A MULTI-SCALAR GLOBAL EVALUATION OF THE IMPACT OF ENSO ON DROUGHTS

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Background

• The El Niño-Southern Oscillation (ENSO) phenomenon is **one of the main sources of variability in the Earth's climate**; the extremes of this atmosphere-ocean coupled mode are known as the El Niño and La Niña phases.

• The influence of ENSO events on the global variability of precipitation and temperature are well known.

• Current interest in climate responses to variations in **atmospheric circulation** is mainly focused **on the occurrence of extreme events** (e.g. floods, droughts, heat waves) that cause major environmental, social and economic damage.

• **HERE WE FOCUS ON THE ENSO IMPACT ON DROUGHTS, MEASURED AT DIFFERENT TIME-SCALES, GLOBALLY.**

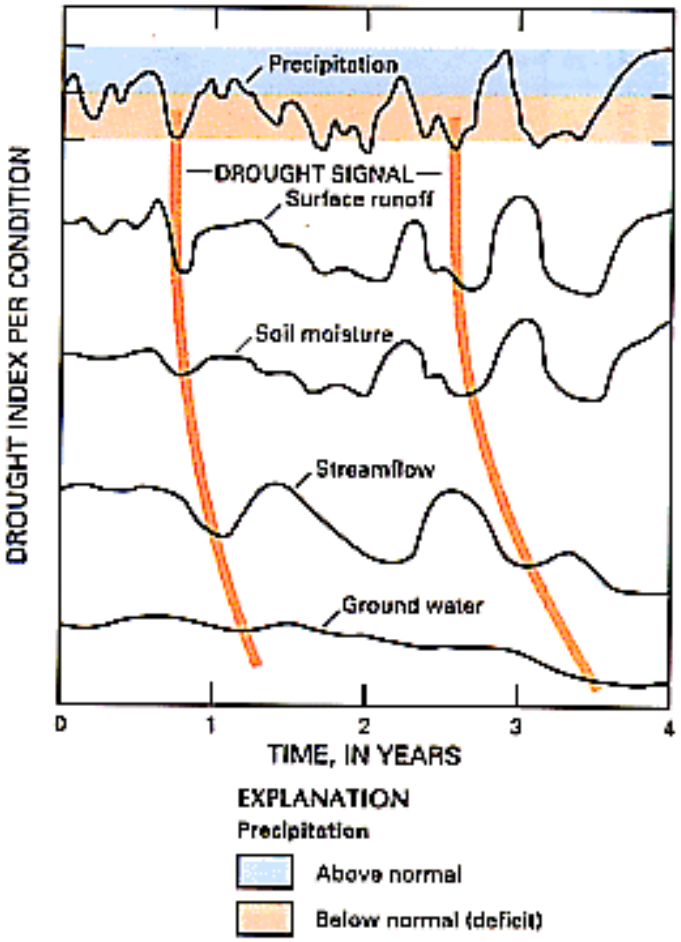
Background

• Drought is a complex natural hazards to identify, monitor and analyze because of problems associated with objectively quantifying their characteristics in terms of intensity, magnitude, onset, cessation, duration and spatial extent. Consequently, **determining drought atmospheric mechanisms is highly problematic**.

• Moreover, **drought is a multi-scalar phenomenon**, which adds much complexity to any analysis, since the **response** of the hydrological (soil moisture, groundwater, river discharge, reservoir storage, etc) and biological (crops, natural vegetation, etc) systems to water shortage **varies markedly** and have **different response times**.

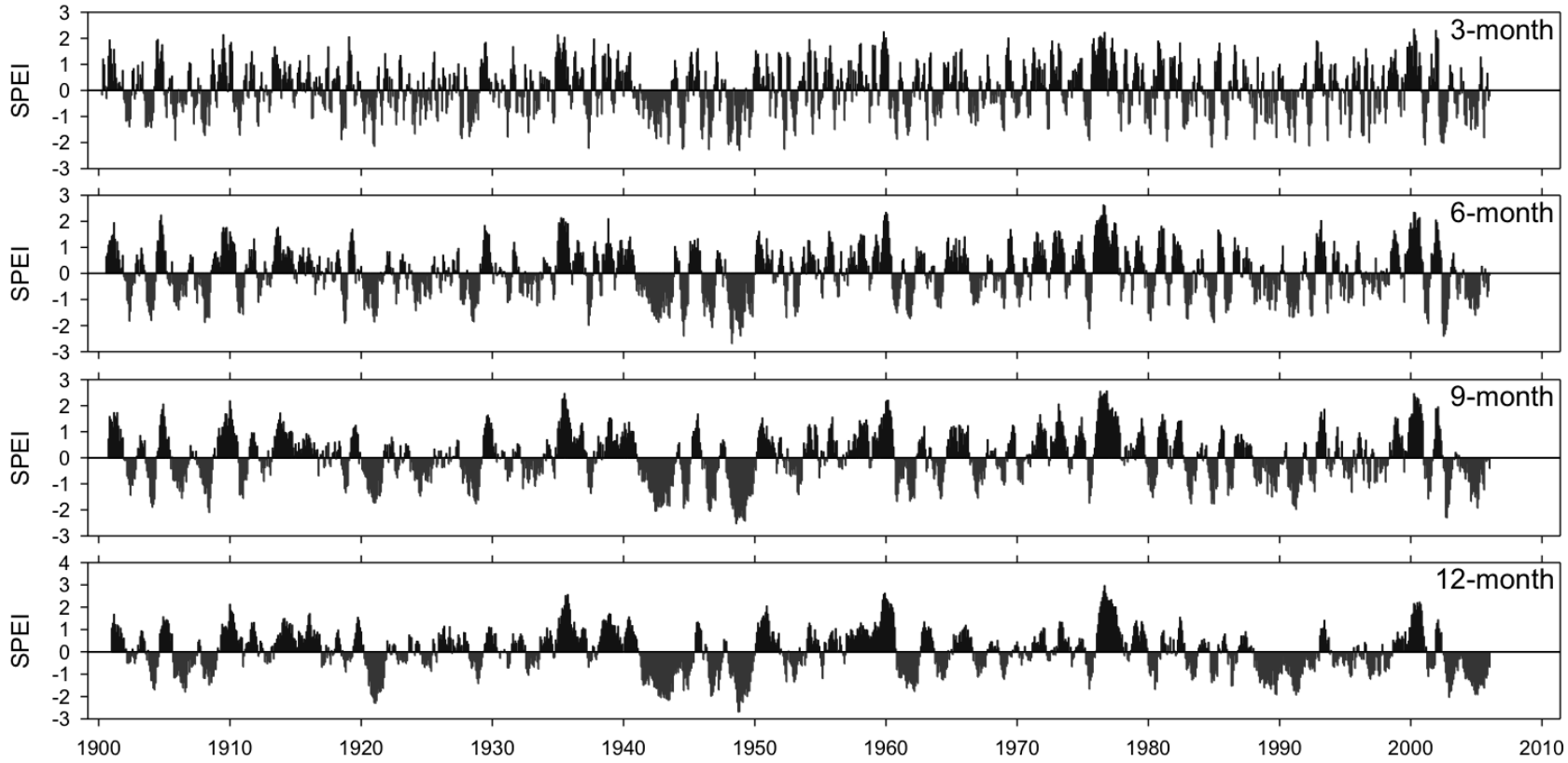
•This explains why severe drought conditions can be recorded in one system (e.g., low river flows) whereas other systems in the same region (e.g., crops) have normal or even humid conditions.

• The **time scale** over which water deficits accumulate becomes **extremely important**, and functionally separates hydrological, environmental, agricultural and other droughts. For this reason, **drought indices must be associated with a specific timescale to be useful** for monitoring and management of different usable water resources.



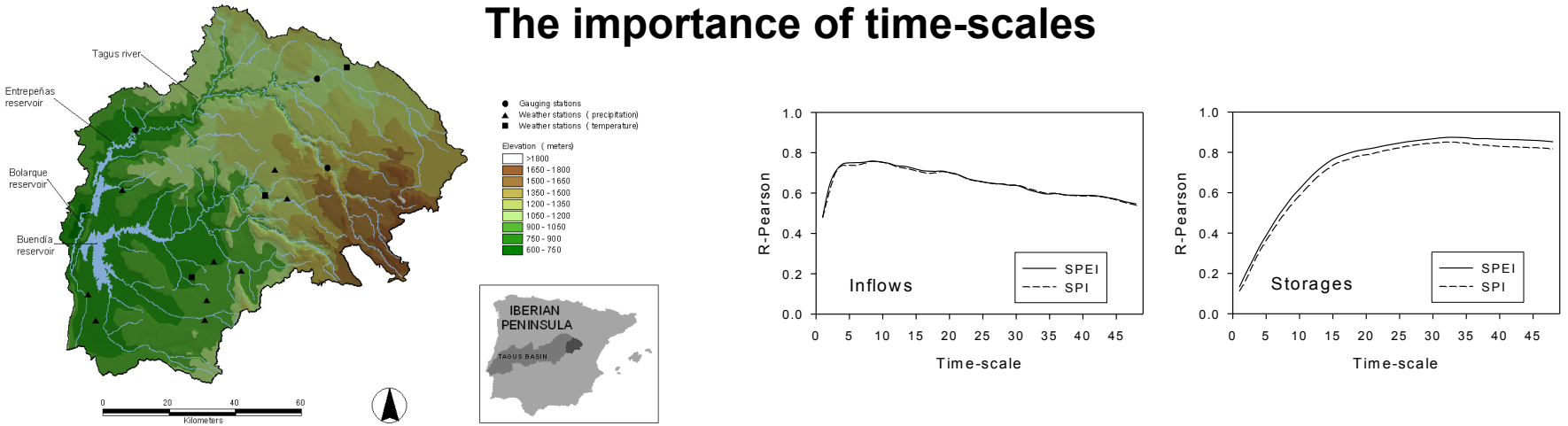
Changnon and Easterling (1989): Wat. Res Bull., 25, 27

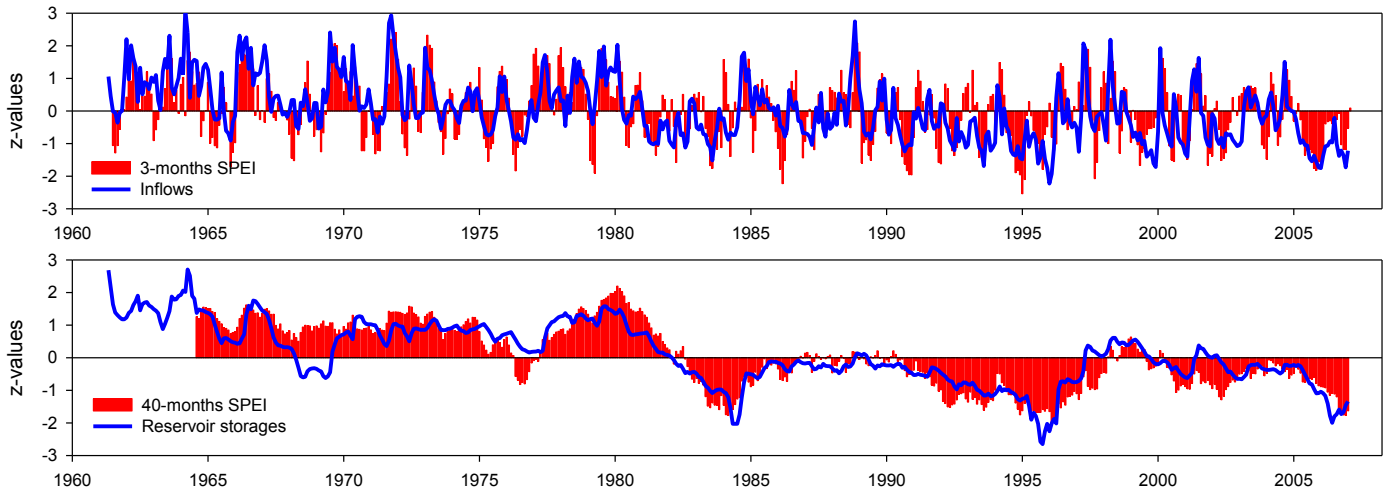
How to quantify the different times of response?



