WEST COAST GOVERNORS ALLIANCE on OCEAN HEALTH
CALIFORNIA OREGON WASHINGTON

West Coast Relevant Sea Level Rise Impact Models:

A review to aid local and regional planning

Ben Reder
West Coast Governors Alliance on Ocean Health
Climate Change Action Coordination Team Fellow
email: rederb@gmail.com
October 2011

Introduction

Natural resource managers and land-use planners may be interested in modeling the vulnerability of coastal habitats and communities for a number of different reasons. Modeling of this nature can help identify potentially vulnerable areas, infrastructure, habitat and communities. Knowledge of coastal vulnerability enables resource managers, land-use planners, and decision-makers to anticipate impacts and prioritize management efforts aimed at reducing risk or mitigating possible consequences.

This document provides an overview of three different sea level rise (SLR) modeling tools: SimCLIM, Coastal Adaptation to Sea Level Rise Tool (COAST), and Sea Level Affecting Marshes Model (SLAMM). These models were chosen because: (1) they can be applied on the West Coast; and (2) have been developed to the point where they are available for immediate use. This paper will also highlight the applicability and unique features of each model. In addition, case studies have been included to provide the reader with examples of potential uses and expected outcomes.

It is important for users to be aware that all models and assessment tools will have their own advantages and limitations. For example, traditional "bathtub" models have been used to assess coastal vulnerability to inundation resulting from storm surges and SLR. These assessments are based on "filling the landscape with sea water up to a prescribed elevation dictated by the height of SLR being evaluated. These models take into account elevation and sea level heights, failing to take into consideration complex processes like subsidence and the movement of sediment (erosion and accretion). The outcome is limited because the model assumes that these physical conditions will remain constant in the future. Despite this limitation, "bathtub" models can still be useful because they are relatively straightforward and low cost.

Some of the more sophisticated models can provide coastal managers with important and useful information about vulnerability of specific habitats or ecosystems at relatively fine scales and levels of detail. For example, these models may provide a more accurate projection of impacts by incorporating factors that affect relative rates of SLR, which include local tectonic activity, tidal ranges, wave heights, coastal slope, geomorphology, and historic shoreline change rates. The models may also allow for the inclusion of potential responses in a landscape given changes in land use (e.g. the ability of habitats to migrate upland in response to rising sea levels). However, highly detailed assessments can require extensive amounts of data and computer capabilities and can be more costly and time consuming.

Ultimately, all models make certain simplifying assumptions and cannot capture every process that affects the vulnerability of coastal areas and habitats to SLR. Within the constraints of a model, the level of uncertainty will depend on the resolution and quality of data. In other words, the validity of model projections is entirely dependent upon the data inputs used to run the model. Vulnerability assessments will only be as good as the data entered into the analysis and the user's knowledge of local processes and data quality.

"Must Watch" Models

Through the course of research for this document we identified other models and tools that are still in a development phase, but are worth highlighting for their potential to inform future work of West Coast managers and decision-makers. These models/tools include:

- National Oceanic and Atmospheric Administration's (NOAA) *Sea Level Rise and Coastal Flooding Impact Viewer* (http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/index.html). Contact Doug Marcy at NOAA Coastal Services Center for more information (email:Doug.Marcy@noaa.gov).
- The *DIVA Wetland Change Model* (http://www.diva-model.net/). Contact Jochen Hinkel for more information (email: hinkel@pik-potsdam.de)
- *Coastal Storm Modeling System* (CoSMoS). For assessing vulnerability in California only. Contact Patrick Barnard for more information (email: pbarnard@usgs.gov).

Sea Level Rise Impact Models

SimCLIM

Developer: CLIMsystems; http://www.climsystems.com/
Location: Hamilton, New Zealand
Contact: Peter Urich; peter@climsystems.com
Tool Type: software
Cost Estimate: $500 – $20,000

Overview

SimCLIM is a flexible computer-based modeling system, or software package, designed to examine the effects of climate variability and change, over time and space. The software can be used to assess both biophysical and socioeconomic effects of climate variability and change.[1] One key attribute of SimCLIM is the program's ability to link and integrate a wide variety of data and models to produce various simulations of climate change-related impacts. The SimCLIM software includes tools that facilitate spatial (monthly, seasonal) and site time-series (hourly, daily, or monthly) analyses.

