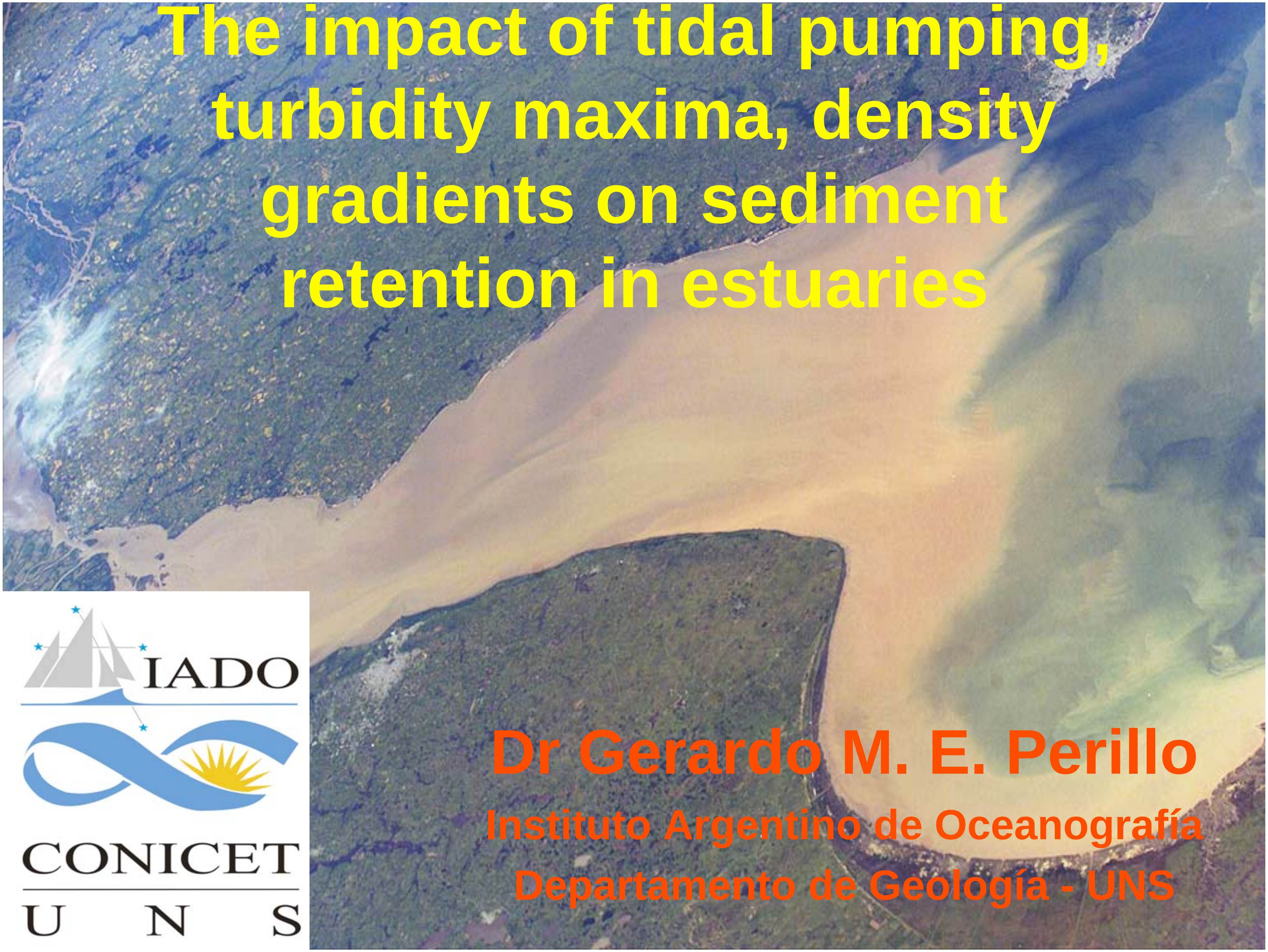
# The impact of tidal pumping, turbidity maxima, density gradients on sediment retention in estuaries



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**Instituto Argentino de Oceanografía**

**Departamento de Geología - UNS**

IADO
CONICET
U N S

# 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.)

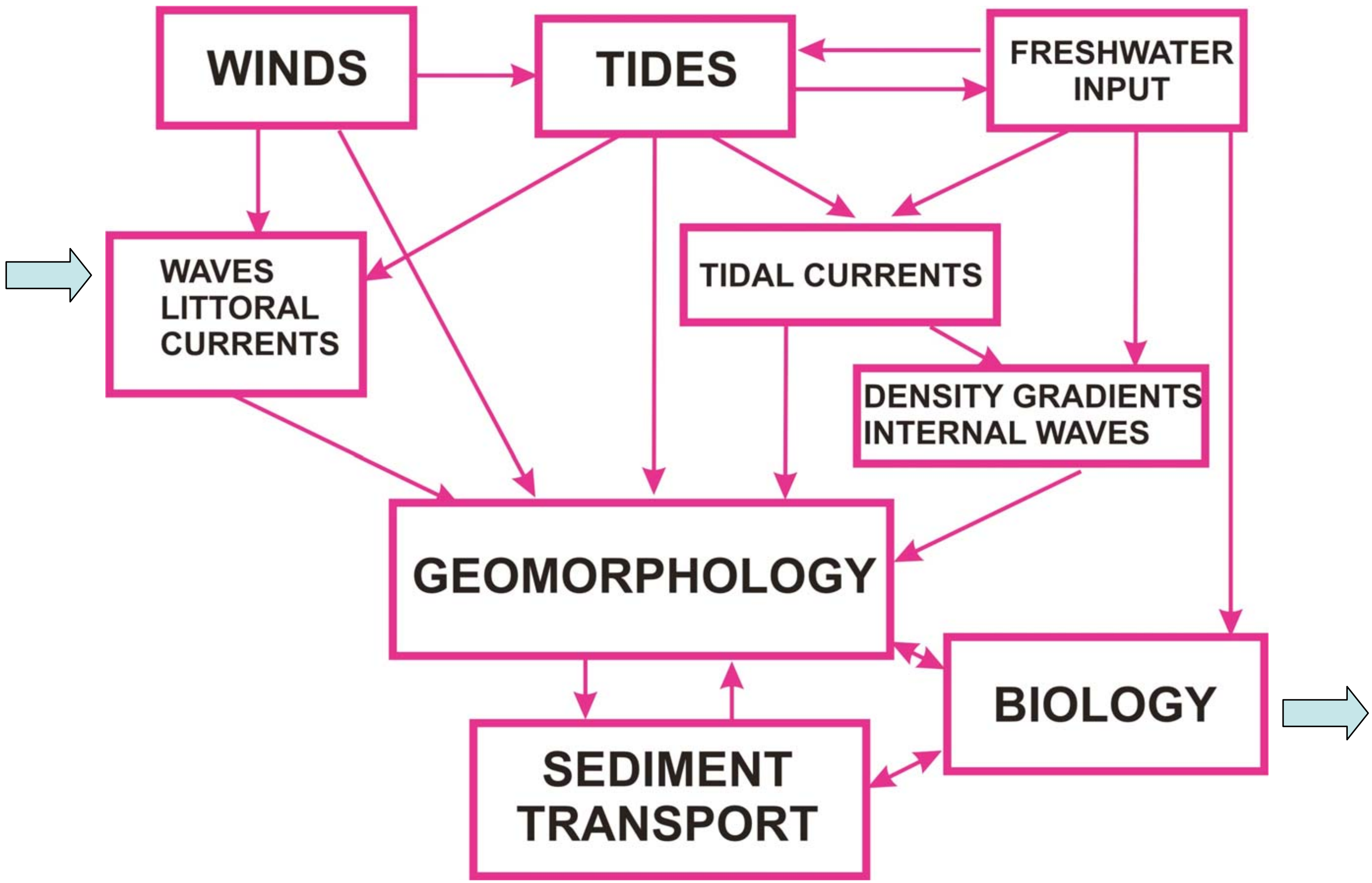
# What traps sediment

- 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

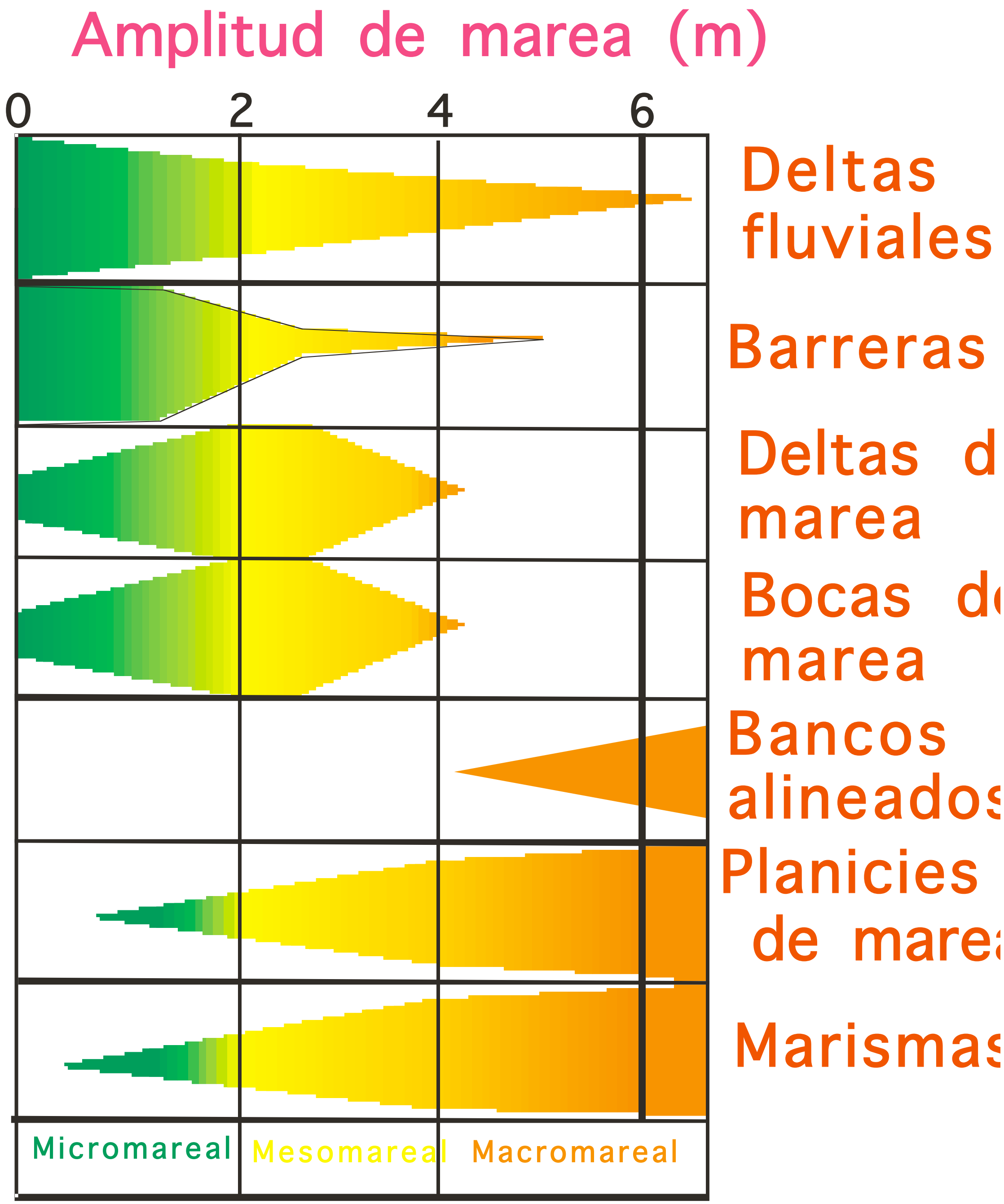
# However!!!!

