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ANALYSIS OF THE SEVERE FLOOD OF 13-16TH OCTOBER 2000 IN PIEDMONT (ITALY)

C. CASSARDO (2)
R. CREMONINI (1)
D. GANDINI (1)
G. PAESANO (1)
R. PELOSINI (1)
M.W. QIAN (2)

(1) Regional Meteorological Service of Piedmont, Piedmont Region, Turin, Italy.

(2) Department of General Physics, Turin University, Italy.

ABSTRACT: During the 13th-16th of October 2000 a disastrous flood occurred in the whole Piedmont associated with heavy rainfall over the North-Western Alpine chain in successive episodes spanning the whole period. The event was originated by a Southern, strong and moist, upper flow established over North-Western Italy, associated at lower layers with an eastern rotation of the air flow and consequently strong convergence on the western Po Valley. The high temperature of the Mediterranean Sea caused a high rate of moisture enrichment of the air mass moving towards Piedmont. The most intense rainfall (values larger than 600 mm in 96 hours have been reported) occurred over the mountainous regions, where the high temperatures forced the snow-rain threshold at very high altitudes. This event was one of the most intense events of the last 200 years in the Piedmont area. The majority of the basins suffered strong flood episodes; most of the mountainous portion of the basins and also part of the city of Turin down the Po Valley were seriously damaged by the strong rainfalls.

RESUMEN: Durante los días 13 a 16 de Octubre de 2000 se produjo una avenida catastrófica en el Piamonte asociada con intensas lluvias en el noroeste de los Alpes. La tormenta fue originada por un flujo meridional muy húmedo en altura sobre el noroeste de Italia, asociado en los niveles inferiores a una rotación oriental del flujo del aire y la consiguiente convergencia en el Po occidental. La elevada temperatura del mar Mediterráneo dió lugar a un alto contenido en humedad de las masas de aire que se desplazaron hacia el Piamonte. Las lluvias más intensas (se registraron valores superiores a 600 mm en 96 horas) ocurrieron en las áreas de montaña, donde las altas temperaturas forzaron el desplazamiento del umbral lluvia-nieve hasta posiciones muy elevadas. Este evento fue uno de los más intensos en el Piamonte durante los últimos 200 años. La mayoría de las cuencas sufrieron intensas avenidas, con daños muy serios en los tramos montañosos y en parte de la ciudad de Turín.

Key-words: Floods, Intense rainfalls, Mediterranean Sea, Alps, Piedmont.

Palabras clave: Avenidas, Lluvias intensas, Mar Mediterráneo, Alpes, Piamonte.

1. Introduction

On the 13th-16th of October 2000 a disastrous flood occurred in the whole Piedmont (in north-western Italy), associated with heavy rainfall over the north-western Alpine chain in successive episodes spanning the whole period. The most intense rainfalls occurred over the mountainous regions, where values larger than 600-700 mm have been reported (ref. [1]).

2. Meteorological overview

The event is originated by a deep cyclone over Great Britain already present on Wednesday 11th October. The low pressure is very large in latitude, arriving to touch the Iberian Peninsula and north-western Italy. It is associated to a minimum of pressure, at surface level, of 964 hPa at h 12 UTC of the 11th October (Figure 1)

On Thursday 12th October the cyclone still stays there, with strong and cold northern winds coming from North Atlantic to Iberian Peninsula and contributing to pressure decreasing in the area of western Mediterranean, while strong and moist flows from South-Southwest direction establish over north-western Italy bringing a lot of moisture to the Piedmont Region (Figure 2).

At the same time a ridge forms on eastern Europe and forces the flow over north-western Italy from Southeast in the following days. The presence of the ridge over eastern Europe creates a dangerous blocking effect because it contributes to immobility of the low pressure and the associated front on the western part of Europe during the whole event.

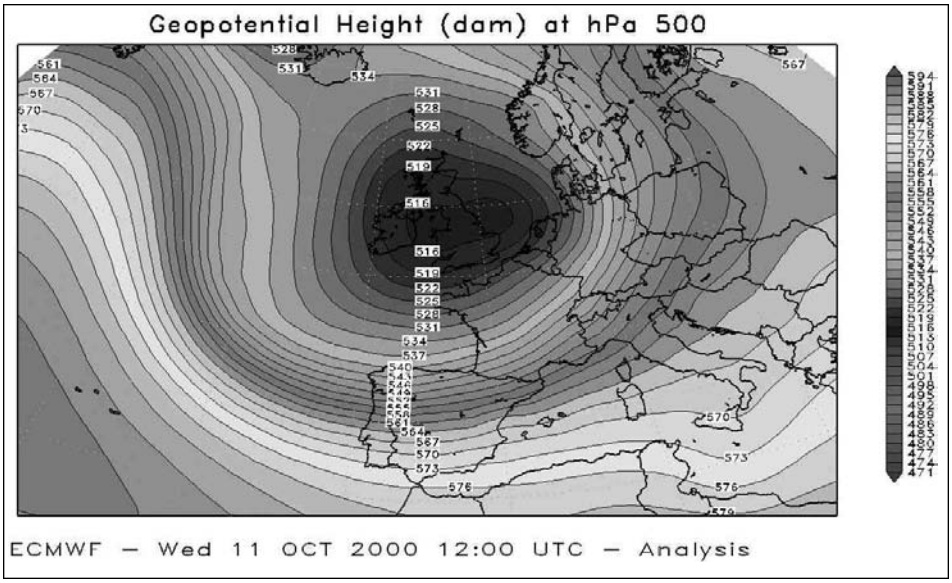

Figure 1: Geopotential height at 500 hPa on Wednesday 11th October 2000 at h 12:00 UTC.

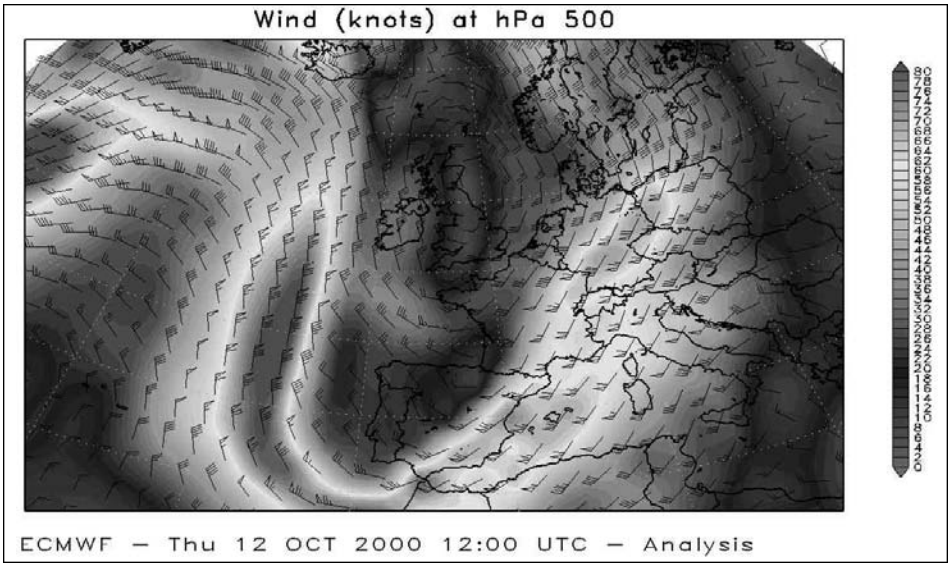

Figure 2: Wind at 500 hPa, on Thursday 12th October 2000 at h 12 UTC.

