Intercomparison of model predictions of estuarine morphology

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Outline

- Objectives
- Models × Estuaries
- Evidence for leaflet conclusions

Objective

- to improve confidence

in model predictions of estuary form

- Various models (B-U, T-D, Hybrid)
- eight varied UK estuaries

  → "ensemble"

- compare model approaches and estuaries

Models:

Emulator; based on 1-D equations, ▽ section, uniform tidal ampl

Regime-Shell; described by Adrian Wright

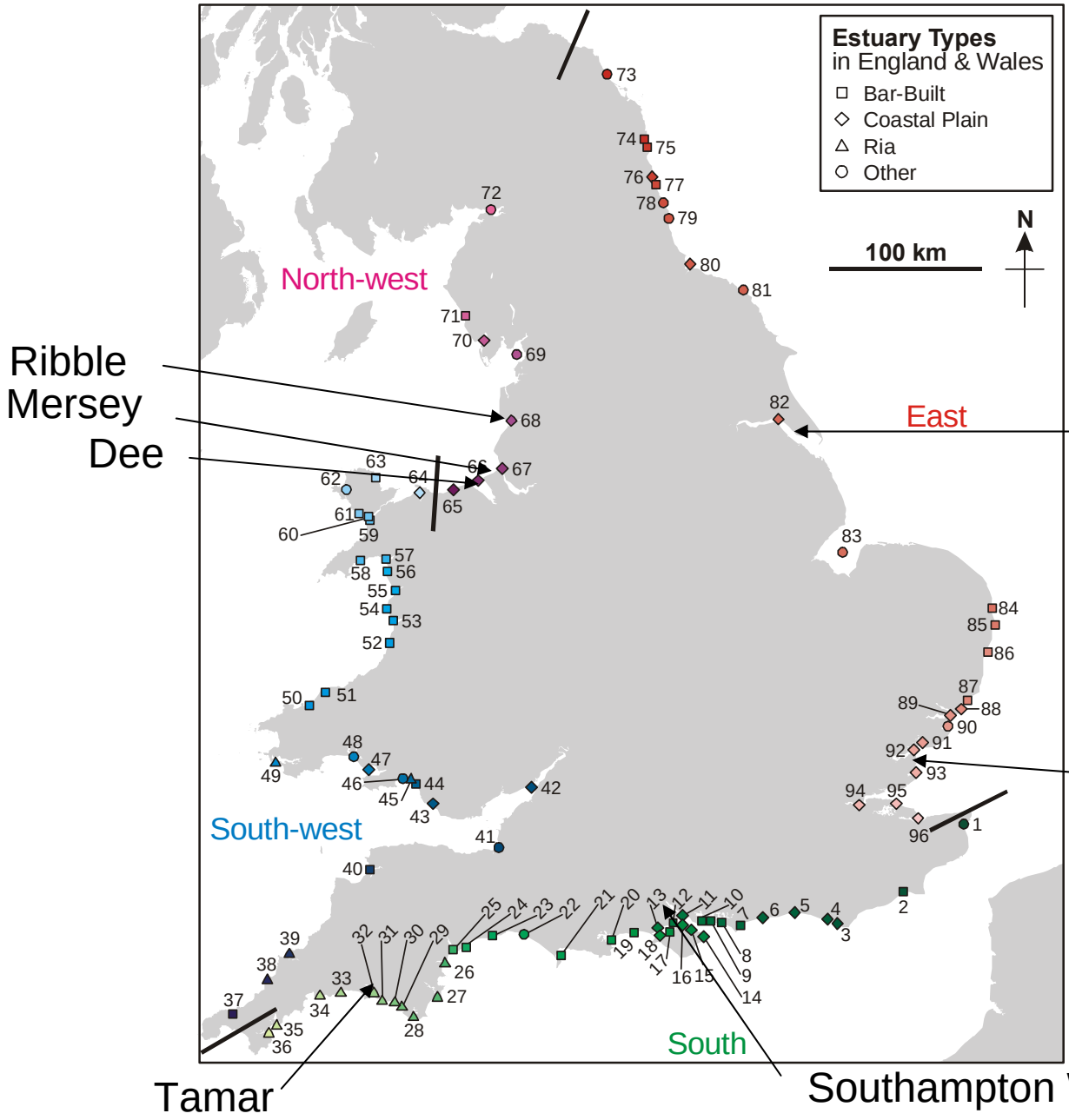
"2.5D"; as used by Andrew Lane

Realignment; described by Richard Soulsby

Inverse; described by Dominic Reeve

Thames and other models: Jez Spearman

Model	*Type*	*Thames*	*Blackwater*	*Humber*	*Mersey*	*Dee*	*Ribble*	*S'ton Water*	*Tamar*
Emulator	Hybrid	Y	Y	Y	Y	Y	Y	Y	Y
TE2100	Trend	Y							
