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Describing a flash-flood event over the North-East Italy using a very-high resolution atmosphere-ocean-wave coupled model

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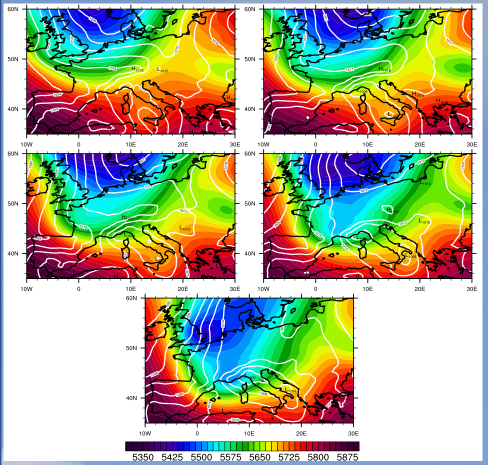

Introduction

From September 25th to 26th, 2007, a large depression developed on the western Italian seas. The depression was characterised by two minima at the ground, one on the Ligurian Sea and one on the South Tyrrhenian Sea. The positioning of the depression caused an intense flow of warm air from the south-east (Scirocco Wind) over the Adriatic Sea (Figure 1). From about 00:00 UTC of 26th Sept 2007 a high pressure wedge over the north-east Alps, activated a very dry air flow on North-Eastern Italy (Davolio et al 2009).The encountering between the warm and humid air mass flowing from the Adriatic Sea and the dry air mass from the Alps took place along a convergence line that develops close to the lagoon of Venice. From this convergence line at the ground, an intense thunderstorm occurred, which, from about 06:00 to 12:00 UTC of 26th Sept 2007, produced rainfall of about 340 mm between Venice Mestre and Marghera (Figure 2). In this work, we studied the described phenomenon by using WRF model with different SST simulation and implementation techniques, in order to evaluate how much a better description of SST, and its interaction with the atmosphere, produces better results in terms of localization, intensity and duration of the convective phenomenon.

Figure 1. The image show the synotic analysis of Sea Level pressure (3 hpa for each line) and the geopotential height, take from ERA-Interim datasets. In panel A) are shown the data from 12:00 UTC of 25/09/2007, in panel B) are shown the data from 18:00 UTC of 25/09/2007, in panel C) are shown the data from 00:00 UTC of 26/09/2007, in panel D) are shown the data from 06:00 UTC of 26/09/2007, in panel E) are shown the data from 12:00 UTC of 26/09/2007.

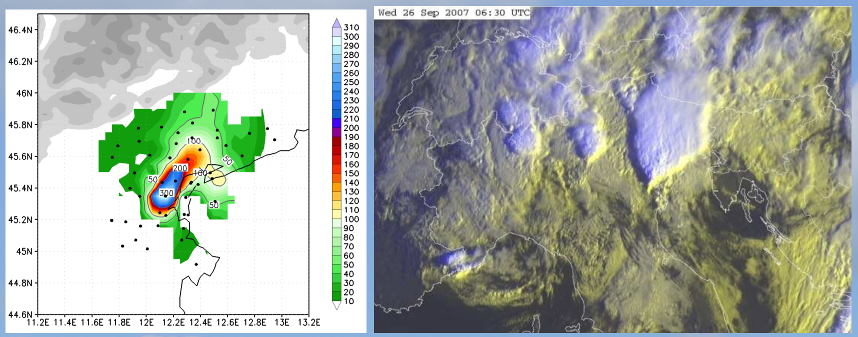

Figure 2. Panel A) show the total accumulated rain (recorded by ARPAV weather station) (Davolio et al 2009). In panel B) we can see the satellite image in the maximun intensity of event. Convergence line and deep convection are easily visible. You can also notice the formation of the overshooting top on the area where the flash flood recorded.

