River and Plume Deposition Ocean Storm Reworking

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Course outline 1

- Lectures by Irina Overeem:

  - Introduction and overview
  - Deterministic and geometric models
  - Sedimentary process models I
  - Sedimentary process models II → Coastal-marine models; → Case-study US margin
  - Uncertainty in modeling

Modeling stratigraphy with process models: the workflow

INPUT

- River Basin data
- Tectonic evolution
- Climate data
- Marine Basin data
- Sea Level data

•Variability of data

MODEL PROCESSES

- River Deposition
- Delta Plumes
- Barrier Deposition
- Marine Reworking
- Turbidity Currents

•Variability of processes

OUTPUT

- Analyze output
- Sensitivity tests
- Comparison real-world data
- Uncertainty analysis

Hypopycnal Plume

- **Steady 2D advection-diffusion equation:**

$$\frac{\partial uI}{\partial x} + \frac{\partial vI}{\partial y} + \lambda I = \frac{\partial}{\partial y}\left(K \frac{\partial I}{\partial y} \right) + \frac{\partial}{\partial x}\left(K \frac{\partial I}{\partial x} \right)$$

where: **x, y are coordinate directions**

u, v are velocities

K is turbulent sediment diffusivity

I is sediment inventory

λ is the first-order removal rate constant

Steady 2D advection-diffusion equation:

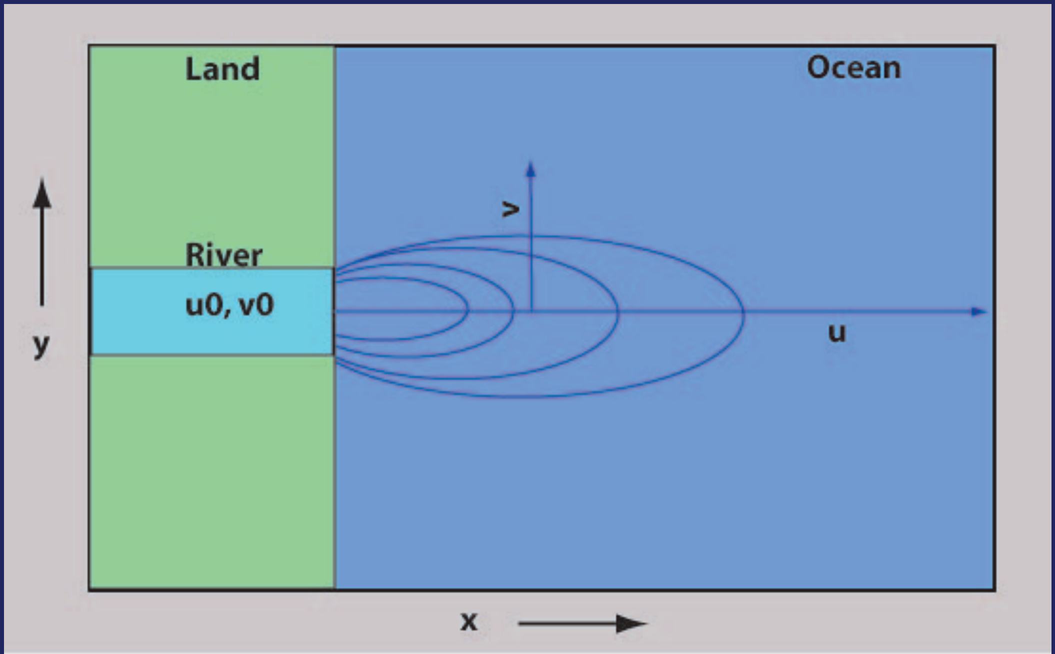
$$\frac{\partial uI}{\partial x} + \frac{\partial vI}{\partial y} + \lambda I = \frac{\partial}{\partial y}\left(K\frac{\partial I}{\partial y}\right) + \frac{\partial}{\partial x}\left(K\frac{\partial I}{\partial x}\right)$$

where: **x, y are coordinate directions (m)**

u, v are velocities (m/s)

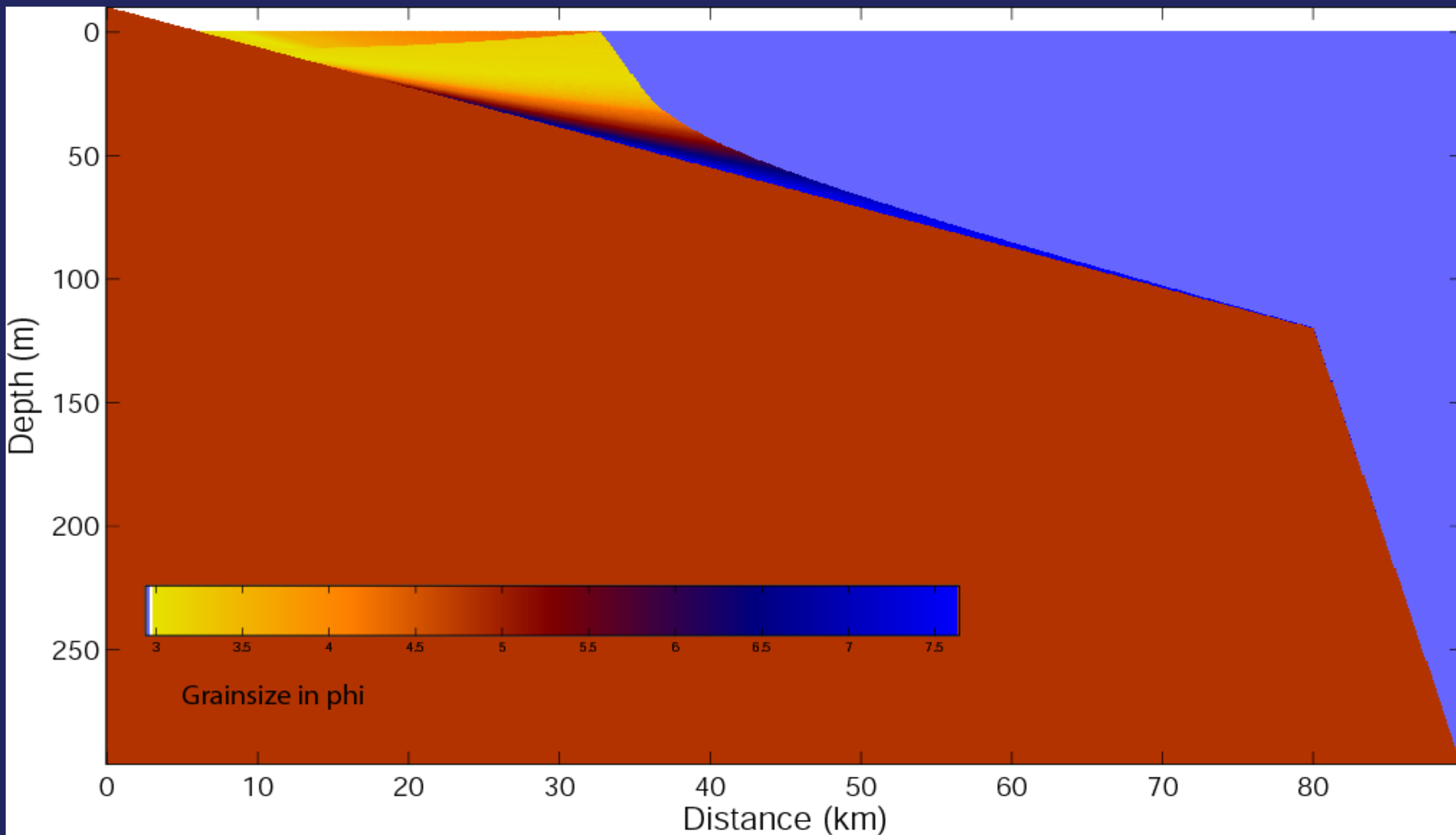
K is turbulent sediment diffusivity (m^2/s)

I is sediment inventory (kg/m^2)



λ is defined per grainsize, it is the removal rate constant (1/s). This is also often called the settling rate.

