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Coral Reef Islands from Space

Examining shoreline dynamics across small islands
to inform climate change adaptation

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für Marine Tropenforschung



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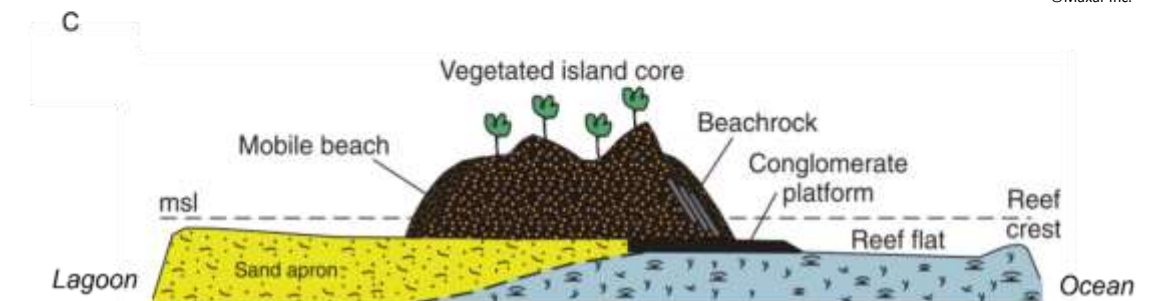
Introduction

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.



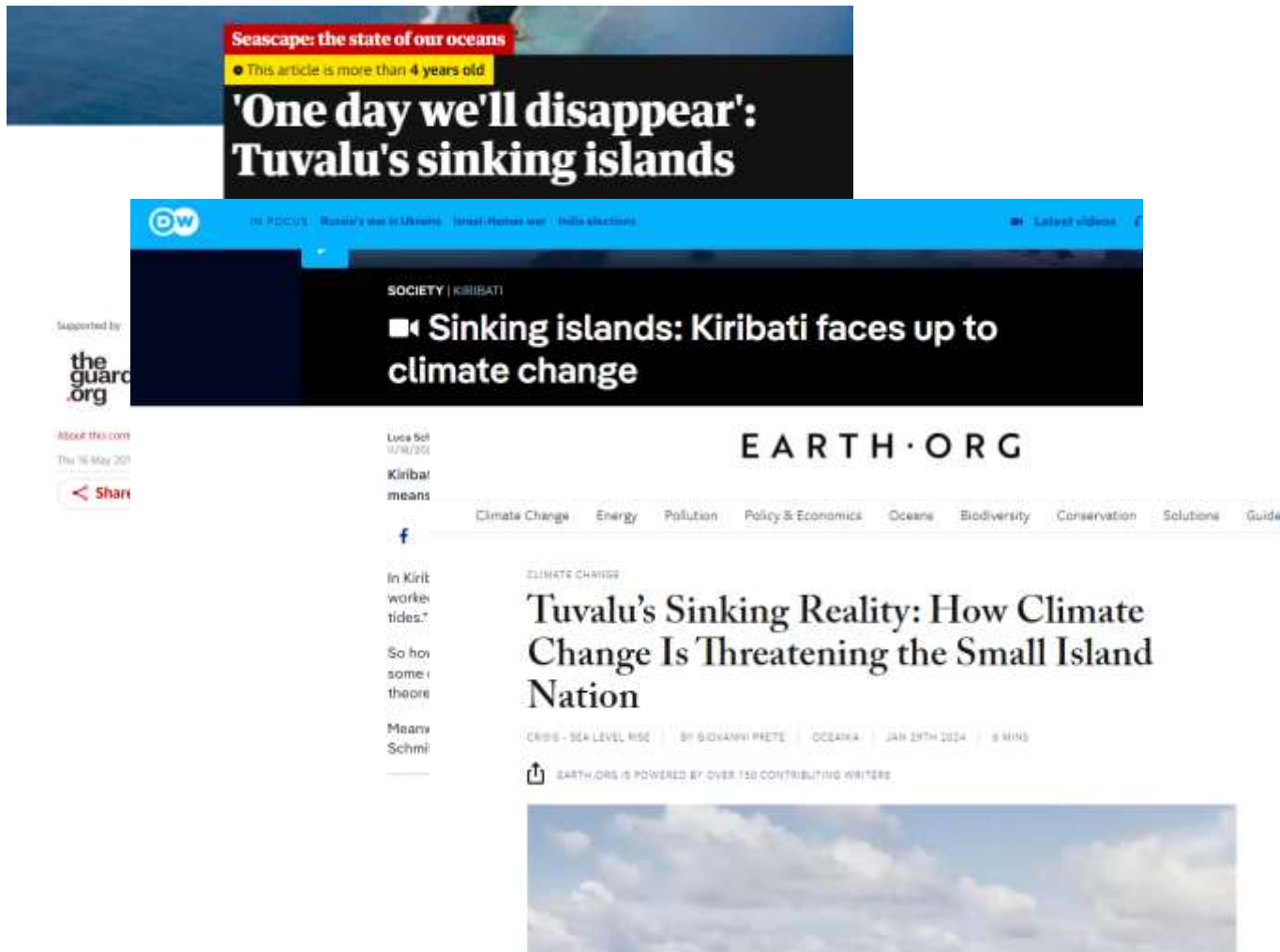
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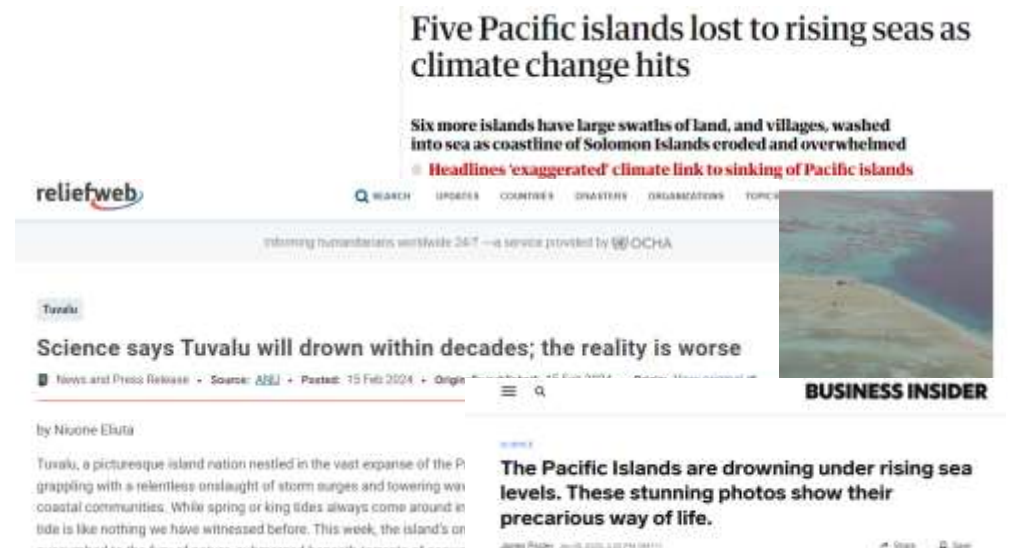
From McLean and Kench, 2015

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.