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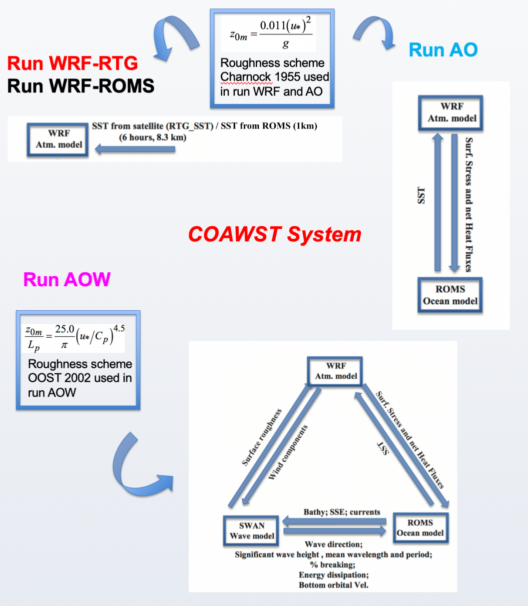

Run WRF-RTG
Run WRF-ROMS

$$z_{0m} = \frac{0.011(u_*)^2}{g}$$

Roughness scheme Charnock 1955 used in run WRF and AO

WRF Atm. model ← SST from satellite (RTG_SST) / SST from ROMS (1km) (6 hours, 8.3 km)

Run AO

WRF Atm. model ⇄ ROMS Ocean model: SST; Surf. Stress and net Heat Fluxes

COAWST System

Run AOW

$$\frac{z_{0m}}{L_p} = \frac{25.0}{\pi}(u_*/C_p)^{4.5}$$

Roughness scheme OOST 2002 used in run AOW

WRF Atm. model – SWAN Wave model: Surface roughness; Wind components

WRF Atm. model – ROMS Ocean model: SST; Surf. Stress and net Heat Fluxes

ROMS Ocean model → SWAN Wave model: Bathy; SSE; currents

SWAN Wave model → ROMS Ocean model: Wave direction; Significant wave height , mean wavelength and period; % breaking; Energy dissipation; Bottom orbital Vel.

Figure 3. Configuration scheme of numerical runs performed with COAWST System

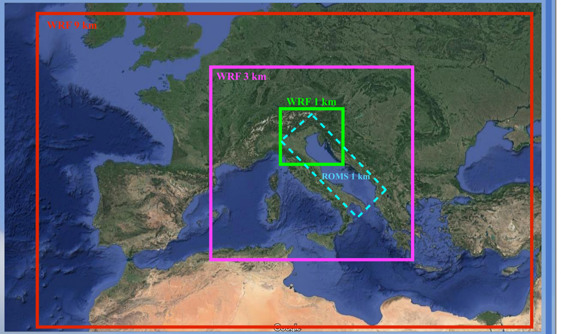

Figure 4. Computational domain used for WRF (red 9km, purple 3km green 1km) , ROMS-SWAN (magenta plot)

In this work we used the COAWST System. COAWST (Coupled Ocean Atmosphere Wave Sediment Transport) is a complex framework that couples the WRF model for the atmosphere side, the ROMS model for the ocean environment and the SWAN model to simulate the wave dynamics. In this work we have run four different simulation. In the first case WRF-RTG works in standalone modality with RTG_SST Sea Surface Temperature at 8.4 km of resolution. In the second case **WRF-ROMS,** WRF works in standalone modality but using the high resolution SST produced by ROMS model at 1 km of resolution In AO case WRF and ROMS are coupled in 2-way configuration. In AOW run WRF-ROMS and SWAN are used in fully-coupled modality. All runs work over domain showed in Fig.4, at 25-5-1 km horizontal resolution for WRF model and 1 km for ROMS/SWAN. In the areas of domains, without coupled model grids, WRF model use a RTG SST with OML (Pollard et al 1973) simple ocean model.

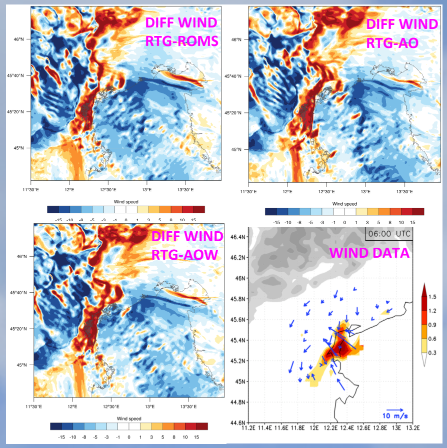

Figure 5. Wind intensity difference between RTG and other runs. A small displacement of the convergence line implies very different intensity, mostly evident in the mainland downstream of the convective phenomenon. Differences are weaker on the sea. Differences between AO and AOW appear mostly on the sea, with AOW producing less intense winds due to wave coupling, producing higher surface roughness.

