climate change initiative

RIVER DISCHARGE

RIVER DISCHARGE PRECURSOR PROJECT

river discharge cci

S. Biancamaria on behalf of the project

CCI Colocation Meeting

18/10/2024

Context and objectives

River discharge = New ECV (project started Feb. 2023)

➔ Proof-of-concept of the **feasibility of a long term (at least over 20 years) river discharge ECV** product at selected locations from satellite nadir altimeter data and multispectral images, and ancillary data

Science lead = S. Biancamaria (CNRS-LEGOS)

Project manager = A. Andral (CLS)

7 Partners: CNRS-LEGOS, CNRS-CNRM, CNR-IRPI, EOLA, Magellium, Hydromatters and CLS

Users requirements

Interview several key persons (10 oral & 7 written interviews from GCOS, GRDC, CCI projects, modelers)

Main requirements =

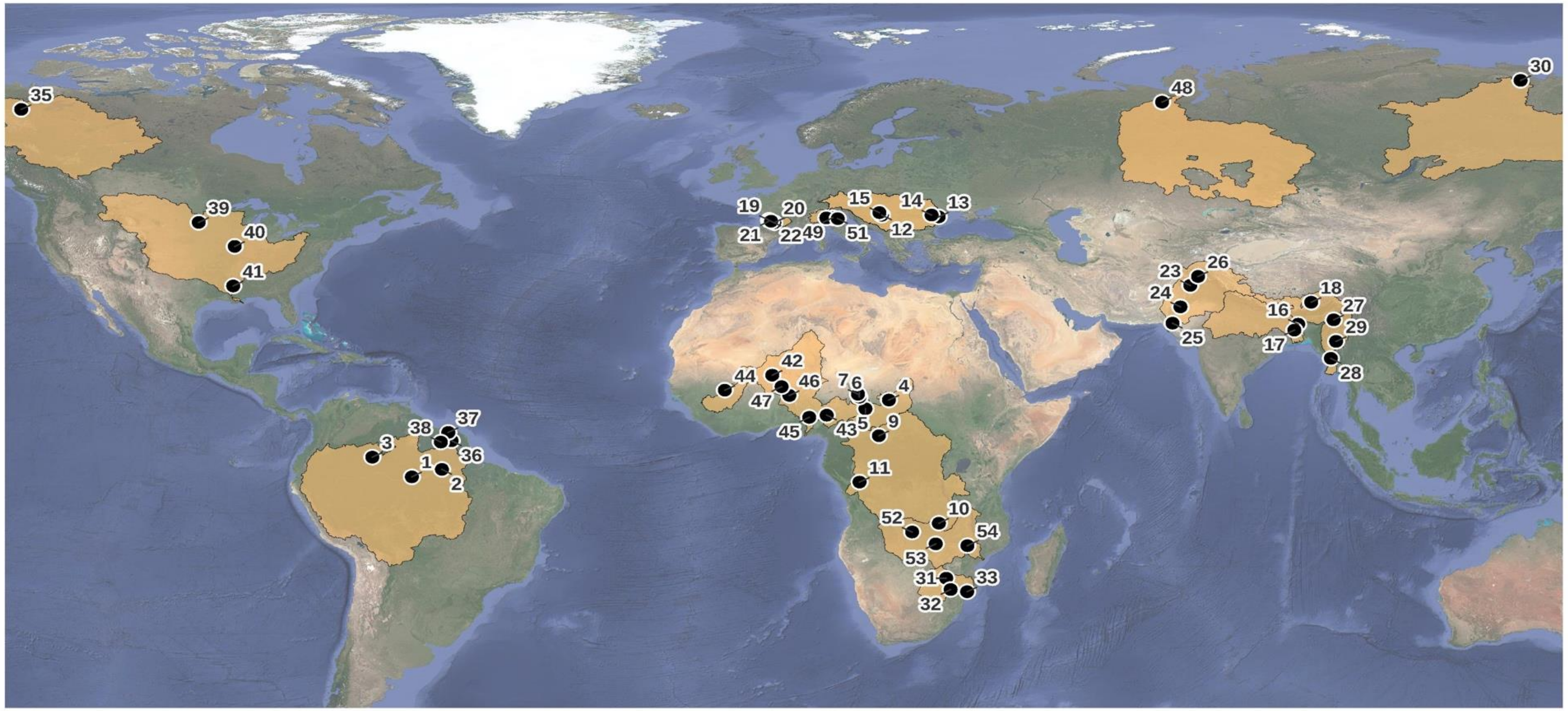
- **Time step/span**: products delivered at EO observation sampling dates (in UTC time) **over 20 years** (2002-2022)
- River basin coverage: **at least 15 river basins**, different climatic zones/latitudes/level of anthropization, include both exorheic and endorheic basins.
- Locations: **multiple locations per basins**. For each basin, location **near the outlet** (but not affected by tides) shall be considered. Locations shall cover different drainage area, from multiple 10,000 km2 to near the Amazon outlet. Mountain (sub-)basins shall be excluded
- **Uncertainty**: based on comparison with in-situ measurements, shall be at least mission dependent
- **Ancillary data**: gauge coordinates, drainage area, river info. to locate river reach where discharge is computed

Target for the precursor project =

- Time step/span: **monthly average and daily time series product from 1995-2022**
- Uncertainty: having **uncertainty around 15%** on monthly average discharge product

Selected river basins and locations

18 basins covering different climatic zones chosen regarding the climate, data availability, mean discharge at the outlet, free flowing / human impact – **54 locations**



- Selected basins
- 1_AMAZON_MANACAPURU
- 2_AMAZON_OBIDOS
- 3_AMAZON_SAO-FELIPE
- 4_CHAD_AM-TIMAN
- 5_CHAD_LAI
- 6_CHAD_MAILAO
- 7_CHAD_NDJAMENA
- 8_COLVILLE_UMIAT
- 9_CONGO_BANGUI
- 10_CONGO_CHEMBE-FERRY
- 11_CONGO_KINSHASA
- 12_DANUBE_BOGOJEVO
- 13_DANUBE_CEATAL
- 14_DANUBE_LUNGOCI
- 15_DANUBE_MOHACS
- 16_GANGES-BRAHMAPUTRA_BAHADURABAD
- 17_GANGES-BRAHMAPUTRA_HARDINGE-BRIDGE
- 18_GANGES-BRAHMAPUTRA_YANGCUN
- 19_GARONNE_LA-REOLE
- 20_GARONNE_LAMAGISTERE
- 21_GARONNE_MARMANDE
- 22_GARONNE_TONNEINS
- 23_INDUS_CHASHMA
- 24_INDUS_GUDDU
- 25_INDUS_KOTRI
- 26_INDUS_TARBELA
- 27_IRRAWADDY_HKAMTI
- 28_IRRAWADDY_PYAY
- 29_IRRAWADDY_SAGAING
- 30_LENA_KYUSUR-EOLA
- 31_LIMPOPO_BEITBRUG
- 32_LIMPOPO_FINALE
- 33_LIMPOPO_SICACATE
- 34_MACKENZIE_ARCTIC-RED
- 35_MACKENZIE_NORMAN-WELLS
- 36_MARONI_DEGRAD-ROCHE
- 37_MARONI_LANGA-TABIKI
- 38_MARONI_TAPA
- 39_MISSISSIPPI_NEAR-BROOKINGS
- 40_MISSISSIPPI_VALLEY-CITY
- 41_MISSISSIPPI_VICKSBURG
- 42_NIGER_ANSONGO
- 43_NIGER_IBI
- 44_NIGER_KOULIKORO
- 45_NIGER_LOKOJA
- 46_NIGER_MALANVILLE
- 47_NIGER_NIAMEY
- 48_OB_SALEKHARD
- 49_PO_BORGOFORTE
- 50_PO_PIACENZA
- 51_PO_PONTELAGOSCURO
- 52_ZAMBEZI_KABOMPO-PONTOON
- 53_ZAMBEZI_KASAKA
- 54_ZAMBEZI_MATUNDO-CAIS