Regime-Shell	T-D	Y	Y	Y	Y			Y	
"2.5D"	B-U				Y	Y	Y		
ASMITA-type	Hybrid	Y							
Sandtrack	Hybrid	Y							
Realignment	process		Tollesbury						
Inverse	Hybrid			Y					


Estuary Types
in England & Wales
Bar-Built
Coastal Plain
Ria
Other
N
100 km
North-west
South-west
South
East
Ribble
Mersey
Dee
Humber
Blackwater
Tamar
Southampton Water

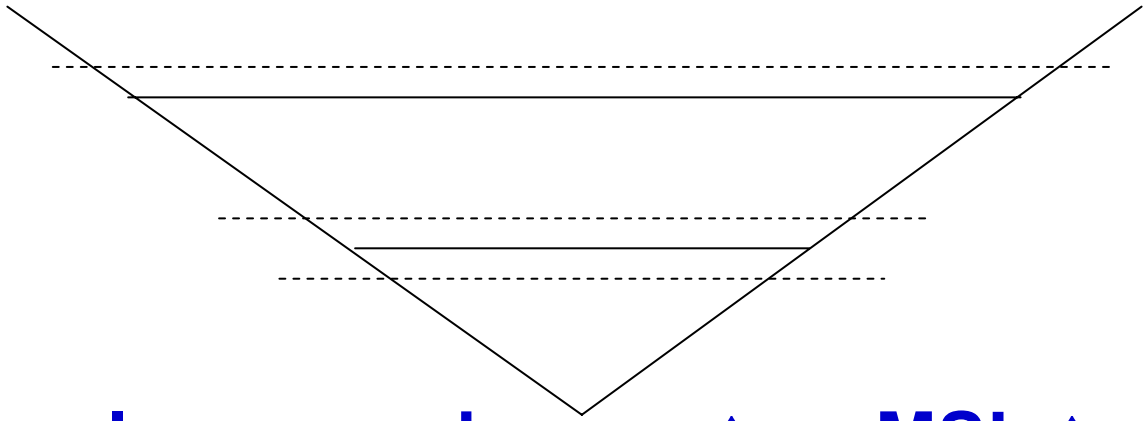
Estuary Properties

Properties (Future-Coast + …)	*Thames*	*Black-water*	*Humber*	*Mersey*	*Dee*	*Ribble*	*S'ton Water*	*Tamar*
Spring tidal range (m)	5.3	4.6	6.0	8.9	7.6	7.9	4.0	4.7
Mean river flow (m^3/s)	66	3.8	234	67.1	31.2	33.3	18.1	27
Length (km)	100	21.2	144.7	45.6	37.0	28.4	20.2	34.1
HW Area (km^2 Emulator)	193	46.1	618	194	99	119	38.6	37.7
Intertidal Area (km^2)	52	27.8	455	118	43	107	13.8	18
Marsh Area (km^2)	2.1	11.0	14.2	8.5	21	22	3.6	3.6

