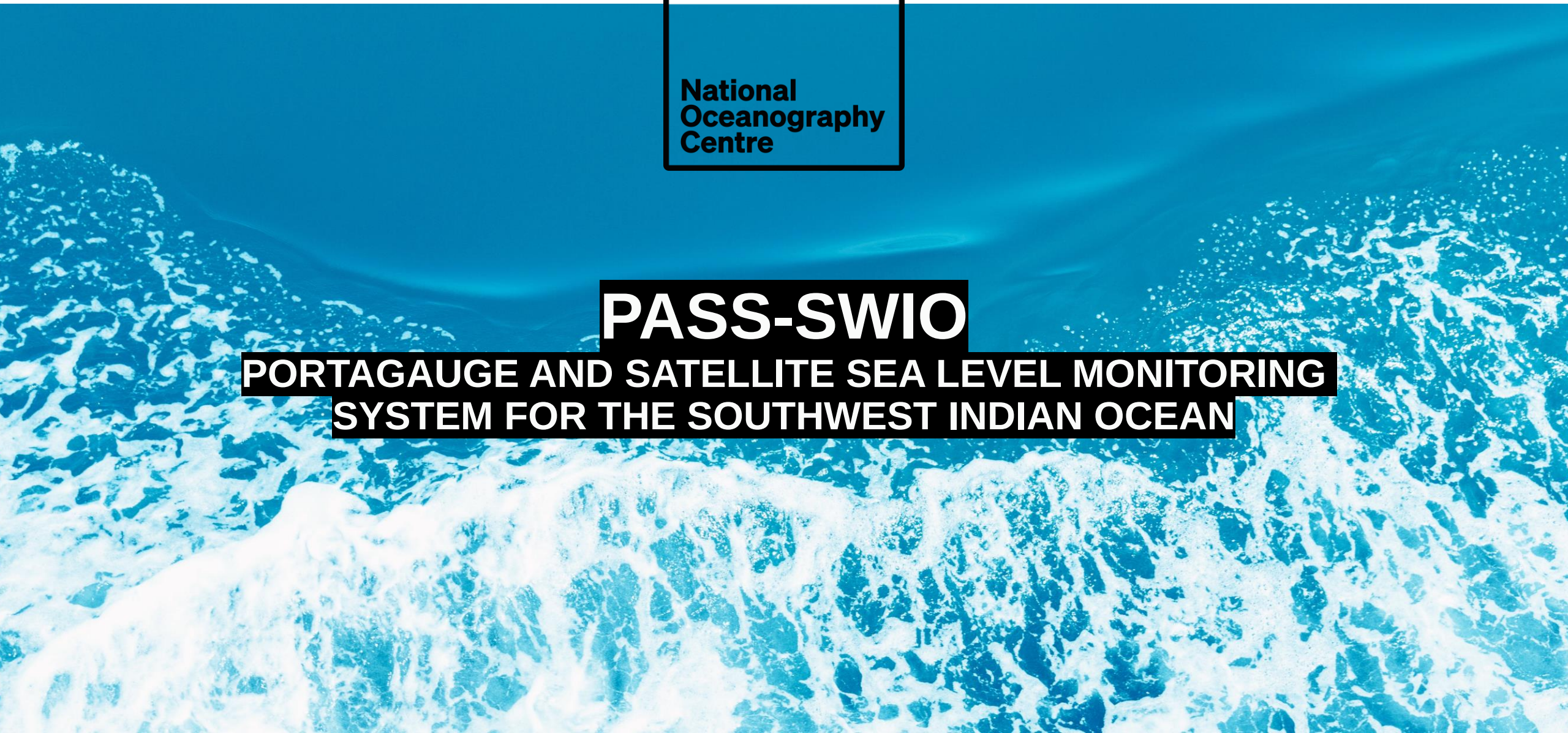

PASS-SWIO

PORTAGAUGE AND SATELLITE SEA LEVEL MONITORING SYSTEM FOR THE SOUTHWEST INDIAN OCEAN

THE PASS-SWIO TEAM

National Oceanography Centre


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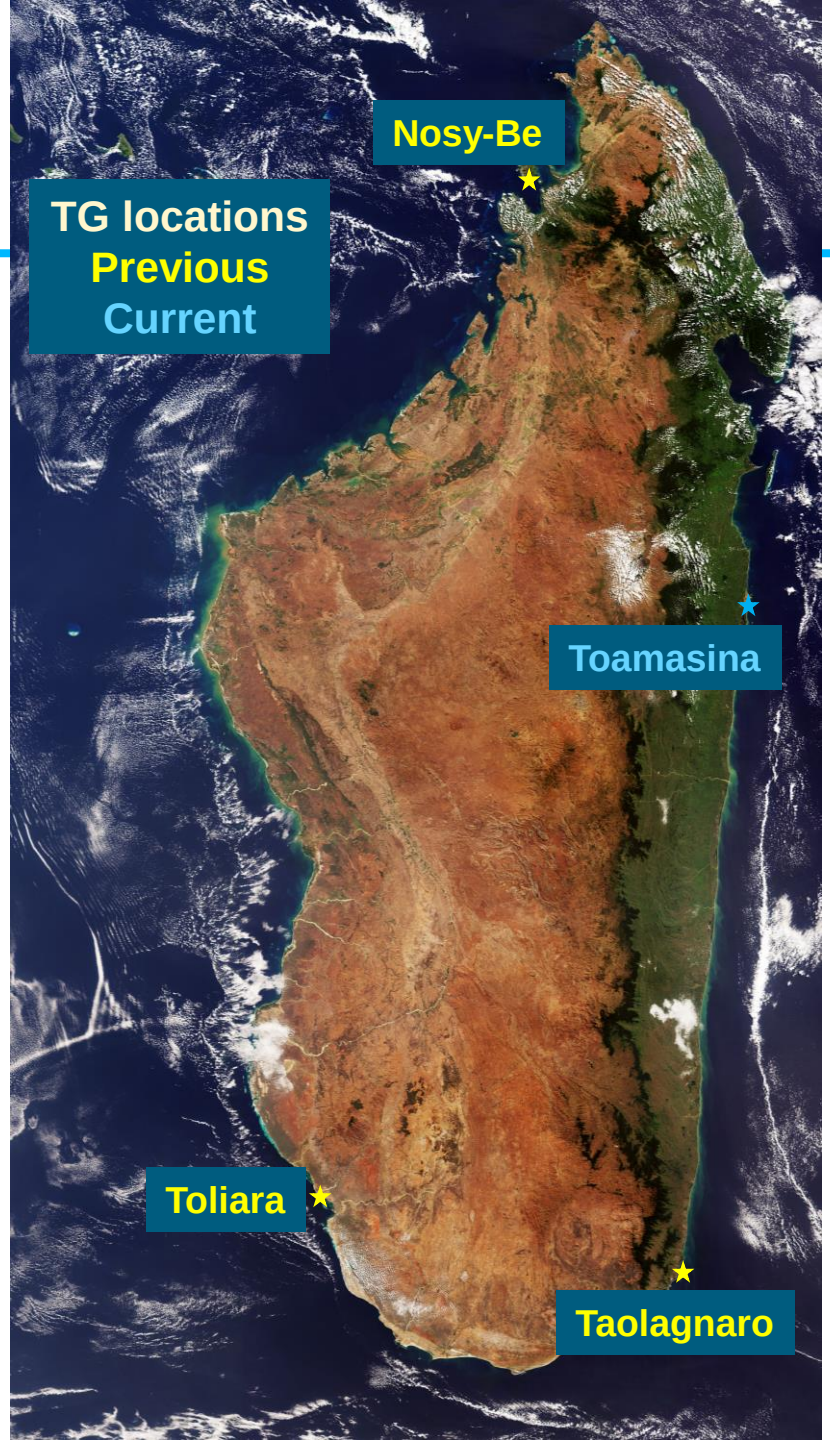
David Cotton

