RAINFALL NOWCASTING ALGORITHM BASED HYDRO-ESTIMATOR DATA AND DETECTING WARM RAINING CLOUDS

Joan Manuel Castro-Sánchez[1], Nazario D. Ramirez-Beltran[1],
NOAA-Colaborator: Robert J. Kuligowski[2]
[1]University of Puerto Rico, P.O. Box 9040, Mayagüez, PR 00681, U.S.A, joan.castro@upr.edu , nazario.ramirez@upr.edu
[2]NOAA/NESDIS Center for Satellite Applications and Research (STAR), Camp Springs, MD 20746, U.S.A. bob.Kuligowski@noaa.gov

Introduction

During last three years, we constructed a couple algorithms for predict rainfall distribution for Puerto Rico and Caribbean Basin. The proposed model consider temporal and spatial analysis based on a sequence of **Hydroestimator** images and atmospheric parameters obtained from numerical model (**NAM** Files). We generated a couple algorithms for **identifying potential raining clouds cells** and forecast **short-term rainfall accumulation**.

Objectives:

The Short Term Rainfall Prediction Algorithm (STRaP) includes temporal and spatial components to detect where rain occurs, and forecast the evolution of rainy clouds during short intervals (Generation, Intensification and Dissipation). The main goal is to improve potential rainfall detection, and rainfall intensity in Puerto Rico and the Caribbean Basin.

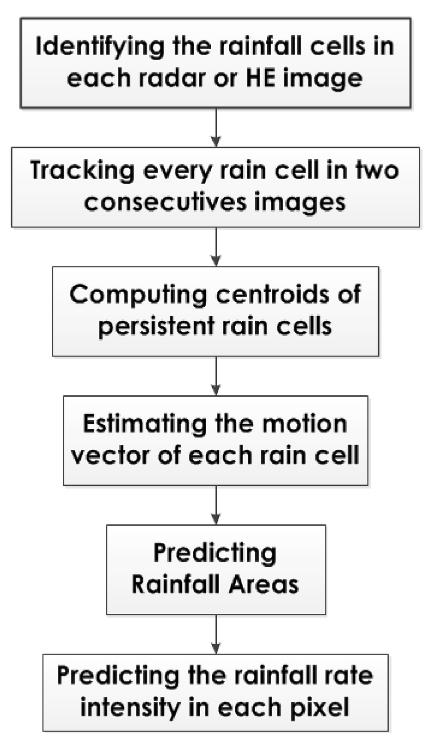
Methodology:

The proposed algorithm is divided in two mainy components:

1. **Determine rainy cloud pixels** (Tracking Raining Cells)
2. **Rainfall estimation** (Rainfall Prediction Model)

A **tracking rainfall cells method** is introduced to forecast the cloud displacement based on a **Pattern Recognition Scheme** and **Cloud Motion Vector.** A **Rainfall Prediction Models** are introduced to forecast **short term precipitation**, based on **linear and non linear regression equations**.

The proposed nowcasting algorithm includes the implementation of six major steps:



Identifying rainfall cells:

Detecting rainy cloud cells

Unsupervised cluster approach **(Otsu Method)** is considered to identify **potential raining cells** for each image. The previous **two images** from Hydro-Estimator are selected to obtain potential matching cells. ***Temporal scale is 15 minutes.*** Potential raining cells minimum member are **25 pixels/cell**. ***Spatial resolution is 4 km*** based on GOES resolution for Channel 4.

