TUDelft

Deltares
Enabling Delta Life

net transport of fine sediments in a narrow, converging estuary – the Sea Scheldt

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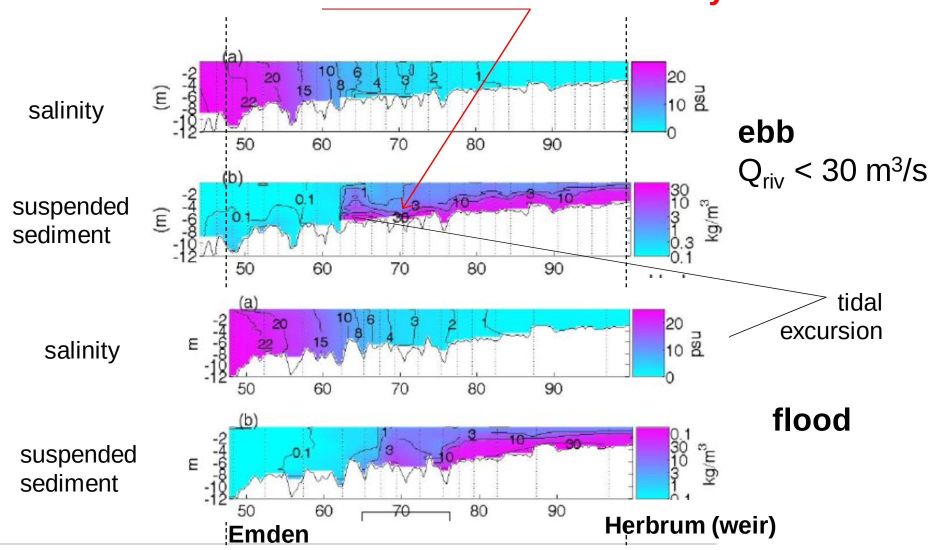
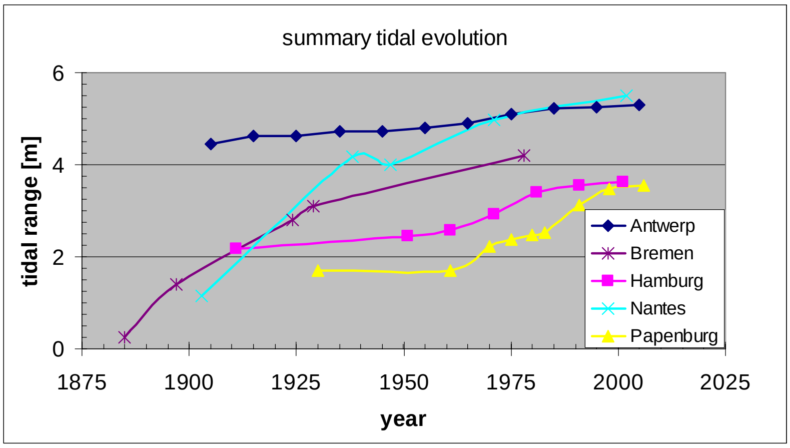
the hyper-turid Ems River

