National Oceanography Centre

PASS-SWIO

Portagauge and Satellite Sea Level Monitoring System for the Southwest Indian Ocean

Data Set and Report for Portagauge, Tide Gauge and Satellite Data

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Contents

1. Introduction

This document describes the data sets produced and analysed by the PASS-SWIO project, as follows:

- In situ data
  - The Portagauge Radar gauge data
  - The Portagauge GNSS data
  - Historical Toamasina Tide Gauge data

- Satellite altimeter data
  - Along-track time series satellite altimeter data
  - Reprocessed satellite altimeter data
  - EUMETSAT L2 and L2P products

2. In-Situ Data

2.1. Introduction

Three sets of in-situ data have been used in the PASS-SWIO project. Radar gauge and GNSS data from the NOC Portagauge and radar gauge data from the tide gauge installed by SHOM in 2010 at Toamasina Port, that was operational until March 2022.

The NOC Portagauge was successfully installed at Toamasina Port on 12-16 June 2023 (Figure 1). Both the radar gauge and GNSS sensor have been fully operational since that date. The first data available are from 10:04 on 13 June 2023.

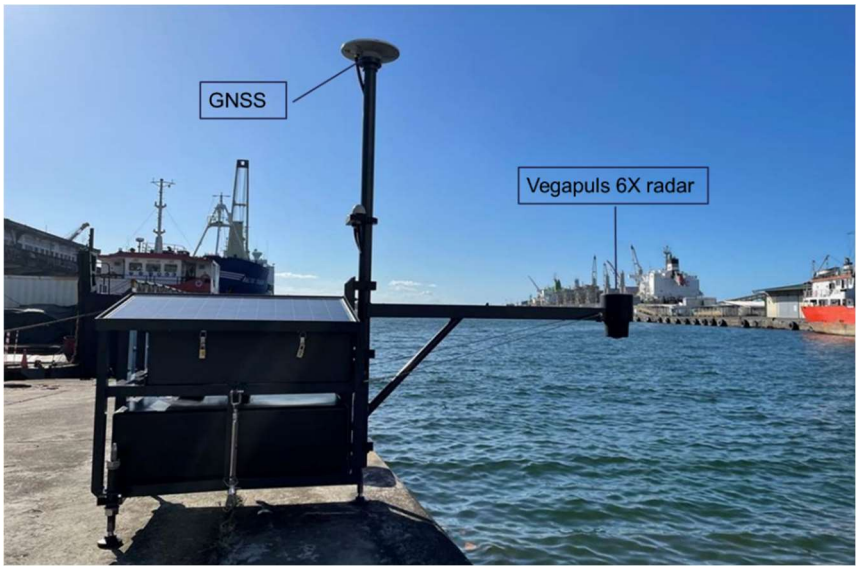

Figure 1. The NOC Portagauge as deployed at Toamasina Port, Madagascar

2.2. Portagauge Radar data

The NOC Portagauge provides sea level measurements via a Vegapuls 6X radar sensor.

- The station name is set to MadagascarPG1.
- The radar reference plane is 196mm below the benchmark on the radar arm. The datum level for sea level readings is 10m below the radar reference plane.
- The data set runs from 10:04 13/06/23 to 05:32 31/01/24.
- One measurement is provided every minute.
- The raw tide gauge data set as recorded as a csv file. Recorded parameters are:
    - Time (GMT)
    - Range to the water from the radar plane (mm),
    - Water level with respect to the reference plane (mm),
    - Atmospheric pressure (mb).

The raw sea level measurements have been quality controlled and reformatted using the TASK (Tidal Analysis Software Kit) processing software. This produces a primary results file which provides the harmonic tidal constituents, and TASK format .t2k (text) file of quality controlled one minute sea level measurements.

The one-minute data are provided in TASK (.t2k) text format, as specified in Table 1.

The TASK software was also used to generate daily average and monthly average sea level measurements data file (tidal signal removed).

