

# From Miami to Shanghai: 3C of warming will leave world cities below sea level

An elevated level of climate change would lock in irreversible sea-level rises affecting hundreds of millions of people, Guardian data analysis shows



How Shanghai would look with a rise of just 2C: the UN warned this week of a potential 3C scenario. Photograph: Nickolay Lamm/Courtesy Climate Central

## Jonathan Watts

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Hundreds of millions of urban dwellers around the world face their cities being inundated by rising seawaters if latest UN warnings that the world is on course for 3C of global warming come true, according to a Guardian data analysis.

Famous beaches, commercial districts and swaths of farmland will be threatened at this elevated level of climate change, which the UN warned this week is a very real prospect unless nations reduce their carbon emissions.

Data from the Climate Central group of scientists analysed by Guardian journalists shows that 3C of global warming would ultimately lock in irreversible sea-level rises of perhaps two metres. Cities from Shanghai to Alexandria, and Rio to Osaka are among the worst affected. Miami would be inundated - as would the entire bottom third of the US state of Florida.

The Guardian has found, however, that local preparations for a 3C world are as patchy as international efforts to prevent it from happening. At six of the coastal regions most likely to be affected, government planners are only slowly coming to grips with the enormity of the task ahead - and in some cases have done nothing.

This comes ahead of the latest round of climate talks in Bonn next week, when negotiators will work on ways to monitor, fund and ratchet up national commitments to cut CO<sub>2</sub> so that temperatures can rise on a safer path of between 1.5 and 2C, which is the goal of the Paris agreement reached in 2015.

The momentum for change is currently too slow, according to the UN Environment Programme. In its annual emissions gap report, released on Tuesday, the international body said government commitments were only a third of what was needed. Non-state actors such as cities, companies and citizens can only partly fill this void, which leaves warming on course to rise to 3C or beyond by the end of this century, the report said.

The UN's environment chief, Erik Solheim, said progress in the year since the Paris agreement entered into force has been inadequate. "We still find ourselves in a situation where we are not doing nearly enough to save hundreds of millions of people from a miserable future," he said.



South Beach, Miami, would be mostly underwater. Photograph: Nickolay Lamm/Courtesy Climate Central

Nature's ability to help may also be diminishing. On Monday, the World Meteorological Organisation said concentrations of carbon dioxide in the atmosphere rose last year at a record speed to reach 403.3 parts per million - a level not seen since the Pliocene era three to five million years ago.

A 3C rise would lead to longer droughts, fiercer hurricanes and lock in sea-level rises that would redraw many coastlines. Depending on the speed at which icecaps and glaciers melt, this could take decades or more than a century. Colin Summerhayes of the Scott Polar Research Institute in Cambridge said three-degrees of warming would melt polar and glacier ice much further and faster than currently expected, potentially raising sea levels by two metres by 2100.

At least 275 million city dwellers live in vulnerable areas, the majority of them in Asian coastal megacities and industrial hubs such as Shanghai, Shenzhen, Bangkok and Tokyo.

Japan's second biggest city, Osaka, is projected to lose its business and entertainments districts of Umeda and Namba unless global emissions are forced down or flood defences are built up. Officials are reluctantly accepting they must now put more effort into the latter.

"In the past our response was focused on reducing the causes of global warming, but given that climate change is inevitable, according to the Intergovernmental Panel on Climate Change (IPCC), we are now discussing how to respond to the natural disasters that will follow," said Toshikazu Nakaaki of the Osaka municipal government's environment bureau.

In Miami - which would be almost entirely below sea level even at 2C warming - the sense of urgency is evident at city hall, where commissioners are asking voters to approve a "Miami Forever" bond in the November ballot that includes \$192m for upgrading pump stations, expanding drainage systems, elevating roads and building dykes.

Elsewhere, there is less money for adaptation and a weaker sense of urgency. In Rio de Janeiro, a 3C rise would flood famous beaches such as Copacabana, the waterfront domestic airport, and many of the sites for last year's Olympics. But the cash-strapped city has been slow to prepare. A report compiled for Brazil's presidency found "situations in which climate changes are not considered within the scope of planning".

