Coastal mobility a response to forcing factors

- If, at least a marine or a continental variable evolves, the coast tempts to adapt to this new condition
- Characterization of the pluri-decadal coastal mobility is relatively easy, but identifying the cause(s) of this mobility is not trivial
- The present question is: what is (and will be) the impact of climatic sea level rise on coasts?

The 5 main families of forcing factors

- Coastal changes is driven by 5 main categories of factors:
  - Climate
  - Others external geodynamics processes
  - Internal geodynamics processes
  - Biological processes
  - Anthropogenic actions and impacts

> The coast, the forcing factors and related parameters constitute the "Coastal system"
> Numerous interactions and feedbacks are existing between factors & attribution of causes of coastal changes to one or another factor is complex and difficult

Forcing Factor: The Climate

- Evolution of climatic parameters are spatially highly variable
  - Sea level
  - Temperature
  - Salinity and acidity of ocean etc.

- Others climatic parameters and processes acting on the coastal evolution
  - Dominant winds (trade winds...)
  - Storms and Cyclones intensity and frequency
    - In general: there remains high uncertainties on the effects of CC on cyclogenesis
  - Atmospheric Pressure

Definitions and context

- The coast is the interface between ocean and land in consequence the coast is under the influences of
  - marine processes
  - continental processes
  - human communities

- The coast evolves at different nested timescales: from geological time scale (pluri-millennia), historical time scale (centuries, decades), event time scale (few hours to few days) to physical process (hours, minutes, seconds...)

The question is: Why it's impossible to directly assign a new coastline to a given variation of the sea level?
External geodynamics processes

- CC can potentially modify winds climate (trade winds, storms and cyclones) inducing wave climates changes (wave height, orientations, frequency,…) which modify:
  - The wave energy during “normal” and extreme events at coast
  - The cross-shore currents
  - The long-shore drift currents
  - They can modify the coastal behaviour (erosion or stability) and the level of coastal erosion and flooding hazards at which each coastal segment is exposed
  - The wave climate changes have an impact on the coastline position

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Internal geodynamics processes

- At coast the relative sea level is composed by:
  - the regional climatic sea level
  - Vertical movements of ground
  - The vertical movements can counteract, compensate or amplify the climatic sea level rise giving the local relative sea level
  - Vertical movements can be of different origins:
    - Tectonic (Tuvalu, Alexandre, Loyalty islands…)
    - Isostatic (isostatic rebound linked to ice sheets melting: Fennoscandia or Laurentides, hot spot volcanoes…)
    - Thermic and linked to the cooling of volcanoes...
  - Example of biological factors: the reefs

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Example of biological factors: the reefs

- Reefs play a crucial role in the evolution of tropical islands as a biological resource, a sediment suppliers, and a protective barrier against swells and waves during storms and cyclones
- Climatic parameters like sea level, ocean temperature, salinity and acidity are crucial for coral reef life
  - The reefs have been able to accommodate the sea level changes during the Quaternary as demonstrated by numerous researchers...
  - But the remaining question is: what will be the capacity of coral reefs to accommodate in the context of higher rate of sea level rise as predicted in the future decades?

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External geodynamics processes

- The CC affects also precipitations (pattern, frequency, intensity) on lands which indirectly modify:
  - At the watersheds scale
    - Runoff and surficial erosion of soils
    - Triggering of landslides (impact on frequency and intensity)
    - >> inducing indirectly modification the supply of sediment to the rivers
  - Water and sediment discharges of rivers at outlets
    - >> modification of the sediment supply at the coast and thus the coastal sedimentary budget which can lead to a modification of the coastal behaviour and mobility (erosion or stability) of the coast
    - Likely indirect incidence of rainfall changes on the coastline position

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Example of biological factors : the reefs

- CC induced also an increase of SST and of the acidity of ocean
- Reefs are very sensitive to these parameters; exceeding a threshold for one of these parameters leads to a coral bleaching… and decreases their adaptation capacity to accommodate to the sea level rise.
- >> What will be the impact on the reefs (barrier and fringing) of SST, salinity and acidity changes?
- What will be the impact of reefs evolution on the coastal mobility, on coastal hazards?
Example of biological factors: the mangroves

- Important role of the mangroves in the coastline evolution: role in the sedimentation rates and protection against erosion and waves during extreme events.
- Mangroves are influenced by rises of sea level, CO2, air and water temperatures, precipitation: pattern, frequency and intensity.
- All these parameters influence the mangroves evolution, what impact on mobility of coastline?

Example of anthropic factors: coastal systems

- Two different types:
  - Direct actions on the coast
  - Indirect actions which didn’t affect the coastal system but have an impact on it.
- Direct and indirect actions have impacts on the coastal system, wanted or not... sometime at short time and sometimes at longer timescale.
- Direct anthropogenic actions
  - Coastal defense works (against erosion or submergence)
    - Hard: breakwaters, dikes, groynes, rip-rap, levees etc. (strategy "hold the line")
    - Soft: vegetation, polders etc...
    - Intermediate: beach nourishment (strategy "advance the line")

Example of biological processes

- In more temperate seas, biologic productivity of benthos (bivalves, gastropods...) can be affected by CC with incidences on the production of biofilms
  - This modification of bioclasts production can modify the sedimentary budget of bioclastic sandy beach and shells ridges
  - Modifications of the beach resilience to erosion and in consequence to coastline changes.

