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Coordinated global wave climate projections.

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Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
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CSIRO

Environment Canada
Environnement Canada

Coastal impacts and climate change

Warming Oceans and Climate

Sea-level rise
(0.2 – 0.8 m by 2100, IPCC AR4)

Changes to weather systems and storms

CHANGING RISK OF COASTAL IMPACTS
(Felt most acutely via extreme events –
storm surges and large wave events)

Disturbance (aquatic & terrestrial)

Inundation (SLR/Surge/Setup)

Erosion (SLR/runup/wave dir^{n} changes)

Outline

Consideration of Ocean Waves in IPCC AR4
  - Disparity between WG-1 and WG-2
- **Wave Climate Projections since IPCC AR4**
  - Do these meet the needs of the climate impacts community?
- **IPCC AR5 CMIP5 proposed experimental design**
- **Proposal for co-ordinated global wave projections**
- **Discussion**

Recommendations

To address the needs of the global coastal impacts to climate change community, a greater number of wave climate projections are required

GCM experimental design will enable a shift from regional wave climate projections to coordinated global wave climate projections.

Global coverage (projections for most at-risk nations)

Coordination aims to

- **Reduce repeated effort (minimise computational effort)**
- **Increase ensemble number (improved results, with increased knowledge of uncertainty)**
- **Projections for larger number of SRES scenarios**

IPCC AR4
(WG-I: Ch. 3. Observations: Sfce and Atm. Climate change)

Trenberth et al. (2007)

