Portagauge and Satellite Sea level monitoring system for the Southwest Indian Ocean – PASS-SWIO

D Cotton[1], A Becker[2], A Hibbert[2], S Williams[2],

H Razafindraibe[1], M Restano[3], J Benveniste[4], Roberto Sabia[5]

(1) SatOC (UK), (2) National Oceanography Centre (UK), (3) SERCO/ESA (Italy), (4) beneviste.space (France), (5)ESA-ESRIN (Italy)

PASS-SWIO project

PASS-SWIO was a capacity building project to establish a sea level monitoring system for Madagascar based on the installation and deployment of a low-cost relocatable tide gauge (Portagauge, Fig. 1) combined with the analysis of satellite altimeter sea level data to provide validation and wider scale knowledge on sea-level variability. The project worked closely with the national Madagascar Meteorological Agency (DGM, Direction Générale de la Météorologie) who took responsibility for the local maintenance and operation of the Portagauge, and who were trained to carry out the data processing and analysis.

Discussions were held with key stakeholders to review the project and agree a Road Map for the sustainable long-term implementation of a national sea-level monitoring system for Madagascar, which can serve as model for other island states and coastal countries in the South-West Indian Ocean (SWIO) region and beyond.

The NOC Portagauge

The Portagauge (Fig. 1), developed and built at the NOC, includes a conventional radar gauge and a GNSS receiver, which enables monitoring of relative sea level, absolute sea level and land motion relative to the geoid and to local datums. It is a stand-alone system powered by batteries recharged by solar panels with a robust aluminium frame construction and a water tank for ballast and stability.

The NOC Portagauge was successfully installed in Toamasina, Madagascar on 13 June 2023 and has been providing high quality data since that date.

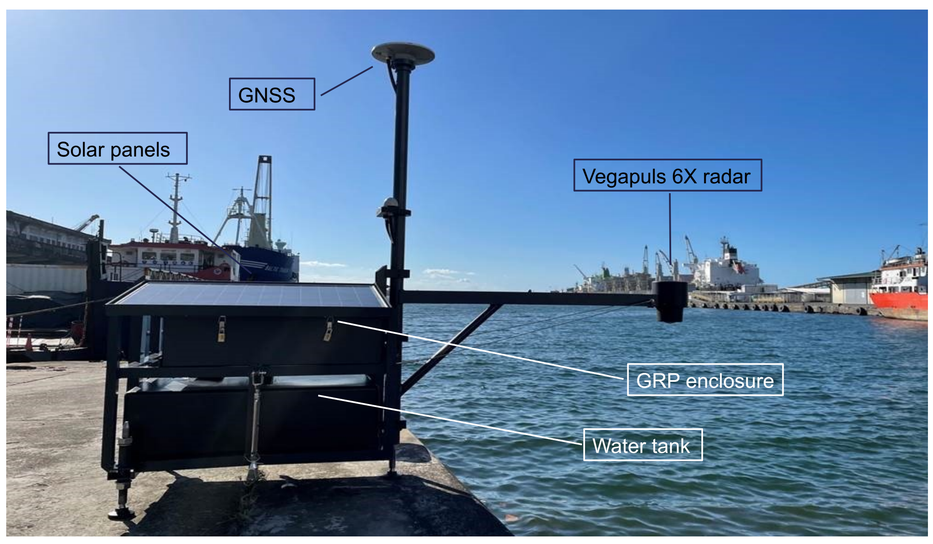

Figure 1. The NOC Portagauge deployed at Toamasina, Madagascar

Sea level variability and the importance of measurement

The main characteristics of sea level variability around the Madagascar coast are:

- Tidal range varies from 4m in the northwest to less than 1m on the east coast.
- Long term trends in sea level also vary around the coast of Madagascar, from 3.9 $mmyr^{-1}$ in the northwest to 2.1 $mmyr^{-1}$ in the southeast. This does not include the effect of any vertical land movement at the coast, which should be investigated.
- The seasonal cycle in sea-level is of the order of 5-10cm, and so is not significant compared to other factors.
- The storm surge associated with tropical cyclones can be up to 2m. The impact of storm surges can be felt at all locations on the Madagascar coast, but analysis of historical storms indicates the northeast coast and central west coast are most at risk.
- The maximum runup from the 26/01/2004 Indian Ocean Tsunami was 5.4m at Betanty in the south.

