SATCAST and UW–CTCR Proposals Toward Future Fusion Capabilities in Convective Storm Nowcasting

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NOAA Satellite Science Week Agenda 2012
April 30–May 4, Kansas City, Missouri

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Plan Forward

Two part focus:

1) **Improved nowcast (0-1 hr)**
   - UW Cloud-Top Cooling Rate & UAH-SATCAST Convective Initiation Strength of Signal (probabilistic) nowcasts as input in OU-CIMMS Probabilistic Hazards Information (PHI)

2) **Improved forecast/Data assimilation (0-6 hr)**
   - UAH-SATCAST CI integrated into NOAA/ERSL HRRR (High Resolution Rapid Refresh)

Motivation & Purpose

Development of a fused solution to convective initiation nowcasting and storm intensity estimation

- Fuse multiple relevant data sets
  - NWP model data
  - Satellite observations and algorithm output
    - Today: Current GOES Tomorrow: GOES-R
  - NEXRAD & Dual-polarimetric radar data
  - Lightning/GLM observations
  - Object tracking allows for temporal trends of each dataset

- Integrate with existing models/systems
  - OU – Probabilistic Hazards Information – Co-PI Valliappa Lakshmanan (OU/NSSL)
  - RUC/HRRR – coordination with Stan Benjamin (NOAA/ESRL)

