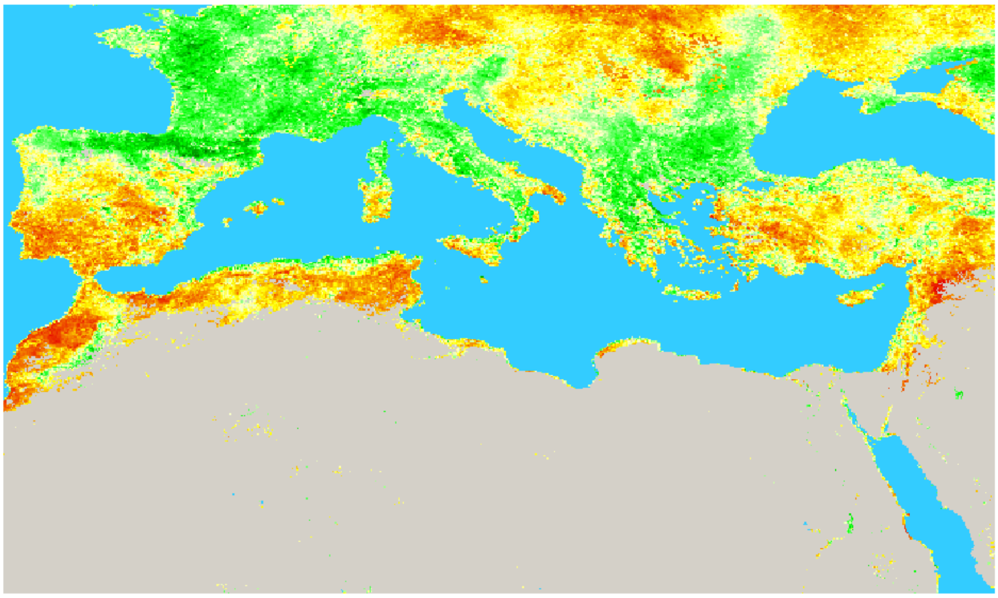
Scientific Report ESF - Exchange Grant 2009



Ref. Exchange Grant No: 2358
Activity Title: Identification of drought vulnerability in the Mediterranean using satellite derived vegetation indices.
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IDENTIFICATION OF DROUGHT VULNERABILITY IN THE MEDITERRANEAN USING SATELLITE DERIVED VEGETATION INDICES.

1) Introduction

Currently the determination of the ecological, agricultural and environmental impacts of climatic change in the Mediterranean region is considered to be a scientific priority. This results because future scenarios point towards an important decrease in the availability of water resources, as a consequence of the precipitation decrease and temperature rise (Giorgi and Lionello, 2008). Thus, indicating a potential increase of drought risk in the Mediterranean basin, with increase frequency of drought events and also of their magnitude. In the Mediterranean region, drought periods can result in significant losses to crop yields (Austin et al., 1998), and additionally, increasing the risk of forest fires (Pausas, 2004), forest decline (Martínez-Villalta et al., 2008) and triggering processes of land degradation and desertification (Schlesinger et al., 1990). In the present context of climate change and increasing land degradation and desertification, the evaluation of drought impacts is crucial in determining the environmental consequences of a hypothetical change in climatic conditions.

Several studies have analysed the impacts of droughts on ecosystem and agricultural dynamic in different areas of the Mediterranean region considering crop production yields, tree ring analysis, remote sensing and biophysiological models. However, there are no studies that cover the complete basin, integrating different cover types, ecosystems and geographic and bioclimatic conditions to assess the vulnerability of each area to climate droughts. In the last decade a number of studies were undertaken with the aim of developing new indices particularly suited for drought analyses, quantification and monitoring (see the reviews in Heim, 2002 and Keyantash and Dracup, 2002). Recently, Vicente-Serrano et al. (2009) has proposed a new climatic drought index: the Standardized Precipitation Evapotranspiration Index (SPEI). The SPEI is based on the simultaneous use of precipitation and temperature fields, and has the advantage of combining a multi-scalar character. This ability can be crucial to determine the impacts of droughts since the response of vegetation may be very different to different time scales) with the capacity to include the effects of temperature variability on drought assessment. In order to monitor the agricultural and environmental impact of droughts, drought indices that are using evapotranspiration data seems to have better results than precipitation-only drought indices (Naramsimhan and Srinivasan, 2005).

