



DRIVERS OF SHORELINE CHANGES IN THE NORTHERN TUAMOTU REEF ISLANDS, FRENCH POLYNESIA



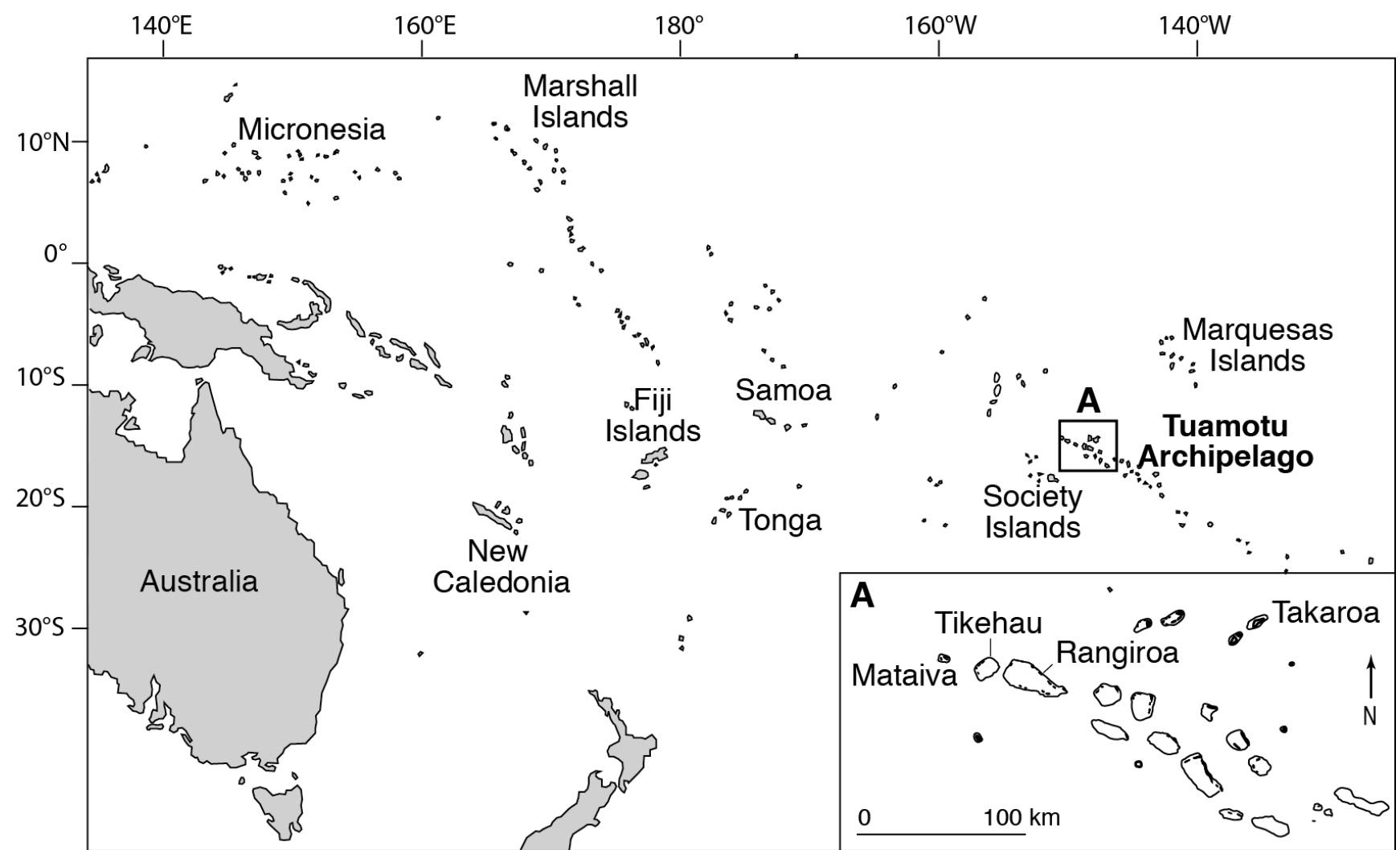
Virginie DUVAT, UMR LIENSs 7266, University of la Rochelle-CNRS, France

&

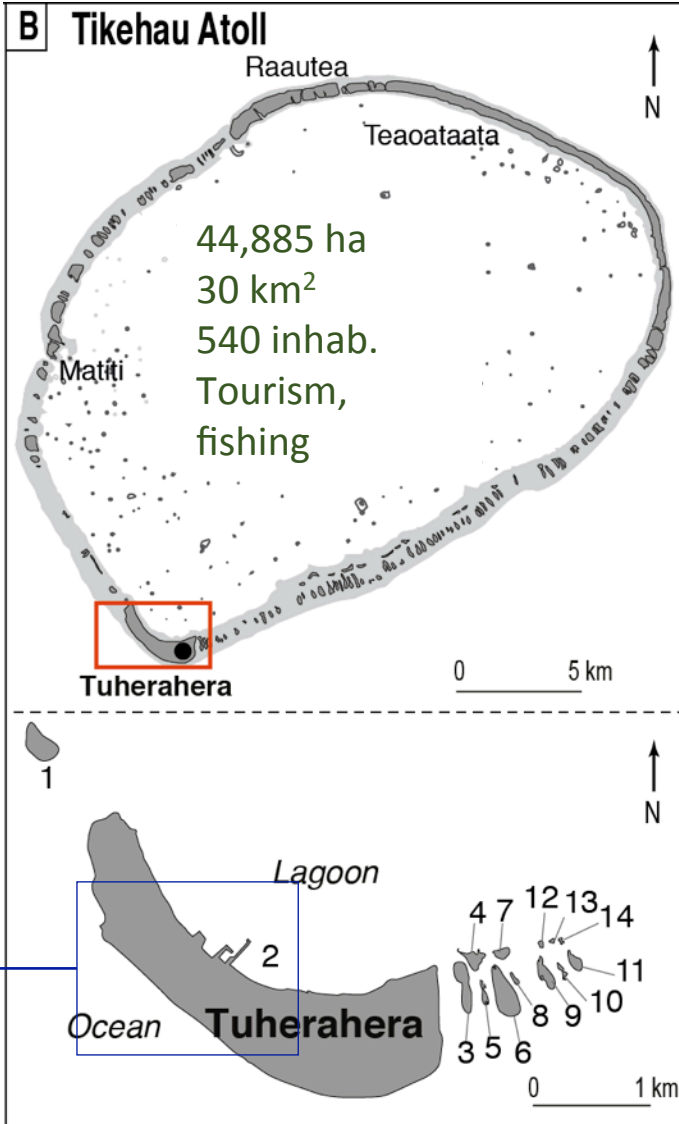
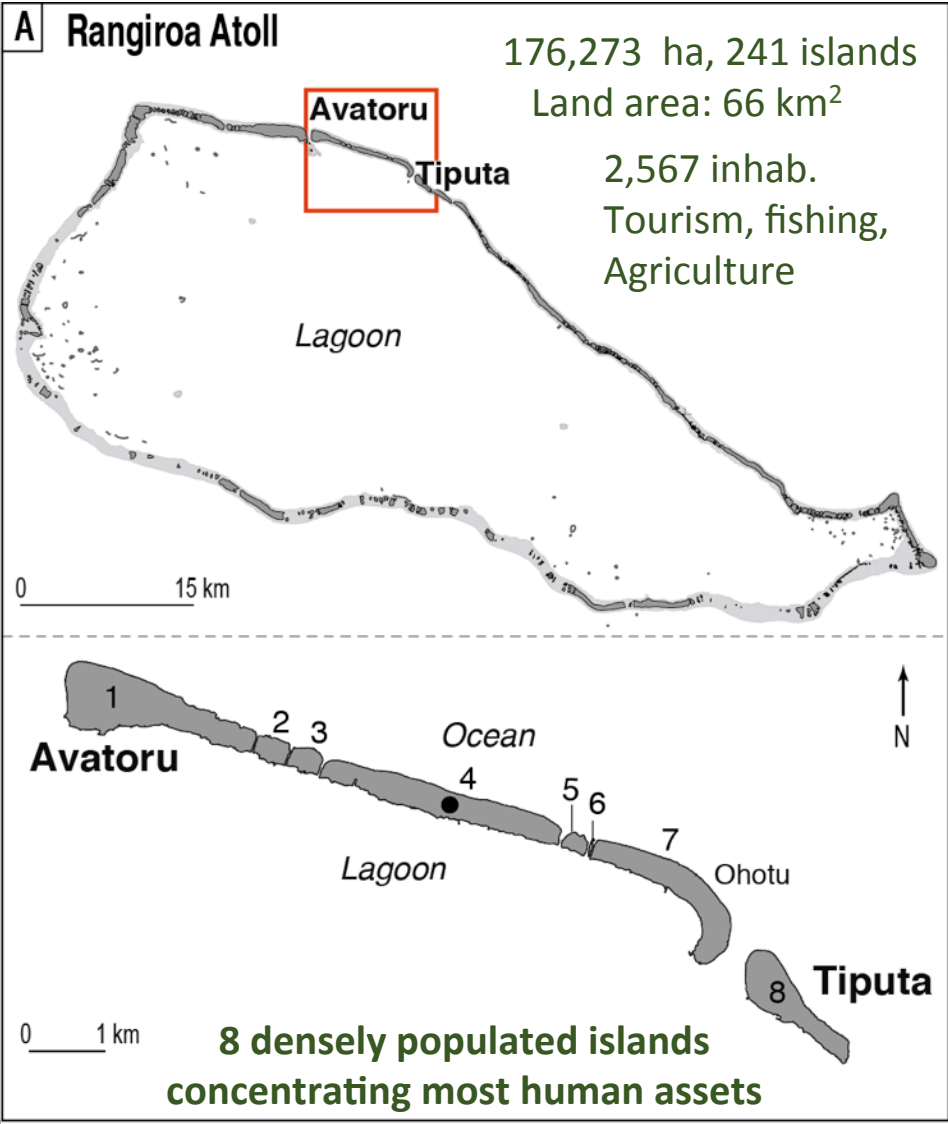
Bernard SALVAT, USR 3278, EPHE CNRS UPVD, Perpignan-Moorea, France



