Modeling Sea Level Rise in Caribbean SIDS: The Need for Tide Gauge Data

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SUMMARY

It is important for Small Island Developing States (SIDS), such as those in the Caribbean Region, to develop appropriate adaptation and mitigation strategies to deal with the potential perilous threats of climate change. Not the least among the threats is sea level rise, especially because most of the populations in Caribbean SIDS live along the coasts of the islands that they occupy. Many projects have been, or are being, undertaken to support the development of sea level rise adaptation and mitigation strategies for SIDS. Among them is an International Community-University Research Alliance (ICURA) project supported by Canada's Social Sciences and Humanities Research Council (SSHRC) and the International Development Research Centre (IDRC). The project is titled "Managing Adaptation to Coastal Environmental Change: Canada and the Caribbean" and includes researchers from the University of the West Indies, the University of Ottawa, the University of New Brunswick, the University of Western Ontario, The University of British Columbia, and Simon Fraser University. Study sites in the Caribbean include Georgetown (Guyana), San Pedro (Belize), and two SIDS sites: Grande Riviere (Trinidad and Tobago) and Bequia (St. Vincent and the Grenadines). The ICURA project includes spatial modeling of sea level rise threats to the SIDS sites as part of the methodology to develop appropriate adaptation and mitigation strategies. However the lack of long-term tide gauge data poses problems to the construction of these models. This paper describes these problems

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1. BACKGROUND

According to Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization (IOC/ UNESCO) (2006) global mean sea level has been observed since 1992, by high accuracy satellite altimetry, to be rising at a rate of approximately 3mm per year (i.e., 3.2 ± 0.4 mm/year). The Intergovernmental Panel on Climate Change (IPCC) (2007a) reported that the global average sea level had risen "at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003 and at an average rate of about 3.1 [2.4 to 3.8] mm per year from 1993 to 2003". Both sources support the perception that there is an increase in the rate of rise in global mean sea level, since the early 1990s.

Small Island Developing States (SIDS) ought to be concerned about this increase in the rate of rise in global mean sea level. These States, generally characterized by "relative isolation, small land masses, concentration of population and infrastructure in coastal areas, a limited economic base and dependency on natural resources, combined with limited financial, technical and institutional capacity for adaptation" (Davis et al. 2012), are especially at risk from rising sea levels that have the potential for adversely affecting their socioeconomic wellbeing (Turner et al., 1996; IPCC 2007b).

Caribbean SIDS are apparently vulnerable to rising sea levels. A significant amount of the population in the Caribbean settles along coasts because these areas not only sustain biological productivity but also increase economic opportunities (Turner et al. 1996). Most of the populated coastal areas are of low-lying elevations, which exacerbates the vulnerability of coastal societies to inundation, beach erosion, rising water tables and saltwater intrusion (Klein 2002) resulting in loss of land space and utilization (Davis et al., 2010).

The measurement and monitoring of sea level change ought to be of importance to Caribbean SIDS. These actions can serve to insinuate long term national socioeconomic and environmental consequences. To consolidate the efficacy of existing measurements, GIS can be used to create multidimensional geospatial models of projected sea level rise impacts. These models, based on reliable long term empirical data, can be utilized for climate projections which estimates the magnitude and rate of sea level change resulting from selected global and regional warming factors (Nicholls et al 2011).

The only source of long term sea level change data in the Caribbean is provided by tide gauges located inconsistently across the islands (Church et al., 2001; Sutherland, Dare and Miller 2008). Although many stations have been installed over the past 20 years, many of them are in various states of disrepair, the majority of which are no longer collecting data and some sites no longer exist (Sutherland, Dare and Miller 2008; Davis et al, 2010). In addition to data gaps created from the mentioned drawbacks, there are also questions surrounding the reliability of tide gauge estimates and the corrections applied to account for vertical land movement. The lack of long term datasets and high resolution elevation data provides a fundamental barrier to the improved quantification of impacts from sea level rise (Holgate and Woodworth, 2004; Wöppelmann et al., 2006; 2007; Holgate, 2007).

