Global Sea-Level Rise & Implications

Key facts and figures

WORLD METEOROLOGICAL ORGANIZATION

WEATHER CLIMATE WATER

Foreword

H.E. Prof. Petteri Taalas
Secretary-General
World Meteorological Organization

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**Global Sea-level changes induced by climate change and the melting of major ice masses will exert a significant impact on communities worldwide especially small island developing states and in densely populated low lying urban areas.

Rising Sea-level also threatens coastal farmlands and water reserves. The impacts of average sea level rise are boosted by storm surge and tidal variations.

Human drivers have played a significant role in both the increases in sea-level and the exposure vulnerabilities to the impacts.

The speed of the melting of the largest global ice mass Antarctica has uncertainties. Over the next 2000 years, global mean sea-level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia. The likelihood and impacts of abrupt and/or irreversible changes increase with further global warming.

Sea-level rise will bring cascading and compounding impacts resulting in losses of coastal ecosystems and ecosystem services, groundwater salinization, flooding and damage to coastal infrastructure. It imposes risks to economies, livelihoods, settlements, health, well-being, food and water security and cultural values in the near to long-term.

Sea-level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and the magnitude of extreme sea level events which will escalate in the coming decades.

**This WMO SG overview summary February 2023 content is based on WMO flagship reports Global State of the Climate 2020 and provisional state of the Global climate 2021 and IPCC The physical Science Basis 2021 Summary for policy makers and Special Report on the Ocean and Cryosphere in a Changing Climate 2019. Full Ref see Page 10.

Cover : Photographer: Heungsoon Park
Location: Gyeongju-si, Gyeongsangbuk-do, Republic of Korea
WMO 2023 Calendar Competition

The threat from Sea-level rise:

Sea-level rise threatens several low-lying small islands, It is a major threat for countries like Netherlands, Bangladesh, India and China some of which comprise **large coastal populations**. Several big cities on all continents are threatened, such as Shanghai, Dhaka, Bangkok, Jakarta, Mumbai, Maputo, Lagos, London, Copenhagen, New York, Los Angeles, and Buenos Aires. It is a major economic, social and humanitarian challenge.

Sea-level rise threatens coastal farmlands and water reserves and resilience of infrastructures as well as human lives and livelihoods. **The impacts of average sea-level rise are boosted by storm surges and tidal variations**, as was the situation during the landfall of hurricane Sandy in New York and Cyclone Idai in Mozambique.

Sea-level rise since pre-industrial times has been measured with coastal mareographs (Tide Gauges), and for the past decades also with satellite altimeters. According to future estimates based on climate models and ocean-atmosphere physics, **the speed of the melting of the largest global ice mass Antarctica is uncertain.** There is a risk of a much higher sea-level rise due to potential intrusion of sea water under the Antarctic glaciers, as NASA has demonstrated in its recent published scientific studies.

Global mean sea-level increased by 0.20m between 1901 and 2018. The average rate of sea level rise was 1.3 mm yr–1 between 1901 and 1971, increasing to 1.9 mm yr–1 between 1971 and 2006, and further increasing to 3.7 mm/yr between 2006 and 2018. **WMO has reported that during the period 2013-22 sea level rise has been 4.5 mm/yr** (Figure 1). **Human influence was very likely the main driver of these increases since at least 1971.**

Global mean sea-level has risen faster since 1900 than over any preceding century in at least the last 3000 years. The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago).

