GOES-R AWG Aviation Team: Convective Initiation

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Outline

- Executive Summary (1 slide)
- Algorithm Description (15 slides)
- Examples of Product Output (4 slides)
- Validation Approach (3 slides)
- Validation Results (3 slides)
- Summary (1 slides)

Executive Summary

- The ABI Convective Initiation (CI) algorithm generates one Option 2 product.
- Software Version 3 was delivered in March, with a delta delivery in May to correct a memory issue. ATBD (80%) and test datasets are scheduled to be delivered in June 2010.
- Algorithm performs spectral and temporal differencing using several ABI IR channels to monitor cloud growth properties.
- Validation Datasets: Use of the MSG 5-minute temporal resolution dataset is used as proxy and radar data from within the MSG domain when available. Also, use model simulated ABI brightness temperatures and model-derived radar reflectivities for proxy and validation.
- Validation studies indicate spec compliance for the CI product.

Requirements
Convective Initiation

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Resolution	Horizontal Resolution	Mapping Accuracy	Measurements Range	Measurements Accuracy	Product Refresh Rate/Coverage Time	Vendor Allocated Ground Latency	Product Measurement Precision	Temporal Coverage Qualifiers	Product Extent Qualifier	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Convective Initiation	GOES-R	C	N/A	2 km	1 km	Binary Yes/No detection	70% Probability of Correct Detection	5 min	159 sec	5%	Day and night	Quantitative out to at least 65 degrees LZA and qualitative beyond	Clear conditions down to feature of interest associated with threshold accuracy	Over specified Geographic area
Convective Initiation	GOES-R	M	N/A	2 km	1 km	Binary Yes/No detection	70% Probability of Correct Detection	5 min	159 sec	5%	Day and Night	Quantitative out to at least 70 degrees LZA and qualitative beyond	Clear conditions down to feature of interest associated with threshold accuracy	Over specified Geographic area

C - CONUS M - Mesoscale

Algorithm Description

Convective Initiation Algorithm Processing Components

- The GOES-R ABI convective initiation algorithm can be broken into 4 separate steps.

1. Defining cloud objects.
2. Tracking cloud objects.
3. Performing Spectral/Temporal Differencing.
4. Determining whether there is a high likelihood for Convective Initiation.

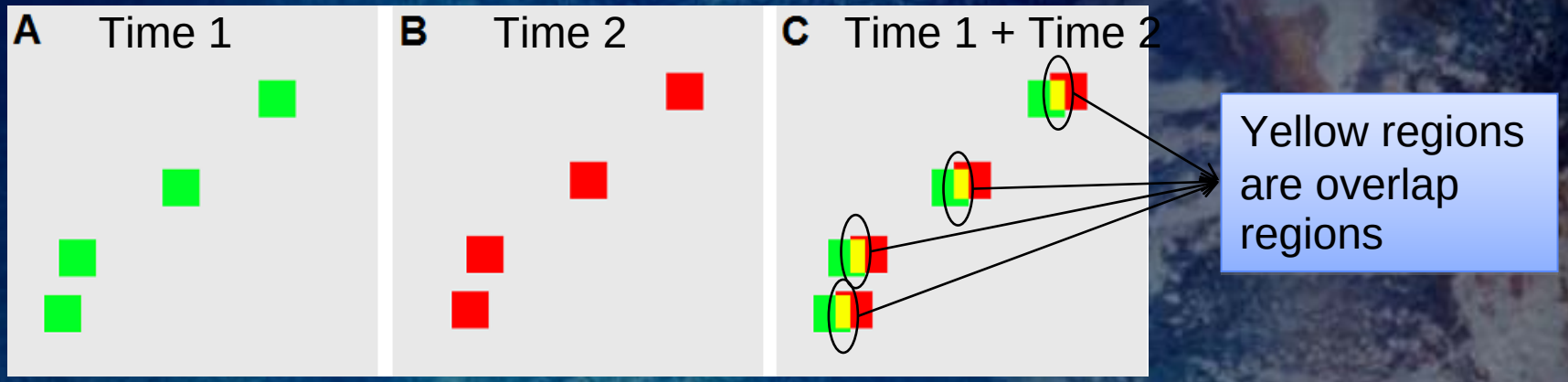
Physical Description

- Identifying objects will first be accomplished using the AWG cloud typing algorithm.

- Using pixels which have been identified as water is assuming that those clouds are immature and pre-convective. The algorithm, through multi-spectral differencing will be able to distinguish the stage of growth of the cloud.

