Use of GIS and Remote Sensing for risk assessment related to climate change in the Pacific

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Two parts to this presentation

- **Developing a Regional-Scale Index for the Indicative Susceptibility of Pacific Islands to Climate Change**
- **Exposure of coastal built assets in the South Pacific to climate risks**

Developing a Regional-Scale Index for the Indicative Susceptibility of Pacific Islands to Climate Change

A project funded by the Department of Climate Change and Energy Efficiency, Australia

Project Partners

Professor Patrick Nunn – University of the Sunshine Coast

Professor Roger McLean – Australian Defence Force Academy, Canberra

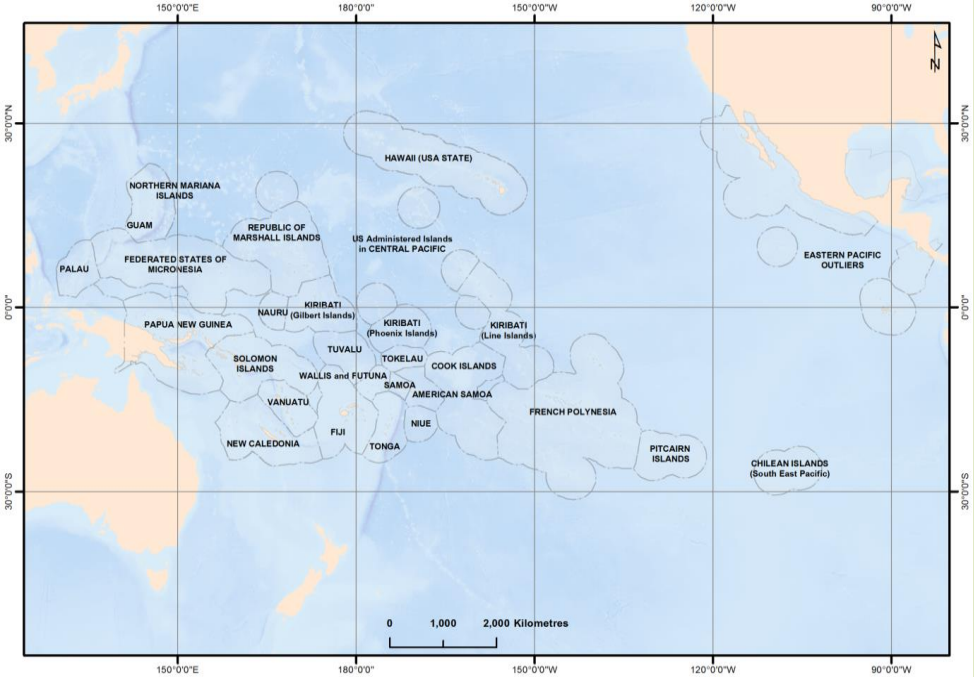
Dr Ian Elliot – University of Western Australia

Department of Climate Change and Energy Efficiency

Geoscience Australia

Project Aims

- The intent was to develop a relative regional scale island susceptibility index based on physical characteristics and relevant climate change drivers.
- Broad index at island scale
- Readily developable based on existing data or readily available or collectable data
- Why are we doing this?



Started off with Physical Variables

- Lithology
- Elevation
- Area
- Shape

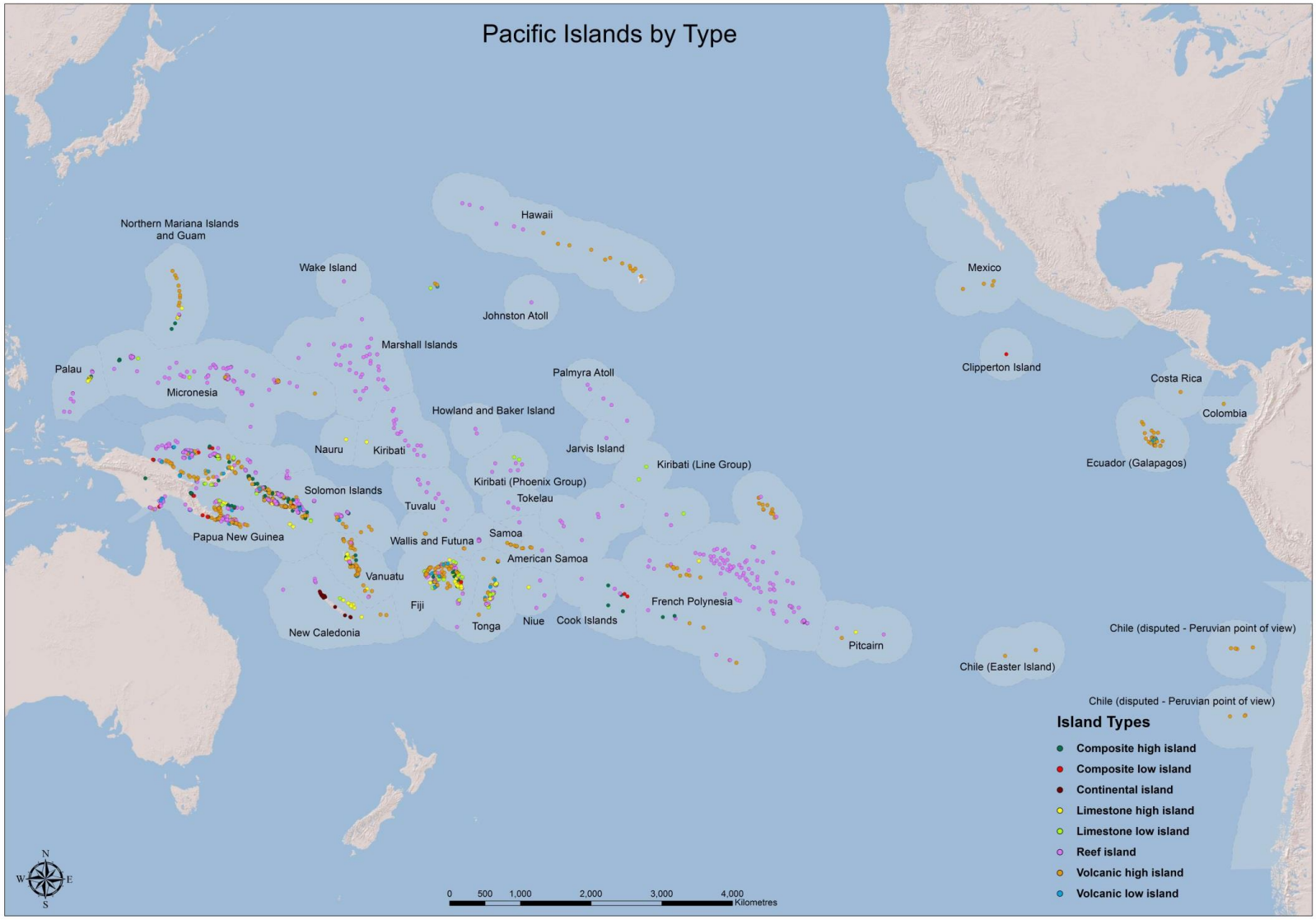
Lithology

- Premise: Hard-rock island islands are less likely to change through weathering and erosion compared to islands comprised of unconsolidated sediments

- Volcanic Islands: Islands which are composed of at least 80% igneous rock type.
- Limestone Islands: Islands which are composed of at least 80% calcareous rock types.
- Composite Islands: Islands which are composed of both volcanic and calcareous rock types with each type being less than 80%.
- Reef Islands: Islands which are composed of at least 80% unconsolidated sediments (derived from adjacent offshore areas) that have accumulated on a shallow reef flat.
- Continental Islands: Islands which are composed of at least 80% continental rocks.

- A 30m cutoff was used between high and low islands.

Lithology


Pacific Islands by Type
Northern Mariana Islands and Guam
Hawaii
Wake Island
Mexico
Johnston Atoll
Marshall Islands
Palau
Palmyra Atoll
Clipperton Island
Micronesia
Costa Rica
Howland and Baker Island
Colombia
Nauru
Kiribati
Jarvis Island
Kiribati (Line Group)
Ecuador (Galapagos)
Kiribati (Phoenix Group)
Solomon Islands
Tokelau
Tuvalu
Samoa
Papua New Guinea
Wallis and Futuna
American Samoa
Vanuatu
French Polynesia
Fiji
Tonga
Niue
Cook Islands
New Caledonia
Pitcairn
Chile (disputed - Peruvian point of view)
Chile (Easter Island)
Chile (disputed - Peruvian point of view)
Island Types
Composite high island
Composite low island
Continental island
Limestone high island
Limestone low island
Reef island
Volcanic high island
Volcanic low island
N
W
E
S
0
500
1,000
2,000
3,000
4,000
Kilometres

Elevation

- Premise: A higher island is less susceptible than a lower island (all other factors being equal)

- Maximum elevation provides a surrogate measure of susceptibility of an island to marine inundation
- Maximum elevation was used since it is the most readily available elevation data
- Median elevation may be a better factor to use.
- Maximum elevation data was obtained from country reports, topographic maps and satellite data such as Google Earth

- Maximum elevation ranged from 0m to 4205m.

