UN-COSPAR Symposium Session

Space-Observation Contributions Supporting Climate Action

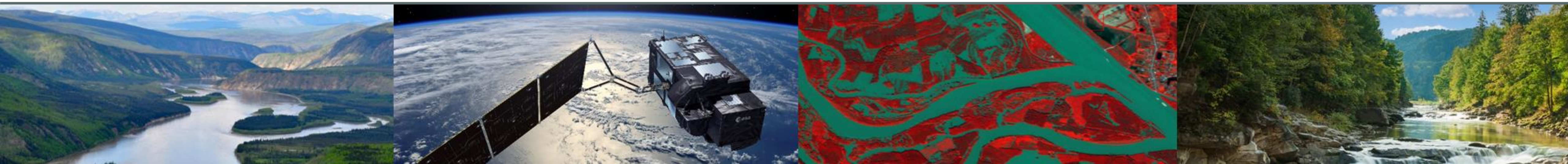
Earth Observation monitoring of African rivers in a climate change context to inform water management

Angelica Tarpanelli and the IRPI Hydrology Group

irpi

Istituto di Ricerca per la Protezione Idrogeologica

Research Institute for Geo-Hydrological Protection (CNR-IRPI) Perugia, Italy



Rationale

CLIMATE CHANGES

Rising temperatures and shifting precipitation patterns are causing major **changes on the rivers**.

EFFECTS

The risk of **catastrophic floods or droughts** has increased.

WATER MONITORING WITH IN SITU STATIONS

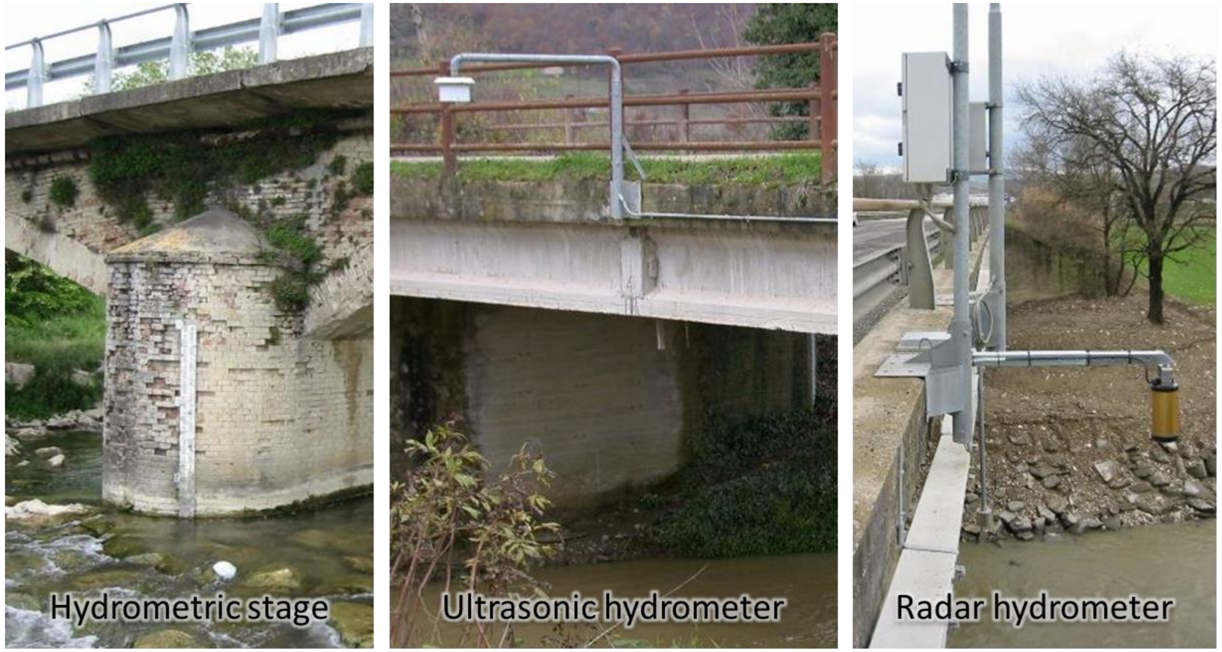
Environmental, especially fresh water, monitoring is a key component in addressing aspects related to water management, flood risk mitigation and climate change assessment.

Ground hydro-monitoring network

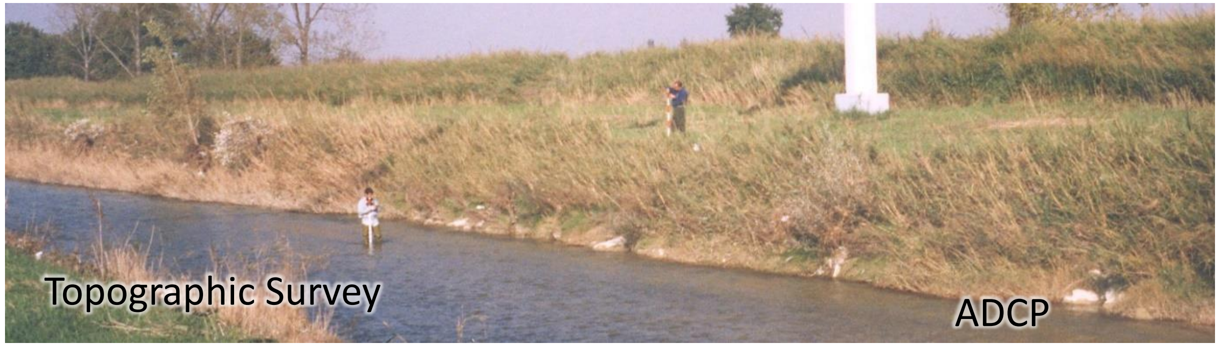
Sensors represent an irreplaceable resource for measuring river discharge in situ, thanks to their high quality, reliability and consistency.

