Natural hazards

https://doi.org/10.1038/s41561-026-01932-3

Early action for coastal communities

Sanne Muis

Check for updates

Shifts in large-scale climate patterns are reshaping flood risk worldwide. Advances in modelling now offer the potential to provide early warnings and develop effective tools for managing rising coastal hazards.

Large-scale climate patterns strongly influence extreme weather and the coastal flooding that can result. During El Niño events — marked by unusually warm surface waters in the central and eastern tropical Pacific Ocean and a weakening of equatorial trade winds[1] — sea levels rise along the eastern coast of South America, while shifts in atmospheric circulation redirect storm tracks and landfall locations, both affecting the occurrence of coastal extremes. These coupled atmosphere–ocean changes heighten coastal flood risk and erosion[2,3], highlighting the need for early warnings that help communities anticipate impacts. Writing in *Nature Geoscience*, Boucharel et al.[4] demonstrate that such long-range prediction is now within reach. By linking coastal flooding episodes to major climate modes, they show that these events can be anticipated several months in advance, paving the way for global early-warning systems to reduce coastal risk.

Coastal regions are facing rapidly increasing flood risk under climate change. By the end of this century, sea level rise alone is expected to turn what is currently a 1-in-100-year coastal flood into an annual event across a large part of the globe[5]. Additional increases in flood risk are likely to arise from changes in the frequency or intensity of extra-tropical storms and tropical cyclones[6,7], as well as from shifts in the characteristics of major climate modes, such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation[8,9]. Boucharel et al. go beyond state-of-the-art approaches that typically treat ENSO and the North Atlantic Oscillation separately, showing that these modes often co-occur in the same season and that their interaction can amplify risks beyond individual impacts.

The authors reconstruct coastal water levels from 1953–2023 using global climate and hydrodynamic models and show that their estimates align with observed levels from historical events such as the Xynthia flooding that hit France in 2010 (pictured). They find that variations in flood potential when water levels exceed local coastal elevations are tied to major climate modes — the North Atlantic Oscillation raises risk in Northern Europe and lowers it in the Mediterranean during its positive phases, with the opposite pattern during its negative phases.

Boucharel et al. show that by linking large-scale climate modes with coastal water-level variability, it is now possible to generate seasonal-to-annual forecasts of coastal risk — a major advance for hazard preparedness. Forecast lead times range from five months in the European Atlantic regions to more than a year in parts of the Pacific. These long lead times arise from delayed climate feedback linked to the ocean's slow response to atmospheric adjustments. Anticipation on the order of several months could be a game changer for coastal risk management, providing sufficient time to strengthen preparedness and enhance the resilience of coastal communities to flooding. Potential early actions include maintaining flood protection measures, undertaking beach nourishments, updating evacuation plans, raising community awareness, and adjusting agricultural practices such as early crop harvesting.

Flooded houses near the beach of Aytre, western France, after the Xynthia storm battered the French Atlantic coast.

CREDIT: AFP / STRINGER / GETTY IMAGES

Of course, the reality of coastal flooding is much more complex than can be captured in Boucharel et al.'s modelling. Most importantly, the coastal water levels used to estimate flood potential do not fully capture local extremes because of the relatively coarse resolution of the climate and hydrodynamic models used to produce them. Tropical cyclones — which can trigger some of the most destructive flooding — remain poorly represented in global climate models because their small scale, high intensity, and complex physical processes exceed the models' spatial resolution and process-level capabilities. Moreover, their low occurrence probabilities mean that even multidecadal simulations typically do not generate enough extreme events to robustly characterize their behaviour. A global forecasting system like the one presented by Boucharel et al. is not designed to resolve extreme events in detail, but rather to identify regions and periods in which flood risk is amplified relative to neutral climate conditions. Physics-based global forecasting systems of coastal water levels that can capture localized storm surges are under development[10], relying on hydrodynamic models and meteorological forecasts, but they typically offer lead times of only several days. Forecasting of tropical cyclone-induced extreme would require high-resolution ensemble simulations, which are computationally expensive.

As coastal flood risk intensifies under the combined pressures of sea level rise, evolving storm patterns, and shifts in major climate modes, Boucharel et al. demonstrate that regional coastal flooding hazards can be forecasted months in advance. Although long-term investments in coastal flood protection remain essential, they may not keep pace with the speed that climate-driven risks are evolving.

In this context, skilful seasonal-to-interannual forecasting can anchor early warning systems and trigger anticipatory action. Early warnings offer a scalable approach to managing rising flood risk and provide an effective way to reduce impacts before flooding occurs.

Sanne Muis [1,2]
[1]Vrije Universiteit Amsterdam, Amsterdam, Netherlands.
[2]Deltares, Delft, Netherlands.
e-mail: sanne.muis@vu.nl

Published online: 12 March 2026

References

1. Timmermann, A. et al. *Nature* **559**, 535–545 (2018).
2. Muis, S., Haigh, I. D., Guimaraes Nobre, G., Aerts, J. C. J. H. & Ward, P. J. *Earths Future* **6**, 1311–1322 (2018).
3. Almar, R. et al. *Nat. Commun.* **14**, 3133 (2023).
4. Boucharel, J. et al. *Nat. Geosci.* https://doi.org/10.1038/s41561-025-01903-0 (2026).
5. Tebaldi, C. et al. *Nat. Clim. Change* **11**, 746–751 (2021).
6. Camargo, S. J. et al. *Trop. Cyclone Res. Rev.* **12**, 216–239 (2023).
7. Priestley, M. D. K. & Catto, J. L. *Weather Clim. Dyn.* **3**, 337–360 (2022).
8. Cai, W. et al. *Nat. Rev. Earth Environ.* **4**, 407–418 (2023).
9. Smith, D. M. et al. *Nat. Clim. Change* **15**, 403–410 (2025).
10. Bernier, N. B. et al. *Weather Clim. Extrem.* **45**, 100689 (2024).

Competing interests

The author declares no competing interests.