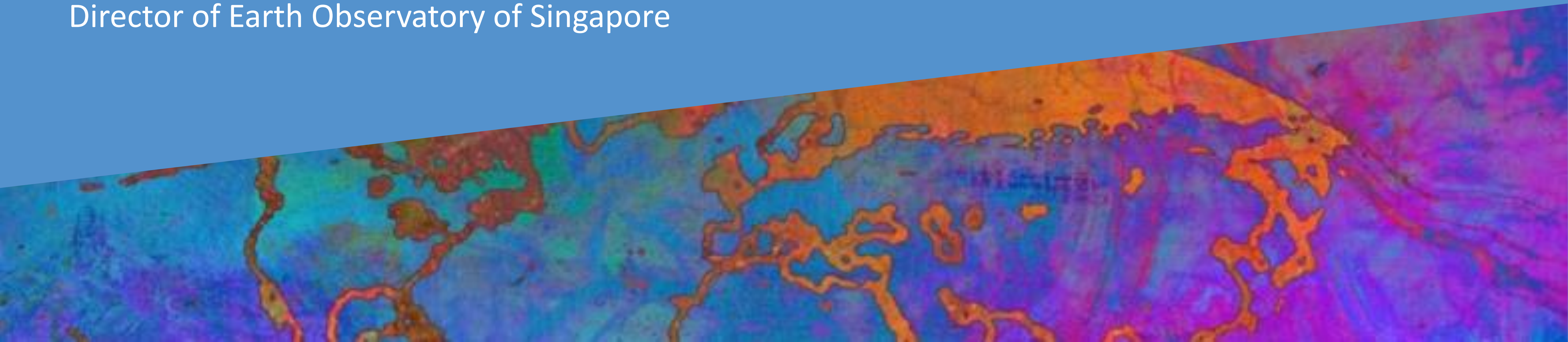
SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

INTERGOVERNMENTAL PANEL ON climate change

# IPCC
# Sea level change


Professor Benjamin P Horton
Director of Earth Observatory of Singapore

INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

## Author Team

**234** authors from **65** countries

**30%** new to the **IPCC**

## Review Process

**14,000** scientific publications assessed

**78,000+** review comments

**46** countries commented on Final Government Distribution


WORKING GROUP I CONTRIBUTION TO THE IPCC SIXTH ASSESSMENT REPORT
FIRST LEAD AUTHOR MEETING
GUANGZHOU, CHINA, 25-29 JUNE 2018

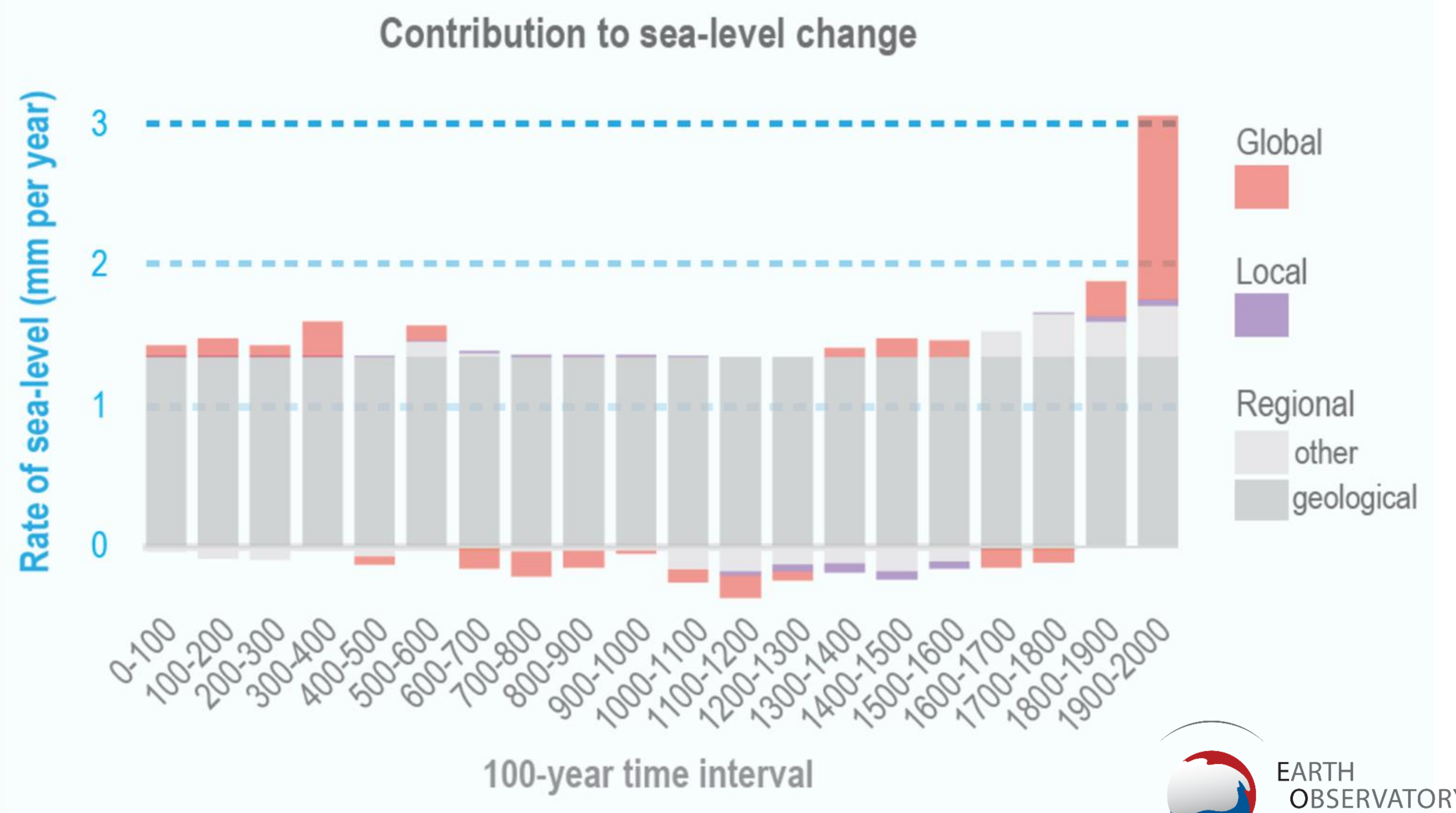

IPCC AR6 Working Group I Third Lead Author Meeting
Toulouse, France, 26-30 August 2019