In Egypt, even a 0.5m sea-level rise is predicted to submerge beaches in Alexandria and displace 8 million people on the Nile Delta unless protective measures are taken, according to the IPCC. But local activists say the authorities see it as a distant problem. "As far as I'm concerned, this issue isn't on the list of government priorities," said Ahmed Hassan, of the Save Alexandria Initiative, a group that works to raise awareness of the effects of climate change on the city.

The impacts will also be felt on the economy and food production. Among the most vulnerable areas in the UK is Lincolnshire, where swaths of agricultural land are likely to be lost to the sea.

"We're conscious that climate change is happening and perhaps faster than expected so we are trying to mitigate and adapt to protect people and property. We can't stop it, but we can reduce the risk," said Alison Baptiste, director of strategy and investment at the UK Environment Agency. She said the measures in place should protect most communities in the near and medium term, but 50 years from now the situation will become more challenging. "If climate change projections are accurate, we're going to have to make some difficult decisions."

*Additional reporting by Justin McCurry, Dom Phillips and Ruth Michaelson*

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# The three-degree world: the cities that will be drowned by global warming

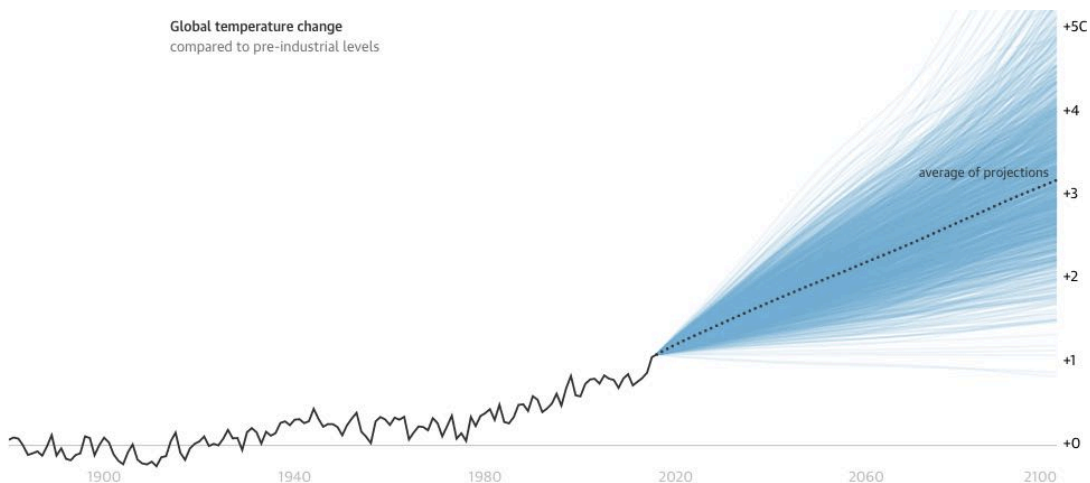
The UN is warning that we are now on course for 3C of global warming. This will ultimately redraw the map of the world

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When UN climate negotiators meet for summit talks this month, there will be a new figure on the table: 3C.

Until now, global efforts such as the Paris climate agreement have tried to limit global warming to 2C above pre-industrial levels. However, with latest projections pointing to an increase of 3.2C by 2100, these goals seem to be slipping out of reach.

