GOES-R Risk Reduction New Initiative: Storm Severity Index

Wayne M. MacKenzie

John R. Mecikalski

John R. Walker

University of Alabama in Huntsville

Project Goal: To develop a diagnostic algorithm for estimating thunderstorm intensity using geostationary satellite imagery and space-based lightning information.

Project Summary:

- Proxy GOES-R data will be supplied to this effort from MSG SEVIRI (8 IR and 1 HRV channel) and TRMM Lightning Imaging Sensor (LIS) Global Total Lightning Flashes product.

- Utilize established methods that determine the general vigor and strength of active moist convection will be used. These include:
  - Convective cloud identification algorithms (for GOES-R and research)
  - SEVIRI "object tracking" methods
  - Monitoring satellite temporal trends of the spectral channels.
  - SEVIRI IR and Visible data "interest field" research → physical attributes
  - TRMM LIS data

What factors are associated with intense storms?

(a) Rapid expansion rates – anvils, convective cores
(b) Strong updrafts
(c) Overshooting tops* – above the local EL
(d) Frequent lightning/High lightning flash rates*
(e) Deep cumulonimbus clouds
(f) "Enhanced V" signatures*
(g) Gravity wave signatures
(h) Strong surface outflows
(i) Longevity – intense storms last longer
(j) Hail
(k) Heavy rainfall (>40 dBz) *

See Adler et al. (1985); Zipser et al. (2006)

*Existing GOES-R Algorithms

What of these factors can be observed by satellite (GEO and LEO)?

(a) Rapid expansion rates – anvils, convective cores
(b) Strong updrafts
(c) Overshooting tops – above the local EL
(d) Frequent lightning/High lighting flash rates
(e) Deep cumulonimbus clouds
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What of these factors will this study consider towards forming a "Thunderstorm Severity Index"?

(a) Rapid expansion rates – anvils, convective cores
(b) Strong updrafts
(c) Overshooting tops – above the local EL
(d) Frequent lightning/High lighting flash rates
(e) Deep cumulonimbus clouds
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MSG IR Interest Fields per Physical Process

Cloud Depth

- 6.2-10.8 μm difference
- 6.2-7.3 μm difference
- 10.8 μm T_B
- 7.3-13.4 μm
- 6.2-9.7 μm difference
- 8.7-12.0 μm difference

Glaciation

- 15-min Trend Tri-spectral
- Tri-spectral
- 15-min 8.7-10.8 μm
- 15-min 12.0-10.8 μm Trend
- 15-min 3.9-10.8 μm Trend
- 12.0-10.8 μm difference

Updraft Strength

- 15-min 10.8 μm Trend
- 15-min 6.2-7.3 μm Trend
- 15-min 6.2-12.0 μm Trend
- 15-min 7.3-9.7 μm Trend

Channels related to the following were found to contain redundant information as they were highly correlated:

8.7-13.4 μm, 8.7-10.8 μm, 7.3-10.8 μm, 13.4-10.8 μm, 8.7-12.0 μm, and Time Trends of these fields.

12 Unique IR indicators for Nowcasting CI from MSG (*GOES-R*).

Physical Description – Development of the Interest Fields

- Monitoring the trends of the spectral methods can monitor the cloud top changes in cloud depth, cloud top glaciation, and updraft strength (Roberts and Rutledge 2003; Mecikalski and Bedka 2006; Mecikalski et al. 2009)

10.8 µm Temporal Trend	Roberts and Rutledge (2003)
6.2-10.8 µm	Ackerman (1996); Zinner et al. (2008)
Tri-spectral method [(8.7-10.8)-(10.8-12.0) µm]	Strabala et al. (1994); Ackerman et al. (1990)
10.8-12.0 µm	Inoue 1987; Prata (1989); Strabala et al. (1994); Holtz et al. (2006)
13.4-10.8 µm	Ellrod (2004)
8.7–10.8 µm	Ackerman et al. (1992)

