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TAKING THE PULSE OF OUR PLANET FROM SPACE

Multi-sensor fusion and data assimilation in an hydrology-hydraulics model for the estimation of discharge in the Middle Niger

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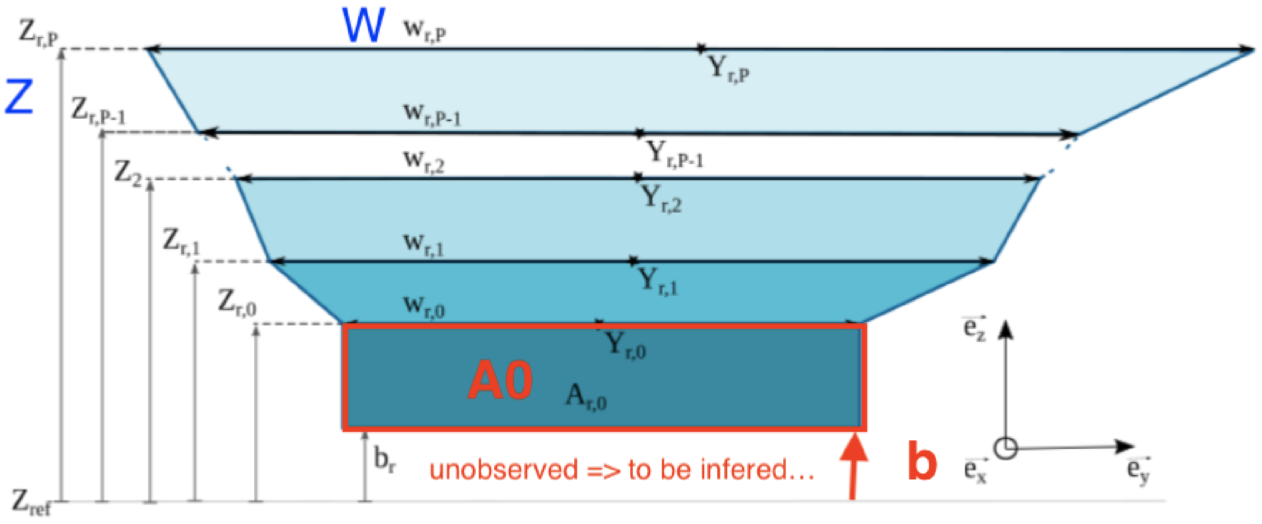
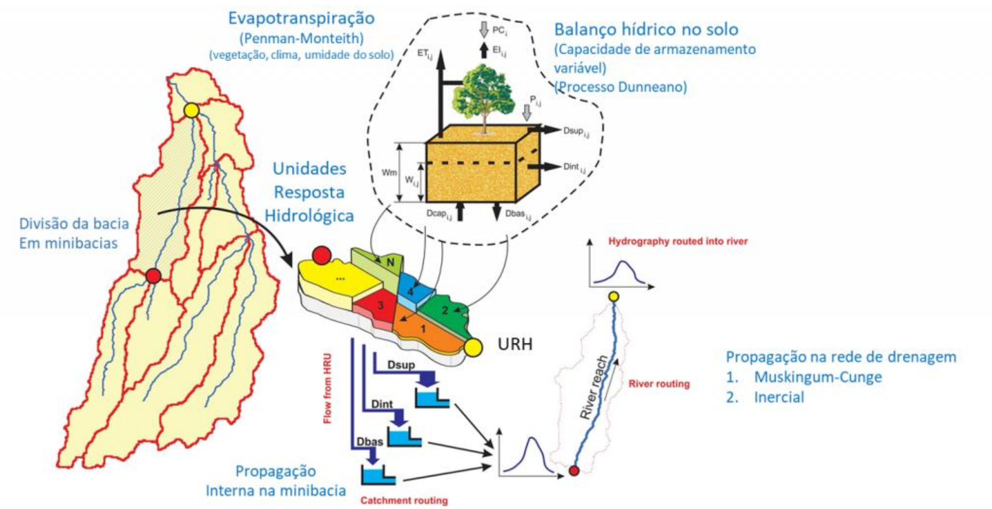
Context and Objectives

