Modelling flooding in a coastal estuary from combined storm surge and rainfall during hurricanes

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ABSTRACT: During extreme storms, intense precipitation and wind-driven water levels contribute to coastal flooding. To investigate the impacts of these processes, a coupled flow-wave model that includes precipitation is used to simulate two major storm events (Hurricane Matthew and Tropical Storm Hermine in 2016). The Delft3D-SWAN model is applied over a domain covering coastal North Carolina, USA, including the Albemarle-Pamlico estuarine system. Within this area, a long and narrow back-barrier estuary (Currituck Sound) is investigated in detail with a high-resolution (50 m) grid, and results are compared with observations of surface waves, currents, and water levels from five monitoring platforms. Model results were in agreement with observations, and show that wind speed and direction are the primary drivers of coastal flooding. Precipitation over water provided an additional contribution to flooding, and model results were improved when rainfall was included. A complex bidirectional flow pattern was observed, with flows in alternating directions at the surface and bed of Currituck Sound.

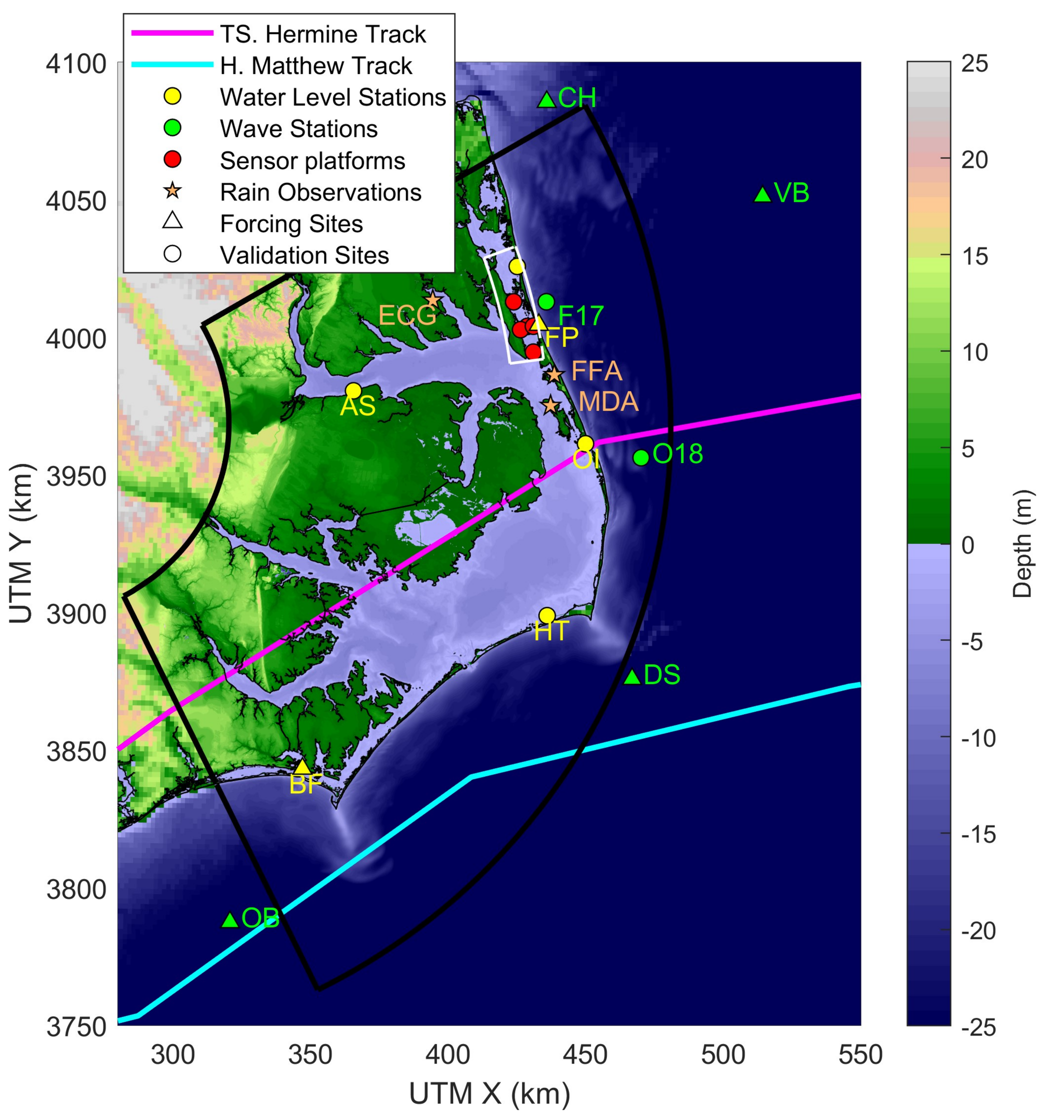

Figure 1: Map of the model domain, including bathymetry, model forcing locations, validation sites, and best available hurricane tracks.

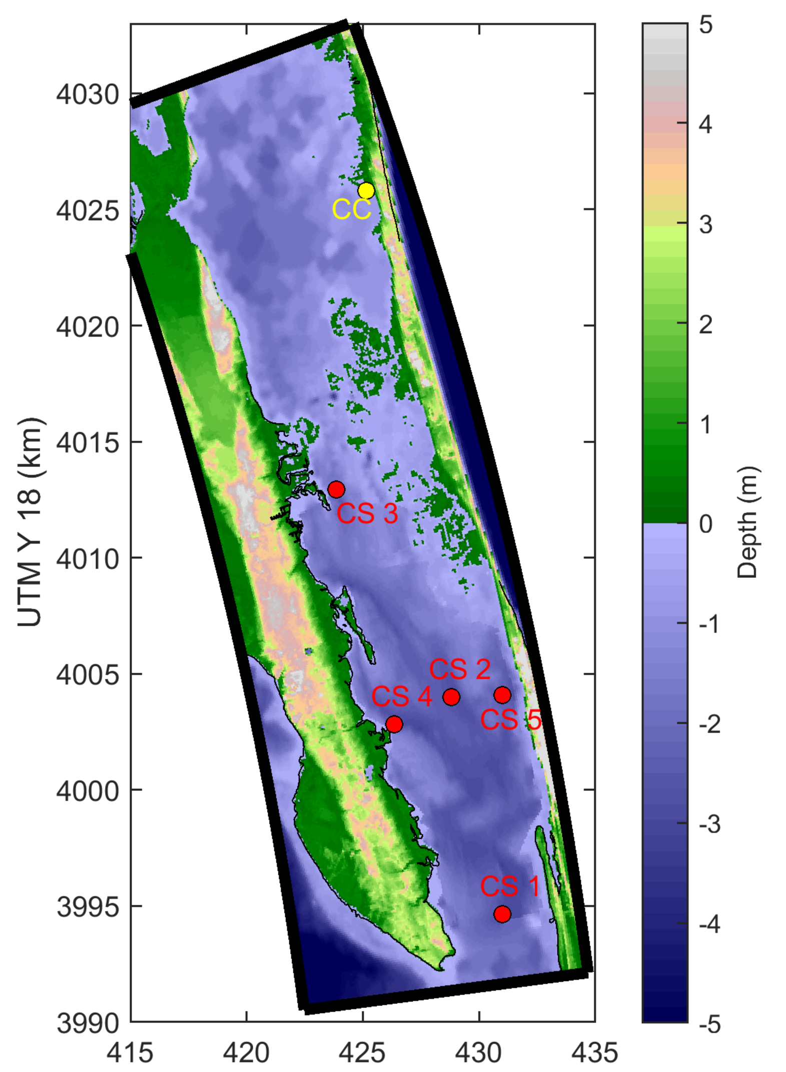

Figure 2: Detailed map of Currituck Sound and five observation stations.

