4th Hydrospace-GEOGloWS 2021 | 7-11 June 2021
"Inland Water Storage and Runoff: Modeling, In Situ Data and Remote Sensing"
Hosted as a Virtual Event from ESA-ESRIN, Frascati (Rome), Italy

Hydrogeomorphological Parameters Extraction From Remotely-Sensed Products for SWOT Discharge Algorithm

Charlotte M. Emery[1], K. Larnier[1], M. Liquet[1], J. Hemptinne[1], A. Vincent[1], S. Pena Luque[2]

(1) CS GROUP-France, Space Business Unit, Toulouse, France
(2) CNES, Toulouse, France

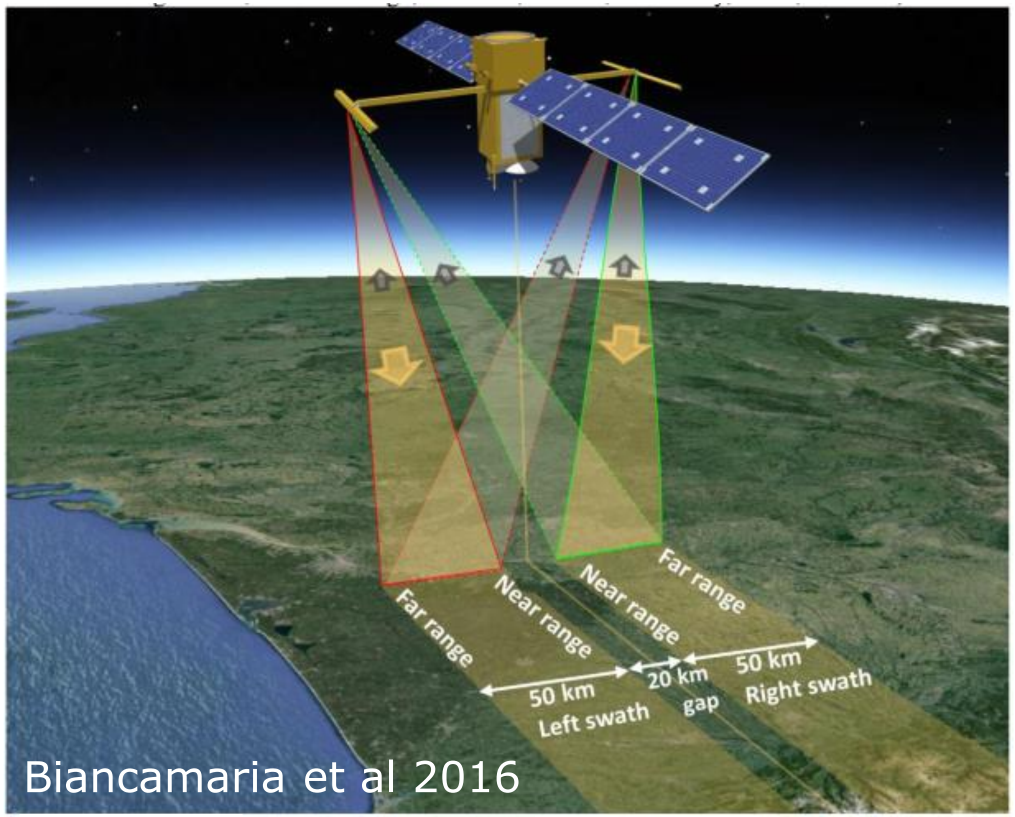
CONTEXT – The SWOT mission and its river products

Surface Water and Ocean Topography (SWOT) mission:

- Launch scheduled for 2022,
- Monitor oceans, lakes (area > 250 m^2) and rivers (width > 100 m)

- For rivers, SWOT will provide:
    - 2D-maps of water surface elevations (Z),
- \+ along river centerline
    - Estimation of river width (W),
    - Estimation of surface slope (S)

⇒ **SWOT Discharge product using (Z, W, S)**

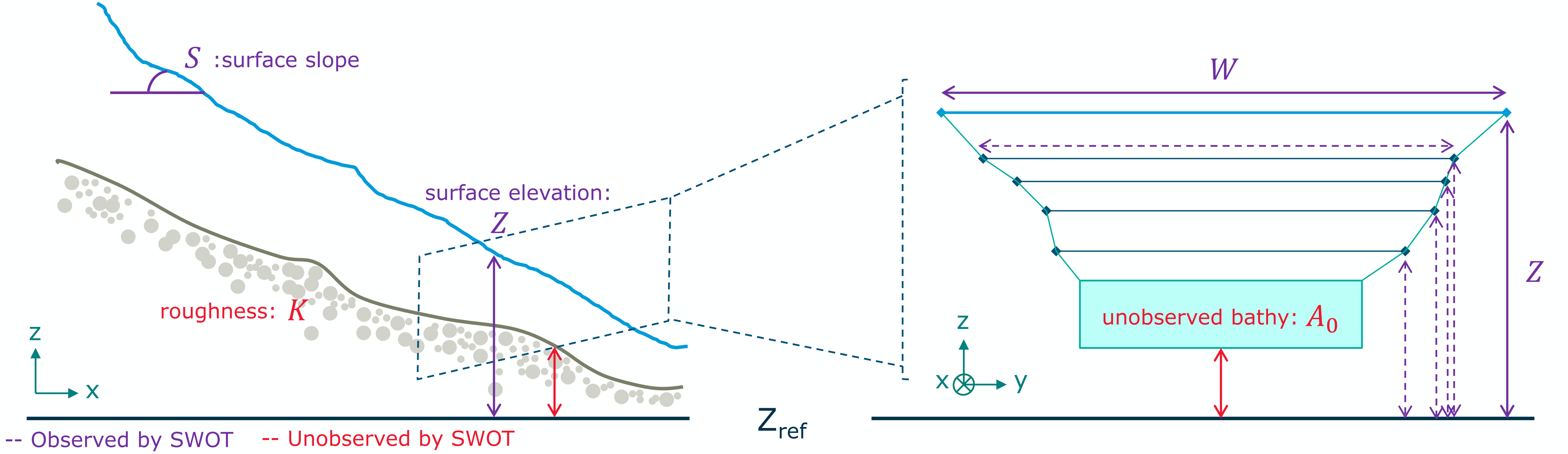


Biancamaria et al 2016

CONTEXT –SWOT Discharge product

SWOT discharge product derived from the Manning equation:

$$Q = K S^{1/2} (A_0 + \delta A)^{5/3} W^{-2/3}$$



⇒ Need to **know bathymetry and roughness**: inferred simultaneously with discharge

