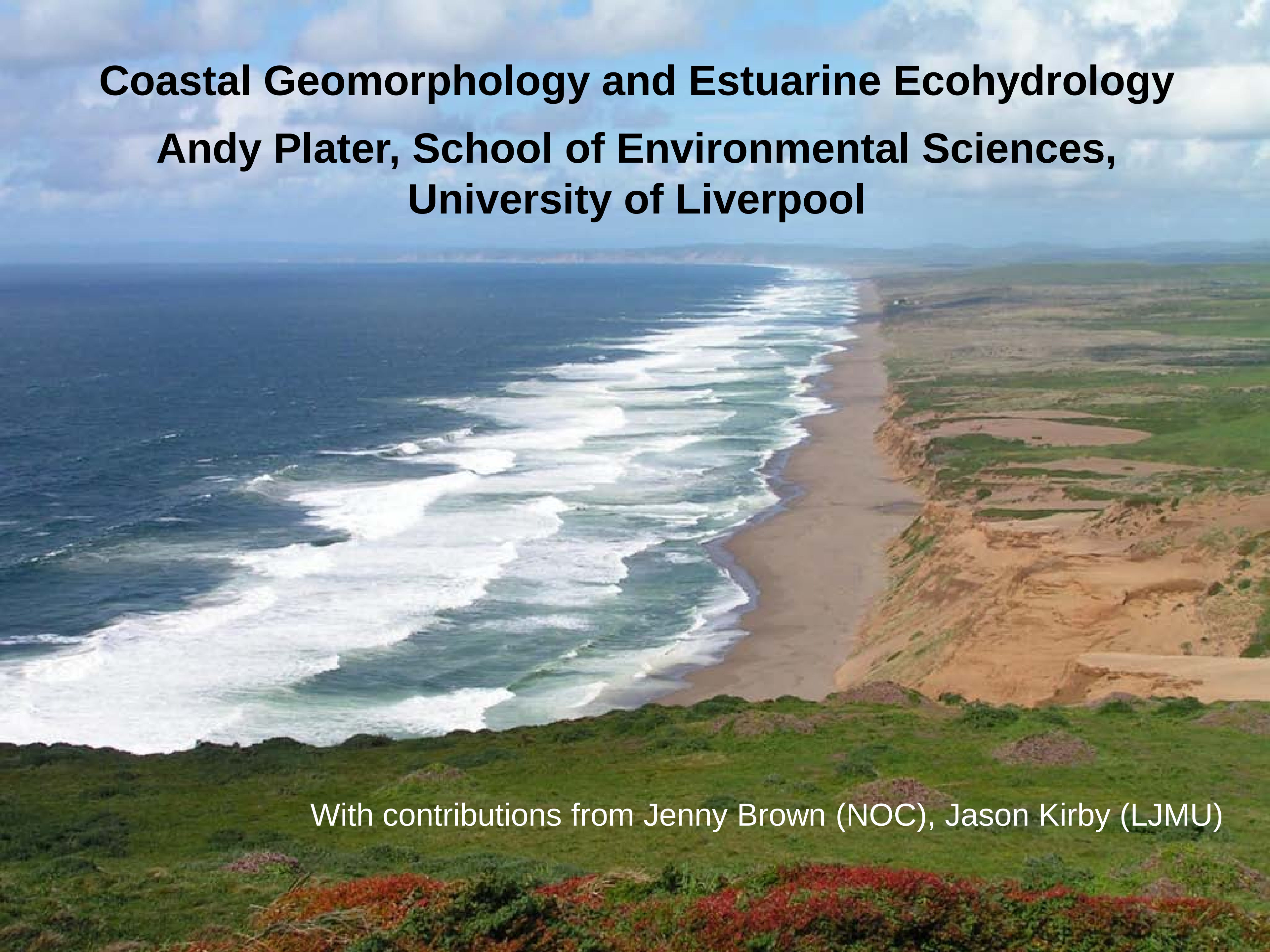
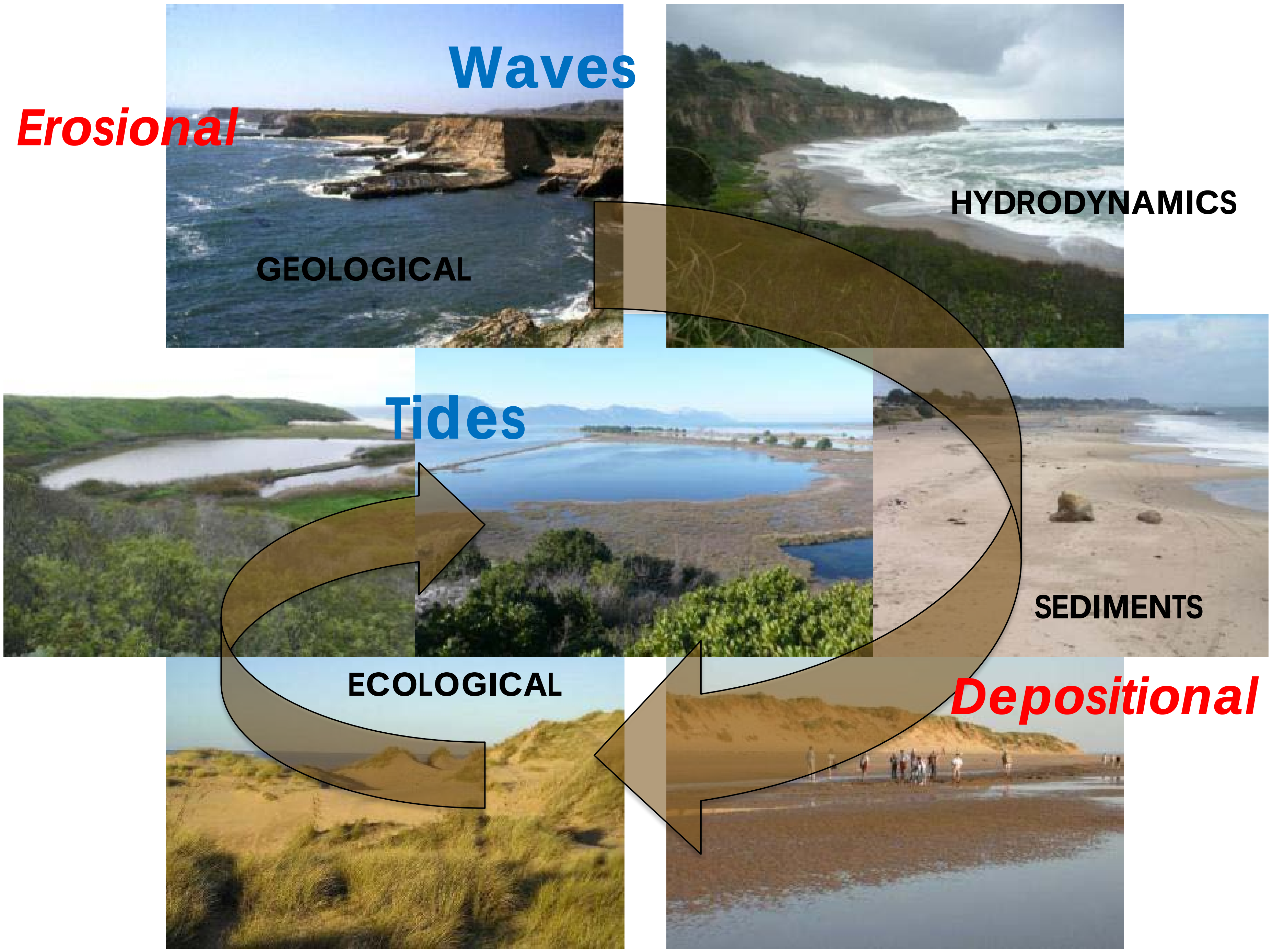
Coastal Geomorphology and Estuarine Ecohydrology

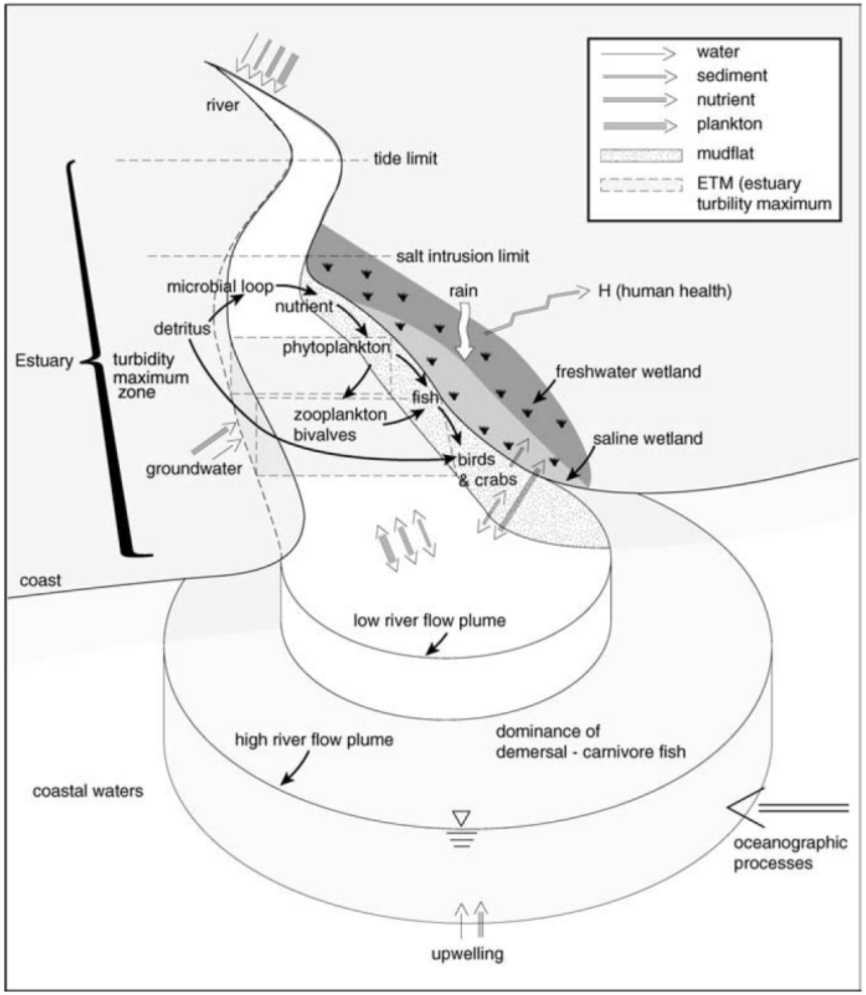
Andy Plater, School of Environmental Sciences, University of Liverpool



With contributions from Jenny Brown (NOC), Jason Kirby (LJMU)


Waves
Erosional
GEOLOGICAL
HYDRODYNAMICS
Tides
SEDIMENTS
ECOLOGICAL
Depositional

Estuarine Ecohydrology (Biogeomorphology, Hydroecology, Soft Engineering)



Interactions between biota, hydrology, sedimentary processes, biogeochemistry

Wolanski et al. (2004). Wetlands Ecology and Management 12, 235–276.

Sedimentation

Sediment accretion controlled by ***Hydroperiod*** (frequency *x* duration of inundation as per surface elevation)

Aided by biomass (stems and leaves) = turbulence, friction, surface area; root binding; algae; primary productivity

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Sedimentation

Role of creeks.

'Over-bank' deposition as flood tide spills onto saltmarsh surface.

Levees, distance decay in grain size, microtopography influences ecology, entrenched meanders, migratory creeks.

