

## HYDROLOGICAL AND SEDIMENTARY STRUCTURE OF THE WATER COLUMN IN THE BACH DANG - CAM ESTUARY

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### Abstract:

*The present study aimed to describe the hydrological functioning of the Northern branch of the Red River estuary (Song Hong). This research results obtained from the project "Hydrodynamic and anthropogenic influences on phytoplankton and bacterioplankton of the Bach Dang estuary"(2008-2010) funded by VAST, IRD and the French National Program EC2CO. A very contrasted functioning was observed between wet and dry seasons. During the wet season, the strong freshwater discharge dominated the flow, producing high turbulence levels. During the dry season, as the steady fluvial component weakened, the action of tidal intrusion became predominant with a significant action of tidal pumping during the dry season which is responsible of a strong silting up of the estuarine system.*

### Tóm tắt:

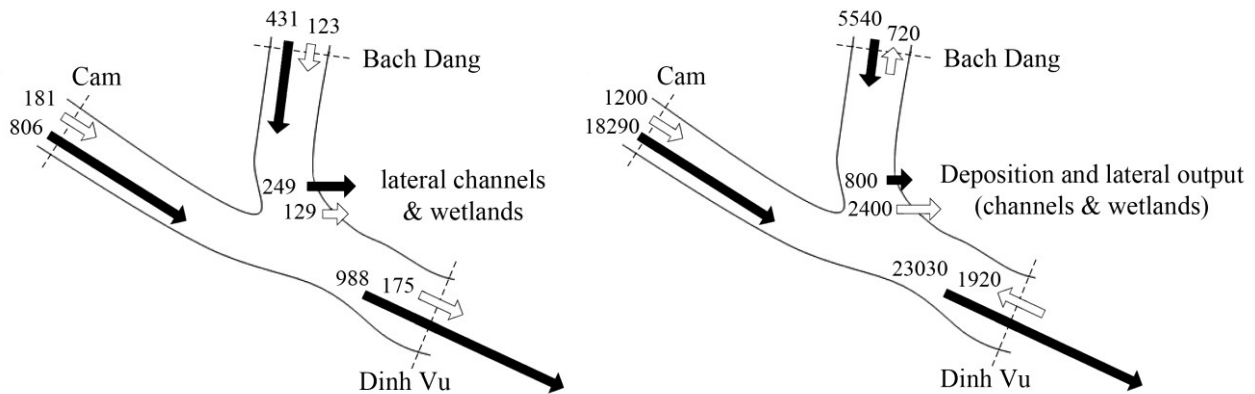
#### CẤU TRÚC TRẦM TÍCH VÀ THỦY HỌC CỦA CỘT NƯỚC Ở VÙNG CỬA SÔNG BẠCH ĐẰNG - CẨM

*Nghiên cứu này nhằm mục đích mô tả chức năng thủy học của nhánh sông phía Bắc thuộc vùng cửa sông Hồng. Các kết quả nghiên cứu này có được từ dự án "Ảnh hưởng nhân sinh và thủy động lực tới thực vật phù du và vi khuẩn nổi ở vùng cửa sông Bạch Đằng" (2008-2010) do Viện Khoa học và Công nghệ Việt Nam, Viện Nghiên cứu vì sự phát triển và Chương trình quốc gia EC2CO, Pháp tài trợ. Có sự tương phản rất rõ về chức năng giữa mùa mưa và mùa khô. Vào mùa mưa, dòng nước ngọt đổ ra mạnh chiếm ưu thế, gây ra các mức xáo trộn cao. Trong mùa khô, do thành phần sông ổn định bị yếu đi, ảnh hưởng của sự xâm nhập thủy triều trở nên chiếm ưu thế với tác động đáng kể của bơm thủy triều trong mùa khô là nguyên nhân gây lắng bùn mạnh của hệ thống cửa sông.*

