Comparison of dissolved inorganic and organic carbon yields and fluxes in the watersheds of tropical volcanic islands, examples from Guadeloupe (FWI)

M.F Benedetti[1], E. Lloret[1], C. Dessert[2,3], P. Albéric[4], J. Gaillardet[3]
[1]Equipe de Géochimie des Eaux, Institut de Physique du Globe de Paris (IPGP), Université Paris-Diderot, Paris, France
[2]Observatoire Volcanologique et Sismologique de Guadeloupe, Guadeloupe, French West Indies
[3]Laboratoire de Géochimie et Cosmochimie, IPGP, Université Paris-Diderot, Paris, France
[4]Institut des Sciences de la Terre d' Orléans, Orléans, France

I. Introduction

The total carbon flux to ocean is globally 0.9 Gt/yr. The organic carbon (dissolved DOC and particulate POC) represents about 42 % and the inorganic carbon (dissolved DIC and particulate PIC) represents 58 % of this flux (*figure 1*).
Moreover, the soil organic matter with 1400 Gt is a major pool of carbon at the Earth surface (*Gregory et al., 1999*). The soil erosion is therefore the major input of organic carbon in aquatic ecosystems.

Recent studies suggest that, since the mid-1970s, the tropical hurricanes have longer lifetimes and greater intensities (*Emanuel, 2005; Webster et al., 2005*). This increase of activity is likely to exert major effects on Atlantic tropical islands. Tropical storms and cyclones perturb the weathering engine and exert a strong impact on fluxes of dissolved and suspended material derived from soils.

The aims of this project are to calculate the DOC and DIC yields and fluxes, to ... ify ... log ... en

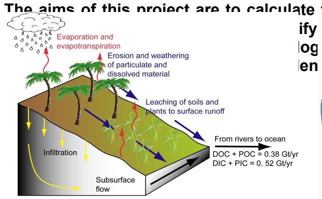


Figure 1 : Schema of export on a watershed

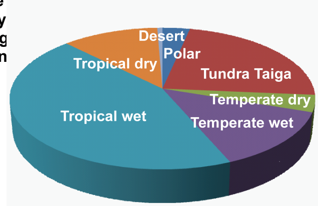


Figure 2 : Graph of world DOC fluxes. Ludwig et al., 1996

II. Field Sites

The Guadeloupe Island, in the French West Indies (*figure 3*), is a particularly adapted field site to investigate climatic impact on ecosystem dynamic, because of its location in wet tropical area (*figure 2*). Indeed, recent studies have shown the importance of chemical weathering of volcanic rocks; especially under tropical climate; on CO_2 consumption, carbon cycle and climate (*Dessert et al., 2001-2003; Louvat, 1997; Rad et al., 2006).*

We have developed our investigations on the Basse-Terre island which is the volcanic part of Guadeloupe island, with the active volcano of La Soufrière. The steep slopes and the abundant precipitations in the Basse-Terre determine a dense water system which sculpts easily materials deposited

We ... ershed on Basse-Terre island, which are ... hydrological network on Basse-Terre.

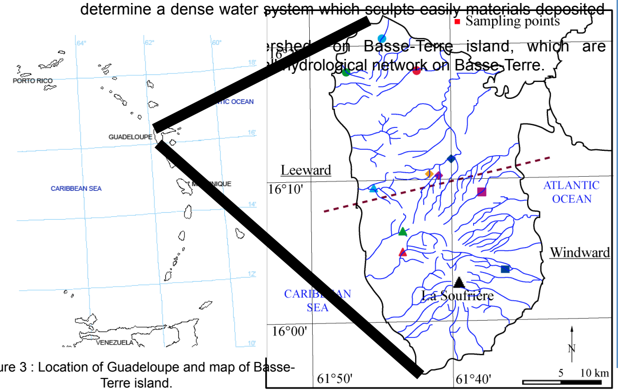


Figure 3 : Location of Guadeloupe and map of Basse-Terre island.

III. Materials and Methods

• ***Hydrological regimes of Guadeloupean Rivers*** (Figure 4) (DIREN data)

• ***DOC measurements***: Shimadzu TOC-V$_{CSH}$ analyzer, precision 2

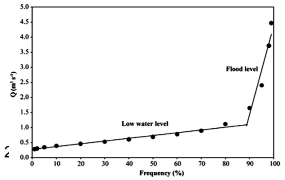


Figure 4: Frequency versus discharge ($m^3\ s^{-1}$)

• ***DIC calculations***: The measure of alkalinity with an automatic titrator by Gran titration (precision 1%), pH, ionic strength and temperature give the different parameters to calculate the different parts of carbonate system.

$$\text{With: } Alk = [HCO_3^-] + 2*[CO_3^{2-}] + [OH^-] - [H^+]$$
$$\mathbf{DIC = \Sigma CO_2 = H_2CO_3 + HCO_3^- + CO_3^{2-}}$$

• ***$\delta^{13}C_{DOC}$***: IR-MS (Delta V Plus – Thermo Scientific) coupled with a HPLC (Finnigan Surveyor), precision 0.3 ‰.

