



Process-based Long Term Morphological Modelling
the present state-of-the-art and the way ahead

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Les littoraux à l'heure du changement climatique (18-20 Nov 2011)



Strategic *Measures* in Dealing with our Coasts

- Protect
 - improvement of existing or design of new high water protection works
- Adjust/Adapt
 - make overflowing proof structures, create local safe areas; floating communities; houses on local mounts of sediment,
- Managed retreat
 - shift of human activities to higher, safer regions; include flood risks in spatial planning

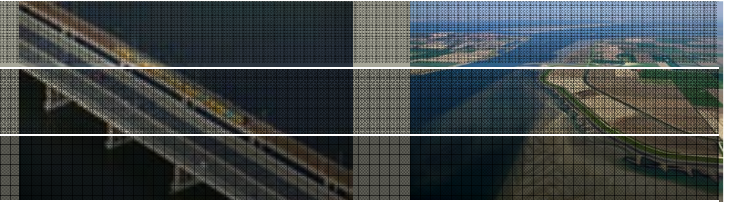
Rotterdam Barrier (1998)



dwelling mounds *(old concept)*



Coastal Defence *Strategies*



Multiple lines of defence

- Enhance stability and resilience of coastal and inland areas,
- Reducing (extreme) wave impact,
- Allowing wave overtopping and water overflowing,
- Resisting (extreme) wave impact,
- Reducing extreme flood levels,

- Risk-based and vulnerability-based approaches,
- Working with (and not against) ecosystems
- Long term coastal stability imperative for flood defence measures

Working on a range of time scales

Small scales (O(0.1 – 1) Km's & Days – Years)

- Small bays, channel siltation, storm impact, rip channels
- Effectiveness and impact of protection measures (e.g. nourishments, constructions, channel re-alignments)

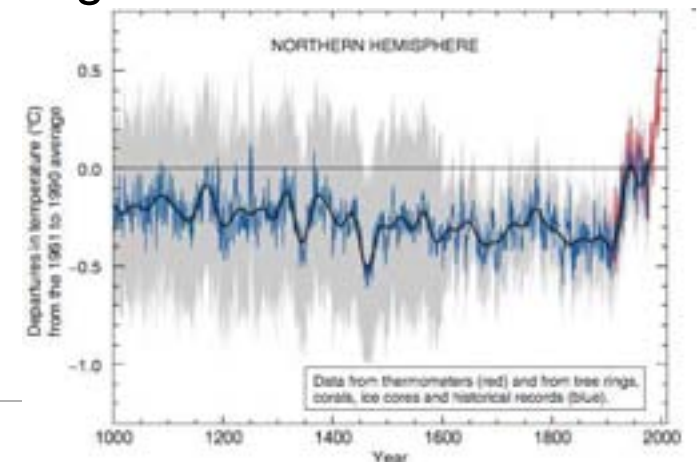
Weather forecast @ 8 O'clock news



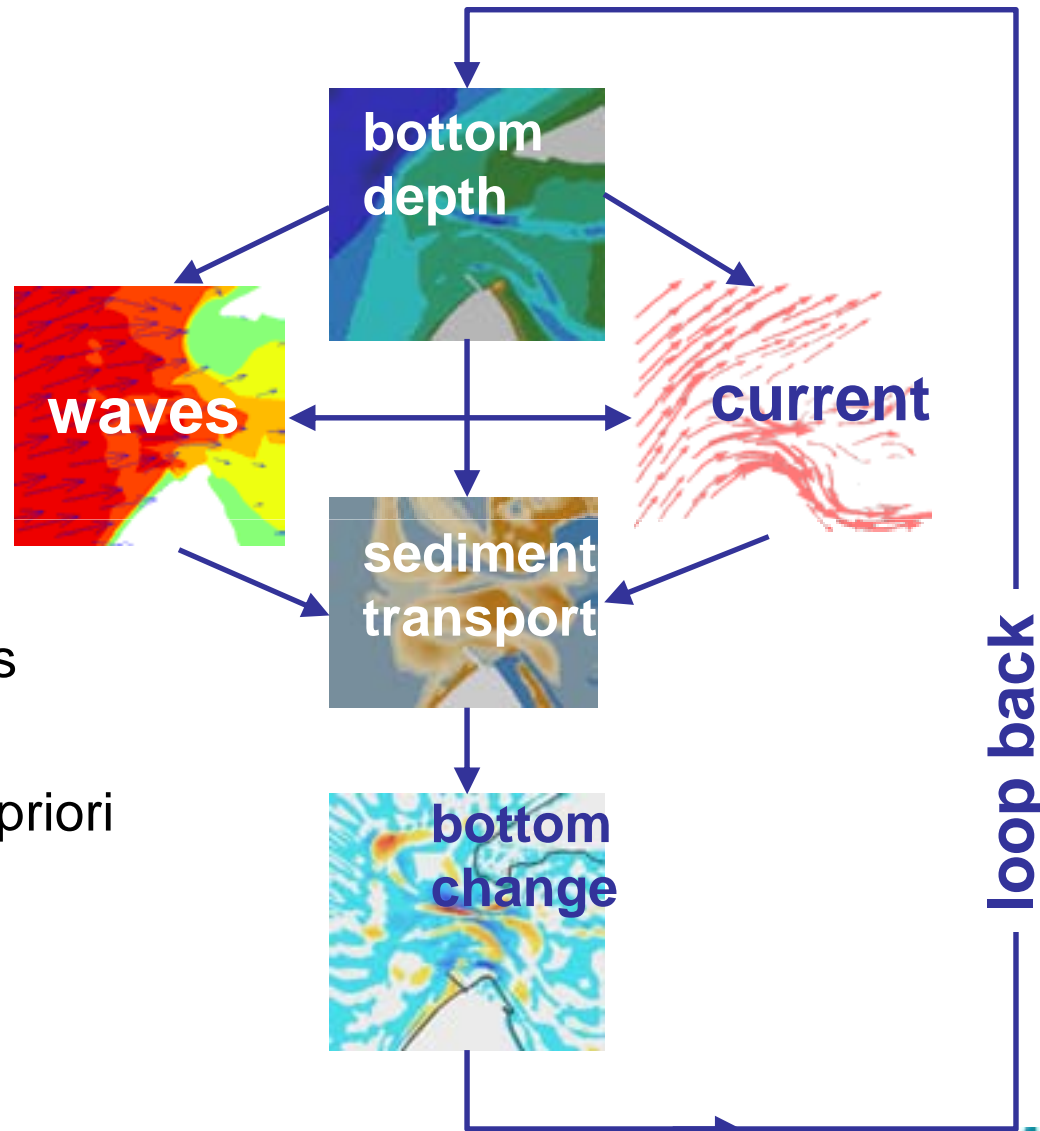
Large Scales (O(10-100) Km's & Decades – Centuries)

- Coastal systems (e.g. basins, estuaries, coastal cells, delta's)
- (Relative) Sea Level Rise, Meteorological changes (storminess, river floods)

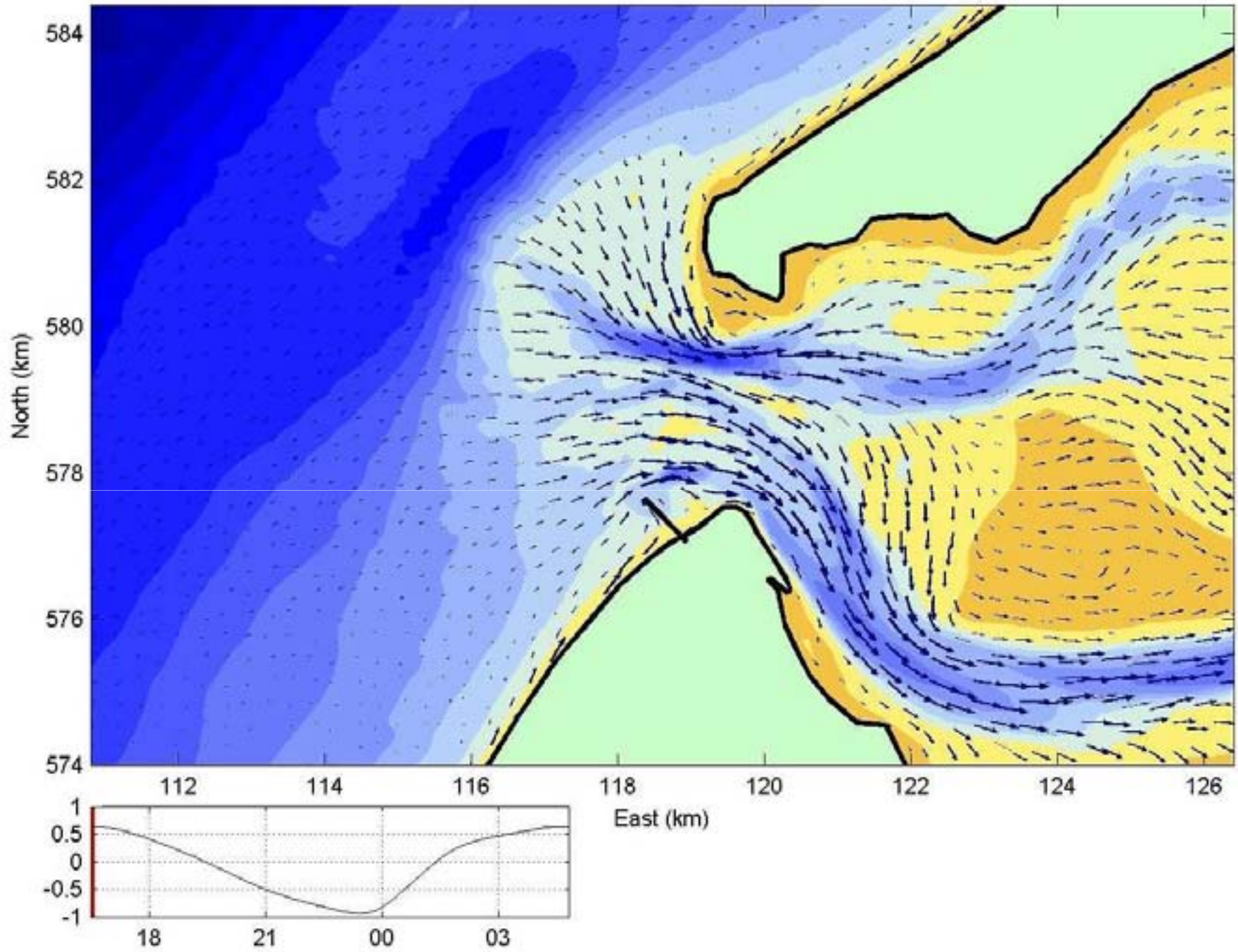
Climate forecasting: The “infamous Hockey Stick”

