

Sea-Level Rise and Coastal Zone Management

Michael SUTHERLAND, Canada

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SUMMARY

Higher global ambient temperatures, thermal expansion of ocean waters, subsidence of coastal lands and increased melting of sea ice are just some of the factors that can contribute to sea level rise. Some estimates predict that sea level rise of approximately 50 cm could result from these factors. The effect on vulnerable coastlines, coastal communities, and coastal infrastructure would then range from serious to catastrophic. The social, economic, cultural, and ecological foundations of human life in these areas could be seriously affected. This paper will proffer coastal zone management as one adaptation strategy (among other strategies) to sea level rise. Various types of information are necessary to mitigate and adapt to the possible effects of sea level rise and therefore this paper will look at what role hydrographic information can play in adaptation strategies to sea level rise.

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1. INTRODUCTION

Climate change can have many impacts upon human societies. The Impacts will vary from region to region. These impacts include, among other things [Michaelowa, 2001; Darwin, Richards and Tol, 2001; Natural Resources Canada, 2003]:

- Sea-level rise
- Melting of mountain glaciers
- Floods (from especially heavy precipitation events)
- Droughts
- Changes in storm intensities
- Changes in biological variables that have impacts upon human societies

Additionally, the severity of the impacts of climate change upon a community is related to the level of dependence of that community on local resources. Climate change can affect ecosystems's physical and biological constituents. Constituents may be added, reduced, lost, and modified and these changes can have negative or positive impacts on the communities that depend upon the constituents. This is demonstrated in Table 1, which shows how changes in natural systems, caused by climate variability and climate change, can therefore positively or negatively affect the nature of human activities [Michaelowa, 2001; Hardy, 2003; Mendis, Mills and Yantz, 2003]. Therefore climate change and its impacts is now an important topic of focus in the international community [Mendis, Mills and Yantz, 2003].

The discussions herein will focus on sea-level rise as one impact of climate change, and will examine coastal zone management as one adaptation strategy (i.e. among other strategies) to sea level rise. Various types of information are necessary to mitigate and adapt to the possible effects of sea level rise. Therefore this paper will also look at what role hydrographic information can play in adaptation strategies to sea level rise.

Table 1
Impacts of Climate Variability and Climate Change
(After Michaelowa, 2001)

SYSTEM	NEGATIVE IMPACTS	POSITIVE IMPACTS
Water Resources	Decreased availability in many water-scarce regions, e.g. sub-tropics and island states	Increased availability in many water-scarce regions e.g. South-East Asia
Agriculture and Forestry	Reduced crop yields in most tropical and sub-tropical regions; and in the mid latitudes for strong warming	<ul style="list-style-type: none"> – Increased crop yields in most mid-latitude regions for low to moderate warming – Potential increase in timber supply from appropriately managed forests
Fisheries	Decreased cold fish stock in some areas	Increased warm fish stock in some areas
Human settlements, energy and industry	<ul style="list-style-type: none"> – Widespread increase in flooding, landslides and avalanches – Permafrost melting directly destroys infrastructure – Increased demand for space cooling in mid- and low latitudes – Decreased hydro power potential and waterway transport capacity due to low water levels and decreased glacier areas – Loss of tourist attractiveness in mid and low latitudes and many mountain areas – 	<ul style="list-style-type: none"> – Reduced energy demands for space heating in mid and high latitudes – Increased hydro power and waterway transportation capacity potential in areas with increased water levels – Gain in tourist attractiveness in higher latitudes and some mountain areas
Insurance and financial services	Increase in payments due to damages	
Human Health	Increase in number of people exposed to vector- and water-borne diseases	Reduced winter mortality in mid and higher latitudes

2. SEA-LEVEL RISE

Some of the possible deleterious impacts of climate change include (among other things) increases in global ambient temperatures, thermal expansion of ocean waters, subsidence of coastal lands and increased melting of sea ice. These factors can, in various combinations, contribute to sea level rise. Some estimates predict that sea level rise of approximately 50 cm could result from these factors, while others predict as much as 65 cm by 2100. Of course local sea level rise events will differ from the global average because of many factors including (but not limited to) local climatic conditions, local physical coastal features, local tidal cycles etc. [NASA, 1996; Darwin, Richards and Tol, 2001].

3. SEA-LEVEL RISE AND COASTAL COMMUNITIES

The need for humans to achieve their socio-economic objectives causes them to perform (or locate) their socio-economic activities near to the resources supporting those objectives. Therefore much of human activities tend to be near coasts that provide (among other things) [Darwin, Richards and Tol, 2001; Payoyo, 1994]:

- Proximity to seafood sources
- Fertile and productive coastal and delta lands
- Transportation opportunities
- Many other socio-economic opportunities provided by coastal regions.

