U. S. Contributions to COPS: Satellite-estimated Convective Initiation

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UAH

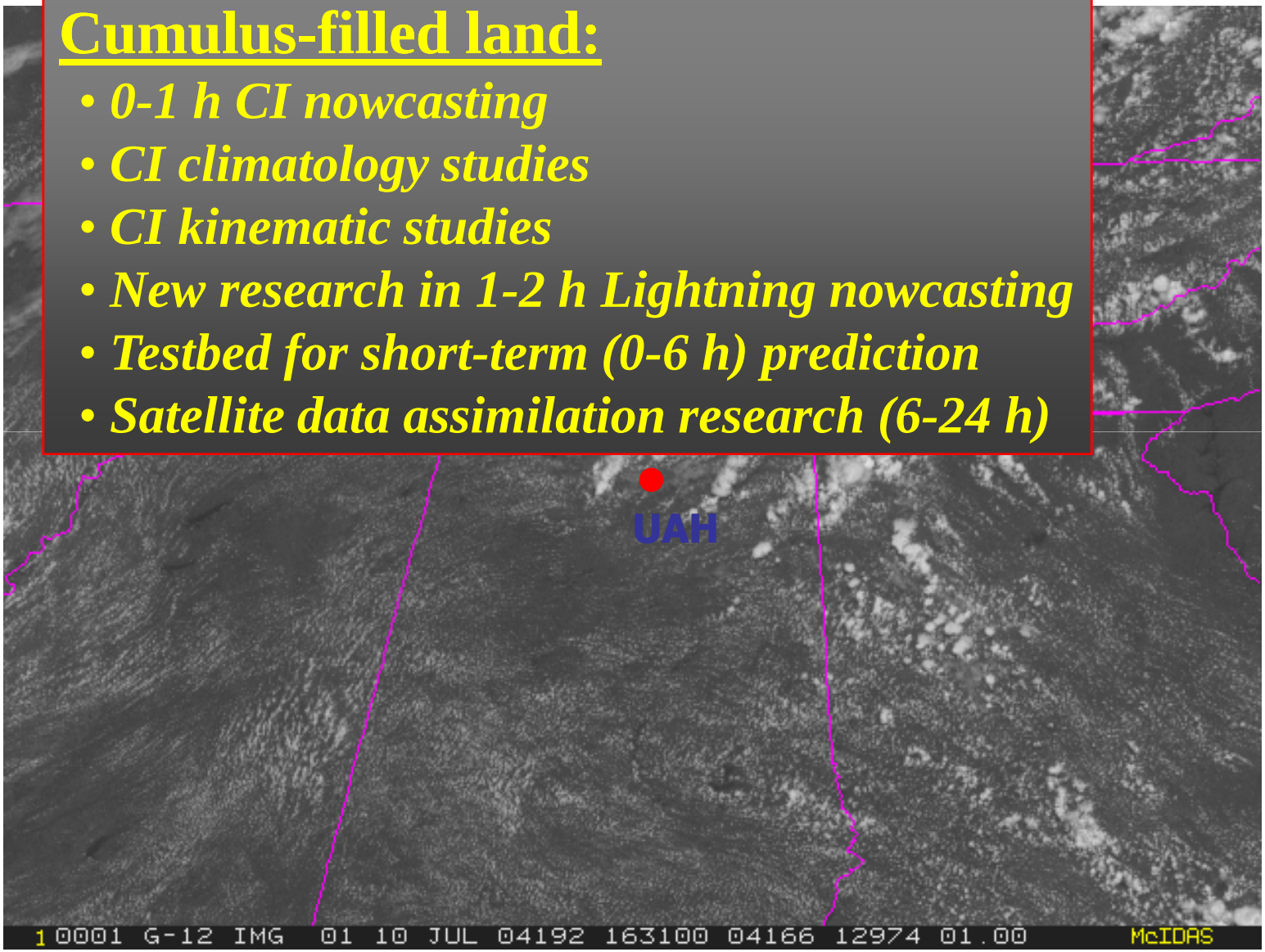
National Aeronautics and Space Administration

CIMSS UNIVERSITY OF WISCONSIN MADISON

Outline

- Current capability: Overview
- Related initiatives
  - Nighttime convective initiation
  - Lightning (event) forecasting
  - CI climatology, motion and flood forecasting
- COPS & research support
  - Real-time/case study
  - Follow-on Study

Cumulus clouds…

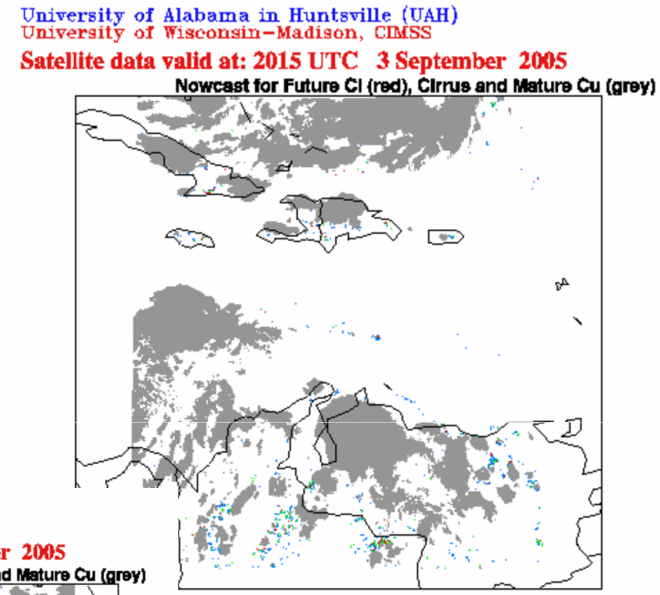


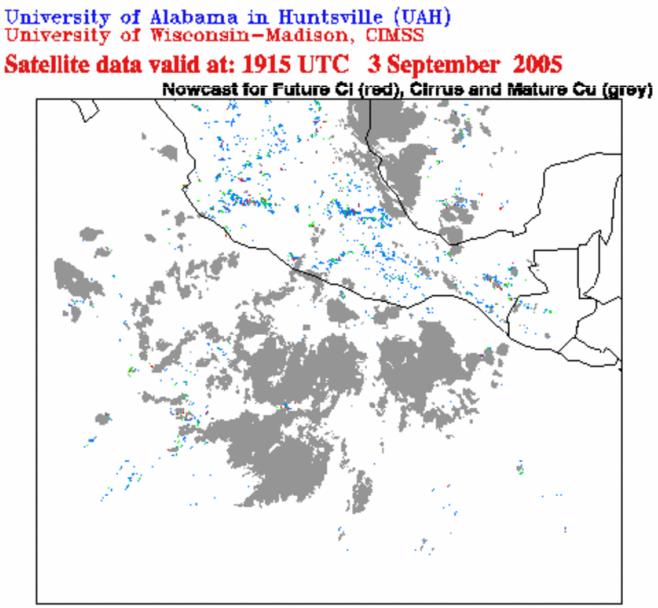
Cumulus-filled land:

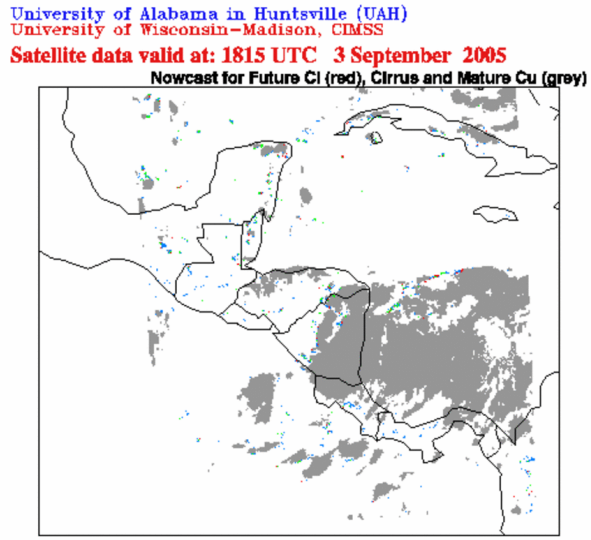
- *0-1 h CI nowcasting*
- *CI climatology studies*
- *CI kinematic studies*
- *New research in 1-2 h Lightning nowcasting*
- *Testbed for short-term (0-6 h) prediction*
- *Satellite data assimilation research (6-24 h)*

Where are we now …

- **Applying CI algorithm over U.S., Central America & Caribbean**
- **Validation & Confidence analysis**
- **Satellite CI climatologies/CI Index: 1-6 h**
- **Work with new instruments**
- **Hydrological applications**







Input Datasets for Convective Nowcasts/Diagnoses

- **Build relationships between GOES and NWS WSR-88D imagery:**

  - Identified GOES IR T_B and multi-spectral technique thresholds and time trends present before convective storms begin to precipitate

  - Leveraged upon documented satellite studies of convection/cirrus clouds [*Ackerman (1996), Schmetz et al. (1997),* ***Roberts and Rutledge (2003)***]

  - After pre-CI signatures are established, test on other independent cases to assess algorithm performance

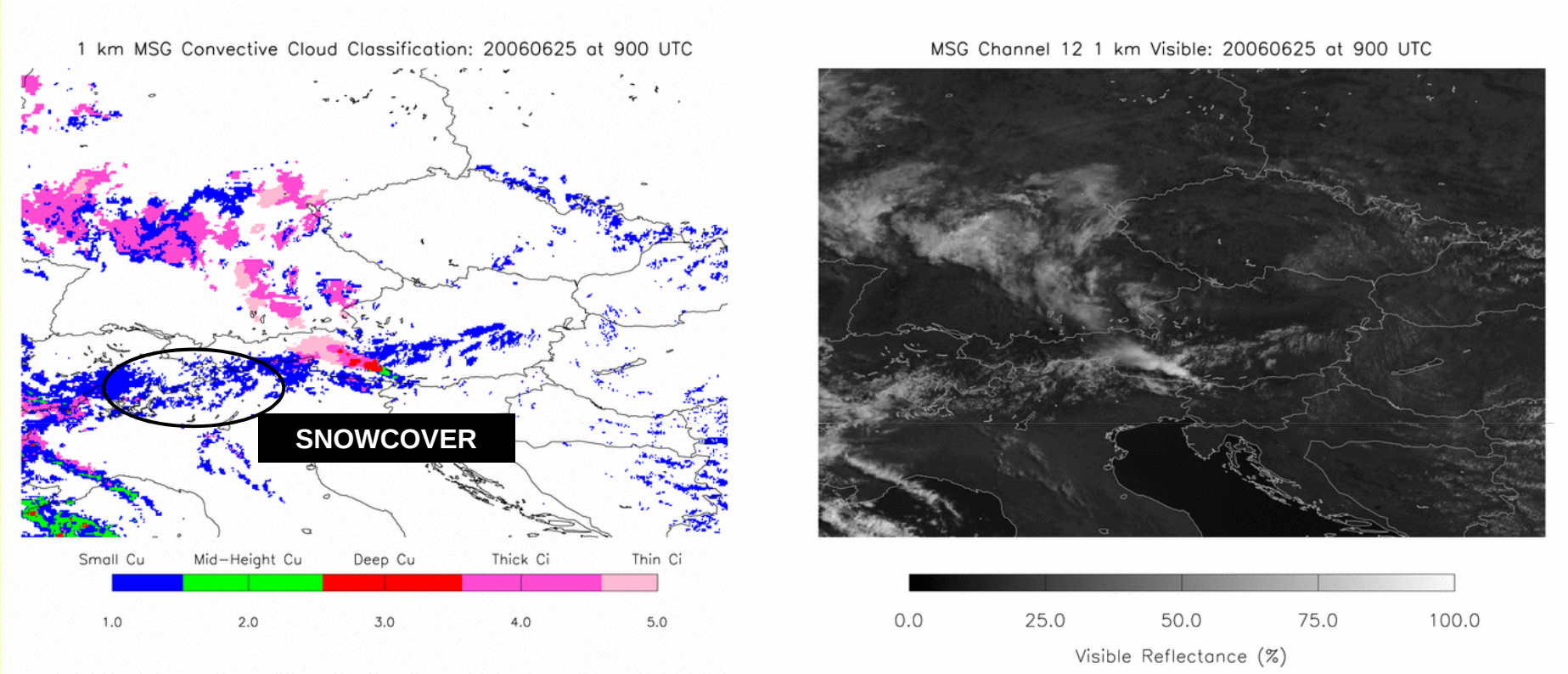
Use McIDAS to acquire data, generally NOT for processing:

- **GOES-12 1 km visible and 4-8 km infrared imagery every 15 minutes**
- **UW-CIMSS visible/IR "Mesoscale" *Atmospheric Motion Vectors* (AMVs)**
- **WSR-88D base reflectivity mosaic used for real-time validation**
- **NWP model temperature data for AMV assignment to cumulus cloud pixels … based on relationship between NWP temp profile and cumulus 10.7 μm T_B**

Other non-McIDAS data:

- **UAH *Convective Cloud Mask* to identify locations of cumulus clouds**

MSG Convective Cloud Mask



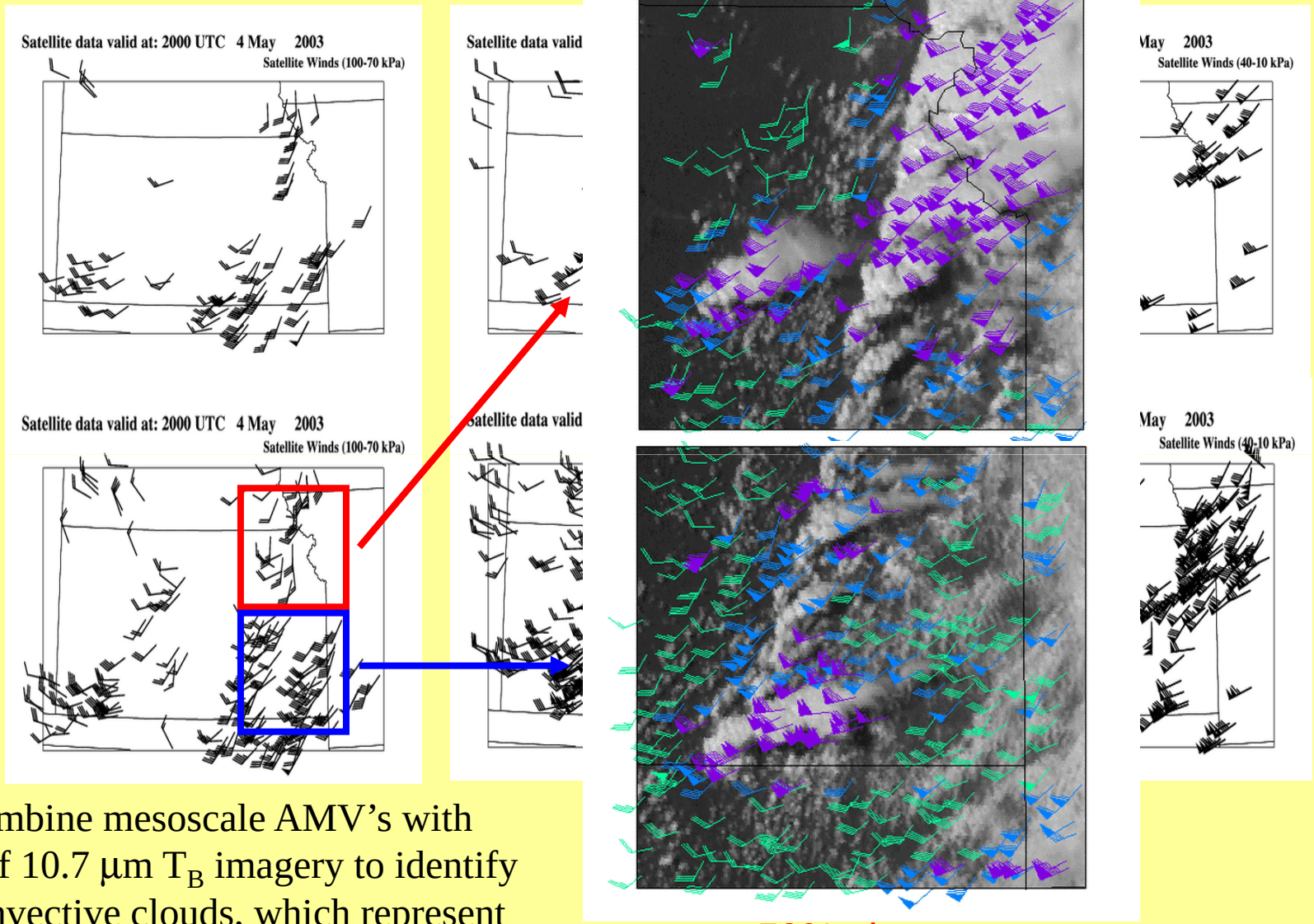
- MSG convective cloud mask utilizes 1 km HRV and all 11 channels of 3 km IR imagery, including channel differencing parameters and visible texture
- Currently a day-time only product, but work being done at UAH to evaluate feasibility of a IR-only night-time product

"Mesoscale" Atmospheric Motion Vector Algorithm

"Operational Settings"

New Mesoscale AMVs

(only 20% shown)

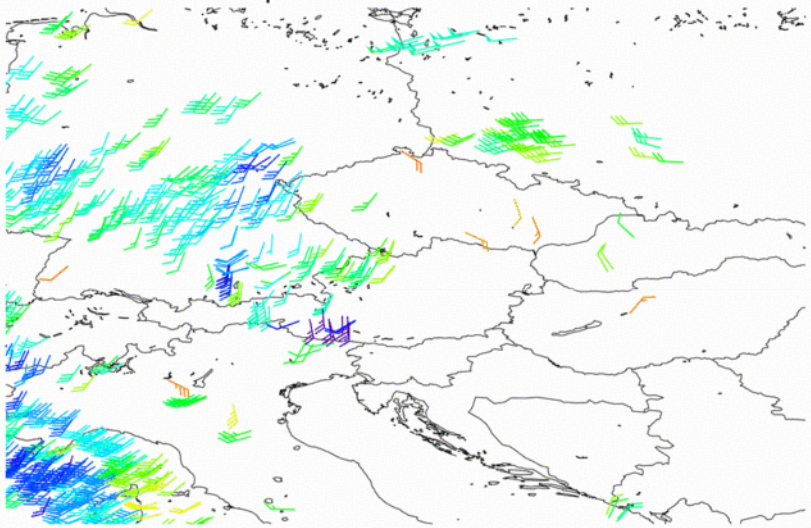


50% shown

- We can combine mesoscale AMV's with sequences of 10.7 μm T_B imagery to identify growing convective clouds, which represent a hazard to the aviation community

MSG "Mesoscale" Atmospheric Motion Vectors

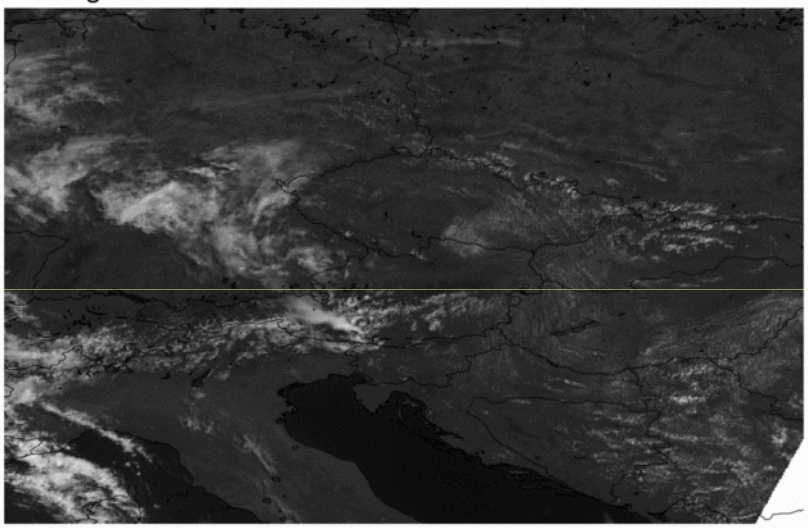
MSG Mesoscale Atmospheric Motion Vectors: 20060625 at 945 UTC



100.0 250.0 400.0 550.0 700.0 850.0 1000.0

AMV Height Assignment (hPa): 570 Vectors Shown

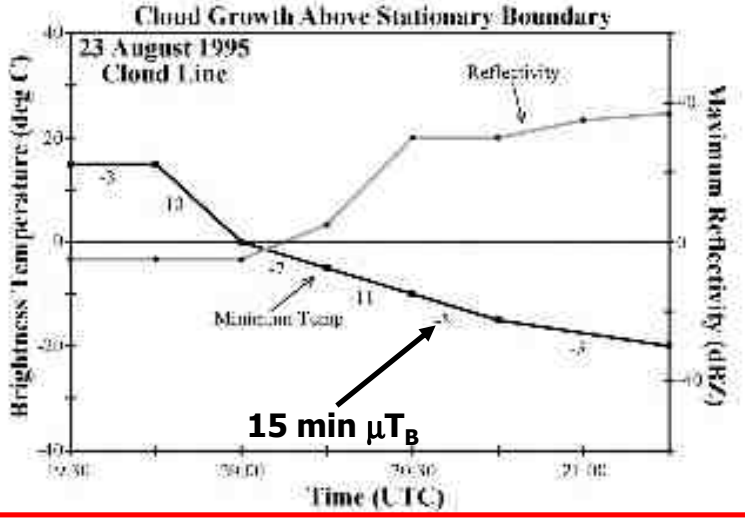
MSG High Resolution Visible Reflectance: 20060625 at 930 UTC



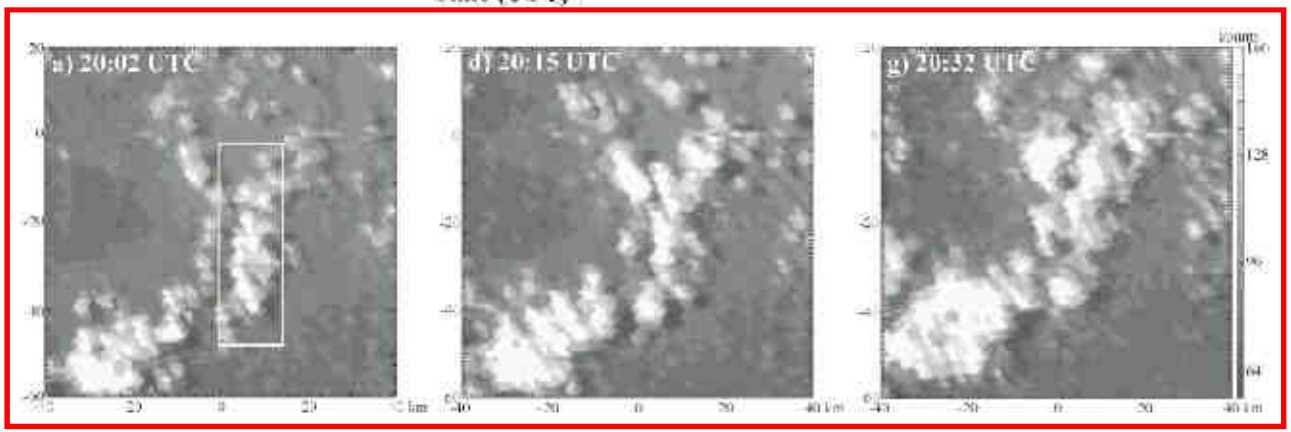
0.0 20.0 40.0 60.0 80.0 100.0

Visible Reflectance (%)

Cloud-Top Cooling Rates for CI Assessment



- Study of co-located 10.7 μm T_B and radar reflectivity trends for stationary convection along the Colorado Front Range
- Found that sub-freezing 10.7 μm T_B's and –4°C/15mins (–8 °C/15mins) correspond to weak (vigorous) growth



"By monitoring, via satellite, both the cloud growth and the occurrence of sub-freezing cloud-top temperatures, the potential for up to 30 mins advance notice of convective storm initiation (> 35 dBz), over the use of radar alone, is possible."

Roberts and Rutledge (2003), Wea. Forecasting

CI "Interest Fields": 8 Total from GOES

CI Interest Field	Critical Value
10.7 µm T_B (1 score)	< 0°C
10.7 µm T_B Time Trend (2 scores)	< -4°C/15 mins ΔT_B/30 mins < ΔT_B/15 mins
Timing of 10.7 µm T_B drop below 0°C (1 score)	Within prior 30 mins
6.5 - 10.7 µm difference (1 score)	-35°C to -10°C
13.3 - 10.7 µm difference (1 score)	-25°C to -5°C
6.5 - 10.7 µm Time Trend (1 score)	> 3°C/15 mins
13.3 - 10.7 µm Time Trend (1 score)	> 3°C/15 mins

- **Use of 8.5-11 & 3.7-11 µm from MODIS have been considered**

"Interest Field" Importance: POD/FAR

CI Interest Field	Critical Value
10.7 µm T_B (1 score)	< 0°C
10.7 µm T_B Time Trend (2 scores)	< -4°C/15 mins ΔT_B/30 mins < ΔT_B/15 mins
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13.3 - 10.7 µm Time Trend (1 score)	> 3°C/15 mins

- Instantaneous 13.3–10.7 um: **Highest POD (84%)**
- Time-trend 13.3–10.7 um: **Lowest FAR (as low as 38%)**
- **Important for CI & Lightning Initiation**