As it is shown in the map of precipitation occurred along all the days of the event (Figure 6), it is already starting to rain on the day of Thursday 12th, with still light rainfall rates, locally heavier near the mountains of North and South Piedmont.

During day 13th the trough grows very well over Iberian Peninsula and the ridge on East-Europe spreads more and more to north (Figure 3). The depression is well developed in altitude, arriving up to the tropopause level, and it is strongly barocline with the low pressure centred over Pyrenees mountains at upper layers and on the north-African coasts of Algeria and Tunisia at lower layers.

The baroclinity causes wind shear: flow comes from South-Southwest at upper layers and from East-Southeast at lower layers, with strong convergence's effects in the lower layers over the western Po Valley, increasing the turbulence and the vertical motions of the atmosphere.

For the whole day of Friday 13th a minimum of sea level pressure stays on western Mediterranean sea (Figure 4): it is not very deep, but it is quite wide. The temperature of the sea is very high: Autumn is the season of the year that presents the warmest temperature of the sea surface: values of 19 °C are measured on the Ligurian sea and 23-24 °C near the coast of north-Africa. The width and persistency of the pressure minimum and the warm temperature of the sea (together with the turbulence effects of the barocline low pressure) cause a high rate of moisture's enrichment of the air mass up to the higher layers of the atmosphere.

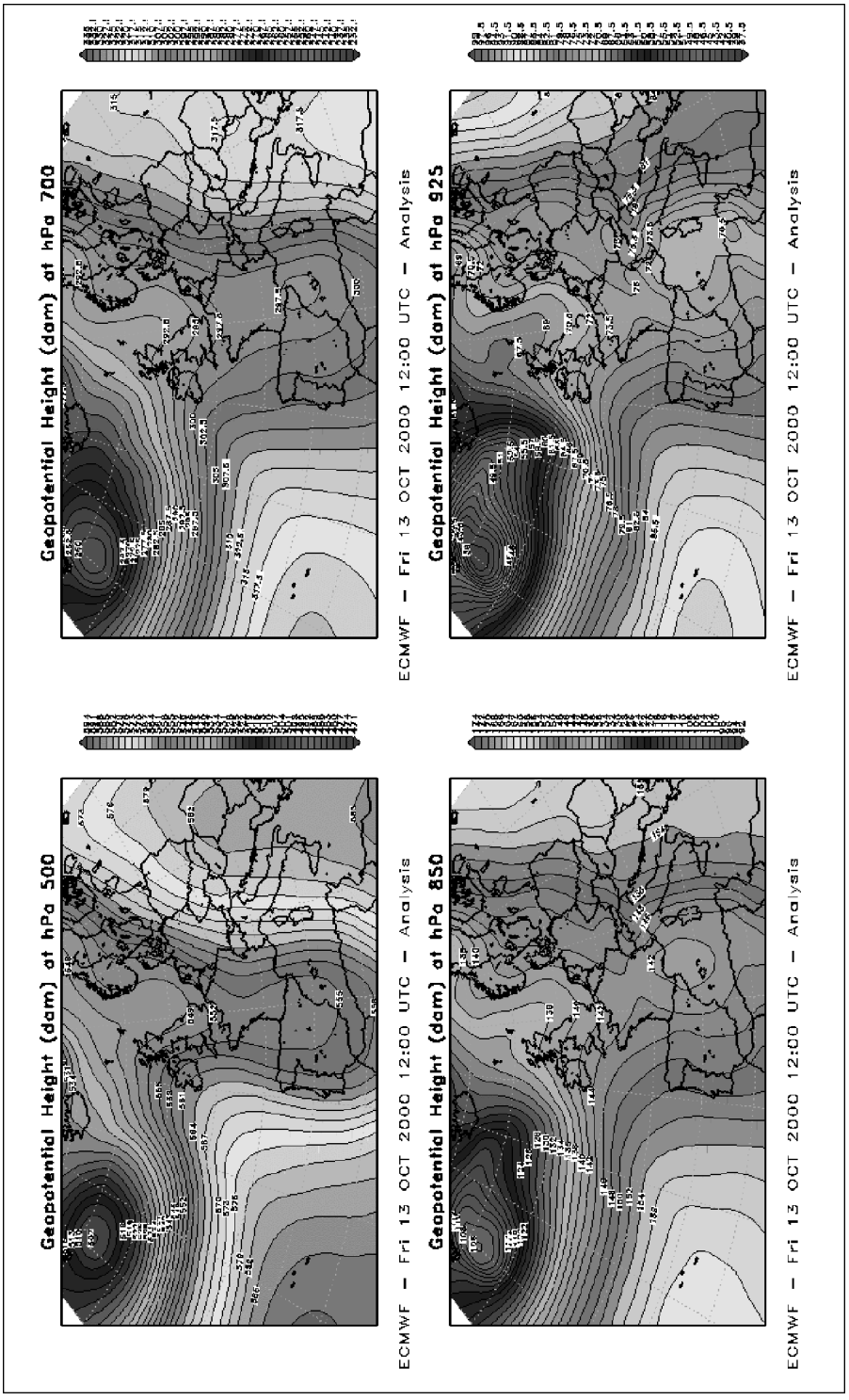

Figure 3: Geopotential height at four standard levels of 500, 700, 850 and 925 hPa on Friday 13th October 2000 at h 12 UTC.

