Dynamics of January 2018 Eleanor Storm at English Channel

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Objective

Evaluate the performance of the numerical model Delft3D FLOW on estimating water level changes due to storms and tides;

Investigate the spatial variability of the storm dynamics on the French coast of English Channel. Study results will be used to predict the impact of increase in sea level rise on inundation limits of probable storms on the French coastline.

Background

Global warming increased the intensity of the storms and the water levels in the English channel in the last century. Very little is known about the effects of these changes on the French coast. However, these effects can be predicted by mathematical models. As the first stage of our research, we modeled storms and tides in the channel with Delft3D. We validated our results with the tide gauge observations. Then, we investigated the spatial variability of storm dynamics on the coast. In the second stage, the model will be used to create inundation maps for probable storm and sea level increase scenarios.

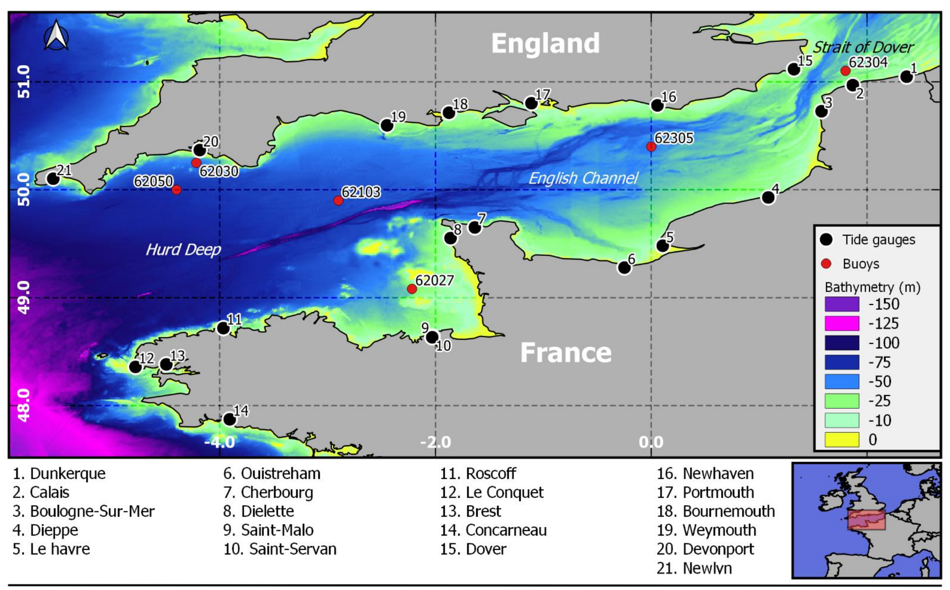


Figure 1. English Channel. In the main panel, the location of tide gauges(black dots) and buoys (red dots) used for model validations are numbered. The colorbar shows the depth in meters. The location of the English Channel is marked with a red rectangle in the inset at lower right map.

Study Area

English Channel (Fig. 1) is a sleeve-like shallow sea between Northern France and South England, connecting Atlantic Ocean to North Sea. A megaflood due to melting of retreating glaciers in the southern North Sea geographically separated Britain from Europe and formed English Channel at the last Quarternary Period (Collier et al. 2015).

The funnel shape and shallow depth of the English Channel makes for strong semi-diurnal and quarter diurnal tides (Hsu et al., 2008). Tides are semi-diurnal, with amplitude ranging from less than 1 m at the Isle of Wight to more than 12m spring tide largest in Saint-Michael's Mount Bay. Associated maximal mean spring tidal currents ranging from a few cm/s to about 5 m/s north-west of Cotentin headland (SHOM, 2000). The storms of this area is mostly occurred by low pressure systems from the Atlantic Ocean, propagating eastwards or by surges propagating south from the North Sea (Law, 1975).