Area

- Premise – A larger island is less susceptible than a smaller island (all other factors being equal)
- Area completes the three-dimensional geometric description of the island, with height and circularity
- Area calculated from island polygons in ArcGIS. Polygons obtained from World Vector Shorelines data and manual digitisation of many islands. 1779 islands in database.

Area (sq km)	No. of Islands	% of Islands	Cumulative %	Total Area (Sq Km)	% area
< 0.1	154	8.79	8.79	9.16	0.00
0.1 to 1.0	637	36.36	45.15	285.50	0.03
1.0 to 5.0	456	26.03	71.18	1082.73	0.11
5.0 to 10.0	121	6.91	78.08	871.88	0.09
10.0 to 50.0	222	12.67	90.75	5035.07	0.52
50.0 to 100	55	3.14	93.89	3850.71	0.40
100 to 1000	81	4.62	98.52	29245.09	3.00
> 1000	26	1.48	100.00	932852.92	95.85
Totals	1752	100.0		973233.05	100.0

Shape Factor

- Circularity was the shape measure used
- Premise: Circular islands are less susceptible to change in structure with changing climate-ocean processes compared to irregular or thin and long islands.
- Calculated in ArcGIS using the island polygon database.

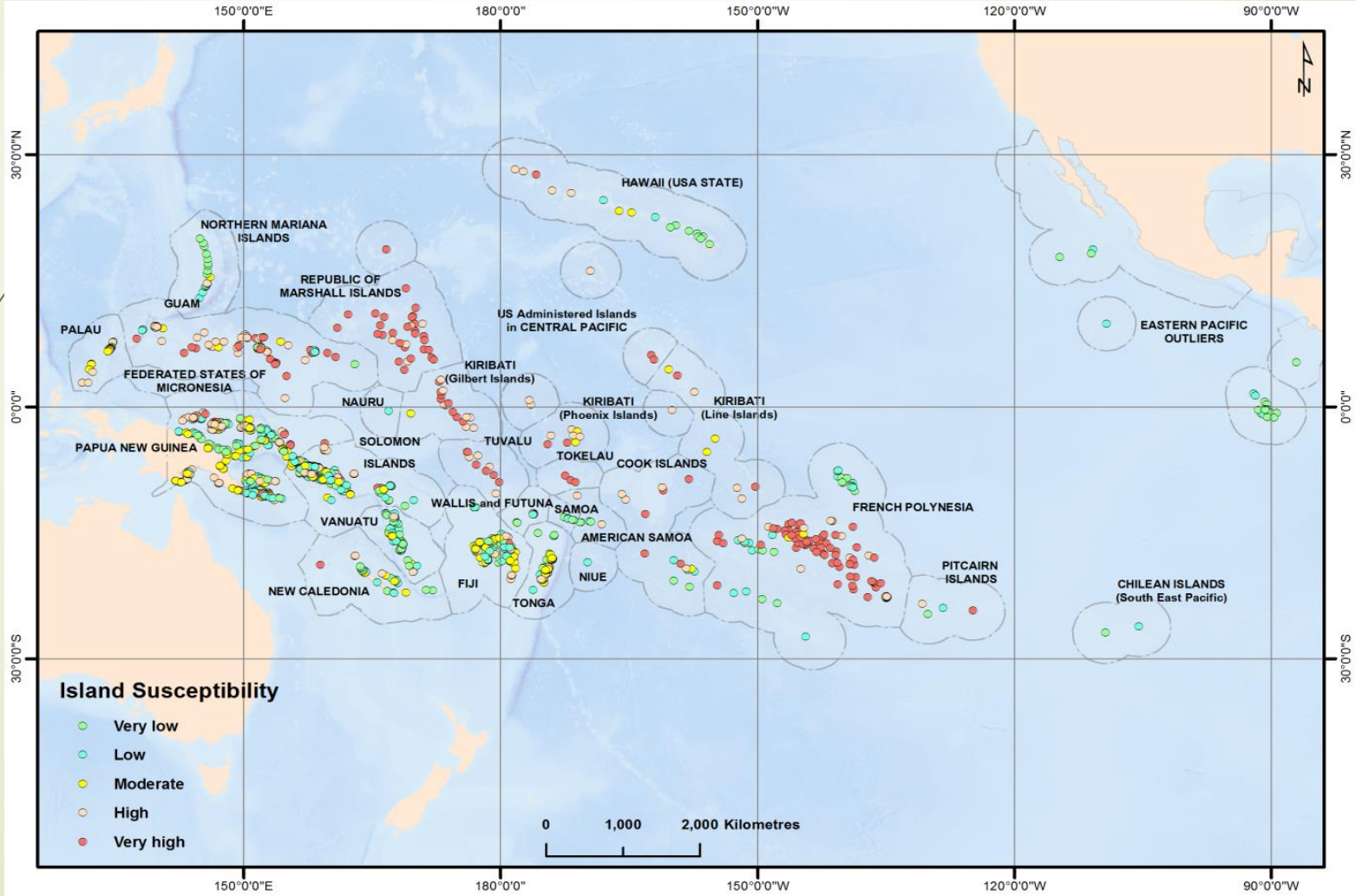
Shape Factor

- Shape of an object = convexity of circle / convexity of object
  - Where Convexity = $P / \sqrt{A}$ (P = perimeter and A = the area)
- So convexity of a circle = $P_{circle} / \sqrt{A_{circle}} = 2\pi r / \sqrt{(\pi r^2)} = 2\sqrt{\pi} = 3.54$
-
- Therefore shape of object (island) = 3.54 / convexity of island
-
- For a circular island, shape = 3.54 / convexity of a circle = 1
-
- For a square object, shape = 3.54 / convexity of a square
-
- Convexity of a square = $P / \sqrt{A} = 4L / \sqrt{L^2} = 4L / L = 4$
-
- So shape of a square = 3.54 / 4 = 0.885
- Values for shape go from 0 to 1, with higher values indicating more circular objects

