Implementation of a new module to simulate trace metals transport in large rivers by coupling SWAT and MOHID models: The case of the Garonne River (France)

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Trace Metal problematic in natural waters

- TM are emerging pollutants
- Exhibits a wide range of behaviour in natural waters
- Controlled by various environmental factors
- Hard to predict

Modelling possibilities

SWAT

Strength:
- Semi-empirical watershed modelling
- Water quality

Weaknesses:
- Crude river modelling
- Very crude trace metal modelling

MOHID

Strength:
- Mechanistic watershed modelling
- 1D, 2D, 3D
- Separation of land, porous media and river

Weaknesses:
- Computer intensive
- Inadequate for large watershed

EQUATIONS: HEAVY METAL ROUTING

Heavy metals are pollutants that are increasingly under scrutiny. Most heavy metals can exist in a number of different valence states and the solubility of a heavy metal is often dependent on the valence state it is in. The complexity of the processes affecting heavy metal solubility make modeling these processes directly unrealistic. At this time, SWAT allows heavy metal loadings to be added to the stream network in point source loading inputs. SWAT currently routes the heavy metals through the channel network, but includes no algorithms to model in-stream processes. Simple mass balance equations are used to determine the movement of heavy metals through the river network.

Objectives

- Develop a module to transport Trace Metals in rivers for SWAT.
- Include the following processes
  - Hydrodynamics
  - Hydromorphology
  - Physico-chemistry
  - Erosion-deposition

Methodology – Model development

- Hydrodynamics
  - Watershed modelling with SWAT
  - Water routing with the MOHID River Network model
    - Full 1D St-Venant equations (Dynamic wave)
- Hydromorphology
  - Variable river slope
  - Affects hydrodynamics and erosion / deposition
- Erosion / deposition
  - Partheniades equation
- Physico-chemistry
  - Constant Kd relation

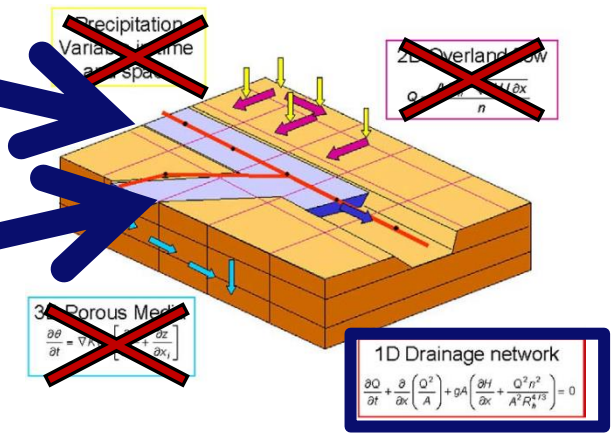
$$Kd = \frac{Sorbed\ TM}{Dissolved\ TM} \left[\frac{\mu g/kg}{\mu g/l}\right]$$

