Resonance properties of a closed rotating rectangular basin subject to periodic wind forcing

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Coastal basins subject to wind forcing often exhibit strong oscillations, leading to a set-up at the coast, which in turn may threaten coastal safety. This is particularly so when the combined properties of the wind field and the basin geometry trigger resonance. The goal of this study is to systematically analyze the influence of spatial variations in the wind field, rotation and basin dimensions on these resonance properties.

To achieve this goal, we have developed an idealized process-based model for closed rectangular basins of uniform depth. The model is forced by imposing a time-periodic wind stress, which can be viewed as a truly periodic event (e.g., a diurnal breeze) or as one of the Fourier modes in the spectrum of a single storm event. We account for spatial variations in the wind field by allowing a linear variation of wind amplitude and phase in the along-wind direction (creating a nonzero divergence) and cross-wind direction (creating a nonzero curl). An essential model feature is that the vertical structure of the flow is resolved in a fully analytical way, and that the horizontal structure is solved by means of a so-called collocation method, using a truncated superposition of analytically obtained channel modes.

The model results (example in Fig.1), supported by an approximate analytical solution for weak rotation, allow us to identify various resonant frequencies and to link them to the spatial structure of the wind field. In particular, some of the resonant modes exist for a spatially uniform wind field, whereas others typically arise from the divergent part and the curl-part of the wind field. Our analysis further shows how cross-wind basin dimensions affect resonance properties. The main effect of friction is a damping of the amplification. Finally, for a spatially uniform wind, the symmetry properties of the system allow for a convergence test, which reveals second order convergence in the truncation number of the collocation method. The results obtained here will be used in a follow-up study, carried out with a Finite Element Model, allowing for more realistic geometry (closed and semi-enclosed basins, possibly including elements such as large-sand pits and artificial islands), wind and pressure fields.

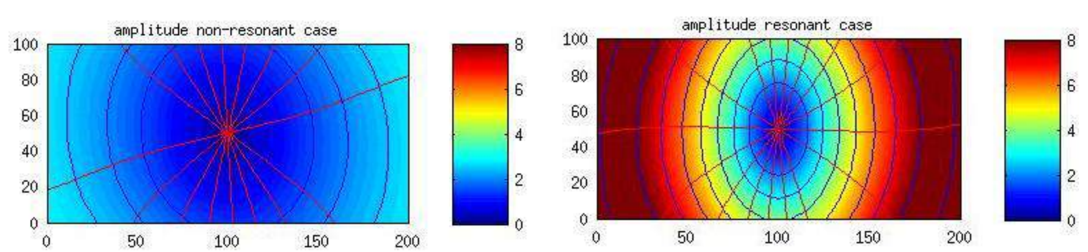

Figure 1. Wind-driven set-up is studied in a closed rectangular basin, of horizontal dimensions 200 km × 100 km, and uniform depth 10 m. Wind is spatially uniform, parallel to the along-basin direction, and time-periodic. Two different frequencies are considered: one well away from resonance (left) and one close to one of the resonant frequencies (right). Colours indicate the surface elevation amplitude, whereas the blue and red lines are the co-amplitude and co-phase lines, respectively.