Mediterranean Storms 2000
(Proceedings of the 2nd EGS Plinius Conference on Mediterranean Storms - Siena, Italy - October 2000)

MESOSCALE ANALYSIS OF THE OCTOBER 1998 FRIULI FLOOD EVENT

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ABSTRACT

On October 5-7, 1998 a severe storm system hit the Friuli-Venezia-Giulia region in northeastern Italy with a substantial amount of rainfall and flooding episodes. The meteorological situation is examined using the Local Analysis and Prediction System (LAPS) that makes use of conventional observations and remote sensing data, including radar and satellite imagery. Improvements over the routine synoptic and mesoscale analysis are explored in detail as a basis for operational applications of LAPS for severe storm nowcasting. In particular the study is part of a more extensive investigation on Italy's severe storm hazards that is being conducted in cooperation with several research and operational groups around the country.

1. INTRODUCTION

The Friuli flood episode is a case study selected by the National Defense Group for Hydrogeological Disasters (GNDCI) with the aim of identifying the contribution of remotely sensed data to the analysis and forecasting of extreme events.

The present analysis focuses on the application of the Local Analysis and Prediction System (LAPS) (McGinley, 1989) to the analysis of the three days. LAPS ingests all kinds of meteorological data from standard observations to remote sensing data such as radar and satellite. The system has been successfully used for the analysis of severe convective events in the Po Valley of Northern Italy and proved to significantly enhance the capabilities of the analysis to describe the short term evolution of mesoscale and local scale features (Alberoni et al., 2000a, b; Costa et al., 2000). Recently it has been used for the daily nowcasting activity during the Special Observing Period of the Mesoscale Alpine Programme (MAP).

2. SYNOPTIC SET UP

The large scale flow features are characterized by a long-lived planetary wave that slowly moves over the Central Mediterranean with a progressive tilt of its axis. The most important fact is that the depression, which covers the whole Western Mediterranean basin and Southern and Central Europe, moves very

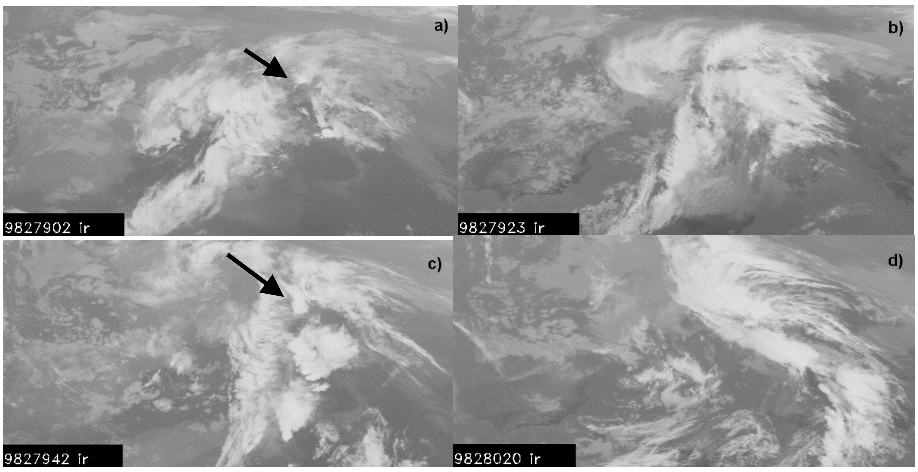

Figure 1 – Meteosat Infrared images a) 6 October 0100 UTC, the arrow indicates the position of the first convective event; b) 6 October 1130 UTC; c) 6 October 2100 UTC, the arrow indicates the second convective event; d) 7 October 1000 UTC.

slowly and influences the mesoscale circulation for more than three days. This has effects on the duration and total amount of precipitation.

Meteosat movie loops in the infrared (IR) and water vapor (WV) bands show that the axis of the frontal system on October 5 and the beginning of 6 is oriented SW-NE and positioned west of Sardinia. The vortex is centered over Southern France (IR image in Fig. 1a).

At noon on October 6 the system axis has tilted to a SSW-NNE direction while the depression has moved north without any appreciable eastward motion. The pre-frontal clouds move over Northeastern Italy following the rotation of the system (Fig. 1b). A cloud-free area north of the Alps shows up in the simultaneous VIS image (not shown) identifying a orographic marked south foehn.

