MADALGO – CENTER FOR MASSIVE DATA ALGORITHMICS

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Impacts of 21st Century Sea-level Rise on a Major Danish City

Abstract

This study examines the potential impact of 21st century sea-level rise on Aarhus, the second largest city in Denmark, emphasizing the economic risk to the city's real estate. We combine a new national Digital Elevation Model (DEM) in very fine resolution (~2 meter), a new highly computationally efficient flooding algorithm that accurately models the influence of barriers, and geospatial data on real-estate values to assess the economic real-estate risk posed by future sea-level rise to Aarhus. Under the A2 and A1FI (Intergovernmental Panel on Climate Change) climate scenarios we show that relatively large residential areas in the northern part of the city as well as areas around the river running through the city are likely to become flooded in the event of extreme, but realistic weather events. As much of the area at risk represent high-value real estate, it seems clear that proactive measures other than simple abandonment should be taken in order to avoid heavy economic losses. Among the different possibilities for dealing with an increased sea level, the strategic placement of flood-gates at key potential water-inflow routes and the construction or elevation of existing dikes seems to be the most convenient, most socially acceptable, and maybe also the cheapest solution. Finally, we suggest that high-detail flooding models similar to those produced in this study will become an important tool for a climate-change-integrated planning of future city development as well as for the development of evacuation plans.

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References

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[2] Nørby. *Århus skal sikres mod stigende vandstand* (Denmark, Aarhus: Jyllands Posten) (2009).
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Conclusion

From this study it is clear that huge areas especially in the northern part of Aarhus and around the Aarhus River (particularly the expensive neighborhoods) will become vulnerable to extreme weather flooding in the 21st century. As fine resolution DEMs logically reveal small features in the landscape not found in coarser terrain models, flooding simulations using fine-resolution topography generates detailed predictive maps of exactly where flooding will take place if the water reaches a given level. Therefore, we suggest that large editions of maps similar to those produced here will become an important tool for the planning of future city development in relation to expected climate changes, hereunder the strategic placement of flooding barriers to efficiently reduce flooding risks, as well as for the development of evacuation plans. The amount of data necessary for the development of such maps obviously calls for data handling by I/O efficient algorithms such as those found in TerraSTREAM.

Northern Aarhus - 21st Century Scenario

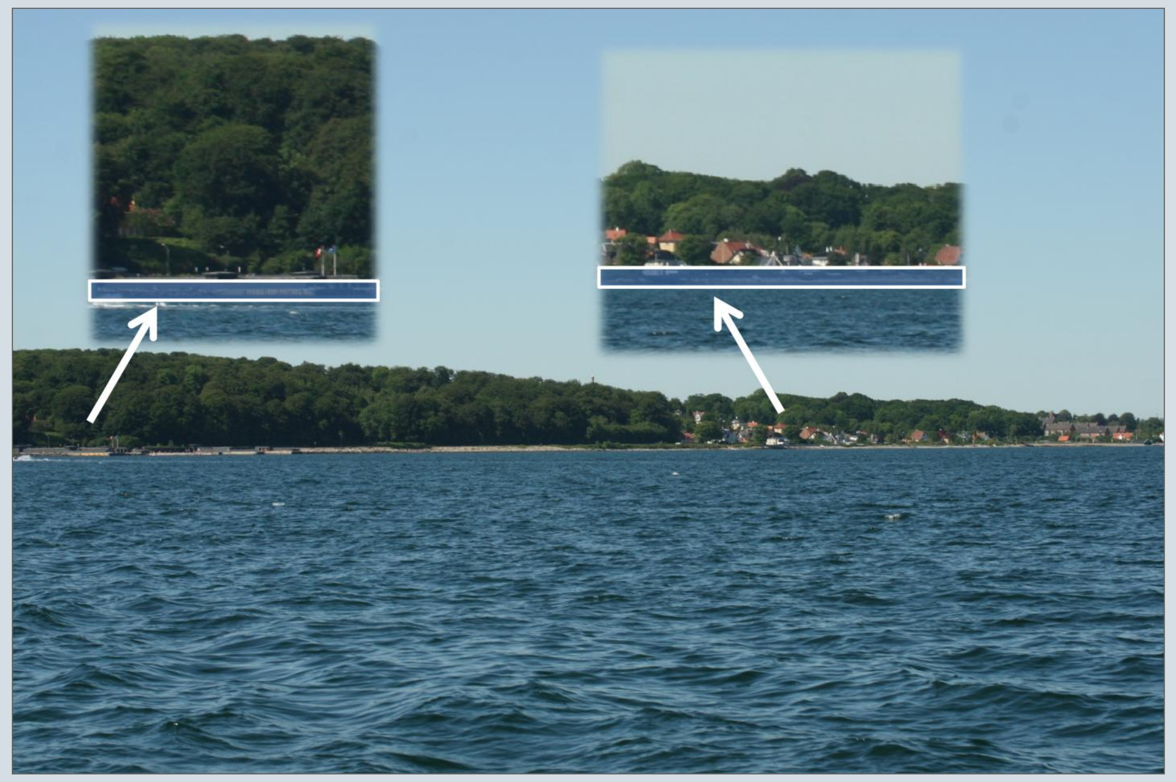


Figure 3. The right (northern) forest limit marks the beginning of the northern residential areas at flood-risk. The enlarged segments illustrate a likely sea level during extreme future weather events (~2.5 – 3.5 m a.s.l.).