Emulator – basic comparator

- **No morphological change except**

  Depth ~ (river flow)$^{0.4}$

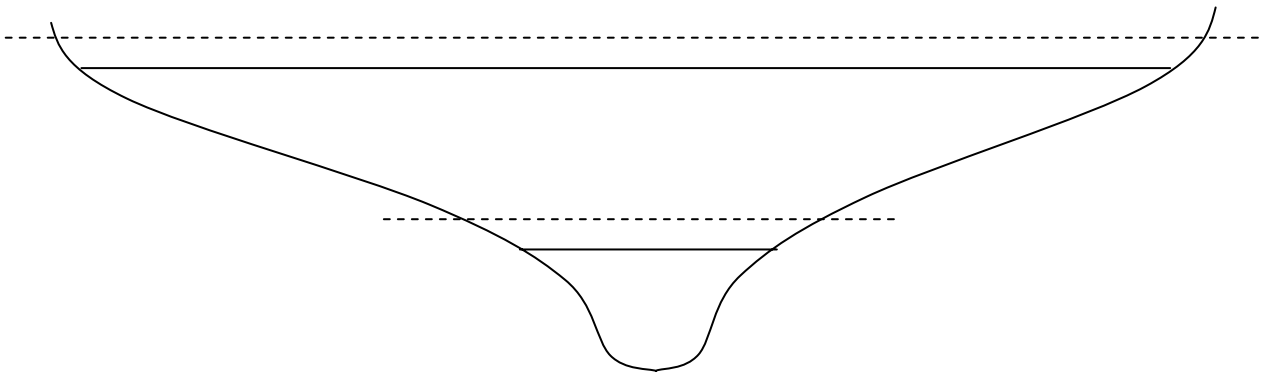


LW, HW volumes and areas ↑ as MSL ↑

Intertidal area unchanged, because fixed slope

but ~ tidal range

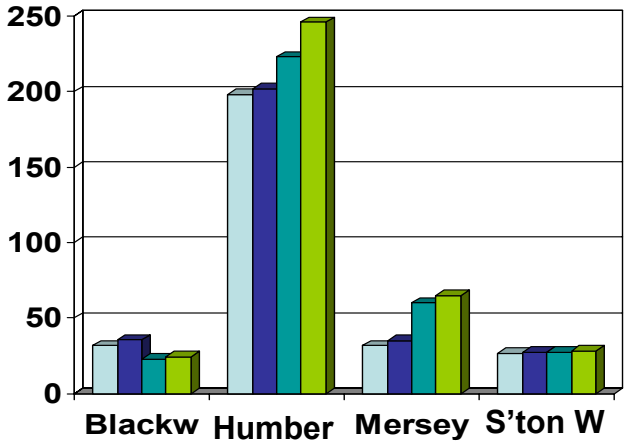
“Convexity”



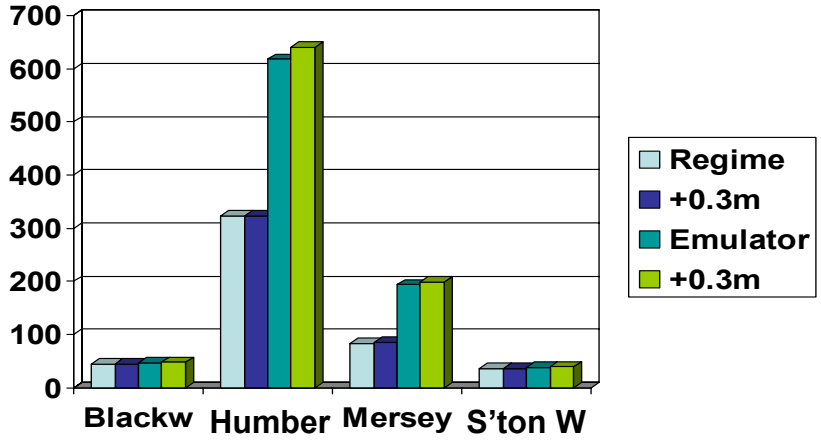
- **Maybe less sensitive LW, HW area, volume**
- **Tendency for intertidal area loss**

Analytical Emulator difficulty representing intertidal consistent with high and low water areas.

Regime-Shell overcomes these limitations.