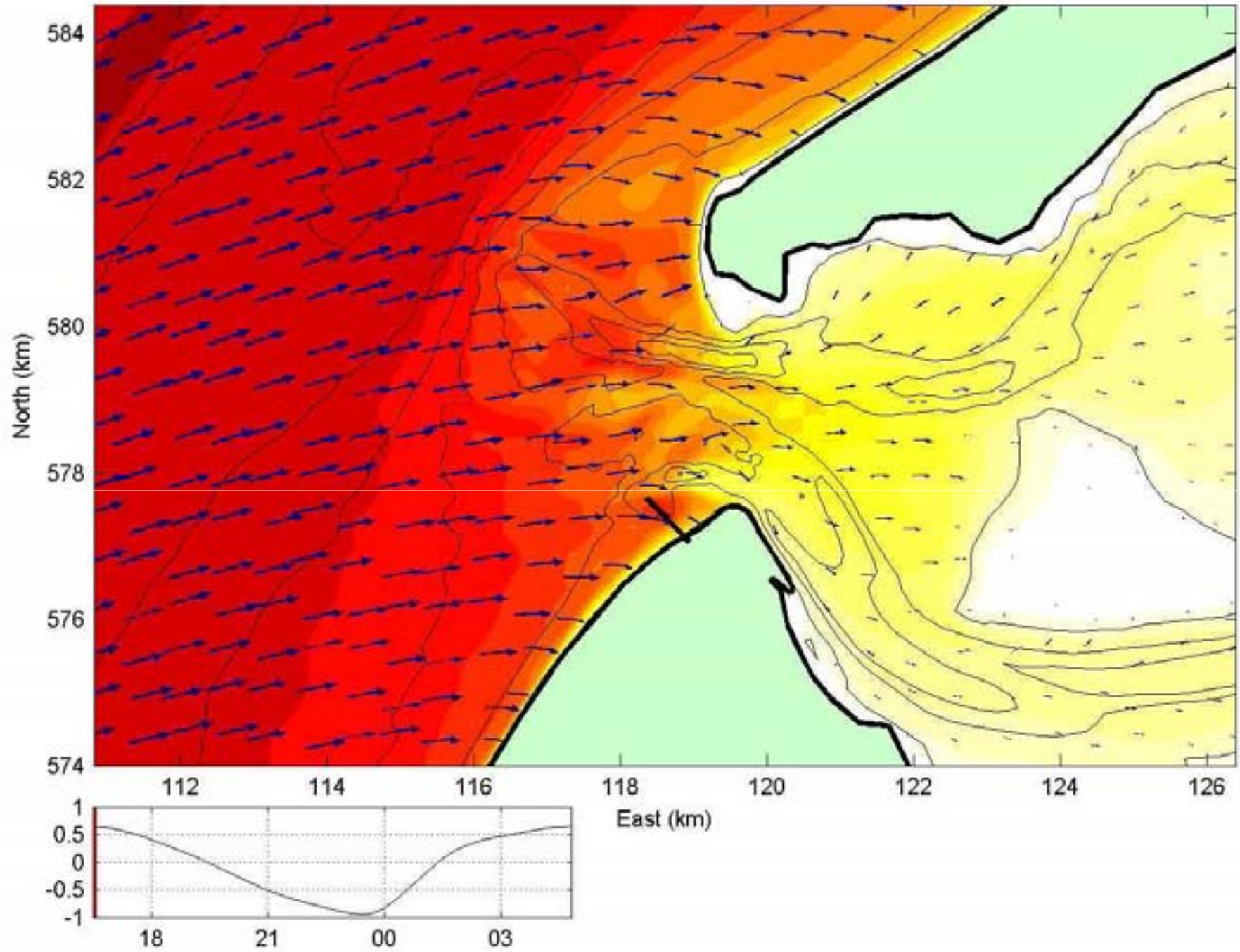


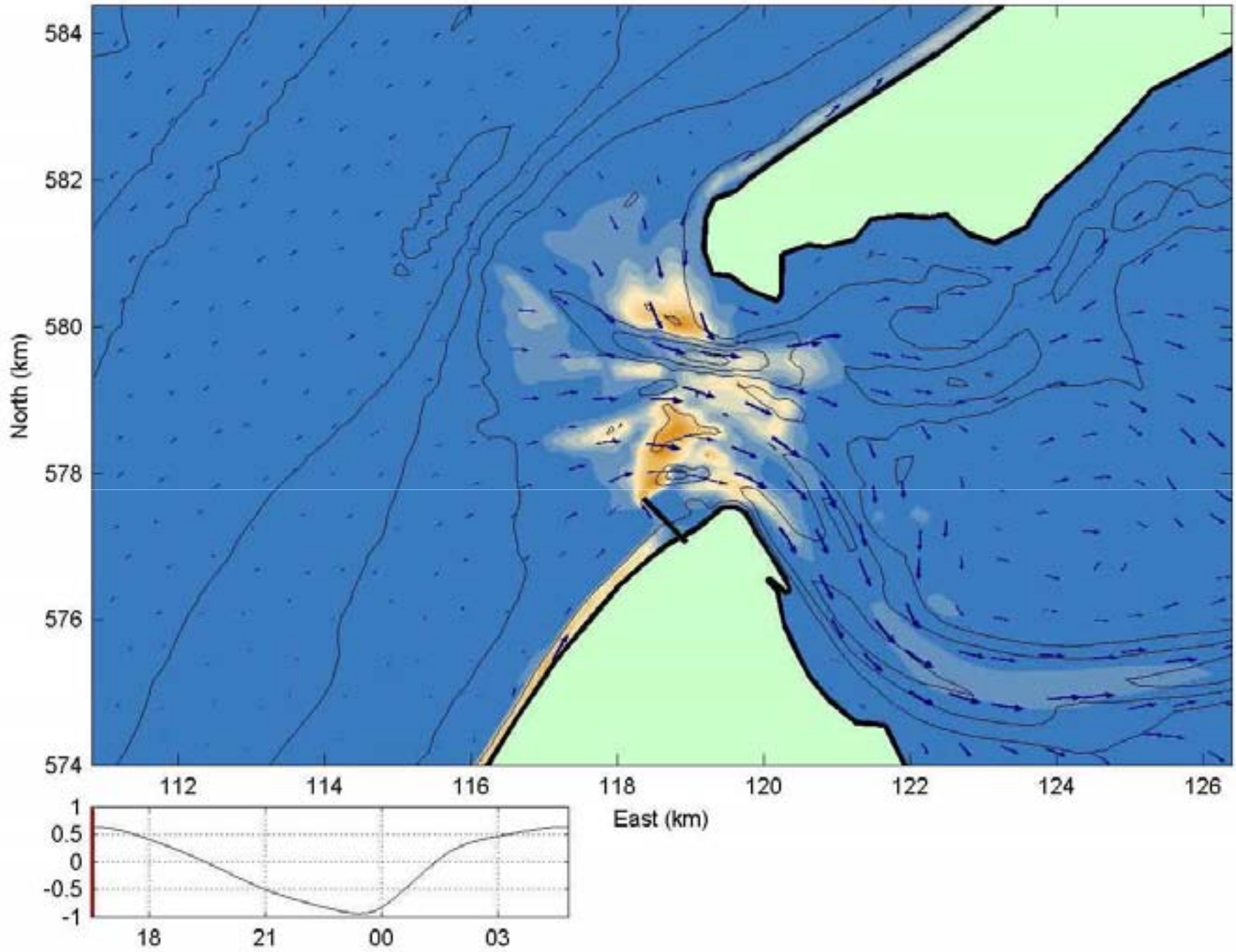
Process-based Models

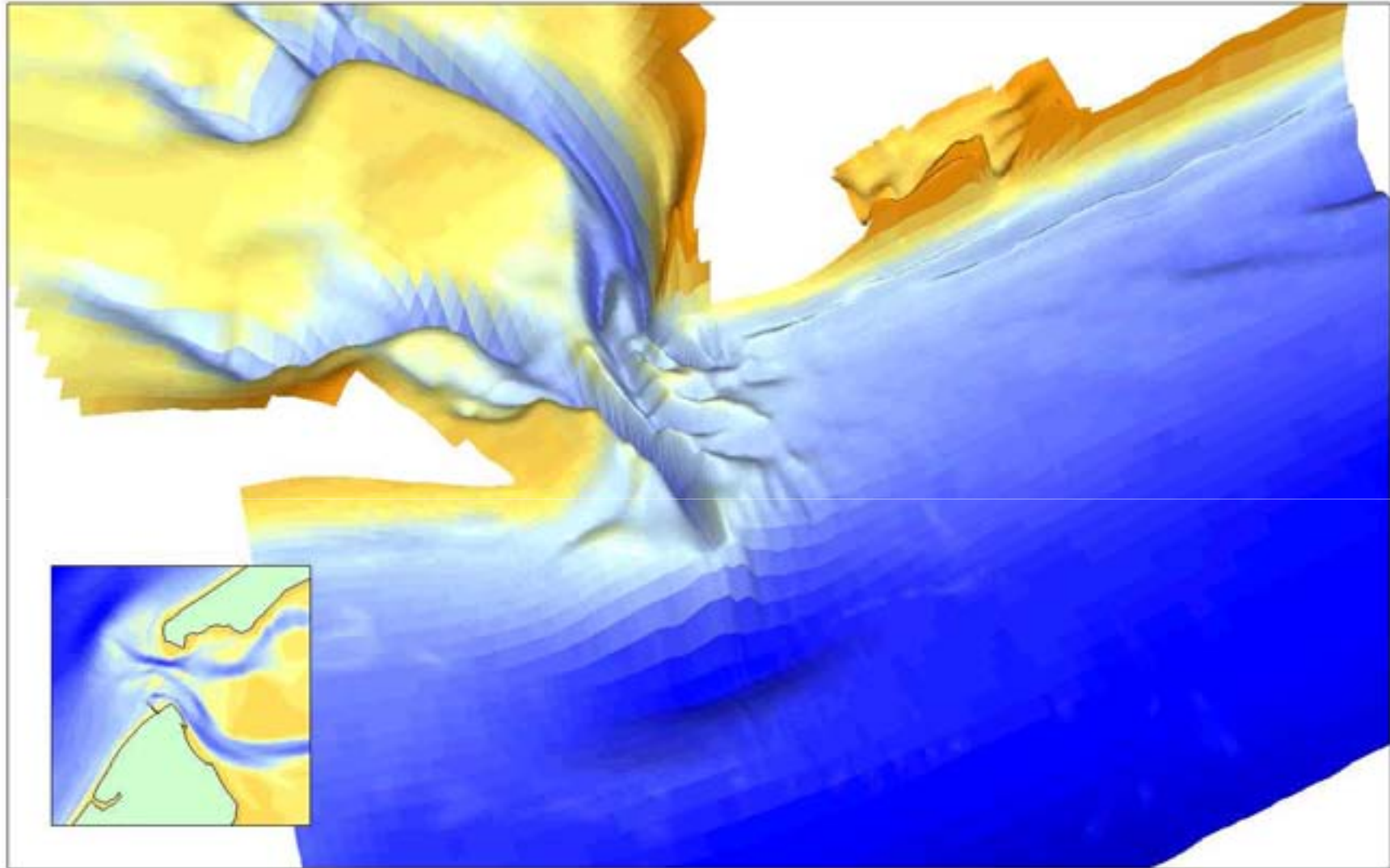


simulate basic processes
'upscaling' approach
equilibrium not known a priori
detailed representation

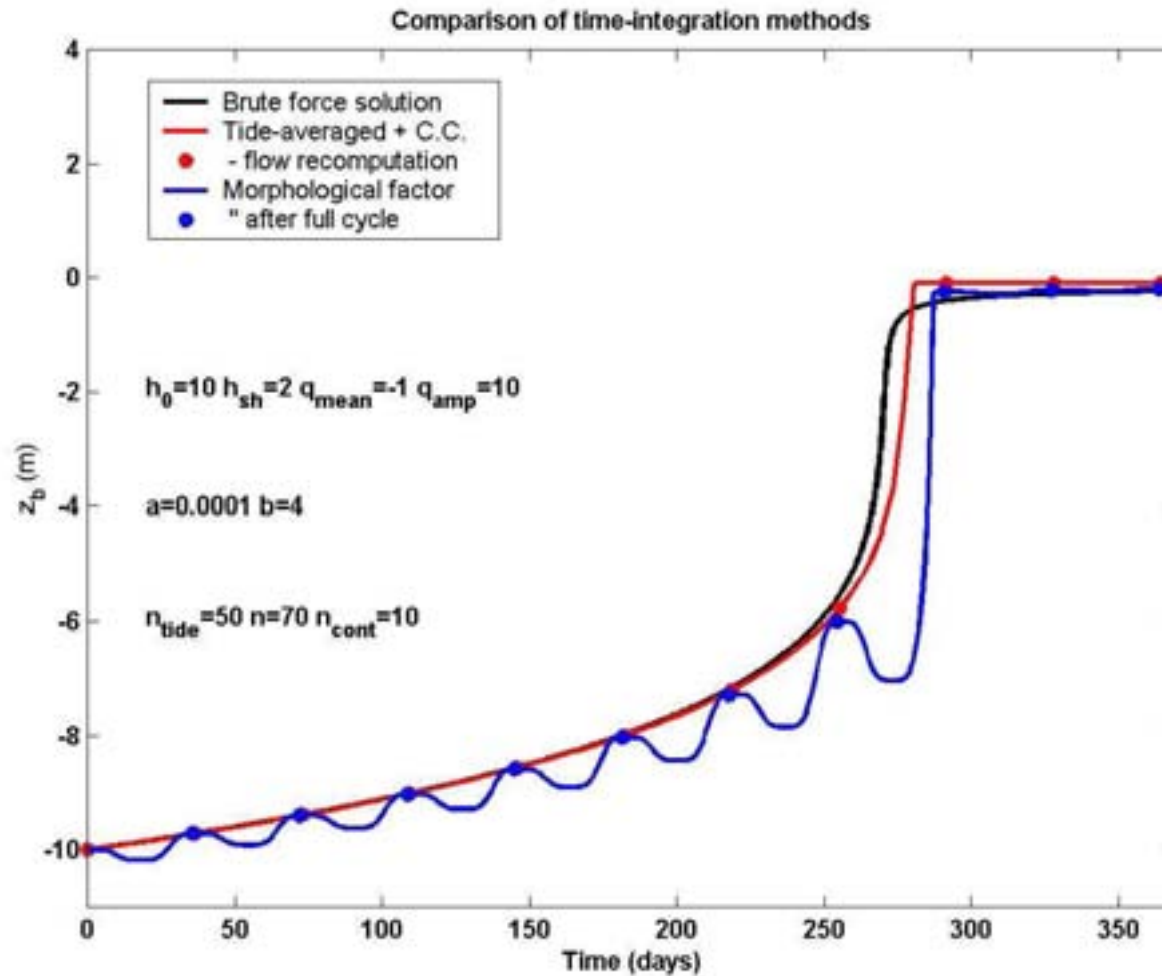








Comparison: morphological upscaling vs brute force



The role of process-based long term modelling

design/develop coastal protection *strategies* and *measures*

Using process models as testing facility (what if)

Underpinning of simpler model concepts

