A SATELLITE RAINFALL RATE ESTIMATION ALGORITHM

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OUTLINE

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GOALS

- To complete the development of an algorithm capable to estimate satellite rainfall rates in the tropical conditions.

- To estimate rainfall rates over warm rainy clouds that are very frequently in the tropical areas.

INTRODUCTION

The general objective of this research is to develop a new algorithm to estimate rainfall rates over tropical regions. The HE has limitations detecting rainfall in warm rainy clouds due to its threshold of 235K. Over 235K rainy clouds can not be detected by the HE.

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RAINFALL RETRIEVAL ALGORITHM

The rainfall retrieval algorithm includes two components:

Cloud rainy pixel detection algorithm + Rainfall rate estimation algorithm = Rainfall Retrieval Algorithm

SATELLITE DATA

- Four (4) bands of GOES has been used for this algorithm:
  - Band 1: visible (0.65 μm)
  - Band 2: near IR (3.9 μm)
  - Band 3: water vapor (6.7 μm)
  - Band 4: thermal IR (10.7 μm)

- Albedo of Band 2

- Two band differences were also calculated:
  - Band 4 – Band 2
  - Band 4 – Band 3
- Difference of two consecutives brightness temperature of :
  - Band 3
  - Band 4

BASIS OF PROJECTION PRINCIPLE

- The algorithm is based on the angle formed by two vectors in the n-dimensional space.
- Projection principle: when two vectors are collinear the radiative variables of clouds used to create the vectors exhibit similar properties, and when the vectors are orthogonal the radiative variables have no elements in common.
- Radar data are used to identify rain/no rain pixels.

BASIS OF PROJECTION PRINCIPLE

- Satellite data are used to create rain and no rain pixel populations. The central tendency of each population is used to generate rain and no rain calibration vectors.
- A pixel from an independent data set is used to create a third vector, which is projected into the previously calibrated vectors, with the purpose of classifying the third vector into a rain or no rain population.

