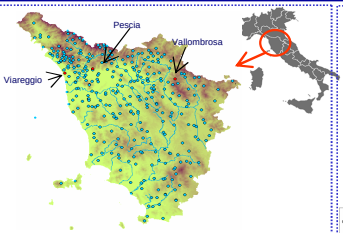
Analysis of long dry spell series for drought detection and monitoring in Central Italy.

R. Magno [1], Guarnieri F. [2], Gozzini B. [1,2], Meneguzzo F. [1], Maracchi G. [1] and Pasqui M.[1,2]
[1] Institute of BioMeteorology, National Research Council (IBIMET-CNR), Florence, Italy
[2] Laboratory for Meteorology and Environmental Modelling (LaMMA), Florence, Italy
Website: http://web.fi.ibimet.cnr.it/ - Contact: r.magno@ibimet.cnr.it

Drought is a recurrent feature of climate and its impacts on human activities depending on the interaction between this natural event and water demand for several purposes, from agriculture to civil and industrial needs. The aim of this study is to analyze long time series of rainfall data for evaluating variability, tendencies and intensity of drought events in three different geographical contexts of Tuscany region (coast, hill and mountain). The drought analysis is carried out using daily records from three central Italy rain gauges, covering, respectively, the periods 1945-2005, 1928-2003 and 1930-2005. The first step of our study is to define the dry spells and its characteristics. The rain threshold is computed taking in to account the minimum amount of water needed for the vegetation growth; number and duration of the spells are considered at seasonal and yearly level. Furthermore a two-parameter General Pareto Distribution (GPD) is applied to study the frequency of all the dry spell events over a chosen threshold (peaks over threshold) for their duration. Afterward we use the Standardized Precipitation Index (SPI) to quantify the precipitation deficit for multiple time scale (12, 24 months). The standardization of the values permits a comparison between meteorological stations climatically and geographically different. The results obtained from the two investigations show a general increase of drought events in the last decades. The SPI highlights, in particular, a negative trend for the long time scale (hydrological drought). Moreover, thanks to the seasonal analysis, we detect an intensification of the phenomenon during the winter period.

Location

The analysis has been conducted on the rainfall data collected by three rain gauges in Tuscany (Italy):
Vallombrosa (1930-2005), Viareggio (1945-2002) and
Pescia (1928-2003).



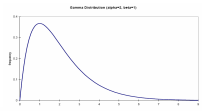
Method

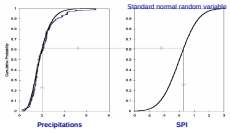
The **SPI** quantifies the precipitation deficit for *multiple time scales*. The use of different time scales allows to assess the effects of a drought event on different water-resources components (soil moisture, groundwater, reservoir storage, streamflow) according to McKee, T.B., Doesken N.J. & Kleist J., "The relationship of drought frequency and duration of time scales. Proc. Eighth Conference on Applied Climatology, Amer. Meteor. Soc., Jan 17-23, 1993, Anaheim CA, 179-186", we have:

Pros:
- Less complex than PDSI (only precipitation)
- Help to assess drought severity
- Standardization permits a comparison between gauges climatically different
- Not negatively influenced from topography

Cons:
- Long-term precipitation record (30 years at least)
- Misleading high values (positive or negative) in areas with low amount of seasonal rainfall for short time scales.

A long-term precipitation record (30 years at least) is fitted to a probability distribution (gamma distribution), that is then transformed into a normal distribution, with a mean of zero and standard deviation of one.





$$G(x) = \int_0^x g(x)dx = \frac{1}{\hat{\beta}^{\hat{\alpha}}\Gamma(\hat{\alpha})}\int_0^x x^{\hat{\alpha}-1}e^{-x/\hat{\beta}}dx$$

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

q = probability of zero

Hence the **SPI** represents a z-score, or the number of standard deviations above or below that an event is from the mean.

