
GWF
GEOSPATIAL WORLD FORUM
CLICK TO KNOW MORE

Coral Reef Islands from Space

Examining shoreline dynamics across small islands to inform climate change adaptation

Dr Meghna Sengupta
Postdoctoral Researcher | Alexander von Humboldt Fellow
Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany

Alexander von Humboldt Stiftung/Foundation

ZMT LEIBNIZ-ZENTRUM für Marine Tropenforschung

THE UNIVERSITY OF AUCKLAND NEW ZEALAND

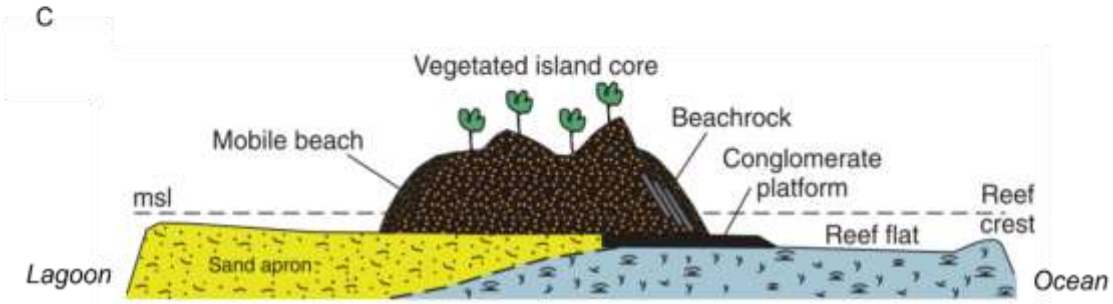
16 May 2024

GWF 2024 GEOSPATIAL WORLD FORUM

Reef islands, formation and morphology

- Low-lying sedimentary landforms formed by the coherent deposition of biogenic sediments on reef platforms.
- They are found across the tropical and sub-tropical oceans – countries like Tuvalu and Kiribati are ‘atoll-nations’ and comprise entirely of reef islands.

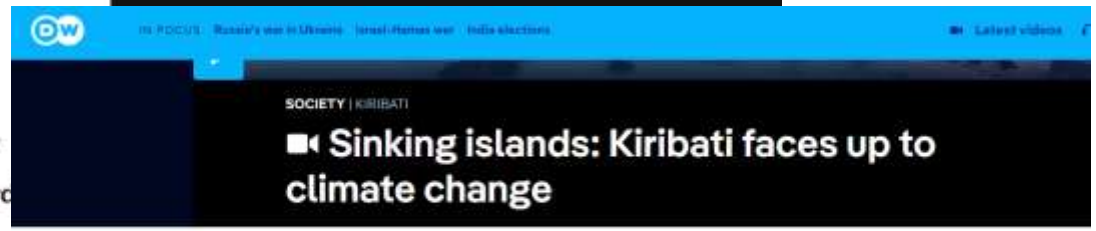
©Maxar Inc.

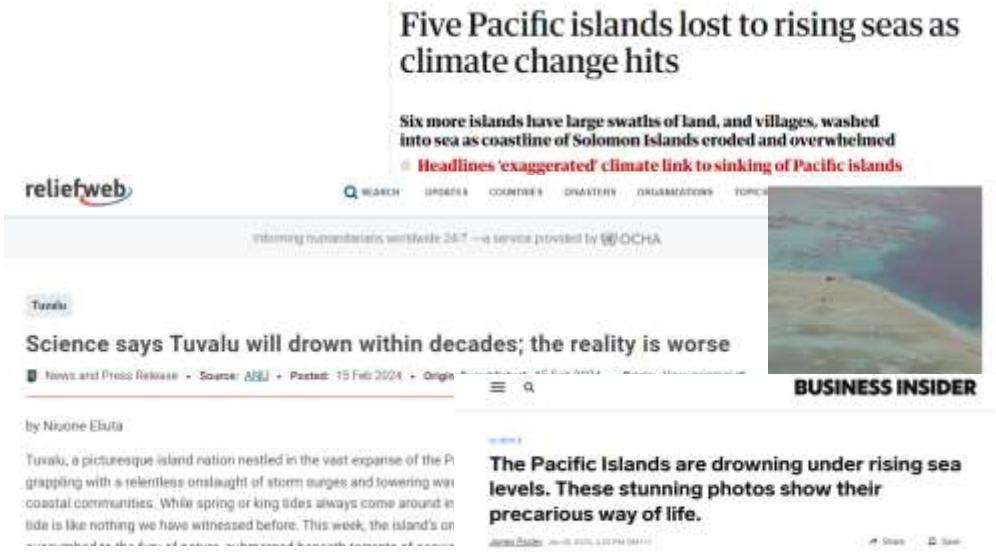


From McLean and Kench, 2015

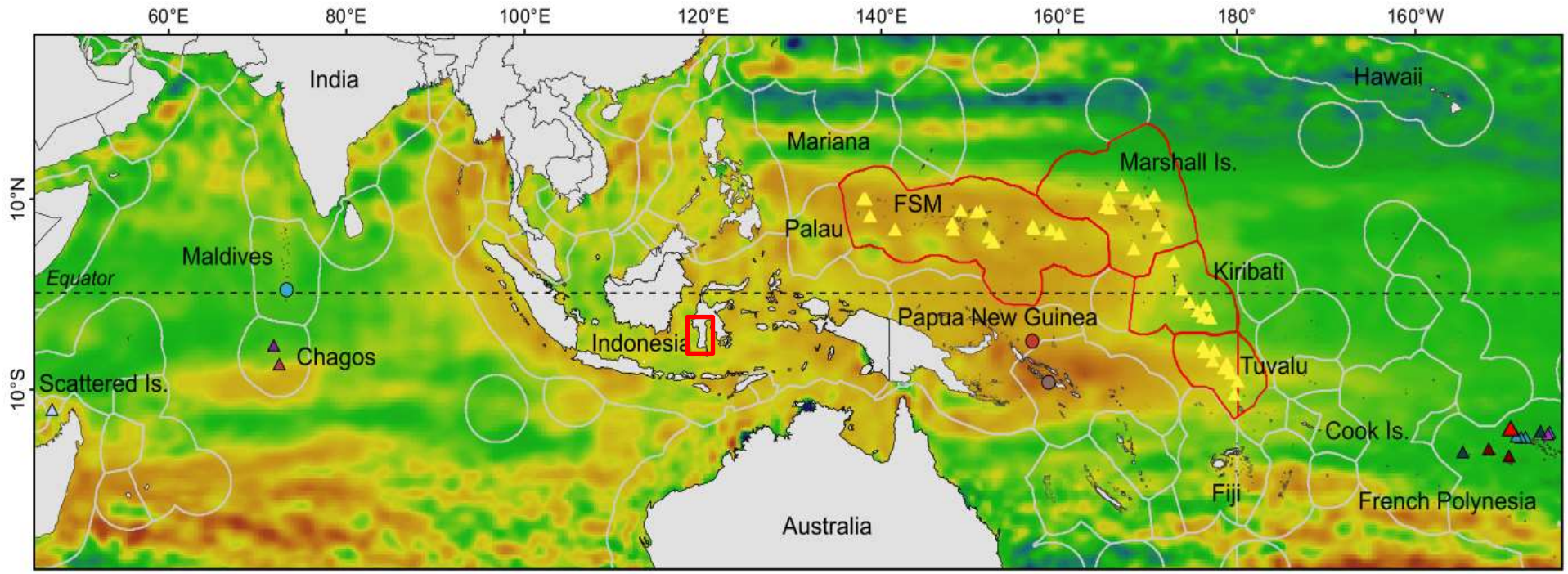
Reef islands and climate change

Due to their low elevation, limited spatial extent and remote location, reef islands are considered ***highly vulnerable to the impacts of climate change***, particularly sea level rise.