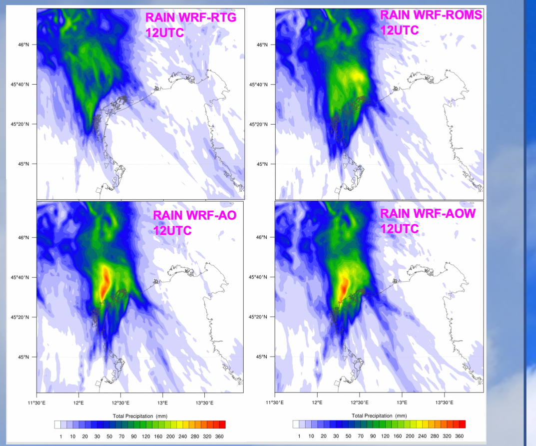

Figure 6. Accumulated rainfall at September 26, 2007, 12:00. Besides underestimating precipitation intensities (top left), RTG run delays by 4 hours the convection developments. ROMS run generates convection with a good timing but again underestimating precipitation. AO and AOW runs produce a convection phenomenon very close to observations in terms of localization, intensity and timing

- The Flash Flood **main characteristics** (timing, location, intensity) are well reproduced just in the atmosphere-ocean **coupled runs**.
- **SST distribution difference** between WRF-RTG and the other runs is quite significant. In general, the WRF-RTG run shows an area of maximum SST in the northeast, while the coupled run shows a maximum SST area between the Po River and the Venetian Lagoon, where convergence was formed at the ground.
- SST conditions influence the **wind fields** both in terms of wind intensity and direction, not only over the sea but also over the land.
- WRF-RTG run has the **coldest SST** (about 2 °C) on the northern area of domain, with particular SST underestimation in the area of formation of the convergence line.
- The WRF-ROMS run shows a higher **wind intensity** than the WRF-RTG case but smaller than the coupled AO and AOW cases.
- In general **the undestimation of SST** and the strong difference in the spatial distribution, in the run WRF-RTG compared to other runs, results in **lower humidity** values in the air column from the ground up to an altitude of about 3000 meters.
- WRF-RTG does not reproduce well the **convergence line** over the Venice lagoon, WRF-ROMS reproduces well the convergence line but with low wind intensity, lower humidity at ground proximity.
- **Coupled runs** show the **best skills** in term of precipitation, strong wind speed close the costal area and high umidity in the air column.
- The cross-sections show that **structure and vertical velocities** associated with the flash flood are more intense and localised in coupled models, reaching the higher levels of the atmosphere.

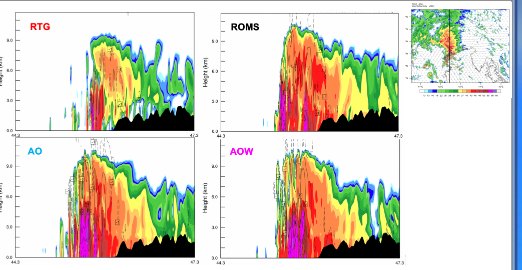

Figure 7. Reflectivity (colour) and vertical velocity (contours) along the cross-section identified in panel A. RTG run produces shallower convection and vertical velocities, whereas atmosphere-ocean coupled runs produce strong vertical velocities up to the top of the atmosphere

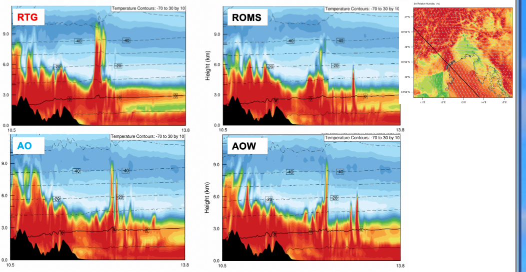

Figure 8. Temperature (contours) and humidity (colour) along the cross section identified in panel A. A dry air layer at approx. 1500-2000 metres partially hampers the effects of convection. Atmosphere-ocean coupled runs (AO and AOW) produce more humid air and a more uniform humidity in the lower layers of the atmosphere.