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Patrice Walker, Vincent Donato

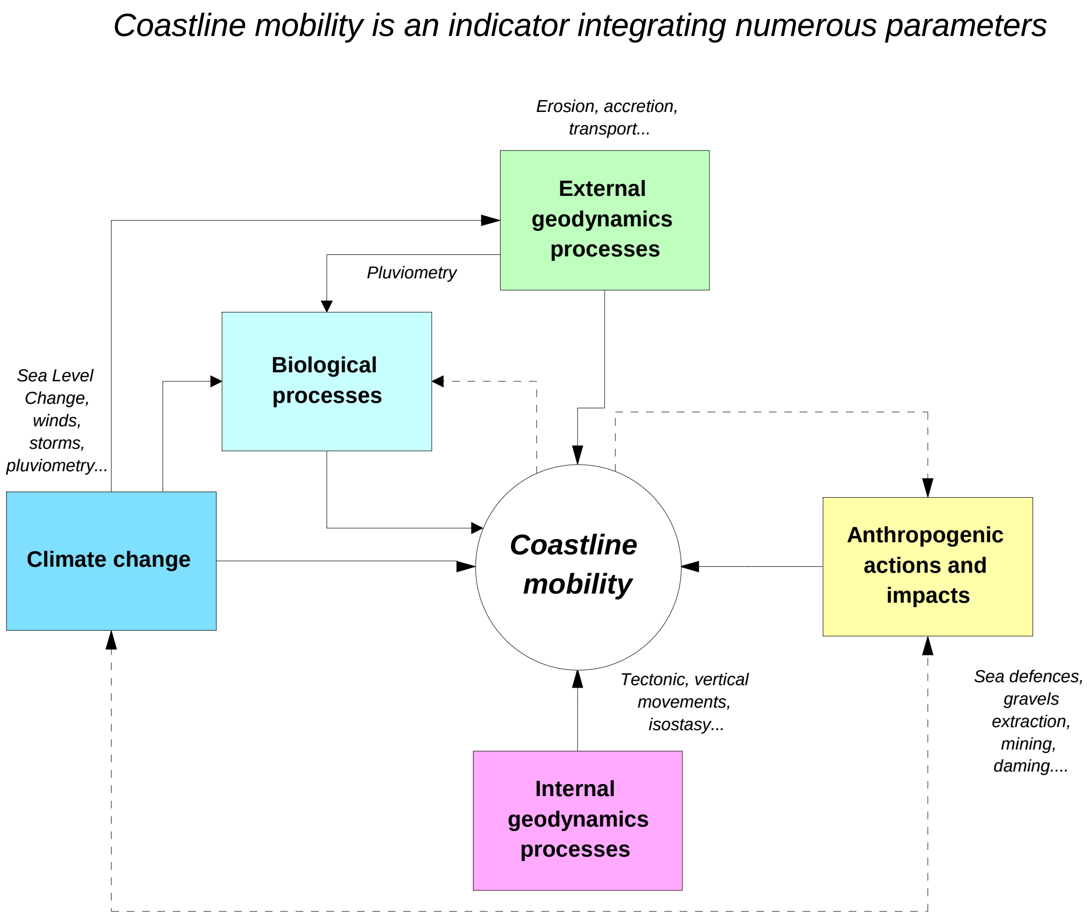
Sea level rise and coastal morphological changes on tropical islands

New Caledonia and French Polynesia (South Pacific)

The Project

- Work completed within the CECILE project **(C**oastal **E**nvironmental **C**hanges: **I**mpact of sea **LE**vel rise)=> See Poster **Le Cozannet et al.** same session
- Project objectives: to contribute to **assessing the physical impact of sea level rise on shorelines** during the recent past (last 50 years) and near future (next 100 years).
- Focus on tropical islands : **New Caledonia, French Polynesia**, La Réunion (Indian Ocean), French Caribbean
- What is the importance of recent sea level rise with respect to other causes of change ?
- What will be the consequences of sea level rise for coastal change in the future ?

Generic driving factors influencing coastline mobility, dynamics and morphology



- 5 families of driving factors affecting coastline mobility
  - Climate change
  - External geodynamic processes linked to climate change
  - Internal geodynamic processes
  - Biological processes
  - Anthropogenic actions and impacts
- To note : interactions & retroactions

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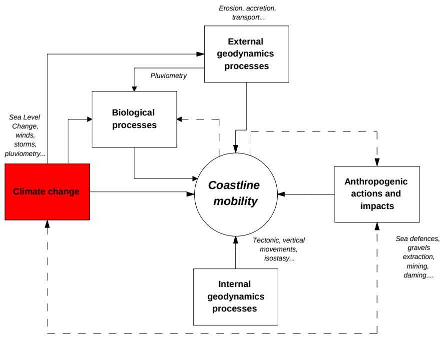
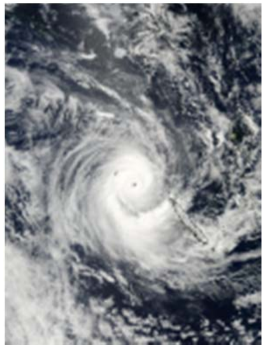
Driving factors
Or The data problem

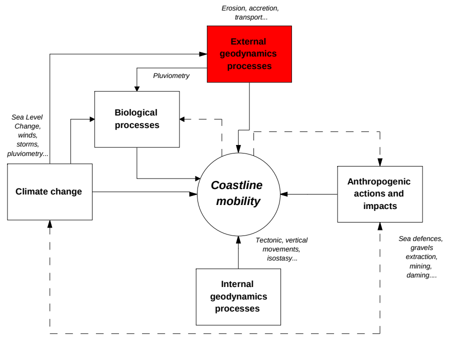


Climate change

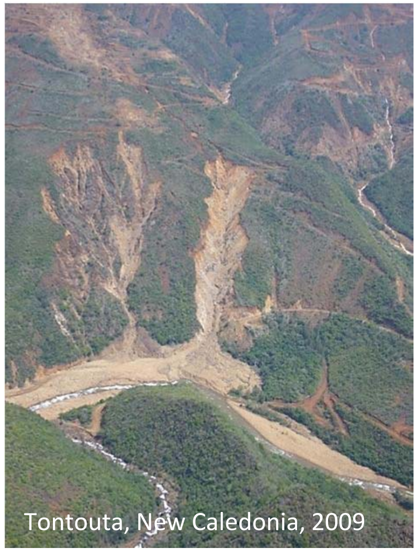


Erica 2003 (Nasa)

- Spatial variability of sea level rise
  - heterogeneous at the global scale but also at the scale of each ocean basin
- Spatial variability of CC impacts on :
  - winds,
  - storms and cyclones (frequency, intensity, trajectories), high level of uncertainty for future evolution
- Sea surface temperature (SST), salinity and acidity (pH)
  - effects on ecosystems and more particularly on coral reef systems

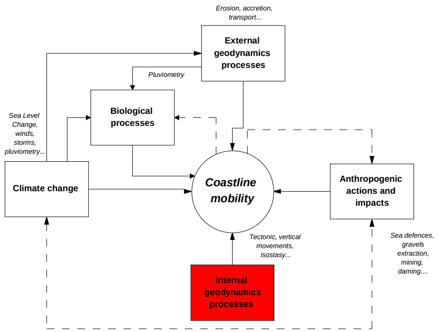


Surficial geodynamical processes



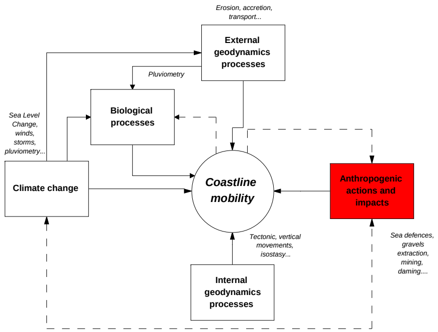
- Coastal geodynamical processes
  - variability of the impact of CC on **wave climates**
  - in consequence, variability of the littoral drift, the coastal behavior at a specific shoreline can be modified

- Surficial geodynamical processes on land that can be modified by Climate Change
  - The **surficial erosion** in the watersheds, the triggering of the **landslides**, the **sedimentary transport** in the rivers …
  - The modifications of processes on land can influence the sedimentary supply at the coast (sedimentary budget at coast), the ongoing processes can change the mobility of the coastline
  - But uncertainties in the evolution of rainfall in the CC context