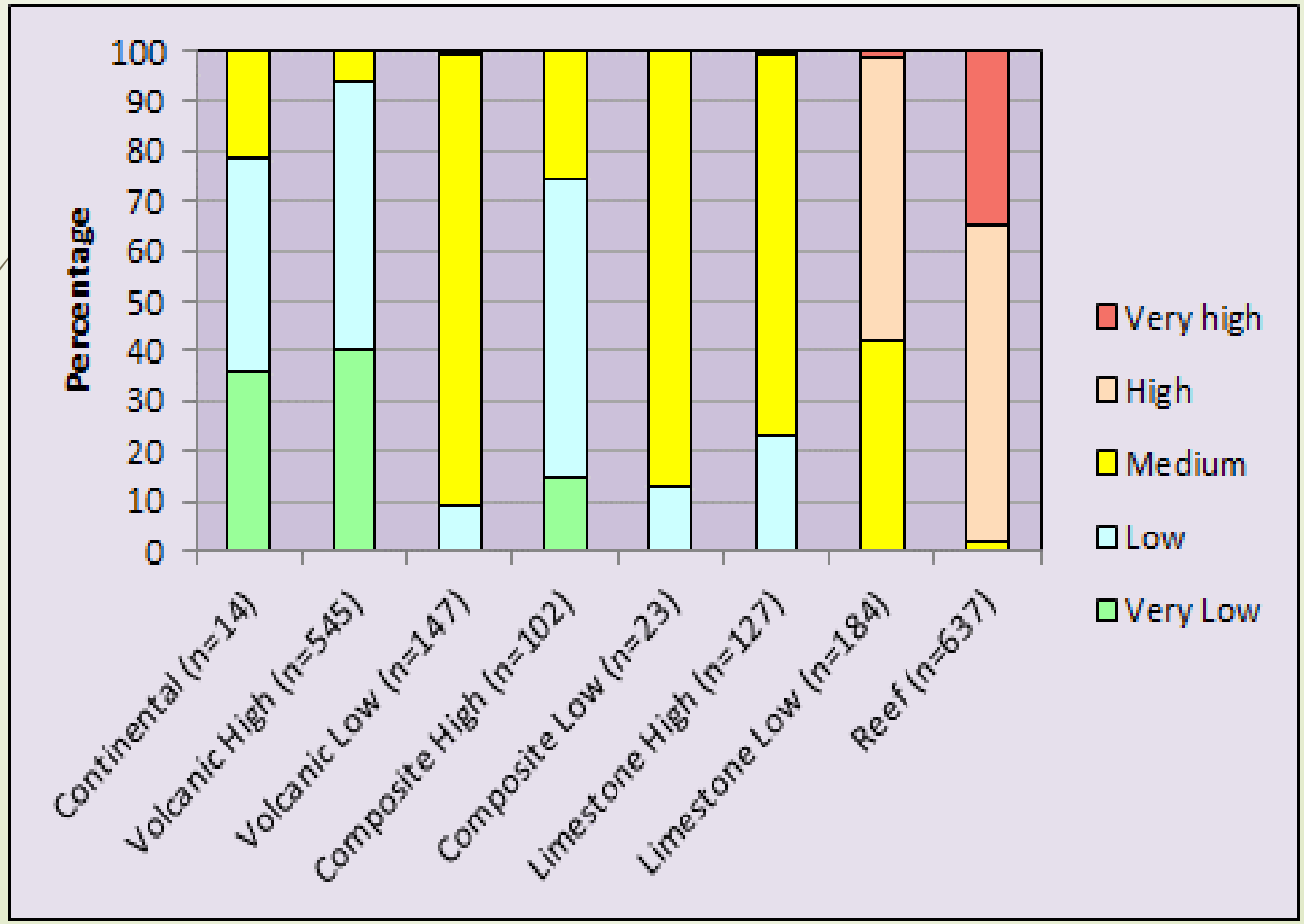
Thresholds

(1) LITHOLOGY		(2) CIRCULARITY		(3) HEIGHT		(4) AREA	
Material	Rank	Roundness index	Rank	Maximum elevation (m)	Rank	Area (Km^2)	Rank
Continental or Volcanic high or Volcanic low	1	Round 0.75 to 1	1	>100	1	>100	1
Composite high or Composite low	2	Sub-rounded 0.5 to <0.75	2	30 to 100	2	10 to 100	2
Limestone high or Limestone low	3	Sub-angular 0.25 to <0.5	3	10 to <30	3	1 to <10	3
Reef Island	4	Angular 0 to <0.25	4	<10	4	<1	4

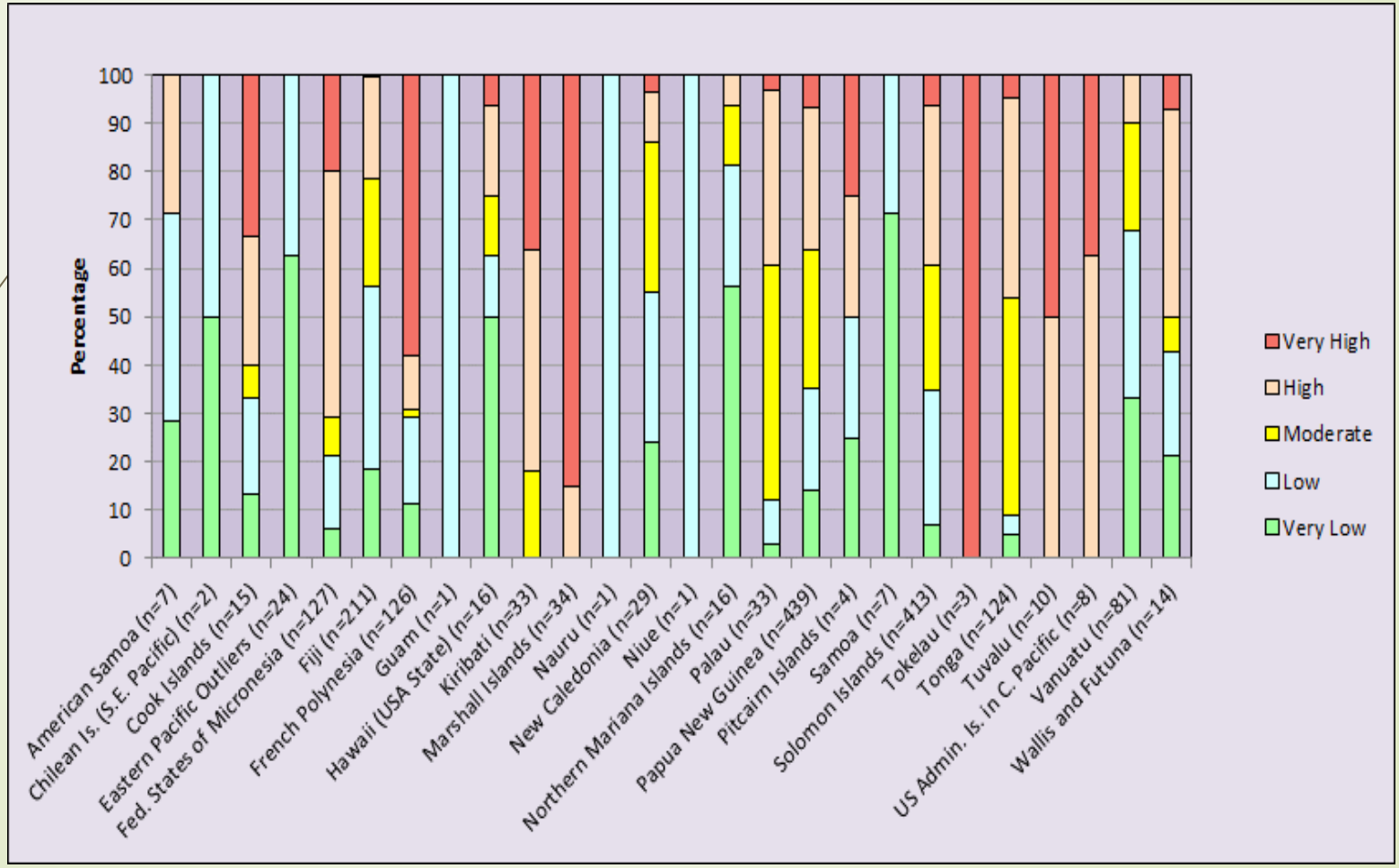
Island Susceptibility Map



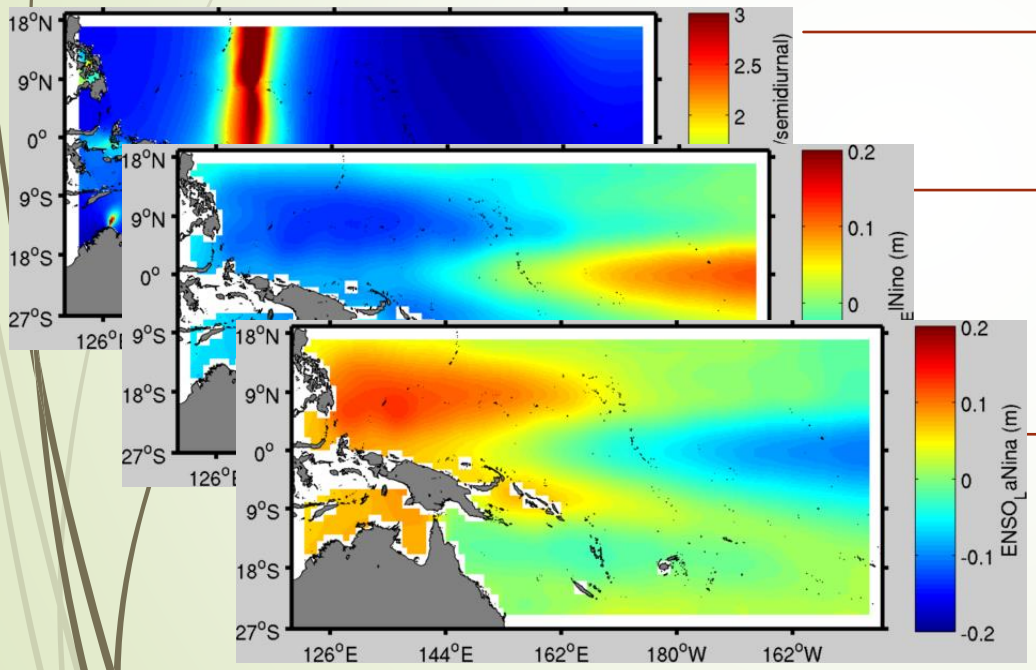
Island Susceptibility - Distribution by Island Type



Island Susceptibility - Distribution by Country



Environmental and Climate-Related Drivers at Regional Scale



Tide Type

Sea Surface elevation during El Nino Phases (departure from average elevation)

Sea Surface elevation during La Nina Phases (departure from average elevation)

Other Data Layers
Sea level – past and projected
Sea Surface Temperature
Wind Speed & Direction

