Ocean-atmosphere-wave coupling: extreme event analysis, forecast and effects in the Mediterranean Sea in May 2010

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Introduction and objectives

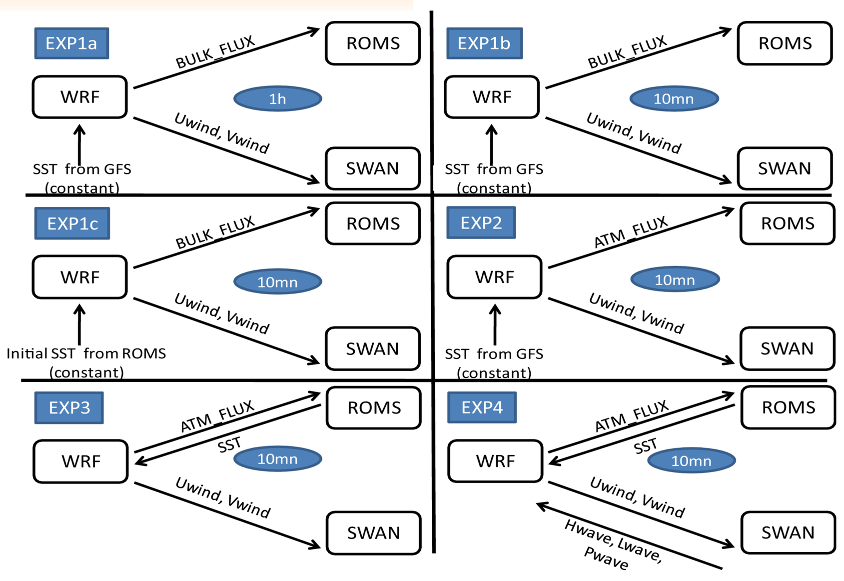
The coastal areas of the western Mediterranean Sea are one of the challenging places in ocean forecasting. This region is exposed to some storms events which occur during a few days. During these events, strong air-sea interactions are observed. To better identify the significant air-sea interactions, we used the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modelling System, which is comprised of the Model Coupling Toolkit to exchange data fields between the ocean model ROMS, the atmosphere model WRF and the wave model SWAN. A severe storm occurred in May 2010 over the western Mediterranean Sea with intense ocean/atmosphere interactions. This storm has been selected as suitable case study for a first implementation of the coupled system at SOCIB/IMEDEA.

The objectives of this study are twofold:

- ➢Assess if coupling is providing a better picture
- ➢Better understanding of the role of key quantities in the storm evolution

Models and methodology:

➢6 experiments



- ➢ WRF: 3 km res, 47 levels. OBC from WRF 9km (nested in WRF27 ←GFS)
- ➢ ROMS : ~1.8km, OBC from MFS
- ➢ SWAN : ~1.8km, OBC from WAM

