climate change initiative

RIVER DISCHARGE

Combined satellite-based river discharge

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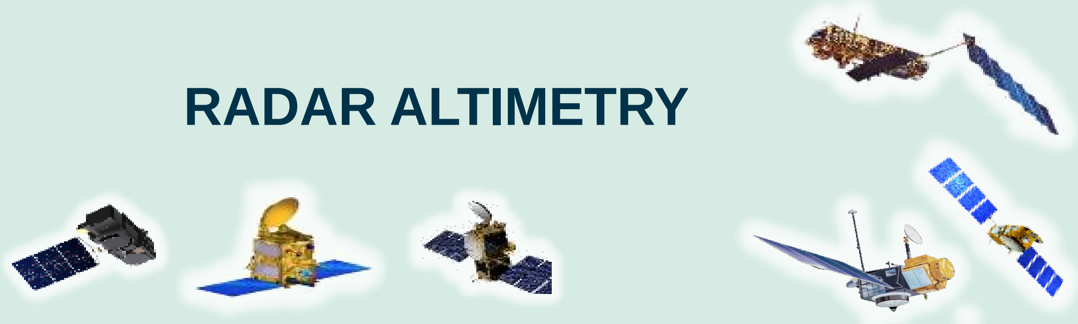
User Workshop

Météo-France, Toulouse

03-04 June 2024

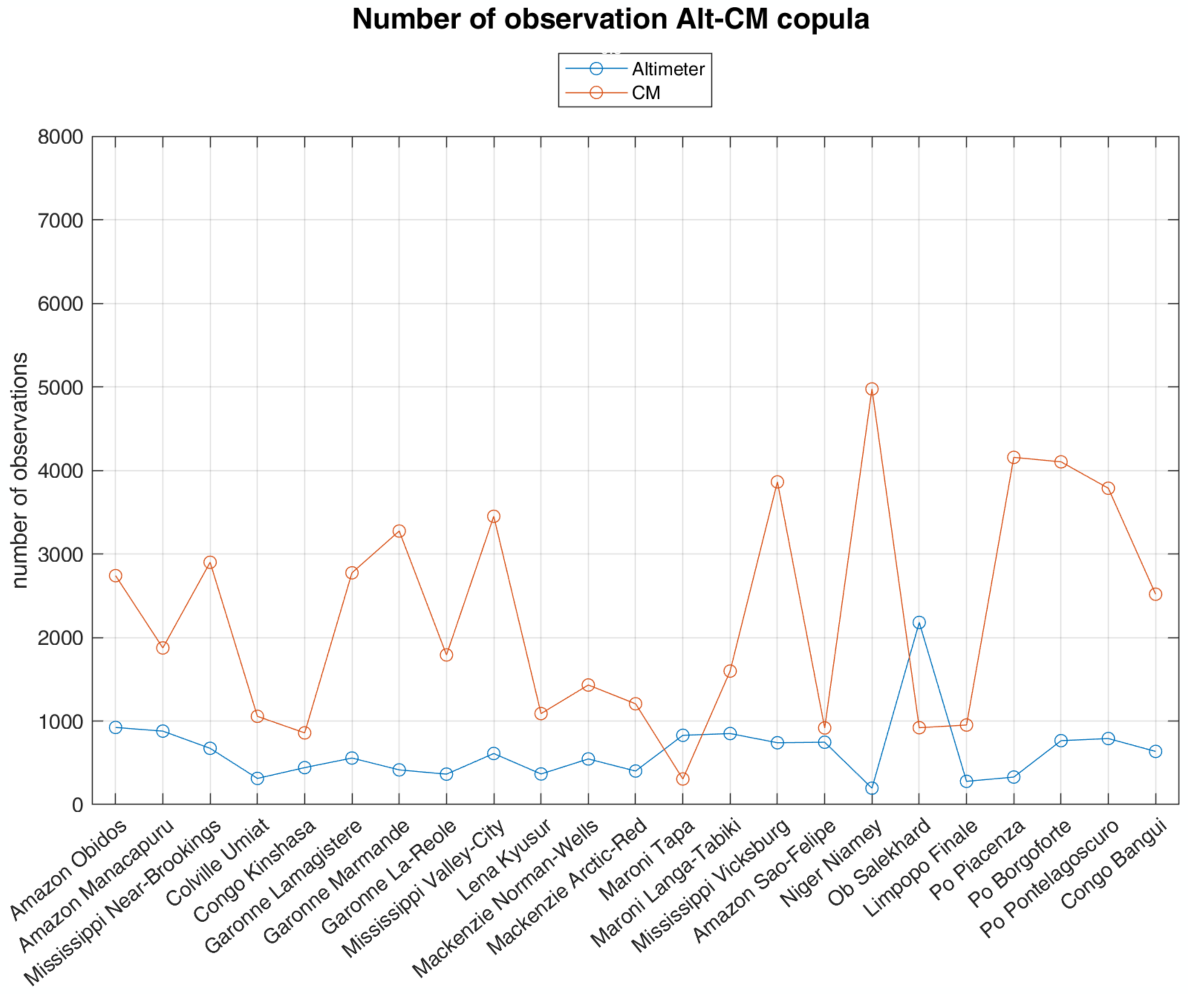
river discharge cci

RATIONALE

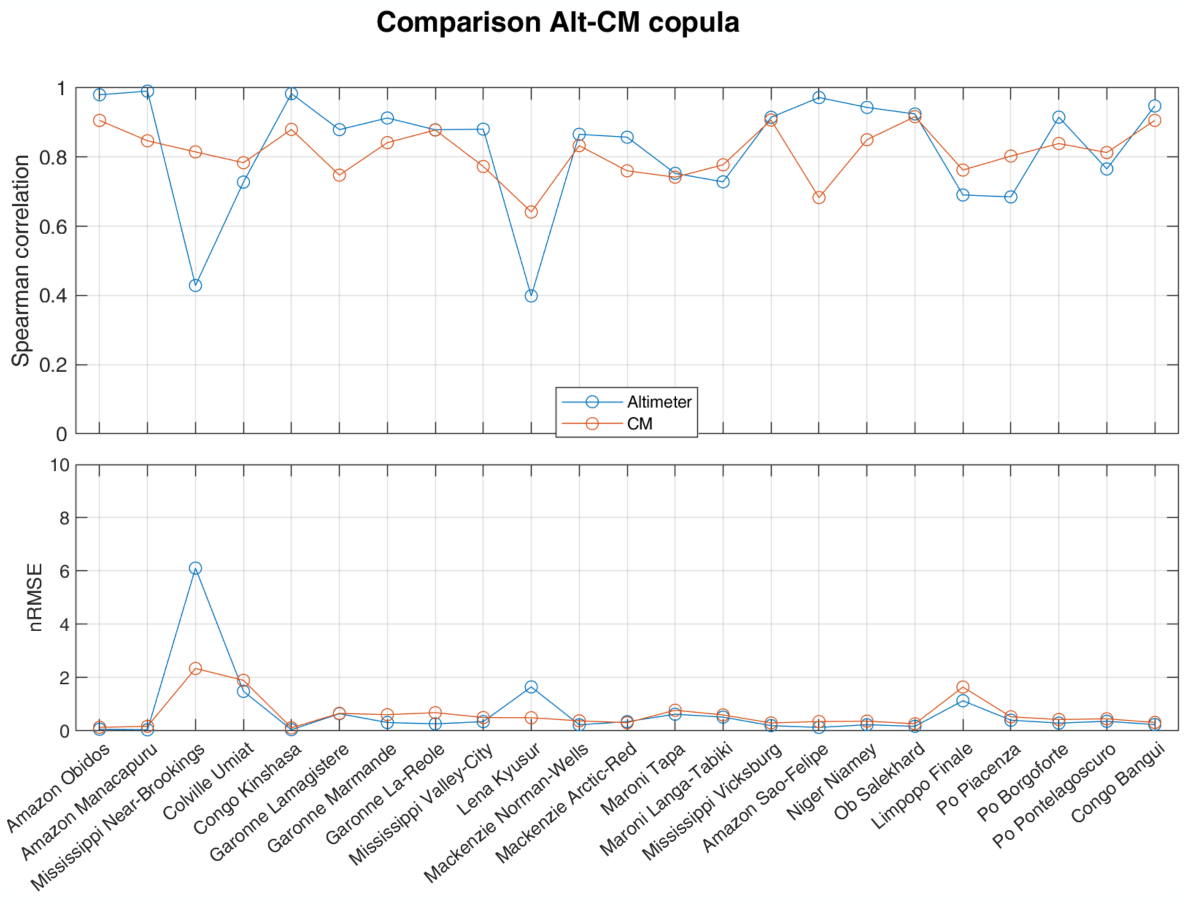
Sensor	Limits	Advantages
RADAR ALTIMETRY 	Problems with spatial coverage and temporal frequency (SWOT and multi-mission can help)	Accurate and reliable
NEAR INFRARED SENSORS 	Cloud coverage, freezing soils and water	Large spatial and temporal coverage