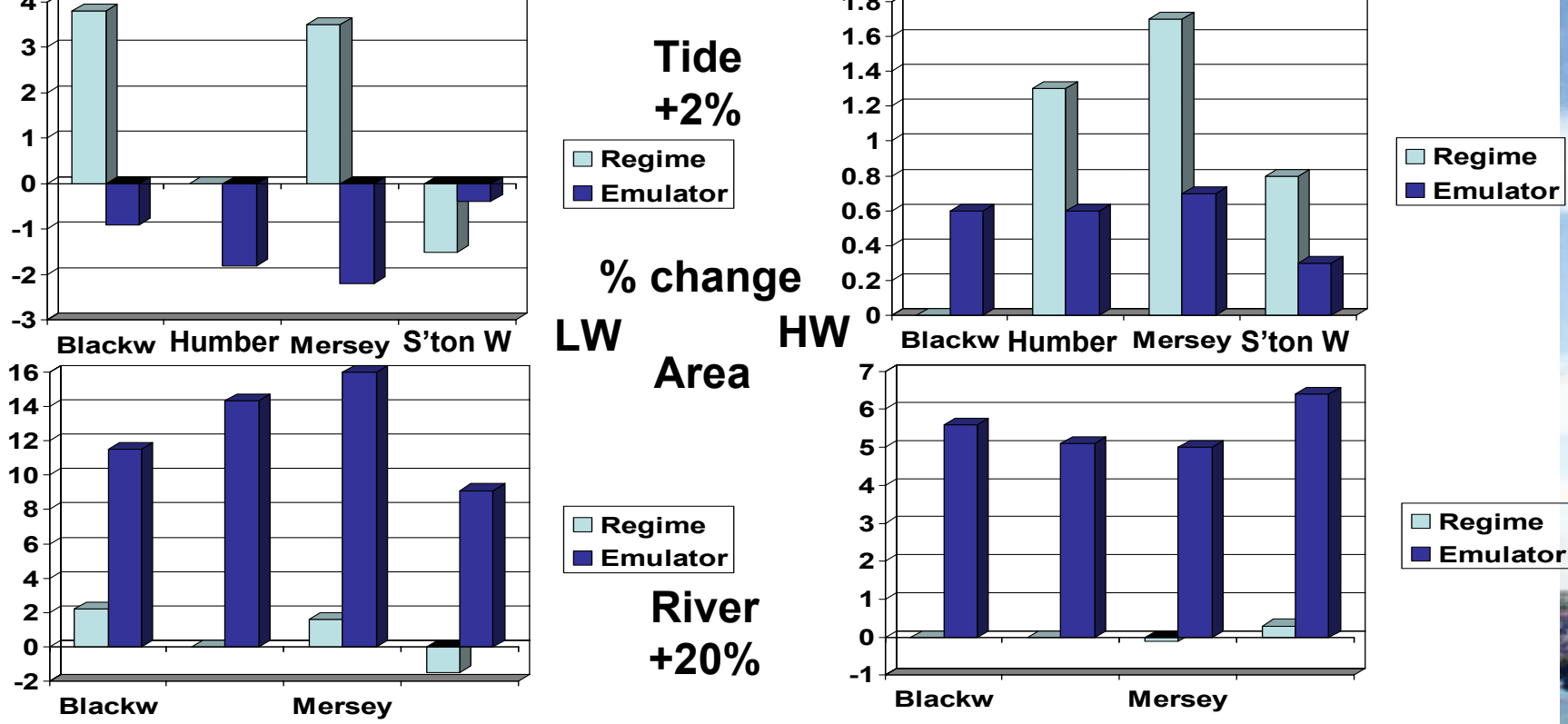


LW area



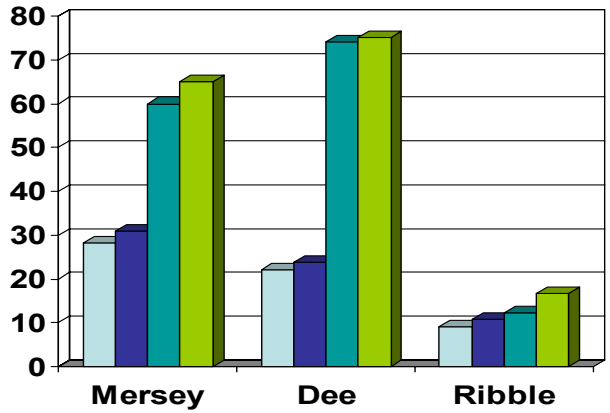
HW area

- LW volumes and areas invariably increase for raised MSL.
- HW volumes and areas generally increase, but less so (Blackwater HW area unchanged in Regime-Shell model).
- Inter-tidal area decreases (especially Blackwater).
- Regime-Shell results do not suggest infill keeping pace with sea-level rise, except for the Mersey.