WATER FLOW VELOCITY

WATER DEPTH



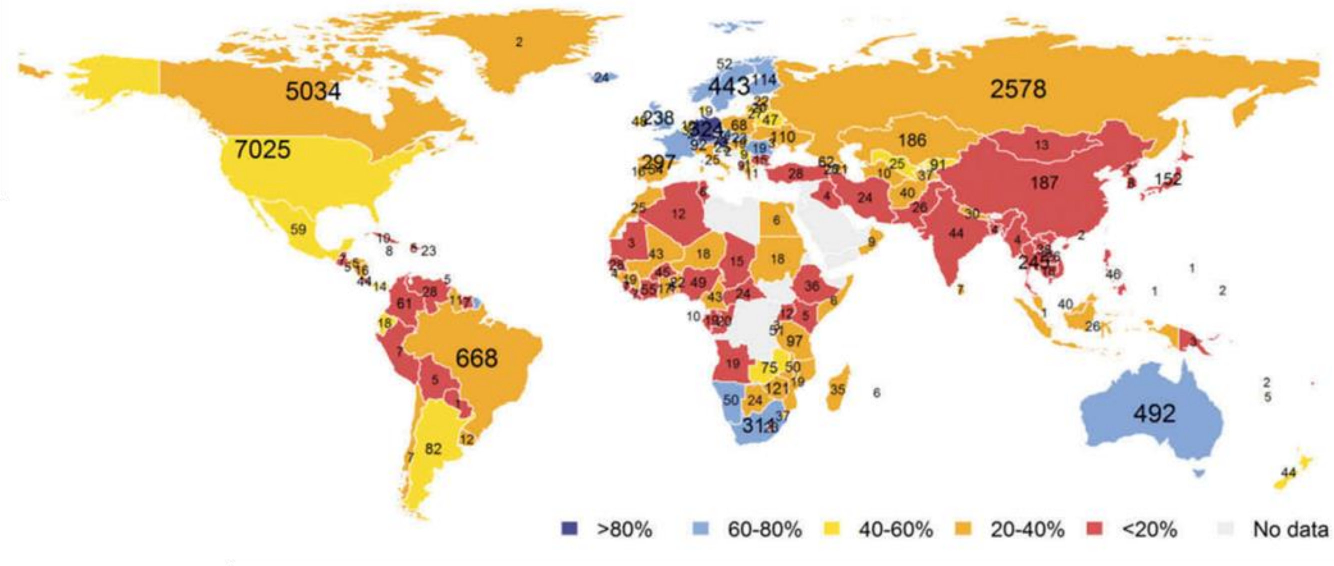
CROSS-SECTION BATHYMETRY



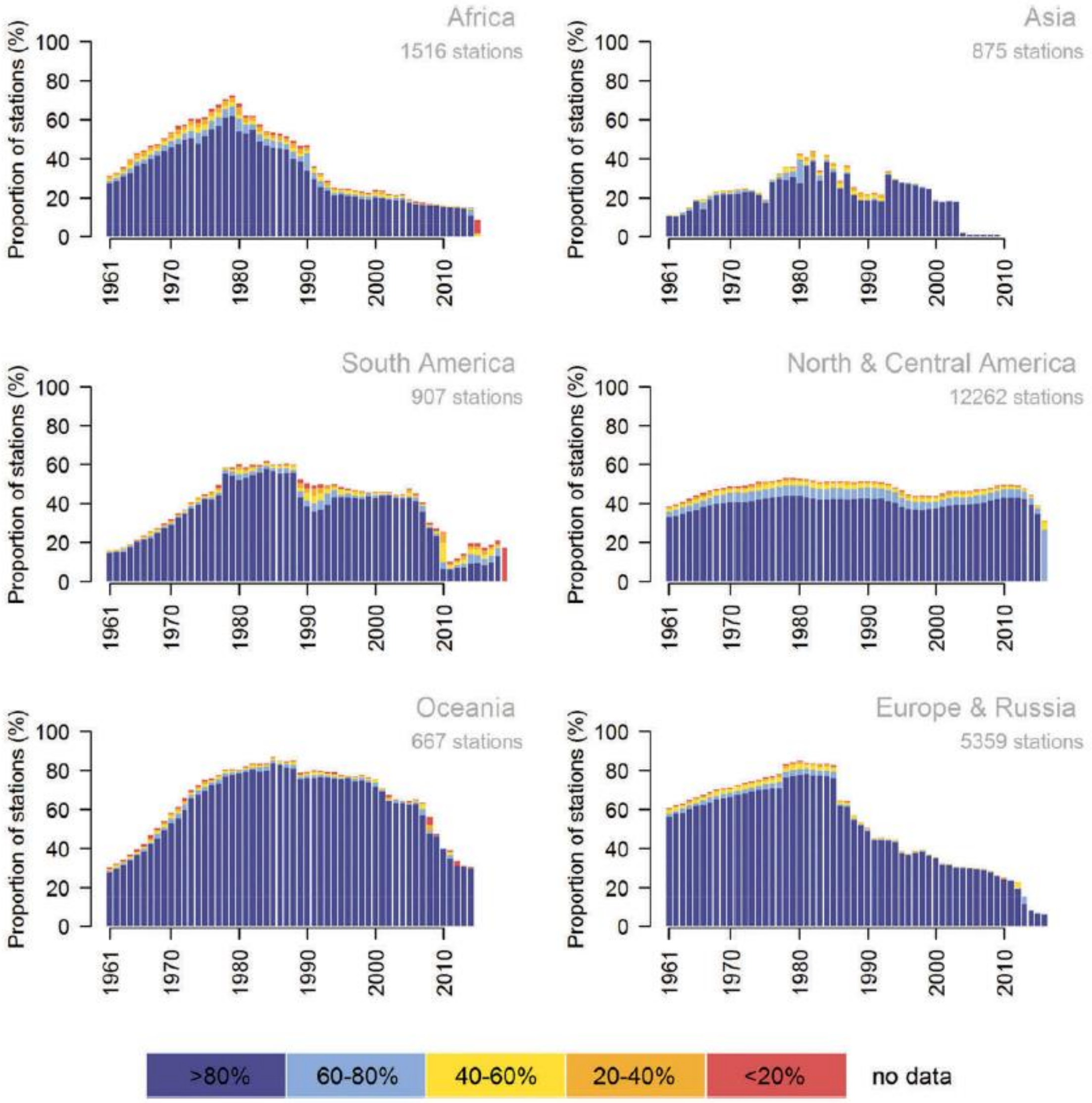
Major limitation of the hydro-monitoring network

- not uniformly distributed in the world
- many areas are still unmonitored
- the number of worldwide gauging stations has decreased

Crochemore et al., 2020 Hydrolog Sci J, Doi:10.1080/02626667.2019.1659509



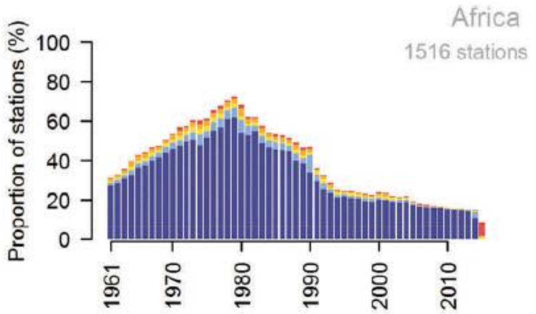
Colours indicate the average percentage of data availability over 1961–2019 for all stations in the country.



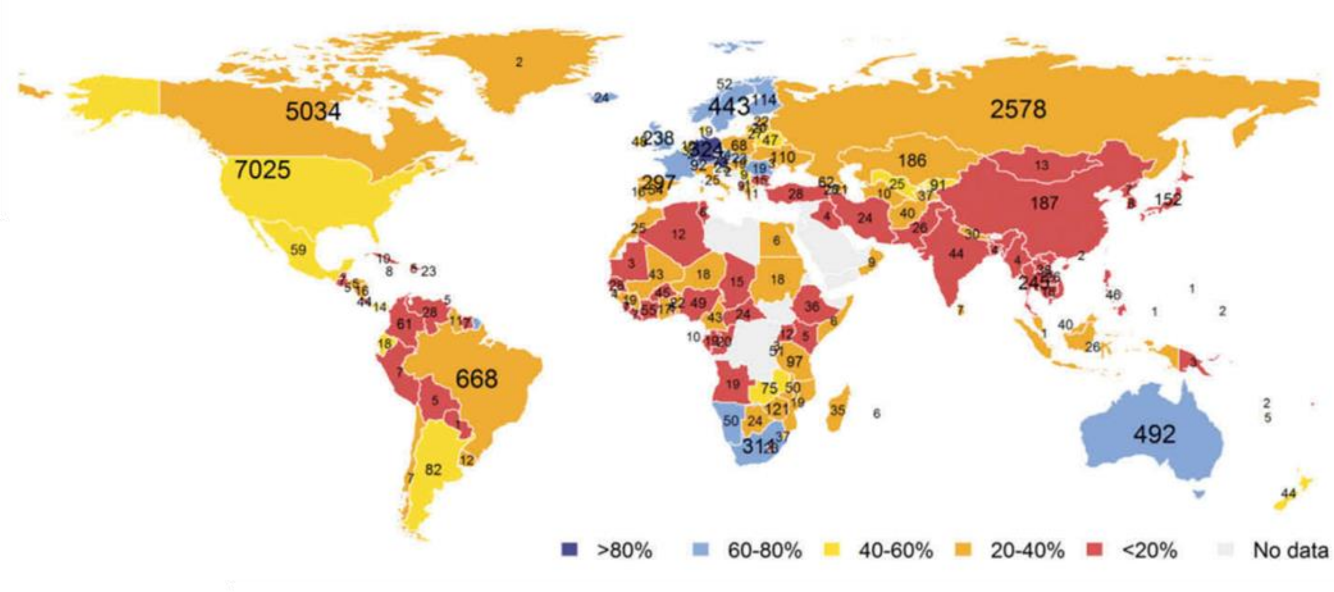
Proportion of river-flow data availability per year and per continent from 1961 to 2019

Major limitation of the hydro-monitoring network

- ❑ not uniformly distributed in the world
- ❑ many areas are still unmonitored
- ❑ the number of worldwide gauging stations has decreased



Crochemore et al., 2020 Hydrolog Sci J, Doi:10.1080/02626667.2019.1659509



Colours indicate the average percentage of data availability over 1961–2019 for all stations in the country.

- ❑ High cost of installation and maintenance
- ❑ Security and political instability issues
- ❑ Transboundary basins (lack of international cooperation)
- ❑ Lack of qualified staff

The insufficient sampling of African watersheds is a real issue for understanding climate change impacts on freshwaters and ensuring a safe, conscient and shared use of inland waters.