Tarpanelli et al. 2019, Adv Space Res, doi:10.1016/j.asr.2019.08.005

RATIONALE



Number of observation Alt-CM copula
Altimeter
CM
number of observations
8000
7000
6000
5000
4000
3000
2000
1000
0
Amazon Obidos
Amazon Manacapuru
Mississippi Near-Brookings
Colville Umiat
Congo Kinshasa
Garonne Lamagistere
Garonne Marmande
Garonne La-Reole
Mississippi Valley-City
Lena Kyusur
Mackenzie Norman-Wells
Mackenzie Arctic-Red
Maroni Tapa
Maroni Langa-Tabiki
Mississippi Vicksburg
Amazon Sao-Felipe
Niger Niamey
Ob Salekhard
Limpopo Finale
Po Piacenza
Po Borgoforte
Po Pontelagoscuro
Congo Bangui



Comparison Alt-CM copula
Spearman correlation
1
0.8
0.6
0.4
0.2
0
Altimeter
CM
nRMSE
10
8
6
4
2
0
Amazon Obidos
Amazon Manacapuru
Mississippi Near-Brookings
Colville Umiat
Congo Kinshasa
Garonne Lamagistere
Garonne Marmande
Garonne La-Reole
Mississippi Valley-City
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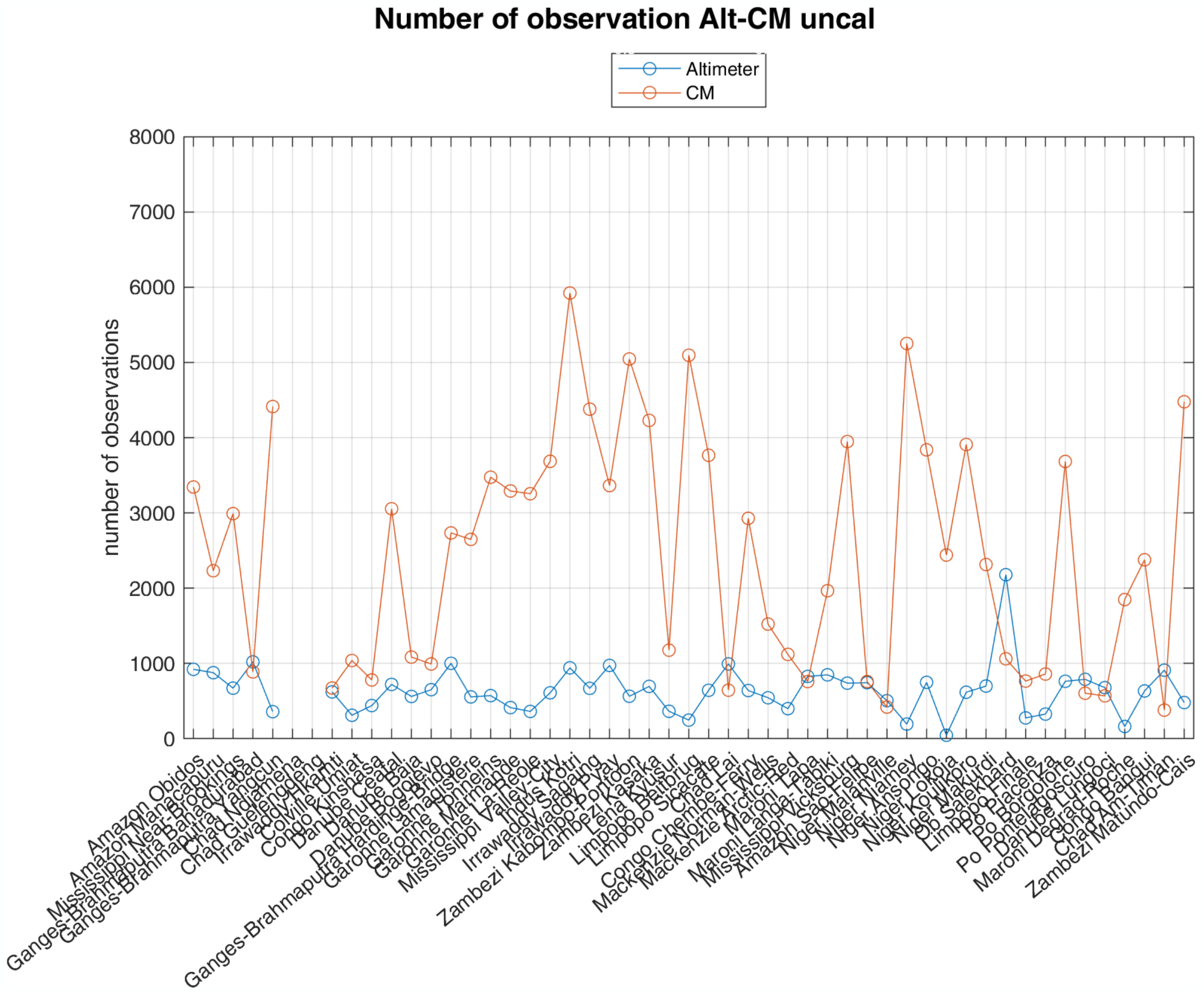
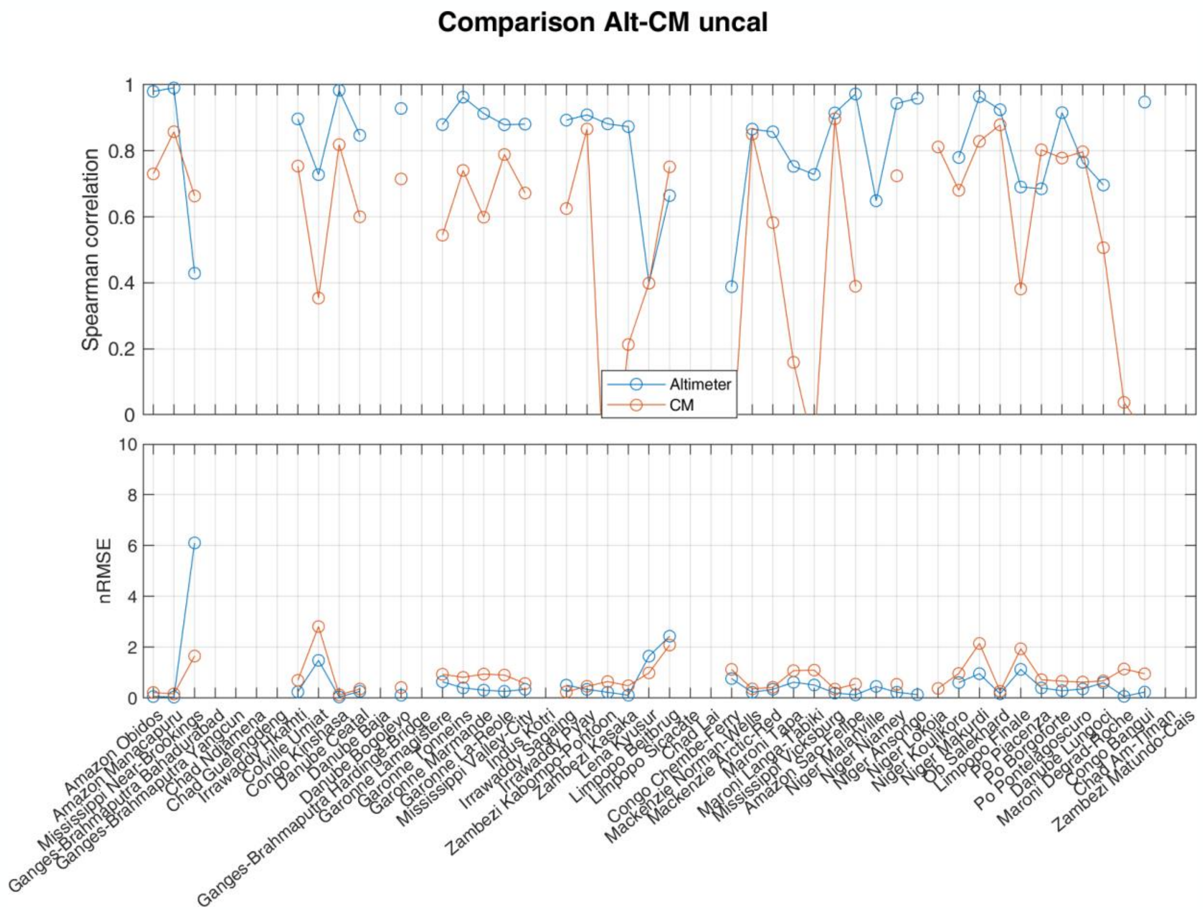
RATIONALE