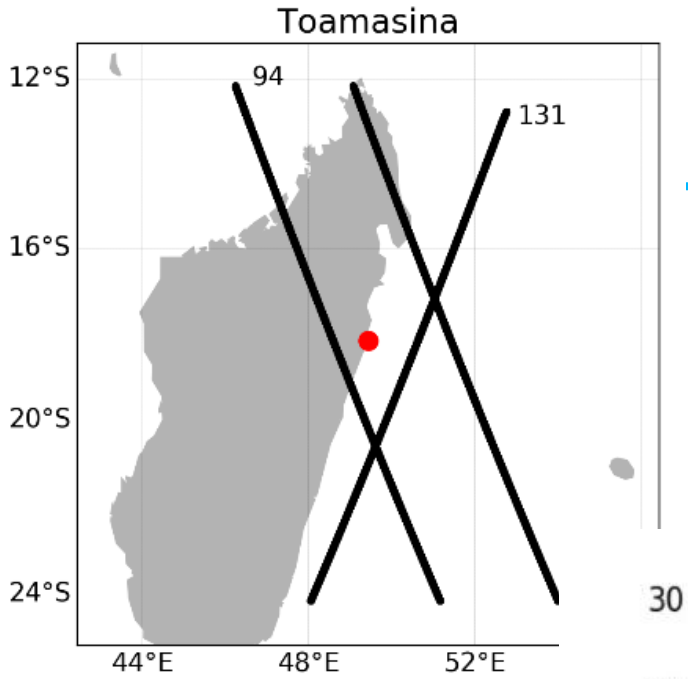

Haja Razafindrainibe

METEO Madagascar


Rhino Rajaonarivony


Dar es Salaam
Tanzania
Comoros
Mayotte
Malawi
Mozambique Channel
Antananarivo
Madagascar
Toliara
Mauritius
Réunion





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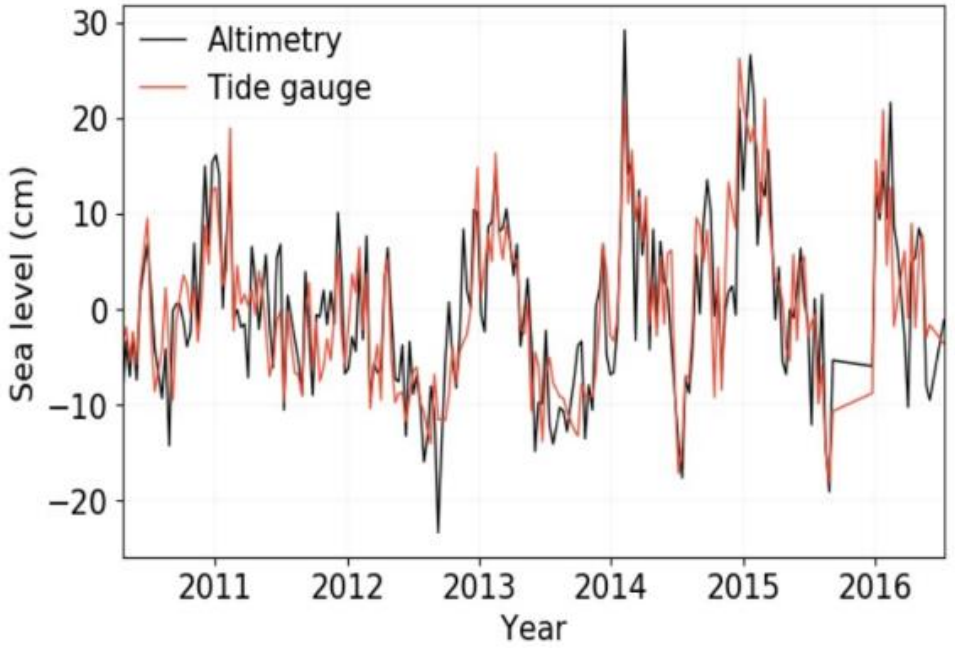
C-RISe
COASTAL RISK INFORMATION SERVICE



Sea level data are vital for

Research into sea level change and ocean circulation

Coastal protection during events such as storm surges

Providing flood warning and monitoring tsunamis

Tide tables for port operations, fishermen, and recreation

Defining datums for national or state boundaries

Sea level is one of the most useful oceanographic variables, used for a wide variety of scientific, economic and social purposes.

Source: GLOSS

ISSUES IN MEASURING COASTAL SEA LEVEL FOR DEVELOPING STATES

The main four reasons that tide gauges are non-operational in developing states, identified by Hoguane (1999), are:

- Lack of equipment (and difficulty acquiring replacement parts (Mundlovo et al., 2007);
- Lack of qualified maintenance personnel;
- Lack of funds to maintain tide gauges;
- Difficulty in accessing remote tide gauges due to poor transport infrastructure, poor roads and insurgency.

“To achieve a fully operational national tide gauge network and make data available to end users, some national capacity development is required” (Razakafoniaina, 2001)

SEA LEVELS VARY ON DIFFERENT TIMESCALES

- Tsunamis (minutes to an hour)
- Seiches (minutes to hours)
- Tides (daily, 2 x daily)
- Storm surges (few days)
- Seasonal cycle (annual, semiannual)
- Mean sea level changes (months – millennia)