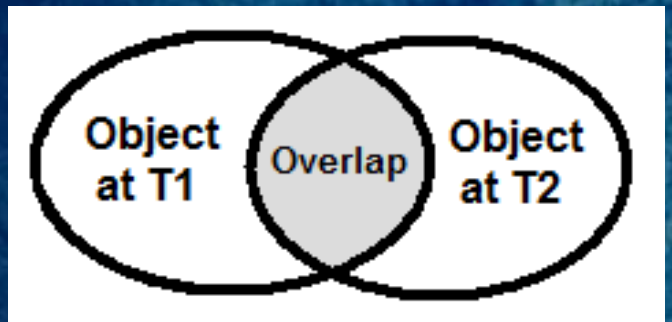
Physical Description: Tracking Methodology

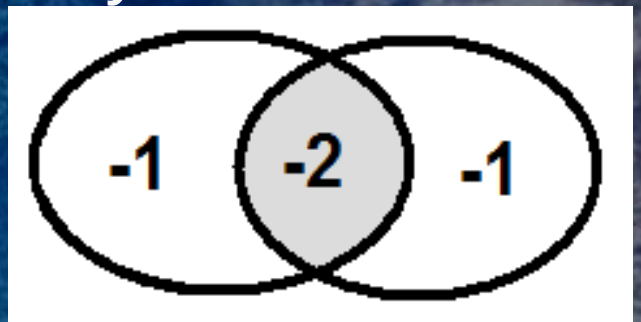
- After the objects have been defined, then tracking begins.
- Tracking is accomplished by using an overlap detection scheme between two times.
- Overlap Detection
  - » Take defined objects at two successive times, and search for overlap between two objects at both times.



Physical Description: Tracking Methodology

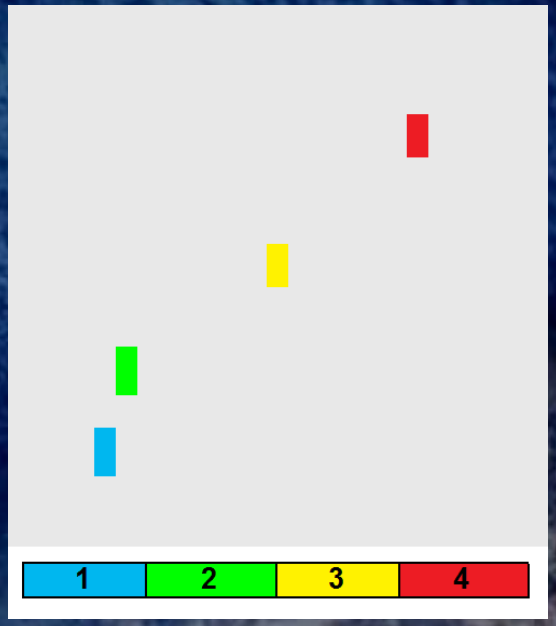
- All pixels within defined objects from both T1 (time 1) and T2 (time 2) are assigned the integer, “-1”.
- Next, the resulting arrays are summed, so that all temporally overlapping regions can be identified wherever the integer “-2” is present.
- Non-overlapping region pixels are left at values of “-1” after the arrays are summed.





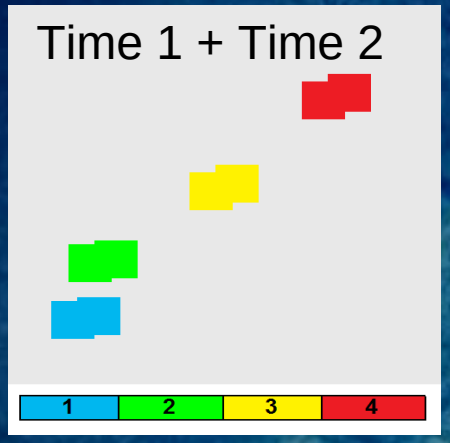
Physical Description: Tracking Methodology

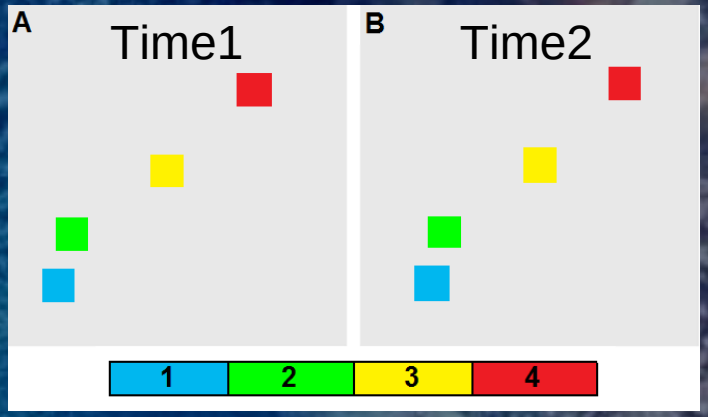
- Once overlap regions are determined, the regions are assigned a unique integer ID number starting with 1.



