DIC dynamics in a tropical estuary (Kidogoweni, Kenya)

Alberto Vieira Borges[1], Michel Frankignoulle[1], Bruno Delille[1], Steven Bouillon[2]

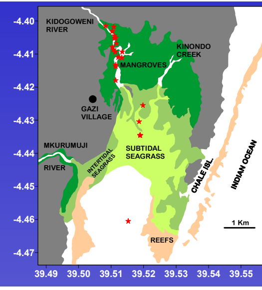

Fig. 1: The Bay of Gazi (Kenya)

The Bay of Gazi is bordered by a tidal creek (Kinondo) and two estuaries (Kidogwedi and Mkurumuji). They are surrounded by dense mangrove forests, while an extensive seagrass bed (dominated by *Thalassodendron ciliatum*) covers 70% of the surface area of the Bay.

✓Abstract:

The Kidogoweni estuary (Gazi Bay, Kenya) was sampled in July 2003 for dissolved inorganic carbon (DIC) and ancillary data. The partial pressure of CO_2 (pCO_2) values ranged from 430 to 6320 ppm and the computed air-water fluxes ranged from 1 to 400 mmol m^{-2} d^{-1}. The integrated air-water flux for the whole estuary converges to a value of 96 mmol m^{-2} d^{-1}. These results are discussed in relation to other tropical and temperature estuaries. DIC and Total Alkalinity (TAlk) in the Kidogoweni estuary showed strong non-conservative behaviour along the salinity gradient. The slope of normalized TAlk versus normalized DIC clearly demonstrates the role of diagenetic processes on water column DIC and TAlk but does not allow to identify them unambiguously.

✓Introduction:

Mangroves are among the most productive coastal inter-tidal ecosystems in the world, confined to the tropics and subtropics and dominate the World's coastline between 25°N and 25°S, and are estimated to occupy between 0.17 and 0.20 10^6 km^2. Aquatic primary production is limited by high turbidity, canopy shadow and large changes in salinity. The water column and sediments receive important quantities of leaf and wood litter from the overlying canopy. Thus, the water column and the sediment metabolisms are largely net heterotrophic and consequently, mangrove surrounding waters are a net source of CO_2 to the atmosphere. Here, we report DIC and ancillary data obtained in the Kidogoweni estuary (Gazi Bay, Kenya, Fig. 1) that is bordered by a dense mangrove forest.

✓Results:

The co-variations of pCO_2 and $\%O_2$ suggest that these variables are controlled by heterotrophic processes (Fig. 2) probably fuelled by the carbon inputs from the mangrove forest. DIC and TAlk show strong non-conservative behaviour along the salinity gradient (Fig. 3). The profiles of these variables show a net production during estuarine mixing. This net production is probably related to the inputs of porewaters rich in TAlk and DIC in relation to diagenetic degradations processes as shown in other mangrove systems (Borges et al. 2003, Geophysical Research Letters, 30(11): 1558). *n*DIC and *n*TAlk are well correlated (r^2 = 0.988) showing that their variations are controlled by the same biogeochemical process(s). The slope of *n*TAlk *versus* *n*DIC (0.72±0.01) is close to the one predicted by denitrification (Fig. 4). However, denitrification is considered as a minor diaganetic carbon degradation pathway, sulfate-reduction and aerobic respiration being the major pathways in mangrove sediments (e.g. Alongi, 1998, Coastal Ecosystem Processes CRC). The combination of sulfate-reduction and aerobic respiration could explain the co-variation of *n*TAlk and *n*DIC (Fig. 4). Sulfate-reduction can have a permanent effect on water column TAlk if one of the following processes occurs :1) dissolution of $CaCO_3$ from proton produced by the oxidation of H_2S to SO_4^{2-} (e.g. Ku et al. 1999, Geochim. Cosmochim. Ac. 63:2529-2546); 2) H_2S is trapped in the sediment as pyrite. Dissolution of $CaCO_3$ does not affect significantly Ca^{2+} and Mg^{2+} profiles during estuarine mixing (Fig. 5) despite the fact that it has been reported in the sediments of Gazi Bay (Middelburg et al. 1996, Biogeochemistry 34: 133-155). This clearly demonstrates the role of diagenetic processes on water column DIC and TAlk but does not allow to identify them unambiguously.

The air-water CO_2 fluxes were computed from field measurements of wind speed and using the gas transfer velocity formulated by Carini et al. (1996, Biol. Bull. 191: 333-334). The computed air-water fluxes range from 1 to 400 mmol m^{-2} d^{-1} and the integrated air-water flux for the whole estuary converges to a value of 96 mmol m^{-2} d^{-1}. This value is close to the lower limit of the range of integrated CO_2 emission rates (85 to 210 mmol m^{-2} d^{-1}) reported by Frankignoulle et al. (1998, Science 282: 434-436) in temperate European estuaries.

