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Influence of El Niño Southern Oscillation in dry and wet events in the Paraná river basin, Brazil

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Introduction

✓ The basin of the Paraná river is located in the southeast and center-south of Braziland in the center-east of South America.

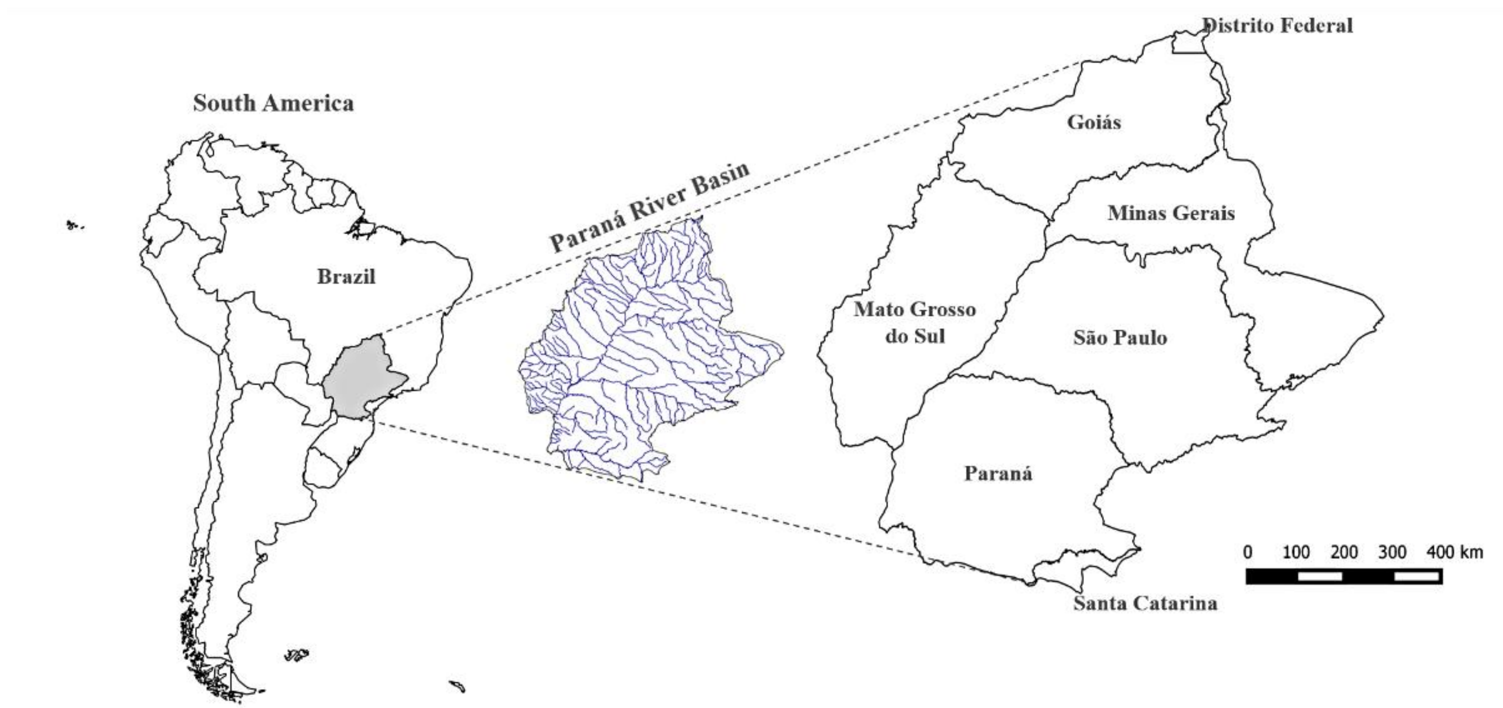


Fig. 1 Location of the Paraná river basin (brazilian part), with emphasis on its main drainage network and Federal units of Brazil.

Introduction

- ✓ It is the second largest hydrographic region of Brazil.
- ✓ It concentrates more than 32% of the Brazilian population and presents the highest energy demand of the country.
- ✓ The Paraná river basin represents 60% of the installed hydroelectric capacity in country (SIPOT, 2015).
- ✓ The climate prediction is necessary for many human activities and a better understanding of the variability and predictability of rainfall is vital, mainly, for those regions where the hydroelectric power is essential to satisfy the energy demands.
- ✓ The interannual rainfall variability in South America is related to the ENSO phenomenon (Ropelewski and Halpert 1987, 1996; Grimm et al. 2000).
- ✓ In the region of the Parana river basin, the signal in the interannual variability is not well defined, since it is located in the transition band between opposing impacts of ENSO (Coelho et al., 2002)

ENSO - El Niño Southern Oscillation

Objective

- ✓ The main objective of this paper is to identify the regions of the Paraná river basin that are significantly influenced by ENSO, and verify which of the Niño regions is better correlated with the dry/wet conditions in Paraná river basin.

Materials and methods

Datasets

- ✓ Daily rainfall dataset: **ANA** and **DAEE**.
- ✓ After verification of data quality, 986 stations were selected, with a maximum of 10% faults, for the period of 1975 and 2014.
- ✓ Besides the precipitation dataset, data sea surface temperature anomalies for the Pacific regions, Niño 1 + 2 (0-10S, 90W-80W), Niño 3 (5N-5S, 150W-90W), Niño 3.4 (5N- 5S, 170-120W) and Niño 4 (5N-5S, 160E-150W) were used.

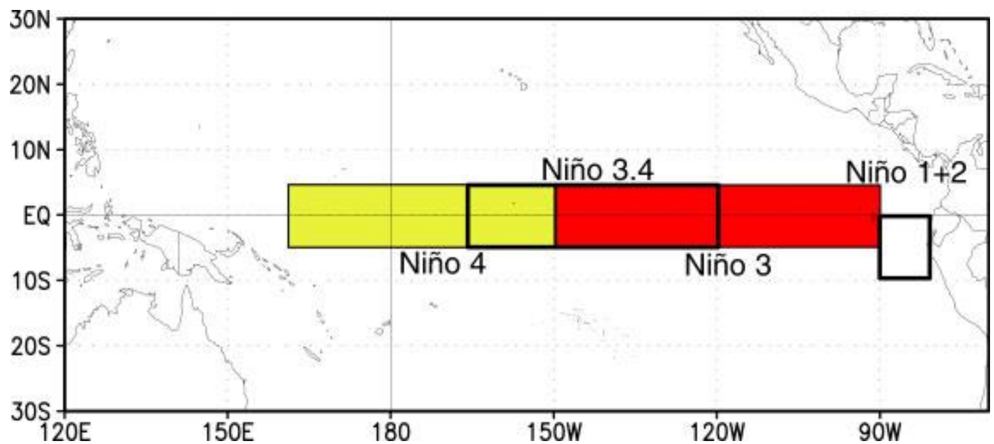


Fig. 2 Niño regions.

Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/nino_regions.shtml

Materials and methods

Methods

✓ **Precipitation Regionalization**

- ✓ Cluster Analysis ➡ average monthly rainfall (986 stations)

1st step ➡ Euclidean distance:

$$d_{xy} = \sqrt{(X_1 - Y_1)^2 + (X_2 - Y_2)^2 + \ldots + (X_n - Y_n)^2} = \sqrt{\sum_{i=1}^{n} \left(X_i - Y_i\right)^2}$$

where X_i and Y_i are the elements to be compared, which in this study are the average monthly rainfall .

Materials and methods

Methods

✓ Precipitation Regionalization

✓ Cluster Analysis ➡ precipitation average (986 stations)

2nd step ➡ Method: hierarchical agglomerative Ward method

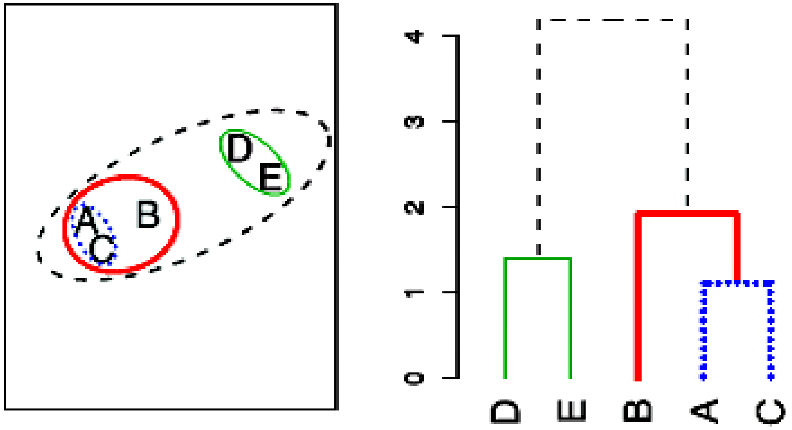


Fig. 3 Dendrogram: agglomerative hierarchical clustering.

Source: Bien and Tibshirani, 2011.

Materials and methods

Methods

- ✓ **Precipitation Regionalization**
  - ✓ Silhouette Index (SI)
    - ➢ Used to evaluate the quality of the groups formed.
    - ➢ The values of this index vary in the interval [-1,1].
    - ➢ The IS (n) is calculated according to the equation:

$$IS(n) = \frac{b(n) - a(n)}{\max\{a(n), b(n)\}}$$

a(n) is the mean distance of the n-th observation to all others within the same cluster, b(n) is the average distance that n-th observation to all other allocated in the closest cluster.