Concerned about socioeconomic and environmental threats from sea level rise, many projects have been, or are being, undertaken to support the development of sea level rise adaptation and mitigation strategies for SIDS. Section 2 of this paper describes one such project. Other sections describe some project outputs to date, including some GIS spatial models of projected sea level rise impacts. The paper also discusses how the lack of long-term tide gauge data poses problems to the construction of these models.

2. THE ICURA PROJECT

2.1 Project Focus

An International Community-University Research Alliance (ICURA) project titled "Managing Adaptation to Coastal Environmental Change: Canada and the Caribbean", and supported by Social Sciences and Humanities Research Council (SSHRC) and the International Development Research Centre (IDRC) was funded in 2009 with the ultimate aim of developing climate change adaptation and mitigation strategies for selected sites in the Caribbean and in Canada. This paper focuses on the Caribbean sites. The Caribbean sites include Georgetown (Guyana), San Pedro (Belize), and two SIDS sites: Grande Riviere (Trinidad and Tobago) and Bequia (St. Vincent and the Grenadines). Project personnel include researchers from University of the West Indies, the University of Ottawa, the University of New Brunswick, the University of Western Ontario, The University of British Columbia, and Simon Fraser University.

The project is multidisciplinary and includes disciplines such as economics, sociology, management studies, planning, and geomatics. Outputs include socioeconomic indices of vulnerability, spatially enabled socioeconomic assessments and modeling using GIS, and the development of adaptation and mitigation strategies to address the potential threats of climate change.

2.2 Tidal Data Relevant Project Components

It is generally known that the city of Georgetown is below mean high tide and that sea level rise would exacerbate the threat of coastal inundation. The ICURA project is therefore investigating the socioeconomic vulnerability of the population to the threat of sea level rise. Much of San Pedro's population depends upon the barrier reef adjacent to its locale, either with regard to tourism or to fishing. Climate change can have adverse effects upon the reef, such as bleaching (Baker, Glynn and Riegl 2008). The ICURA project is focusing on the socioeconomic vulnerability of the population to climate change related effects upon the reef. Although the project objectives include explicit and implicit sea level rise concerns for all for the Caribbean sites, this paper is concerned with GIS based sea level rise models that are being constructed for two sites: (1) Grande Riviere (important as nesting site for leatherback turtles upon which the community is in part economically dependent); and (2) Bequia, an important tourism destination in St. Vincent and the Grenadines.

3. GIS SEA LEVEL RISE MODELS OF THE STUDY SITES

The general project methodology, in relation to those sites for which GIS sea level rise models are being constructed, is graphically represented in Figure 1.