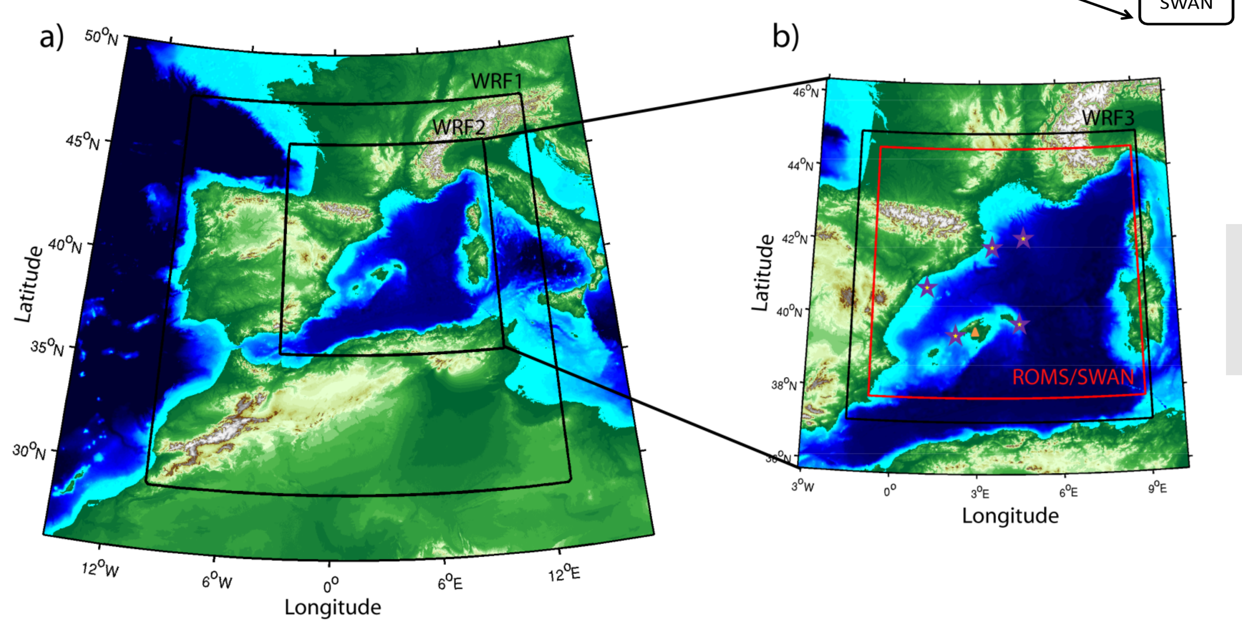


Fig 1: Domain of the coupled domains

The event

- ➢Cyclogenesis Catalan Sea/ Gulf of Lion
- ➢20 mbar decrease in 24 hrs (almost a meteorological bomb)
- ➢Intensification of the Tramontane wind (and also mistral). Up to 27m/s.
- ➢SST decrease 2degC
- ➢Hsig> 7 meters