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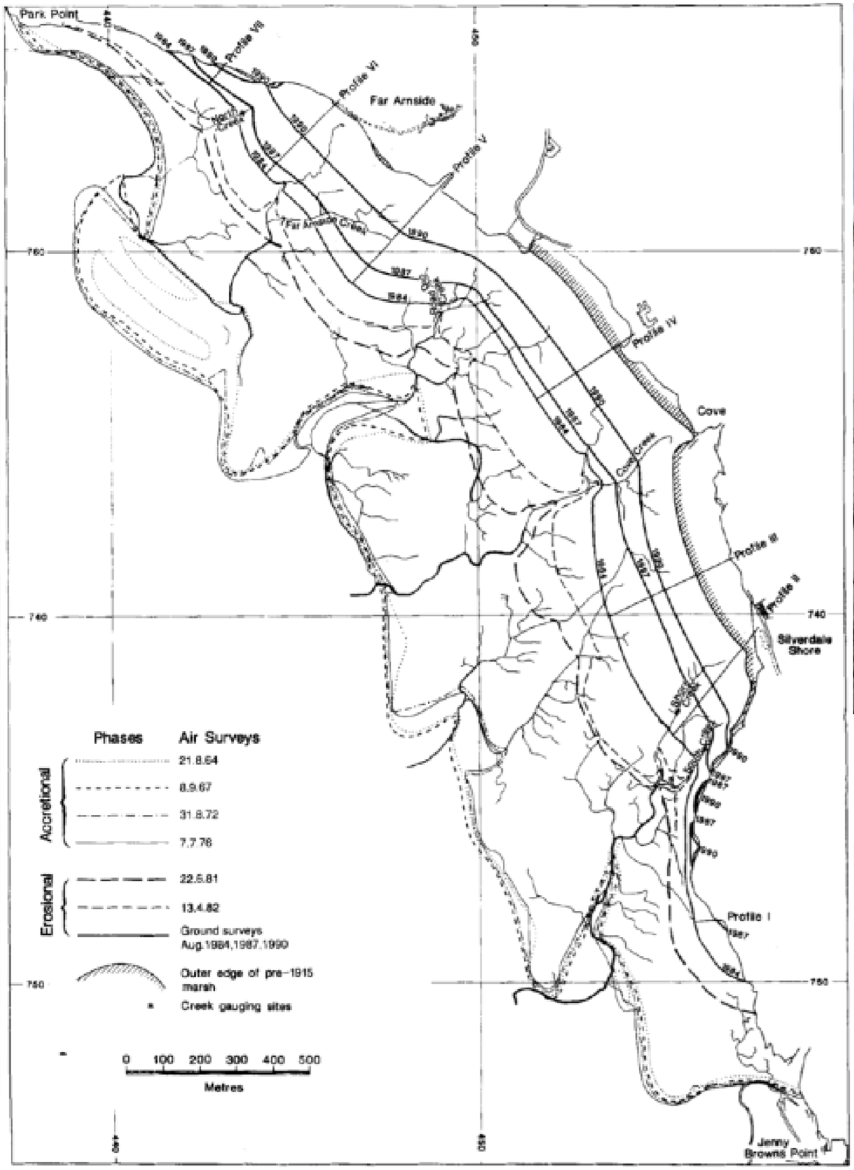
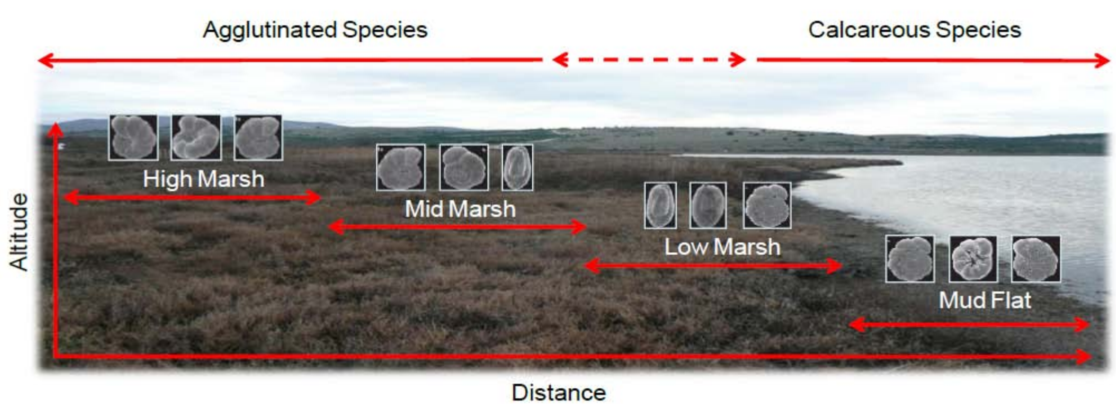


Phases of Erosion/Accretion

Migration/location of low water channel

Pringle, A.W., 1995. Earth Surface Processes and Landforms 20, 387-405.



Zonation

Distribution of plants & organisms (diatoms, forams) as a function of ***Hydroperiod***

Habitats and Biodiversity

Biomass

Carbon storage, nutrient/pollutant sequestration

‘Natural’ Sea Defences: Flood and Erosion Protection

Tsunami villagers give thanks to trees

By Sunil Raman
BBC News, Tamil Nadu

In 2002, a village in India's Tamil Nadu state planted 80,244 saplings to enter the Guinness World Records book.

Little did they realise at the time that the trees would save their lives.

When the tsunami roared into the coast of southern India on 26 December 2004 many villages and towns were crushed as the giant waves swept across open beaches.

But the people of Naluvedapathy in Vedaranyam district, south of the Tamil Nadu's worst affected areas around Nagapattinam, remained almost unscathed.

Managed Realignment: Ecohydrological Restoration

Ecohydrological principles in practice.

Built by the Environment Agency at a cost of £28 million, Medmerry fulfils a number of functions including some flood defence relief to the area around Selsey.

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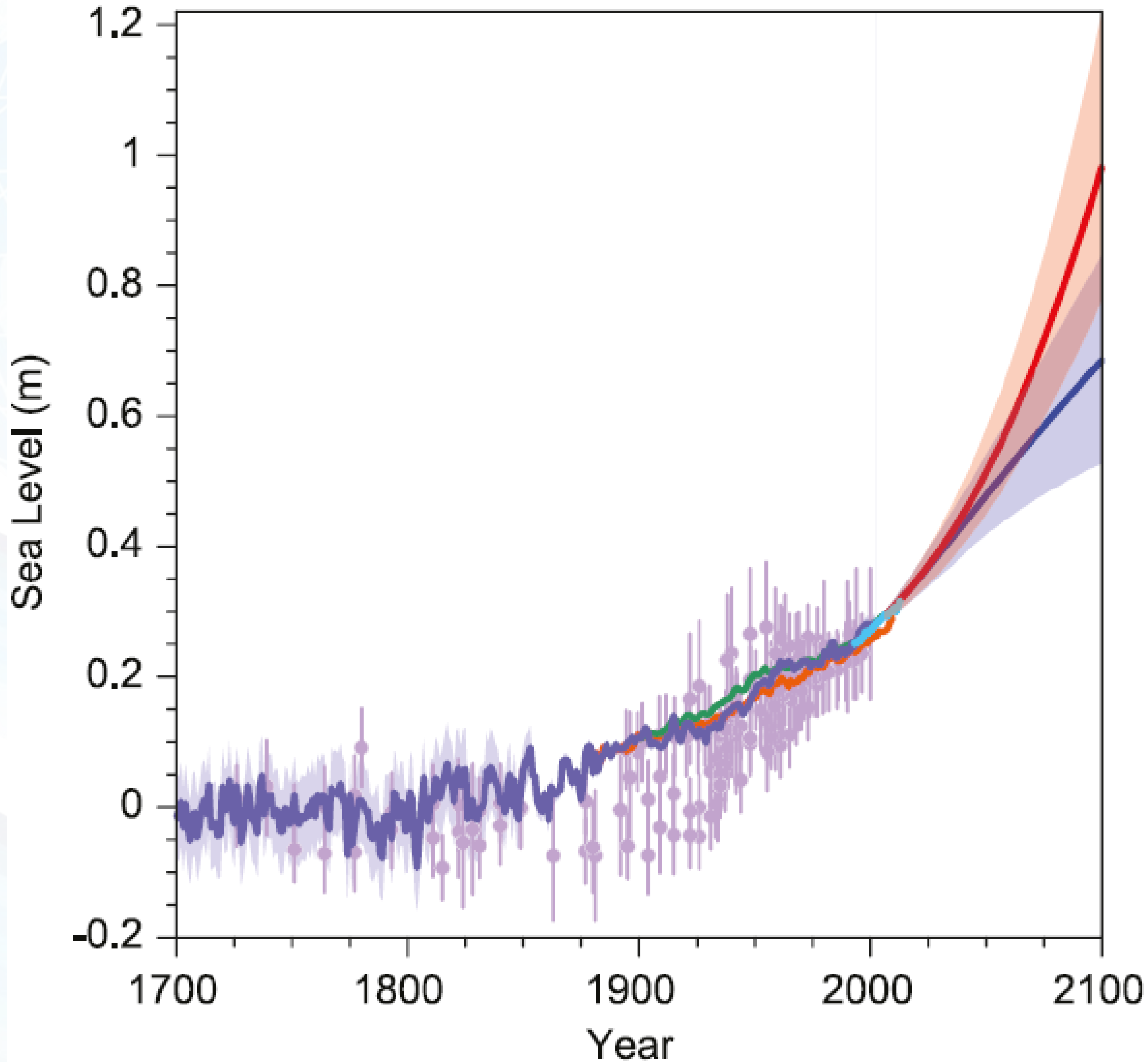
Information Needs for Coastal Stakeholders and Users

Sustainable management of coastal resources, cities, infrastructure...

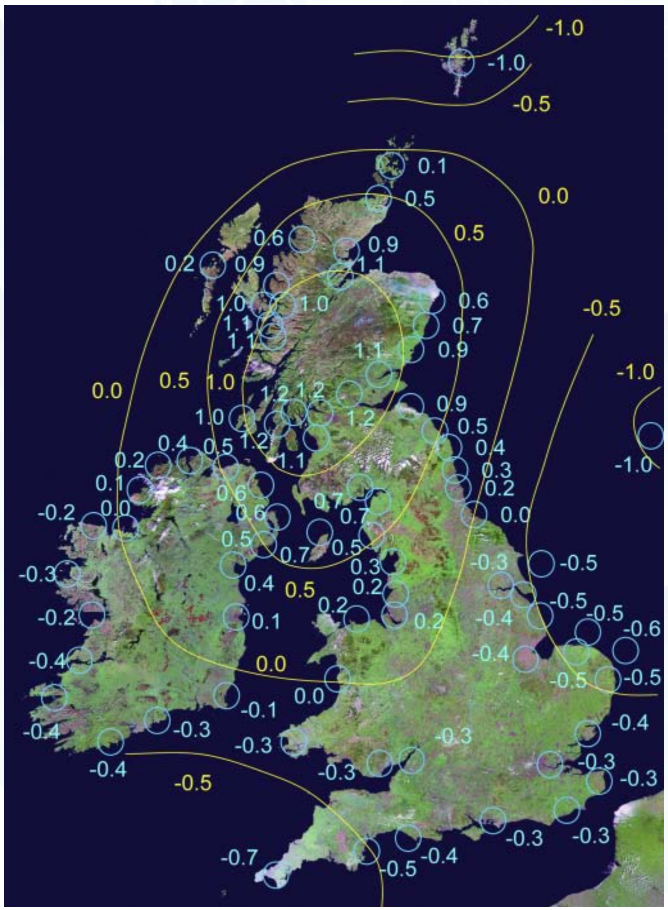
Future response of coastal geomorphology, sedimentary environments and ecosystems to climate change and human impact.

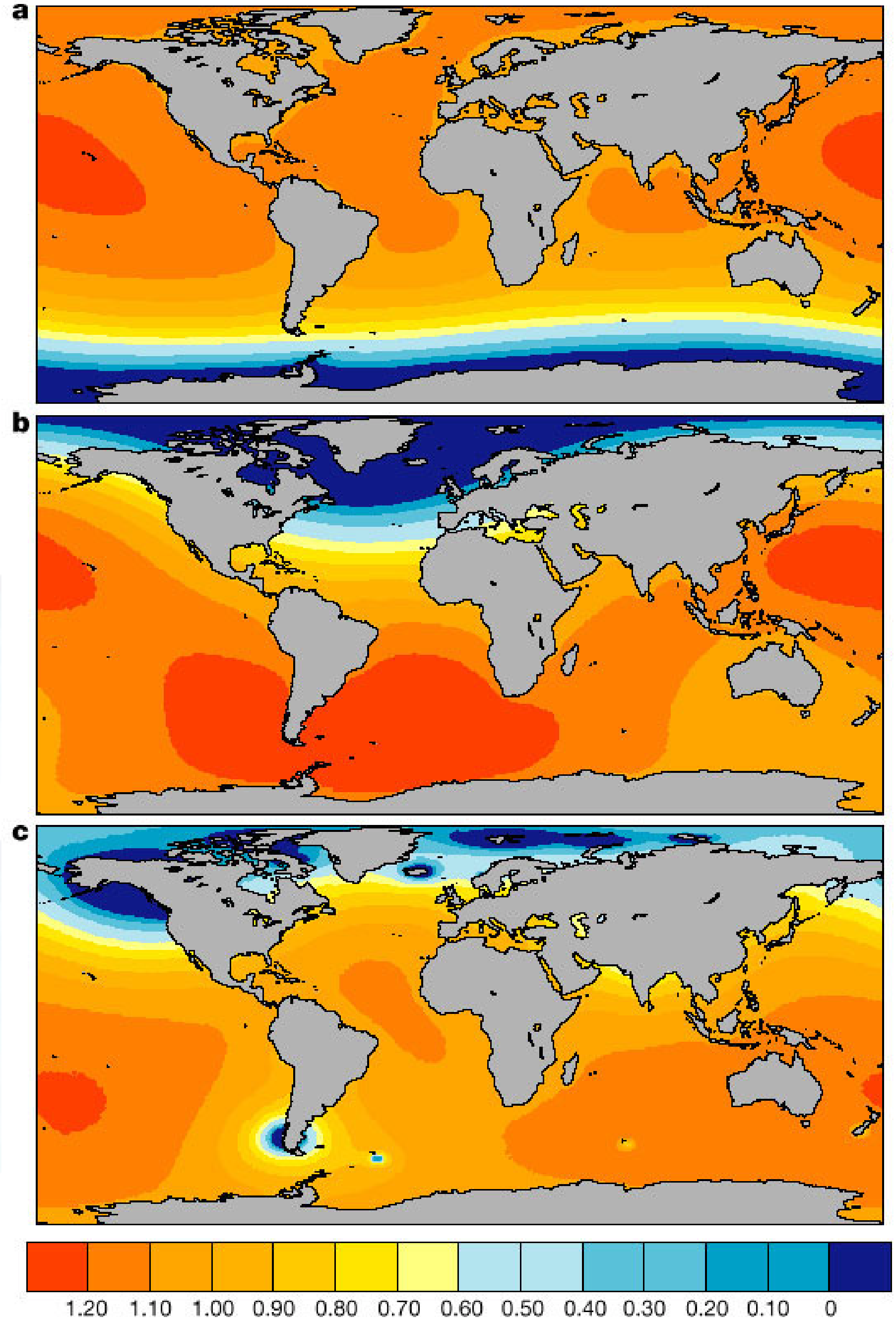
Climate Change and Rising Sea Level



Providing better sea-level information for coastal decision makers.