Example of Direct anthropogenic actions

- Coastal facilities
  - Harbours, Wharf,
  - Embankments for roads, railways, airports...
  - Promenades
  - Sea side urban facilities...
- The main objective of direct actions is to "hold the line" => direct incidence on mobility of coastline and resilience.

Example of Indirect anthropogenic actions

- The indirect anthropogenic actions are various. The feedback effects on coastal zone were generally not wanted or even imagined
  - At the watershed scale
    - Hydroelectric works within the rivers: ex. Damming trapping sediments
    - Extracting sand and gravels in the rivers
    - Changes in the land use and land cover induced to some modification of erosion processes
    - Deformation, reforestation, crops development, urbanization...
    - Open cast mining etc.
  - Modification of the sedimentary fluxes in the river outlets modifying the coastal sedimentary budget
  - Modification of coastal sedimentary budget => potential aqua-environmental changes

Example of Offshore

- Dredging of marine sand and gravel decreasing the shoreface sedimentary stock used during the lowess stage of sandy coastline
- Offshore/offshore
  - Pumping water (e.g. Morobs..), petrol and gas induce ground subsidence with impact on the local relative sea level (e.g. Mexico Gulf...)

The effects of anthropogenic actions can be summarized as follows:
- Modification of coastal sedimentary dynamics and fluxes
- Degradation of the functioning of the coastal systems...
  - all these changes lead frequently to:
    - a loss of coastal resilience to the extreme events...
    - a modification of the coastal hazards...
    - coastline changes...
Concluding remarks on forcing factors

- The number of interacting factors playing a role on the coastal dynamics and coastline mobility is largely enough to explain why the coastal change is highly variable, and why this will remain so...
- Moreover, the forcing factors and parameters act on coasts with highly variable characteristics...

THE COASTAL VARIABILITY

Geomorphological contexts

- 2 main types of coast: accumulating coasts or ablatting coasts
- Accumulating coasts
  - Beaches, marshes, estuaries, deltas, reefs...
  - The behavior of a coastal strip can be variable (erosion, stability, accretion) according to season, year or decades
  - Reversibility of coastline behavior; possibility of a recovery phase after erosional event, resilience
  - Sensitivity to cross-shore and drift currents, waves, storm surge and to evolution of the sedimentary budget

Accretion, stability or erosion

- Ablating coasts: rocky coasts and cliffs
  - Irreversibility of coastline retreat
  - Importance of the lithology, fracturation, weathering (humidity and frost) in the evolution of rocky coasts
  - Sensitivity to wave action and sea level

Geomorphological contexts
SOME EXAMPLES FROM SOUTH PACIFIC ISLANDS...

Geology and geomorphology conclusion

- Same forcing factors applied to different geomorphological and geological contexts:
  - Various and different effects
  - Each coastal type have its own resilience and adaptive capacities to evolution of forcing factors like sea level changes
  - For evaluating the impact of CO2 on coasts it is necessary to realize a typology the coast taking into account the local geomorphological and geological context
  - The analysis of past evolutions on each type of coast to a changing sea level is a key for understanding the future behaviour of the coasts

Simplified scheme of processes affecting the shoreline in a Polynesian atoll

Simplified systemic graph of coastline mobility of an atoll

Schematic of a high island (New Caledonian example)
Simplified systemic graph of coastline mobility of a high island

- Results show that the coastal evolution the last 5 decades is highly related to the % of bare soils generated by open cast mining on the watershed (Garcin et al. 2013)
- An indirect anthropogenic action is the main contributing factor of coastline mobility, during the last 5 decades, while the sea level rise and other parameters seem to be of a secondary importance

Conclusions

- Sea level is only one of the forcing factors of coastal evolution
- Interactions (and feedbacks) between processes are numerous
- Studies about impact of CC on coastal areas must take into account:
  - global, regional and local parameters, each one influencing the coastal behaviour
  - Multi temporal approach: the present and future evolution is linked to the past history and the evolution trend (residual effect of some changes in the parameters and processes affecting the coast)
  - Multi disciplinary works are necessary in order to take into account the complexity of determining the impact of the CC on coastal systems

- Understanding what could be the future of the coasts in a changing climate imply to take into account all processes acting on their evolutions, a systemic analysis of the problem seems to be a possible approach.

The Caledonian estuaries

- In New Caledonia, analysis of 12 peri-estuarine coastal sites were done
- Analysis of the coastline evolution during the 50 years have been realised
- The evolutions of coastline are highly variable from high rate of erosion to high rate of accretion
- Analysis of forcing factors and parameters (marine, continental and human) were done