Vulnerability and Adaptation Assessments Hands-On Training Workshop

for the Africa Region

Global Sea-Level Rise: Analytical Approaches

Maputo, Mozambique

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climate change secretariat

Outline

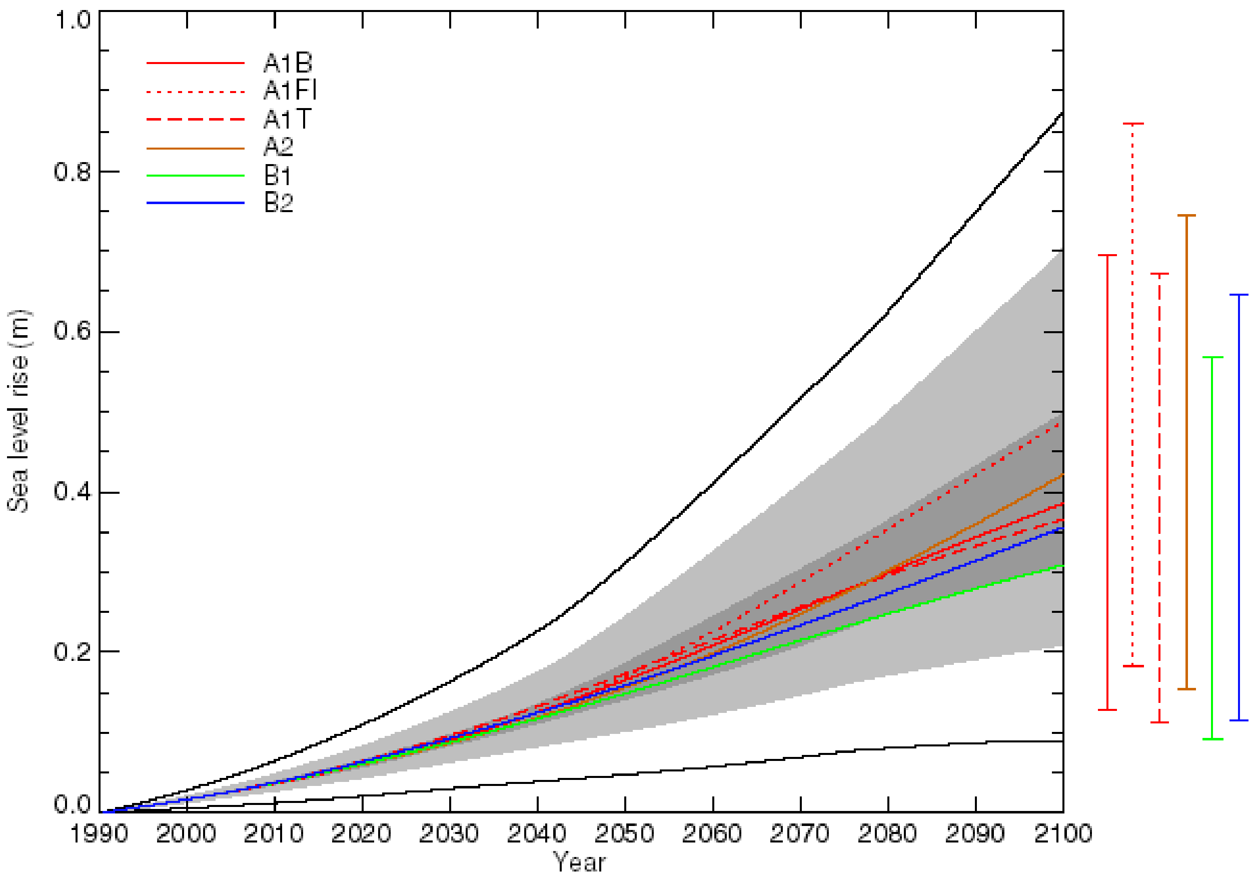
- Sea-level rise (SLR)
  - Predictions
  - Scenarios
  - Global processes
  - Local uncertainties
  - Impacts
- Shoreline management and adaptation
- Methods to assess impacts of SLR
  - Levels of assessment
    - Screening
    - Vulnerability
    - Planning
- Review of African region situation
- Models
- Data sources

Current Global Predictions of Sea-Level Rise

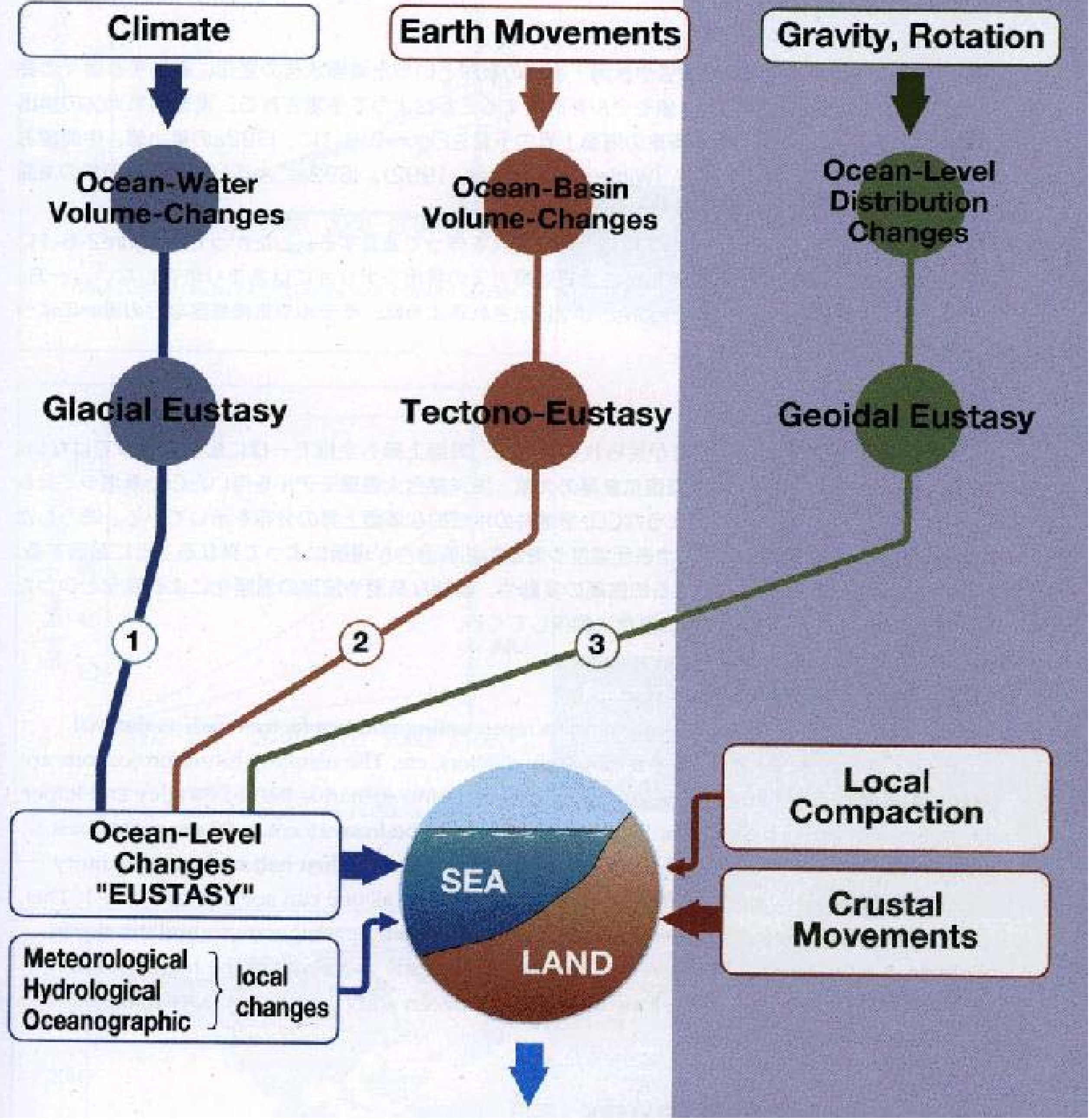
- TAR range for global-mean rise in sea level is between 9 cm and 88 cm by 2100
- Change outside this range is possible, especially if Antarctica becomes a significant source
- There is a "commitment to sea-level rise" even if atmospheric greenhouse gas concentrations are stabilised

Global-Mean Sea-Level Rise

1990 to 2100 (SRES scenarios)



Processes Controlling Sea-Level Change



Relative sea-level changes

Global Components of Sea-Level Rise

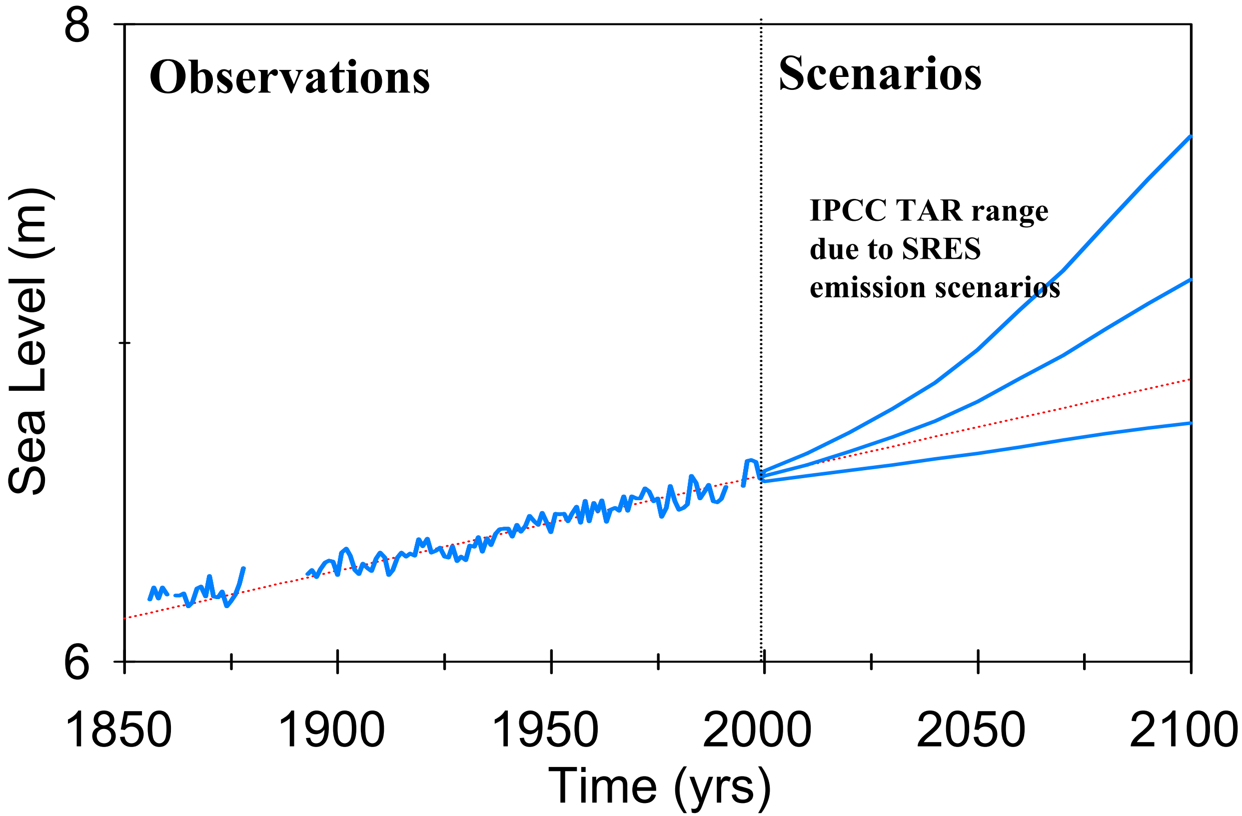
Ocean volume controlled by:

- Ocean temperature – thermal expansion
- Melting of land-based ice
  - Small glaciers
  - Greenland
  - Antarctica
- The hydrological cycle (including human influence)

Uncertainty in Local Predictions

- Relative SLR: global and regional components plus land movement
  - Land uplift will counter any global SLR
  - Land subsidence will exacerbate any global SLR
  - Other dynamic oceanic and climatic effects cause regional differences (oceanic circulation, wind and pressure, and ocean-water density differences add additional component)

Sea-Level Rise at New York City 1850 to 2100



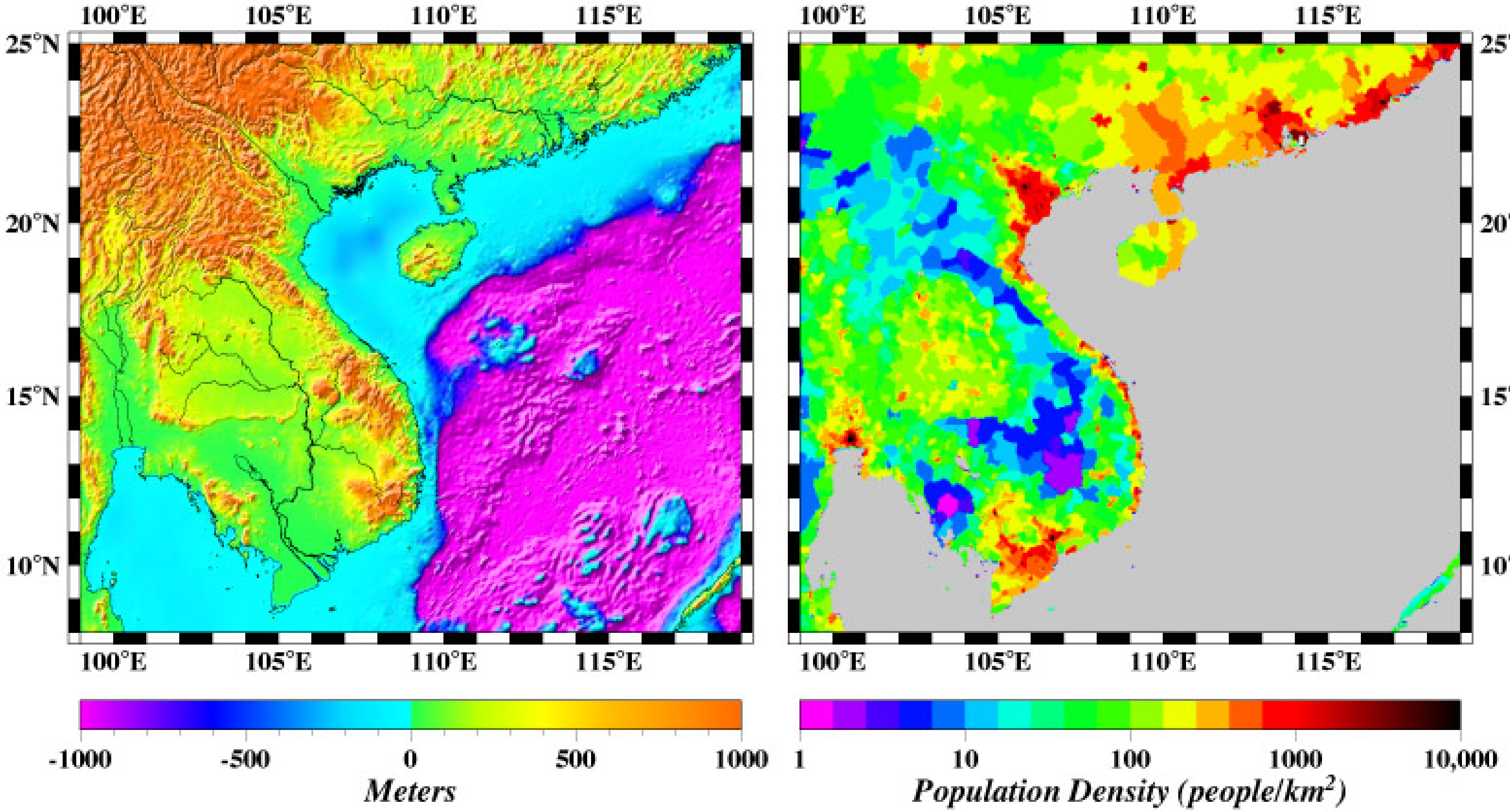
Land Subsidence

Other Climate Change
(Hurricane Andrew)

Impacts of Sea-Level Rise

- Why is SLR important?
- Physical impacts
- Socio-economic impacts
- Impact assessment