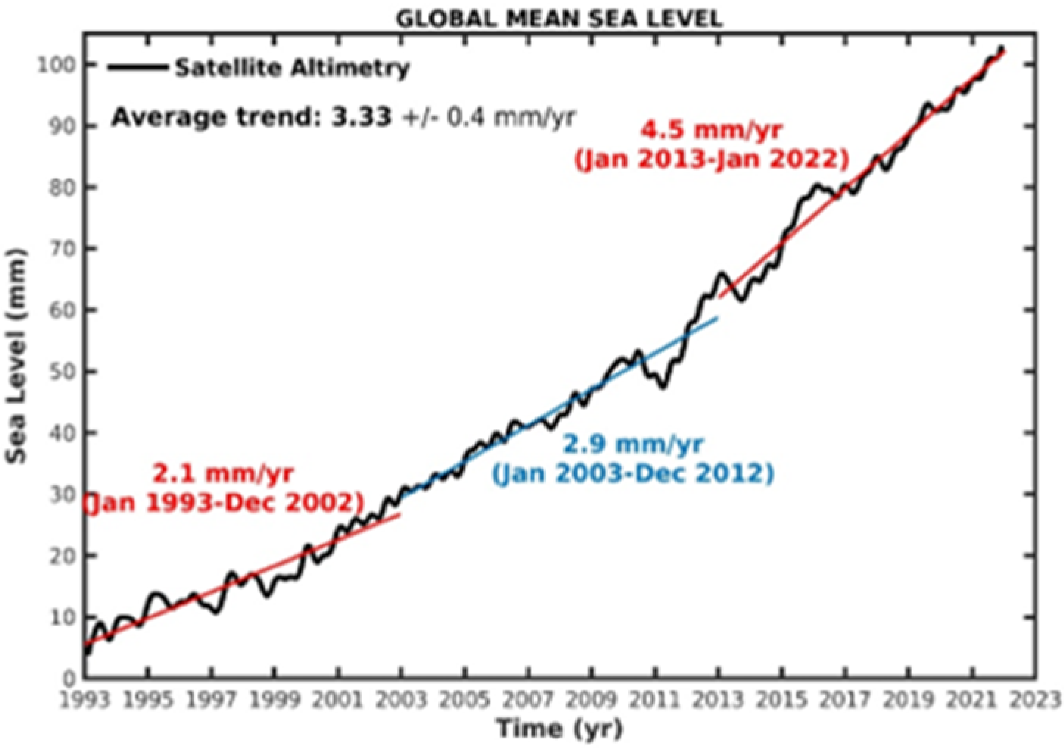

Figure 1. Sea-level rise since 1993 based on satellite measurements
(WMO State of the Global Climate Report).