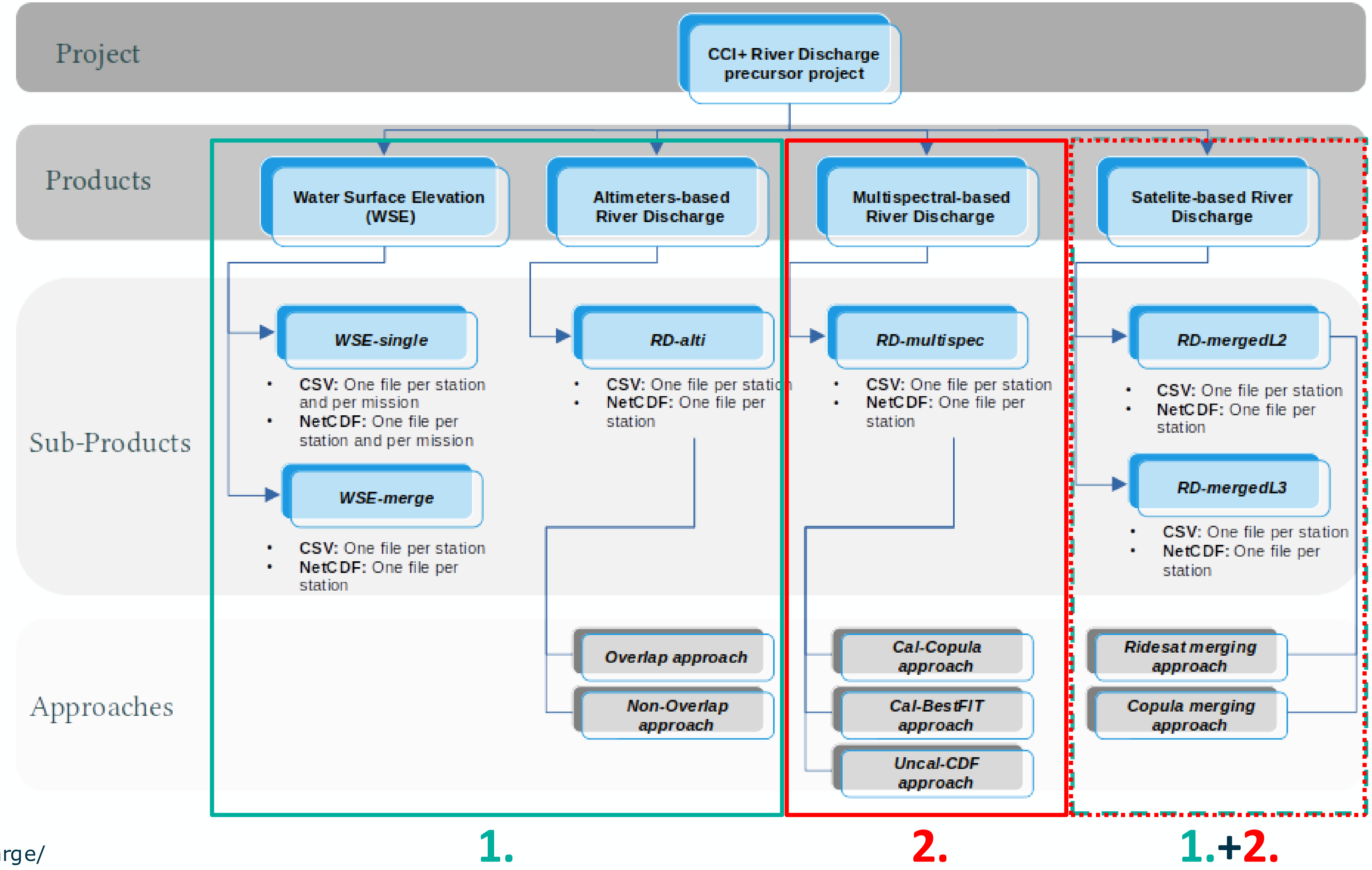
Products

Satellite data used:

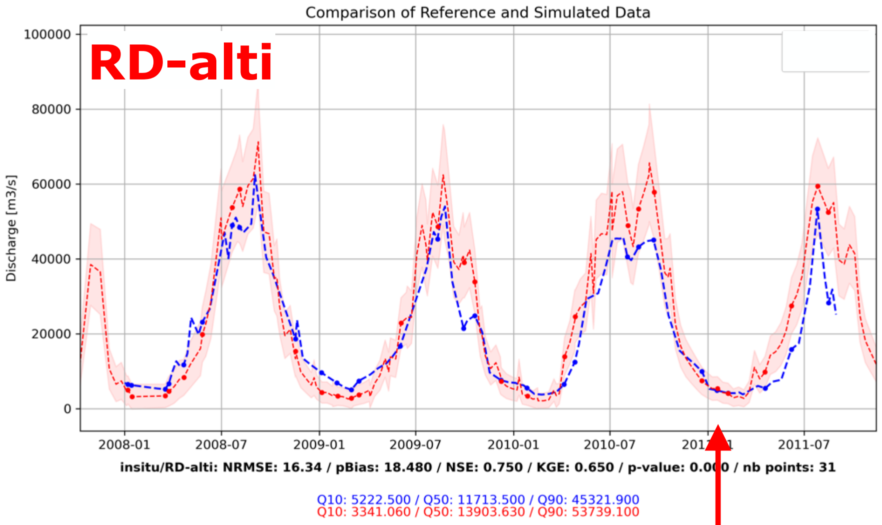
1. **Nadir radar altimeters**
2. **Multispectral images**

