We would like to thank the reviewer for taking the time to review our manuscript and for the valuable comments and suggestions to improve our manuscript. We respond to the comments by referring to the page and line numbers in the original manuscript.

title: Enhancement means an increase or improvement in quality, value, or extent. I do not think that this is meant here. Simply increase might be more appropriate.

We agree and changed ''enhancement'' to ''amplification''

p 2, l 29 higher water levels - higher than what?

The sentence is changed:
''Mainly due to these measures more recent storms, e.g. 1976 or 2013, caused no severe damages although water levels higher than those of 1962 have been observed at various coastal sections …''

p 2, l 39-41 Please reformulate. I do not understand.

The second part of the paragraph is reformulated.

''This information is usually assessed and provided in form of high percentiles or return values obtained from frequency distribution estimates. There is a spectrum of methods used to construct such estimates (e.g. Debernard and Røed (2008), Arns et al. (2015b), Santamaria-Aguilar et al. (2017) for dynamical modeling approach, Wahl et al. (2011) for stochastic modelling 40 approach or Dangendorf et al. (2013) for processing of tide gauge observations). In the present study we are interested in the spatial and temporal evolution of particular very severe storm tide events in coastal areas and estuaries and, thus, diverge from statistical approach. So far, more detailed information and assessment of particular events that are extremely severe and rare are uncommon. Potential sources of such events comprise historical data as well as modelled data for past, present and future.''

p 4, l 118-120 Are these CORDEX simulations? If so, please mention. I helps the reader to recognize these simulations.

The used simulations were partially from CORDEX, we added more description in the text.

Chapter 2 is rearranged and reformulated according to the suggestions of reviewer 2. The description of the area under investigation (2.1) is followed by the description of the ''North Sea'' (2.2) and the ''German Bight'' (2.3) models used in our investigation and by the description of the data set (2.4). Finally, the selection of events and amplification experiments is specified (2.5). Chapters 2.4 and 2.5 are reformulated as follow:

"2.4 Data set

A set of numerical simulations for which atmospheric as well as marine data are available is required for the detection and ranking of extreme storm tides and subsequent modifications. Furthermore, a desired homogeneity and comparability of resulting water level fields suggests that the local water level data should be simulated with the same hydrodynamic model for the North Sea. However, the global and regional atmospheric conditions may and should vary in their origins to ensure diversity of possible storm and storm tide events. Thus, the set of underlying atmospheric conditions comprises a multi-decadal hindcast (Geyer (2014)) for the period 1948-2016 based on downscaled NCEP-NCAR global reanalysis (Kalnay et al. (1996)) and six downscaled climate change realizations. In details, the global climate realizations include four CMIP3 members for the SRES A1B and B1 scenarios (e.g. Nakicenovic and Swart (2000), Houghton et al. (2001)) covering the period 2001-2100 and corresponding present-day conditions for 1960-2000. Other realizations include two CMIP5 members for the AR5 RCP8.5 scenario (e.g. Stocker et al. (2013), Taylor et al. (2010)) for the periods 2006-2100 or 2071-2100 and corresponding present-day conditions for 1971-2005 or 1971-2000. The climate simulations were obtained with different global models (ECHAM5-MPIOM (e.g. Röckner et al. (2003), Marsland et al. (2003)), EC-EARTH as part of EURO-CORDEX (e.g. Hazeleger and Coauthors (2010)) and CMCC (Scoccimarro et al. (2011)) using different initial conditions. The global atmospheric realizations from these simulations as well as the hindcast were downscaled with different regional circulation models (different versions of CCLM (e.g. Rockel et al. (2008), Hollweg et al. (2008))), RCA4 (e.g. Samuelsson et al. (2011)) providing regional atmospheric climate realizations for the Northeast Atlantic. These regional atmospheric data from the hindcast and climate projections were used to force the hydrodynamic model TRIM-NP ("North Sea" model) and to obtain water levels in the North Sea and the Northeast Atlantic (e.g. Gaslikova et al. (2013), Weisse et al. (2014), Weisse et al. (2015)). The resulting set of water level data is used for further analysis in this study and is referred to as "data set" further on. For the entire data and model flow see also Figure 2.

