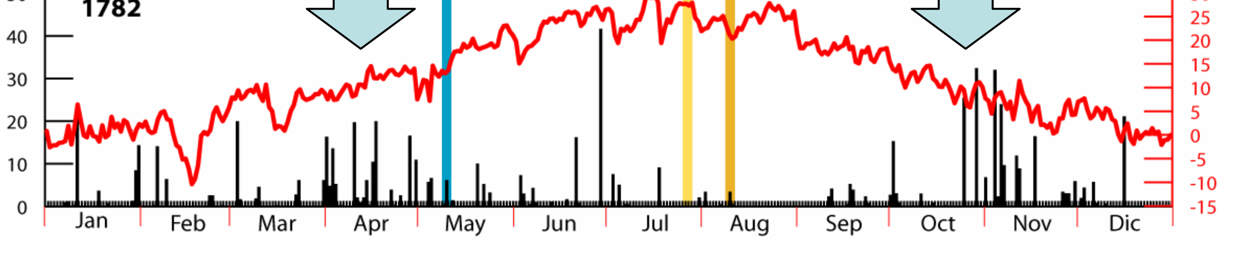
Calibration of rogation records with long instrumental series and their application to drought reconstruction for the last five centuries at the Western Mediterranean



Reference number: 1690

Author: Fernando Domínguez Castro

Host: Dr. Dario Camuffo CNR-ISAC Padova (Italy)

Scientific Report – ESF Exchange Medclivar Grant

1. PURPOSE OF THE VISIT

The main goal of this visit was to study the climate variability from documentary sources and early instrumental data and to learn the methodology used by a pioneer group on this research field.

2. DOCUMENTARY SOURCES: ROGATION CEREMONIES

2.1 Introduction and description of the work

Rogations are religious ceremonies to sight for the end of the Divine punishment of drought periods (pro-pluvia rogations) or of long wet/stormy spells (pro-serenitate rogations). Such ceremonies followed very strict protocols and they changed accordingly to the intensity/length of the phenomena.

They are typical from Roman-Catholic countries and, despite they are known since the Byzantine Empire times, they become a common procedure, and therefore a reasonably continuous record, from the 16th century onwards. This documentary proxy has provided good results in Spain (Álvarez Vázquez, 1986; Martín Vide and Barriendos 1995; Barriendos 1997, 2005; Romero and Mayer 2002; Vicente-Serrano and Cuadrats 2007; Domínguez-Castro et al., 2008) and it has been also used in Italy (Piervitali and Colacino 2001).

Calibration of rogations is troublesome as the oldest available meteorological series begin in the 19th century, when rogations became less frequent and their protocols started to relax due to social, political, technological and economical factors.

In Padova (Figure 1), the Napoleon troops destroyed many libraries and archives, particularly the ecclesiastical ones, and consequently it has been only possible to reconstruct a short but continuous series for the period 1765-1800 from data collected in some churches: Saint Antony (nicknamed *il Santo*), Cathedral, Carmelite, Minor Franciscans (i.e. Cappuccini) from Gennari (1982, 1984). These rogation ceremonies refer either to exceedingly rain (risk of rivers' flooding) or dryness (risk to the agriculture) and, fortunately, they can be compared to the daily instrumental series of Padua precipitation (unpublished data courtesy of D. Camuffo and C. Bertolin, CNR-ISAC, Padova), temperature and pressure (Camuffo and Jones 2002). With these data we have identified the meteorological phenomena that triggered the rogations at Padua.

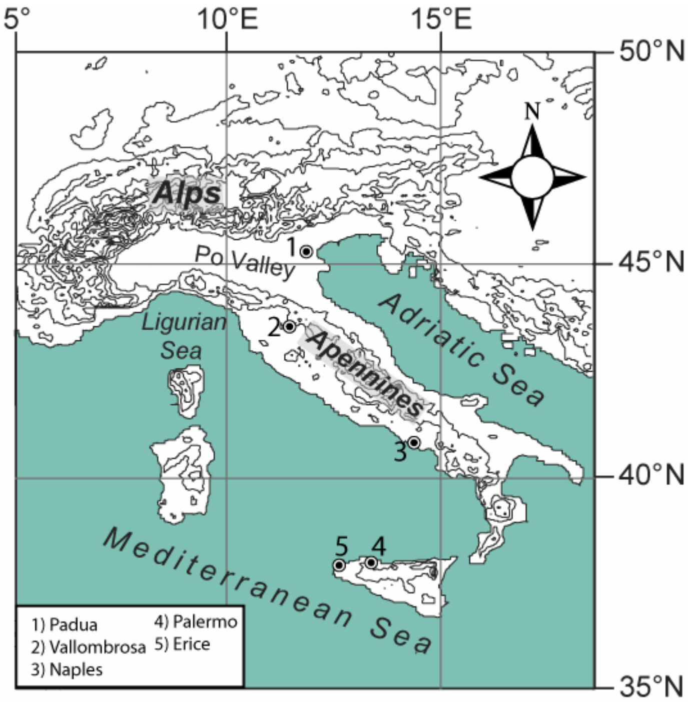


Figure 1: Location of the cities mentioned in the text.

Also, I have digitalized some of the *Ricordanze* books of the Vallombrosa Abbey (Tuscany, Italy) (Figure 2, location Figure 1). These books are the diary of the abbey and contain "continuous" climate information since 1493. We have digitalized some volumes while others are localized at the Florence State Archive (Table 1).