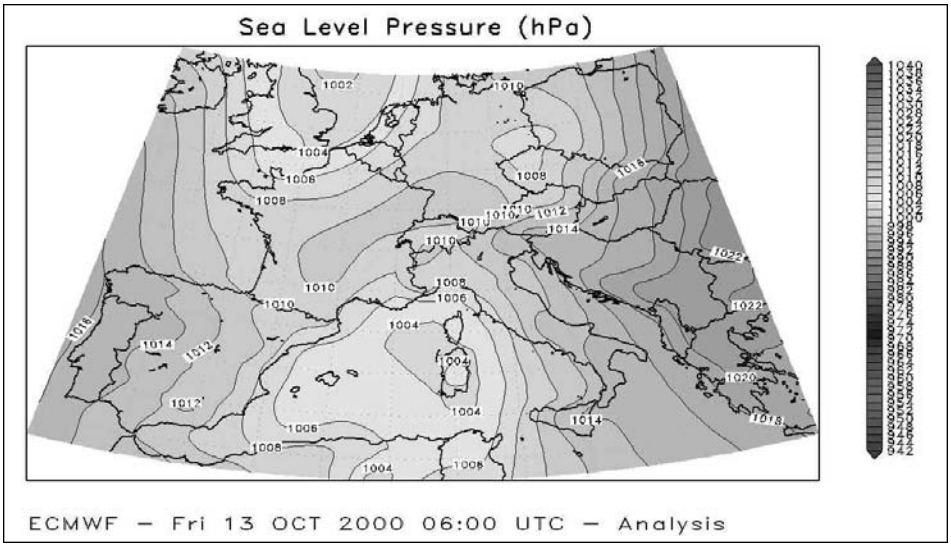

Figure 4: Sea level pressure on Friday 13th October 2000 at h 6 UTC.

Sounding of Friday 13th at h 00:00 UTC in Milan (Figure 5) shows that the atmosphere is very humid, close to saturation (with values of 75% of humidity) up to 8000 m. Wind comes from Southwest at upper layers and East-Southeast at the surface. The high temperatures force the snow-rain threshold at very high levels. The «freezing level», that is the altitude where the temperature reaches the 0 °C, is very high: about 3700 m.

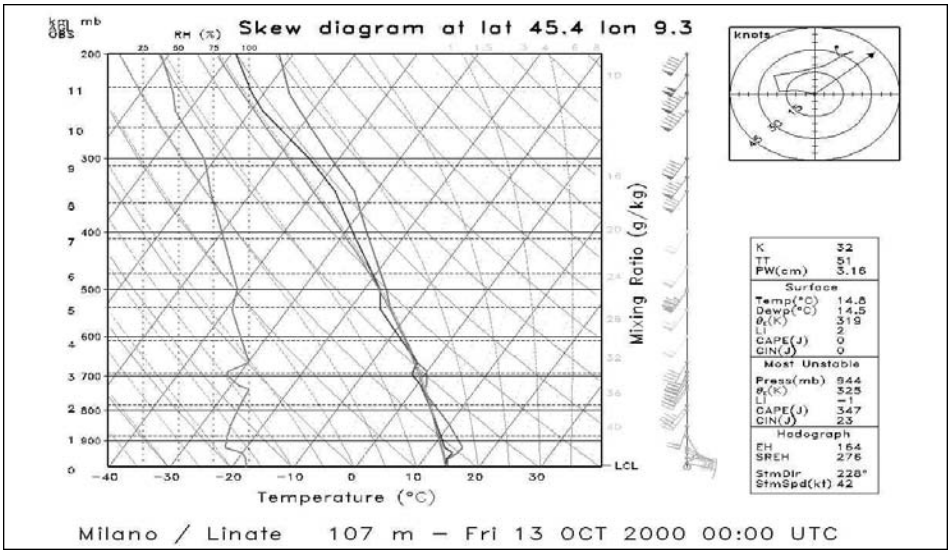

Figure 5: Sounding in Milan at h00 UTC of Friday 13th October 2000.

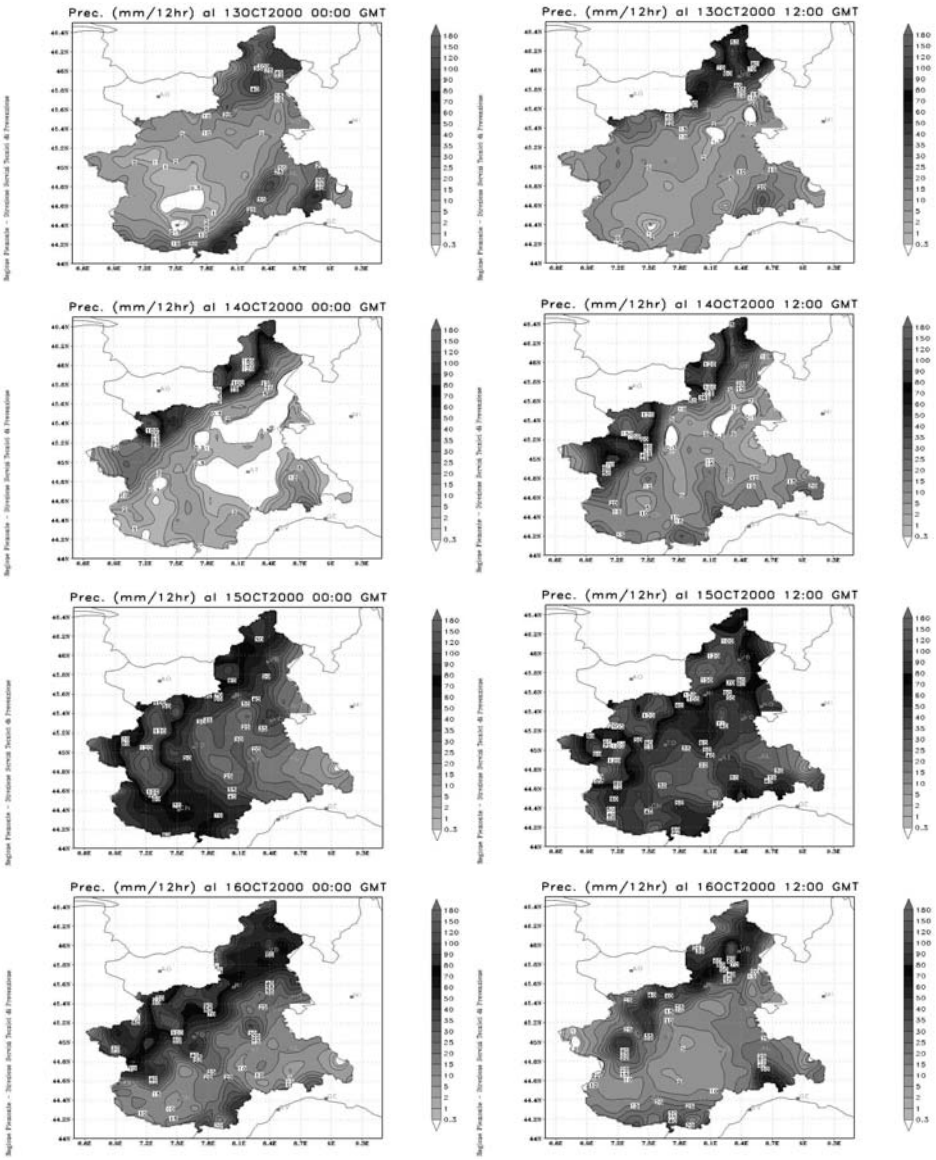

Figure 6: Evolution of accumulated precipitation over 12 hours, from h 12 UTC of Thursday 12th October 2000 until h 12 UTC of Monday 16th, every 12 hours.

