



RECENT INCREASING FREQUENCY OF COMPOUND SUMMER DROUGHT AND HEATWAVES IN SOUTHEAST BRAZIL

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Introduction

✓ **Historical Background:** Positive trends in the frequency and severity of compound drought and heatwave (CDH) events have been reported for numerous regions of the world.

✓ **Introduction:** The univariate analysis of a single climate event typically underestimates the effect of the combination of climatic extremes over different spatial and temporal scales. In the case of hot and dry extreme episodes, the influence of local and remote land–atmosphere feedbacks contributes to their simultaneous occurrence. These feedbacks control the local temperature escalation via surface sensible heat from the drying soils.

✓ **Objectives:** Analyze the historical evolution of summer CDH events in Southeast Brazil (SEB), characterize the land and atmosphere conditions, and disentangle the physical mechanisms behind the observed record-breaking dry and hot events recorded during the austral summer seasons of 2013/14 and 2014/15.

Data and Methods

✓ **Meteorological Variables** → ERA-5 (ECMWF) reanalysis.

✓ **Soil Moisture data** → GLEAM v3.3a.

✓ **Droughts:** Months with a Standardized Precipitation Index (SPI) value <-1.

✓ **Heatwaves:** periods of 3 consecutive days with daily T_{max} values above a certain percentile of T_{max} for the particular calendar day.

✓ **CDH event:** heatwave episode occurring during a monthly drought period.

✓ **Percent (%) change index:**

$$\frac{N.^{\circ} \text{ of CDH events (1st sub-period)} - N.^{\circ} \text{ of CDH events (2nd sub-period)}}{N.^{\circ} \text{ of concurrent events (total analysis period)}}$$

1st sub-period: 1980/81 – 1998/1999 summer seasons (DJF);

2nd sub-period: 1999/00 – 2017/2018 summer seasons (DJF);

✓ **Percent (%) of total gridded summer pixels ($pixels_{total}$) under a compound regime:**

$$pixels_{total} = pixels_{latitude} \times pixels_{longitude} \times pixels_{time}$$

