SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	In case mitigation fails: Exploring alternative methods to protect Europe against sea level rise, using the NEMO ocean model
Computer Project Account:	Spdekje2
Start Year - End Year :	2019 - 2019
Principal Investigator(s)	Joakim Kjellsson
Affiliation/Address:	GEOMAR Helmholtz Centre for Ocean Research Düsternbrooker Weg 20 24105 Kiel Germany
Other Researchers (Name/Affiliation):	Sjoerd Groeskamp NIOZ, Netherlands

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)
Our aim was to study the impact of constructing a Northern European Enclosure Dam (NEED) on the North Sea. The intention is to raise awareness to the kind of solutions that may be necessary in the future if climate change and sea-level rise are left unmitigated. We therefore carried out a reference simulation with no enclosure dam and a series of simulations with dams in various configurations.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

We had some problems with compiling the I/O server XIOS on CCA and also some problems in configuring the I/O server properly. These problems were solved with the aid of ECMWF HPC support and the MetOffice.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

We are very thankful to ECMWF for providing computing resources to our study. We found the application procedure easy. We are also very thankful to ECMWF HPC support for their technical assistance.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

See attached document

List of publications/reports from the project with complete references

Groeskamp, S., and J. Kjellsson (2020), NEED The Northern European En- closure Dam for if climate change mitigation fails, Bulletin of the American Meteorological Society, preprint(2020), doi:10.1175/BAMS-D-19-0145.1.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

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ECMWF Special Project "SPDEKJE2" final report 2019

Joakim Kjellsson

June 2020

1 Performed work

The project SPDEKJE2 - "In case mitigation fails: Exploring alternative methods to protect Europe against sea level rise, using the NEMO ocean model" was carried out at ECMWF supercomputer, CCA, in 2019. A number of simulations with the NEMO ocean model in an AMM7 configuration were carried out (a detailed description is given by *O'Dea et al.* (2017)). The AMM7 configuration was developed by the UK MetOffice to simulate the European shelf circulation at 7 km horizontal resolution. Important for our experiments is that the model explicitly simulates 15 tidal components and uses a hybrid-type vertical coordinate to accommodate large fluctuations in sea-level height. All simulations were integrated for 1 year and used ERA-Interim atmospheric forcing.

Our aim was to study the impact of constructing a Northern European Enclosure Dam (NEED) on the North Sea. The intention is to raise awareness to the kind of solutions that may be necessary in the future if climate change and sea-level rise are left unmitigated. We therefore carried out a reference simulation with no enclosure dam and a series of simulations with dams in various configurations. We found that two large enclosure dams - one across the English Channel and one from northern Scotland to Norway - greatly reduces the tidal amplitudes in the North Sea (Fig. 1). A Kelvin wave that would normally propagate along the French west coast and through the Channel is instead deflected to propagate through the Irish Sea and then over to the Norwegian coast. The effect is a much lower 95th percentile of sea-surface height, η_{95}, in the North Sea but higher along the Norwegian, Irish and western UK coasts (Fig. 2). An additional simulation where the southern dam is placed further east results in a wave-like pattern with both increasing and decreasing η_{95} in the Channel.

Analysis of the individual tidal components showed us that the AMM7 configuration had a sufficient representation of the North Sea circulation (Fig. 3). We therefore opted to carry out more simulations with the 7km configuration rather than moving to the much more expensive AMM60 ($1/60°$) model for which we could only afford one simulation. Among the experiments we made

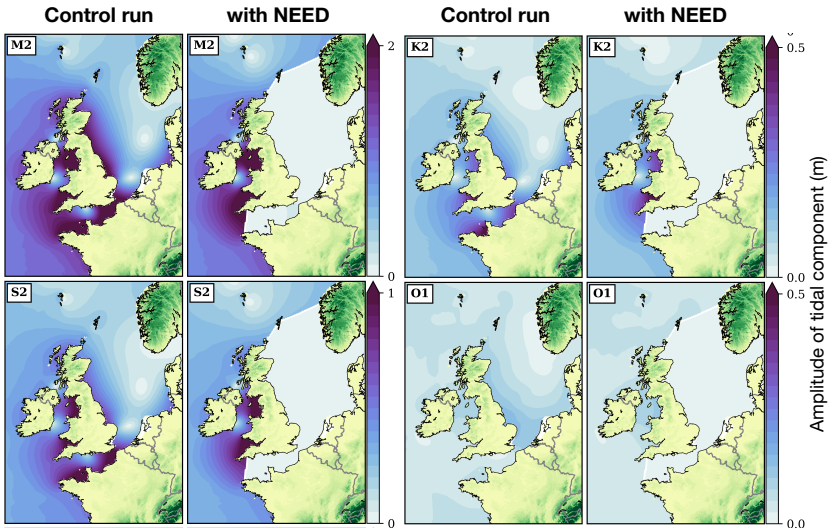

Figure 1: Impact of constructing a Northern European Enclosure Dam (NEED) on four tidal components. Colours show the amplitude of each tidal component in meters.