Madagascar has very limited tidal prediction (primarily based on model data) and no national sea level monitoring capability. Tidal information is vital for the safety of communities, infrastructure and commerce, and as short-term hazards are exacerbated by long-term increases in sea level, knowledge of longer-term change is also essential.

Evaluation and cross validation

Eight months of Portagauge data have been quality controlled and validated and found to be of excellent quality (Fig. 2). Comparison of key tidal constituents between the historical SHOM (12 years' data) and Portagauge time series (eight months' data) displayed good agreement.

Portagauge sea level data were cross validated against satellite altimeter data and showed good agreement (correlation of 0.8987 for S6a-MF data, Fig. 3).

Results give confidence that short-term Portagauge deployment provides sufficient data for accurate tide prediction and validation against satellite altimeter data.

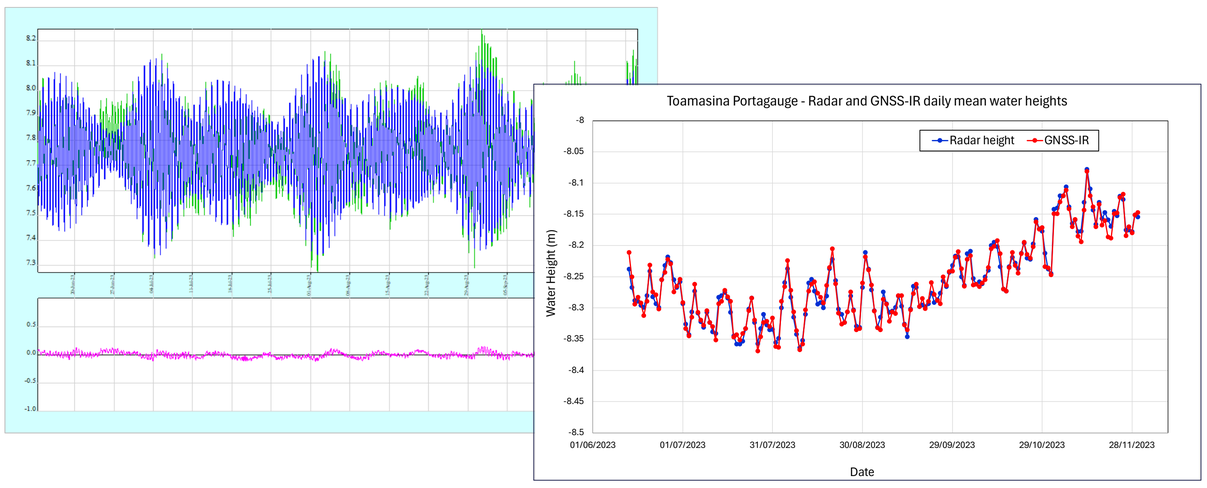

Figure 2. (Left) Portagauge radar gauge data (blue), model tidal predictions (green) and residuals (magenta). (Right) Daily mean water height measurements from the Toamasina Portagauge radar sensor and GNSS-IR