# Chapter 9: Ocean, Cryosphere & sea level change


EARTH OBSERVATORY OF SINGAPORE

# IPCC AR6 REPORT

Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years



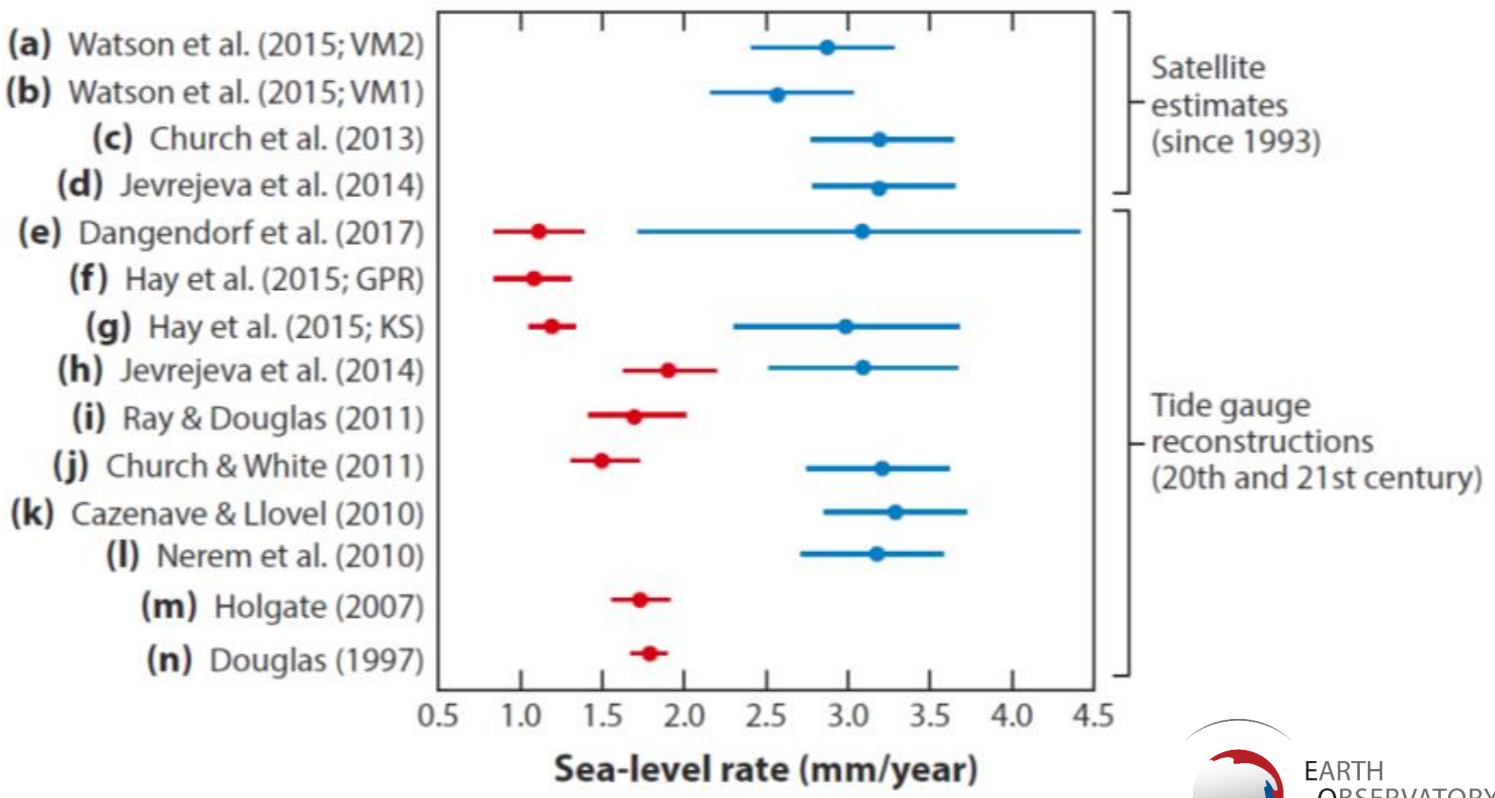

EARTH OBSERVATORY OF SINGAPORE

Source: Walker, J.S., Kopp, R.E., **Shaw, T.A.**, Cahill, N., Khan, N.S., Barber, D.C., Ashe, E.L., Brain, M.J., Clear, J., Corbett, D.R., **Horton, B.P.,** 2021. Common Era sea-level budgets along the U.S. Atlantic coast. *Nature Communications*. 12:1841. https://doi.org/10.1038/s41467-021-22079-2

# IPCC AR6 REPORT

Global mean sea level increased by 0.20 m between 1901 and 2018.

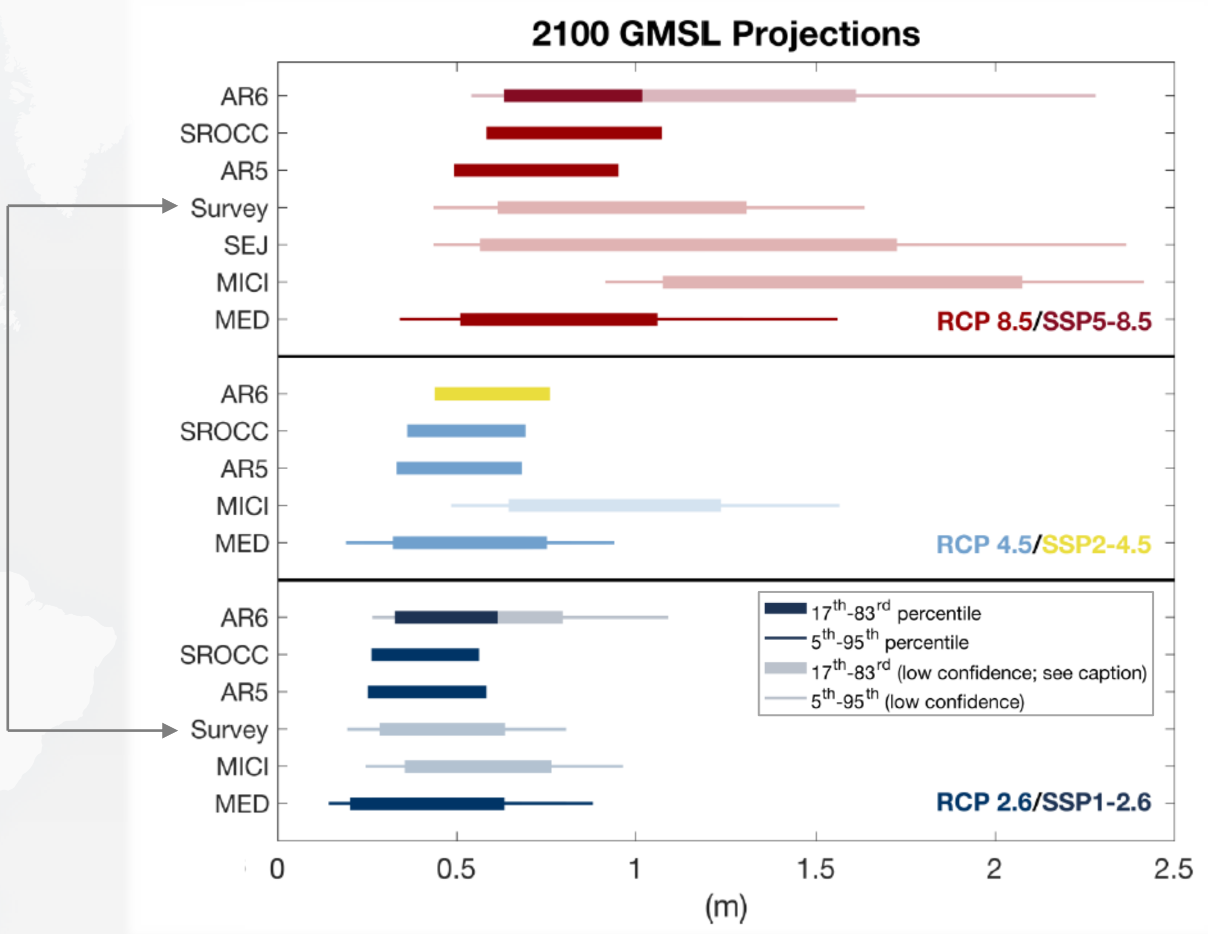
The rate of sea level rise is accelerating. The rate was 1.3 mm/yr [1901–1971]; 1.9 mm/yr [1971–2006] ; and 3.7 mm/yr [2006–2018]




Source: **Horton, B.P.,** Kopp, R.E., Garner, A.J., Hay, C.C., **Khan, N.S., Roy, K., Shaw, T.A.,** 2018. Mapping Sea-Level Change in Time, Space, and Probability. Annual Reviews of Environmental Resources, 43:13.1–13.41. https://doi.org/10.1146/annurev-environ-102017-025826

# IPCC AR6 REPORT

Projections used by IPCC6AR for global mean sea level for 2100
RCP 8.5/SSP5-8.5 (top set), RCP 4.5/SSP2-4.5 2 (middle set), and RCP 2.6/ SSP1-2.6 (bottom set).