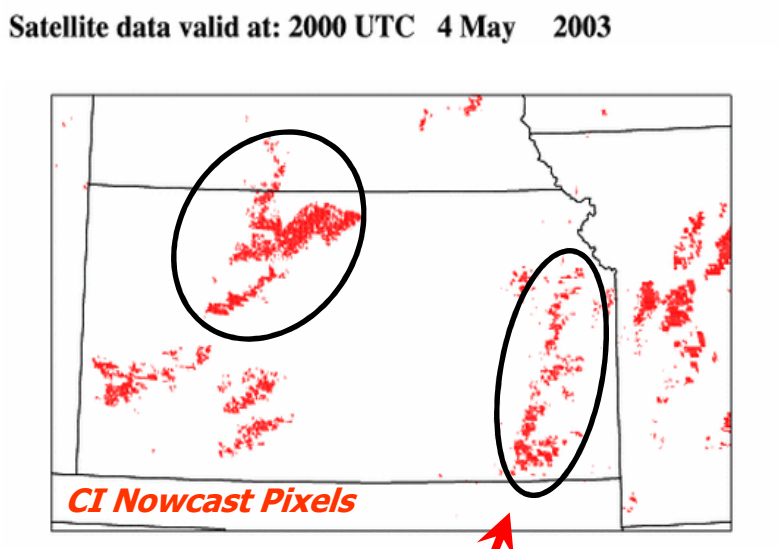
Preliminary MSG CI Nowcasting Criteria

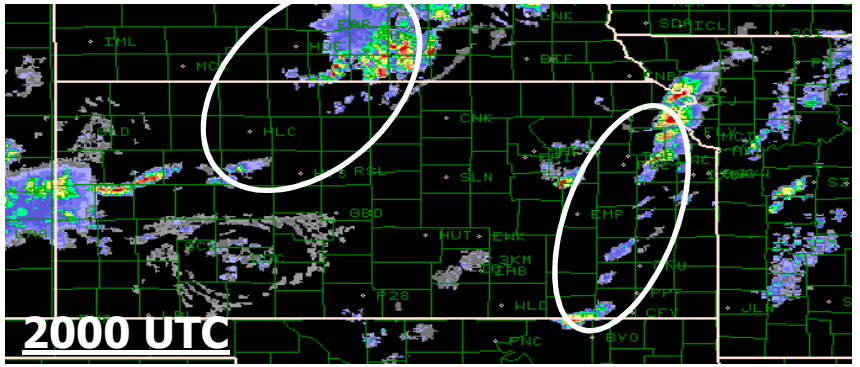
CI Interest Field	Critical Value
10.8 µm T_B	< 0 K
10.8 µm T_B Time Trend	< -4 K/15 mins ΔT_B/30 mins > ΔT_B/15 mins
Timing of 10.8 µm T_B drop below 0° C	Within prior 30 mins
8.5-10.8 µm T_B Difference	< 0 K
12.0-10.8 µm T_B Difference*	-3 to 0 K
CAPE	> 500 J/kg

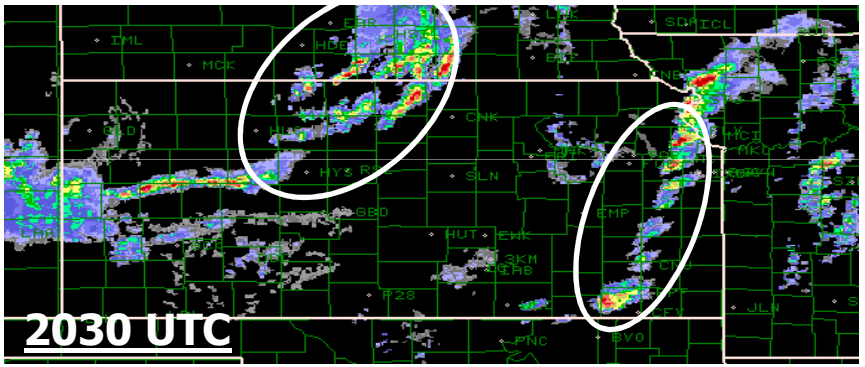
- Microphysical information from 1.6 reflectance is used to improve the convective cloud mask and negative 8.7-10.8 µm differencing values are used to identify cumulus with liquid water tops

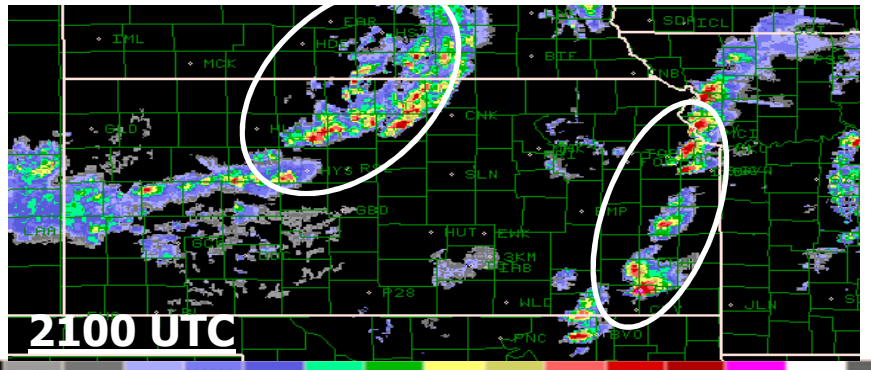
*** Inoue (J. Meteor. Soc. Of Japan, 1987)**

GOES CI Nowcast Algorithm: 4 May 2003





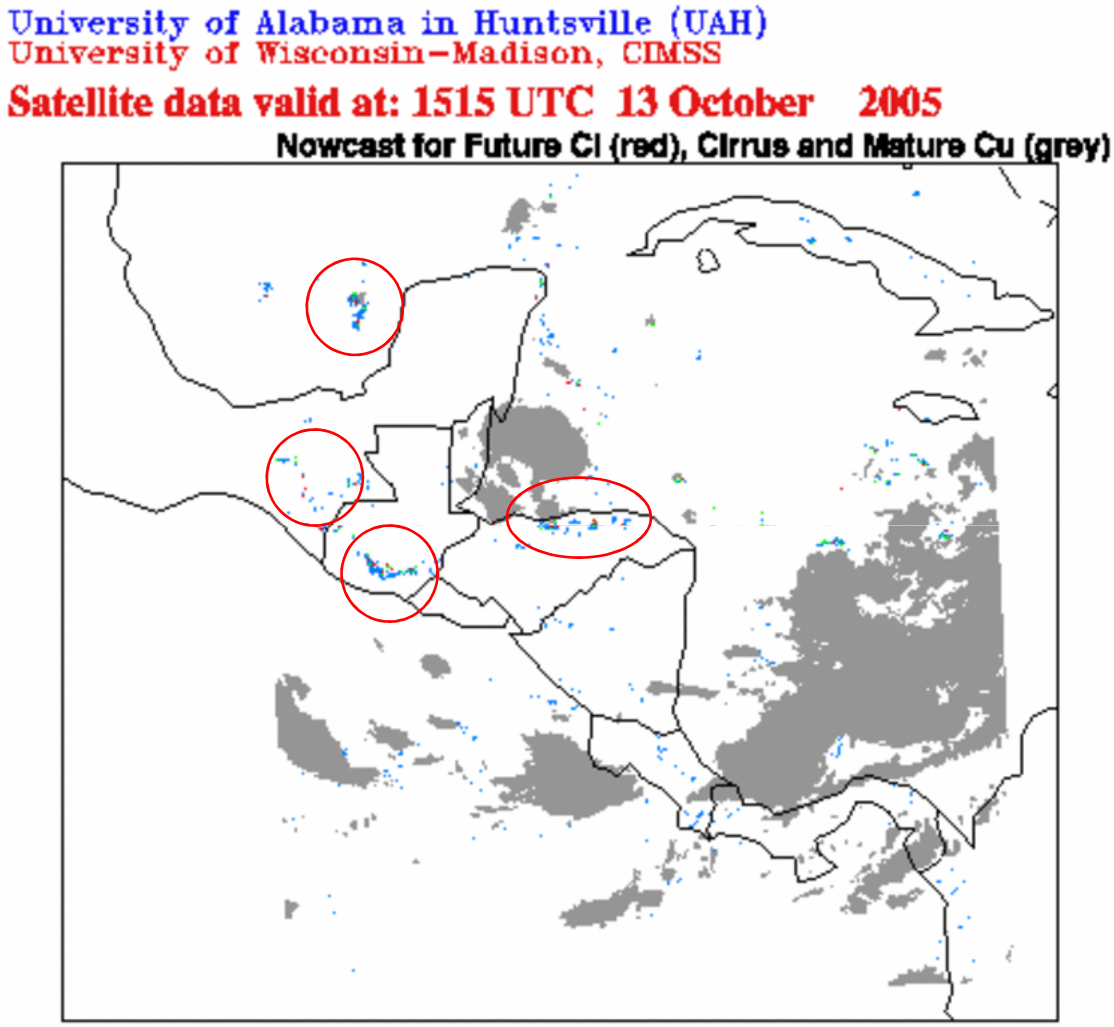




• Satellite-based CI indicators provided *30-60 min advanced notice* of CI in E. and N. Cent. KS

These are forecasted CI locations!

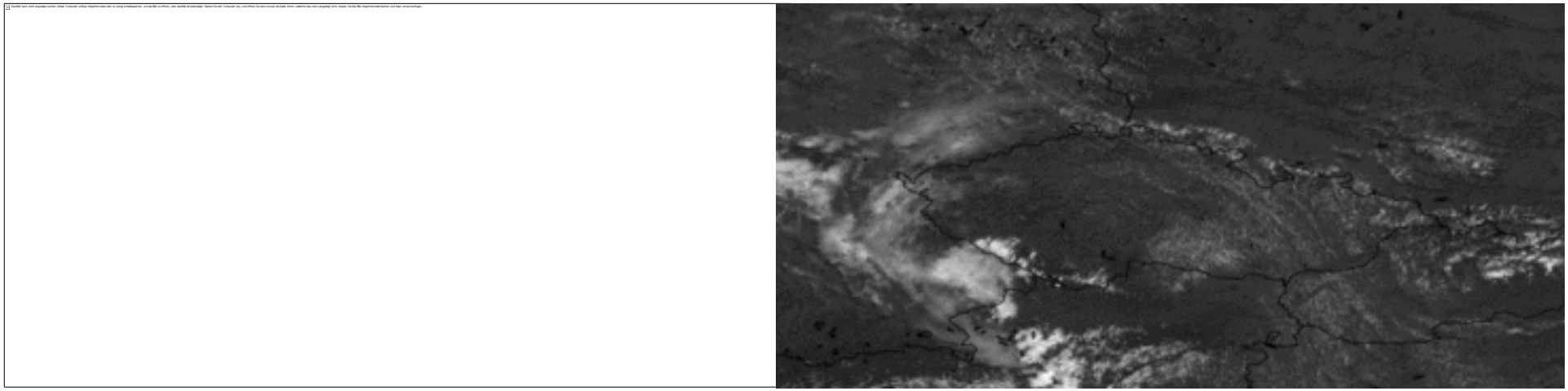
A GOES Example over the Tropics: CI

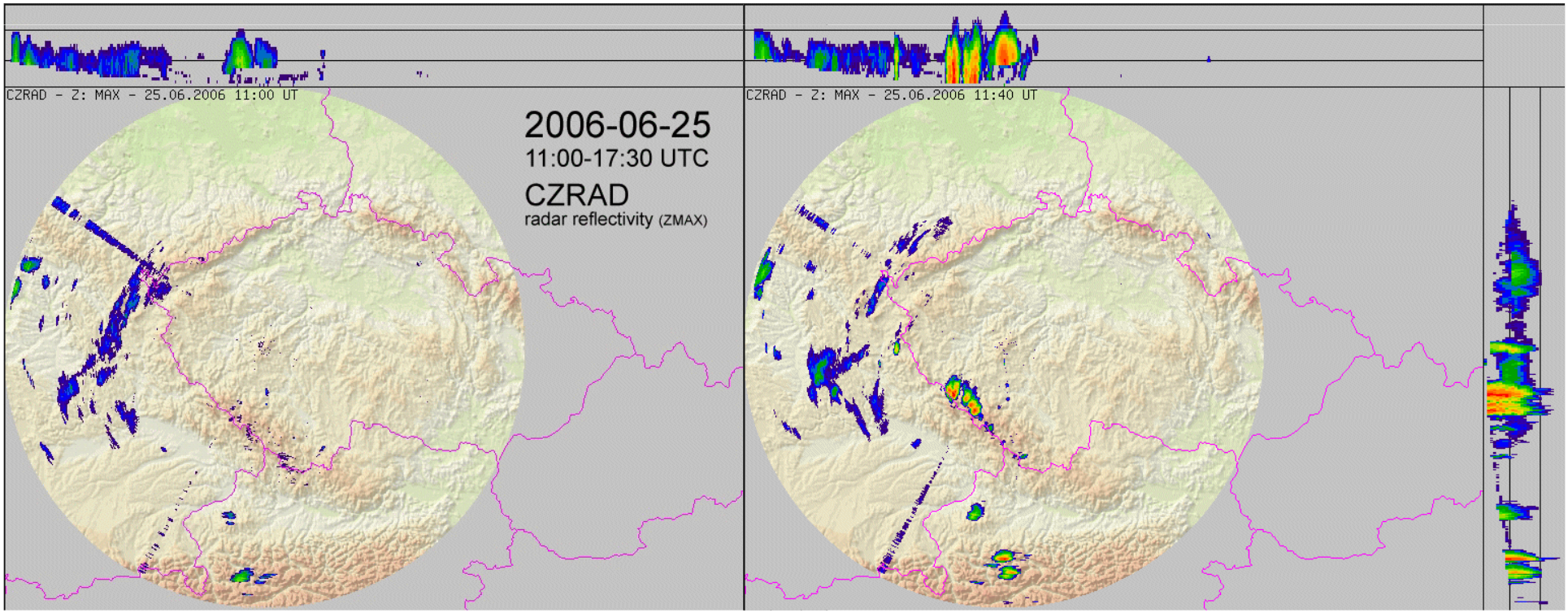


An example of the CI nowcasting method over Central America:

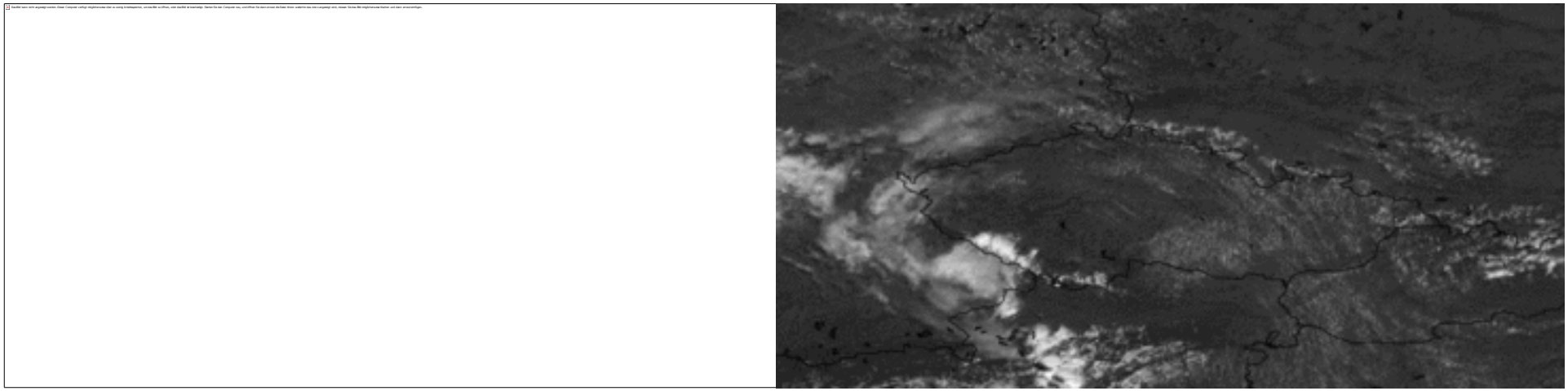
- Real-time
- Every 30 min during the day (*nighttime coming soon*)
- GOES (*MODIS soon*)
- **RED/GREEN pixels have highest CI probability**