Also, the integrated CO_2 emission from the Kidogoweni estuary is within the range of values (5 to 114 mmol m^{-2} d^{-1}) reported by Borges et al. 2003 (Geophysical Research Letters, 30(11):1558) in the waters surrounding 7 mangrove forests. These authors suggest a value of 50 mmol m^{-2} d^{-1} as a consensual CO_2 emission rate for waters surrounding mangrove ecosystems. The extrapolation of this value to the surface area of worldwide mangrove ecosystems gives a global emission of CO_2 to the atmosphere of about 50 10^6 tC yr^{-1}. On a regional scale, the subtropical and tropical open oceanic waters behave as a net source of CO_2 of about 0.43 PgC yr^{-1} (between 32°N and 32°S, based on Takahashi et al. 1997, Proc. Natl. Acad. Sci. USA 94:8292-8299). Thus, mangrove surrounding waters would be an additional CO_2 source of about 12% to the one of open oceanic waters, in tropical and subtropical latitudes, with a surface area about one thousand times smaller.

✓Conclusions:

The present results confirm recent findings on C cycling in mangrove ecosystems (Bouillon et al. 2003, Global Biogeochemical Cycles 17 (4): 1114; Borges et al. 2003, Geophysical Research Letters, 30(11): 1558):

- CO_2 emission from the water column is a major C pathway in mangrove ecosystems
- DIC produced in mangrove ecosystems is ventilated to the atmosphere within the system and is not exported to adjacent aquatic systems.
- Water column DIC dynamics in mangrove ecosystems are strongly influenced by diagenetic C degradation processes.

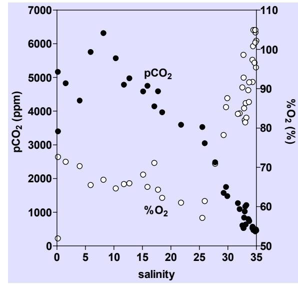

Fig. 2: pCO_2 and O_2 saturation level in surface waters of the Kidogoweni estuary as a function of salinity

The estuary is over-saturated in CO_2 with respect to atmospheric equilibrium (370 ppm). pCO_2 values range between 430 to 6320 ppm for salinities below 35 and are well above the marine end-member value (470 ppm).

The anti-correlation of both variables suggest that they are controlled by degradation processes during estuarine mixing.

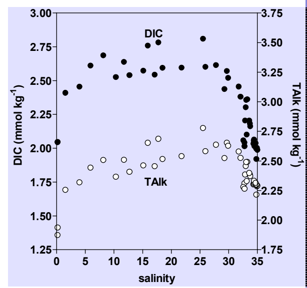

Fig. 3: DIC and TAlk in surface waters of the Kidogoweni estuary as a function of salinity

Both variables show strong non-conservative behaviour along the salinity gradient. Both variables co-vary suggesting that the same process(es) control their distribution.

The input of porewaters rich in TAlk and DIC has been shown to be a major production process of these quantities for the waters surrounding mangroves.

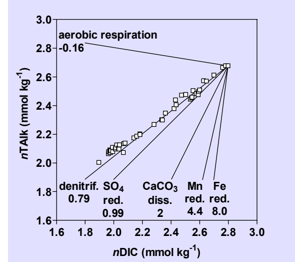

Fig. 4: TAlk and DIC normalized to a constant salinity of 17

Solid lines correspond to the theoretical evolution to attain the highest *n*TAlk and *n*DIC values for the potential biogeochemical processes that can control these variables: aerobic respiration, denitrifcation (denitrif.), sulfate reduction (SO_4 red.), calcium carbonate dissolution ($CaCO_3$ dissol.), manganese reduction (Mn red.) and iron reduction (Fe red.). Numbers correspond to the theoretical slope of the relative variation of *n*TAlk and *n*DIC for each of the biogeochemical processes.

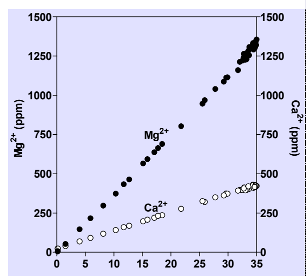

Fig. 5: Mg^{2+} and Ca^{2+} in surface waters of the Kidogoweni estuary as a function of salinity

Ca^{2+} and Mg^{2+} were measured by Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES)

Both parameters show strong conservative behaviour. They are not significantly affected by carbonate dissolution during estuarine mixing.

European Geosciences Union
1rst General Assembly
Nice, France, 25 - 30 April 2004

www.ulg.ac.be/oceanbio/co2/
www.vub.ac.be/mangrove/

Acknowledgements: Jaques Navez, Kenya Marine and Fisheries Research Institute, FNRS (2.4596.01, 1.5.066.03) and FWO (G.0118.02) and Ioen Delille

[1] Université de Liège, Belgium (Alberto.Borges@ulg.ac.be)
[2] Vrije Universiteit Brussel, Belgium