# THE 26TH SEPTEMBER 2007 VENICE EXTREME CONVECTIVE RAINFALL EVENT

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## 1. INTRODUCTION

In the framework of the Regional Agency for Environmental Prevention and Protection of the Veneto (ARPAV), the Meteorological Centre of Teolo (CMT) is the operational regional meteorological service in Veneto, the region of Venice, in Northeastern Italy (Fig. 1). Activities of CMT (a branch of Land Safety Department–DRST) include:

- operational forecasting;
- specific support to Civil Defence, tourism, agriculture, etc;
- participation in national and international projects.

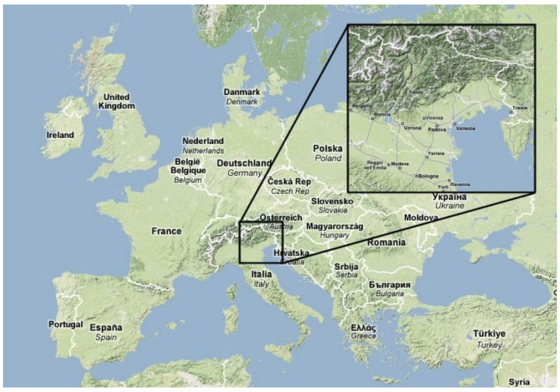

Fig. 1: Veneto region in Europe.

In the early and morning hours of the 26th September 2007 surrounding areas of Venice were hit by extreme rainfall caused by severe thunderstorms which developed close to the central-southern coastline of the north-eastern Italian region Veneto. The multisensor network of ARPAV includes two meteorological C-band radars, Meteosat-9 satellite data, and a high-resolution surface network of automatic weather stations, analysis of which allowed to find some interesting features of the storm environment.

The main effects of the event were the exceptionally high rainfall rates and large amounts of accumulated precipitation in short time intervals. Some different raingauges observed 250 mm in three hours and 300 mm in six hours, numbers close to the 40% of annual total rainfall (700-800 mm).

The specific position of the area of interest close to the western Veneto radar site allows a detailed analysis of the convective event. The area invested by the thunderstorms is densely populated so that many people experience the effects of floods in urban area.

## 2. GENERAL FRAMEWORK AND LOCAL EVOLUTION

In the following a more detailed analysis will be carried on considering:

- synoptic situation;
- satellite and radar records;
- ground stations measurements.

A surface low formed in the very first hours of September the 26th on the Gulf of Genoa in northern Italy. Aloft a trough deepened advecting cold air from North Europe to South France towards the Alps (Fig. 2).

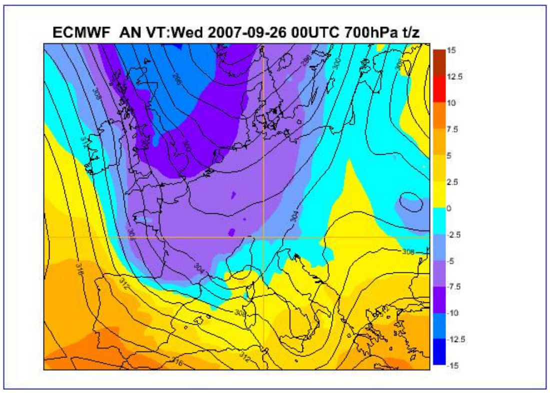

Fig. 2: ECMWF Analysis of geopotential height (dam) and temperatures (°C) at 500hPa valid for 00UTC of 26 September 2007.

Surface winds intensified during the night from southeast on the North Adriatic Sea and from northeast on the Veneto region inland.

The first convective cell formed just after midnight between the Padua and Venice provinces border and developed moving northwards over some areas close to the Lagoon of Venice.
In the following hours three more cells grew in the western part of the Province of Venice. Teolo radar images show that these cells were organized in a linear structure and moved north-westwards over the Province of Padua.