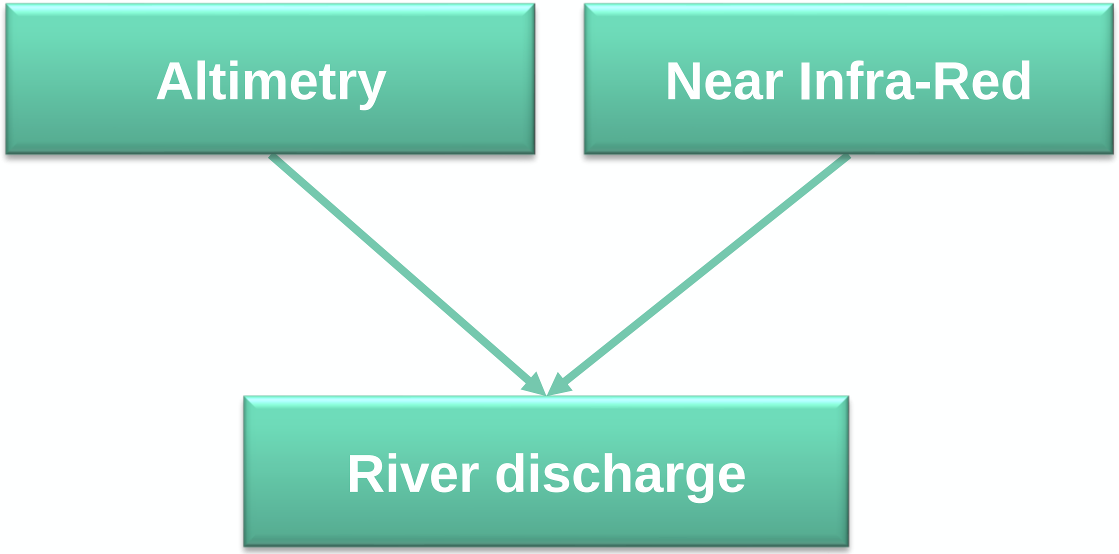
Number of observation Alt-CM uncal
Altimeter
CM
number of observations



Comparison Alt-CM uncal
Spearman correlation
Altimeter
CM
nRMSE

RATIONALE

The solution is to merge the two information but HOW?



Several approaches have been implemented within the ESA projects (RIDESAT and STREAMRIDE) that allow to maximize the information coming from both altimetry and multispectral approaches:

- RIDESAT approach
- statistical approach (Copula or cdf)
- Level 3 approach (Q obtained by CM and WL)
- Machine learning

RIDESAT approach

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

Tarpanelli et al. in preparation

satellite altimeter

NIR band

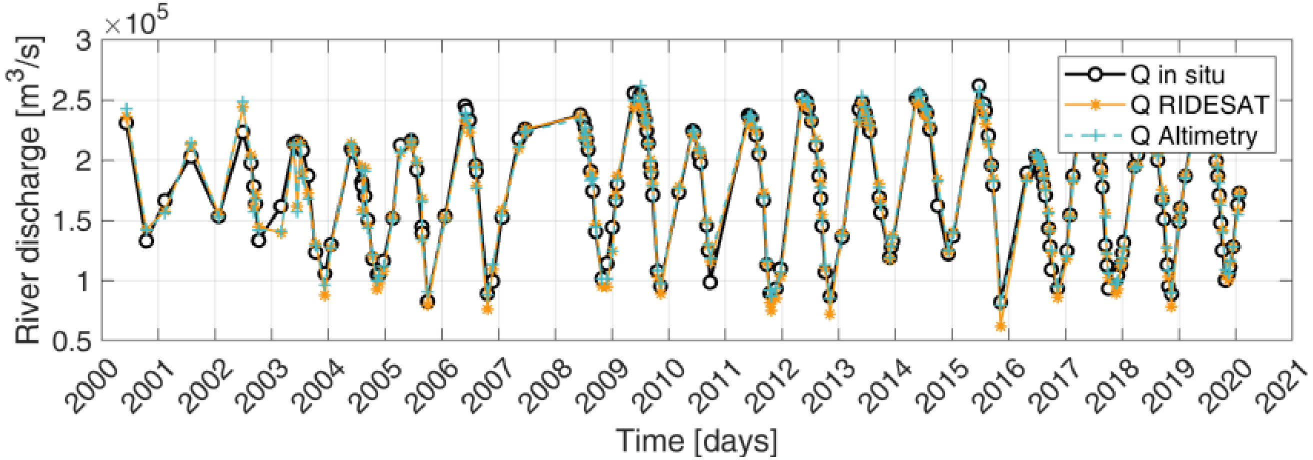
MAIN LIMITATIONS:

- **Underestimation** of the peak values due to multispectral sensors (presence of the clouds during high flow events)
- **Low frequency** of the time series due to the altimeter revisit time

SOLUTION:

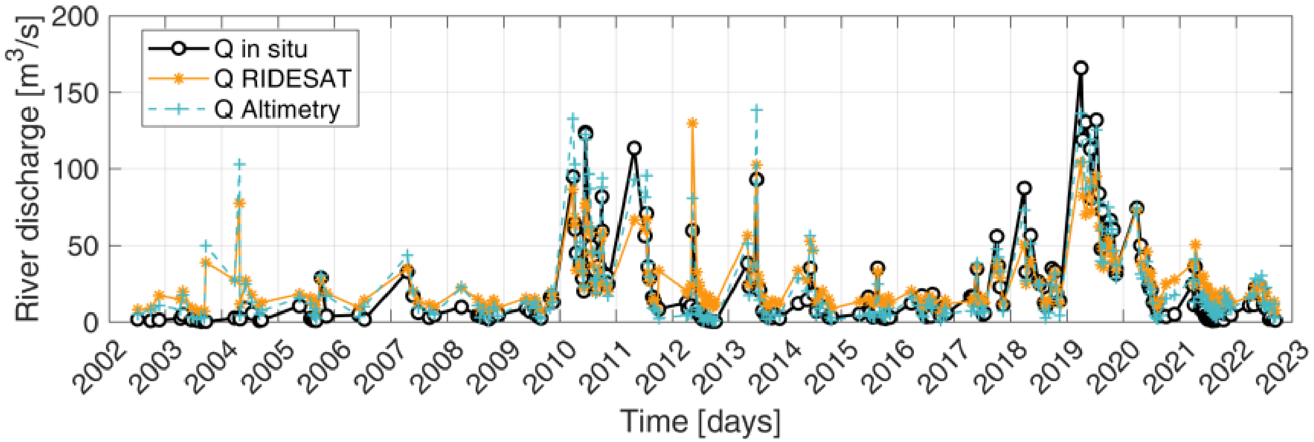
Multi-mission approaches help to increase the frequency of the temporal series and the monitoring of the extreme events with the radar sensors

RIDESAT approach



Amazon at Obidos

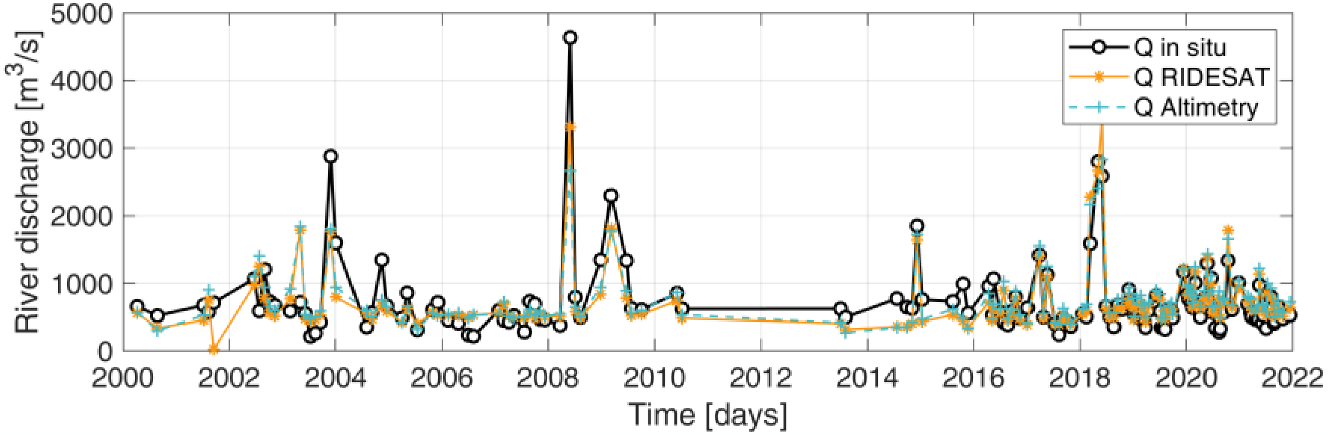
R= 0.982	R=0.985
RRMSE=5.31%	RRMSE=4.92%
NSE=0.964	NSE=0.969
KGE=0.982	KGE=0.981