TASK File Naming Convention:

- HA_HHH_XXXXXX_YYYYYY_AA_SS_FF.txt
    - HA – Harmonic Analysis
    - HHH – No of Harmonics analysed for
    - XXXXXX – Record number of first record included in analysis.
    - YYYYYY – Record number of last record included in analysis.
    - AA – Analysis method used: GS – Gauss-Seidel; PC – Pivotal Condensation
    - SS – Sequence Number
    - FF – File type: PR – Primary Results; TS- Time Series

List of data sets:

- Primary Results File - *HA_053_000001_005563_GS_03_PR.txt*
    - Tidal harmonics (amplitude, phase, name, speed etc)
    - QC Statistics (residual mean should be very close to zero)
    - Max/min residual could show signs of bad data being left in the file.
    - Raleigh criterion (type of tidal regime)

- Time Series Results File - *HA_053_000001_005563_GS_03_TS.t2k*
    - Header Lines
    - Location Name

- Latitude, Longitude
- Time series of data, format in Table 2.

- Daily mean sea level File - *HA_053_000001_005563_GS_03_DM.txt*
  - Date, daily mean sea level

- Monthly mean sea level File - *HA_053_000001_005563_GS_03_MM.txt*
  - Header lines
  - Year, Month, monthly mean sea level, number of days used to calculate mean.
  - Annual mean sea level (with headers and comments)

Table 1. Format of TASK time series ride gauge data file

Column	Variable	Description	Format
1	Record No.	Number of record (sequential)	I1
2	Data Flag	0 - Good; 1 - Bad, Suspect; > 1 Advisory	I1
3	Year	Year	I4
4	Day number	Day number of year	I3
5	Time	Decimal hours	F8.3
6	sealevel_obs (m)	Observed sea level above reference plane	F8.3
7	sealevel_pred (m)	Predicted sea level above reference frame, based on harmonic analysis	F8.3
8	sealevel_resid (m)	Residual sea level (observed minus predicted	F8.3
9-11	Data Channels	Additional data channels not used here	F8.3

These data are available on the PASS-SWIO Project web page at:
https://www.satoc.eu/projects/pass-swio/data_new.html

2.3. Portagauge GNSS data

The GNSS instrument in the NOC Portagauge is a Trimble Alloy GNSS receiver. The GNSS receiver receives direct GNSS signals to provide a precise location measurement, and indirect signals reflected from the sea surface.

The direct and reflected signals have been processed into daily mean files for location and sea-surface height:

- Quality controlled daily mean sea level: *PG1_GNSS_swio_daily.txt*
  - Text File
  - Time coverage: 13/06/2022 to 29/04/2024
  - No header lines
  - 3 columns data
    - Date (dd-mm-yyyy); time (hh:mm:ss); sea surface height (f6.3)
  - Reference for sea surface height is WGS84

- Quality controlled daily mean GNSS position: *SWIO00MDG_IGS20.neu*
  - Text file
  - 15 header lines,
    - File creation information
    - Analysis centre CACS PP, Datum IGS20
    - Reference Epoch; reference latitude, longitude and height
  - Time coverage: day 13/06/2023 to 29/04/2024
  - 9 columns data:
    - Year (i4); day number (i3); DN (f7.4); DE (f7.4); DU (f7.4); SDN (f7.4); SDE (f7.4); SDU (f7.4);
    - DN, DE, DU North, East and vertical position differences relative to reference in m
    - SDN, SDE, SDU formal errors in North, East and vertical position differences relative to reference in m

These data are available on the PASS-SWIO Project web page at:
https://www.satoc.eu/projects/pass-swio/data_new.html

2.4. Historical tide gauge data

Historical Toamasina tide gauge data were used for cross-validations against satellite altimeter data. This tide gauge was installed by SHOM in 2010 but was taken out of commission in March 2022 because of port development at Toamasina.

The original plan had been to make direct comparisons between the SHOM tide gauge and the NOC Portagauge, but this was not possible due to the decommissioning of the SHOM gauge.

These data cover the period 01/01/2010 to 29/03/22, and are available in the TASK format as described above in the file *HA_112_000001_058741_GS_02_TS_Toamasina.t2k*, on the PASS-SWIO project web pages (https://www.satoc.eu/projects/pass-swio/data_new.html)

3. Satellite Altimeter Data

3.1. Introduction

Three sets of satellite altimeter data have been used in the PASS-SWIO project.