⇒ Need **« good » priors** to initialize algorithms

⇒ Current project focuses on deriving roughness coefficients

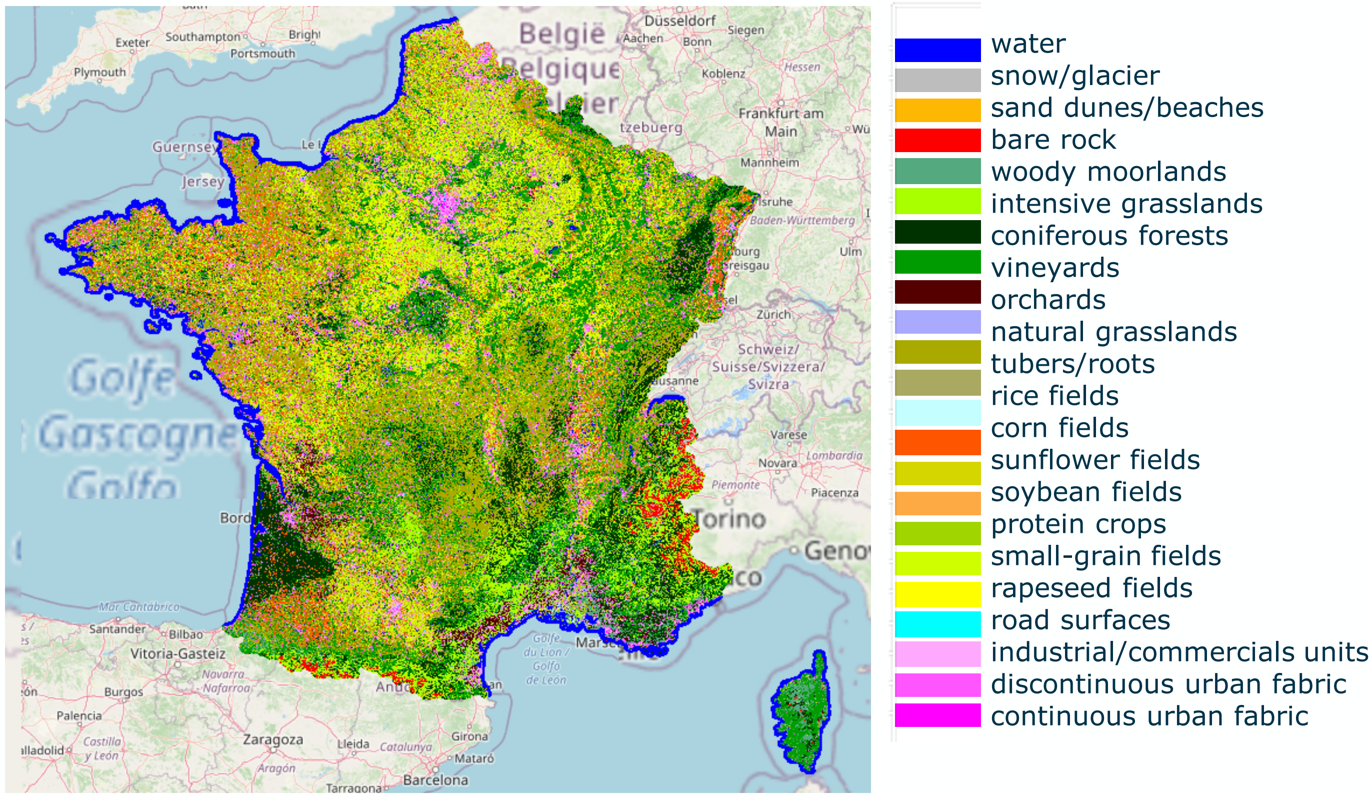
CONTEXT: Land cover map from the iota2 chain

Constrain: method applicable at global-scale

Assumption: roughness coefficient correlated to soil occupation

- **IOTA²** chain [Inglada et al, 2017]: build land cover maps from S2 images using a supervised machine learning method,
- Maps produced yearly over France with currently 23 classes
- Chain can be applied anywhere given a training database

