

Utilización del *Standardized Precipitation Evapotranspiration Index (SPEI)* en el análisis y monitorización de las sequías: características, recomendaciones y comparación con otros indicadores

Application of the Standardized Precipitation Evapotranspiration Index (SPEI) for drought analysis and monitoring: characteristics, recommendations and comparison with other indices

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César AZORÍN-MOLINA**

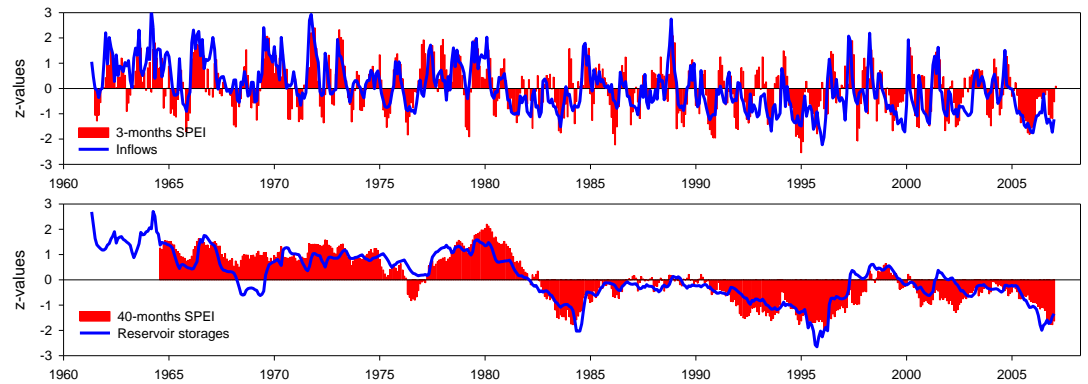
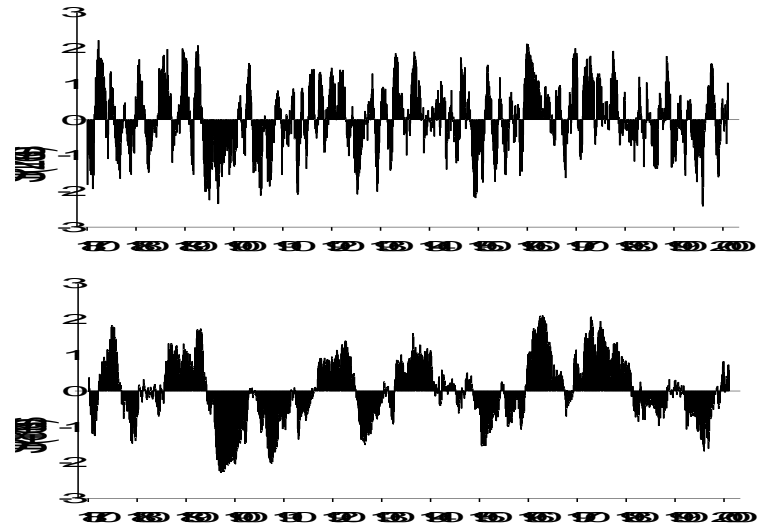
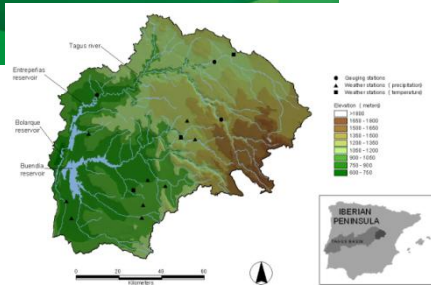
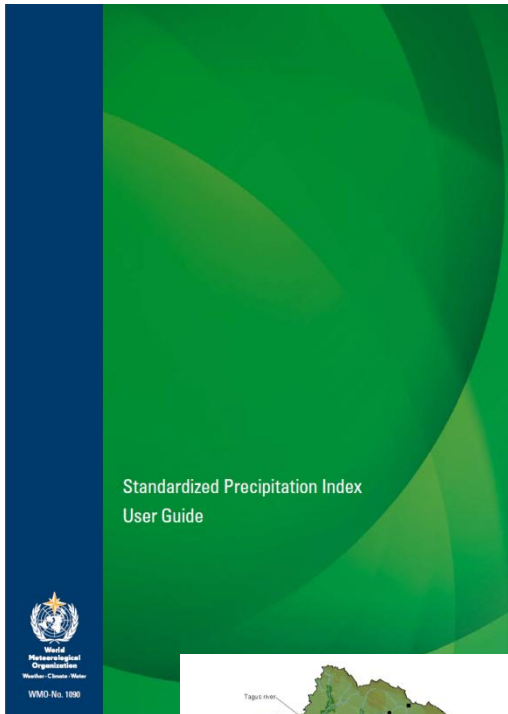
**Consejo Superior de Investigaciones Científicas
(Spanish National Research Council – Spain)**

THE COMPLEXITY OF DROUGHT QUANTIFICATION AND ANALYSIS

- Droughts are difficult to pinpoint in time and space given different economic sectors and natural systems affected.
- We identify a drought by its effects or impacts on different types of systems (agriculture, water resources, ecology, forestry, economy, etc.), but there is not a physical variable we can measure to quantify droughts.
- Long-term drought objective metrics (streamflows, soil moisture, lake levels, etc.) are commonly not available. Moreover, using only objective metrics other relevant variables to determine drought severity (e.g. the atmospheric water demand) are not taken into account.
- We use the so-called “DROUGHT INDICES” for drought quantification and analysis.



EXISTING DROUGHT INDICES



EXISTING DROUGHT INDICES

Precipitation-based drought indices, including the SPI, rely on two assumptions:

- 1) The variability of precipitation is much higher than that of other variables, such as the atmospheric water demand
- 2) The other variables are stationary (i.e., they have no temporal trend).

In this scenario, the importance of these other variables is negligible, and droughts are controlled by the temporal variability in precipitation.

Is this scenario plausible nowadays?



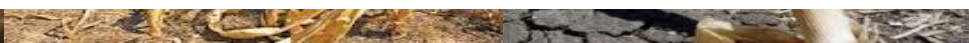
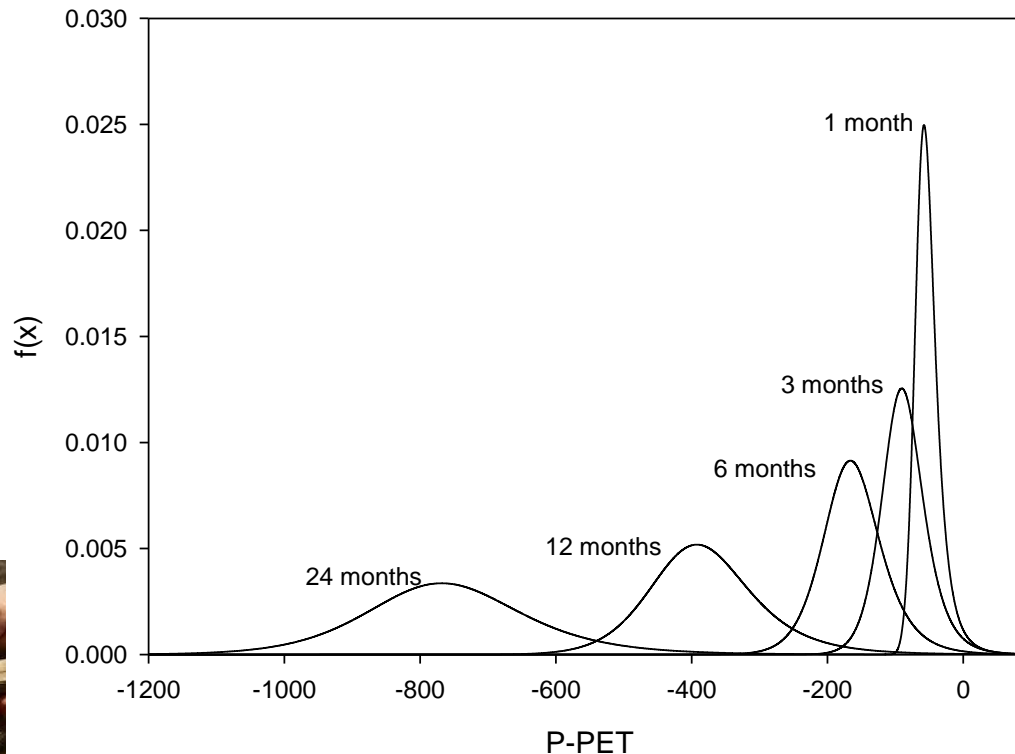
STANDARDIZED PRECIPITATION EVAPOTRANSPIRATION INDEX (SPEI)

The SPEI uses the difference between precipitation and ETo. This represents a simple climatic water balance which is calculated at different time scales to obtain the SPEI.

With a value for ETo, the difference between the precipitation (P) and PET for the month i is calculated according to:

$$D_i = P_i - ETo_i,$$

The calculated D values are aggregated at different time scales



STANDARDIZED PRECIPITATION EVAPOTRANSPIRATION INDEX (SPEI)

Vicente-Serrano S.M. et al., (2010) A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index – SPEI. *Journal of Climate* 23: 1696-1718.