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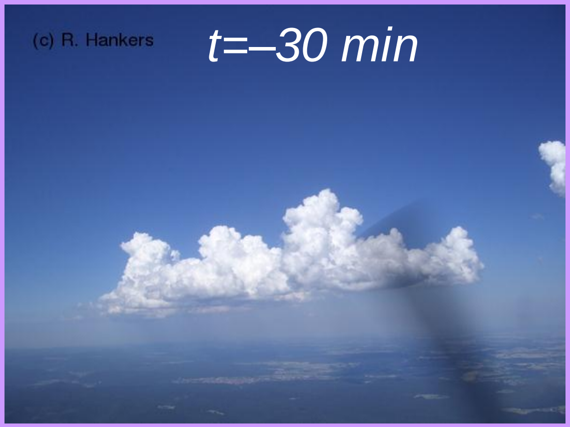
New Physically-based Scoring for Storm Severity: *An example*

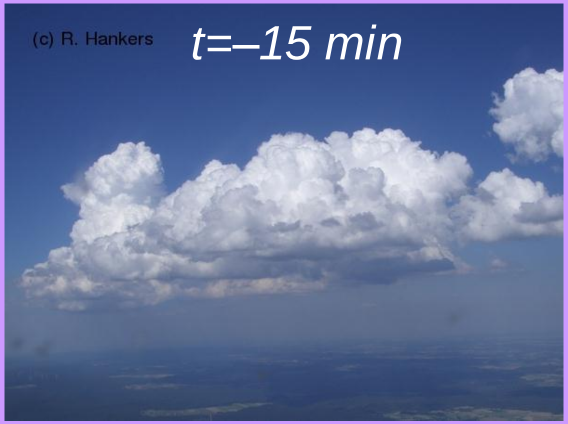
Total Score:	**13/21**
Cloud Depth	5/6
Glaciation	6/7
Updraft Strength	2/8

Cloud depth provides information into stage of growth of cloud.

Glaciation provides information into stage of growth of cloud.

Updraft strength indicators may be used to help gauge the “intensity” or vigor of the convection.





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Additional Information

- Cloud Object Aerial Coverage
  - Systems such as WDSS-II and RDT can monitor aerial coverage.
- Overshooting tops/Enhanced V's
  - Existing AWG
- Storm Longevity
  - Monitor the length of convection within object tracking framework.
- Lightning Information

Using Lightning as Proxy for Storm Intensity

- Many studies have been performed defining intense storms using TRMM (Zipser et al. 2006, Nesbitt et al. 2000, Cecil et al. 2005 and Cecil 2009) and the Lightning Imaging Sensor (LIS) and the TRMM Microwave Imager (TMI) instruments.
- Lightning flash rates from LIS have been broken into five categories:

	Flash rate (fl min^{-1})
CAT-0	0-0
CAT-1	0.7-2.2
CAT-2	2.2-30.9
CAT-3	30.9-122
CAT-4	122-296
CAT-5	>296

Cecil et al. (2005), Nesbitt and Zipser (2003), Nesbitt et al. (2000)

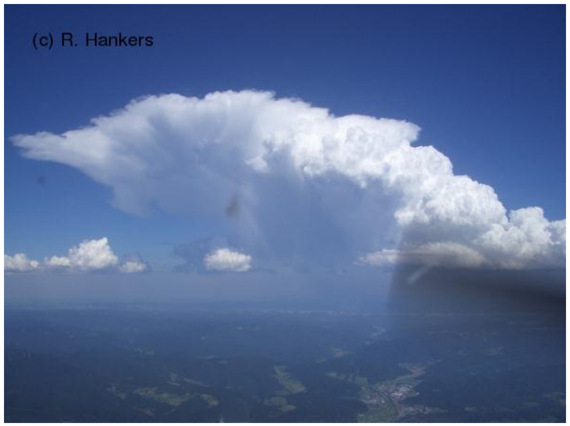
- Its important to note that not all convective storms produced lightning and Cecil et al. (2005) suggest that some of those storms may be electrically active but LIS may not be able to reliably detect those flashes.

Life Cycle Monitoring

- Initial, growing cumulus can be monitored for cloud depth, glaciation, and updraft strength from IR.
- Mature convection can be monitored for lightning (instantaneous and temporal), overshooting tops/enhanced V’s, and temporal trends.
- Decaying convection can be monitored via temporal warming in 11 μm.