⇒ **Use land cover maps from IOTA² to derive roughness coefficients**



2019 land cover map over France

https://www.theia-land.fr/ceslist/ces-occupation-des-sols/

OUTLINE

1. Study domains
2. Methodology
3. Comparison against models
4. Application: SWOT discharge algorithm

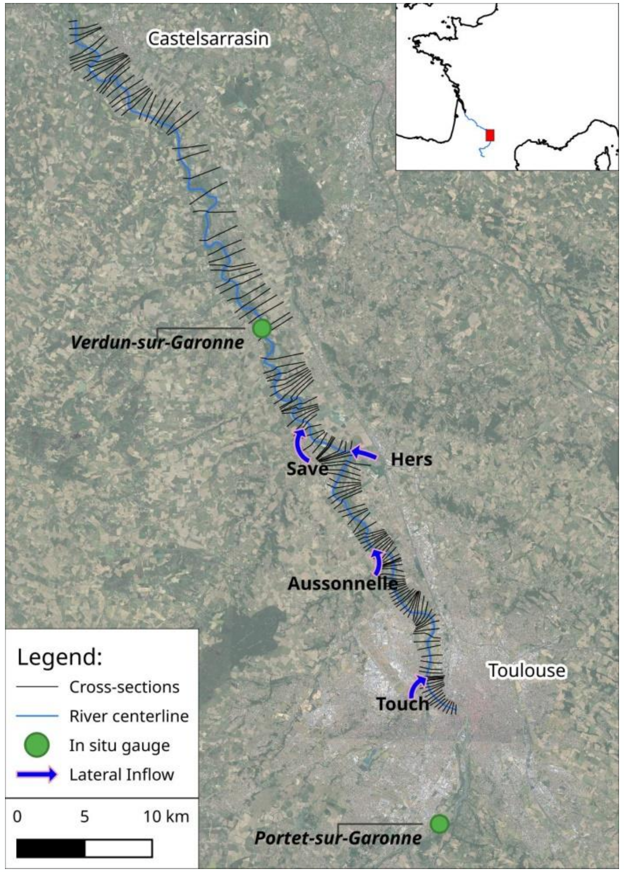
OUTLINE

1. Study domains
2. Methodology
3. Comparison against models
4. Application: SWOT discharge algorithm

STUDY DOMAINS

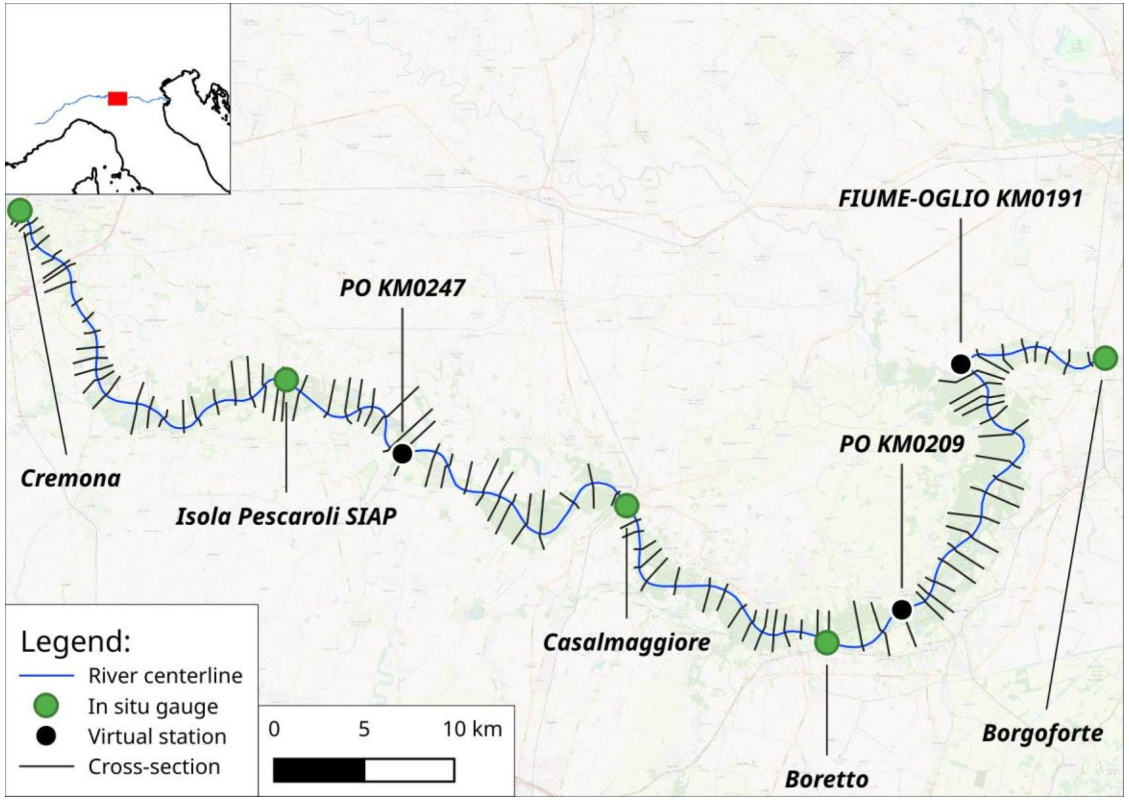
Upper Garonne river (France)

- 75-km-long reach between Toulouse and Castelsarrasin



Middle Po river (Italy)

- 96-km-long reach between Cremona and Borgoforte



OUTLINE

1. Study domains
2. Methodology
3. Comparison against models
4. Applications: SWOT discharge algorithm

METHODOLOGY: Principle

Derivation of Manning coefficient from **Cowan formula**: $n = (n_b + n_1 + n_2 + n_3 + n_4) \times m$

- [Arcement & Schneider, 1989]: decision tables based on local observation and expert/user decision,

⇒ Derive automatic version using remote global dataset

	n_b	n_1	n_2	n_3	n_4	m
Description	*Basic roughness from soil composition*	*Cross-sectional irregularities*	*Longitudinal irregularities*	*Obstructions*	*Vegetation effects*	*Meandering ratio*
Source Floodplain	SoilGrids[1]	IOTA[2] maps	=0.0	IOTA[2] maps	IOTA[2] maps	=1.0
Source Main channel	SoilGrids[1]	Cross-section profiles	GRWL[2]	=0.0	=0.0	WorldRiverDatabase[3]

- Expert/user decision for qualitative features (based on Arcement & Schneider)
- Publically available dataset : 1: global-scale soil composition database / 2: global-scale riverwidth database at 30-m resolution / 3:global-scale river centerline database with meander and sinusoity attributes

METHODOLOGY: Floodplains roughness specificities

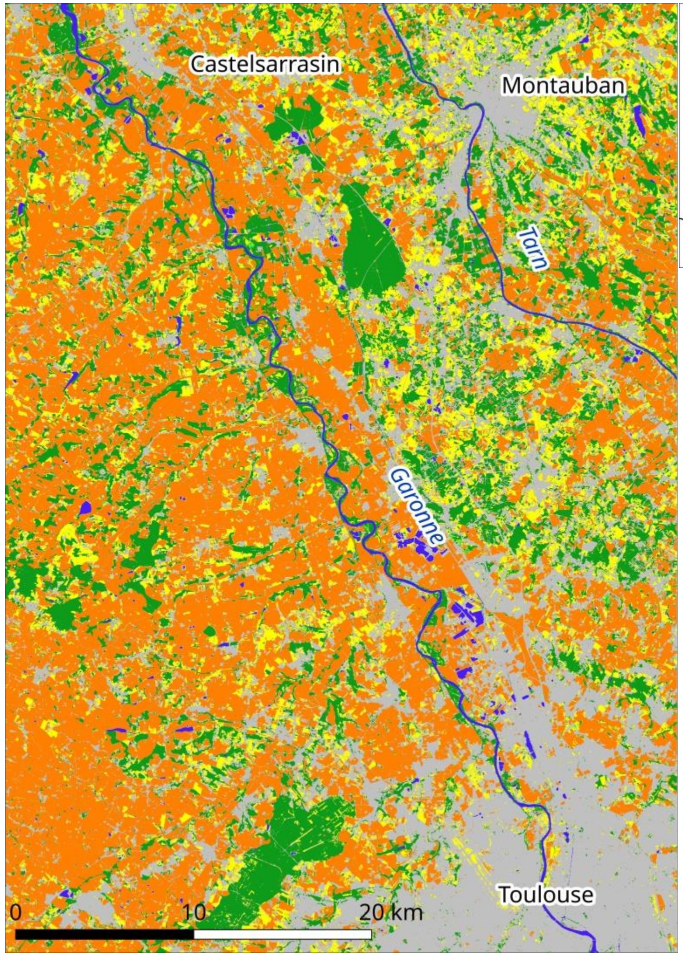
Derivation of Manning coefficient from **Cowan formula**: $n = (n_b + n_1 + 0 + n_3 + n_4) \times 1.0$