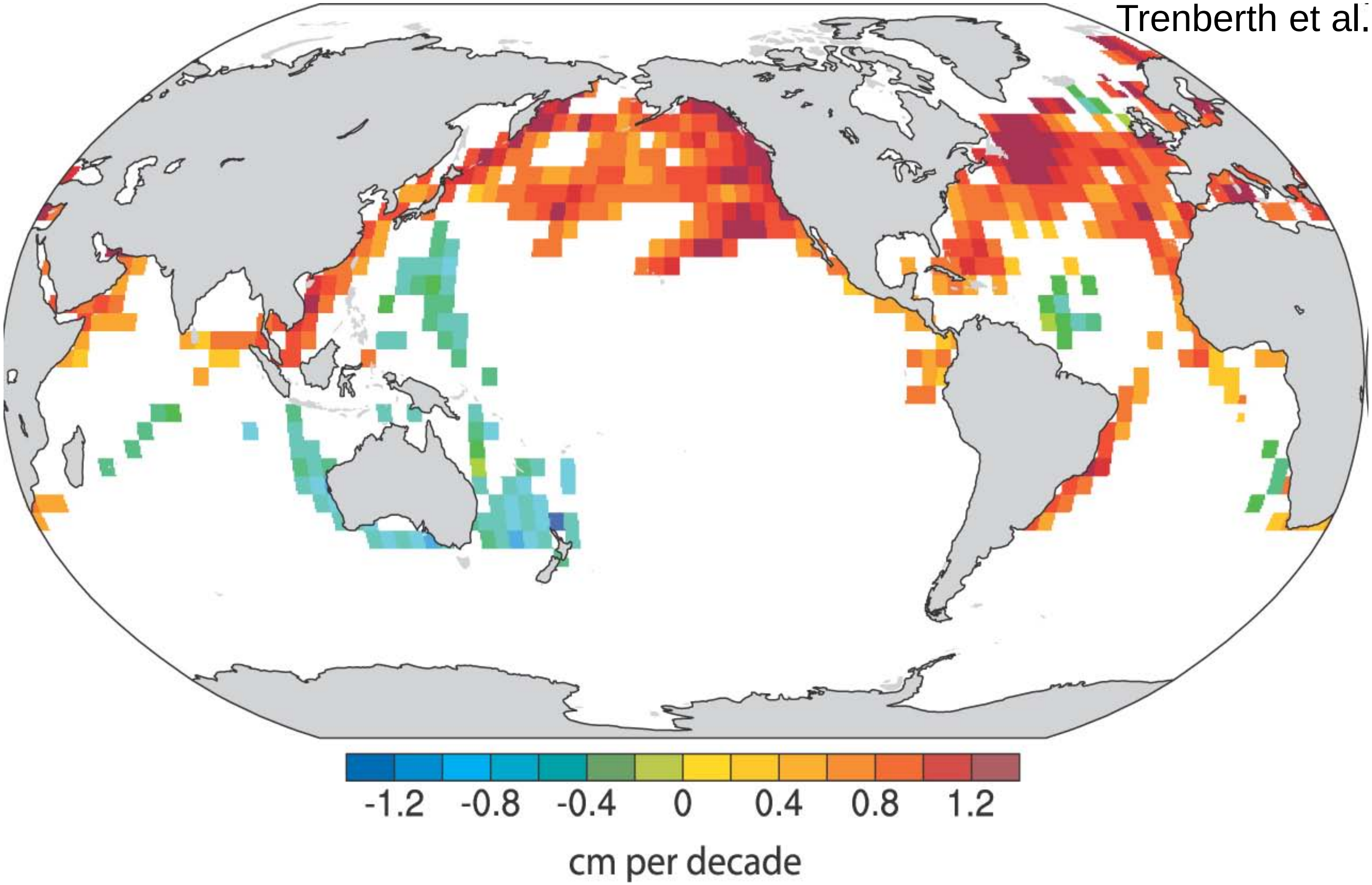


Figure 3.25. Estimates of linear trends in significant wave height (cm per decade) for regions along major ship routes of the global ocean for 1950 to 2002. Trends are shown only for locations where they are significant at the 5% level. Adapted from Gulev and Grigorieva (2004)

Waves in IPCC AR4 (2)

IPCC AR4 WG-1

Chapter 10: Global Climate Projections.

10.3 Projected changes in the physical climate system

10.3.6 …. A new feature that has been studied related to extreme conditions over the oceans is wave height. Studies by Wang et al. (2004), Wang and Swail (2006a,b) and Caires et al (2006) have shown that for many regions of the mid-latitude oceans, an increase in extreme wave height is likely to occur in a future warmer climate. This is related to increased wind speed associated with mid-latitude storms, resulting in higher waves produced by these storms, and is consistent with the studies noted above that showed decreased numbers of mid-latitude storms by more intense storms.

Meehl, G.A. et al. (2007) Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC AR4 (WG-I)

Box 11.5: Coastal Zone Climate Change

Introduction

Climate change has the potential to interact with the coastal zone in a number of ways including inundation, erosion and salt-water intrusion into the water table. Inundation and intrusion will clearly be affected by the relatively slow increases in mean sea level over the next century and beyond. Mean sea level is addressed in Chapter 10; this box concentrates on changes in extreme sea level that have the potential to significantly affect the coastal zone. **There is insufficient information on changes in waves or near-coastal currents to provide an assessment of the effects of climate change on erosion.**

…

Changes in storm surges and wave heights have been addressed for only a limited set of models. Thus, we cannot reliably quantify the range of uncertainty in estimates of future coastal flooding and can only make crude estimates of the minimum values (Lowe and Gregory, 2005).

Christensen, J.H. et al. (2007) Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