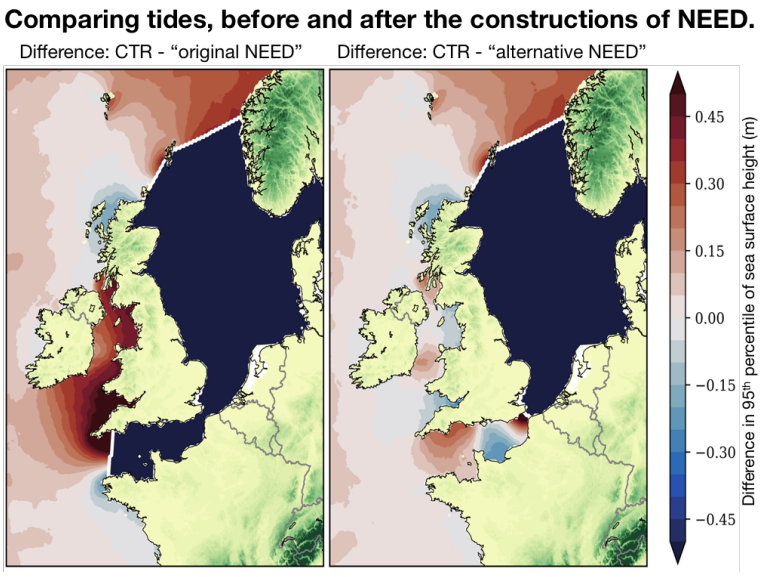

Figure 2: Difference in 95th percentile of sea-surface height, η_{95}, between the control run and two simulations with enclosure dams. One configuration encloses most of the English Channel (left), while the other instead encloses only part of it (right). Placing the southern dam between Dover and Calais leads to a wave-like pattern of η_{95} increase and decrease in the Channel.

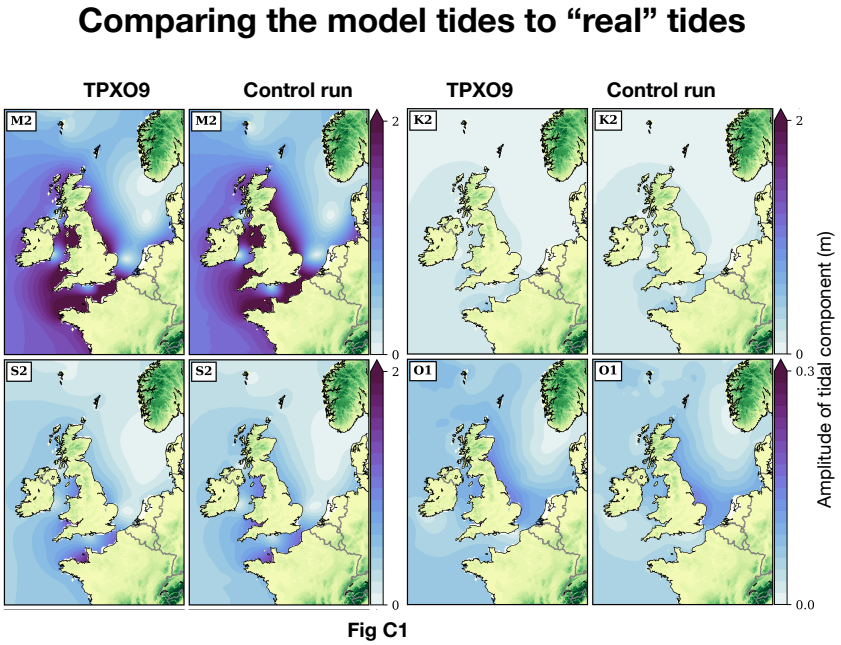

Figure 3: Amplitudes of

was to explore the effect of placing dams at different tilts. For instance, we learned that placing the northern dam from Scotland to Norway with more southwest-northeast tilt leads to less increase in η_{95} around the Bergen area. If the dam is placed along the shortest distance from northern Scotland to Norway the Kelvin wave propagating along the dam will dissipate near Bergen and cause a large rise in η_{95} (not shown).

Output from our three simulations are publicly available at `https://thredds.geomar.de/thredds/kjellsson_et_al_2019_review/catalog.html`. An animation of the sea-surface elevation with and without NEED can be found at `https://www.youtube.com/watch?v=WHUj2StdG68`.

2 Outcomes

We recently published our results in *Groeskamp and Kjellsson* (2020). The paper relies heavily on the simulations conducted in this project and could not have been made without it and the support from ECMWF.

The paper gathered a fair bit of media attention and, we hope, sparked some awareness about climate change and sea-level rise and future mitigation plans. A number of follow-up studies are in progress. As an example, we are

exploring more alternative configurations of the dams in order to disentangle to what extent sea-level extremes in the North Sea are due to tides vs atmospheric forcing. We are also investigating the economic cost-to-benefit ratio for different coastal protection measures.

References

Groeskamp, S., and J. Kjellsson (2020), NEED The Northern European Enclosure Dam for if climate change mitigation fails, *Bulletin of the American Meteorological Society*, *preprint*(2020), doi:10.1175/BAMS-D-19-0145.1.

O'Dea, E., R. Furner, S. Wakelin, J. Siddorn, J. While, P. Sykes, R. King, J. Holt, and H. Hewitt (2017), The CO5 configuration of the 7 km Atlantic Margin Model: large-scale biases and sensitivity to forcing, physics options and vertical resolution, *Geoscientific Model Development*, *10*(8), 2947–2969, doi:10.5194/gmd-10-2947-2017.