Remote sensing data allows to analyse vegetation activity and to estimate different biophysical parameters such as the area index, the vegetation biomass, the net primary production, photosynthetic activity etc. Given the spectral properties of vegetation, vegetation indices can be calculated and used to analyse vegetation dynamics and climate impacts. A number of studies have used remote sensing datasets to analyse changes in ecosystems (e.g., Myneni et al., 1997) and to determine the impact of droughts (Kogan, 1997; Vicente-Serrano, 2007; Gouveia et al., 2009).

In this work we have analysed in detail the drought impacts on Mediterranean vegetation over the last three decades, using means of remote sensing data with the purpose of determining the most vulnerable areas and biomes. A database (for the larger Mediterranean region) of drought impacts on vegetation activity was created, containing an evaluation of the vulnerability of each sector to drought and the hazard thresholds and time scales most suitable to monitor drought impacts according to the climate drought indices used. The combined (and independent) effect of precipitation and temperature on vegetation greenness will be assessed statistically quantifying the relationship between the monthly anomalies of the most widely used vegetation index: the normalized Difference Vegetation Index (NDVI) and two multi-scalar drought indices: the SPI and the SPEI.

2) Data and Methodology

Drought corresponds to a severe chronic problem for several countries located around the Mediterranean basin. This problem has worsened in recent decades as a result of growth in population and the corresponding increment on water necessities. In addition, a slight downward trend has been found in the annual precipitation over the Mediterranean basin. Despite the spatial variability, the decrease is more pronounced in the southern Mediterranean, while the north is more concentrated in the winter season. One might expect sharp contrasts in the influence of the climate droughts on vegetation given the climate diversity and the variability of ecological and geographical region.

Moreover the impact of droughts is ought to be seasonal dependent and also be different as a function of distinct temporal scales used to compute drought indices.

The NDVI monthly anomalies, with 8 km of spatial resolution, will be obtained from the Global Inventory Modeling and Mapping Studies (GIMMS) dataset. This dataset holds 24 values per year (i.e. twice a month) and corresponds to the most complete and longest remote sensing dataset covering the entire Mediterranean region, for the period 1982 - 2006. We have applied a temporal filter that avoids the residual noise allowing to obtain smooth anomalies, that are than monthly standardized NDVI anomalies.

The two multiscalar drought indices, SPI and SPEI (derived at *Instituto Pirenaico of Ecologia, IPE*) were computed at the monthly scale, between 1982 and 2006, using the database of the Climatic Research Unit (CRU) with a spatial resolution of 0.5 º. The monthly data of the latest version of the database (CRU TS 3.0) are covering the period between 1901 and 2006, coinciding with the database GIMMS during the period 1982-2006. The computation of the indices was made based on algorithms and computer codes developed and implemented at IPE (http://digital. csic.es/handle/10261/10002 , http://digital.csic.es/handle/ 10261/10006). The time scales used here range between 1 and 48 months in order to verify the response of vegetation to water deficit of different duration. The computation is performed in the period 1901-2006 to ensure the soundness of the indicators. Finally, the indices of drought were interpolated to the resolution of the images GIMMS, for the period 1982-2006.

With the aim of identifying the regions and seasons most affected by climatic droughts we have computed monthly spatial distribution of correlations maps between monthly anomalies of NDVI vs. SPI and NDVI vs. SPEI. This analysis was performed using different temporal scales in order to understand if the impact is higher when we have considered the pluviometric (SPI) or the termopluviometric index (SPEI), as well as to quantify the response of vegetation (usage of different temporal scales of the indices). Vulnerability maps have been obtained, with the indication of the season/month and the temporal scales of the drought index of higher vulnerability for each pixel. The usefulness of each index, SPEI or SPI (or both), has also been assessed.

3) Results

A large amount of time was spent to filter the NDVI dataset, followed by the post-processing of drought indices databases towards the resolution of vegetation index database (8 km). Similarly, a considerable amount of time was spent computing the monthly grid point correlations, using 18 distinct temporal scales, ranging from 1 to 48 months (1 to 12, 15, 18, 24, 30, 36, 48 months) for both drought indices (SPEI and SPI).

The database with the figures of all spatial patterns of the impacts of drought on vegetation dynamics will be soon available at http://www.igidl.ul.pt/cgouveia.html.

