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Sovereigns – Global

Sea level rise poses long-term credit threat to a number of sovereigns

One consequence of climate change is a steady increase in sea levels. While there is a high degree of uncertainty about the magnitude, the direction of change is not in question – sea levels several decades from now will be largely determined by *past* greenhouse gas emissions and temperatures. Sea level rise is gradual, but manifests abruptly, by intensifying the frequency and severity of storm surges, flooding and tropical cyclones, which have credit implications for sovereigns.

» **Sovereigns in Asia, Middle East and North Africa (MENA) and small islands are most exposed to rising sea levels** Different studies yield similar results. Countries including Vietnam (Ba3 negative), the Bahamas (Baa3 stable), Egypt (B2 stable), Suriname (B2 stable) and some in the Gulf are highlighted, with up to 10%-25% of the population or GDP exposed. In absolute terms, the largest populations exposed are in Asia, including Bangladesh (Ba3 stable), China (A1 stable), Indonesia (Baa2 stable), and India (Baa2 negative). Some high-income economies, such as Japan (A1 stable) and the Netherlands (Aaa stable), also feature. Island sovereigns are not always in scope, but analyses of "locked-in" sea level rise in particular highlight the Cayman Islands (Aa3 stable), Maldives (B2 negative) and Fiji (Ba3 stable), with 80% or more of the population exposed.

» **Credit implications are wide-ranging** The economic and social repercussions of lost income, damage to assets, loss of life, health issues and forced migration from the sudden events related to sea level rise are immediate. The main credit channels for sovereigns are economic and fiscal strength. Vulnerability to extreme events related to sea level rise can also undermine investment and heighten susceptibility to event risk, by hindering the ability of governments to borrow to rebuild, increasing losses for banks, raising external pressures, and/or amplifying political risk as populations come under stress. While one isolated shock related to sea level rise is unlikely to materially weaken a sovereign's credit profile, repeated shocks could do.

» **Increase in frequency, severity of sea level-related disasters and effectiveness of adaptation will determine rating implications** Through our assessment of exposure and credit impact, we find that Vietnam, Egypt, Suriname and a number of small islands face material credit risk. The extent of risk will be determined by the pace of increase in the frequency and severity of natural disasters related to sea level rise, which is currently highly uncertain, and by the effectiveness of adaptation measures, so far largely untested.

Overview: Global sea level rise will accelerate significantly

Sea level rise is among the major trend manifestations of human-induced climate change, which is accompanied by shocks such as storm surges, flooding and land subsidence.[1]

Global sea levels have been rising for the past century, a result of meltwater from glaciers and ice sheets, and expansion of seawater as it warms. Since satellite records began in 1993, the average rate of sea level increase has been 3.2 millimetres per year.[2]

As temperatures continue to climb, the pace of sea level rise is likely to accelerate, resulting in significant social and economic costs for some countries.[3] Given the lagged impact of emissions on ocean warming, even if emissions were reduced to zero today, sea levels would continue to rise well into the future.

Based on the projections of various studies, we consider the implications of sea levels rising by 1-3 metres by 2100. For some countries, sea levels will temporarily reach higher levels due to storm surges and floods. As these events become increasingly frequent and severe, the exposure to and credit implications of sea level rise for sovereigns are likely to increase (see Highlight Box for a summary of available evidence).

Sea level rise in large part determined for the next 100 years

A number of studies, including by the United Nations' Intergovernmental Panel on Climate Change (IPCC), find that sea levels are positively correlated with surface temperatures, which themselves are linked to global emissions of greenhouse gases.

There is no one-to-one correspondence between carbon emissions, temperature increases and sea level rise. But there is very broad consensus and, according to the IPCC, high confidence that the pace of global mean sea level rise will steepen markedly in the second half of this century.

An update[4] by the IPCC released in September 2019 projects sea levels to rise 0.4-0.8 metres on average by 2100 relative to 1986-2005, based on various emission scenarios, marking annual increases that range between 4-15 millimetres.

The lower bound of these estimates corresponds to RCP 2.6 – the lowest of the IPCC's Representative Concentration Pathways, which are scenarios of different rates of change of greenhouse gas emissions. It is also in line with Paris Agreement goals, under which greenhouse gas emissions stabilise following policy action late this century. But, judging from announced climate change mitigation measures and actual implementation, there is a broad consensus that RCP 2.6 looks increasingly ambitious.

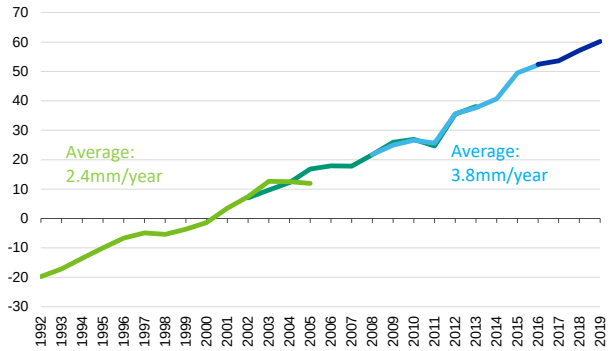
Under the RCP 8.5 scenario, where emissions continue to rise in the absence of new policy action, sea level rise would be close to 1 metre on average globally.[5]

The IPCC's projections appear to be toward the lower end of scientific studies. Looking at the evidence available, even a 1-metre rise may be a relatively favourable scenario, with most studies pointing to rises between 1-3 metres[6] by 2100. And while the IPCC's projections take into account some ice sheet decay from glaciers, Greenland and Antarctica, the instability of Antarctic ice may result in a more significant rise in sea levels.[7]