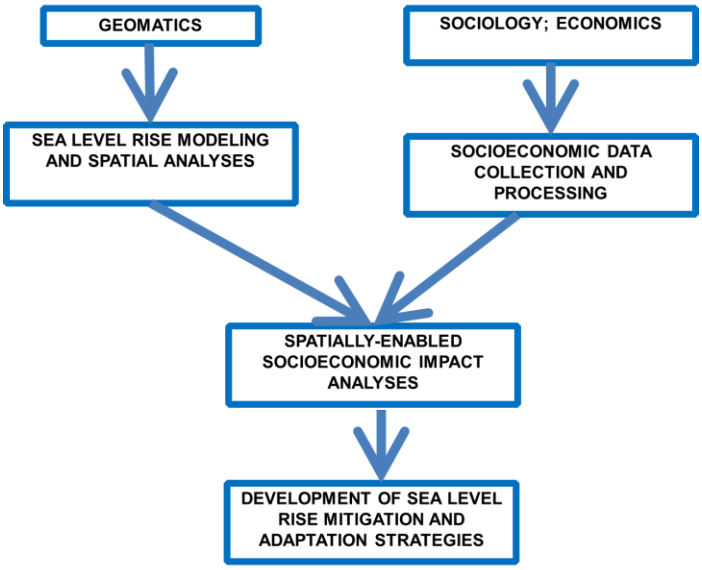

Figure 1 – ICURA Methodology Related to Sea Level Rise Modeling

3.1 Grande Riviere

The methodology relating to Grande Riviere was reported in Sutherland and Seeram (2011). As stated by the authors, the sea level rise models for Grande Riviere were constructed *via* the collection of primary spatial data (i.e., using topographic and hydrographic surveying techniques) and secondary spatial and thematic data which were then processed in ArcGIS (i.e., the creation and reclassification of a Triangulated Irregular Network (TIN), thematic datasets overlays, and static sea level rise flooding simulations through the digitization of flood polygons based on selected Intergovernmental Panel on Climate Change (IPCC) projections).

In terms of the collection of data representing mean sea level in the models, a tidal datum transfer from Toco fishing village (east of Grande Riviere and where a tide gauge was located at the time) was done because long term tidal observations were not available for Grande Riviere. The tidal data was tied into topographic surveys at the site through precise leveling. Only five hours of tidal data were collected at Grande Riviere at that time but simultaneous observations taken at Toco fishing village. The simultaneous observations taken at Toco fishing village were used to transfer its tidal datum to the beach at Grande Riviere (Sutherland and Seeram 2011). Samples of the models constructed, based on the topographic and tidal data collected are displayed in Figures 2 and 3.