1. STUDY AREA

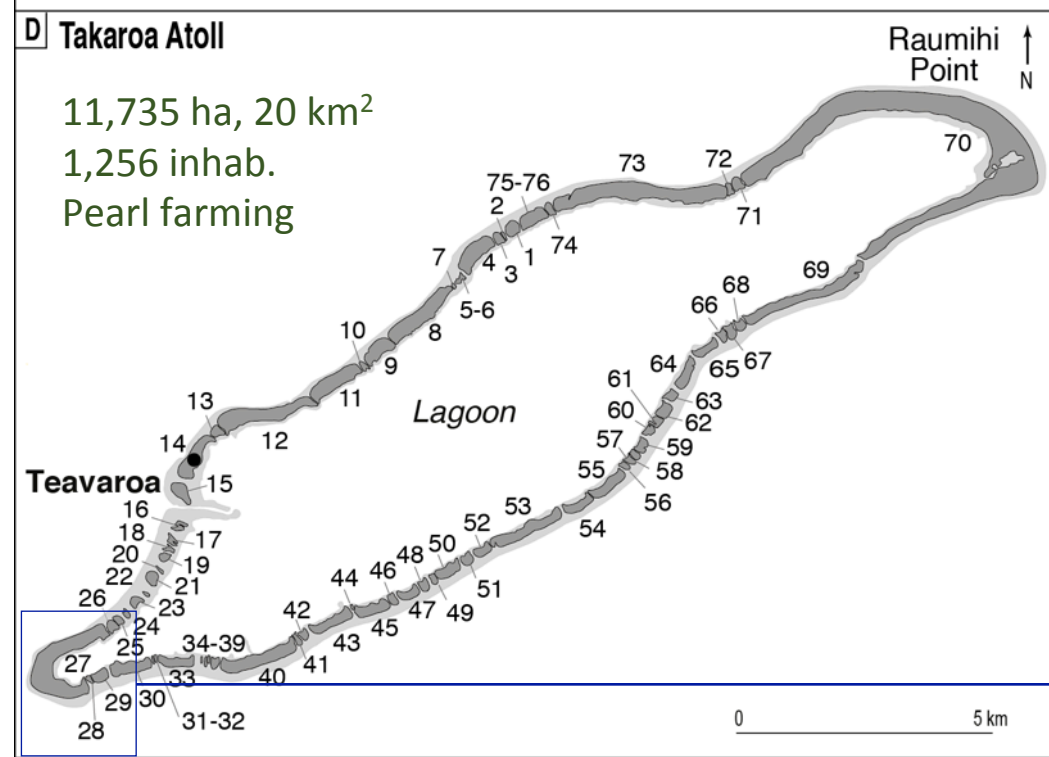
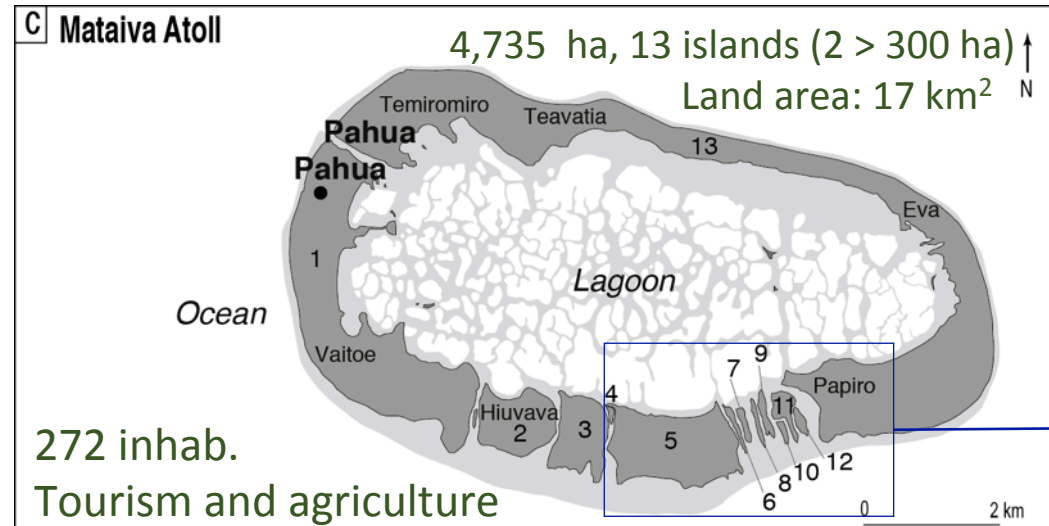


- 111 reef islands distributed among four atolls located between 14°51'S and 15°30'S
- Contrasting geomorphic (size, shape, structure) and human features (urbanised vs. uninhabited and unexploited islands)
- Including the islands concentrating human assets, i.e. major infrastructures, main villages and economic activities



**Main village (Tuherahera)
and nearby islets (14 islands)**

- Study area
- Reef flat and shallow lagoon
- Reef Islands
- Tiputa** Main village
- Airstrip
- 6 Island number

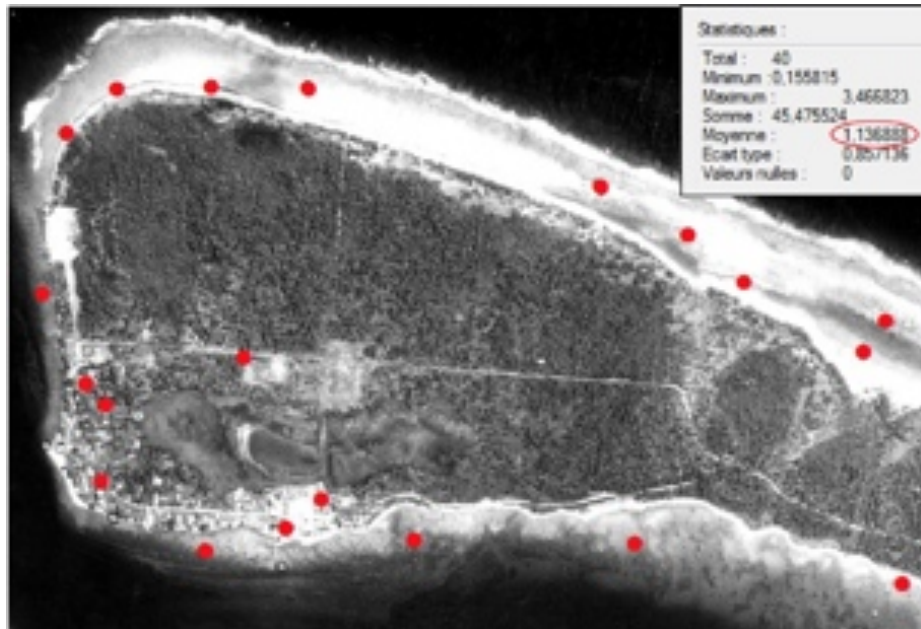


- Reef flat and shallow lagoon
- Reef Islands
- Tiputa** Main village
- Airstrip
- 6 Island number

2. MATERIAL AND METHODS

➤ Aerial imagery (33- to 52-y time period)

1. Georeferencing of aerial photographs, using ground control points extracted from the 2013/2014 high-resolution satellite images (RMS error: 0,26-1,72 m)

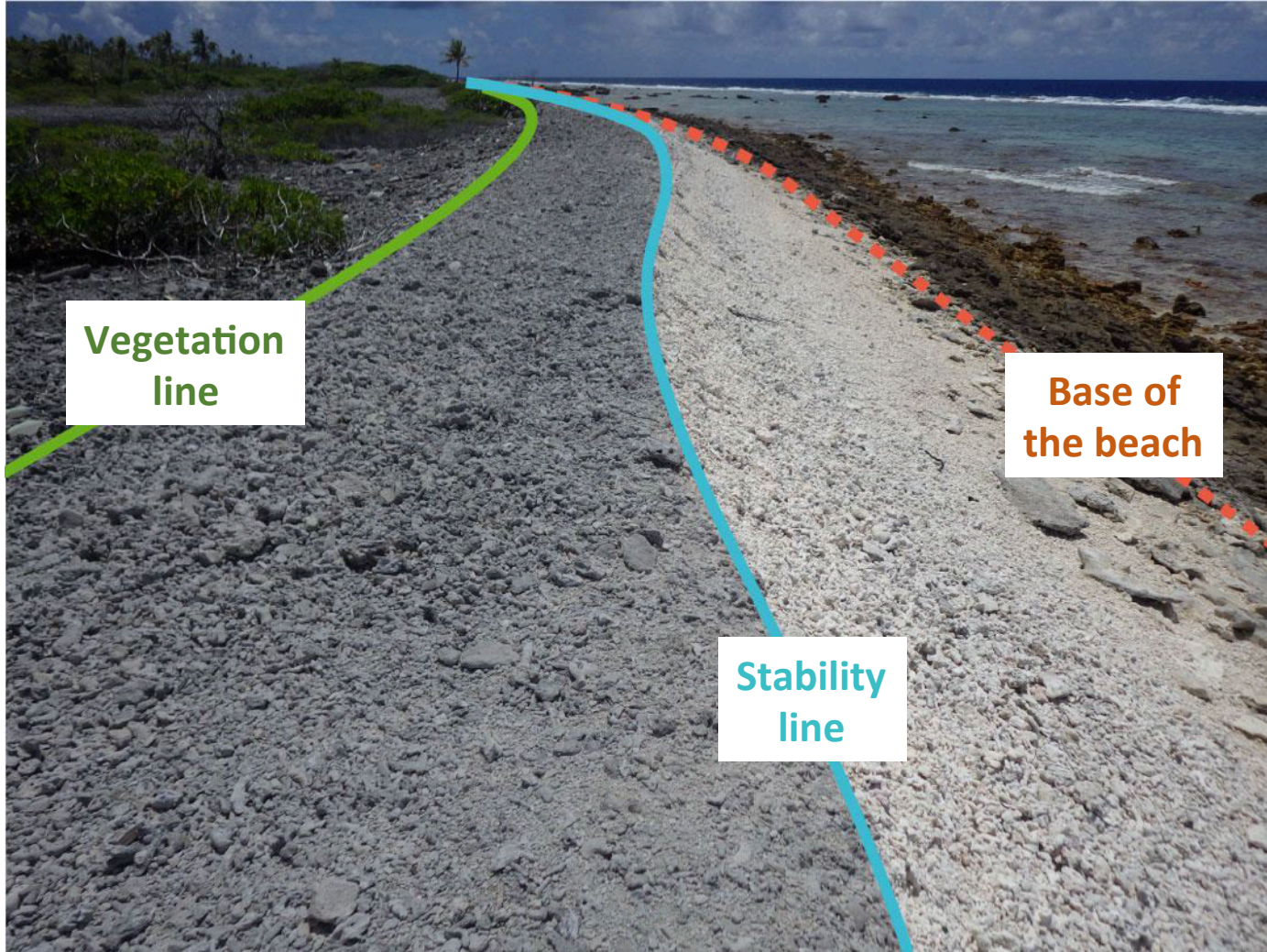


Atoll	Date	Image type	Scale
Rangiroa	17-18/10/1966	B/W aerial	1: 10,000
	20/10/1981	B/W aerial	1:15,000
	27/03/1984	B/W aerial	1:15,000
	26/09/1998	Color aerial	1:15,000
	01/10/2013	Pleiades SI	
Tikehau	1962	B/W aerial	1:10,000
	20/10/1981	B/W aerial	1:5,000
	27/03/1984	B/W aerial	1:15,000
	26/09/1998	Color aerial	1:15,000
	22/08/2014	Pleiades SI	/
Mataiva	04/02/1976	B/W aerial	1:5,000
	04/02/1976	B/W aerial	1:10,000
	27/03/1984	B/W aerial	1:15,000
	13/11/1994	Color aerial	1:15,000
	01/11/2013	Pleiades SI	/
Takaroa	08/03/1969	B/W aerial	1:20,000
	21/10/1981	B/W aerial	1:25,000
	21/10/1981	B/W aerial	1:8,000
	22/10/1984	B/W aerial	1:30,000
	01/03/1995	Color aerial	1:15,000
	01/03/1995	Color aerial	1:4,000
	01/10/2013	Pleiades SI	/

B/W photographs: Topographic Section of the Town Planning Division of the Government of French Polynesia; Pléiades satellite imagery 2013 and 2014 from the French National Centre for Spatial Studies (CNES)

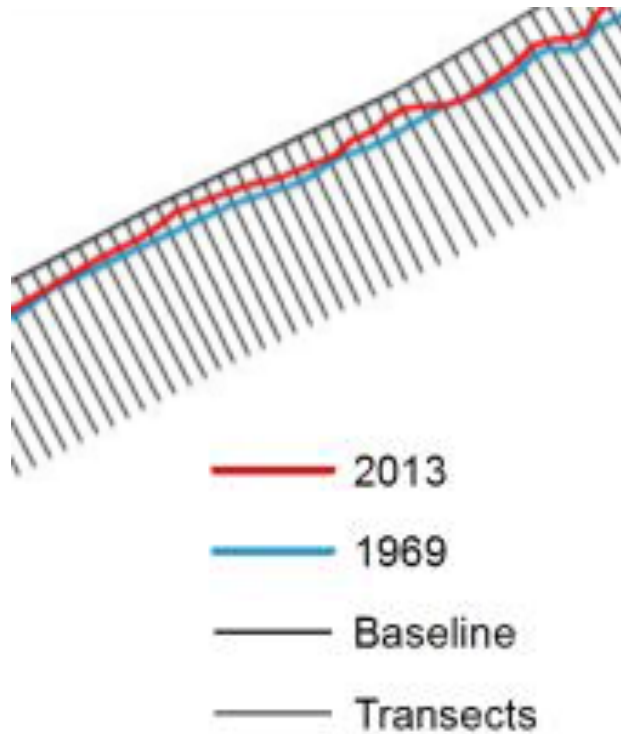
2. Digitization of the “stability line” (SL) + base of the beach (BB)

SL: seaward edge of the vegetation or of the stabilised beach ridge in non-vegetated areas along natural coastline; seaward edge of human-built structures along modified coastline



