Coastal protection
Assessing the flood-risk reduction value of mangroves

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Publication date
2024

Document Version
Final published version

Published in
The State of The World's Mangroves 2024

Citation (APA)
van Zelst, V., van Wesenbeeck, B., Luijendijk, A., & Tiggeloven, T. (2024). Coastal protection: Assessing the flood-risk reduction value of mangroves. In M. Spalding, & M. Leal (Eds.), *The State of The World's Mangroves 2024* (pp. 63-68). Global Mangrove Alliance.

4.3 Coastal protection: assessing the flood-risk reduction value of mangroves

The unprecedented resolution of a new 2D modeling approach greatly improves our understanding of how mangroves reduce flood risk.

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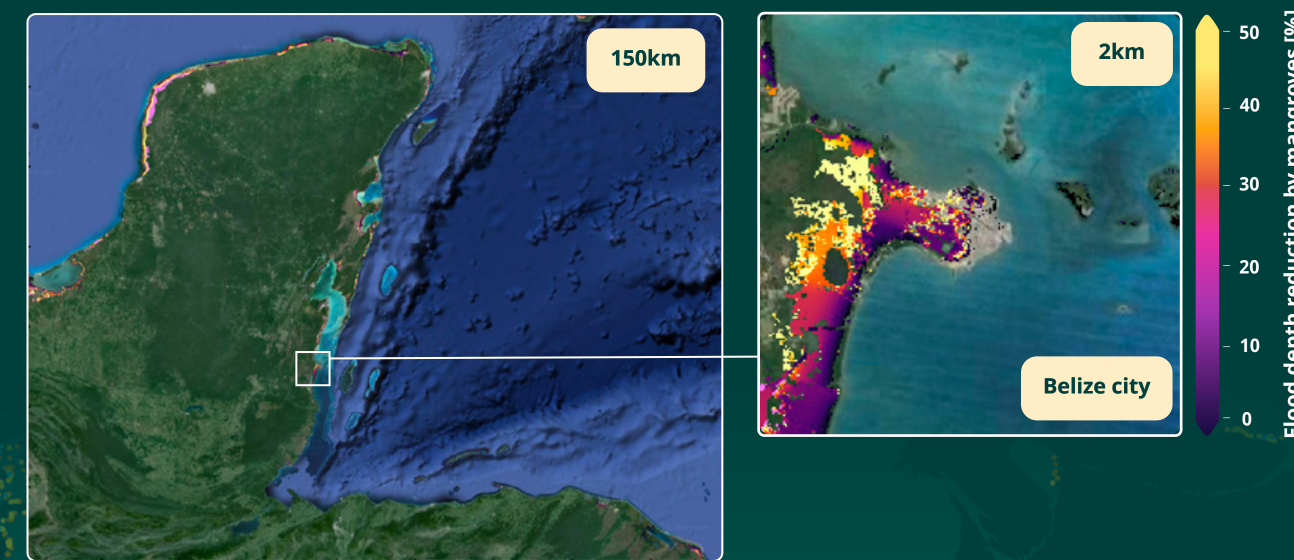
Figure 20:
Flood depth reduction in the region of Yucatan, Quintana Roo, Belize, and Honduras and then right hand inset: Zoom in of Belize City corresponding to a 1-in-100-year storm in the current climate.