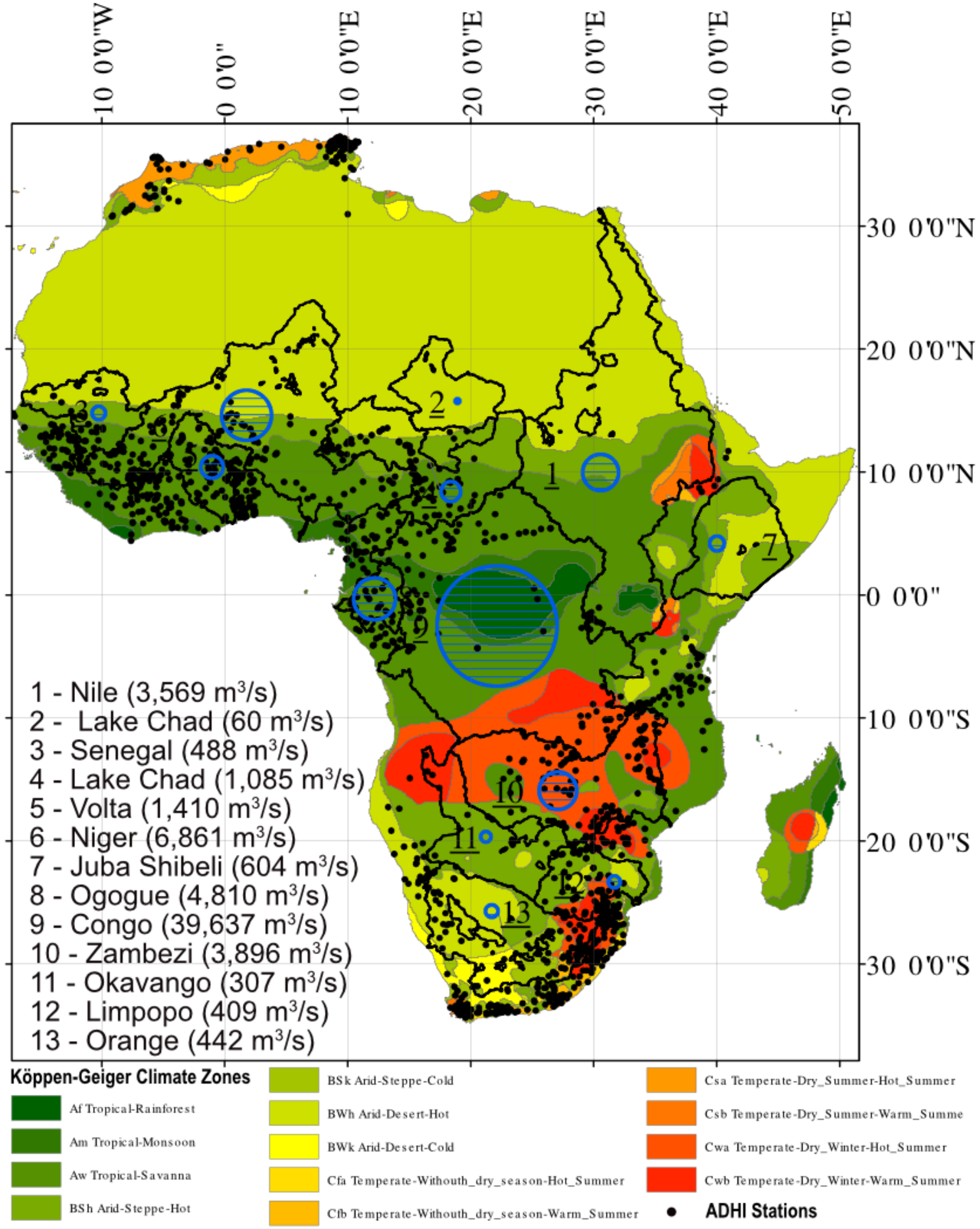
Major limitations of the hydro-monitoring network

Strict conditions related to the national authorities make not possible the sharing of original and real time data.

African Dataset of Hydrometric Indices (ADHI)
(e.g., minimum, mean and maximum daily streamflow, baseflow magnitude, slope of flow duration curve)

- ❑ n° stations: 1529
- ❑ original datasets: GRDC and SIEREM database
- ❑ data: minimum 10 full years of daily river discharge data
- ❑ period: 1950 - 2018

The largest ever built database of daily discharge data in Africa and the only source of data currently available and updated over the African continent.



Tramblay et al., 2021 ESSD, Doi:10.5194/essd-13-1547-2021

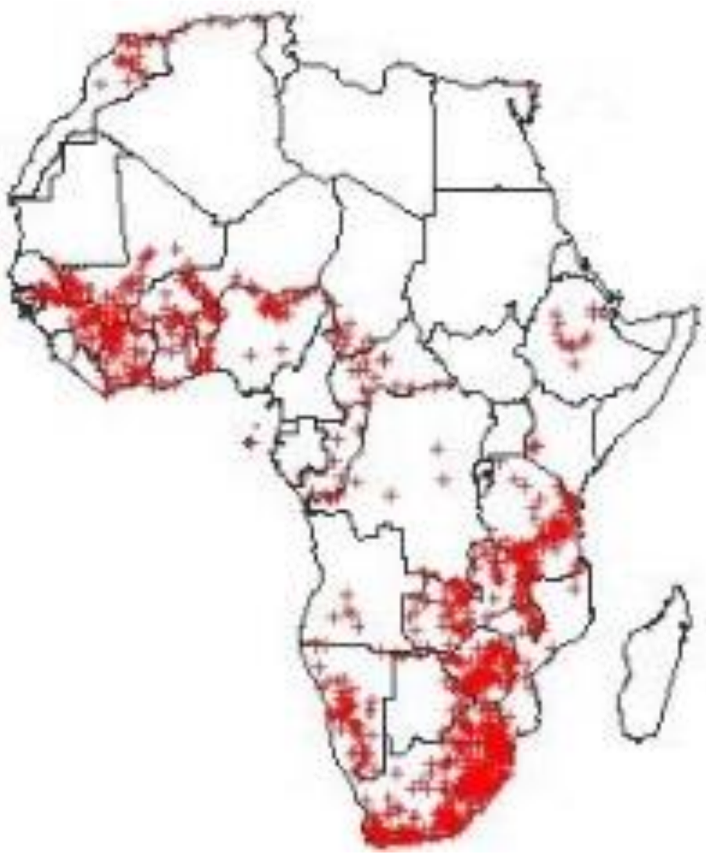
Satellite monitoring

Decades of available Earth observations data represent a tool complementary to the hydro-monitoring network and recently they have demonstrated their potential, especially for data-poor regions.

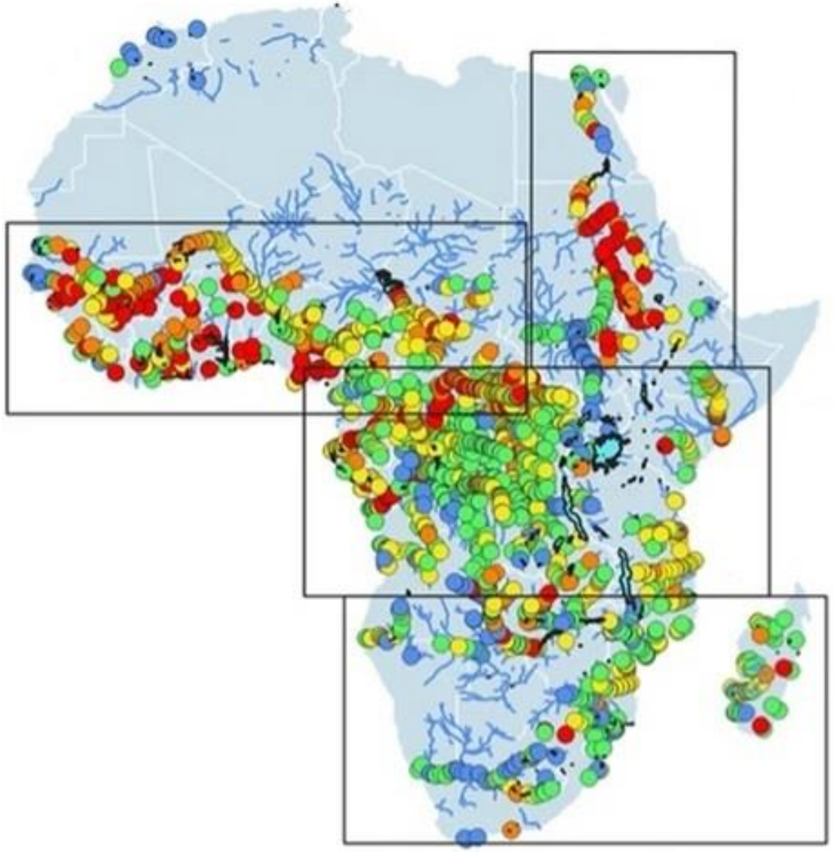
Satellite data are characterized by

- ❑ Short latency
- ❑ Continuity in time
- ❑ Large coverage

Here, a comparison between the number of satellite altimetry stations (on the right) and the in situ stations (on the left) for the water level monitoring: a significant increase in the number of measuring stations is evident.



