Effects of Climate Change on the Physical Dynamics of South African Estuaries

Jill Slinger and Susan Taljaard

Challenge the future

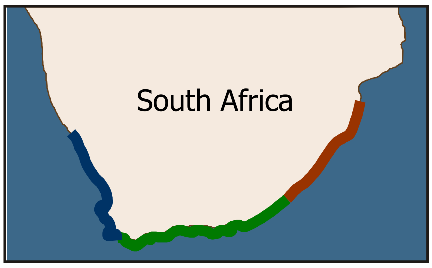
Content

- South African estuaries: the biogeographical setting
- Present method for determining ecological freshwater requirements
- Shortcomings of the present method
- A method to include climate change
- Preliminary results
- Concluding remarks

South African estuaries

Semi-arid country with river basins ranging in size from very small (< 1 km^2) to large (>10 000 km^2)

Cool temperate



Sub-tropical

South African estuaries

- About 290 predominantly microtidal, wave-dominated, shallow (~2-3 m) estuaries
- More than 90% have constricted mouths, 75% closed by a sand berm for varying periods

Present method: Ecological freshwater requirements

FRESHWATER INFLOW SCENARIOS

Translating flow scenarios into consequences for physical habitat

PHYSICAL HABITAT:
- Hydrodynamics
- Sediment Dynamics
- Water Quality

Packaging information on physical habitat modifications for biologists

BIOTIC RESPONSE:
- Microalgae
- Macrophytes
- Invertebrates
- Fish
- Birds

Shortcomings of the present method

Now

- Connect freshwater inflow to frequency distribution of physical states
- Present method can accommodate modifications in freshwater flows

But

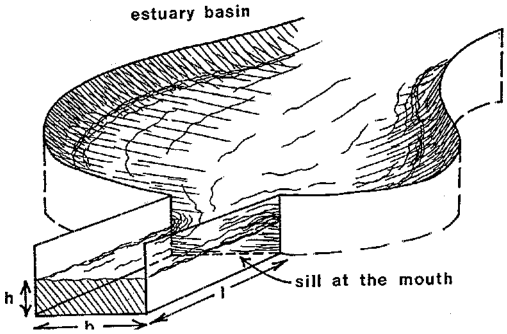
- What about the influence of climate change on the forcing from the marine environment?

Unknown

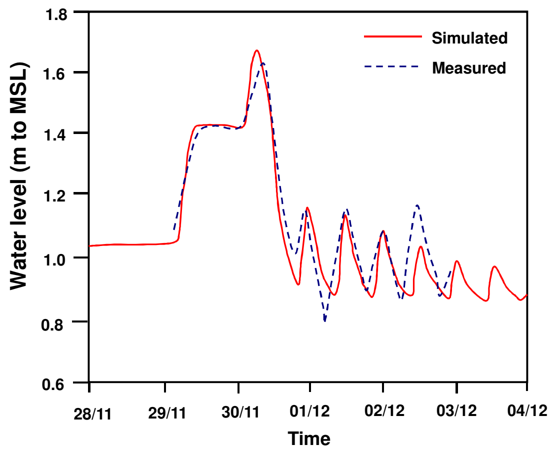
- Synergistic effects - modified freshwater inflow, sea level rise, altered wave climate

A method to include climate change

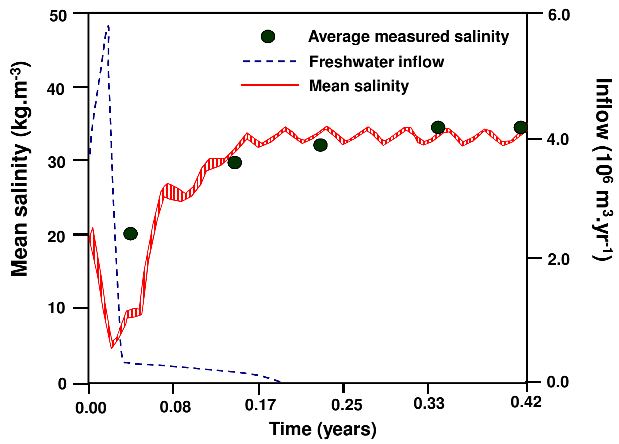
- System Dynamics approach
  - Non-linear, ordinary differential equations $\frac{dx_j}{dt} = F_j(x,p,t) \quad j = 1,7$
  - Semi-empirical approach
- Seven state variables
  - Water volume (water level)
  - Salt content
  - Stratification
  - Circulation
  - Freshwater flushing
  - Tidal flushing
  - Sill height at the mouth



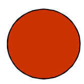
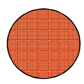
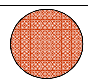
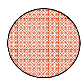
Calibration of the model



Calibration of the model cont.



Preliminary results: Sensitivity to forcing

Exogenous Forcing	Parameter	Sensitivity	State variables affected
Flood events	Total volume		Sill height Water volume Stratification state
Waves	Wave height		Salt content Stratification state Sill height
Base Flow	Average base flow		Salt content Stratification state
Tidal influence	Diurnal tidal amplitude Spring neap amplitude		Salt content Stratification state

Preliminary results: Influence of wave event after a re-setting flood

Wave height (m)	Freshwater Flows (x 10^6 pa)				
	34 (natural)	24	10	2	1
3.82	open	open	open	open	open
3.97	open	open	open	open	open
4.00	self breaching	self breaching	open	closed	closed
4.05	self breaching	self breaching	closed	closed	closed
4.25	self breaching	self breaching	closed	closed	closed
4.45	self breaching	closed	closed	closed	closed
5.00	self breaching	closed	closed	closed	closed
6.00	closed	closed	closed	closed	closed

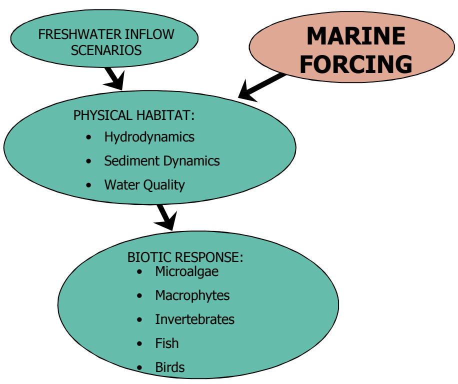
Preliminary results: Influence of wave event without re-setting flood

Wave height (m)	Freshwater Flows (x 10^6 pa)				
	34	24	10	2	1
3.82	open	open	open	open	open
3.97	open	open	closed	closed	closed
4.00	self breaching	closed	closed	closed	closed
4.05	self breaching	closed	closed	closed	closed
4.25	self breaching	closed	closed	closed	closed
4.45	self breaching	closed	closed	closed	closed
5.00	closed	closed	closed	closed	closed
6.00	closed	closed	closed	closed	closed

Concluding remarks

- Reduction in freshwater flows reduces the resilience of small, microtidal estuaries with restricted mouths to closure
- With this model we demonstrate that the combination of reduced flows and high wave events reduces the resilience of the estuary to mouth closure even more (synergistic effect)
- Because increased storminess (high waves) is predicted, we can no longer ignore these effects when setting ecological freshwater requirements

Concluding remarks cont.



- Higher flow required to maintain desired ecological status
- In a water scarce country, this will exacerbate the conflict between nature and humans for freshwater