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High-resolution numerical modeling of tides in the western Atlantic, Gulf of Mexico, and Caribbean Sea during the Holocene

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Temporal changes in tidal amplitudes are an important component in the reconstruction of relative sea-level (RSL) change. RSL data in turn help quantify variations in crustal movements since the Last Glacial Maximum (LGM) and help calibrate models of earth rheology. Changes in RSL originate from many sources including eustatic change, glacial rebound, tectonic effects and local processes. Changes in tidal range, over time, are one contribution to these local proceses.

To investigate the significance of these changes, tidal constituents and tidal datums were computed on a high-resolution grid of the northwestern Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea. A global model was first used to determine tidal parameters on a grid with a nominal resolution of 800 x 800. The global model included self-attraction and loading, drag in shallow marginal seas, and internal tide drag in the deep ocean. Simulations were performed at 1000-year intervals from 10,000 calibrated years before present (10 ka) to present day in combination with changes in bathymetry and coastline location derived from a glacial isostatic adjustment model. The global model results were then used to force a regional barotropic tidal model. The regional model used an unstructured finite-element grid, with very high resolution at the coastline.

The model results revealed significant variations in tidal constituent amplitudes throughout the Holocene. In the northwestern Atlantic, semi-diurnal components showed a strong amplification at around 9 ka while in the Gulf of Mexico, the response was much more muted. Variations in diurnal tidal parameters were found to be less significant than semi-diurnal parameters throughout the model domain. The high spatial resolution of the regional model also allowed for the investigation of tidal changes at spatial scales (individual bays, e.g.) much smaller than in previous studies. Finally, changes in tidal range, of great relevance to changes in RSL were investigated throughout the Holocene. The overall structure was similar to the patterns observed in the M2 tide, with peak increases of 2-300%, relative to present day, being observed along the east coast of the US from 9 to 8 ka.