Multiscale karst sediment dynamic study: from the flood scale to the pluriannual scale. Example with Bruisseresse spring, Normandy, France

S. Chédeville [1,2,3], B. Laignel [1], J. Rodet [2,4], E. Hauchard [1-5], D. Todisco [6], N. Massei [1], G. Hanin [1]

(1) Université de Rouen, CNRS UMR 6143 - M2C ; SFR SCALE, 76821 Mont-Saint-Aignan, France
(2)Centre Normand d'Étude du Karst, 76450 Saint-Martin-aux-Buneaux, France
(3)Université de Montpellier, UMR 5569 CNRS-IRD, Hydrosciences Montpellier Maison des Sciences de l'Eau, 300 avenue du Professeur Emile Jeanbrau, 34090 Montpellier, France
(4) CNRS UMR 6143 M2C, Université de Rouen ; SFR SCALE, 76821 Mont-Saint-Aignan, France
(5) Communauté de l'Agglomération Havraise (CODAH), Hôtel d'agglomération, 19 rue Georges Braque, 76085 Le Havre cedex, France
(6) Université de Rouen ; Département de géographie ; UMR IDEES 6266; SFR SCALE, 76821 Mont-Saint-Aignan, France

INTRODUCTION

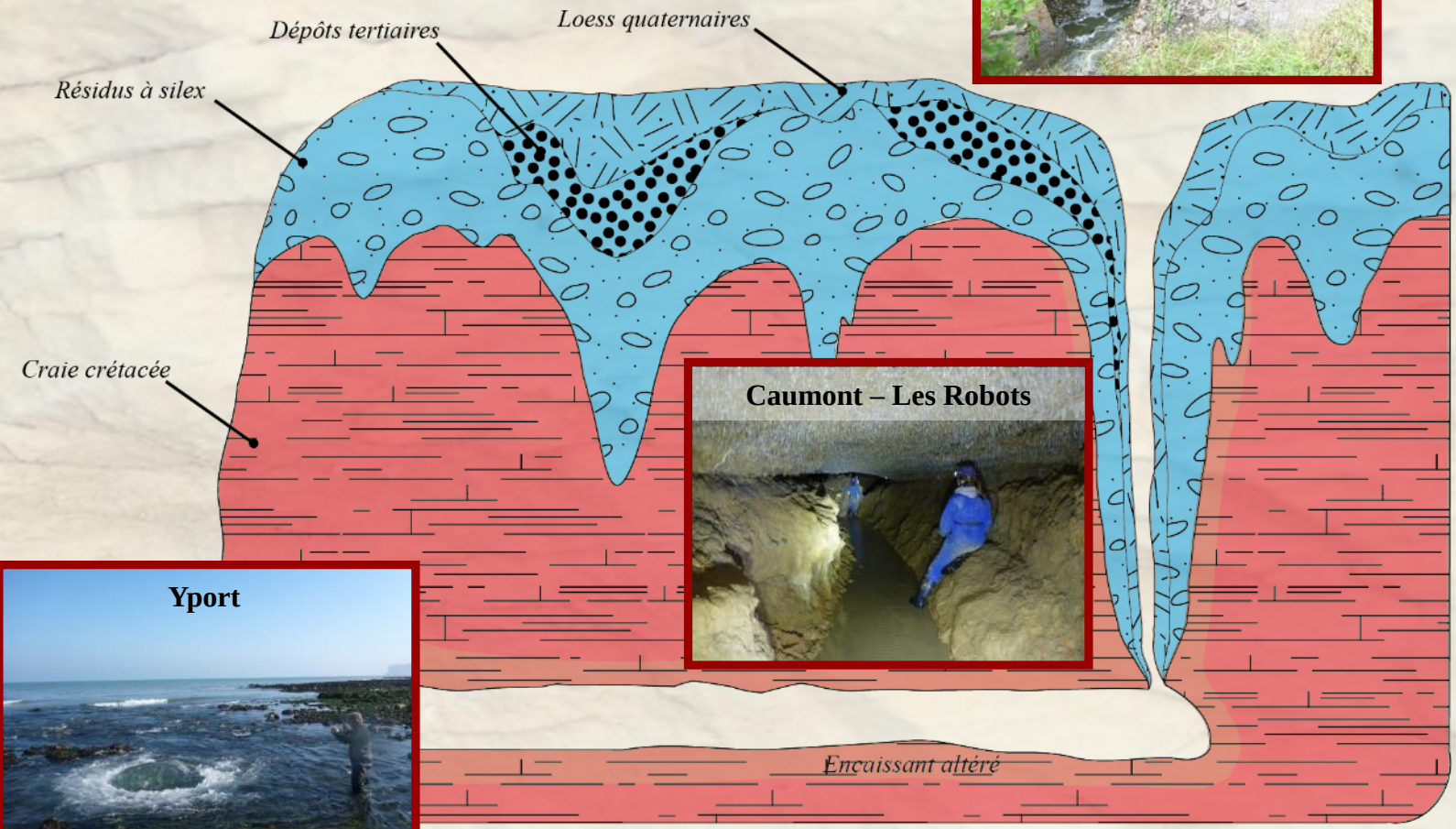
- **Karstification processes => void formations:**
  - **Connected voids, fluid circulation (water, air) and sediments**
  - **Sediment traps (erosion, transport and particule sedimentation)**

- **Study of karst sediment provides some informations of:**
  - **Cave genesis and evolution**
  - **Hydrodynamism (sedimentation setlement and flow velocity)**
  - **…**

- **Upper Normandy :**
  - **≈ 100 % tap water => chalk mixed aquifer (karstified)**
  - **Sediment transported into the karst: one of the micribiological and chemical contaminatiuon sources of drinking water**
    - **Applied interest to study sediment and it transfert conditions**