The internal geodynamical processes

- The internal geodynamics can be of primary importance for coastline mobility.
  - Vertical movements generated by both tectonics or isostasy or cooling of volcanoes can counteract, compensate or amplify the local sea level change.
- Vertical movements are not necessarily homogeneous for large territories => site dependent



Anthropogenic actions with direct and indirect impacts on the shoreline mobility

- Actions with direct impacts
  - Sea defense works including (groynes, sea walls, rip rap …beach nourishments, embankments etc.)
- Actions with indirect impacts
  - Gravel and sand **extraction** (from the sea floor, from rivers)
  - River **hydraulic works** like damming (sediment trapping, lack of sediment supply to the coast by rivers)
  - **Mining activities** in the watersheds (supplementary sediment supply)
  - Modification of the **land use** (erosion processes) ;
  - Ground subsidence (exploitation of petroleum or water)
  - **Urbanization** and **pollution**


Anse Vata, Nouméa (New Caledonia)


Huahine, French Polynesia

Remarks about driving factors & coastal geomorphology

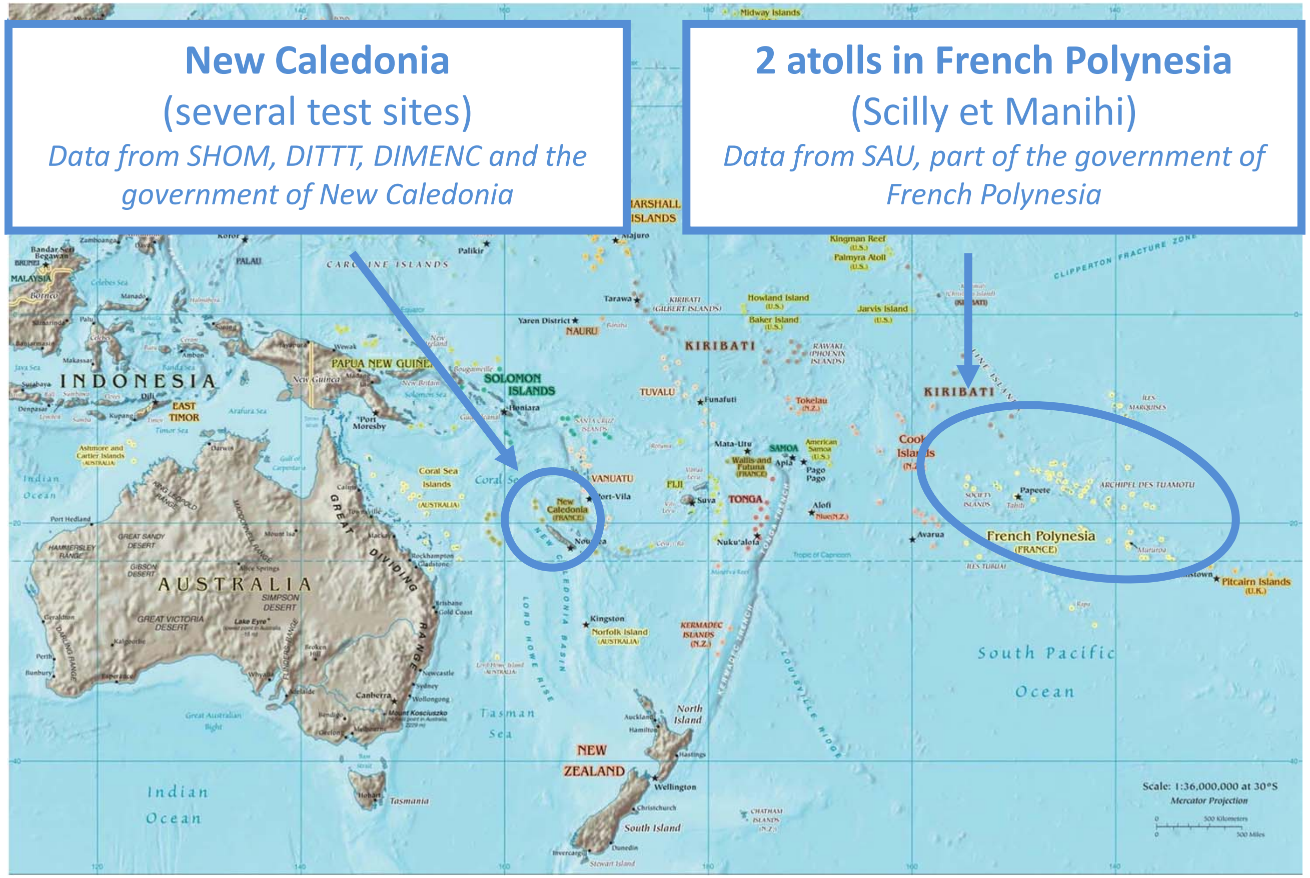
- The **variability of the forcing factors** in itself can explain why the coastline mobility is not homogeneous everywhere and why it will not be homogeneous in the next 100 years
- The same forcing factors applied in various geological & geomorphological contexts :
  - different effects
  - each type of coastal geomorphology has a different **resilience** and **coping capacity**
- Analysis of the **past evolution** of each **type of coast** to **climate changes** can give some keys to understanding the future

- The question is what is the Sensitivity of coastlines to SLR ?
  - Method
    - systemic analysis => identification of active forcing factors for each site
    - Reconstruction of past evolution of the forcing factors
      - sea level rise, vertical movements, anthropogenic actions etc.
    - Classical analysis of coastline evolution (Comparison between aerial photos (from the 50's) with recent HiRes satellite images => evolution of coastline
    - Analysis of the causal effects for the system
    - Numerous Uncertainties => SLR, quantifications of others forcing factors, complex system

Preliminary results on 2 test sites in South Pacific

New Caledonia
(several test sites)
Data from SHOM, DITTT, DIMENC and the government of New Caledonia

2 atolls in French Polynesia
(Scilly et Manihi)
Data from SAU, part of the government of French Polynesia



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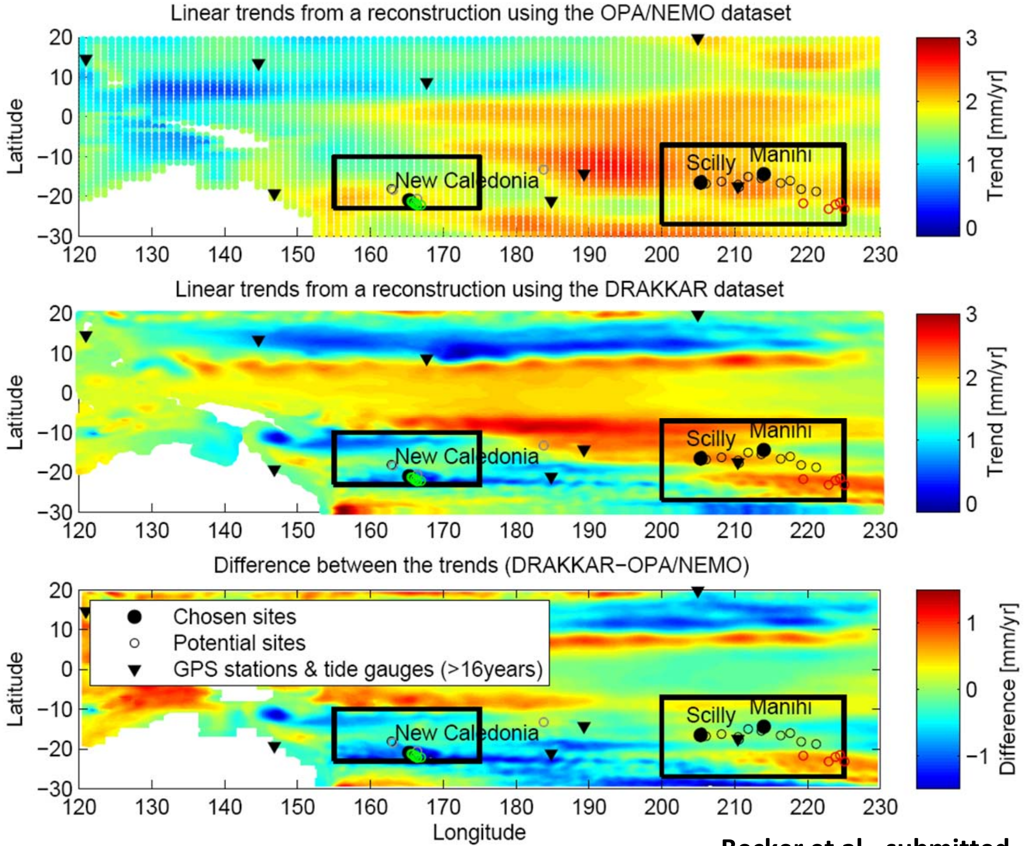
Recent SLR at the scale of the South Pacific