no relation between SPM & salinity



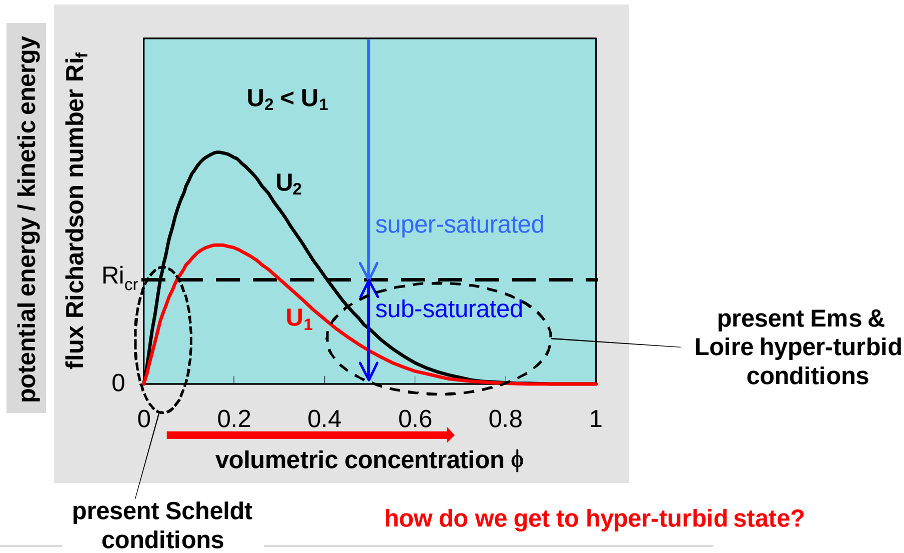
Talke et al., 2009 - data Aug 2, 2006

historical evolution of the tidal range



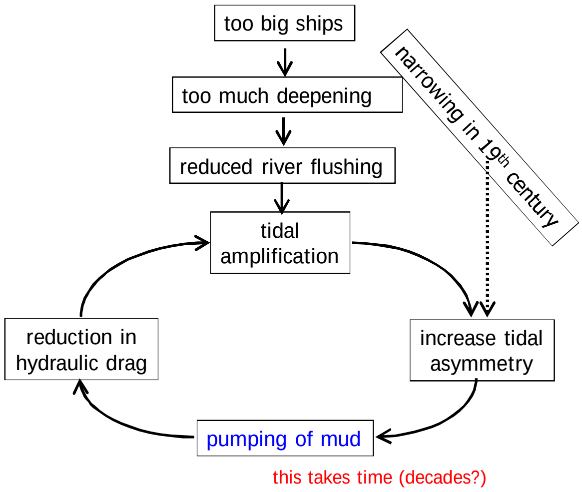
tidal amplification in Loire (Nantes) and Ems (Papenburg) can be explained for 50% by deepening and narrowing and for 50% by sediment-induced reduction in hydraulic drag

our research question – the stability diagram



how do we get to hyper-turbid state?

our research question



what triggers the increase in the net up-estuary transport of mud, e.g. the “pumping of mud”

net sediment transport processes

net sediment balance		SPM over water column	water-bed exchange
ΔSPM/Δt =	import by estuarine circulation	2DV or 3D	not relevant
	import (or export) by tidal asymmetry	see next slide	necessary
	export by river flushing	depth-averaged	not relevant
	source by bed/bank erosion	depth-averaged	-
	sink by sedimentation	depth-averaged	-
	transport by tidal advection = gross effect		

2DV or 3D: vertical SPM gradients required for net transport

vertical gradients are affected by sediment-induced stratification

net transport by tidal asymmetry

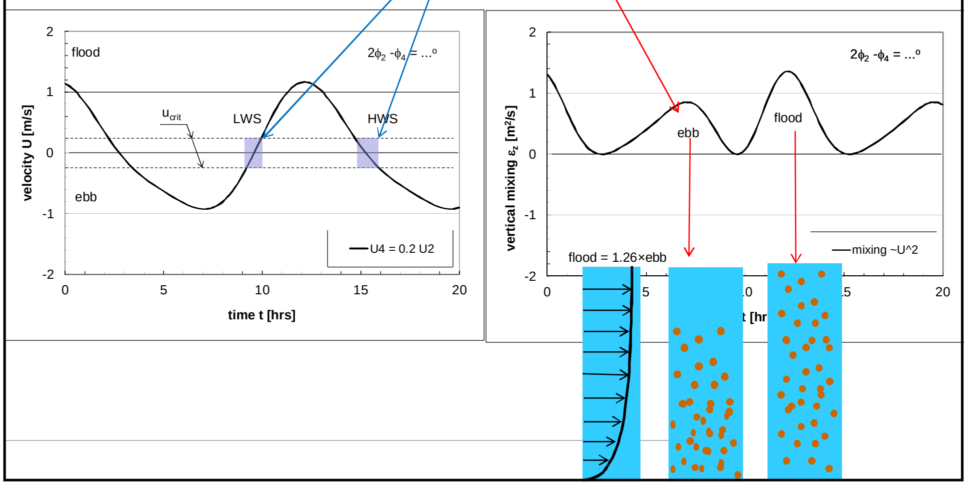
net transport by tidal asymmetry			SPM over water column	water-bed exchange
alluvial bed (hyper-turbid estuary)	peak flow asymmetry	$T \propto U^4$	depth-averaged	necessary
	ebb/flood asymmetry (settling lag)	$(\mathrm{d}u/\mathrm{d}t)_T$	depth-averaged	necessary
starved bed ("normal" estuary)	internal asymmetry (vertical mixing)	$\varepsilon_z \propto U^2$	2DV or 3D	necessary
	slack water asymmetry (scour lag)	$(\mathrm{d}u/\mathrm{d}t)_{u=0}$	depth-averaged	necessary

we start here, thus we look for balance between:

- estuarine circulation
- river-induced flushing
- tidal asymmetry in vertical mixing and slack water

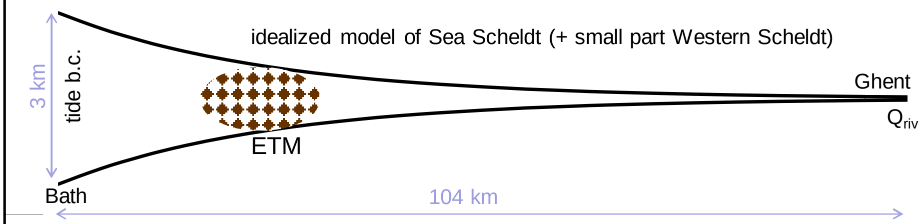
asymmetry for starved bed conditions

for starved-bed systems: slack-water asymmetry & asymmetry in mixing

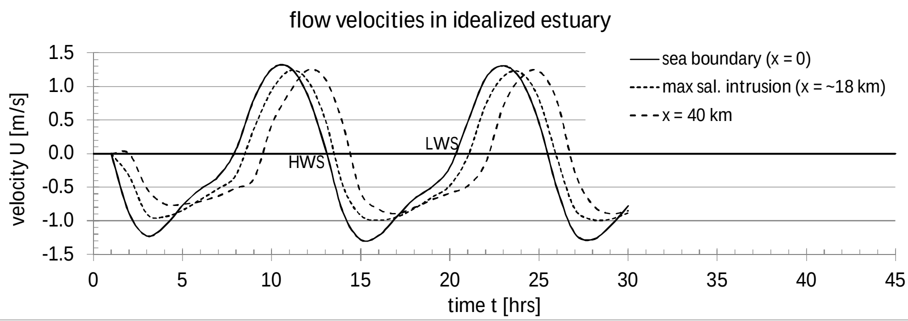


our approach

- idealized, converging estuary with constant depth
- dimensions, tidal forcing and river flow from Sea Scheldt river
- no intertidal area, hence flood-dominant
- implemented in Delft3D
- switch on/off various processes one by one (or combinations)
- vary boundary conditions (Q_{riv} and external M_4 amplitude & phase)
- vary internal processes (equation of state, erosion/deposition)



first results – development of asymmetry



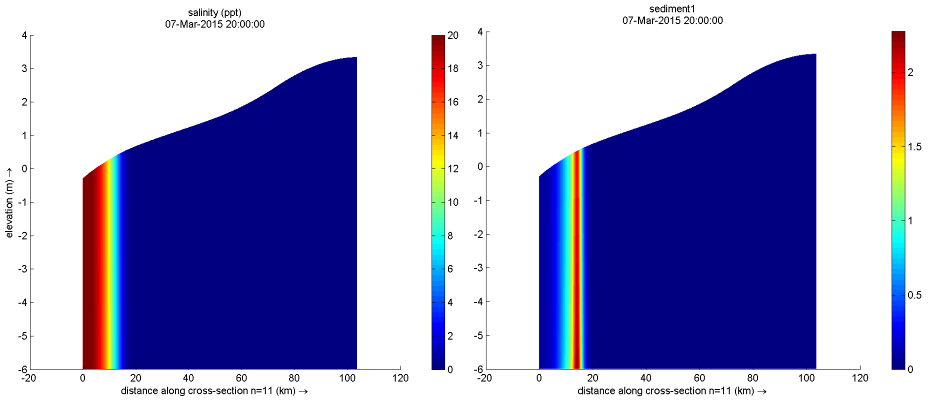
- profound development of asymmetry in peak velocity, hence vertical mixing: induces up-estuary transport
- $t_{LWS} < t_{HWS}$, hence down-estuary transport, but reducing in up-estuary direction

mouth *x* = 0		maximum salinity intrusion		*x* = 40 km	
LWS	HWS	LWS	HWS	LWS	HWS
45 min	24 min	33 min	24 min	24 min	21 min

first results – effect estuarine circulation

salinity

sediment (SPM)