Around 2100 UTC on October 6 the front has a S-N orientation and has slowly moved eastward. Substantial pre-frontal convection is shown in the IR (Fig. 1c) from North Africa to Central Italy and local convective storms over Northeastern Italy. The front itself shows a strong embedded convective activity.

The final stage of the rotation is reached in the morning of October 7 (Meteosat IR at 1000 UTC in Fig. 1d) when the front is aligned along the Italian peninsula over the Adriatic Sea. The most active part of the system translates towards NW sweeping northeastern Italy for the rest of the day.

Rainfall patterns during the three days follow an enduring background stratiform regime that eventually varies according to the orography. Heavy

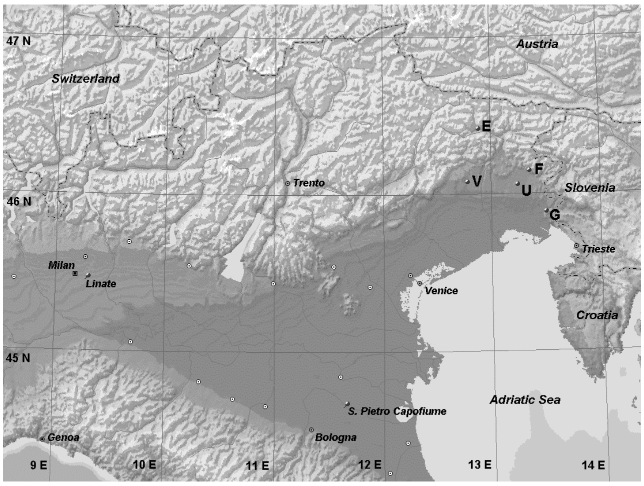

Figure 2 – Map of northeastern Italy. The position of five raingauges in the Friuli region are indicated: Gradisca d'Isonzo (G), Udine (U), Faedis (F), Vivaro (V), Enemonzo (E). The two sounding stations of S. Pietro Capofiume and Linate are positioned. One more sounding station is located in Udine.

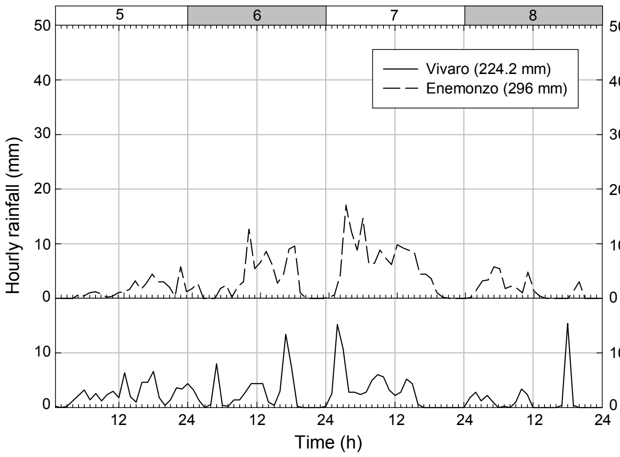

Figure 3 – Hourly rainfall at the two stations of Vivaro and Enemonzo in western Friuli on October 5-8.

rainfall from local convective storms superimposes on two separate occasions on October 6. The scales are different and the triggering mechanisms are connected to synoptic features on one side and to mesoscale conditions on the other.

3. FRONTAL CONVECTIVE-STRATIFORM PHENOMENA

The frontal system produces a more or less continuous rainfall over the Friuli region (geographic map in Fig. 2, Friuli is the region on the border with Austria and Slovenia) as shown in Fig. 3. The two raingauges of Vivaro and Enemonzo in the western sector of the region register a stratiform precipitation always below 10 mm. Higher values are measured at Enemonzo (438 m asl) since the station is on the mountains north of Vivaro (142 m asl) along the Tagliamento river valley and the orography influences the precipitation levels. Peaks show up from time to time due to embedded frontal convection: in particular peak precipitation is measured in the late morning and afternoon of October 6 and early morning of October 7.