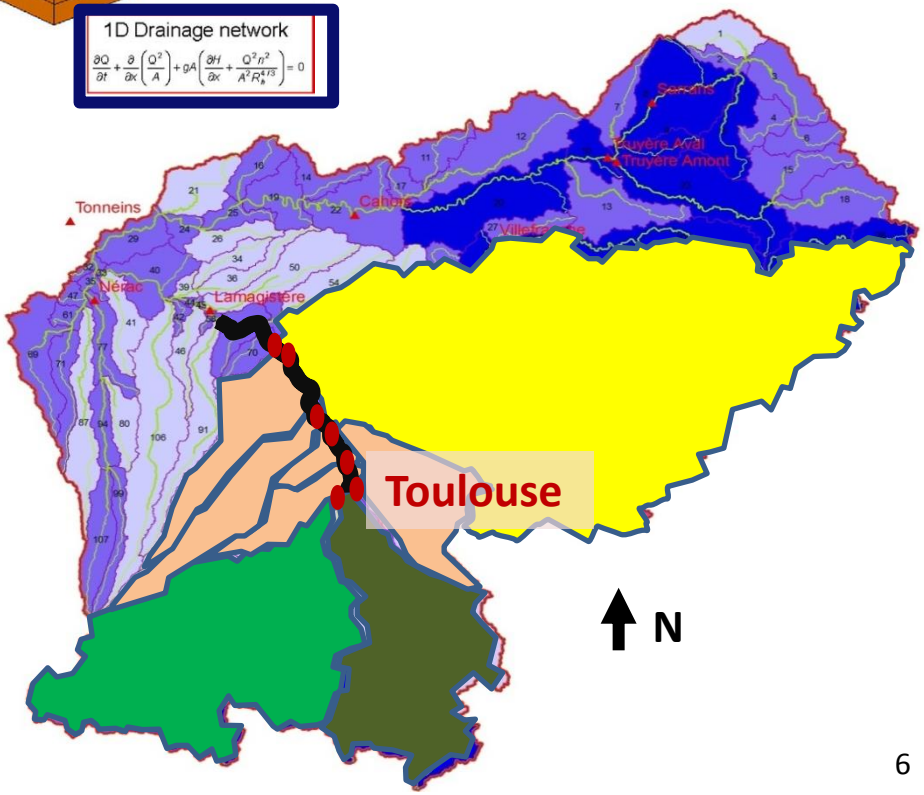
Methodology – Coupling SWAT and MOHID

Upstream watershed

SWAT

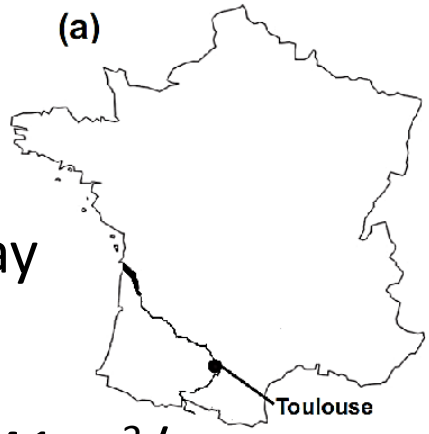
Tributaries





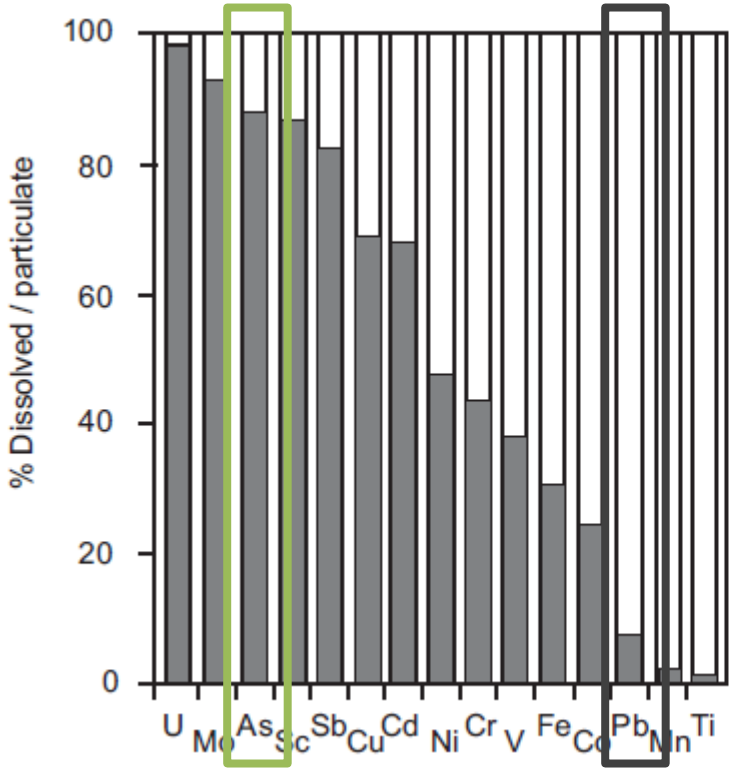
Methodology – Study case

- Garonne River
  - Reach of 80 km
  - Watershed of 13800 km^3 halfway in the sector
  - Monthly average flow from 75 to 341 m^3/s