GEOMORPHO-KARSTIC CONTEXT OF THE CHALKY WESTERN PARIS BASSIN

- **Karst undercovered according to he Nicod [1992, 1995] classification:**

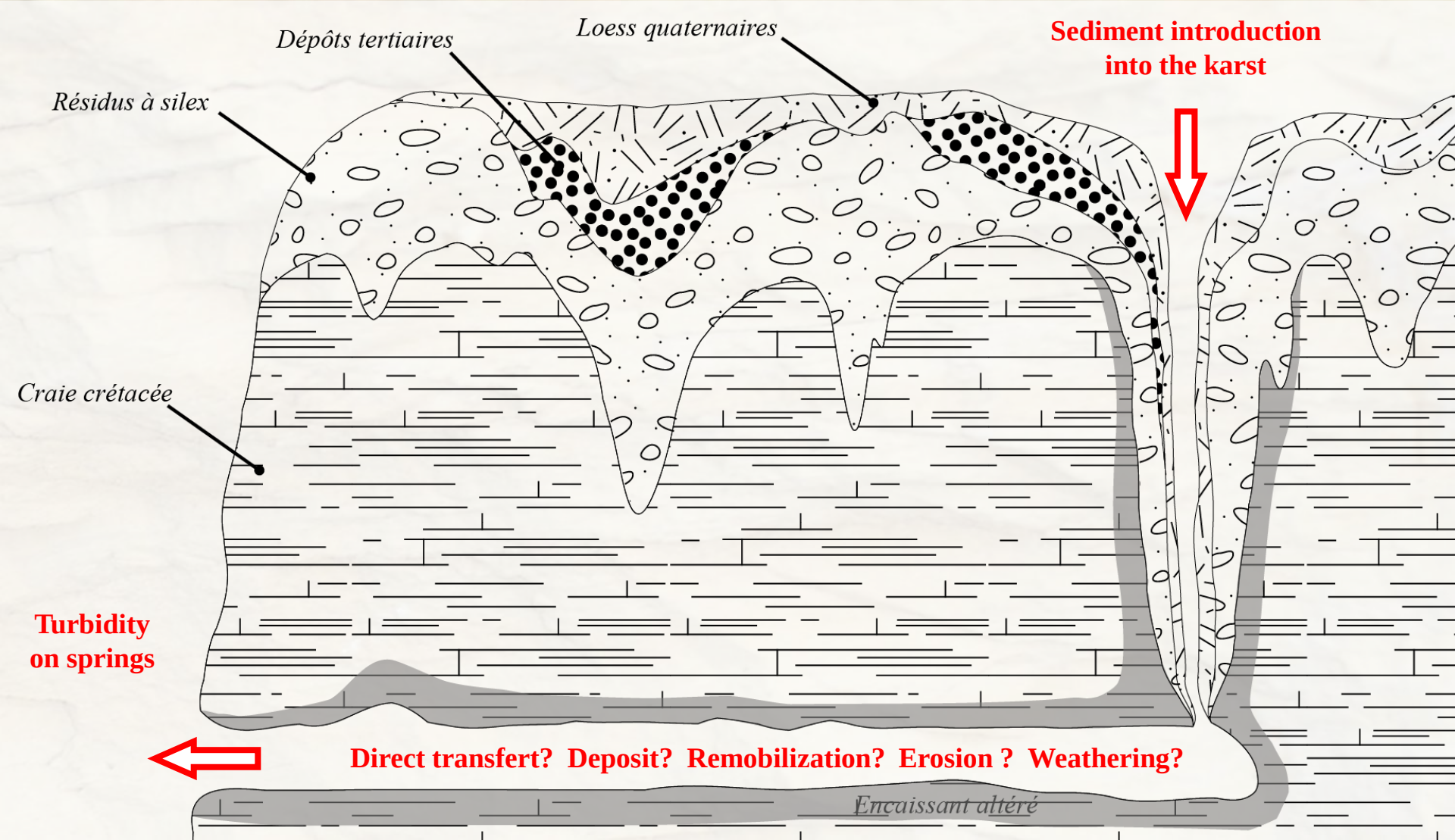


Surface formations

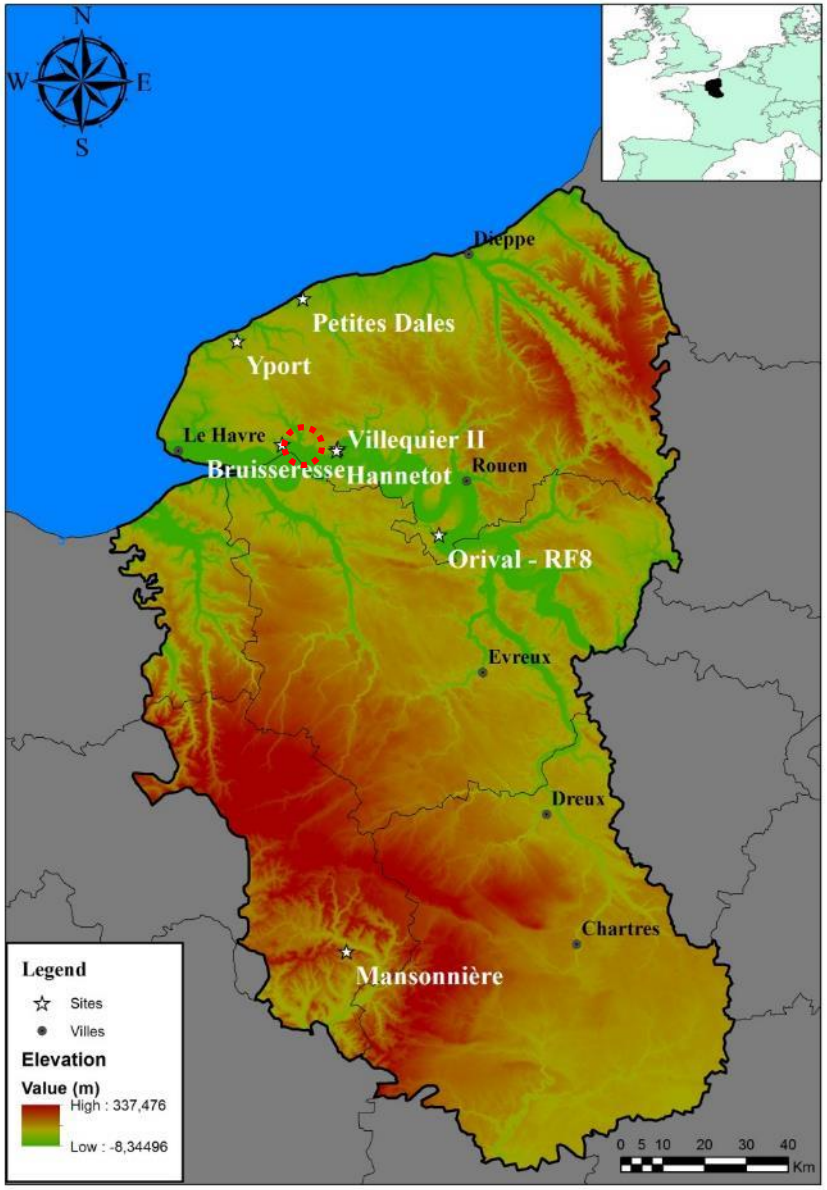
Karstified substratum

PROBLEMATIC

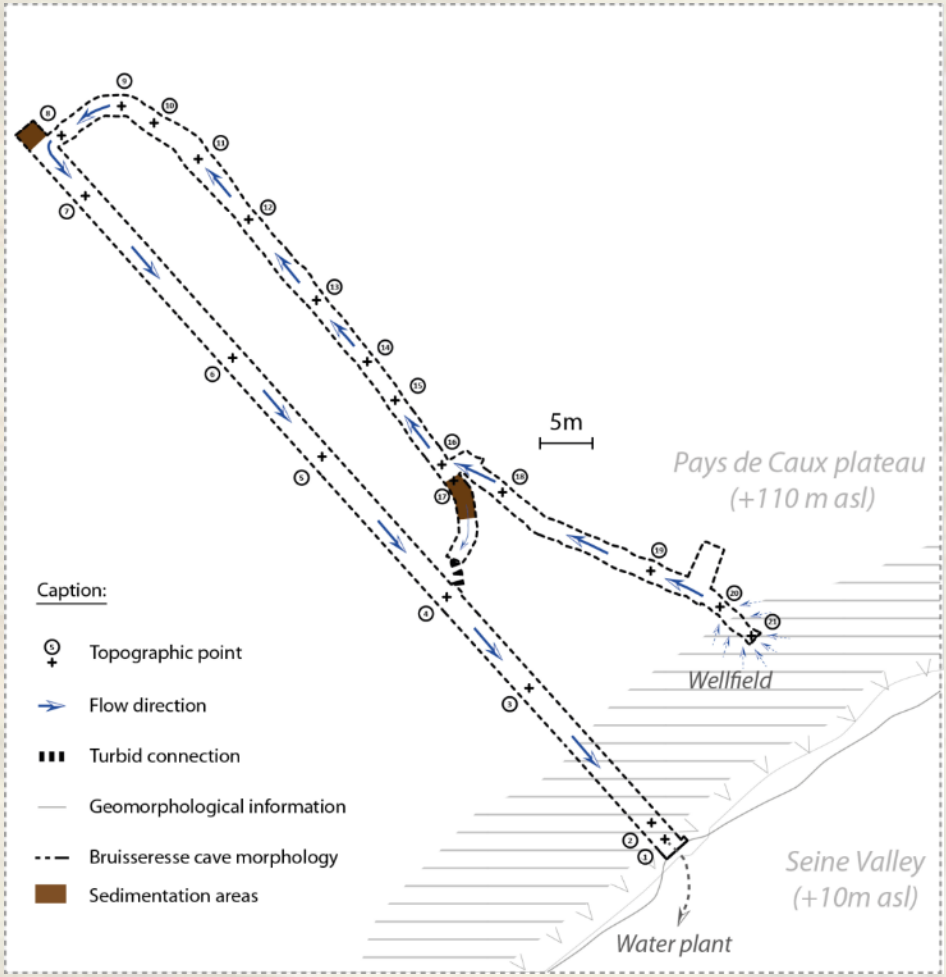
- **Conditions of the transfer and sediment deposition in karst chalk?**



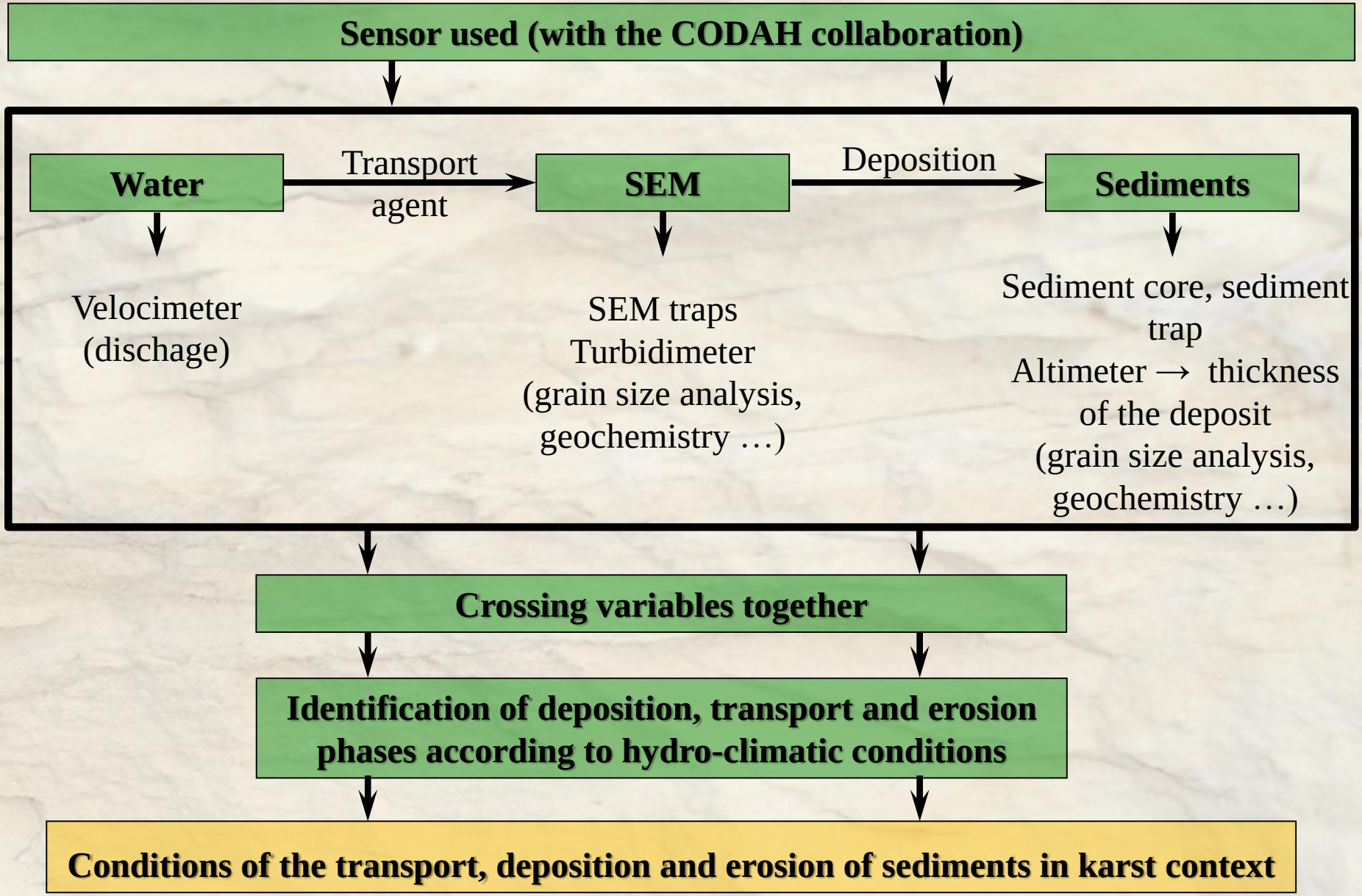
APPROACHES AND METHODOLOGIES



➢ Bruisseresse karst spring:



APPROACHES AND METHODOLOGIES

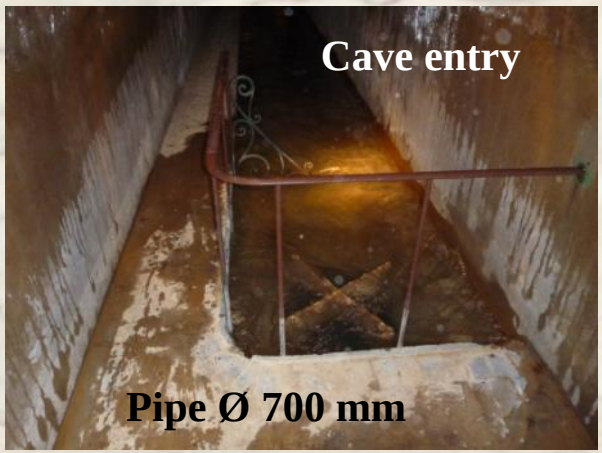


- **Sedimentary variability from the small scale (flood event scale to the annual scale)**

  - **Bruisseresse spring (with the CODAH collaboration)**

SMALL SCALE SEDIMENT VARIABILITY

➢ Bruisseresse spring: a well field



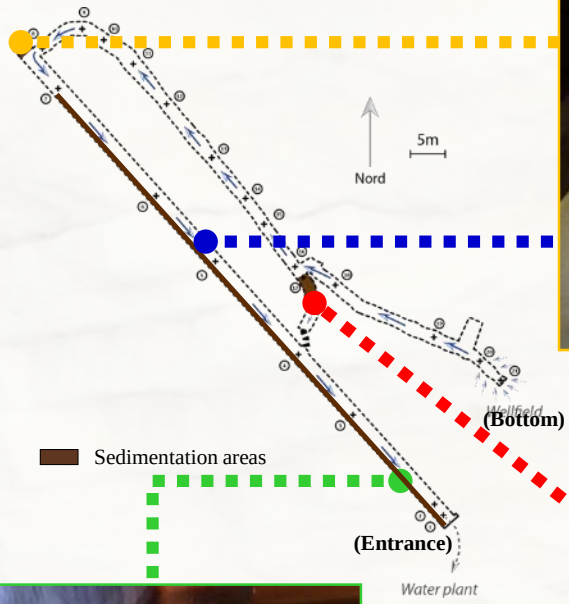
Water flow from the wall into the cave

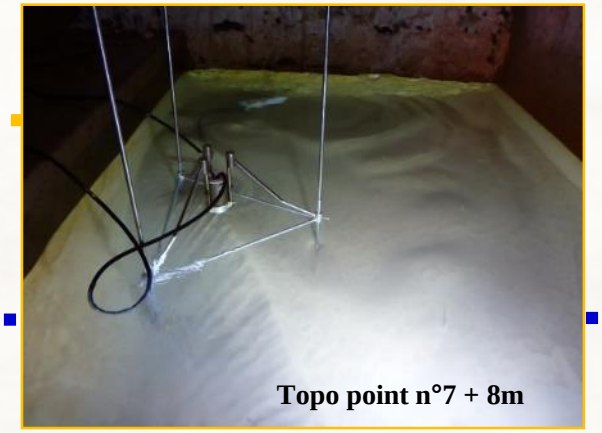
Key :