✓ **Recent evolution of CDH events:**

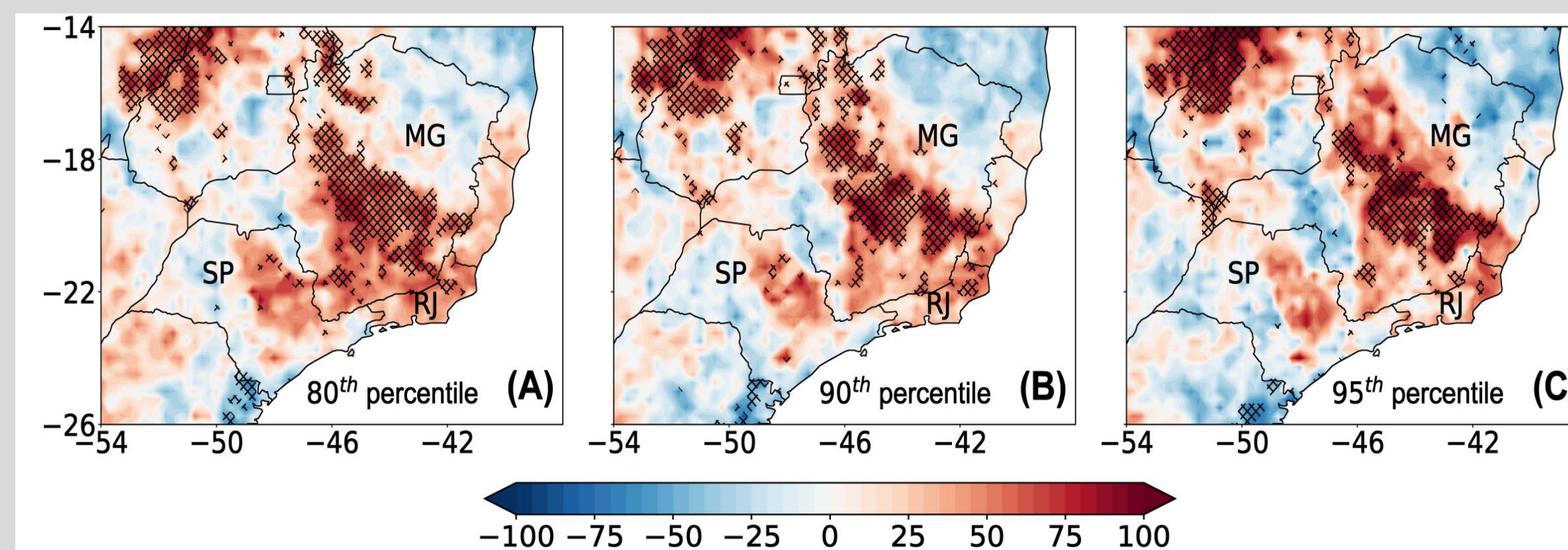


Fig.1. Percent change (%) in CDH events during 1999/00–2017/18 summer seasons relative to 1980/81–1998/99 summer seasons. Each panel shows a different heatwave severity, based on (A) 80th, (B) 90th, (C) 95th temperature percentile thresholds. Statistically significant ($p < 0.1$) percentage changes are identified by black crosses. SP, RJ and MG denotes, respectively the states of São Paulo, Rio de Janeiro and Minas Gerais.

✓ **The role of drought and atmospheric blocking conditions during 2013/14 and 2014/15**