From Island Susceptibility to Geomorphic Vulnerability

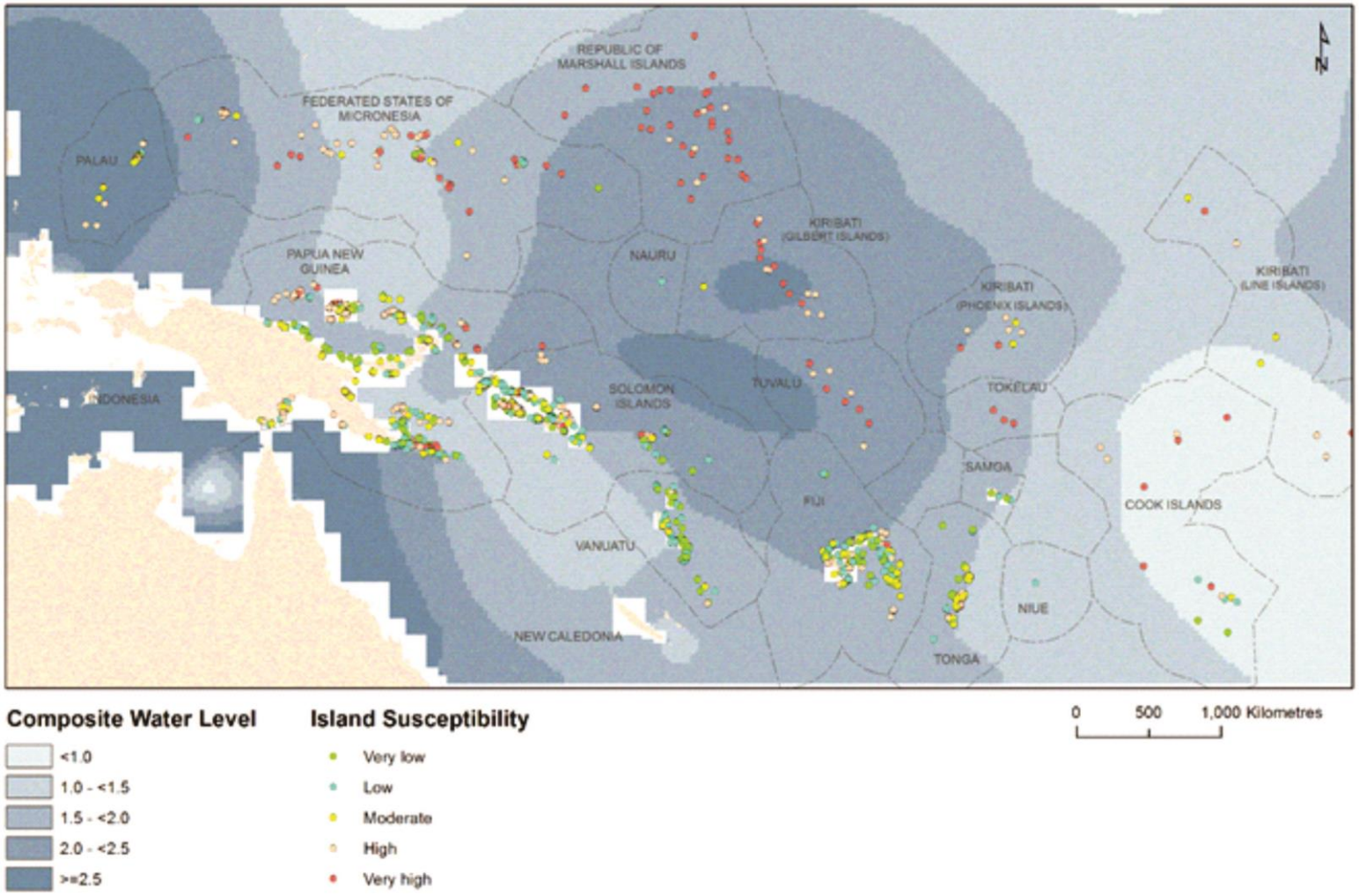
- Combined physical properties (island susceptibility) with broad-scale climate and oceanic processes to develop a geomorphic sensitivity of islands

- Developed a composite water level index
- CWL = (HAT – LAT) + 2 * ENSO Ranging
  - HAT/LAT – Highest and lowest astronomical tide.

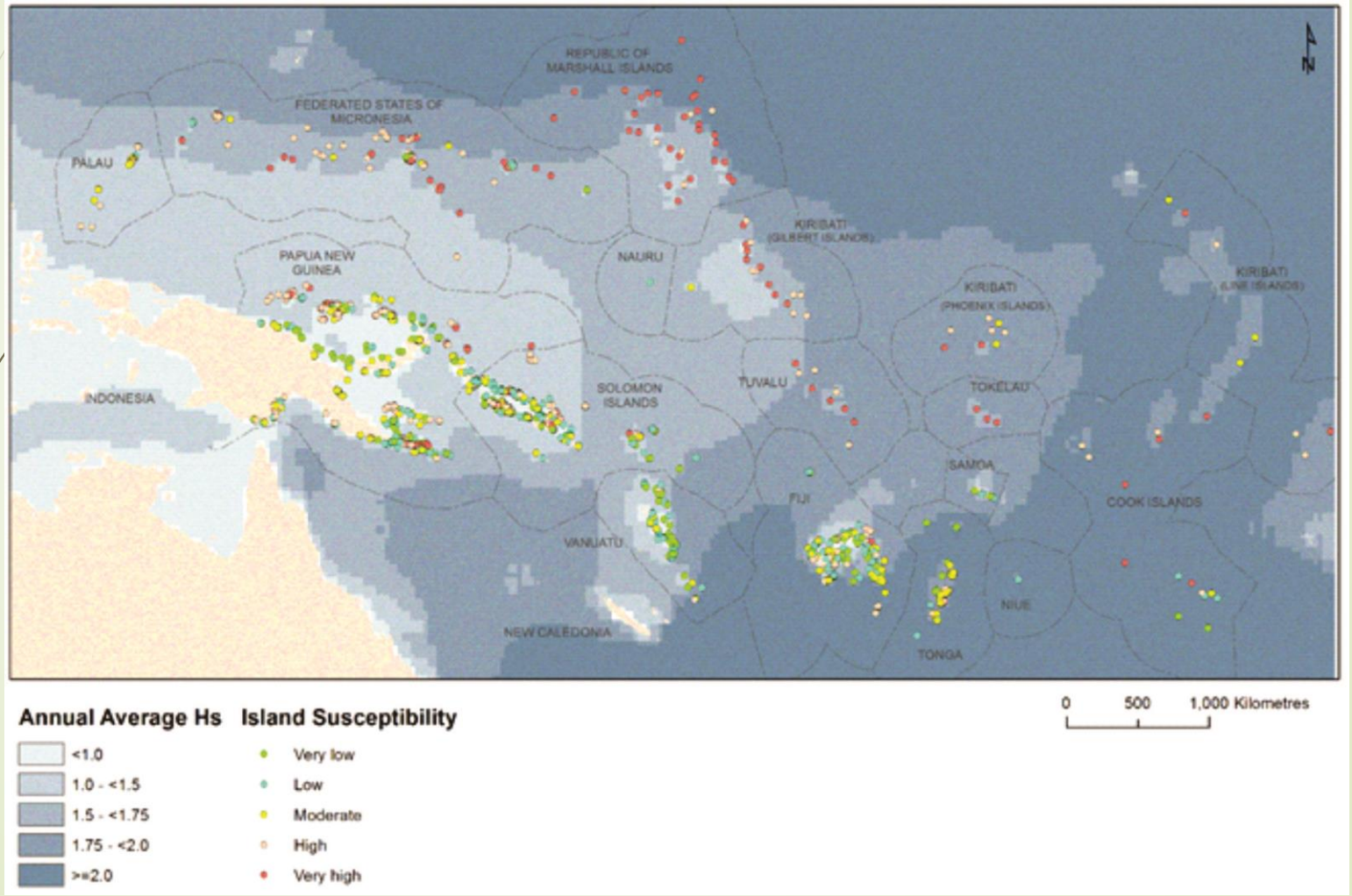
- Annual Average Significant Wave Height. This is an annual average of the wave height that is greater than two thirds of all modelled wave heights. The parameter is a proxy for the average wave energy.