Captured by tide gauges

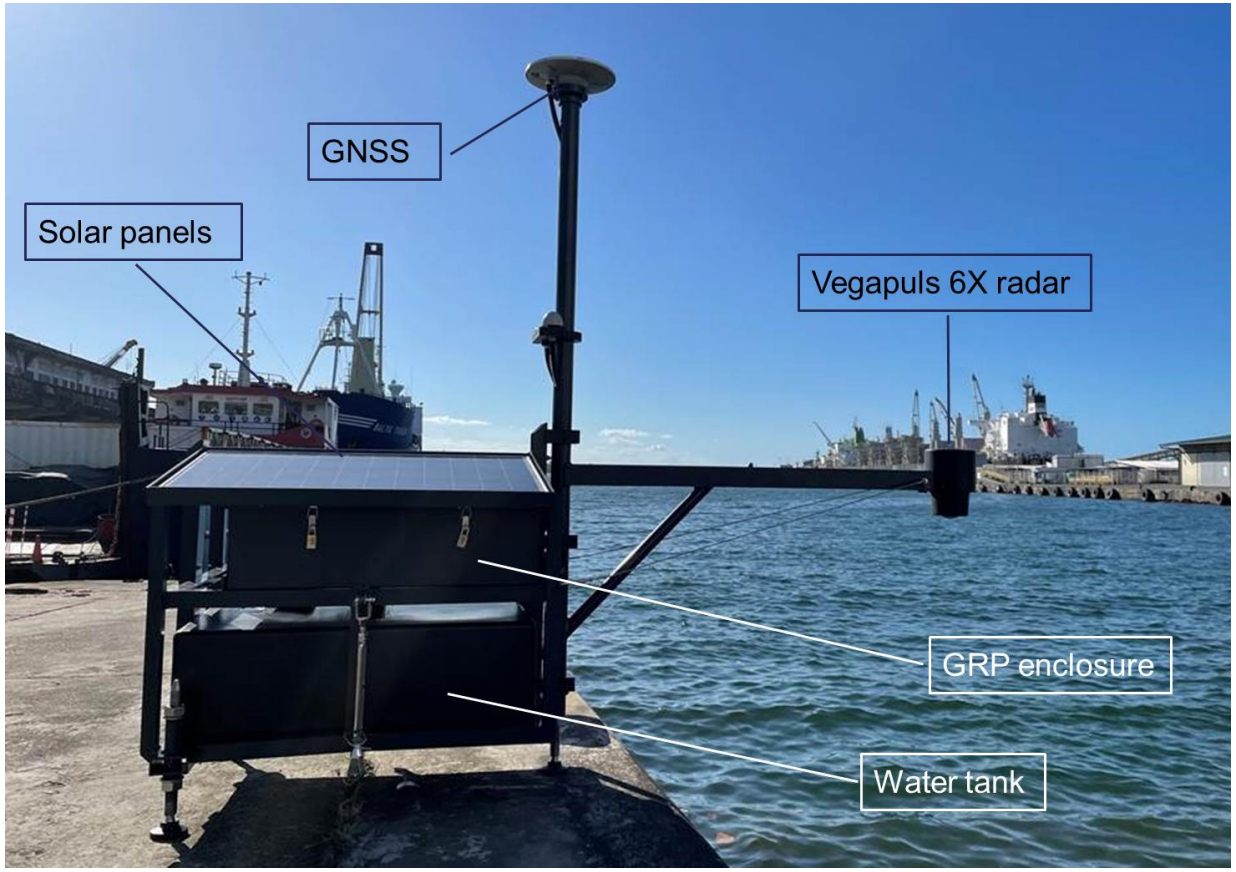
Captured by satellite altimetry

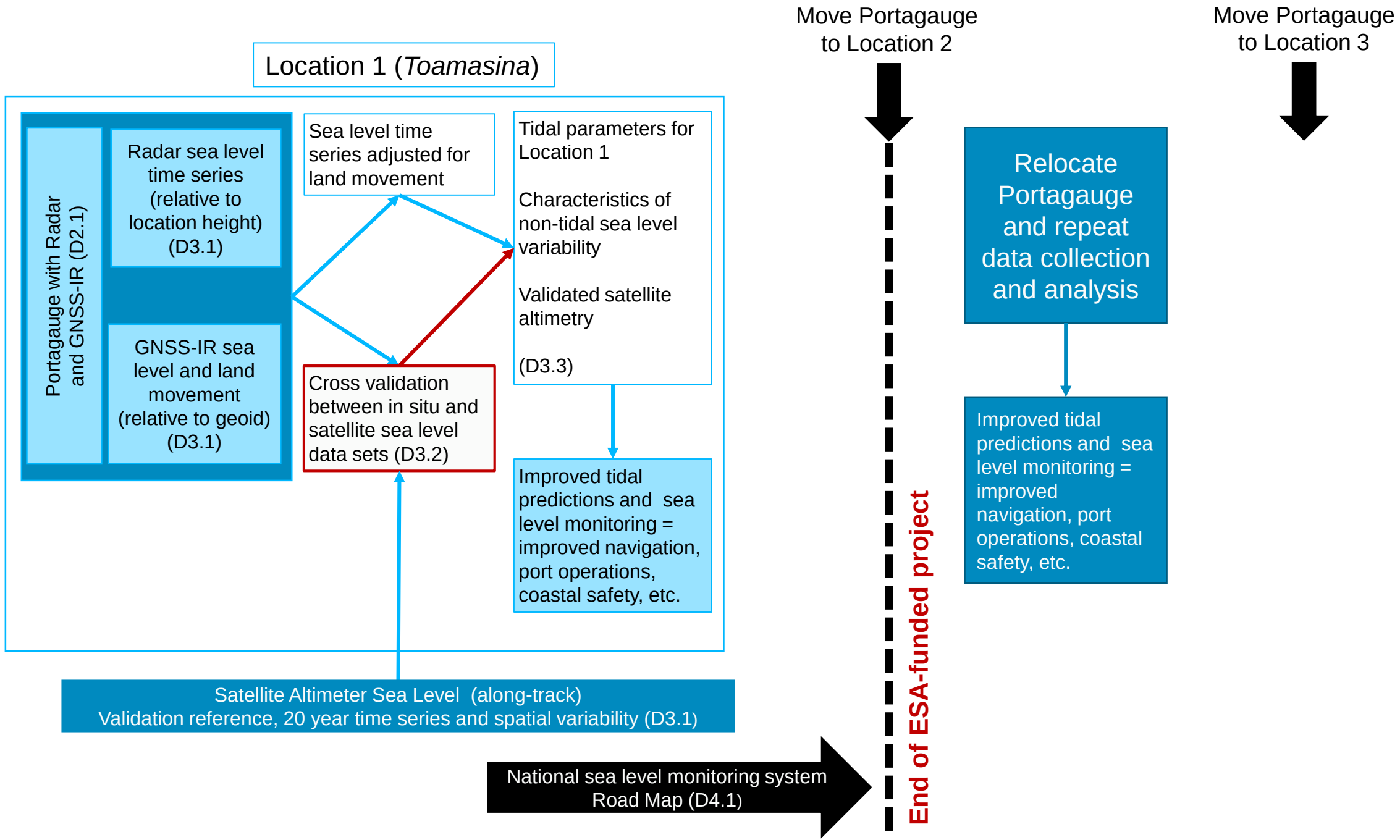
Tide gauges can measure all of these features provided they offer high frequency sampling and long (>30yr) duration. Satellite altimetry can capture the longer-term variations.

PORTAGAUGE

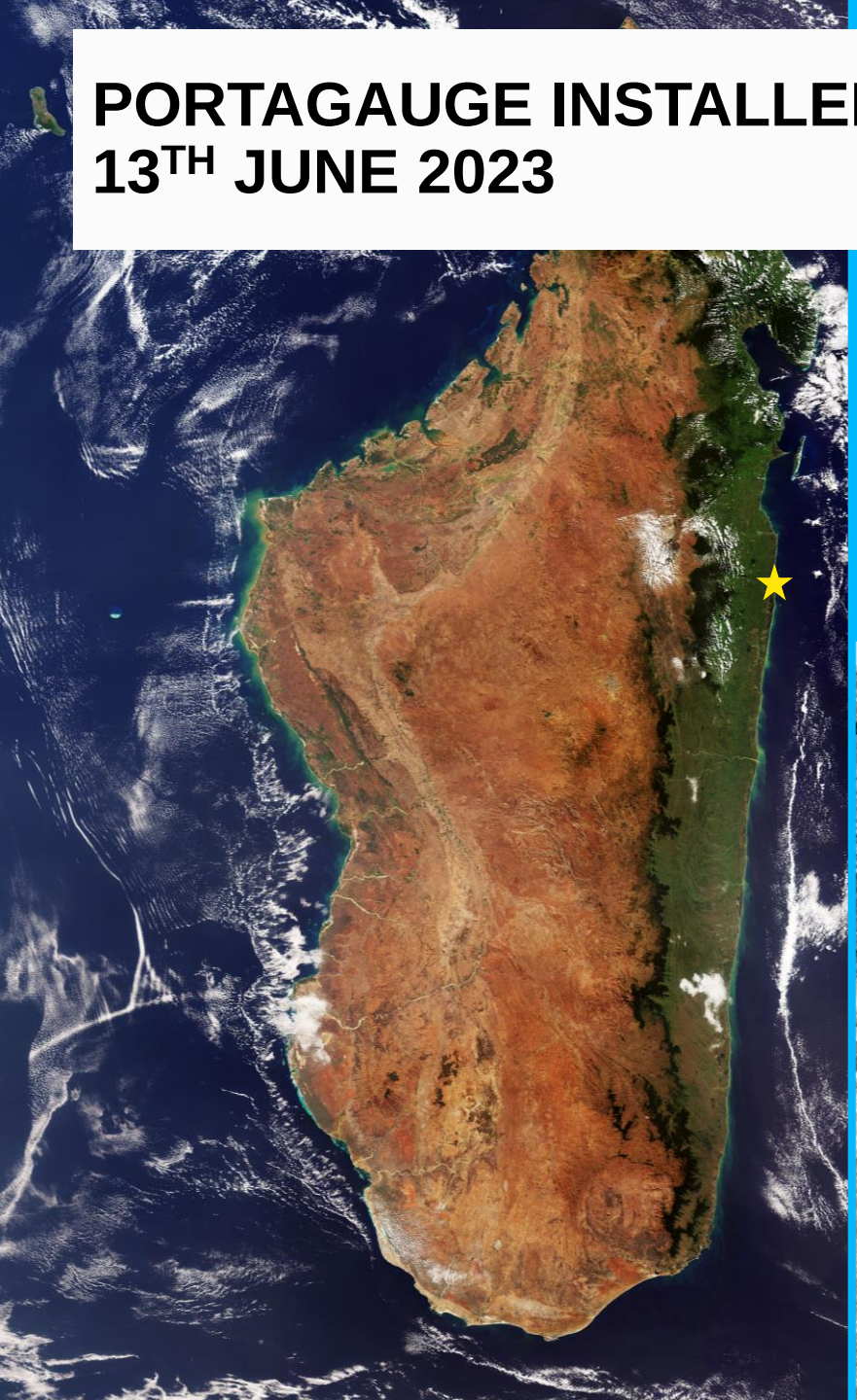
The project aims to establish a sea level monitoring system for Madagascar based on the installation and deployment of a low-cost relocatable tide gauge – Portagauge.

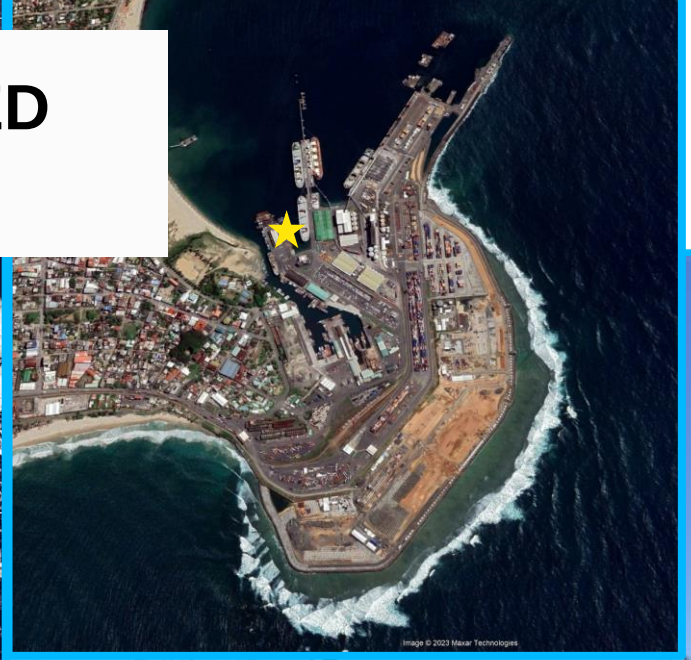
- Conventional radar tide gauge (measuring sea level to local fixed datum on land)
- GNSS measuring sea level and land motion relative to geoid
- Relocatable platform for campaign measurements where tide gauges are few
- Post-process GNSS-IR data, vertical land motion and radar data to establish relationship between local benchmarks, geoid, absolute sea level and relative sea level




Location 1 (*Toamasina*)
Portagauge with Radar and GNSS-IR (D2.1)
Radar sea level time series (relative to location height) (D3.1)
GNSS-IR sea level and land movement (relative to geoid) (D3.1)
Sea level time series adjusted for land movement
Tidal parameters for Location 1
Characteristics of non-tidal sea level variability
Validated satellite altimetry
(D3.3)
Cross validation between in situ and satellite sea level data sets (D3.2)
Improved tidal predictions and sea level monitoring = improved navigation, port operations, coastal safety, etc.
Satellite Altimeter Sea Level (along-track)
Validation reference, 20 year time series and spatial variability (D3.1)
National sea level monitoring system
Road Map (D4.1)
End of ESA-funded project
Move Portagauge to Location 2
Move Portagauge to Location 3
Relocate Portagauge and repeat data collection and analysis
Improved tidal predictions and sea level monitoring = improved navigation, port operations, coastal safety, etc.

