POTENTIAL OF RAINFALL PRODUCTS FOR USE IN LANDSLIDE HAZARD ASSESSMENT IN THE CARIBBEAN REGION

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Precipitation is one of most significant drivers of hydrological and geomorphic hazards in the Caribbean Region. Rainfall-triggered landslides occur frequently within mountainous areas and pose a substantial economic and social threat to local populations. Studies generally characterize the potential for a rainfall-triggered landslide event according to a rainfall intensity-duration threshold from past landslide and rainfall occurrences. These thresholds have been produced on the global, regional, and local scales and rely on landslide mapping and rainfall gauge information.

The development of a threshold relationship requires information on the intensity (km/hour) and duration (hours) of the rainstorm event that corresponds to the location of the landslide and time it occurred. This information is often challenging if not impossible to retrieve due to the relatively sparse network of rain gauges in most parts of the world and the inability to determine exactly when landslides were initiated. This article provides a brief discussion of the current issues in precipitation estimation within the context of effective landslide hazard assessment as well as a potential future path for this type of analysis.

Past landslide hazard research has relied on spatially and temporally heterogeneous rainfall gauge data. To improve upon these studies and to broaden their applicability, landslide hazard assessment requires more comprehensive and widespread rainfall data. Rain gauges provide accurate measurements of precipitation in small areas, but they can be highly affected by wind and gauge placement, causing significant underestimations of rainfall. Some developed countries use measurements from operational surface radars to provide near-complete coverage at high spatial and temporal resolution, although results in mountainous areas—where landslides occur—are questionable due to beam shielding errors.

Rainfall estimates from remote sensors on orbiting satellites can provide frequent and consistent coverage over large areas. In the mid-latitudes and tropics, low-orbiting satellites such as the National Aeronautics and Space Administration (NASA's) Tropical Rainfall Measuring Mission (TRMM), image the rainfall structure using active and passive microwave sensors. Other passive microwave instruments on polar-orbiting satellites also provide precipitation information over land. While TRMM and other individual orbiting platforms can provide relatively accurate instantaneous rainfall rates, the return period of individual satellites limits the ability to estimate storm intensity and duration on small temporal scales.

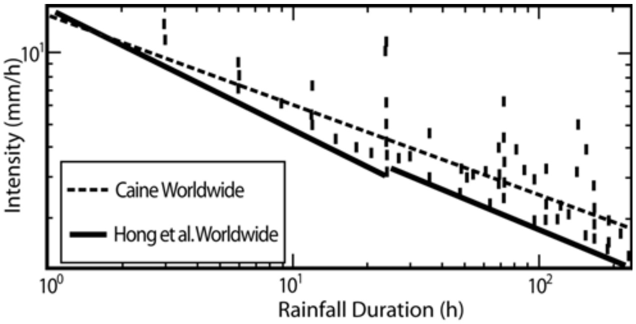
Infrared cloud-top brightness temperature sensing from geostationary infrared data provide 4 km, 15-minute resolution rain rates of cloud-top temperature and other information. The generally poor correlation between the coldest cloud areas and rainfall intensity suggests that these rain rates may be difficult to use independently, although they can be used to enhance other precipitation products.

To improve upon single-instrument precipitation estimates, many studies have made use of more sophisticated methodologies or have merged satellite information to produce enhanced products. The TRMM Multi-Satellite Precipitation Analysis (TMPA; Huffman et al., 2007) integrates data from multiple microwave satellites to provide a 3-hourly 0.25º product. More than 9 years of the TMPA product is available for research including a real-time version available for use in hydrological applications. Another example, the PERSIANN-CCS algorithm (Hong et al., 2005) uses geosynchronous infrared data that provide quasi-global rainfall estimates at 4 km hourly resolution by incorporating information on cloud temperature, texture and geometry. The table on page 6 summarizes some of the rainfall products.

Orography limits the accuracy and availability of the majority of many rainfall products and has sizeable consequences for landslide hazard assessment. In mountainous areas, precipitation generally increases with elevation as moist air is forced upwards, causing significant rainfall on the windward side of a mountain. For all types of *in situ* and remote sensing instruments, mountains can bias the areas in which gauges are installed, cause large signal interference of radar beams, and alter atmospheric flows in ways that can distort the typical cloud-top temperature-rain rate relationship. Studies have attempted to correct for orographic precipitation effects by introducing additional surface data such as terrain, elevation and surface wind direction. While these studies assist rainfall estimation in mountainous settings, they still do not provide the spatial and temporal resolution required for landslide hazards assessment.

Landslide hazard assessment is performed on a wide array of scales. For studies at the slope or watershed level, gauge or radar data remain the most reliable sources available. However, for large scale studies and for evaluating areas without an *in situ* network, satellite data can provide crucial information for general landslide hazard analysis and susceptibility mapping. The lead author examined rainfall events over Puerto Rico using the highest resolution satellite database available, PERSIANN-CCS, by comparing the data with rain gauge information over the same area. Preliminary results indicate that at a 4 km resolution, the satellite data were able to resolve the timing of large rainfall events over the island but had limited ability to accurately provide intensity values for those events or total seasonal accumulation measurements. The figure at the top of page 16 illustrates satellite data resolution differences over Puerto Rico and compares them to landslide inventories.

Given the improved resolution capabilities of merged satellite information, new studies are using these data on the global scale to assess susceptibility to landslide events. By using precipitation information from the TMPA, Hong et al. (2007) developed a satellite-based rainfall intensity/duration threshold from landslide cases in various climate and geological locations and mapped out a global landslide susceptibility index by combing land surface characteristics such as topography, soil type, and land cover (see figure in next column). Knowledge of landslide susceptibility and the ability to detect heavy rain events that meet threshold conditions provide the basis for exploring the potential and limitations of such approaches for analyzing and studying the occurrences of landslides on a global basis, and even possibly forecasting them.



Rainfall intensity duration thresholds derived from a global study by Caine (1980) from rainfall gauge data, and from Hong et al. (2006) from TMPA. Figure from Hong et al. (2006).

Although important advances are being made to integrate satellite precipitation data into landslide hazard assessment, it is important to recognize the relative scale at which this type of analysis can be executed. Because of the current limitations in providing accurate rainfall information on small spatial and temporal scales, satellite-based landslide hazard analyses cannot resolve rainfall events that trigger a landslide in less than 3 hours in a relatively small area. While this may serve to limit the application of the satellite-based rainfall information to larger-scale events, the current products and steps already taken demonstrate that satellite information will be increasingly important in enhancing our knowledge of landslide hazard assessment.

References

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Rainfall Product	Coverage (Geographic)	Spatial Resolution	Temporal Resolution	Limitations
Rainfall Gauges (NCDC, USGS)	Variable, 10,000 stations globally monitored by NCDC	Point Source (~30 cm radius)	Hourly, 1970s to present	Wind errors, reporting issues, gauge placement
Surface Radar	US, Canada, Europe, China, and Japan. 400 km max. radius	4 km gridding	4-10 minutes, hourly products, 1988 to present	Beam shielding and errors in mountain areas
IR calibrated with merged-MW (PERSIANN-CCS)	Global	~4 km	Hourly, 2001 to present	Large uncertainty at small spatial and temporal scales
Low-Orbit Satellites, e.g., TRMM (TMI, PR)	50° N-S	0.25º	Instantaneous, 12+ h, 1997 to present	Limited temporal sampling, algorithm inconsistencies
TMPA	50º N-S	0.25º	3h, 1998 to present	Not available at small spatial scales (<25km)

Overview of different precipitation data sets, their coverage, resolution, time of operation and general limitations.