- Tropical Cyclone Frequency

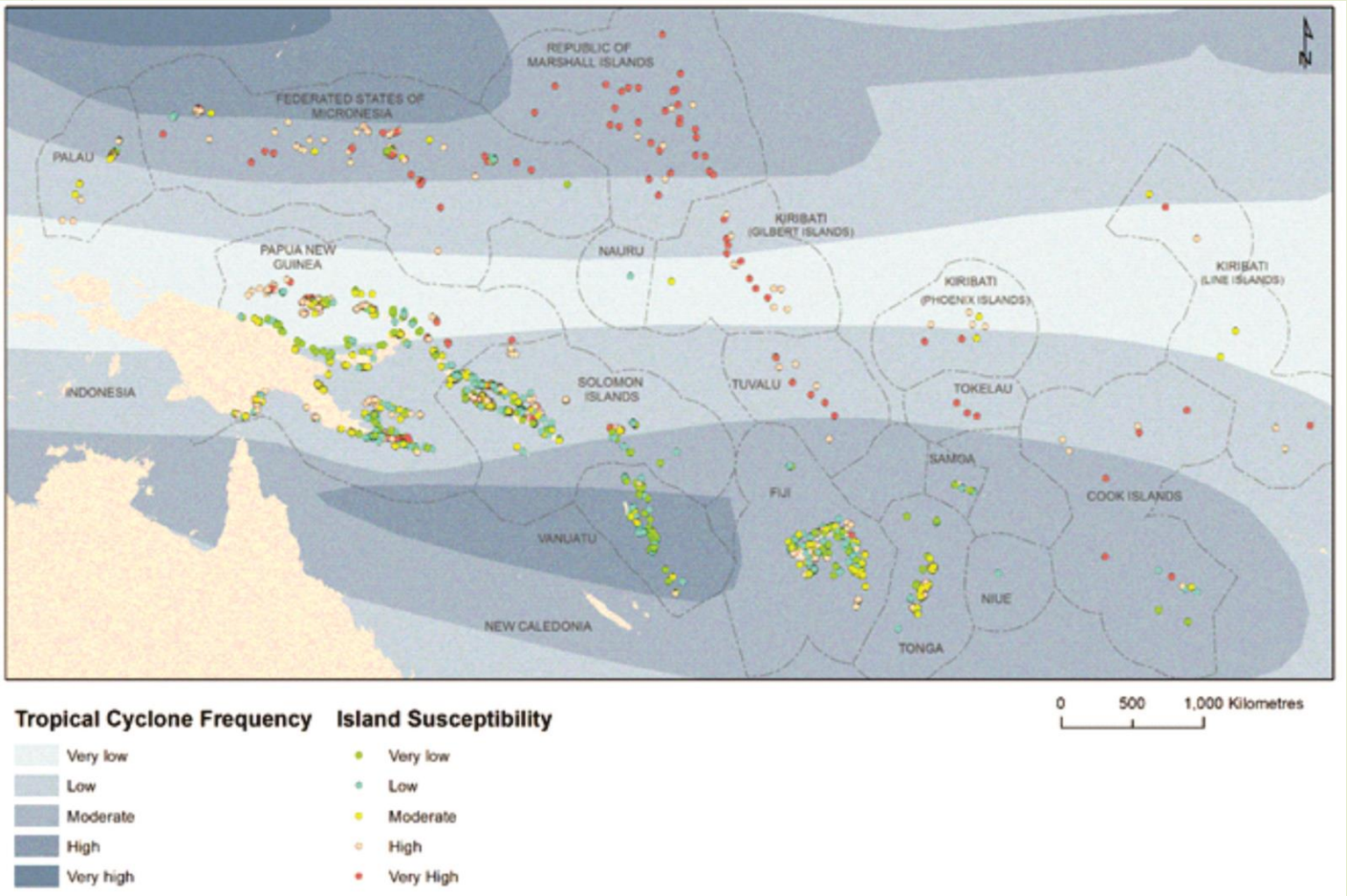
Composite Water Level



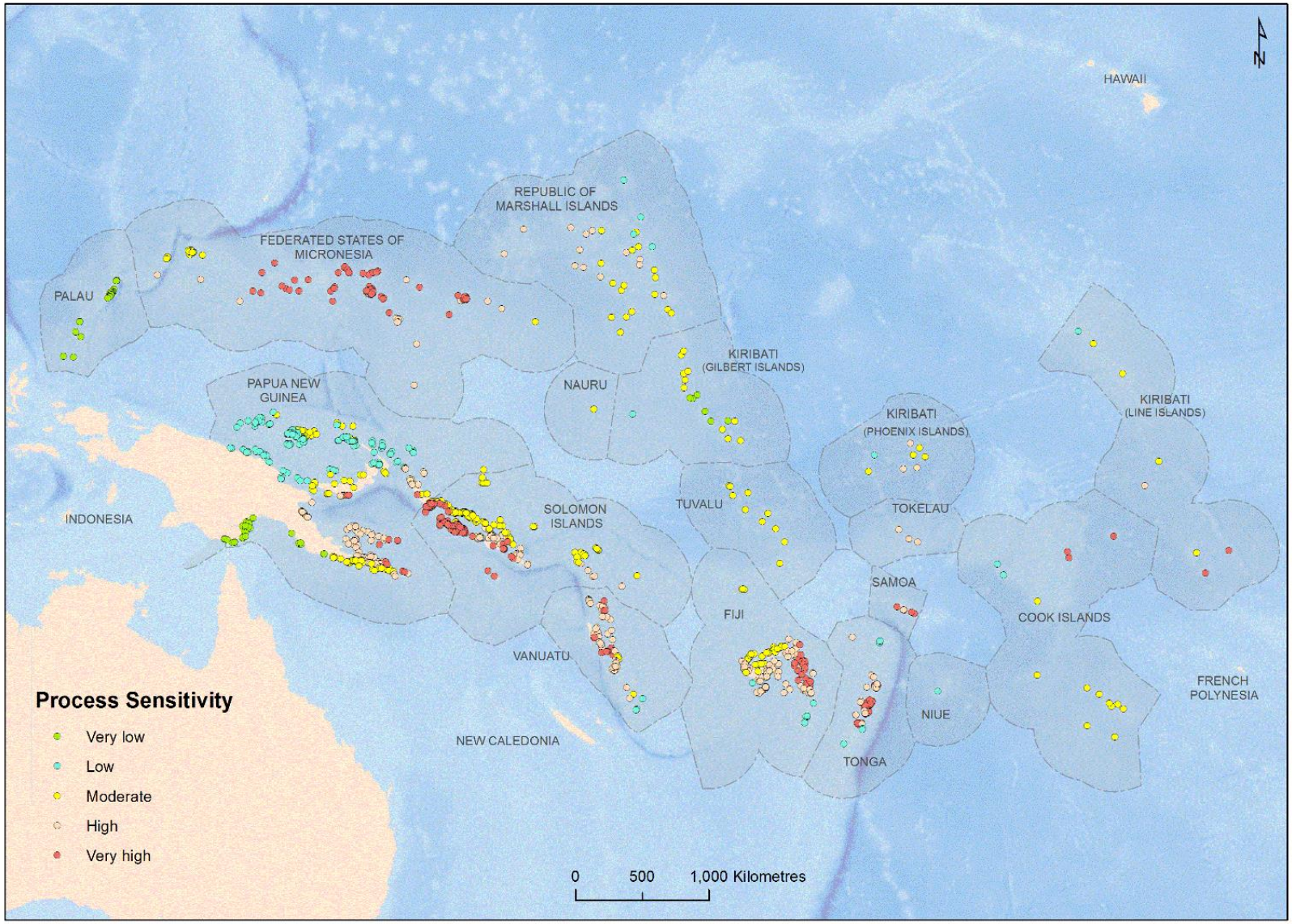
Annual Average H_s



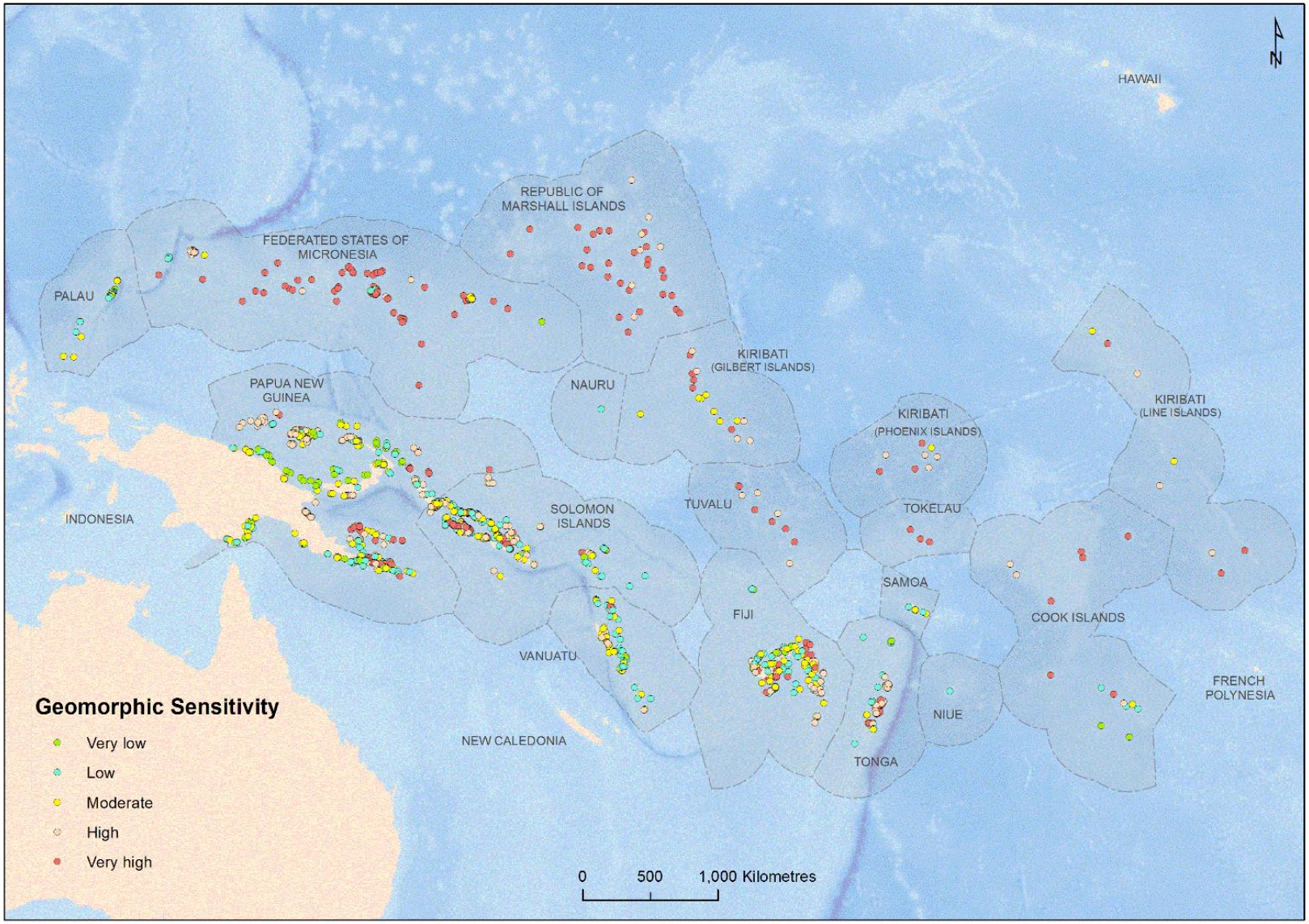
Tropical Cyclone Frequency



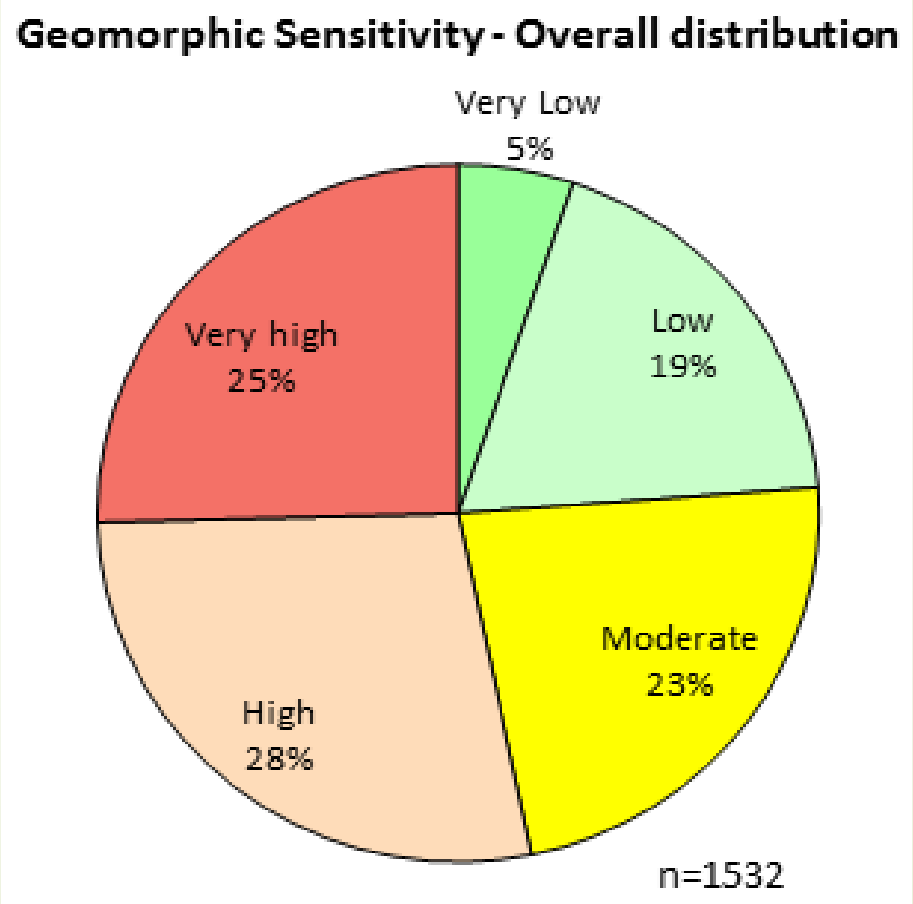
Process Sensitivity (CWL, Hs, TC)



Geomorphic Sensitivity



Distribution



Limitations and caveats

- This work does not give a definitive framework for risk analysis, however it does suggest ways we could use technologies and data to develop indices giving relative vulnerability, and something that is relevant to this region.
- Need to cross-check with individual case studies.
- Whole of island index, so of limited use.
- Need to consider within island variability.

Project 2: Exposure of coastal built assets in the South Pacific to climate risks - Rapid Assessment

A project funded by the Department of Climate Change and Energy Efficiency, Australia