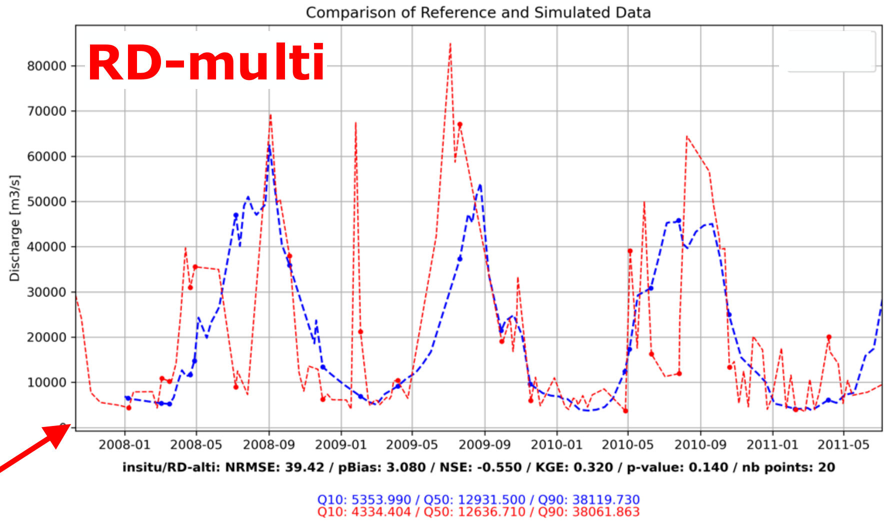
Need ancillary river discharge (with or without time overlap with satellite data)

