Reconstruction of daily pressure maps over Italy during some extreme events of the 19th century (*)

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Summary. — The quality and availability of daily meteorological data for the reconstruction of atmospheric circulation over Italy in the period between the Italian political Unity (1860) and the development of the Central Office for Meteorology (1879) is studied. Examples of atmospheric circulation reconstructed for some extreme events are presented.

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1. – Introduction

Although the knowledge of the climate of the last 100/150 years has been improved to a large extent (Jones, 1994), two basic problems still keep unsolved: at present a sufficient number of complete, long and homogeneous time series is not available and the existing ones are often not multi-elemental, but limited to temperature and precipitation.

Therefore, a very small number of long time series of air pressure and wind speed and direction data, which are essential for the reconstruction of the atmospheric circulation in the past, is available today.

As a consequence, the knowledge of the atmospheric circulation in the last centuries is not exhaustive, but is limited to a few geographical areas and some periods that have been studied with great care (Lamb and Johnson, 1966; Lamb, 1972, 1977; Kington, 1988; Frenzel, 1994).

As far as Italy and the Mediterranean area are concerned, even if very interesting results have been obtained in the last years (Colacino and Conte, 1993; 1995; Sneyers *et al.*, 1997), a systematic reconstruction and analysis of the atmospheric circulation in the last 100/150 years is not yet available.

Within this context, the purpose of this paper is to show that the data and the other information available at present allow a rather detailed reconstruction of atmospheric circulation over Italy, starting from a few years after its political Unity (1860).

(*) The authors of this paper have agreed to not receive the proofs for correction.

2. – The availability, quality and homogeneity of the data

The availability of Italian meteorological data and facility of access to them show a sharp and sudden improvement after 1865, thanks to the wide growth of public and private meteorological networks that were developed in Italy just after its political Unity (Palazzo, 1911; Camuffo, 1994; Maugeri *et al.*, 1995A, Beltrano and Esposito, 1996).

The data prior to 1865 are mainly available from hand-written registers or bulletins edited by single observatories or from monographic works of reconstruction and analysis of single meteorological series. In the former case, this means remarkable difficulty for data collection; in the latter, in spite of easier access to the data, low time resolution and information about a few meteorological parameters are only obtainable.

Starting from 1865, year books (Ministero di Agricoltura, Industria e Commercio, 1865-1878; Denza, 1865-1880; Ufficio Centrale di Meteorologia, 1879-1925; Ufficio Centrale di Meteorologia, 1880-1927; Associazione Meteorologica Italiana, 1881-1884; Società Meteorologica Italiana, 1885-1924) that report data for quite a high number of stations become available. As an example, table I shows the data published in the year books of Italian Public Network for climatology in the years 1865-1899.

As far as data quality and homogeneity are concerned, before 1865 the Italian situation was not uniform. Along with some prestigious observatories equipped with excellent instrumentation and headed by great meteorologists, there were several

TABLE I. – *Meteorological data reported in the year books of the Italian Public Network for Climatology* (Ministero di Agricoltura, Industria e Commercio, 1865-1878; Ufficio centrale di Meteorologia, 1879-1925). *Other data are reported in the daily weather reports published by the forecast section of the Central Bureau for Meteorology since 1880* (Ufficio Centrale di Meteorologia, 1880-1927) *and in the year books edited by Father Denza* (Denza, 1865-1880) *and by the Associazione Meteorologica Italiana* (1881-1884) *and the Società Meteorologica Italiana* (1885-1924). *All these year books are available in the archives of Milan-Brera Observatory and, at the present, their classification is in progress* (Maugeri *et al.*, 1995B).

	65		67		69		71		73		75		77		79		81		83		85		87		89		91		93		95		97		99
A: daily data																																			
Pressure (9 a.m.; 3, 9 p.m.)	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Temperature (9 a.m.; 3,9 p.m.)	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Relative Umidity (9 a.m.; 3,9 p.m.)	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Vapor Pressure (9 a.m.; 3,9 p.m.)	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Cloudiness (9 a.m.; 3,9 p.m.)	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Total Precipitation	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒														
Wind Direction (9 a.m.; 3,9 p.m.)															▒	▒	▒	▒	▒	▒	▒														
Wind Strenght (9 a.m.; 3,9 p.m.)															▒	▒	▒	▒	▒	▒	▒														
B: data on 10 days and month																																			
Mean Pressure (9 a.m.; 3, 9 p.m.)		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean Temperature (9 a.m.; 3,9 p.m.)		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean of Daily Min/max Temperature		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean Relative Umidity (9 a.m.; 3,9 p.m.)		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean Vapor Pressure (9 a.m.; 3,9 p.m.)		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean Cloudiness (9 a.m.; 3,9 p.m.)		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Total Precipitation		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Duration of precipitations		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒																								
Frequency of Wind Directions		▒	▒	▒	▒	▒	▒		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Mean wind Strenght (9 a.m.; 3,9 p.m.)															▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Days with rain, snow, hail, thunderstorm		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Clear, cloudy, overcast days		▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Number of observatories	21					65					84					100					134					134					136				

