Mitigating and adapting to climate change in coastal areas: what can we do?

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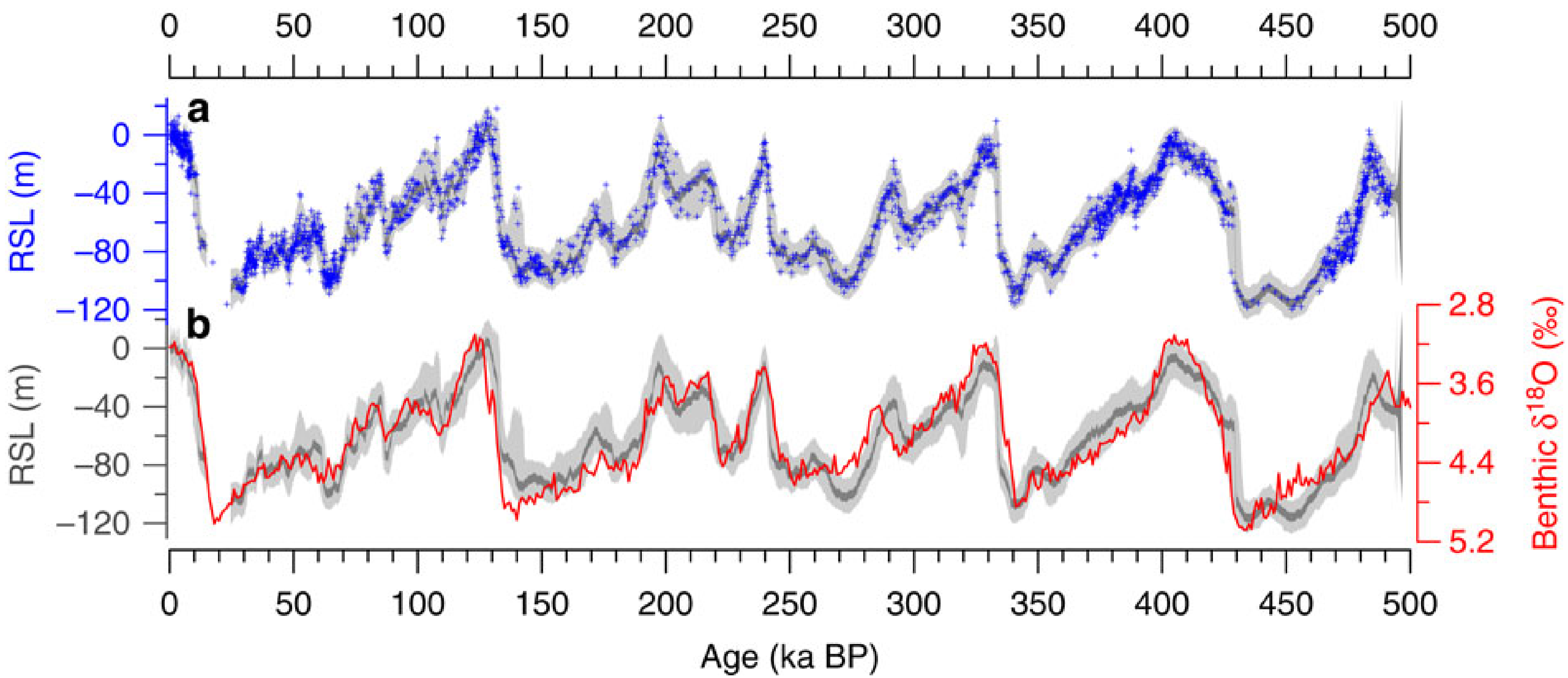
Consequences and Behaviour:
An event showcasing "Clean Carbon" research
18 May 2016 | 15:00 - 17:00 | Building 58/1067, Highfield Campus

Plan

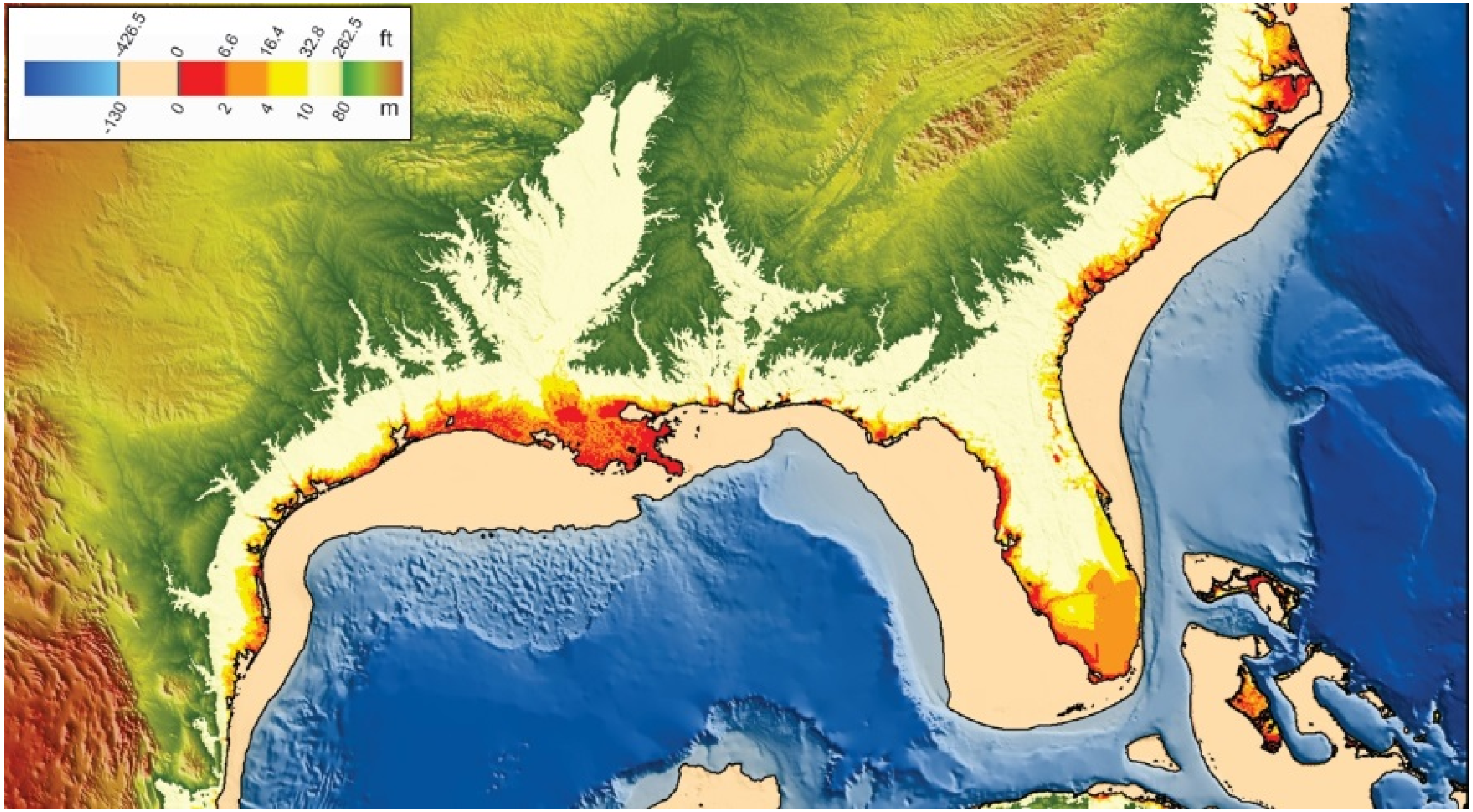
- Introduction
- Sea-Level Rise
- Climate Mitigation
- Adaptation
- Concluding Thoughts

Sea levels over the last 500,000 years

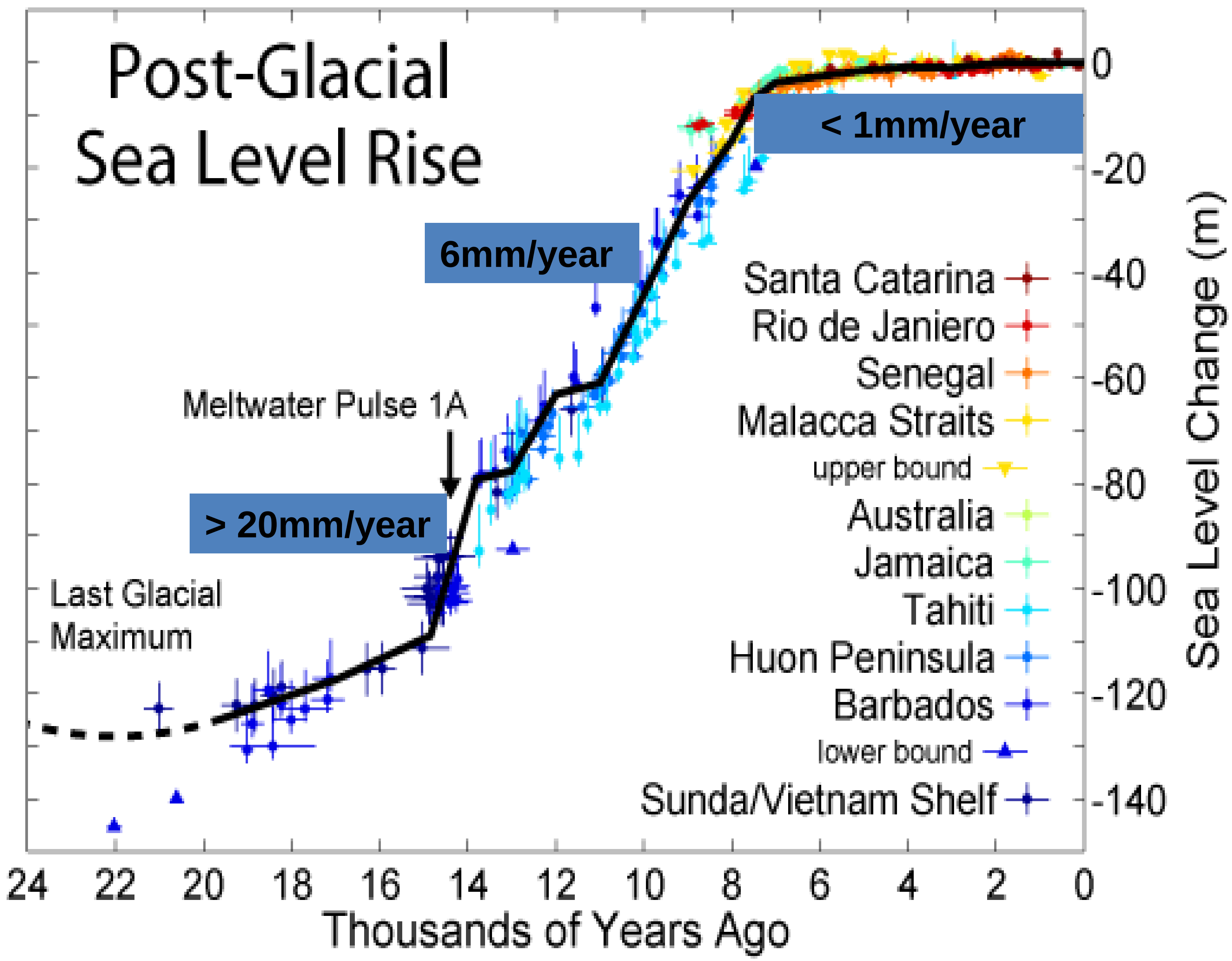


From Grant et al., 2014 doi:10.1038/ncomms6076

South-east USA Continental Shelf



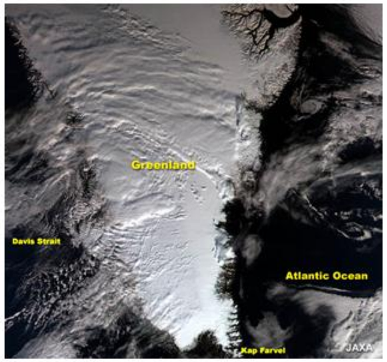
Map by Emanuel Soeding, Christian-Albrechts University, using U.S. National Oceanic & Atmospheric Administration Etopo2v1 elevation data.



