NEW SCHEME TO IMPROVE THE DETECTION OF RAINY CLOUDS IN PUERTO RICO

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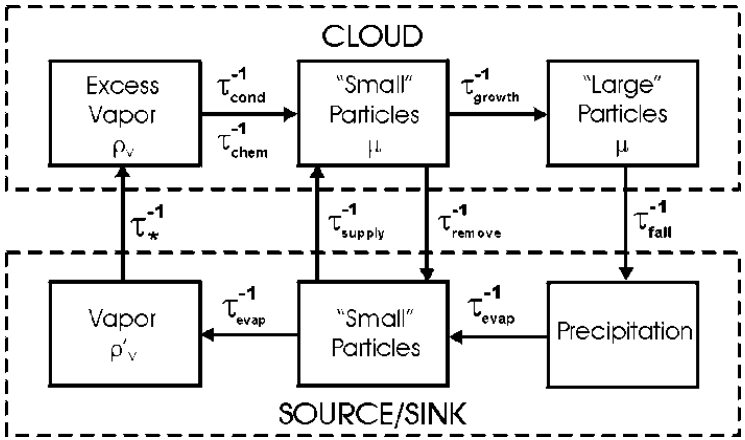
Introduction

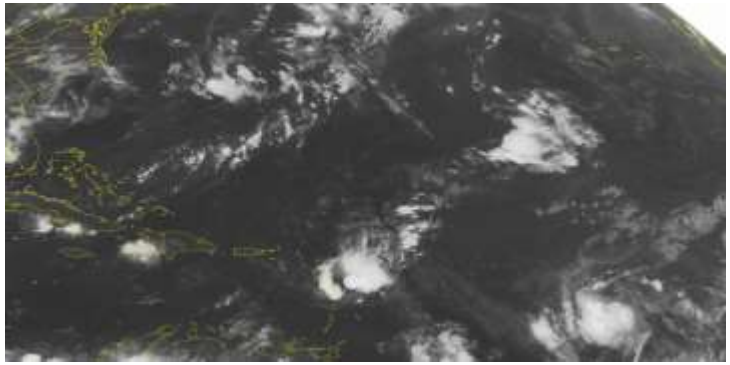
- A cloud rainfall event is the result of a complex thermodynamic process that starts with nucleation of cloud drops, continues with drop growth, and finishes with water drop precipitation.



The Hydrologic Cycle: Thermodynamic processes which govern cloud microphysics. Source: National Weather Service (2010)

Rainfall Cloud Identification

- **Caribbean Rainfall:**
  - **Tropical Systems** (waves, storms, and hurricanes) summer and autumn season
  - **Cold Fronts**: winter and spring season
  - **Troughs** during all year
  - **Orographic Effects** (water vapor, mountains and winds integrations)



GOES Images at Water Vapor Band (10.7 um)

GOES Images at Infrared Band (3.9 um)

Research Tasks

- Generate a couple algorithms for predict rainfall spatial distribution for Puerto Rico and Caribbean Basin.
- The proposed model consider temporal and spatial analysis based on a sequence of rainfall rate. For instance, images generated from **Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) algorithm**.
- Produce a couple algorithms for **identifying potential raining clouds cells** and forecast **short-term rainfall accumulation**.

STRaP

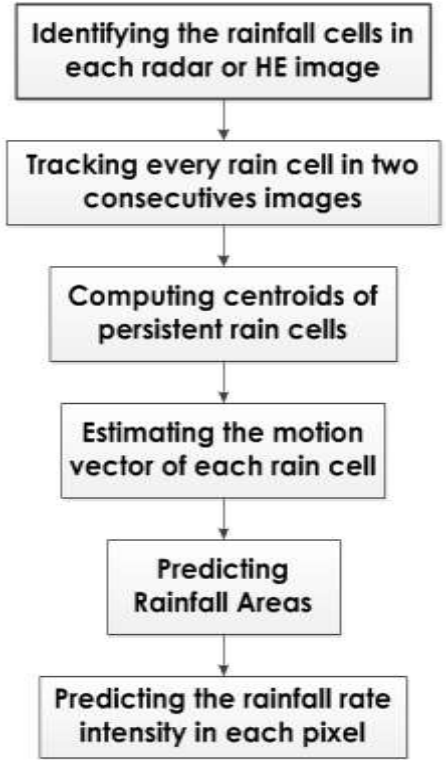
- **The Short Term Rainfall Prediction Algorithm includes temporal and spatial components** to detect where rain occurs, and forecast the evolution of rainy clouds during short intervals (***Generation, Intensification and Dissipation***).
- The main goal is to improve the rainfall detection of **SCaMPR**, which is the operational rainfall rate algorithm of **GOES-R**.

