# Hailstorm on 04 July 2003 - a case study

Nataša Strelec Mahović and Dunja Drvar

Meteorological and Hydrological Service, Grič 3, 10 000 Zagreb, Croatia
E-mail: *strelec@cirus.dhz.hr, drvar@cirus.dhz.hr*

**Abstract:** A case of severe convective storm is shown. The region of interest was under strong upper-level south-westerly flow on the leading side of the through, making the large-scale circumstances favourable for convective development. The sequence of satellite images shows the beginning of the strongest development over an island, near the coastline i. e. the orographic lifting was responsible for the initiation of strong convection. In Aladin model fields and cross-sections strong vertical wind shear, as well as higher humidity content was present above the island where the convection was triggered. The dynamic adaptation of the wind also depicts strong convergence in the region of interest. The most precise are the results obtained by nowcasting system based on satellite images. Atmospheric motion vectors and development fields show almost exact velocity and extent of the system.

*Keywords – severe storm, orographic triggering, meso-scale forecast, nowcast*

## 1. INTRODUCTION

In the early morning on 04 July 2003, the region of central Dalmatia was devastated by a severe storm. Heavy rain and hail destroyed all the crops and vegetables in the fields in just a few hours. The amount of rainfall exceeded 30 mm in less then an hour, and there were also stations measuring 50 mm or even more in only 30 minutes. In many places this was also total monthly rainfall. Some towns were flash flooded (Fig. 1a), the water was flowing on the streets and the roads had to be closed.

**a**

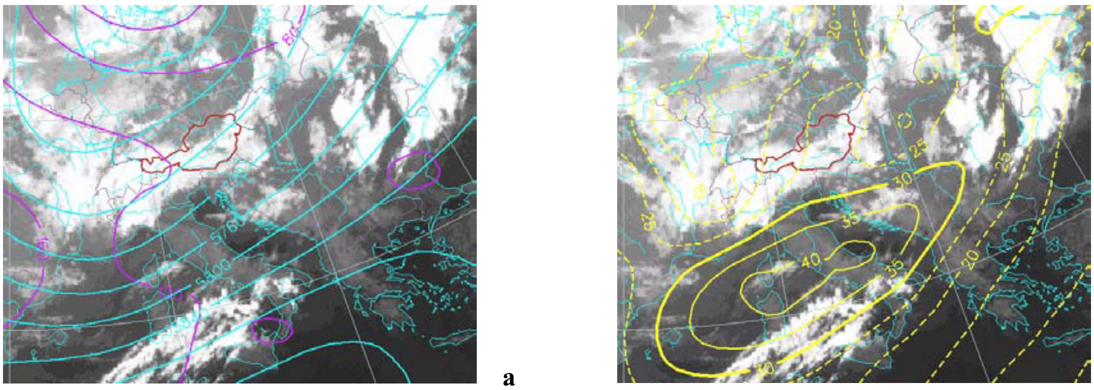
**b**

**Figure 1. a)** Flash flood in Split; **b)** Hail stones fallen in Dalmatian inland; photographs courtesy of daily newspapers 'Jutarnji list', 05.07.2003.

In addition to that, heavy hail and hail showers as well as strong winds occurred on many locations. In the vicinity of Šibenik hail was the size of walnut (Fig. 1b) and in the inland of Dalmatia vegetable, vineyards and olives were almost completely destroyed by strong hail showers. Damages to houses, cars and trees were also numerous.

## 2. SYNOPTIC SITUATION

The large-scale situation preceding the storm, given by the analysis fields of the ECMWF, shows that the region of Italy and Adriatic Sea was under strong upper-level south-westerly flow on the leading side of the through connected to the low above south Scandinavia. (Fig. 2a). At surface level (1000 hPa) there is very weak pressure gradient, but in upper levels (500hPa) there is very pronounced gradient along the Adriatic.



a b

**Figure 2.** ECMWF analysis fields for 04 July 2003 at 00:00 UTC: **a)** AT 1000 hPa (violet) and AT 500 hPa (cyan) ; **b)** isotachs at 300 hPa (yellow)

The large-scale circumstances were obviously favourable for convective development (Bluestein, 1993). However, although the quasigeostrophic triggering conditions were present in this case, those conditions alone are usually relatively slow in producing precipitation. In order to produce a convection of such intensity, there must have been some mesoscale processes in addition. According to the ECMWF analysis the jet stream at 300 hPa was stretching across Italy and Adriatic with the jet-streak entering the central Adriatic as seen in Fig. 2b. Therefore, mesoscale ascent could have partly been connected to upward motion in the left front quadrant of the jet streak.

## 3. THE DEVELOPMENT - SATELLITE OVERVIEW

Convective development started with a small cell above the Adriatic Sea and reached the coastal area. The triggering of the strongest convection seems to have taken place between 5:00 and 5:30 UTC, to the right of the initial cell, above the island of Dugi Otok, moving towards the inland of Dalmatia and growing rapidly. Meteosat 8 high-resolution visible images combined with IR channel 10.8 µm, shown in Fig. 3, give a clear insight into the development and enable the discrimination of different cloud phases (MSG Interpretation Guide).