Moreover, tail events will result in much larger increases in sea levels, at least locally and temporarily. In particular, and before 2100, storm surges and floods are likely to expose a number of countries and regions to short-lived but increasingly frequent increases in sea levels of more than 1 metre. In fact, as climate risk data company Four Twenty Seven, a Moody's affiliate, points out in a recent report, in the next two to three decades the main uncertainty about the severity of climate change including sea level rise and related events stems less from the path of future global emissions than from the effects of past emissions.[8]

Exhibit 1

Sea level rise has increased over the past decade
(Change in global mean sea level, millimetres)



The different lines correspond to measurements by different satellites
Source: NOAA using findings from TOPEX/Poseidon, Jason 1, Jason 2 satellite radar altimeters

Exhibit 2

IPCC's projections point to global sea level rise of up to close to 1 metre on average in a high emissions scenario
(Median values for global mean sea level rise vs 1986-2005, metres)

	RCP 2.6	RCP 4.5	RCP 8.5
2031-2050	0.17	0.18	0.20
2046–2065	0.24	0.26	0.32
2081–2100 (AR 5+ Antarctica)	0.39	0.49	0.71
In 2100	0.43	0.55	0.84
Rate (mm/yr)	4.00	7.00	15.00

AR5 refers to the IPCC's earlier projections in the Fifth Assessment report in 2014. Adding the projections on Antarctic contributions has resulted in higher estimates.
Source: IPCC

Sovereigns in Asia, MENA and small islands are most exposed

We incorporate material environmental risk, including sea level rise, into our assessment of sovereign credit profiles. We judge environmental considerations to be material when we are relatively confident that a sovereign is – or will be – exposed to them and that this exposure will have a credit impact.

Exhibit 3

Various studies come to similar conclusions on countries that are exposed to sea level rise

	World Bank	Kopp et al (2017)	ND-GAIN	Climate Central
Exposure indicators	Various (GDP, population, land, agriculture, urban area; %)	Population (% total)	Land (% total)	Population (absolute terms)
Methodology	Estimates the proportion of inundated zones in a given GMSL scenario	Links projections of GMSL with Antarctic ice sheet probabilities	Proportion of ocean-adjacent land lower than 4m above sea level	Introduces new coastal digital elevation method
Global mean sea level rise	1-3m	3m	4m	0.4-0.9m
Exposed sovereigns	Vietnam	Netherlands	Bahamas	China
	Egypt	Vietnam	Bahrain	Bangladesh
	Bahamas	Suriname	Denmark	India
	Suriname	Macao	Maldives	Vietnam
	Tunisia	UAE	Netherlands	Indonesia
	UAE	Bangladesh	Singapore	Thailand
	Benin	Japan	Vietnam	Philippines
	Ecuador	Bahrain	Qatar	Japan
	China	Thailand	Saint Vincent	Egypt
	Belize	Hong Kong	Solomon Islands	Netherlands

GMSL: Global Mean Sea Level. Shaded areas depict sovereigns that are marked as exposed on multiple studies. Sovereigns are represented in no particular order of exposure.
Sources: World Bank, Kopp (2017), Climate Central and Four Twenty Seven

Various studies rely on the same broad approach, combining projections or assumptions about the extent of sea level rise with estimates of the population or size of the economy below certain elevations (see Exhibit 3). Differences stem from the methods used to project sea levels and measure elevation, as well as the geographic scope of the studies.

These studies yield similar results. Vietnam is one of the most exposed sovereigns to sea level rise, whether measured by the share of the population, land area or economic activity threatened. Others include Bahrain (B2 stable), Egypt, Suriname and islands such as the Bahamas, Cayman Islands, Fiji and the Maldives.

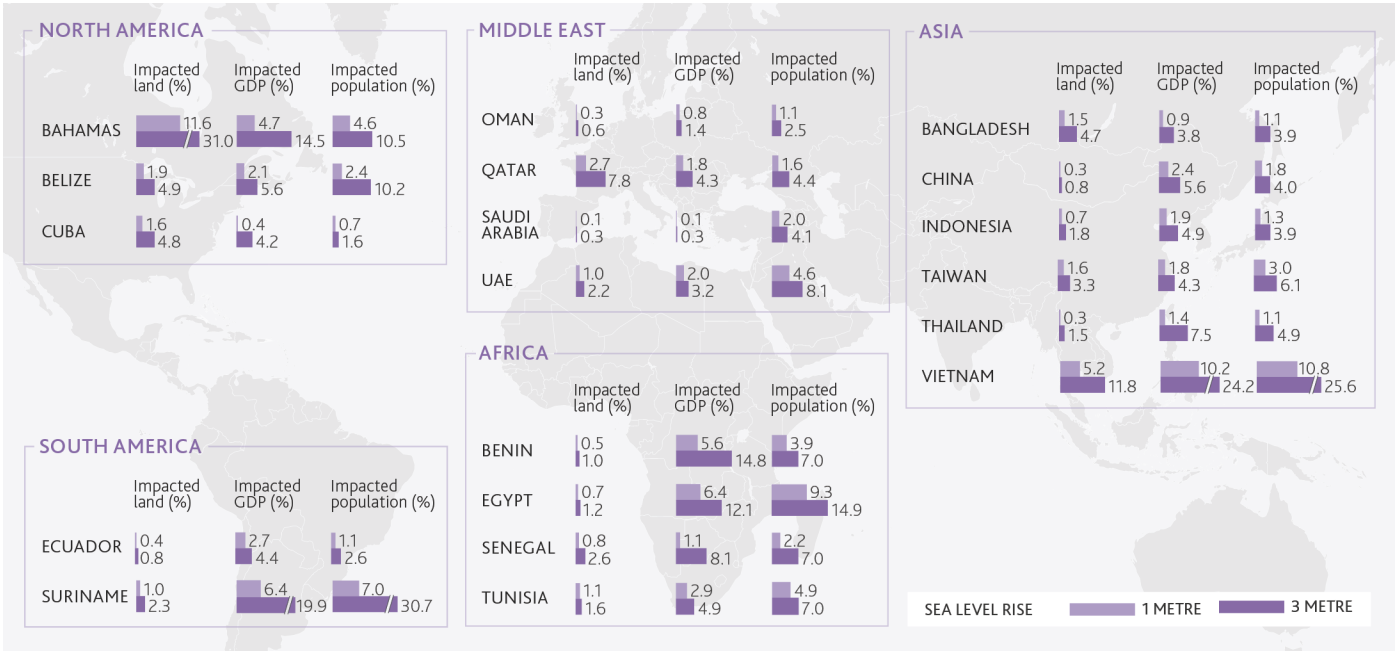
Whether measured as a share of GDP or population, exposure is significant for some sovereigns