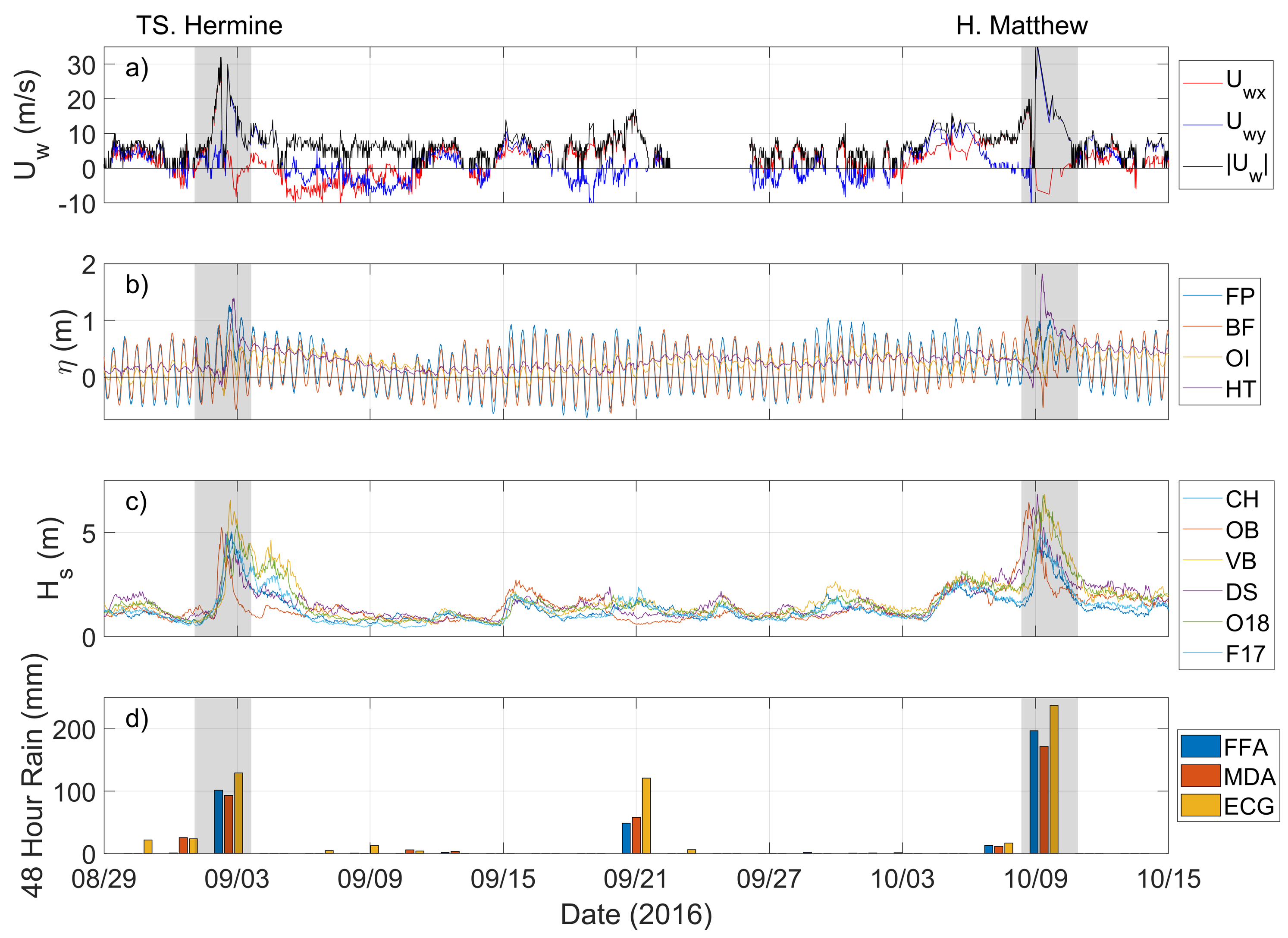

Figure 3: Observations of: a) wind speed and direction at the First Flight Airport (FFA); b) water levels at selected tide gauges; c) significant wave heights at selected offshore buoys; and d) 48 hour precipitation totals from selected National Weather Service monitoring sites.

