Storm surge around New Zealand: From hindcasts to future projections

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Figure 1: Storm of 5th January 2018 in Raglan (Photo: Stephen Hunt).

What is storm surge and why is it important in New Zealand?

Storm surge is defined as the rise of water level generated by a storm over and above the astronomical tide. It is primarily caused by the strong winds generated with a storm and by the influence of sea level pressure changes. As a weather system approaches land, storm surge tends to increase, particularly at the shoreline, resulting in flooding of coastal areas especially when combined with large astronomical tides and wave-induced contributions.

Although storm surge in Aotearoa New Zealand is generally lower than in other areas in the world, as it 'only' reaches maximum values of approximately 0.8 meters compared to 3-9 meters in places such as the Gulf of Mexico or the North Sea, it is still a key contributor to total water elevations that ultimately control coastal flooding in low-lying areas. Furthermore, because of high tides and large storm surge, oceanic waves can approach closer to the coast, release more energy at the shoreline, and exacerbate coastal erosion (Bell et al., 2000). In addition, and as a result of climate change, the rise of sea levels will only increase existing flooding and erosion problems and cause new ones.

In New Zealand, the scarcity of long records and the sparse spatial distribution of tidal gauges makes it difficult to study the spatial and temporal variability of storm surge. For this reason, we developed a database of storm surge data around New Zealand for both hindcast and projections, and provide the data, free of any cost, to the New Zealand coastal community.

Modelling storm surge

To predict storm surge we need to be able to model how the large-scale global climate patterns relate to local storm surge at the coast. There are two different approaches to address this problem. Dynamical downscaling usually involves running climate models into a subdomain and reproducing the physical processes that ultimately lead to storm surge. The other approach is usually called statistical downscaling and consists of finding a relationship between the large scale weather patterns and the local storm surge.

In this study, performed in collaboration with scientists from the University of Cantabria (Spain), we decided to use statistical downscaling as it is computationally less expensive and it allows us to reproduce long time series over large regions. A similar technique has already been successfully applied to reconstruct storm surges from tidal gauges and from numerical models globally (Cid et al., 2017a; Cid et al., 2017b).

To develop our algorithm, we found a relationship between the daily maximum storm surge from DAC (Dynamic Atmospheric Correction, http://www.aviso.altimetry.fr/) and the principal components of the mean sea level pressure fields and gradients from ERA-Interim, a global atmospheric reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF). Assuming such a relationship holds in time, we were able to reconstruct the storm surge from 1870 based on the 20th Century Reanalysis (hindcasts). We also developed a storm surge database from the present until 2100 using the output from different Global Climate Models (projections).

Comparing the model against real data

In order to validate the reconstructed time series in the historical period, we made a comparison against 17 tidal gauge records around New Zealand (with data kindly provided by NIWA). Figure 2 shows a two year comparison of both series for Charleston and Kapiti Island. For every tidal gauge, we obtained errors as low as 7 cm (on average) and high, significant correlations.

Dealing with climate change

When we deal with climate change projections, Global Climate Models are the most useful source of information. However, one of the first questions that arises is which of the dozens of available models we should use. The most common approach nowadays is to use multi-model ensembles, but even in that case we need to make a choice on the number and models to use.

To make an informed decision about the models we are using, we performed a ranking of the best models at reproducing the past climatology of New Zealand following the methodology proposed in Perez et al. (2014). This methodology ranked the model ACCESS1.0, produced by CSIRO and the Bureau of Meteorology in Australia, to be the most accurate model to reproduce past conditions, followed by EC-EARTH, developed by a consortium of 11 European countries.

