Global Analysis of Extreme Sea Levels During the Last Interglacial

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Abstract

Coastal risks are increasing due to the warming of the climate, resulting in rising mean sea levels and changes in storminess. Projections of future coastal flooding rely on global climate models based on greenhouse gas scenarios with inherent large uncertainties. The past warm climate of the Last Interglacial (LIG, ~127,000 years ago) is considered a partial analogue of a future warmer world. Therefore, understanding how coastal systems were affected by changes in atmospheric and relative sea levels during the LIG can inform us about possible future changes. In this contribution we will analyze extreme sea levels and coastal flooding during the LIG. The analysis is based on the hydrodynamic Global Tide and Surge Model (GTSM; Muis et al., 2016, doi: 10.1038/ncomms11969). To simulate storm surges during the LIG GTSM will be forced by 6-hourly wind and surface pressure fields from LIG simulations of IPCC-type climate models. Due to non-linear effects, tides and surge levels will be influenced by changes in mean sea level. Therefore, a key input variable is map of regional mean sea levels during LIG. However, there is still considerable uncertainty on sea level high-stands and regional patterns during the LIG. Using output from a Glacial Isostatic Adjustment model (GIA), we will model tides and surges for a set of plausible scenarios of relative sea levels and assess sensitivities.

Global modeling of sea level extremes during the Last Interglacial

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Learning from the past

Coastal risk are increasing due to the warming of the climate resulting in rising mean sea levels and changes in storminess. Besides relying on global climate models forced with greenhouse scenarios, we can look at past climates to enhance our understanding of coastal flooding in a warmer world. The Last Interglacial (~127,000 years ago) is considered a partial analogue to a future warmer climate. During the Last Interglacial the global temperature was warmer than the present, especially in the Northern Hemisphere, and the sea level may have been 6-9 meters higher. Such high sea levels imply substantial contributions from the melting of the Greenland and Antarctic ice sheets. In addition, a better understanding of tides and storm surges during the LIG may help to provide constrains to regional sea level reconstructions and to address questions such as what propelled giant boulders up Bahamas' cliffs.

We analyze extreme sea levels during the Last Interglacial, to understand what coastal storms in a warmer world looked like, and to help reconstruct past sea levels.

