# Application of radar altimetry in surface water bodies monitoring of the second largest worldwide river basin


## Abstract

Despite being the second-largest river basin and tropical forest worldwide, with significant impacts on the socio-economic growth at the regional scale and in regulating Earth's climate, the Congo River basin's hydro-climatology remains among the least studied worldwide due to the lack of situ observations. Almost 2300 virtual stations of large records over 21-year of satellite-derived water levels from different radar altimetry missions are used to better understand the surface hydrology of the Congo basin. This satellite dataset provided relevant information in support of policy decision of river basin management and adequate management strategies such as prediction of navigation water levels.


## 1. Introduction

The Congo River basin (CRB) is located in the equatorial region of Africa. It is the second largest river system in the world, both in terms of drainage area (~3.7 x $10^6$ $km^2$) and discharge (~40 500 $m^3$ $s^{-1}$) (Laraque et al. 2020). Its drainage area spans over nine countries that are Central Africa Republic, Cameroon, Republic of the Congo, Angola, Democratic Republic of Congo (DRC), Zambia, Tanzania, Rwanda, and Burundi (Figure 1). In DRC, the Congo River and its tributaries are the main and sometimes only transportation corridor (Tshimanga et al., 2022).

About 45% of the CRB land area is covered by dense tropical forest, accounting for ~20% of the global tropical forest (Verhegghen et al., 2012). It is the world's largest tropical peat carbon that accounts for ~28% of the total area of tropical peat carbon (Crezee et al., 2022). Additionally, more than 80% of the human population within the CRB rely on the basin water resources for their livelihood and are particularly vulnerable to climate variability and to any future changes that would occur in the basin water cycle (White et al., 2021). Bele et al. (2010), Ingram et al. (2011), Tshimanga and Hughes (2012) evidence the changes in land use practices that pose a significant threat to the basin water resources availability, including hydrological processes in the basin. These environmental alterations require a better comprehension of the overall basin hydrology. Surprisingly, despite its major importance, the CRB is still one of the least studied river basin in the world. Therefore, the knowledge of the CRB hydro-climatic characteristics and their spatio-temporal variability that should help improve water resources management in the basin is still insufficient. This is sustained by the lack of in situ data networks that keep the basin poorly monitored at a large scale (Tshimanga, 2022).

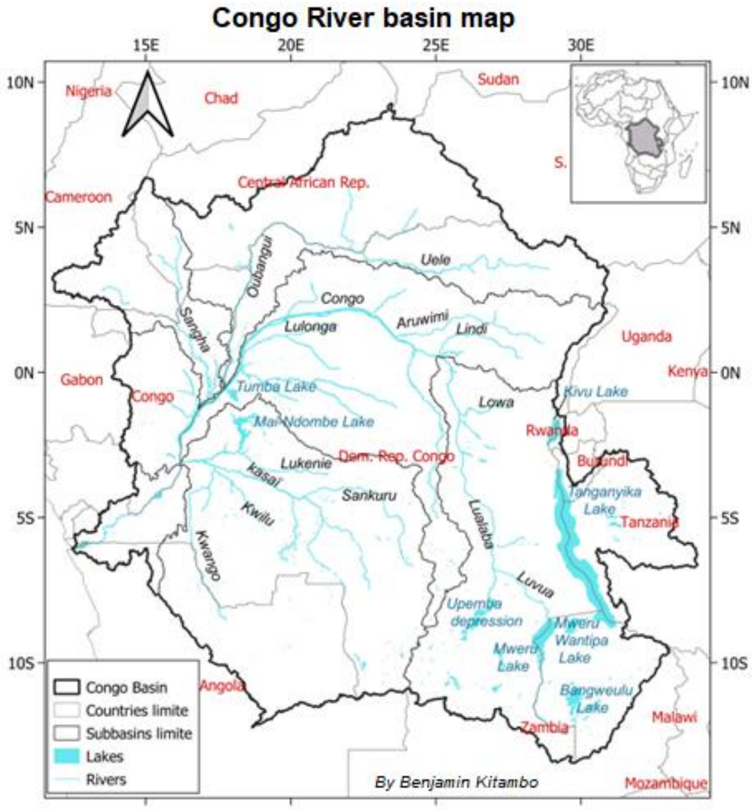


*Figure 1. Main physiography features of the CRB. Smal dark line shows the major subbasins. Red colour names indicate countries.*

A better understanding of hydrological processes across the basin therefore becomes fundamental for addressing these current challenges and for reducing uncertainty in future evolutions of water availability (Tshimanga et al., 2022). Earth observation (EO) is a unique means to address these questions and is very useful for monitoring large drainage basin climate and hydrology where in situ information is lacking (Fassoni-Andrade et al., 2021).

## 2. Application of radar altimetry in surface water bodies monitoring

Since the 1960s, there has been a drastic decline in the hydro-meteorologic monitoring networks in the CRB so that, currently, there are no more than 15 gauges considered as operational (Figure 2, Tshimanga et al., 2016). Satellite remote sensing techniques offer a cost-effective means for monitoring the various components of the terrestrial water cycle, with a relatively continuous, high spatio-temporal coverage and reasonable accuracy (Chawla et al., 2020).

