Large-scale modular mangrove planting – adaptation to sea-level rise

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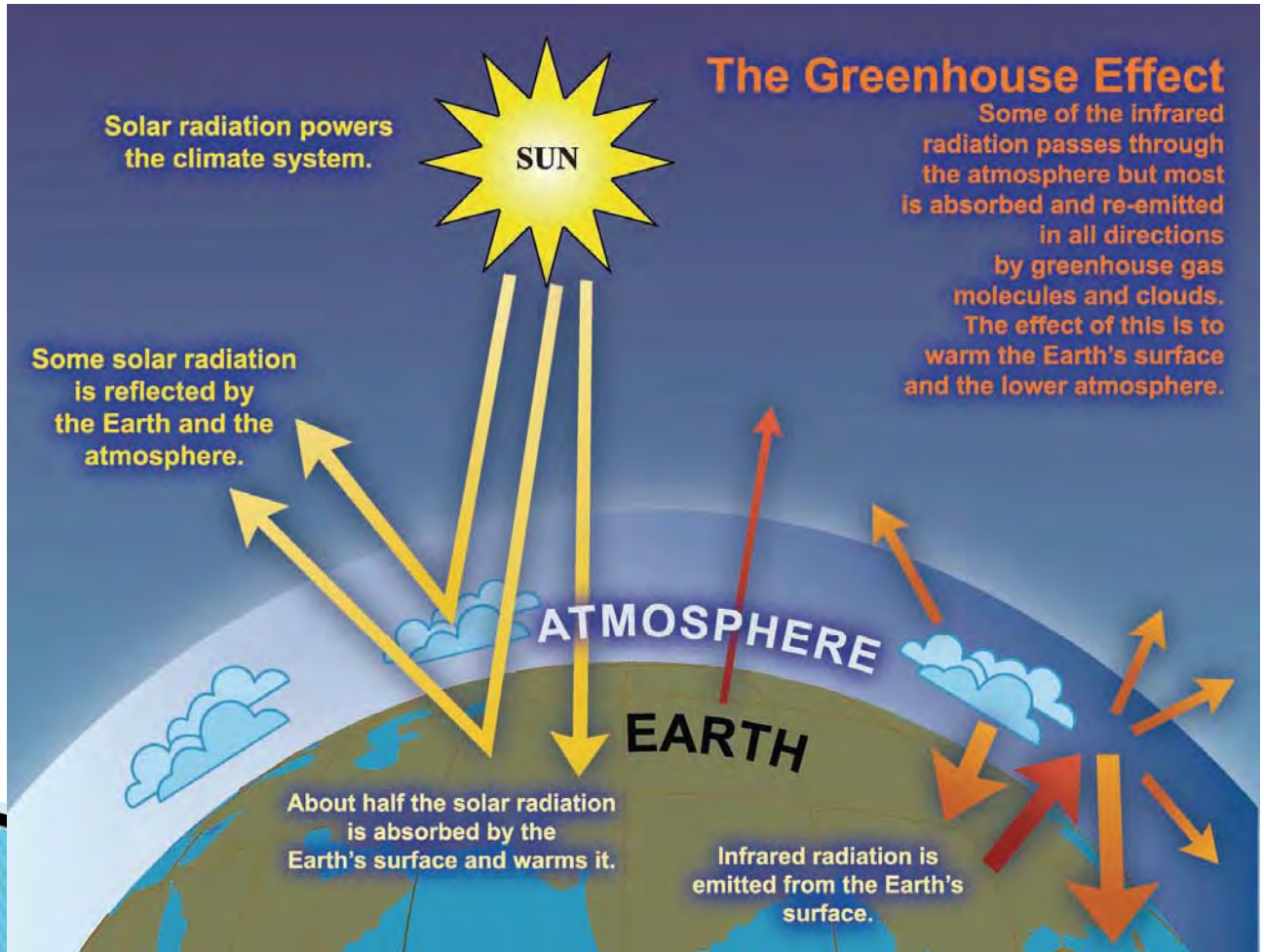
Topics

- Climate change
- Sea-level rise and adaptation measures
- Mangroves, especially after 2004 Indian Ocean tsunami
- Large-scale modular mangrove planting

CLIMATE CHANGE

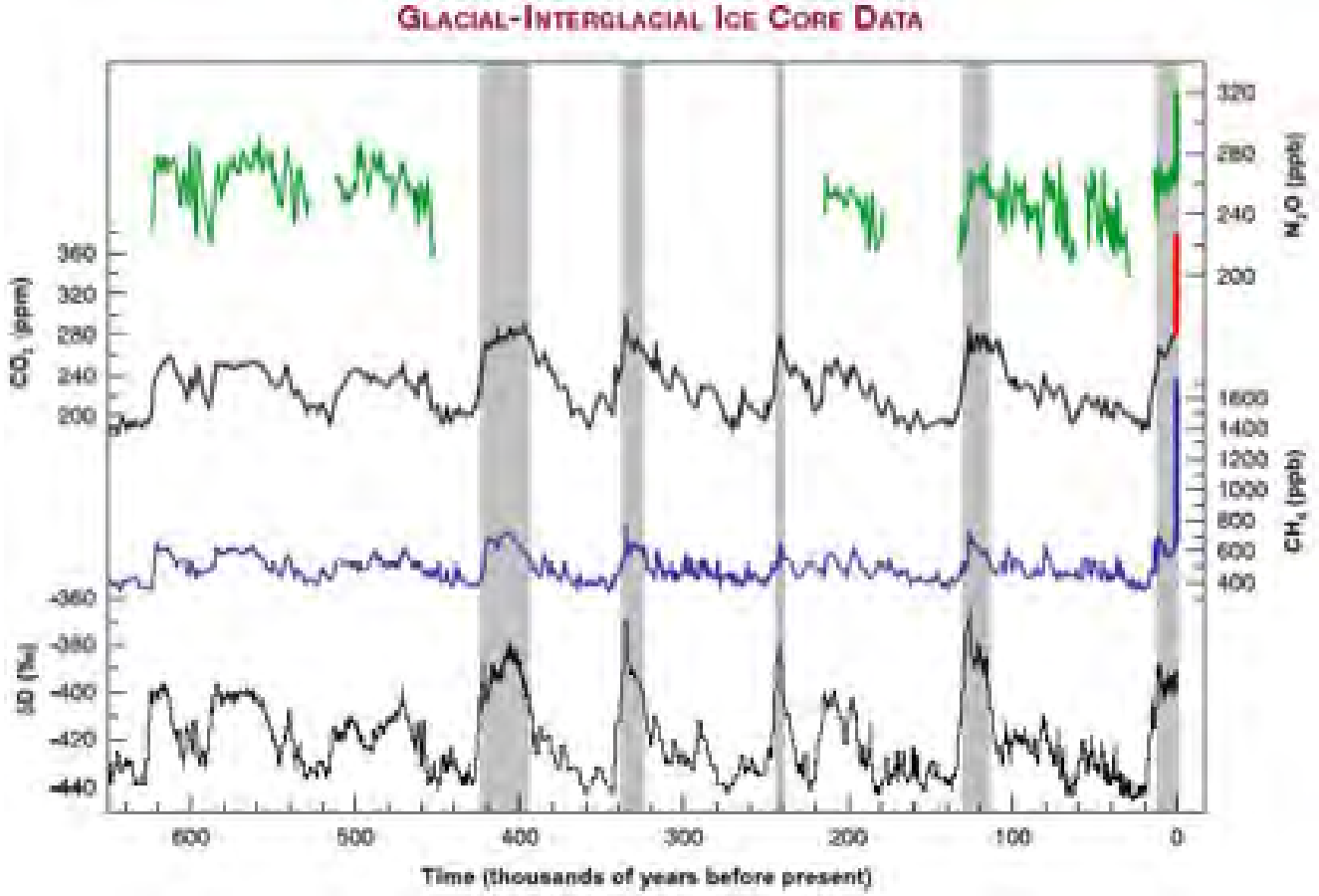
Greenhouse effect

- Trapping of heat energy by GHGs (principally water vapour, CO^2, methane, nitrous oxide) known as 'greenhouse effect' and keeps global average surface temperature at 15°C instead of -18°C



(IPCC)