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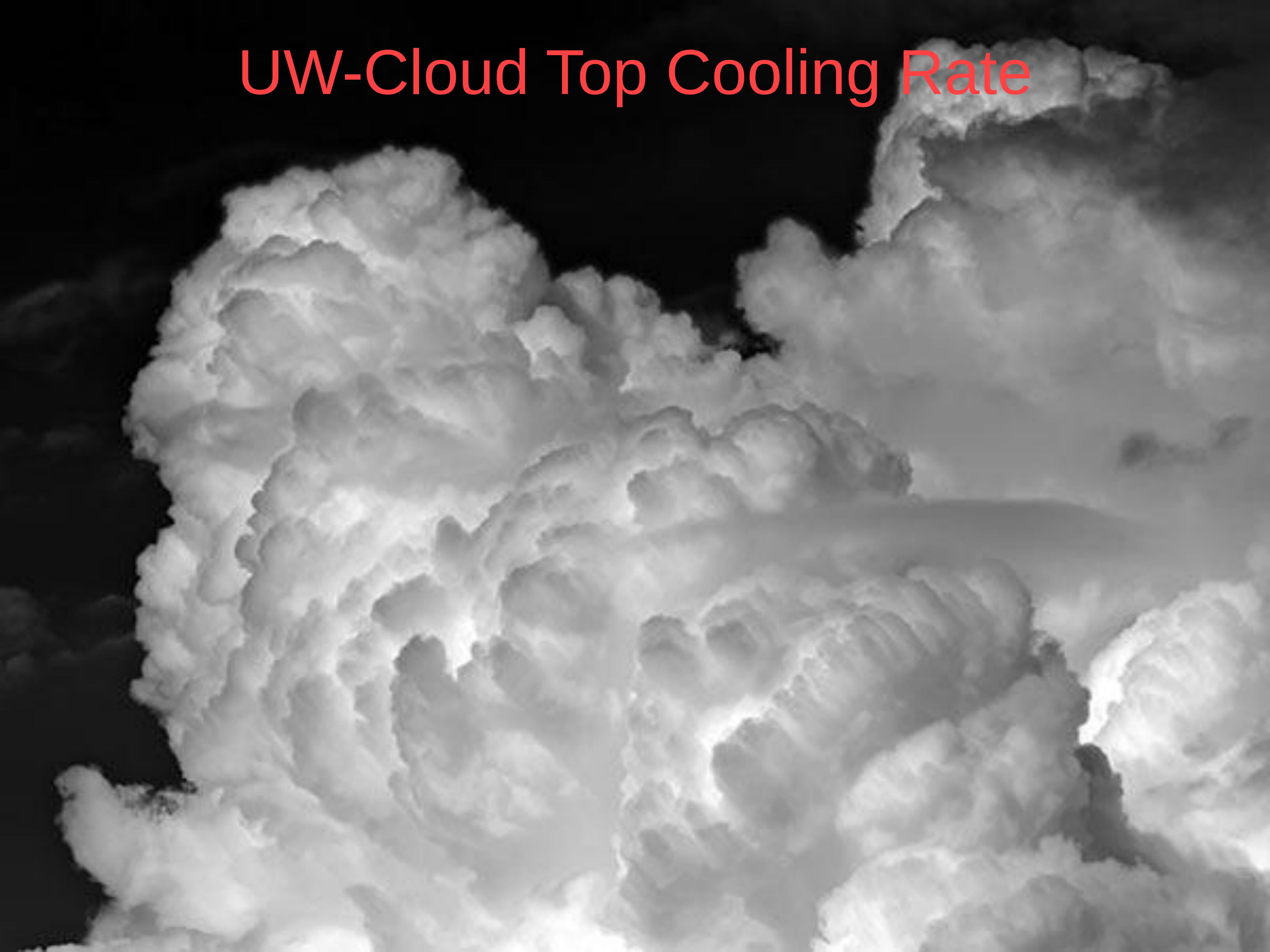
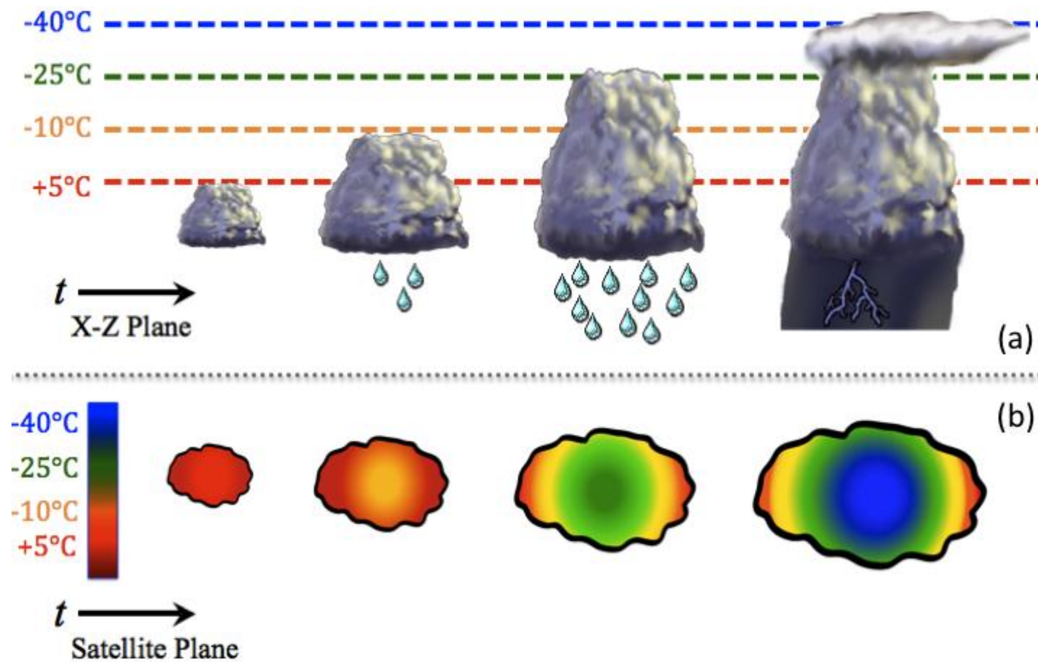
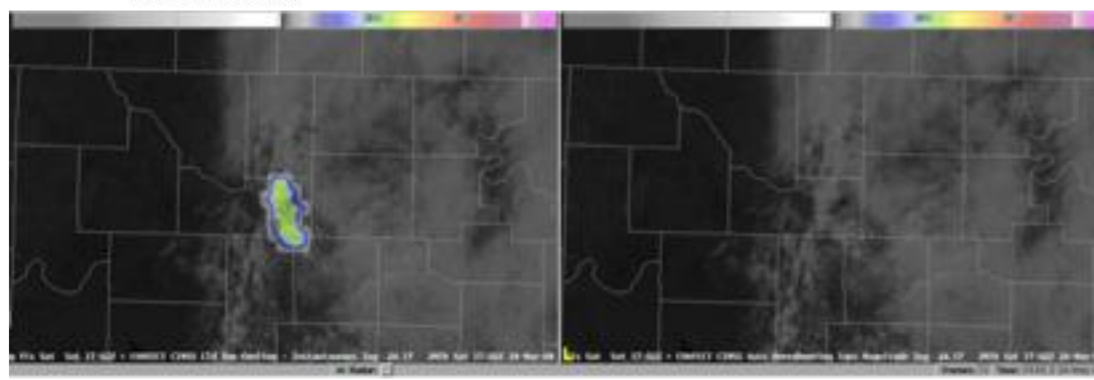
UW-Cloud Top Cooling Rate