Elevation and Population Density Maps for Southeast Asia



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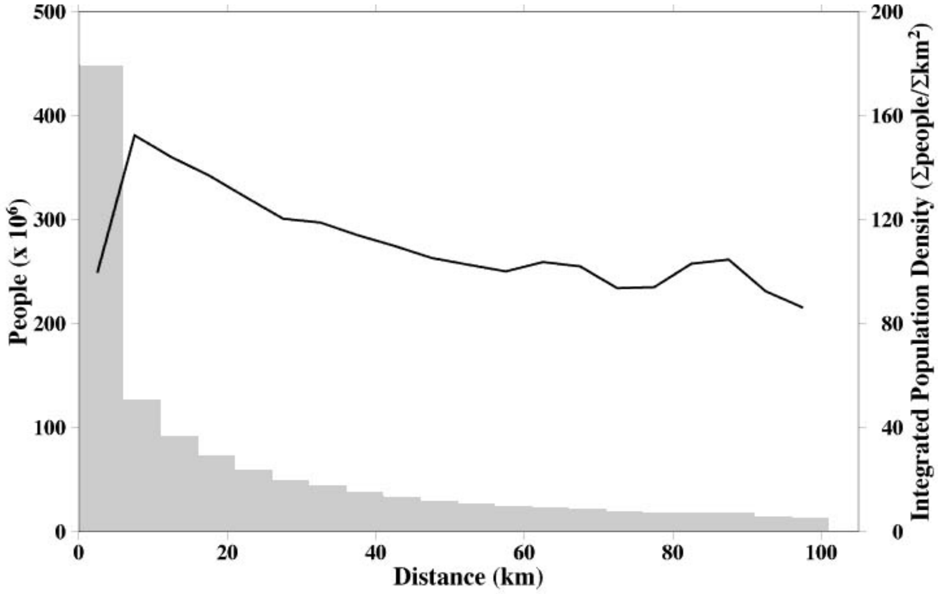
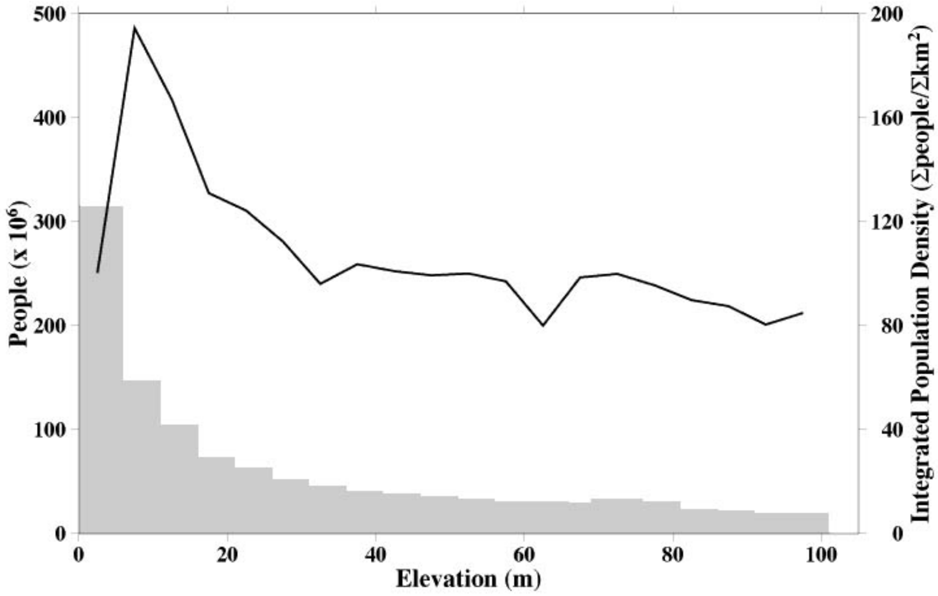
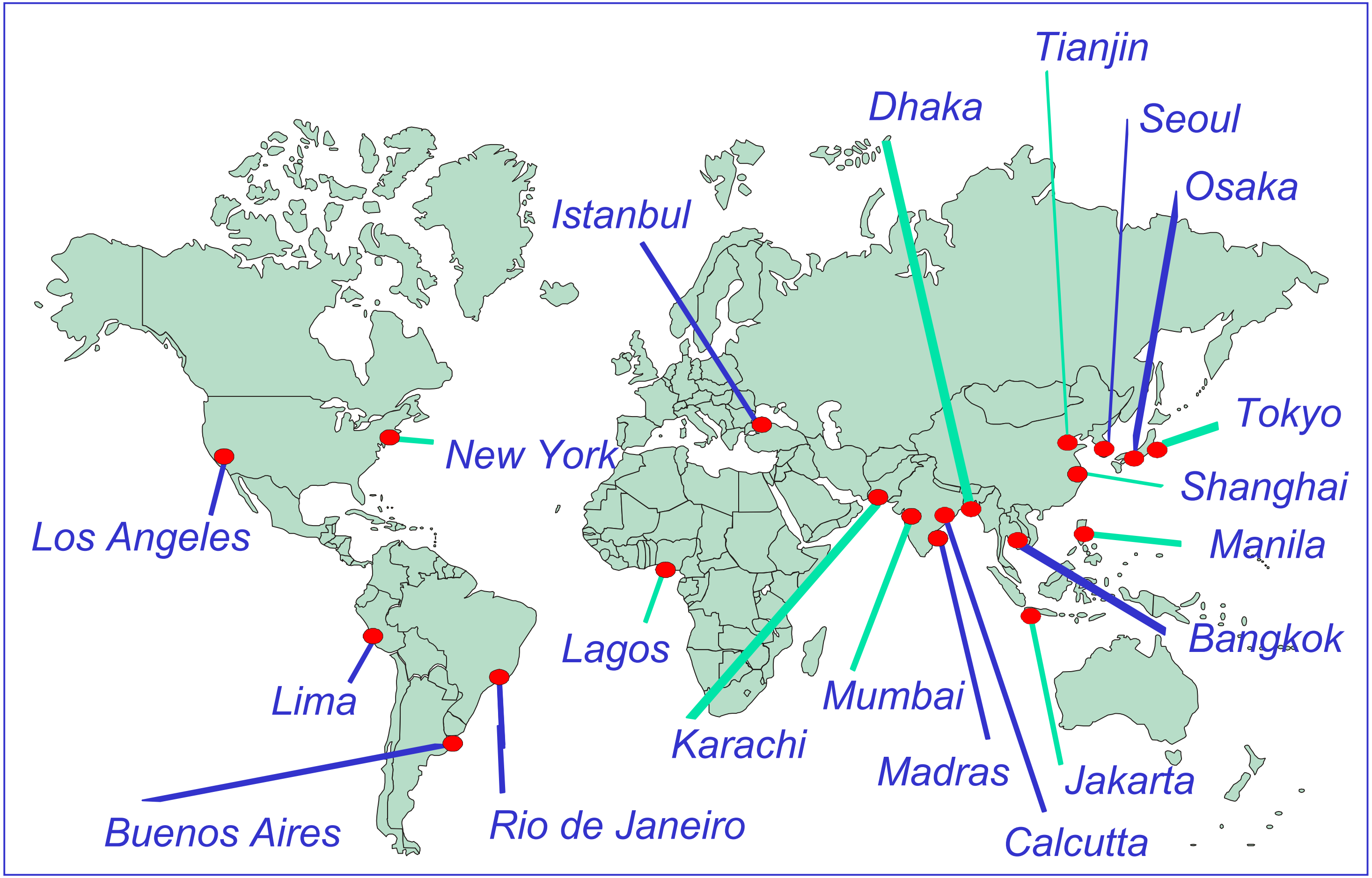


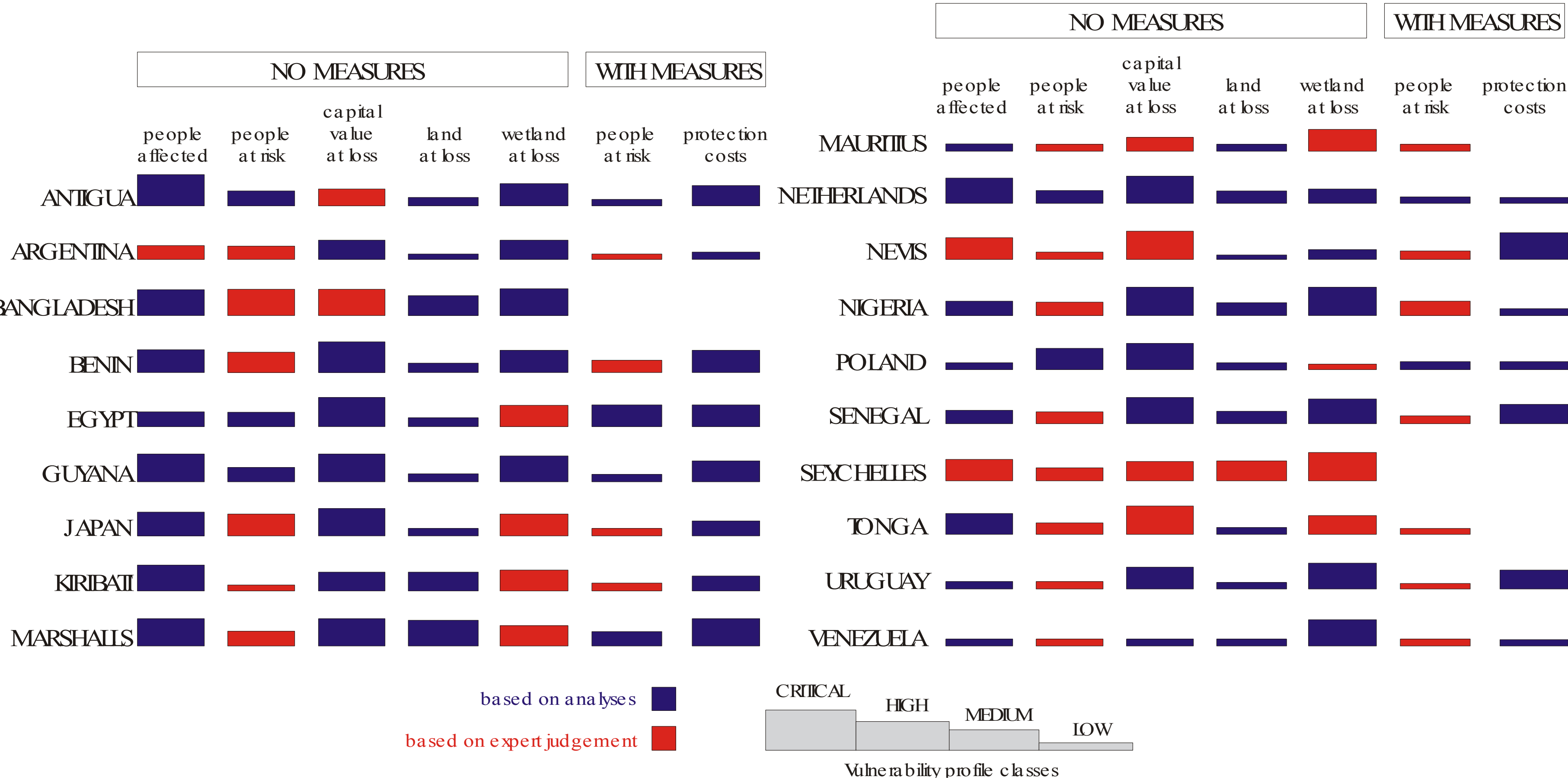


Population and Population Density vs. Distance and Elevation in 1990

Coastal Megacities (> 8 million people) Forecast for 2010



National Vulnerability Profiles



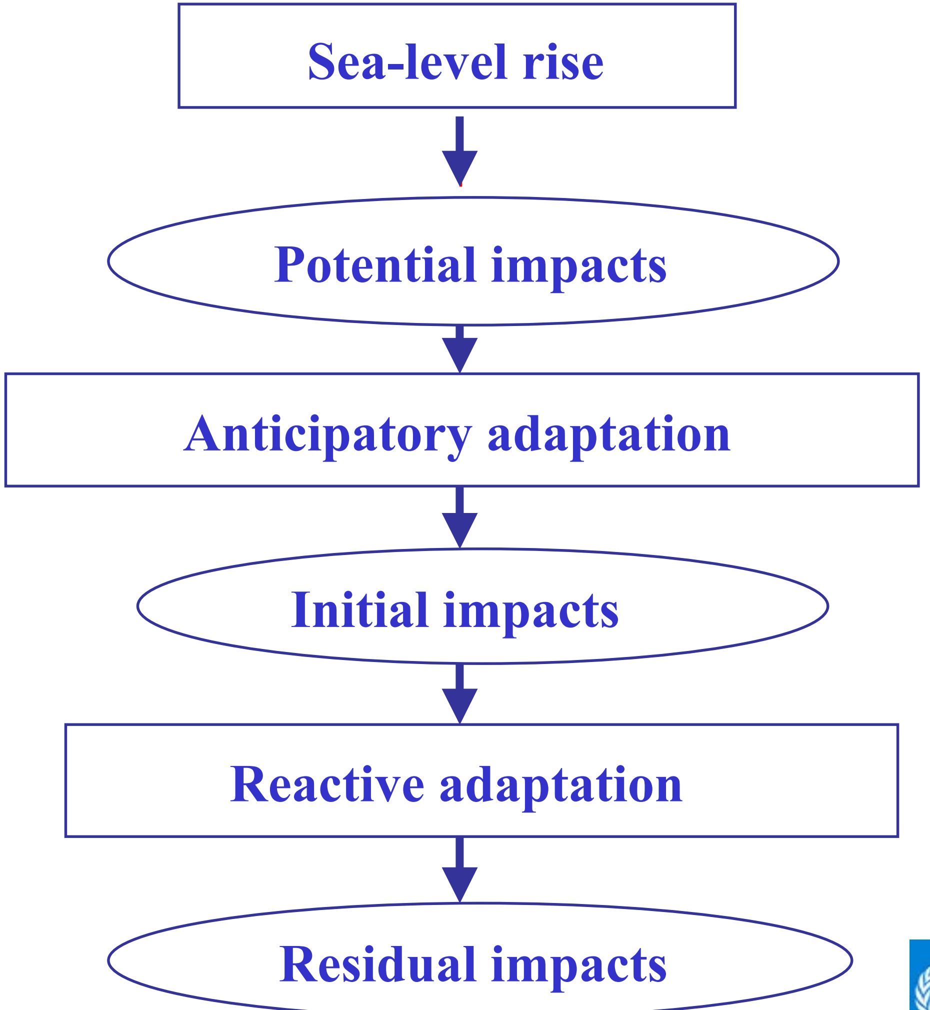
Biogeophysical Effects of Sea-Level Rise

- Displacement of coastal lowlands and wetlands
- Increased coastal erosion
- Increased storm and flood damage
- Salinisation of surface and ground waters
- Plus others

Socio-Economic Impacts

- Loss of property and land
- Increased flood risk / loss of life
- Damage to coastal protection works and other infrastructure
- Loss of renewable and subsistence resources
- Loss of tourism, recreation and coastal habitats
- Impacts on agriculture and aquaculture through decline in soil and water quality

Definition of Impacts

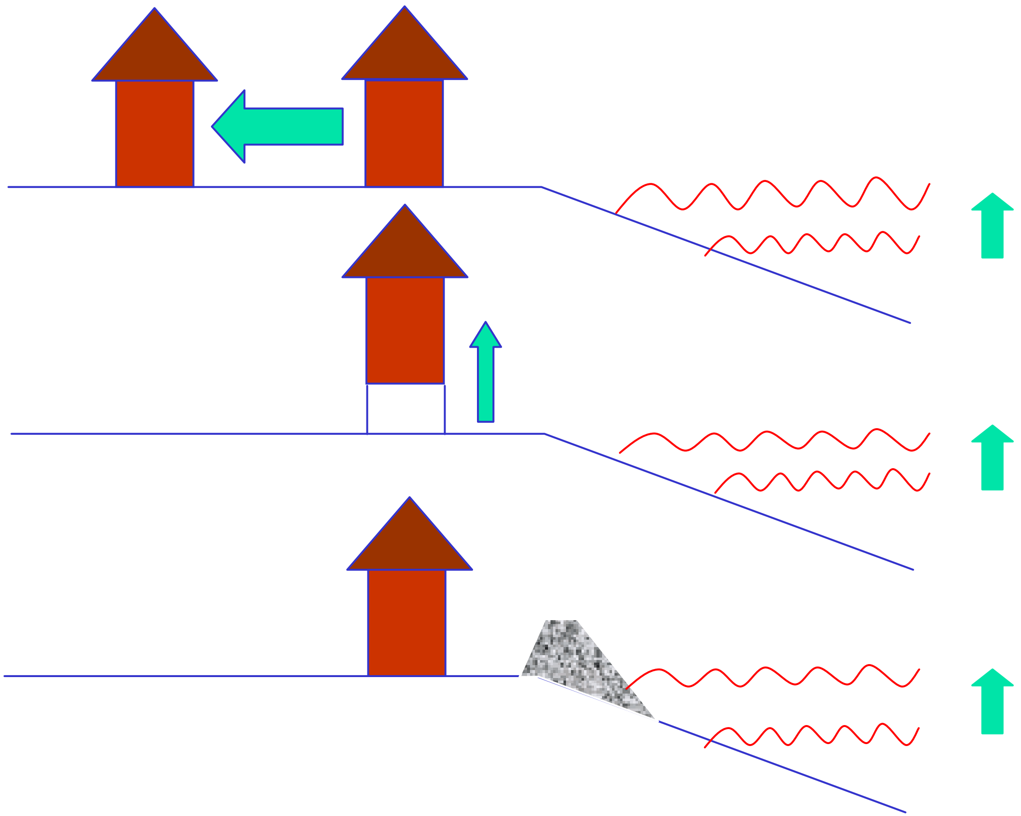


Shoreline Management and Adaptation

Proactive Adaptation	Coastal Adaptation (IPCC)	Shoreline Management (Defra)
Increasing robustness	Protect	Hold the line
Increasing flexibility	Accommodate	Advance the line
Enhancing adaptability	Retreat	Managed realignment
		No active intervention
Reversing maladaptive trends		(Project appraisal methods)
Improving awareness and preparedness		(Flood plain mapping and flood warnings)

Responding to Coastal Change
(including sea-level rise)

- Retreat
- Accommodation
- Protect
  - Soft
  - Hard



Shoreline Management and Adaptation

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Methods to Assess Impacts of Sea-Level Rise

- Develop SLR scenarios
- Levels of assessment
- Screening assessment
- Vulnerability assessment
  - Erosion
  - Flooding
  - Coastal wetland loss
- Planning assessment

Coastal Vulnerability and Risk Assessment

- Three levels of assessment
  - Screening assessment (3-6 months)
  - Vulnerability assessment (1-2 years)
  - Planning assessment (ongoing)

Screening Assessment

- Rapid assessment to highlight possible impacts of a SLR scenario and identify information/data gaps
- Qualitative or semi-quantitative
- Steps

1. Collection of existing coastal data
2. Assessment of the possible impacts of a 1-m SLR
3. Implications of future development
4. Possible responses to the problems caused by SLR

Step 1: Collection of Existing Data

- Topographic surveys
- Aerial/remote sensing images – topography/land cover
- Coastal geomorphology classification
- Evidence of subsidence
- Long-term relative SLR
- Magnitude and damage caused by flooding
- Coastal erosion
- Population density
- Activities located on the coast (cities, ports, resort areas and tourist beaches, industrial and agricultural areas)