The wind field at 850 hPa at 1200 and 1800 UTC on October 6 and 1000 UTC on October 7 are shown in Fig. 4. The 500 hPa level on the same occasions is reported in Fig. 5. At 1200 UTC on October 6 the wind blows from SW over the Mediterranean and Central Italy. At 850 hPa it veers over Friuli from SSW due to the large scale depressionary pattern and the interactions with the eastern Alps. At 1800 UTC on the same day the preferred wind direction at 850 hPa is from SE. The shear with altitude is documented by the wind field at 500 hPa,

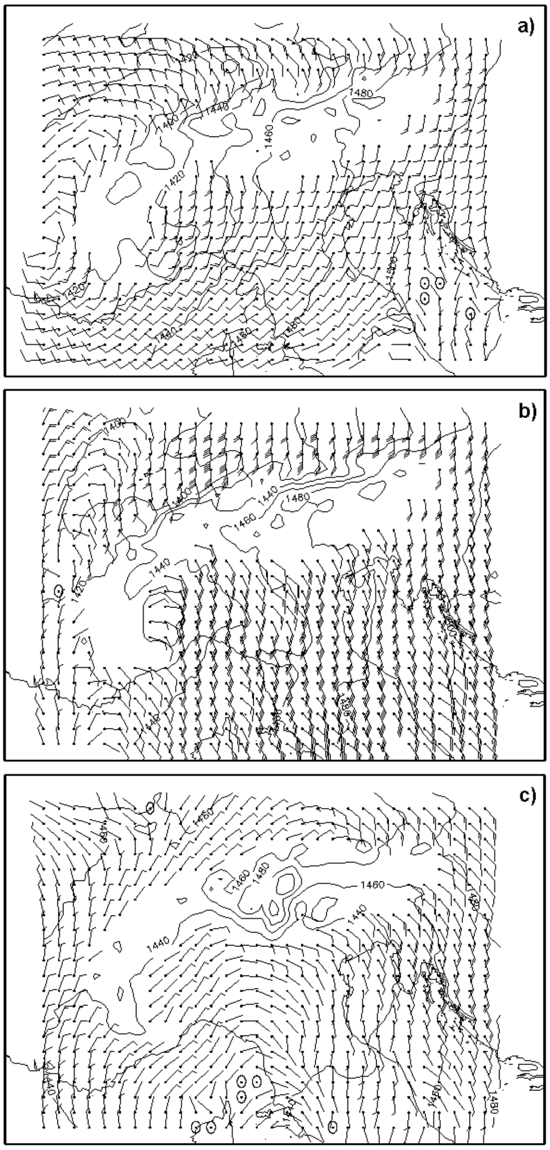

Figure 4 – 850 hPa geopotential height (thin contours, unit m, 20 m intervals) and wind barbs (m s^{-1} WMO convention): a) 6 October 1200 UTC; b) 6 October 1800 UTC; c) 7 October 1000 UTC. Wind barbs in the vicinity of the Alpine chain are removed.

which is oriented from SSW. The next day at 1000 UTC the rotation is complete at 850 hPa and the wind comes from SE over the Friuli area while SSE is the direction at 500 hPa. Note the motion in time of the depression at 850 hPa, which is evident also at the LAPS small scale.