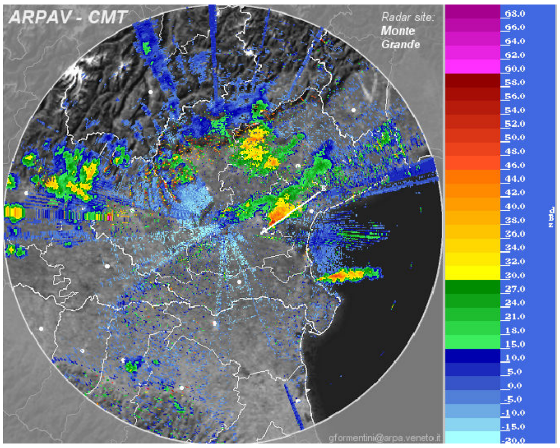

Fig. 3: Reflectivity of the Teolo radar PPI 0.8° product valid for 00:40UTC 26 September 2007.

Following these cells, the two most interesting events took place. At first a low topped supercell (echo-top below the height of 6-7km) formed with the typical weak echo region and mini hook echo as nicely visible in the radar data (Fig. 3 and 4). The main effect of this low-topped supercell was the high precipitation rate.

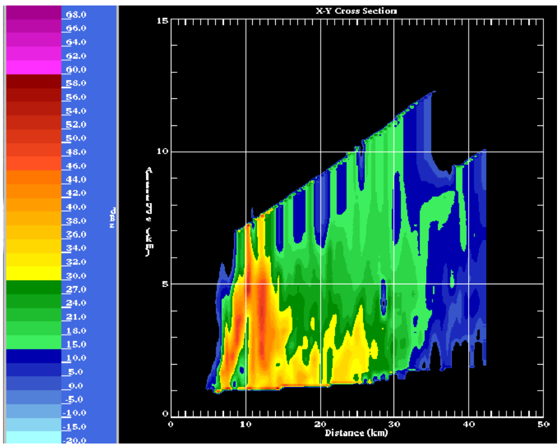

Fig. 4: Vertical cross section of reflectivity of the Teolo radar along A-B segment in Fig. 3.

At 3:50 the supercell dissipated moving westwards but the convergence between its outflow and the south-easterly winds over the north Adriatic Sea gave rise to a second low-topped supercell. The evolution of this second cell was disturbed by a number of small cells present in southern Veneto at that time.

Between 4-5UTC convection changed its characteristics from supercellular to multicellular. The main contribution was provided by the injection of very humid and unstable air from east, enhancing both the convergence effect and instability.

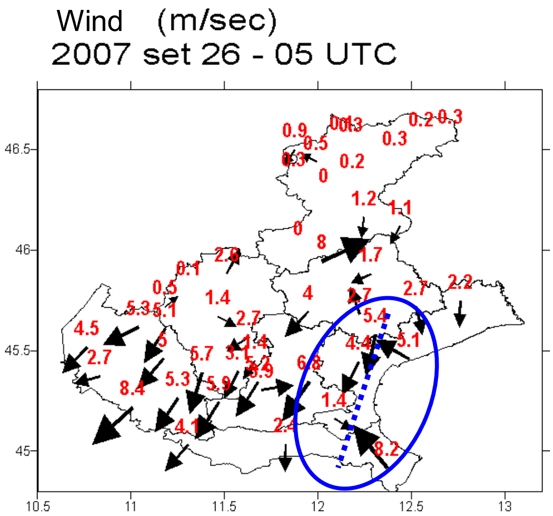

Fig. 5: Wind vectors from automatic surface station network valid for 05UTC 26 September 2007. The blue dashed line denotes the low-level wind convergence.

A very strong convergence between northeastern cold continental and warm and humid southeastern air formed close to the shoreline and became the focus point that triggered and drove the convection from this time onward (Fig. 5).
For many hours different cells originated, developed and dissipated much over the same geographical area. The main system took the form of a multicell convective system with very low translation velocity causing large amounts of rain accumulations.
In the morning the surface winds were opposite to the winds at medium-high levels for many hours supporting the continuous regeneration of cumulonimbus

clouds in the same geographical area and limiting the eastward propagation of the system. Satellite images confirmed the severity of the convective activity displaying a typical V-shape multicell thunderstorms complex.
All the cells were organized along the north-south direction and continued regenerating for hours. After 05UTC the system reached its maximum intensity as shown also by MET-9 satellite images with top infrared temperature below -55°C (Fig. 6).