PORTAGAUGE INSTALLED 13TH JUNE 2023





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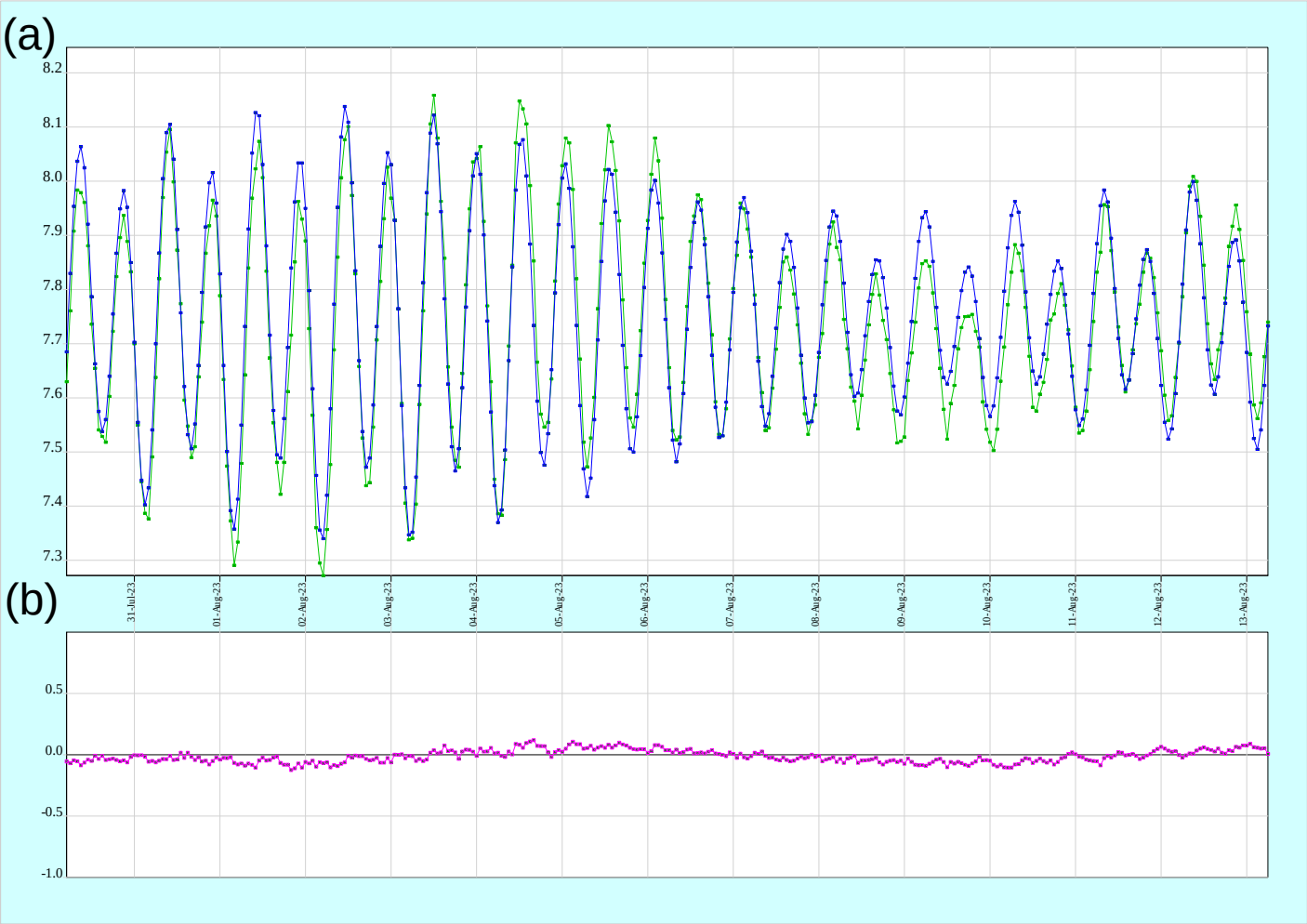
TOAMASINA PORTAGAUGE DATA

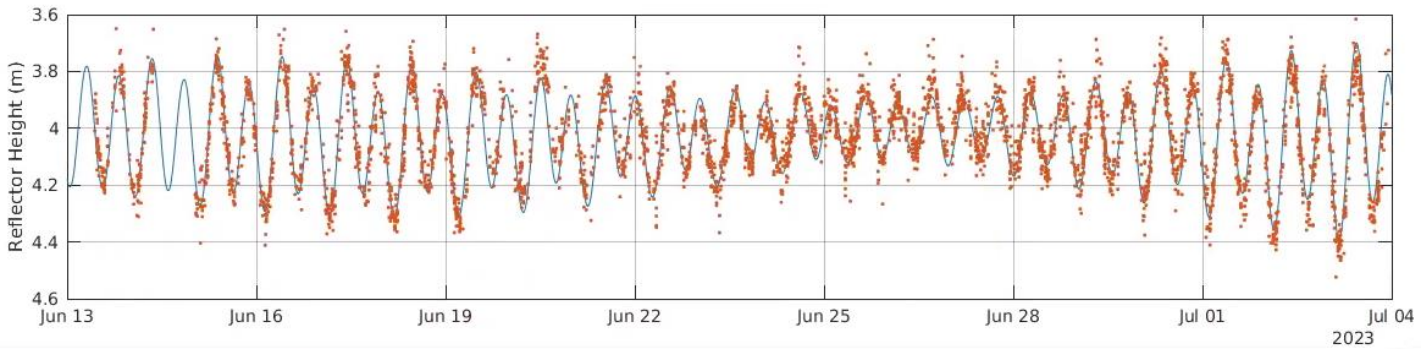


Portagauge water levels for 14 days from 31/07/23 to 13/08/23
(a) Predictions (blue) vs measured (green) and (b) residuals

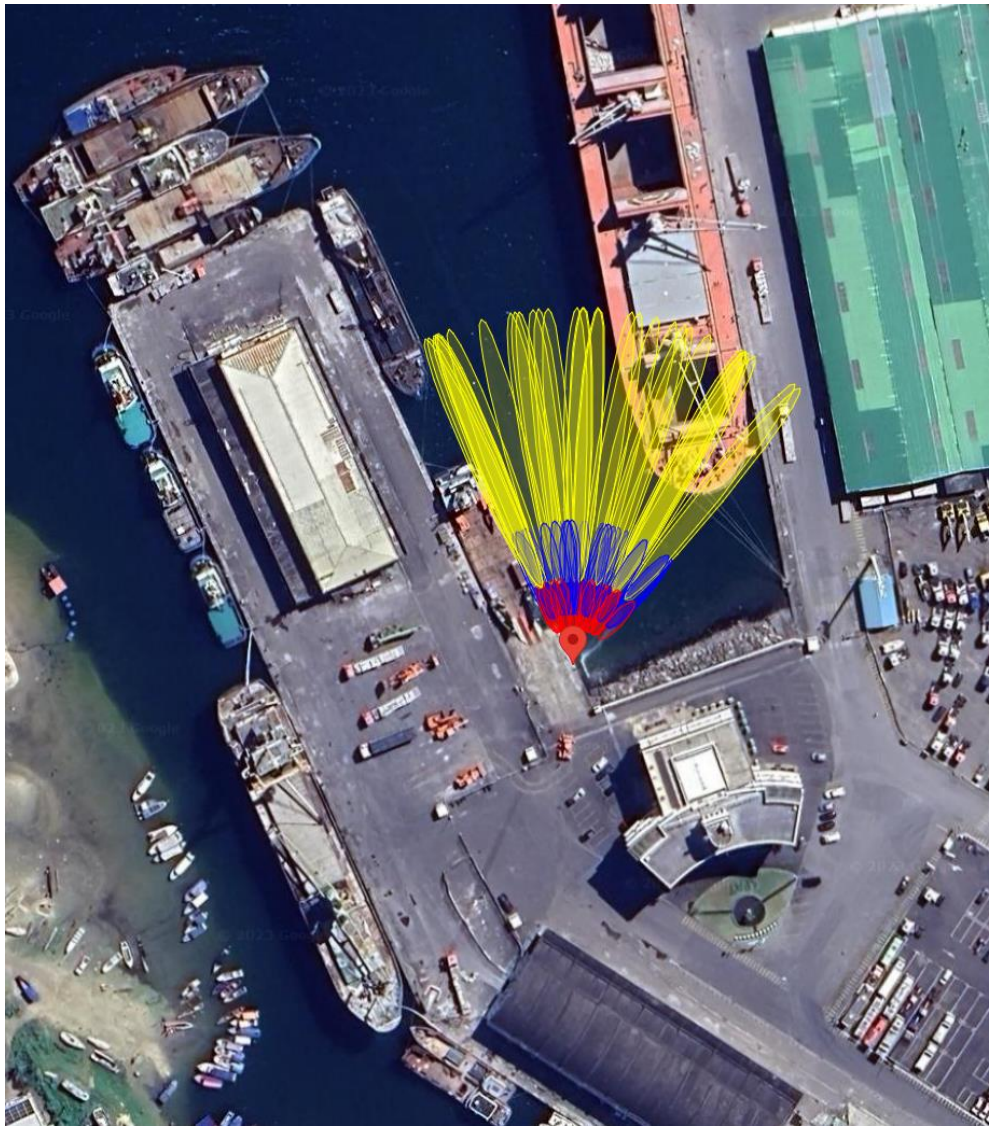
- Portagauge data are good quality
- DGM have used TASK to generate tidal coefficient, similar to those from long term tide gauge
- DGM can use POLTIPS to generate predictions
- Validation against satellite altimetry to be completed when those data are available