Period	Name	Location
1493-1513	Libro di Ricordanze B	Florence State Archive
1515-1541	Libro di Ricordanze A	Digitalized
1540-1597	Libro di Ricordanze verde A	Digitalized
1597-1632	Libro di Ricordanze Rosso B	Florence State Archive
1632-1662	Libro di Ricordanze AC	Florence State Archive
1661-1694	Libro di Ricordanze M	Florence State Archive
1694-1709	Libro di Ricordanze N	Digitalized
1707-1743	Libro di Ricordanze O	Digitalized
1743-1764	Libro di Ricordanze P	Florence State Archive
1764-1783	Libro di Ricordanze Q	Florence State Archive
1783-1785	Libro di Ricordanze Ab	Florence State Archive
1785-1786	Libro di Ricordanze S	Florence State Archive
1786-1789	Libro di Ricordanze T	Florence State Archive
1789-1799	Libro di Ricordanze V	Florence State Archive
1800-1899	Libro di Ricordanze X	Digitalized

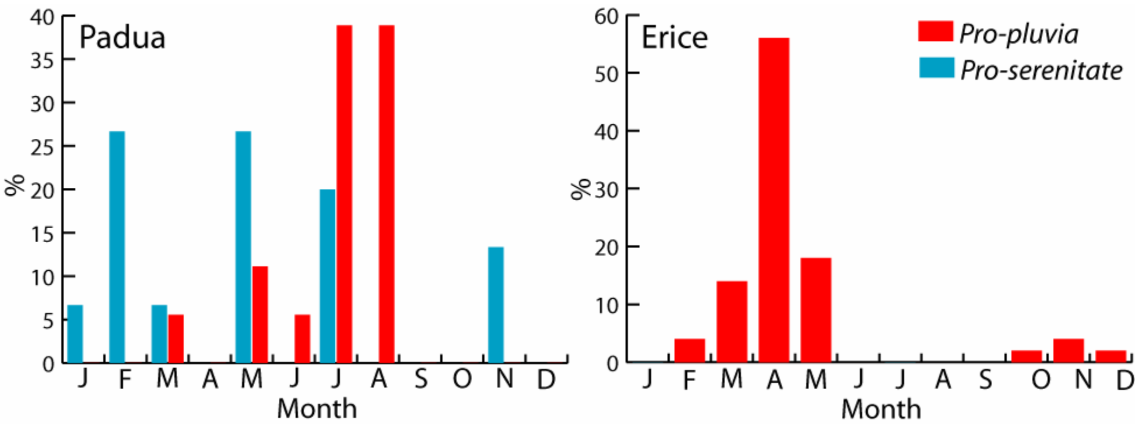
Table 1: Ricordanze books status.

Figure 2: a) Vallombrosa Abbey b) *Ricordanze* book volume O c) First page of the *Ricordanze* book volume O.

Another goal in visiting the Vallombrosa abbey was to look for the possible location of early thermometers, to help in the interpretation and correction of the series.

2.2 Main Results

Differences in climate and agricultural activities are responsible of changes in the climatic meaning of the rogation ceremonies among locations. For example, the annual distribution of the rogation ceremonies from Padua (Northern) and Erice (Southern) (Figure 3) shows noticeable differences as being the pro-pluvia ceremonies more frequent in spring in Erice while in Padova they were more frequent in summer. This discrepancy become from climatic differences on these locations. In Erice the scarcity of rain during summer (aprox. 20 mm) made really hard farming, but in Padova rainfall in summer is around 150 mm, allowing gardening. Consequently, Padova is more sensitive to water deficit in summer than Erice. Toledo (Central Spain) has a rogation distribution and climatology similar to Erice, with a really dry summer.



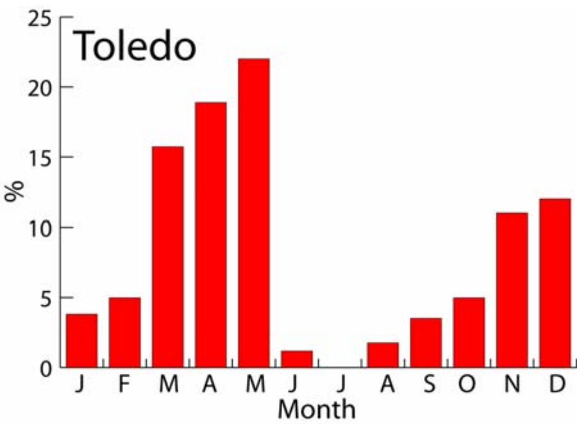


Figure 3: Monthy distribution of rogations in Padua, Erice and Toledo.

The climatic conditions that trigged rogation ceremonies at Padua for the period 1765-1800 were:

Pro-serenitate:

- A great increase of rain in the month of the celebration, i.e. 1796, or also in the precedent month, i.e 1772 (Figure 4). This is the more common cause.
- An important fall of temperature, i.e. 1787 (Figure 4).