- Context
  - Steady decrease of in-situ stations over the past 3 decades
  - Real time monitoring mostly available only in developed countries
  - Strong potential benefits of remote sensing in developing countries such as in Africa
    - EO by Copernicus Sentinels constellation
    - The future SWOT mission
- Objectives
  - Use of EO Open-Data to generate coupled hydrologic-hydrodynamic model
  - Data Fusion to account for different scales in time and space
  - Data assimilation of only EO Water Surface Elevation (so far), no in-situ data

Materials and Methods

- Methods
  - 1D hydrodynamic model : DassFlow-1D software (IMT, INSA Toulouse, France, Open Source)
  - Large scale hydrological model : MGB-IPH (UFRGS, Porto Alegre, Brazil)
  - Data assimilation technique : 4D VAR + preconditioning
  - Sensitivity analysis (ANOVA) to get insight on correlations between variables in the control vector





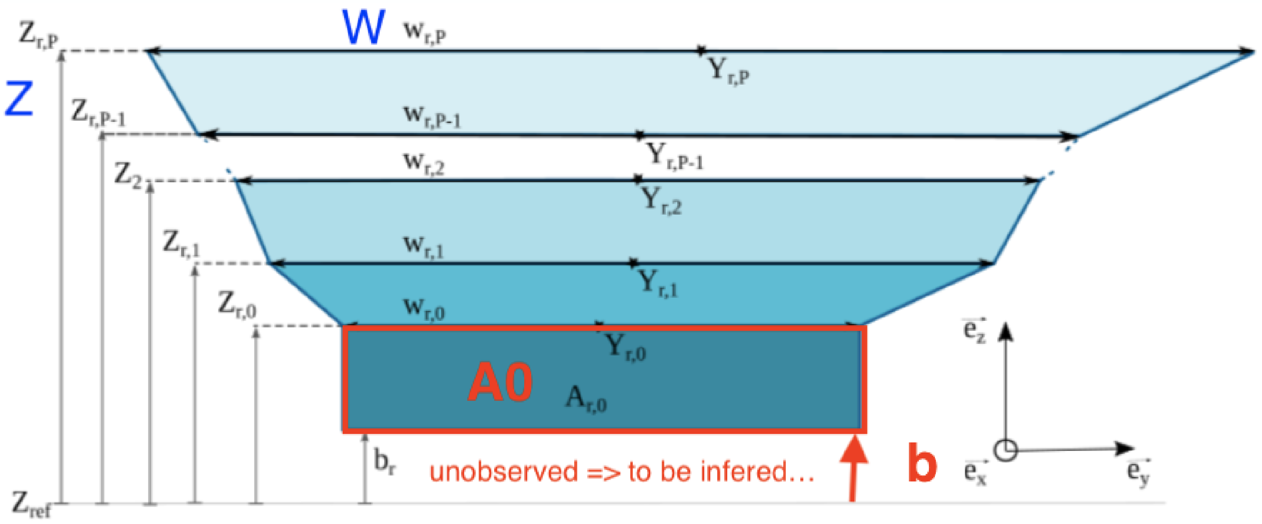
Materials and Methods

- Data sources
  - Hydrological model
    - Land use : Global Land Cover, EEA
    - Climate variables : Climatic Research Unit
    - Soil properties : Harmonized World Soil Database, FAO
    - Rainfall : GSMAP-NRT (daily)
  - Hydrodynamic model and data assimilation
    - River centerline : Global River Width from Landsat
    - Sentinel 2 L2 data product : watermasks for the computation of river widths
    - Sentinel 3 SRAL data : timeseries of WSE at virtual stations from Hydroweb[1] portal