All of the foregoing supports the idea that the effects of sea-level rise upon vulnerable coastlines, coastal communities, and coastal infrastructure would range from serious to catastrophic. Inundation of outlying islands and loss of land above the high-tide mark could result in [United Nations Development Programme (UNDP), 2003; Darwin, Richards and Tol, 2001]:

- Loss of dry land without protection
- Loss of wetlands without protection
- Loss of exclusive economic rights over extensive areas
- Destruction of existing economic infrastructure as well as of existing human settlements
- Damage to subsistence and commercial fisheries production.
- Saline intrusion that adversely affect freshwater resources
- Negatively affected economies.

The ability of communities to resist the effects of climate change such as sea-level rise, or to adapt to its effects depends on those communities' vulnerability to change, resilience, and adaptive capacity. Vulnerability to change is described as exposure to threats that can negatively modify the *status quo*. Threats can be environmental, i.e. spatial proximity to potentially destructive environmental phenomena such as sea-level rise and other impacts of climate change. Environmental threats in turn threaten the socioeconomic basis of communities. It is to be noted that vulnerability of similar sectors or systems varies widely from region to region due to "regional differences in local environmental conditions,

preexisting stresses to ecosystems, current resource-use patterns, and the framework of factors affecting decision-making—including government policies, prices, preferences, and values” [Mendis, Mills and Yantz, 2003; Saleemul, Reid and Murray, 2003; Intergovernmental Panel on Climate Change (IPCC), 2001]. A community’s vulnerability may be [UNFCCC Secretariat, 2003]:

- Legal (Regulation function)
- Economic (habitat function; production function)
- Socio-Cultural (Regulation function; habitat function; production function)
- Technical (information function)

Resilience is a measure of the amount of change a system can undergo without changing state. It is the capacity to withstand and recover from hardship. Resilience is a measure of how much a system can maintain controls, functions, structure, self-organization, capacity for learning etc. in the face of threats [Mendis, Mills and Yantz, 2003; Alisos Institute, 2003].

Adaptive capacity is the ability to anticipate and deal with events and impacts. It is the ability to respond to internal and external stresses, create and take advantage of opportunities, and meet the diverse needs of the community in the face of beneficial or deleterious changes. Adaptive capacity focuses on [Mendis, Mills and Yantz, 2003]:

- Ecological capital (environmental stock and services)
- Economic/Physical capital (financial, infrastructure etc.)
- Human capital (skills, education, experience etc.)
- Social capital (relationships among families, the demography, community and the power structure etc.)
- Capacity building also includes (among other things) [UNFCCC Secretariat, 2003]:
 - Strengthen disaster warning systems
 - Strengthen coastal zone management
 - Identify, assess, and evaluate coastal technologies
 - Provide specialized capacity building packages on adaptation
 - Strengthen socio-economic analysis of adaptation options

4. COASTAL ZONE MANAGEMENT AS AN ADAPTATION STRATEGY TO SEA-LEVEL RISE

Coastal spaces are of high and varied values to many groups of stakeholders and therefore coastal spaces are subject to sustained and intensive use that often have negative impacts on the environment. The “complex interaction between biological and geophysical forces make coastal areas the most fertile for fisheries” [Ekert, 1979] and therefore fishing activities in these areas are intensive and have been known to cause the depletion of fish and other aquatic stocks. Also, the inefficient exploitation of other coastal resources, together with tourism and transportation activities among other things serve to negatively impact coastal spaces. Additionally, coastal spaces are subject to the deleterious impact of human land-based

activities. Uncontrolled discharge of industrial by-products and municipal and household wastes, the polluting run-off from farming activities, the erosion of banks from logging activities, the destruction of marshes to support residential activities, and the destruction of riparian zones by domestic livestock are just some of the land-based activities that negatively impact coastal spaces [Department of Fisheries and Oceans, 2002; Food and Agriculture Organization, 1998].

The dilemma is that these negative impacts are from activities that are considered to be essential and of social, economic and even political importance to societies. However, when there is clear evidence that coastal resources are decreasing in value, coastal uses are in conflict, or the coastal environment is facing destruction from natural hazards or man-made activities it is time to implement good coastal governance practices such as coastal zone management. Additionally, coastal zone management becomes imperative to prevent the weakening and devaluing of coastal resources that would make coastal regions that much more susceptible to sea-level rise [Sorensen, McCreary and Hershman, 1984; UNFCCC Secretariat, 2003]. This is supported by the IPCC [2001] that stated "Integrated coastal zone management (ICZM) is an iterative and evolutionary process for achieving sustainable development by developing and implementing a continuous management capability that can respond to changing conditions, including the effects of climate change".