Materials and methods

Methods

- ✓ **Precipitation Regionalization**
  - ✓ Silhouette Index (SI)
    - ➢ The overall quality of the cluster can be measured by the average $SI(n)$, according to the equation:

$$\overline{IS} = \frac{\sum_{n=1}^{N} IS_n}{N}$$

where N is the total number of observations.

Materials and methods

Methods

- ✓ **Precipitation Regionalization**
  - ✓ Confidence intervals (CI)

$$P\left(\lambda_i < X_F < \lambda_s\right) = 1 - \alpha$$

Considering the 95% CI, α is 5% which is the error that can occur when stated that 95% of the time interval $(\lambda_i < X_F < \lambda_s)$ contains X_F .

Materials and methods

Methods

- ✓ **Standard Precipitation Índex (SPI)**
  - ✓ The SPI was developed by McKee et al. (1993).
  - ✓ Based on the long-term precipitation record for a desired period (at least 30 years).
  - ✓ This long-term record is **fitted to a probability distribution**, which is then **transformed into a normal distribution** so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997).
  - ✓ The SPI may be computed using different time Periods (e.g., one month, three months and 24 Months) (McKee et al., 1993).
  - ✓ In this study, the SPI severity level was analyzed **at period of 1 month**, that reflects short-term conditions and its application can be related closely to **meteorological types of drought**.

Materials and methods

Methods

- ✓ **Standard Precipitation Índex (SPI)**
  - ✓ **Positive SPI values** indicate greater than median precipitation, and **negative values** indicate less than median precipitation.

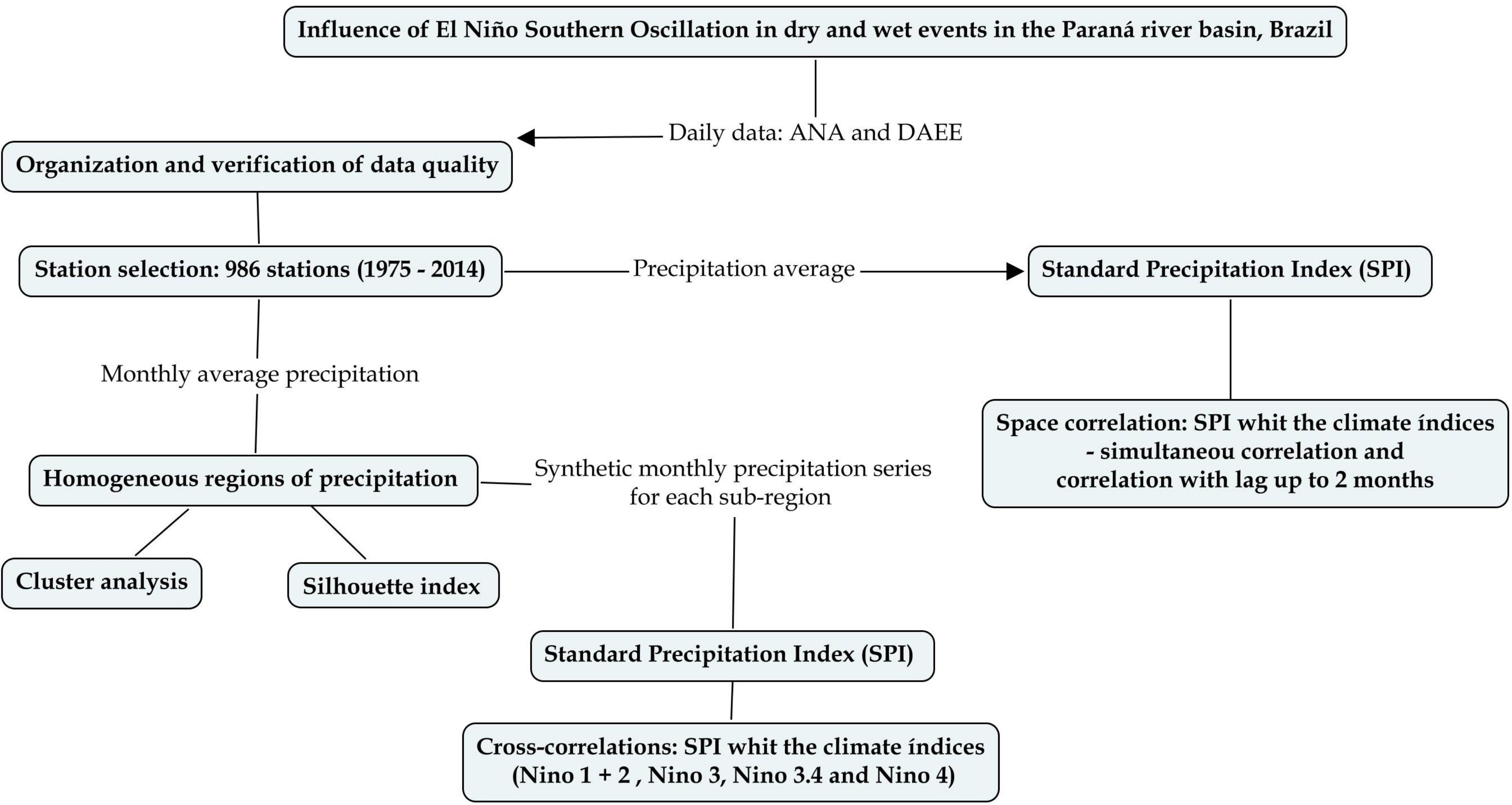
Table 1 Wet and dry events levels according to SPI values

SPI Range	Classes
$[2.0, +\infty)$	Extremely wet
$[1.5, 2.0)$	Severely wet
$[1.0, 1.5)$	Moderately wet
$(-1.0, 1.0)$	Near normal
$(-1.5, -1.0]$	Moderately dry
$(-2.0, -1.5]$	Severely dry
$(-\infty, -2.0]$	Extremely dry

Materials and methods

Methods

- **Pearson correlation:** quantifies the relationship between two continuous variables that are linearly related.
  - In the space correlation, the climate índices were correlated with the SPI of the 986 stations, in the same months (lag 0) and with 2 months lag, with the climate índices up to 2 months preceding the SPI.
  - With the SPI of the synthetic series (constructed with the average monthly accumulated of each sub-region), cross correlations were made with the climatic indices, for lag of up to 12 months.
  - The correlation coefficient significance level was defined using the Student's t test.


Influence of El Niño Southern Oscillation in dry and wet events in the Paraná river basin, Brazil
Daily data: ANA and DAEE
Organization and verification of data quality
Station selection: 986 stations (1975 - 2014)
Precipitation average
Standard Precipitation Index (SPI)
Space correlation: SPI whit the climate índices - simultaneou correlation and correlation with lag up to 2 months
Monthly average precipitation
Homogeneous regions of precipitation
Synthetic monthly precipitation series for each sub-region
Cluster analysis
Silhouette index
Standard Precipitation Index (SPI)
Cross-correlations: SPI whit the climate índices (Nino 1 + 2 , Nino 3, Nino 3.4 and Nino 4)