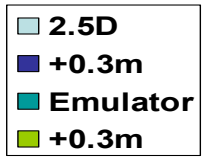
- **Realistic changes in tidal range (e.g. +2%)**
  - Likely effects of are relatively modest.
- **20% increase in river flow**
  - small changes in LW and HW areas and volumes
  - Mersey and sensitive Blackwater lose inter-tidal
  - Emulator is sensitive

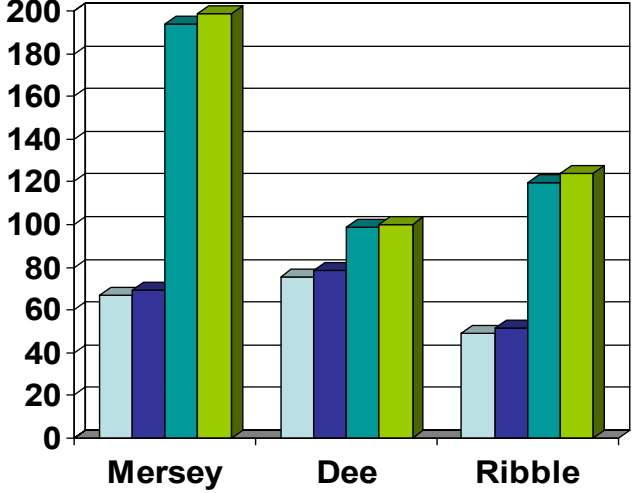
Emulator and "2.5-D" model:

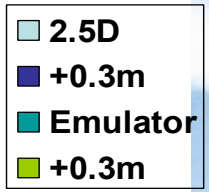


LW HW

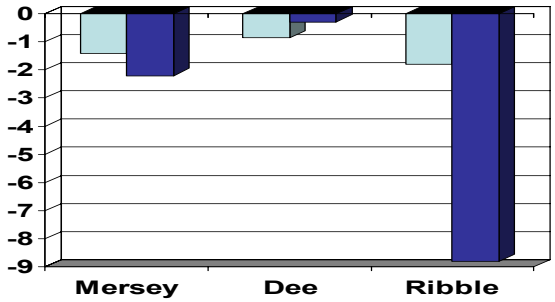
Area, km²





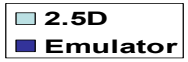


Discrepant representations but changes similar for raised MSL

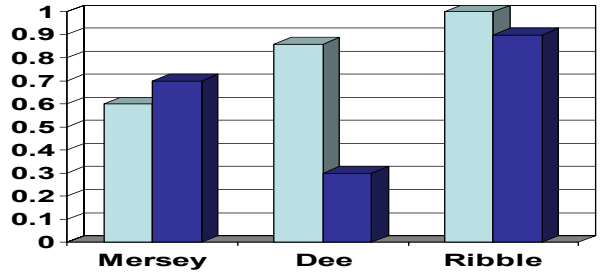


Tide + 2%:

% change



LW Area HW

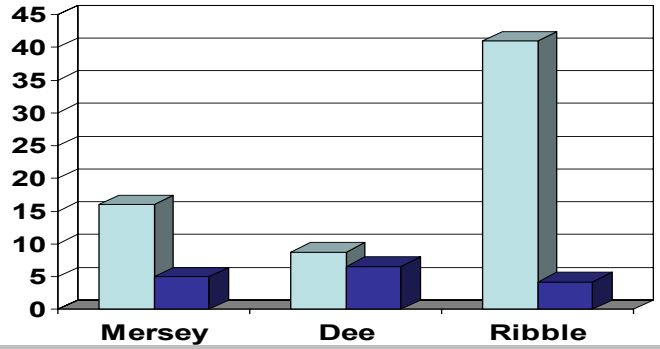


Emulator LW area is small so sensitive to lower LW, river flow

River flow + 20%:

% change of area

(Emulator only)



