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RESONANTLY COUPLED DEVASTATING AIR-SEA EVENT IN THE EAST ADRIATIC: THE ATMOSPHERIC COMPONENT

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1. INTRODUCTION

In the early morning hours of 27 June 2003, an exceptional sea-level rise occurred in the east Adriatic. It resulted in the devastation of shellfish farms in the area and in flooding of the seafront of Stari Grad on the Island of Hvar due to the maximum sea-surface elevation of 1.3 m. Vilibić et al. (2004) studied the episode and found that it resembled a 'meteotsunami' event where the origin of the forcing is in the propagating atmospheric pressure disturbance. As recorded by the array of barographs in the area, the pressure disturbance in this event lasted for 2 – 3 hours with maximum amplitude reaching 8 hPa, and with the estimated phase speed of approximately 22 m s^{-1}.

Similar phenomena have also been reported to occur in other parts of the world (see Vilibić et al., 2004 for references). However, the forcing, i.e. the atmospheric component of these events, has been extensively less studied. A few previous studies have reported on the ducted gravity waves as the origin of the propagating pressure disturbances.

This study deals with the dynamics and predictability of the atmospheric pressure disturbance responsible for the 26/27 June event.

2. LARGE-SCALE ENVIRONMENT

A cold front reached the Alpine area from the northwest by 00 UTC 27 June (Fig. 1).

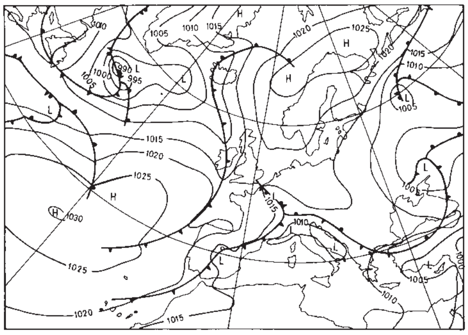

Figure 1. Surface synoptic situation at 00 UTC 27 June 2003.

Figure 2 shows the appearance of the mesoscale convective system (MCS) above the Adriatic at 05 UTC 27 June.

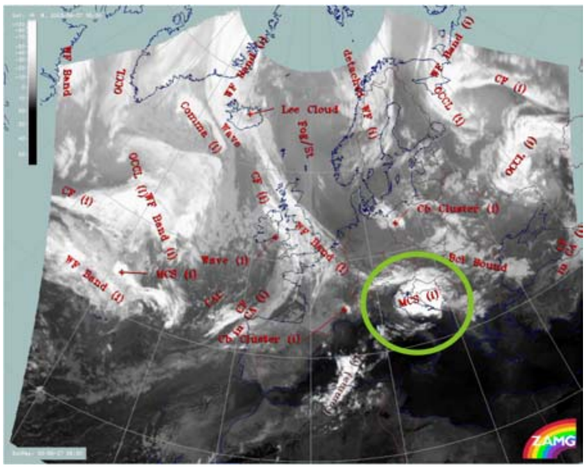

Figure 2. Satrep based on the satellite image at 05 UTC 27 June 2003. Source ZAMG.

Reports of rain showers and lightning were issued during the passage of the MCS by synoptic stations along the east Adriatic coast and the nearby islands. The barographs in the area recorded the propagating pressure disturbance in the middle part of the east Adriatic between 04 and 06 UTC 27 June, thus exactly when the MCS was located above the area. The propagating speed of the MCS is estimated as 20 m s^{-1}, which is very close to the estimated phase speed of the pressure disturbance (Belušić et al., 2007). It is therefore very likely that the pressure disturbance was linked to the MCS. This will be further studied using a numerical model.

