Vulnerability and change: A management issue

(Perspectives from IPCC AR4)

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Barcelona
18 October 2007

Draws Heavily on Chapter 6: Coastal Systems and Low-lying Areas IPCC AR4 Working Group II Report

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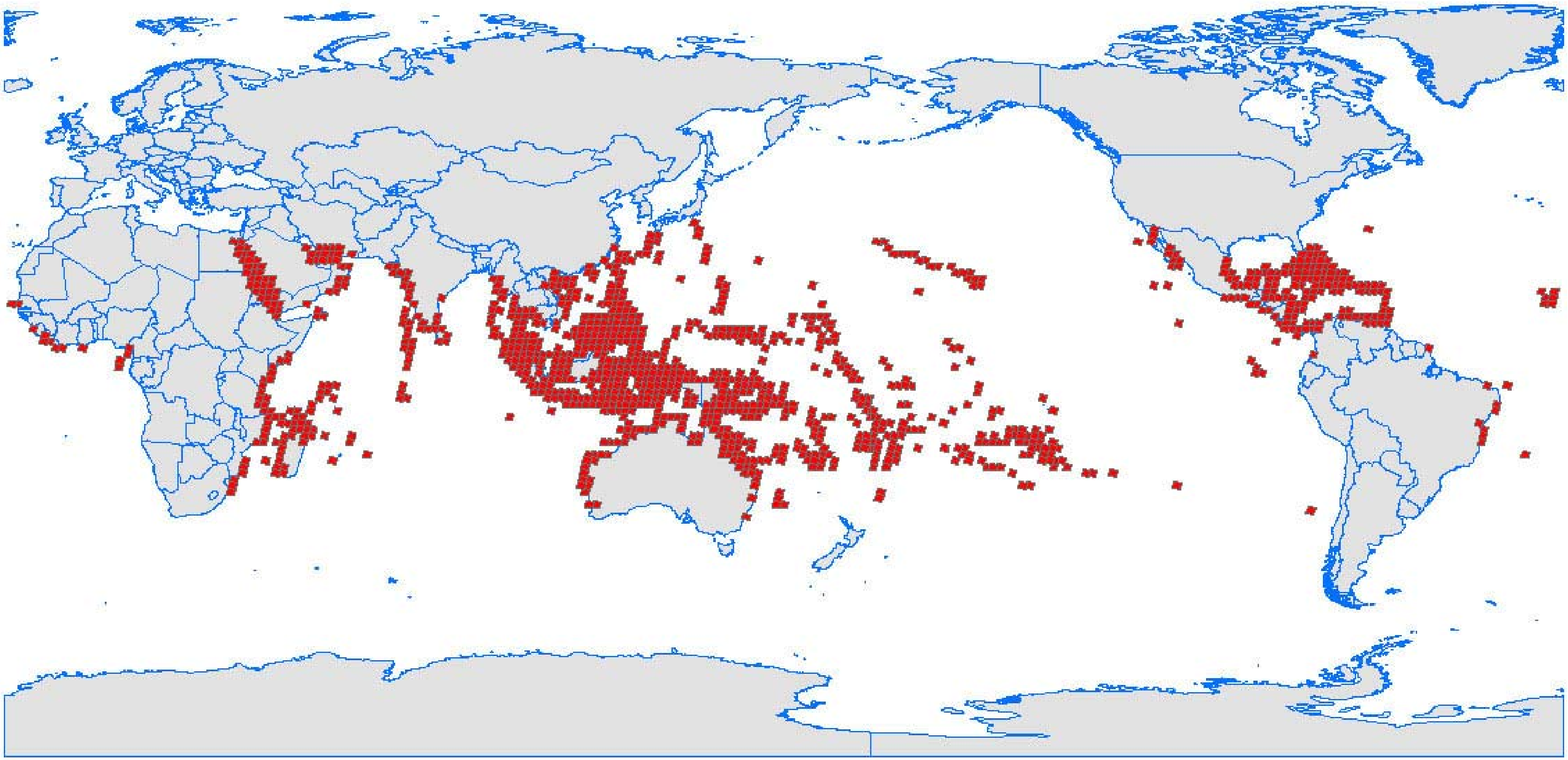
PLAN