Step 2: Assessment of Possible Impacts of 1-m SLR

- Four impacts are considered

1. Increased storm flooding
2. Beach/bluff erosion
3. Wetland and mangrove inundation and loss
4. Salt water intrusion

Step 3: Implications of Future Developments

- New and existing river dams and impacts on downstream deltas
- New coastal settlements
- Expansion of coastal tourism
- Possibility of transmigration

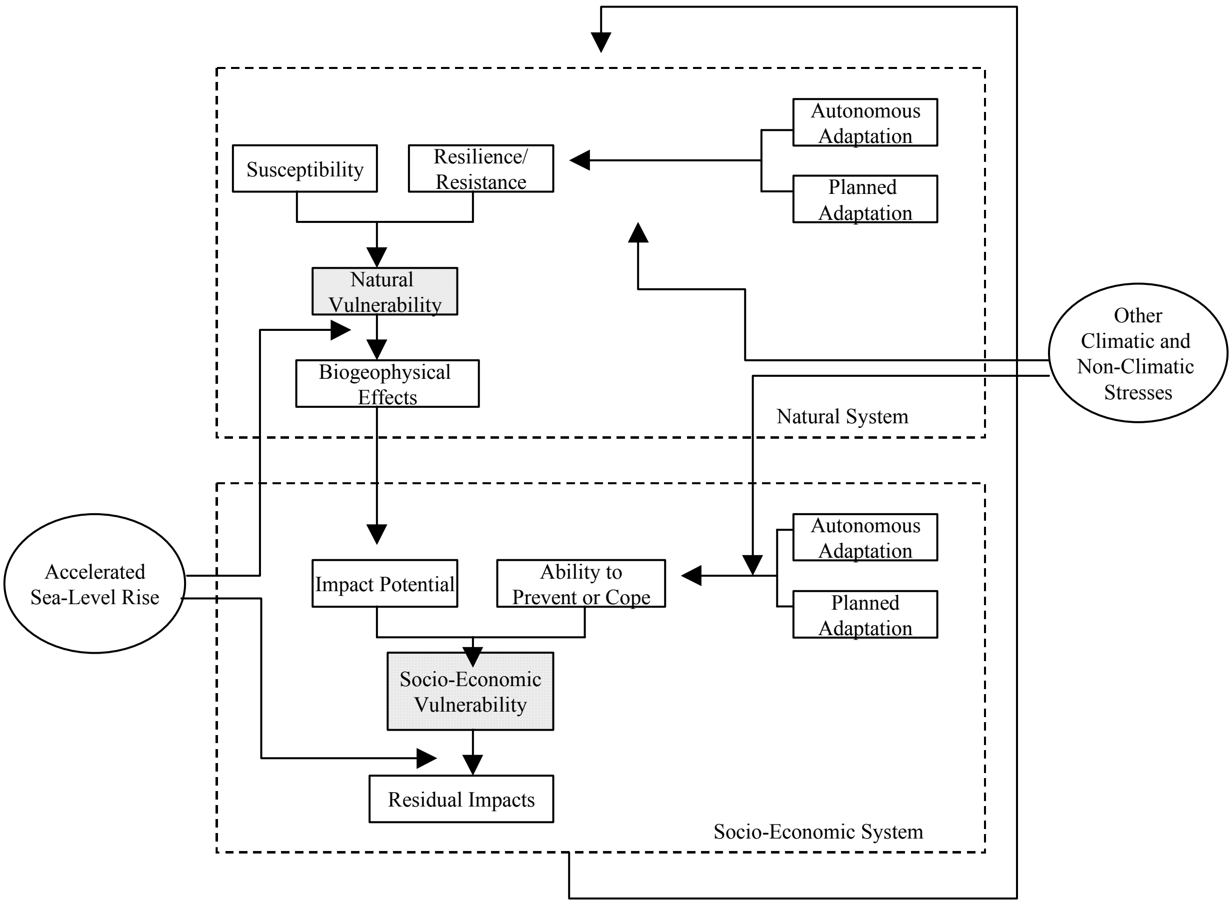
Step 4: Responses to the SLR Impacts

- Planned retreat (i.e., setback of defences)
- Accommodate (i.e., raise buildings above flood levels)
- Protect (i.e., hard and soft defences, seawalls, beach nourishment)

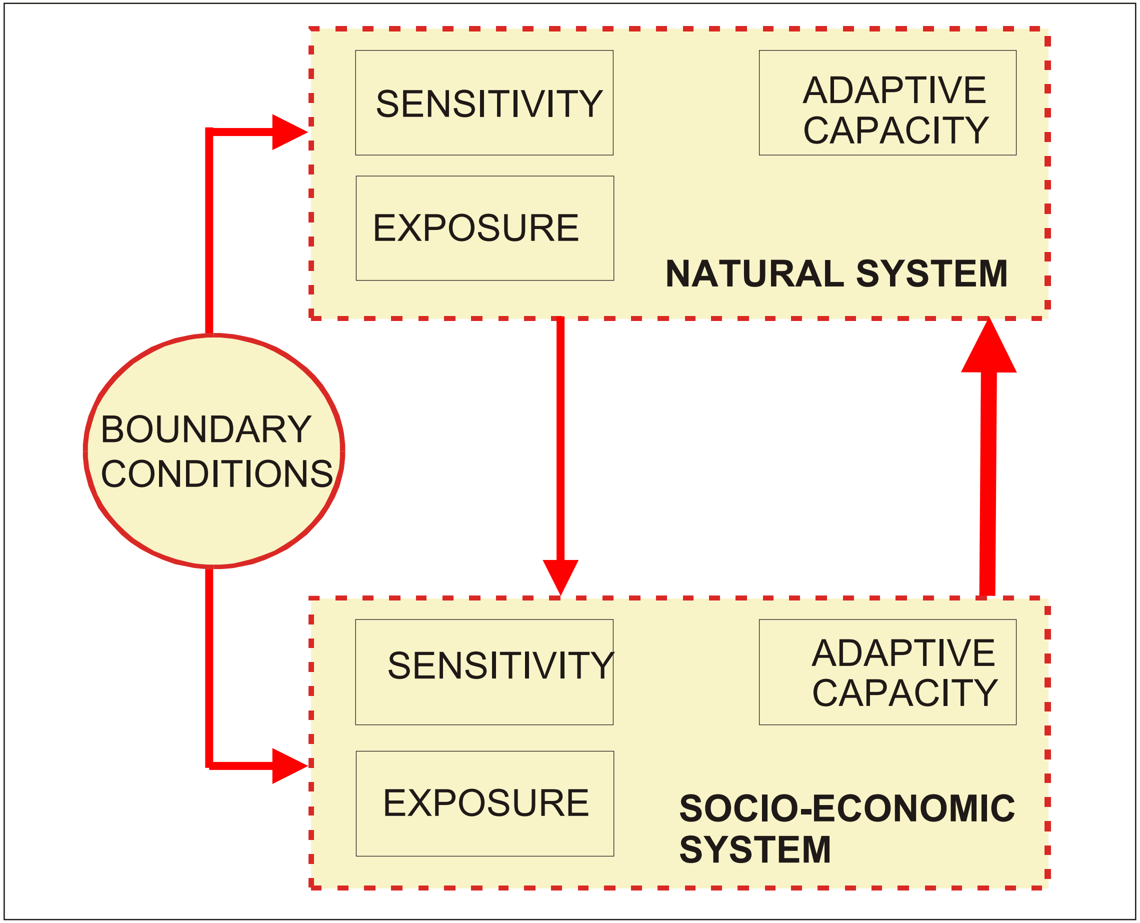
Screening Assessment Matrix
Biophysical vs. Socio-Economic Impacts

Biophysic-al Impact of Sea-Level Rise	Socio-economic impacts							
	Tourism	Human Settlements	Agriculture	Water Supply	Fisheries	Financial Services	Human Health	Others?
Inundation								
Erosion								
Flooding								
Salinisation								
Others?								

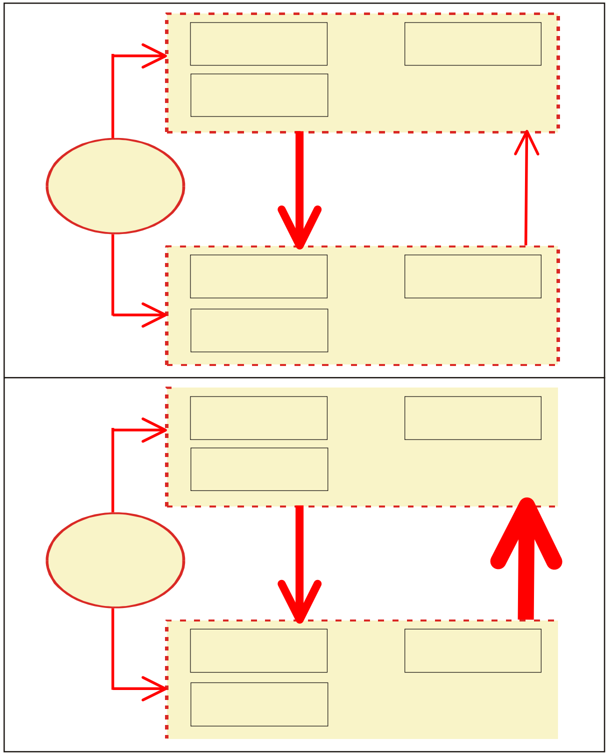
Vulnerability Assessment



The Co-Evolving Coastal System



Historic

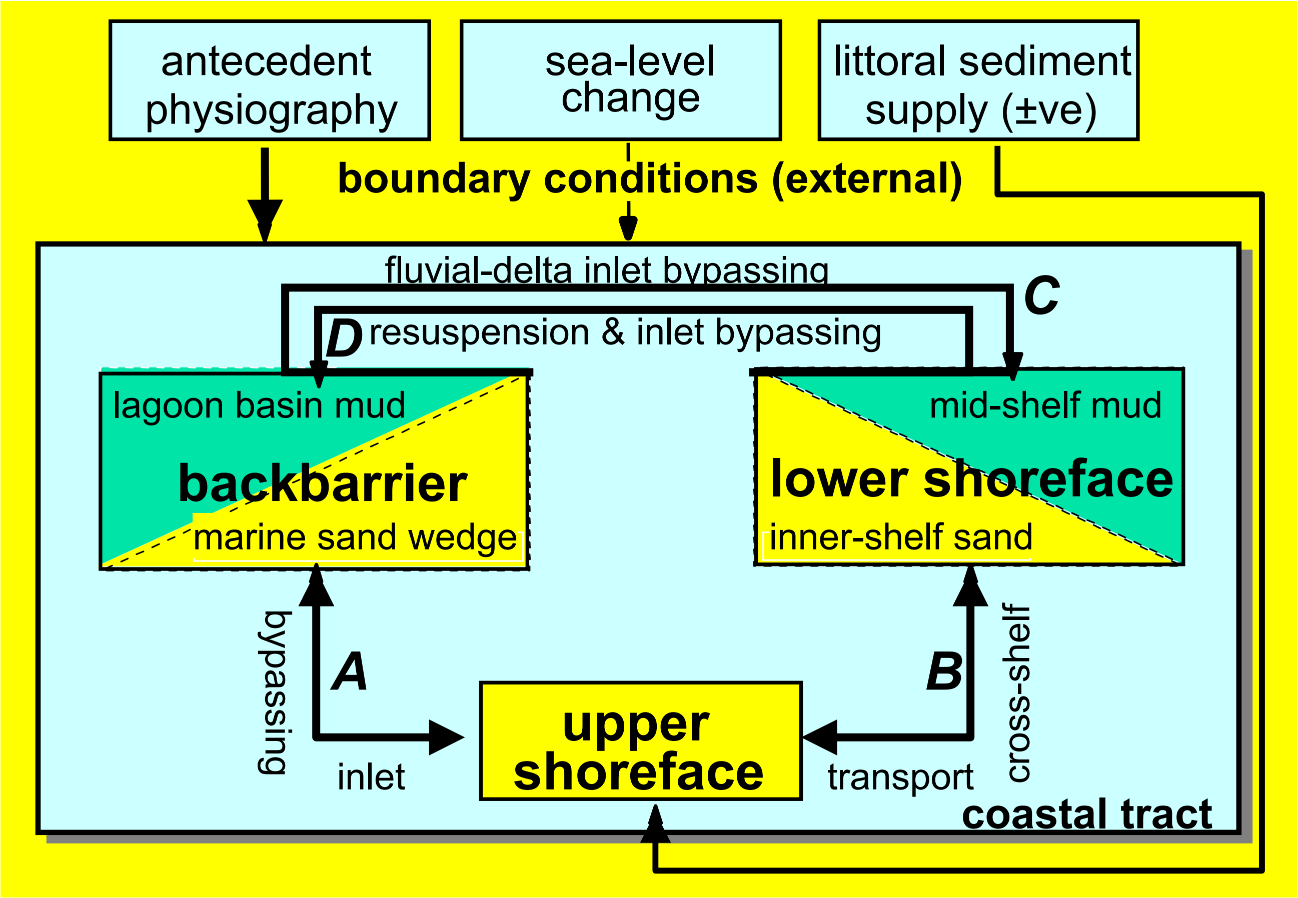


Future

Barriers to Conducting VA

- Incomplete knowledge of the relevant processes affected by SLR and their interactions
- Insufficient data on existing physical conditions
- Difficulty in developing the local and regional scenarios of future changes
- Lack of appropriate analytical methodologies
- Variety of questions raised by different socio-political conditions

Controls on Coastal Position

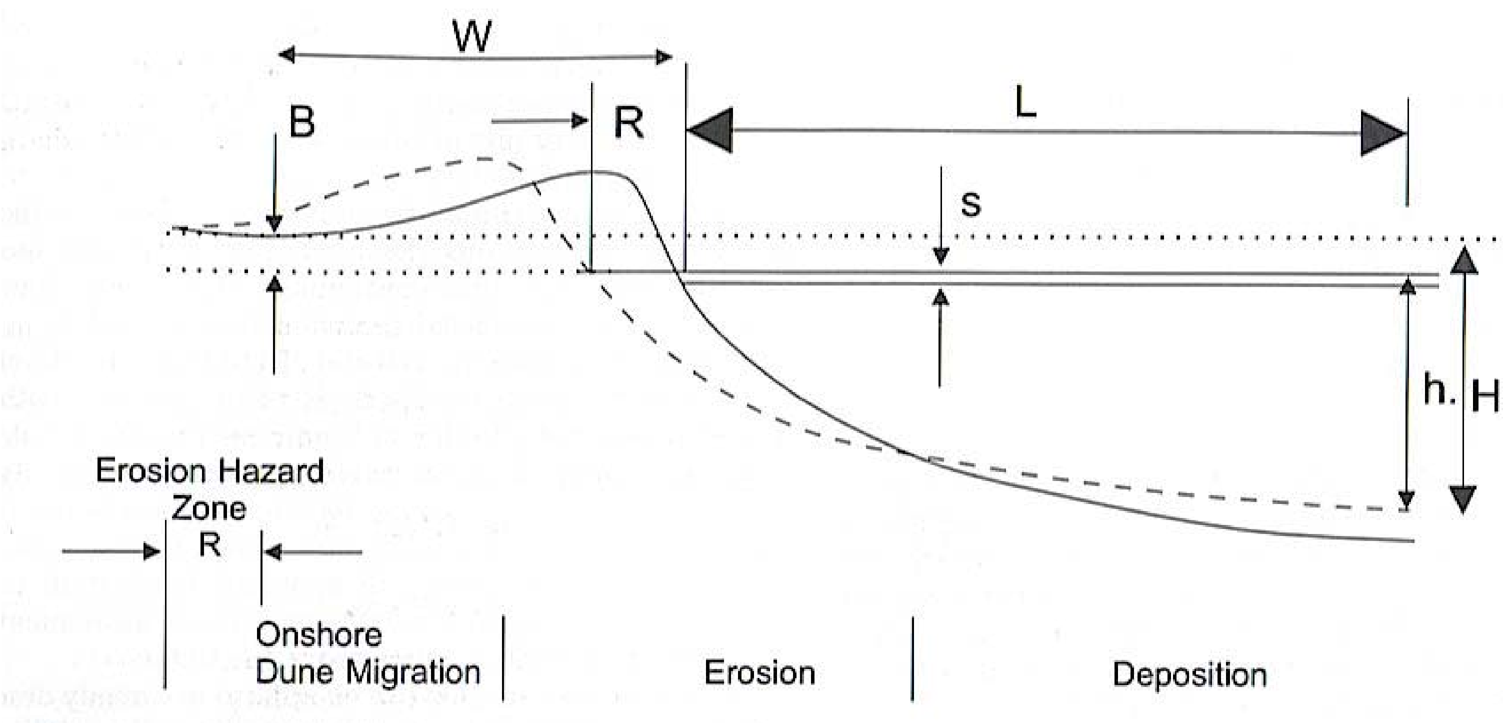


Erosion

- 70% of world's sandy beaches lost
- Integral response to changes in coastal system sediment budget
- Use of the Bruun Rule
- Limitations of the Bruun Rule

An Atoll

Bruun Rule


W
B
R
L
s
h.
H
Erosion Hazard Zone
R
Onshore Dune Migration
Erosion
Deposition

Bruun Rule (2)

$$R=G(L/H)S$$

where: $H = B + h_*$

- R = shoreline recession due to a sea-level rise S
- h_* = depth at the offshore boundary
- B = appropriate land elevation
- L = active profile width between boundaries
- G = inverse of the overfill ratio