Studies on reef island dynamics – using remote sensing data

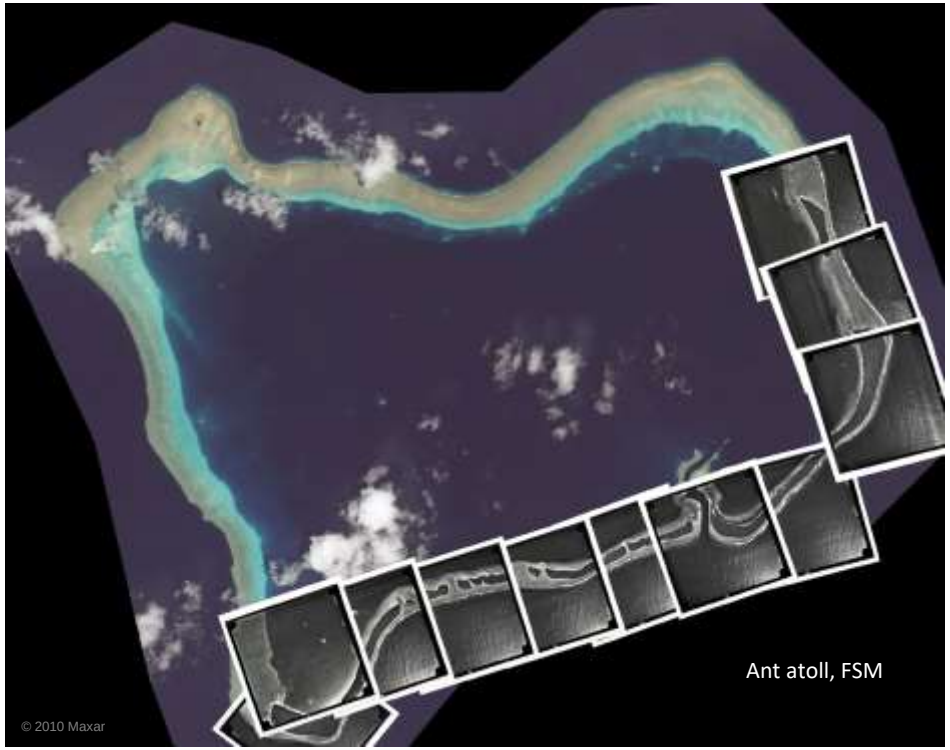


42 atolls

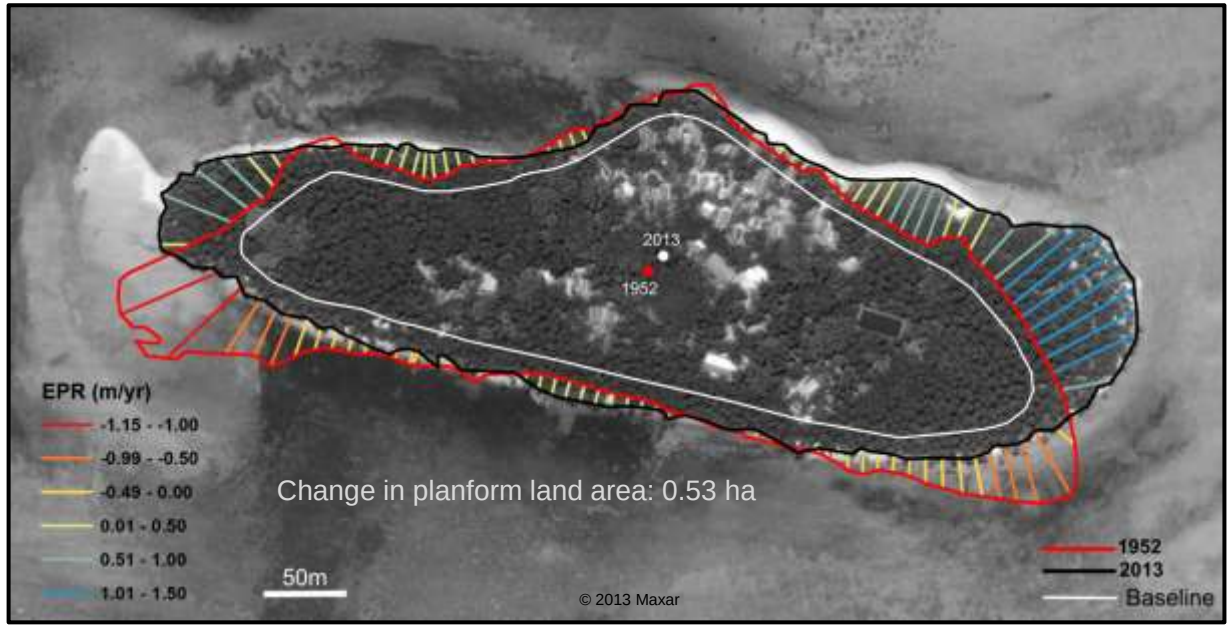
500+ islands

Sengupta et al., 2021a
Sengupta et al., 2021b
Sengupta et al., 2023

Shoreline interpretation and computation of island change



Records from WWII Air Reconnaissance Missions and additional aerial surveys –
1940s-1970s used alongside **recent high resolution** satellite imagery

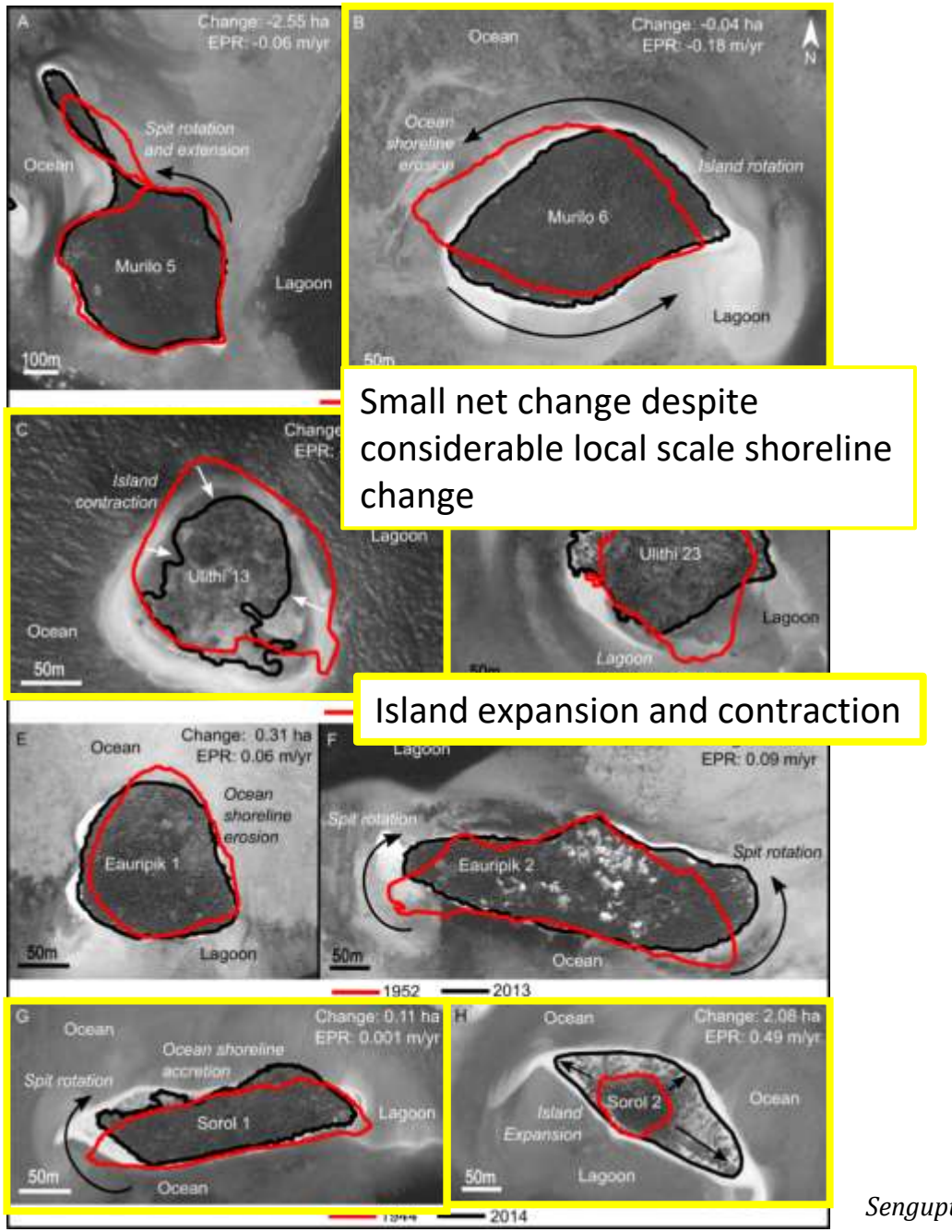


Transects are cast at equal intervals (10 m) from a reference baseline.

The Digital Shoreline Analysis System used to compute shoreline change rates.