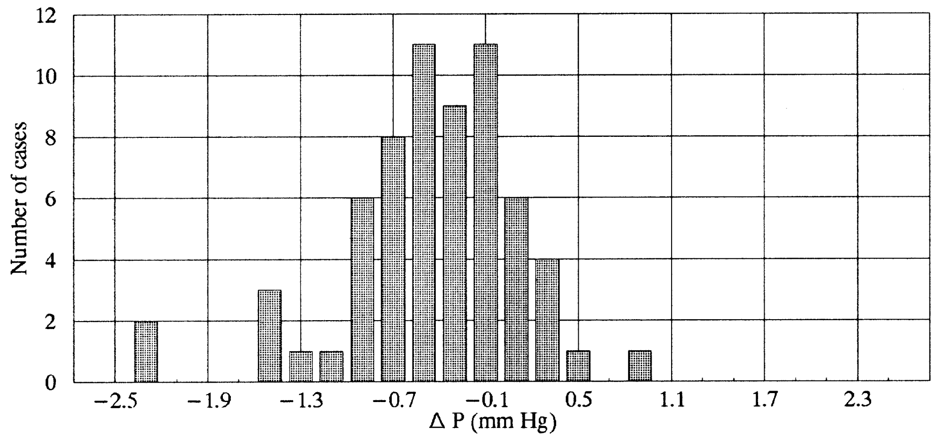

Fig. 1. – Distribution of the errors of 64 Italian barometers in the period 1870-1875. The data are expressed in mm of Hg, the values reported on the abscissa are central points of 0.2 mm intervals. For some cases these values have not to be considered errors but only differences between barometric readings, as the errors of the instruments were known by comparisons with other barometers and the data were usually corrected.

minor observatories that used poor instrumentation and worked with low organisation. A first attempt to reduce such differences was made in 1865, when the *Ministero di Agricoltura, Industria e Commercio* (Ministry of Agriculture, Industry and Trade) began to collect data for the whole Italian territory and started to work to homogenise the instruments and procedures used in Italian observatories. This effort was increased in the following years until a complete reorganisation of the Italian Public Meteorological Network was accomplished between 1876 and 1879 and the *Ufficio Centrale di Meteorologia* (Central Bureau for Meteorology) was founded (1879).

One of the most important meteorologists involved in this project was Father Francesco Denza that visited a number of Italian observatories in order to verify the quality of their data. An example of the results of his work is reported in fig. 1 that shows the distribution of the errors of 64 barometers used by 48 observatories in the period 1870-1875 (Denza, 1875). These errors have been detected with a Fortin barometer which was compared with the reference barometer of Moncalieri Observatory before and after each intercomparison campaign. The reference barometer was also a Fortin one; it had been built in Paris by Tonnelot and compared with the reference barometers of some of the principal European observatories, *e.g.*, Paris, Kew and Vienna.

The mean values of the errors detected by Denza is -0.45 mm of Hg, their standard deviation 0.58.

Actually, as some observatories corrected their data by comparisons with other barometers already before Denza's calibrations, the errors of Italian pressure data were probably less than this value. Unfortunately, Denza is ambiguous on this important point and it is sometimes not clear if these corrections have been considered. This ambiguity may be due to the problem of publishing a paper on the errors of other observatories and so Denza probably preferred to be not completely clear and to report

TABLE II. – *Autumn mean air pressures for some Italian observatories in the periods* 1866-1872, 1880-1900 *and* 1951-1973. *The values of the period* 1880-1900 *are based on Marini's isobaric charts* (*resolution* 0.5 mm Hg) *that have been drawn using a great number of data generally of the last* 20 *years of the* 19th *century* (Mennella, 1967).

Station	Longitude	Latitude	Autumn mean air pressure (mmHg)		
			1866-72	1880-1900	1951-73
Aosta	7.31	45.73	762.7	762.5	
Biella	8.05	45.57	762.6	762.5	
Turin	7.68	45.07	762.3	762.0	763.2
Mondovi	7.80	44.38	762.4	762.0	
Sanremo	7.77	43.83	761.6	761.6	
Genua	8.92	44.40	761.8	761.6	761.9
Alessandria	8.62	44.90	762.2	762.0	
Pavia	9.15	45.18	762.2	762.2	
Milan	9.18	45.47	762.0	762.5	763.0
Brescia	10.28	45.42		762.5	763.1
Vicenza	11.52	45.57		762.2	763.1
Venice	12.33	45.50		762.0	762.9
Udine	13.22	46.07	762.1	762.5	763.1
Trieste	13.75	45.65		762.0	762.5
Parma	10.28	44.82		762.1	763.1
Guastalla	10.64	44.92	761.8	762.2	
Modena	10.93	44.65	762.3	762.2	
Bologna	11.33	44.50	762.3	762.5	763.3
Rimini	12.62	44.03		762.5	762.4
Florence	11.25	43.77	762.2	762.0	762.5
Leghorn	10.30	43.55	761.8	761.5	762.2
Siena	11.32	43.32	762.1	762.0	
Grosseto	11.07	42.75		761.5	762.0
Urbino	12.65	43.73	761.9	762.4	
Ancona	13.52	43.62	762.5	762.4	762.6
Perugia	12.38	43.12	762.8	762.4	
Camerino	13.06	43.14	762.1	762.4	
Rome	12.52	41.88	762.5	761.7	762.5
Naples	14.25	40.86	762.6	762.0	762.4
Termoli	15.00	42.00		762.2	762.3
Bari	16.78	41.13		762.1	761.9
Lecce	18.15	40.23		762.0	762.4
Crotone	17.07	39.00		762.0	762.3
Reggio C.	15.65	38.10	760.9	761.8	
Catania	15.05	37.47		761.8	762.2
Panormo	13.38	38.13	761.2	761.9	762.2
Cagliari	9.05	39.25		761.5	762.1

values that could be errors but that could also simply be differences between barometric readings.

