Abstract

The present thesis investigates non-linear interaction of storm surges, tides and wind waves and associated coastal inundation along the west coast of India. Storm surge is one of the most devastating components of a tropical cyclone, especially on the densely populated low-lying coast of India. The impact of tides and wind waves modifies the surge and the resultant water level is named as total water elevation (TWE). A state-of-art model, ADCIRC in a standalone mode and ADCIRC+SWAN in a coupled mode are used for the study. The role and dependence of continental shelf width and coastline geometry on the non-linear interaction mechanism among storm surges, tides, and wind-waves are analyzed. In this study, 13 idealized cyclone tracks are considered, separated by about 100 km each, which are made landfall perpendicular to the coast. Simulations are performed for all these tracks by using idealized, as well as actual bathymetry of the west coast of India. The analysis shows that the surge gets amplified by about 10-12 cm for every 10 km increase in the shelf width from south to north. During different phases of tide, surge-wave interaction modifies the water elevation and its occurrence as the tidal range significantly increases towards the north. The maximum interaction of tides on surge-wave is observed at a low-tide, whilst it is minimal during a flood-tide. Non-linearity is computed for each track and tidal phase to estimate the modification in TWE during surge-tide-wave interaction. In general, the non-linear interaction is found to be 15-20% for any cyclone track or tidal phase. The study also highlights effect of wind-wave on the total water elevation, which is incremental up to the shelf width of 100-120 km, beyond that the effect becomes marginal. Experiments related to the effect of local coastline shape and shallow bathymetry suggest that the coastal curvature and very shallow depths less than 5m significantly contribute towards surge, tide and wave interaction.
The number of extreme severe cyclonic events are increasing in the Arabian Sea in response to climate change. Impact of future climate change on tropical cyclones are studied in terms of Extreme Water Elevations (EWE) and associated coastal inundation for Gujarat and Maharashtra. Regions from Rann of Kutch to Gulf of Khambhat and the northern part of Maharashtra have broad low-lying topography and shallow near-shore bathymetry. In addition, the presence of high tidal range (11-12 m) inside the gulf region also enhances the EWE and associated coastal vulnerability. Coastal flooding may alter the shorelines and its impact can be diverse because the coastal flooding is tightly coupled to the morphological development of these coastal systems. Hence, a potential storm surge flooding maps for Gujarat and north Maharashtra coast are generated using climate change projections on the tropical cyclones. The inundation due to EWEs are computed using most probable synthetic cyclone tracks having a uniform pressure-drop of 66 hPa, which are generated based on historical cyclone tracks. Three different climate change scenarios are considered, which are No-climate change, moderate scenario (7% increase in wind speed) and extreme scenario (11% increase in wind speed). Highest EWEs ranging from 10-11 m are computed in the gulfs of Khamhat and Kutch and also along the coast of Navi Mumbai from these scenarios. And, the lowest EWE of 4.5 m is computed along the coast from Porbandar to Diu from all scenarios. The maximum extent of inundation is noted in Rann of Kutch and adjoining areas of Gulf of Khambhat and Mumbai. The simulations show that, the impact of climate change scenarios on the extent of inundation is comparatively less for the entire study region. However, a noticeable increase of 5 m in the height of inundation is simulated near Mumbai coast and gulfs of Kutch and Khambhat. The analysis concludes that the most vulnerable regions to EWE and cyclone induced inundation are Rann of Kutch and adjoining areas of Gulf of Khambhat and Mumbai.
A 3D model allows more accurate representation of physics by including different boundary conditions. The 3D model equations are important for modelling the stratified and wind-driven circulation in a semi-enclosed or enclosed region, in which the bottom and surface boundary layers encompass a significant part of the water column, or if the circulation is affected by wave and current interaction. In such cases, it is required to solve the equations for the vertically varying profile of horizontal velocity. In the regions like gulfs of Kambhat and Kutch along the west coast of India, which represents the most complicated shallow coastal waters, very large amplitude of tides are observed resulting from strong tidal currents. Thus, a significant vertical current structure also could be evolved during this process. Hence, an analysis is made to compare 2D and 3D ADCIRC model simulations of tides, surges and its interactions, particularly in the gulf regions. The 3D simulated tides using various combination of vertical parameters, viz., bottom drag coefficient, eddy viscosity and bottom and surface roughness lengths. It is observed from the simulations that the 3D model results are sensitive to the vertical parameters. The smaller values of bottom drag coefficient, eddy viscosity and bottom roughness length produce higher tides, whilst, large values of surface roughness length generate higher tides in the gulf regions. The analysis reveals that steep slope in the strong vertical velocity from bottom to surface modifies the bottom stress and modulate tides in the gulf regions. The vertical velocity is one order less and its slope is gentle along the straight-line coasts. The tides are better predicted with 3D in the Gulf of Kambhat and the RMSE at Bhavnagar is 0.05. Both the models have reproduced similar tidal heights along the straight-line coasts. It concludes that the 3D model computations are inevitable inside the gulf regions, whilst, the 2D model could be able to simulate tides accurately along the straight-line coasts. The simulations of surge-tide-wave interaction for the gulf regions emphasize that the TWE during the interaction is varied significantly with the 3D model in comparison to 2D.