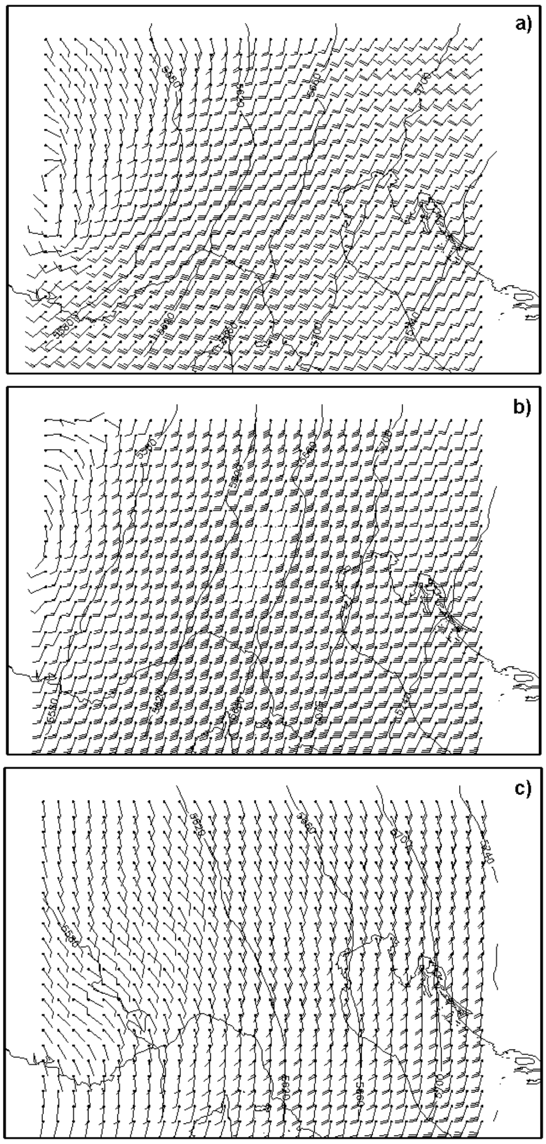

Figure 5 – 500 hPa geopotential height (thin contours, unit m, 40 m intervals) and wind barbs (m s^{-1} WMO convention): a) 6 October 1200 UTC; b) 6 October 1800 UTC; c) 7 October 1000 UTC.

The slow veering of the frontal system on October 6 and 7 forces the frontal precipitation to hit the Friuli region more or less continuously as seen in Fig. 3. The Adriatic Sea acts as an important humidity source that feeds the precipitation formation within the system. The equivalent potential temperature

(θ_e) map at 850 hPa at 1000 UTC (Fig. 6) supports this very important observation. High values of θ_e are directly associated to the development of embedded frontal convection as it is documented in Fig. 7 where the evolution of θ_e in time from 2100 UTC on October 6 to 0300 UTC on October 7 is shown.

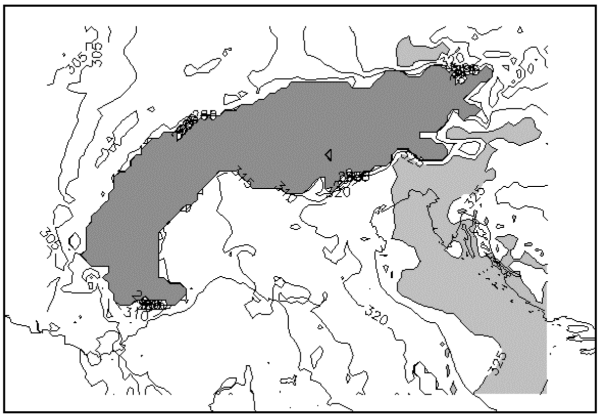

Figure 6 – 7 October 1998 1000 UTC. Equivalent potential temperature analysis at 850 hPa (units K, 5 K intervals). The light grey shading refers to values greater then 325 K. The dark grey area delimits the Alps.

4 LOCAL CONVECTIVE EVENTS

Two convective events take place after midnight and around 2000 UTC on October 6 as shown in the Meteosat IR images of Fig. 1a and 1c, respectively. The storms develop in the vicinity of the city of Udine in Eastern Friuli and evolve locally with heavy precipitation. The hourly rainfall data for the city of Udine in Fig. 8 display a peak of 47 m at 0100 and 62.2 mm at 2000 UTC. The local character of the storms is demonstrated by the data from Faedis a few kilometers NE of Udine, which show the same peaks with a 1 h delay due to the storm propagation. The data from Gradisca d'Isonzo about 25 km south east of Udine do not document any heavy rainfall occurrence on the same occasions, once more proving the local character of the storms.

The Lifted Index (LI) evolution for Southeastern Friuli is shown in Fig. 9 where the negative peaks (unstable atmospheric profile) of the index are in phase with the two local convective events. The instability is short living and delimited in space to this area. The same evolution of LI in Western Friuli is completely different and shows no trace of such negative values associated to substantial convective activity.