Storm Eleanor

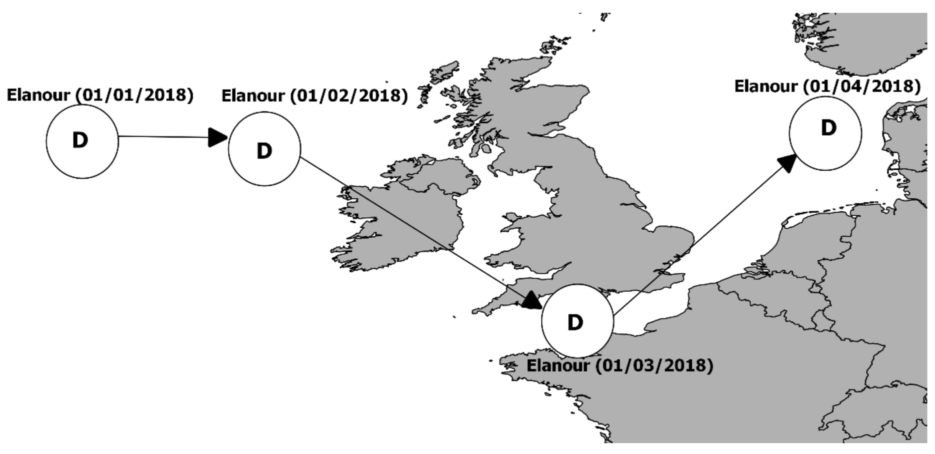


Figure 2. Eleanor Storm Track (Meteorological Agency of France, 2018)

- generated on 1st of January 2018, over Atlantic and ended on 4th of January 2018 (Fig. 2)
- the sixth most severe storm since 1995
- the main regions affected are Haute Normandie, Nord Pas de Calais, Alsace and Corsica with wind speeds > 100 km/h.
- duration was 44 hours with a maximum speed of 180 km per hour at Cap Corse and with an intensity of “strong” (Meteorological Agency of France, 2018).

Modeling the storm with Delft3D

We simulate the flow conditions using the Delft3D FLOW hydrodynamic module of Delft3D open source model for simulation of ocean conditions(Deltares Systems, 2017). Delft3D is a validated and tested flow and wave model at coastal, river and estuarine area (Hsu et al., 2006, 2008). The computational domain for FLOW regional bathymetry datasets were compiled and used to create the model grid. We defined an orthogonalized and refined curvilinear bathymetric grid (grid resolution ~100 m). The vertical datum is taken as mean sea level. The spatial reference is WGS 84. The hydrodynamic time step was set to 1 min. The circulation model was forced by the astronomic tidal potential over the whole domain for the tidal constituents. The far-field tidal predictions to the model were calculated from TPXO Model (Egbert and Erofeeva 2002). Along its open boundaries, the FLOW model was forced by the 35 main tidal constituents in the region.