This explains the wide acceptance of the **SPI**, considered by the **WMO** as the **reference drought index.**

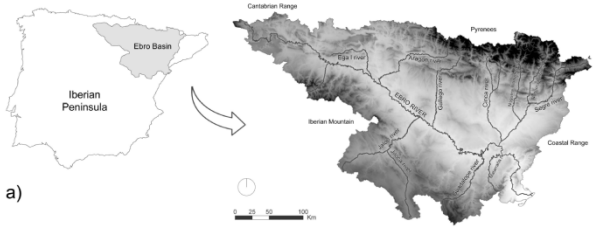
The importance of time-scales

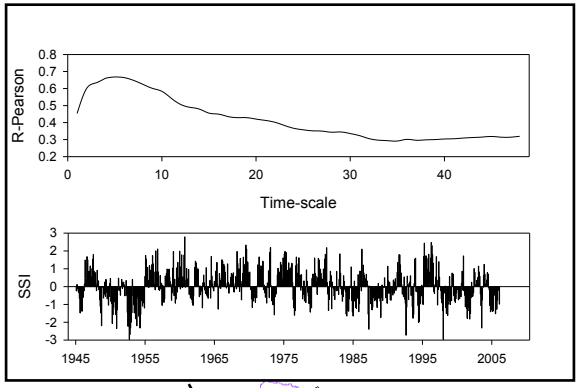


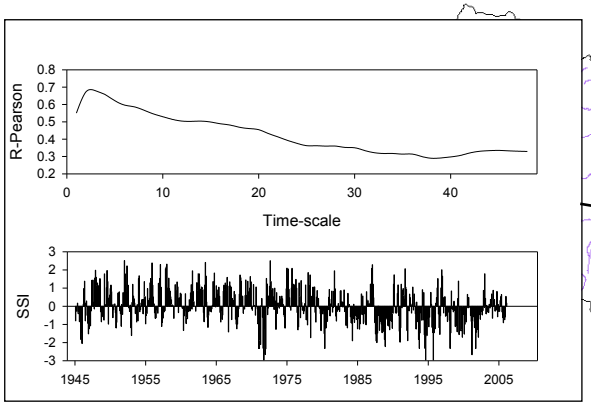


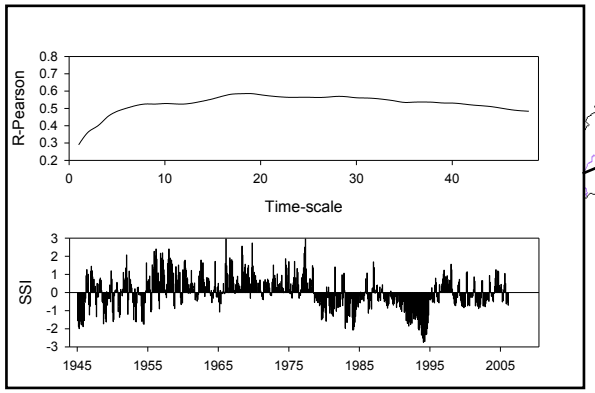
Lorenzo-Lacruz et al. (2010): Journal of Hydrology, 386: 13

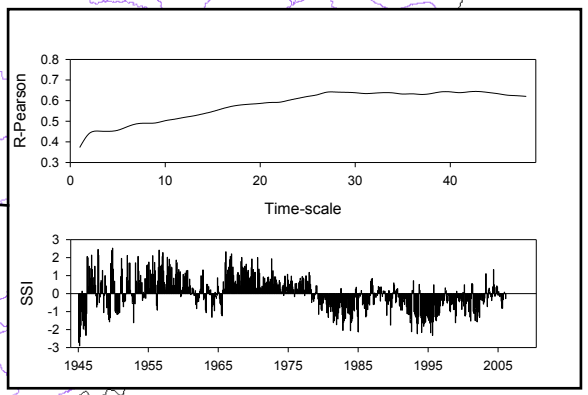
The importance of time-scales

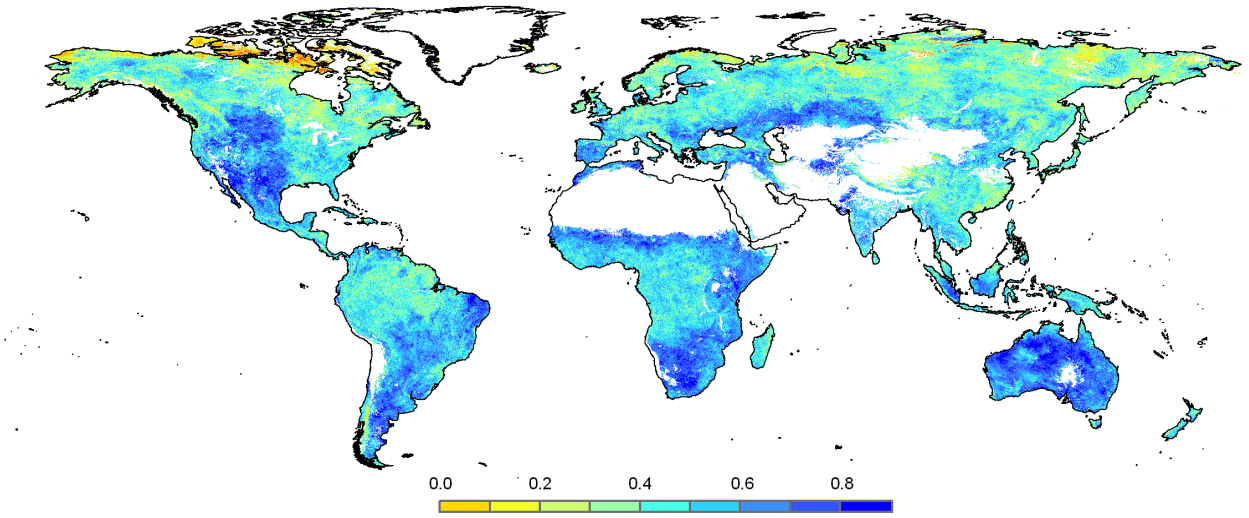


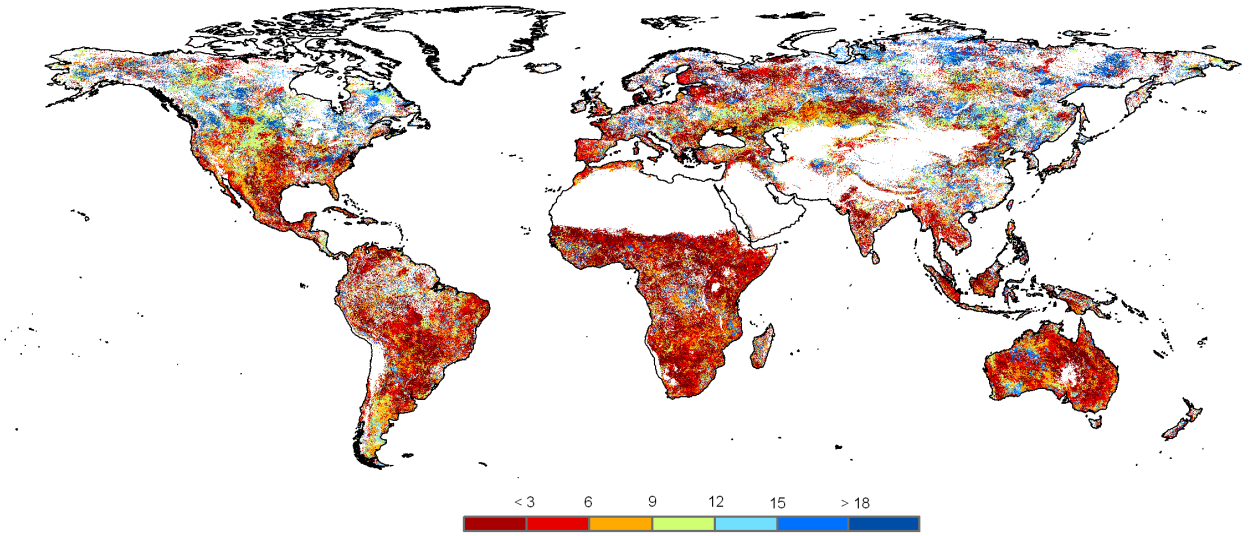












More details in poster Session 4

This multi-temporal character makes it **difficult to identify clear relationships** between **atmospheric circulation** patterns and **drought** variability.

This **difficulty** is **exacerbated** by the **lags** that commonly occur in the response of climatic conditions to atmospheric circulation events, such as El Niño and La Niña.

Objective:

To provide a general picture of drought conditions at various time scales associated with warm (El Niño) and cold (La Niña) ENSO events.

Methodology

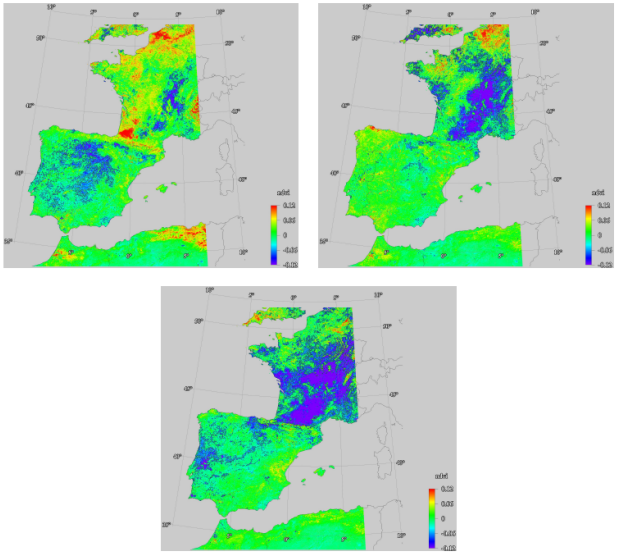
Drought data set

We used the **Standardized Precipitation Evapotranspiration Index (SPEI),** which can be calculated at different time scales and considers the combined effects of precipitation and temperature. The SPEI combines the sensitivity of the Palmer Drought Severity Index (PDSI) to changes in evaporation demand (caused by temperature fluctuations and trends) with the multi-temporal nature of the Standardized Precipitation Index (SPI).