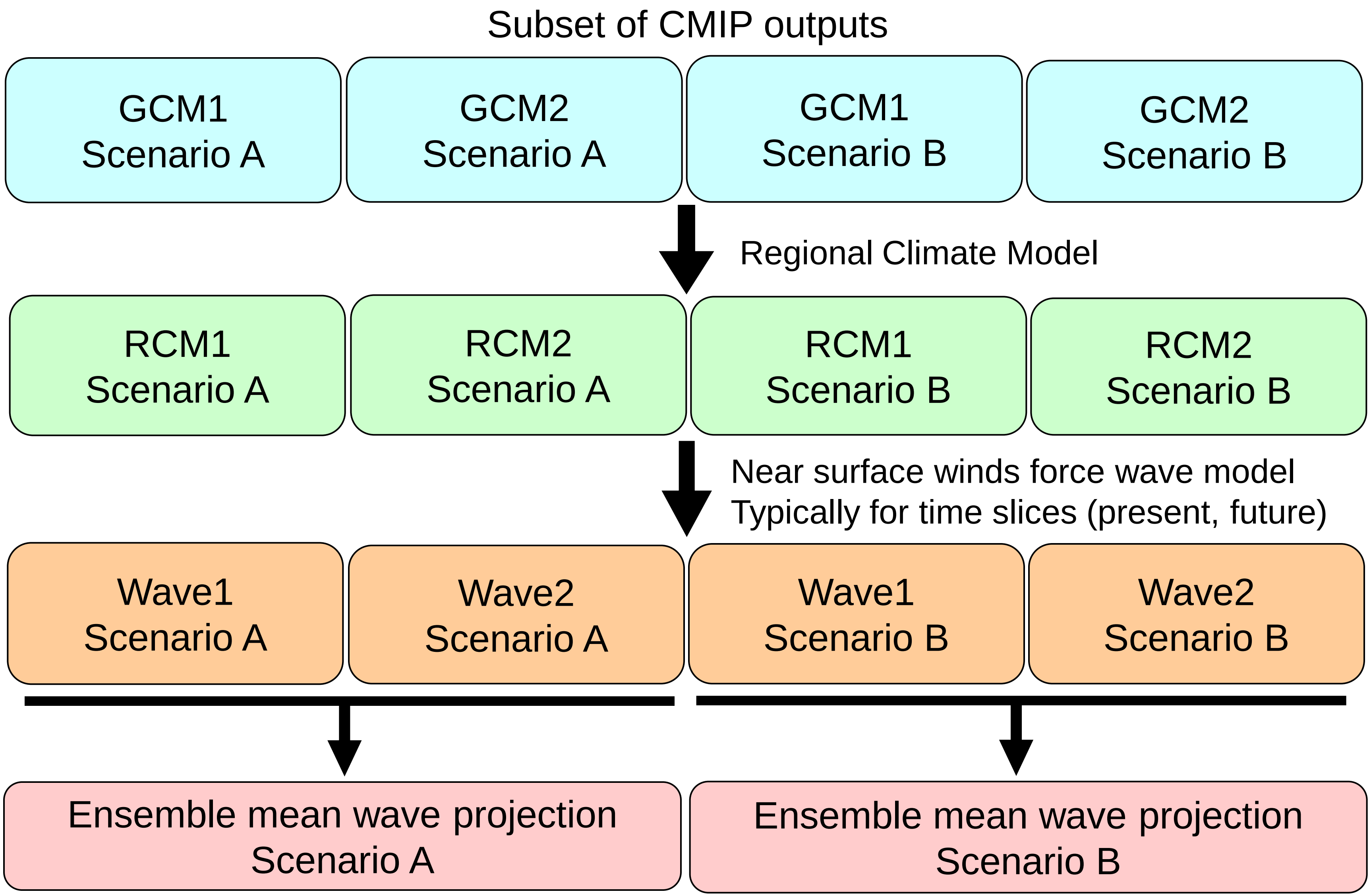
IPCC AR4 (WG-2)

Table 6.2. *Main climate drivers for coastal systems (Figure 6.1), their trends due to climate change, and their main physical and ecosystem effects. (Trend: ↑ increase; ? uncertain; R regional variability).*