M Sengupta et al. (2021a), *'Shoreline changes in coral reef islands of the Federated States of Micronesia since the mid-20th century', Geomorphology, 377, 107584* https://doi.org/10.1016/j.geomorph.2020.107584

Results



Small net change despite considerable local scale shoreline change

Island expansion and contraction

Styles of geomorphic changes across islands of FSM: West Pacific

High variability in rates and spatial patterns of island change

Lagoon and ocean shoreline adjustments

Net island change can often mask large local-scale gross changes along island shorelines

A number of styles of geomorphic adjustments were identified including dynamic spits, island rotation, expansion and contraction

Sengupta et al (2021a)

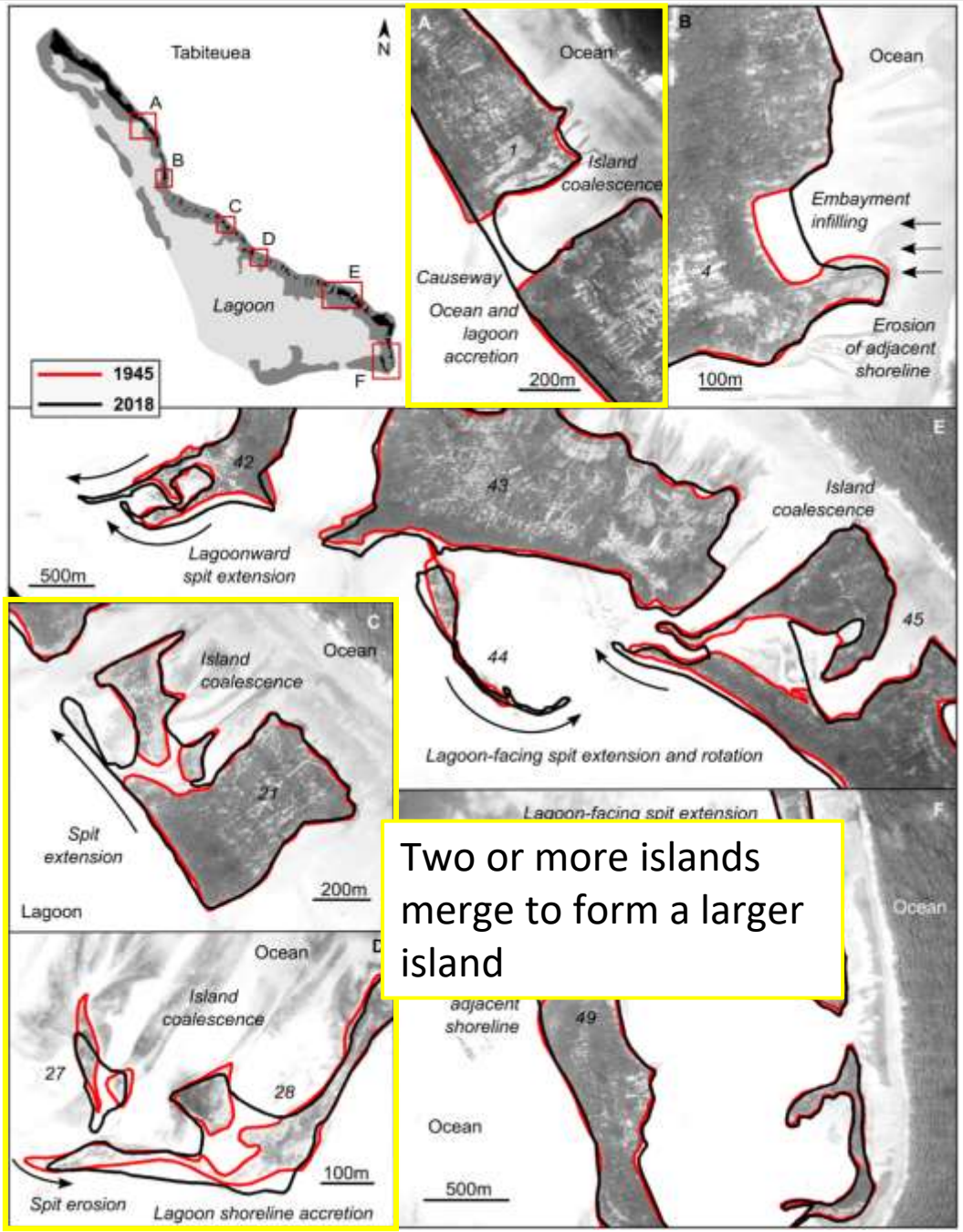
Atoll vs. platform islands

Atolls are annular reefs with a prominent central lagoon sheltered from ocean swells and can support a chain of discrete or near continuous reef islands on the atoll rim.

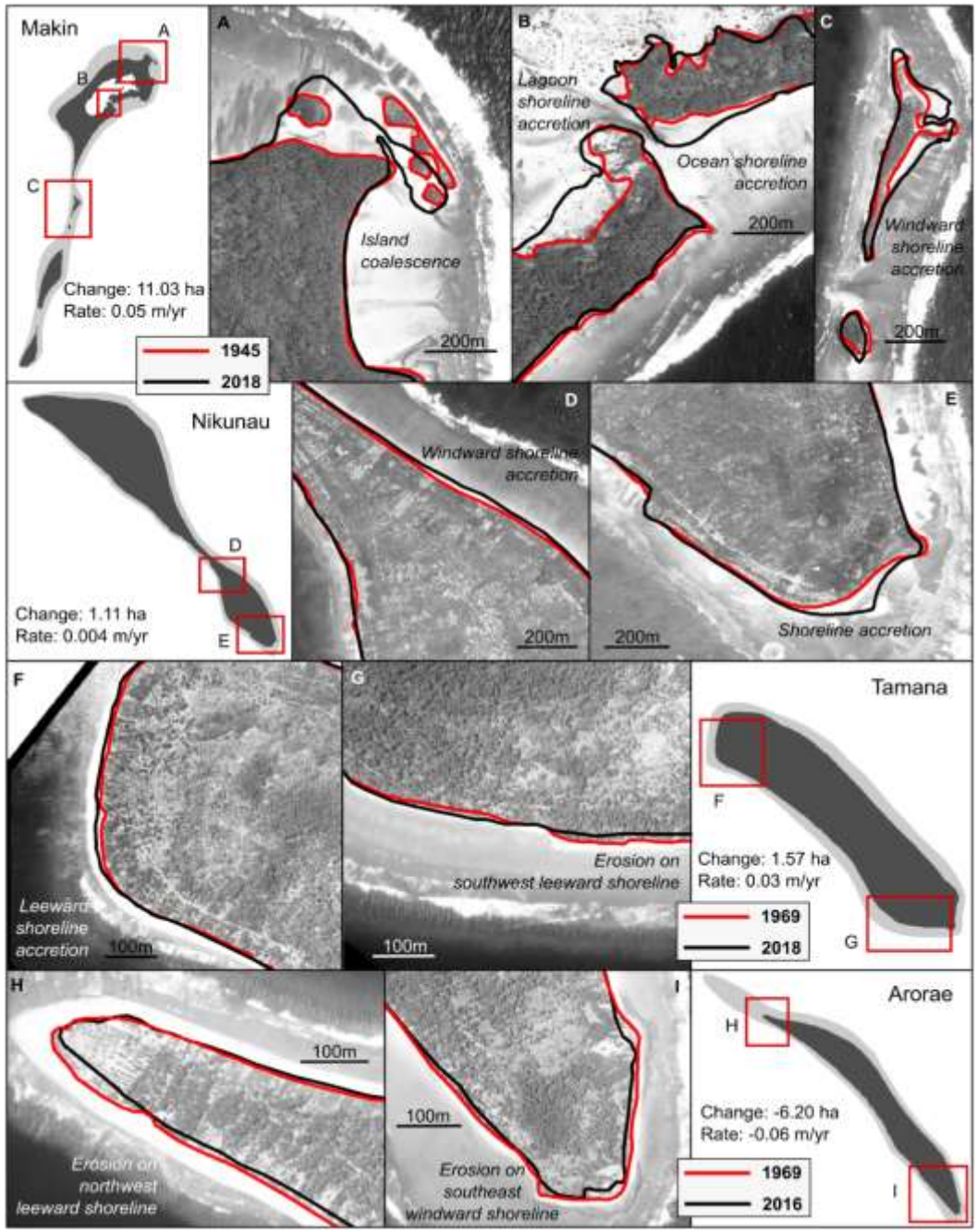
Isolated reef platforms, also called table reefs are generally smaller and usually support a single island that occupies the central reef platform.