SATellite Convection AnalySis and Tracking (SATCAST): Convective Cloud Analysis

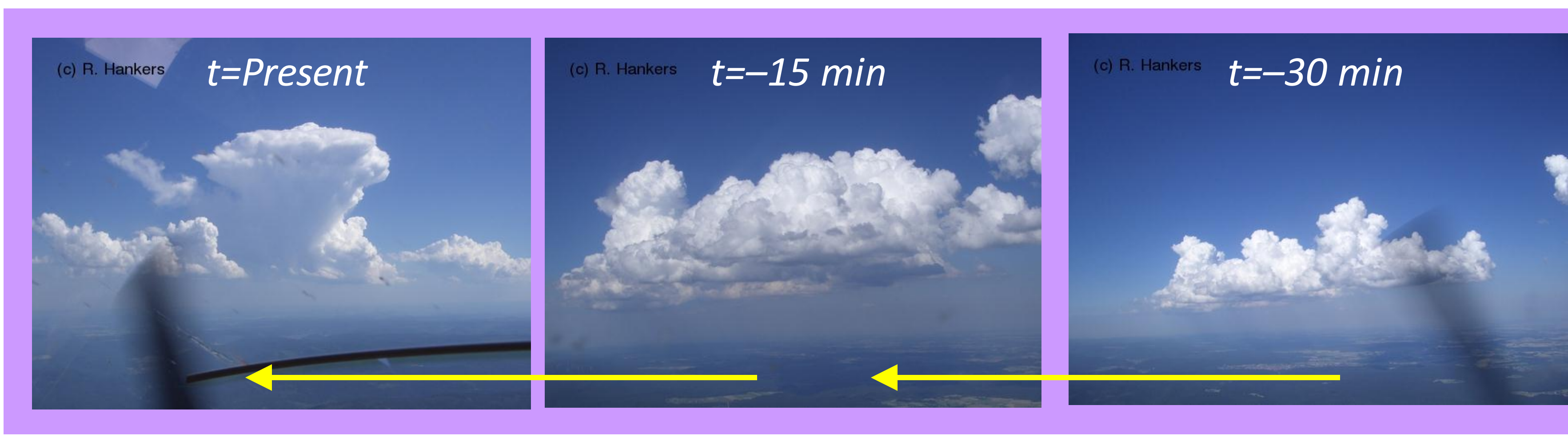
Monitor… 12 IR fields from SEVIRI



Thunderstorm: Satellite-observed

Once a thunderstorm “object” has been identified, backwards (in time) analysis of the cloud object will be done.

Updraft strength, feature expansion, cloud-top altitude and storm longevity will be monitored per object