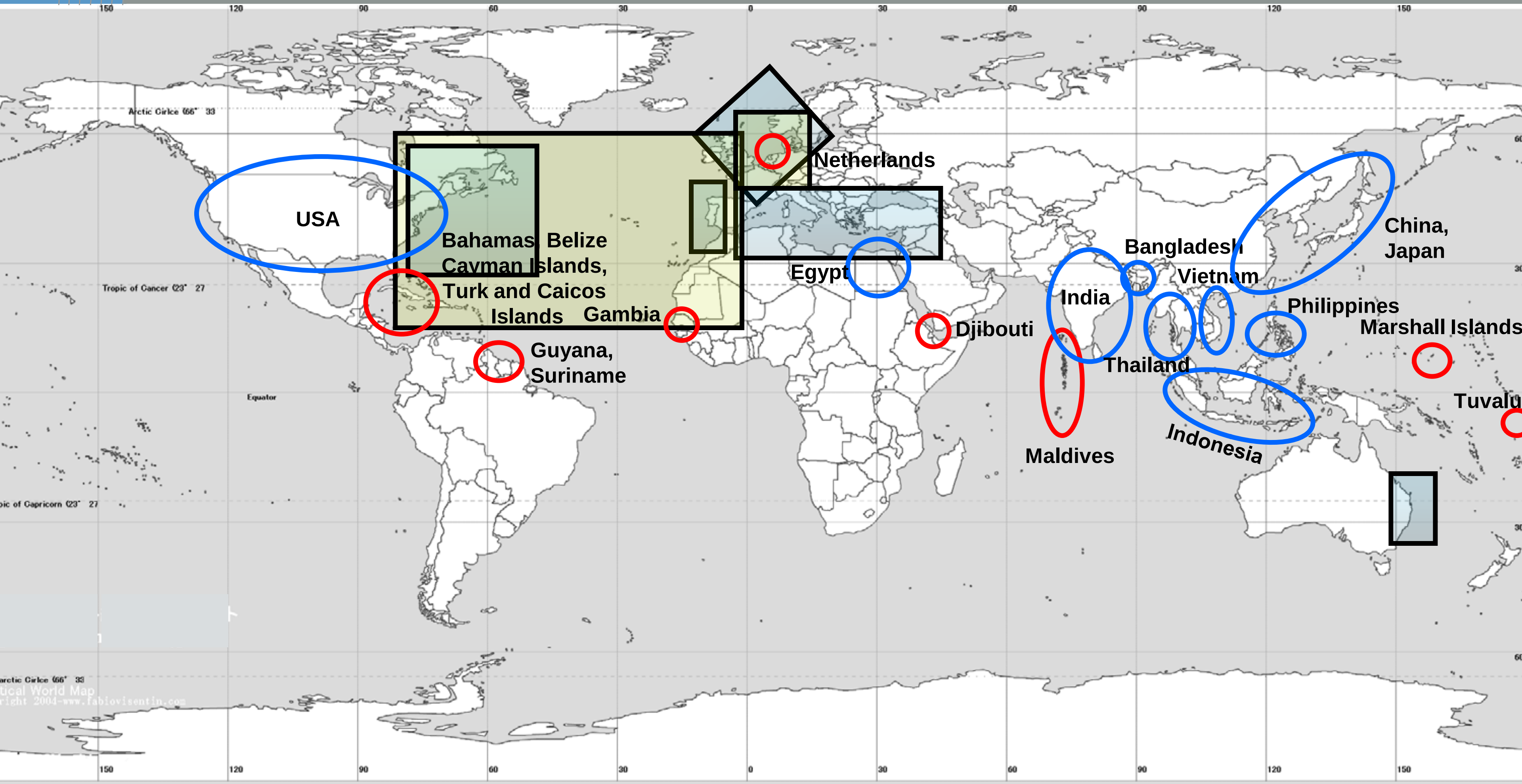
Climate driver (trend)	Main physical and ecosystem effects on coastal systems (discussed in Section 6.4.1)
CO_2 concentration (↑)	Increased CO_2 fertilisation; decreased seawater pH (or 'ocean acidification') negatively impacting coral reefs and other pH sensitive organisms.
Sea surface temperature (↑, R)	Increased stratification/changed circulation; reduced incidence of sea ice at higher latitudes; increased coral bleaching and mortality (see Box 6.1); poleward species migration; increased algal blooms
Sea level (↑, R)	Inundation, flood and storm damage (see Box 6.2); erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change).
Storm intensity (↑, R)	Increased extreme water levels and wave heights; increased episodic erosion, storm damage, risk of flooding and defence failure (see Box 6.2).
Storm frequency (?, R) Storm track (?, R)	Altered surges and storm waves and hence risk of storm damage and flooding (see Box 6.2).
Wave climate (?, R)	Altered wave conditions, including swell; altered patterns of erosion and accretion; re-orientation of beach plan form.
Run-off (R)	Altered flood risk in coastal lowlands; altered water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply.