M Sengupta et al. (2021b), *'Multi-decadal planform changes on coral reef islands from atolls and mid-ocean reef platforms of the equatorial Pacific Ocean: Gilbert Islands, Republic of Kiribati', Geomorphology, 389, 107831.* *https://doi.org/10.1016/j.geomorph.2021.107831*

Results: Styles of changes on islands of the Gilbert Is., Kiribati: Central Pacific



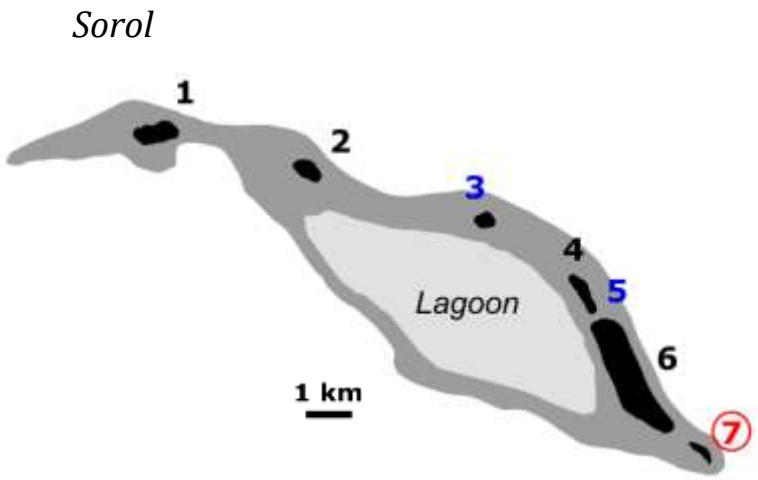
Two or more islands merge to form a larger island

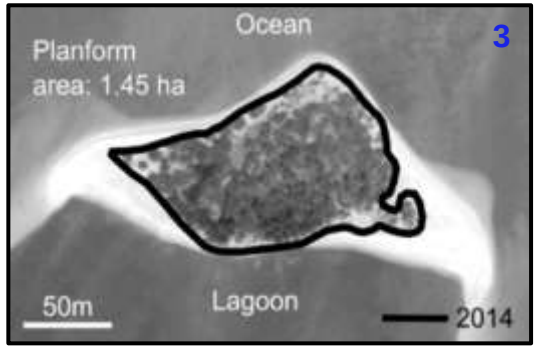


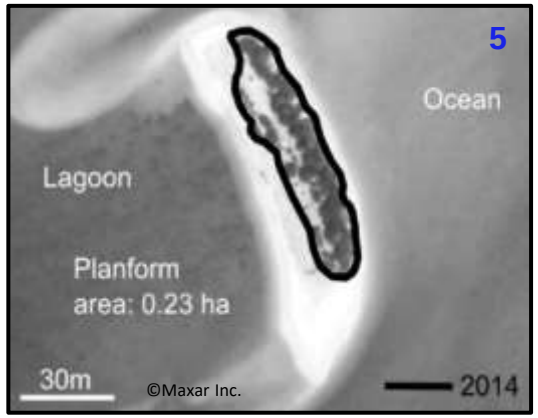
Imagery: SPC Archives, Suva, Fiji

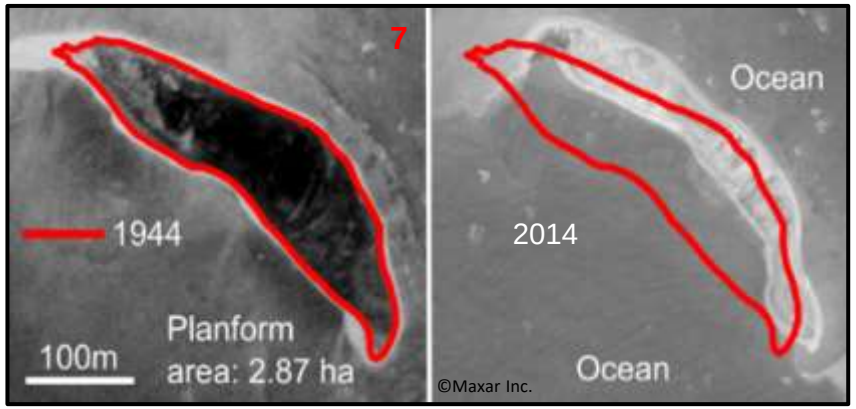
Sengupta et al (2021b)

Concurrent island formation and loss at Sorol (1944-2014)









Aerial imagery: Bishop Museum Archives (www.bishopmuseum.org), Hawai'i

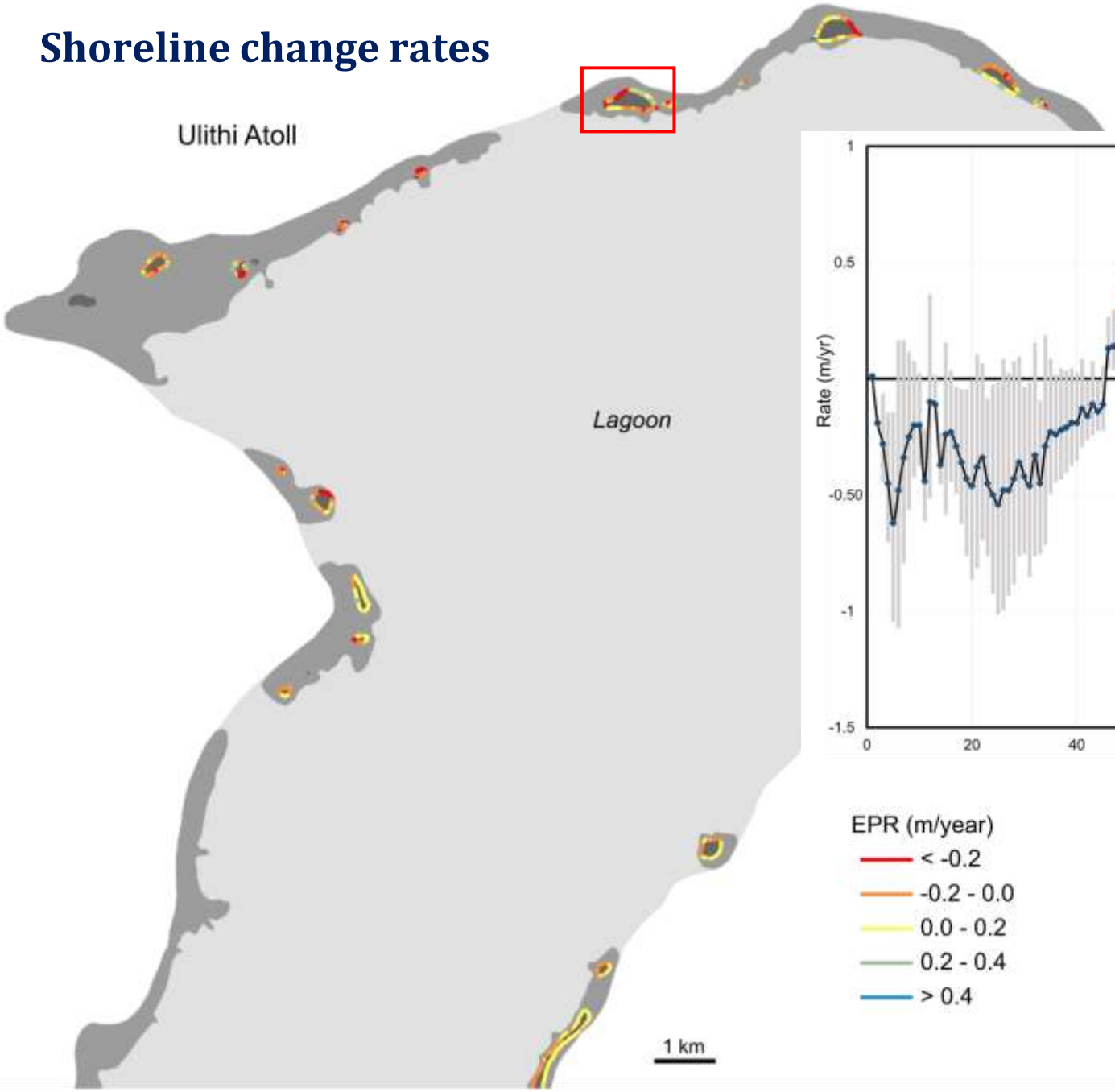
Sengupta et al (2021a)