Figures 1 and 2 present the spatial distribution of correlation values of NDVI vs. SPI (left panel) and NDVI vs. SPEI (right panel) for April, using a time scale of 3 months (Figure 1) and for July, using a time scale of 8 months. All pixels without vegetation or with irrigated crops (coded respectively as desert, urban and irrigated crops using the GLOBCOVER classification) were masked and are represented in gray in the following figures.

The correlation patterns of NDVI vs. SPEI seem to be more intense and have higher spatial homogeneity (e.g. south of Iberia in April and north of Black Sea in July). It may be noted the positive higher positive correlation NDVI vs. SPEI and NDVI vs. SPI for July in almost all Mediterranean area and the most restricted patterns in April (in southern Iberia, Northern Africa and Eastern Mediterranean).

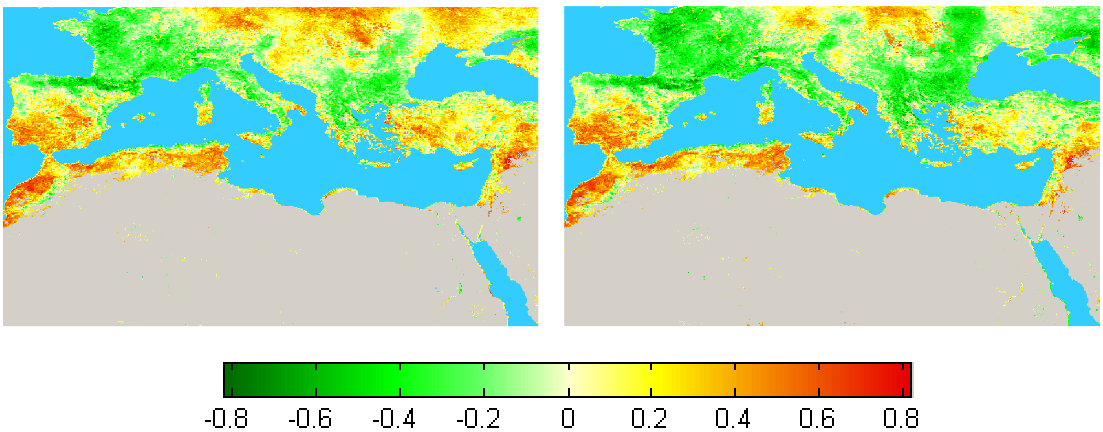

Figure 1. Spatial distribution of correlation values between NDVI vs. SPI (left panel) and NDVI vs. SPEI (right panel) for April, using a temporal scale of 3 months.

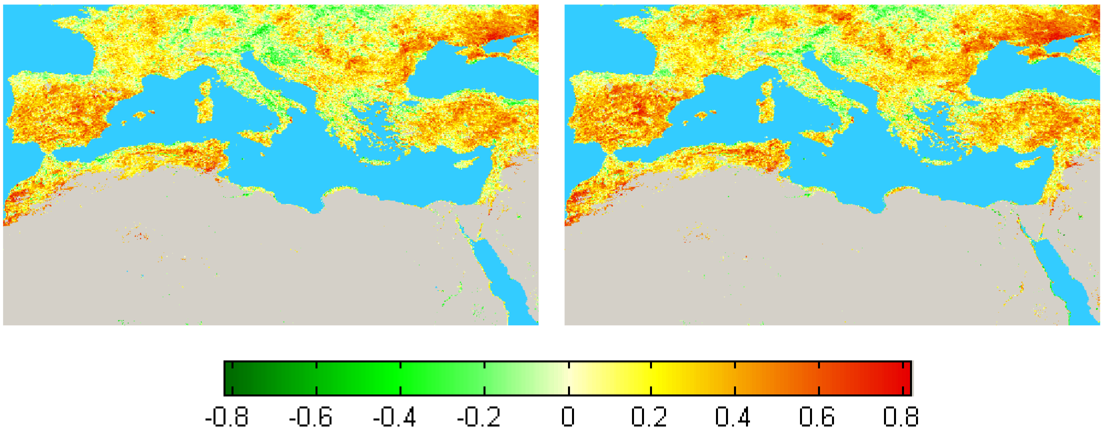

Figure 2. Spatial distribution of correlation values between NDVI vs. SPI (left panel) and NDVI vs. SPEI (right panel) for July, using a temporal scale of 8 months.