3. Total shoreline position error (image resolution + georeferencing + shoreline digitization): **<4 m**
(**±4 m = stable**)

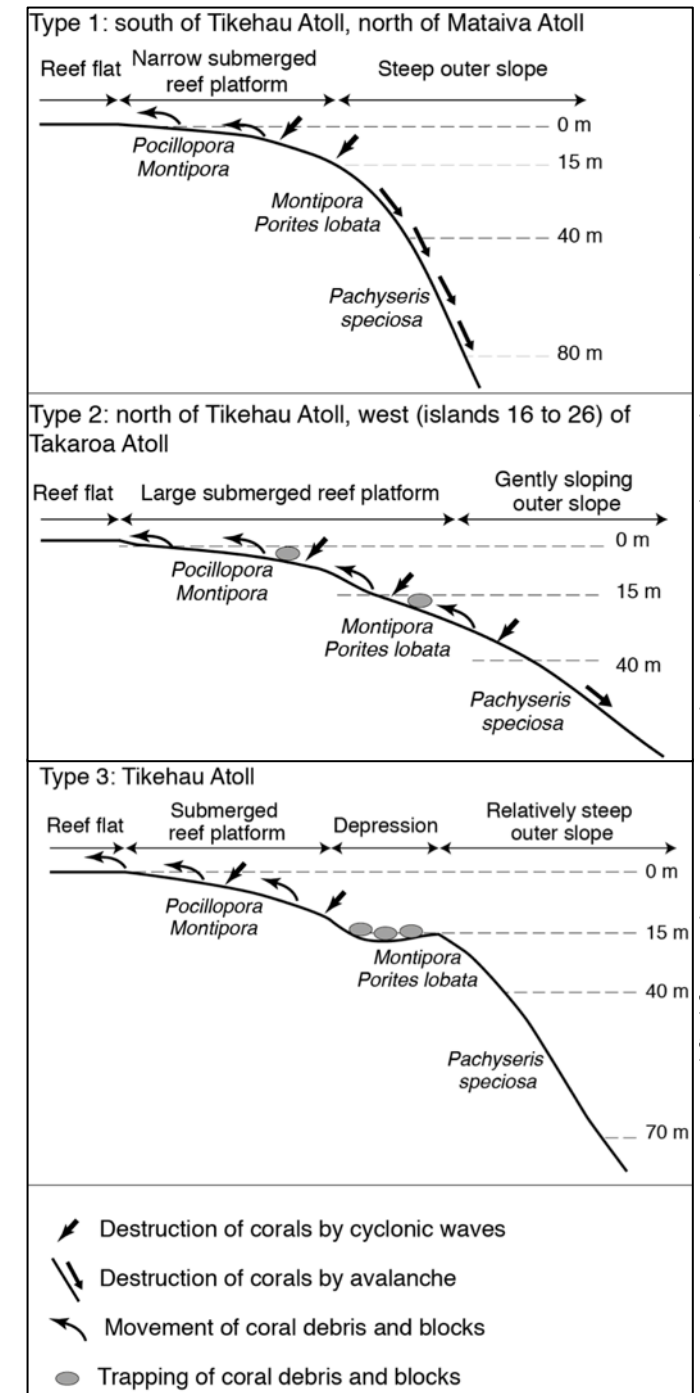
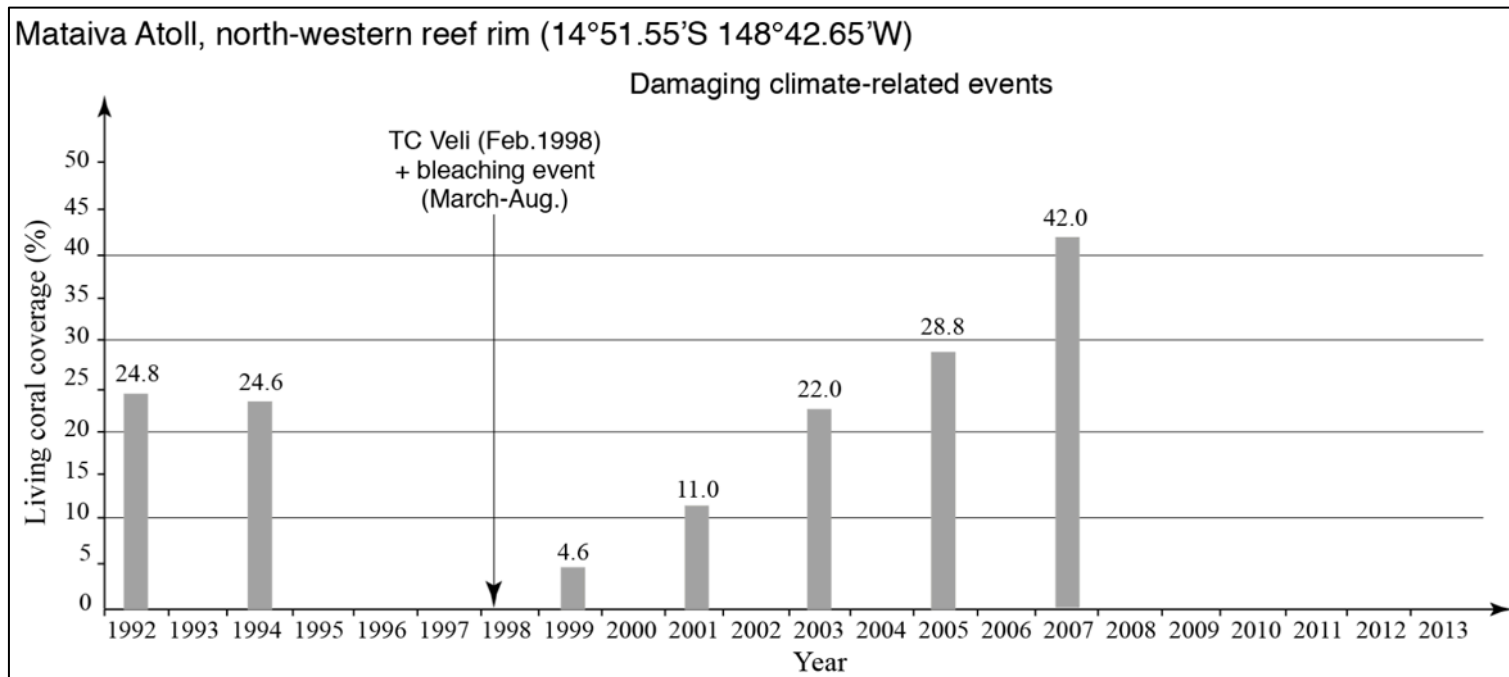
4. Generation of shoreline change statistics using DSAS extension (NSM + EPR)



➤ Coral reef data collected since the beginning of the 1980s

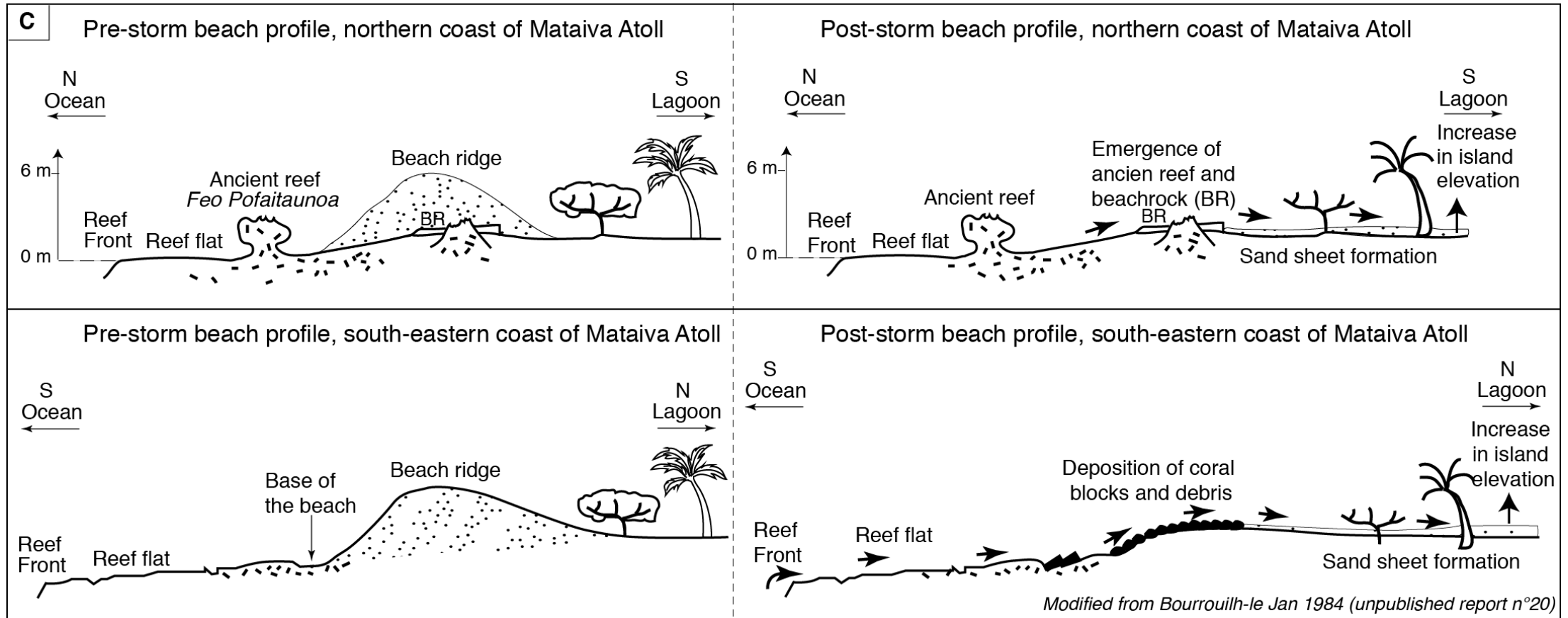
1. Detailed descriptions of the impacts of the 1983 TCs on the reef outer slopes (% of coral destruction, processes at work), based on the comparison of pre- and post-cyclone data