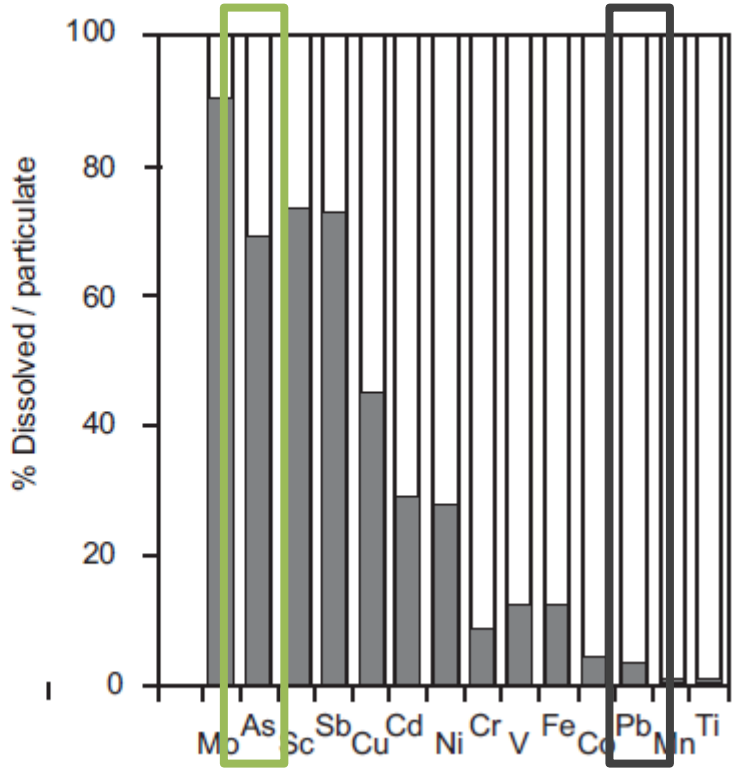


- Four sampling campaigns in 2004-2005 of the study site and its tributaries
  - Instantaneous measures of 13 stations
    - Nutrients
    - Major ions
    - Physico-chemistry
    - 15 Trace metals

