



Complex coastal groundwater systems

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Coasts: Critical zone

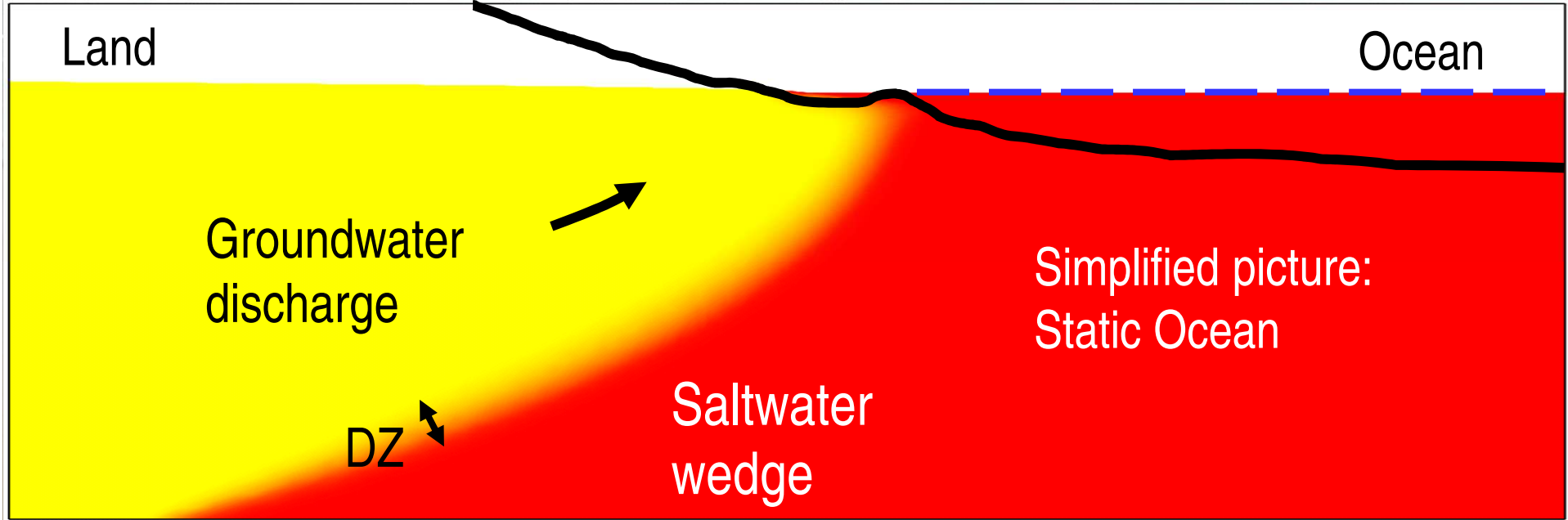
Large proportion of the world's population lives near coastlines

Understanding Matter Fluxes:

“What is the role of the coastal zone in matter fluxes between land and ocean?”

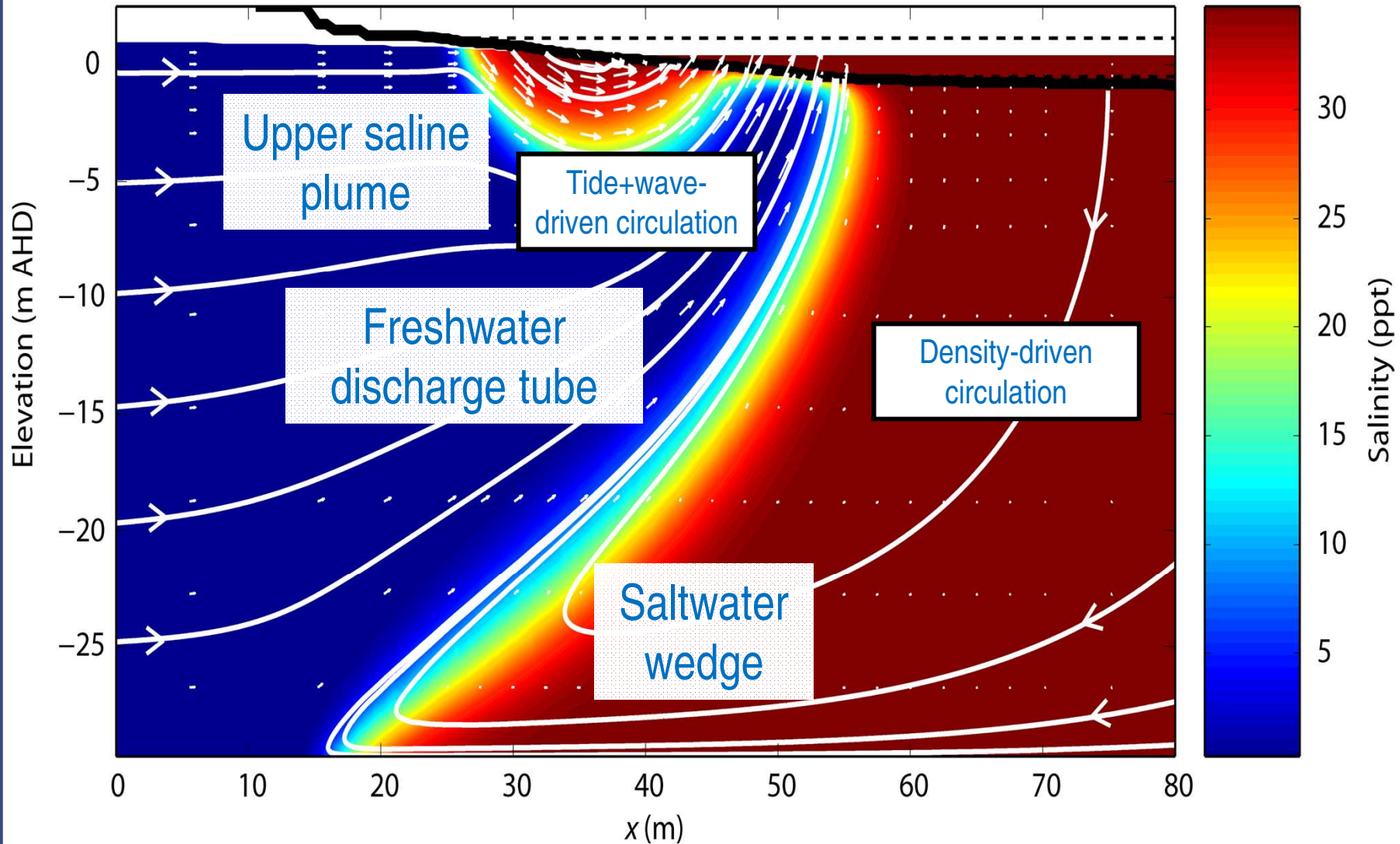
“An unresolved issue is the quantity and quality of matter flow across the various reactive zones ... (... coastal zone)”





How does fresh groundwater discharge to the ocean?

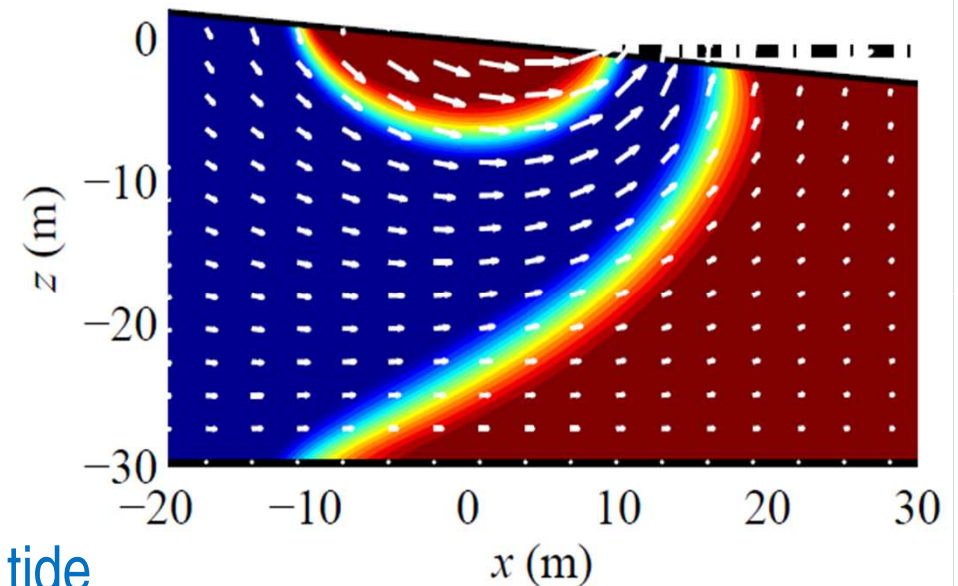
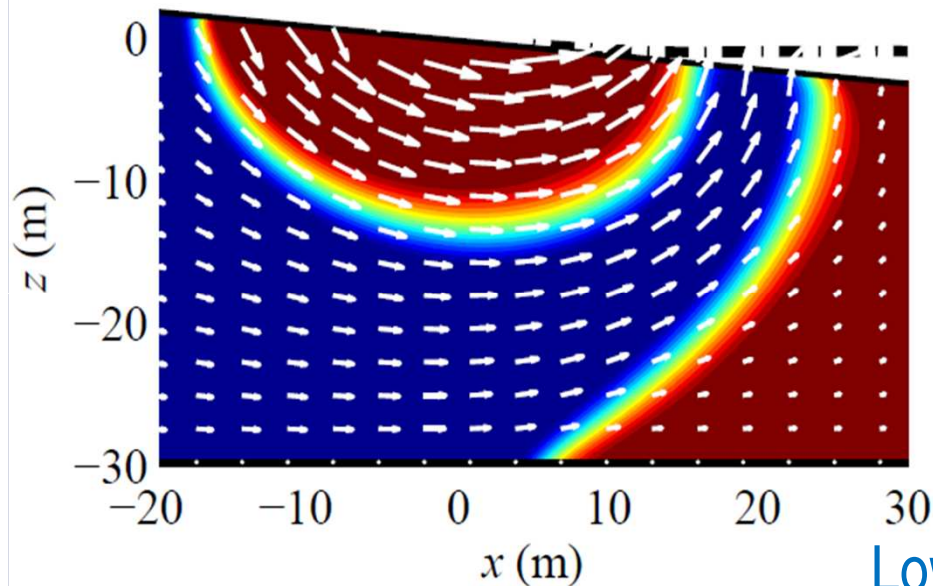
Measured and simulated salinity distributions



