

Science for Environment Policy

Rapid and significant sea-level rise expected if global warming exceeds 2 °C, with global variation

The world could experience the highest ever global sea-level rise in the history of human civilisation if global temperature rises exceed 2 °C, predicts a new study. Under current carbon-emission rates, this temperature rise will occur around the middle of this century, with damaging effects on coastal businesses and ecosystems, while also triggering major human migration from low-lying areas. Global sea-level rise will not be uniform, and will differ for different points of the globe.

Sea-level rise is one of the biggest hazards of climate change. It threatens coastal populations, economic activity in maritime cities and fragile ecosystems. Because sea-level rise is a delayed and complex response to past temperatures, sea levels will continue to climb for centuries into the future, even after concentrations of greenhouse gases in the atmosphere have been stabilised.

This study, partly conducted under the EU RISES-AM project¹, projected sea-level rise around the world under global warming of 2 °C (widely considered to be the threshold for dangerous climate change), 4 °C, and 5 °C, compared with pre-industrial temperatures. This was achieved by combining the results of 5 000 simulations of future sea level at each point on the globe, using 33 different climate models.

The researchers considered how different factors would affect sea levels, including the effects of ice loss from glaciers and ice sheets, and the influence of how much [water](#) is stored on land — which depends on how much we store in artificial reservoirs and on how much groundwater we extract; reservoir storage prevents water from reaching the sea, and so offsets some of the sea-level rise that would otherwise have occurred, whereas groundwater extraction can contribute to sea-level rise by causing land to subside.

Under current carbon-emission rates (judged according to the business-as-usual Representative Concentration Pathway (RCP), 8.5 climate change scenario²), global temperature rises of well over 2 °C will occur this century³. Warming is expected to reach 2 °C by 2041, 4 °C by 2083, and almost 5 °C by 2100. Even under the more moderate RCP 4.5 scenario, the 2 °C threshold will be reached by around 2050, although it should stabilise after this point. The study calculates that these temperature rises will be associated with global median average sea-level rises of 0.22, 0.63 and 0.86 metres (m), respectively, meaning that many coastal sites have very little time to adapt to higher sea levels after mid-century if we continue to emit carbon at current levels.

Sea-level rise will not be the same the world over, because dynamic ocean processes and the gravitational effects of ice sheets and glaciers melting into the ocean will redistribute seawater in complex patterns. Hence, more than 70% of global coastlines will experience sea-level rise above the median global rise of 0.22 m under 2 °C warming, and most will experience over 0.3 m of sea-level rise. Rises of up to 0.4 m are expected along the Atlantic coasts of North America and Norway.

If warming continues above 2 °C, then, by 2100, the study predicts that sea levels will be rising faster than at any time in the history of human civilization. If global warming reaches 4 °C, then more than 80% of coastlines will experience sea-level rise over the global median average of 0.63 m. The highest rises, exceeding 2 m, may be expected in small-island Pacific and Indian Ocean nations, such as Micronesian countries.

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1. [RISES-AM](#) (Rising Climate Change Impacts: Innovative Strategies to Adapt Coastal Systems to High End Scenarios) was supported by the European Commission under the Seventh Framework Programme.

2. Representative Concentration Pathways (RCPs) are climate change scenarios used by the [IPCC](#) that represent different levels of radiative forcing (the amount of heat that is absorbed by the earth versus the amount that is radiated back into space) in watts per square metre. Each depends on how many greenhouse gas emissions are released. For further information: http://sedac.ipcc-data.org/ddc/ar5_scenario_profiles/RCPs.html

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3. The Paris Agreement, signed by over 190 countries in 2015, aims to keep global temperature rise well below 2 °C above pre-industrial levels. The pledges made to contribute to this agreement, if fully implemented, should be sufficient to limit temperature rise to around 3 °C. Limiting the rise to below 2 °C will, therefore, require an increase in global ambition, which is the subject of continuing negotiations under the UN Framework Convention on Climate Change (UNFCCC).

With a 5 °C rise, 80% of the world's coastline will exceed a global sea-level rise of 1.8 m. Almost all of the world's 136 largest coastal cities are projected to experience sea-level rises of at least 0.9 m by 2100, with levels of 2 m in megacities of south-east and south Asia, and large cities along North America's Atlantic coast. Globally, only a few cities in northern Europe, including Dublin (Ireland), Glasgow (UK) and London (UK) would have relatively low rises of around 0.5–0.7 m.

These changes in sea level bring major socio-economic implications. The study points out that many cities are under pressure to expand and are spreading into flood-prone zones. For example, 6% of the population in Guangzhou, China, currently lives on land that is within 0.5 m above normal sea level. By the middle of this century, this city could experience financial losses of \$254 million (€234.87 million) per year under a sea-level rise of 0.2 m, making it the world's most economically vulnerable city to sea-level rise.

Economic development is also driving demand for groundwater, which increases subsidence rates and, consequently, flood risk. Jakarta, Indonesia, could subside by 1.8 m by 2025, for example and, in Europe, the western Netherlands could subside by 0.7 m by the same date. Appropriate adaptation measures are needed to stop parts of many cities, including Jakarta, Indonesia; Ho Chi Minh City, Vietnam; and Bangkok, Thailand; sinking below sea level. Such measures could include restrictions on groundwater extraction and development of alternative water supplies; without such measures, the global cost of rising sea levels for coastal cities could exceed \$1 trillion (€92 billion).

Sea-level rise will also affect human migration. A 2 m rise will lead to the displacement of 2.5 million people living in low-lying areas of Miami, USA; 2.1 million in Guangzhou and 1.8 million in Mumbai, India, for instance.

The study also questions geoengineering as a [technological](#) response to sea-level rise. It suggests that although it has the potential to reduce global temperatures, for example, through injecting sulfate aerosols into the stratosphere, there are doubts that it could sufficiently reduce radiative forcing from RCP 8.5 to more acceptable levels, such as RCP 4.5. In addition, to be effective at combatting sea-level rise, geoengineering schemes would need to prevent warm ocean waters from reaching the undersides of floating Antarctic ice masses, which may not be possible with aerosol injections.

