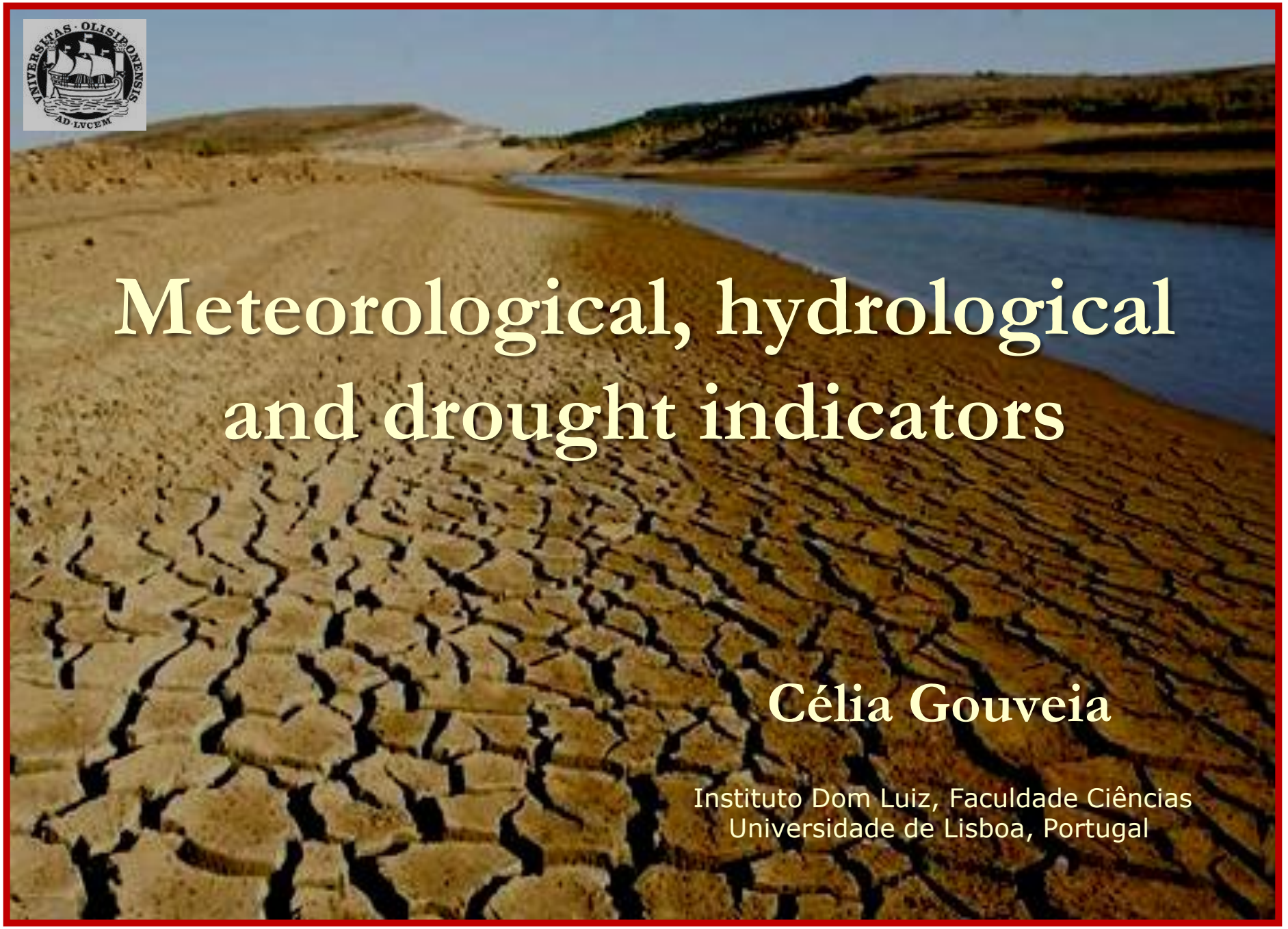
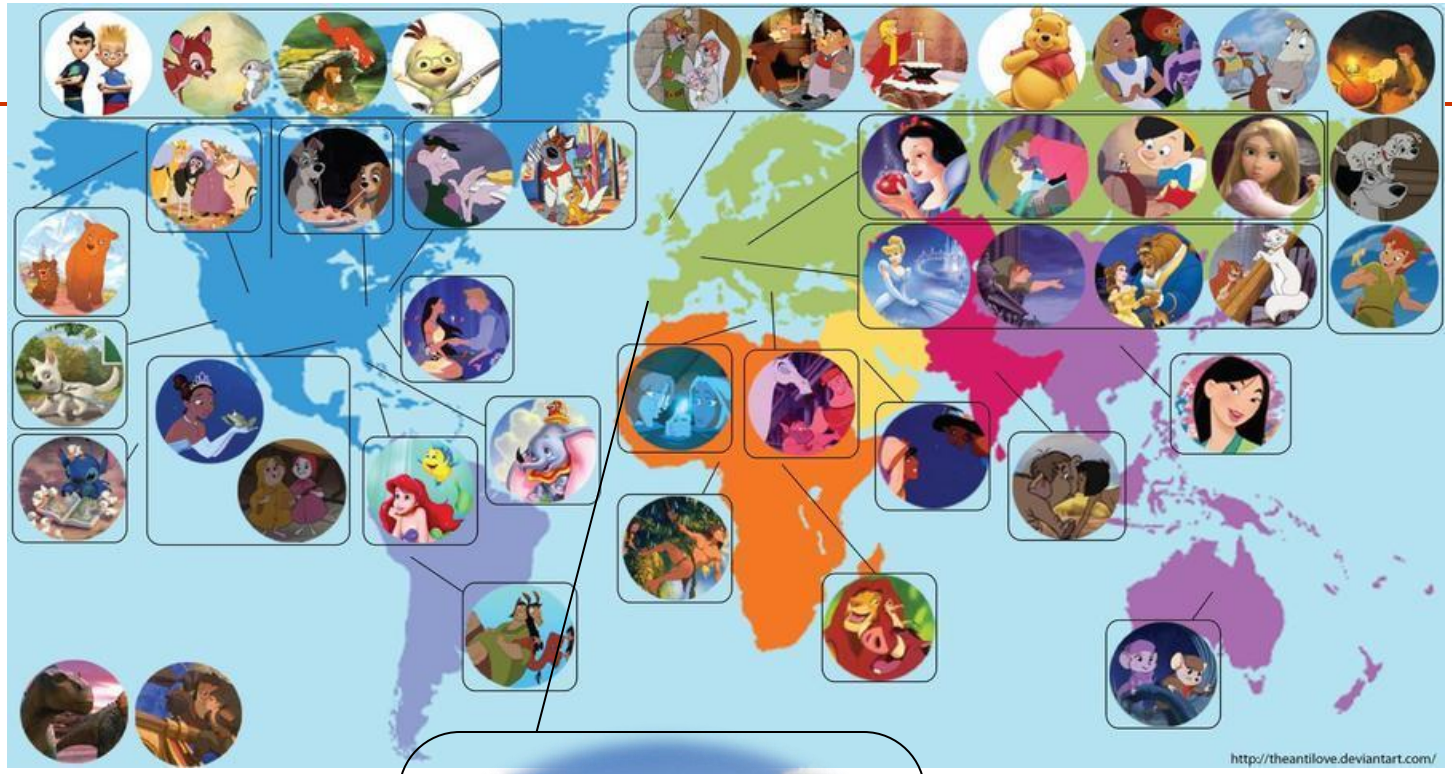


Meteorological, hydrological and drought indicators

Célia Gouveia

Instituto Dom Luiz, Faculdade Ciências
Universidade de Lisboa, Portugal



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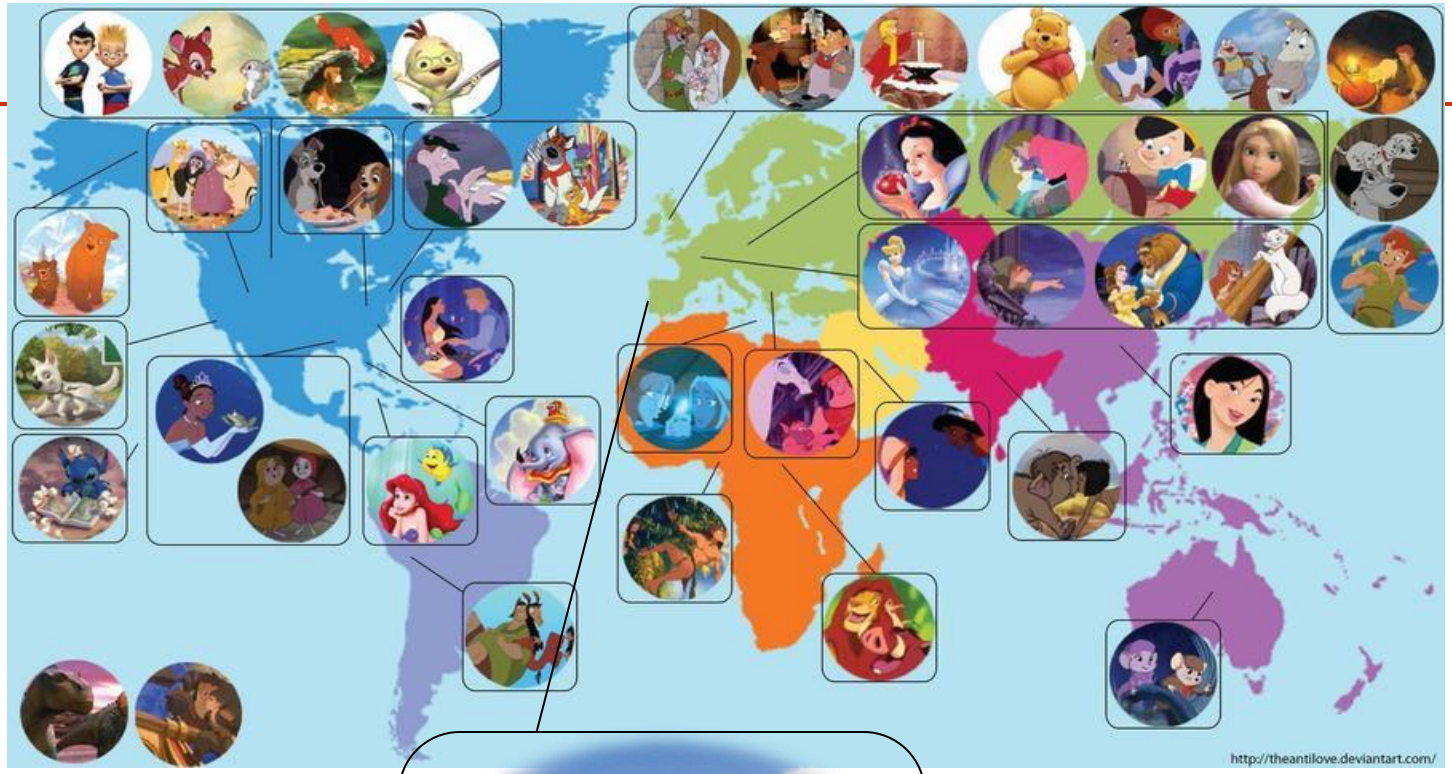
Instituto Dom Luiz, Faculdade Ciências Universidade de Lisboa, Portugal



and you?

Célia Gouveia

Instituto Dom Luiz, Faculdade Ciências Universidade de Lisboa, Portugal

Outline

- Drought Complexity
- Drought impacts
- Drought Assessment
  - Vegetation Indices
  - Drought indicators: PDSI
  - Drought indicators: SPI
  - Drought indicators: SPEI
- Drought severity and warming
- Drought impacts on vegetation dynamics

Drought Complexity

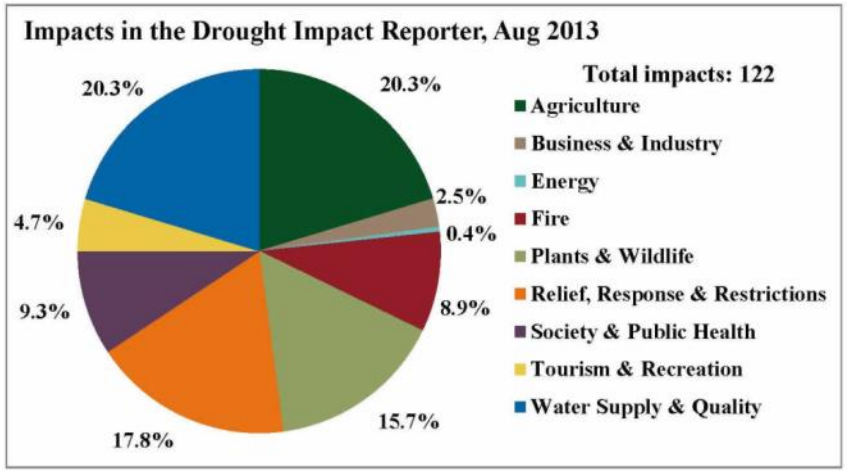
Drought is challenging to identify over space and time.

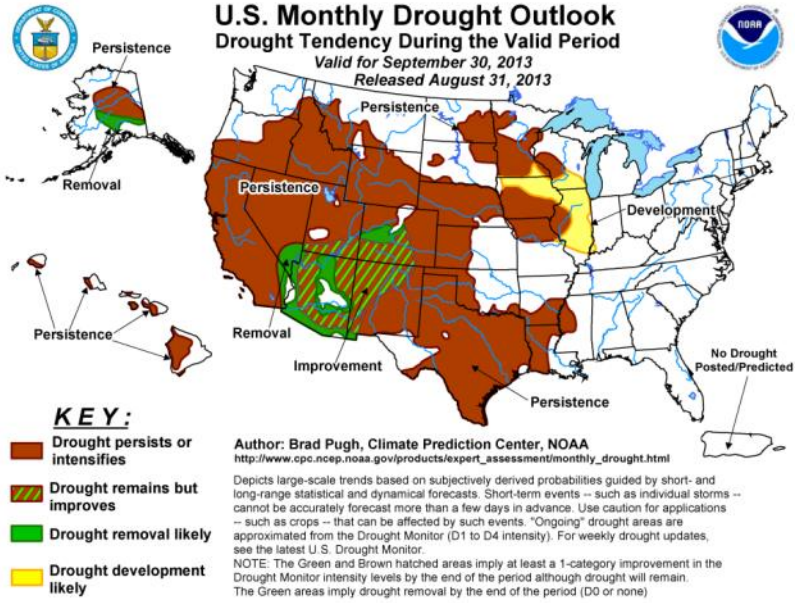
Quantification of droughts include intensity, magnitude, duration and surface extent.

This quantification is an hard job!

There is no a variable that we can use to measure drought.

Droughts are identified by means of impacts.





Drought Impacts

Drought is the most damaging meteorological hazard affecting large areas.

Droughts also cause several environmental impacts: forest decline, forest fires, soil degradation, wetland degradation, desertification.





Drought Impacts

However, unlike other natural disasters, such as earthquakes, droughts can be 'predictable.

This makes it more easy to respond to droughts as they occur.

Thus, **assessing and monitoring droughts** become of crucial importance.

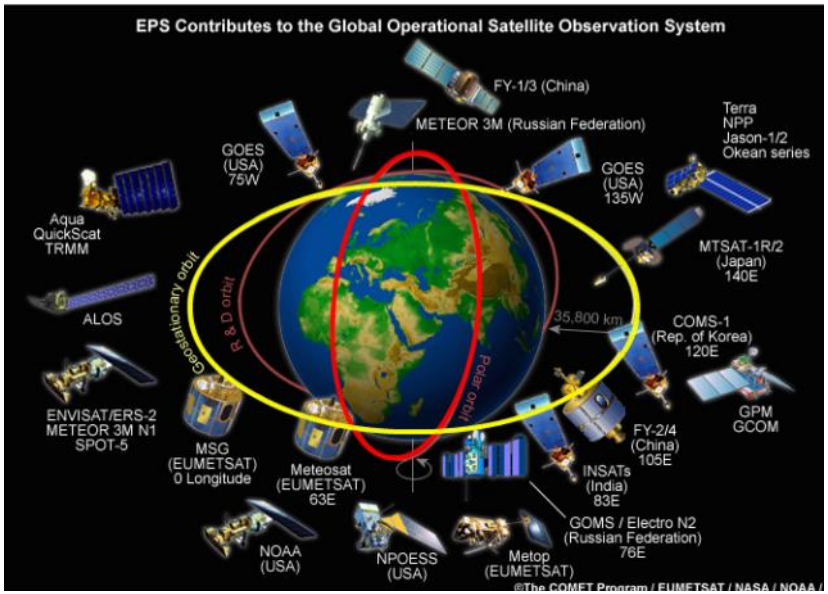
Drought Assessment

Traditional methods of drought assessment and monitoring rely on rainfall data as recorded in meteorological and hydrological networks.

Drought Assessment

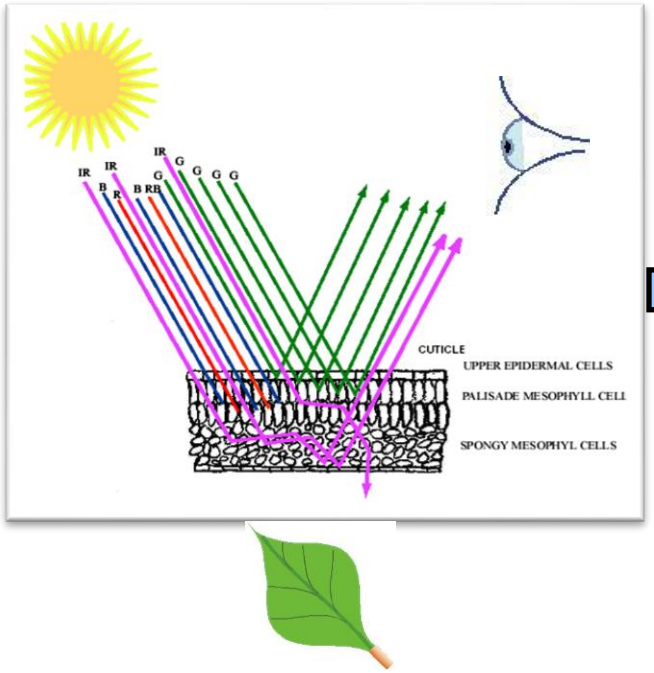
Traditional methods of drought assessment and monitoring rely on rainfall data as recorded in meteorological and hydrological networks.