(1950->2002)



Becker et al., submitted

- Global sea level is rising but shows regional variability (e.g. Lombard et al. 2005)

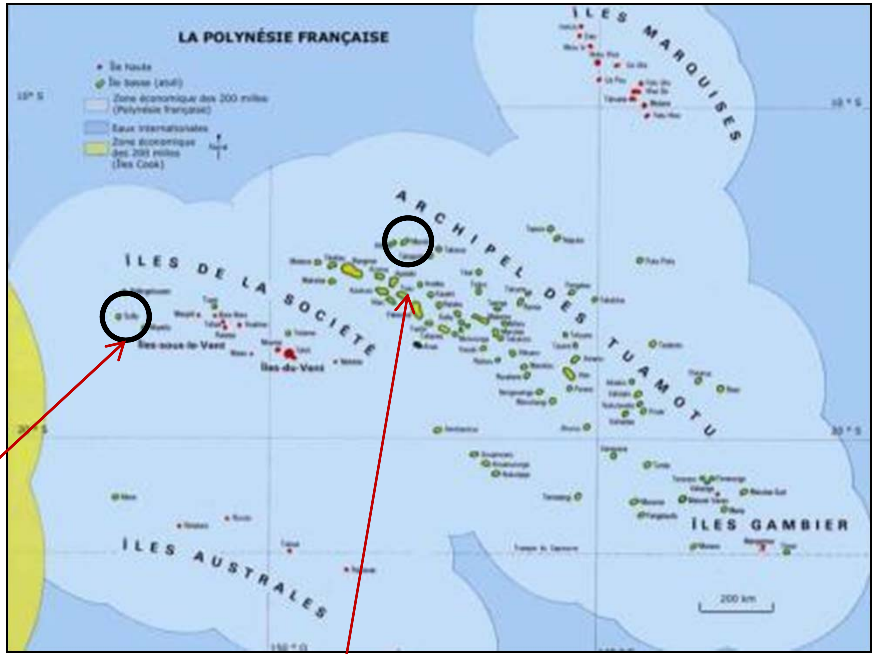
  => need to perform a regional reanalysis in order to assess the recent trends in the areas of interest

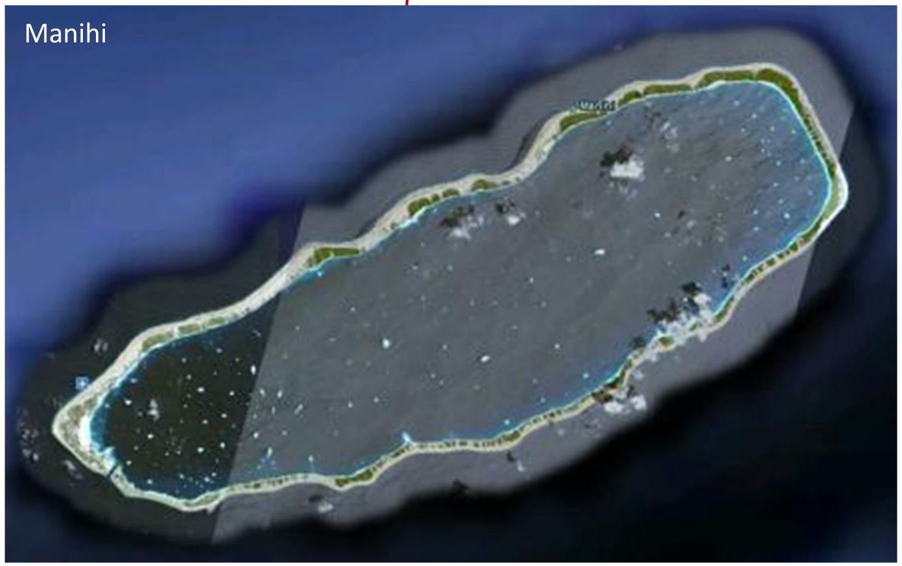
- The climate component of sea level rise can be reconstructed using global ocean modeling and tide gauge records (Becker et al., submitted) over the past 50 years

- Results obtained show that :
  - French Polynesia is affected by about **2mm/yr** of sea level rise for the 52-year period from 1950 to 2002
  - New Caledonia is affected by about **1.3mm/yr** sea level rise for the 52-year period from 1950 to 2002

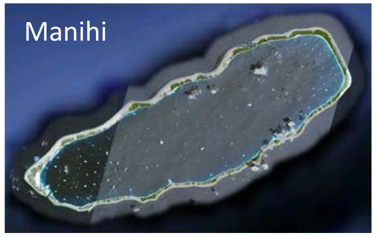
French Polynesia examples

- Work in progress on 2 atolls :
  - Manihi in the Tuamotu archipelago (27x 8 km)
  - Scilly in the Society archipelago (13x 13 km)