2. Coral reef monitoring data collected since the establishment of permanent stations in the early 1990s

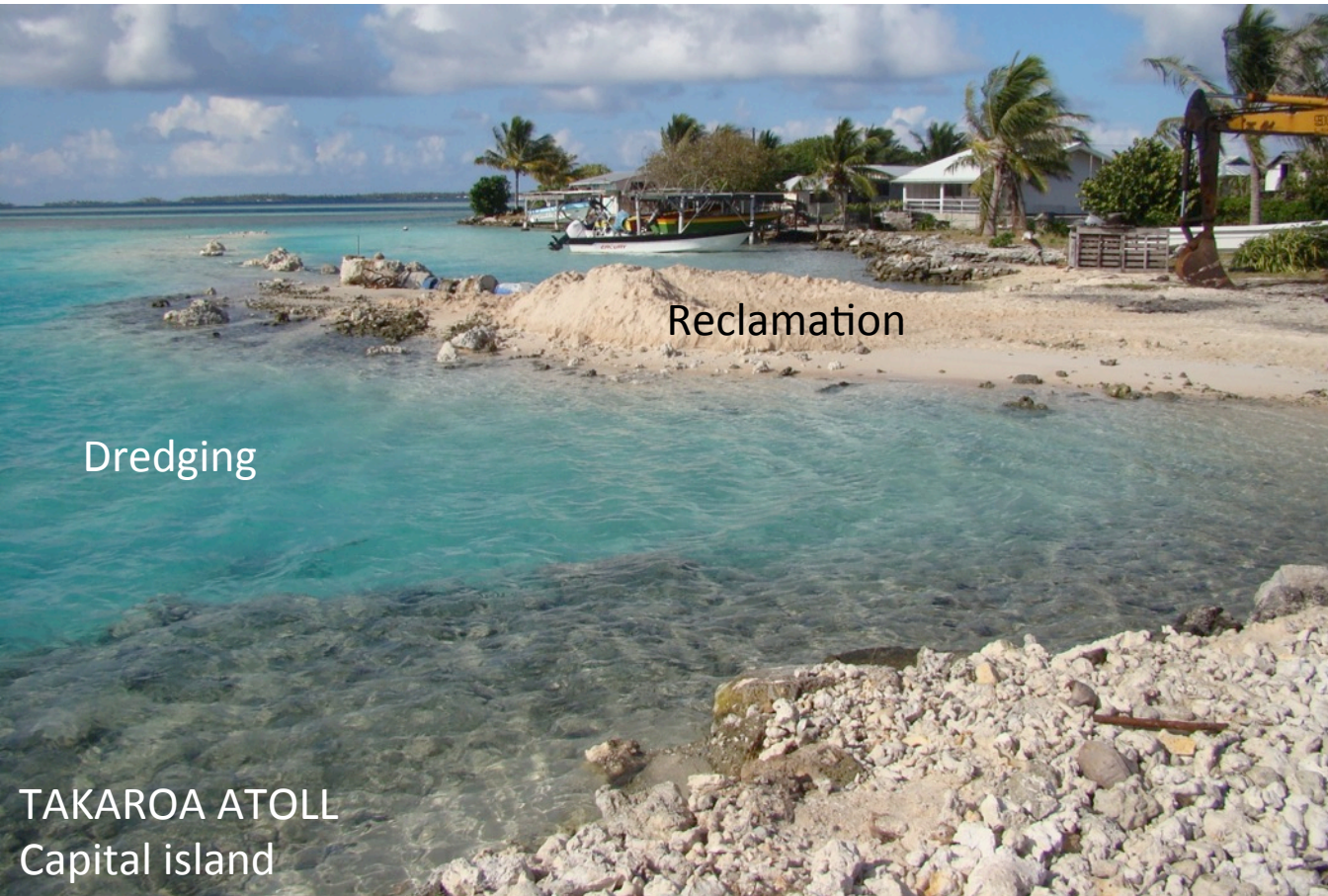


Modified from Laboute 1985, Harmelin-Vivien 1985, and Harmelin-Vivien and Laboute 1986

➤ Information on the impacts of the 1983 TCs on shoreline position and island morphology

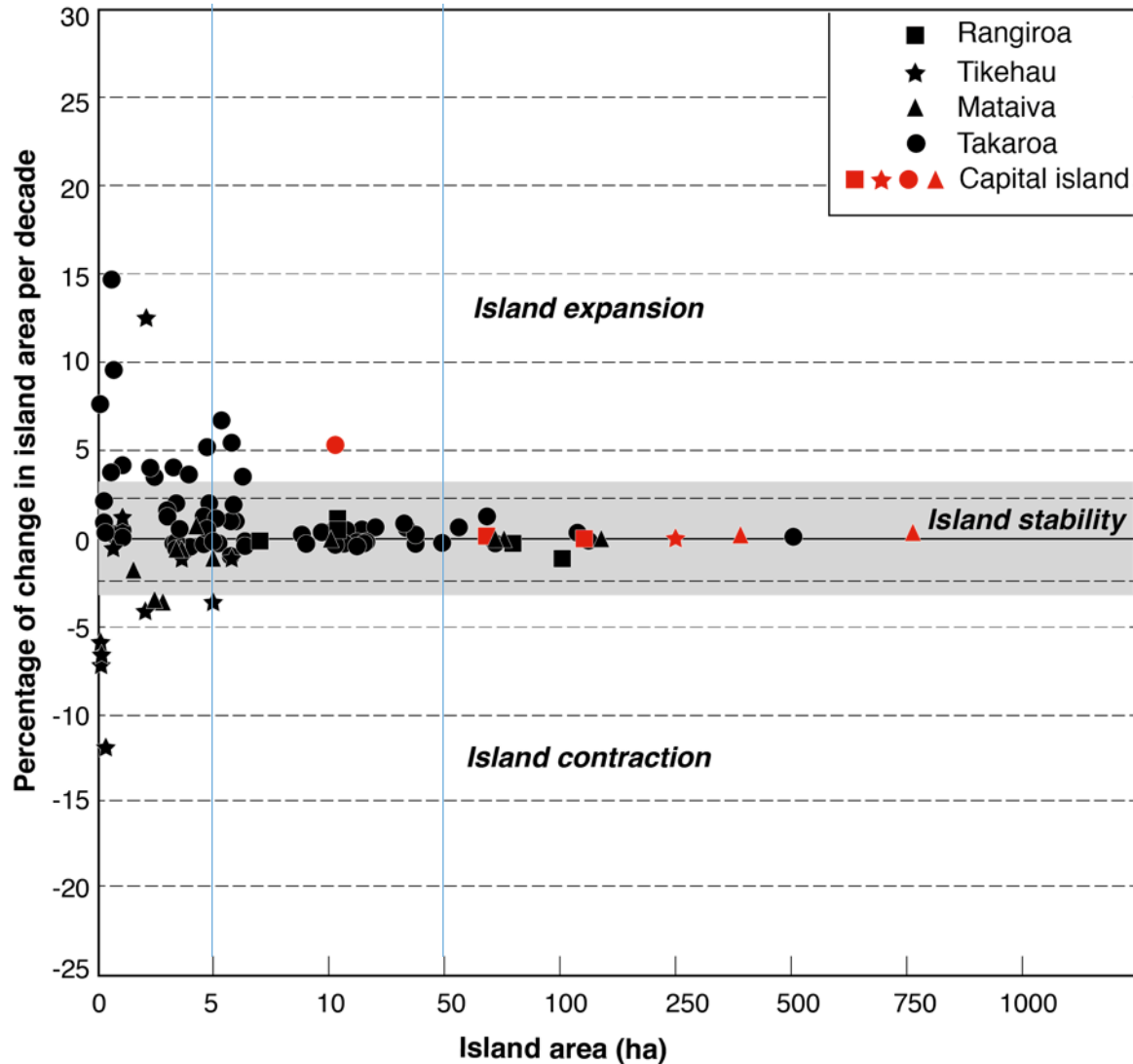


- **Generation of data on human pressures** (coastal developments, engineered structures, mining, dredging in reef flats, etc.), **based on image analysis and fieldwork**



3. RESULTS

CHANGES IN ATOLL AND REEF ISLAND LAND AREA



- No significant change in the total net land area of the study atolls (-1.12 to +1.66%)
- 78 (77 %) islands exhibited no significant change in area, while 15 islands (15 %) increased and 8 islands (8 %) decreased in size
- The smallest islands recorded the highest rates of change ($\pm 14.64\%$ per decade)
- 7 out of the 8 islands that decreased in area are very small (<3 ha); and the islets that disappeared were tiny (<0.6 ha)
- All of the islands (16) larger than 50 ha were stable in area, including 5 capital islands out of 6



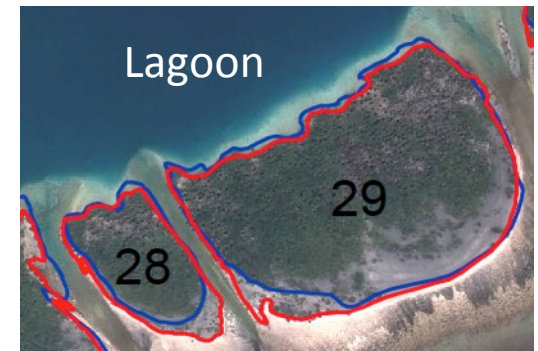
Reef islands are robust landforms

CHANGES IN SHORELINE AND ISLAND POSITION

- **Ocean shorelines are more dynamic than lagoon shorelines:** 33 islands (31 %) showed changes in ocean shoreline position – 19 advance/14 retreat- vs. 11 islands (10%) showed changes in lagoon shoreline position – 5 advance/6 retreat
- **90 islands (85 %) were stable in position while 16 islands (15 %) migrated**
- **Migrating islands:** 10 islands <5 ha; 3 islands are 5<x<10 ha; 3 islands are 15.7<x<36.2 ha. **The largest islands (>60 ha) are the most stable in position**
- **Lagoonward migration:** 5 islands out of 6 are located on the southern and south-eastern margins of Tikehau, Mataiva and Takaroa atolls, suggesting that the trade winds contribute to island migration
- **Oceanward migration:** 9 islands out of 10 are located on the south-western side of Takaroa Atoll