Results

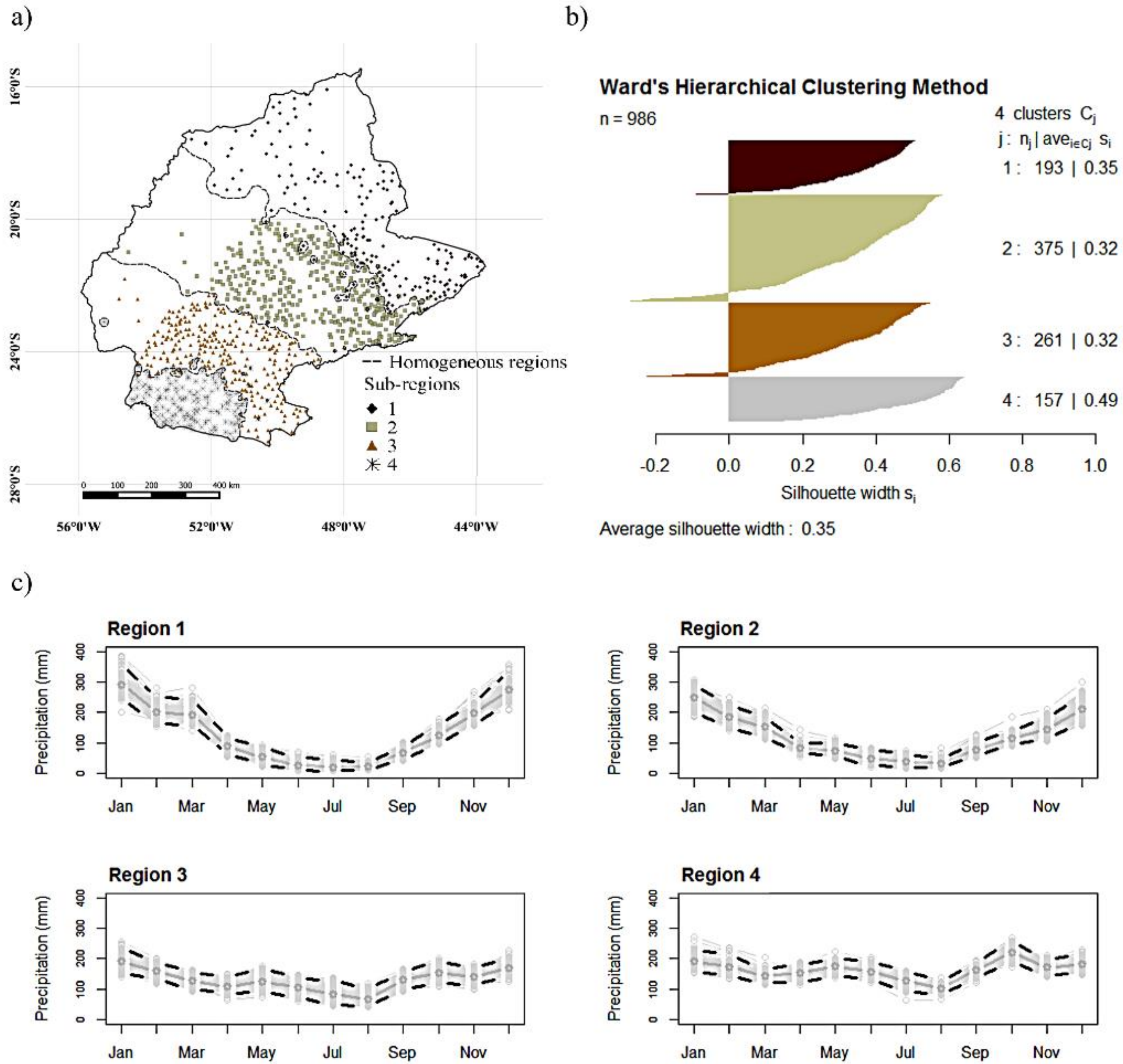


Fig. 4 (a) Spatial distribution of stations used in this study, for the four rainfall homogeneous sub-regions of the Paraná river basin, (b) SI graph and (c) Average monthly rainfall from 1975 to 2014 (light gray lines) by region; The dark gray lines represent the average overall rainfall and the dotted black lines represent the CI.

Results

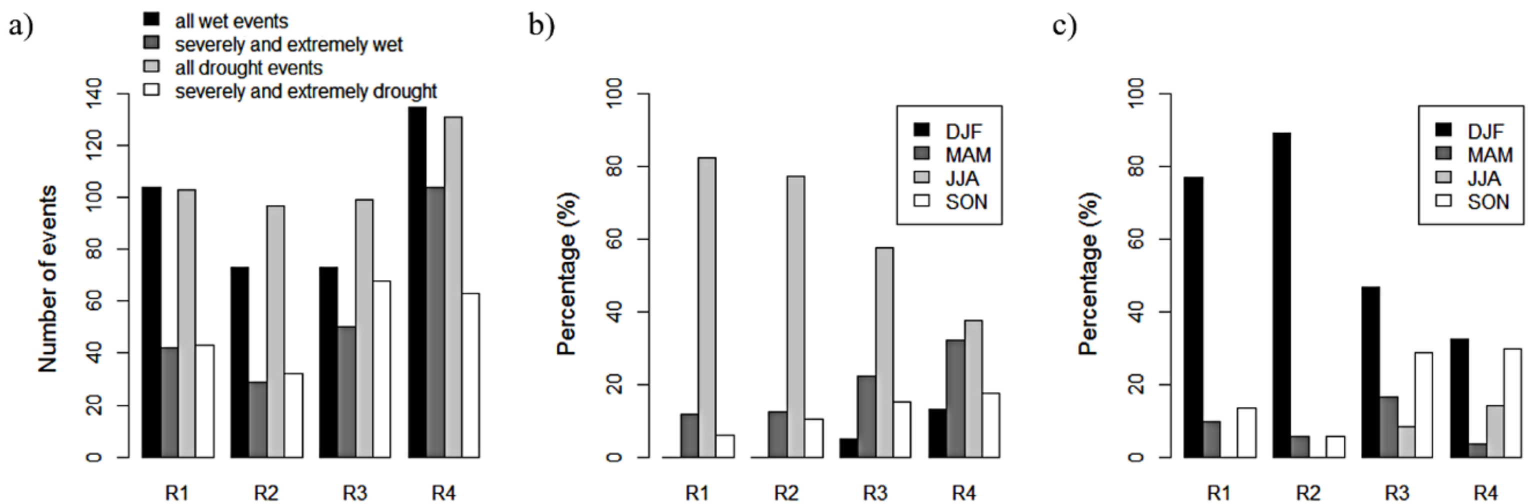


Fig. 5 (a) Number of dry and wet events in each region, (b) Percentage of the number of dry events (all dry events) separated by season of the year and (c) Percentage of the number of wet events (all wet events) separated by season of the year.

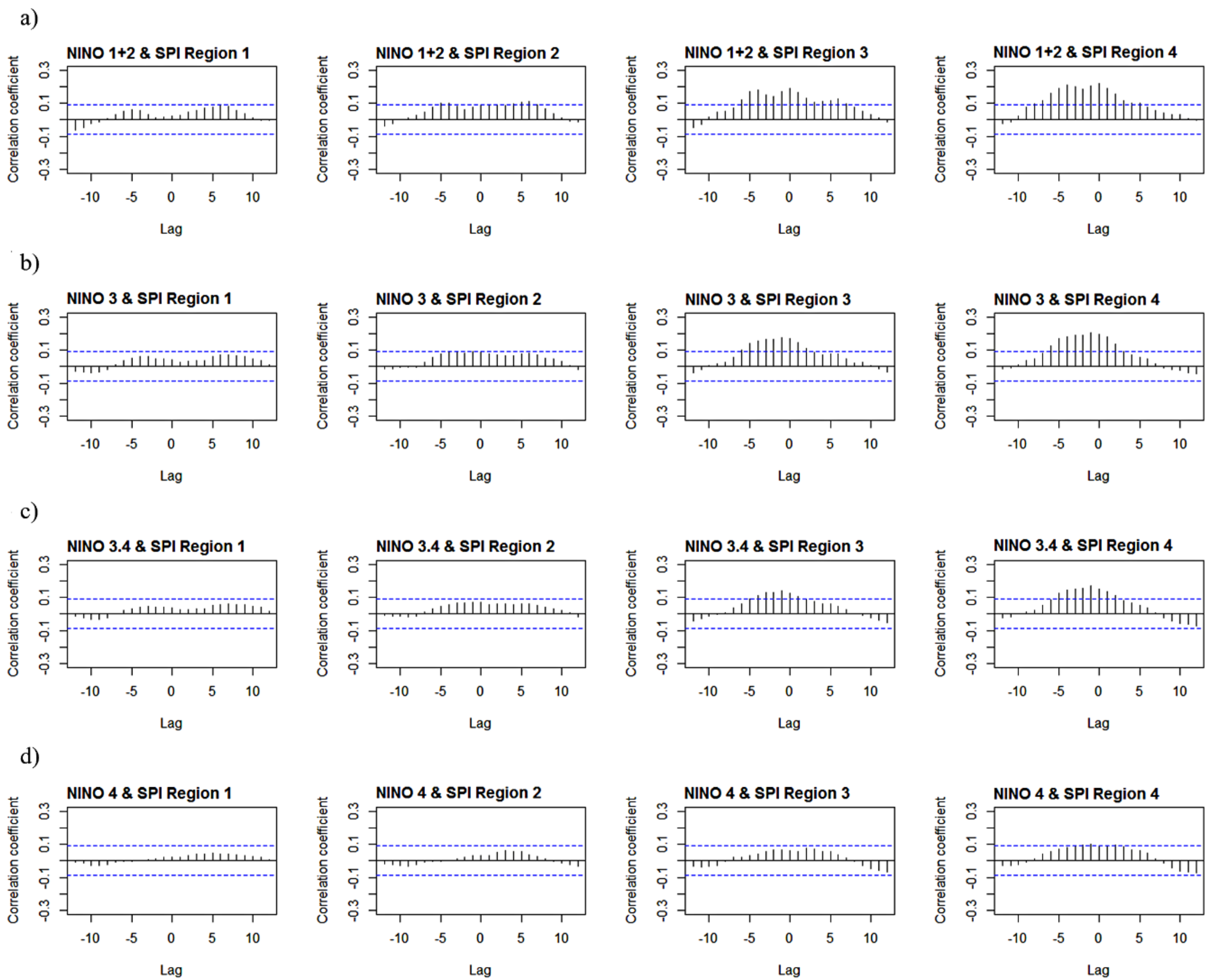


Fig. 6 Cross-correlation among the SPI of the sub-regions and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4. The dotted lines represent at 5% significance level.