Krabbenhoft et al. 2022, Nat Sustain, *doi:10.1038/s41893-022-00873-0*



Papa et al. 2022, Surv Geophys, *doi:10.1007/s10712-022-09700-9*

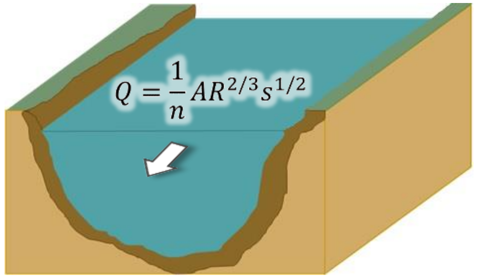
How to monitor freshwater from satellite?

Direct use in the hydraulic traditional laws or machine learning tools (local scale)

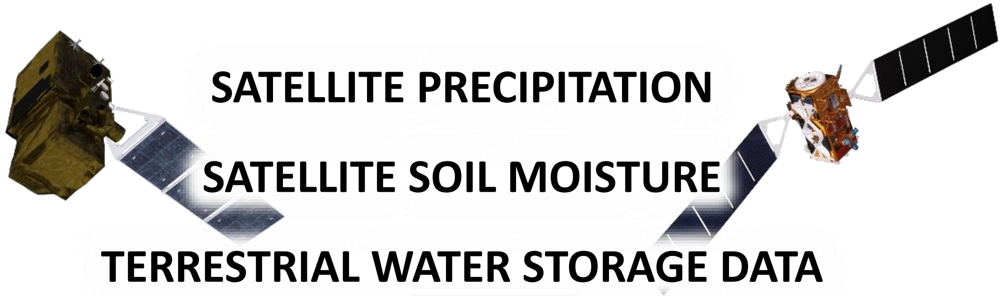
RADAR ALTIMETRY

NEAR INFRARES SENSORS

HYDRAULIC LAWS



Use of the satellite products into models (basin scale)

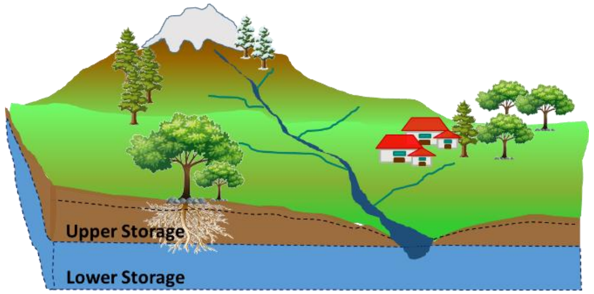


SATELLITE PRECIPITATION

SATELLITE SOIL MOISTURE

TERRESTRIAL WATER STORAGE DATA

CONCEPTUAL HYDROLOGICAL MODEL



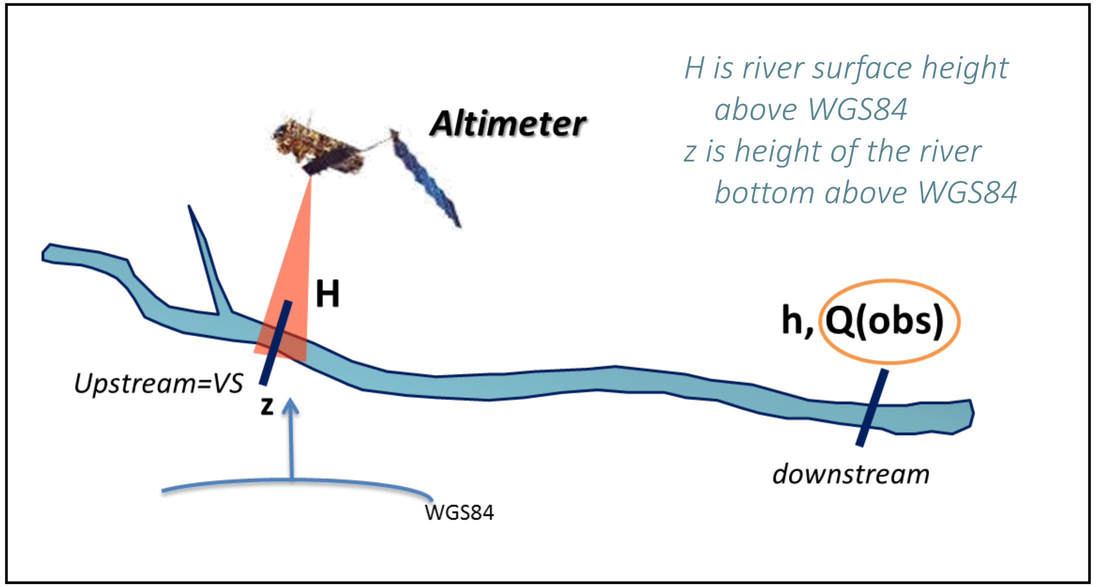
Tarpanelli et al., 2019, Adv Space Res, doi:10.1016/j.asr.2019.08.005

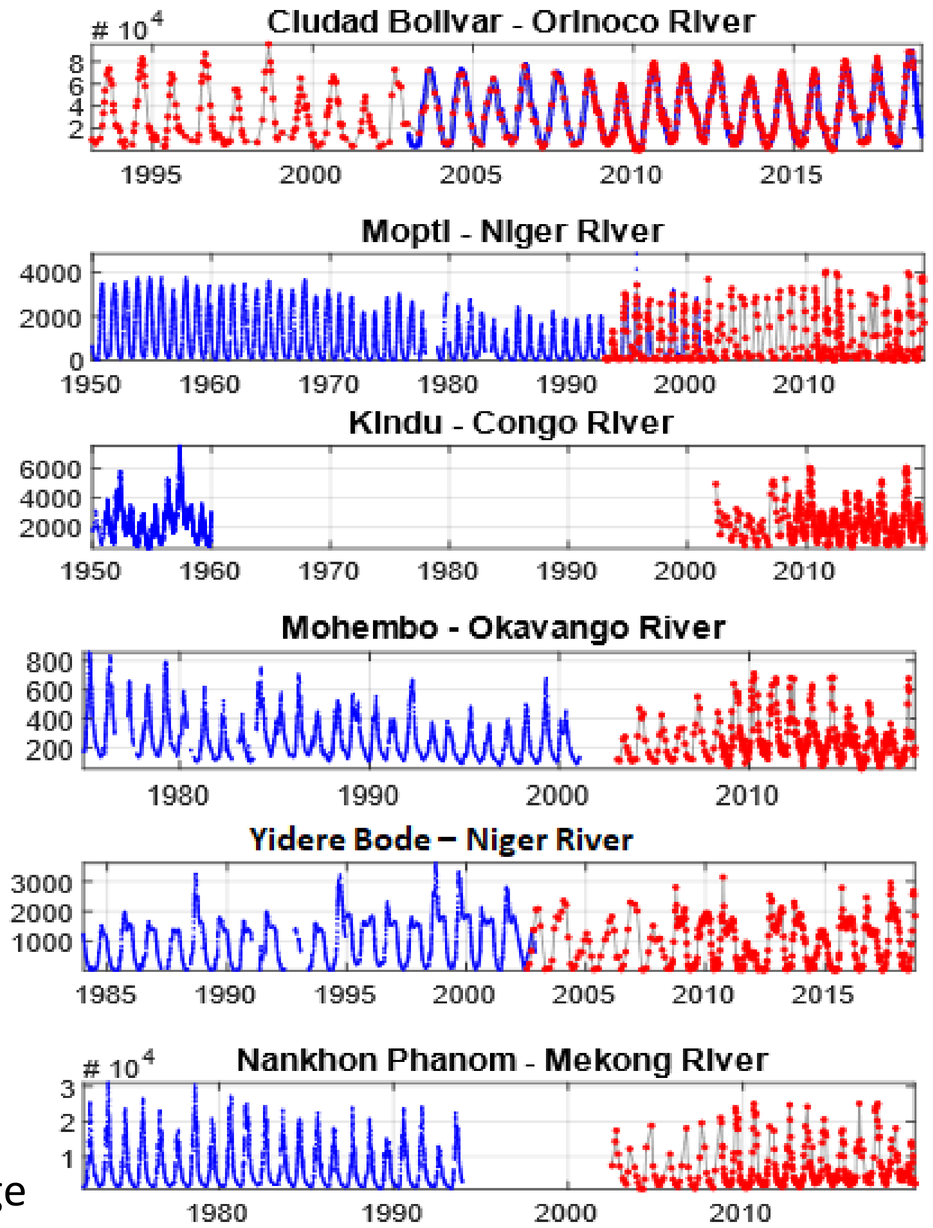
Camici et al., 2022, GMDD, doi:10.5194/gmd-2020-399