In order to identify the time scales most suitable to monitor drought impacts according to the climate drought indices used, the time scales of higher seasonal correlation for each pair NDVI vs. SPEI and NDVI vs. SPI were selected for each pixel in the whole Mediterranean region. Afterwards the average of the normalised SPEI, SPI and NDVI were plotted (Figures 3 and 4) for February (upper left panel), May (upper right panel), August (lower left panel) and November (lower right panel). The time scales and the values of correlation are presented in Tables 1 and 2.

The time scale of 9 months is the one that reveals the highest (negative) correlation with NDVI, during November for both indices, presenting higher negative values for SPEI (-0.43). On the other hand, the remaining considered months (February, May and August) the time scale most suitable to monitor drought impacts is 3 months for both indices. However we should stress that the correlation NDVI vs. SPEI and NDVI vs. SPI is negative for February and May and positive for August for both indices, but presenting higher correlation values with SPEI.

The spatial distributions of seasonal composites of correlations were computed for both indices, using the maximum of correlation for the usual monthly definitions:

- Winter (DJF) – December, January and February
- Spring (MAM) – March, April, May
- Summer (JJA) – June, July and August
- Autumn (SON) – September, October and November

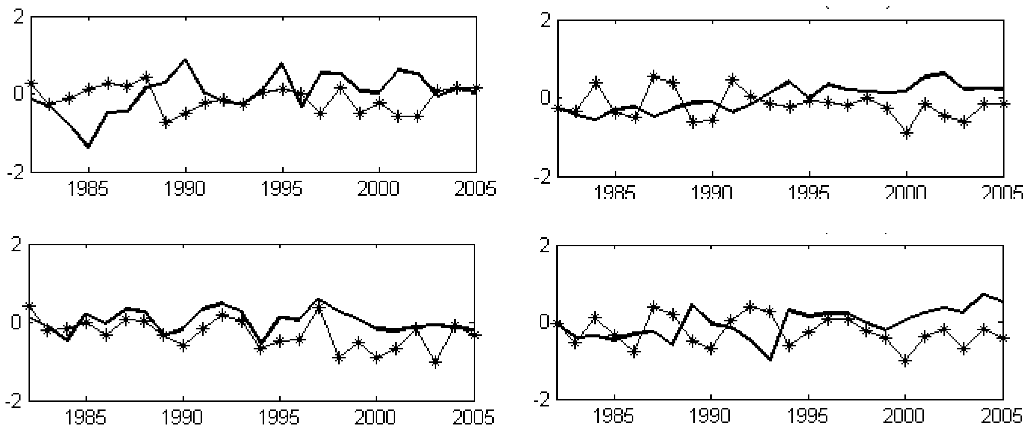

Figure 3 Temporal evolution of NDVI (solid line) and SPEI (line with stars) for the average of the pixels over the Mediterranean region, for the time scale that presented higher NDVI vs. SPEI correlation.

Table 1. Time scales and correlation values that present the best correlation NDVI vs. SPEI for the average of the pixels over Mediterranean region.

NDVI vs. SPEI	*Feb*	*May*	*Aug*	*Nov*
Time Scale	*03*	*03*	*03*	*09*
Correlation	*-0.39*	*-0.40*	*0.52*	*-0.43*

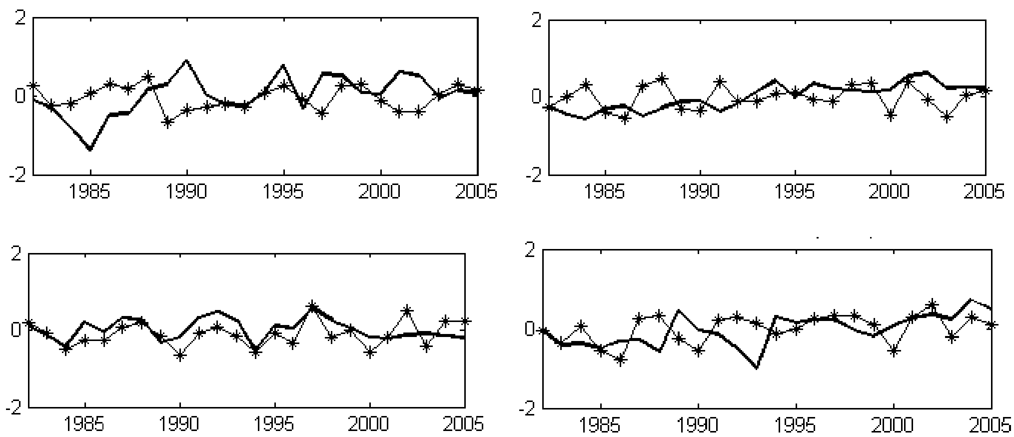

Figure 4 As in Figure for, but respecting to NDVI (solid line) and SPI (line with stars) indices.