World Bank analysis[9] estimates the exposure of GDP and other economic parameters to sea level rise by 2100.

According to the study, which looks at 84 developing economies, **a 1-metre rise in sea levels** would affect 1.3% of the population of these countries or 56 million people, based on the population size in 2000 – most likely significantly more based on today's population and population density – and 0.3% of their land area (see Exhibit 4).

Exhibit 4

In a World Bank study, countries in APAC and MENA are most exposed to sea level rise
(Based on distribution of GDP and populations in 2000)



Study does not include advanced economies and a number of small islands.
Sources: Moody's Investors Service and World Bank

The average conceals much larger exposure in some countries, in particular in East Asia and MENA, and a concentration of exposure within them. Moreover, the geographic coverage of this research, while broad, does not include all rated sovereigns. In particular, some small-island economies that likely face significant repercussions from sea level increases do not feature.

The rated sovereigns with the largest shares of population whose living areas would be submerged are Vietnam, Egypt and Suriname. The greatest inundation by proportion of land area would be in the Bahamas, followed by Vietnam and Qatar (Aa3 stable). Measured by GDP, the World Bank finds that exposure is greatest in Vietnam (10.2% of GDP), Egypt (6.4%), Suriname (6.4%) and Benin (B2 positive, 5.6%).

Taking a broader view of exposure, by combining several indicators (GDP, population, land area, agricultural area, degree of urbanisation, wetlands), Vietnam, Egypt, Suriname and the Bahamas feature among the most exposed countries.

In a scenario where **sea level rise reaches 3 metres**, the population below sea level more than doubles to 3% of the total population, according to the World Bank study. Suriname, Vietnam and Egypt remain the most vulnerable, with 31%, 26% and 15% of their populations exposed respectively. Vietnam and Suriname are also the most exposed countries by economic output, followed by Benin and the Bahamas.

To extend our analysis, we look at another study, Kopp et al (2017),[10] which links projections of Antarctic ice sheet changes with a sea level rise projection framework. The study finds that proportions ranging between 10-41% of the populations of the Netherlands, Vietnam, Suriname, Macao (Aa3 stable) and the United Arab Emirates (UAE, Aa2 stable) live on land that will be submerged by 2100, based on a 1-metre rise in sea levels under a RCP 8.5 scenario (see Exhibit 5).

The study uses projections that estimate sea level rise ranging between 0.8-1.5 metres under a high emissions (RCP 8.5) scenario, and between 0.5-0.6 metres under a low emissions (RCP 2.6) scenario, broadly consistent with the IPCC's estimates. Differences in exposure estimates from the World Bank study stem in part from different geographic scope. But Vietnam and Suriname feature among the most exposed in both studies.

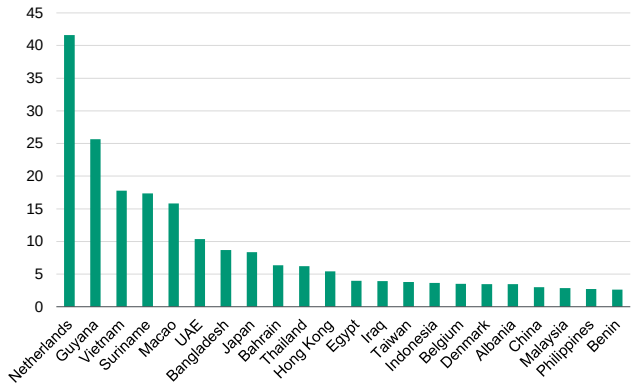
Another recent study by Climate Central,[11] published in October 2019, uses the estimates of Kopp et al (2014),[12] which are based on sea level rise ranging from 0.3-0.8 metre (RCP 2.6) to 0.5-1.2 metre (RCP 8.5), and combines these with a new method to measure coastal elevation and determine population exposure. This methodology to estimate elevation has not been used more widely so far. It finds that, by 2050, land occupied by 300 million people will fall below the elevation of an average annual coastal flood, up from 250 million currently. By 2100, land home to 200 million people could sit permanently below the high-tide line, up from 110 million currently. In both the mid-century and 2100 projections, the largest exposed populations in absolute terms are in Asia, in China, Bangladesh, India, Vietnam, Indonesia and Thailand (Baa1 positive). Climate Central finds that the starting point, 2050 and 2100 exposures are all larger than estimates based on previous elevation estimation technology.

Other types of risk indicators, such as the Notre Dame Global Adaptation Initiative (ND-GAIN) indices, calculate the proportion of a country's land area adjacent to the ocean that is lower than 4 metres above sea levels. Based on ND-GAIN data, Bahamas, Bahrain, Denmark (Aaa stable), Maldives, the Netherlands, Singapore (Aaa stable) and Vietnam are among the most exposed (see Exhibit 6).