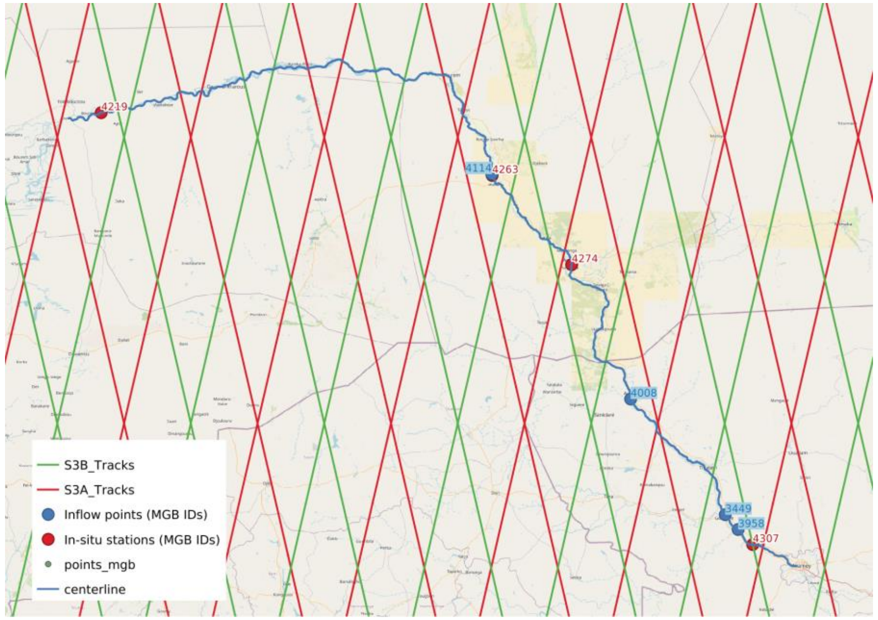
[1] https://hydroweb.theia-land.fr/

Materials and Methods

- Mesh generation



Overview of a cross-section for the hydrodynamic model



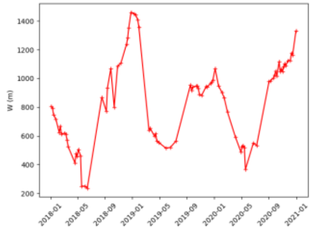
S2A and S2B tracks crossing the centerline at the so-called virtual stations

Materials and Methods

- Mesh generation
  - Computation of river widths timeseries:

watermasks from Sentinel 2 images

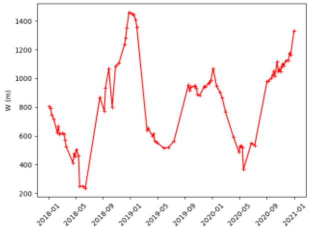
Automatic determination of cross-sections planform



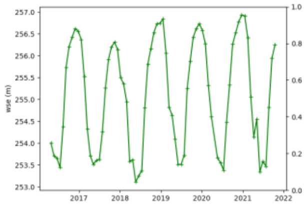
Computation of widths using GIS functions

Materials and Methods

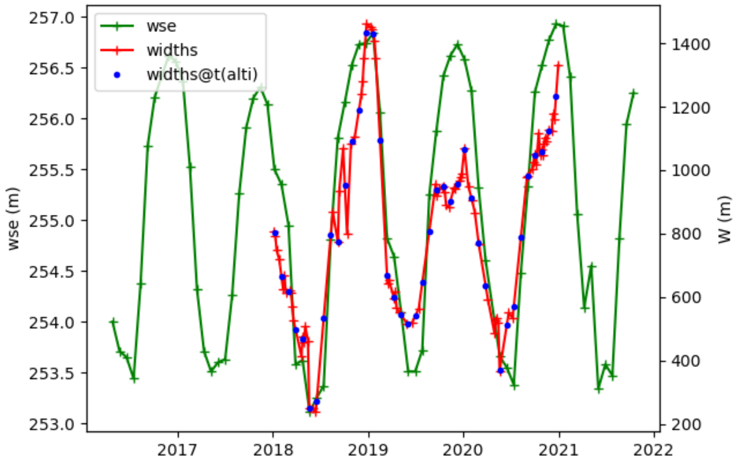
- Mesh generation
  - Computation of river widths timeseries:



  - Fusion with altimetric timeseries (S3 SRAL):

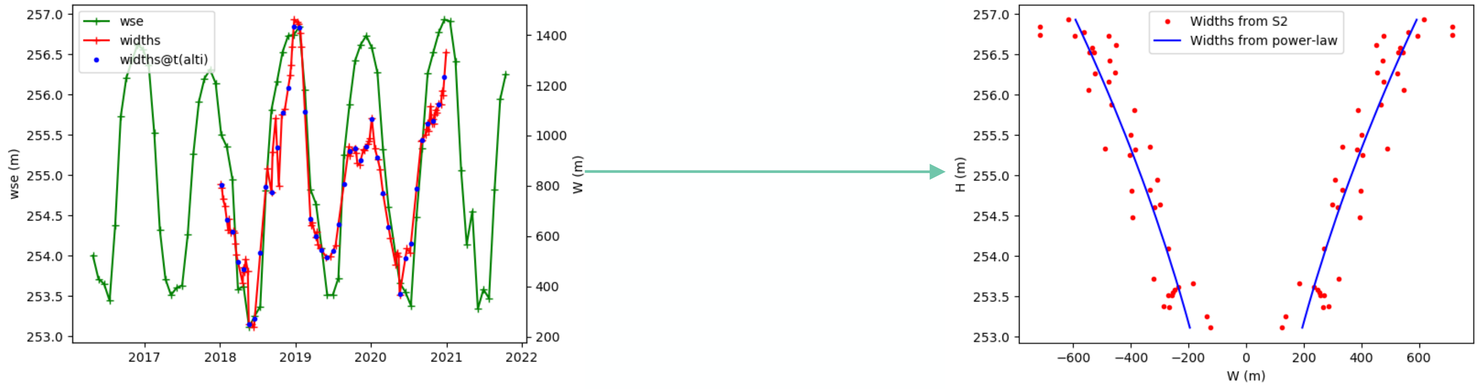


WSE timeseries
at the VS



Materials and Methods

- Mesh generation
  - 1D mesh generation



  - Inversion of steady-state (backwater curve) model to get unobserved bathymetry.
  - Dedicated interpolation technics to compute cross-sections between virtual stations.
  - Final mesh : 831 cross-sections (from 19 virtual stations)

Materials and Methods

- Data assimilation framework :
  - 4D-VAR, embedded in DassFlow-1D software.
    - The inverse problem to solve is:

$$\min\big(j(c)\big) \text{ with } j(c) = \|Z(c) - Z_{obs}\|_R \text{ and } c = \left(Q_{in}(t), \{Q_{trib}^{k}(t)\}_k, b(x), \alpha(x), \beta(x)\right)$$

