HEAVY RAINFALL AND FLASH FLOOD IN DUBROVNIK ON 22ND NOVEMBER 2010

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I. INTRODUCTION

The flash flood event on 22nd November 2010 in Dubrovnik, Croatia, is analyzed using available in situ measurements, satellite data and NWP model runs with various configurations. The rainfall in Dubrovnik was the highest ever measured. The flood water level reched 1.5 m caused camage and endangered lives.

II. THE SYNOPTIC SITUATION

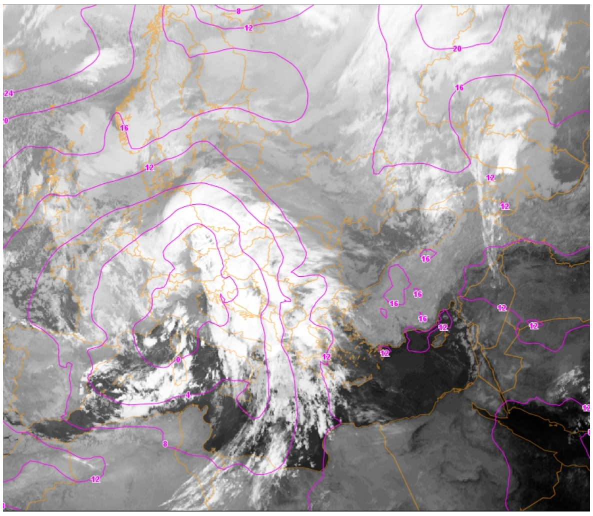

FIG. 1a: METEOSAT9 IR 10.8 micron image with ECMWF 1000hPa height at 06 UTC 22 Nov 2010.

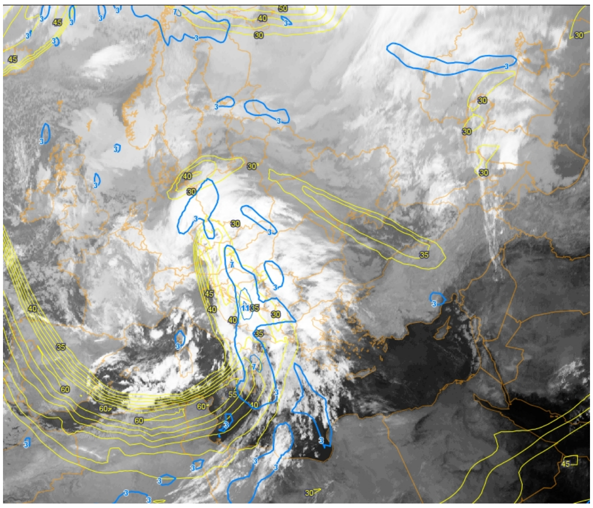

FIG. 1b: As Fig 1, IR 10.8 micron image with 300hPa isotachs and TFP.

The synoptic situation was characterized by a huge low moving over the Alps (Fig 1a) with the frontal system covering most of Central Europe and Mid-Mediterranean. Jet streak at the rear side of the cold front was crossing the frontal cloud band at a large acute angle causing the intensification of the process over the Mid-Mediterranean (Fig 1b). PV anomaly developed with the intrusion of the dry stratospheric air reaching below 450hPa (Fig 1c). Intensive Positive Vorticity Advection (PVA) as a consequence of the deepening trough in the neighbourhood of the left exit region of the jet streak constributed to the strong upward motion in the area (Fig 1d). Over the southern Italy and Adriatic Sea, a secondary cyclone developed and the meso-scale convective system grew within

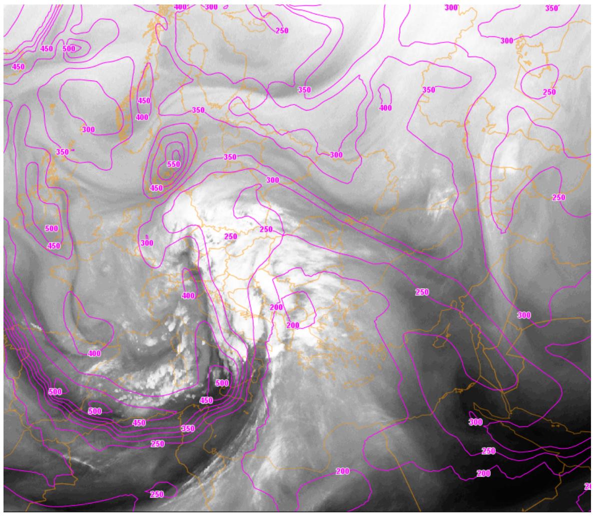

FIG. 1c: As Fig 1, WV 6.2 micron image with 2 PVU height (hPa).