This screenshot shows a news article on Earth.org. The main headline is "'One day we'll disappear': Tuvalu's sinking islands". A secondary headline reads "Seascape: the state of our oceans" with a note that the article is more than 4 years old. The article is categorized under "SOCIETY | KIRIBATI" and "Sinking islands: Kiribati faces up to climate change". The author is Luca Soli, dated 17/01/2021. The article title is "Tuvalu's Sinking Reality: How Climate Change Is Threatening the Small Island Nation". It is tagged with "CRISIS - SEA LEVEL RISE", "BY GIOVANNI PRETE", "OCEANIA", "JAN 28TH 2024", and "6 MINS". The Earth.org logo and navigation menu are visible at the top.

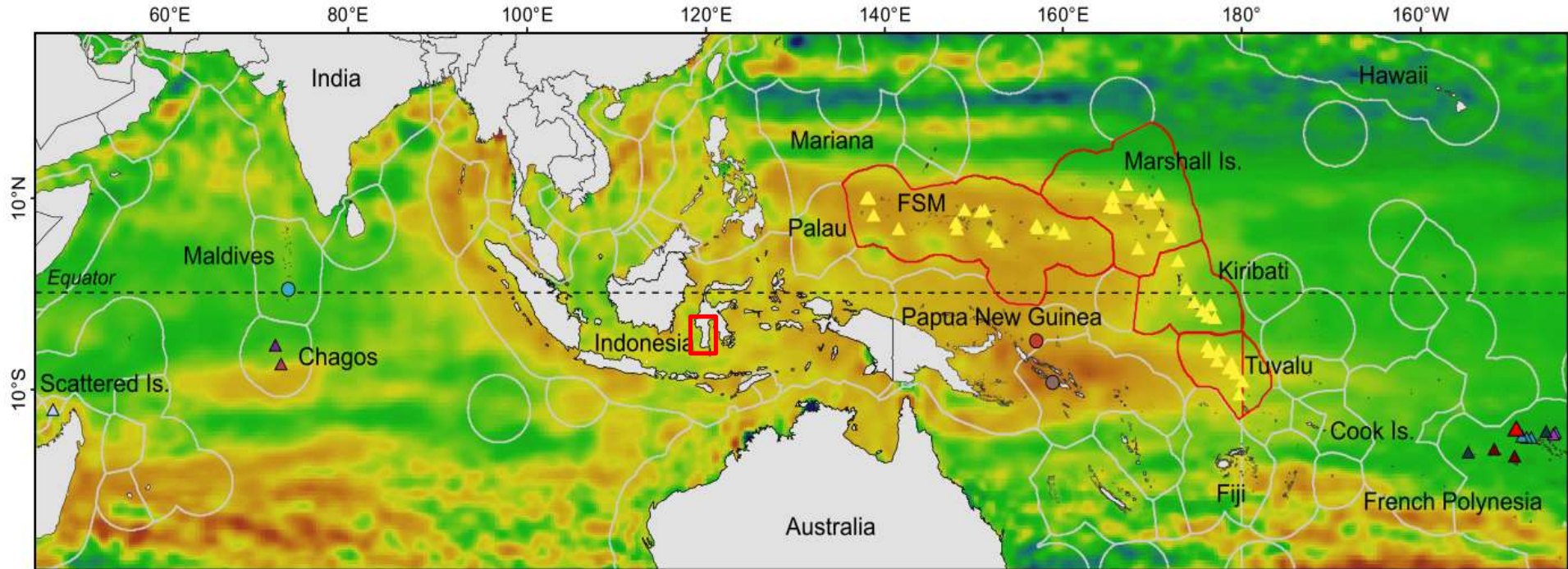


This screenshot shows a news article on reliefweb. The main headline is "Five Pacific islands lost to rising seas as climate change hits". A sub-headline states "Six more islands have large swaths of land, and villages, washed into sea as coastline of Solomon Islands eroded and overwhelmed". A red tag indicates "Headlines 'exaggerated' climate link to sinking of Pacific islands". The article is dated 15 Feb 2024. The author is Niune Eluta. The article title is "Science says Tuvalu will drown within decades; the reality is worse". The article text begins: "Tuvalu, a picturesque island nation nestled in the vast expanse of the Pacific is grappling with a relentless onslaught of storm surges and towering waves that are washing away coastal communities. While spring or king tides always come around in Tuvalu, the island's spring tides are like nothing we have witnessed before. This week, the island's spring tides were..."



This screenshot shows a YouTube video thumbnail. The title is "The final tide". The video is about Kiribati, a small island nation in the South Pacific. The thumbnail image shows a tropical island with a blue lagoon and a red play button in the center. The video title is "Kiribati: A drowning paradise in the South Pacific". The video description states: "Climate change and rising sea levels mean the island nation of Kiribati in the South Pacific is at risk of disappearing into the sea." The video has 16,557 views and 2,092 likes.

Studies on reef island dynamics – using remote sensing data



- | | |
|------------------------------|--------------------------|
| ▲ Webb and Kench, 2010 | ● Albert et al., 2016 |
| ● Rankey, 2011 | ▲ Purkis et al., 2016 |
| ■ Ford 2012, 2013 | △ Testut et al., 2016 |
| ▲ Biribo and Woodroffe, 2013 | ▲ Duvat and Pillet, 2017 |
| ▲ Yates et al., 2013 | ▲ Duvat et al., 2017 |
| ▲ Le Cozannet et al., 2013 | ● Aslam and Kench, 2017 |
| ● Mann and Westphal, 2014 | ▲ Kench et al., 2018 |
| ● Ford and Kench 2014, 2015 | ▲ Wu et al., 2021 |

▲ This study



www.aviso.altimetry.fr

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.