STRaP 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**.



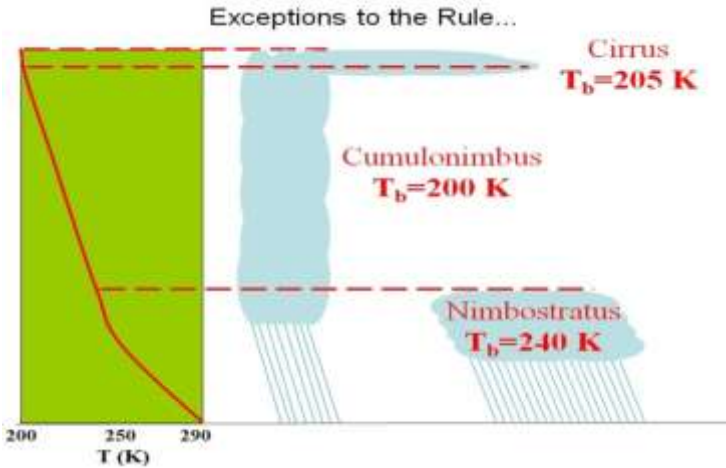
Preliminary Results

- 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.
- Eight rain events was selected occurred in Puerto Rico since 2008 and 2014.

Rainfall Events

- September 29, 2008 (Warm Clouds)
- June 24, 2010 (Cold Clouds)
- July 14, 2011 (Cold Clouds)
- October 18, 2011 (Warm Clouds)
- October 22, 2012 (Warm Clouds)
- December 1, 2012 (Warm Clouds)
- July 18, 2013 (Cold Clouds)
- August 19, 2014 (Cold Clouds)

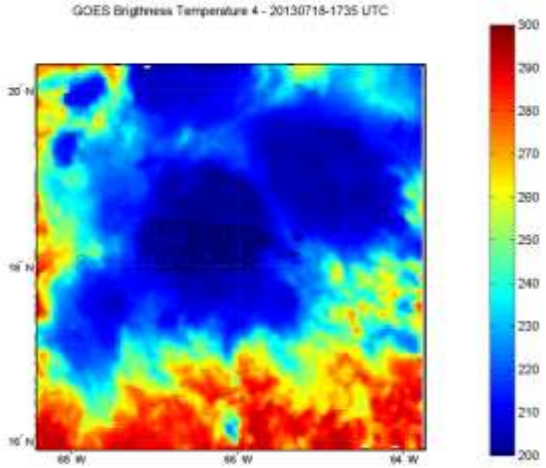
Colder Clouds: Vertical Convection
Highest Vapor elevation and lower top cloud temperature. BT Band 4 < 235 K



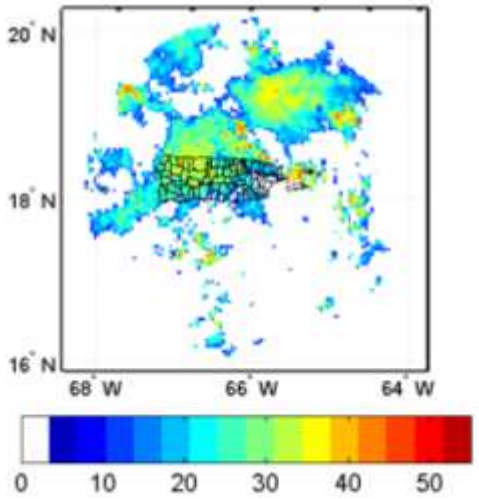
Warmer Clouds: Horizontal Convection
Lower vapor elevation and higher top cloud temperature. (BT Band 4 > 235 K)