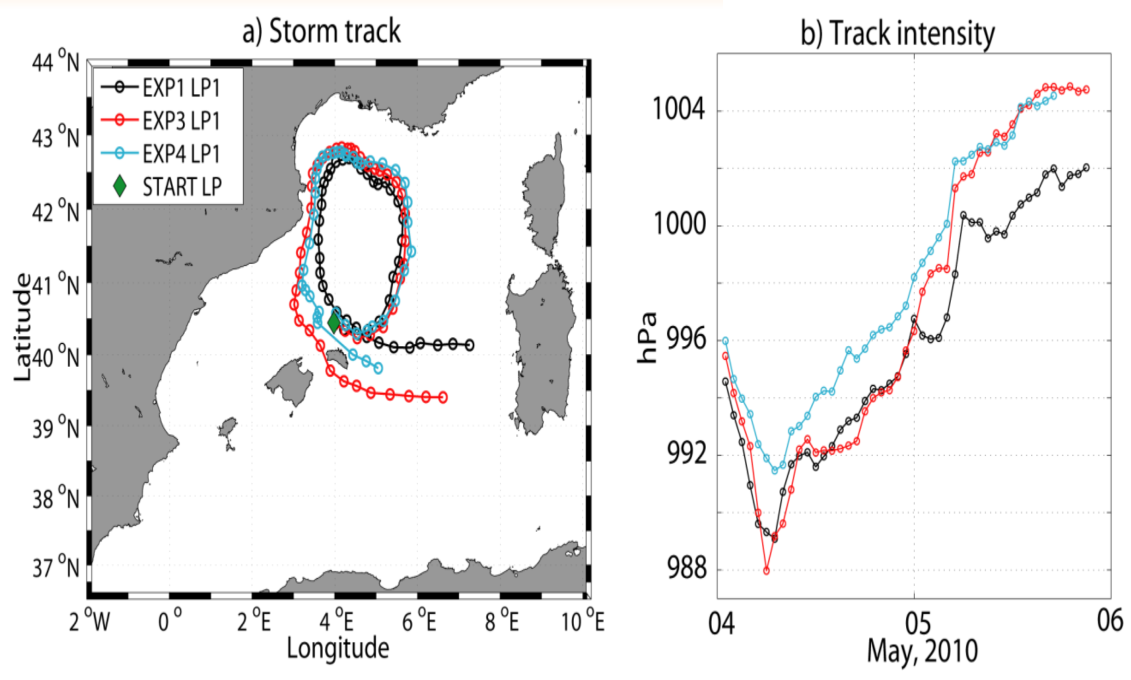


Fig. 2:a) Track trajectory. b) Track intensity

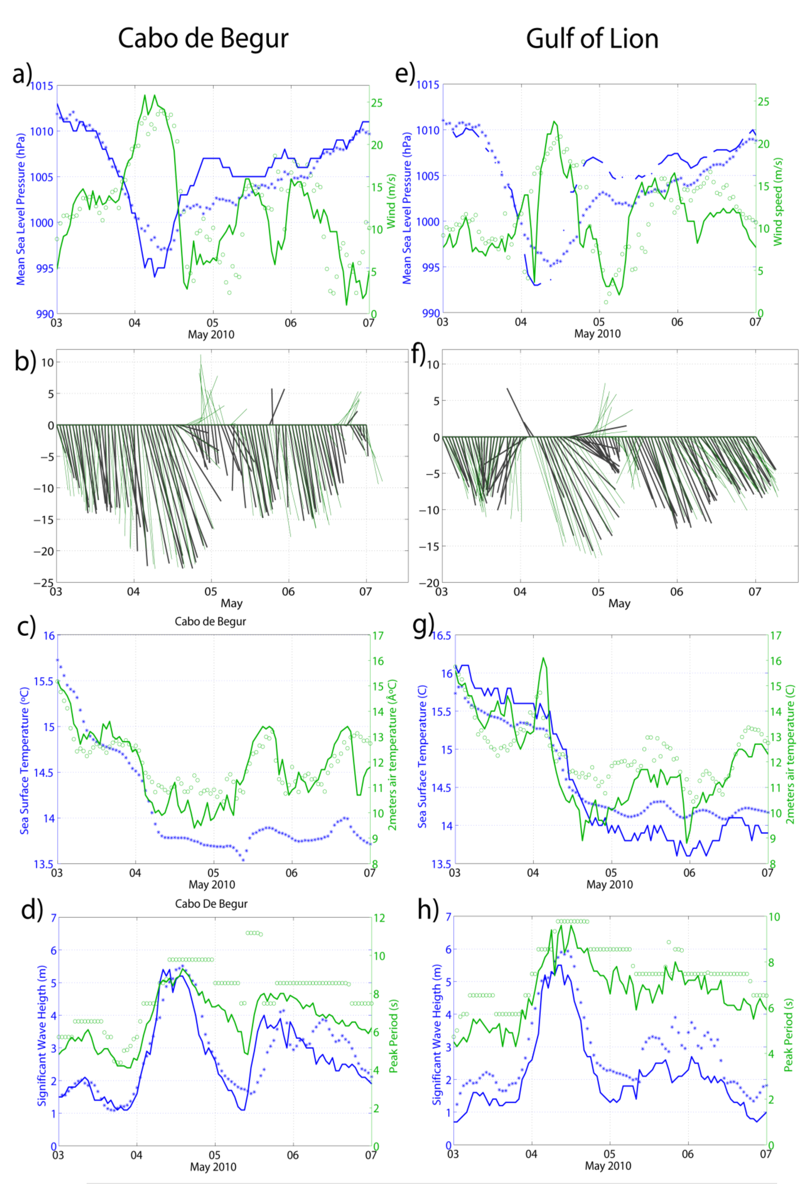


Fig. 3: in situ measurements vs. model

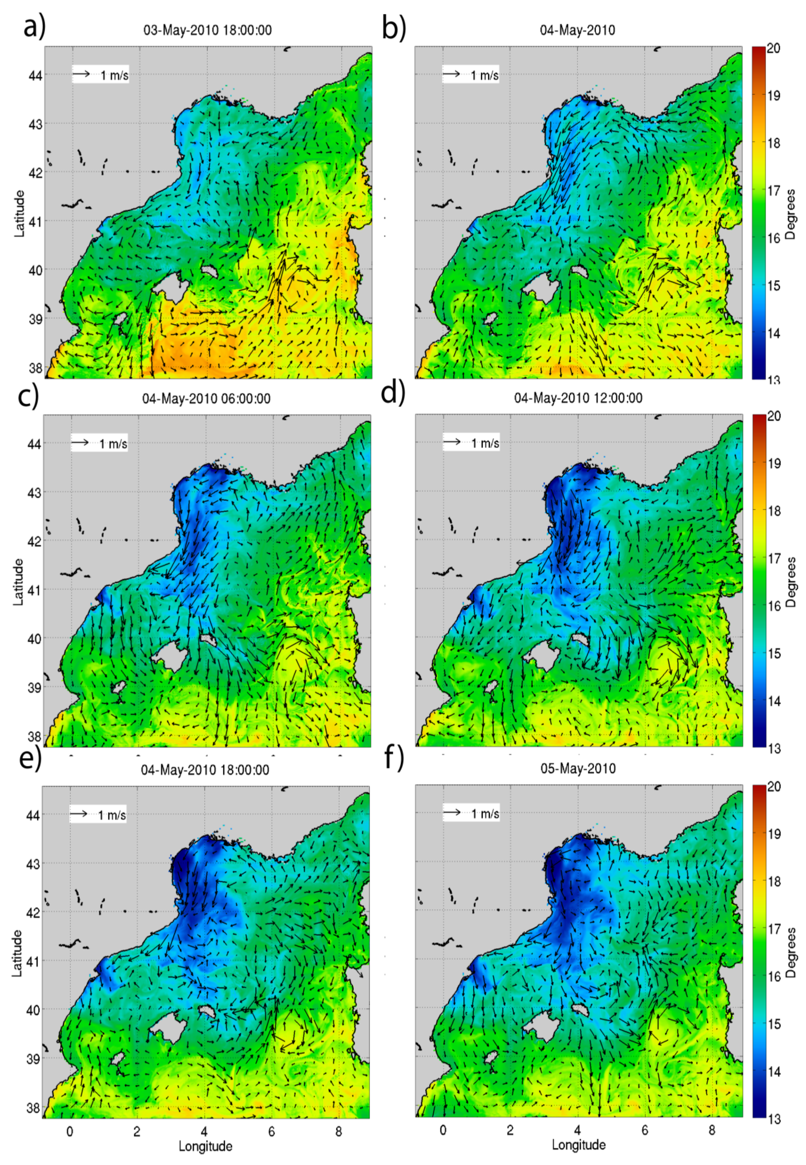


Fig. 4:SST and currents fields snapshots during the event

Air-sea coupling sensitivity

- ➢Strong sensitivity of the low pressure trajectory to the SST coupling (fig 2).
- ➢Strong influence on the wind core position (translation to the northeast), refer to figure 2and 5
- ➢SST sensitivity : less cooling → more realistic due to changes in the turbulent heat fluxes, vertical mixing and mixed layer depth.
- ➢ Wave sensitivity: decreased due to a weaker wind and position of the core, more realistic feature