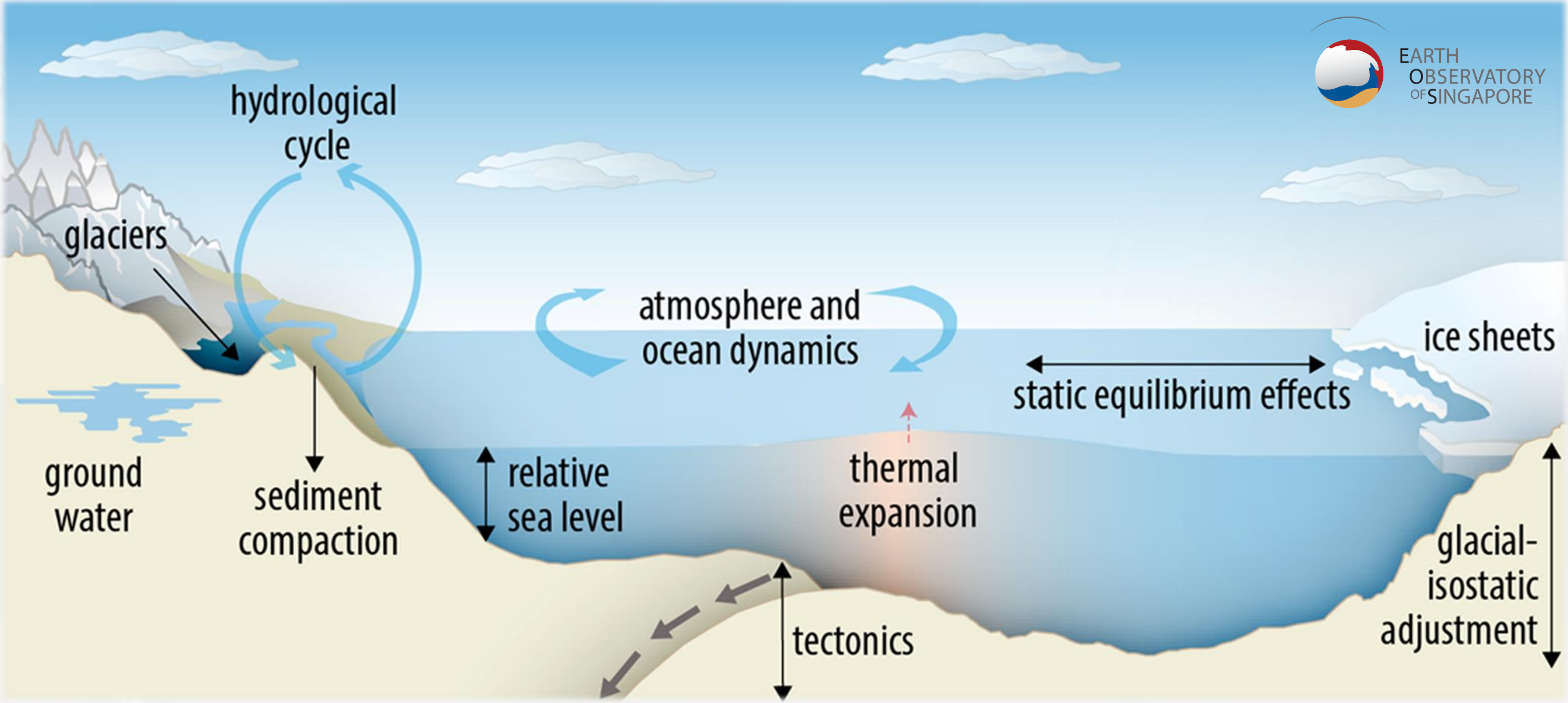

EARTH OBSERVATORY OF SINGAPORE

Figure source: Fox-Kemper, et al. 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Survey source: **Horton, B.P., Khan, N.S.,** Cahill, N., **Lee, J.S.H., Shaw, T.S.,** Garner, A.J., Kemp, A.C., Engelhart, S.E., Rahmstorf, S., 2020. Estimating global mean sea-level rise and its uncertainties by 2100 and 2300 using an expert survey. npj Climate and Atmospheric Science. https://doi.org/10.1038/s41612-020-0121-5

# SEA LEVEL DRIVING PROCESSES

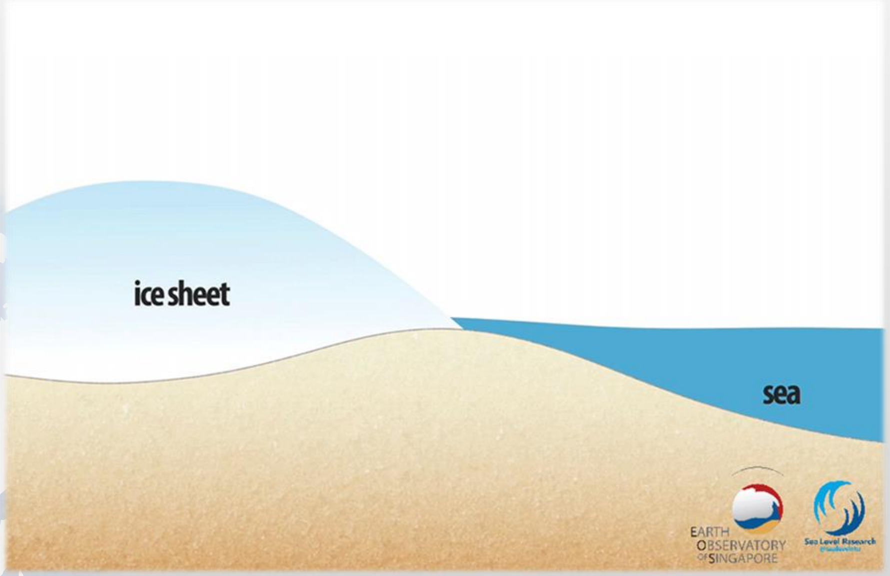
Sea levels are driven by a variety of <u>global</u>, regional and local processes that vary spatially and temporally.

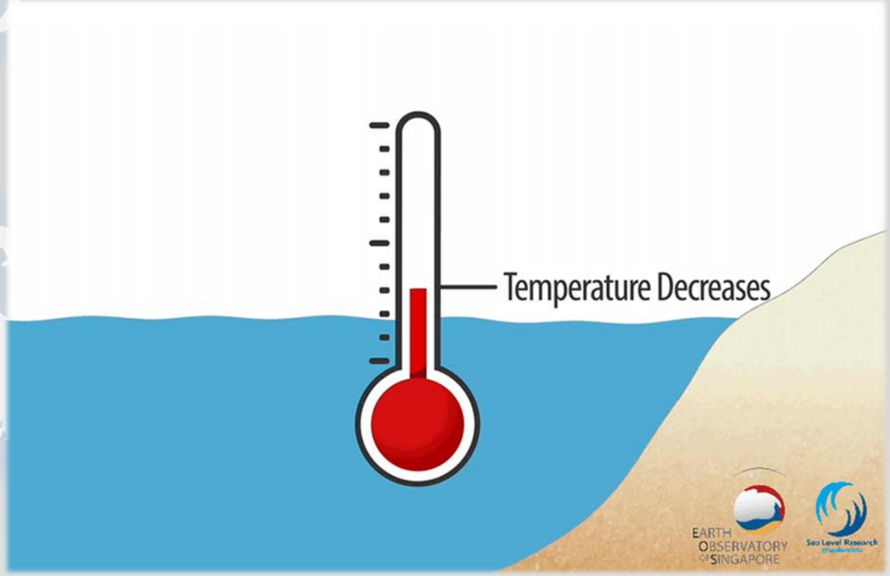


# GLOBAL DRIVING PROCESSES

Sea levels are driven by a variety of global, regional and local processes that vary spatially and temporally

Global response to an increase in ocean mass and volume

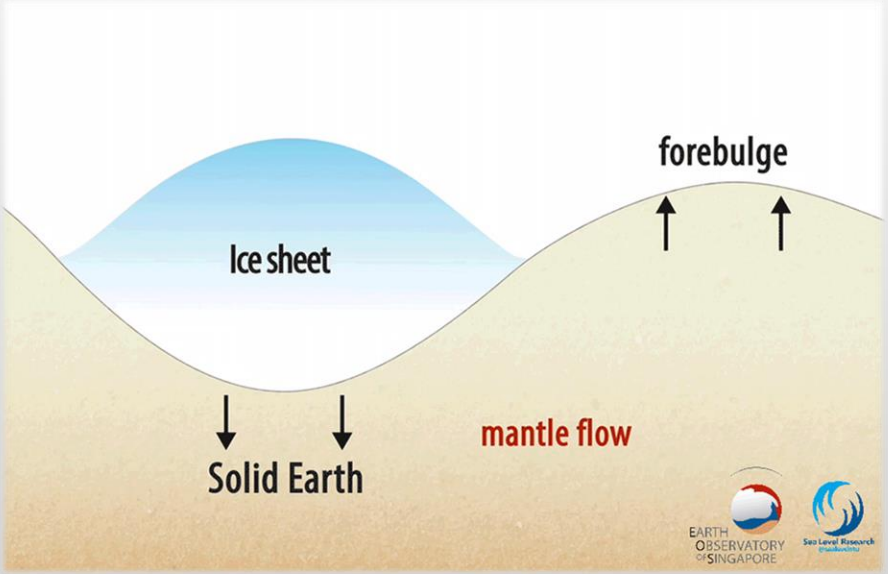


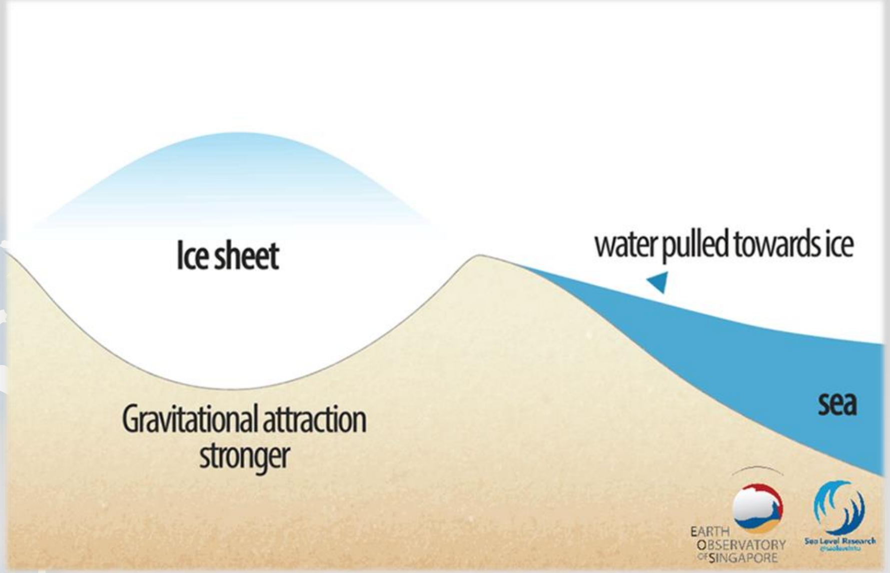



# REGIONAL DRIVING PROCESSES

Sea levels are driven by a variety of global, <u>regional</u> and local processes that vary spatially and temporally