Preliminary Results: Cold Clouds

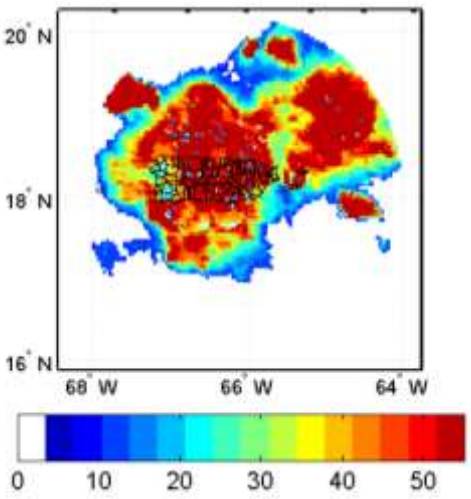
Over detection



GOES



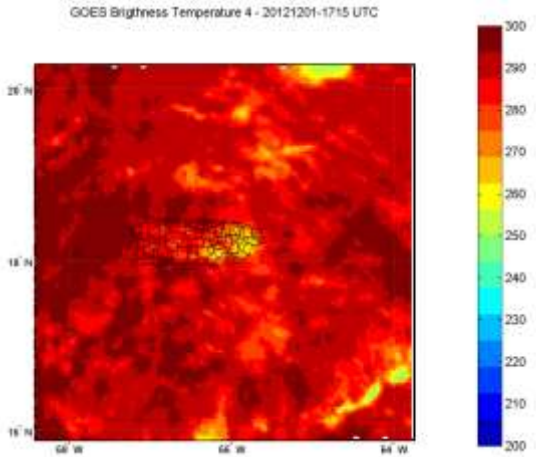
NEXRAD



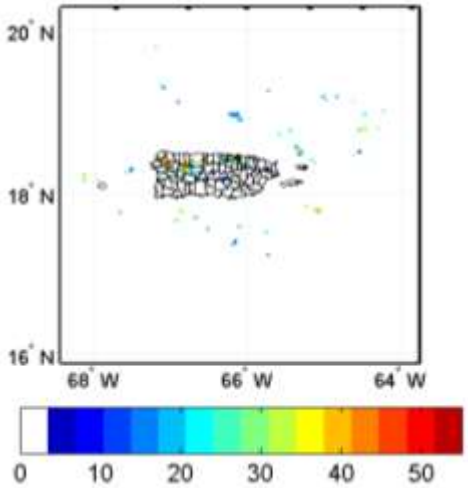
SCaMPR/ STRaP

Band 4 GOES-13, NEXRAD, SCaMPR and 30 minutes forecast (STRaP). Rainfall event in Puerto Rico, during July 18, 2013 at 1730 UTC.