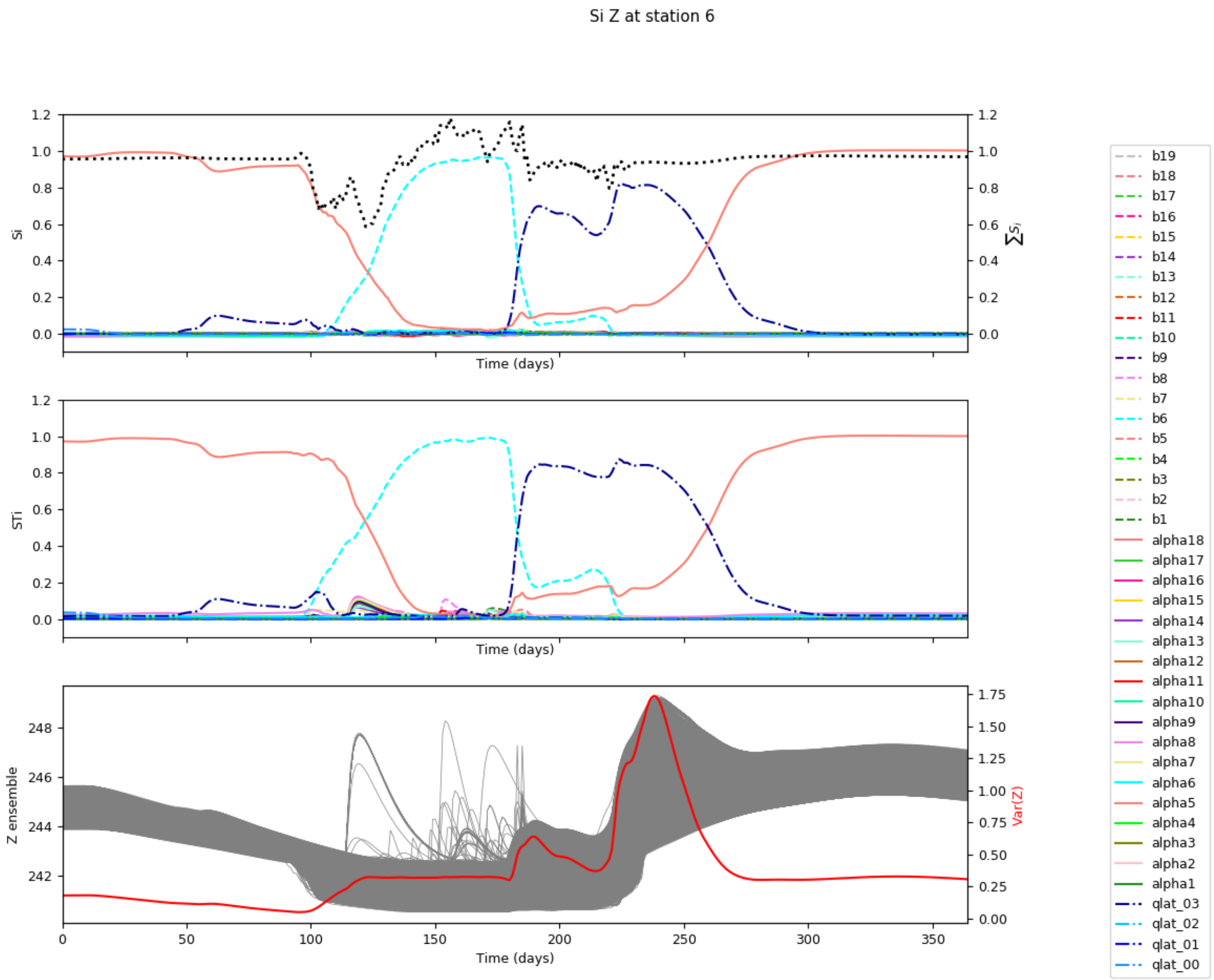
  - Preconditioning using change of variable and covariance matrix

$$k = B^{1/2}\left(c - c^{(0)}\right) \text{ with } B = diag(\{B_X\}_X),\ B_X = \sigma_X^2 \exp\left(-\frac{|x_i - x_j|}{L_X}\right)$$

  - Sensitivity analysis (ANOVA) to get insight on correlations length (L_X) between variables in the control vector