Lagoonward migration
SE Takaroa Atoll

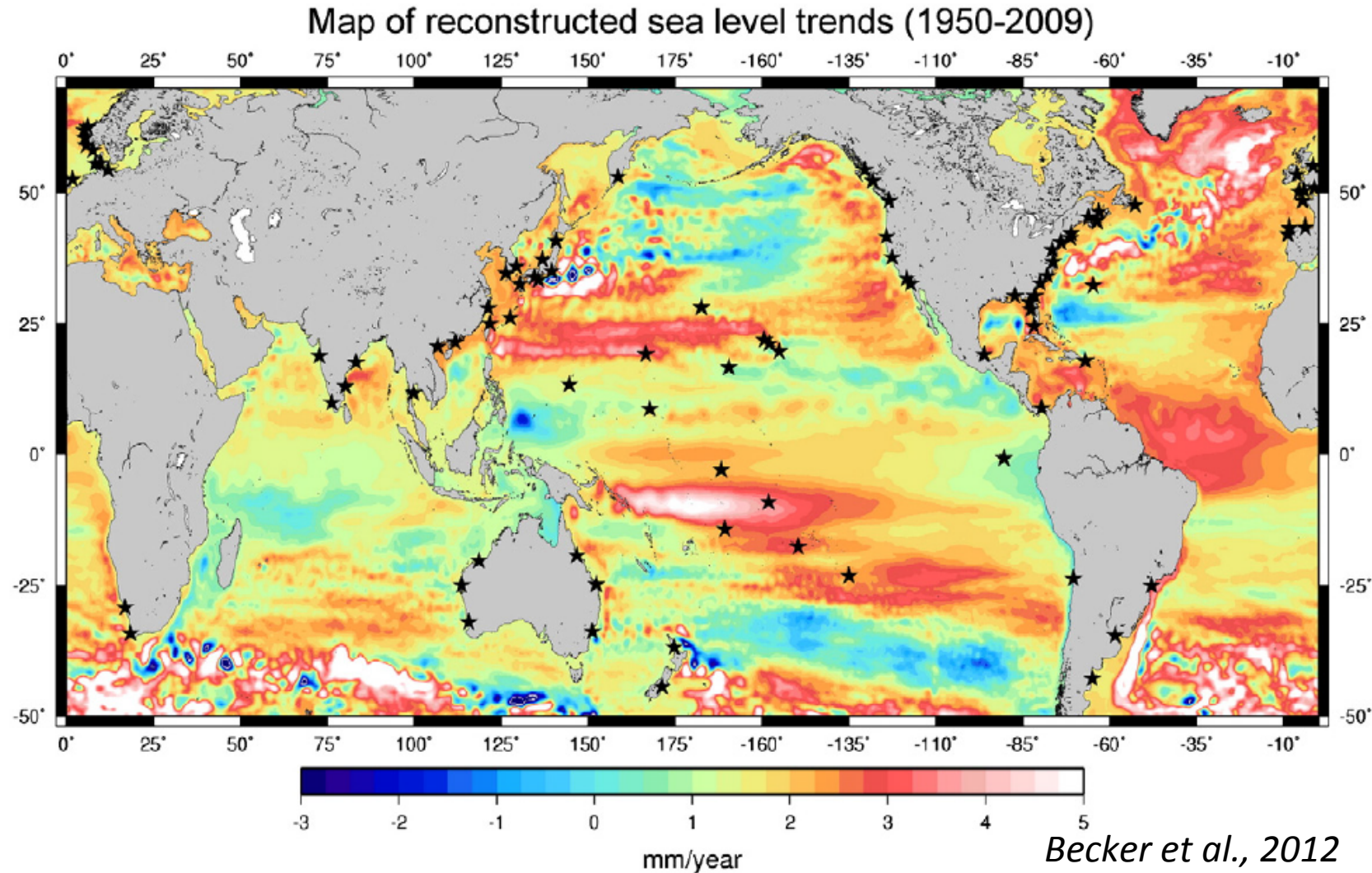


Oceanward migration
SW Takaroa Atoll

➡ **Most reef islands are stable in position**

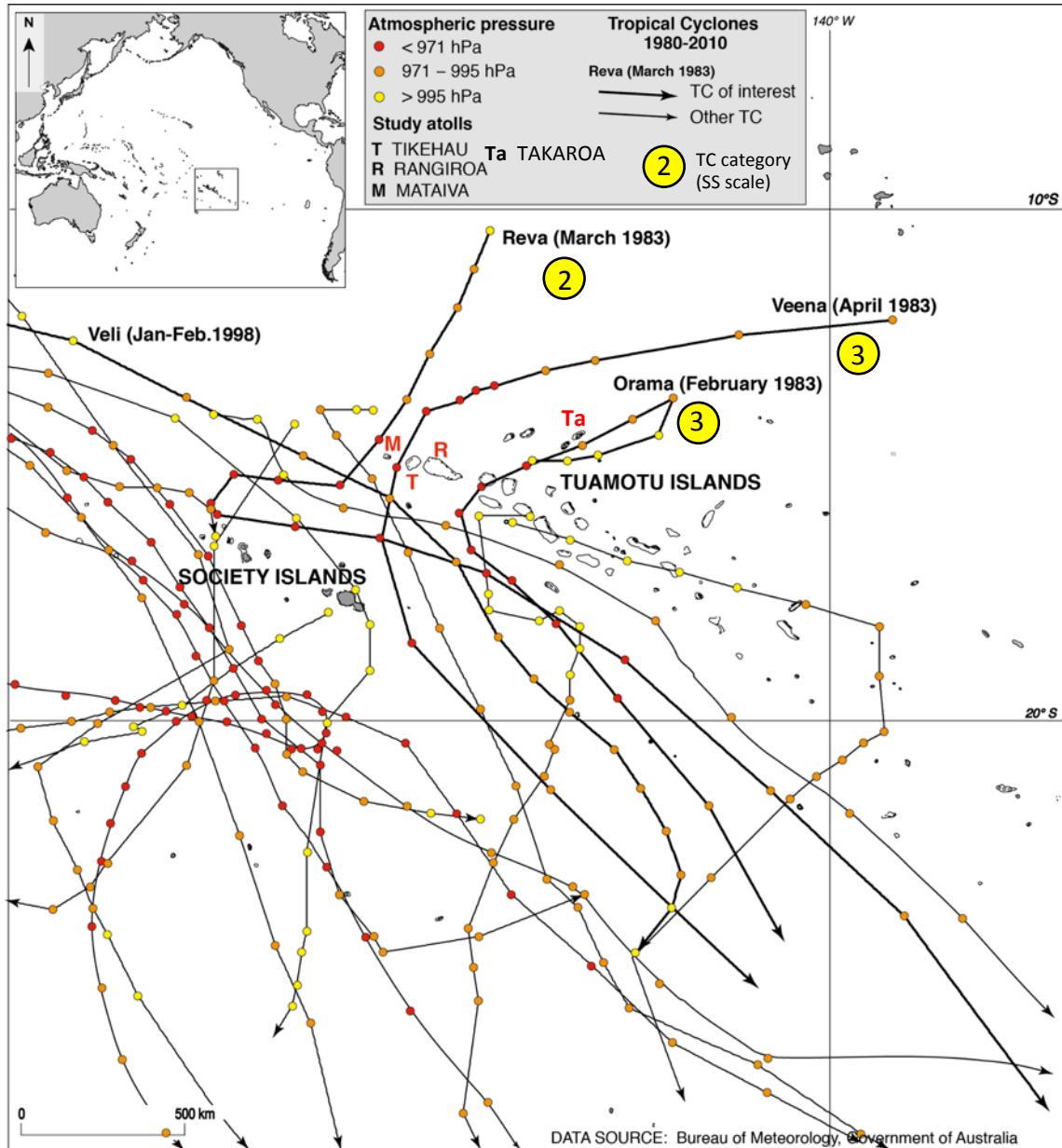
DRIVERS OF SHORELINE CHANGE

- Sea-level rise
- Storms: TCs + distant source swells
- Coral reefs
- Human disturbances