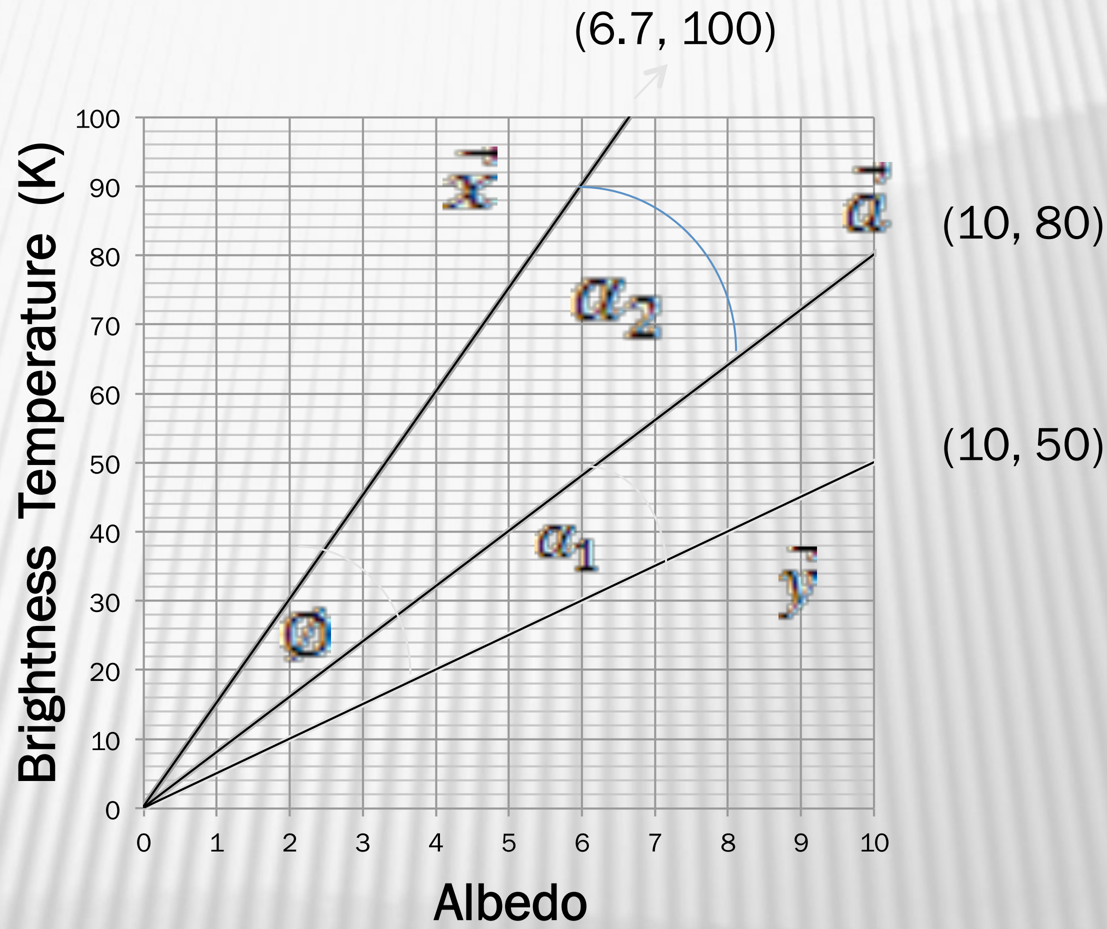
PROJECTION IN TWO DIMENSIONS

$\phi = 7.5^o$

$\alpha_1 = 3.3^o$

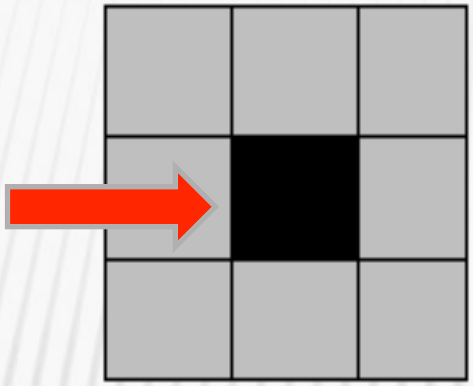
$\alpha_2 = 4.2^o$

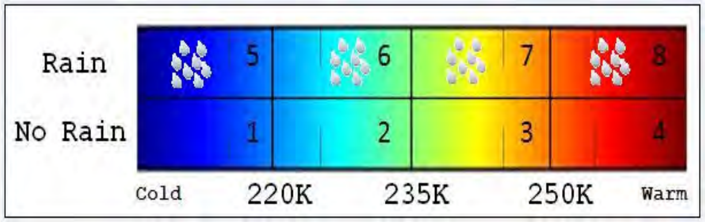
$\alpha_1 + \alpha_2 = \phi$



DETECTION ALGORITHM

Selected pixel surrounded by eight neighbor pixels

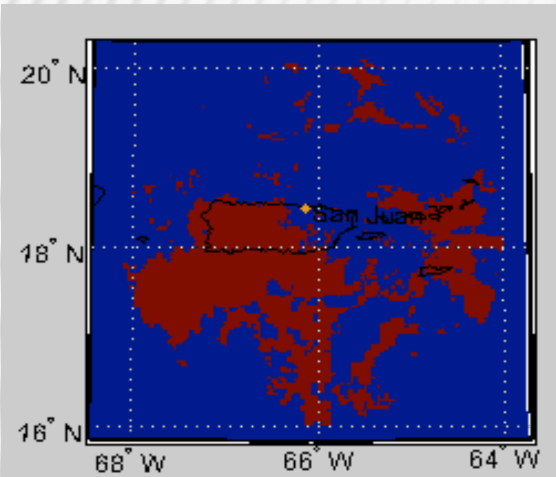




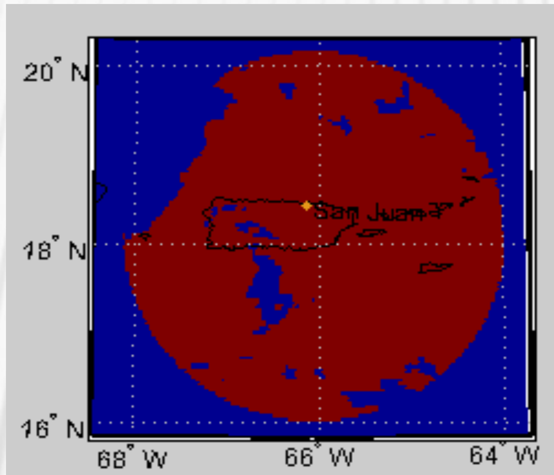
Detection algorithm select up to eight (8) neighbor pixels to reduce noise and derive a more consistent estimator for the pixel that is located in the center of square.