For more information: ATBD, PUG, PVIR, and PVASR available

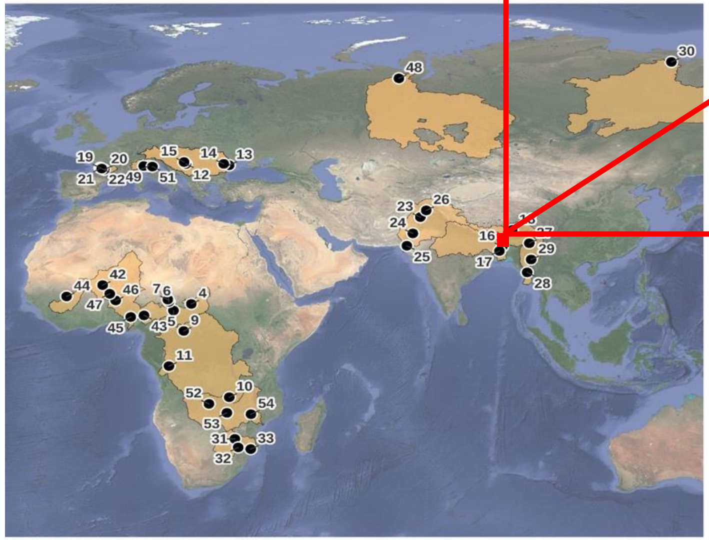


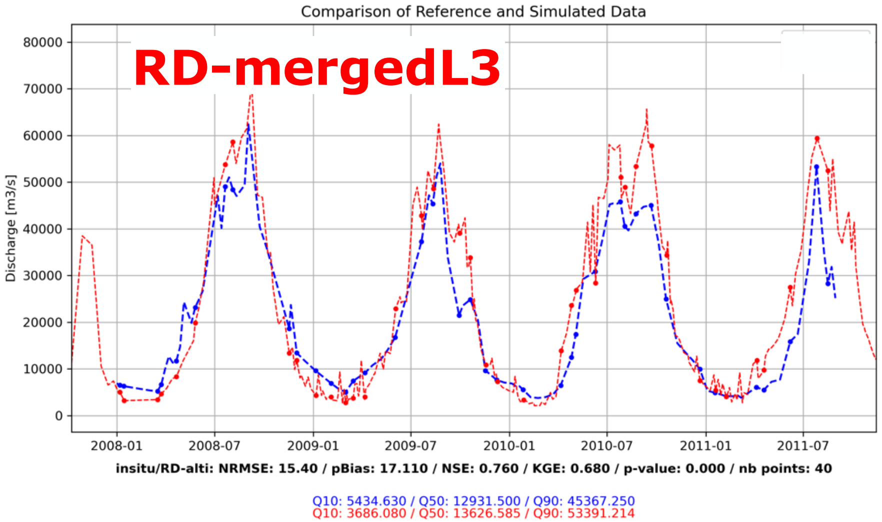
Example of products: Brahmaputra River



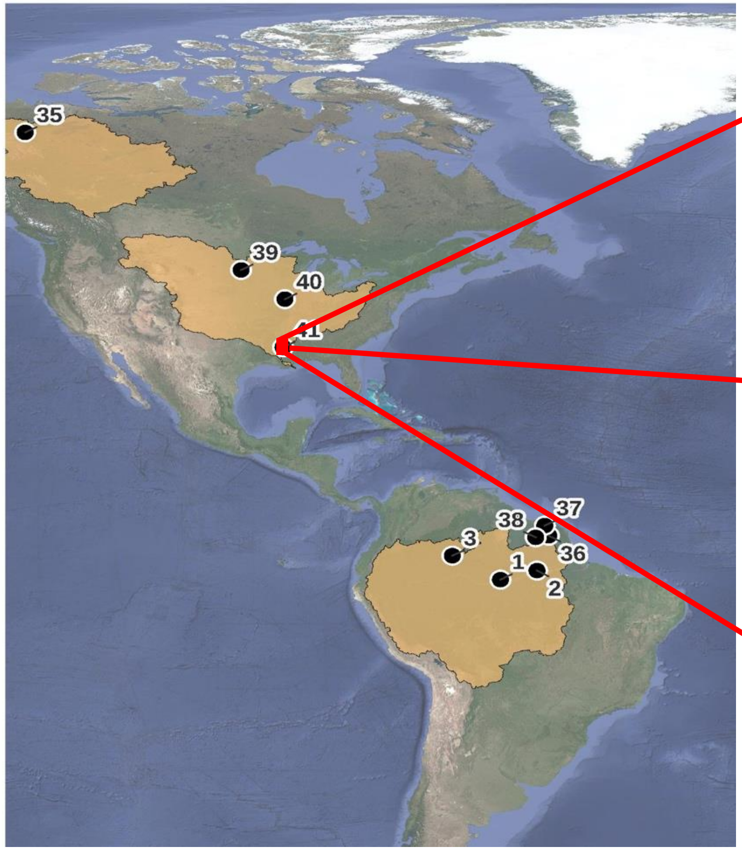


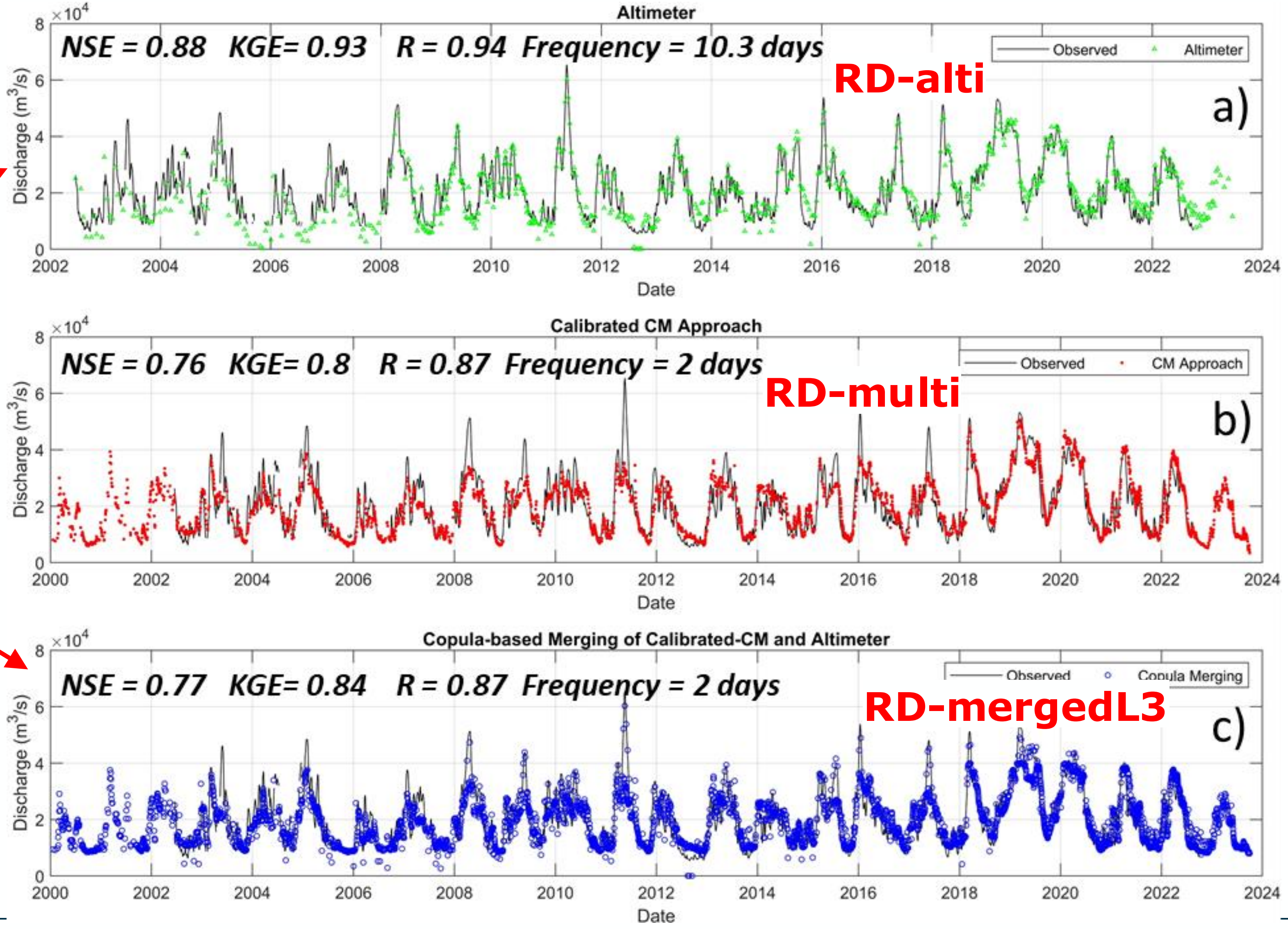
in situ RD





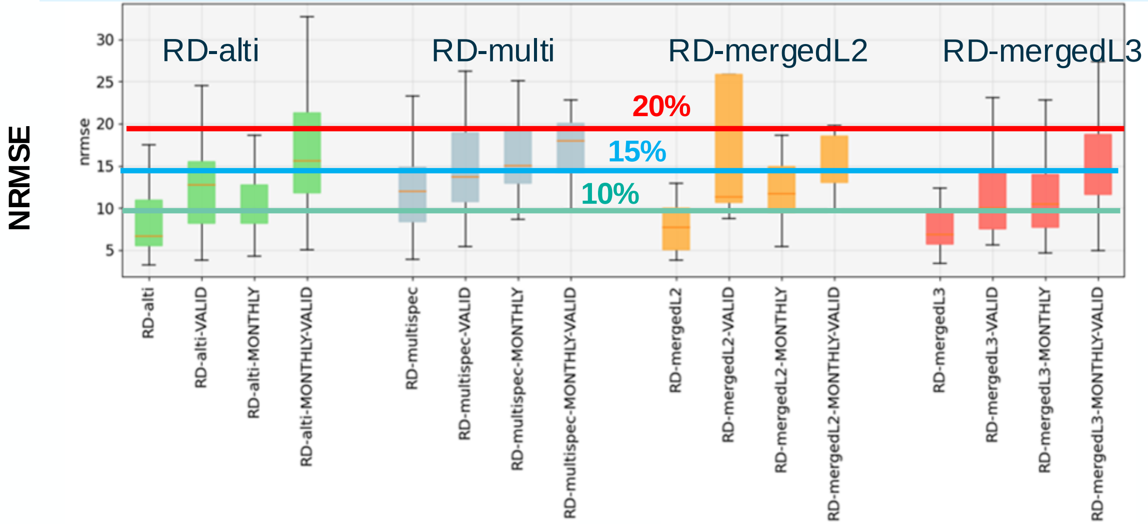
Example of products: Mississippi River



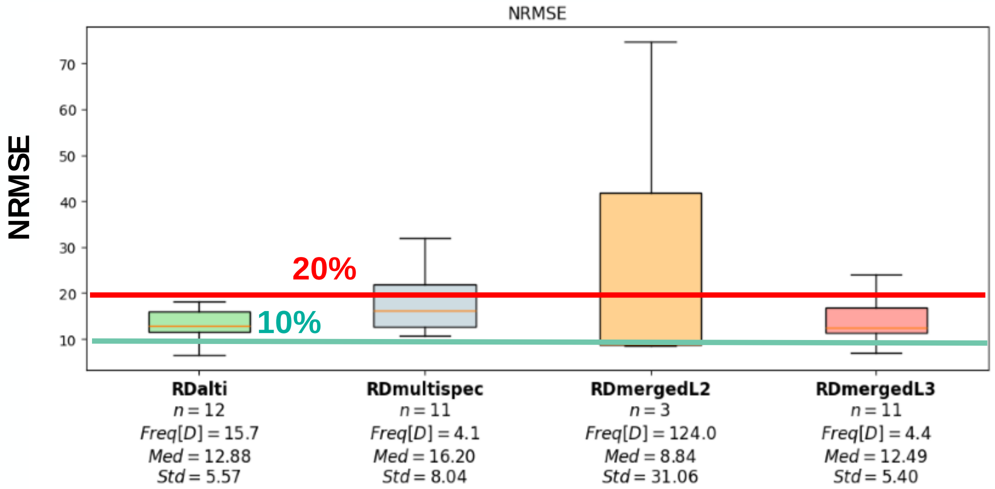


Validation and round-robin

Validation period at 33 locations with in-situ RD used for RD products



With Independent in-situ data



Round robin

	RD-alti	RD-multispec	RD-mergedL2	RD-mergedL3
Format				
Temporal resolution				
Spatial coverage				
Error				
Uncertainty				
Trends and variability				
Total	16	14	12	16

