Monitoring of vegetation dynamics and assessing vegetation response to drought in the Iberian Peninsula

F. J. García-Haro[1], A. Moreno[1], A, Perez-Hoyos[1], M.A. Gilabert[1], J. Meliá[1], F. Belda[2], D. Poquet[3], B. Martínez[1], A. Verger[1]

(1) Departament de Física de la Terra i Termodinàmica. Universitat de València. C/Dr. Moliner, 50. 46100 Burjassot, València (España). E-mail: j.garcia.haro@uv.es

(2) Delegación Territorial en Murcia. AEMET, Libertad 11, 30107, Guadalupe, Murcia, Spain

(3) Delegación Territorial en Valencia. AEMET, Botánico Cavanilles 3, 46071 Valencia, Spain

ABSTRACT

Monitoring the vegetation activity over long time-scales is necessary to discern ecosystem responses to climate variability. Spatial and temporally consistent estimates of the biophysical variables such as fractional vegetation cover (FVC) and leaf area index (LAI) have been obtained in the context of DULCINEA Project. We used long-term monthly climate statistics to build simple climatic indices (SPI, moisture index) at different time scales. From these indices, we estimated that the climatic disturbances affected both the growing season and the total amount of vegetation. This implies that the anomaly of vegetation cover is a good indicator of moisture condition and can be an important data source when used for detecting and monitoring drought in the Iberian Peninsula. The impact of climate variability on the vegetation dynamics has shown not to be the same for every region. We concluded that the relationships between vegetation anomaly and moisture availability are significant for the arid and semiarid areas.

Keywords: fractional vegetation cover (FVC); climatic parameters; drought indices; vegetation dynamics

INTRODUCTION

Monitoring the vegetation activity over long time-scales is necessary to discern ecosystem responses to climate variability. The importance of the relationships between water availability and vegetation has been traditionally recognised in Mediterranean and other regions and is a subject of growing interest (Lobo and Maisongrande, 2006). Biophysical variables such as fractional vegetation cover (FVC) and leaf area index (LAI) have proven to be appropriate for modeling terrestrial ecosystems on the global, continental and regional scales. The main objective of the DULCINEA project is to provide coherent estimates of these variables in the Iberian Peninsula. Adapted variants of a probabilistic spectral mixture analysis algorithm (García-Haro et al. 2005), which is currently used operationally in the context of the EUMETSAT/LSA SAF mission, have been used. The considered data set covered a 9-year period (February'2000-January'2009), presenting a 1km spatial resolution over 16-day periods. The potential of derived biophysical variables in the field of drought conditions monitoring has been assessed. The aim is to analyse the vulnerability of natural ecosystems against the effects of climate fluctuations like drought and extreme events in the Iberian Peninsula.

RESULTS

Figure 1 shows several examples of derived FVC maps at different time periods comprising the annual cycle of vegetation. We can observe a strong north-south gradient shift in the timing of greenup onset. This complex spatio-temporal variation comes about not only through climatic variability but also through variations in community composition, soils and land management.