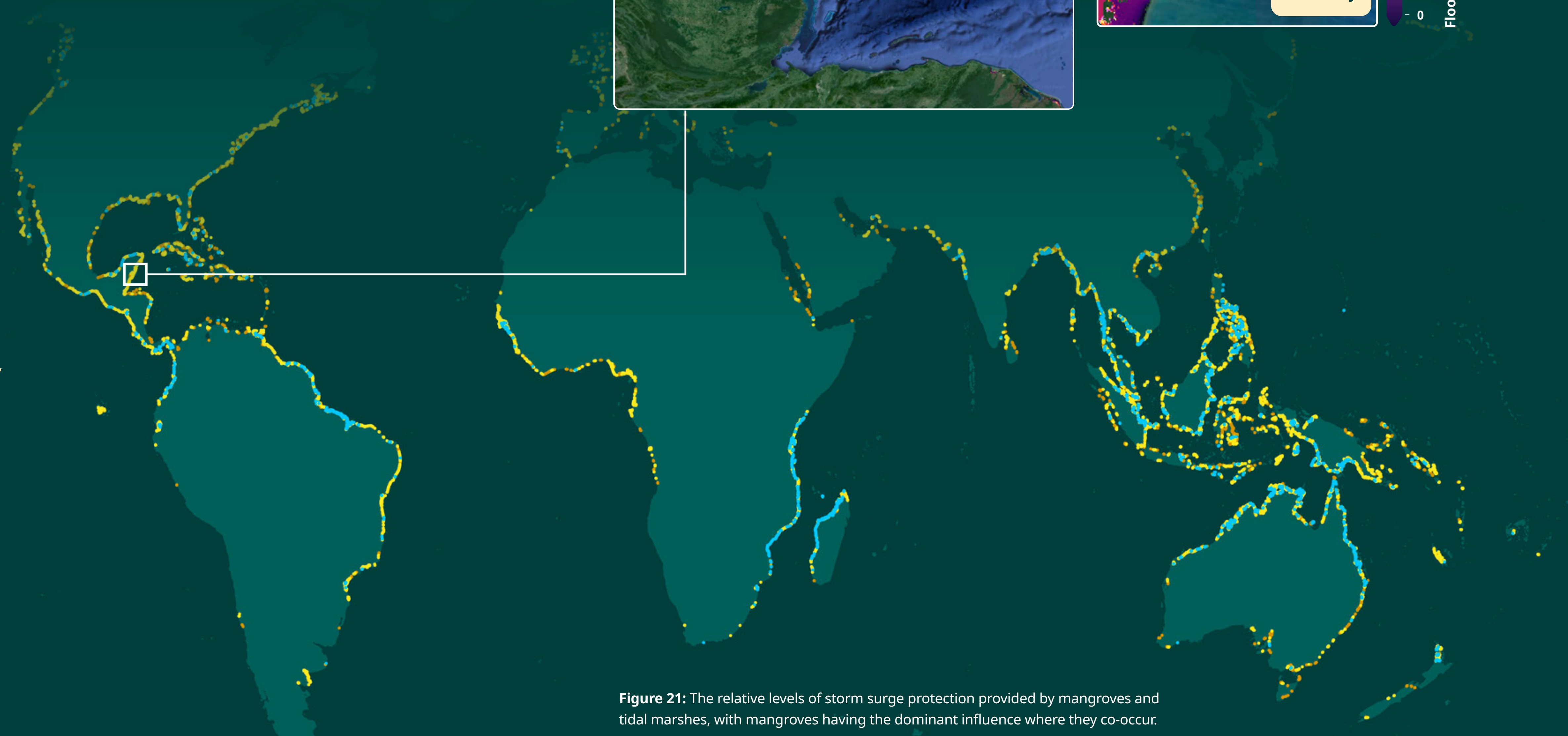


Figure 21: The relative levels of storm surge protection provided by mangroves and tidal marshes, with mangroves having the dominant influence where they co-occur.

Mangroves' interaction with incoming coastal stormwaters

Flooding is the most frequently occurring natural disaster. According to the results of global studies, approximately 1.3% of the global population live in areas that are exposed to 1-in-100-year coastal flood events[11]. This number is expected to increase due to population growth, climate change, and subsidence.

Coastal flood events are caused by high tides, storm surges, and waves that submerge low-lying coastal land in seawater. Globally, coastal flooding is predominantly determined by storm surges that are largely driven by the strong winds of a cyclonic storm. Flood levels due to storm surges can be locally aggravated by the local wave set-up, especially in areas with rapid transitions in bed level.

Coastal vegetation can substantially reduce flood depths in the current climate, especially in regions where continuous mangrove belts are still present.

Mangroves affect patterns of coastal flooding by slowing down and redirecting storm surges and attenuating wind and swell waves. Mangroves cannot completely block high water levels that are generated during a storm surge, but they do lower propagation speeds, inundation depths and overall flood extents.