4 points | 3 points | 2 points | 1 points

Main conclusions from validation/round robin:

- Accuracy and reliability of The CCI River Discharge Products
- Better results with RD-alti than RD-mergedL3 when comparing to in situ
- RD-mergedL3 has higher observations than RD-alti thanks to inclusion of RD-multi

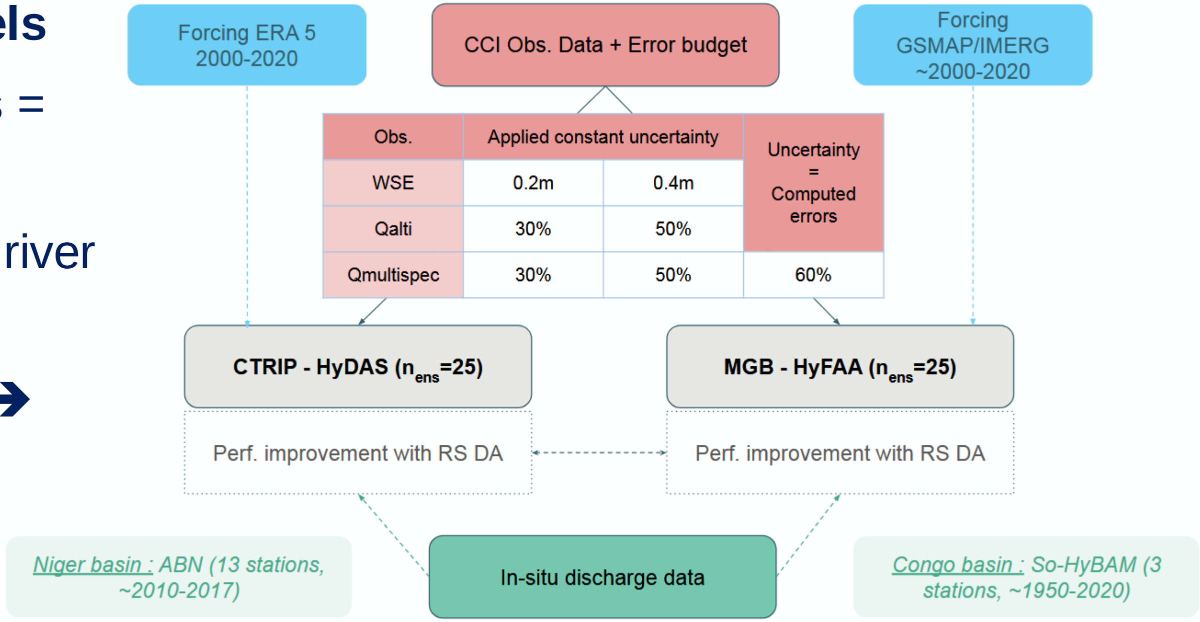
Use cases

Preliminary climate assessment:

- 56-59% of CCI_RD products allow estimation of monthly RD with 10% error, 65-68% - with 15% error.
- RD-alti and RD-mergedL3 has highest capacity to catch long-term changes in annual river flow
- 60-80% of recorded flood-related hazard events could be identified with CCI_RD products

RD-products assimilation in large-scale hydrology models

- Models= ISBA-CTRIP and MGB, Method = EnKF, Basins = Congo and Niger, RD and H corrected with CCI products
- Assimilating Q and WSE improves significantly modelled river discharge at locations
- Balance btw data quality and temporal density is crucial ➔ need to increase locations with RD products



Current status and prespectives

- CCI RD products meets user requirements (but not goals)
- CCI RD products are available on the CEDA Catalog, see: https://catalogue.ceda.ac.uk/uuid/dbba9cfe8d104648b19e39f4c2da1a27
- A roadmap to go to global scale RD products has been defined (still 'point-based' data), issue for ungaged basins
- Connexion with other CCI needs to be investigated (coastal sea level, SSS, lake…)

river discharge cci

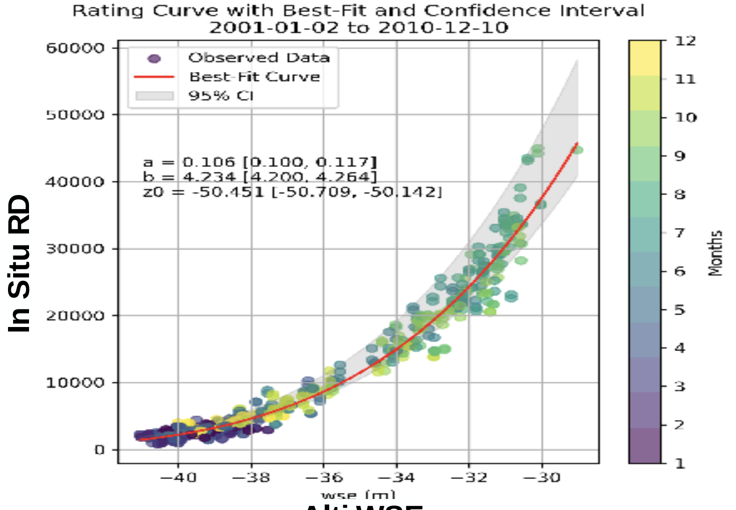
Website: https://climate.esa.int/projects/river-discharge

CCI RD products: https://catalogue.ceda.ac.uk/uuid/dbba9cfe8d104648b19e39f4c2da1a27

Water surface Elevation (WSE)
& River discharge (RD) from altimetry – RD_alti

- **Objectives**: Compute RD time series from river WSE time series and ancillary discharge at selected locations, at least from 2002-2022 (goal: 1992-2022)
- **Methodology:**
  - **If overlap between WSE and Discharge observation:**
    - First 1/3 part of the common period = validation period and the last 2/3 parts: Calibration period
    - Then ,estimation of the rating curve
  - **If no overlap**, use of a quantile function to get the rating curve