Features
SimCLIM comes pre-packaged with various "scenario generators." The "climate scenario generator" is used to create predictions of future climate-related and sea-level changes. The "sea-level scenario generator" allows users to incorporate regional and local components that will have an influence on relative patterns of sea-level change. This component of the software is useful because it allows for the development of place-based sea-level scenarios.[2] The "land use scenario generator" can be used to examine vulnerability and risk of a particular area based on future growth and development patterns.[3]

SimCLIM features an "open-framework," which allows users flexibility in customizing and maintaining the system to meet their specific needs. Users have the ability to import data sets and impact models for different areas and resolutions (in addition to the prepackaged information).[4] For example, users can import: (1) shape files (e.g. boundaries, streams, roads); (2) patterns of climate and sea level changes from General Circulation Models (GCMs); (3) impact models driven by climate variables; (4) other spatially explicit data (e.g. predicted climate patterns, elevation surfaces); and (5) time-series data.[5]

The software package includes six different global emission scenarios and 22 General Circulation Model (GCM) patterns. For each of the emission scenarios, the program will produce a projection, spanning the years 1990-2100, with low, medium, and high estimates. Users are allowed the flexibility of choosing among the global projections and GCM patterns, and also modifying model sensitivity values and future time horizons.[6] Users can produce outputs from individual GCMs or averages of multiple GCM runs (referred to as "ensembles").

Use and Application
SimCLIM can be applied at local, regional, and global scales and used to examine climatic patterns resulting from historical trends or future predictions. Key outputs of the software include spatial images, time-series projections, and summary data in both graphical and table format. The software enables users to[7]:

- Describe baseline climates;
- Generate scenarios of future climate and sea-level changes;
- Assess risks – present and future;
- Project sectoral impacts (e.g. impacts on agriculture, coastal communities, and water resources) of climate and sea-level change;
- Conduct sensitivity analyses; and
- Evaluate and document the range of uncertainty associated with various predictions.

SimCLIM is described as very user-friendly software, with user and technical manuals available for download at no cost from the CLIMsystems website. The software is licensed commercially and the cost is variable. Estimates range from $500 for student purposes, to over $20,000 for private consultant use. Special rates may be available for government agencies and non-profit groups.

For users already familiar with climate science, very little training will be required to execute the basic functions of the software. Training is available for users with limited background in climate change or for those who wish to understand the full functionality of the system. CLIMsystem also offers a software package called “TrainCLIM” which comes equipped with supportive manuals, training modules, and exercises. TrainCLIM is designed to introduce new users to the modeling capacity of CLIMsystems products and important concepts required when assessing vulnerability to climate change and adaptation options.

Case Study: Preliminary Climate and Sea Level Changes for Vanuatu – a South Pacific Island Nation (2009)[8]

Vanuatu is an island nation located in the South Pacific, approximately 1090 miles east of Australia. Vanuatu is made up of 83 islands and is situated in the “ring of fire” and the “cyclone belt” of the Pacific. According to the World Bank, Vanuatu ranks as one of the countries with the highest exposure to multiple natural hazards.[9]

The Vanuatu National Advisory Committee on Climate Change (NACCC) worked with CLIMsystems staff to develop a customized version of SimCLIM known as VanuaCLIM. VanuaCLIM was used to model the effects of SLR and climate change and as a resource to inform future management discussions with the United Nations Framework Convention on Climate Change (UNFCCC). This project exemplifies how users can potentially work with CLIMsystems personnel to develop unique aspects of the software and customize tools to meet a user’s particular needs.

VanuaCLIM was customized for the Vanuatu Archipelago by integrating locally-specific data into the software (e.g. a local digital elevation model for all the islands and locally specific historical climate data). For this project, CLIMsystem staff customized a software tool which facilitated collation of hundreds of individual Excel spreadsheets of climate data. The tool saved a substantial amount of time by digitizing over 50 years of data.

