GLOBAL SEA LEVEL RISE: POLICY AND PLANNING IMPLICATIONS FOR HAWAII'S COASTAL COMMUNITIES

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Introduction

The last century has seen a rapid increase in land use along the coasts with continued development of heavily populated coastal regions worldwide. Communities have become increasingly vulnerable to sea-level rise and variability. Rising sea levels will contribute to increased storm surge and flooding, and may lead to more frequent and destructive damage to coastal infrastructure. Rising sea levels will also contribute to the erosion of sandy beaches. Global sea level rise projections for this century range from 0.2 m to 5 meters. Research of sea-level rise and variability along with projected shoreline positions will result in improved recognition of hazards and allow government to evaluate and plan for various response strategies. Future structural and non-structural adaptation measures will need to include updating flood zone maps and shoreline setbacks to include sea level rise projections, enhancing coastal building codes, elevation-based building restrictions and relocating critical infrastructure vulnerable to coastal hazards.

The coastal zone has dramatically changed in nature and function due to increasing urbanization and development. The last century has seen a rapid increase in land use along the coast with continued development of heavily populated coastal regions worldwide. Simultaneously, human populations and related development have spread into many new coastal and low-lying areas with relatively little regard or recognition for potential natural hazards and shifting ecosystem baselines. In 1990, 23 percent of the world's population (or 1.2 billion people) lived both within a 100 km distance and 100 m elevation of the coast at densities about three times higher than the global average. By 2010, 20 out of 30 mega-cities will be on the coast, with many low-lying locations threatened by sea-level rise (WCRP, 2006).

Coastal communities have become increasingly vulnerable to sea-level rise and variability—as Hurricane Katrina recently demonstrated in the Gulf coast. Rising sea levels will contribute to increased storm surges and flooding, and may lead to more frequent and destructive damage. Rising sea levels will also contribute to the erosion of the world's sandy beaches, 70 percent of which have been retreating over the past century (WCRP, 2006). The impact of higher Global Mean Sea Level (MSL) has especially profound impact to low-lying islands and other coastal-dominated communities such as Hawaii.

Hawaii's vulnerability to coastal hazards will be greatly exacerbated due to sea level rise. Hawaii's resource and regulatory agencies must evaluate the potential for coastal hazards and assess the impact of elevated sea level. An improved level of understanding of sea-level rise by Hawaii's policymakers and land use planners will help reduce misconceptions and uncertainties associated with sea-level rise projections. Media and public attention to the issue may also encourage serious dialogue about responses eventually leading to proactive mitigation measures. Specific coastal hazard adaptation measures that can be implemented now include enhanced building codes, restrictions building in flood zones and relocating existing infrastructure.

Contributions to Sea Level

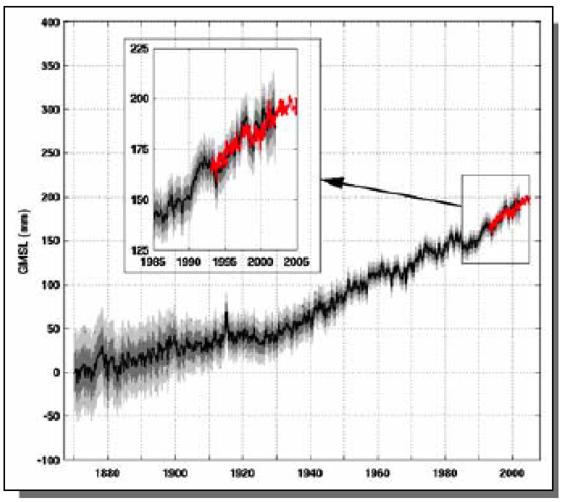

Figure 1. Monthly averages of Global Mean Sea Level from tide gauges (black 1880-2001) and altimeters (red, 1993-2004) (WCRP, 2006)

Modern global sea level rise rates are on the order of 3.0 mm/yr and are projected to continue to increase. Modern climate research has been intensely focused on the mechanics of the resultant sea level change from ice sheet melting. Some scientists estimate polar warming by the year 2100 may reach levels similar to those of 130,000 to 127,000 years ago that were associated with sea levels several meters above modern levels (Overpeck et al, 2006).

Historical and Present Sea-level Change

Modern measurements of sea level change are carried out by either tide gauges or satellite altimetry. Satellite observations available since the early 1990s provide more accurate sea level data with nearly global coverage. Beginning in 1992, global mean sea-level has been observed by both tide gauges and altimeters to be rising at a rate of 3.2 ± 0.4 mm/year, compared to a rate of 1.7 ± 0.3 mm/year from tide gauges over the previous century (Figure 1).

Discussion

Global and local sea level change is of profound interest to researchers and planners due to it enormous potential impact on human populations living in coastal regions. A brief evaluation of current sea level rise projections for this century produces a wide range of estimates with various damage estimates are projected based on these estimates (Table 1). The Brunn Rule is a commonly used coastal engineering principle that provides a generic ratio for sea-level rise to shoreline retreat given that every increment of vertical rise will produce 50 to 200 units of horizontal change in shoreline position (Brunn, 1962). The theoretical ratio of horizontal change is largely dependant on the slope and the geology of the region. If we assume a conservative ratio of 1:100 (vertical to horizontal) we can estimate the shoreline position change for a given predicted sea level rise scenario (Table 1).