In spite of this problem, Denza's paper shows that Italian pressure data of the years around 1870 have generally small errors, usually less than ± 0.7 mm of Hg, with the exception of a few series, *e.g.* Panormo.

The quality of Italian pressure data for the years around 1870 can also be tested by plotting the spatial pattern of their normal values and by comparing it with the normals of periods that should have more homogeneous data (table II). This comparison shows that the spatial patterns of seasonal and yearly pressure normals of the years around 1870 (Ragona, 1872) are generally in good agreement both with those of the last 20 years of the 19th century (Mennella, 1967) and with the ones of the period 1951-1973 (Aeronautica Militare Italiana, 1981). Only a few observatories have anomalous values and these are generally the ones that showed the greatest errors in Denza's comparisons.

In this paper the data of these observatories have been corrected with a procedure of data homogenisation based on the comparison of the previous normal values (Bellumé, 1996).

The situation is even more complex when the analysis involves the European area: already in 1865 several nations, *e.g.*, France, Switzerland and the Austro-Hungarian Empire, showed high level of organisation of national meteorological services with good procedures of data collection and publication, whereas others get to this result only in the last decades of the 19th century.

Putting together the data of the Italian, French, Swiss and Austro-Hungarian bulletins, about 100 daily data of the principal meteorological parameters are, for example, available for the year 1868 (Ministero di Agricoltura, Industria e Commercio, 1868; Observatoire Imperial de Paris, 1868; Wolf, 1868, Jelinek and Fritsch, 1870). The French bulletins are particularly interesting as they report, beside national data, also data for some other European countries.

As in Italy, also in other European countries a great effort of data homogenisation was in progress in this period and a number of intercomparison campaigns of barometers were organised (Denza, 1875).

Homogeneity of national data unfortunately is not sufficient for the reconstruction of European weather charts as data of different nations have to be used.

Homogeneity of instruments and measuring procedures of the various European countries was greatly improved after the First International Conference of Meteorology held in Vienna in 1873 (Denza, 1873; 1874). During this conference and in some other conferences and meetings (Utrecht, 1874; London, 1876; Rome, 1878), the bases were laid for the present planetary network of meteorological stations. In 1875 for the results that followed the Vienna Conference it was possible to plot daily weather charts for Europe. In the subsequent years these charts became more detailed and, thanks to the telegraph availability and to the consequent possibility of plotting them on-line, they began to be used for provisional aim.

In a short survey, it can be concluded that since 1880 there is great availability of rather homogeneous data and also daily isobaric charts are available both for Italy and a large portion of Europe. The data are not lacking prior to 1865 either, but difficult access and poor homogeneity makes the reconstruction of atmospheric circulation of this period difficult and rather approximate. For the years 1865-1880, the situation is intermediate with good data availability and continuous data evolution as for quantity and quality.

Some examples of reconstruction of atmospheric circulation over Italy during some extreme events which occurred in this last period will be reported hereinafter.

3. – The heavy rainfalls during September/October 1868

The two last decades of September and the first one of October 1868 were characterised by very heavy rainfalls over Northern Italy that involved catastrophic overflows with huge losses of human lives and serious material damages (Ministero di Agricoltura, Industria e Commercio, 1868; Denza, 1868). The daily rainfall data recorded by a number of stations in Northern Italy, Switzerland and the Austro-Hungarian Empire (Wolf, 1868; Cantoni, 1869; Jelinek and Fritsch, 1870) allow one to evaluate the relevance and the extension of this event. In addition to rainfalls, also the levels reached by Maggiore, Como and Ceresio Lakes and by Po and Ticino Rivers (Cantoni, 1869) and their comparison with the data of some main overflows in the latest 300 years, confirm the exceptional meteorological conditions of autumn 1868.