The NACCC used the VanuaCLIM SLR generator to conduct a climate impact assessment and develop various SLR scenarios. The SLR scenario generator was customized to include local tidal and vertical land movement data. This helped to improve the accuracy of modeling the local conditions. The group used this information to construct alternative scenarios based on a variety of assumptions about future conditions. By examining the range of possibilities within each scenario, the group gained a better understanding of the uncertainty that exists with the assessment.

Case Study: Scientific Capacity Building for Climate Impact and Vulnerability Assessments. Albay, Philippines (2011)[10]

Stakeholders in Albay used SimCLIM software as a component of a capacity building project to learn how to conduct an impacts, vulnerability, and adaptation assessment. Once again, SimCLIM software was developed for local application in Albay (known as AlbayClim). AlbayCLIM was used in assessing and creating climate change scenarios. This aided in characterizing future risks and vulnerabilities unique to the Philippine province.

In this project, stakeholders learned how to combine the computer-based modeling system results and participatory approaches into an assessment. In addition to the AlbayClim results, participatory techniques were used to solicit local knowledge of observed events and experiences. This information was used to confirm modeling results and helped stakeholders gain a clear sense of vulnerability within their community by linking the modeling results to previously observed occurrences during extreme events.

CLIMsystems partners were hired to conduct the training and customize the software for local application. Participants generated climate change and sea-level rise scenarios using various GCMs, as well as conducted extreme events analyses.

Using AlbayCLIM, climate change and sea-level rise scenarios were generated for the study sites. Climate change scenarios were developed for 2100 using a 21-GCM ensemble. The scenario for SLR used a 13-GCM ensemble. These parameters were used to construct a worst-case scenario anticipated by the local communities to better prepare them from the adverse effects of these likely events. The opinion of the local communities on the potential impacts of these feasible scenarios was solicited through interviews and household surveys.

The project resulted in a greater understanding of the concepts of climate change by the local stakeholders, and trained capacity in conducting vulnerability and adaptation assessment, particularly with the aid of AlbayClim. It also directly contributed to an important undertaking in the province for policy planning, which was the revision of their Comprehensive Land Use Plan. Feasibly, this information would have also been valuable to government agencies to inform various planning efforts such as emergency management and climate adaptation.

Coastal Adaptation to Sea Level Rise Tool (COAST)

Developer: New England Environmental Finance Center, http://efc.muskie.usm.maine.edu/
Location: Portland, Maine
Contact: Sam Merrill; smerrill@usm.maine.edu
Tool Type: adaptation assessment tool
Cost Estimate: $30,000 – $200,000

Overview

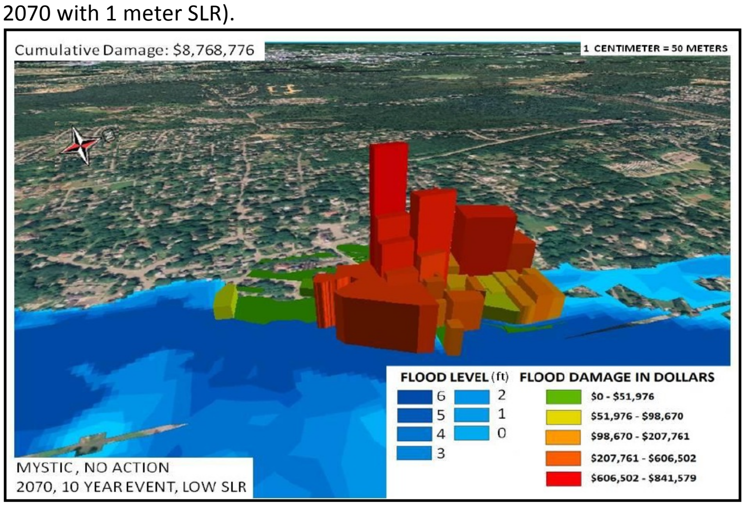
The Coastal Adaptation to Sea Level Rise Tool (COAST) combines modeling capabilities with the ability to quantify risks to vulnerable assets such as businesses, schools, private property, etc. COAST can be used to model the interaction between SLR and storm surges. The program also allows users to calculate and visualize costs and benefits of implementing various adaptive actions in response to different scenarios of SLR and storm surge intensity. The tool includes the following adaptation actions: beach nourishment, revetments, sea walls, geotextile tubes, jetties, flood proofing on businesses, and zoning and regulatory changes. Graphically and in table format, COAST displays location-specific avoided costs associated with individual adaptation actions, and also includes the implementation cost for the particular action. This feature assists users to identify appropriate strategies that make financial sense. The economic analysis highlights upfront costs and projected maintenance costs as well, ultimately enabling the user to estimate long-term economic impact for particular adaptive actions.

