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Influence of spatially correlated noise in the generation of meteotsunamis in Ciutadella

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Meteotsunamis are sea waves with frequencies ranging from 2 minutes to 2 hours (the same frequency band than seismically generated tsunamis) that are generated by high frequency atmospheric perturbations. Extreme meteotsunamis can cause high frequency sea level oscillations of a few meters at the coast which are dangerous for coastal populations. The meteotsunami generation involves both the amplification of the inverse barometer response by Proudman resonance and also harbour resonance. For this reason, meteotsunami generation is highly dependent on the bathymetric and topographic characteristics of the basins, some of them being more suitable than others for the meteotsunamis occurrence. This is the case of the Ciutadella harbour, in the Balearic Islands (Western Mediterranean), where several meteotsunamis of >1 meter of amplitude (difference in the sea level elevation between consecutive maximum and minimum) occur every year. This hotspot for meteotsunamis has been studied for four decades and several forecasting systems have been implemented in the region. However, the accuracy of those systems, in particular in terms of predicting the amplitude at the coast, is still limited.

In a previous work (Villalonga et al., 2022), a new set of ultra dense atmospheric observations allowed a detailed characterization of the atmospheric disturbances generating meteotsunamis. We found that these disturbances are highly heterogeneous both in time and space, and that heterogeneity is very difficult to reproduce with atmospheric models. With the aim of understanding what is the impact of that heterogeneity in the final meteotsunami amplitude, we have conducted several experiments with the SYMPHONIE model (Estournel et al., 2021). The model has been configured to cover the whole Balearic Islands with a variable spatial resolution reaching up to 5 meters inside Ciutadella harbour. It has been forced with different kinds of atmospheric disturbances, namely analytical functions and observed time series with tuneable propagation velocities over the model's domain. Random noise with different spectral and spatial characteristics has also been added.

The model has been able to accurately reproduce the amplitude and spectra of real meteotsunamis events when forced with the observed atmospheric pressure time series. We have also tested the sensitivity of the model outputs to different model configurations by changing the friction parameters and comparing 2D to 3D simulations. The results suggest that 3D simulations

provide a more realistic energy dissipation by friction, particularly in the higher frequencies. Finally, the experiments forcing the model with random spatially correlated noise have allowed understanding the impact of atmospheric spatial heterogeneities. In particular, the results show that the size of the random structures is a key parameter that determines the amplification of sea level oscillations. Namely, the structures with a spatial scale of 10-30 km generate more signal amplification than larger structures.

All in all, these simulations have provided new results that will allow a better understanding of the generation of meteotsunamis in the Balearic Islands and the limits of their predictability.