Space correlation among the climate indices and the SPI: dry period

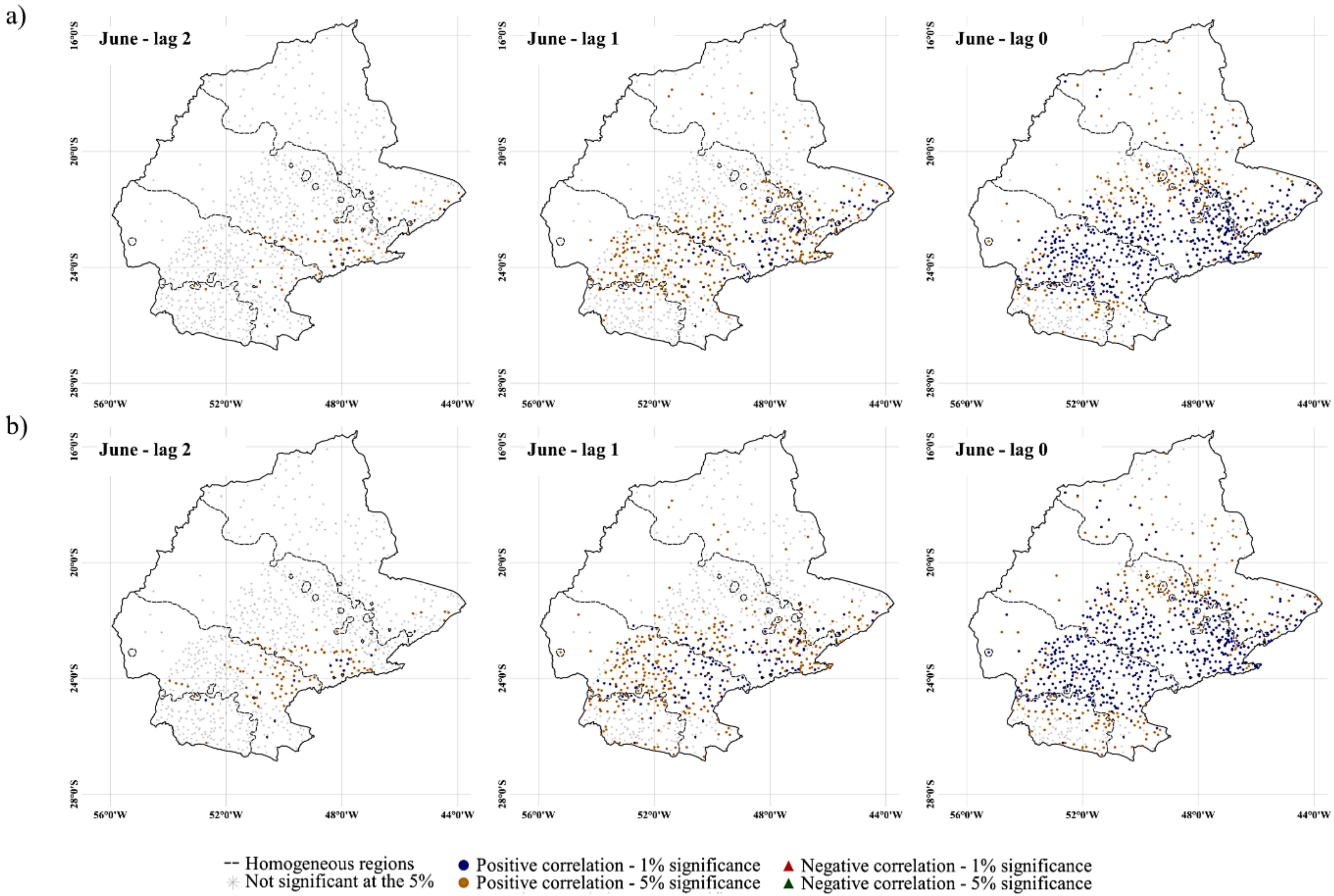


Fig. 7 Space correlation among the SPI in June and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: dry period

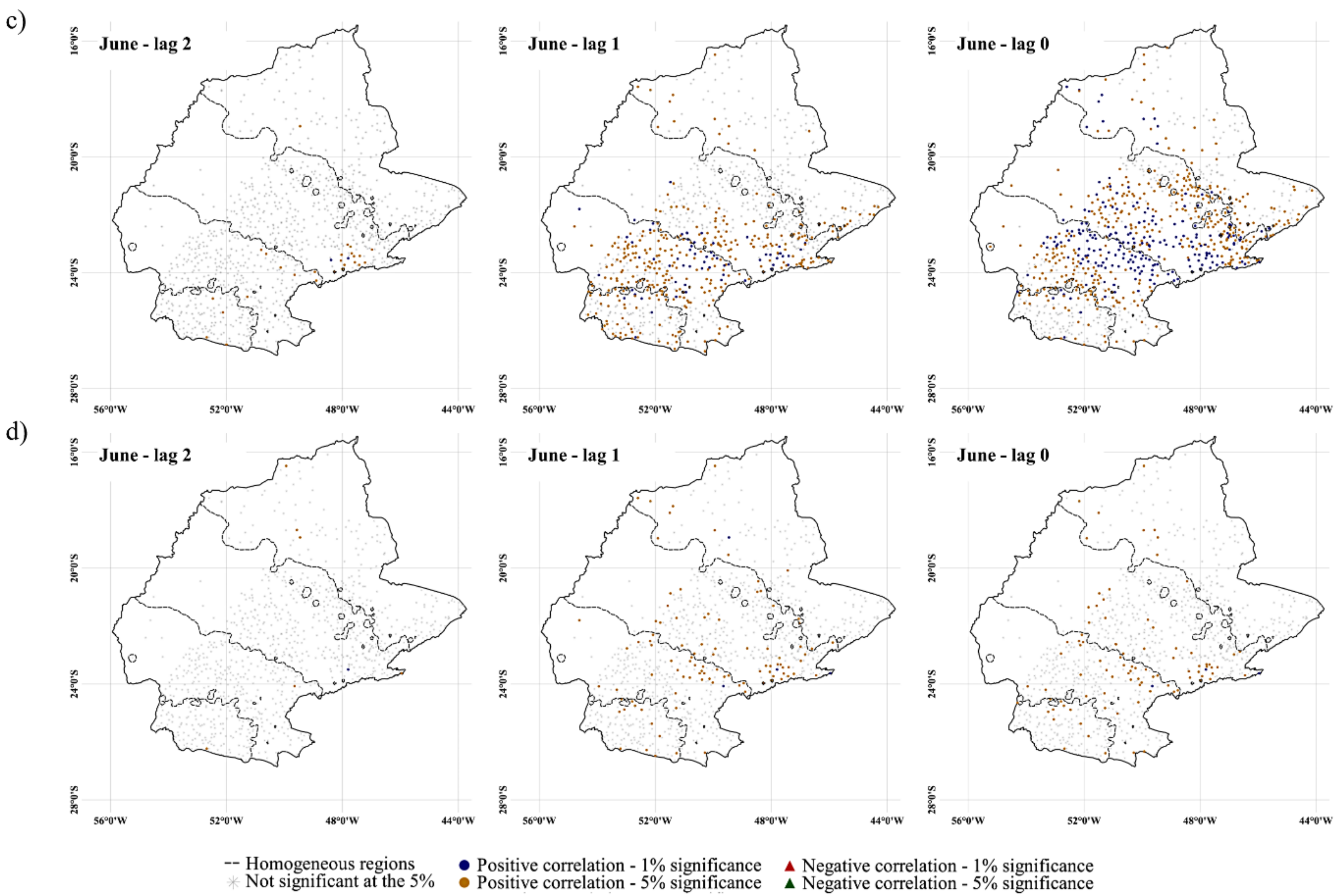


Fig. 7 Space correlation among the SPI in June and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Space correlation among the climate indices and the SPI: dry period

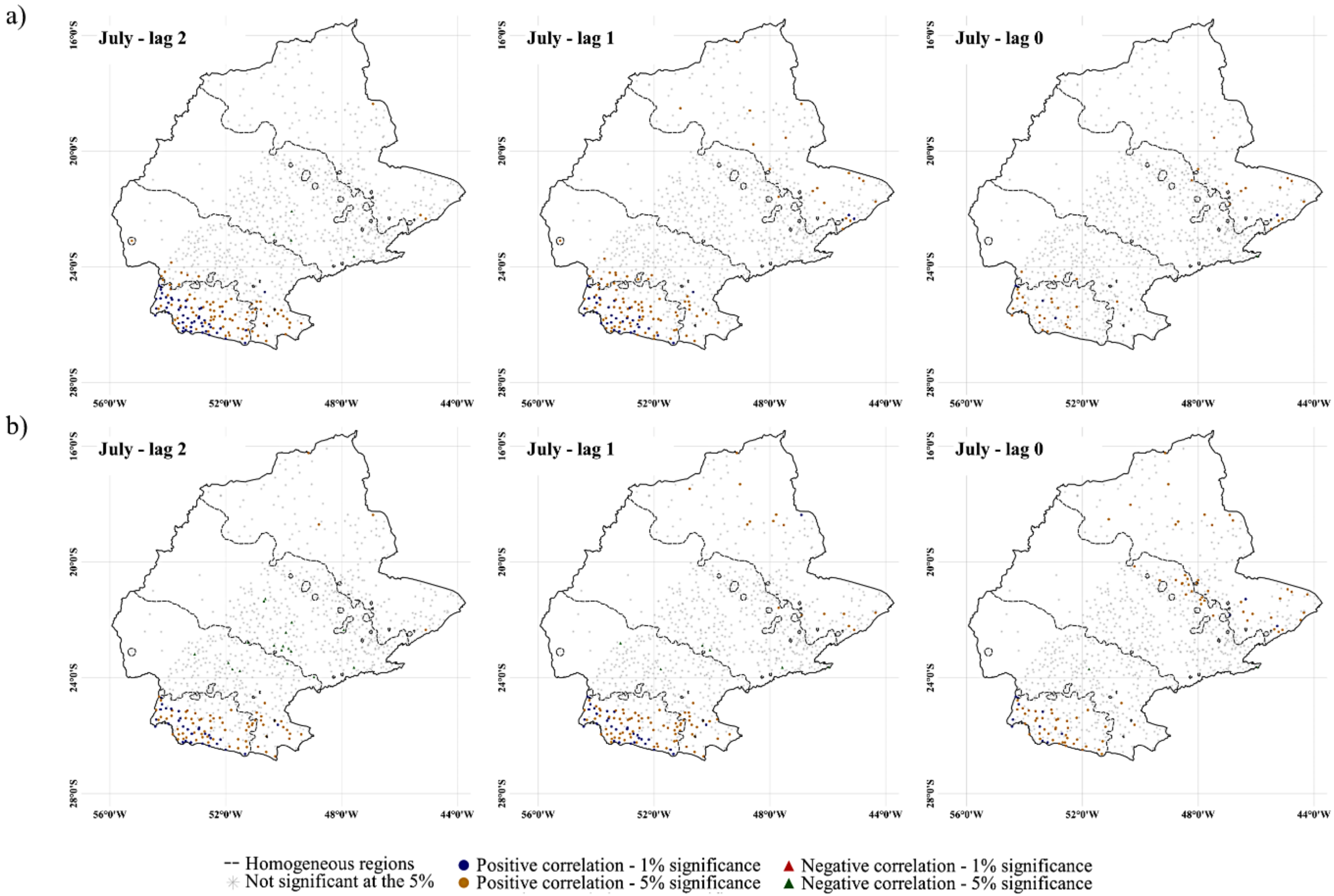


Fig. 8 Space correlation among the SPI in July and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: dry period