Coastal zone management is therefore a tool for good governance of coastal spaces, and an adaptation strategy for sea-level rise. The governance of coastal spaces is usually framed in terms of "management" or "protection" depending on the nature of the value of the resources to the stakeholders. Both perspectives are usually based upon the principles of sustainable development through the regulation of access to, and impact upon, coastal resources [Pinto, 1994]. Coastal zone protection is geared towards ensuring the future social and economic viability of the coastal areas through advances in environmental protection. Although framed as "protection" the basis of the operational aspects is management [New Brunswick Environment and Local Government, 2002]. Coastal zone management, according to Ketchum [1972], is a process designed to achieve the following objectives:

- The maintenance and improvement of the coastal zone's "usefulness for man by ensuring the quality and extent of the natural system upon which he depends"
- The development of an understanding of the coastal zone
- The use of the knowledge to create a dynamic plan for the zone's best use
- The implementation and enforcement of the created plan

5. HYDROGRAPHIC INFORMATION AND ADAPTATION STRATEGIES TO SEA-LEVEL RISE

Adaptation strategies are derived from the analysis of a wide range of data and information. For any particular geographic area or region of interest, knowledge of climate-related trends for that area may be derived from traditional ecological knowledge, or naturalized knowledge. Traditional ecological knowledge is cumulative knowledge passed on through generations regarding person-land relationships. Naturalized knowledge is that held by any

person with an interest in land regardless of cultural or ethnic background. Data and information gathering is important to support (among other things) [Sharma, Ravi, 2002; Mendis, Mills and Yantz, 2003; UNDP, 2003]:

- The building of climate histories
- The analysis of climate-related threats to communities
- The analysis of environmental sensitivity
- The analysis of socioeconomic sectoral sensitivity
- The assessment of a community's vulnerability
- The assessment of a community's resilience
- The assessment of a community's adaptive capacity
- The dissemination of relevant information to communities, policy-makers, and other stakeholders

Climate change research usually comprises any combination of (or focus on) certain data types. These types of data include [Mendis, Mills and Yantz, 2003]:

- Instrument data: Wind, temperature, extreme weather, precipitation data etc. from weather stations (meteorological data)
- Documentary data: historical archives, oral histories, historical texts etc. about timing, intensity and duration of weather phenomenon
- Proxy data: reconstructions of climate histories from core samples, lake bed sediments, observations related to ice freeze and thaw, snow cover, storm surge events etc.

As can be deduced from the previous paragraph, hydrographic data and information is part of the proxy data classification group, specifically with reference to storm surge events (among other things relevant to sea-level rise). When modelling storm surge events hydrographic information is an important contributor in terms of tidal datums, tidal cycles, wave heights, soundings that facilitate hydrographic modelling etc. Hydrographic information is also important in the formulation of coastal zone management policies in providing tidal datum information that in many cases determine the spatial extents to which coastal zone policies apply [New Brunswick Environment and Local Government, 2002]. Therefore hydrographic data and information is important to adaptation strategies to sea-level rise.

6. CONCLUSION

Higher global ambient temperatures, thermal expansion of ocean waters, subsidence of coastal lands and increased melting of sea ice are just some of the factors that can contribute to sea level rise. Coastal spaces are of high importance to the soci-economic objectives of many societies. The threat of sea-level rise combined with much human activity in coastal areas make it imperative that these coastal areas become subject to sustainable management and protection. Coastal zone management and protection policies can provide this function, as well as help to minimize the impacts of sea-level rise (e.g. in terms of storm surges). As such coastal zone management and protection is also an adaptation strategy for sea-level rise. Hydrographic data and information is important to both coastal zone management and

protection, and sea-level rise strategies by providing components for modelling and spatial dimensions for the application of policies.

BIOGRAPHICAL NOTES

Michael Sutherland obtained in 1995 a Master of Science (Engineering) in Land Information Management from the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada. He is currently pursuing a Ph.D. at the University of New Brunswick where he is developing global boundary requirements models in coastal and ocean management. He has more than 18 years international experience in land information management including the development of land information management software in both Canada and Jamaica. He has also lectured in land administration at the University of New Brunswick. Michael is a member of the Canadian Institute of Geomatics, and is a Vice-Chair of the International Federation of Surveyor's Commission 4.

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CONTACTS

Michael Sutherland
Department of Geodesy and Geomatics Engineering
University of New Brunswick
Fredericton, NB
CANADA E3B 5A3
Tel.+ 1 506 451 6812
Fax + 1 506 453 4943
Email: michael.d.sutherland@unb.ca
Website: <http://www.unb.ca/web/GGE/Research/LandStudies/Sutherland.htm>