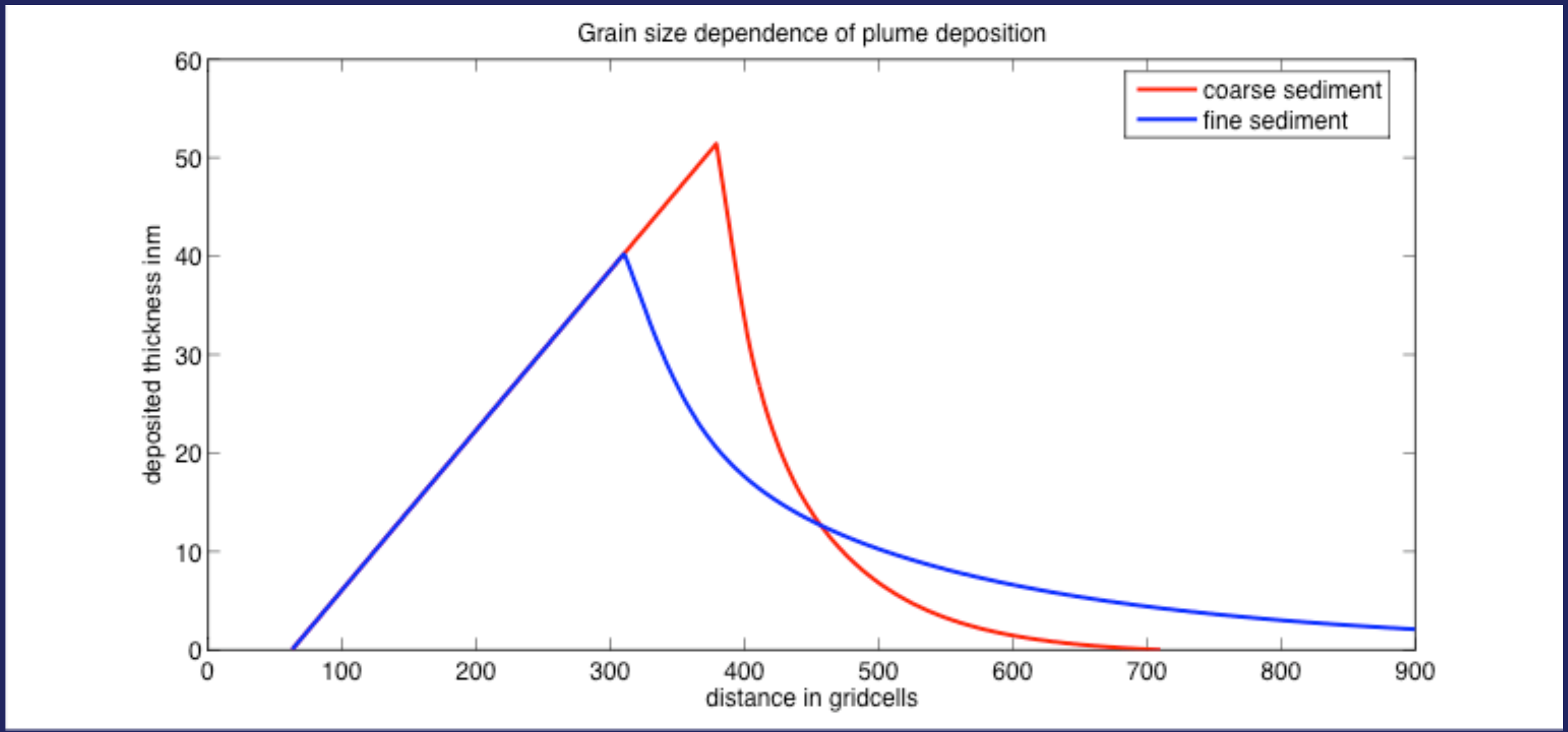
Simple Plume Experiment



Simple 1000 year 2D SedFlux experiment of 1000 year duration♪

- generic bathymetric profile (at 80 km, -120m waterdepth, dropping to 300m)♪
- stable sediment input and water discharge♪
- slow sea level rise♪

Grain Size dependent deposition

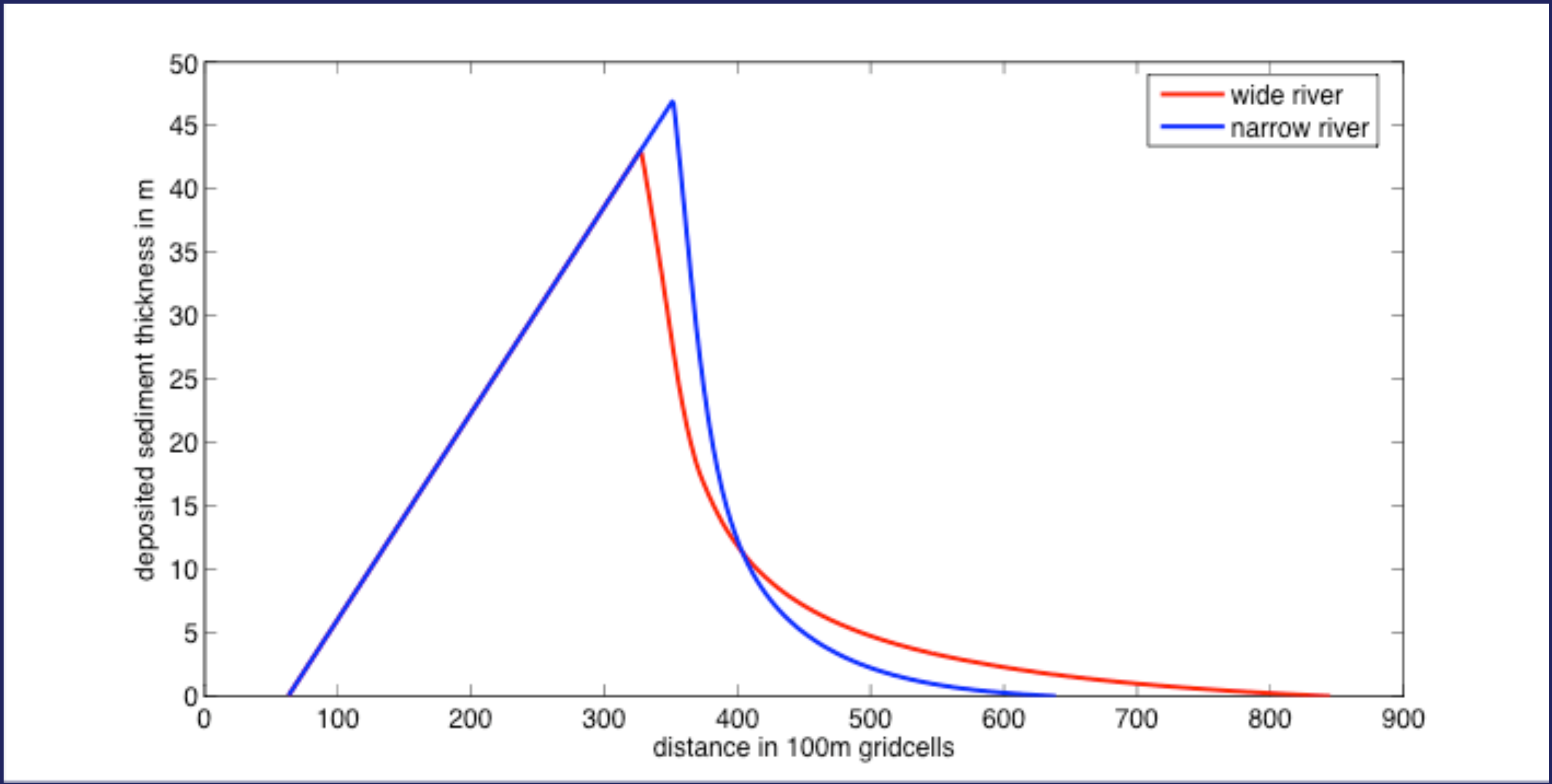


Simple 1000 year 2D SedFlux experiment with stable sediment input and slow sea level rise:

Coarse sediment scenario: 1200, 400, 250, 60, 30 micron

Fine sediment scenario: 400, 150, 60, 5, 2 micron

River mouth dependent deposition



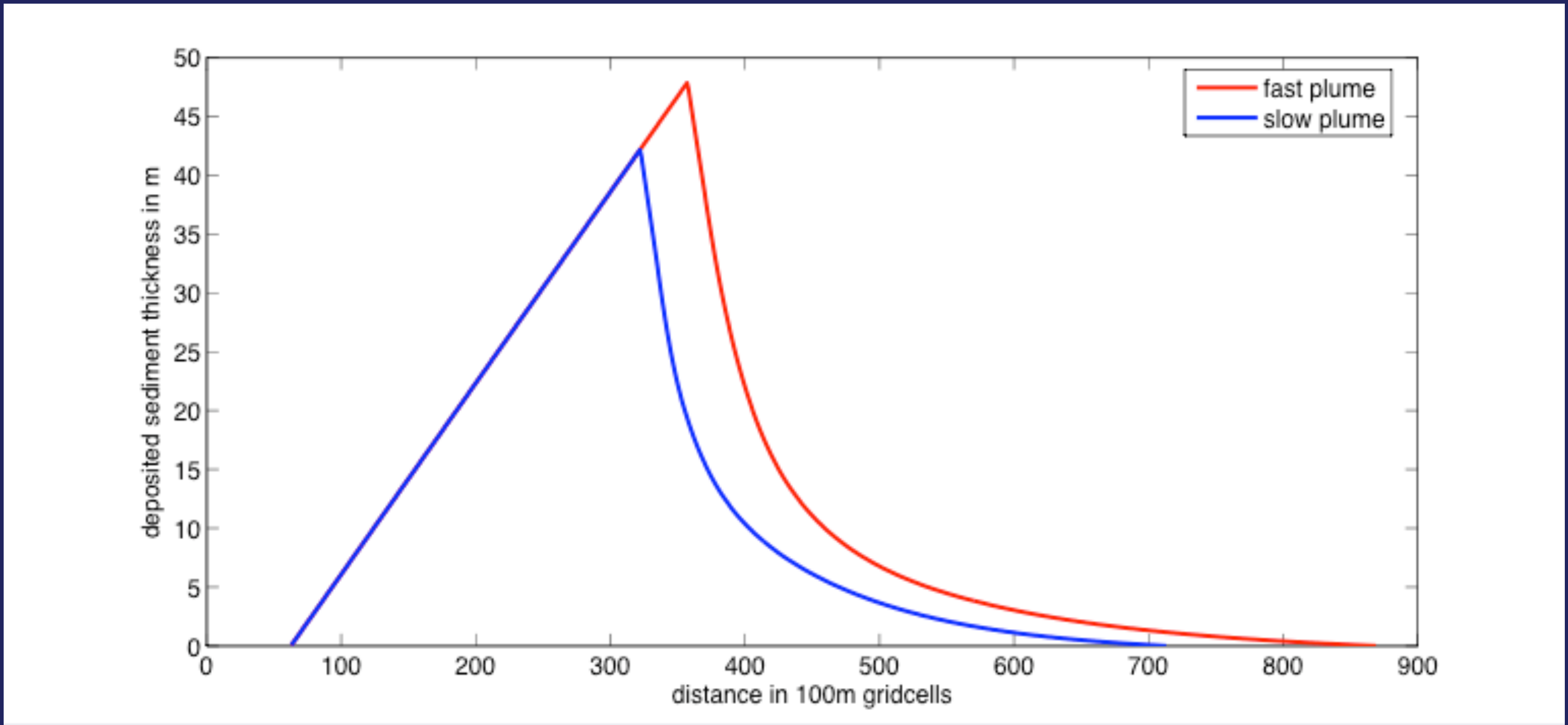
Simple 1000 year 2D SedFlux experiment with stable sediment input and slow sea level rise, stable total daily discharge:♪

Wide River scenario: w0 = 750m, b0=1.66m ♪

Narrow River scenario: w0 = 125 m, b0 =10m♪

♪

River velocity dependent deposition

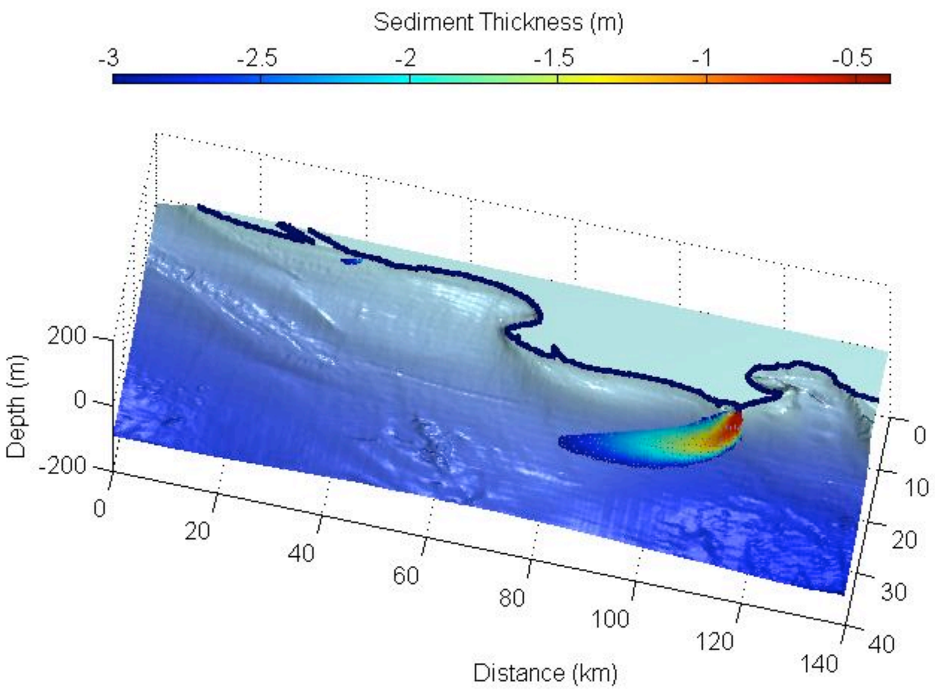


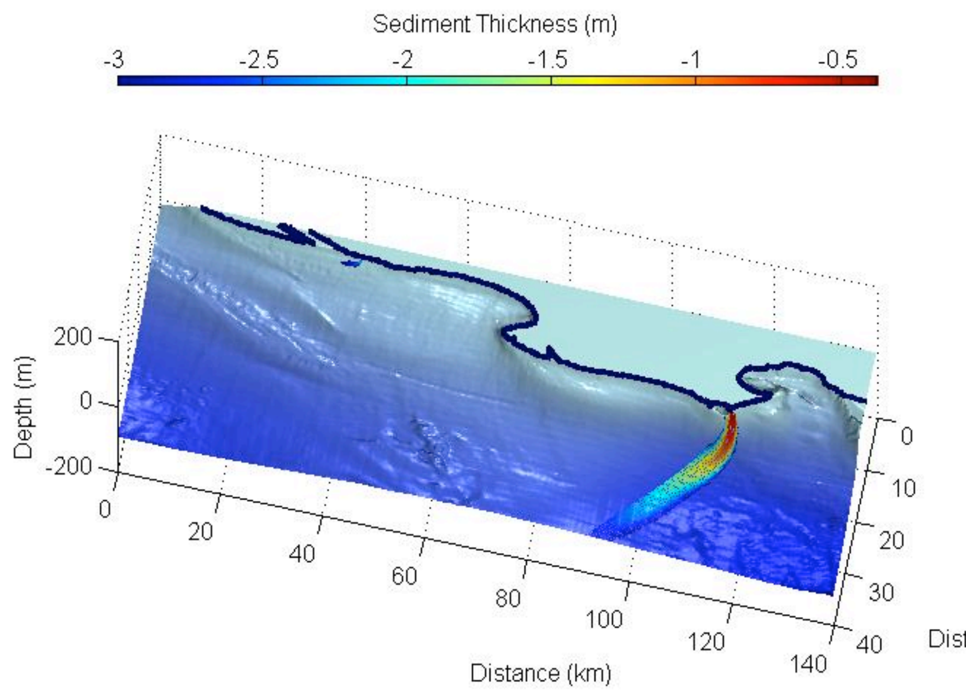
Simple 1000 year 2D SedFlux experiment with stable sediment input and slow sea level rise, stable total daily discharge:

Fast Plume scenario: u0 = 1.2 m/sec

Slow Plume scenario: u0 = 0.8 m/sec

Plume examples





River Mouth Angle = 15 º

River Mouth Angle = 45 º

Data courtesy, Kettner and Hutton, CSDMS

External factors influencing plumes

The shape that a hypopycnal plume will have, depends on a variety of factors:

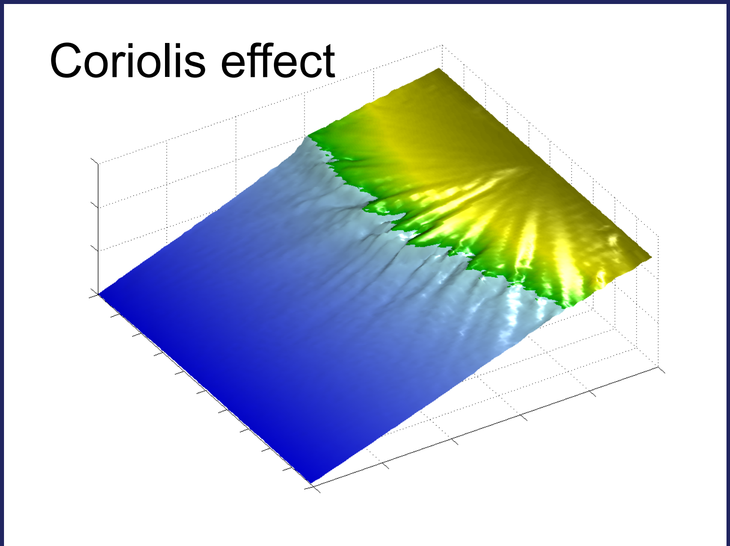
•Angle between the river course at the entry point and the coastline.