RAINFALL DETECTION COMPARISON

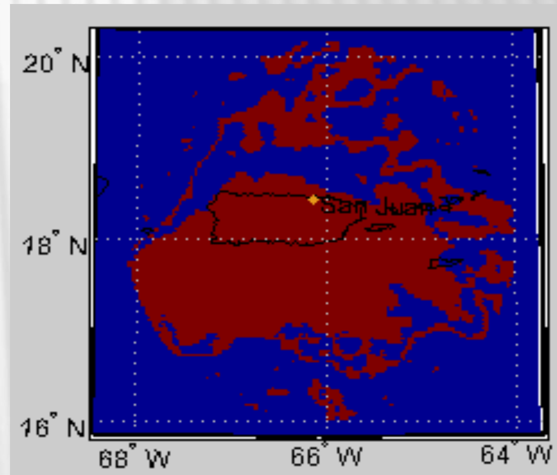
(17:45 UTC, October 27, 2007)



NEXRAD Radar



Hydro-Estimator



Projection Algorithm

DETECTION ALGORITHM RESULTS

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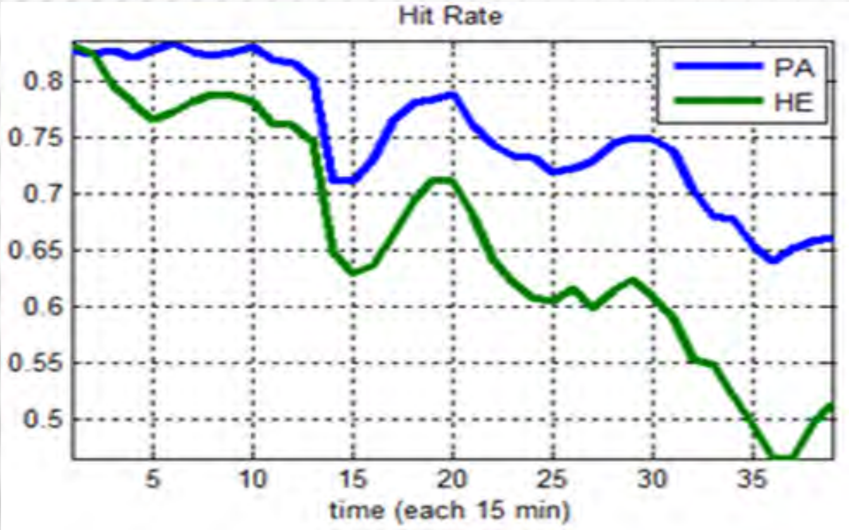
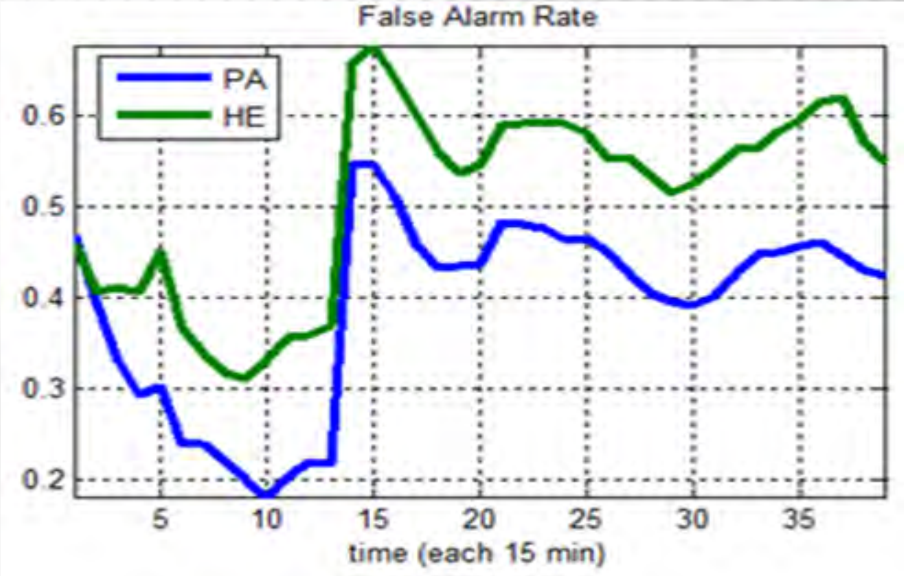
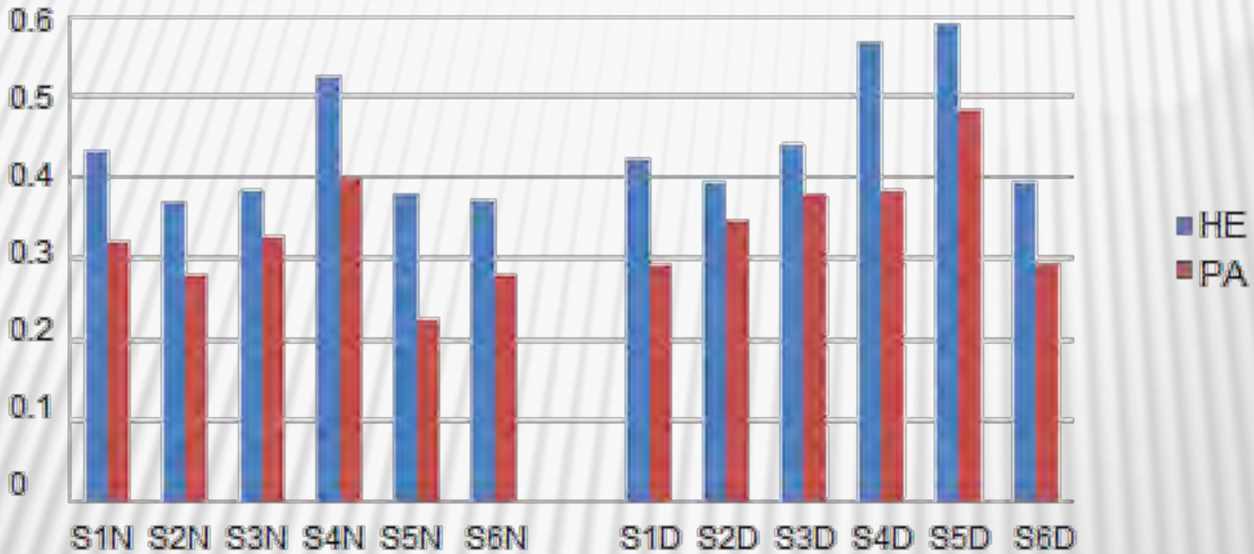
April 17, 2003





