Satellite observations for runoff and river discharge estimation: STREAMRIDE approach

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INTRODUCTION

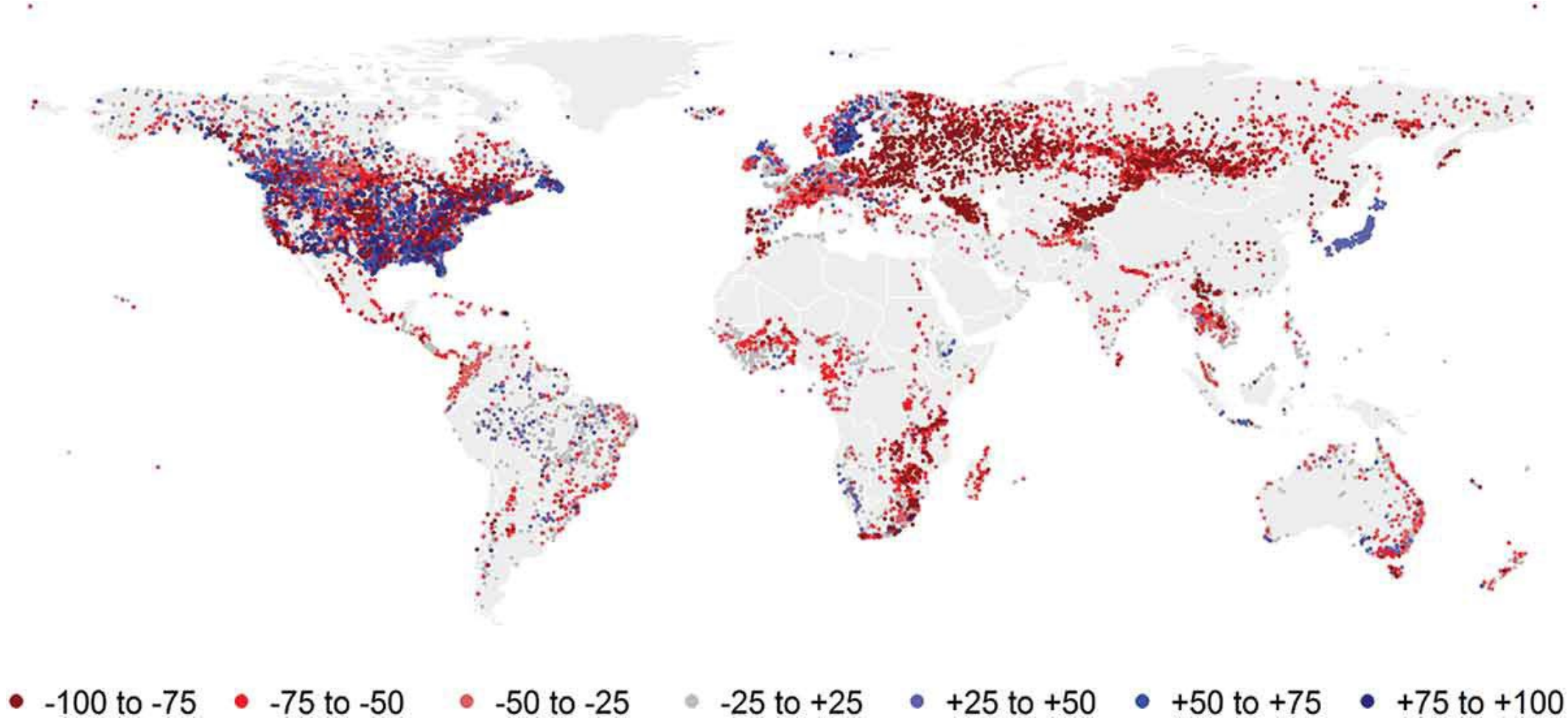
River discharge monitoring is important both for scientific and operational purposes

Credit@ESA

- **Water cycle analysis**
- **Land/oceans freshwater exchanges**
- **Climatic studies**
- **Water quality**
- **Flood risk**
- **Water management**
- **Drought monitoring**

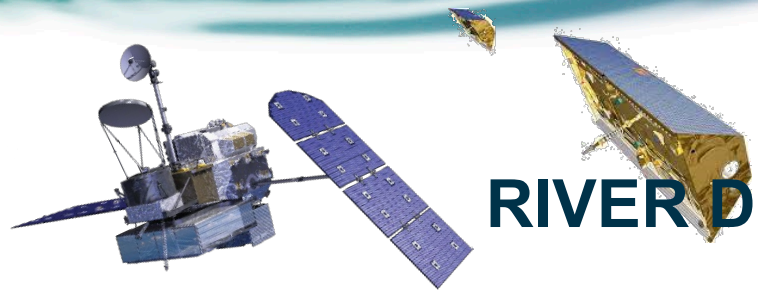
INTRODUCTION

The percent change in data availability between the periods 1961–1990 and 1991–2019 is decreasing



https://doi.org/10.1080/02626667.2019.1659509

RATIONALE



RIVER DISCHARGE ESTIMATION FROM SATELLITE DATA

STREAM model

Conceptual hydrological model based on:

- satellite precipitation
- soil moisture
- terrestrial water storage data

Distributed information over a basin

RIDESAT Algorithm

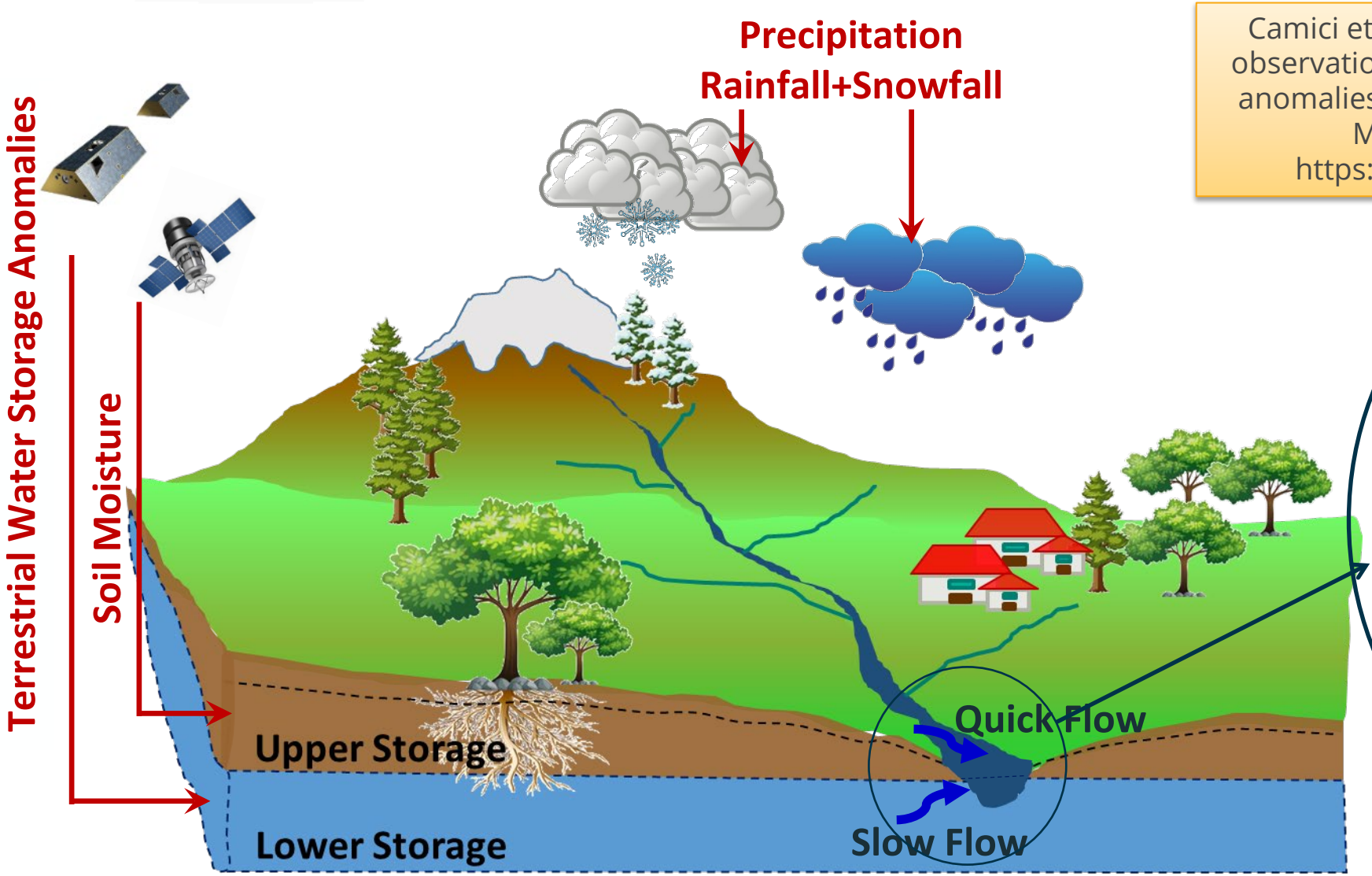
Algorithm based on:

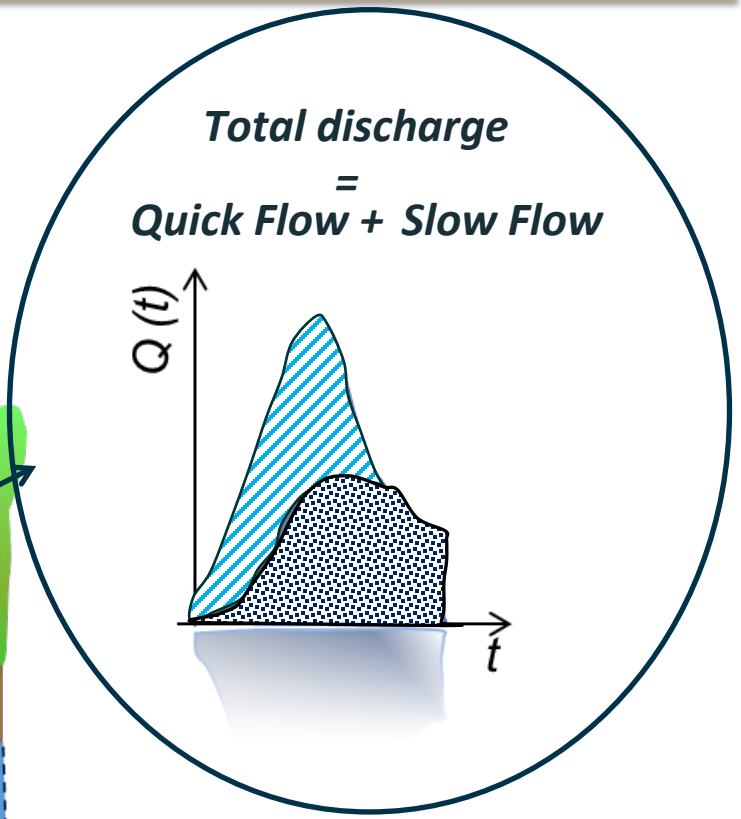
- altimetry
- NIR data
- Hydraulic relationships

Local information over a basin

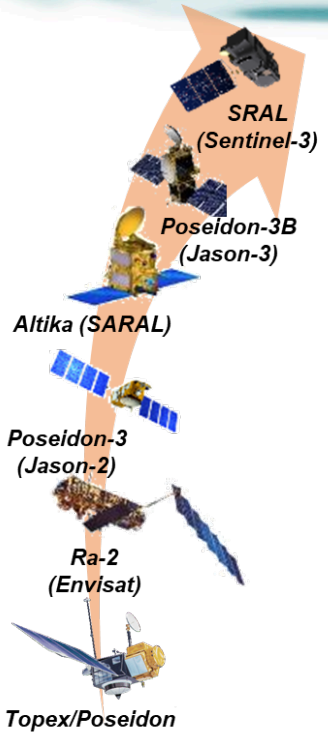
STREAM: THE MODEL

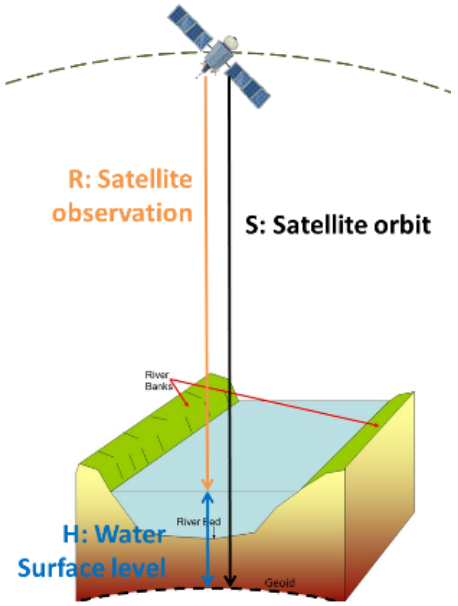
Camici et al. (2021). Synergy between satellite observations of soil moisture and water storage anomalies for global runoff estimation. Geosci. Model Dev. Discuss, In review. https://doi.org/10.5194/gmd-2020-399