Understanding variability in coastal behaviour (a shift in response)

Trying to understand what is predictable and what not

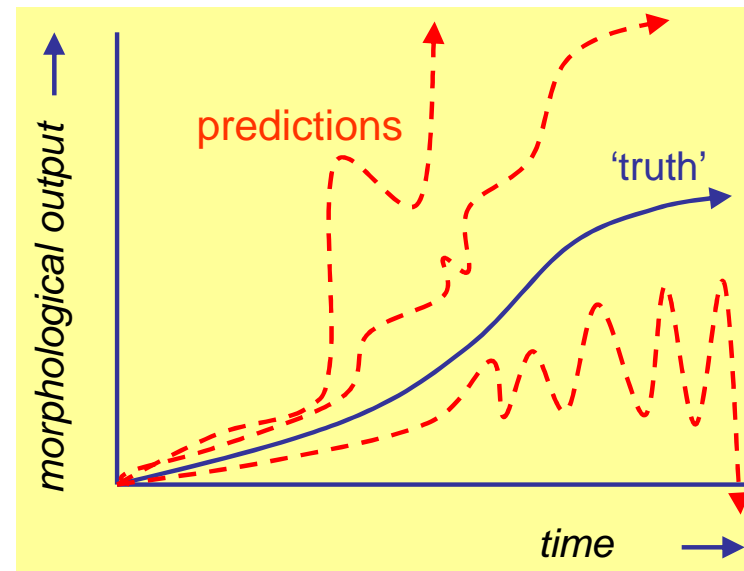
Modelling impacts of modified forcing (e.g. sea level rise, extreme events)

Challenges

Small Scales → Direct validation often possible (e.g. observed hydrodynamics & morphodynamics in field and laboratory)

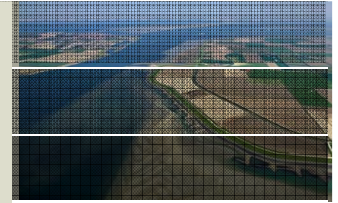
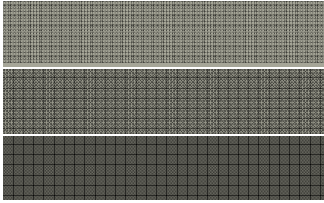
Large Scale → No direct validation possible, forcing unknown

Validity of Process Based Long Term Modelling?