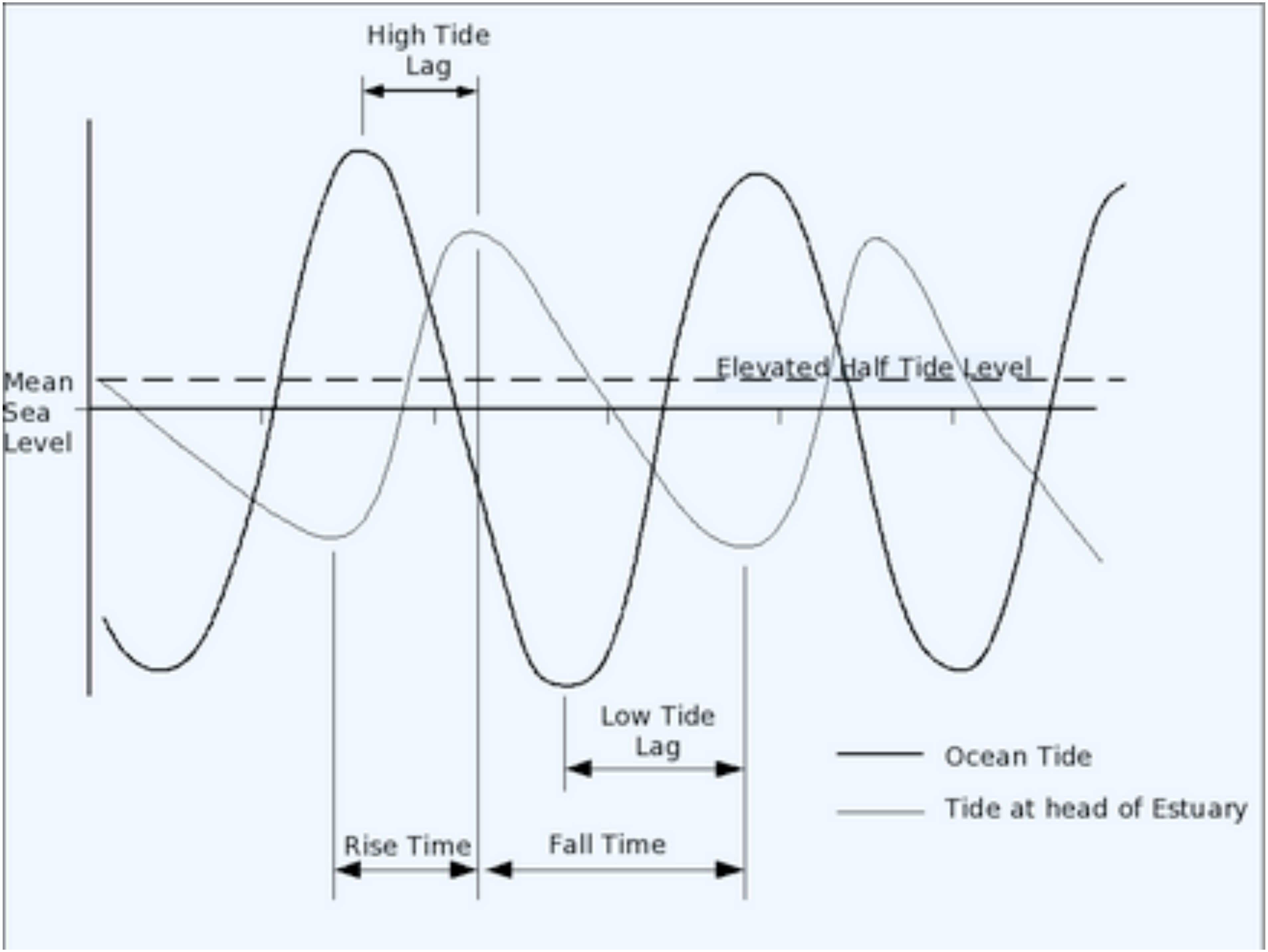
- **Sediment and water input from rivers**
  - **What happens with dams and watershed retention??**
  - **How much sediment is retained in lower catchment (below the last gaging station)**
- **Sediment input from the sea**
  - **Barrier effects (i.e., tidal deltas, barriers)**

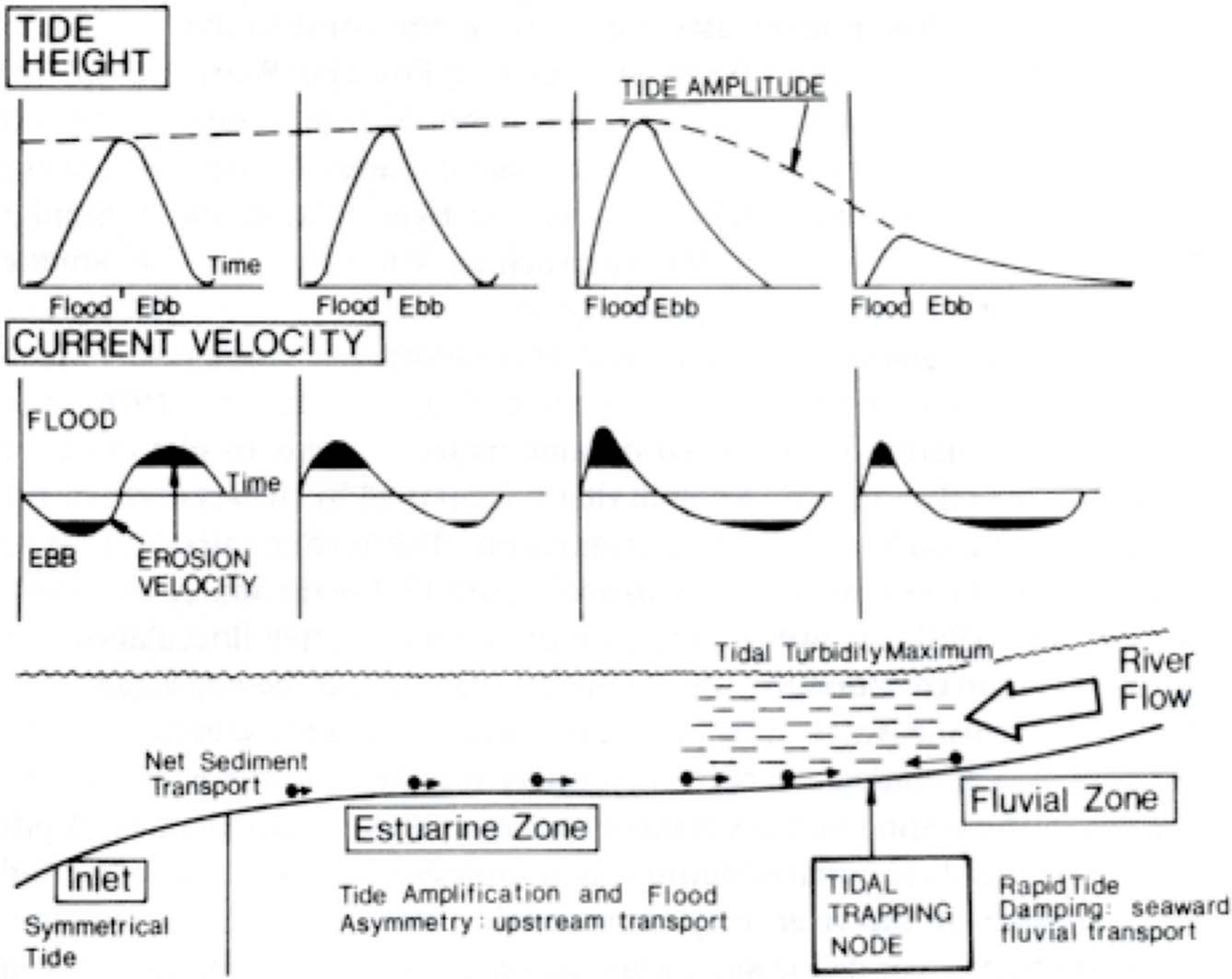
**Lack of input implies internal erosion and sediment export**

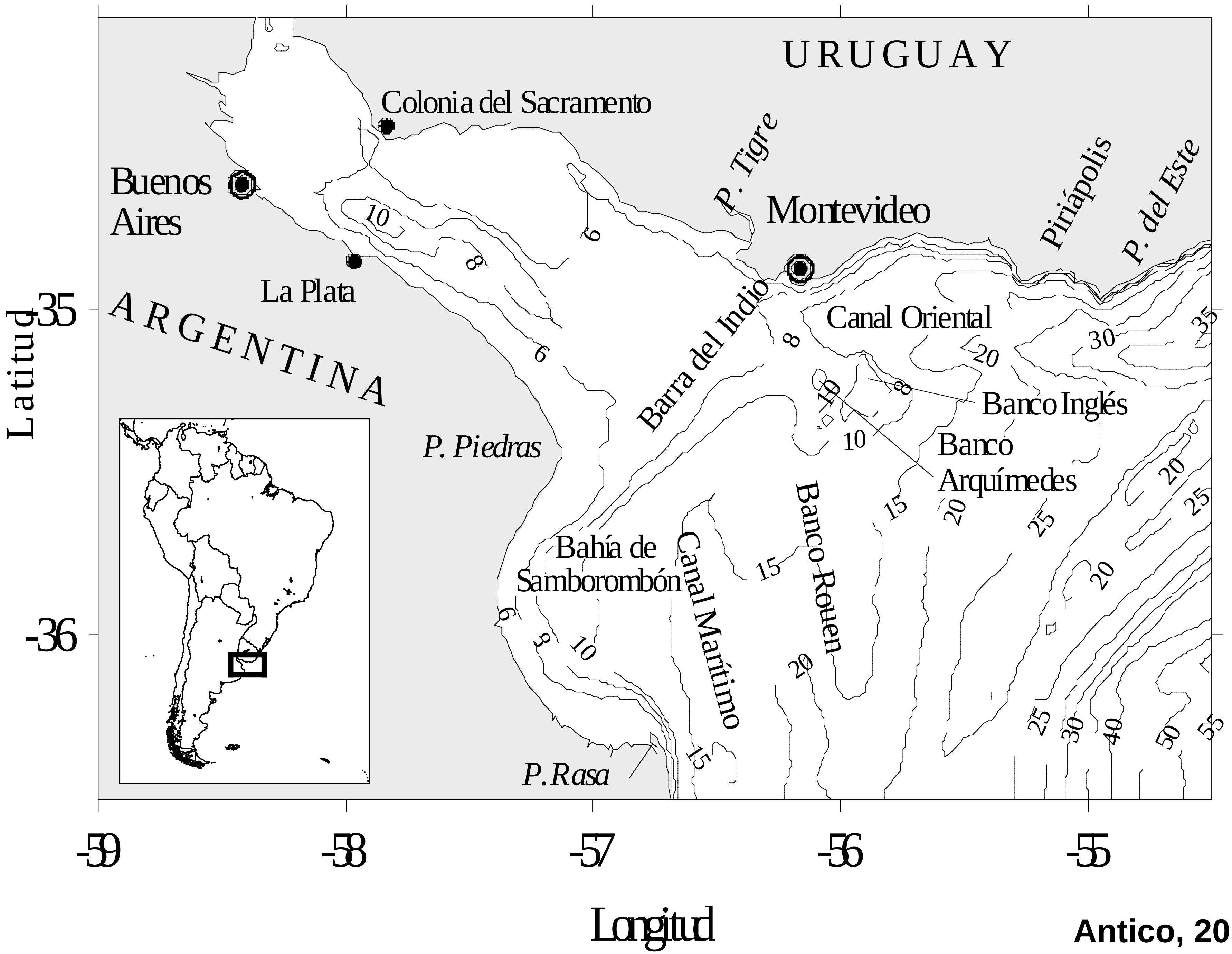

WINDS
TIDES
FRESHWATER INPUT
WAVES LITTORAL CURRENTS
TIDAL CURRENTS
DENSITY GRADIENTS INTERNAL WAVES
GEOMORPHOLOGY
BIOLOGY
SEDIMENT TRANSPORT

- Ratio ocean vs continental E.
- Sediment input
- Coastal stability
- Climatic regions