The effectiveness of mangroves' capacity to mitigate coastal flooding depends on various factors. For example:

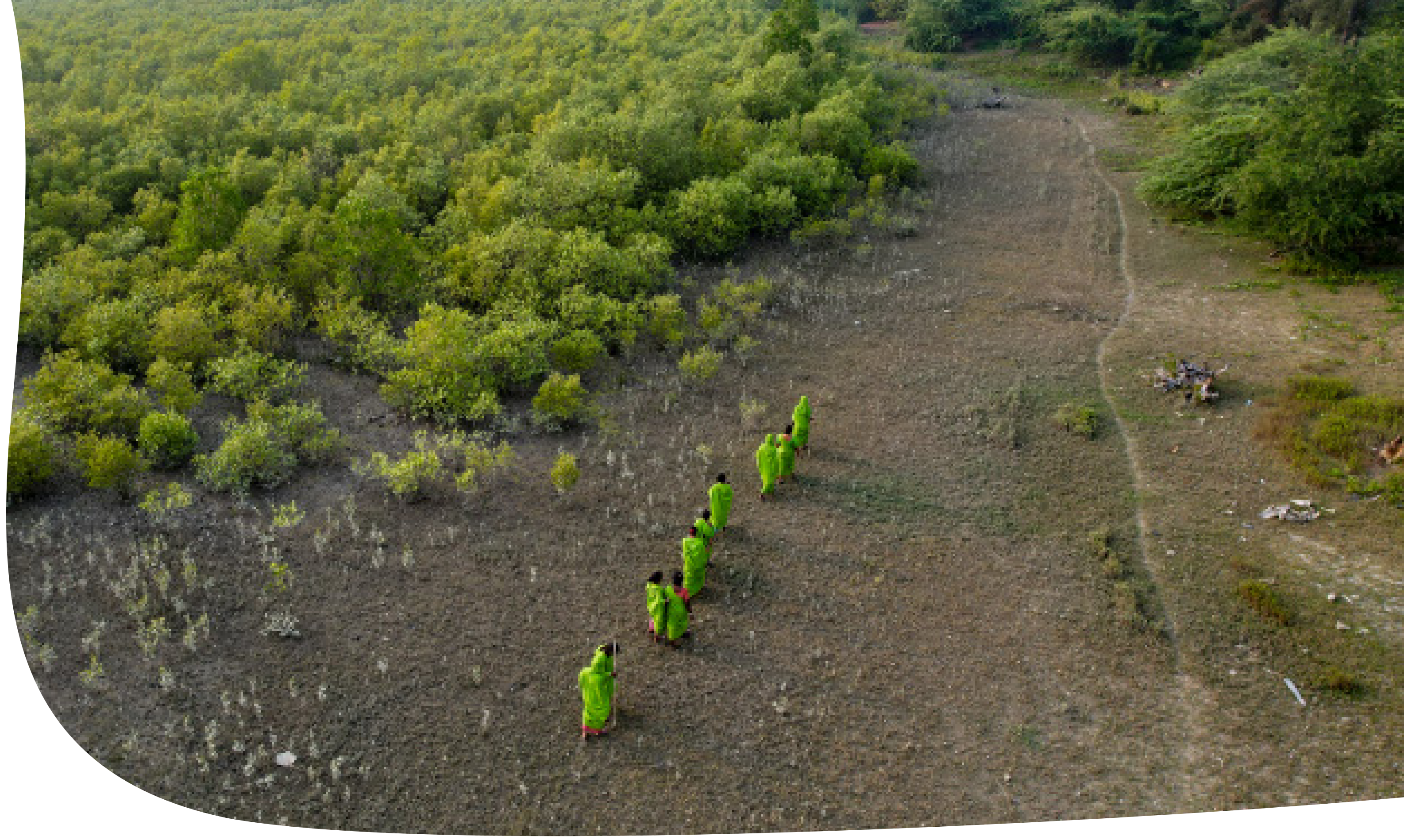
- The forest's characteristics (width and vegetation density).
- Coastal topography.
- Storm conditions (e.g. storm surge height, storm duration).

Scientific literature indicates that extensive mangrove green belts (on the kilometer scale between sea and inland areas) are typically required to achieve considerable reductions in coastal flood impacts. Although smaller mangrove patches are unlikely to fully prevent flooding, they may still lower flood depths in adjacent areas, and will reduce the impact of waves.