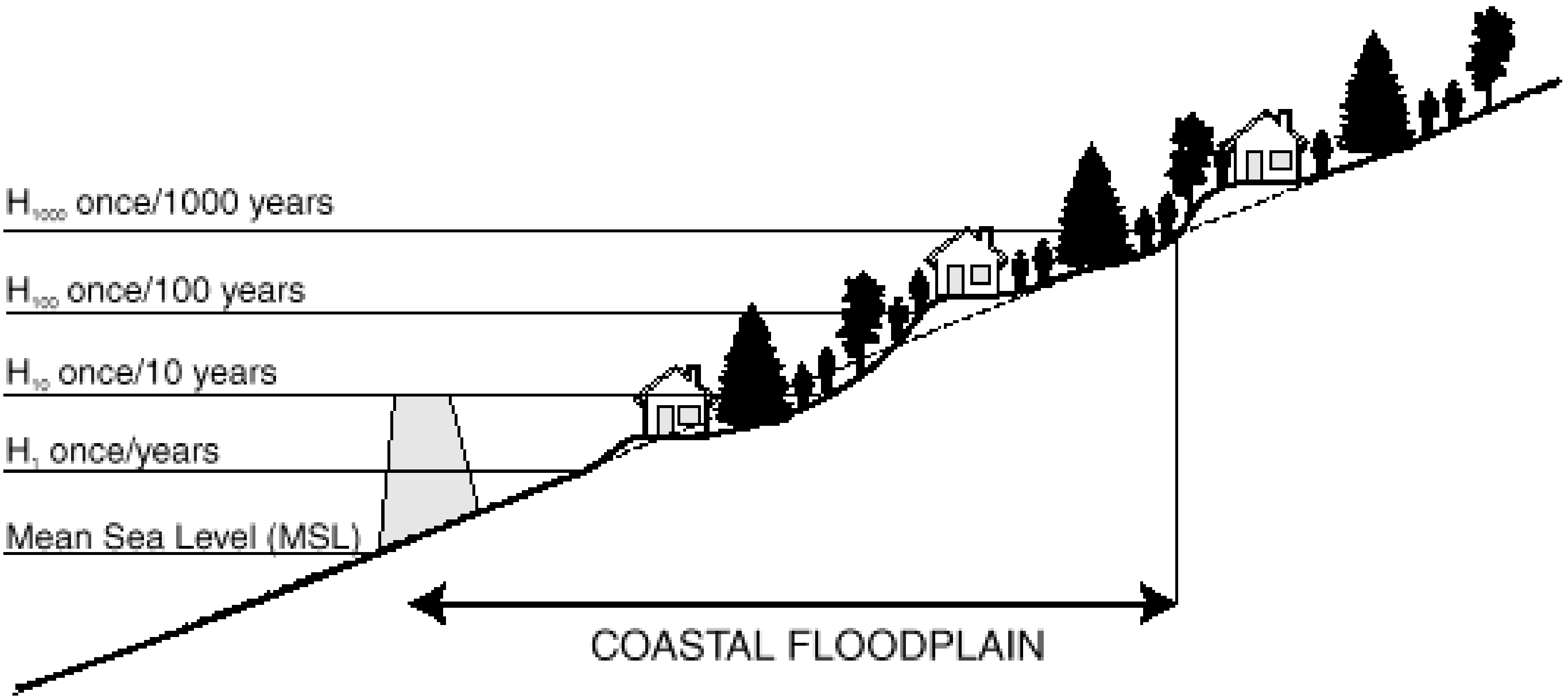
Limitations of the Bruun Rule

- Only describes one of the processes affecting sandy beaches
- Indirect effect of sea-level rise
  - Estuaries and inlets maintain equilibrium
  - Act as major sinks
  - Sand eroded from adjacent coast
  - Increased erosion rates
- Response time – best applied over long timescales

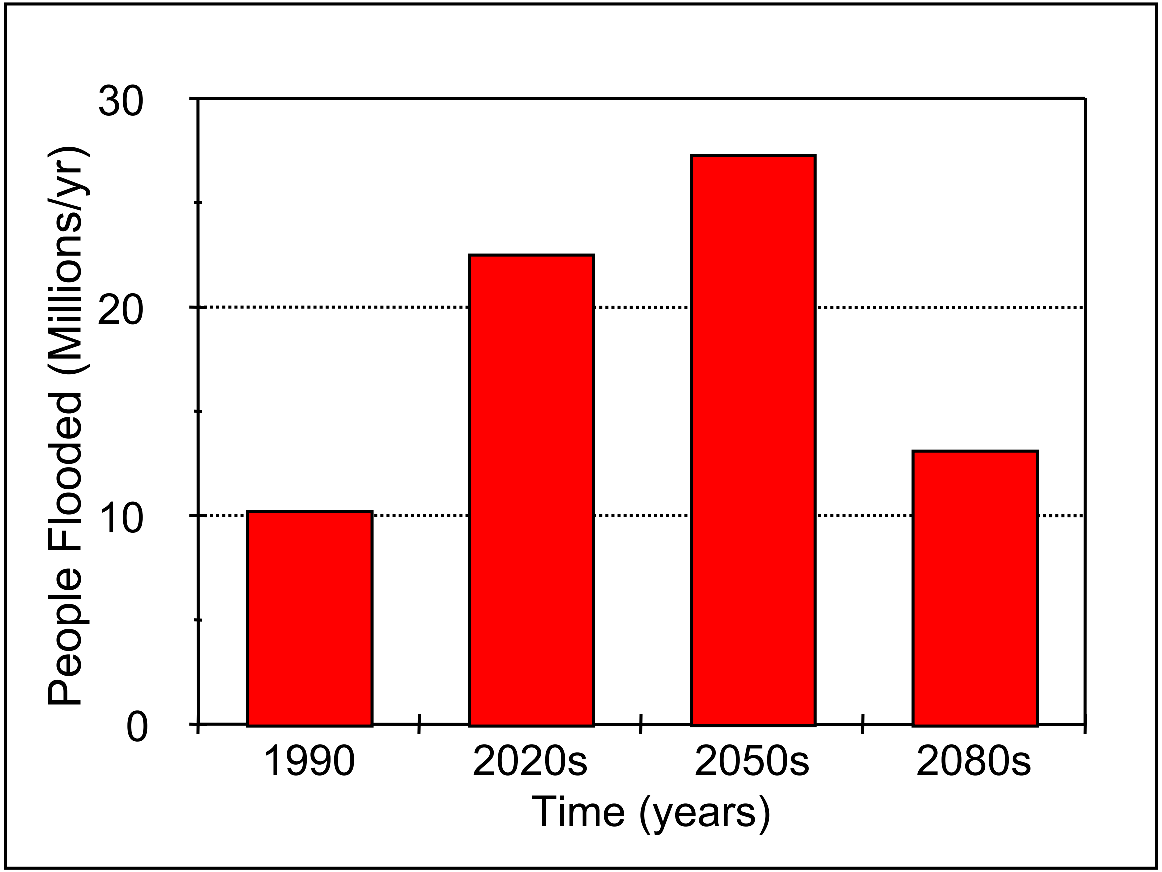
Flooding

- Increase in flood levels due to rise in sea level
- Increase in flood risk
- Increase in populations in coastal floodplain
- Adaptation
  - Increase in flood protection
  - Management and planning in floodplain

Coastal Flood Plain

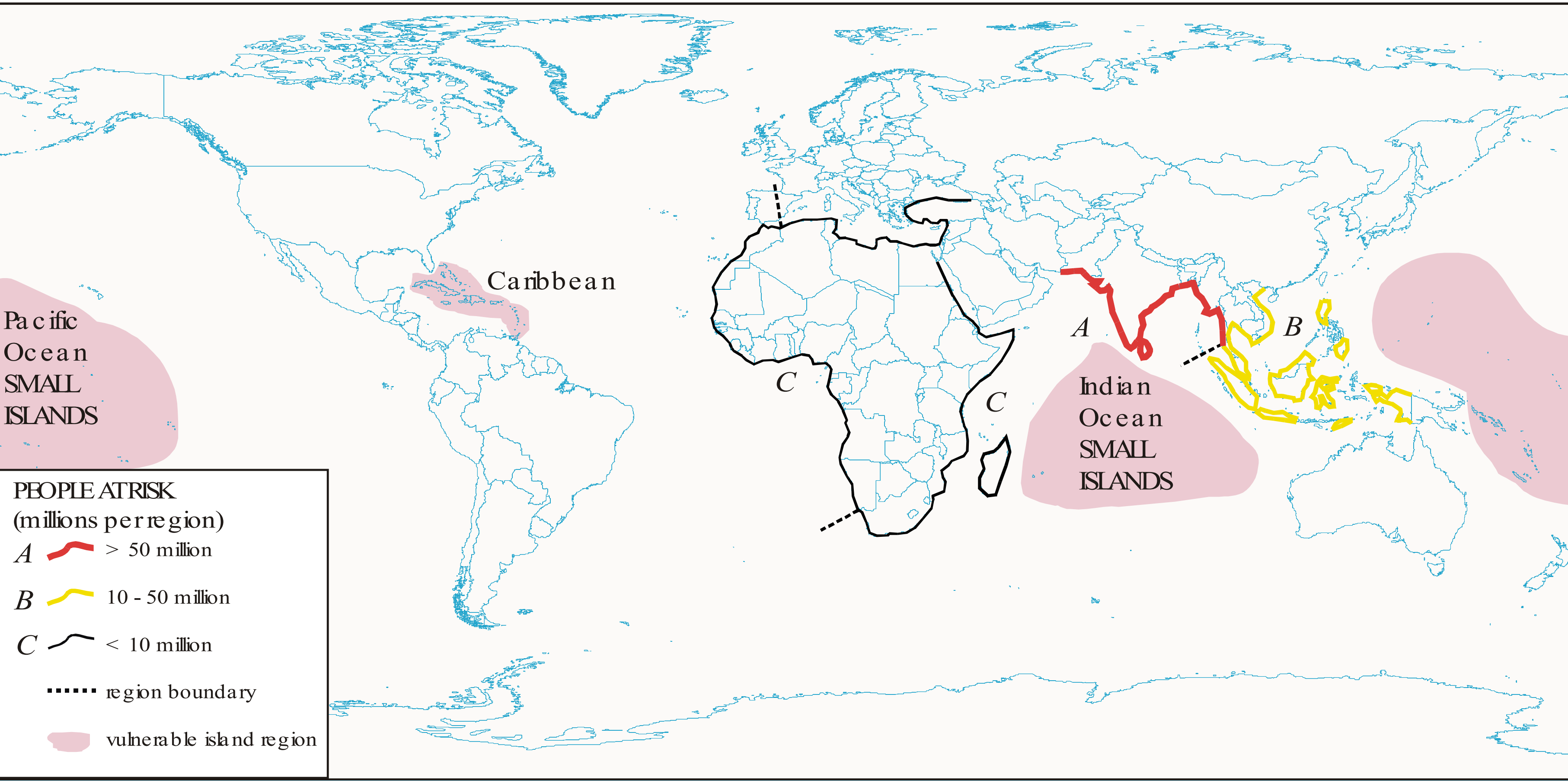


Global Incidence of Flooding
No Sea-Level Rise



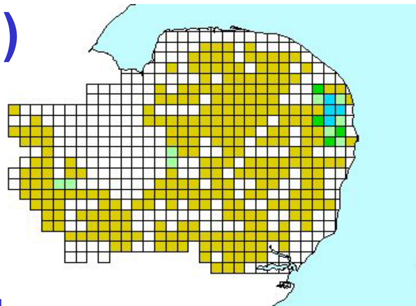
Vulnerable Regions

Mid-estimate (45 cm) by the 2080s



Impacts of Flooding on Arable Agriculture in 2050 – No Adaptation

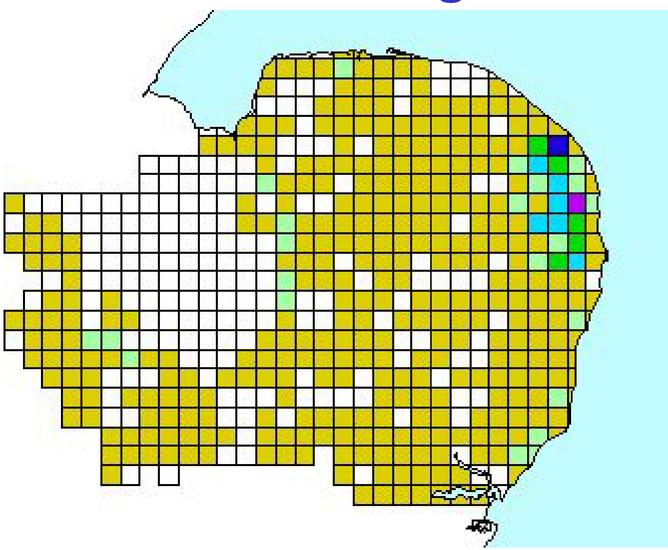
Reference (1990)



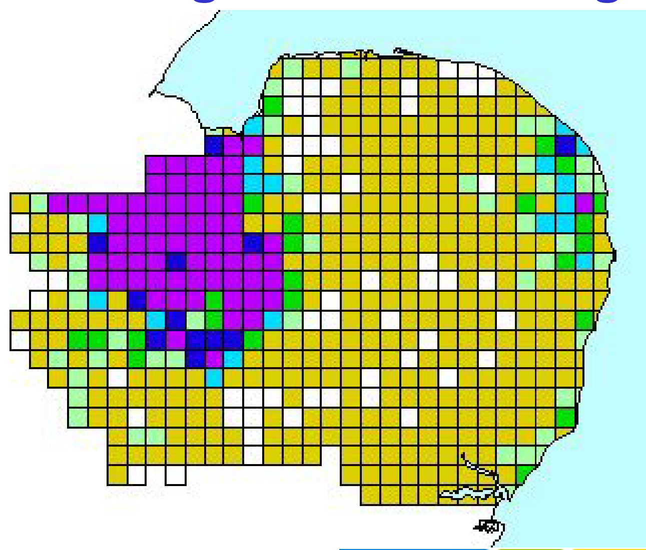
- 0
- 1 - 17
- 17 - 33
- 33 - 50
- 50 - 67
- 67 - 83
- 83 - 100

Land unavailable for arable Agriculture (% cell)