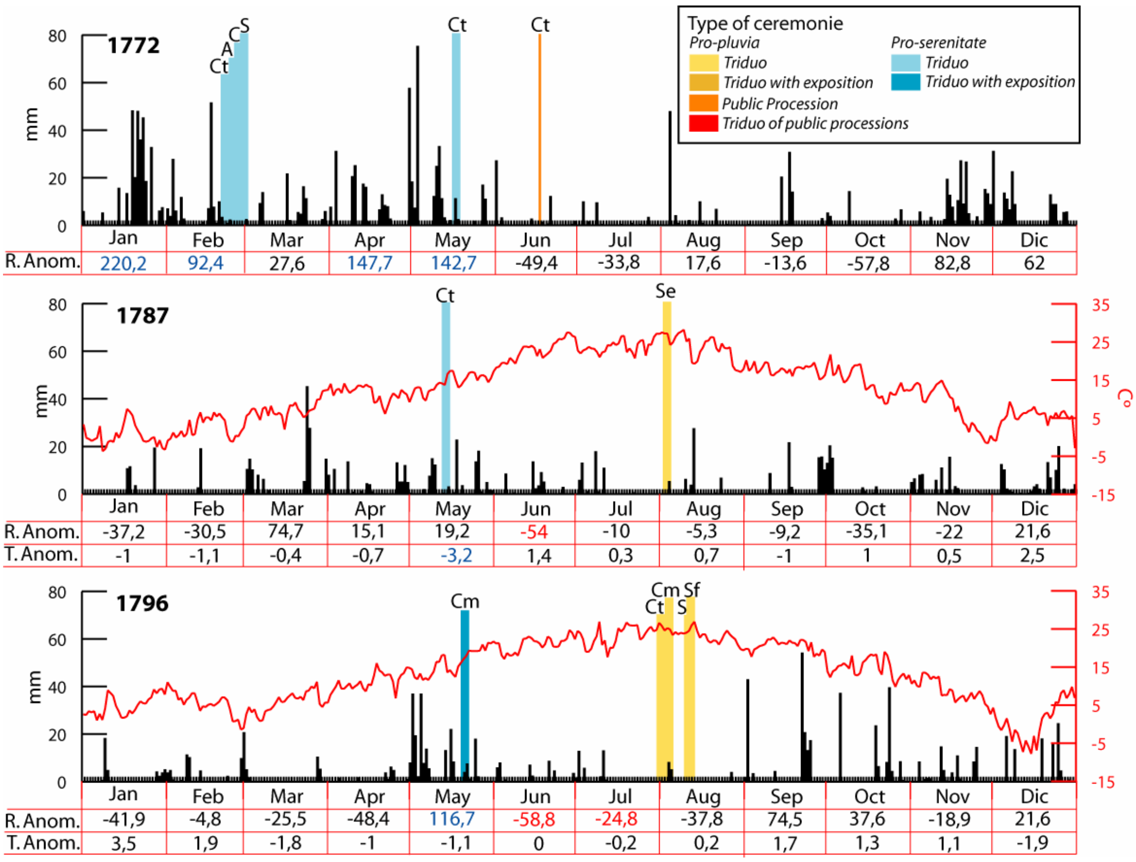
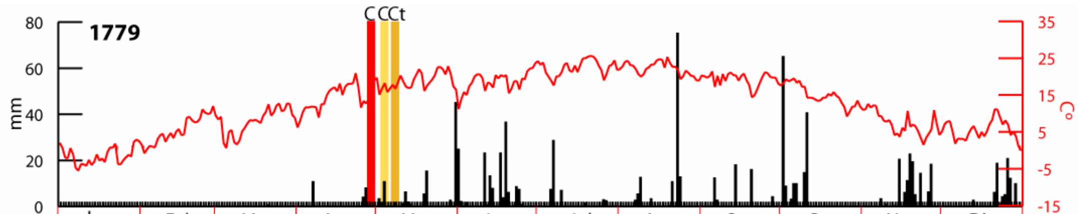
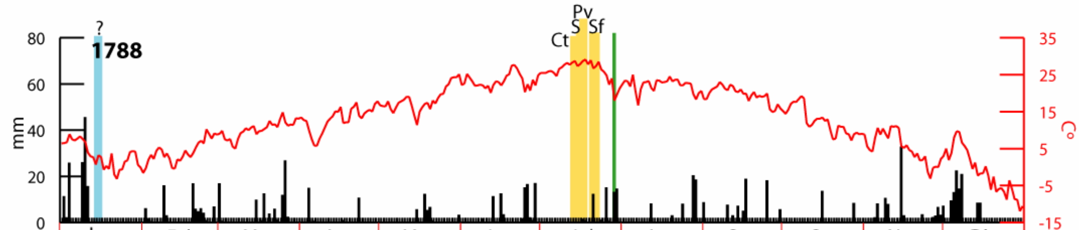


Figure 4: Black bars: daily precipitation, red line: daily temperature, colour bars: rogation ceremonies. Table below the graphics: monthly rain and temperature anomalies referred to the 1768-1800 period.

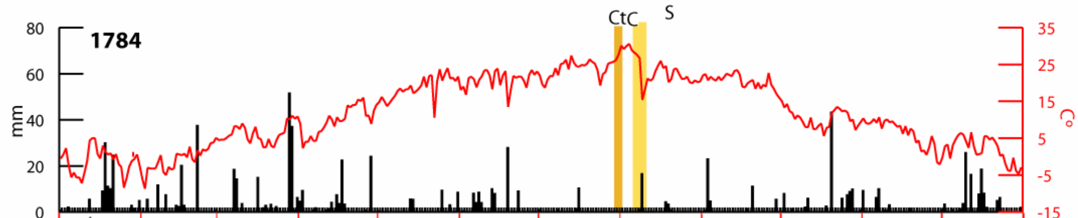
Pro-pluvia: These ceremonies were carried out mostly during summer and spring. These rogations were triggered by a dry spell longer than two months, i.e. 1779, 1784, or by periods of high temperatures longer than one month, i.e. 1788 (Figure 5).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic
Precipitation	-82,1	-52,5	-68,2	-45,3	8,7	62,5	-10	68,4	-29,4	62	40,3	6,7
Temperature	-2,9	1,6	0,6	1,6	1,6	-2,7	-1	-0,9	0,4	1,7	0	2,8



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic
Precipitation	43,9	20,2	22,9	-41	-55,2	-17	-1,6	2,5	-8,6	-68,8	-6	30,7
Temperature	1,9	0,7	2,7	0,7	0,8	2,2	2,5	-0,9	0,7	-1	-2,3	-4



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic
Precipitation	21,7	39,6	91	18,6	-56	-18,2	-45,6	-27,7	-35,5	7,2	-56,6	30
Temperature	-2,6	-4,2	-1,2	-2,5	1,3	-0,2	0,5	0,3	1,7	-3,1	-1,1	-0,9

Figure 5: Black bars: daily precipitation, red line: daily temperature, colour bars: rogations ceremonies (same key than figure 5). Table below the graphics: monthly rain and temperature anomalies referred to the 1768-1800 period.