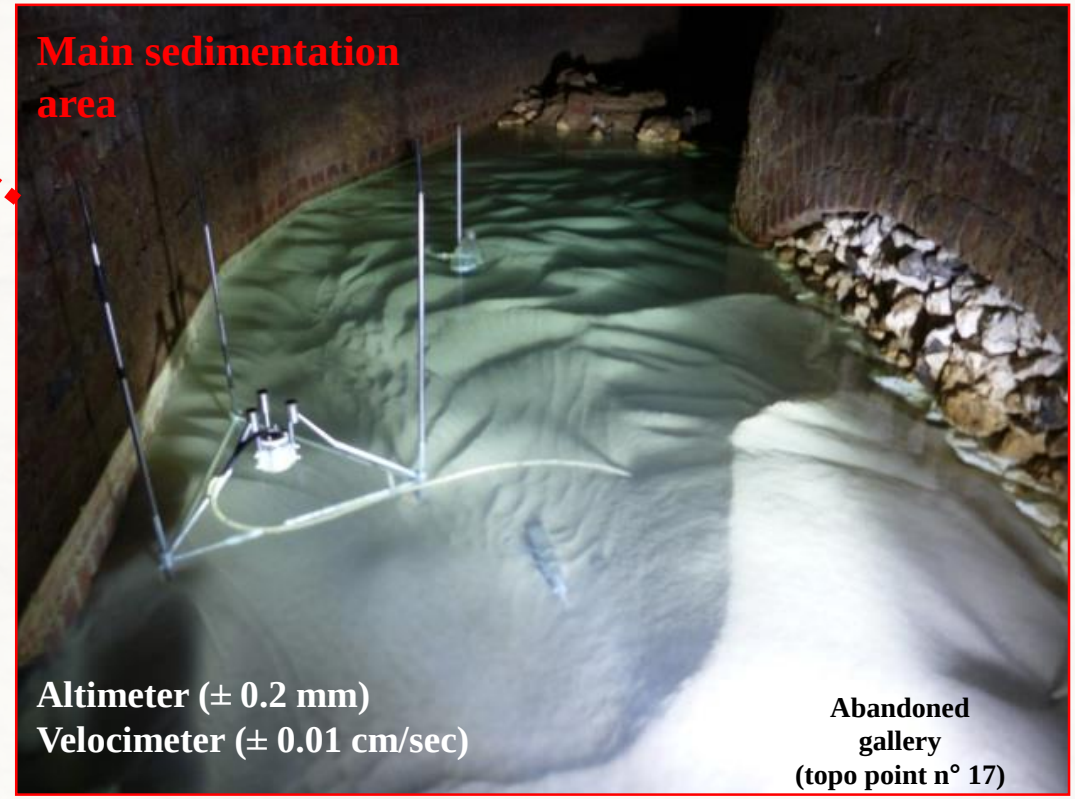
- Sediment trap
- Altimeter: Altus
- Velocimeter
- Sedimentation areas with stake stations

⊕ Water catchment iron pipe

SMALL SCALE SEDIMENT VARIABILITY



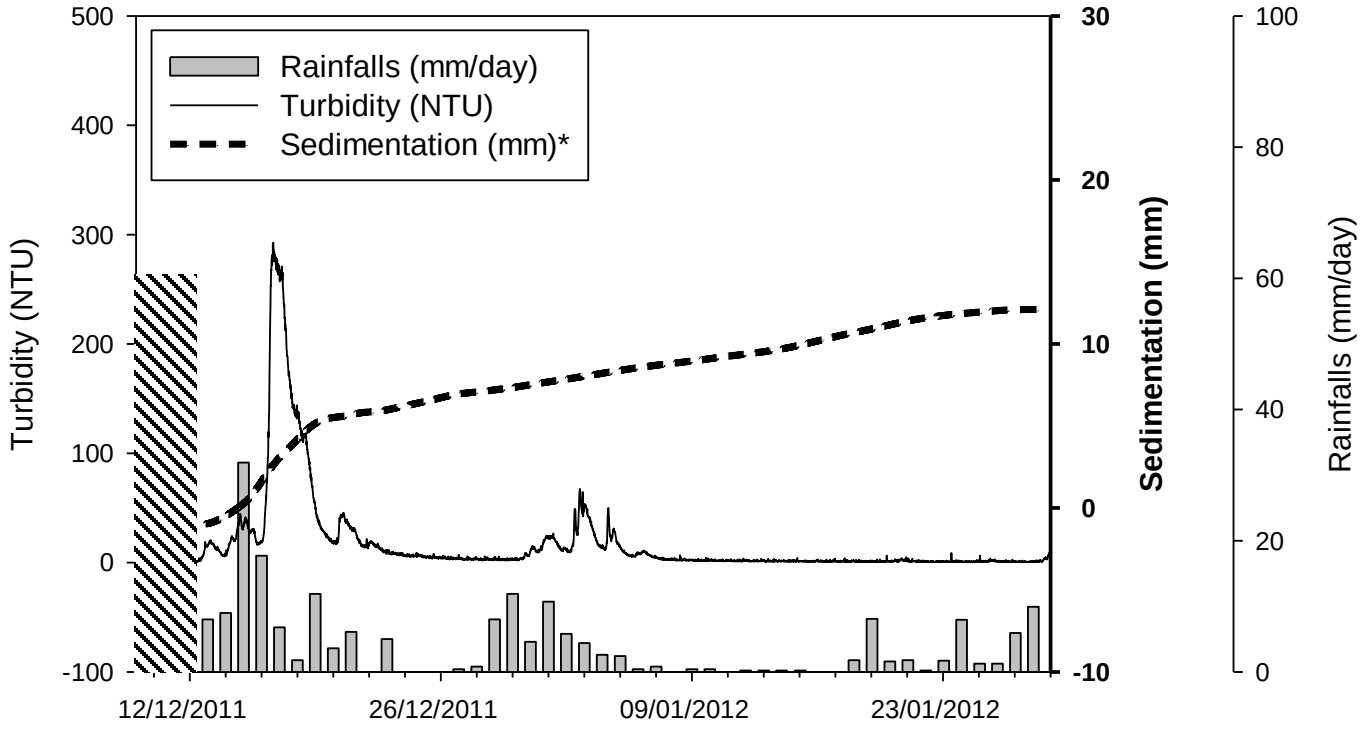




SMALL SCALE SEDIMENT VARIABILITY

- **Altimetric and hydro-sedimentary variables:**

December 2011 flood event



* Smoothed data in order to delete noise device sensors (use of polynomial smooth)

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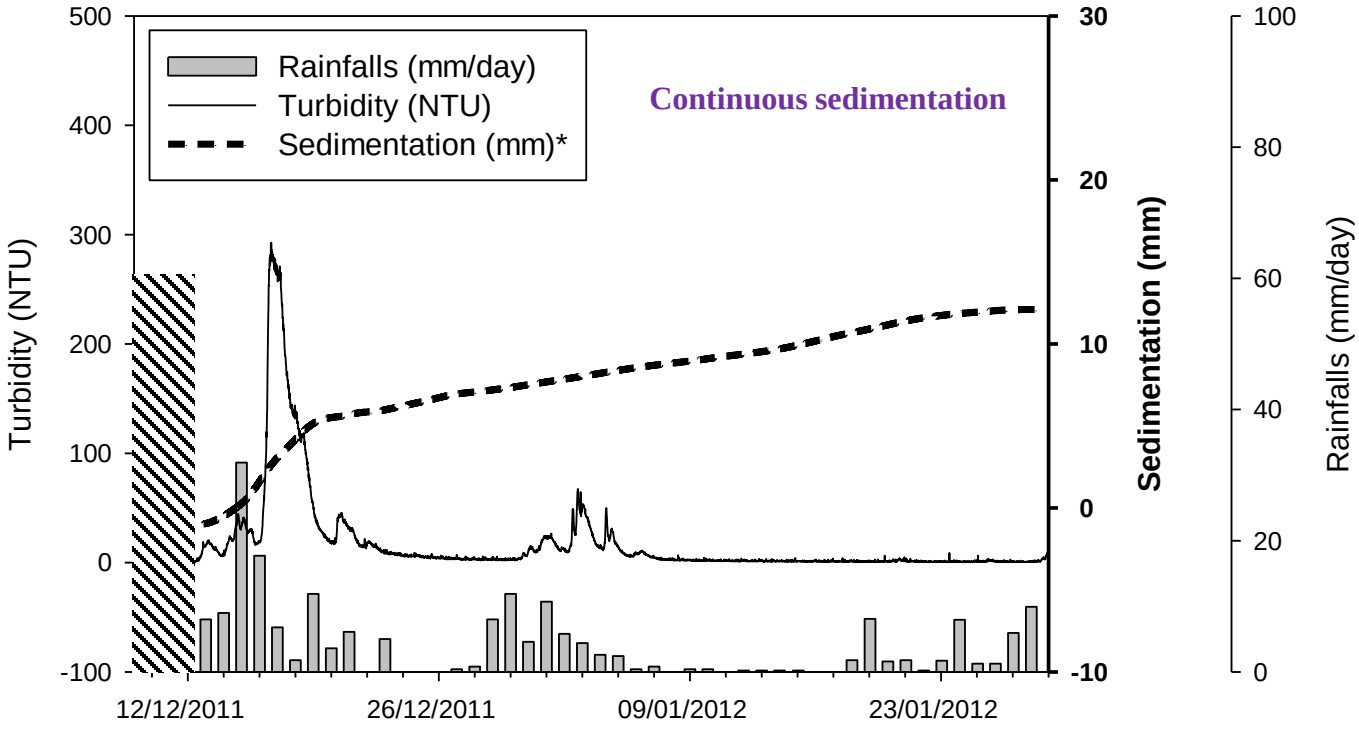

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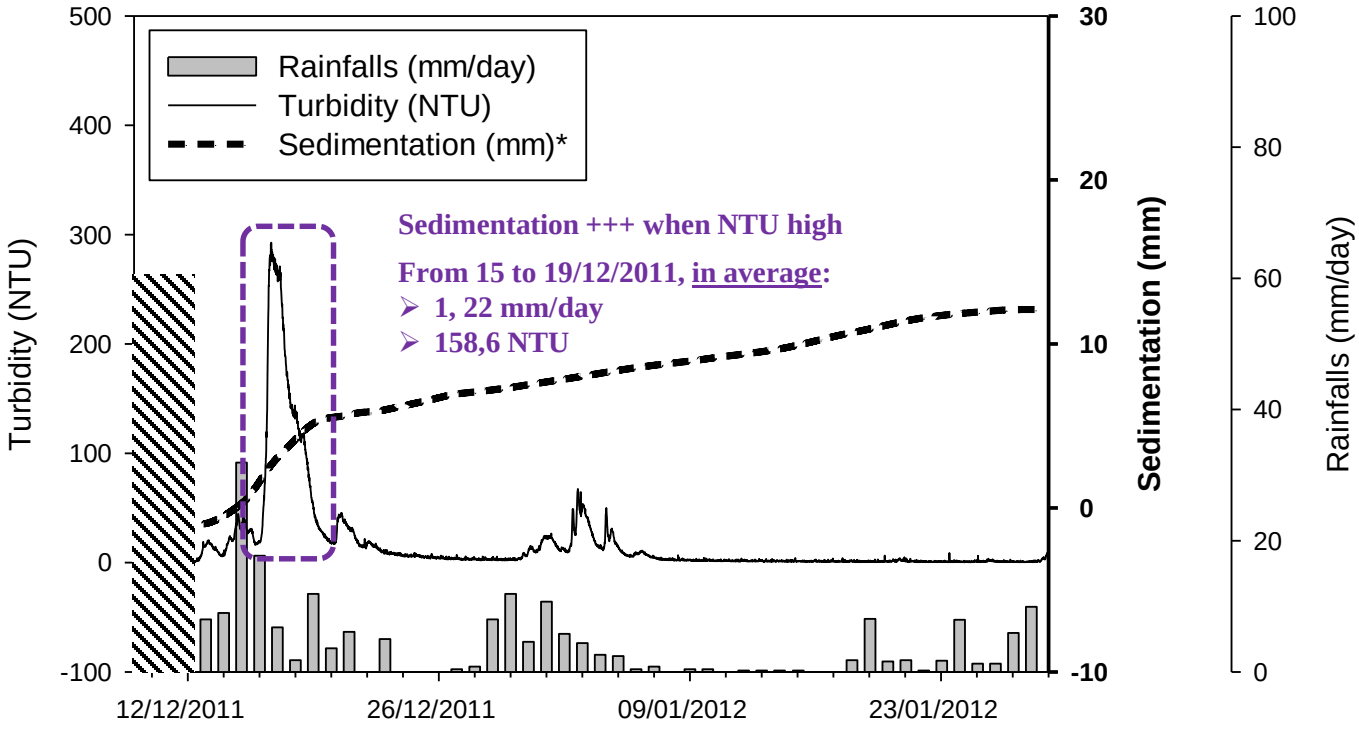