Combined effects of tides and waves

Tide + wave

Tide

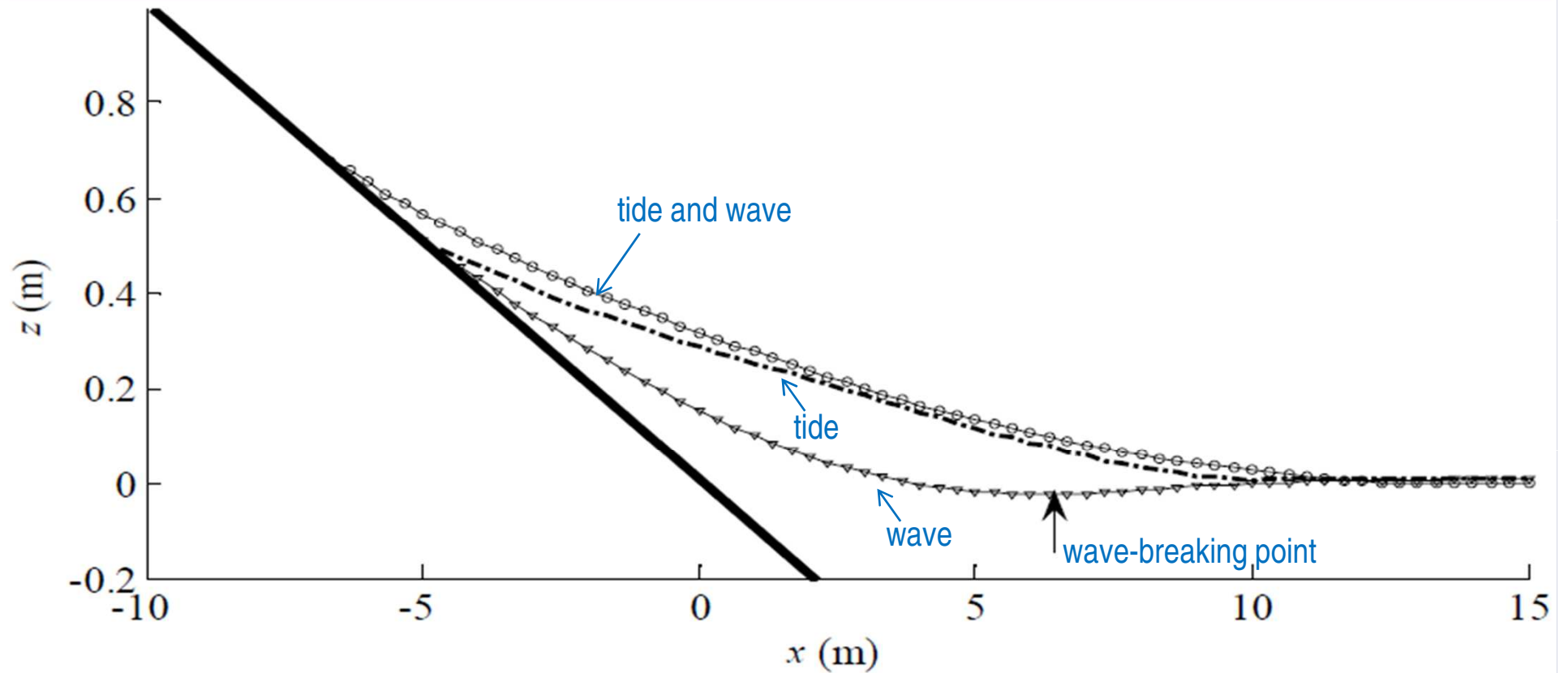


Low tide

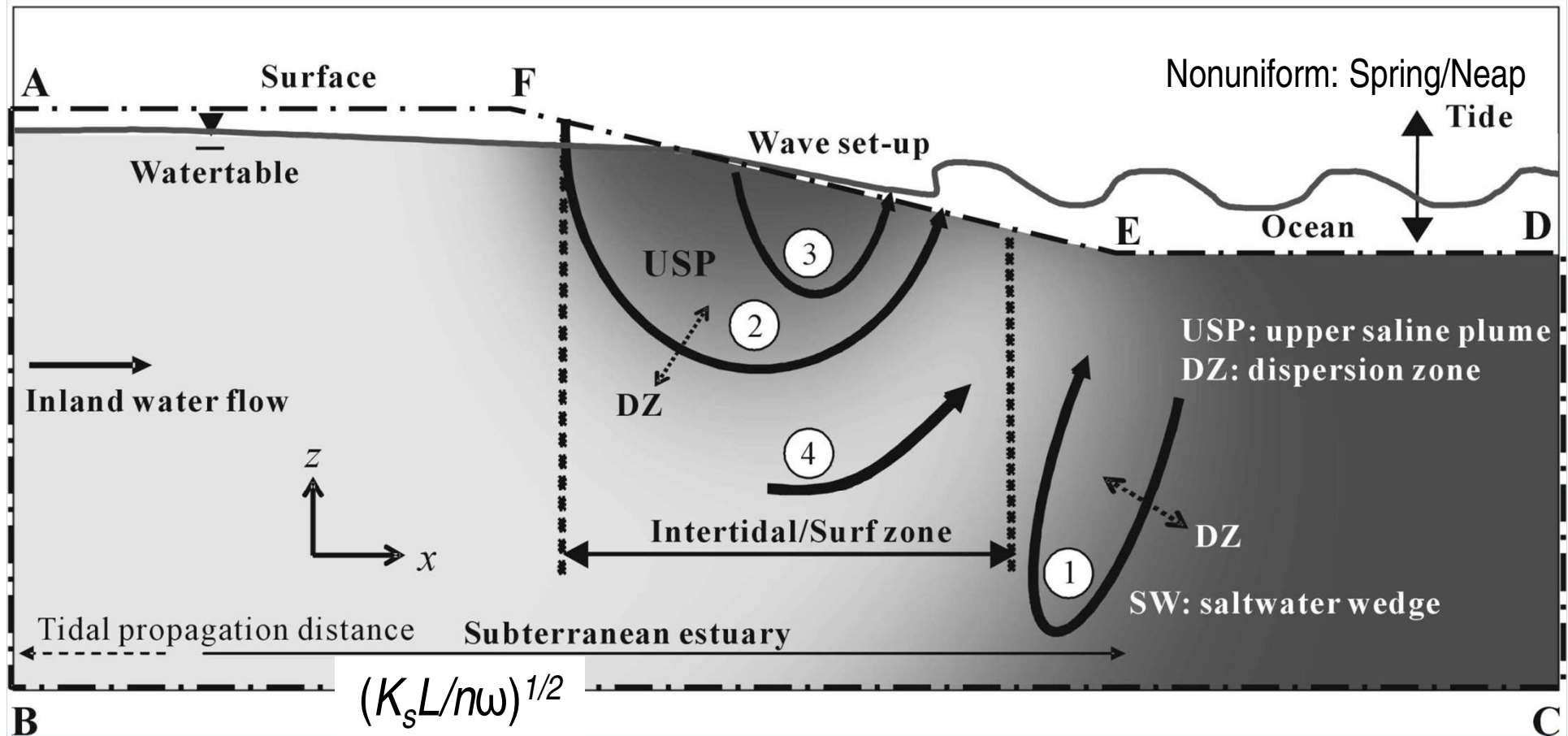
Wave + tide:

- Seaward movement of the wedge
- Circulation below the low-tide mark
- More intense circulation