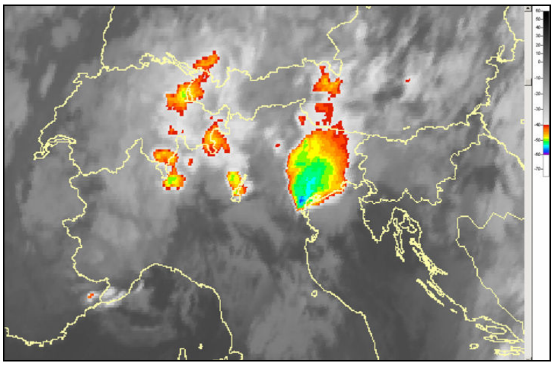

Fig. 6: Infrared 10.8 MSG image in false colours at 05UTC 26 September 2007. Temperatures below -55°C are depicted in blue.

During these hours a number of rain gauges measured very high rain rates: more than 90mm in 30 minutes, 120mm in one hour and 200mm in three hours.
From 07UTC the system became a V-shape mesoscale convective system causing floods in the very densely populated Mestre-Venice metropolitan area (Fig. 7).

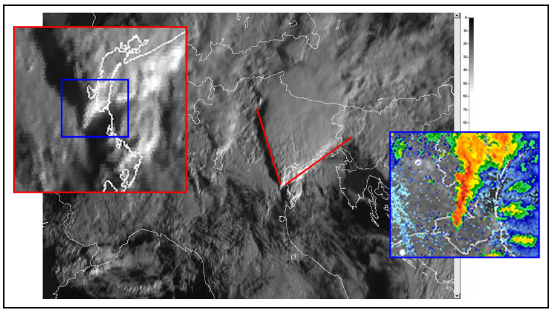

Fig. 7: HRV MSG satellite image with superimposed radar image at 07:00 26 September 2007 in which V-shape of thunderstorms system is evident.

During the morning the multicell system started to evolve moving eastwards and showing progressively decreasing rain rates.
A second multicell system developed in the Po river delta area but moving east onto the sea thus not hitting populated areas (Fig. 9).

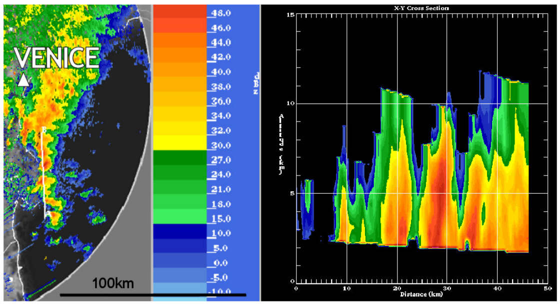


Fig. 9: Reflectivity of the Teolo radar at 08:50 UTC 26 September 2007 showing the multicell structure of precipitation.

From a qualitative point of view, positioning of reflectivity maximum didn't match with raingauges. This suggests that locally even larger precipitation amounts could be fallen compared to raingauge data.

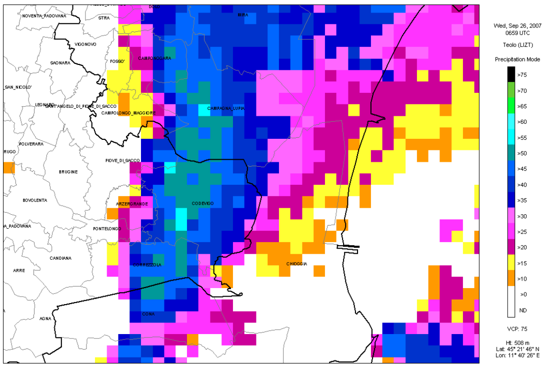

Fig. 10: detailed image of Teolo Radar CMAX product at 06:50UTC 26 September 2007 with villages and towns borders superimposed.