Based on data from Fleming et al. 1998, Fleming 2000, & Milne et al. 2005

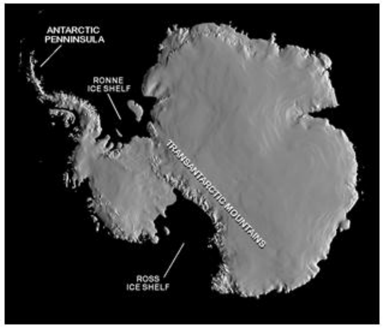
Human Drivers of Climate Change

Climate-induced Sea-Level Rise



Rising temperatures lead to:

- Thermal expansion of seawater;
- Melting of land-based ice
  - Small glaciers (e.g., Rockies, Alaska)
  - Greenland ice sheet
  - West Antarctic ice sheet



Paper by Mercer (1978)

West Antarctic ice sheet and CO_2 greenhouse effect: a threat of disaster

Nature 271, 321 - 325 (26 January 1978);
doi:10.1038/271321a0

Hoffman et al. (1983) EPA Report

By 2100:

1.44 to 2.17 m rise is most likely

0.56 to 3.45 m rise cannot be ruled out

United States
Environmental Protection Agency

Office of Policy
& Resource Management
Washington, DC 20460

October 1983

230983007

EPA

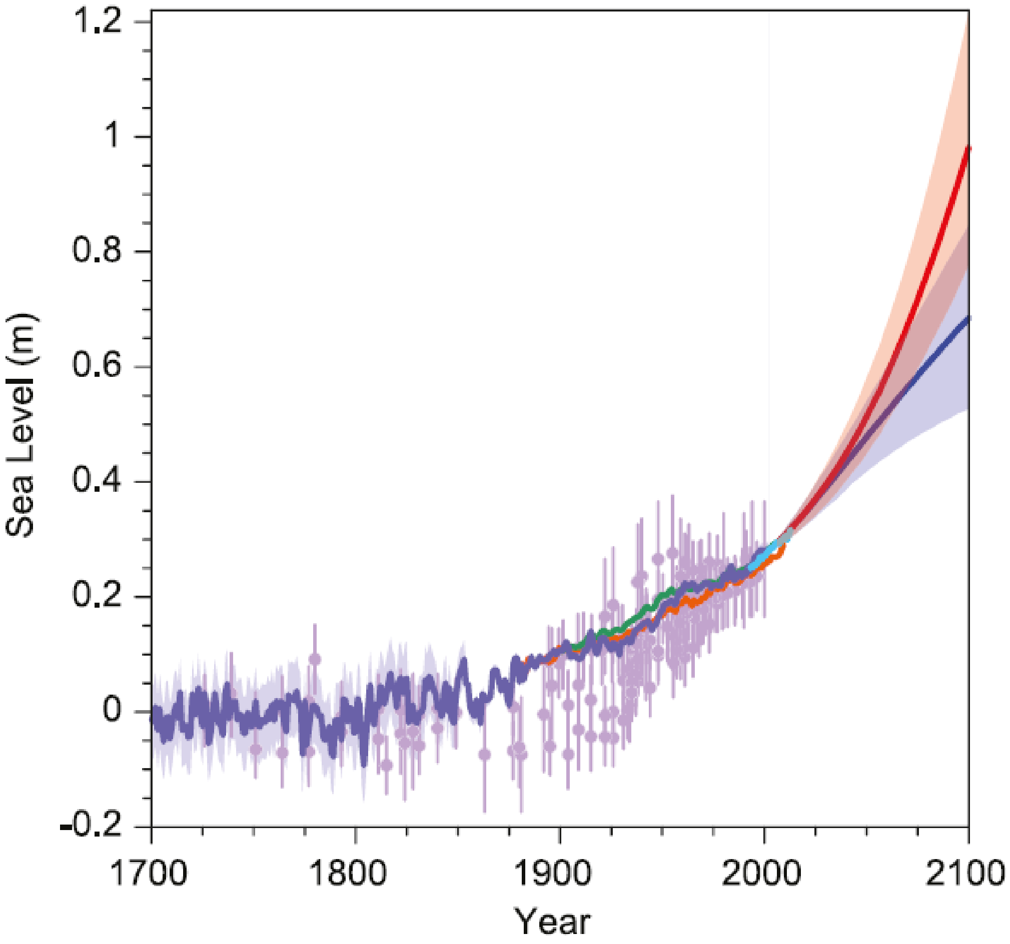
Projecting Future Sea Level Rise

Methodology,
Estimates to the Year 2100,
& Research Needs

Hurst Spit

Global Sea-Level Rise: 1700 to 2100

IPCC AR5 Report 2013



Source: Figure 13.27 -- Chapter 13 IPCC AR5 WG1 Report. Compiled paleo-sea-level data from geological evidence to 1880, tide gauge data from 1880 to present, altimeter data since 1993 to present, and central estimates and likely ranges for projections from present to 2100 based on RCP2.6 (blue) and RCP8.5 (red) emission scenarios.

nature geoscience

LETTERS

PUBLISHED ONLINE: 22 NOVEMBER 2009 | DOI: 10.1038/NGEO694

Accelerated Antarctic ice loss from satellite gravity measurements

J. L. Chen[1]*, C. R. Wilson[1,2], D. Blankenship[3] and B. D. Tapley[1]

Accurate quantification of Antarctic ice-sheet mass balance and its contribution to global sea-level rise remains challenging, because *in situ* measurements over both space and time are sparse. Satellite remote-sensing data of ice elevations and ice motion show significant ice loss in the range of −31 to −196 Gt yr^{-1} in West Antarctica in recent years[1–4], whereas East Antarctica seems to remain in balance or slightly gain mass[1,2,4], with estimated rates of mass change in the range of −4 to 22 Gt yr^{-1}. The Gravity Recovery and Climate Experiment[5] (GRACE) offers the opportunity of quantifying polar ice-sheet mass balance from a different perspective[6,7]. Here we use an extended record of GRACE data spanning the period April 2002 to January 2009 to quantify the rates of Antarctic ice loss. In agreement with an independent earlier assessment[4], we estimate a total loss of 190 ± 77 Gt yr^{-1}, with 132 ± 26 Gt yr^{-1} coming from West Antarctica. However, in contrast with previous GRACE estimates, our data suggest that East Antarctica is losing mass, mostly in coastal regions, at a rate of −57 ± 52 Gt yr^{-1}, apparently caused by increased ice loss since the year 2006.

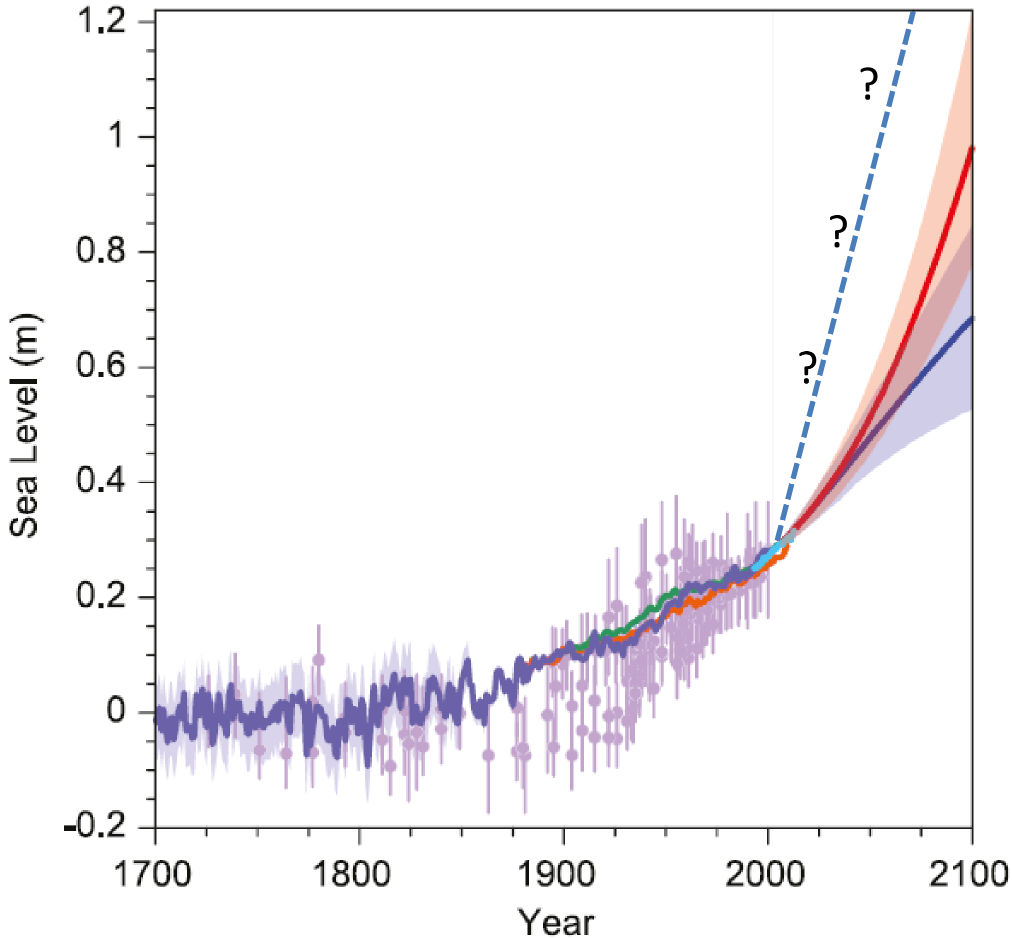
mass-rate estimates for the Patagonia ice fields of South America[16], Graham Land of the Antarctic Peninsula[14] (using GRACE spherical harmonic solutions) and Alaskan mountain glaciers[15].

GRACE estimates of Antarctic mass balance have been variable, ranging from −80 to −152 Gt yr^{-1} (refs 6, 11, 17). The wide range is due in part to uncertainty associated with other geophysical signals in GRACE data, especially post-glacial rebound (PGR). Other causes include variable time spans analysed, varied analysis methods and use of different versions of GRACE products. Still, all GRACE estimates show significant ice loss over the West Antarctic Ice Sheet (WAIS) since 2002, with estimated rates in the range −96 to −148 Gt yr^{-1} (refs 6, 11, 17). However, over the East Antarctic Ice Sheet (EAIS) there has been uncertainty in the sign of the estimated mass rate, from both GRACE and other remote-sensing data[1].

This letter presents new estimates of Antarctic ice mass rates (Fig. 1) using 79 monthly samples of the most recent GRACE release-4 (RL04) spherical harmonic solutions for the period April 2002 to January 2009. RL04 is produced at the Center for Space Research of the University of Texas of Austin[18]. With nearly seven

