# Development of Site Specific Climate Scenarios for River and Sediment Discharge using Macrophysical Climate Models: An Example From Puerto Rico

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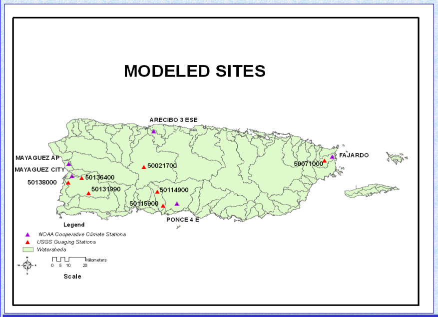
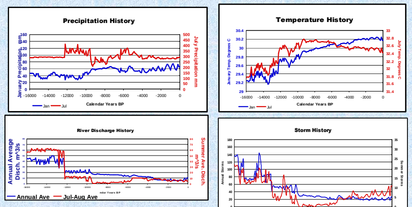
## Abstract

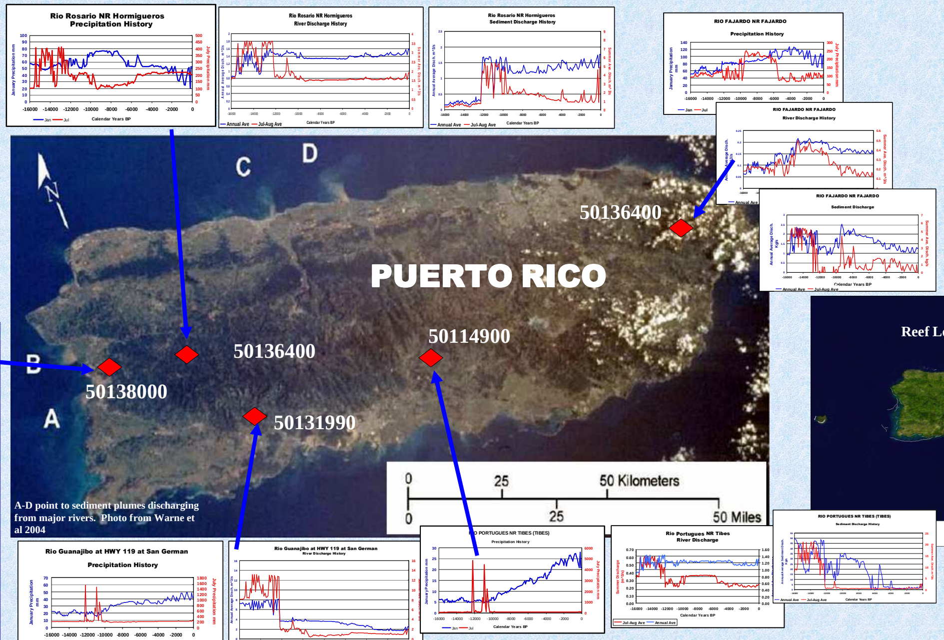
Climate change and land use change are the primary drivers of changes in ecosystem services globally. Global climate models suggest that in the future Puerto Rico and other small islands in the Caribbean will experience changes in rainfall seasonality. It is anticipated that water demands during low-rainfall periods may not be met, and an overall increase in river discharge due to greater amounts of rainfall during wet periods will cause increased damage from flooding and landslides. Land derived sources of sediment and nutrients carried to the marine environment by streams may also increase significantly. Changes in stream flow due to climate change may have profound effects on the downstream production of ecosystem services provided by the marine environment. Global climate models cannot predict the site specific changes in rainfall. However, site specific rainfall data is precisely what is needed in order to assess the potential localized impacts of increased stream flow and sediment discharge on reefs and other benthic communities providing essential ecosystem services to island populations. The Bryson Macrophysical Climate Model (MCM) was used to model average monthly temperature, rainfall and its seasonality, and river and sediment discharge for nine USGS gauging stations in Puerto Rico for the past 14,000 years. Temperature and rainfall was calibrated to NOAA HCDN 1961-1990 climate normal's. River and sediment discharge was calibrated to USGS gauging station data downloaded from their website. We provide an example from one of our modeled river basins, of how site specific climate scenarios may be developed from MCM output.

Hydrologic models such as SWAT, SEDMOD/RUSLE, or AnnAGNPS use daily rainfall data as model input. We chose the wettest and driest years (highest and lowest rainfall years) from the MCM results for the Guanajibo River near Hormigueros. As these data are monthly averages, we used the ratio of average daily rainfall to total monthly rainfall for the 30 year climate normal's to derive daily rainfall datasets for use in hydrologic models. Stream and sediment discharge for the basin was modeled using modern (1961-1990) rainfall data and compared to model runs using the derived rainfall data for today and wet and dry scenarios.