Features

The 3D capabilities of COAST allows for a visual representation of various socioeconomic impacts including real property loss, lost infrastructure vale, demographic variables (e.g. displaced persons) and lost cultural assets.[11] The visual representation facilitates a parcel-based quatification of vulnerability.

The COAST program incorporates a variety of existing tools and data sets. As described by the creators, COAST combines "U.S. Army Corps of Engineers' depth-damage functions; NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model; and other flood methods, as well as projected SLR scenarios over time, property values, and infrastructure costs" into a Geographic Information System (GIS)-based representation of potential economic damage.[12] Figure 1 provides a screen-shot of the visual representation.

Figure 1 Example screen shot from COAST
(Groton, Connecticut: expected losses in real property and building damage from a simulated 10-year flood event projected for 2070 with 1 meter SLR).



Source: Merrill, 2010 EBM TOOLS Webinar

The COAST program operates by constructing a polygon-shaped grid, derived from the SLOSH model, and overlaying georeferenced points for vulnerable assets such as infrastructure, businesses, homes, and others on an X and Y axis. This information is then linked to the Army Corps of Engineers' depth damage function, giving an estimation of real estate value losses at different depths of inundation. By projecting this on the Z axis, a 3D representation of relative vulnerability and economic damage is achieved. In regards to west coast relevance, Sam Merrill (Director of the New England Environmental Finance Center), one of the lead developers of COAST, advises that SLOSH model polygons (used for predicting impacts resulting from hurricanes) could be replaced with "reasonable polygons of anticipated extreme weather events, including conventional SLR overlays, non-SLOSH storm surge models, etc.".[13]

Use and Application

COAST is most appropriate for local evaluations and modeling. Eventually, the developers hope to offer the tool as an official GIS extension. Currently, interested parties must contact and work directly with Merrill and his collaborators to customize the tool for specific uses or projects. Estimated costs range from $30,000 for a small jurisdiction to $200,000 for a large city.

Case Study: The Effects of Climate Change on Economic Activity in Maine: Coastal York County Case Study (2008)[14]

COAST is particularly useful for its visual display of economic impacts from climate change impacts. In a recent article, Sam Merrill and his colleague, Charle Colgan, describe the significance of the COAST approach. They state, "the economic effects are the way in which most people will most fully experience the realities of climate change" (67). As a modeling tool COAST will help raise awareness of potential economic impacts and this aspect alone can act as a compelling force to motivate adaptive action.

COAST was used to help communities in coastal York County, Maine evaluate the upfront costs of various mitigation actions and compare that data to the range of likely economic damages, under various SLR and storm surge scenarios over the next century. The case study involved analyzing the impacts of increased coastal storm intensity and estimating risks of SLR. The estimated impacts on economic assets (specifically for trade and commerce) were determined using employment data from the Quarterly Census of Employment and Wages. This data had been geo-coded so that each place of employment was assigned a latitude and longitude. This enabled the points to be located within a GIS relative to other features. Base maps, including town boundaries and road maps, were provided by the Maine Office of Geographic Information Systems. Vulnerability to coastal flooding for the various communities was defined by an overlay of maps depicting the SLOSH (Sea, Lake, and Overland Surge from Hurricanes) model results. Using these two key pieces of information, economic impacts from storm surges can be determined. The analysis of possible effects of sea level rise integrates projected sea level rise scenarios. Using COAST, a comprehensive GIS-based picture of potential economic damage can be constructed. The COAST analysis will visually represent and calculate estimated property value loss, the number of "at-risk" establishments, number of jobs affected, annual total wages, and the proportion of each town's economy "at-risk". Although for this specific case study it did not occur, COAST users could have then applied various adaptive actions and observed how the impacts change, both physically and economically. COAST can also calculate location-specific avoided costs that would result from implementing a particular adaptive action.