The climate realizations do not include any rise in mean sea level.Water level changes are due to changes in the atmospheric forcing only. Furthermore, possible changes in bathymetry within the course of the time are neglected in the hindcast as well as in the climate realizations.

2.5 Selection of events and amplification experiments

Different classifications of storm tides exist using e.g. water levels above a reference height or the probability of water levels. Here, the classification of the Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency ,see Müller-Navarra et al. (2003)) is used: A storm tide is an event with water levels exceeding mean tidal high water at least by 1.5 m, a severe and a very severe storm tide denote events exceeding MHW by 2.5 m and 3.5 m, respectively.

The analysis of extreme storm tides is mainly focused on the East-Frisian coast in particular on Borkum and the Ems estuary. However, the impact of storms in the North Sea varies along the coasts depending on the wind direction and the resulting wind set up. Therefore, from the data set, time series of water levels were extracted for a location seaward of the island of Borkum (in the following labeled as "Borkum") and two other locations in the German Bight (Figure 1): one location in the outer Elbe estuary (labeled as "Elbe Mouth") and one location seaward of the North-Frisian island of Amrum (labeled as "Amrum").

Figure 2 describes the workflow for the simulation of the original water levels included in the data set and for the construction of the amplified water levels. A potential amplification due to tidal variations is tested for selected events at Borkum, whereas Elbe Mouth and Amrum are used to compare the effects at Borkum with those at other coasts of the German Bight. The methodology used to investigate the potential amplification of the selected storm tide events comprises four steps.

In step 1, extreme storm events are selected from the corresponding time series using three criteria:

- height of water levels,
- duration of water levels continuously exceeding NHN+1.15 m (MHW at Borkum, DGJa (2014))
- series of storm tides with high water levels exceeding MHW + 1.5 m within one week

Water levels are considered with respect to NHN. The storm tide events for Borkum are ranked with respect to their water levels and their durations. For the further analysis of a possible amplification, the event with the highest high water was defined as "EH". The event with the maximum duration was defined as "EL". The strongest event chain from the selected events was defined as "EC", where "strongest" describes the combination of the maximum number of storm tides within a week and the maximum intensity. The intensity is given by the area between the water level curve and a threshold.

In step 2, possible amplification of the selected extreme events due to different combinations between wind field and astronomical tide was tested. Maximum water levels may be increased by variations of relative propagation and arrival time of tidal high water and atmospheric storm. They may also become higher if the specific storm occurs around spring tides rather than around neap tides.

Thus, ensembles of large-scale North Sea water level simulations for each selected event were generated. For ensemble one, the astronomical tide given at the open model boundaries was shifted hourly within +/-6 h around the wind speed maximum near Borkum. For ensemble two, the highest astronomical spring tide found in the tidal simulations for the period 1948-2100 was used instead of the original tide and the astronomical tides were shifted again hourly. For each member of ensemble one and two, water level time series were extracted for the three locations. The time series were analysed and members were selected focusing on the strongest amplification for Borkum. Comparing the time series for the three locations, it is estimated how the amplification for Borkum affected the water levels at Elbe Mouth and Amrum.

Respective data from the ensemble members with the highest amplified water levels near Borkum (in the following identified by "_a") for each event were used for further fine-grid simulations of the German Bight and the Ems estuary in steps 3 and 4.

In step 3, high resolution water level simulations for the German Bight and the attached estuaries for the ensemble member with the highest amplified water levels near Borkum for the selected events derived from step 2 were performed.

In step 4, the events from step 3 were further amplified by applying an increased river runoff to examine the impact of runoff variations and a sea level rise to place the results in the context of future climate change. For these amplification simulations the highest observed river runoff for the Ems of 1200 m^3s^{-1} (1946, DGJb (2018)) was assumed. This extreme river runoff was measured in February 1946, i.e. in a season where storm tides are probable. Furthermore, simulations with two sea level rise scenarios of 50 cm and of 100 cm were investigated. These values cover the likely range of median values for the global sea level rise as well as the bandwidth of the local sea level rise for the North Sea until 2100 as reported by Stocker et al. (2013). The sea level rise was applied at the open boundary of the German Bight model by shifting the boundary values for water level by the selected amount of sea level rise.

In order to investigate the impact of the storm surge barrier in the Ems on water levels, the storm tides were simulated with open and with operated barrier in steps 3 and 4."

p 5, l 151 wind speed maximum - where is the maximum taken? Does it matter, by the way? As far as I understand, you shift the astronomical tide with respect to the whole storm, don't you?