Global temperature change  
compared to pre-industrial levels



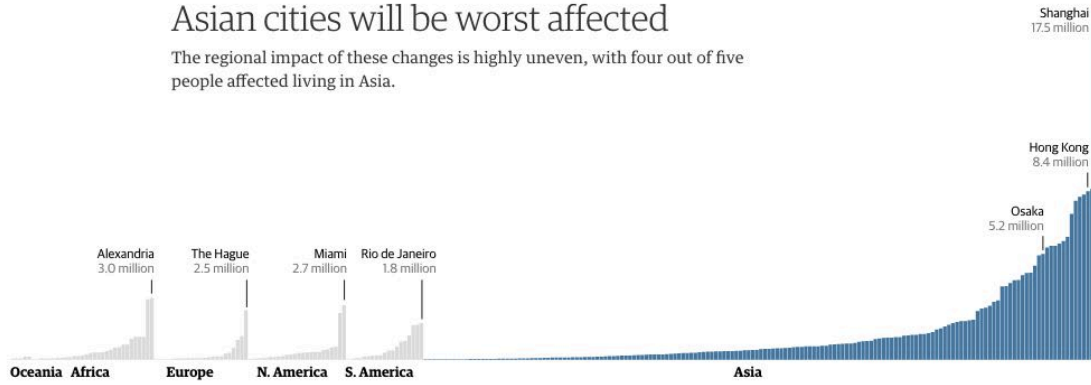
"[We] still find ourselves in a situation where we are not doing nearly enough to save hundreds of millions of people from a miserable future," said Erik Solheim, the UN environment chief, ahead of the upcoming Bonn conference.

One of the biggest resulting threats to cities around the world is sea-level rise, caused by the expansion of water at higher temperatures and melting ice sheets on the north and south poles.

Scientists at the non-profit organisation Climate Central estimate that 275 million people worldwide live in areas that will eventually be flooded at 3C of global warming.

## Asian cities will be worst affected

The regional impact of these changes is highly uneven, with four out of five people affected living in Asia.



Although sea levels will not rise instantaneously, the calculated increases will be “locked in” at a temperature rise of 3C, meaning they will be irreversible even if warming eventually slows down.

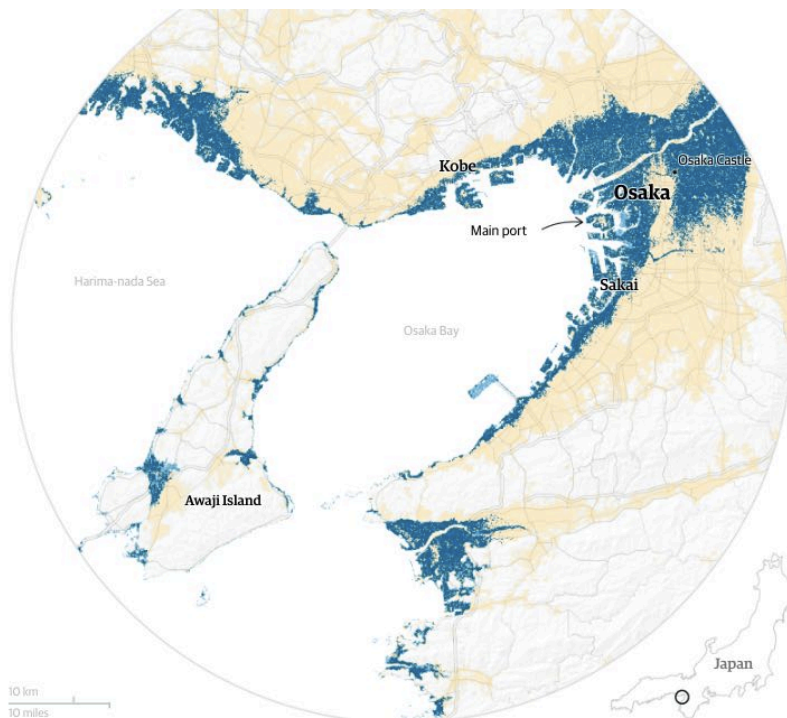
## Osaka, Japan

5.2 million people affected

At the end of a month in which it has been battered by unseasonably late typhoons and relentless rain, **Japan** is already confronting the threat posed by climate change-induced flooding.

Image modelling shows that swaths of Osaka – the commercial heart of a region whose GDP is almost as big as that of the Netherlands – would disappear beneath the water in a 3C world, threatening the local economy and almost a third of the wider region’s 19 million residents.

Millions of people live in the urban area surrounding Osaka. Sea-level rise will reshape densely and sparsely populated areas.