Regional response to the loading and redistribution of water



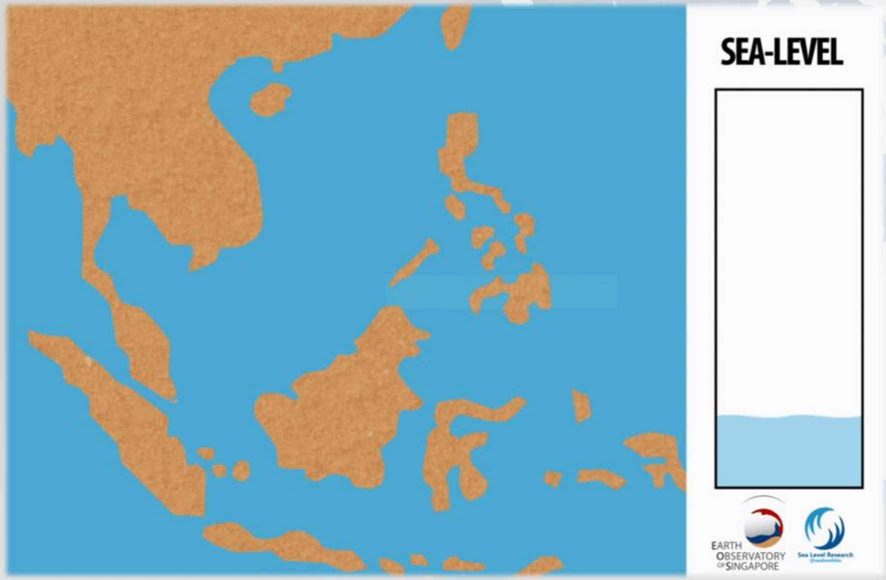



# LOCAL DRIVING PROCESSES

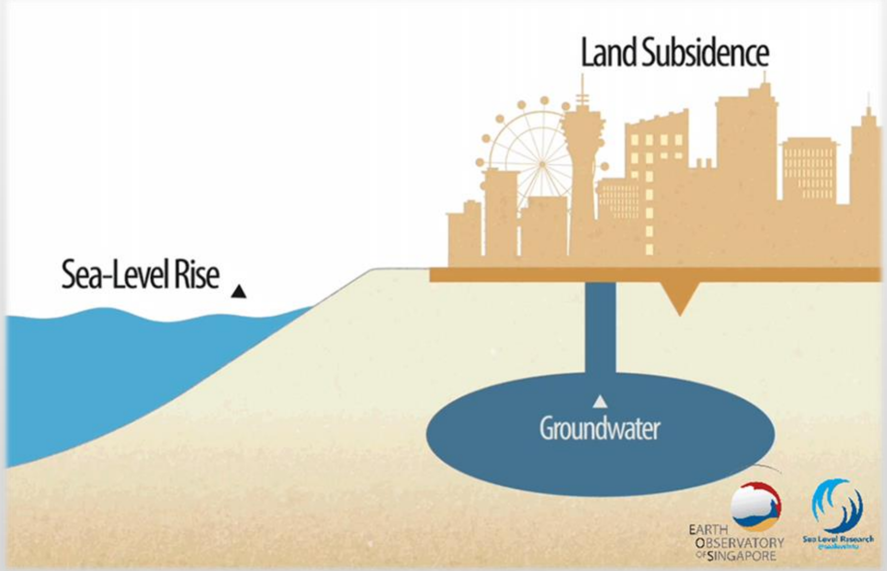
Sea levels are driven by a variety of global, regional and local processes that vary spatially and temporally

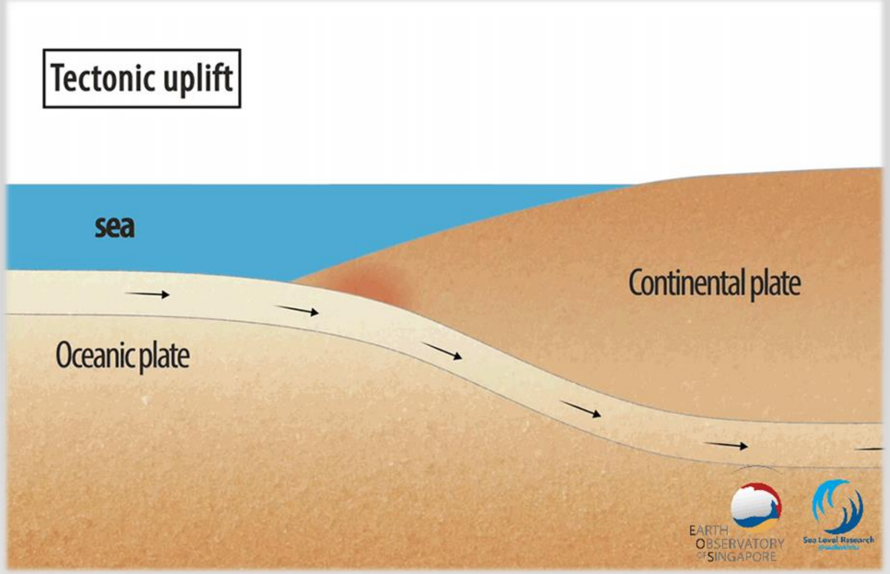
e.g., Manila, Philippines

Local response to processes such as subsidence and tectonics




[Note: these are poorly constrained or not accounted for in sea-level rise projections and their uncertainty. They are a focus of National Sea Level Program at EOS]



# IPCC AR6 SCENARIOS

Sea level projections are provided for five Shared Socioeconomic Pathway (SSP) scenarios that consider driving processes for which we have least medium confidence. Presented as likely ranges representing 17th-83rd percentile representing a probability of at least 66%.

## SSP1-1.9

Globally averaged surface air temperature over the period 2081–2100 is very likely (at least a 90% probability) to be higher by **1.0°C–1.8°C** compared to 1850-1900. Net zero $CO_2$ emissions around the middle of the century.