Phase-averaged head on the beach

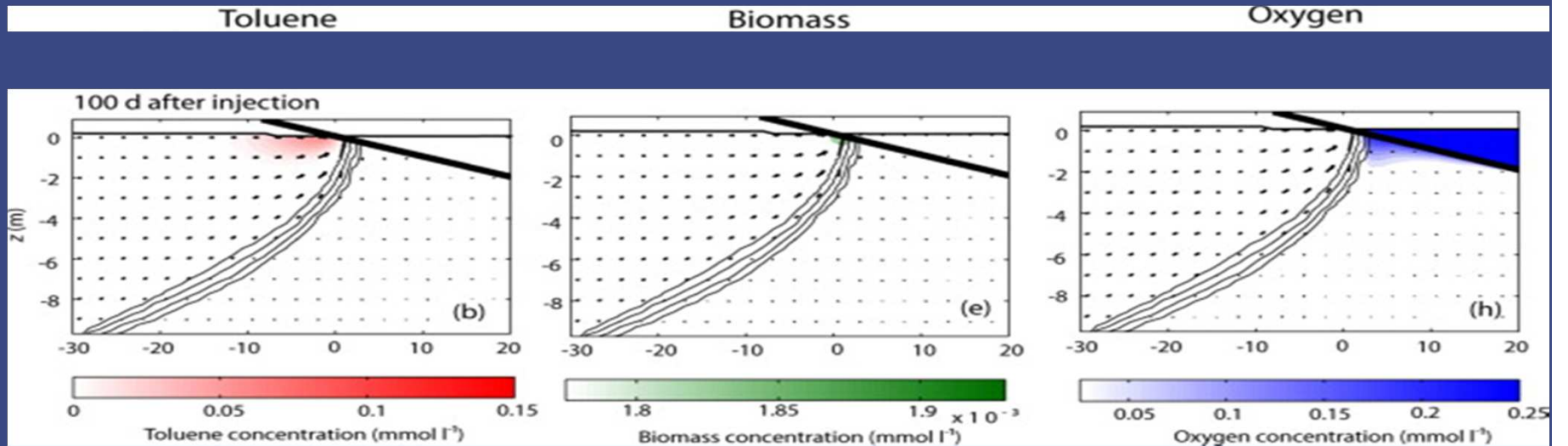


Complex groundwater flow in the intertidal zone: Subterranean estuary – 2D Cross-shore analysis



BTEX biodegradation

Static Ocean

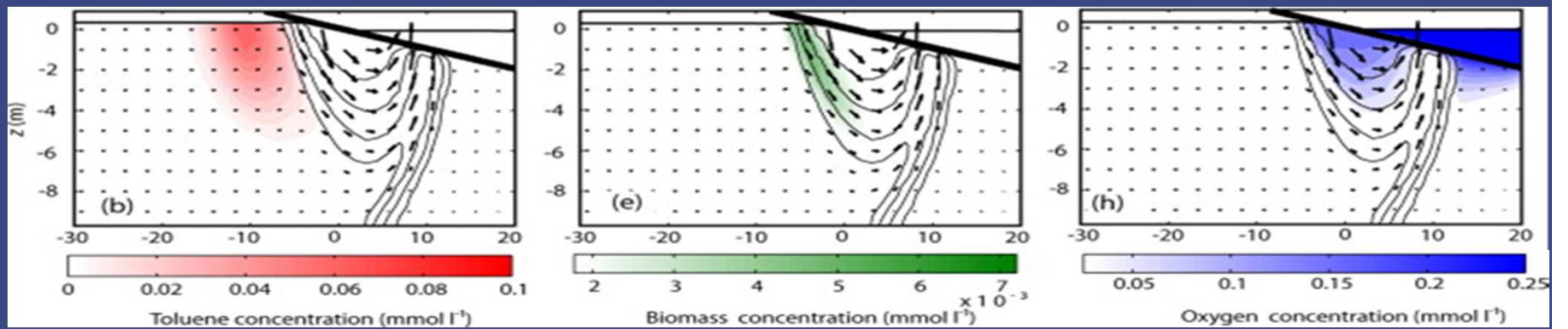


Slower movement,
wedge displacement

Biomass growth

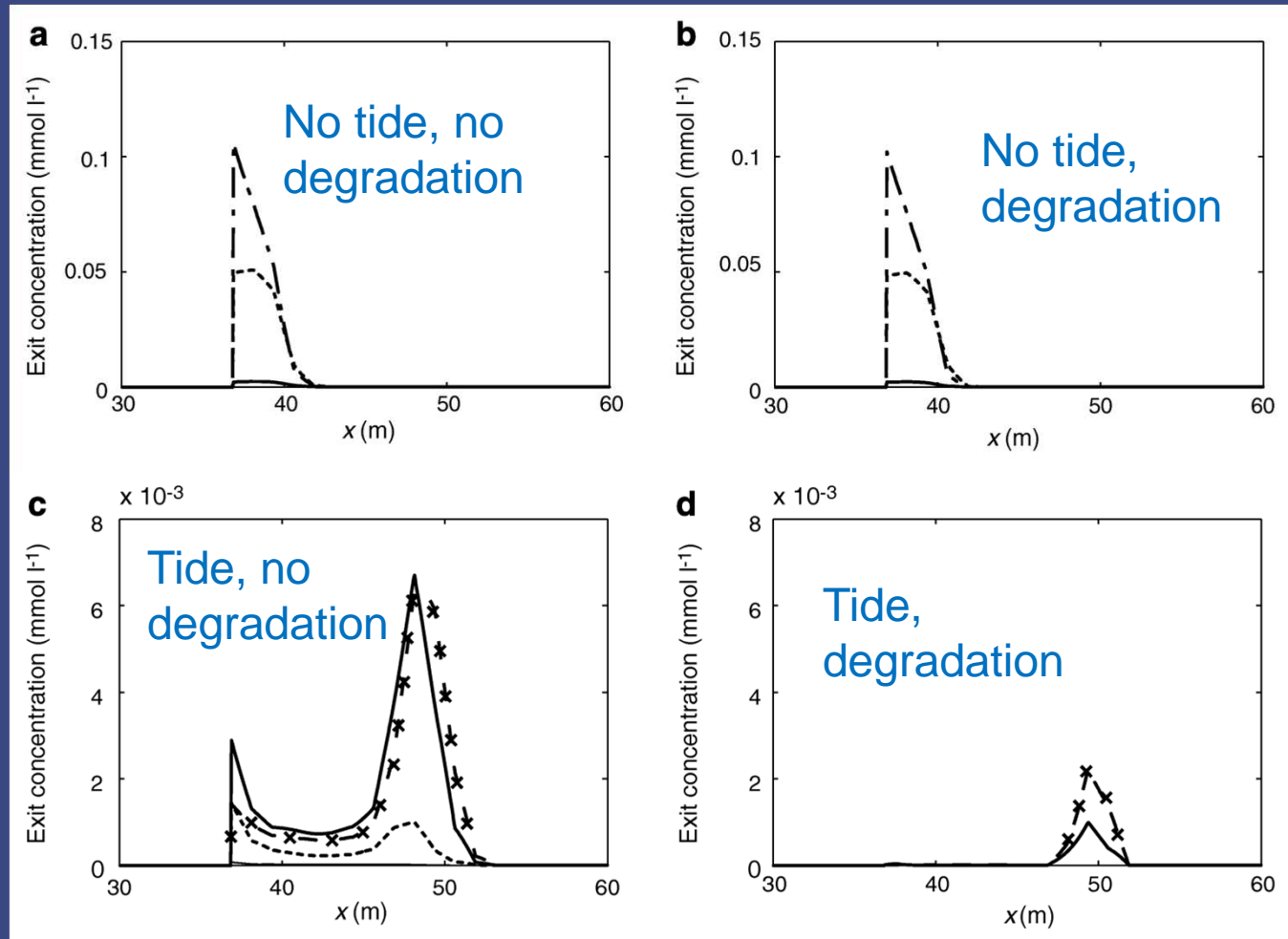
Oxygen penetration

Dynamic Ocean



Tides enhance biodegradation

Beachface toluene concentrations, day 75, 100, 125, 150



Coastal water quality: Lyngbya blooms

High concentrations of

- Organic carbon
- Nitrogen
- Phosphorus
- Bio-available iron

with

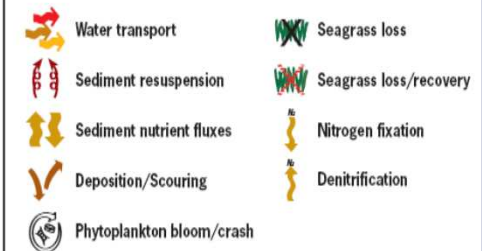
- Shallow, warm waters
- High light availability



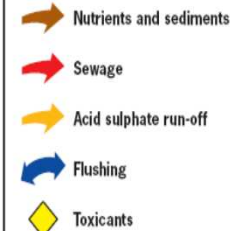
Lyngbya in Moreton Bay, Queensland, Australia