Exhibit 5

Separate studies find that populations in Netherlands, Vietnam, Suriname and Macao are significantly exposed

(% share of population below sea levels by 2100, rated countries only)

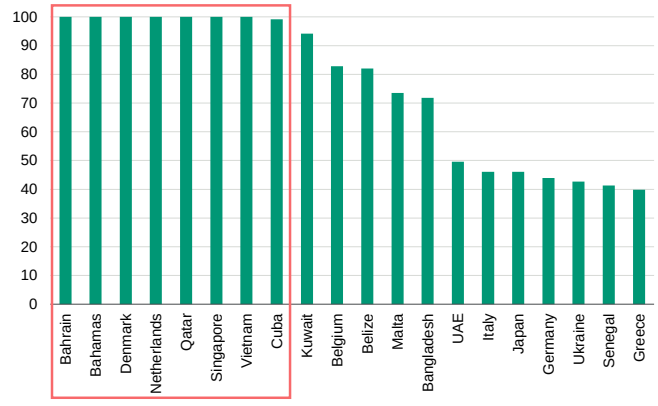


Source: Kopp et al (2017)

Exhibit 6

Sovereigns gauged to have land area that is significantly exposed to higher sea levels are similar across most studies

(Score for land area exposed to a 5-metre rise in sea level)



Source: Four Twenty Seven

Impact of eventual, already irreversible, sea level rise is even larger

In all the studies above, the projected or assumed sea level rise is largely dependent on past emissions. Past emissions will also lead to further increases in sea levels beyond 2100. "Committed" or "locked-in" sea level rise – which will occur independent of efforts to mitigate global warming and is based on cumulated emissions to date – is the subject of a number of research studies.

These studies quantify the ultimate rise in sea levels, rather than providing estimations over a particular horizon. The exposure revealed in these studies is relevant to our sovereign credit analysis since it is likely to correlate to exposure to more frequent and severe natural disasters in the next few decades.

Strauss et al (2015) find that cumulative emissions through 2015 have *already* locked in 1.6 metres of global sea level rise relative to the present level. This figure rises to 2.2 metres after factoring in future emissions implied by current energy infrastructure. Under RCP 2.6 or RCP 8.5, by 2100, committed sea level rise reaches medians of 2.4 or 7.1 metres, respectively.[13]

These findings form the basis of another analysis by Climate Central, assessing the implications of locked-in sea level rise across countries.[14] Combining the analysis on sea level rise with data on elevation, the study indicates that the population shares at risk of submersion will be largest in small island economies.

If temperatures were to rise by 3 degrees Celsius (C), affected rated sovereigns would include Cayman Islands with 83% of the population submerged, Suriname (81%) and Bahamas (67%, see Exhibit 7). If warming were limited to 2 C, the most affected sovereigns would be similar, but the share of population below sea level would reduce by 2-18 percentage points.

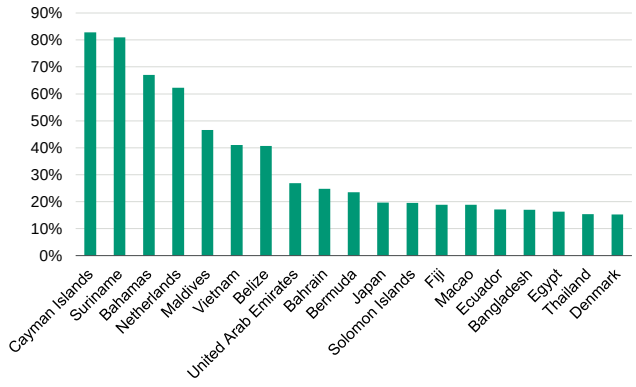
Outside small island economies, the most exposed countries when considering locked-in sea level rise are Vietnam, Bahrain, the UAE and Bangladesh. Among advanced economies, the Netherlands and Japan are particularly at risk.

Major cities that would be submerged include Alexandria, Bangkok, Dhaka, Dubai, Ho Chi Minh City, Miami Aa2 stable) Mumbai and Shanghai. Various cities around the Pearl River Delta would also be impacted, as would some Tier 2 cities in Asia. In the Netherlands, more than 95% of the population would be at risk of submersion in The Hague and Amsterdam.

Credit implications are wide-ranging

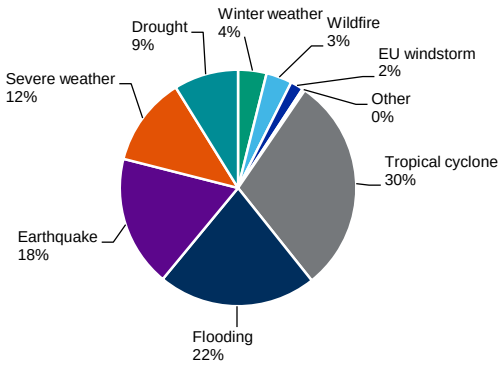
Sea level rise is a gradual trend, projected to take place over centuries. Much more visible now are the associated shocks, including storm surges, flooding and tropical cyclones. These unpredictable shocks have accounted for more than one-half of aggregate climate- and weather-related economic losses since 2000, according to risk management and reinsurance service provider, Aon Plc (Baa2 stable, see Exhibit 8).

