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Extreme coastal water levels will increase considerably due to climate change, posing an increasing threat of coastal floods due to 'overtopping' — a cause of flooding

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Contact:
rafael.almar@ird.fr

Climate change and anthropogenic pressures are widely expected to exacerbate hazards such as coastal flooding. One process that could contribute to this is overtopping which occurs when the extreme coastal water level exceeds the maximum elevation of the coastal system (such as dunes, dykes or cliffs). A new global analysis — using satellite-derived models of coastlines — estimates that under a high emissions scenario, the incidence of overtopping, globally, will accelerate faster than the global mean sea-level.

Overtopping generally drives nearby localised flooding, but in extreme cases can also damage natural barriers or engineered defences, leading to catastrophic floods. Episodes result from a combination of storm surges, tides, wave effects and sea-level anomalies, explain the researchers behind this study. They highlight that ocean waves — influenced by shore landscape — play an important role, however, their contribution to coastal water levels has been little investigated, mostly due to lack of detailed knowledge of shore topography in many parts of the world.

To address this knowledge gap and refine the estimates of coastal overtopping potentials, the researchers combine an innovative global digital surface elevation model, capturing the natural and built/artificial surfaces of the environment, (ALOS World 3D-30 m from JAXA[1]) with extreme coastal water levels derived from satellite data, tide and surge models, and wave analyses. The researchers quantify potential overtopping events in recent decades, worldwide, and projections of future overtopping, given average sea-level rise predicted for the 21st century.

Among the globe's 1.5 million km of coastline, open coasts directly exposed to wave action are highly variable, featuring sandy shores, cliffs and engineered structures. The foreshore slope (from shoreline to overtopping threshold) influences the 'runup' of waves — i.e. the vertical height they reach on shore. These slopes exhibit regional patterns — for example, relatively low gradients on the west coast of North America and on Africa's sandy coasts, and steeper on rockier coastlines.

Extreme coastal water levels will increase considerably due to climate change, posing an increasing threat of coastal floods due to 'overtopping' — a cause of flooding (continued)

Based on sea-level anomaly, storm surge and tide data, combined with wave runup computations, the researchers identified extreme water levels at over 14 000 open coasts from 1993 to 2015.

Results show an increasing trend: incidence of overtopping increased globally by about half over the 22-year period. Hotspots are highlighted and some of the highest rates of increase are in the Gulf of Mexico, Baltic Sea and Southern Mediterranean. Even small increases in sea-level in these regions can have a large impact on overtopping, the researchers explain.

While overtopping events are mostly affected by wave runup and tides, including an analysis of these cannot solely account for the increasing trend observed, say the researchers. Instead, they identify the increasing trend in regional sea-level as the main driver. Based on predicted sea-level rise under a high GHG-emissions scenario, the aggregate of annual hours of overtopping could almost multiply by 50 by the end of the century, they project.

In addition, the overtopping trend is accelerating faster than the rate of sea-level rise itself, the study suggests, and it will occur increasingly, especially in the Tropics, north-western USA, Scandinavia and far eastern Russia.

The researchers acknowledge limitations in their analysis; for example, they were unable to consider the complex impacts of waves on river deltas/estuaries, and digital elevation models are not perfectly accurate representations of complex local topography[2]. They also note that they have used simplifications in estimating extreme water levels, and modelled waves based on a formula developed for sandy beaches. Wave runup over rocks will, therefore, be reduced, and in areas with a large amount of suspended sediment, wave action will be dampened. The study may, therefore, have produced overestimations of overtopping in such locations. Nevertheless, the study highlights a trend and indicates how satellite data can be used in further research.

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1. Tadono, T. et al. (2016) Generation of the 30 M-MESH global digital surface model by Alos Prism. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences; ISPRS Archives* 157–162

2. However, these models are becoming ever more advanced, enabling more reliable impact assessment where they are used. Comparison with light detection and ranging (LIDAR) imaging of sites in France and the Netherlands shows that the digital elevation model used in this study is more accurate than many others, in respect to maximum coastal elevations. While global-scale studies cannot be expected to capture intricate local-scale details, they can indicate trends and regional hotspots, for further investigation. It is also worth noting that in Europe, in the context of the Copernicus Programme, a digital elevation model with 30 m spatial resolution has recently been built and made publicly available.