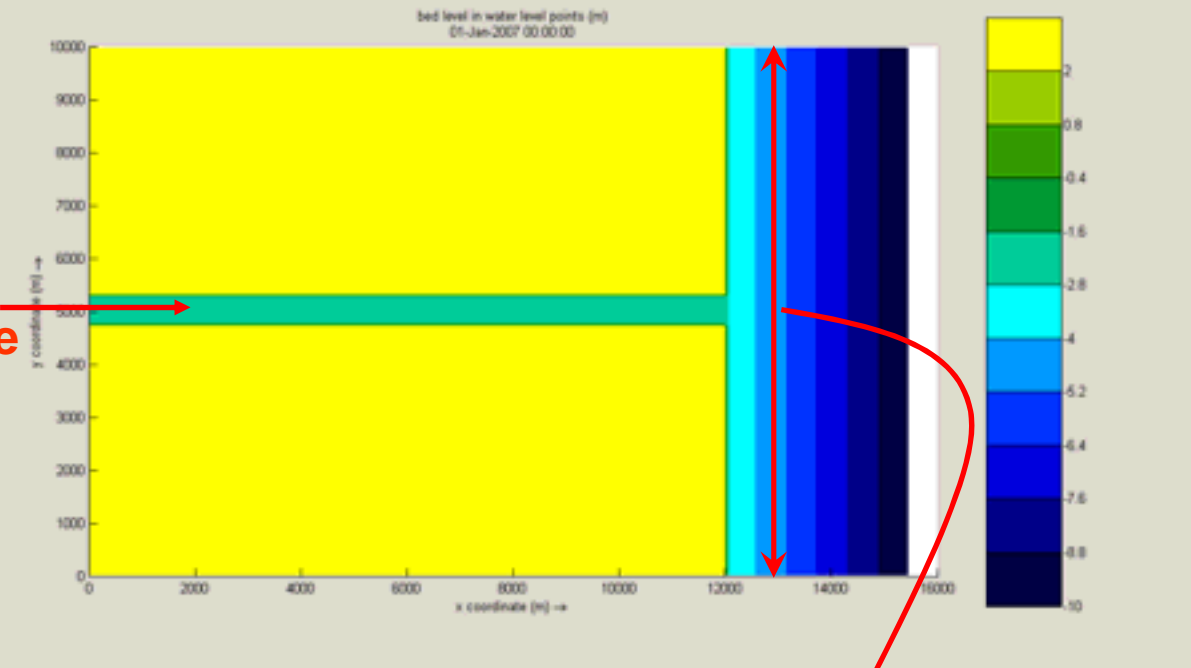


Approach to P.B. Long-term modelling

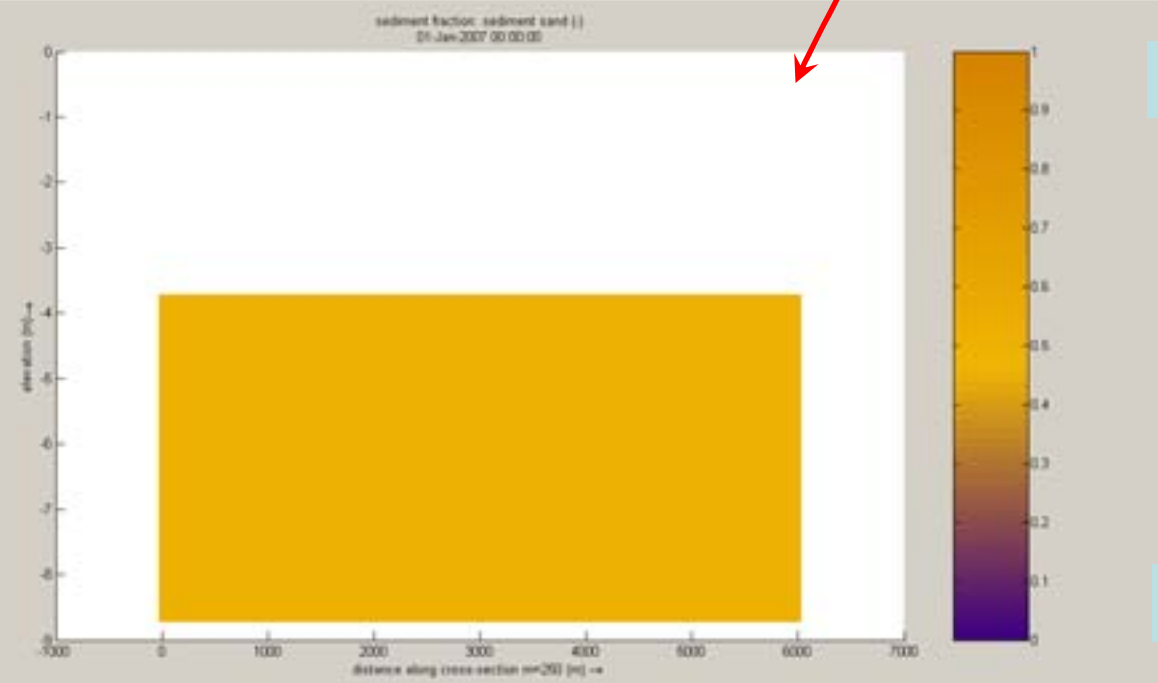
- Simple schematised cases (proof of concept)
 - Resemble empirical (equilibrium) relations
 - Identify dominant mechanisms (e.g. forcing or paleostratigraphy)
 - Identification of equilibrium
 - Impact of modified forcing
 - Interpretation based on patterns and aggregated results
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- Real cases
 - Scenarios (e.g. climate forecasts)



River Discharge



Transect

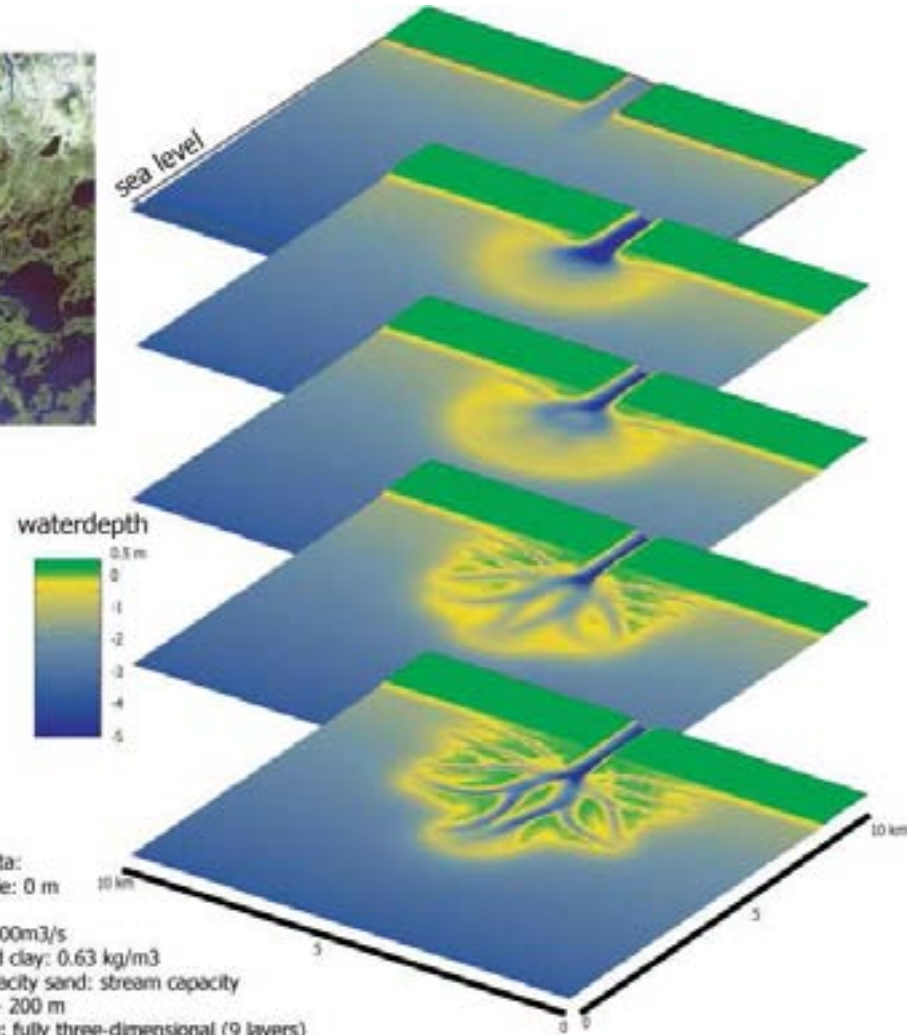
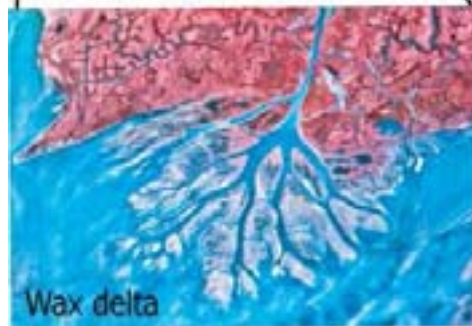


SAND

SILT

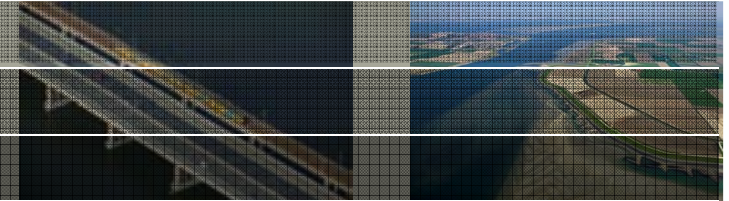


A first analogue: The Wax Delta (USA)