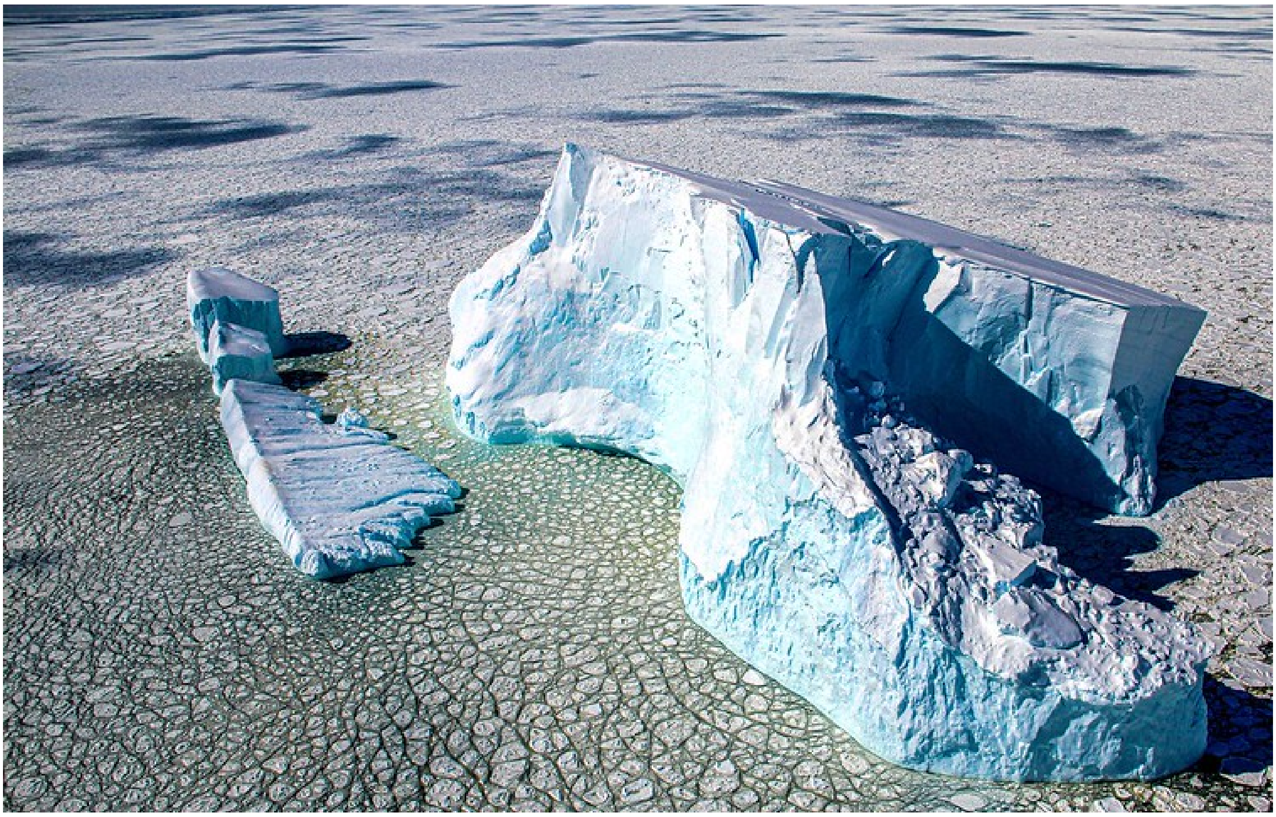

Photo by: Gonzalo Bertolotto
Location: Mar de Bellingshausen, Antartica
WMO 2021 Calendar Competition Entries

Impact of warming on ice mass loss and thermal expansion:

Heating of the climate system has caused global mean sea-level rise through ice loss on land, melting of glaciers and ice sheets and thermal expansion from ocean warming. **Thermal expansion explained 50% of sea level rise during 1971–2018**, while **ice loss from glaciers** contributed 22%, ice sheets 20% and changes in land-water storage 8%. **The rate of ice-sheet loss increased by a factor of four between 1992–1999 and 2010–2019.** Together, ice-sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006–2018.

Scenarios for the future:

It is virtually certain that global mean sea-level will continue to rise over the 21st century. Relative to 1995–2014, the likely global mean sea level rise by 2100 is 0.28–0.55 m under the very low GHG emissions scenario (SSP1-1.9, equals about 1.5 C target); 0.32–0.62 m under the low GHG emissions scenario (SSP1-2.6, equals about 2 C target); 0.44–0.76 m under the intermediate GHG emissions scenario (SSP2-4.5); and 0.63–1.01 m under the very high GHG emissions scenario (SSP5-8.5); and by 2150 is 0.37–0.86 m under the very low scenario (SSP1-1.9); 0.46–0.99 m under the low scenario (SSP1-2.6); 0.66–1.33 m under the intermediate scenario (SSP2-4.5); and 0.98–1.88 m under the very high scenario (SSP5-8.5) (Figure. 2).