Bix Sioux at Near Brookings

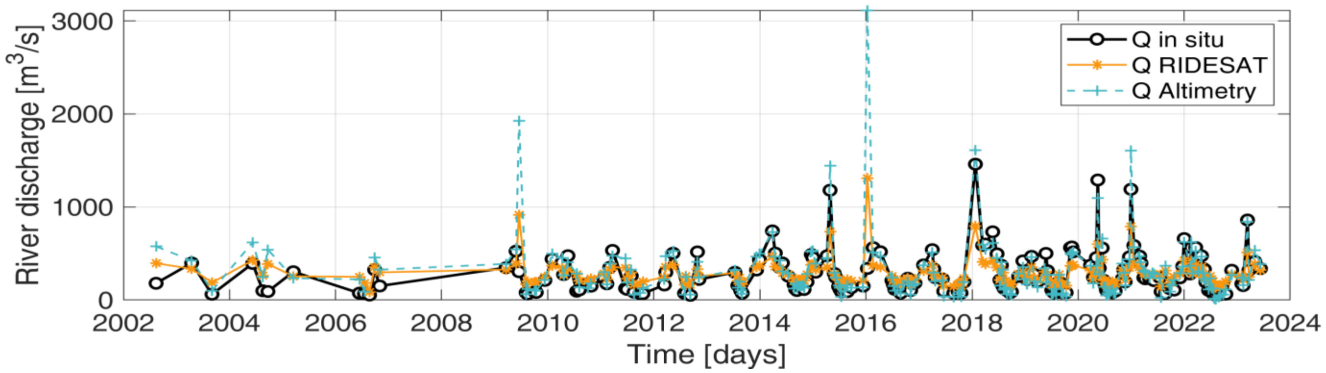
R= 0.87	R=0.913
RRMSE=71.1%	RRMSE=58.7%
NSE=0.714	NSE=0.805
KGE=0.626	KGE=0.829

RIDESAT approach



Po at Borgoforte

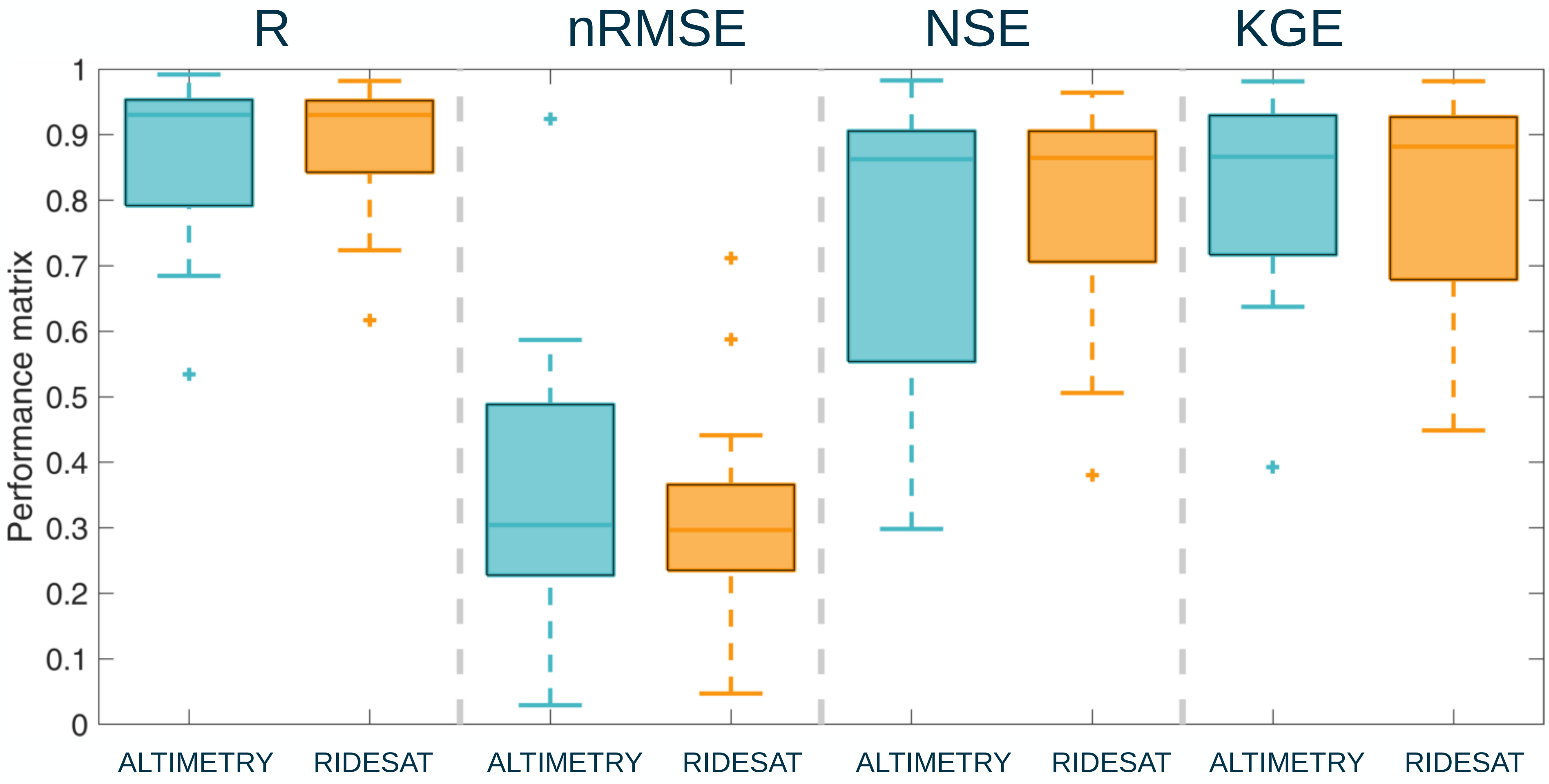
R= 0.838	R=0.745
RRMSE=29.3%	RRMSE=40.4%
NSE=0.699	NSE=0.426
KGE=0.732	KGE=0.722