Emulator-estimated in-fill times

149-765 years

	Thames	*Blackwater*	*Humber*	*Mersey*	*Dee*	*Ribble*	*S'ton Water*	*Tamar*
flushing time, days	7	9	6.3	7.5	21.3	4.7	14.9	11.5
mean SPM, mg/l	127	69	112	164	214	125	77	74
in-fill time, years	218	516	223	182	395	149	765	619

Most ≤ time scale for volume change with MSL

Just implies enough sediment, not actual infill

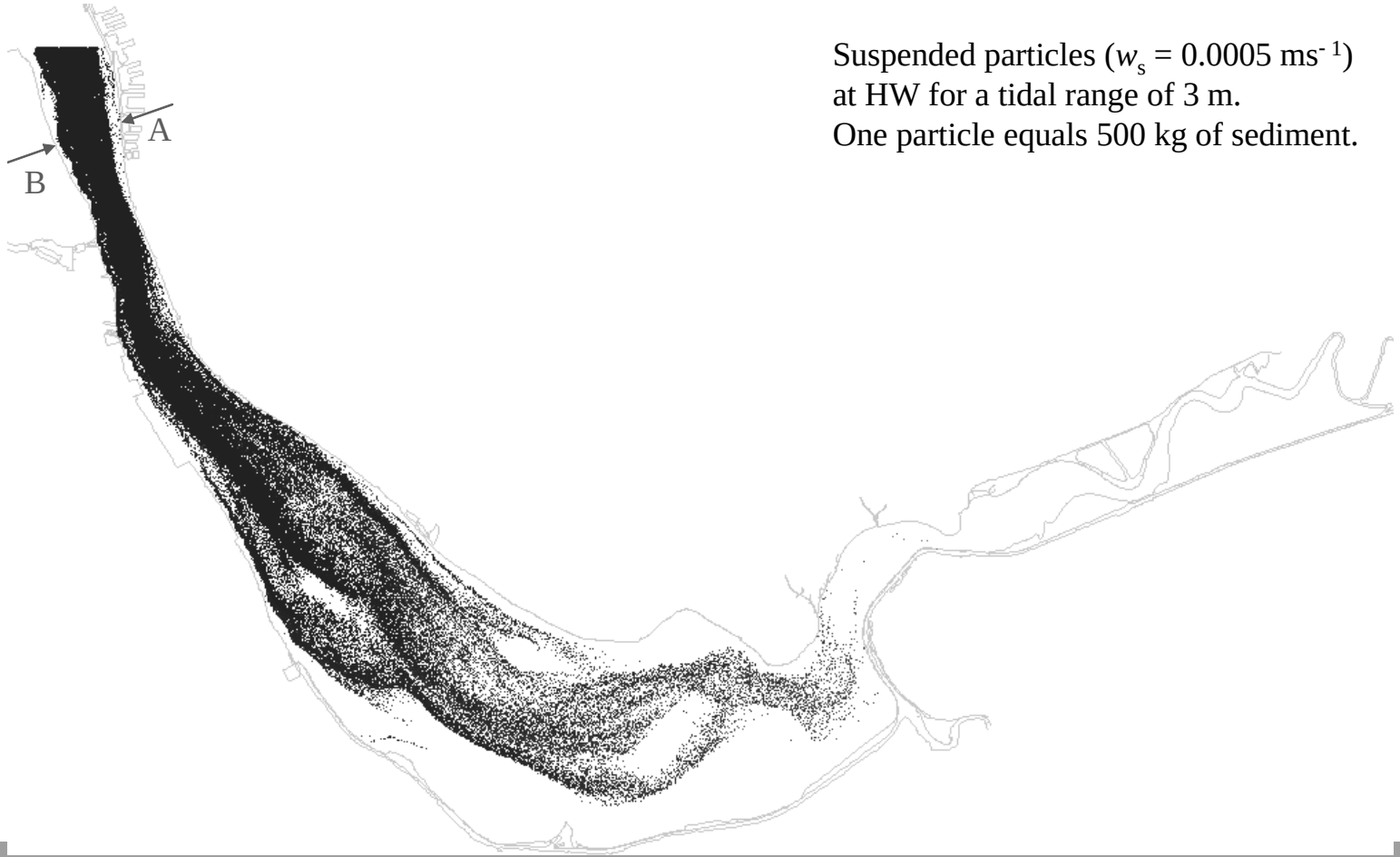
- Role of dynamics!