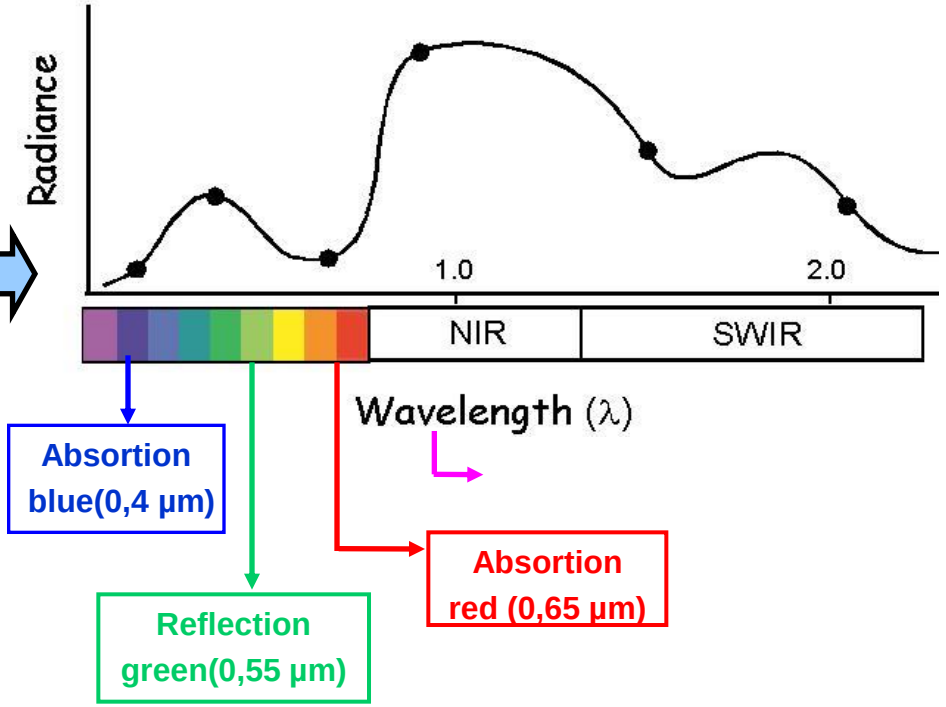
The role of remote sensing in drought monitoring has been reinforced in recent years due to the availability of reliable satellite imagery covering wide regions over long periods.



Vegetation Indices

Spectral characteristics of vegetation



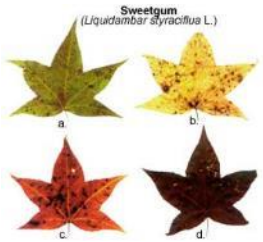


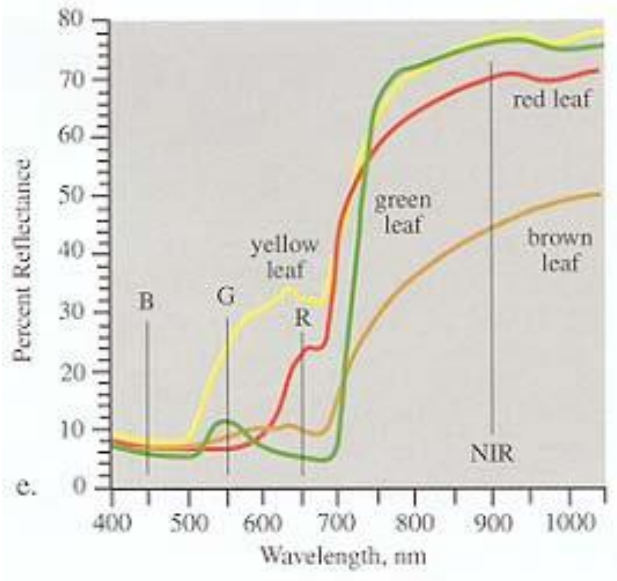
Leaves are green because they reflect the green radiation.

Vegetation Indices

The Normalized Difference Vegetation Index (NDVI) was successfully tested to monitor vegetation dynamics.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$





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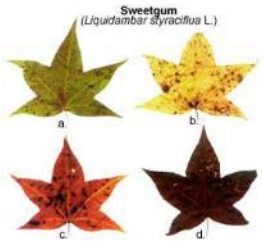
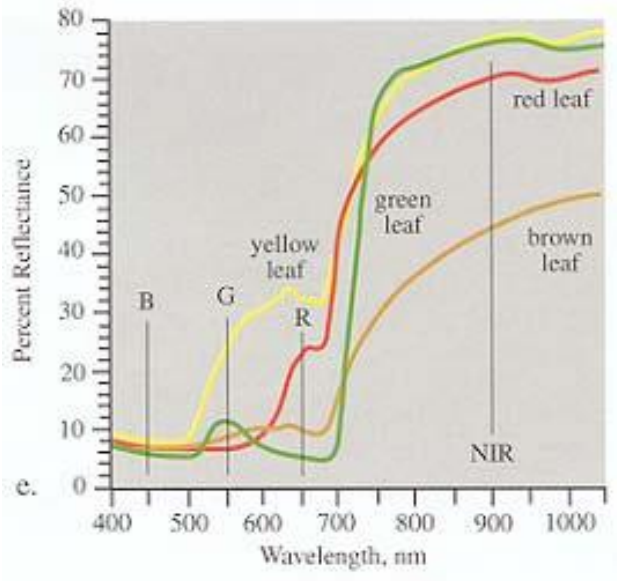
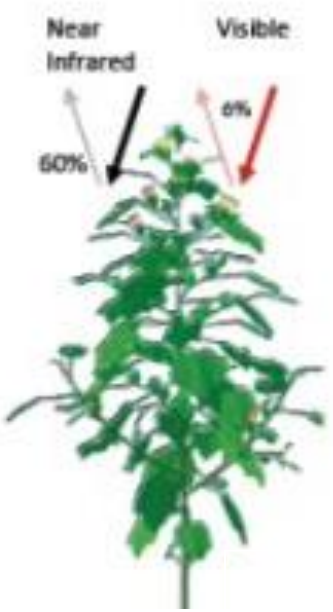
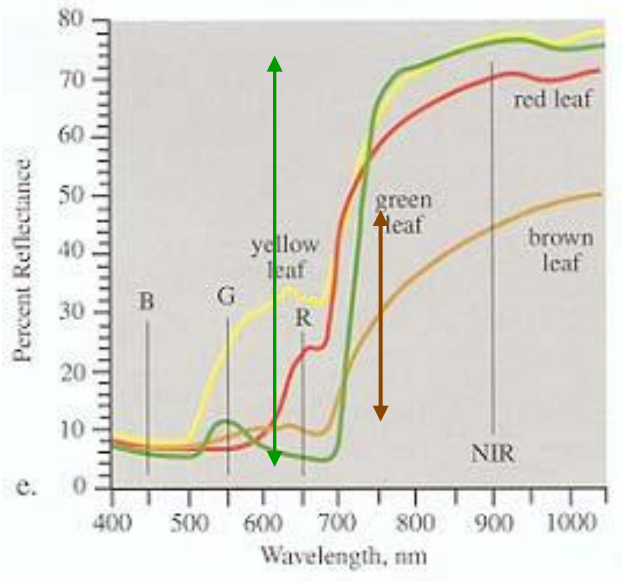




Q1: NDVI is higher for green or brown leaf?

Vegetation Indices





$$NDVI=\frac{0,60-0,06}{0,60+0,06}=0,82$$

$$NDVI=\frac{0,50-0,40}{0,50+0,40}=0,11$$

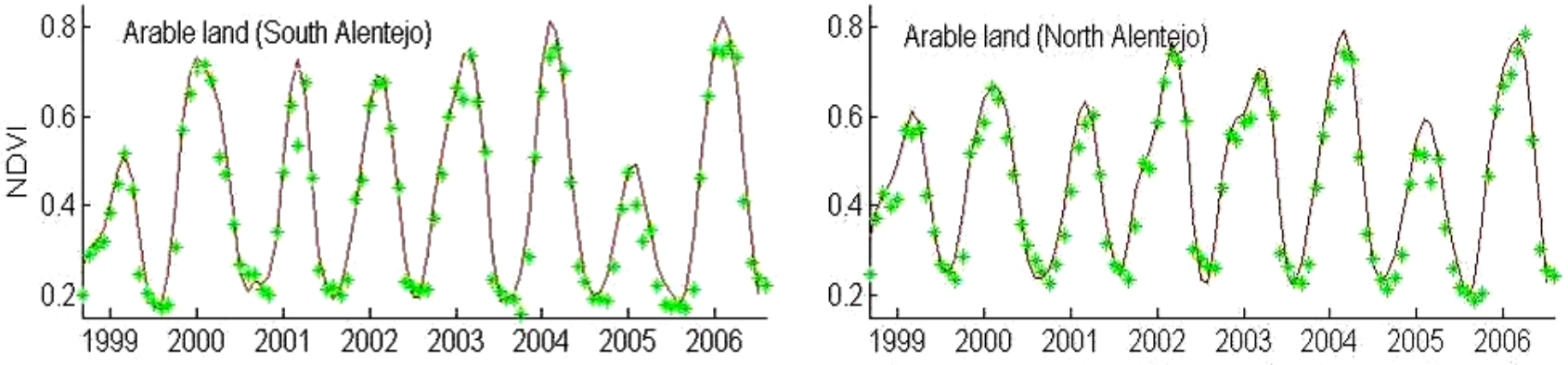
NDVI is higher for green vegetation

NDVI is lower for old and/or stressed vegetation

Vegetation Indices

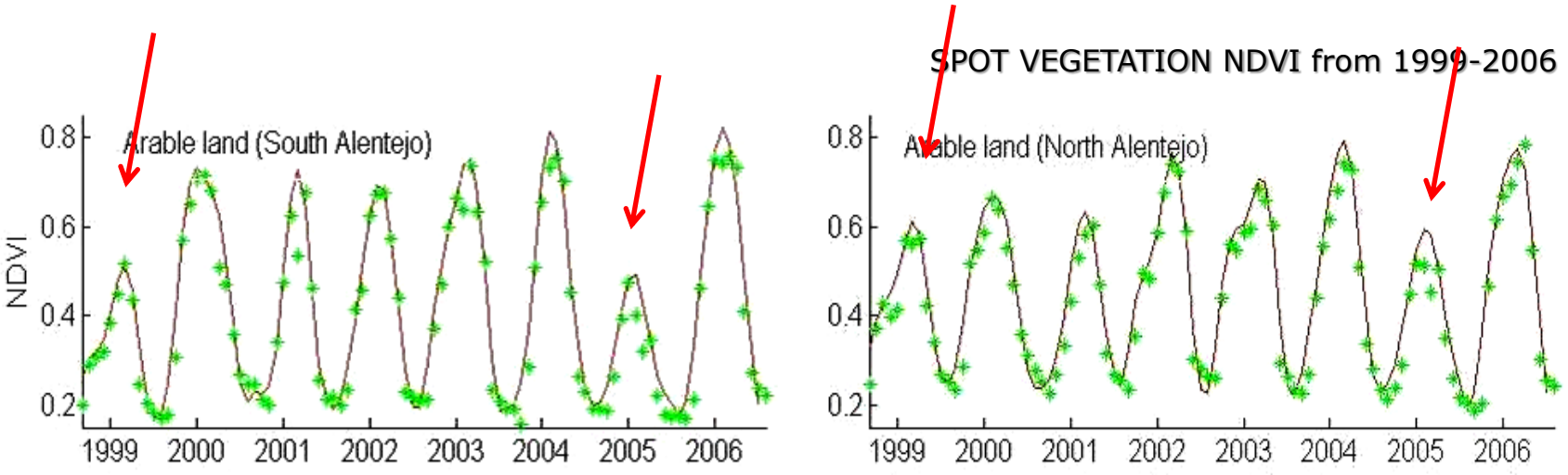
Monthly time-series of NDVI (1999–2006) for different land cover types

SPOT VEGETATION NDVI from 1999-2006



Vegetation Indices

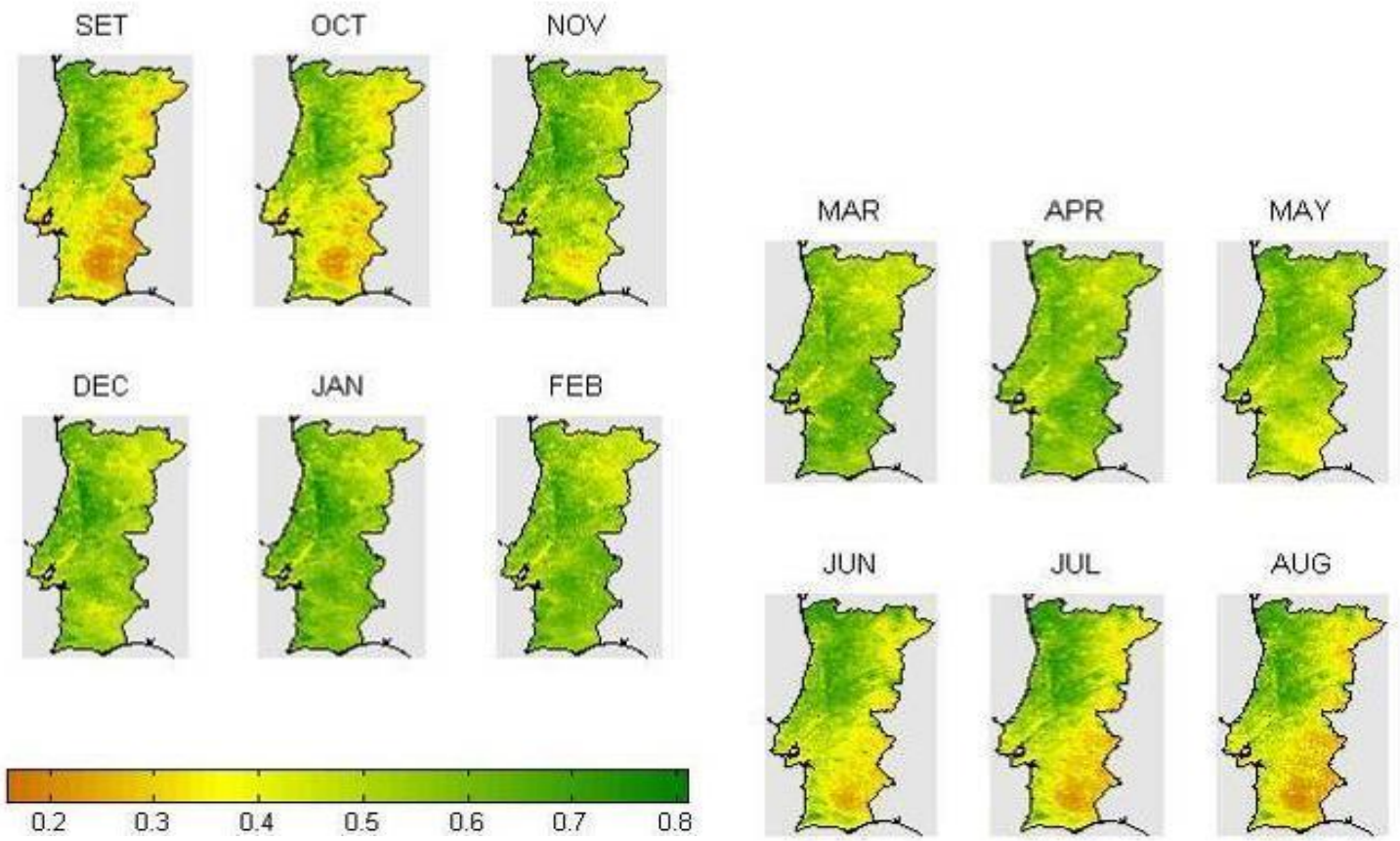
Monthly time-series of NDVI (1999–2006) for different land cover types



During 2004/2005, the Iberian Peninsula was hit by one of the two worst drought episodes in the last 60 years.