Regional/local projections





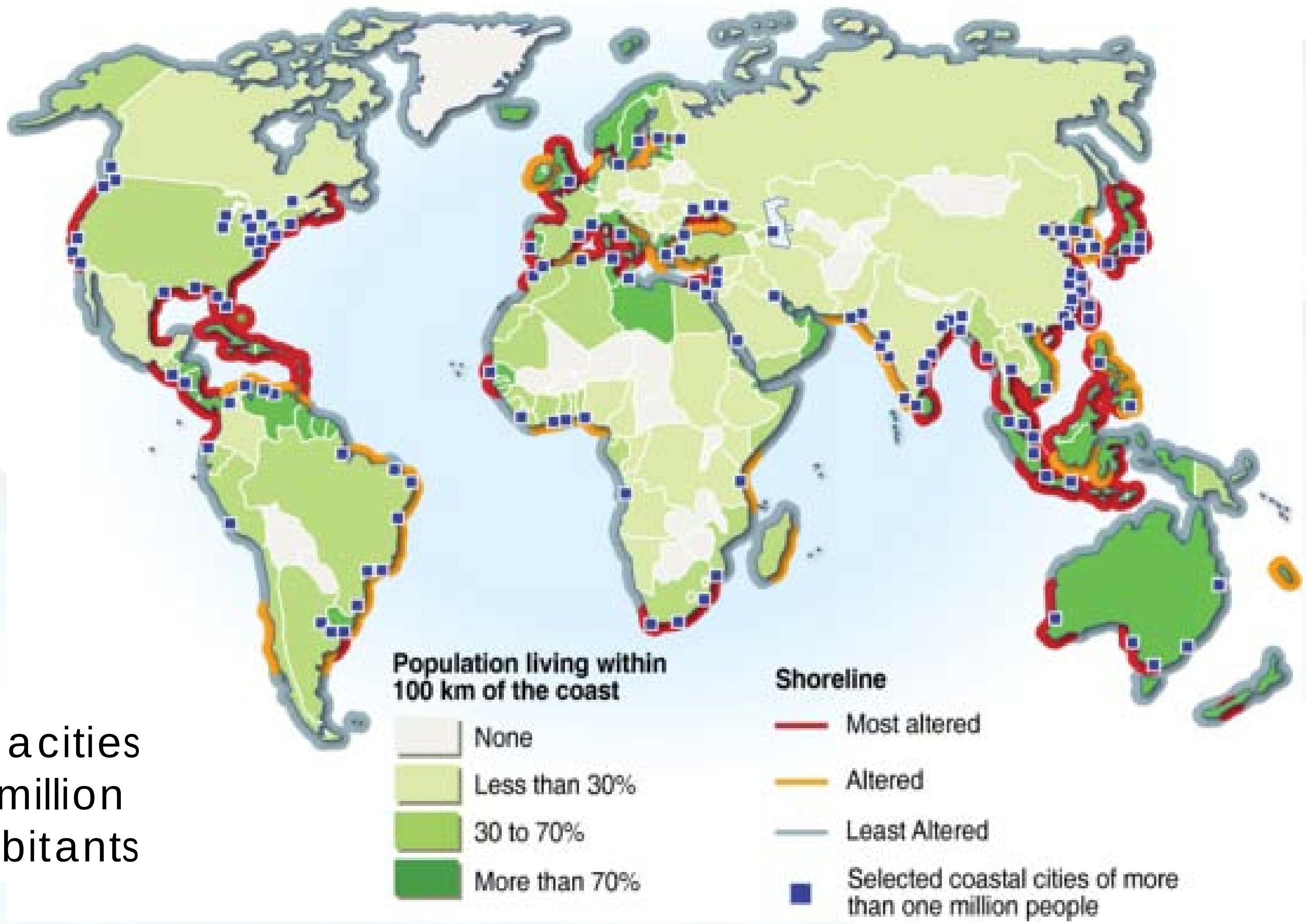
Shennan et al. (2012)
http://onlinelibrary.wiley.com/doi/10.1002/jqs.1532/pdf

Coastal Vulnerability to Extreme Events

Sandy, 29th Oct 2012

- Largest Atlantic hurricane – winds up to 110 mph at sea
- Storm surge of up to 4.2 m
- More than 286 people killed across 7 countries (affected 24 states)
- 2nd costliest Atlantic hurricane: $50-68 billion in damages

Megacities
>10 million
inhabitants



http://www.grida.no/graphicslib/detail/coastal-population-and-altered-land-cover-in-coastal-zones-100-km-of-coastline_7706

Increased water needs... more dams on rivers

- Changing hydrological regime
- Changing floodplain inundation frequency
- Changing water quality
- Displaced people(?)
- Reducing sediment flux – especially to coastal zone
- Changing coastal ecosystems

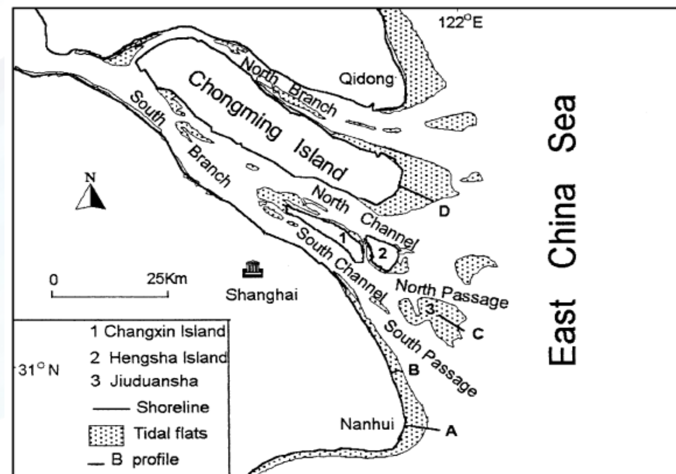
e.g. Colorado, Nile, Guadiana

Yangtze tidal flats

- Reduced sediment accretion
- Enhanced vulnerability to erosion

Table 1
Estimates of shoreline progradation rate (m/year) in the forward end of the river mouth based on historical records of seawalls and archaeological studies

Period	Lateral progradation (m/year)	Data source
Eastern shore of Nanhui		
6500–2000 BP	2	1
2000 BP–AD 713	17	1, 2, 3, 4
AD 713–1172	32	4, 5
AD 1172–1733	2	4, 5, 6
AD 1733–1882	40	4, 5, 6
AD 1882–1950	9	5
AD 1950–1995	35	5, 7
2000 BP–1995	17	1–7
Eastern shore of Chongming Island		
AD 825–1762	2	8
AD 1762–1955	7	8
AD 1955–1990	226	8, 9
AD 825–1990	10	8, 9



National Ecosystem Assessments

editorial

The EU Water Framework Directive – Aspirations and Lessons Learned

Ten years have passed since the adoption of the EU Water Framework Directive (WFD) – a law that prescribes steps to identify and analyse European waters on the basis of river basins, and requires the adoption of measures to achieve good water status in all water bodies. Today, the impact and success of this comprehensive directive on Integrated Water Resources Management are visible across the continent.

Considering the magnitude of the task, the European Parliament and the EU Council of Ministers provided a generous timetable for the Member States' implementation of the very significant governance reforms required by the Directive and for the achievement of its ambitious targets for water quality. The deadline for achieving the targets was set for 2015 while the first River Basin Management Plans were required to be finalised by the end of 2009. Out of the 27 EU Member States, 15 have by the end of May 2010 adopted the River Basin Management Plans, while four more expect to do so within a relatively short timeframe.

This means that for 80 percent of the EU population, River Basin Management Plans are, or will soon be, in place. Eight Member States are clearly lagging behind and have to yet conduct the necessary public consultations. It is a source of particular concern that most of the delays are occurring in Mediterranean states, some of which have serious problems in balancing water demand with availability. In such situations, ensuring that the water available is of good quality is even more important. However, the Directive has had a very significant impact despite these concerns. But the size of the challenge should not be underestimated.

"One of the most important lessons learned so far is that the need to work together does not end with the adoption of an EU Directive."

The WFD transformed water management from a purely scientific and technical subject for engineers and scientists to an issue at the forefront of political attention. It has done so by requiring Member States to introduce a whole series of important changes in water governance, such as using hydrological basins as the basic management units across administrative and national boundaries; establishing basin authorities and River Basin Management Plans for each River Basin District; cooperating with and between stakeholders in launching extensive public information campaigns and consultations; a complete assessment of ecological aspects of the water environment; and a fully-transparent application of economic analysis of "the polluter pays" principle through water pricing and cost recovery.

Many water managers from non-EU countries aspire to have something like the WFD. Delegations have been flying in to learn about the directive from non-EU OECD countries such as the USA or from emerging economies such as China, India or Brazil – and the general consensus is that we have made this directive into a unique and inspiring instrument at our disposal.

The applied WFD approach is clearly working well, as it transformed water management in most parts of Europe. However, it is only until the end of the first policy cycle in 2015, when the targets should be attained, that we are able to assess the effectiveness of the Directive and the limitations of this approach.

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EU-WFD

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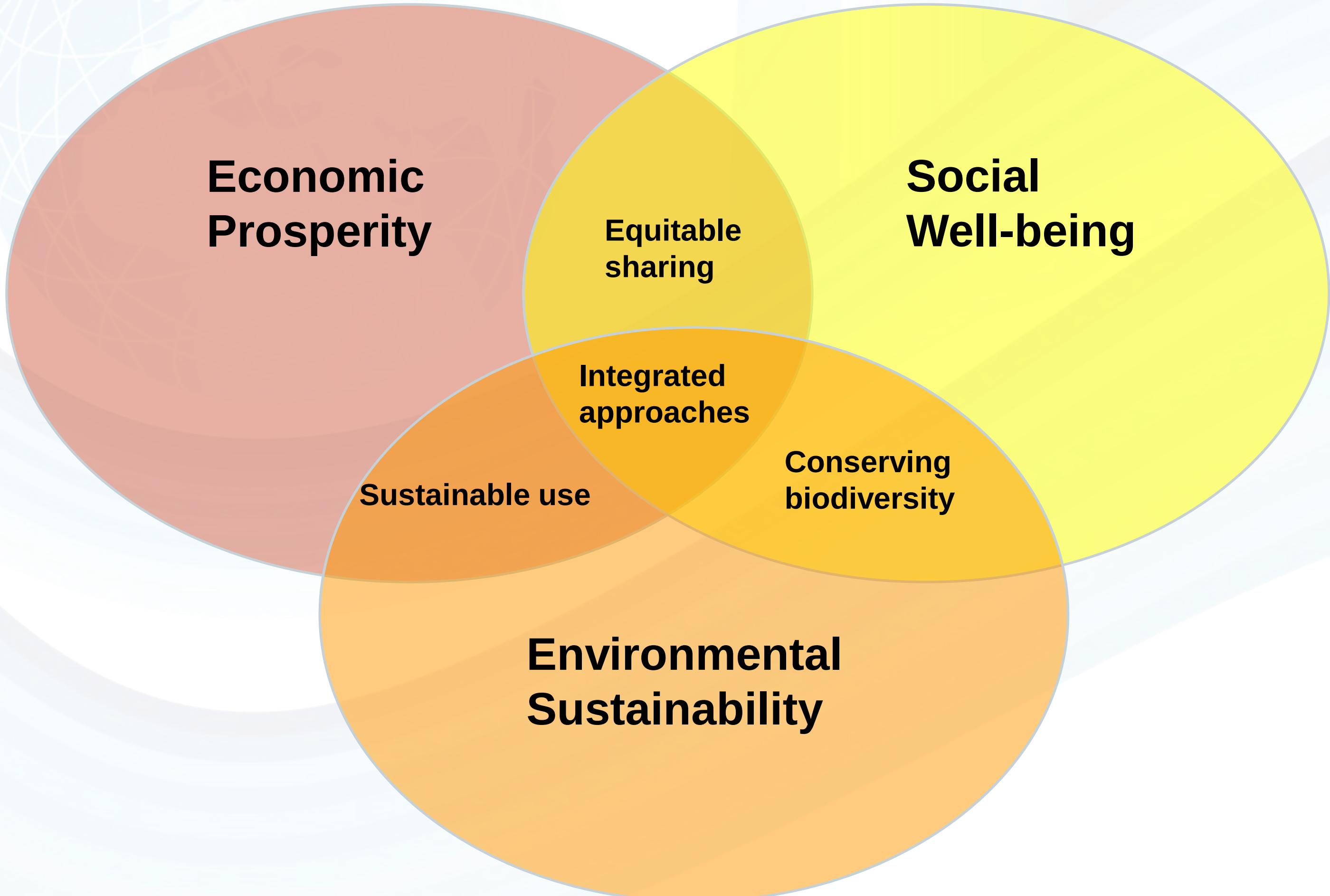
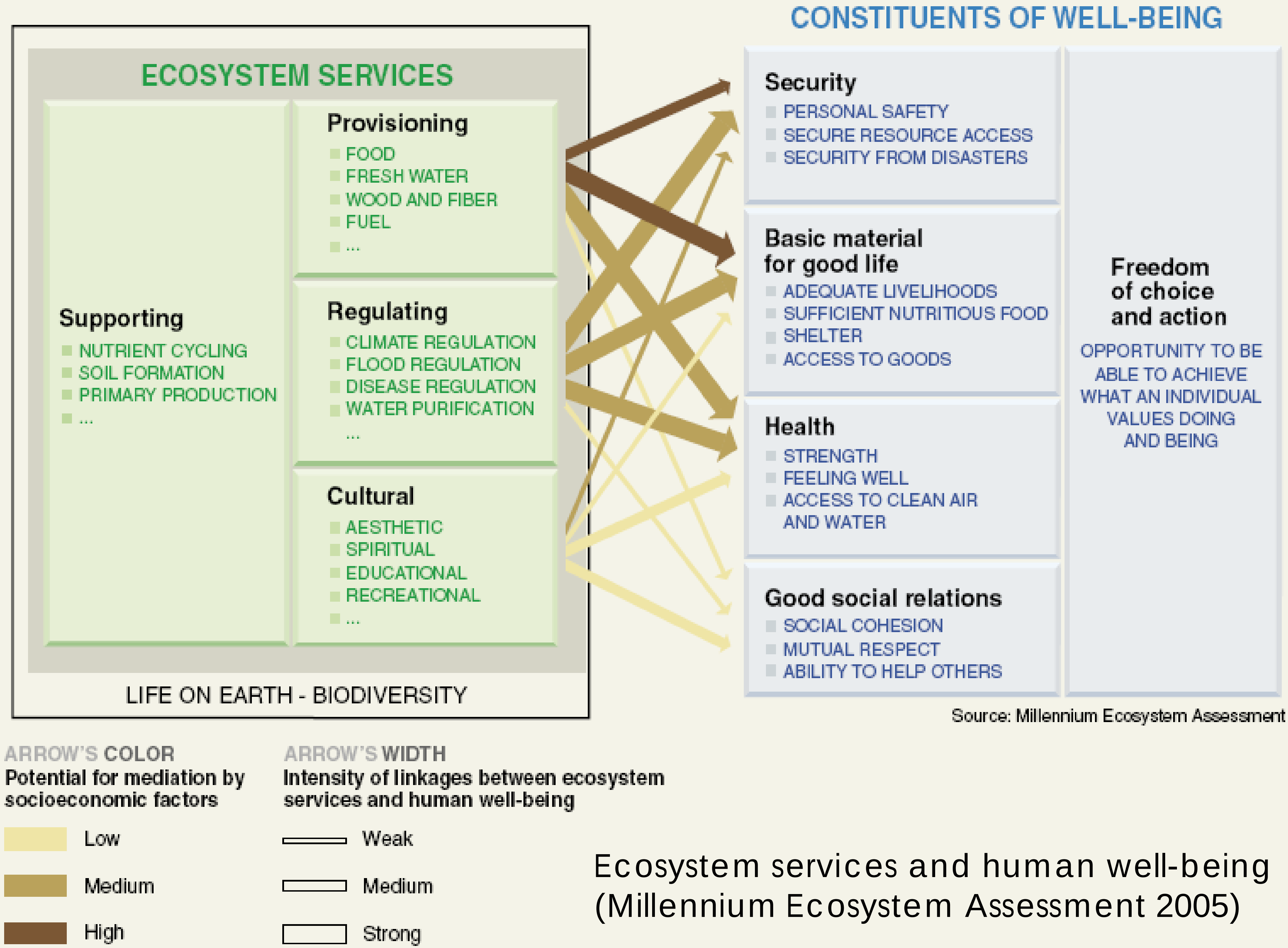
Ecosystem Approach: Structure & Outcomes