As a result of global sea-level rise, storm surges and other factors, economists project that coastal flooding could put almost \$1tn of Osaka’s assets at risk by the 2070s, according to the Union of Concerned Scientists.

“The costs of protecting cities from rising sea levels and storms are also likely to rise - as are the costs of repairing storm damage,” it said. “Decisions we make today could have a profound impact on the security and culture of the people of this ancient city.”

Like much of Japan, Osaka already has a network of seawalls and other coastal defences in place to combat tsunami – although their effectiveness was disputed in the aftermath of the 2011 triple disaster.

Osaka city authorities are investing in other infrastructure to mitigate the effects of flooding, but public education is also vital, according to Toshikazu Nakaaki of the Osaka municipal government’s environment bureau.

“In the past our response was focused on reducing the causes of global warming, but given that climate change is inevitable, according to the Intergovernmental Panel on Climate Change (IPCC), we are now discussing how to respond to the natural disasters that will follow,” Nakaaki said.

“We anticipate that Osaka will be affected by natural disasters caused by climate change, but we have yet to establish exactly what might happen or how much financial damage they would cause.

“It’s not that we expect sea levels to rise at some point in the future – they are already rising.”

Keiko Kanai has long been aware that her home city is susceptible to natural disasters. “I’d heard that historically, tsunamis caused by earthquakes put many parts of Osaka underwater, and I knew that some parts of the world were at risk from rising sea levels,” said Kanai, who teaches at a local university.

“But I didn’t put two and two together. Until now I haven’t given much thought to the idea that Osaka too could be engulfed by rising sea levels.”

Kaori Akazawa, a nursing care consultant, said flooding was a consideration when she was deciding where in Osaka to live.

“When I moved here I talked to my colleagues about the risks,” she said. “That’s why I’ve always rented apartments on the fourth storey or higher.”



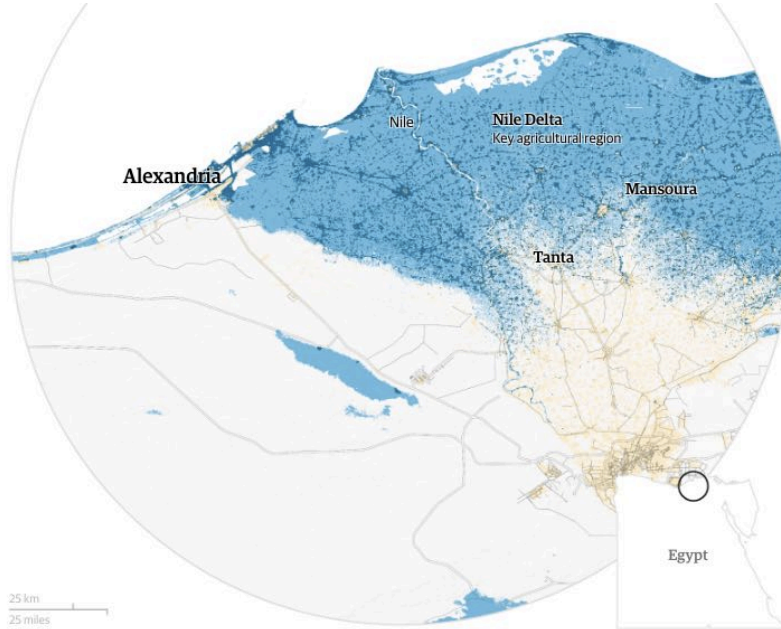
"It's worrying, but I've never considered moving."

*Justin McCurry in Tokyo*

## Alexandria, Egypt

3 million people affected

On the Alexandria Corniche, waves slowly lap at a shoreline dotted with plastic chairs and umbrellas from the beachside cafes. Students perch on the steps of the imposing Alexandria library. But the same coastline that draws locals to its scenic vistas is threatening to slowly engulf the historic city as sea levels rise due to global warming.



The IPCC reported that Alexandria's beaches would be submerged even with a 0.5-metre sea-level rise, while 8 million people would be displaced by flooding in Alexandria and the Nile Delta if no protective measures are taken. A 3C world threatens far greater damage than that.