In summary the main points of the precipitation event were:

- low level convergence, with strong southeasterly winds on the sea and shoreline and moderate-strong northeasterly winds inland kept system stationary.
- advection of very humid and warm air from the sea that contributed to enhance instability, also due to the

contrast between the sea and land temperature;

- moderate shear supported the multicell organization of the convection;
- moderate medium troposphere winds (3000-5000m) supported continuous regeneration of cumulonimbus clouds in the same area (flanking line);
- divergence in the left-exit region of the jet stream at high levels enhanced the convergence in the low levels.

## 3. PRECIPITATION MEASUREMENTS

The main effects of the event were the very high rainfall rates and large amounts of precipitation accumulated in short time intervals in a restricted area of the region invested by the thunderstorms. This area, on the central-southern coastline of Veneto, is close to Venice and densely populated so that many people experienced the effects of floods in urban area. Figure11 shows the isolines of total daily precipitation measured for the day of 26 September 2007 by 161 ARPAV raingauges in Veneto.

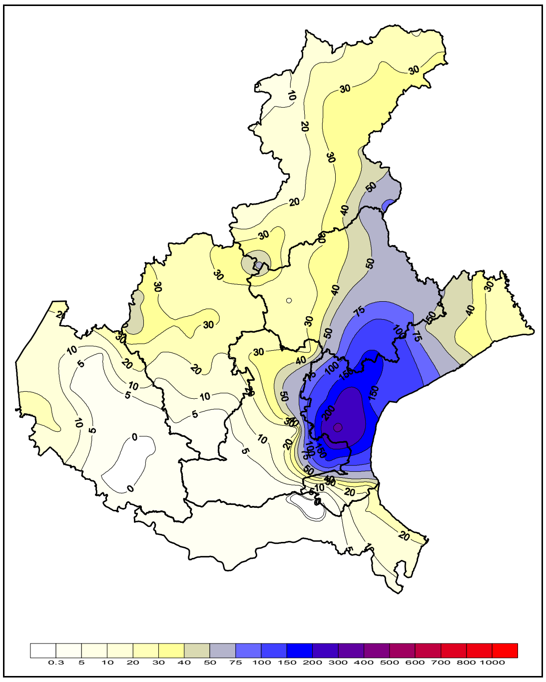


Fig. 11: Daily precipitation accumulation for 26 September 2007 for Veneto based on the 161 rain gauges ARPAV network.

The rainiest area is the central and southern part of Venice Province, close to the lagoon, where 5 rain gauges measured more than 160mm, with maximum values of 260.4mm (Mestre rain station) and 324.6mm (Valle Averto rain station). The extreme behaviour of the 26 September event is described in the maps of Figs. 12-13-14, where a composite map of the maximum 30 minutes, 1 hour and 6 hours precipitation accumulation recorded at each station is shown. Note that the maximum did not necessarily happen in the same time.

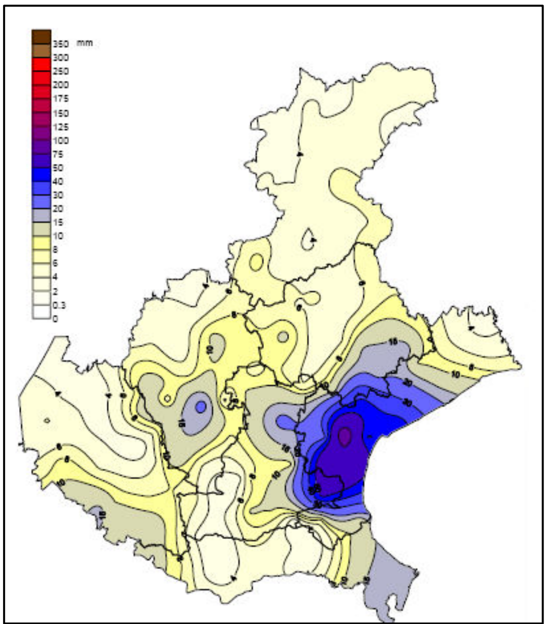


Fig.12: the 26th September composite map of the maximum 30 minutes precipitation accumulation recorded at each station: the highest value monitored is 91.2mm registered in Mestre rain station.