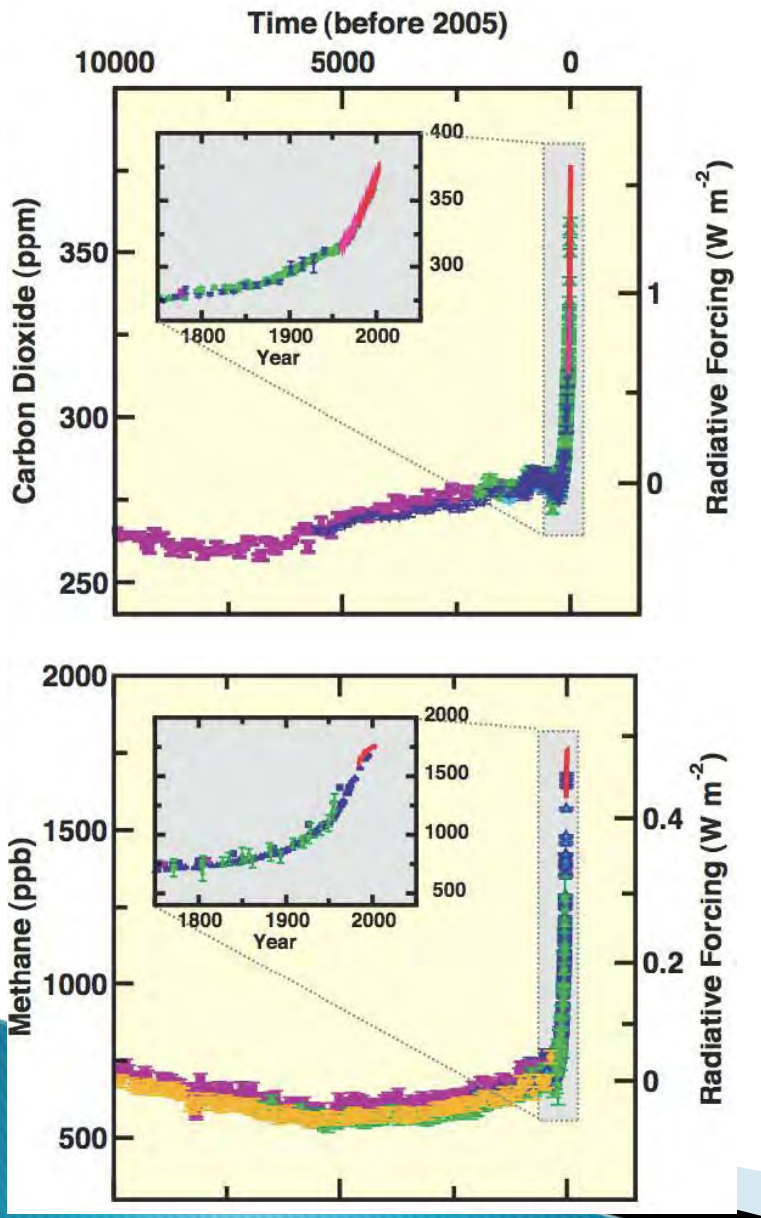
GHGs – 650,000 yr



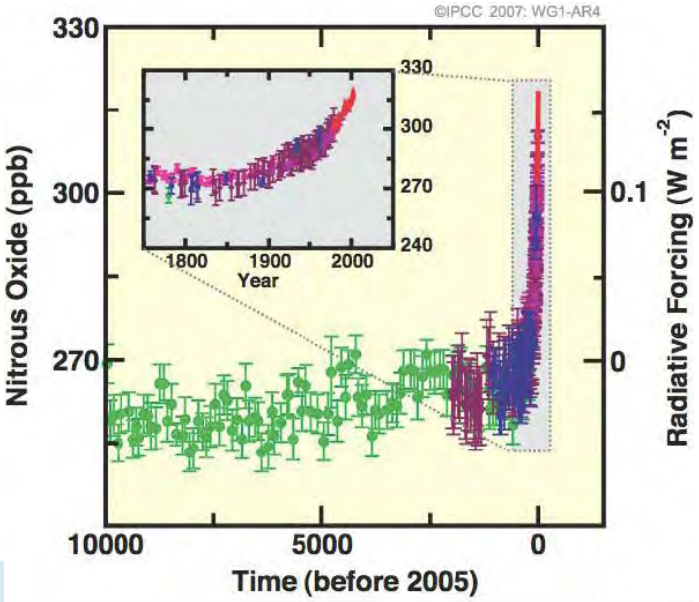
(IPCC)

- In ice cores records of atmospheric composition dating back to 650,000 years, CO_2 and CH_4 far exceeded preindustrial values.
- Present GHGs concentration has exceeded level of past 650,000 years.

GHGs – 10,000 yr

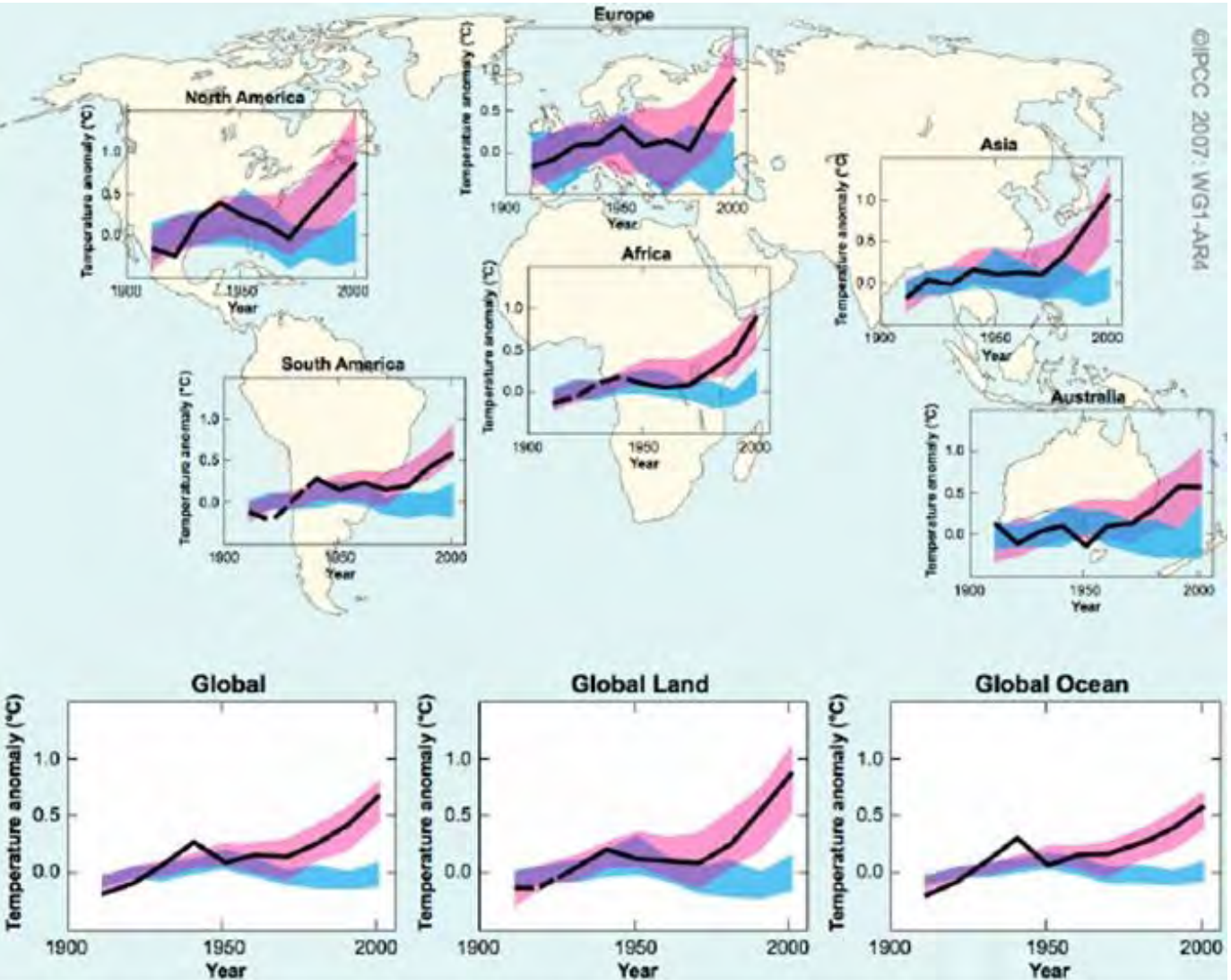


- Increase by CO_2, CH_4 and N_2O since 1750 is unprecedented in more than 10,000 yrs.
- CO_2 increased from preindustrial level of 280 ppm to 379 ppm in 2005 and 385 ppm in 2007 (393 ppm in Jan 2012).