You are right, we shift the whole fields and the exact wind maximum is unimportant. But we use the wind maximum near Borkum (added in the text) as a reference because it roughly coincides with water level maximum and helps us to identify the time frame where we are looking for the new water level maximum.

p 5, l 141 chain of events - this criterion should be explained in more detail. What does it mean? The maximum number of storms in a week? The longest storm? Successive storms from different directions?

Chain of events is explained in more detail in section 2.5 (former section 2.3), see above.

p 6, bottom For model performance the reader is referred to earlier publications. Fine, but for most readers one or two general sentences about the model quality would remove the necessity to look up those papers.

A sentence is added.
''The model has been validated against tide gauge observations at the German coasts.''

p 7, l 207-208 the height of the gates was increased from 7 to 8 m in nature to 9 m. – I am confused about the height of the gates. Has the height of the real gates already been increased from 7 to 8 m? Or did you increase them twice in the model?

In reality some gates have the height 7 m and some are 8 m. They all were set to 9 m in the model simulation. The sentence is modified to clarify this.
''…. the height of the gates were increased from 7 m (2 gates) respectively 8 m (5 gates) in nature to 9 m in the model.''

p 8, l 221 original simulated events – you mean the simulations without shift of lag between tides and storm?

yes

p 8, l 226 Please specify the EC event – how does it look like?

Chain of events is explained in more detail in section 2.5 (former section 2.3), see above.

p 8, l 246 15 cm, but previously you mentioned water levels of 3.93 m and 4.88 m, the difference of which is 95 cm. It's a bit confusing. Just reformulate the sentence, and it will become much clearer why the increase is only 15 cm.

The sentences are reformulated to clarify the differences.

''Due to the diurnal inequality, peak 1 of the corresponding astronomical tide is about 20 cm higher than peak 2. Due to the 5 h shifting, peak 1 of the tide coincides with stronger wind velocities, whereas peak 2 coincides with weaker wind velocites. Thus, by only shifting the astronomical tide against the wind field, an amplification of the maximum high water in the event EH of 15 cm (from original 4.73m to 4.88 m) is obtained.''

p 9, l 158 by only a few centimeters
p 9, l 164-266 I do not understand what is meant here

The text is reformulated.

''…by only a few centimeters. In the original event EL the highest high water already coincides with an astronomical spring tide about 7 cm lower than the highest one. Thus, both applied procedures lead to relative changes of the three highest water level peaks, however not to a substantial absolute increase of the maximum water level during EL. Furthermore, the length of EL shows nearly no changes. Possible amplification was also tested for the entire EC event including EL. The storm tides following EL experience an increase of some single high waters up to 20 to 30 cm together with a decrease of other high waters for some ensemble members. Thus, there was no general amplification regarding the intensity (see chapter 2.5) of the event chain EL/EC. Therefore, the amplification procedures for EL/EC were discarded.''

p 11, ll 330 rises ! Raises

changed

p 12, l 372 it's the insert in Figure 7 that you have to look at

The sentence is changed accordingly.

''This effect can be observed e.g. in Figure 7 looking at the water level of the event EH_a (red line) and in the insert of Figure 7 showing the difference between the water levels for operated and open storm surge barrier.''

p 13, l 411-413 hard to follow, please reformulate

The sentence and the following text are reformulated.

''These events originate from the first half of the emission scenario period of two different climate realizations. Gaslikova et al. (2013) showed that the annual maximum water levels of these climate realizations displayed strong multi-decadal variability but no significant long-term trends from 1961 to 2100. Thus, the found highest water levels exceeding the water levels measured since the beginning of the 20th century at Borkum (Figure 3) could be possible already under present-day conditions as no sea level rise is included in the original climate realizations.''

p 14, l 446 last word: there ! Their

changed

p 24, Figs. 7 and 8 the dashed lines (0 m, 1200 m3/s, and 1 m, 1200 m3/s) are not visible. Probably, they are covered by the respective solid lines. If so, please mention in the caption.

We add a sentence that the dashed and solid lines are similar.
''As the impact of Q on the water levels at Emden is small, the dashed red and green curves nearly match the solid red and green curves.''