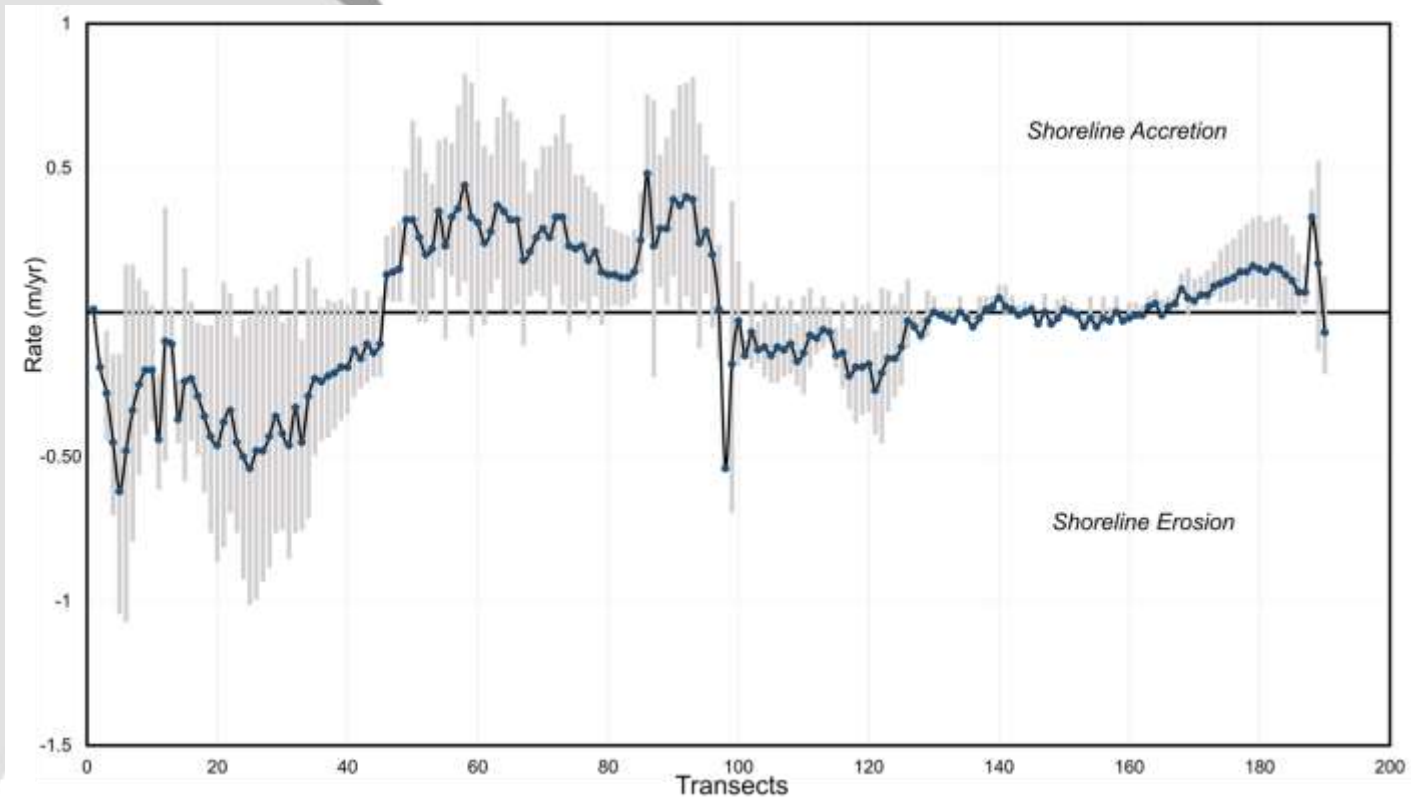
Within FSM, three new islands were formed while three islands disappeared

At Sorol, island formation and loss occurred concurrently -
On the same reef platform within a distance of ~8km.

*All instances of island formation and loss occurred within a **high storm frequency setting** on atolls of Yap (west FSM)*

Shoreline change rates

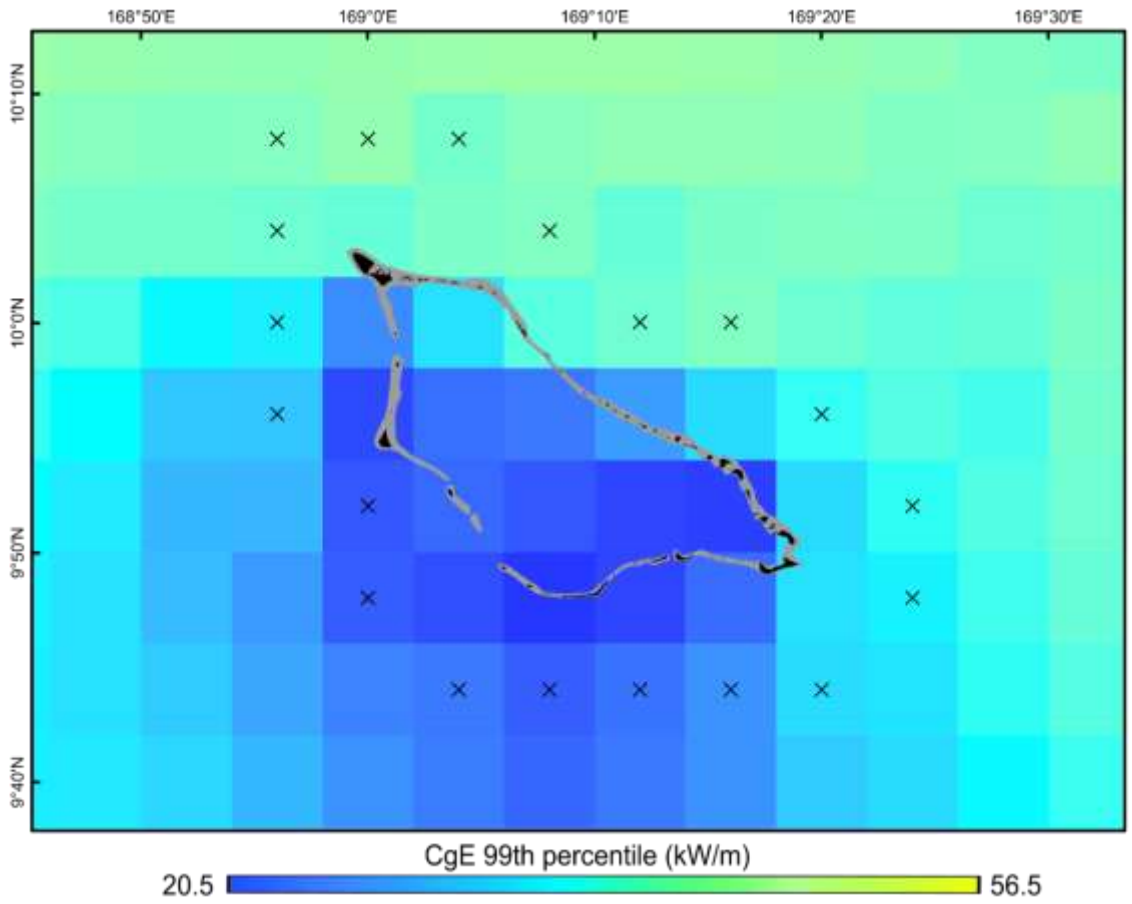




EPR (m/year)
- < -0.2
- -0.2 - 0.0
- 0.0 - 0.2
- 0.2 - 0.4
- > 0.4

Error bars indicate 95.5% C.I

Linking island change to potential drivers



Cross-marks indicate pixels used to extract values for islands of Likiep Atoll, Marshall Islands (WaveWatch III)

Oceanographic and Climatic Controls:

- Sea level rise trend (altimetry records, AVISO)
- Storms (NOAA IBTracs)
- Wave climate variables (WaveWatchIII)
  - Significant Wave Height (Hs)
  - Wave Energy Flux (CgE)

    Mean, min, max, std. dev., 99th percentile
- Tidal range (FES2014)
- Precipitation (ECMWF)

M Sengupta et al. (2023), *Drivers of shoreline change on Pacific coral reef islands: linking island change to processes. Reg. Environ. Change 23, 110.* https://doi.org/10.1007/s10113-023-02103-5

Local / geomorphic controls:

Continuous:

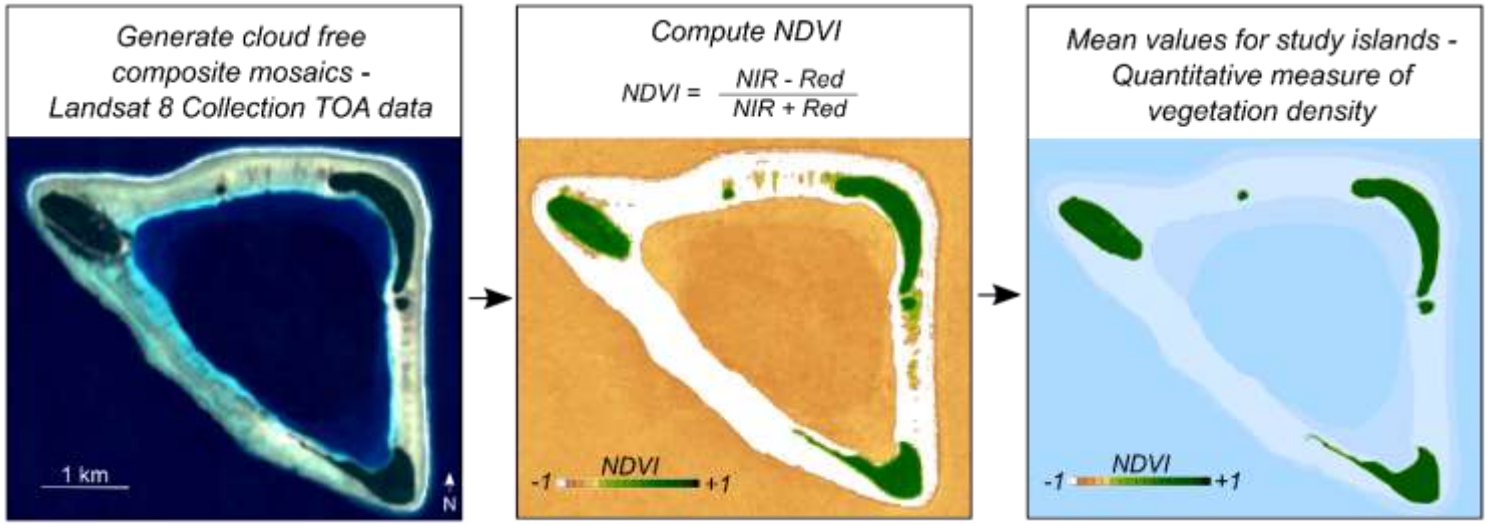
- Island size
- Reef width
- Circularity Ratio
- Ratio – island width to reef width
- Distance from reef edge
- Vegetation density

Categorical:

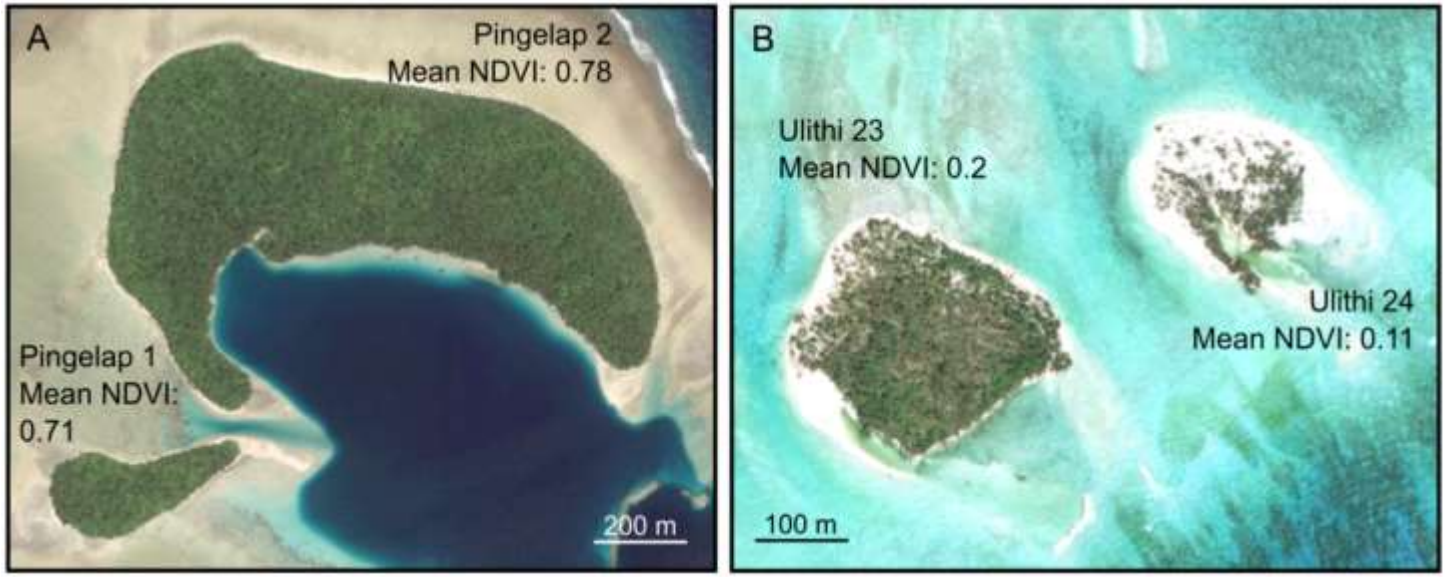
- Local position – windward/leeward
- Anthropogenic modification

Sengupta et al. (2023)

Methods: Linking island change to potential drivers



Measure of vegetation density using Normalised Difference Vegetation Index (NDVI) on Google Earth Engine



Sengupta et al. (2023)

Classification and Regression Tree Model

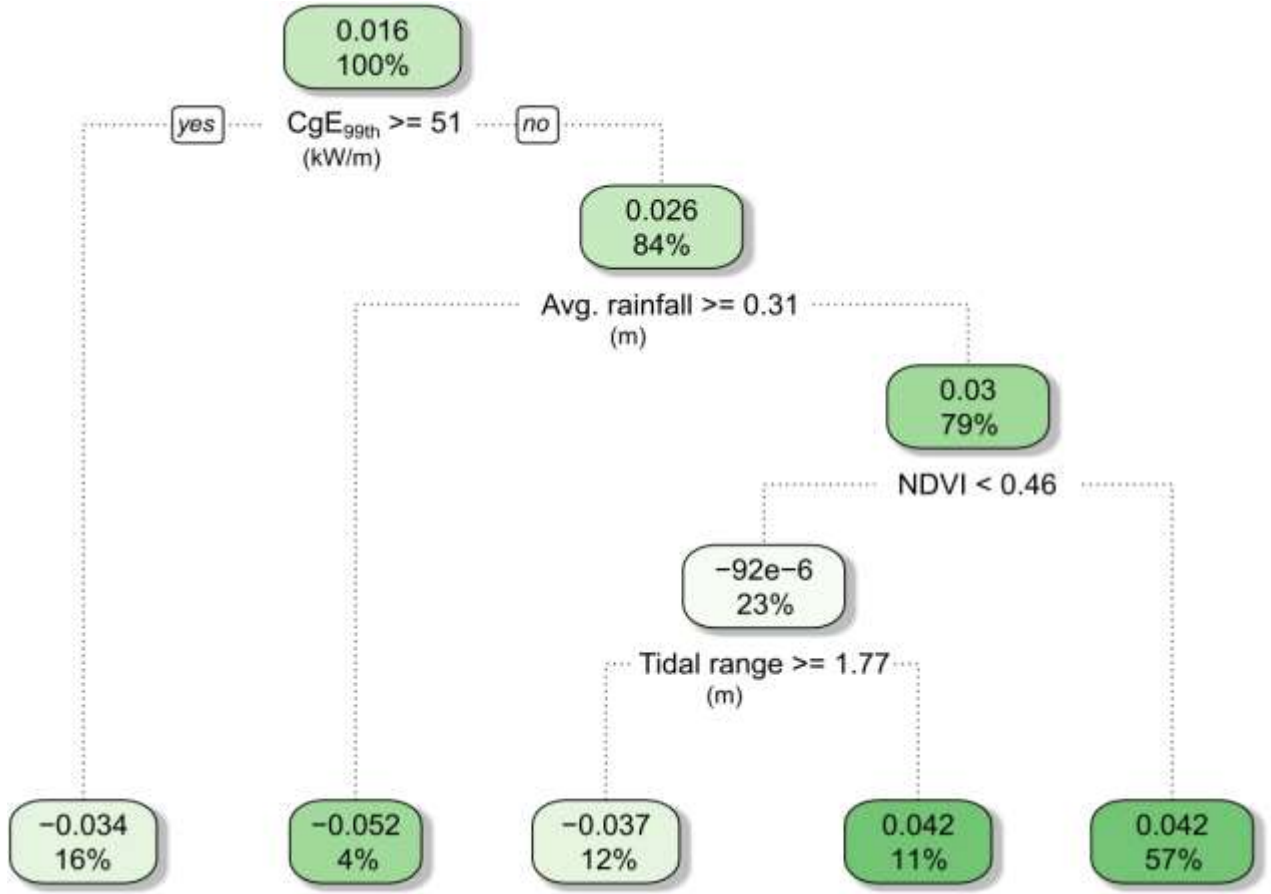
Tree based model based on 'binary recursive partitioning' – *heuristic model*