2.3 Conclusions

Rogation ceremonies are a good proxy for the reconstruction of past climates but they need to be calibrated with instrumental series in order to weight the local factors.

Rogations are mostly used to elaborate rainfall indexes without considering that they can be related to temperature changes, as we have demonstrated for Padova. In fact, rogations are related to evapotranspiration and, therefore, to both variables, and to local agricultural practices in addition.

Consequently, in order to make a good reconstruction, it is necessary to collect enough information about the local/regional climate and land use in addition to the rogations.

3. EARLY INSTRUMENTAL DATA

3.1 Introduction and description of the work

The early instrumental data are the most accurate source of knowledge about climate before the industrial revolution. The earliest instrumental observations are known to be started in 1654 (Camuffo, 2002a), while following measurements in Italy started during the 18th century (Figure 6).

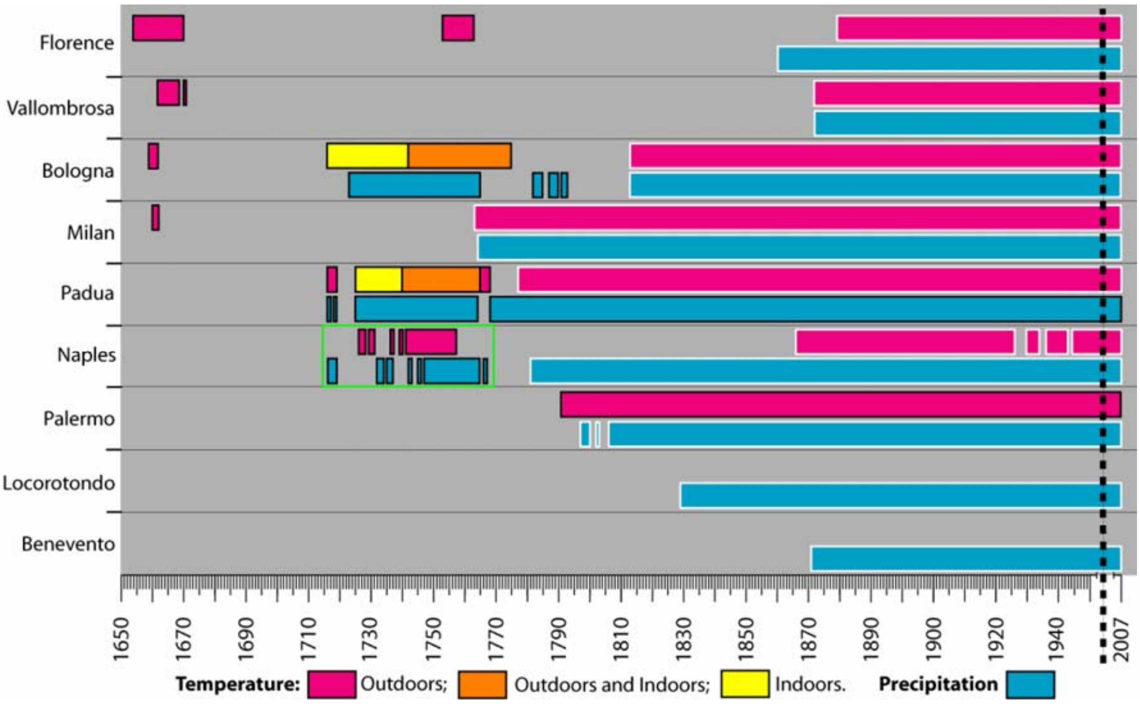


Figure 6: Overview of the Italian series, including the early instrumental observations of temperature and rainfall. Green square: the Naples series digitalized and checked during the visit.

There are several papers concerning the history of meteorology and the long series of instrumental data (e.g. Glaser et al, 1999; Camuffo et Jones, 2002; Luterbacher et al., 2006).

We have collected, digitalized and checked the early instrumental series of Naples (1716-1757: temperature, pressure and precipitation) (Figure 6). These series show daily resolution and they are compiled in a document preserved in the British Library under the title “Tabulae meteorologicae Vol VII - British Library ADD 19315-Observations from Italy (CI8) various” in which Francesco Serao sent his readings to Giuseppe Toaldo (Figure 7). This document has a high scientific interest because is the earliest known series for South Italy. The beginning of this series at 1716 coincides with other Italian locations as Padova and Bologna, arising the suspicion that all of them are part of a common initiative, probably an early network not well documented.