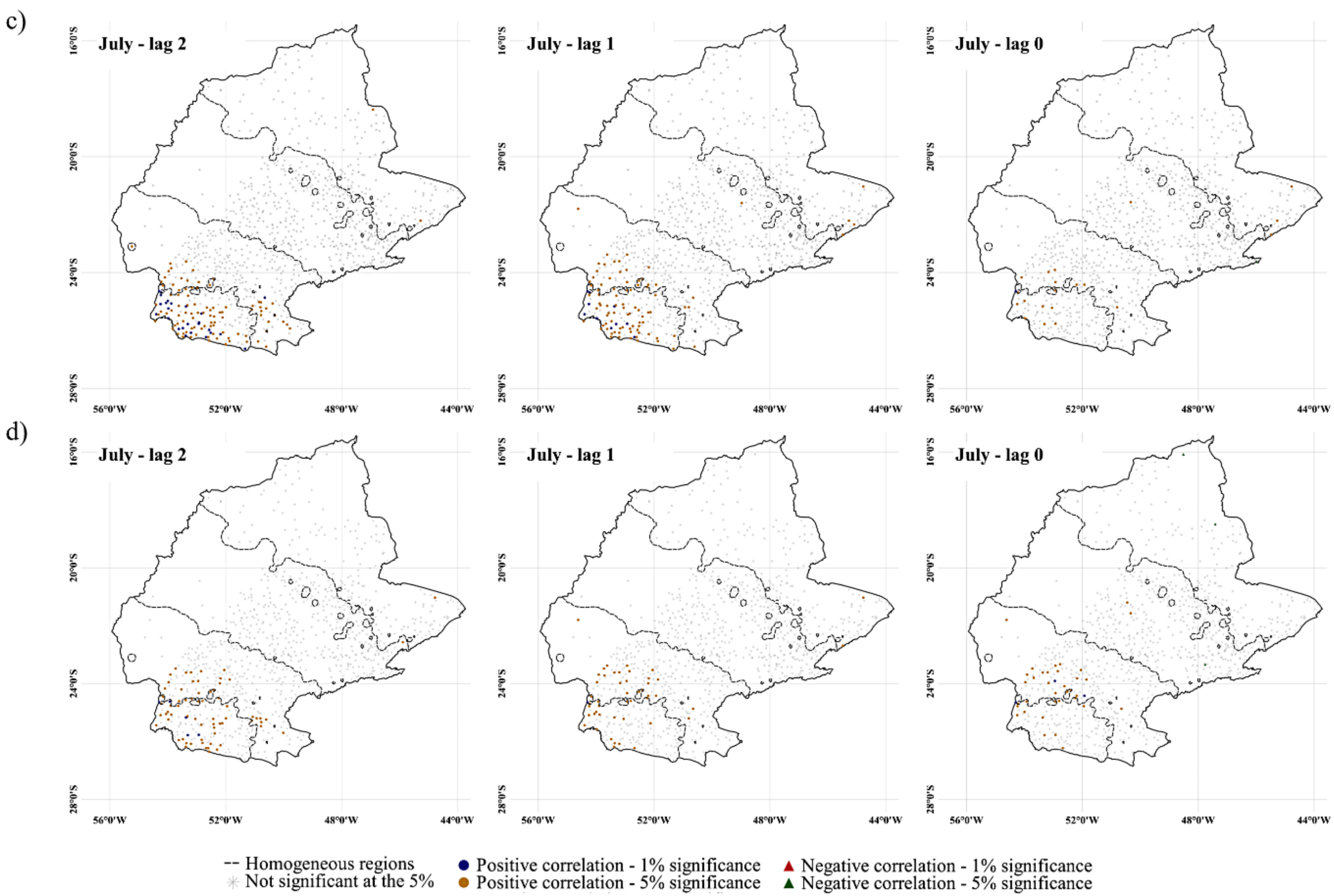


Fig. 8 Space correlation among the SPI in July and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Space correlation among the climate indices and the SPI: dry period

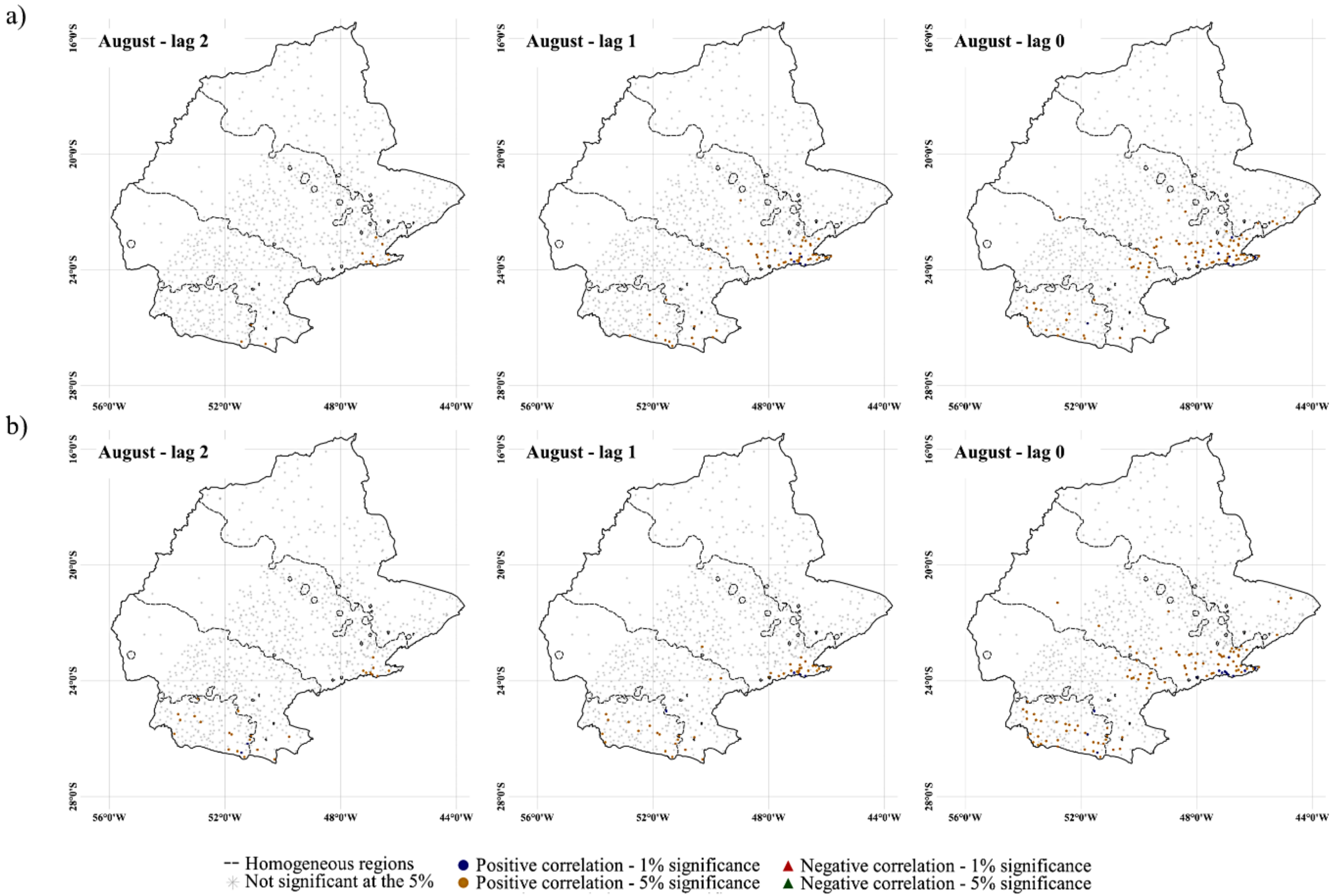


Fig. 9 Space correlation among the SPI in August and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: dry period