Preliminary Results: Warm Clouds

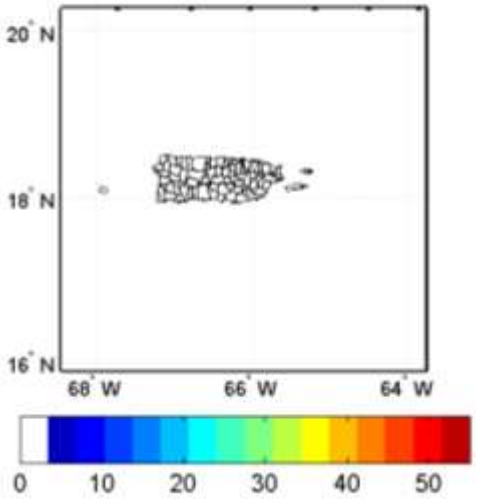


GOES



NEXRAD

No Rainy Detection



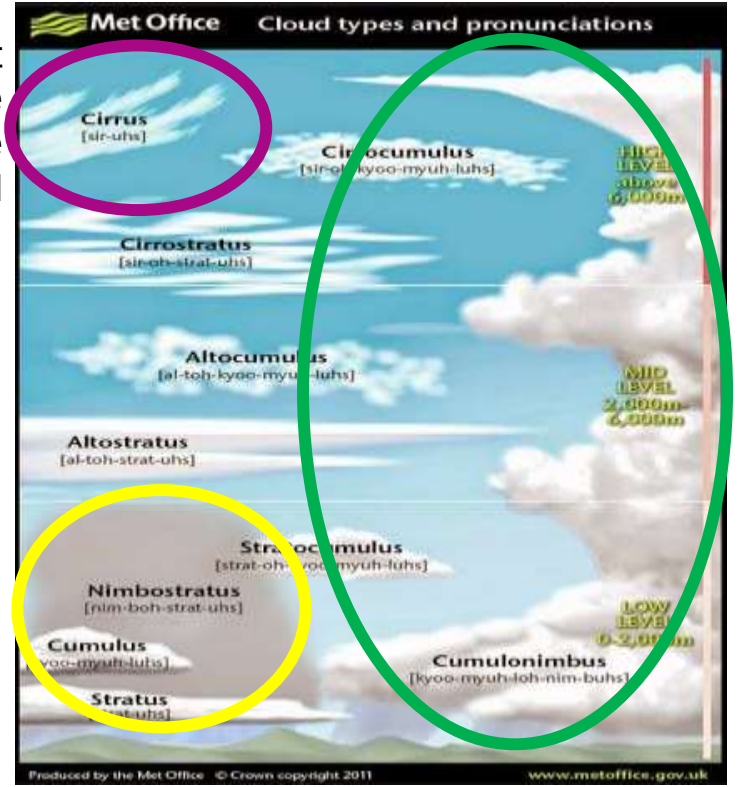
SCaMPR/ STRaP

Band 4 GOES-13, NEXRAD, SCaMPR and 30 minutes forecast (STRaP). Rainfall event in Puerto Rico, during December 1, 2012 at 1715 UTC.

Rainy Cloud Detection Problems

Cirrus are cold clouds but don't generate rainfall. Low Temperature changes across vertical profile. Stable conditions in troposphere affected rainfall potential activity.

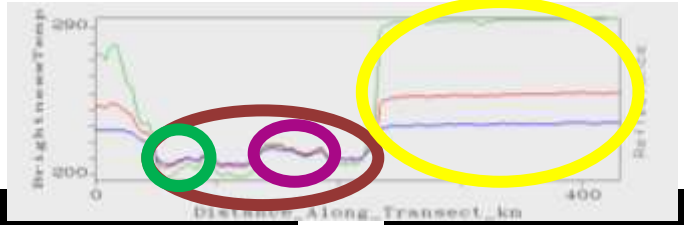
Nimbostratus are warm clouds with relative rainfall activity. Temperature is warmer than 235 K. Temperature changes across vertical profile. Unstable conditions in troposphere affected rainfall potential activity.



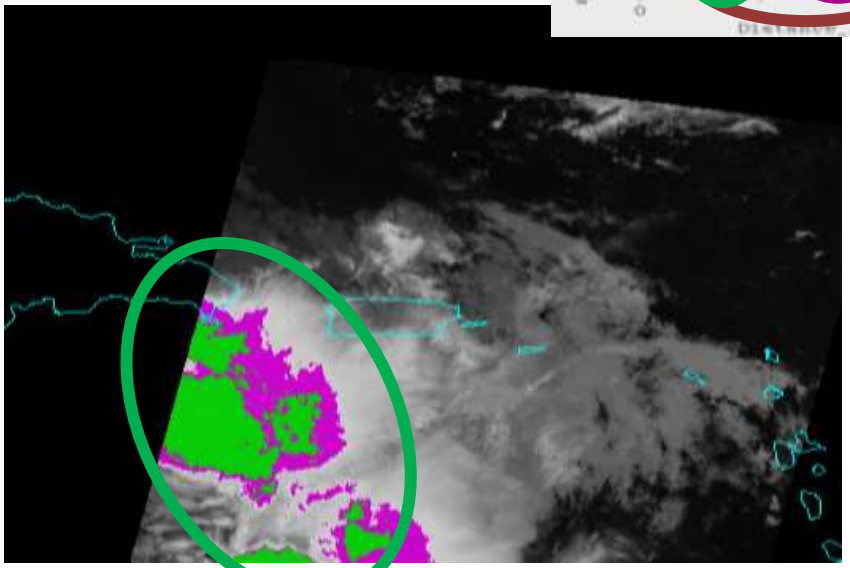
Cumulonimbus are cold clouds with strong rainfall activity. High temperature changes across vertical profile shows unstable conditions in troposphere that affected rainfall potential activity.