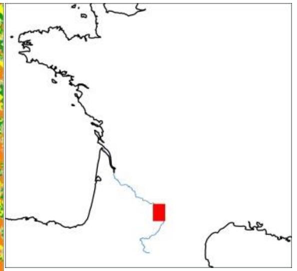
	n_b	n_1	n_2	n_3	n_4	m
Description	*Basic roughness from soil composition*	*Cross-sectional irregularities*	*Longitudinal irregularities*	*Obstructions*	*Vegetation effects*	*Meandering ratio*
Source Floodplain	SoilGrids	IOTA² maps	=0.0	IOTA² maps	IOTA² maps	=1.0

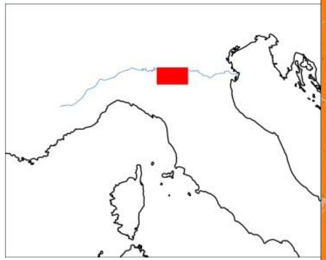
- Predominant use of land cover maps
- Native land cover classes aggregated over 8 macro-classes (including classes “water” and “glaciers and snow”)
    1. Artificial surfaces,
    2. High-height agricultural areas
    3. Low-height agricultural areas
    4. Forests
    5. Natural bare grounds
    6. Woody moorlands

METHODOLOGY: Floodplains roughness specificities

Upper Garonne river (France)



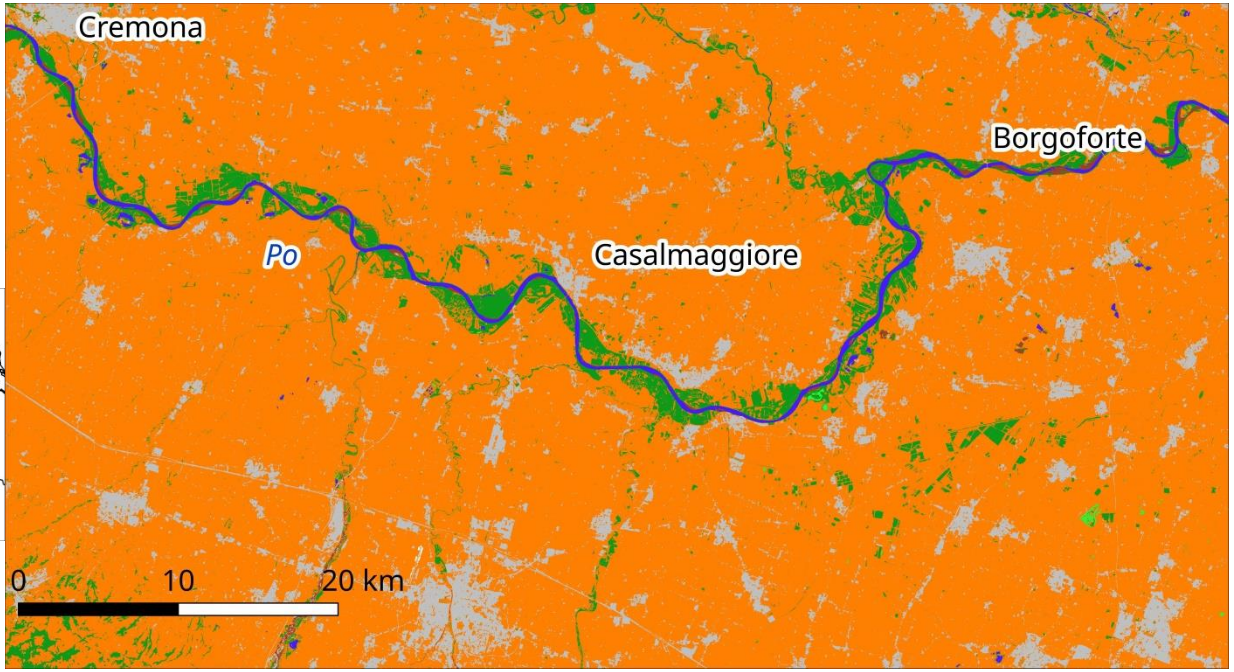




Land cover classes:

- Artificial Surfaces
- High height agricultural areas
- Low height agricultural areas
- Forests
- Woody moorlands
- Natural bare ground
- Water bodies
- Glaciers and perpetual snow

Middle Po river (Italy)

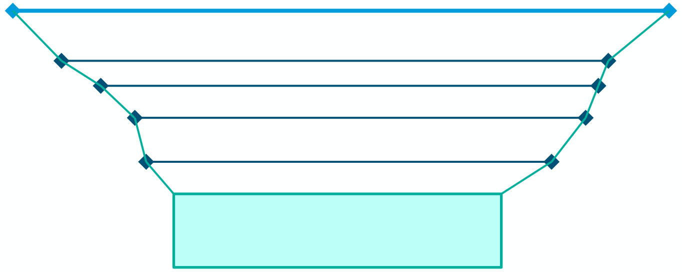


METHODOLOGY: Main channel roughness specificities

Derivation of Manning coefficient from **Cowan formula**: $n = (n_b + n_1 + n_2 + 0 + 0) \times m$

	n_b	n_1	n_2	n_3	n_4	m
Description	*Basic roughness from soil composition*	*Cross-sectional irregularities*	*Longitudinal irregularities*	*Obstructions*	*Vegetation effects*	*Meandering ratio*
Source Main channel	SoilGrids	Cross-section profiles	GRWL	=0.0	=0.0	WorldRiverDatabase