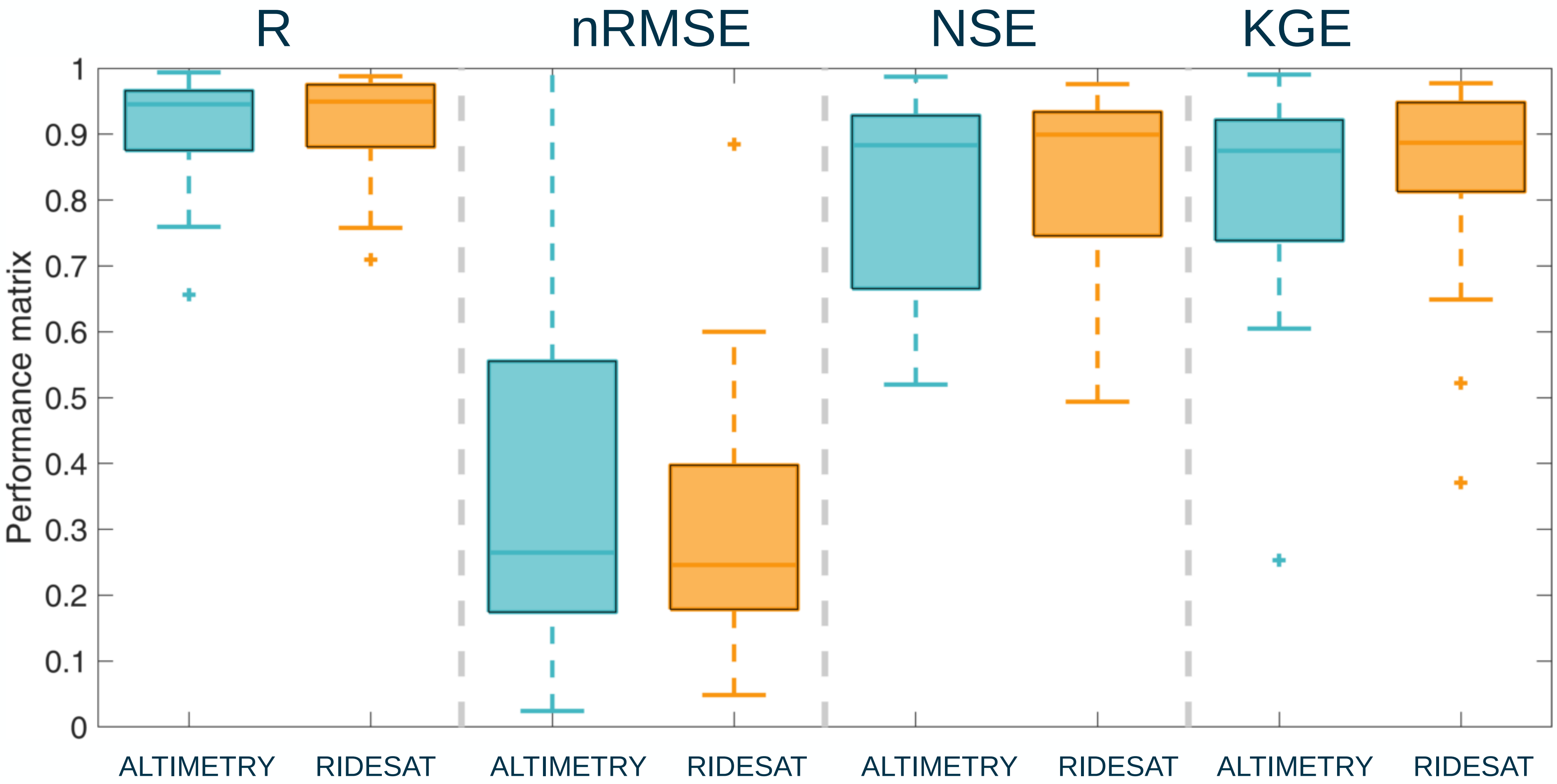
Garonne at Lamagistere

R= 0.724	R=0.685
RRMSE=58.8%	RRMSE=92.4%
NSE=0.506	NSE=-0.216
KGE=0.514	KGE=0.393

Results for 16 sites with CM from calibrated procedure

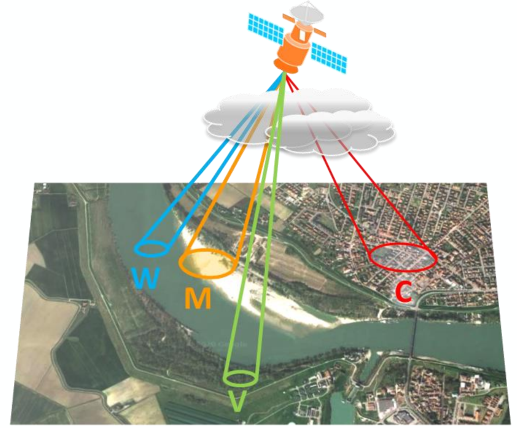


Results for 16 sites with CM from uncalibrated procedure



Copula Approach

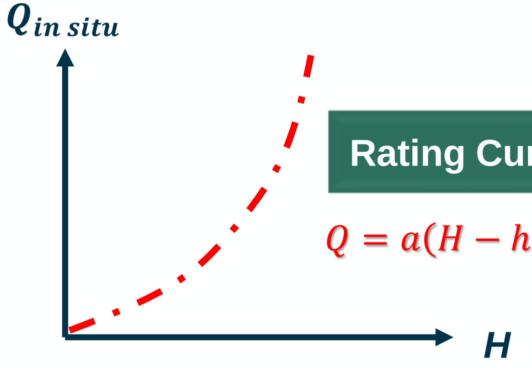
Multi-mission CM timeseries



Best-Suitable for the sites

Altimeter-derived WL

Coincident CM and WL (Altimeter) timeseries extraction



Rating Curve

$Q = a(H - h_o)^b$

Date Pre-processing & Analysis

- Estimation of marginal density
- Estimation of scale-free association

Fitting the Copula Model

- Fitting copula functions preserving the dependence
- Estimation of dependence Parameter

Kolmogorov-Smirnov & Cramér-von Mises Statistic

Goodness -of-fit stat

Selection of best-fit Copula Model

Development of joint distribution among the CM and WL (Altimeter)

CM Time series

WL Time series (Altimeter)

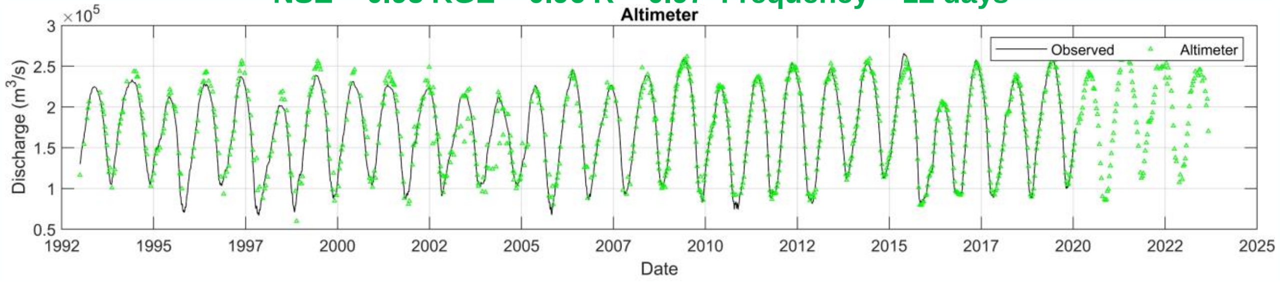
WL Time series (CM)

WL Time series (Altimeter +CM)

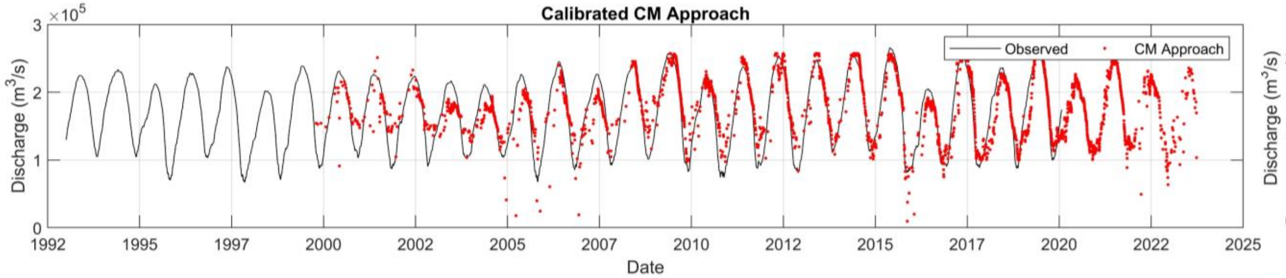
Copula Approach

Obidos Station, Amazon River

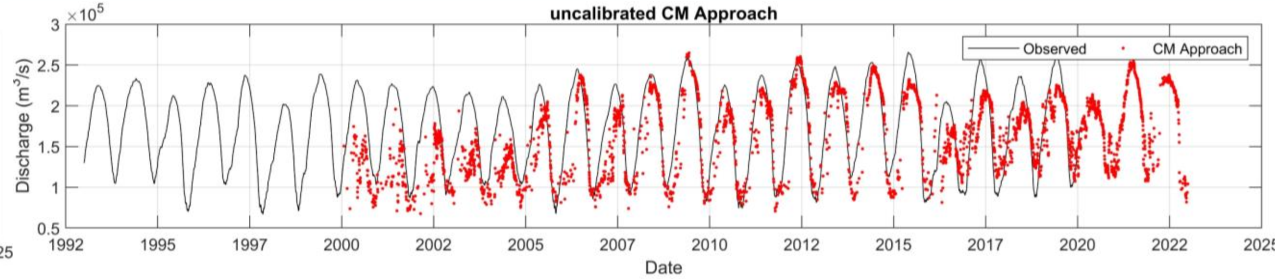
NSE = 0.95 KGE = 0.96 R = 0.97 Frequency = 12 days



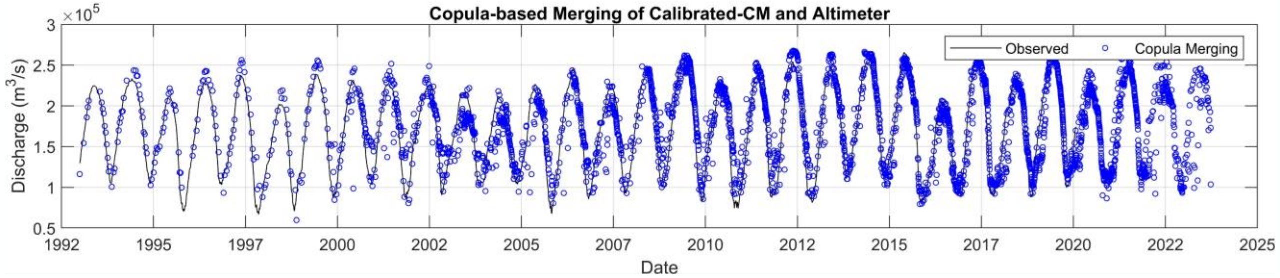
NSE = 0.77 KGE = 0.83 R = 0.89 Frequency = 3.1 days



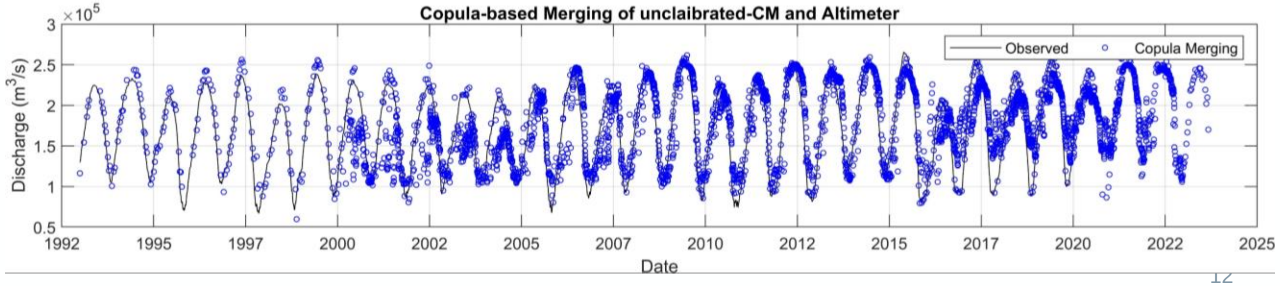
NSE = 0.36 KGE = 0.70 R = 0.72 Frequency = 2.51 days



