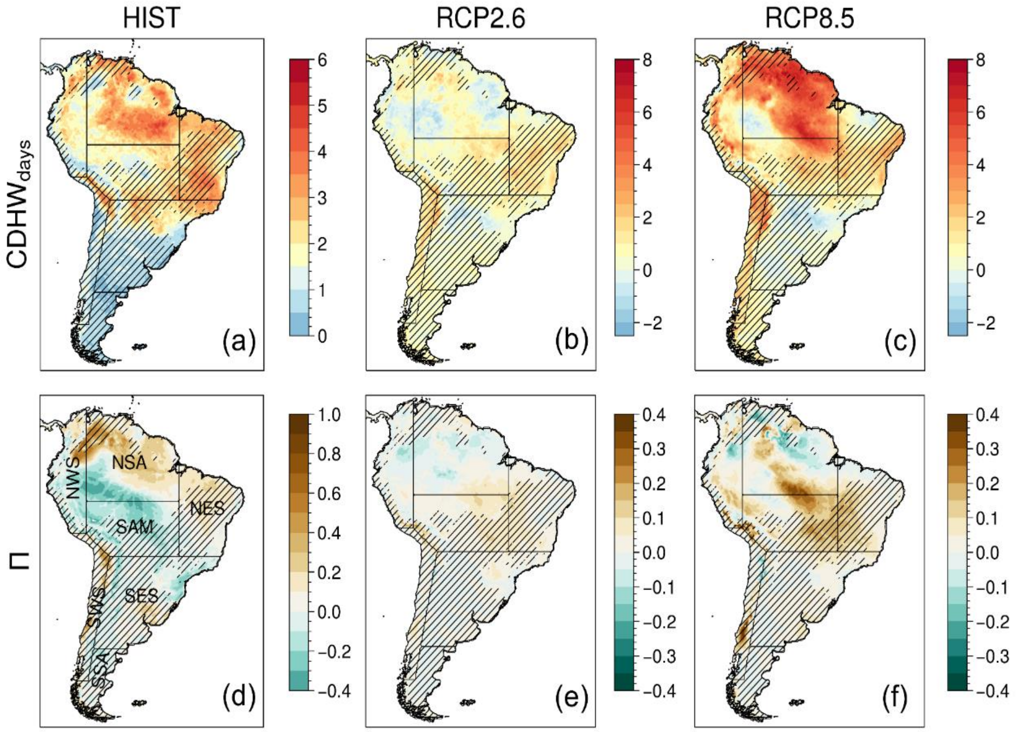
$CDHW_{days}$	Π

- Future changes in $CDHW_{days}$ are spatially coherent. The future evolution of Π depends on the region and the RCP considered.
- From the twelve regions, seven expect a simultaneous strengthening of $CDHW_{days}$ and Π under RCP8.5.
- For RCP2.6, this number decreases to six with many regions showing an increase in $CDHW_{days}$ being followed by either an absence of significant changes, or even a weakening of Π (e.g., NWS).
- Over SES non-wet domain, although an overall spatial amplification of the Π is expected, the opposite is observed for $CDHW_{days}$

Future influence of soil moisture-temperature coupling on compound hot an dry conditions

- The **hotspots of $CDHW_{days}$** for the historical period are mainly concentrated over the **NSA and NES wet domains**, and over **the NES and SES non wet domains**