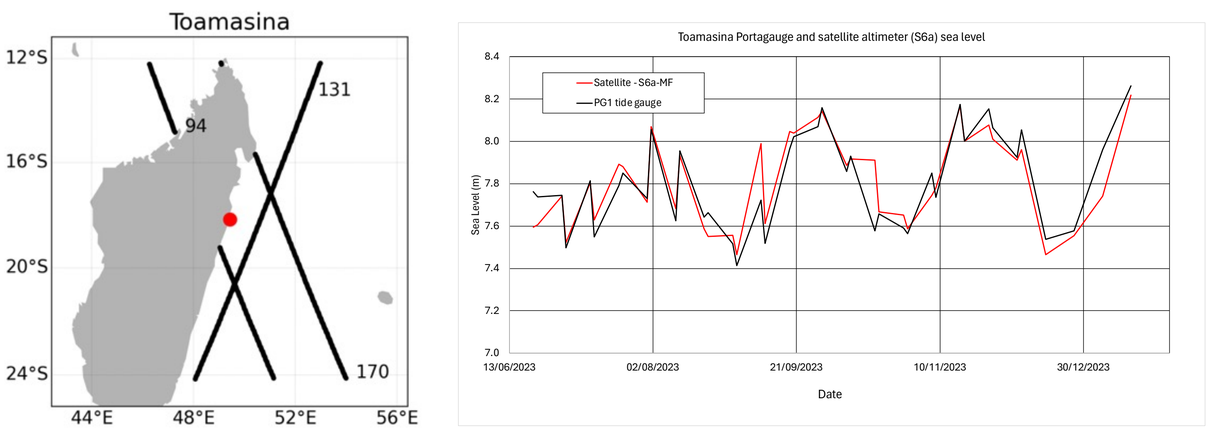

Figure 3. Cross-validation between Toamasina Portagauge and S6a-MF satellite altimeter sea level. The satellite measurements are at the crossover points between relative orbits 094 and 131 (top panel)

Recommendations for future implementation

There is a widespread recognition of the need for sea level data in Madagascar and a strong interest in improving data coverage and accessibility, for use in a wide range of applications and locations. Noting key features of sea level variability and requirements for hosting tide gauges, an "Implementation Road Map" was developed in consultation with stakeholders in Madagascar, with two main recommendations:

Implementation of Portagauge based sea level monitoring system

An implementation of a rolling programme of installation of the Portagauge at the five remaining Madagascar Ports of International Interest (Fig. 4) is recommended. This would include a minimum period of 6 months at each location, with the next two installations at Mahajanga and Nosy Be.

The total cost of this programme is estimated at €181,200 over four years.

Madagascar Sea Level Data Management Infrastructure

The establishment of a national data management infrastructure for sea level data is also recommended. This system would be linked to international sea level data measurement systems, to ensure the sea level data are available nationally and internationally. This should include the provision of tidal predictions for the sites where tidal harmonics are available.

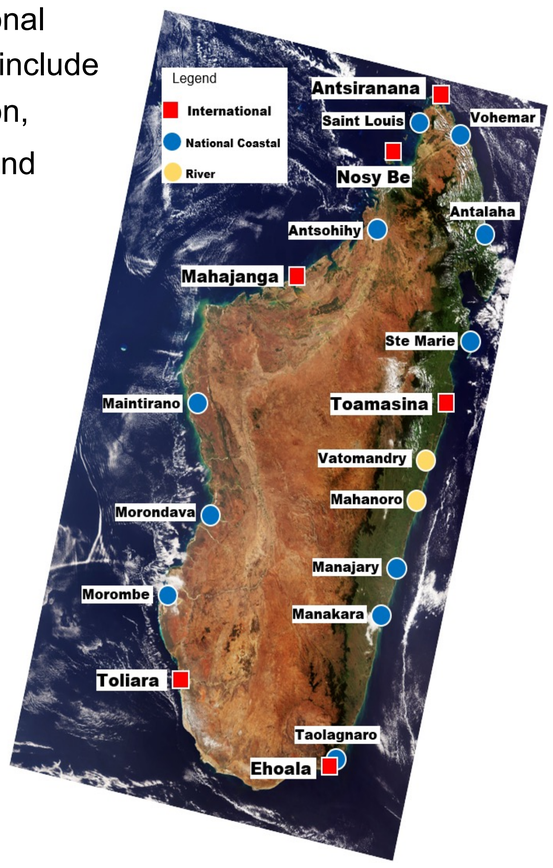

Figure 4. Madagascar ports. Information provided by Agence Portuaire Maritime et Fluviale (APMF)

Acknowledgements

PASS-SWIO was funded by ESA through the Science for Society Programme EO Open Call.
ESA NoR Sponsorship supported the processing of Sentinel 3A and 3B satellite altimeter data using specialised coastal processor settings.

30 Years of Progress in Radar Altimetry Symposium

2–7 September 2024 | Montpellier, France

Data and reports are available from:

www.satoc.eu/projects/pass-swio

eo4society.esa.int/projects/pass-swio