Vegetation Indices

Monthly means of NDVI (1999-2006) from September to August



Gouveia et al. (2009)

Vegetation Indices

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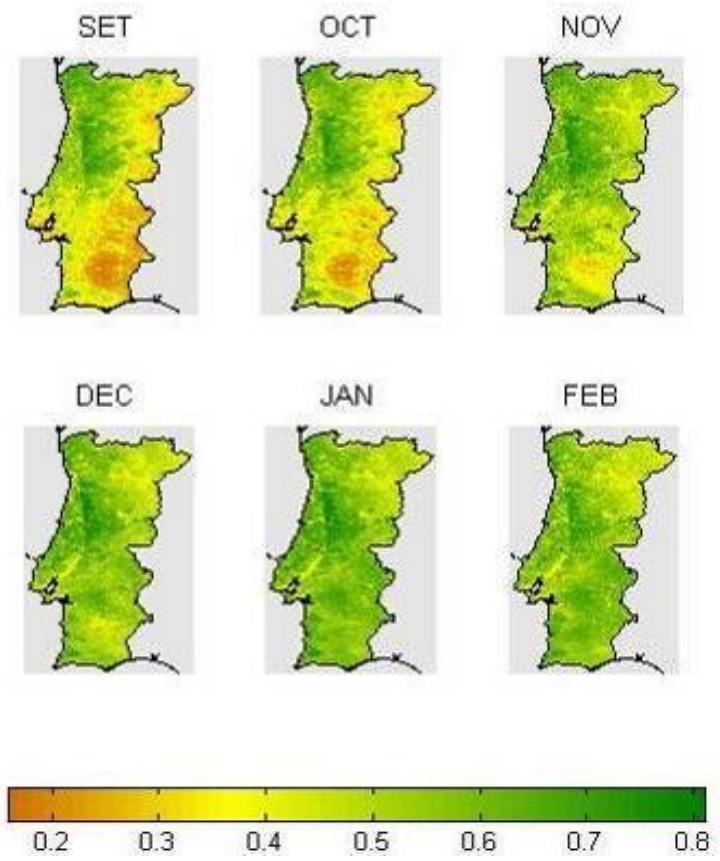
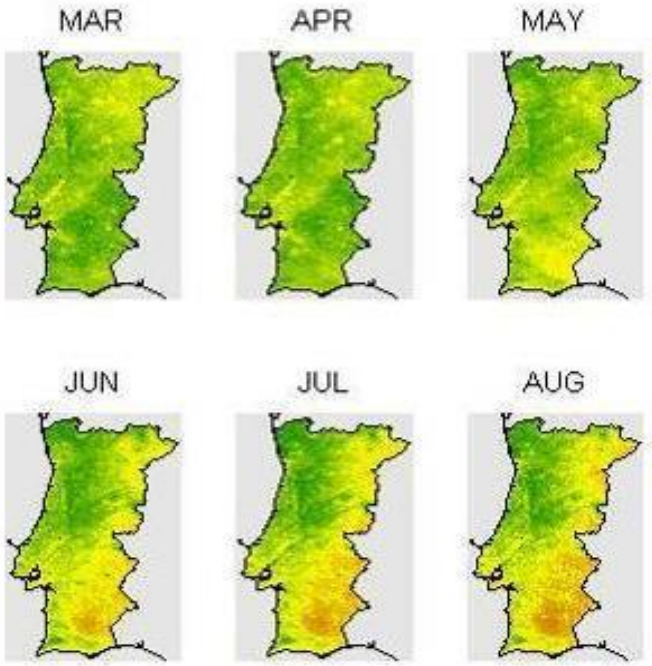


Q2: When (which month) vegetation is greener in Portugal?



Gouveia et al. (2009)

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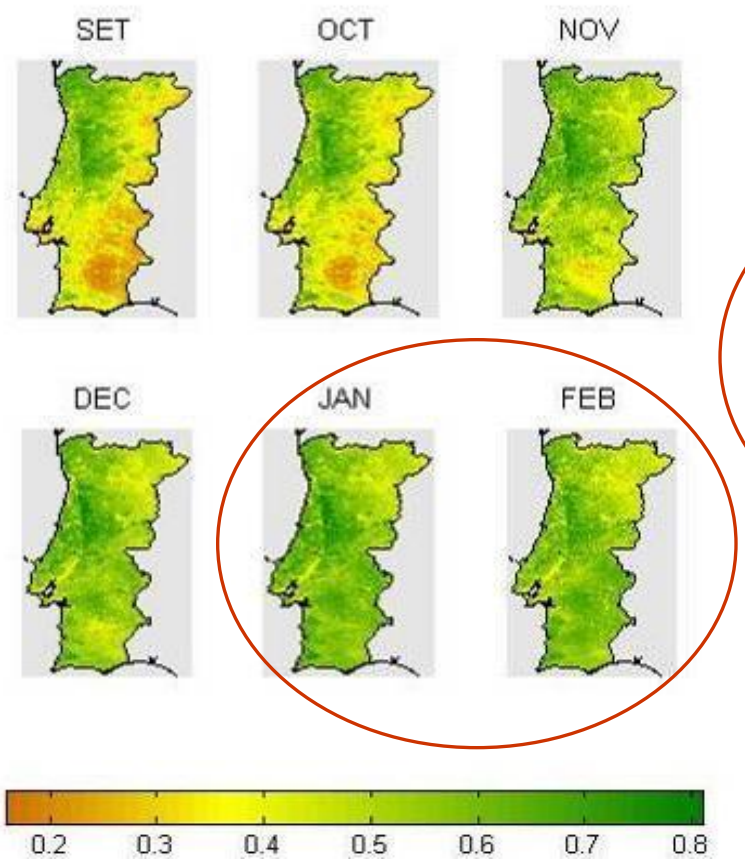

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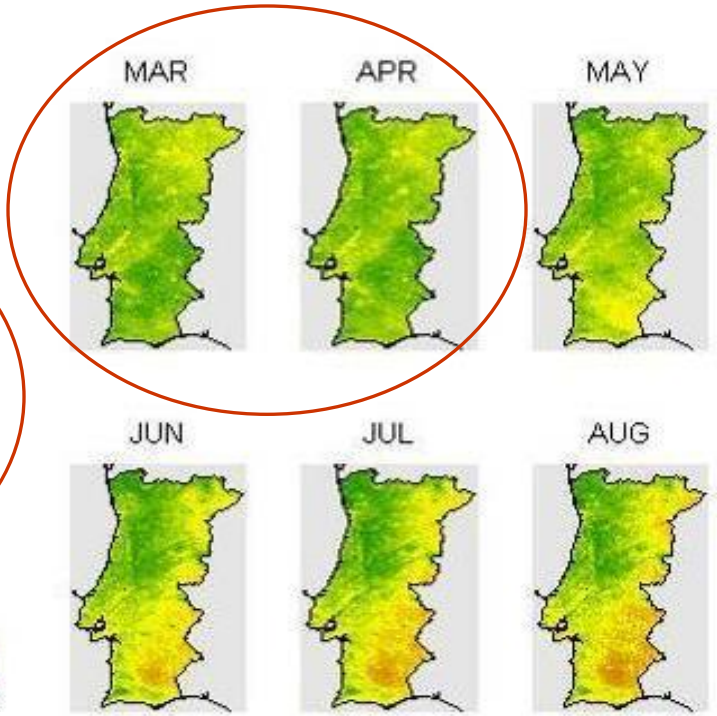
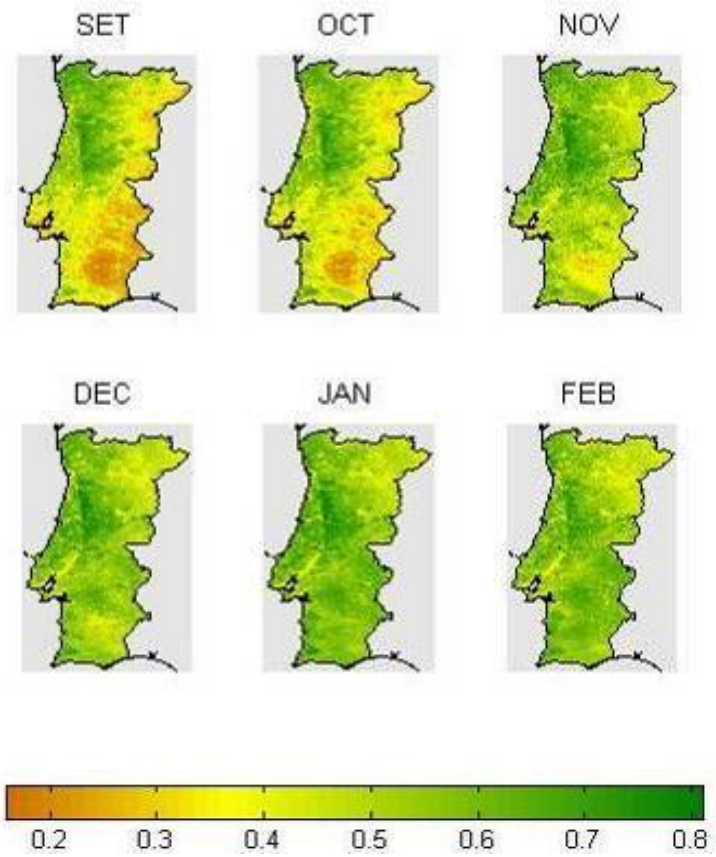


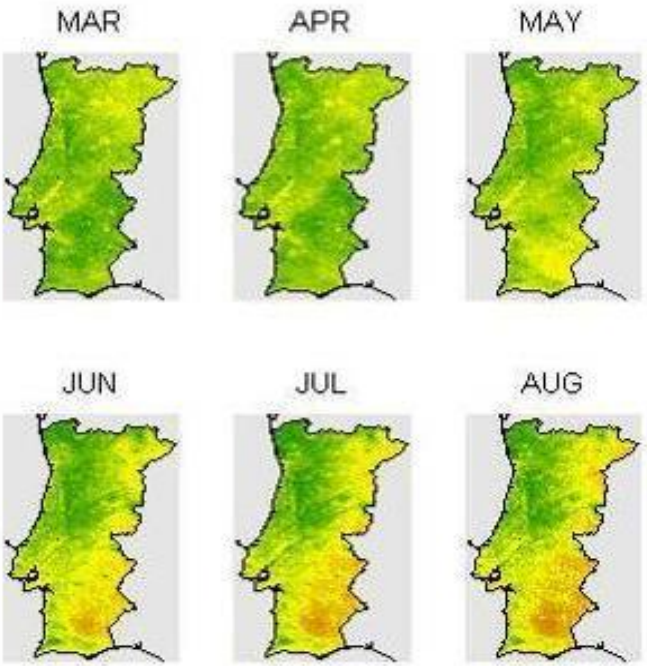
Gouveia et al. (2009)

Vegetation Indices

Monthly means of NDVI (1999-2006) from September to August



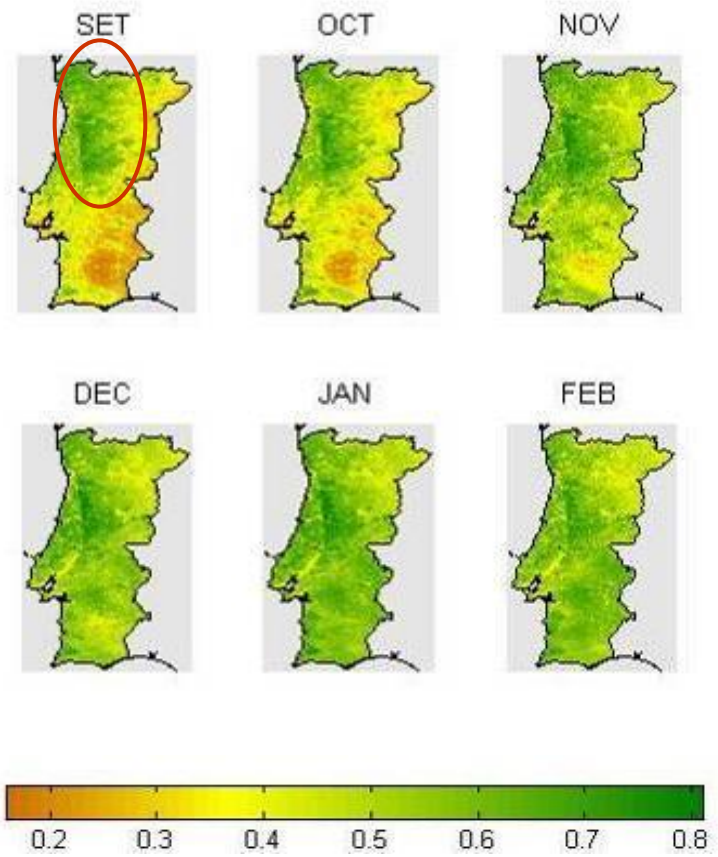
Q3: where is located the coniferous forest?



Gouveia et al. (2009)

Vegetation Indices

Monthly means of NDVI (1999-2006) from September to August



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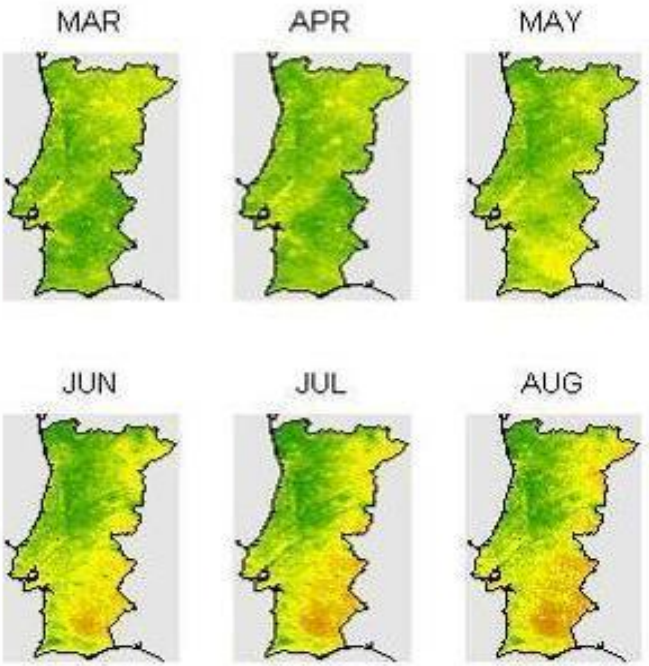
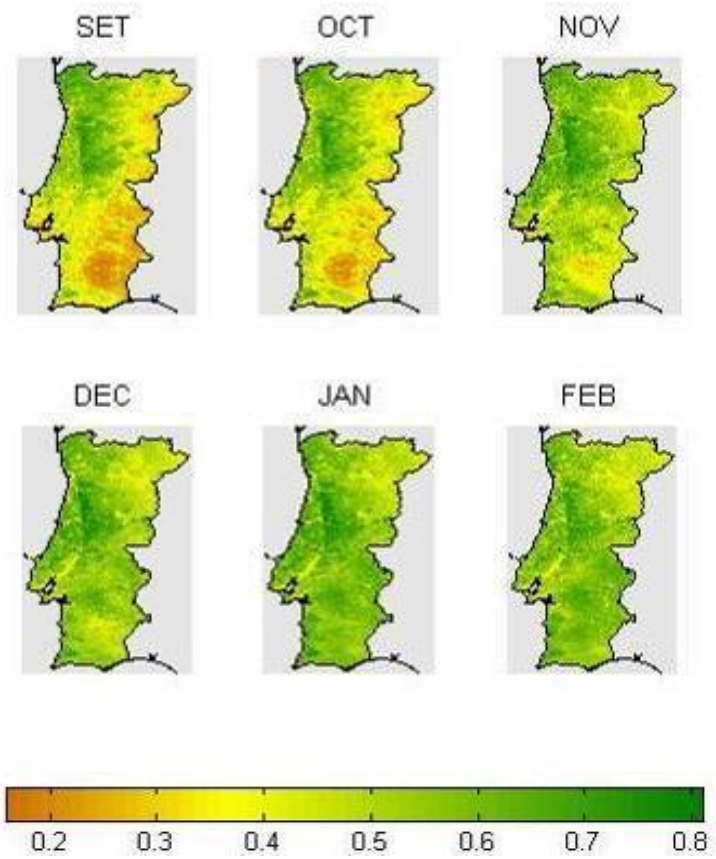


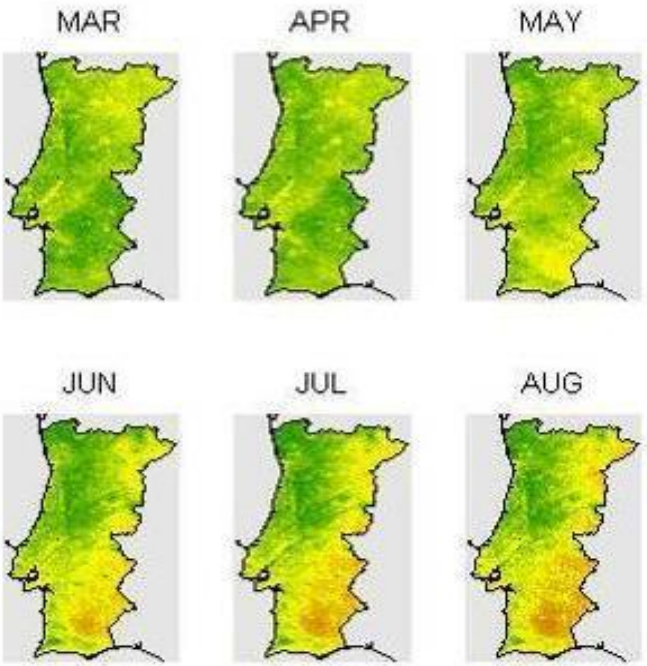
Gouveia et al. (2009)

Vegetation Indices

Monthly means of NDVI (1999-2006) from September to August

Q4: and arable land?