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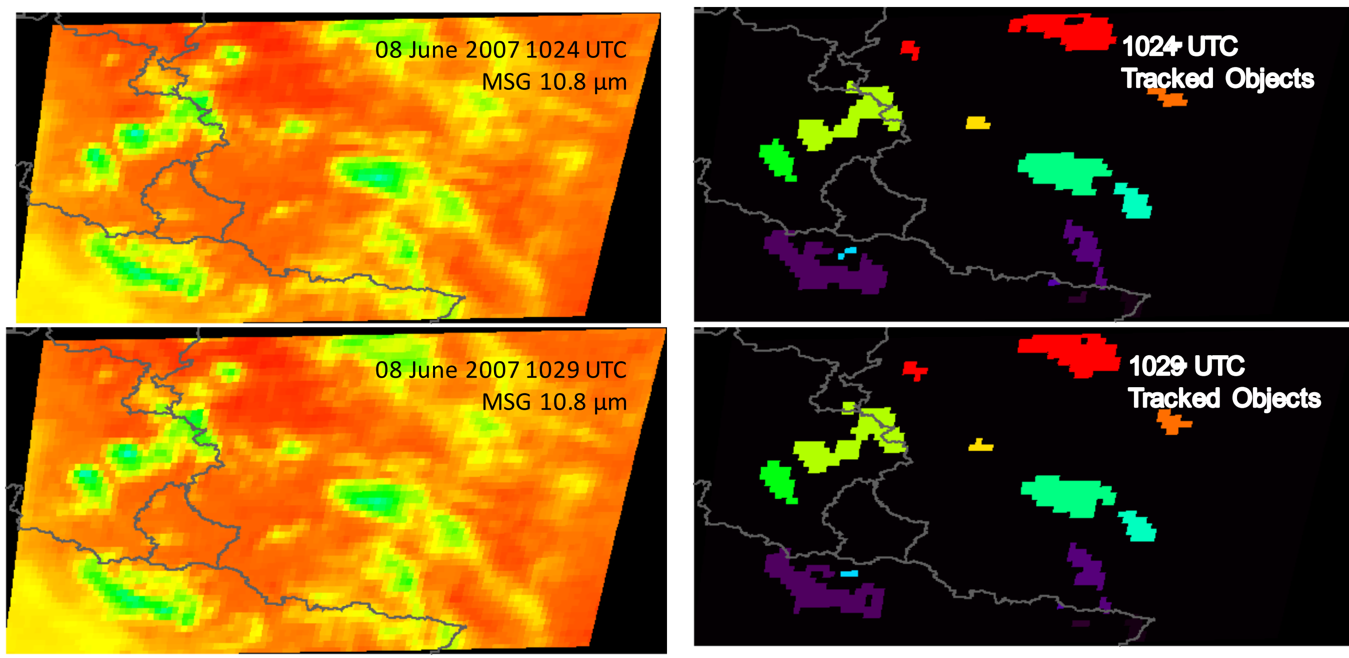
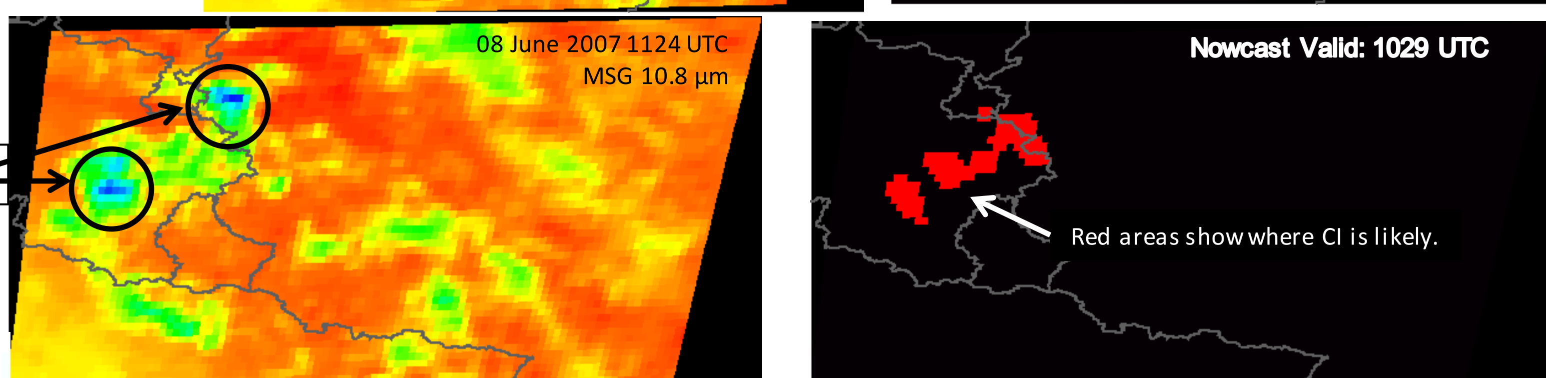
GOES-R AWG Convective Initiation Algorithm Example

10.8 µm image 54 minutes ahead of the nowcast shows the areas highlighted continued to grow. Radar data was not available at this location in Europe.