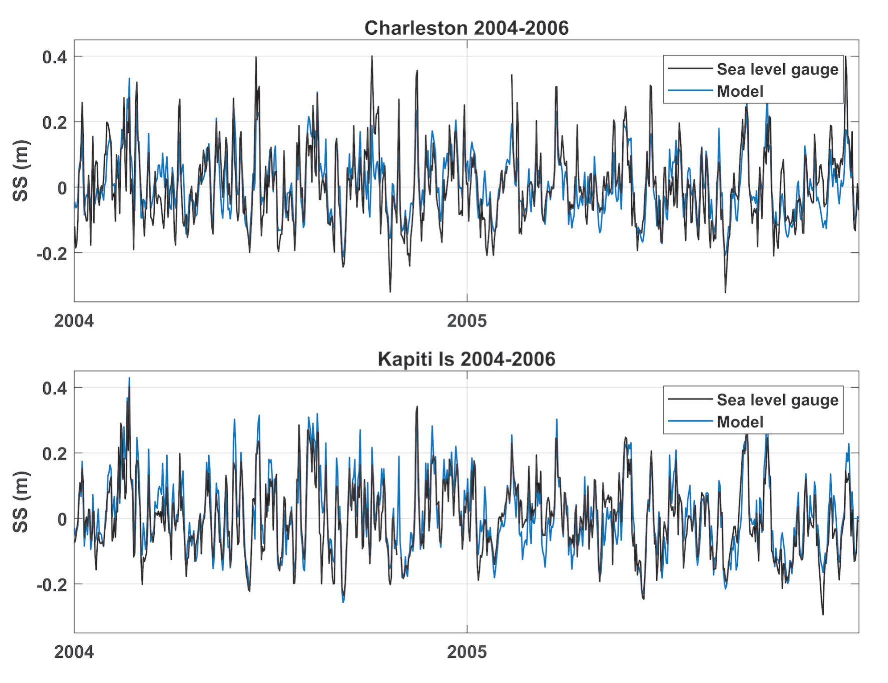

Figure 2: Comparison of model reconstruction against sea level gauge storm surge (data provided by S Stephens, NIWA).

We then generated storm surge time series until 2100 for these two models (we also tried five others to look at the impact of model ensembles). To have a better understanding of the future storm surge conditions in New Zealand, we compared a 50 year return period level in the future and in the past for the different models and model ensembles. Figure 3 shows the changes expected in the New Zealand area for ACCESS1.0 under the worst case emission scenario, rcp8.5. Our results are encouraging in the sense that a general reduction of storm surge will be experienced in most areas of the North Island, while an increase will be experienced in some areas of the South Island. It is not all good news unfortunately, since our results also indicate that in the future, larger storm events than previously experienced are likely to occur.

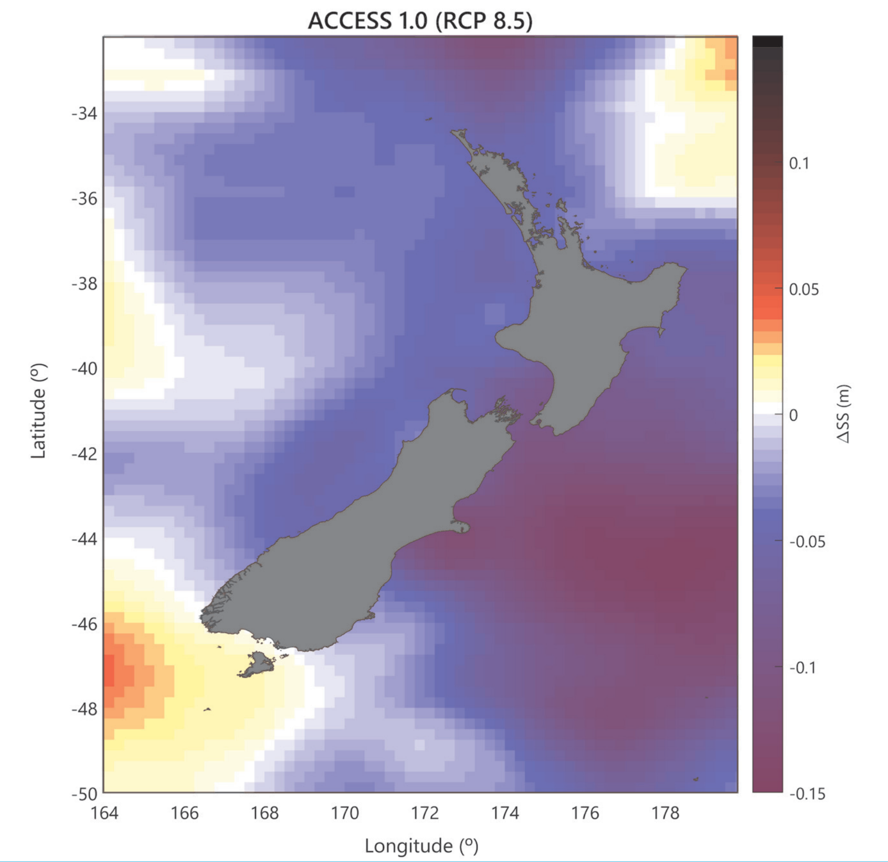

Figure 3: Change in 50 years return level for ACCESS1.0 and rcp8.5 scenario between 2070-2100 towards the reference period 1975-2004.