- Why are coasts important?
- The systems approach
- Vulnerability and Responses

  (mainly from IPCC AR4)
- Vulnerability and Scale
- Conclusions

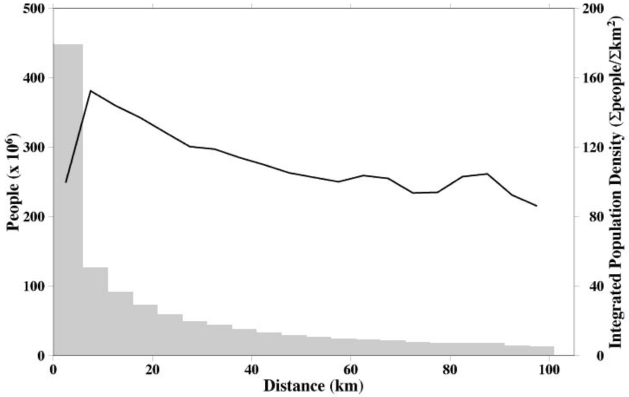
Coasts and ecosystems

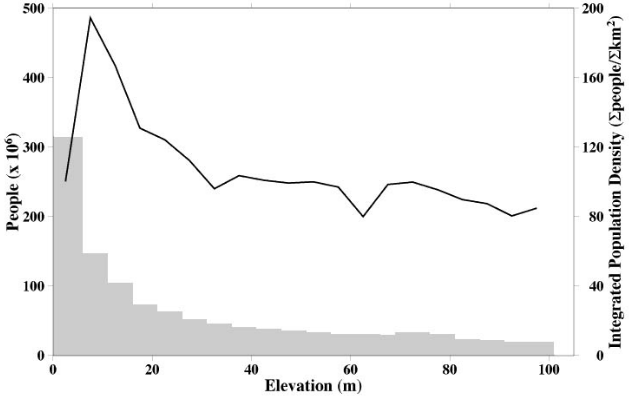
e.g. coral reefs



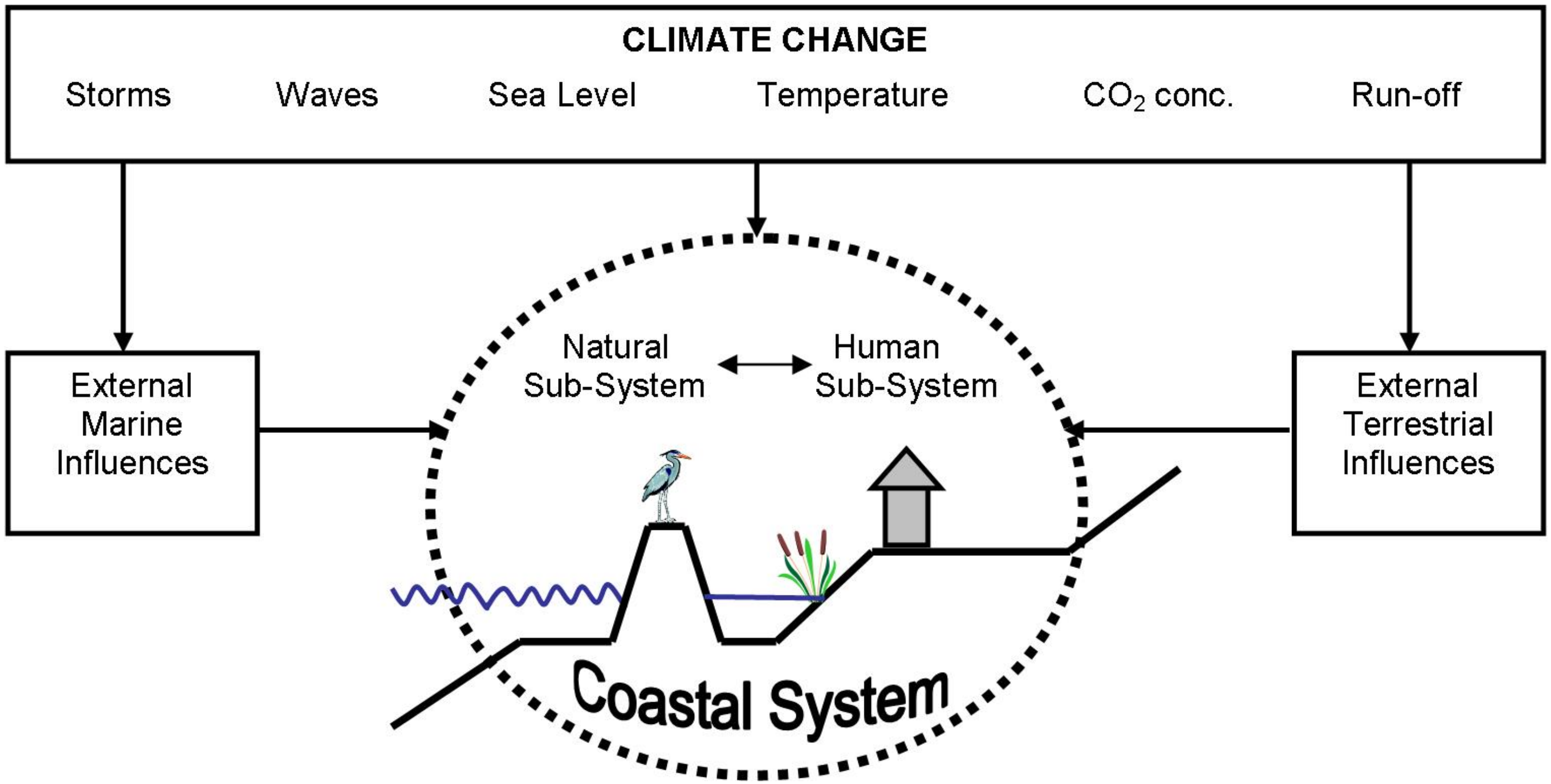
Coasts and people

Population and economic density in the coastal zone is greater than other areas of the earth's surface.





The coastal system



Main IPCC AR4 conclusions

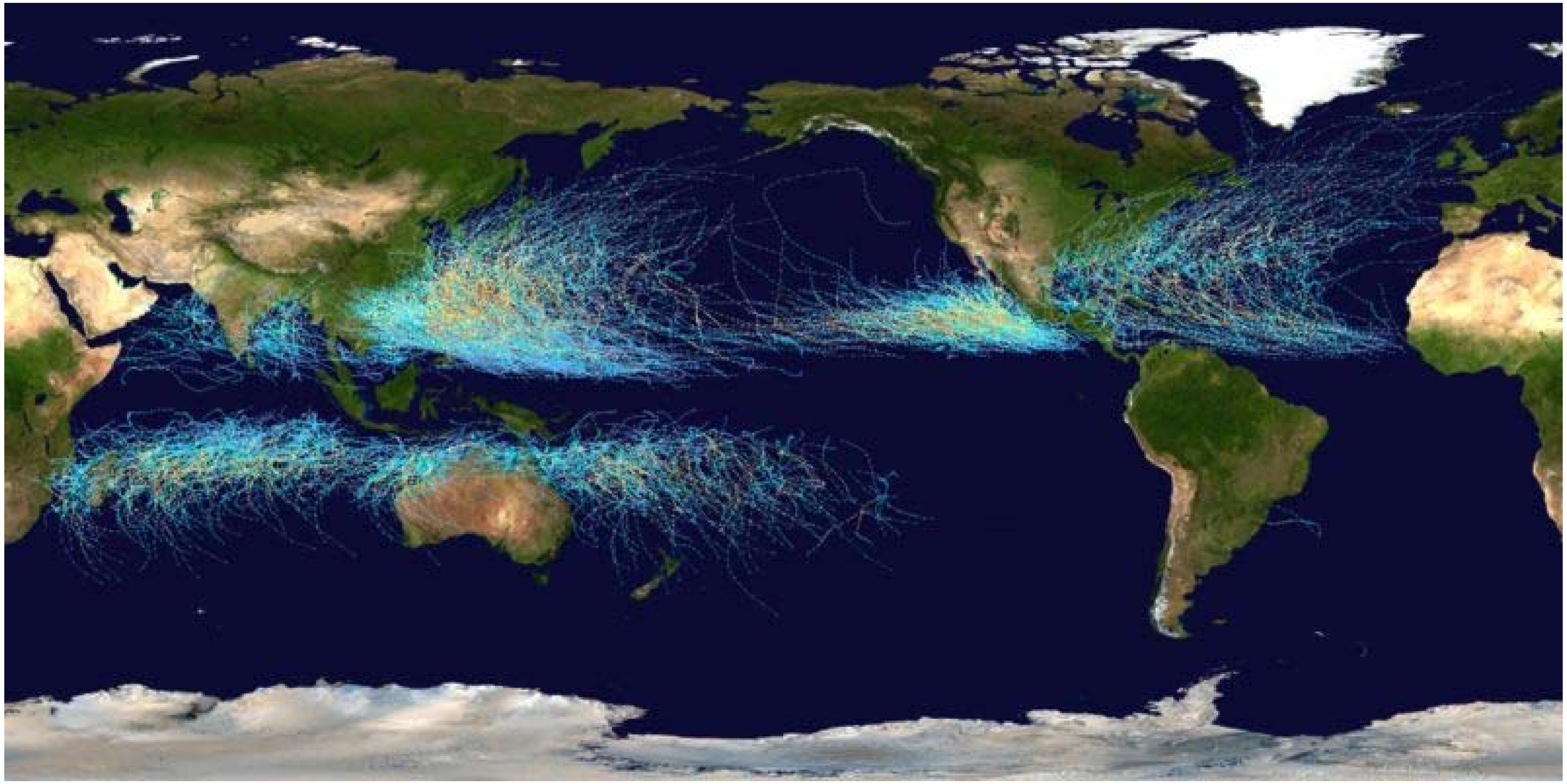
1. Coasts are experiencing the adverse consequences of hazards related to climate and sea level.
2. Coasts will be exposed to increasing risks over coming decades due to many compounding climate-change factors.
3. The impact of climate change on coasts is exacerbated by increasing human-induced pressures.
4. Coastal adaptation for developing countries will be more challenging than for developed countries, due to constraints on adaptive capacity.
5. Adaptation costs for vulnerable coasts are much less than the costs of inaction.
6. The unavoidability of sea-level rise even in the longer-term conflicts with human development patterns and trends.

Observed impacts

due to climate variability (and change)

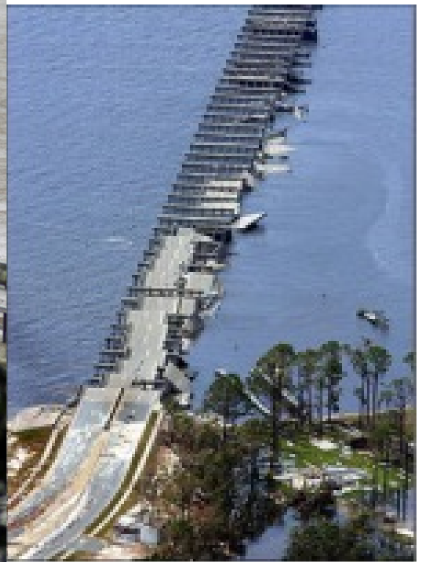
- Storms impose substantial costs on coastal societies.
- Annually, about 120 million people are exposed to tropical cyclone hazards
- 250,000 people were killed by tropical cyclones from 1980 to 2000.