GNSS - INTERFEROMETRIC REFLECTOMETRY

- GNSS signals suffer from reflections from surfaces near to the antenna.
- If we understand the interference effects on the signal e.g. when the reflection is off a flat surface such as a body of water then we can use this to extract information about these surfaces.
- We can measure the height of the antenna above the water



Data from the portagauge, solid line is tidal prediction



MEETINGS IN MADAGASCAR FEBRUARY 2024

National Oceanography Centre

CONSIDERATIONS FOR FUTURE LOCATIONS

National Oceanography Centre

Important considerations

- Sea level variation
- Locations prone to flooding and erosion
- Most vulnerable populations
- Vulnerable infrastructure
- Port operations

Practicalities

- Cross validation of tide gauge and portagauge
- Security
- Suitable site available
- People available to operate
- Site access

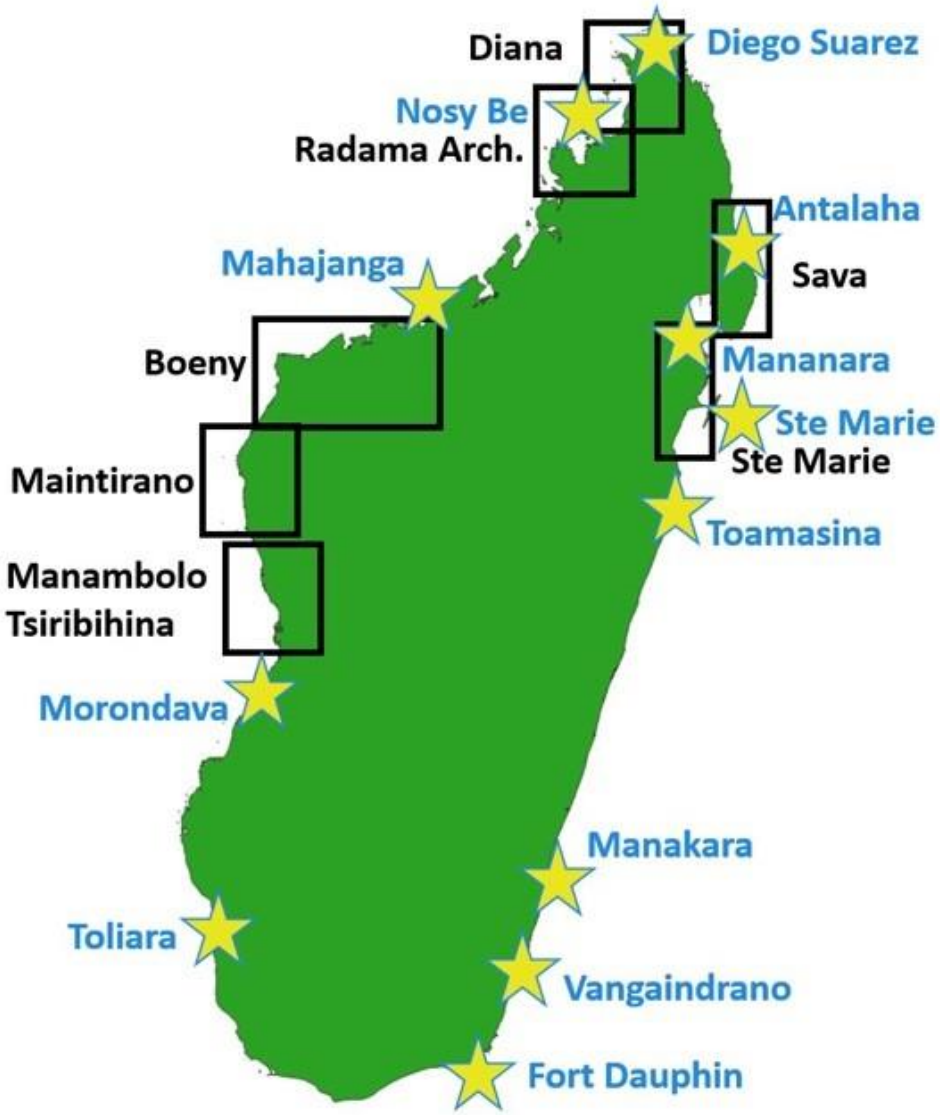
SITE SUITABILITY FOR TIDE GAUGES

An ideal location for a tide gauge:

- Away from risks of shipping and construction
- On flat, solid, stable ground
- Does not dry out at low water
- Exposed to the open ocean (i.e. not up-river, in an estuary or behind sand banks or lagoons).
- Harbours are suitable as they are exposed to the ocean, but also provide some protection from extreme conditions

FROM PASS-SWIO QUESTIONNAIRE

The locations of the regional areas (black boxes) and specific sites (stars) for which sea level data was required by respondents