Model Results

Tide Gauge Comparisons

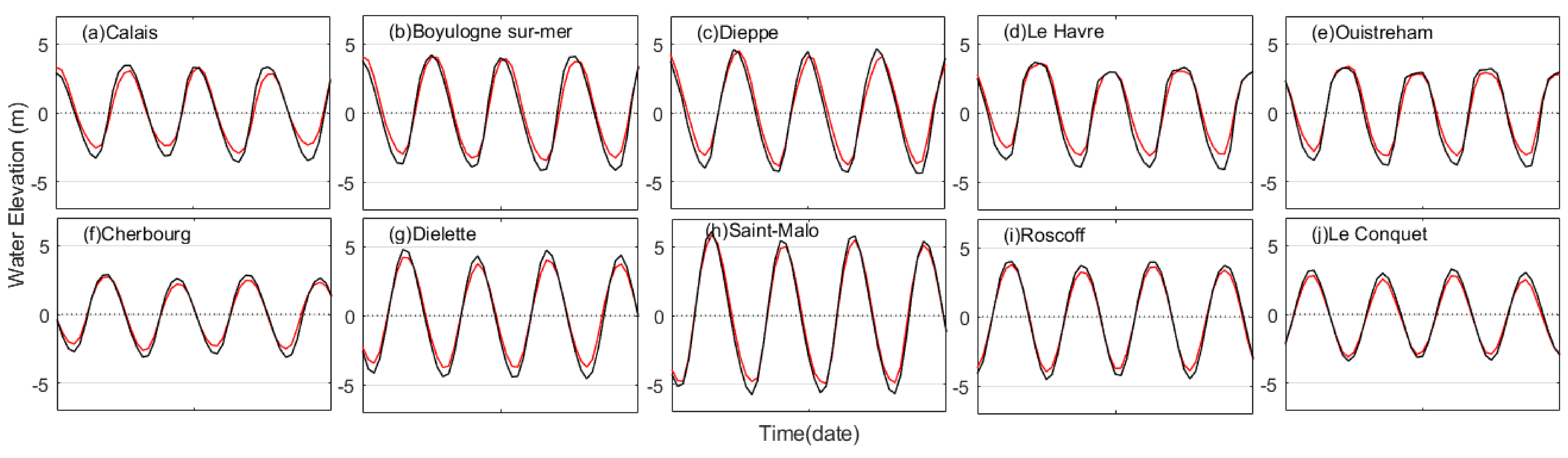


Figure 3. Comparison of observed (red) and simulated (black) water levels at 10 tide gauges at French coasts of English Channel (see Fig. 1) during the storm starting at t=0 (00:00:00 UTC, on Jan 2nd, 2018).

- The maximum storm tide is 5.98m in Saint Malo.
- Delft3D estimated storm tide patterns, amplitudes and phases well.