Yet for many residents, there is little public information to connect the increasingly chaotic weather and floods with climate change. "The vast majority of Alexandrians don't have access to knowledge, and that's what worries me. I don't expect the government to raise awareness of this problem until it's already happening," said 22-year-old student Kareem Mohammed.

"Everyone thinks we should act on this problem 50 or 80 years from now," agreed his friend, Hazem Hassan, a student in marine biology at the nearby Alexandria University.

Officials maintain that protective measures are being taken, but with little fanfare. "Egypt spends 700m EGP [£30m] annually to protect the north coast," said Dr Magdy Allam, head of the Arab Environmental Experts Union, who was previously part of the Egyptian environment ministry.

Allam cited the Mohammed Ali sea wall built in 1830 as a key protection, as well as the concrete blocks lining the shoreline designed to "detour flood water away from residential neighbourhoods". But critics say that this is far from enough given the scale of the problem.

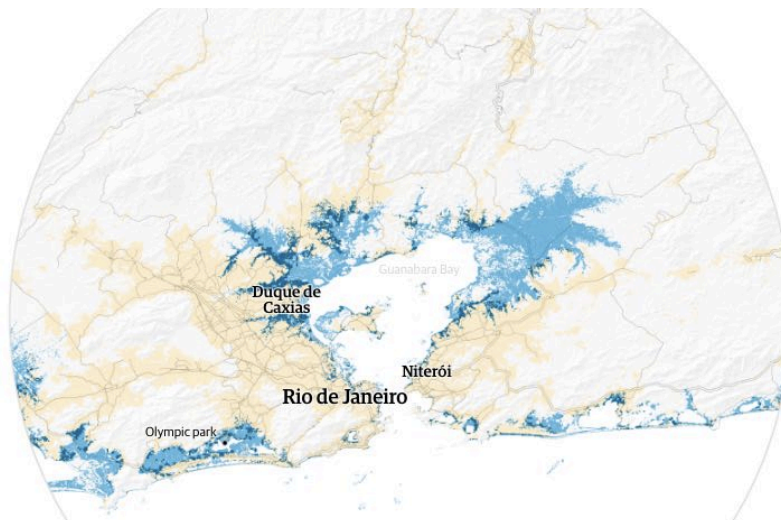
"There are studies indicating that our city is one of many coastal human settlements around the world which will be partially submerged by 2070 if nothing is done," said Ahmed Hassan, of the Save Alexandria Initiative, a group that works to raise awareness of the effects of climate change on the city.

*Ruth Michaelson in Alexandria*

## Rio de Janeiro, Brazil

1.8 million people affected

Residents of Brazil's postcard city have plenty of reasons to fear global warming – even if they don't quite know it. According to Climate Central, a temperature rise of 3C would cause flooding of not just Rio's famous beaches such as Copacabana and its waterfront domestic airport, but also inland areas of the Barra de Tijuca neighbourhood, where last year's Olympic Games were held.



Barra is built around a network of heavily polluted lagoons that empty into the sea. The prospect of it being underwater alarmed resident Sueli Gonçalves, 46, who runs pensioners' health projects, as she and her 23-year-old son Yuri Sanchez carried their shopping past the Olympic Park. "My God. Oh Jesus," she said, with a nervous laugh. "I will leave here. I will go to the United States. To Canada." The family knew about global warming but were unaware of the potential scale of the impact on their upscale neighbourhood of smart condominiums and a shopping mall. "Nobody takes it seriously. People do not think long term," Gonçalves said.

Storm surges recently destroyed hundreds of metres of beachfront pavement overlooking the Macumba beach, a popular surfing spot on Rio's western fringes. Last year, heavy waves in another storm surge felled an elevated, cliff-top cycle path between Leblon beach and Barra de Tijuca which had not been built to survive such high seas, killing two people.

