Cameroon Advanced Measurements for Enhanced Observations of Water levels using Affordable GNSS-IR

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Scientific Background and Objectives

1) Monitoring sea and river levels using innovative, low-cost, low-power sensors based on Global Navigation Satellite System Interferometric Reflectometry (GNSS-IR), known as Raspberry Pi Reflectors (RPR), to support a national network for water resource management, multi-scale coastal flood monitoring, and its relationship to storm surges, tides, and sea-level rise.

2) Validate the water and sea level estimates produced by the ESA Sentinel-3&6 satellites through direct comparisons with RPR measurements. Assessing the potential of fully-focused SAR (FFSAR) altimeter data for coastal and estuarine monitoring.

Research Outline

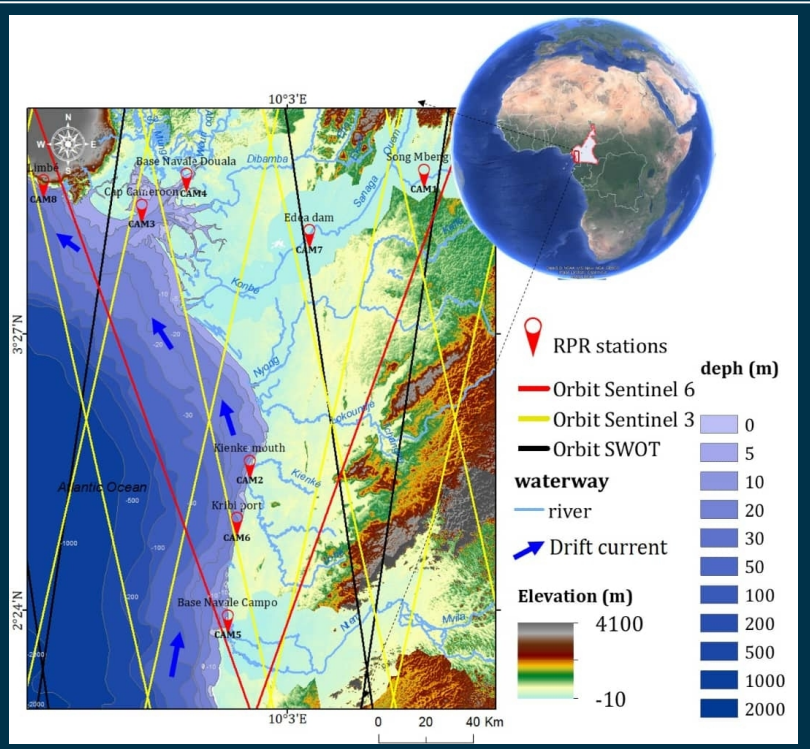
* We defined ESTCON initiative in this project as:

1. **Establish (EST):** a cost-effective, low-maintenance monitoring infrastructure that can be implemented in developing countries to support operational early-warning systems for floods and droughts. We established Africa's first GNSS-IR network dedicated to coastal and inland water level monitoring.

2. Contribute (CON): to an operational reference measurements production chain by providing continuous, high-quality reference data for the validation of Sentinel-3 and Sentinel-6 altimetry measurements over coastal and inland waters.

3. Strengthen capacity: develop local technical expertise and establish enduring data-sharing collaboration frameworks based on open-science and FAIR data principles. Together with other existing projects at the University of Bonn, the data hub www.GNSS4SurfaceWater.com was developed as an open-access platform to host and disseminate water level time series generated by this project and related initiatives.

Study Area



Eight RPRs were deployed across a range of hydrodynamic environments in Cameroon between May and June 2025.