Exhibit 7
Impact of irreversible sea level rise is even greater
(Percentage of population affected under a 3 C scenario)



Source: Climate Central (2015)

Exhibit 8
Sea level-related events such as cyclones and flooding have driven weather-related losses
(Economic loss by cause since 2000)



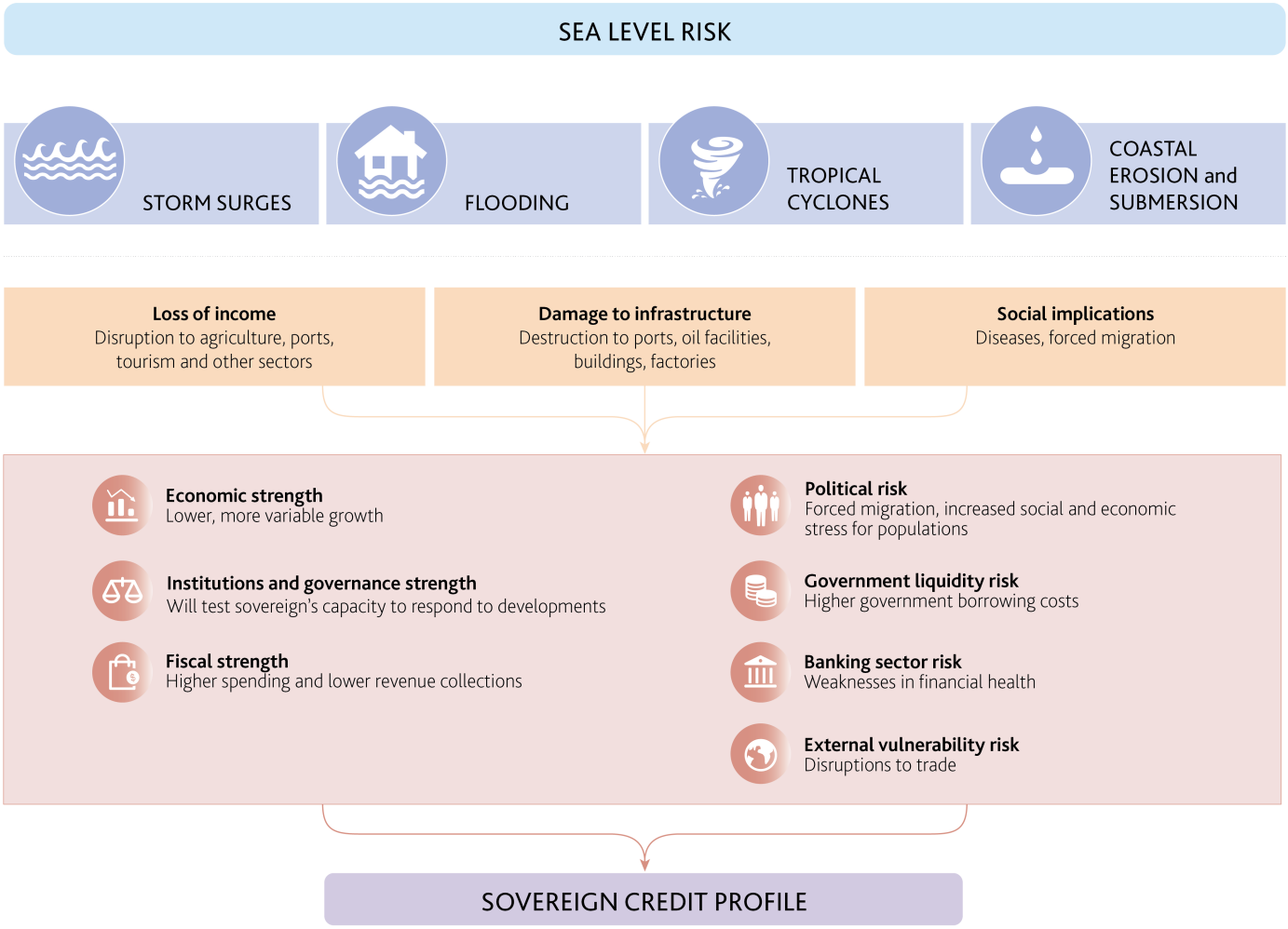
Source: AON

Our credit assessment factors in the likely impact of plausible shocks related to sea level rise. As their frequency and severity increases, we may take into account the credit impact of possible shocks for a rising number of exposed sovereigns. In the event of a shock, evidence that the affected sovereign is less able to recover than we had assumed could also exert downward credit pressure.

Such trends and shocks mainly impact sovereigns' credit profiles through their effect on economic and fiscal strength (see Exhibit 9).

Exhibit 9

Rising sea levels and associated effects will have credit implications for affected sovereigns through a range of channels



Source: Moody's Investors Service

They may also raise a sovereign's susceptibility to event risk, by hurting investor confidence at a time when the country is borrowing to rebuild, increasing losses for banks, heightening external pressures, or raising social risk as populations come under significant stress.

For a given degree of exposure, different sovereigns may face different credit impacts depending on the strength of their institutions and governance, economic structures and fiscal health.

While one isolated sea level rise-related shock is unlikely to weaken a sovereign's credit profile materially, repeated shocks could do, especially for those with weak fiscal or external starting points.

Sovereign credit profiles factor in environmental risk, where material

Loss of income

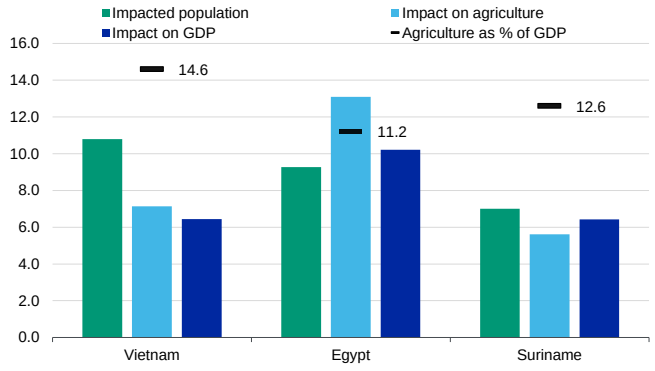
For countries with a sizeable proportion of land and population at risk of submersion, sea level rise will lead to relative income loss as a trend when coastal economic activity is no longer possible, and through shocks when cyclones, floods and other severe weather events interrupt output. Gradual trends and repeated shocks will curb investment and potential growth, and raise economic volatility.