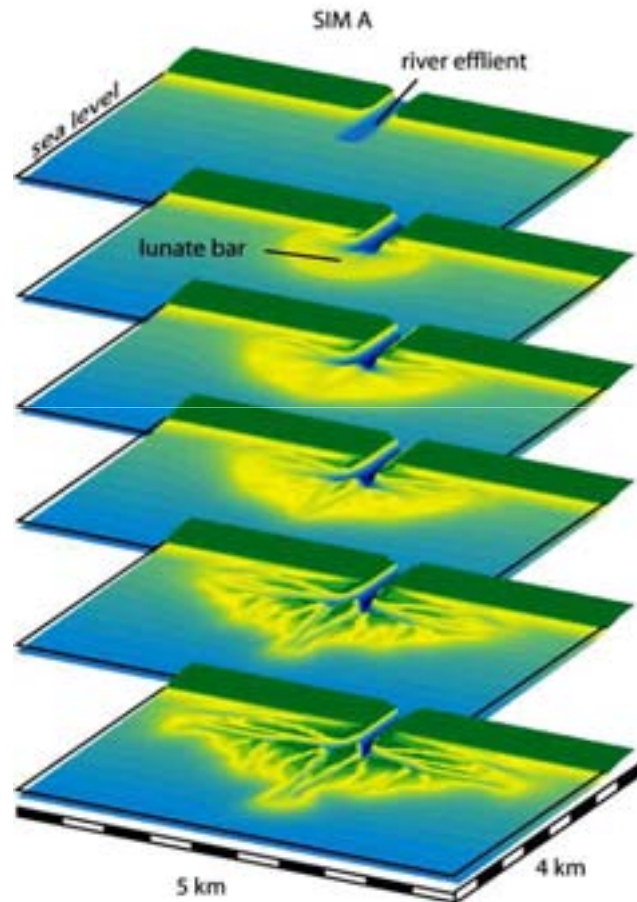


Storms et al., 2007

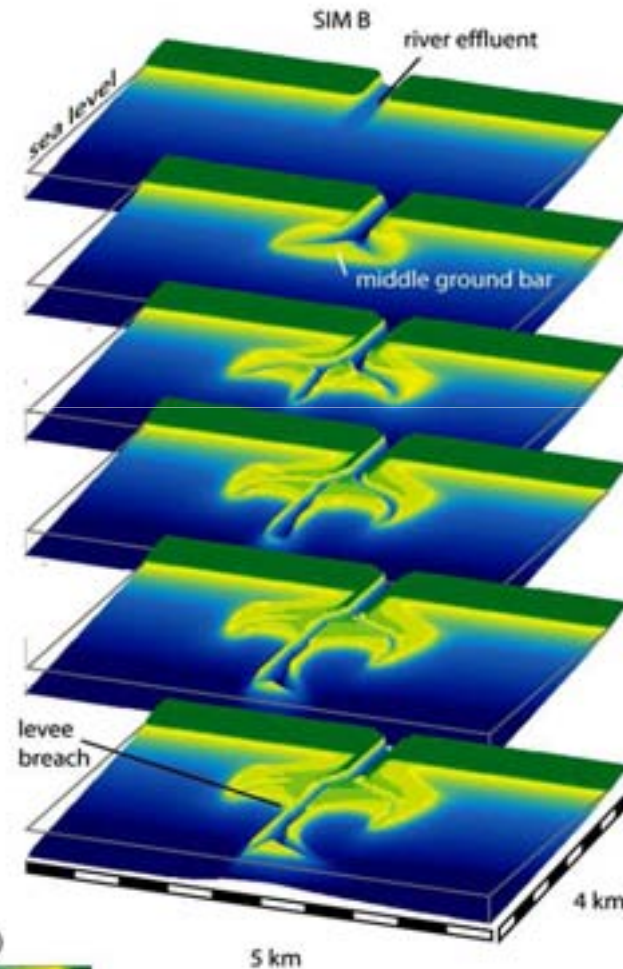
Influence of initial conditions



shallow basin



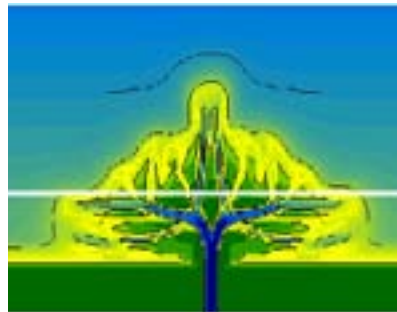
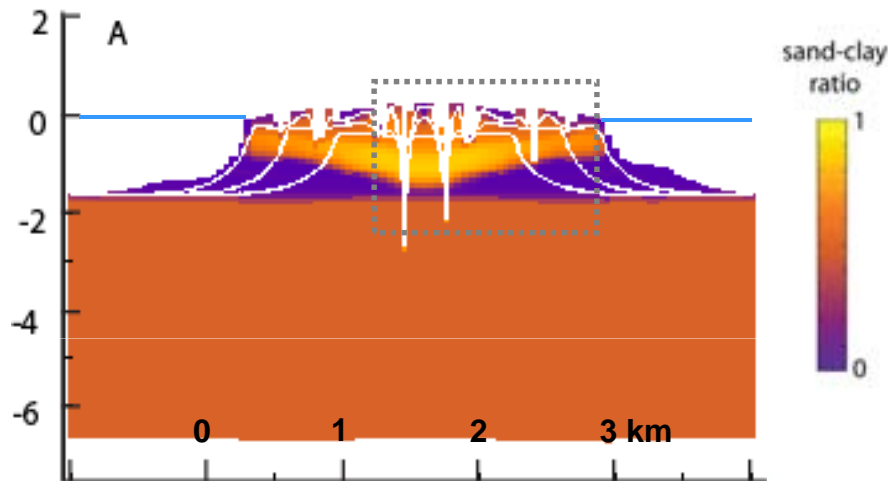
deep basin



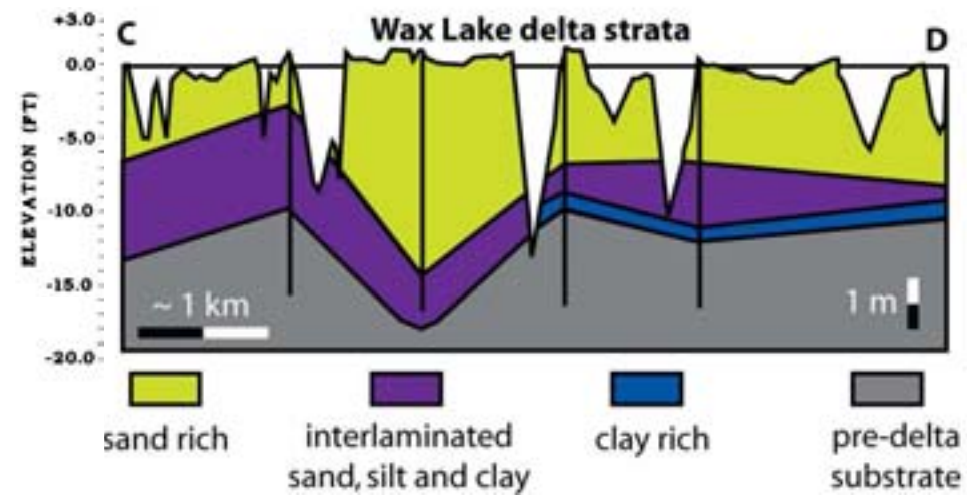
Identification of morphodynamic-stratigraphic coupling

Simulated

field data

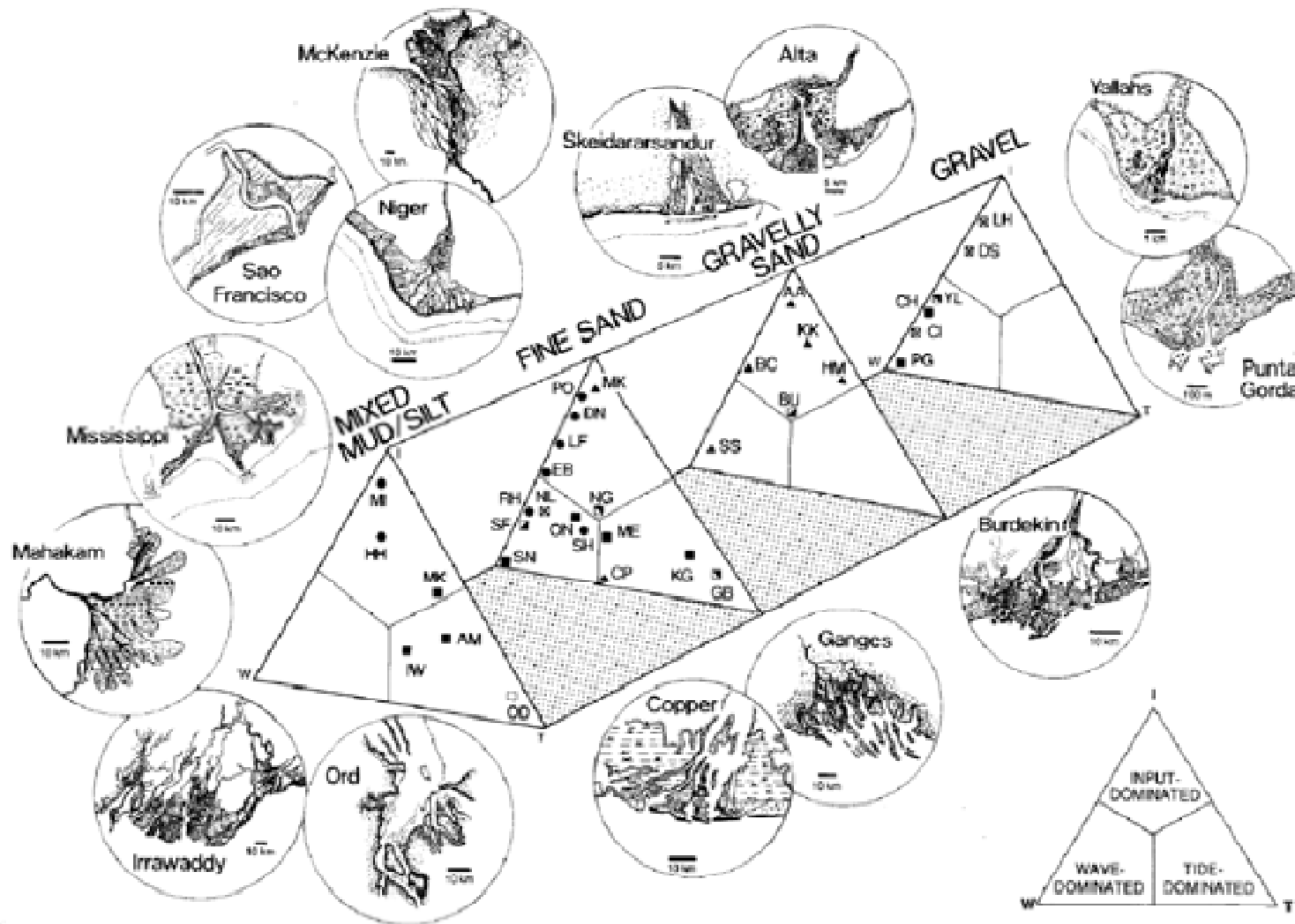
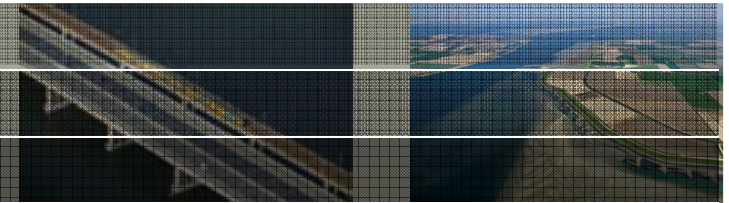