Storm surge data tool

As part of our research, we make all databases freely available. Here we present a storm surge data tool developed with the help of the Centre for eResearch of the University of Auckland. This tool is available online at https://coastalhub.science/storm-surge and provides a user-friendly environment to visualize and export all the databases we have generated at 0.25° x 0.25° spatial resolution. This means that data from 1871 to 2100 is available for the area shown in Figures 3 and 4 and for different climate change scenarios and models. Figure 4 explains in detail the different functionalities of the tool and the steps to be followed by the user in order to download the data of interest.

References

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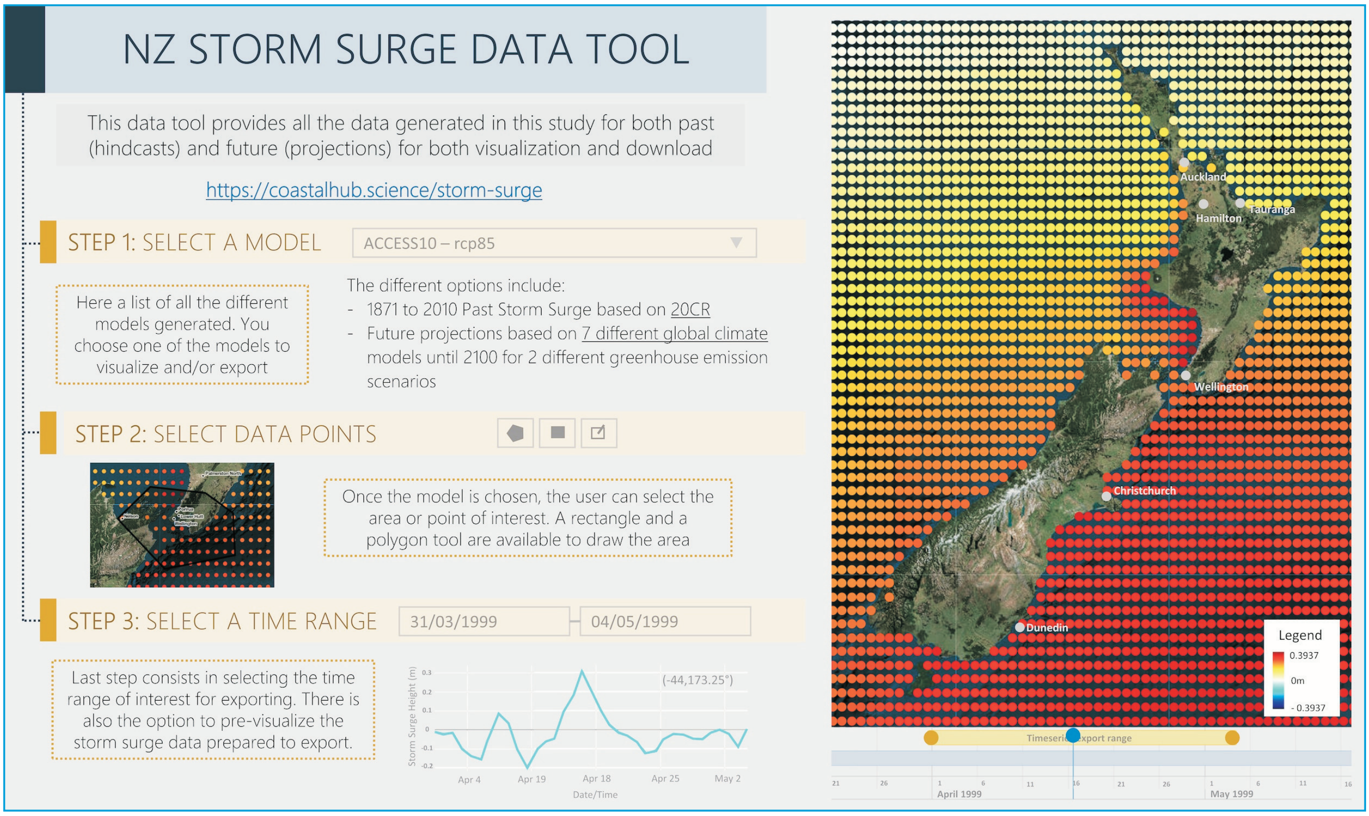

Figure 4: New Zealand Storm Surge Data Tool.