Toward the predictability of meteotsunamis in the Balearic Sea using regional nested Atmosphere and Ocean Models

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I. Introduction and objectives

Meteotsunamis are oceanic long waves with tsunami-like characteristics but meteorological in origin. They occur in oceans all over the world, usually under their local names such as "Rissaga" in Ciutadella harbor (Menorca Island, Spain). In the western Mediterranean, travelling atmospheric pressure oscillations generate these long oceanic surface waves that can become amplified and produce strong seiche oscillations (up to 4meters) inside harbors causing major damages to boats and harbor infrastructures. We analyze a June 2006 "Rissaga" event in Ciutadella harbor (Menorca Island, Spain), studying numerically the phenomenon during its full life cycle, from the early atmospheric stages to the atmosphere-ocean resonant phase and the final highly amplified harbor oscillation.

Objectives :

- **Demonstrate the capability of numerical models to reproduce the atmospheric and oceanic processes involved during meteotsunamis**
- **Discuss the development of steps towards improvement of the predictive capability for the meteotsunamis events**

Fig. 1: The Ciutadella harbor, normal conditions (left) and Rissaga conditions (right)

II. Models configuration

Oceanic model:

- ROMS
- Analytical Boundary conditions
- Forced by WRF MSLP and wind, every 2 minutes
- 20 sigma levels
- Two embedded domains (offline):1km and 10meters resolution

Atmospheric model:

- WRF - Weather Research and Forecasting -
- Boundary conditions from FNL analysis
- 97 vertical levels
- Two embedded domains: 20km and 4km resolution

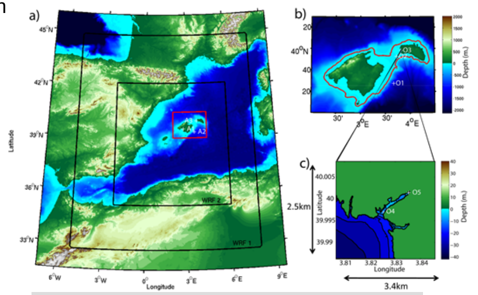

Fig. 2: Domains of the models

III. Atmospheric results

- Three atmospheric layers (warm surface northeastwards flows and cold upper layers) with inversion and gravity waves development at 950-1000hPa
- Deep convective nucleus, C=26m/s, delay of 1 hour
- Traveling disturbance with pressure jump of 5 hPa over the channel

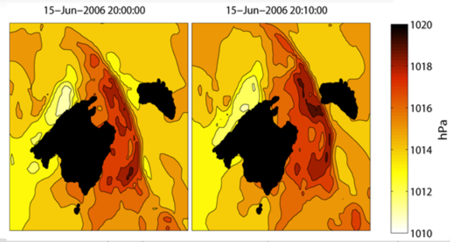

Fig. 3: Simulated Mean Sea Level Pressure snapshots

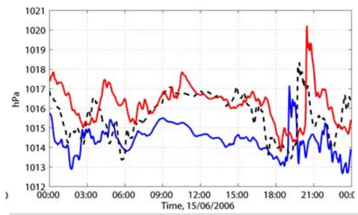

Fig. 4 Simulated MSLP jump near Palma de Mallorca, channel and Maó

IV. Oceanic response

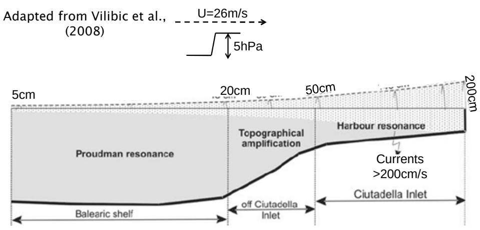

Fig. 5: Oceanic response processes

Solution (Proudman, 1929) for sea level perturbation forced by travelling atmospheric pressure disturbance in channel of uniforme depth

Forced barotropic wave : Free barotropic waves

$$\xi = \frac{1}{1-Fr^2}(x-Ut) - \frac{1}{2(1-Fr)}P(x-ct) - \frac{1}{2(1+Fr)}P(x+ct)$$

$$Fr = \frac{U}{c} = \frac{U}{\sqrt{gH}}$$

Phase 1: Isostatic Open Ocean

Inverse barometer response : 5hPa → 5cm

Phase 2: Proudman Shelf resonance response

Proudman Shelf resonant response and topographical amplification: 5cm → 50cm

Phase 3: Harbor resonant response

Harbor normal mode amplification: 50cm →2m

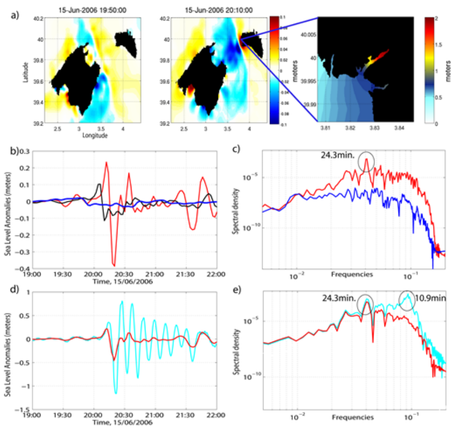

Fig. 6: Oceanic response to the June 2006 Rissaga. (a) Sea Level Anomaly (SLA) snapshots and maximum difference of SLA during the Rissaga event in the Ciutadella Harbor. (b) SLA at the points O1, O2 and O3. (c) associated spectrum of the SLA. (d) The same as Figure 4b but for the points O4 (red line) and O5 (cyan line). (e) associated spectrum

V. Conclusion

We have implemented an atmosphere-ocean model to assess the 15 June 2006 meteotsunami ('Rissaga') extreme event at Ciutadella harbor. WRF adequately reproduces the atmospheric gravity waves and the pressure jump associated with the convective system. ROMS ocean model also realistically reproduces the different resonant coupling that drive the oceanic response and the final "seiche" extreme oscillation of 3 m at Ciutadella harbor.

Agreement between results and observations is encouraging to advance toward the predictability of meteotsunamis.

VI. References

Candela, J., Mazzola, S., Sammari, C., Limeburner, R., Lozano, C. J., Patti, B., and Bonnano, A.: The "Mad Sea" phenomenon in the Strait of Sicily, J. Phys. Oceanogr., 29, 2210–2231, 1999.

Jansá, A., S. Monserrat, and D. Gomis (2007), The Rissaga of 15 June 2006 in Ciutadella (Menorca), a meteorological tsunami, Adv. Geosci., 12, 1–4, doi:10.5194/adgeo-12-1-2007

Liu, P. L.-F., S. Monserrat, M. Marcos, and A. B. Rabinovich (2003), Coupling between two inlets: Observation and modeling, J. Geophys. Res.,417 108(C3), 3069, doi:10.1029/2002JC001478.

Renault, L., G. Vizoso, A. Jansá, J. Wilkin, and J. Tintore (2011), Toward the predictability of meteotsunamis in the Balearic Sea using regional nested atmosphere and ocean models, Geophys. Res. Lett., VOL. 38, L10601, 7 PP., 2011 DOI:10.1029/2011GL047361

Tintoré, J., D. Gomis, S. Alonso, and D. P. Wang (1988), A theoretical study of large sea-level oscillations in the western Mediterranean, J. Geophys. Res., 93, 10,797–10,803, doi:10.1029/JC093iC09p10797.

Vilibić, I., S. Monserrat, A. B. Rabinovich, and H. Mihanović (2008), Numerical modelling of a destructive meteotsunami of 15 June, 2006 on the coast of the Balearic Islands, Pure Appl. Geophys., 165, 2169–2195, doi:10.1007/s00024-008-0426-5.