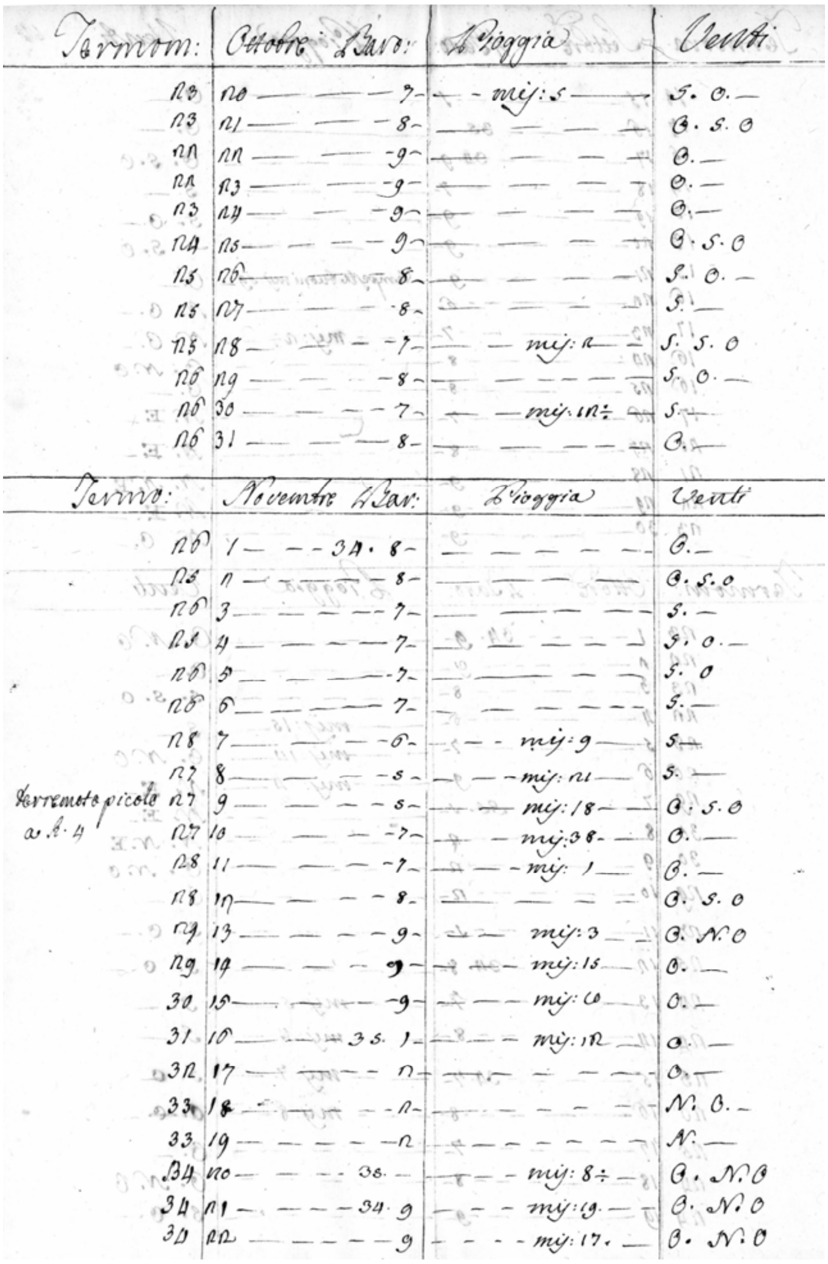


Figure 7: Sheet of the meteorological observations from 1745 at Naples, made by Professor Francesco Serao. From left to the right: temperature, date, pressure, precipitation and wind direction.

3.2 Main results

The Naples series is not a well documented series, only two paragraphs at the beginning of the text shows us some metadata about the units of the readings and the observational methodology. Serao took only one measure per day probably at midday.

We have made an important effort to know the instruments used and the conditions of the observations to homogenize the series, obtaining better results in some variables than others.

Temperature: The inverse scale and the maximum and minimum data suggest that the thermometer used on these measurements was the Royal Society Thermometer, more commonly called Haukfbee (Figure 8). Moreover, Nichol Cyrillus (Serao´s mentor), in a letter published in *Philosophical Transactions (1683-1775)*, Vol. 37, pp. 336-338 wrote “The thermometer used in this diary, was made by Haukfbee”.

Figure 8: Royal Society thermometer from 18th century preserved at the Greenwich Royal Observatory.

A comparison between Serao´s data with the reference period (1961-1990) of Naples suggests that the measurement were taken outside. The transformation of the royal society grades to the centigrade scale was calculated on the basis of the text of Derham (1733-1734) where he said that the ice point (0ºC) correspond to 65ºRS (Royal Society grades) and the point of extreme hot is -5ºRS. Considering extreme hot as 32,22ºC (maximum mean temperature in London) we obtain the following transforming function:

$$ºC= -0,4603\ ºRS + 29,919$$

Figure 9 shows the series before and after the correction compared to the reference period.