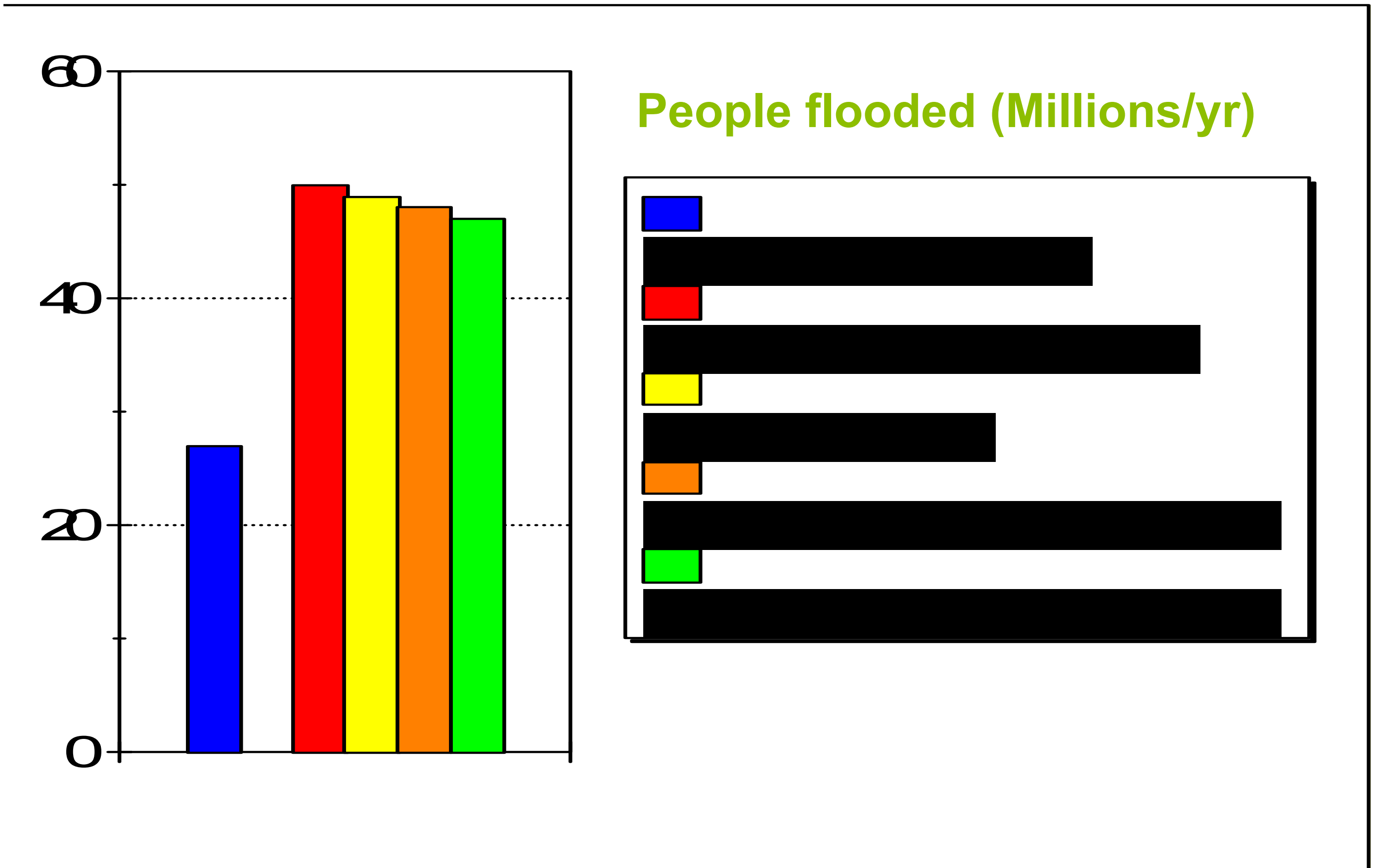
Low climate change



High climate change

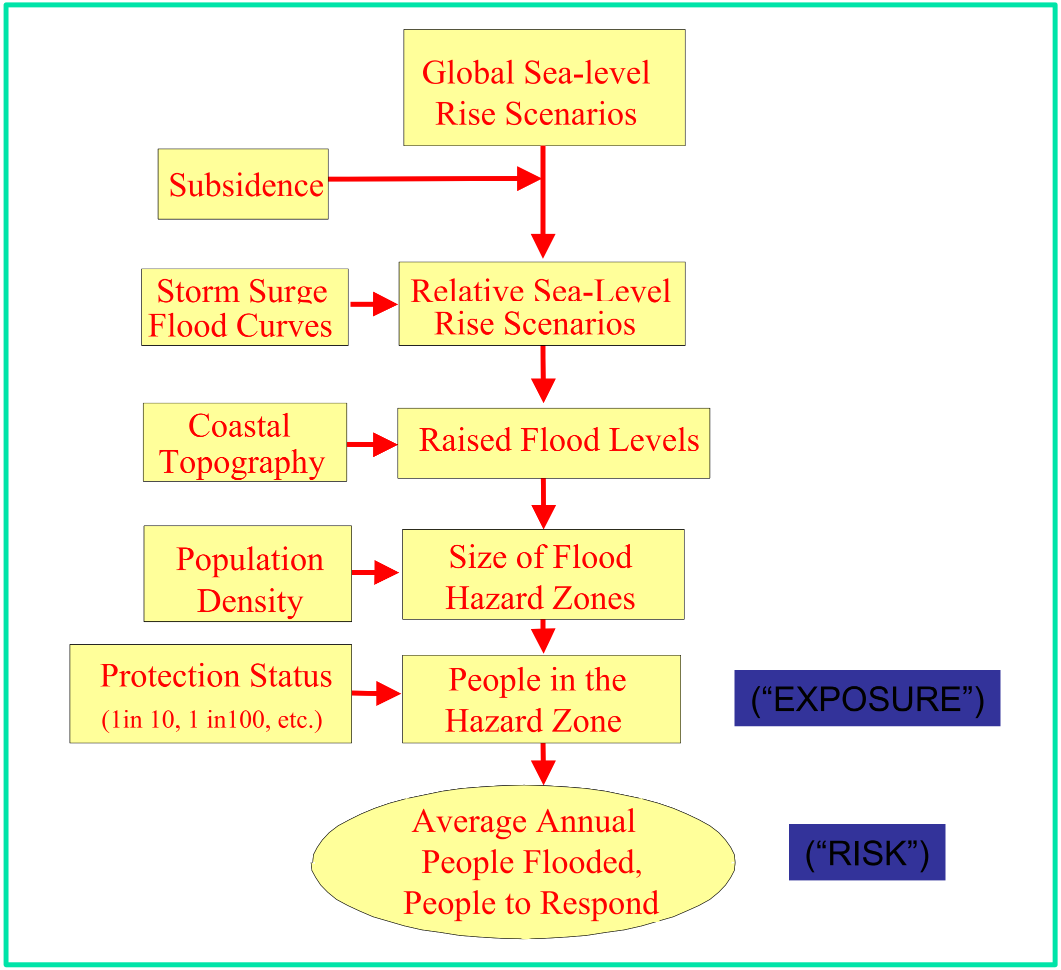


Global Impacts of Flooding in 2050
Effects of Mitigation



The Thames Barrier

Flood Methodology



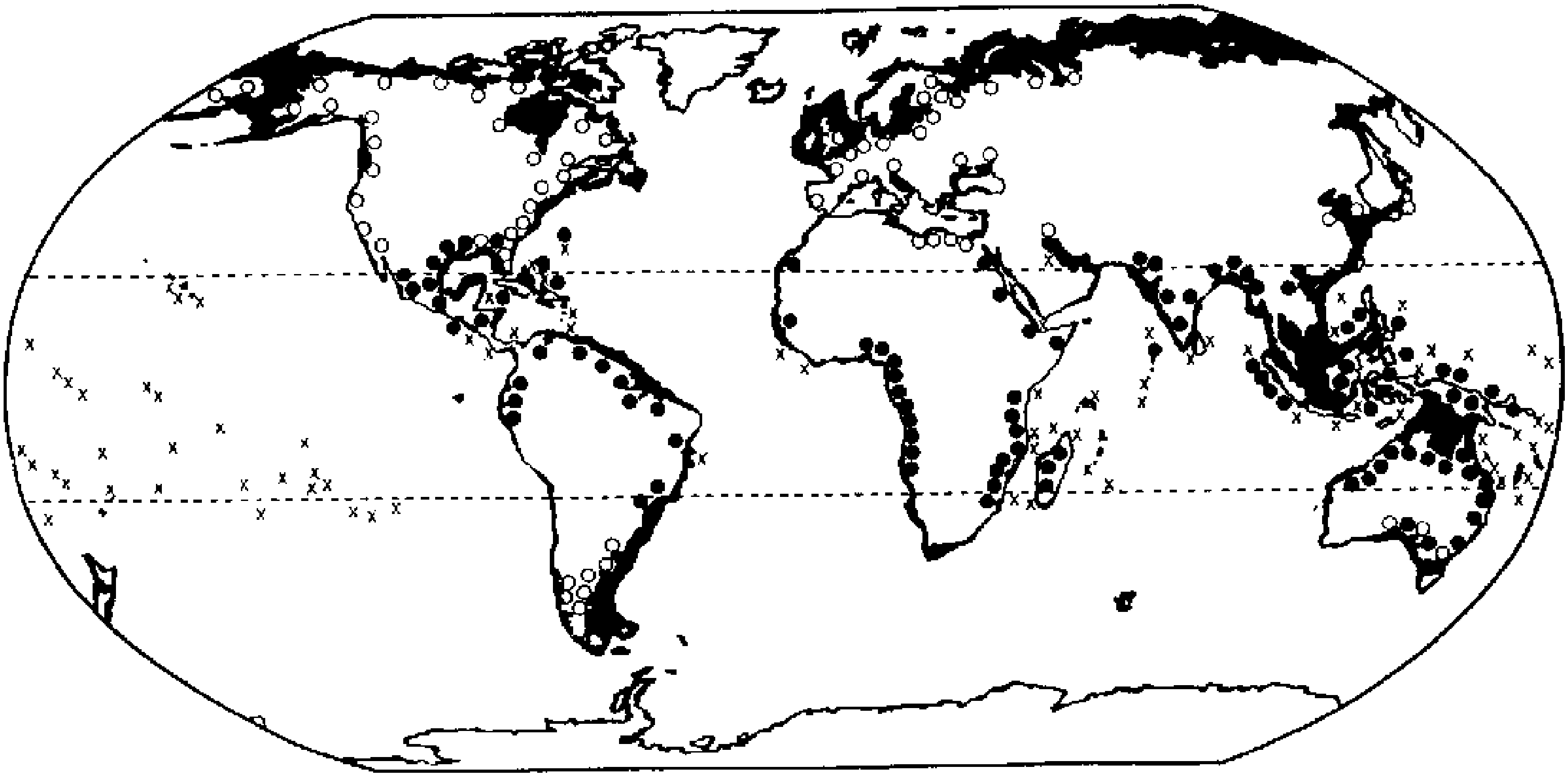
Ecosystem Loss

- Inundation and displacement of wetlands
  - E.g., mangroves, saltmarsh, intertidal areas

- Areas provide
  - Flood protection
  - Nursery areas for fisheries
  - Important for nature conservation

- Loss of valuable resources, tourism

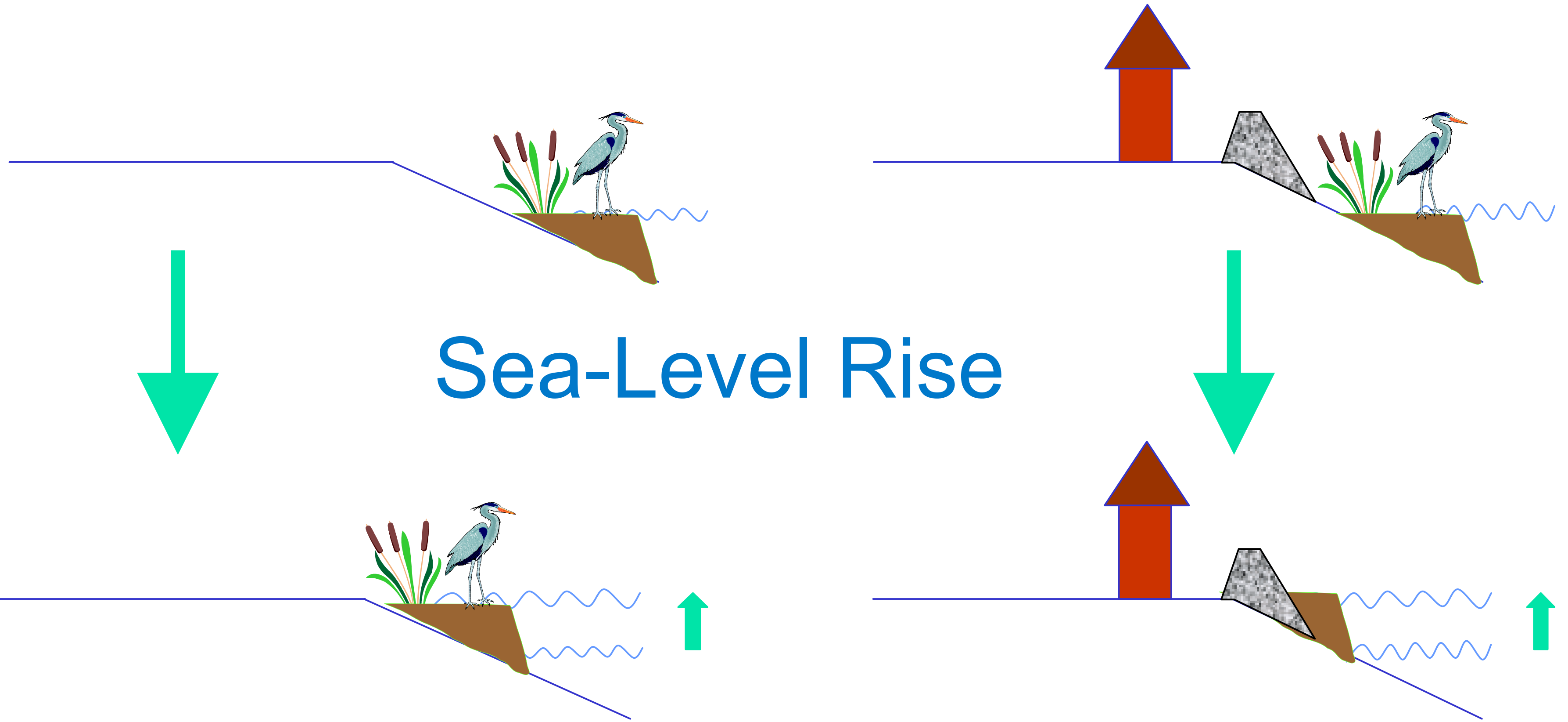
Coastal Ecosystems



KEY:

- ■ **mangroves, o saltmarsh, x coral reefs**

Coastal Squeeze
(of coastal wetlands)

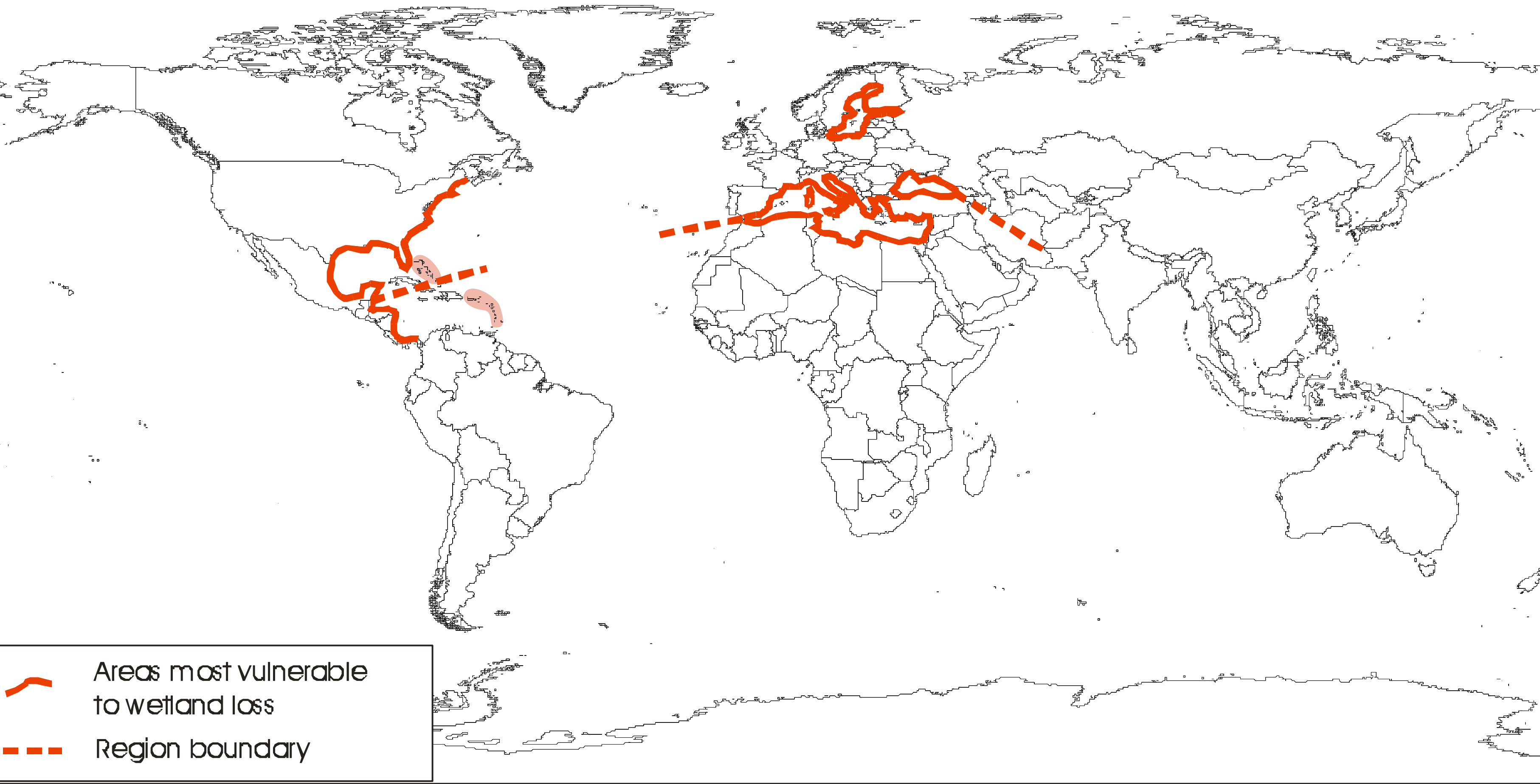


(a) no hard defences

(b) hard defences

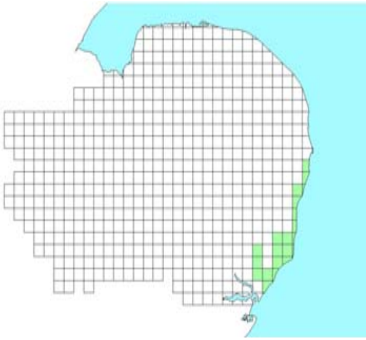
Mangrove Swamp

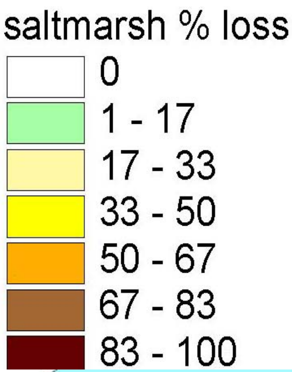
Areas Most Vulnerable to Coastal Wetland Loss



