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
  • Uncertainty in modeling

Coastal-marine models

Case-study US margin
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:

\[
\frac{\partial u I}{\partial x} + \frac{\partial v I}{\partial y} + \lambda I = \frac{\partial}{\partial y} \left( K \frac{\partial I}{\partial y} \right) + \frac{\partial}{\partial x} \left( K \frac{\partial I}{\partial x} \right)
\]

where: 
  \( x, y \) are coordinate directions  
  \( u, v \) are velocities  
  \( K \) is turbulent sediment diffusivity  
  \( I \) is sediment inventory  
  \( \lambda \) 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\(^2\))

\(\lambda\) is defined per grainsize, it is the removal rate constant (1/s). This is also often called the settling rate.
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: \( w_0 = 750 \text{ m}, \; b_0 = 1.66 \text{ m} \)

Narrow River scenario: \( w_0 = 125 \text{ m}, \; b_0 = 10 \text{ m} \)
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: $u_0 = 1.2 \text{ m/sec}$

Slow Plume scenario: $u_0 = 0.8 \text{ m/sec}$
Plume examples

Data courtesy, Kettner and Hutton, CSDMS
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.
Conceptual design of the storm erosion model, BARSIM, (Storms et al, 2003). Sediment supply by longshore drift.
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

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
Experiment conditions are $\Delta$ sea level = 0 my$^{-1}$, and sediment supply = 0 m$^2$y$^{-1}$
Simulated barrier stratigraphy

scenario \( \Delta \) sea level = 0 my\(^{-1} \) and sediment supply = 20 m\(^2\)y\(^{-1} \)
Δ sea level = 0
sediment supply = 20 m²y⁻¹

Shelf slope variability
Δ sea level = 0, sediment supply = 20 m²y⁻¹
Wave height regime variability

Δ sea level = 0
sediment supply = 20 m²y⁻¹
**Model Test:** what kind of variability can be expected in the stratigraphic record resulting from variation in wave-height regime during deposition?
Wave height regime variability
sine shaped

Δ sea level = 0
sediment supply = 15 m$^2$y$^{-1}$
dt$_{min}$ = 40y
total time = 40 ky
Wh$_{min}$ = 3 m; Wh$_{max}$ = 5 m
Wh$_{period}$ = 10 ky
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


References Storm Erosion Models