Results:
Rainy Detection based on MODIS and NEXRAD
August 28, 2015 at 1505 UTC

Cold Clouds Zone
BT < 235 K



No Clouds Zone
BT > 280 K

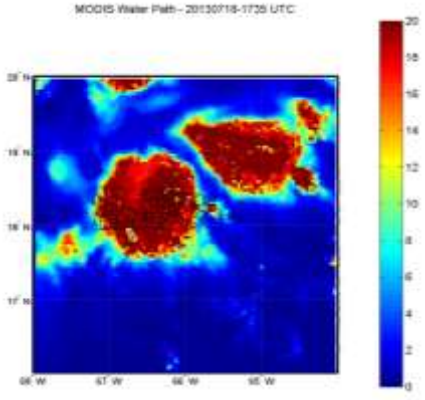


Convective Cloud Detection based on MODIS Infrared Bands (11 and 14.2 um)

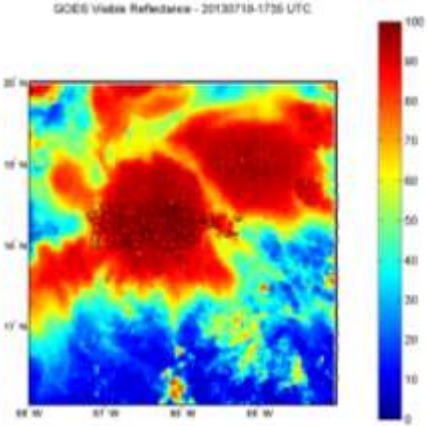
Convective Cloud Detection based on NEXRAD Reflectivity Level 2 at 0.5 degrees.

Potential Rainfall Indicators

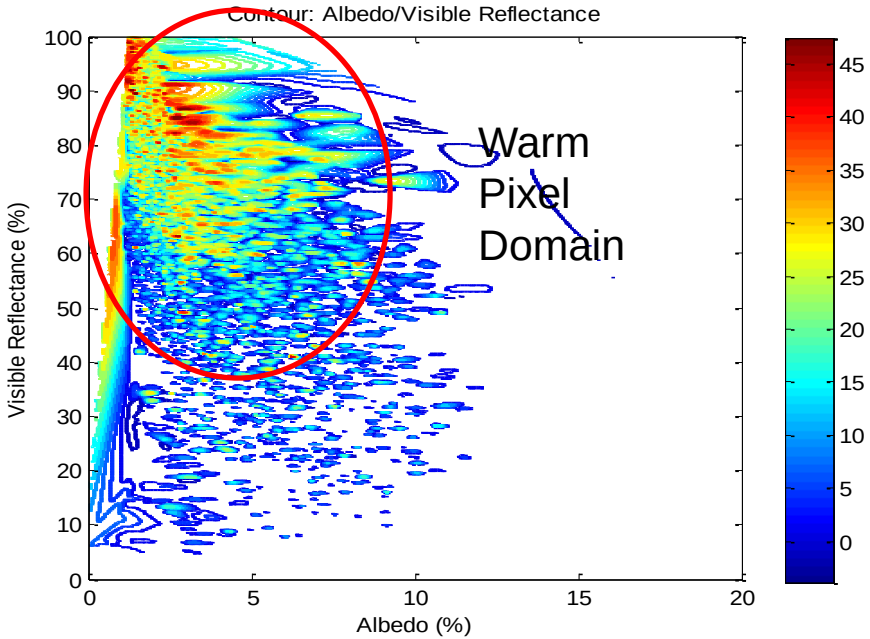
- **Cloud Product combines infrared and visible techniques to determine physical and radiative cloud properties.**
- **MODIS: Microwave Bands(1.6, 2.1, 3.7 um) – Active Sensor – Orbital**
  - **Liquid Water Path (g/m^2)**
  - **Optical Thickness (Cloud depth)**
  - **Effective Radius (Dropsize Distribution - um)**