This will hurt the **economic strength** of these sovereigns, in the absence of offsetting positive economic changes. The impact on economic strength is likely to materialise through several areas of economic activity:

» **Agriculture** For Vietnam, Egypt and Suriname, which have large populations exposed to sea level rise, the share of agriculture in employment and GDP is sizeable (see Exhibit 10). Lower agricultural yields resulting from crop damage due to sea level rise would persistently curb incomes. In Vietnam, in particular, the Mekong River and its tributaries form the country's "Rice Bowl" – four-fifths of the population living in the area is engaged in rice production – which faces inundation. Meanwhile, Egypt's Nile Delta, which provides more than 60% of the country's agricultural output, is experiencing rising sea levels and salinisation.

Exhibit 10

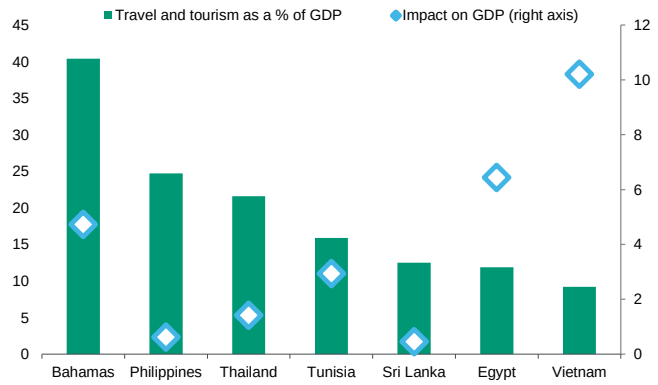
Agriculture – a key sector in Vietnam, Egypt, Suriname – is exposed
(Exposure under a 1-metre rise in sea levels, % of total)



Sources: World Bank and World Development Indicators

Exhibit 11

For some countries, the hit to GDP will come through tourism
(GDP exposure to 1-metre sea level rise, %)



Sources: World Bank, and World Travel and Tourism Council

» **Tourism** Over time, coastal erosion or concerns about natural disasters may make some regions less attractive to tourists. For a number of small-island sovereigns, such as the Bahamas, Belize (B3 stable), Fiji or Maldives, tourism is a driver of economic activity, and a major source of export revenue and foreign exchange (see Exhibit 11).

» **Trade** Coastal cities are often densely populated and serve as ports and nodes for regional and global supply chains and trade. Several ports in Asia are particularly exposed to sea level rise. For Vietnam, Singapore and Hong Kong (Aa2 negative), unmitigated repeated or long-lasting disruption to the main ports' activity would hurt trade and GDP growth. Thailand, India, China and the US (Aaa stable) also have large port cities that are exposed to sea level rise, but the impact on these sovereigns' economic strength will be limited by the number of ports and their size (sovereigns with a limited number of trade hubs may face more disruption), the greater diversification of their economies, and lower reliance on exports as a source of economic revenue. Domestic transportation networks beyond ports can face disruption from rising sea levels, with knock-on effects on the economy as a whole.

Permanently lower growth may weaken a government's **fiscal strength**. Moreover, government compensation for lost income through higher spending or tax moratoria would widen budget deficits and raise debt. Among the sovereigns exposed to sea level rise, fiscal strength is particularly weak in Egypt, Bahamas, Belize, Suriname and Tunisia (B2 negative).

A significant hit to the tourism sector or a long-lasting shock to exports could also raise **external vulnerability risk.**

» **Tourism** While tourist inflows generally recover following natural disasters, the recovery period varies, and can be longer in the aftermath of more extreme events. In the Bahamas, storms or hurricanes have not hit key tourist destinations recently, but Hurricane Matthew in 2016 resulted in a slowdown in tourist inflows to Grand Bahama, which are yet to recover to pre-2016 levels. We see similar vulnerabilities for Belize and the Maldives, where we already assess external vulnerability risk to be elevated.

» **Trade** Weaker trade flows were apparent, for example, following Cyclone Idai on Mozambique (Caa2 stable). In Fiji, following Cyclone Winston, the current account deficit widened to 5.4% of GDP in 2016 from 1.5% in 2015, as exports of timber and sugar fell, and imports rose to support reconstruction.[15]

Damage to infrastructure and assets

Sea level rise and its associated effects have the potential to damage assets, including infrastructure, buildings and vehicles. The consequences would materialise on a sovereign's fiscal strength, and likely also impair economic strength.

In terms of **economic strength**, loss of income and assets is often pronounced for what the IPCC describes as "coastal megacities", where a dense population and infrastructure, coupled with a high concentration of income and wealth, result in greater degrees of exposure. Examples include Typhoon Winnie which struck Shanghai in 1997 and Hurricane Sandy in New York (Aa1 stable) in 2012. They are also apparent for small-island cities (Male), and agricultural deltas (the Mekong Delta in Vietnam, and the Ganges-Brahmaputra-Meghna Delta, which mostly lies in Bangladesh and India). Various countries that are categorised as exposed have populations and economic activity concentrated in key cities, such as Ho Chi Minh City, Alexandria, Dhaka, Mumbai and Shanghai.

While asset rebuilding and rehabilitation efforts often support growth in the aftermath of natural disasters, over the longer term such events are detrimental since assets are destroyed or damaged before the end of their economic life, lowering productivity and hindering growth potential.