Sea Level Affecting Marshes Model (SLAMM)

Developer: Warren Pinnacle Consulting, Inc.; http://www.warrenpinnacle.com/prof/SLAMM/
Location: Warren, Vermont
Contact: Jonathan Clough; jclough@warrenpinnacle.com
Tool Type: model of sea level rise, habitat conversion, and shoreline modification
Cost Estimate: free

Overview

Sea Level Affecting Marshes Model (SLAMM) is a tool that can be used to assess how rising seas may impact coastal habitats at local and regional scales. SLAMM simulates the dominant processes involved in wetland conversion and shoreline modifications that may result from gradual SLR.[15] Within SLAMM, there are five main processes that influence wetland and habitat conversion under different SLR scenarios: inundation, erosion, overwash, saturation, and accretion.

One of the key attributes of SLAMM is that it can simulate habitat conversion over various time steps, between 5 – 25 years, and compute sea level inundation and habitat responses for relatively large areas (30 – 100 square miles) at high resolutions relatively quickly.

To estimate the effects of SLR, SLAMM integrates global trends of SLR with locally specific information such as tidal patterns, elevation, land cover, and wetland characteristics. Table 1 provides a summary of the various types of data required to run the model. For example, SLAMM may be applied to assess the degree to which sea water inundation contributes to the conversion of one habitat to another by looking at elevation, habitat type, slope, sedimentation and accretion, erosion, and the extent to which the affected area is protected by dikes and other artificial structures.

Data Type	Model Use
Elevation Maps	Defines land elevation in relation to sea level
Vertical Datum Conversion	Ties Elevation data to water levels
Land Cover Categories	Defines initial conditions for land types
Vertical Uplift or Subsidence	Aids in the conversion of average global SLR to local SLR
Accretion Rates	Affects vertical movement of wetlands
Erosion Rates	Affects horizontal retreat of beaches and dry lands
Tide Ranges	Defines water height

Source: Clough 2010.[16]

Features

To those already familiar with SLAMM, the most recent version (SLAMM 6.0) features a number of improvements from previous versions. Notably, the model is now able to incorporate dynamic accretion feedbacks. In the model, sediment accretion rates influence horizontal and vertical migration of wetlands. Older versions assumed linear changes in accretion rates over time.[17] Accretion feedbacks in SLAMM 6.0 include wetland elevation, distance to channel, and salinity. Sea level rise is offset by sedimentation accumulation and accretion. Users are now given three options for specifying accretion rates within the model[18]:

- Use average or site-specific values for each wetland category;
- Use spatially varying values for each wetland category; or
- Specify accretion as a time-varying function of elevation, wetland type, salinity, and distance to channel.

SLAMM 6.0 also features a salinity model which allows users to specify time-variable fresh water flows. This is an important feature when applying the model to areas where site-specific data indicate that accretion rates cannot be described on the basis of elevation and distance to channel alone.[19] The salinity model will estimate and map salinity levels at mean lower low water, mean higher high water, and half-tide level (mean tide level).

Other improvements include habitat switching functions which allow habitat changes to based specifically on the outputs of the salinity model; an integrated elevation analysis which integrates site-specific elevation ranges derived from LiDAR or other high resolution elevation data; flexible elevation ranges for land categories (useful if the default settings do not accurately portray site characteristics); and the incorporation of spatial maps of uplift and subsidence.[20]

Use and Application

SLAMM should not be used to create precise forecasts about what will happen to a particular region's habitats in the future. More appropriately, SLAMM should be used as a tool to create a picture of possible outcomes under a range of scenarios. As a model, SLAMM is a valuable resource to spatially depict vulnerability to SLR and habitat conversions across a landscape.