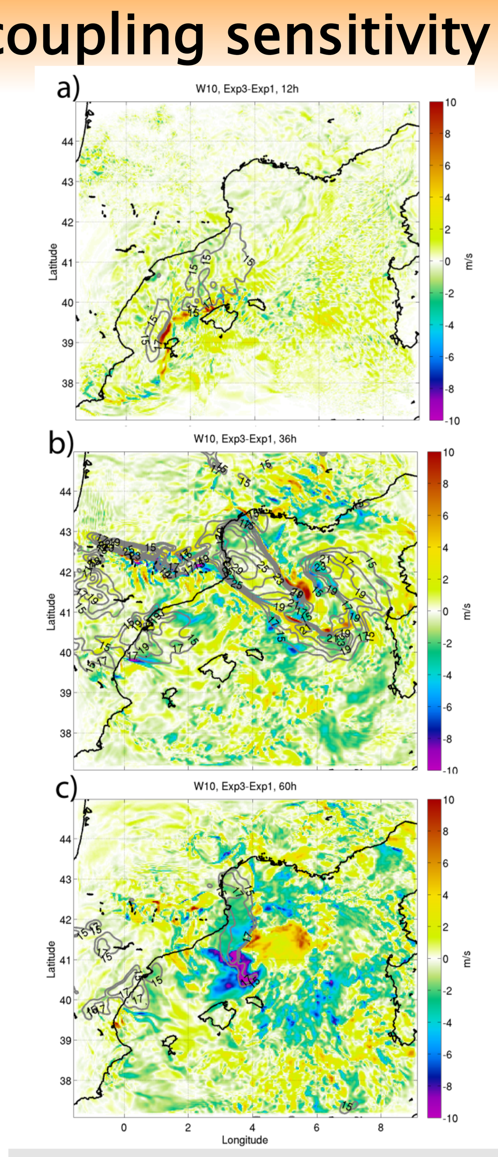


Fig. 5: Wind sensitivity to SST coupling

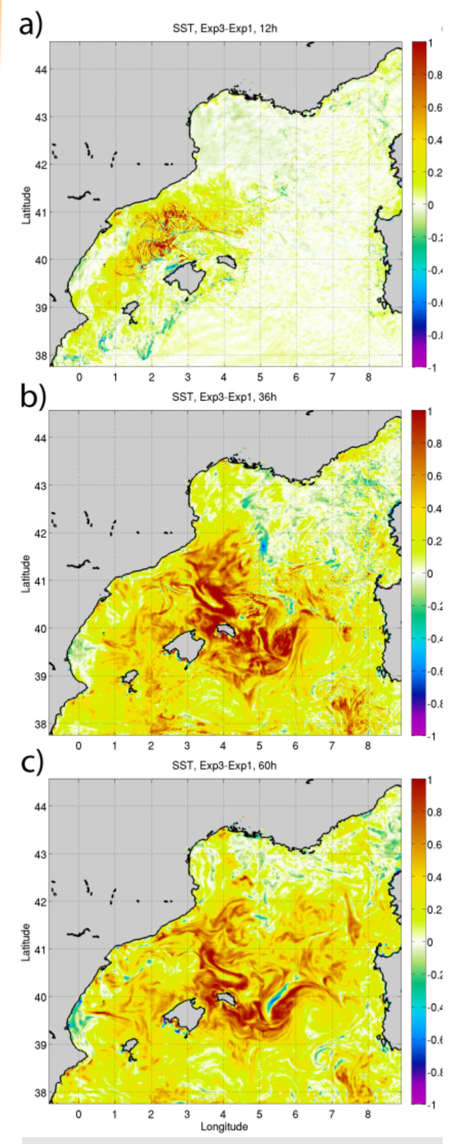


Fig. 6: SSTsensitivity (ºC) to SST coupling

More realistic features. The SST cooling during the event induces a stabilization of the atmospheric air column and then a weakening of the wind speed which in turn, by changes on the vertical mixing and turbulent heat fluxes , induces a weaker cooling.

Air-wave coupling sensitivity

- ➢The wave coupling leads to a decrease of the wind speed (roughness)
- ➢ But increase of the wind stress due to the Drennan parametrization (roughness)
- ➢Turbulent heat fluxes and vertical mixing stronger induce an amplification of the cooling (fig 10).
- ➢Wind decreased → wave decreased (more realistic)