Gouveia et al. (2009)

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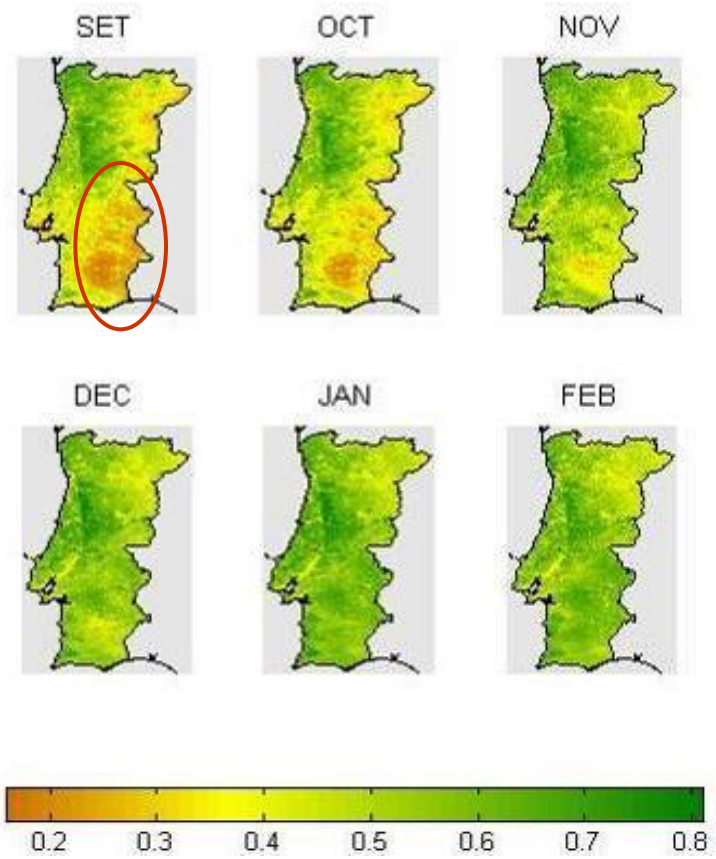
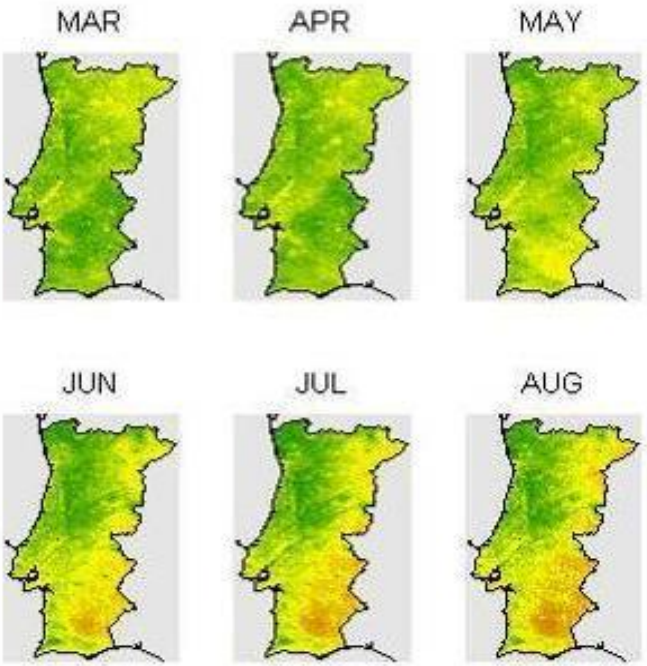
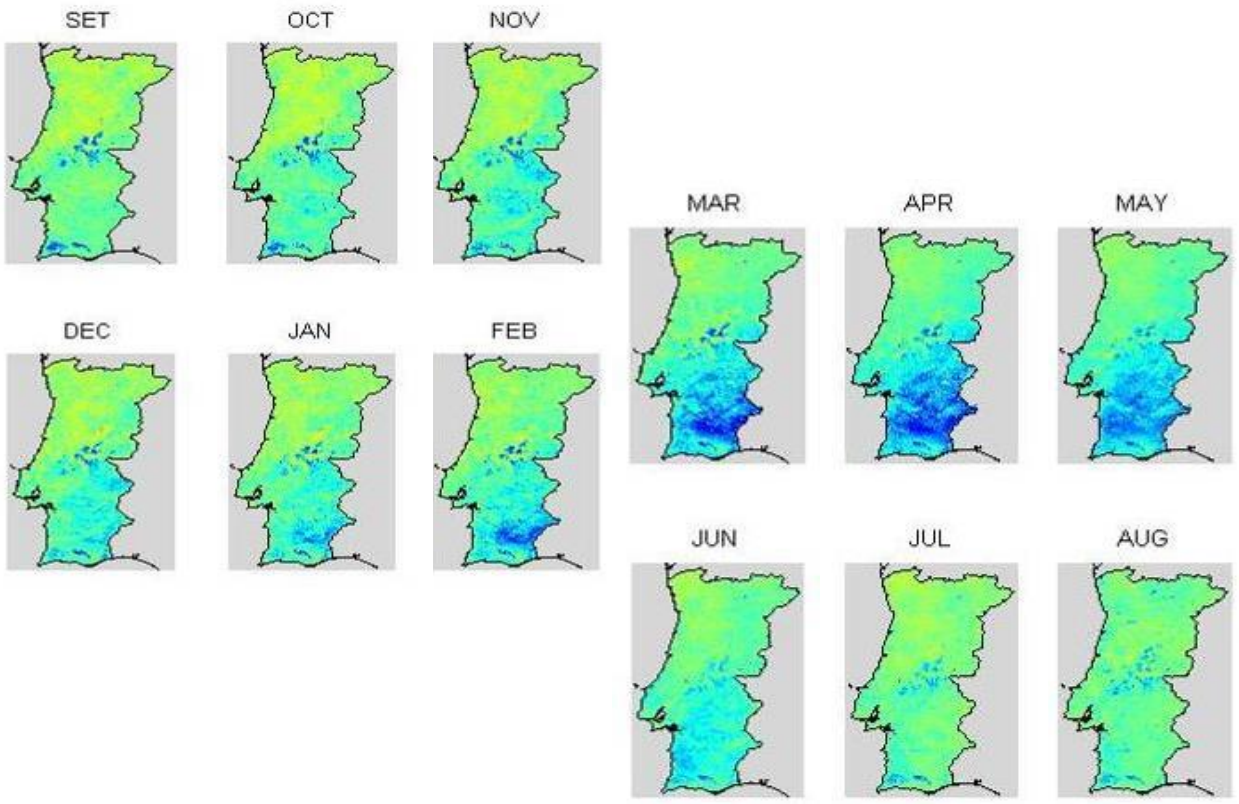




Gouveia et al. (2009)

Vegetation Indices

NDVI anomalies from September to August of the year 2004/2005.



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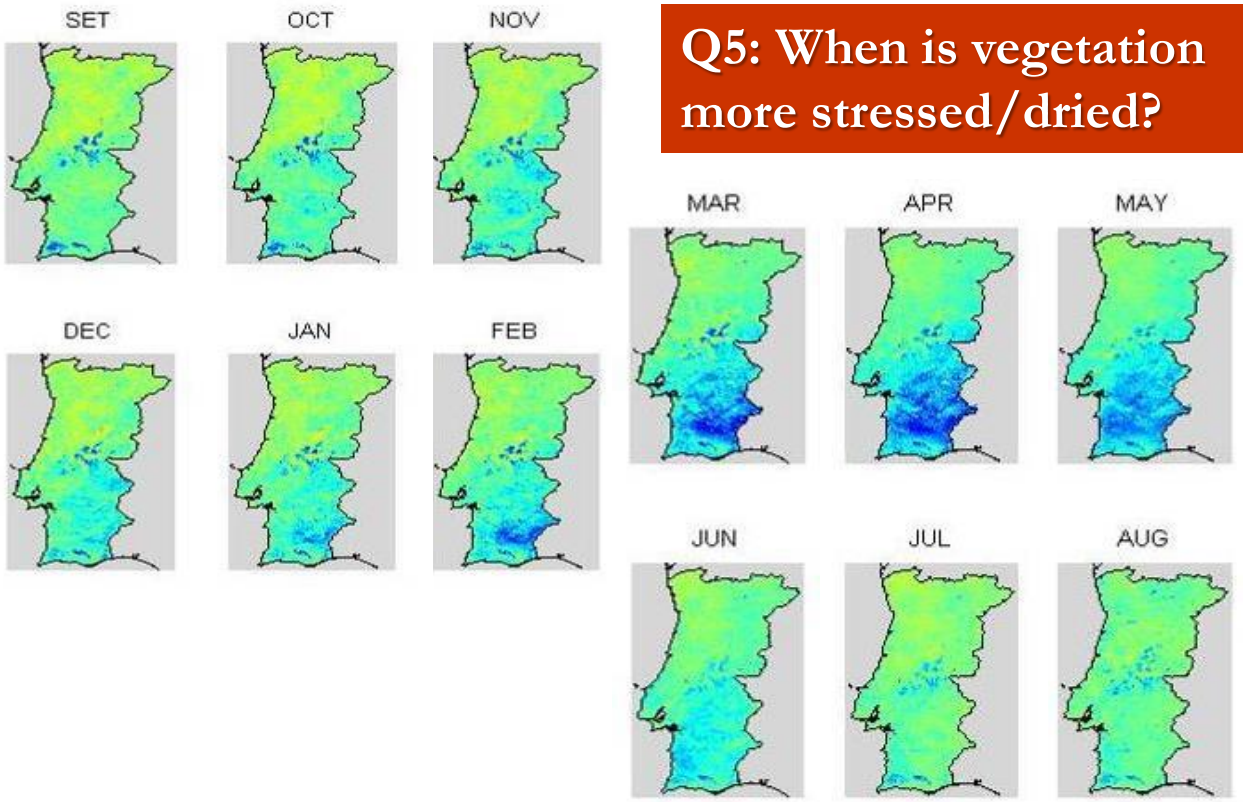
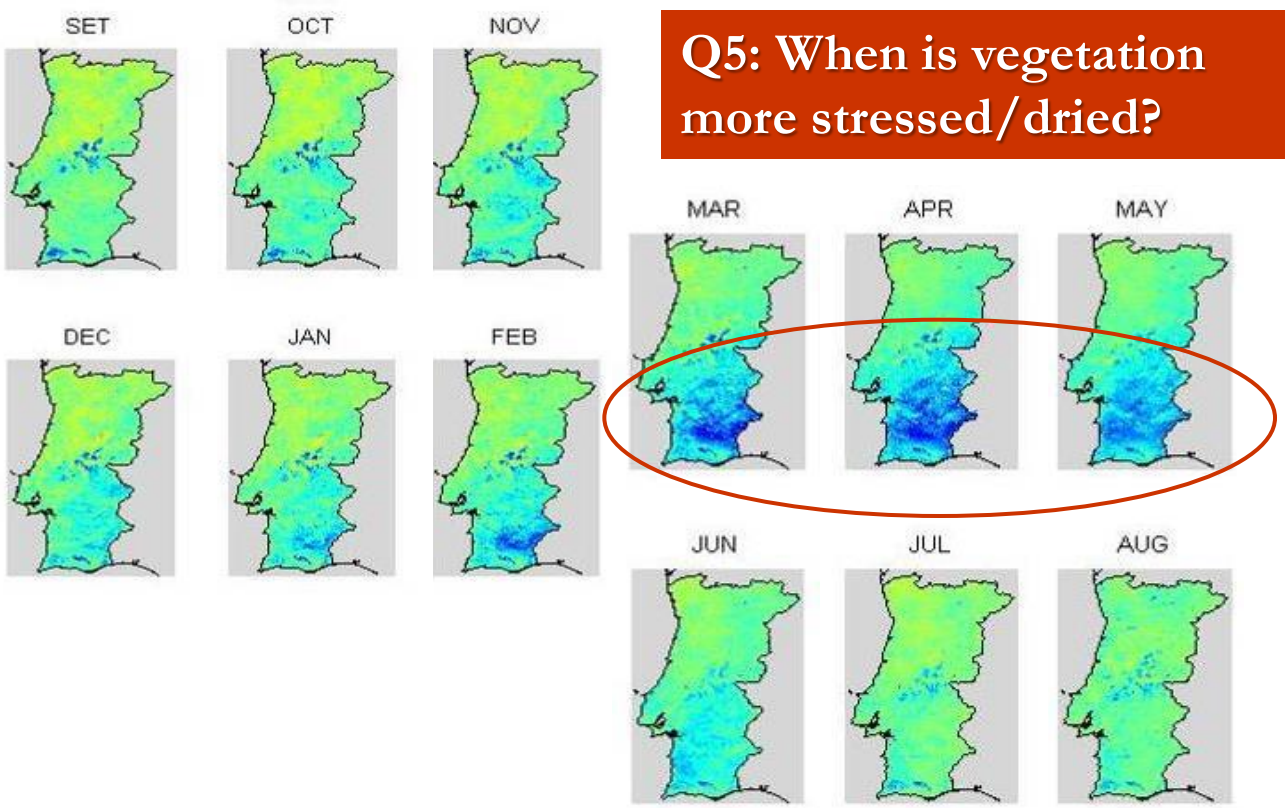


Q5: When is vegetation more stressed/dried?

Gouveia et al. (2009)

Vegetation Indices

NDVI anomalies from September to August of the year 2004/2005.



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Gouveia et al. (2009)

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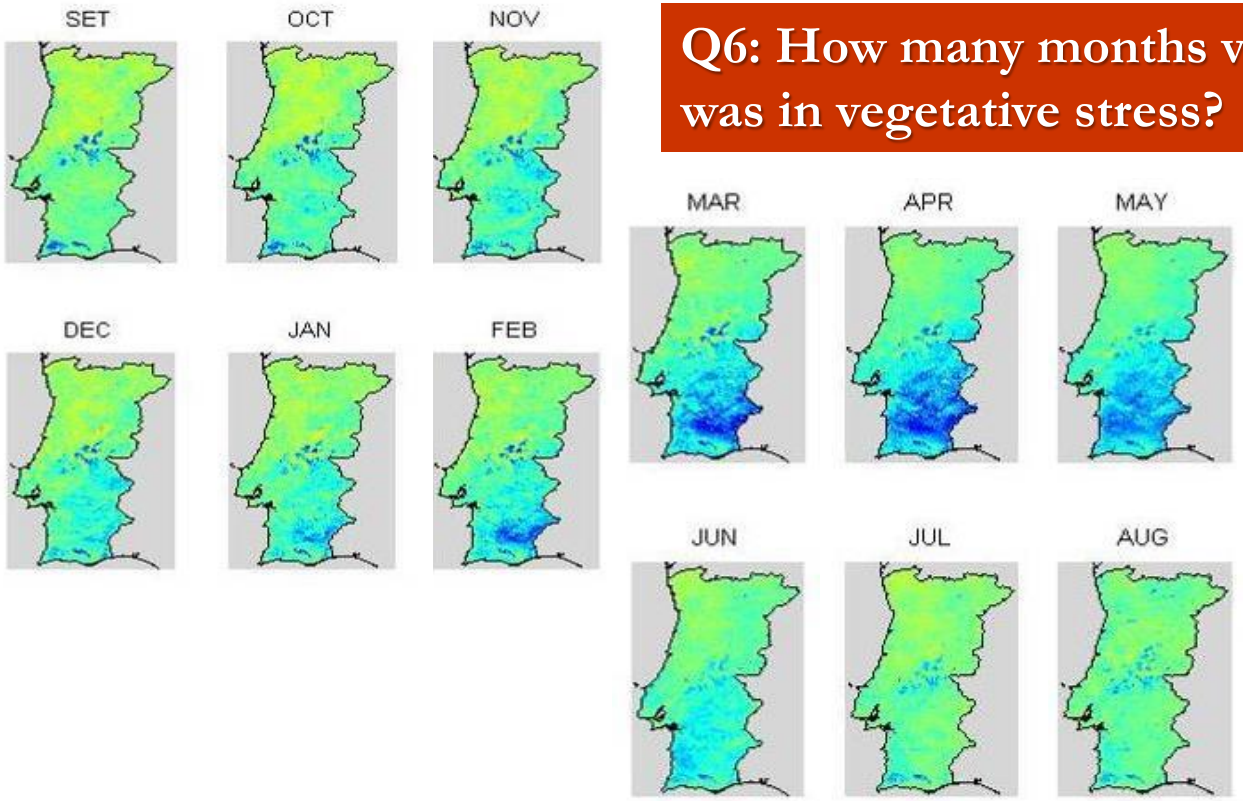
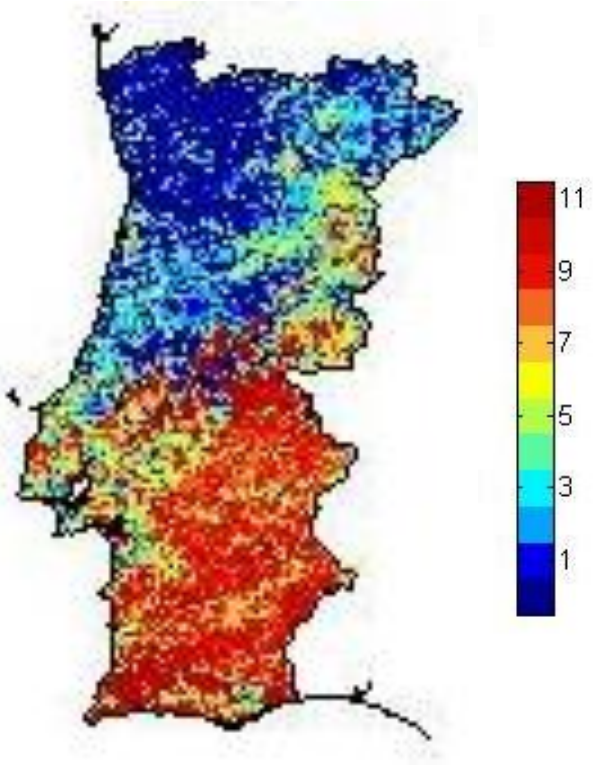


Q6: How many months vegetation was in vegetative stress?