- CMEMS L3 satellite altimeter data, subset and reformatted to an along-track time series – for validating against historical tide gauge data and analyses of sea level variability.
- Reprocessed Sentinel-3A and Sentinel-3B data – for assessing potential improvements from coastal processors.
- EUMETSAT non-time critical L2 and L2P for validating portagauge data.

3.2. Along-track time series data

Along-track time series of sea surface height anomaly data were used in PASS-SWIO for validating satellite sea level measurements against historical Toamasina Tide Gauge data and for analyses of sea level variability.

The source product for these data was the SEALEVEL_GLO_PHY_L3_MY_008_062 product, downloaded from the Copernicus Marine Service, for the following satellites and time periods:

- Jason-1, Jason-2 and Jason-3: 2002-2022
- Sentinel 3A 2016-2022
- Sentinel 3B 2018-2022

These data were subsetted by NOC and SatOC to within a latitude and longitude range around Madagascar (36°-56° E, 8°-30° S), and then processed into a reduced netcdf format.

There is one file per satellite track. The naming convention is *sss*_cmems_p*oooo*.nc, where *sss* is satellite series (s3a, s3b or j1j2j3) and oooo is relative orbit number, e.g. s3a_cmems_p0012.nc, j1j2j3_p0222.nc.

At each along-track location, the following parameters are available:

- Latitude (1D), longitude(1D), time (1D)
- sea surface height anomaly (2D), dynamic atmospheric correction (2D)

These data are available through the PASS-SWIO project website: https://www.satoc.eu/projects/pass-swio/data_new.html.

Appendix A gives a full list of the along-track data sets produced.

3.3. Reprocessed Sentinel-3A and Sentinel-3B SRAL data

A PASS-SWIO Technical Note: "Technical Note on the Analysis of Sentinel-3 Altimeter data at the coast of Madagascar" compares "standard" ESA / EUMETSAT L2 products to a data set processed through the SARvatore for Sentinel-3 service with settings specific for coastal processing. The purpose was to assess if the specific coastal processing provides any improvements in performance over the standard product. The Technical Note is available on the PASS-SWIO project website: https://www.satoc.eu/projects/pass-swio/documents/PASS-SWIO_S3AltimeterData%20TechnicalNote_V1.1%20final.pdf

Financial support for the generation of the coastal data set was provided through ESA Network of Resources sponsorship.

The source data set for both products is along-track Sentinel-3A and Sentinel-3B SRAL SAR altimeter data from orbits 362 and 041 in the vicinity of Toamasina, on the NE coast of Madagascar (Figure 2), for the years 2020 and 2021.