Global Sea-Level Rise: 1700 to 2100

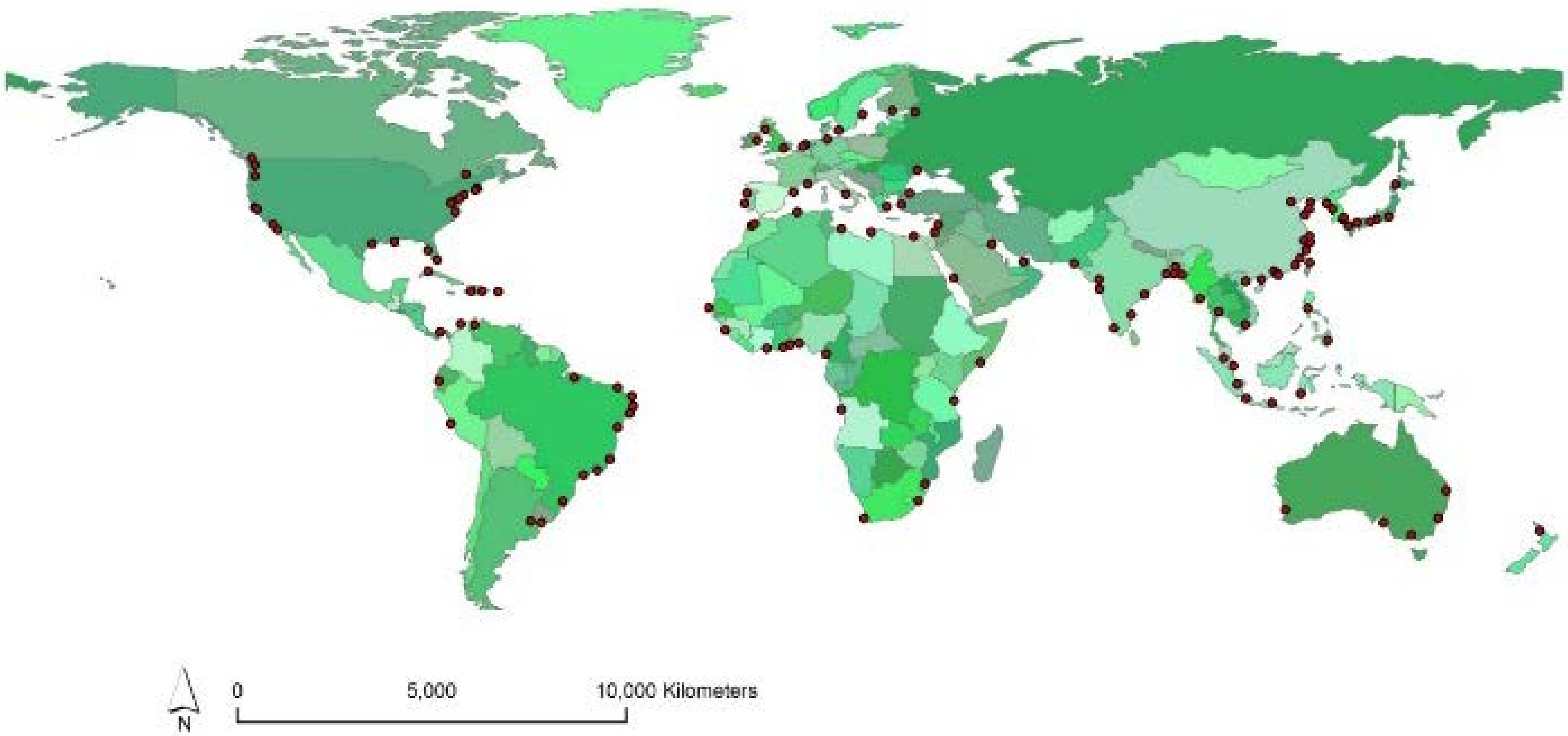
IPCC AR5 Report 2013



Source: Figure 13.27 -- Chapter 13 IPCC AR5 WG1 Report. Compiled paleo-sea-level data from geological evidence to 1880, tide gauge data from 1880 to present, altimeter data since 1993 to present, and central estimates and likely ranges for projections from present to 2100 based on RCP2.6 (blue) and RCP8.5 (red) emission scenarios.

What’s at stake?

Coastal Cities with more than one million people in 2005



Physical Impacts of Sea-Level Rise

NATURAL SYSTEM EFFECT		INTERACTING FACTORS	
		CLIMATE	NON-CLIMATE
1. Inundation, flood and storm damage	a. Surge (flooding from the sea)	Wave/storm climate, Erosion, Sediment supply.	Sediment supply, Flood management, Erosion, Land reclamation
	b. Backwater effect (flooding from rivers)	Run-off.	Catchment management and land use.
2. Wetland loss (and change)		CO_2 fertilisation of biomass production, Sediment supply, Migration space	Sediment supply, Migration space, Land reclamation (i.e., direct destruction).
3. Erosion (of 'soft' morphology)		Sediment supply, Wave/storm climate.	Sediment supply.
4. Saltwater Intrusion	a. Surface Waters	Run-off.	Catchment management (over-extraction), Land use.
	b. Ground-water	Rainfall.	Land use, Aquifer use (over-pumping).
5. Higher water tables/ impeded drainage		Rainfall, Run-off.	Land use, Aquifer use, Catchment management.

Source: Nicholls (2010) Book on "Understanding Sea-Level Rise and Variability"

Need for Action

orld-europe-36255749

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Asia | China | India

Five Pacific islands disappear as sea levels rise

10 May 2016 | Asia

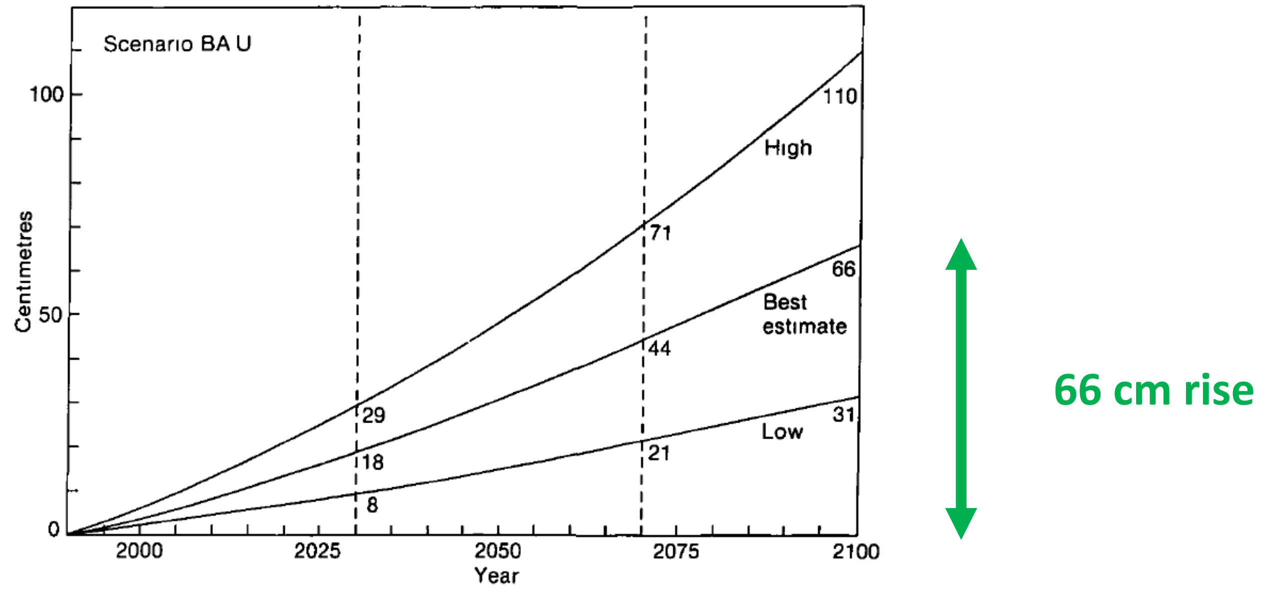
REUTERS/SIMON ALBERT

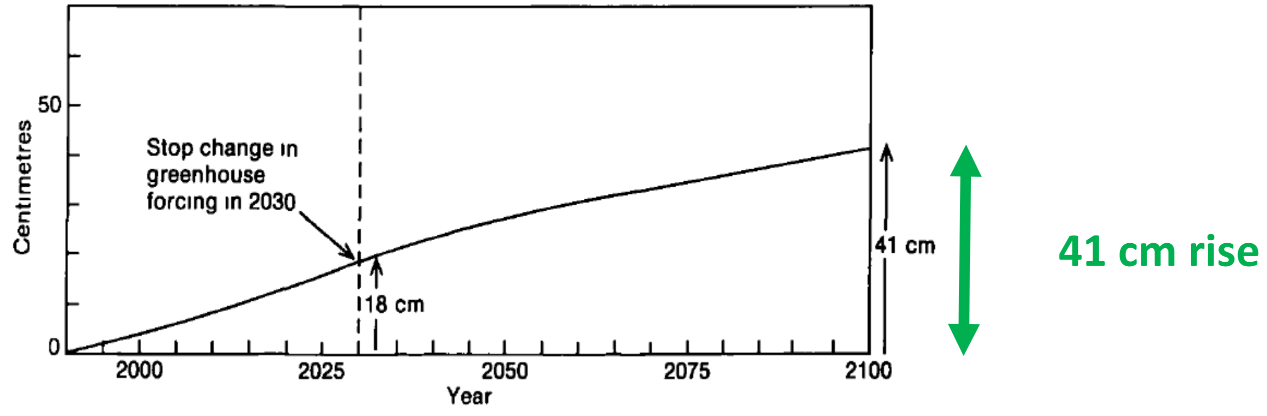
Images show the remains of six partially eroded islands in the Solomon Islands

Climate Mitigation and Sea-Level Rise

First IPCC Sea-level rise scenarios

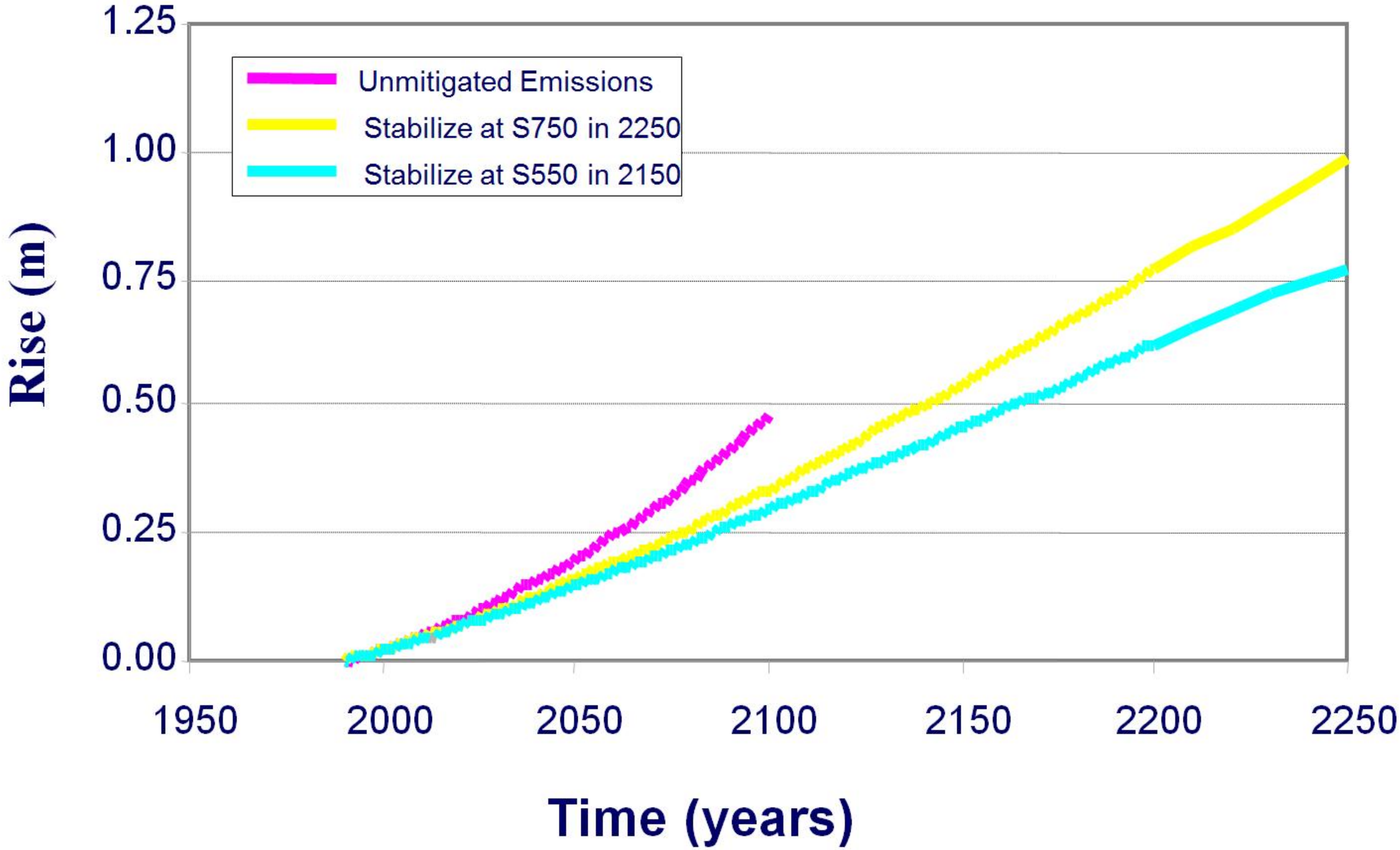
Source: Warrick and Oerlemans (1990)





