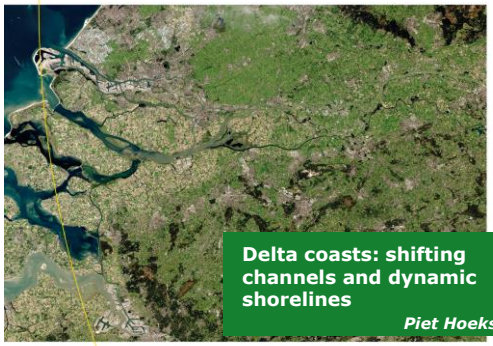
Universiteit Utrecht

Future Deltas



Delta coasts: shifting channels and dynamic shorelines

Piet Hoekstra

Universiteit Utrecht

Scientific challenge

- **What explains the variability in delta morphology in response to fluvial, estuarine and marine processes and conditions ?**
- **Delta morphodynamics: mutual interactions between hydrodynamic processes, sediment transport and morphology.**
- **Triple D: DDD**
  - **Development**
  - **Distribution of water and sediment: Dynamics**
  - **Degradation**

Universiteit Utrecht

Societal impact and potential for development

- **Delta morphology: relevant for size, available surface area to develop, length of shorelines to protect;**
- **Stability of shorelines: erosion and accretion;**
- **Dimensions of channels: navigation, irrigation, degree of salt intrusion;**
- **Exploration: gas, oil, other mineral resources.**

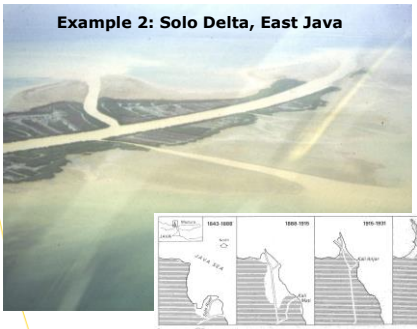
Universiteit Utrecht

Example 1:

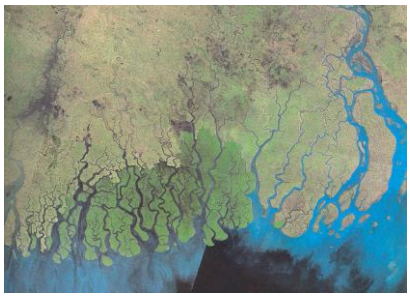
Nile Delta, Egypt

Universiteit Utrecht

Example 2: Solo Delta, East Java



Universiteit Utrecht



Example 3: Ganges-Brahmaputra Delta, Bangladesh

Universiteit Utrecht

1. Development

River-Dominated processes

- Low energy wave and tidal regime
- Outflowing effluents: relative role of three main processes:
  - Bed friction
  - Flow inertia
  - Buoyancy of outflowing water mass

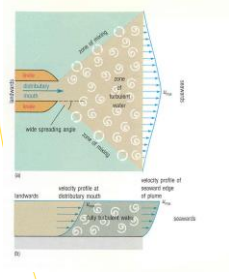
Universiteit Utrecht

Outflow conditions: two contrasting examples

- Inlet geometry and basin depth
- Outflow velocities – river discharge
- Degree of tidal mixing in estuary

Universiteit Utrecht

Outflow regime: plane turbulent jet

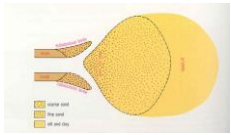


Conditions:

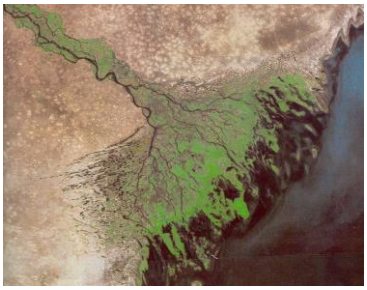
Large discharges – high current velocities