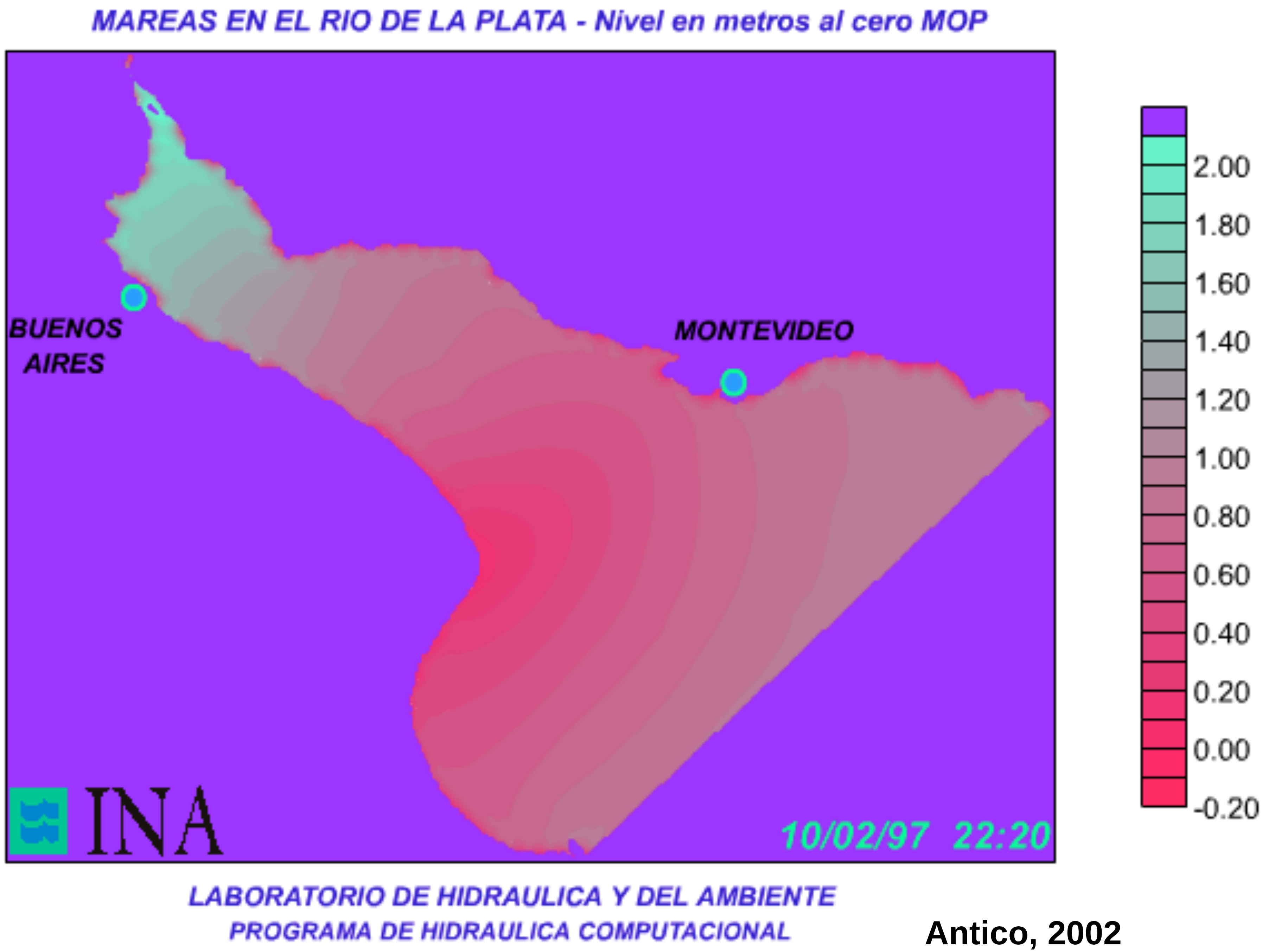



High Tide
Lag
Mean
Sea
Level
Elevated Half Tide Level
Low Tide
Lag
Ocean Tide
Tide at head of Estuary
Rise Time
Fall Time

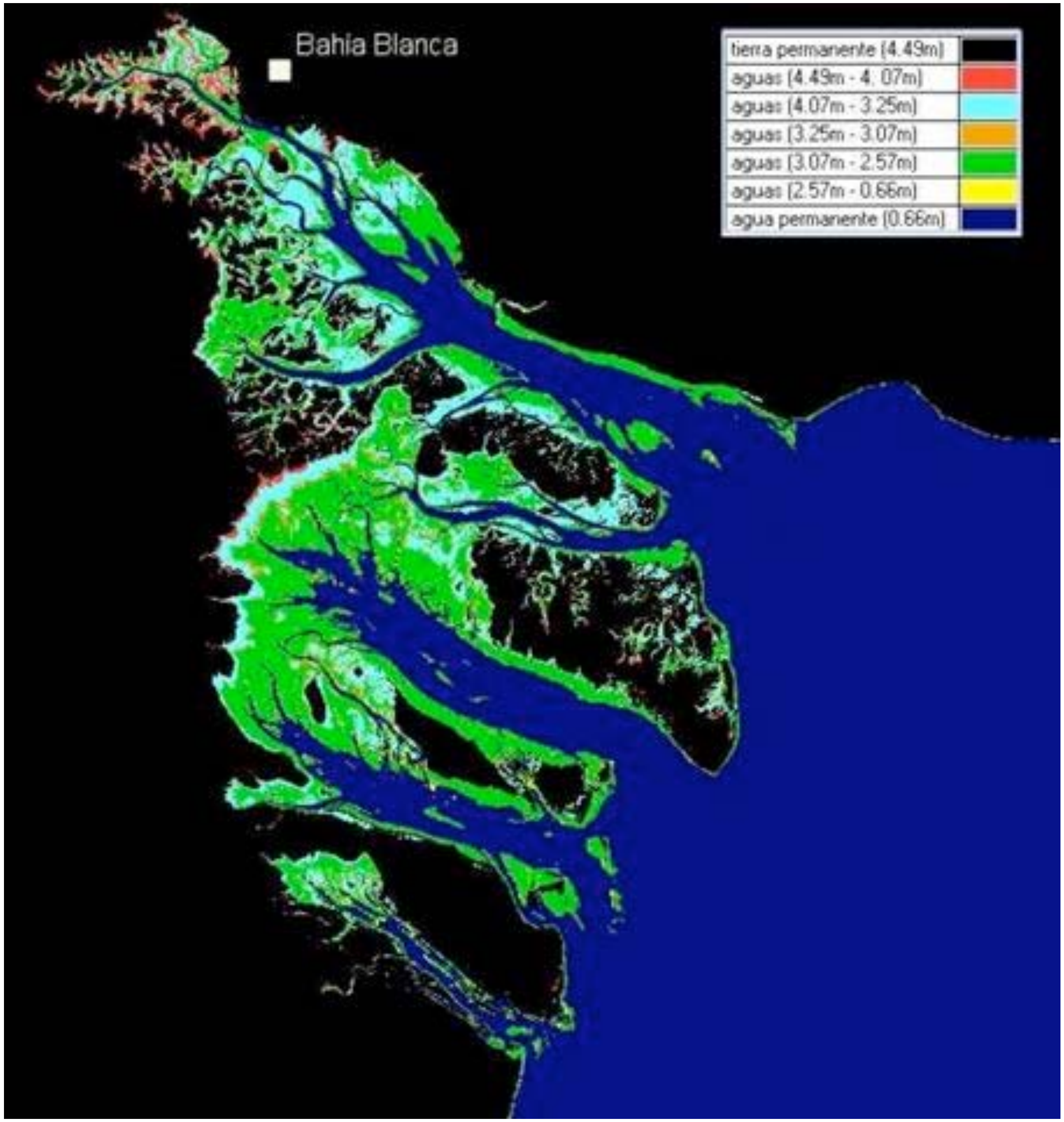

TIDE HEIGHT
TIDE AMPLITUDE
Time
Flood
Ebb
Flood
Ebb
Flood
Ebb
Flood
Ebb
CURRENT VELOCITY
FLOOD
Time
EBB
EROSION VELOCITY
Tidal Turbidity Maximum
River Flow
Net Sediment Transport
Estuarine Zone
Fluvial Zone
Inlet
Symmetrical Tide
Tide Amplification and Flood Asymmetry: upstream transport
TIDAL TRAPPING NODE
Rapid Tide Damping: seaward fluvial transport

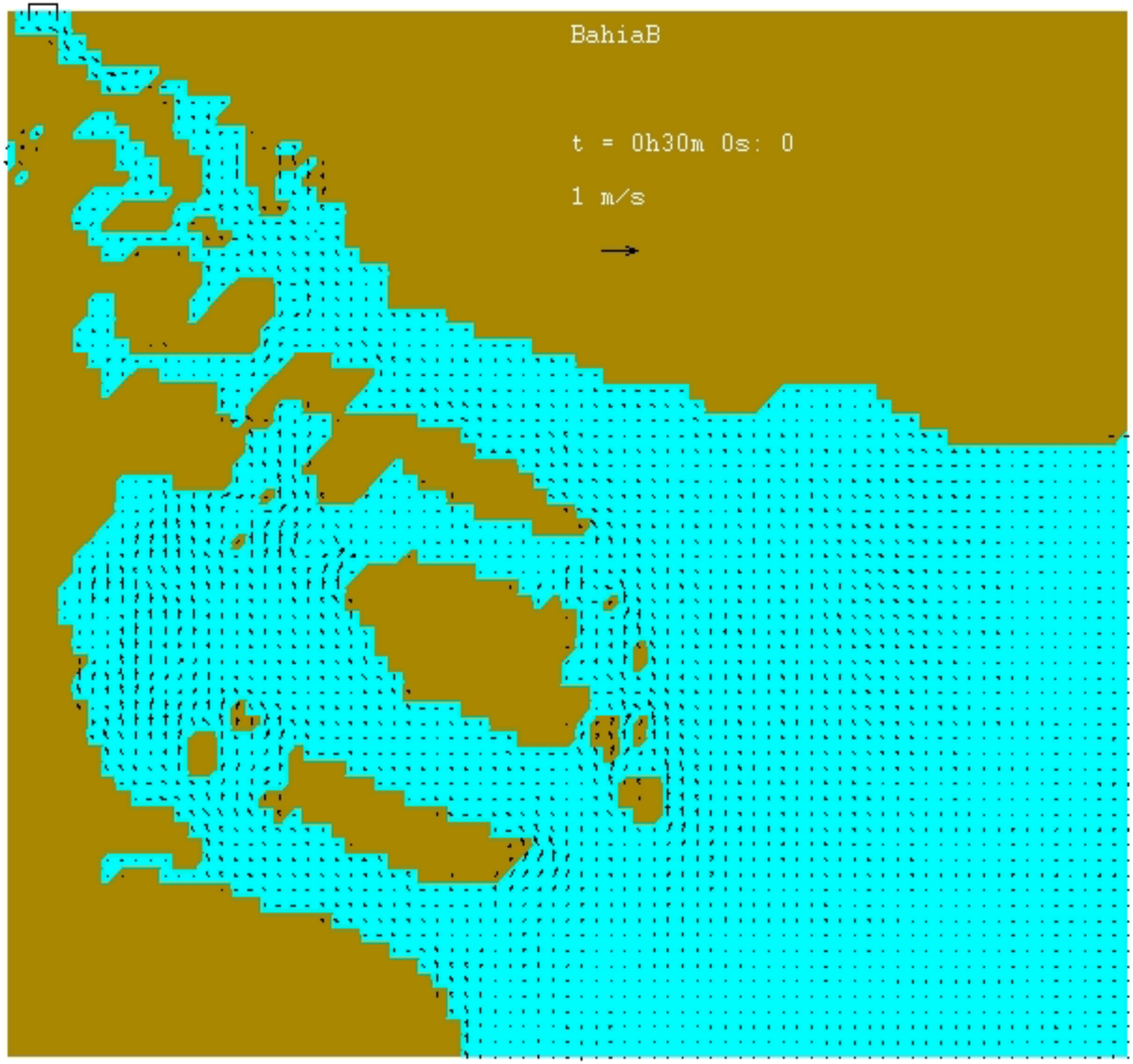

URUGUAY
Colonia del Sacramento
Buenos Aires
La Plata
ARGENTINA
P. Tigre
Montevideo
Piriápolis
P. del Este
Barra del Indio
Canal Oriental
Banco Inglés
Banco Arquímedes
P. Piedras
Bahía de Samborombón
Canal Marítimo
Banco Rouen
P.Rasa
Latitud
Longitud
-35
-36
-59
-58
-57
-56
-55

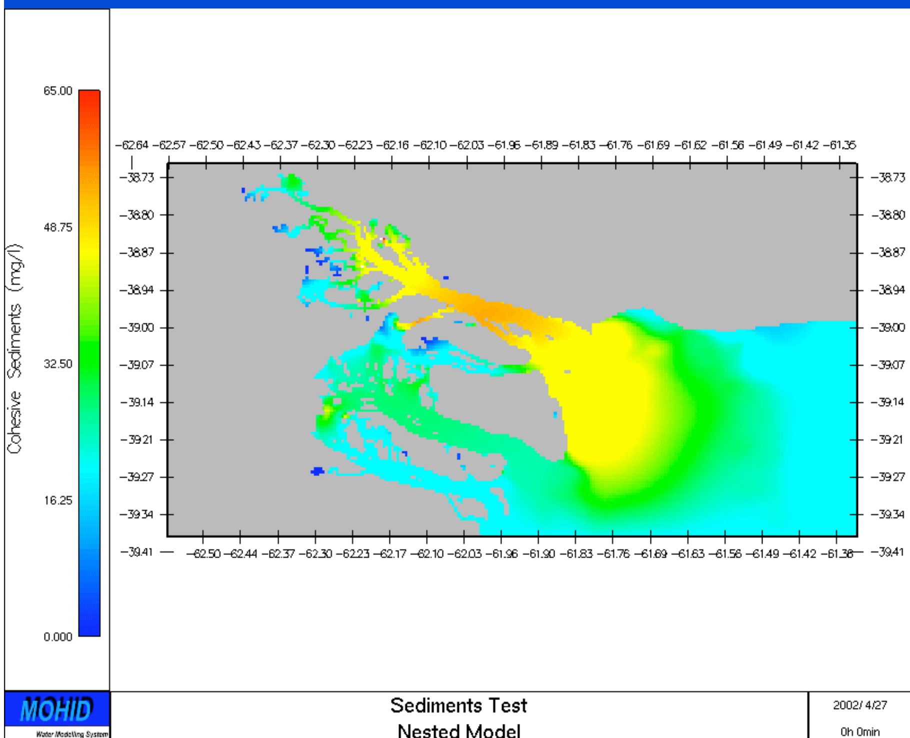
Antico, 2002


MAREAS EN EL RIO DE LA PLATA - Nivel en metros al cero MOP
BUENOS AIRES
MONTEVIDEO
INA
10/02/97 22:20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
LABORATORIO DE HIDRAULICA Y DEL AMBIENTE
PROGRAMA DE HIDRAULICA COMPUTACIONAL