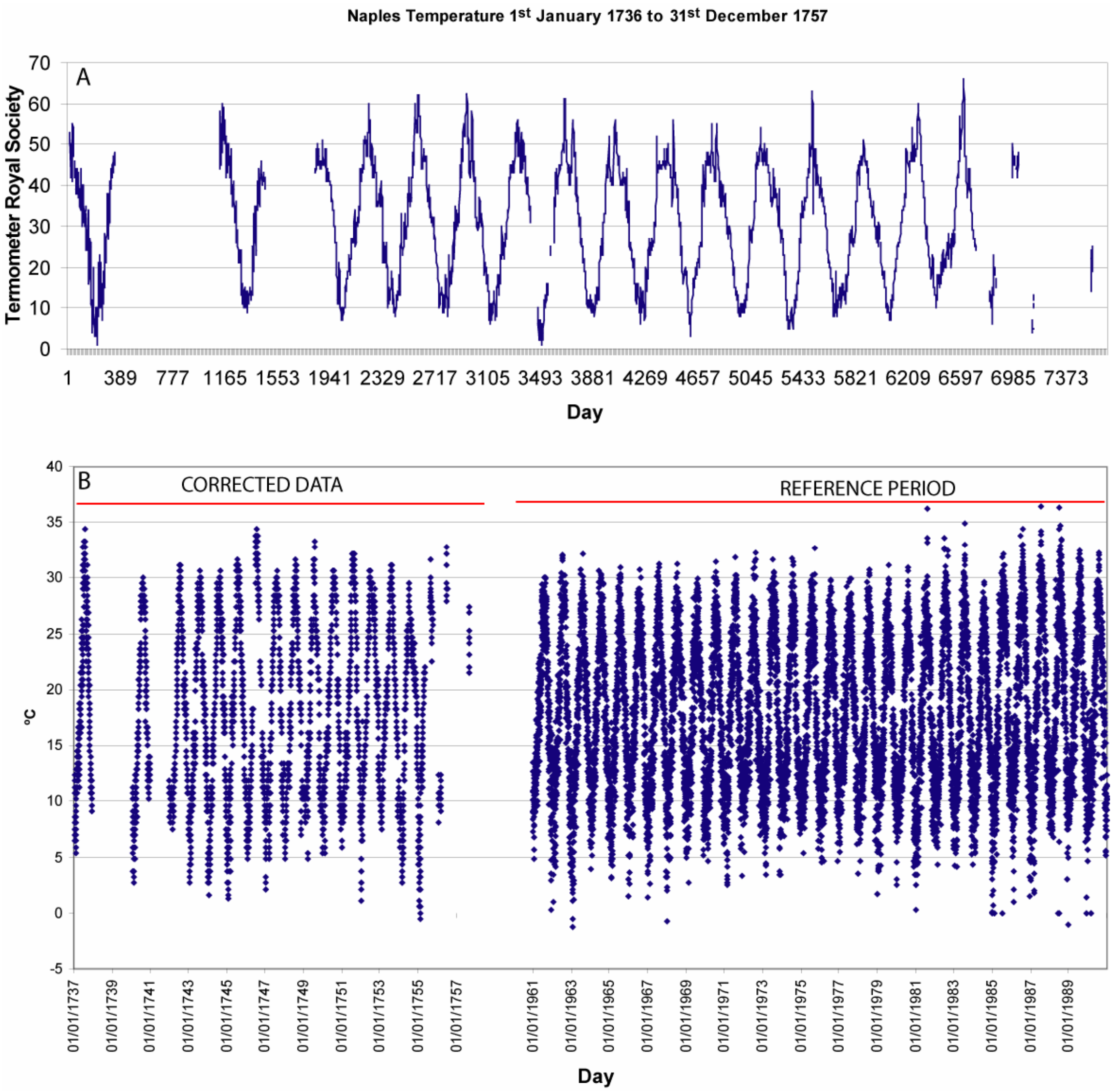


Figure 9: Naples temperature series; A: Original data B: Serao´s corrected series and reference period (1961-1990).

Precipitation: It is really difficult propose corrections to the precipitation series without good metadata. The comparison within reference periods is not very useful due to the high spatial and temporal variability of rainfall. My own reconstruction has been limited to make a good conversion of units between the Naples span to millimetres (Figure 10). In the original text the measurements were in "Measures refer to the Naples span" and we know that 2 "measures" was 1 lines, 10 line was 1 Naples inch, and 1 Naples inch was 0,02197m (Cristiani, 1760). Finally 1 line is 0,002197m and 1 "measure" is 0,0010985m (1,0985mm).