Vicente-Serrano, S.M. et al. (2010): A new global 0.5° gridded dataset (1901-2006) of a multiscalar drought index: comparison with current drought index datasets based on the Palmer Drought Severity Index. *Journal of Hydrometeorology*. 11: 1033–1043

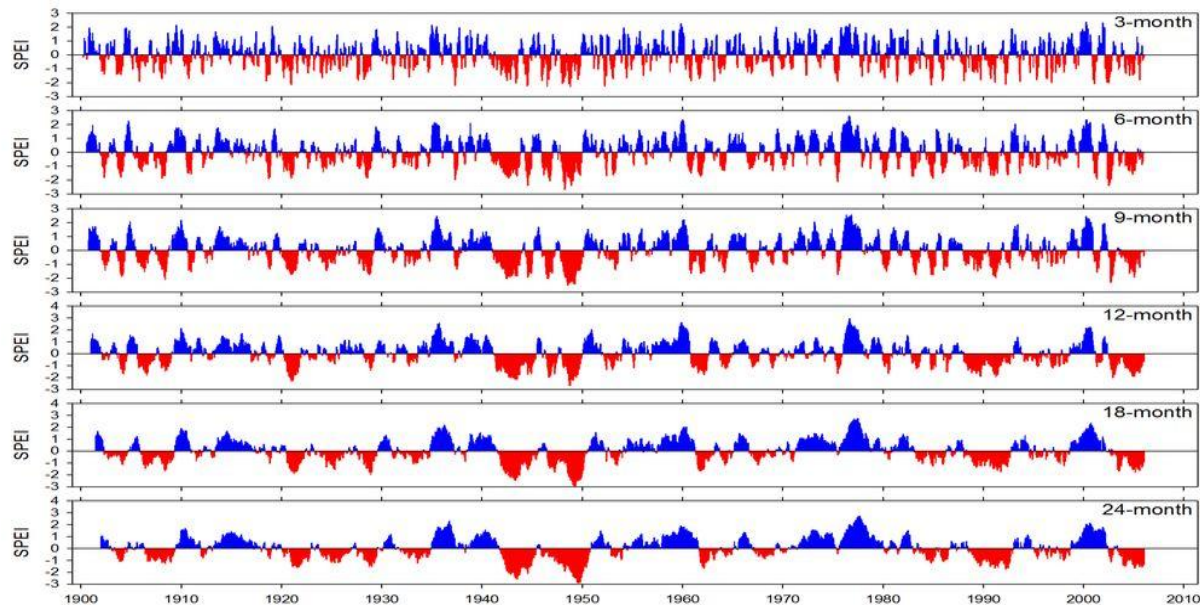
Beguería, S. et al., (2010): A multi-scalar global drought data set: the SPEIbase: A new gridded product for the analysis of drought variability and impacts. *Bulletin of the American Meteorological Society*. 91, 1351-1354

Vicente-Serrano, S.M. et al., (2011). Comment on “Characteristics and trends in various forms of the Palmer Drought Severity Index (PDSI) during 1900-2008” by A. Dai. *Journal of Geophysical Research-Atmosphere*. 116, D19112, doi:10.1029/2011JD016410

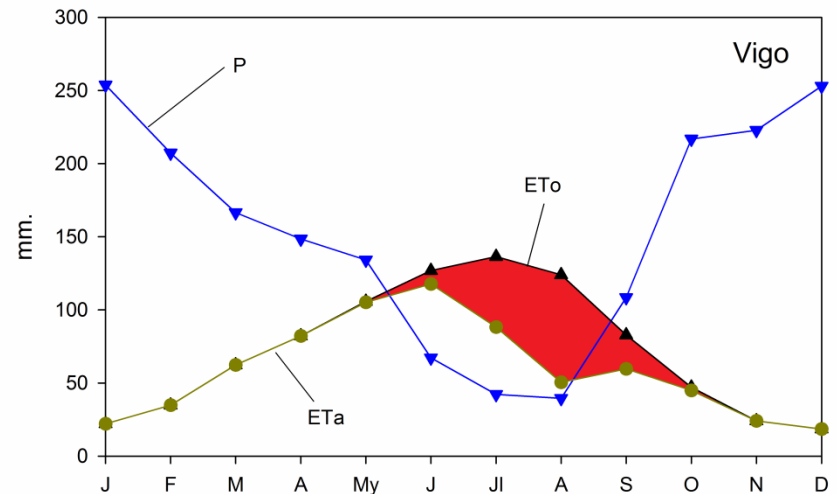
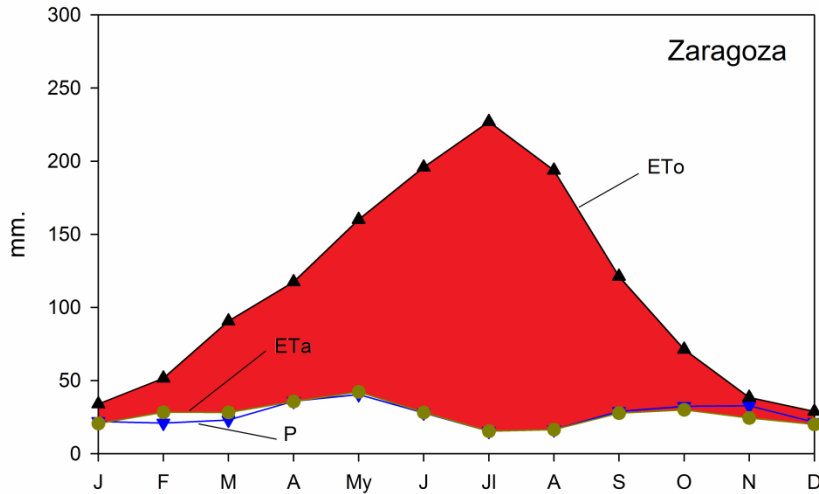
Vicente-Serrano, S.M. et al., (2012). Performance of Drought Indices for Ecological, Agricultural, and Hydrological Applications. *Earth Interactions*. 16:10.

Beguería, S., et al. (2014). Standardized Precipitation Evapotranspiration Index (SPEI) revisited: parameter fitting, evapotranspiration models, kernel weighting, tools, datasets and drought monitoring. *International Journal of Climatology*, 34: 3001–3023.

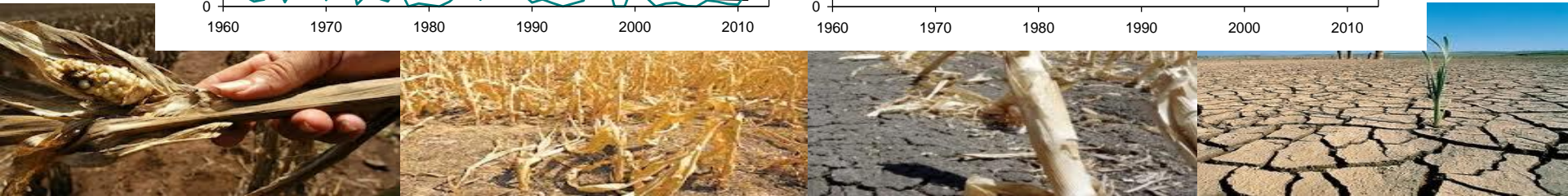
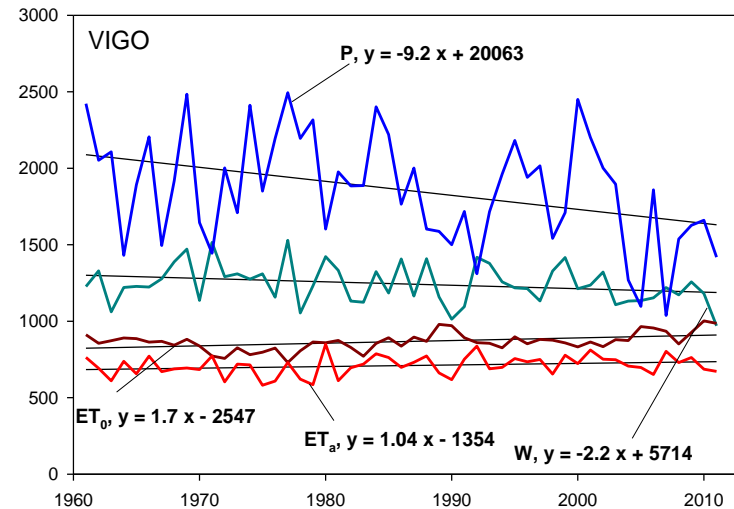
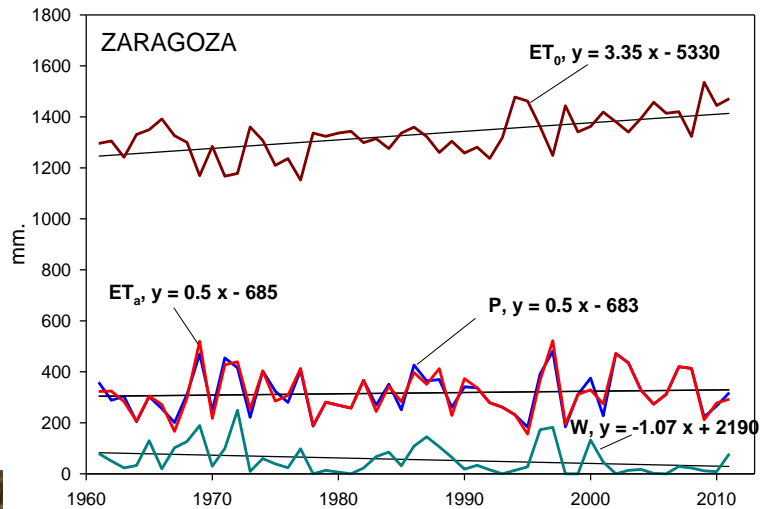
Vicente-Serrano, S.M., Gerard Van der Schrier, Santiago Beguería, Cesar Azorin-Molina, Juan-I. Lopez-Moreno. Contribution of precipitation and reference evapotranspiration to drought indices under different climates. *Journal of Hydrology*. In press.