Table 2. As in table 1, but respecting to correlation NDVI vs. SPI.

NDVI vs. SPI	*Feb*	*May*	*Aug*	*Nov*
Time Scale	*03*	*03*	*03*	*09*
Correlation	*-0.19*	*-0.03*	*0.50*	*16*

Figure 5 presents the spatial distributions of seasonal composites of correlations for NDVI vs. SPEI relative to DJF (upper left panel), MAM (upper right panel), JJA (bottom left panel) and SON (bottom right panel). These maps represent the maximum correlation value obtained at each grid-point within the seasonal window considered, some of the grid points shown for winter (upper left) are relative to correlation values obtained for January, while others correspond to either February or December. The maximum positive correlations in the order of 0.80 can be seen spread over all Mediterranean region during summer, while such high values are restricted to north of Africa, Iberian Peninsula and eastern Mediterranean countries during winter. In autumn the most affected areas are located north and west of the Black sea while during spring these are confined to the African shore in western Mediterranean.

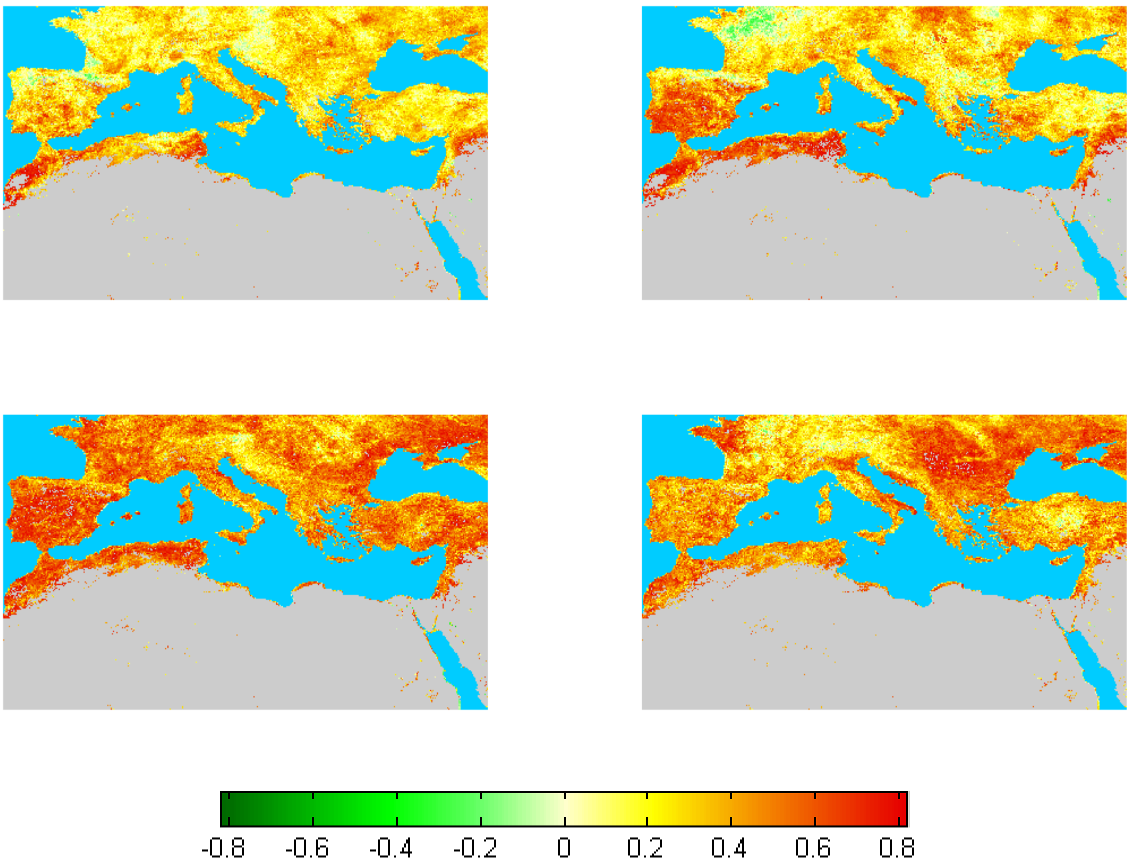

Figure 5 Spatial distribution of seasonal composites of correlations NDVI vs. SPEI computed using the maximum of correlation for DJF (upper left panel), MAM (upper right panel), JJA (bottom left panel) and SON (bottom right panel).