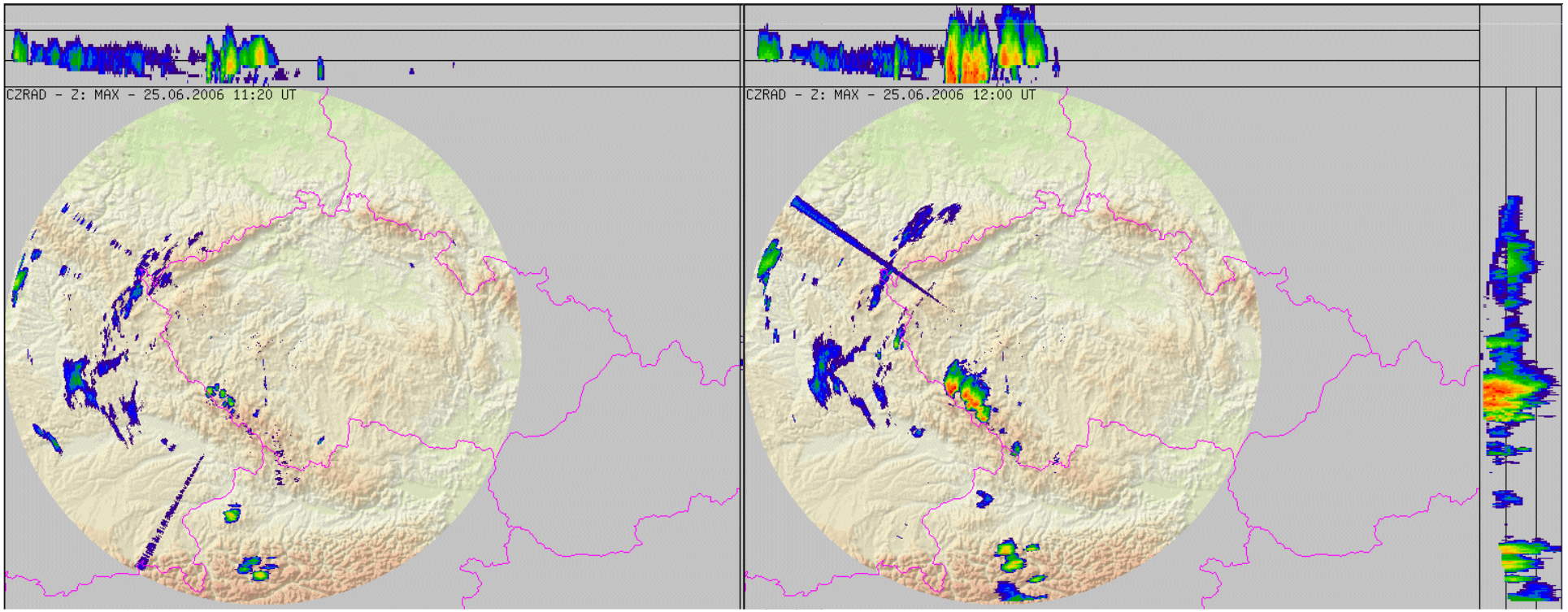
MSG CI Nowcast: 20060625 at 1100 UTC



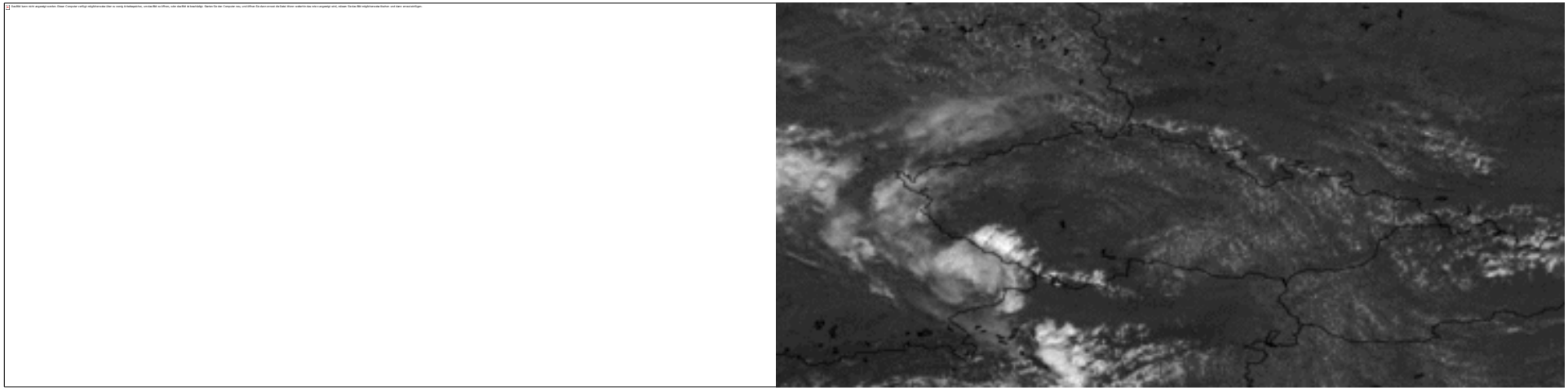


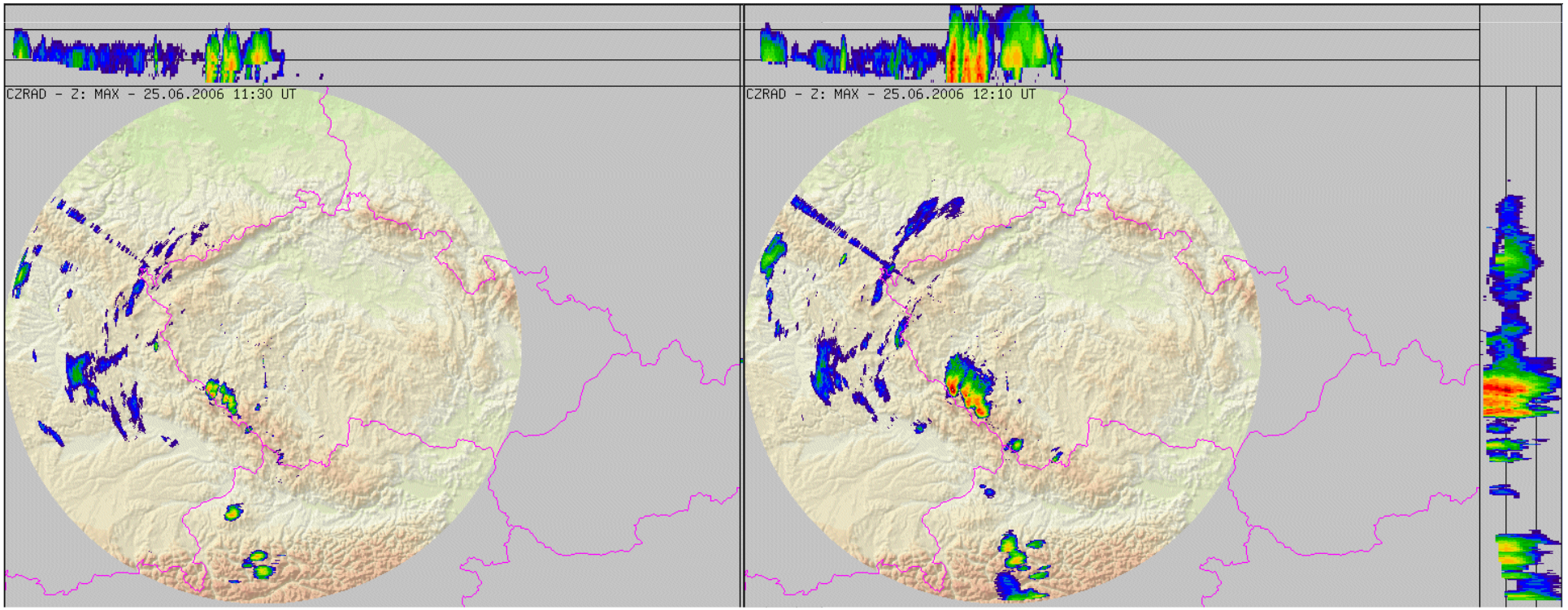
MSG CI Nowcast: 20060625 at 1115 UTC



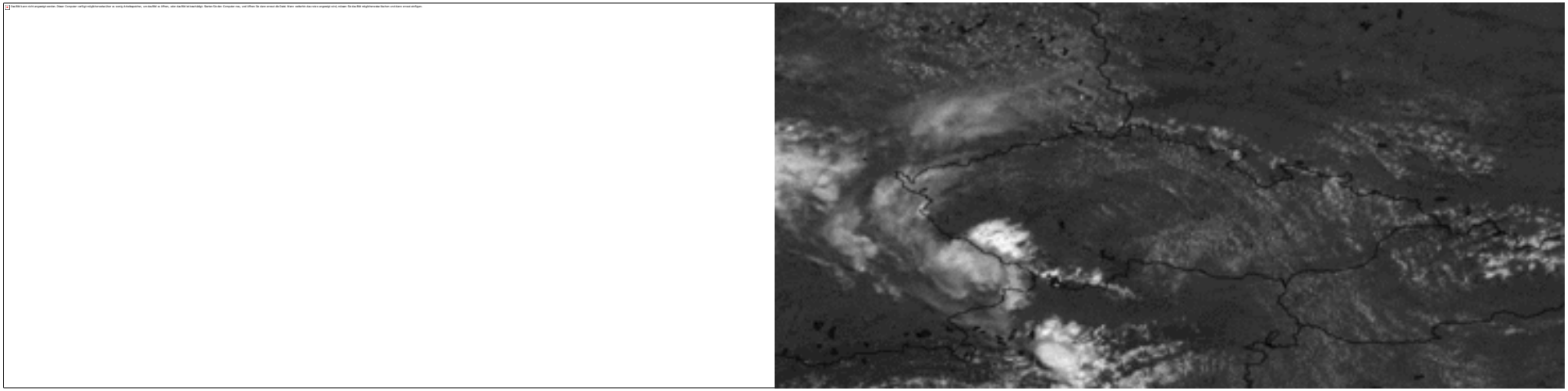


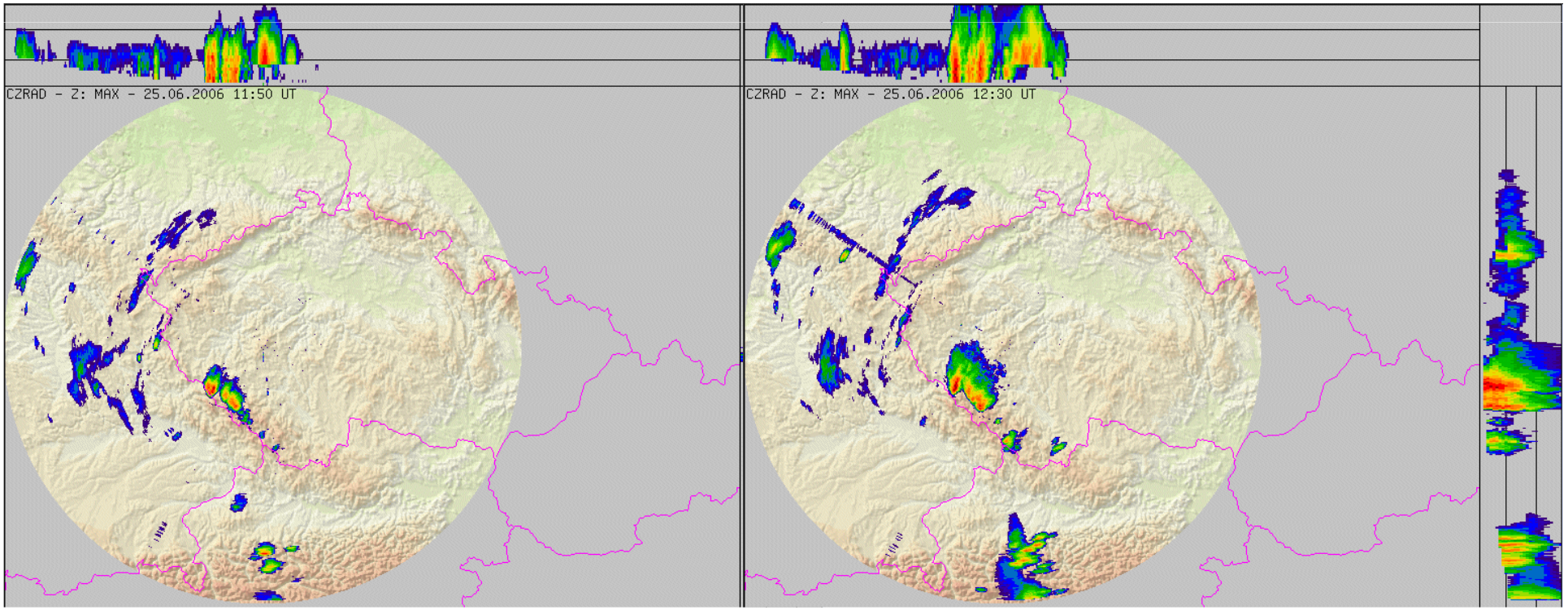
MSG CI Nowcast: 20060625 at 1130 UTC



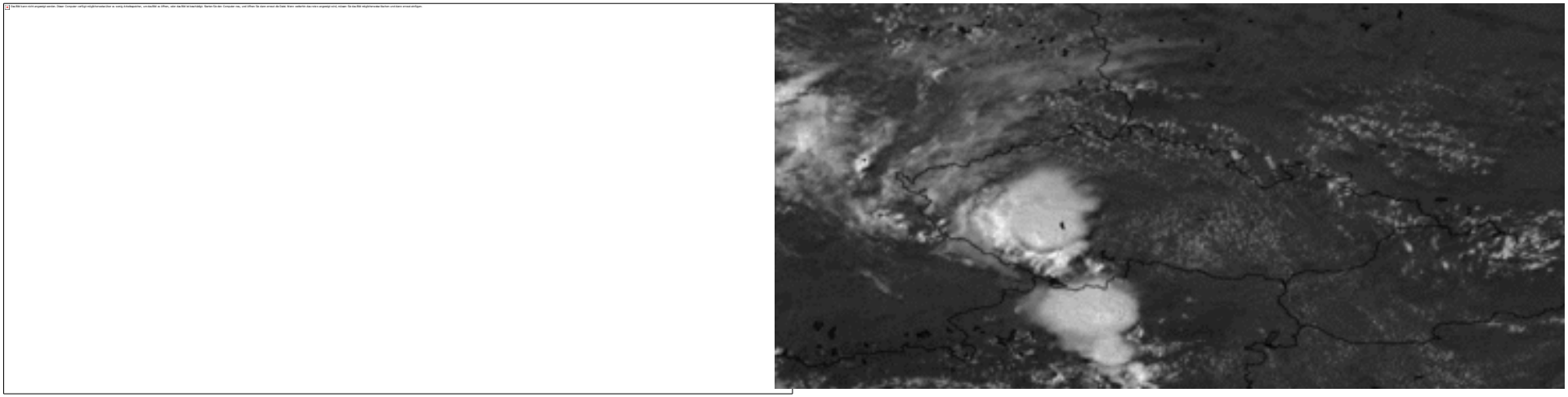


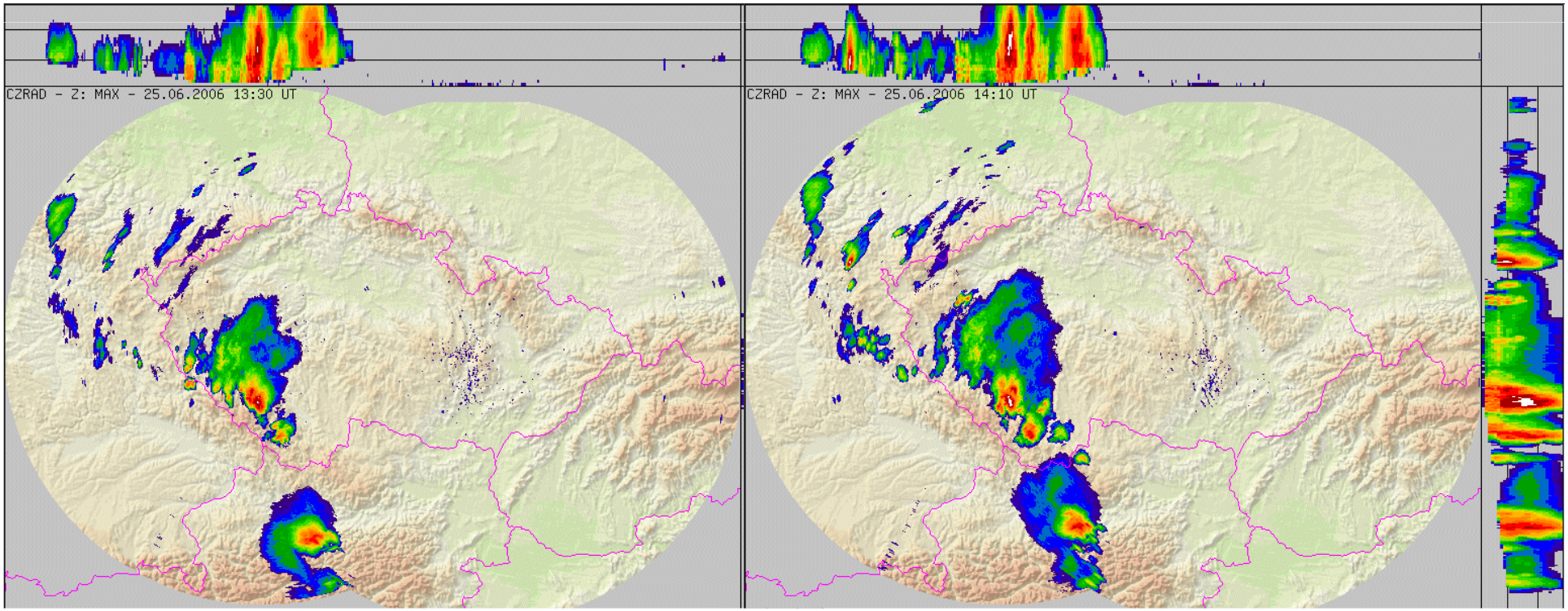
MSG CI Nowcast: 20060625 at 1145 UTC



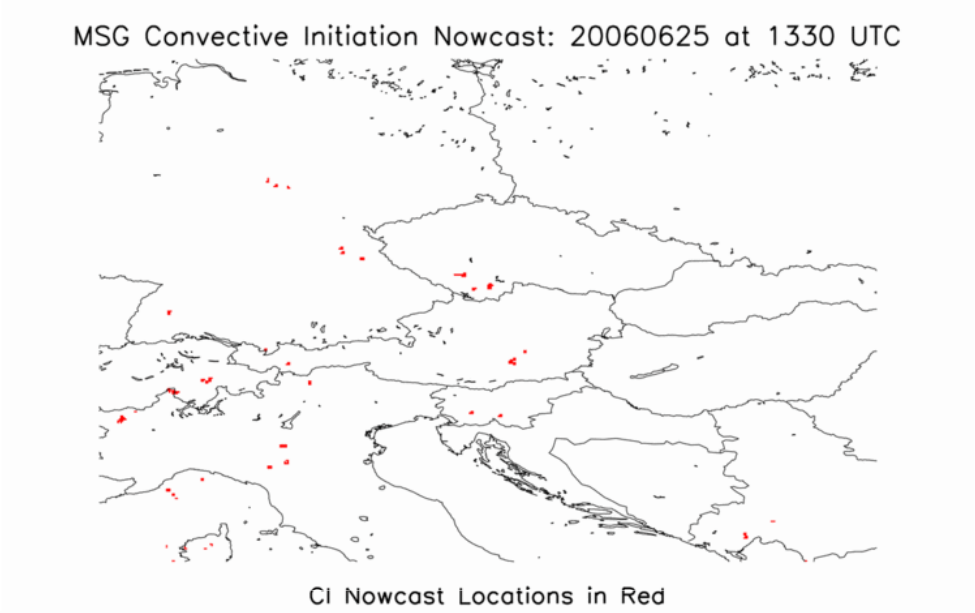


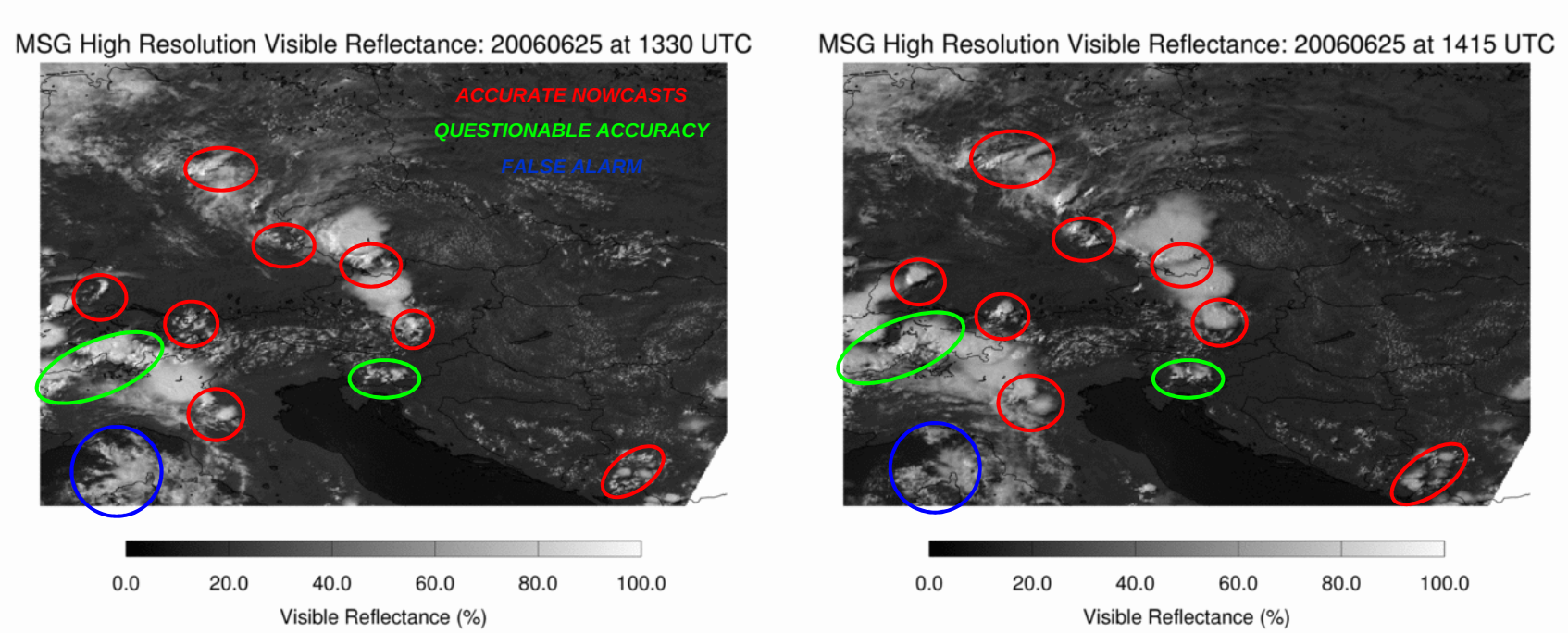
MSG CI Nowcast: 20060625 at 1330 UTC





Qualitative MSG Nowcast Validation





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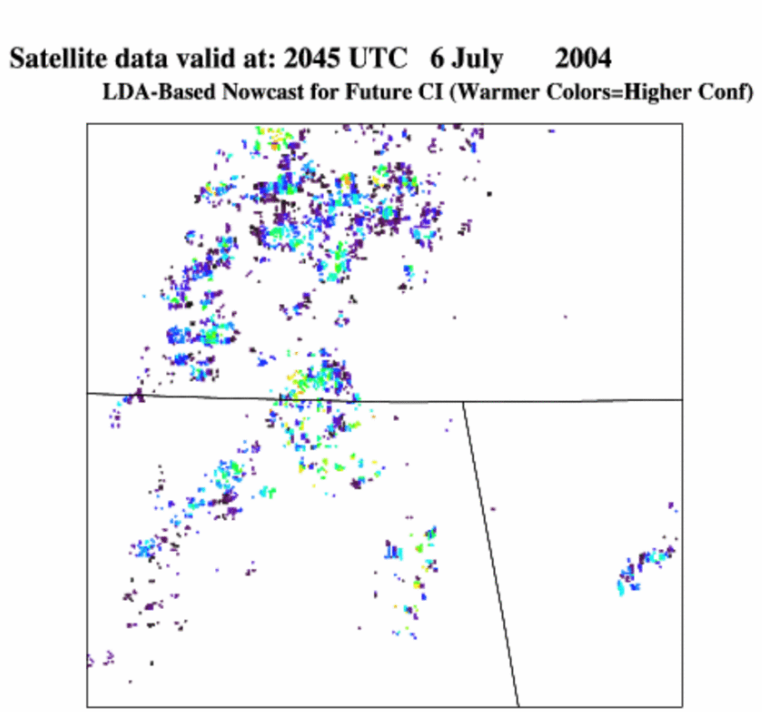
CI/LI Linear Determinant Analysis (LDA)

