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Role of coastally-trapped long waves in the evolution of storm surge induced by atmospheric cyclones

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Some of the most severe storm events in the Mediterranean are forced by translating atmospheric cyclones. When the atmospheric cyclone approaches the coastline, it induces a storm surge, which can propagate along the continental shelf as a long wave trapped by bathymetry and/or coastline. Arrival of this wave at a certain location can significantly modify coastal circulation driven by the local wind. A set of numerical experiments has been performed in order to analyze a long-wave response of the coastal ocean to the translating mesoscale atmospheric cyclone crossing the continental shelf and approaching the coastline at a close to normal angle. The model is forced by a radially-symmetric atmospheric pressure perturbation with a corresponding gradient wind field. The cyclone's translation speed, radius, and the continental shelf width are considered as parameters, whose impact on the long wave period, modal structure, and amplitude is studied.

When the Eulerian time scale of the atmospheric cyclone is comparable to or longer than the inertial period, subinertial continental shelf waves (CSW) dominate the response. They are strongly affected by earth's rotation and propagate in the downstream (in the sense of Kelvin wave propagation) direction. These conditions are typically associated with extra tropical (synoptic-scale) atmospheric cyclones. Tropical-like mesoscale atmospheric cyclones are less frequent in the Mediterranean, and their Eulerian time scale can be less than the inertial period. In this case the generation of edge waves is possible, especially on wider shelves. Superinertial edge wave modes have a higher free surface amplitude and faster phase speed than the CSW modes and propagate in both directions relative to the coastline. Edge waves with the highest amplitude (up to 60% of the forced storm surge) propagate upstream. They are produced by the storm system with an Eulerian time scale equal to the period of a zero-mode edge wave with the wave length of the storm spatial scale. When the storm trajectory deviates from the normal approach, most of the edge wave energy propagates in the direction of the alongshore component of the cyclone's translation velocity.

Since the dimensions of sub-basins in the Mediterranean are smaller than typical synoptic-scale atmospheric systems, the adjustment of trapped waves to the curvilinear coastline and continental shelf is important, especially when the coastline changes orientation rather abruptly, in a corner-like manner. Such a configuration of the coastline causes a multi-mode response with smaller-scale but more energetic transient jets aligned with the "blocking" (deviating) coastline. The predominant trajectory of atmospheric cyclones in the Mediterranean is zonal so that numerous meridional coastal boundaries there can be affected by the described dynamics. For instance, coastally trapped waves generated at the southeastern coast (Tuscany) of the Ligurian Sea and subsequently entering Gulf of Genoa could exacerbate the impact of storm system on January 1-2, 2010, which resulted in unexpectedly high coastal damage.