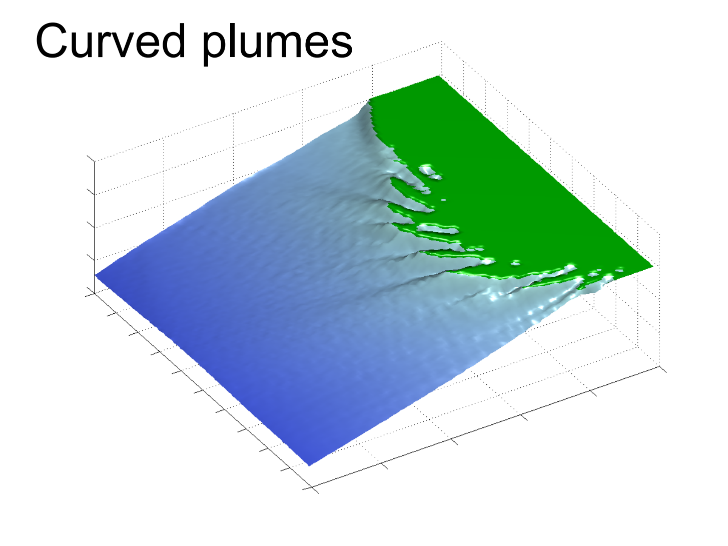
•Strength and direction of the coastal current.

•Wind direction and its influence on local upwelling or downwelling conditions.

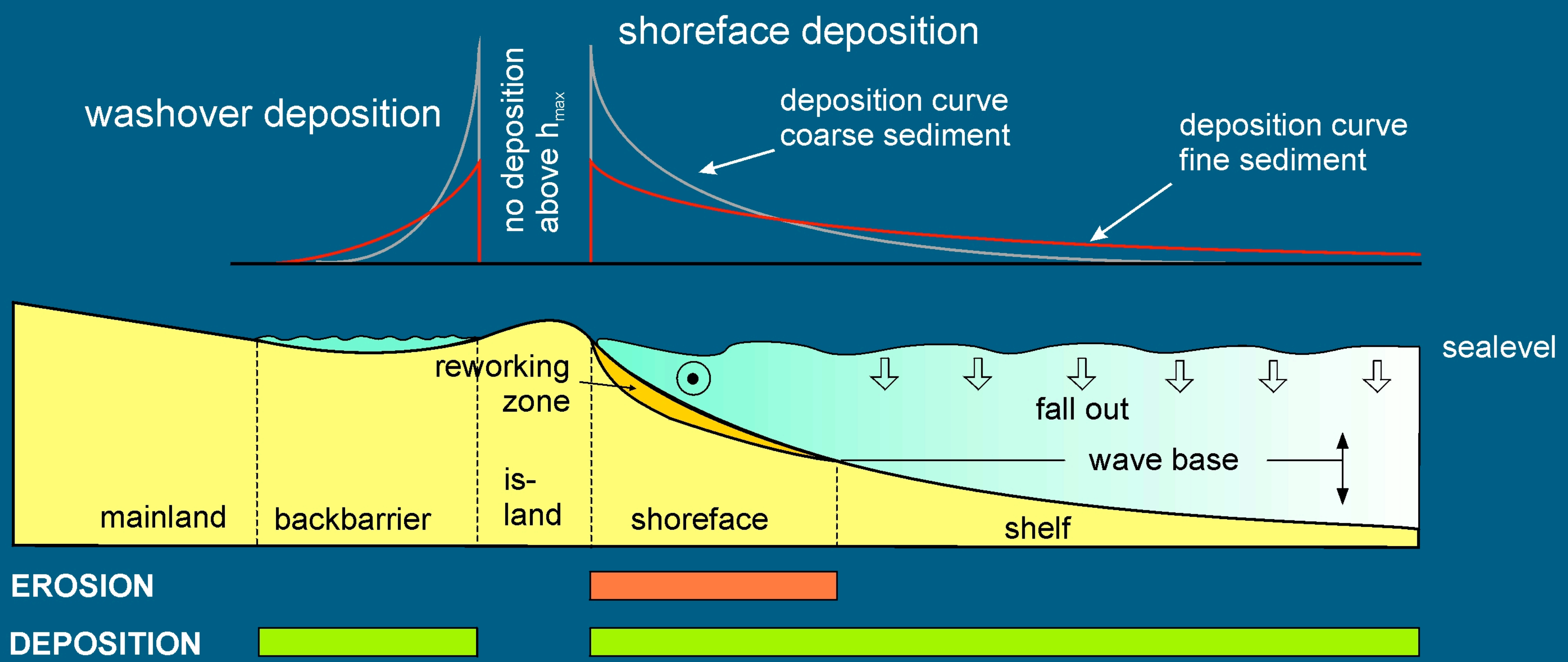
•Mixing (tidal or storm) energy near the river mouth.

•Latitude of the river mouth and thus the strength of the Coriolis effect.



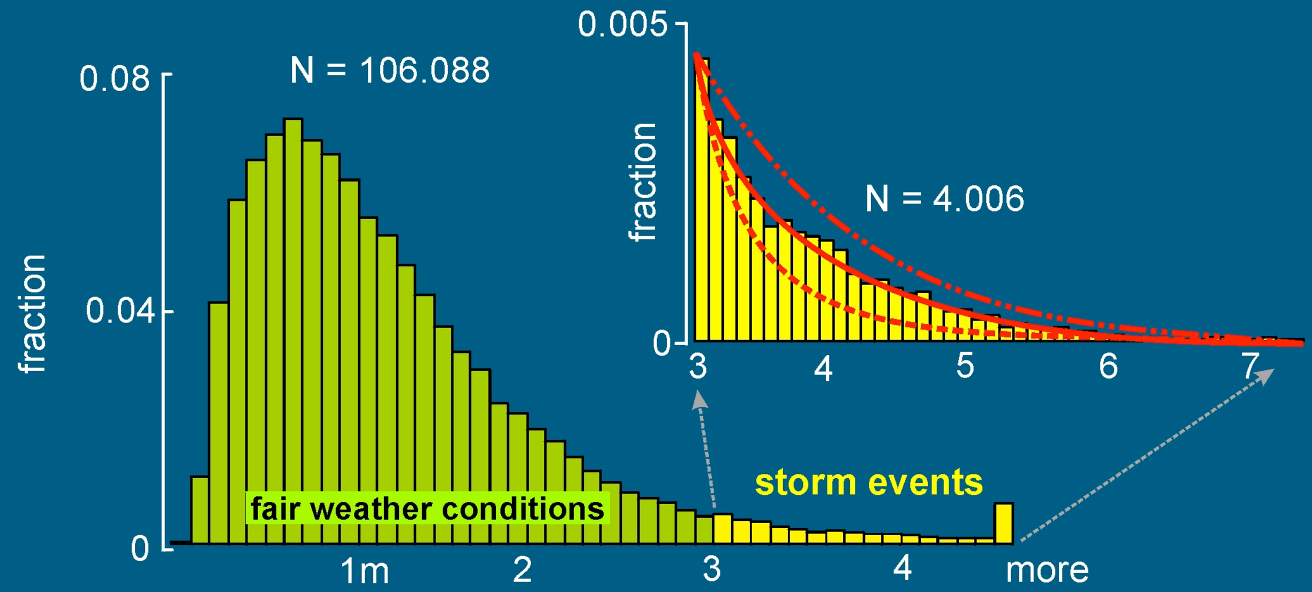


Storm and Wave Erosion



Conceptual design of the storm erosion model, BARSIM, (Storms et al, 2003). Sediment supply by longshore drift