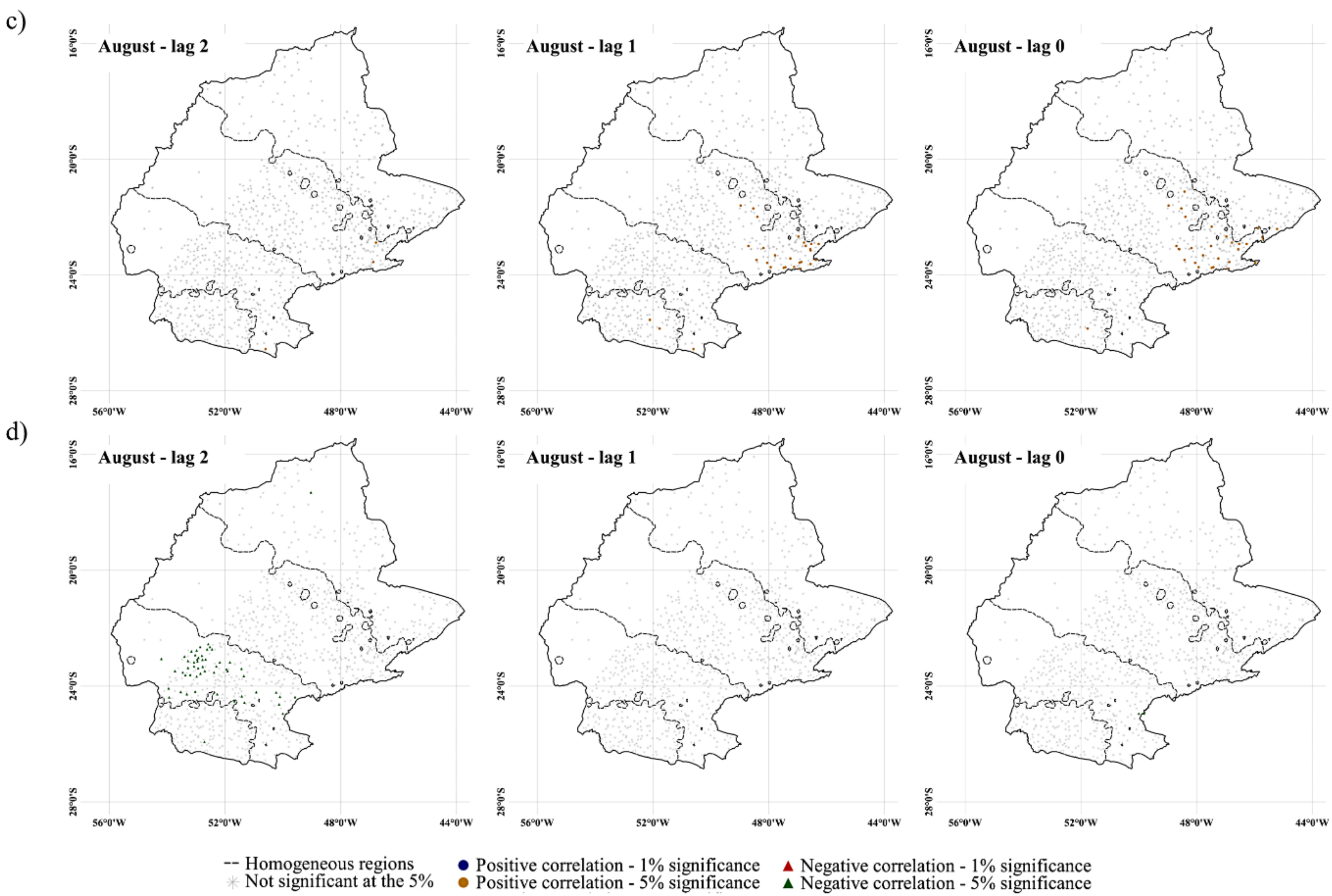


Fig. 9 Space correlation among the SPI in August and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Space correlation among the climate indices and the SPI: wet period

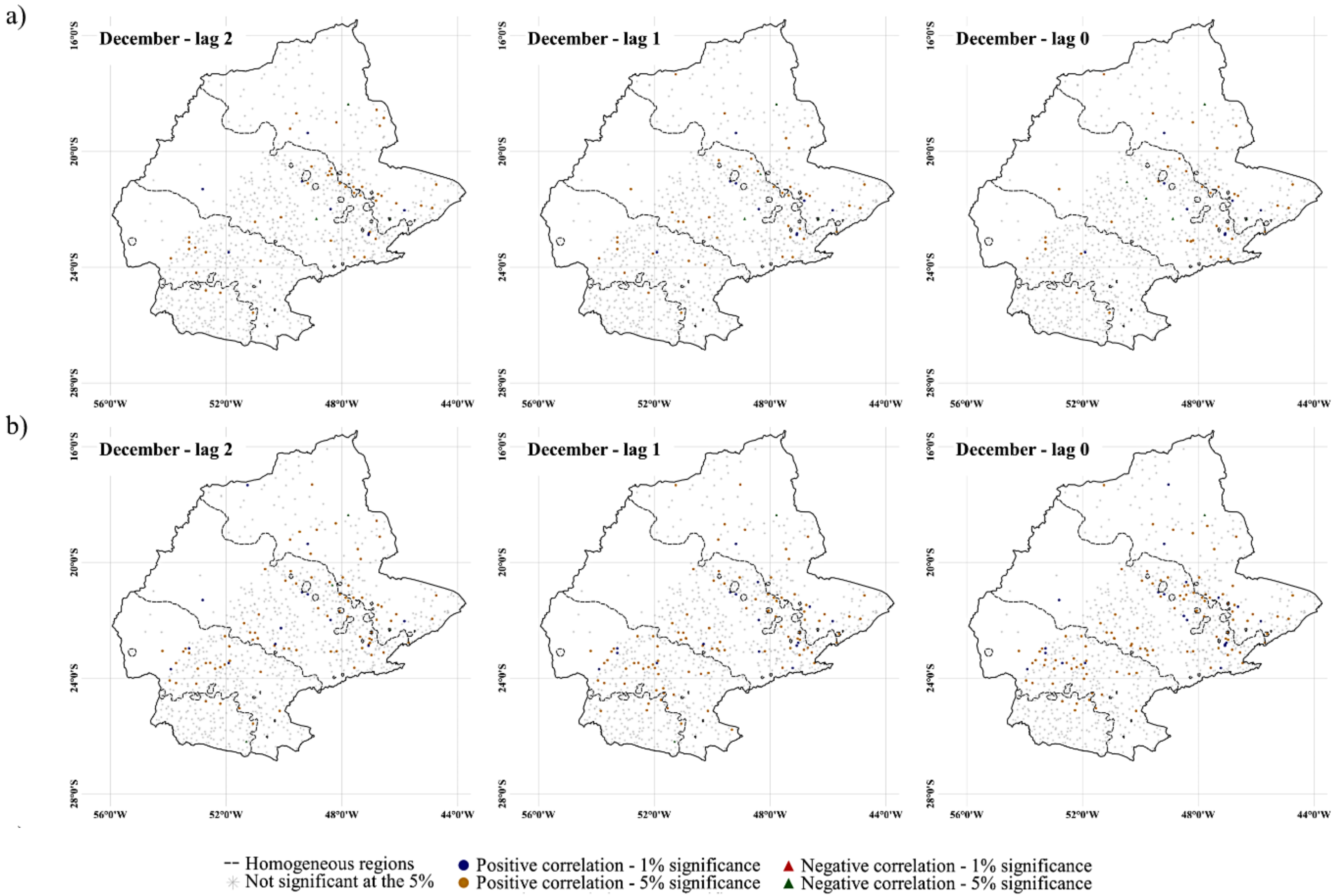


Fig. 10 Space correlation among the SPI in December and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: wet period