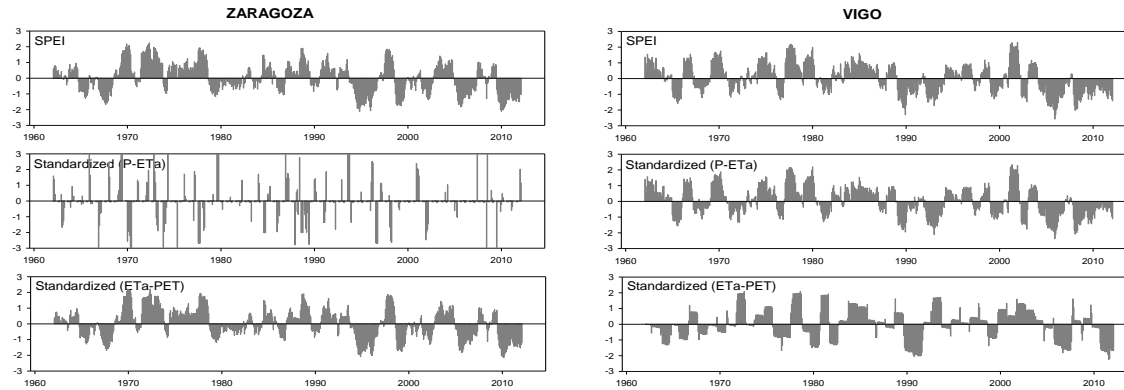
STANDARDIZED PRECIPITATION EVAPOTRANSPIRATION INDEX (SPEI)



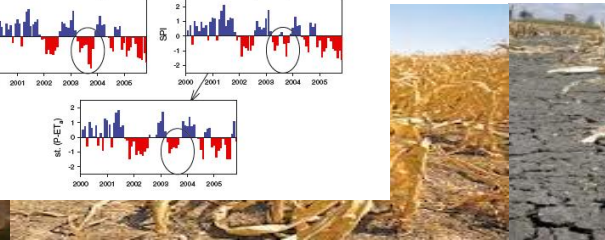
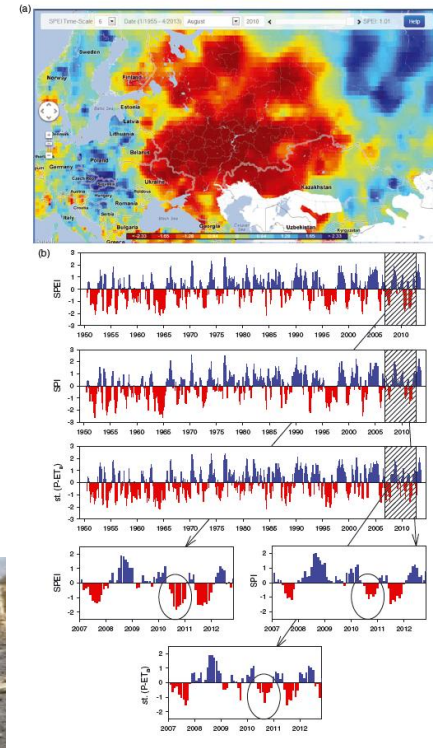
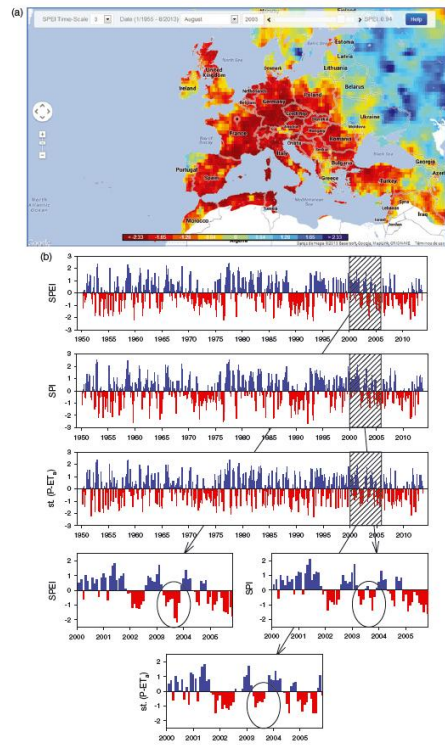
Beguera et al. (2014): International Journal of Climatology. 34: 3001–3023



STANDARDIZED PRECIPITATION EVAPOTRANSPIRATION INDEX (SPEI)



Beguera et al. (2014): International Journal of Climatology



ADVANTAGES IN COMPARISON TO OTHER INDICES

- The SPEI solves the problems of spatial comparability of the PDSI.

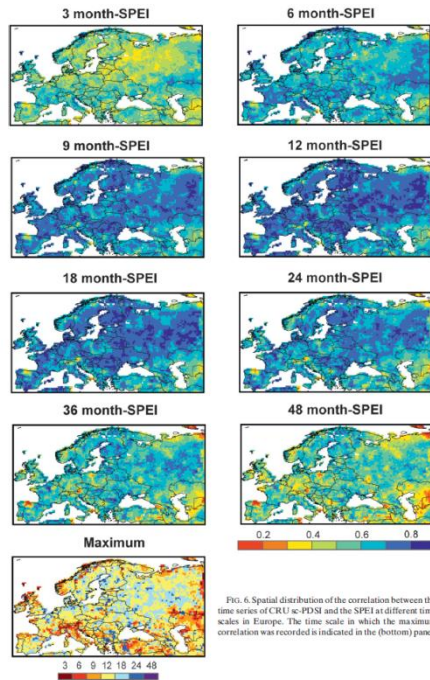


FIG. 6. Spatial distribution of the correlation between the time series of CRU uc-PDSI and the SPEI at different time scales in Europe. The time scale in which the maximum correlation was recorded is indicated in the (bottom) panel.

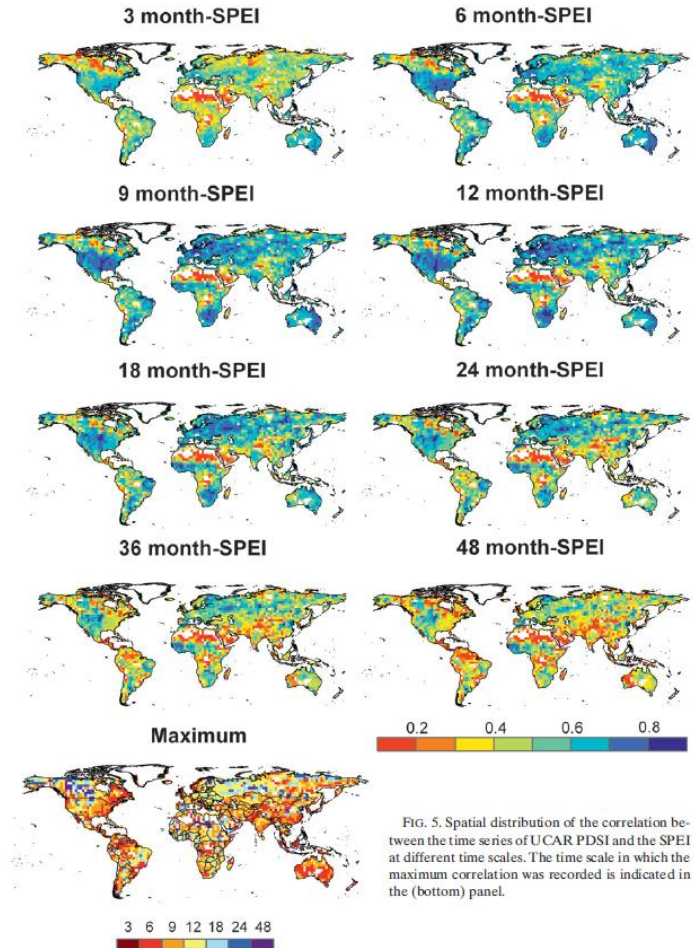


FIG. 5. Spatial distribution of the correlation between the time series of U CAR PDSI and the SPEI at different time scales. The time scale in which the maximum correlation was recorded is indicated in the (bottom) panel.