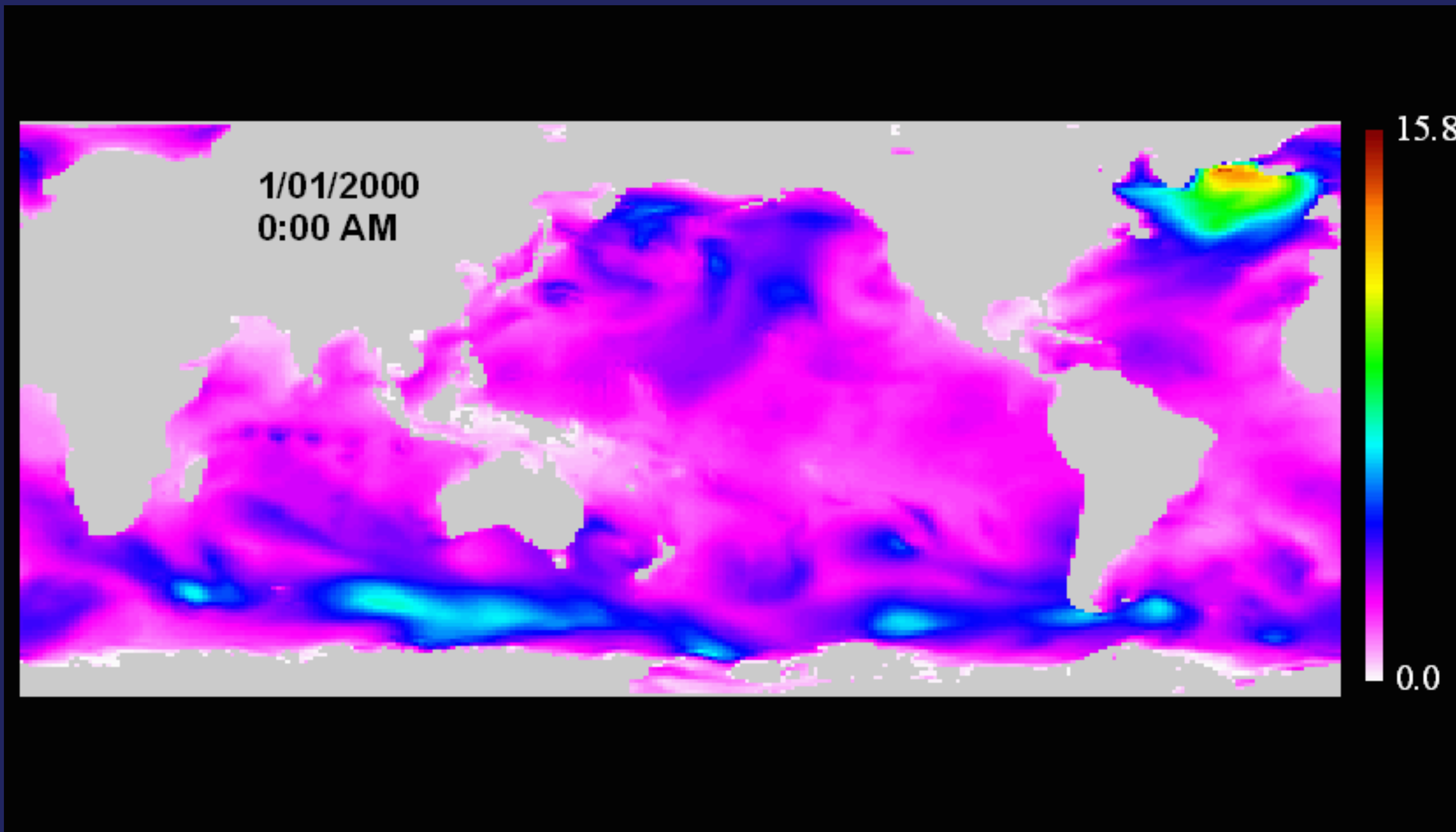
Ocean Storms from buoy observations



Wave height (m) at Schiermonnikoog, the Netherlands, between 1979 - 1999

Buoy data leads to pick an exponential function to fit the storm wave-height distribution for the sedimentary process model.

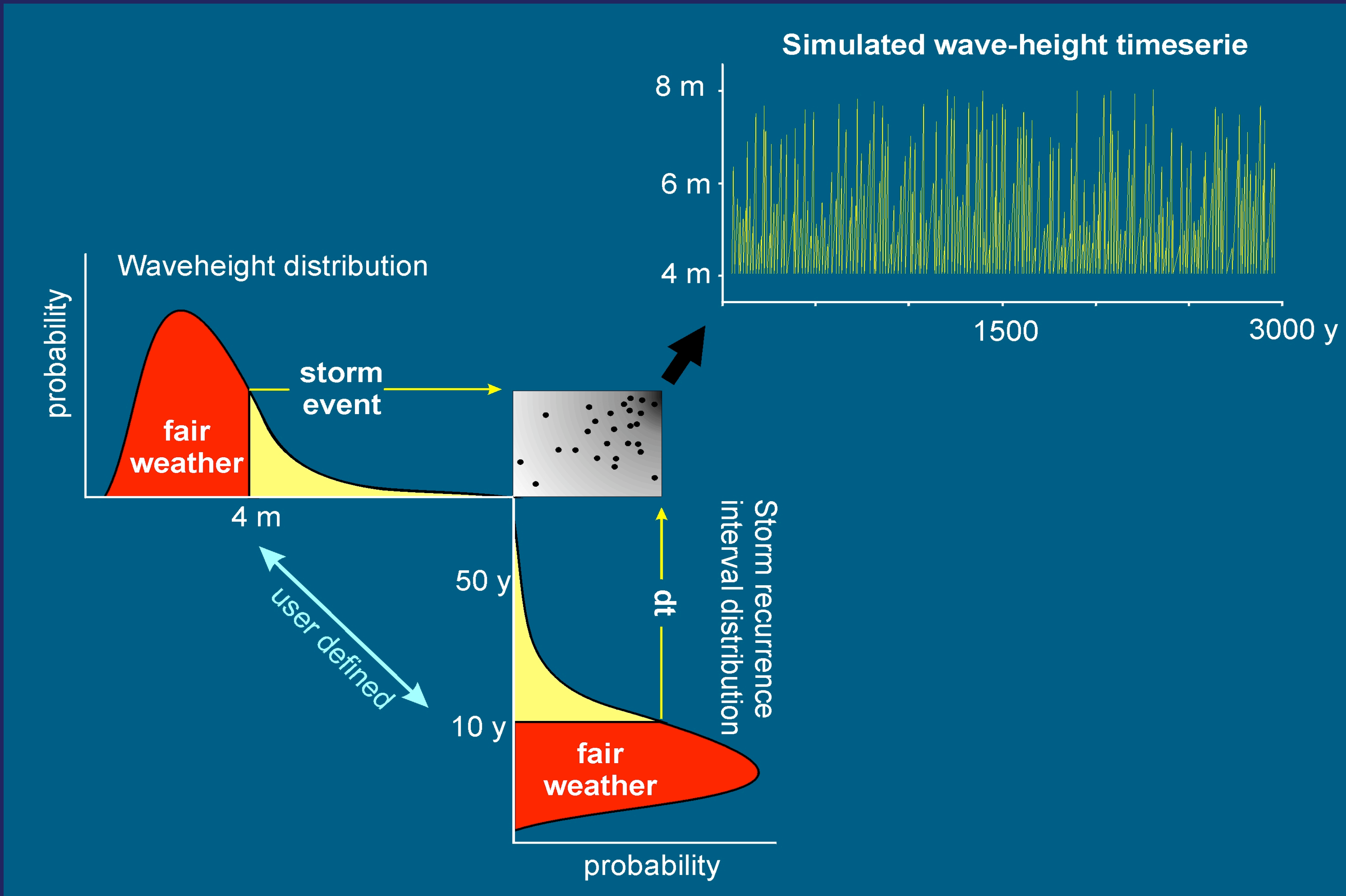
Ocean Storms from wave models



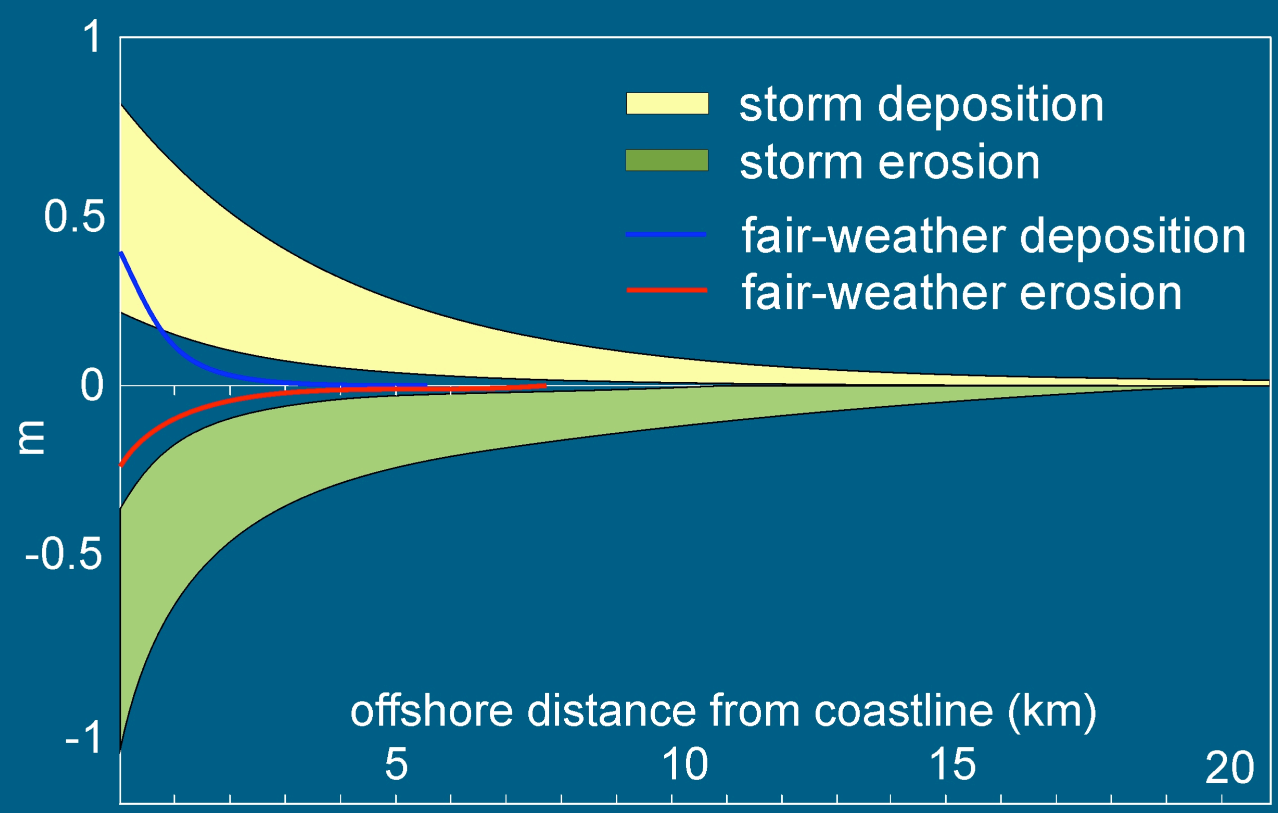
Wave height in m

WaveWatch III model, predicts 3-hourly global waves
The description of the wave field is done with the 'significant wave height' = average height of highest 33% of waves. (Tolman, a.o. 2000-2003).