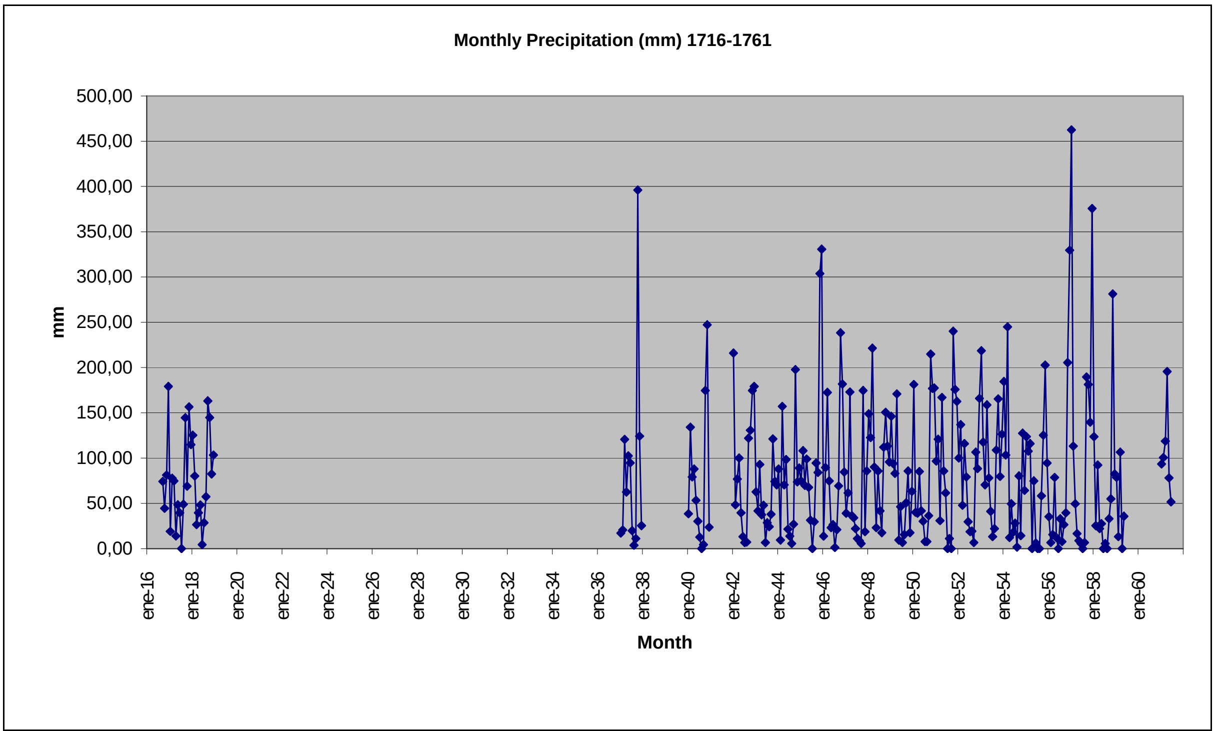


Figure 10: Monthly precipitation record for Naples from 1716 to 1761.

The daily variance of Serao´s series and the reference period are 52,24 and 60,02 respectively. Figure 11 show that the monthly distribution of this period (1716-1761) is similar to other periods as the reference period (1961-1990) and the 1872-2005 period.

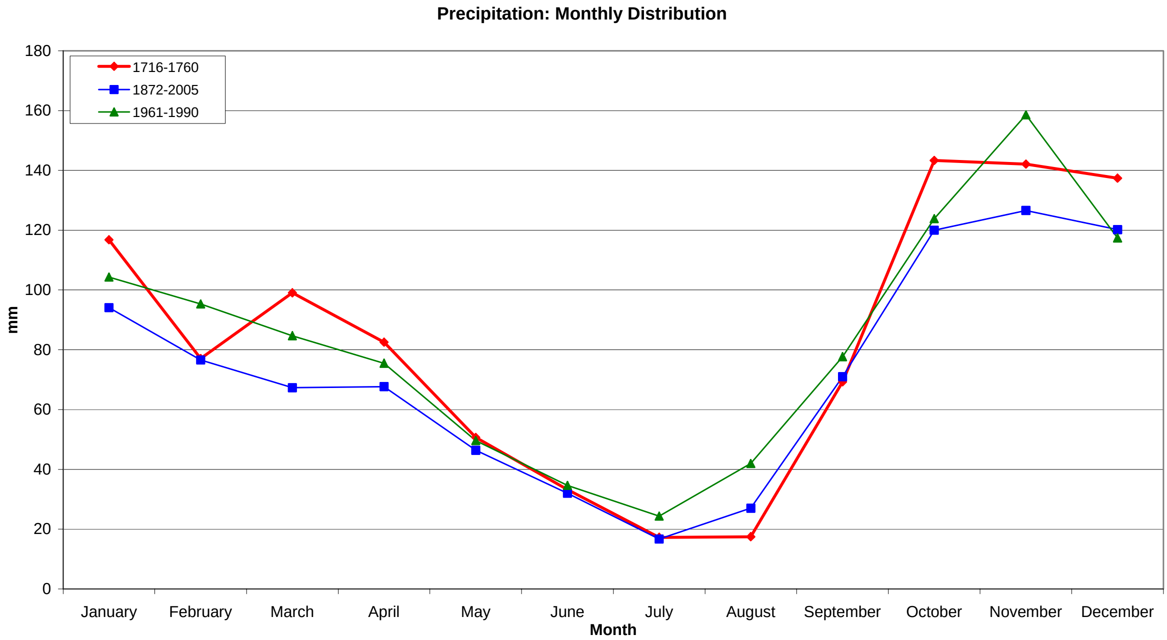


Figure 11: Precipitation monthly distribution.

Pressure: The Serao´s pressure record, after the change of units and the temperature and altitude corrections, shows many erratic data (Figure 12). We have tried to correct the series but, after comparison with the Naples SLP for the reference period and with Padua and Bologna for the 1737-1756 period, we think that is impossible correct the whole series but some years could be useful for specific studies particularly during the period 1743-1750 because later than 1750 the barometer did not measure the high pressures.

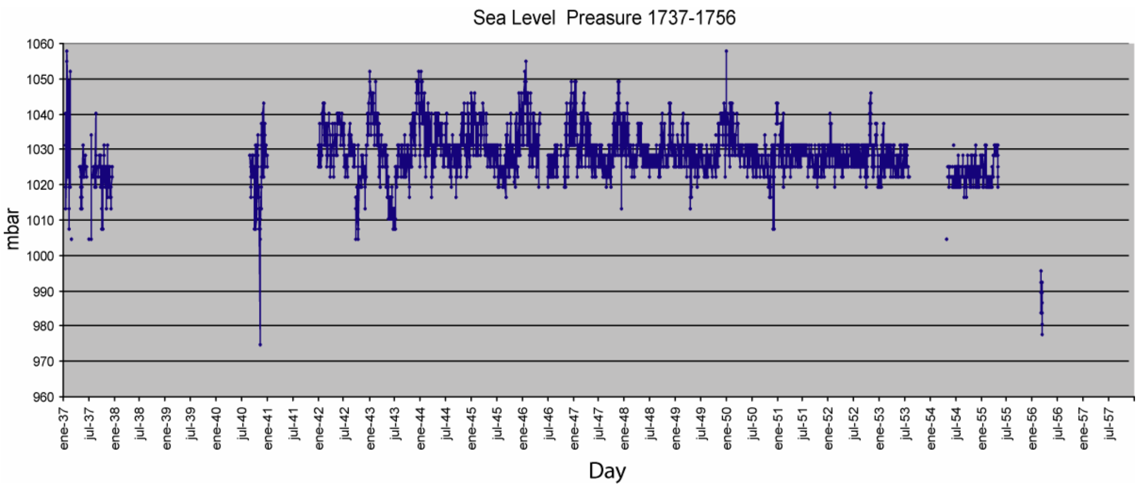


Figure 12: Naples sea level pressure 1737-1756.