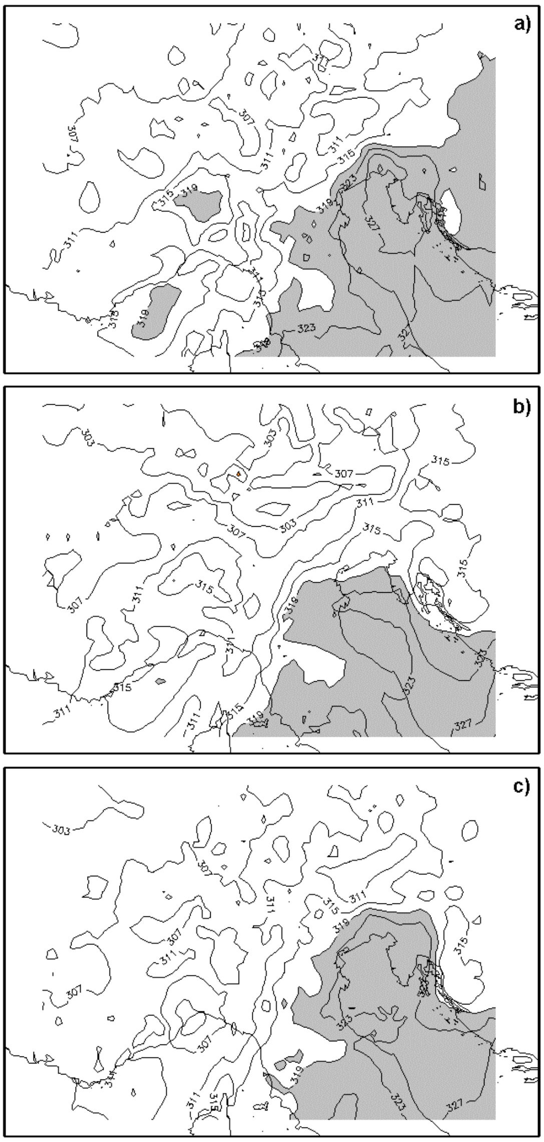

Figure 7 – Surface equivalent potential temperature analysis (units K, 4 K intervals): a) 6 October 2100 UTC; b) 7 October 0000 UTC; c) 7 October 0300 UTC. The light gray shading refers to values greater than 319 K.

5 IMPACT OF SATELLITE DATA ON THE ANALYSIS

The LAPS analyses discussed in the previous sections were all conducted using satellite IR and VIS data from Meteosat. LAPS uses satellite radiances for the

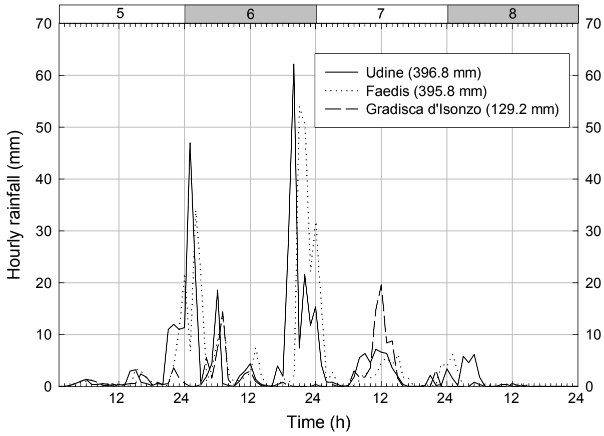

Figure 8 - Hourly rainfall at the stations of Udine, Faedis and Gradisca d'Isonzo in eastern Friuli on October 5-8. Note the two peaks at the beginning and the end of October 6 due to the two heavy convective events shown in Fig. 1a and c.

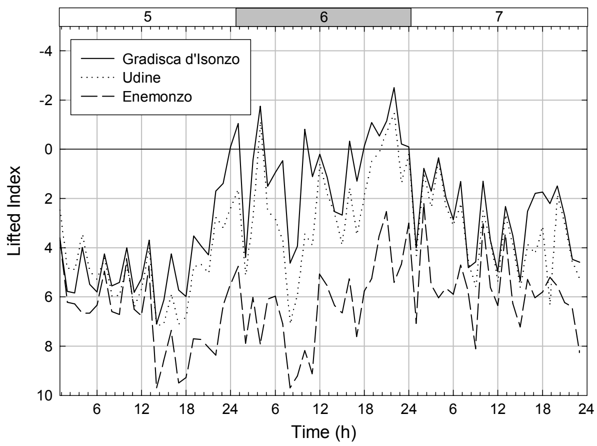

Figure 9 – LI behavior at the two eastern stations of Gradisca d'Isonzo and Udine and the mountain eastern station of Enemonzo on October 5-7. The difference between the very low values at the first two stations within the area where convection developed at the beginning and the end of 6 October and the other outside it is evident.

three dimensional cloud and humidity analysis (Albers et al., 1996; Birkenheuer, 1991).