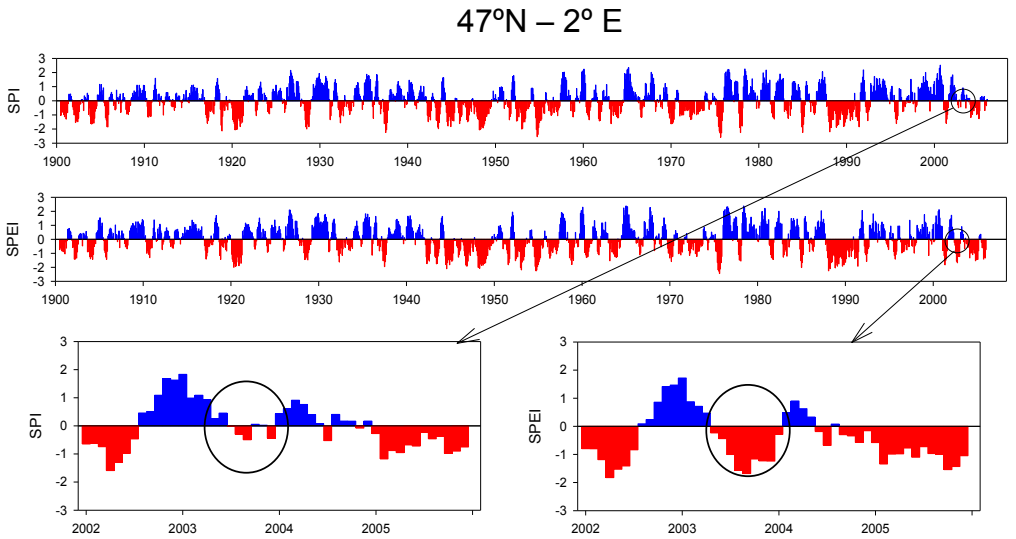
The drought dataset used (the **SPEIbase**, which is based on SPEI) covers the entire Earth at time scales from 1 to 48 months at a spatial resolution of 0.5°, providing temporal coverage for the period 1901-2006.

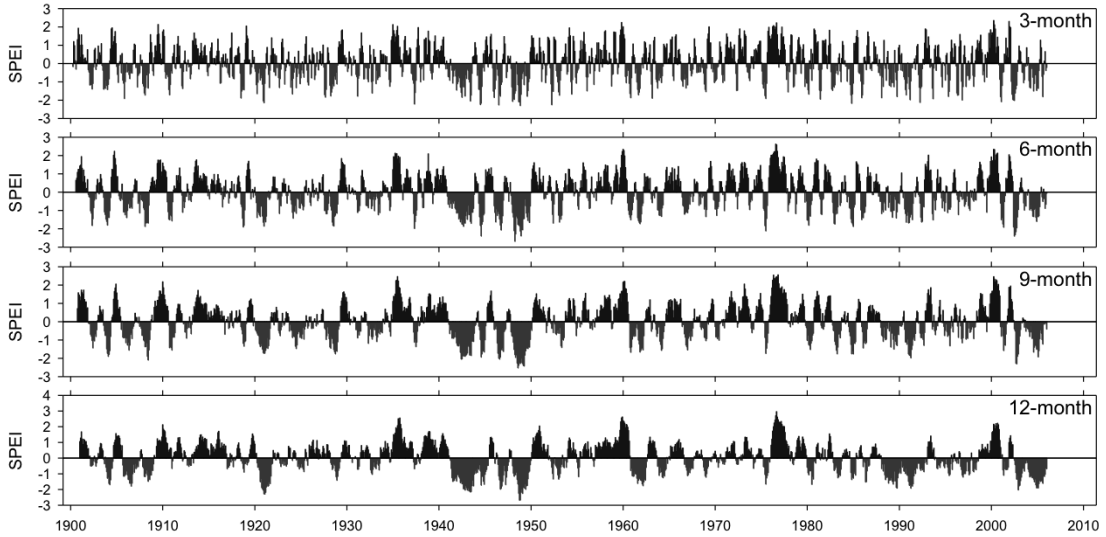
Vicente-Serrano et al. (2010): J. Clim. 23: 1696.
Vicente-Serrano et al. (2010): J. Hydrom. 11: 1013
Beguería et al. (2010): BAMS. 91: 1351.

…**and more details in poster Session 4**.



Lobo, A. and Maisongrande, P., 2006. Hyd.Earth Sys.Sci., 10: 151.





Methodology

Identification of ENSO events

Composites based on ENSO events are commonly used to analyze the nonlinear influence of the ENSO on world climate because the composite warm event ENSO anomalies are not the exact inverse of their cold event counterparts.

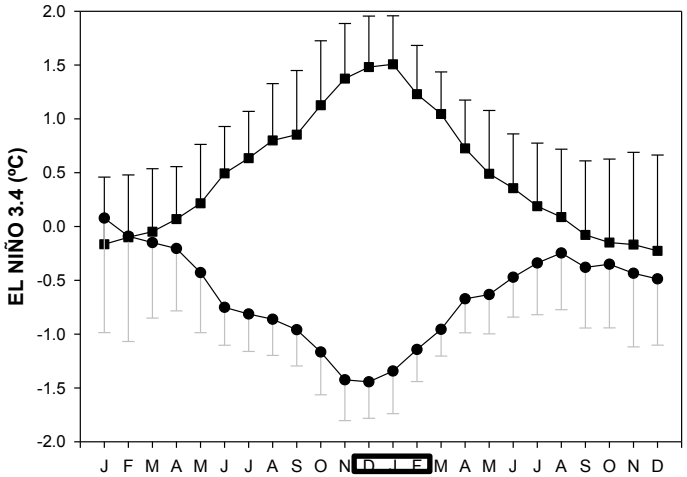
In this study the El Niño and La Niña events were identified using the winter (December-February) **El Niño 3.4 index** between 1901 and 2006. El Niño events were defined by a winter El Niño 3.4 index > 1, and La Niña events were defined by an index <-1.

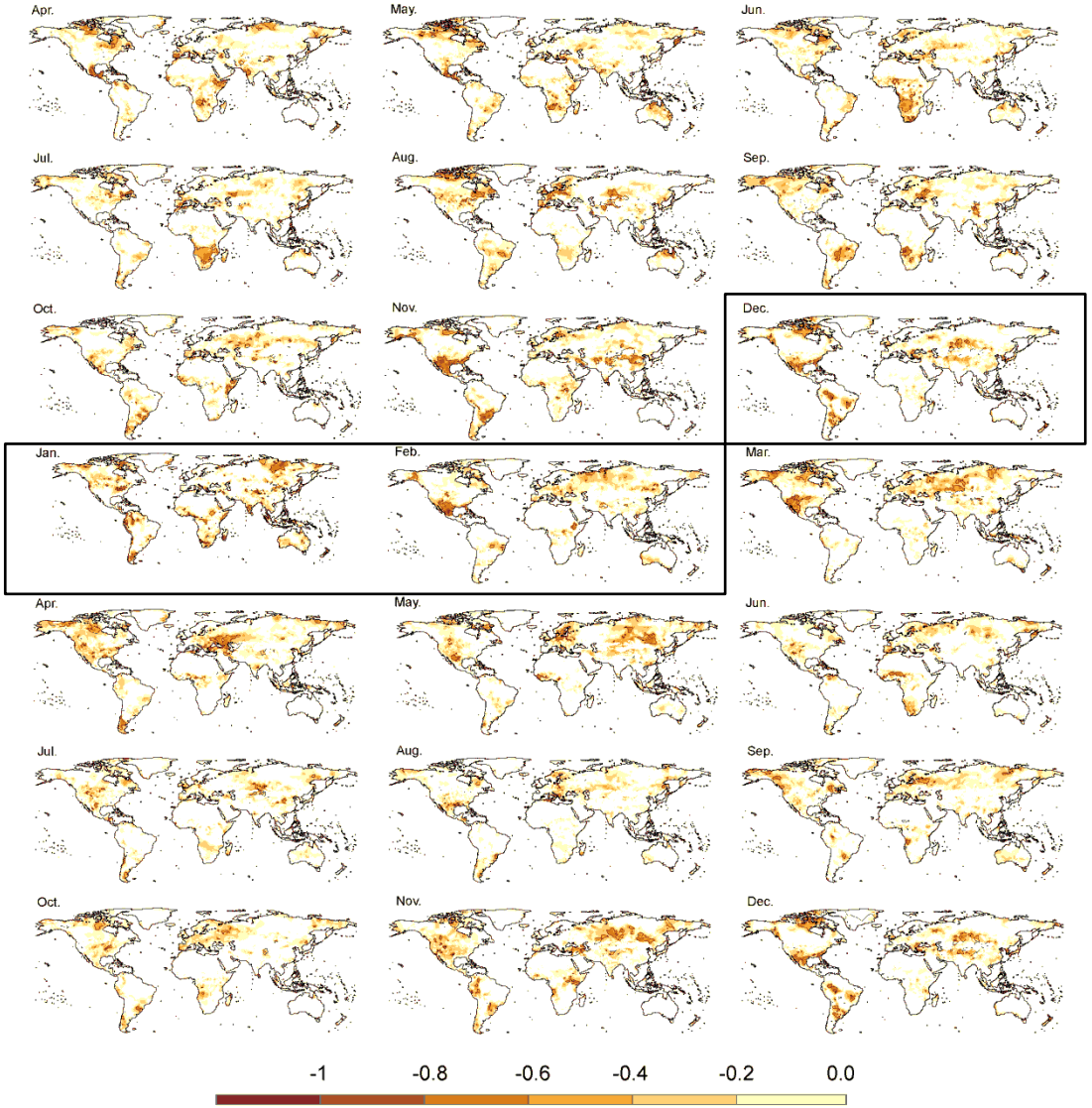
Analysis

Average SPEI anomalies at various time scales were calculated for El Niño and La Niña years, and the year preceding. To determine whether the SPEI at different time scales reflected significant humid or dry conditions during El Niño or La Niña phases, the Wilcoxon-Mann-Whitney test was used. The significance level was defined as $\alpha < 0.05$.