Shallow basin with bed friction

No density effects



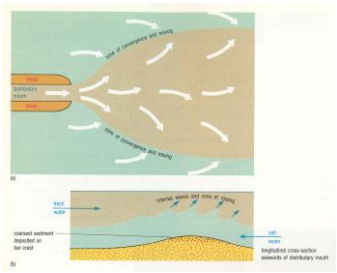
Universiteit Utrecht



Example Wolga Delta – Caspian Sea

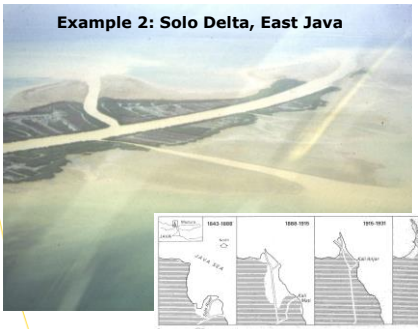
Universiteit Utrecht

Outflow regime: Buoyant jets and plumes



Universiteit Utrecht

Example 2: Solo Delta, East Java

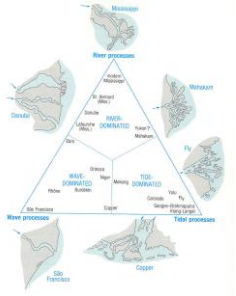


Universiteit Utrecht

Mahakam River buoyant plume in Strait Makassar, Indonesia

Universiteit Utrecht

Marine processes: waves and tides



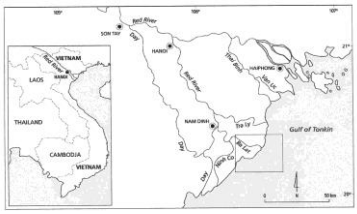
Effects on delta morphology:

- **Mixing and dispersion of water masses**
- **Bi-directional flow patterns – funnel shaped estuaries**
- **Highly indented coastline**
- **Meandering tidal channels and creeks**
- **Longshore drift, bars and spits; redistribution of delta deposits**

(Based on : Galloway, 1975)

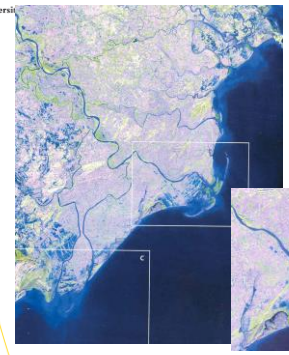
Universiteit Utrecht

Red River Delta, Vietnam: seasonal variability



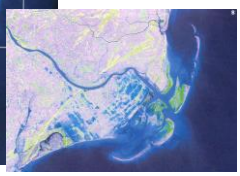
Van Maren, 2004

Universiteit Utrecht



Tide-dominated (Haiphong and Ha Long Bay)

Wave-dominated

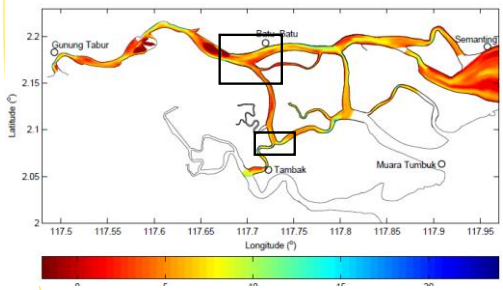


Universiteit Utrecht

2. Dynamics of Deltas

- **Distribution of water and sediment over delta distributary network; major challenge – no trivial problem !**
  - **Distribution of water**
    - River flow and (bed) geometry at tidal junctions
    - Tidal water levels and currents
    - Salinity effects
  - **Distribution of sediment**
    - Bedload and suspended load (time lags)
- **Channel switching and migration**

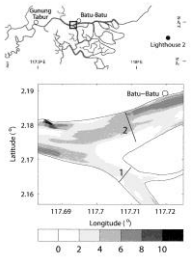
Universiteit Utrecht

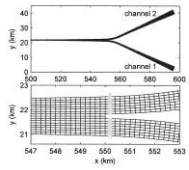


Buschman, 2011

Universiteit Utrecht

Subtidal flow division at a tidal junction; schematized model simulation





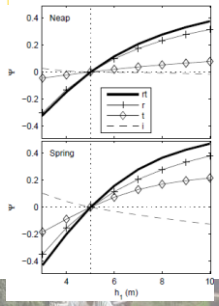
Response to asymmetries in:

depth, length, width convergence and bed roughness

Buschman et al., 2009

Universiteit Utrecht

Tidally-averaged flow distribution



Ψ asymmetry index =

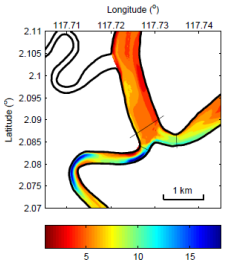
$\langle Q_1 \rangle - \langle Q_2 \rangle / \langle Q_1 \rangle + \langle Q_2 \rangle$

- **Depth (example)**
- **Length**
- **Width (e-folding length scale)**
- **Hydraulic roughness**