Figure 6 and 7 present respectively the spatial distributions of the time scale of the drought index SPEI and the month corresponding to the maximum correlation NDVI vs. SPEI, for DJF (upper left panel), MAM (upper right panel), JJA (bottom left panel) and SON (bottom right panel). The low time scales (1 to 6 months) are the most frequent in the Mediterranean region for all seasons, with exception of northeastern Iberia in winter and fall, for North of Black Sea in spring and the countries in the North of Aegean Sea for all seasons. However the last case presents higher time scales (12 to 24 months) in winter and autumn. It may be noted that in winter the month that presents higher correlation is February, with exception for Northwest of Black Sea that is December. In spring the most frequent month is May, in summer June and July and in Autumn September.

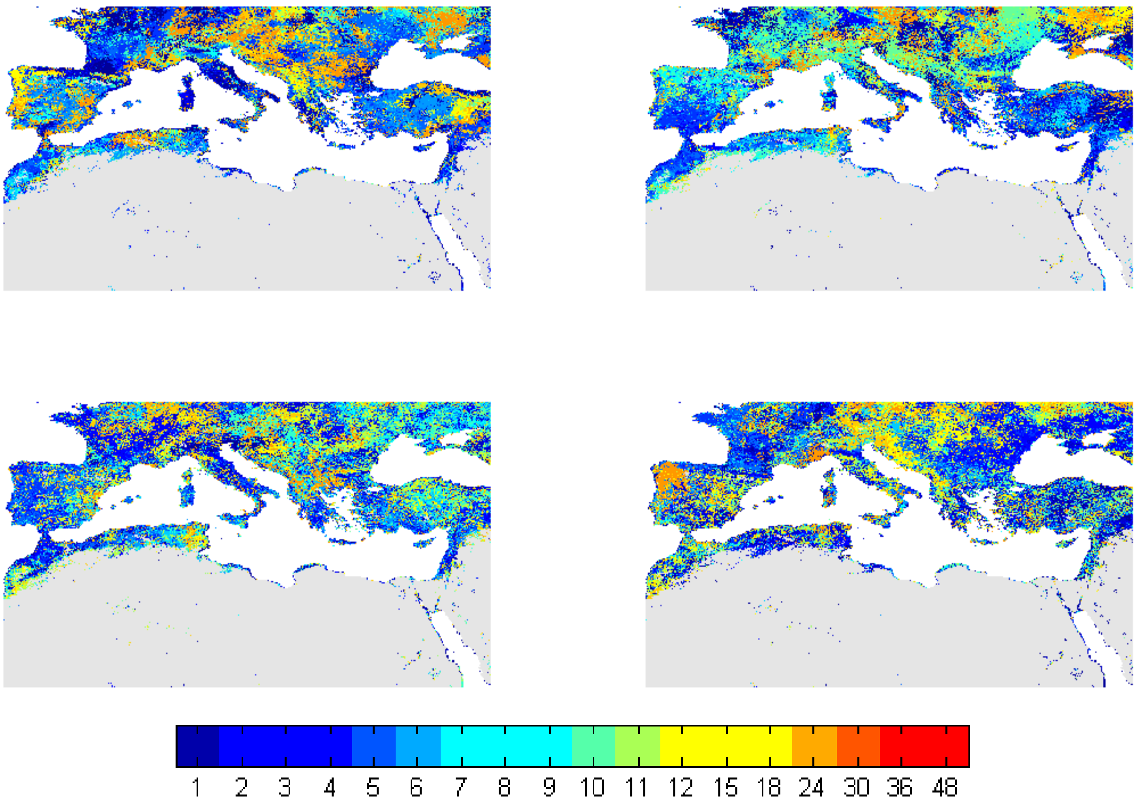

Figure 6. As in Figure 5, but respecting to the time scale of the drought index SPEI corresponding to the maximum correlation NDVI vs. SPEI.