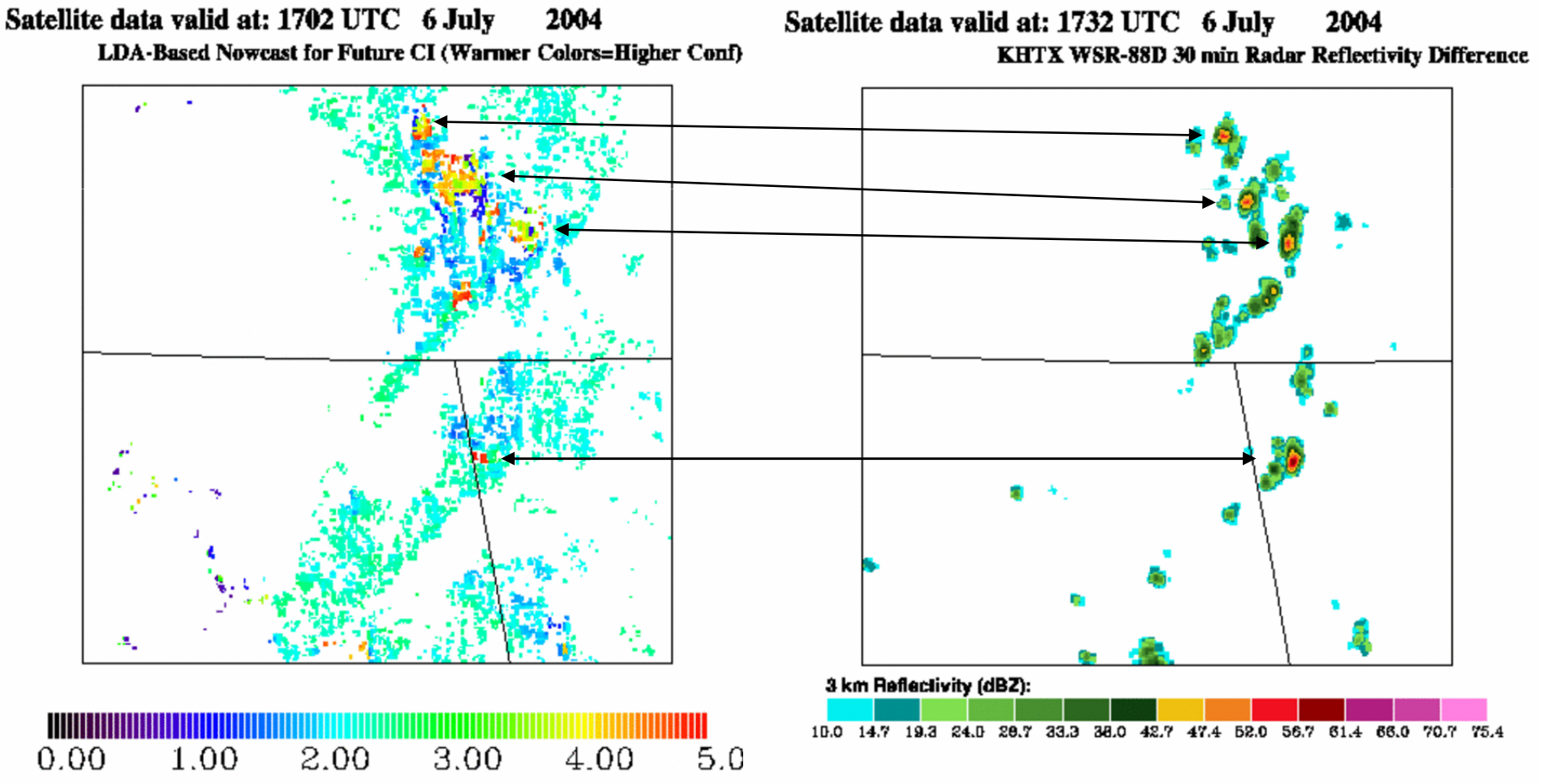
1) **Remap GOES data to 1 km gridded radar reflectivity data**
   - Correct for parallax effect by obtaining cloud height through matching the 10.7 μm T_B to standard atmospheric T profile
2) **Identify radar/lightning pixels that have undergone CI/LI at t+30 mins**
   - Advect pixels forward using low-level satellite wind field to find their approximate location 30 mins later
3) **Determine what has occurred between imagery at time t, t-15, & t-30 mins to force CI/LI to occur in the future (t+30 mins)**
4) **Collect database of IR interest fields (IFs) for these CI/LI pixels**
5) **Apply LDA: identify relative contribution of each IF toward an accurate nowcast**
   - Test LDA equation on independent cases to assess skill of new method



CI/LI Linear Discriminant Analysis (LDA)

Some correlation between a confidence in CI [*f*(LDA score)] and 30-min dBZ (increase): *QPE nowcast*

- Improved POD of **~70% (90%)**
  FAR of **~34%**
- A virtual-radar from satellite



Detecting Convective Initiation at Night

Detection of convective initiation at night must address several unique issues:

a) Restricted to 4 km data (unless MODIS is relied upon)
b) Visible data cannot be used to formulate cumulus mask
c) Highly-dense, GOES visible winds are unavailable for tracking
d) Forcing for convection often elevated and difficult to detect
(e.g., low-level jets, bores, elevated boundaries)

However, the advantages are:

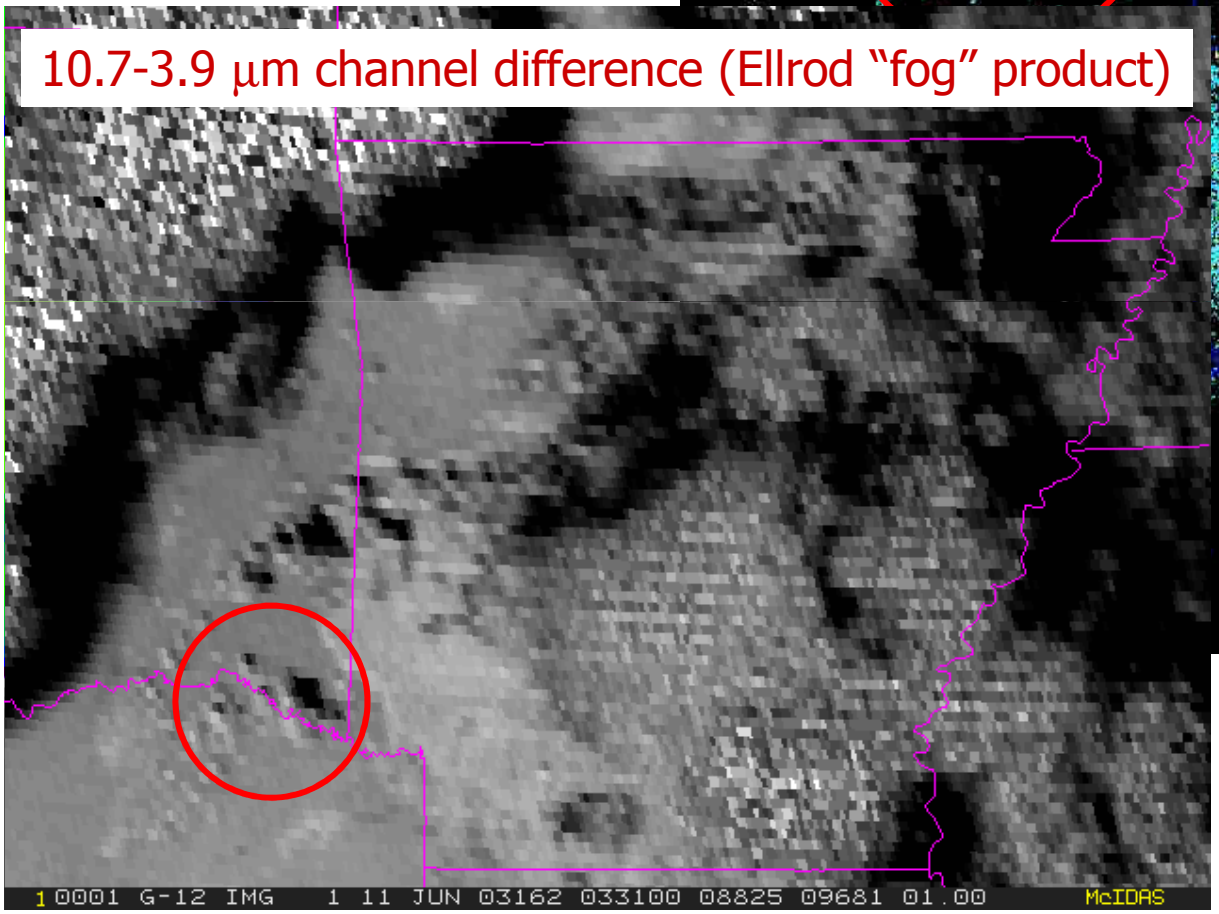
a) Ability to use ~3.9 μm channel (near-infrared) data
b) More "interest fields" become available for assessing cumulus cloud development

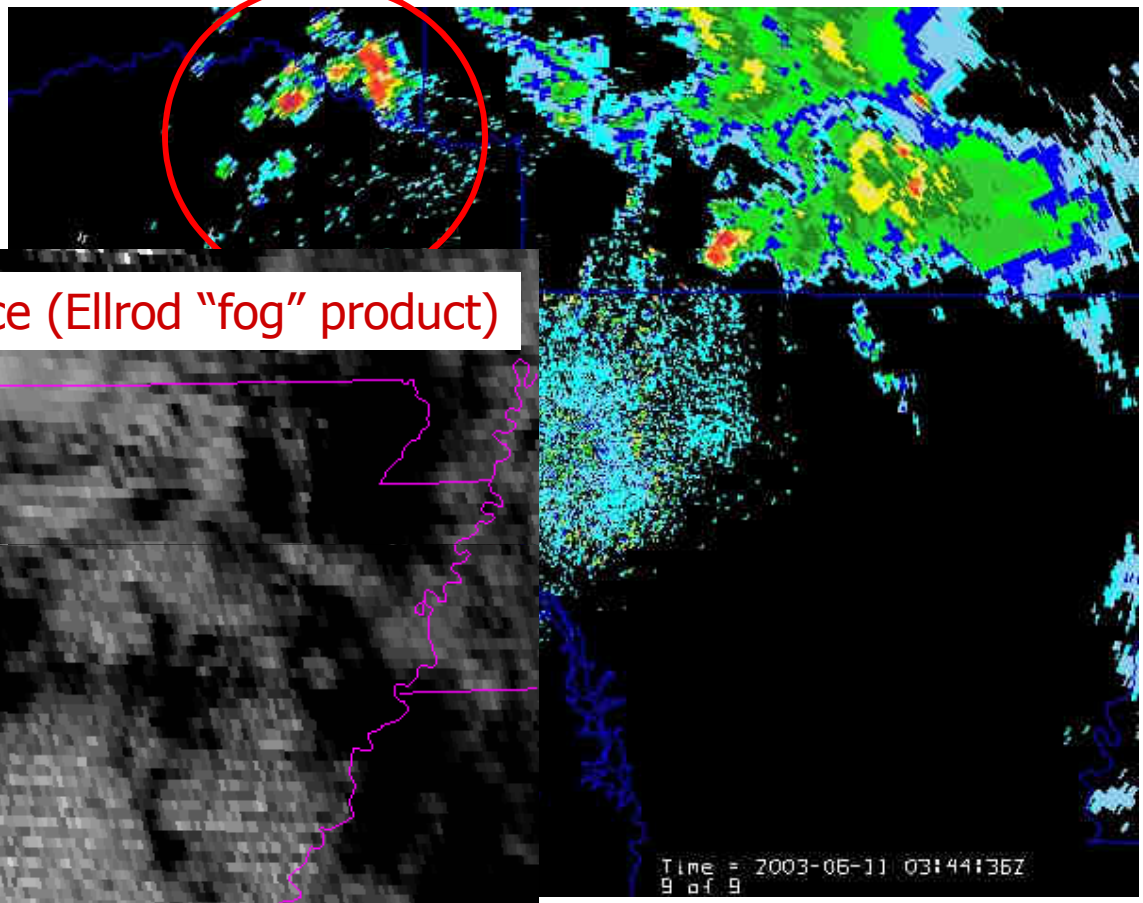
CI detection during nocturnal conditions suggests that up to 1.5 hour nowcasts are likely, esp., *where lower resolution are preferred* (i.e. "mesoscale" forcing for CI).