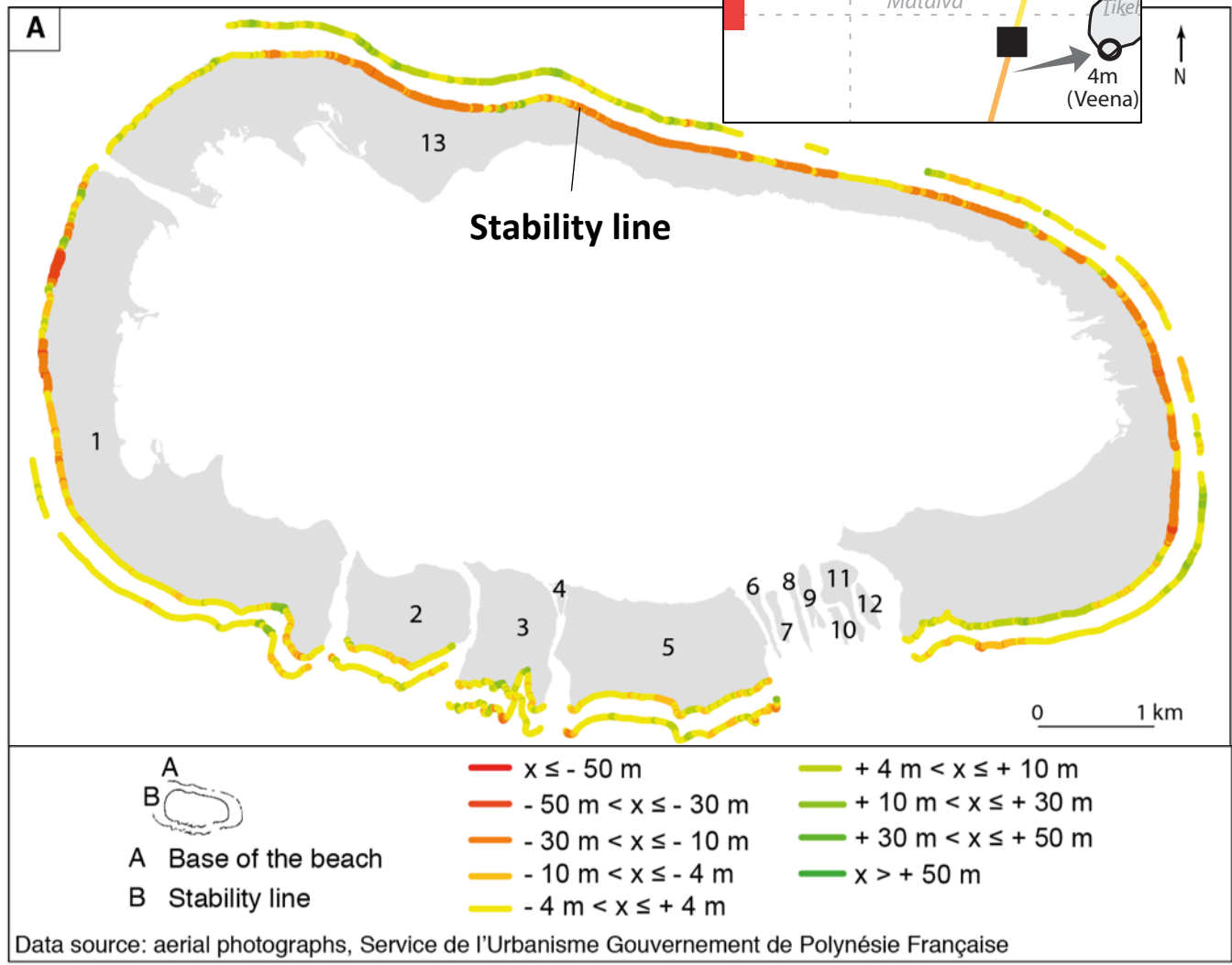


Northern Tuamotu: 2.5 ± 0.5 mm > Majuro, Tarawa, but < Funafuti

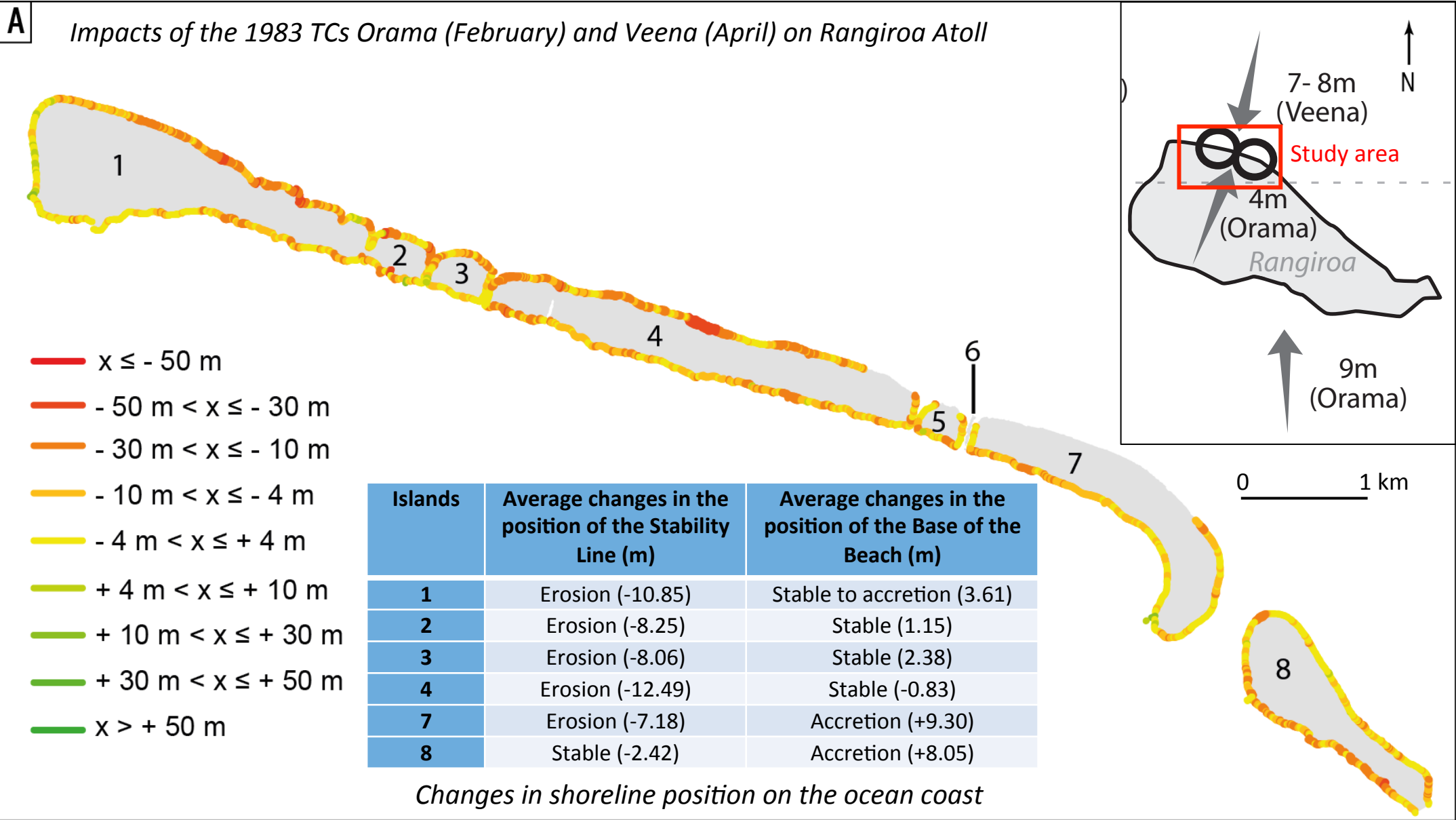
1983 TCs



STABILITY LINE

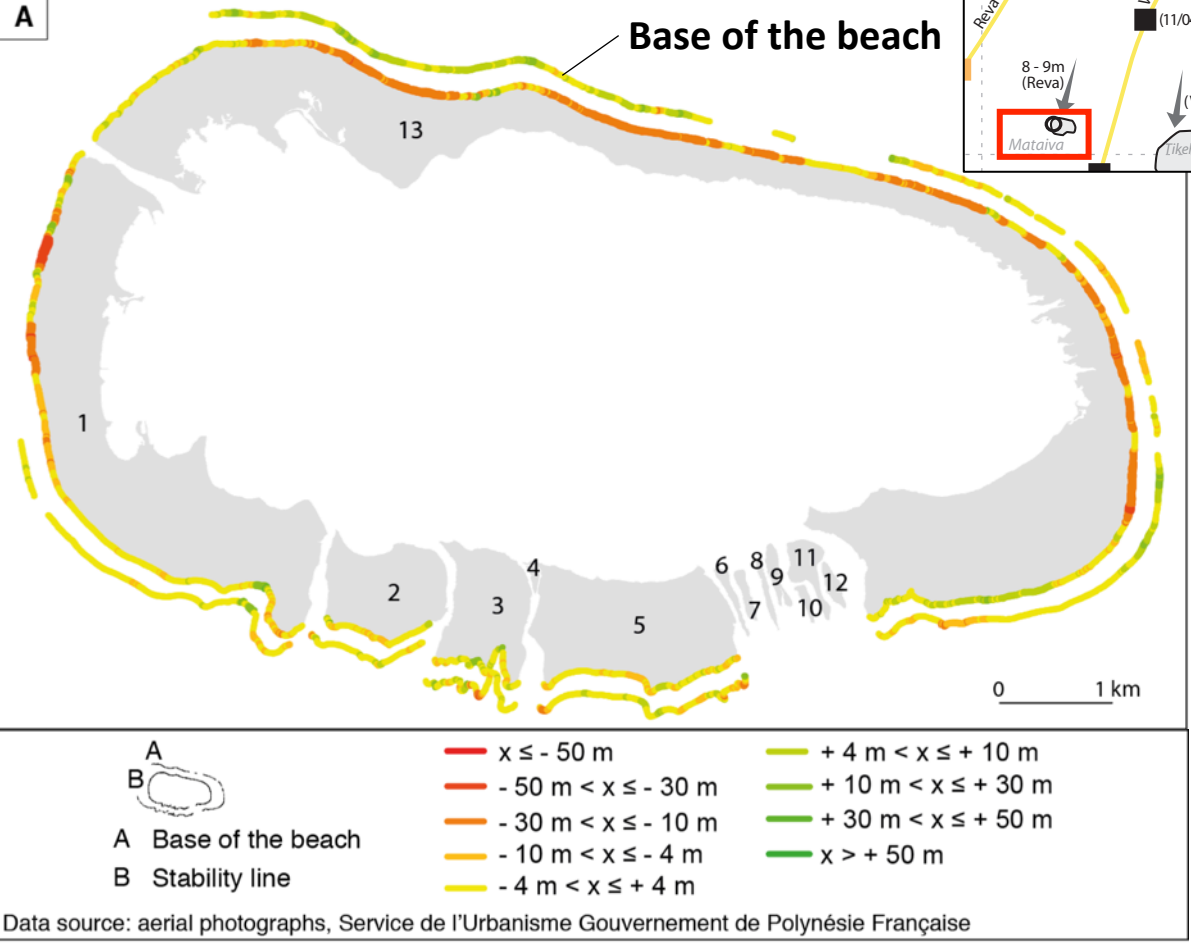
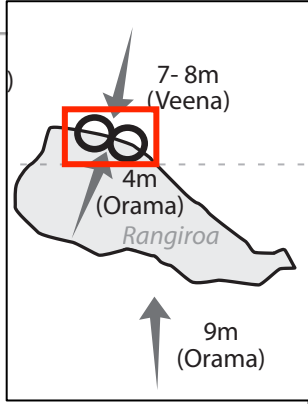
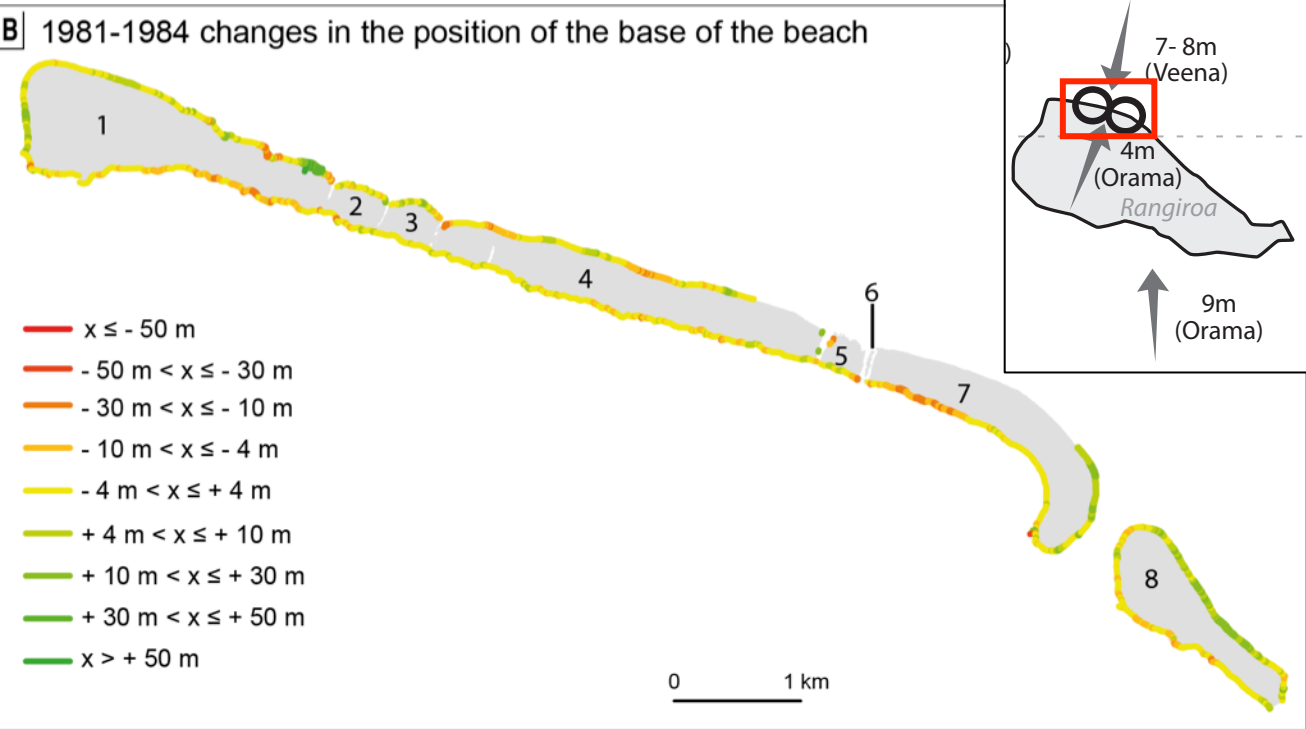


Impacts of the 1983 TCs Reva (March) and Veena (April) on Mataiva Atoll

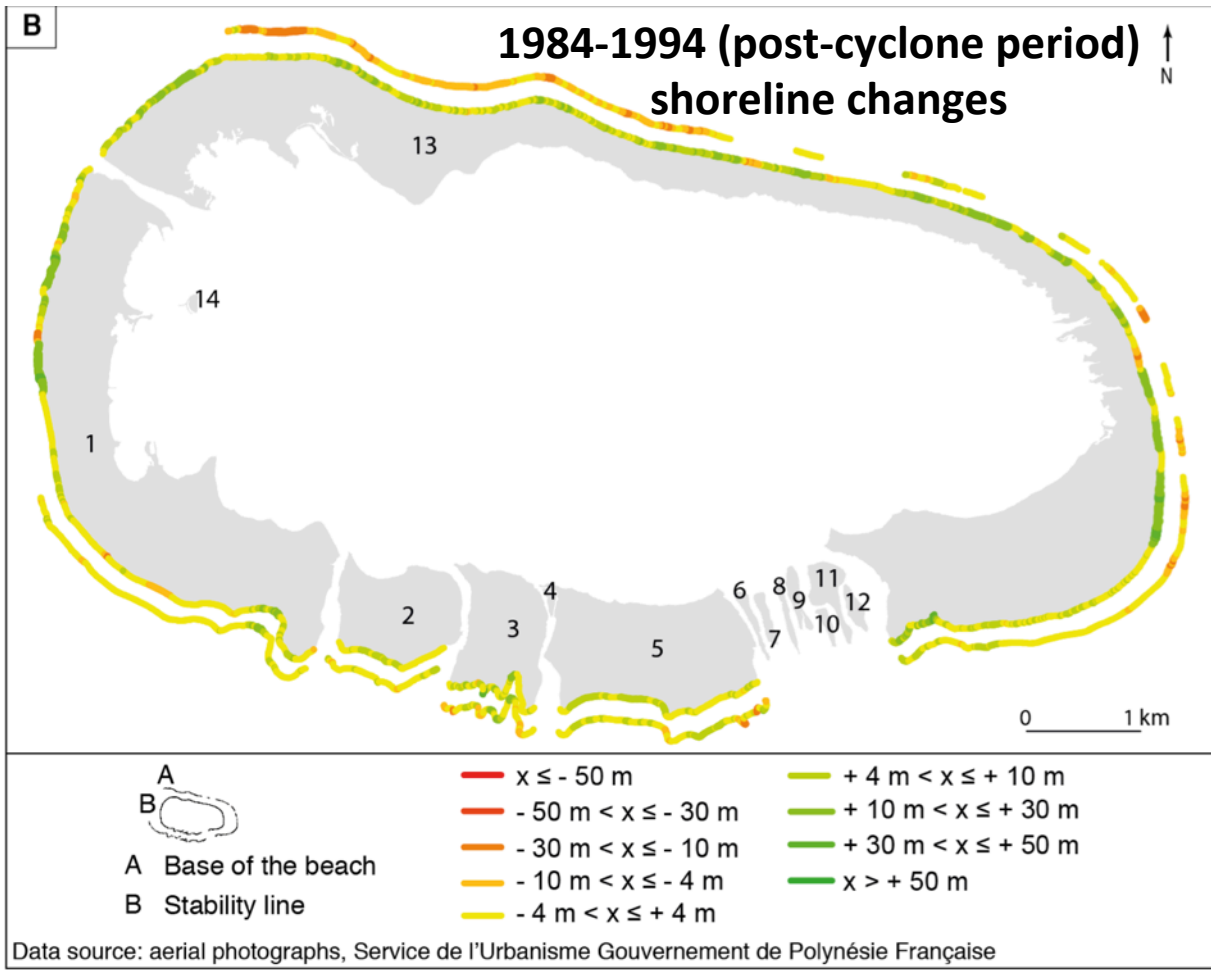


➡ **Marked retreat of the Stability Line: erosional impact of the cyclonic waves**

BASE OF THE BEACH



➔ On the ocean side of islands, the **Base of the Beach** mainly exhibited either **stability**, or **advance** (>30 m in places), indicating that coral reefs (healthy) provide sediments to the island system

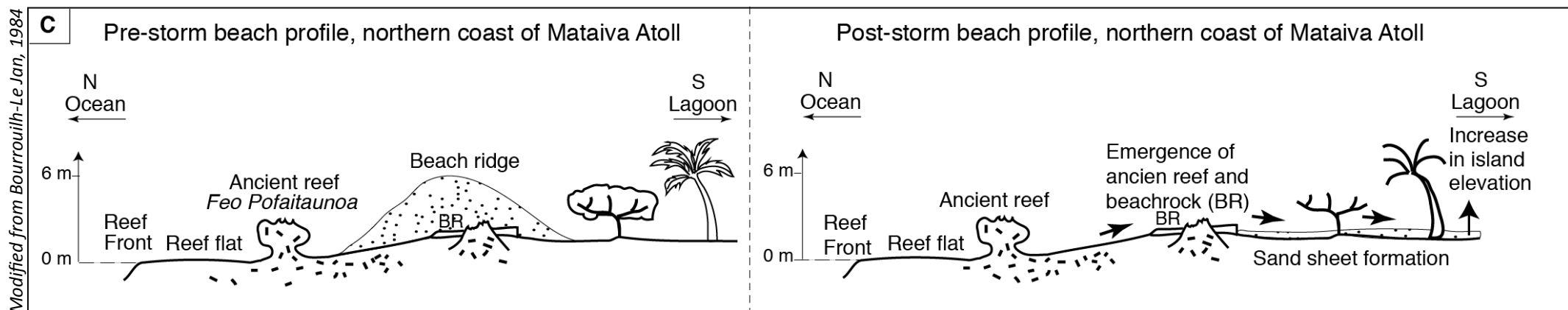


1. The rate of shoreline change remained high over the post-cyclone decade, compared to the values obtained for fair-weather periods that are not consecutive to TCs