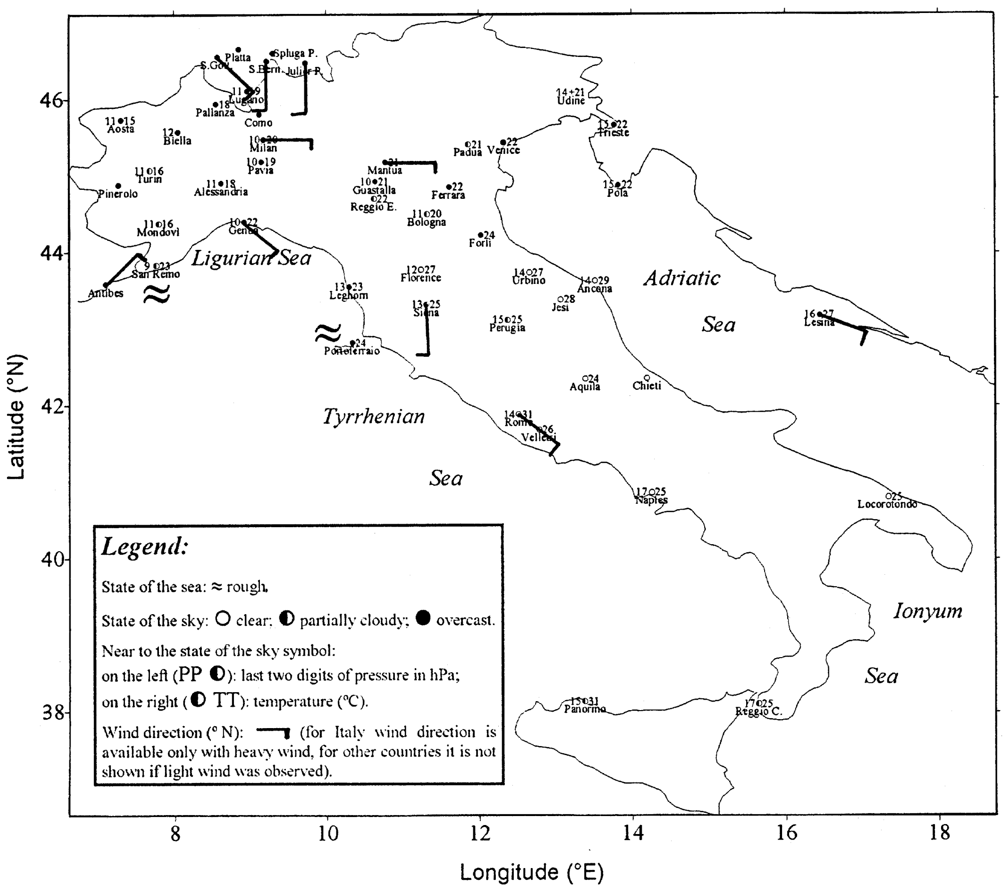

Fig. 2. – October 3, 1868. Observed temperature, pressure, state of the sky and wind direction data.

Unfortunately, although there is availability of a large number of air pressure data collected both in Italy and in neighbouring areas (Ministero di Agricoltura, Industria e Commercio, 1868; Observatoire Imperial de Paris, 1868; Denza, 1868; Wolf, 1868; Jelinek and Fritsch, 1870), the reconstruction of atmospheric circulation starting only from atmospheric pressure data is made difficult by the uneven spatial distribution of the observatories, the bad homogeneity of the measurement methods and the presence of systematic errors that cannot be completely removed by the procedure of data homogenisation we adopted (Bellumé, 1996).

Let us now concentrate on the Italian situation at 9.00 a.m. on October 3rd, 1868 (local time)—*i.e.* one of the most critical periods of the event—and let us consider, beside air pressure, some other meteorological data (Ministero di Agricoltura, Industria e Commercio, 1868).

Air pressure and wind and cloud direction

Air pressure was 1014-1017 hPa over the eastern part of Northern Italy and over Central and Southern Italy, whereas it was lower (1009-1012 hPa) over the western part of Northern Italy (fig. 2).

Wind directions were generally East, Southeast or South (Cantoni, 1869); wind speed data are not available but heavy wind was observed in Milan, Mantua, Genua, Rome and Siena (fig. 2).

Also over the main passes of Central Alps these wind directions were observed (Wolf, 1868). For these stations, however, it is more interesting to consider the direction of the clouds that was South to North at the Julier and Spluga Passes and Southeast to Northwest at St. Gotthard Pass (fig. 2).

State of the sky and of the sea

The sky was clear or only partially cloudy over Central and Southern Italy. It was only partially cloudy also over the western parts of Piedmont and Liguria (Turin, Mondovì and Sanremo), the eastern part of Northern Italy (Padua and Triest) and some stations of Emilia (Bologna and Reggio Emilia). On the contrary, it was overcast over the other areas of Northern Italy (fig. 2).

The Ligurian Sea (San Remo) and the High Tyrrhenian Sea (Portoferraio) were rough or very rough, whereas the Adriatic Sea (Ancona, Trieste, Pola and Lesina) was generally calm (Jelinek and Fritsch, 1870) (fig. 2).

Temperature distribution

The temperature was high all over Italy and, in particular, over the Central and Southern areas where at 9.00 a.m. on October 3rd the temperature values ranged between 27 °C and 31 °C (fig. 2). At 3.00 p.m. of the same day, temperatures higher than 30 °C were measured at Panormo (32.1 °C), Naples (31.8 °C), Locorotondo (31 °C) and Jesi (30.4 °C). At the same time, in the Po Valley temperatures of about 18 °C were measured in Milan (17.7 °C), Turin (18.3 °C), Pavia (18.6 °C) and Alessandria (18.9 °C) whereas in the Southern and Eastern areas of the Po Valley temperatures were higher (Guastalla: 22.2 °C; Reggio Emilia: 23.2 °C; Padua: 24 °C; Bologna: 28.4 °C; Forlì: 27 °C; Ferrara: 24.3 °C; Venice: 23.1 °C and Udine: 25.3 °C).

In the Central Alps, at about 2000 metres above sea mean level, the temperature was of about 8 °C (Wolf, 1868).

Rainfall distribution

The heaviest rainfall of October 3rd occurred on the Central Alps (Platta: 170 mm; St. Gotthard: 165 mm; St. Bernhardin: 142 mm—all in 24 hours) but also in Pallanza, Pinerolo and Turin more than 50 mm in 24 hours were recorded (Cantoni, 1869).

Considering the five-day period October 1st–October 5th, the heaviest rain was recorded in St. Bernhardin (665 mm), Platta (486 mm) and St. Gotthard (395 mm); extending the same analysis to the 30 day period September 11th–October 10th the highest value is St. Bernhardin (1718 mm), but also in the area of Maggiore, Como and Ceresio Lakes the values are remarkable, ranging from 559 mm (Como) to 809 mm (Pallanza) (Cantoni, 1869).