Wayne Mackenzie, MS student

Detecting Convective Initiation at Night

Nighttime CI: Southeast Oklahoma



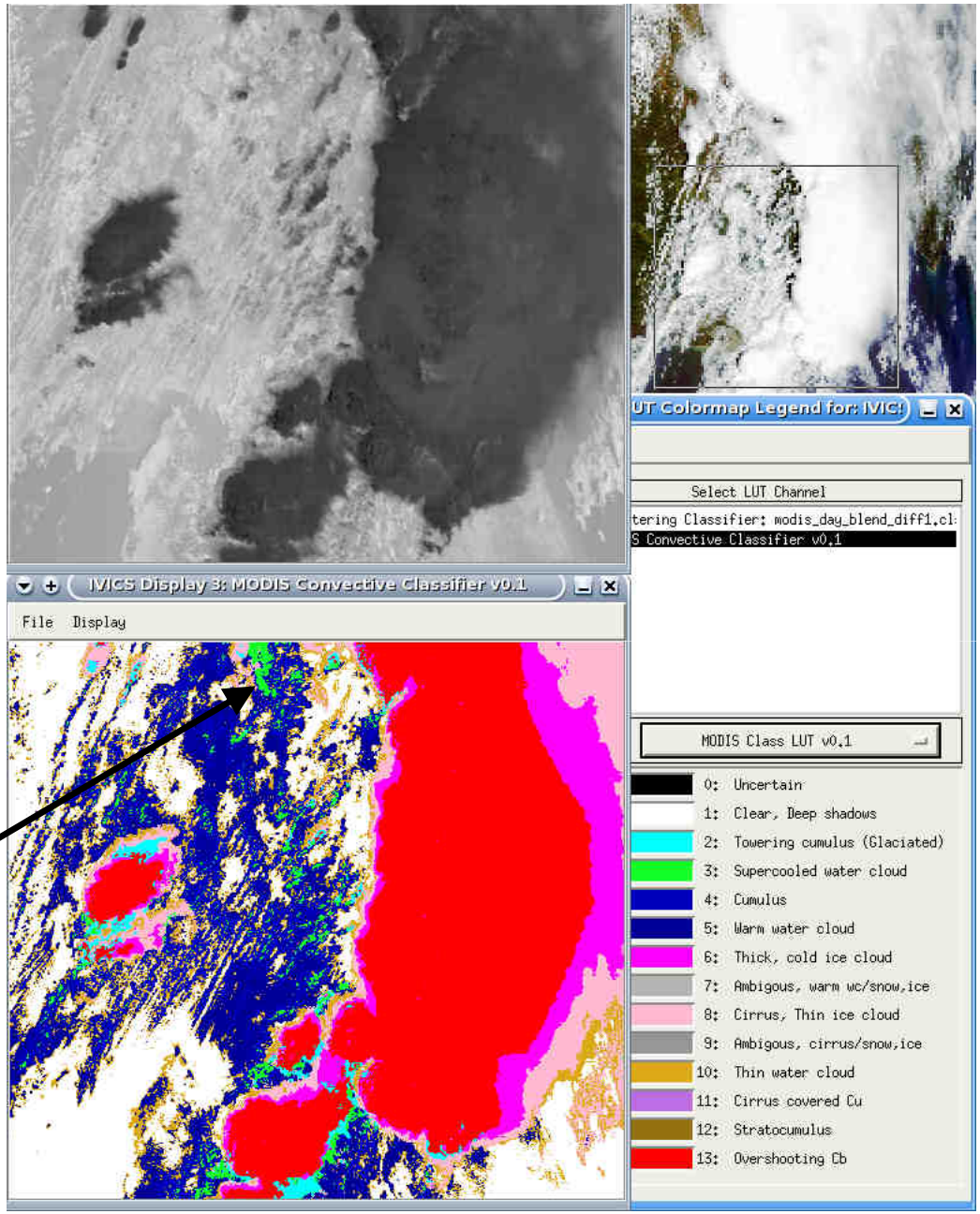


SHV: 3:44 UTC

Enhanced 10.7 μm

• The lower right shows the supercooled water in green.

• Proof of concept for determining the difference between supercooled water and glaciated towering cumulus clouds.

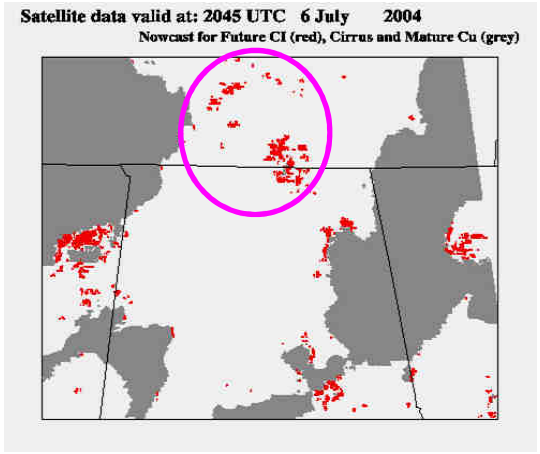


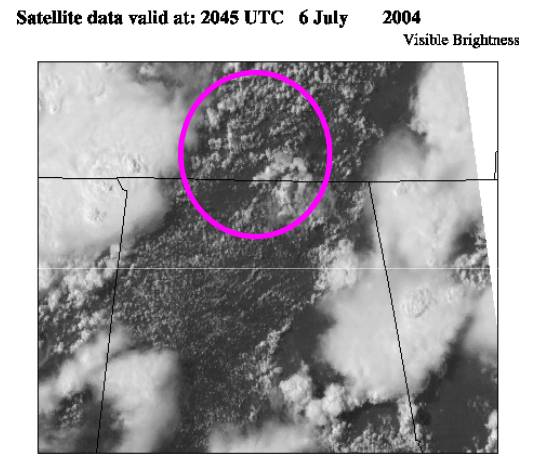
Super-cooled tops: Lightning indicator as a function of convective environment

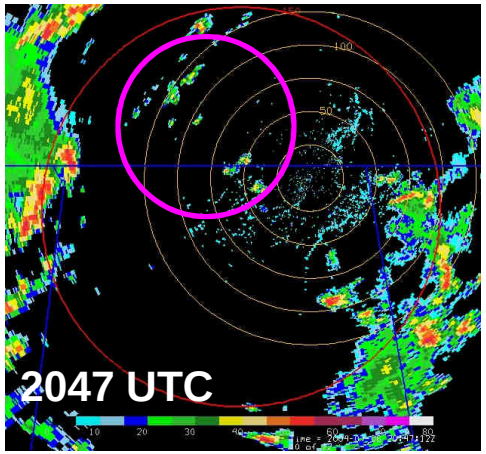
Satellite-Lightning Relationships

- *Current Work:* Develop relationships between IR T_B/T_B trends and lightning source counts/flash densities toward nowcasting (0-2 hr) future lightning occurrence

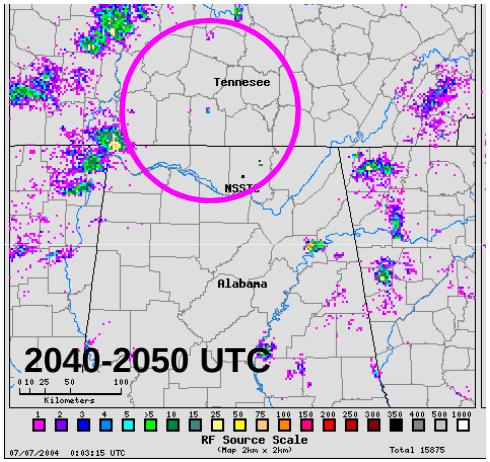
* *Supported by the NASA New Investigator Program Award #:NAG5-12536*