2. Over the post-cyclone decade, trends reverse:

- The Stability Line advances
- The Base of the Beach exhibits either stability, or retreat

= **reformation of beach ridges** that were washed away by the cyclonic waves (*sediment input to the inner part of islands = island upward growth*)

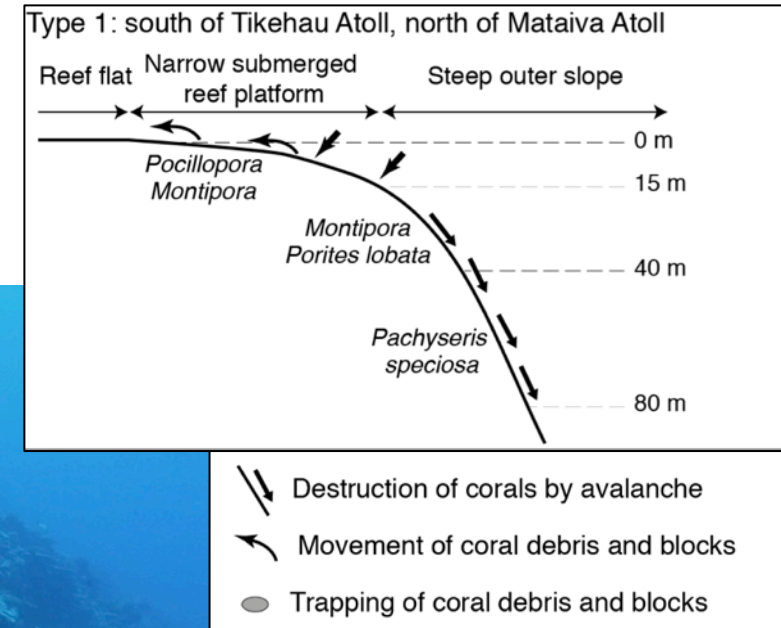
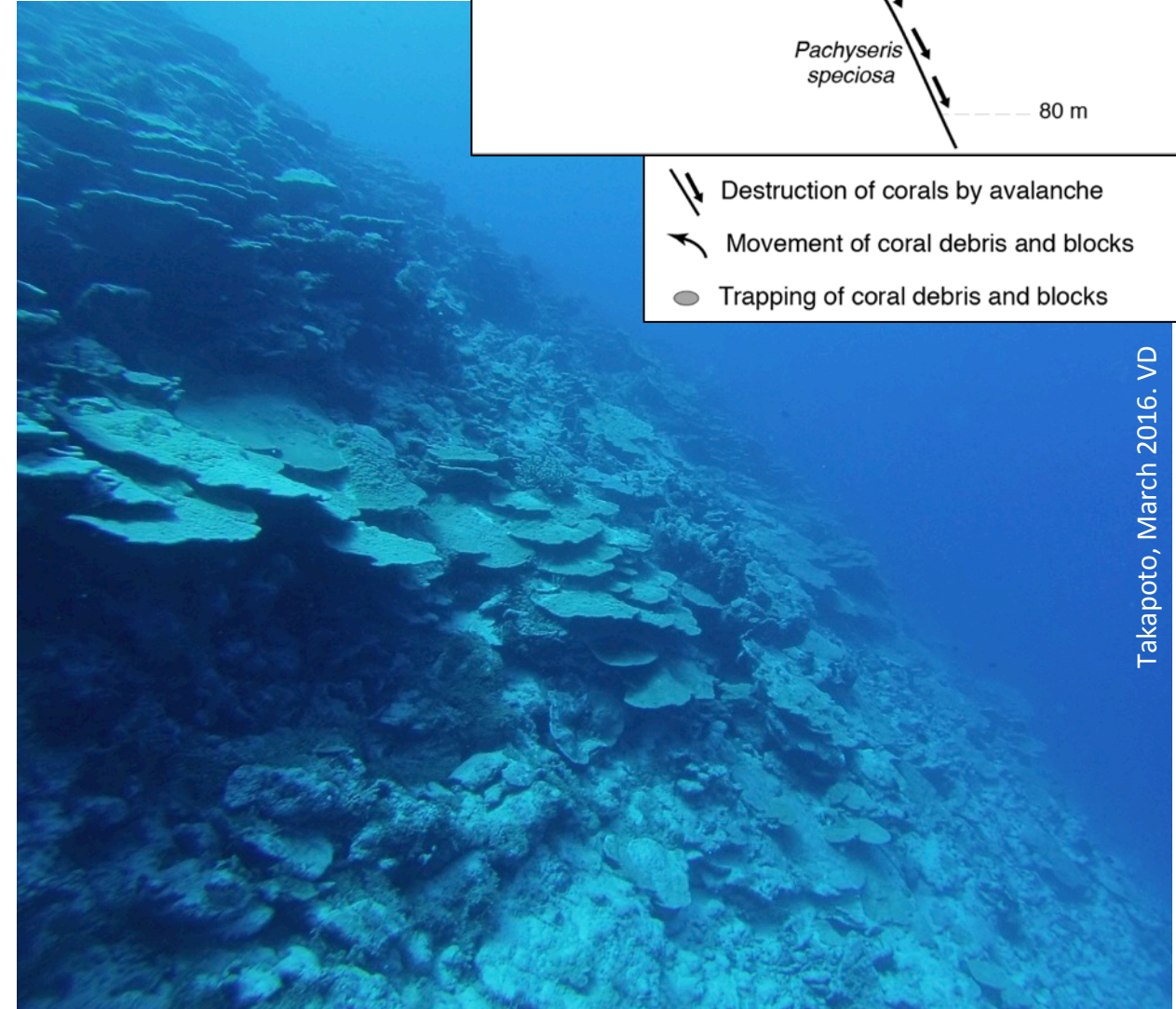


CROSS-ANALYSIS OF SHORELINE AND CORAL REEF DATA

1. Storm events make the living coral coverage on the reef outer slopes fall from 50-60 % to 4-5 %, indicating that sediment production occurs

2. But, the predominance of steep ($>45^\circ$) outer slopes makes around 75 % of broken corals be lost to islands

Despite “limited” sediments inputs to islands during TCs, islands were found to be resilient



HUMAN INFLUENCE ON CURRENT AND FUTURE ISLAND RESILIENCE

- **Human activities currently influence shoreline change on 63 islands** representing 57.5% of the island sample: their influence on shoreline change is not limited to island capitals (6)
- **Among these 63 “disturbed islands”, 29 are highly-modified and have lost their resilience as a result of human disturbances** (entirely fixed shoreline/reclaimed reef flats obstructing sediment deposition)

HUMAN INFLUENCE ON CURRENT AND FUTURE ISLAND RESILIENCE

➤ The fact that most “disturbed islands” were either stable (53%), or expanded (14%) over the study period **does not mean that these islands are still healthy and would be resilient in the future if they were eroded by a TC:**

➤ **Two arguments:**

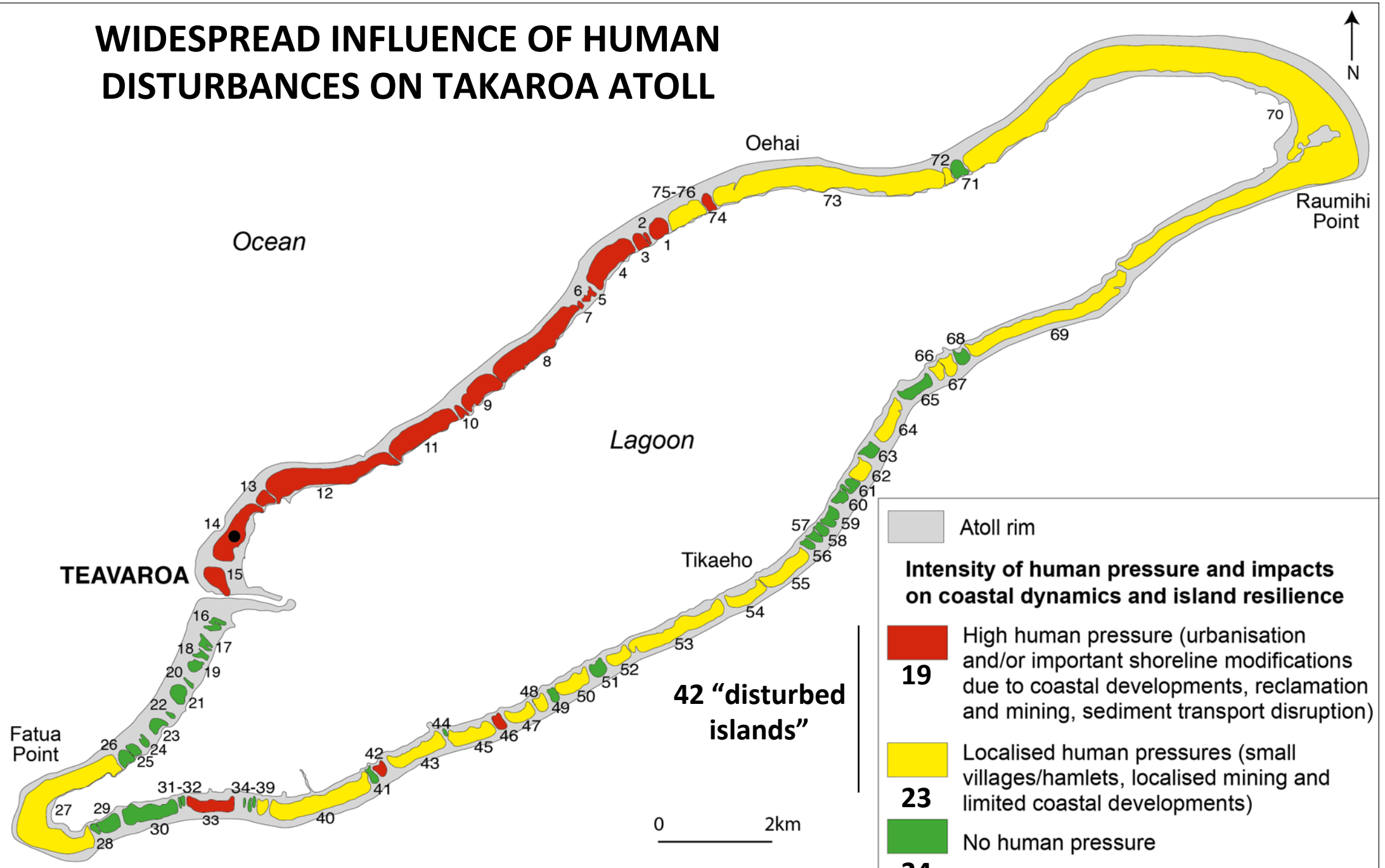
- Stability in island area is often due to the compensation of the retreat of the natural shoreline by an artificial advance of the modified shoreline
- Many islands have experienced accelerated shoreline destabilisation and beach loss over the last three decades: caused by human disturbances on some islands, but not on others – *decrease in sand supply?*

Human activities increasingly influence shoreline change and will probably remain a key driver of island resilience in the next decades.