Tropical cyclone tracks

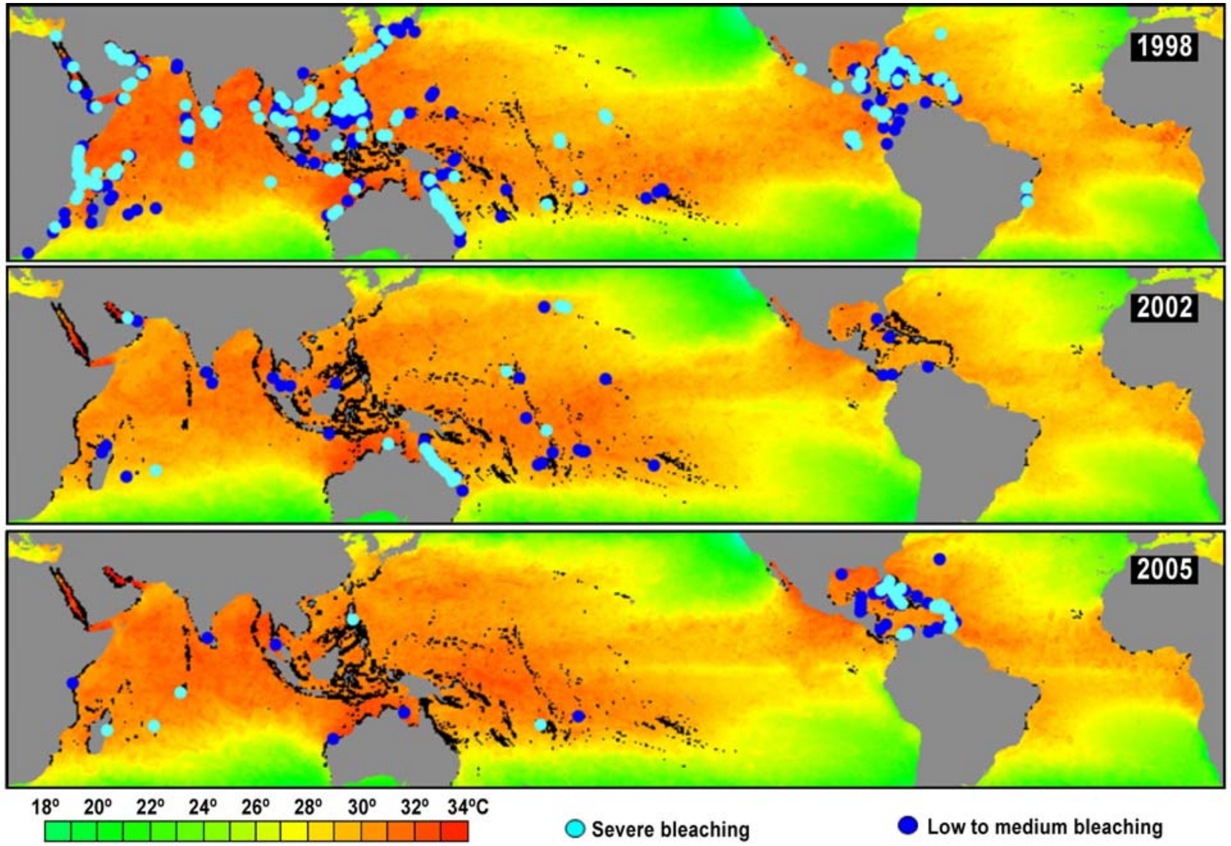


Cumulative tracks of all tropical cyclones during the period 1985–2005.

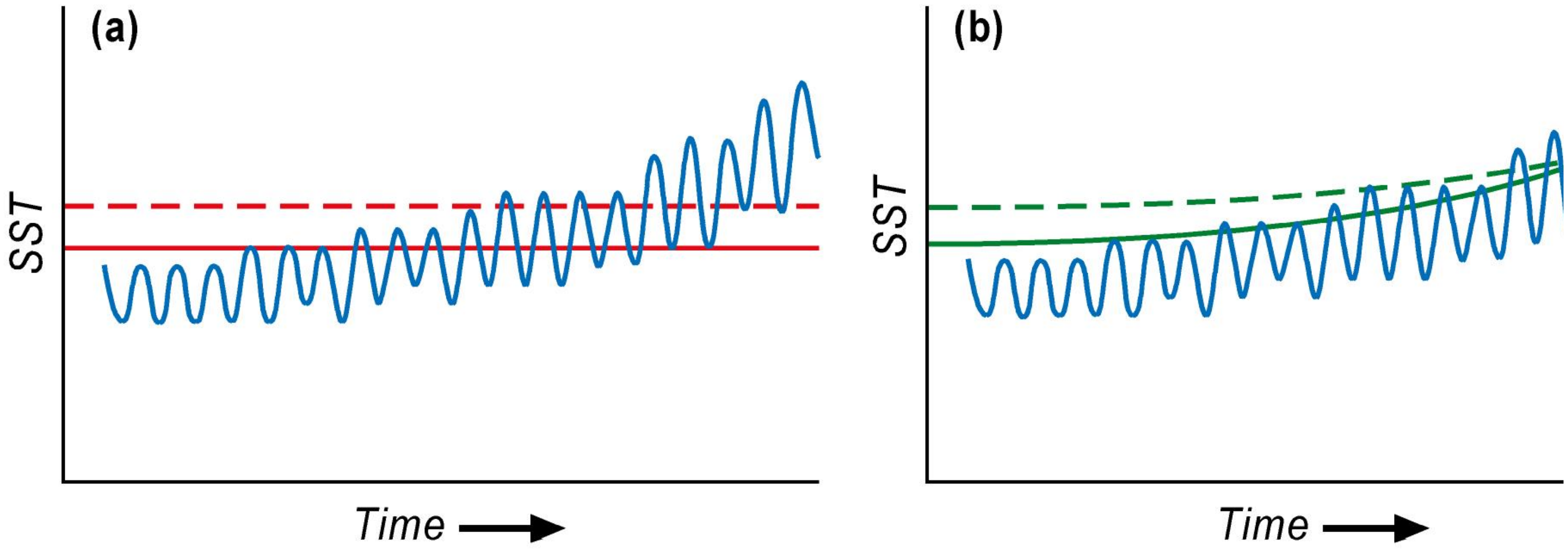
Flooding and Storm Damage in New Orleans



Recent coral bleaching events



Corals and thermal thresholds



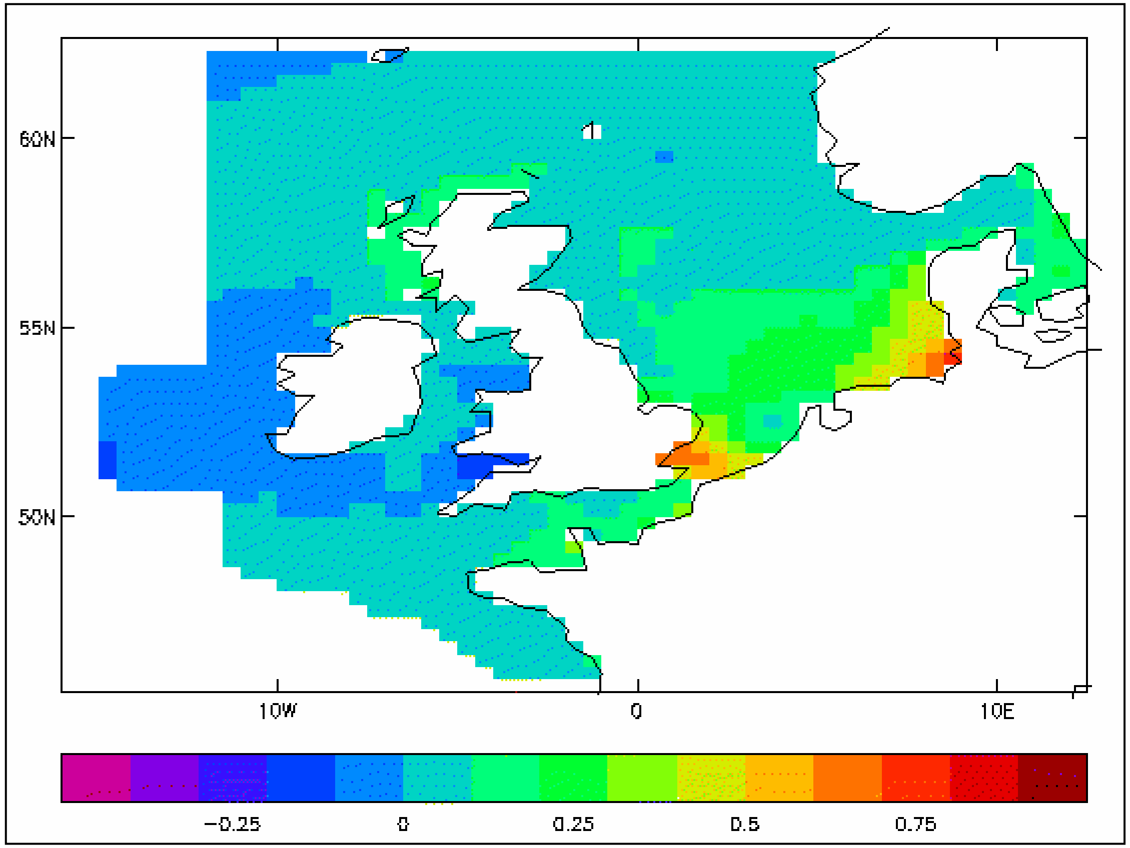
Climate risks will increase through the 21st Century