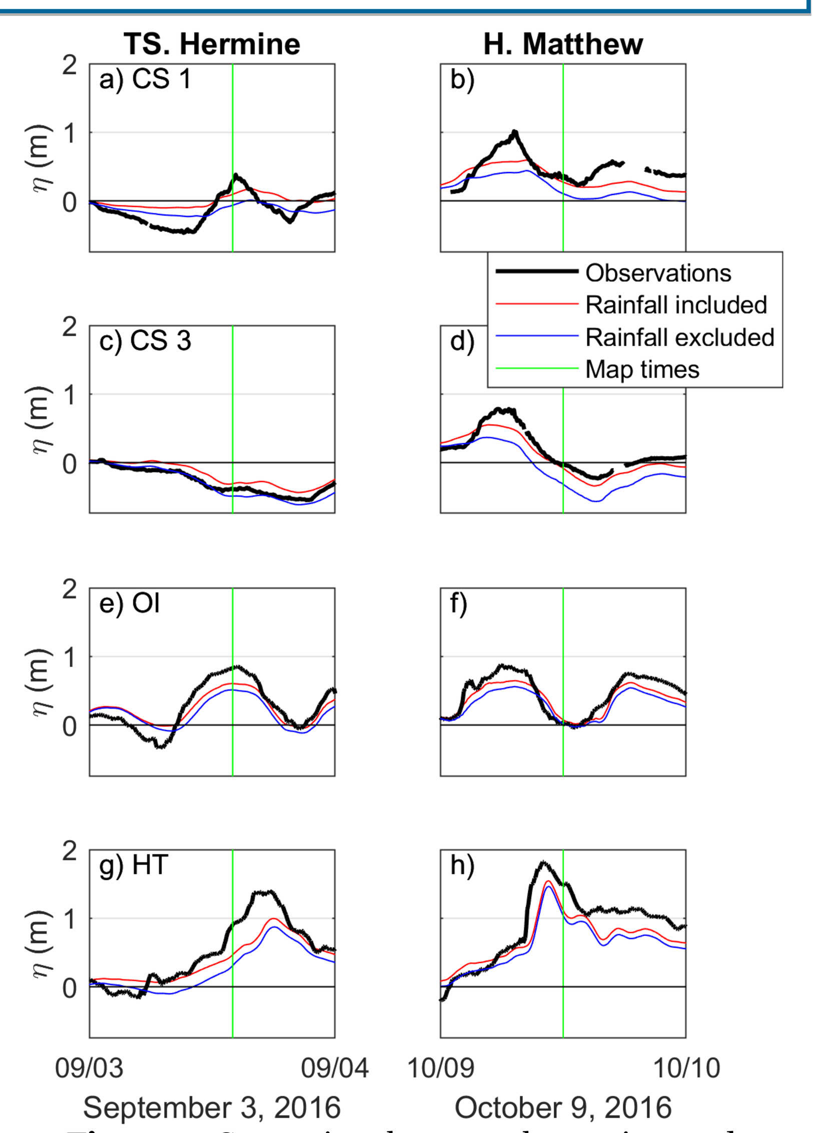

Figure 4: Comparison between observations and model results with and without precipitation at 4 sites