Mapping the global flood risk reduction value of mangroves

Computer models can be used to simulate the effects of mangroves on the impact of storm surges. These models use theoretical formulations, calibrated using field and lab observations. In such models, mangroves represent a rough surface. Although permeable, they generate friction that slows and alters water flow.

[11] Muis, S., Verlaan, M., Winsemius, H. C., . Aerts, J. C. J. H and Ward. P. J. (2016). A global reanalysis of storm surges and extreme sea levels. *Nature Communications* 7:11969.



Marching towards building resilience, members of the Green Brigade in the Indian Sundarbans stride forth amidst mangroves, their mission clear: to restore the mangroves and strengthen the natural barrier against cyclones. © NEWS Archive.

Currently available global studies have used a transect approach, which models water movements across thousands of parallel transects perpendicular to the shore. Such an approach may work well for open and uniform coastlines, but does not reflect reality for more complex coastal settings, such as estuaries, deltas, and lagoons, where most mangroves occur. Here it is important to model lateral water flow and 2D effects, such as funneling and redirection of high waters, which are extremely important during storm surges.

The Nature Conservancy (TNC) and the University of Cambridge are collaborating with Delft University of Technology, Deltares, and the Institute of Environmental Studies (IVM) Amsterdam in a global study of the role of mangroves and tidal marshes in reducing flood risk that is induced by a combination of storm surges and tides. The researchers are disentangling more complex surge and wave processes in interaction with realistic coastal geographical representation in a 2D global numerical modeling approach and aim to resolve the interaction between vegetation, topography, and incoming flood waters.

To date, 2D modeling approaches are typically applied in local and regional studies. To the research team's knowledge, the current global 2D approach with a resolution of 100 x 100 m is unprecedented and is expected to greatly improve our understanding of the role of mangroves in reducing global flood risk.