Results

Styles of geomorphic changes across islands of FSM: West Pacific

High variability in rates and spatial patterns of island change

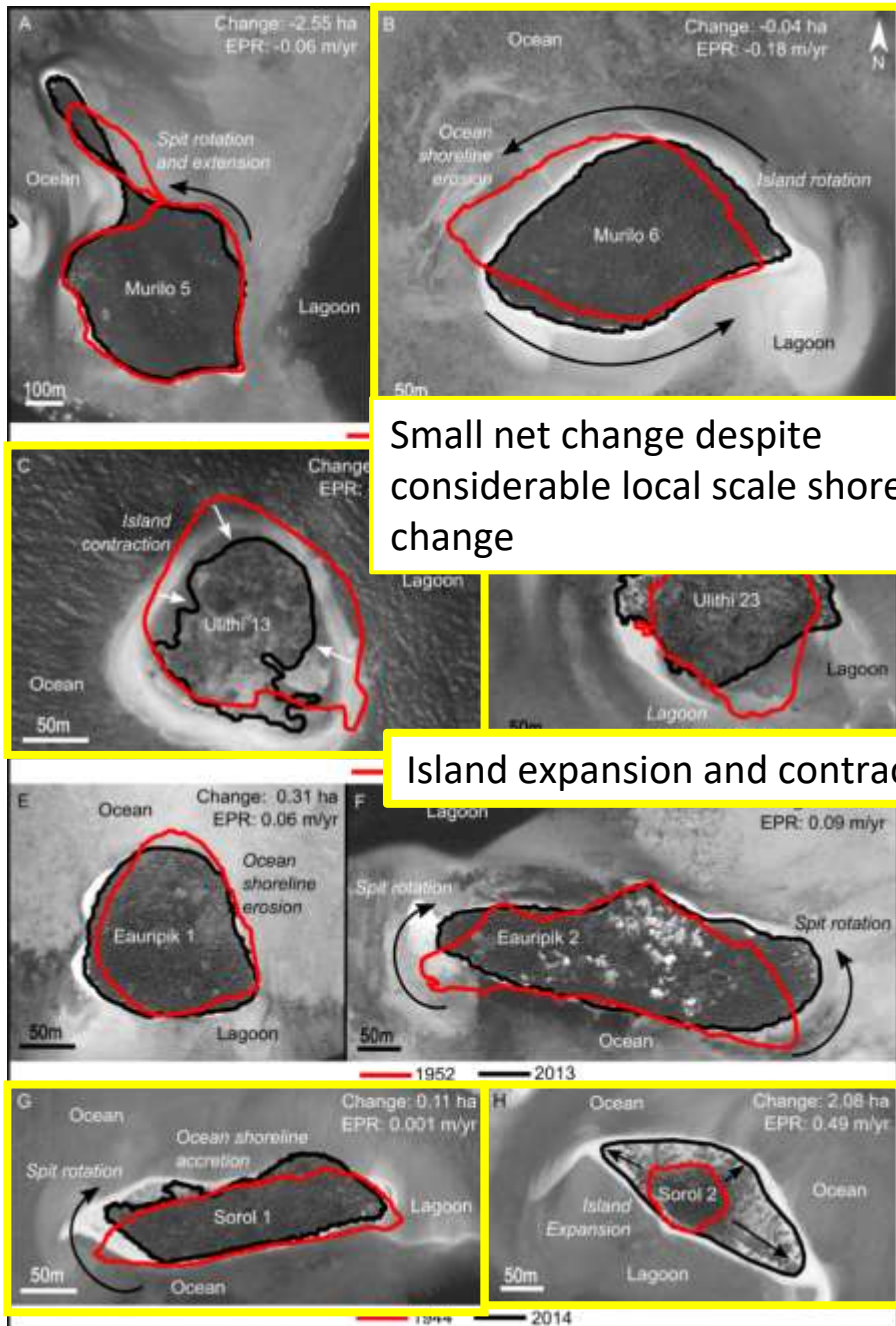
Lagoon and ocean shoreline adjustments

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

Small net change despite considerable local scale shoreline change

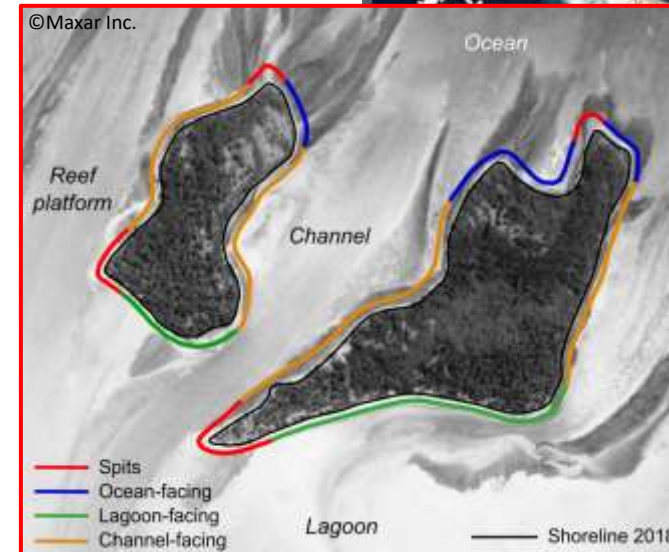
Island expansion and contraction



Sengupta et al (2021a)