3.3 Conclusions

In general, Naples temperature for the studied period presents “normal” deviations from the average of the reference period and does not show any remarkable tendency. The average temperature for the reference period is 15,6ºC and for the studied period 15,2ºC. This difference is higher during the winters and summers and lower during the springs and autumns. It could be caused by the thermal island effect of Naples city or by a non accurate transformation of the old data due to the scarce metadata.

Only some years were remarkable by their extreme temperatures (Table 2).

Location Period	**Temperature Extreme**	**Years**
Naples 1737-1757	Coldest winter	1756
	Hottest summer	1746
	Cold spring	**1740**, **1742**, 1746

Table 2: Extreme seasons.

Looking for regional trends for these years we can only found that the years 1740-1743 were also years with cold springs in the north of Italy, and 1740 shows a cold winter in the north of Italy and France.

About rainfall, looking figure 11, we can conclude that the springs were a little bit wet and the summers drier during the studied period than during the reference period.

The wettest year was 1757 and the driest period was from 1728-1732, but we do not found concordance with other areas in the Mediterranean.

Further conclusions on a regional scale will be published in a short time in the paper “500-year temperature and precipitation reconstruction in Mediterranean basin” elaborated during my visit to the ISAC Padova, where we present more detailed evidences for the climate during the last 500 years in the Mediterranean basin including the data from Portugal, Spain, France, Italy (including Naples), and Greece. The main conclusion of this paper is:

“What is the Mediterranean climate today and what is the present-day trend? Is it true that we are living in the hottest and the driest period in the last 500 years? A key problem is to recognize trends and know how the Mediterranean climate is transforming. DP (Documental Period) are convenient to establish the occurrence of extreme events, year-by-year variability, the existence of some time periods in which dry or wet, cold or warm situations were repeated, but not long-term trends. These can be assessed only with IO (Instrumental Observations), and for the first time we can see their evolution for approximately 350 years in Italy and France, and for shorter periods in the other Mediterranean countries.

In general, no main trends are visible that affect the whole period under investigation, and both the temperature and the precipitation oscillate for a few tens of years around the mean level with many year by year fluctuations. In the recent time, i.e. the last 20-30 years, a warming is evident for all Mediterranean stations. In general, the exceptionally warm seasons in the present warming period do not exceed much other maxima in the series. Today we are facing a recent warming that in some cases has exceeded the levels of past oscillations, sometimes not. Much contributions is due to some isolated extremes, from 2001 to 2007, the most relevant of them was 2003. Briefly, the average is raised by a few isolated cases that have occurred in a relatively short period. These cases are too few to establish that the climate has changed, and the recent average level has not exceeded the natural past variability. The distribution of seasonal precipitation has no general evident tendency toward a changed precipitation regime in the Mediterranean. However, the combination of the recent tendency to warming and the short-term repetition of extreme events constitute an alert against the risk of a future worsening of the situation."

Also I am working with CNR-ISAC Padova in the possibility of generate a better series from Naples from some documents of the Royal Society that can fill the gap of the second half of 18^{th} century and the first half of 19^{th} century if at the end we can do it we can realize a much better series for the whole period.

4. CONCLUSIONS OF THE VISIT

This visit has been a great experience for me; I have learned many techniques and methodologies for working with documentary sources and with early instrumental data.

I think that the data recovered from Naples can be very useful for the scientific community mainly for studies of Mediterranean climate variability.

On the other hand, the study about the rogation ceremonies can be very interesting looking for a more accurate methodology for work with them in different places.

The localization and digitalization of some *Ricordanze´s* books from Vallombrosa will allow us to make a preliminary study to evaluate the climatological interest of these documents, evaluating the density of references to the climate and the quality of these references. By the short of time it was impossible work this information but I think that could be a interesting work for the future, because this documental source has a interesting overlapping with one of the earliest temperature measures made in Europe (start at 1654 by the observers Paceschi and Casini), that will permit a good calibration of the documentary information.

5. ACKNOWLEDGMENTS

Thanks are due to the ESF MedCliVar committee for give me the opportunity of made this visit and to the staff of my host institution CNR-ISAC especially to the Dr. Dario Camuffo, Chiara Bertolin and Antonio della Valle for their hospitality.

6. PROJECTED PUBLICATIONS

Thanks to this visit I have participated in the paper under revision:

D. Camuffo, C. Bertolin, M. Barriendos, **F. Dominguez-Castro**, C. Cocheo, S. Enzi, M. Sghedoni, A. della Valle, E. Garnier, M.-J. Alcoforado, E. Xoplaki, J. Luterbacher, N. Diodato, M. Maugeri, M.F. Nunes, R. Rodriguez. 2008: 500-year temperature and precipitation reconstruction in Mediterranean basin, *Climatic Change*, special issue.

7. FURTHER COLLABORATION WITH THE CNR-ISAC PADOVA

To improve the series from Naples and other Spanish series with the objective of put together the longer series in the Mediterranean Basin to study de Mediterranean climate variability from 1643 to 2008.

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