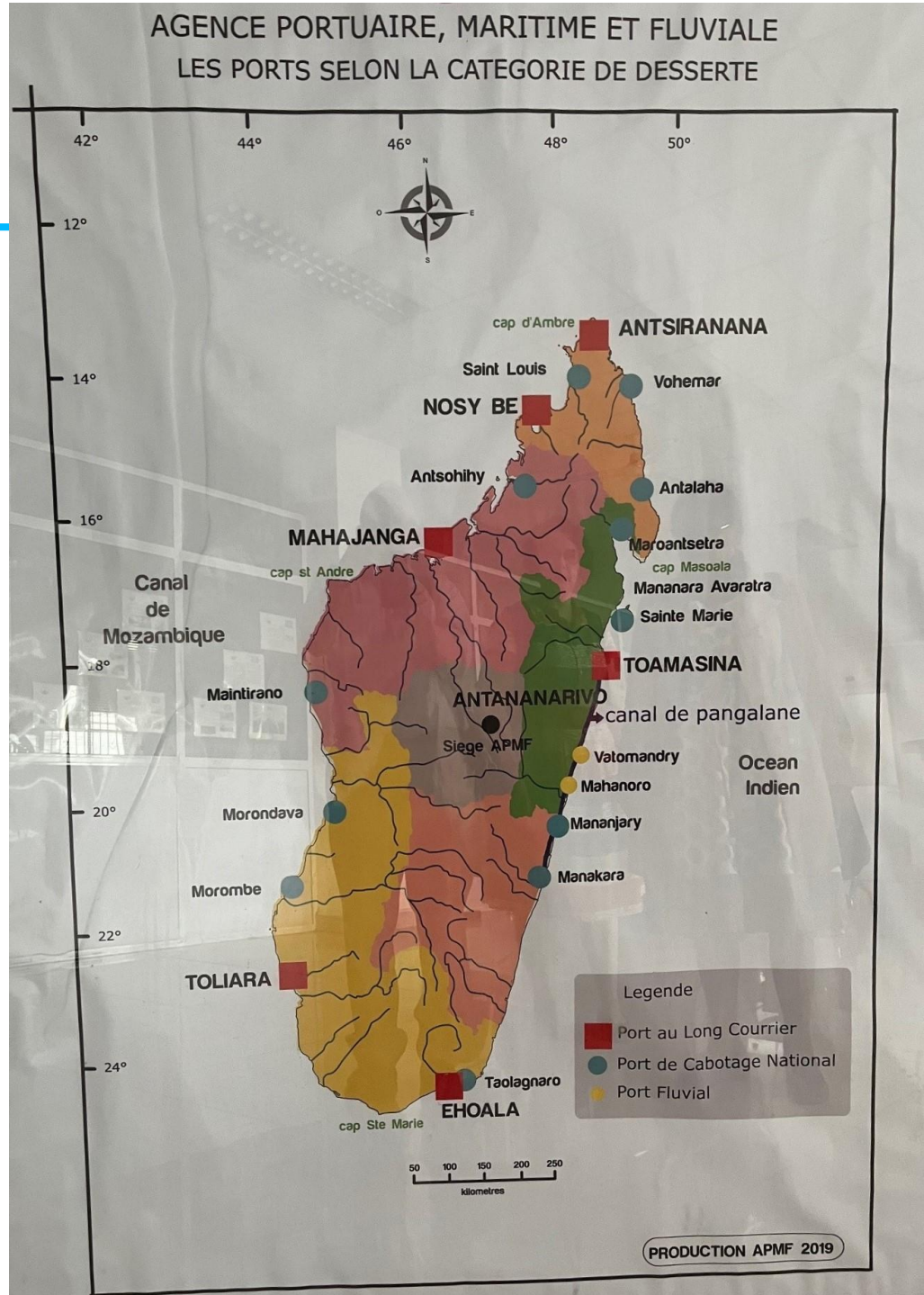


PORTS

Ports of International Interest: Toamasina, Toliara, Antsiranana (Diego Suarez), Mahajanga, Nosy Be and Ehoala (Fort Dauphin)

Ports of National Interest: Taolagnaro, Mananjary, Manakara, Morondava, Morombe, Maintirano, Antsohihy, St Louis, Vohemar, Antalaha, Maroantsetra, Ste Marie

River Ports: Vatomandry, Mahanoro

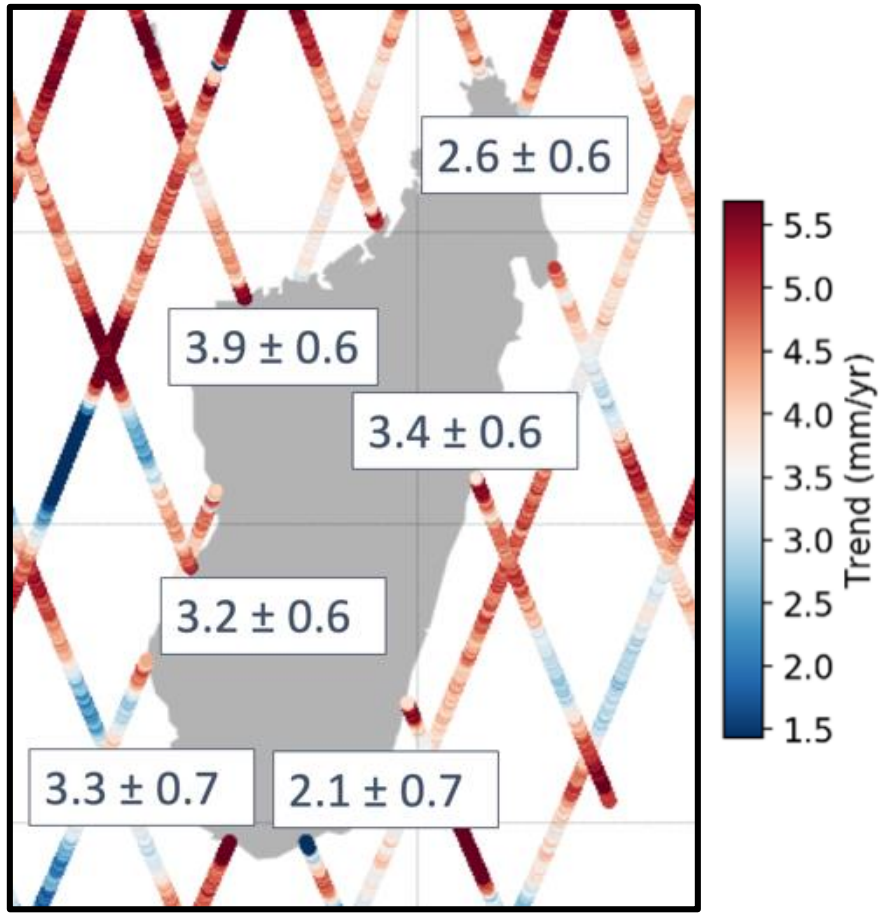


SEA LEVEL VARIABILITY

Tidal variability

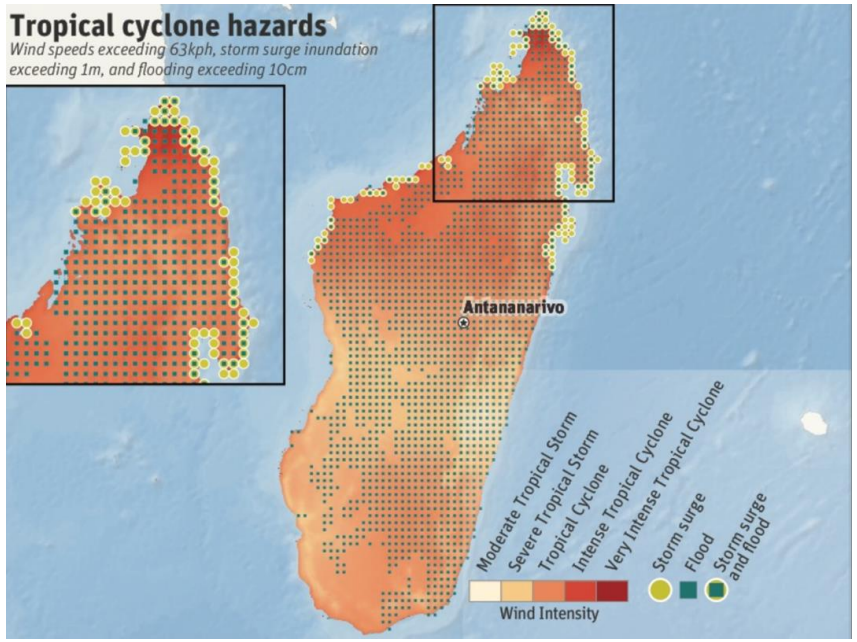
Location	Mahajanga	Morondava	Toliara	Toamasina	Mananjary
Highest Astronomical Tide	2.07m	1.96m	1.49m	0.36m	0.27m
Lowest Astronomical Tide	-1.98m	-1.95m	-1.47m	-0.37m	-0.29m
Maximum Range	4.03m	3.91m	2.96m	0.72m	0.55m

Long term sea level trend

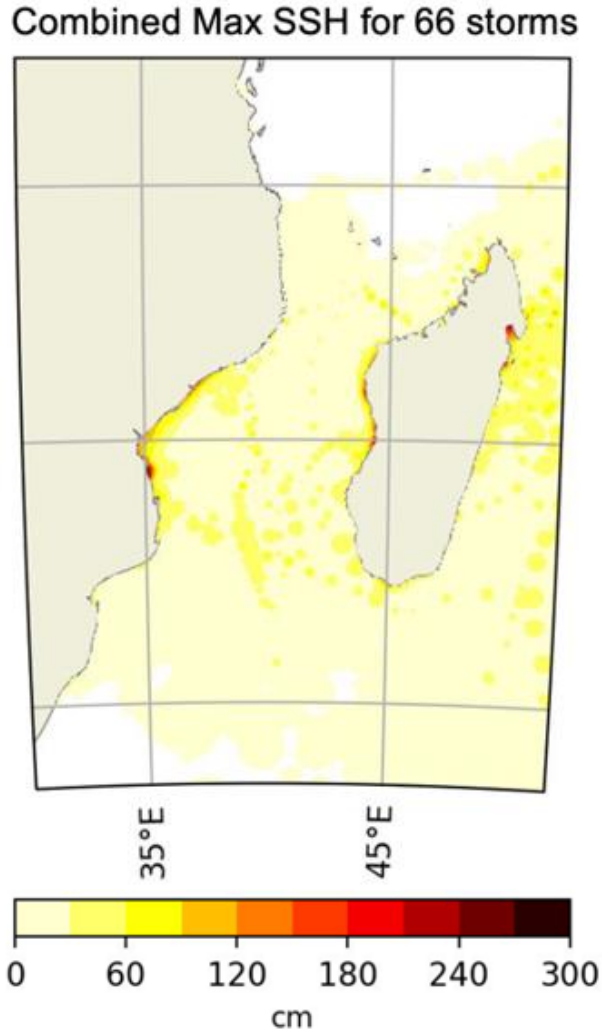


For the coast of Madagascar – trend is 2.1 to 3.9 mm/yr (2000-2020, C-RISe)