Gouveia et al. (2009)

Vegetation Indices

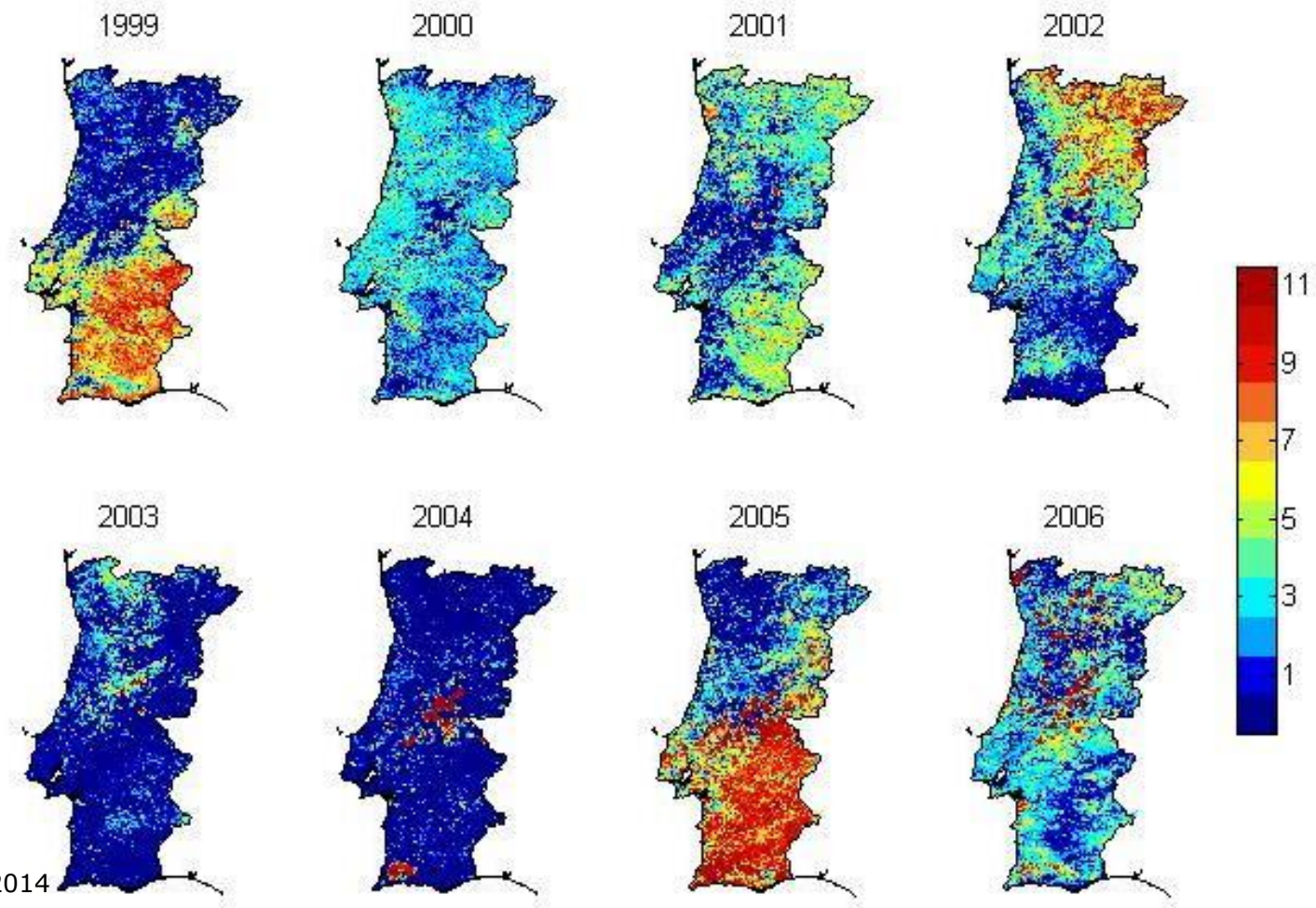
Drought persistence was evaluated by adding up (for each pixel) the number of months with corrected NDVI anomalies lower than a specific threshold (-0.025).



Q7: How exceptional was the 2004/2005 event?

Gouveia et al. (2009)

Vegetation Indices



Gouveia et al. (2009)

Drought Indices

A large number of indices have been developed using different meteorological variables

Table 1. Major drought indices discussed in this paper.

Index	Year introduced	Variables analyzed; application
Munger's Index	1916	Length of period without 24-h precipitation of 1.27 mm; daily measure of comparative forest fire risk
Kincer's Index	1919	30 or more consecutive days with less than 6.35 mm of precipitation in 24 h; seasonal distribution maps
Marcovitch's Index	1930	Temperature and precipitation; climatic requirements of the bean beetle
Blumenstock's Index	1942	Length of drought in days, where drought terminated by occurrence of 2.54 mm of precipitation in 48 h; short-term drought
Antecedent Precipitation Index	1954	Precipitation; a reverse drought index used for flood forecasting
Moisture Adequacy Index	1957	Precipitation and soil moisture; agricultural drought
Palmer's Index (PDSI and PHDI)	1965	Precipitation and temperature analyzed in a water balance model; comparison of meteorological and hydrological drought across space and time
Crop Moisture Index	1968	Precipitation and temperature analyzed in a water balance model; agricultural drought
Keetch–Byram Drought Index	1968	Precipitation and soil moisture analyzed in a water budget model; used by fire control managers
Surface Water Supply Index	1981	Snowpack, reservoir storage, streamflow, and precipitation; computed primarily for western river basins; statistical properties not well analyzed or understood
Standardized Precipitation Index	1993	Precipitation; allows measurement of droughts and wet spells in terms of precipitation deficit, percent of "normal," probability of nonexceedance, and SPI at multiple simultaneous timescales with potentially different behavior at all of them
Vegetation Condition Index	1995	Satellite AVHRR radiance (visible and near-IR); measures "health" of vegetation
Drought Monitor	1999	Integrates several drought indices and ancillary indicators into a weekly operational drought-monitoring map product; multipurpose

Heim (2002). Bulletin of the American Meteorological Society

Agricultural Drought Index	Rainfall	Temp.	Estimated soil moisture	Vegetation index	Stream flow	Potential evapo-transpiration	Crop coefficient	Soil type
Palmer Drought Severity Index	X	X						
Deciles	X							
Prescott Ratio Index								
Hutchinson Index	X							
Plant Growth Index								
Soil Moisture Anomaly	X	X	X?					
Enhanced Vegetation Index								
TCI								
NDVI								
Aridity Anomaly Index	X		X			X		
Two reservoir water balance model	X					X		
Soil Water Index	X			X		X		X
scPDSI	X	X						
Drought Severity Index	X							
Warm-spell duration Index		X						
Cold-spell duration Index		X						
Simple Daily Intensity Index	X							
Relative Soil Moisture	X	X	X			X		
Relative Water Deficit	X	X	X			X		
Accumulated Water Deficiency	X	X	X			X		
Accumulated Drought Index	X	X				X		
Crop Moisture Index (CMI)	X					X		
Days without rainfall	X							
Soil Moisture						X		
SPEI	X	X						
CMI-Palmer based	X	X						
Crop Specific ET	X	X						
Drought Monitor	X	X	X	X	X	X		
Standardized Precipitation Index (SPI)	X							
Percent Normal	X							
Relative Soil Moisture	X	X	X					
Soil Moisture Anomaly	X	X						
Cumulative rainfall	X							

Sivakumar et al. (2010): Agricultural Drought Indices, WMO

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Q8: What type of indice is better?

i) Using only precipitation?

ii) Using only temperature?

iii) Using precipitation AND temperature?

0:

Heim (2002). Bulletin of the American Meteorological Society

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Deciles	X							
Prescott Ratio Index								
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Plant Growth Index								
Soil Moisture Anomaly	X	X	X?					
Enhanced Vegetation Index								
TCI								
NDVI								
Aridity Anomaly Index	X		X			X		
Two reservoir water balance model	X					X		
Soil Water Index	X			X		X		X
scPDSI	X	X						
Drought Severity Index	X							
Warm-spell duration Index		X						
Cold-spell duration Index		X						
Simple Daily Intensity Index	X							
Relative Soil Moisture	X	X	X			X		
Relative Water Deficit	X	X	X			X		
Accumulated Water Deficiency	X	X	X			X		
Accumulated Drought Index	X	X				X		
Crop Moisture Index (CMI)	X					X		
Days without rainfall	X							
Soil Moisture						X		
SPEI	X	X						
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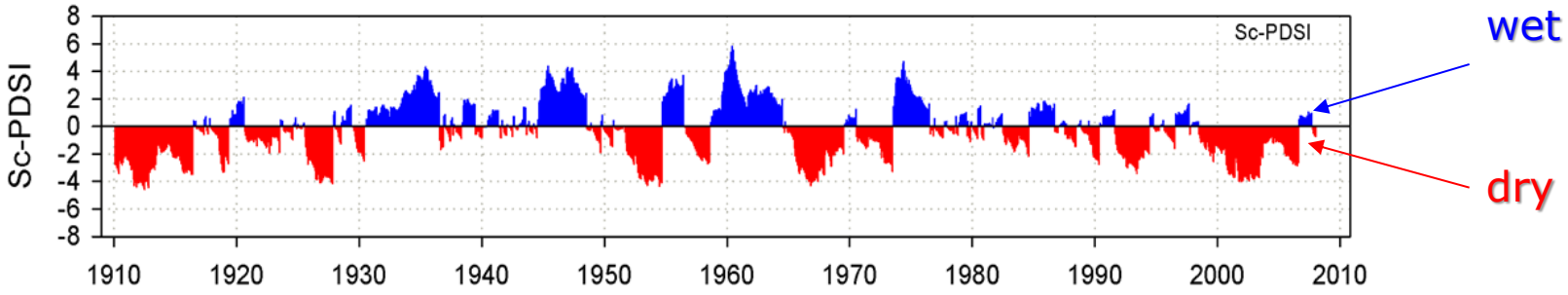
Crop Specific ET	X	X						
Drought Monitor	X	X	X	X	X	X		
Standardized Precipitation Index (SPI)	X							
Percent Normal	X							
Relative Soil Moisture	X	X	X					
Soil Moisture Anomaly	X	X						
Cumulative rainfall	X							

Sivakumar et al. (2010): Agricultural Drought Indices, WMO

Drought Indices

The most famous drought index is the Palmer Drought Index (PDSI). Uses precipitation and temperature data.



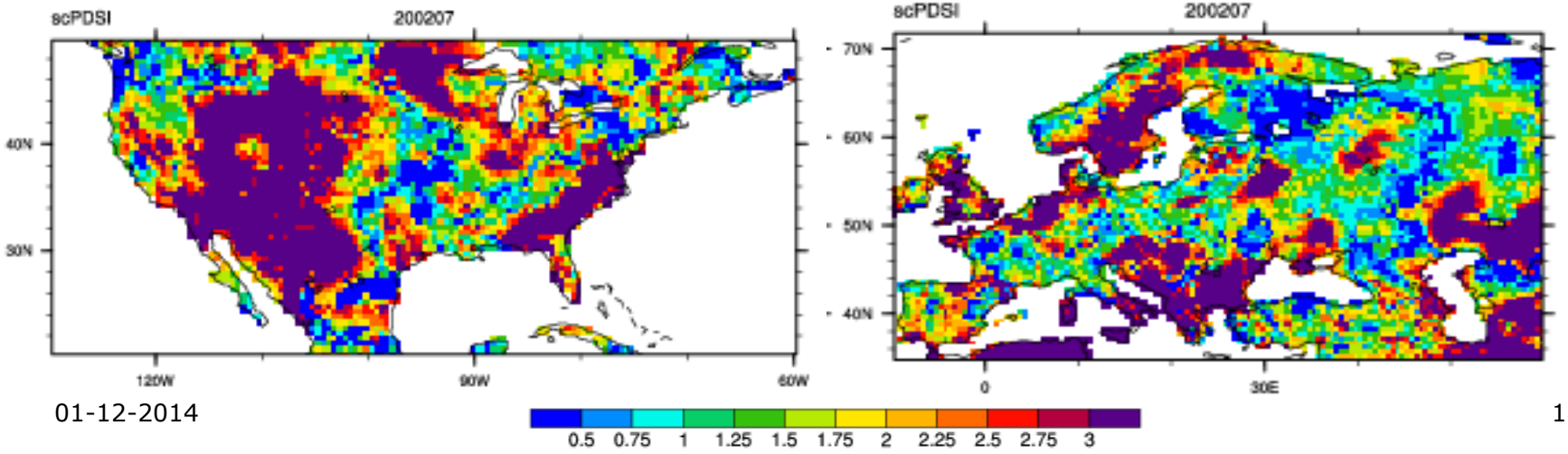
However this index presents several limitations:

- Strong dependence with the calibration period. To avoid these problems the calibration period should be higher than 50 years.
- Many parameters of PDSI are obtained empirically for the USA region. This situations limits the applications to other regions.

Drought Indices

Well et al. (2004) have developed the self calibrated PDSI (**scPDSI**). The calibration is made based on the original dataset, improving its performance.

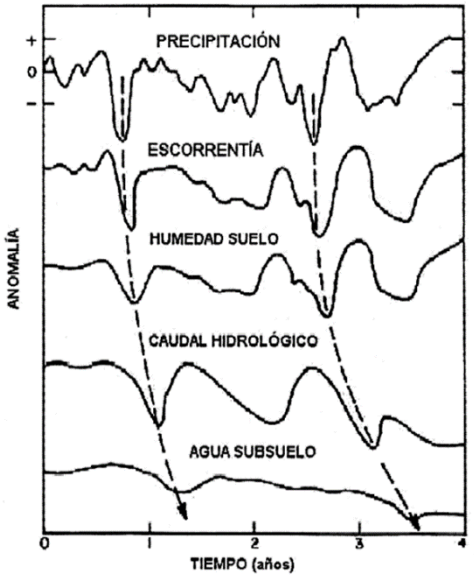
Maps of scPDSI have been calculated for the period 1901–2002 for United States (20°–50°N; 130°–60°W) and Europe (35°–70°N; 10°W–60°E) with a spatial resolution of 0.5°×0.5° (https://climatedataguide.ucar.edu/climate-data/cru-sc-pdsi-self-calibrating-pdsi-over-europe-north-america).

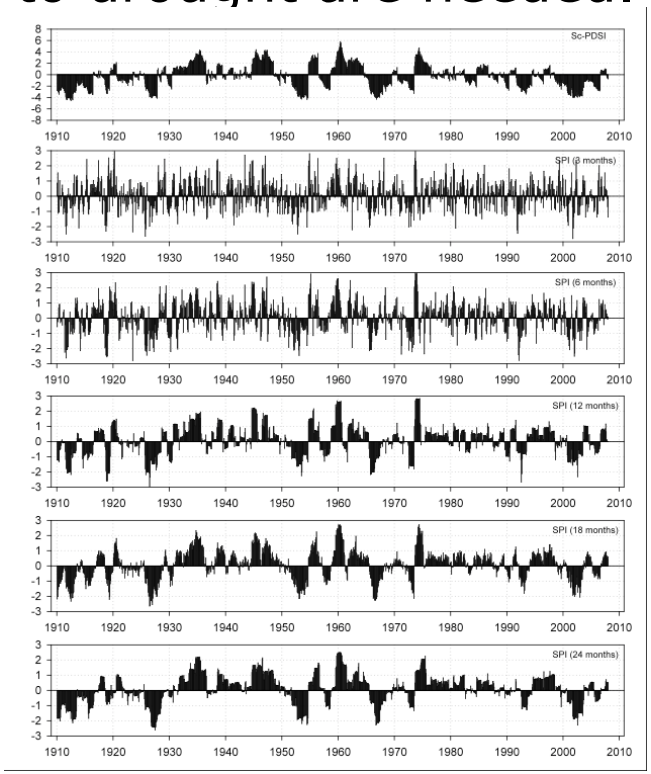


Drought Indices

Different systems responds to water scarcity with different temporal scales.

Flexible indicators to quantify the drought impacts given the different response times of hydrological, agricultural, economic systems to drought are needed.





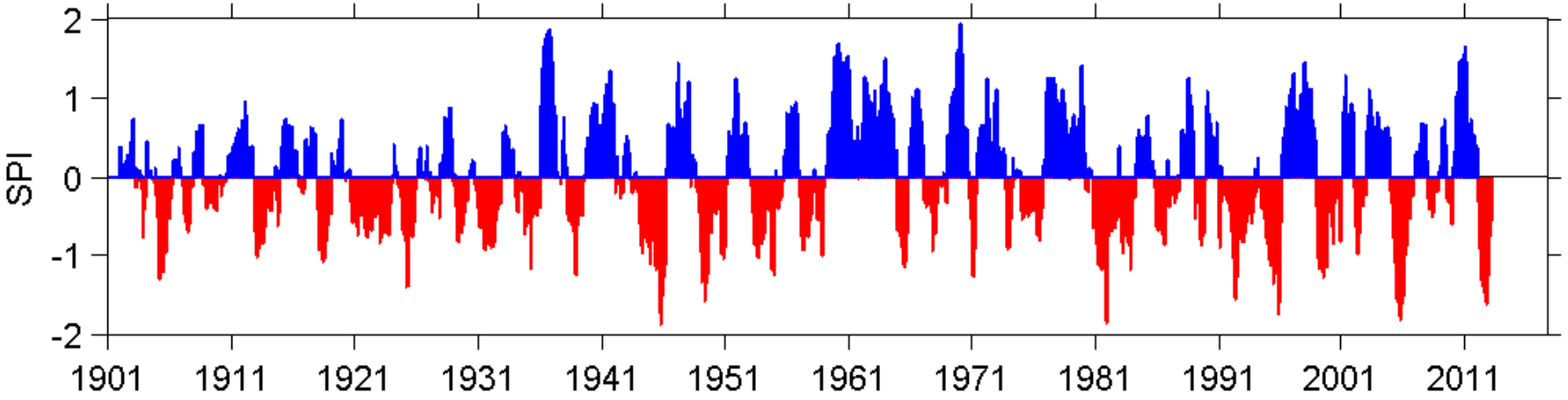
Time series of the sc-PDSI and 3-, 6-, 12-, 18- and 24-month SPIs in Indore (India) (1910–2007). (Vicente-Serrano et al. 2010)

The Standardised Precipitation Index (SPI), based on *precipitation* data, permit the analysis of the drought at different temporal scales.

SPI is very adjustable index, extremely useful for drought monitoring and assessing impacts.

Drought Indices

Time series of the 6 month Standardized Precipitation Index (SPI) averaged over Iberian Peninsula between 1901-2012.