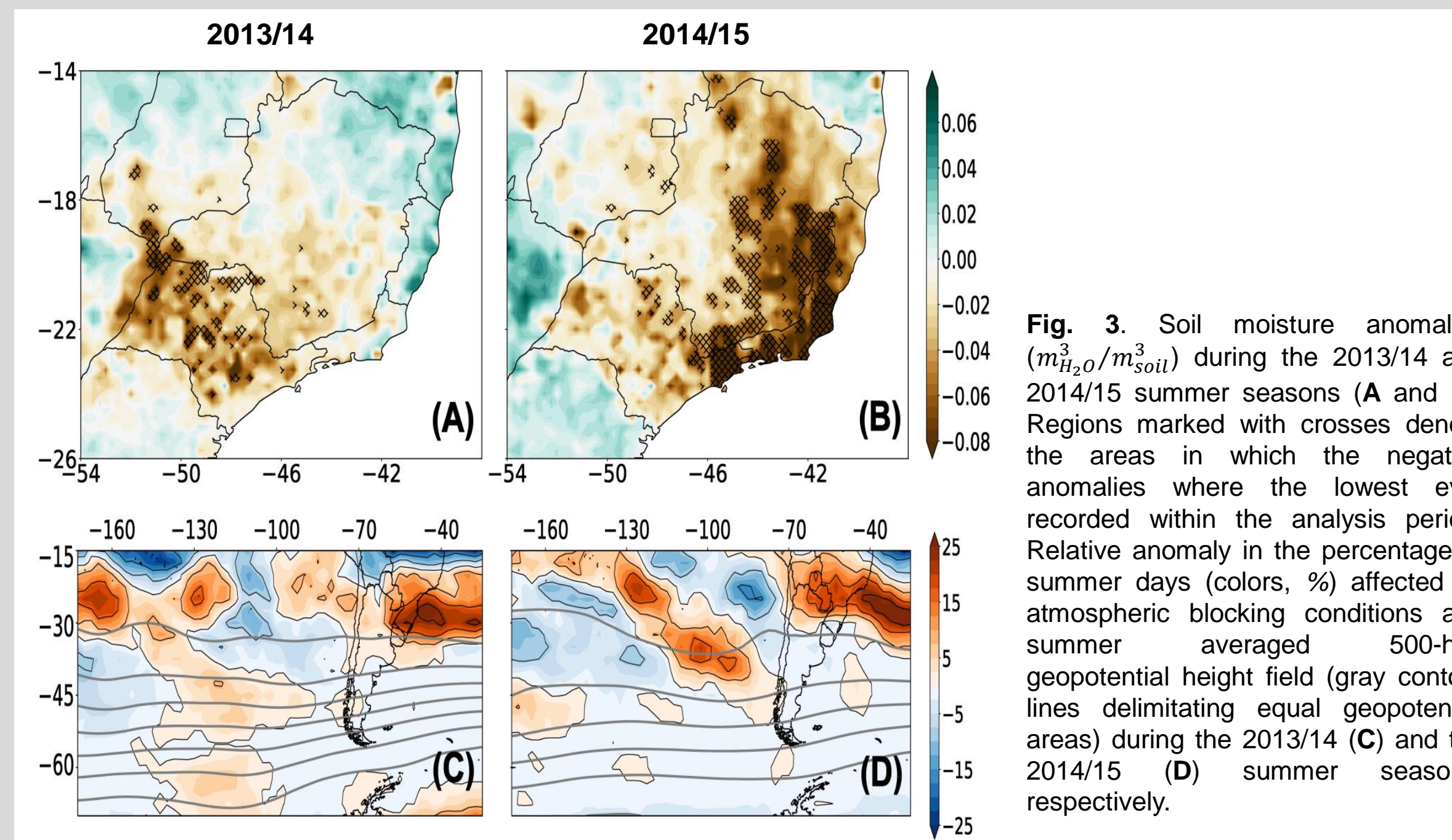


Fig. 3. Soil moisture anomalies ($m^3_{H_2O}/m^3_{soil}$) during the 2013/14 and 2014/15 summer seasons (A and B). Regions marked with crosses denote the areas in which the negative anomalies where the lowest ever recorded within the analysis period. Relative anomaly in the percentage of summer days (colors, %) affected by atmospheric blocking conditions and summer averaged 500-hpa geopotential height field (gray contour lines delimitating equal geopotential areas) during the 2013/14 (C) and the 2014/15 (D) summer seasons, respectively.

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Results

✓ **Annual evolution of CDH events**

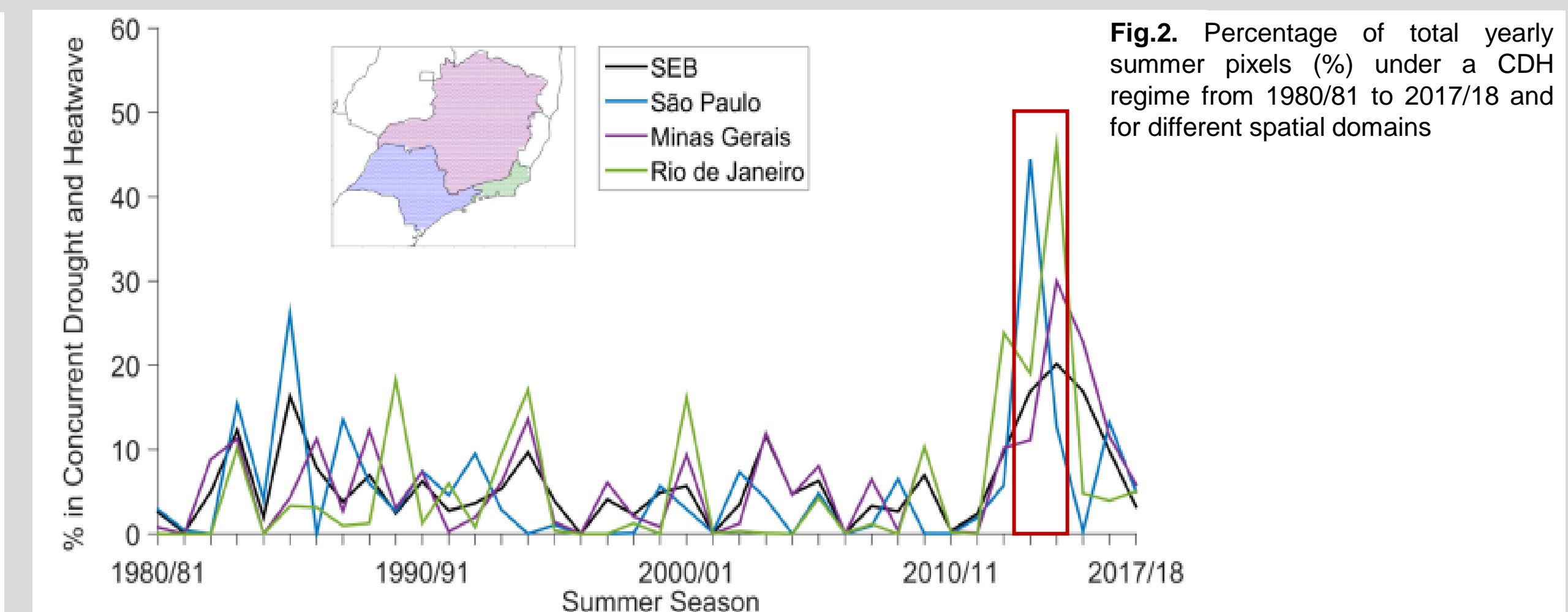
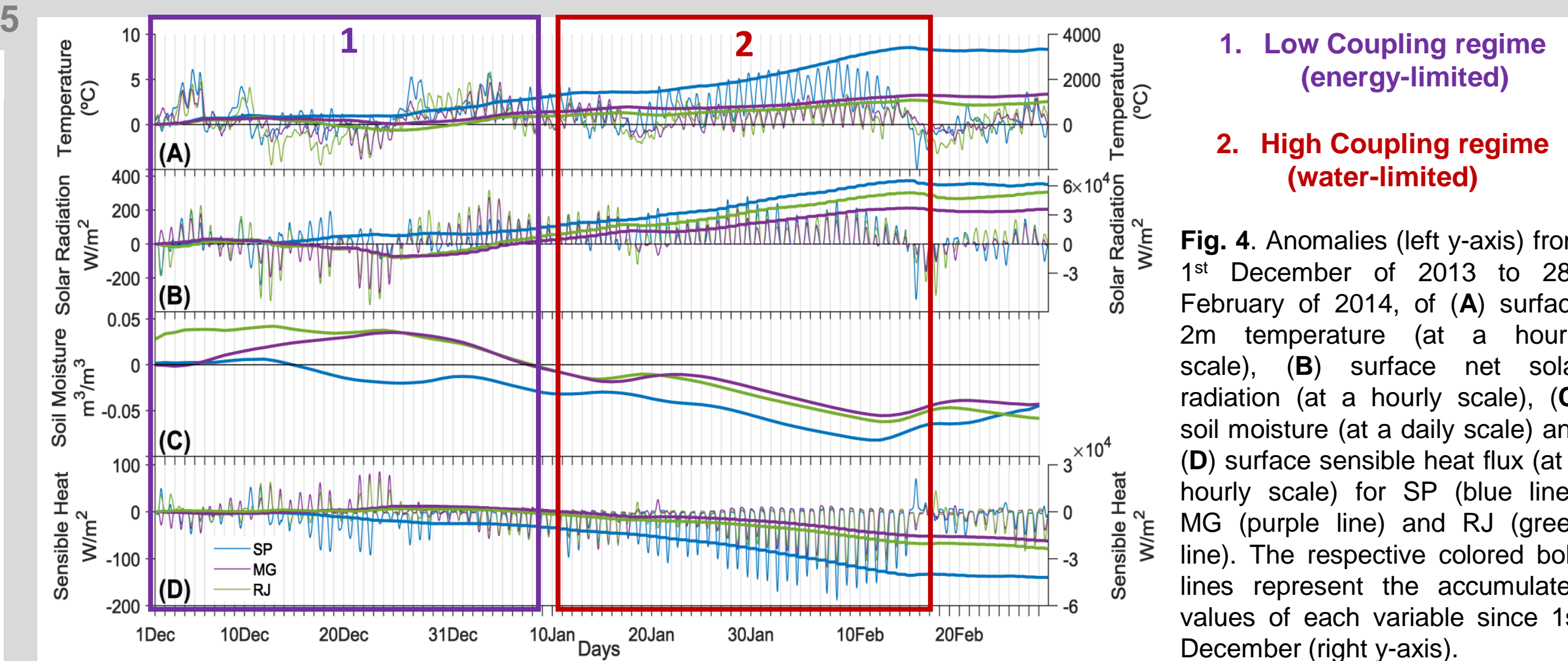