(IPCC)

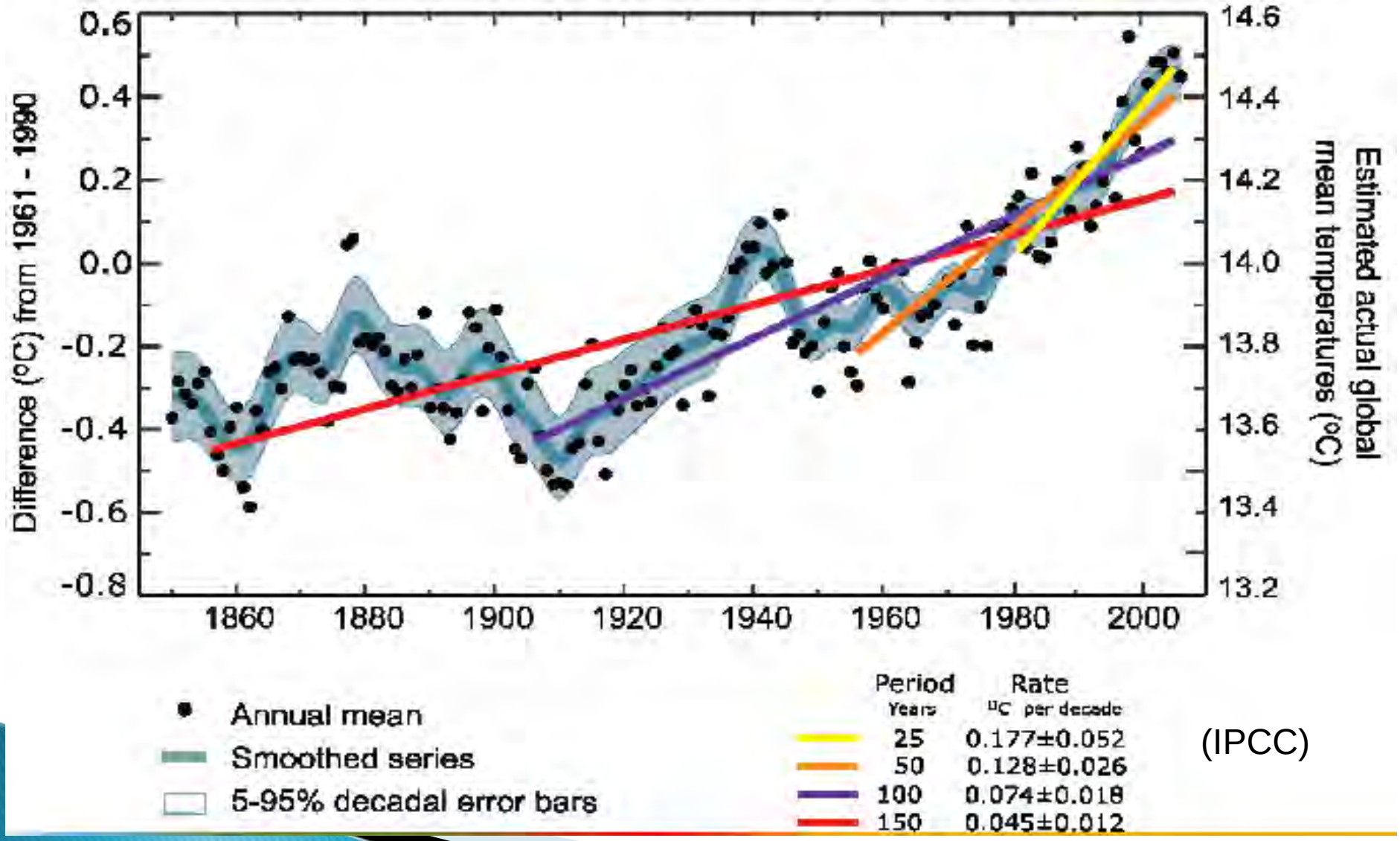
Global and continental temperature change



- Significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica.

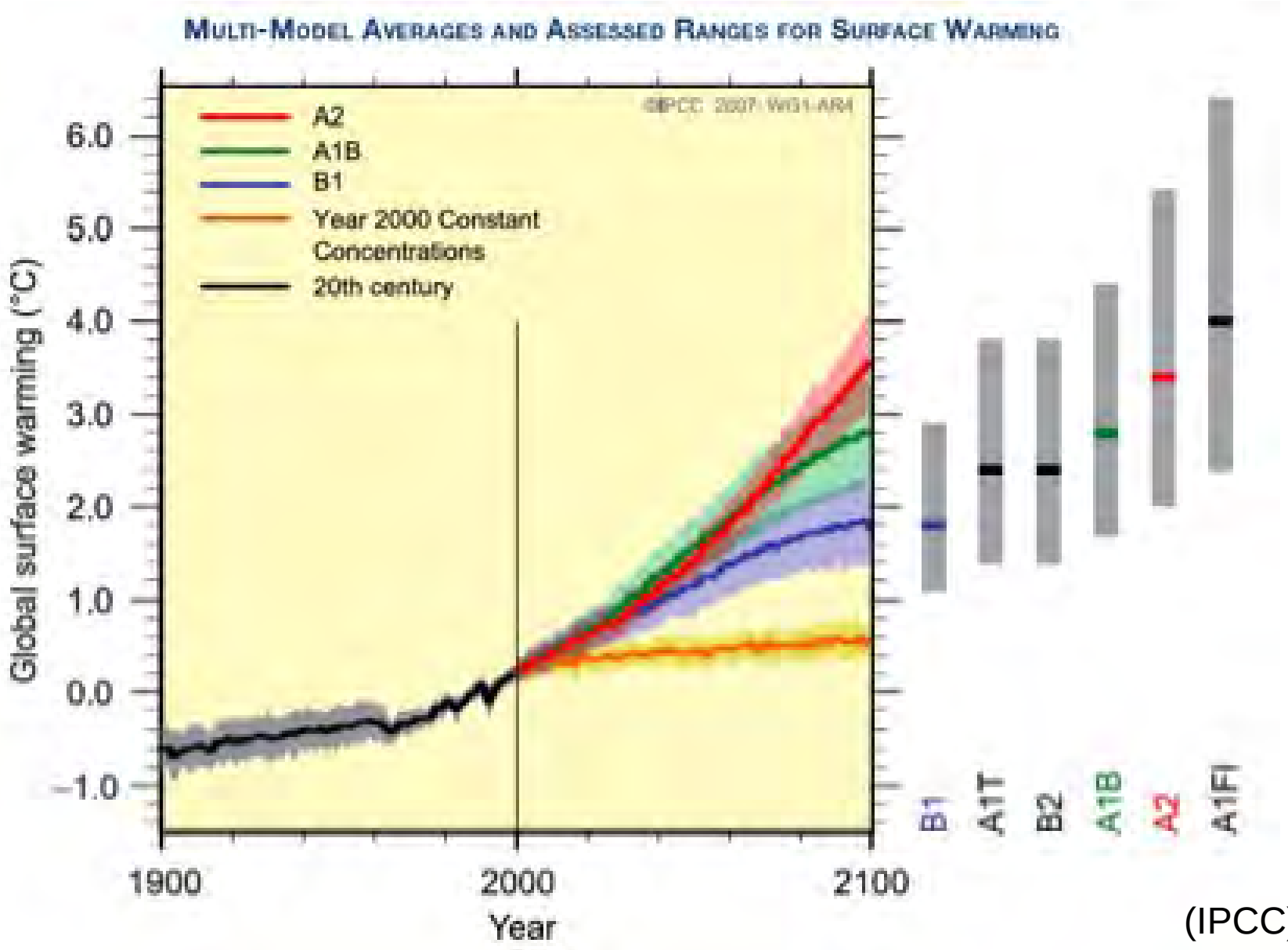
(IPCC)

Global mean temperature



(IPCC)

Projected temperature trends



(IPCC)