Precipitation intensify on Friday the 13th over the Northern sector of Piedmont (Figure 6), where the warm front coming from the South makes the freezing level rise from 2900 m to 3400 m and causes rain mixed with sand carried from north-Africa. The local intensification is due to the orographic effect of the mountains which are perpen-

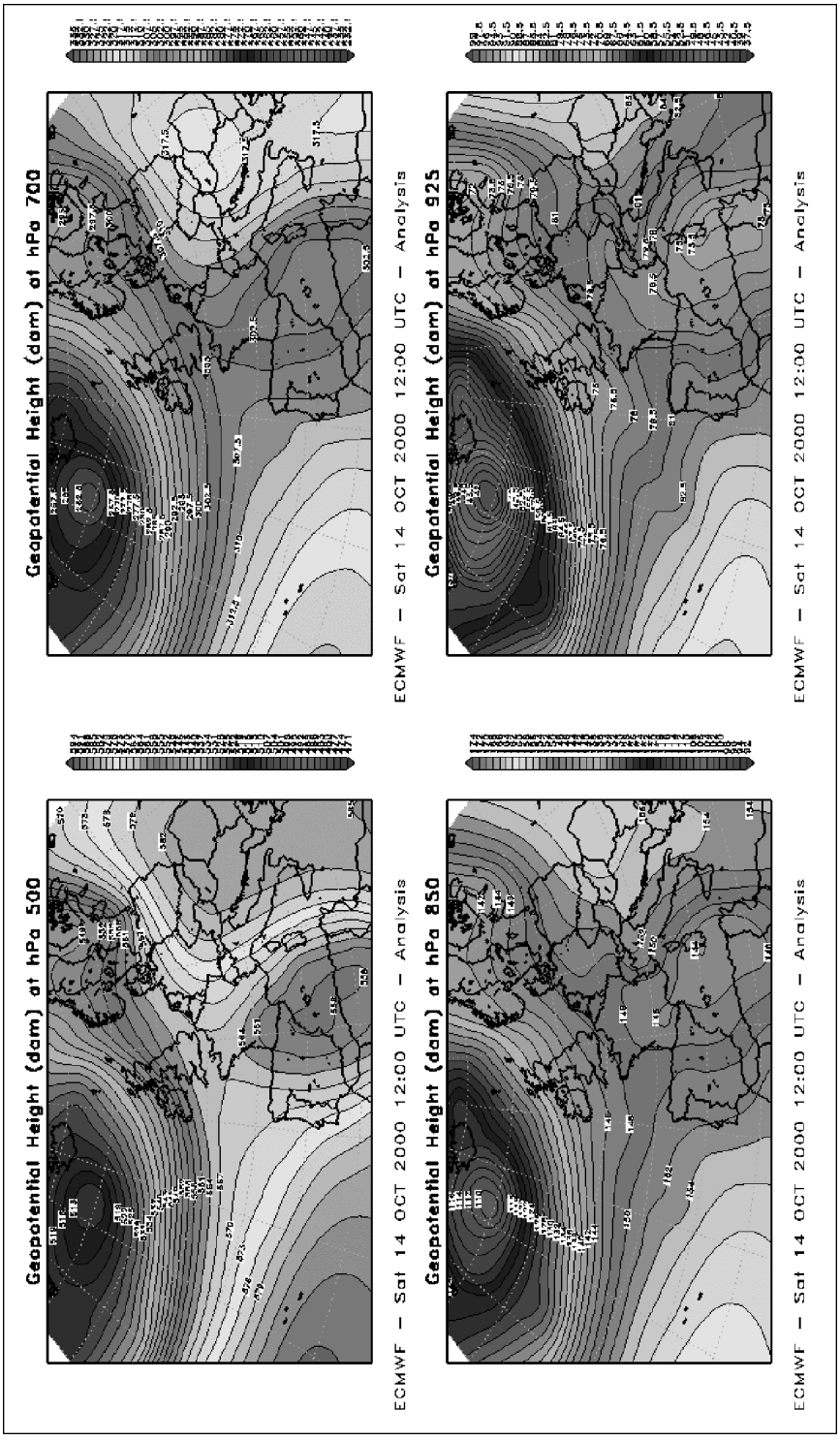

Figure 7: Geopotential height at four standard levels of 500, 700, 850 and 925 hPa on Saturday 14th October 2000.