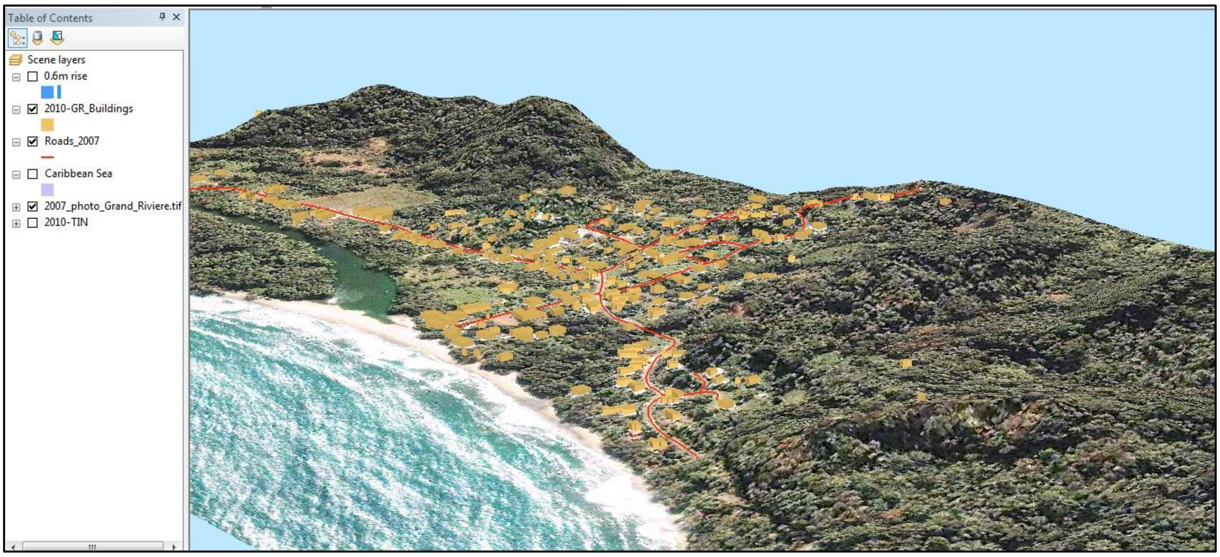

Figure 2 – Topographic 3D GIS Model of Grande Riviere

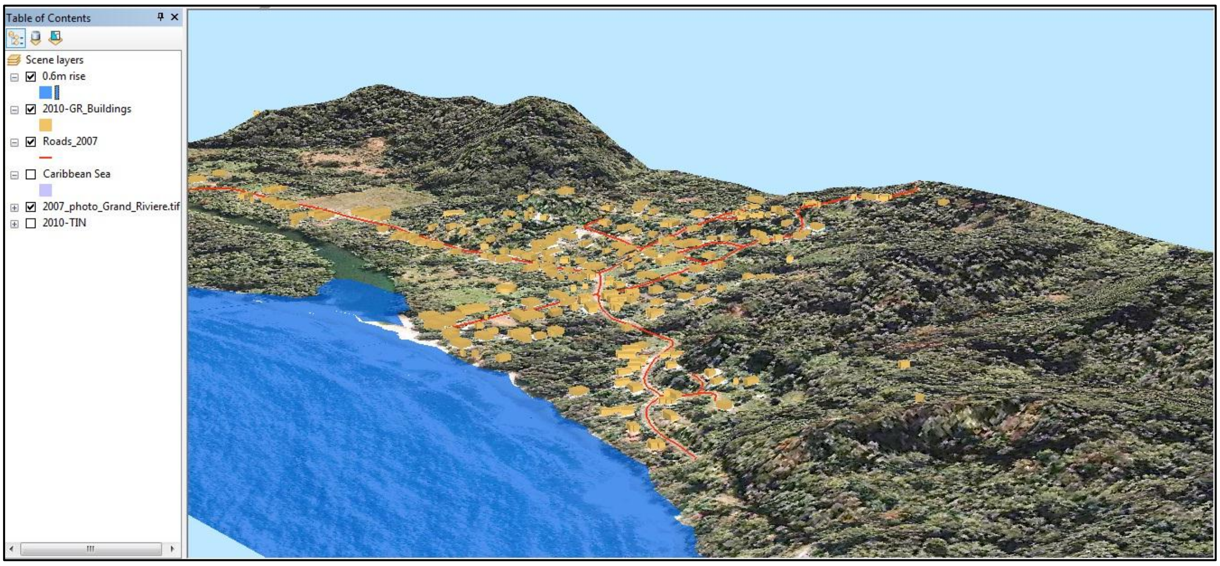

Figure 3 – 0.6m Sea Level Rise Projection at Grande Riviere

Figure 3 displays spatial inundation impacts of 0.6m sea level rise upon the beach at Grande Riviere, as an example of model outputs. Inundated beach areas represent potential loss of leatherback turtle nesting sites, which could have negative economic ripple effects upon the community.

3.2 Bequia

Samples of the GIS sea level rise models constructed for Bequia are displayed in Figures 4 and 5. Figure 5 displays inundated coastal areas affected by projected 1.4m sea level rise above simulated mean sea level, as an example of model outputs. At this level, according to the model, the airport is seriously affected.