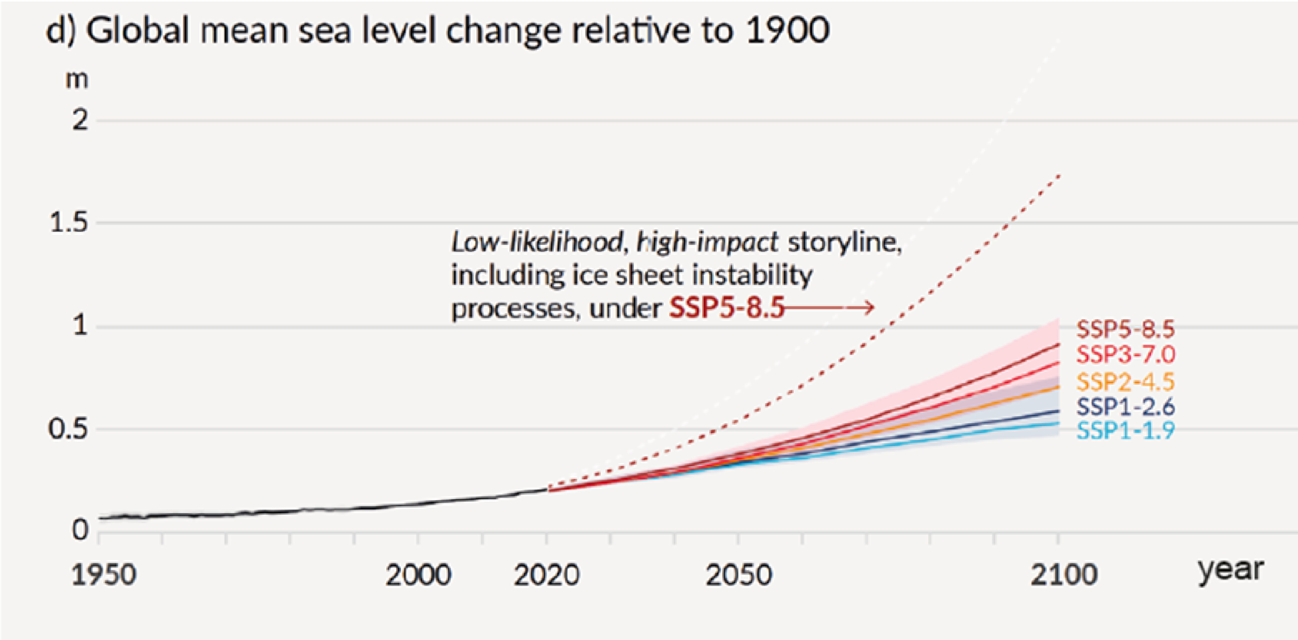

Figure 2. Sea-level rise by 2100 depending on greenhouse gas emission scenarios. **In the longer term, sea-level is committed to rise for centuries to millennia** due to continuing deep-ocean warming and ice-sheet melt and will remain elevated for thousands of years. ref: IPCC WG 1 SPM Summary for policy makers 2021.

Photo by: Danier Ernesto González Velazquez (Cuba)
Location: Gibara, Cuba

Photo by: Mr. Nelson Tiong (Malaysia)
Location: Tanjung batu beach bintulu

Over the next 2000 years, global mean sea-level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia. Projections of multi-millennial global mean sea-level rise are consistent with reconstructed levels during past warm climate periods: likely 5–10 m higher than today around 125,000 years ago, when global temperatures were very likely 0.5°C–1.5°C higher than 1850–1900; and very likely 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher. **Sea-level rise is not globally uniform and varies regionally** Figure 3.

Abrupt increase of sea-level and irreversible loss of Glaciers and Ice masses

The likelihood and impacts of abrupt and/or irreversible changes increase with further global warming. At sustained warming levels between 2-3 C, the Greenland and West Antarctic ice sheets will be almost completely and irreversibly lost over multiple millenia causing potentially multi-meter sea-level rise. The mass loss is higher with higher warming rates. In case of very high greenhouse gas emissions (total failure of mitigation) there is a risk of sea-level rise by of 2 m by 2100 and even 15 m by 2300.