Ecosystem services and human well-being (Millennium Ecosystem Assessment 2005)

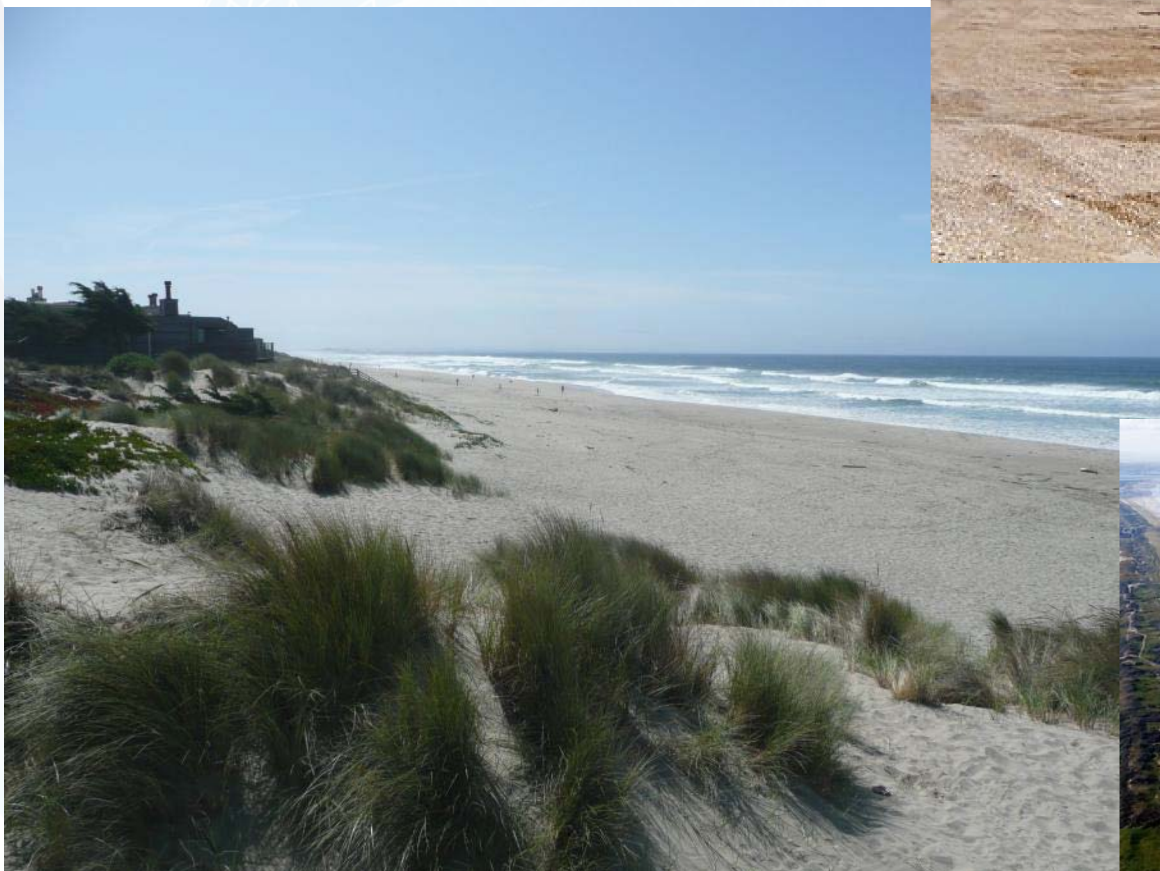
Better Understanding of Coastal Response and Resilience:

environments
geomorphology
sediment and flow patterns
water quality
ecosystems
urban infrastructure
resources
economy
people

sea-level
extreme events
sediment supply
hydrodynamics
human interventions

Promoting Dynamic Coasts

Maintaining 'Healthy' Beaches



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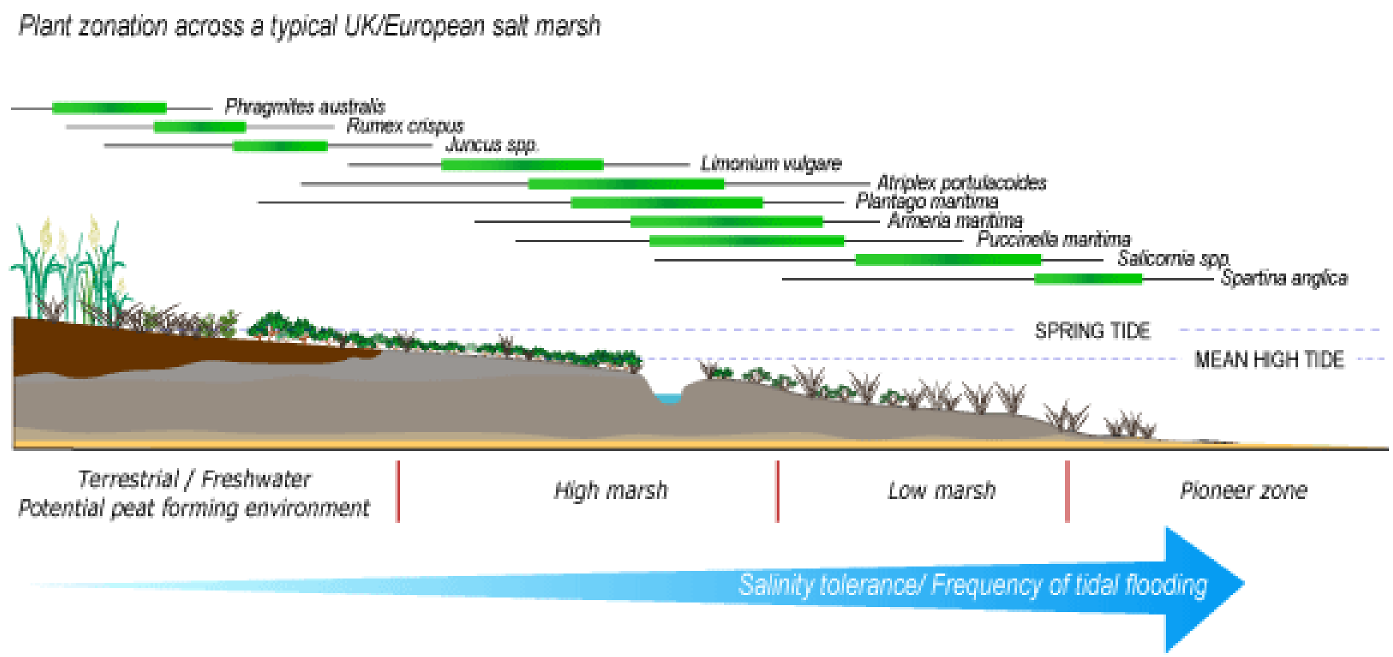
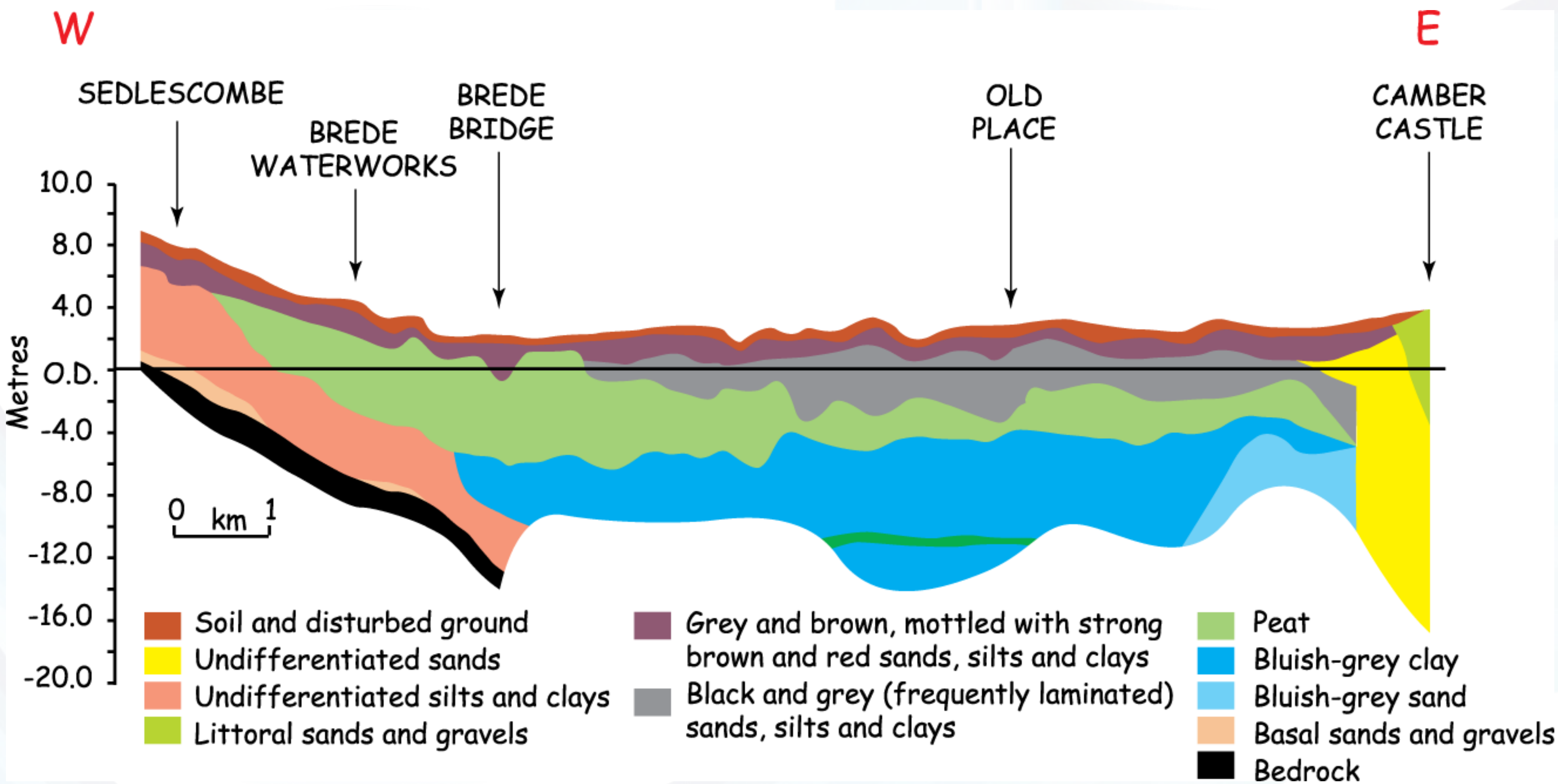
Coastal and Perimarine Wetlands:



A New Realignment continuum?

