European Geosciences Union General Assembly 2016
Vienna, Austria, 17-22 April 2016
Session HS7.4: Change in climate, hydrology and society,
Vol. 18, EGU2016-18537, 2016.

Comparative assessment of different drought indices across the Mediterranean

Michele Giglioni [a], Andreas Efstratiadis [b], Federico Lombardo [a], Francesco Napolitano [a], Fabio Russo [a]

[a] Sapienza Università di Roma, Dipartimento di Ingegneria Civile, Edile, Ambientale, DICEA
[b] Department of Water Resources and Environmental Engineering, National Technical University of Athens, Greece

e-mail: michele.giglioni@uniroma1.it, andreas@itia.ntua.gr, federico.lombardo@uniroma1.it, fabio.russo@uniroma1.it, francesco.napolitano@uniroma1.it

1. Abstract - Introduction

Droughts have become one of the most challenging issues in hydrological sciences due to their major socio-economic impacts all over the world. In the context of the everyday water resources management practice, the identification and evaluation of droughts are mainly based on simplified indices, which are estimated through easily accessible information. In this work, we employ several meteorological indices, i.e. Standardized Precipitation Index (SPI), Standardized Precipitation and Evapotranspiration Index (SPEI), Reconnaissance Drought Index (RDI), Palmer Drought Z Index, and Palmer Drought Severity Index (PDSI), in order to evaluate the severity and duration of the observed drought events. The main purpose of this study is to underline the difference in the onset time of drought, the distance between events, and the discrepancies in the magnitude assessment for the same event. Various temporal aggregation scales, from one month to one year, have been considered in order to investigate the impacts of the adopted time scale on the drought characteristics. Our analysis focuses to the Mediterranean region, using data from Southern Italy and Greece.