3. NUMERICAL SIMULATIONS

The nonhydrostatic MM5 model (Grell et al., 1995) has been used. The model setup consists of three one-way nested domains with horizontal resolutions of 24 (domain 1), 12 (domain 2) and 4 km (domain 3), and 113 x 126, 117 x 129 and 157 x 145 grid points, respectively (Fig. 3). The vertical layer thickness increases with height; the domains 1 and 2 have 39 sigma levels, and the domain 3 has 62 levels. The Gayno-Seaman scheme (Shafran et al., 2000) is used for the parameterization of turbulence. The convective processes are parameterized only for the

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domains 1 and 2, using the Grell scheme (Grell, 1993). The microphysics processes are treated with the Simple-ice scheme (Dudhia, 1989). The initial and boundary conditions are obtained from the ECMWF operational 4D-Var data available every three hours. The simulations start at 18 UTC 25 June for the domain 1, at 00 UTC 26 June for the domain 2 and at 12 UTC 26 June for the domain 3. All three domains end at 18 UTC 27 June.

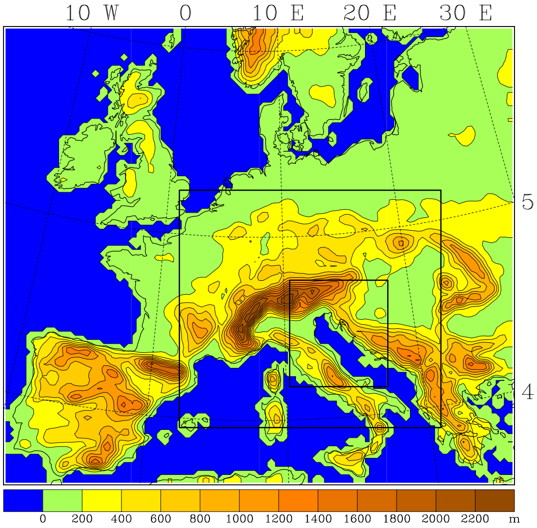

Figure 3. The domain 1 terrain with the domains 2 and 3 indicated.

4. RESULTS

The initiation of the disturbance can be traced in the region northwest of the Alps. As Fig. 4 shows, the frontal zone is characterized by the westerly advection of dry air over the flank of humid air. This creates strong equivalent potential temperature gradient and the atmosphere becomes potentially unstable.

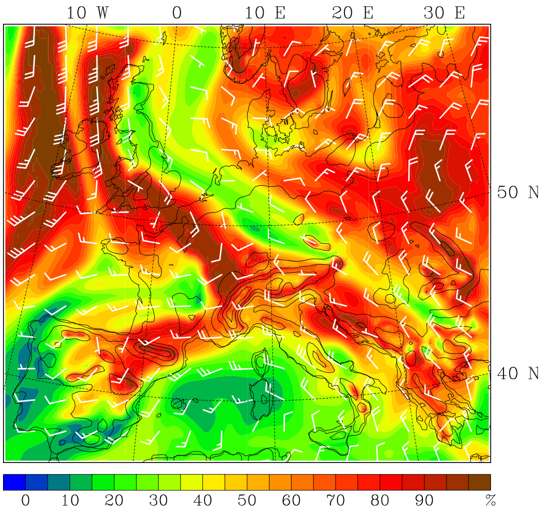

Figure 4. 800 hPa relative humidity and wind barbs at 11 UTC 26 June 2003. Terrain is given every 500 m.

As the potentially unstable air impinges on the Alps, the forced uplift onsets the moist convection and a wave that is in phase with the convection (Figs. 5 and 6).