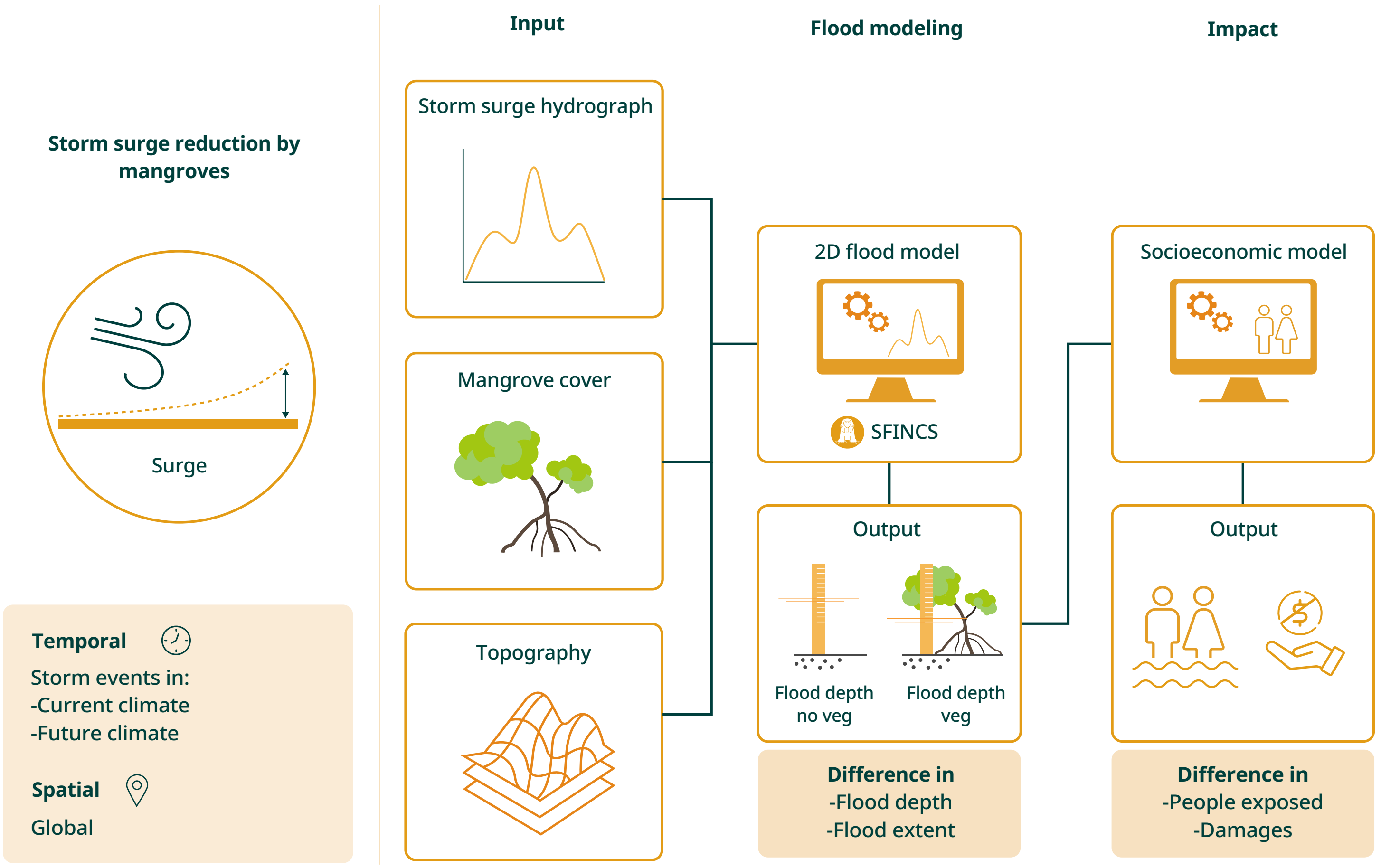


Figure 22. Modeling framework for estimating storm-surge reduction by mangroves.

Global 2D model set-up

Using an automated approach, numerical computer models have been generated in all coastal mangrove and tidal marsh areas across the globe. The seaward edges of the model domains are situated a few kilometers out from the coast and are aligned with the Global Tide and Surge Model, which is a global 2D flow model developed by Deltares and IVM Amsterdam[12].

The model is forced with a time-varying storm surge level for tropical and extratropical storms. Thus, the rising and falling of the storm is included, which is essential for estimating the degree to which coastal wetlands are slowing down the storm propagation speed.

Inundation is modeled using a process-based model that is using a state-of-the-art map of ground elevation or Digital Terrain Model (DTM). This new Delta DTM corrects the earlier CopernicusDEM with space-borne LiDAR from ICESat-2 and GEDI missions, correcting the elevation bias that has hampered previous predictions of coastal flood risk without locally generated elevation models.

Flooding or inundation maps are generated with coastal wetlands, and in a hypothetical situation without them. The difference between these determines the influence of mangroves and tidal marshes on reducing flood extent and flood depth. These maps of reduced or avoided flooding are then used to calculate avoided damages and the reduction in the numbers of people exposed. Model simulations are run for multiple return periods and various sea-level rise scenarios to provide a well-founded overview of the capacity of these ecosystems to reduce global coastal flood risk.

Initial results

The global modeling study confirms that coastal vegetation can substantially reduce flood depths in the current climate, especially in regions where continuous mangrove belts are still present. On the contrary, the effect of mangroves is far less pronounced in areas that are heavily channelized.

The results show that mangroves typically lower flood depths by 15-20% with maxima exceeding 70% for storms with a return period of 100 years in the current climate. The effect on overall flood extent is more limited however: in this storm scenario they reduce the flood extent by more than 50% in just 1.5% of the studied regions.

Mangroves typically lower flood depths by 15-20% with maxima exceeding 70% for storms with a return period of 100 years in the current climate.

The location and extent of mangroves on longer temporal scales (50-100 years) is difficult to project given many feedback loops and wide ranges in sea-level rise scenarios. The study shows that if the current extent of mangroves is maintained there will be increasing flood-risk reduction benefits of mangroves with higher water levels, but the exact value heavily depends on the ability of mangrove ecosystems to keep up with sea-level rise.

[12] Muis, S., M. I. Apecechea, J. Dullaart, J. de Lima Rego, K. S. Madsen, J. Su, K. Yan, and M. Verlaan. 2020. A High-Resolution Global Dataset of Extreme Sea Levels, Tides, and Storm Surges, Including Future Projections. *Frontiers in Marine Science 7.*