2. Areas of interest

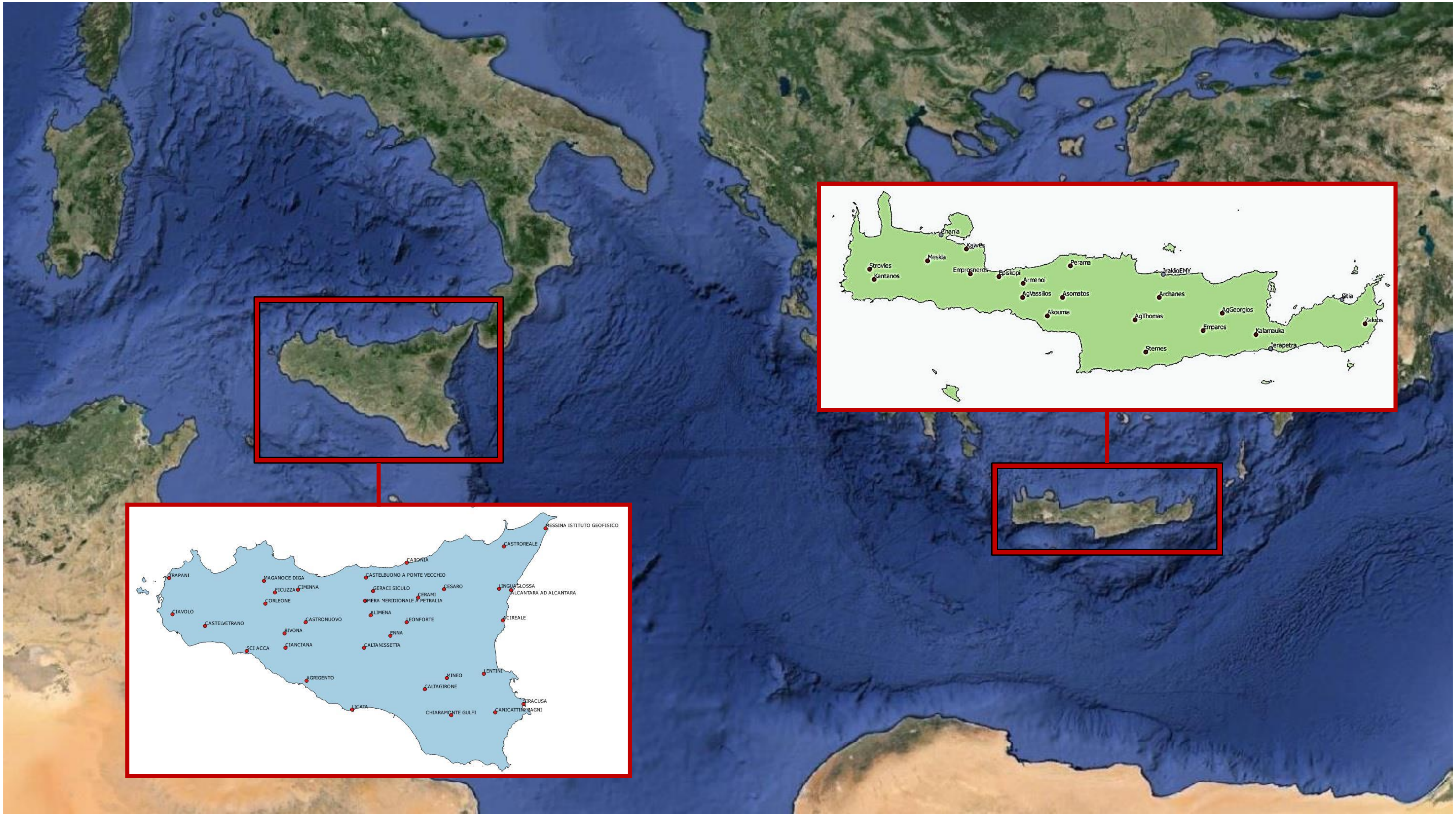


Figure 1: Map of the Mediterranean basin, indicating the two islands of interest (i.e. Sicily and Crete), as well as the locations of the associated meteorological stations.

3. Climatology

For both islands, the diagrams indicate typical Mediterranean climatic patterns, with hot and dry summers and mild and wet winters.