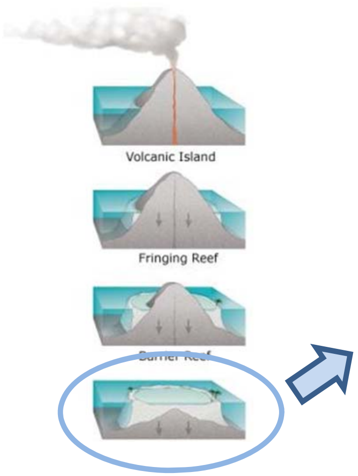


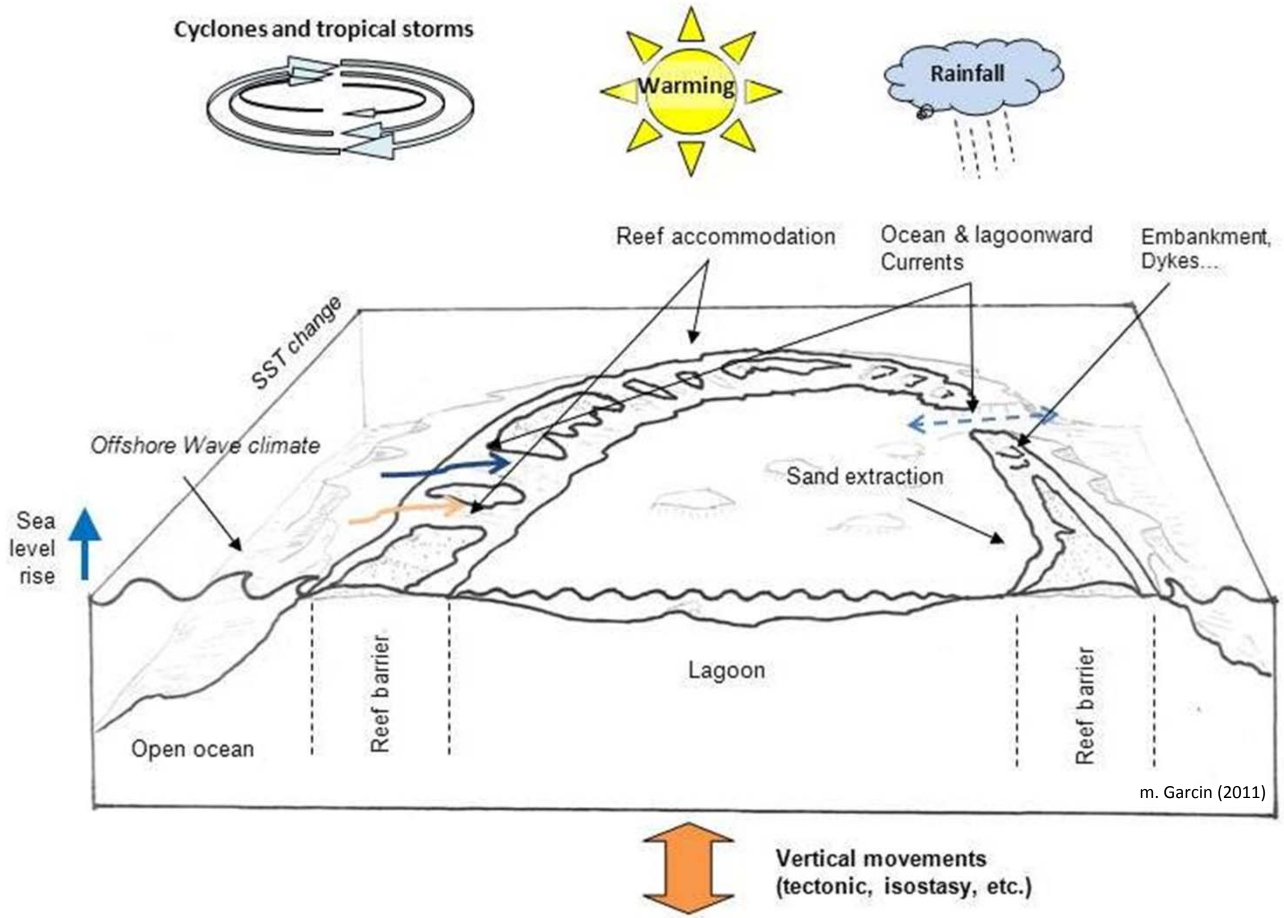


Atoll



- Reef atoll on volcanoes of relatively small size
- Relatively simple geological history
- Relatively homogen
coastal morphologi
- Direct anthropogen
impacts (embankm
sand extraction)
- No influence of
continental process





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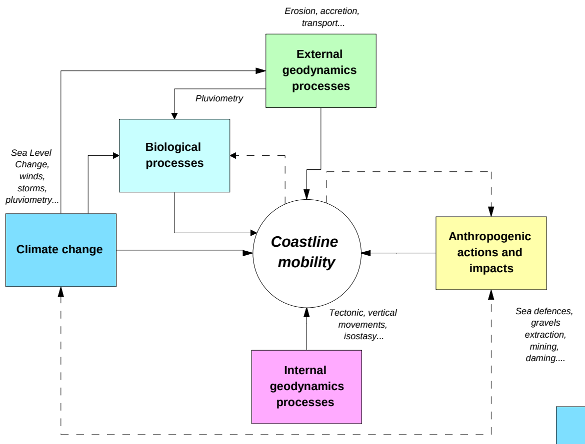
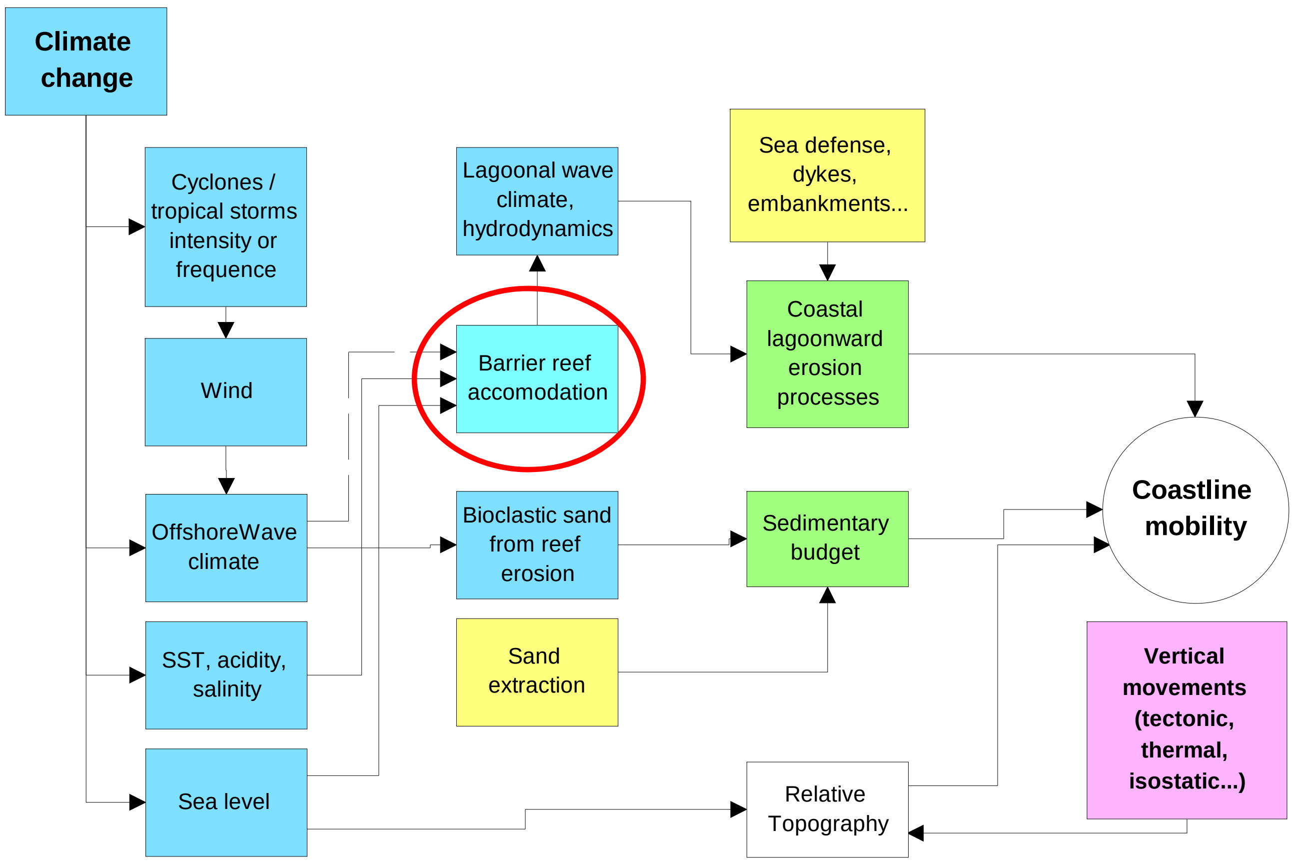