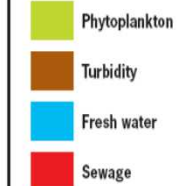
Processes



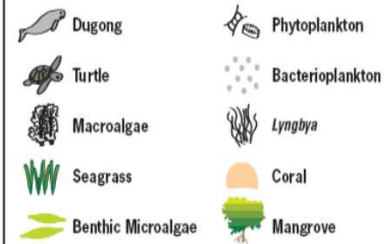
Inputs



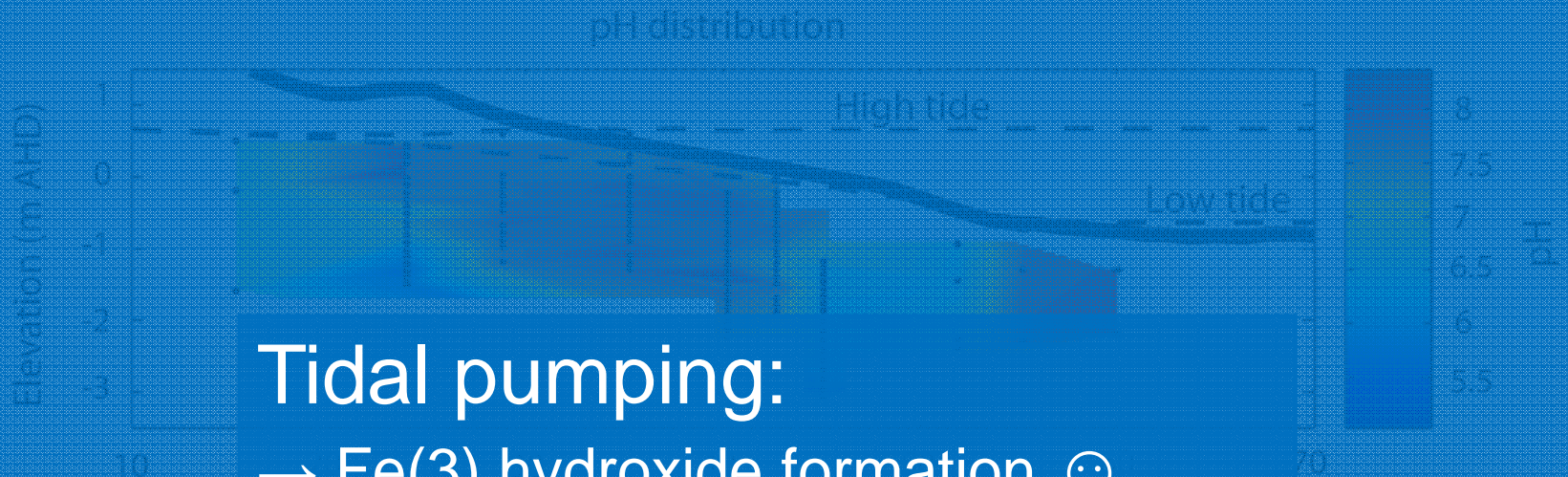
Zones



Biota



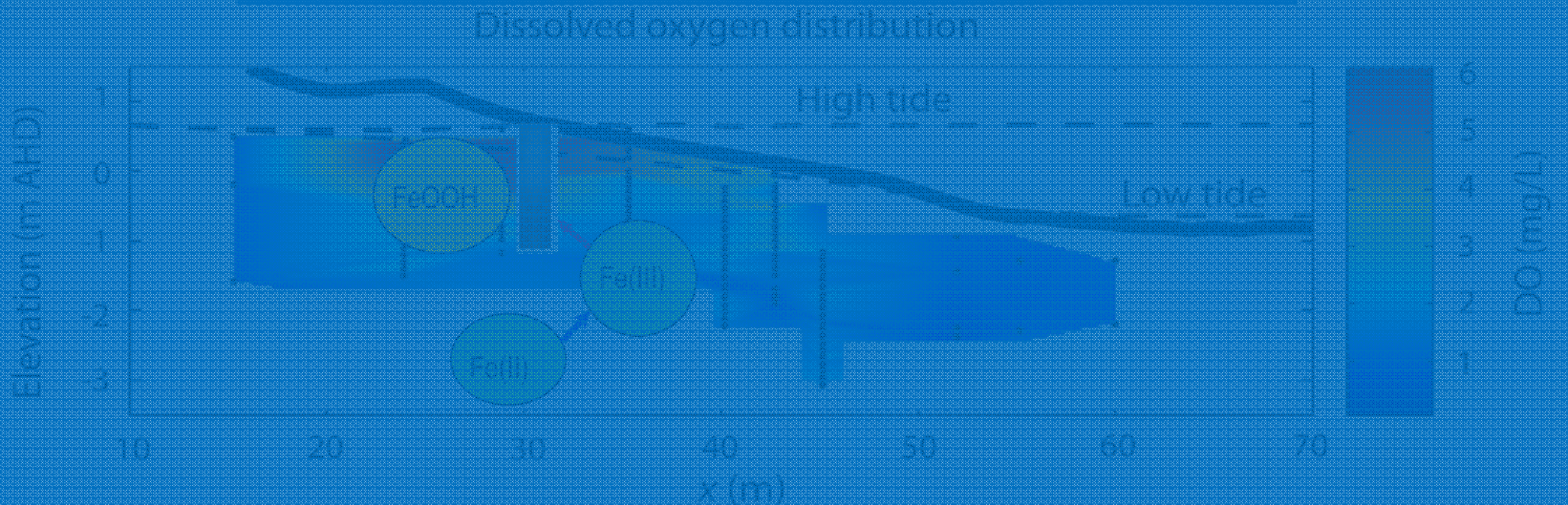
Biogeochemical zonation: Iron curtain



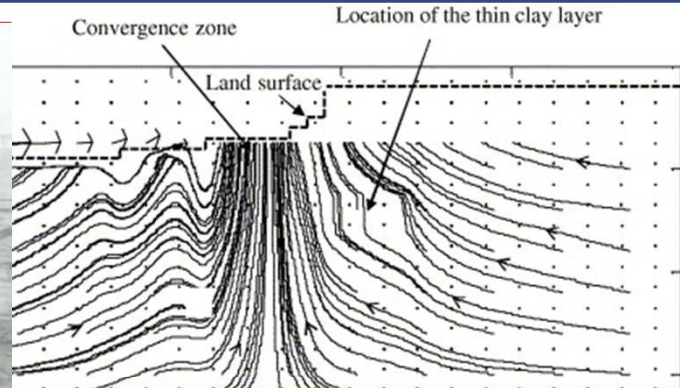
Tidal pumping:

→ Fe(3) hydroxide formation ☺

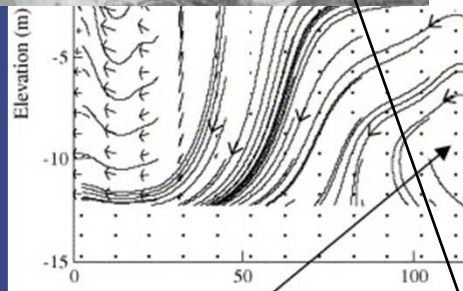
→ Oxidation of dissolved organics ☺



Estuary: Tide-induced circulation



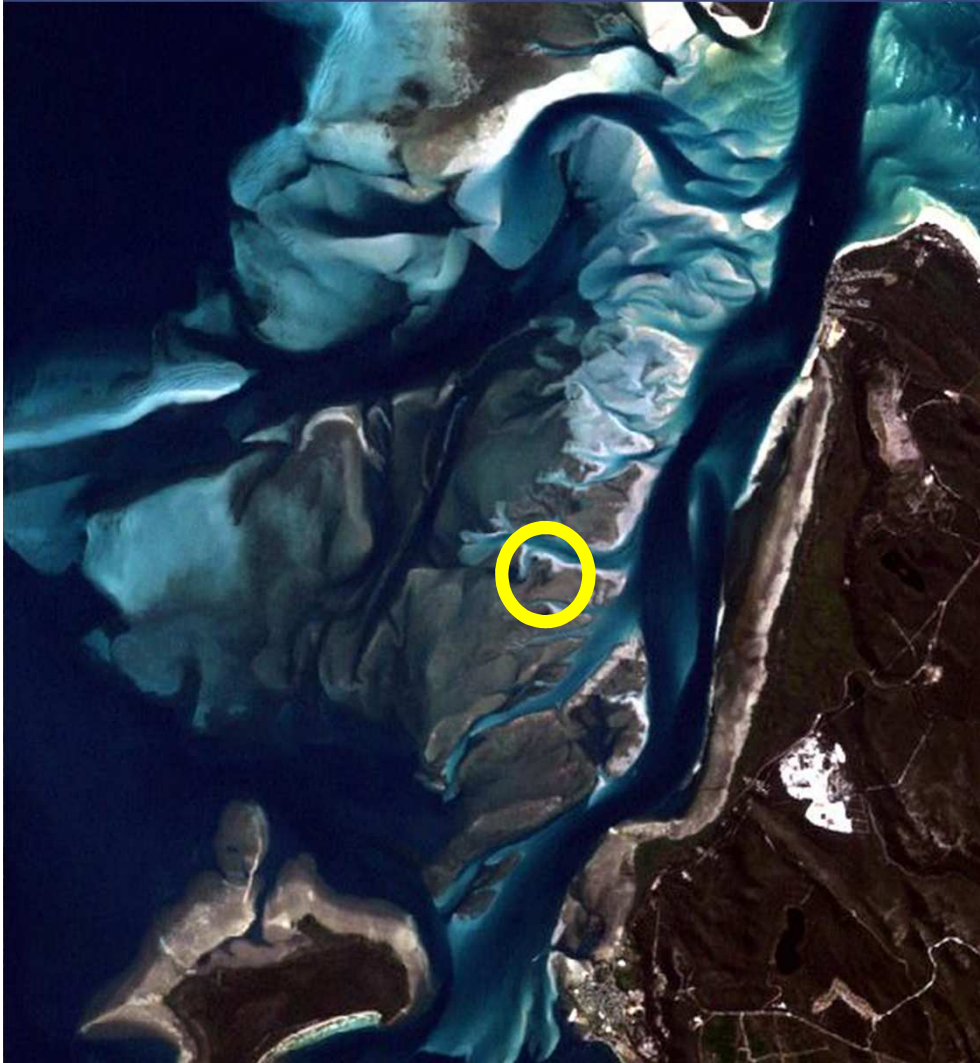
Instantaneous
flow fields



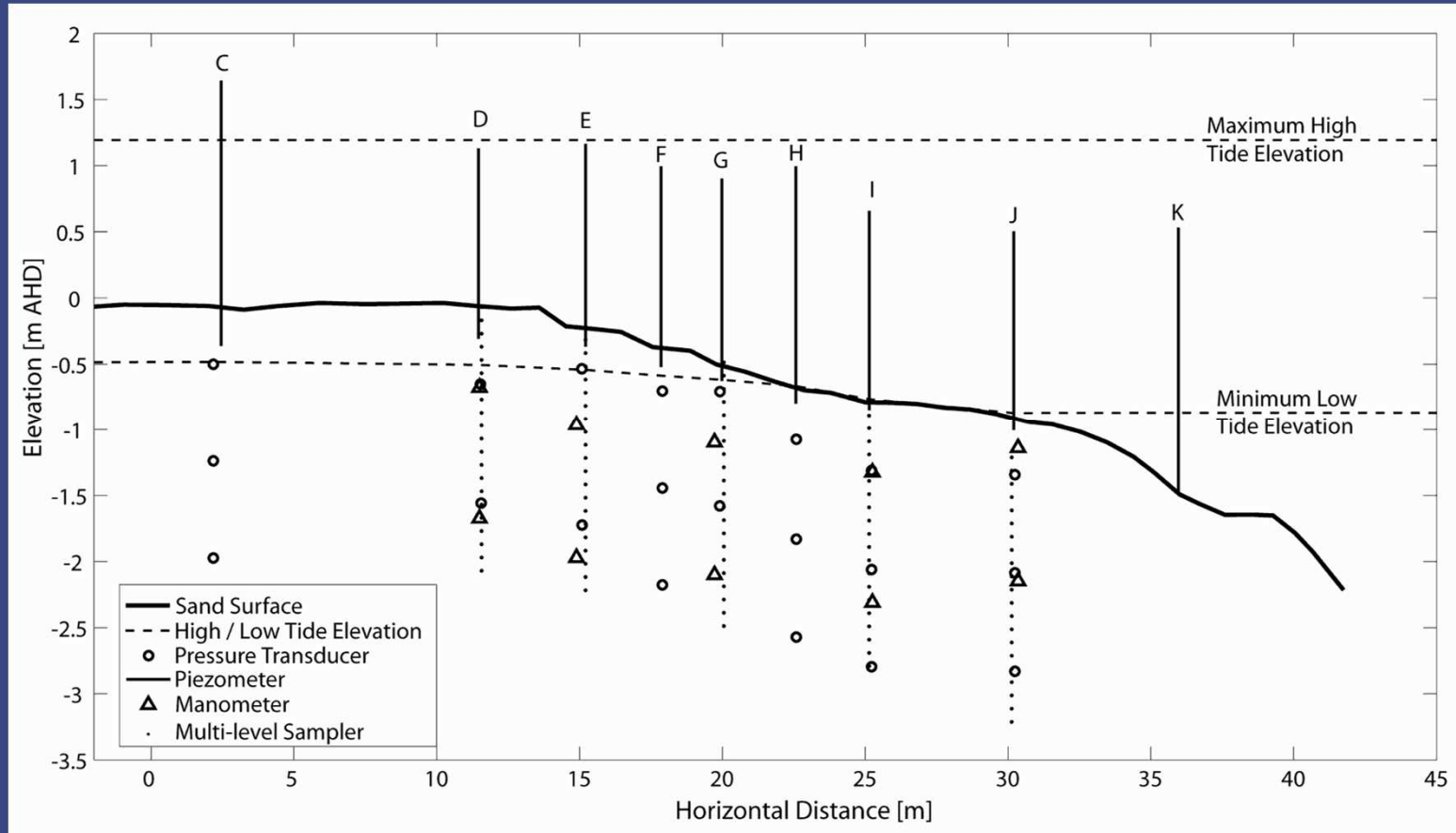
b

Anti-clockwise circulation zone

Exchange and circulation between an offshore intertidal sandbank and coastal water