CI likely occurring



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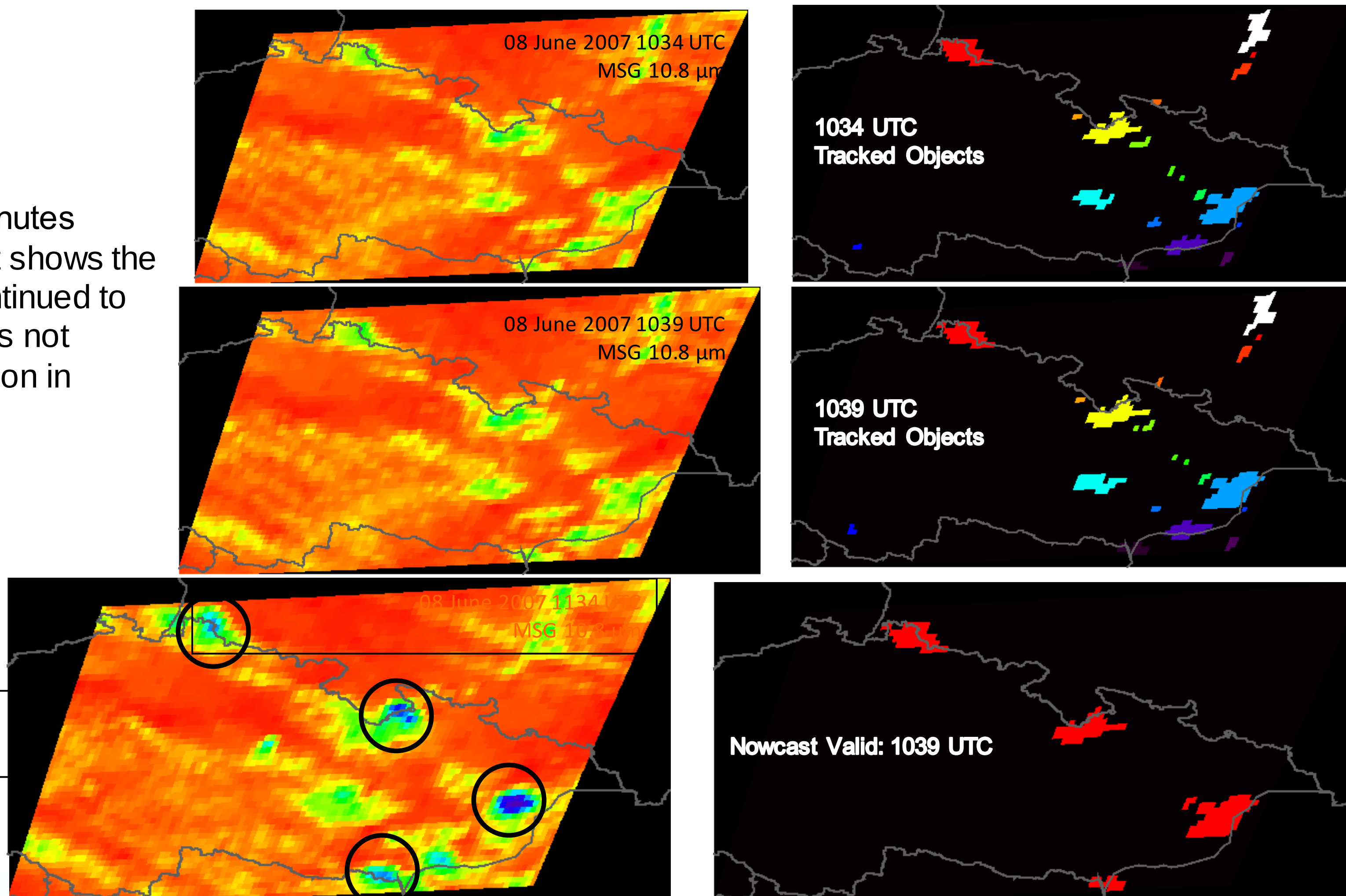

Red Circles indicate where CI likely occurring

Red areas show where CI is likely.

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Research Plan

• This research will leverage TRMM products as developed from the precipitation radar (PR), and the Lightning Imaging Sensor (LIS). **LIS will be used as a proxy for GLM.**

• **Use of the Meteosat Second Generation (MSG) SEVIRI imager as a proxy for GOES-R ABI.**

• Using the database from Nesbitt and Zipser (2003) and Liu et al. (2008) of precipitation features from TRMM over Equatorial Africa, and the MSG full disk image....examine coupled TRMM PR, LIS and MSG SEVIRI data.

• Develop storm severity based upon the coupled data and using the SATCAST framework for monitoring cloud top spectral trends from MSG SEVIRI.

• Using Object Tracking approach developed within the CI AWG, monitor object size as related to storm/anvil expansion rates and storm longevity. Use of WDSS-II will be explored.

Relevance to GOES-R Program

- Important indicators of cloud top properties will be able to be diagnosed on small temporal scales with high spatial resolution.
- Monitoring cloud top properties, lightning activity and storm strength is important over areas with little or no radar coverage (Oceanic Convection).
- The current Convective Initiation algorithm for GOES-R is a prognostic algorithm for future cloud growth. **The information we have and will learn from the CI AWG will be applied to this algorithm in a diagnostic sense.**
- This new algorithm would continue to monitor storms after development in a diagnostic sense, monitoring clouds past the current GOES-R AWG CI algorithm timeframe.