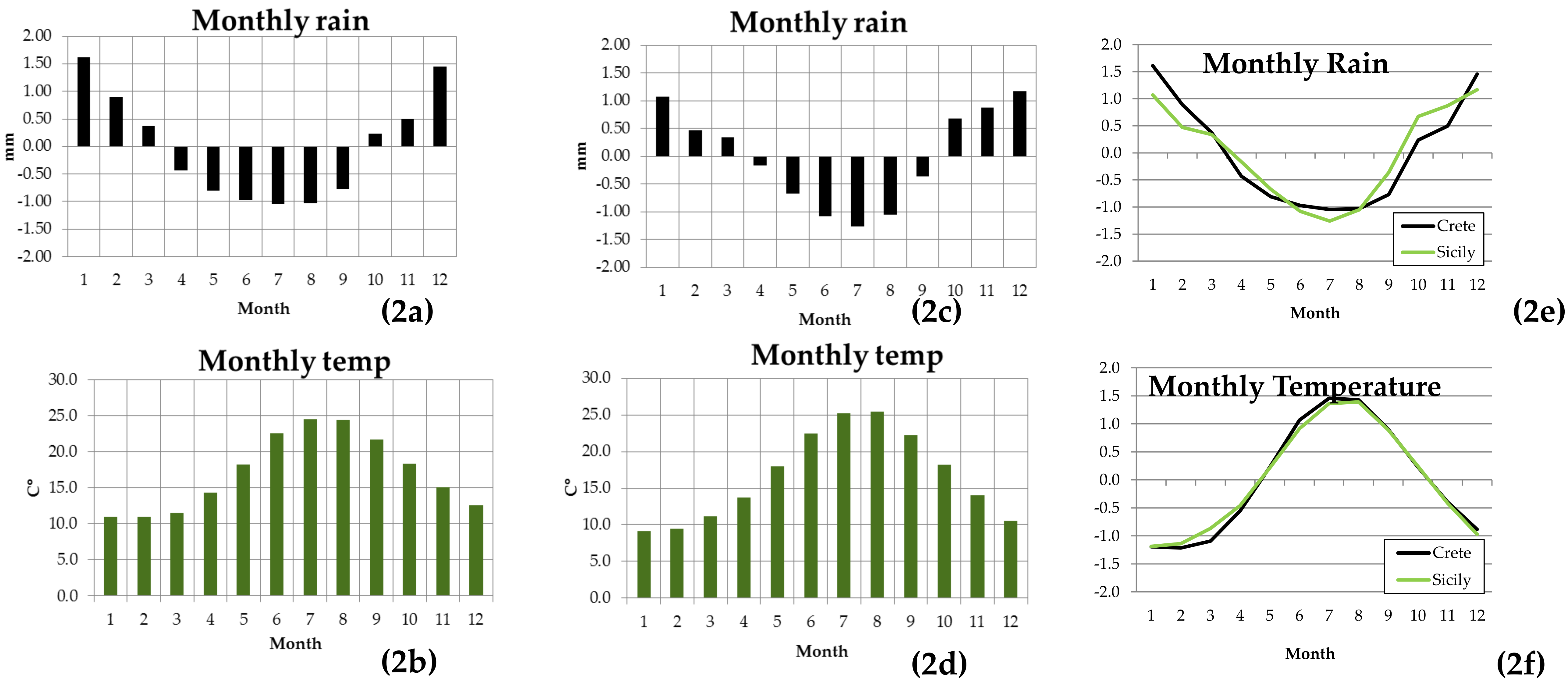


Figure 2: Normalized monthly rain for Crete (2a) and Sicily (2b), normalized monthly temperature for Crete (2c) and Sicily (2d); average monthly temperature for Crete (2e) and Sicily (2f).

4. Datasets

Raw data comprises monthly rainfall and average monthly temperature from several stations over Sicily and Crete:

- Data for **Sicily** are available at Osservatorio delle Acque Regione Sicilia; here we considered data from stations equipped with both pluviometer and thermometer (35 time series in total, with length up to 87 years).
- Data for **Crete** are available from the National Meteorological Service and the Ministry of Environment of Greece, and include rainfall time series at 16 stations and temperature time series at only 4 stations; the rest of temperature data were empirically estimated by:

$$T(z) = c\, T_0\, (z - z_0) \,/\, 100$$

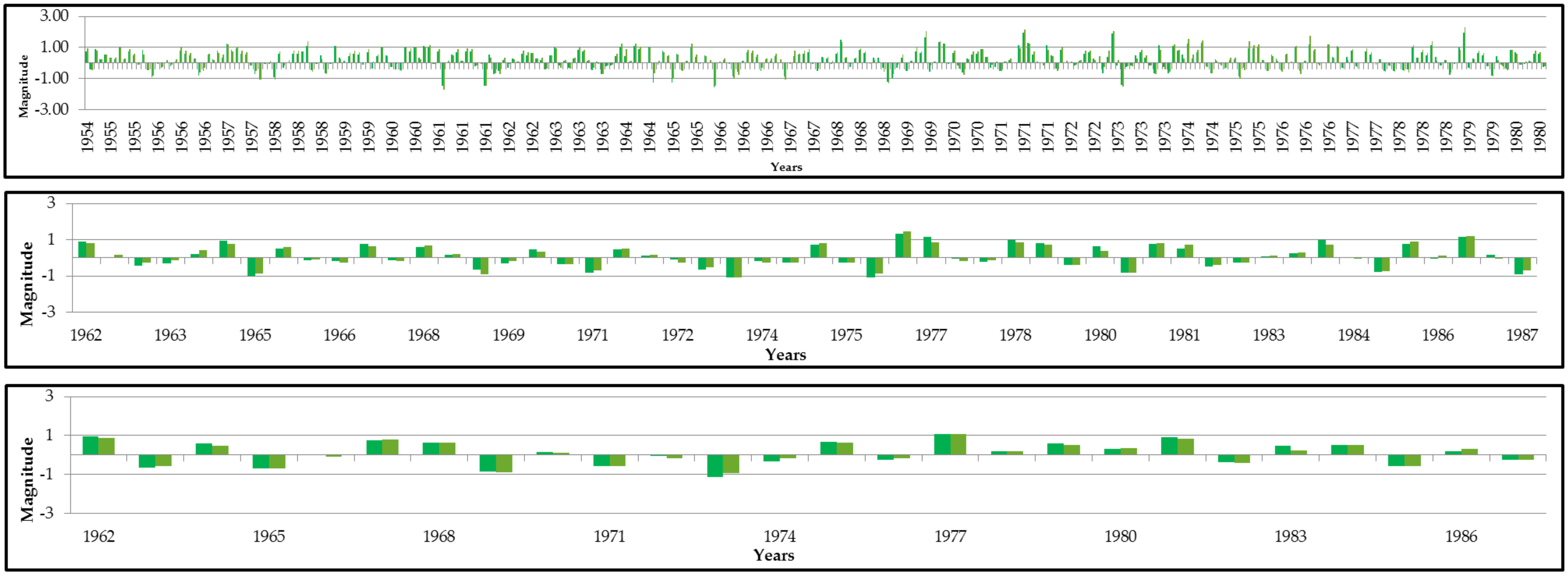
where $T(z)$ is the monthly temperature at elevation z, T_0 is the temperature at elevation z_0, and c is a seasonally varying parameter (temperature slope), for which typical values over the Mediterranean are given in Table 1.

Table 1: Typical temperature slope values across the Mediterranean

Month	c (°C/ 100 m)
Oct	-0.53
Nov	-0.43
Dec	-0.34
Jan	-0.31
Feb	-0.38
Mar	-0.56
Apr	-0.63
May	-0.63
Jun	-0.63
Jul	-0.61
Aug	-0.59
Sep	-0.59

5. Timescale

To investigate the impact of time scale over drought estimations, we used three aggregation scales, i.e. one month, six months and one hydrological year (starting October 1st, for the Mediterranean climate), and then we applied the following drought magnitudes: 0 = non drought; 1 = moderate; 2 = severe; 3 = extreme.



(4a)

(4b)

(4c)

Figure 4: Diagram of SPI for different aggregation times: a) one month, b) six months, c) 12 months.

6. Standardized precipitation index

$$SPI = -\left(t - \frac{c_0 + c_1 \mathrm{t} + c_2 t^2}{1 + d_1 \mathrm{t} + d_2 t^2 + d_3 t^3}\right), \qquad \mathrm{t} = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)}, \qquad 0 < H(x) \le 0.5$$

$$SPI = +\left(t - \frac{c_0 + c_1 \mathrm{t} + c_2 t^2}{1 + d_1 \mathrm{t} + d_2 t^2 + d_3 t^3}\right), \qquad \mathrm{t} = \sqrt{\ln(\frac{1}{(1.0 - H(x))^2})}, \qquad 0.5 < H(x) < 1$$

$$H(x) = q + (1 - q)G(x)\ ;$$

$$\mathrm{g(x)} = \frac{1}{\Gamma(\alpha)\beta^{\alpha}} x^{\alpha - 1} e^{-x/\beta}, \qquad x > 0$$

where c_0, c_1, c_2, d_1, d_2, d_3 are dimensionless coefficients.

7. Standardized Precipitation and Evapotranspiration Index

$$SPEI = W - \frac{c_0 + c_1 w + c_2 w^2}{1 + d_1 w + d_2 w^2 + d_3 w^3}$$

$$W = \sqrt{-2\,ln(P)}, \qquad P \leq 0.5$$

$$P = 1 - F(x),$$

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\left[1 + \left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right]^{-2}$$

where c_0, c_1, c_2, d_1, d_2, d_3 are dimensionless coefficients.