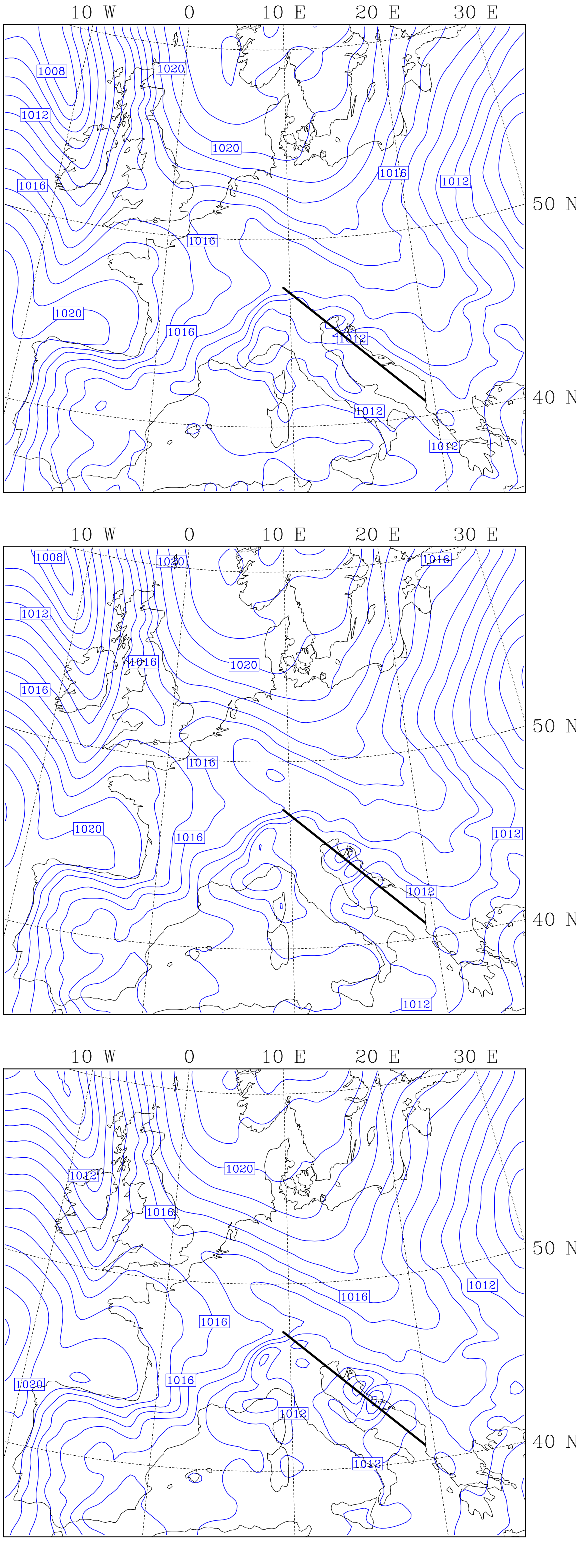

Figure 5. The development of the coupled wave-MCS: MSLP at 22 UTC 26 June (top), 00 (center) and 02 (bottom) UTC 27 June 2003. The thick black line along the Adriatic denotes the cross sections shown in Fig. 6.