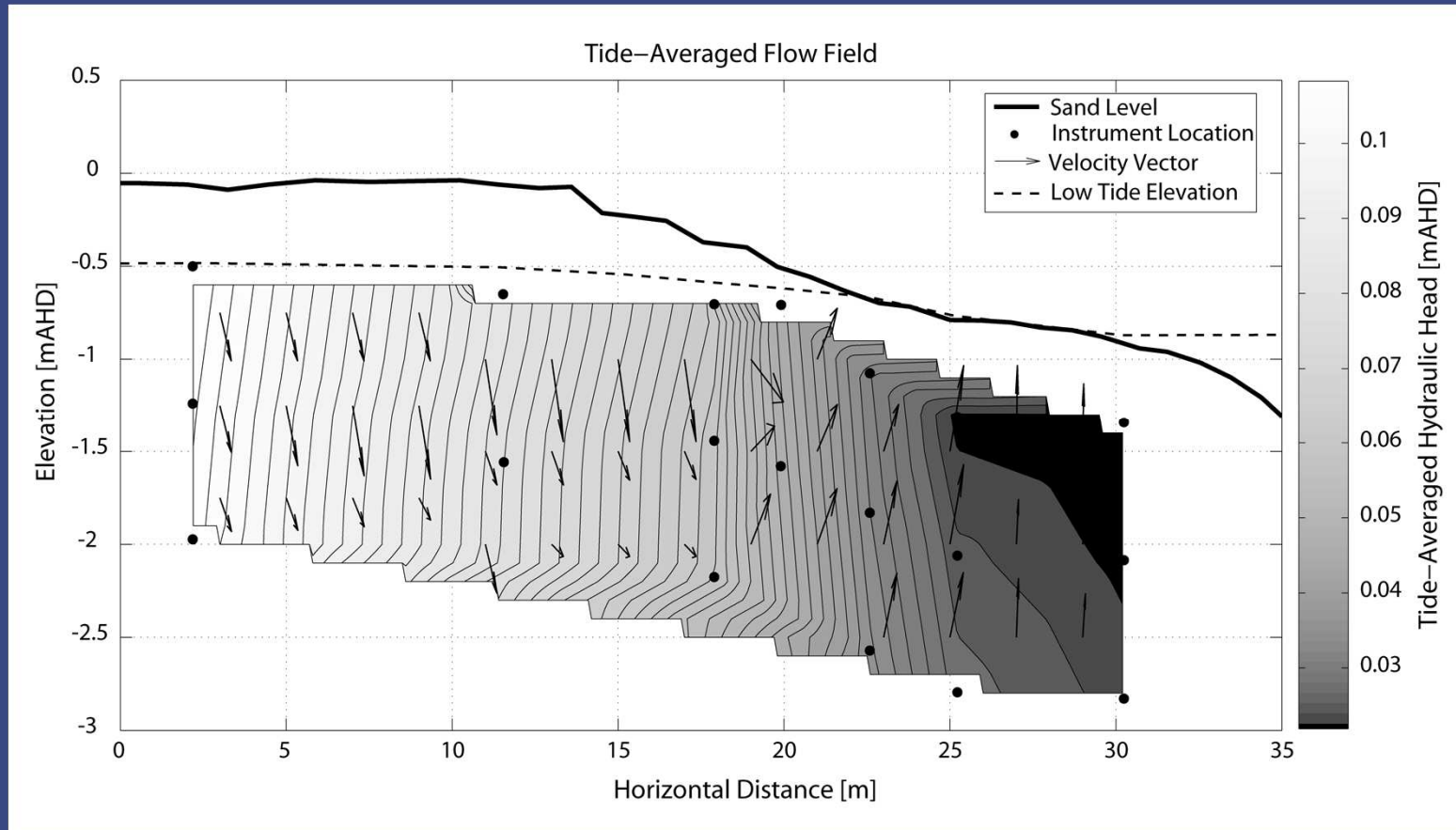


Field measurement: Tide-induced circulation



Tide-induced circulation in an offshore intertidal sandbank

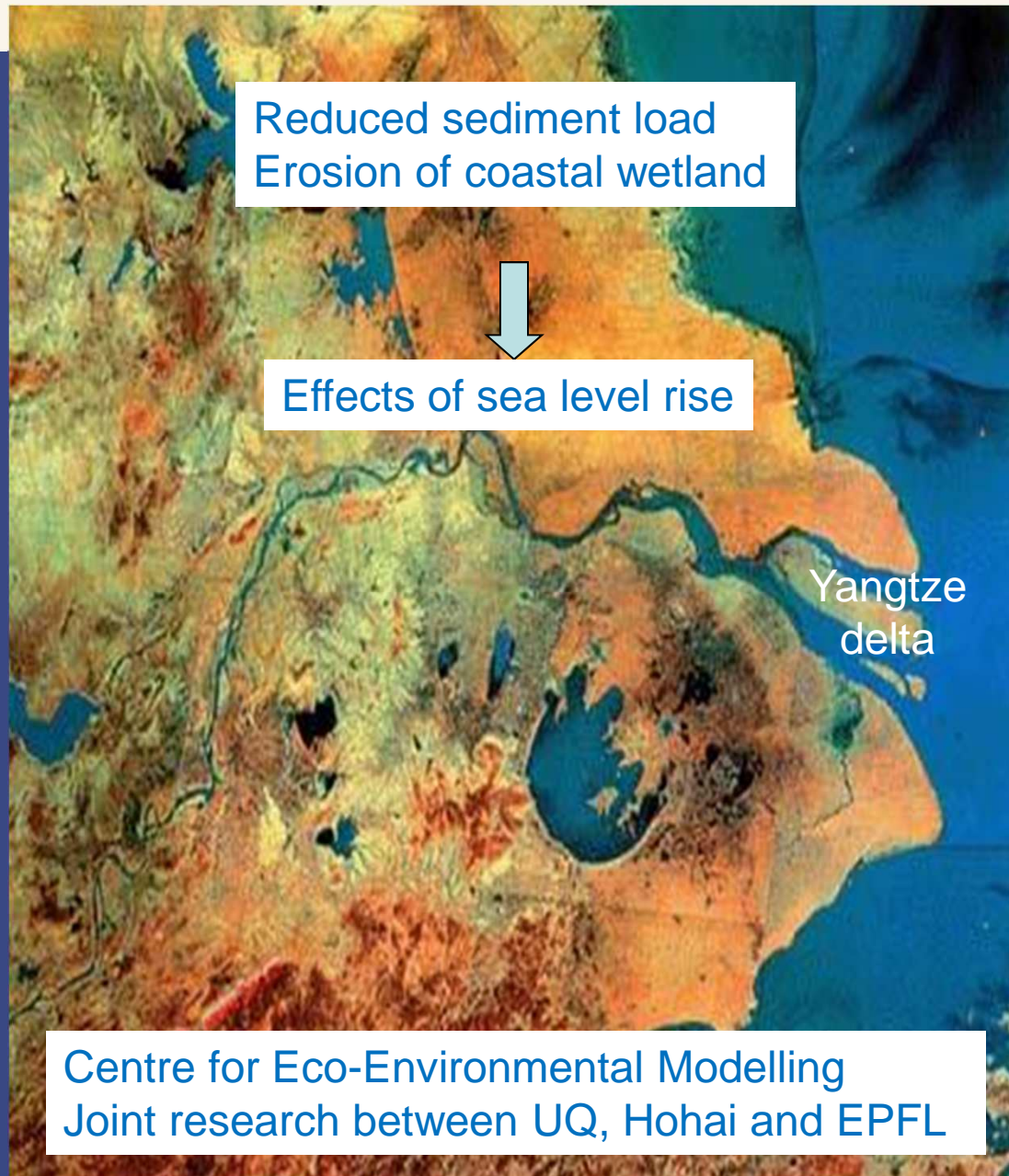
Field measurement: Tide-induced circulation



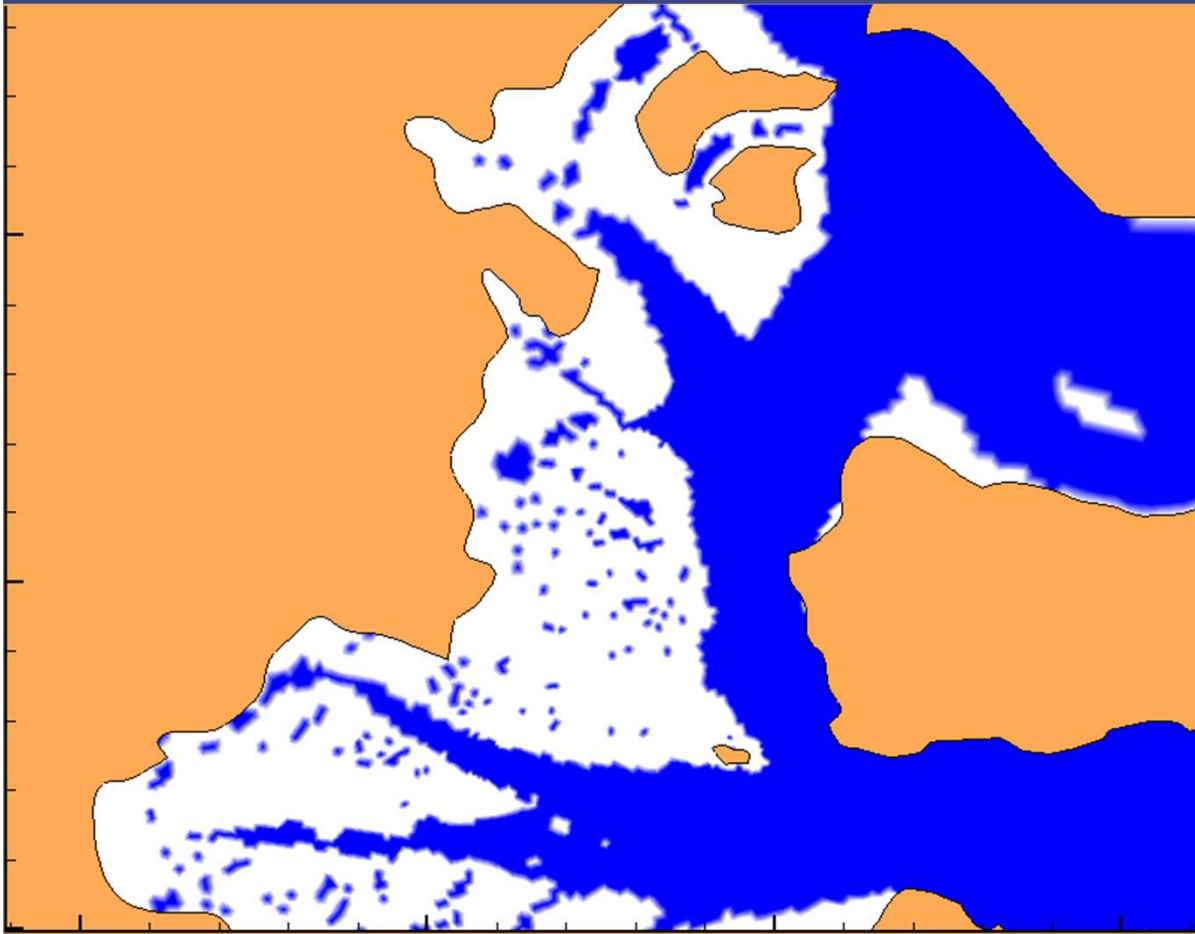
Tide-induced circulation in an offshore intertidal sandbank



Impact of the Three-Gorges Dam



Salt marshes: Coupled surface/subsurface flow



- What role is played by the subsurface in transport of dissolved materials in the system?
- What controls the marsh soil aeration?