8. Reconnaissance Drought Index

Reconnaissance drought index is based on the ratio between the aggregated precipitation and potential evapotranspiration, which is evaluated through the Thornthwaite method.

$$a_k = \frac{\sum_{j=1}^{j=k} P_j}{\sum_{j=1}^{j=k} PET_j}$$

$$RDI_{st} = \frac{y_k - \bar{y}_k}{\hat{\sigma}_k}$$

$$y_k = ln(a_k)$$

$$PET = K \left[1{,}6 (10 \frac{Ti}{I})^a \right]$$

where PET is the potential evapotranspiration by the Thornthwaite formula.

Table 2: Drought class conversion chart from non drought state, to severe drought, for the three standardized indices (SPI, SPEI, RDI).

Index Value	**Drought classes**	**Code**
-1 or more	Non-drought	0
-1 to -1.5	Moderate drought	1
-1.5 to -2	Severe drought	2
-2 or less	Extreme drought	3

9. Palmer’s Indices

Palmer’s indices are widely used meteorological indices (mostly by government agencies in the United States).

PDSI is more used in long term prediction, wile Z- Index is more reliable in short term moisture deficiencies.

$$PDSI = 0.897X_{i-1} + {}^{Z_i}/_{3}$$

$$Z\ index = k(P - \hat{}P)$$

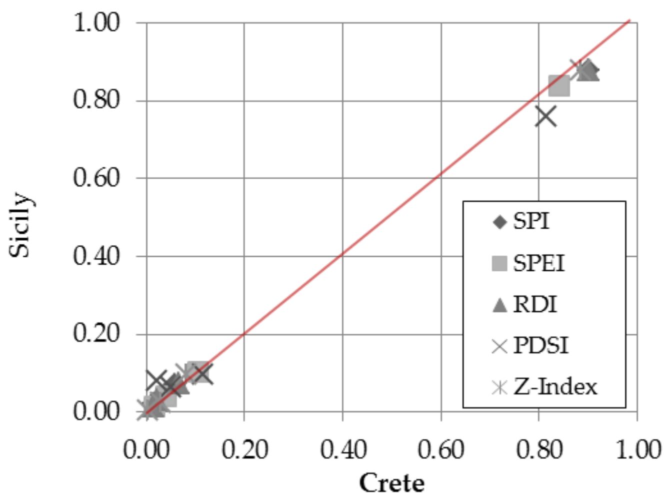
where Xi is the current PDSI, X_{i-1} is the PDSI of the previous month, and Z_i is the Z-Index..

Table 3: Drought class conversion chart from non drought state, to severe drought, for both Palmer’s and Z-indices.

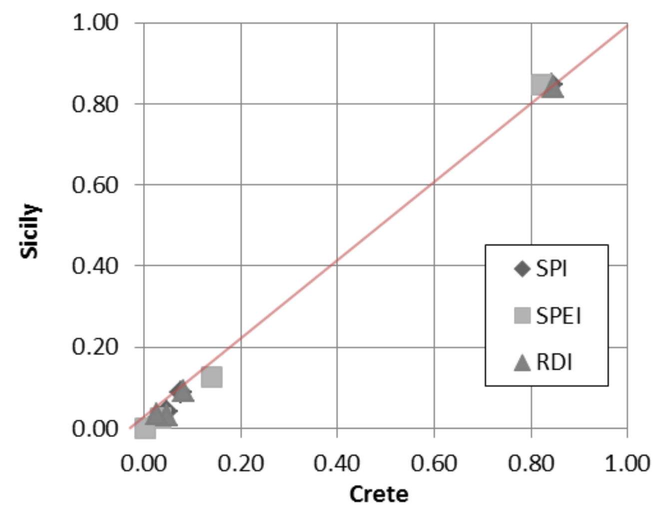
Index value	Drought classes	Code
-1.99 or more	Non-drought	0
-2 to -2.99	Moderate drought	1
-3 to -3.99	Severe drought	2
-4 or less	Extreme drought	3