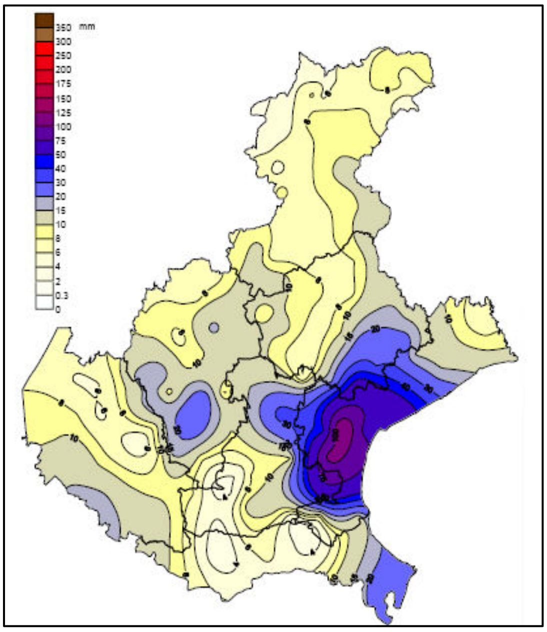


Fig.13: as in Fig.12 but for accumulation time of 1 hour: the highest value monitored is 126.6mm registered in Mestre rain station.

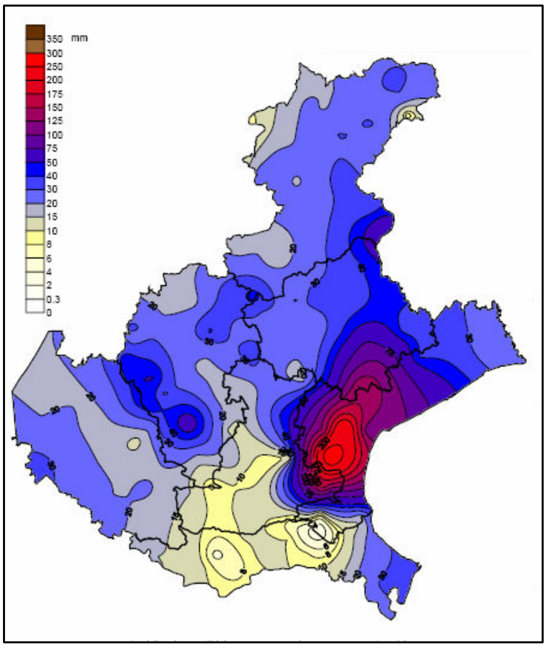


Fig.14: as in Fig.12 but for accumulation time of 6 hours: the highest value monitored is 301.4 mm registered in Valle Averto rain station.

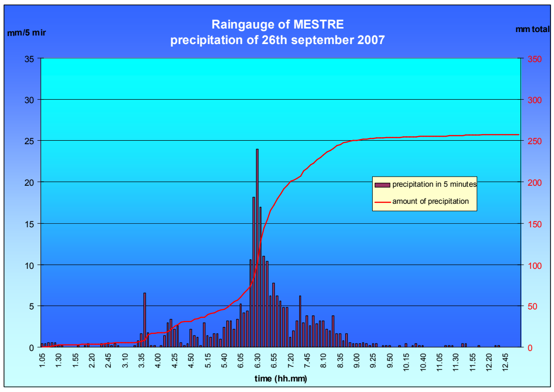


Fig.15: Time series of the rain gauge station Mestre from 01-13UTC 26 September 2007 for 5-minute intervals (histogram) and accumulated (red line).