Physical Description: Tracking Methodology

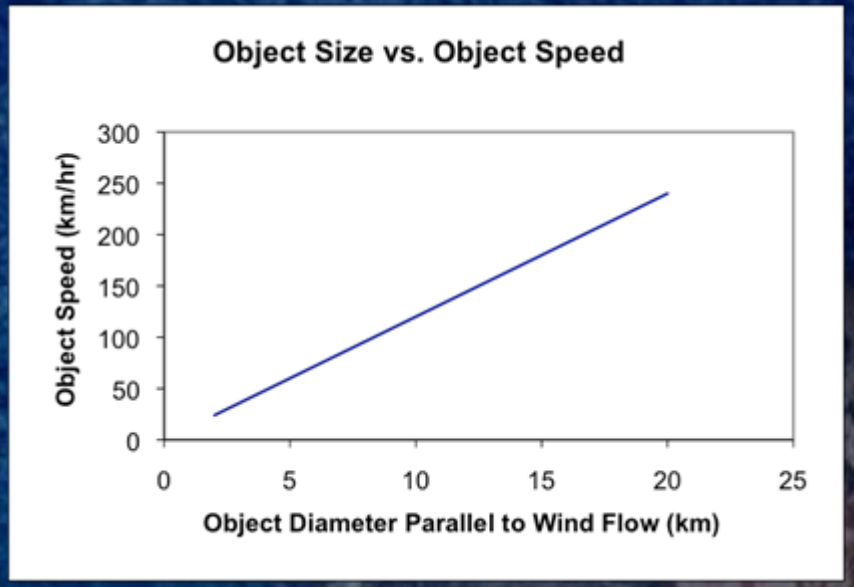
- Then the ID numbers are spread across to all pixels within object.
- For both time 1 and time 2, each object with overlap will have the same ID number.





Physical Description: Tracking Methodology

- Since storm overlap is limited by storm motion, there is a dependence on environmental wind speed.
- For large objects, tracking via overlap is sufficient.
- For small objects with fast motion, it can be assumed that the cloud will grow horizontally over time, thus majority of clouds will be able to be tracked.



Physical Description: Spectral Tests

- Channel brightness temperatures are used to perform spectral analysis on updraft regions of the storm that represent growing cumulus.

- Use the coldest 25% of 11 μm channel data associated with each object and averaging those pixels to come away with a brightness temperature for each spectral channel for each object.

- Compute spectral and temporal differencing for each object using the average temperature.

Defining an Interest Field

- Mecikalski and Bedka (2006) defined “interest fields” as a spectral and temporal thresholding technique of various spectral and temporal differencing.

- The summation of these interest fields will allow for a multi-spectral approach which will help the algorithm perform best in all types of convective environments.

Physical Description – Development of the Interest Fields

- A review of the literature shows that spectral and temporal differencing can be used to find physical parameters of cloud tops.
- The cloud properties theoretical basis document (Ackerman et al. 2002) provides a detailed use and summary of all Brightness Temperature Threshold techniques used for cloud properties.
- Some of the widely used techniques are listed to the side.

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)

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. 2010)

10.8 μm Temporal Trend	Roberts and Rutledge (2003)
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13.4-10.8 μm	Ellrod (2004)
8.7–10.8 μm	Ackerman et al. (1992)

Physical Description – Development of the Interest Fields

- These critical values were developed by using the information from Mecikalski and Bedka (2006) on current GOES and the MSG interest fields by Mecikalski et al. (2010) and further tested by Siewert et al. (2010).
- Need to determine how many of these thresholds must be met before CI is likely.

Interest Field	Physical Basis (Mecikalski et al.. 2009)	Critical Value
6.2-10.8 μm	Cloud Depth	-35ºC to -10ºC
6.2-7.3 μm	Cloud Depth	-25ºC to 3ºC
10.8 μm	Cloud Depth/Glaciation	-20ºC to 0ºC
8.7-10.8 μm	Glaciation	-10ºC to 0ºC
Tri-channel Diff	Glaciation	-10ºC to 0ºC
15 min Tri-Channel	Glaciation Trend	>0ºC
15 min 12.0-10.8 μm	Cloud Depth	>0ºC
12.0-10.8 μm	Cloud Depth	-3ºC to 0ºC
15 min 10.8 μm	Cloud Growth	< -4ºC
15 min 6.2-7.3 μm	Cloud Depth Trend	>0ºC
15 min 6.2-10.8 μm	Cloud Depth Trend	>3ºC
13.4-10.8 μm	Cloud Depth	-25º to -5ºC