Computing centroids:

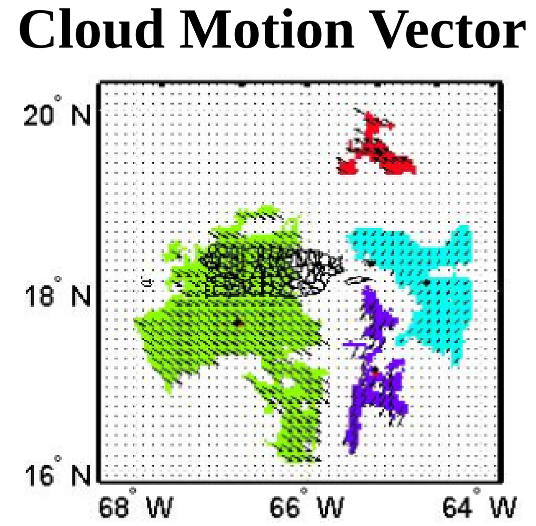
The weighted average of reflectivity were used to estimate the centroids. Thus, the average reflectivity on zonal and meridional components were computed.

Tracking Rainfall Cells:

Prediction of rainy pixels

Using the equation of the line for two point, temporal **tracking cell** is estimated. Estimation of the most likely rain fields requires estimation of the cloud motion vector. The **cloud motion vector** can be estimated by computing the displacement between the **centroids** of the same rain cell observed at two consecutives instant of time. Using the equation of the line for two point, temporal tracking cell is estimated.

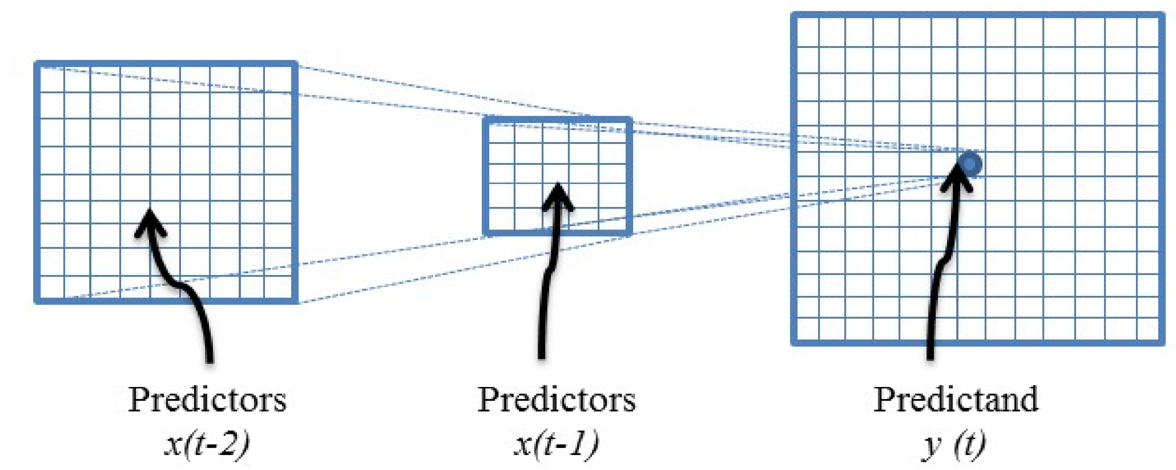
Cloud Motion Vector



The motion vector for a rainfall event that occurred on October 27, 2007 (at 1930 UTC)

Predicting rainfall intensity : STRaP

STRaP is introduced in this work. The linear model is an approximation of the stochastic transfer function (STF) model, which is typically used to represent the dynamic response of a system affected by several input variables and usually modeled by impulse response functions (Box and Jenkins, 1994). Two lags images provided by **HE** or **SCaMPR** are used to forecast raining pixels (spatial and magnitude). Neighbor rainfall pixels predictors with one and two lags ***(106 possible predictors***). **Forward Selection and Division Group Variable Scheme** was applied to obtain better forecast predictors to estimate rainfall intensity.