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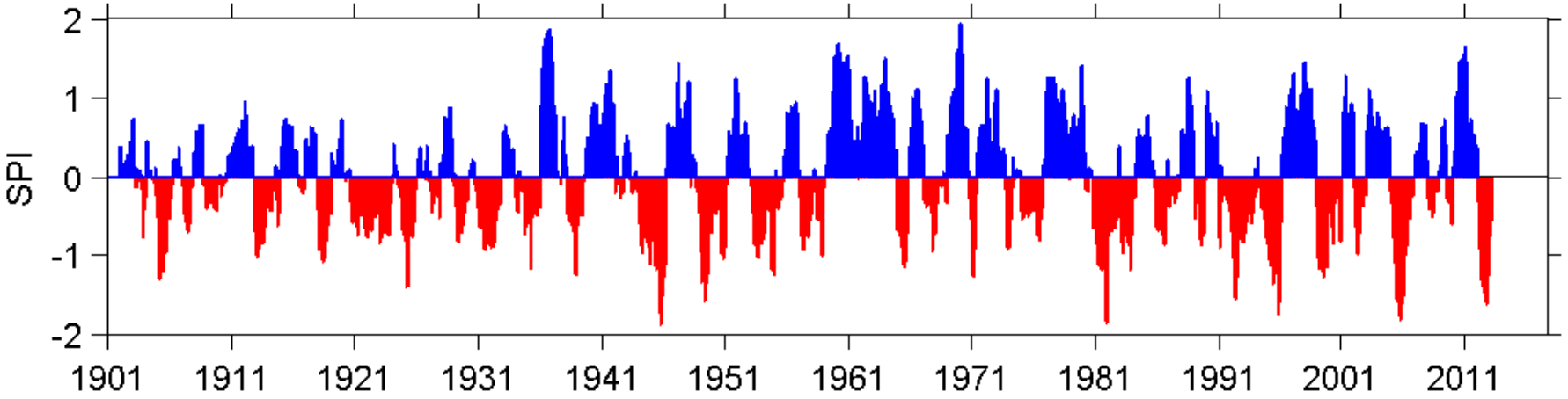

Q9: Identify one wet and one dry episode.

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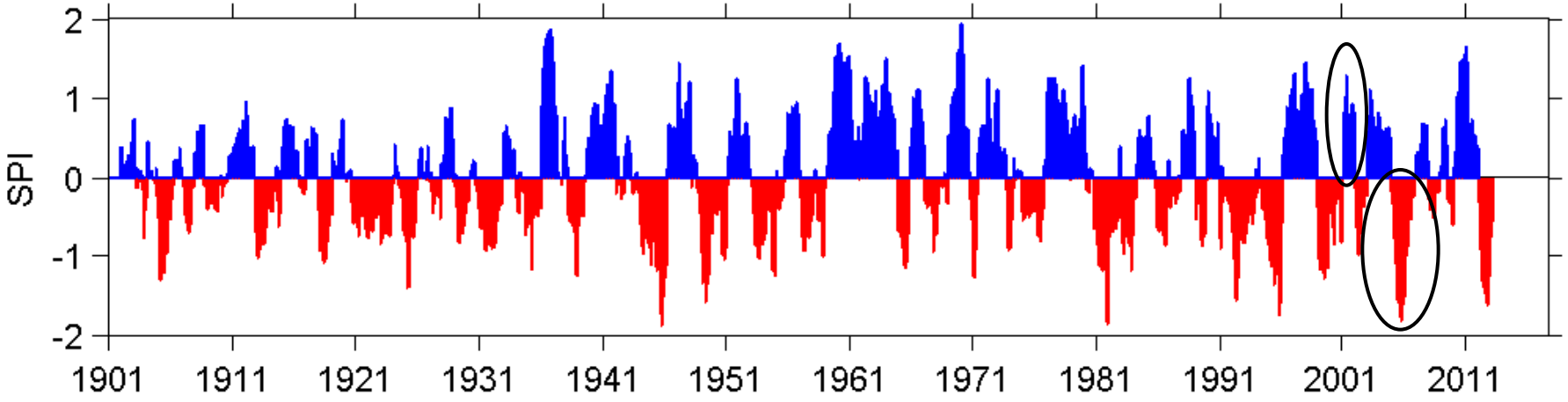
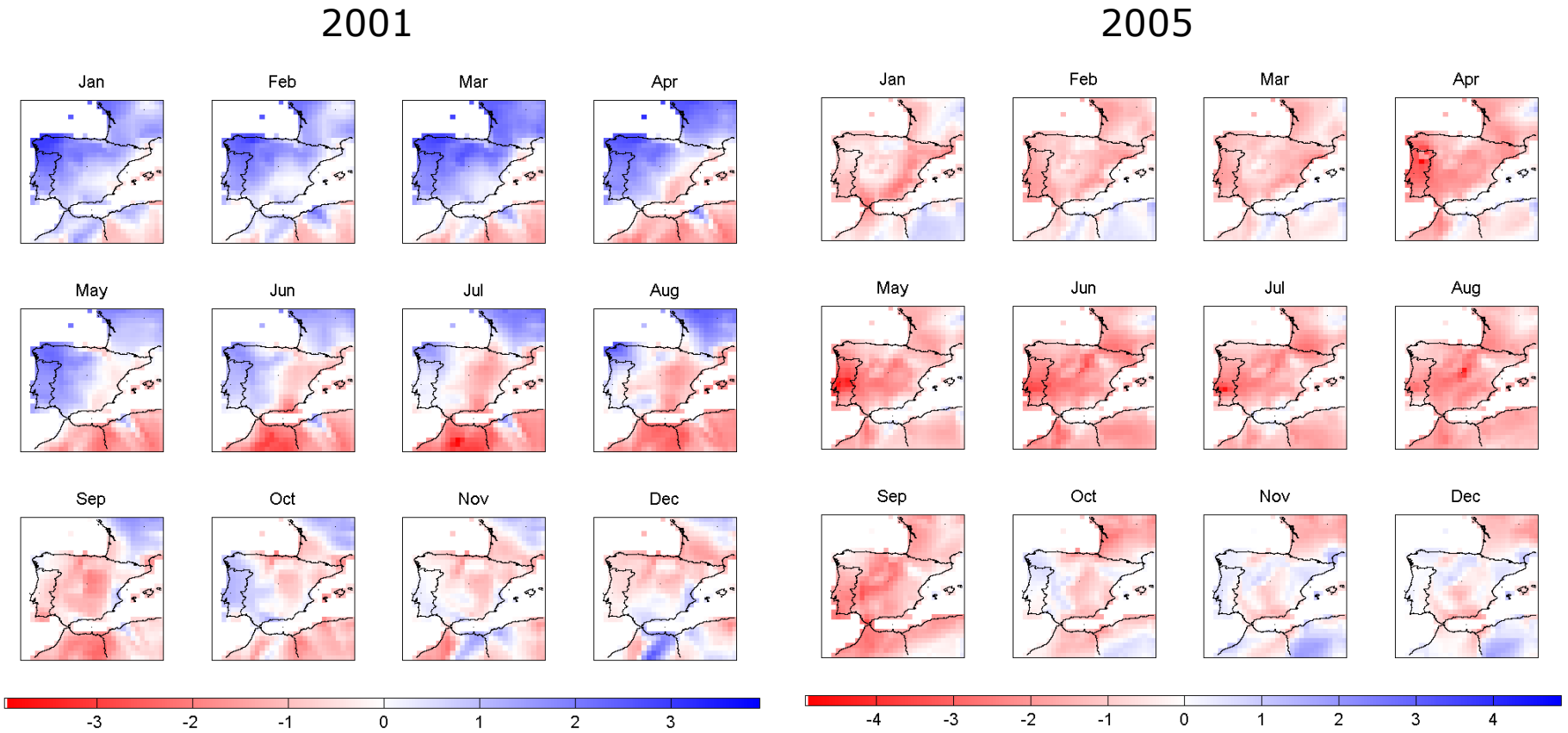


Q9: Identify one wet and one dry episode.

Drought Indices

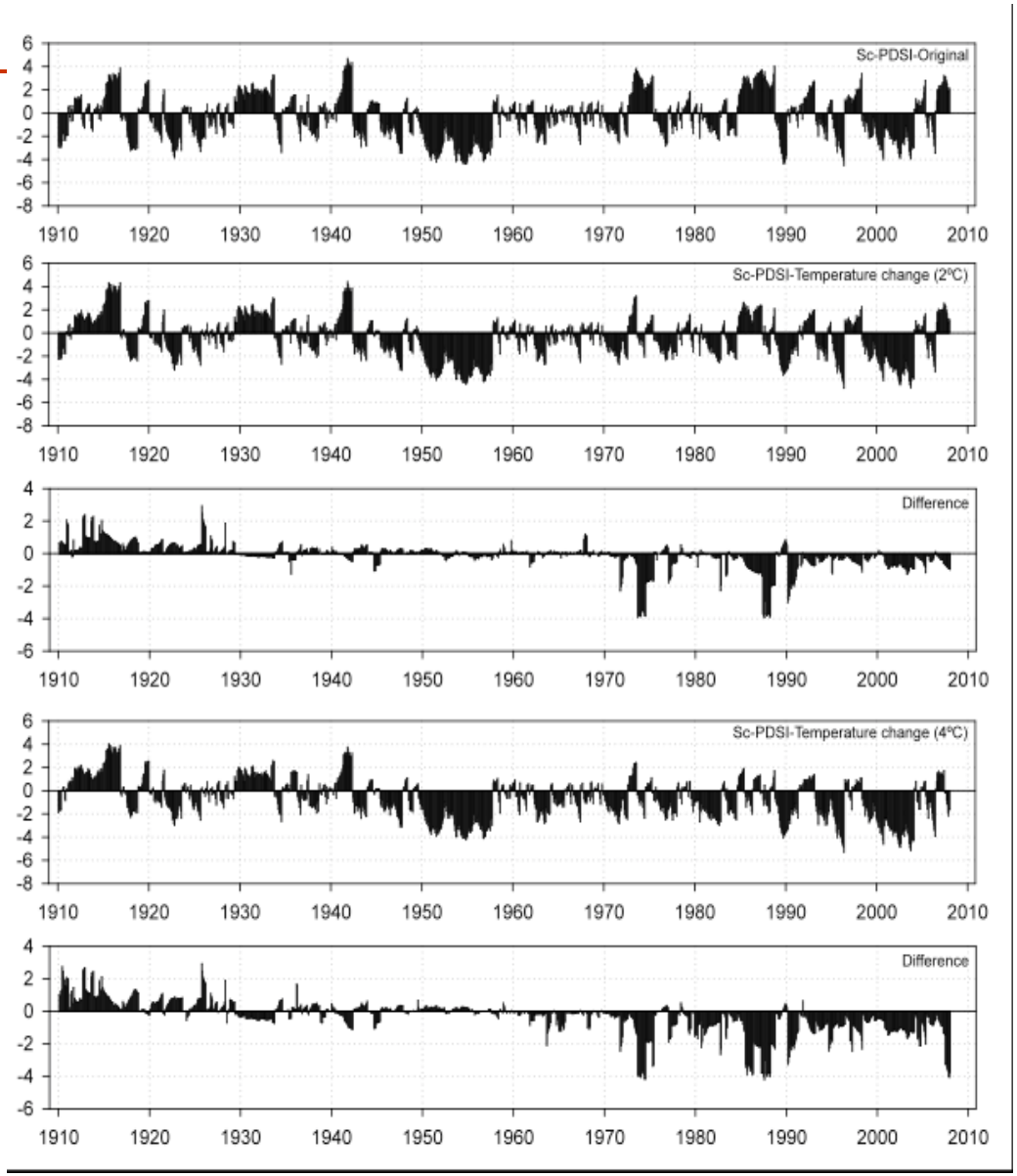
SPI for 6 months over Iberia for 2001(left) and 2005(right)



Drought Indices

However, SPI is only based on precipitation and doesn't take in account variables such as temperature or evapotranspiration.

- *What will happen if the temperature increase significantly?*
- *What will happen in the case of extreme events, such as heat waves?*
- *What will happen in the case of the possible scenarios of increase temperature?*

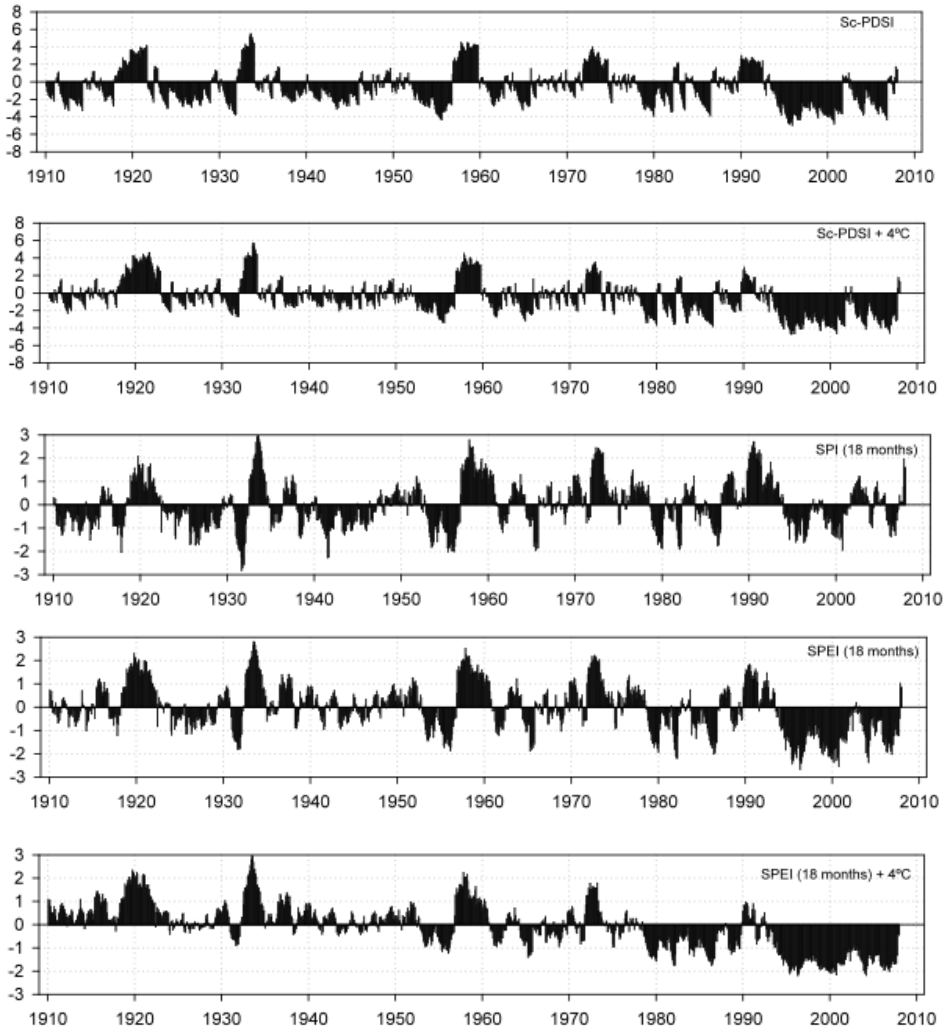


Vicente-Serrano et al., 2010

Drought Indices

Vicente-Serrano et al. (2010) have developed a new multi-scale index, the Standardized Precipitation and Evapotranspiration Index (SPEI)

SPEI uses as input precipitation and temperature



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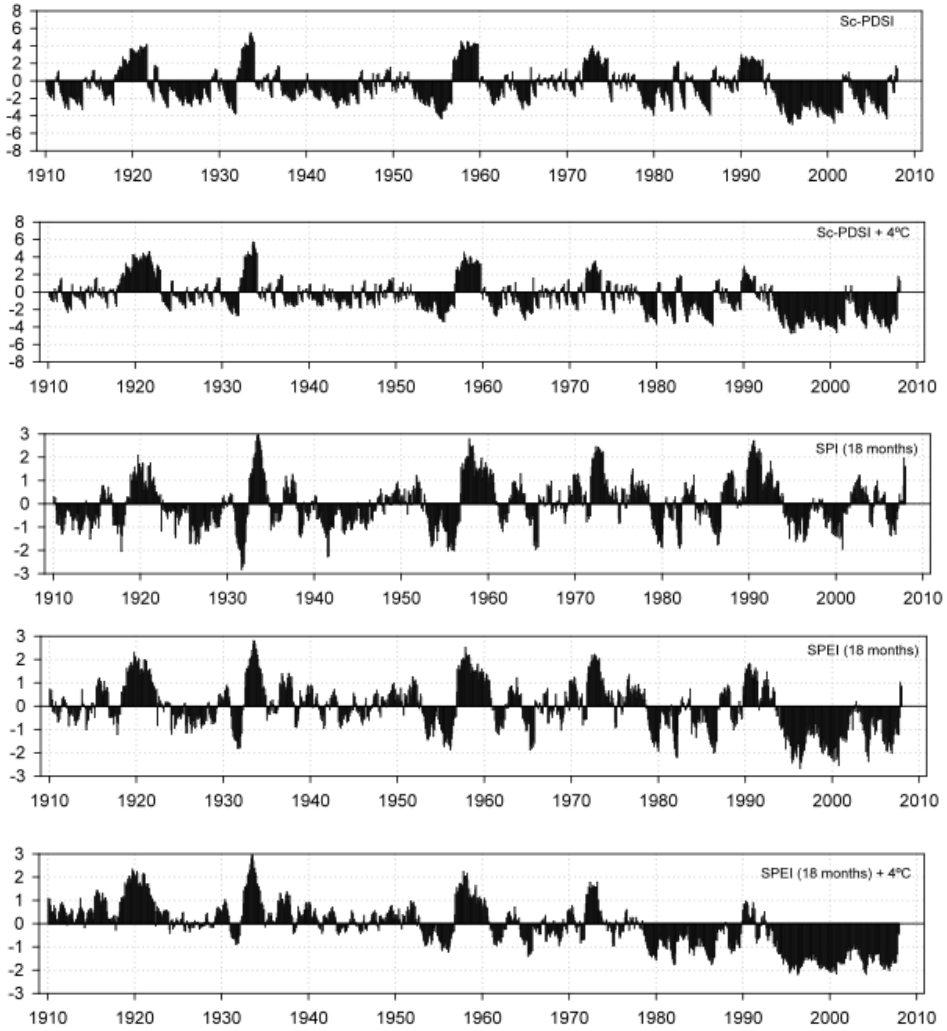