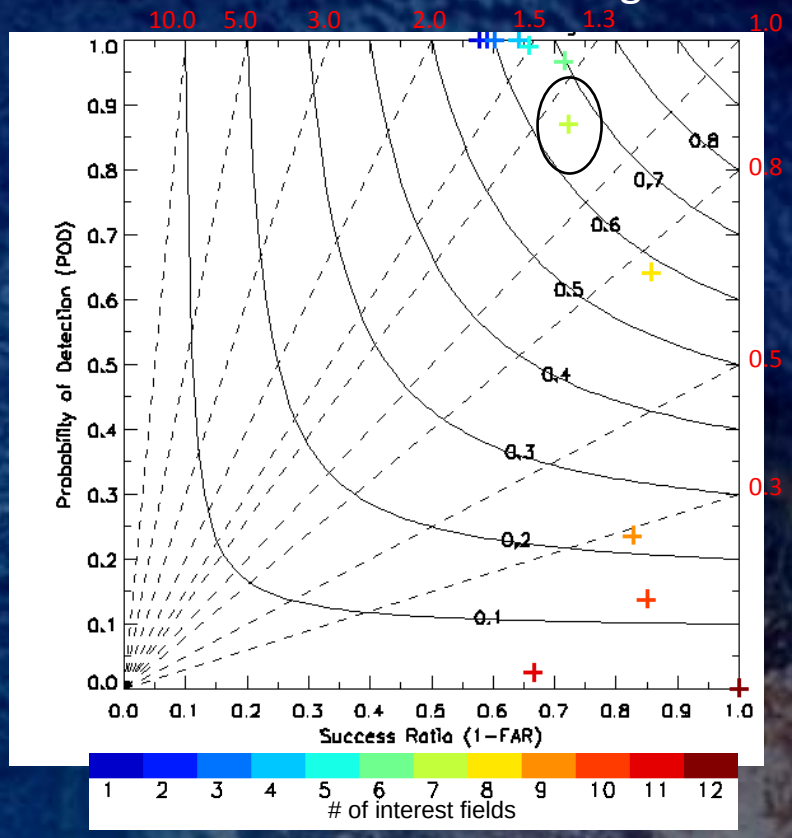
Physical Description

- Spectral Information can improve and optimize the statistics.
- Using 7 interest fields, over forecasts CI by 7% however 8 interest fields under forecast CI by 25%.
- Using 213 CI and non-CI events from MSG, we obtain statistics for each sum of the interest fields.

$$Accuracy = \frac{hits + correct\ negatives}{total}$$

# of interest fields	Accuracy
1 or greater	57.7%
2 or greater	60.56%
3 or greater	61.97%
4 or greater	67.6%
5 or greater	69.95%
6 or greater	76.06%
7 or greater	80.75%
8 or greater	73.24%
9 or greater	53.05%
10 or greater	48.83%
11 or greater	43.2%
12 or freater	42.25%

Statistical Performance Diagram



Physical Description

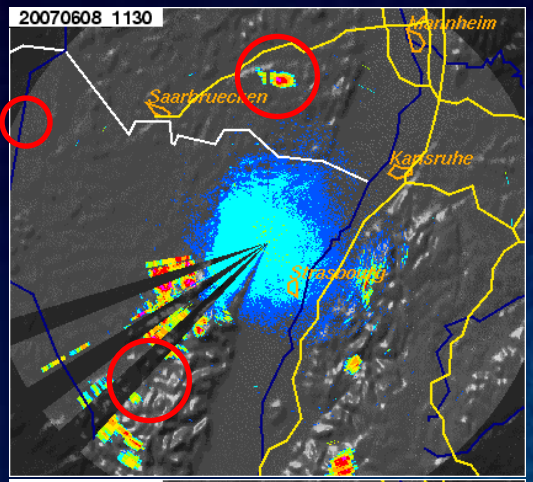
- For each identified object, sum all interest fields that the threshold has been met.
- If 7 or greater of the interest fields have been met, then flag the object as likely for CI.

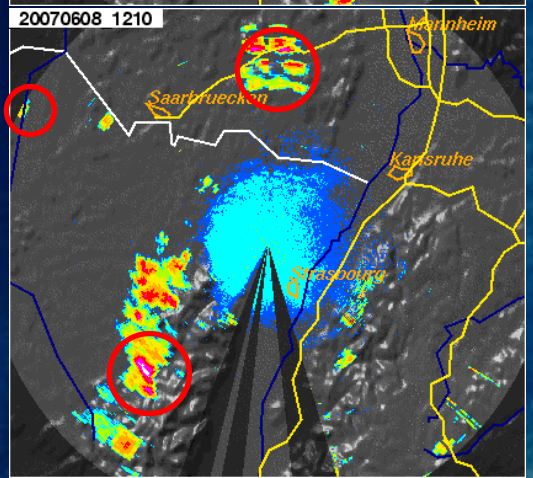
Convective Initiation Algorithm Summary

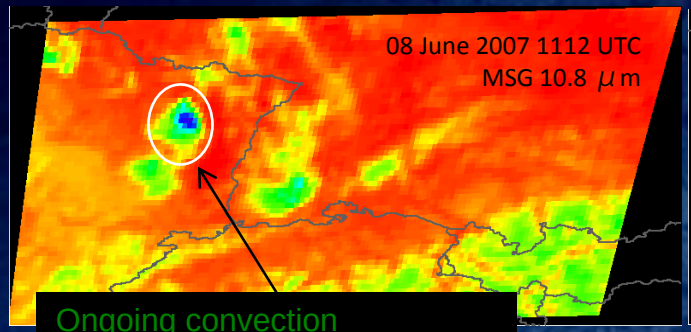
- Cloud objects are defined using the cloud typing algorithm.
- Track the cloud objects using an overlap technique to ensure the correct objects are matched between time 1 and time 2.
- Once objects are matched, find the coldest 20% of pixels within the object from the 11 μm channel and average those pixels within the object.
- Perform spectral and temporal differencing and determine the number of interest fields which have met their respective thresholds. This is to ensure that false alarms are minimized.
- If the minimum number of thresholds are met from the interest fields, then all pixels within the entire object is flagged for convective initiation within the next 60 minutes.