## SSP1-2.6

## SSP2-4.5

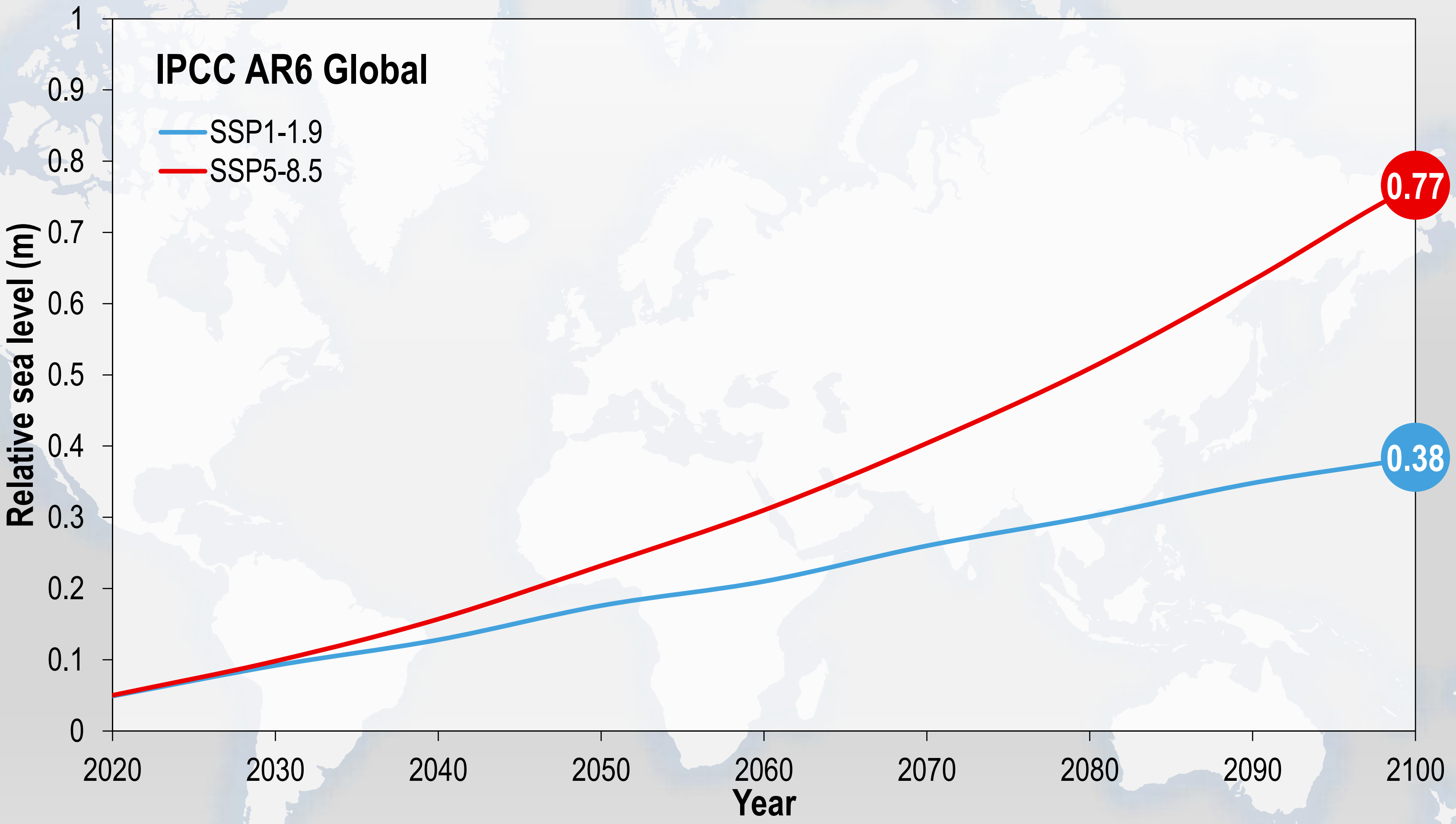
## SSP3-7.0

Increasing temperature and emissions

## SSP5-8.5

Globally averaged surface air temperature over the period 2081–2100 is very likely to be higher by **3.3°C–5.7°C** compared to 1850-1900. High reference scenario with no additional climate policy. Emission levels as high as SSP5-8.5 are not obtained by Integrated Assessment Models (IAMs) under any of the SSPs other than the fossil fueled SSP5 socioeconomic development pathway.

# FUTURE SEA LEVELS: Global mean sea level

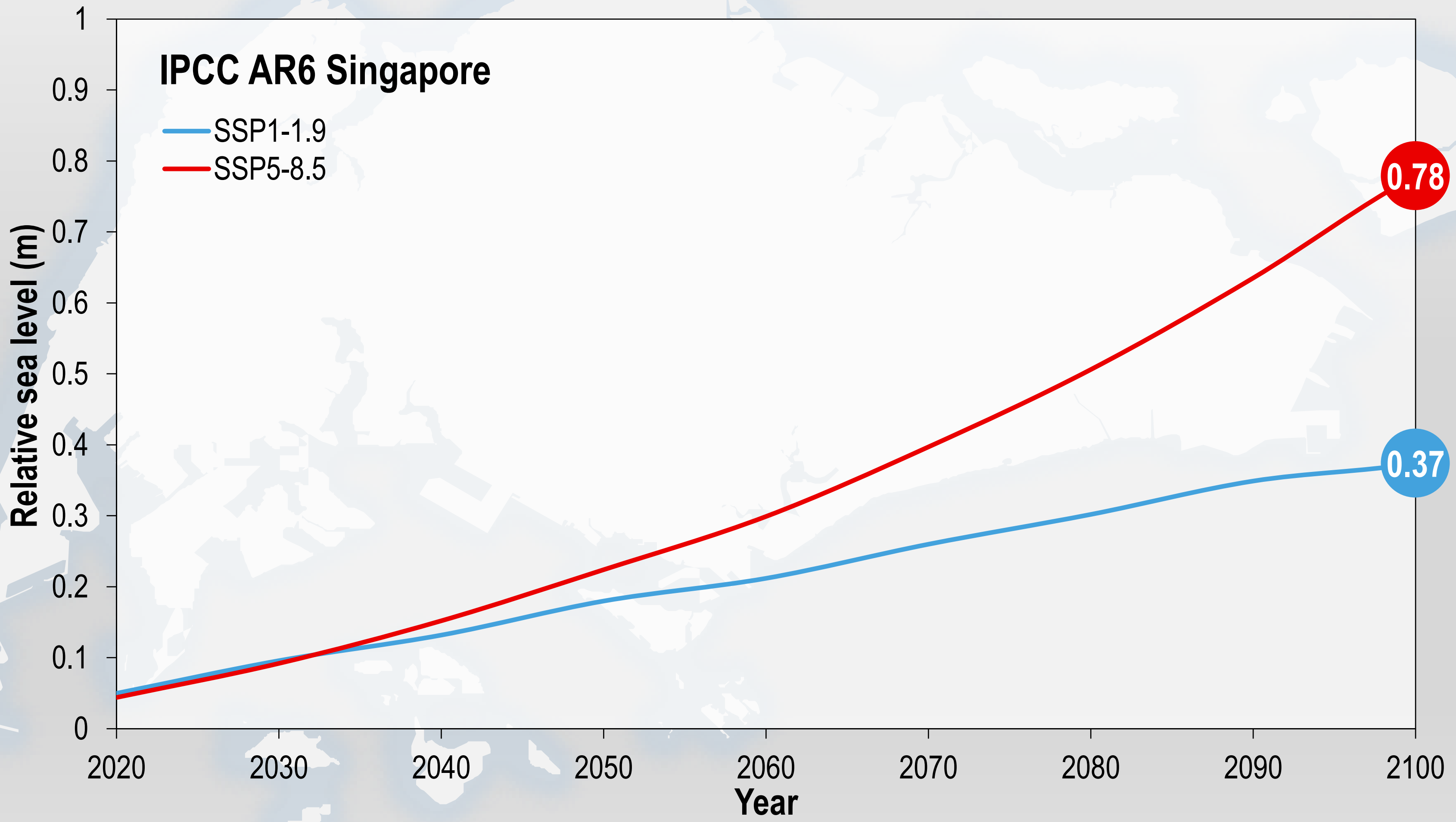



| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.77 | 0.63–1.01 |

| Year | SSP1-1.9 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.38 | 0.28–0.55 |

Data source: IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

# FUTURE SEA LEVELS: Singapore




| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.78 | 0.44–1.18 |

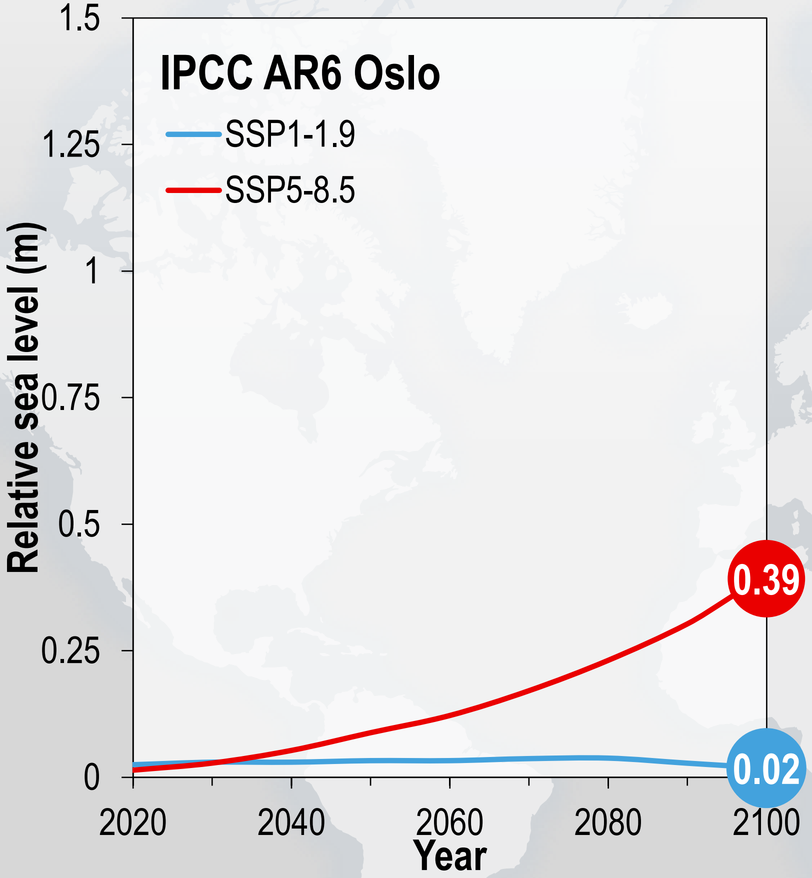
| Year | SSP1-1.9 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.37 | 0.07–0.71 |