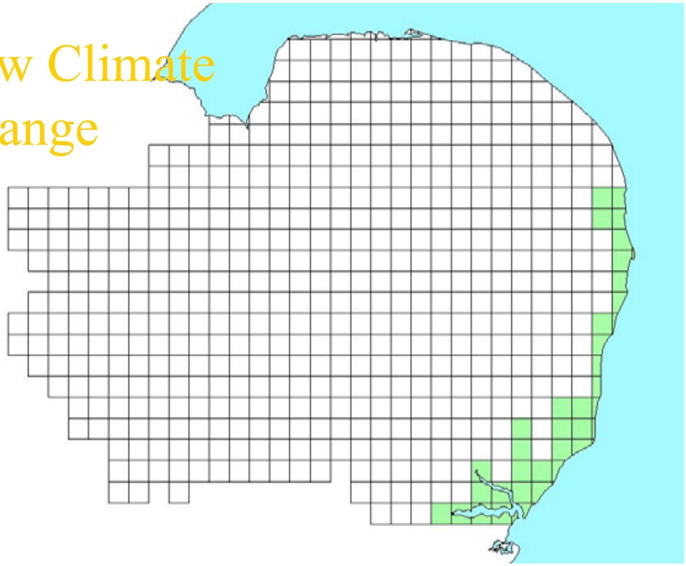
Saltmarsh Losses to 2050

Present day loss rate

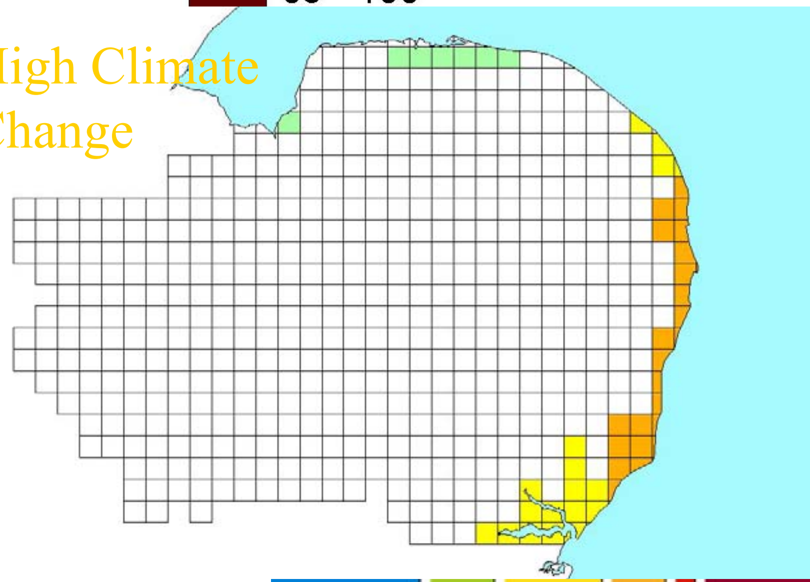




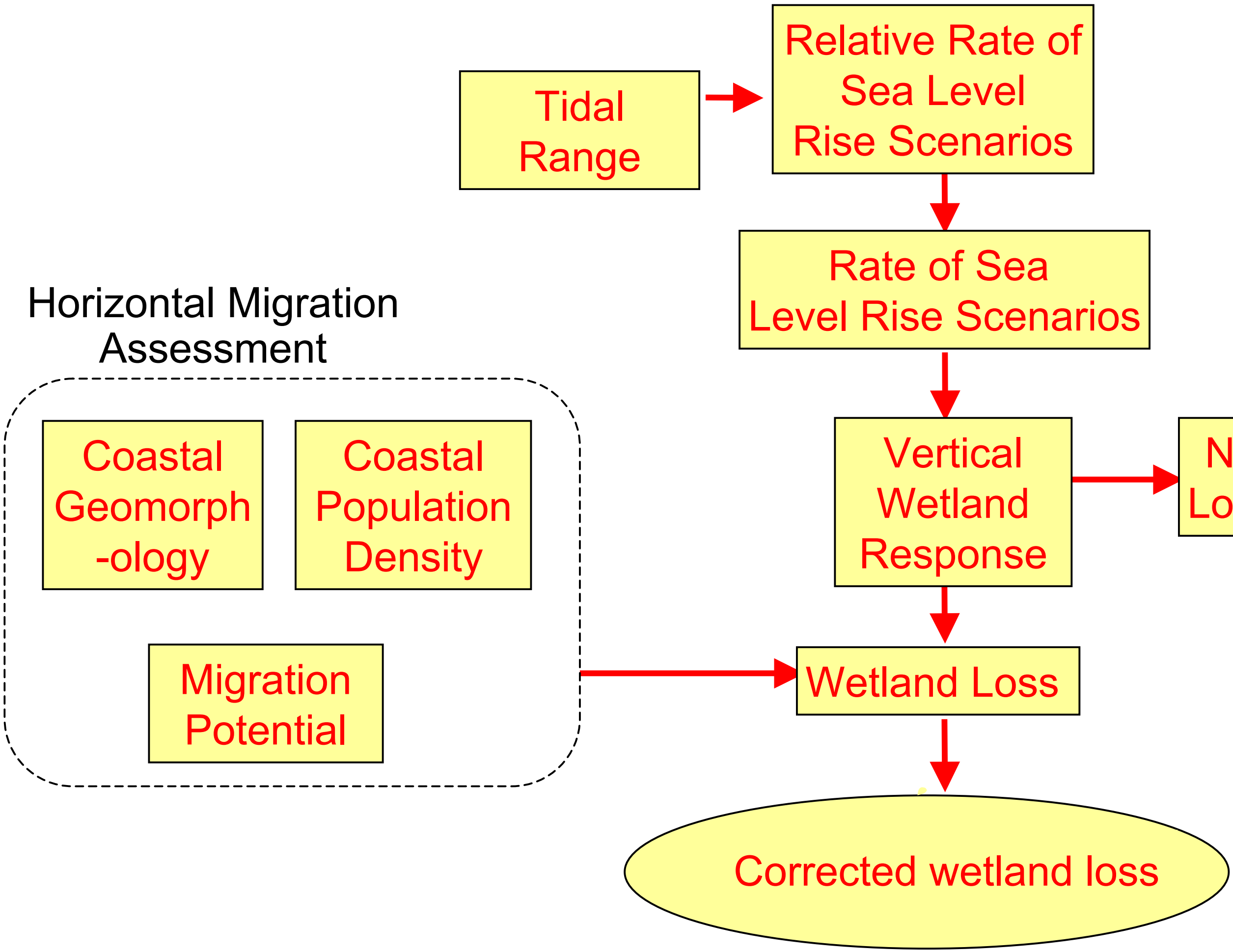
Low Climate Change



High Climate Change



Wetland Loss Model Structure



Wetland Vertical Response Model

$$RSLR^* = RSLR/TR$$

where:

- RSLR = the rate of relative sea-level rise (meters/century)
- TR = the mean tidal range on spring tides in meters

- $RSLR^* > RSLR^*_{crit}$ loss
- $RSLR^* \leq RSLR^*_{crit}$ no loss

Planning Assessment

- Ongoing investigation and formulation of policy
- Requires information on
  - Role of major processes in sediment budget
    - Including human influences
    - Other climate change impacts
- Example of assessment from the UK
- Combined flood hazard and erosion assessment

The Problem

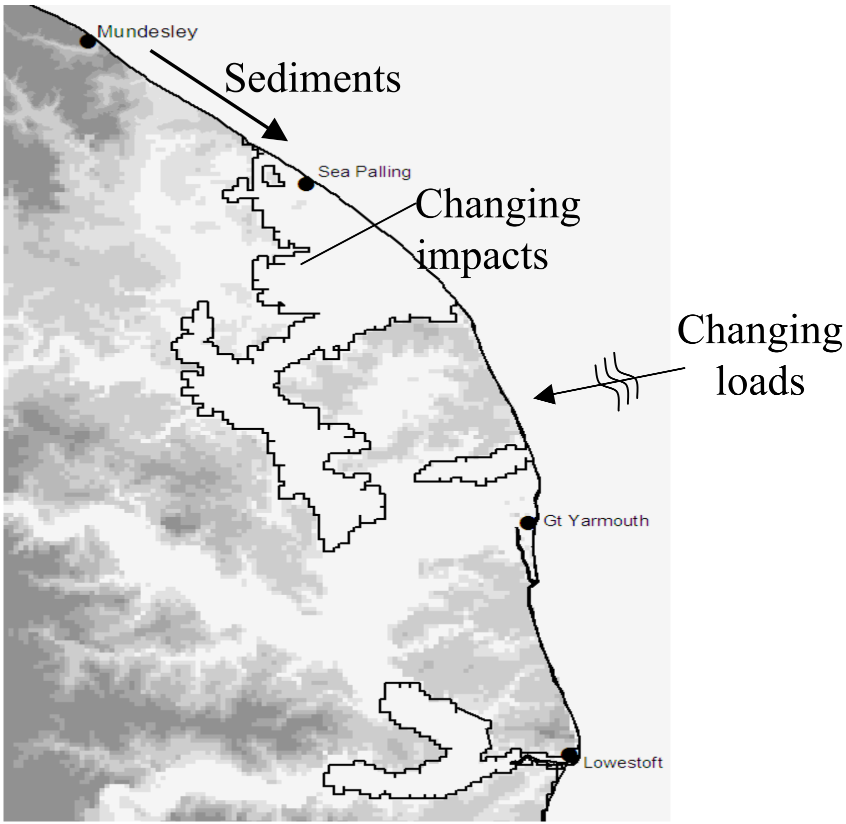
Cliff Protection Has Local and Wider Effects

Erosion

Often Exported Alongshore

Coastal Flood Risk

Exacerbated by Declining Sediment Input

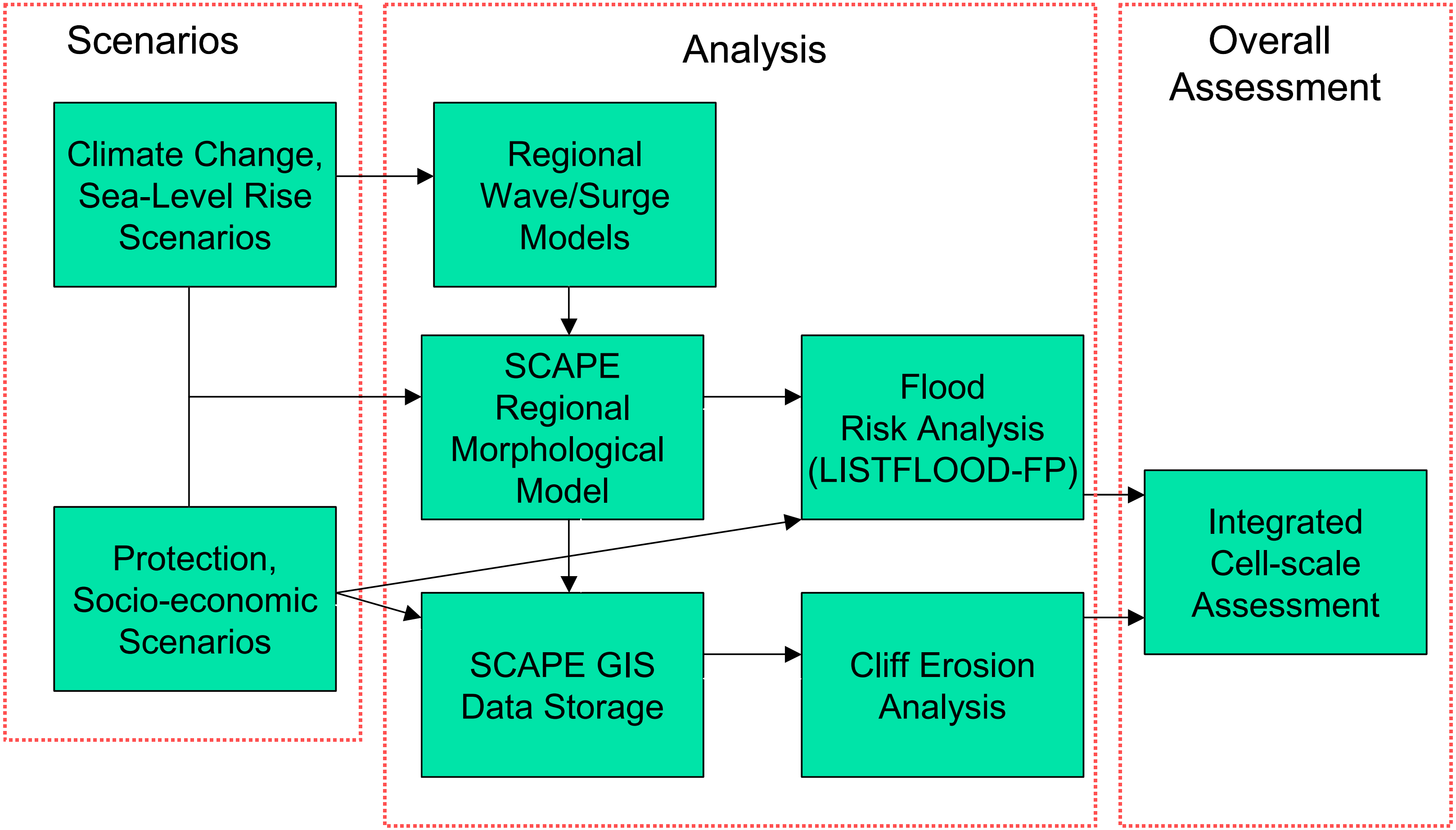


- Beach evolution
- Defence degradation/upgrades
- Socio-economic changes
- Sea-level rise
- Increased storminess

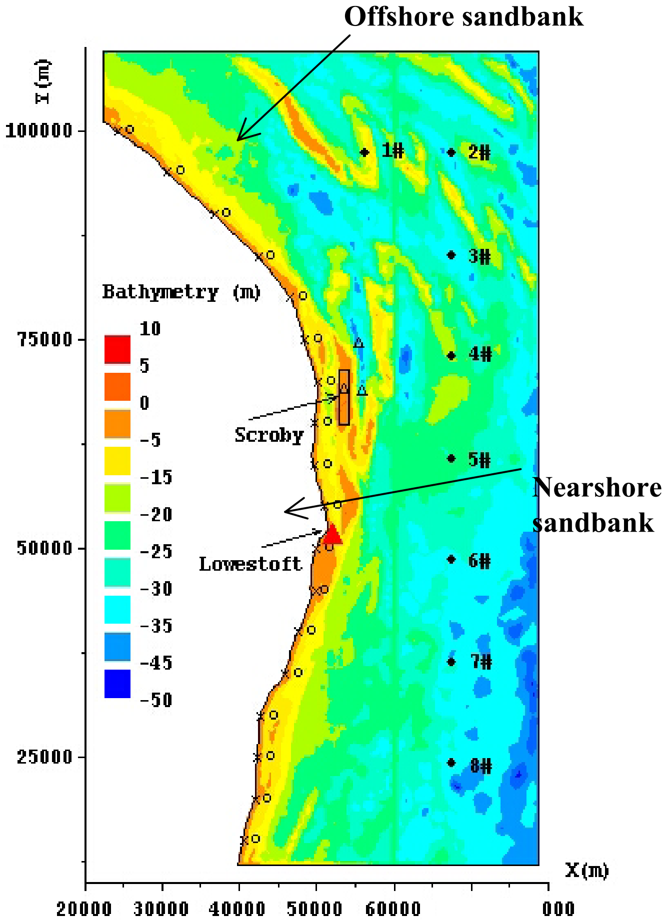
Goals for Planning Assessment

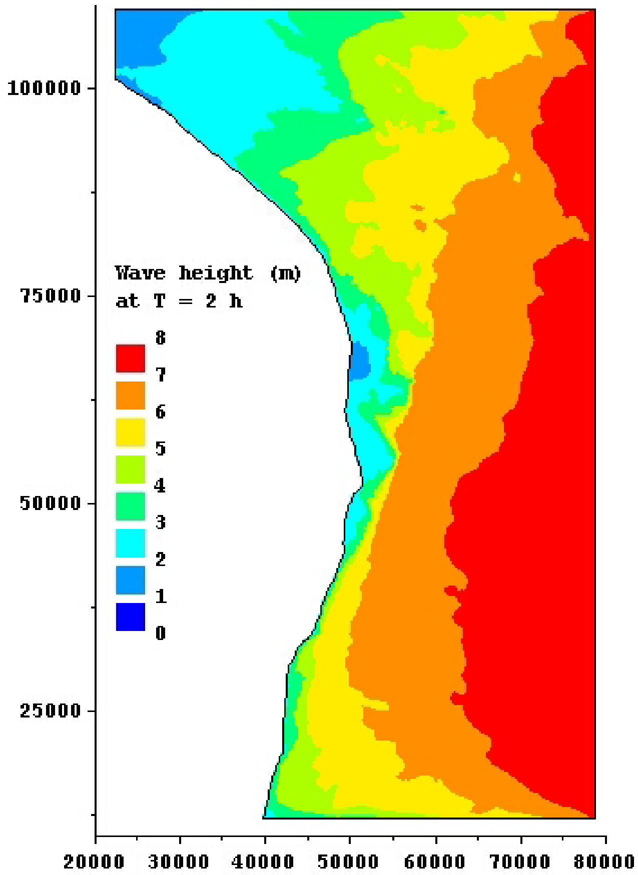
- For future climate and protection scenarios, explore interactions between cliff management and flood risk within sediment sub-cell (in Northeast Norfolk)
- In particular, quantify
  - Cliff retreat and associated impacts
  - Longshore sediment supply/beach size
  - Flood risk
  - Integrated flood and erosion assessment