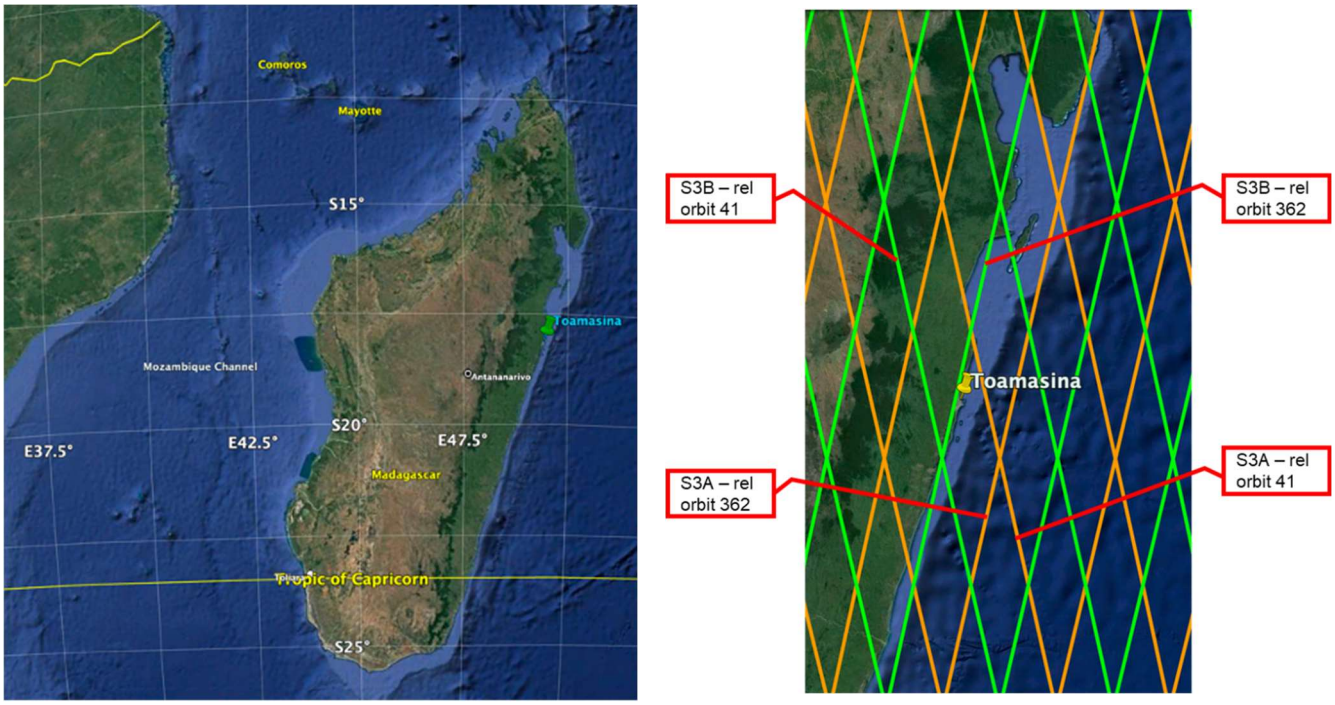

Figure 2. Madagascar (left) and close up (right) of coastline near Toamasina with Sentinel-3A (orange) and Sentinel-3B (green) tracks overlaid.

The first data set is the "standard" EUMETSAT / ESA Level 2 marine product available through the EUMETSAT EO portal and data store (version BC005).

The second data set is based on the same source data, processed with specific coastal settings (including the SAMOSA+ retracker) using the SARvatore for Sentinel-3 service on the ESA Altimetry Virtual Laboratory, on EarthConsole ((https://earthconsole.eu/altimetry-virtual- lab/).

3.4. EUMETSAT Sentinel-6A, Sentinel-3A and Sentinel-3B L2 products

Standard EUMETSAT Altimeter L2 products for the Sentinel 6A MF (the latest in the "Jason Series" satellites), Sentinel-3A and Sentinel-3B were used for cross validation against the NOC Portagauge data. This was necessary because the CMEMS L3 along-track product is not yet available.

These data were downloaded from the EUMETSAT Earth Observation portal / EUMETSAT Data Store.

Sentinel-3A, Sentinel-3B:

The Sentinel-3A and Sentinel-3B data used were the *SRAL Level 2 Altimetry Global (version BC005) - Sentinel-3 – Reprocessed* Product, as follows.

- Relative Orbits 041 and 362
- Dates: 01/06/23 - 31/01/24

Data from the reduced measurement product were selected by latitude (within 18.3° S to 18.8° S), and the following parameters extracted:

- Sea surface height anomaly, 1Hz Ku band (ssha_01_ku)
- Geocentric ocean tide height (GOT4.10) (ocean_tide_sol1_01)
- Mean Sea Surface (DTU21) (mean_sea_surf_sol2_01)

Sentinel-6A MF:

The Sentinel-6A MF data used were the *Poseidon-4 Altimetry Level 2 High Resolution (baseline version F08) - Sentinel-6 - Reprocessed* Product, as follows.