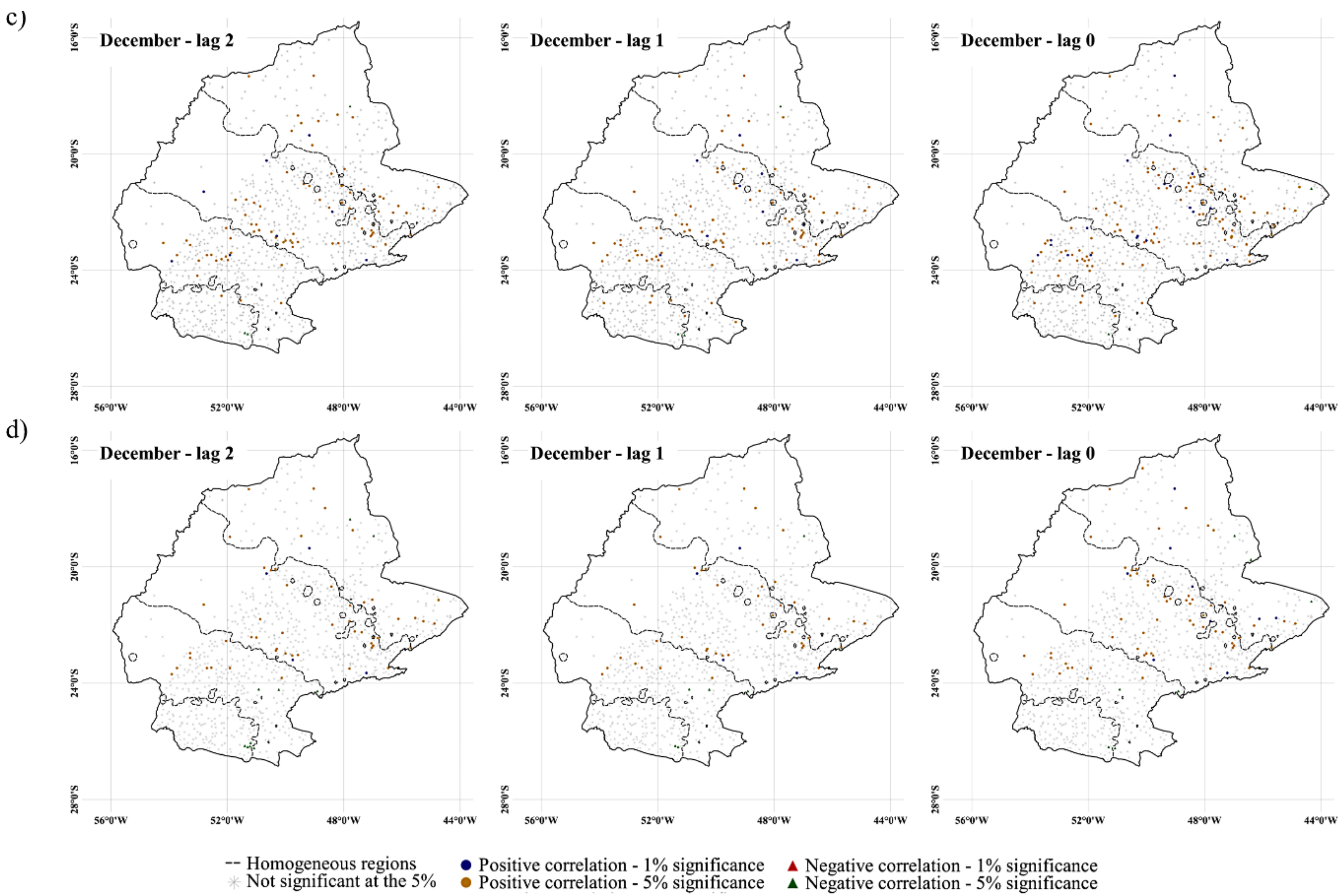


Fig. 10 Space correlation among the SPI in December and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Space correlation among the climate indices and the SPI: wet period

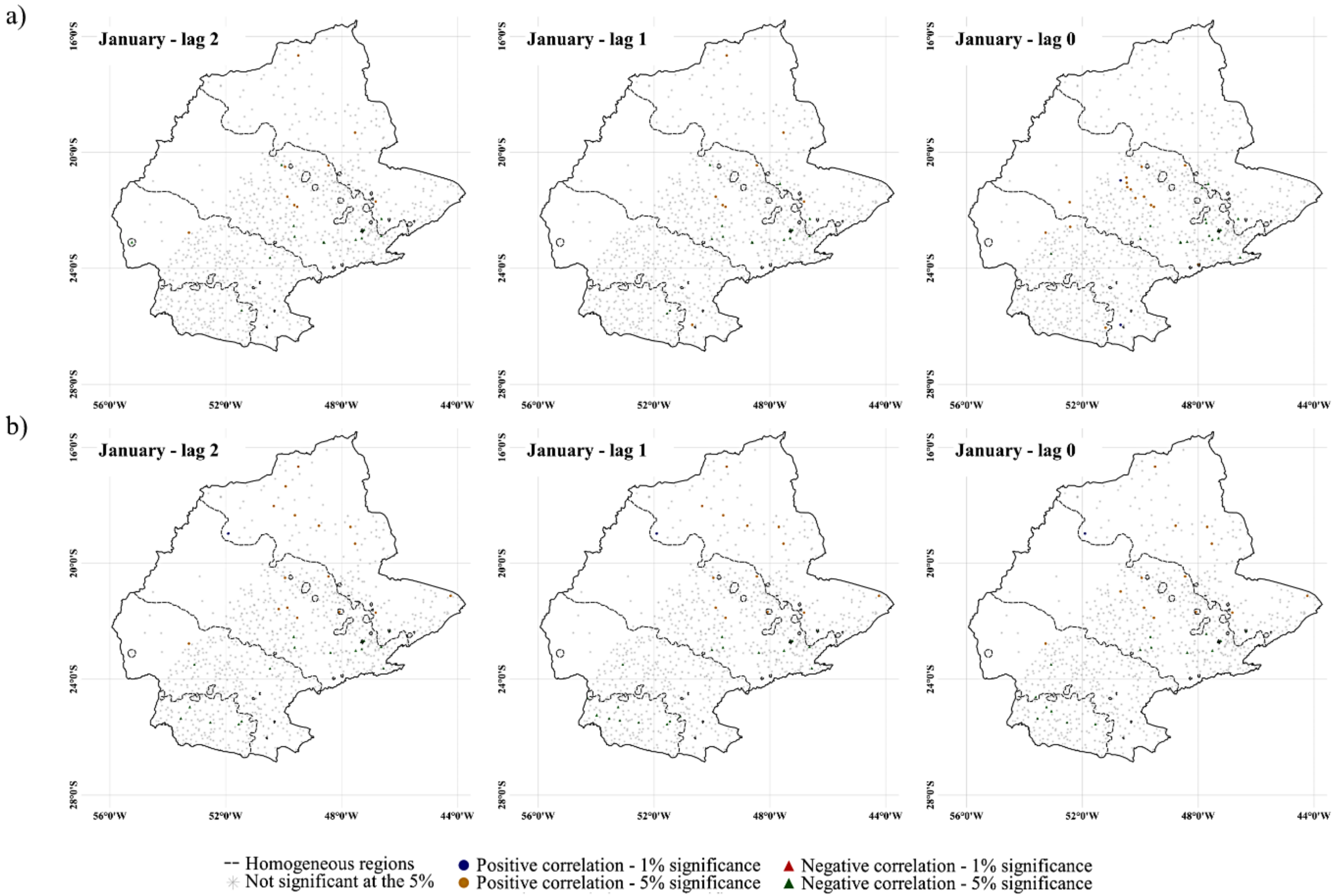


Fig. 11 Space correlation among the SPI in January and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: wet period

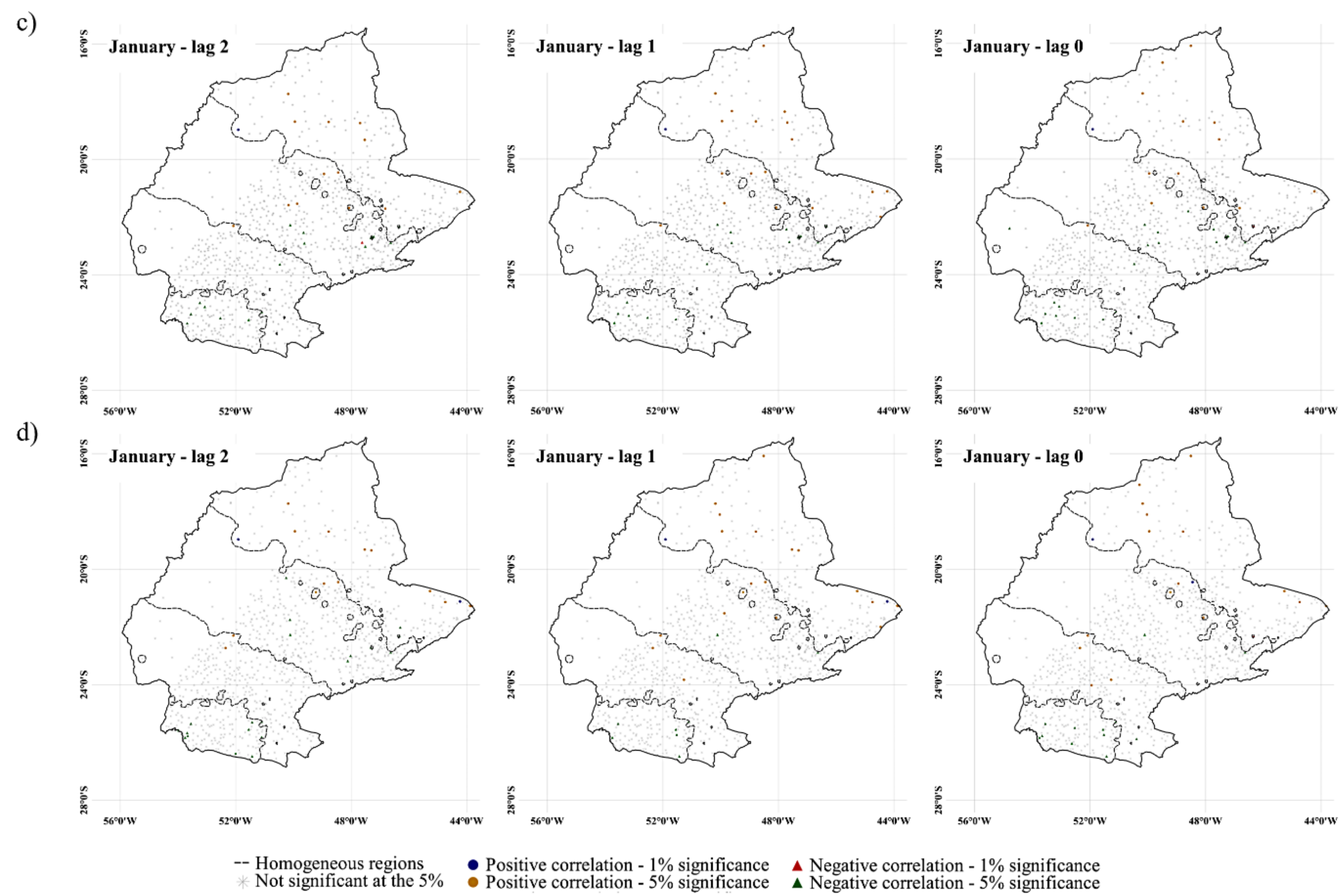


Fig. 11 Space correlation among the SPI in January and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Space correlation among the climate indices and the SPI: wet period