Sample storm conditions from real-world wave height distribution

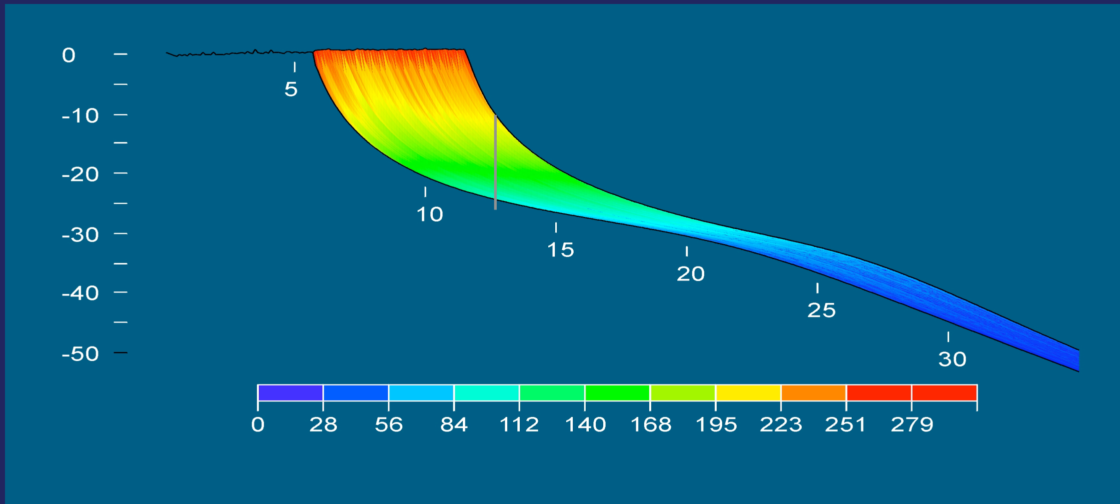


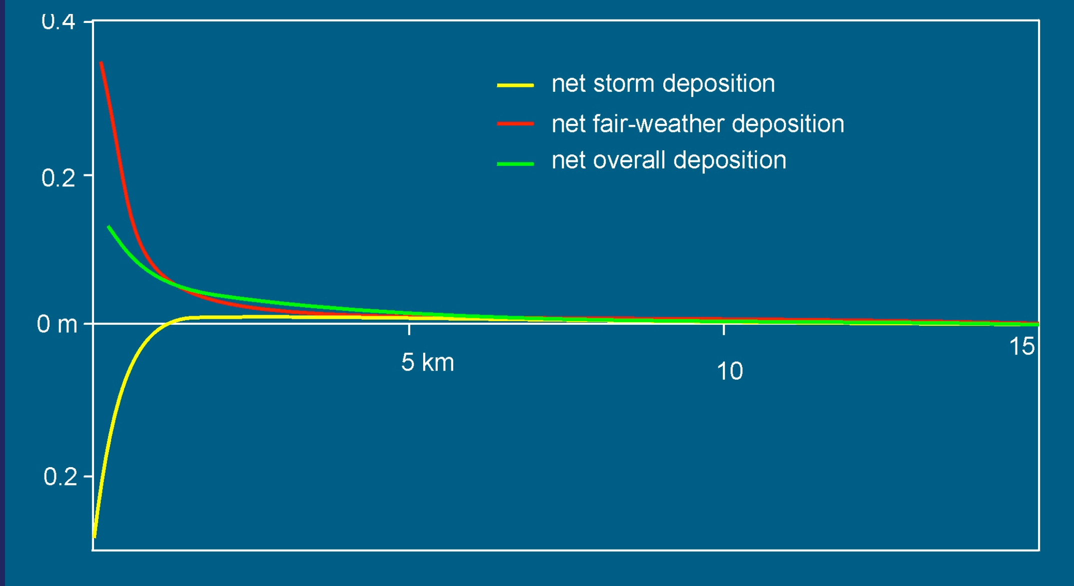
Simulated depositional pattern

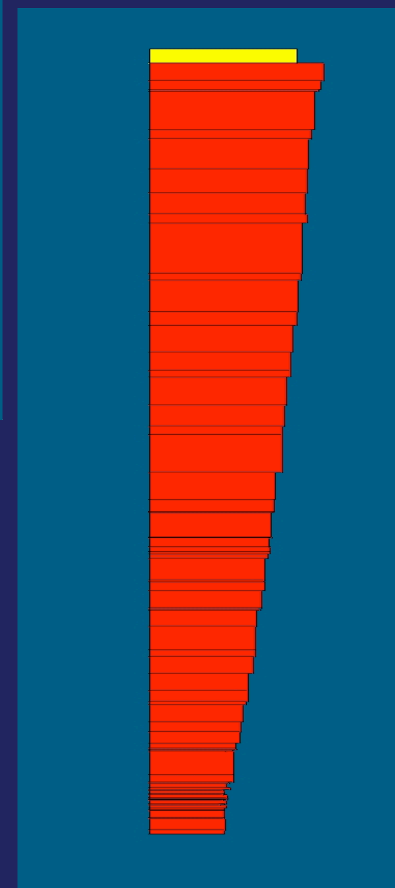


Experiment conditions are Δ sea level = 0 my^{-1}, and sediment supply = 0 m^2y^{-1}