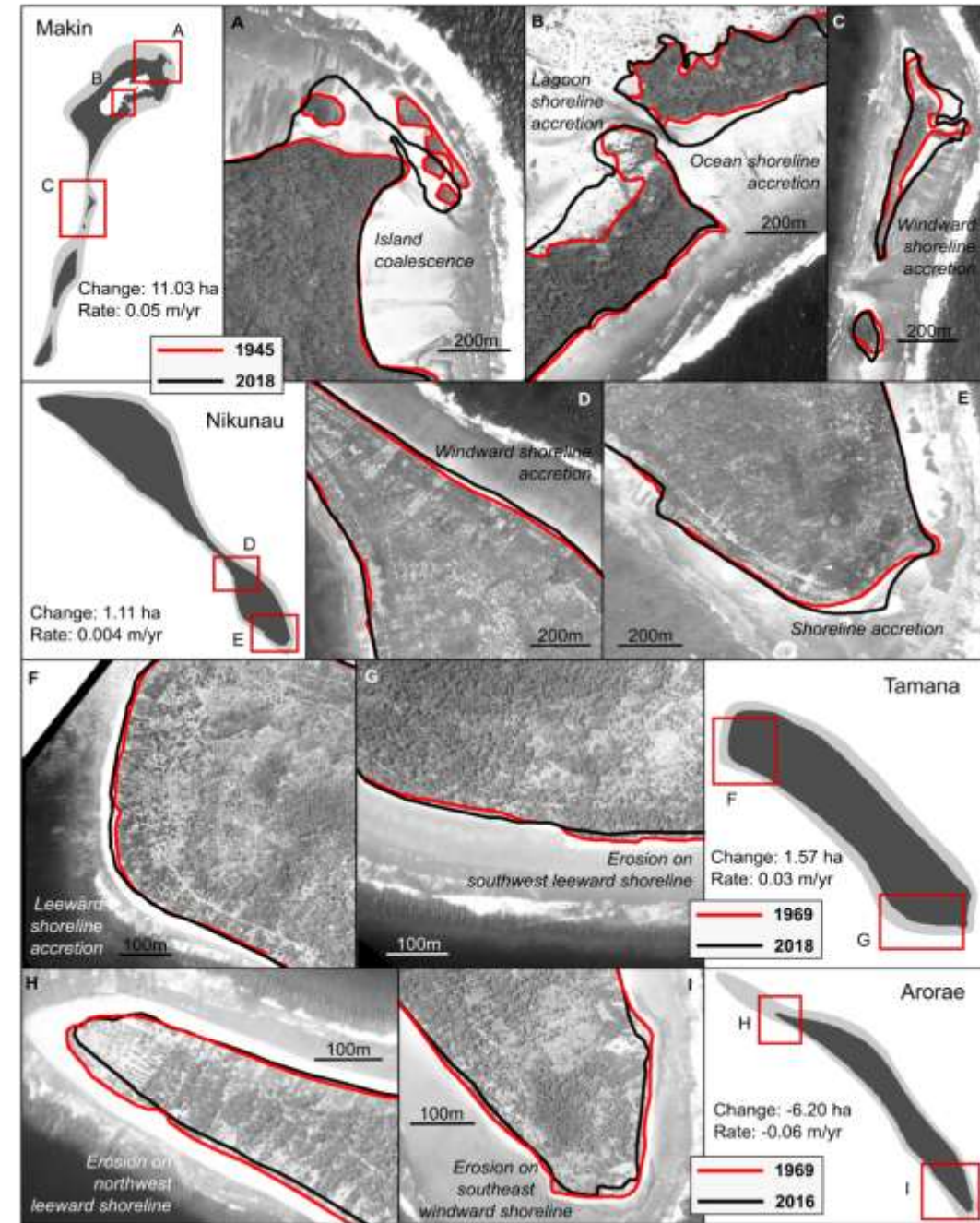
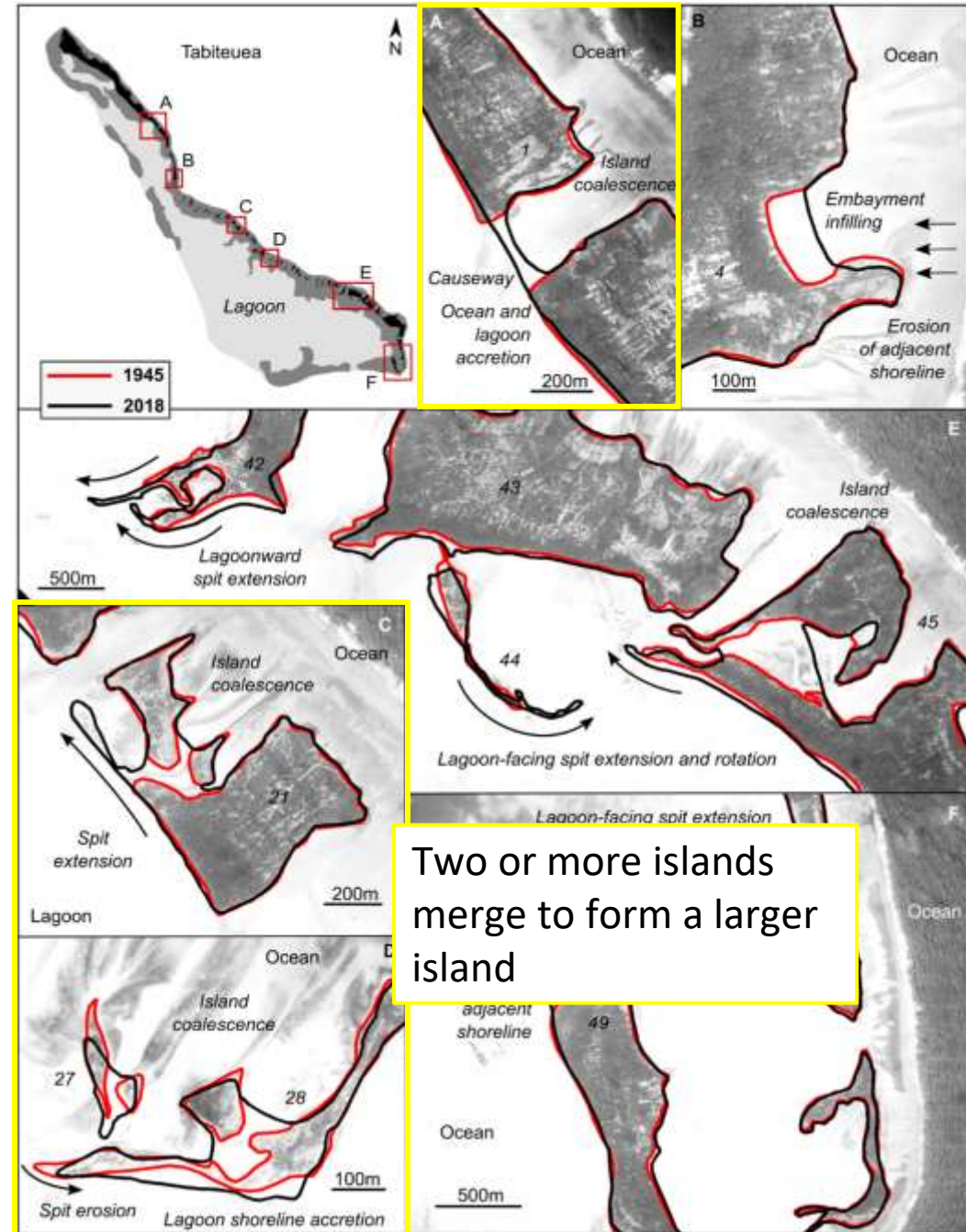
Atoll vs. platform islands

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.

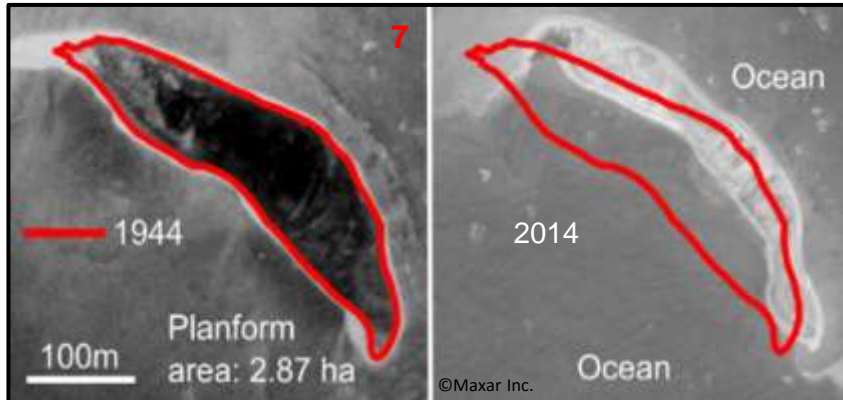
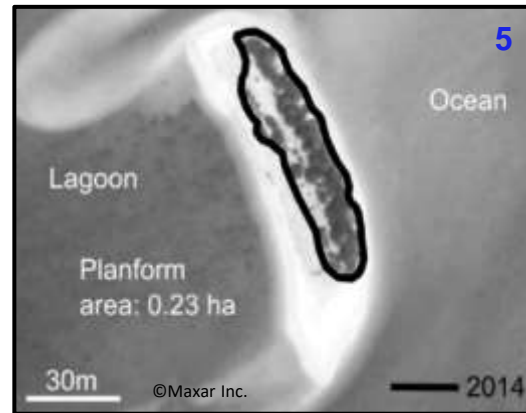
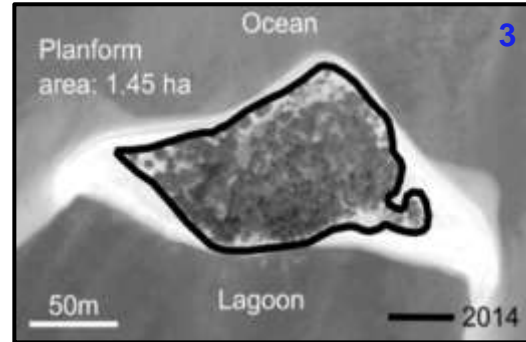
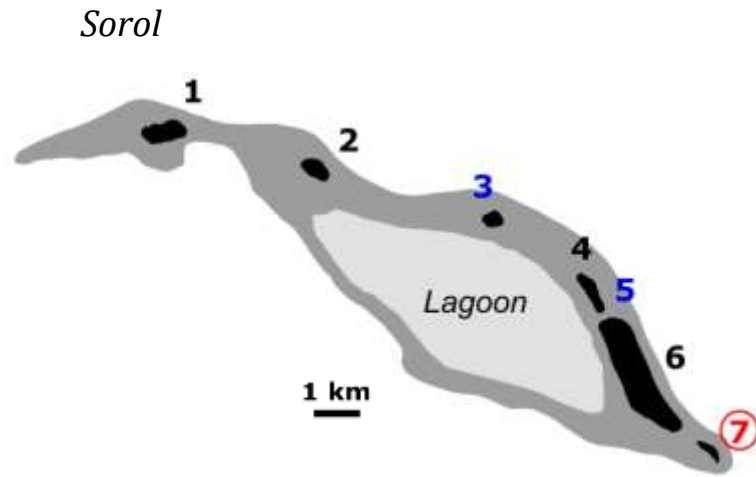
Results: Styles of changes on islands of the Gilbert Is., Kiribati: Central Pacific