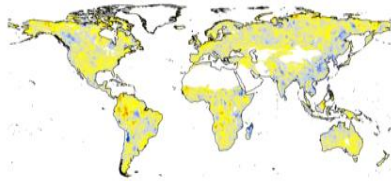
Vicente-Serrano, S.M., et al. (2010). Journal of Hydrometeorology. 11: 1033–1043



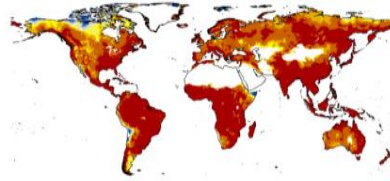
ADVANTAGES IN COMPARISON TO OTHER INDICES

PRECIPITATION

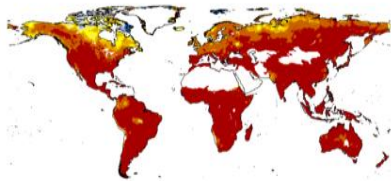
PDSI



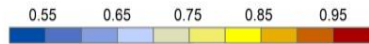
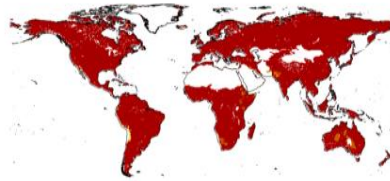
SPEI



RDI

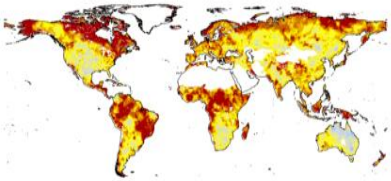


SPDI

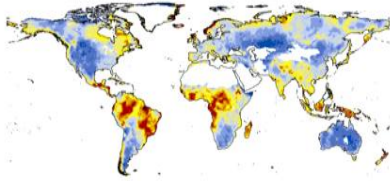


REFERENCE EVAPOTRANSPIRATION

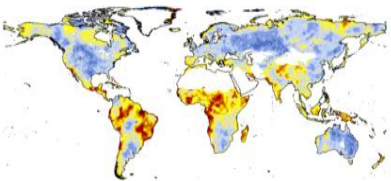
PDSI



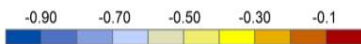
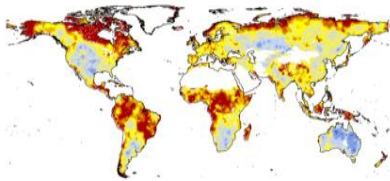
SPEI



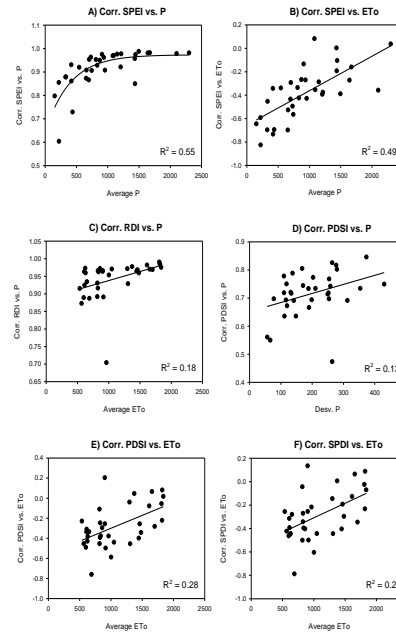
RDI



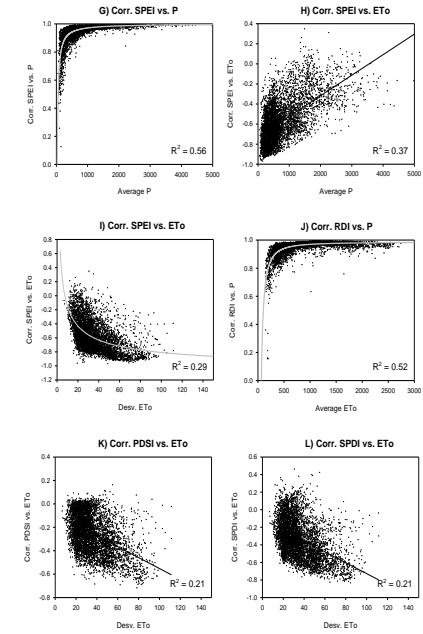
SPDI



OBSERVATORIES



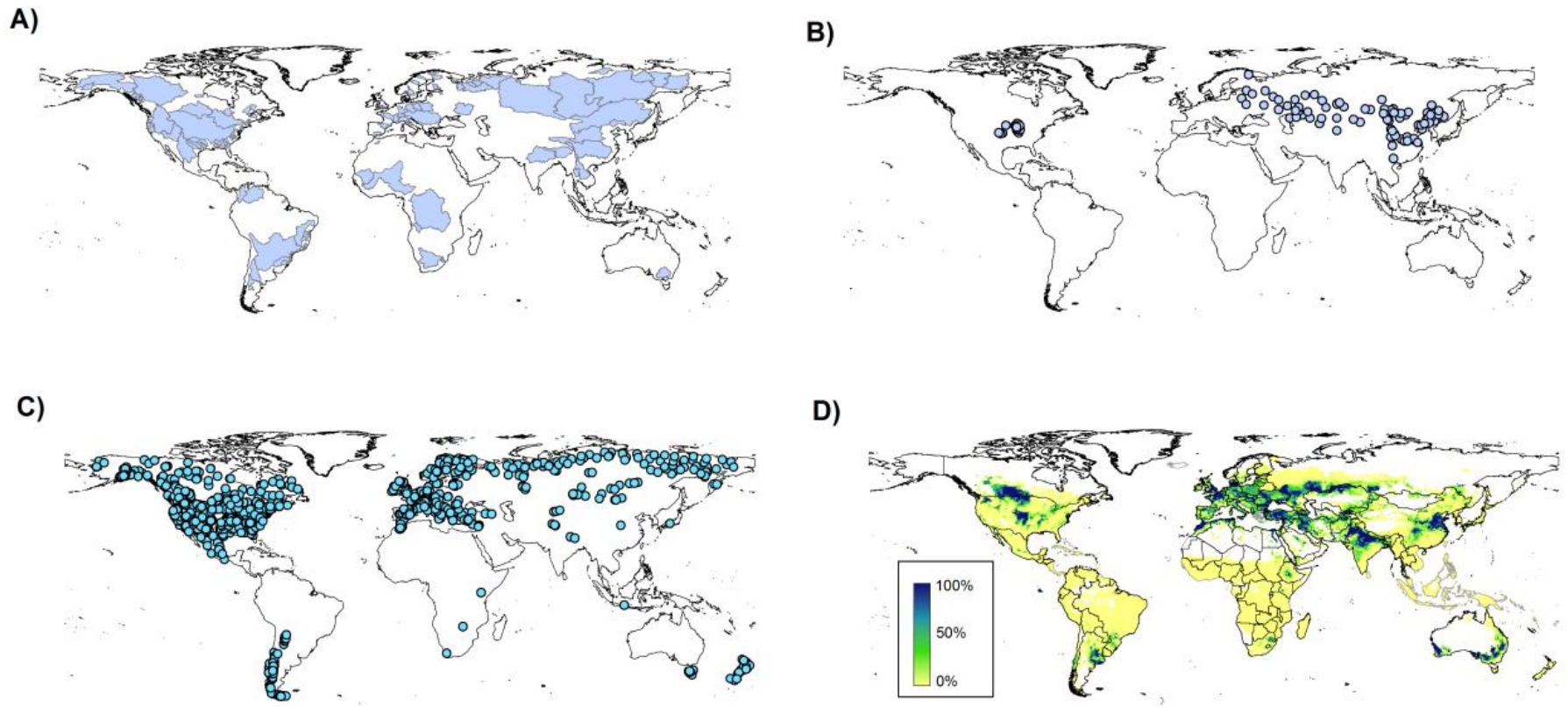
GRIDDED DATA



Vicente-Serrano, S.M., Gerard Van der Schrier, Santiago Beguería, Cesar Azorín-Molina, Juan-I. Lopez-Moreno. Contribution of precipitation and reference evapotranspiration to drought indices under different climates. *Journal of Hydrology*. In press



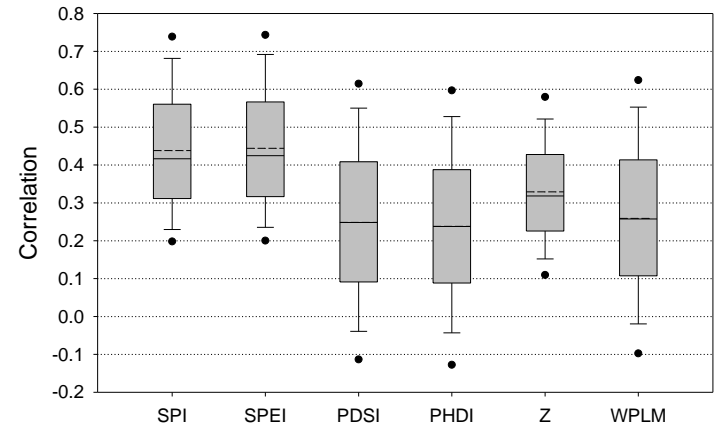
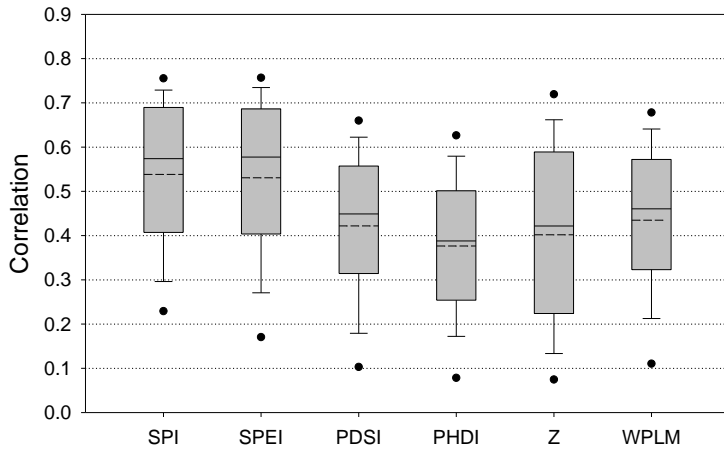
ADVANTAGES IN COMPARISON TO OTHER INDICES



Vicente-Serrano, S.M., et al. (2012) Performance of drought indices for ecological, agricultural and hydrological applications. *Earth Interactions* 16, 1–27.