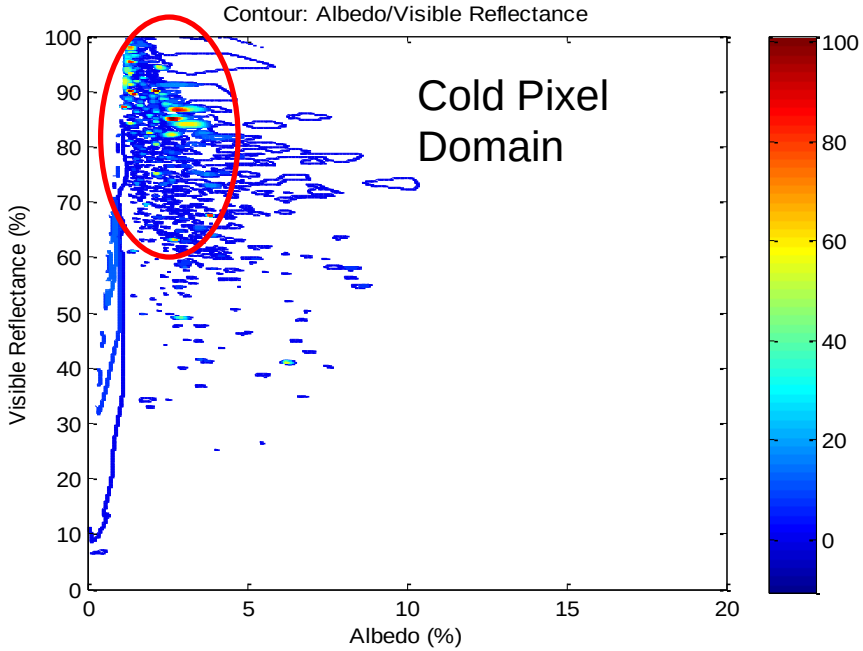
- **GOES: Visible and IR Bands (0.65, 3.9, 6.7, 10.7 um) – Passive Sensor – Geostationary**
  - **Visible Reflectance (Visible Band)**
  - **Effective Radius: (IR Bands 2 and 4)**
  - **Albedo (Bands 2)**
  - **Bands Ratio (Bands 2,3 and 6)**
  - **Band Differences (Bands 2,3 and 6)**



Cold and Warm Clouds: Rainy Contour Analysis



Warm Raining Clouds



Cold Raining Clouds

Optimal Rainy Pixel Detection algorithm (ORPD)

- **Input Variables**: The subroutine selects the potential rainy pixels (**PRP**) based on Albedo and Visible Reflectance.

  $AL < Al_{max}$ and $VR > VR_{min}$

- **Binary Output**

  PRP = 1; This is a potential rainy pixel

  otherwise

  PRP = 0; This is a non potential rainy pixel

ORPD Goal Criteria

- Maximize pixel **Hit Rate** (HR), and **Probability of Detection** (POD) of rainy pixels.
- Minimize rainy pixel **False Alarm Rate** (FAR)
- Obtain the best **Heidke Skill Score (HSS)** for detected rainy pixels.