UW-Cloud Top Cooling Rate

- Quantitatively diagnose vertical convective cloud growth using cloud-top cooling rate; capture more significant convection
- Relate UW-CTC rate to future NEXRAD observations for the same storms
  - Allows for relationships to be determined between UW-CTC rate magnitudes and NEXRAD observations
  - Show *prognostic value* of satellite-based measure of vertical cloud growth rate





UW-CTC overlaid on GOES-visible imagery in AWIPS

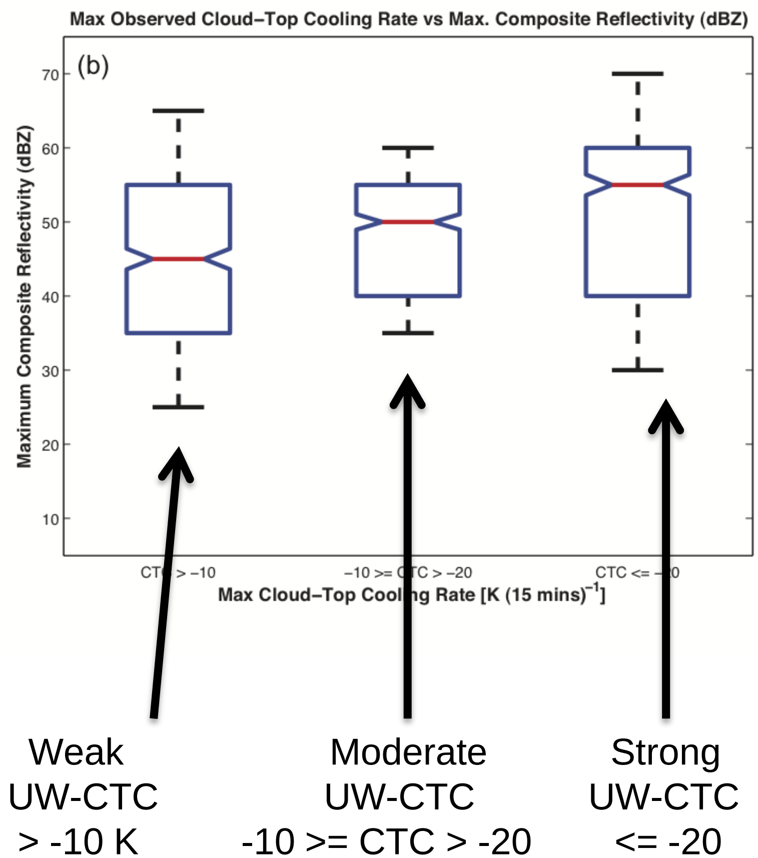
UW-CTC Inputs

- ~11 μm brightness temperatures
- **GOES(-R) Cloud Mask** (utilizes multiple spectral bands)
  - Heidinger, 2010
- **GOES(-R) Cloud Type** (utilizes multiple spectral bands)
  - Pavolonis, 2010
- **GOES(-R) Cloud Optical Depth Retrievals**
  - Walther et al., 2012