In order to verify the contribution of the satellite data input and its quality two soundings were used on October 6 at 1200 UTC from two northern Italy stations. The sounding of S. Pietro Capofiume north of Bologna is shown in

Fig. 10a where the specific humidity is plotted from a) the sounding itself, b) the analysis using only the Meteosat data, and c) the analysis background from the Regional Meteorological Service of Emilia-Romagna model LAMBO (Mesinger et al., 1988). The same plot for the Milano Linate airport station is reported in Fig. 10b.

The model background does not reproduce the sounding profile of S. Pietro Capofiume displaying an almost monotonic decrease of the humidity with height. On the contrary, the injection of the satellite data into LAPS analysis saturates the layer between 900 and 750 hPa thus reproducing the profile shape. The situation above 750 hPa is not changed since no clouds are introduced in the analysis. Absolute values from the analysis do not perfectly overlap those from the sounding because the model output was roughly 2 K warmer than the sounding.

Results from the Milano Linate sounding are somehow similar except that in this case higher level clouds above 800 hPa are present.

6 CONCLUSIONS

The analysis has demonstrated that the system's dynamics was indeed very slow and that the rainfall accumulation is due to this persistence over the Friuli region. The rainfall character was twofold: a) a background associated to the convective-stratiform frontal precipitation, and b) a local convective activity that caused the heaviest episodes.

The LAPS detailed analysis has proved to be very effective in identifying both mesoscale and local contributions to the system evolution. Dynamic and thermodynamic effects were clearly observed with a reasonably high level of spatial and temporal resolution. In particular, the contribution of the Adriatic Sea to the humidification of the area was apparent together with the instability induced in the eastern part.

Acknowledgements. The authors are grateful for support from Agenzia Spaziale Italiana, Project "Studio del Ciclo Idrologico da Piattaforme Satellitari: Nubi e Precipitazioni" and CNR Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche, Project "Osservazioni di precursori di eventi estremi e gestione del rischio – Sensori remoti e precipitazioni estreme". NOAA-Forecasting System Laboratory (FSL) is acknowledged for making available the LAPS software and EUMETSAT for the provision of Meteosat data.

REFERENCES

Alberoni, P. P., Levizzani V., Watson, R. J., Holt, A. R., Costa, S., Mezzasalma, P., and Nanni, S., The 18 June 1997 companion supercells: multiparametric Doppler radar analysis, *Meteorol. Atmos. Phys.*, 75, 101-120, 2000a.

Alberoni, P. P., Levizzani, V., Paccagnella, T., Patruno, P., Costa, S., Mezzasalma, P., and Cesari, D., Geostationary satellite data assimilation for nowcasting purposes, *Proc. The 2000 EUMETSAT Meteorological Satellite Data Users' Conference*, EUMETSAT, 660-667, 2000b.

Albers, S., Mc Ginley, J. A., Birkenheuer, D., and Smart, J. R., The Local Analysis and Prediction System (LAPS): Analysis of clouds, precipitation, and temperature. *Weather and Forecasting*, 11, 273-287, 1996.

Birkenheuer, D., An algorithm for operational water vapor analysis integration GOES and dual-channel radiometer data on the local scale. *J. Appl. Meteor*., 30, 834-843, 1991.

Costa, S., Mezzasalma, P., Alberoni, P. P., and Levizzani, V., Mesoscale and radar analysis of the 30 June 1998 supercell, *Phys. Chem. Earth (B)*, 25, 1289-1291, 2000.

Mc Ginley, J. A., The Local Analysis and Prediction System, *Prepr.12th Conf. Wea. Analysis and Forecasting*, AMS, 15-20, 1989.

Mesinger, F., Janijc, Z., Nickovic, S., Gavrilov, D., and Deaven, D. G., The step-mountain coordinate: Model description and performance for cases of Alpine lee cyclogenesis and for a case of Appalachian redevelopment. *Mon. Wea. Rev*., 116, 1493-1518, 1988.