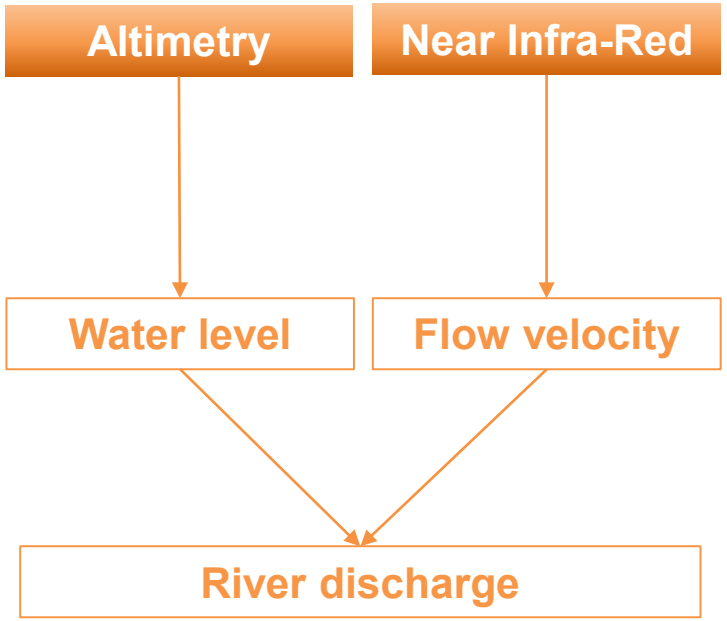


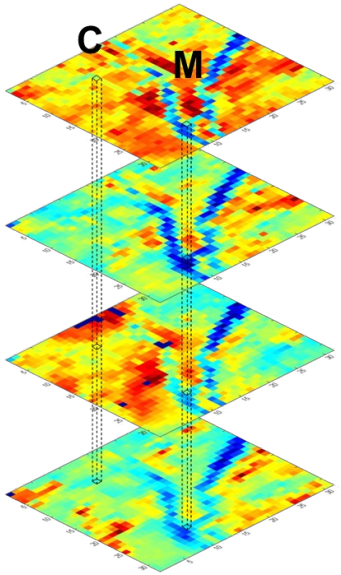
RIDESAT: THE ALGORITHM

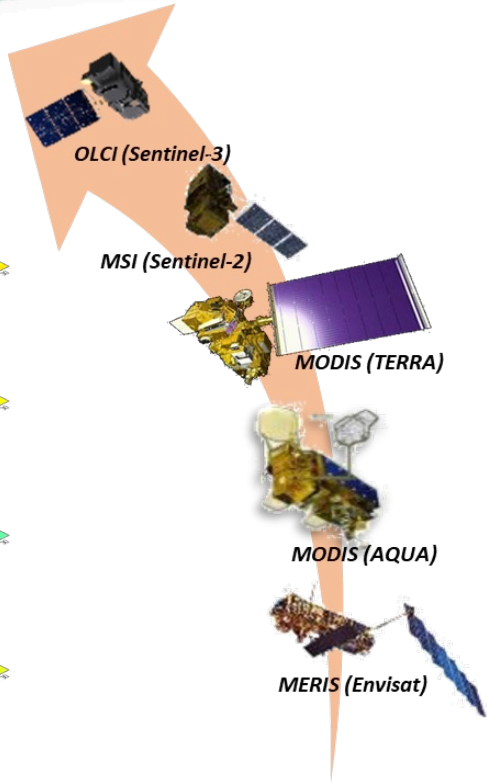




Water Surface Level: $H=S-R$



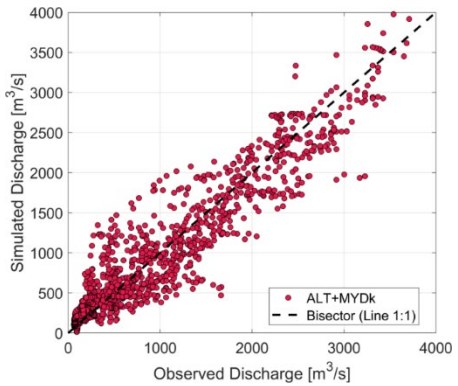




$$\frac{Q}{A_b} = \alpha(H - H_{min})^{\beta} \cdot \left(\frac{C}{M}\right)^{\gamma}$$

A_b	Basin Area
H	Water surface (from altimetry)
C/M	Reflectance ratio (from NIR band)
α, β, γ	Parameters

Despite the altimetry product is highly performing, the rating curve built with the water level derived by altimetry and observed discharge provides lower performances w.r.t. the proposed approach in which also the contribution of NIR bands is included.



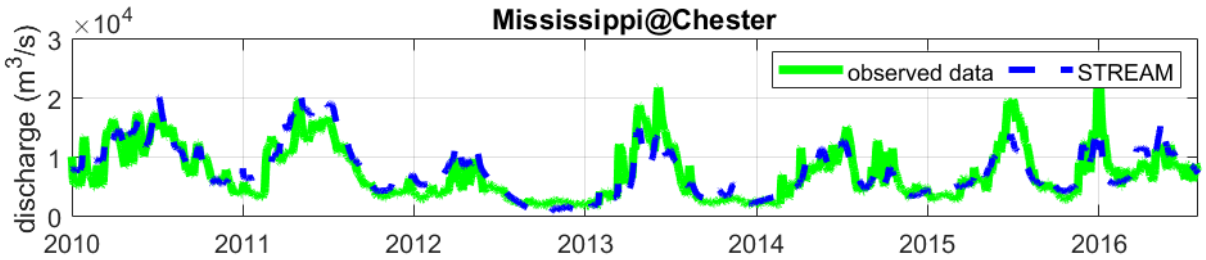
ADVANTAGES/LIMITS OF THE MODELS

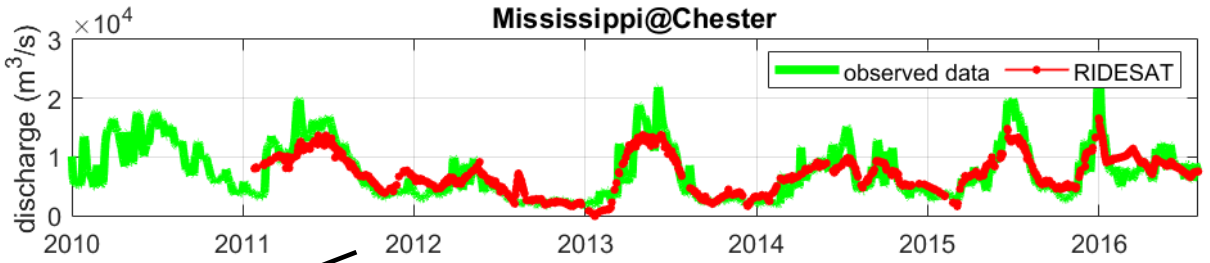
STREAM	RIDESAT
Spatial information over a basin	Local information on hydraulic variables
Good capability to reproduce runoff and river discharge times series at daily time step	Good capability to reproduce river discharge times series about every 3 days
Fast modelling set-up	Time consuming pre-processing of the satellite data

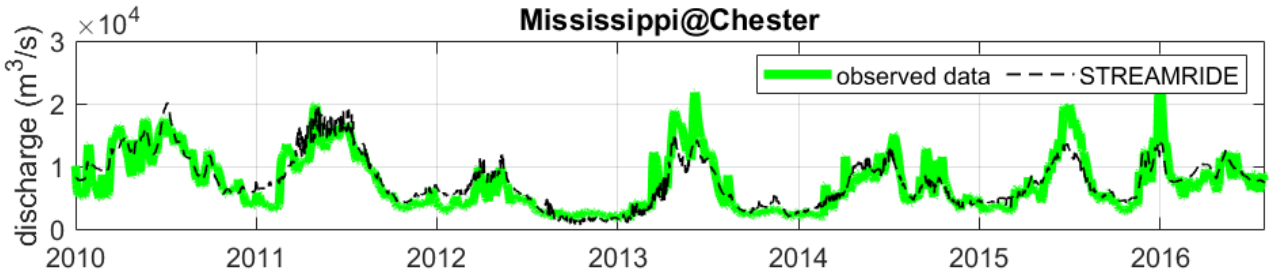
Poor reliability in the river discharge (and runoff) estimation over: ❑ **mountainous** basins and **snow** covered areas ❑ highly **vegetated** areas	❑ Inconsistency of the reflectance derived by **different multispectral satellite sensors** ❑ Presence of **vegetation**, **sediments** and snow that affect the reflectance derived by multispectral sensors
Poor reliability in the river discharge (and runoff) estimation in presence of: ❑ **dam, reservoirs**/floodplains ❑ Basins with high anthropogenic impact (**irrigation**)	❑ Poor reliability in presence of morphological **discontinuity** along the river (reservoirs or dykes) not modelled by altimetry river model ❑ Presence of **outliers** in the water level estimated by altimeters with consequent erroneous estimation of river discharge