Tarpanelli et al., 2022, Surv Geophys, doi:10.1007/s10712-022-09744-x

River discharge estimation by radar altimetry

Satellite radar altimetry can be used to extent the temporal series of ground observed river discharge time series in dismissed stations.





Ground river discharge

Satellite-derived river discharge

Belloni et al., (2021) JoH doi:10.1016/j.jhydrol.2021.126870

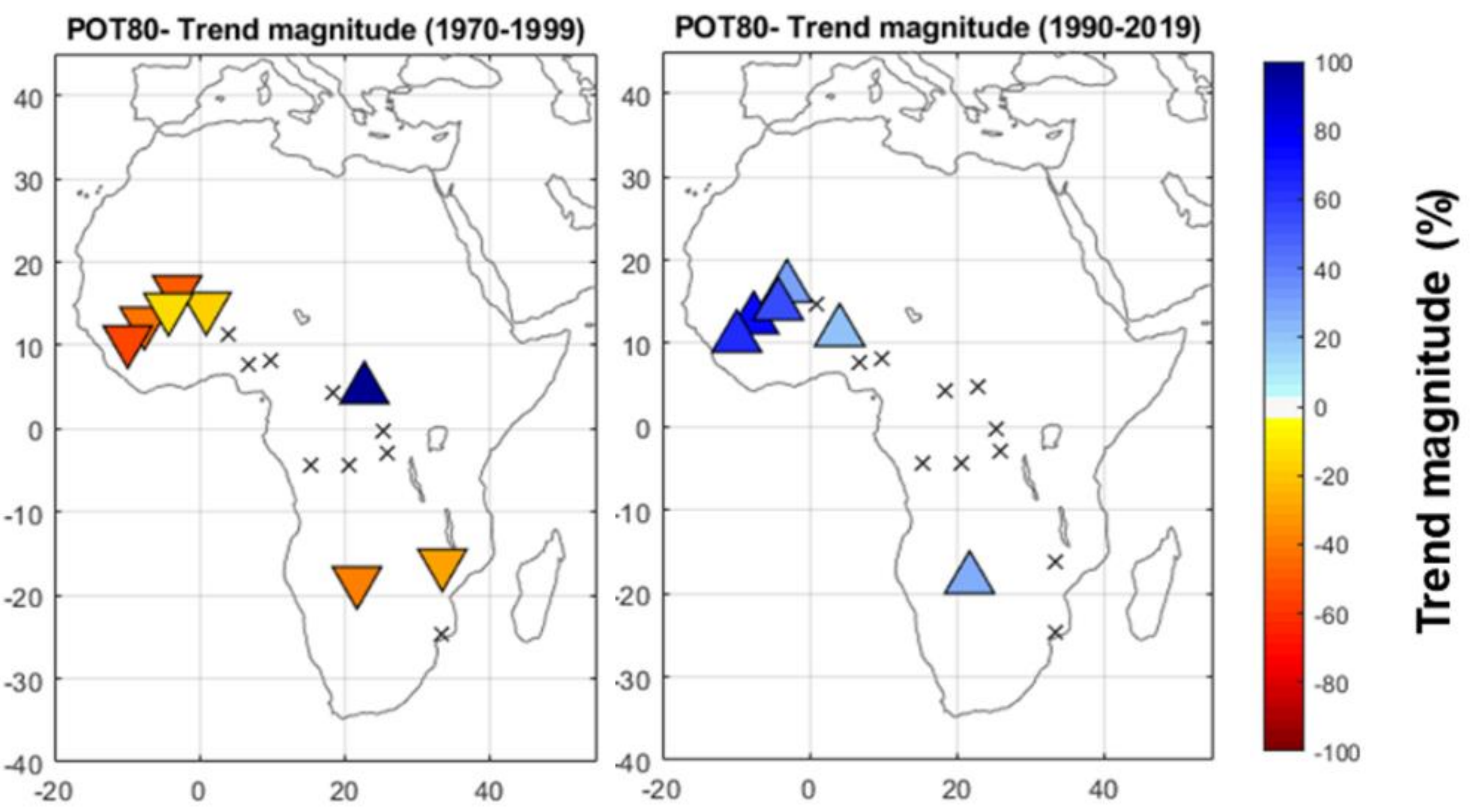
River discharge estimation by radar altimetry

Trend analysis of peak over threshold, POT, of high flow events (80th percentile) for two periods:

- ❑ 1970–1999
- ❑ 1990–2019

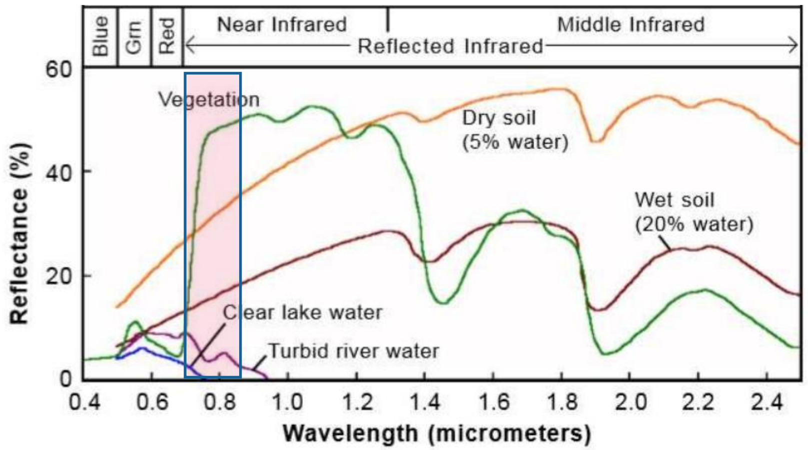
Legend:

- ❑ Crosses no significant trend
- ❑ red triangles indicate sites with significant negative trend
- ❑ blues triangles indicate sites with significant positive trend