ADVANTAGES IN COMPARISON TO OTHER INDICES



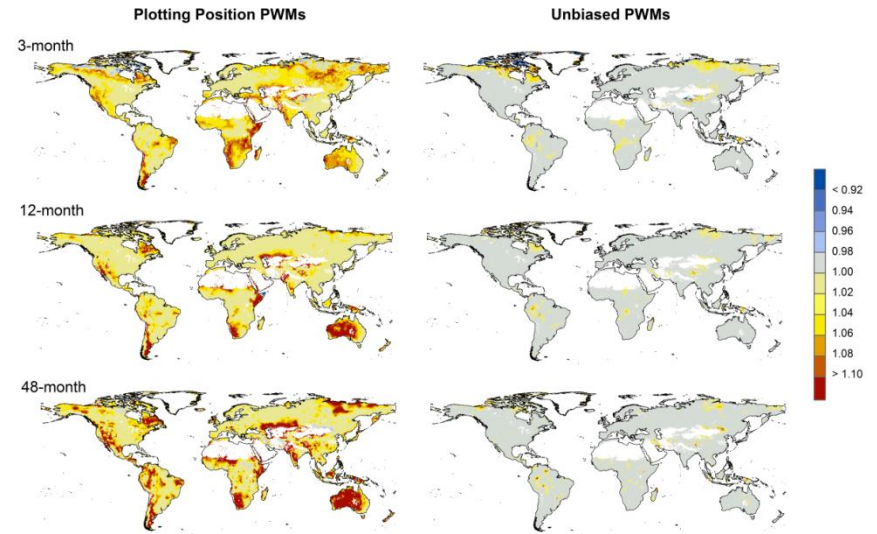
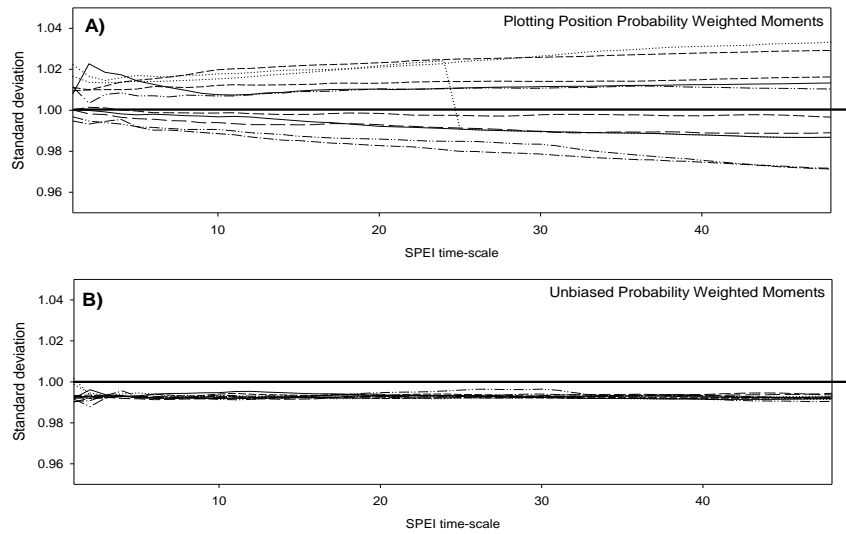
	CONTINUOUS	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
SPI	38.4	49.0	57.6	52.3	48.3	37.1	31.8	33.8	29.8	42.4	57.6	59.6	53.0
SPEI	44.4	33.1	31.1	37.7	40.4	52.3	54.3	47.0	53.0	43.0	31.8	32.5	30.5
PDSI	4.0	0.7	2.0	3.3	3.3	2.0	4.0	4.6	6.0	2.6	1.3	2.6	2.0
PHDI	0.0	2.0	1.3	1.3	2.0	1.3	2.0	2.0	2.0	2.6	0.7	1.3	2.6
Z-Index	7.3	13.9	4.0	4.0	5.3	4.6	5.3	6.0	4.0	5.3	5.3	2.6	10.6
WPLM	6.0	1.3	4.0	1.3	0.7	2.6	2.6	6.6	5.3	4.0	3.3	1.3	1.3

DROUGHT INDEX	April	May	June	July	August	September	October
SPI	48.3	43.1	44.8	31	31.9	32.8	42.2
SPEI	44.0	46.6	44.8	56	51.7	49.1	44.0
PDSI	4.3	3.4	2.6	6.9	5.2	3.4	3.4
PHDI	0.9	2.6	3.4	0.9	3.4	3.4	2.6
Z	1.7	2.6	2.6	1.7	4.3	6.0	3.4
WPLM	0.9	1.7	1.7	3.4	3.4	5.2	4.3

Vicente-Serrano, S.M., et al. (2012) Performance of drought indices for ecological, agricultural and hydrological applications. Earth Interactions 16, 1–27.