Climate Driver (trend)		Main Physical and Ecosystem Effects on Coastal Systems
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 (SST) (↑, R)		Increased stratification/changed circulation; Reduced incidence of sea ice at higher latitudes; Increased coral bleaching and mortality; Poleward species migration; Increased algal blooms.
Sea level (↑, R)		Inundation, flood and storm damage; 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;
	Frequency (?, R)	Altered surges and storm waves and hence risk of storm damage and flooding.
	Track (?,R)	
Wave climate (?, R)		Altered wave conditions, including swell; Altered patterns of erosion and accretion; Re-orientation of beach planform.
Run-off (R)		Altered flood risk in coastal lowlands; Altered water quality/salinity; Altered fluvial sediment supply; Altered circulation and nutrient supply.

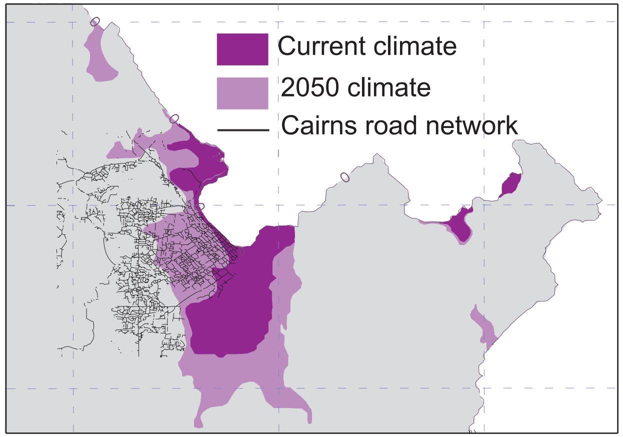
These phenomena will vary considerably at regional and local scales, but the impacts are virtually certain to be overwhelmingly negative.

Extreme sea-level simulations

including mean sea-level rise and storms



Cairns, Australia



Major impact types

Ecosystems

- Corals are threatened with increased bleaching and mortality due to rising sea surface temperatures.
- Coastal wetland ecosystems, such as salt marshes and mangroves are threatened, especially where they are sediment-starved or constrained on their landward margin.

People

- Degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the well-being of societies dependent on the coastal ecosystems for goods and services.
- Increased flooding and the degradation of freshwater, fisheries and other resources could impact hundreds of millions of people and socio-economic costs will escalate as a result of climate change for coasts.

Summary of climate-related impacts

Coastal Socio-economic Sector	*Climate-related impacts (and their climate drivers)*						
	Temperature Rise (Air and seawater)	Extreme Events (Storms, waves)	Floods (Sea level, run-off)	Rising water tables (Sea level)	Erosion (Sea level, storms, waves)	Saltwater intrusion (Sea level, run-off)	Biological effects (All climate drivers)
Freshwater Resources	X	X	X	X	-	X	x
Agriculture and forestry	X	X	X	X	-	X	x
Fisheries and Aquaculture	X	X	x	-	x	X	X
Health	X	X	X	x	-	X	X
Recreation and tourism	X	X	x	-	X	-	X
Biodiversity	X	X	X	X	X	X	X
Settlements/ infrastructure	X	X	X	X	X	X	-

'X' - strong; 'x'- weak; '-' - negligible or not established.

Climate change in the coastal zone is an additional stress

- Human utilisation of the coast increased dramatically during the 20th century
- This trend is virtually certain to continue through the 21st century with a growing coastal population and associated assets.
- Increasing numbers of people and assets at the coast are subject to additional stresses due to non-climate stresses
  - e.g., dams that reduce sediment supply to the coast.

Broad environmental and socio-economic trends for coastal areas

Environmental and Socio-economic Factors	*Global non-climatic changes and trends (by SRES Future)*			
	"A1 World"	**"A2 World"**	**"B1 World"**	**"B2 World"**
Population (2080s) (billions)[1]	1.8 to 2.4	3.2 to 5.2	1.8 to 2.4	2.3 to 3.4
Coastward migration	Most likely	Less likely	More likely	Least likely
Human-induced subsidence	More likely		Less likely	
Terrestrial freshwater/sediment supply ***(due to catchment management)***	Greatest reduction	Large reduction	Smallest reduction	Smaller reduction
Aquaculture growth	Large increase		Smaller increase	
Infrastructure growth	Largest	Large	Smaller	Smallest
Extractive industries	Larger		Smaller	
Adaptation response	More reactive		More proactive	
Hazard risk management	Lower priority		Higher priority	
Habitat conservation	Low priority		High priority	
Tourism growth	Highest	High	High	Lowest

[1] Population living both <100 m elevation above sea level and <100 km distance of the coast.

Vulnerable areas

Hotspots of coastal vulnerability occur where the stresses on natural systems coincide with low human adaptive capacity and high exposure.

- Vulnerable coastal types
  - Populated deltas (especially Asian megadeltas)
  - Low-lying coastal urban areas
  - Atolls
- Vulnerable regions
  - south, south-east and east Asia
  - Africa
  - small islands (Caribbean, Indian Ocean, and Pacific Ocean)

Threatened deltas

Relative vulnerability of coastal deltas

Indicative population potentially displaced by <u>current</u> sea-level trends to 2050.

