Heat extremes in southern South America: from historical regional analysis to future storylines

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INTRODUCTION & MOTIVATION

How is South American climatology?

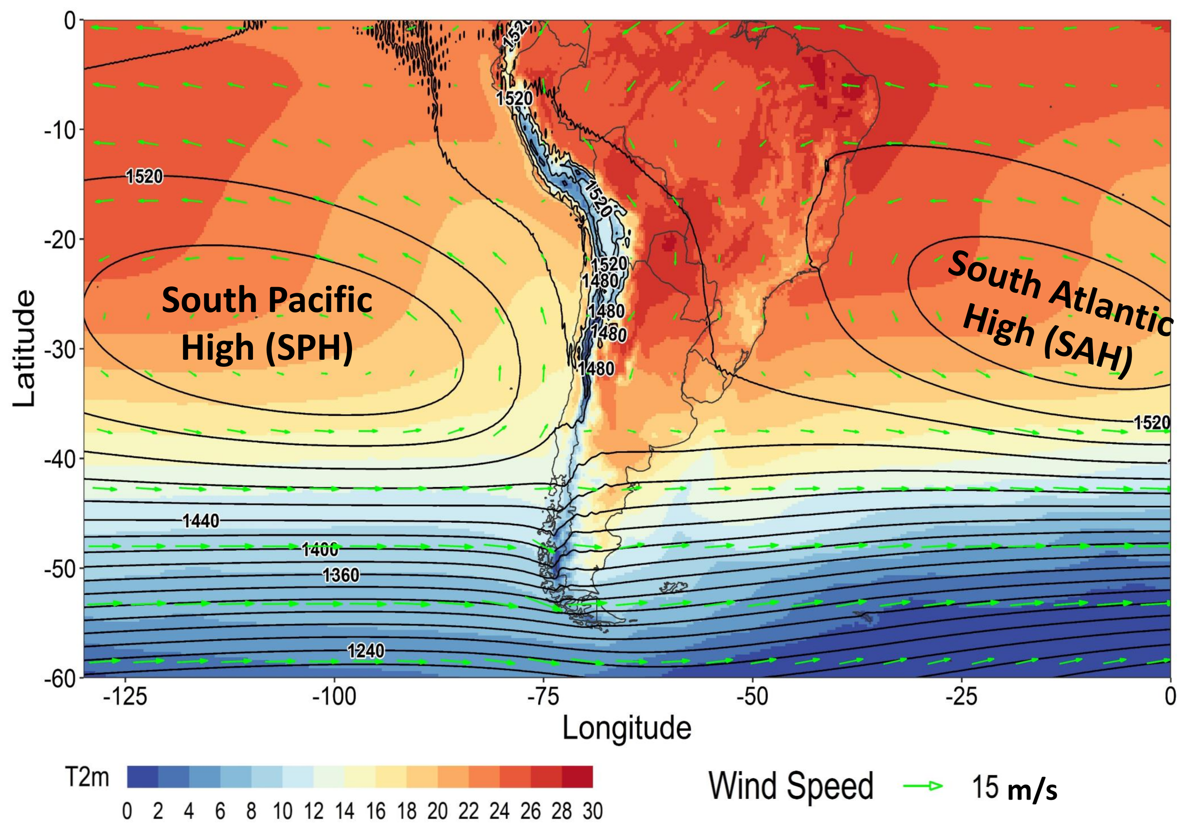


Figure 1. Climatology (1981–2010) of the low-level atmospheric circulation over South America during the warm season: 2 m temperature (colour shading, °C), 850 hPa geopotential height (contours, m) and 850 hPa vector wind (arrows, m s^{-1}) from the ERA5 reanalysis

Why do we study heat waves in South America?

- **Heat waves (HWs)** have become **more intense and frequent** across most land regions since the 1950s [1]
- Regional HWs are **understudied** in **Southern South America (SSA)** due to **scarce observations**.
- **Uncertainties** in global climate models (GCMs) strongly **affect projections of temperature extremes in SSA**, underlining the **need** for **effective regional adaptation strategies**.