Climate Mitigation Scenarios

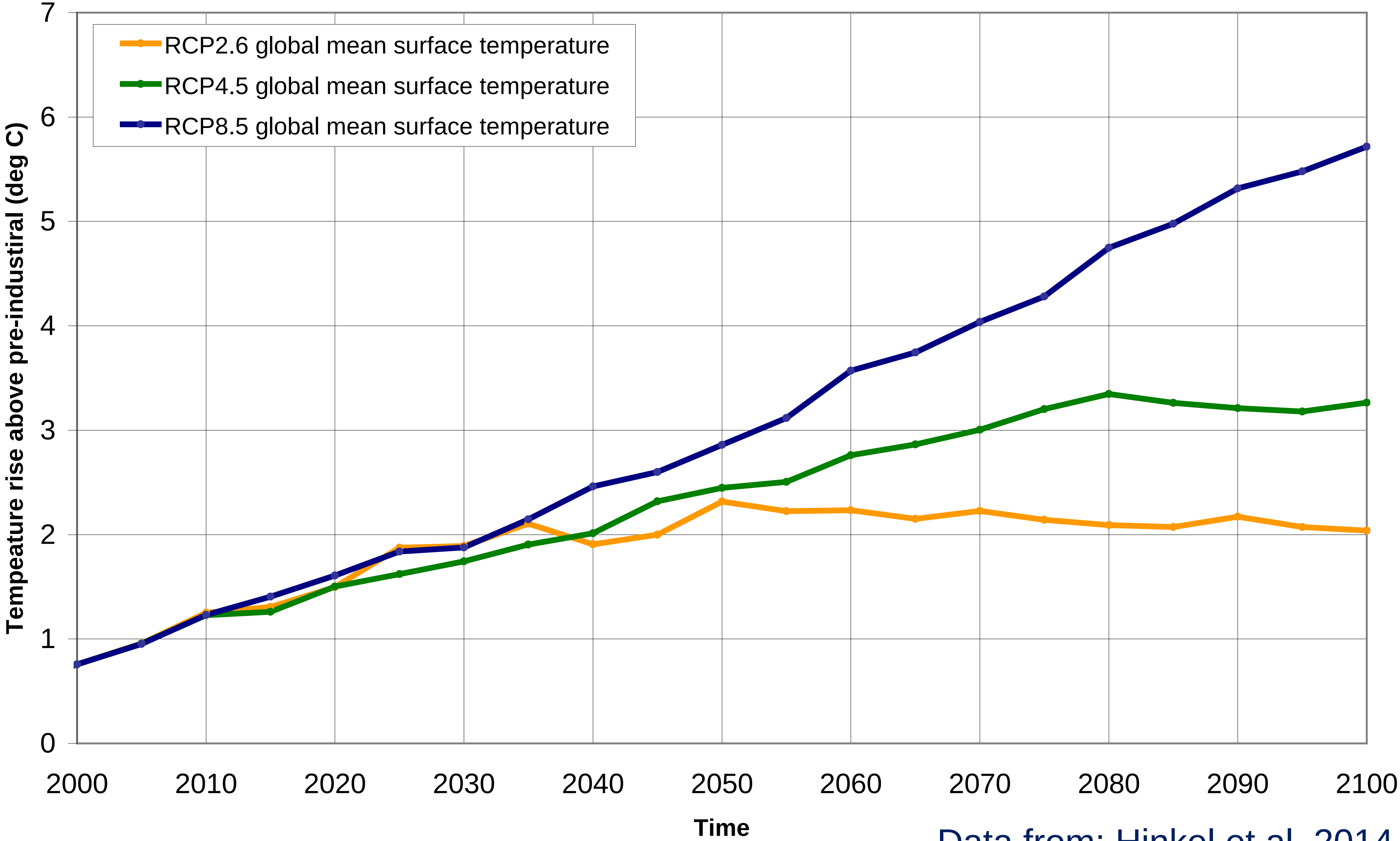
Hadley Coupled Ocean-Atmosphere Model 2



Source: Nicholls and Lowe (2004) Global Environmental Change

Global Temperature Rise

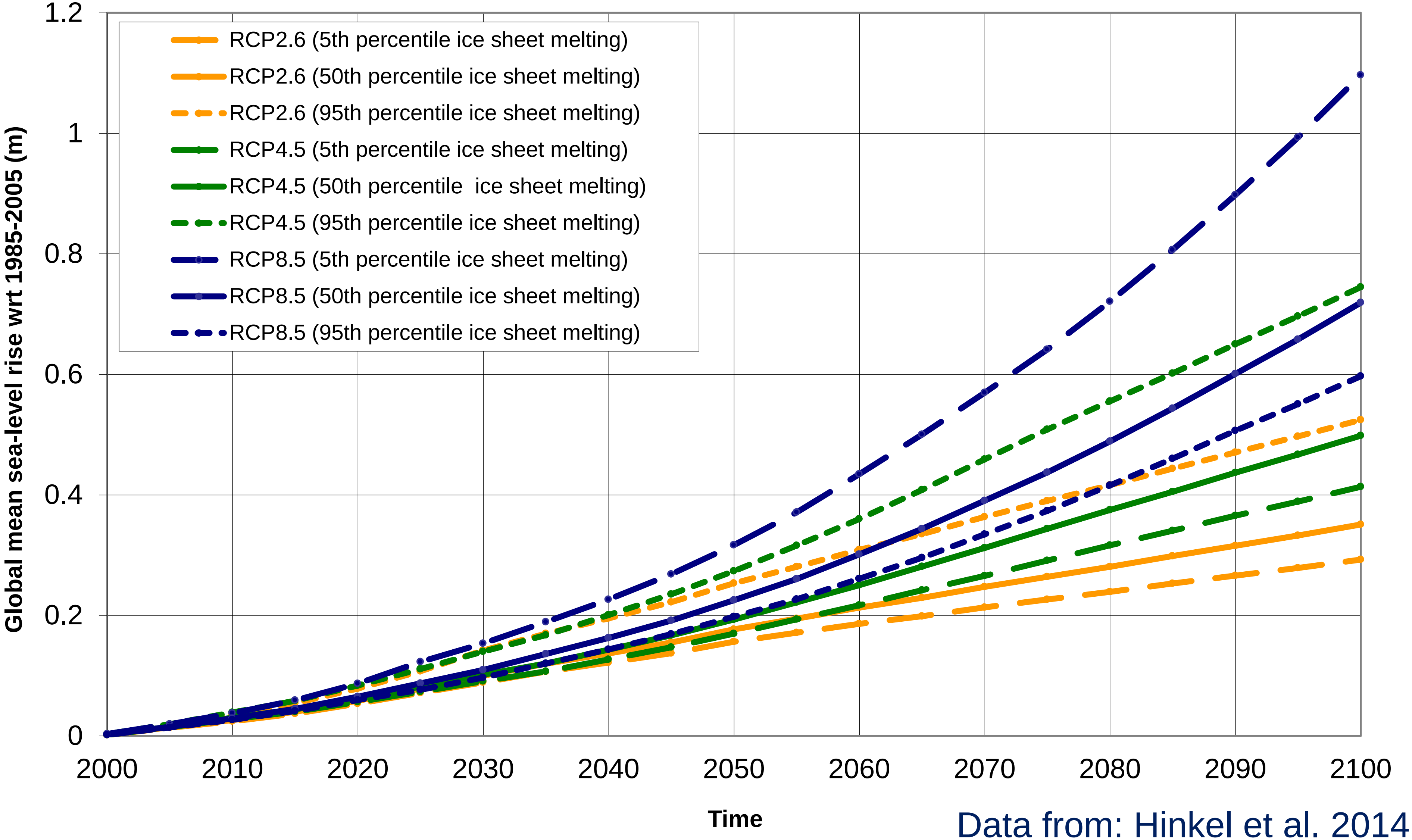
Model: HadGEM2-ES



Data from: Hinkel et al. 2014

Sea-level rise (Maldives)

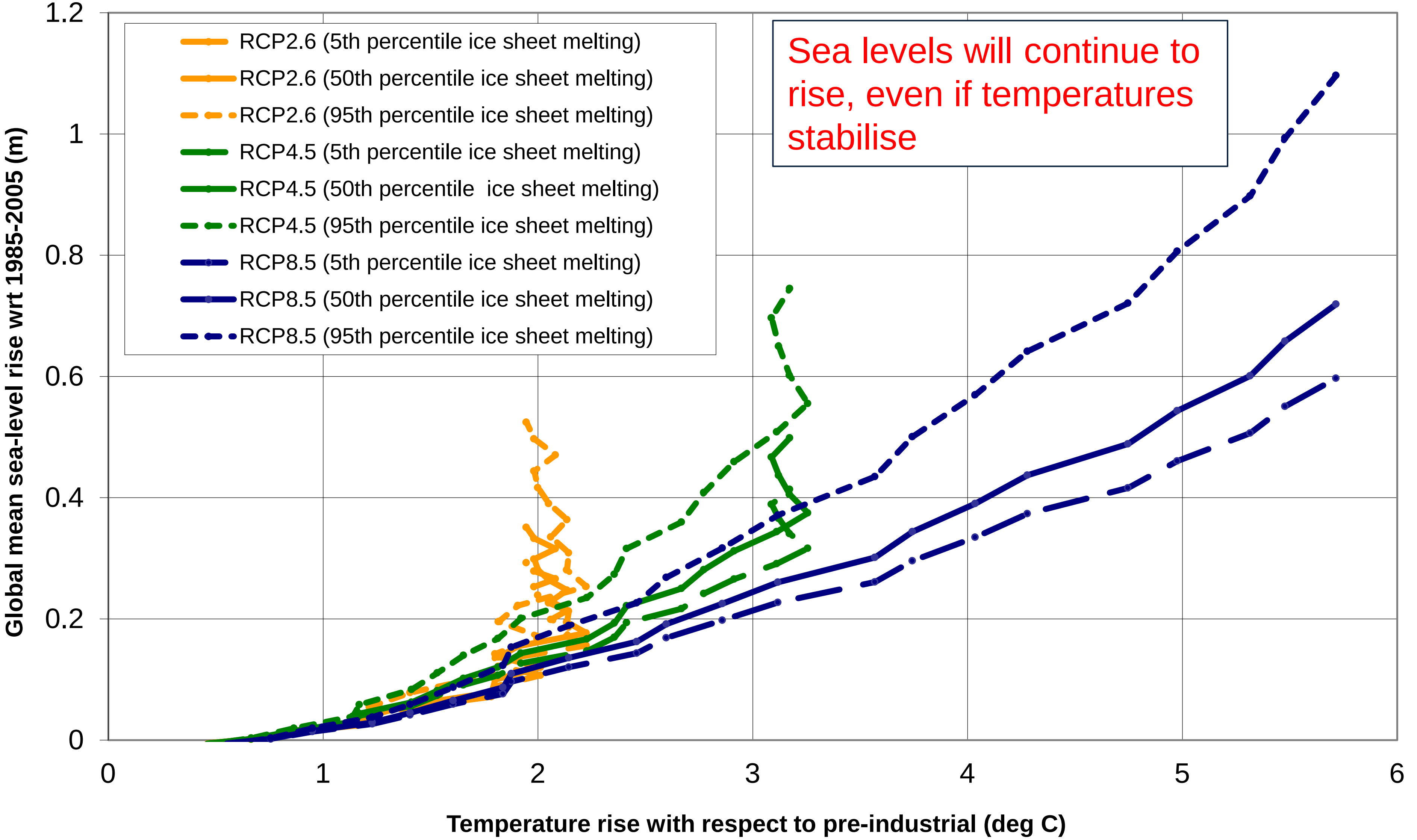
Model: HadGEM2-ES, including regional (patterned) sea-level rise