Nicholls, R.J. et al. (2007) Coastal systems and low-lying areas. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L. et al. (eds.)]. Cambridge University Press, Cambridge, Uniited Kingdon and New York, NY, USA.

Regional projections (methodology)



Map of current regional projections



Global projections: Wang & Swail, 2006
Mori et al., 2009

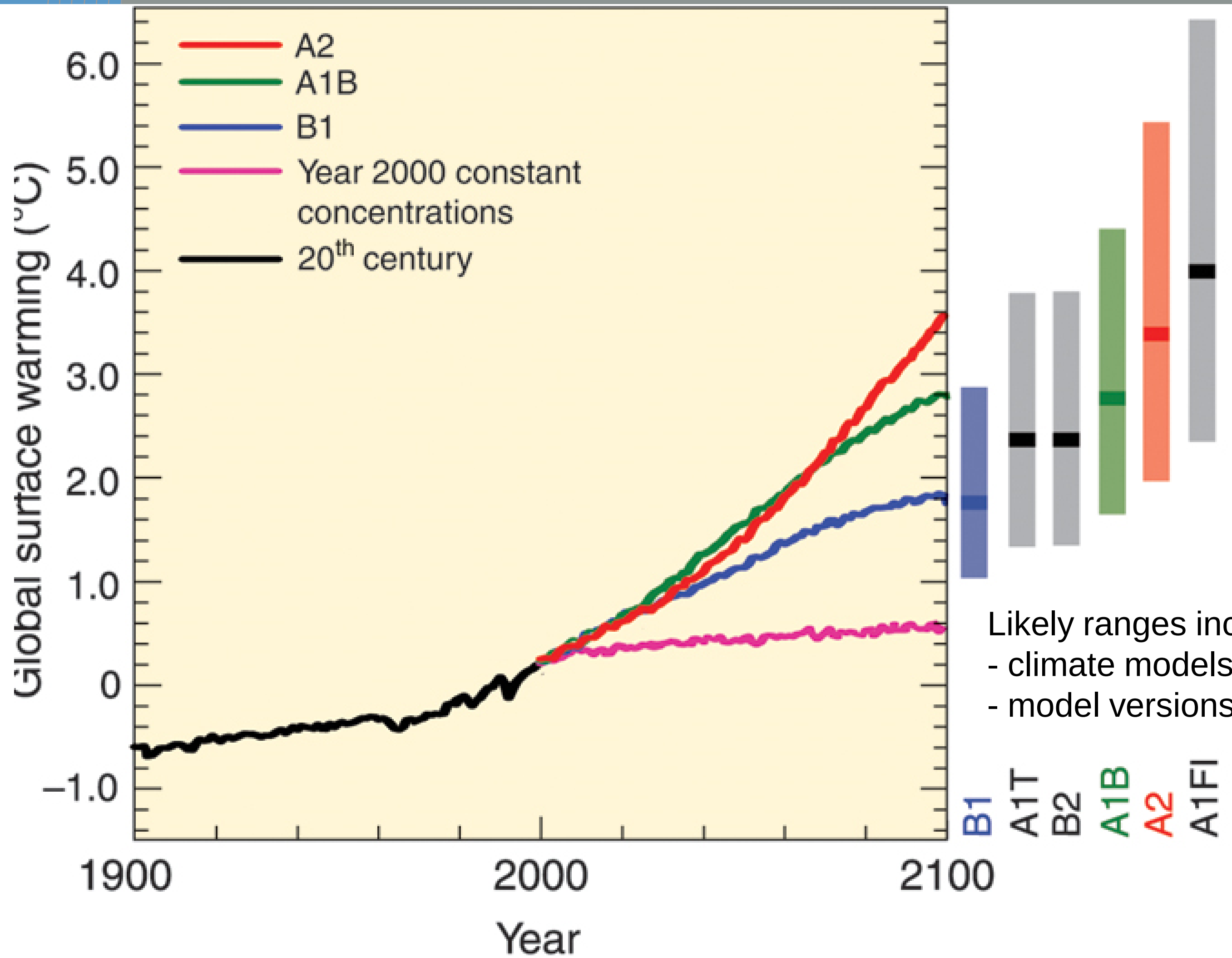
Countries with highest share of population within Low Elevation Coastal Zone (all countries)