Overall Method

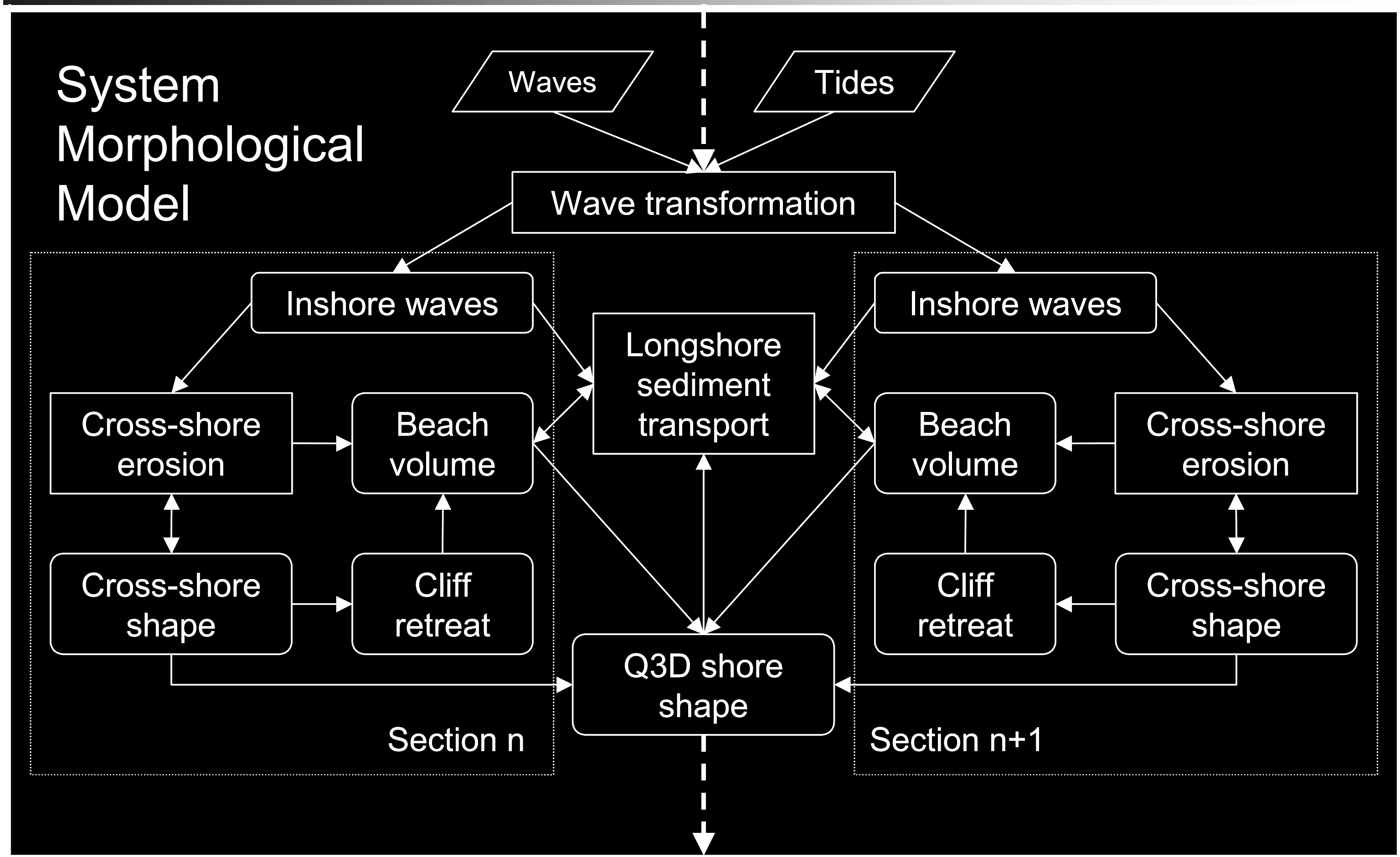


Bathymetry and Wave Modelling



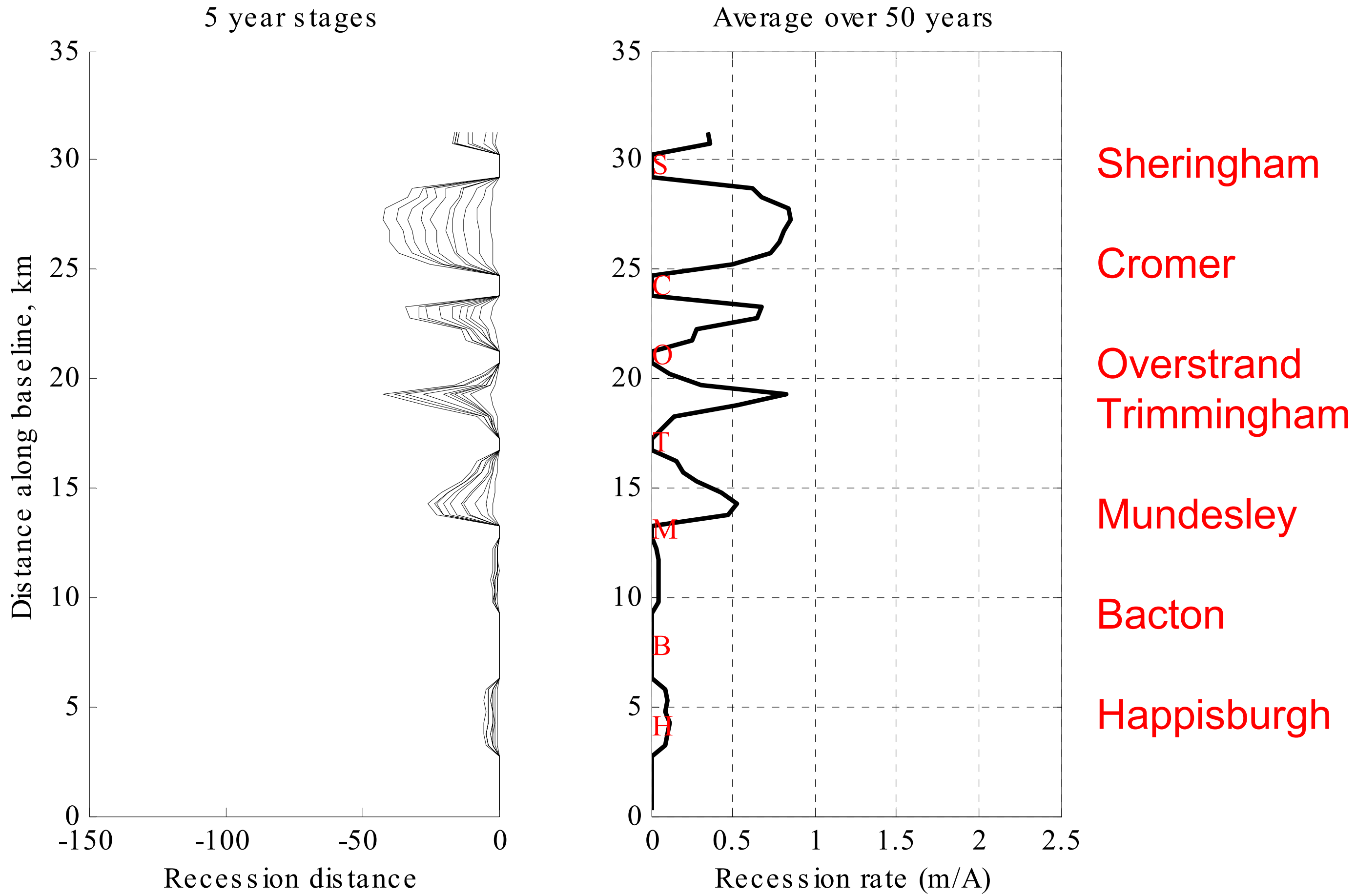


SCAPE Model of Cliff Retreat



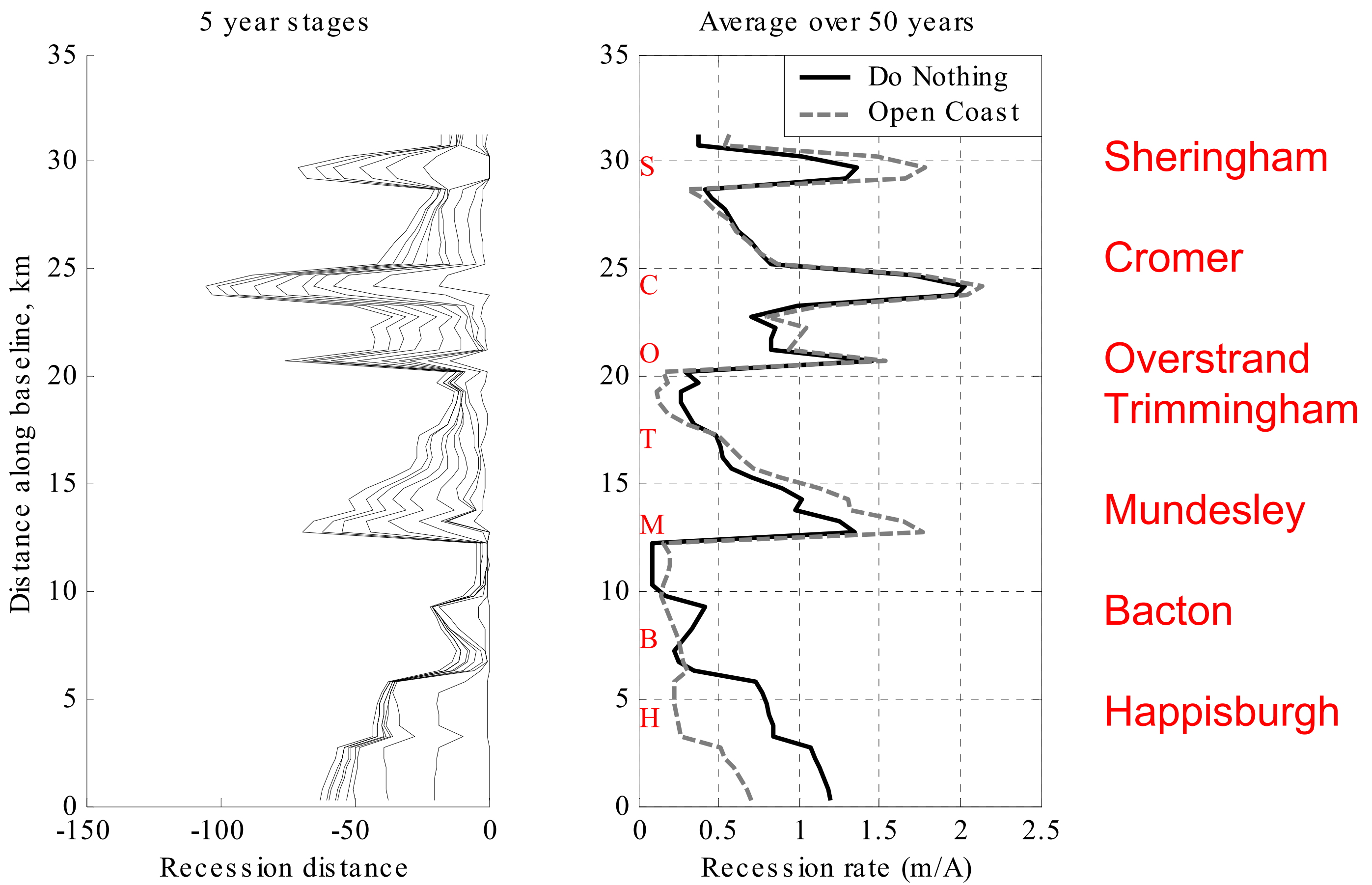
Future Policy

Maintain Defences, 6 mm/yr Sea-Level Rise



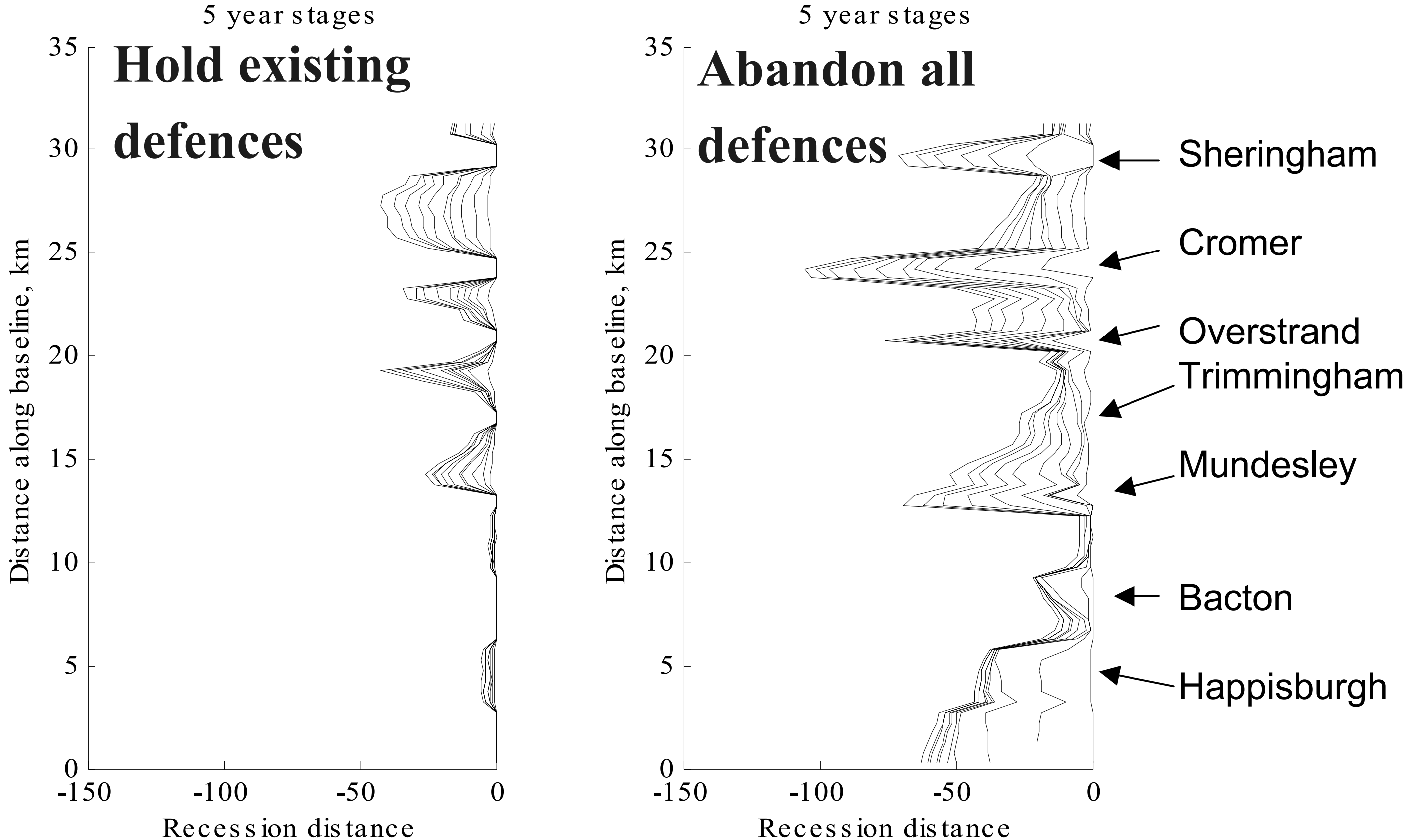
Future Policy

Abandon All Defences, 6 mm/yr Sea-Level Rise



Policy Comparison

Maximum Retreat at Abandoned Defences



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Erosion Visualisation

Protection Abandoned (10 year time steps)

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Conclusions

- 45 sea-level/wave/protection scenario combinations assessed
- Used to assess implications for flood risk
- Data management, visualisation, and stakeholder involvement used
- Further improvements to the overall method are being developed

Review of African Region

- Coast relatively undeveloped
- Coastal hazards a concern
- Rapidly growing coastal population
- Data availability issues
- Lack of long-term sea level data

Impacts and Costs for 1m Sea-Level Rise (1990)

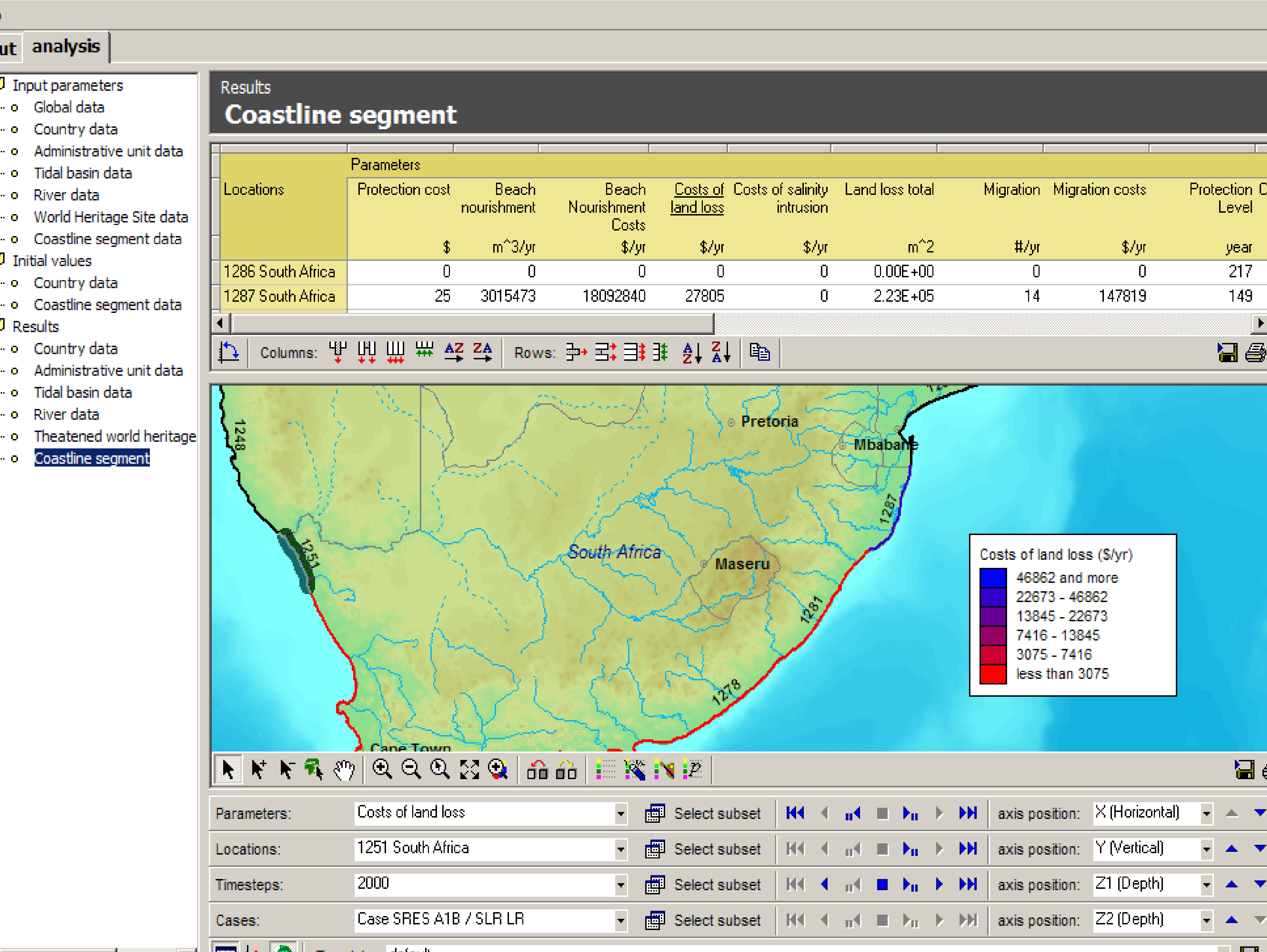
Country	Land Loss		Population affected		Capital value loss		Adaptation/ protection costs	
	Km^2	%	1000s	%	Million US$	%GNP	Million US$	%GNP
Senegal	6000	3.1	>110	>1	>500	>12	>1000	>21
Nigeria	18000	2	3200	4	17000	52	>1400	>4
Benin	230	0.2	1350	25	118	12	>400	>41

The Nile Delta

Models

- DIVA: Dynamic and Interaction Vulnerability Assessment
  - Project: DINAS-Coast