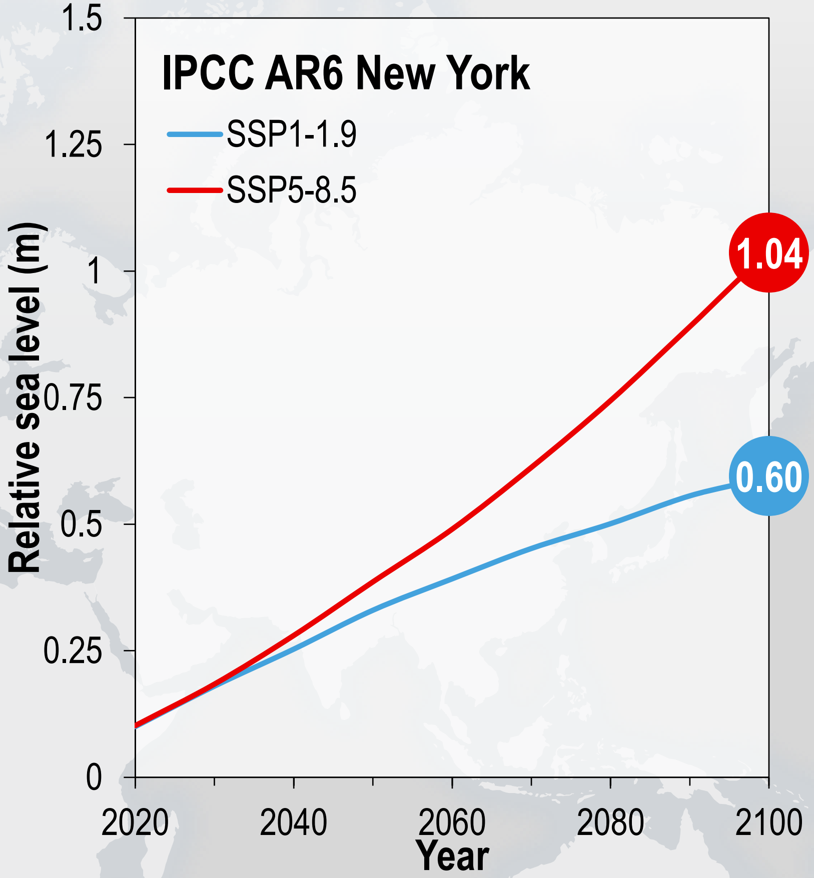
Data source: Fox-Kemper, et al. 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

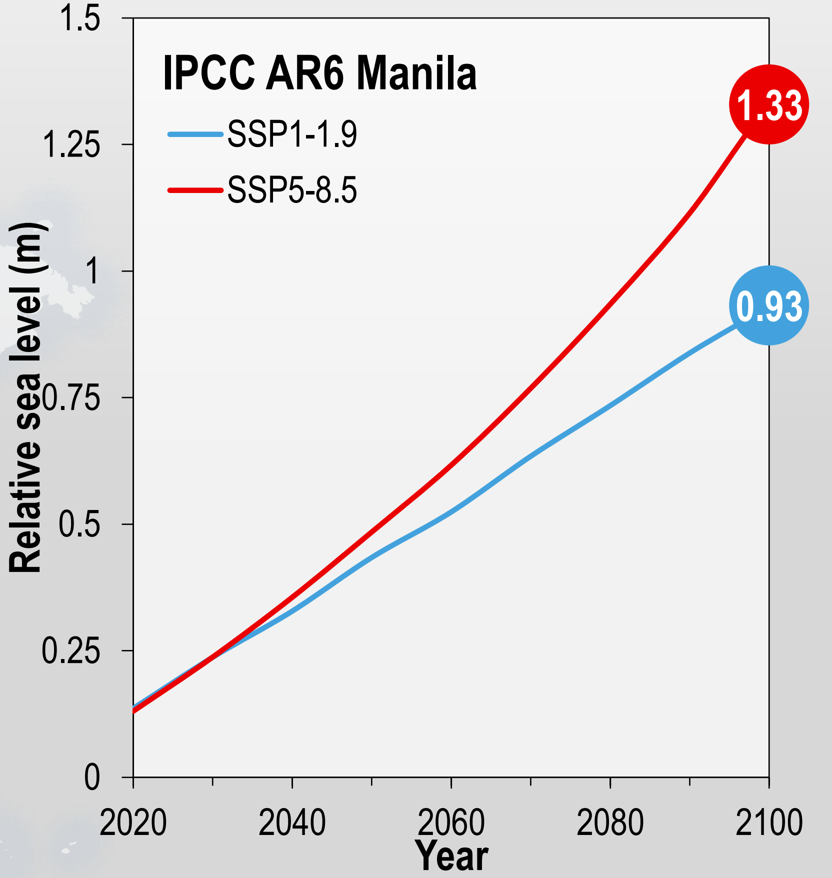
# FUTURE SEA LEVELS

Data source: Fox-Kemper, et al. 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

## To illustrate spatial variability due to these processes:




| Year | SSP1-1.9 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.02 | -0.21–0.29 |

| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.39 | 0.15–0.70 |

| Year | SSP1-1.9 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.60 | 0.39–0.84 |

| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 1.04 | 0.83–1.34 |

| Year | SSP1-1.9 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.93 | 0.76–1.15 |

| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 1.33 | 1.13–1.63 |

# IPCC AR6 SCENARIOS

To indicate the potential impact of deeply uncertain ice sheet processes, about which there is currently a low level of agreement and limited evidence, low confidence projections are also provided