WORKING FRAMEWORK

1. Improvement of the STREAM model and the RIDESAT algorithm



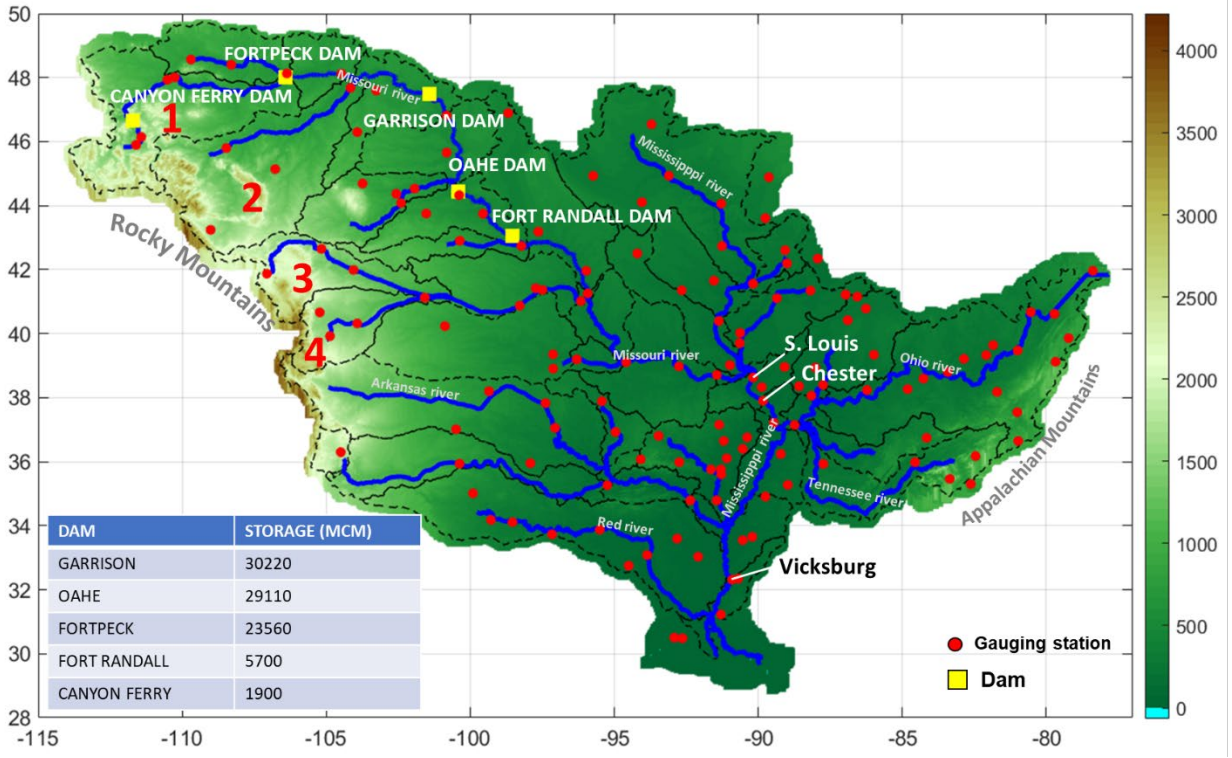




2. Integration of the two satellite-based approaches for river discharge estimation

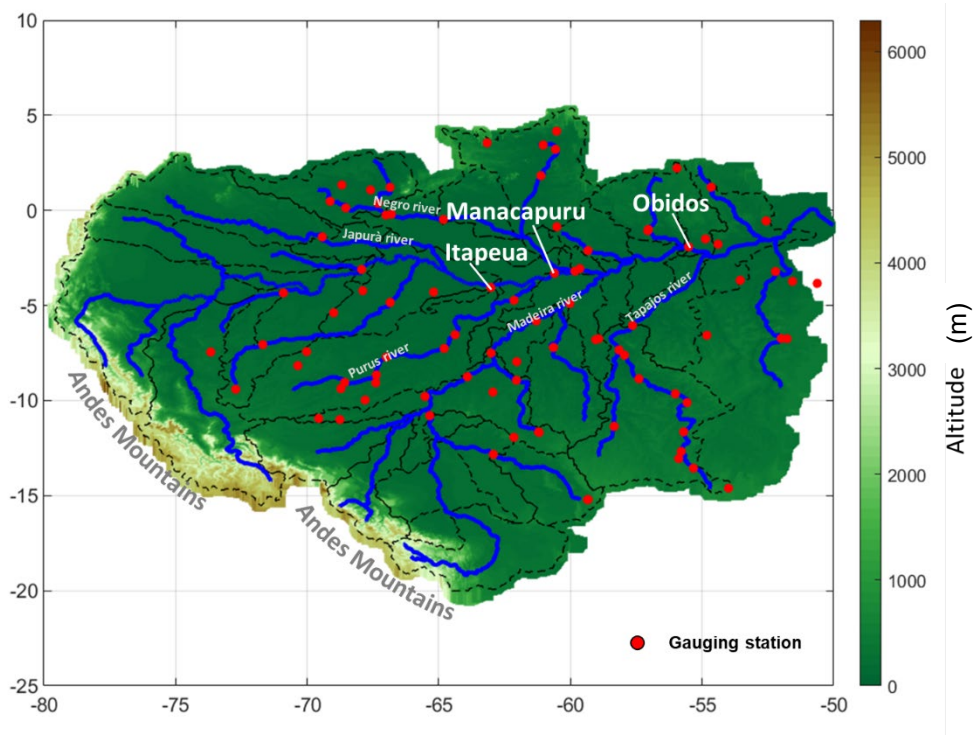
STUDY AREAS

Mississippi river basin



DAM	STORAGE (MCM)
GARRISON	30220
OAHE	29110
FORTPECK	23560
FORT RANDALL	5700
CANYON FERRY	1900

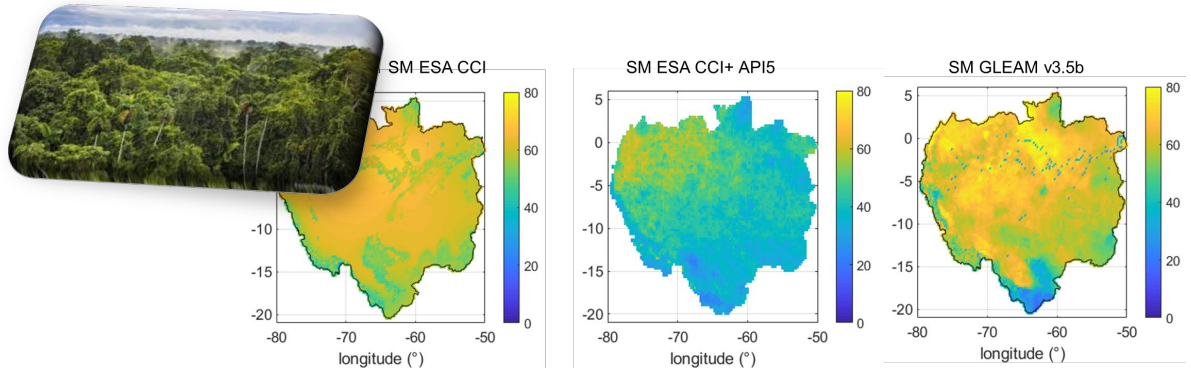
Amazon river basin