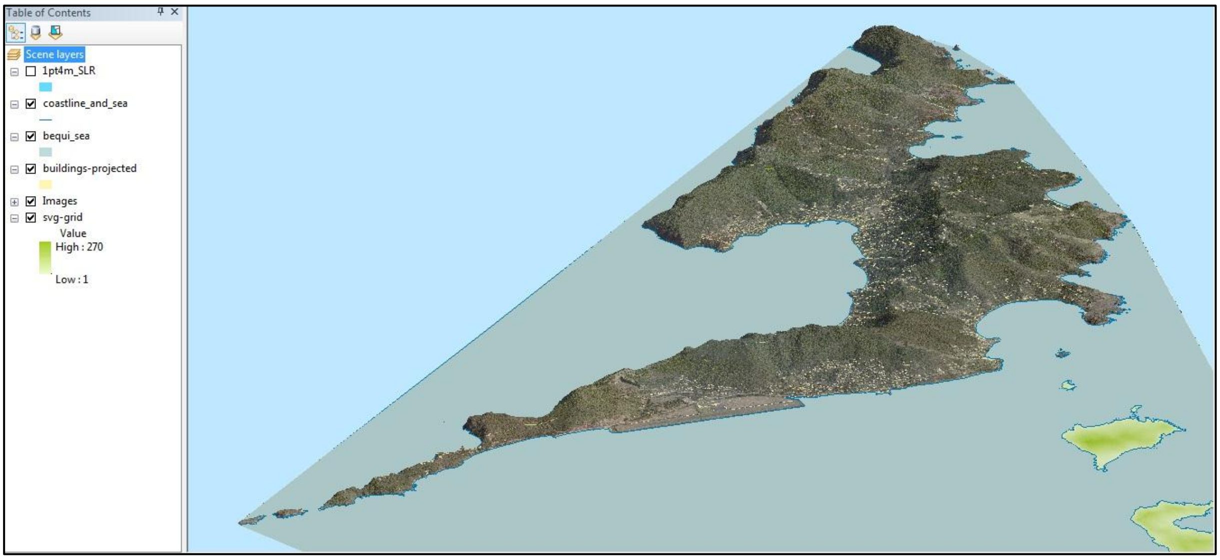

Figure 4 – Topographic 3D GIS Model of Grande Riviere

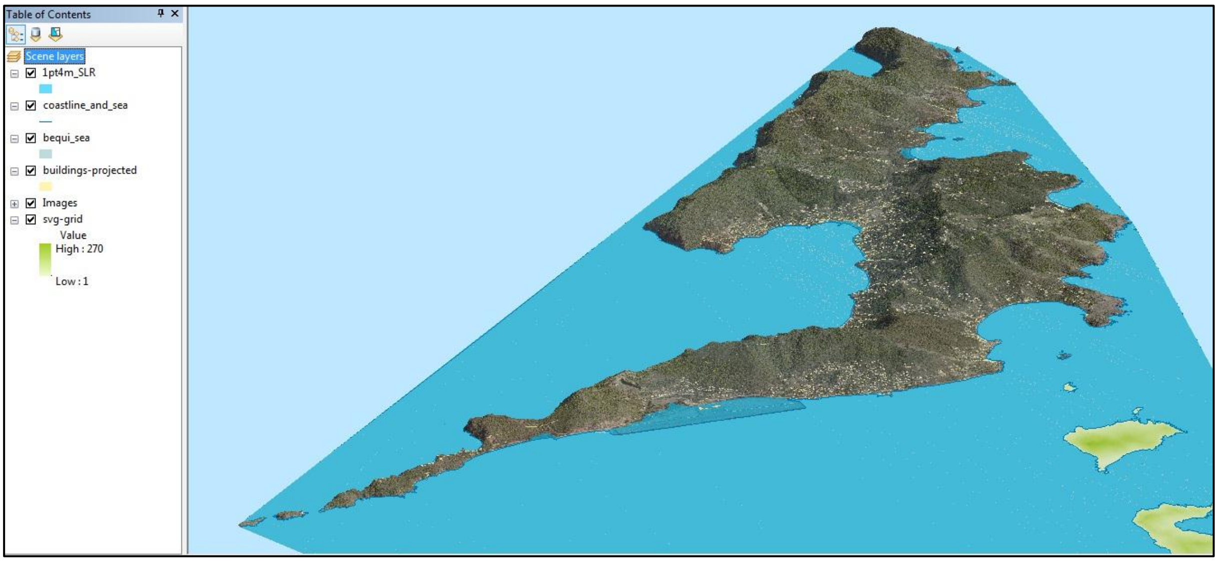

Figure 5 – 1.4m Sea Level Rise Projection at Bequia

Regarding Bequia, the models are being constructed using primary and secondary spatial data. Secondary data includes buildings, transportation infrastructure, contours and a coastline digitized by St. Vincent and the Grenadines Physical Planning Unit from analogue maps and referenced to the St. Vincent 1945 datum. The model displayed at Figure 5 was, of necessity, comprised of sea level rise projections greater than 1 metre above estimated mean sea level. This is due to the fact that the secondary data not include a mean sea level contour, and the included contours began at 1 metre. To improve model outputs and to verify the accuracies of the secondary data, it was necessary to collect tidal data and construct a mean sea level contour. Primary data were collected by the authors and others[1] over a one-month period. Primary data included GPS control points and spot heights, and tidal data collected over a one-month period. Data was collected in the field at Friendship Bay, Adams Bay and Port Elizabeth. Estimated mean sea level was derived from the collected tidal data and, using ArcGIS, is being integrated into the secondary datasets to construct a more accurate and relevant 3D spatial model of Bequia (i.e., thematic spatial data draped over an appropriately reclassified TIN). Flood polygons representing selected IPCC sea level rise projections will then be digitized to determine more accurate spatial impacts of the projected sea levels upon Bequia's coastal phenomena.