- Undertook an analysis of exposure of built infrastructure to current and future climate risk for 12 PICs
- Identified the proportion of built infrastructure at four intervals from coastline:

  0-50 m, 50-100 m, 100-200m and 200-500m from the coastline

- Analysis undertaken on infrastructure assets (ports, airports, etc), buildings (residential, commercial, public, industrial), and soil type (soft, medium and hard).

Data

- Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) provided the data that was used in this analysis – drawn from Pacific Risk Information System (PacRIS)
- Data initially collected by AIR Worldwide for the World Bank

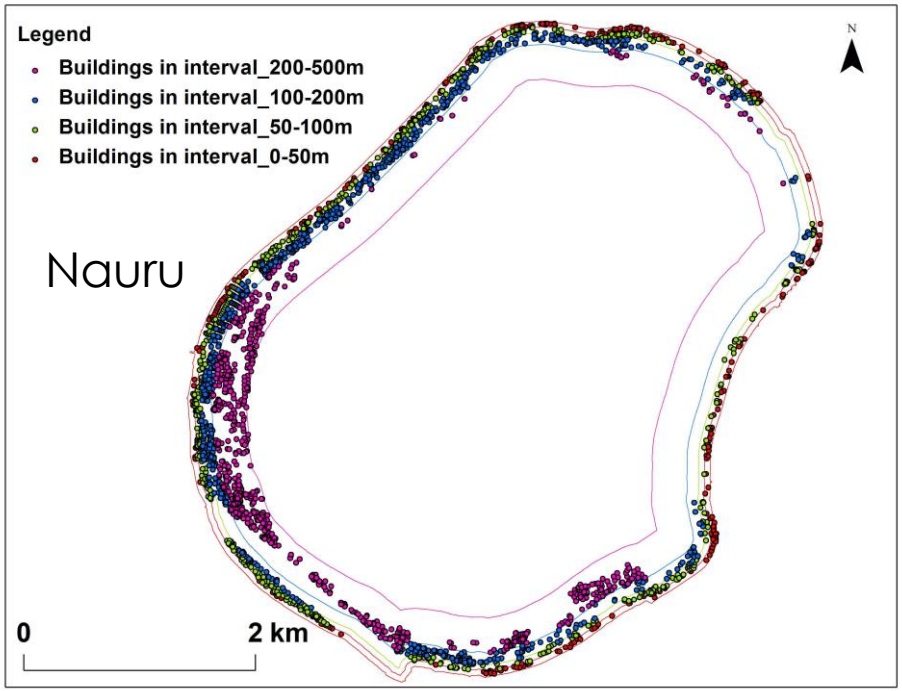
- Major issues with the data
  - Buildings off coastline
  - Coastlines do not match with baseline
  - Projection issues

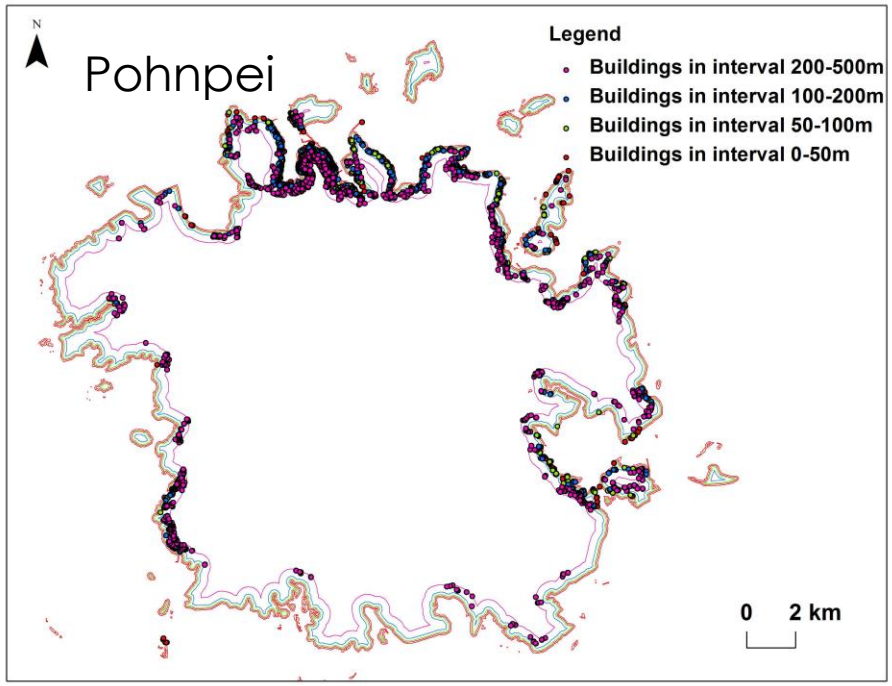
- High resolution satellite data used to fix many of the problems.
- Most arduous task of this project