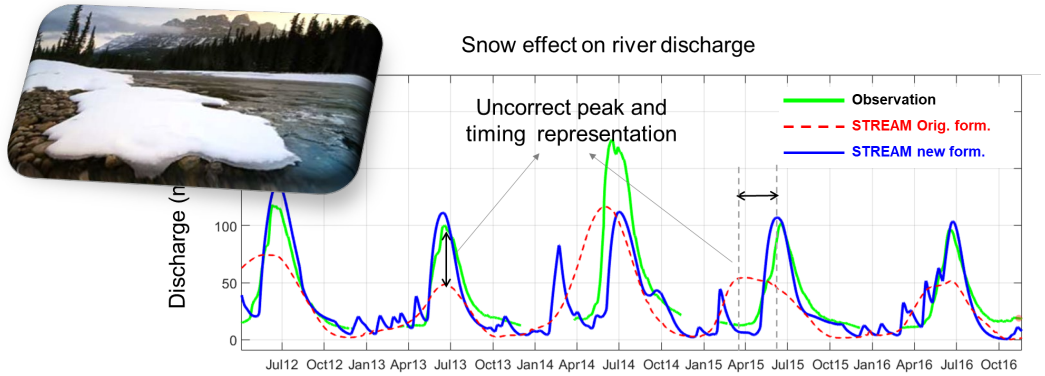


IMPROVEMENT OF STREAM MODEL

Data issues

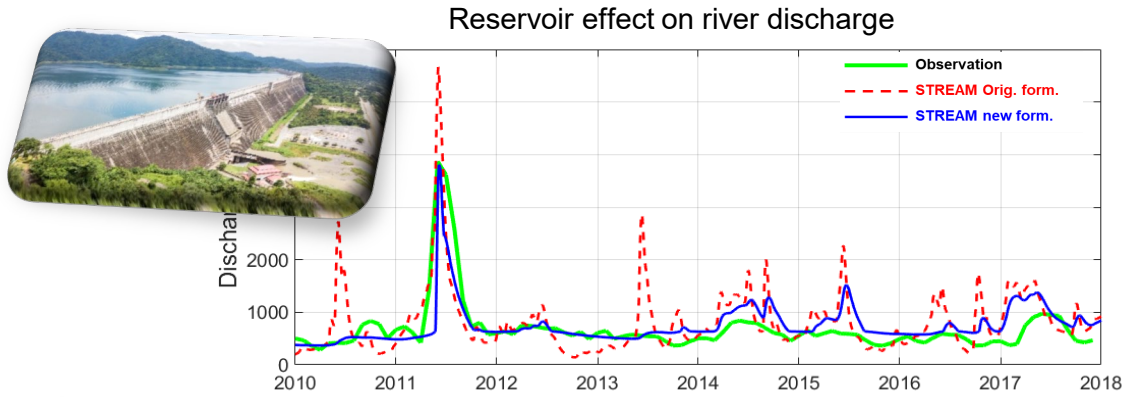
- Soil moisture data analysis over highly **vegetated areas**
- Modification of the original model to simulate the presence of **snow**

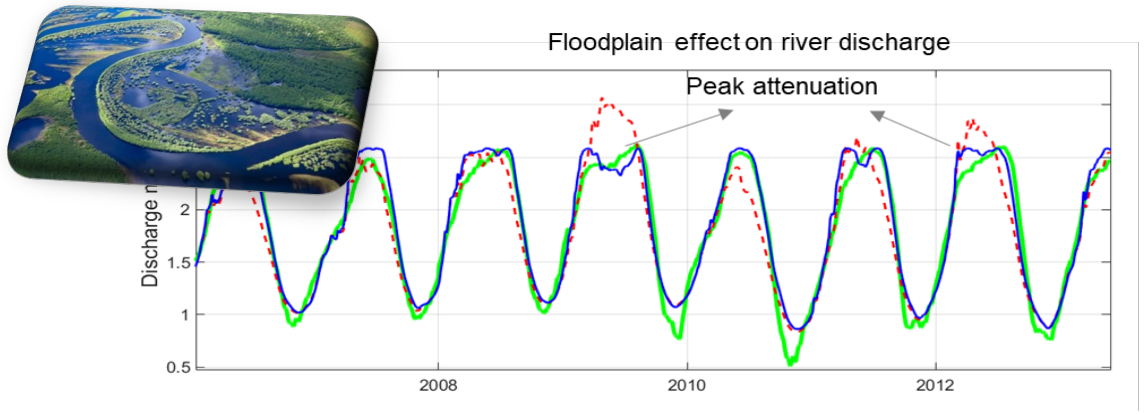




Modelling issue

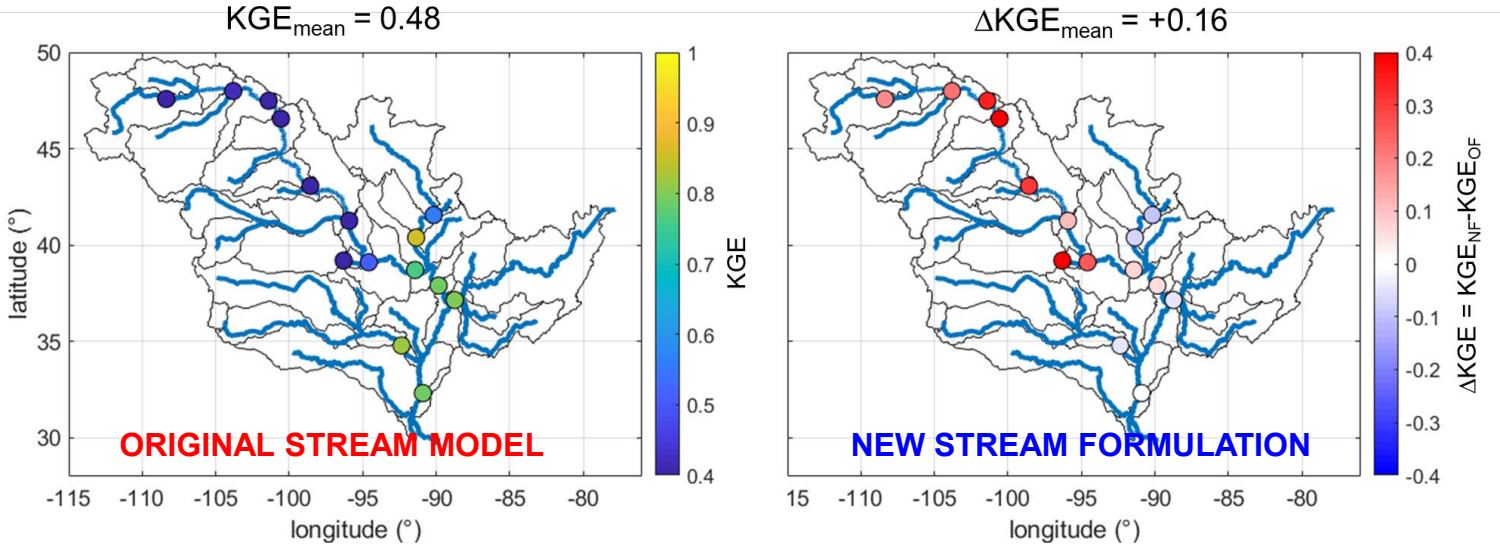
- Modification of the original model by adding two modules for **reservoirs** and **floodplains**