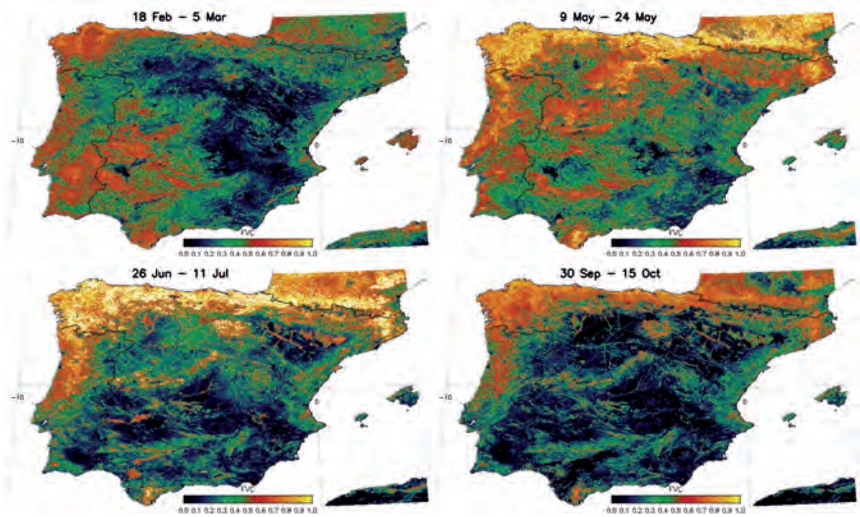
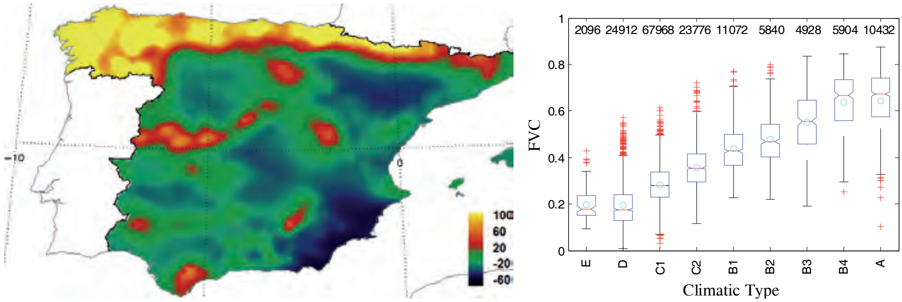


Figure 1. Monthly average (2000–2008) fractional vegetation cover for the Iberian Peninsula at four different time periods.

Monthly climatic maps of precipitation and temperature in Spain were derived during the 1950-2008 period at a 2-km spatial resolution using Geostatistical approaches for interpolation (García-Haro et al. 2008). The climatic data used in the study were obtained from the AEMET (*Agencia Estatal de Meteorología*) and correspond to between 2500 and 4800 (depending on the period) recording stations distributed over Spain. We calculated potential evapotranspiration (PET) from the monthly temperature maps according to Thornwaite (Thornwaite and Mather, 1957). The Thornthwaite moisture index was computed using the difference between monthly precipitation and evapotranspiration (P-PET) (see figure 2a). This index reflects the portion of total precipitation used to nourish vegetation over a certain area. A five-category classification for the moisture index: A, very humid (≥ 100); B, humid (20 to 100); C, subhumid (-20 to 20); D: semiarid (-40 to -20); E, arid (≤-40). A strong linear trend was observed between the values of mean fractional vegetation cover and moisture index (figure 2b), evidencing the importance of the relationships between water availability and vegetation coverage in Spain.



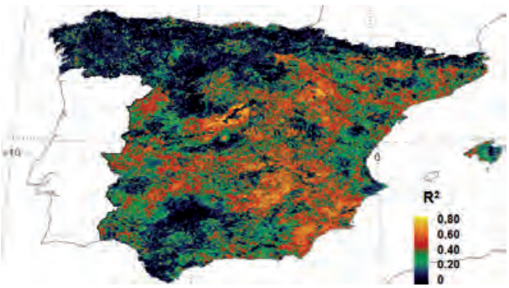
(a) (b)

Figure 2. (a) Average values (1950-2007) of moisture index corresponding to a 59 year (1950-2008) period (b) Boxplots of mean fractional vegetation cover for the main moisture regions in Spain. The upper and lower edges of the box plot are placed at the first and third quartile.

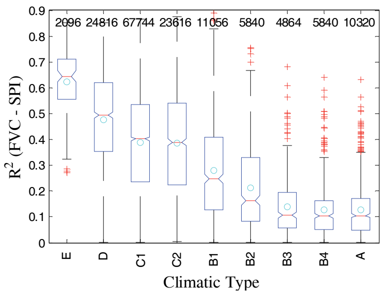
Both the soil moisture conditions and the vegetation activity respond to precipitation anomalies on a relatively short scale (Ji and Peters, 2003). The Standard Precipitation Index (SPI) was selected because of its flexibility to measure drought at different time scales (McKee et al 1993). Since the impact of water deficits on vegetation is cumulative, cero to six months of preceding rainfall amounts were used for linking drought severity and duration with the vegetation cover.