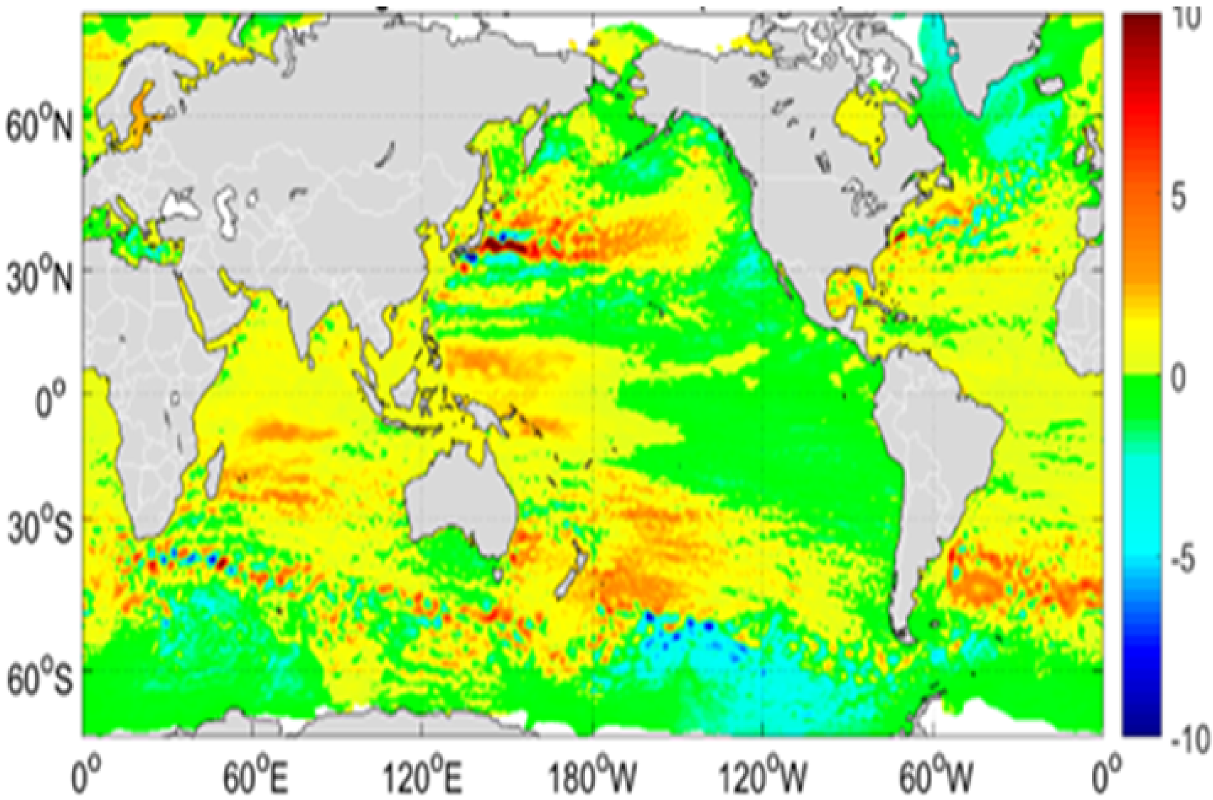

Figure 3. Global sea-level rise 1993-2021, deviations from the global average. In 2021 0.8 mm rise was caused by the melting of Greenland glaciers, and 0.4 mm by Antarctica. WMO State of Global Climate Report

Sectoral and economic impacts of rising Sea-level

** Based on Ref IPCC Special Report Oceans and Cryosphere in a changing climate 2019

Sea-level rise imposes significant risks for small islands, coastal ecosystems, people and infrastructure and will continue to increase beyond 2100. Sea-level rise is unavoidable for centuries to millennia due to continuing deep ocean warming and ice sheet melt, and sea-levels will remain elevated for thousands of years. However, deep, rapid and sustained GHG emissions reductions will limit further sea-level rise acceleration and projected long-term sea-level rise.

Continued and accelerating sea-level rise will encroach on coastal settlements and infrastructure and commit low-lying coastal ecosystems to submergence and loss. If trends in urbanization in exposed areas continue, this will exacerbate the impacts, with more challenges where energy, water and other services are constrained.

Climate change will increasingly put pressure on food production and access, especially in vulnerable regions, undermining food security and nutrition and increases in frequency, intensity and severity of droughts, floods and heatwaves, and **continued sea level rise will increase risks to food security in vulnerable regions between 1.5 C and 2 C Global warming level.**

The population, (Figure 4) potentially exposed to a 100-year coastal flood is projected to increase by about 20% if global mean sea level rises by 0.15 m relative to 2020 levels; this exposed population doubles at a 0.75 m rise in mean sea level and triples at 1.4 m without population change and additional adaptation. **Sea-level rise poses an existential threat for some Small Islands and some low-lying coasts.** By 2100 the value of global assets within the future 1-in-100 year coastal floodplains is projected to be between US$7.9 and US$12.7 trillion (2011 value) rising to between US$8.8 and US$14.2 trillion (failure of mitigation).

Sea-level rise will bring cascading and compounding impacts resulting in losses of coastal ecosystems and ecosystem services, groundwater salinization, flooding and damage to coastal infrastructure that cascade into risks to livelihoods, settlements, health, well-being, food, displacement and water security, and cultural values in the near to long-term.