The rainfall distributions both of October 3rd and of the 5 and 30 day periods were certainly affected by the Alpine and Apennine orography; however, very heavy rainfalls in the Central Alps point out that important convergence phenomena might also have occurred.

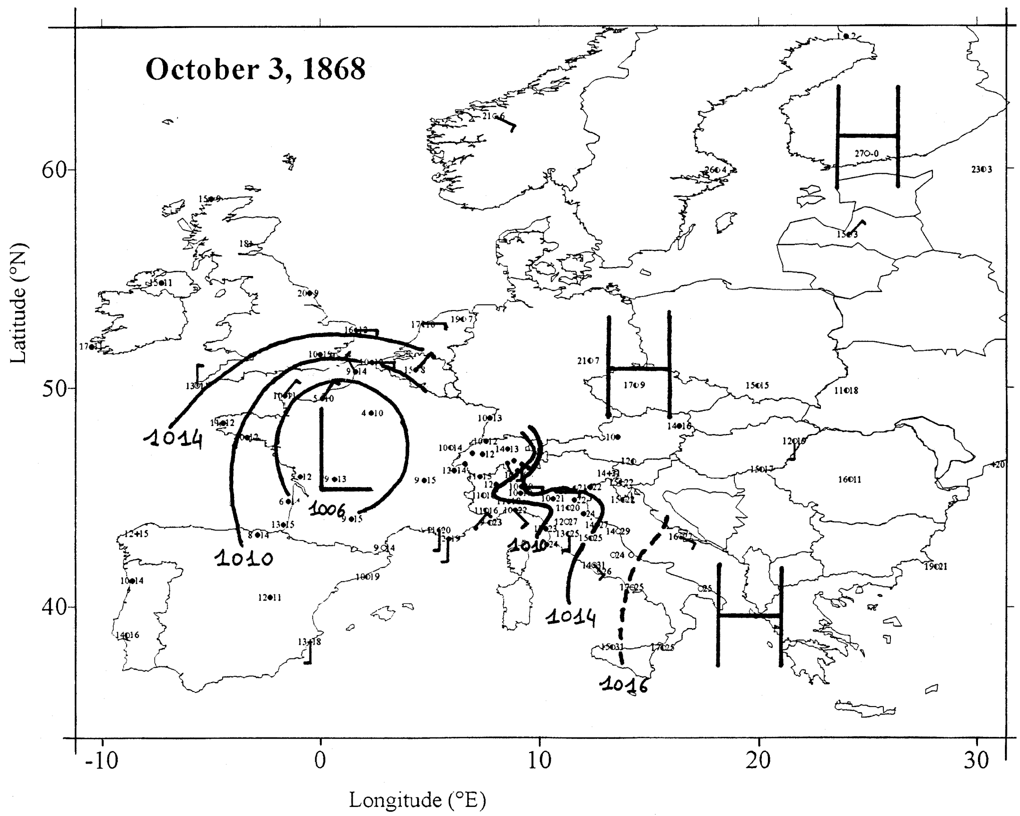

Fig. 3. – Temperature, pressure, state of the sky and wind direction data of October 3, 1868 and tentative reconstruction of isobaric chart. For the meaning of the symbols see legend of fig. 2.

All the previous data (fig. 2) seem to show the presence over Italy both of an area characterised by cyclonic circulation (Piedmont, Valle d'Aosta, Lombardy, Liguria, Ligurian Sea, and the coast of Tuscany) and an area characterised by anticyclonic curvature (eastern part of Northern Italy and Central and Southern Italy).

The extension of the analysis to a larger scale is more complex as no simultaneous data are available. Also, Italian data are not strictly simultaneous as they are observed at 9 a.m. local time, but this is a little problem compared to the use of data observed all over Europe at a time ranging from 7 to 9 a.m., local time. Moreover, using data of different countries, a number of homogeneity problems arises and completely different conventions are used for the registration of state of the sky, state of the sea and wind speed and direction data.

In spite of these problems, European pressure and wind direction data (Observatoire Imperial de Paris, 1868; Denza, 1868; Wolf, 1868; Jelinek and Fritsch, 1870) show interesting features with a clear air pressure minimum over France and a ridge over the Balkans. Pressure, wind, temperature and state of the sky and the sea data, seem to show that the cyclonic circulation over Northwestern Italy belongs to a greater cyclonic area over Western Europe (England, Belgium, Netherlands, Spain, Portugal, Northwestern Italy and Switzerland), whereas anticyclonic curvature extends over the Balkans, Eastern, Central and Southern Italy.

