Physical Basis of Vulnerability in Small Island Developing States

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Physical exposure and associated vulnerability ... represent just one aspect of the social-ecological system in island communities.

Vulnerability ...

can be far broader, extending to health, poverty, equity, access to basic services, technical capacity, critical infrastructure, among others.

Community resilience ...

requires appropriate institutional, cultural, social, and policy mechanisms to support flexible and proactive adaptation.
But physical exposure, safety, impacts on infrastructure are important considerations

The geological, climatic, and oceanographic context are fundamental to the nature of exposure, vulnerability, and risk in any island community

Manihiki, Cook Islands
© S.M. Solomon, SOPAC, 1996
Components of physical forcing …

- sea-level rise and variability
- saline intrusion
- sea-surface temperature
- wave climate
- storm surges
- tsunamis

Some issues such as local (relative) sea-level rise, saline intrusion into island aquifers, or tsunamis, involve a combination of geological and climatic or oceanographic factors
Combined with management practices and the nature of development, these define exposure to coastal hazards which may engender impacts requiring adjustment (adaptation) to minimize their negative effects.
Small islands

- remoteness
- extensive exposure to coastal hazards
- small size + low elevations
- institutional constraints
- high costs and limited financial resources
- limited technical capacity
Tropical small islands

- coral reefs (atolls, fringing reefs)
- mangrove
Island types

Atolls

• volcanic core submerged
• reef-rimmed lagoon
• settlement on atoll-rim islands
• thin freshwater lens
• no high ground
Island types

High islands

• volcanic highlands or continental fragments
• runoff & sediment discharge
• settlement on fringing lowlands
• protective fringing reefs

Mahé, Seychelles
© GSC, 2005
Island types

**Raised atolls**

- uplifted atolls
- dry interior former lagoon basin
- fossil reef rim
- terraces and cliffs
- narrow fringing reef

Niue
© Forbes, SOPAC, 1996
Coastal hazard exposure varies with island type (and region)

Tsunamis –
All islands exposed but shallow shelves may promote shoaling and amplification - islands atop seamounts may be less susceptible (example: Seychelles)

Wave impacts and overtopping –
Atolls and low-lying fringes of higher islands, also raised atolls with deep water adjacent to cliffs (example: Niue)

Sea-level rise, inundation, coastal stability –
Atolls and low-lying coastal fringes of higher islands, exposure mitigated by mangrove or healthy reefs (examples: Fiji and Kiribati)
2004 Indian Ocean Tsunami – impact on the Seychelles

- Broad shelf promoted shoaling and refraction/diffraction to back side of high islands (Mahé and Praslin)
- Seychelles atolls rising from abyssal depths were largely unaffected

Jackson et al., 2005, GSC Open File 4539
Niue (raised atoll) – wave impacts

Cyclone Ofa (Feb 1990)
• Max wave height ~18 m
• Church destroyed (25 m asl)
• Hospital 50% destroyed (18 m asl)
• Hotel wrecked & boulder in bar
  (100 m landward of 18 m cliff)

Cyclone Heta (Jan 2004)
• Category 5 storm
• Catastrophic damage in Alofi
• $85M damage (2004 NZD)
  (5 x 2003 GDP)
Coastal stability is a function of …

• wave energy
• sea level
• resistance to erosion
• sediment supply

→ which may depend on reef health and production of biogenic sand
Exposure may be mitigated and resistance to erosion increased where mangroves are present along the shore …

Removal of mangrove exposed this community to erosion, leading to construction of partially effective shore protection.
Changing sea levels

- Rising mean sea-level
- Tides, ENSO variability, storm surges, extreme high water events all ride on the mean sea level
- Deepening over fringing reefs promotes erosion
- Seawater contamination of freshwater aquifers
- Potential for inundation of atoll islets and other low coastal lands

Extreme high-tide
South Tarawa
January 1996
Past, Present and Future Global Sea Level

AR4 - Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

© IPCC AR4 2007
Global sea-level projections – IPCC AR4 and later

- 90 year projections (2010-2100)
- post-IPCC papers project greater sea-level rise
Projected SLR departures from 2070 mean

Source: CSIRO
Meltwater from ice sheets and glaciers is not distributed uniformly ...

Central Pacific islands, in particular, see amplified sea-level rise from all three meltwater sources

Range of models and geographic effects of fingerprinting

- 90 years local sea-level rise (2010-2100)
- Fingerprinting augmentation can be additive in tropics
- Examples from Gilberts, Marshalls, Grenadines, & Seychelles

![Graph showing local sea-level rise (2010-2100) with indications of 1.0 m and 2.0 m increments.]
Summary

- Realistic physical impact projections are a prerequisite for effective adaptation planning.
- There is a need for monitoring of evolving physical exposure.
- Hazard mix and severity vary with island type and regional setting.
- Coastal stability requires maintenance of healthy coastal ecosystems.
- Degradation of protective reefs will increase exposure to erosion.
Summary
(continued)

- Effective adaptation to sea-level rise requires realistic projections, which need to incorporate latest climate science, knowledge of local vertical motion, regional ocean dynamics, and ice-melt fingerprinting
- Precautionary approach requires robust island-specific projections for the full range of realistic SLR scenarios
Thank you  Merci
Vinaka
Kam rabwa
谢谢 (Xie Xie)