4. IMPACTS OF LACKING LONG TERM TIDAL DATA

The least potential utility of the models, when linked with socioeconomic data for project sites are:

- Discovery of the spatial distribution of socioeconomic phenomena;
- Discovery of the intersection (or spatial impacts) of projected sea levels with/on physical, environmental, and socioeconomic phenomena; and
- Information to support decision making in relation to the development (and implementation) of appropriate mitigation and adaptation strategies.

However, in consideration of the methodologies described above, for collecting tidal data representing mean sea level, the models' results are questionable in degrees (even if useful) because of the lack of long term tidal data that would improve the accuracies of the mean sea level contours used in the model and, in turn, the spatial representations of projected sea levels. Decisions, based on the projected spatial impacts of sea levels modeled, can also detract from the potential precision of adaptation and mitigation policy implementation. Quite apart from impacts on model construction, the lack of long term tidal data blurs perceptions of local rates of sea level rise, which is vital in community planning to deal with the threat.

5. CONCLUSIONS

Caribbean SIDS are spatially and probably socioeconomically vulnerable to rising sea levels. It is important to understand potential impacts of probable sea level rise, in relation to the SIDS, so that appropriate adaptation and mitigation strategies may be developed to address the threat. Accurate empirical primary and secondary data (spatial and socioeconomic) have the potential to model threats from projected sea level rise through the construction of scenarios. These modeled scenarios (using GIS) can contribute to the development of appropriate adaptation and mitigation strategies. However, the accuracies of the models are

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undermined by the lack of long term tidal data that would be used to construct mean sea level contours, a vital part of the models. The situation existing at Grande Riviere and Bequia (i.e., the lack of long term tidal data) is common at many sites throughout Caribbean SIDS. There is definitely the need for long term, reliable tidal data in the Caribbean to assist in addressing the potential threat of rising sea levels.

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BIOGRAPHICAL NOTES

Dr. Michael Sutherland holds an M.Sc.E. and Ph.D. in Geomatics Engineering from the University of New Brunswick, Canada specializing in land information management and GIS. He is currently lecturer in Land Management in the Department of Geomatics Engineering and Land Management, and the Deputy Dean (Undergraduate Students Affairs), Faculty of Engineering, University of the West Indies, St. Augustine, Trinidad and Tobago. He is a member of the Canadian Institute of Geomatics and the Institute of Surveyors of Trinidad and Tobago, and is an elected member of the Royal Institution of Chartered Surveyors. Dr. Sutherland is also an Associate of the Canadian Fisheries, Oceans, and Aquaculture Management (C-FOAM) research group, Telfer School of Management, University of Ottawa, Canada. In 2011 Michael was appointed as an Honourary Fellow, Sir Arthur Lewis Institute of Social and Economic Studies, University of the West Indies, St. Augustine, Trinidad and Tobago. In 2012 he was appointed as an adjunct professor in the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada. Dr. Sutherland is currently Chair of Commission 4 (Hydrography), International Federation of Surveyors

Demi Singh attained a Bachelor of Science Degree in Geomatics at the University of the West Indies, Trinidad and Tobago, in the year 2010. She is currently pursuing a Master of Science Degree in Geoinformatics at the same university. She previously worked on an International Community-University Research Alliance (ICURA) project dealing with the effects of climate change on coastal communities in Canada and the Caribbean. Ms. Singh has also worked on a marine cadastre project at the Land Management Division, Ministry of Agriculture, Land and Marine Affairs, Government of the Republic of Trinidad and Tobago.

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