NSE = 0.84 KGE = 0.89 R = 0.91 Frequency = 2.5 days



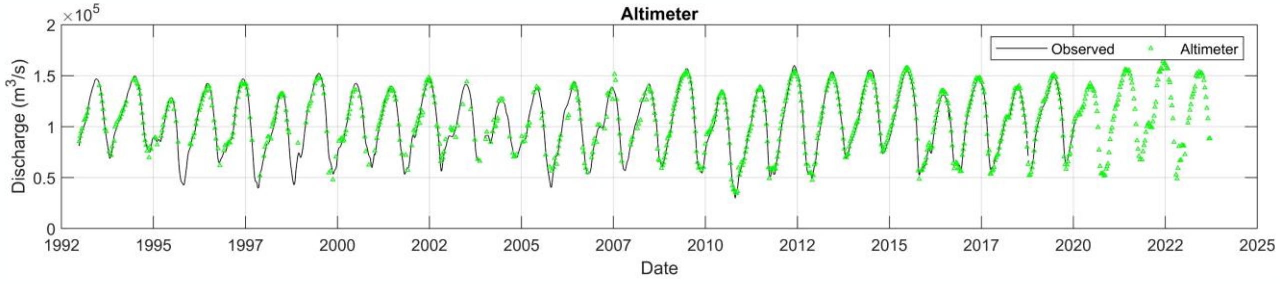
NSE = 0.61 KGE = 0.76 R = 0.78 Frequency = 2.21 days



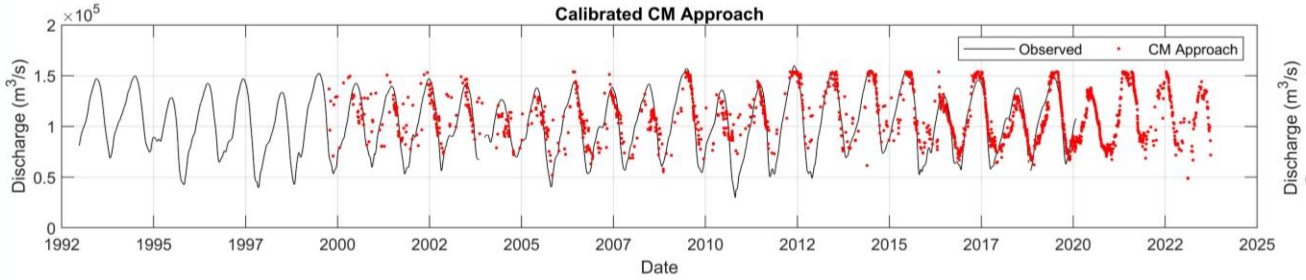
Copula Approach

Mancapuru Station, Amazon River

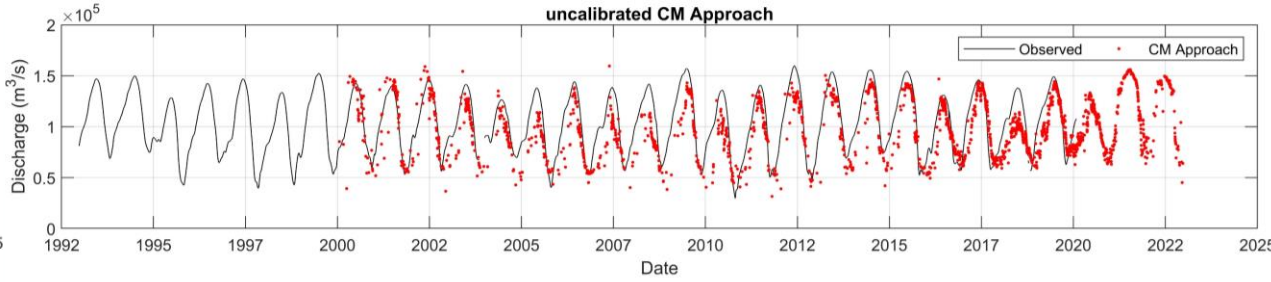
NSE = 0.95 KGE = 0.96 R = 0.97 Frequency = 12 days



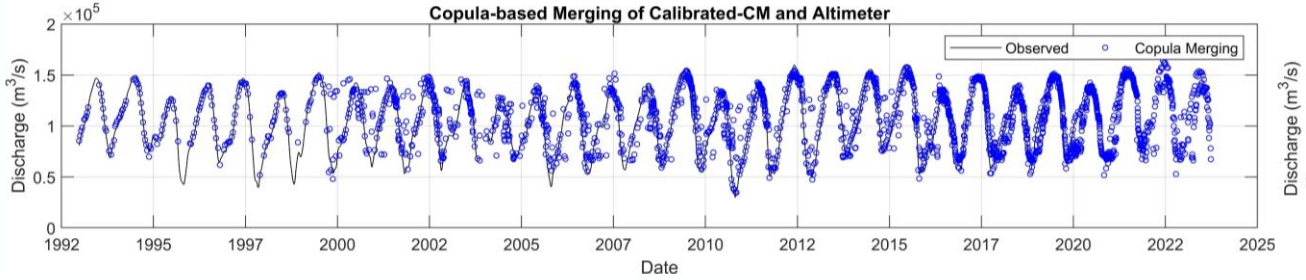
NSE = 0.63 KGE = 0.72 R = 0.79 Frequency = 4.7 days



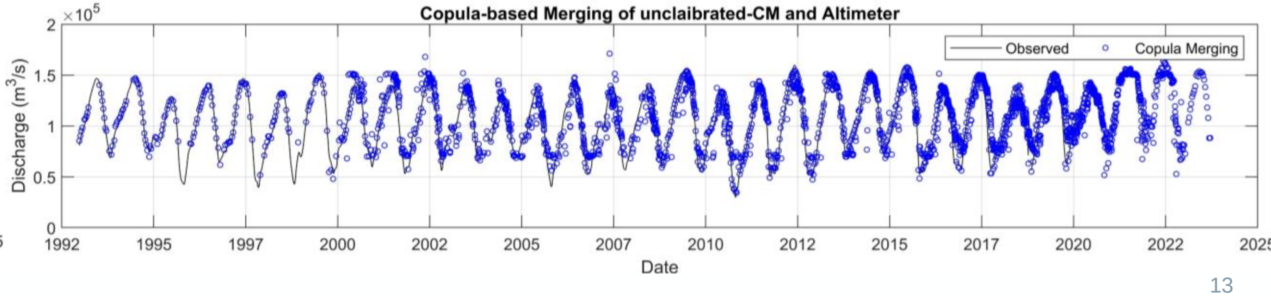
NSE = 0.48 KGE = 0.78 R = 0.83 Frequency = 4.6 days



NSE = 0.75 KGE = 0.84 R = 0.87 Frequency = 3.5 days



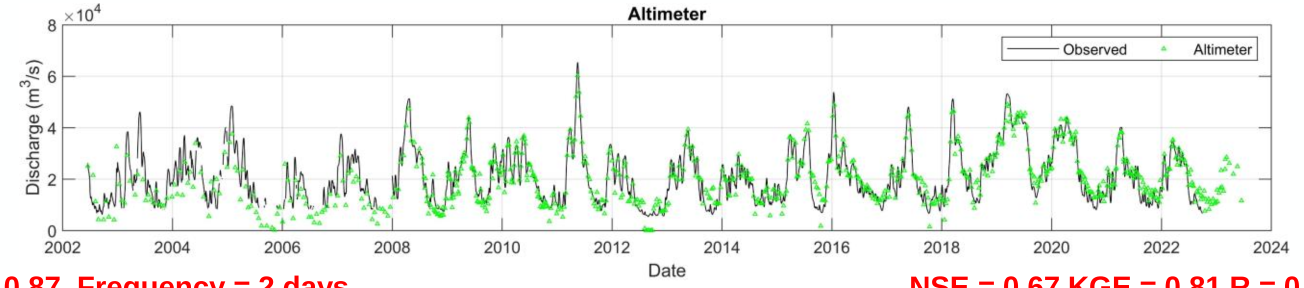
NSE = 0.8 KGE = 0.85 R = 0.89 Frequency = 3.2 days



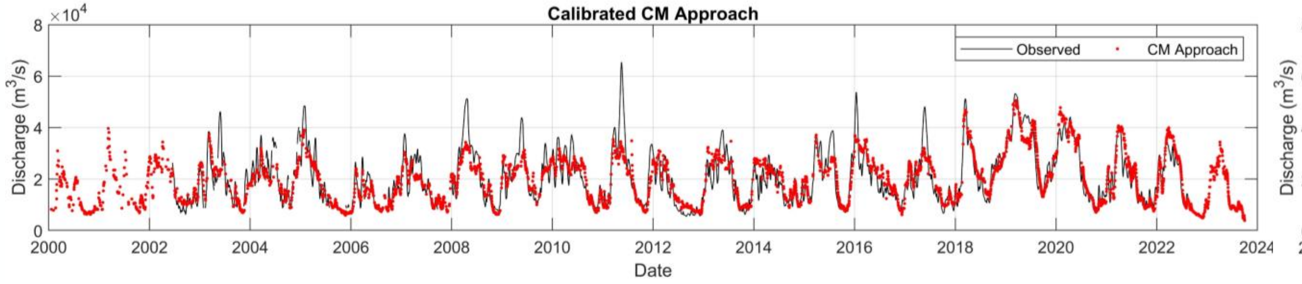
Copula Approach

Vicksburg Station, Mississippi River

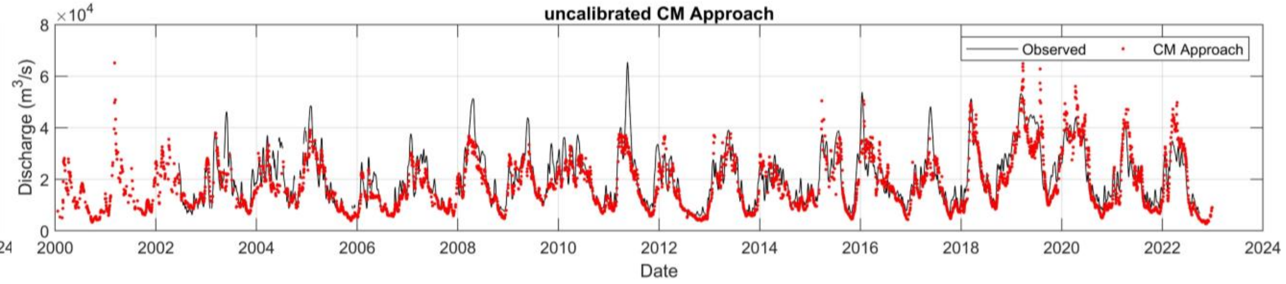
NSE = 0.95 KGE = 0.96 R = 0.97 Frequency = 12 days