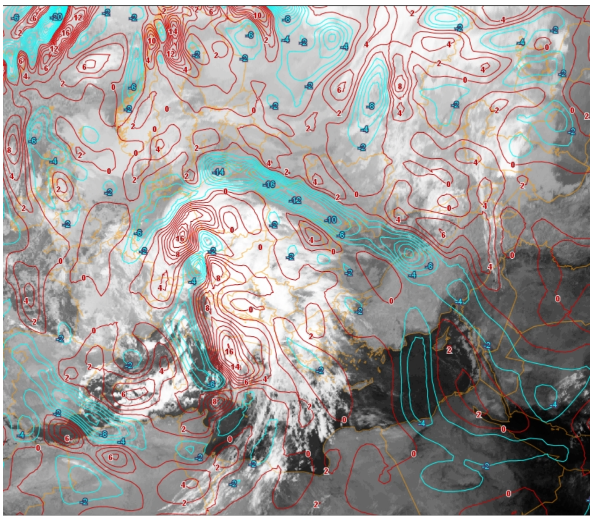

FIG. 1d: As Fig 1a, IR 10.8 micron image with VA at 300 hPa (positive in red, negative in blue).

The rain gauge measurements exceeded 100 mm/24hr in the area and the one in Dubrovnik measured 161.4 mm/24hr, with a peak intensity of 71.5 mm/h. The satellite derived precipitating clouds, convective rainfall rate and severe storm figures show high intensity (Fig 2).

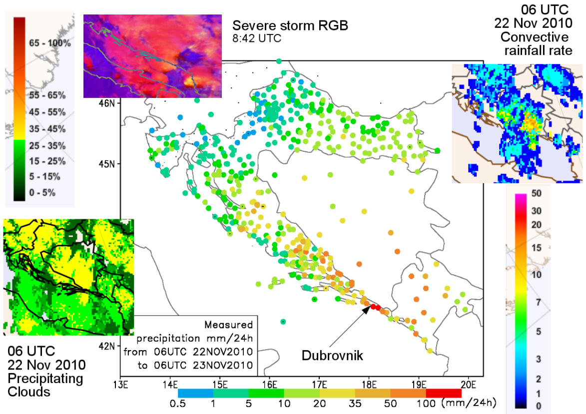

FIG. 2: The measured 24 hr precipitation from the rain-gauges, METEOSAT9 Severe storms RGB at 8:42 UTC, satellite derived conv. rainfall rate and prec. clouds at 6 UTC 22 Sep 2010.

III. RESULTS AND CONCLUSIONS

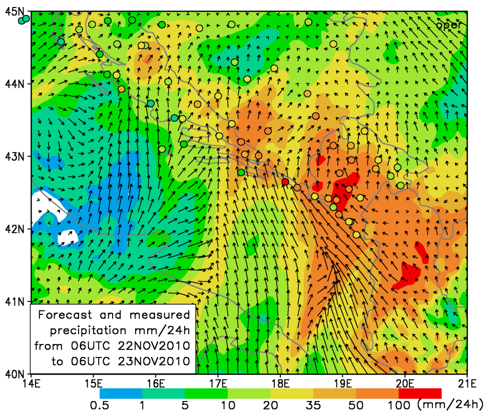

FIG. 4a: The operational 24 hour precipitation forecast (shaded), measurements on rain gauges (circles) and wind for 09 UTC 22 Nov 2010 (coupled to ARPEGE, DFI).