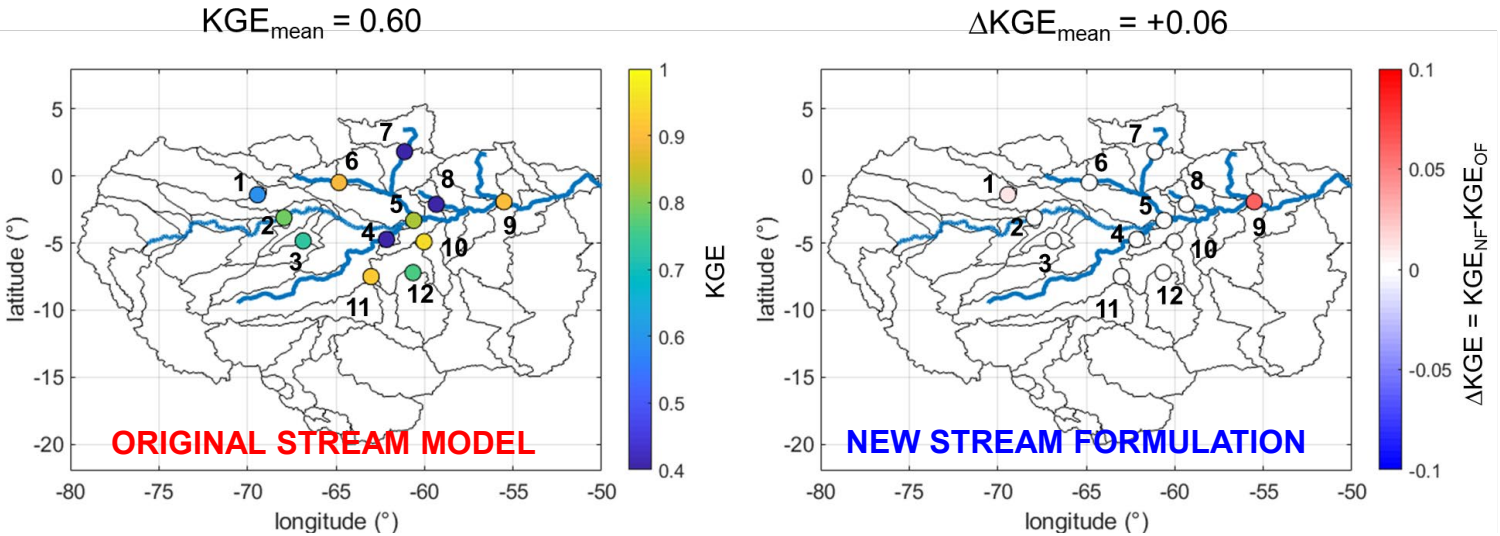
IMPROVEMENT OF STREAM MODEL

Mississippi river basin



Over the mountainous part of the basin and downstream large dams

Amazon river basin

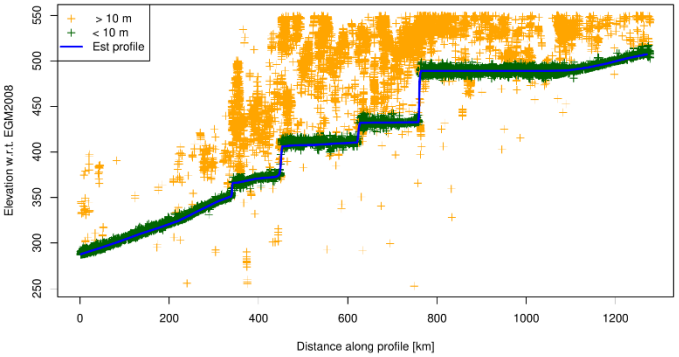


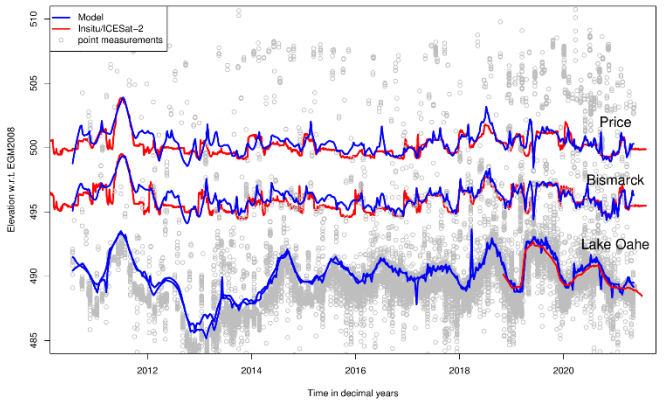
In presence of floodplain

IMPROVEMENT OF RIDESAT ALGORITHM

Altimetry

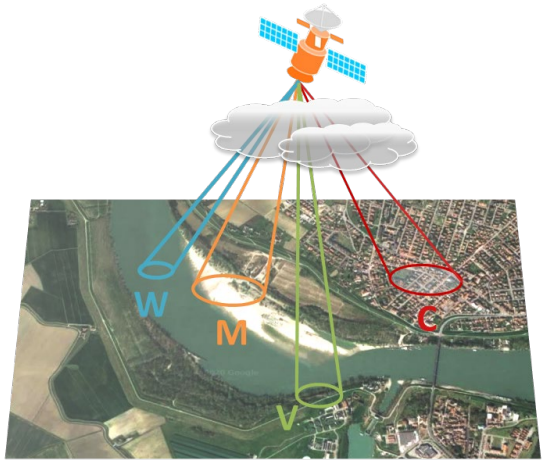
- Identification of **outliers** and removing thanks to Ice-sat 2 satellite slope profile
- Overcome of the **discontinuity** related to the reservoirs or dam with a modification of the state-space model that modelled the multi-mission time series from several altimetry data

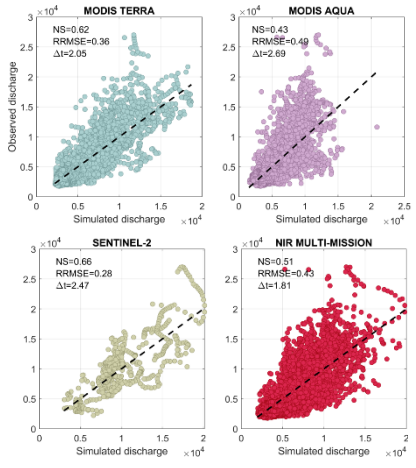




Near Infra-Red

- Modification of the original algorithm by adding two components: **sediments** and **vegetation**.
- Improving the temporal sampling of the time series by considering **multi-mission NIR approach** to reach the nearly daily resolution.





IMPROVEMENT OF RIDESAT ALGORITHM

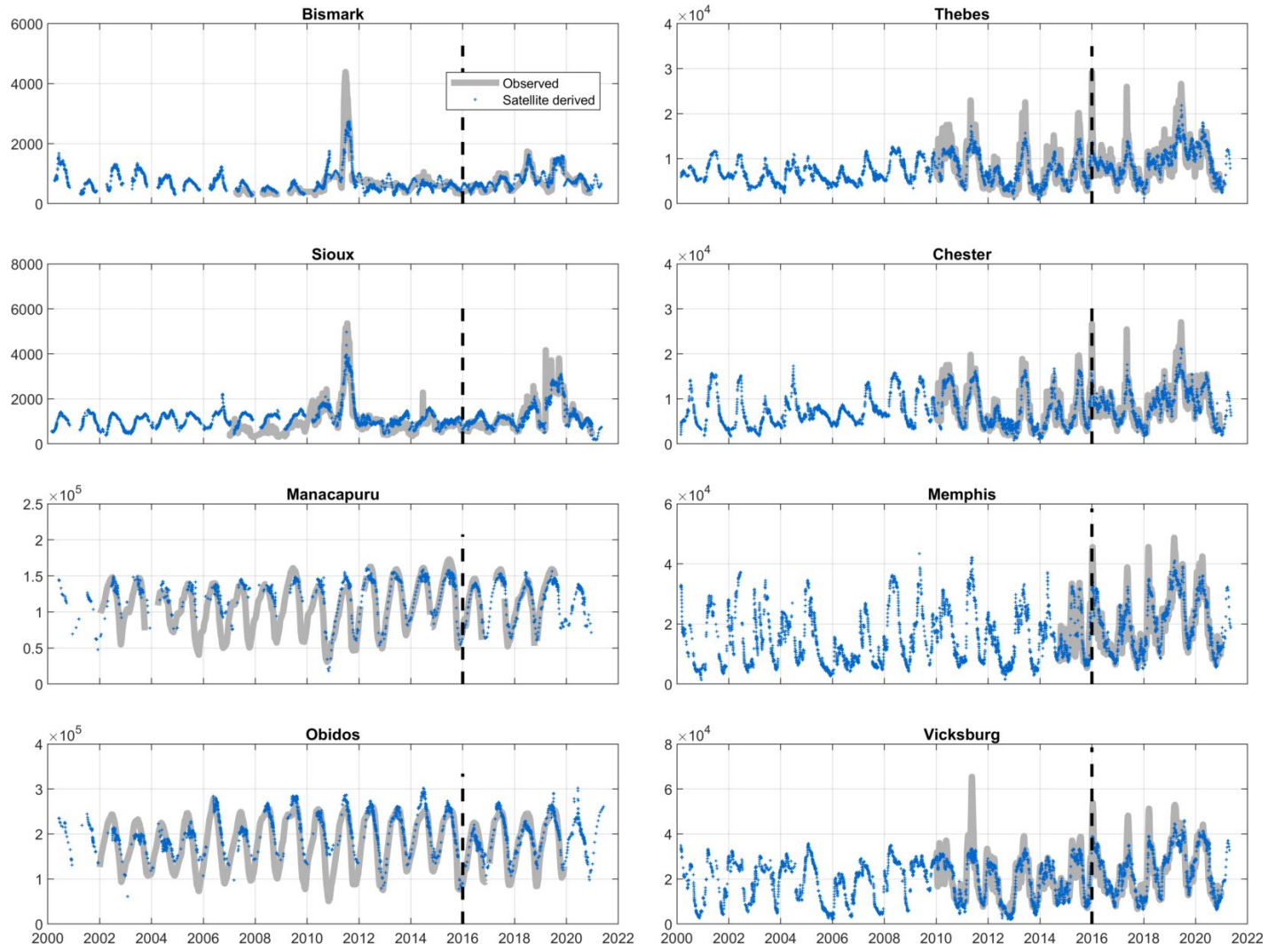
$$Q_{ridesat}=\alpha \cdot (h-h_{min})^{\beta} \cdot CM^{\gamma}$$