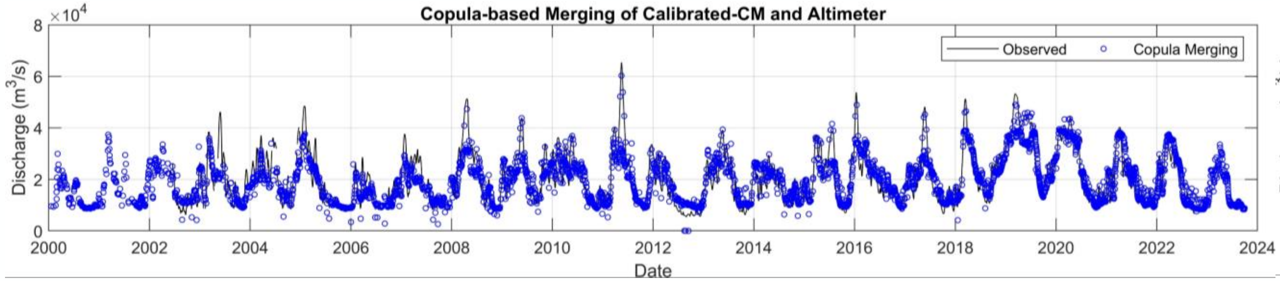
NSE = 0.75 KGE = 0.8 R = 0.87 Frequency = 2 days



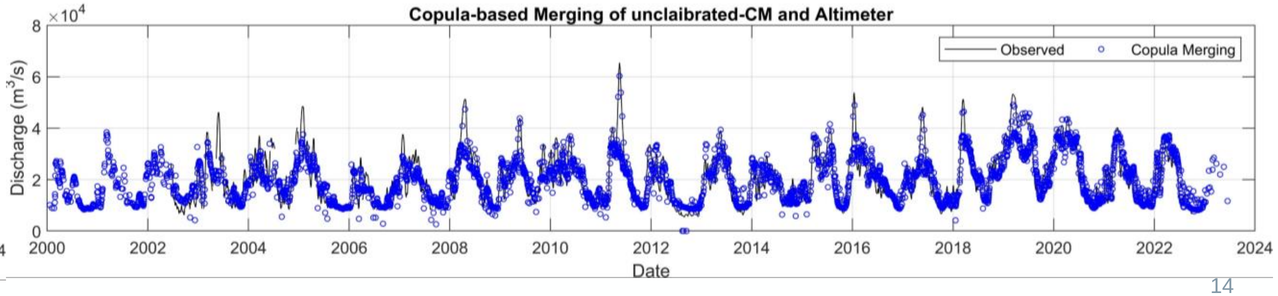
NSE = 0.67 KGE = 0.81 R = 0.84 Frequency = 2 days



NSE = 0.76 KGE = 0.76 R = 0.89 Frequency = 2 days

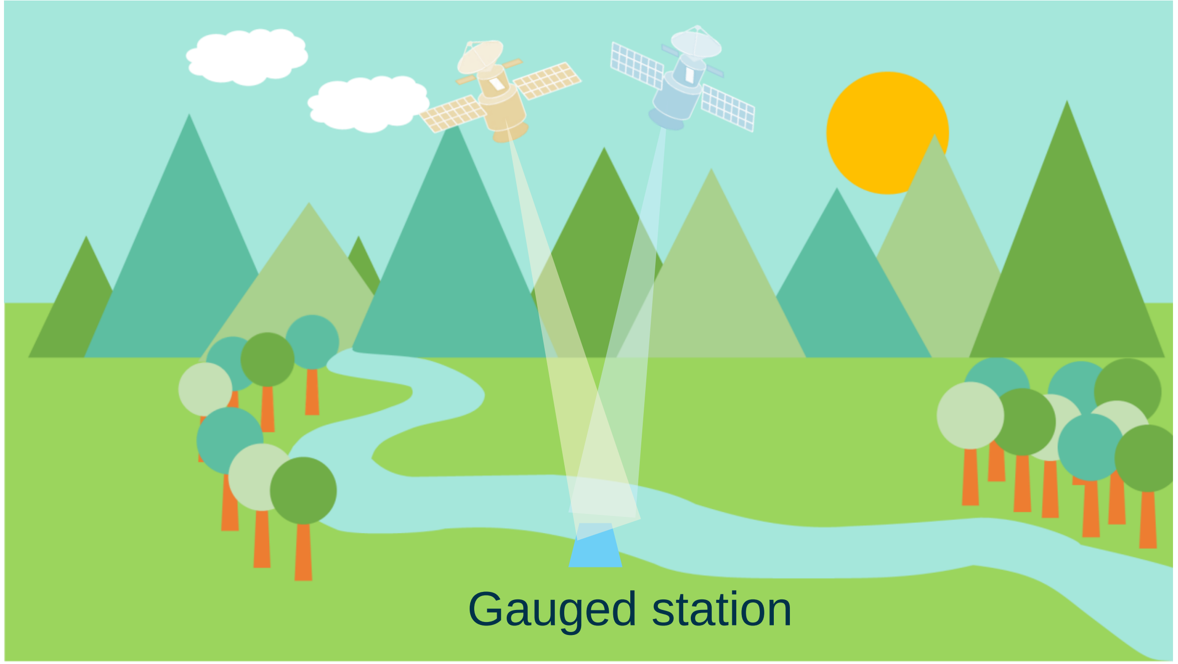


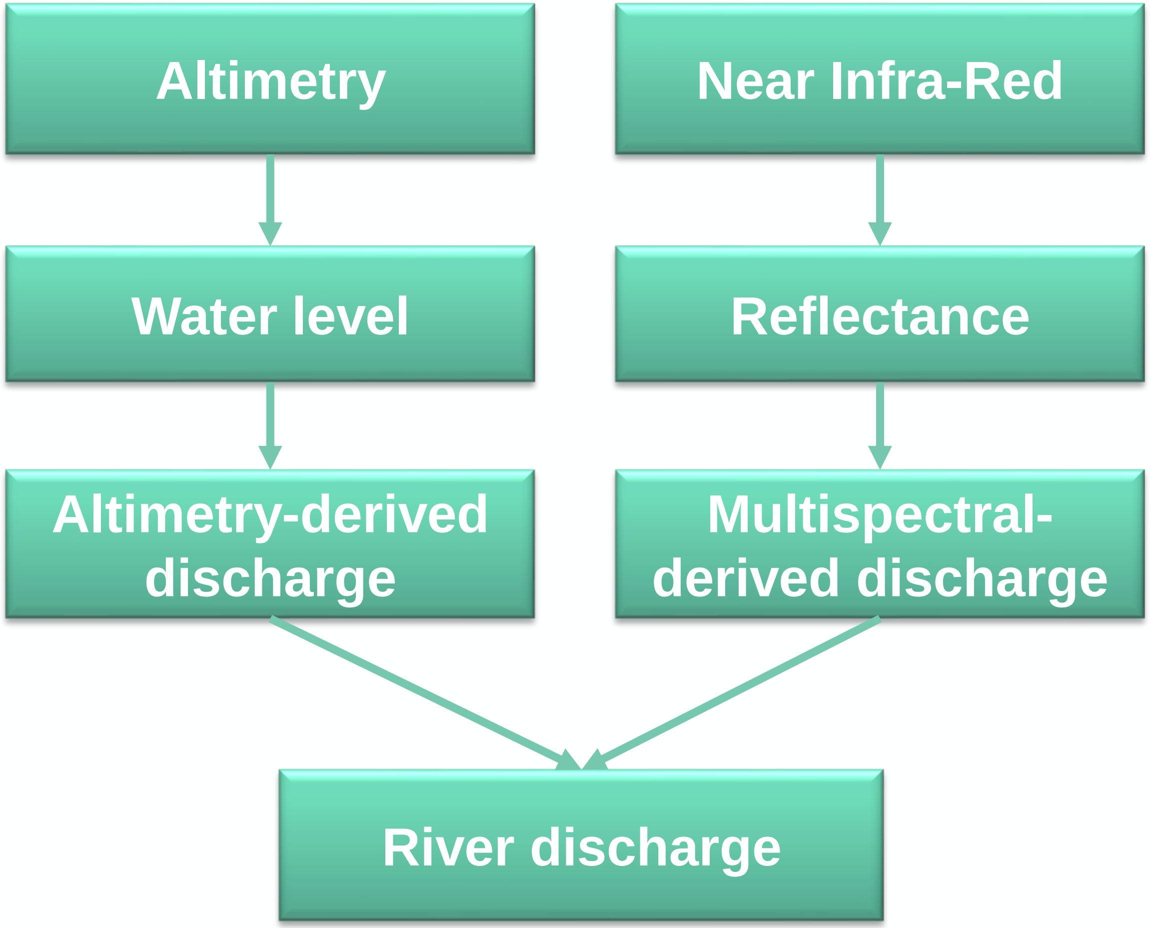
NSE = 0.73 KGE = 0.73 R = 0.86 Frequency = 2 days