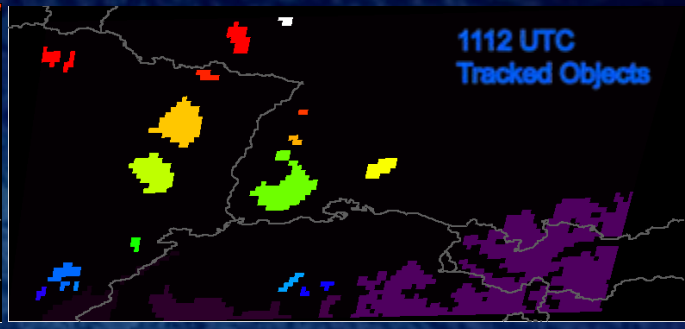
Examples of Product Output

Algorithm Example

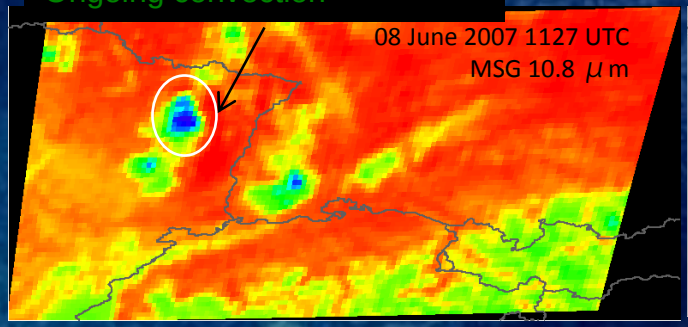


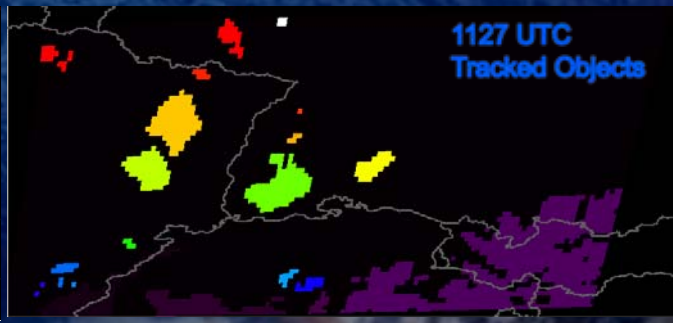




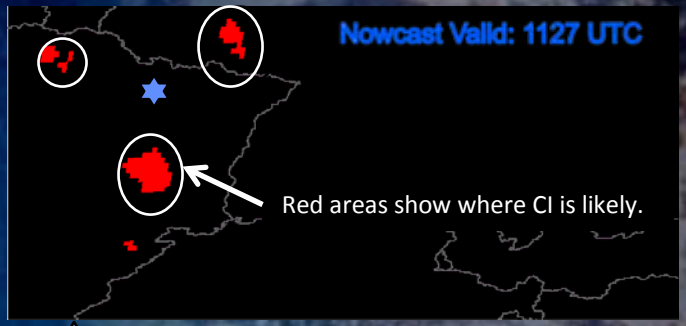


Ongoing convection





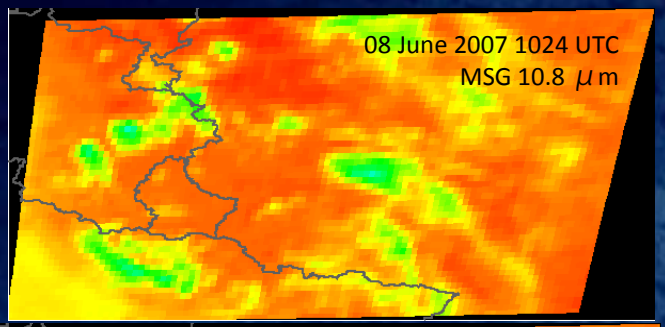
Circled areas show the nowcasted regions, and their locations on the radar. There was ongoing convection, and the CI algorithm picked up on regions where CI was going to occur with ~40 minute lead time.

