A HYDRODYNAMIC MODEL TO COMPREHEND SEDIMENT TRANSPORTS IN CATCHMENTS: FOCUS ON BASSE-Terre ISLAND

ABSTRACT Mass wasting erodes hillslopes and supplies sediments to catchment rivers (Schuster & Highland, 2007). To assess sediment transports in drainage networks, it is crucial to (1) estimate the volume of sediment delivered to the drainage network, and (2) evaluate the time needed and processes involved in rivers to evacuate these sediments out of the watershed. To address these questions, we focus on a catchment located on Basse-Terre Island in Guadeloupe. In this tropical island, hurricanes and storms generate destructive floods and mass wasting. The resulting erosion and weathering rates are among the highest on Earth (Allemand et al., 2014; Gaillardet et al., 2011). Using the data collected by the Observatory of Water and Erosion in the Antilles (ObsErA), we investigate sediment transport in streams at the scale of one flood. Focusing on the suspended load, we find that the peak of sediment transport falls (almost) systematically behind the discharge peak. We propose a first order model which accounts for this hysteretic behaviour. Using data assimilation, we aim to find the parameters values of the model explaining sediment transport within our catchment. Ultimately, we will assess the response of the alluvial transport to sediment fluxes induced by mass wasting.

I. IN SITU SENSING: CATCHMENT, SAMPLING & CALIBRATION

- What?
  - Understanding how rivers transport sediments
  - Within Cap Casterre catchment

- How?
  - By monitoring hydrology
    - Water stage $h$, turbidity $T$ (1pt/min)
    - Suspended load concentration $C_s$ (manual)
  - Data clean-up & analyses:
    - Events-detection: floods

- Schematisation of the set up

II. HYSTERETIC BEHAVIOURS IN SEDIMENT TRANSPORT DATA

- Shift between water stage and $C_s$ peaks
- Counter-clockwise and figure-eight loops

- HOW TO EXPLAIN SUCH BEHAVIOUR?
  - By modelling what happens in the river

III. HYDRODYNAMIC MODELLING OF SEDIMENT TRANSPORT Hysteresis

a. Theoretical framework
Two processes:
- Erosion $E$ & Deposition $D$

Schematisation of the set up

\[ \frac{d \phi_s}{dt} = E - D \]

c. Hypotheses (river-based)
i. $E \propto$ shear stress
shear stress $\propto h_h, h_l$
$\rightarrow E \propto h_h, h_l$
ii. $D$
  - $D \propto \frac{U \phi_s}{h}$
  - Stockes’ law

\[ \frac{d \phi_s}{dt} = \epsilon \left( h_i - 1 \right) H \left( h_i - 1 \right) - \frac{1}{\tau_D} \frac{\phi_s}{h} \]

\[ C_s = \phi_s / \epsilon \]

d. Final equation

e. Parameters
  - Water level $h$
  - Water level threshold $h_i$
  - Erosion rate
  - Deposition time

HOW TO FIND THEIR VALUES?
- Using data assimilation
  - Erosion rate
  - Deposition time

IV. DATA ASSIMILATION TO DETERMINE THE EROSION RATE, WATER LEVEL THRESHOLD AND DEPOSITION TIME OF A HYSTERESIS

- Method: python scipi curve fitting
- Best fit parameters output:
  - Parameters bounds:

  | Parameter          | Estimate | Range
  |--------------------|----------|-------
  | $\epsilon$         | 0.1      | 1.5e-3 to 3.0e-3
  | $h_i$              | 0.1      | 1 to 0.9
  | $\tau_D$           | 0.1      | 1 to 0.9

  Best fit results. Both cycles are counter-clockwise.

V. CONCLUSION

- Parameters derived from the model are consistent with expectations
  - But the model cannot produce double-peak $C_s$ -- what causes it ?
  - $\rightarrow$ find out with remote sensing

VI. PERSPECTIVES: REMOTE SENSING

- Determination of
  - Landslide sources, repartition
  - Volumes $\rightarrow$ Fluxes in time and space
  - Gradient effects : Rainfall (E-W) & Lithology (N-S)

REFERENCES


Gaillardet et al., 2011, Orography-driven chemical denudation in the Lesser Antilles: evidence for a new feedback mechanism stabilizing atmospheric CO2