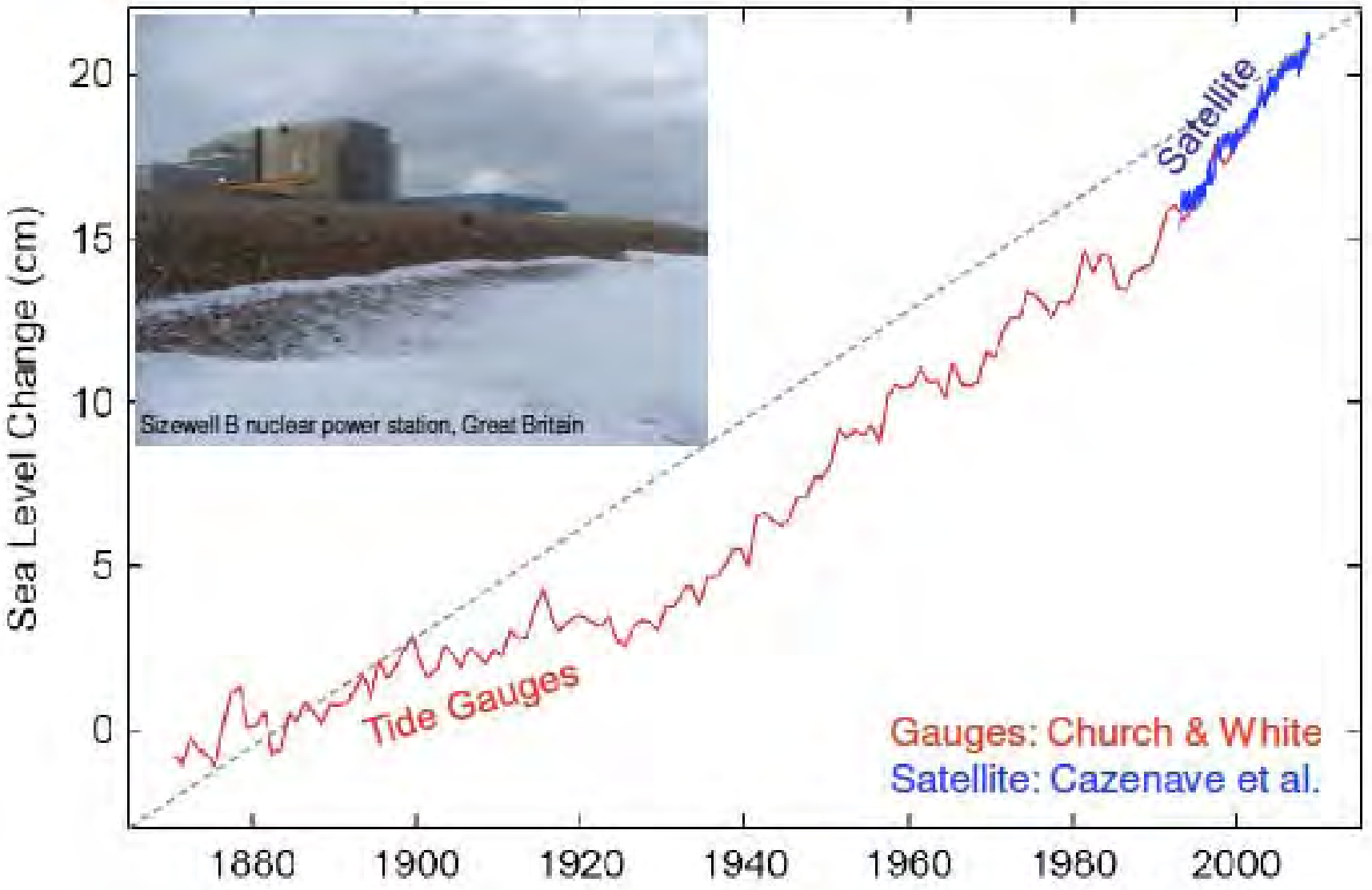
Tropical cyclones

- Number of category 4 and 5 hurricanes increased 75% since 1970 with largest increases in North Pacific, Indian and Southwest Pacific Oceans

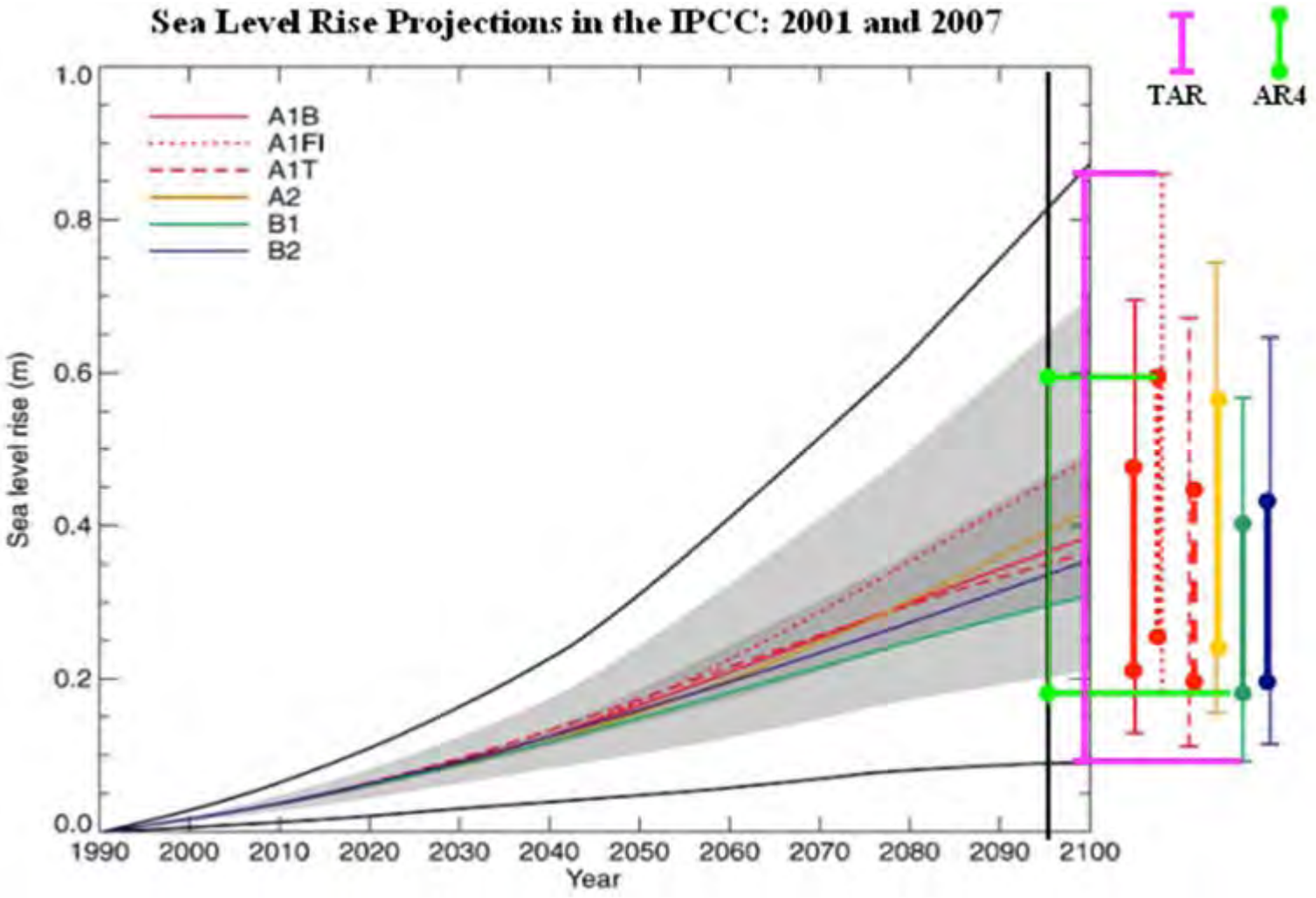
(IPCC)

SEA-LEVEL RISE

Observed SLR



Projected sea-level rise



TAR 9-88

AR4 18-59

(IPCC)