Countries with most population within Low Elevation Coastal Zone, McGranahan et al. (2007)

North Sea Wave Climate Projections

Study	GCM Scenario	Projected time-slice	RCM	Proj Method	Results
DNMI (Debenard & Roed, 2008)	ECHAM4 MPI GSDIO	2030-2050	HIRHAM (55km res)	WAM (55km res)	Insig. Change Hs.
DNMI (Debenard et al., 2002)	HADAM3H SRES A2 HADAM3H SRES B2 ECHAM4 SRES B2 BCCR SRES A1B	2071-2100	HIRHAM (55km res)	WAM (55km)	Insig. Change Hs.
GKSS (Grabemann & Weisse, 2008)	HADAM3H SRES A2 HADAM3H SRES B2 ECHAM4 SRES A2 ECHAM4 SRES B2	2071-2100	Swedish RCAO (~49 km res)	WAM (NE Atl ~ 50km) North Sea ~5.5km)	5-8% increase in Hs
Tyndall (Leake et al., 2007)	HADAM3H SRES A2 HADAM3H SRES B2	2071-2100	HADRM3H	PROWAM (Atlantic 1deg) (NEA, Nth Sea, ~5.5km)	Increase of 10 cm (mean) and 20 cm (max) in Hs. Decrease of 4 cm (mean) and 19 cm (max) in Hs
Deltares (Caires et al., 2008)	ECHAM5 ESSENCE SRES A1B	1950-2100	-	Statistical WAM/SWAN	Insig. Change.

IPCC AR4 projections

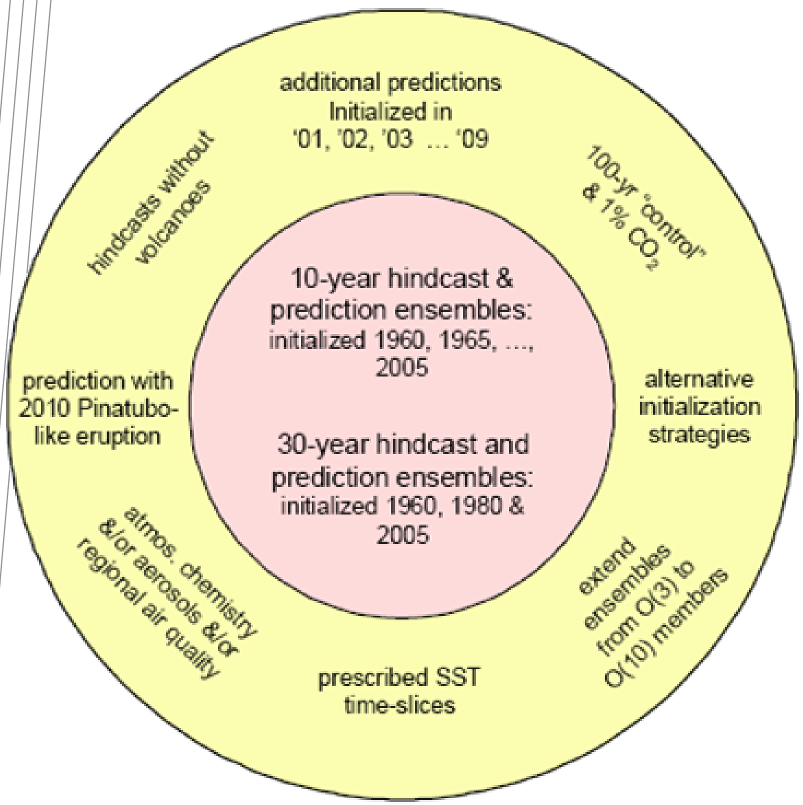


Likely ranges include uncertainties between:
- climate models (multi-model ensembles), and
- model versions (perturbed physics ensembles)