Methodology – Trace Metals

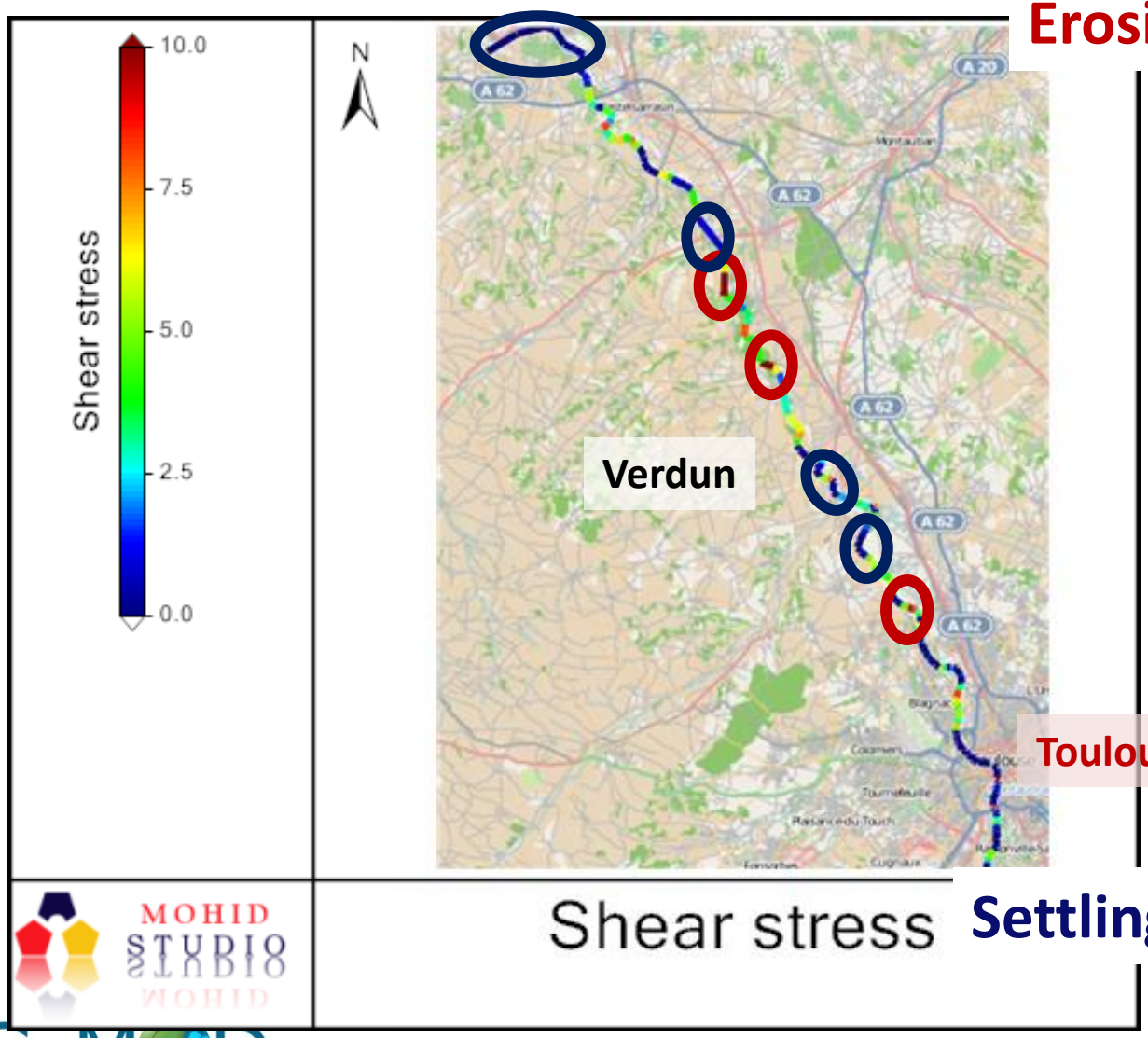


Low flow



Flood event

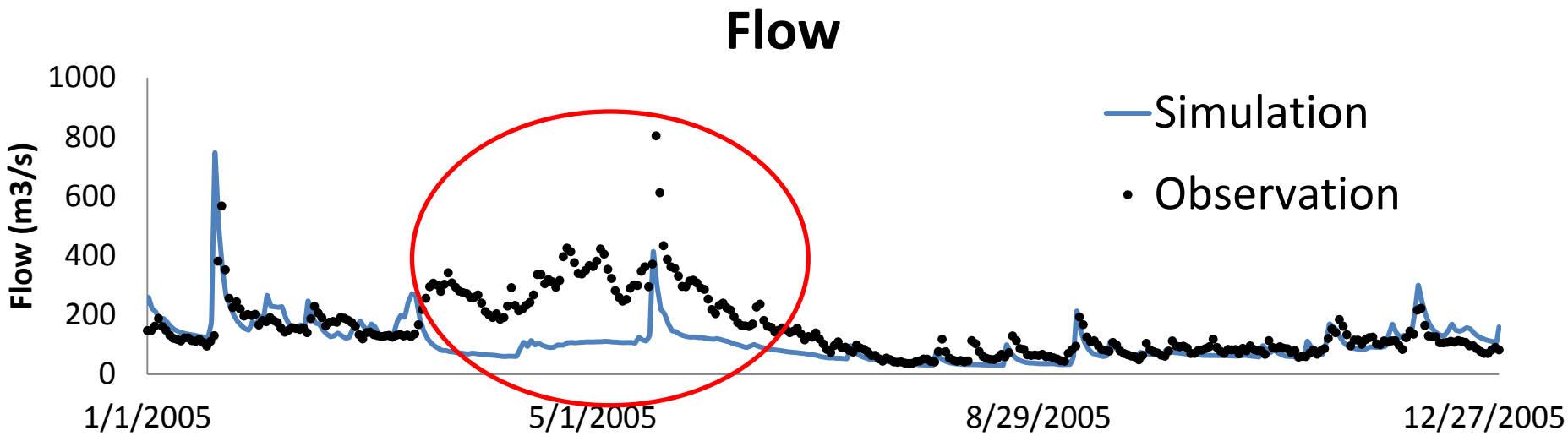
Results - Hydromorphology

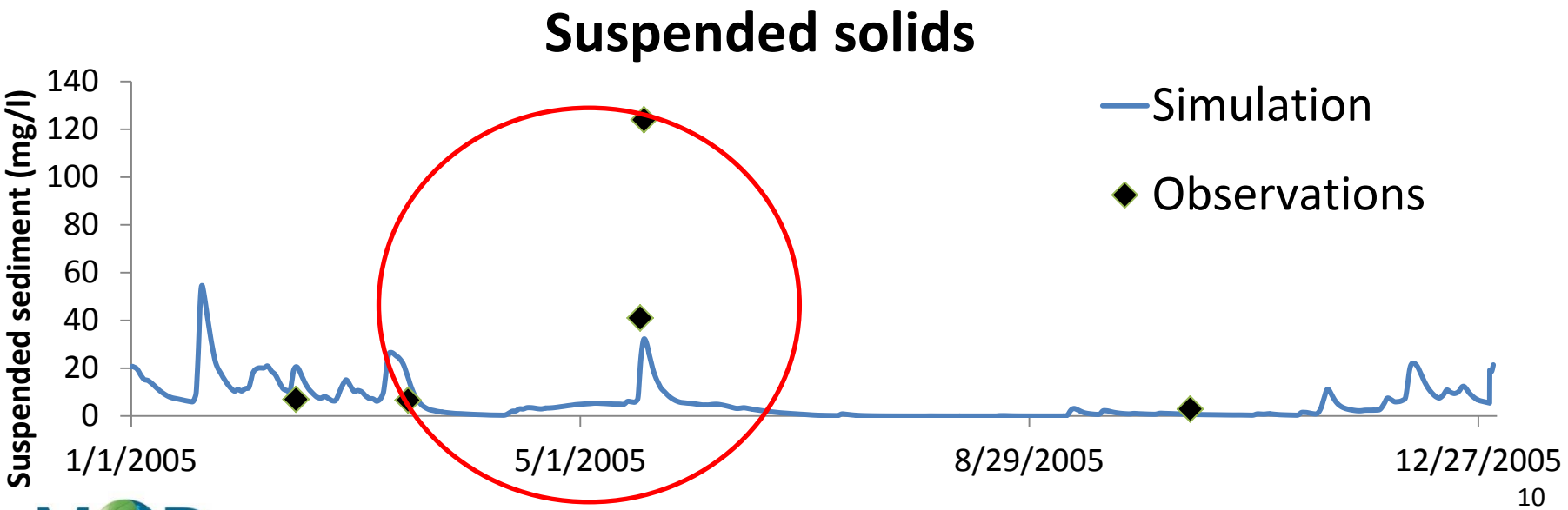


Erosion zones

Settling zones