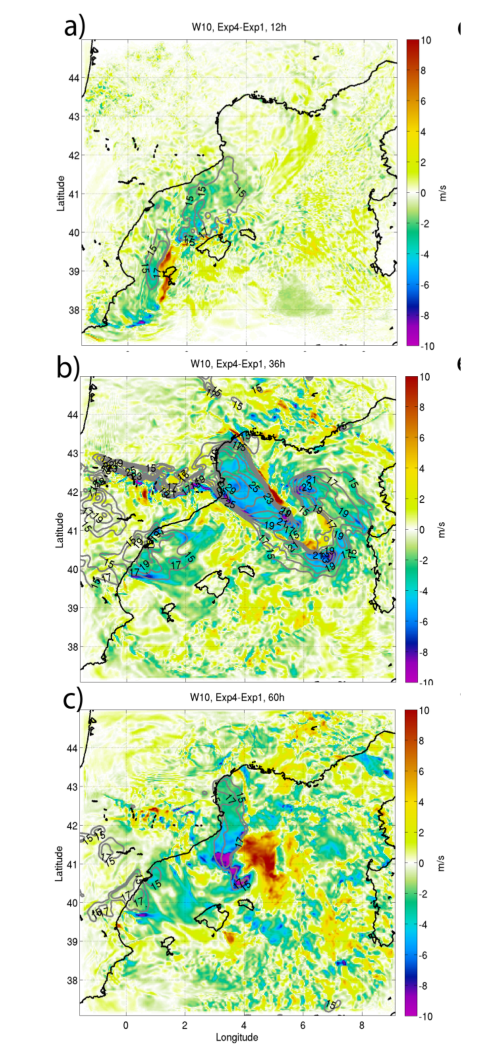


Fig. 7: Wind sensitivity to wave coupling

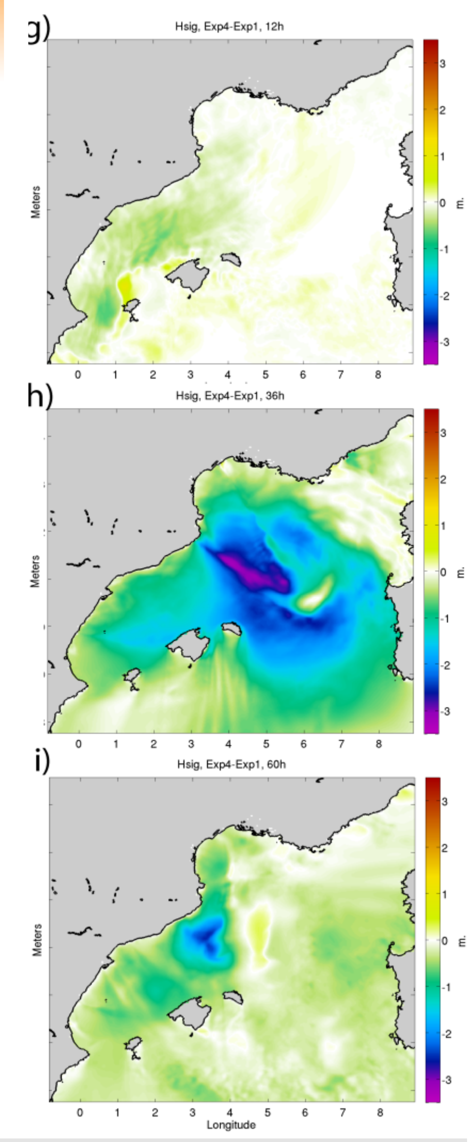


Fig. 8: Wave sensitivity to wave coupling

Again, more realistic features. Roughness → weakening of the wind but stronger wind stress. It induced changes in turbulent heat fluxes and vertical mixing → colder SST. Weakening of the significant wave height (more realistic).