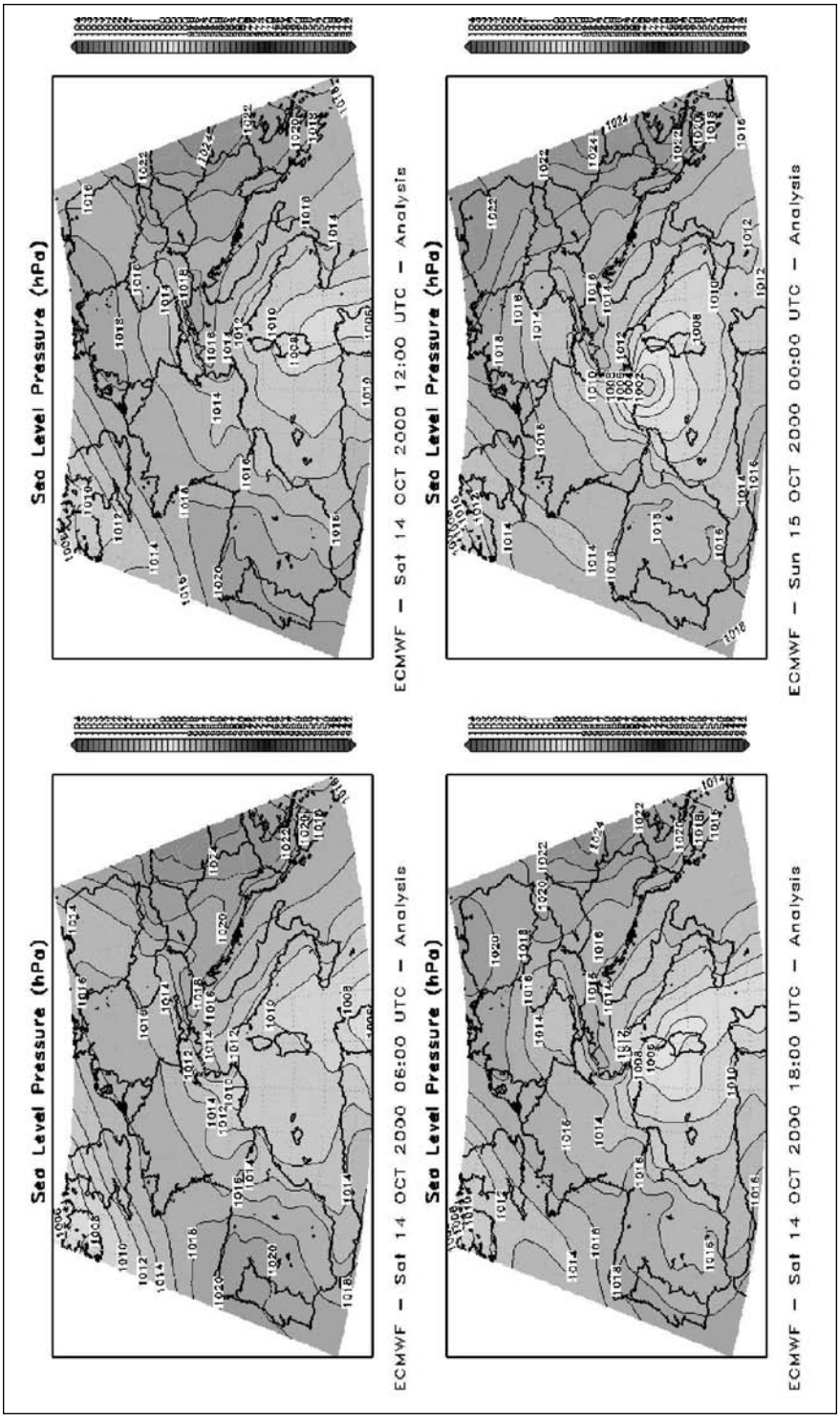

Figure 8: Evolution of sea level pressure every 6 hours, from h 6 UTC of Saturday 14th October 2000 until h 00 UTC of Sunday 15th

dicular to the southern flow: two maxima are detected on the two sides of Ossola Valley on the northern mountains.

During day 14th, the meteorological configuration changes slowly causing an eastern rotation of the airflow: so the areas affected by the strongest precipitation are the Western basins of Piedmont.

In fact, on Saturday 14th the trough over West-Europe generates a cut-off with a closed depression at all levels over Western Mediterranean: Figure 7. The depression is still barocline and the associated front is basically stationary.

After the minimum of sea level pressure of the previous day is filled up, a new one forms over the northern coasts of Tunisia and moves slowly northward (Figure 8). While it moves across the Mediterranean sea, it gets deeper and deeper because of the latent heat from the sea which favours the convective phenomena.

On the night between Saturday and Sunday, the minimum of sea level pressure arrives to the Mediterranean coasts of France where it is reported a pressure decrease of 10 hPa in 12 hours.

The location of the minimum creates a strong baric gradient between western Po Valley and Cote d'Azur: north-western Italy is interested by strong eastern flows at lower layers which bring humidity also from the Adriatic sea over the Piedmont region.

The strong mass' convergence at lower layers on Western Po Valley induces again high values of vertical velocity over Piedmont, stimulated by the interaction of flow with the Alps and Apennines.

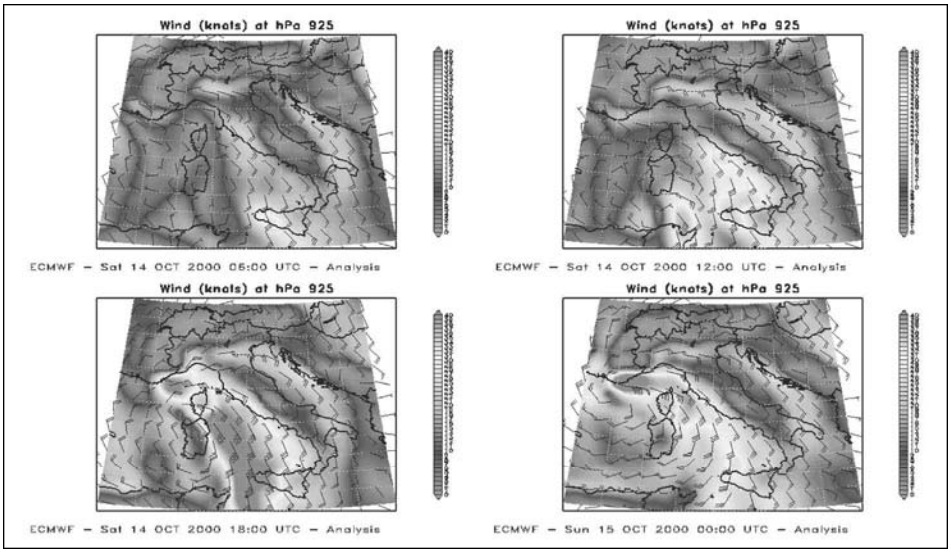

Figure 9: Evolution of wind at 925 hPa every 6 hours, from h 6 UTC of Saturday 14th October 2000 until h 00 UTC of Sunday 15th.

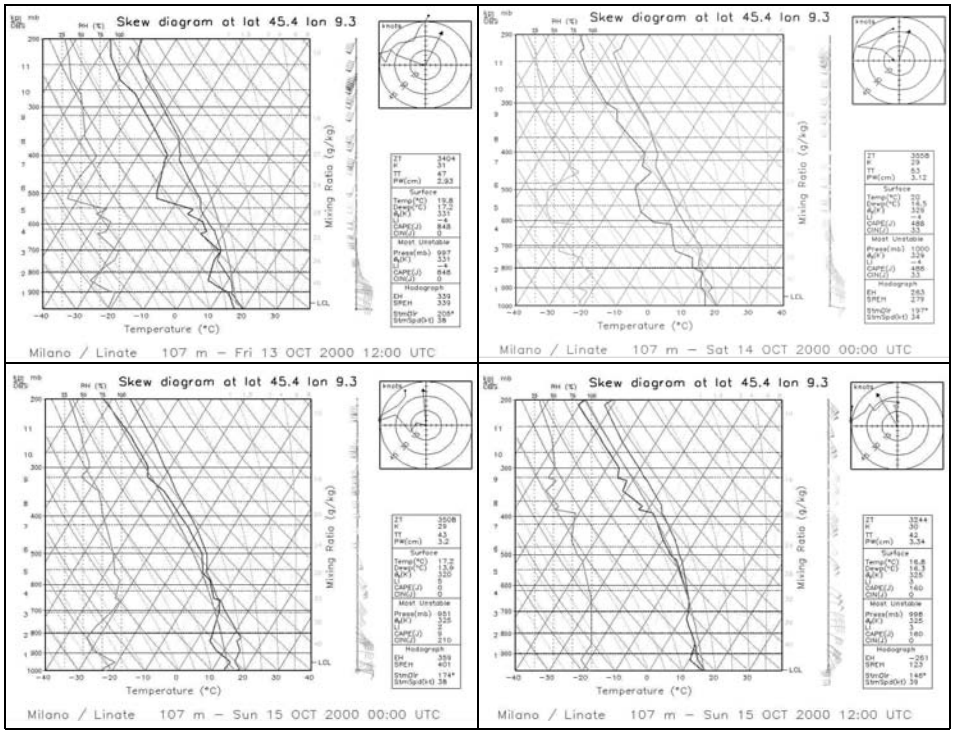

Figure 10: Evolution of atmosphere's vertical profiles shown by the soundings in Milan, from Friday 13th October 2000 until Sunday 15th.