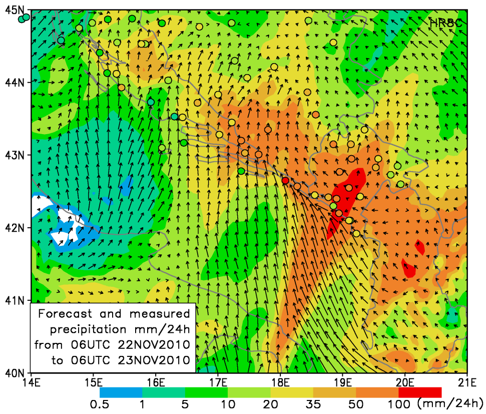

FIG. 4b: As Fig 4a, but using 3Dvar initialization.

Different options for initial and boundary conditions are tested. In DHMZ, two options are operationally available. The first set is from ARPEGE (Action de Recherche Petite Echelle Grande Echelle, Meteo France) and the second set is obtained from the IFS (Integrated Forecast System) model run operationally in ECMWF (European Center for Medium-Range Weather Forecast). A possibility of improving the initial and lateral boundary conditions via the data assimilation is investigated. The data assimilation procedure can use surface analysis alone, or in combination with the upper air analysis (3Dvar, Fig 3). IFS initial file requires at least surface analysis.

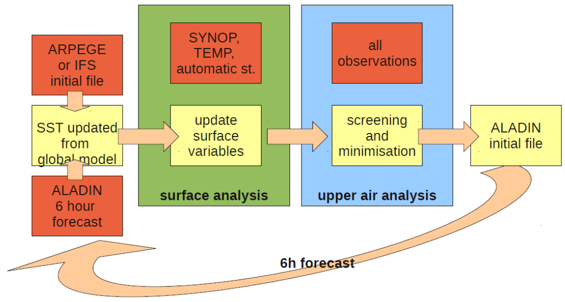

Fig 3. The data assimilation scheme.

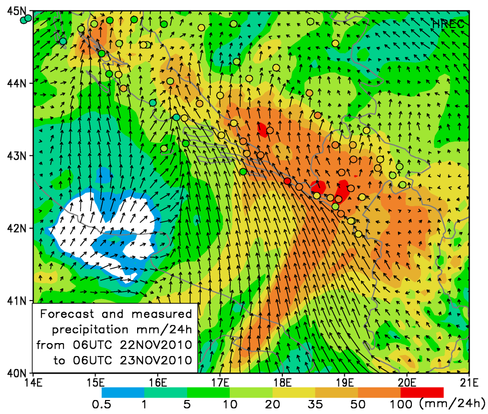

FIG. 4c: As Fig 4a, but coupled to IFS and using surface analysis.

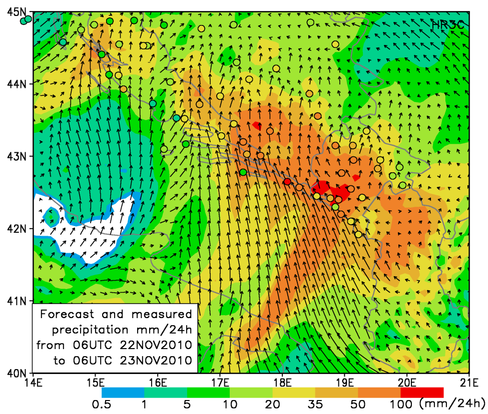

FIG. 4d: As Fig 4c, but using 3Dvar initialization.

The operational ALADIN forecast (Fig 4a) uses ARPEGE initial and boundary conditions and digital filter initialization (DFI). The parallel suite (Fig 4b) uses 3Dvar data assimilation. The operational and parallel suite model results forecast large 24 hour accumulated rainfall amounts in the area around Dubrovnik, with the maxima over 100 mm situated above the surrounding areas of Montenegro and Bosnia and Hercegovina. The peak intensity of precipitation in all model runs is late. The peak in runs coupled to IFS is several hours later than in runs coupled to ARPEGE (Fig 5).

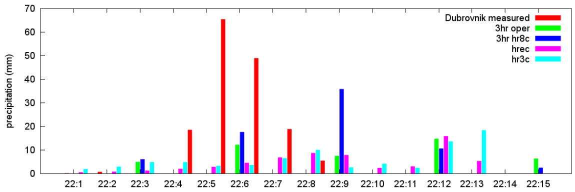

FIG. 5: Hourly or 3 hourly measured and 8 km model precipitation.