A regression model with seasonal dummy variables was used to build relationships between the FVC and SPI at different time scales. When monitoring the vulnerability of natural ecosystems against drought conditions, both the seasonal timing and the time lag in the vegetation response to precipitation were taken into consideration. In general, the 3-month SPI lagged 1 month was found to have the best correlation, indicating lag and cumulative effects of precipitation on vegetation. Different temporal windows covering a 4 month period were considered. A stepwise multiple regression was applied to determine a minimum number of regressors which explained the largest amount of variation in the anomaly of FVC. At each step, the p-value of an F-statistic is computed and the variable with maximum p-value (higher than 0.05) was removed from the model. The regression model contains 8 different coefficients assigned to the 4 intercepts and 4 slopes of the linear relationship for the considered months. In most of the area the 4 intercepts were no significant ($p>0.05$). This suggests that irrespectively of the month the signs of both SPI and anomaly of FVC are equal (both positive or negative). In general, the number of slope coefficients selected by the stepwise multiple regression model was small (1-2), revealing a moderate temporal variability in the causality.

Figure 3a shows the spatial distribution of the determination coefficient (R^2) between SPI-3 and anomaly of FVC. It is represented the April-July period, which covers the growing season in most of the area. Statistically significant correlations have been found between SPI and satellite-derived anomalies of vegetation activity, although they are highly dependent on the regional climate and vegetation community. Such influences are further documented in Figure 3b, which reveals a negative linear trend of R^2 against moisture index level. The most important correlations (R^2=0.4-0.7) were found in the arid and semiarid areas. This reveals the notorious impact of water availability on vegetation activity for the summer period in these environments. By contrast, rain has a low impact on summer vegetation activity over humid regions, presenting moderate to weak correlations.



(a)



(b)

Figure 3. (a) Determination coefficient (R^2) of the regression model with seasonal dummy variables between 3-month SPI lagged one month and anomaly of fractional vegetation cover (FVC) estimates. It is represented the period from April to July over a nine-year (2000-2008) period. (b) Boxplots of mean FVC (a) and coefficient of variation between SPI and FVC during the same period for the main moisture regions. The upper and lower edges of the box plot are placed at the first and third quartile.

CONCLUSIONS

Ecological and climate models require high-quality biophysical parameters as input. Time series of remotely-sensed vegetation products derived in the context of DULCINEA have provided spatial and temporally consistent parameters such FVC and LAI in the Iberian Peninsula. These datasets offer a means for obtaining direct indicators of vegetation biomass, structure and condition from a regional to global scale. We used long-term monthly climate statistics to build simple climatic indices (SPI, water stress) at different time scales. The spatial and temporal dynamics of satellite-derived vegetation products and climatic indices enabled spatially explicit comparisons of vegetation condition in response to precipitation.

FVC has shown meaningful relationships with inter-annual climate variability. Significant positive correlations have been found between anomalies of the vegetation cover and water drought indices which employ cumulative rainfall summed over the preceding months. This implies that the anomaly of vegetation cover is a good indicator of moisture condition and can be an important data source when used for detecting and monitoring drought in the Iberian Peninsula. This is not only because of the perceived response to drought, but also because vegetation is a relatively complete integrator of the physical variables that are affected by climatic conditions. Although the climatic disturbances affect both the growing season and the total amount of vegetation, these relationships are highly dependent on the regional climate and vegetation community. In general, they are more significant in arid and semiarid areas, since water availability most strongly limits vegetation growth in these environments.

ACKNOWLEDGMENTS

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