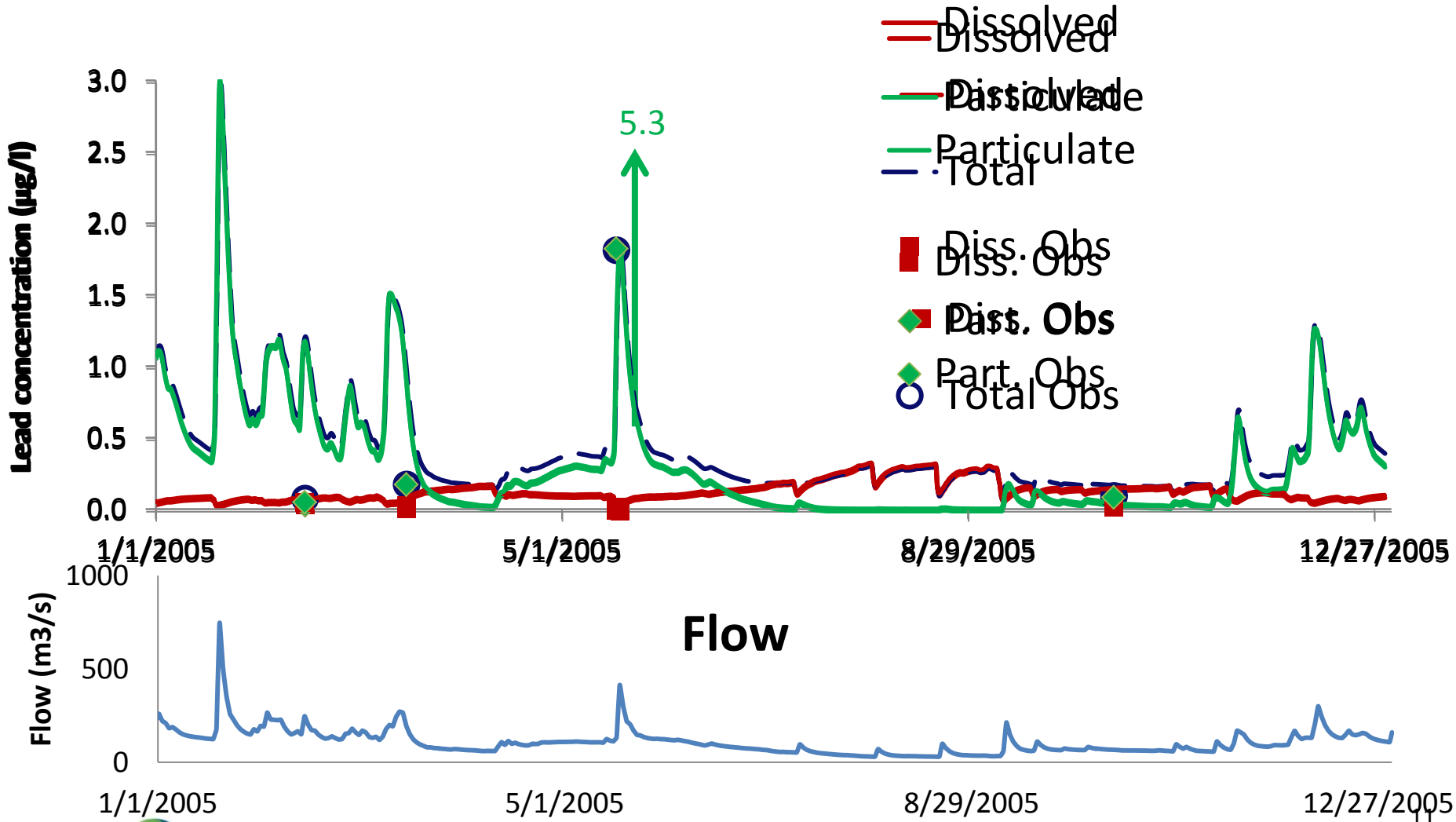
Results – Flow and suspended solids



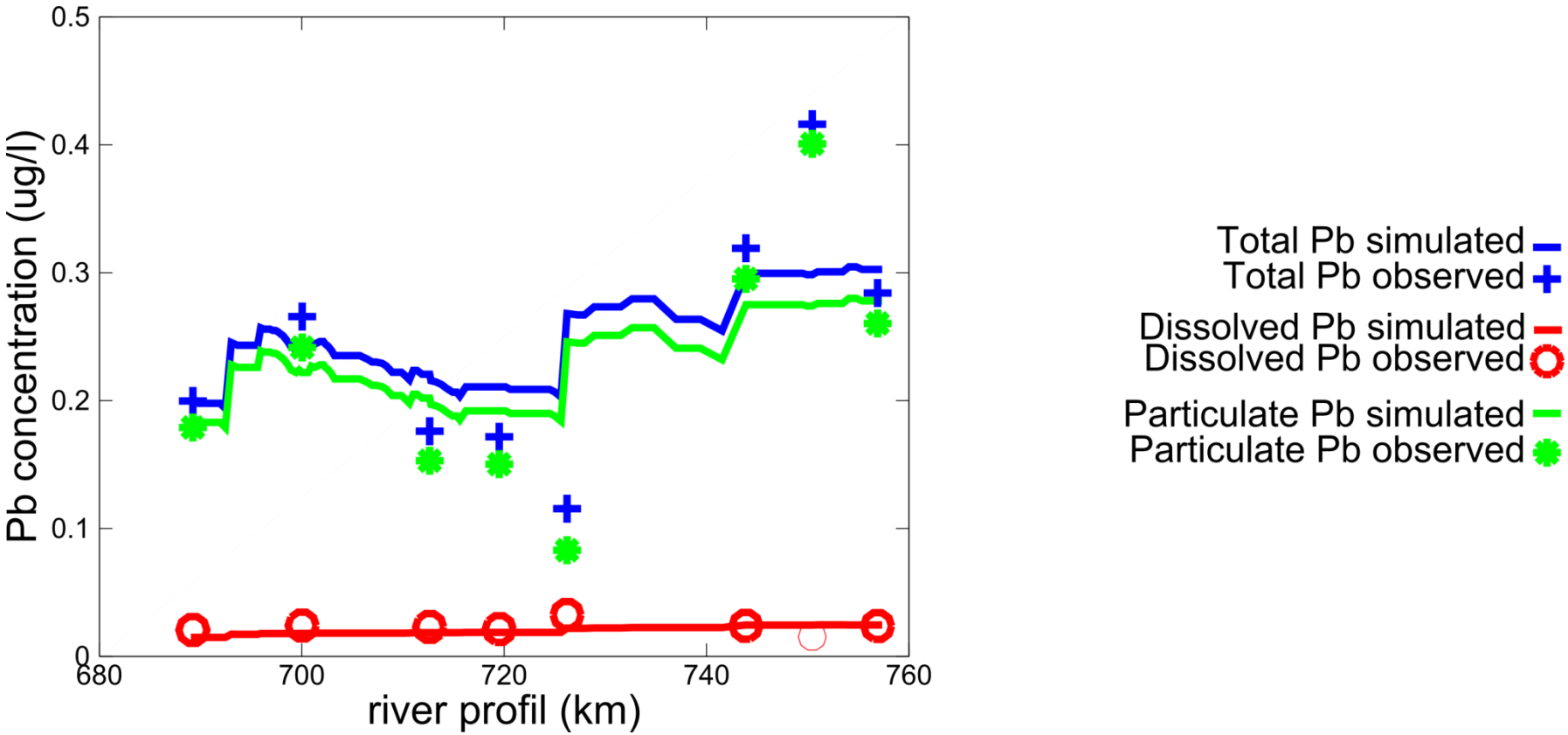


Results – Lead, time serie

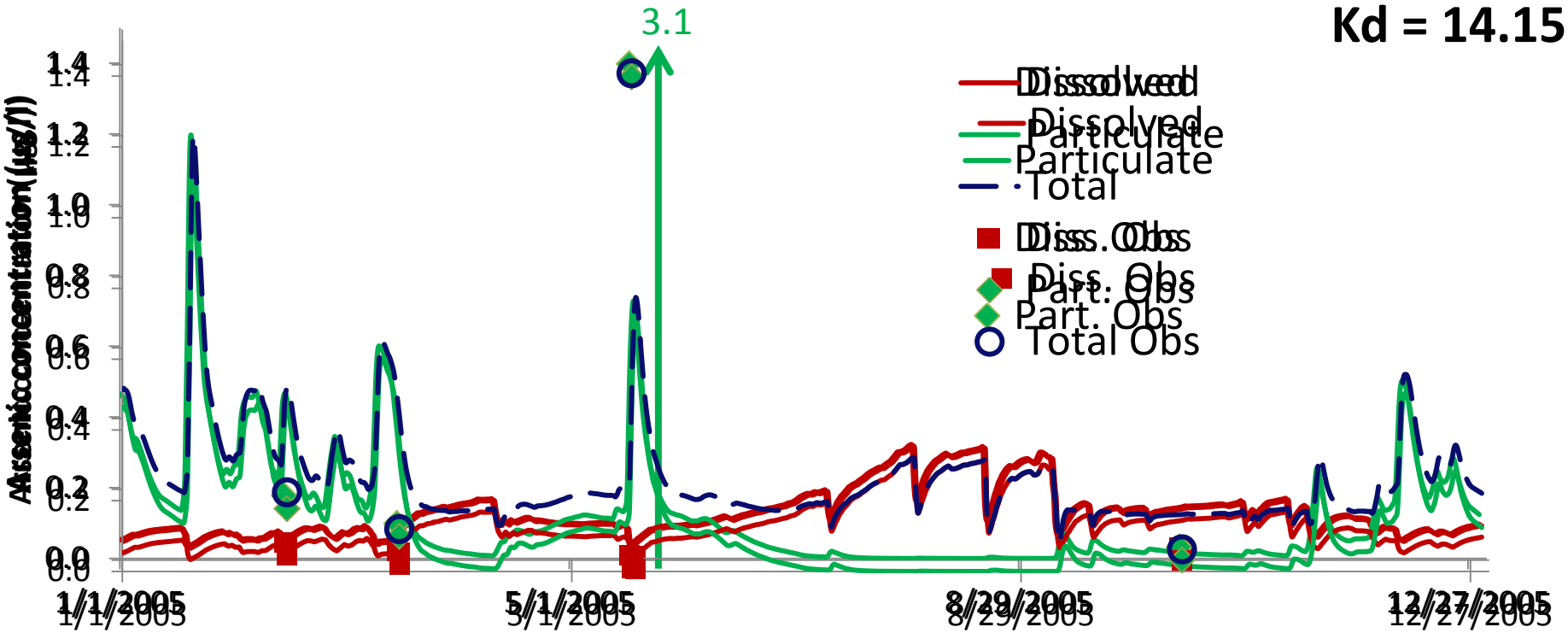
Kd = 3000

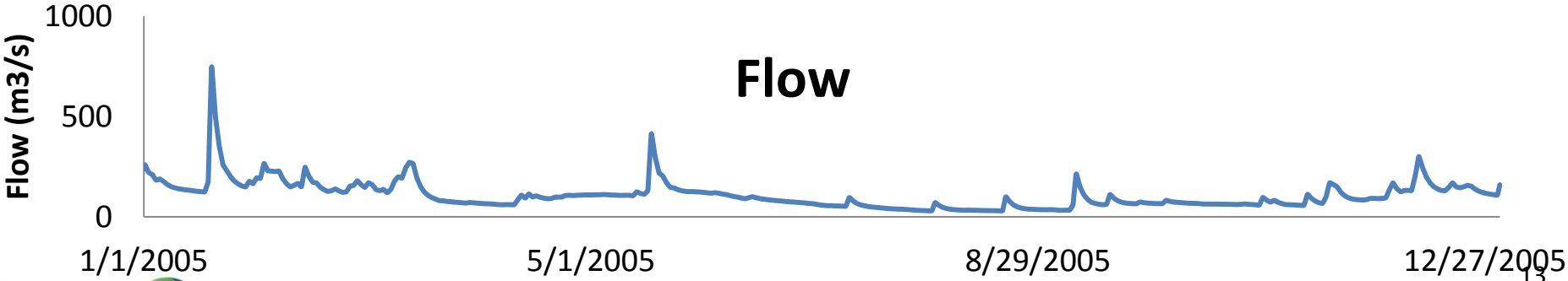


Results – Lead, longitudinal profile