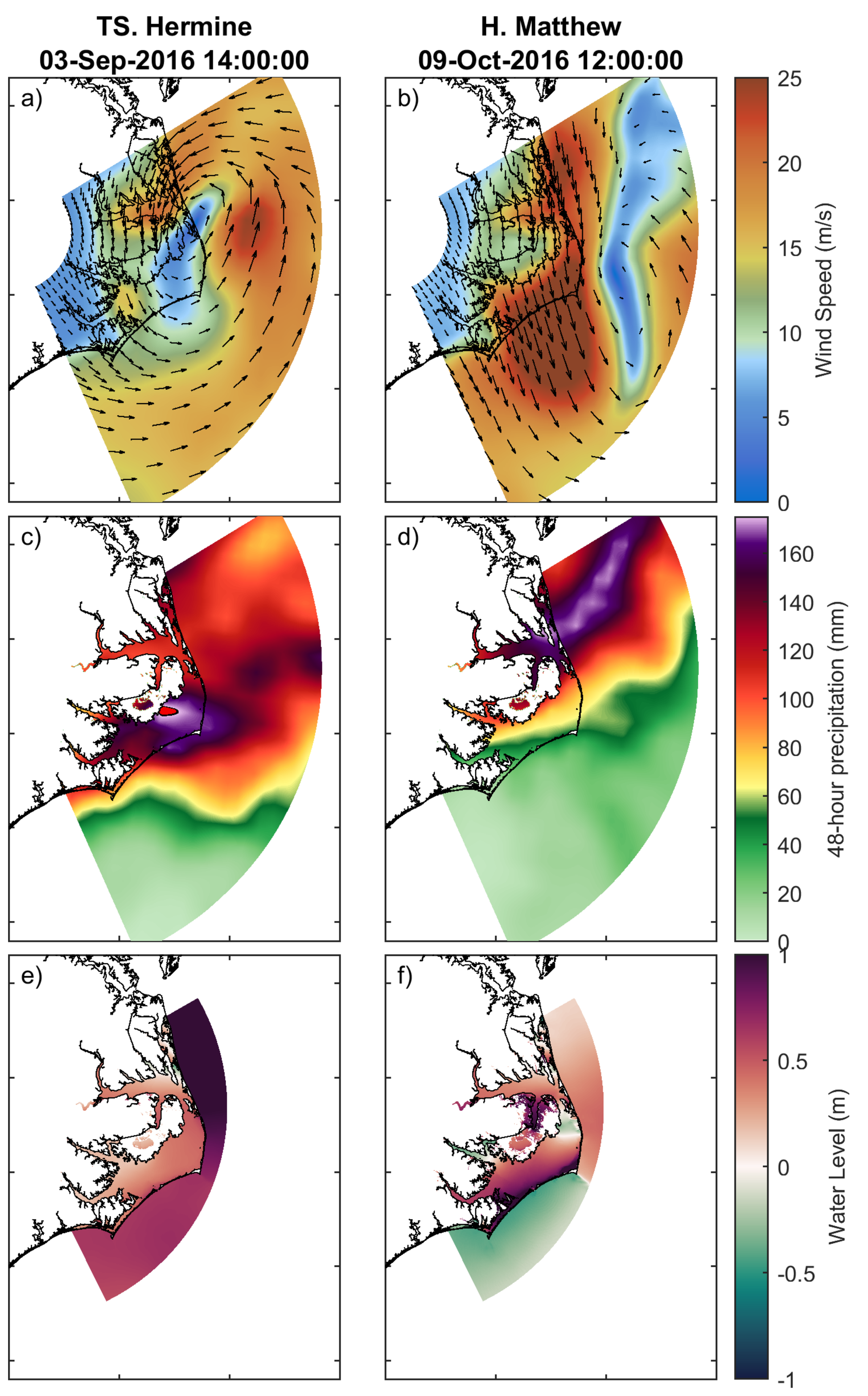

Figure 5: Model forcing and results for: a-b) winds and c-d) 48-hour precipitation from the RAP model; e-f) output water levels on 03/09 14:00 and 09/10 12:00. Note that precipitation over land has ben removed.

