Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates

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A combination of existing project under Wang dealing with microwave/lightning relations and new proposal by Adler on IR/lightning rain estimation, both focused on improving GOES-R Baseline rain algorithm (Kuligkowski).

2 journal papers recently submitted

Issues and Motivation

Limitations of infrared-based rain estimates:
-- Only “see” the top of precipitating cloud;
    (though cloud growth or structure can be considered)
-- May treat cold cirrus clouds as intense convection;
-- May misrepresent convective rain: location, area
    and rain intensity;
    (especially under relatively uniform cold cloud shields in
    mature MCSs)

(But geostationary rain estimation still very important because of temporal
resolution and rapid access)

How would lightning information help?
-- Provide information associated with convection location and
  intensity (~ rainfall rate)
Objectives

Design a lightning-enhanced geostationary IR technique to

- Remove false IR-defined intense convection
- Identify convective cores and conv. rain area below cloud shields
- Define correct rain intensity (on pixel scale)
- Improve microwave-based calibration of IR technique

Recent Work/Approach

Examine lightning-cloud-rain relations with TRMM observations (papers submitted)

- Develop a rain estimation technique to take advantage of lightning information potential—apply to TRMM data
- Compare to Baseline algorithm
Relationships between Lightning and Convective Rainfall
Precipitation Features (radar raining clusters)
From University of Utah TRMM Precipitation Feature (PF) Database
Storm discrimination by lightning

(a) Storm Occurrence, Maxht20
(b) Storm Occurrence, Maxht30

With Lightning
W/O Lightning

Echo top

Intense echo top

(c) Storm Occurrence, Min85pct
(d) Storm Occurrence, MinIR

Ice scattering

Cloud top

temp.
Defining Conv. Area (by lightning flash area)

(a) Scatter diagram, conv

(b) Scatter diagram, 35dbz

(c) Scatter diagram, 40dbz

(d) Scatter diagram, 45dbz
Improvement of Passive Microwave Retrievals (Used as Calibrator for IR Baseline Algorithm)  An Example: Lightning Impact on Rain Rate Retrievals

Overall impact of lightning on rainrate is 5-10%, but focused on highest rainrates
IR (and IR + Lightning) Rain Estimation Applied to TRMM Data

• Initial IR technique is variation of Convective Stratiform Technique (CST, Adler and Negri, 1988)
• Defines convective core/areas by IR T$_b$ minima (with some tests) and stratiform rain area by T$_b$ threshold (usually cold ~215K). Rain rates in convective and stratiform areas derived separately and empirically
• Lightning information will be used to define convective cores “unseen” by IR and eliminate IR cloud top minima incorrectly identified as “convective”
IR-based C/S Technique (CST)

STEPS: (Adler and Negri, 1988)
1. Local Tb minima; 2. Slope test;

CST (and most IR techniques) does a GOOD job in catching young convective cells.
CST becomes **VAGUE** as convective systems develop (too many convective cores)
IR-based C/S Technique (CST)

CST (and all IR techniques) does a relatively **POOR** job for mature convective systems.
1. Conv. cores w/o lightning in mature systems are removed
2. Conv. areas (with flash) missed by CST are added;
Identification of Convective Cores by Adding Lightning

* Estimates of Convective ID evaluated by PR;
* CST and CSTL run in an area (600x600 km$^2$);
* 2000 cases (> 20 lightning flashes) are selected;

1. Lightning improves the convective detection (POD)
2. Lightning lowers the false alarm (FAR)
“Full” Version of CSTL with Rainfall Rate
Flash Rate Density/ Rain Rate Relationships

Used to guide assignment of rain rate based on flash density (fl/min/100km²)

At 20 km resolution:

<table>
<thead>
<tr>
<th>FD</th>
<th>dBZ</th>
<th>RR(mm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>45</td>
<td>22</td>
</tr>
<tr>
<td>35</td>
<td>55</td>
<td>45</td>
</tr>
</tbody>
</table>
Assigning Rainfall Rate

1. Stratiform: 2.5 mm/hr; 2: Convective: 12.5 mm/hr;
2. CSTL is assigned discretely with flashes in 20 km;

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(a) TMI 2A12 Rainrate
(b) 2A25 near surface rainrate
(c) CST Surface Rainrate
(d) CSTL Surface Rainrate (+Lightning)
Assigning Rainfall Rate (20 km resolution)

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(a) TMI 2A12 Rainrate
PMW RR

(b) 2A25 near surface rainrate
Radar RR

(c) CST Surface Rainrate
IR RR

(d) CSTL Surface Rainrate (+Lightning)
IR + L RR

Potential of GOES-R GLM/ABI Rain Product
Evaluation by PR 2A25 (5 cases)

5 cases of mature MCSs are selected for statistics

CST (IR only) Vs. PR

R = 0.19

CSTL (w lightning) Vs. PR

R = 0.68
Comparison with SCaMPR/Baseline

1. VIRS and GOES Channels are slightly different
2. Time difference is a few minutes apart

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(a) CH4 $T_B$ (TRMM VIRS)  
(b) CH4 $T_B$ (GOES East)
Comparison with SCaMPR

20120320, 0854UTC, Orbit: 81709, Lat: 31.0, Lon: -97.0

(a) TMI 2A12 Rainrate
(b) 2A25 near surface rainrate
PMW
Radar

(c) SCaMPR Surface Rainrate
(d) CSTL Surface Rainrate (+Lightning)
SCaMPER
IR+L

Potential of ← GOES-R
GLM/ABI
Rain Product
Comparison with SCaMPR

Vs. PR

SCaMPR Vs. PR

R = 0.22

CSTL Vs. PR

R = 0.44

Vs. TMI

SCaMPR Vs. TMI

R = 0.47

CSTL Vs. TMI

R = 0.71
Summary/Next Steps

• Lightning/cloud/rain relations have been established for use in developing GLM/ABI combined rain estimation (papers submitted)
• Initial work completed in developing framework for testing IR (and IR + lightning) rain estimation with TRMM data and for comparing results with GOES-R baseline algorithm
• Preliminary results indicate obvious value of lightning information to establish location of convective cores “unseen” by IR and eliminate incorrect core identification by IR. Preliminary statistics indicate significant improvement in rain estimation with use of lightning data
• Next steps include:
  - full analysis of TRMM IR and IR+L rain estimation to carefully quantify lightning impact and its potential and limitations in comparison/combination with Baseline algorithm
  - use of CHUVA and other data sets to evaluate IR+L with Baseline and test with time resolution/evolution
  - continue analysis of lightning impact on microwave rain retrievals using TRMM data