Global modeling of extreme sea levels

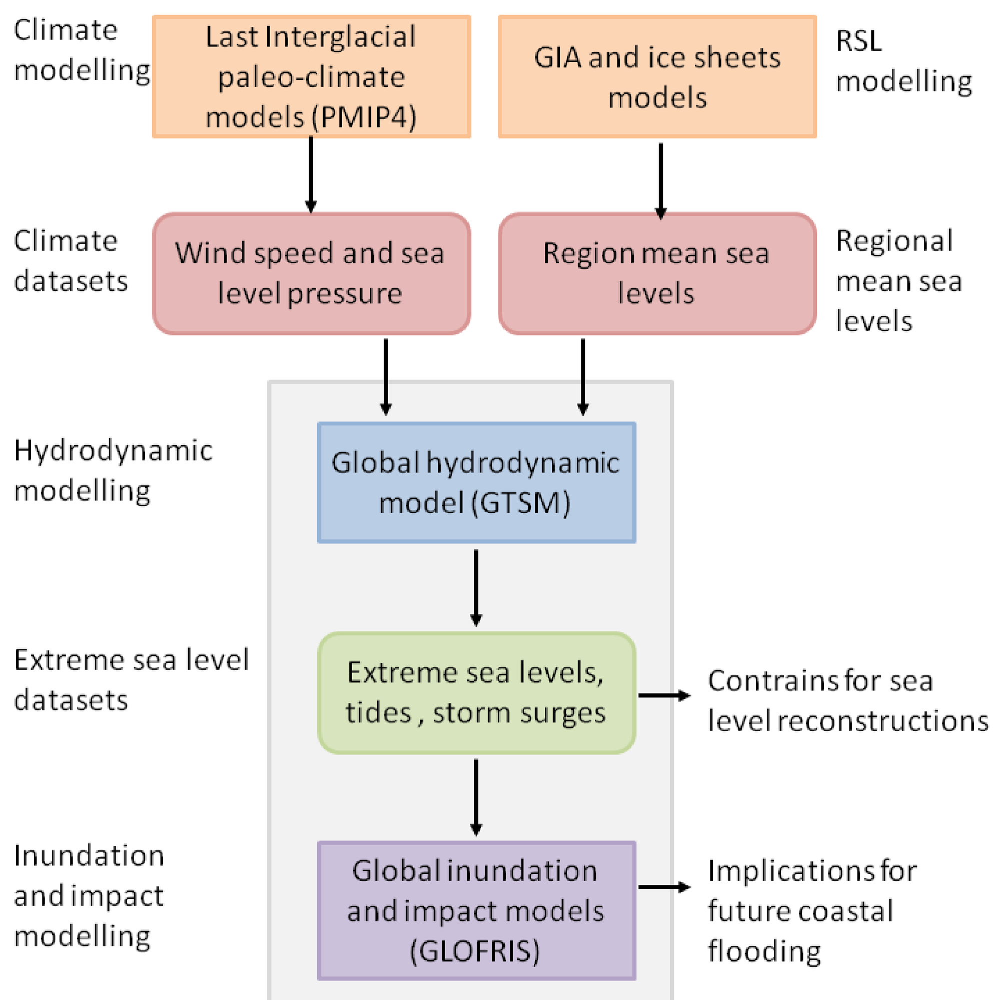


Fig. 1: Flowchart of the main model approach.

General approach

In this project, we use the Global Tide and Surge Model (GTSM) to simulate extreme sea levels, which are defined as the sum of mean sea level, tides and storm surges. To model storm surges we force GTSM with 3-hourly wind and pressure fields from LIG simulations by PMIP4 climate models (i.e., CESM1.2 and EC-Earth) with high resolution (~1 degree). Relative sea level (RSL) is taken from a glacio-isostatic adjustment model combined with glacio-eustatic responses of Greenland and Antarctica.

We produce time-series of storm surges, astronomical tides, and total sea levels. Based on these time-series, we will compute several indicators (e.g. tidal range, return periods of extreme sea levels). This will be analyzed against the climate in the pre-industrial.

Modeling of tides and storm surges

- Global Tide and Surge Model (GTSM), global hydrodynamic model that makes use of the Delft3D Flexible Mesh software
- Unique high resolution near the coast (<2.5 km), and coarser resolution in deeper oceans (25 km) to enhance the computational efficiency
- Its high resolution and accuracy makes it possible to compute changes in mean sea levels, astronomical tides and storm surge dynamically, including non-linear interaction effects.

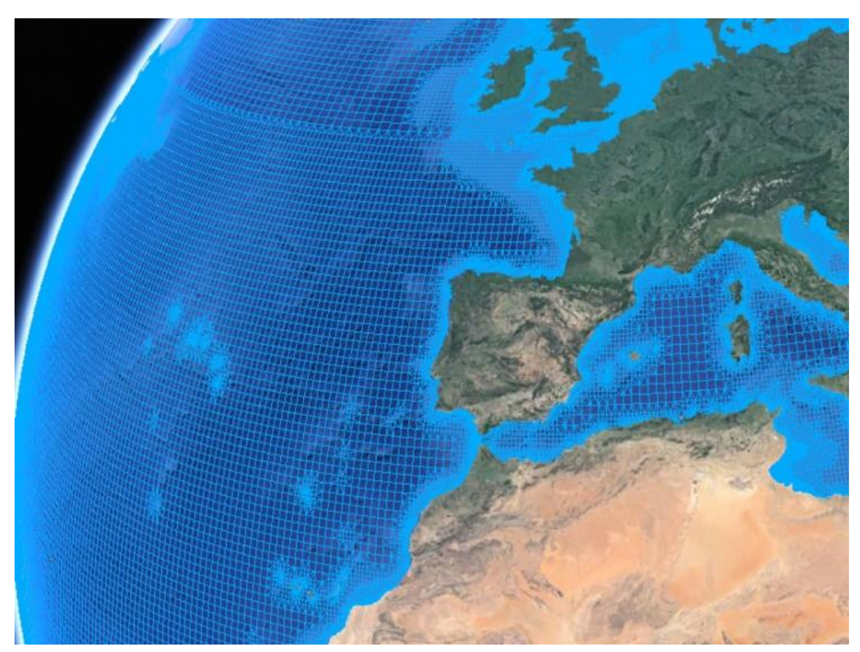


Fig. 2: Computational grid of GTSM.