$Q_{ridesat}$	Cal|Val
rRMSE	14% | 22%
NS	0.89 | 0.84
KGE	0.94 | 0.87

Improvements w.r.t. RIDESAT original

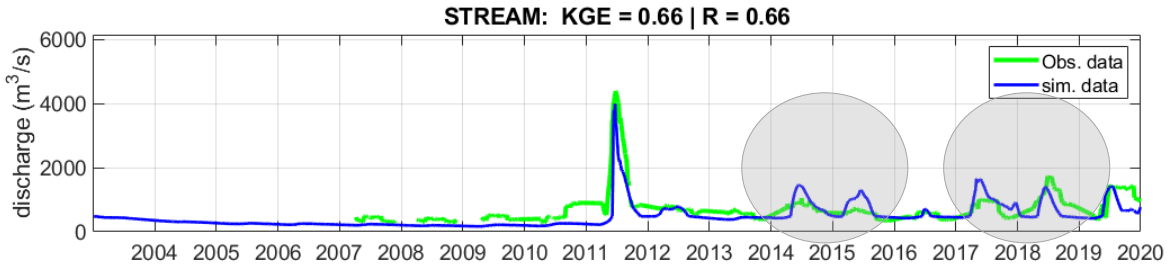
Chester	ΔNS=+7%
Memphis	ΔNS=+1%
Manacapuru	ΔNS=+1%

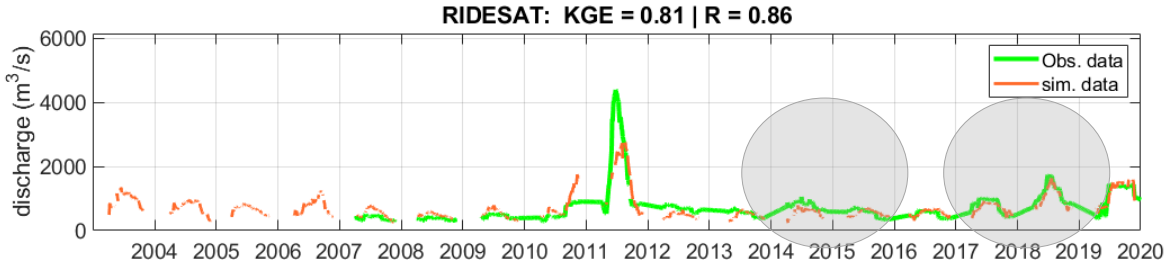
Frequency on average 1 measurement every 1.66 days (compared to 3 days)