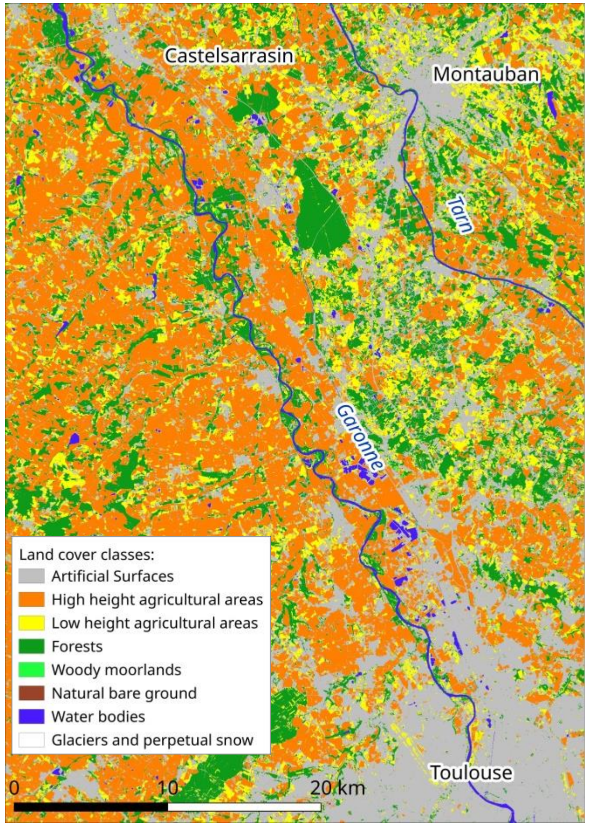
- Roughness estimated along a centerline at cross-sectional profiles
- n_1: Local survey cross-section profiles or extracted from *SWOT-like DEM* (see below)
- n_2/m: Cross-section closest line features from GRWL/WorldRiverDatabase selected to extract width and sinusoity
- n_3/n_4: effects of obstructions/vegetation neglected in large rivers

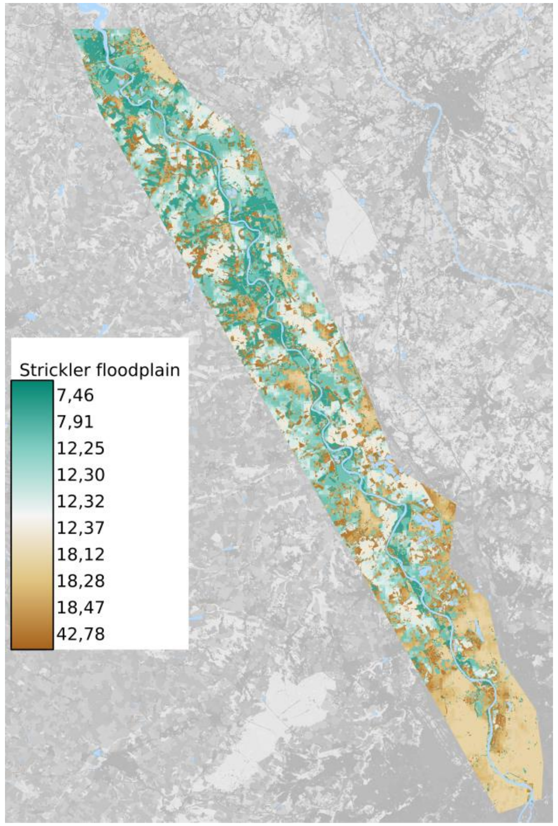


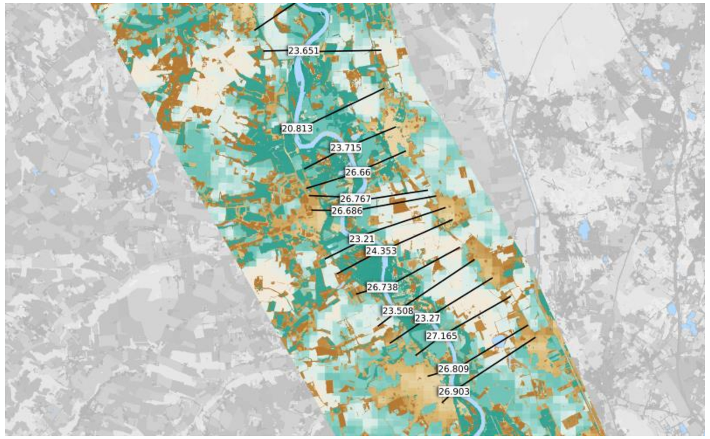
METHODOLOGY: application over the Garonne domain

Maps of roughness output

- CLC* + BD Topo** (src:IGN) + agricultural Land Parcel Information System + Randolph Glacier Inventory used as training database,
- 145 cross-sections extracted from French DEM (src:IGN) + local topographic survey





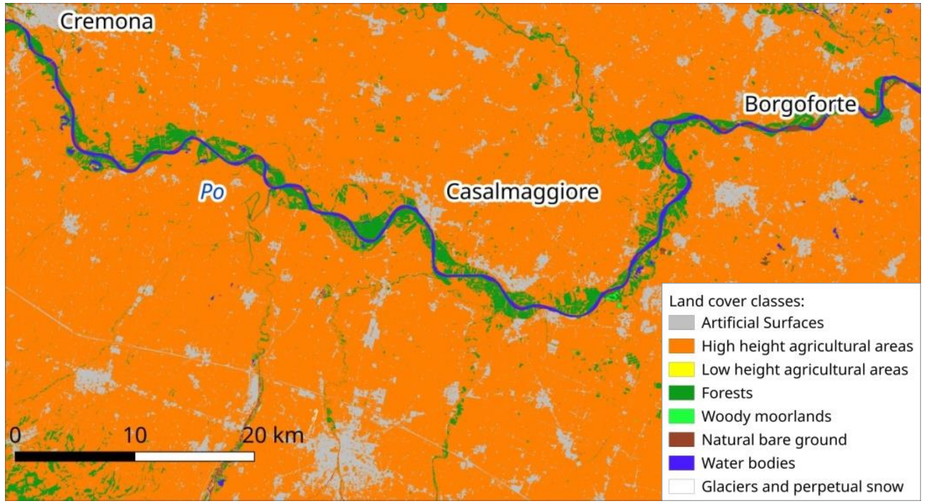


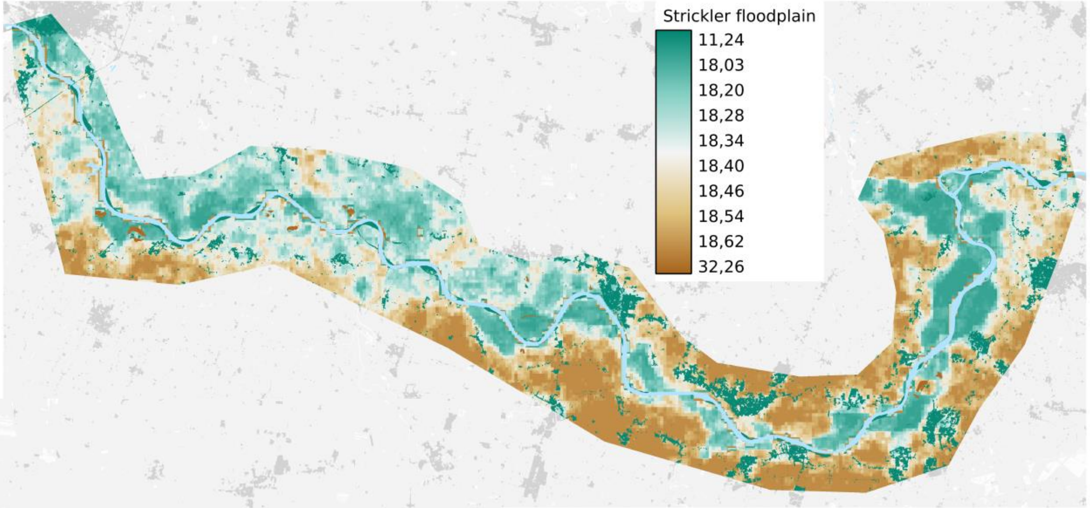
Up (Zoom in) : floodplain Strickler (colormap) + main channel Strickler (boxed value along channel)
Left : non-main channel Strickler (colormap) with original land cover map (greys)