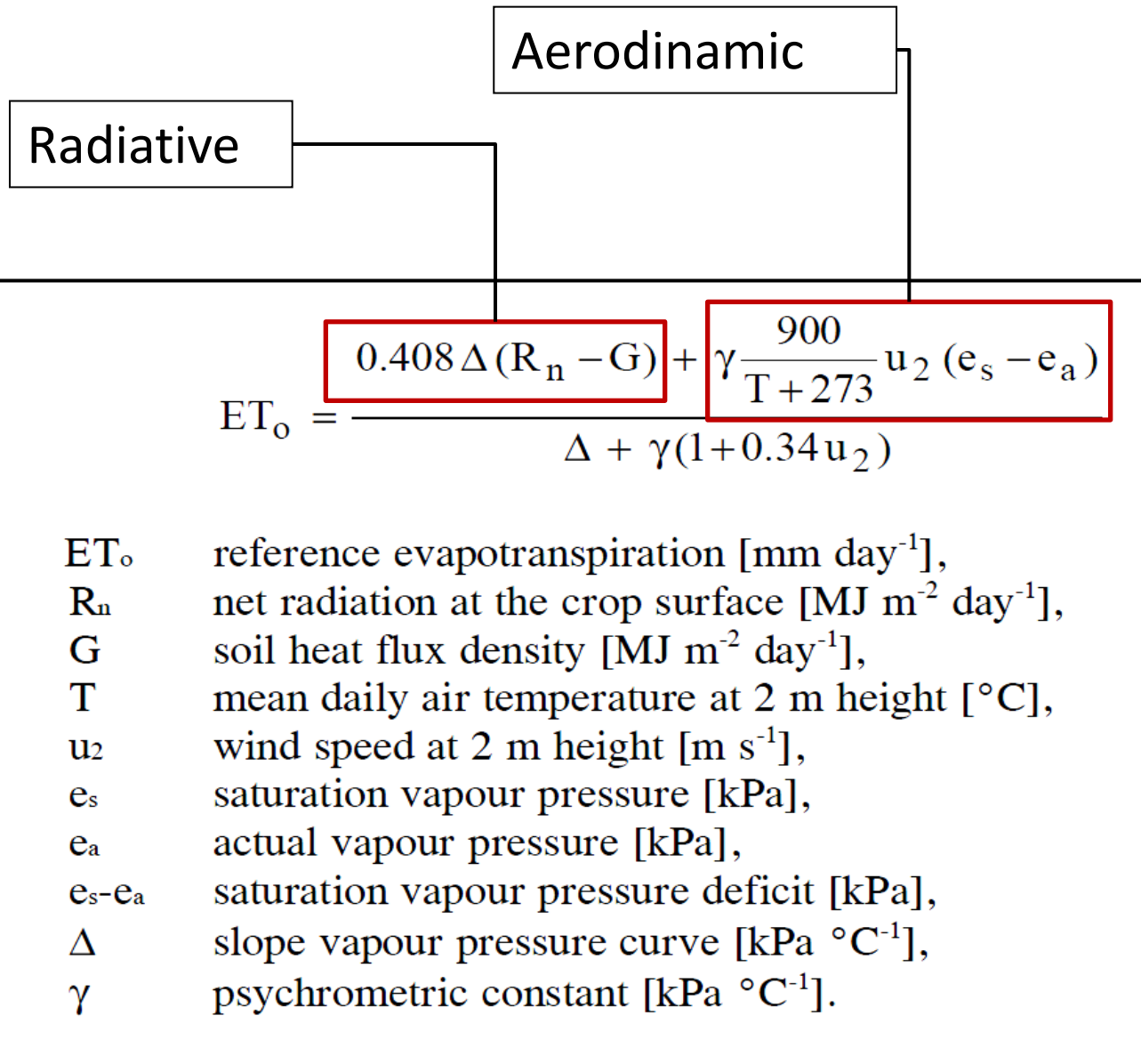
RECOMMENDATIONS TO CALCULATE THE SPEI



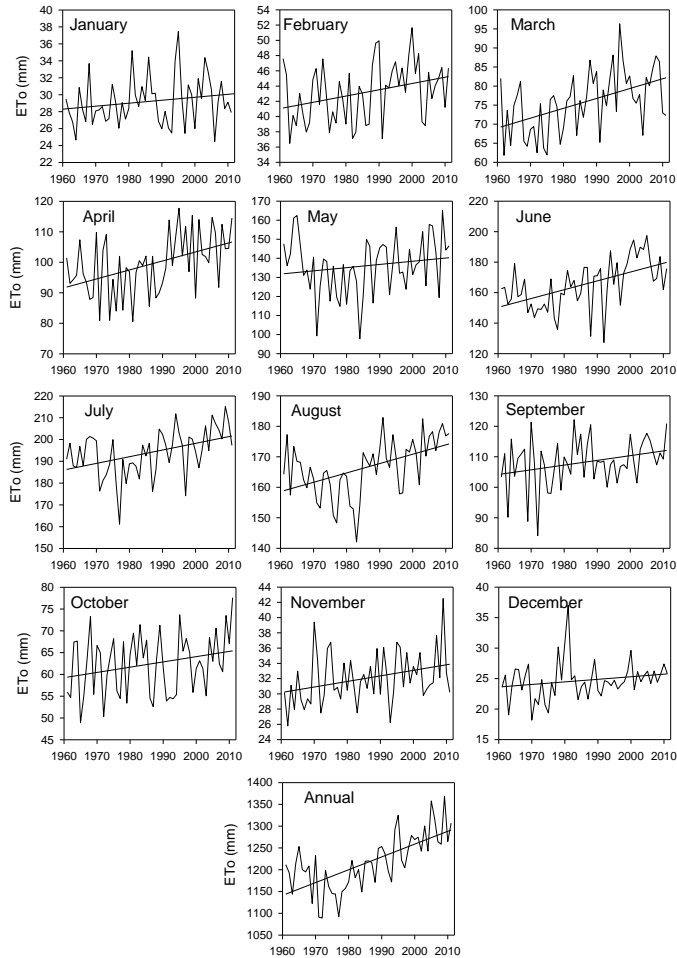
Beguéría et al. (2014): International Journal of Climatology. 34: 3001–3023



RECOMMENDATIONS TO CALCULATE THE SPEI

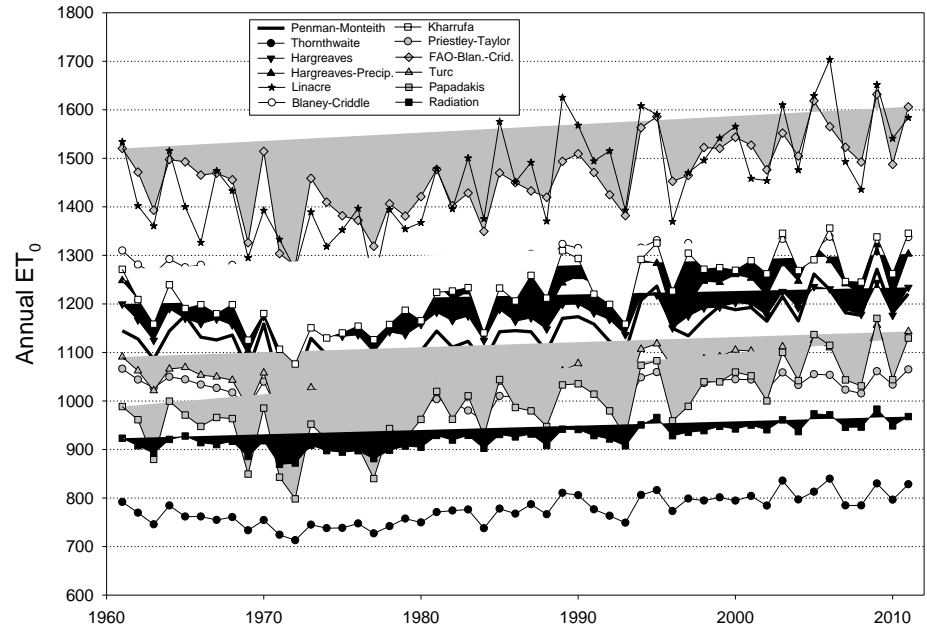


RECOMMENDATIONS TO CALCULATE THE SPEI

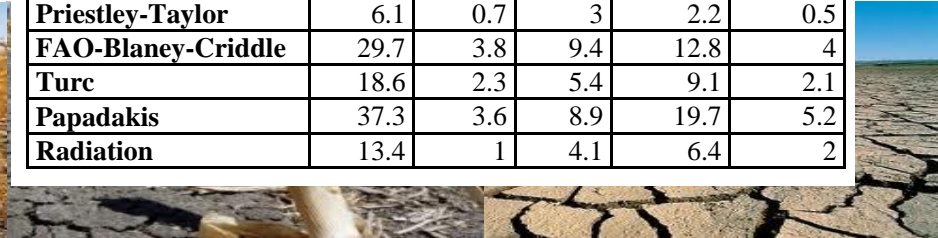


Vicente-Serrano, S.M., et al. (2014). Sensitivity of reference evapotranspiration to changes in meteorological parameters in Spain (1961-2011). *Water Resources Research*.

Vicente-Serrano, S.M., et al (2014). Reference evapotranspiration variability and trends in Spain, 1961–2011. *Global and Planetary Change*.

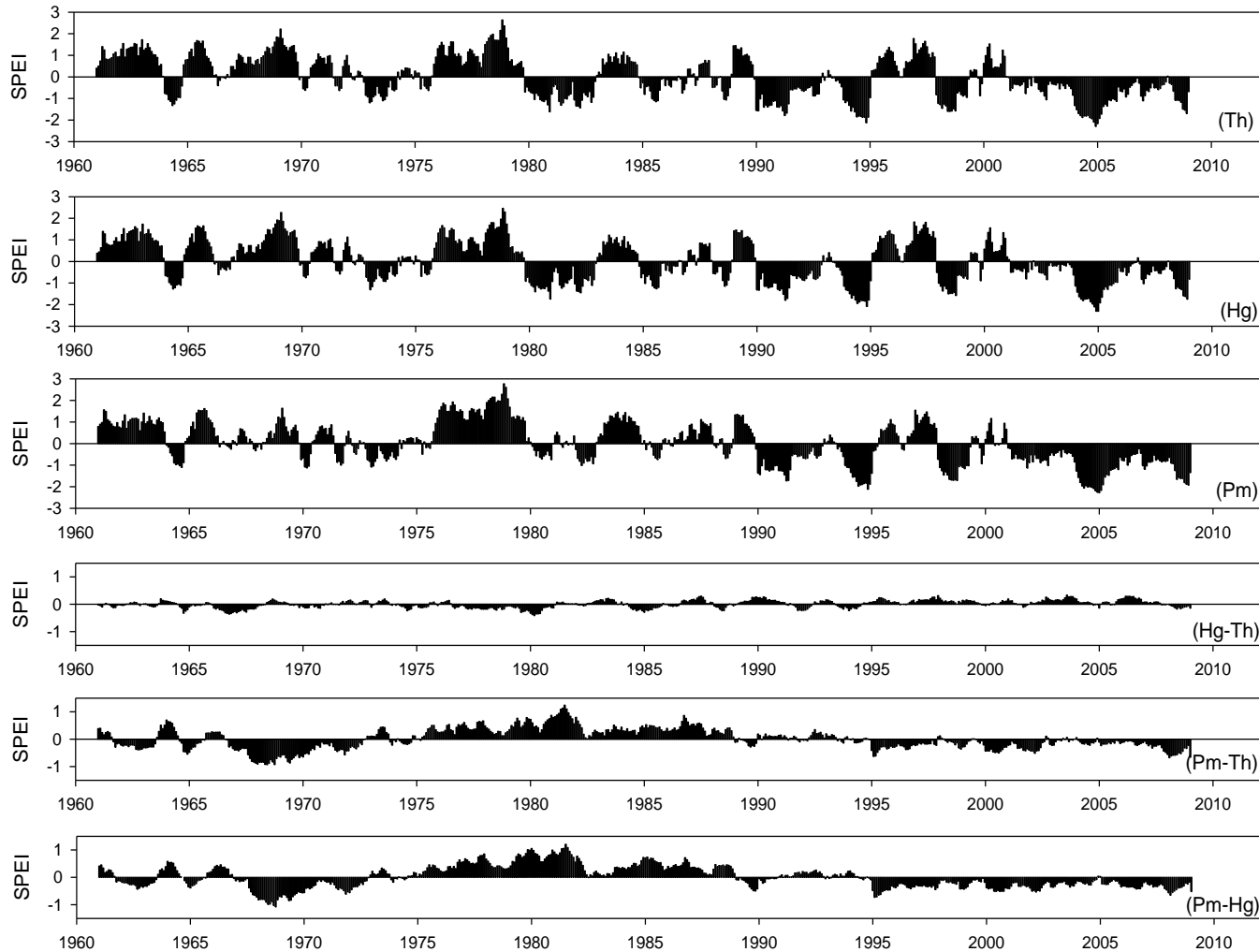


	Annual	Winter	Spring	Summer	Autumn
Penman-Montheith	24.5	1.8	7.3	12	3.5
Thornthwaite	14.3	0	3.5	9.8	1
Hargreaves	15.1	1.9	5.6	6.4	1.3
Hargreaves-pp.	19.2	2.8	7.1	8.2	1.4
Linacre	42.8	7.2	12.4	16.7	7.2
Blaney-Criddle	12.3	1.5	4	5	1.9
Kharrufa	31.6	3	9.7	14.4	4.8
Priestley-Taylor	6.1	0.7	3	2.2	0.5
FAO-Blaney-Criddle	29.7	3.8	9.4	12.8	4
Turc	18.6	2.3	5.4	9.1	2.1
Papadakis	37.3	3.6	8.9	19.7	5.2
Radiation	13.4	1	4.1	6.4	2