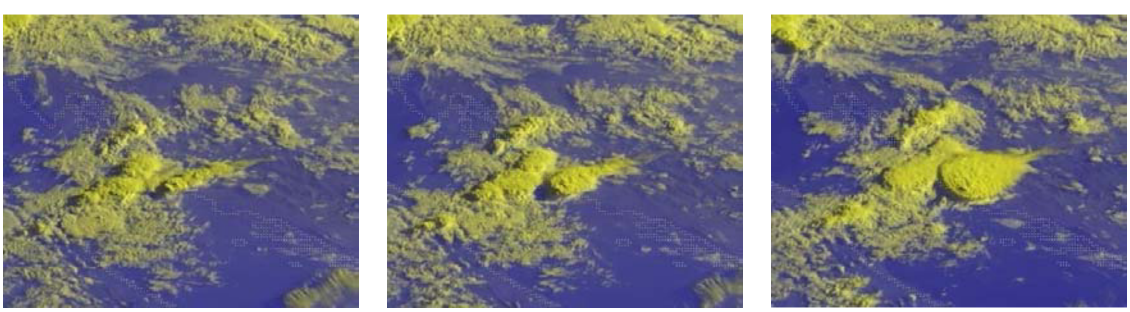


**Figure 3**. Meteosat 8 High resolution visible image combined with IR (10.8 µm) channel (RGB composite HRVIS-HRVIS-10.8) on 04 July 2003 at **a)** 05:15 UTC; **b)** 05:30 UTC); **c)** 06:00 UTC.

At 05:15 the cell over the island is starting to grow while at 05:30 it is already a well defined convective system with overshooting tops and an elongated shadow showing its huge vertical size. In the next 30 minutes cell developed rapidly and synop stations in its vicinity already reported thunder and hail. At 06:00 UTC image the overshooting tops as well as cirrus anvil are clearly seen.

## 4. FORECASTS

Mesoscale convective systems such as this one are usually very difficult to forecast because their own internal dynamics evolves on a small scale and it is not conveniently reflected in the operational synoptic scale numerical models. To get closer to the scale of the event, a meso-scale model is consulted, namely Aladin model with 8 km resolution. Since the possible triggering mechanism could be the orographic lifting, the cross sections across the Dugi Otok island are shown in Fig. 4. What draws the attention is rather abrupt change of the wind direction with height in the vicinity of the mainland (Fig. 4a). This feature is caused by land-sea circulation being overflowed by south-westerly upper level stream. Additionally, relative humidity is higher above the island then above the surrounding sea (Fig. 4b).

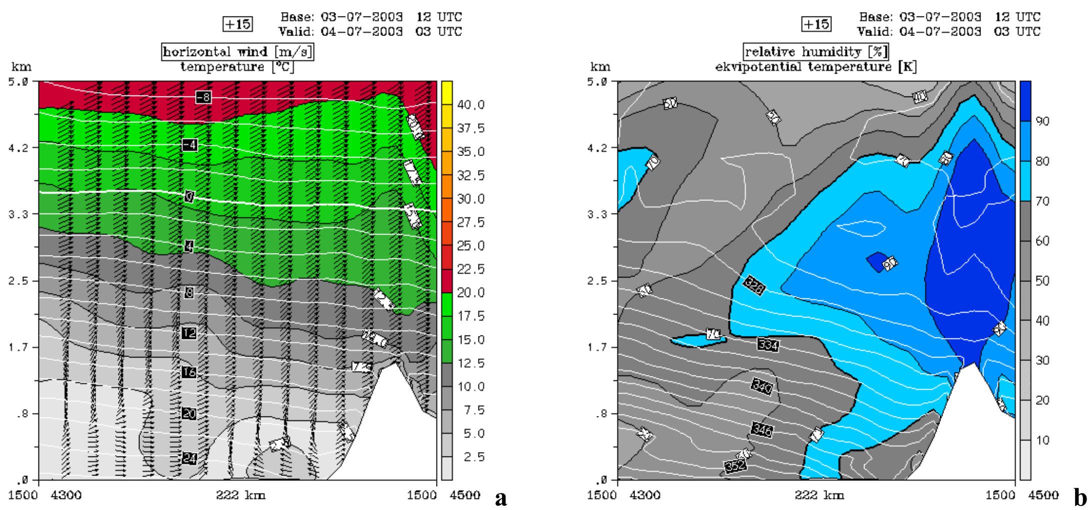



**Figure 4.** ALADIN model cross-sections for 04 July 2003 at 03:00 UTC; **a)** white lines: temperature, arrows: horizontal wind, grey shades: isotachs; **b)** white lines: equivalent potential temperature, blue shades: relative humidity