Storminess during the Last Interglacial

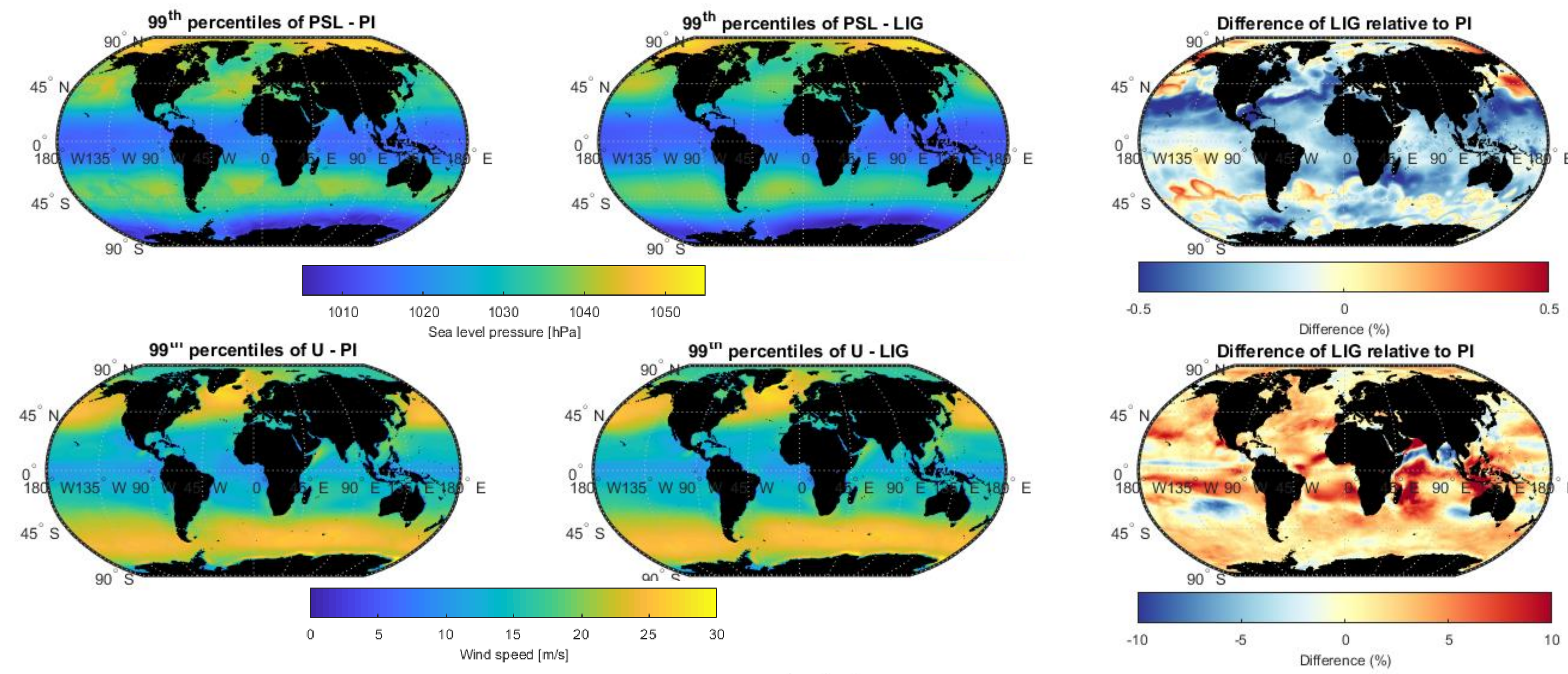
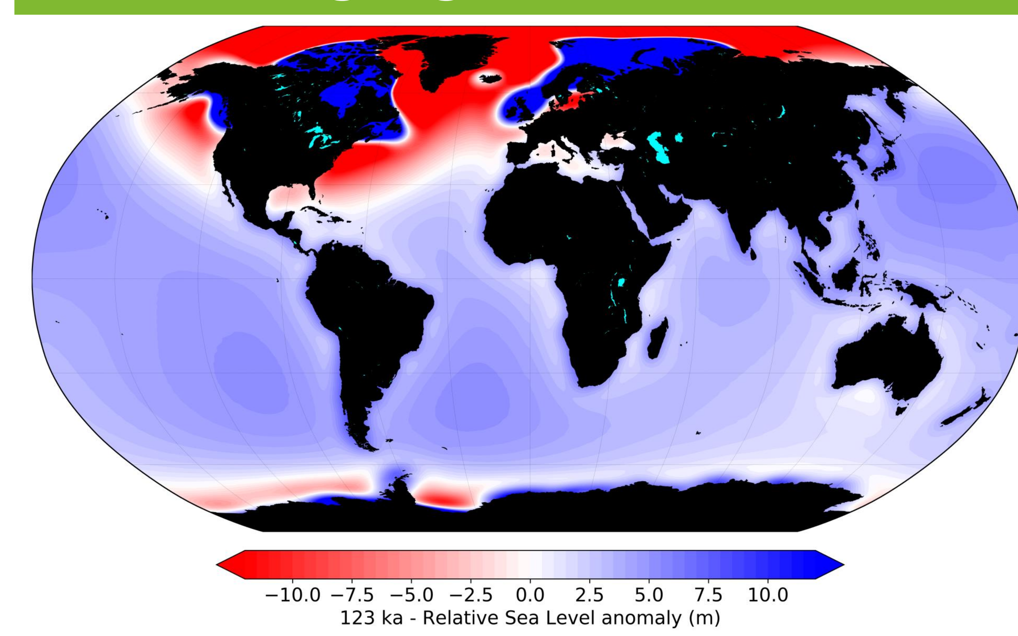