Last year, Rio's city government and the Federal University of Rio de Janeiro produced a study entitled Strategy for Adapting to Climate Change. "The current challenge consists in deepening knowledge and monitoring of oceanic phenomena and the evolution of the sea bed and coast," a spokeswoman for the city's secretariat of the environment said in an email. An "adaption plan" for climate change produced with professors from the federal university suggested strategies to deal with vulnerabilities in areas such as transport, health and housing. But so far little has been done.

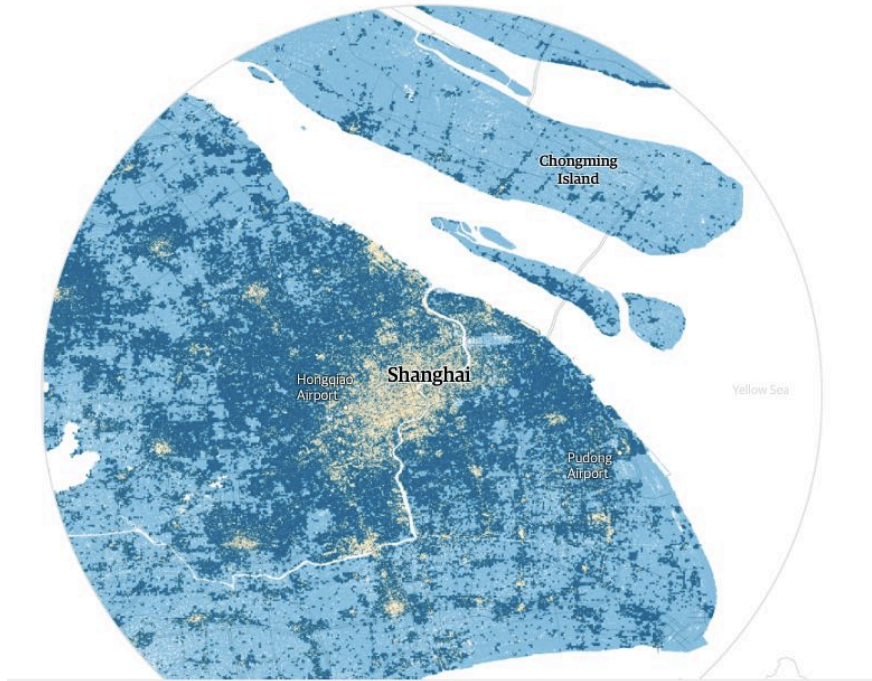
Nara Pinto, who lives in the sprawling Rocinha favela and sells snacks on the pavement overlooking Copacabana beach, said the loss of Rio's famous beaches would cost a lot of jobs.

"The beach is a tourist point," she said. "What can be done to stop this?"  
*Dom Phillips in Rio de Janeiro*

## Shanghai, China

**17.5 million people affected**

"Shanghai is completely gone – I'd have to move to Tibet!" says resident Wang Liubin, when he is shown projections for the city after 3C of global warming. When it comes to flooding, the coastal city is one of the world's most vulnerable. Now one of the world's biggest ports, the former fishing village is bordered by the Yangtze river in the north and divided through the middle by the Huangpu river; the municipality involves several islands, two long coastlines, shipping ports, and miles of canals, rivers, and waterways.



In 2012, a report from a team of UK and Dutch scientists declared Shanghai the most vulnerable major city in the world to serious flooding, based on factors such as numbers of people living close to the coastline, time needed to recover from flooding, and measures to prevent floodwater. According to Climate Central projections, 17.5 million people could be displaced by rising waters if global temperatures increase by 3C.

Projections show the vast majority of the city could eventually be submerged in water, including much of the downtown area, landmarks such as the Lujiazui skyline and the historical Bund, both airports, and the entirety of its outlying Chongming Island.

Since 2012, the government has been making steady inroads to tackle the threat, including building China's largest deepwater drainage system beneath the Suzhou Creek waterway, made up of 15km of pipes to drain rainwater across a 58 sq km area. It has also rolled out a 40bn yuan (£5bn) River Flood Discharge project which will stretch for 120km between Lake Taihu and the Huangpu river to try and mitigate the risk of the upstream lake flooding.