SSP1-1.9 SSP1-2.6 SSP2-4.5 SSP3-7.0 SSP5-8.5

Increasing temperature and emissions

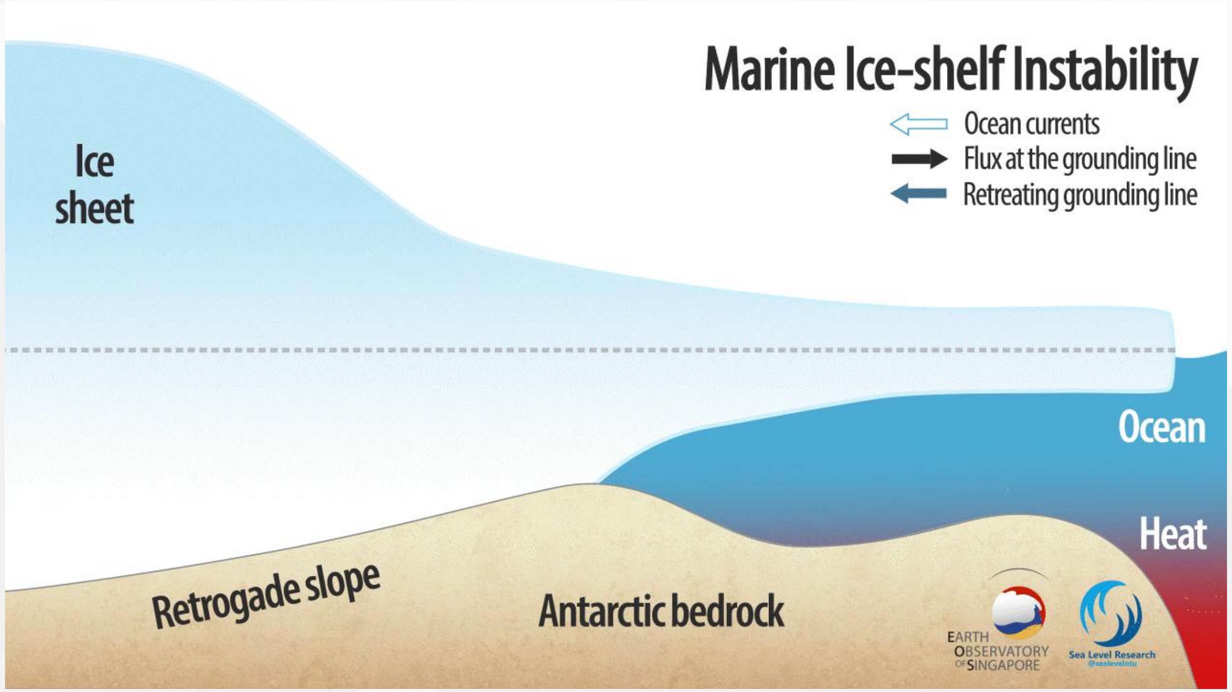
**SSP5-8.5 Low Confidence**

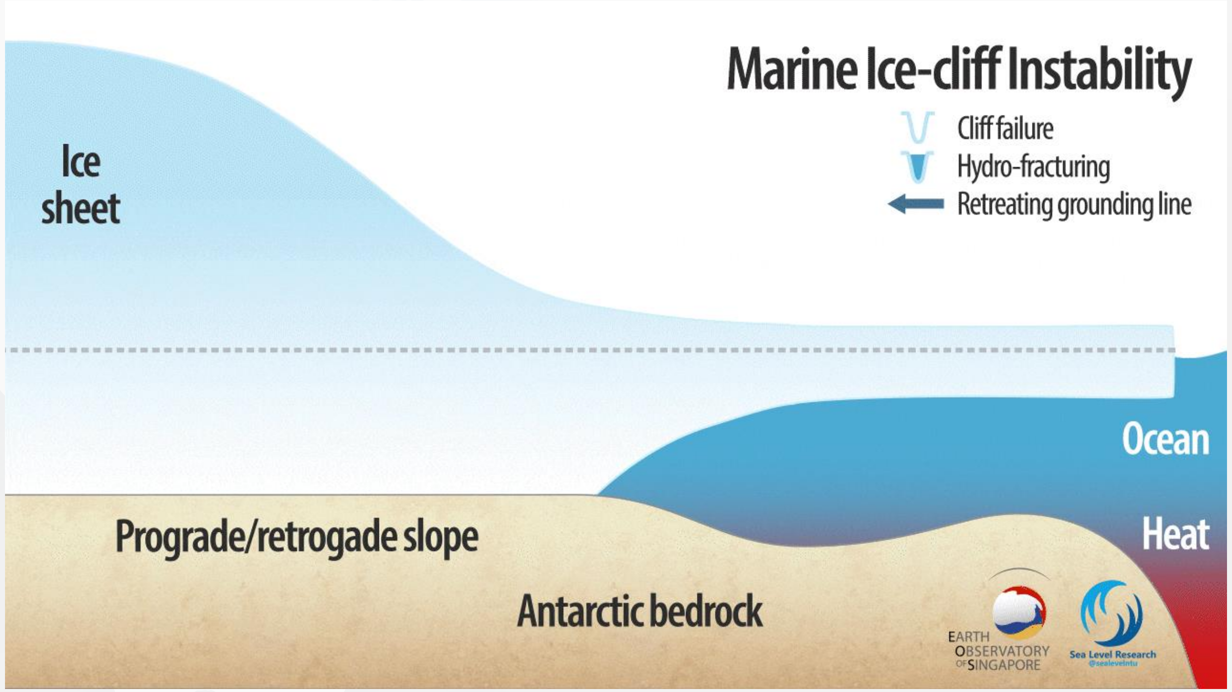
Same global temperature and emission scenario at SSP5-8.5 but integrates information from the Structured Expert Judgement and results from a simulation study that incorporates Greenland and Antarctica ice sheet processes for which we have low confidence.

**High Impact Low Likelihood (HILL)**

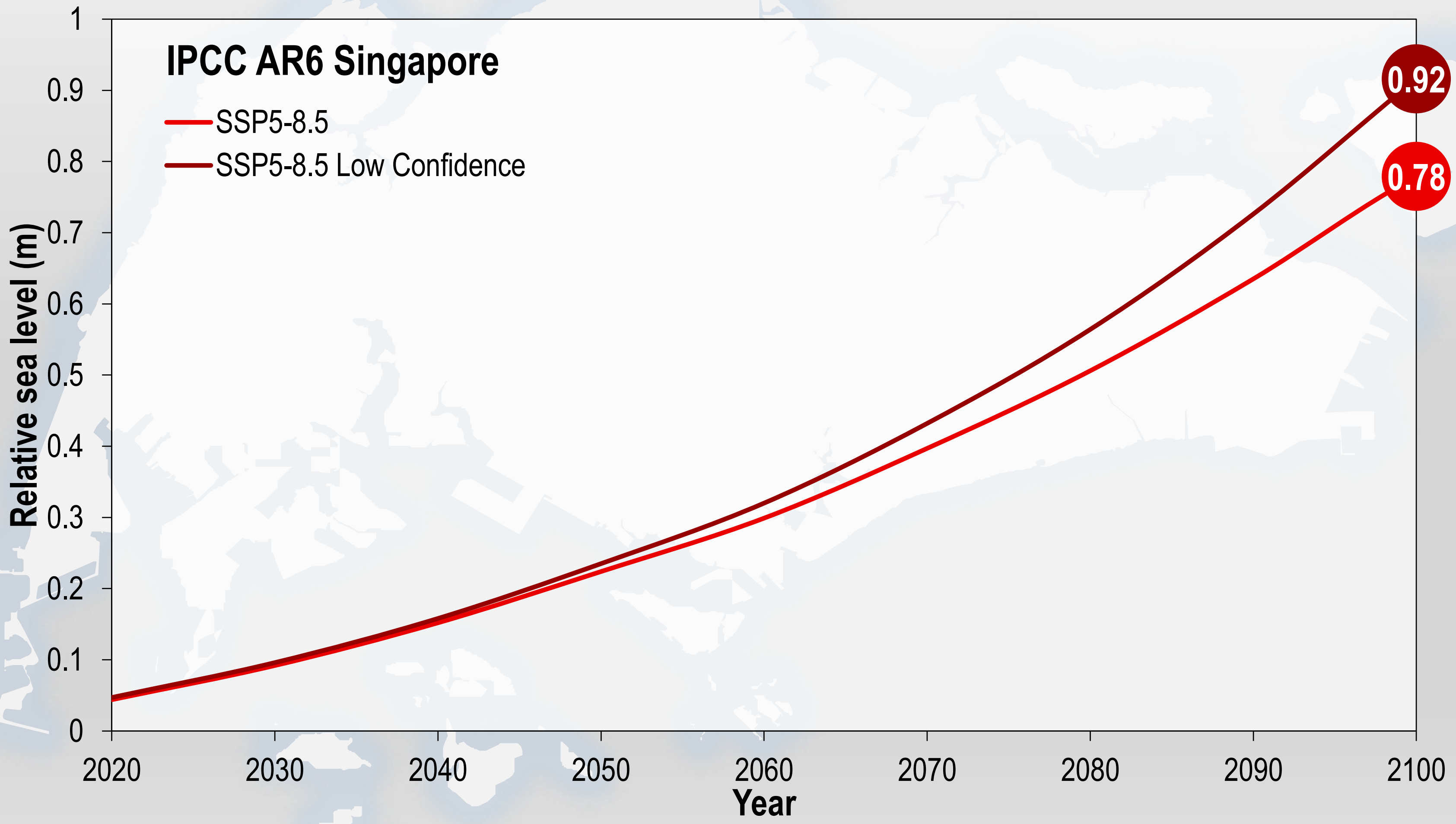
# DRIVING PROCESSES

Higher amounts of sea-level rise before 2100 could be caused by earlier-than-projected disintegration of Antarctica through the abrupt, widespread onset of Marine Ice Sheet Instability and Marine Ice Cliff Instability.