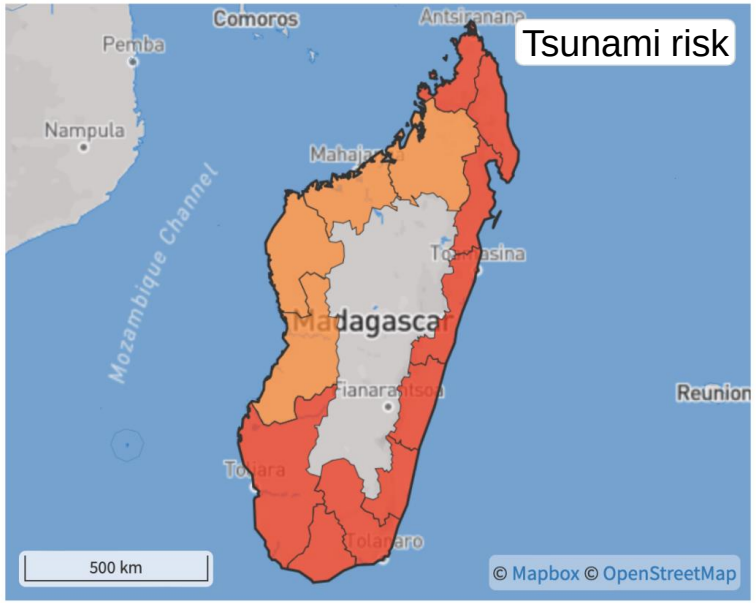
STORM SURGE AND TSUNAMI



GFDRR 2016



NOC modelled surge from 66 storms, 1990-2015 (C-RISC)



https://thinkhazard.org/en/report/150-madagascar/TS

VULNERABILITY

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Esteves, L.S. and Ballesteros, C. 2019. Building an index of exposure to coastal change in Eastern Africa with applications to conservation of cultural heritage. *Coastal Sediments* 1063-1077.

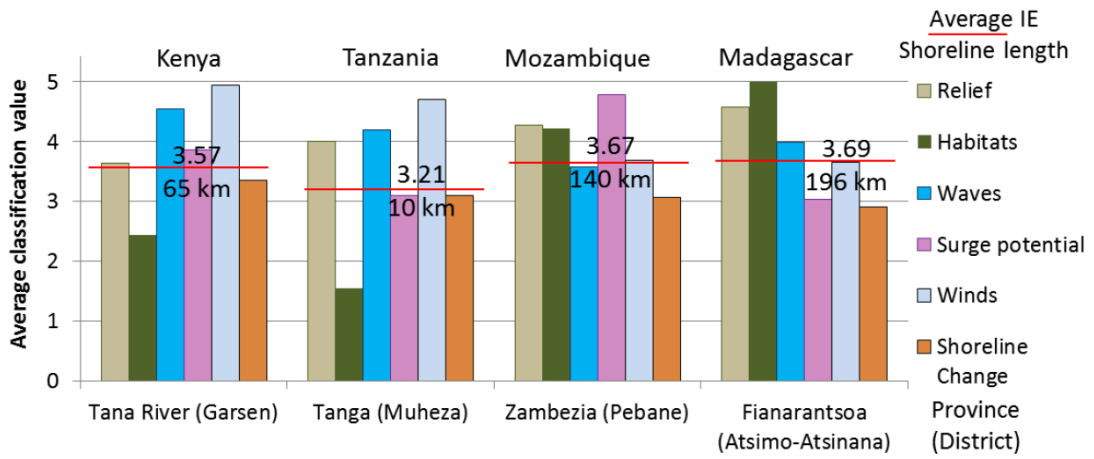
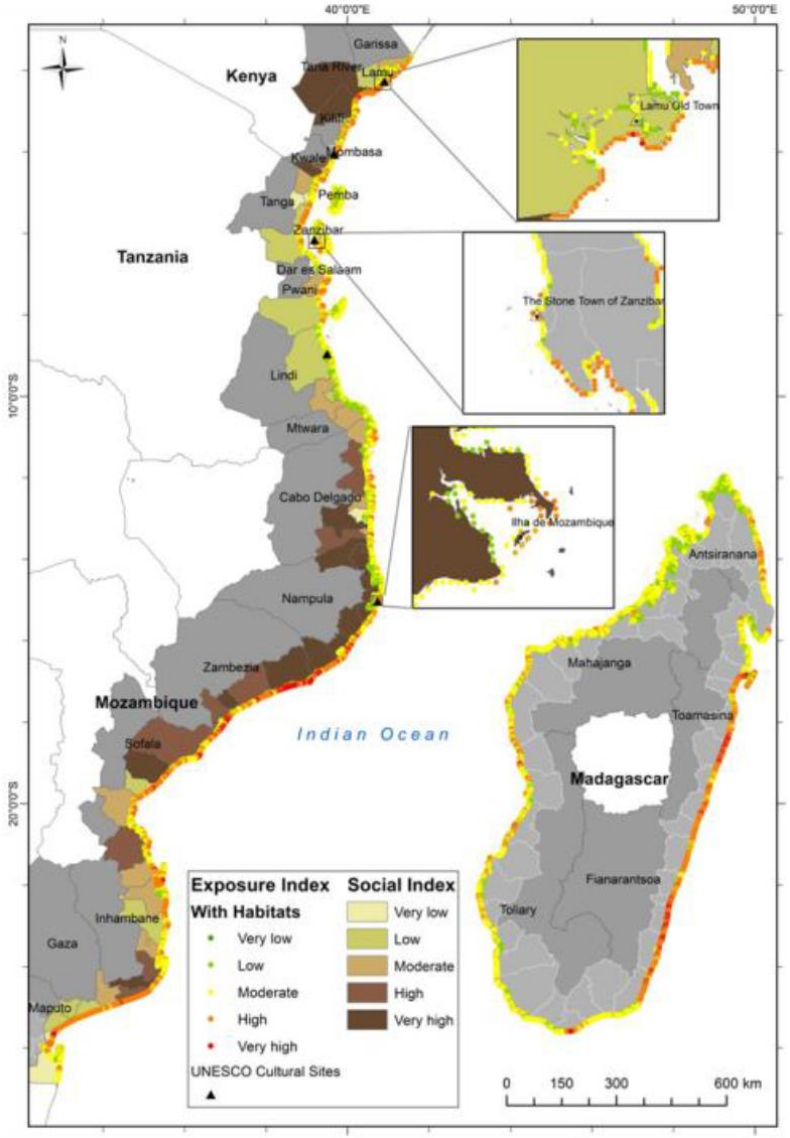
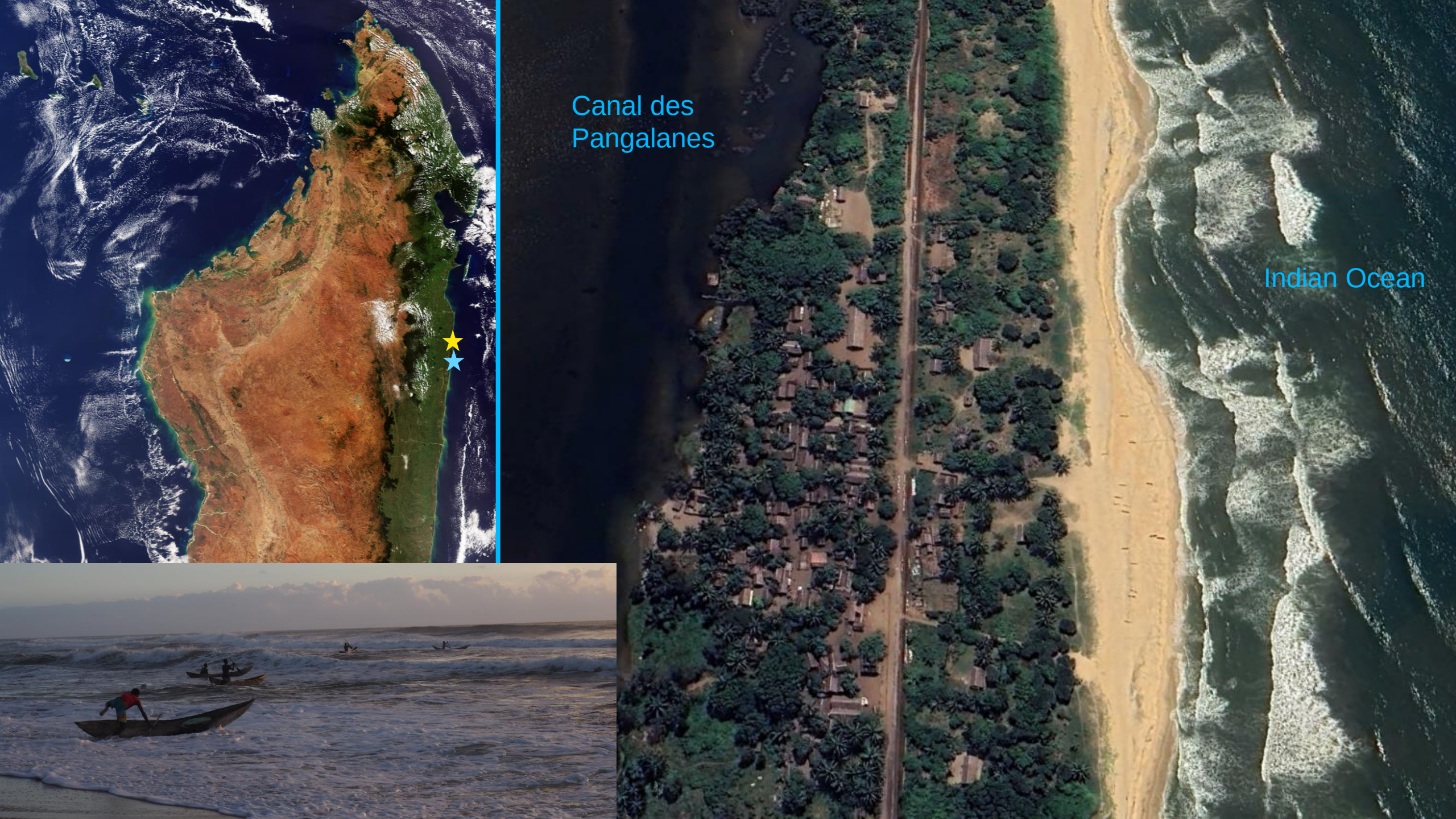