UW-CTC utilizes operational GOES (and later GOES-R) products

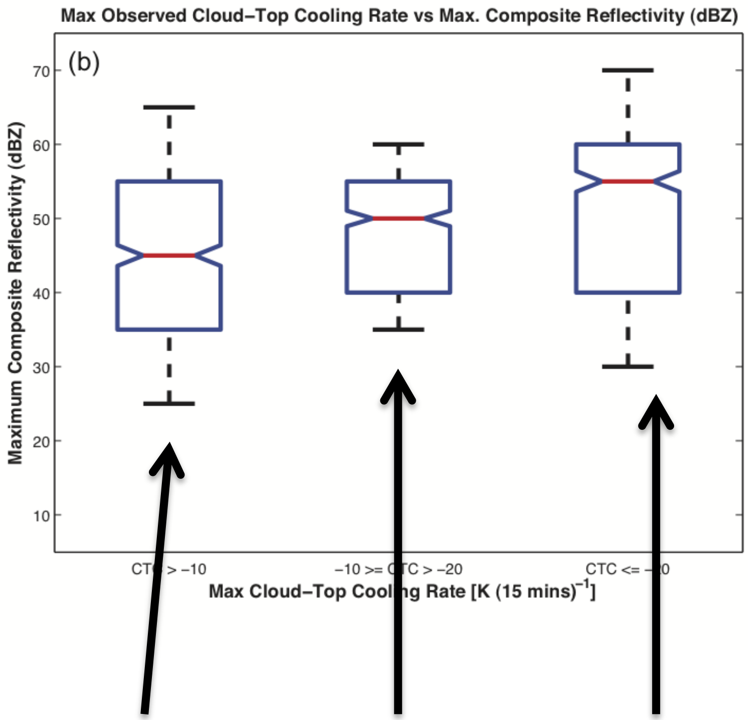
Relating UW-CTC to Max Reflectivity

- Analysis grouped UW-CTC rates into three bins; weak, moderate, and strong for 34 convective events over the Central US
- Red line indicates median value of each UW-CTC bin, blue box represents 25th and 75th percentiles of the data, and whiskers correspond to 1σ values of each bin
- Lack of overlap of notches in the blue boxes between each UW-CTC bin indicates the medians are statistically different to the 95% confidence level



Relating UW-CTC to Max Reflectivity

- Stronger UW-CTC rates correlates to higher composite reflectivity when compared to weaker UW-CTC rates
  - Weak UW-CTC Median Composite : 45 dBZ
  - Mod. UW-CTC Median Composite : 50 dBZ
  - Strong UW-CTC Median Composite : 55 dBZ
- Strongest UW-CTC rates have strongest 1σ composite reflectivity (70 dBZ)
- False alarm rate decreases with stronger UW-CTC rates (not shown)