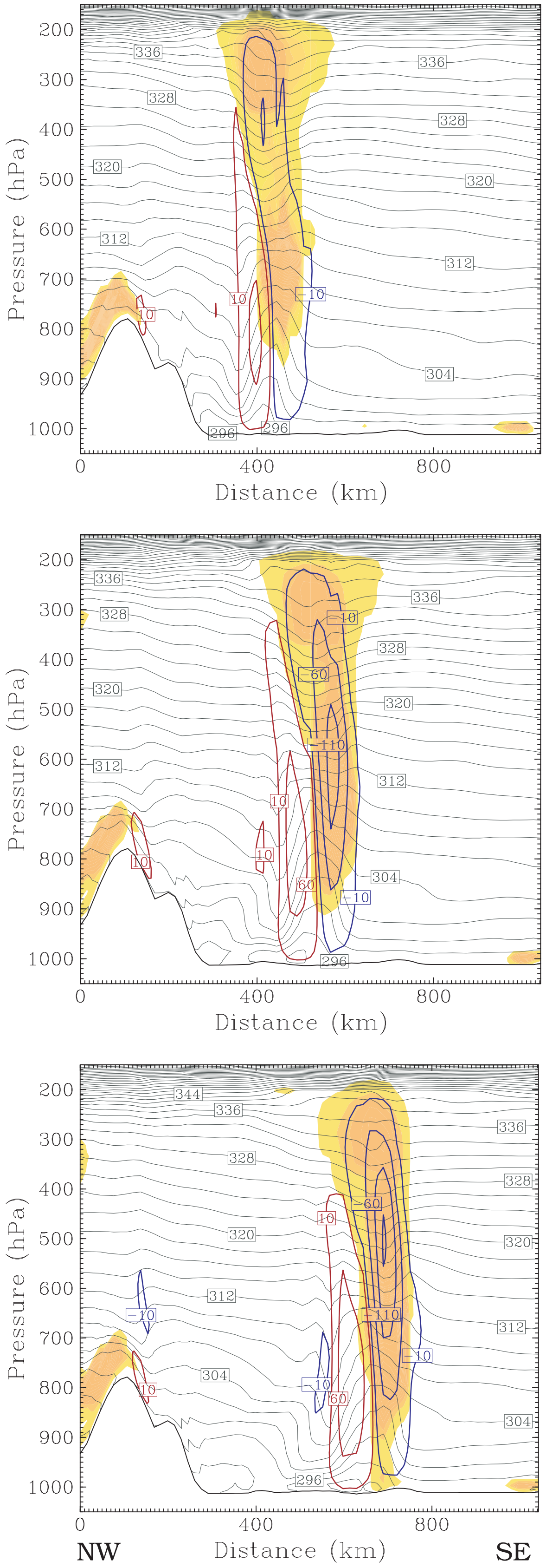

Figure 6. Vertical cross-sections along the line indicated in Fig. 5. Shown are potential temperature (gray contours, 2 K interval), cloud water/ice mixing ratio (color above 0.005 g kg^{-1}) and ω (|ω|>10 dPa s^{-1}, updrafts blue, downdrafts red). Times as in Fig. 5.

As seen in Figs. 5 and 6, the coupled system starts to propagate towards southeast after the initiation. The precipitation-chilled air forms a density current that spreads as the system propagates, so its horizontal wavelength increases from ~140 km in the lee of the Alps to ~200 km over the Adriatic. This is accompanied by the increase in the phase speed of the system, from ~15 m s^{-1} to ~20 m s^{-1}. In this lower layer, which extends from the surface to approximately 2 – 3 km, the updrafts (downdrafts) are approximately 1/4 of the horizontal wavelength in front of the wave ridge (trough). The temperature and pressure are almost out of phase (not shown). This is consistent with the propagating wave dynamics (e.g. Eom, 1975). There is no phase tilt in the vertical in this layer which points to wave trapping.

The layer above, extending from 2 – 3 km to the troposphere, is characterized by the backward tilted updrafts and downdrafts, while the maximum heating is in phase with the updrafts. The upper-layer maximum heating and updrafts are 1/4 horizontal wavelength behind the lower-layer maximum updrafts. This is consistent with the wave-CISK (Conditional Instability of the Second Kind) explanation of the coupled wave-convection propagation (Cram et al., 1992).

Finer-scale domain results reveal the multicell structure of the MCS (not shown, also see Belušić et al., 2007). Nevertheless, the general features seen in the coarse-domain simulation remain.

5. CONCLUSIONS

The atmospheric component of a devastating air-sea event that occurred in the east Adriatic in the early morning hours of 27 June 2003 is studied using the MM5 numerical model. The observed propagating pressure disturbance is shown to be related to the MCS above the area. It seems that the wave and convective system coupled and propagated in a wave-CISK mode, while no wave duct was present. This implies that different atmospheric mechanisms can induce the observed sea response and hence there is a need for further study of similar events with the goal of their better forecasting.

A multitude of test numerical simulations that were performed point to great sensitivity of such cases on different parameterizations and model setups. In this case, the highest sensitivity is on the treatment of moist and convective processes, and on the initialization setup. Therefore, the prediction of similar processes is possible with current models but is still not sufficiently precise in terms of timing and detailed features of the phenomena.

ACKNOWLEDGMENTS

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