Several experiments using high-resolution (2 km) non-hydrostatic ALADIN and WRF model runs have been performed. The 8 km resolution ALADIN run coupled to IFS with 3Dvar initialization (Fig 4d) was used for initial and boundary conditions of the 2 km ALADIN NH experiments. The results of these runs show dependency on the model, input data from initial and lateral boundaries. The position (Fig 6) and time (Fig 7) of the precipitation maxima in the high resolution ALADIN output fields is similar to the lower resolution (8 km) run used for initial and lateral boundary conditions.

There are options in ALADIN model that control the advection and horizontal diffusion of the prognostic variables that describe microphysics (cloud liquid water and ice, rain and snow) and deep (rain producing) convection (updraft and downdraft vertical velocities and mesh fractions). Several experiments have been performed that assess the impact of these options. The accumulated 24 hr precipitation field shown in Fig 6 is from the experiment with the advection and no horizontal diffusion of microphysics variables and "static" prognostic convection scheme (the prognostic convection variables were neither advected nor diffused horizontally).

In the high-resolution experiments of the ALADIN model, significant part of the precipitation was given by the convection scheme, when it was switched on. This result suggests the importance of using the convective parameterization in the ALADIN model even for resolutions in which it is assumed that the convection is resolved.

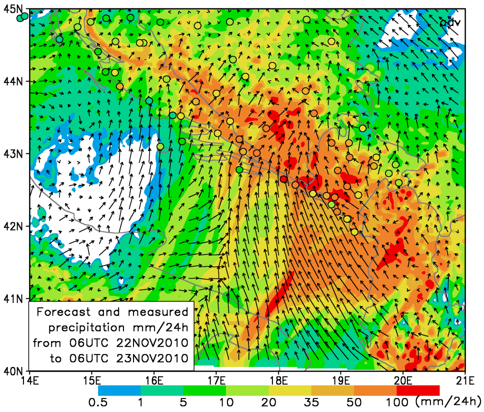

FIG. 6: 2km resolution 24 hour precipitation forecast (shaded), measurements on rain gauges (circles) and wind for 09 UTC 22 Nov 2010 (advected hydrometeors and convection).

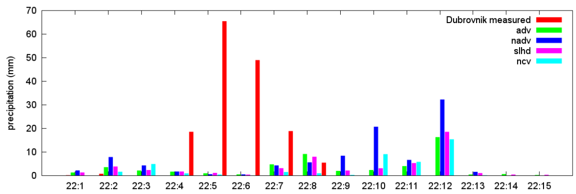

FIG. 7: Hourly measured and 2km model precipitation.

WRF simulations were initialized on 12 UTC 21 Nov 2010 for 42 hr forecast range with ECMWF LBC using the following parameters: 41 sigma levels, 2 domains, outer at 8 km (d01), inner at 2 km (d02), Betts-Miller_Janjic cumulus (only in d01), Morrison 2-moment microphysics, Noah land-surface model, Monin-Obhukov-Janjic (eta) surface scheme, Mellor-Yamada-Janjic TKE scheme for PBL parametrization with 1.5 order TKE closure, 2nd order diffusion on coordinate surfaces, 3rd order Runge-Kutta time-integration scheme, 5th order momentum advection and no assimilation. The WRF simulation gives a rainfall over 100 mm in the Dubrovnik area (Fig 8).

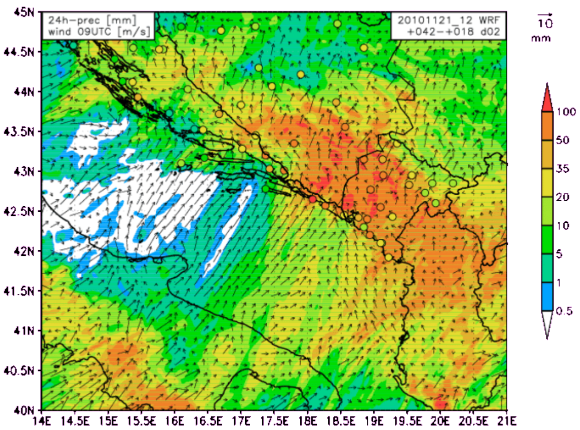

FIG. 8: WRF simulation of 24 hr precipitation.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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