❖ **Aromaticity** is calculated formula obtained by Weishaar et al., 2003, Peuravuori and Pihlaja, 1997, with S ... OC]), UV ... T

IV. Results

❖ **Weathering and major ions sources**

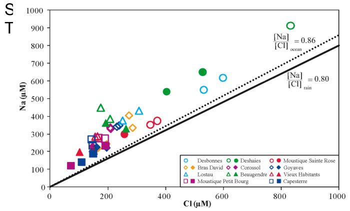


Figure 5: Na as a function of Cl (µmol/L)

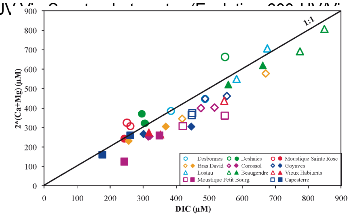


Figure 6: 2*(Ca+Mg) as a function of DIC (µmol/L)

The Na/Cl ratios of rivers are systematically higher than those of rainwater, symbolized by the straight line with a slope of 0.8 (Na/Clrain), emphasizing the additional sources of sodium coming from water–rock interactions (Figure 5).
During floods, the DIC is partially diluted by rainfall inputs as the lowest calcium and magnesium concentrations (Figure 6).

❖ **Characterization of the DOC sources**

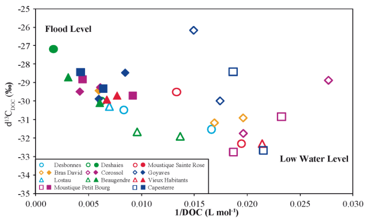


Figure 7: Isotopic composition of DOC as function of 1/DOC (1/(µmol/L))

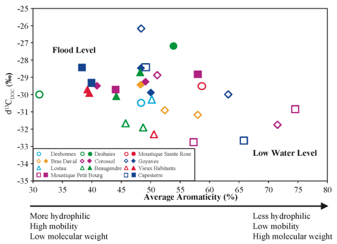


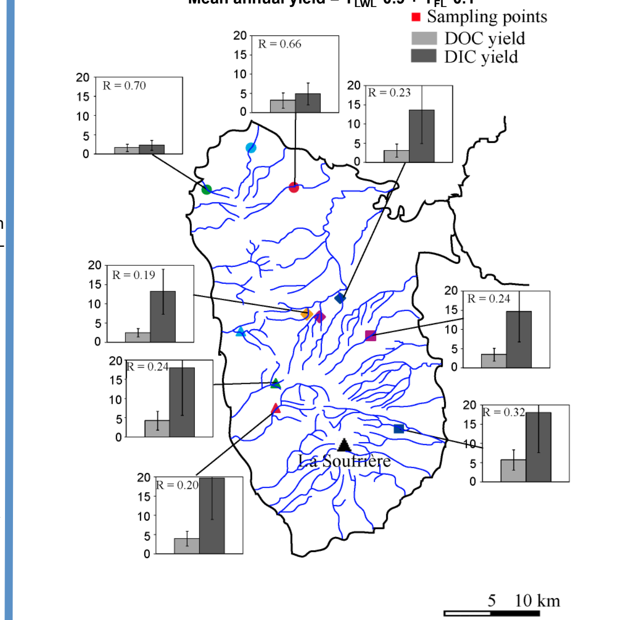
Figure 8: Isotopic composition of DOC as function of the aromaticity

The correlation observed in figure 7 between the $\delta^{13}C_{DOC}$ and 1/DOC indicates the mixing between two sources. This is confirmed with the correlation between aromaticity and $\delta^{13}C_{DOC}$ in Figure 8.
Probable source of DOC during LWL is groundwater inputs. This source has high aromaticity and very negative $\delta^{13}C_{DOC}$.
Probable source of DOC during FL is soils lixiviation input. This source has low aromaticity, and the less negative $\delta^{13}C_{DOC}$. According to Violleau, 1999, this is an indicator of a stronger oxidation of the source material.

Estimation of DOC and DIC yields

The yields of carbon have been calculated from the mean runoff values (Fig. 4) and mean carbon concentrations for each river.
Low water level:
DOC yields = 0.4 - 2.1 $tkm^{-2}\ year^{-1}$; DIC yields = 1.7 - 14.8 $tkm^{-2}\ year^{-1}$
Floods:
DOC yields = 11.3 - 42.4 $tkm^{-2}\ year^{-1}$; DIC yields = 7.3 - 75.7 $tkm^{-2}\ year^{-1}$

Mean annual yield = Y_{LWL}*0.9 + Y_{FL}*0.1



IV. Conclusion

❖ Differences in carbon origin during two hydrological regimes. During LWL, rivers were mainly fed by soil ground flow; during FL rivers were fed by runoff and quick flow.

❖ 60% of DOC export and 25-45% of DIC export occurred during flash floods. Neglecting these flash floods leads to an underestimation of the global carbon export from these islands (estimated for volcanic arc islands under tropical climate: FDOC = 5-19 Mt yr^{-1}, FDIC = 8-65 Mt yr^{-1}).

❖ Spatial variation of DOC and DIC yields is evidenced around the Basse-Terre Island. The DOC and DIC yields are higher in the southern part of the island where the bedrock is younger and the slopes are steeper than in the northern part. The southern part receives the maximum of precipitations.

❖ For a carbon mass balance perspective, the export of OC by small tropical rivers can no longer be neneglected.

References :
Carey et al. (2005) Geophysical Research Letters 32.
Dessert et al. (2001) Earth and Planetary Science Letters 188. 459-474
Dessert et al. (2003) Chemical Geology. 202. 257-273
Emanuel (2005) Nature 436
Gregory et al. (1999) International Geosphere-Biosphere Program Book Series 4, Cambridge, United Kingdom, pp. 229-270.
Ludwig et al. (1996) Global Biogeochemical Cycles 10. 23-41
Louvat (1997) pHD Thesis, IPGP. 322 pp
McDowell and Asbury (1994) Limnology and Oceanography 39. 111-125.
Peuravuori and Pihlaja (1997) Analytica Chimica Acta
Rad et al. (2006) Journal of Geochemical Exploration 88. 308-312
Rivé (2008) phD thesis
Webster et al. (2005) Science 309. 1844-1846
Weishaar et al (2003) Environmental Science and Technology