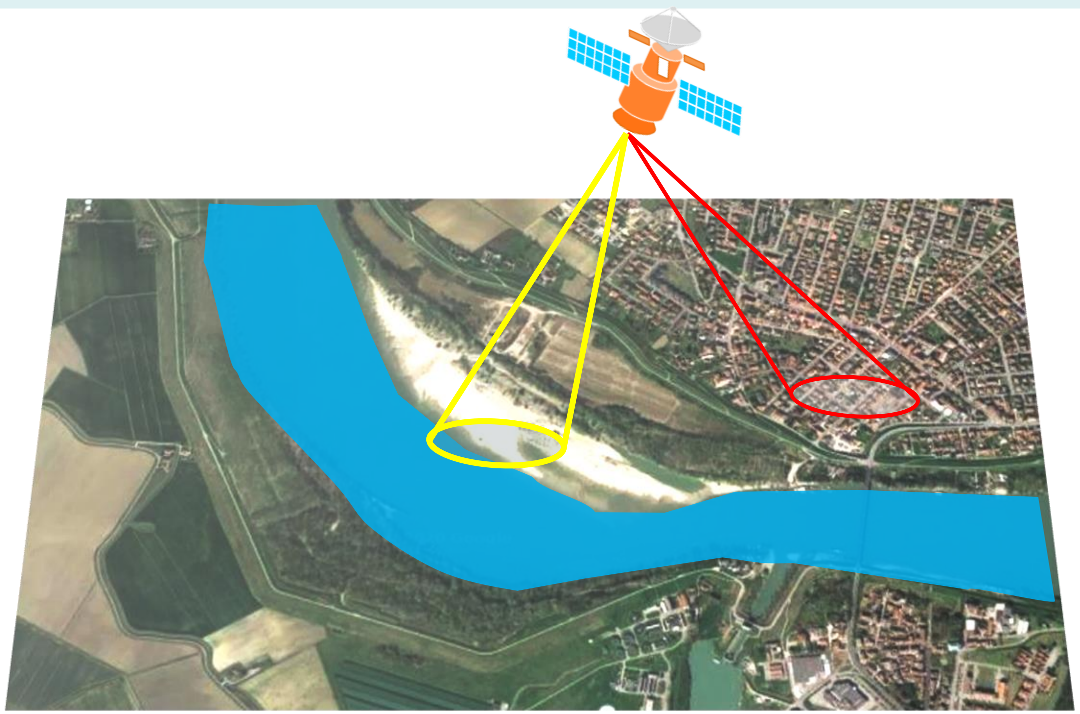


Belloni et al., (2021) JoH [*doi:10.1016/j.jhydrol.2021.126870*](https://doi.org/10.1016/j.jhydrol.2021.126870)

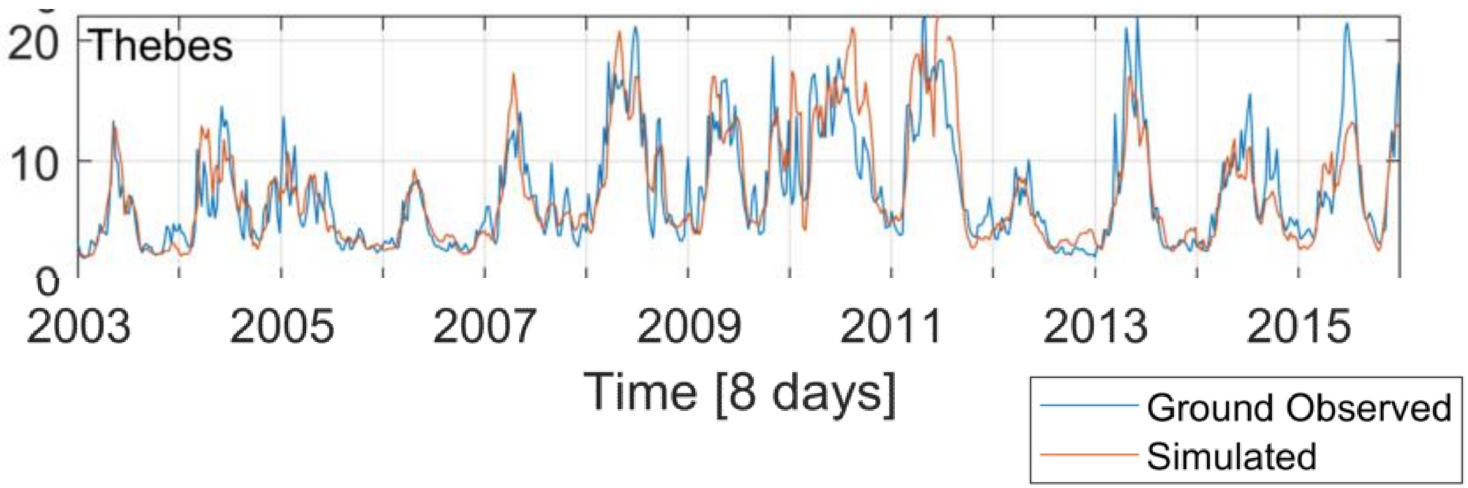
River discharge estimation by near infrared images



Spectral reflectance of clear water, turbid water, vegetation, dry soil and wet soil (**Mercan and Alam, 2011**)



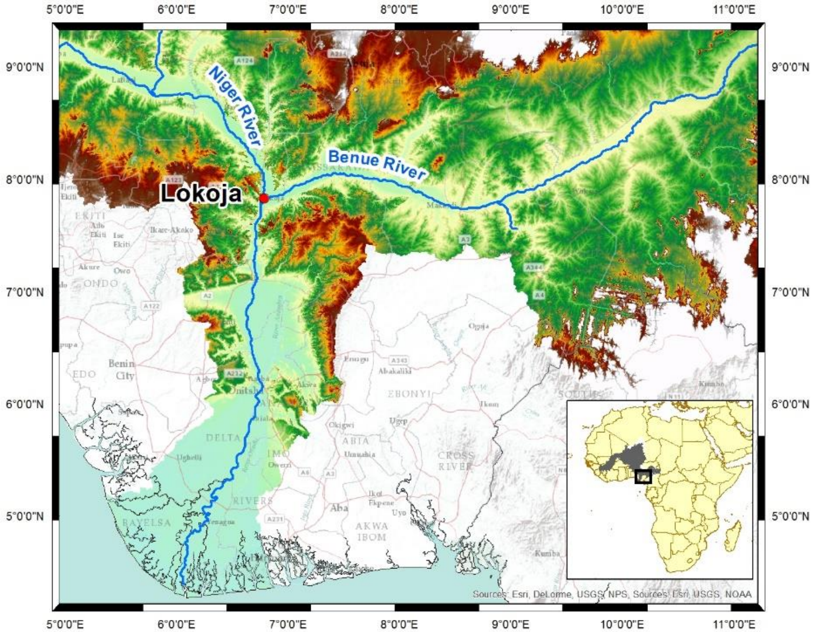
As for the altimetry, the reflectance indices in NIR band can be used to derive river discharge for long time periods. Currently, we are able to reproduce more than 20 years of satellite-derived river discharge data.

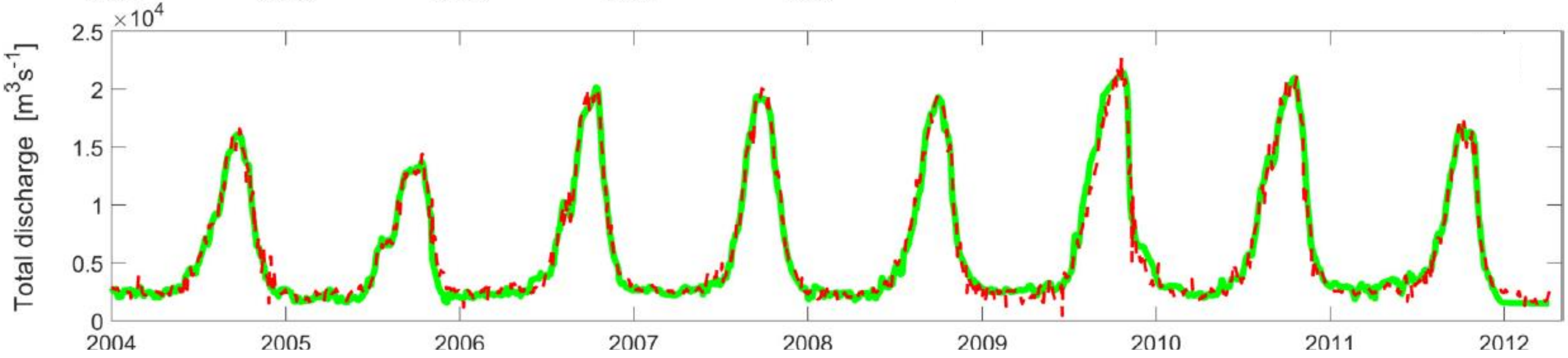


River discharge estimation by combination of near infrared images & altimetry

Niger at Lokoja

Combining multiple missions (near infrared images approach and satellite altimetry) along with the ground observations, river discharge time series become more reliable and robust for hydrological applications.