(Time scales not correlated with size)

2-D and 3-D particle-tracking models can represent LW and HW areas and volumes; resolution is only limit.

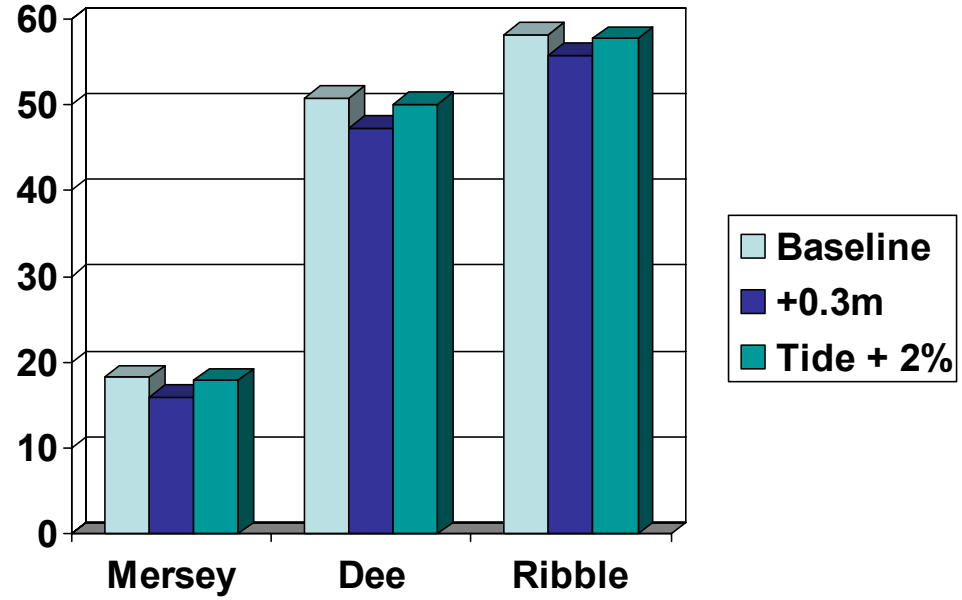
They predict sediment transport and deposition.

They have to repeat flow model runs as bathymetry evolves (computing cost).

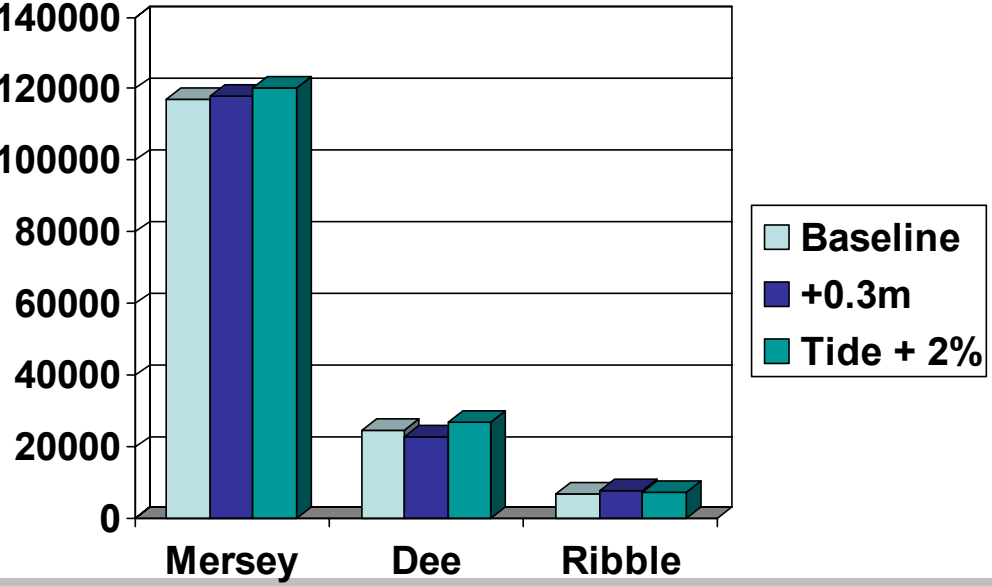


Suspended particles (w_s = 0.0005 ms^{-1})
at HW for a tidal range of 3 m.
One particle equals 500 kg of sediment.

