Seminar Coastal Morphodynamics
IMAU, Utrecht University, 2008

Lecturers:

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General objective of this seminar

Discuss physical processes that cause the presence of undulations of the sea bottom

Example 1: Ripples at the beach

- Horizontal length scale ~ 10 cm; height ~ 2 cm
- Generation timescale ~ hours
- Due to: waves
- Relevance: wave prediction, estimation of sediment transport

Example 2: Tidal sand waves

- Horizontal length scale ~ 500 m; height ~ 2 m
- Generation timescale ~ years
- Due to: tides
- Relevance: e.g. buckling of pipelines, navigation
Sand waves in the Marsdiep

Example 3: Sand ridges on the outer and inner shelf

- Tidal sand ridges
- Shoreface-connected sand ridges

Horizontal length scale ~ km; height ~ 5-10 m
Generation timescale ~ 100 years
Due to: tides and storm-driven currents
Relevance: sand mining, coastal stability
Research questions

1. Which mechanisms are responsible for the formation and maintenance of rhythmic topography in coastal seas?

2. Can we predict the characteristics of bedforms?
   - spatial pattern
   - migration speed
   - height

3. What is the response of bottom patterns to
   - human interventions (e.g., extraction of sand)?
   - sea level changes?

Research approaches:

1. Collection and analysis of field observations
   (identify phenomena + describe behaviour)

Problems:
   - lack of data
   - selection of spatial + temporal resolution
   - selection of spatial + temporal extent
   - what is transient/nontransient behaviour?
2. Collection and analysis of **laboratory data**

Advantages: data obtained under controlled conditions
Problems: link to reality (scaling problems)

3. Use of **empirical** or **semi-empirical models**

Model is proposed, field data -> parameter values, next predictions

Example: Regeneration of sand waves after dredging (Seto Inland Sea, Japan)

Advantages: fast and flexible
Disadvantage: yields little insight in basic physics
4. Use **process-oriented numerical models**

These models use physical laws for water motion, sediment transport and bottom evolution.

**Examples:**
- DELFT3D-MOR
- MIKE21 (Denmark)
- Telemac (France)

**Advantages:** based on physics, results often reliable and useful

**Disadvantages:** slow, difficult to gain insight
4. Use **idealised process-oriented models**

- Based on simplified descriptions regarding the
  - geometry
  - physical processes involved
- Designed to gain understanding about the basic physics

**Example 1:** model for tidal sand waves

![Diagram of tidal sand waves](image1)

**Advantages:** fast + flexible, suitable for sensitivity studies

**Disadvantages:** how to choose relevant processes?

**Example 2:** Model for shoreface-connected sand ridges

![Diagram of shoreface-connected sand ridges](image2)

**Advantages:** fast + flexible, suitable for sensitivity studies

**Disadvantages:** how to choose relevant processes?

link with reality
Idealised models are successful in explaining the formation of many different types of bottom patterns.

Two types of models:

1. **Template models**
   - Pattern in the water motion forces the pattern in the bottom.
   - No feedback bottom → water motion.

   Example of template pattern: submarine longshore bars.

2. **Self-organisation models**
   - Bed forms develop as inherent (or free) instabilities of the coupled water-coupled system.
   - Feedback water motion and erodible bottom is crucial.

   Spatial/temporal scales of bedforms are uncorrelated with those of external forcing.
Specific objectives of this seminar

1. Discuss structure of models that simulate water motion + their feedbacks with sediment transport and morphology in coastal seas.

2. Demonstrate that many bottom patterns in coastal seas emerge as inherent instabilities of the coupled water-bottom system (focus on sand ridges, sand waves and ripples).

3. Behaviour of bedforms can be analysed with mathematical methods (stability analysis).

Structure of morphodynamic models:

- We need to
  - solve the flow structure
  - find expressions for transport of sediment (due to the water motion)
  - evolution of the bottom
Four steps to explore morphodynamic self-organisation:

1. **Formulation of a model:**
   - Water motion
   - Sediment transport
   - Bottom evolution

2. **Find an equilibrium state** (without bedforms)

3. **Perform linear stability analysis**
   - Dynamics of small perturbations, arbitrary scales, do they grow?
   - Each perturbation → growth rate
   - Mode with the largest growth rate: the preferred mode
   => spatial pattern, migration speed, growth time scale

4. **Perform nonlinear (stability) analysis**
   - Finite-amplitude behaviour of bars and ridges

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Example of model output

(Here: shoreface-connected sand ridges)

- Growth rate versus longshore wavenumber:
  - Spacing: 7.6 km
  - Timescale: ~1000 yr
  - Migration: 2 m/yr

- Spatial patterns of modes:
  - Light colours: crests
  - Dark colours: troughs
Overview of this seminar:

- 9 oral sessions (default: Monday 11.00-13.00)
- 9 practise periods (Wednesday 9.00-11.00)

Specific time schedule:
www.phys.uu.nl/~deswart/morpho08_seminar

Credits (3.75 ECTS) will be based on
- * presence at oral lectures
- * answers to exercises during practise periods

Oral sessions

- based on recent key literature
- read 1 paper/session as preparation

Practise periods

- questions about theory
- simulations with numerical codes
Session 2: Modelling sediment transport  (29-09-2008)

Literature:

Session 3: Introduction boundary layer theory  (06-10)

- Internal friction and coastal morphodynamics
- Laminar versus turbulent flow
- Vertical structure of oscillatory currents and streaming

Literature:
Session 4: Tidal sand ridges

(13-10-2008)

Literature:

Session 5: Sand waves

(20-10-2008)

Details of the bathymetric survey of the "Sand Hills" area along the pipeline LANGELED.

Literature:
Session 6: Shoreface-connected sand ridges

Literature:
Trowbridge, J. 1995. A mechanism for the formation and maintenance of shore-oblique sand ridges on storm-dominated shelves. J. Geophys. Res. 100 (C8), 16071-16086.

Session 7: Turbulent boundary layers under sea waves

Literature:
lecture notes of G. Vittori
Session 8: Turbulent bottom boundary layers II (17-11)

Computed shear stress at the wall versus dimensionless time $\omega t$

Literature:
lecture notes of G. Vittori

Session 9: Sand ripples under sea waves (24-11)

Brick-pattern ripples 3D Vortex ripples

Literature:
lecture notes of G. Vittori
Session 8: Turbulent bottom boundary layers II

Literature:
lecture notes of G. Vittori
Computed shear stress at the wall versus dimensionless time $\omega t$.

Literature:
lecture notes of G. Vittori