Alternatives and Solutions

As we have seen, even small but rapid increases of sea level can have profound environmental, social, and economic impacts on the world's coastal areas. The latest IPCC report (IPCC 2007) highlights the consequences of decisions made in today's world regarding climate change. With a conservative estimate of sea level rise of one meter, most coastal communities will be forced to choose

Table 1. Sea Level Rise Coastal Damage Scenarios Oahu, Hawaii.

Sea Level Estimate by 2100	Sea Level rise (m)	Shoreline Change Brunn Rule	Damage Threat	Possible Impacts	Vulnerable Infrastructure
IPCC 2007 B1 (Low)	0.18-0.38	18 – 38 m	Low	Tidal inundation, minor erosion.	Wetlands, Private property.
IPCC 2007 A1F1 (High)	0.26-0.59	26-59 m	Low-Moderate	Tidal inundation, increased erosion	Roads, harbors unstable sandy beaches
Rhamstorf 2007	1.0	100 m	Moderate to high	Permanent inundation, severe erosion	Stable beaches, marine ecosystems, wastewater infrastructure
Otto-Blienser, 2006	2.0-3.0	200-300 m	High to v. high	Inundation and wave damage.	Airports, harbors and some public utilities.
Overpeck, *et al* 2006	3.0-5.0	300-500 m	Very High	Flooding, structural damage	Airports, harbors and most utilities. All beaches.
Hansen, 2007	5 +	500+ m	Extreme-Catastrophic	Widespread structural damage.	Coastal facilities and some aquifers.

between several undesirable and increasingly expensive adaptation strategies. The coastal management policies and plans for Hawaii are currently limited to options 1 through 3 below although there is progress in developing a state land acquisition program as recommended in the state coastal management plan (COEMAP, 2000).

Structural Approaches:

1. Invest substantial resources to maintain beaches and wetlands in their current location. This might be achieved by conducting large beach restoration projects utilizing offshore sand deposits.
2. Continue armoring the coast to protect property and allow beaches and marshes to erode away except where it is not feasible to carry out option 1 above. This has been the historical practice worldwide and currently the preferred alternative by most governments.

Non-structural Approaches:

3. Allow beaches and marshes to encroach inland onto previously developed land. This approach is politically sensitive and is likely to generate the most opposition from coastal landowners.
4. Acquire undeveloped private property in coastal areas to be maintained as public open space (such as beach parks) for storm protection.

Data Needs and Recommended Initiatives

1. Formation of a coastal hazard task force. A state-sponsored group of scientists, planners and public safety officials equipped to conduct coastal hazard assessments related to sea level rise.
2. Assessment of historical shoreline positions (Erosion Analysis) The analysis of island shoreline positions (erosion analysis) for all islands. This data is critical for land use planning and coastal hazard mitigation.
3. Inundation vulnerability mapping with coastal hazard zone overlays. Develop state GIS layers identifying major infrastructure, elevations, projected sea level positions and projected hazard zones.
4. Reclassify FEMA flood Insurance rate maps (FIRMS). Using the results from the shoreline erosion analysis and predictions for sea level rise to reclassify and map projected flood (AE) and wave hazard (VE) zones.
5. Land use rules and zoning policies review. A careful review and amendment of current statutes and rules that regulate land uses in the coastal zone to establish more stringent building codes.
6. Public education and awareness of risks. Improved societal awareness will assist in supporting political will to make controversial decisions.
7. State Land Acquisition Program. Efforts to conserve coastal buffer zones as open space will improve public access to valuable coastal resources. Formation of a state land acquisition program will be fundamental to the protection and preservation of high-value coastal ecosystems and beaches.

Conclusions

Increased vulnerability to flooding inundation and coastal hazards will necessitate a new planning approach to managing these risks. Future hazard mitigation and land use planning will need to incorporate ecosystem-based management using traditional Hawaiian Ahupua'a management strategy. Governments also need to develop and implement more integrated planning and management policies that include a wider variety of ecosystem and watershed principles. Often planning and land use decisions are made on an ad hoc basis with little if any consideration for broader ecosystem impacts.

There are many benefits for communities that take action to mitigate potential impacts due to climate change and sea level fluctuations. Coastal communities' land use policies need to better recognize and anticipate the increasing risk from coastal hazards. Coastal resource conservation and ecosystem-based planning initiatives often serve the multiple benefit of protecting a specific resource while significantly reducing vulnerability to coastal hazards. Proactive efforts to increase open space, restore and expand coastal wetlands and relocate major improvements away from the coastline will need to be implemented, especially in low lying areas. New research and more mainstream recognition of potential climate change impacts only make taking those actions more compelling.

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