shallow basin

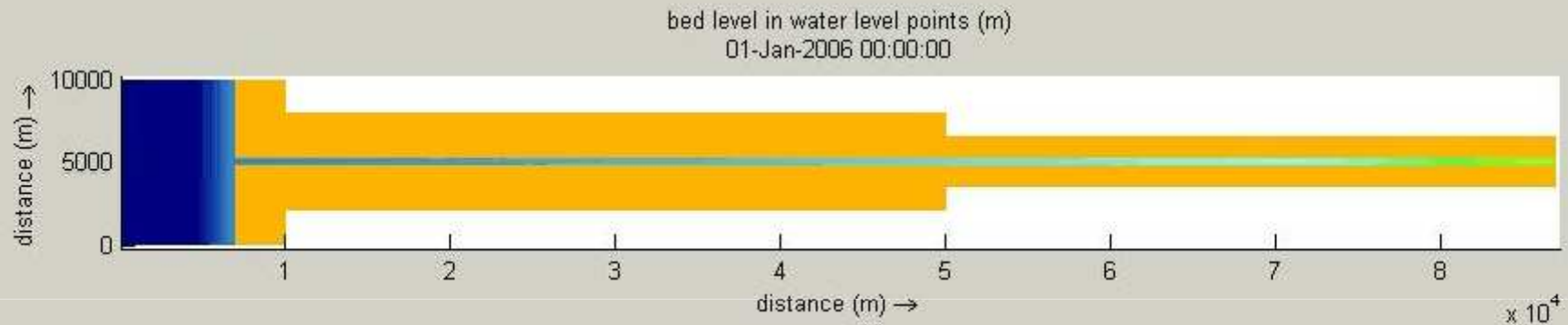


Majersky et al., 1997. BRI Bulletin

Classification of Delta's



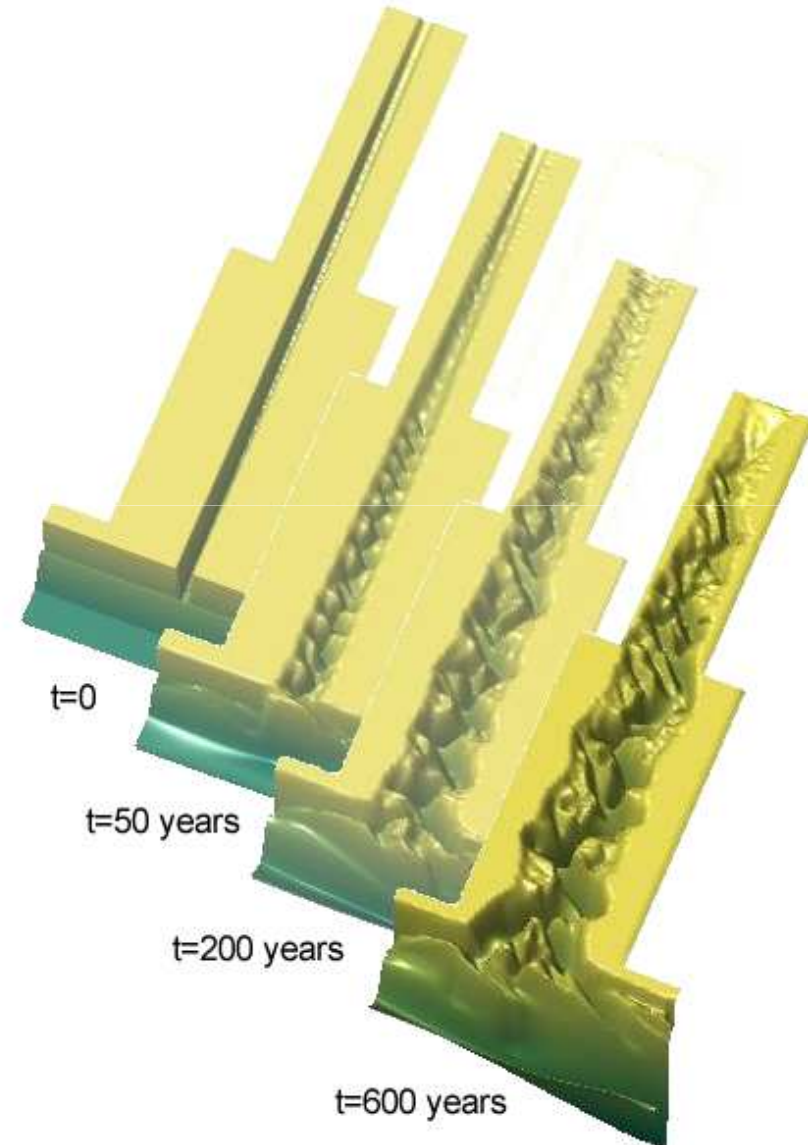
Free development of tidal estuary



Long-term behaviour of estuaries

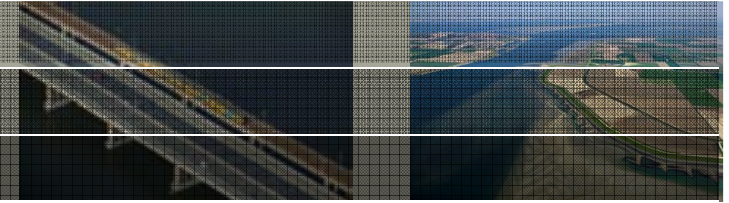
Given coastline and tidal boundaries, can we predict channel shapes, cross-section?

Does equilibrium exist?

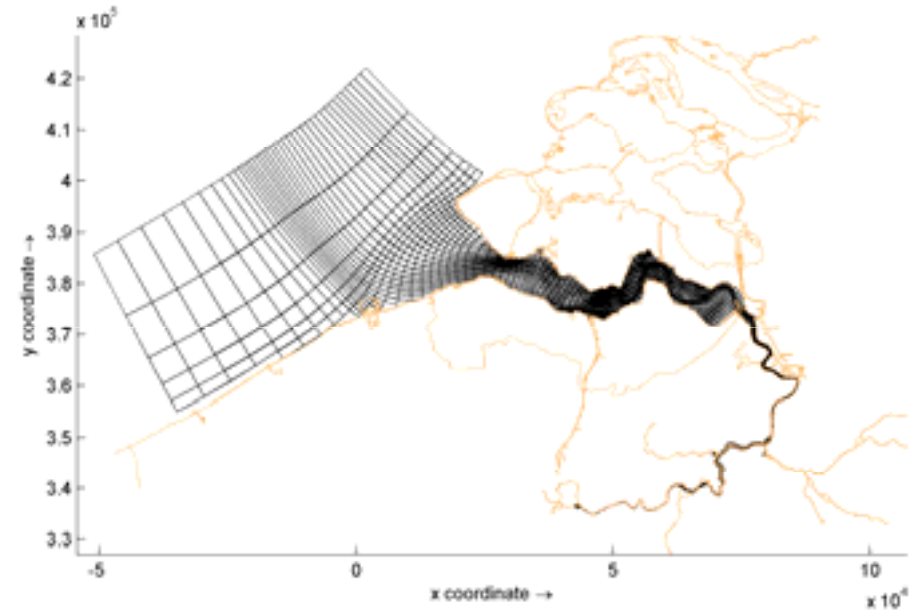
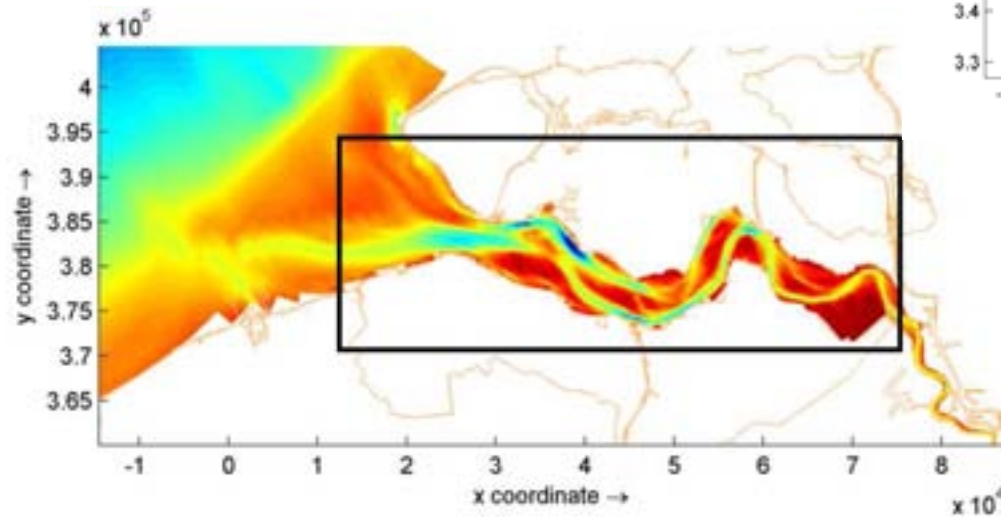


vd Wegen et al, 2008

Predicting morphology

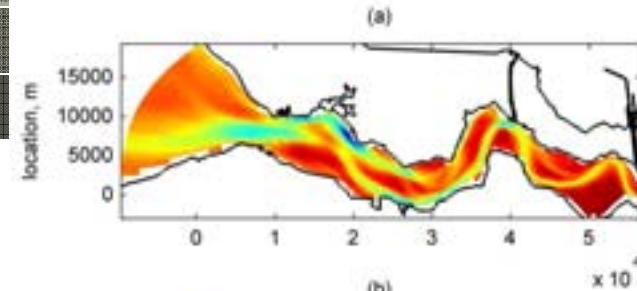


Evaluate capability of model to create morphology from flat-bed
Given tide and landboundaries
Example: Western Scheldt