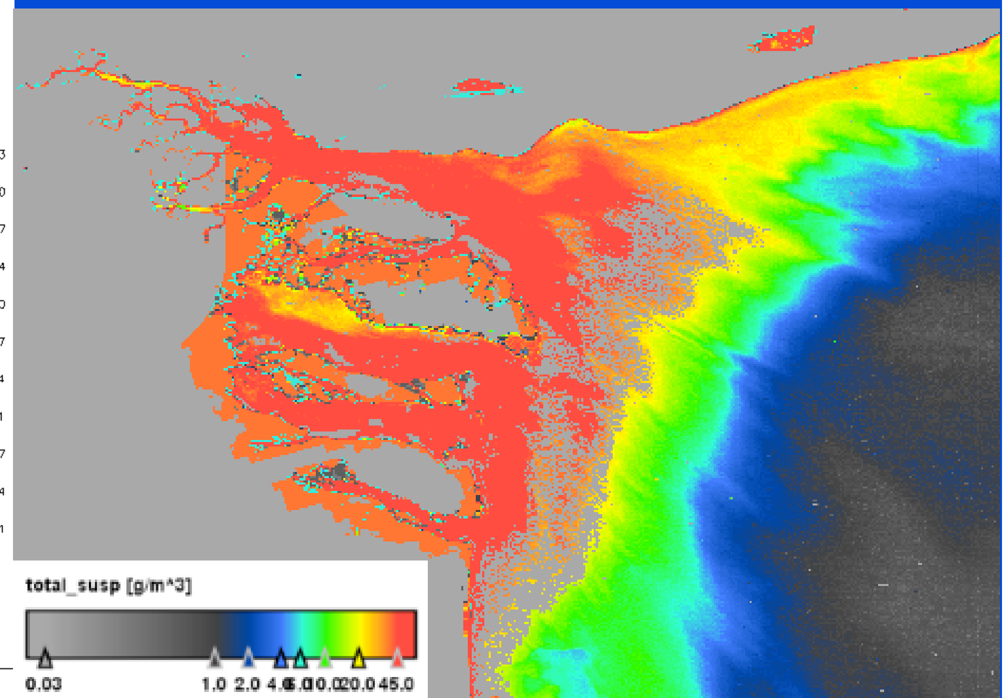
Antico, 2002


Bahia Blanca
tierra permanente (4.49m)
aguas (4.49m - 4. 07m)
aguas (4.07m - 3.25m)
aguas (3.25m - 3.07m)
aguas (3.07m - 2.57m)
aguas (2.57m - 0.66m)
agua permanente (0.66m)

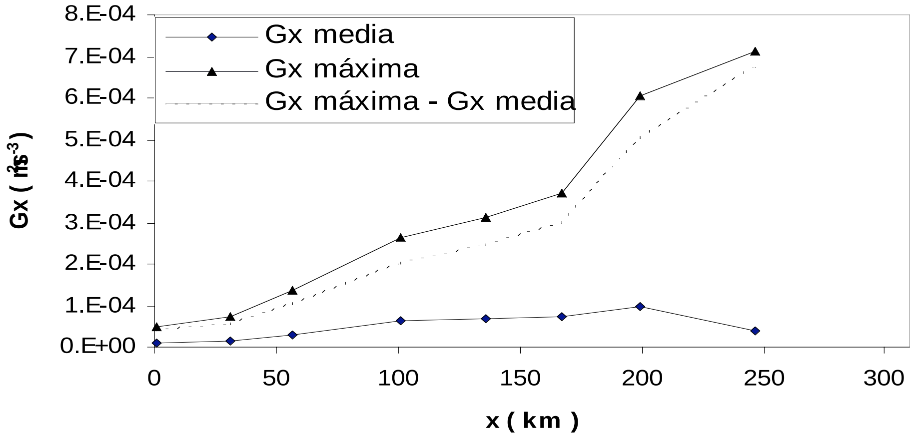

BahiaB
t = 0h30m 0s: 0
1 m/s



65.00
48.75
32.50
16.25
0.000
Cohesive Sediments (mg/l)
MOHID
Water Modelling System
Sediments Test
Nested Model
2002/ 4/27
0h 0min