Implications for:

- Filtering/buffering functionality of salt marshes (land-derived materials)
- Nutrient exchange between salt marsh and coastal water (nutrients produced within the salt marsh)
- Biogeochemical reactions and plant growth in the marsh

Water exchange over a tidal cycle

Low tide

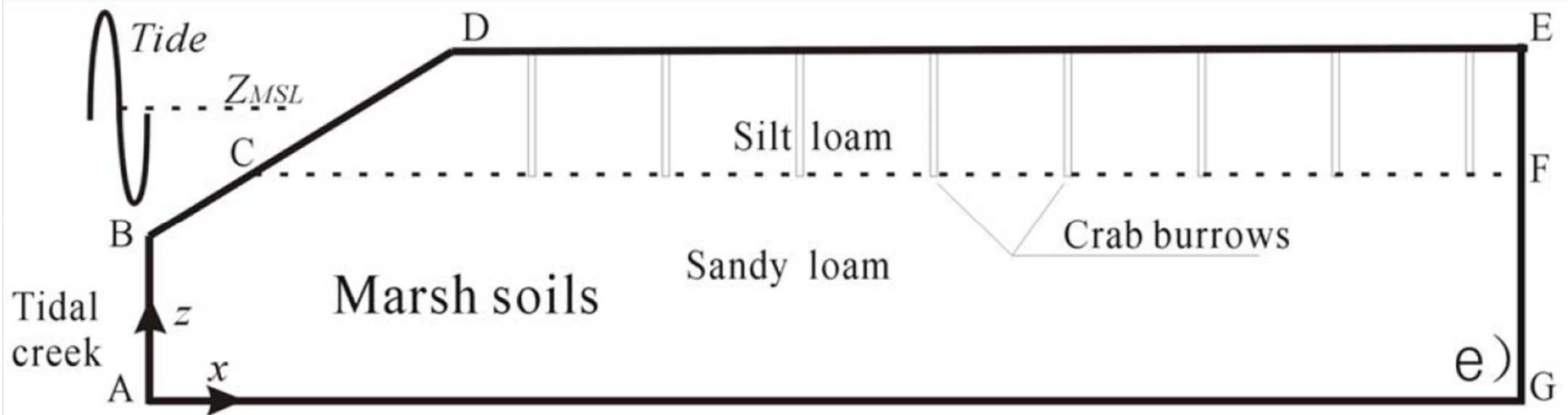


High tide



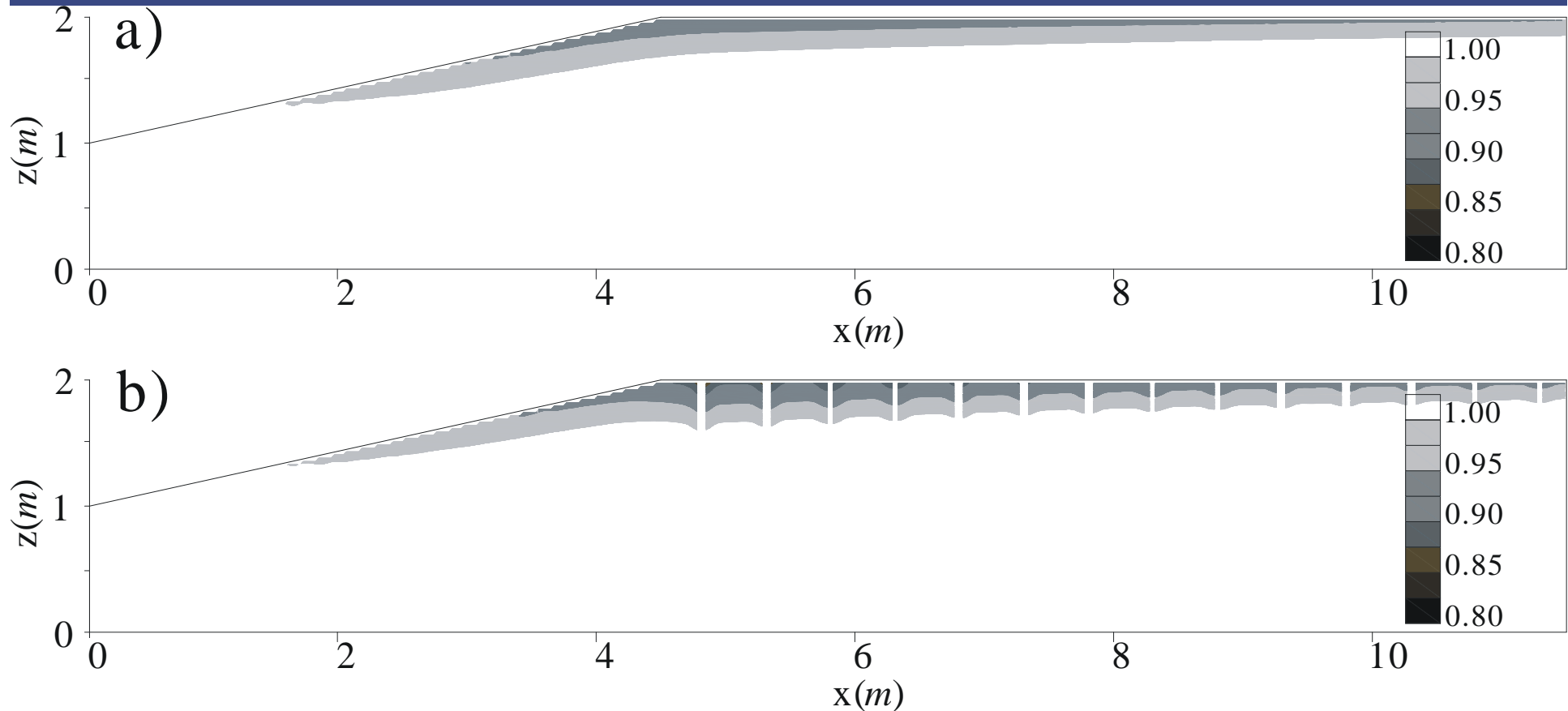
Tide-dominated hydraulics (spring-neap)

Enhanced exchange due to crab burrows



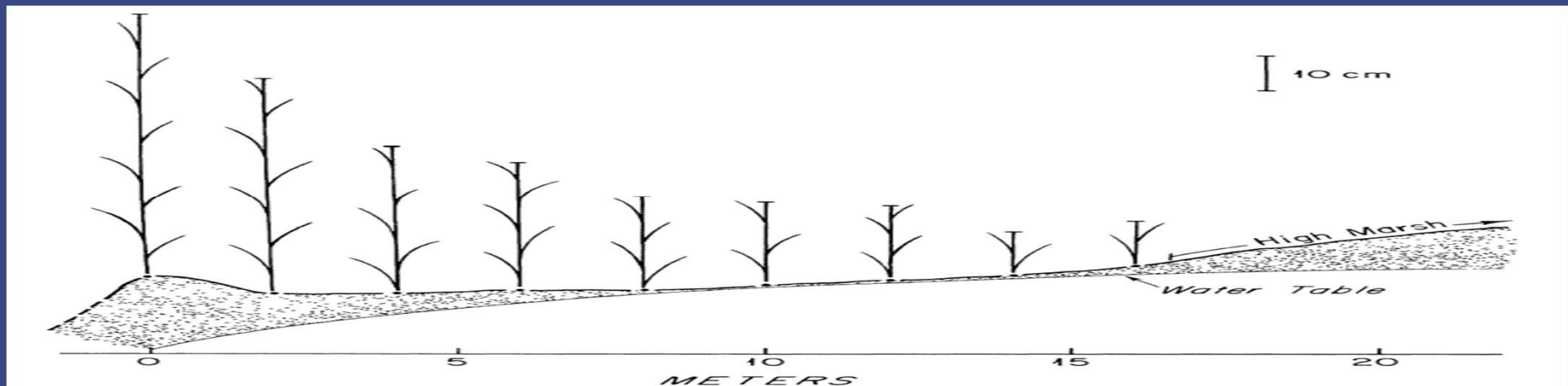
Enhanced aeration due to crab burrows

Tidally averaged

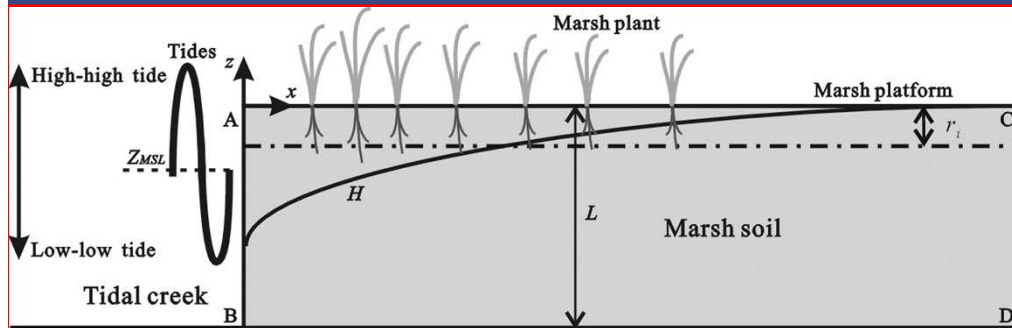


Net exchange rate over one tidal cycle (17% difference)
With burrows: 82 l/m; Without burrows: 70 l/m