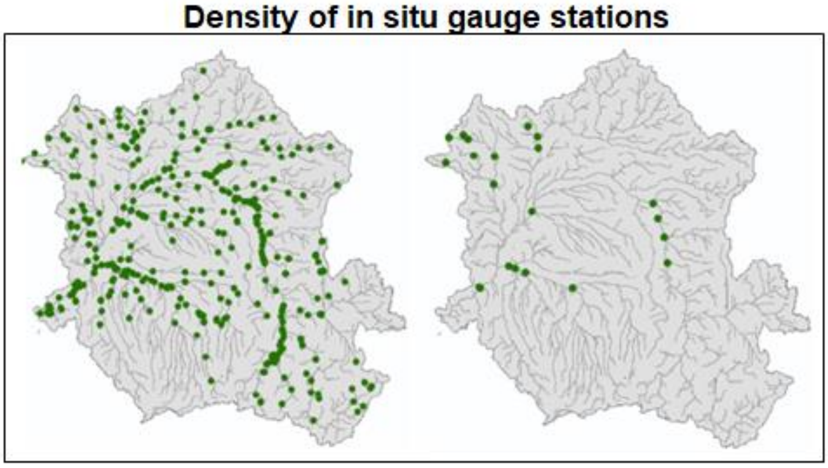


*Figure 2. Density of streamflow gauges in the CRB before 1960 (left) and the current situation (right) (Tshimanga et al., 2016).*

For instance, since the late 1990s, radar altimetry missions provide observations of Surface Water Level (SWL) of lakes, rivers and floodplains under their orbit tracks, now with the potential of long-term monitoring at thousands of Virtual Stations (VSs, crossings of a satellite ground track with a water body where surface water levels can be retrieved with temporal resolution provided by the repeat cycle of the orbit) (Cretaux, 2022). In the CRB, a number of ~2300 VSs covering the period 1995 to 2020 and spatially distributed were analyzed with a total number of 323 VSs from European Remote Sensing-2 satellite, 706 VSs for Environmental Satellite mission, 146 and 98 VSs respectively for Jason-2 and 3 satellites, 358 VSs for Satellite with ARgos and ALtika, 354 and 326 VSs for Sentinel-3A and 3B, respevtively. The analysis carried out with these altimetric data enabled to get a spatial distribution map with information on the maximum amplitude, the time of maximum and minimum of SWL across the whole basin as ever done before (Figure 3, Kitambo et al., 2022). This real-time estimates of SWL from satellite radar altimetry is of major importance for operational monitoring and informed decision making.

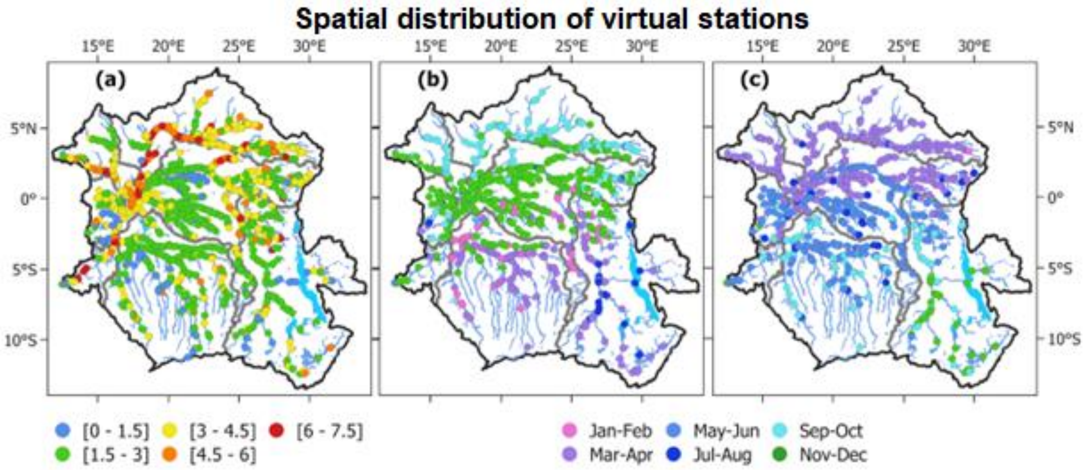


*Figure 3. Spatial distribution of VSs over the CRB. Maximum amplitude of SWL (in meters) (a). Average month of the maximum of SWL (b). Average month of the minimum of SWL (c) (Kitambo et al., 2022).*

The current operational satellite altimetry constellation enables therefore, first, to provide a good control of SWL for navigation to facilitate export of goods and services to internal market. Second, the operational radar altimetry in combination with large-scale hydrological model allow a near-real time monitoring of CRB's surface hydrology by providing long-term river discharge all over the basin using the rating curve method (Paris et al., 2022) with applications in the analysis of climate trends and forecasting of extreme events such as flood. An example of the latter application is given by the MGB-HYFAA plateform for the Niger basin (https://mgb-hyfaa.pigeo.fr/site/, last access 04 January 2023). Therefore, the use of satellite data in monitoring surface water resources in the CRB plays a crucial role for the International Commission of the Congo-Ubangi-Sangha Basin in charge to promote inland navigation and integrated water resources management in the CRB (Brachet et al., 2022).

## 3. Conclusions

This essay highlighted the suitability of satellite radar altimetry to understand the hydro-climatic characteristics in a large ungauged tropical basin. The very first use of large radar altimetry dataset spanning the period of more than 20 years in the sparse gauged of the CRB permitted an unprecedented analysis of the spatio-temporal dynamics of CRB's surface freshwater that helps improve practices of water resources management in the basin and address impacts of environment change. EO advances are therefore a breakthrough for surface hydrology and a unique opportunity to develop comprehensive observing systems to predict navigation water levels and extreme events, flood or drought that impact negatively people.

This unique dataset of SWL from radar altimetry opens opportunity to generate estimates of surface water and groundwater storage in combination with other remotely sensed data.

## 4. References


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