- RegIS2 : Development of a metamodel tool for regional integrated climate change management
- COSMO
- RamCo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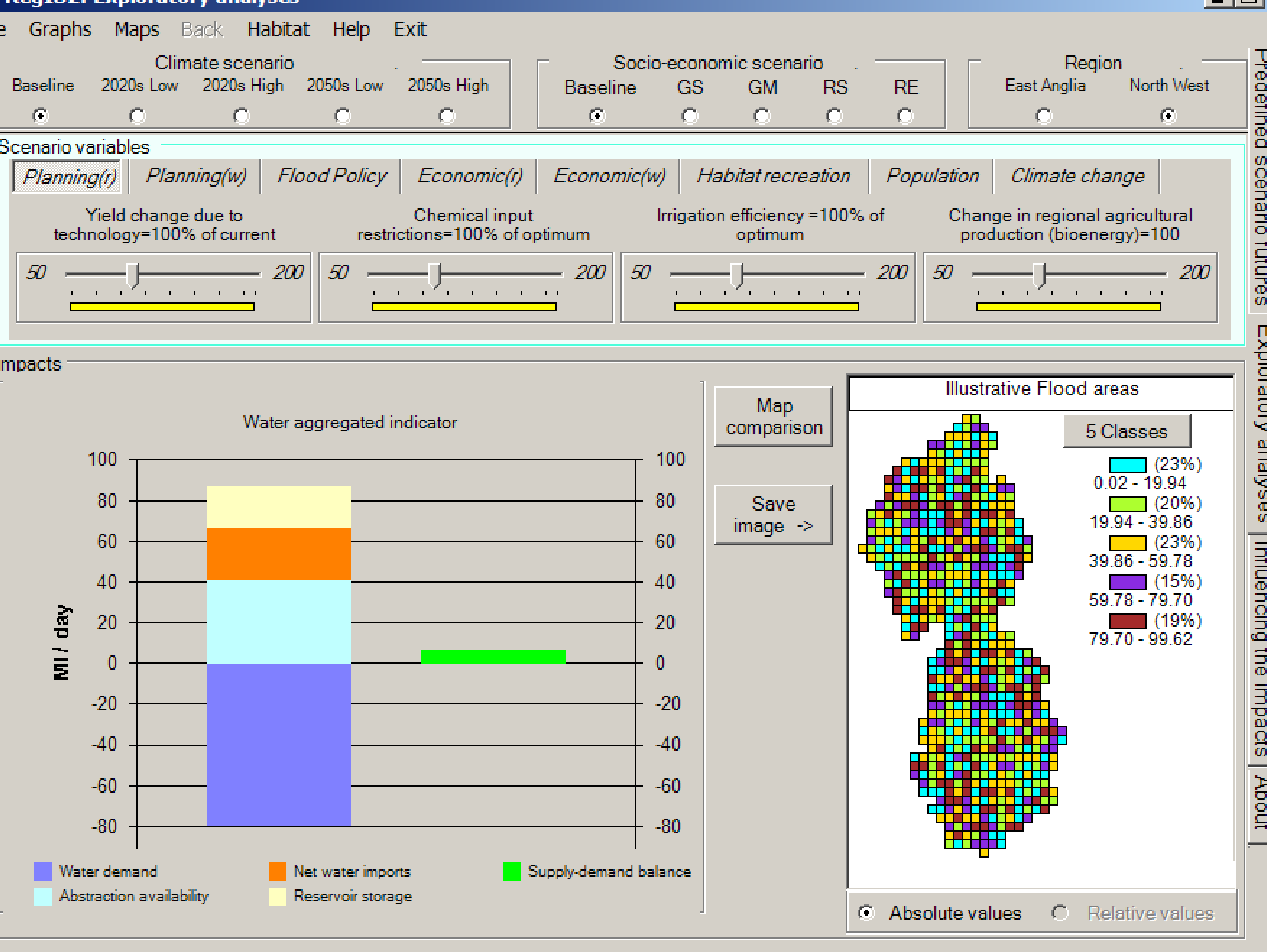
analysis
Input parameters
Global data
Country data
Administrative unit data
Tidal basin data
River data
World Heritage Site data
Coastline segment data
Initial values
Country data
Coastline segment data
Results
Country data
Administrative unit data
Tidal basin data
River data
Theatened world heritage
Coastline segment
Results
Coastline segment
Parameters
Locations
Protection cost $
Beach nourishment m^3/yr
Beach Nourishment Costs $/yr
Costs of land loss $/yr
Costs of salinity intrusion $/yr
Land loss total m^2
Migration #/yr
Migration costs $/yr
Protection Level year
1286 South Africa 0 0 0 0 0 0.00E+00 0 0 217
1287 South Africa 25 3015473 18092840 27805 0 2.23E+05 14 147819 149
Columns:
Rows:
Pretoria
Mbabane
South Africa
Maseru
Cape Town
1248
1251
1287
1281
1278
Costs of land loss ($/yr)
46862 and more
22673 - 46862
13845 - 22673
7416 - 13845
3075 - 7416
less than 3075
Parameters:
Costs of land loss
Select subset
axis position:
X (Horizontal)
Locations:
1251 South Africa
Select subset
axis position:
Y (Vertical)
Timesteps:
2000
Select subset
axis position:
Z1 (Depth)
Cases:
Case SRES A1B / SLR LR
Select subset
axis position:
Z2 (Depth)


Graphs
Maps
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Climate scenario
Baseline
2020s Low
2020s High
2050s Low
2050s High
Socio-economic scenario
Baseline
GS
GM
RS
RE
Region
East Anglia
North West
Scenario variables
Planning(r)
Planning(w)
Flood Policy
Economic(r)
Economic(w)
Habitat recreation
Population
Climate change
Yield change due to technology=100% of current
Chemical input restrictions=100% of optimum
Irrigation efficiency =100% of optimum
Change in regional agricultural production (bioenergy)=100
50
200
mpacts
Water aggregated indicator
Ml / day
100
80
60
40
20
0
-20
-40
-60
-80
Water demand
Abstraction availability
Net water imports
Reservoir storage
Supply-demand balance
Map comparison
Save image ->
Illustrative Flood areas
5 Classes
(23%) 0.02 - 19.94
(20%) 19.94 - 39.86
(23%) 39.86 - 59.78
(15%) 59.78 - 79.70
(19%) 79.70 - 99.62
Absolute values
Relative values
Predefined scenario futures
Exploratory analyses
Influencing the impacts
About

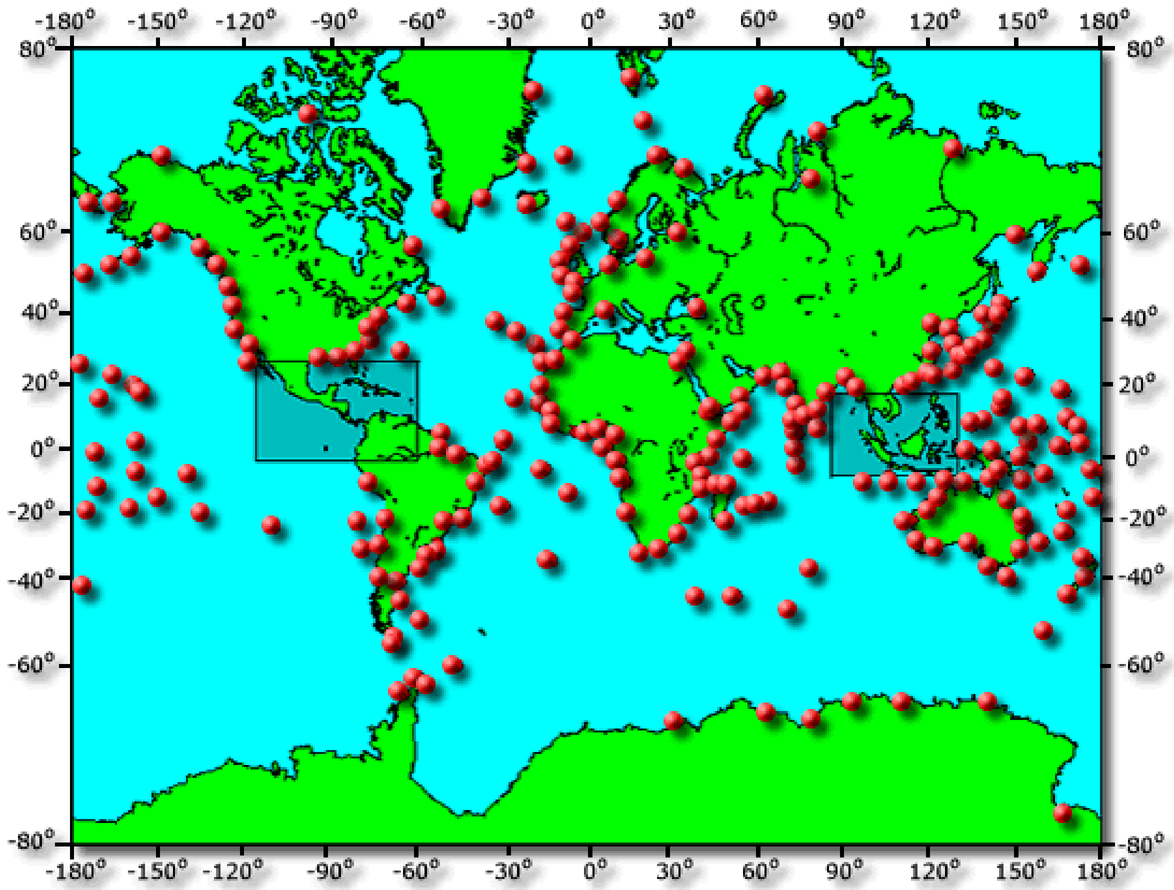
Data Sources

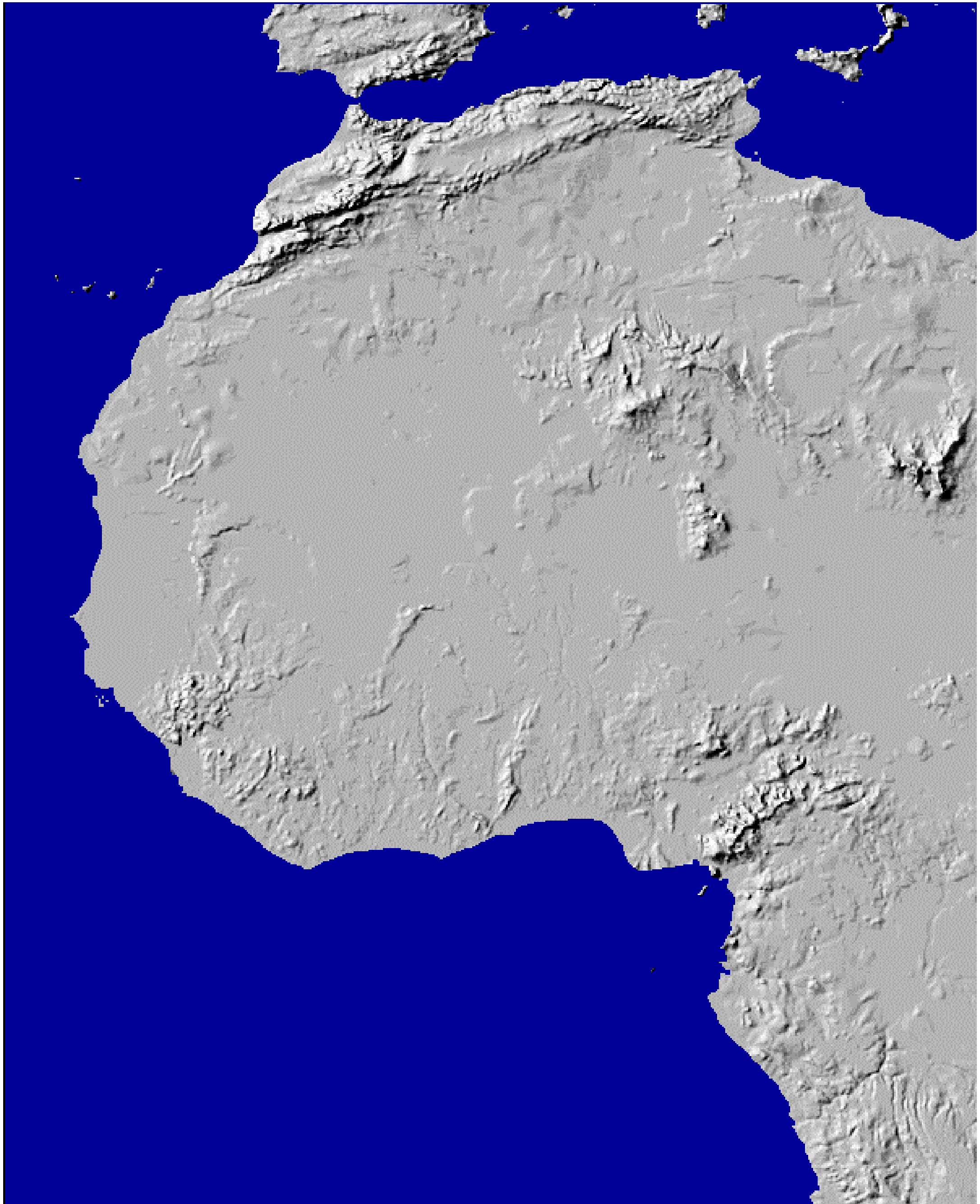
- IPCC Data Distribution Centre

- Sea level data
  - Permanent service for mean sea level
  - GLOSS – Global Sea-Level Observing System

- Remotely sensed data
  - Land Processes Distributed Active Archive Centre (NASA)
  - Shuttle radar topography mission

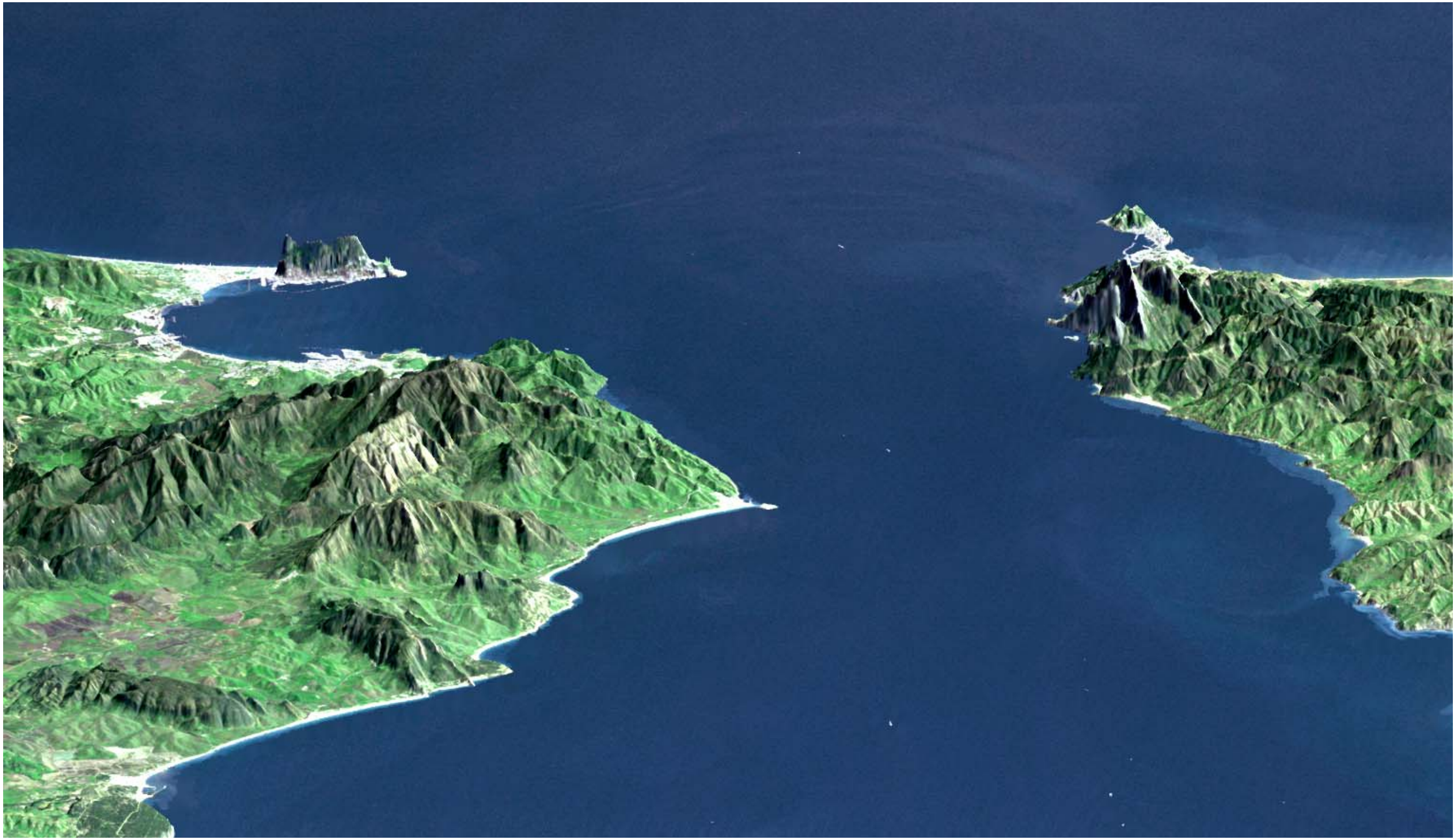
GLOSS Tide Gauges





GTOPO30 Global Digital Elevation Model

SRTM Data – Morocco and Gibraltar (vertically exaggerated)



Data Sources (2)

- Local observational data
  - Sea level measurements
  - Elevation/topography
  - Wave recording
  - Aerial photography
  - Habitat mapping

Concluding Remarks

- Sea-level rise could be a serious problem, but the uncertainties are large
- Impacts are strongly influenced by human choice
- Reducing greenhouse gas emissions reduces but does not avoid sea-level rise impacts
- Preparing to adapt would seem prudent, in the context of multiple stresses and managing existing problems