The impact of tidal pumping, turbidity maxima, density gradients on sediment retention in estuaries

Dr Gerardo M. E. Perillo
Instituto Argentino de Oceanografía
Departamento de Geología - UNS
Where sediment is trapped

- Estuarine deltas (head, tidal, tributary mouths)
- Inner wetlands (mangroves, marshes, tidal flats)
- Point and interchannel bars
- Other geomorphologic and hydrodynamic induced traps
- Artificial structures (harbours, jetties, etc.)
What traps sediment

- General and local geomorphology
- General and local sediment inputs
- Within-estuary tidal range gradients
- Tidal pumping
- Turbidity maxima
- Vertical and longitudinal density gradients
- Coastal dynamics
- Climate dynamics
- Events
- Biological interactions
However!!!!

• Sediment and water input from rivers
  – What happens with dams and watershed retention??
  – How much sediment is retained in lower catchment (below the last gaging station)

• Sediment input from the sea
  – Barrier effects (i.e., tidal deltas, barriers)

Lack of input implies internal erosion and sediment export
- Ratio ocean vs continental E.
- Sediment input
- Coastal stability
- Climatic regions
Antico, 2002
MAREAS EN EL RIO DE LA PLATA - Nivel en metros al cero MOP

BUENOS AIRES

MONTEVIDEO

INÁ

LABORATORIO DE HIDRAULICA Y DEL AMBIENTE
PROGRAMA DE HIDRAULICA COMPUTACIONAL

Antico, 2002
BahiaB

t = 0h30m 0s: 0
1 m/s
ENERGY DISSIPATION

TIDAL ASYMMETRY

Bahía Blanca Est.
Perillo & Piccolo, 1991

 Rihanna de la Plata – Antico, 2002
Fluvial effect on the tidal range.
- Increase inland
- Changes in tidal asymmetry
- Potential sediment outflow

San Francisco Bay Headward influence increase

http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1
Tidally-averaged flow on bend

a. Neap

b. Spring

measured near bottom flow
hypotheical bottom flow

Intertidal Region

(bigger at spring)
residual velocity profiles

residual seaward current
residual current landward
null-zone
river-discharge
area of vertical gravitational circulation

Wurpts, 2006
PARTLY MIXED (B)
Residual Fluxes Interaction with

- Estuarine Geomorphology
- Density gradients
- Wind
- Freshwater discharge

\[ u_L = u_S + u_E \]

Lagrangian Flux = Stokes Drift + Eulerian Flux
Stokes Drift ($u_s$)

- Interaction between the partly progressive tidal wave and the topography
- Headward
- Associated to Tidal Pumping

\[
 u_s = \frac{\langle \tilde{A} \tilde{u} \rangle}{\langle A \rangle}
\]
Eulerian Flux ($u_E$)

- Response to the set up induced by the tidal pumping
- By continuity generates seaward flow

\[ <Q_E> = -<Q_S> \quad u_E = <Au>/<A> \]

- Valid for steady state
- Without river discharge
Lagrangean Flux \( (u_L) \)

- Transport due to density gradient
  \[
  u_L = \frac{\langle Q_{vt} \rangle}{\langle A \rangle}
  \]

- River runoff \( (u_f) \)
  \[
  u_f = \frac{\langle Q_f \rangle}{\langle A \rangle} \quad \langle Q_f \rangle = R
  \]

\[
  u_L = u_f
  \]

In steady state, near the head
Residual Flux Calculation

\[ F = \int uCdA \]

Datos \( U_{i,k} \), \( S_{i,k} \), \( C_{i,k} \), \( A_{i,k} \)

Donde \( i = \text{total # of levels} \ldots, I; j = \text{total # of columns} \ldots, J; k = \text{time} \), \( k = 0, 1, \ldots, n\Delta k = T \)
\[ F_{vtk} = IJUCA + J A \sum_{i} u'_i c_i + I A \sum_{j} u'_j c_j + F^* \]

\[ F_L = F_{TP} + F_{VS} + F_{TS} + F^* \]

Where

\[ F_L = \langle \bar{Q} \rangle < \bar{C} > \]

\[ F_{TP} = \langle \tilde{Q} C \rangle \]

\[ F_{VS} = \left\langle \bar{A} \sum_{i} u'_i s'_i \right\rangle \]

\[ F_{TS} = \left\langle \bar{A} \sum_{j} u'_j s'_j \right\rangle \]
CONCLUSIONS

• Hydraulic processes are key to sediment retention/export in estuaries
• Geomorphology is as or more important
• Some processes have been considered only for the whole system or in individual portions of some estuaries