Atoll coastal system

Systemic causal graph



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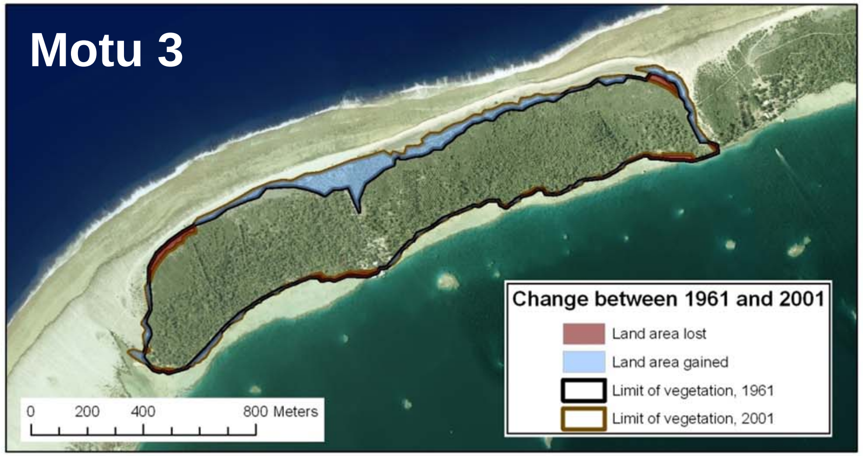
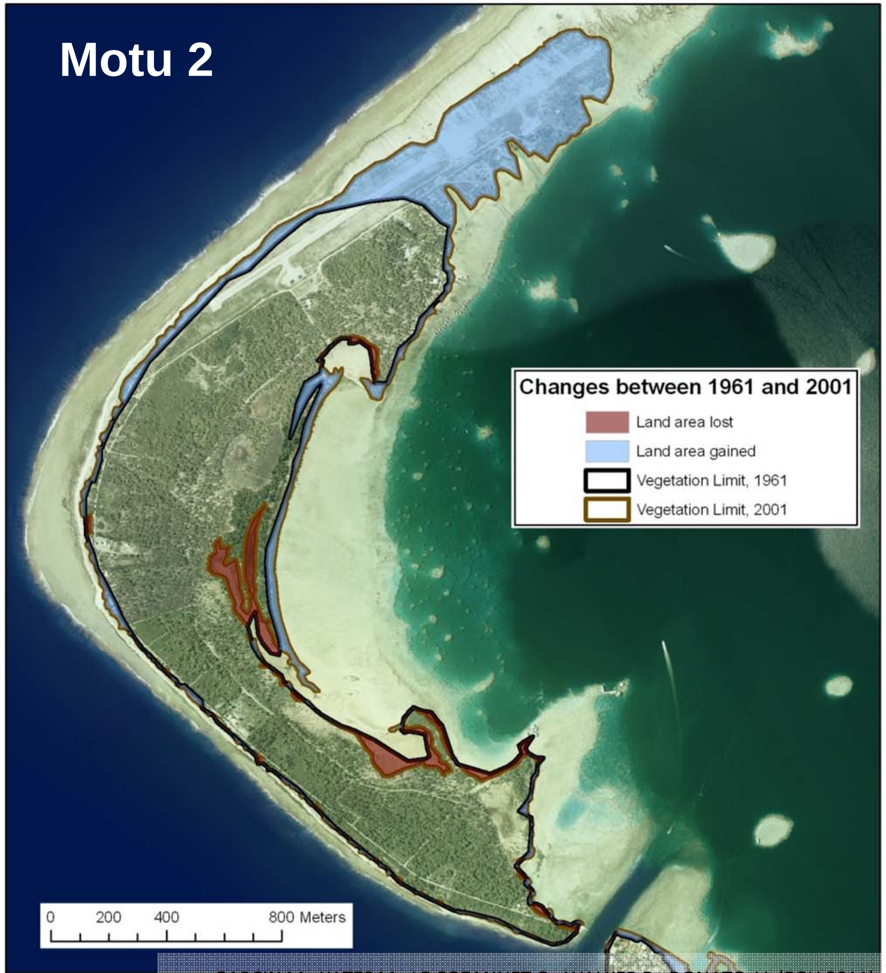
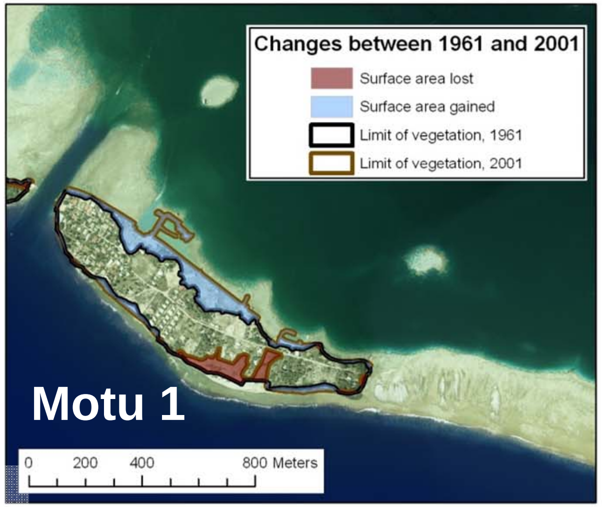
Changes in surface area of islands
(1961-2001, Manihi)



Motu	Net change	Eroded areas	New surfaces
1	*+32 910 m²*	***-19 220 m²***	***+52 120 m²***
2	*+265 420 m²*	***-70 280 m²***	***+335 700 m²***
3	*+50 140 m²*	***-17 920 m²***	***+68 060 m²***





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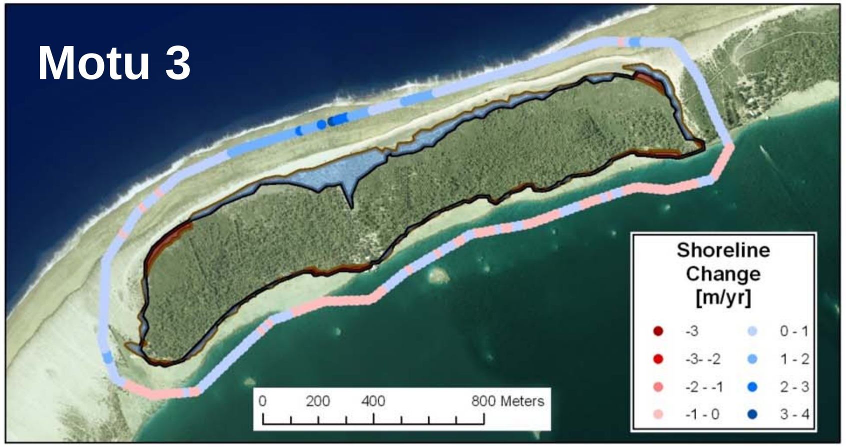
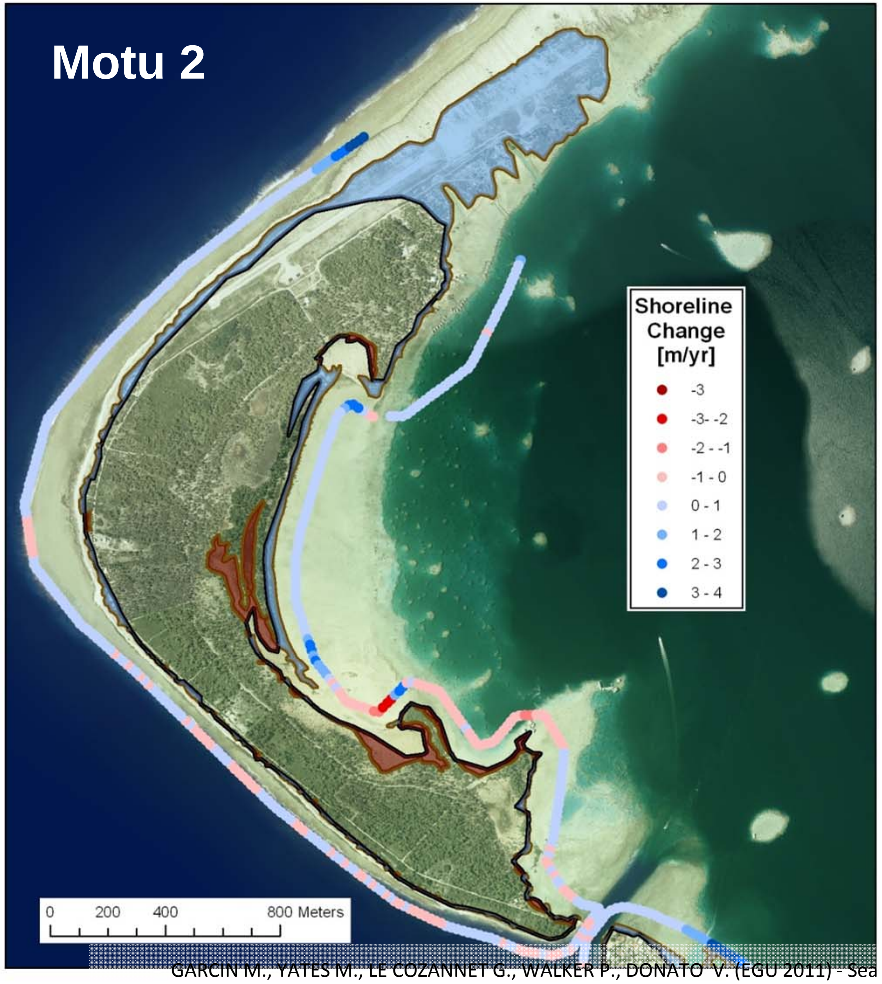
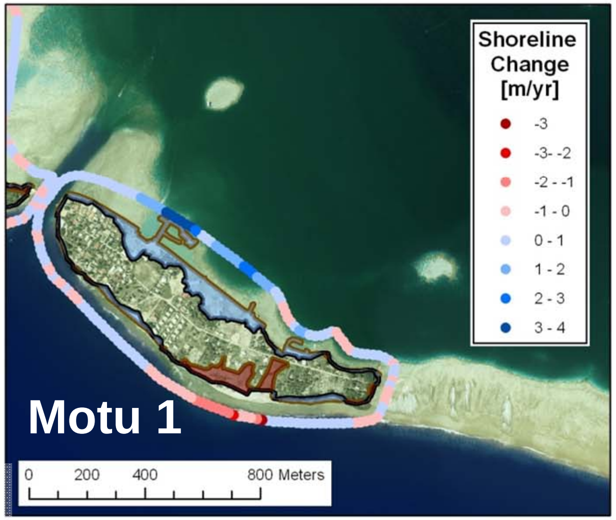
Erosion & accretion rates
Coastline evolution
(1961-2001, Manihi)