Main Objectives

PAST

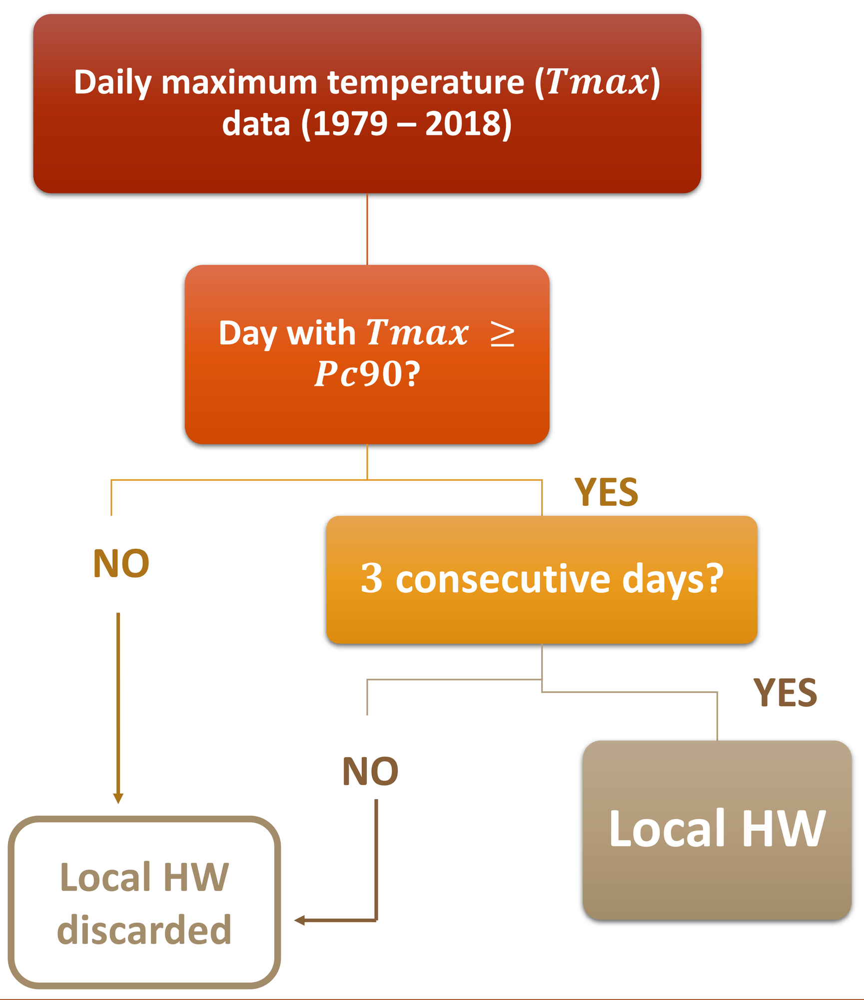
Characterise regional HWs in SSA and **identify** the main atmospheric mechanisms behind them.

FUTURE

Assess the **sources of uncertainty** in global climate models (GCMs) projections of summer temperature extremes (**TXx**) in **SSA**.

DATA & METHODOLOGY

What is a local HW?



What is a REGIONAL HW?