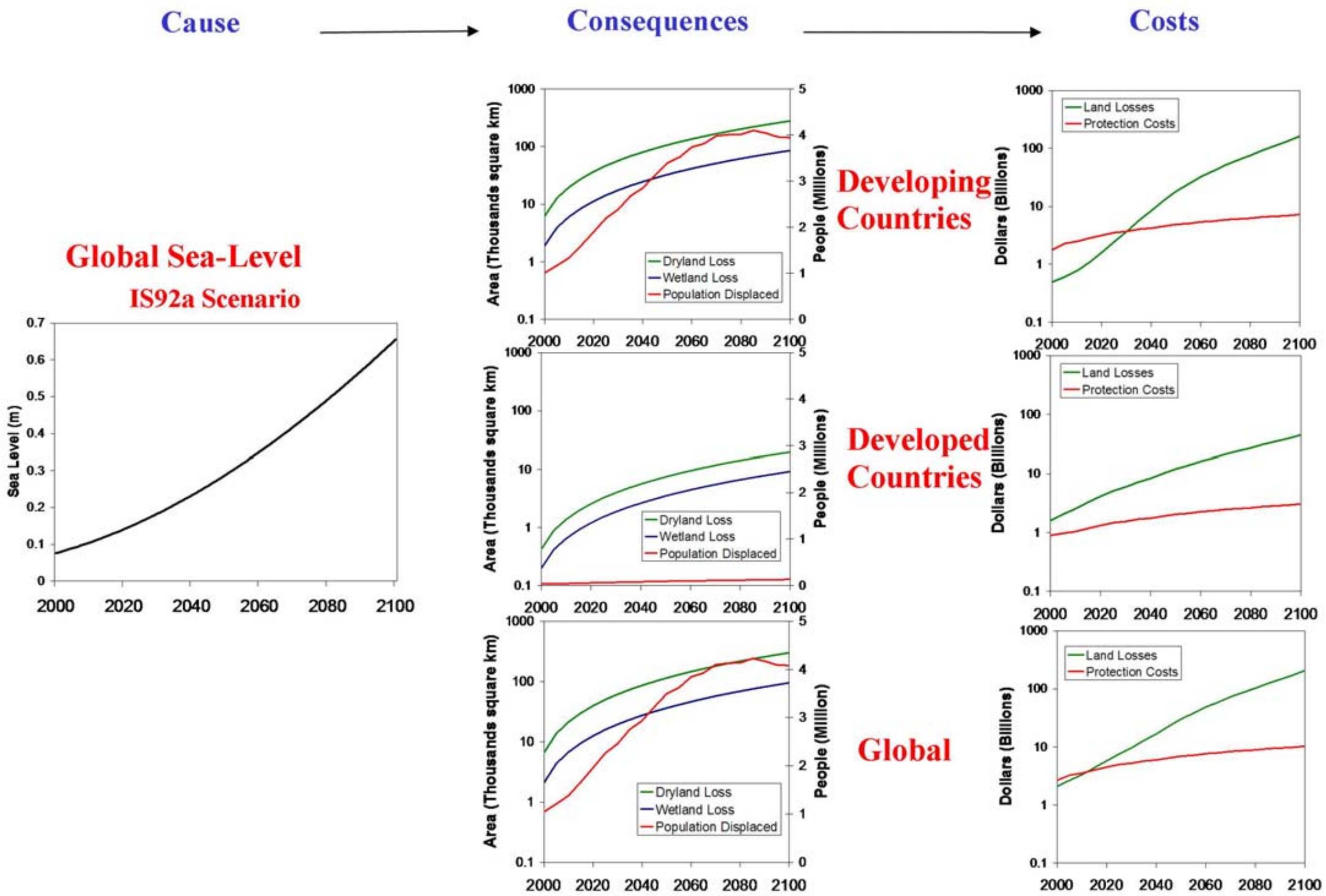
Extreme	≥ 1 million people displaced
High	1 million to 50,000 people displaced
Medium	50,000 to 5,000 people displaced

Adaptation is challenging, especially in developing countries

- Vulnerability also varies between developing countries, while developed countries are not insulated from the adverse consequences of extreme events (e.g., Katrina).

Integrated assessment of sea-level rise

(FUND results of Richard Tol)



Many adaptation options are available to reduce vulnerability

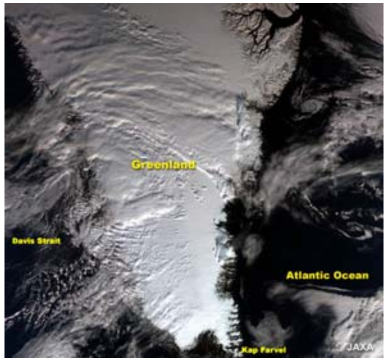
Coastal adaptation (IPCC CZMS, 1990)	Adaptation objectives (Klein and Tol, 1997)	Adaptation responses (after Cooper et al., 2002; Defra, 2001)	Example
Protect	Increased robustness	Advance the line	Land claim; empoldering Estuary closure
		Hold the line	Dyke; beach nourishment
Accommodate	Increased flexibility		'Flood proof' buildings Floating agricultural systems
Retreat	Enhanced adaptability	Retreat the line	Managed realignment
		Limited intervention	Ad hoc seawall
		No intervention	Monitoring only
	Reversing maladaptive trends	Sustainable adaptation	Wetland restoration
	Improved awareness and preparedness	Community-focussed adaptation	Flood hazard mapping; flood warnings

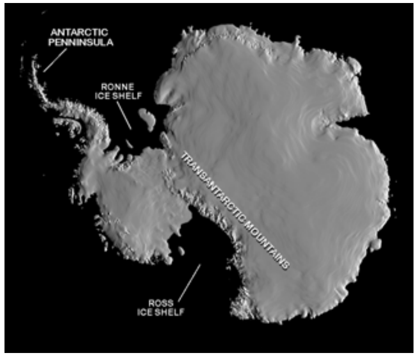
Inaction will cost more than adaptation (or management pays!!)

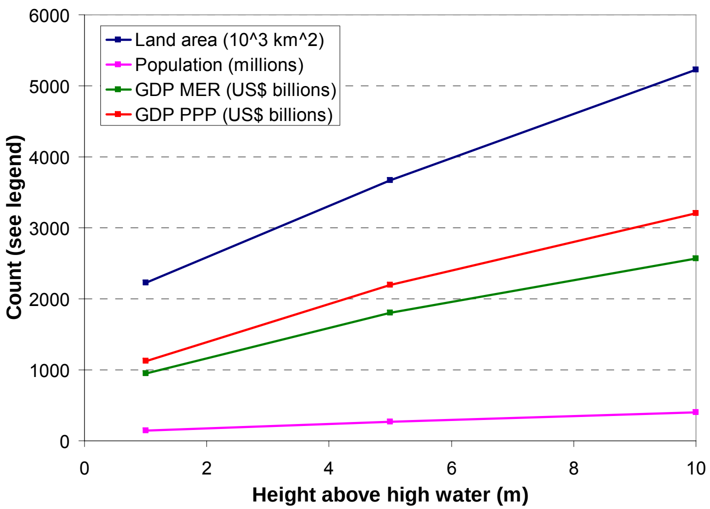
- Adaptation costs for climate change are generally lower than direct damage costs (property losses and human deaths).
- Hence, the full benefits of adaptation (including indirect impacts) are even larger.
- Without adaptation, some islands and low-lying areas many become unviable by 2100.
- Hence, effective adaptation is urgently required.

Sea-level rise will continue beyond 2100

- Sea-level rise has substantial inertia and will continue beyond 2100 for many centuries.
- Irreversible breakdown of the West Antarctica and/or Greenland ice sheets, if triggered by rising temperature, would make this long-term rise significantly larger
- This would ultimately question the viability of many coastal settlements across the globe.







Implications of long-term change

- Settlement patterns also have substantial inertia, and this issue presents a challenge for long-term coastal spatial planning.
- Stabilisation of climate could reduce the risks of ice sheet breakdown, and reduce but not stop sea-level rise due to thermal expansion.
- Hence, it is now more apparent than the TAR that the most appropriate response to sea-level rise for coastal areas is a combination of *adaptation* to deal with the inevitable rise, and *mitigation* to limit the long-term rise to a manageable level.