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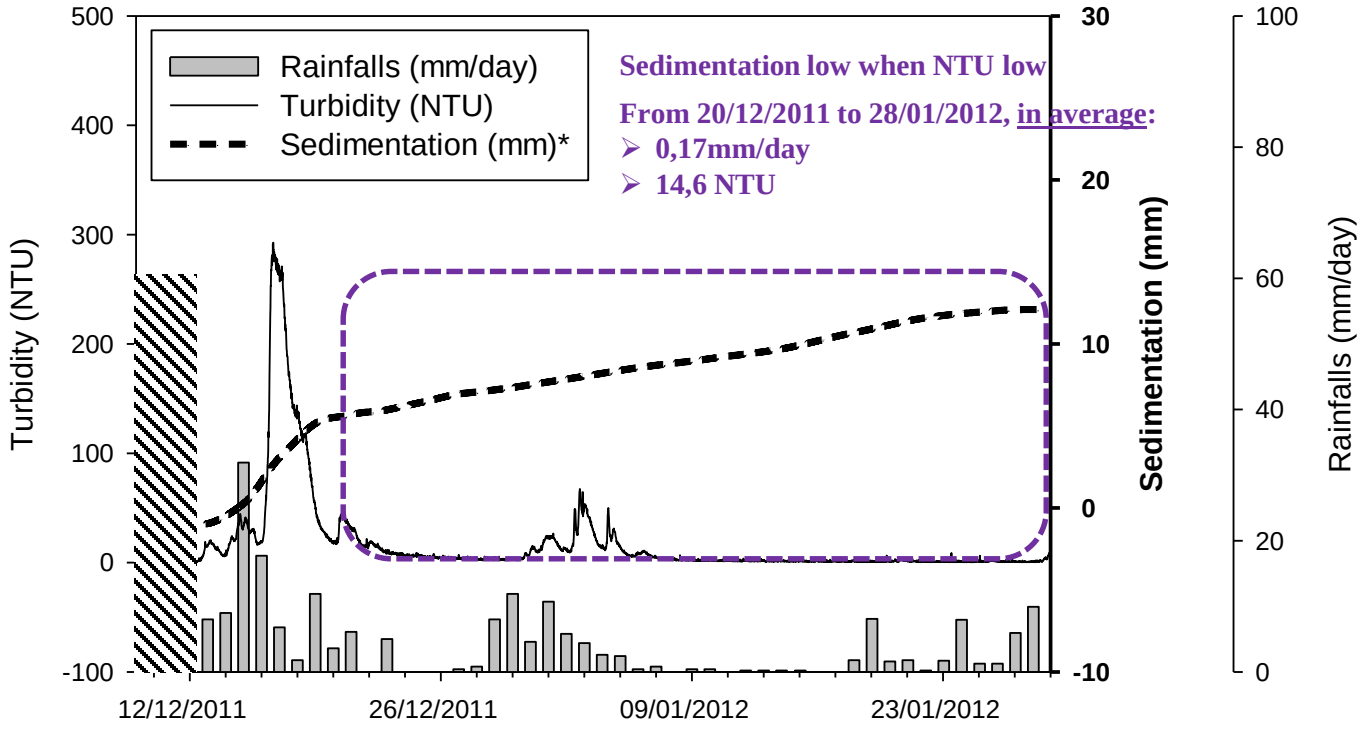

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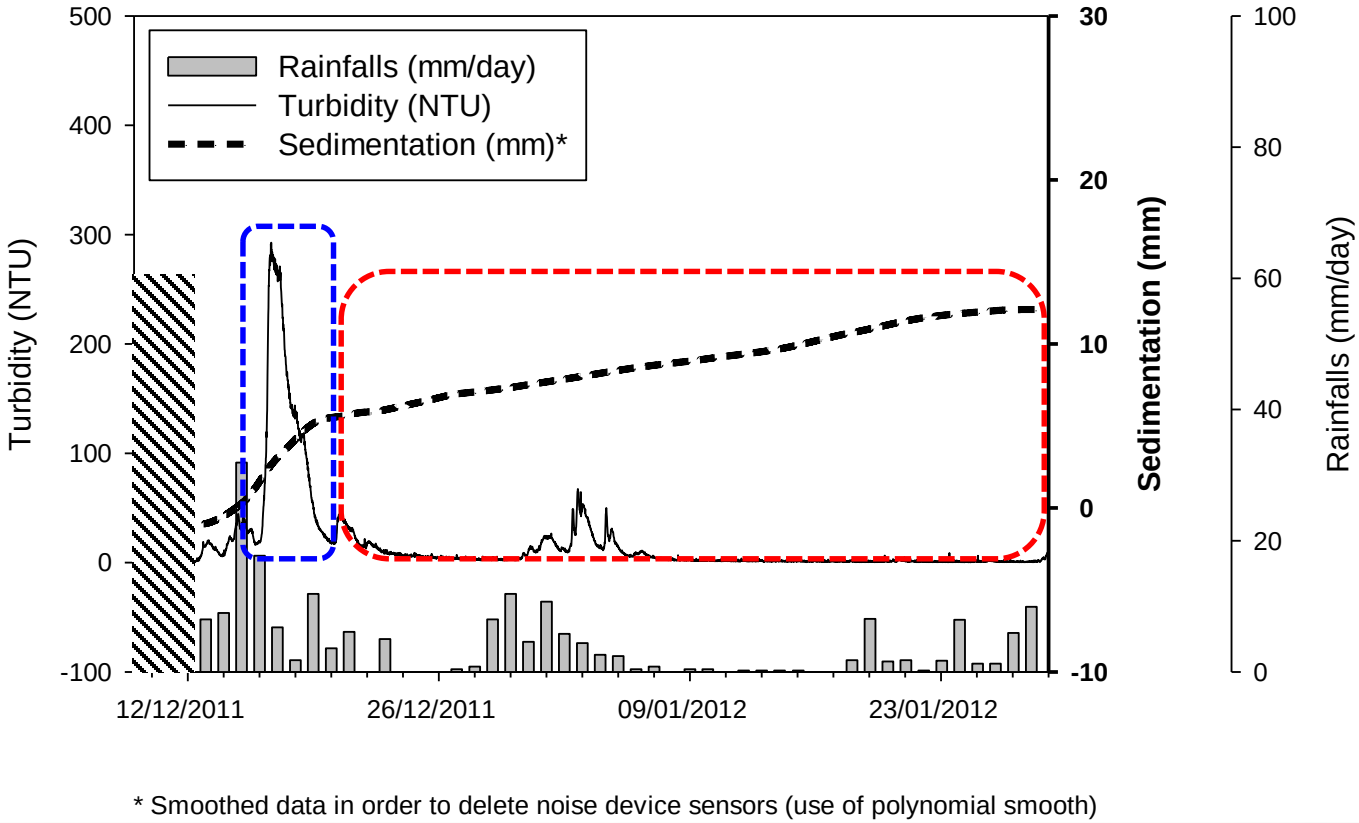

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Sedimentary signal: **Impulse response** + **trend response**

SMALL SCALE SEDIMENT VARIABILITY

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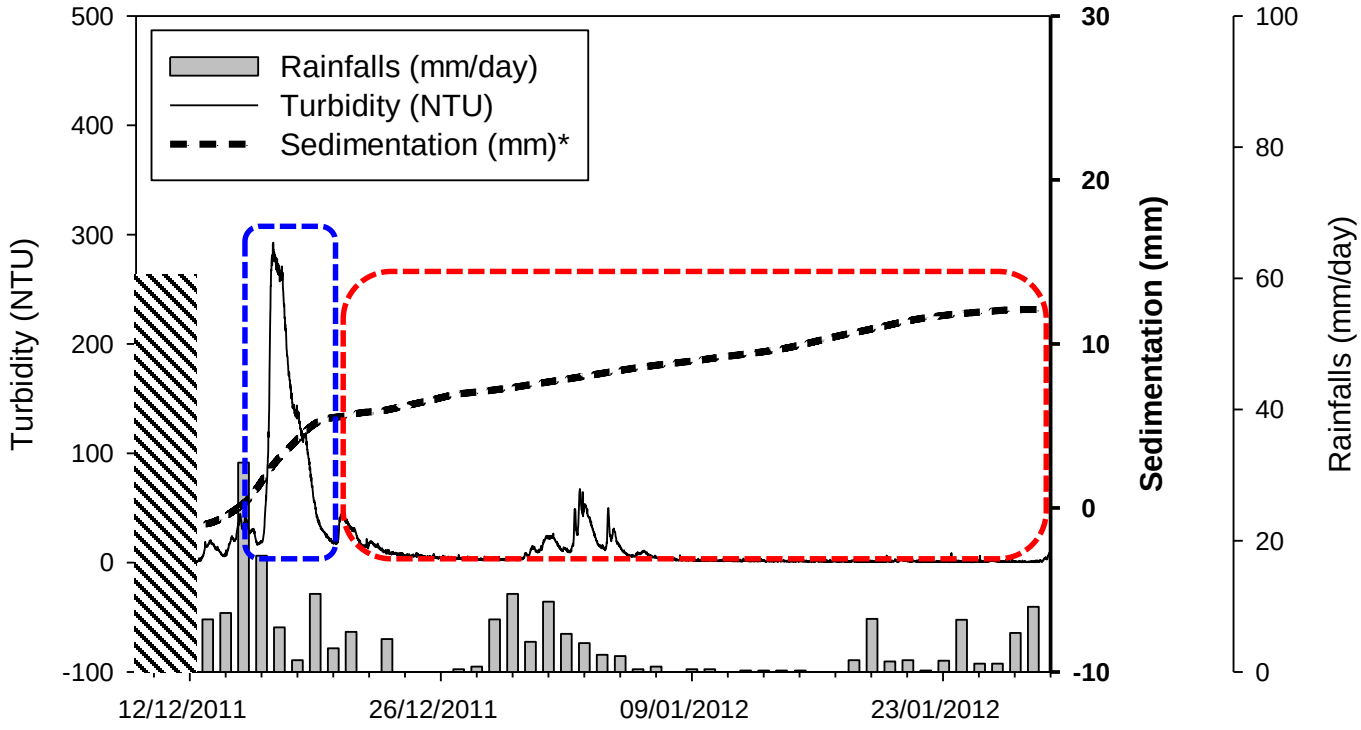