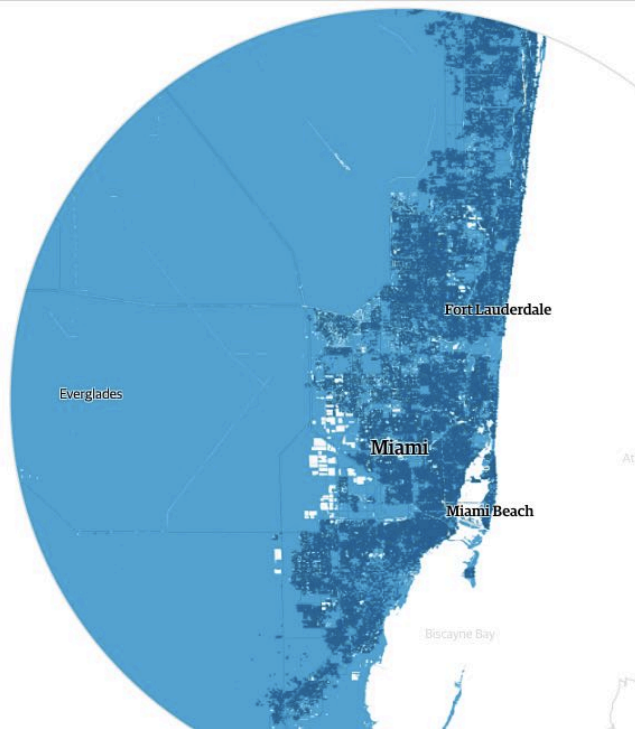
Flood prevention walls are being built along the waterfront – in places so high the river is blocked from view – and 200km more are promised across the city's outlying districts. Flood controls have been put in place along the famous Bund waterfront, where the walkway has been raised to help counter a flood risk, as well as a series of water controls and dams.

*Helen Roxburgh in Shanghai*

## Miami, US

**2.7 million people affected**

Few other cities in the world have as much to lose from rising sea levels as Miami, and the alarm bells sound ever louder with each successive "king tide" that overwhelms coastal defences and sends knee-deep seawater coursing through downtown streets.



Locals consider this the “new normal” in the biggest city of Florida’s largest metropolitan area, which would simply cease to exist with a 3C temperature rise. Even at 2C, forecasts show almost the entire bottom third of Florida – the area south of Lake Okeechobee currently home to more than 7 million people - submerged, with **grim projections** for the rest of the state in a little more than half a century. In Miami-Dade county alone, almost \$15bn of coastal property is **at risk of flooding** in just the next 15 years.

A sense of urgency is evident at city hall, where commissioners are asking voters to approve a “Miami Forever” bond in the November ballot that includes \$192m for upgrading pump stations, improving drainage and raising sea walls.

“We have a really precious city that many people love and are willing to invest in right now, but it’s going to take some funds to protect it,” said Ken Russell, the city commission’s vice-chair.

Last year, the city of Miami appointed sea-rise expert Jane Gilbert into the newly created role of chief resilience officer with instructions for a robust stormwater management plan that also looks at storm surge, such as that from Hurricane Irma in September which brought significant flooding to downtown Brickell and neighbouring Coconut Grove.

Proposals include elevating roads and even abandoning neighbourhoods to the water to protect others.

“We need universal recognition that we’re all in this together, to protect this amazing global city that we’ve become,” she said.

Natalia Ortiz, who grew up in Miami, fears the future. “It’s very scary,” said Ortiz, who works with Cleo, a climate change advocacy group. “My son is 11 and my daughter is nine, so they’re young but I think about their future, will they be able to raise their children in Miami the way I had the luxury of raising mine?”

*Richard Luscombe in Miami*

**Methodology**

*Flood maps were created using sea-level rise estimates from Climate Central and digital elevation data. Population estimates refer to urban agglomerations which comprise the built-up area of a city and the suburbs linked with it. Maps include OpenStreetMap data.*

*Temperature projections are based on University of Washington emissions modelling and UN warming estimates. Trajectories have been updated to match latest temperatures as recorded by the Met Office Hadley Centre.*