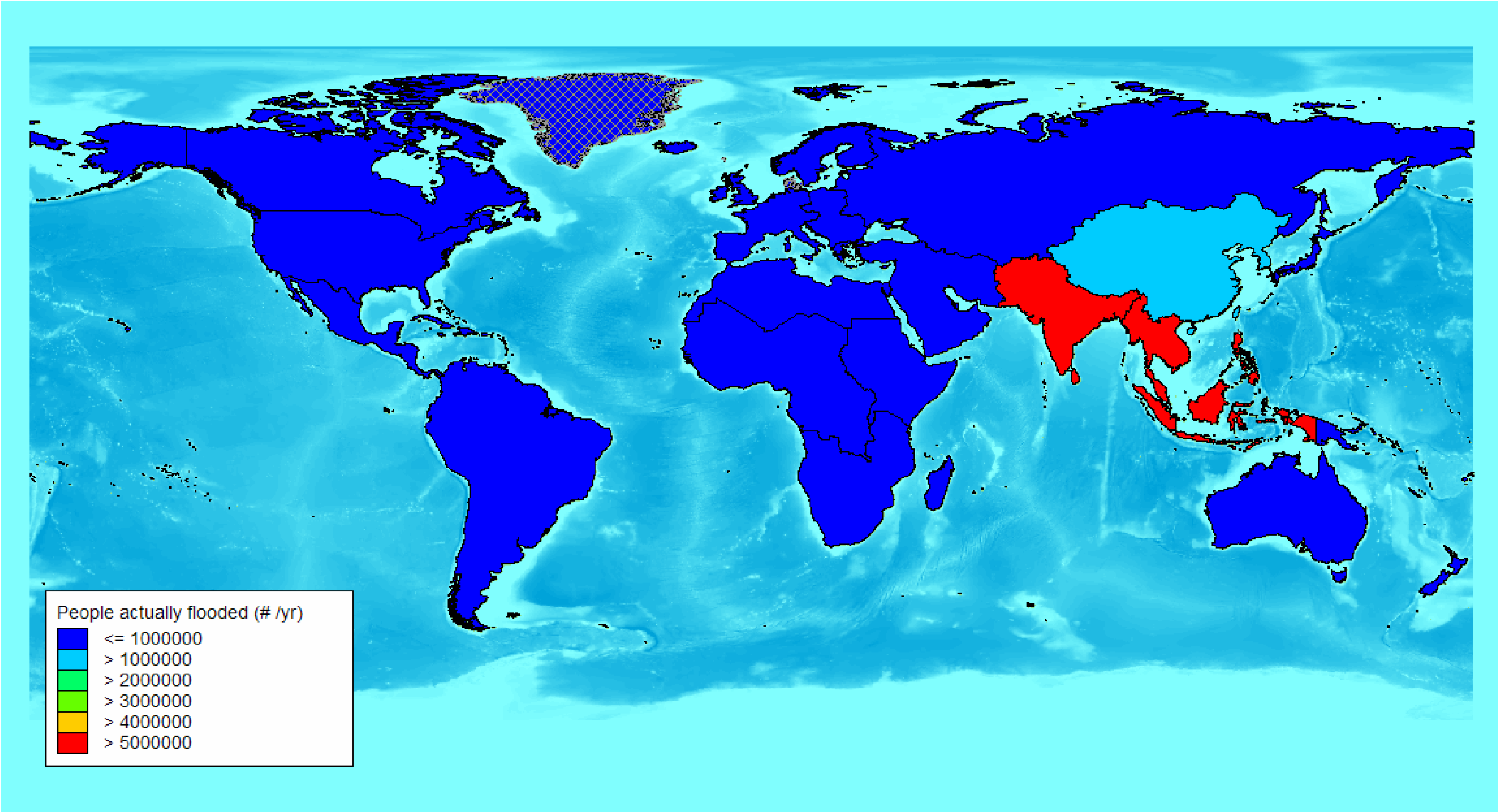
Research Needs

- Better baselines of actual coastal changes and their drivers.
- Better predictive models of future coastal change due to climate and other drivers.
- Better understanding of the adaptation of the human systems in the coastal zone.
- Improved impact and vulnerability assessments within an integrated assessment framework.
- Better methods for identification and prioritisation of coastal adaptation options.
- Develop and expand networks to share knowledge and experience among coastal scientists and practitioners.

Vulnerability and Scale

Sample DIVA[1] Outputs

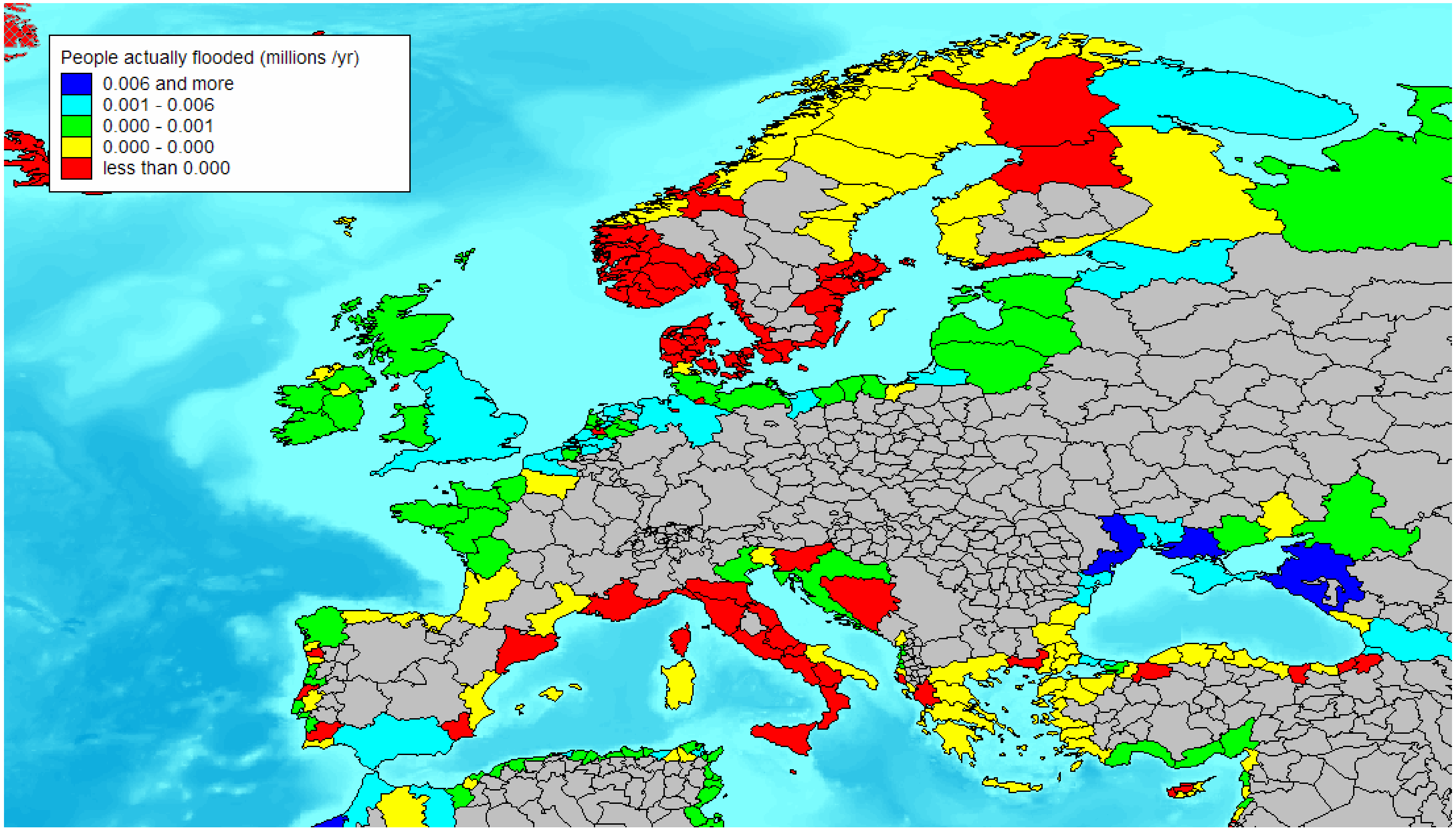
Estimated People Flooded (per year) by surges in 2000