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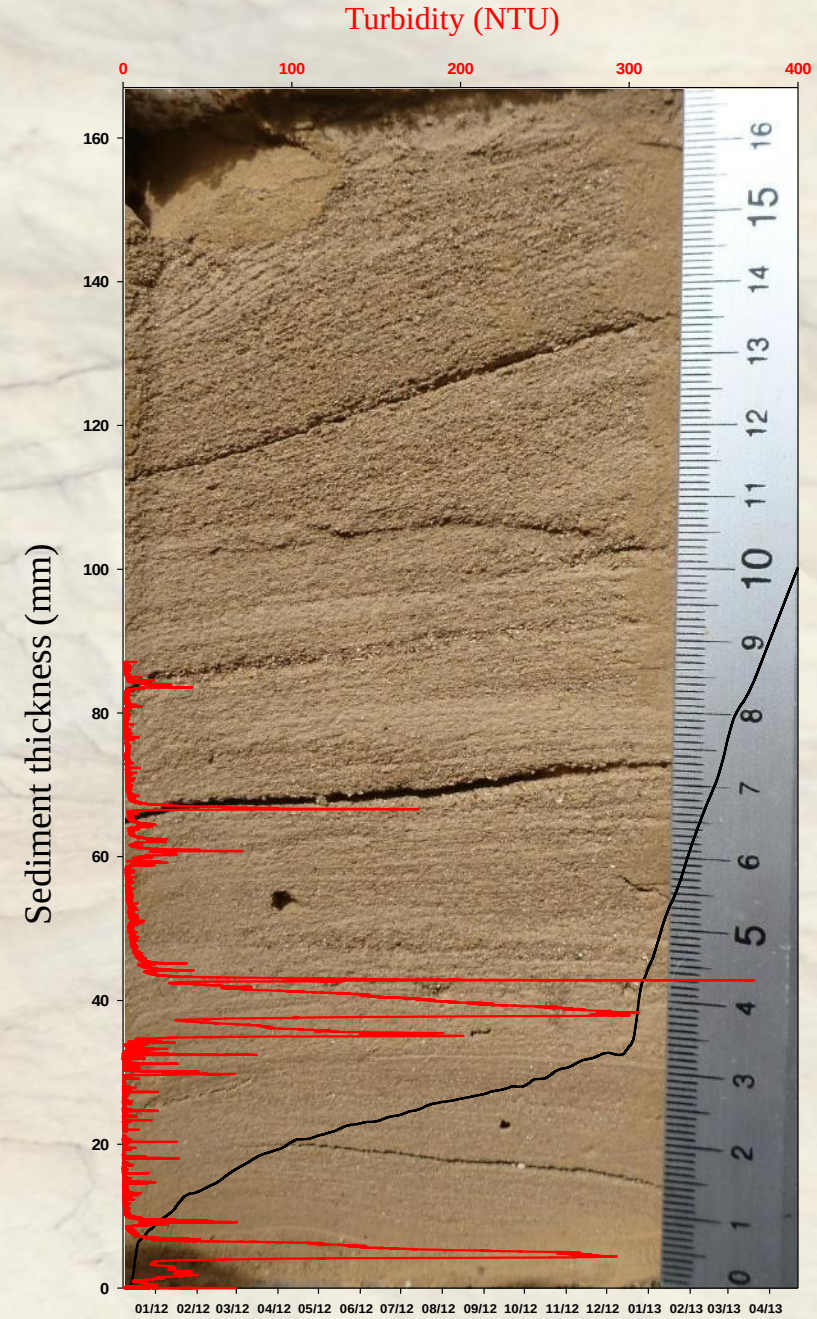
Sedimentary signal: **Impulse response** + **trend response**

Tank effect Bruisseresse

Both transfert and storage sediment from the upstream

Both direct transport and remobization from the upstream

SMALL SCALE SEDIMENT VARIABILITY



- **Relationship between sediment and hydro-sedimentary variables:**

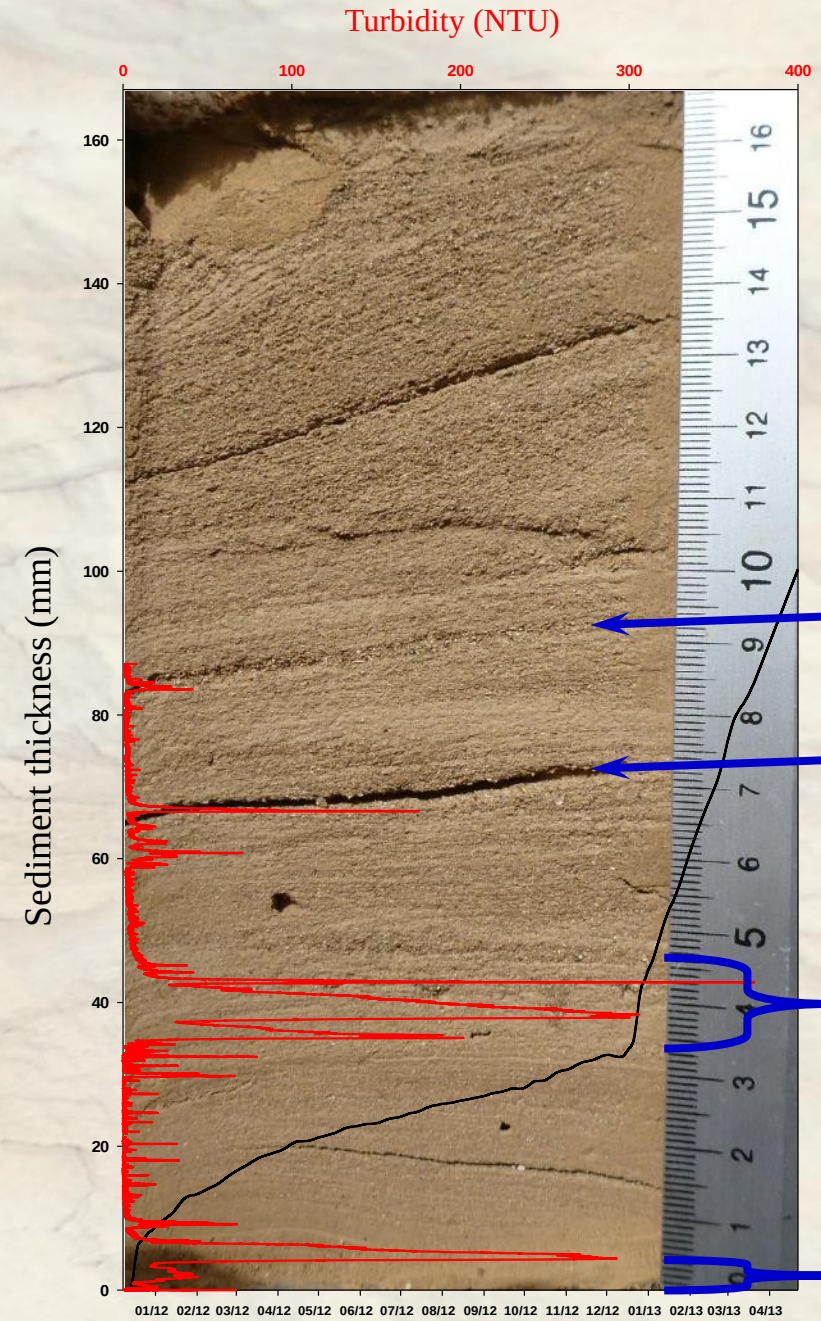
Core (C40) done right under the atltimeter

Thanks to the altimetric data :

=> Sediment filling dating at ultra high resolution

=> Fixing the turbidity curve on the core

SMALL SCALE SEDIMENT VARIABILITY



- **Relationship between sediment and hydro-sedimentary variables:**

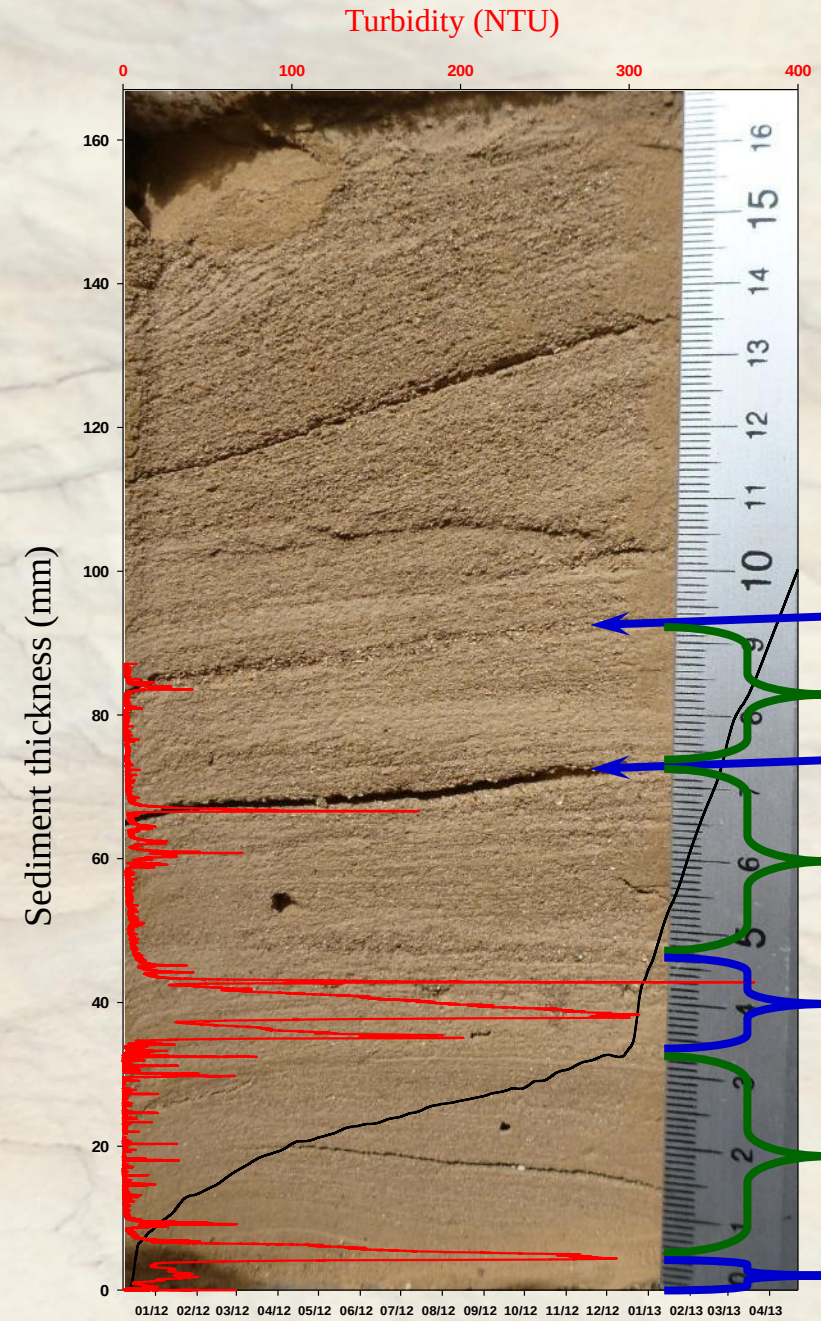
Sandy level (42 NTU)

Sandy level (170 NTU)

Sandy level (374 NTU)

Sandy level (292 NTU)

SMALL SCALE SEDIMENT VARIABILITY



- **Relationship between sediment and hydro-sedimentary variables:**

Sandy level (42 NTU)

Altenating deposit (< 10 NTU)

Sandy level(170 NTU)