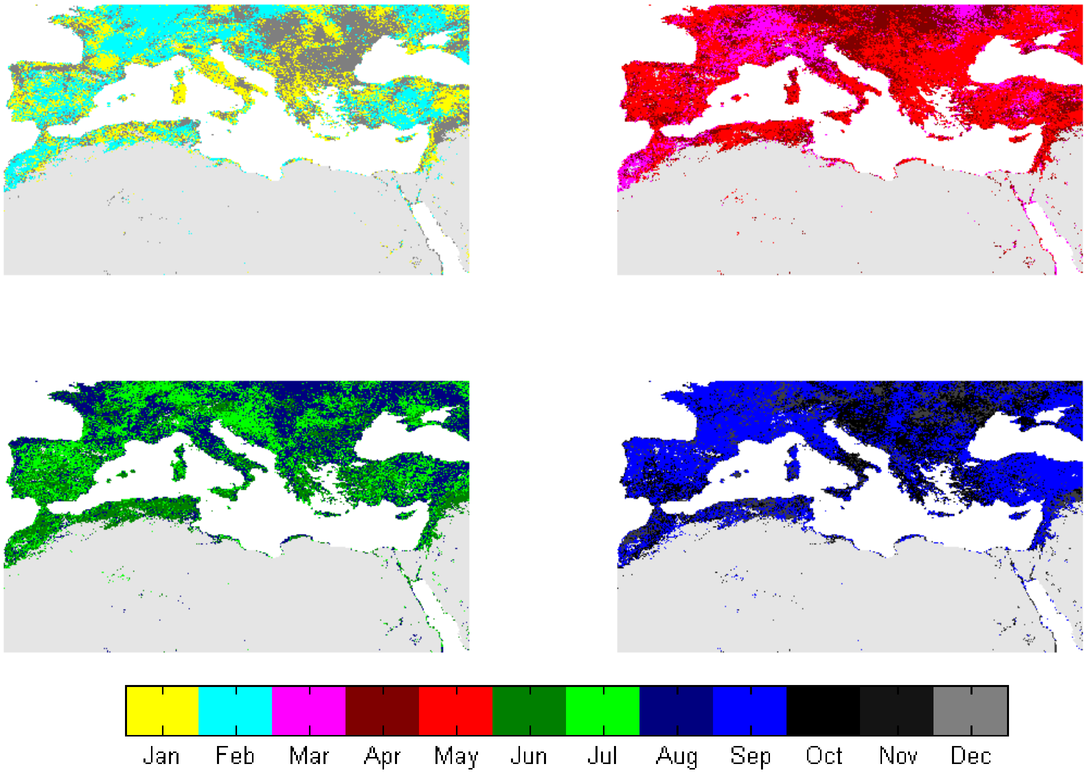

Figure 7. As in Figure 5, but respecting to the month corresponding to the maximum correlation NDVI vs. SPEI.

4) Future Collaboration with the host Institute

As expected, the 9 weeks spent at IPE were a relatively short time-frame to finish the entire project. Nevertheless, a large amount of work was carried out at the host institution and additional work is currently being developed in Lisbon. In fact, the preliminary results obtained in Zaragoza and presented here are currently being analyzed with more detail. The next steps of this project include an analysis of results, as a function of the vegetation type, regionalization of bio-climate and topography, major Mediterranean biomes and geographical conditions.

It should be emphasize that these results will constitute the basis of two scientific papers, currently in preparation, that will be submitted to appropriate international journals within the next 6 months, in order to disseminate the results more prominent. Therefore the collaboration between University of Lisbon and *Instituto Pirenaico of Ecologia* will therefore continue, first for finishing the articles, and thereafter also for future collaboration within this topic, potentially investigating in more detail some aspects not assessed in the first stage of this study.