Time overlap btw in situ RD and alti WSE
31/54 stations

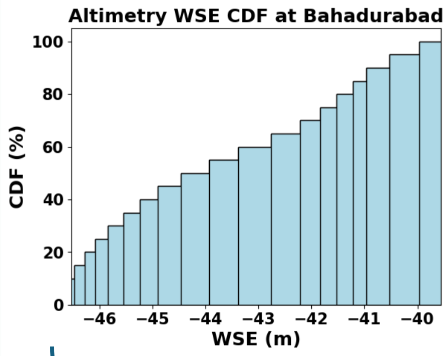


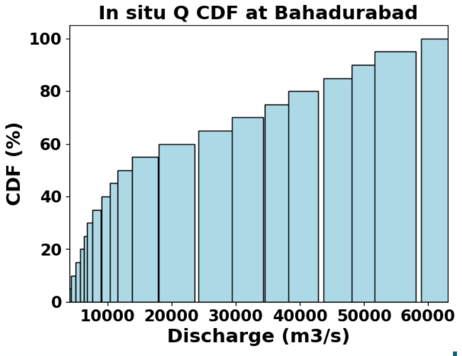
Alti WSE

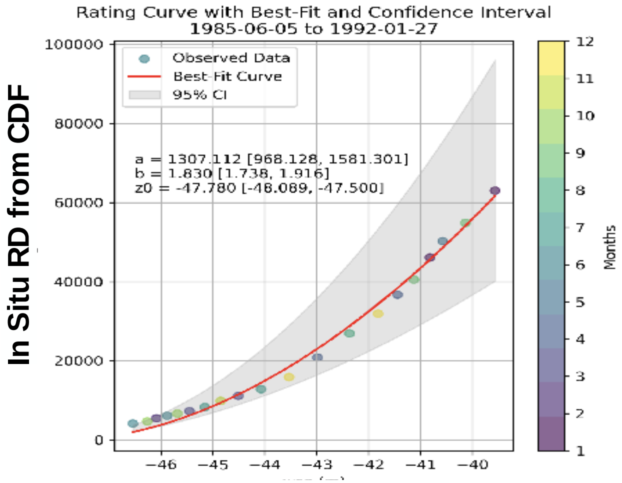
4 missing

(WSE or in-situ RD in-situ unavailable)