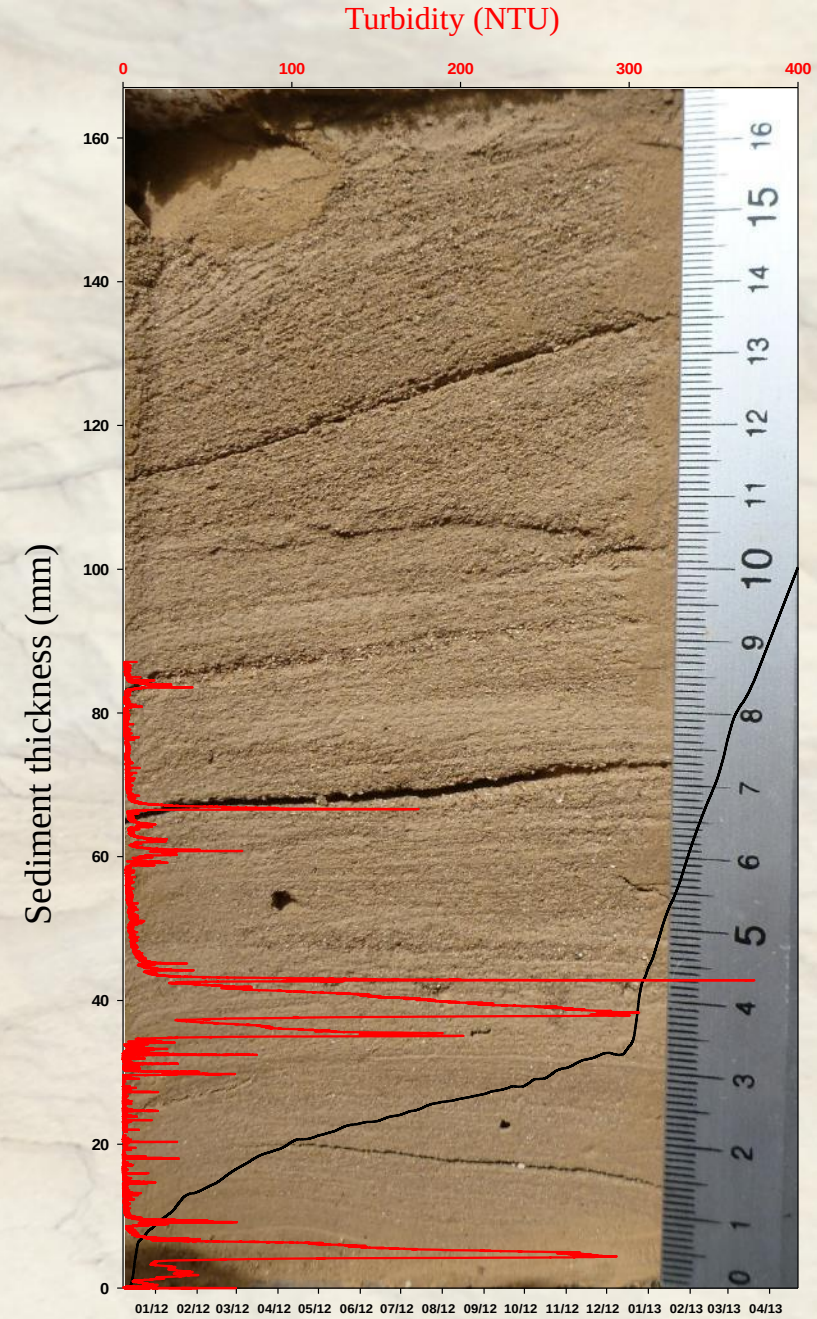
Altenating deposit (< 80 NTU)

Sandy level (374 NTU)

Altenating deposit (< 80 NTU)

Sandy level (292 NTU)

SMALL SCALE SEDIMENT VARIABILITY



- **Relationship between sediment and hydro-sedimentary variables:**

Attribution of one sediment facies according to a specific hydrodynamic behaviour:

- Sandy levels correspond to the highest tubid flood events
- Alternating deposits correspond to small turbid flood event

- **Climate effects on the pluriannual scale (large scale) sedimentary variability of the Bruisseresse spring)**

  [Chédeville et al., 2016] HSJ

CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

➢ Available data:

- Daily time series of :
  - Rainfalls (1981 => today)
  - Piezometry (since 1969)
  - Turbidity measured by the CODAH (since the end 1987)

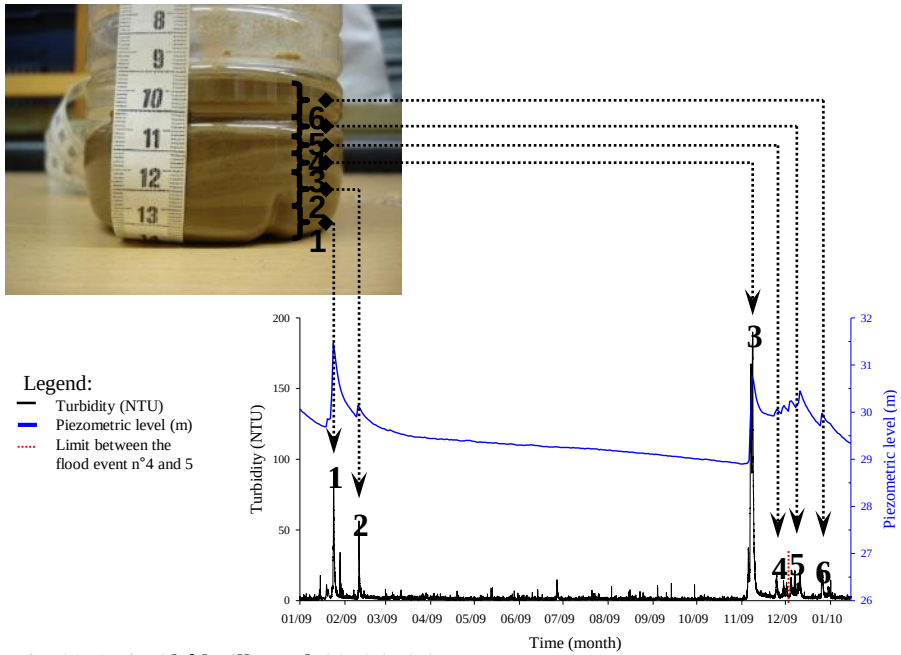
- Sedimentary filling on the same period (1988-2009)
  - Core made (C5)

- North Atlantic Oscillation climatic index (NAO), the most used on the region

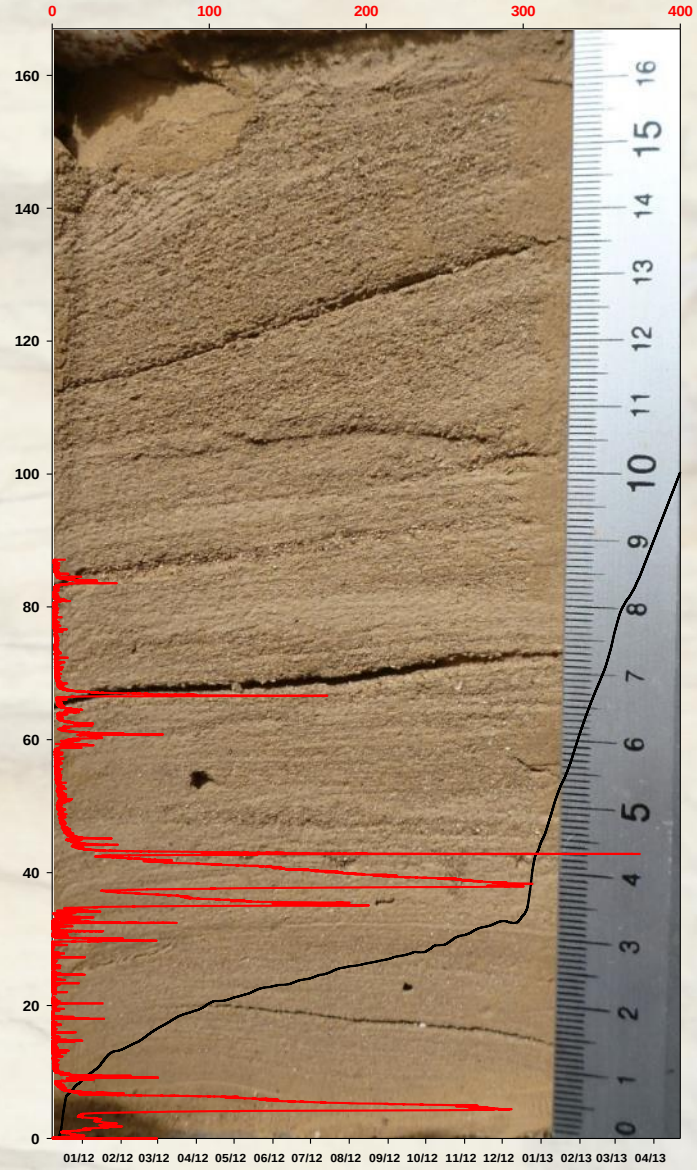
Use of signal analysis tools => highlight the climate influence on the hydro-sedimentological variables

CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

➢ Suspended sediment trap and hydro-sedimentary variables



Hanin, 2010 ; in Chédeville et al. 2016 (HSJ)



Fixing the turbidity time serie with on the sediment filling from the previous results

CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

➢ **From previous results: correlation between turbidity and core sediment**

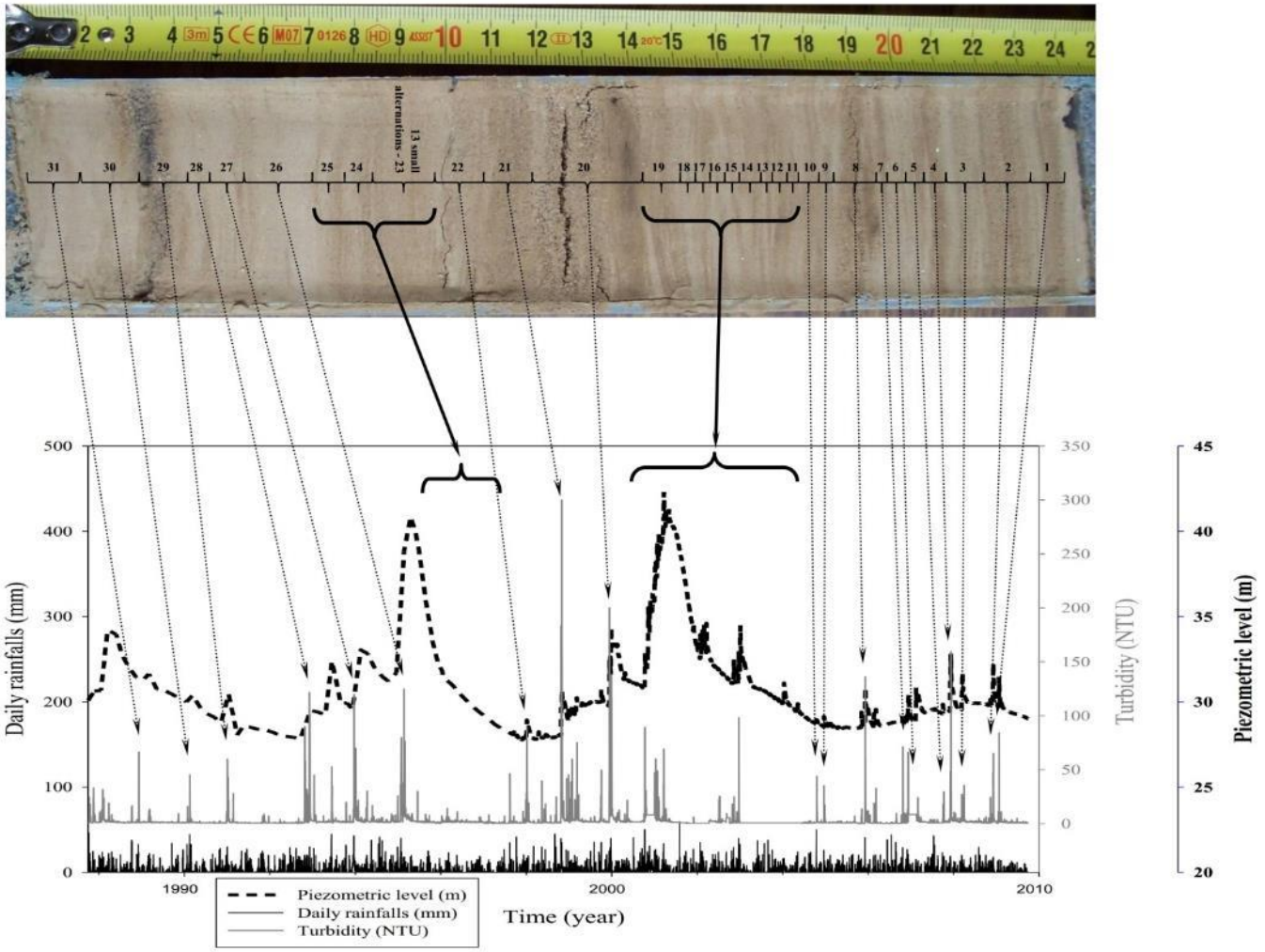


Figure 5: Coupling of hydrological and sedimentary data: adjustment of C5 core with turbidity (in Nephelometric Turbidity Unit) and piezometric level (above sea level)

Hanin, 2010 ; in Chédeville et al. 2016 (HSJ)