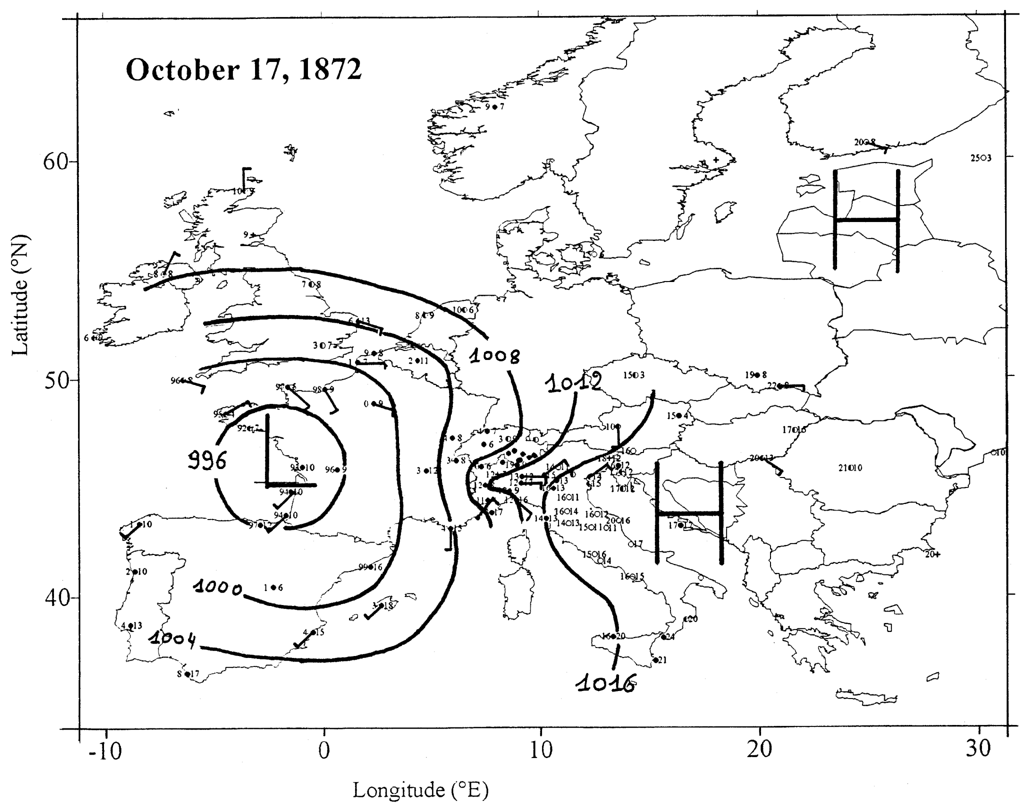

Fig. 4. – Temperature, pressure, state of the sky and wind direction data of October 17, 1872 and tentative reconstruction of isobaric chart. For the meaning of the symbols see legend of fig. 2.

The presence of a strong contrast between two different air masses over Northwestern Italy was observed already by Father Denza who in 1868 wrote that "*the persistence of bad weather was due to the very hot equatorial streams, which in the first days of the month blew all over Europe and especially in Southern and Eastern regions where they acquired unusual strength. They were contrasted by counter-streams of cold air that coming down from the high latitudes followed them and spread all over the West almost as far as our Alps*" (Denza, 1868).

Figure 3 shows a tentative reconstruction of an isobaric chart over Italy and some European areas on October 3rd 1868.

The method used to plot this isobaric chart can be applied to the whole period of heavy rainfalls of autumn 1868 so that it is possible to reconstruct the evolution of the event with daily resolution.

4. – Other events

The same methodology used to describe the event of autumn 1868 is applicable to the reconstruction of atmospheric circulation over Italy during other heavy rainfall events of the period 1865-1880. In particular, the case of October 17th, 1872 is shown in fig. 4. This event made the Po River rise to levels even higher than those recorded

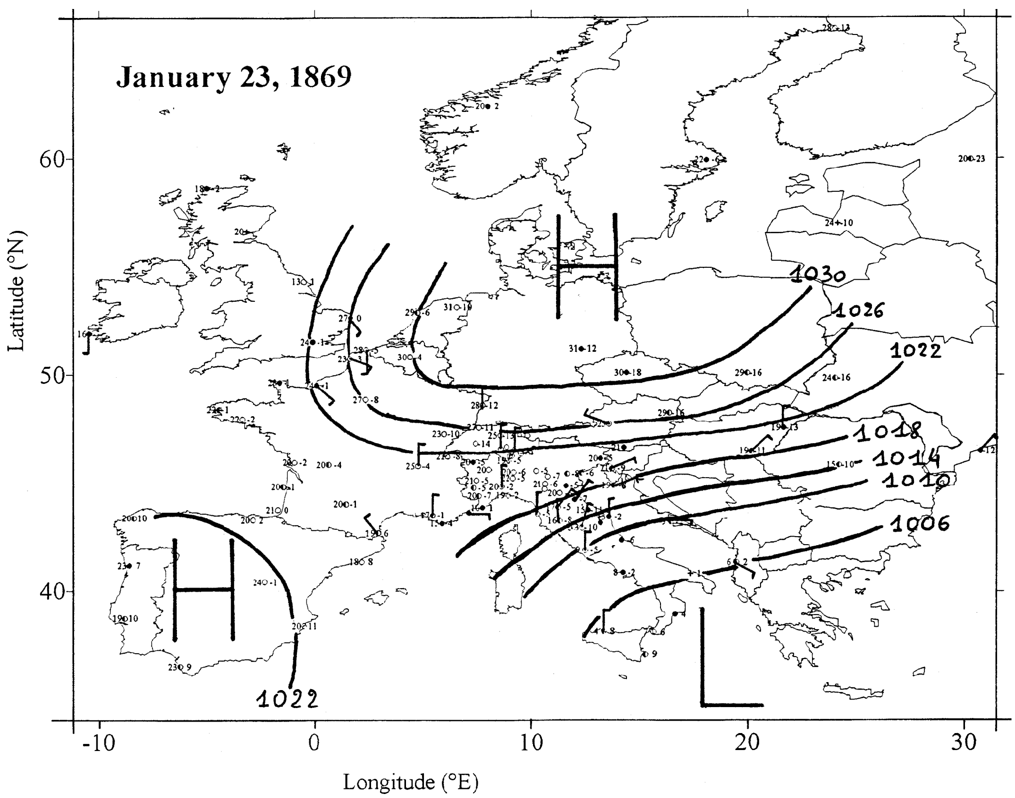

Fig. 5. – Temperature, pressure, state of the sky and wind direction data of January 23, 1869 and tentative reconstruction of isobaric chart. For the meaning of the symbols see legend of fig. 2.