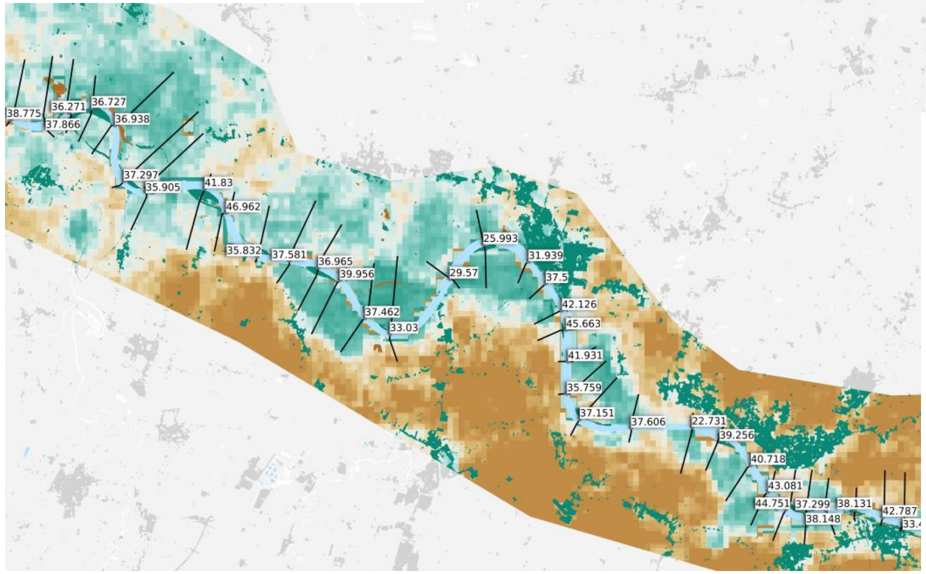
- *: Corine Land Cover,
- **: French territory and infrastructures database

METHODOLOGY: application over the Po domain

Maps of roughness







- Corine Land Cover used as training database,
- 91 cross-sections extracted from 2m-DEM from Lidar/underwatersonar/ground survey (src:AdBPo)

Up: non-main channel Strickler (colormap) with original land cover map (greys)
Left (Zoom in): floodplain Strickler (colormap) + main channel Strickler (boxed value along channel)

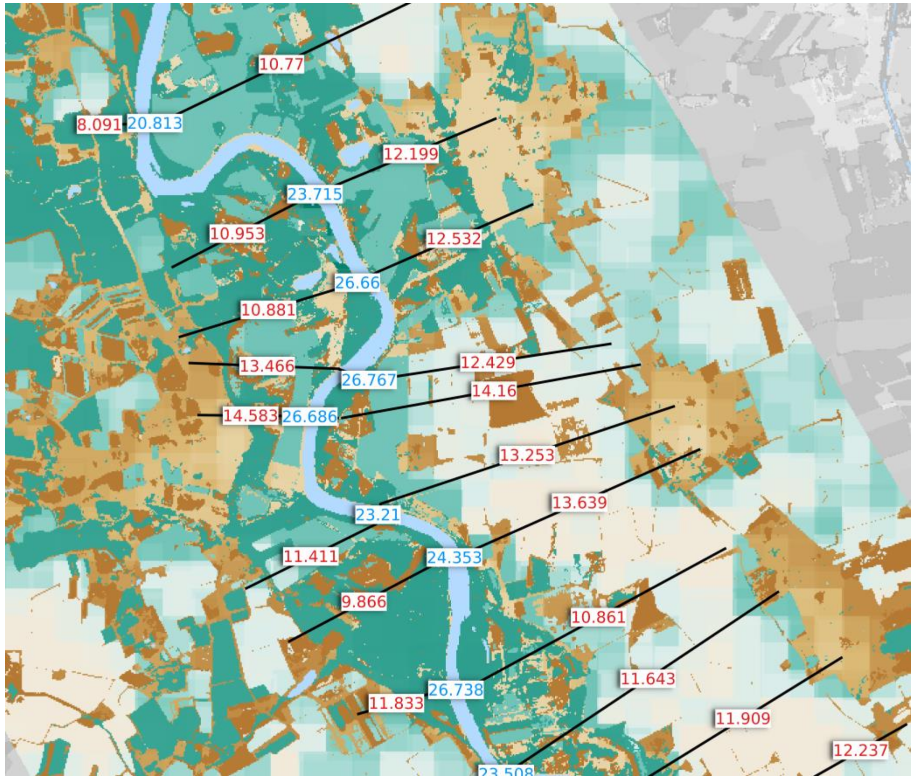
OUTLINE

1. Study domains
2. Methodology
3. Comparison against models
4. Application: SWOT discharge algorithm

COMPARISON AGAINST MODELS : APPROACH

1. In situ and remotely-sensed observations of hydraulic variables were gathered over the study domains,
2. Mascaret 1D-hydraulic model used as proxy to simulated observed variables constrained by roughness coefficients from:
    1. Calibrated model,
    2. “Direct” model from our method
3. Friction in floodplain is the averaged friction over floodplain cross-section profiles

4. Models performances are evaluated against in situ data using classical metrics



Aggregated Strickler along cross-section profiles (Garonne model)