1. DIVA – Dynamic and Interactive Vulnerability Assessment developed in the EU 5th Framework Project: DINAS-COAST

Sample DIVA Outputs

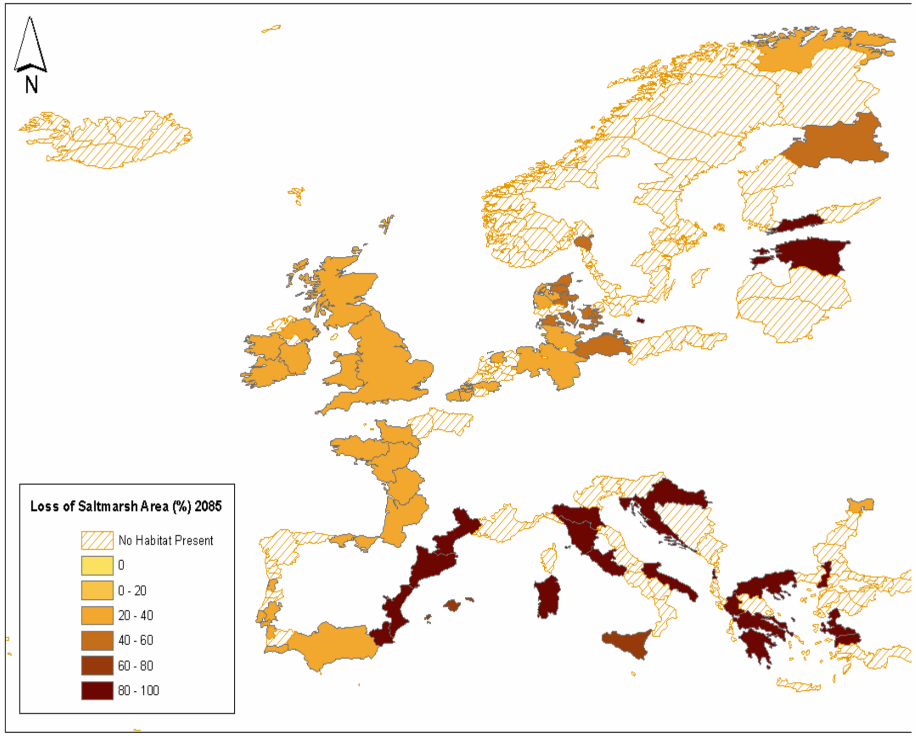
Estimated People Flooded (per year) by surges in 2000 (in Europe)



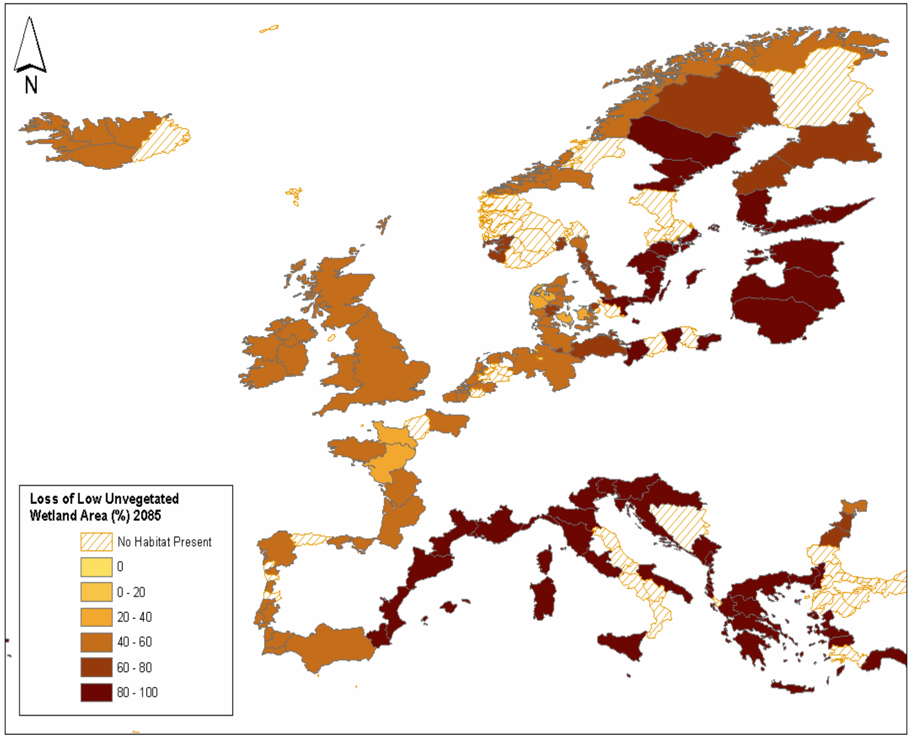
Sample DIVA Outputs

Relative loss by the 2080s under the high sea-level rise scenario
(compared to 2000 baseline)

Saltmarsh



Low unvegetated areas (mudflat)

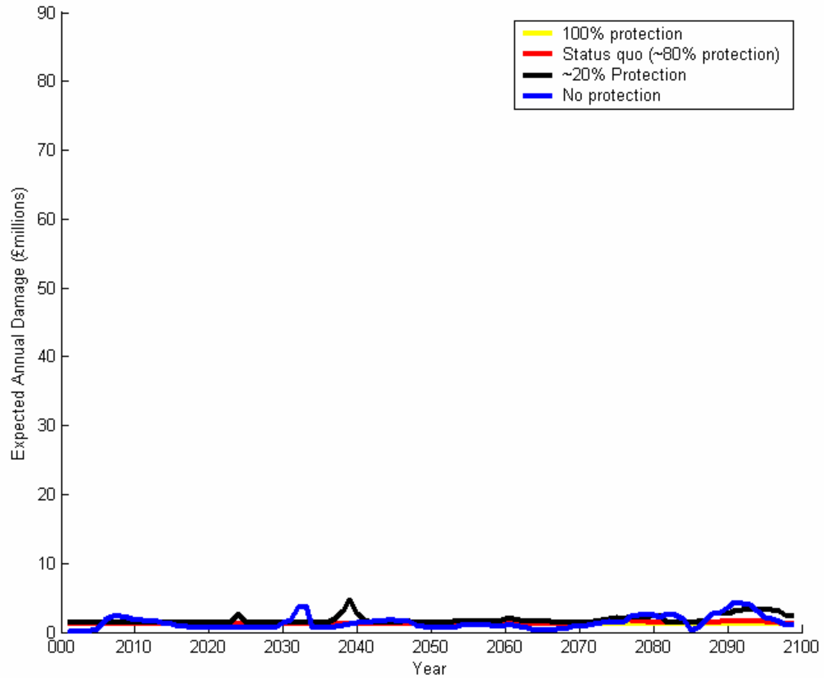


Tyndall Centre Coastal Simulator

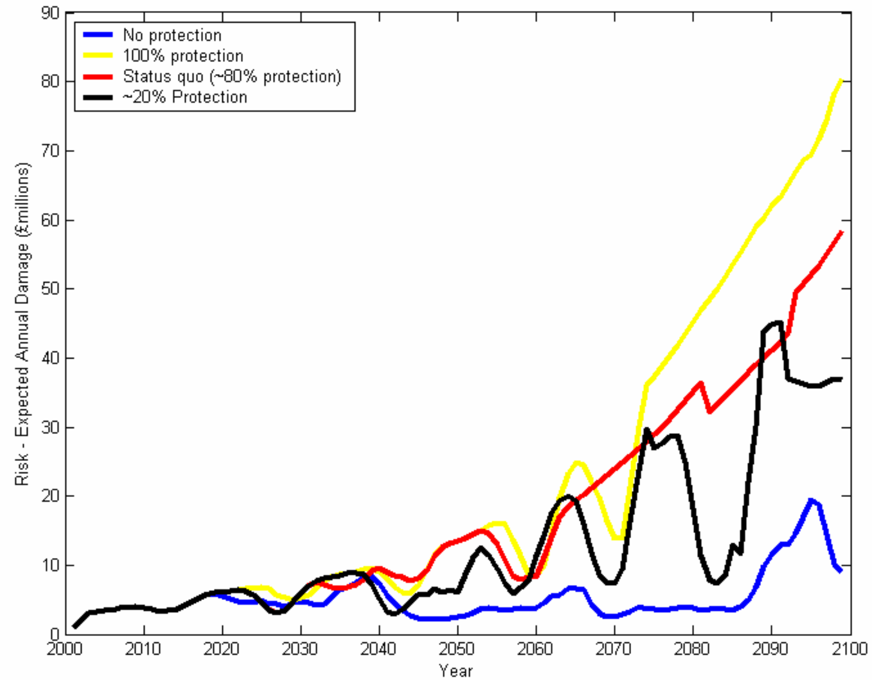
Erosion versus Flood Risk in sub-cell 3b