Heat budget over the MLD

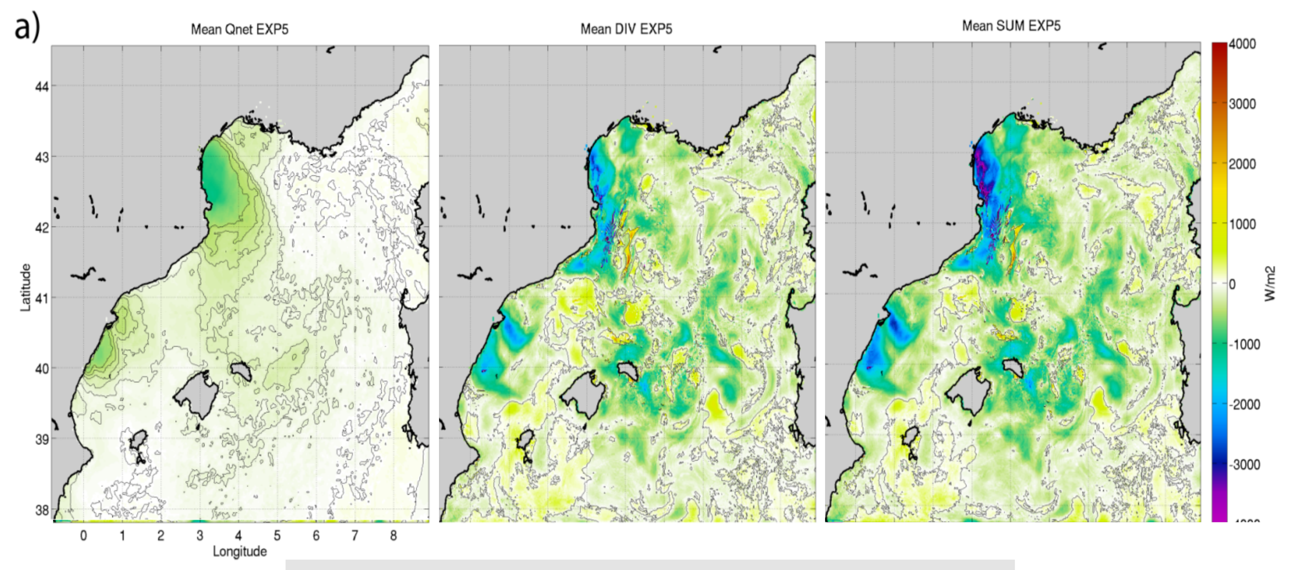


Fig. 9: Heat budget during the storm

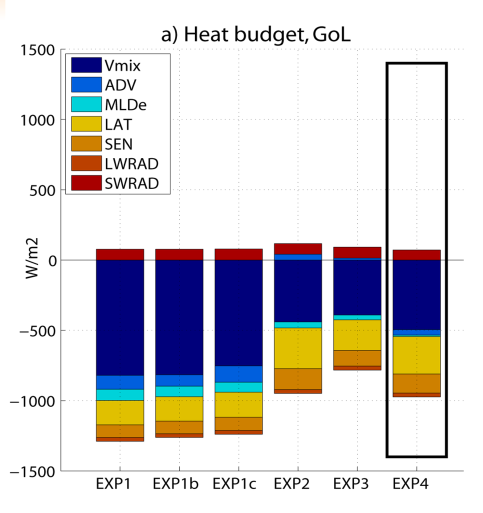


Fig. 10: Contribution to the cooling of each tendency and for each EXP.

→Cooling driven by a combination of heat fluxes (mainly latent and sensible) and vertical mixing (linked to buoyancy flux and wind stirring)

Conclusion:

To summary, model simulations reproduced realistically both the atmospheric and oceanic feature of the studied storm event. The large observed cooling is driven by a combination of turbulent heat fluxes and vertical mixing.

The SST coupling has a strong influence on the wind core position (translation to the northeast) whereas the wave coupling leads to a decrease of the wind speed (roughness) but an increase of the wind stress. Changes on the simulated wind induce different turbulent heat fluxes, vertical mixing and mixed layer depth which in turn induce more realistic SST cooling and significant wave height.

Finally, coupling the SST improves the realism of the simulation and more again when coupling the wave. The full-coupled simulation appears the provide a better picture than the other simulations.

References:

Warner, J. C., B. Armstrong, R. He and J. B. Zambon, 2010, Development of a Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modeling System. Ocean Modelling, 35, 230-244.

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