Exposure of coastal built assets in the South Pacific to climate risks

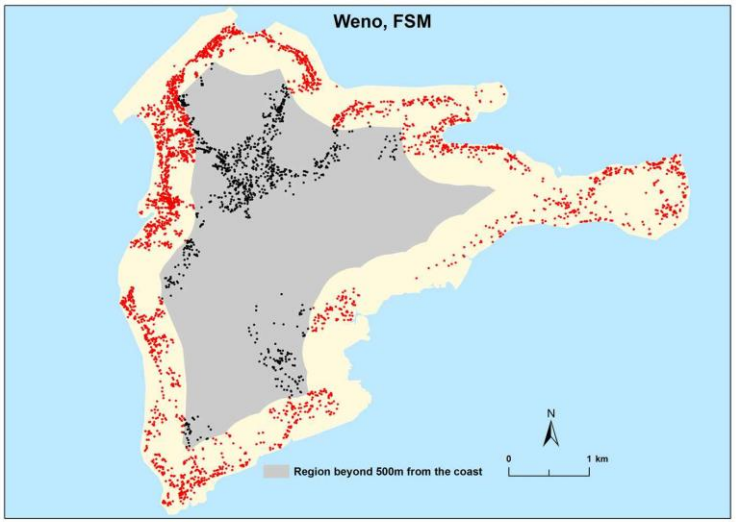
- 12 PICs
  - Cook Islands
  - Federated States of Micronesia (FSM)
  - Kiribati
  - Marshall Islands
  - Nauru
  - Niue
  - Palau
  - Samoa
  - Solomon Islands
  - Tonga
  - Tuvalu
  - Vanuatu