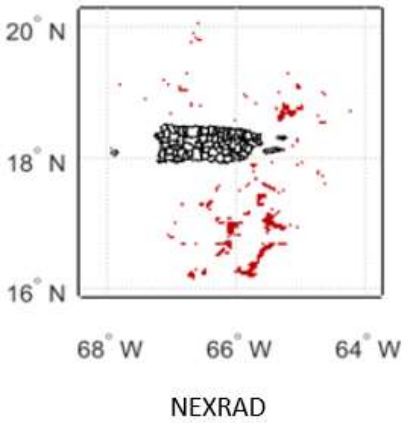
True Table: Rainy Events

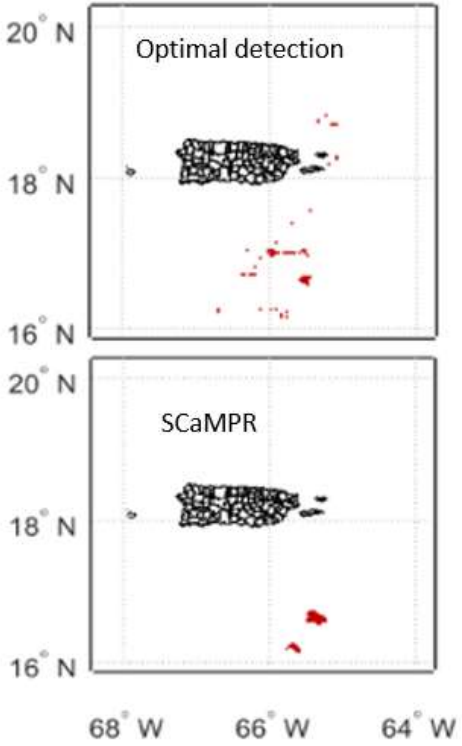
Parameters	SCaMPR	Rainy Cloud Detection Algorithm
Hit Rate (HR)	0.93	0.96
Probability of Detection (POD)	0.59	0.50
False Alarm Rate (FAR)	0.71	0.55
Bias (B)	2.02	1.11
Heidke Skill Score	0.36	0.47

Rainy Detection based on ORPD

December 1, 2012

at 1215



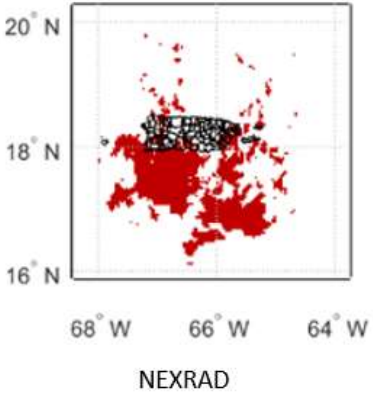


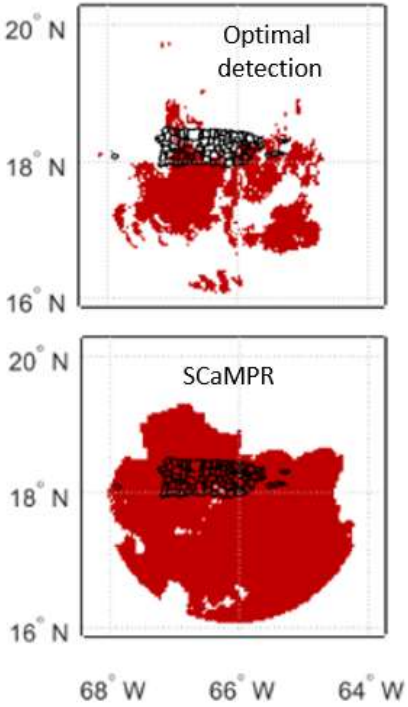
underestimation

Pixel detection spatial distribution during a warm rainy cloud

July 18, 2013

at 2015





overestimation

Pixel detection spatial distribution during a cold rainy cloud

Final Thoughts

- One of the main purposes of this work is to improve the detection of warm raining clouds from **SCaMPR**, using Puerto Rico as a testbed.
- Data from several sensors and in different spectral ranges are studied. Specifically this work had been focus on study data from **MODIS**, **GOES** and **NEXRAD**.
- Generate new empirical equations to detect potencial rainy pixels based on **GOES Products**.
- Improve warm clouds detection for **SCaMPR,** using Albedo and Visible Reflectance.

Acknowledgements

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