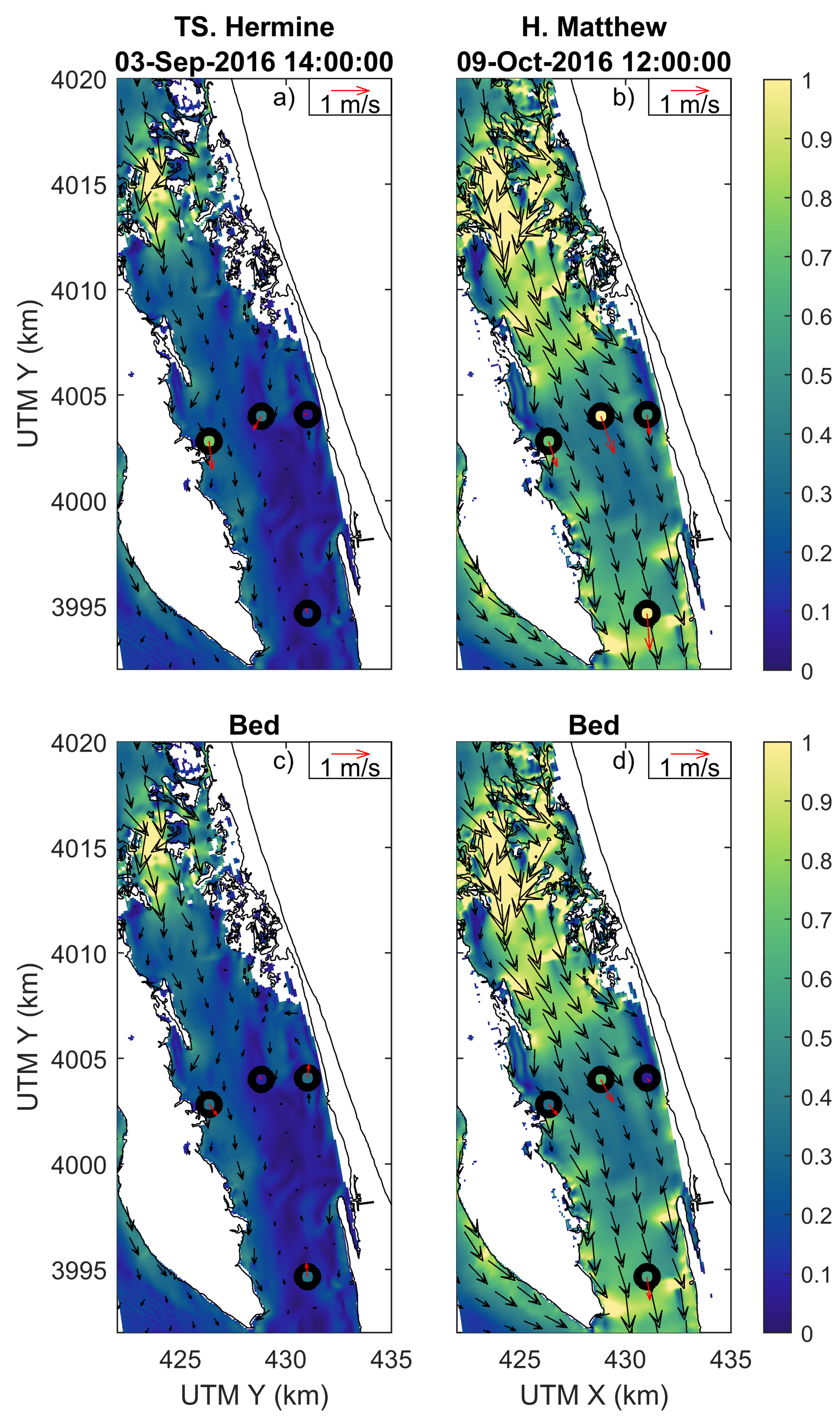

Figure 6: Model horizontal velocity outputs (black) and observations (black circles with red vectors) at 03/09 14:00 and 09/10 12:00 for: a-b) surface and c-d) bed.