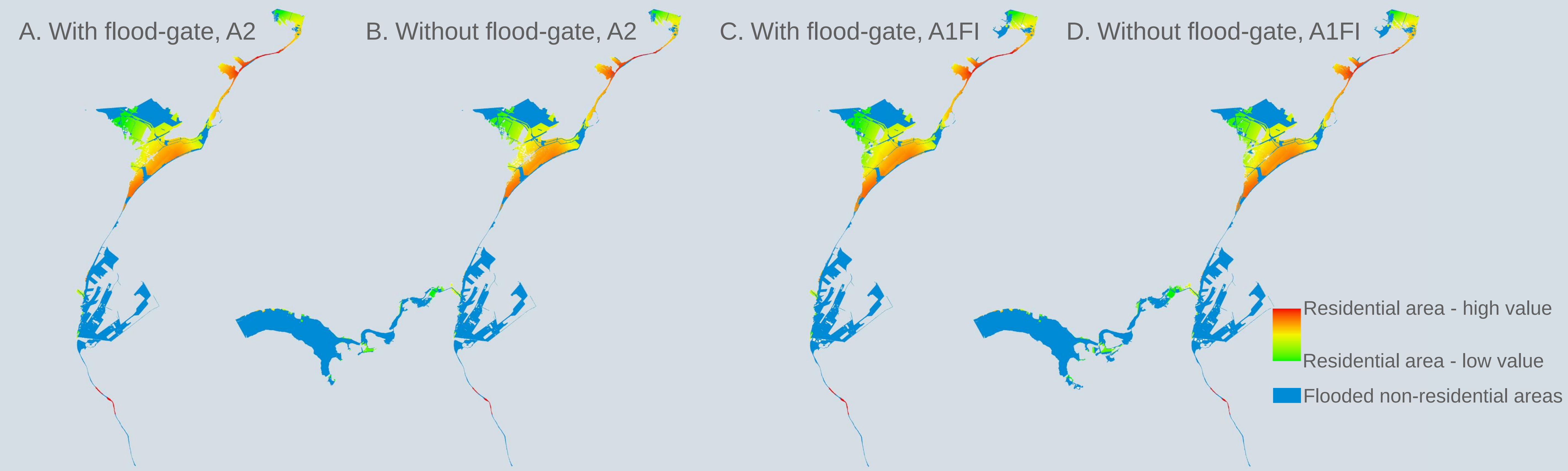


Figure 2. Simulated extreme-weather flooded areas of Aarhus in 2090-2099 under the A2 (A, B) and A1F1 (C, D) climate change scenarios. In A and C, strategically placed flood-gates were simulated by setting bridges in the DEM as water impervious barriers.

Methods

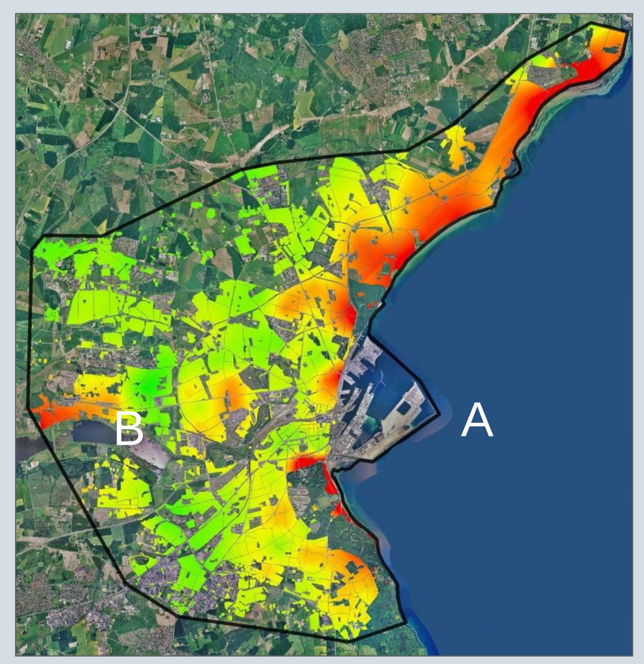
The low-lying residential parts of Aarhus (N 56°9', E 10°12') are found in the northern part of the city (flood-protected by a 2.1-m tall dike) and along the central Aarhus River and the Brabrand Lake (Fig 1). Detailed topographic data was extracted from two LIDAR DEMs: (1) one DEM without bridges, and (2) one that included all bridges in the landscape as impervious barriers (to assess the potential role of flood-gates at the bridges in flood-prevention). We used geospatial data on real-estate values (Fig 1) and sea-level rise scenarios predicting a mean sea-level rise of 1.15 m and 1.35 m by 2090-2099, respectively [1]. The November 2006 high-water level of 1.68 m a.s.l. [2] was added to these, yielding future extreme weather high-water levels of 2.83 and 3.03 m a.s.l., respectively. Residential flooding simulations were performed for both DEMs and the two future extreme high-water estimates using the TerraSTREAM [3] flooding algorithm.

Results

Generally, a considerable part of the residential areas is estimated to become flooded in 2090-2099 under extreme high-water situations similar to the November 2006 storm (Fig 2). The flooding simulations for the DEM that represented bridges revealed that flood-gates would prevent the flooding of the residential areas around the Aarhus River (Fig 2, A and C). The flooding simulations for the DEM without artificial infrastructures showed that relatively large residential areas in northern part of the city (Fig 1) as well as areas around the Aarhus River are likely to become flooded (Fig 2, B and D).

Study Area

Figure 1. The residential areas of Aarhus (red indicates relatively expensive real-estate, green indicates relatively cheap real-estate). The harbour of Aarhus is seen in the central part (A) of the image while the Brabrand Lake is located westernmost in the analysis area (B).



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