

Detecting anomalous sea-level states in North Sea tide gauge data using of auto associative Neural Network

Review

The manuscript aims to investigate the skill of Auto Associative Neural Networks (AANNs), trained with different set of observation- and model-based data, to emulate sea-level and detect extremes in the North Sea. The method proposed by the authors relies on the capabilities of linear and non-linear models based on principal components (PCs) and AANNs, respectively, to reconstruct sea-level states. The departures between the reconstructed and observed sea states are then used to detect extreme events in the North Sea. The results, focused on two events characterized by low pressure systems and high wind speeds over the North Sea, show the potential of AANNs trained with tide-gauge records in detecting accurately the occurrence of extremes, both as a very localized and larger scale events, while underline the inaccuracies of the emulators based on PCs (false positives) and trained with model-based sea-surface height outputs due to model physics (Gaussian distribution of errors). The latter can be used to enhance representation of sea-level extreme events in ocean models. The authors highlight the high potential of their approach which can be easily extended to other sea-level observing networks.

The work is well developed, and the publication is recommended after a minor revision of the manuscript

Here follow some suggestions, which could help improve certain parts of the manuscript.

General Comments

1. A few sentences (e.g in the Introduction and Section 2) should be rephrased, and relevant references to the literature should be acknowledged (see Specific Comments).
2. Sometimes test, validation, and control are used as synonyms: check it and ensure consistency.
3. The trained AANNs used in this work should be named appropriately (e.g. reference) and summarized in a dedicated Table giving a short description of the data sets used in training and testing phase.
4. Description of error distribution of AANNs (Figure 4): those results guide your analysis and conclusions, but it is hard to distinguish between the tail of error distributions in Figure 3 and Figure 4. This is probably due to poor quality of the graphics (see specific comments about Figures), which should be improved, but a more extended description of the results would help the reader to capture the actual meaning of the results.
5. The organization of text in the different Sections should be revised (see Specific Comments).

Specific Comments

Introduction

Line 17: “tidal motion tidal motion” - rephrase.

Line 22-23: add relevant references.

Line 25-26: explain shortly the improvements you are mentioning.

Line 31-34: Rephrase (e.g. change the order of the sentences)

Line 34: the sentence on numerical models can move further down in the text

Line 38-42: Rephrase

Line 42-43: This sentence can move e.g. to line 37: “Ponte et al., (2019) Sea-level variability. Therefore,...”

Line 44: This sentence should be linked to the findings of previous work (e.g Zangh et al. 2020).

Line 47-51: Rephrase and add relevant references to the literature.

Line 58-59: Add references.

Line 83-84: Rephrase.

Section 2.1

Line 111: Rephrase.

Section 2.2

Line 134: add references.

Line 143: avoid “very”.

Line 144: Rephrase.

Line 144: check punctuation.

Line 155: avoid repetitions: “Thus,...”

Line 192: “presents” → “shows”

Line 204: Is this choice based on a sensitivity analysis? The choice of the constraints/threshold errors should be explained in the text.

Line 207-2011: “..., we trained the AANN based on the following data sets:

- sea-surface height outputs from CMEMS AMM15 (operational model) extracted at the tide-gauge positions (AANN_NEMO);
- observed total water levels from only 10 tide-gauge stations (with ...) (AANN_less); and
- observed non-tidal water level residuals for the 14 gauge stations (AANN_resid). “

Line 2015: “areal” ?

Lines 225: “...a comparison between observed, modelled and AANN emulated...”.

Line 232: “the reference model” ?. I assume this refers to AANN in Table 1 (See General Comments).

Line 239: “In the following Section,...”: in the current version of the manuscript this Section is followed by the Conclusion. This part of the text should be reorganized.

Line 240: It is unclear which ANN model error you are referring to (ANN_resid ?). The same applies to NEMO model error: is it the error in NEMO ssh outputs?

Comments about Figures

Figure 1: The description in the caption should be improved as well as the labels in the figure (see wind tendency).

Figure 3: It is hard to read the labels.

Figure 4:

- Panels a, b, d, e (see previous comment on Figure 3).
- Panel c: It is very hard to read this panel, both time-series and labels. Also: show hours on x-axis.

Figure 5: The panels should be displayed bigger as well as the labels in each of them.

Caption:

- "...a 14-day..."
- "NEMO model error" – is it the AANN_NEMO ? Clarify.

Figure 6: Make sure the labels on top of the panels correspond with the description in the caption.

Figure 7: see comments on Figure 5.

Figure 8: see comments on Figure 6.

Figure 9: The panels can be displayed better. Avoid legend.