The developers note that obtaining high vertical resolution elevation data is a critically important data requirement.[21] Elevation data is used to delineate where salt water is expected to penetrate, determine the lower elevation range for beaches, wetlands, and tidal flats, and (in combination with tide data) establish the frequency of inundation for wetlands and marshes.

SLAMM is most appropriately applied in area where the impacts of SLR are likely to be high. Coastal zones that have high rates of uplift, high vertical coastlines or bluffs, or wide tidal ranges are likely to be less vulnerable to sea level rise impacts.[22] SLAMM is therefore most useful when applied to areas where uplift is predicted to be minimal or non-existent and where tidal ranges are not extreme.

SLAMM is an open source model and can be downloaded directly from the Warren Pinnacle Consulting website (http://www.warrenpinnacle.com/prof/SLAMM/). The website also provides links to software updates and to a forum where users can provide feedback and discuss technical questions.

Case study: Sea level Rise and Coastal Habitats in the Pacific Northwest[23]

The National Wildlife Federation used SLAMM (version 5.0) to model how various areas in the Pacific Northwest would respond to a variety of different sea level rise scenarios. The goal of the project was to investigate potential impacts caused by sea level rise and raise awareness among coastal managers and decision-makers. The study modeled eleven different sites in Puget Sound and along the Pacific Coast in southwestern Washington and northwestern Oregon. The study sites include (1) Nooksack Delta, Lummi Bay, and Bellingham Bay; (2) Padilla Bay, Skagit Bay, and Port Susan Bay; (3) Whidbey

Island, Port Townsend, and Admiralty Inlet; (4) Snohomish Estuary and Everett; (5) Ediz Hook, Dungeness Spit, and Sequim Bay; (6) Dyes Inlet, Sinclair Inlet, and Bainbridge Island; (7) Elliott Bay to the Duwamish Estuary; (8) Annas Bay and Skokomish Estuary; (9) Commencement Bay, Tacoma, and Gig Harbor; (10) Olympia, Budd Inlet, and Nisqually Delta; (11) Willapa Bay, Columbia River, and Tillamook Bay.

The study utilized the scenarios posed by the Intergovernmental Panel on Climate Change (IPCC) sea level rise scenarios, from a 3.0 inch rise in global average sea level by 2025 to a 27.3 inch rise by 2100. They also modeled a rise in sea level of up to 78.7 inches by 2100 given that several studies suggest SLR will occur much more rapidly during this century than the IPCC models projected[24]. In addition, the following information was used to assess potential impacts:

- Relative SLR data for each site;
- Regional elevation data which included geological factors such as subsidence and uplift; and
- Site specific sedimentation and marsh accretion rates.

SLAMM is also used to model the effects of dike removal. Some of the sites evaluated in this study were relatively less developed, while other agricultural areas were protected by existing dikes. The model was run without the dikes in place, to help inform decisions about removing dikes, which was already happening in various regions as part of coastal restoration efforts.

Model results varied for each site. Based off of the assessment, it was concluded that regionally there will be a dramatic shift in habitat types and extent. Under the scenario that sea level would increase by 27 inches by 2100, SLAMM predicted the following regional outcomes:

- A loss of 65 percent of estuarine beaches due to inundation and erosion,
- As much as 44 percent of the tidal flats will disappear.
- 13 percent of inland fresh water marsh and 25 percent of tidal fresh water marsh will be lost.
- 11 percent of inland swamp will be inundated with salt water, while 61 percent of tidal swamp will be lost.
- 52 percent of brackish marsh will be converted to tidal flats, transitional marsh and saltmarsh.
- 2 percent of undeveloped land will be lost due to inundation or erosion.