Present: estuary-sandflat-mudflat-saltmarsh

Potential: estuary-sandflat-mudflat-saltmarsh-reedswamp-sedge fen-fen carr *(Mangrove equivalent)*



Holocene sea-level rise 3-6 mm/yr, limited sediment

Persistent perimarine wetland in a barrier estuary

Plater, A.J. And Kirby, J.R. (2006). Estuarine, Coastal and Shelf Science 70 (1-2), 98-108

Ecosystem Services of Perimarine Wetlands:

- Truly integrated river basin management (re. UNEP – linking river and coastal systems)
- Development of sustainable ecological solutions to basin management using ecohydrology principles.
- Coastal flood buffer zone – from both fluvial discharge and storm surges.
- Management tool for regulation of water levels – reduced extremes, flood storage, maintenance of low flow conditions
- Increased estuary robustness and lifetime (reduced infilling, space for dynamic response)

Ecosystem Services of Perimarine Wetlands (cont.):

- Reduced vulnerability of coastal populations to climate (rainfall, wave climate) and sea-level change – as well as aperiodic events (tsunami, storm surges)
- Reduced erosion of channel banks
- Sediment (and particulate pollution) trap: active capture of sediments in channels, ponds, lakes, lagoons
- Nutrient (and dissolved pollution) trap: uptake/sequestration of dissolved species by biota (managed by planting, seeding and water level regulation)

Ecosystem Services of Perimarine Wetlands (cont.):

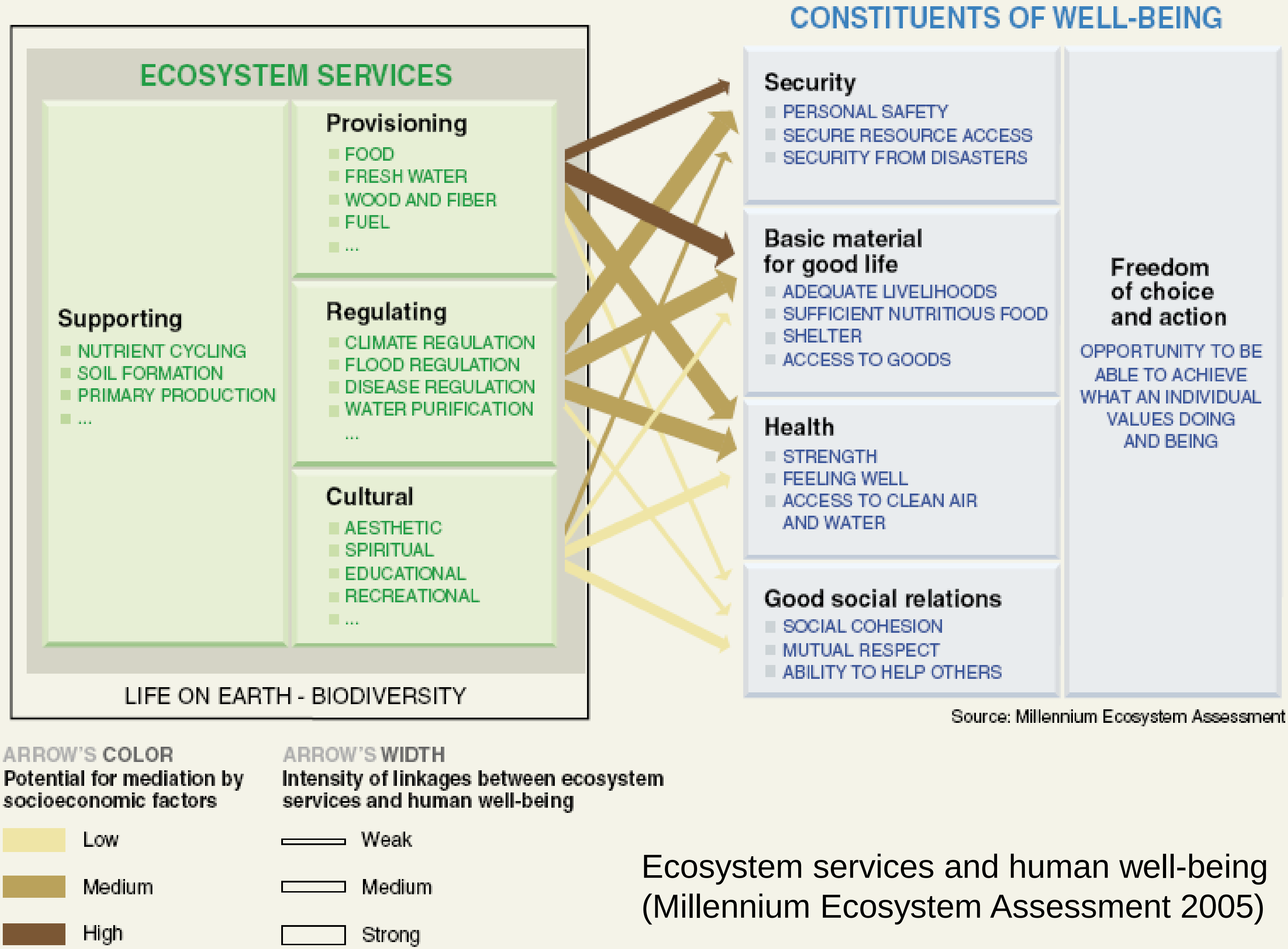
- Improved water quality in enclosed seas and coastal waters – limited nutrient-related blooms, reduced turbidity

- Carbon sequestration and storage in perimarine wetlands

- Increased habitat diversity in coastal (and lowland catchment) zone – meeting biodiversity/habitat targets

- Increased diversity of coastal economies – reeds, timber, peat, wildfowl, wildlife, fisheries, (eco)tourism, salt, storage

- Better preservation of lowland archaeology



Ecosystem services and human well-being (Millennium Ecosystem Assessment 2005)

Sustainable management of coastal resources: more than a science issue...

Arnstein, S.R. (1969) "A Ladder of Citizen Participation," Journal of the American Planning Association 35 (4), 216-224

Value of retaining undisturbed condition vs converted

e.g. Thai mangroves: Conversion to aquaculture gives short-term private benefits, but loss of timber, charcoal, offshore fisheries and storm protection

Conservation enhances human well-being (TEV) above that of ‘development’

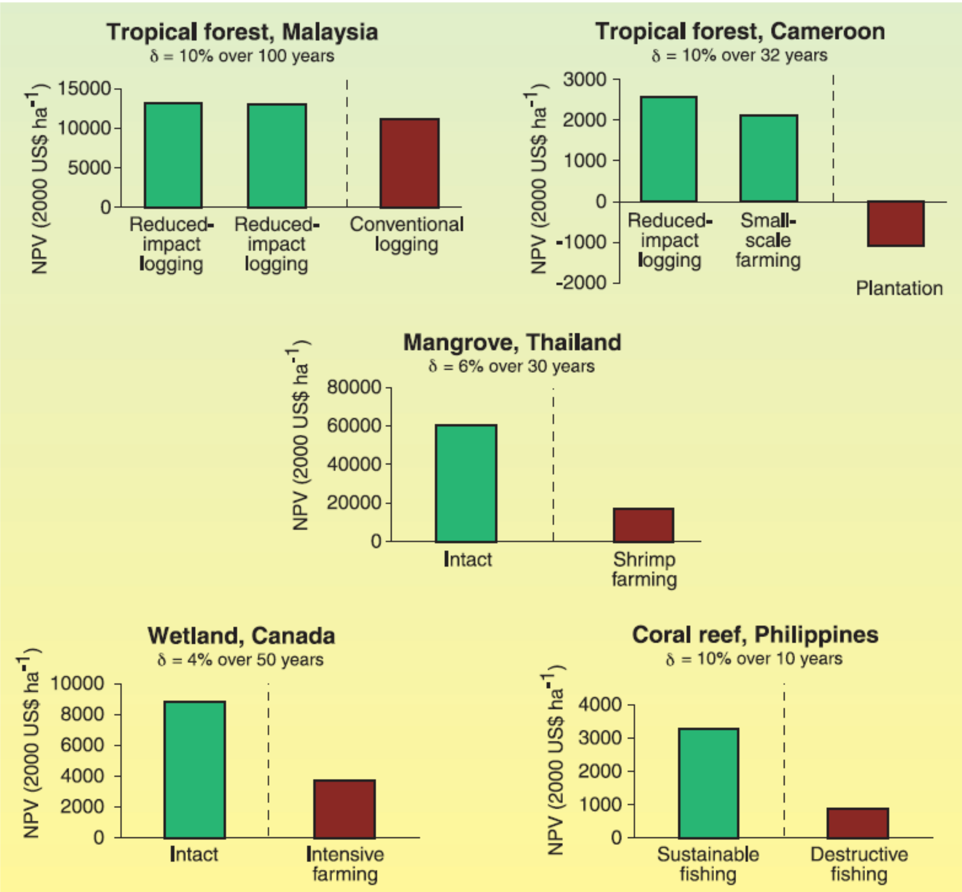


Fig. 1. The marginal benefits of retaining and converting natural habitats, expressed as NPV (in 2000 US$ ha^{-1}) calculated using the discount rates (δ) and time horizons presented. Values of measured goods and services delivered when habitats are relatively intact and when converted are plotted as green and black columns, respectively. [From (*11–15*); see (*10*) for further details.]

Balmford et al., 2002

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Summary

Important to recognize the critical role of ecosystems: natural management tool, habitats & biodiversity, ecosystem services, sustainability, health and well-being, economic growth.

Thinking holistically – catchment to coast, 'downstream' ecosystem impacts/responses.

Aim to promote and maintain dynamic (and adaptable) coasts where sediments provide the 'landscape' for ecosystems as the management goal.

Provide decision-makers and stakeholders with reliable data and understanding at appropriate resolution – ***working in partnership***

Key Challenges for Coastal and Estuarine Resource Management: Data, Understanding & Modelling

1. Reduced complexity modelling/CA models
2. Conceptual models
3. Model integration
4. Spanning timescales of operation (also spatial scales)
5. Better collaboration/data sharing
6. Linking coastal sediment and morphological models to ecohydrology and ecosystem services frameworks

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Thank you for your attention...

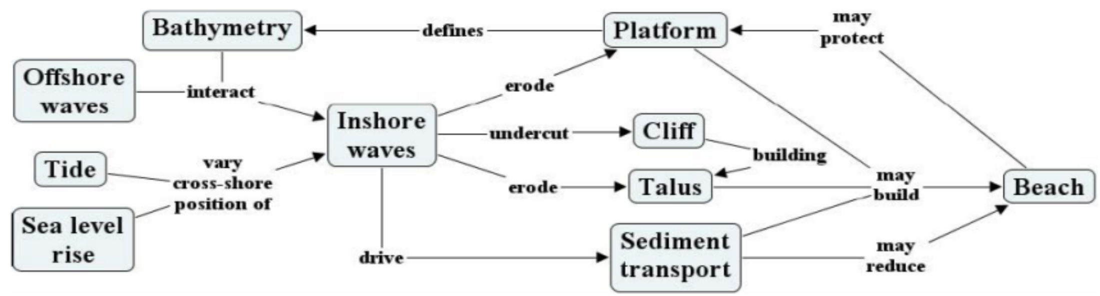
Andy Plater: gg07@liverpool.ac.uk tel: 0151 794 2843

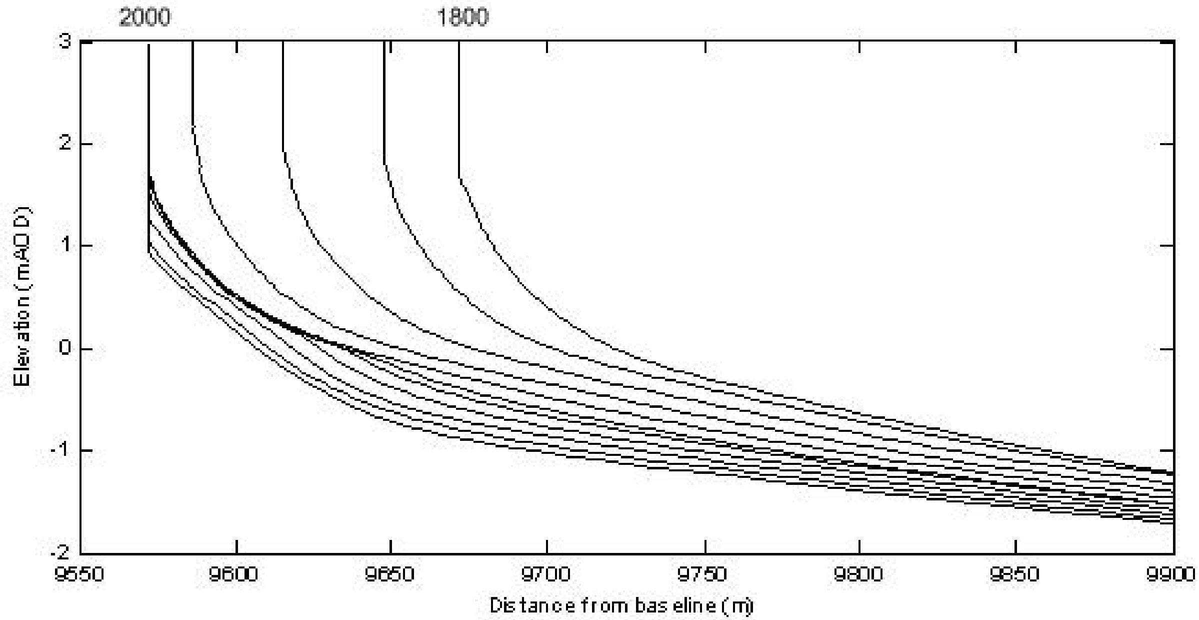
Reduced Complexity Modelling

SCAPE – Soft Cliff and Shoreline Erosion

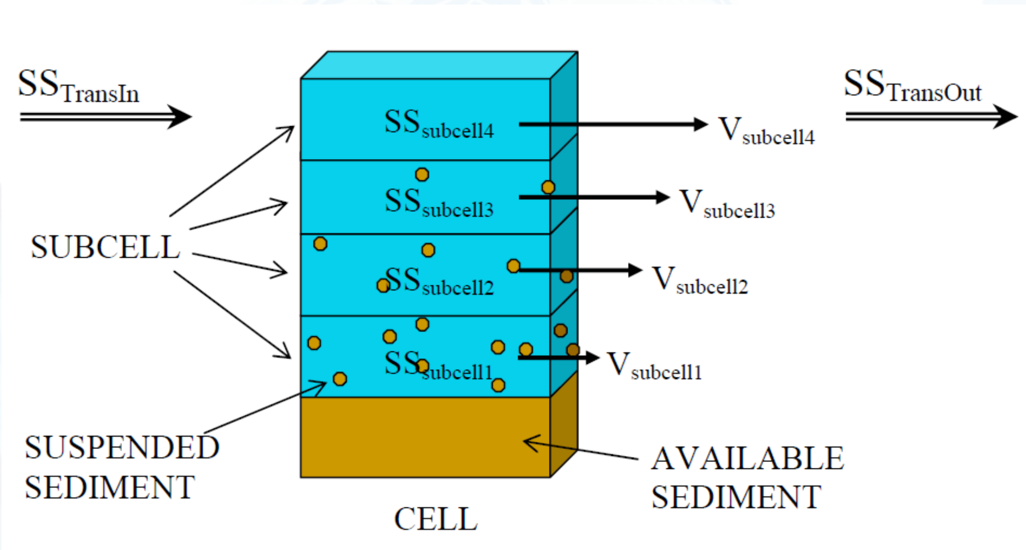
Changing coastal dynamics (sea level, storms, sediment supply) lead to changing coastal geomorphology