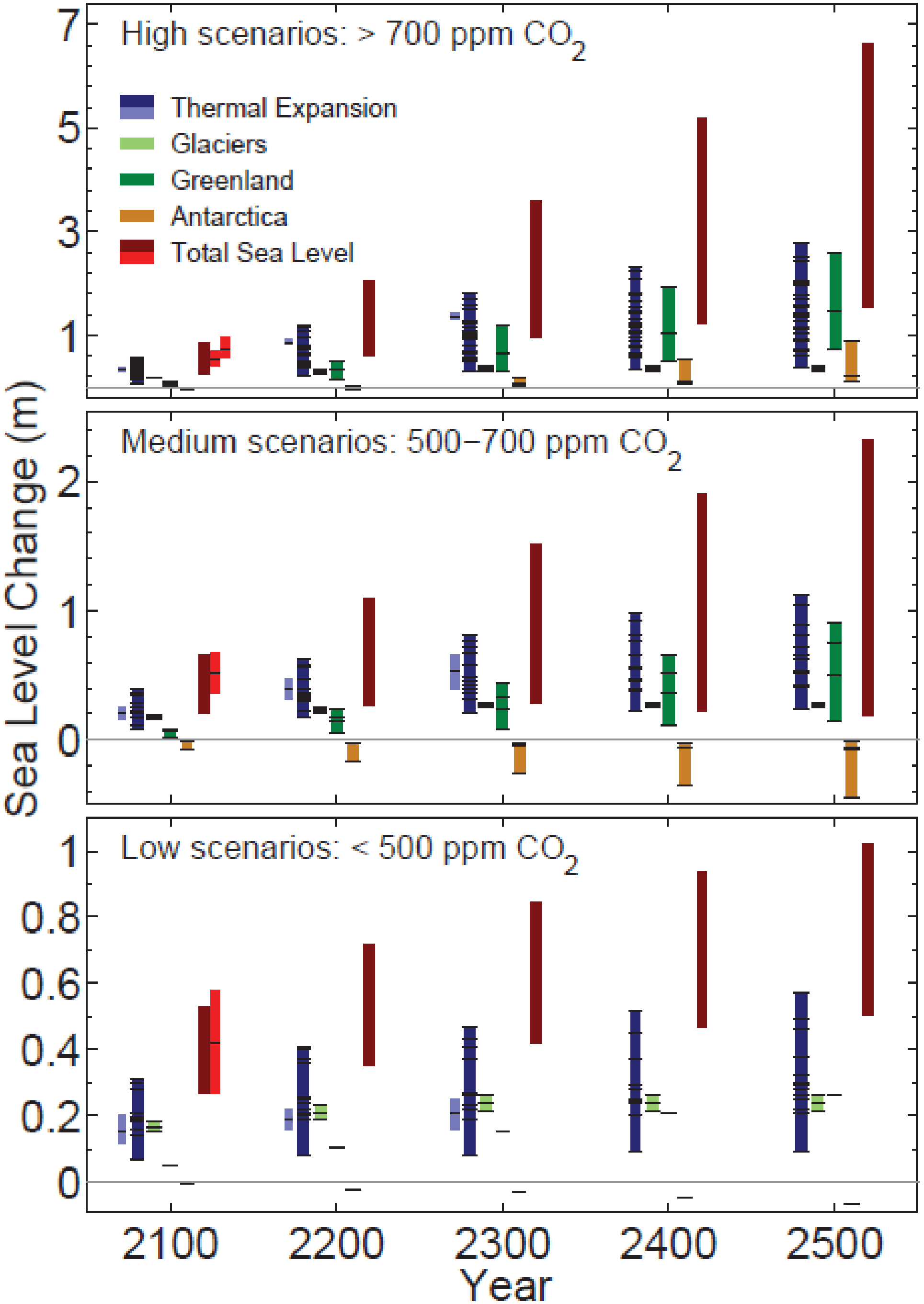
Data from: Hinkel et al. 2014

Temperature and sea level

Model: HadGEM2-ES, including regional (patterned) sea-level rise

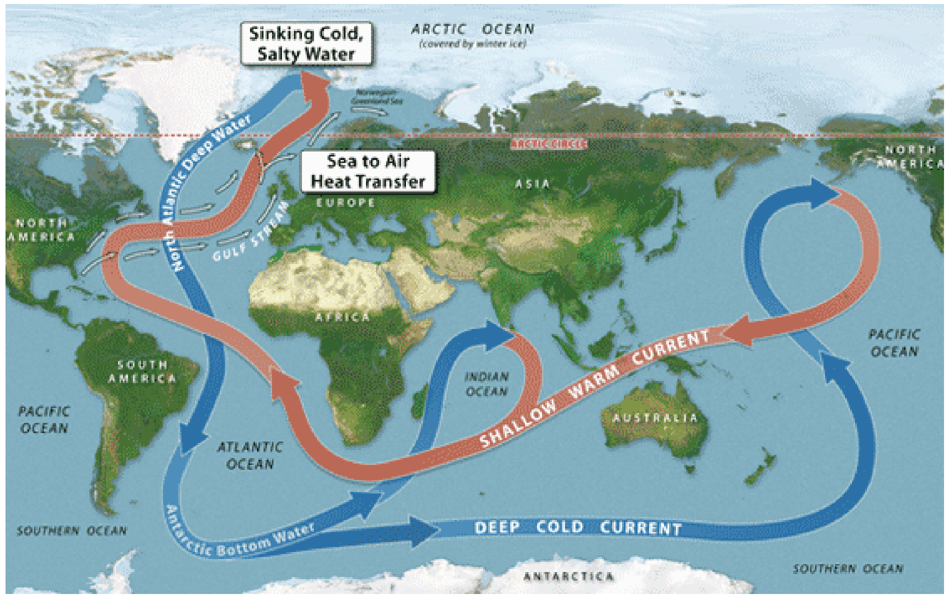


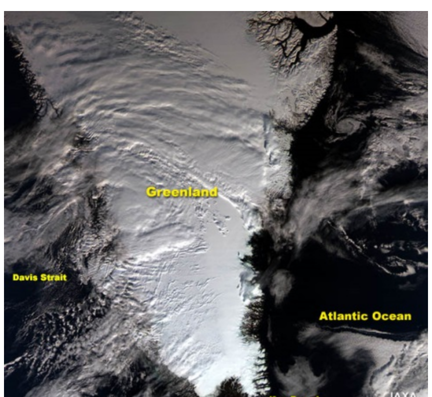
Sea-Level Rise vs. Emissions: 2000 to 2500

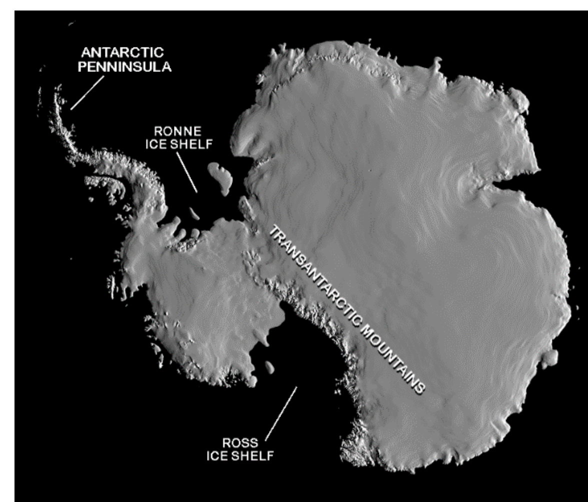


(Source: Figure 13.13 -- Chapter 13 IPCC AR5 WG1 Report)