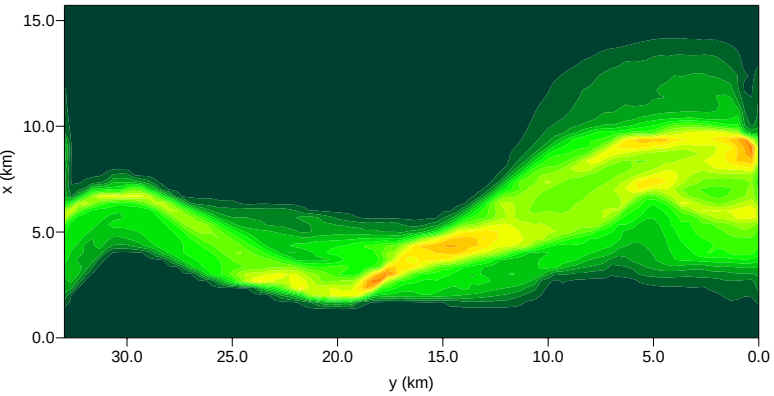
“2.5-D” model (continued)

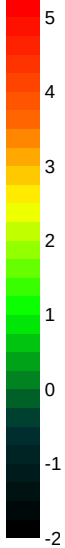


“2.5-D” salt-marsh area
↓ for MSL↑, tide ↑
(concave profile)

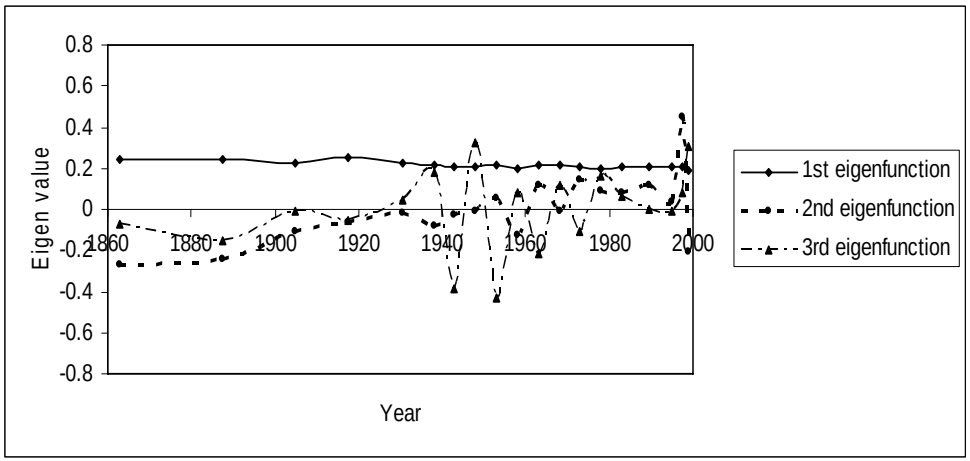


SPM “in” (tonnes/tide)
↑ for tide ↑
variable ↔ MSL





92% of Inverse model "source function" (with 1st time series↓)



- **Trend analysis can guide predications**

if applied within the range of experience.

- **Inverse model uses previous changes, with reference to dynamics**

(bed-evolution equation)

Predictions depend on relatively frequent surveys.

General Conclusions

- **Best practice: validate against historic change**
  - **→ some confidence that model predicts key processes**
  - **– Needs validation data!**
- **Otherwise, generate ensemble of possible outcomes**
- **Need care interpreting results from any one model**
  - **– limitations of routines updating bed-morphology**
  - **– inherent unpredictability**
- **Ideally compare model results with alternatives**
  - **– to help establish the validity**
- **Predicted trends should be broadly consistent with results of bottom-up models.**
- **The results show sensitivities of different estuaries to a range of climate change scenarios**
- **Not all estuaries respond in the same manner!**