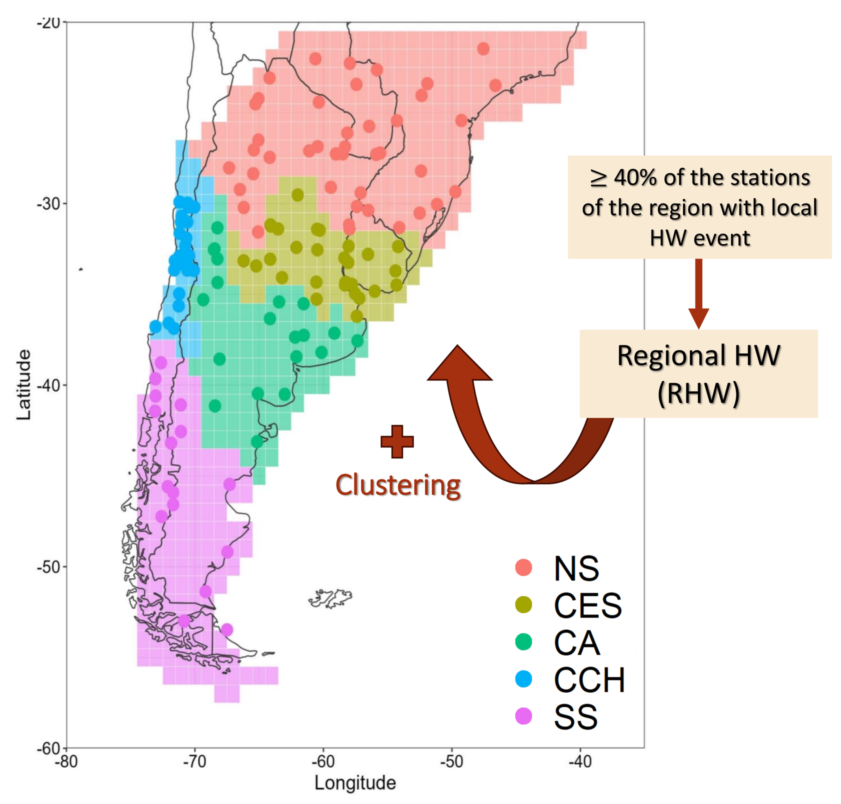


Figure 2. Regionalisation of SSA based on the co-occurrence of HWds during the warm seasons of 1977–2018. Stations (points) are coloured according to the region they belong: C1—northern of SSA (NS), C2—central-eastern of SSA (CES), C3—central Argentina and northern Argentinian Patagonia (CA), C4—central Chile (CCH), C5—Argentinian Patagonia and southern Chile, southern SSA (SS).

How do we study FUTURE temperature extremes?

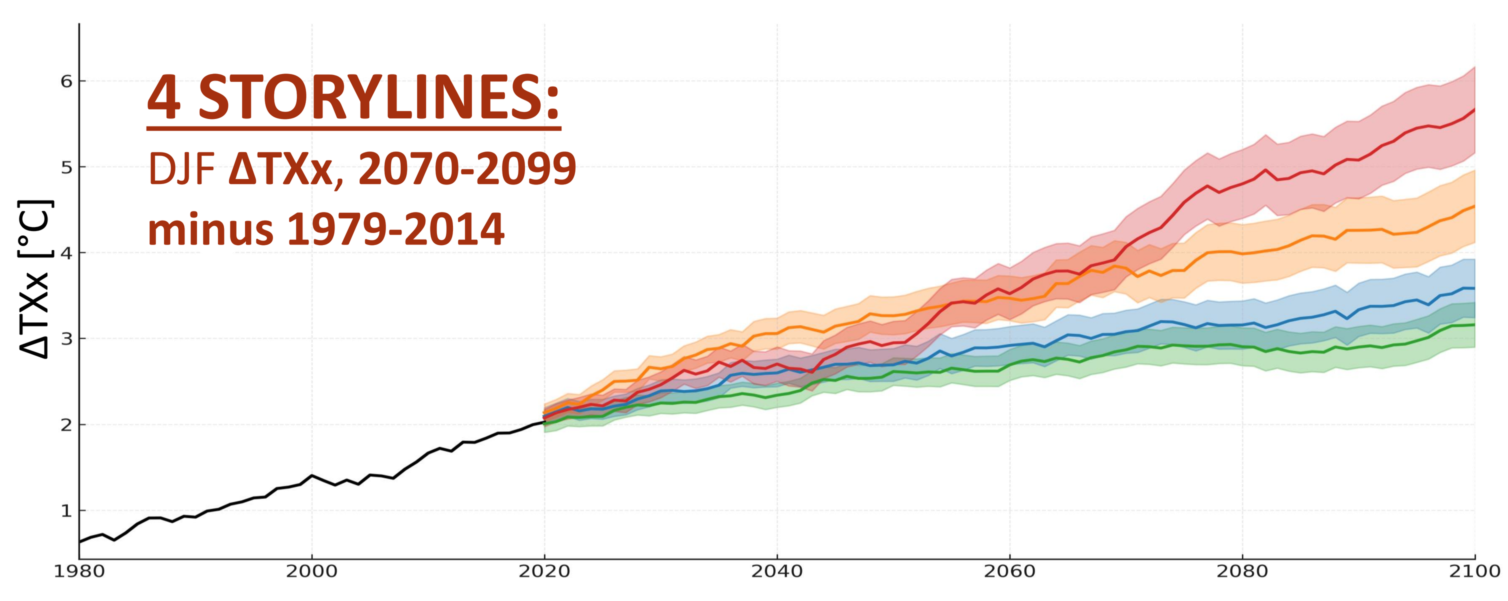
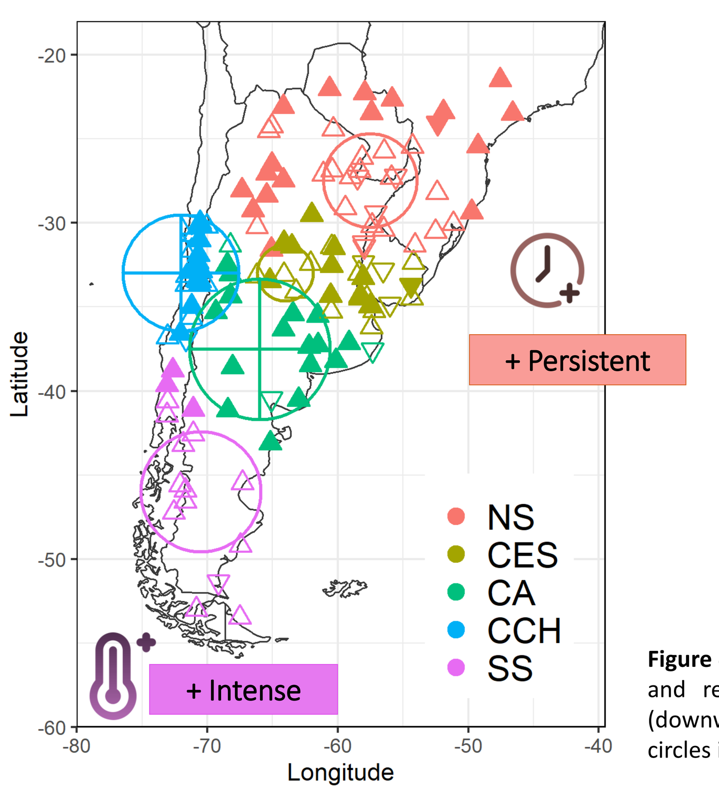