Walkden and Hall (2005)

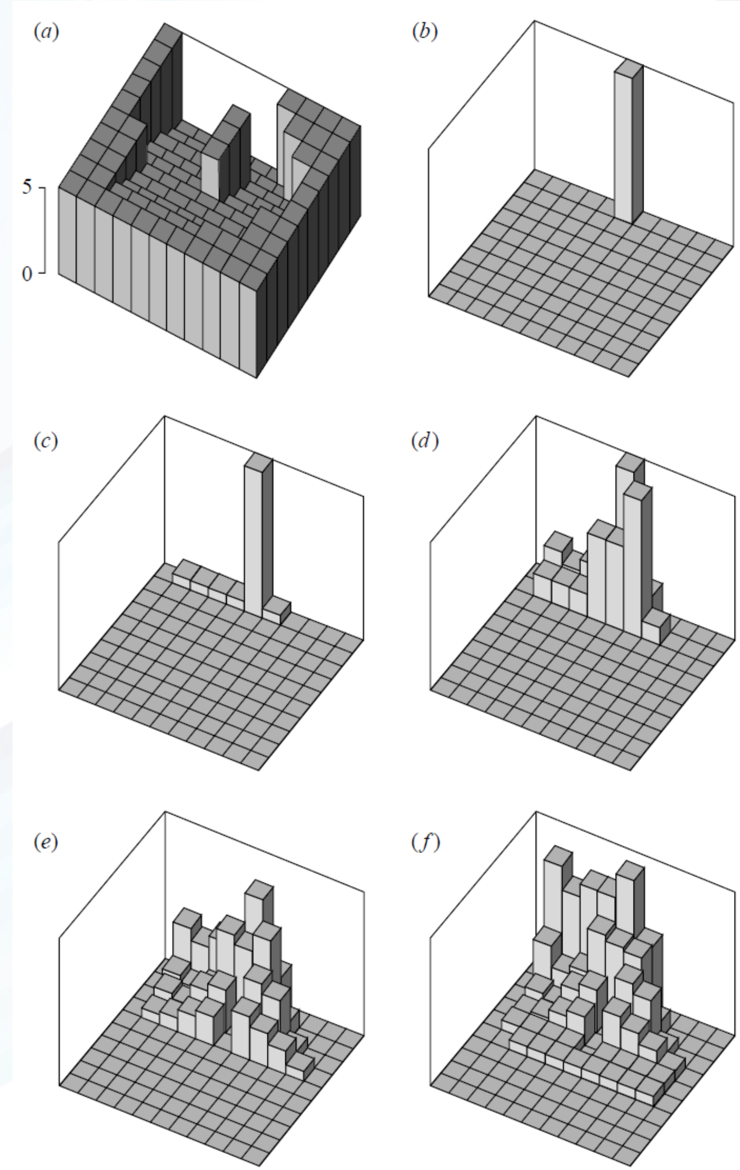




CA Models

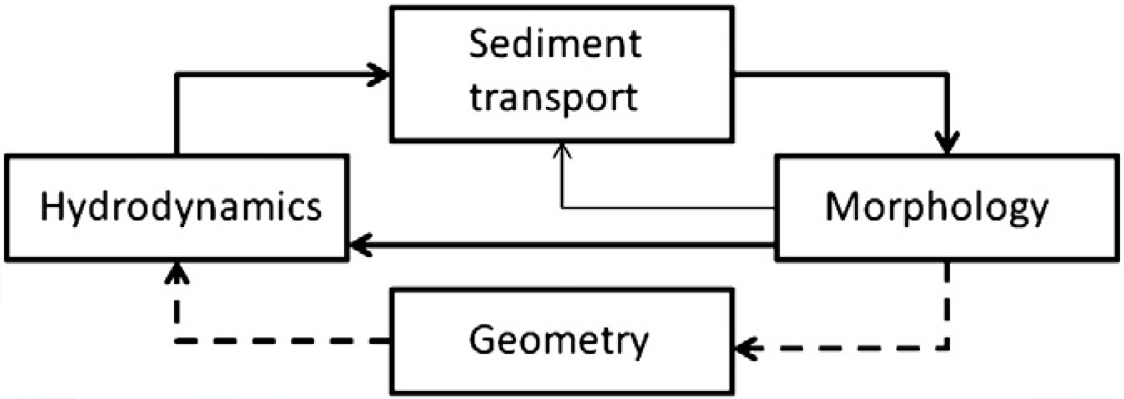


$$SS_{TransOut} = \int_{z=1}^{MaxSubCells} SS_{subcellz} V_{subcellz}$$



CEMCOS

Dearing et al. (2006) Phil. Trans. R. Soc. A 364, doi: 10.1098/rsta.2006.1753



Van der Wegen and Roelvink (2012) Geomorphology 179, 152–167

Delft 3D – channel, shoal and long-profile evolution from flat bed fitted to initial 1998 bathymetry.

Including storm perturbation, erodible channel banks, saltwater density differences, different grain sizes, morphological sensitivities e.g. bed slope

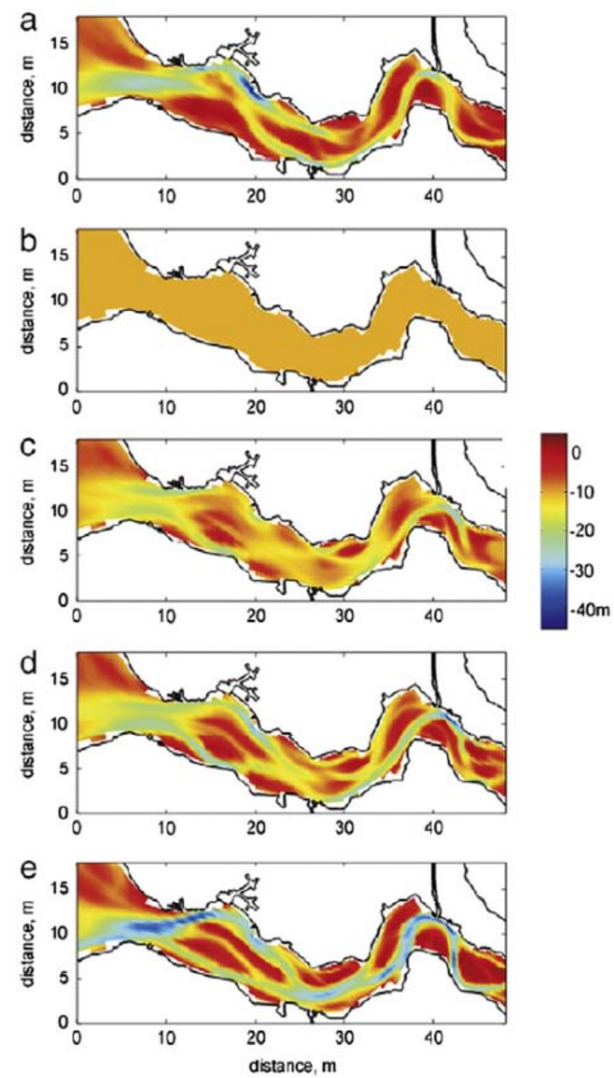
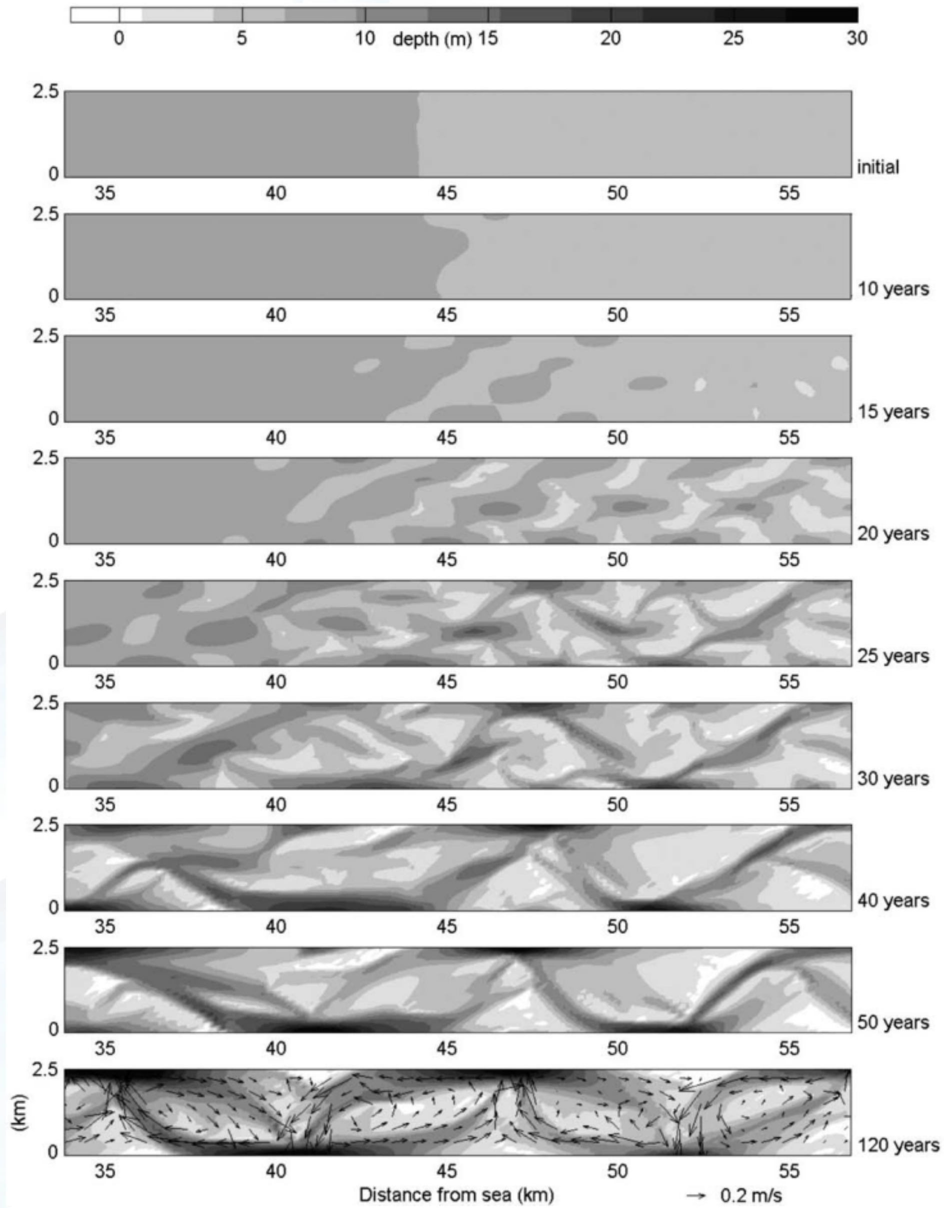


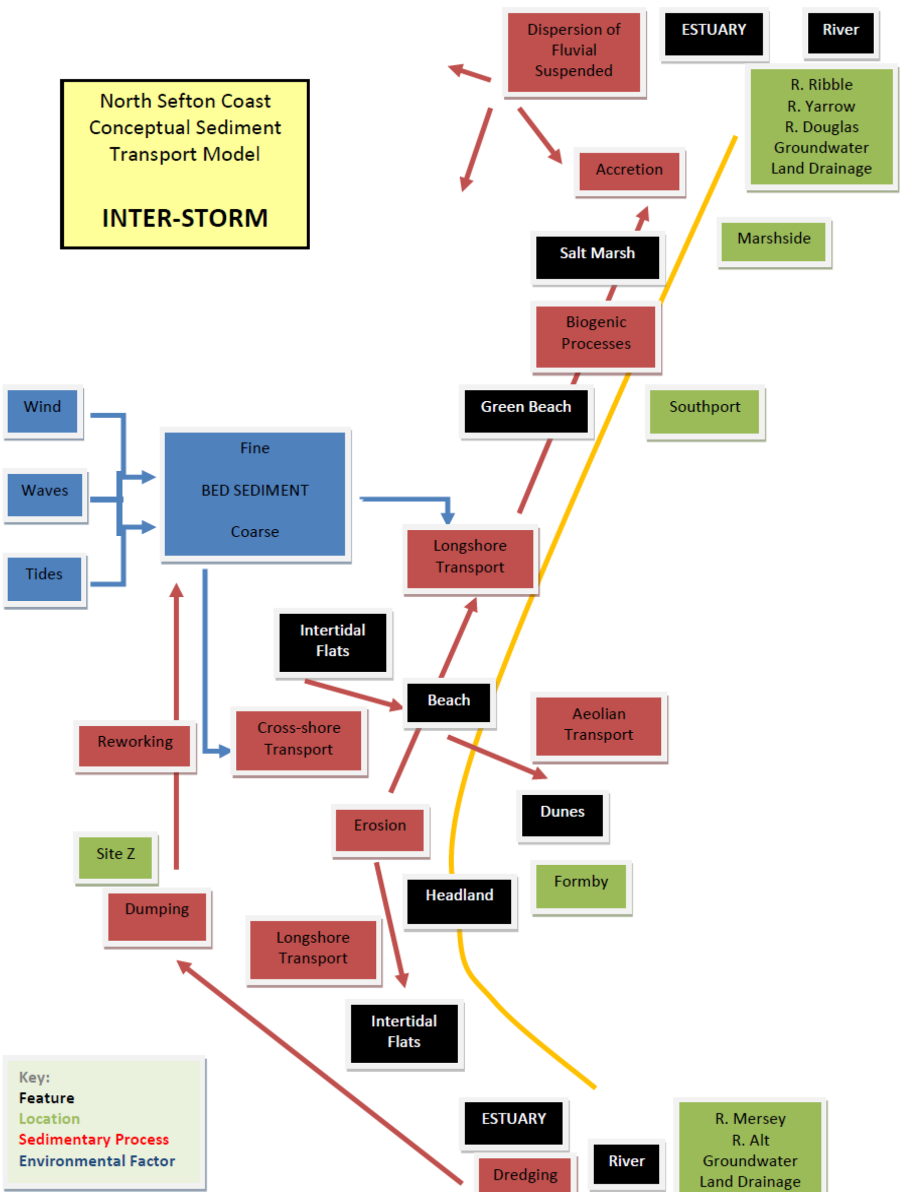
Fig. 5. Bed-level development of EH-3D-abn10-Q15 case. (a) measured 1998 bathymetry; (b) initial bathymetry; (c) bathymetry after 15 years; (d) bathymetry after 30 years with best BSS; (e) bathymetry after 200 years.