- Relative Orbit 094 and 131
- Dates: 01/06/23 - 31/01/24

Data from the reduced measurement product were selected by latitude (within 19.2° S to 20° S), and the following parameters extracted:

- Sea surface height anomaly, 1Hz Ku band (ssha)
- Geocentric ocean tide height (GOT4.10) (ocean_tide_sol1)
- Mean Sea Surface (DTU18) (mean_sea_surf_sol2)

4. References

Tidal Analysis Software Kit, 2017 Edition. Developed by the Marine Data Products Team at the UK National Oceanography Centre. (https://noc-innovations.com/services/tide-prediction-software/tidal-data-analysis/)

Appendix A: Along-Track time series satellite data files

Jason-1, Jason-2, Jason-3 data

j1j2j3_cmems_p0005.nc
j1j2j3_cmems_p0018.nc
j1j2j3_cmems_p0029.nc
j1j2j3_cmems_p0044.nc
j1j2j3_cmems_p0055.nc
j1j2j3_cmems_p0068.nc
j1j2j3_cmems_p0081.nc
j1j2j3_cmems_p0094.nc
j1j2j3_cmems_p0105.nc
j1j2j3_cmems_p0120.nc
j1j2j3_cmems_p0131.nc
j1j2j3_cmems_p0146.nc
j1j2j3_cmems_p0157.nc
j1j2j3_cmems_p0170.nc
j1j2j3_cmems_p0196.nc
j1j2j3_cmems_p0207.nc
j1j2j3_cmems_p0222.nc
j1j2j3_cmems_p0233.nc
j1j2j3_cmems_p0246.nc

Sentinel 3a

s3a_cmems_p0012.nc
s3a_cmems_p0027.nc
s3a_cmems_p0040.nc
s3a_cmems_p0055.nc
s3a_cmems_p0068.nc
s3a_cmems_p0083.nc
s3a_cmems_p0096.nc
s3a_cmems_p0111.nc
s3a_cmems_p0126.nc
s3a_cmems_p0141.nc
s3a_cmems_p0154.nc
s3a_cmems_p0169.nc
s3a_cmems_p0182.nc
s3a_cmems_p0197.nc
s3a_cmems_p0210.nc
s3a_cmems_p0225.nc
s3a_cmems_p0240.nc
s3a_cmems_p0255.nc
s3a_cmems_p0268.nc
s3a_cmems_p0283.nc
s3a_cmems_p0296.nc
s3a_cmems_p0311.nc
s3a_cmems_p0339.nc
s3a_cmems_p0354.nc
s3a_cmems_p0369.nc
s3a_cmems_p0382.nc
s3a_cmems_p0397.nc
s3a_cmems_p0410.nc
s3a_cmems_p0425.nc
s3a_cmems_p0455.nc
s3a_cmems_p0468.nc
s3a_cmems_p0483.nc
s3a_cmems_p0496.nc
s3a_cmems_p0511.nc
s3a_cmems_p0524.nc
s3a_cmems_p0539.nc
s3a_cmems_p0569.nc
s3a_cmems_p0582.nc
s3a_cmems_p0597.nc
s3a_cmems_p0610.nc
s3a_cmems_p0625.nc
s3a_cmems_p0638.nc
s3a_cmems_p0653.nc
s3a_cmems_p0668.nc
s3a_cmems_p0683.nc
s3a_cmems_p0696.nc
s3a_cmems_p0711.nc
s3a_cmems_p0724.nc
s3a_cmems_p0739.nc
s3a_cmems_p0752.nc
s3a_cmems_p0767.nc

Sentinel 3b

s3b_cmems_p0012.nc
s3b_cmems_p0027.nc
s3b_cmems_p0040.nc
s3b_cmems_p0055.nc
s3b_cmems_p0068.nc
s3b_cmems_p0083.nc
s3b_cmems_p0096.nc
s3b_cmems_p0111.nc
s3b_cmems_p0126.nc
s3b_cmems_p0141.nc
s3b_cmems_p0154.nc
s3b_cmems_p0169.nc
s3b_cmems_p0182.nc
s3b_cmems_p0197.nc
s3b_cmems_p0210.nc
s3b_cmems_p0225.nc
s3b_cmems_p0240.nc
s3b_cmems_p0255.nc
s3b_cmems_p0268.nc
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s3b_cmems_p0668.nc
s3b_cmems_p0683.nc
s3b_cmems_p0696.nc
s3b_cmems_p0711.nc
s3b_cmems_p0724.nc
s3b_cmems_p0739.nc
s3b_cmems_p0752.nc
s3b_cmems_p0767.nc

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