* Two stations were installed along the Sanaga River:

CAM7 adjacent to Edea hydropower dam, CAM1 near a planned dam

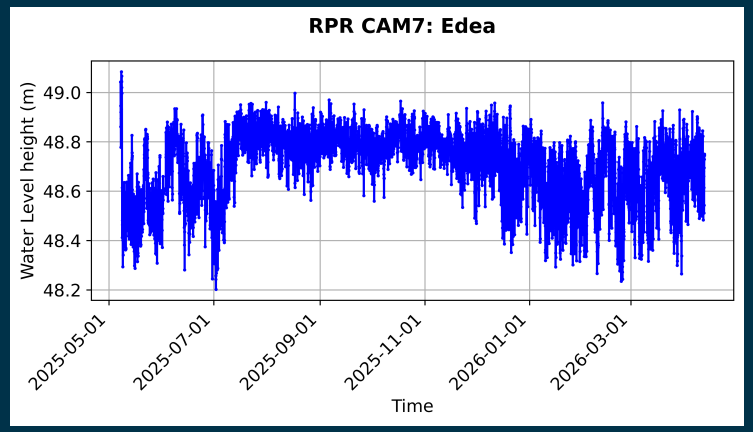
* Six stations covered the coastline:

CAM4 (Wouri estuary), CAM5 (Campo-Ntem) estuary

CAM2 (near the coastal city of Kribi), CAM8 (near the coastal city of Limbe), CAM6 (within the port of Kribi)

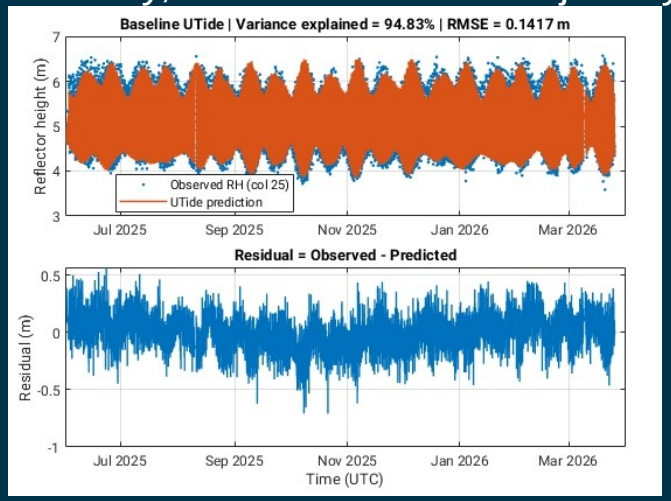
Results

An example of an inland water level monitoring site is the Edea Dam, a major hydropower facility in Cameroon.



This RPR and the other RPR on the Sanaga River, picked up very small diurnal fluctuations in river level caused by regulated water releases for hydropower production. Comparison with a nearby river gauge shows centimetre-scale accuracy.

An example of a coastal water level monitoring site is the Wouri estuary, located near the major city of Douala.



Tidal analysis was carried out at all RPR stations, revealing a flood-dominant tidal regime across the network. The example shown here illustrates the tidal decomposition and the resulting residuals, which were further analysed to derive a surge proxy.

Further work

Building on the success of the CAMEO-WAGST project, a follow-on ESA-funded project has been secured. In the upcoming St3TART-FO project, we will pioneer the use of GNSS-IR as Fiducial Reference Measurements (FRM) for Sentinel-3 inland water validation across West Africa and the Asia-Pacific region. The project is set to kick off in Spring 2026 and will run for three years.

We will rely on technologies such as LoRa for data transfer in regions where mobile network coverage is unavailable, which remains a common challenge across Africa.

We have upgraded the RPR sensor to be more power-efficient and significantly lighter, with new features for autonomous self-maintenance.

Layout for social media posts

Recommended image resolution 1200 x 675 pixels - landscape format

Post for BS and X (max 230 characters including hashtags)

Africa's first GNSS-IR network for water level monitoring is live in Cameroon! 8 low-cost stations, cm-level accuracy, validating Sentinel-3 & 6. Data: www.GNSS4SurfaceWater.com #GNSS #Africa #ESA

Post in LinkedIn: 600-630 characters including links

We established Africa's first dedicated #GNSS-IR network for coastal and inland water level monitoring, deployed in Cameroon as part of the ESA-funded #CAMEO-WAGST project (led by Makan Karegar and Loudi Yap).

Eight low-cost GNSS-IR #RaspberryPiReflector stations were installed in 2025 along the Sanaga River and Cameroon's coast and estuaries. The network reaches cm-level accuracy and serves as validation for Sentinel-3 and Sentinel-6 satellite altimetry.

Raw NMEA data and water level time series are openly available at www.GNSS4SurfaceWater.com

Code and workflows at https://github.com/MakanAKaregar/ESA_CAMEO_WGAST