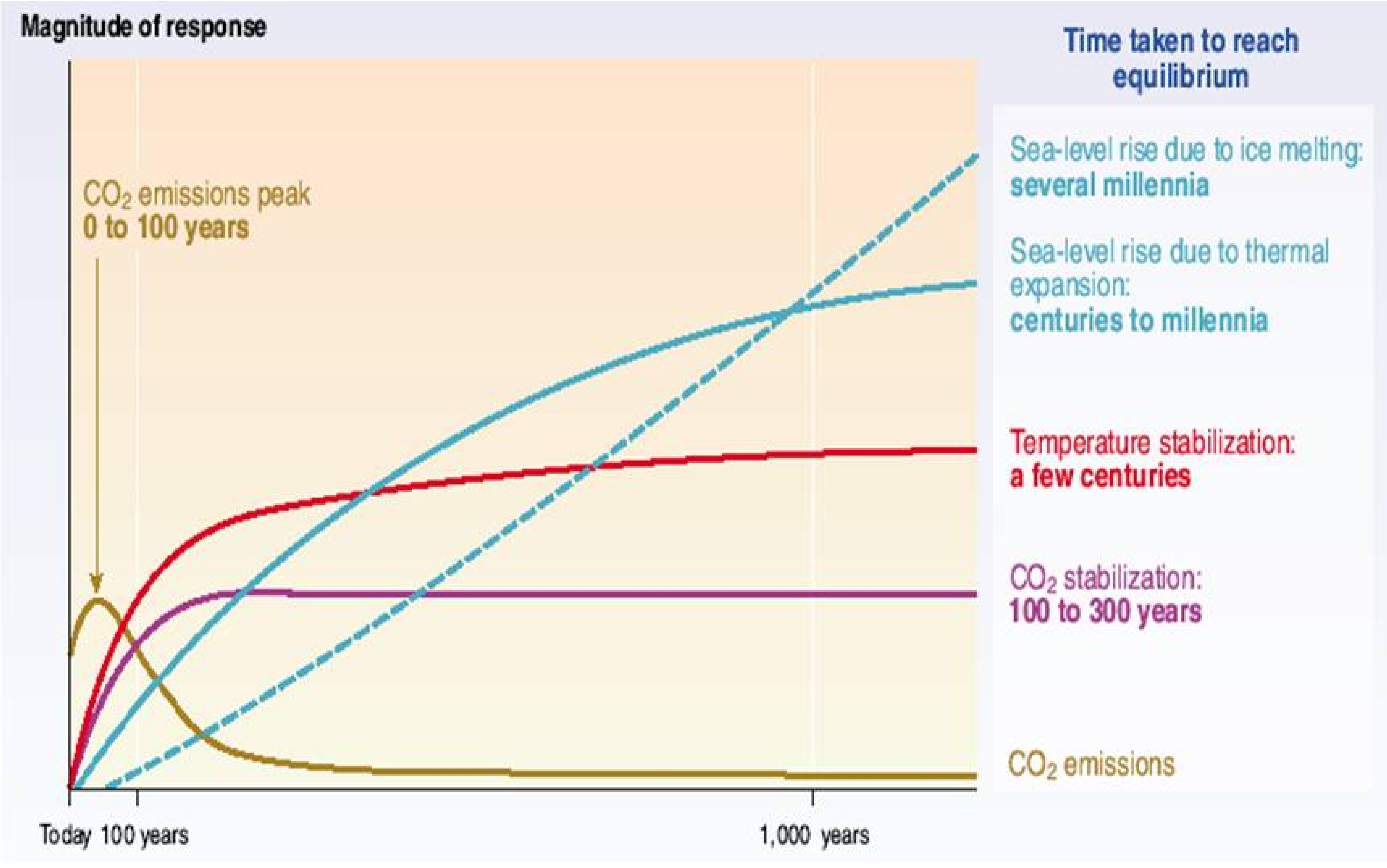
Sea-level timescales





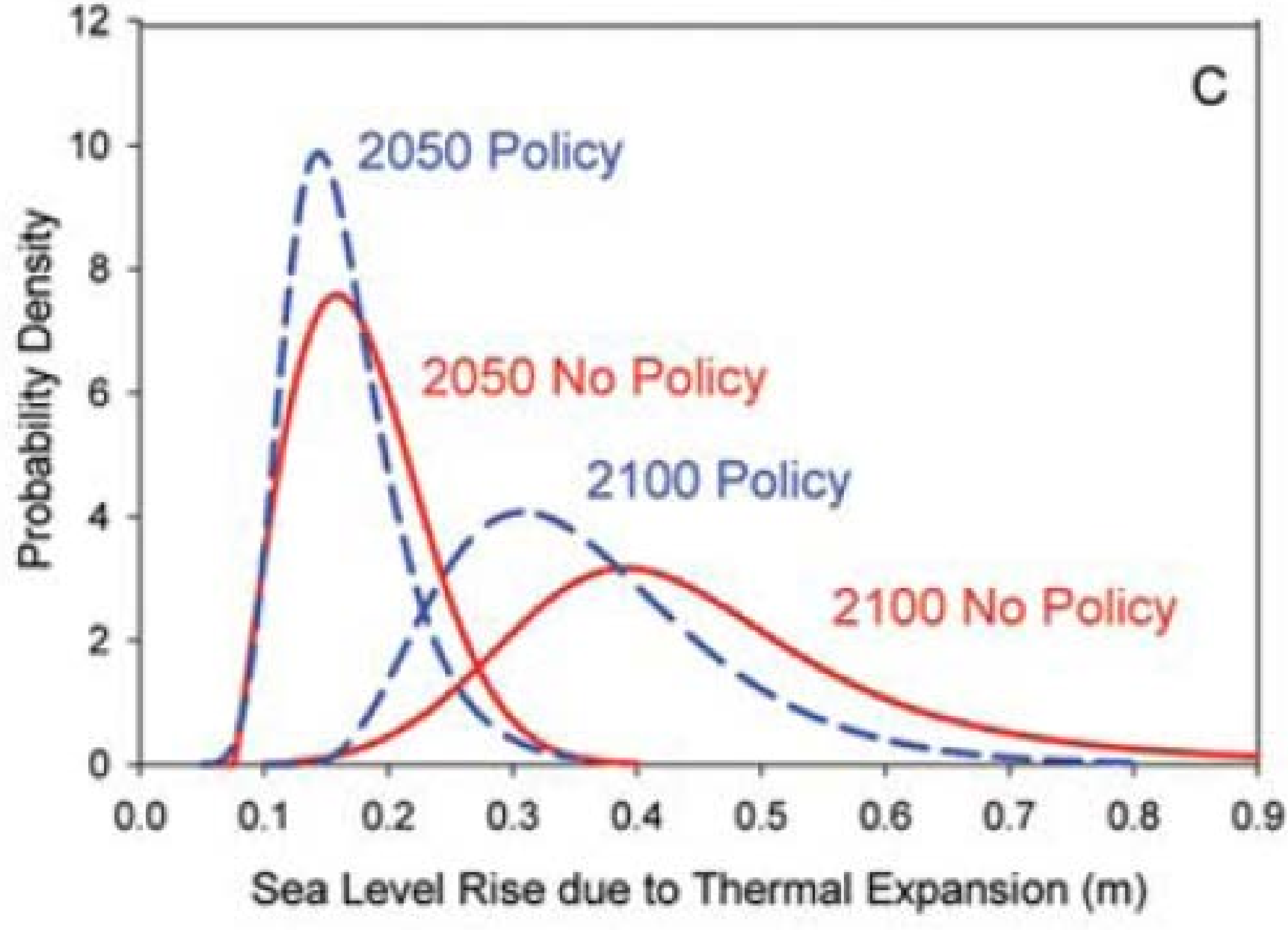


Carbon dioxide, temperature and sea level timescales (source: IPCC TAR, 2001)



Climate Mitigation

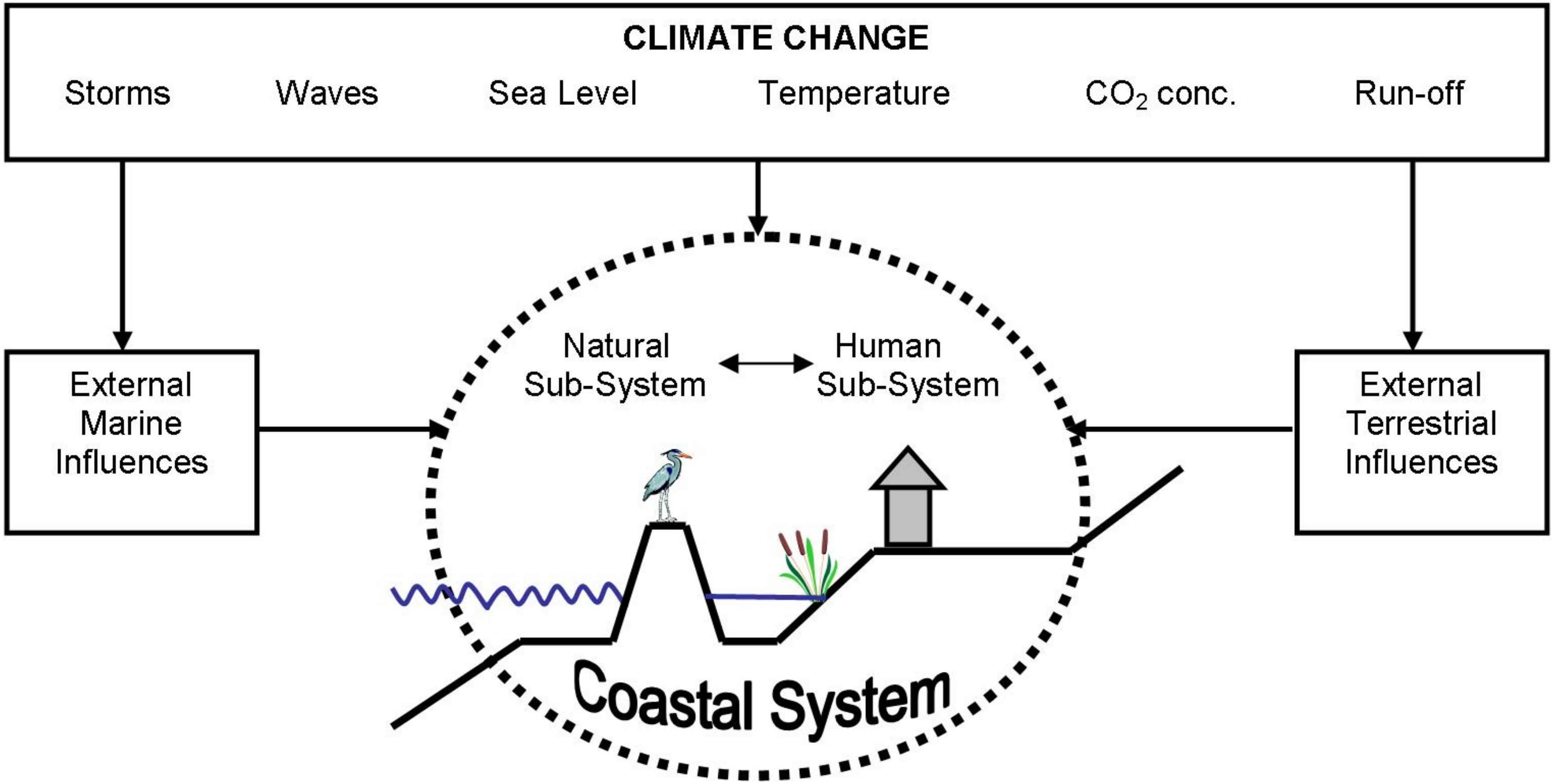
Source: MIT Joint Program on Global Change



Adaptation to Sea-Level Rise

The coastal system:

Other climate drivers



Source: IPCC AR4 WG II

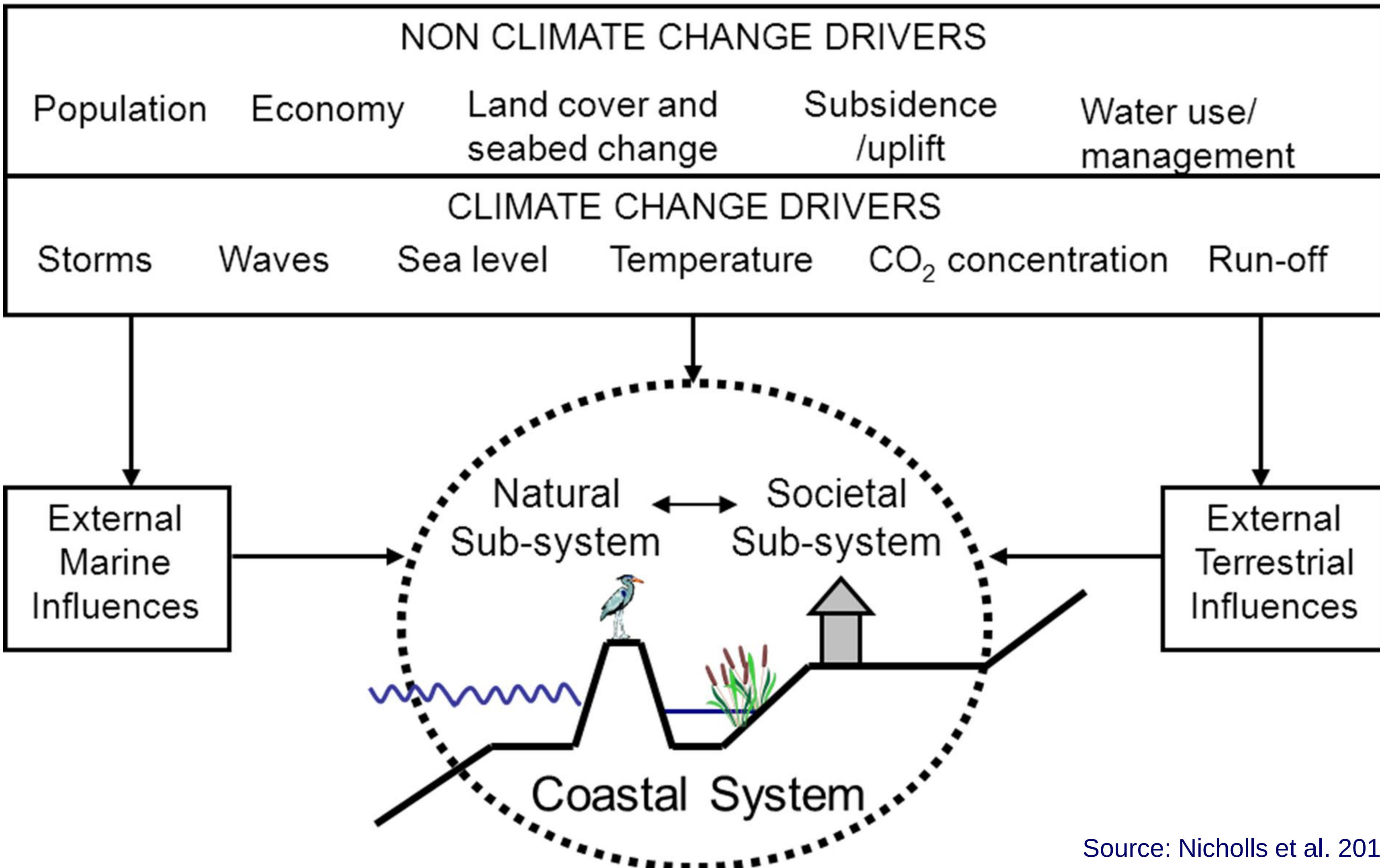
Physical Impacts of Sea-Level Rise

NATURAL SYSTEM EFFECT		INTERACTING FACTORS	
		CLIMATE	NON-CLIMATE
1. Inundation, flood and storm damage	a. Surge (flooding from the sea)	Wave/storm climate, Erosion, Sediment supply.	Sediment supply, Flood management, Erosion, Land reclamation
	b. Backwater effect (flooding from rivers)	Run-off.	Catchment management and land use.
2. Wetland loss (and change)		CO_2 fertilisation of biomass production, Sediment supply, Migration space	Sediment supply, Migration space, Land reclamation (i.e., direct destruction).
3. Erosion (of 'soft' morphology)		Sediment supply, Wave/storm climate.	Sediment supply.
4. Saltwater Intrusion	a. Surface Waters	Run-off.	Catchment management (over-extraction), Land use.
	b. Ground-water	Rainfall.	Land use, Aquifer use (over-pumping).
5. Higher water tables/ impeded drainage		Rainfall, Run-off.	Land use, Aquifer use, Catchment management.