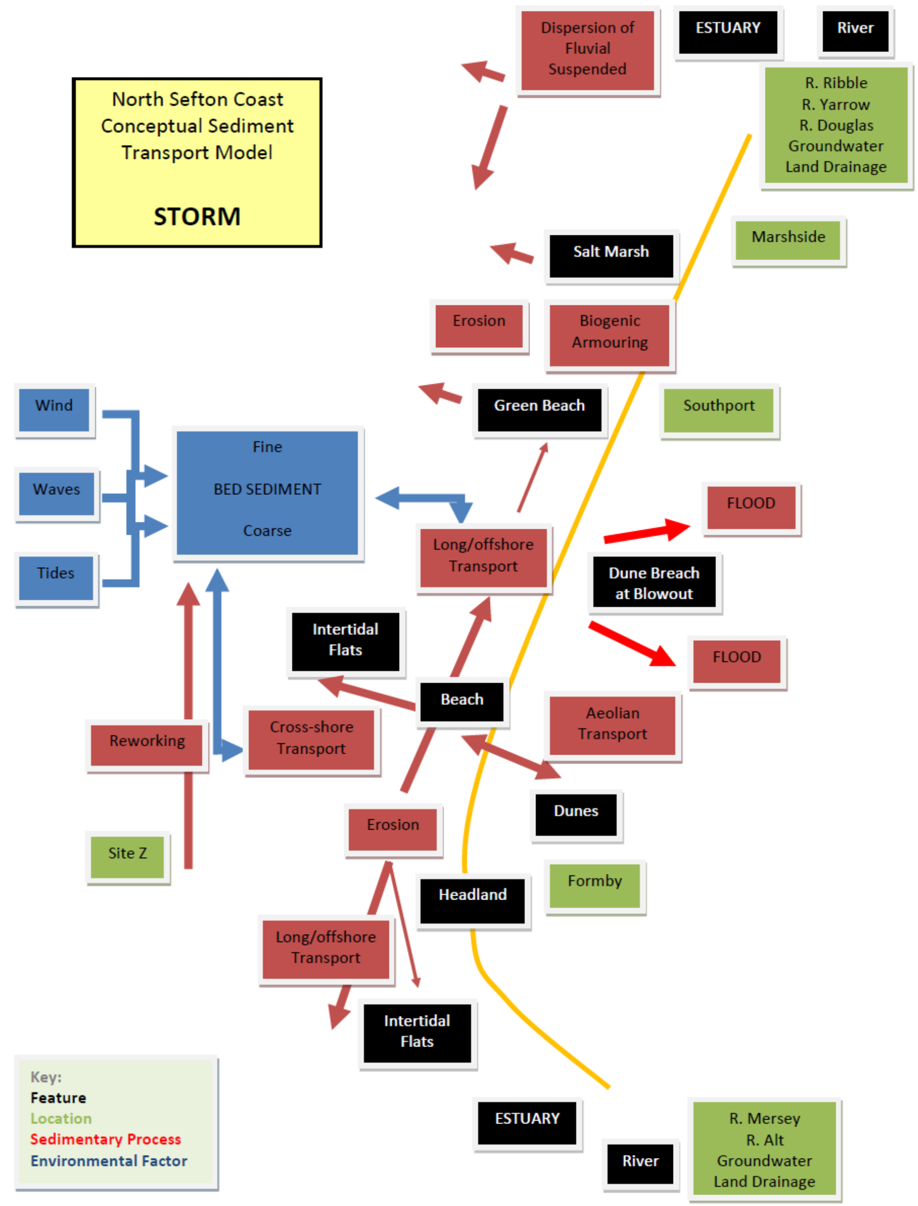
Hibma et al. (2003) Estuarine, Coastal and Shelf Science 57, 981–991.

Delft 3D – channel and shoal evolution based on wetting/drying, small-scale hydrodynamics, sediment transport, (cell) mass balance, bed topography+/-



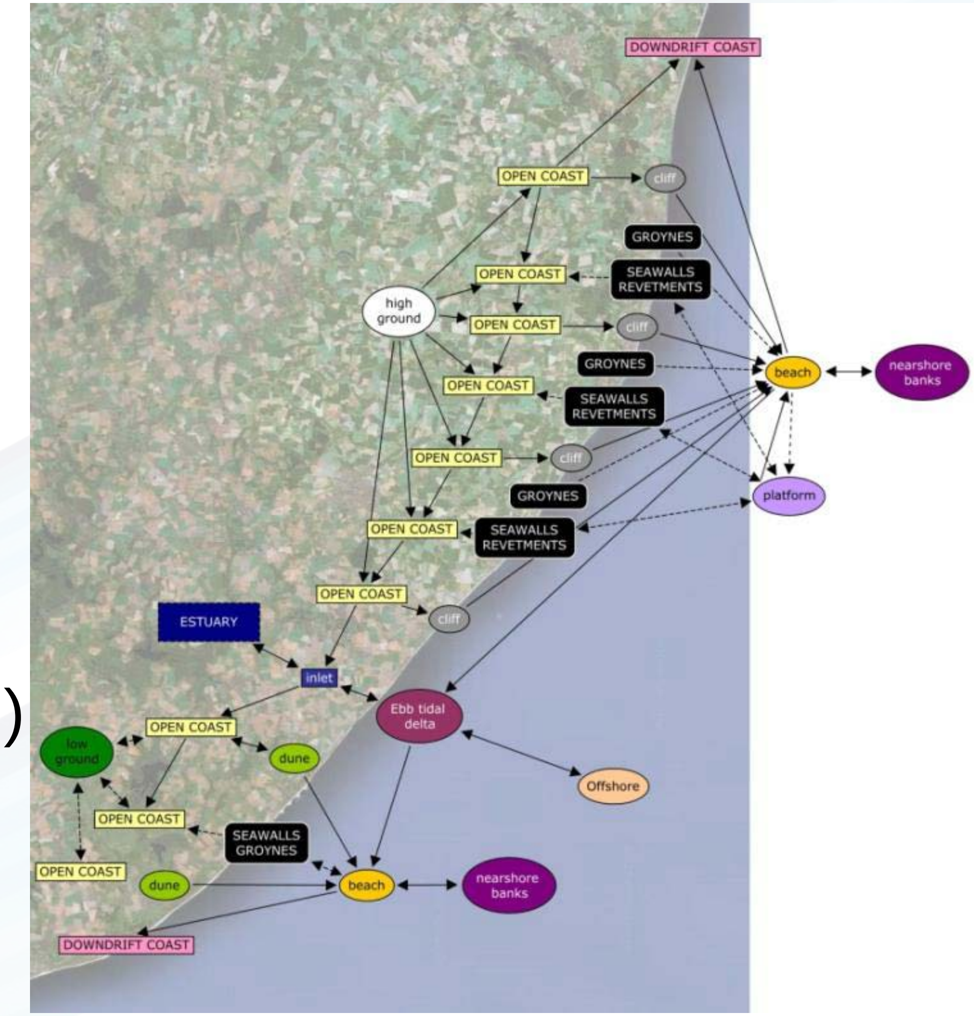
Conceptual Models





Conceptual Models

- Offshore banks
- Longshore beach
- Cross-shore beach
- Soft cliff/platform
- Dune
- Estuary
- (Engineering intervention)



Model Integration

iCOASST
integrating coastal sediment systems

Approach

Integrate three methods

1. **Coastal systems mapping**
2. **Behavioural systems and data-driven modelling**
3. **Process-based modelling**

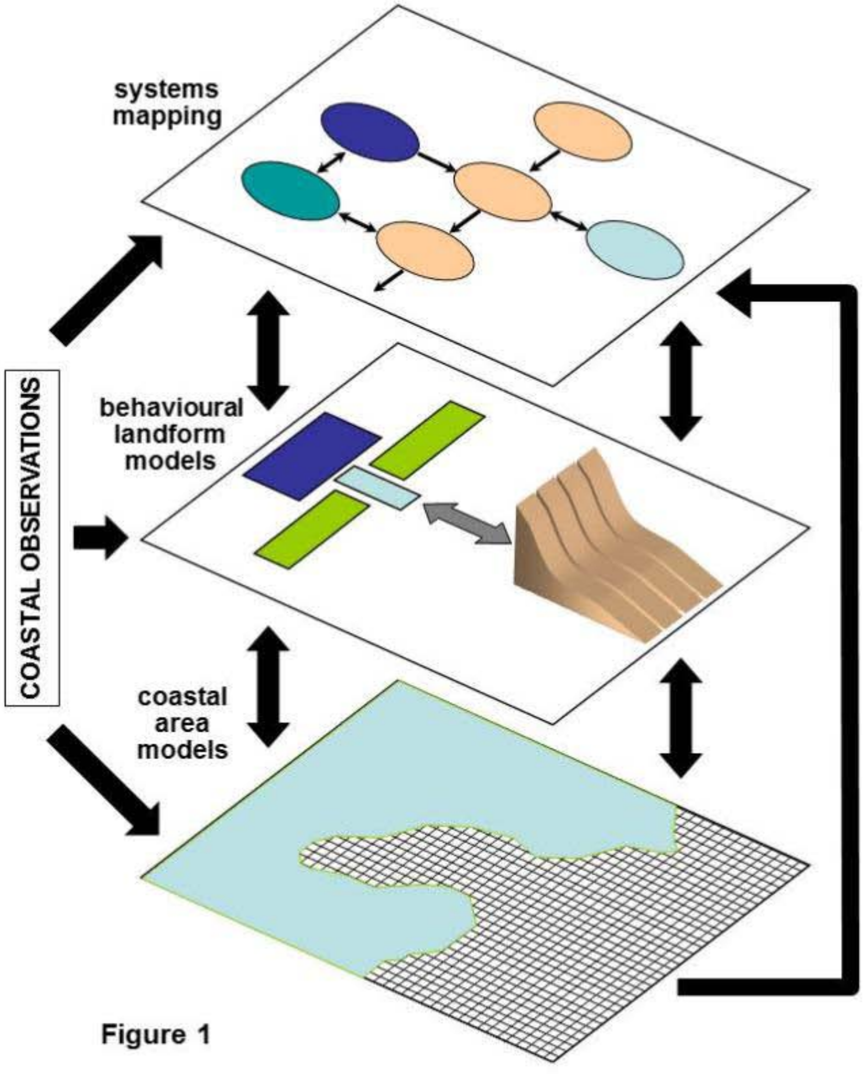


Figure 1

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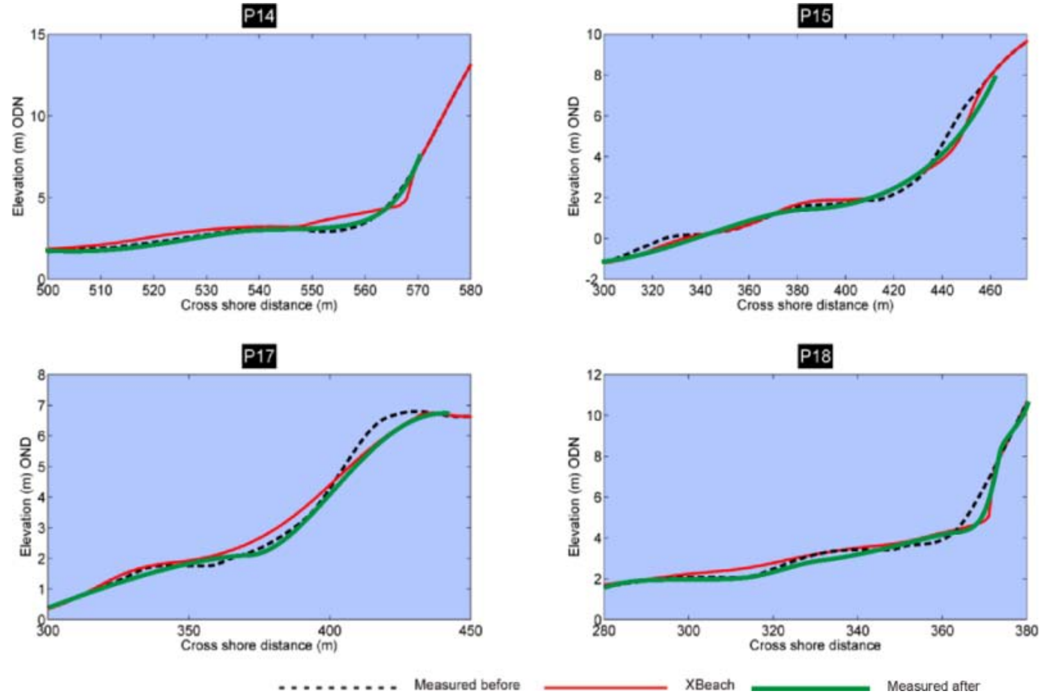
Model Integration