Motu	Seaward		Lagoonward	
	Erosion %	*Average rate*	*Erosion %*	*Average rate*
1	48%	-0.15 m/y	20%	0.66 m/y
2	18%	+0.44 m/y	25%	0.27 m/y
3	2%	+0.72 m/y	53%	-0.06 m/y



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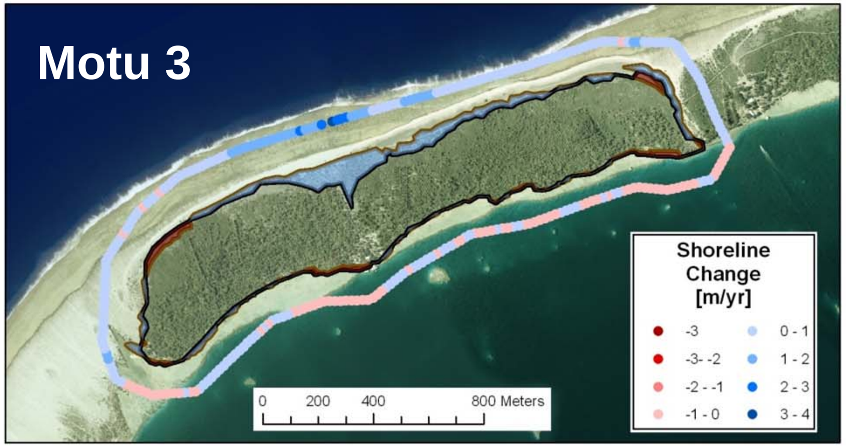
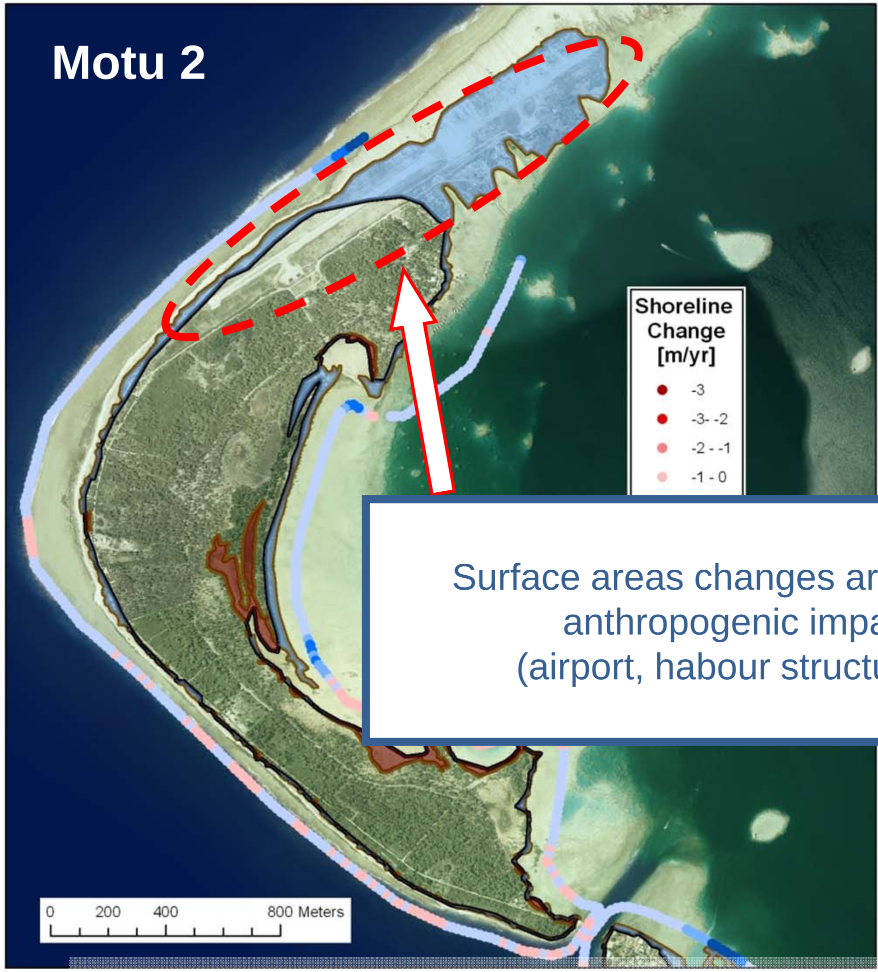
Coastline evolution





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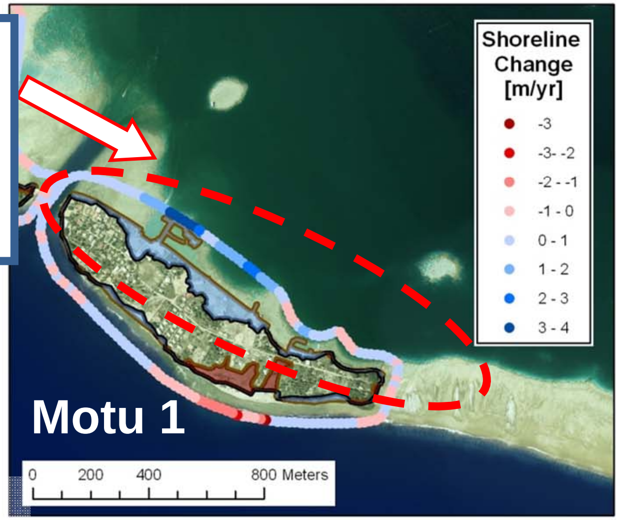
Surface areas changes are linked to anthropogenic impacts (airport, habour structures…)



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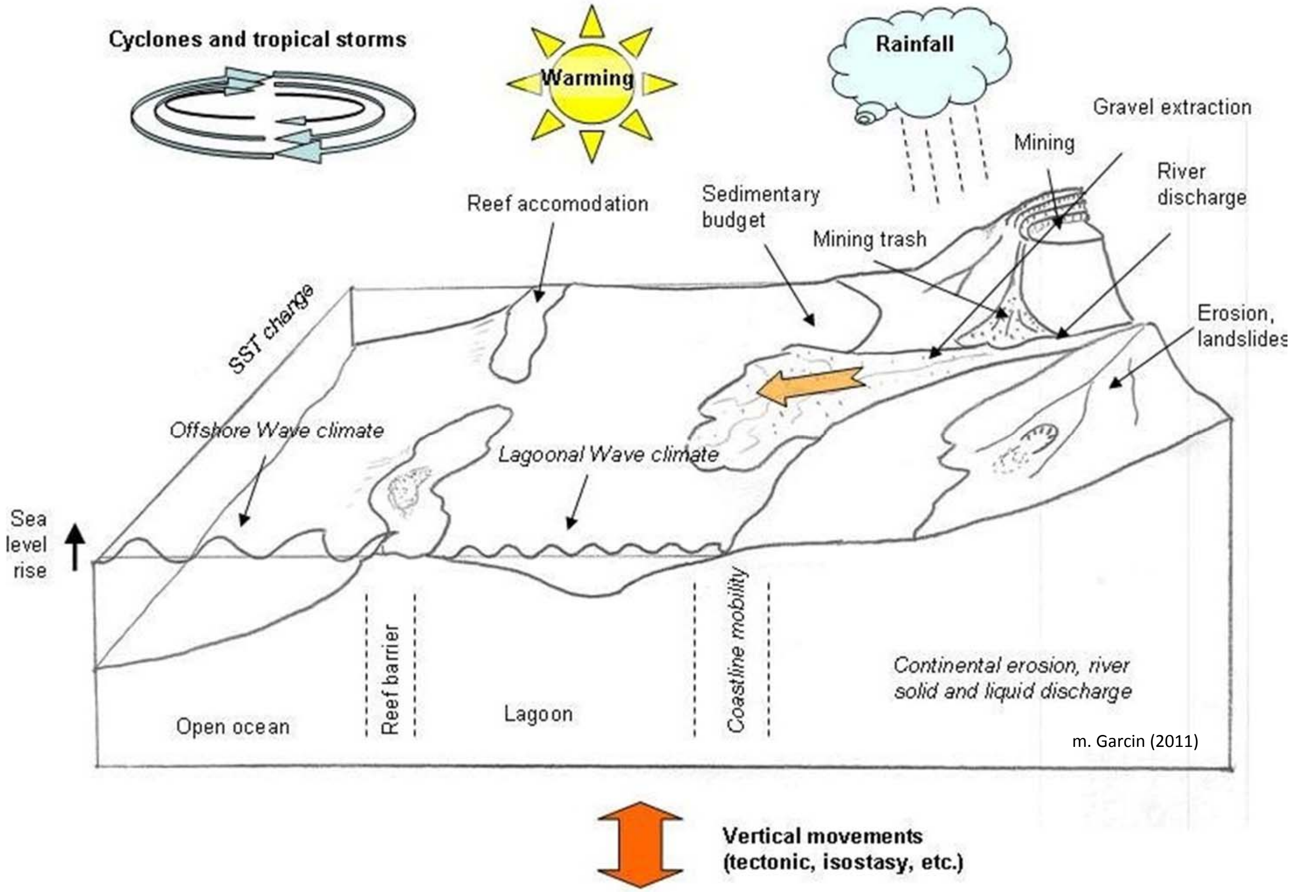
Preliminary results