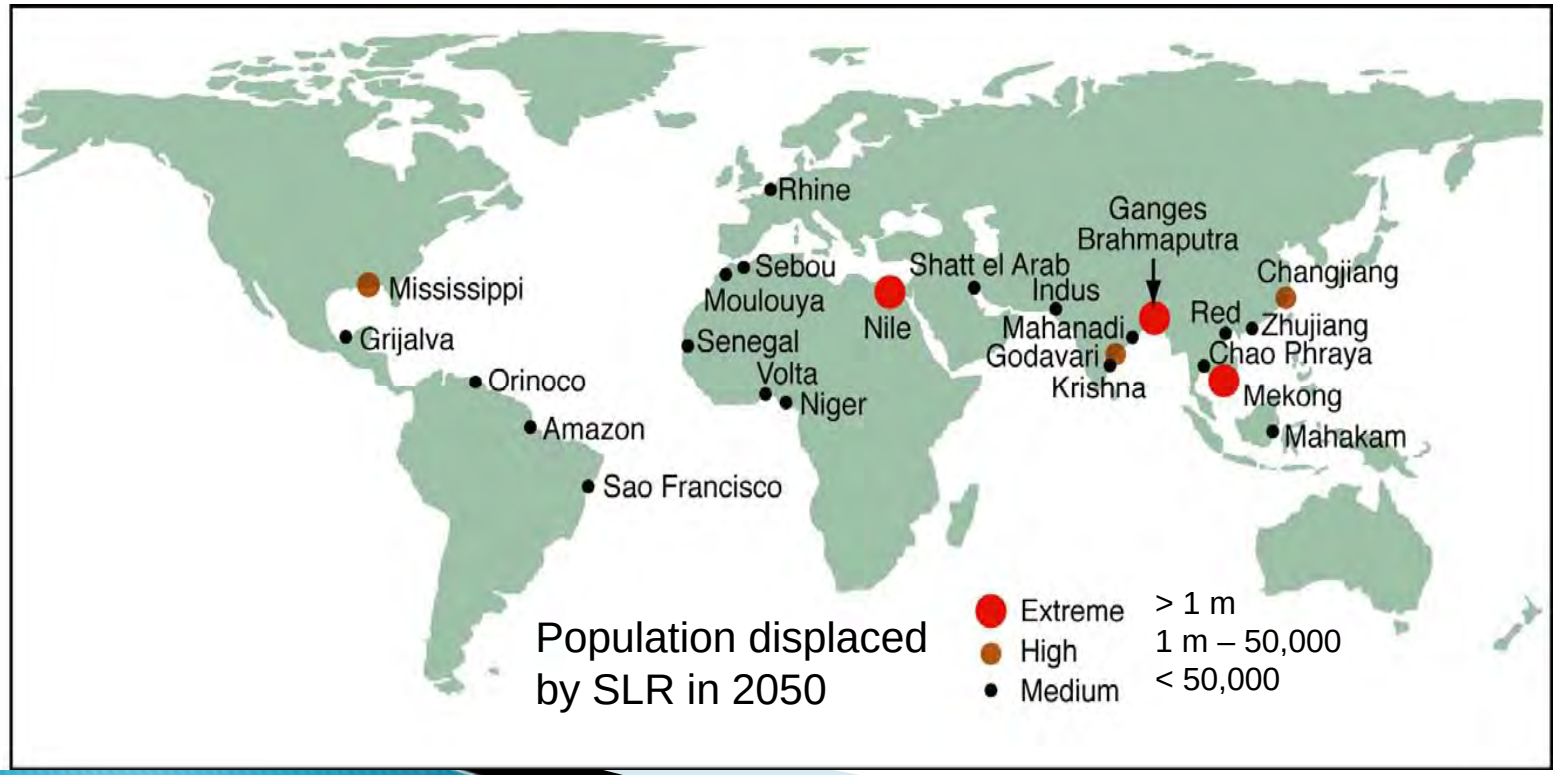
Contributions to SLR

Source	Sea Level Rise (mm yr^{-1}) 1961–2003	1993–2003
Thermal Expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and Ice Caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum	1.1 ± 0.5	2.8 ± 0.7
Observed	1.8 ± 0.5	
		3.1 ± 0.7
Difference (Observed –Sum)	0.7 ± 0.7	0.3 ± 1.0

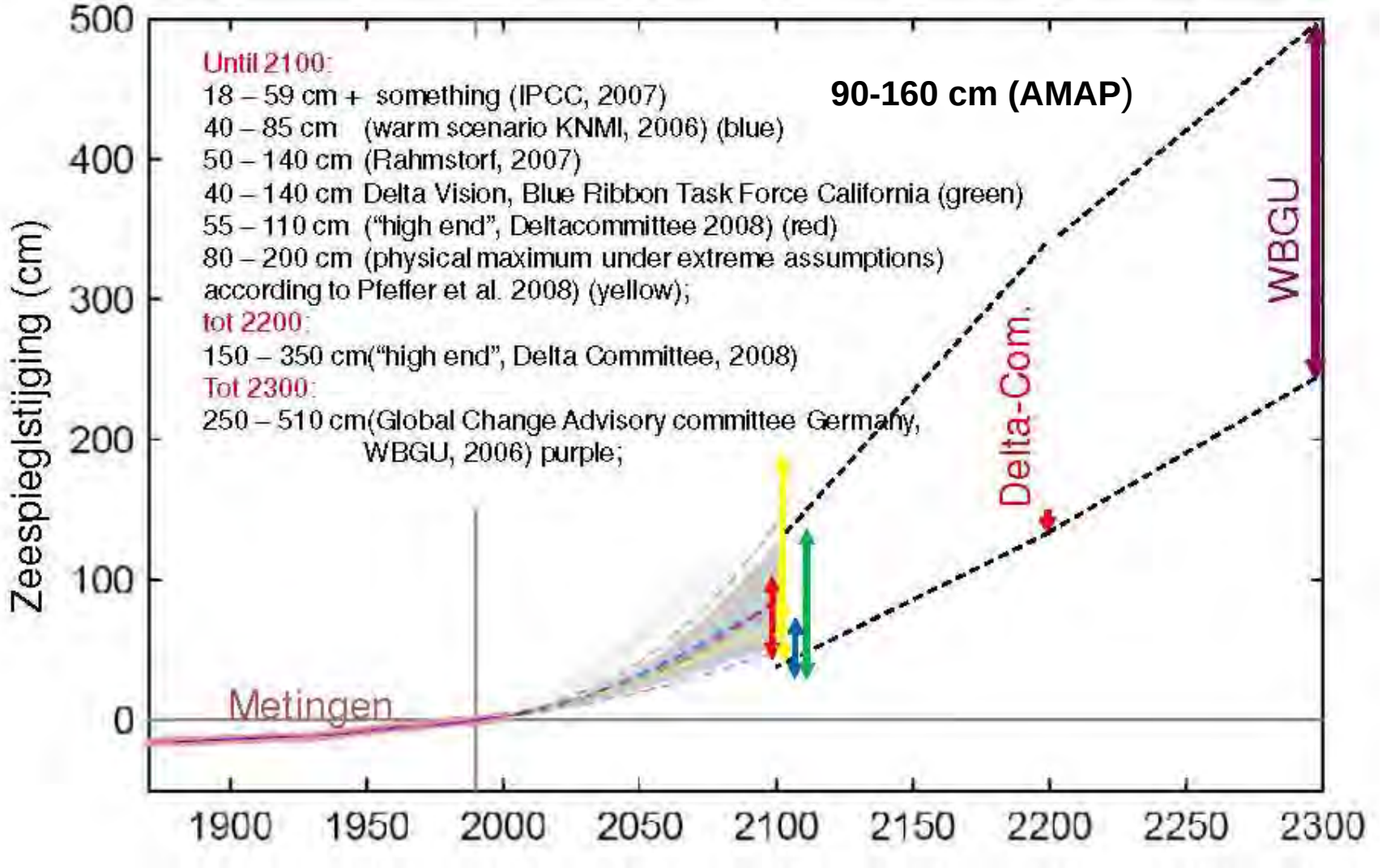
(IPCC)

Impacts on coastal communities

- Hotspots of coastal vulnerability occur where the stresses on natural systems coincide with low human adaptive capacity and high exposure.
- Vulnerable coastal types: (1) Populated deltas (especially Asian megadeltas); (2) Low-lying coastal urban areas; (3) Atolls.
- Vulnerable regions : (1) South, South-East and East Asia; (2) Africa; (3) Small islands (Caribbean, Indian Ocean, and Pacific Ocean).



Post-AR4 – Projected sea-level rise



(Vellinga 2009)

Trilogy of adaptation strategies

	Protect = effort to continue use of vulnerable areas	*Accommodate* = effort to continue living in vulnerable areas by adjusting living and working habits	*Retreat* = effort to abandon vulnerable areas
Hard	Dikes, seawalls, groins, breakwaters, salt water intrusion barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocating threatened buildings
Soft	Sand nourishments, dune building, wetland restoration or creation	New building codes, growing flood or salt tolerant crops, early warning and evacuation systems, risk-based hazard insurance	Land use restriction, set-back zones

(Policy Research Corporation)

Retreat

Accommodate

Protect

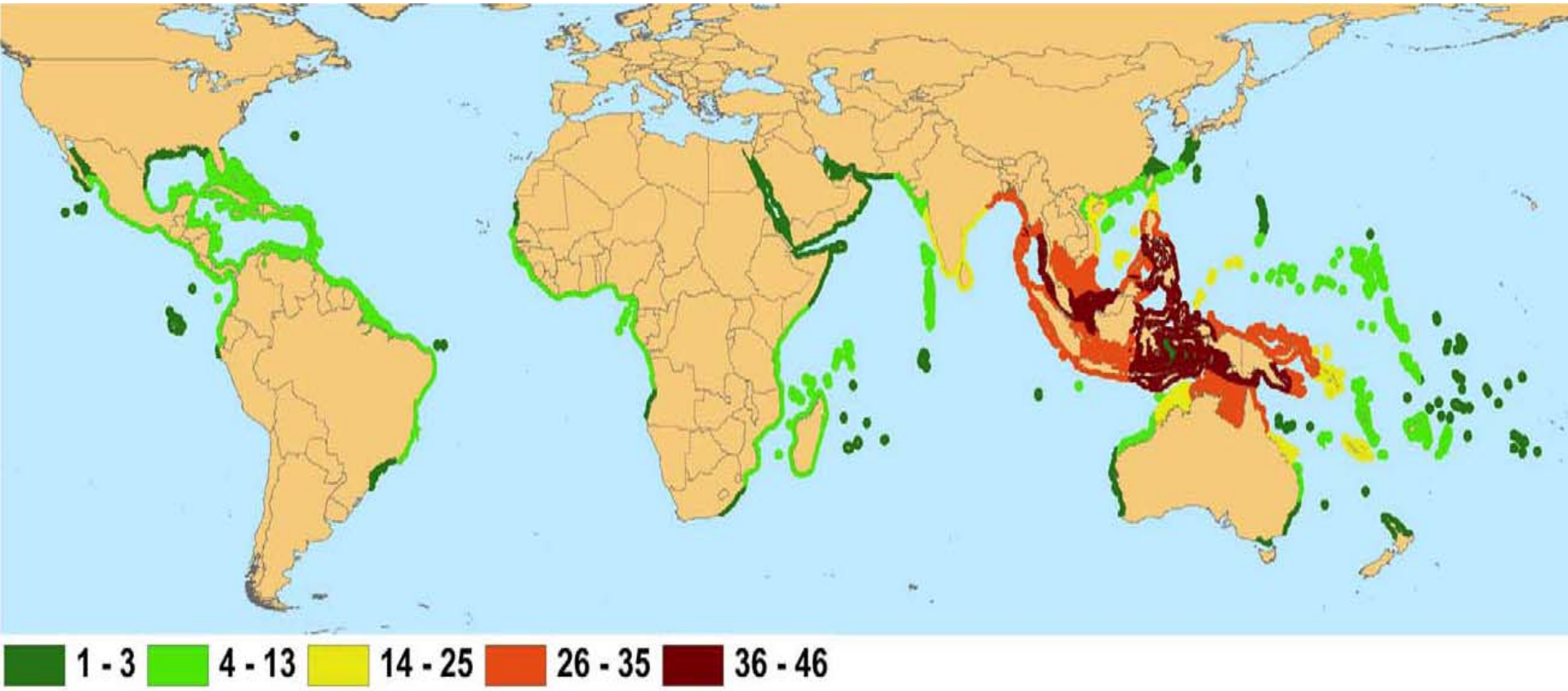
Table 1: Traditional, Modern, and High Adaptation Technologies in the Coastal Zones