As shown in Figure 6, precipitation intensify over the western side of Ossola Valley and over all the Western sector of Piedmont, because flow turns eastward at higher and higher layers. This rotation of flow is clearly illustrated by the vertical profiles of atmosphere, measured by the soundings of Milan airport (Figure 10).

During Sunday 15th, the low pressure moves northward letting the cold front reach Northwest Italy starting from the southern part of Piedmont. In Figure 11 temperature at 700 hPa decreases of 3-4 °C in 18 hours over Piedmont.

The arrival of the cold front from Southwest produces a destabilisation of the atmosphere, causing some thunderstorm activity. In fact the cold air advection causes a sudden over-saturation of present humidity with still heavy precipitation and even thunderstorms over different parts of the all region: also over flat areas and above all over the southern mountains where the cold front arrives first.

Looking at the maps of precipitation of day 15th at h 12:00 UTC and 16th at h 00:00 UTC (Figure 6), the maxima rainfalls are reported in the north-western areas, but high rainfall rates are now observed also in the flat areas.

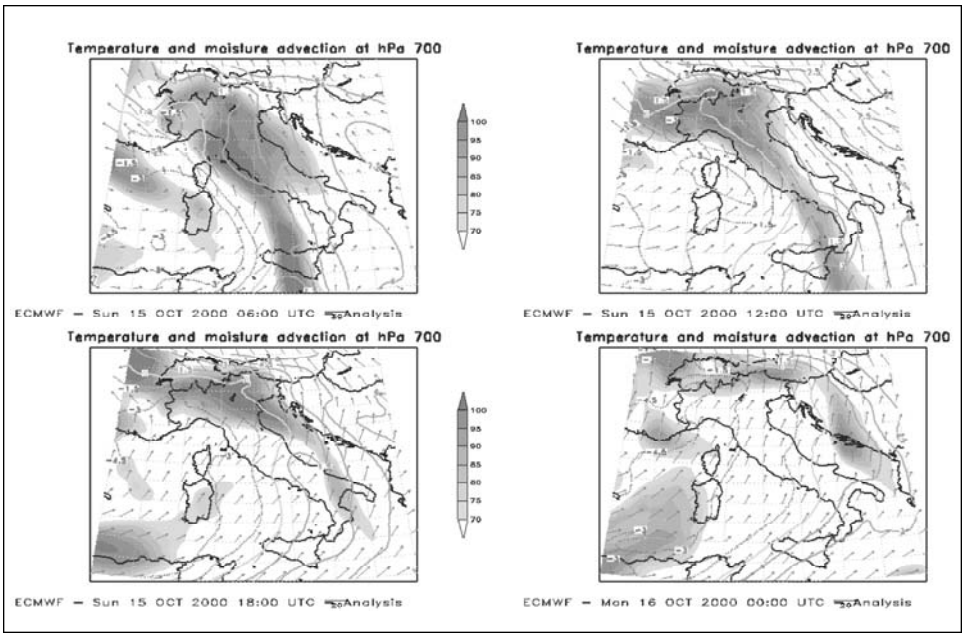

Figure 11: Evolution of temperature and moisture advection at 700 hPa every 6 hours, from h 6 UTC of Sunday 15th October 2000 until h 00 UTC of Monday 16th.

Sounding of Monday 16th at h 00:00 UTC in Cuneo Levaldigi (Figure 12) shows a characteristic after-thunderstorms profile, with clear decreasing of humidity and fall-off of the tropopause (from 12 km down to 9 km: about 3000 m in 12 hours), because of the cold advection.

Finally, during the last day (Monday 16th), the low pressure keeps on moving northward and becomes weaker and less deep and it gets a shape of trough over France (Figure 14). The event is going to end.

Flow at higher layers turns again from Southwest, bringing more humidity from the sea over Piedmont especially across the northern sector of the region. The new influx of moisture creates again a humid and unstable atmosphere from the surface up to 5000 m, as it's shown in Figure 13.

Intensification of the Southern flow causes again strong precipitation in the northern mountain areas of Piedmont (Figure 6) where the orographic effect is more evident.

Afterwards the Azores' anticyclone extends to the Mediterranean basin pushing the low pressure definitively northward. The trough's inclination moves eastward, so the flow over Piedmont region changes coming from West-Northwest direction. Pressure increasing together with drier air coming from West-Northwest create again a stable atmosphere over the region.

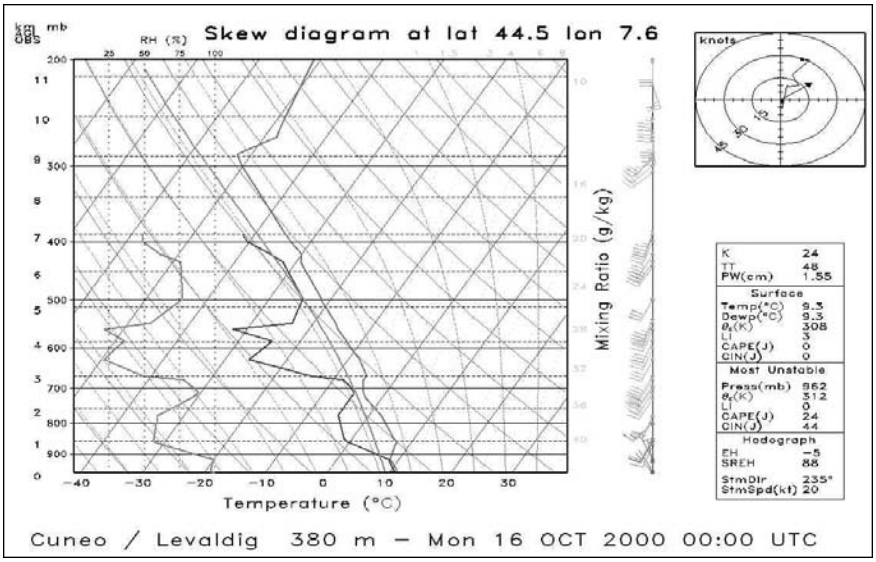

Figure 12: Sounding in Cuneo Levaldigi at h 00 UTC of Monday 16th October 2000.