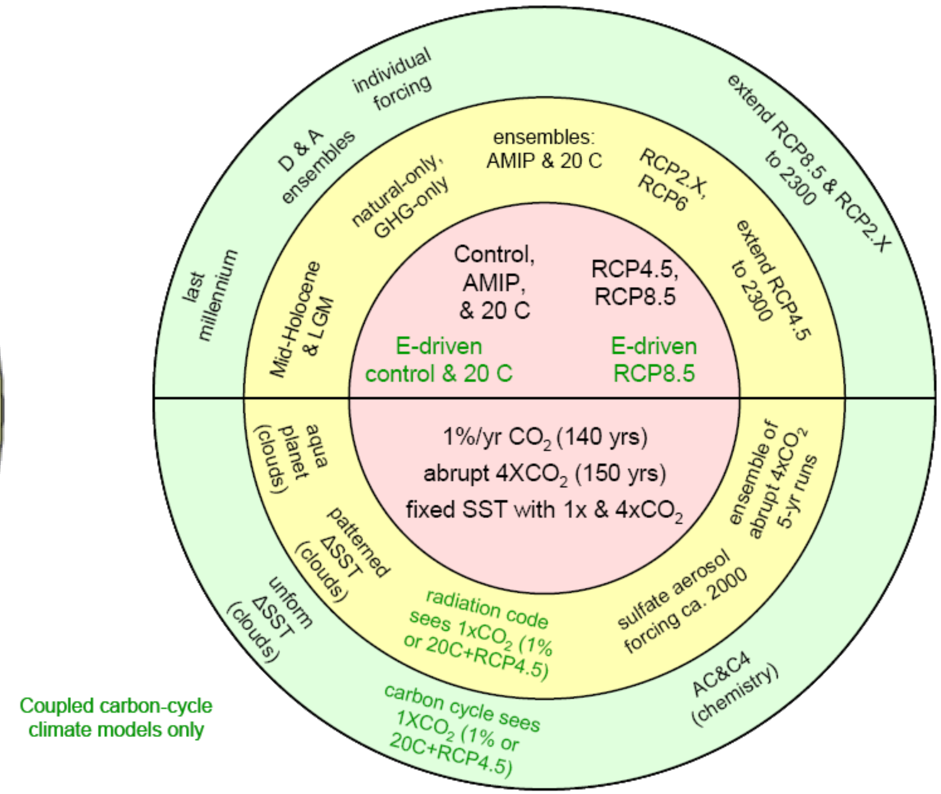
Figure 3.2. Surface warming for SRES scenarios. Best estimates, and 2090-2099 likely ranges
IPCC AR4 (2007) Synthesis Report

CMIP-5 Experimental Design (Taylor et al., 2008)

Near-term, decadal prediction experiments



long-term (century time-scale) experiments



Core tasks	– to be completed by all CMIP groups
Tier 1 tasks	– examine specific aspects of climate model
Tier 2 tasks	– low priority tasks to examine specific aspects of climate model

Summary of core CMIP-5 runs applicable to wave models

Present Day Period (1960-2005).

- Near-term decadal predictions: 10 and 30 yr hindcast and prediction ensembles, initialised from 1960 through to 2005.
- Future long-term (century time-scale) simulations for 20C, and AMIP periods driven by RCP concentrations.

Mid-Century (2026-2045)

- Near-term decadal predictions: 30 yr hindcast and prediction ensembles, initialised in 2005 (2026-2035)
- Future long-term (century time-scale) simulations driven by RCP concentrations (2026-2045)

End-of-Century (2081-2100)

- Future long-term simulations driven by RCP concentrations

Listed runs have 3-hourly 2-D surface fields for the following variables (suitable to force wave models).

Surface wind vector components,
surface pressure,
near sfc air-temp,
water skin temp.

Other applicable variables (i.e., sea-ice conc^{n}, surface ocean currents) are archived monthly for all runs.