Fig. 3: Extreme sea level pressure (PSL) and wind speed (U) from the Last Interglacial (LIG) and the Pre-Industrial (PI) CESM1.2 simulations.

Figure 3 shows the anomalies in extreme sea level pressure and wind speed from the Last Interglacial with respect to the Pre-Industrial. First results suggest ~~a~~ general decrease in sea level pressure, except over the North Pacific and at Southern frontal boundaries. Wind speeds generally increase, but decrease in isolated regions over the northern Indian Ocean and near southwest Australia. In Indonesia, Oman and Madagascar wind speed increase exceed 10%. Overall, results suggest that storminess in the Last Interglacial was higher.

Including regional mean sea levels



We will analyze extreme sea levels during the Last Interglacial for a range of scenarios of RLS. These scenarios reflect the uncertainties in the glacio-eustatic contributions from Greenland and Antarctica and account for pre-MIS5e glacial-interglacial cycles. Figure 4 shows the results for 2.5 and 5.5 m of equivalent sea level from Greenland and Antarctica, respectively (Stocchi et al., QSR, 2018).

Fig. 4: Last Interglacial RSL anomaly (compared to present) from one scenario of the ANICE-SELEN coupled ice-sheet/sea-level model.

Outlook

We present a new project to assess extreme sea levels and coastal flooding during the Last Interglacial, using a global hydrodynamic model. Next steps include running the model using PMIP4 climate simulations, assessing sensitivity of storm surges and tides to changes in mean sea levels, and to changes in the global coastline. Results of these simulations will try to answer how storm surges and tides may have looked like during the LIG and how that differed from the PI. We will then investigate implications for coastal flooding, and compare our results to future scenarios from the IPCC. In addition, our results will provide insights and constrains for the interpretation of RSL proxies.

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