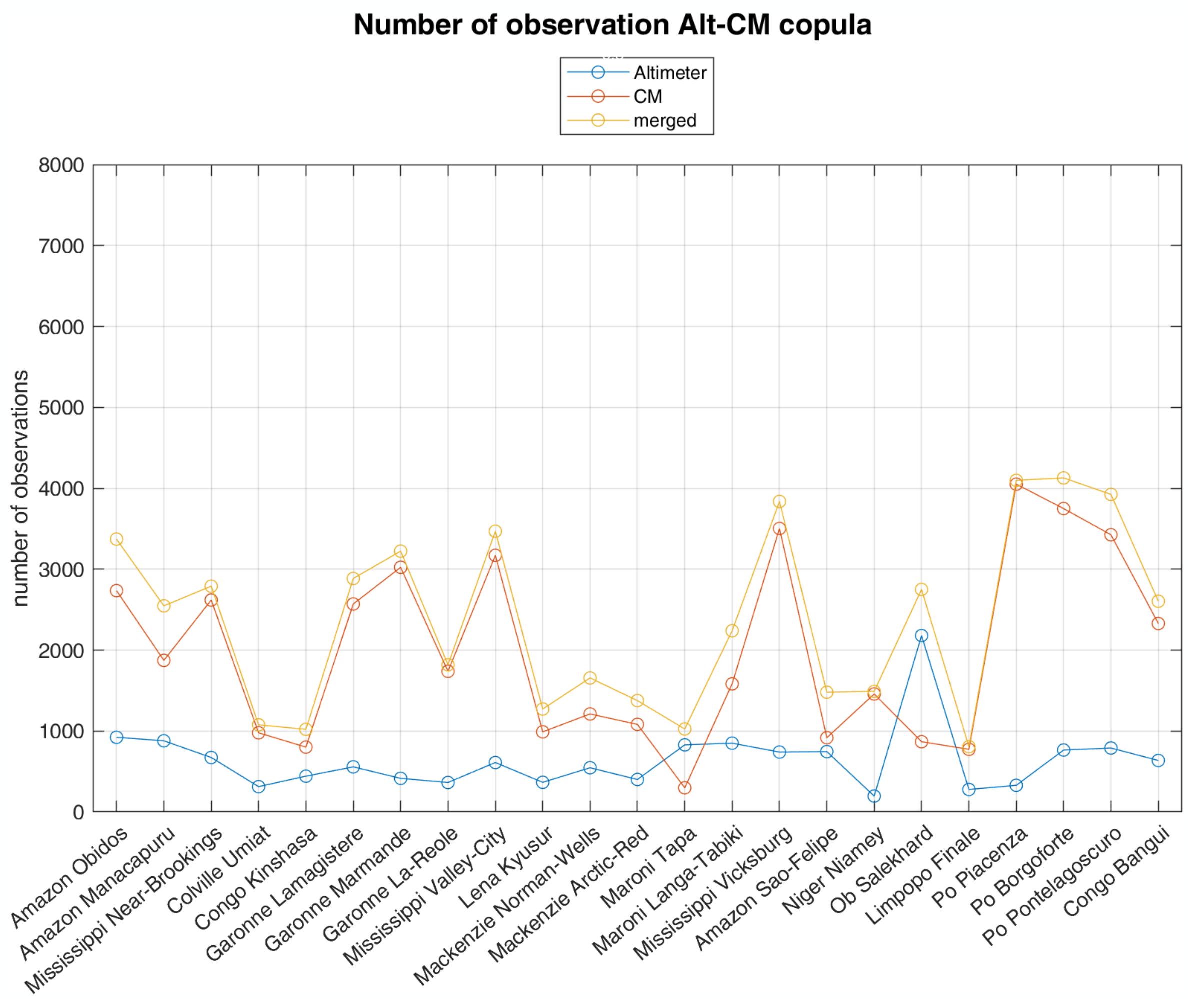
Level 3 approach

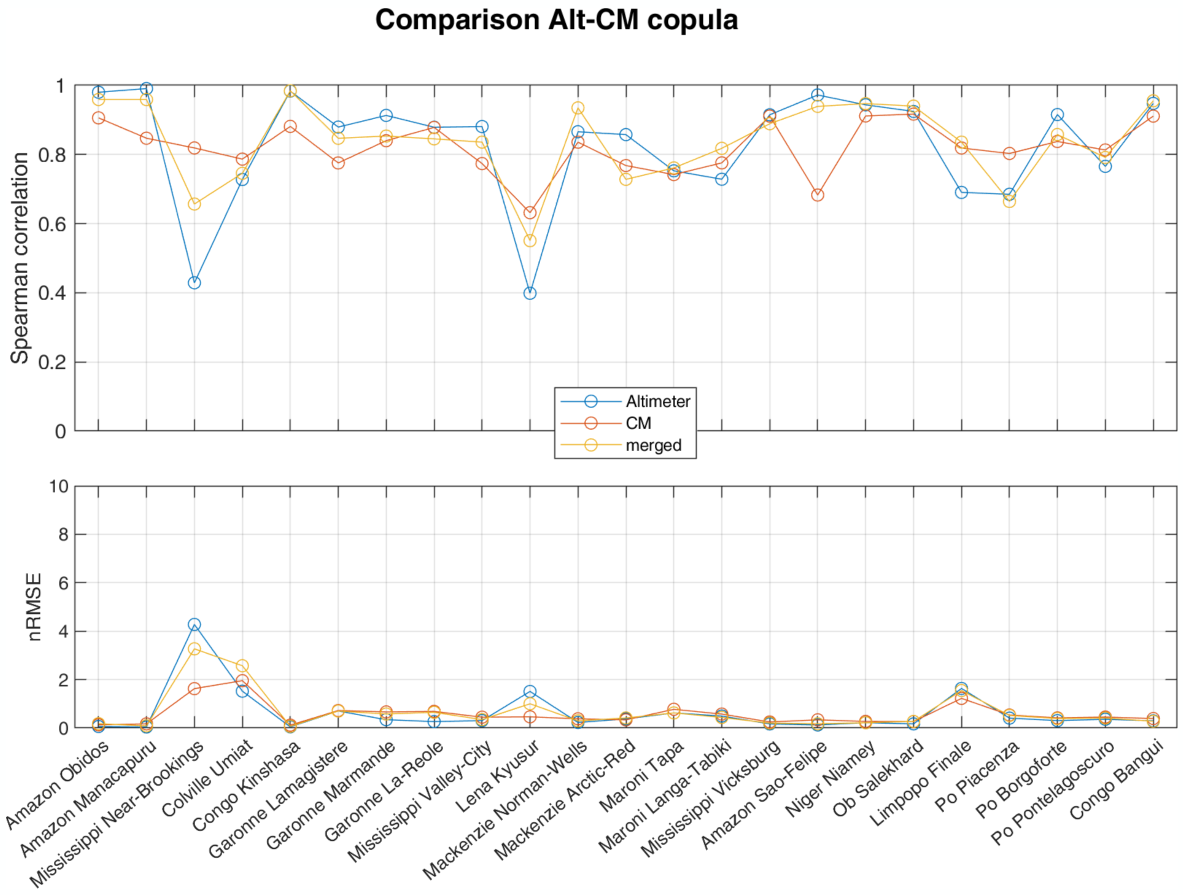
The river discharges obtained by the single sensors are combined at Level 3 by weight averaging.





Level 3 approach





Conclusions and suggestions for the Roadmap

- ✓ The **combination** of the satellite sensors data is necessary to **overcome** the **limitations of the single sensors**.
- ✓ Several methods have been tested with **improvements** on the **river discharge** values or on the **frequency** of the time series. Further analyses are on going to try to obtain both.
- ✓ Further tests are necessary to evaluate the **benefits at monthly scale useful for the climate trends**.
- ✓ A measure of **uncertainty** of the river discharge is important and necessary. Further analysis will be focused on its estimation.

river discharge cci

climate.esa.int/projects/river-discharge