Figure 3. Schematic illustration of the storylines methodology

26 GCMs: Atmospheric and oceanic data → **Selection of drivers** → **Multi-linear regression** → **ΔTXx response (storylines)**

RESULTS

1. What we know about regional HWs in the past?



Significant positive trends in the frequency of RHWds over **CA** (1,7 days decade^{-1}) and **CCH** (1,1 days decade^{-1})

Figure 4. Linear trends (1977-2018) in the frequency of HWds for each station (triangles) and region (circles). Positive (negative) local trends are indicated with upwards (downwards) triangles, with filled colors denoting significance at p<0.01 level. Crossed circles indicate statistically significant positive trends in regional HWds.

2. Which MECHANISMS triggered regional HWs in SSA?

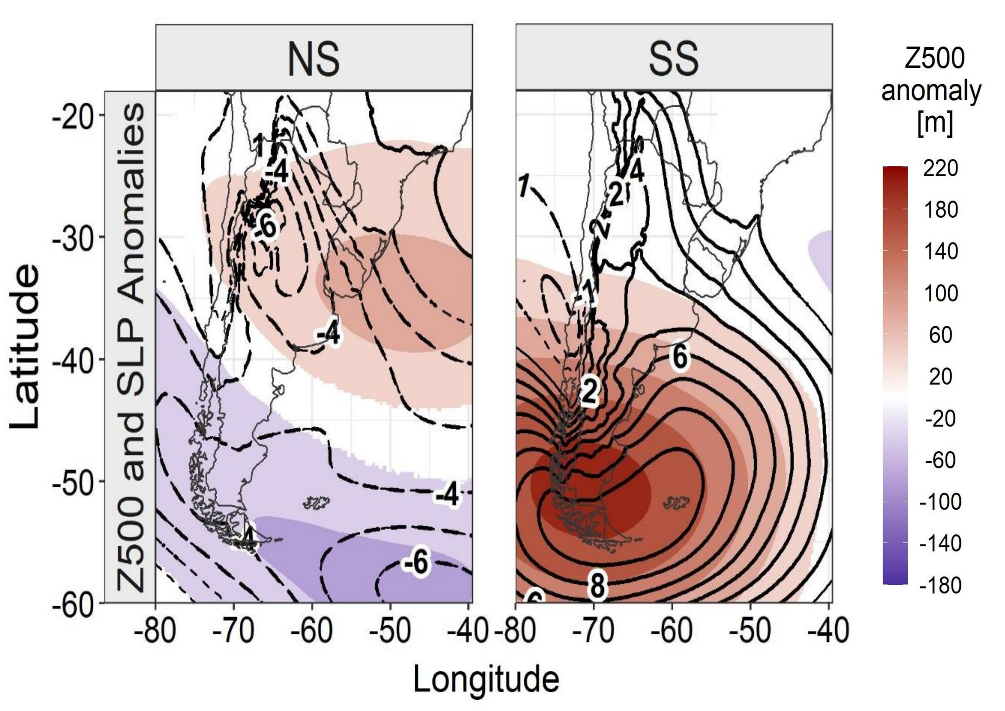


Figure 5. Composites of 500 hPa geopotential height (Z500) anomalies (in m, shading) and sea level pressure (SLP) (in hPa, contours) anomalies for RHWds of each region during the warm seasons of 1979–2018. Shaded fields are only shown for regions where anomalies are statistically significant at p < 0.05.

HWs of **NS**, **CES**, **CA** and **CCH** are related to **shifts/intensification of subtropical** semi-permanent **high-pressure systems**

SS HWs are associated with **extratropical blocking systems**, with a barotropic structure

The synoptic patterns associated with HWs **reveal significant regional differences**