Figures 15-16 show the precipitation for 26 September registered every 5 minutes and the corresponding cumulated value from 1am to 1pm in Mestre and Valle Averto stations: the first weak precipitation started shortly after 01UTC, and intensified at 04UTC; between 6.30 and 6.45UTC the total precipitation reached 100 mm, after half an hour the total increased already to 150 mm, while between 7.15UTC and 7.50UTC it reached 200mm. Around 9UTC the monitored values were for the Mestre and Valle Averto rain gauges 250 and 300 mm, respectively.

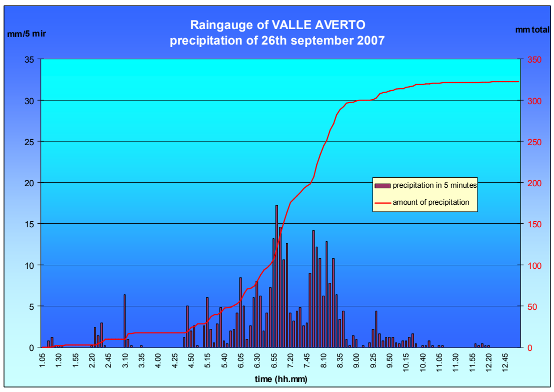


Fig.16: Time series of the rain gauge station Valle Averto from 01-13UTC 26 September 2007 for 5-minute intervals (histogram) and accumulated (red line).

Table 1 shows the maximum precipitation for various accumulation periods recorded by the two rain gauges with the highest values in the event; 100 years return time precipitation amounts (calculated with the Gumbel method) are indicated in parenthesis for historical stations of Mestre and Codevigo (1956-1996 period data set). Owing to availability of data, this comparison is possible only for 1 hour and longer time intervals.

| | 26/09/2007 [TR 100 yr] | 26/09/2007 [TR 100 yr] |
|---|---|---|
| time | **Raingauge Mestre** | **Raingauge Valle Averto** |
| 5 minutes | **24 mm** | **17.2 mm** |
| 10 minutes | **42.2 mm** | **31.8 mm** |
| 15 minutes | **59.2 mm** | **45 mm** |
| 30 minutes | **91.2 mm** | **75.4 mm** |
| 45 minutes | **111.4 mm** | **90.2 mm** |
| 1 hour | **126.6 mm [60 mm]** | **106 mm [70 mm]** |
| 3 hours | **201 mm [90 mm]** | **248.4 mm [100 mm]** |
| 6 hours | **246.8 mm [120 mm]** | **301.4 mm [110 mm]** |
| 12 hours | **257.6 mm [140 mm]** | **322.2 mm [130 mm]** |

Table 1: maximum precipitation for different accumulation periods (5’ to 12 hours), recorded by the two rain gauges with the highest values for the event (Mestre and Valle Averto, Province of Venice). In parentheses the almost 100 years return time precipitation amounts are indicated.

Note that for this event for periods shorter or equal than an hour the Mestre rain gauge recorded the highest precipitation values with 24mm in 5 minutes, 91.2mm in 30 minutes and 126.6mm in 1 hour. For periods longer than one hour the Valle Averto rain gauge measured the highest values with 248.8mm in 3 hours, 301.4mm in 6 hours and 322.2mm in 12 hours.
The extremely high intensity of the events registered in this area are further evidenced by the comparison with the 100 years return time precipitation reference values in that for both stations the 1 to 12 hours maximum precipitation accumulation are two to three times higher than the reference values.

## 4. CONCLUSIONS

- The area surrounding Venice experienced an extremely strong precipitation event on the 26 September 2007;
- Within a few hours 40% of the total annual precipitation amount was recorded.
- Severe weather events frequently happen in September and October in the areas close to the Adriatic sea. The water basin with relative high temperatures plays a crucial role in the triggering and/or enhancement of convection.
- Key factors for the event have been studied thanks to the availability of a very detailed observing system (radar, satellite, dense network of automatic surface weather stations).
- To better understand the convective dynamics and its interplay with the mesoscale environment, further studies should be carried on, including numerical simulations with proper resolution and parametrisation.