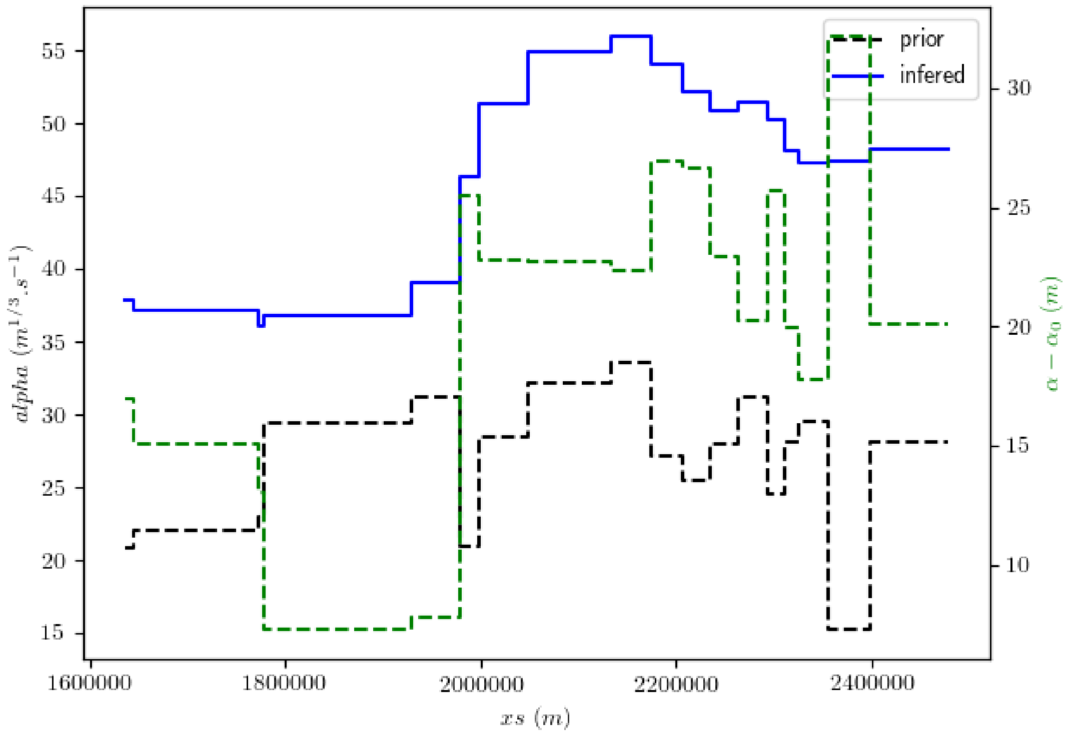
Results

- Sensitivity analysis (ANOVA)
  - Variables:
    - 19 bathymetry points
    - 18 roughness patches (α,β)
    - 4 multiplicative factors for the tributaries
  - 1024 samples