Technology	Traditional	Modern	High
Restoration of coastal forests and coral reefs	X		
Sand dune restoration and construction	X		
Community-based conservation and aquaculture	X		
Seawalls, revetments, and headlands	X		
Beach nourishment and dune restoration	X		
Protection and reconstruction of wetlands	X		
Littoral drift replenishment	X		
Afforestation	X		
Creation of drainage areas	X		
Dikes, dams, levees, nets, and dredging	X	X	
Dikes and groins	X	X	
Saltwater intrusion barriers	X	X	
Tidal barriers	X	X	
Reef protection	X	X	
Detached breakwaters		X	
Coastal and coral erosion monitoring	X	X	X
Sea level and tide monitoring			X
Coastal zone monitoring			X
Impact assessment studies			X
Light detection and ranging			X

(UNFCCC)

MANGROVES

Mangroves – distribution



(Polidoro et al 2011)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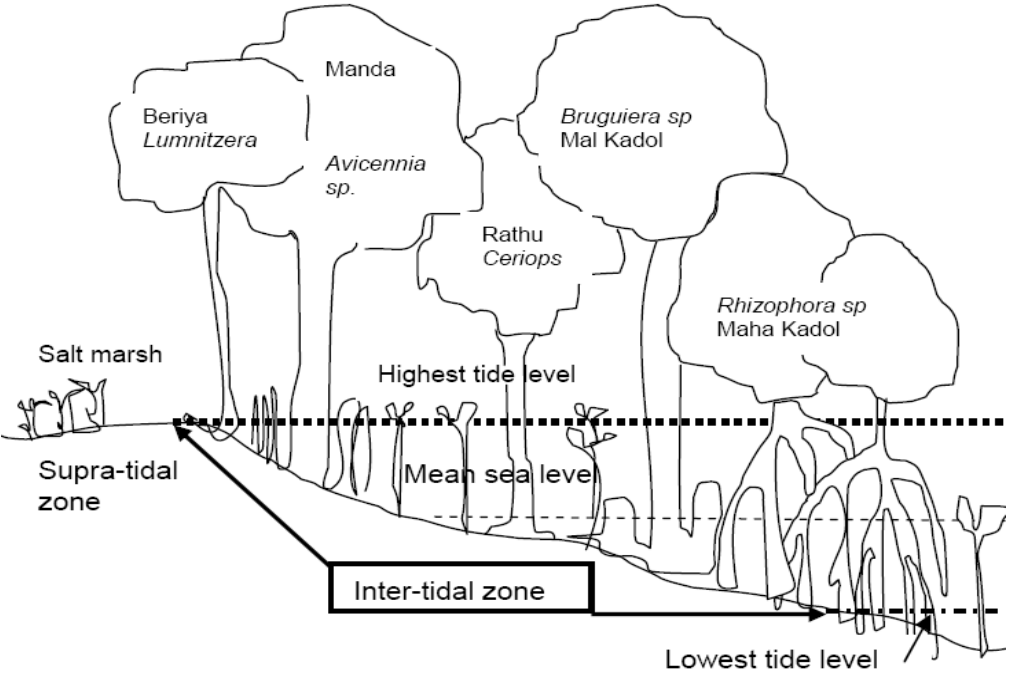
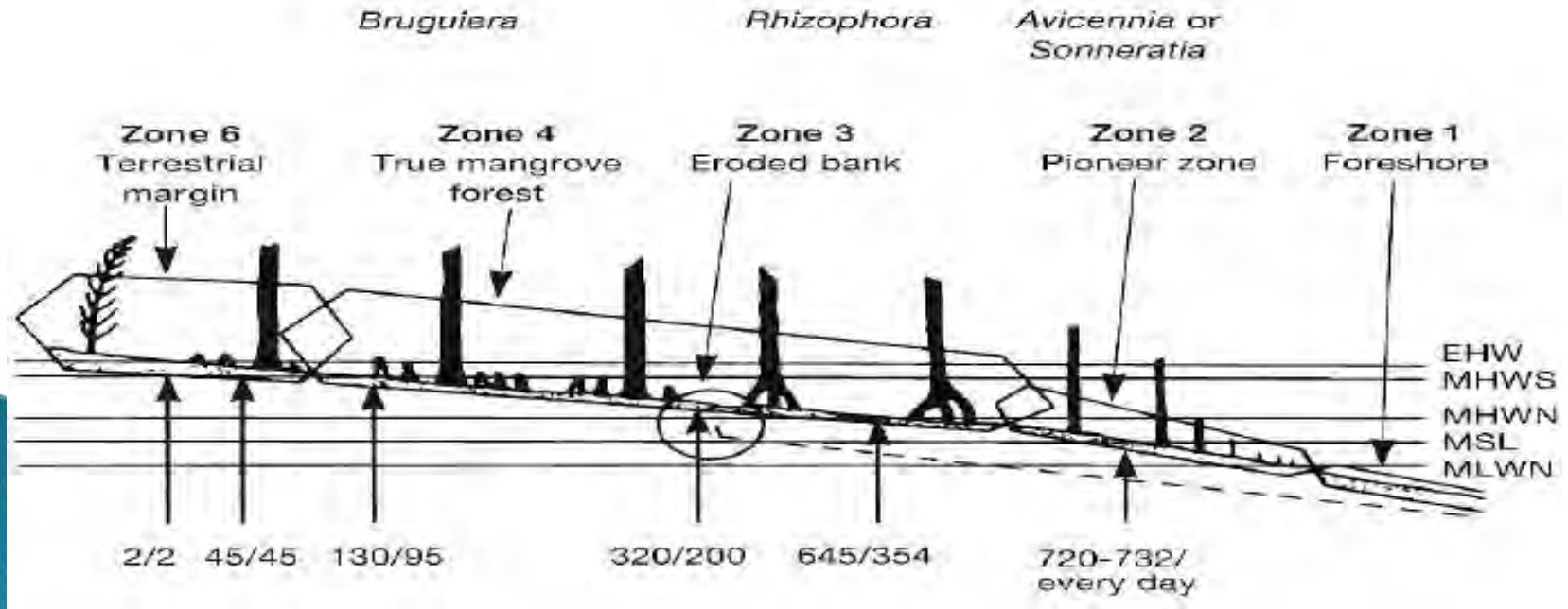
Mangroves – zonation

