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Application of Satellite Imagery for Surface Rain Rate Estimation

INTRODUCTION

Rainfall events can directly affect the surface transportation infrastructure and disrupt routine operations. Extended periods of light to moderate rain can saturate the topsoil, leading to excessive runoff, inundation, and roadway damage. More intense events can cause widespread flooding that may ultimately increase flows in waterways, thereby impacting bridges and overpasses immediately from floating debris and, in the longer term, through potential scouring around supporting structures. Of course, highway safety during rain is a primary concern. Traditionally, characteristics of rainfall events have been derived from rain gage data and radar observations. However, the number of official rain gage stations is relatively small, and their wide spatial distribution may not accurately represent a particular location of interest. Radar rain estimates are well accepted, but anomalous atmospheric propagation and the earth's curvature can introduce errors over distance. More recently, infrared (IR) cloud top temperatures (CTTs) as observed by satellite are being employed to estimate a surface rain rate. A primary advantage of this method is the excellent spatial and temporal resolution of the imagery that is typically available in near real time. The Geostationary Operational Environmental Satellite (GOES) system provides IR imagery at 15- to 30-minute intervals with a resolution of 4 x 4 kilometers, or about 2.5 x 2.5 miles. Since the late 1970s, many algorithms and calibration techniques for relating CTT to surface rain rate have been developed and tested. The most current methods in use by the U.S. federal government rely not only on GOES data, but also numerical model data, microwave rain rates, and other corrective factors to produce rain estimates. An earlier method, the Automated Satellite Rainfall Rate Estimation technique, or Auto-Estimator, developed by Vincente et al. provided a formulation to directly estimate rain rate from IR CTT alone as one part of its computational process. The purpose of this brief study was to determine the applicability of this basic Vincente formulation for operational use in Louisiana. This was be accomplished by comparing the rain rates computed from GOES IR CTTs to actual rain gage measurements under a variety of synoptic weather situations.

LTRC Report 464

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OBJECTIVE AND SCOPE

This study was developed to investigate and apply the burgeoning technology of satellite-derived rain rates to Louisiana weather conditions. These conditions will be described by general synoptic weather type and frequency of occurrence will be discussed. Hourly rain gage measurements from selected surface stations was acquired. Satellite image processing software was used to analyze GOES imagery recorded to the nearest coincident in space and time to the rain gage values. These values were then compared to the Vincente satellite rain-rate formulation. This study only considered GOES satellite imagery, the basic Vincente rain rate formulation, and Louisiana rainfall events. Other more complex rain rate methods and calibration techniques were available and in use operationally, but only the direct CTT-rain rate relation was tested here.

METHODOLOGY

For this analysis, two primary sets of data were required. Five airport surface stations from across Louisiana were selected for hourly rainfall measurements. Actual precipitation values were obtained from *Hourly Precipitation Data Louisiana*, a monthly publication issued by the National Oceanic and Atmospheric Administration. Total accumulated rainfall in inches is recorded for each hour in local standard time (CST). All hourly totals greater than or equal to 0.1 in. were retained to represent moderate to heavy rain conditions. With the Earth Scan Lab, Louisiana State University maintains an archive of approximately 10 years of digital GOES data. Images are saved at 30-minute intervals and include visible (daytime), water vapor, and IR spectral channels. The data were processed using XVU and Terrascan software packages. For each hour with recorded surface rainfall, the corresponding two 30-minute satellite images (15 and 45 minutes past the hour) were examined and IR CTT values over the affected stations were obtained and averaged for an hourly IR temperature. This IR value was then input into the Vincente formulation, and an hourly rain rate was computed for comparison to the measured value.

CONCLUSIONS

GOES IR values observed over Louisiana during 2008 were analyzed with respect to surface measured rain totals and a rain-rate relationship was derived. Within the IR temperature range of approximately -45°C to -61°C, both the derived formula and an existing algorithm developed by Vincente et al. fall between the first and third quartile of the measured rain data. The IR imagery was shown to identify most rain events of multiple hour duration, but the computed estimates often varied significantly from the actual measured amount. There are many contributing factors to this error. Cirrus outflow from a convective system can mask the area of a precipitating cloud beneath. Location errors can occur in regions of wind shear as clouds move in one direction and the rain they produce in another. Heavy rain may only fall from a small portion of a mesoscale convective system. With thin or smaller clouds that do not fill the field of view, IR from lower levels or surface can reach the sensor, making the clouds appear warmer than they actually are. Many computational techniques exist that endeavor to improve the estimated rain rate by adjusting the satellite IR data for atmospheric (sub-cloud) conditions, cloud growth characteristics, and cloud particle size. This study's results suggest that such corrective actions are necessary for a more accurate estimation. Although the technology continues to be developed and tested, satellite rain-rate estimation is an accepted method currently being applied operationally by many agencies. In those regions without an official rain gage station or adequate radar coverage, even direct use of the algorithm as performed here can yield useful estimates, at least as a first approximation. Averaging over a larger spatial domain to capture more of the cloud characteristics may help reduce the errors associated with a single point measurement.

RECOMMENDATIONS

Surface rain accumulations can be estimated from satellite IR information. Direct application of the Vincente or derived formulas provide an initial estimation, which is essential for locations without a rain gage or radar coverage. Larger spatial and temporal averages should be tested during specific events and compared to measured and/or modeled data. Since GOES is the only platform currently providing near continuous data over the contiguous U.S., it remains the sensor of choice. As more data from other satellites (such as the Tropical Rainfall Measuring Mission or TRMM) become routinely available, further comparative analyses should be performed.