Some analyses point out that as asset owners become more acutely aware of the vulnerability of sea level rise in various areas, property prices could either sharply correct lower or see a steady downtrend, resulting in high household debt that may create economic and financial market instabilities.[16]

On **fiscal strength**, for low-income sovereigns, the recovery costs following severe natural disasters are generally at least partly funded by multilateral or bilateral donor support or concessional loans, which limits direct fiscal deterioration. Insurance can also cover part of the cost. The Pacific Islands, for instance, have developed the Pacific Catastrophe Risk Insurance Company, under which policies are designed to pay out within 10 days of a triggered event. The Caribbean has a similar scheme. However, payouts under such platforms are typically not large enough to cover all losses. As shocks become more frequent and severe, availability of affordable insurance may shrink and the willingness of donors to continue to provide support may be tested.

Hanson et al.[17] calculate the exposure of the world's large port cities to coastal flooding due to sea level rise, including storm surges, at around 5% of global GDP in 2005. By the 2070s, the study estimates asset exposure to increase to around 9% of projected global GDP. The study assumes a homogeneous 0.5-metre rise in sea levels. As such, the actual costs to the most exposed port cities are likely to be greater. Cities with the largest value of exposed assets are currently in the US, the Netherlands and Japan. But, by the 2070s, the study finds that asset exposure will be concentrated in China, US, India, Japan, the Netherlands, Thailand, Vietnam and Bangladesh. A large projected increase in wealth and population in many Asian cities drives a sharp rise in asset exposure.

Damaged assets can also hurt bank asset quality, potentially raising **banking sector risk** for sovereigns. For instance, following a hurricane strike, banks may face deposit withdrawals and find it difficult to access funding.[18]

Social implications

Sea level rise also has social implications, mainly through loss of life, and additionally its impact on health and migration. Such social considerations can hurt **economic strength**, via growth rates and per-capita income. They can also challenge a sovereign's

institutions and governance strength, depending on its ability to address demands linked to water-related events. If the electorate perceives the government as unable to address these demands, this could spark social discontent, challenging political stability.

Flooding and some associated effects of sea level rise compound water- and vector-borne diseases. When combined with a disruption of health and sanitation services, this can result in epidemics or, under more severe conditions, pandemics. These effects would be most acutely felt in densely populated cities, where emergency infrastructure facilities may be available but come under significant pressure during such extreme events. This would weigh on near-term growth.

Another social aspect of sea level rise is migration and population movement. This is an adaptation response when carried out in a planned manner. However, cyclones or flooding will lead to forced relocations. For countries with scarce resources or existing divisions (regional, ethnic, income), this may raise the risk of conflict, possibly exacerbating **political risk**, either domestic or geopolitical.

Increase in frequency, severity of sea level-related disasters and effectiveness of adaptation will determine rating implications

We focus on the most exposed sovereigns according to the various studies cited above, taking into account how frequently and prominently a given country is highlighted. We combine exposure with our assessment of institutions, economic and fiscal strength, to derive an assessment of the credit impact of sea level rise.

Sea level rise and related shocks pose material credit risk to **Vietnam, Egypt, Suriname**, the **Bahamas** and other small island sovereigns, including **Maldives** and **Fiji**. The pace of increase in the frequency and severity of natural disasters related to sea level rise and the effectiveness of adaptation measures will determine the extent of the credit constraints that these sovereigns face.

A relatively gradual increase in the frequency and severity of sea level-related disasters would give governments some time to adapt. But if the manifestations of sea level rise intensify abruptly, without effective adaptation, these sovereigns may face some downward rating pressure. As scientific evidence on changes in the frequency and severity of sea level-related shocks evolves, and mitigation measures are tested, our assessment of the credit implications may change.

Bangladesh, India, Indonesia, **Thailand** and the **Philippines** (Baa2 stable) are less exposed, but may also face challenges addressing these risks, and as such could experience some related credit pressure. The **Netherlands, Japan** and **China**, conversely, are exposed, but countermeasures by the local authorities and their credit strengths mean they are unlikely to suffer a material credit impact.

Vulnerable sovereigns tend to resort to a combination of adaptation measures

The effectiveness of adaptation measures is largely untested, and the financial cost as yet unknown. The IPCC divides climate change adaptation measures into three categories:

Protection — Includes "hard" measures, such as building seawalls and other barriers to protect critical infrastructure, and "soft" measures, including increasing coastal vegetation and restoring mangroves to reduce erosion and make the coast a stronger barrier to storm surges;

Accommodation – Includes retrofitting buildings to make them more resistant to the consequences of sea level rise, raising low-lying bridges, or increasing physical shelter capacity;

Managed retreat – Involves moving away from the coast. May be the only viable option.

Most cities and coastal communities resort to a combination of all three measures. Affected areas often aim to emulate initiatives by coastal cities in the Netherlands, which have included decentralising water management functions, and building dykes, dams, seawalls and reservoirs.

Lower-rated sovereigns are undertaking adaptation measures, with so far untested effectiveness

In **Vietnam**, a number of projects have focused on adapting to flood stresses, including upgrading Ho Chi Minh City's storm sewer system. Authorities are also looking to construct a large sea wall or tidal barrier, and ring dykes to protect the city. In rural areas, studies find that households are veered toward soft coping mechanisms, including diversifying sources of income, and shifting to less vulnerable crops.

The policy framework in **Egypt** is anchored on a National Adaptation Strategy that seeks to strengthen agricultural security, protect touristic and archaeological sites, carry out coastal zone management initiatives, and even relocate the city of Alexandria.