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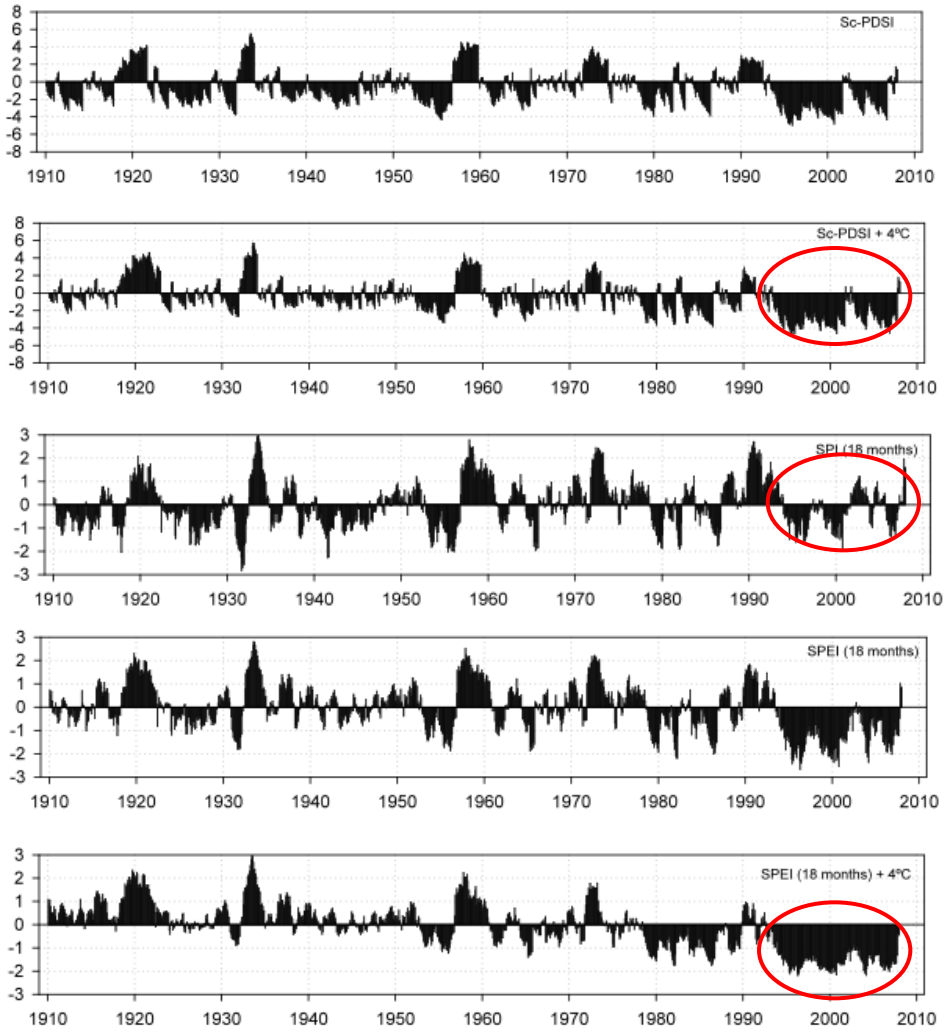
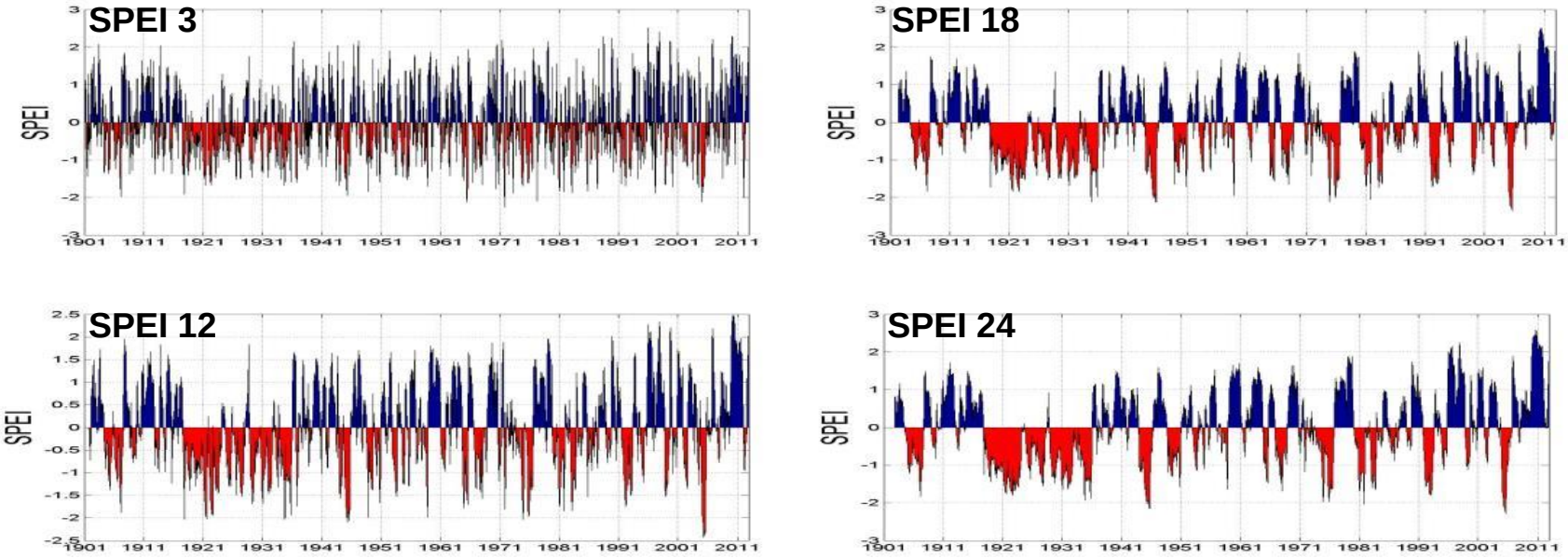


Drought Indices

The 3-, 12- ,18- and 24-month SPEI at Lisbon, Portugal, 1901–2012.



The main prolonged drought episodes occurred in the decades of 1920-30.

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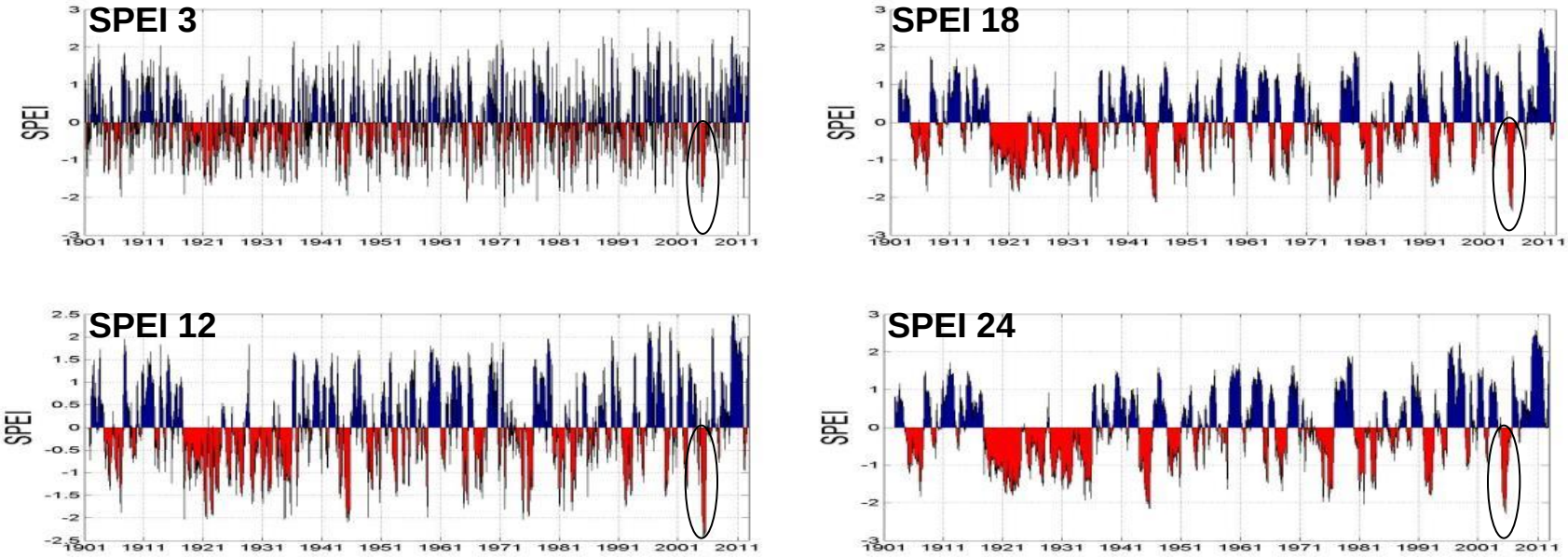
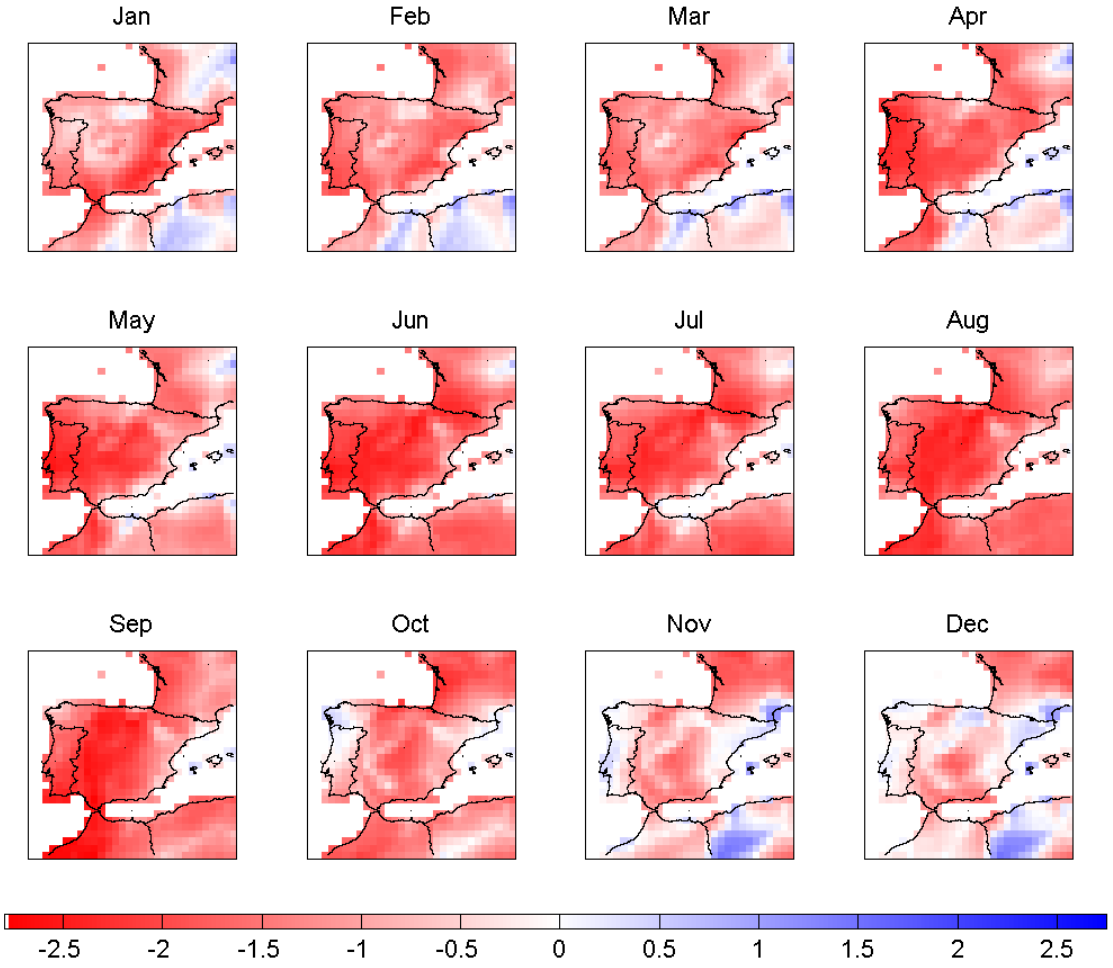


The main prolonged drought episodes occurred in the decades of 1920-30.

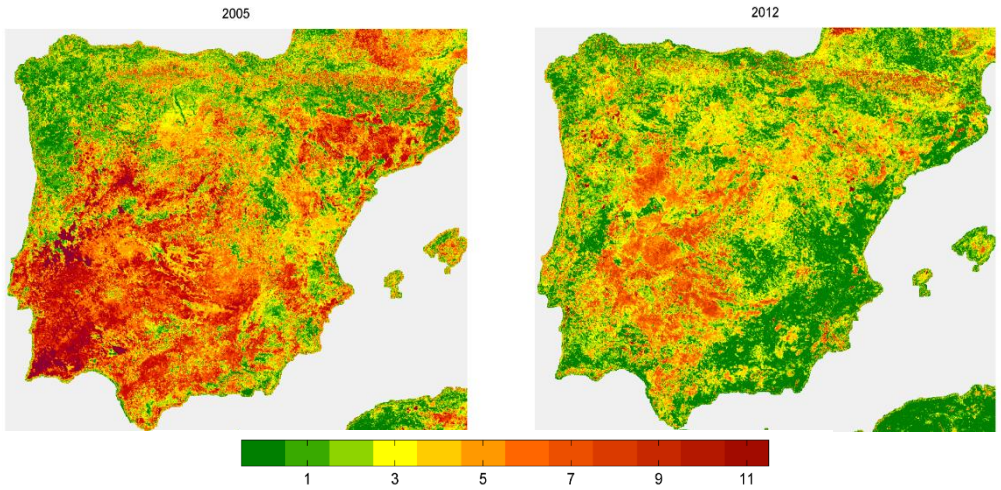
The year 2005 is extremely striking, reaching most of cases very low SPEI (<-2)

Drought Indices

SPI for 6 months over Iberia for 2005

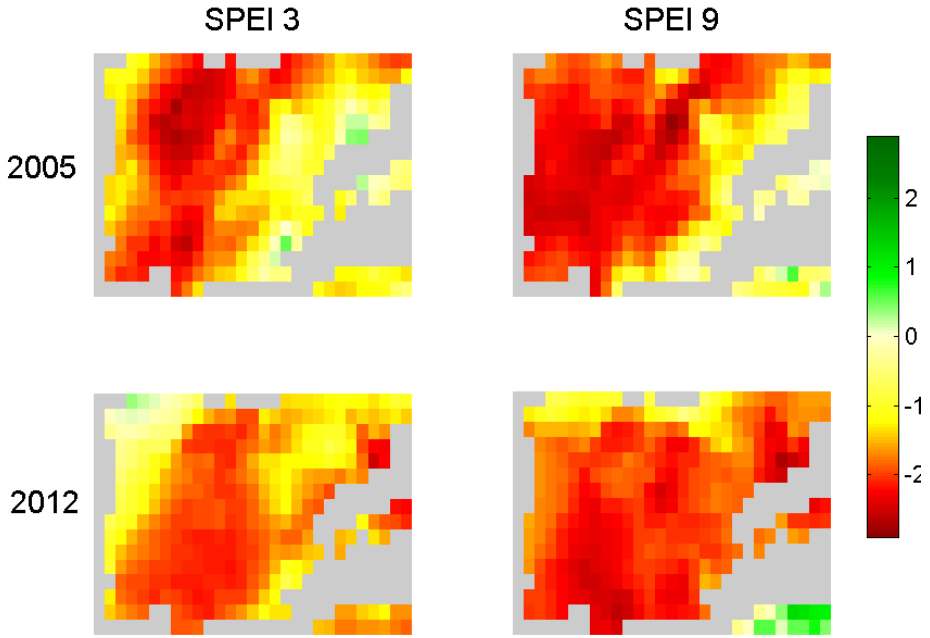


Drought Indices



Number of months between September and August of 2004/2005 (left panel) and 2011/2012 (right panel) characterized by NDVI anomaly values below 0.025.