# FUTURE SEA LEVELS:
# Singapore - low probability but high impact

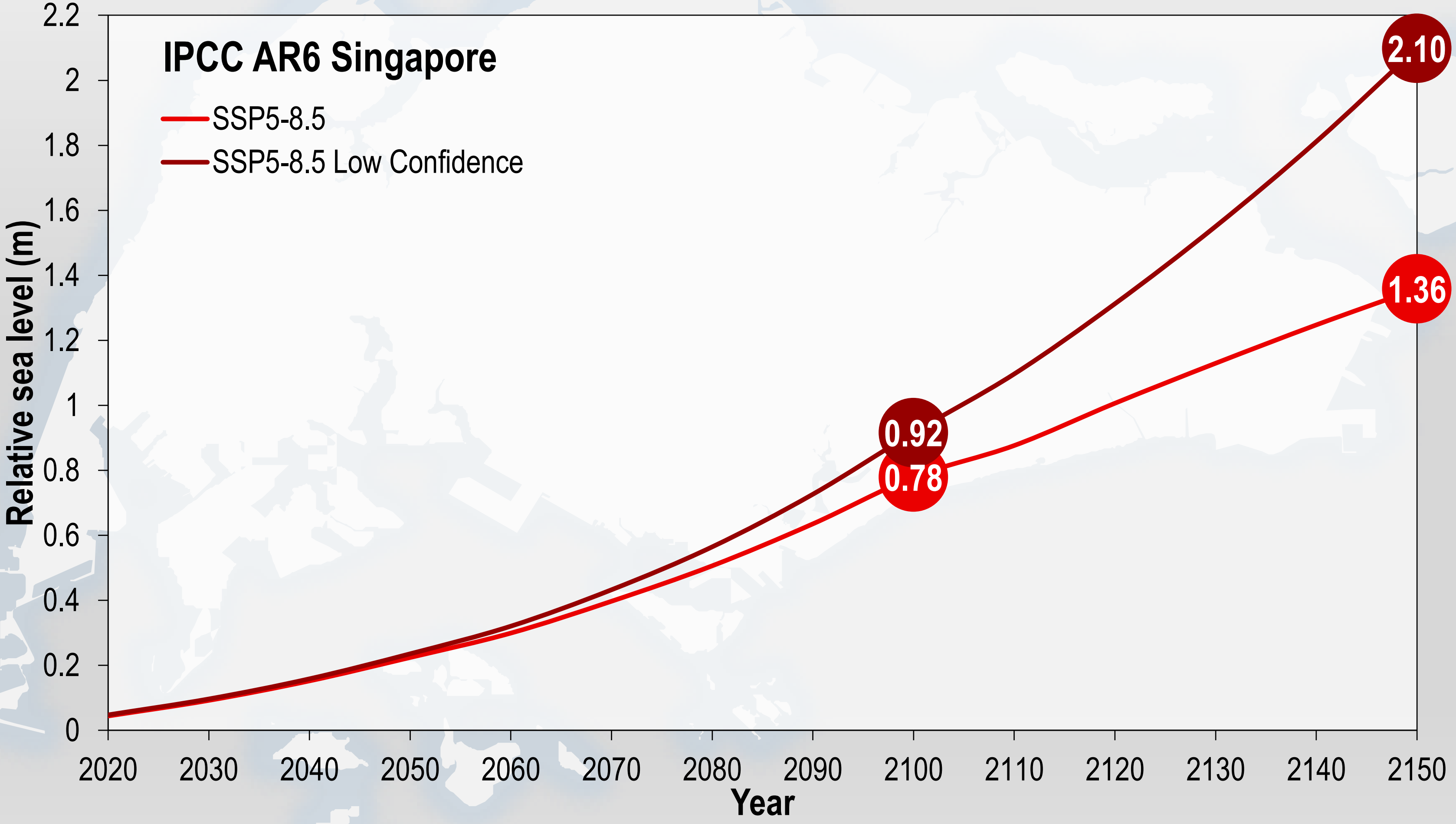



| Year | SSP5-8.5 Low Conf. (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.92 | 0.44–1.75 |

| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.78 | 0.44–1.18 |

Data source: Fox-Kemper, et al. 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

# FUTURE SEA LEVELS:
# Singapore - low probability but high impact (longer term)




| Year | SSP5-8.5 Low Conf. (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.92 | 0.44–1.75 |
| 2150 | 2.10 | 0.73–5.20 |

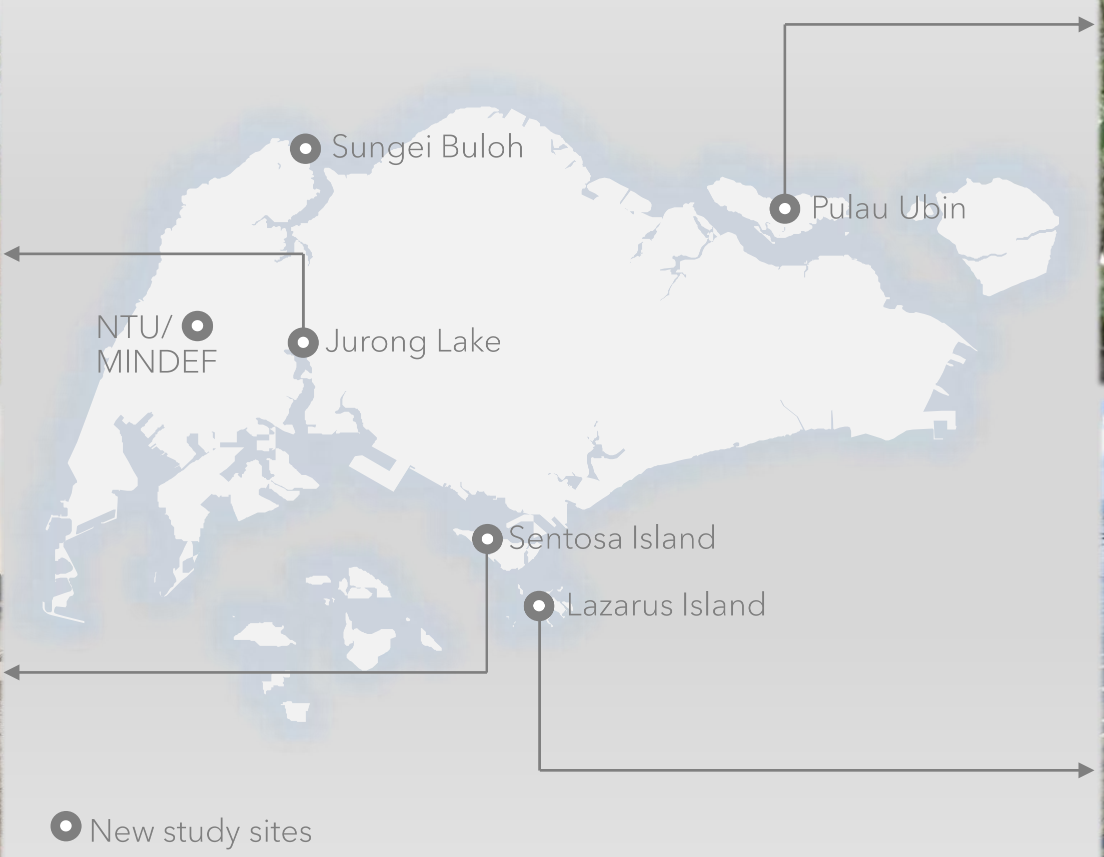
| Year | SSP5-8.5 (m) | |
|---|---|---|
| | 50% | 17–83% |
| 2100 | 0.78 | 0.44–1.18 |
| 2150 | 1.36 | 0.73–2.14 |

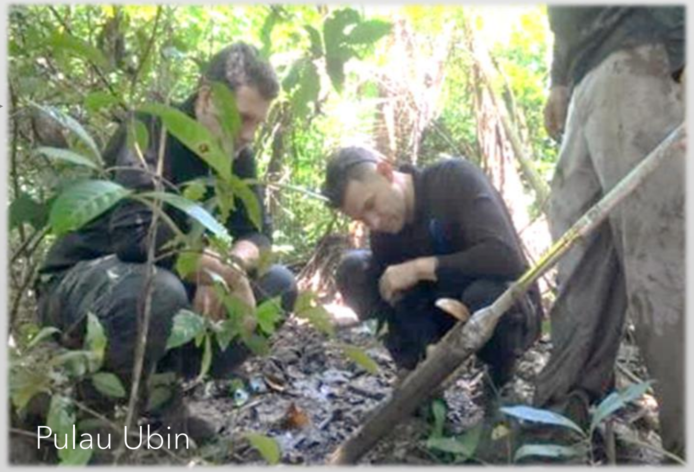
Data source: Fox-Kemper, et al. 2021, Ocean, Cryosphere and Sea Level Change. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

# OBSERVING PAST AND PRESENT SEA LEVEL

Past and present records of sea level have varied in response to a wide range of boundary conditions and climate forcings and can serve as a valuable guide to projecting future sea-level rise. EOS are currently investigating new sites using instrumental (GPS) and geological (mangroves and coral microatolls) methods.






# SUMMARY FOR SINGAPORE

Ice mass loss from Glaciers, Greenland and Antarctica is accelerating and will continue to lose mass throughout the 21st century under all considered SSP scenarios.

GMSL will continue to rise through 2100. GMSL will rise by 2050 between 0.18 m (SSP1-1.9) and 0.23 m (SSP5-8.5), and by 2100 between 0.38 m (SSP1-1.9) and 0.77 m (SSP5-8.5).

Higher amounts of GMSL rise before 2100 could be caused by Marine Ice Sheet Instability and Marine Ice Cliff Instability. Such processes could contribute more than one additional meter of sea level rise by 2100.

Past and present records of sea level have varied in response to a wide range of boundary conditions and climate forcings and can serve as a valuable guide to projecting future sea-level rise and its uncertainty. The focus of EOS research.