Small flood => alternating deposit (bright then dark)
Heavy flood => sandy level

CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

➢ Grey level core extraction

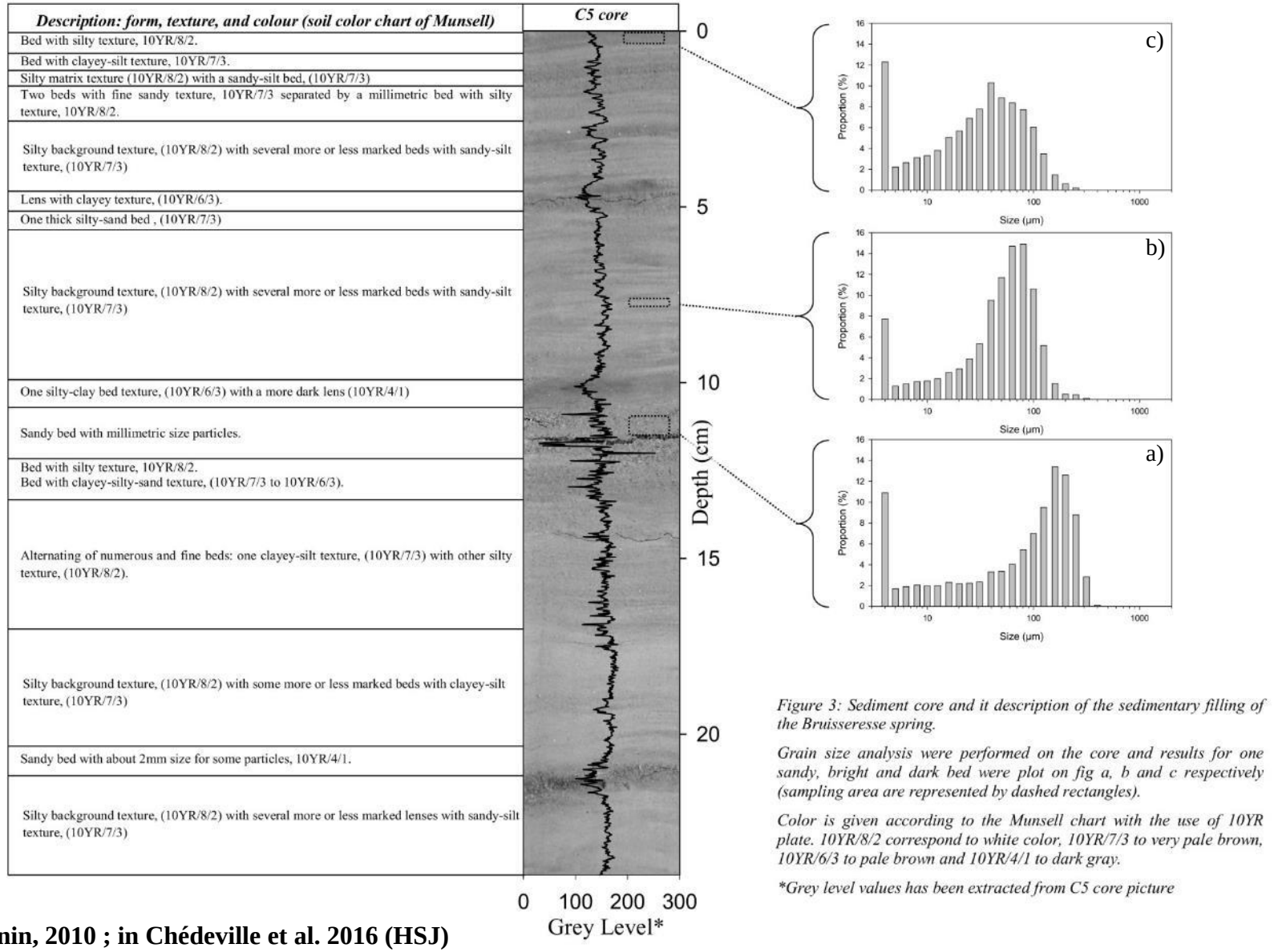


Figure 3: Sediment core and it description of the sedimentary filling of the Bruisseresse spring.

Grain size analysis were performed on the core and results for one sandy, bright and dark bed were plot on fig a, b and c respectively (sampling area are represented by dashed rectangles).

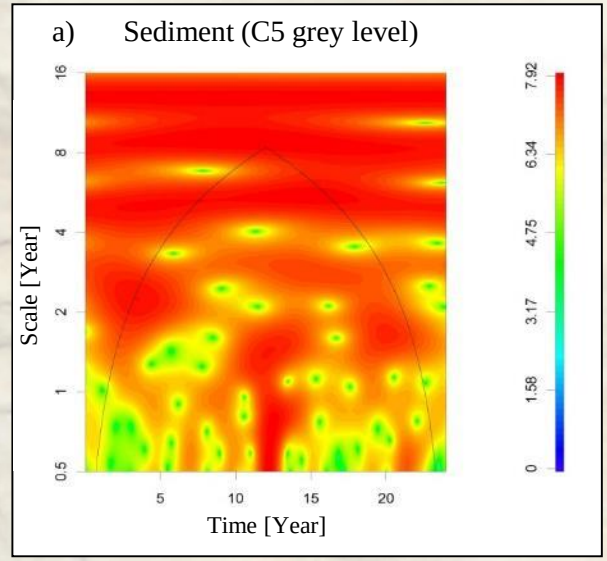
Color is given according to the Munsell chart with the use of 10YR plate. 10YR/8/2 correspond to white color, 10YR/7/3 to very pale brown, 10YR/6/3 to pale brown and 10YR/4/1 to dark gray.

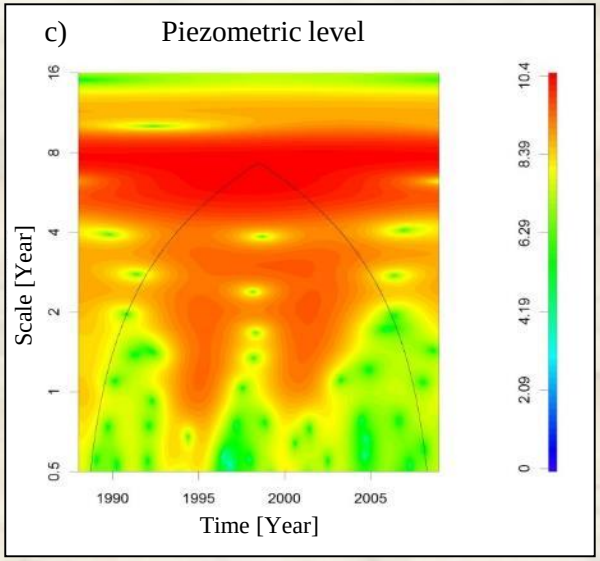
**Grey level values has been extracted from C5 core picture*

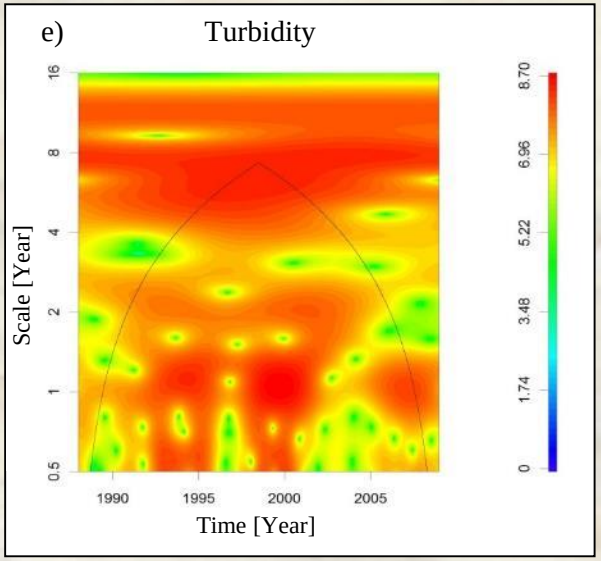
Hanin, 2010 ; in Chédeville et al. 2016 (HSJ)

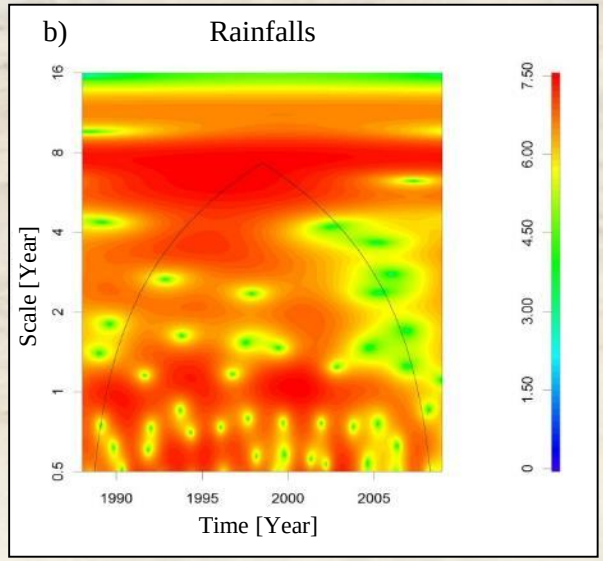
CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

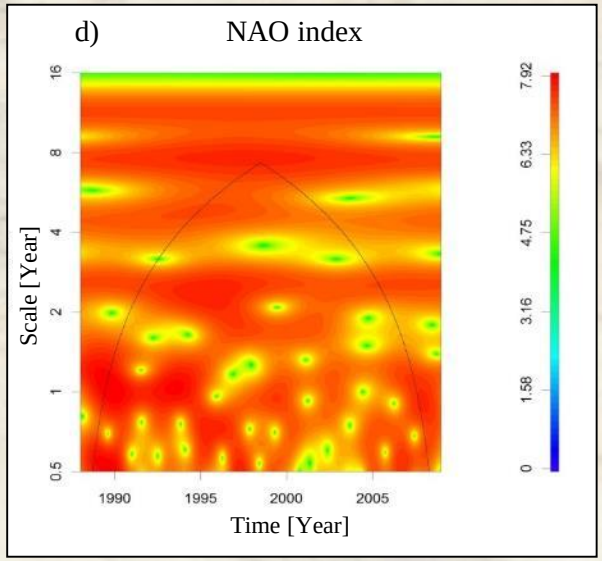
➢ Wavelet analysis











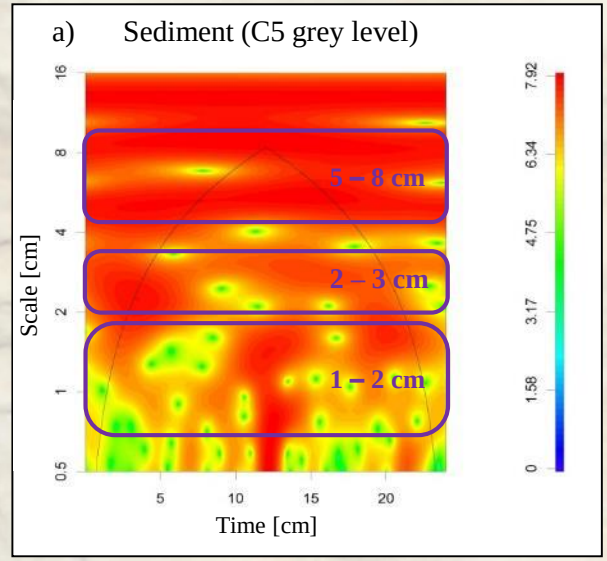
Hanin, 2010 ; in Chédeville et al. 2016 (HSJ)