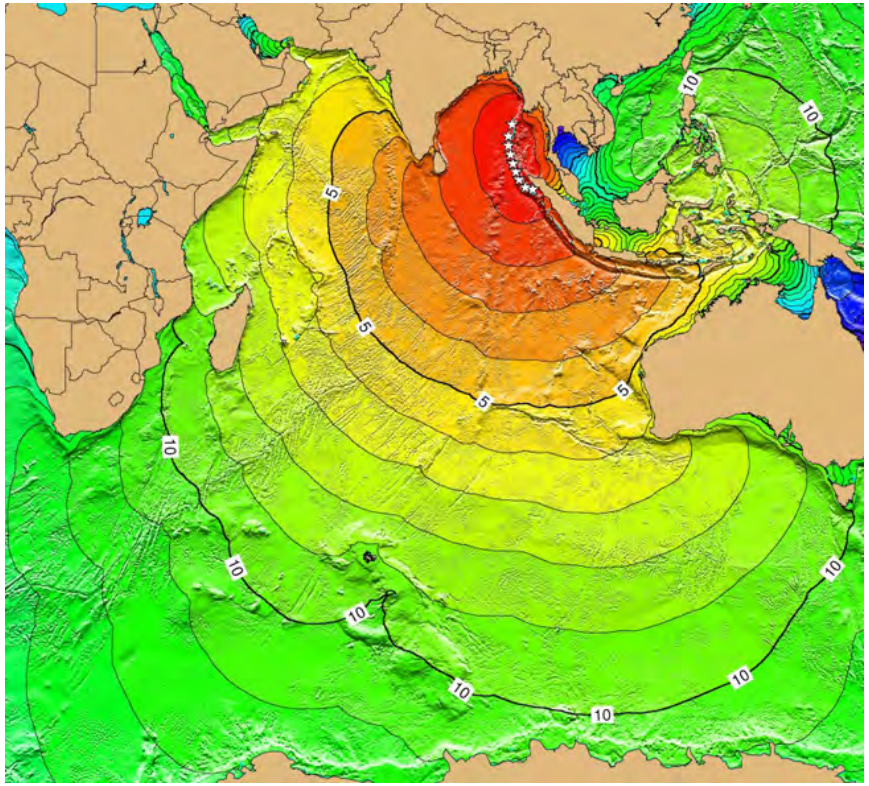


SRI LANDA
(Wetlands
International)

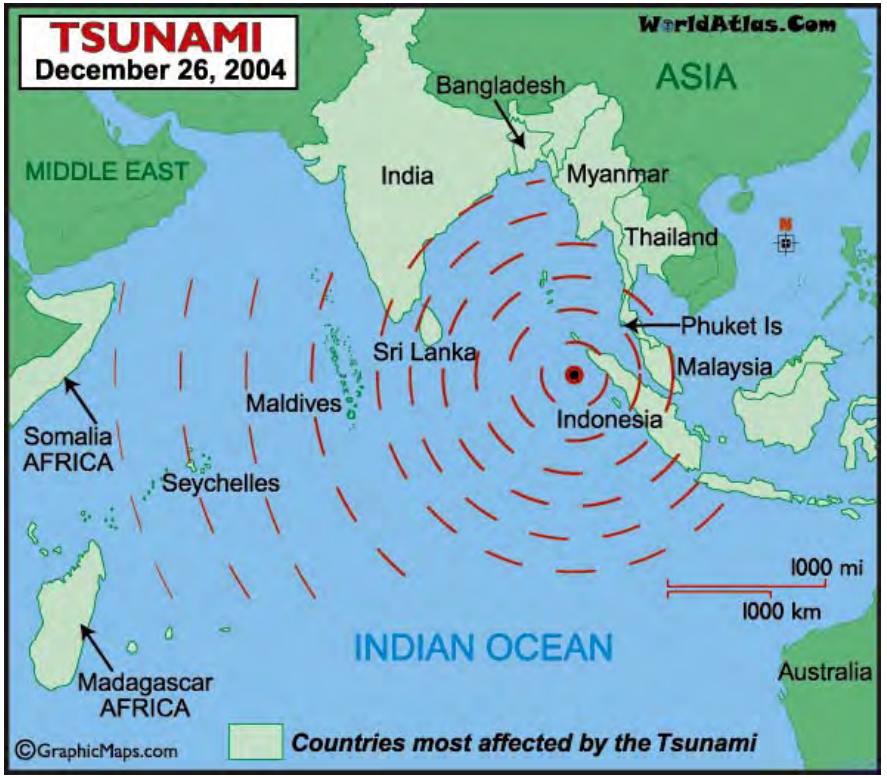
INDONESIA (Whitten et al 1997)



26 Dec 2004 Indian Ocean tsunami



(NOAA)



(WorldAtlas)

2004 tsunami and mangroves

- Anecdotal evidence of mangroves protecting villages in the rear of mangrove forests which slow down the tsunami waves.
- Publications on protection include (Danielson et al 2005; Dahdoub-Guebas et al 2005; Kathiresan & Rajendran 2005; Chang et al 2006; Tanaka et al 2007).
- Publications disputing the evidence/countering argument include (Kerr et al 2006; Kerr & Baird 2007; Bhalla 2007).

Mangroves as buffer

- Publications on experiments and field studies done on effectiveness of mangroves (Mazda et al 2007).
- Review by Cochard et al (2008) summed up and put controversy to rest to some extent.

Ecosystem type	Dominant ecosystem processes	Dominant buffer composition	Approximate wave buffer effectiveness range				Expected tsunami energy exposure
			Normal waves	Storm waves	<4 m high tsunami	>8 m high tsunami	
(c) Mangrove forests	Biotic/ physical	Biotic	▼~▼[1]	▾~▼[1,4]	▾~▼[4]	▲~▼[4]	▮–▮

Legend:

▲ Hazard amplification
▼ Hazard mitigation
X No effect

▾ ▲ Slight effect (not evident, but measurable)
▼ Moderate effect (evident, ~20–50% energy reduction)
▼ Considerable effect (~50–100% energy reduction)

▮ Small
▮ Medium
▮ High

Mangrove planting - success

Mangrove planting - failure

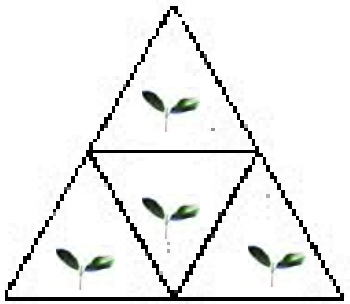
LARGE-SCALE MODULAR PLANTING

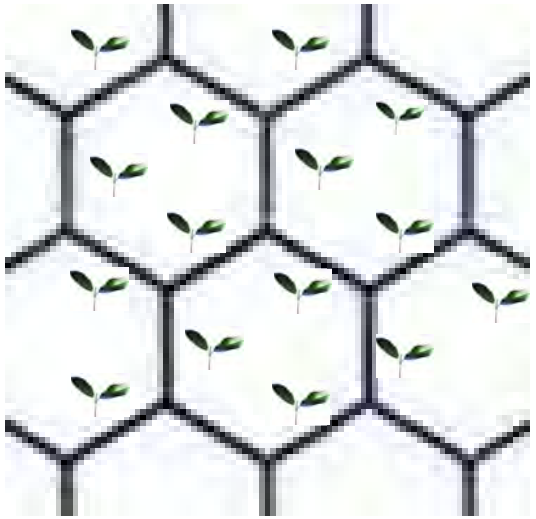
Proposed large-scale modular planting

- Large-scale planting using modular system to meet needs of various coastal locations.
- Modular system of planting and deployment is comparable to LEGO® set on a large scale.
- Suitable for wide range of coastal types and not confined to muddy tidal flats.

Modules

- Ideally of space-fitting shapes (triangles, squares, rectangle, hexagons) containing sediments with mangroves grown to various heights or maturity.
- Made of mixture of compressed sediments that become self-destructive and formed part of sediments supporting mangroves. Alternatively of local materials.
- Nutrients and sediments added to growing mangroves in field.





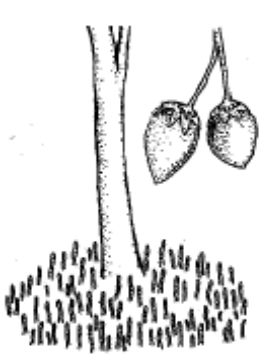
Deployment

- Depending on wave and coastal conditions, modules deployed rapidly to coast from land side or water side.
- Where labour is easily available and to keep costs low, modules can be floated and positioned at required locations.
- Alternatively, mechanized means using small crane from flat-bottom boat or from truck on land.

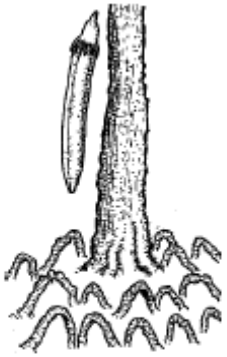
Root adaptation

- Mangroves have special root systems and may adapt to changes in sea level by growing upward in place, or by expanding landward or seaward.

(Bunaken 1999)



Peg roots of *Avicennia*



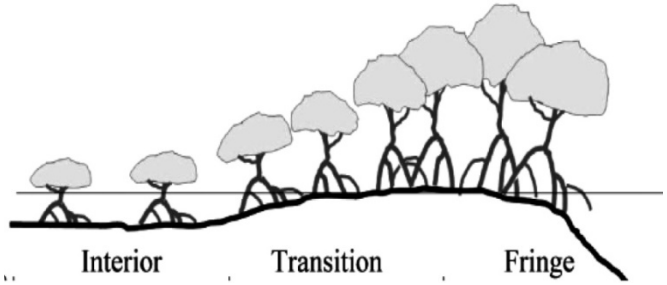
Knee Roots of *Bruguiera*

Peg roots of *Sonneratia*

Prop roots of *Rhizophora*

Roots and surface elevation

- 3-yr study, *R. mangle*, Belize.
- Root accumulation.
- Addition of nutrients (N and P).
- Altering root dynamics.