3. How will summer temperature extremes change in the FUTURE in SSA?

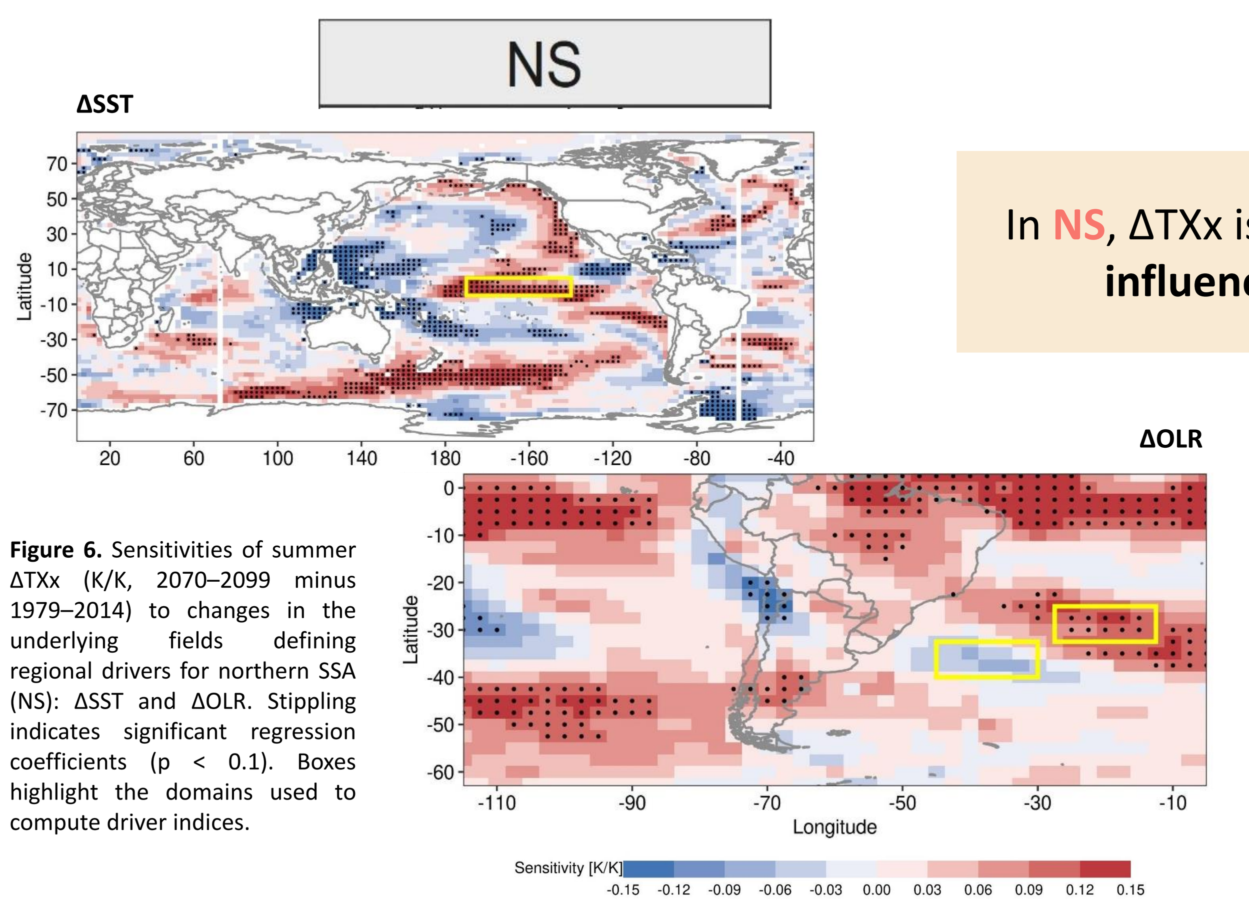


Figure 6. Sensitivities of summer ΔTXx (K/K, 2070–2099 minus 1979–2014) to changes in the underlying fields defining regional drivers for northern SSA (NS): ΔSST and ΔOLR. Stippling indicates significant regression coefficients (p < 0.1). Boxes highlight the domains used to compute driver indices.

In **NS**, ΔTXx is primarily linked to **remote influences** (ΔN3.4 and ΔSACZ)

Different drivers influence ΔTXx **depending** on the **region**

NS region shows the **greatest sensitivity** to drivers' combinations (ST4 > 50% higher ΔTXx than ST1)

The **inter-storyline variability captures** the **full range of uncertainties** in ΔTXx projections

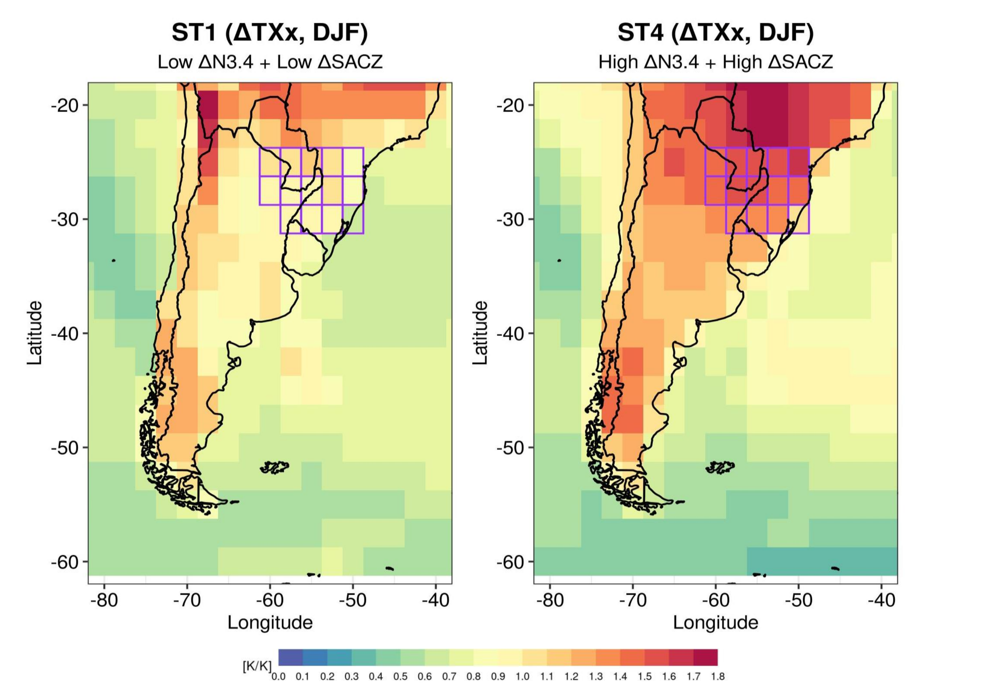


Figure 7. Scaled ΔTXx (K/K) responses under opposite storylines (STs) for northern SSA: ST1 (Low ΔN3.4, Low ΔSACZ) and ST4 (High ΔN3.4, High ΔSACZ). STs are computed as future (2070–2099) minus historical (1979–2014) periods during DJF. Purple boxes denote NS and SS regions.

CONCLUSIONS

- Five homogeneous SSA regions were identified based on hierarchical clustering of stations with high co-occurrence of HW conditions.
- Significant increases in the frequency of RHWds were only detected over CA and CCH.
- The magnitude of the projected summer warming in regional ΔTXx depends on specific combinations of its climate drivers, which vary from region to region.
- The storylines in ΔTXx effectively represent the inter-model variability of future changes in TXx and help explain the physical mechanisms behind their uncertainties.

REFERENCES

[1] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate.

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