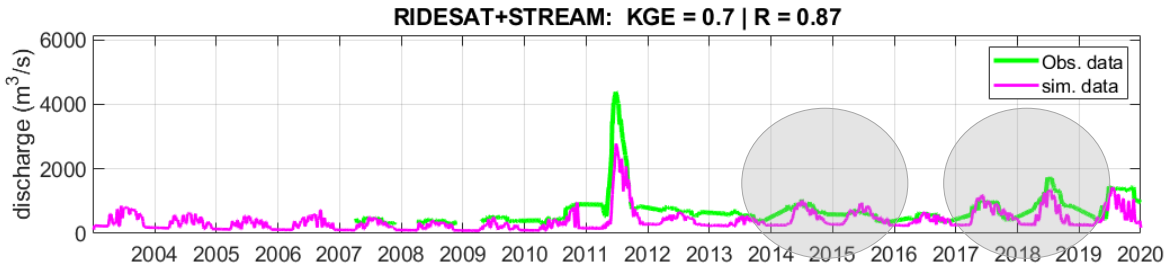


THE ADVANTAGE OF RIVER DISCHARGE INTEGRATION

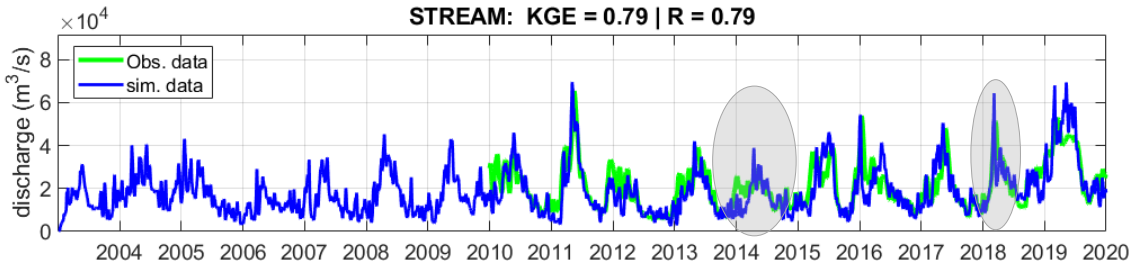
Mississippi@Bismark

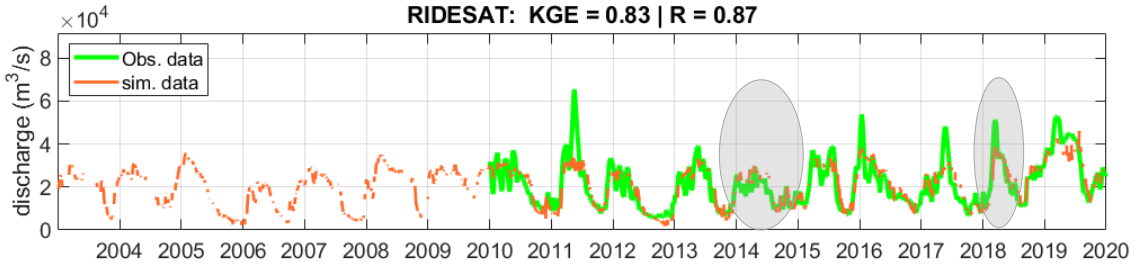


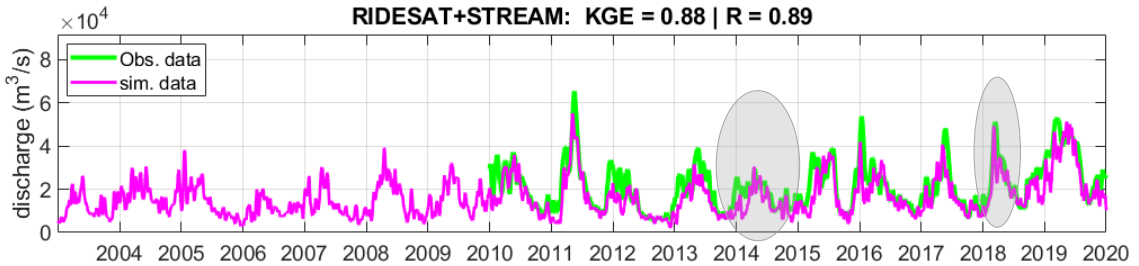




Mississippi@Vicksburg



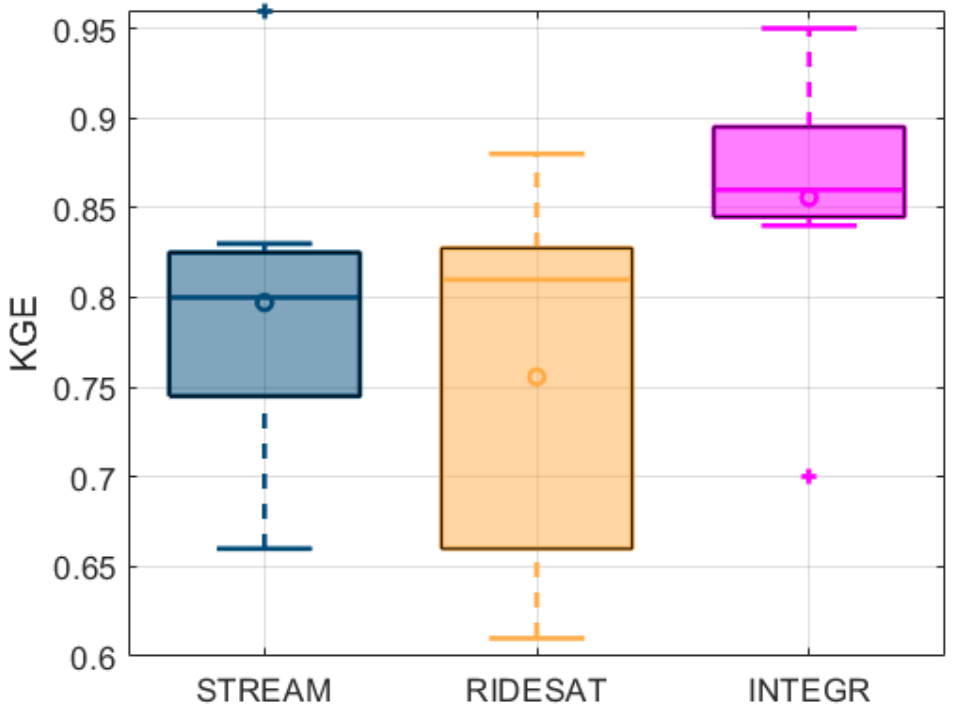




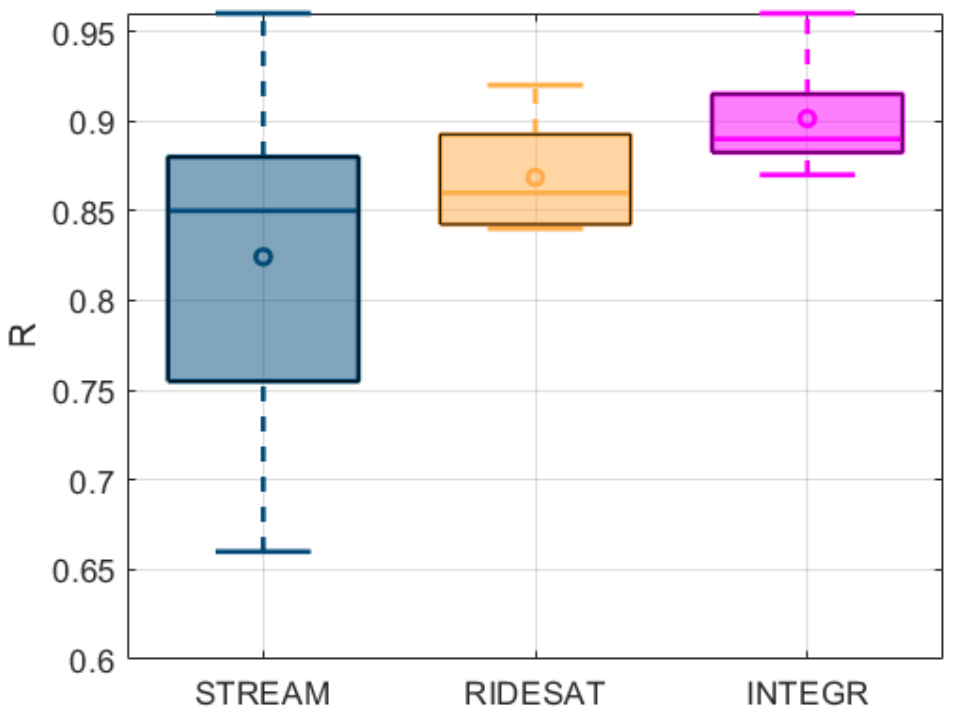
The integration provides **continuous and more accurate time series**

THE ADVANTAGE OF RIVER DISCHARGE INTEGRATION

KGE_{med}	0.80	0.81	0.86

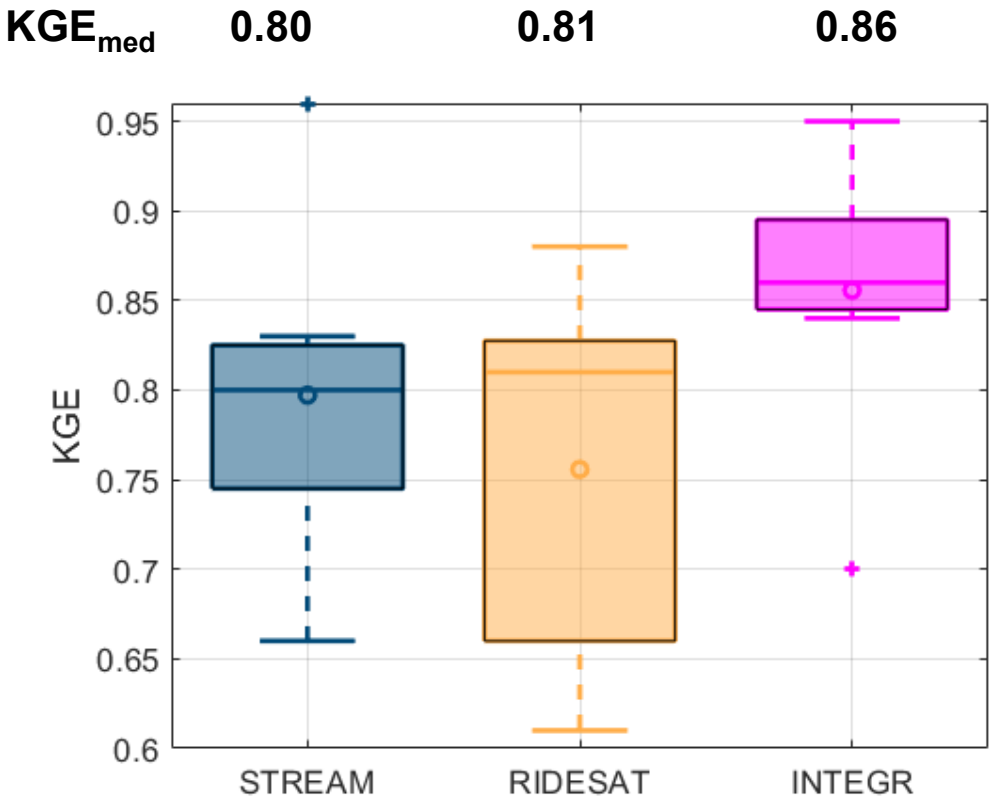


R_{med}	0.85	0.86	0.89



The integration improves the performances over all the analysed stations

CONCLUSIONS AND FUTURE PERSPECTIVE



- STREAM model and RIDESAT algorithm, each one with its intrinsic limits, provide accurate satellite-based river discharge estimation
- A simple integration method is able to improve the river discharge estimates
- Both the methods are ready to be extended at global scale
- Different approaches will be used to integrate the method (e.g., data assimilation)

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THANK YOU FOR YOUR ATTENTION