Imagery: SPC Archives, Suva, Fiji

Sengupta et al (2021b)

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

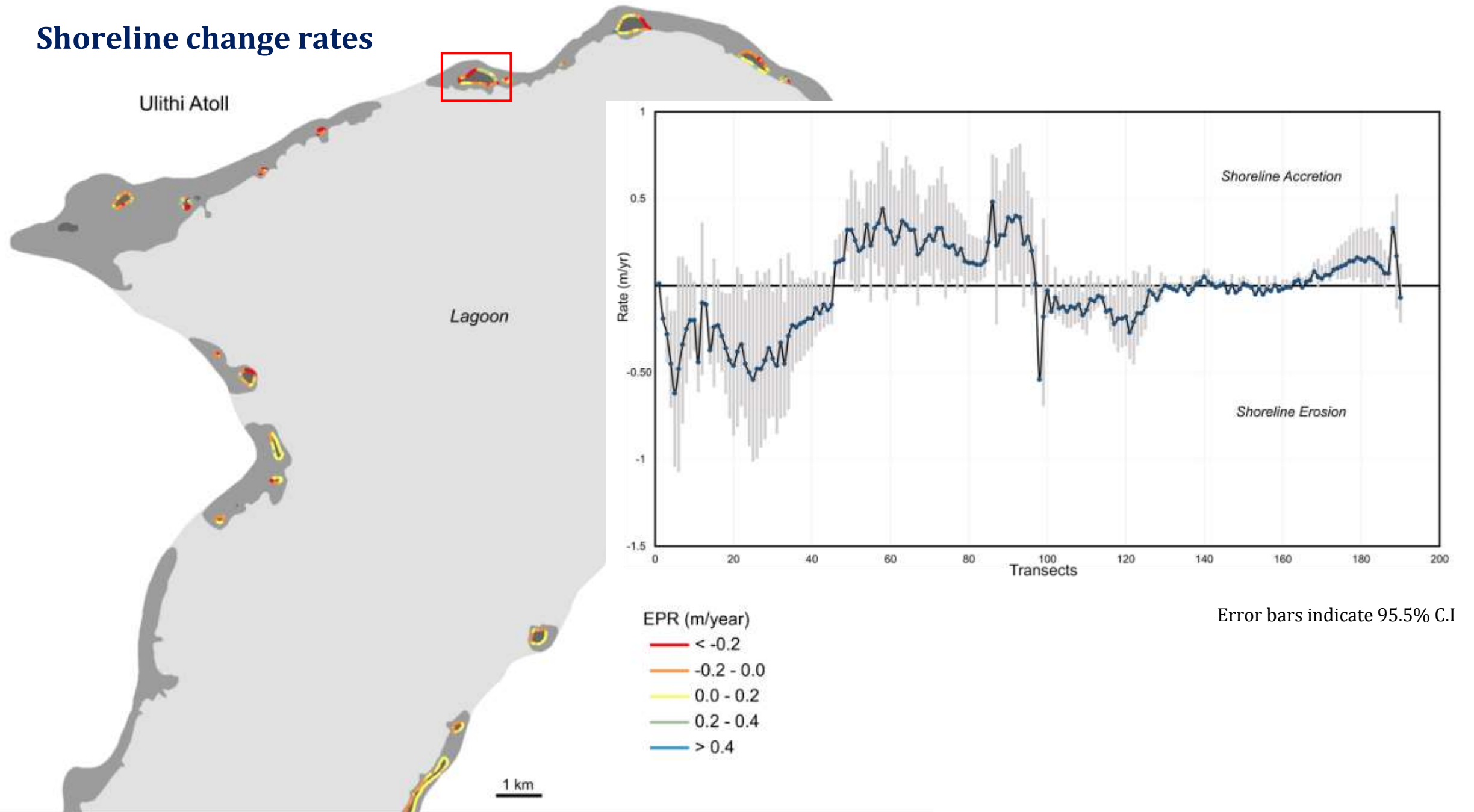


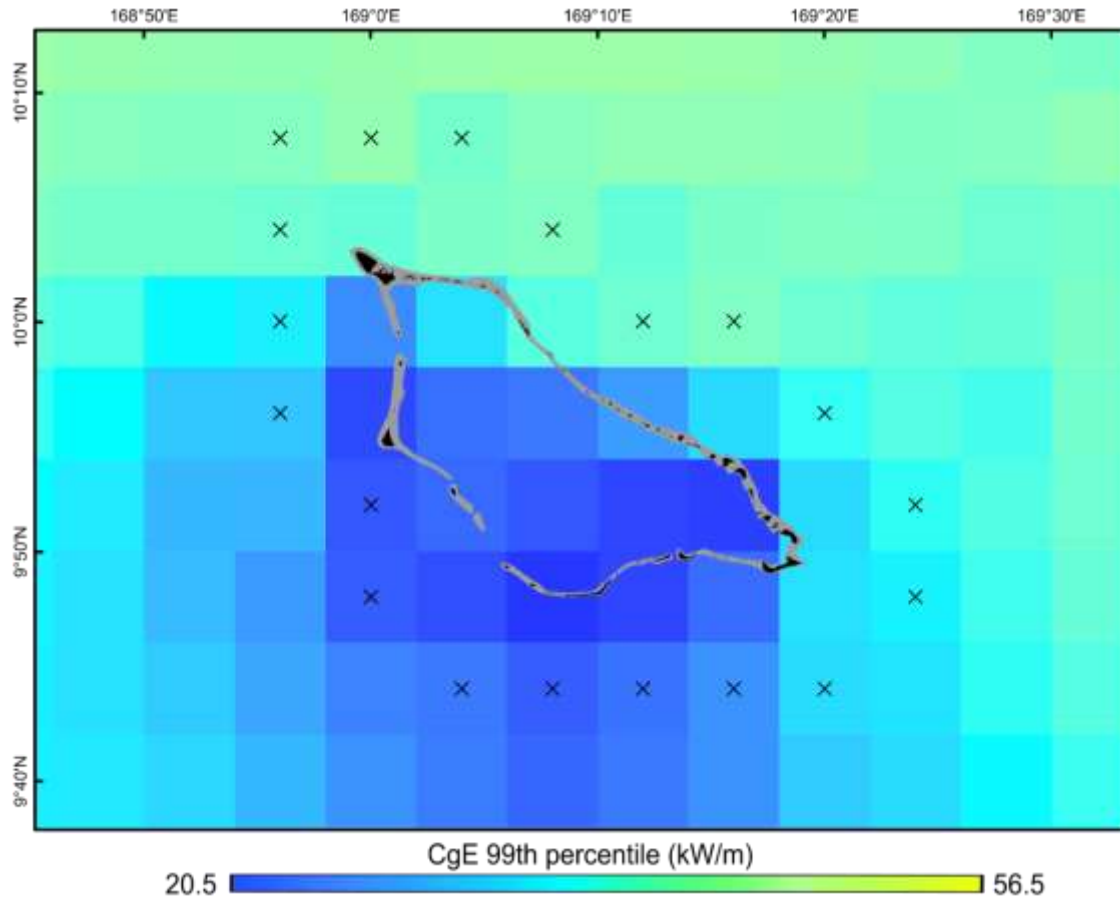
Within FSM, three new islands were formed while three islands disappeared