No time overlap btw in situ RD and alti WSE
19/54 stations

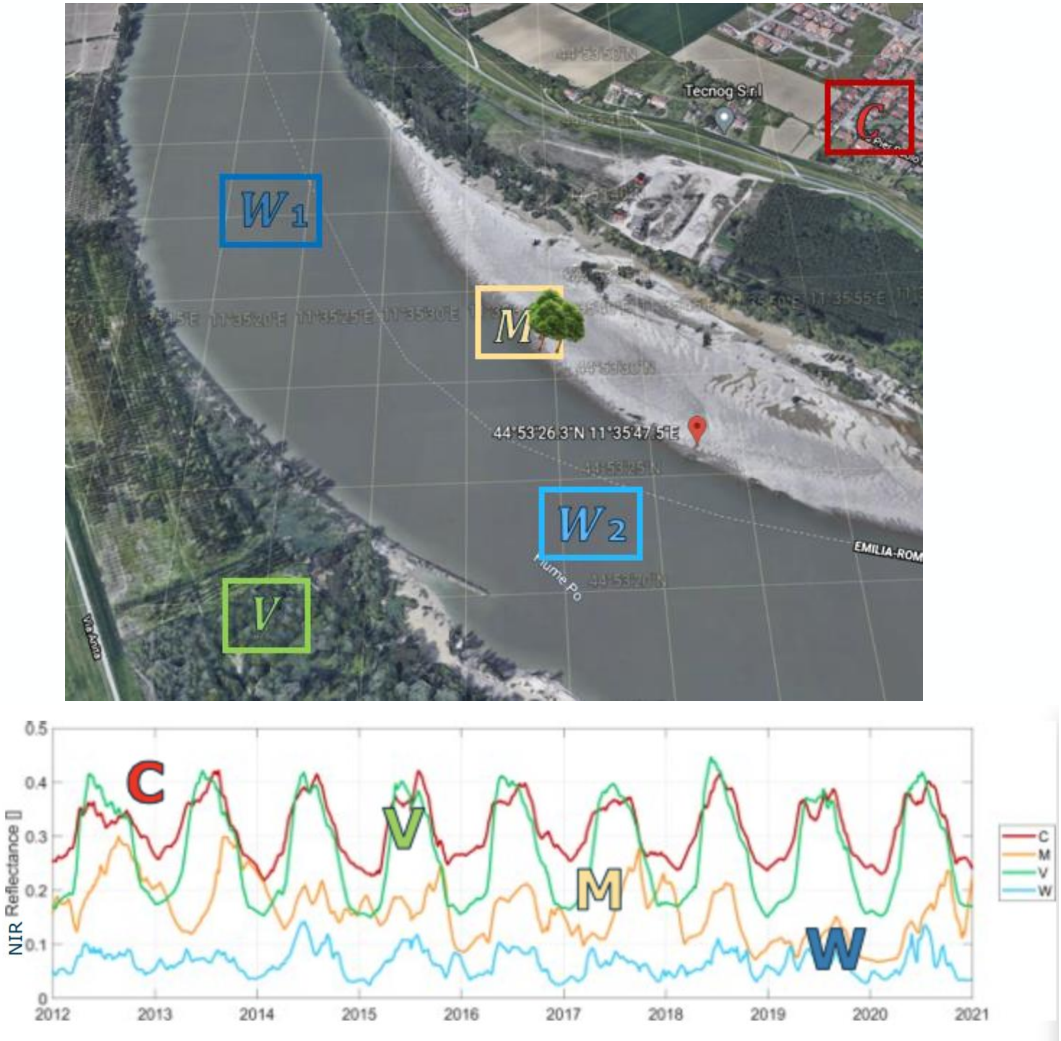




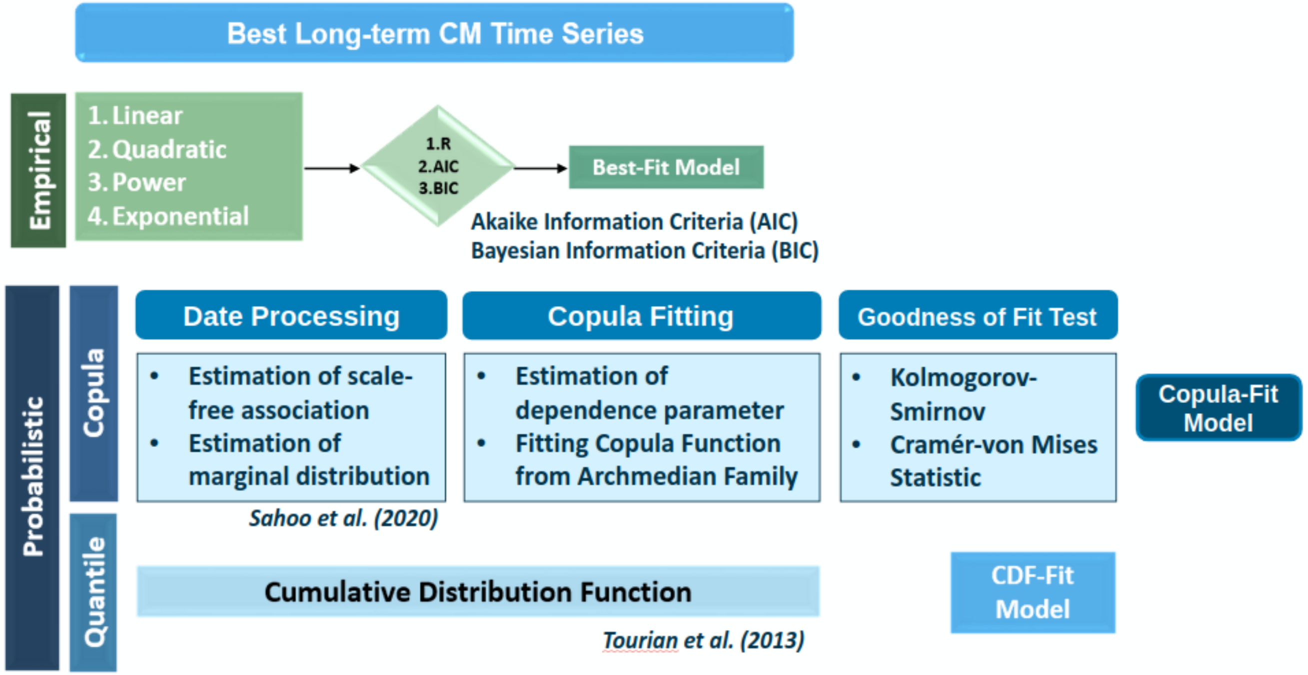


Alti WSE from CDF

River discharge from multispectral images – RD_multi



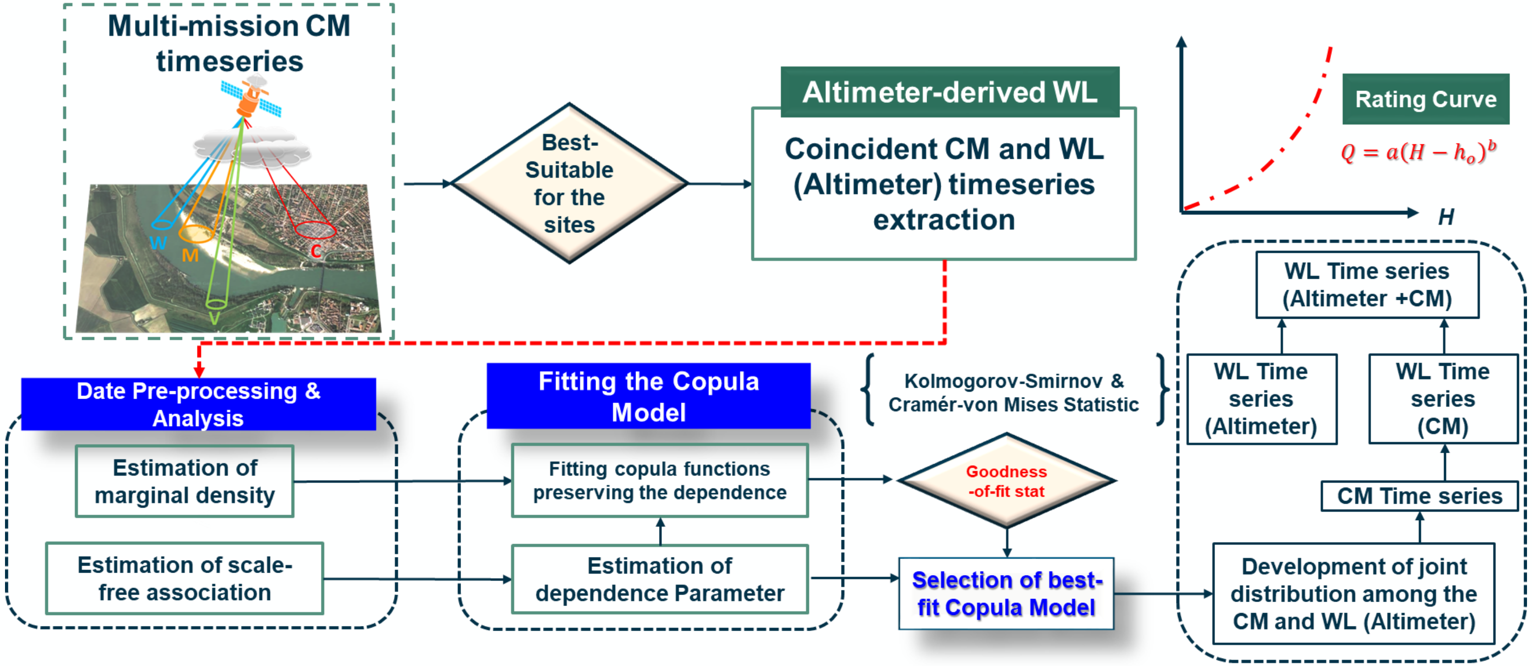
- **Objectives:** Compute river discharge time series from reflectance indices time series at selected locations, at least from 2002-2022 (goal: 1992-2022)
- **Methodology: Apply best method** - using the best long-term CM reflectance time series - according to the coincident observation of CM and River Discharge



Combination of RD_alti and RD_multi = Merged product RD-merge

- **Objectives:** Compute river discharge time series by merging results from altimetry and multispectral images at selected locations, at least from 2002-2022 (goal: 1992-2022)
- **Methodology:**
  - Level 2: merge data from WSE and CM reflectance indices
  - Level 3: merge data from RD_alti and RD_multi

At level 2: combine alti WSE and CM indices -> rating curve to compute RD



At level 3:

RD-alti and RD-multi are combined by weight averaging.