e.g. Xbeach modeling

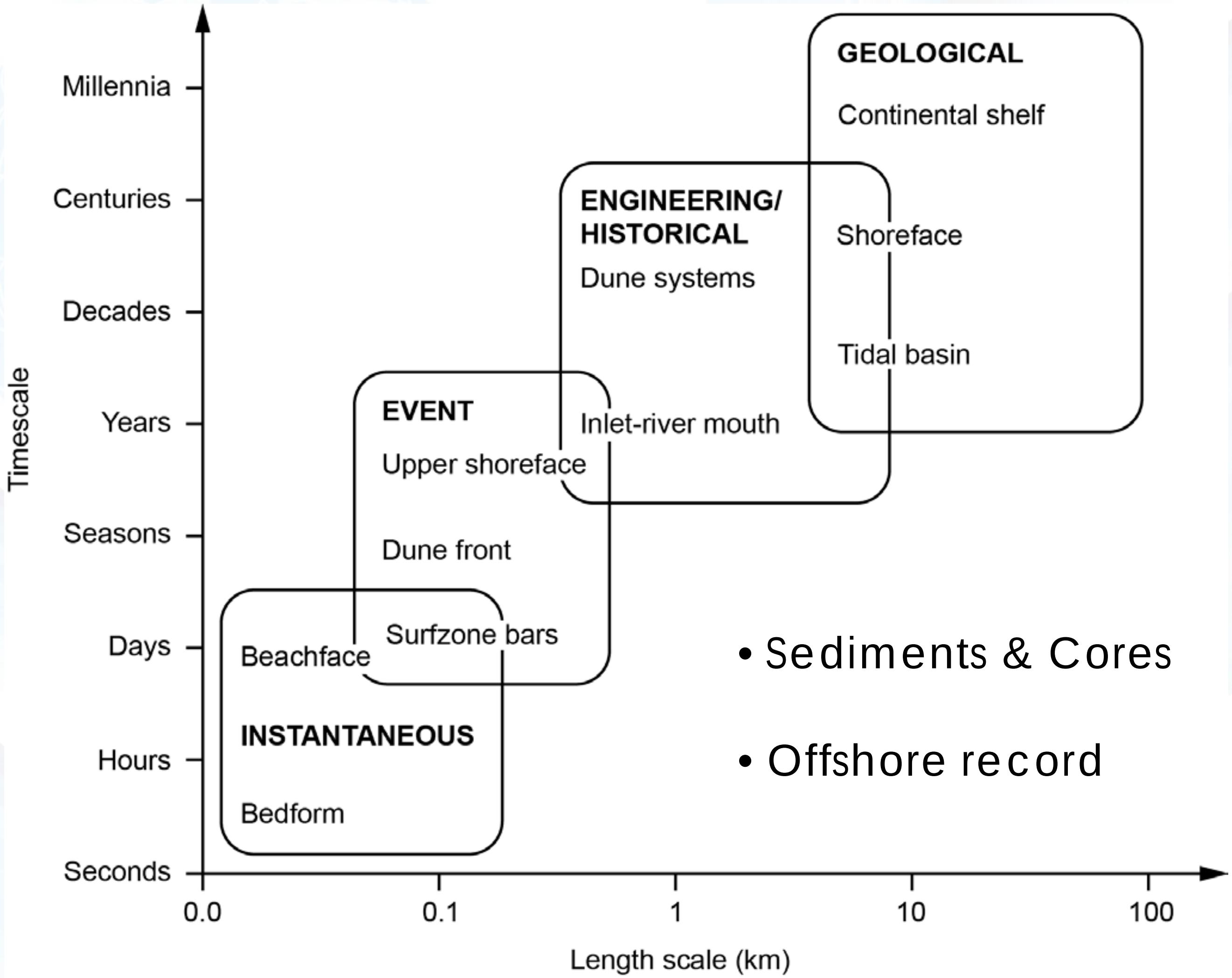
Esteves et al (2012)

e.g. Probabilistic shoreline retreat

Ranasinghe (2012)

Panzeri et al. (2012)

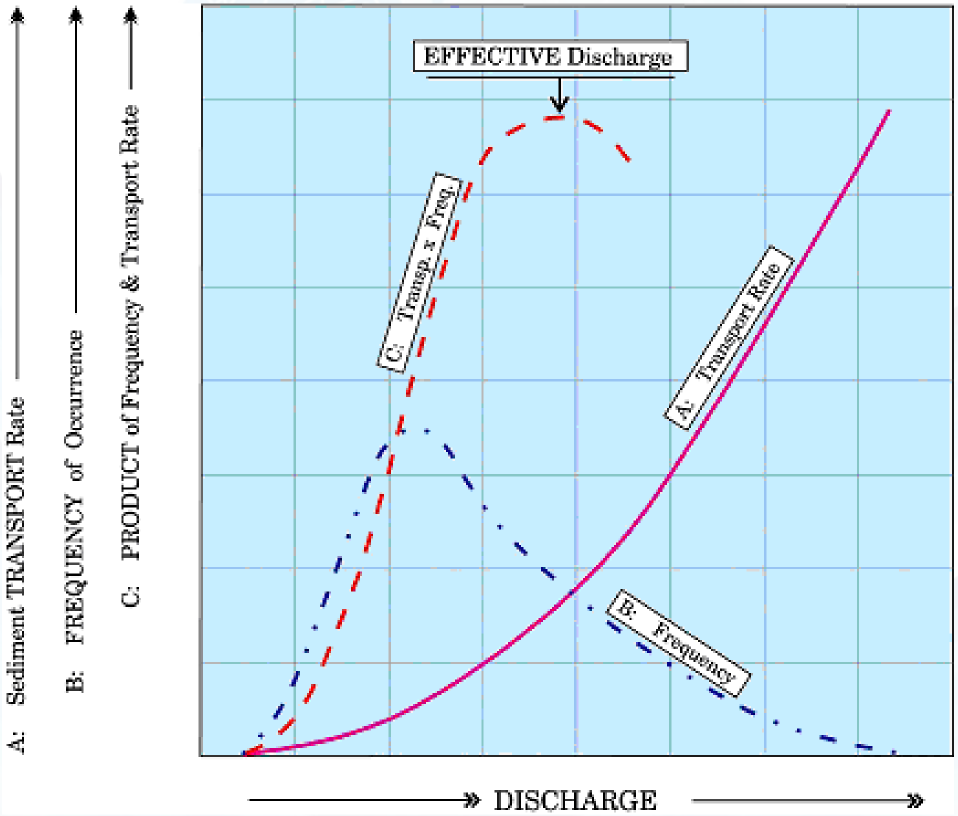
Bridging Operational Scales...



- Sediments & Cores
- Offshore record

After Cowell and Thom (1994)

Magnitude & Frequency?



Wolman and Miller (1960)
http://geomorphology.sese.asu.edu/Papers/Wolman_and_Miller_1960.pdf

Gradual (mm/yr) vs.
Catastrophic (m/hr)

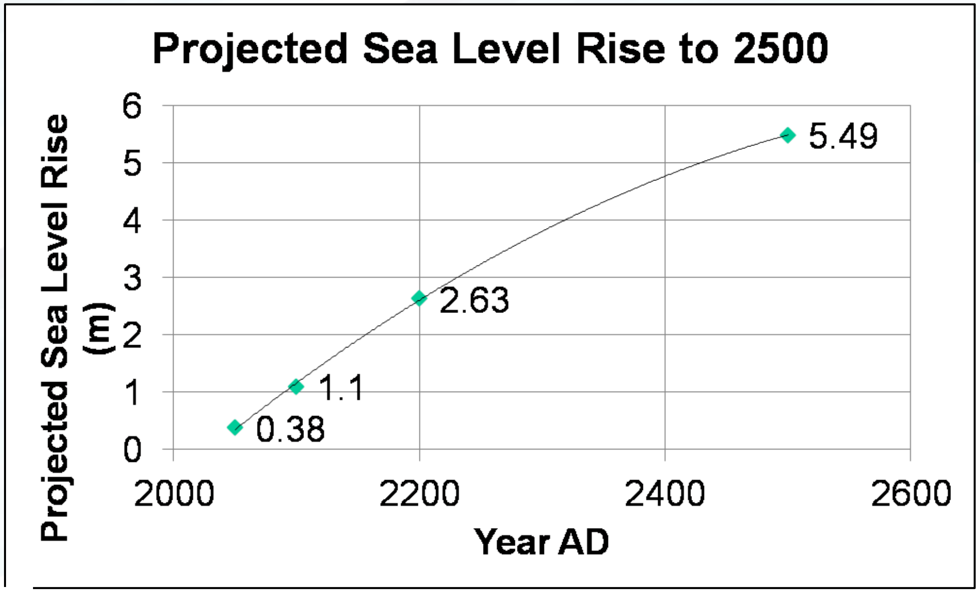
ARCoES Flood Risk Assessments to 2500 AD

Flood and coastal risk mapping requirement according to EA guidelines for NNB (Cefas, EDF, NDA)

Jevrejeva et al. (2012) Global and Planetary Change 80-81, 14-20.

First assessments are based on low probability but plausible events from the higher Representative Concentration Pathway scenario values.

LISFLOOD-FP modelling

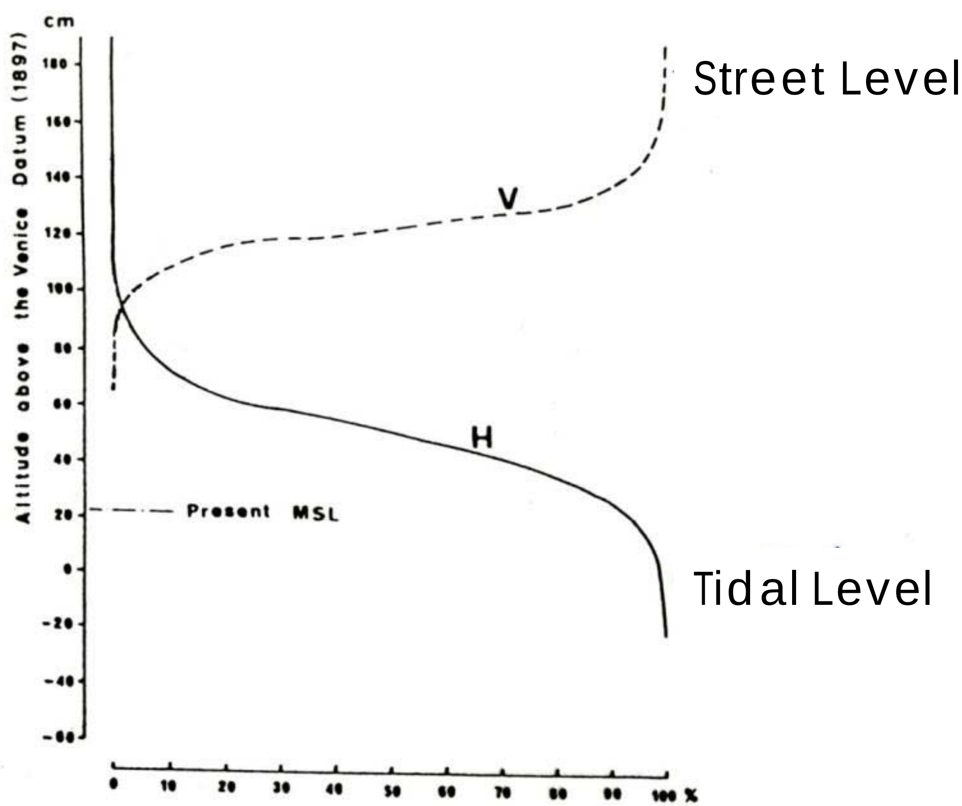


When does sea-level rise flooding change from an inconvenience to a life-threatening hazard?

+ 30cm: St. Mark’s Square flooded on 75% of tides, for 27% of the year

+100 cm: 40% of street level below MSL, St. Mark’s Square >50cm below MSL

Pirazolli (1991)
http://www.jstor.org/stable/4297819?seq=7



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Ecosystem Services from Rivers and Wetlands

Provisioning Services	Cultural Services
Food (fish, game, fruit, grain etc) Fresh water (storage, retention, supply) Fibre and Fuel (timber, fuel, peat, aggregates) Biochemicals (materials from biota) Genetic materials (medicine, resistance to pathogens, ornaments)	Spiritual (well-being, religion) Recreation (tourism, activities) Aesthetic (appreciation) Education (opportunities)
Supporting Services	**Regulating Services**
Biodiversity (habitats) Soils (retention, accumulation) Nutrient cycling (storage, processing) Pollination (habitat and support)	Climate (GHGs, temp, rain, CO_2) Hydrology (recharge, discharge, storage) Pollution (retention, removal) Erosion (protection, retention) Natural Hazards (floods, storms)