Fig.2. Percentage of total yearly summer pixels (%) under a CDH regime from 1980/81 to 2017/18 and for different spatial domains

✓ **Daily evolution of key variables controlling the land-atmosphere coupling**



1. Low Coupling regime (energy-limited)
2. High Coupling regime (water-limited)

Fig. 4. Anomalies (left y-axis) from 1st December of 2013 to 28th February of 2014, of (A) surface 2m temperature (at a hourly scale), (B) surface net solar radiation (at a hourly scale), (C) soil moisture (at a daily scale) and (D) surface sensible heat flux (at a hourly scale) for SP (blue line), MG (purple line) and RJ (green line). The respective colored bold lines represent the accumulated values of each variable since 1st December (right y-axis).

Conclusions

✓ The n.º of CDH events have increased pronouncedly across several SEB areas.

✓ Outstanding CDH conditions were recorded during 2013/14 and 2014/15 summers.

✓ Such conditions were stemmed by severe precipitation and soil moisture deficits and a higher-than-average occurrence of blocking patterns responsible for a strong diabatic heating. As a consequence, high evaporation rates and a low coupling regime was observed during the first half of both summer seasons (until soil dry-out).

✓ During the second half, a high coupling regime (water-limited) was imposed, in which the surface started to disproportionately dissipate the incoming radiation as sensible heat, leading to the re-amplification of the heatwave events.