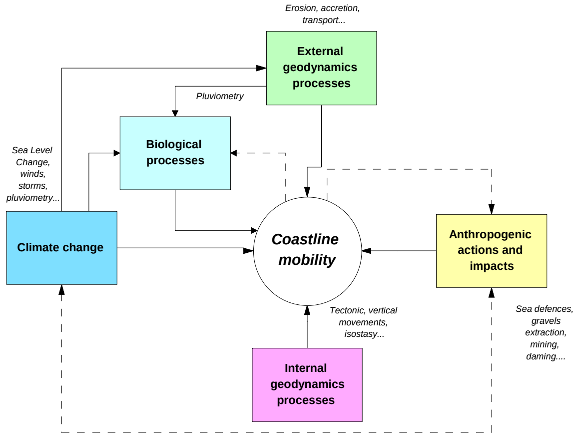
- For the 3 motu
  - The 40 yr evolution shows an increase in the surface area of the islands
  - But “Aggradation” is mainly linked to anthropogenic actions that alter the perception of the general evolution of each island
  - Currently, we have no evidence of the impact of past (recent) sea level rise, which seems to be hidden by anthropogenic effects.
  - Future work will focus on islands and atolls without anthropogenic actions in order to analyze the “natural” response
  - Then the results of the coastline evolution will be discussed taking into account the forcing factors (slr, both seasonal and cyclonic wave climates, and tectonics)

New Caledonia

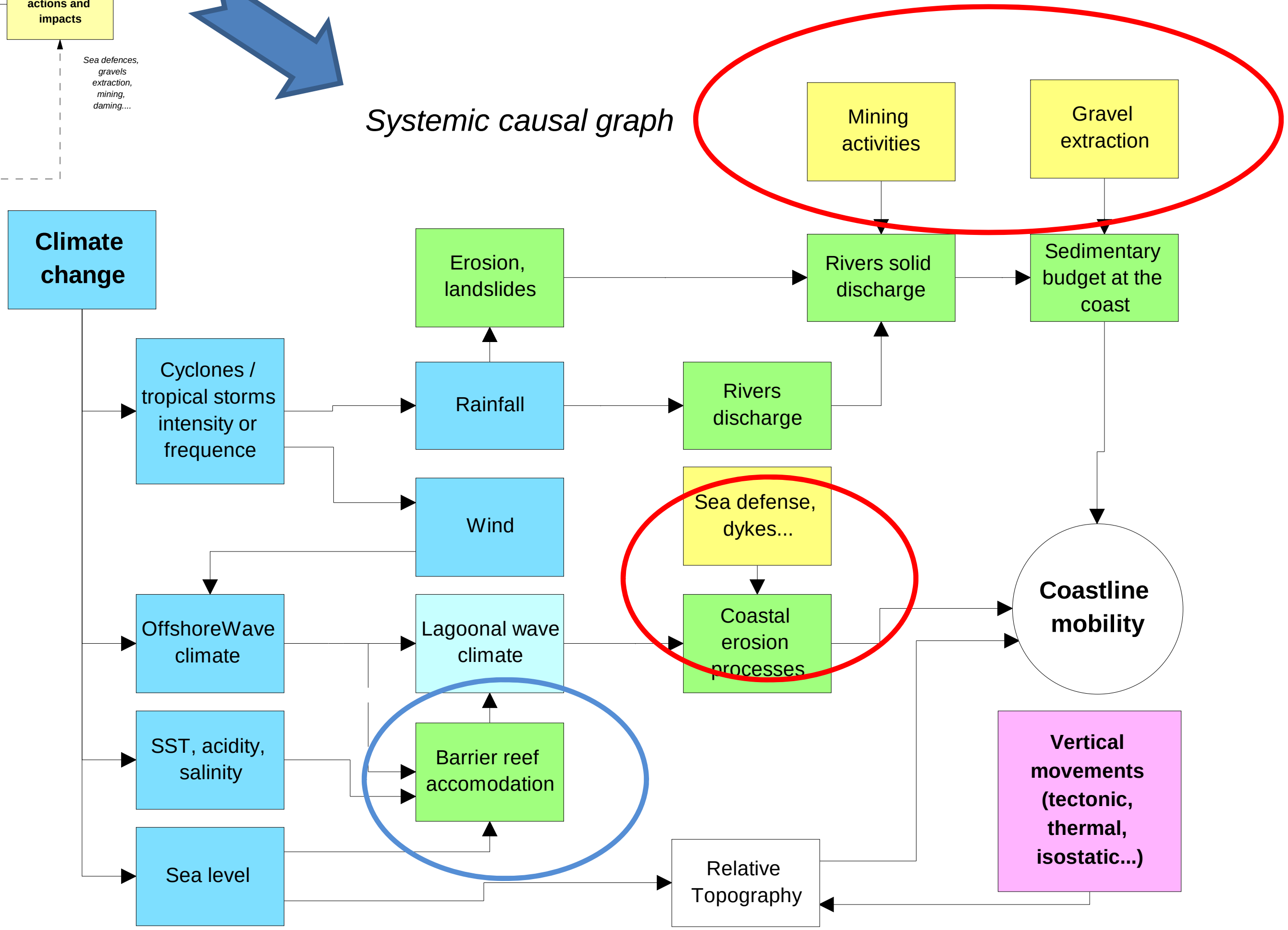
- Mountainous island (400x50km)
- Complex geological history
- Various coastal morphologies
- Large lagoon with distant barrier reef
- Influence of continental processes
- Anthropogenic impact due to mining activities
- Minimal local urbanization



coastal system of New Caledonia



Systemic causal graph



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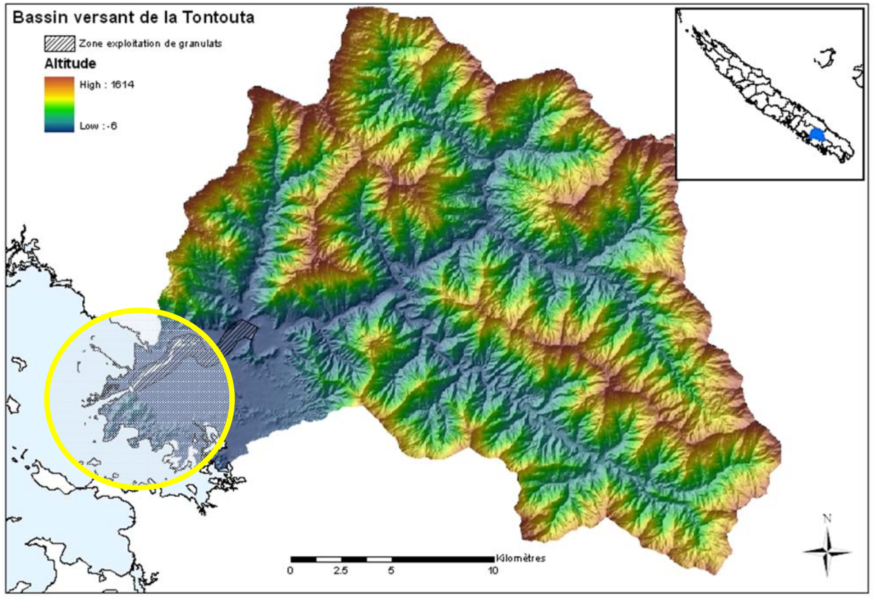
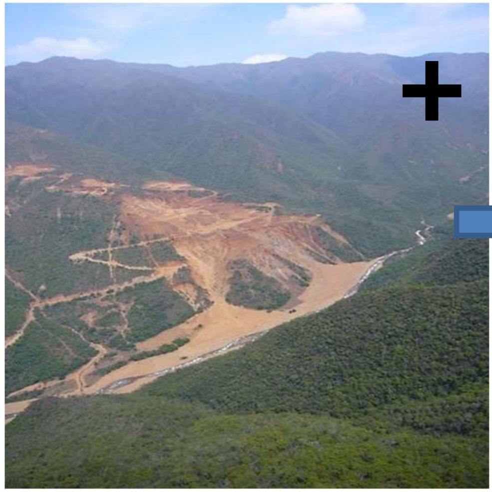
The Tontouta example