The results of the SLAMM analysis were used illustrate the likely habitat conversions resulting under probable SLR scenarios. It was intended that this information be used by "coastal managers and other relevant decision-makers" to identify and implement mitigation strategies.

---

[1] Mcleod, Elizabeth, Benjamin Poulter, Jochen Hinkel, Enrique Reyes, and Rodney Salm. "Sea-level rise impact models and environmental conservation: A review of models and their applications". *Ocean & Coastal Management*. 2010.
[2] Mcleod et.al. 2010.
[3] UNFCC. "compendium on methods and tools to evaluate impacts of, and vulnerability and adaptations to, climate change". Accessed on July 20, 2011. http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5482.php
[4] Warrick, W., W. Ye, P. Kouwenhoven, J.E. Hay, and C. Cheatham. "New Developments of the SimCLIM Model for Simulating Adaptation to Risks Arising from Climate Variability and Change". Proceedings of the 28th Modelling and Simulation Conference. 2005
[5] Warrick, Richard. "SimCLIM: Recent developments of an integrated model for multi-scale, risk-based assessments of climate change impacts and adaptation". 2007.

[6] Warrick 2007.
[7] SimCLIM Essentials Training Book 1. Version 2.0. 2011.
[8] PRWeb. Press Release, November 28, 2009. Accessed on August 5, 2011. http://www.prweb.com/releases/Climate_Changes/Sea_Level_Changes/prweb3267604.htm
[9] Dilley, Max, Robert S. Chen, Uwe Deichmann, Arthur L. Lerner-Lam, and Margaret Arnold. "Natural Disaster Hotspots; A Global Risk Analysis". World Bank , 2005.
[10] Pulhin, Juan M. "Capacity Development on Integration of Science and Local Knowledge for Climate Change Impacts and Vulnerability Assessments". Asia-Pacific Network for Global Change Research. 2011.
[11] Merrill, Sam. EBM Tolls Webinar. April 21, 2011.
[12] Merrill, Sam, Damon Yakovleff, David Holman, Joe Cooper, and Paul Kirshen. "Valuing Mitigation Strategies: A GIS-based approach for climate change analysis". *ArcUser*. 2010.
[13] Merrill, Sam. Personal communication. July 21, 2011.
[14] Colgan, Charles. S., and Samuel B. Merrill. "The Effects of Climate Change on Economic Activity in Maine: Coastal York County Case Study". *Maine Policy Review* 2008.
[15] Clough, Jonathan S., Richard A. Park, and Roger Fuller. "SLAMM 6 beta Technical Documentation". Warren Pinnacle Consulting, Inc. May 2010.
[16] Clough, Jonathan. "A White Paper on Data Requirements and Data Inventory for Alaska SLAMM Analyses". Warren Pinnacle Consulting Inc. June 2010.
[17] Clough 2010.
[18] Clough, Jonathan S., Richard A. Park, and Roger Fuller. "SLAMM 6 beta Technical Documentation". Warren Pinnacle Consulting, Inc. May 2010.
[19] Matson, Noah. Personal Correspondence to Kurt Johnson, National Climate Change Coordinator U.S. Fish and Wildlife Service. "Re: Comments on the Fish and Wildlife Sevice's Strategic Plan for Responding to Accelerating Climate Change, SLAMM". 2010.
[2020] Clough, Jonathan S., Richard A. Park, and Roger Fuller. "SLAMM 6 beta Technical Documentation". Warren Pinnacle Consulting, Inc. May 2010.
[21] Clough, Jonathan. "A White Paper on Data Requirements and Data Inventory for Alaska SLAMM Analyses". Warren Pinnacle Consulting Inc. June 2010.
[22] Clough, Jonathan. "A White Paper on Data Requirements and Data Inventory for Alaska SLAMM Analyses". Warren Pinnacle Consulting Inc. June 2010.
[23] Glick, Patty, Jonathan Clough, and Brad Nunley. "Sea-level Rise and Coastal Habitats in the Pacific Northwest, An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon". National Wildlife Federation. 2007.
[24] Ibid.