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





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)

Local / geomorphic controls:

Continuous:

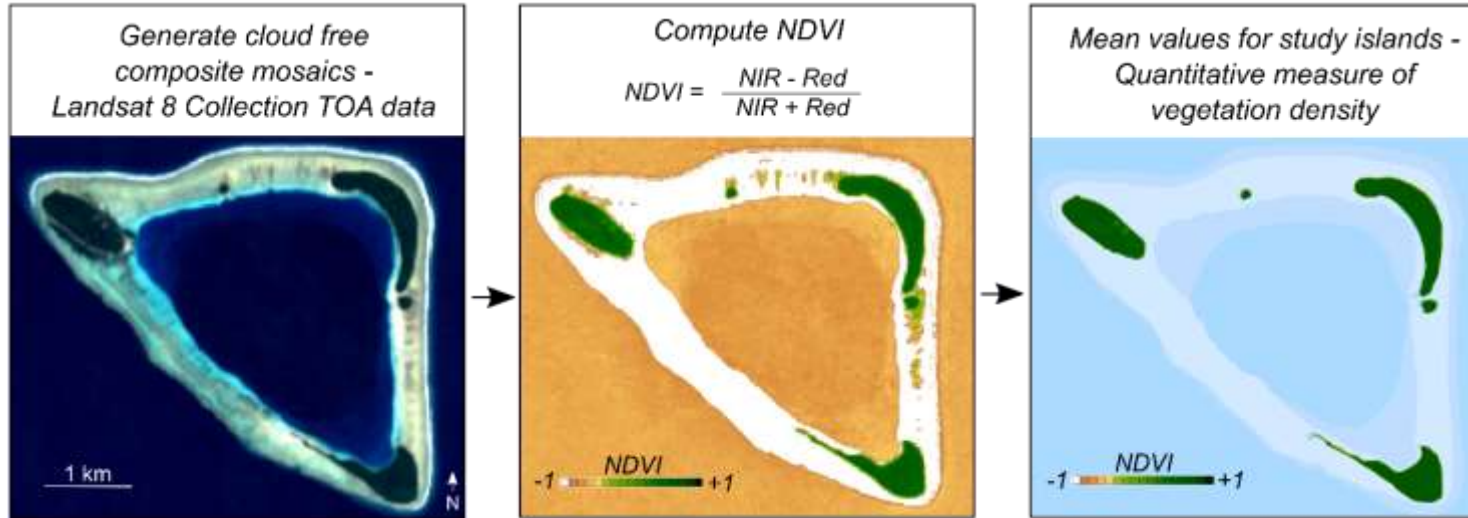
- Island size
- Reef width
- Circularity Ratio
- Ratio – island width to reef width
- Distance from reef edge
- Vegetation density

Categorical:

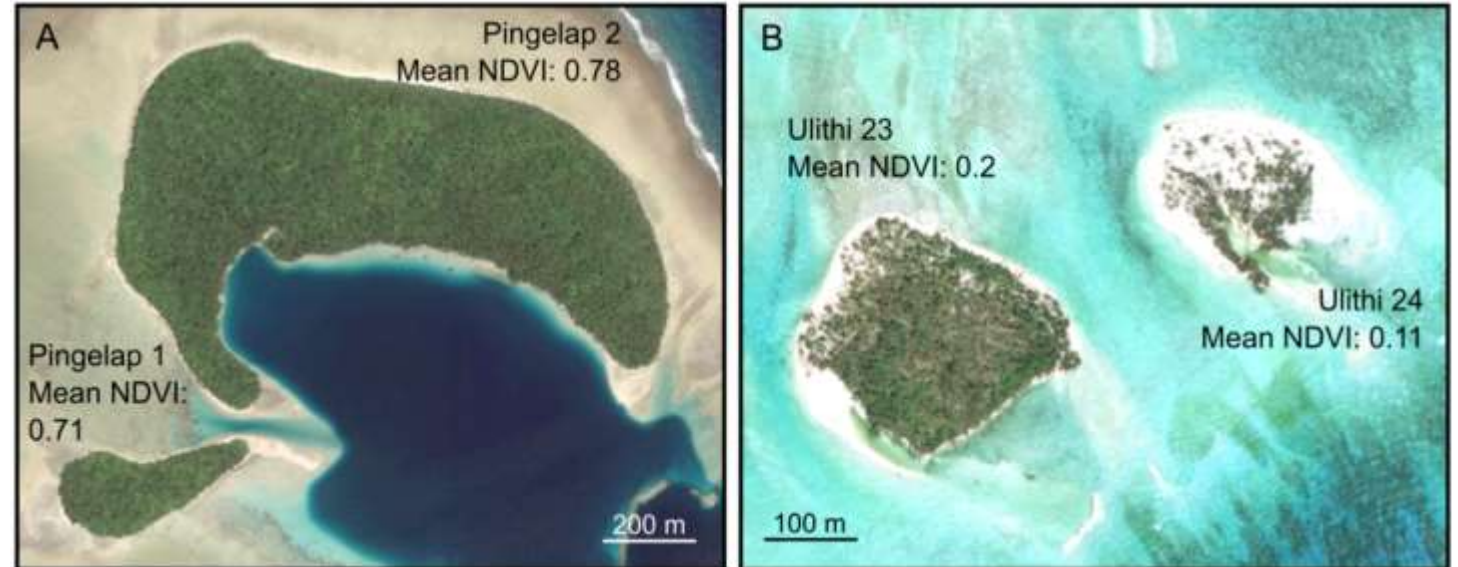
- Local position – windward/leeward
- Anthropogenic modification