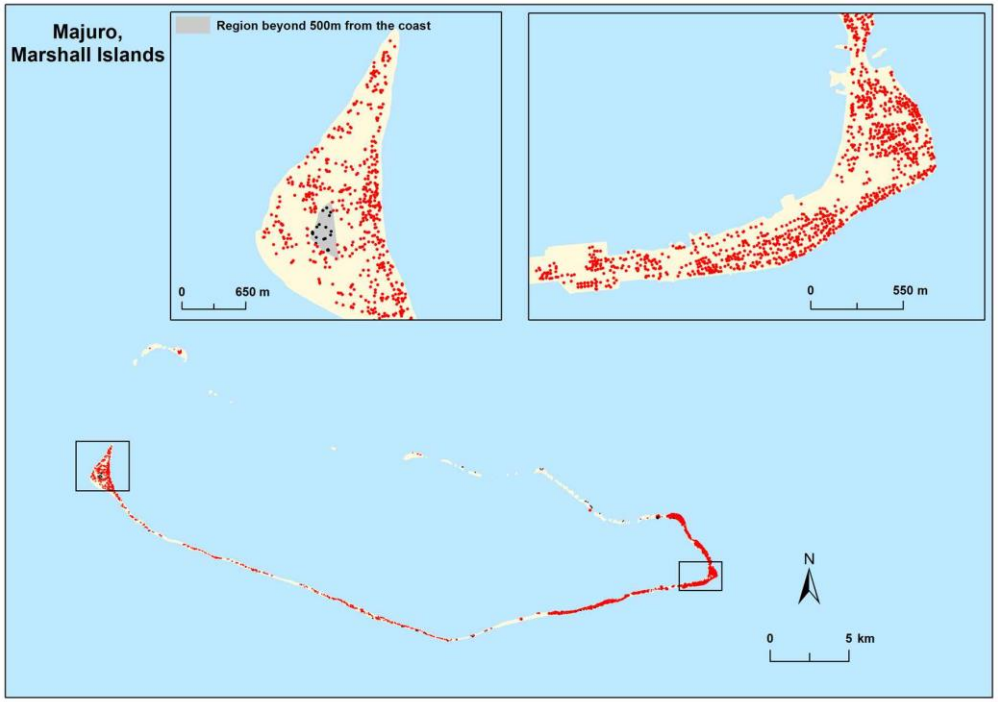
Examples of work undertaken



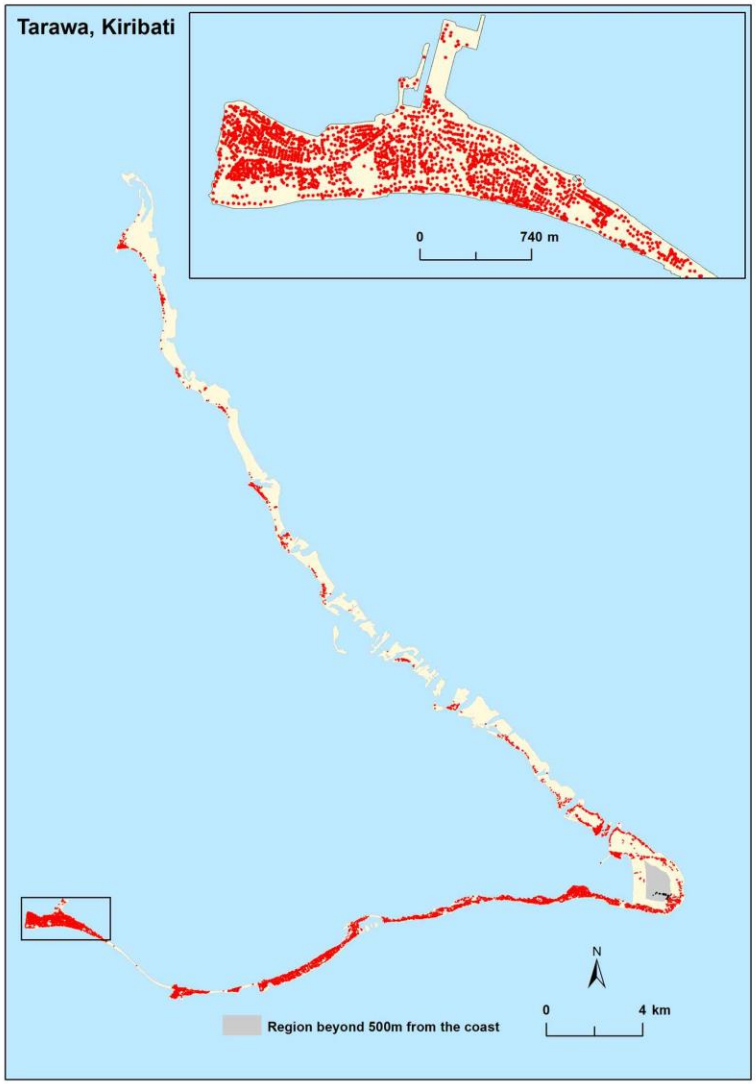


Examples of work undertaken

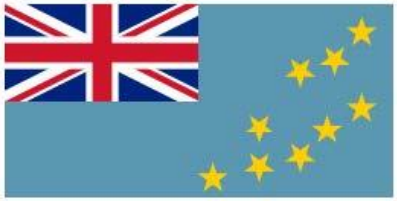




Examples of work undertaken



Pacific-Australia Climate Change Science and Adaptation Planning program



TUVALU

EXPOSURE OF COASTAL ASSETS TO CLIMATE RISKS

RAPID ASSESSMENT

Associate Professor Lalit Kumar
University of New England
March 2014

Australian Aid

Australian Government

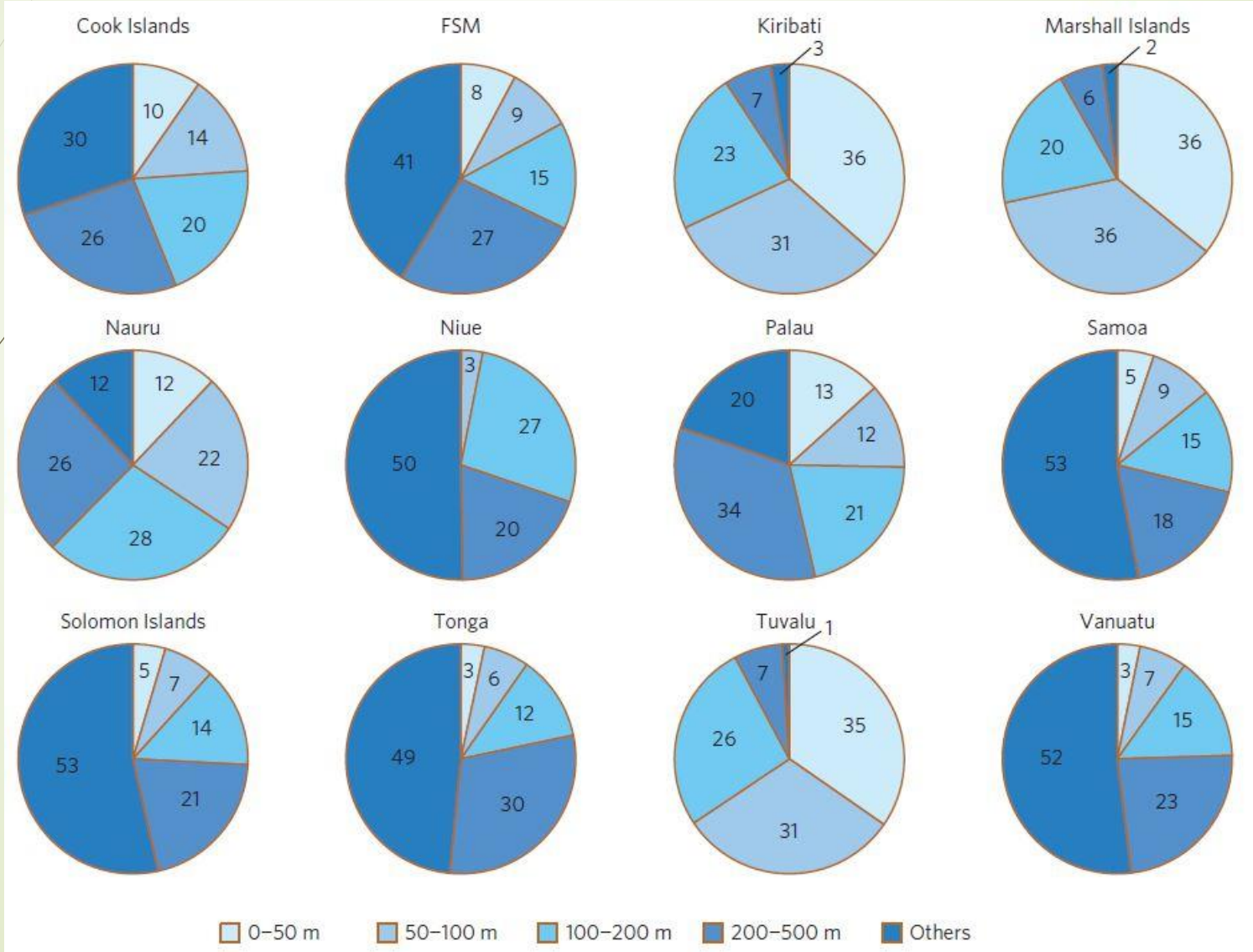
une University of New England

Example Tables in Report (for Tuvalu)

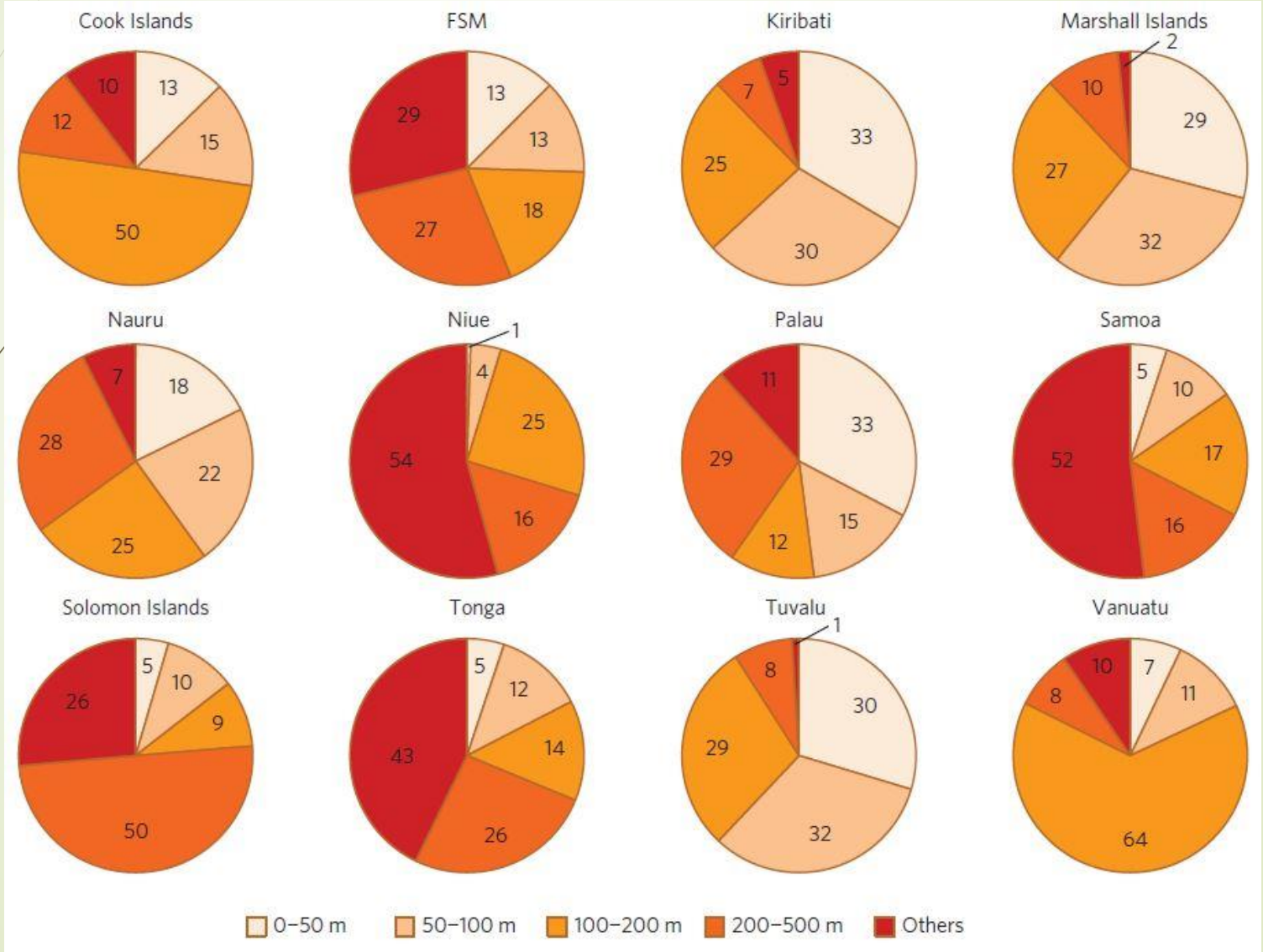
Table 6. Occupancy types of buildings located within specified distances from the coastline

Occupancy Type	0- 50m	50 - 100m	100 - 200m	200 - 500m
Residential-permanent dwelling single family (e.g. house, "fale")	590	540	488	128
Residential-permanent dwelling multi-family (e.g. flats)	13	11	14	-
Residential-out building (e.g. garages, out-houses, toilets, kitchens)	31	22	9	2
Commercial-accommodation (e.g. guest houses, hotels, resorts)	10	5	12	2
Commercial-gasoline station (e.g. petrol stations, pump buildings)	1	2	-	-
Commercial-general commercial (e.g. supermarkets, stores, offices)	34	24	36	11
Commercial-out building (e.g. garages, small storage facilities)	-	-	-	-
Industrial chemical processing (e.g. chemical plants, chemical storage facilities)	1	-	1	-
Industrial - Food and drug processing (e.g. food, crop and drug manufacturing and processing facilities)	1	2	-	-
Industrial - General industrial (e.g. mining buildings, oil/gas processing buildings)	3	3	1	-
Public – Education (e.g. preschools, primary/secondary schools, colleges/universities)	14	13	5	3
Public - Emergency services (e.g. firefighting and police station buildings)	1	2	-	-
Public - General public facility (e.g. community halls, sports facilities)	10	10	6	2
Public – Government (e.g. government offices, army barracks)	29	19	9	-
Public - Health care services (e.g. clinics, hospitals)	1	15	-	-
Public – Religion (e.g. churches)	5	8	4	2
Public - Out buildings (e.g. garages, storage facilities)	2	-	3	-
Other - Out building (e.g. garages, storage facilities)	1	-	-	-
Other	6	1	2	-
Infrastructure buildings (e.g. airport buildings)	11	6	5	3

Counts of built infrastructure (percentage of country total) within each interval from the coastline.



Replacement value of built infrastructure (percentage of country total) within each interval from the coastline.



Acknowledgements

CSIRO and the Bureau of Meteorology have provided the environmental and climate data, including projections.

The National Library of Australia, Bishop Museum, Royal New Zealand Airforce and SOPAC provided the old aerial photos.

Recent satellite images were purchased from GeoImage.

Infrastructure data supplied by PCRAFI

Please note that numbers and figures presented here are part of an ongoing research and are not final and not for citation, except for the published papers.

Further Reading and References

- Kumar, L., Taylor, S. (2015) Exposure of coastal built assets in the South Pacific to climate risks. *Nature Climate Change*, 5: 992-996. DOI: 10.1038/NCLIMATE2702.

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