RECOMMENDATIONS TO CALCULATE THE SPEI

Beguera et al. (2014): International Journal of Climatology. 34: 3001–3023


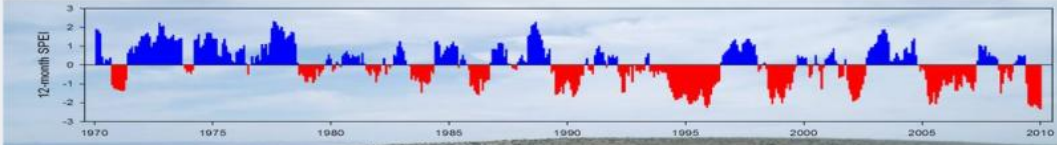


RECOMMENDATIONS TO CALCULATE THE SPEI

<http://sac.csic.es/spei/index.html>

Home About the SPEI Global drought monitor Global SPEI database Tools Contact SPEI

SPEI



Steppe areas affected by degradation processes in the central Ebro basin (Spain) and the evolution of the 12-month SPEI in the area. See details in Vicente-Serrano et al. (2012) Dryness is accelerating degradation of vulnerable shrublands in semiarid Mediterranean environments. *Ecological Monographs*, 82, 407–428.

The Standardised Precipitation-Evapotranspiration Index

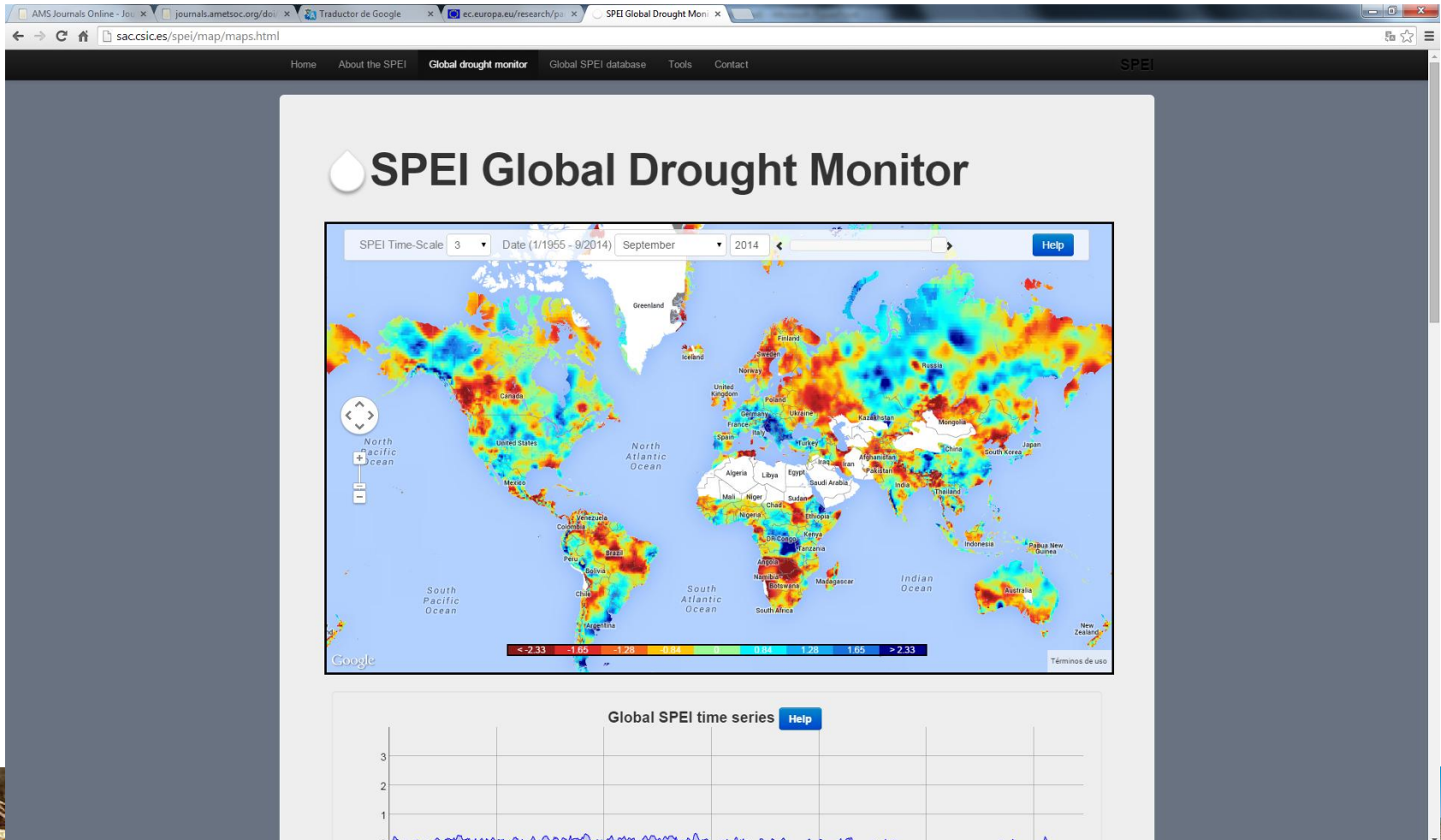
The SPEI is a multiscalar drought index based on climatic data. It can be used for determining the onset, duration and magnitude of drought conditions with respect to normal conditions in a variety of natural and managed systems such as crops, ecosystems, rivers, water resources, etc.

[Learn more »](#)



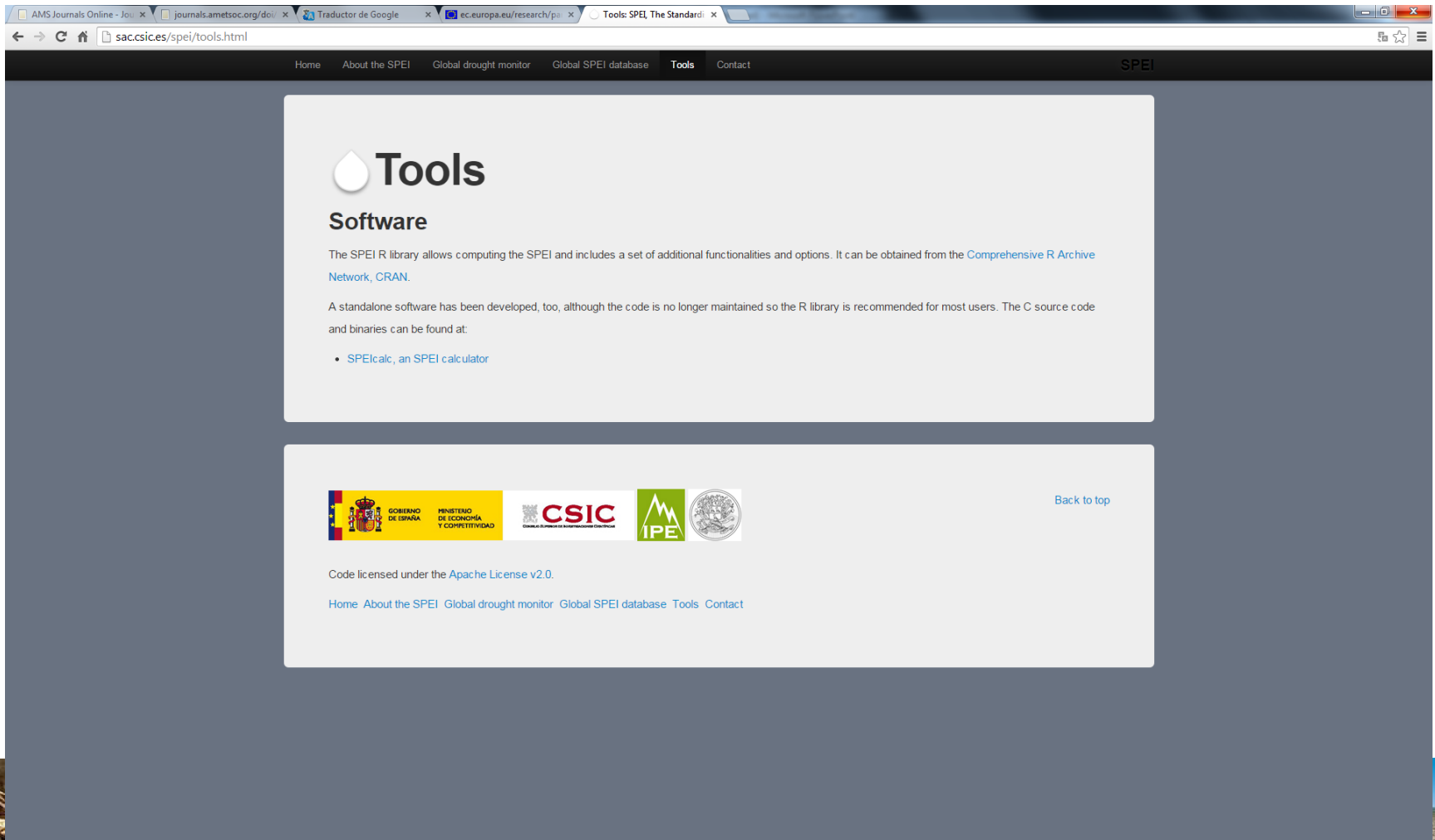
RECOMMENDATIONS TO CALCULATE THE SPEI

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RECOMMENDATIONS TO CALCULATE THE SPEI

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The screenshot shows a web browser window with the URL sac.csic.es/spei/tools.html. The page has a dark navigation bar with links for Home, About the SPEI, Global drought monitor, Global SPEI database, Tools, and Contact. The main content area is white and features a large 'Tools' heading with a water drop icon. Below this is a 'Software' section with text explaining the SPEI R library and a link to the Comprehensive R Archive Network (CRAN). A standalone software option is also mentioned. A list of tools includes 'SPEIcalc, an SPEI calculator'. At the bottom, there are logos for the Spanish Government, CSIC, and IPE, along with a 'Back to top' link and a footer with navigation links.