total_susp [g/m^3]
0.03
1.0
2.0
45.0

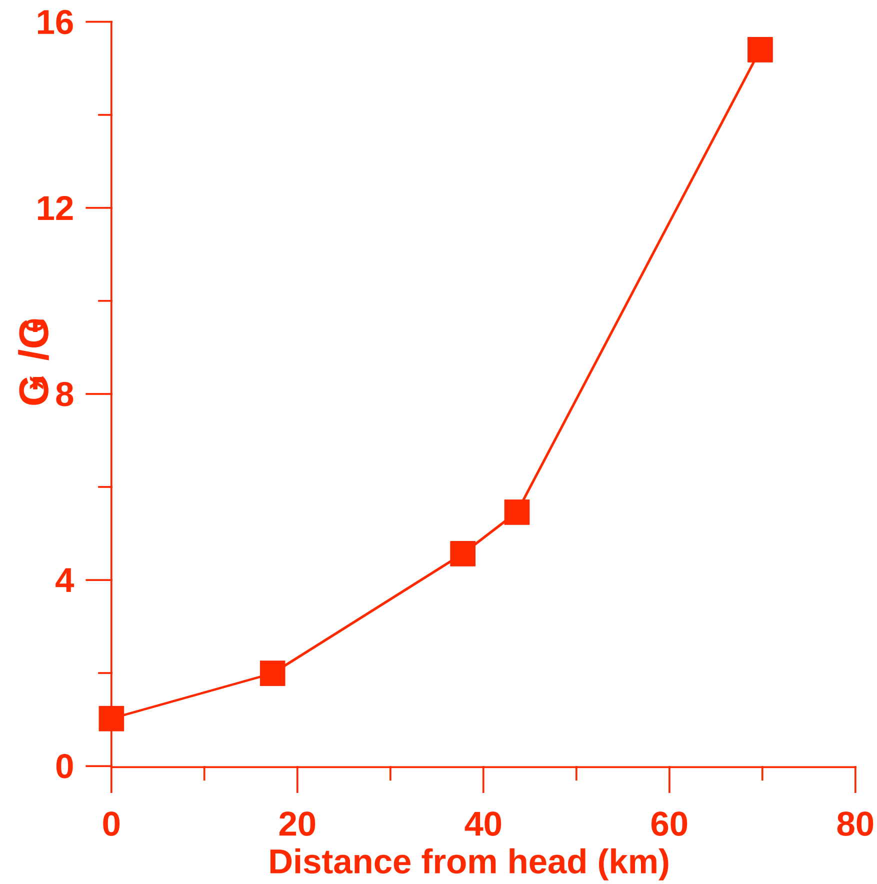


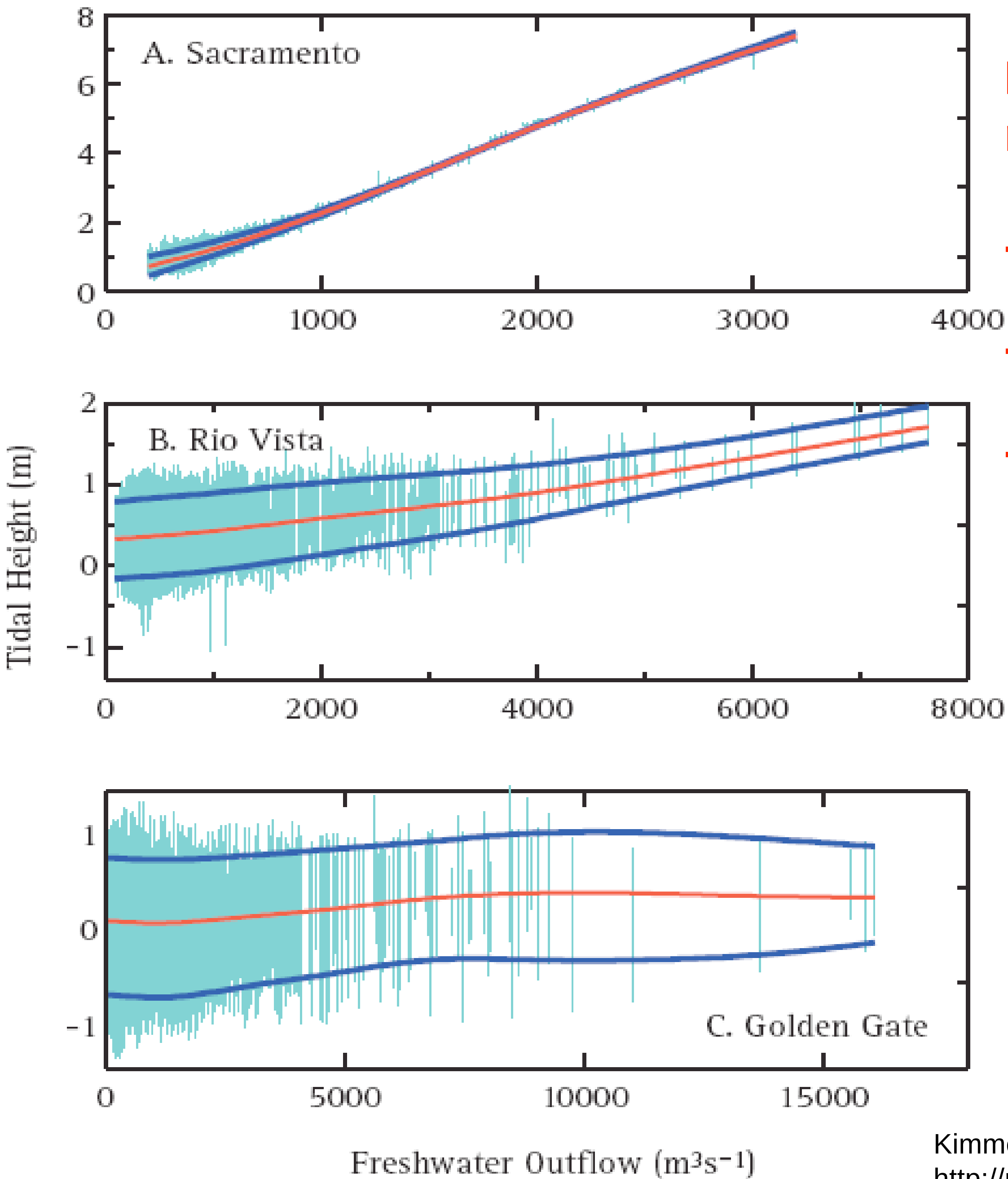

## Río de la Plata – Antico, 2002

# ENERGY DISSIPATION

# TIDAL ASYMMETRY

**Bahía Blanca Est.**
**Perillo & Piccolo, 1991**



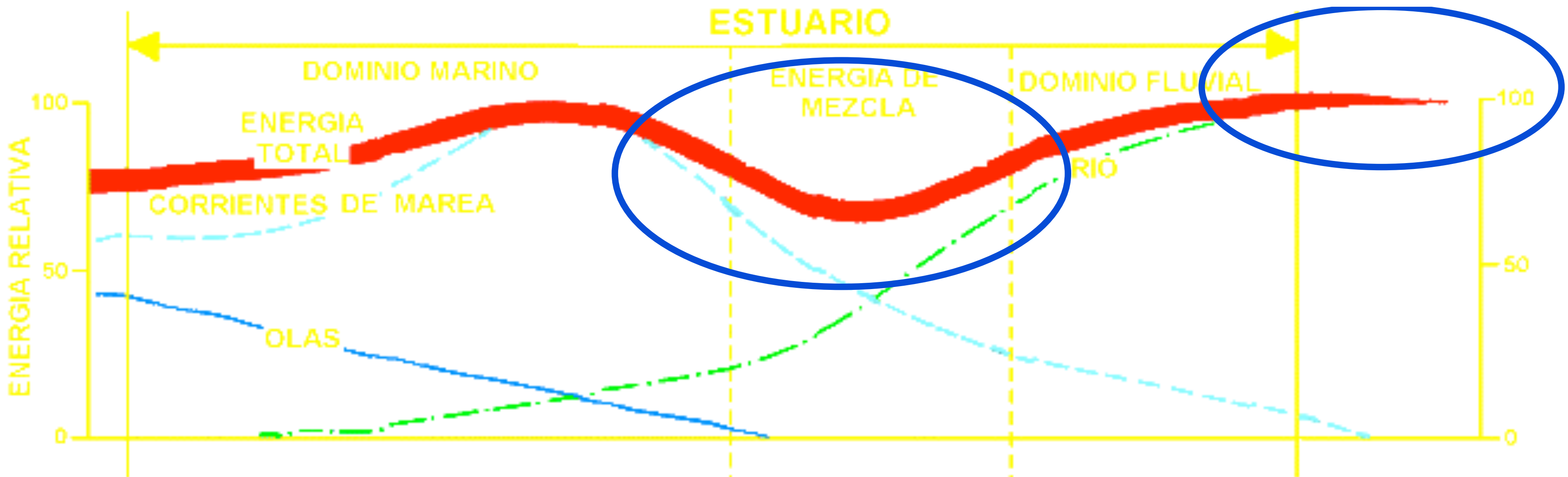


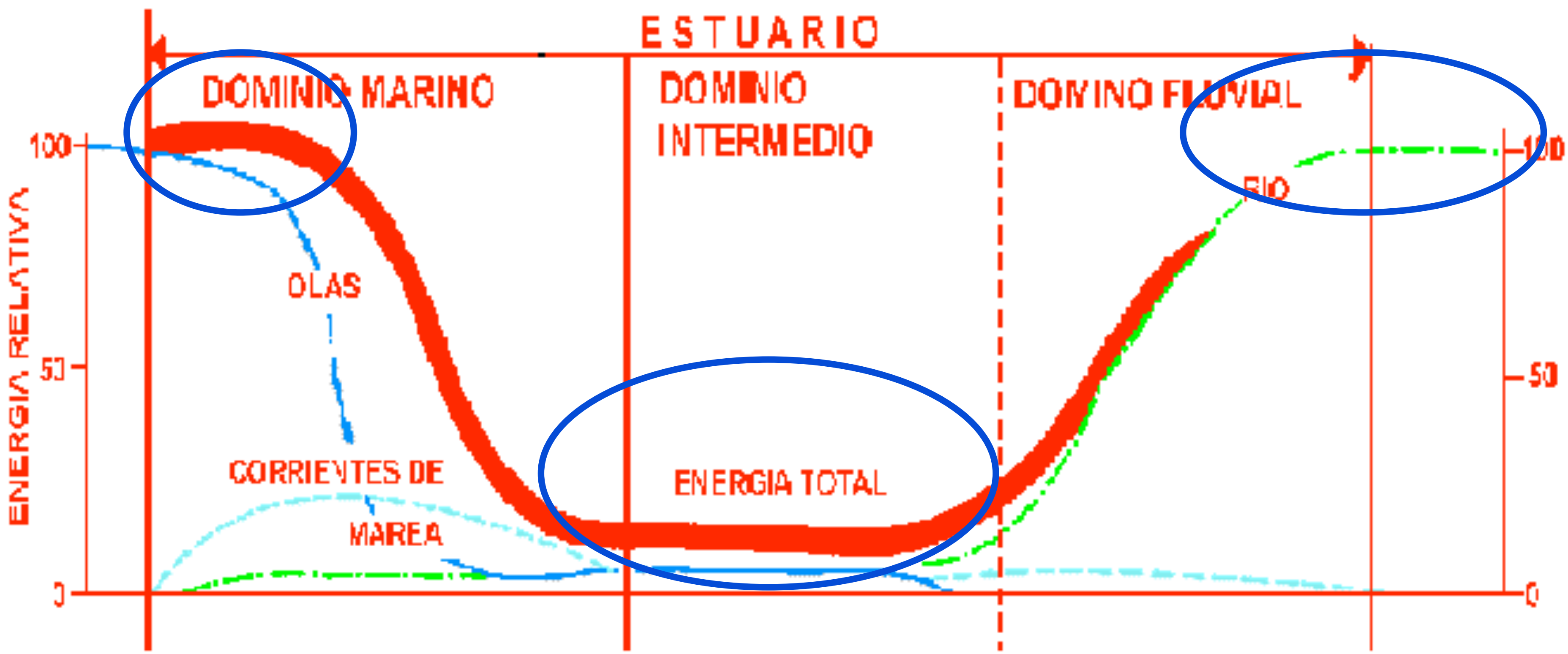

## Fluvial effect on the tidal range.

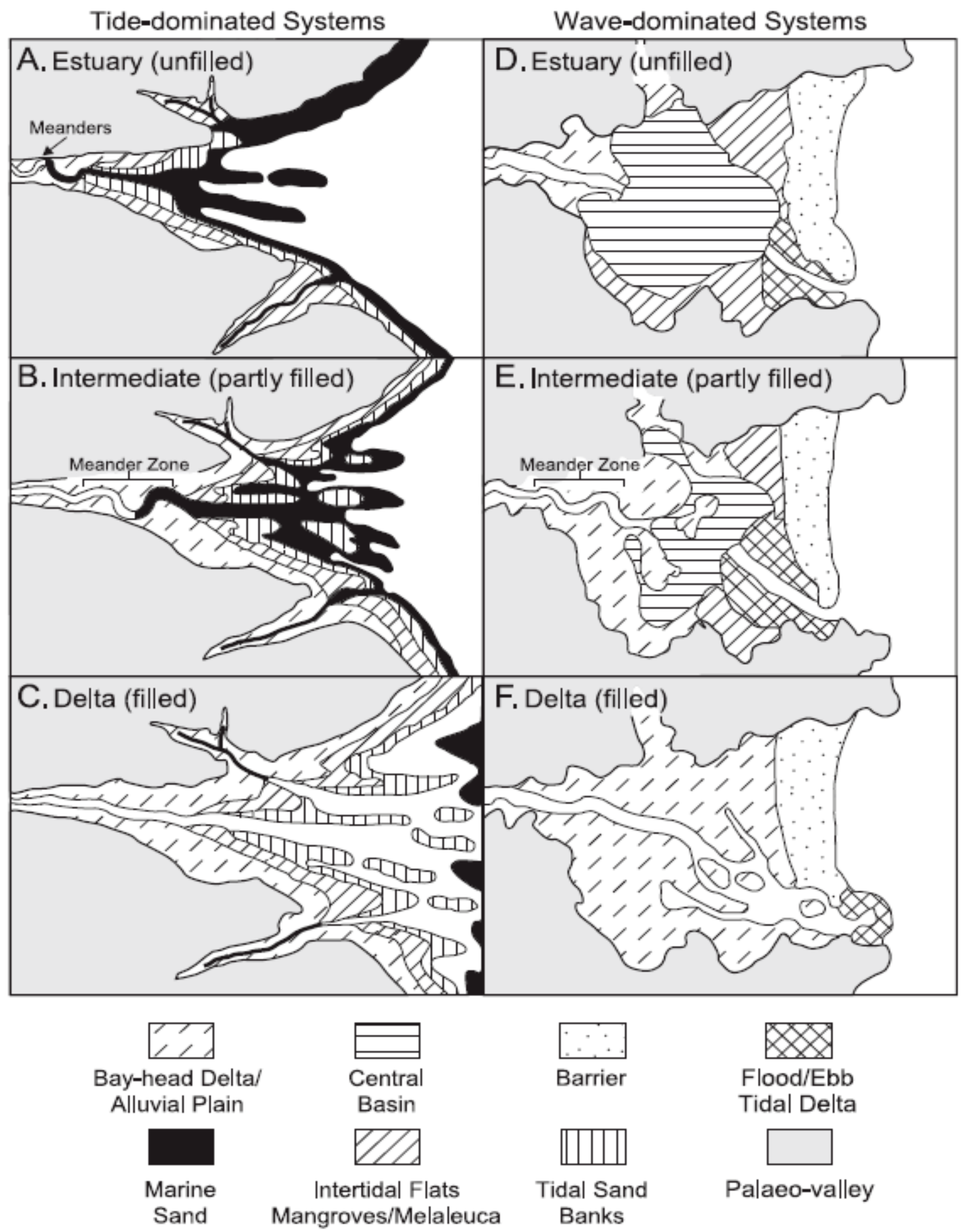
- Increase inland
- Changes in tidal asymmetry
- Potential sediment outflow

San Francisco Bay
Headward influence increase

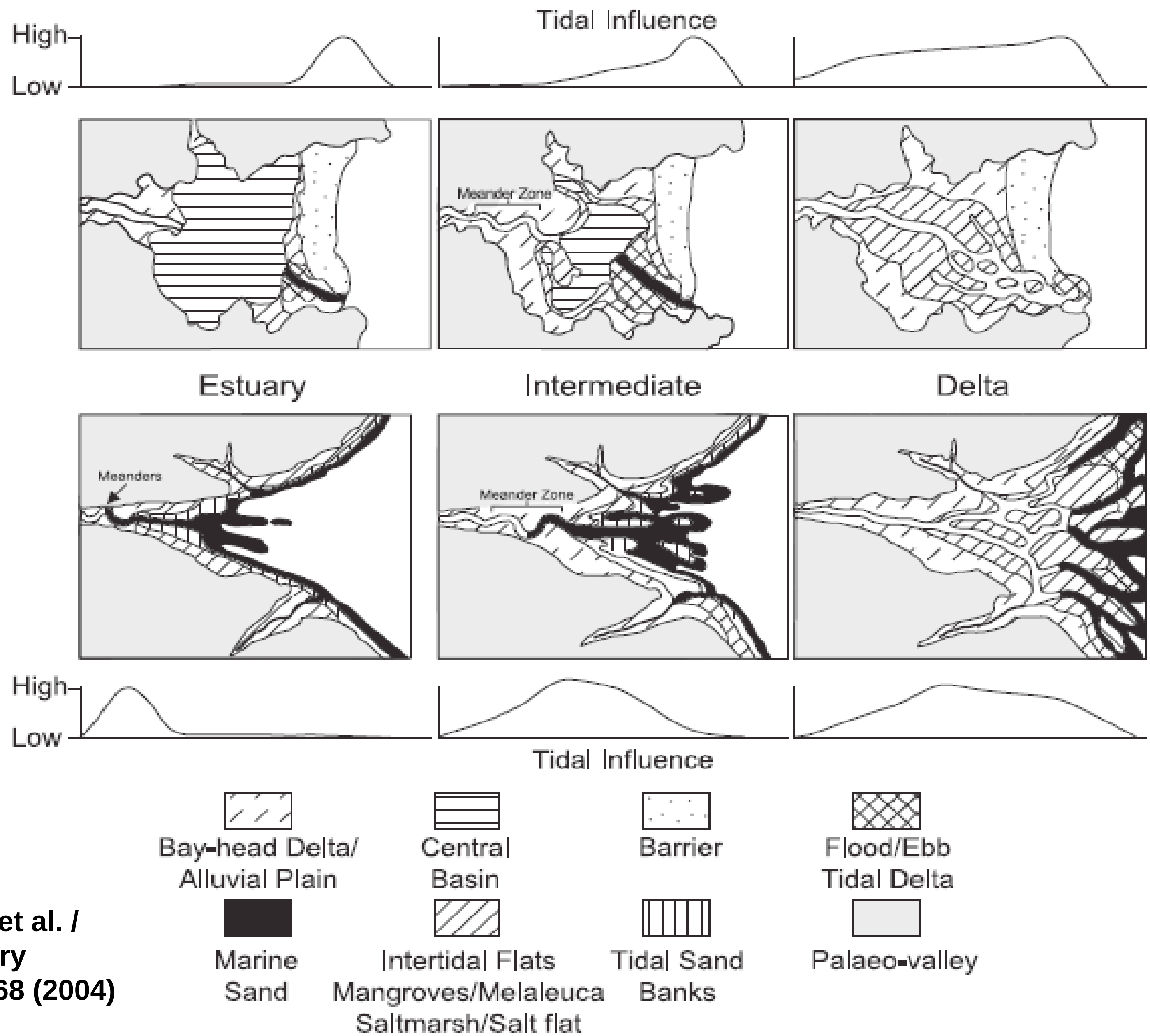
Kimmerer WJ. 2004.
http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1