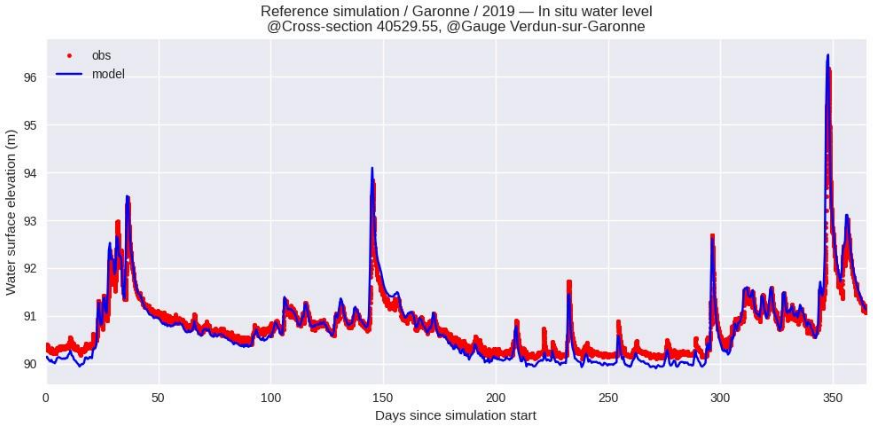
COMPARISON AGAINST MODELS : RESULTS

Upper Garonne river (France)

Garonne simulation over 2019 at Verdun-sur-Garonne:

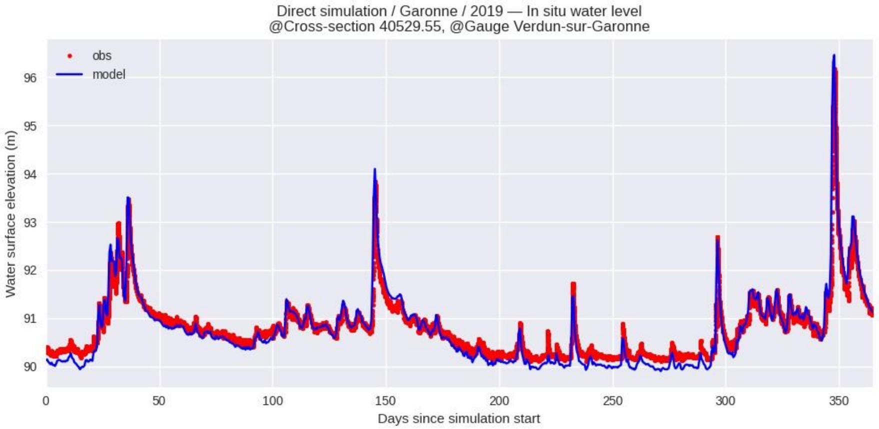
Top: calibrated model (constant Ksmin=24, Ksmaj=16)

NSE = 0.90



Bottom: tuned roughness model

NSE = 0.89

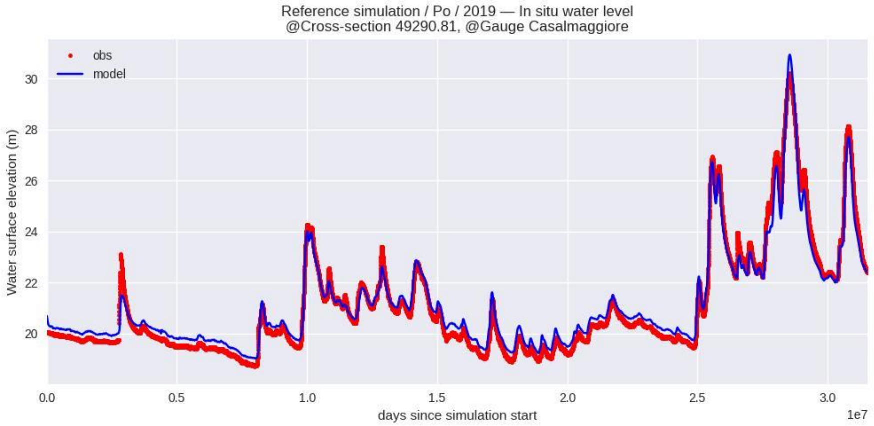


Middle Po river (Italy)

Po simulation over 2019 at Casalmaggiore:

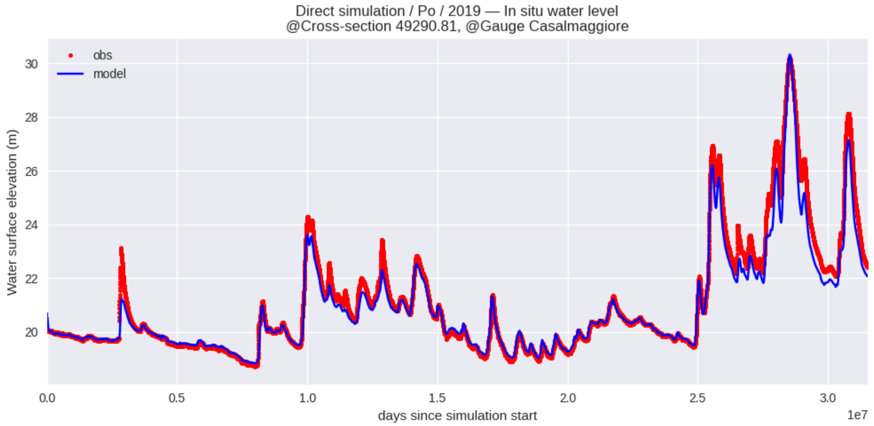
Top: calibrated model (constant Ksmin=34, Ksmaj=8)