Fig. 2. Average classification value of each indicator for the four districts showing the highest average exposure index in each country.




Canal des
Pangalanes
Indian Ocean

MOVING THE PORTAGAUGE

220km in 8 hours!

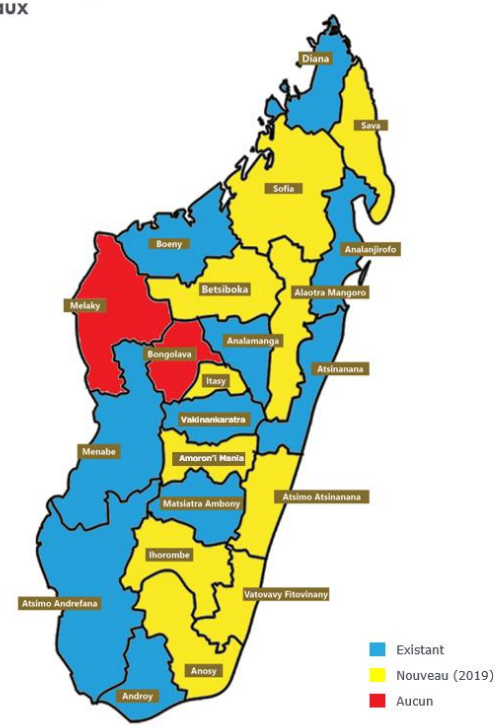
Easier to transport by ship?

HUMAN RESOURCE AND CAPACITY BUILDING

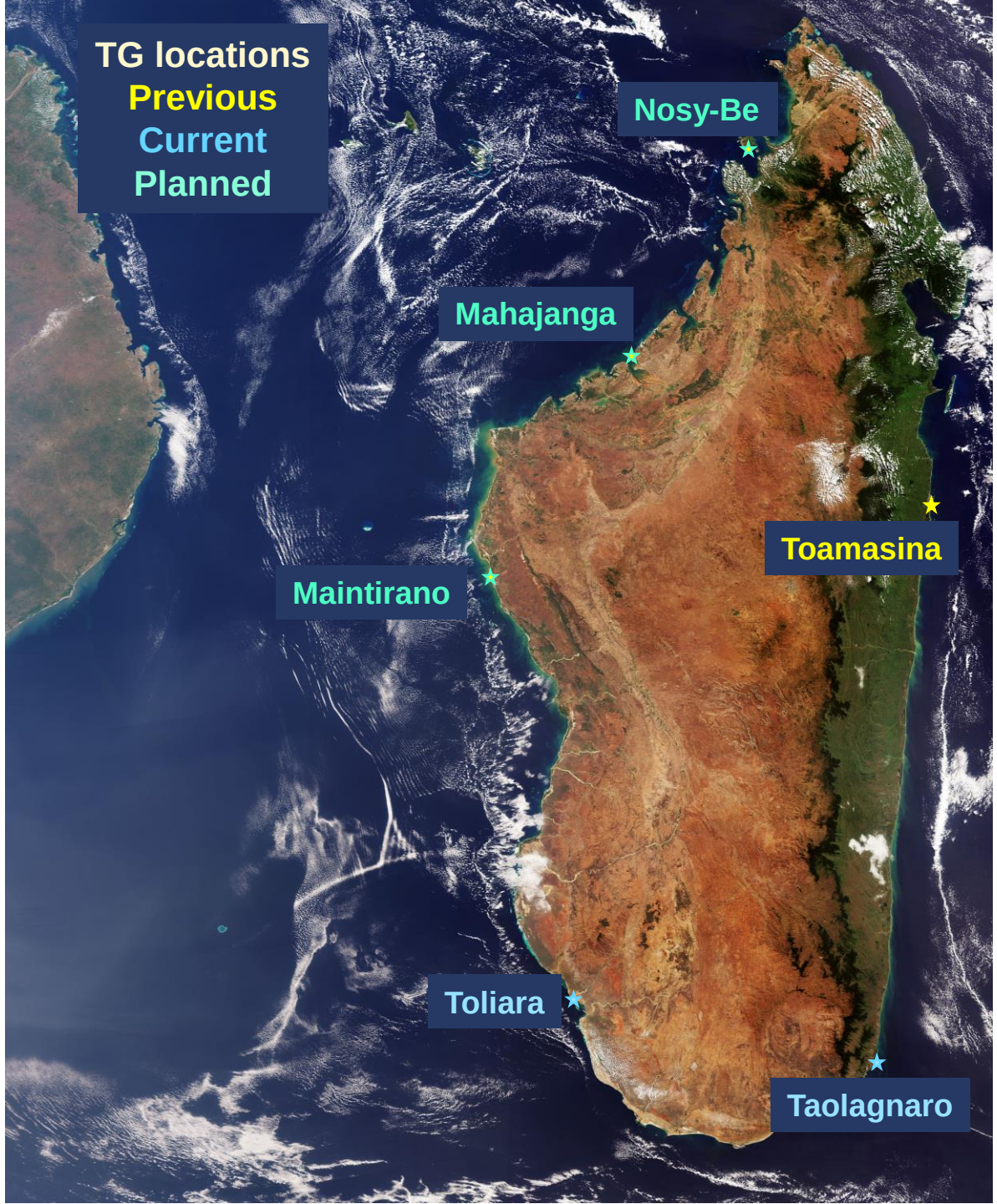
Installation

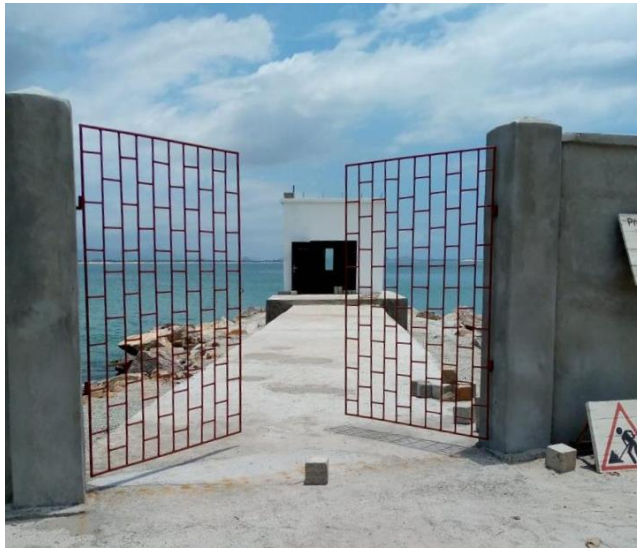
Operation – trouble shooting problems, downloading data

Data processing



METEO Madagascar


TG locations
Previous
Current
Planned
Nosy-Be
Mahajanga
Toamasina
Maintirano
Toliara
Taolagnaro



SATOC
SATELLITE OCEANOGRAPHIC CONSULTANTS

METEO Madagascar

esa

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