ESTUARIO
DOMINIO MARINO
ENERGIA DE MEZCLA
DOMINIO FLUVIAL
ENERGIA TOTAL
CORRIENTES DE MAREA
RIO
OLAS
ENERGIA RELATIVA
100
50
0

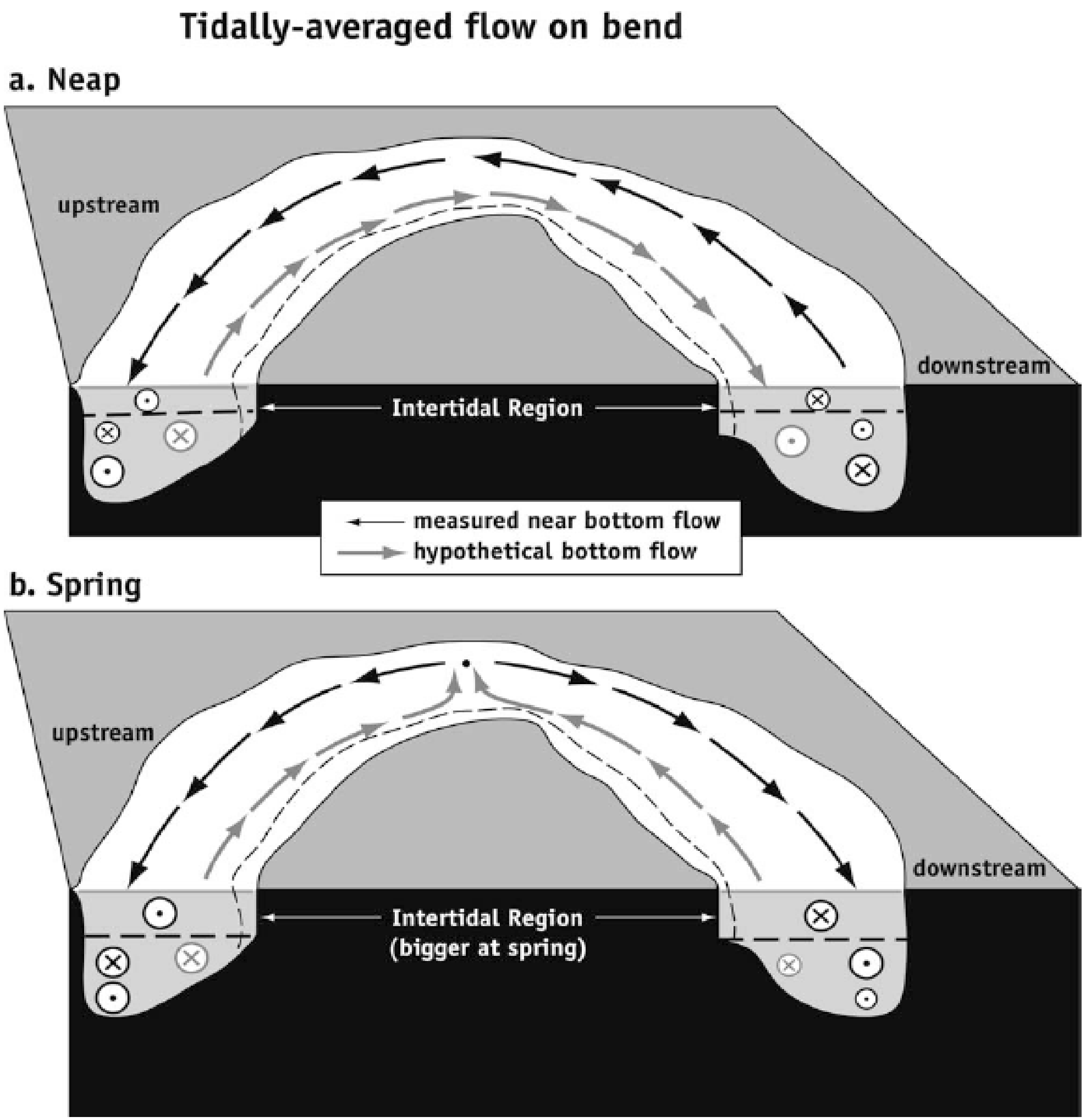

ESTUARIO
DOMINIO MARINO
DOMINIO INTERMEDIO
DOMINO FLUVIAL
OLAS
RIO
CORRIENTES DE MAREA
ENERGIA TOTAL
ENERGIA RELATIVA
100
50
0