Model Results

Model Performance

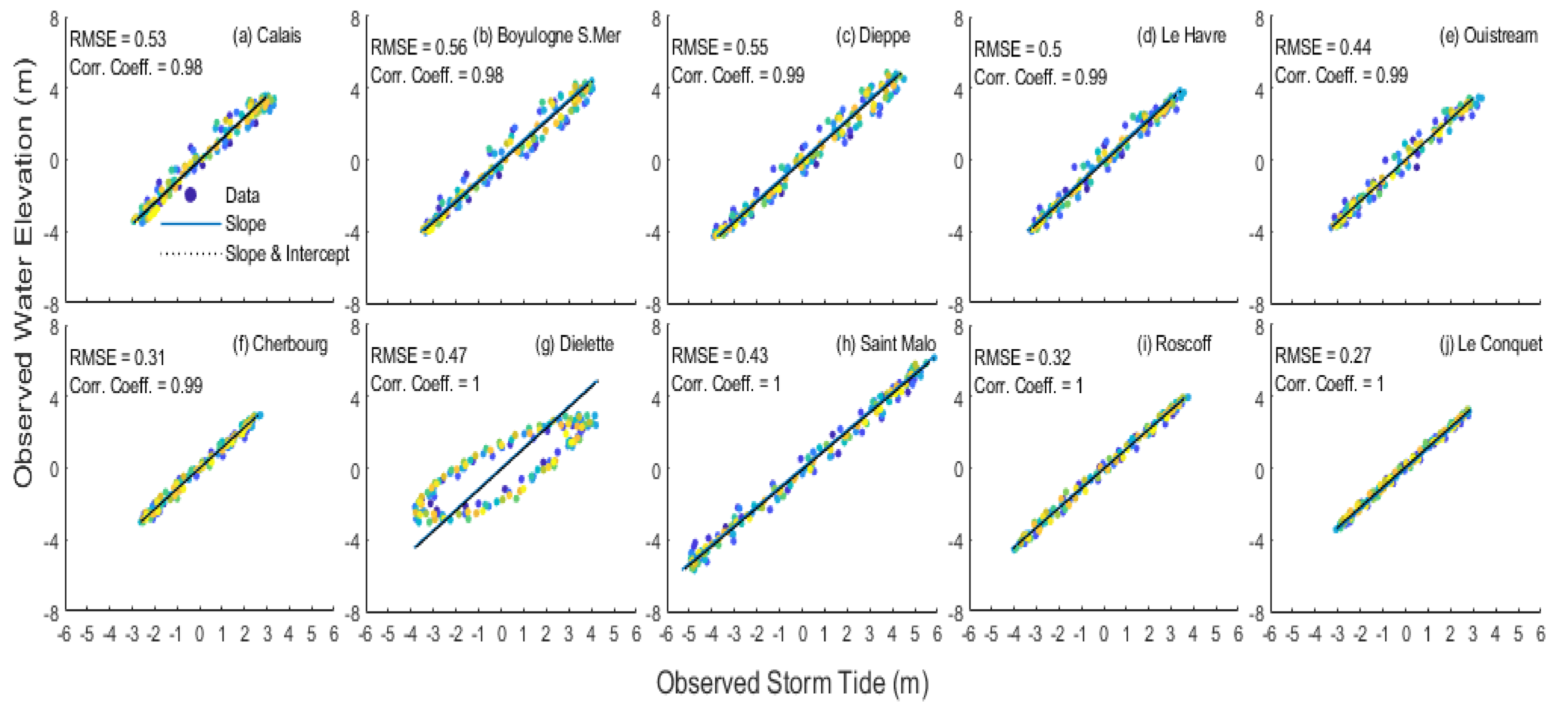
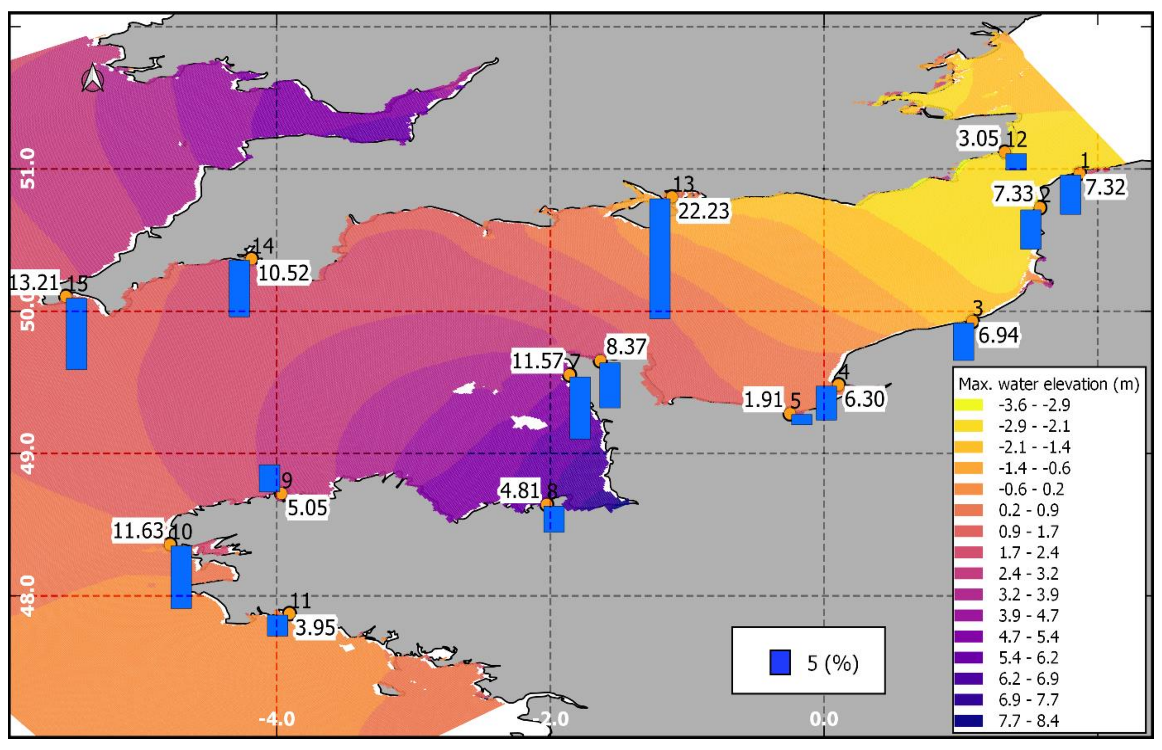


Figure 4. Scatterplot of Simulated vs observational water surface elevations (m), given with RMSE and correlation coefficients at 10 tide gauge stations.