Buschman et al, 2010

Universiteit Utrecht

Tidal junctions and "local"effects



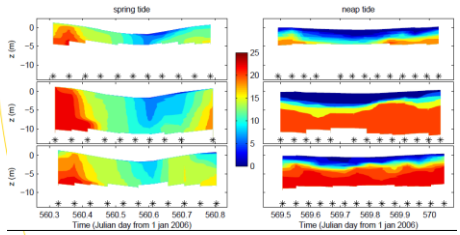
- Morphology and geometry
- Curvature effects
- Density (salinity) distribution

Effect on SPM distribution

Buschman et al, 2010

Universiteit Utrecht

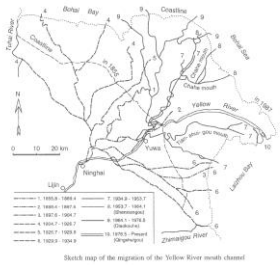
Salinity (psu) distribtion in N (top), Western (middle) and Eastern Channel (bottom



Buschman, 2011

Universiteit Utrecht

Delta scale: channel switching Yellow River delta, China; 1855-2000: 10 different systems

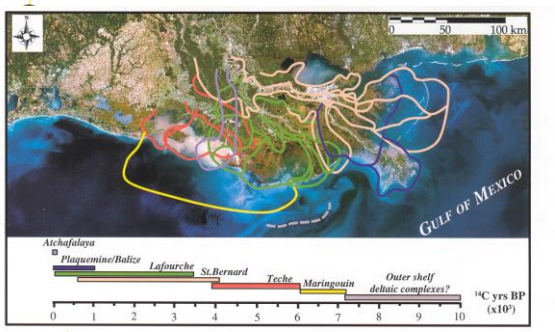


Sketch map of the migration of the Yellow River mouth channel

Universiteit Utrecht

3. Degradation of deltas

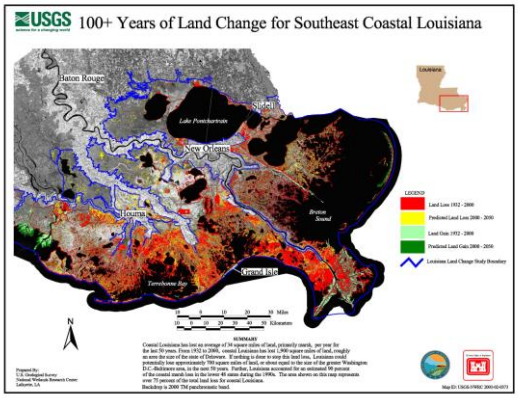
- **Coastal erosion of passive lobes**
- **Large scale and spatial variability in subsidence**
  - Natural compaction of sediment
  - Ground water extraction
  - Peat compaction, oxydation
  - Mineral resources (oil and gas)
- **Loss of water and sediment input (dams, reservoirs)**



Universiteit Utrecht

3. Degradation (cont.)

- **Redistribution of sediment**
- **Wetland losses**
- **Major deltas worldwide are presently eroding due to reduction of water and sediment load**
  - **Examples Mediterrenean:**
    - **Ebro Delta, Spain – lost 96 % of sediment load**
    - **Nile delta, Rhone delta, Po delta**



Universiteit Utrecht

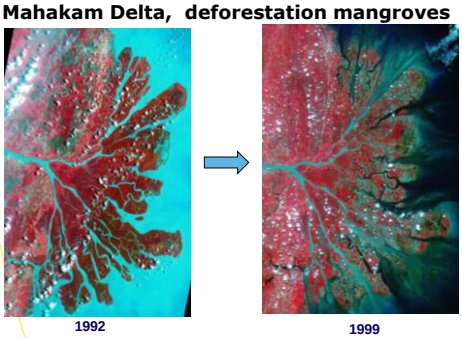
Ebro Delta, Spain

Universiteit Utrecht

Rhône Delta, France

Universiteit Utrecht

Mahakam Delta, deforestation mangroves



1992 1999

Universiteit Utrecht

Mangroves versus aquaculture; enhanced coastal erosion

Universiteit Utrecht

Some conclusions:

- **General understanding of main processes and conditions determining delta morphology and shoreline dynamics**
- **Distribution of fresh water, saline water and sediment in delta networks still a major challenge**
- **Even in data-rich and well-studied areas (Rhine-Meuse delta)**
- **Major issue for delta development and management**

Universiteit Utrecht

Future Deltas
www.uu.nl/futuredeltas