### Communication

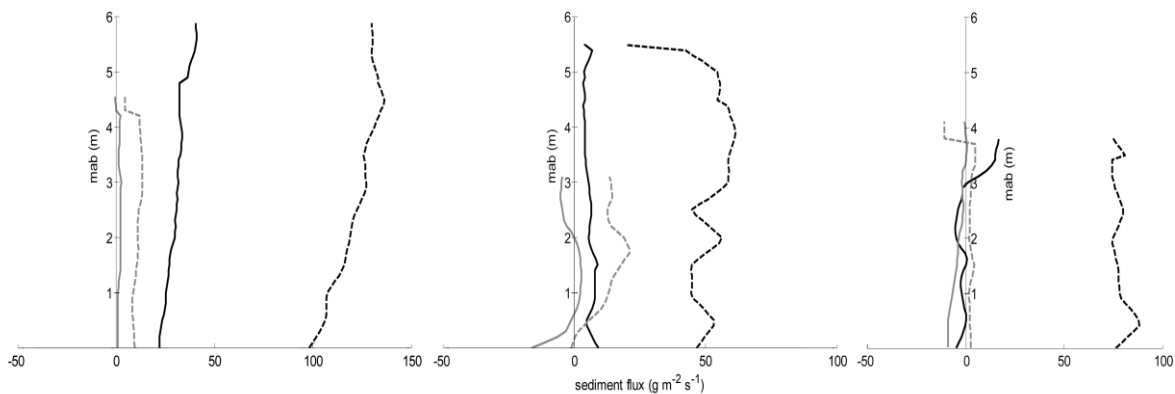
In order to analyze the variability in the functioning of the Bach Dang-Cam estuarine system at both the tidal and seasonal scales, two field campaigns were conducted, one in July 2008 (wet season) and the other in March 2009 (dry season). During these two campaigns, 24-hours surveys corresponding to one spring tidal cycle were achieved at key spots of the estuarine system. During every survey, the tidal elevation was approximately 2 m. Two stations were located on the main rivers flowing into the Haiphong bay; one on the Cam River, which is connected to the Red River, and one on the Bach Dang River, at about five kilometers upstream to the mouth; the third station was located close to the mouth of the system near Dinh Vu. Water fluxes and suspended solid averaged over one tidal cycle showed high seasonal variations. Water discharge was about 4 times higher in the wet season than in

the dry season at each station. The budget indicated a water loss by leakage through channels, mangroves and wetlands, which accounts for 20% and 42% of the liquid contributions of the total inputs in the wet and dry season, respectively. These budgets also indicated that during the wet season, the massive influx of sediment originated from the watershed passed through the estuary with a weak loss by deposition or leakage. During the dry season, the quantity of transported sediment was lower and the major input of sediment into the system came from the coastal area. The estuarine domain was silting up whatever the season (with a settling rate of approximately 2,400 metric tons per day in dry season, 3 times higher than deposit in wet season)(Fig. 1).



**Figure 1.** Liquid flow budget  $Q$  ( $m^3 s^{-1}$ ) (left) and solid transport (metric tons  $day^{-1}$ ) (right) during wet (black) and dry (white) season

Since the celerity of the tidal wave propagates faster with increasing water depth, the shape of the tidal wave gets distorted for shallow estuary, where the difference in water height is significant between ebb and flood. Due to their shape, large with shallow lateral shoals and a deep narrow channel, as it moves landward toward the Cam and Bach Dag stations; the rise of the tide becoming faster than its fall and, consequently, the current peak at flood faster than the one at ebb. This asymmetry is referred to as ‘tidal pumping’ and causes the sediment to be transported upstream. An elevation of the tidal level counterbalances the liquid budget so that the overall balance of tidal flow is null. The upward solid flux is located near bed (Fig. 2).



**Figure 2.** Tidal (solid line) and advective (dashed line) sediment flux during the wet (black) and dry (grey) seasons at the Cam (left), Bach Dang (center) and Dinh Vu (right) stations, averaged over a tidal cycle

Different sources of perturbation can influence the structure of the water column (heat flux, fresh water input, salt concentration, wind, rain...). The potential energy anomaly  $\phi$  ( $J.m^{-3}$ ) used to quantify the level of stratification, was calculated as [1]:

$$\phi = \frac{1}{h} \int_0^h (\langle \rho \rangle - \rho) g z dz \quad (1)$$

where  $\rho$  is water density calculated according to the UNESCO 1983 polynomial formula,  $h$  is the water depth,  $g$  is the acceleration of gravity and  $\langle \rangle$  stands for averaging over the water column.

As the water density is mostly related to the salt concentration, the saline intrusion driven by tidal propagation contributes to the structure of the water column. The increase in potential energy anomaly from wet to dry season is similar at the Bach Dang (x 7.96 ) and Dinh Vu stations (x 7.26). Between these two stations, the proportionality factor varied little from one season to another (x 0.88 in wet season, x 0.80 in dry season). The structuring is mainly related to the marine water entries but can also depend on the weather conditions. Thus, the Cam river, rather homogeneous in rainy season showed a vertical structure in dry season during a short episode when wind speed was at its minimum.