Simulated barrier stratigraphy

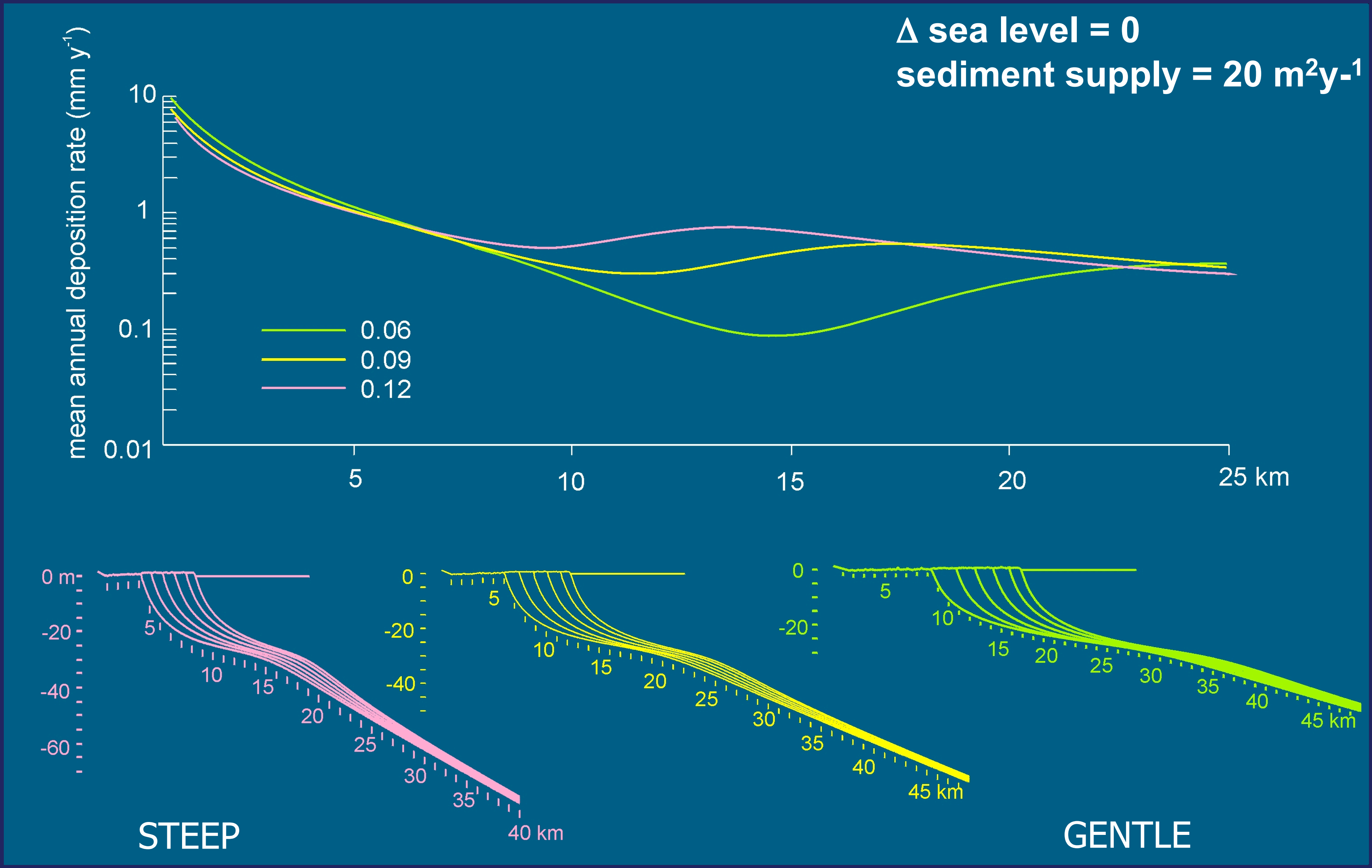




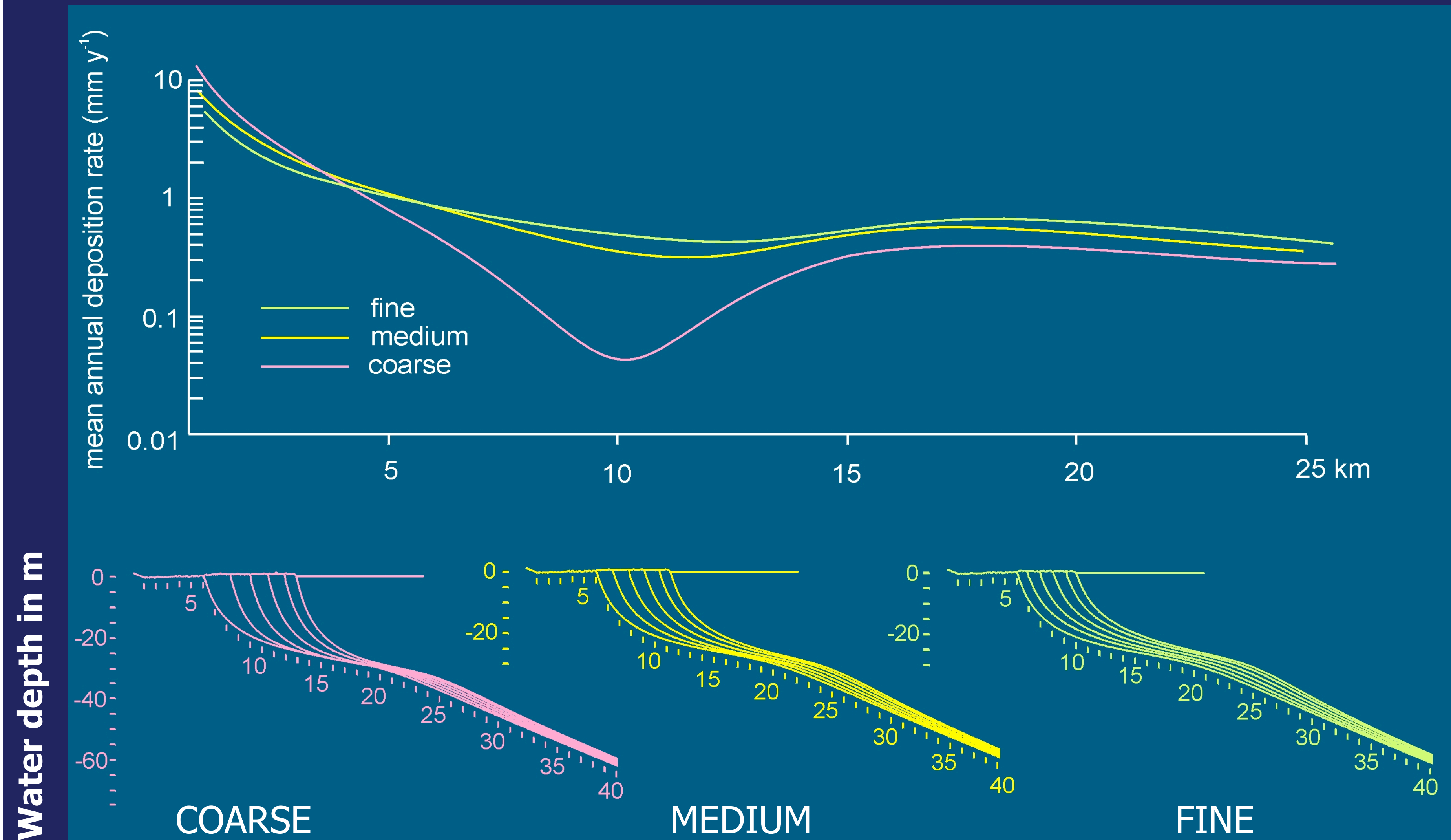


scenario Δ sea level = 0 my^{-1} and sediment supply = 20 m^2y^{-1}

Shelf slope variability

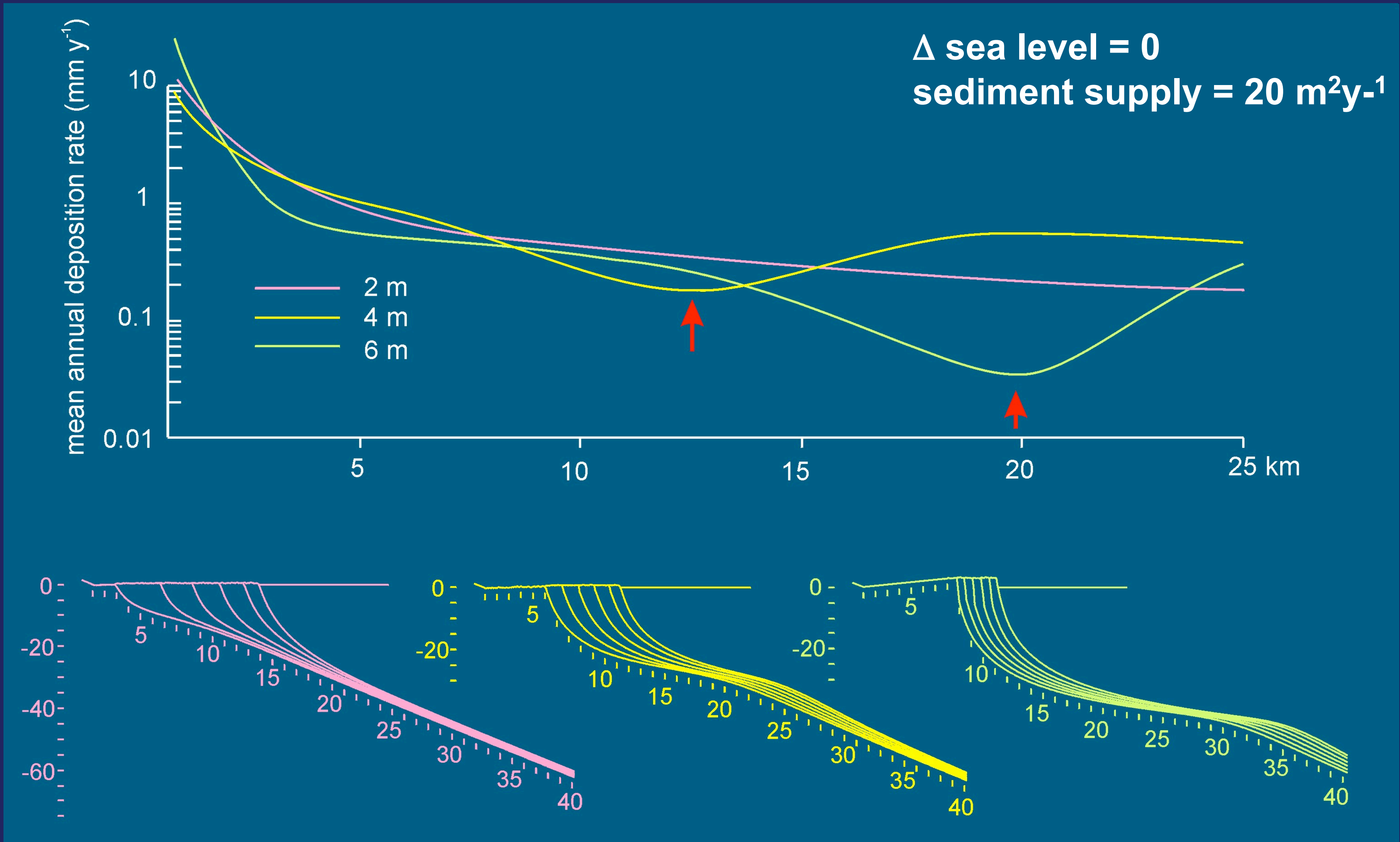


Grain Size variability



Δ sea level = 0, sediment supply = 20 m^2y^{-1}

Wave height regime variability



Model Test: what kind of variability can be expected in the stratigraphic record resulting from variation in wave-height regime during deposition?