10. Results

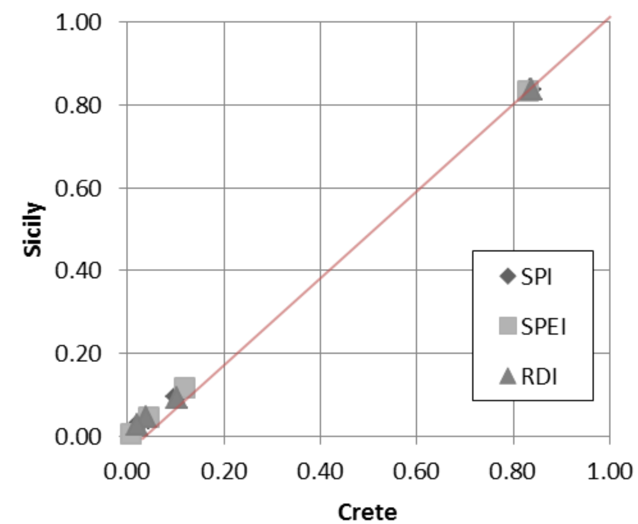
The results of the analysis for each pluviometer have been distributed over the region by using the Thiessen polygons. As control parameter have been chosen the magnitude, duration and distance between events.



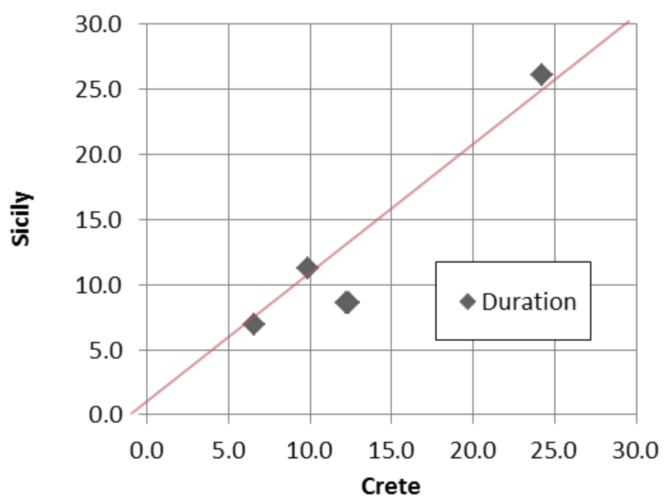
(5a)



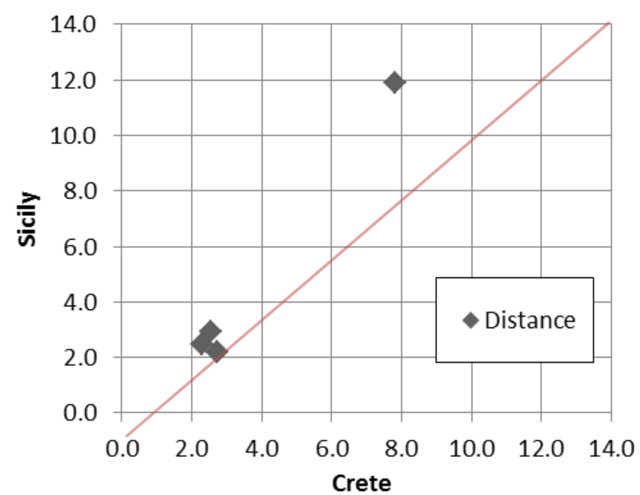
(5b)



(5c)



(6a)