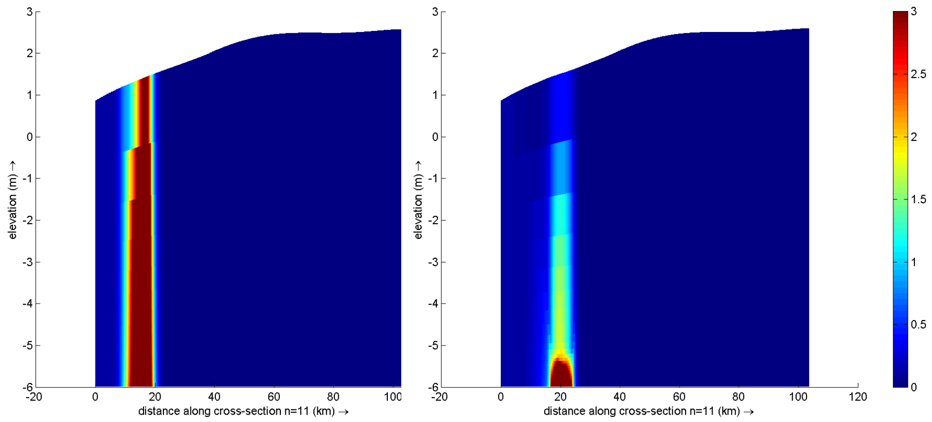
simulating 3 months sediment input from sea-side:

- no water-bed exchange
- no sediment-induced buoyancy destruction

first results – effect buoyancy destruction

without buoyancy destruction

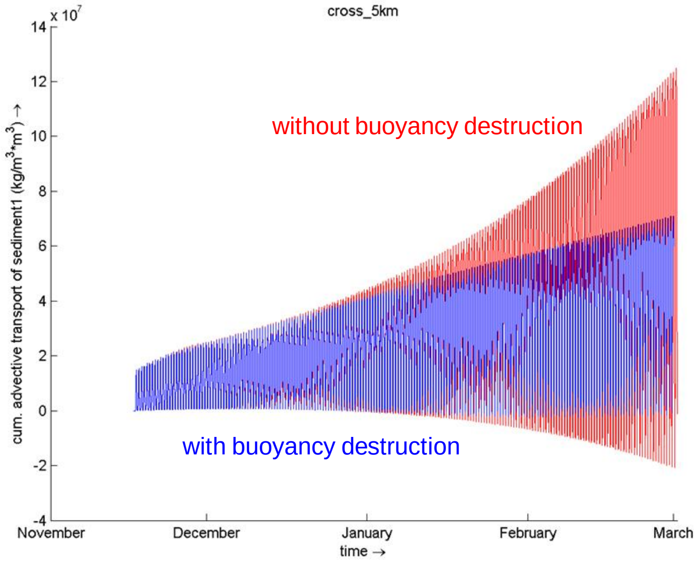
with buoyancy destruction



maximal up-estuary ETM after 6 months simulation time

sediment-induced buoyancy destruction =
effect sediment-induced stratification on vertical turbulent mixing

cumulative sediment flux through kmr 5



discussion and conclusions

- we used Delft3D for studying net transport of fine sediments in schematized estuary, resembling Sea Scheldt,
- this approach seems promising, but many more analyses are required,
- the first results indicate:
  - ETM can be produced by estuarine circulation alone,
  - sediment-induced buoyancy destruction keeps fines closer to the bed, reducing horizontal transports,
  - the realistic effect of sediment-induced buoyancy destruction is large, hence cannot be omitted in sediment transport studies,
  - tidal asymmetry without water-bed exchange does not induce net transport of fine sediment,
  - these numerical results are in line with theory, but have never been quantified.