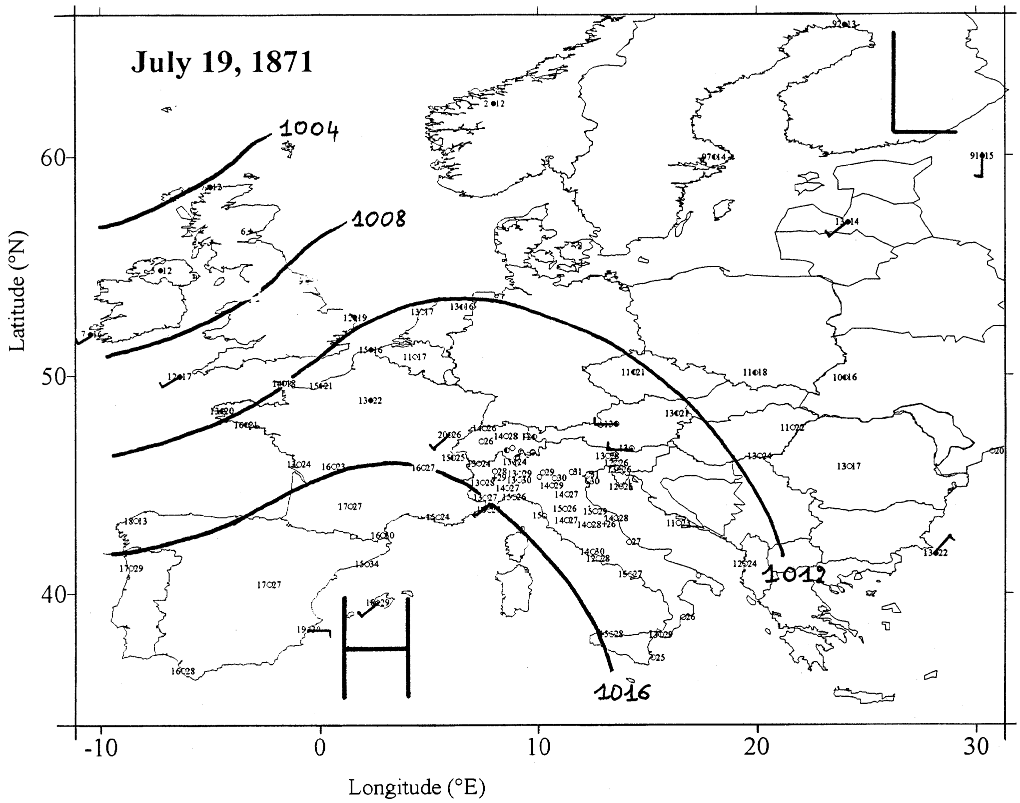

Fig. 6. – Temperature, pressure, state of the sky and wind direction data of July 19, 1871 and tentative reconstruction of isobaric chart. For the meaning of the symbols see legend of fig. 2.

during the event of autumn 1868. In this case also, there were huge losses of human lives and very serious material damages.

The methodology is not only applicable to heavy rainfall events. Figures 5 and 6 show, as examples, the reconstruction of the weather charts, of two other cases: a cold wave over Central Italy (January 23rd, 1869), with temperatures ranging between -13 °C and -5 °C and a hot wave over Northern Italy (maximum daily temperatures of 34–38 °C) and Central Europe (July 19th, 1871).

5. – Conclusions

The work evidences how it is possible to reconstruct the atmospheric circulation present over Italy and the neighbouring areas already starting from 1865.

The reconstruction of the synoptic weather situation during events of heavy rainfalls and/or high wind speeds is particularly easy both since they show strong baric gradients that make it possible to minimise the effects of pressure data errors and because they are generally well described and, beside the usual data, a lot of other information is normally available.

The analysed events, *i.e.* two cases of heavy rainfalls, represented by cold waves due to continental polar air masses and a heat wave probably due to anticyclonic subsidence, evidence how the methodology described in this paper is suitable to reconstruct the evolution of atmospheric circulation during extreme events with daily resolution.

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REFERENCES

AERONAUTICA MILITARE ITALIANA - CENTRO NAZIONALE DI METEOROLOGIA E CLIMATOLOGIA AERONAUTICA, *Tabelle climatologiche della pressione atmosferica* (Roma) 1981.

ASSOCIAZIONE METEOROLOGICA ITALIANA, *Bollettino Mensuale* (Collegio degli Artigianelli, Torino) 1881-1884.

BELLUMÉ M., *Ricostruzione di campi barici per la Penisola Italiana per il periodo 1865-1878,* Tesi di Laurea in Fisica (Università di Milano, Milano) 1996.

BELTRANO M. C. and ESPOSITO S., *La rete meteorologica dell'Ufficio Centrale di Ecologia Agraria dalle origini ai nostri giorni, Agricoltura*, **277** (1996) 27-40.