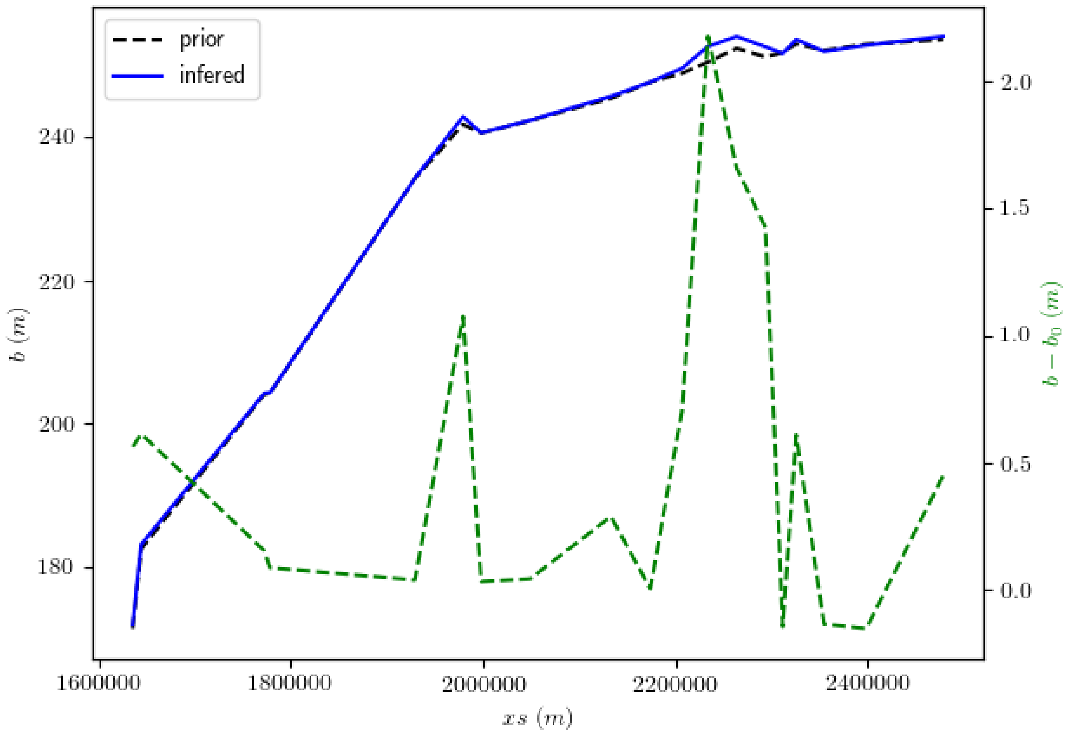


Results

- Data assimilation



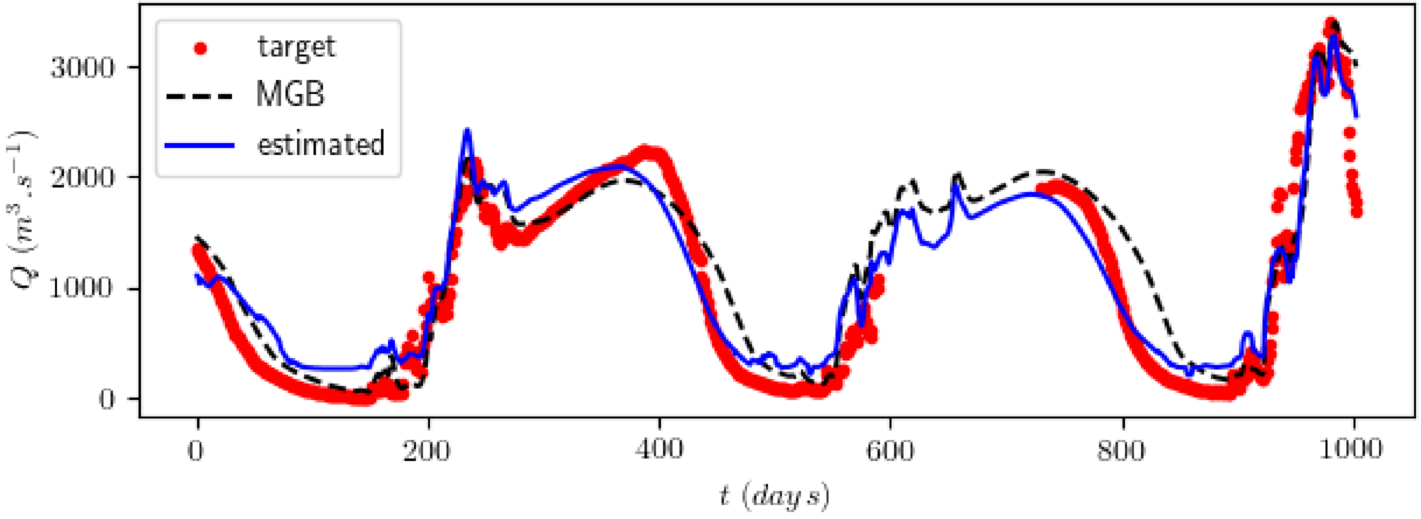
Prior and infered α values (K=αh^{β})



Prior and infered α values (K=αh^{β})

Results

- Data assimilation



	RMSE	nRMSE	NSE
MGB	276 m3/s	28.1%	0.90
MGB + DassFlow-1D	332 m3/s	33.8%	0.86

Prior and infered discharge timeseries at Niamey

Conclusion and Perspectives

- Conclusion:
  - Weak coupling of a rainfall/runoff model and a 1D hydrodynamic model
  - Data fusion of Sentinel 2 and 3 products to generate the 1D mesh using dedicated algorithm
  - Slightly better performance (at Niamey) than the hydrological model alone
  - Allows the estimation of discharge between the virtual stations

- Perspectives
  - Application of the method on other basins (Rio Negro-Rio Branco in Amazon basin, Maroni in French Guyana)
  - Combination with other EO missions (Sentinel 6, SWOT).
  - Use of past missions (Jason, Envisat, etc.) to enrich the dataset for the mesh generation.