Scales	Lag	Lag
Temporal	1	2
Spatial (pixels)	25 (5 x 5)	81 (9 x 9)
Resolution (km)	4	4
Area (km2)	20 x 20	36 x 36

STRaP1: Linear Equation Model

$$Z(t) = a_o + \sum_{i=1}^{n} b_i Z_i(t-1) + \sum_{j=1}^{m} c_j Z_j(t-2)$$

STRaP2: Non-Linear Equation Model

$$Z(t) = \alpha + (\beta - \alpha) e^{-\left(a_o + \sum_{i=1}^{n} b_i Z_i(t-1) + \sum_{j=1}^{m} c_j Z_j(t-2)\right)}$$

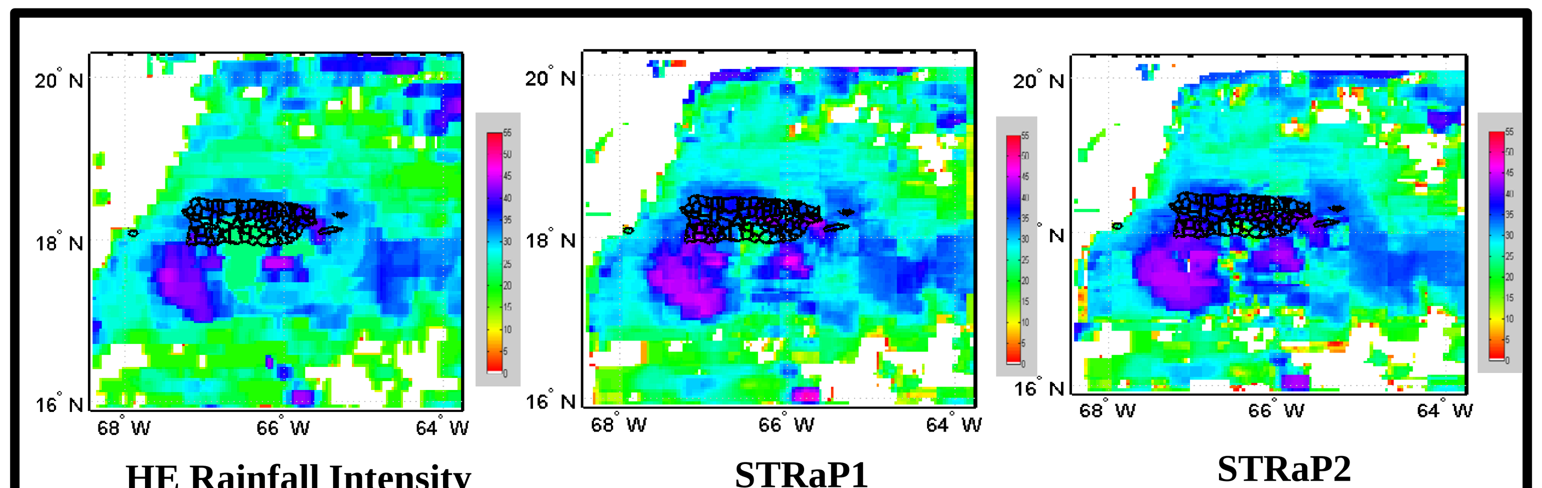
where:
Z(t): Rainfall Intensity:
estimations provided by HE in mm/hr and converted to dBZ
a, b, c: coefficients
n, m : predictors
$n + m \leq 5$
$\alpha = \min(Z(t-1), Z(t-2))$
$\beta = \max(Z(t-1), Z(t-2))$

