A comparison study of tidal prediction techniques for applications in the German Bight

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Motivation

Tidal analyses and predictions for the German Bight are difficult because of shallow waters and long rivers. The classic harmonic method often fails to deliver adequate results, e.g., when modelling the steep rise after low water (Fig. 1). In this study, we compare observations with tidal predictions using five different techniques.

Tide Gauges

The maps show the locations of the German Bight and the investigated 40 tide gauges. The gauges are grouped into two classes: Coast and Rivers.

Methods

We investigate five different techniques that can be used to predict times and heights of high and low water (HW/LW = vertices) and/or the full tidal curve.

1) Harmonic representation of inequalities (HRoI) - vertices
The HRoI is based on the assumption that the variations in the individual heights and luni-solar periods of high and low tide waters around their respective mean values can be described by sums of harmonic functions. The HRoI calculates 31 long-period constituents. This method is used at BSH since 1954 for official tidal predictions of high and low water.

2) Harmonic representation of inequalities (HRoI) - curve
The full tidal curve can be analysed with this generalization of the HRoI. The curve is resampled and investigated at equal fractions of the mean lunar day.

3) Harmonic method: BSH
An implementation developed at BSH of the classic harmonic method using 69 constituents. Nodal corrections are omitted as 19 years of observations are used. The analysis includes two iterations with a 3 sigma-clipping in between.

4) Harmonic method: UTide
With the widely used Matlab-Package UTide the harmonic analysis is solved with the ordinary least squares method, assuming a white noise floor. The constituents are selected with the automated decision tree method. The confidence interval is determined with the linearized least squares method, assuming a white noise floor. The constituents are selected with the automated decision tree method. The confidence interval is determined with the linearized least squares method.

5) Mean observed tide stretched to HRoI-vertices
Mean tide curves derived from observations are fitted to HW/LW calculated with the HRoI. This method combines the observed hydrological information of a curve’s shape with astronomically driven predictions of times and heights of the vertices.

Observational Data for Tidal Analyses

Years of observational data being used for tidal analyses with the above introduced methods 1-5:

1) Officially validated heights and times of high and low water: 1997-2015
2) - 4) Raw observations with basic data validation/verification: 1997-2015 (Δ t = 10 min)
5) Mean tide curve: Raw observations with basic data validation/verification: 2015 (Δ t = 1 min)

Results

Tidal predictions with methods 1-5 are compared against observations for the year 2017 (Δ t = 10 min). For seven days in July observations and the different predictions together with the corresponding residuals are shown in Fig. 2.

Similarity of curves

The standard deviation of the curves’ residuals considers only the differences at each time step, but does not take into account the shape of the curves. However, observations can differ from predictions due to the weather, while still following a similar trend. The similarity of the two curves is measured using the Dynamic Time Warping (DTW) algorithm: a lower value indicates a higher similarity (Tab. 2).

Conclusions

The presented results suggest that best predictions for HW/LW are achieved in total with the HRoI (vertices). Only for HW/LW-heights in the group “Coast” is the harmonic method a good alternative. For full tide curve predictions, the harmonic method leads to the lowest standard deviations of the residuals and the lowest DTW-values for the group “Coast”. For the group “Rivers”, the shape of the curve is better reconstructed using the mean observed tide stretched to HRoI-vertices.