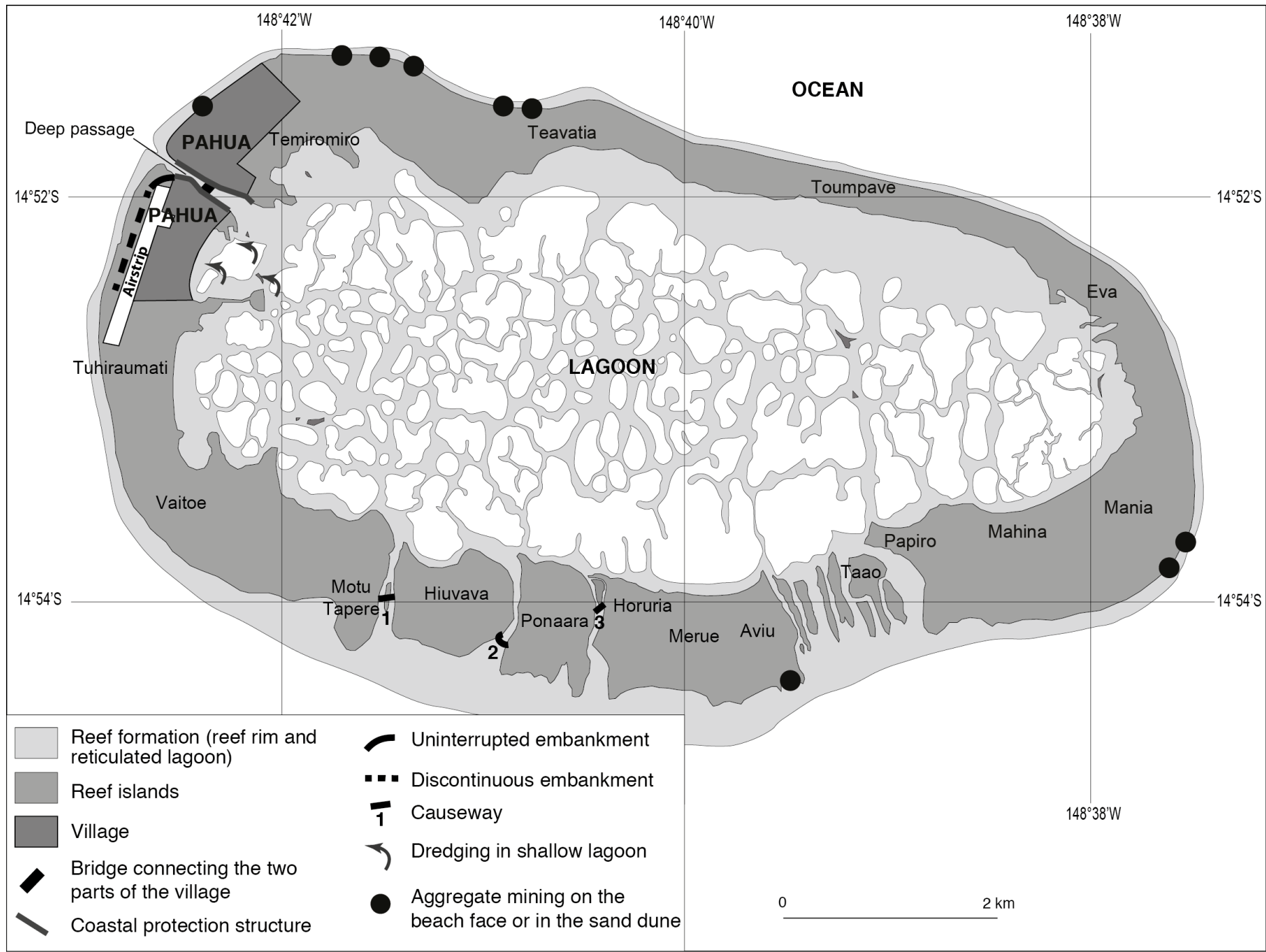
Highly-modified islands (26%) have lost the capacity to respond to TCs by upwards growth, which is concerning in the context of accelerated sea level rise.



WIDESPREAD INFLUENCE OF HUMAN DISTURBANCES ON TAKAROA ATOLL



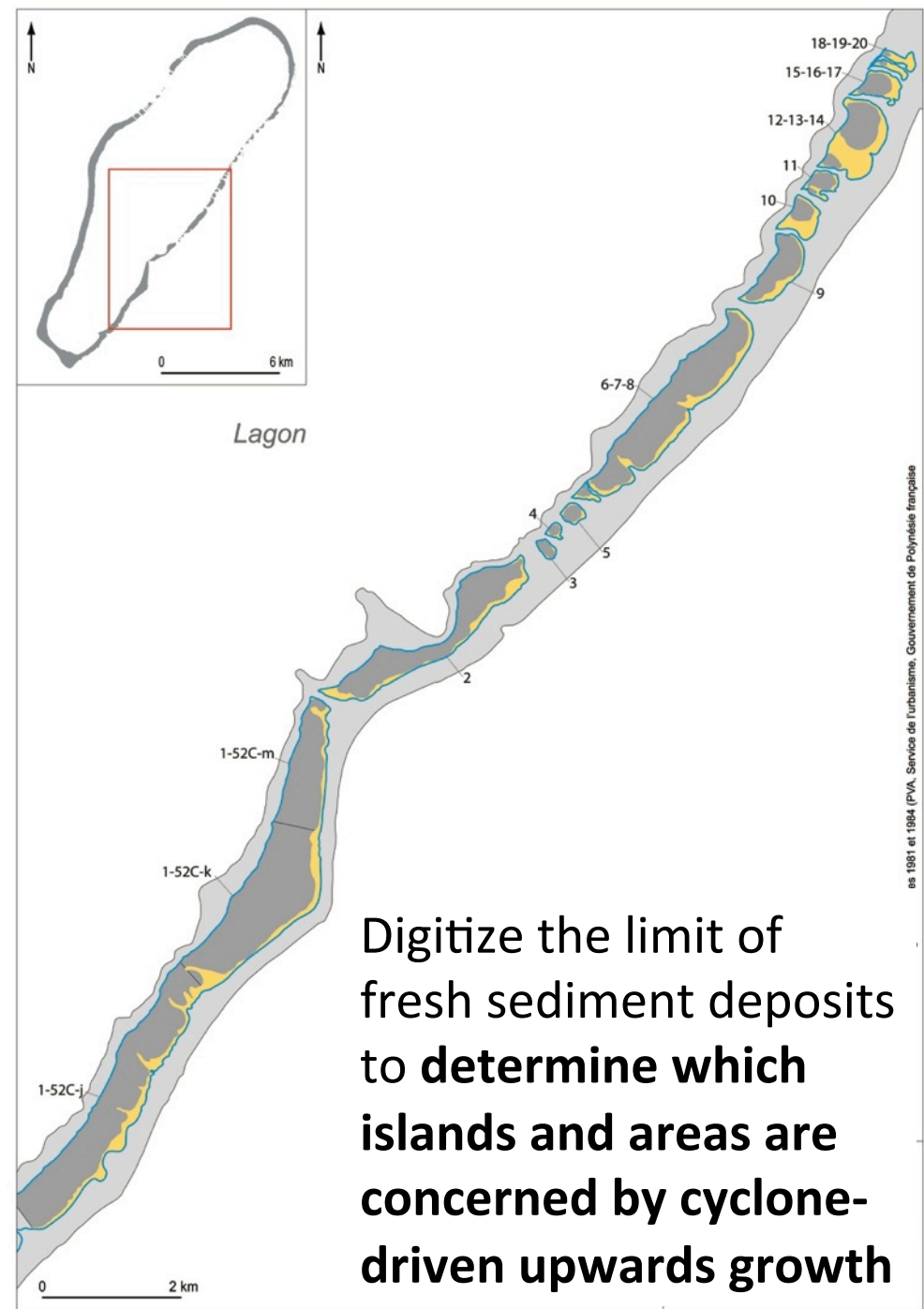
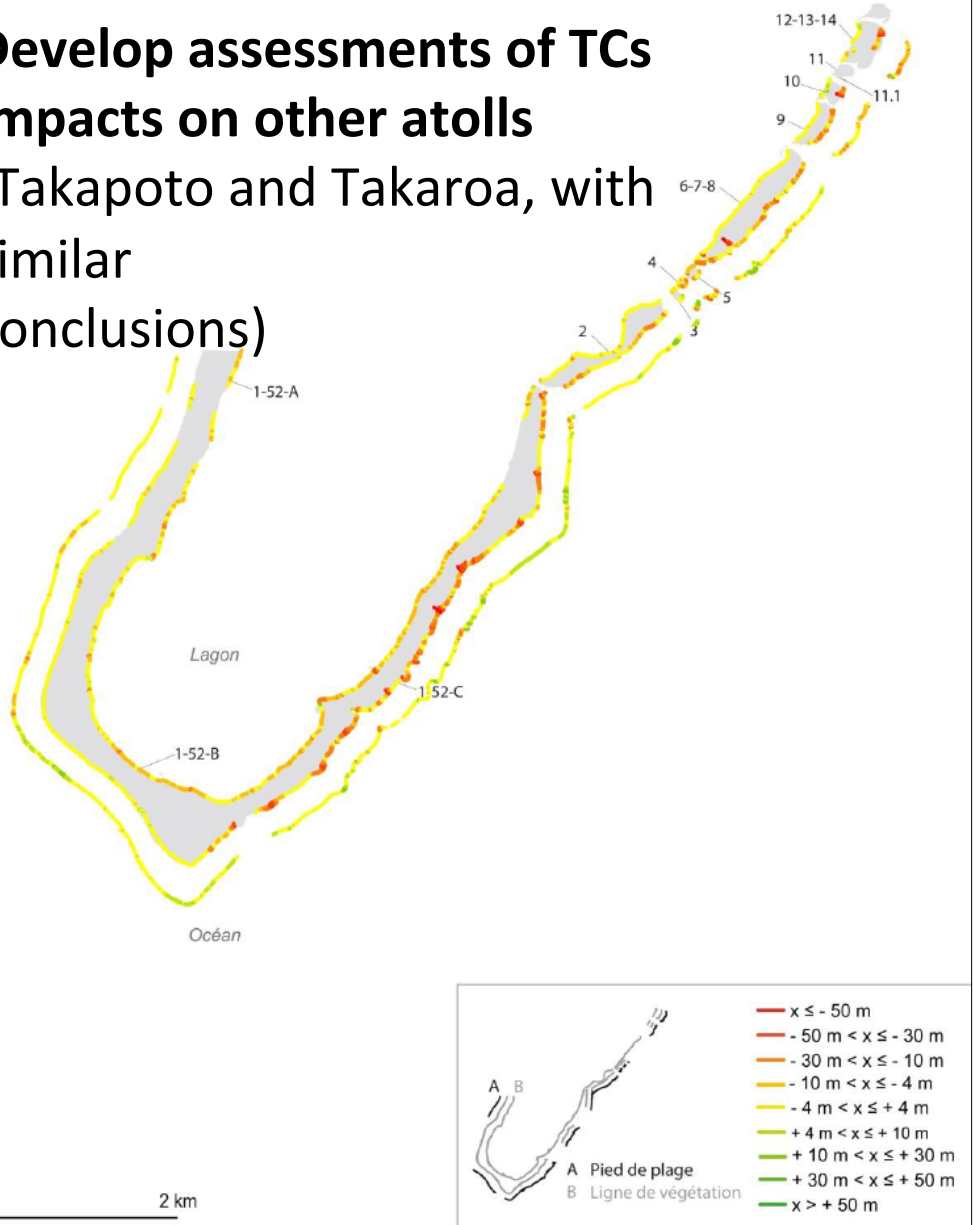
WIDESPREAD SAND MINING ON MATAIVA ATOLL... IMPACTING THE SEDIMENT BUDGET OF SOME BEACHES



FURTHER STUDIES...

Develop assessments of TCs impacts on other atolls (Takapoto and Takaroa, with similar conclusions)

Source des données : traitements images aériennes 1981 et 1984 (PVA, Service de l'urbanisme, Gouvernement de Polynésie française)



Digitize the limit of fresh sediment deposits to determine which islands and areas are concerned by cyclone-driven upwards growth

+
 Use remote sensing techniques to generate topographic profiles of the reef outer slopes to link sediment inputs to the island system and the reef outer slopes profile
 +
DOCUMENT THE IMPACTS OF HUMAN ACTIVITIES