**Table 1.** Potential energy anomaly

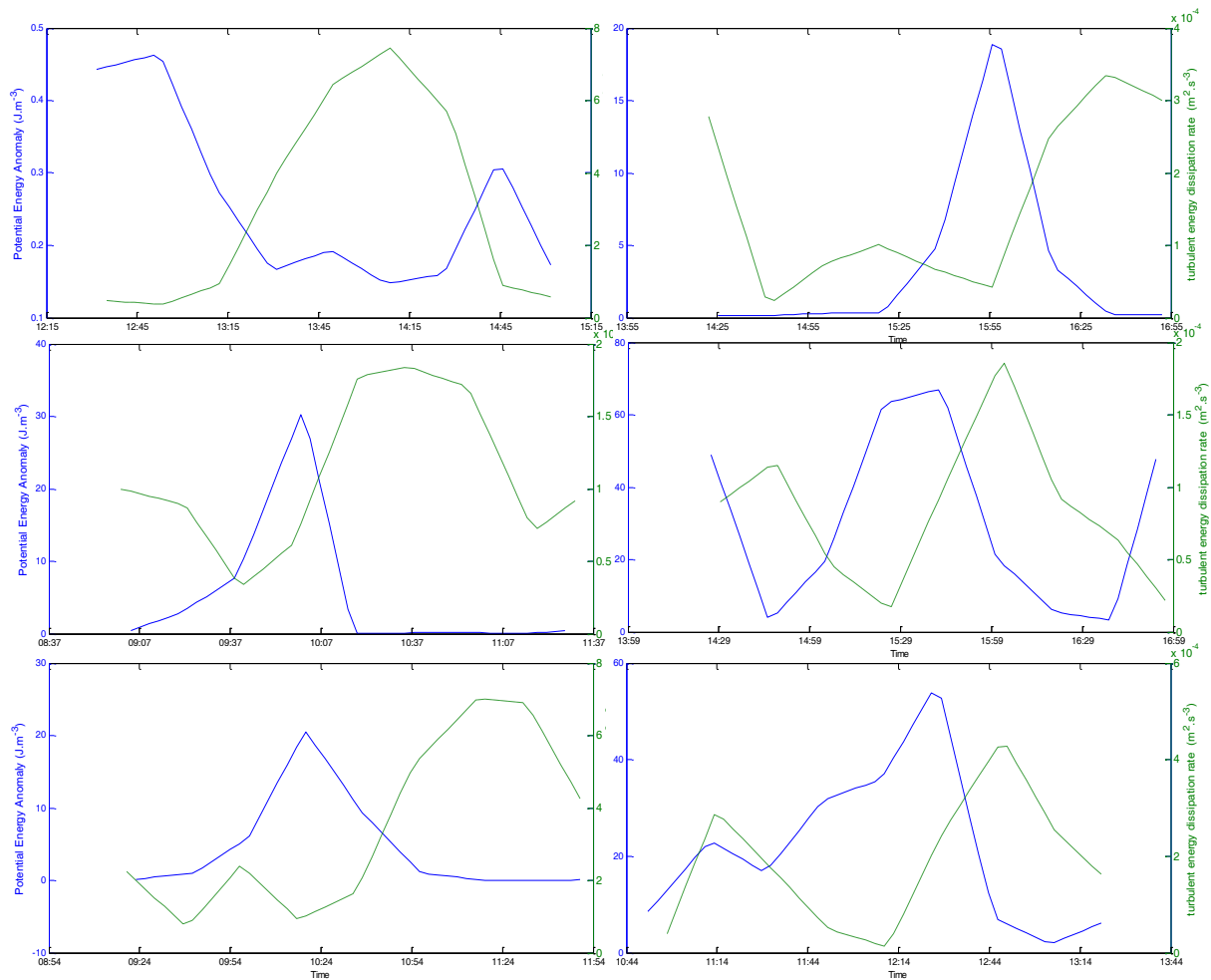
Station	Wet season (July 2008)			Dry season (March 2009)		
	Mean	Min	Max	Mean	Min	Max
Cam	0.26	0.15	0.46	5.78	0.84	32.48
Bach Dang	4.79	0.04	31.14	38.15	5.35	81.63
Dinh Vu	4.22	0.00	20.66	30.64	7.69	69.18

The turbulent kinetic energy dissipation rate ( $\varepsilon : m^2 s^{-3}$ ) integrated over the water column can be expressed as a function of wind and averaged current magnitude [2] :

$$\varepsilon = k_b \frac{\langle u \rangle}{h} + k_s \frac{w^3}{\psi h} \quad (2)$$

where  $k_b$  and  $k_s$  are the bottom and surface drag coefficients,  $\langle u \rangle$  is the depth-averaged water velocity,  $h$  is the water height,  $w$  is the wind velocity, and  $\psi$  the ratio between water and air density.

High turbulence levels promote vertical advection of salt. It results a homogeneization of the water column that corresponds to low potential energy anomaly values. At the contrary, near slack water of high tide, the low turbulence level does not influence significantly the strong stratification induced by the presence of an upper layer of freshwater and a bottom layer of marine water in the flow (Fig. 3).



**Figure 3.** Potential energy anomaly (solid line) and turbulent energy dissipation rate (dashed line) during a tidal cycle at at the Cam (up), Bach Dang (center) and Dinh Vu (down) stations during wet(left) and dry (right) season.

## References

1. Simpson JH, Brown J, Matthews J, Allen G. Tidal Straining, Density Currents, and Stirring in the Control of Estuarine Stratification. *Estuaries* 13(2):125-132 (1990).
2. Van der Lee EM, Bowers DG, Kyte E. Remote sensing of temporal and spatial patterns of suspended particle size in the Irish Sea in relation to the Kolmogorov microscale. *Cont Shelf Res* 29:1213–1225 (2009).