The 3- and 9- SPEI for August 2005 and 2012 obtained from CRU TS3.21



Drought Impacts on Vegetation Dynamics

With the aim to determine:

- *the most vulnerable areas/land cover types,*
- *the seasons and drought-time scales more prone to cause negative effects on vegetation.*

The data used:

- *NDVI from GIMMS as obtained from NOAA-AVHRR (1982-2006)*
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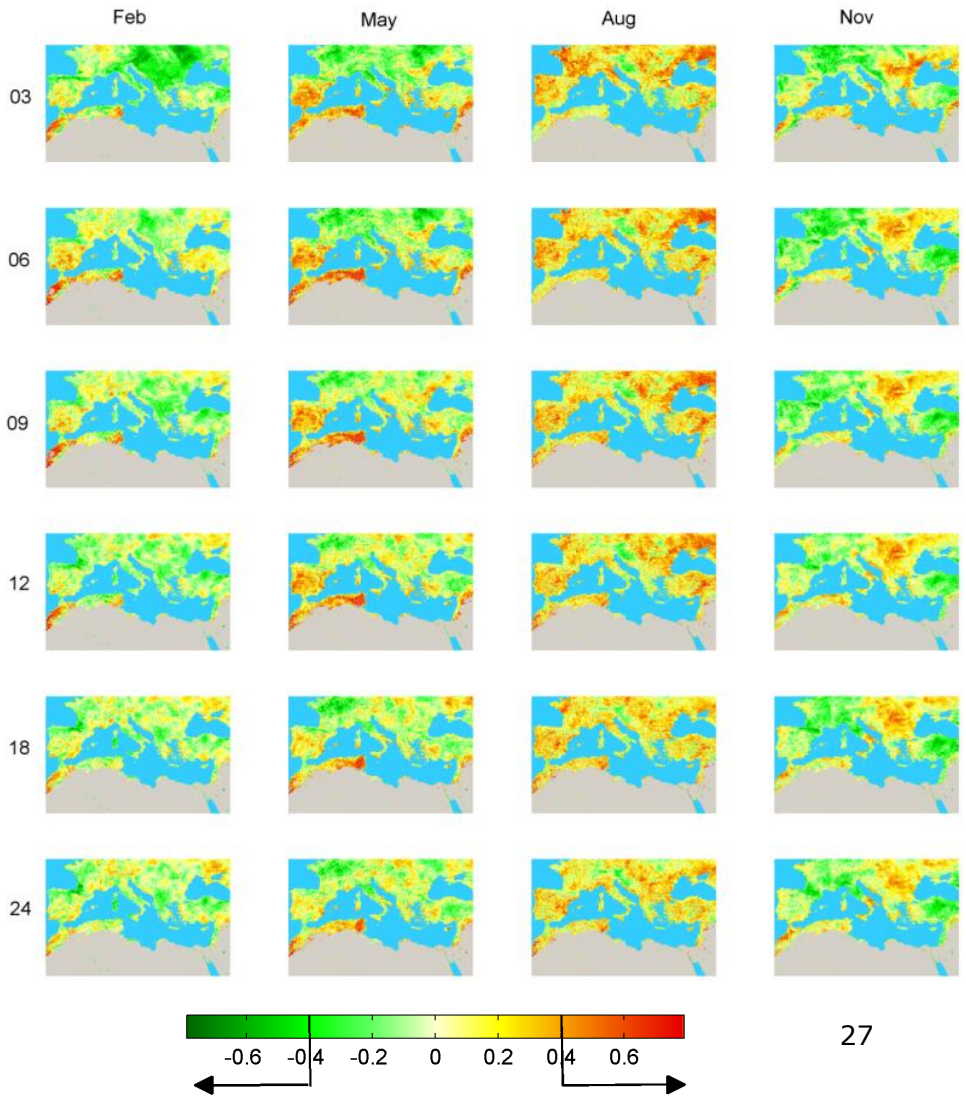
Spatial distribution of correlation values between NDVI vs. SPEI for February, May, August and November, using the temporal scales of 3, 6, 9 12, 18 and 24 months.



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- *on.*

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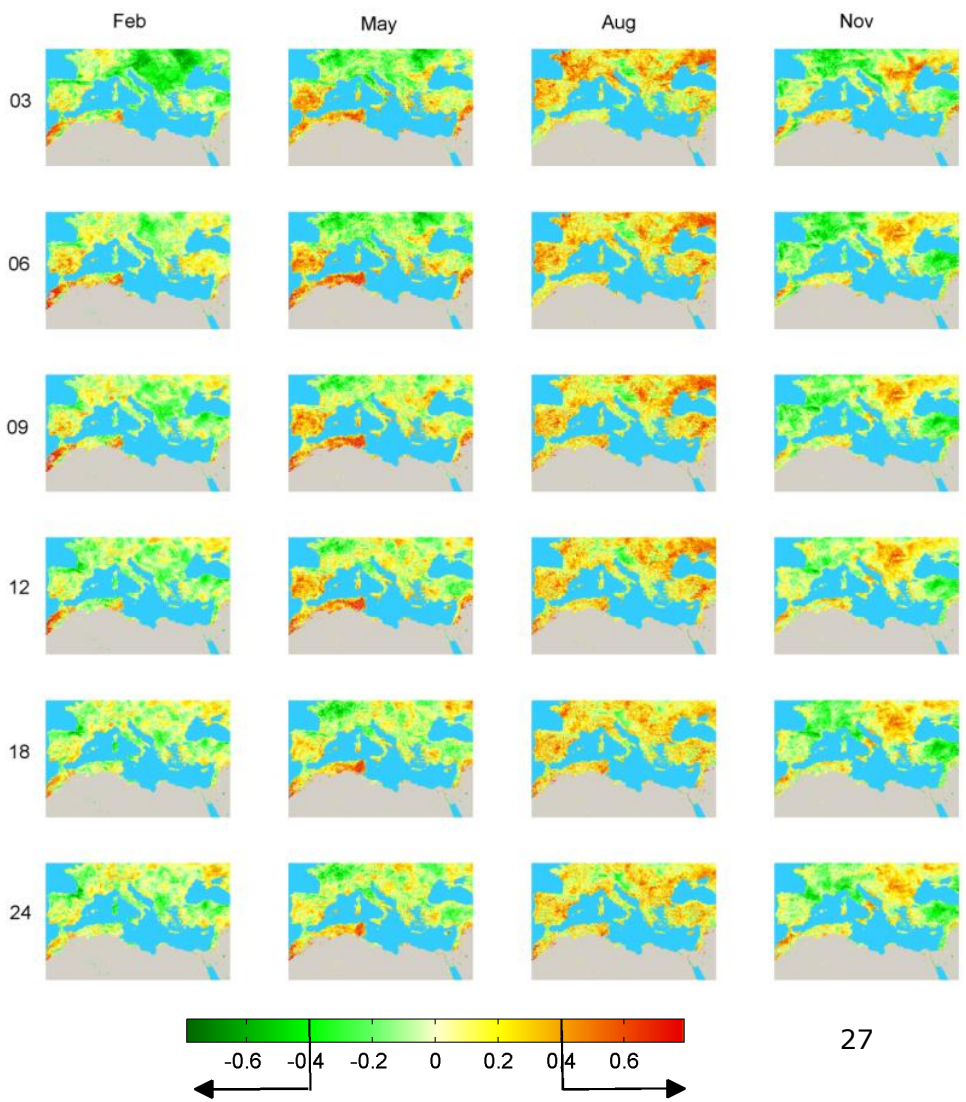

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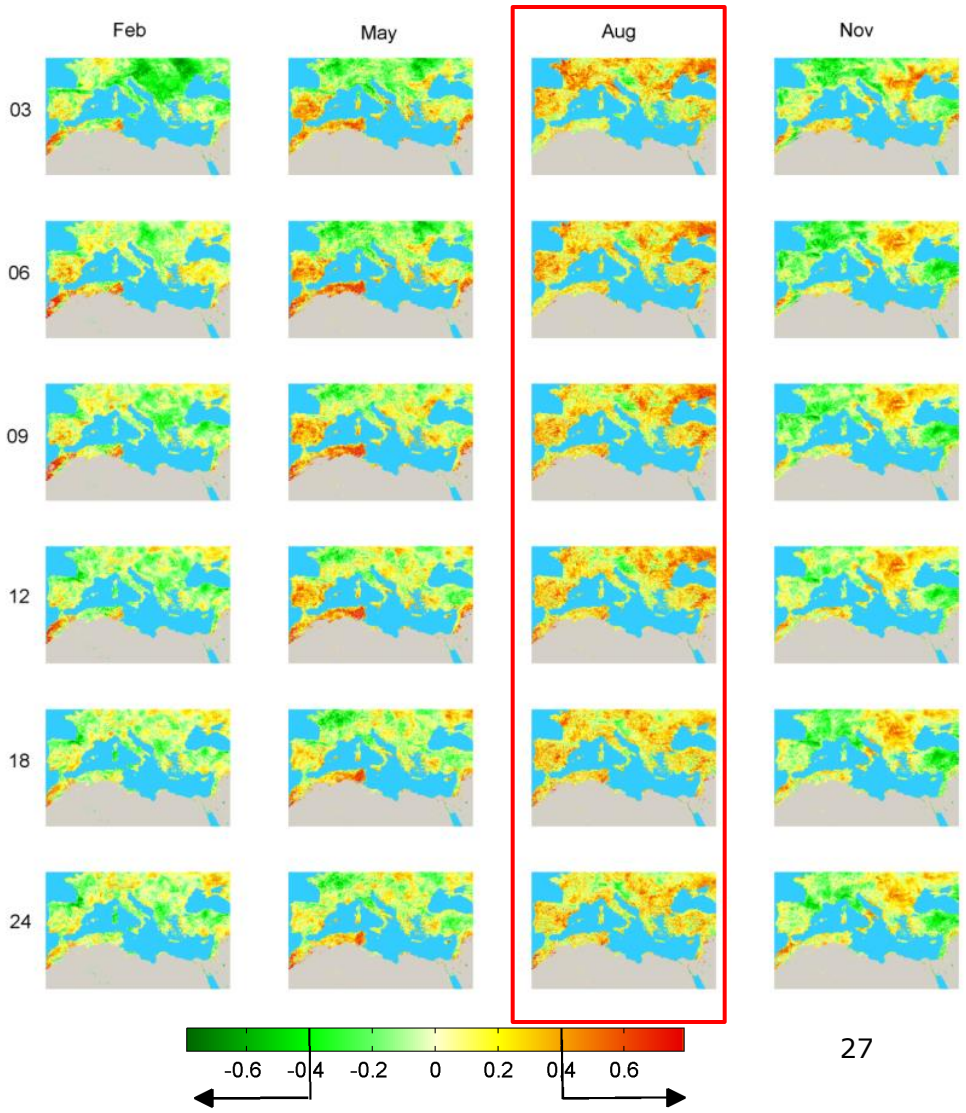
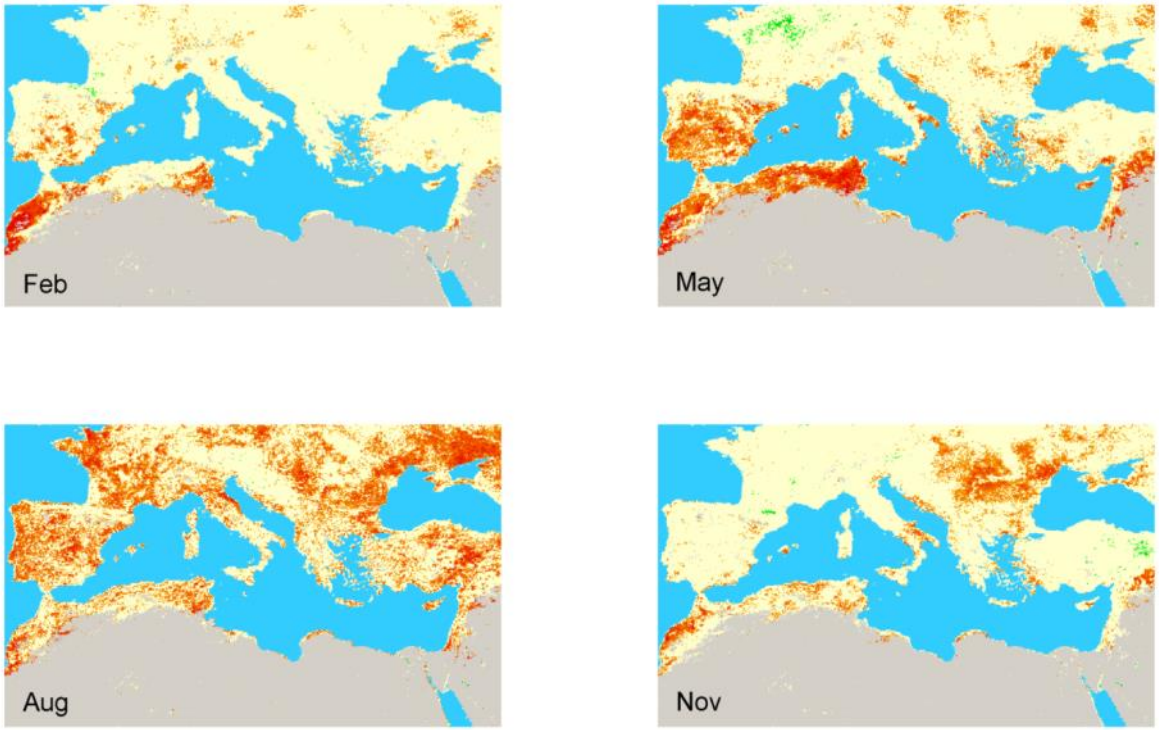


Drought Impacts on Vegetation Dynamics

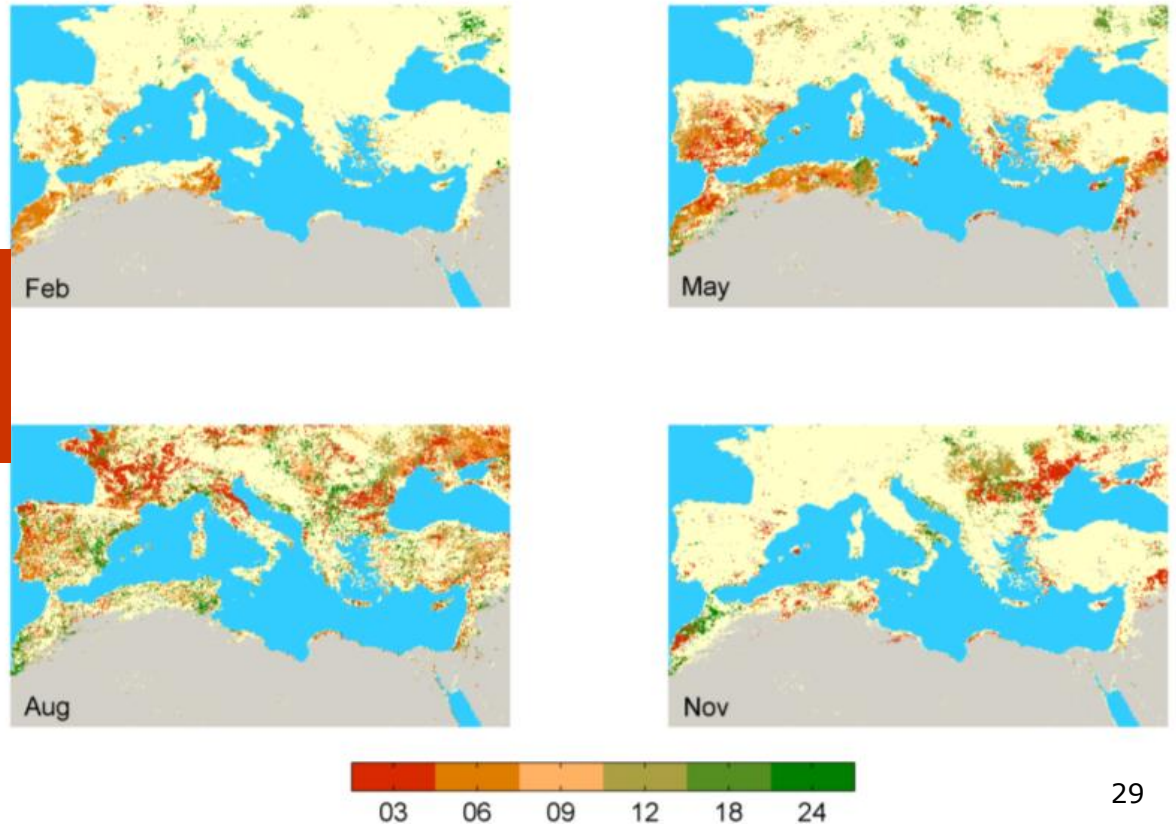
Spatial distribution of the maximum of the significant ($p<0.05$) grid point correlations (NDVI vs. SPEI), during February, May, August and November



Drought Impacts on Vegetation Dynamics

Spatial distribution of the time scale of the drought index SPEI corresponding to the maximum correlation NDVI vs. SPEI

Q11: What time scale/s is/are more frequent for May? And August?



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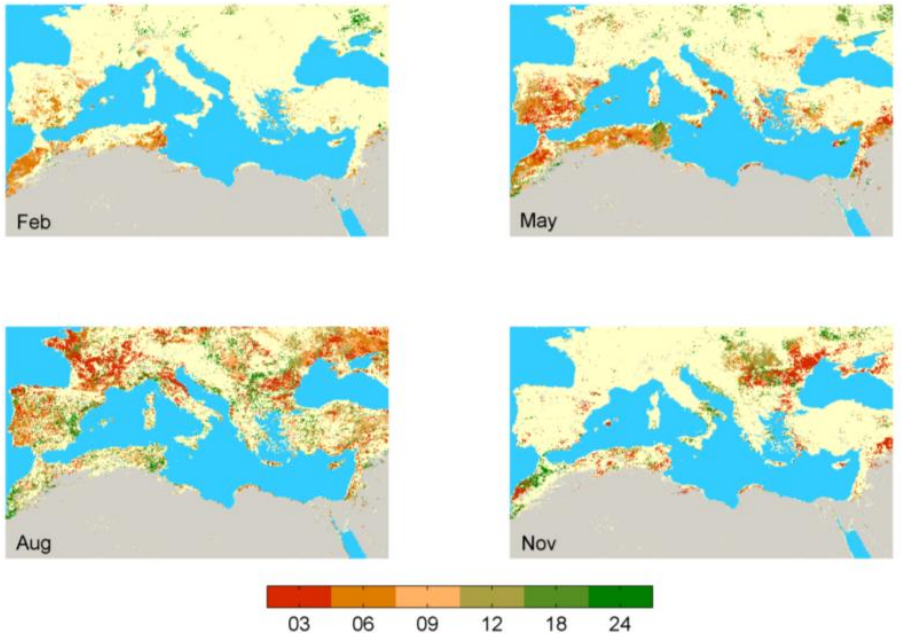

	SPEI03	SPEI06	SPEI09	SPEI12	SPEI18	SPEI24
Feb	7	54	15	3	8	13
May	24	30	21	10	7	8
Aug	29	17	18	14	10	12
Nov	42	10	5	16	13	14

Questions?

The end