Preliminary Results

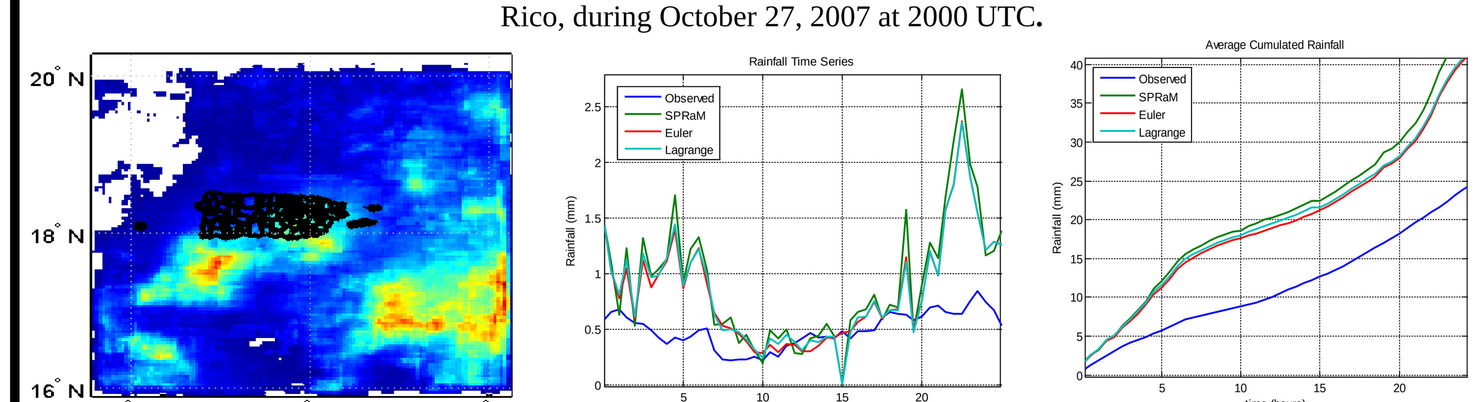
Skill Score validation is applied to compare convective cloud pixel detection generate by **STRaP's**. Errors and Bias analysis is used to estimate intensity and accumulate rainfall. Five rain events was selected occurred in Puerto Rico since 2003 and 2013.

Considerations when selecting rainfall events

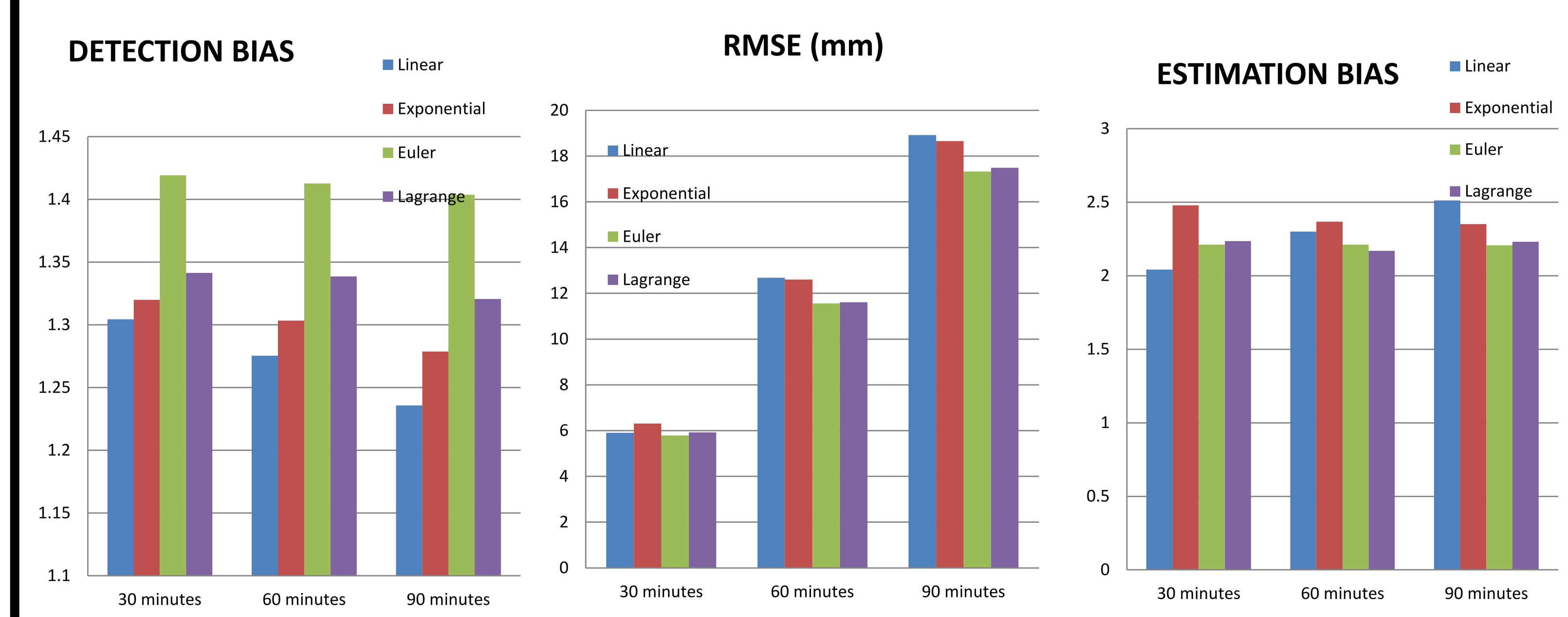
- Causes precipitation
- Trough (cold fronts)
- Tropical systems (wave, tropical storms, hurricanes),
- Local events caused by high humidity in surface levels, mountains interaction, and trade winds effects
- Duration of rainfall events: (short, medium and extended events)
- Considered 24 hours total rainfall accumulation