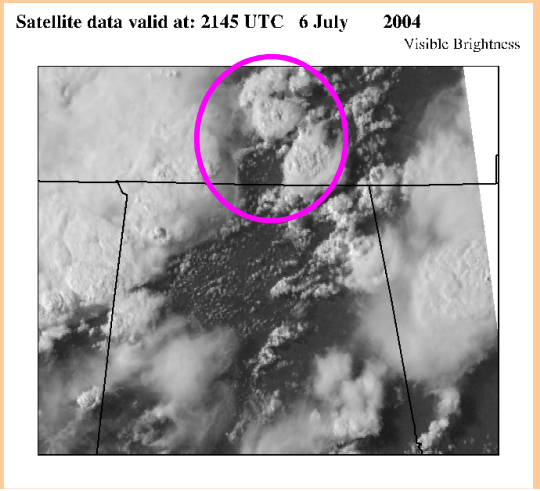


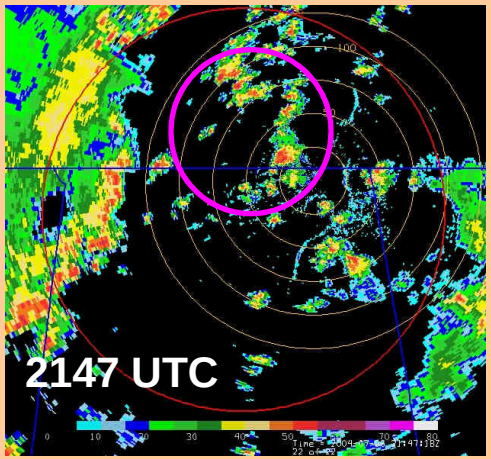


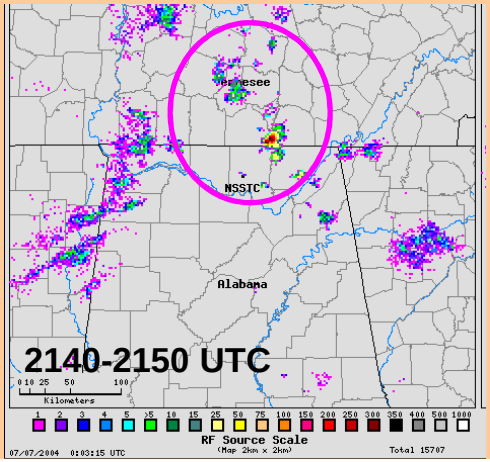


Northern Alabama LMA Lightning Source Counts



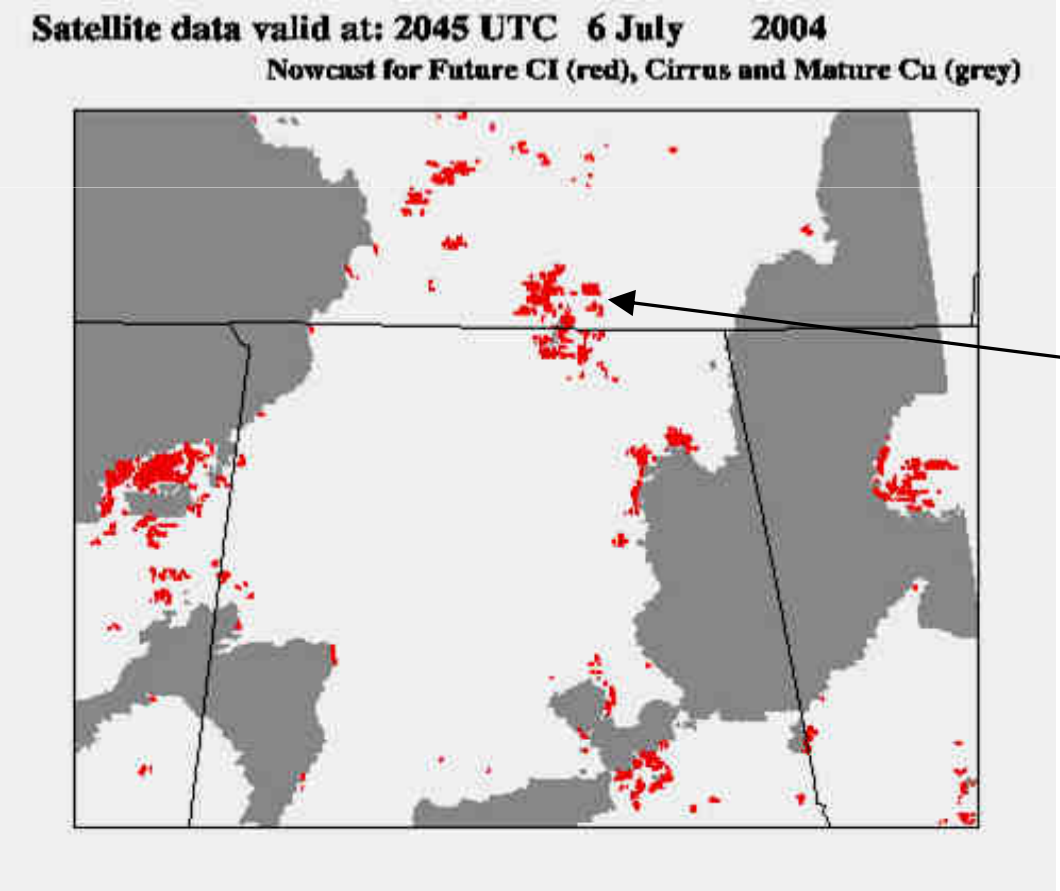


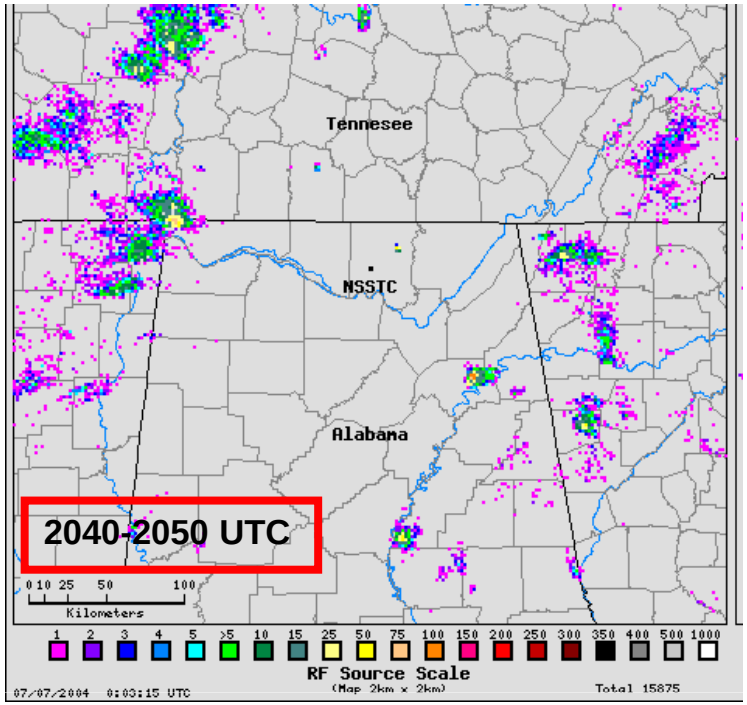


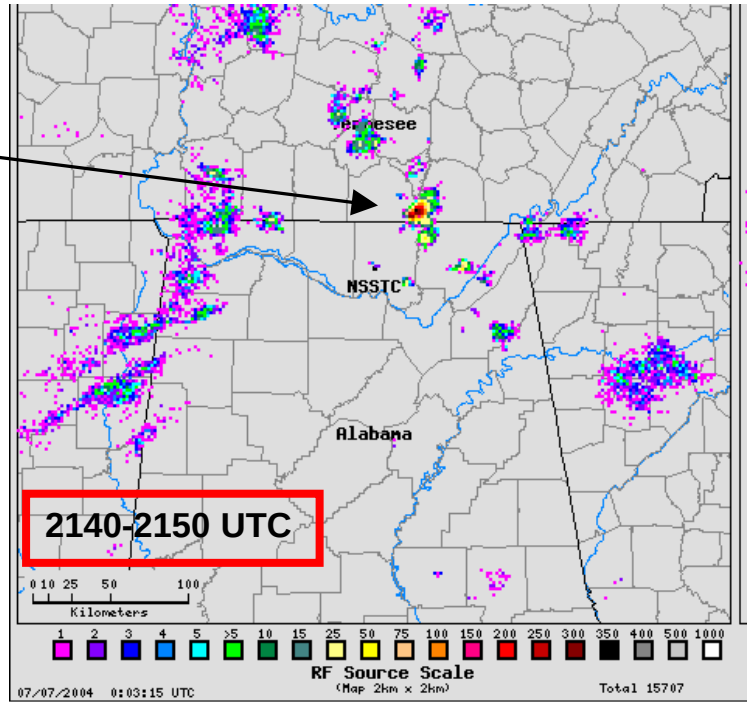


Northern Alabama LMA
Lightning Source Counts

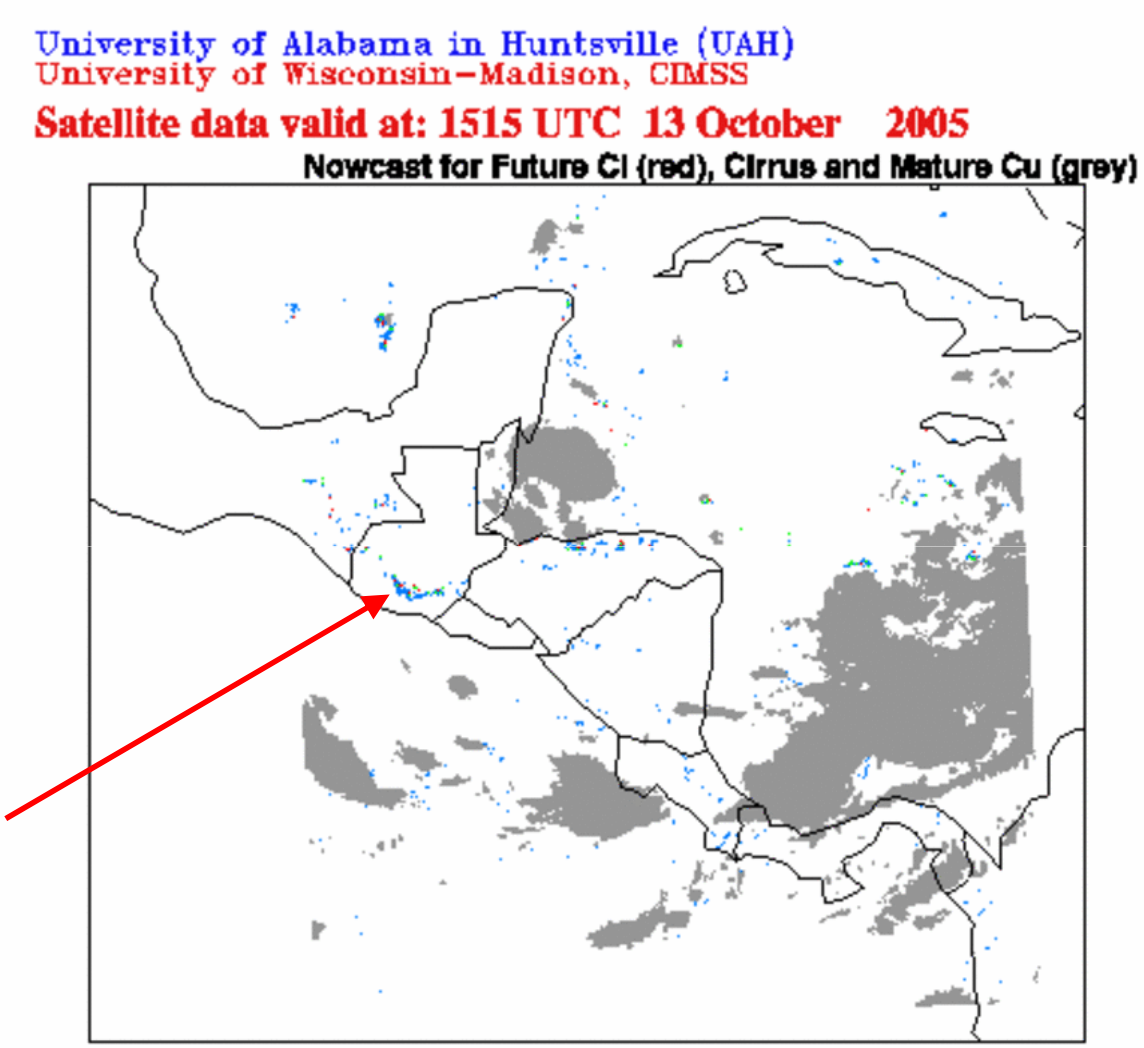
Lightning Initiation Potential







CI Climatology Research



Simply put…

If all the CI locations as obtained from the GOES satellite are integrated, clear signals of how the land surface, weather regime, convective regime/environment influences CI should become apparent.

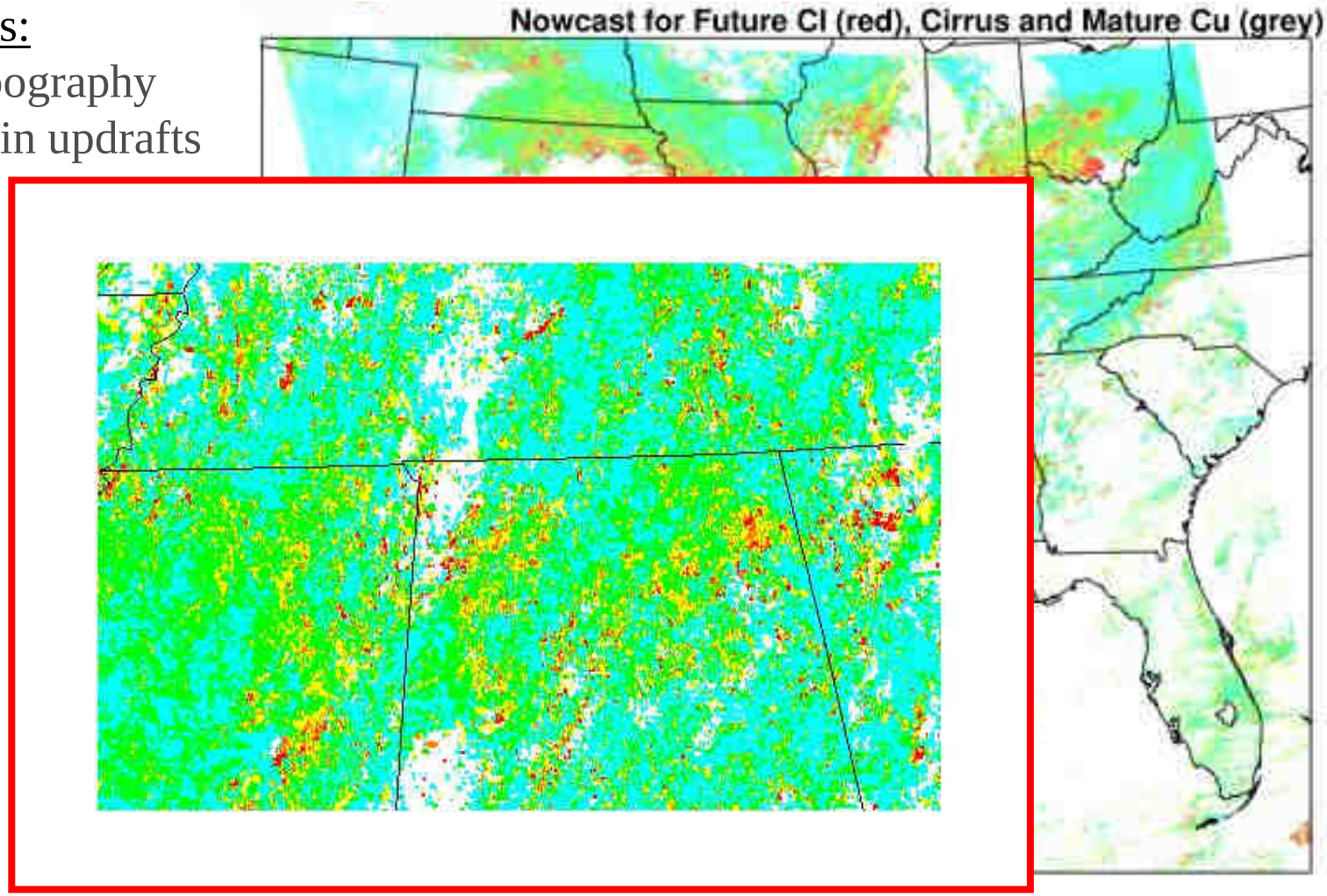
CI Climatology Research

GOES CI Interest Fields: 21 July 2005 (afternoon)

Details:

-topography

-main updrafts



1 km Resolution

…for LI

COPS Support

- Real-time (??) CI nowcasting support (i.e. automated every 15-30 min).
- Pre-COPS development of a convective cloud climatology (K. Bedka at The Univ. of Wisconsin-Madison).
- Software set-up for daily CI nowcasts as driven by field planning decisions.
- Convective cloud identification and tracking in pre-storm environment.
- Joint MSG/SEVIRI–GOES-R/ABI instrument-related research.

Post-COPS Research: UAH & UW-CIMSS

1. Mapping of convective storm initiation, both in a 0-2 h prediction mode, and from a realtime and climatological perspective;
2. Mapping of the frequency of occurrence of CI across COPS domain;
3. Storm path and motion climatologies;
4. Classification of convective storm intensity (in terms of lightning, rainfall potential, or other derived index); Convective initiation index.

Contact Information/Publications

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Web Pages:

nsstc.uah.edu/johnm/ci_home (biscayne.ssec.wisc.edu/~johnm/CI_home/)
http://www.ssec.wisc.edu/asap

Publications:

Mecikalski, J. R. and K. M. Bedka, 2006: Forecasting convective initiation by monitoring the evolution of moving cumulus in daytime GOES imagery. *Mon. Wea. Rev.* (IHOP Special Issue, January 2006), **134**, 49-68.

Bedka, K. M. and J. R. Mecikalski, 2005: Applications of satellite-derived atmospheric motion vectors for estimating mesoscale flows. *J. Appl. Meteor*. **44**, 1761-1772.

Mecikalski, J. R., K. M. Bedka, and S. J. Paech, 2007: A statistical evaluation of GOES cloud-top properties for predicting convective initiation. In preparation. *Mon. Wea. Rev.*

Mecikalski, J. R., S. J. Paech, and K. M. Bedka, 2007: Lightning initiation forecasts within the 2-hour timeframe. In preparation. *Geophys. Res. Letters.*