Results

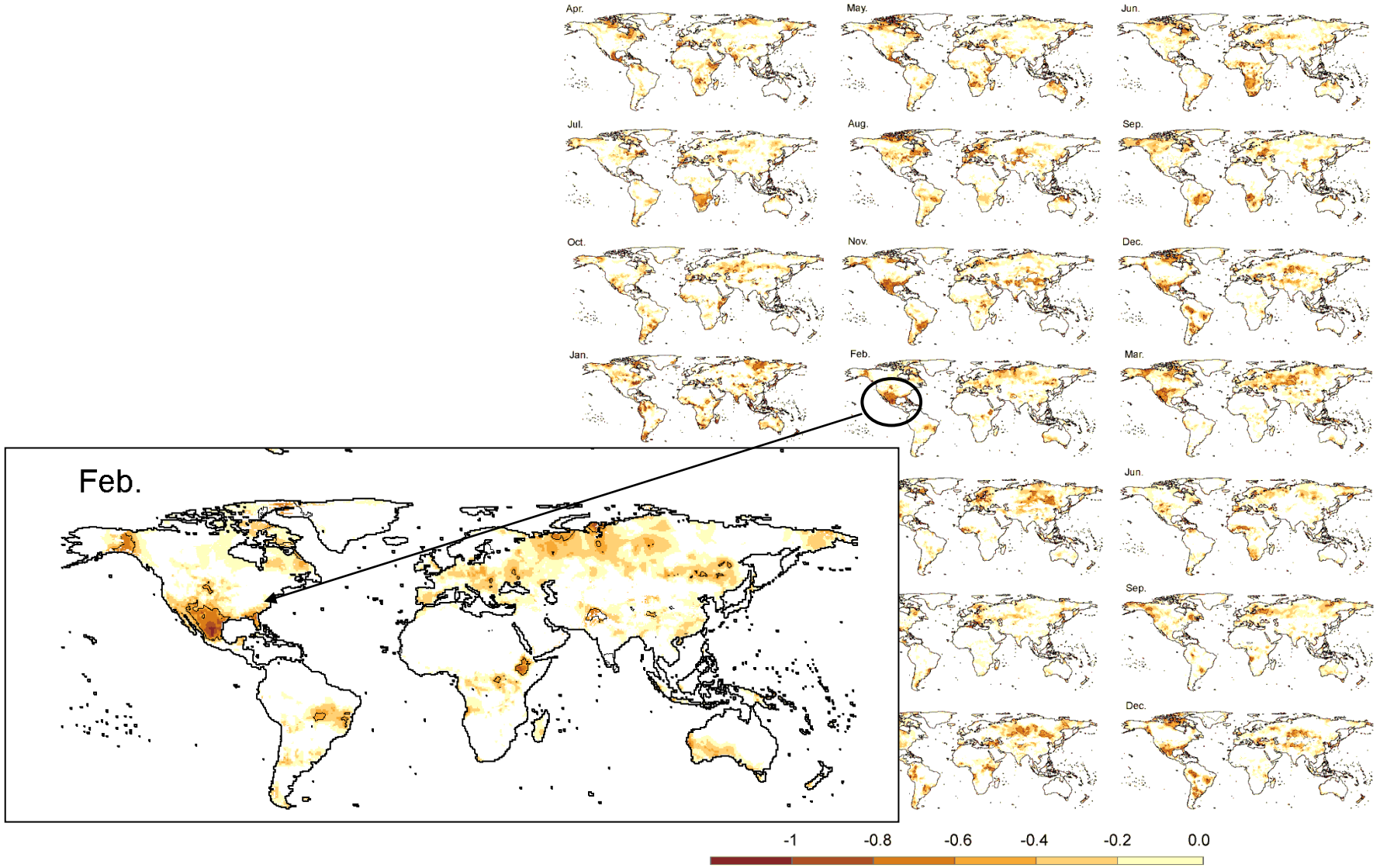
La niña phases – 1 month





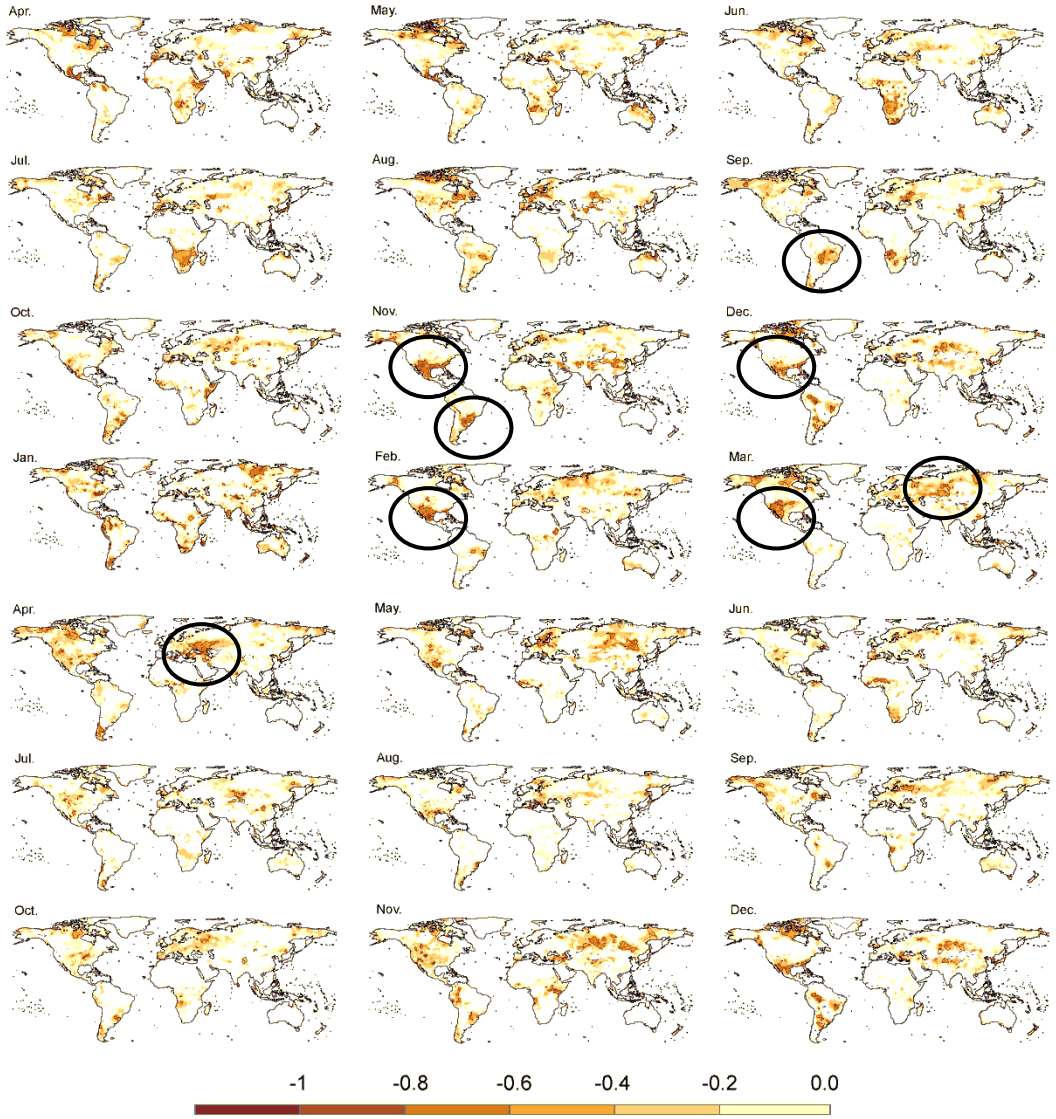
Results

La niña phases – 1 month

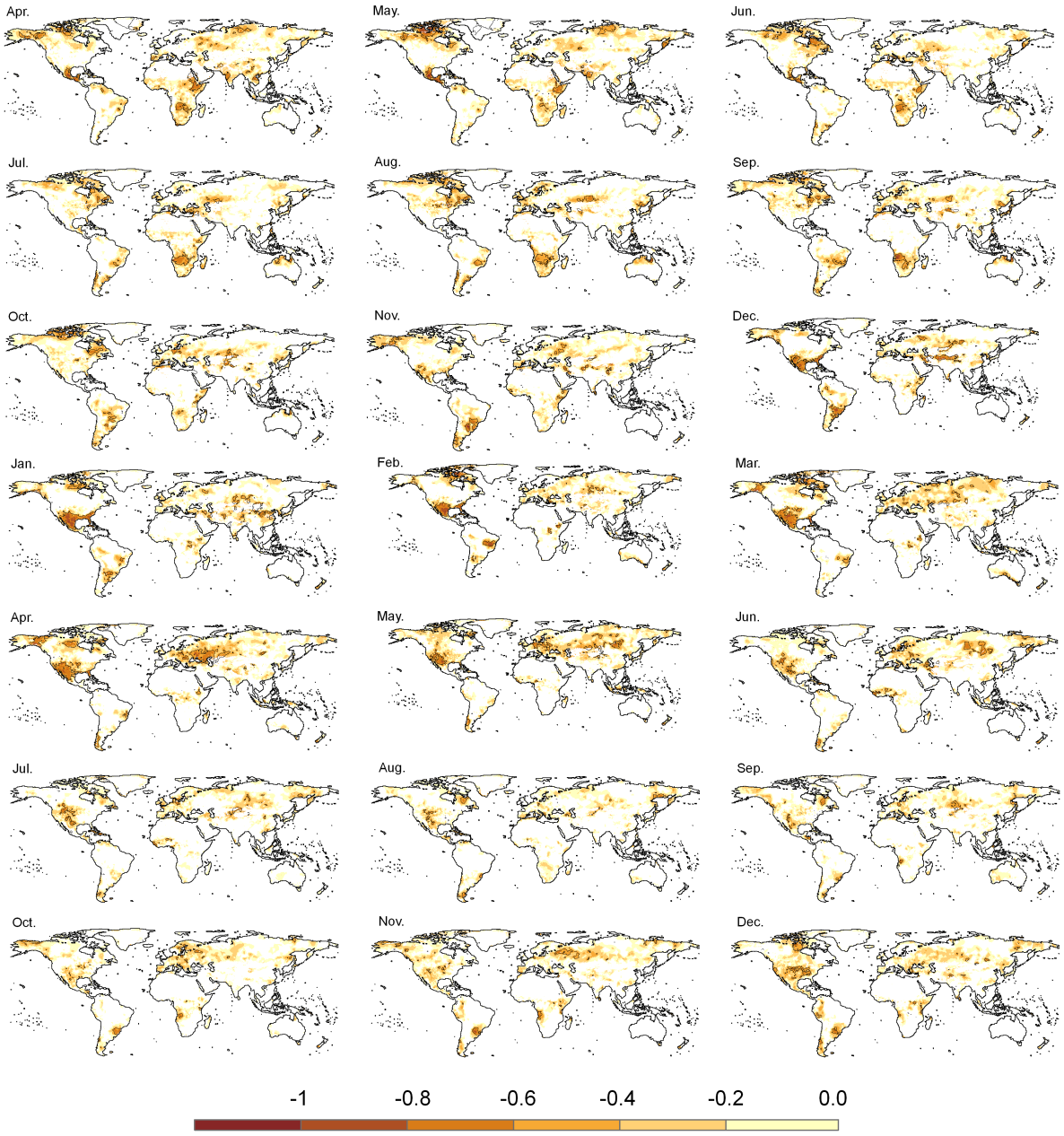


Results

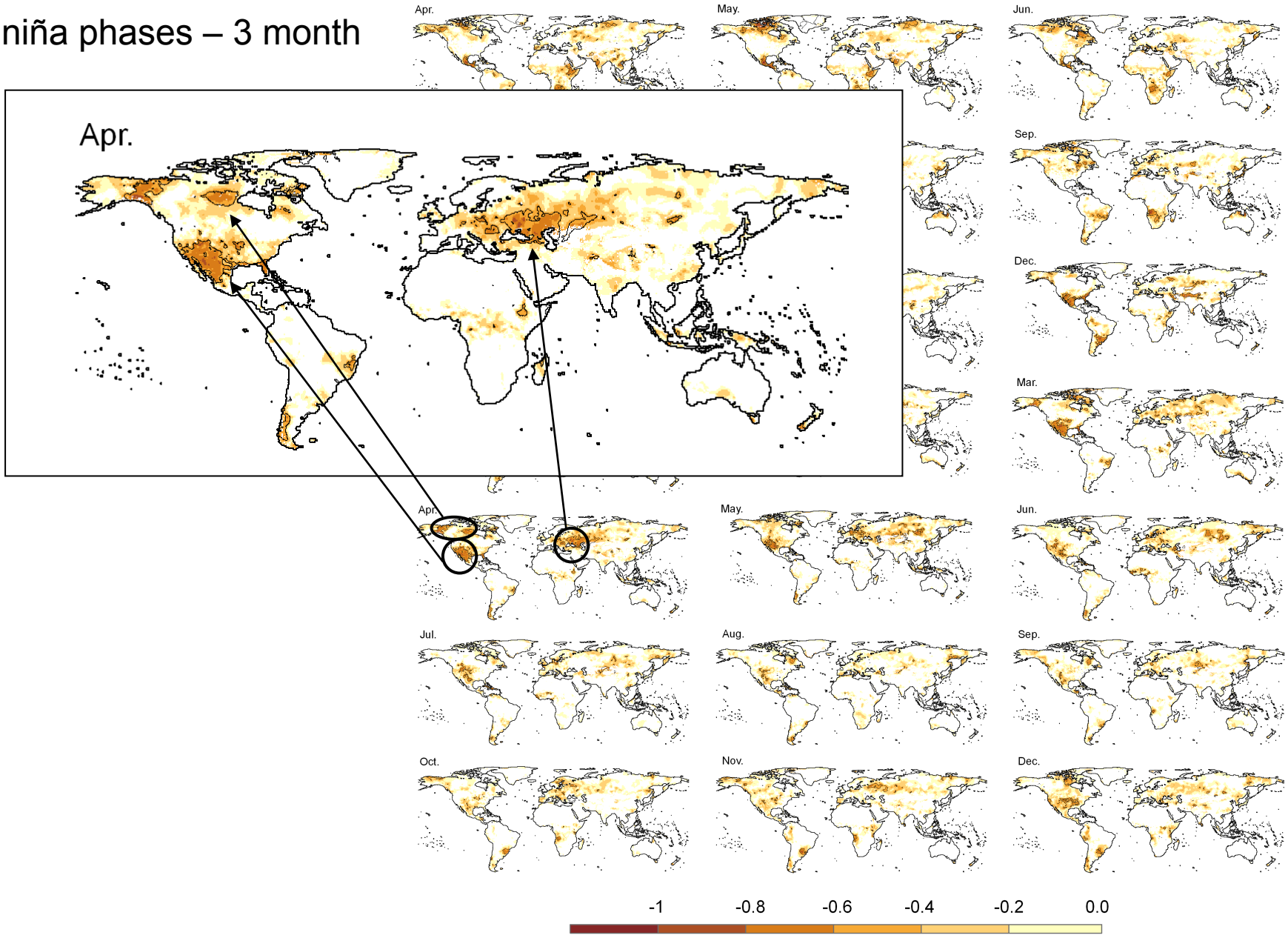
La niña phases – 1 month



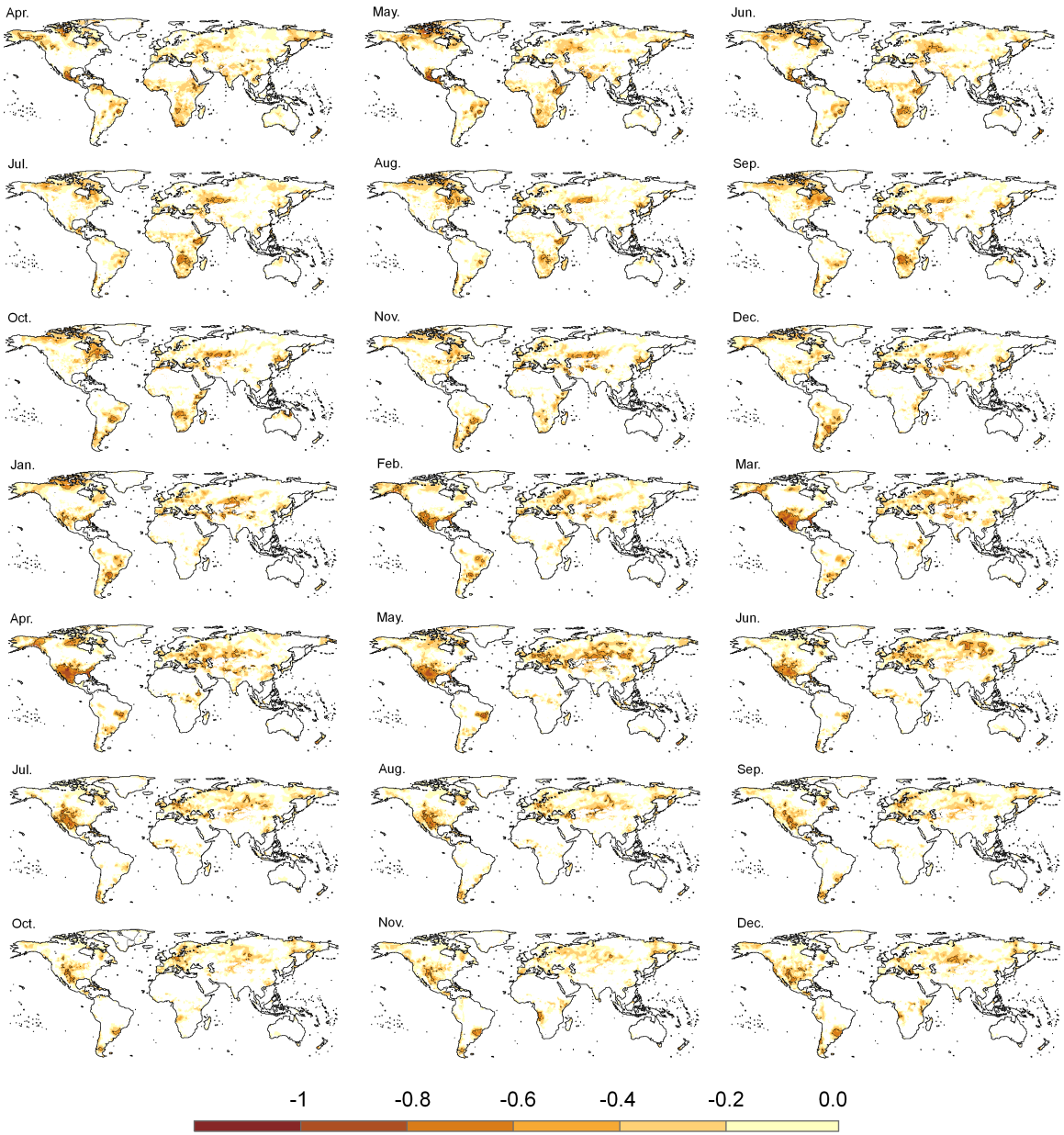
La niña phases – 3 month



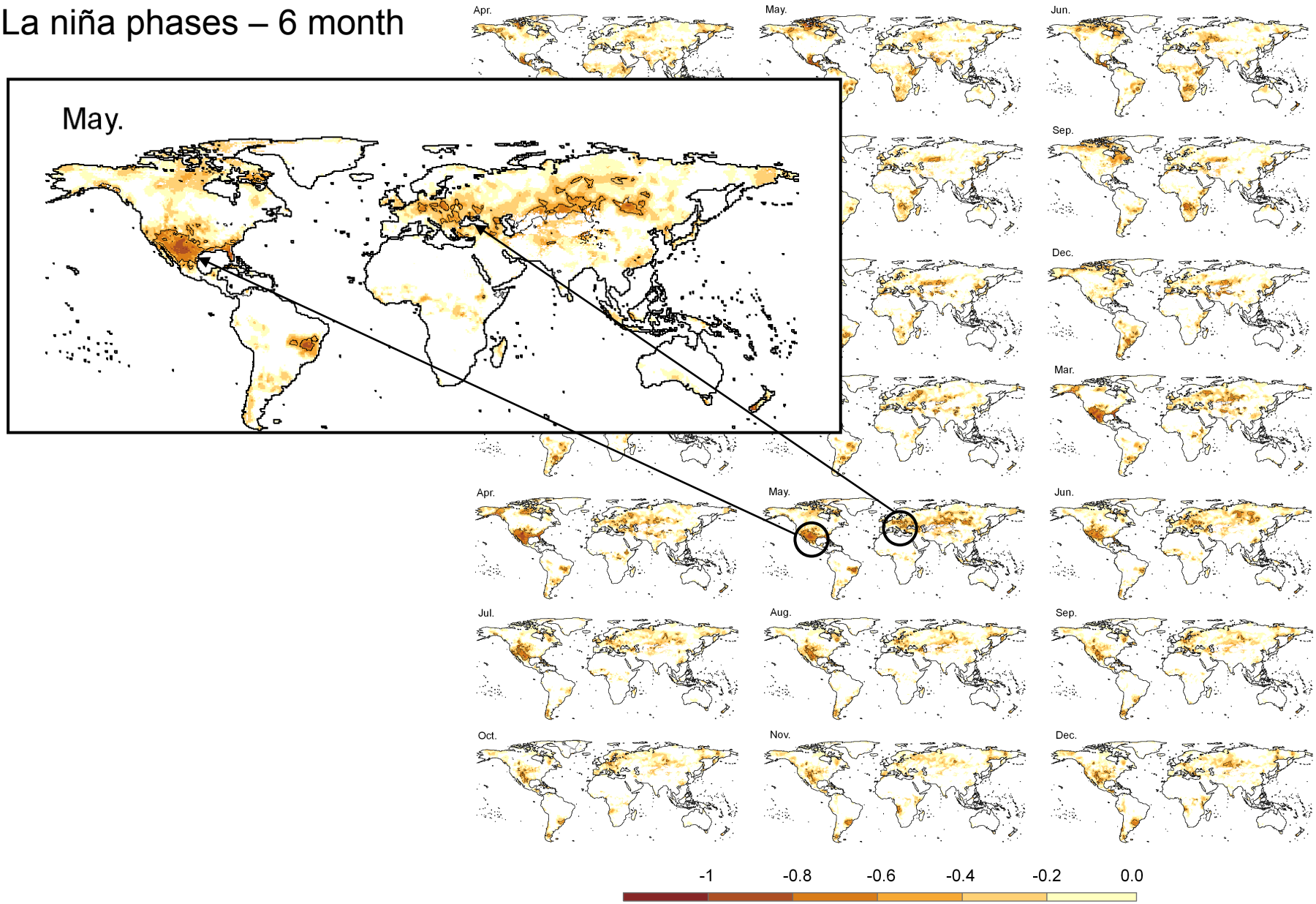
La niña phases – 3 month



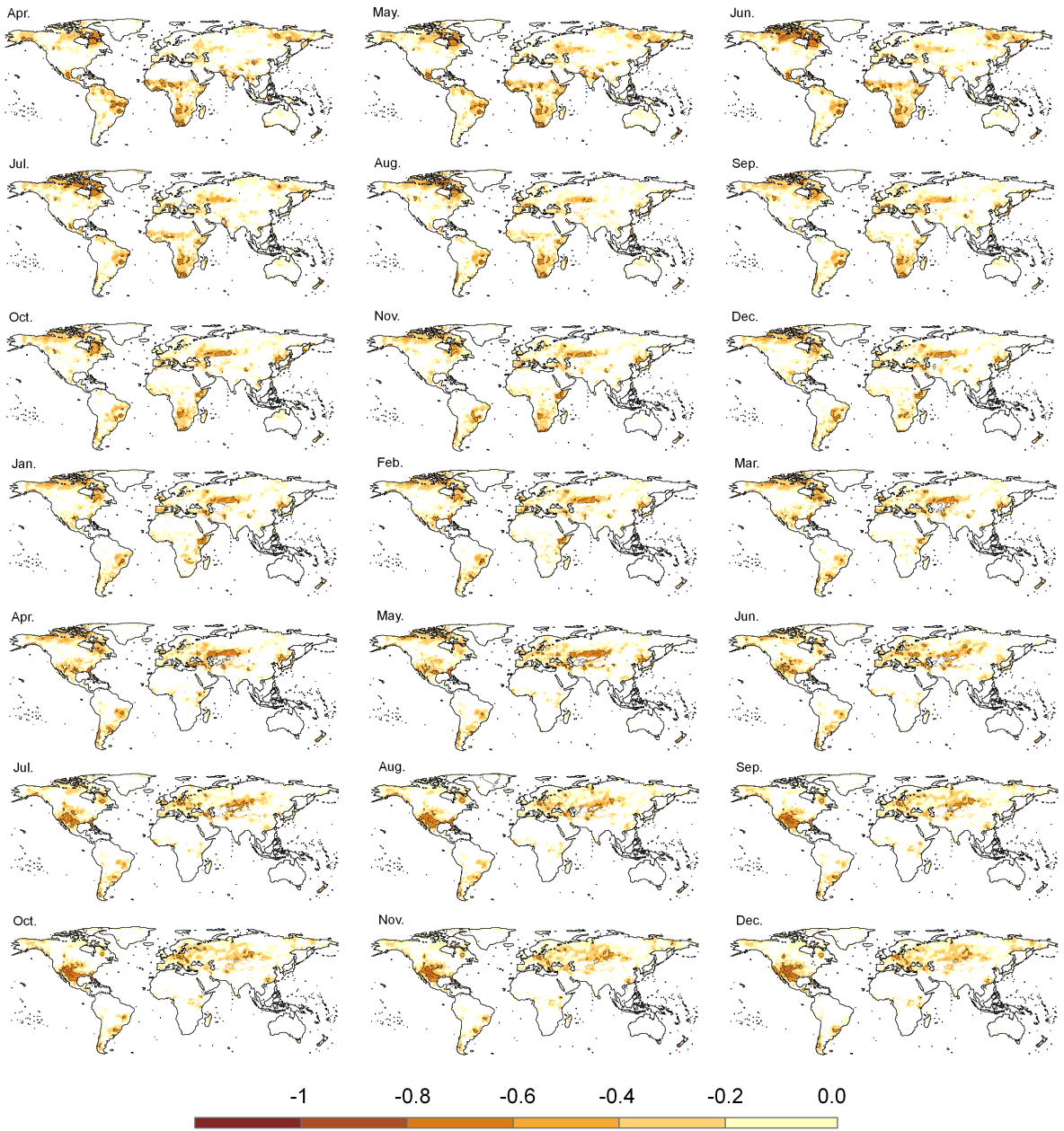
La niña phases – 6 month



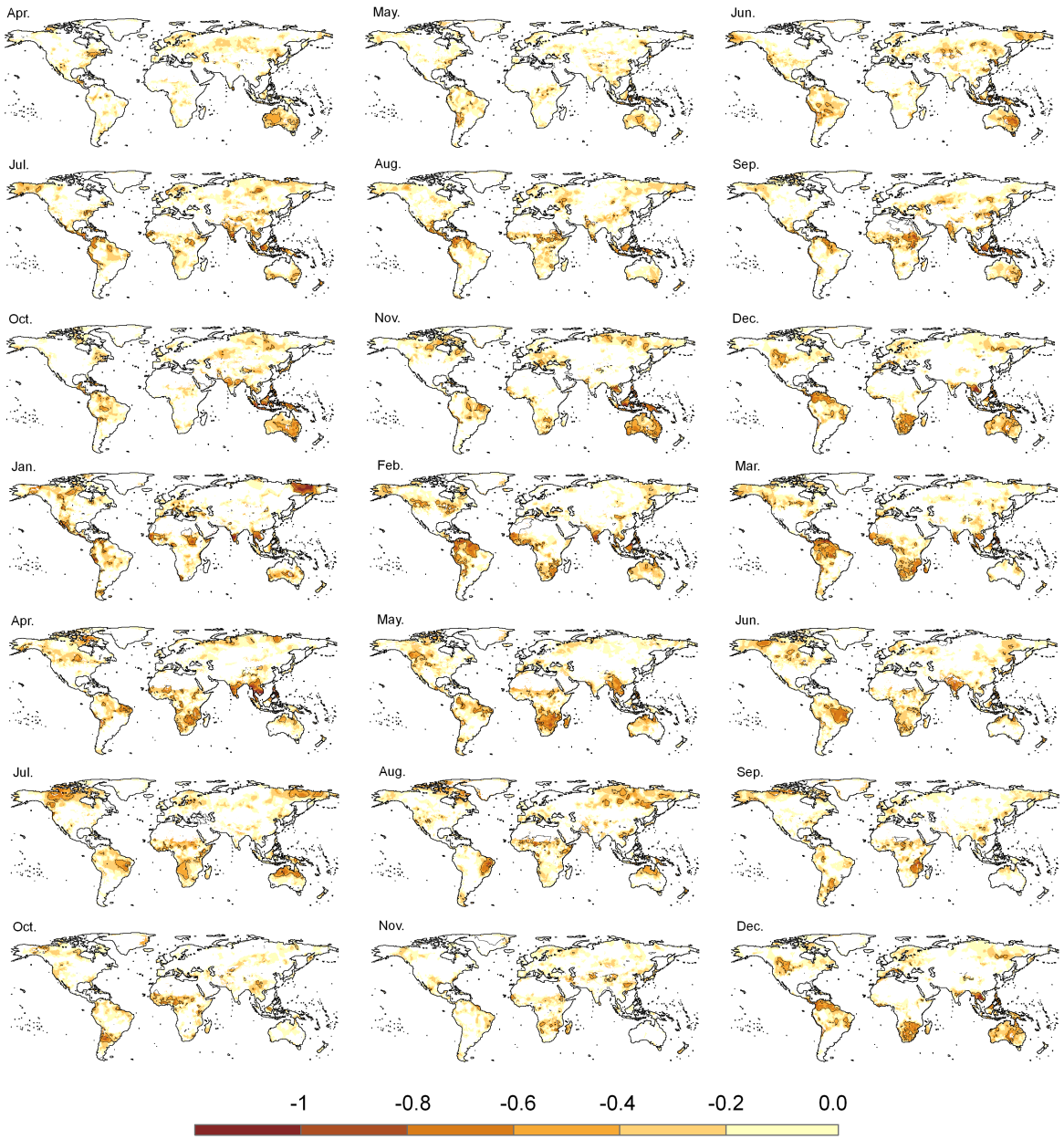
La niña phases – 6 month



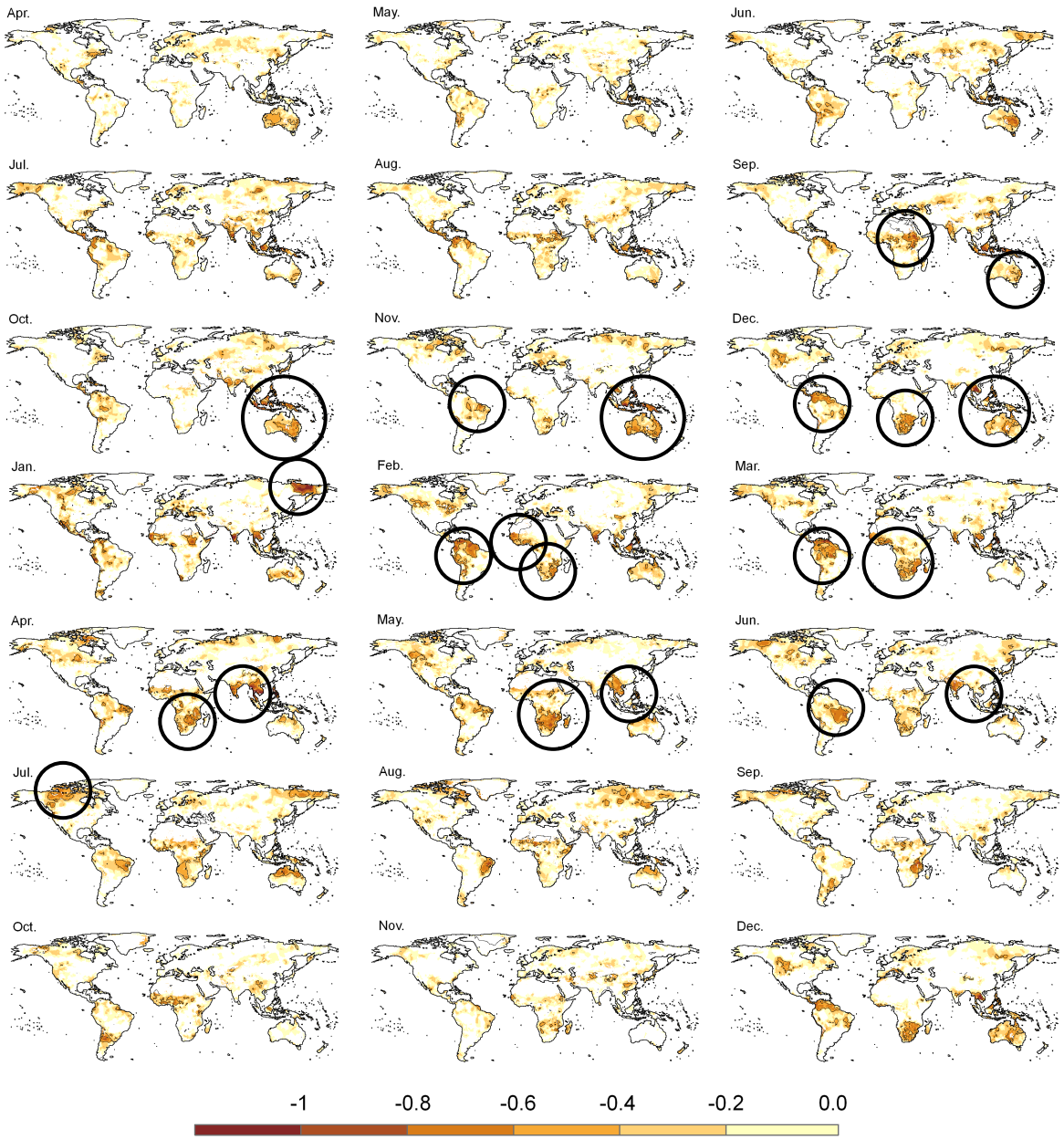
La niña phases – 12 month



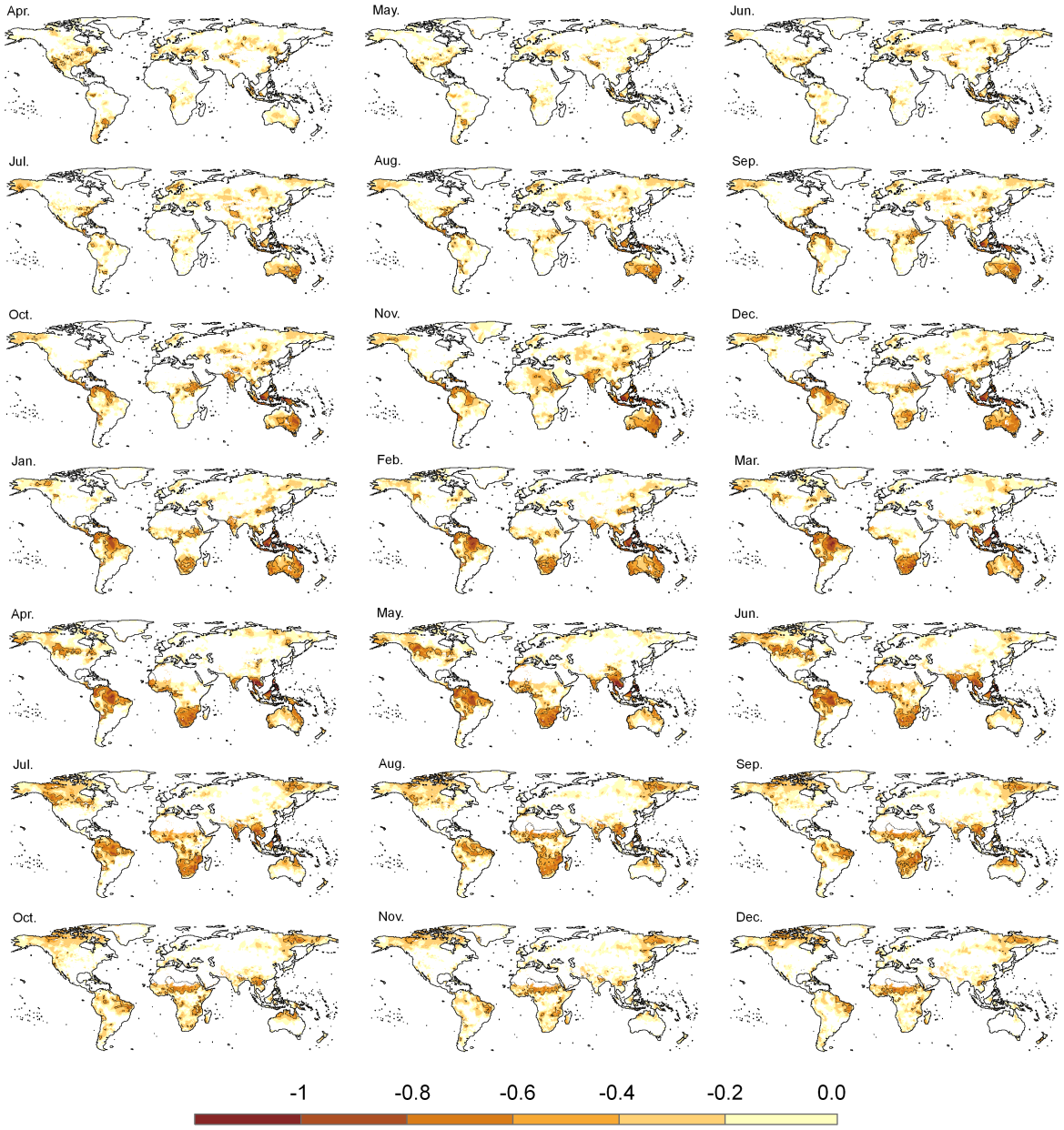
El niño phases – 1 month



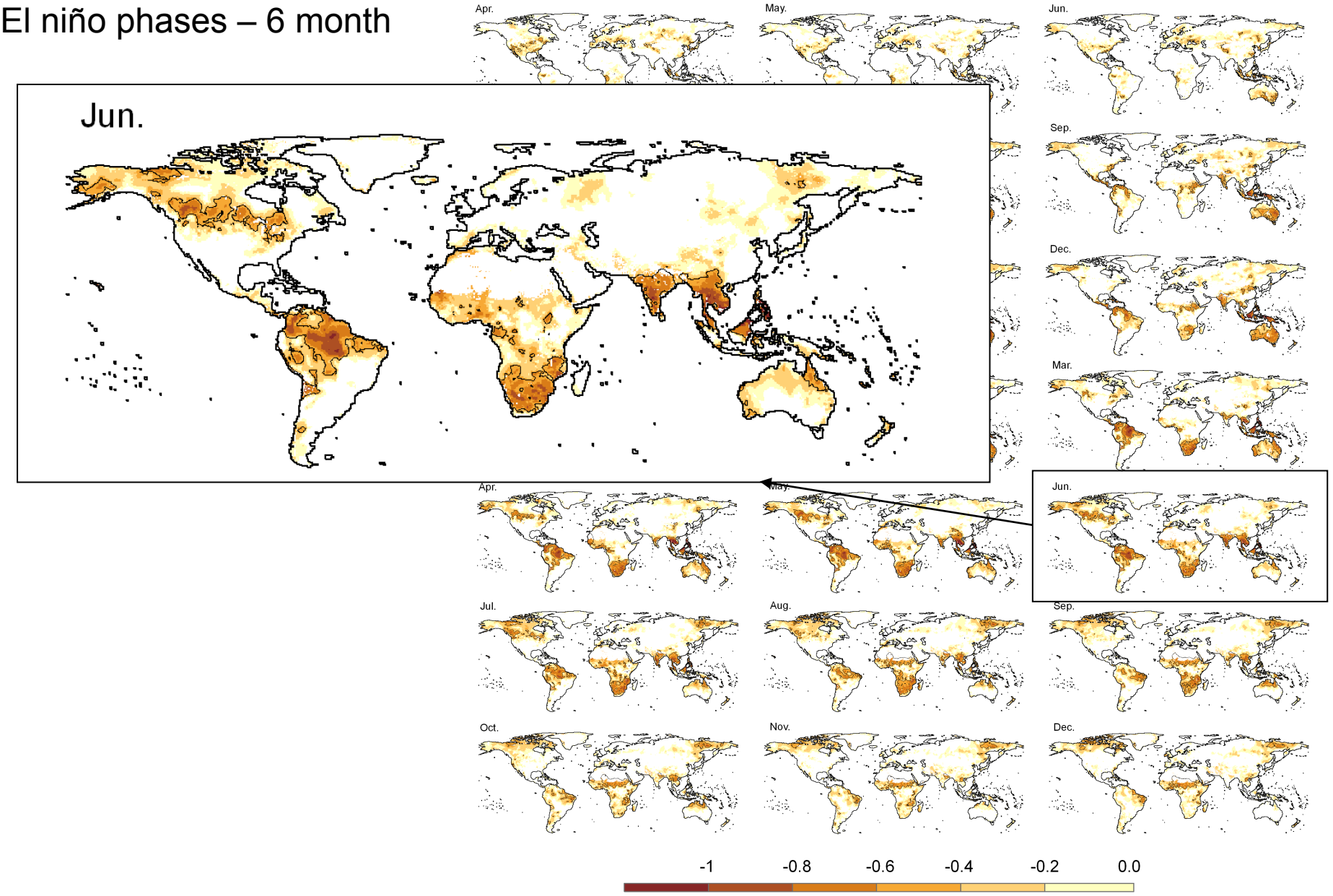
El niño phases – 1 month