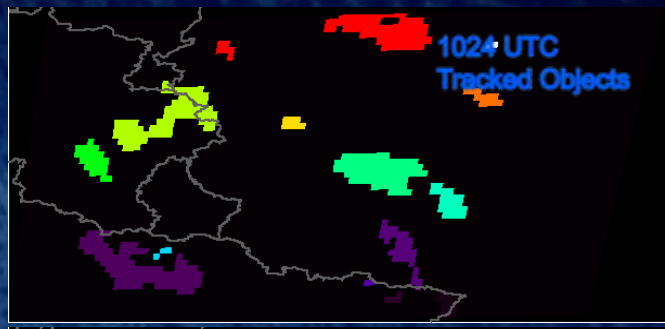


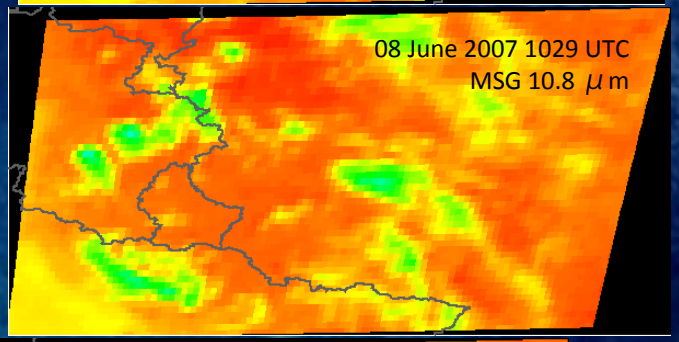
Denotes radar location.

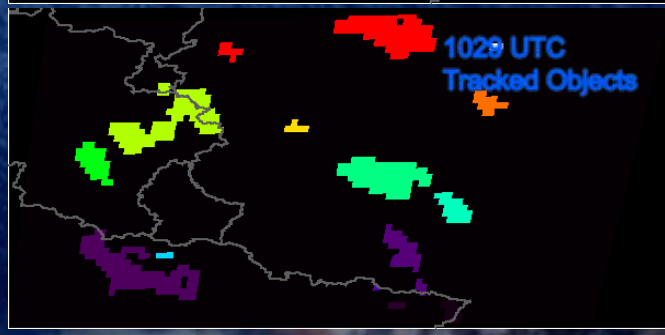
Algorithm Example

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.