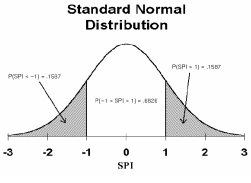
$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0 < H(x) \le 0.5$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad \text{for } 0.5 < H(x) < 1.0$$

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \quad \text{for } 0 < H(x) \le 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(1.0 - H(x))^2}\right)} \quad \text{for } 0.5 < H(x) < 1.0$$

SPI Values	
2.0 +	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2.0 and less	extremely dry

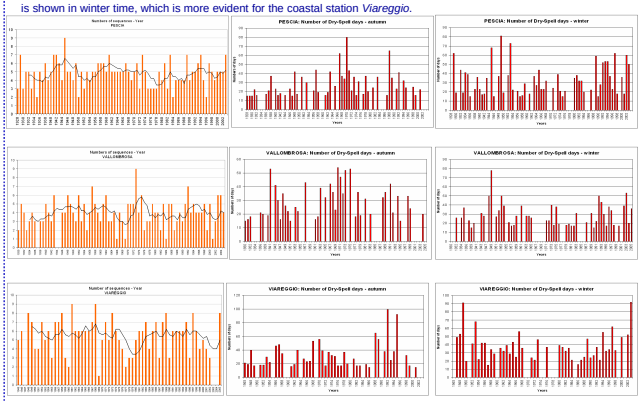


SPI may be used for monitoring both dry and wet conditions. A *drought event* start when **SPI** value reaches -1.0 and ends when **SPI** becomes positive again. The positive sum of the **SPI** for all the months within a drought event is referred to as "*drought magnitude*".

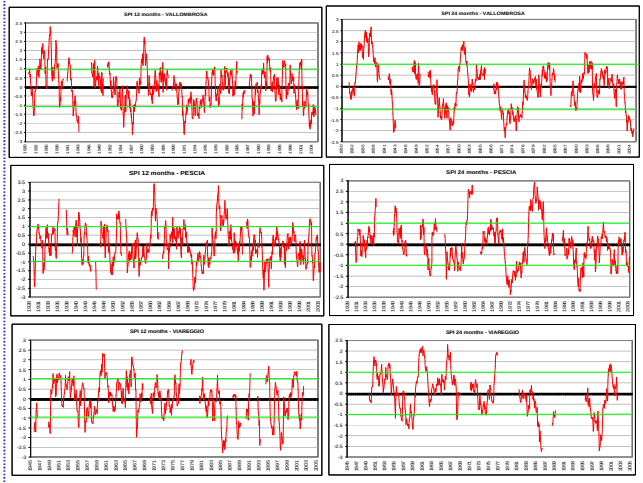
Dry Spell Analysis

The method used to evaluate the Dry Spell series for these locations, is that one explained in the paper : "British Rainfall, p.15, 1919 [from Meteorological Glossary, Air Ministry, 3rd ed., London, 1944, p.68]. [from Glossary of Geology and Related Sciences, American Geological Institute, Washingtonn, D.C., 1957, p.89.]. This method evaluates days with rainfall under the threshold of 2mm for 15 consecutive days at least.

The analysis has been conducted both on annual and interannual level, to highlight an eventual change in dry spell characteristics, for the data concerning three rain gauges data in Tuscany (Itlay). The number of sequence reveals no major trends along the entire period, while the seasonal number of total dry – spell days shows some signals especially for autumn and winter. In particular there is a decrease, since '70, during autumn in all stations. A clear increase of total dry – spell days is shown in winter time, which is more evident for the coastal station *Viareggio*.



SPI Analysis



From the SPI monthly time series, computed for a 12 – months period, no major trends are evident. No clear trends are present in the SPI time series covering the year time window as well. But in these latter graphs a sequence of long regimes are present. And in particular it seems that the since the '70 the dry regimes are more likely. It is interesting to note that for the Vallombrosa mountain station the last 10 years belongs to the driest period of his history and now we are, probably, at the minimum value.

Conclusions

The availability of very long time series it is a fundamental tool in order to characterize low frequency variability of precipitation anomalies in a small region. From our data analysis no clear trends appears for yearly anomalies of dry – spells even if a signal is present on the seasonal time scale. In particular there is a light decrease during autumn and a clear increase of dry – spell days in winter. In other words there is a shift in the precipitation's distribution from winter to autumn. From the analysis of SPI index, over 12 and 24 months time period, it is shown that since '70 dry periods are more likely, especially for inland stations. More analysis should be produced in order to identified climatic regimes responsible of these behaviour, but a general attention should be paid, since now, to the water management.