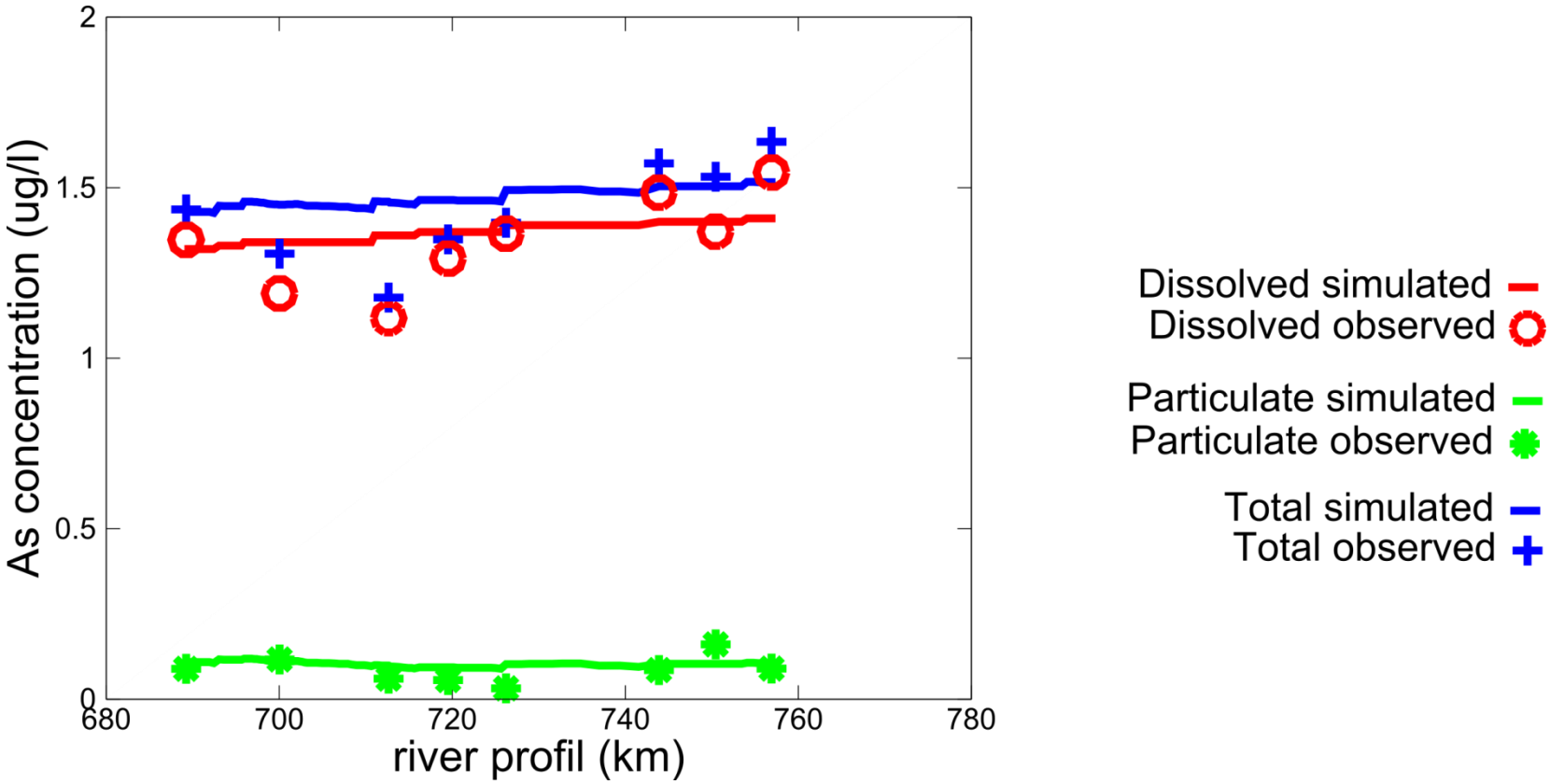


Results – Arsenic, time serie





Results – Arsenic, longitudinal profile



Conclusion

- SWAT can be used to model the fate of trace metals but…
  - A complex river model is needed to take into account morphology and the full St-Venant equations
  - A fixed Kd model is necessary to describe the state of the trace metals

Perspectives

- Implement a complex sorption / desorption chemical model.
  - Separate total suspended solids in three classes: Organic matter, oxides, clays
- Implement biological reactions
  - Organic matter production / consumption
- Perform sensitivity analysis to quantify the influence of each processes.
- Extract dominant processes and implement them in SWAT.