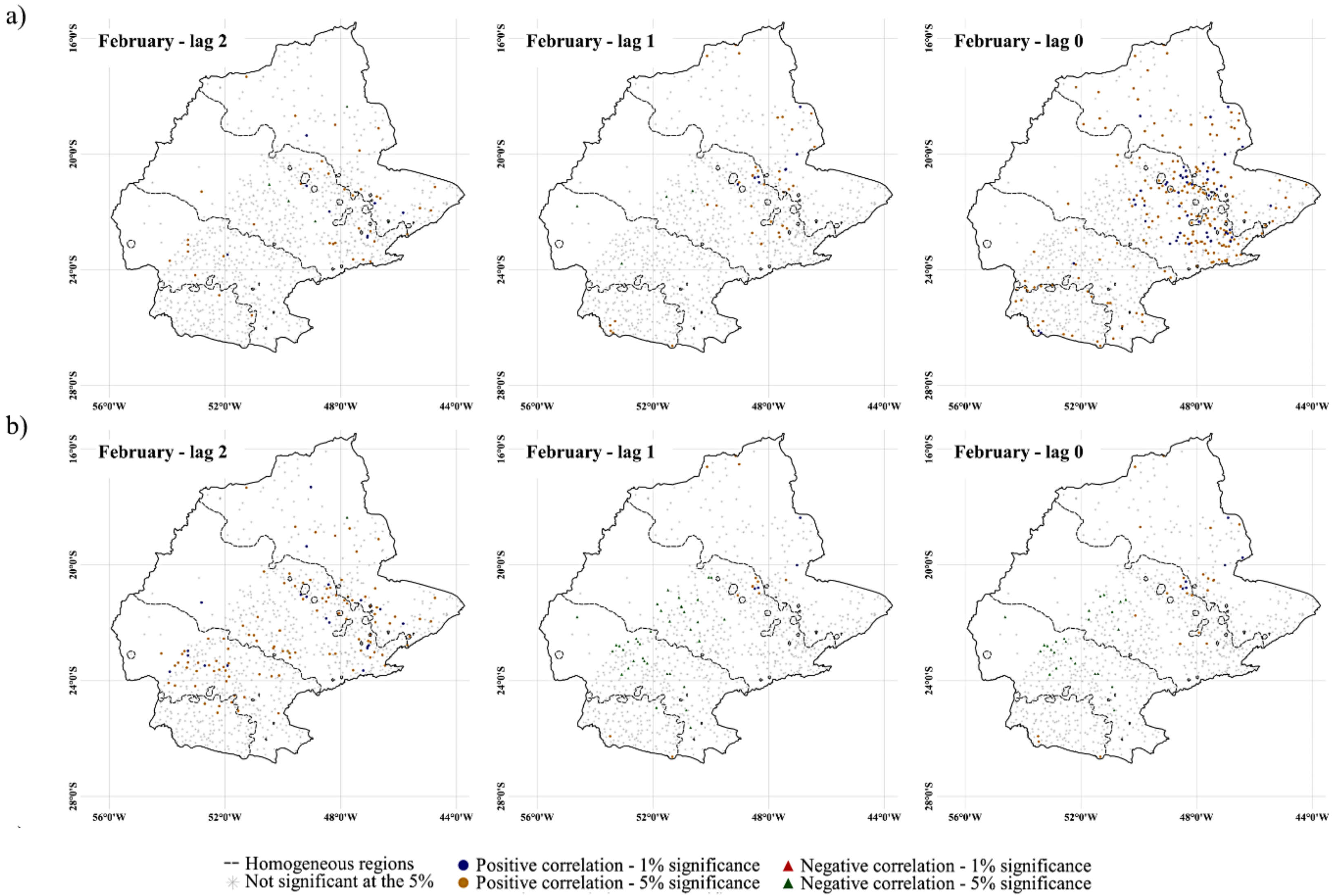


Fig. 12 Space correlation among the SPI in February and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4.

Space correlation among the climate indices and the SPI: wet period

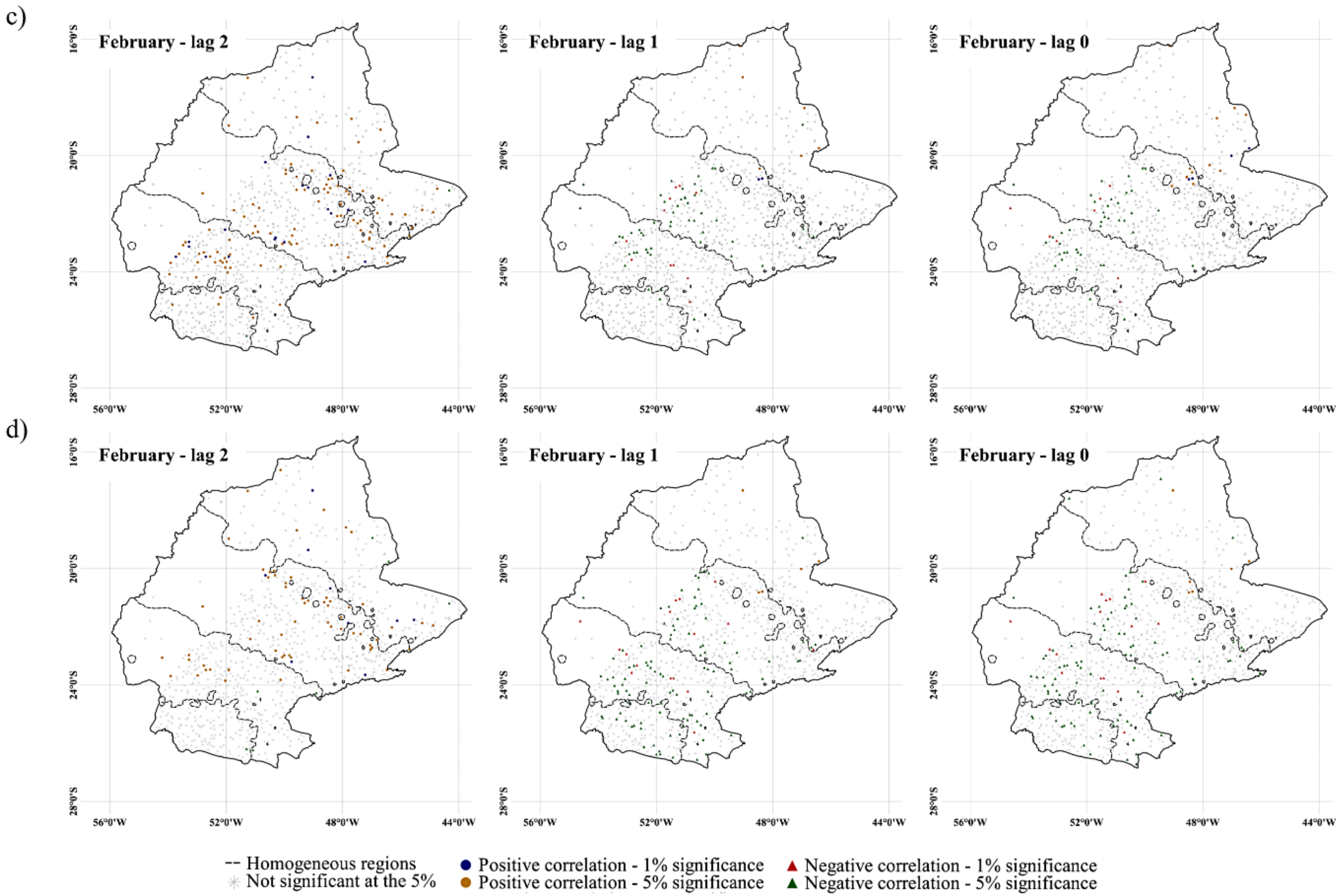


Fig. 12 Space correlation among the SPI in February and the climate indices: (a) Niño 1+2, (b) Niño 3, (c) Niño 3.4 and (d) Niño 4 (continuation).

Final considerations

- ✓ Both the formation of two as the formation of four sub-regions presented coherent results with the reality, in which near points present similar behavior in the regime of rains.
- ✓ The subdivision these homogeneous regions of precipitation is consistent with the systems operating in the region.
- ✓ The highest occurrence of the dry events was observed in the austral winter.
- ✓ The highest occurrence of the wet events was observed in the austral summer.
- ✓ The southern Paraná (R4) is the region with the highest number of selected (dry and wet events).

Final considerations

- ✓ The results obtained with the correlations suggests that the dry conditions is associated with the ENSO:
  - In June - in the north of Paraná (R3) and in São Paulo (R2)
  - In July - southern Paraná
- ✓ The indices Niño 1+ 2 and Niño 3, located in the east equatorial Pacific, presented the highest coefficients.
- ✓ The correlations with significant coefficients at 5% and 1% were positives, showing an direct.
  - ✓ As the ENSO phenomenon is characterized by anomalies, positive (El Niño) or negative (La Niña), this result suggests that o El Niño (La Niña) contributes to the excess (lack) of rainfall in the region.

THANK YOU!