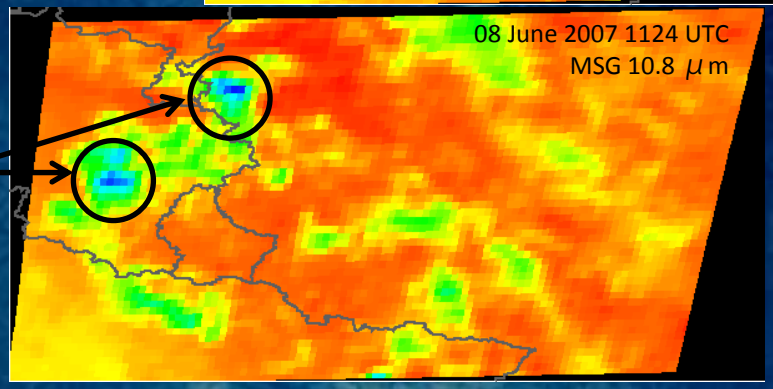


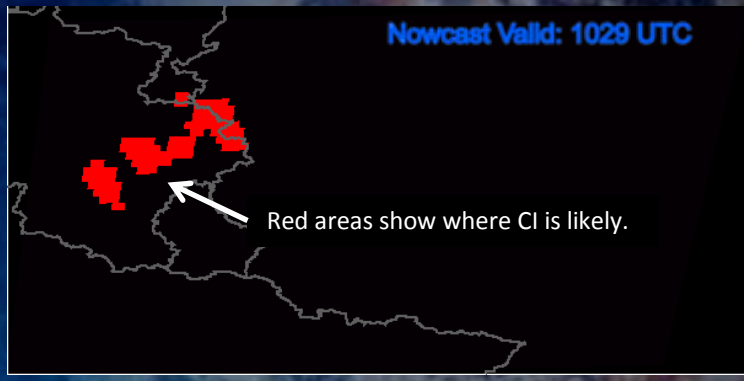






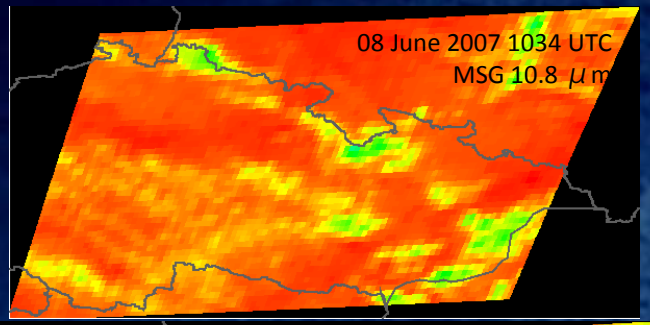
CI likely occurring

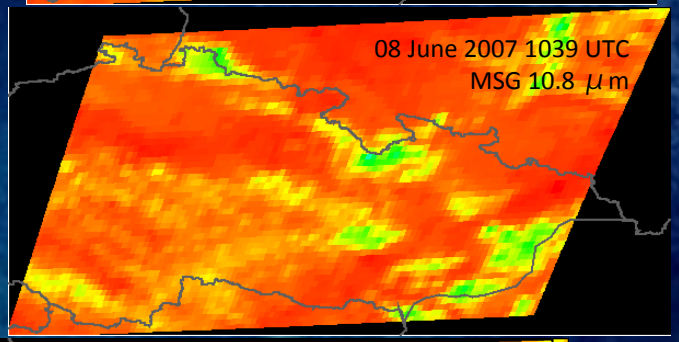


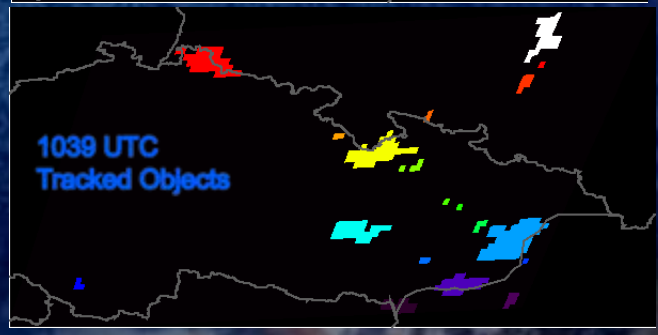


Algorithm Example

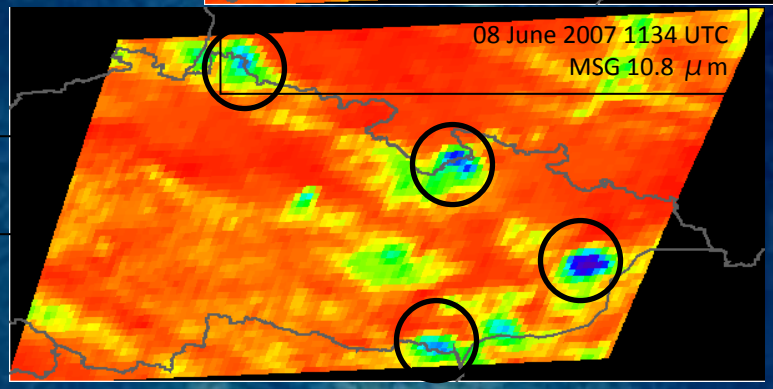
10.8 μm image 54 minutes ahead of the nowcast shows the areas highlighted continued to grow. Radar data was not available at this location in Europe.

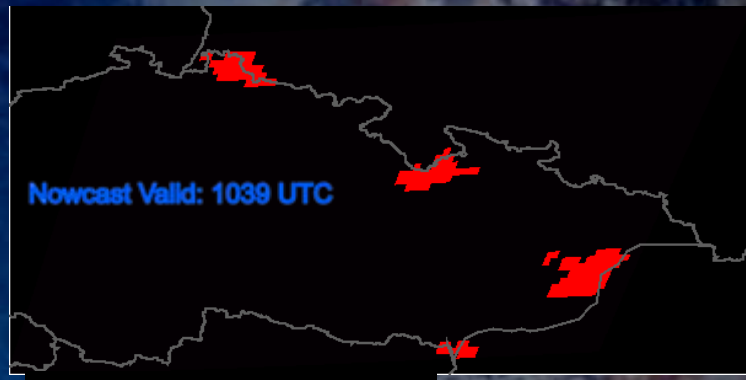






Black Circles indicate where CI likely occurring

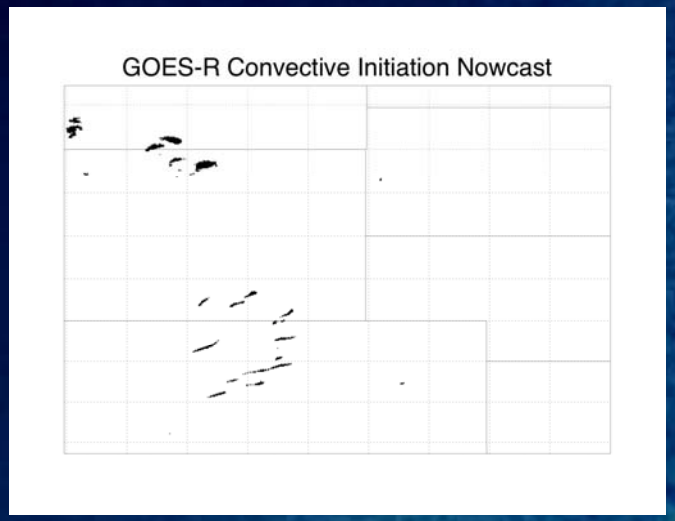


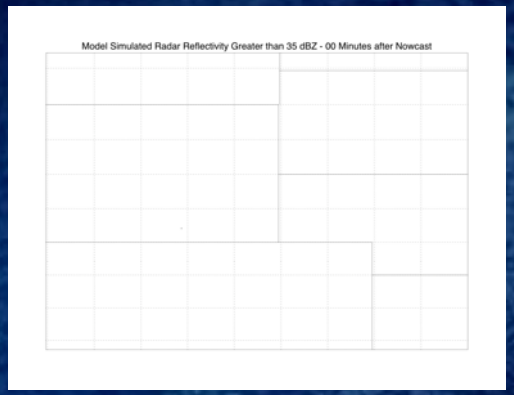


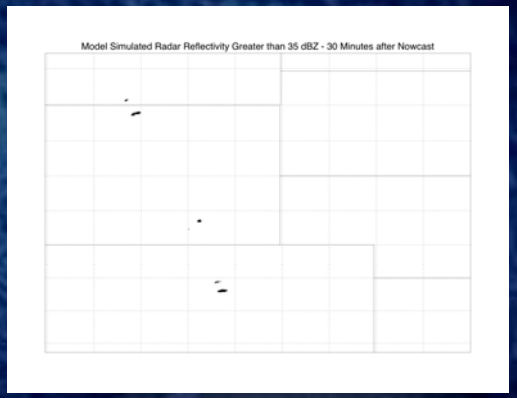
Red areas show where CI is likely.