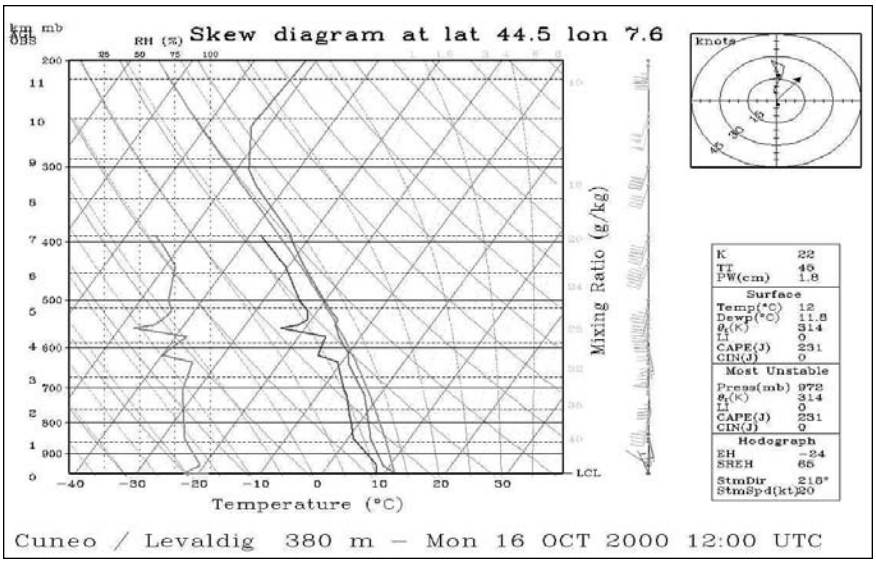

Figure 13: Sounding in Cuneo Levaldigi at h 12 UTC of Monday 16th October 2000.

3. Conclusions

a) Meteorological remarks

In this event the synoptical situation has played an important role in governing the phenomena. The deep and wide low pressure, typically barocline over western Europe,

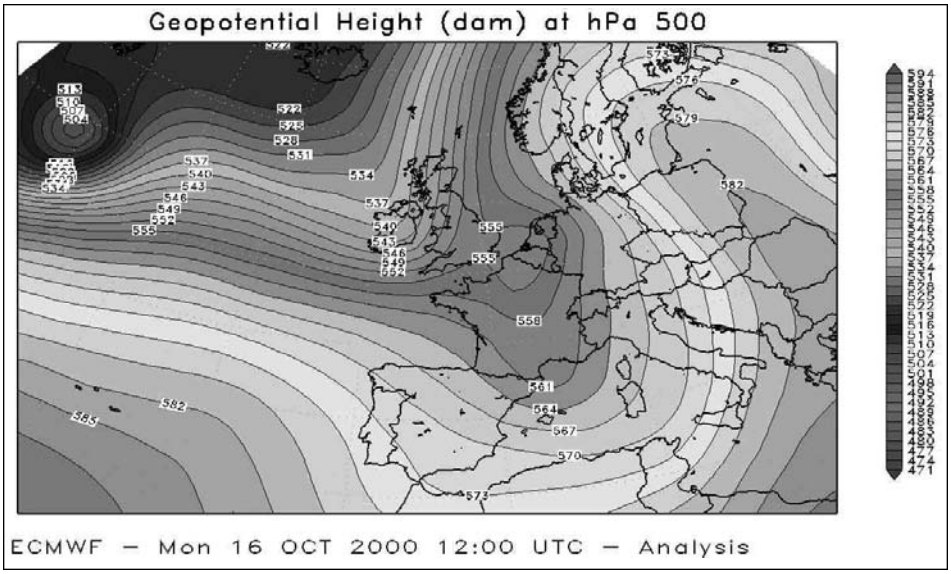

Figure 14: Geopotential height at 500 hPa on Monday 16th at h 12 UTC.

and the blocking ridge over eastern Europe have caused a dangerous immobility of the cyclonic circulation and humid flows from South-Southeast over the involved area.

Precipitation rates have been very high continuously for about 80 hours, from Friday the 13th to Monday morning the 16th, even if the mechanisms, which have intensified the rainfall, have been different in the various days of the event.

On Friday and Saturday the orographic effect has been decisive, first with the moist flow coming from South on the 13th and then with the humidity coming from East-Southeast because of the minimum of sea level pressure located over the Ligurian Gulf.

On Sunday the 14th, instead, the cold advection of the cold front coming from South has been the determining factor of the thunderstorm activity.

On Monday the orographic effect has been again significant for the southern flow.

A decisive factor of this event, which also makes the difference from some other previous floods (ref. [2], [3]), is the high temperature of atmosphere which has kept the freezing level at very high altitude: so that heavy precipitation over the mountain areas couldn't be snow but have continually fed all the rivers of the basins.

Comparing the event with two previous (smaller but still big: Figure 15) floods of the last years, the freezing level has been at about 3500 m in this event and it was at 3200 m in 1993 and 2500 in 1994 (ref. [2], [3]).

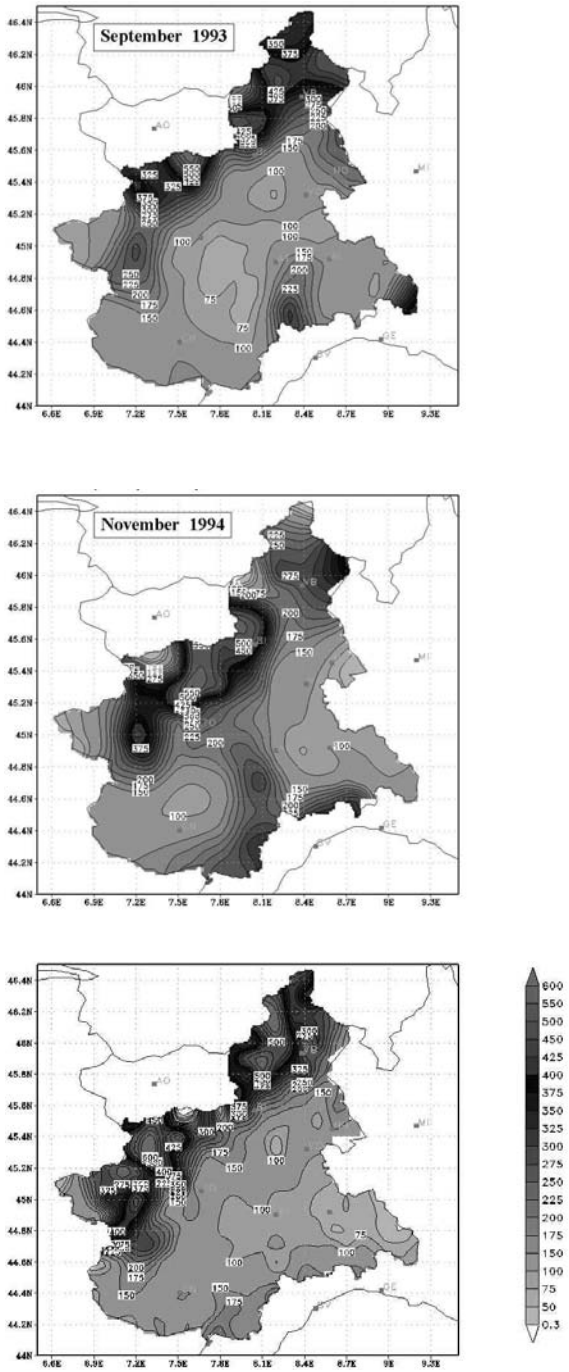

Figure 15: Comparison of the floods of last years in Piedmont.