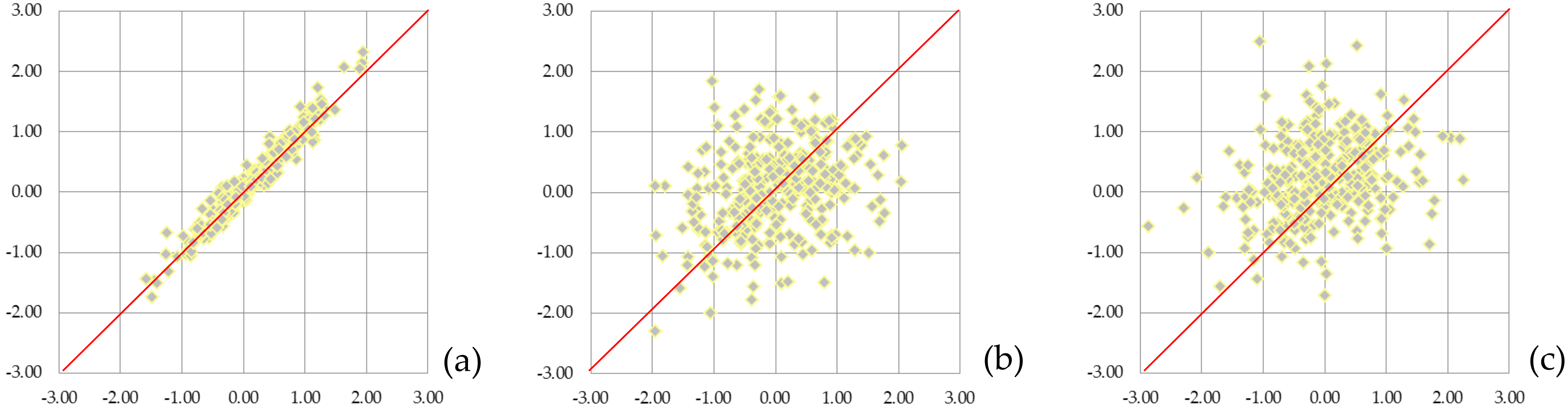
(6b)

Figure: 5 a), b), c) Comparison between percentage of events for each class in Crete and Sicily; aggregation time 1, 6, 12 months.

Figure: 6 a), b) Comparison of average distance and duration

11. Results

Finally we investigate the behavior of the two islands under drought conditions, by comparing the different indices:



Index	Correlation
SPI	0.97
SPEI	0.28
RDI	0.23
PDSI	0.09
Z Index	0.10

Figure 7: Correlation between indices for the two islands: a) SPI, b) SPEI, c) RDI, for one month aggregation time.

Table 4: Correlation coefficient between indices for monthly time scale of aggregation.

12. Conclusions

- All indices indicate similar drought characteristics for the two islands, for all aggregation scales, in terms of intensity, duration and distance between drought events.
- The SPI indices of the two islands are highly correlated, the SPEI and RDI exhibit moderate correlation, while PDSI and Z Index do not indicate any correlation.

References

- McKee, T.B., Doesken, N.J., Kleist, J., 1993. The Relationship of Drought Frequency and Duration to Time Scales, In: Paper Presented at 8th Conference on Applied Climatology. American Meteorological Society, Anaheim, CA.
- Vicente-Serrano, S.M., Beguería, S., López-Moreno, J.I., 2010. A multi-scalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index – SPEI. J. Clim. 23, 1696–1718.
- Tsakiris, G., Vangelis, H., 2005. Establishing a drought index incorporating evapotranspiration. Eur. Water 9 (10), 3–11.
- Palmer, W.C., 1965. Meteorologic Drought. US Department of Commerce, Weather Bureau, Research Paper No. 45, p. 58.
- Pedro-Monzonís M., Solera A., Ferrer J., Estrela T. and Paredes-Arquiola J. ,2015 A review of water scarcity and drought indexes in water resources planning and management .J. Hydrol. 527 482–93.
- Mishra, A.K., Singh, V.P., 2010. A review of drought concepts. J. Hydrol. 391 (1–2), 202–216.

Acknowledgement

This research was elaborated in the context of collaboration between the National Technical University of Athens and La Sapienza University of Rome, within a program of students exchange.