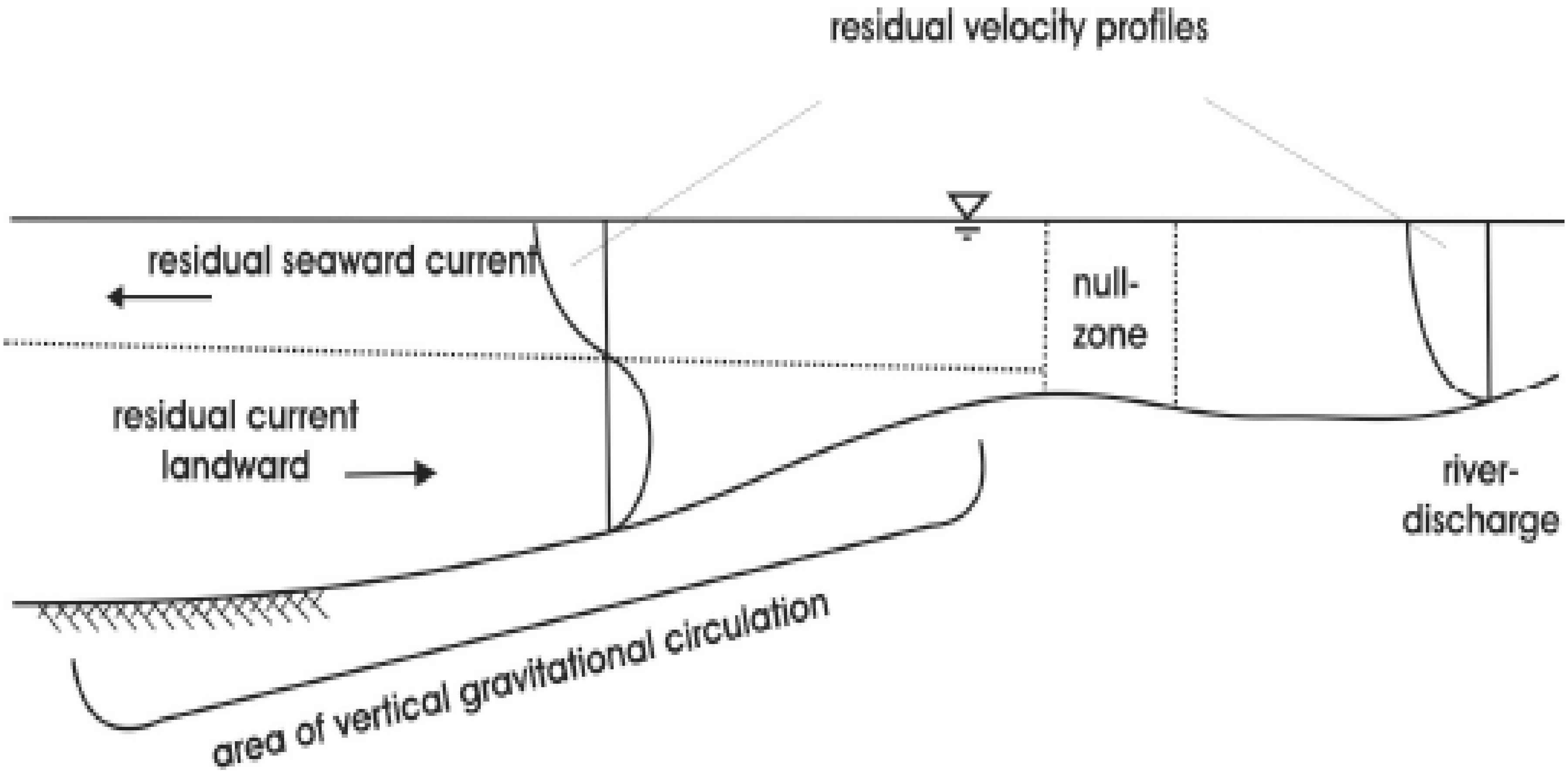

**A.D. Heap et al. / Sedimentary Geology 168 (2004) 1–17**




**A.D. Heap et al. / Sedimentary Geology 168 (2004) 1–17**

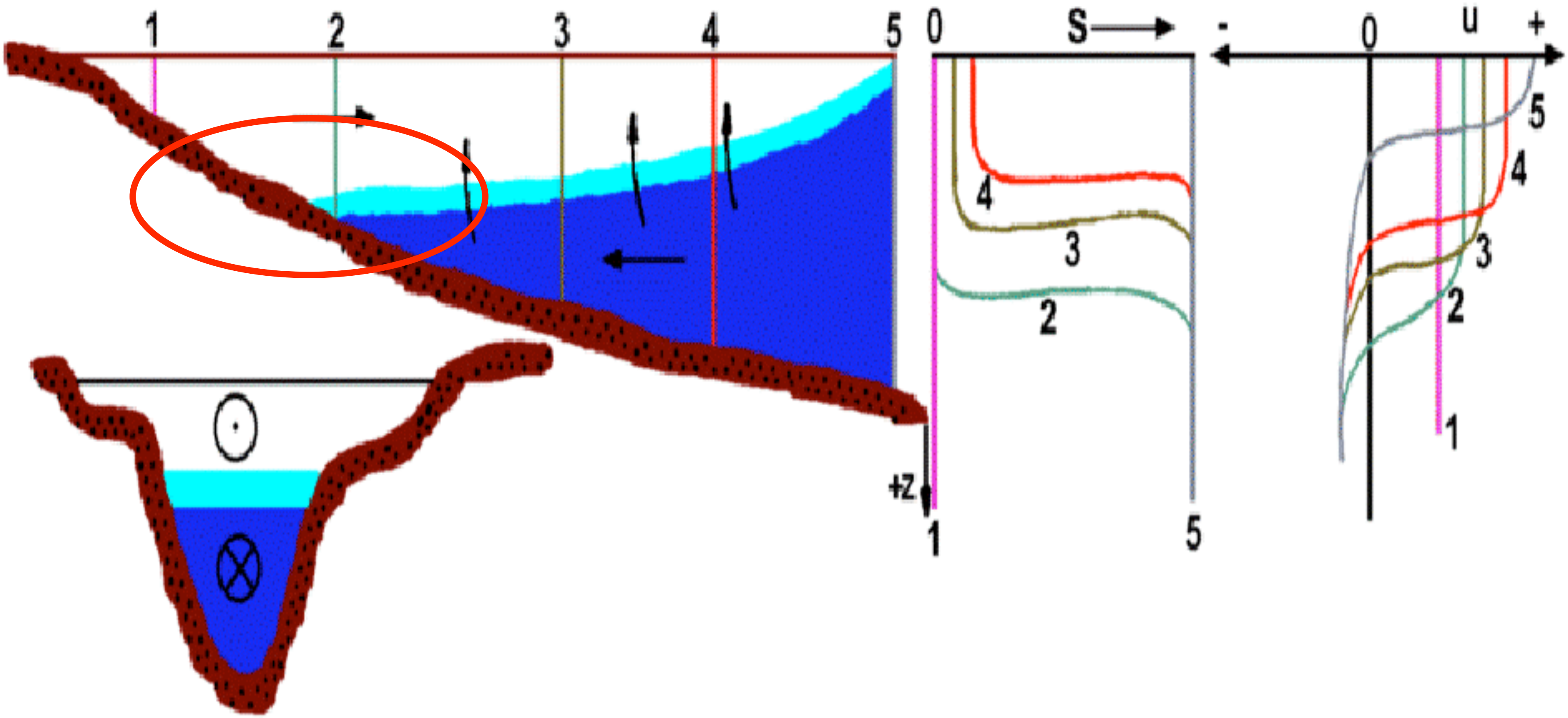



J.O. Blanton et al. / Estuarine, Coastal and Shelf Science 57 (2003) 993–1006

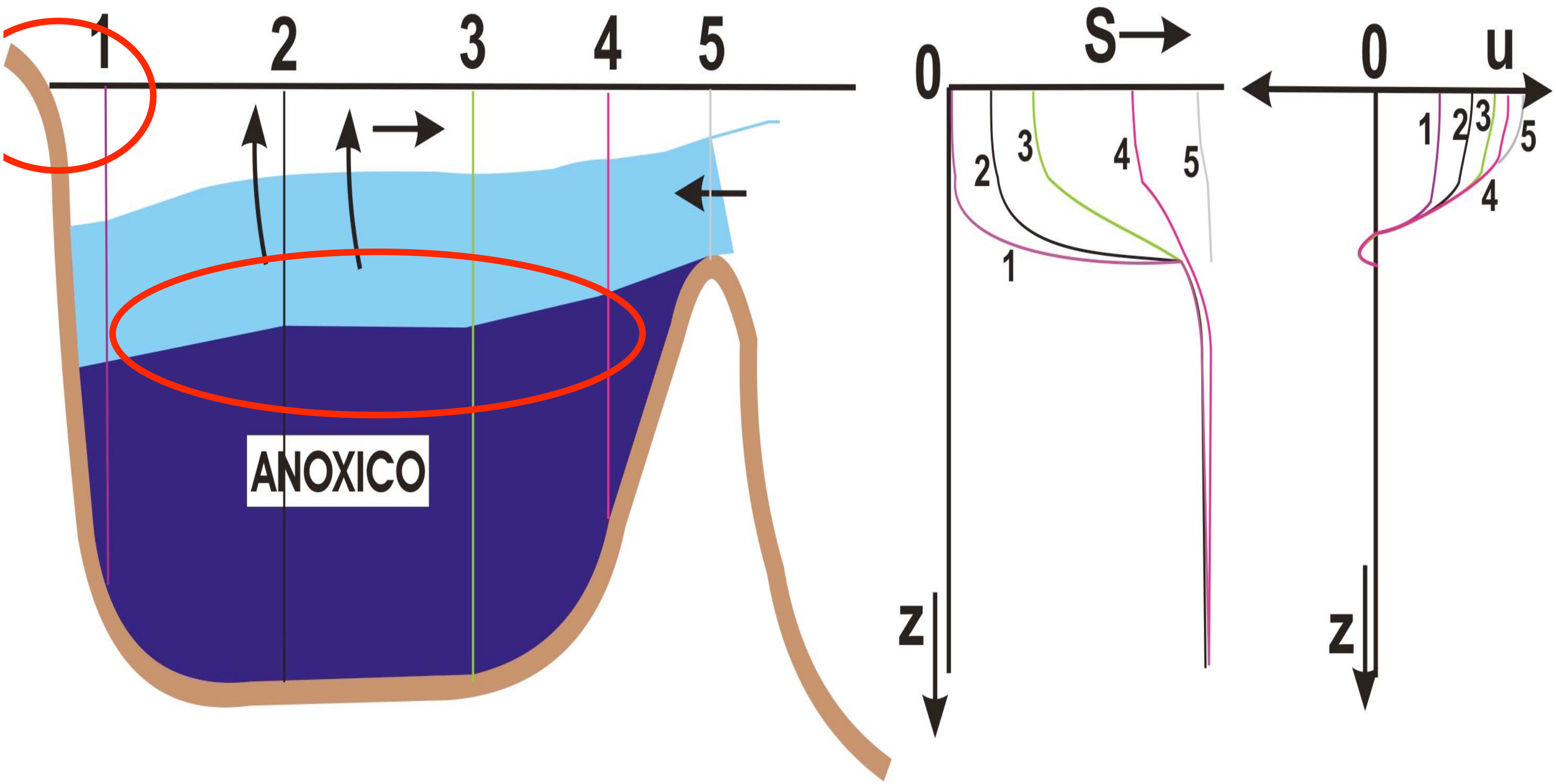

residual velocity profiles
residual seaward current
residual current
landward
null-
zone
river-
discharge
area of vertical gravitational circulation

Wurpts, 2006

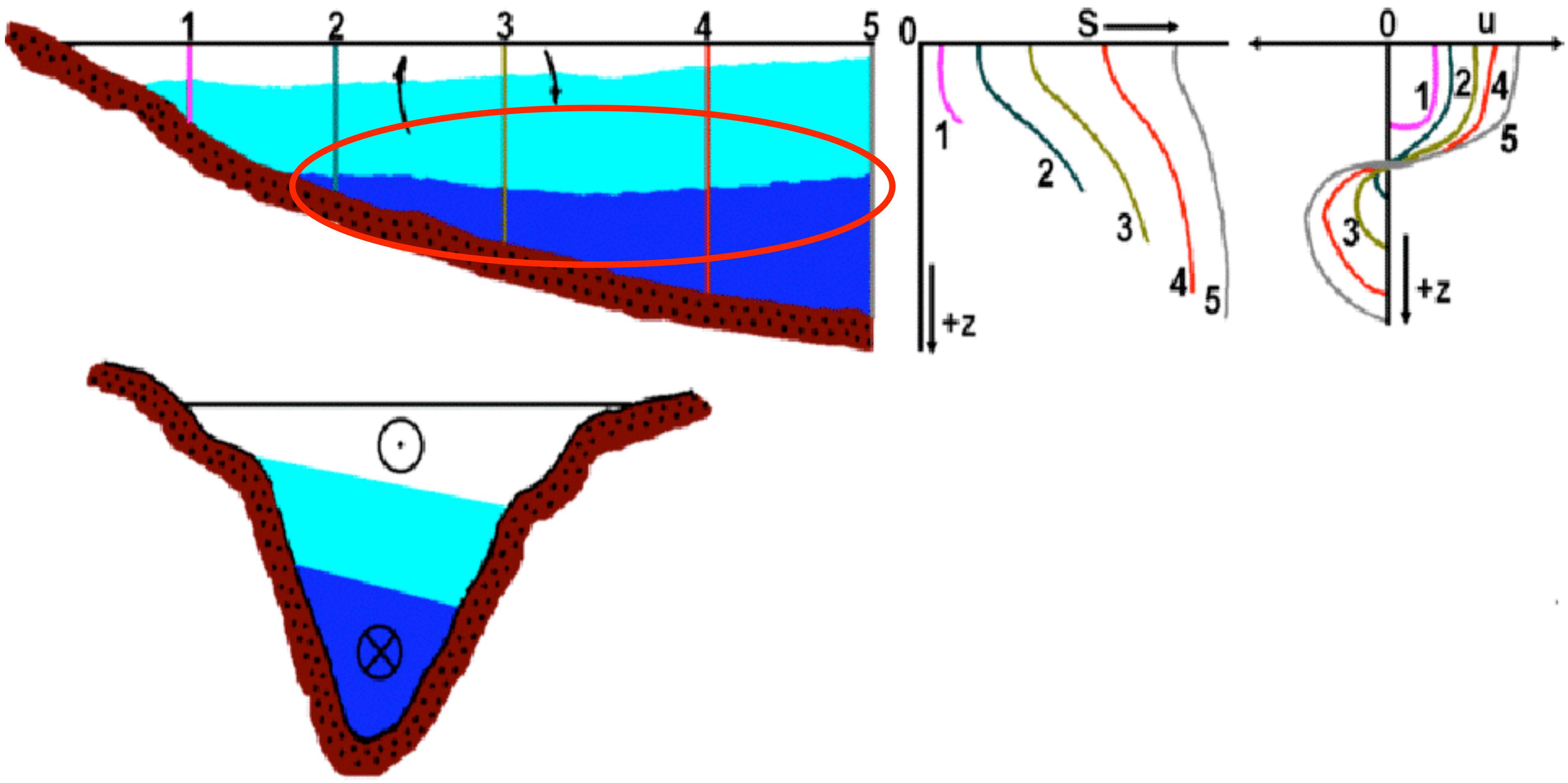
# SALT WEDGE (A)



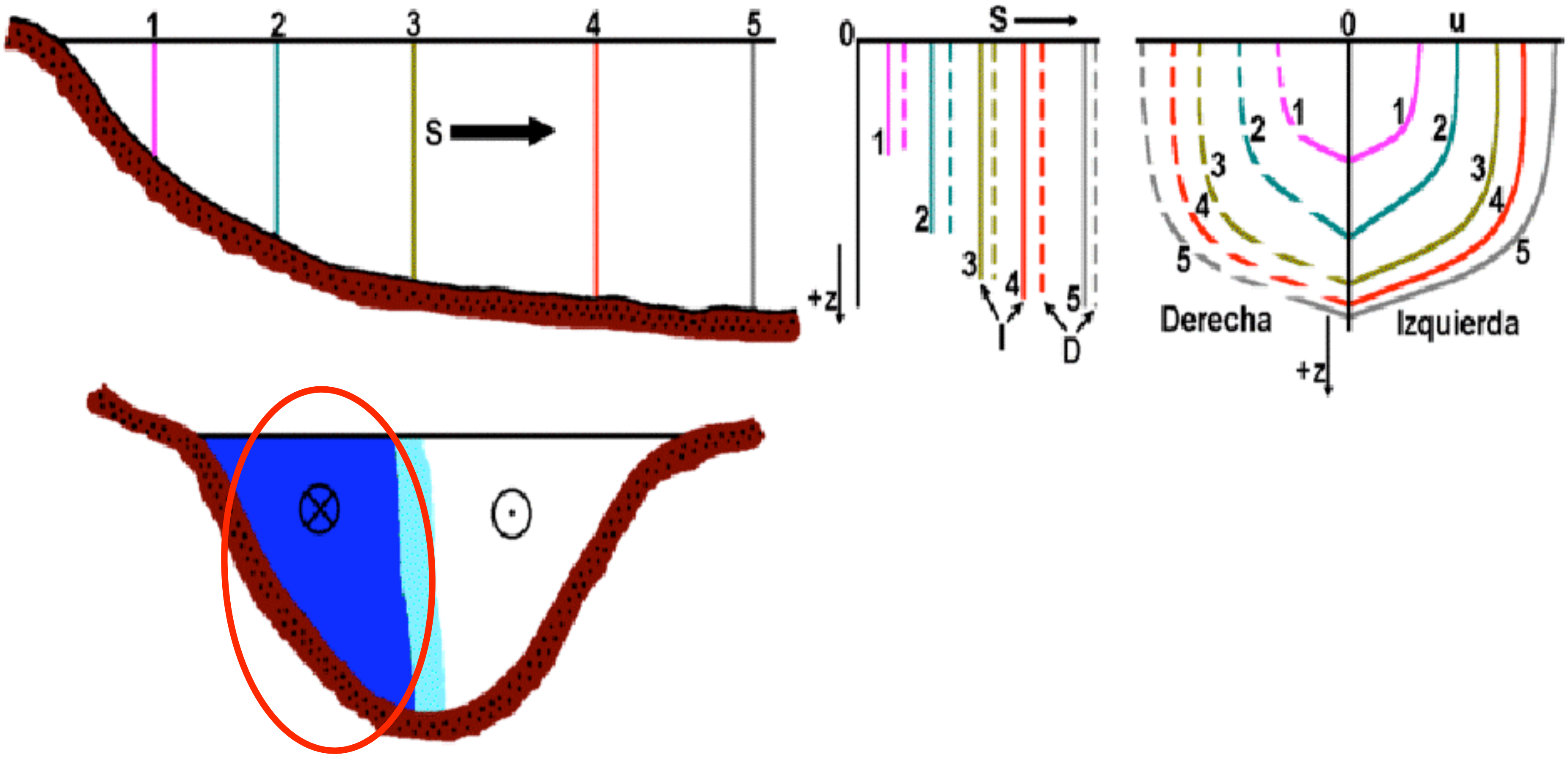
# FJORD



# PARTLY MIXED (B)



# VERTICALLY HOMOGENEOUS



# Residual Fluxes
# Interaction with

- Estuarine Geomorphology
- Density gradients
- Wind
- Freshwater discharge

$$u_L = u_S + u_E$$

**Lagrangean Flux = Stokes Drift + Eulerian Flux**

# Stokes Drift ($u_s$)

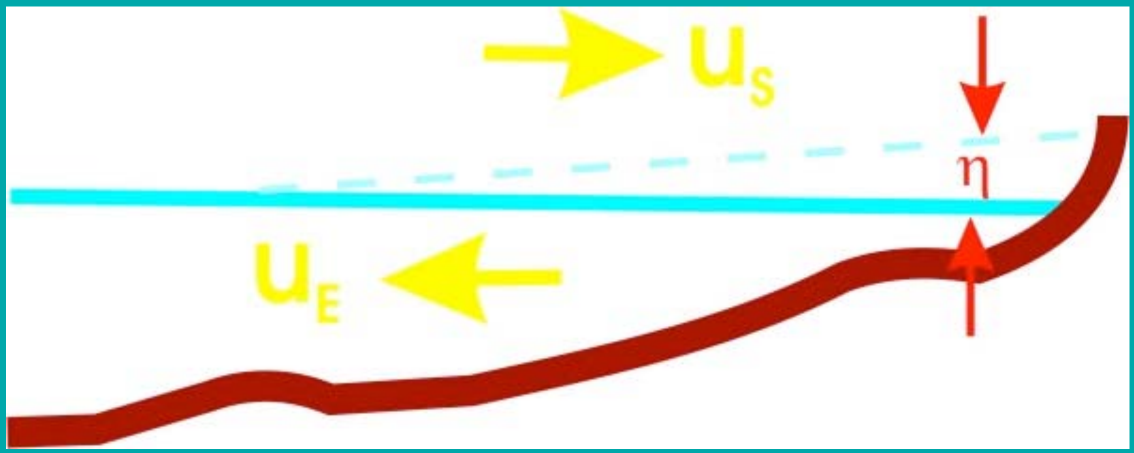
- Interaction between the partly progressive tidal wave and the topography
- Headward
- Associated to Tidal Pumping