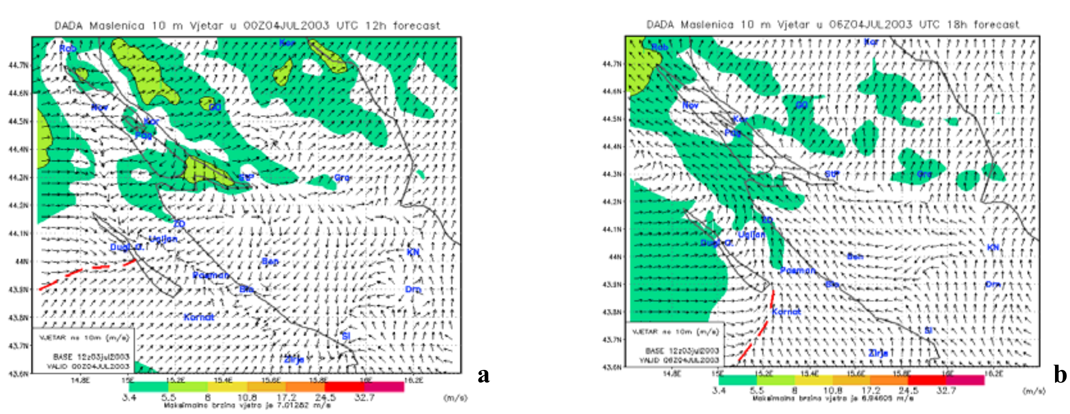
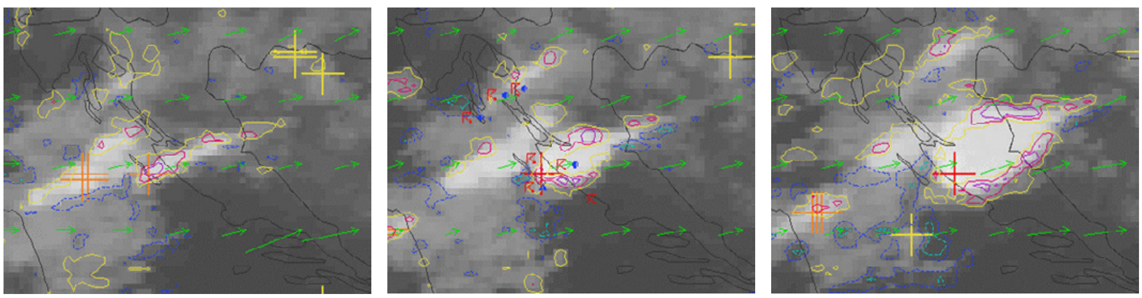



**Figure 5.** ALADIN model dynamical adaptation of the wind field, forecasts for 04 July 2003 a) 00.00 UTC; b)06:00 UTC; arrows: 10 m wind, colour shades: isotachs, red: line of convergence

Horizontal wind field also shows some interesting features. Dynamical adaptation of ALADIN model on a 2x2 km grid for the area of interest is shown in Fig. 5. Convergence line (marked by red dashed line) can clearly be observed at 00 UTC (Fig. 5a) pointing towards the island where convection was presumably triggered. At 06 UTC (Fig. 5b) convergence was again indicated, but a little more to the south. This combination of horizontal wind convergence and strong vertical wind shear seen in the vertical cross-section has most probably played an important role in triggering of the convection.

## 5. NOWCAST

Nowcasting tools shown in Fig. 6 are based on the satellite imagery. For the purpose of following the development, several nowcasting tools are joined together: atmospheric motion vectors, automatically detected convective cells and development contours.



a b c

**Figure 6.** Meteosat IR image combined with nowcasting tools; red, orange and yellow crosses: convective cells, yellow, pink and violet lines: development, light blue and blue: decay, green arrows: atmospheric motion vectors; synop observations ; 04 July 2003 at a) 05:30 UTC, b) 06:00 UTC, c) 06:30 UTC

At 04.30 UTC convective cell was detected and first development was indicated over the island Dugi Otok. In the first frame (Fig. 6a) it already turned into a higher cell, developing further on. Half hour later (Fig. 6b), again over the same island, there is more development, growing now rapidly with a lot of thunder and some hail reported at 06.00 UTC.

## 6. CONCLUSIONS

Convective development resulting in severe storms is usually very difficult to forecast using only synoptic-scale models. On the other hand, as shown in this example, meso-scale models come much closer to the scale of the system and can give a probable mechanism of the development. In this case it was horizontal convergence combined with strong vertical wind shear. Both effects were noticed in the vicinity of an island, so orographic lifting was probably the triggering mechanism. However, looking from the point of view of the operational forecast even meso-scale model was not precise enough because the effects shown were shifted in both time and space. The most precise for following the development were nowcasting tools based on satellite images, giving the exact location and the extent of the developing system.

## REFERENCES


Bluestein, Howard B., 1993: Synoptic_Dynamic Meteorology in Midlatitudes. Volume II, Oxford University Press, 592 pp.

MSG Interpretation Guide: at http://www.eumetsat.int/ (Data, Products and Services)