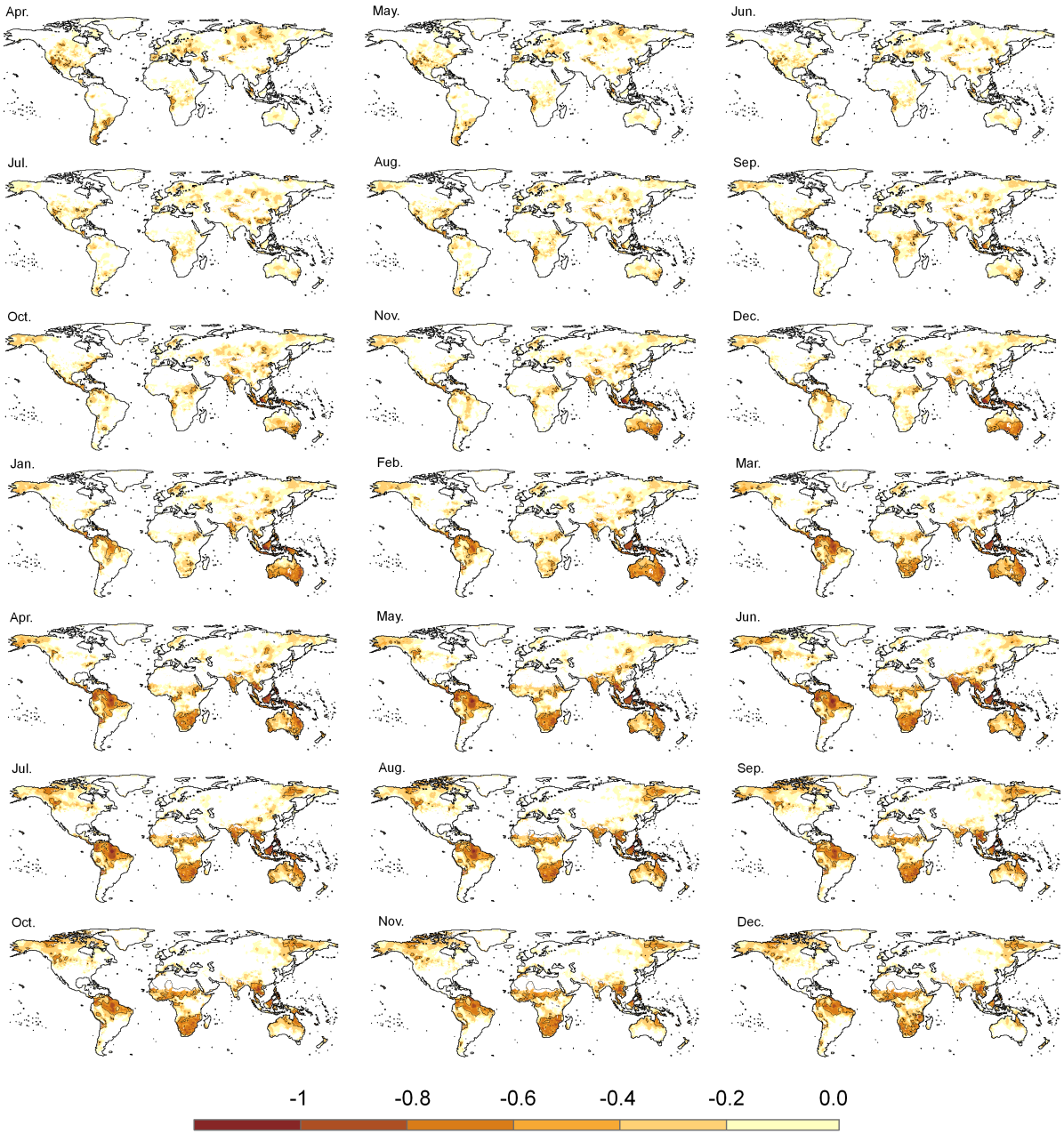
El niño phases – 6 month



El niño phases – 6 month

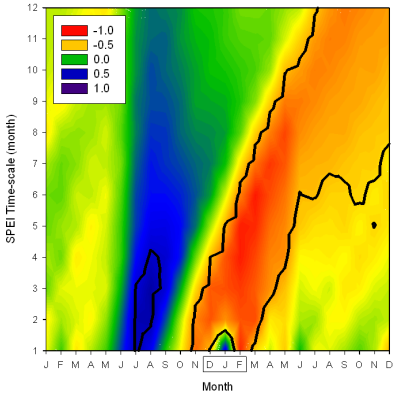


El niño phases – 12 month

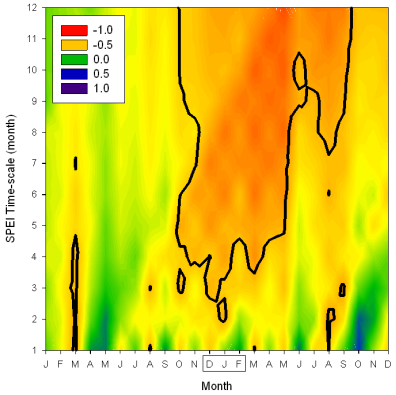


La Niña

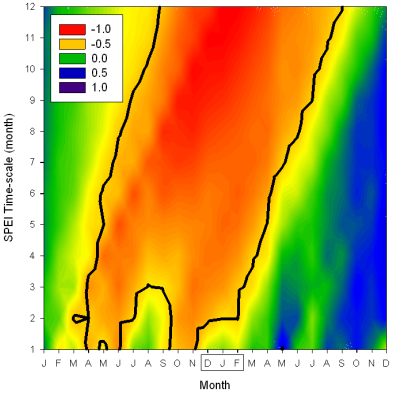
North Mexico (103ºW,27.5ºN)



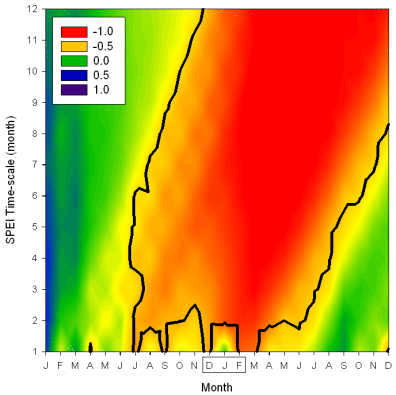
South Russia (80.5ºE,49.5ºN)



East Australia (150.5ºE,31.5ºS)

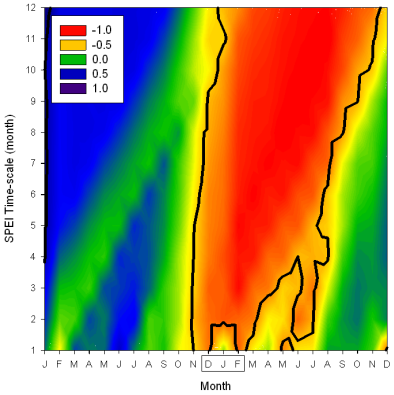


North Brazil (56.8ºW,0ºN)

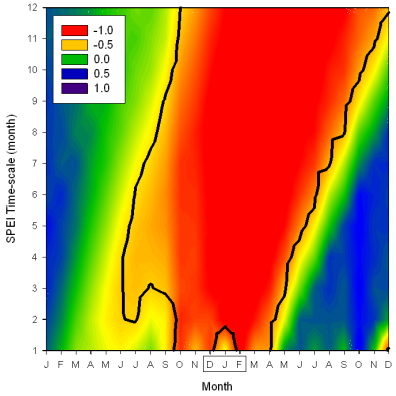


El Niño

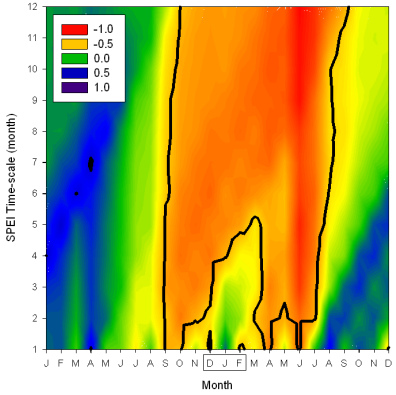
South Africa (29.5ºE,25ºS)



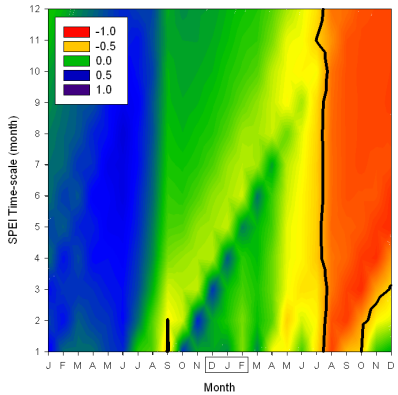
Indonesia (116.5ºE,5ºN)

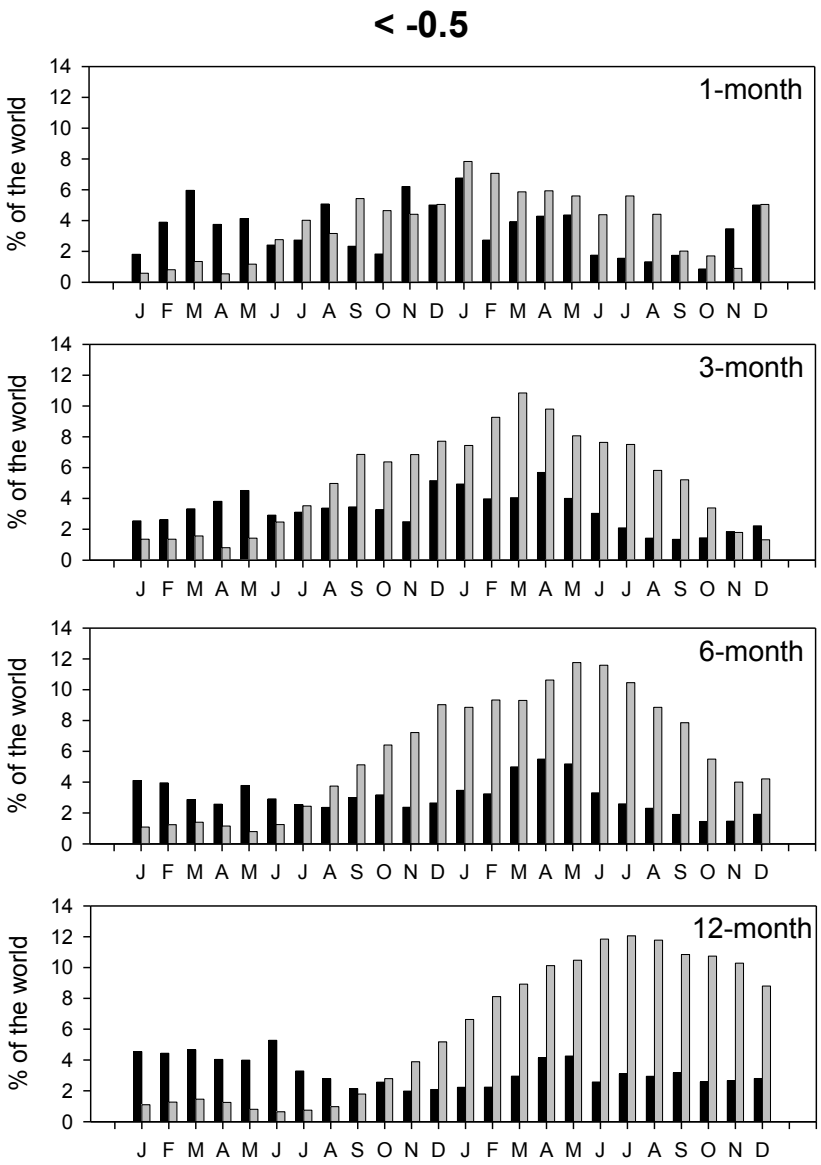


India (76.5ºE,18.5ºN)



Sahel (11ºE,12ºN)