Tools

Software

The SPEI R library allows computing the SPEI and includes a set of additional functionalities and options. It can be obtained from the [Comprehensive R Archive Network, CRAN](#).

A standalone software has been developed, too, although the code is no longer maintained so the R library is recommended for most users. The C source code and binaries can be found at:

- [SPEIcalc, an SPEI calculator](#)



[Back to top](#)

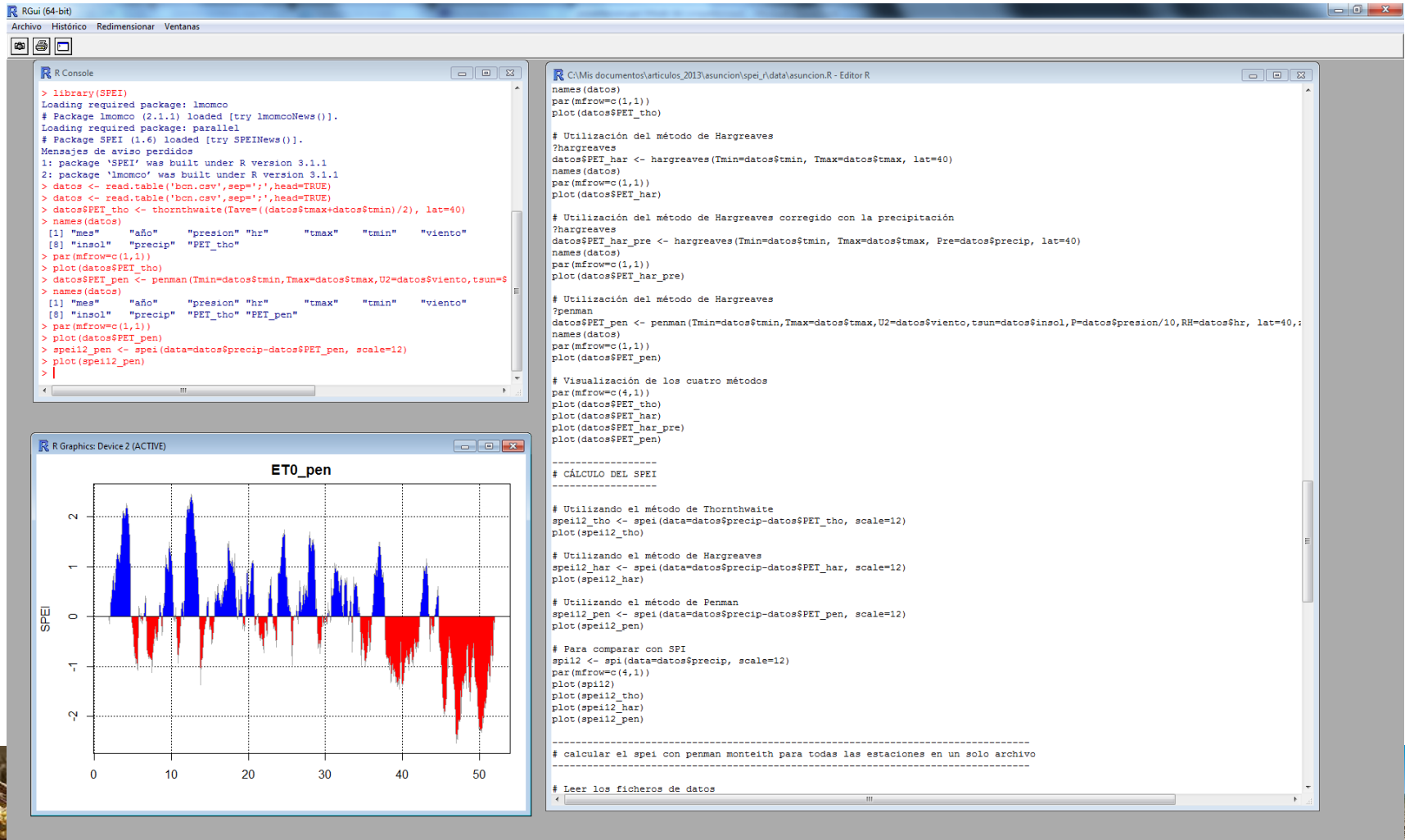
Code licensed under the [Apache License v2.0](#).

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RECOMMENDATIONS TO CALCULATE THE SPEI

<http://sac.csic.es/spei/index.html>



The screenshot displays the R GUI interface with two main windows. The top-left window is the R Console, showing the execution of R code to load the 'SPEI' package and process data. The top-right window is the R Editor, containing the source code for calculating SPEI using various methods: Thornthwaite, Hargreaves, Hargreaves corrected with precipitation, and Penman-Monteith. The bottom-left window is the R Graphics Device, showing a plot titled 'ET0_pen' with SPEI values on the y-axis (ranging from -2 to 2) and time on the x-axis (ranging from 0 to 50). The plot shows a highly variable time series with positive values (blue) and negative values (red).

```
> library(SPEI)
Loading required package: lmomco
# Package lmomco (2.1.1) loaded [try lmomcoNews()].
Loading required package: parallel
# Package SPEI (1.6) loaded [try SPEINews()].
Mensajes de aviso perdidos
1: package 'SPEI' was built under R version 3.1.1
2: package 'lmomco' was built under R version 3.1.1
> datos <- read.table('bcn.csv', sep=';', head=TRUE)
> datos <- read.table('bcn.csv', sep=';', head=TRUE)
> datos$PET_tho <- thornthwaite(Tave=(datos$Tmax+datos$Tmin)/2, lat=40)
> names(datos)
[1] "mes"      "año"      "presion"  "hr"       "tmax"     "tmin"     "viento"
[8] "insol"    "precip"   "PET_tho"
> par(mfrow=c(1,1))
> plot(datos$PET_tho)
> datos$PET_pen <- penman(Tmin=datos$Tmin, Tmax=datos$Tmax, U2=datos$Viento, tsun=$
> names(datos)
[1] "mes"      "año"      "presion"  "hr"       "tmax"     "tmin"     "viento"
[8] "insol"    "precip"   "PET_tho"  "PET_pen"
> par(mfrow=c(1,1))
> plot(datos$PET_pen)
> spei2_pen <- spei(data=datos$precip-datos$PET_pen, scale=12)
> plot(spei2_pen)
|
```

```
names(datos)
par(mfrow=c(1,1))
plot(datos$PET_tho)

# Utilización del método de Hargreaves
?hargreaves
datos$PET_har <- hargreaves(Tmin=datos$tmin, Tmax=datos$tmax, lat=40)
names(datos)
par(mfrow=c(1,1))
plot(datos$PET_har)

# Utilización del método de Hargreaves corregido con la precipitación
?hargreaves
datos$PET_har_pre <- hargreaves(Tmin=datos$tmin, Tmax=datos$tmax, Pre=datos$precip, lat=40)
names(datos)
par(mfrow=c(1,1))
plot(datos$PET_har_pre)

# Utilización del método de Hargreaves
?penman
datos$PET_pen <- penman(Tmin=datos$tmin, Tmax=datos$tmax, U2=datos$Viento, tsun=datos$insol, P=datos$presion/10, RH=datos$hr, lat=40,
names(datos)
par(mfrow=c(1,1))
plot(datos$PET_pen)

# Visualización de los cuatro métodos
par(mfrow=c(4,1))
plot(datos$PET_tho)
plot(datos$PET_har)
plot(datos$PET_har_pre)
plot(datos$PET_pen)

-----
# CÁLCULO DEL SPEI

# Utilizando el método de Thornthwaite
spei2_tho <- spei(data=datos$precip-datos$PET_tho, scale=12)
plot(spei2_tho)

# Utilizando el método de Hargreaves
spei2_har <- spei(data=datos$precip-datos$PET_har, scale=12)
plot(spei2_har)

# Utilizando el método de Penman
spei2_pen <- spei(data=datos$precip-datos$PET_pen, scale=12)
plot(spei2_pen)

# Para comparar con SPI
spi12 <- spi(data=datos$precip, scale=12)
par(mfrow=c(4,1))
plot(spi12)
plot(spei2_tho)
plot(spei2_har)
plot(spei2_pen)

-----
# calcular el spei con penman monteith para todas las estaciones en un solo archivo

# Leer los ficheros de datos
```