- Mountainous watershed of 500 km^2
- Homogeneous lithology: Peridotite
- Huge mining activities since the 60's (Nickel) => surficial erosion of mining areas
- Mining trash in the slopes until the mid 70's => supply of "sediment" in the watersheds
- Gravel and sand extraction in the downstream river mainly since the 90's => extraction of sediment of specific granulometry
- Vertical movement negligible
- Sea level rise around 2mm/ years

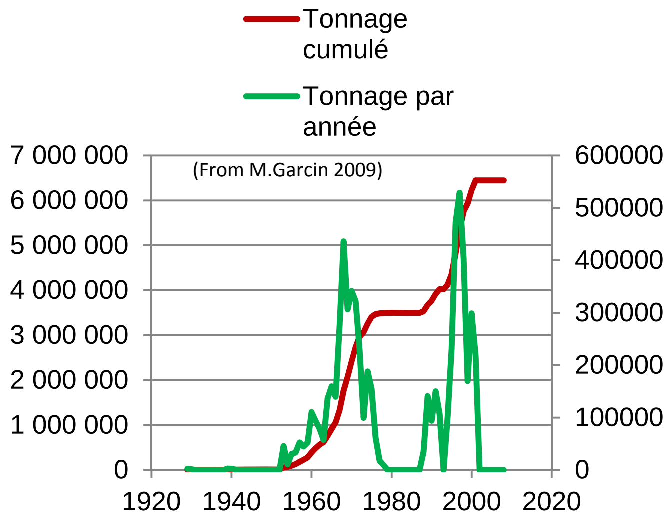
Indirect anthropogenic impacts on coastal areas: modifications of river solid discharges

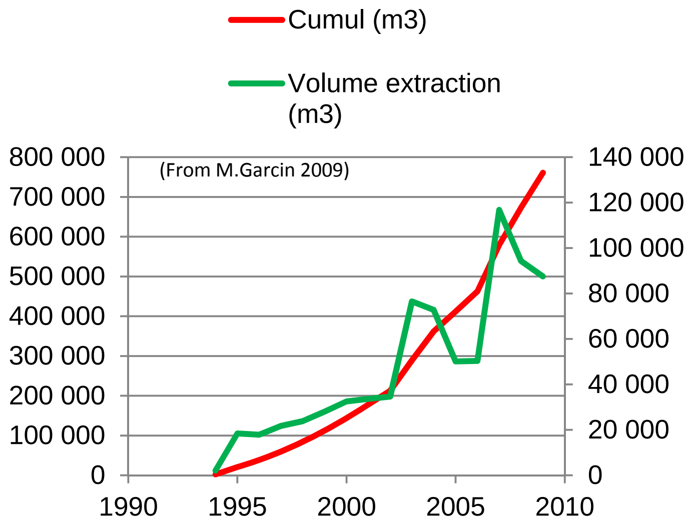
Upstream Material production
(Mining trash in watershed)



Downstream Material extraction
(Sand and gravels)

Modification of the
sedimentary budget at the coastline





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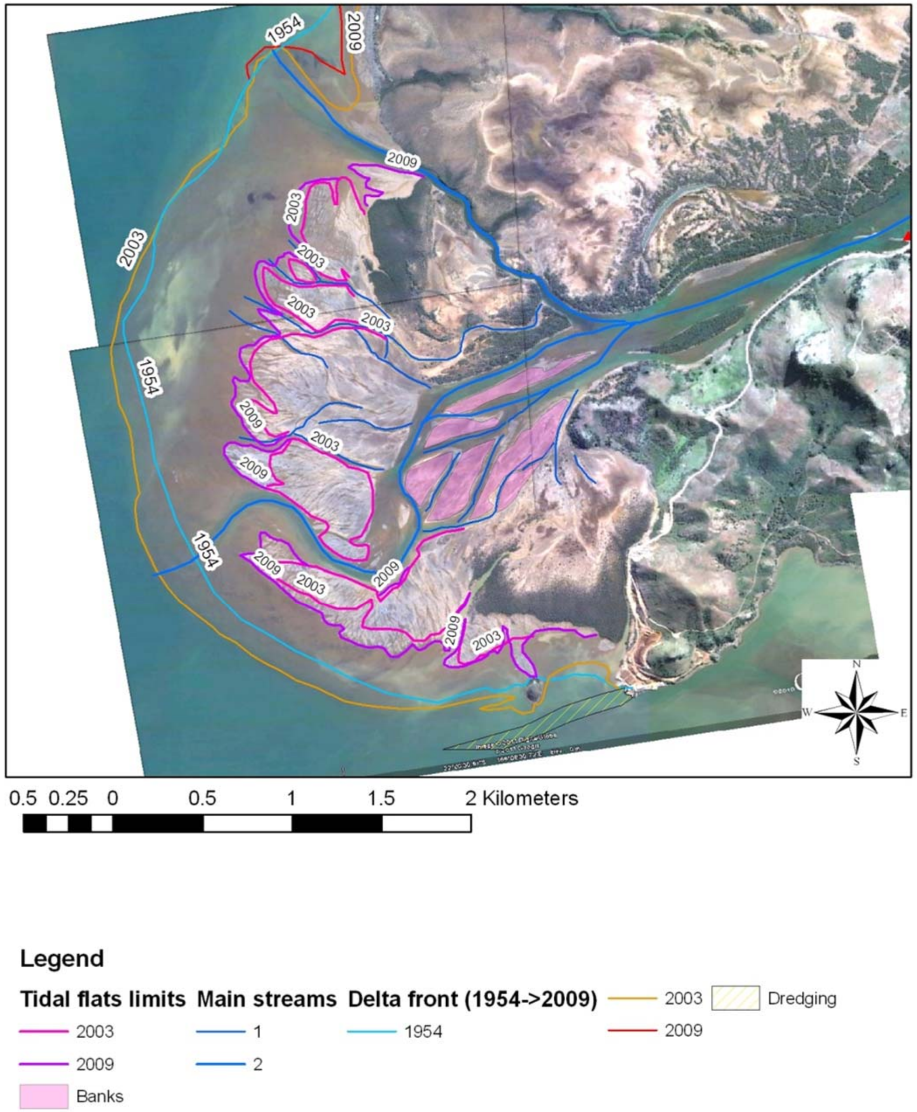
Provisional results

- Major morphological changes between 1954 and 2003, main streams pattern changes.
- Progradation of the front of the delta from 1954 to 2009 of around 200m (progradation of fine lateritic deposits)
- Apparition of silty deposit in the lower estuary of the Tontouta river
- Increasing of tidal surfaces from 1954 to 2003 and from 2003 to 2009. Progradation seaward up to 250 m but generally between 50 and 100m
- Indirect impact of human activities seems to be the major forcing factor of recent evolution



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Preliminary results

- Indirect impacts of human activities seem to be the major forcing factor of recent evolution near the Tontouta outlet
- Currently, we have no evidence of the impact of past (recent) sea level rise which seems to be hidden by anthropogenic effects
- Other sites with and without mining activities and in different New Caledonian environments and contexts will be studied in order to analyze the potential impacts of SLR

Conclusion

- Sea Level Rise
  - Non homogeneous response of the coastline
    - Function of numerous forcing factors
  - Need to assess the SLR impact on various sites in order to analyse the coastal sensitivity
  - Coastal sensitivity to SLR analysis will provide keys for the assessment of potential future effects of SLR with respect to others forcing factors
- Work in progress !

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