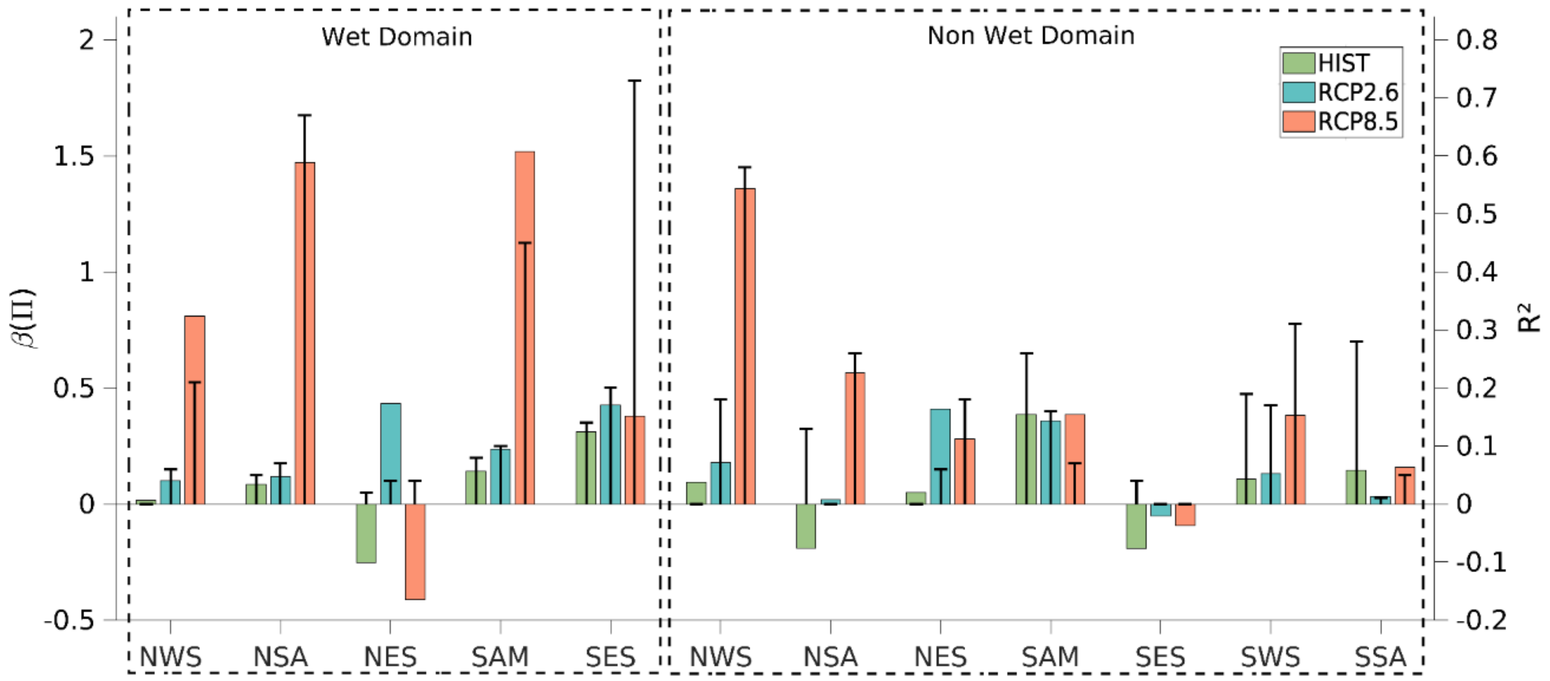


Future influence of soil moisture-temperature coupling on compound hot an dry conditions

- The **regression coefficients** are expected to increase under both RCP's and for all regions, although some exceptions (NES – wet domain; SAM – non wet domain; SSA)

- Overall, the explained variance tends to increase from the historical to RCP8.5, particularly when considering the experiments conducted for the wet domains.

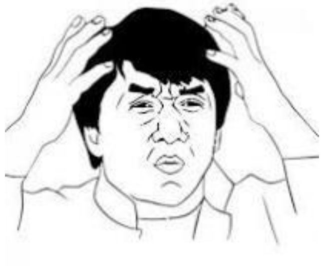
$$CDHW_{days} = \beta_0 + \beta_{\prod}\Pi + \varepsilon$$



In future, grid-points with enhanced CDHW conditions are estimated to be more closely linked to strong soil moisture–temperature coupling and vice-versa

Future influence of soil moisture-temperature coupling on compound hot an dry conditions

There is a large variability on future projections regarding the temperature–moisture coupling and summer CDHW conditions over SA



A high spatial variability, characterized by contrasting changing patterns observed within short-distance areas

+

A large disparity between the projections given by two RCP's

Still....

- An overall increment of CDHW conditions is estimated over most of the continent (excepting over SES).
- This changing pattern is estimated even when the direct effect of the global warming trends is disregarded.
- A strengthening of the soil moisture–temperature coupling stands as a valid candidate to leverage this future aggravation of droughts and heatwaves particularly over the tropical regions of SA (NWS; NSA wet domain; SES; SAM non wet domain).

THANK YOU!

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