$$u_s = \frac{< \tilde{A}\tilde{u} >}{< A >}$$

# Eulerian Flux ($u_E$)

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

**$\langle Q_E \rangle = -\langle Q_S \rangle$ $\qquad$ $u_E = \langle Au \rangle / \langle A \rangle$**




- **Valid for steady state**
- **Without river discharge**

# Lagrangean Flux ($u_L$)

- **Transport due to density gradient**

$$u_L = \langle Q_{vt} \rangle / \langle A \rangle$$

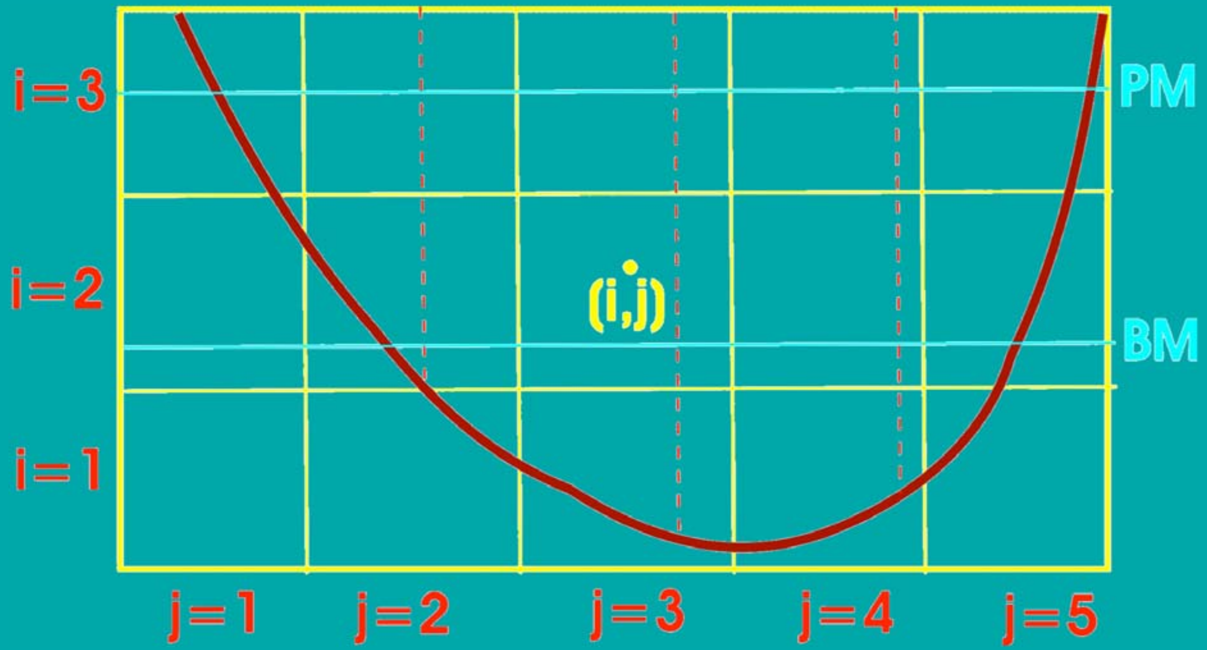
- **River runoff ($u_f$)**

$$u_f = \langle Q_f \rangle / \langle A \rangle \qquad \langle Q_f \rangle = R$$

$$u_L = u_f$$

**In steady state, near the head**

# Residual Flux Calculation




**Datos $U_{i,j,k}$ ; $S_{i,j,k}$ ; $C_{i,j,k}$ ; $A_{i,j,k}$**
**Donde i = total # of levels …. I ; j = total # of columns…. J;**
**k = time k = 0, 1, …, n$\Delta$k = T**

$$F = \int uCdA$$

$$F_{vtk} = IJ\overline{UCA} + J\overline{A}\sum_i u'_{i\bullet} c_{i\bullet} + I\overline{A}\sum_j u'_{\bullet j} c_{\bullet j} + F^*$$

$$F_L = F_{TP} + F_{VS} + F_{TS} + F^*$$

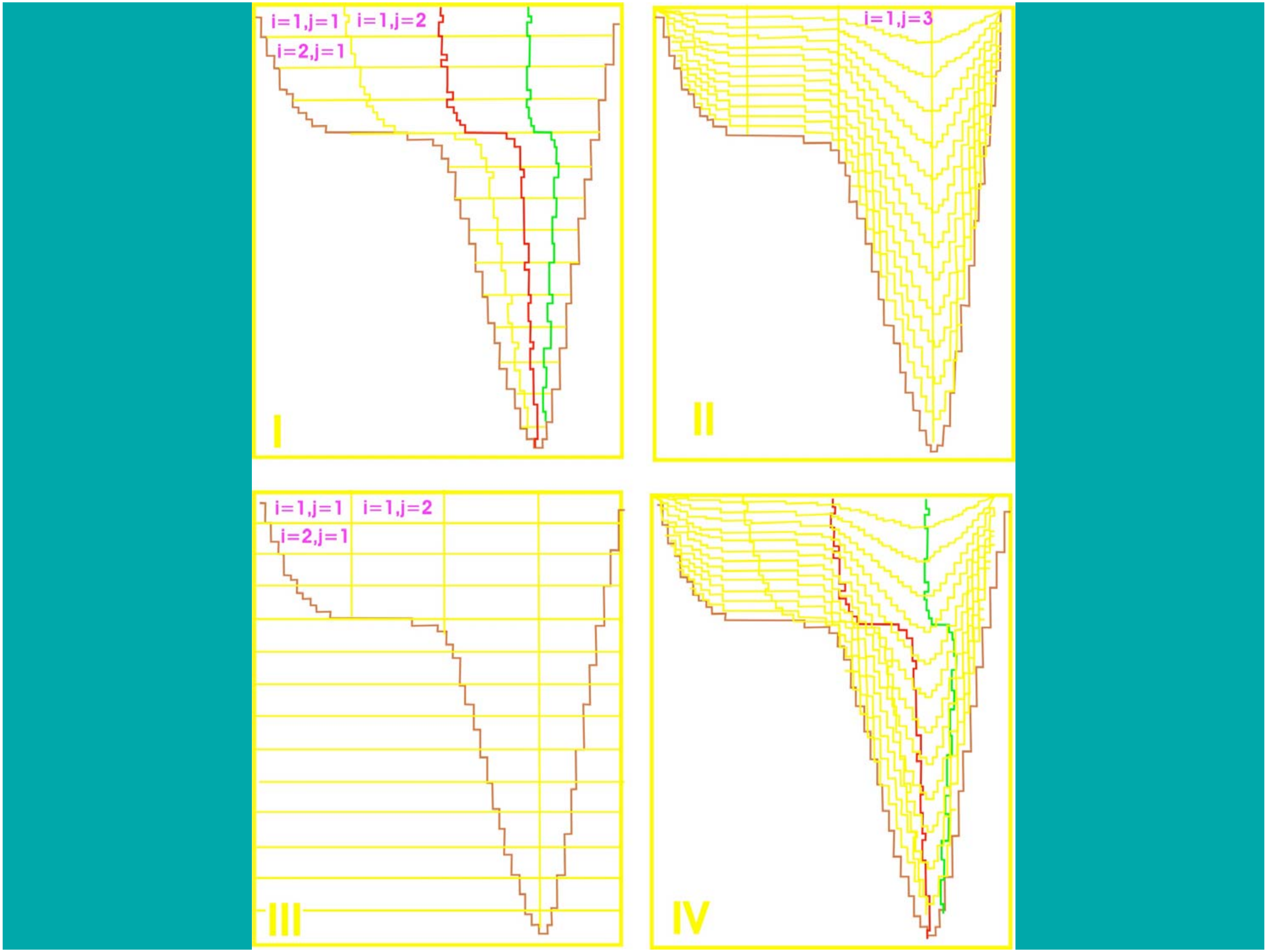
**Where**

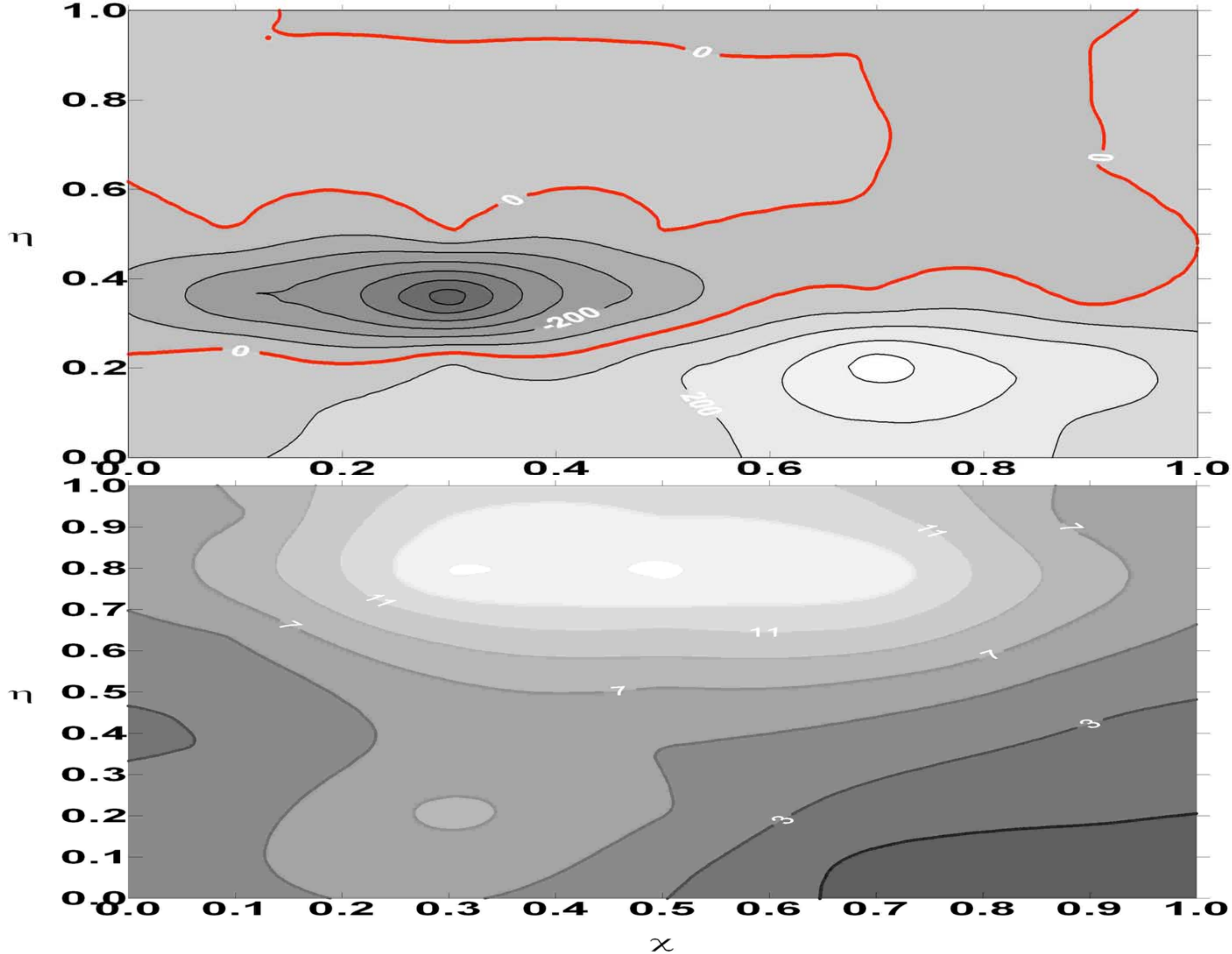
$$F_L = <\overline{Q}><\overline{C}>$$

$$F_{TP} = <\tilde{Q}C>$$

$$F_{vs} = \left\langle \overline{A}\sum_i u'_{i\bullet} s'_{i\bullet} \right\rangle$$

$$F_{ts} = \left\langle \overline{A}\sum_j u'_{\bullet j} s'_{\bullet j} \right\rangle$$


i=1,j=1
i=1,j=2
i=2,j=1
I
i=1,j=3
II
i=1,j=1
i=1,j=2
i=2,j=1
III
IV



η
0
-200
200
11
7
3
x

# 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