Observed (Hydro-Estimator) vs 30 minutes Forecast Rainfall Intensity (STRaP's). Rainfall event in Puerto Rico, during October 27, 2007 at 2000 UTC.

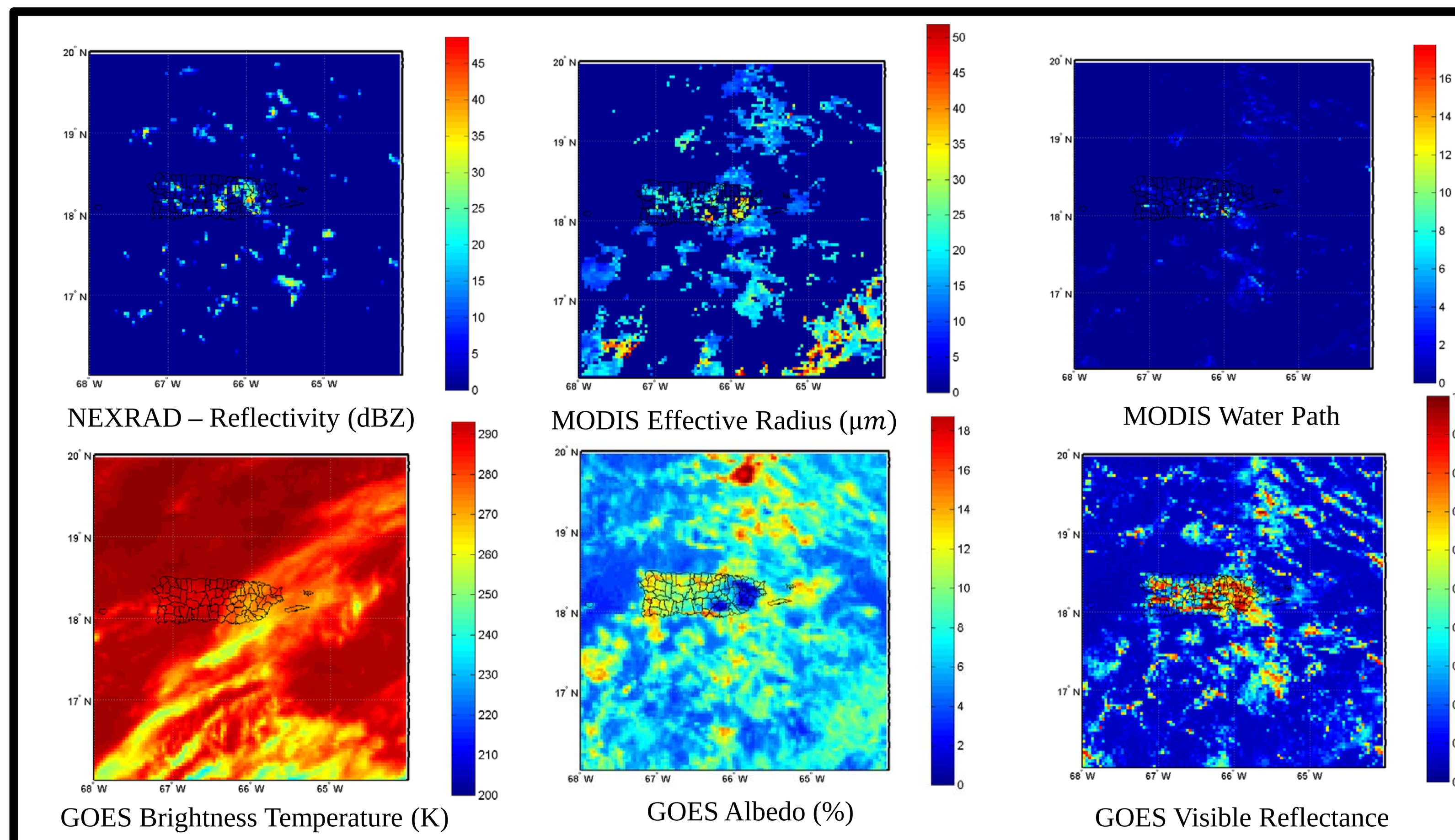


24 Hours Observed Rainfall Accumulation (HE), Estimated and Estimated (STRaP2) , during October 27, 2007



Tracking potential rainy cells scheme based on cloud motion vector algorithm and Lagrange rainfall estimations reduce false alarm rate for rainy pixels detection during rainfall events. Hydro-Estimator overestimate detection of rainy pixels and rainfall accumulation.

It has been shown passive microwave techniques significantly underestimate warm rain, and most of the underestimations occur for clouds with low tops (< 3.5 km). Thus, Puerto Rico is the ideal testbed to study the warm raining clouds, since warm rain usually occurs in low-level liquid water clouds with no ice-phase process and also because Puerto Rico is heavily affected by rainfall due to warm-top convective processes that are induced by local sea breeze and/or orographic features.



Comparison between MODIS and GOES Products observed at same time. December 1st, 2012 at 1735 UTC

Future Work:

One of the main purposes of this work is to improve the detection of warm raining clouds of the SCaMPR satellite algorithm, using Puerto Rico as a testbed. Data from several sensors and in different spectral ranges are studied. Specifically this work will focus on study data from MODIS, GOES and NEXRAD.

References

Ramirez-Beltran, N.D., J. M. Castro, and J. Gonzalez. **An algorithm for predicting the spatial and temporal distribution of rainfall rate**, *An International Journal of Water*. IJW 2015 Vol. 9 No 4.
Rosenfeld, D., 1987: **Objective method for analysis and tracking of convective cells as seen by radar**. *J. Atmos. Oceanic Technol.*, 4, 422–434.
Witt A., and J.T. Johnson, 1993: **An enhanced storm cell identification and tracking algorithm**. *Preprint. 26th Conf. on Radar Meteorology*, Norman Oklahoma, Amer. Meteor. Soc. in press
Kuligowski, R. J., 2002: **A self-calibrating real-time GOES rainfall algorithm for short-term rainfall estimates**. *J. Hydrometeor.*, **3**, 112-130.
Scofield, R. A., and R. J. Kuligowski, 2003: **Status and outlook of operational satellite precipitation algorithms for extreme-precipitation events**. *Mon. Wea. Rev.*, **18**, 1037-1051.

Acknowledgements

This research was fully or partially funded by NOAA-CREST. Cooperative Agreement No: NA11SEC4810004 and for the NSF, under the award number: CBET-1438324. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the NOAA and NSF.