b) Hydrological effects

With this event the Northwest of Italy experienced one of the largest floods on record. Some estimates consider it as one of the most intense events of the last 200 years. Some rivers'flood values have reached the 200 years return period curve (ref. [1]).

Heavy and prolonged rainfalls have involved the entire Po River basin. The upper Po River basin in the Piedmont Region is a catchment basin of approximately 37,000 Km^2, which includes the entire Piedmont Region, the Aosta Valley Region and parts of Switzerland.

The majority of the basins of the area suffered strong flood episodes; the strong rainfalls seriously damaged most of the mountainous portions of the basins and also part of the city of Turin.

The areas, which were involved by the strongest precipitation, have been especially the Northern and Western sectors of Piedmont region: that's where the majority of rivers tributary of Po River comes.

The Po River flood lasted long, staying at the very top value even for 8-10 hours continuously, despite of all the overflowing points, because at each point it got the new influx from different tributaries.

The maximum rate of Po river's flow in Turin has been 2350 m^3/s and has overcome the historical maximum of 2230 m^3/s of the year 1949.

For the maximum rainfall rates of the whole event (96 hours) have been reported values of: 740 mm in Ossola Valley on North Piedmont, 712 mm in Lanzo Valley on Northwest Piedmont and 600 mm in Sangone Valley in West Piedmont.

The flood inundated large areas causing widespread damages. 20,000 people have been warned and alerted to evacuate. The FloodWatch System, a physically-based flood forecasting system installed at the Piedmont Region Office in Turin together with the Regional Meteo Service, provided decision-makers with valuable information in order to take accurate and timely decisions. Also thanks to this smart attendance and surveillance of the Piedmont Region, during this flood only few people died: a less number of people in comparison with the previous floods when the accumulated precipitation were smaller but more people were wounded and killed.

So this can be view as a good management of a very critical situation, a good example of human -first- forecasting and -then- reacting possibilities against a nature nowadays wilder and wilder and sometime unpredictable or unknown…

References

[1] Regione Piemonte, Rapporto sull'evento alluvionale del 13-16 Ottobre 2000, parte I e II, Torino 24-10-2000

[2] Regione Piemonte, Gli eventi alluvionali del Settembre-Ottobre 1993 in Piemonte, Torino 1996

[3] Regione Piemonte, Eventi alluvionali in Piemonte, 2-6 Novembre 1994, 8 Luglio 1996, 7-10 Ottobre 1996, Torino 1998

These publications are available at the Regional Meteorological Service of Piedmont, Piedmont Region, in Turin, c.so Unione Sovietica 216, 10134 Italy, www.regione.piemonte.it.

Place	**Daily accumulated precipitation**				**Total**
	13th/10	**14th/10**	**15th/10**	**16th/10**	
Bognanco - Pizzanco	339.0	210.6	148.2	42.2	740.0
Antrona - Alpe Cheggio	232,0	225,0	145,4	29,8	632,2
Varzo - San Domenico	269.4	173.0	127.6	40.6	610.6
Macugnaga - Pecetto	153,0	182,0	179,2	44,0	558,2
Valstrona - Sambughetto	121.6	99.0	191.6	125.2	537.4
Montecrestese - Lago di Larecchio	131,6	135,2	151,0	85,0	502,8
Formazza - Bruggi	143,0	129,8	130,4	29,6	432,8
Domodossola - Nosere	118.4	91.6	158.4	44.0	412.4
Crodo - Istituto Agrario	81.6	68.0	133.4	40.8	323.8
Boccioletto - Ronchi	172,0	204,4	235,0	51,4	662,8
Trivero - Alpe Camparient	88,8	189,2	240,0	118,0	636,0
Carcoforo - Carcoforo	138.4	175.0	213.0	51.4	577.8
Fobello - Fobello	192.0	149.0	172.8	58.0	571.8
Rassa - Rassa	133.4	167.2	217.6	58.0	576.2
Alagna Valsesia - Bocchetta Delle Pisse	184.8	179.0	123.6	0.0	487.4
Piedicavallo - Piedicavallo	115,8	105,6	189,0	75,6	486,0
Sabbia - Municipio	77.2	89.4	190.6	75.6	432.8
Andrate - Pinalba	40,0	98,0	226,2	65,0	429,2
Ala Di Stura - Vivaio Forestale La Fabbrica	112.2	346.2	210.6	42.6	711.6
Groscavallo - Forno Alpi Graie	137.2	282.6	234.6	29.8	684.2
Corio - Piano Audi Case Rui	69.6	249.8	240.0	78.2	637.6
Varisella - Filiè	23,8	168,2	242,4	70,2	504,6
Valprato Soana - Piamprato	88,8	261,8	314,8	32,4	697,8
Ceresole Reale - Villa	112.0	202.8	163.4	14.2	492.4
Viù - Niquidetto	34,2	192,0	228,0	34,8	489,0
Locana - Lago Di Valsoera	66.6	202.0	155.6	13.2	437.4
Locana - Bertodasco	73.4	186.6	141.2	32.6	433.8
Ceresole Reale - Lago Agnel	132.6	192.2	82.2	0.0	407.0
Coazze - Ruata	41.6	239.8	246.0	68.2	595.6
Chiomonte - Finiere	22.6	126.6	152.8	10.0	312.0
Giaglione - Val Clarea	25,2	118,6	148,8	14,6	307,2
Angrogna - Vaccera	23.0	226.8	236.2	44.0	530.0
Bobbio Pellice - Colle Barant	35.8	134.4	262.6	5.0	437.8
Torino - Buon Pastore	11,2	37,6	81,0	17,6	147,4
Barge - Valle Infernotto	8,6	162,4	162,8	38,6	372,4
Briga Alta - Piaggia	12,4	77,2	112,0	82,6	284,2
Frabosa Sottana - Borello	11,0	114,0	88,8	36,4	250,2
Villanova Mondovì - Rifugio de Giorgio	8,6	94,4	91,8	51,6	246,4