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Conclusions

• The magnitude of the drought conditions recorded in each region shows **large variations as a function of the drought time scale.**

• Thus, the results showed that the period in which **dry conditions** were identified in each affected region **tended to increase** by some months **as the time scale became longer**.

• **At longer time scales** the spatial pattern of negative anomalies was more coherent; **fewer but larger regions were affected**, and the temporal variability in the affected areas and the magnitude of the anomalies was low.

• **Longer time scales emphasized the ENSO effects** and clearly distinguished regions where the expected influence of the ENSO phases was uncertain or statistically significant.

• Number of **regions** that are **markedly affected by drought** at a wide range of time scales:

La Niña phases: southern USA/northern Mexico ,southern Russia/eastern Europe, Argentine

El Niño phases: South Africa, Indonesia and the western Pacific area, Australia, the northern part of South America and the Amazon, India and the Indochina peninsulas, central and western Canada, and large areas of the Sahel.

• **El Niño** events tended to generate **more droughts globally** than La Niña events, and the dry conditions are **more persistent over time**.

• Our results also showed **differences in the timing of the influence of ENSO** events in different regions of the world, independent of the drought time scale.

Conclusions

• **Lags in the impacts of ENSO** events and their propagation to neighboring areas offer a **mechanism for drought prediction** because there is commonly a delay of some months from the onset of ENSO events (typically in April-May of the previous year) to the occurrence of drought.

• The prediction can be even more robust for those **water sources, ecosystems and economic activities related** to **long drought time scales** (e.g. ground water and reservoir storages).

• Given the large temporal lag between the development of ENSO phenomena and the identification of drought conditions in some regions/time-scales, it appears possible to **detect in advance** the likely **impact of the ENSO on drought** in some regions, at time scales comparable to those in this study.