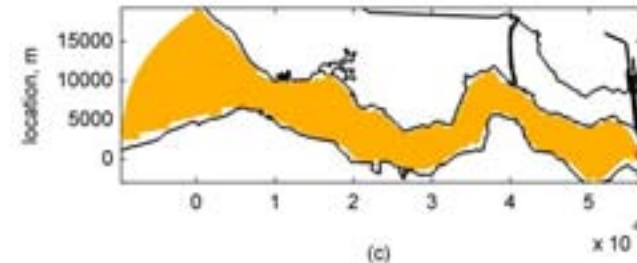


Results of Delft3D run

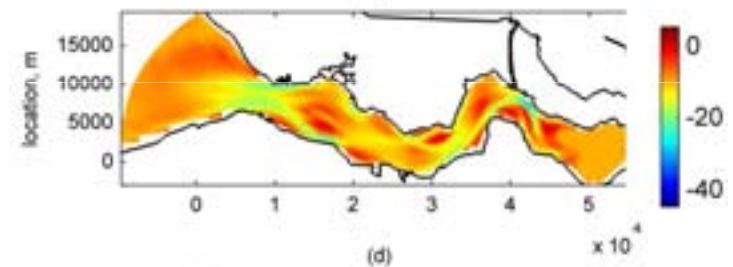
Observed 1998



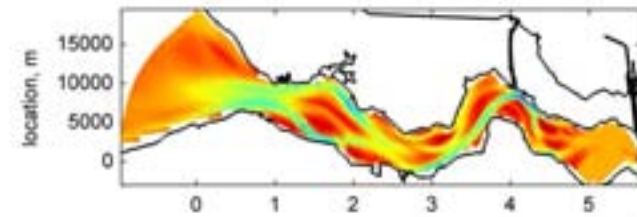
Initial flat bathymetry



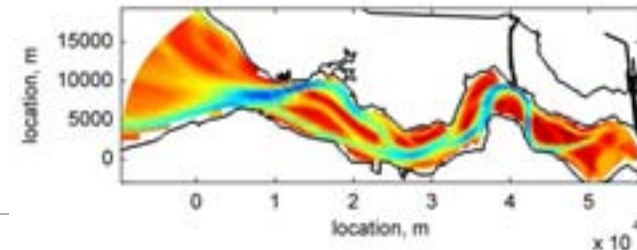
Modelled, 15 yrs



Modelled, 30 yrs

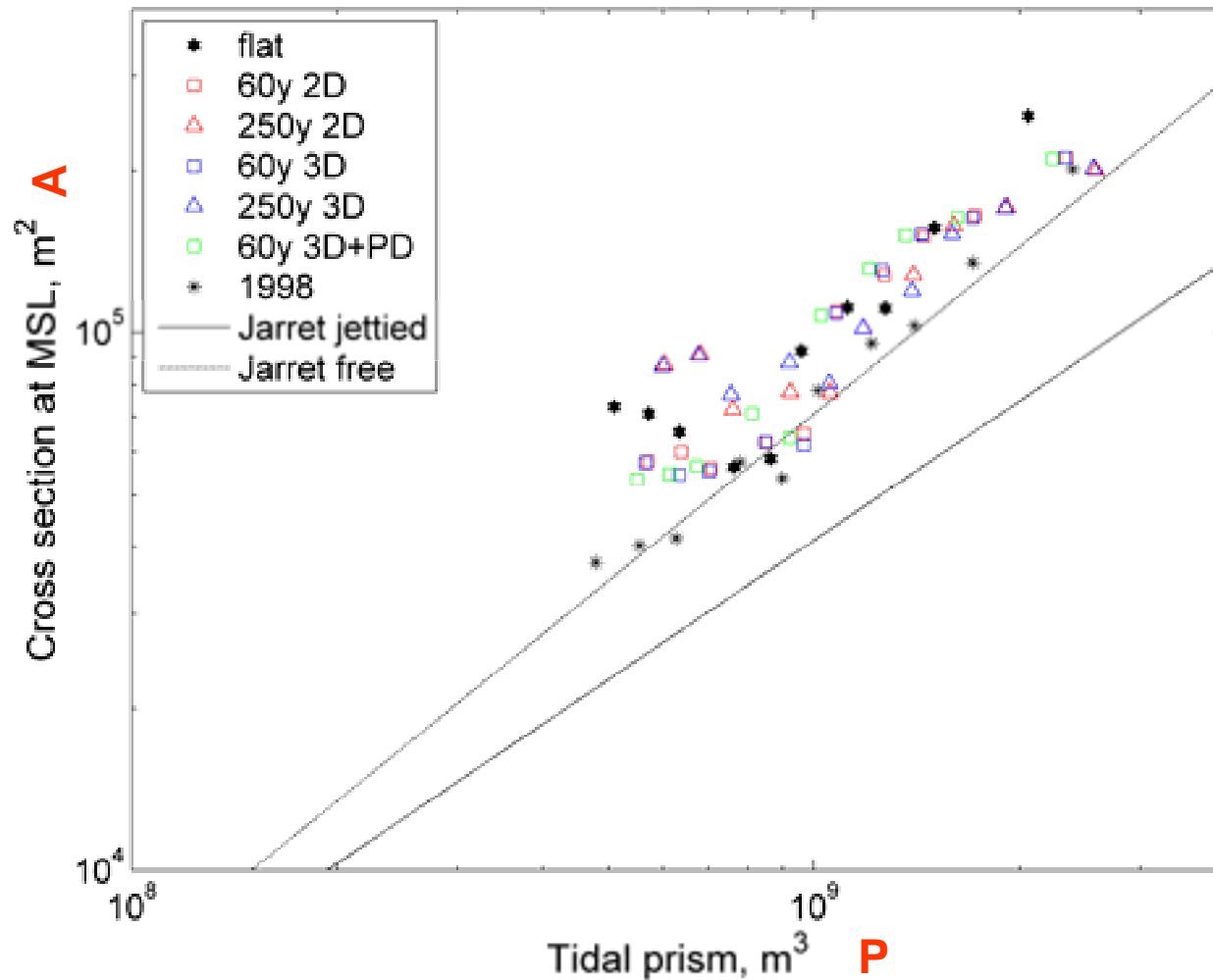


Modelled, 200 yrs

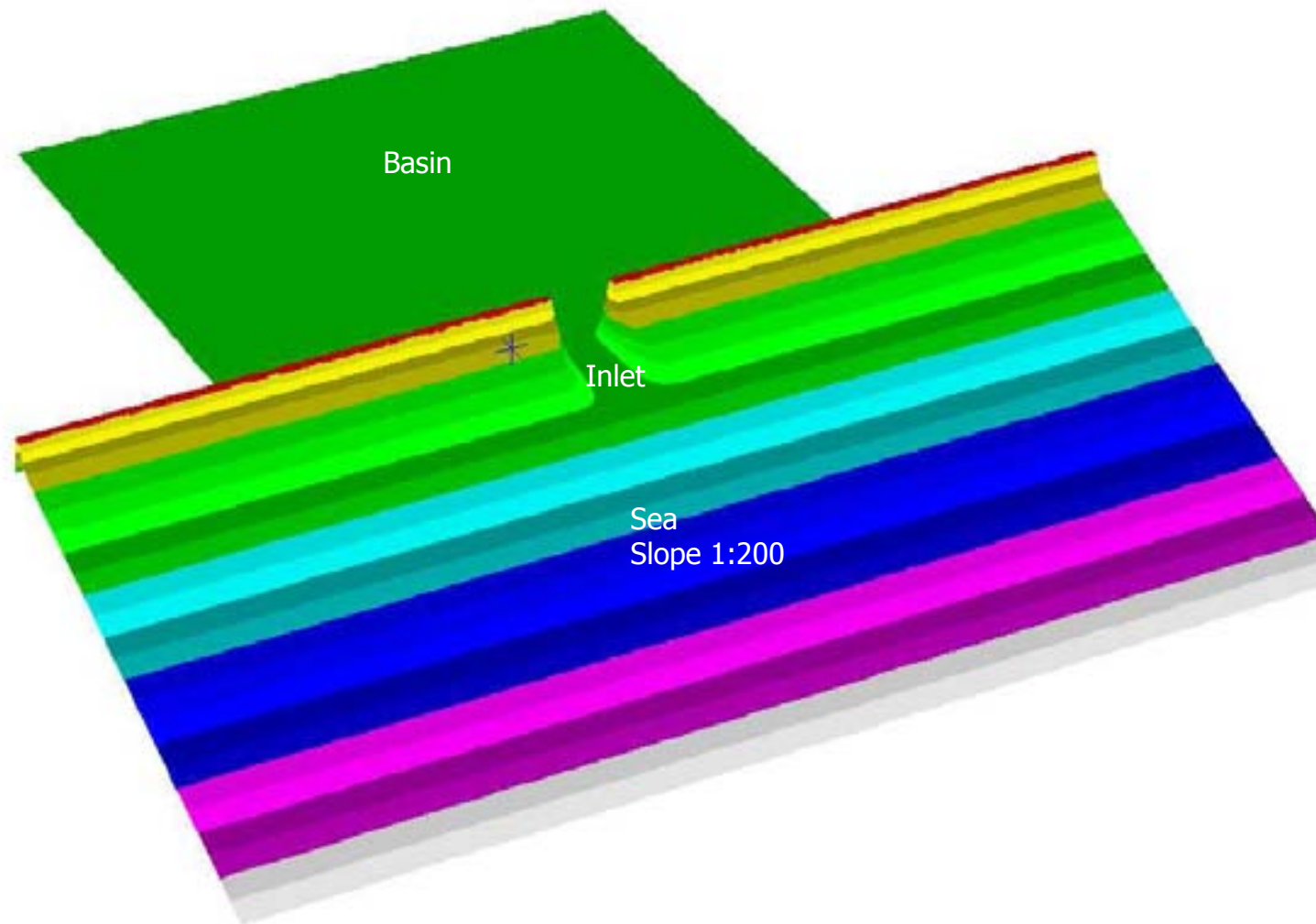


Comparison with empirical formulation

$$\text{Jarrett (1976)} \quad A = C * P^n$$

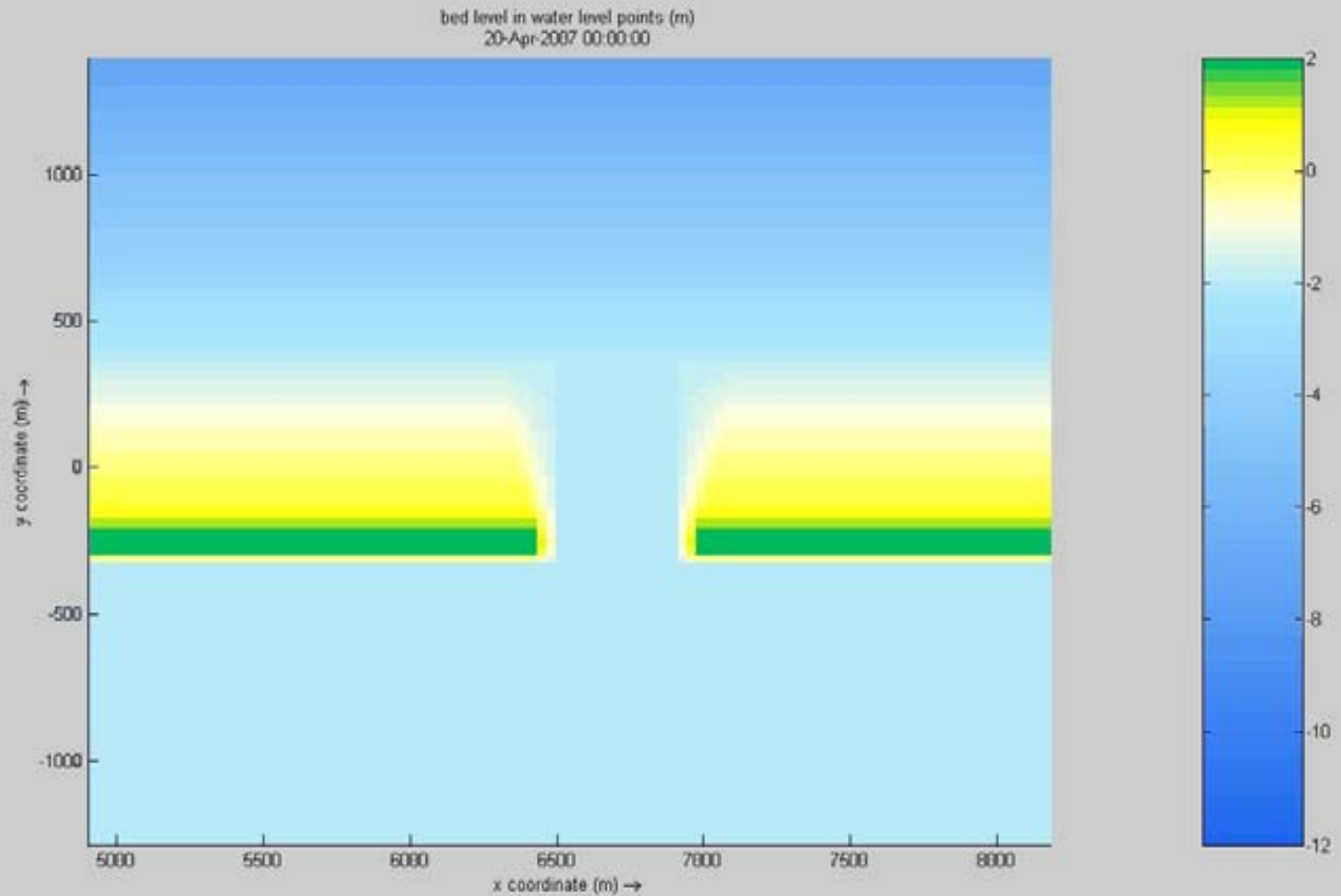


Inlet Response to combined Tide & Wave action



109

Schematic inlet systems (Tide & Waves)

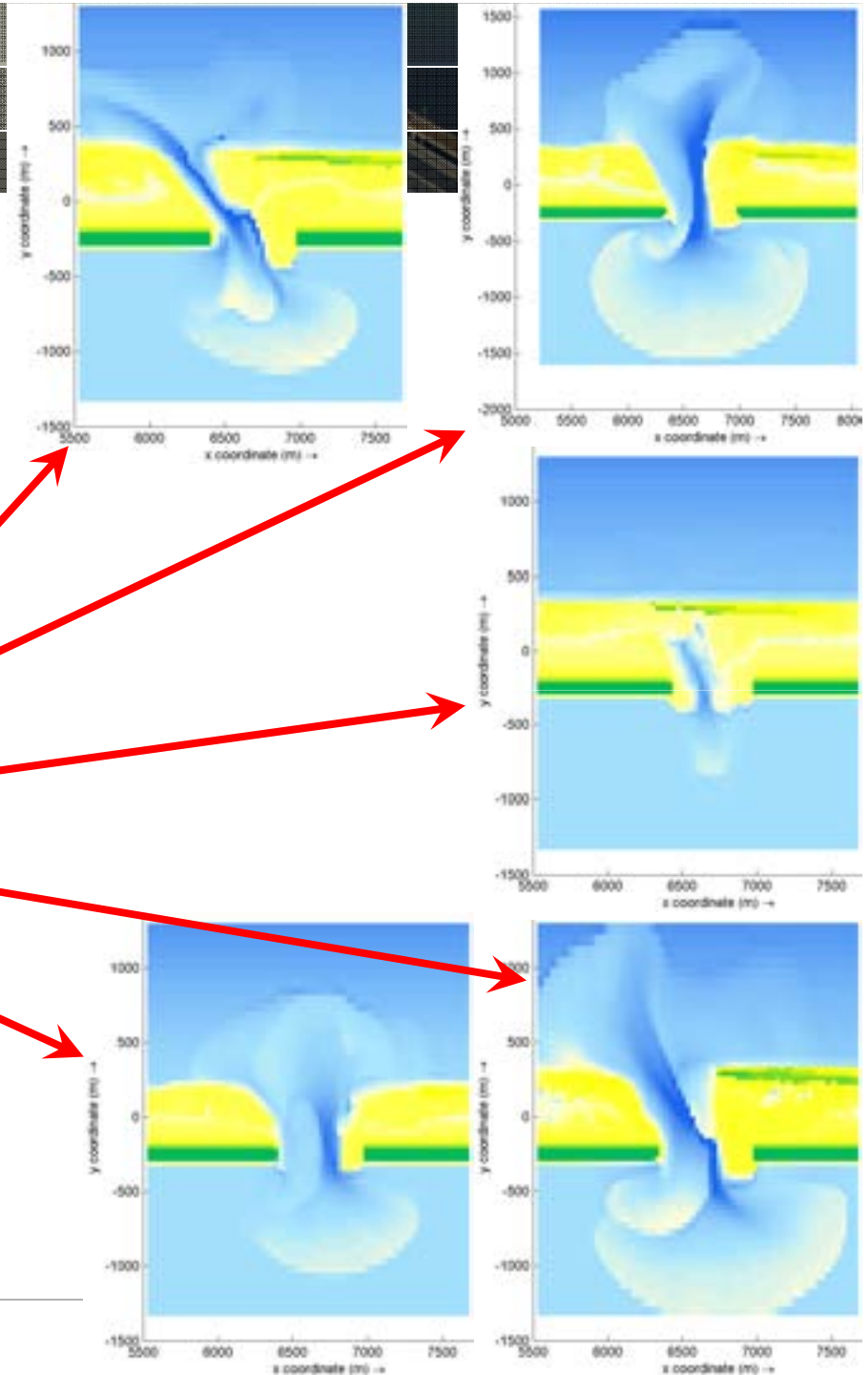


Comparison to Empirical Formulation

Scenario name	Boundary conditions			Ratio Tidal Prism and Longshore Transport
	Basin Area (km ²)	Tidal Ampl (m)	Wave Height (m)	
SIM1	15	0.50	1.5	18
SIM2	30	0.50	1.5	42
SIM3	15	0.25	1.5	4
SIM4	15	0.75	1.5	25
SIM5	15	0.50	0.75	138

(Initial $A_c = 850 m_2$; $\phi = 25^\circ$,
Tidal period = 12 hrs)

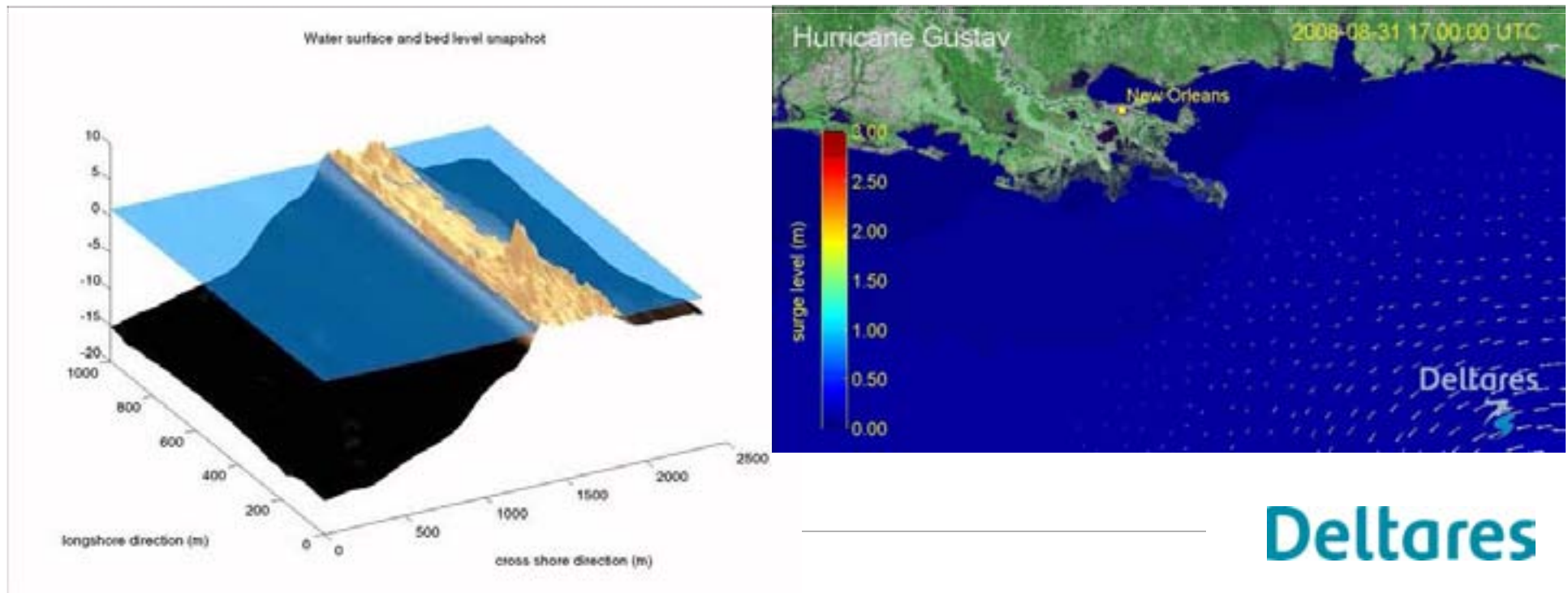
Ratio Tidal Prism and Longshore Transport



So far “average” conditions, but...

Impact of extreme events (e.g. hurricanes, floods and tsunamis)

- Perturbation of equilibrium
 - > Dune Erosion
- Shift to new equilibrium or different state
 - > Inlet Closure/Generation, Delta Lobe switching



Conclusions P.B. Long-Term modeling

A lot of natural behavior is captured in simple physics (depth-averaged tidal flow, waves, simple transport formula, no sediment interaction and simple stratigraphy)

A number of empirical relationships are reproduced

Long-term, process based simulations do not necessarily get out of hand: they tend towards realistic equilibrium situations

Present generation of morphological models is becoming robust enough to survive long simulations and to model extreme events

This allows us to use them as numerical lab

The way ahead

Adding more processes will have limited added value

Main challenge is to learn how to apply p.b. long term models

- Forcing (average conditions vs. extreme events)
- Initial conditions (bathymetry, sediment, paleostratigraphy)
- Interpretation of results (patterns, aggregation, detailed results)
- Embedding results in coastal management/policy plans

Further validation

Develop standardised approaches