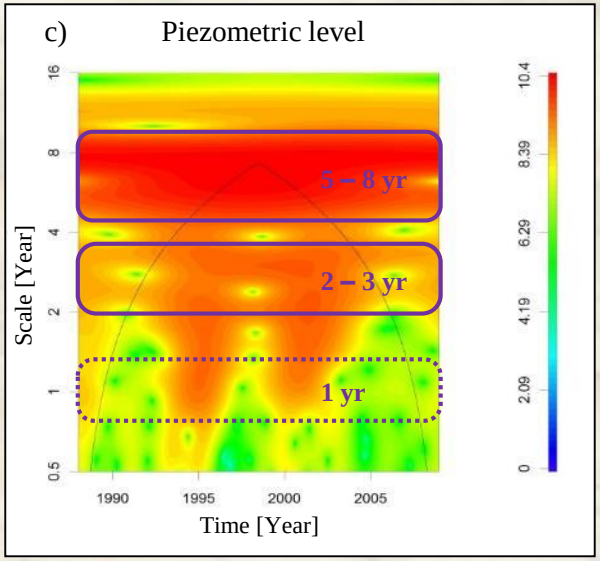
<u>Wavelet analysis</u>:

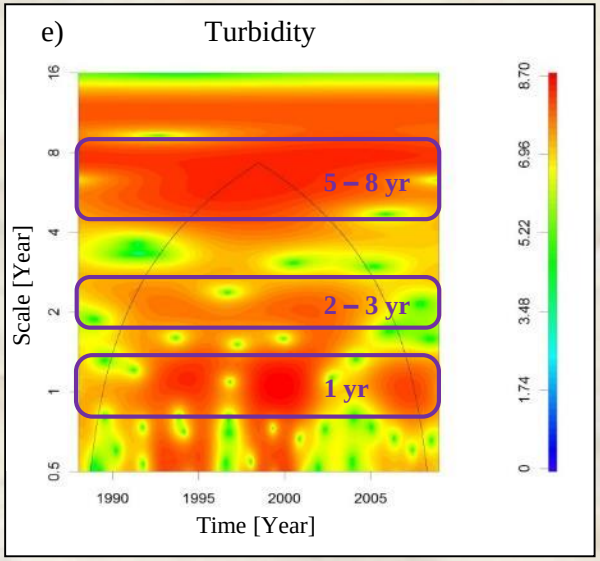
- **Time / frequency diagram**
- **Signal power on Z axis**
- **Power max=> Red**
- **Power min=> Blue**
- **Identification cycles and breaking cycles**

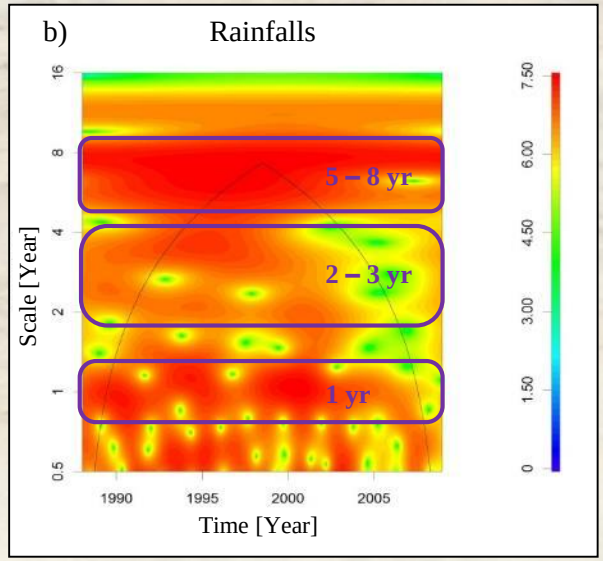
CLIMATE AND SEDIMENT RELATIONSHIP AT THE PLURIANNUAL SCALE

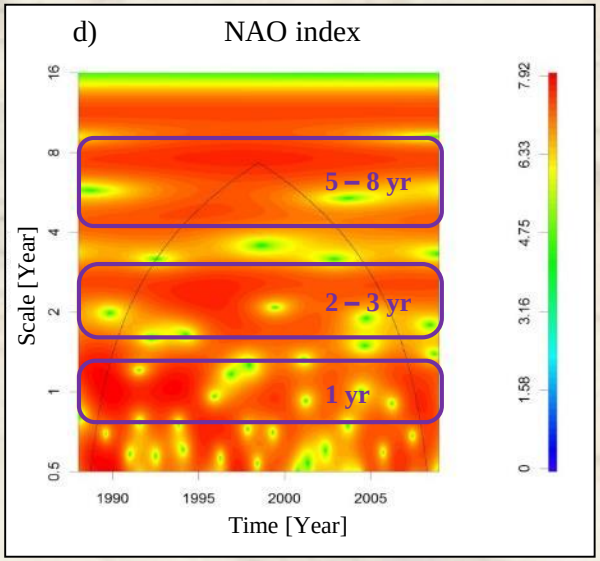
➢ Wavelet analysis











Rythmicities observed on whole spectra with following spectral bands:

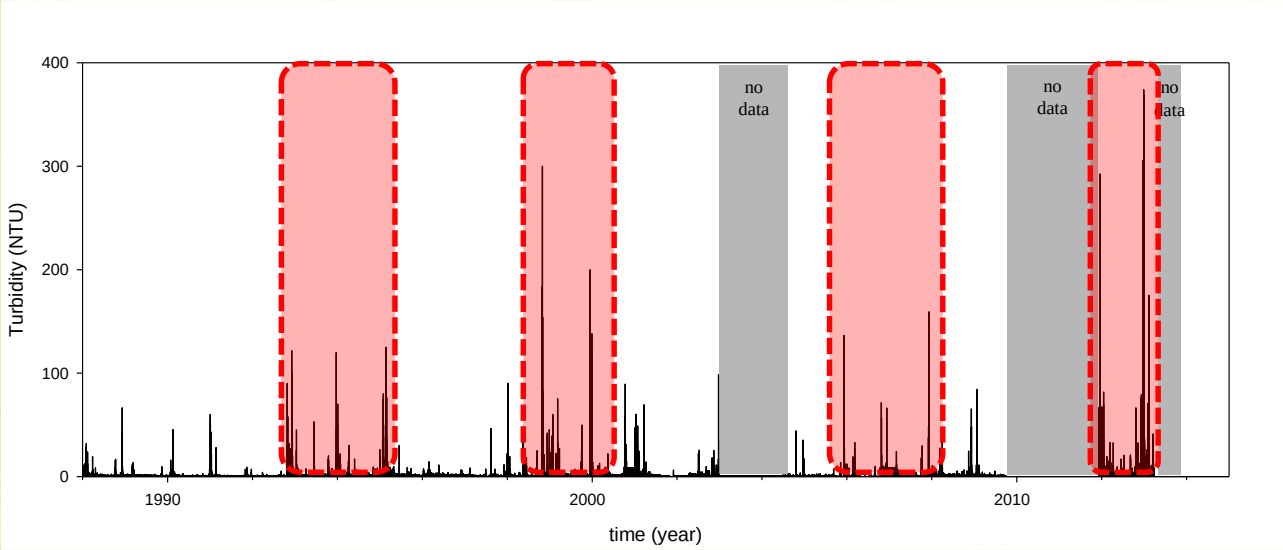
- **5-8 yrs => Pluriannual band (NAO)**
- **2-3 yrs => Quasi – biennial band (NAO)**
- **1 yr => Hydrological cycle**

Hanin, 2010 ; in Chédeville et al. 2016 (HSJ)

CONCLUSIONS

Large scale (under climatic control with the NAO index) succession of:

- Very wet periods with high turbid flood events



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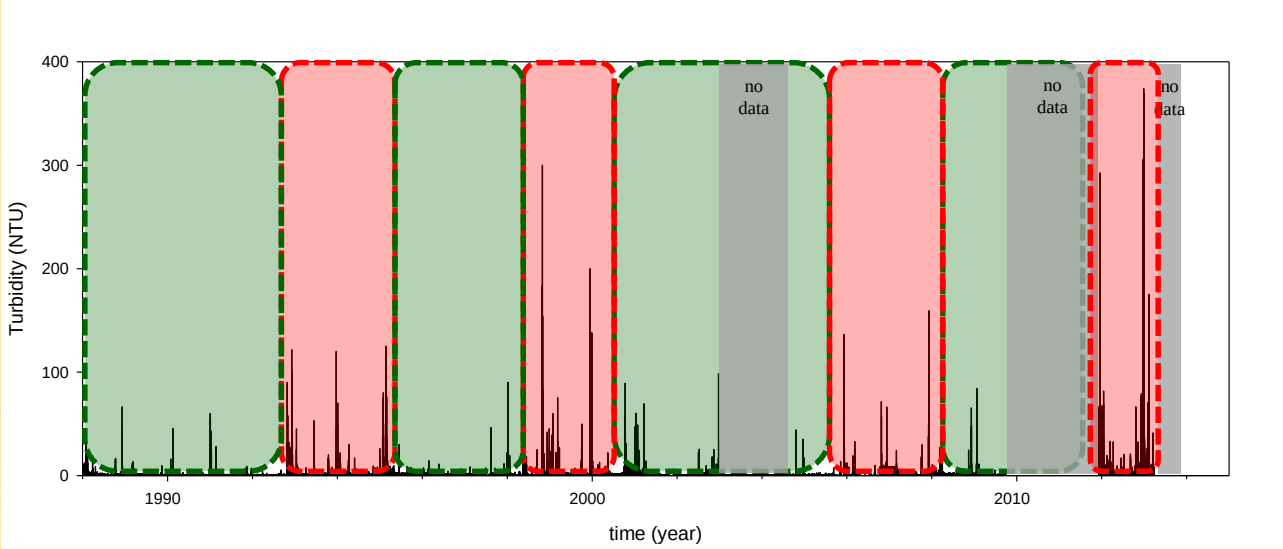

CONCLUSIONS

Large scale (under climatic control with the NAO index) succession of:

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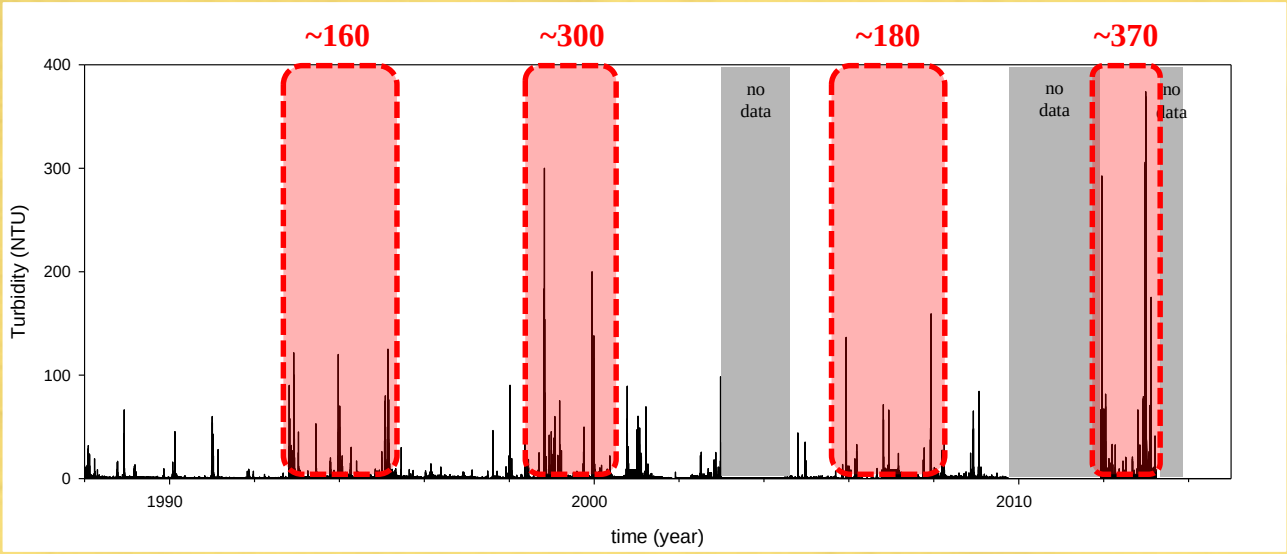
- Few wet periods with numerous low turbid flood events
  - 15-20 years period seem appear on the time serie with very high turbidity flood events




Thanks for
your attention