Methods: Linking island change to potential drivers



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



Results: Linking island change to potential drivers using Machine Learning

Classification and Regression Tree Model

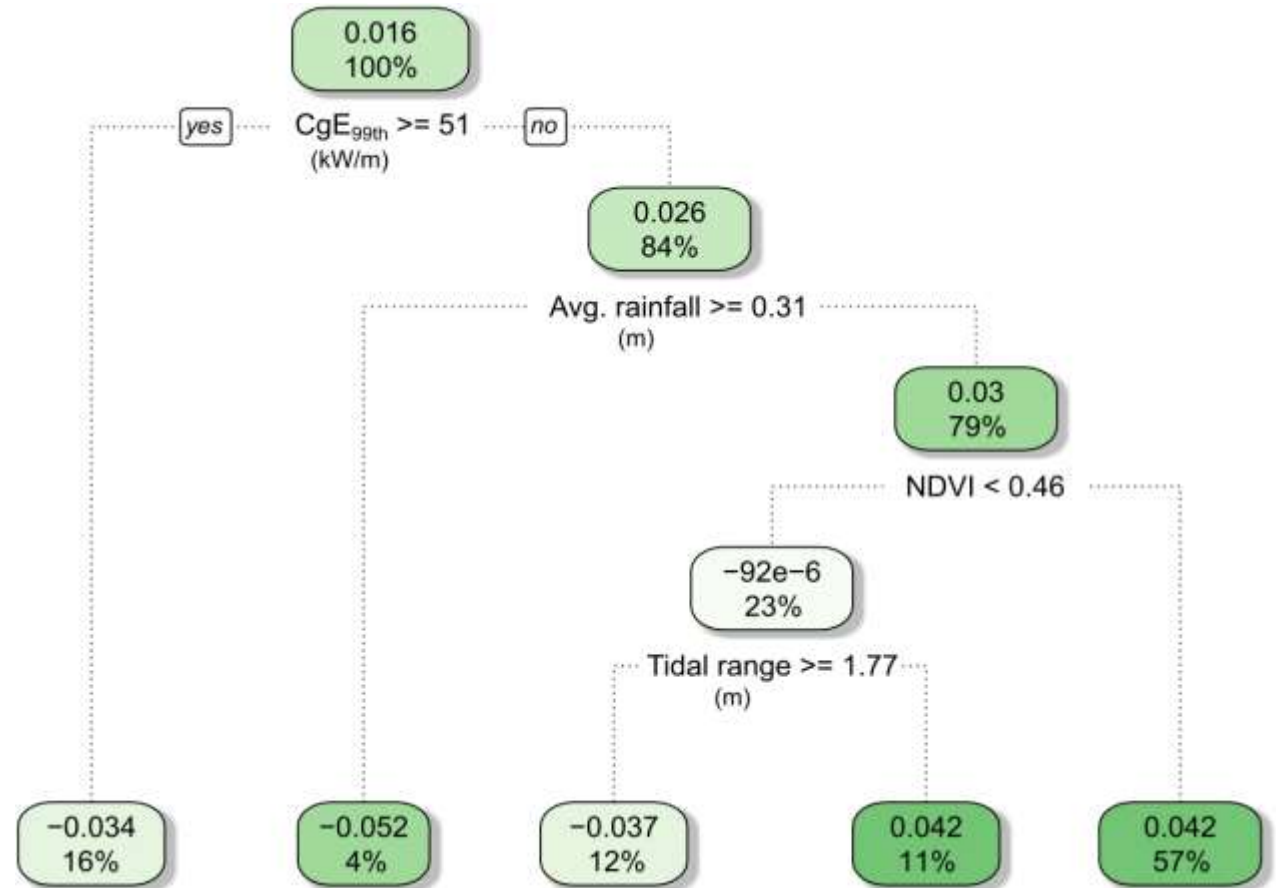
Tree based model based on 'binary recursive partitioning' – *heuristic model*

Dataset:

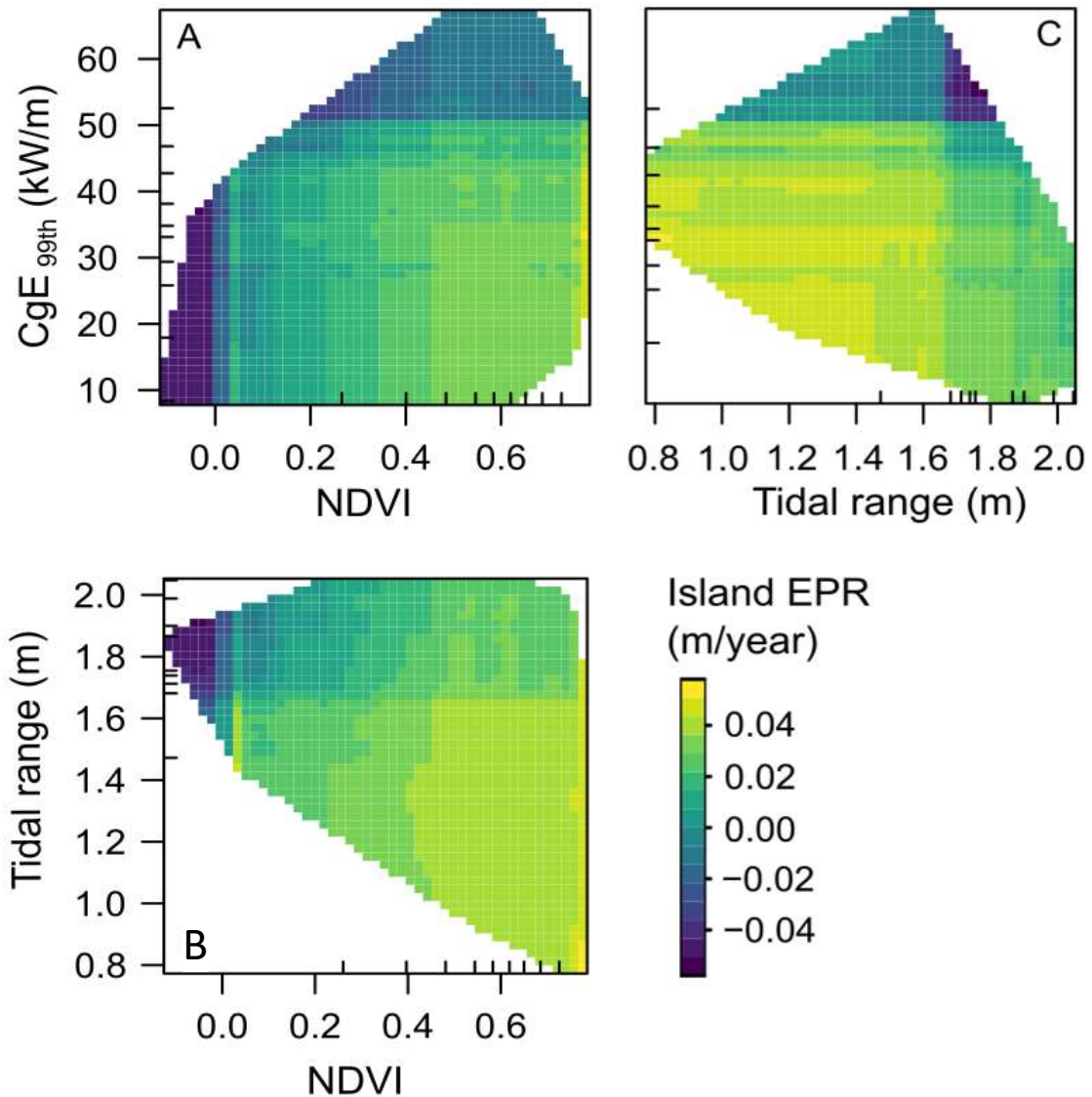
500+islands (100,000 + transects)
25 potential predictors

Response Variable:

Island average shoreline
change rate (m/year)



Results



*Investigating interactions
between identified key variables
from the Random Forest models*

Ongoing work:

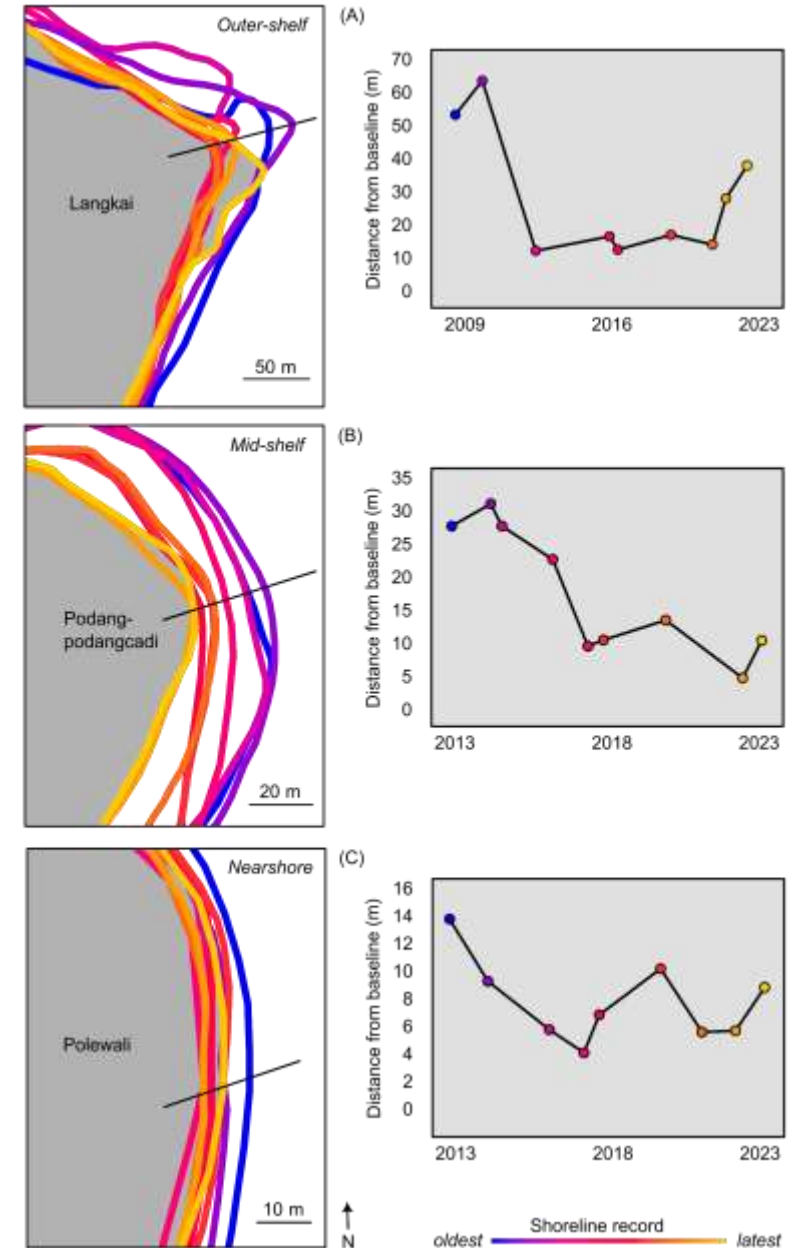
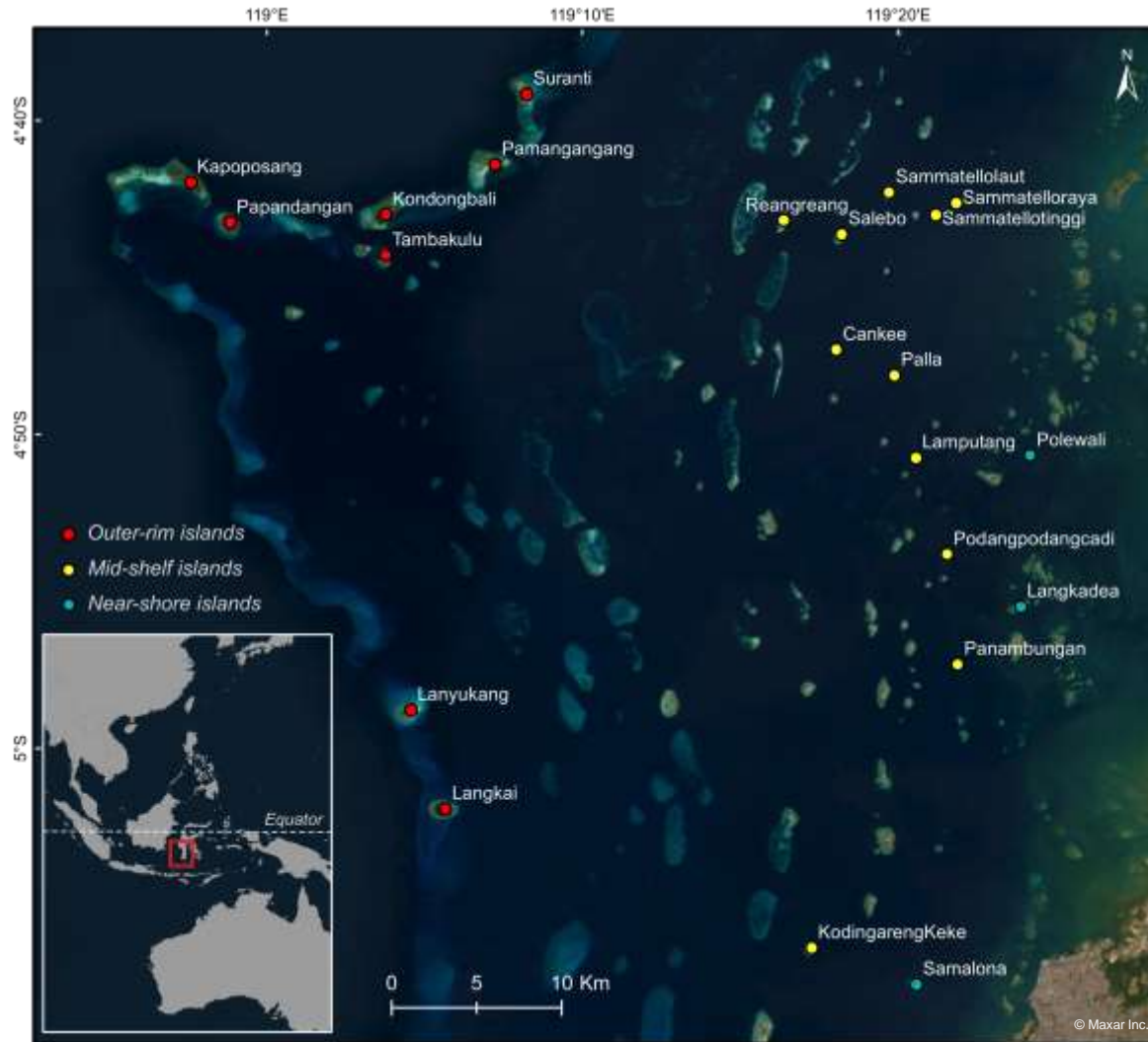
Generating a high-frequency dataset of shoreline change in the altimetry era (past two decades)

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

Results

Preliminary results from a 'climate change hotspot': Indonesia



An aerial photograph of a tropical coastline, showing a mix of green vegetation, white sandy beaches, and clear turquoise water. The image is overlaid with a dark, semi-transparent horizontal band across the middle, which contains the text. The overall scene is bright and clear, typical of a high-resolution satellite or drone shot.

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

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