Dataset:

500+islands (100,000 + transects)
25 potential predictors

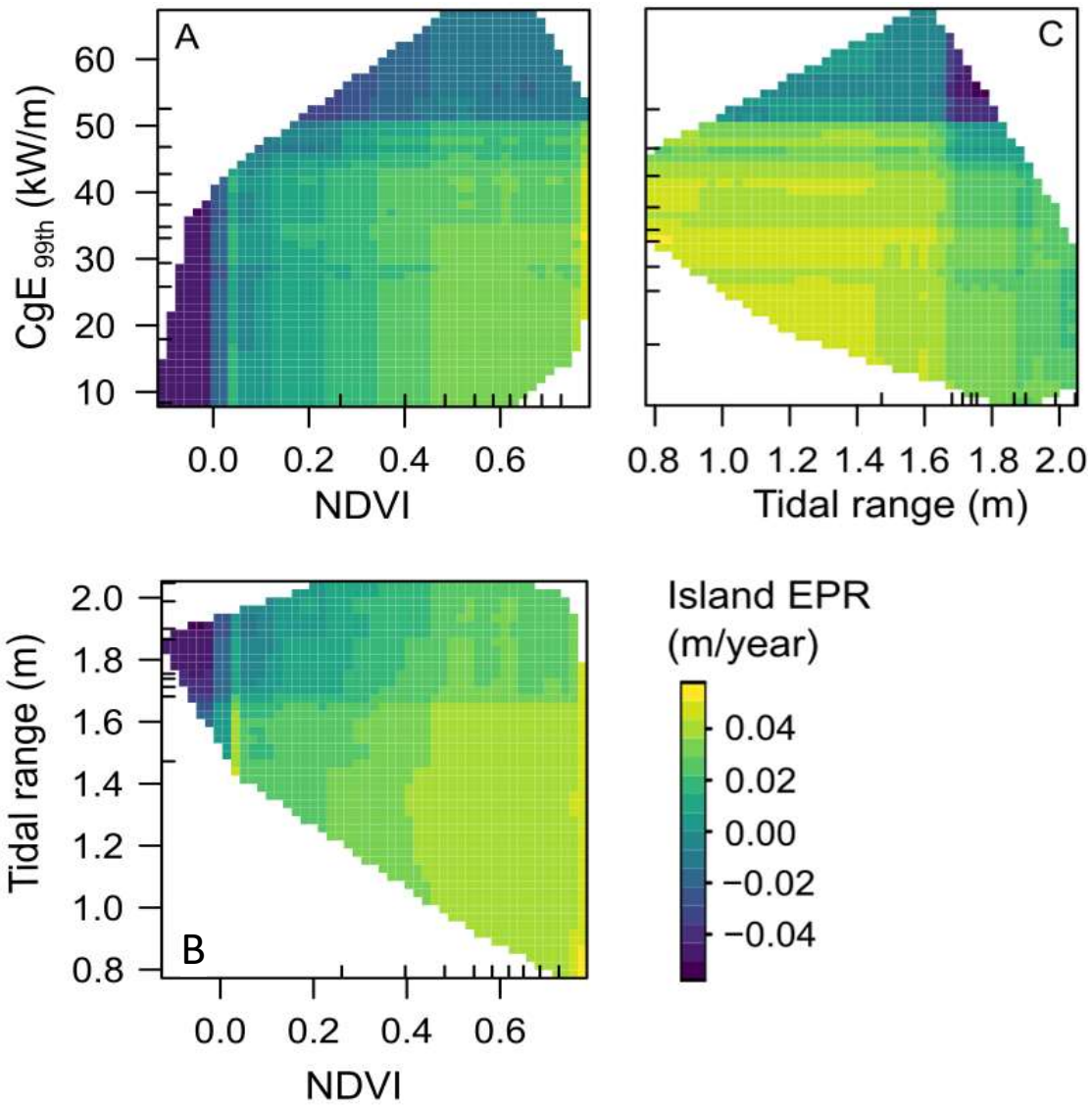
Response Variable:

Island average shoreline change rate (m/year)



M Sengupta (2021). *Reef islands from space: A remote sensing-machine learning approach to identify the drivers of shoreline change on Pacific coral reef islands (Doctoral dissertation, ResearchSpace, University of Auckland, New Zealand).*
https://researchspace.auckland.ac.nz/handle/2292/58574

Results



Investigating interactions between identified key variables from the Random Forest models

M Sengupta (2021). *Reef islands from space: A remote sensing-machine learning approach to identify the drivers of shoreline change on Pacific coral reef islands (Doctoral dissertation, ResearchSpace, University of Auckland, New Zealand).* https://researchspace.auckland.ac.nz/handle/2292/58574

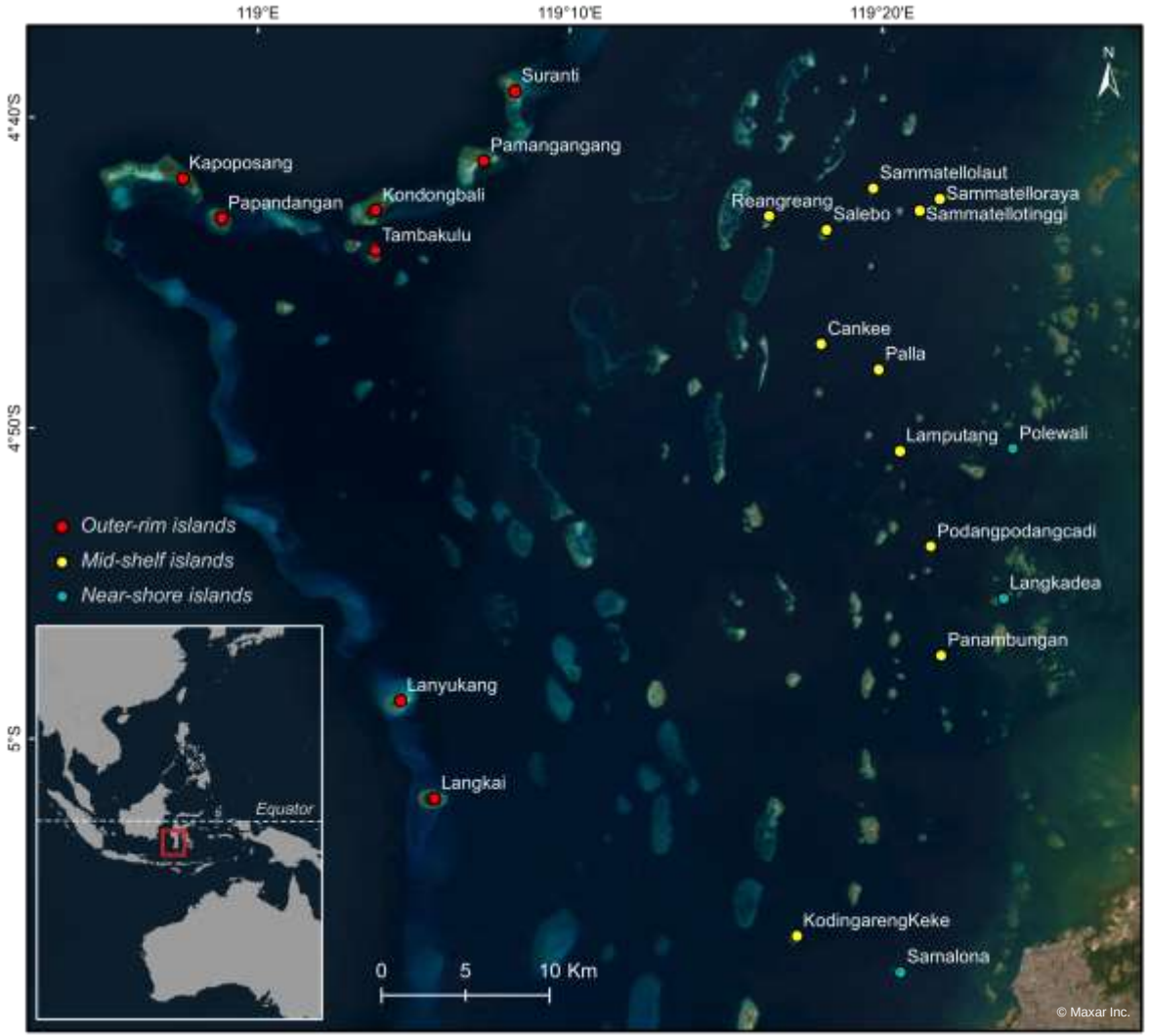
Ongoing work:

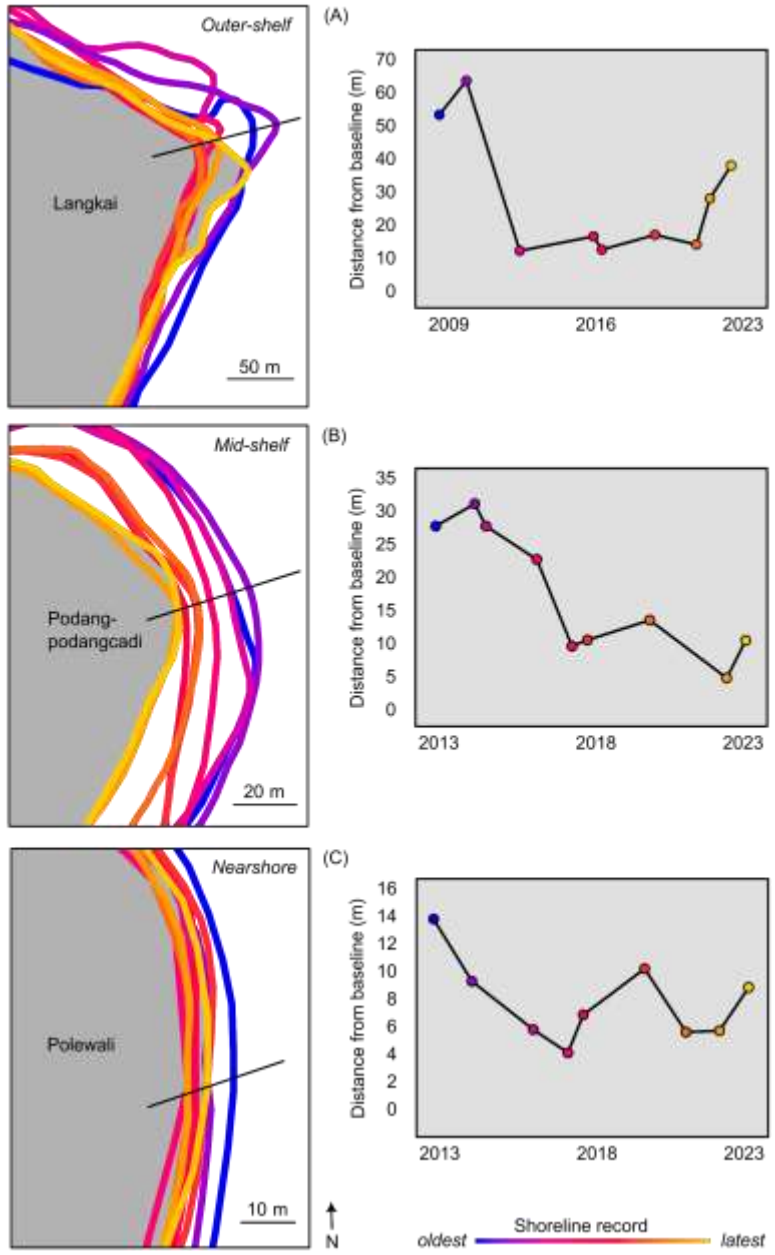
Generating a high-frequency dataset of shoreline change in the altimetry era (past two decades)

Motivation

- Understand island dynamics under current sea level rise and wave climate
- Generate and examine contemporary trend of island change – spatial and temporal
- Direct implications for climate change adaptation strategy and planning

Preliminary results from a ‘climate change hotspot’: Indonesia

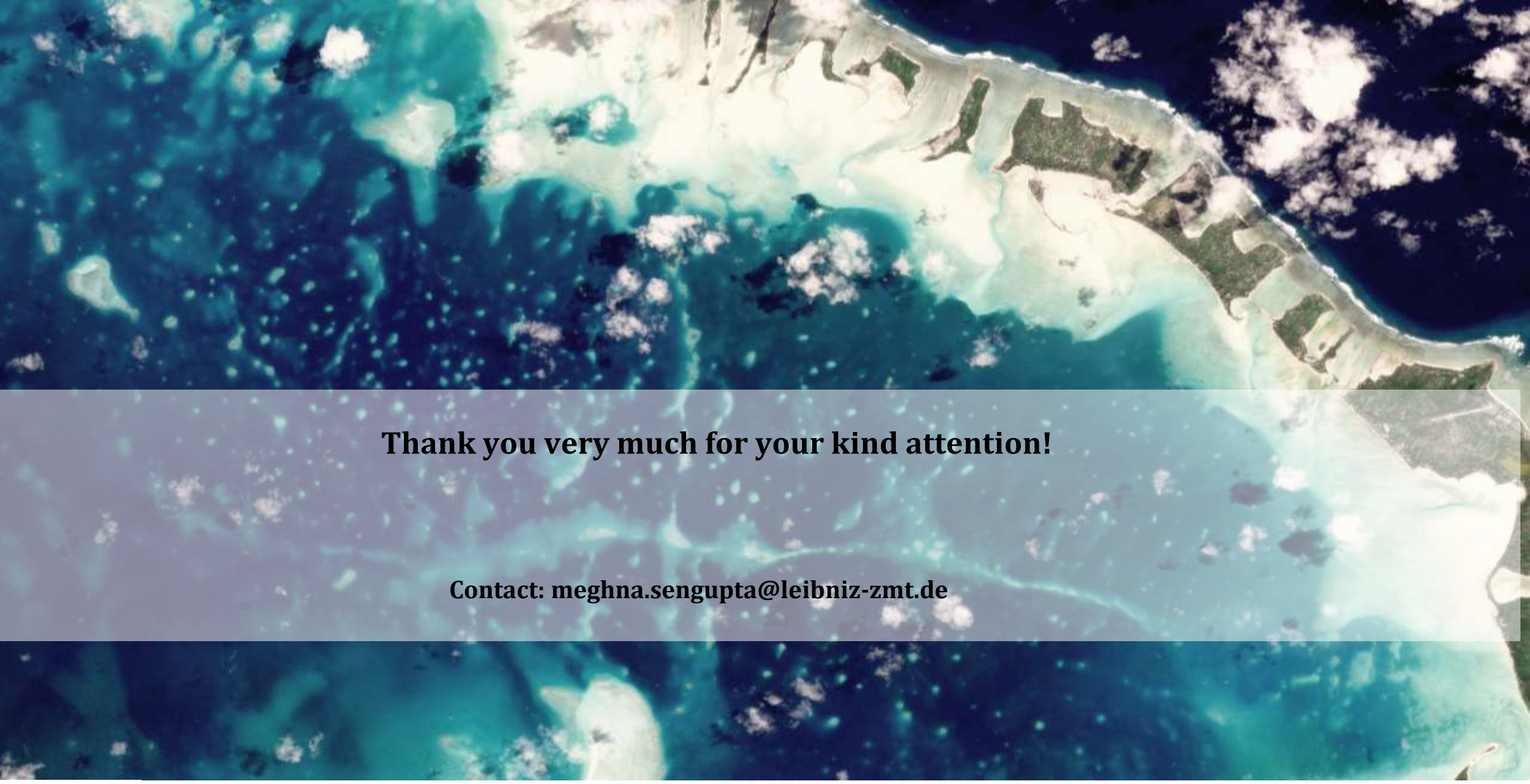




Implications for Climate Change Adaptation and Way Ahead?

Implications for Climate Change Adaptation and Way Ahead

- **Provide local-scale high-resolution empirical record** of shoreline change – rates and trends
- Identify hotspots of erosion – enabling visualization through GIS interface – e.g. interactive web maps (particularly of interest for stakeholders, and adaptation planners)
- Identify the effects of coastal protection structures and practices
- Provide robust training data for generating forecasts of trajectories of island change under various RCP scenarios



Thank you very much for your kind attention!

Contact: meghna.sengupta@leibniz-zmt.de

Alexander von Humboldt Stiftung/Foundation

ZMT LEIBNIZ-ZENTRUM für Marine Tropenforschung

THE UNIVERSITY OF AUCKLAND NEW ZEALAND

GWF 2024 GEOSPATIAL WORLD FORUM