5) References

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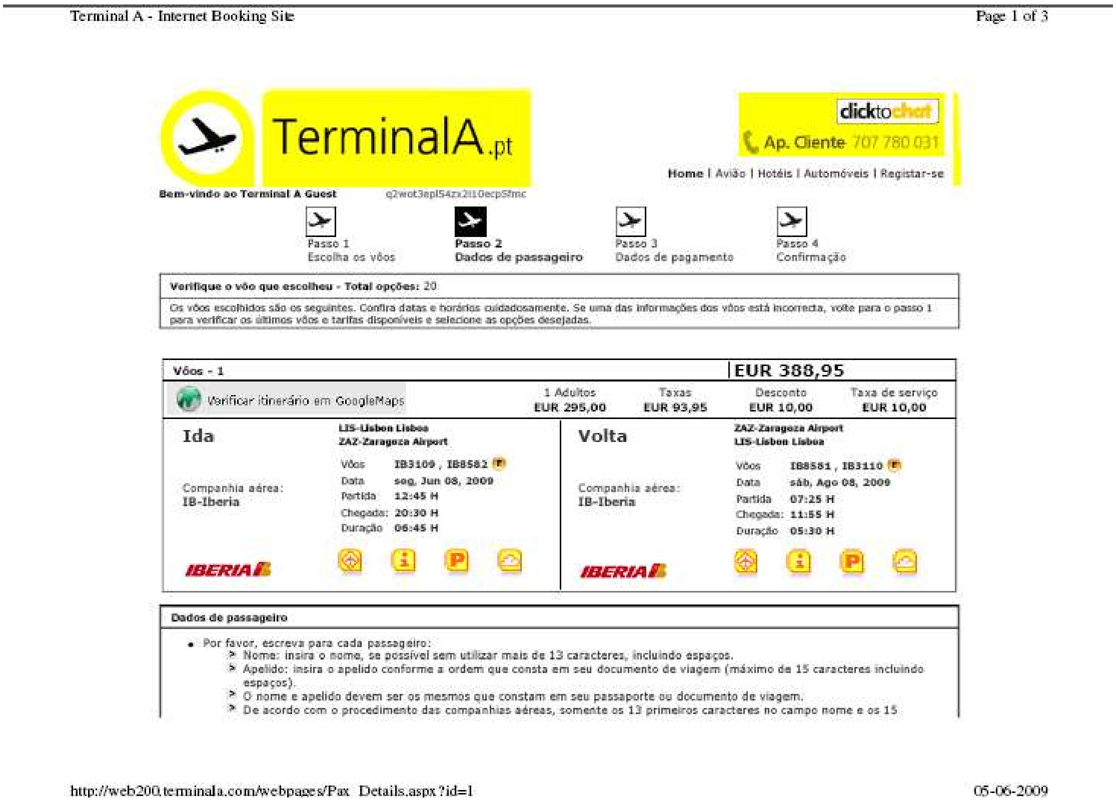
6) Travel Costs

The travel was by car Lisbon to Zaragoza and Zaragoza to Lisbon.

An indication of the rate of a cheap flight is provided in Terminal A (see the doc bellow) with the value of 388.95 €



Terminal A - Internet Booking Site   Page 1 of 3

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Passo 1 Escolha os vôos | Passo 2 Dados de passageiro | Passo 3 Dados de pagamento | Passo 4 Confirmação

Verifique o vôo que escolheu - Total opções: 20

Os vôos escolhidos são os seguintes. Confira datas e horários cuidadosamente. Se uma das informações dos vôos está incorrecta, volte para o passo 1 para verificar os últimos vôos e tarifas disponíveis e selecione as opções desejadas.

Vôos - 1   **EUR 388,95**

Verificar itinerário em GoogleMaps

1 Adultos	Taxas	Desconto	Taxa de serviço
EUR 295,00	EUR 93,95	EUR 10,00	EUR 10,00

Ida

Companhia aérea: IB-Iberia

LIS-Lisbon Lisboa
ZAZ-Zaragoza Airport

Vôos	IB3109 , IB8582
Data	seg, Jun 08, 2009
Partida	12:45 H
Chegada:	20:30 H
Duração	06:45 H

Volta

Companhia aérea: IB-Iberia

ZAZ-Zaragoza Airport
LIS-Lisbon Lisboa

Vôos	IB8581 , IB3110
Data	sáb, Ago 08, 2009
Partida	07:25 H
Chegada:	11:55 H
Duração	05:30 H

Dados de passageiro

- Por favor, escreva para cada passageiro:
  - Nome: insira o nome, se possível sem utilizar mais de 13 caracteres, incluindo espaços.
  - Apelido: insira o apelido conforme a ordem que consta em seu documento de viagem (máximo de 15 caracteres incluindo espaços).
  - O nome e apelido devem ser os mesmos que constam em seu passaporte ou documento de viagem.
  - De acordo com o procedimento das companhias aéreas, somente os 13 primeiros caracteres no campo nome e os 15

http://web200.terminala.com/webpages/Pax Details.aspx?id=1   05-06-2009