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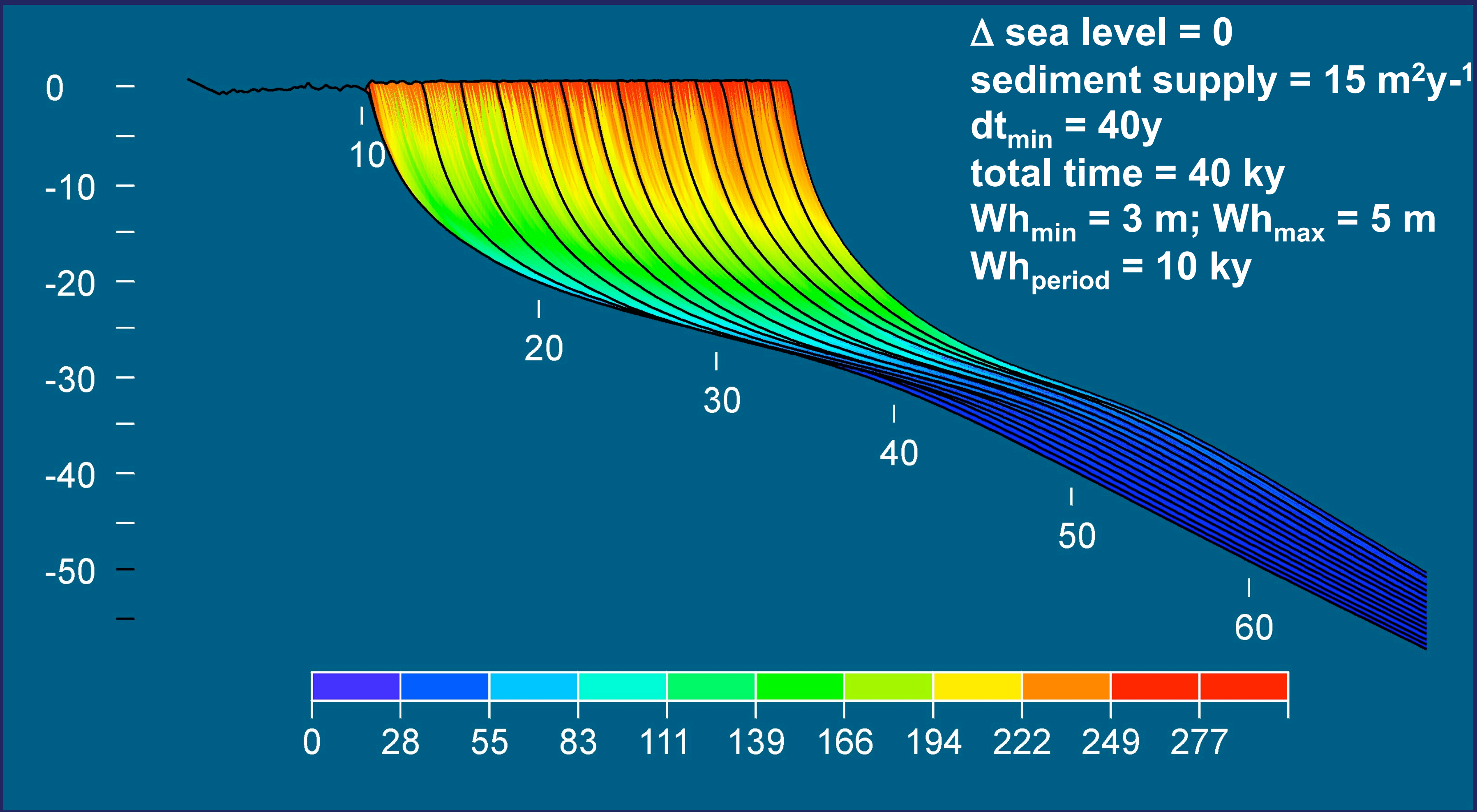
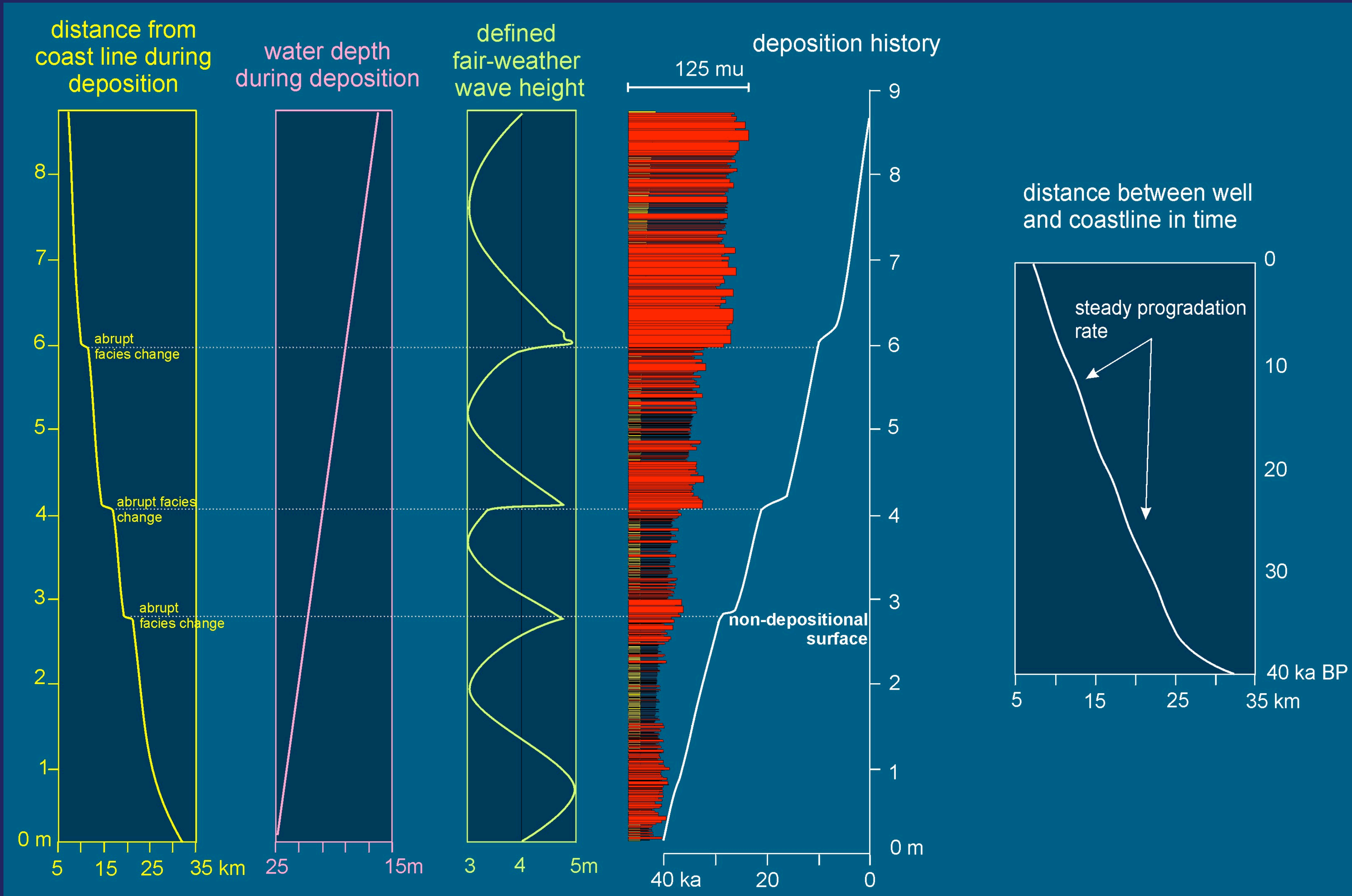
Wave height regime variability
sine shaped



Simulated barrier stratigraphy



Summary

- Prediction of inter-well stratigraphy by process-response modelling is fundamentally different from geostatistical interpolation techniques
- Numerical models that simulate detailed sedimentary processes are a tool to experiment with the different factors controlling the reservoir-scale geometry (grain size, slope, river regime, wave regime).
- Such models are usually restricted in spatial scale and represent a single environment

References Delta Plumes

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- Storms et al., 2002. Process-response modeling of wave-dominated coastal systems: simulating evolution and stratigraphy on geological timescales. J. Sedimentary Research, 72, 226-239.

- Storms, 2003. Event-based stratigraphic simulation of wave-dominated shallow-marine environments. Marine Geology 199, 83-100.

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