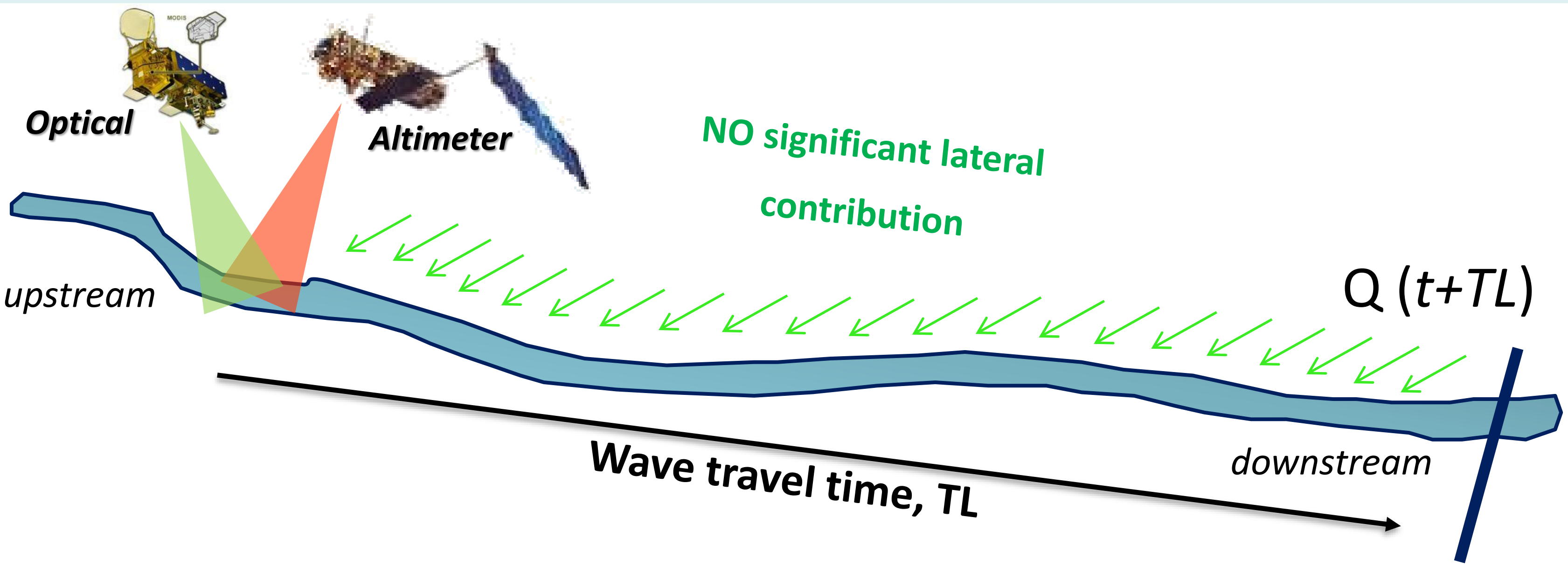




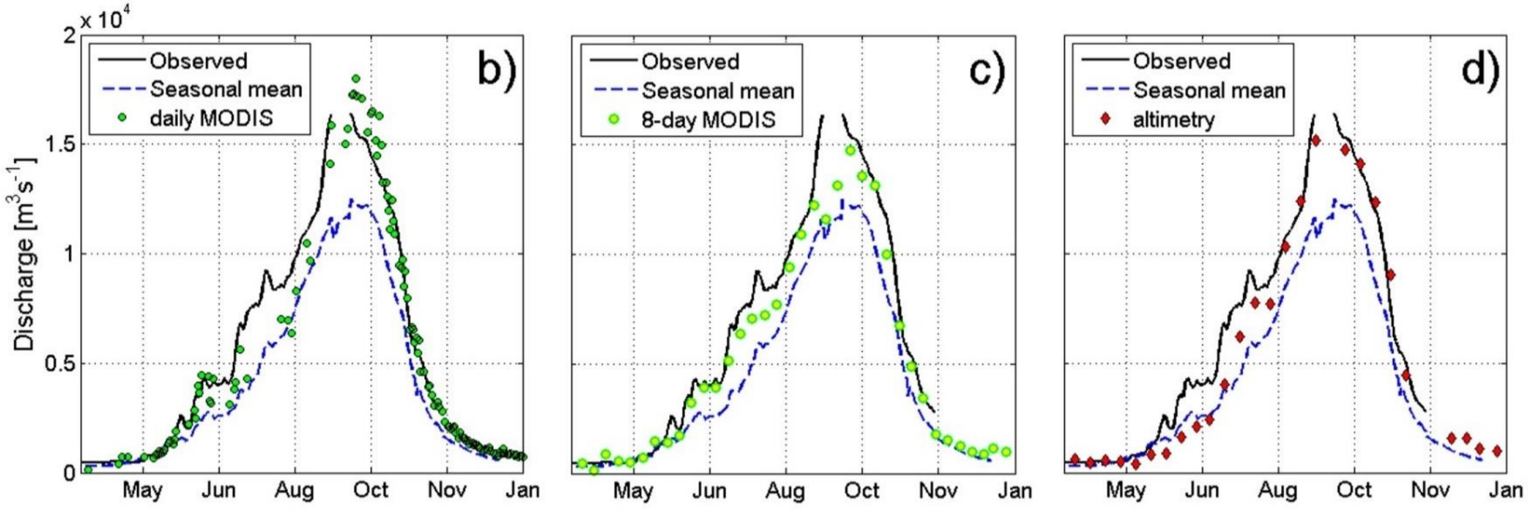
Tarpanelli et al., IEEE TGRS, 2019. Doi:10.1109/TGRS.2018.2854625

River discharge forecasting by imaging sensors & altimetry

The observations acquired some days before at an upstream section is informative of the downstream river discharge. The time of forecast is equal to the wave travel time (some days).