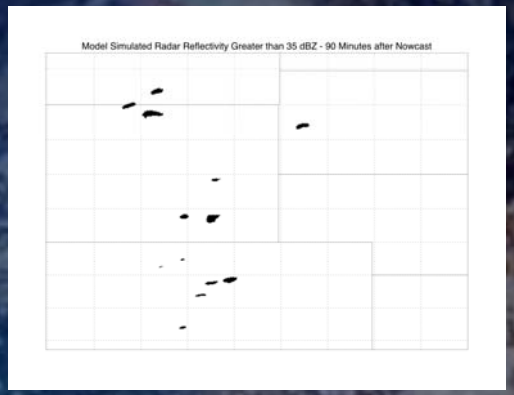
Algorithm Example

The CI Algorithm was ran on CIRA RAMS simulated ABI data with 5 minute temporal resolution









Validation

CI Test Plan – Offline Validation: Test Data

- RAMS simulated datasets are used as ABI proxies in algorithm verification/validation
  - » 28 June 2005 – Convective Day over midwest US
  - » 5 min temporal resolution and 2 km spatial resolution.

- Gostationary satellite datasets are used as ABI proxies in algorithm verification/validation
  - » Spinning Enhanced Visible and Infra-red Imager (SEVIRI), onboard the European Meteosat Second Generation (MSG) satellite
  - » Several convective days during the summer 2007 at the Convective and Orographically-induced Precipitation Study over southern Germany

CI Test Plan – Offline Validation: Truth Data

- CI is defined as the first occurrence of a 35 dBZ radar reflectivity.
- Truth data is using the radar data to find the first occurrence of a 35 dBZ return within the first hour.
- For RAMS Simulated data, use model derived reflectivity for validation.
- For MSG, use radar within the COPS domain in southern Germany for validation.

CI Test Plan – Offline Validation Test Methods

Methodology for computing CI Performance Statistics

Dichotomous Forecast Verification	
Was CI Forecasted? **YES** Did CI Occur? **YES** ***Hits***	Was CI Forecasted? **YES** Did CI Occur? **NO** ***False Alarms***
Was CI Forecasted? **NO** Did CI Occur? **YES** ***Misses***	Was CI Forecasted? **NO** Did CI Occur? **NO** ***Correct Negatives***

Match satellite clouds in time and space with radar reflectivity,

- Then perform dichotomous forecast verification.
- Based upon the contingency table to the left, compute the following statistics to ensure overall algorithm performance.

$$Accuracy = \frac{hits + correct\ negatives}{total} \qquad BIAS = \frac{hits + false\ alarms}{hits + misses} \qquad POD = \frac{hits}{hits + misses}$$

$$FAR = \frac{false\ alarms}{hits + false\ alarms} \qquad POFD = \frac{false\ alarms}{correct\ negatives + false\ alarms} \qquad TS = CSI = \frac{hits}{hits + misses + false\ alarms}$$

Performance Results

RAMS Simulated ABI Dataset

- Using data from 28 June 2005 1800 – 1900 UTC
- Using 7 of 12 interest fields, and a lead time of 5-60 minutes. 76 total events.

HITS **21**	**False Alarms** **9**
MISSES **7**	**Correct Negatives** **37**

Accuracy – 78.9%
Bias Score – 1.07
POD – 75%
False Alarm Ratio – 30%
POFD – 19.6%
CSI – 56.8%

MSG Dataset

- Several convective days during the COPS field experiment in Europe in summer 2007
- Using 7 of 12 interest fields, and a lead time of 30-45 minutes. 213 total events.

HITS **107**	**False Alarms** **20**
MISSES **16**	**Correct Negatives** **41**

Accuracy – 80.75%
Bias Score – 1.07
POD – 86.99%
False Alarm Ratio – 18.93%
POFD – 27.7%
CSI – 72.29%

Steps to reach 100%

- Continue code enhancements for speed and efficiency.
- Additional validation/evaluation using simulated ABI values and MSG data.

Summary

- The CI Algorithm provides a new capability for monitoring the cloud top properties of growing cumulus clouds.
- Improved ABI spatial and temporal resolution will allow for monitoring small scale cumulus clouds and provide for monitoring of cloud top properties.
- Multi-spectral and temporal monitoring of cloud top properties provides knowledge of cloud growth which is instrumental in providing lead-time before clouds initiate.
- Algorithm exceeds all performance requirements.