NSE = 0.97



Bottom: tuned roughness model

NSE = 0.96

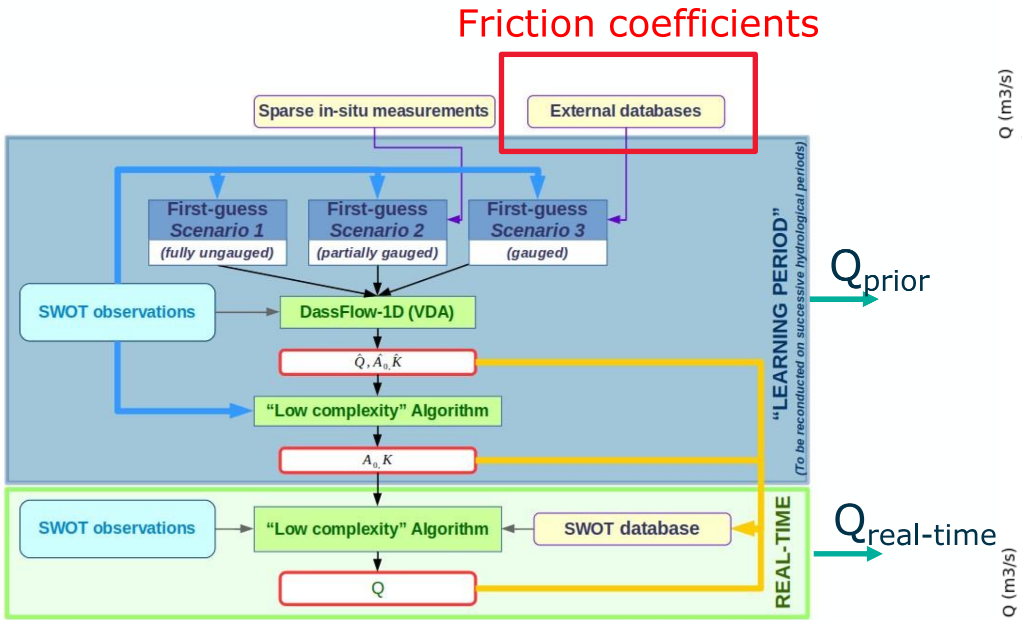


⇒ Similar performances

OUTLINE

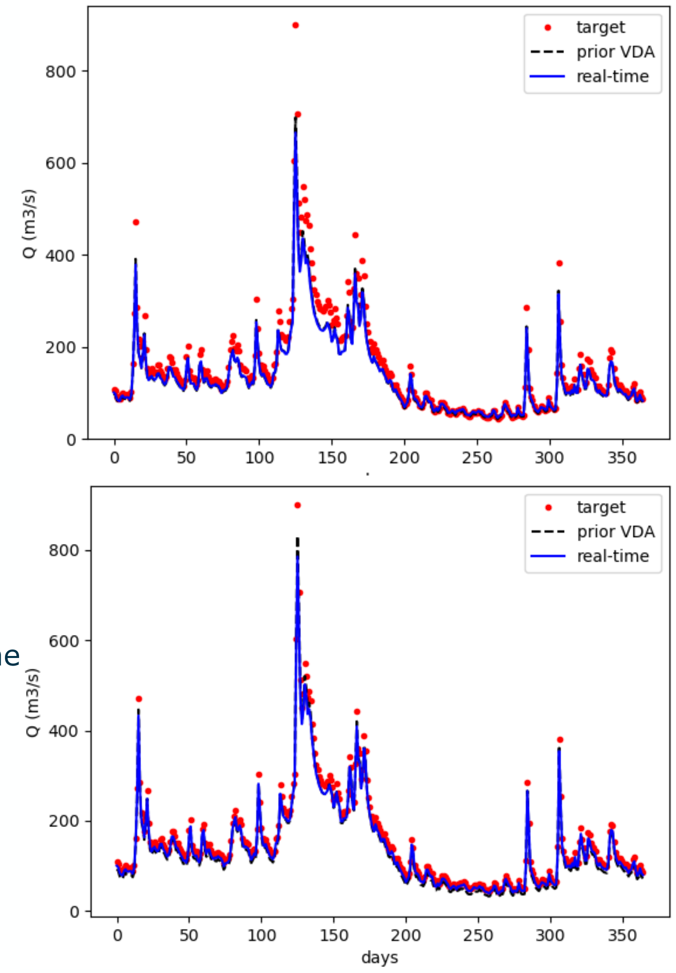
1. Study domains
2. Methodology
3. Comparison against models
4. Application: SWOT discharge algorithm

APPLICATION: SWOT DISCHARGE ALGORITHM - HiVDI



HiVDI chain (Larnier et al 2020)

Experiment with the Garonne SWOT-like data (src: PEPSI)



HiVDI-simulated discharge from calibrated-model Strickler

	CALIBRATED	DIRECT
NSE(prior)	0.93	0.97
NSE(real-time)	0.91	0.98
NRMSE(prior)	19.0 %	12.7 %
NRMSE(real-time)	20.6 %	10.8 %

HiVDI-simulated discharge from direct-model Strickler

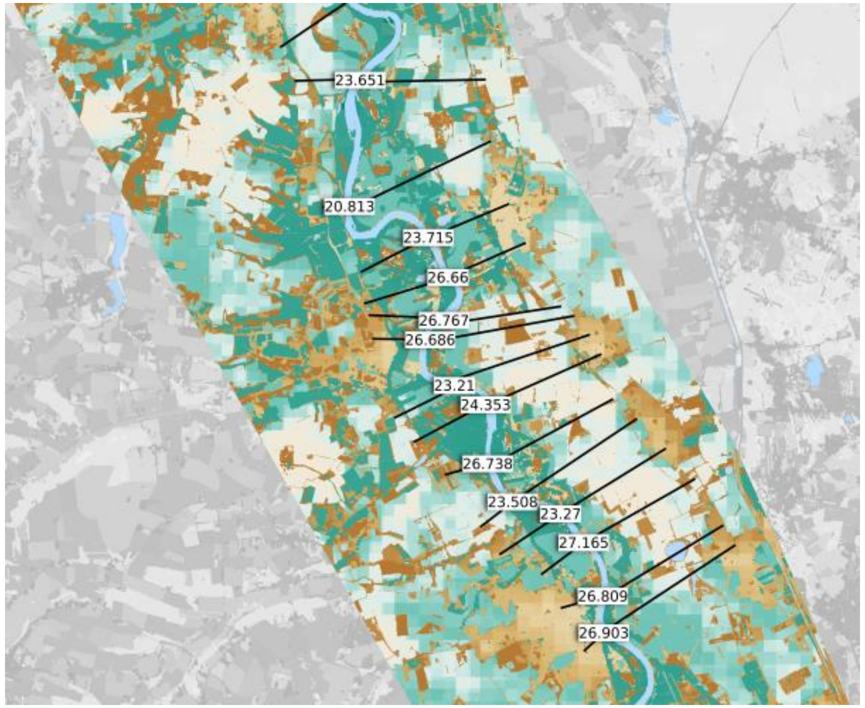
CONCLUSIONS

- Presentation of a **processing chain to derive roughness** coefficients from:
  - Land cover maps, soil composition maps,
  - River geomorphology databases

- Outputs provide:
  - **Maps** of roughness coefficients in **floodplains**,
  - Roughness coefficients at **nodes** along centerlines in **main channel**

- Generated roughness coefficients appears **satisfying priors** for SWOT discharge algorithms (or other applications)

- Processing could be **applied anywhere** thanks to:
  - Publically-available global-scale databases,
  - Possible extension of IOTA^2 chain globally



An example of generated Strikcler coefficients

THANK YOU FOR YOUR ATTENTION

Do you have any questions ?