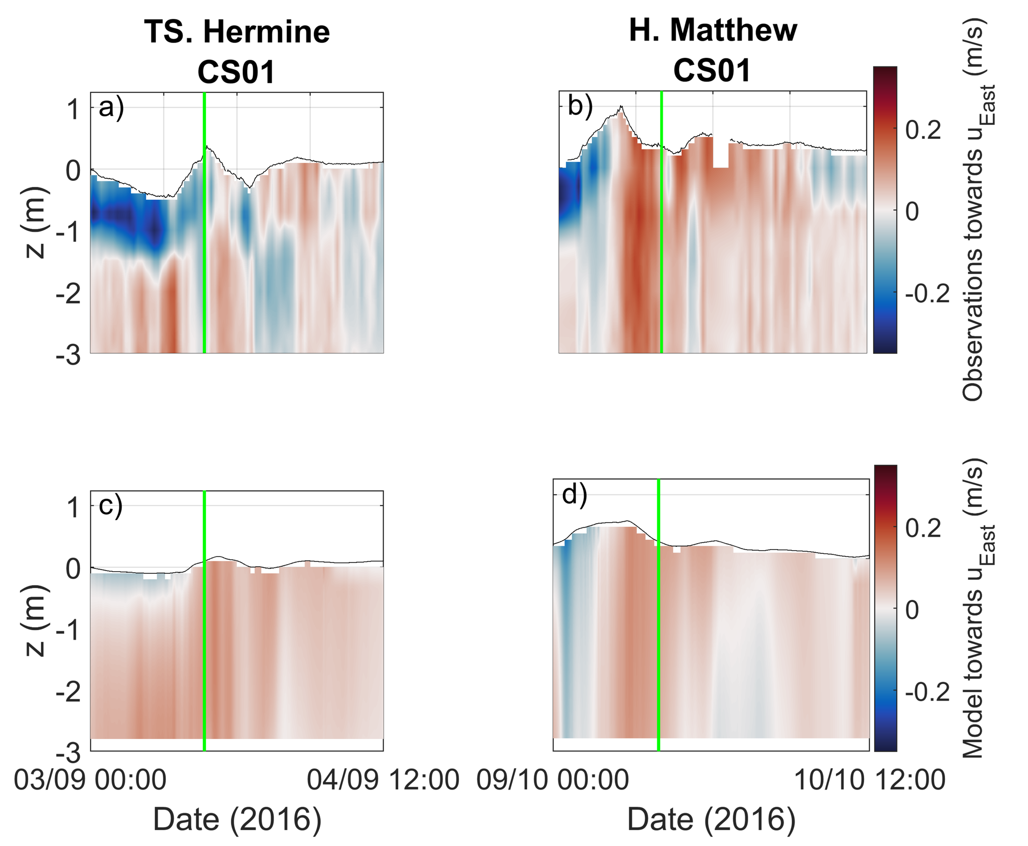

Figure 7: Vertical profiles of the a-b) observed and c-d) modelled East component of horizontal velocity during the two storm events.

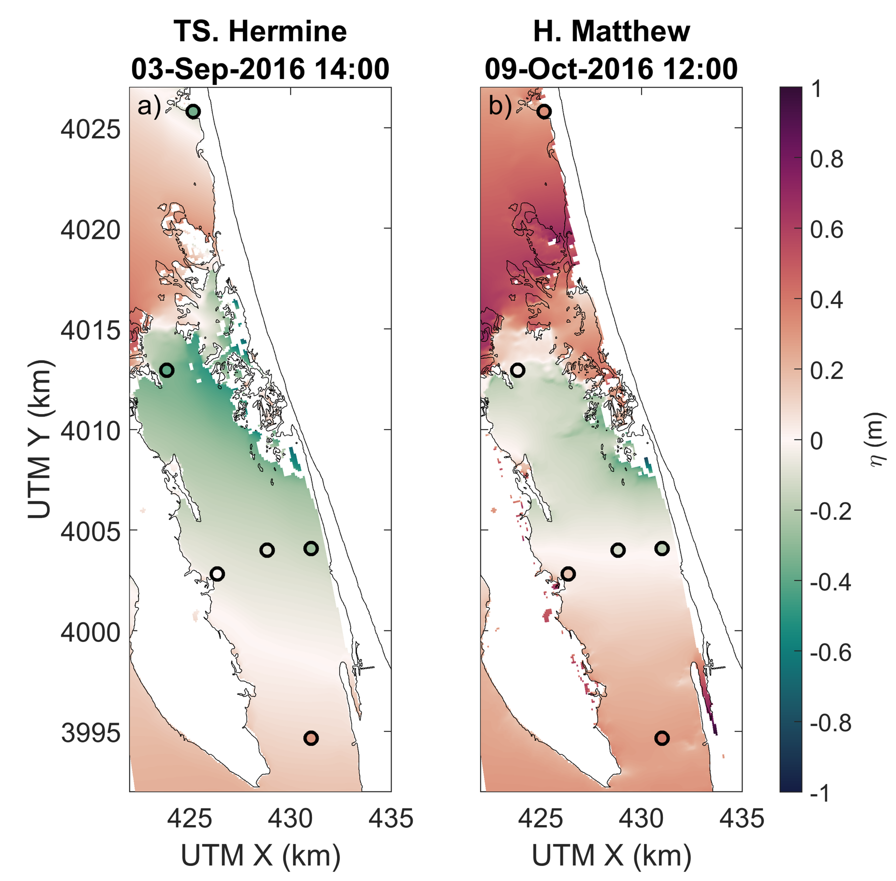

Figure 8: Modelled water levels on a) 03/09 14:00 and b) 09/10 12:00, with observations shown in black circles.

Key Conclusions

1) After calibration Delft3D was able to model the complex hydrodynamic conditions that occurred in Currituck Sound during Tropical Storm Hermine and Hurricane Matthew
2) Wind direction was the primary driver of water levels, and varying wind patterns produced raid changes in water levels, both spatially in Currituck Sound and through time
3) Precipitation over water surfaces had an important role in coastal flooding, and model water levels were underpredicted without the inclusion of precipitation

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