- Min. RMSE value is 0.32 (Boulogne sur-mer) with a correlation coefficient of 1.
- Max RMSE value is 0.56 (Roscoff) with a correlation coefficient of 0.98
- The comparison shows a distinctive difference in Dielette Station.

Spatial Variability in Storm Tide Estimations

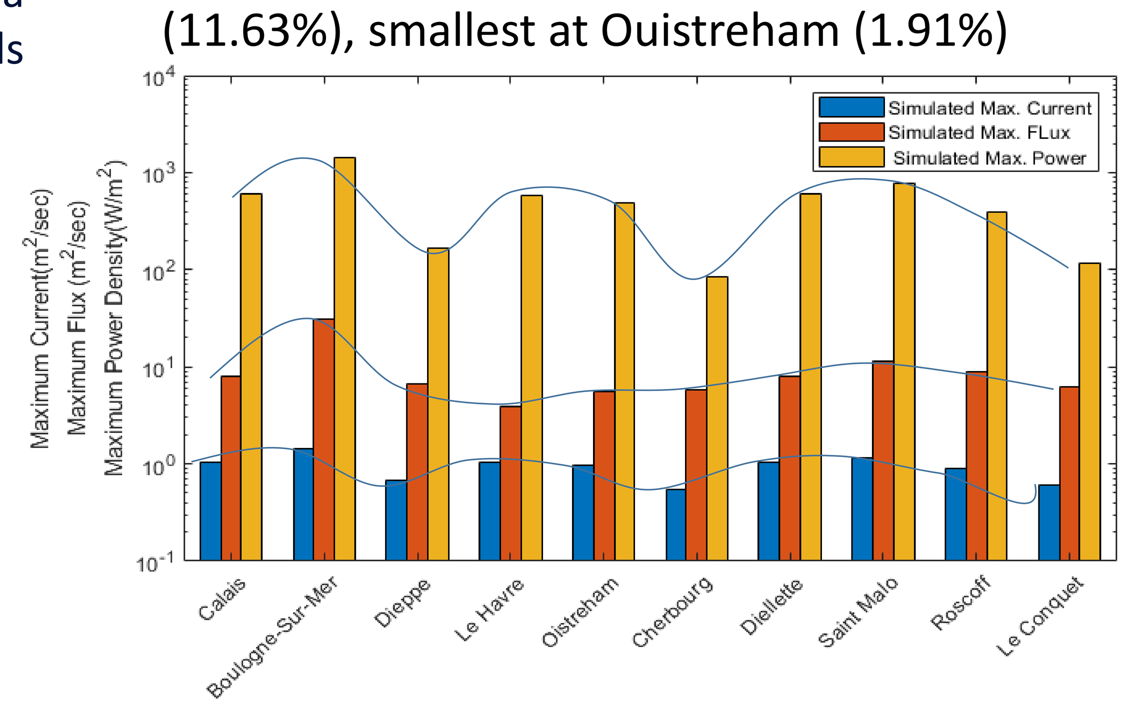


Peak errors (PE) estimated as:

$$PE = \frac{Y_{m,peak} - Y_{o,peak}}{Y_{o,peak}} x100\ \%$$

Figure 5. Peak error comparisons for the tide gauge stations overlaid with water levels at 7:30 UTC (at max. storm speed)

- The highest % difference between model and observations is at Le Conquet (11.63%), smallest at Ouistreham (1.91%)



Flux and Power density estimated as:

$$F = h_0\sqrt{u^2 + v^2}$$

$$P_d = \frac{1}{2}\rho\sqrt{u^2 + v^2}^3$$

u, v= current speed in horizontal and vertical directions
h_0= water depth

Figure 6. A summary of the comparison between model run-up skill

- The highest simulated maximum current, fluxes and power density occurred in Boulogne sur-mer.

Summary

1. The numerical model simulates storm tide with a high correlation with the observations, there is also a tendency to underestimate run-up in some regions.
2. Overall in 13 stations, storm tides are under-estimated with less than 10%
3. The maximum currents, fluxes, and power densities do not always occur where we see highest amplitudes of storm tides. These parameters should be considered while estimating probable damages due to storms.

Acknowledgments

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