## Rio Guanajibo NR Hormigueros USGS Gauge # 50138000

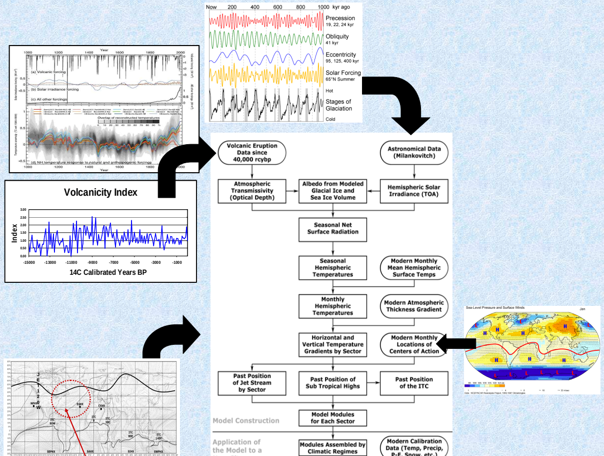



A-D point to sediment plumes discharging from major rivers. Photo from Warne et al 2004


## The Working MCM Model

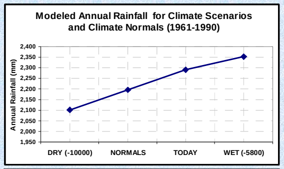
1. Uses measured solar radiation as it varies with Milankovitch cycles and probability of volcanic eruptions (Volcanicity Index)
2. Calculates net surface radiation for each hemisphere using the albedo, irradiance and volcanic aerosol values (Berger 1978; Hopkins, 1985).
3. Derives monthly mean hemisphere temps from seasonal hemisphere temps and modern mean surface temps as a control.
4. Calculates large scale meridional temp gradients, combines this with modern synoptic data (locations of centers of action like ITCZ, etc.) using monthly hemisphere temps.
5. Creates site specific MCMs using multiple non-linear regression techniques to link modern positions of the synoptic features to monthly weather station data (temperature, rainfall, storm frequency, snowfall, etc) and stream gauge data (river, sediment, nutrient discharge etc.).



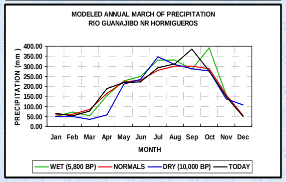

- North Pacific High
- ITCZ
- Jet Stream
- Azores High

## Climate Scenario Development – Rio Guanajibo NR Hormigueros

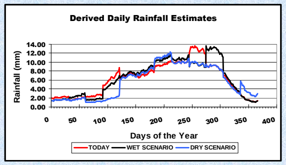
1. We modeled monthly rainfall using the Bryson MCM and selected the wettest and driest years based on total annual rainfall over the last 10,000 years.




2. Using the monthly average rainfall from the climate normal period (1961-1990) and the daily average normal's we calculated the daily to monthly rainfall ratio.




3. We derived daily rainfall estimates by multiplying the normal's ratios with the modeled monthly averages for the chosen wet and dry scenarios. These daily values can be used as input to hydrologic models in order to determine stream discharge and sediment discharge given present land use and soil type.




## Summary

The Bryson Macrophysical Climate Model provides site-specific, local response to changing circulation regimes within a region. It is site specific by virtue of the fact it implicitly considers topography and other local factors via calibration to local climate stations. The MCM has been validated with paleoecology and archaeology data at sites throughout the world (Bryson & DeWall 2007). In contrast to the MCM, the resolution (1-2 degrees of lat/long) of general circulation models (GCM) make GCMs unsuitable for local questions of climate change particularly in mountainous areas.

Using the Bryson Macroclimate Model (MCM) we modeled rainfall, stream and sediment discharge for several USGS gauging stations in Puerto Rico. We used climate normal's (1961-1990) for the nearest NOAA cooperative climate station obtained from NOAA. Stream discharge data for USGS gauges and sediment discharge data for 4 of these stations were obtained from the USGS NWIS website. Stream and sediment discharge data for Puerto Rican basins that have previously been calculated (Warme et al. 2004) were obtained from the USGS Caribbean Water Science Center. We used the Guanajibo River NR Hormigueros gauge as an example of our climate scenario development.

Because our models are calibrated to local conditions, realistic site specific climate scenarios based on site histories can be developed . Although currently the MCM is not predictive, by using daily to monthly average ratios for rainfall normal's data can be used in hydrologic models that consider current land use and soils. Future work includes SWAT modeling using the climate scenarios developed using the MCM.

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