Interaction of the deep and coastal waters of the Caspian Sea: results of a three-dimensional circulation and sea-ice model

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The Caspian Sea is the largest totally enclosed water body on Earth. The elongated geometry (1000 km in length and 200-300 km in width) and strong topography of the basin, acted upon by variable wind forcing and baroclinic effects result in spatially and temporally variable currents in the Caspian Sea. Topographical features consisting of the shallow northern basin, the wide eastern shelf, and the mid-basin sill, and the irregular coastline geometry result in complicated circulation and upwelling structures.

A free-surface three-dimensional primitive equation dynamical ocean model coupled with ice thermodynamics and air-sea interaction sub-models is used to study the seasonal variability of the Caspian Sea circulation. The spatial resolution of the model (10 km horizontal grid size and 22 vertical levels) allows realistic simulation of baroclinic eddies and coastal currents. The boundary conditions are formulated to allow momentum and buoyancy fluxes through the air-sea interface and the open lateral boundaries. Hindcast experiments were run for the period 1982-99, which are the years of dramatic Caspian mean sea level rise. We concentrate on the analysis of intra-annual variability of the 1991 circulation, to describe observed features on a seasonal basis.

The Caspian Sea circulation is a combination of basin scale gyres and shelf currents constrained by the closed basin geometry and complex topography. An east-west sea surface gradient is set up as a result of the predominantly south- to westward winds, the east-west anti-symmetry in water fluxes comprised of precipitation, evaporation and the river run-off along the north-western coast. The seasonal variations of heat fluxes and wind stress result in distinct thermohaline structures in the deep and shallow regions, yielding significant seasonal variability of continental shelf and continental slope currents. Different types of interaction and mixing of the deep basin and shelf waters are clearly indicated in the model and supported by observed data. The most important features are: i) dense water formation by winter convection and freezing of sea-ice in coastal regions; its transport to the continental slope by eddies followed by gravitational sinking to the deep sea region; ii) wind driven upwelling along the eastern coast in summer; iii) local upwelling on the western coast driven by a seaward current system generated through the interaction of the southward flowing coastal current originated from the Volga river influence with an anti-cyclonic circulation in the deep basin.