Validation methodology

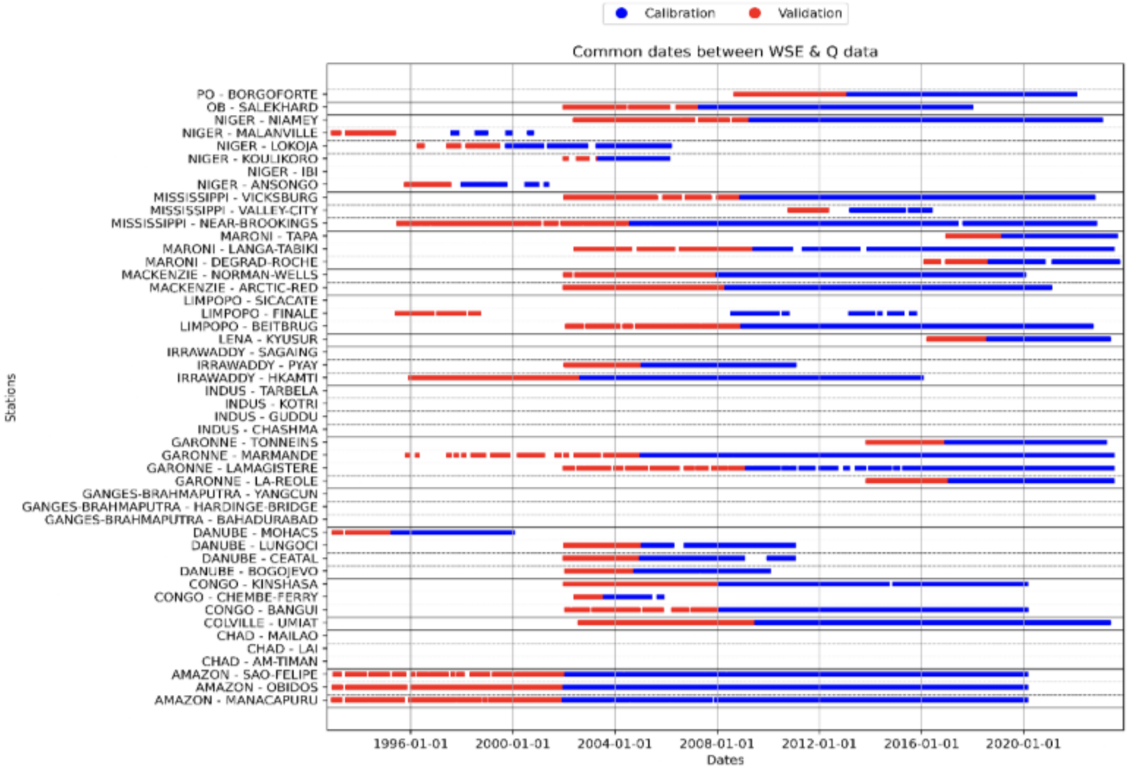
esa

With Cal/Val in-situ data

- Identify overlap period between merge WSE from altimeters and in-situ discharge = closest date with time gap < 24H
- Divided this common period into Cal/Val periods
  - First 1/3 part = Validation period (Red)
  - Last 2/3 parts = Calibration period (Blue)

Validation period

All period (cal/val)



With Independent in-situ data

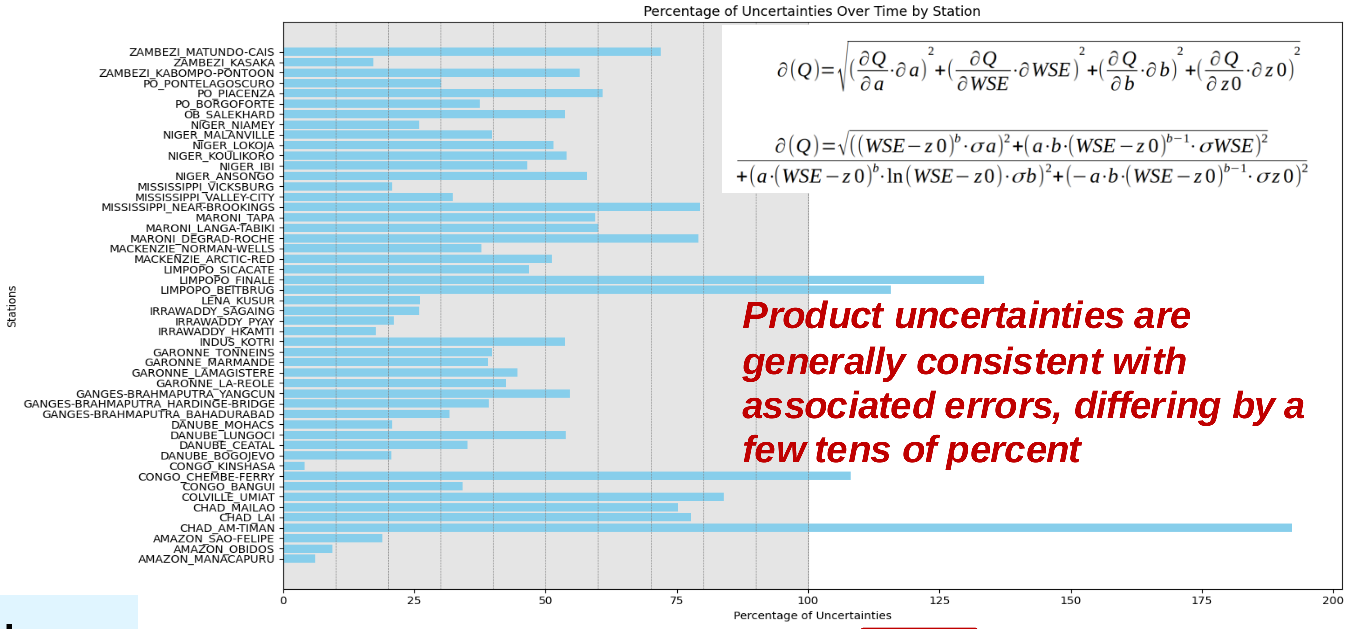
- Identify overlap period between satellite-based RD products independent in-situ discharge = closest date with time gap < 24H
  - **Over all available stations per products**
  - **Over common stations between products**

RD-alti uncertainty

Uncertainty propagation

- Essential for assessing the **reliability of RD estimations**
- **Method**: Gaussian error propagation quantifies uncertainties in parameters a, WSE, b, and z0.
- **Assumptions**: Assumes parameter uncertainties are independent and based on linearization.
- **Average Uncertainty:**

- Sensor changes over time.
- Misinterpretation of altimeter data.
- Challenges with rating curves and spatial disparities.
- Increased sensitivity during extreme flow events.



$$\partial(Q)=\sqrt{\left(\frac{\partial Q}{\partial a}\cdot\partial a\right)^2+\left(\frac{\partial Q}{\partial WSE}\cdot\partial WSE\right)^2+\left(\frac{\partial Q}{\partial b}\cdot\partial b\right)^2+\left(\frac{\partial Q}{\partial z0}\cdot\partial z0\right)^2}$$

$$\partial(Q)=\sqrt{\left((WSE-z0)^b\cdot\sigma a\right)^2+\left(a\cdot b\cdot(WSE-z0)^{b-1}\cdot\sigma WSE\right)^2 +\left(a\cdot(WSE-z0)^b\cdot\ln(WSE-z0)\cdot\sigma b\right)^2+\left(-a\cdot b\cdot(WSE-z0)^{b-1}\cdot\sigma z0\right)^2}$$

Product uncertainties are generally consistent with associated errors, differing by a few tens of percent

Error from using Quantile approach vs. Overlap approach

- RD estimates using the quantile function (non-overlap) approach have **higher uncertainties** compared to the overlap approach over the same period:
  - Non-Overlap Approach: Median KGE = 0.62 , NRMSE = 14.0%
  - Overlap Approach: Median KGE = 0.90 , NRMSE = 9.9%
- **Larger time gaps** (> 10years) between Q and WSE data lead to **decreased statistical performance**, particularly in rivers with high variability
- Quantile approach = s**ensitive to temporal distribution of hydrological events:** leading to variability in performance across different stations and periods.