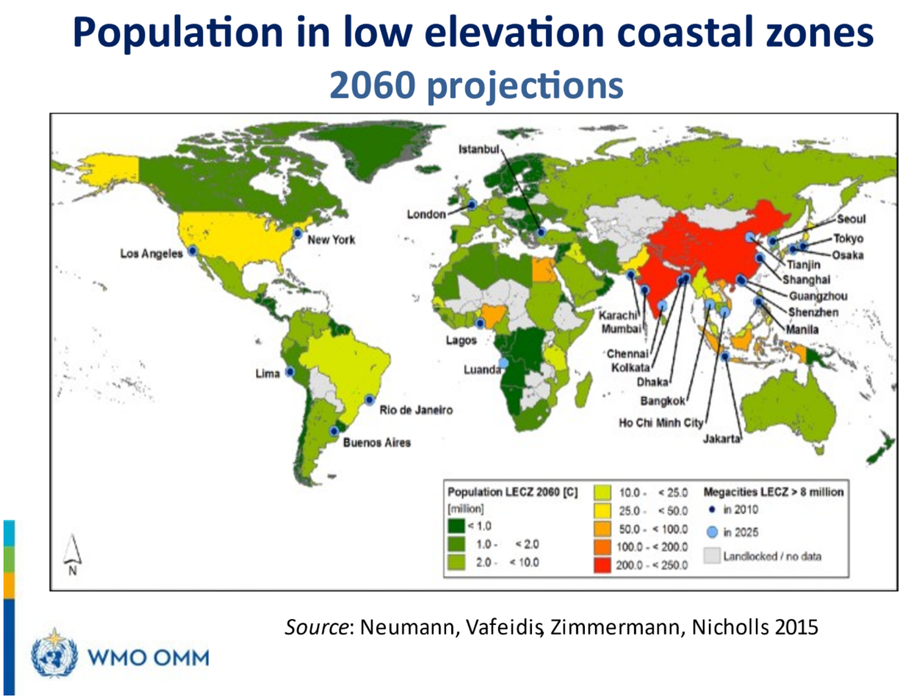

Figure 4.

Adaptation challenges to Sea-level Rise

** Ref based on IPCC Special Report Oceans and Cryosphere in a changing climate 2019

Sea-level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and magnitude of extreme sea level events which will escalate in the coming decades. Such adaptation challenges would occur much earlier under high rates of sea-level rise, in particular if low-likelihood, high impact outcomes associated with collapsing ice sheets occur.

Responses to ongoing sea-level rise and land subsidence in low-lying coastal cities and settlements and small islands include protection, accommodation, advance and planned relocation and ecosystem based approaches. **These responses are more effective if combined and/or sequenced, planned well ahead, aligned with sociocultural values and development priorities, and underpinned by inclusive community engagement processes.**

Urban systems are critical, interconnected sites for enabling climate resilient development, especially at the coast. **Coastal cities and settlements play a key role in moving toward higher climate resilient development given firstly, almost 11% of the global population –896 million people – lived within the Low Elevation Coastal Zone in 2020, potentially increasing to beyond 1 billion people by 2050, and these people, and associated development and coastal ecosystems, face escalating climate compounded risks, including sea level rise.** These coastal cities and settlements make key contributions to climate resilient development through their vital role in national economies and inland communities, global trade supply chains, cultural exchange, and centers of innovation. There are significant specific impacts and challenges to those populations faced with sea-level rise and living in coastal urban areas in least developed and low-middle income countries.

Key Messages:

- **Sea-level rise threatens several low-lying small islands and high-population coastal cities.**
- **The impacts of average sea-level rise are boosted by storm surges and tidal variations**
- **The speed of the melting of the largest global ice mass Antarctica has uncertainties.**
- **Human influence was very likely the main driver of these Sea-level increases since at least 1971.**
- **The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago).**
- **Thermal expansion explained 50% of sea-level rise during 1971–2018**
- **Ice loss from glaciers contributed 22%, ice sheets 20% and changes in land-water storage 8%. The rate of ice-sheet loss increased by a factor of four between 1992–1999 and 2010–2019.**
- **Sea-level will continue to rise over the 21st century. Relative to 1995–2014.**
- **Sea-level rise is not globally uniform and varies regionally.**
- **Over the next 2000 years, global mean sea-level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming**
- **Continued sea-level rise will increase risks to food security in vulnerable regions between 1.5 C and 2 C Global warming level.**
- **Sea-level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and magnitude of extreme sea-level events which will escalate in the coming decades.**
- **There are significant specific impacts and challenges to those populations faced with sea-level rise living in coastal urban areas in least developed and low-middle income countries.**

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