(McKee et al 2007)

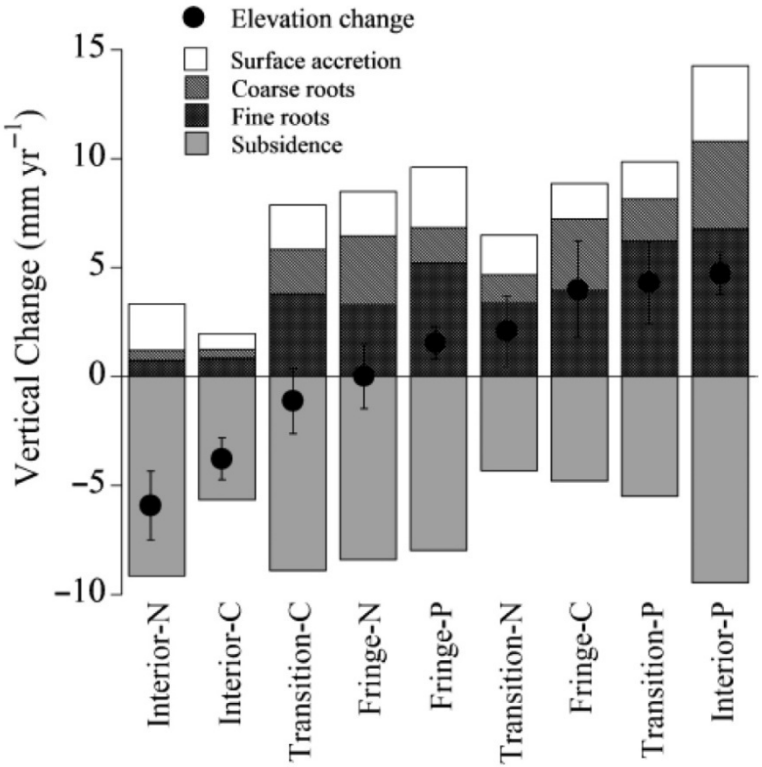


Figure 3 Variation in surface elevation change (●) relative to vertical change attributable to surface accretion, fine and coarse root production, and shallow subsidence (physical compaction and decomposition) across mangrove zones and nutrient treatments at Twin Cays, Belize; mean ± 1 SE ($n = 3$); SE not plotted on stacked bars for clarity.

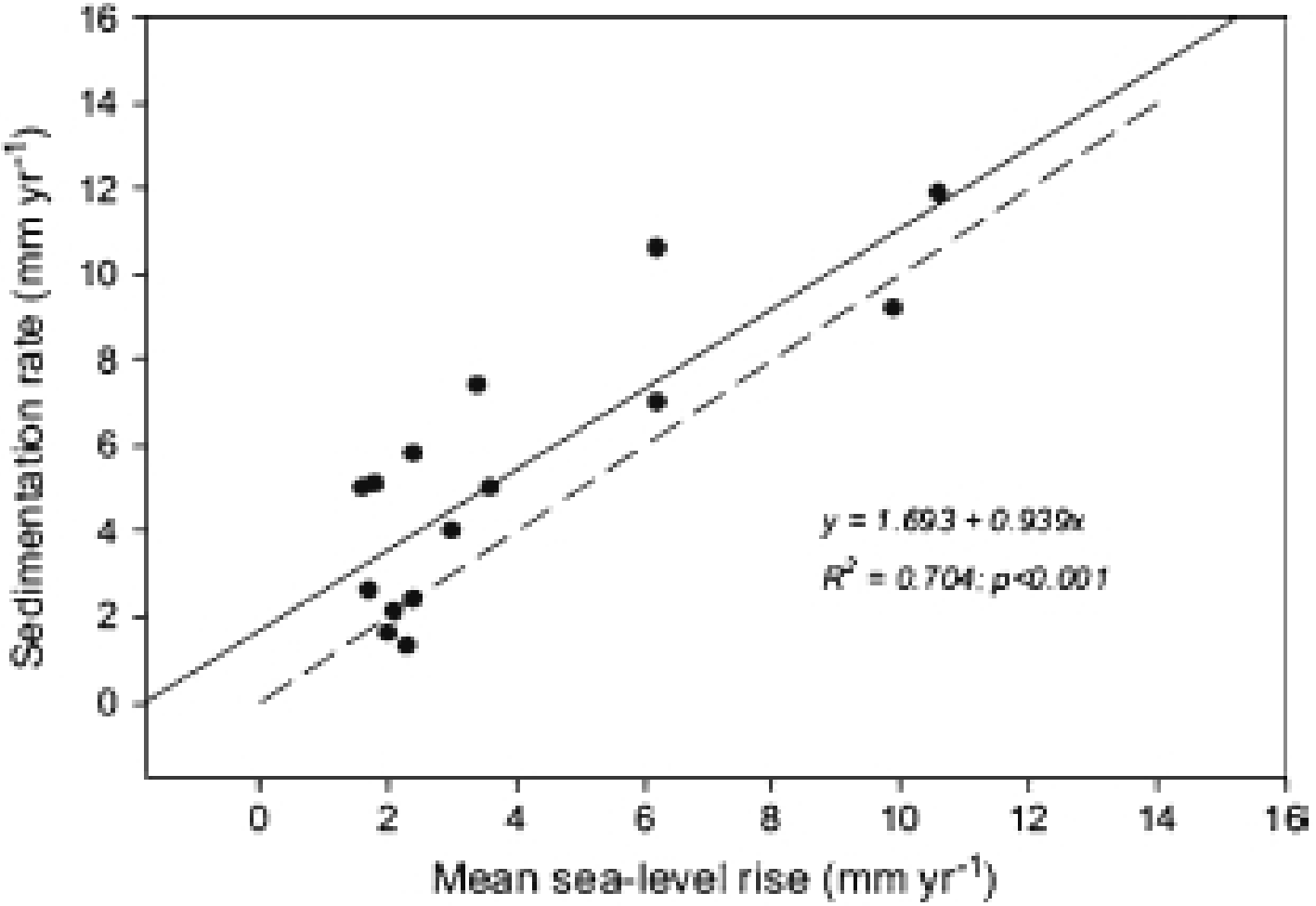
N Nitrogen fertilized. P Phosphorus fertilized. C Unfertilized control.

Mangroves and vertical growth

- “Intact and healthy mangrove systems can adapt to sea level rise; their growth can accommodate to increases of 3.8 up to 9 millimetres per year depending on local circumstances. Mangroves can also provide a buffer against salt water intrusion.”

(Wetlands International)

Mangroves and elevation increase



Solid line = linear regression. Dashed line = 1:1 relation

(Alongi 2008)

Processes controlling sedimentation

In review of climate change threats to mangroves:

- Sediment accretion and erosion – tides, waves, storms, etc.
- Biotic contributions – leaf litter, algal mats.
- Belowground primary production – roots, soil organic matter.
- Autocompaction.
- Fluctuations in water table and pore water – hydrology and groundwater inputs.

(Gilman et al 2008)

Avicennia marina

- Widest latitudinal range, ability to adapt to wide range of physical conditions, only mangrove to survive in arid areas.
- Present on both seaward & landward margin of mangrove belt.
- 'Opportunistic' colonization due to its ecological characteristics.
- Grows on mud, sand, gravels, rock surfaces.

Short-term and long-term benefits

- Provides employment; utilizes existing skills of coastal communities in mangrove planting.
- Restores degraded coasts caused by shrimp farming and other activities.
- Improves biodiversity; mangroves are nurseries for fish.
- Low cost protection measure compared to seawalls and dykes.
- Offers coastal protection from erosion, storm surges and buffer to tsunami waves. Integrated CCA and DRR.
- Important carbon sink.
- 'No regrets' measure; beneficial irrespective of future outcome of climate change.

Mangroves – food supply

Sonneratia Wajit (Sticky Mangrove Apples).....
Sonneratia Lempok (Candied Mangrove Apples).....
Sonneratia Juice (Mangrove Apple Juice).....

Bolu Api-Api (Avicennia Spongecake).....
Bolu Agar-Agar Api-Api (Avicennia Agar-agar cake)..
Onde-Onde Api-Api (Round Fried Avicennia cakes)..

(MAP)

New Scientist, 6 Nov 2010

I have argued that atoll nations should think of sacrificing some islands now in order to raise the level of others – a strategy of "better to save some than not to have any" (*Wiley Interdisciplinary Reviews: Climate Change*, DOI: 10.1002/wcc.84).

A new method of large-scale modular planting of mangroves, complemented by the addition of sediments, is another option that should be considered. Mangroves can grow on non-muddy substrates, including sand, gravels, coral flats, rock surfaces and even on the boulders of some sea defences.

Singapore

New Scientist
6 Nov 2010

Thank you