High sea-level rise and varying shoreline
management options on the cliff coast

Erosion risk



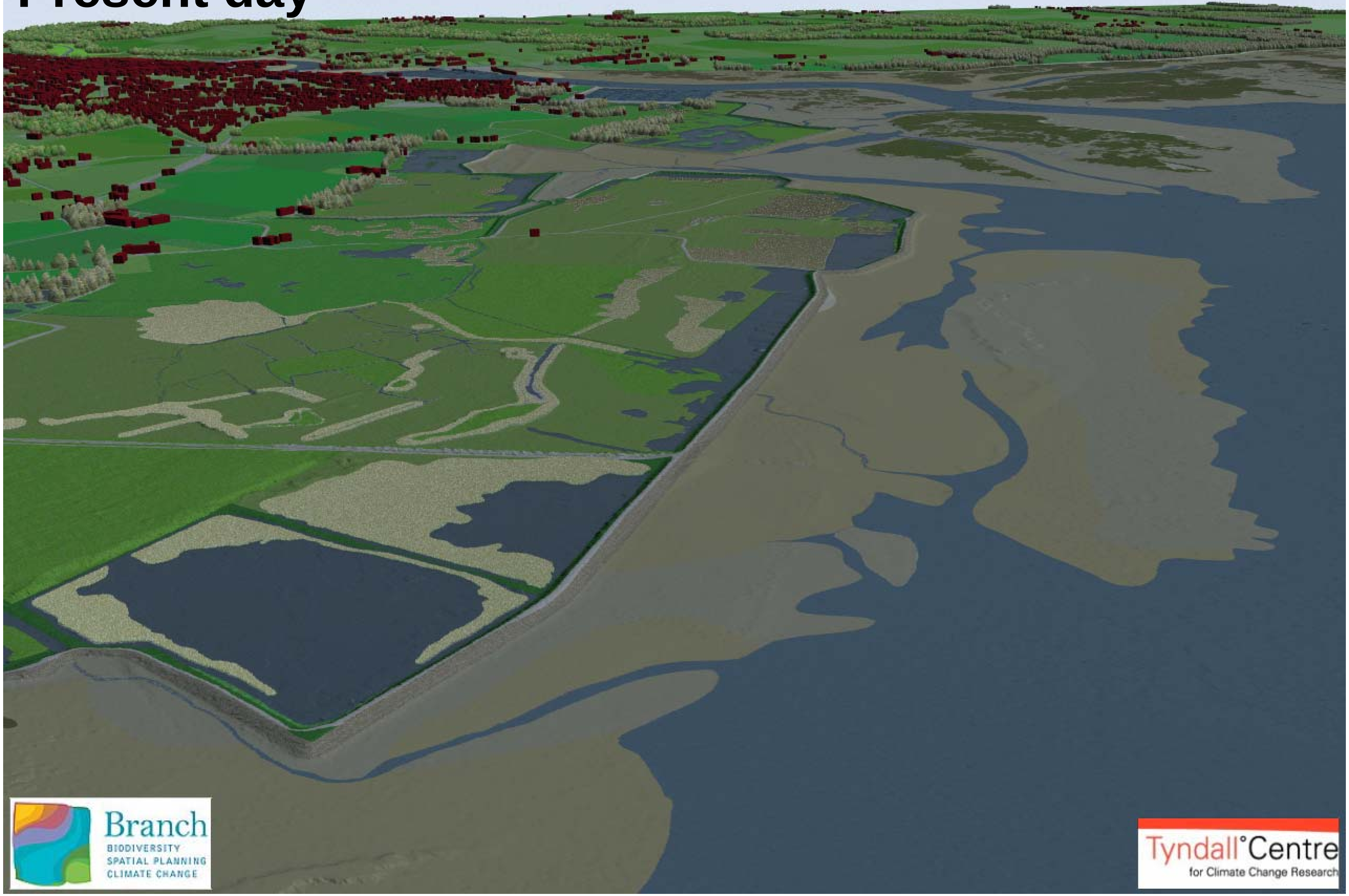
Flood risk



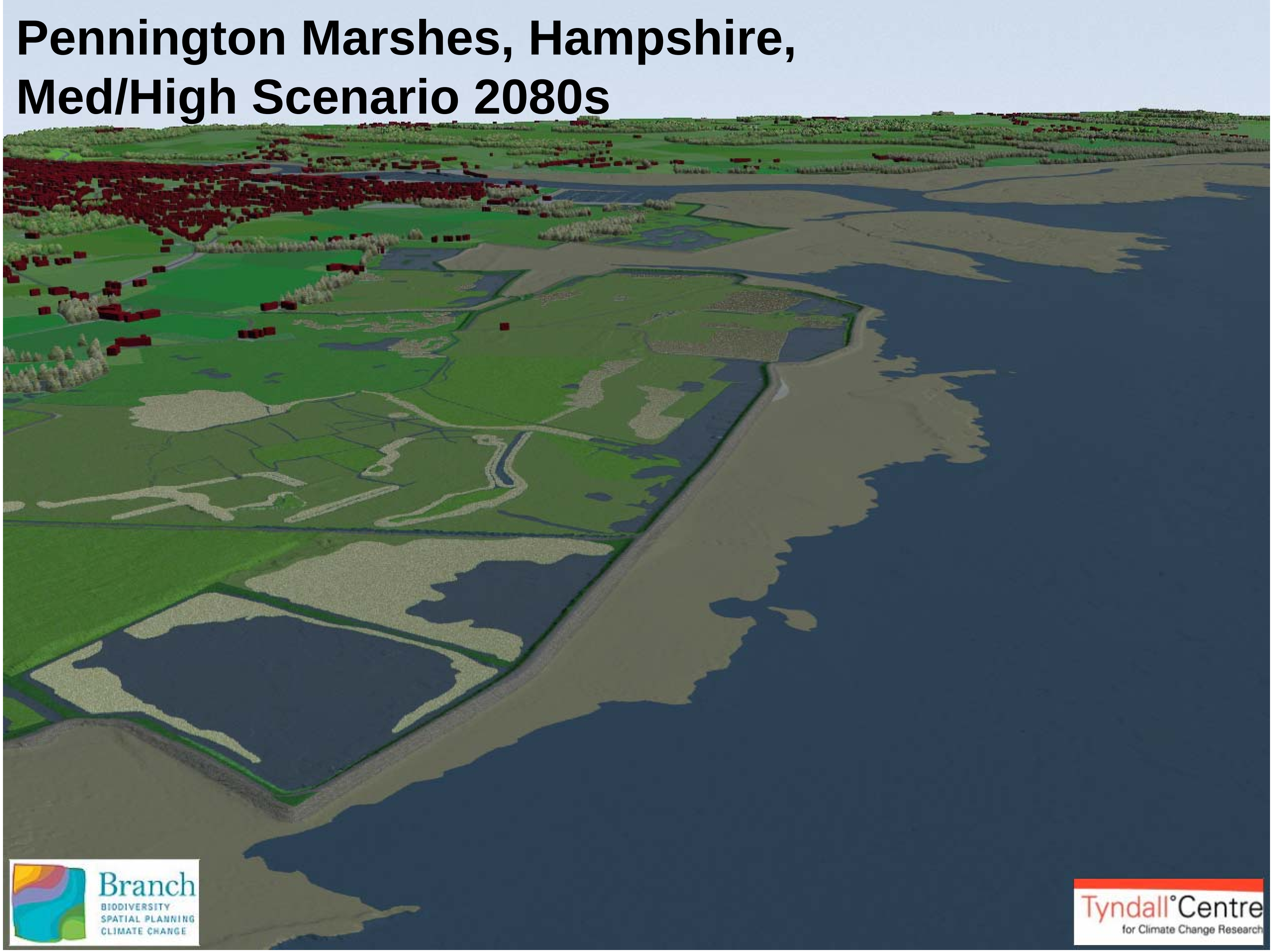
Sample Visualisation

of cliff retreat in 10 year time steps

Pennington Marshes, Hampshire, Present day



Pennington Marshes, Hampshire, Med/High Scenario 2080s



Vulnerability and Scale

Conclusions

- Climate change presents significant challenges in the coastal zone.
- The challenge is here today and will grow substantially into the future.
- To understand this challenge integrated assessment is fundamental, both across and between scales.
- While our knowledge needs to be expanded a range of response options are available, and we need to start implementation today (in an adaptive management manner).

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