CAMUFFO D., *La nascita delle reti meteorologiche,* in *Atti del Convegno: Padre Francesco Denza nel centenario della morte* (Regione Piemonte, Settore Informazione Stampa Relazioni Esterne, Torino) 1994.

CANTONI G., *Su le pioggie dell'autunno 1868 nell'Alta Italia*, in *Supplemento alla Meteorologia Italiana - Anno 1869* (Ministero di Agricoltura, Industria e Commercio, Direzione di Statistica, Roma) 1869.

COLACINO M. and CONTE M., *Greenhouse effect and pressure patterns in the Mediterranean basin, Nuovo Cimento C*, **16** (1993) 67-76.

COLACINO M. and CONTE M., *Heat waves in the central Mediterranean. A synoptic climatology, Nuovo Cimento C*, **18** (1995) 295-304.

DENZA F., *Bullettino meteorologico dell'osservatorio del Real Collegio Carlo Alberto in Moncalieri* (Collegio degli Artigianelli, Torino) 1865-1880.

DENZA F., *Rivista meteorologica del mese di ottobre 1868,* in *Bullettino meteorologico dell'osservatorio del Real Collegio Carlo Alberto in Moncalieri*, Anno III, Vol. III (1867-68) (Collegio degli Artigianelli, Torino) 1868.

DENZA F., *Atti del Congresso Internazionale di meteorologia di Vienna,* in *Bullettino meteorologico dell'osservatorio del Real Collegio Carlo Alberto in Moncalieri*, Anno VIII, Vol. VIII (1872-73) e Anno IX, Vol. IX (1873-74) (Collegio degli Artigianelli, Torino) 1873, 1874.

DENZA F., *Confronti barometrici delle stazioni meteorologiche italiane eseguiti dal 1870 al 1875 dal P. Francesco Denza, Direttore dell'Osservatorio di Moncalieri,* in *Supplemento alla Meteorologia Italiana - Anno 1875*, Fascicolo II (Ministero di Agricoltura, Industria e Commercio, Direzione di Statistica, Roma) 1875.

FRENZEL B., *Climatic trends and anomalies in Europe 1675-1715* (Fischer Verlag, Stuttgart) 1994.

JELINEK C. and FRITSCH C., *Jahrbücher der K. K. Central-Anstalt für Meteorologie und Erdmagnetismus - Jahr 1868*, Vienna, 1870.

JONES P. D., *Hemispheric surface air temperature variations: a reanalysis and an update to 1993*, *J. Climate*, **7** (1994) 1794-1802.

KINGTON J. A., *The Weather of the 1780's over Europe* (Cambridge University Press, Cambridge) 1988.

LAMB H. H. and JOHNSON A. I., *Secular variations of the atmospheric circulation since 1750*, *Geophys. Mem.*, **110**, London (1966).

LAMB H. H., *Climate Present, Past and Future* (Methuen & Co., London) 1972.

LAMB H. H., *Climatic History and the Future* (Princeton University Press, Princeton) 1977.

MENNELLA C., *Il clima d'Italia* (Fratelli Conte, Napoli) 1967.

MAUGERI M., LOMBARDI E., BUFFONI L., CHLISTOVSKY F. and MANGIANTI F., *Evolution of the Italian meteorological network in the period 1865/1905 and analysis of the data availability*, in *International Conference on Past, Present and Future Climate*, edited by P. HEIKINHEIMO (Academy of Finland, Helsinki) 1995A.

MAUGERI M., LOMBARDI E., BUFFONI L. and CHLISTOVSKY F., *Gli archivi dell'Osservatorio di Brera: un'eccezionale fonte di dati sul clima degli ultimi due secoli*, in *Atti del Convegno: un servizio meteorologico per la Lombardia*, edited by L. ALBANO and G. P. MINARDI (ERSAL, Milano) 1995B.

MINISTERO D'AGRICOLTURA, INDUSTRIA E COMMERCIO - DIREZIONE DI STATISTICA, *Meteorologia Italiana* (Roma) 1865-1878.

OBSERVATOIRE IMPERIAL DE PARIS, *Bulletin International* (Paris) 1868.

PALAZZO L., *Meteorologia e Geodinamica, in Cinquanta anni di storia italiana (1860-1910)* (Regia Accademia dei Lincei, Roma) 1911.

RAGONA D., *Sulle pioggie di Ottobre 1872*, in *Supplemento alla Meteorologia Italiana - Anno 1872* (Ministero di Agricoltura, Industria e Commercio, Direzione di Statistica, Roma) 1872.

SOCIETÀ METEOROLOGICA ITALIANA, *Bollettino Mensuale* (from 1906 *Bollettino Bimensuale*) (Collegio degli Artigianelli, Torino) 1885-1924.

SNEYERS R., SIANI A.M. and PALMIERI S., *Characterizing trends in climatological time series. An application to Brera Observatory (Milan) rainfall series. Applications of Time Series Analysis in Astronomy and Meteorology* (Chapman and Hall, London) 1997.

UFFICIO CENTRALE DI METEOROLOGIA, *Annali* (Roma) 1879-1925.

UFFICIO CENTRALE DI METEOROLOGIA, *Bollettino Meteorico Giornaliero* (Roma) 1880-1927.

WOLF R., *Schweizerische Meteorologische Beobachtungen* (Zürich) 1868.