Plant zonation hypothesis: Aeration

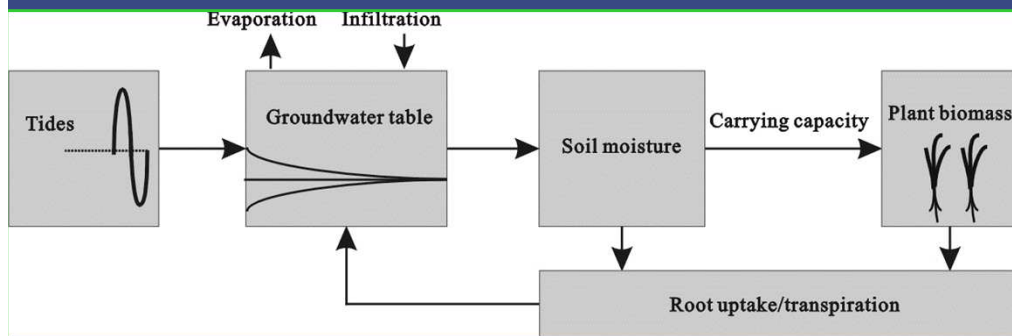


Vegetation-groundwater interactions in tidal marshes



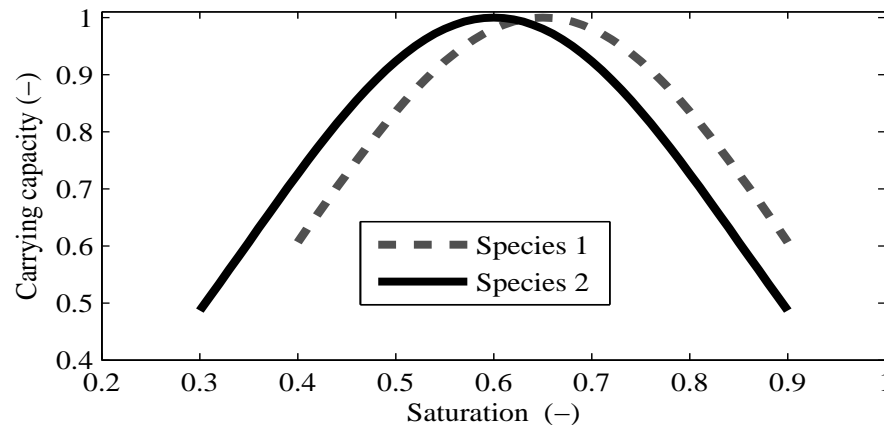
Groundwater dynamics

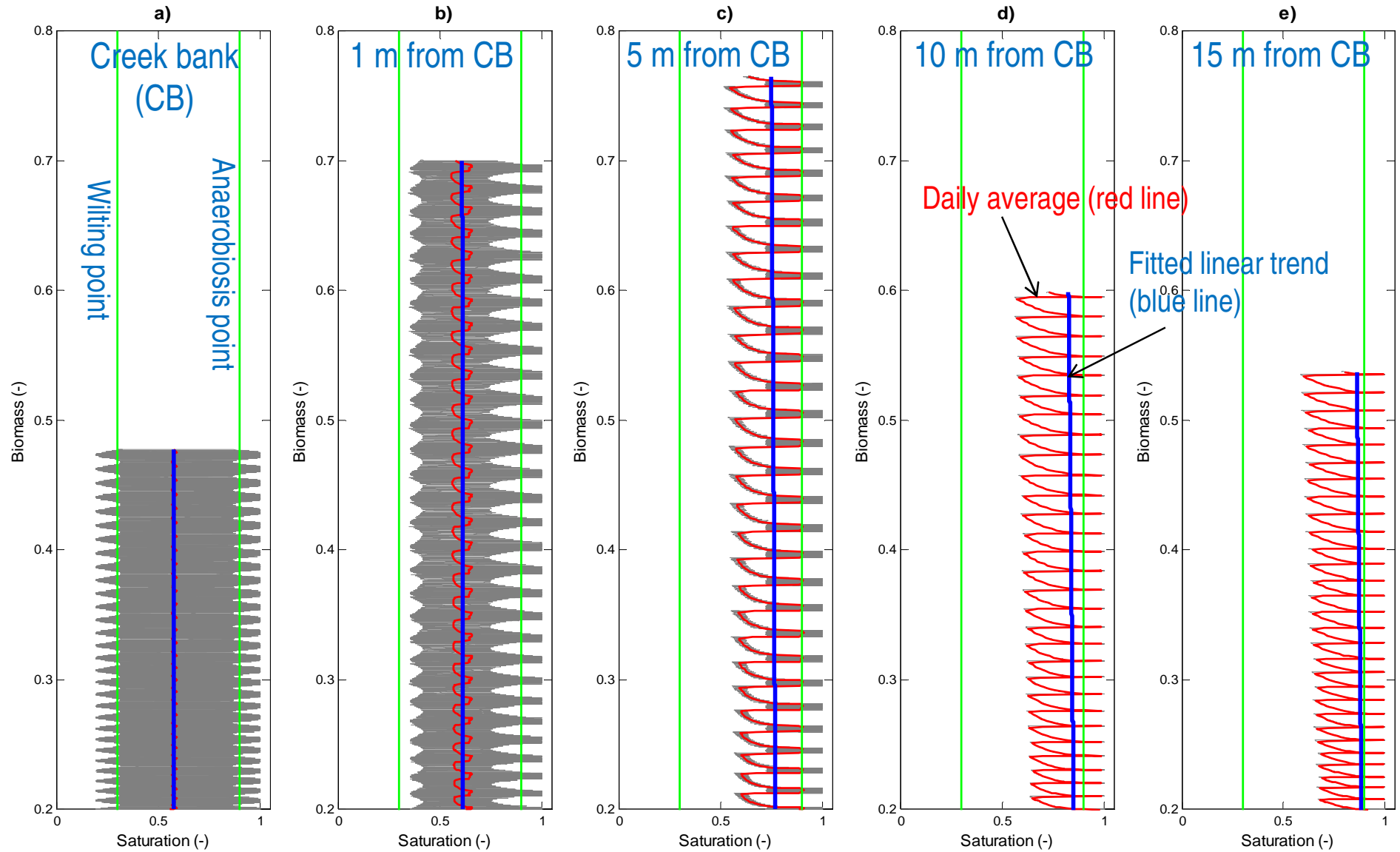
$$\begin{aligned}
 & \underbrace{n_e \frac{\partial H}{\partial t}}_1 - \underbrace{n_e \exp(\alpha H) \frac{\partial H}{\partial t}}_2 \\
 &= \underbrace{K_s \frac{\partial}{\partial x} \left[(L + H) \frac{\partial H}{\partial x} \right]}_3 + \underbrace{K_s \frac{\partial}{\partial x} \left[\frac{1 - \exp(\alpha H)}{\alpha} \frac{\partial H}{\partial x} \right]}_4 + I - EP
 \end{aligned}$$



Biomass dynamics

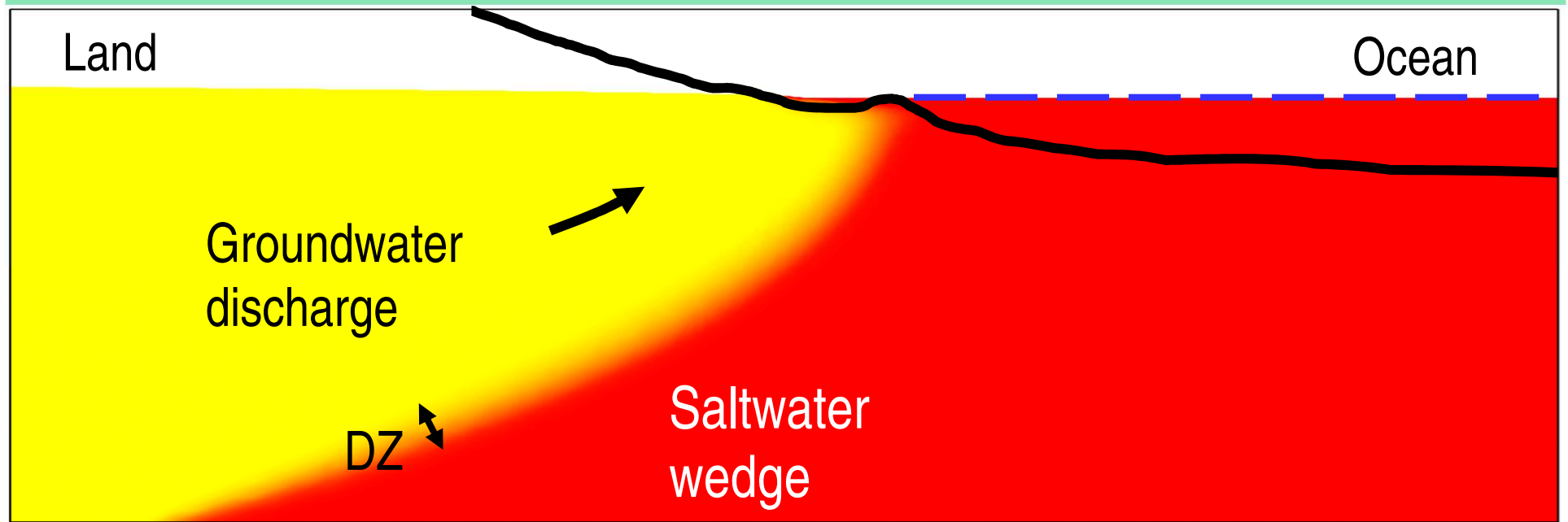
$$\frac{\partial N_i}{\partial t} = G_i N_i \frac{L_i (S_i^R) - N_i - F'(N_j)}{C_i} - M_i N_i + D_i \frac{\partial^2 N_i}{\partial x^2}$$





Mean soil saturation versus biomass at observation points over time (increasing upward):
increasing biomass improved aeration (positive feedback)

Traditional view: Static boundary



Coastal and marsh systems strongly controlled by boundary forcing