DETECTION ALGORITHM RESULTS



$$I = \begin{cases} 0, & \text{best performance} \\ 1, & \text{worst performance} \end{cases}$$

$$I = \frac{\overline{FAR} - \overline{POD} - \overline{HR} + 2}{3}$$

A total of six (6) storms were selected to compare performance with the HE

ESTIMATION ALGORITHM

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Estimation algorithm considers simultaneously the variation of intensity of reflectivity in space and in time. This algorithm requires a sequence of consecutive images of reflectivity to estimate rainfall rates. The raining pixels observed at time *t*, at time *t-1 and at time t-2* will be considered.

ESTIMATION ALGORITHM

Variables used in the estimation algorithm:

Variable Name	Variable	Source	Time lags	Spatial lags
Z	Reflectivity (dBz)	radar	0, 1, 2	$i \pm 1, j \pm 1$
T_2	Brightness Temperature Channel 2	satellite	0, 1, 2	$i \pm 1, j \pm 1$
T_3	Brightness Temperature Channel 3	satellite	0, 1, 2	$i \pm 1, j \pm 1$
T_4	Brightness Temperature Channel 4	satellite	0, 1, 2	$i \pm 1, j \pm 1$
T_{42}	Difference of $T_4 - T_2$	satellite	0, 1, 2	$i \pm 1, j \pm 1$
T_{43}	Difference of $T_4 - T_3$	satellite	0, 1, 2	$i \pm 1, j \pm 1$
A	Albedo Channel 2	satellite	0, 1, 2	$i \pm 1, j \pm 1$
V	Visible Reflectance Channel 1	satellite	0, 1, 2	$i \pm 1, j \pm 1$

ESTIMATION EQUATION

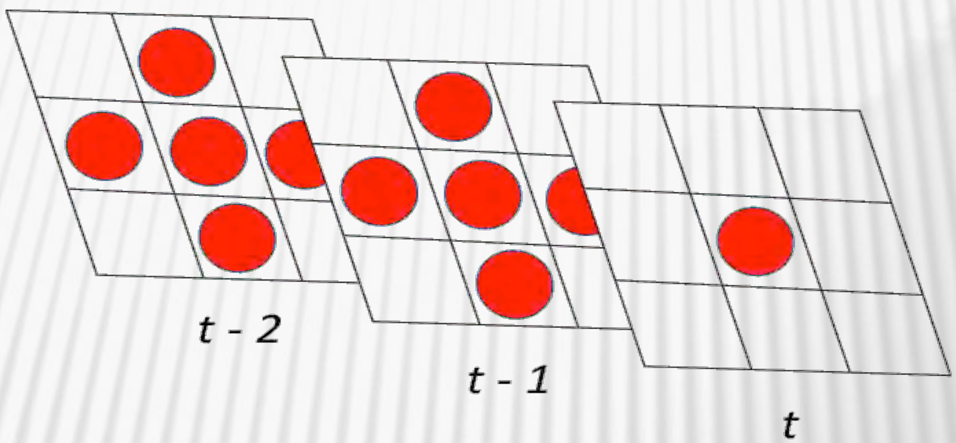
Reflectivity model may be expressed as follows:

$$\begin{aligned} Z_t(i,j) = a_0 &+ a_1X_t(i,j) + a_2X_{t-1}(i,j) + a_3X_{t-1}(i,j-1) + a_4X_{t-1}(i-1,j) \\ &+ a_5X_{t-1}(i+1,j) + a_6X_{t-1}(i,j+1) + a_7X_{t-2}(i,j) \\ &+ a_8X_{t-2}(i,j-1) + a_9X_{t-2}(i-1,j) + a_{10}X_{t-2}(i+1,j) \\ &+ a_{11}X_{t-2}(i,j+1) + \varepsilon_t \end{aligned}$$

Where Z is reflectivity and X represents a radiative variable (T4, T3, T4-3, Albedo and Visible Reflectance)

This is a dynamic model that requires of the motion vector to activated the corresponding parameters.

ESTIMATION ALGORITHM



The estimation algorithm requires a sequence of consecutive images of reflectivity and satellite imagery. To reduce computational effort three consecutive images will be used to estimate reflectivity.

ESTIMATION ALGORITHM RESULTS

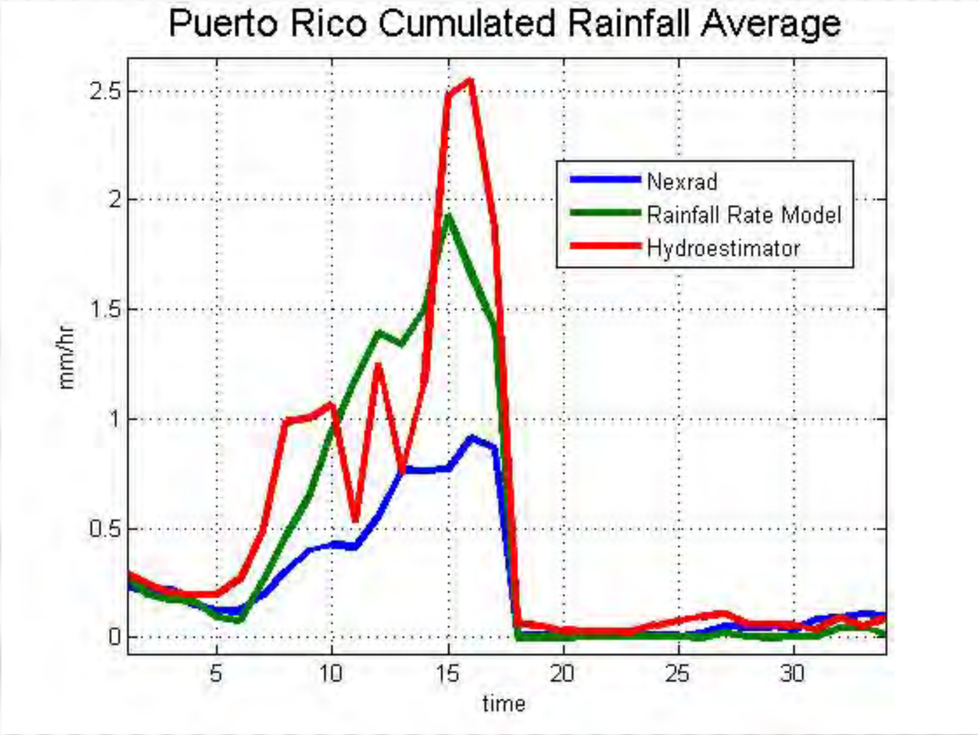


Figure shown above represents the average rainfall (Rain Rate) Observed and Estimated between October 29 and October 30, 2007 during daytime (1200 UTC and 2045 UTC) since 8:00 am to 4:45 pm.

CONCLUSIONS

- Preliminary results show that the detection algorithm outperformed the rainy pixel detection of the HE.

- In an overall comparison between the PA and HE the PA outperformed the HE in terms of detection and estimation for the tropical climate conditions.

FUTURE WORK

- Finish the rainfall rate algorithm
- Perform the comparison between the new algorithm and the HE.
- Increase the spatial lag and measure the computational effort.

QUESTIONS?