In **Suriname**, the government has established a National Coordination Center for Disaster Relief, which is aimed at disaster risk prevention and collaboration with regional governments. It is also developing a coastal plain strategy, including protection of mangroves and other natural defences, fortification and strengthening the resilience of key infrastructure susceptible to flooding, such as canals and urban drainage systems, and via riverbank protection works. The country's National Development Plan includes developing catastrophe risk insurance to lessen the impact of floods and climatic shocks.

In the **Bahamas**, a regulatory framework is in place to curb the effects of sea level rise. However, a lack of coordination among institutions, and a high degree of private ownership of coastal lands hamper these efforts.

In other small-island economies, relocation measures are proceeding, often at a more urgent pace. In the **Maldives**, the government has built a new island to relocate the population of and ease congestion in its capital Male, and is fortifying sea defences on its existing islands. Protection of existing natural barriers, such as coral reefs, will be an integral part of managing the effects of sea level rise.

In **Fiji**, government efforts to manage sea level rise are underway, with considerable support from international agencies. The primary focus has been on relocation, with the government releasing planned relocation guidelines and identifying 48 communities as being in urgent need of relocation. Additionally, the authorities have proposed initiatives to alleviate flooding and inundation in the Nadi Basin, including hard protection and engineering measures (ring dykes, river widening, bridge rebuilding, dams and diversion channels) and accommodation measures (early flood warnings, improved land management practices in upper basin).

Some emerging markets may see aspects of their credit profiles weaken

Several large emerging market sovereigns, including India, Indonesia, Thailand and the Philippines, as well as other smaller economies, such as Bangladesh, are also identified as being exposed to sea level rise. Based on various studies, the exposure of these sovereigns appears significantly lower than for those we identify above. However, they too are likely to experience increasingly frequent and severe water-related shocks.

Many of these sovereigns have begun taking action. In 2019, **Indonesia** announced that it would move its capital away from Jakarta to the island of Borneo, to relieve the city from congestion and overcrowding, and because parts of the city are sinking below sea levels. Jakarta is also building sea walls, and planning to relocate communities away from threatened riverbanks and reservoirs.

In **Thailand**, Bangkok is building an extensive canal network and central park with capacity to drain 4 million litres of rainwater into underground containers.

Higher-rated sovereigns should face limited credit impact, although their adaptation capacity will be tested too

Some higher-rated sovereigns are also exposed to sea level rise, notably Japan, Singapore, Hong Kong, the Netherlands and China. Mitigating and adapting to risks will test even those with very high institutional strength and significant capacity to respond, but the credit implications will be limited compared with lower-rated sovereigns that have weaker institutions and fiscal strength.

Across **China**, the government has been building "sponge cities" where stormwater is collected or absorbed by wetland and rooftops to reduce run-off and counter floods. By 2020, China hopes that 80% of its urban areas will absorb and re-use at least 70% of rainwater. In Shanghai, the government has constructed extensive protective seawalls.

In the **Netherlands**, more than 40% of the population is exposed to sea level rise, but a very concerted policy focus has ensured that flood protection systems are the most stringent in the world, with defences in some areas sufficient to withstand 1-in-10,000-year disaster events.[19]

Moody's related publications

Sector In-Depth

» Sovereign credit implications of environmental, social and governance risks (presentation), December 2019

» Environmental Risks - Sovereigns - Credit profiles of small, agriculture-reliant sovereigns most susceptible to climate change risk, May 2018

» Environmental Risks – Global - Heat map: 11 sectors with $2.2 trillion debt have elevated environmental risk exposure, September 2018

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Endnotes

1 See Committed sea-level rise under the Paris Agreement and the legacy of delayed mitigation action, Nature, February 2018

2 See NASA data here.

3 Widely researched, as for example in Nicholls (2011), Hinkel et all (2014) and other literature referenced later in this report.

4 See Chapter 4: Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities, IPCC SR Ocean and Cryosphere, June 2019

5 A high-emission scenario of RCP 8.5 would imply that temperatures rise by around 3-4 degrees Celsius. To meet the Paris Agreement target of keeping the global average temperature to less than 2 C above preindustrial levels, global greenhouse gas concentration would need to fall within RCP 2.6, which calls for "stringent and immediate" mitigating efforts.

6 For instance, see Risk of sea-level rise: high stakes for East Asia & Pacific region countries, Susmita Dasgupta, World Bank, March 2018

7 See Antarctic model raises prospect of unstoppable ice collapse, Nature, March 2016; Church et al (2001)

8 See Demystifying Climate Scenario Analysis for Financial Stakeholders, December 2019

9 See Dasgupta et al (2007)

10 See Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections

11 See Flooded Future: Global vulnerability to sea level rise worse than previously understood, Climate Central, October 2019

12 See Earth's Future: Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites, August 2014

13 See Carbon choices determine US cities committed to futures below sea level, Proceedings of the National Academy of Sciences, November 2015

14 See Mapping Choices: Carbon, Climate, and Rising Seas, November 2015

15 See Sovereigns - Africa: Cyclone Idai weakens Mozambique, Malawi and Zimbabwe growth and fiscal metrics, March 2019; and Government of Fiji: FAQ on climate change risk, policy effectiveness, and the country's fiscal and economic outlook, September 2017

16 See What are the Major Economic Implications of Sea Level Rise?, Union of Concerned Scientists, July 2018

17 See A global ranking of port cities with high exposure to climate extremes, Hanson et al., 2010

18 See, for example, The impact of natural disasters on the banking sector: Evidence from hurricane strikes in the Caribbean, May 2019

19 See Developments in the management of flood defenses and hydraulic infrastructure in the Netherlands, Sebastian N Jonkman et al; and other research.

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