Source: Nicholls (2010) Book on "Understanding Sea-Level Rise and Variability"

The coastal system:

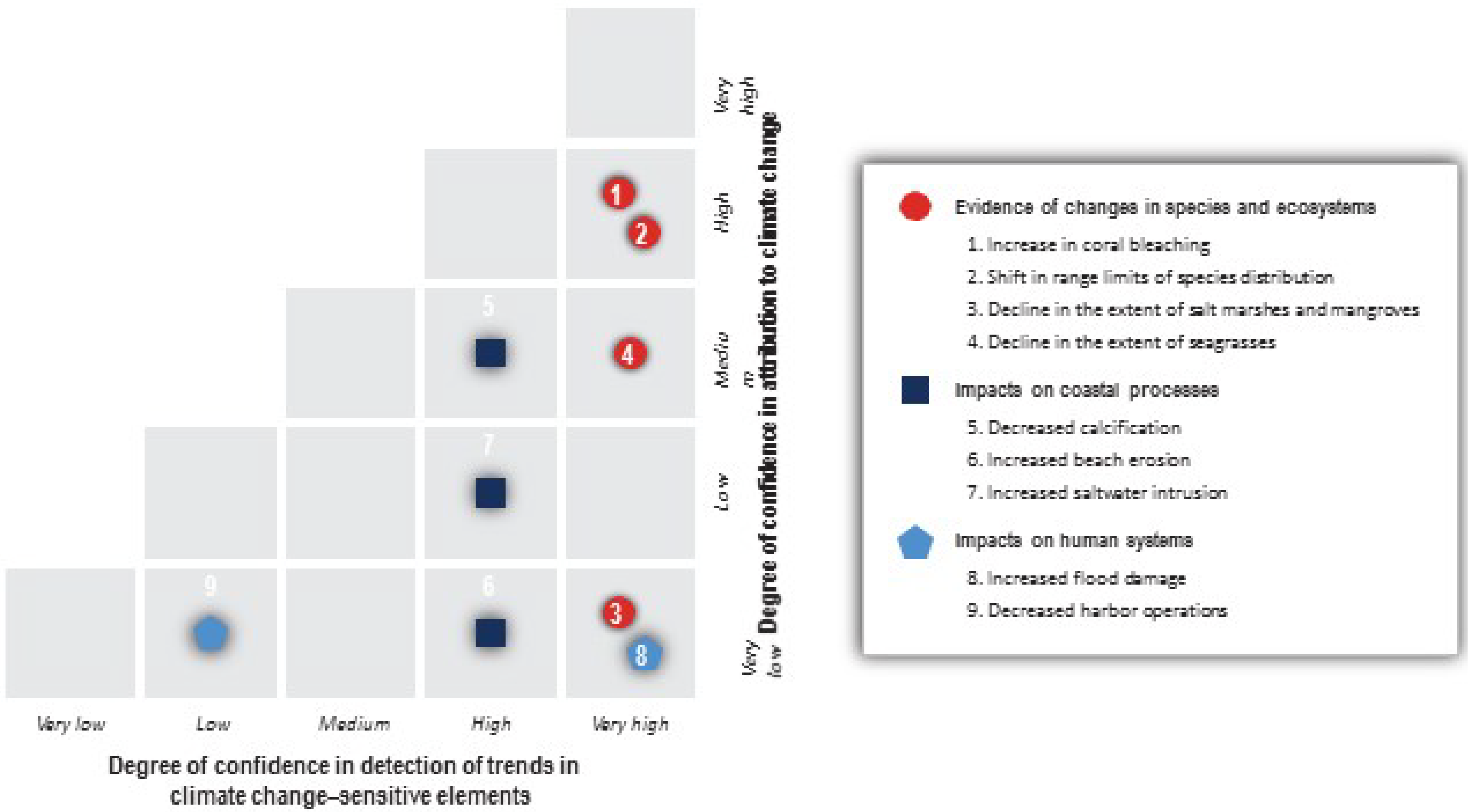
Non-climate drivers



Source: Nicholls et al. 2014
Masselink and Gehrels (eds)

Observed coastal impacts

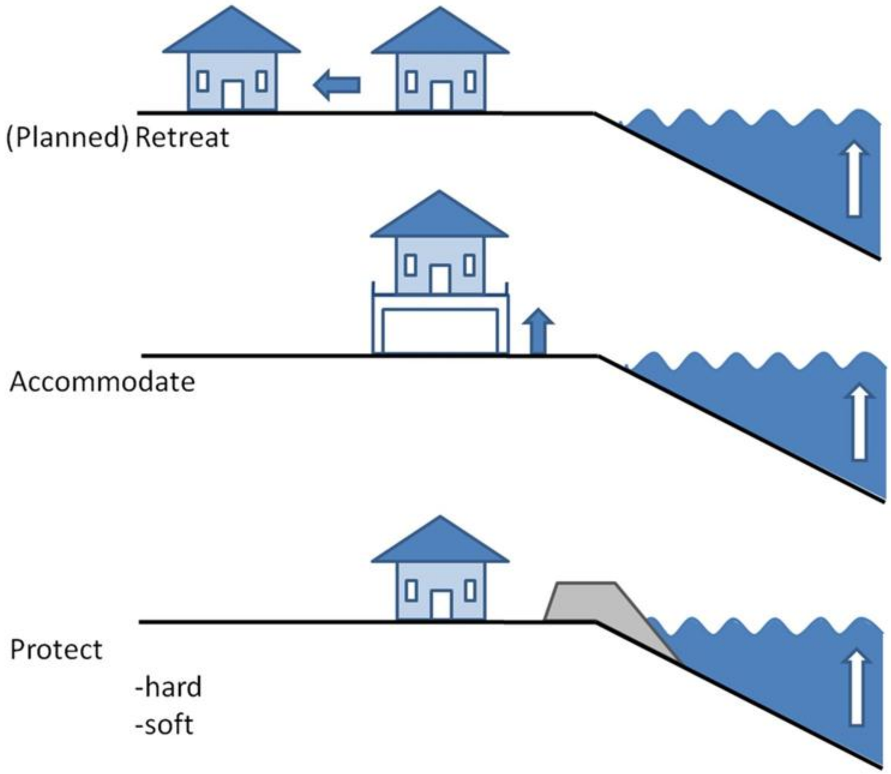
Summary of detection and attribution of climate change in IPCC AR5 Report



Source Figure 5.5 in Wong et al. (2015)

Planned Adaptation to SLR

The IPCC Approach



Source: Nicholls (2010) Book on "Understanding Sea-Level Rise and Variability"

Many Adaptation Options are Available

P – Protection; A – Accommodation; R – Retreat.

NATURAL SYSTEM EFFECT		POSSIBLE ADAPTATION RESPONSES
1. Inundation, flood and storm damage	a. Surge	Dikes/surge barriers [P], Building codes/floodwise buildings [A], Land use planning/hazard delineation [A/R].
	b. Backwater effect	
2. Wetland loss (and change)		Land use planning [A/R], Managed realignment/ forbid hard defences [R], Nourishment/sediment management [P].
3. Erosion (of 'soft' morphology)		Coast defences [P], Nourishment [P], Building setbacks [R].
4. Saltwater Intrusion	a. Surface Waters	Saltwater intrusion barriers [P], Change water abstraction [A/R].
	b. Ground-water	Freshwater injection [P], Change water abstraction [A/R].
5. Rising water tables/ impeded drainage		Upgrade drainage systems [P], Polders [P], Change land use [A], Land use planning/hazard delineation [A/R].

Source: Nicholls (2010) Book on "Understanding Sea-Level Rise and Variability"

Beach Nourishment – Bournemouth

BIS4

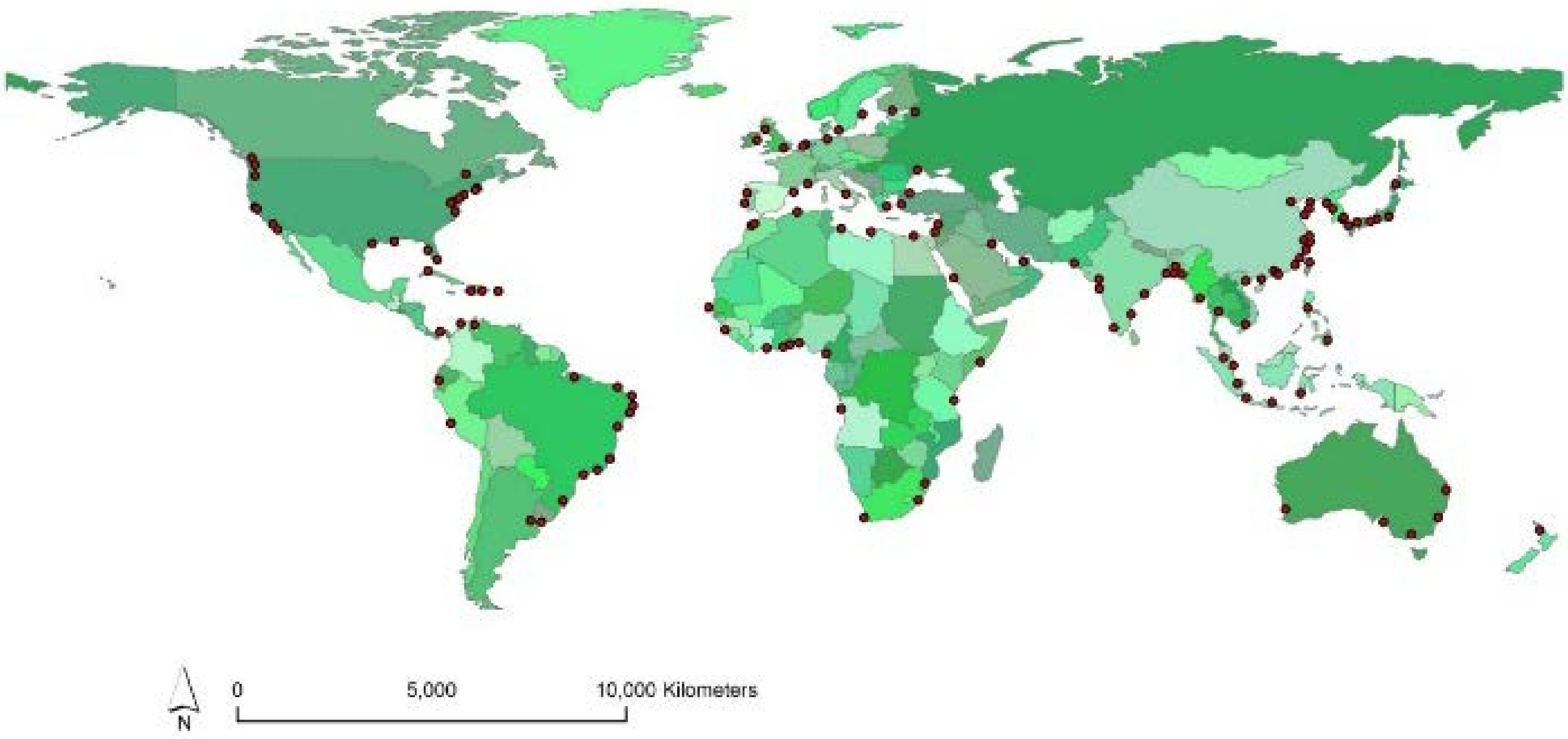
Photo courtesy of Dr. David Harlow, Bournemouth Corporation

Building with Nature, Sand Motor, Holland Coast

Photo courtesy of Bas Jonkman, TUD

Coastal Cities

More than one million people in 2005



Coastal Cities and Sea-Level Rise

(Hallegatte et al., 2013; *Nature Climate Change*)

- Failing to adapt (protect) is not a viable option in coastal cities: damages could reach $1 trillion per year
- Indicative annualized adaptation (protection) costs are about $350 million per year per city, or approximately $50 billion per year for the 136-city sample.
- These are of the same order of magnitude as residual losses with adaptation.
- Managing coastal flood risk requires doing more than maintaining today's standard of protection (and current probability of flooding).
- While improving standards of protection could maintain or reduce risk levels (expected annual damages) and decrease the number of floods, the magnitude of losses when floods do occur will still increase. So expect bigger disasters!

What are the limits to protection?

(Nicholls et al., 2015)

Three types of limit might exist?