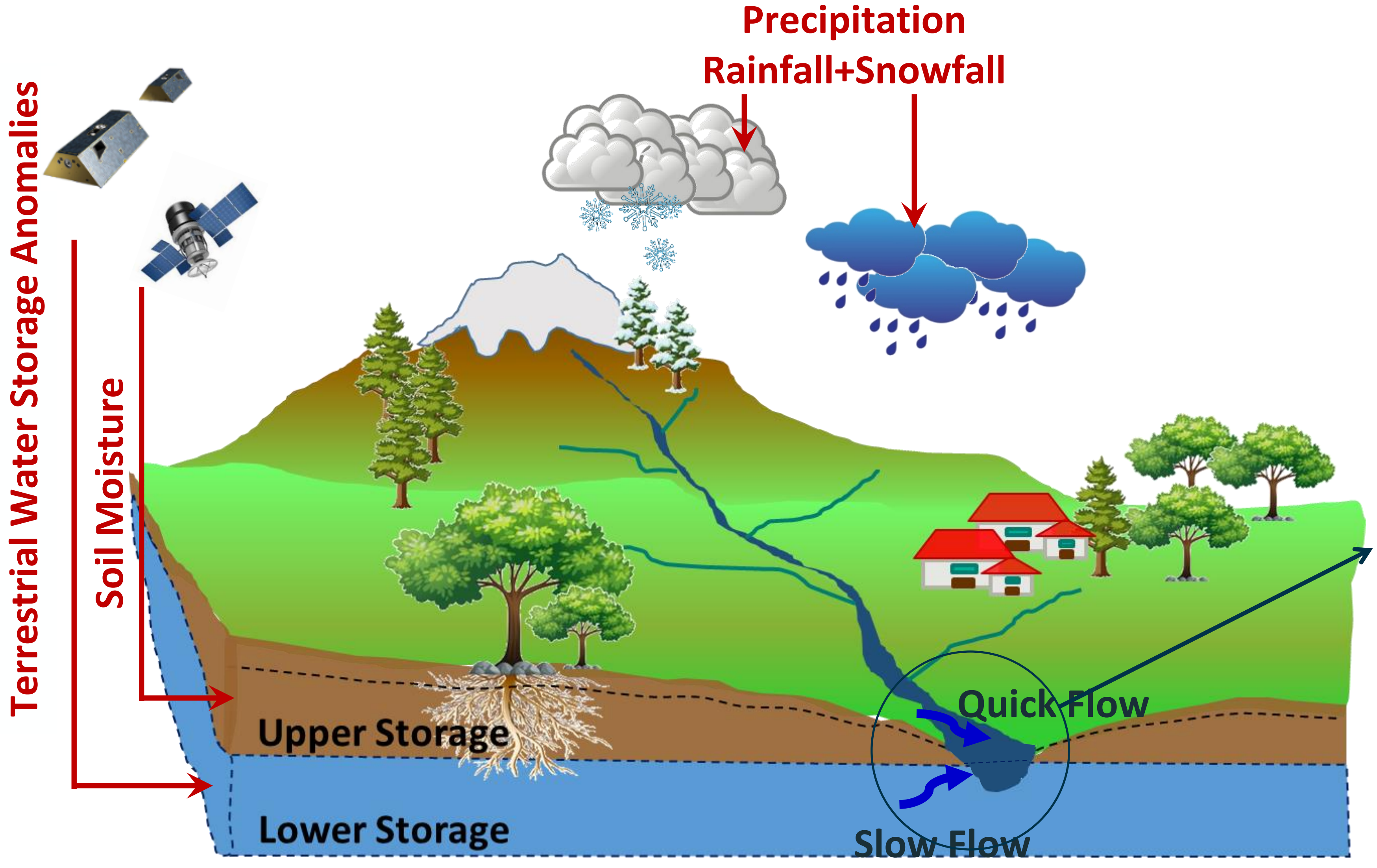


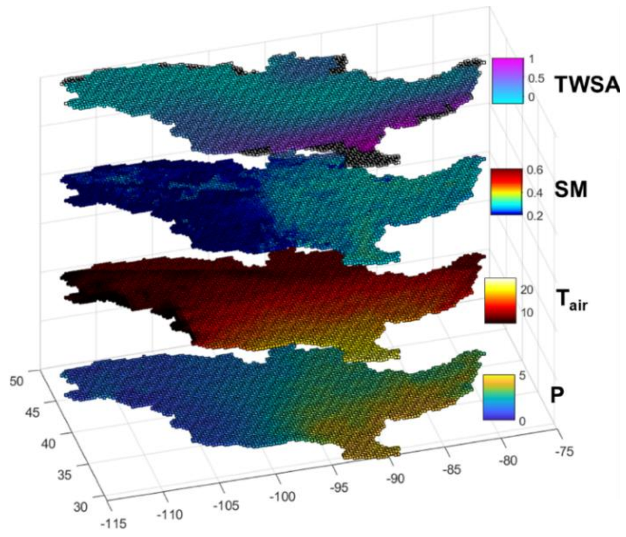
Example in Benue River



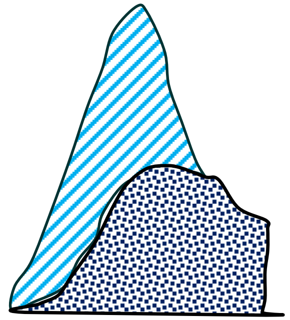
Tarpanelli et al., 2017, Remote Sens Environ,
Doi:10.1016/j.rse.2017.04.015

River runoff and discharge from the conceptual model STREAM





Total discharge
=
Quick Flow + Slow Flow

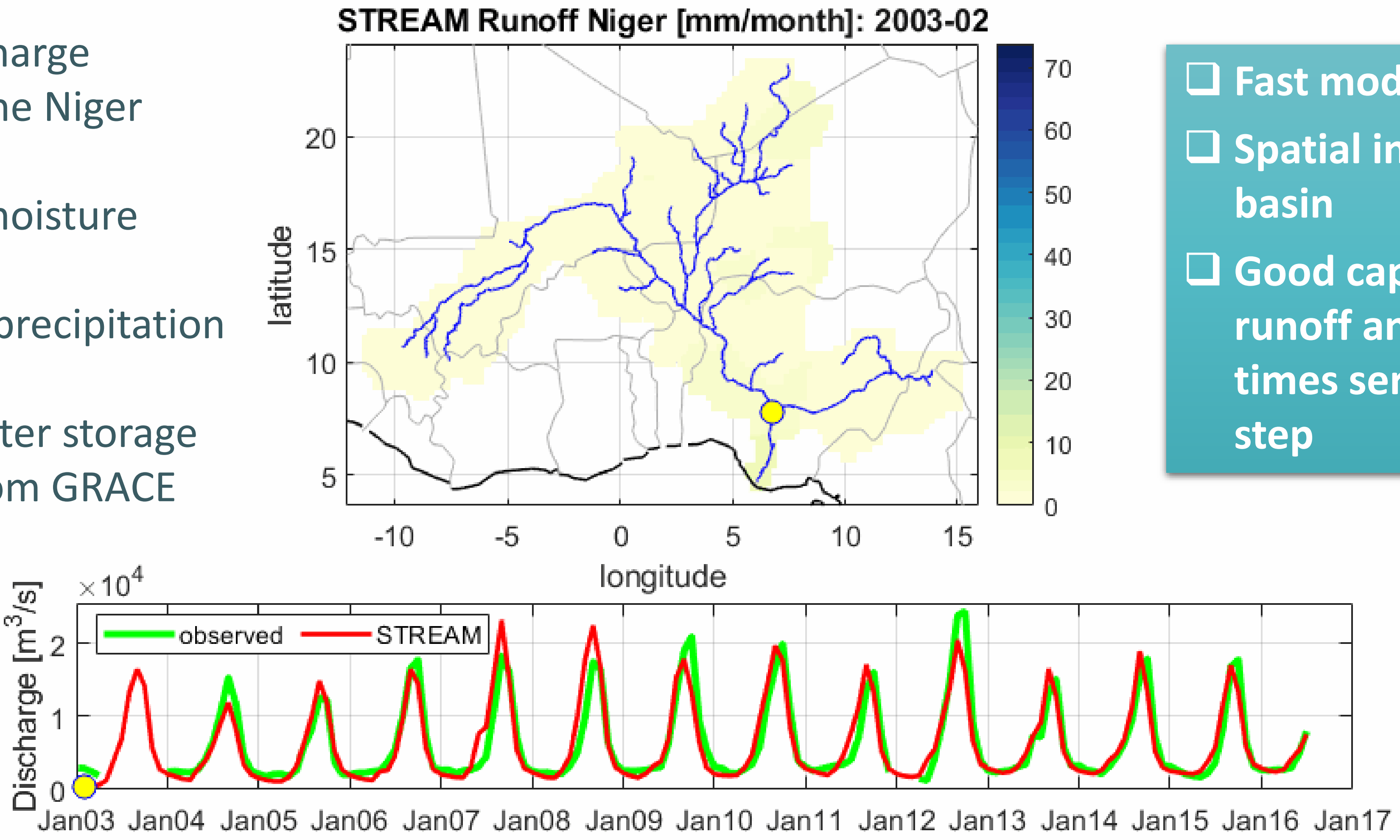


Camici et al., 2022, GMDD, doi:10.5194/gmd-2020-399

River runoff and discharge from the conceptual model STREAM

Runoff and discharge estimation for the Niger basin from

- ❑ ESA CCI soil moisture product
- ❑ TRMM 3B42 precipitation product
- ❑ terrestrial water storage anomalies from GRACE



- ❑ **Fast modelling set-up**
- ❑ **Spatial information over a basin**
- ❑ **Good capability to reproduce runoff and river discharge times series at daily time step**

Camici et al., 2022, GMDD, doi:10.5194/gmd-2020-399

Conclusions and future perspectives

- **Great advantage of having satellite data** that are freely available, continuous over time, with a wide spatial coverage, and independent of any political aspect to be used in data scares areas.
- The **water availability** has a central role in **improving the climate resilience of Africa** and the **monitoring** become one of the **essential tools** to manage the water resources and assess the flood and drought risks.
- The role of satellite and in situ data, together with the modelling and the data assimilation techniques can offer a large support on this aspect and with **the future perspective of high-resolution products** the reproducibility of the implemented approaches for large basins to small regions appears increasingly feasible.
- The ongoing initiative by the scientific community on **existing or future satellite missions**, as well the **exploration of new techniques** and the recent advances in **the machine learning methods** represent good opportunities:

i) to improve the **understanding of hydrological processes** at various spatial and temporal scales,
ii) to play a determining role in the **decision-making activities** and
iii) to maintain **a long-term archive of hydrological data**.

- The **promotion** and the **dissemination** of remote sensing is important for the process of developing and strengthening the skills, the processes and resources that African organizations and communities need to survive and adapt to the climate change.

Thank you for your attention

Contact Information

angelica.tarpanelli@irpi.cnr.it
idrologia@irpi.cnr.it

http://hydrology.irpi.cnr.it

@ATarpanelli
@Hydrology_IRPI