- Physical/engineering limits
- Economic/financial limits
- Socio-political limits

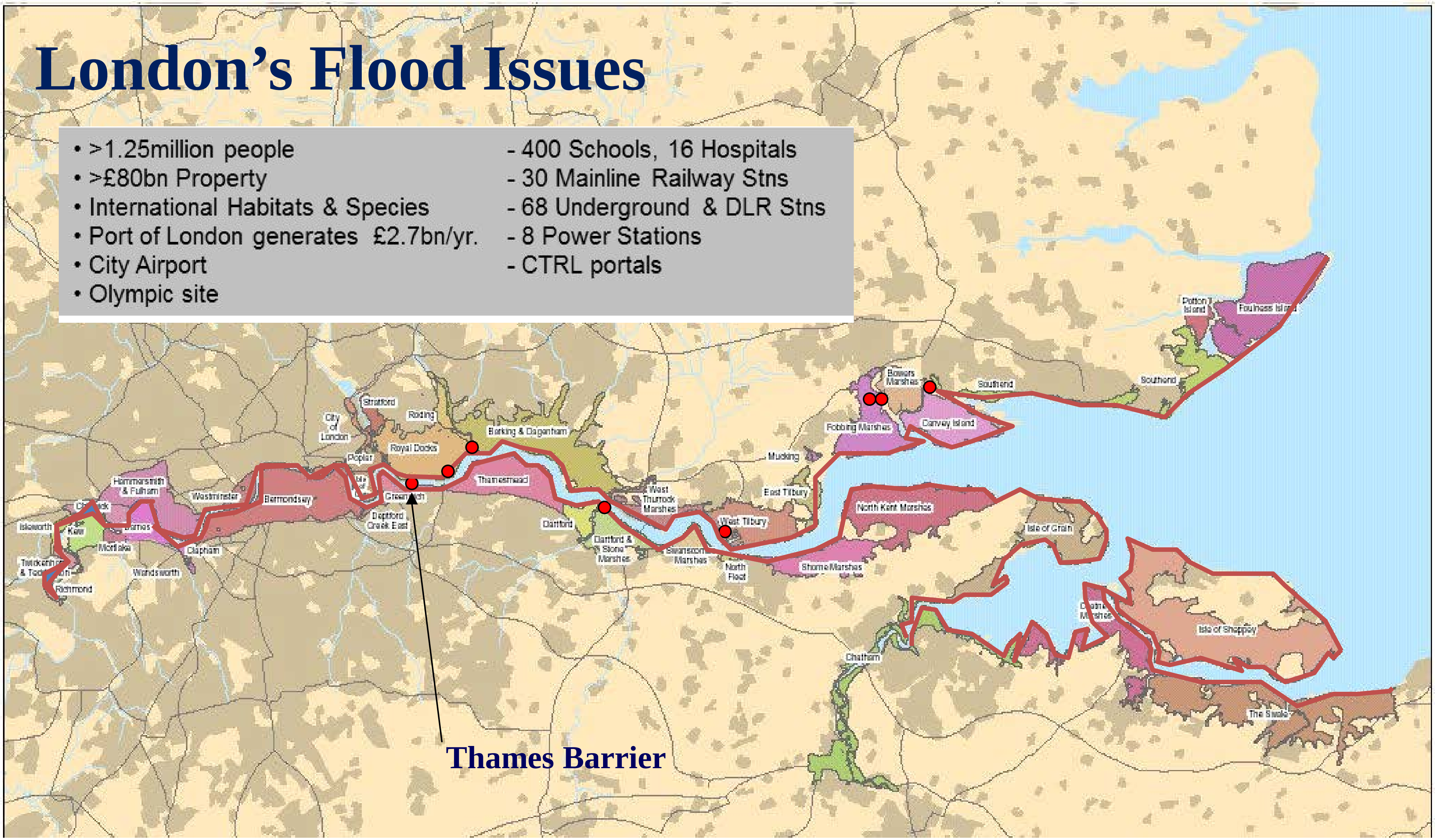
If you cannot protect you will use other adaptation methods – essentially retreat and maybe (forced) migration

Thames Barrier

London’s Flood Issues

- >1.25million people
- >£80bn Property
- International Habitats & Species
- Port of London generates £2.7bn/yr.
- City Airport
- Olympic site

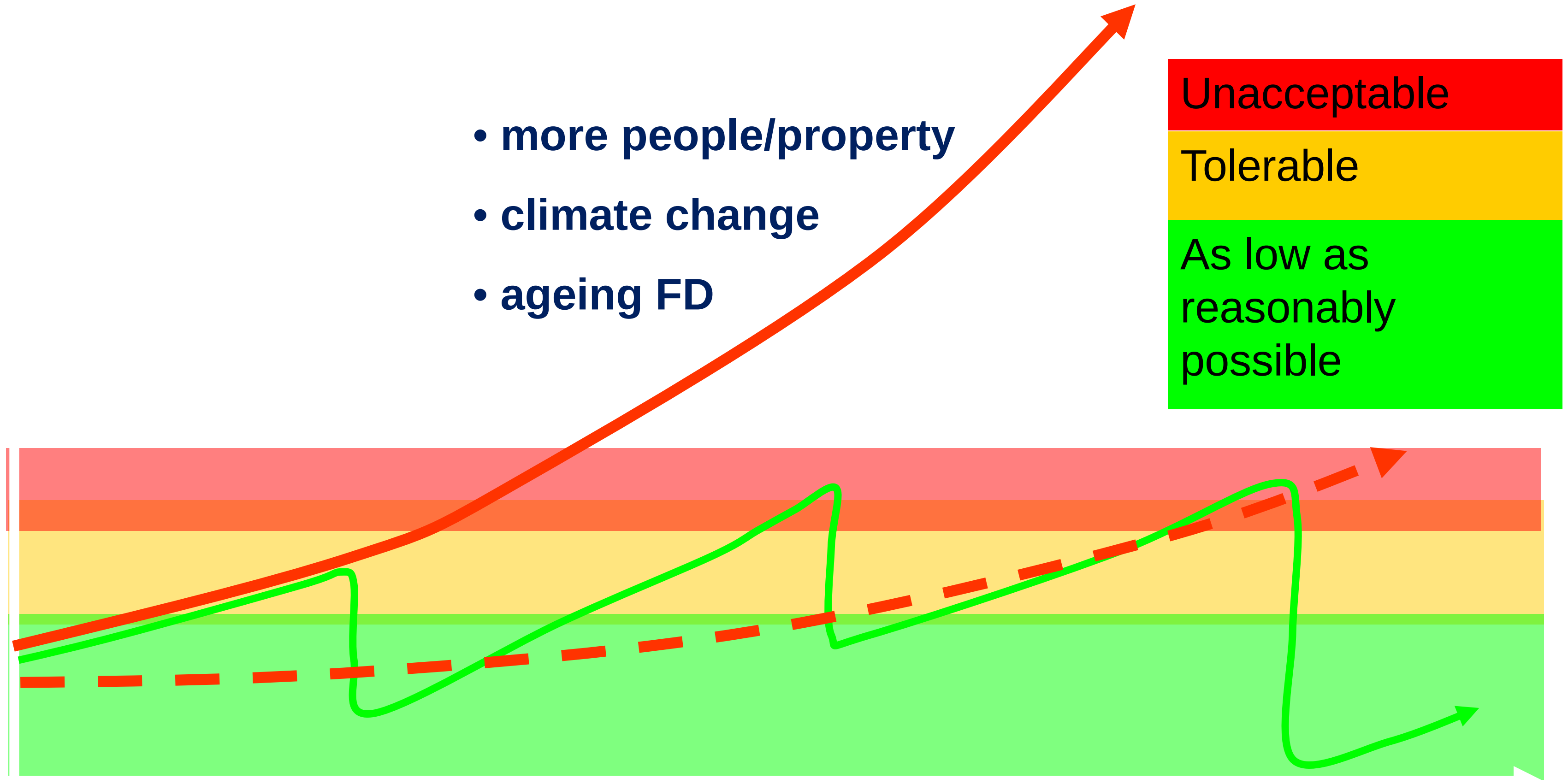
- 400 Schools, 16 Hospitals
- 30 Mainline Railway Stns
- 68 Underground & DLR Stns
- 8 Power Stations
- CTRL portals



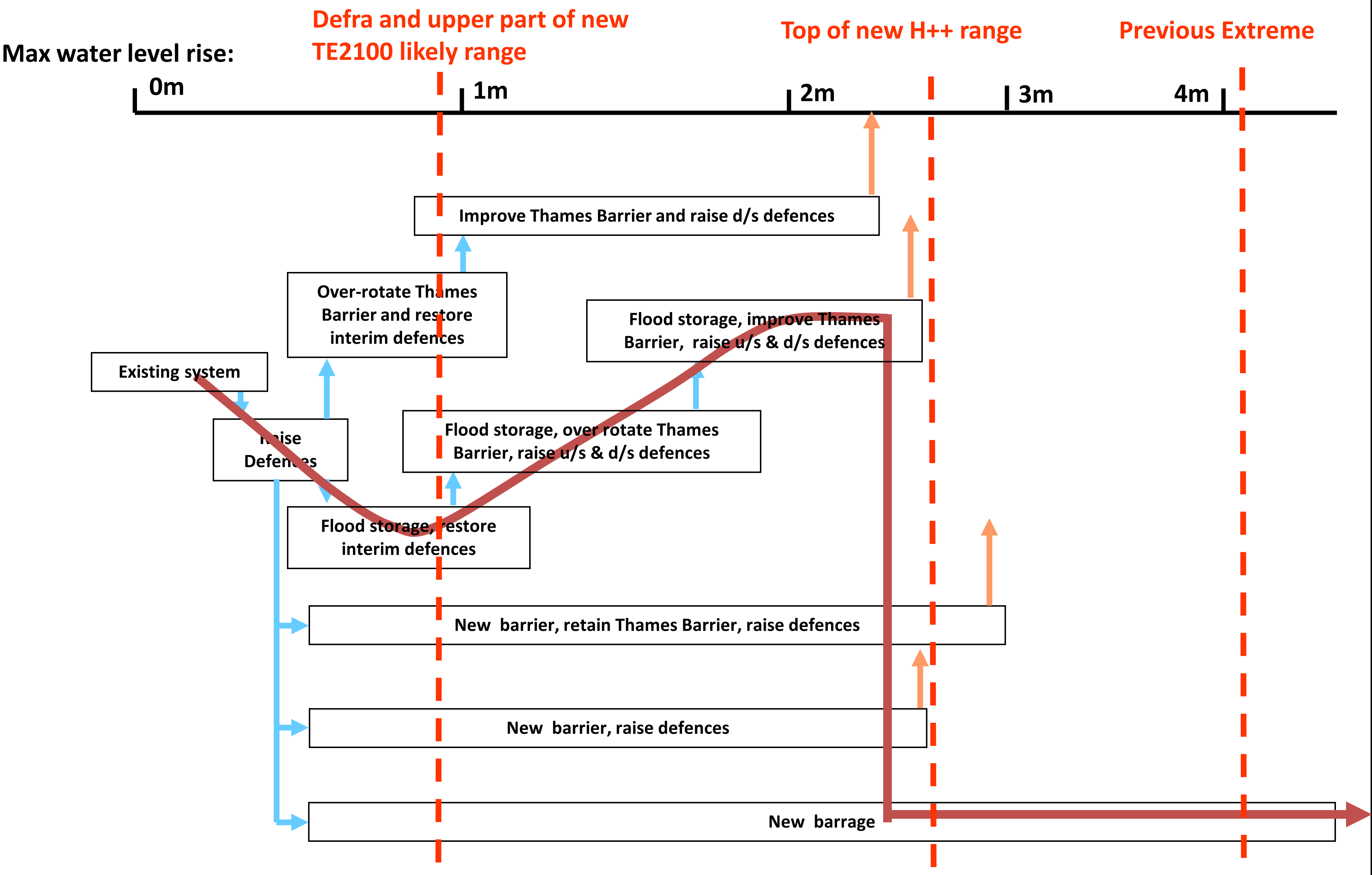
- Barriers
- Defences – 337 km long

Source: Tim Reeder, Environment Agency

Managing Flood Risk through the Century



Source: Tim Reeder, Environment Agency



TE2100 developed options

Source: Tim Reeder, Environment Agency

Concluding Remarks

- Sea level has shaped the world's coast through time
- Human-induced sea-level rise has a major impact potential over the 21st Century (and beyond)
- Planning for these issues would seem prudent
- The most appropriate response will be a combination of climate mitigation and adaptation
- Mitigation has the goal of minimising the high-end changes
- Adaptation is required to the "residual" committed sea-level rise
- Limits to adaptation and protection are poorly understood
- These issues require considerably more research coupled to policy formulation

Mitigating and adapting to climate change in coastal areas: what can we do?

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Consequences and Behaviour:
An event showcasing "Clean Carbon" research
18 May 2016 | 15:00 - 17:00 | Building 58/1067, Highfield Campus