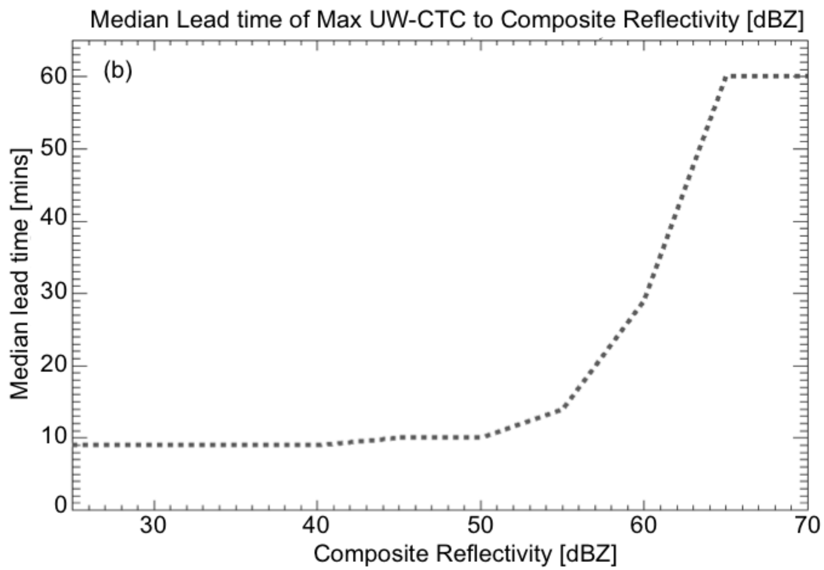
Weak UW-CTC > -10 K

Moderate UW-CTC -10 >= CTC > -20

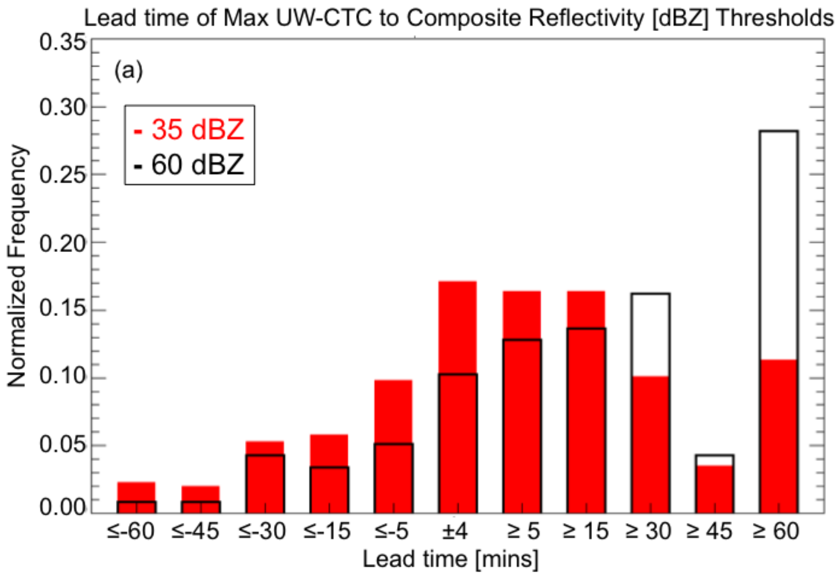
Strong UW-CTC <= -20

Lead Time UW-CTC to Max Reflectivity

- Median lead-time of maximum UW-CTC rate versus composite reflectivity thresholds
  - ~10 min median lead-time for 30 → 50 dBZ; then rapid increase of lead-time
    - 55 dBZ: ~15 min
    - 60 dBZ: ~25 min
    - 65+ dBZ: 60+ min



- Distribution of 35 and 60 dBZ shows the spread (negative lead-times are largely due to larger temporal gaps of satellite data compared to NEXRAD; e.g.-satellite scans at 1902 and 1915 UTC, NEXRAD might observe at 1900, 1905, 1910, 1915 UTC)

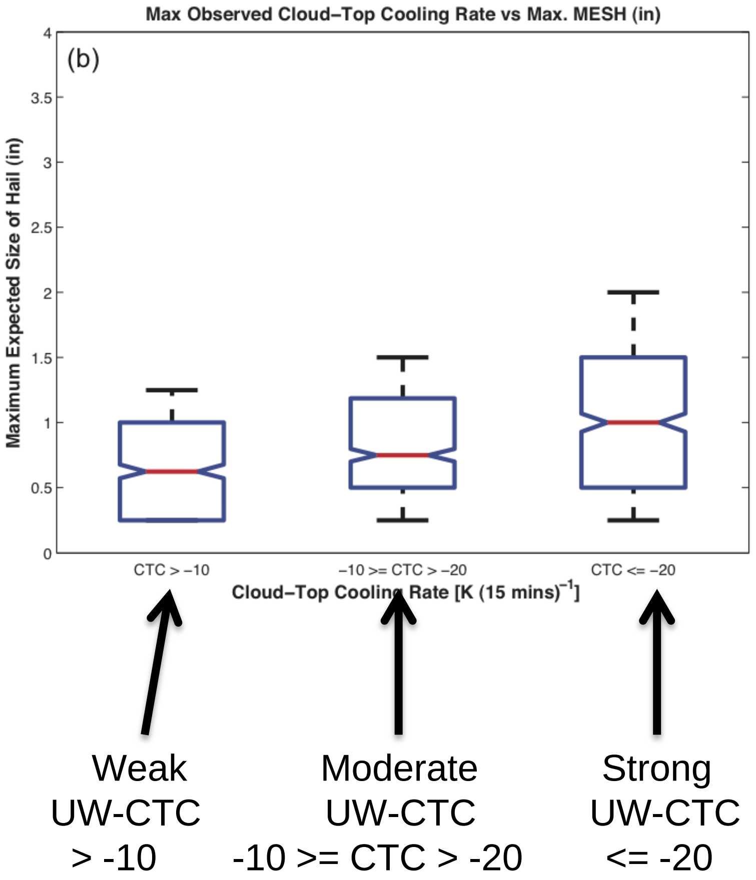


Relating UW-CTC to Max Hail Size

- Stronger UW-CTC rates correlates to higher MESH (maximum expected hail size) when compared to weaker UW-CTC rates
  - Weak UW-CTC Median MESH : 0.63”
  - Mod. UW-CTC Median MESH : 0.75”
  - Strong UW-CTC Median MESH : 1.00”

- Strongest UW-CTC rates have largest 1σ MESH (2.00”) (weak 1.25” and moderate 1.5”)

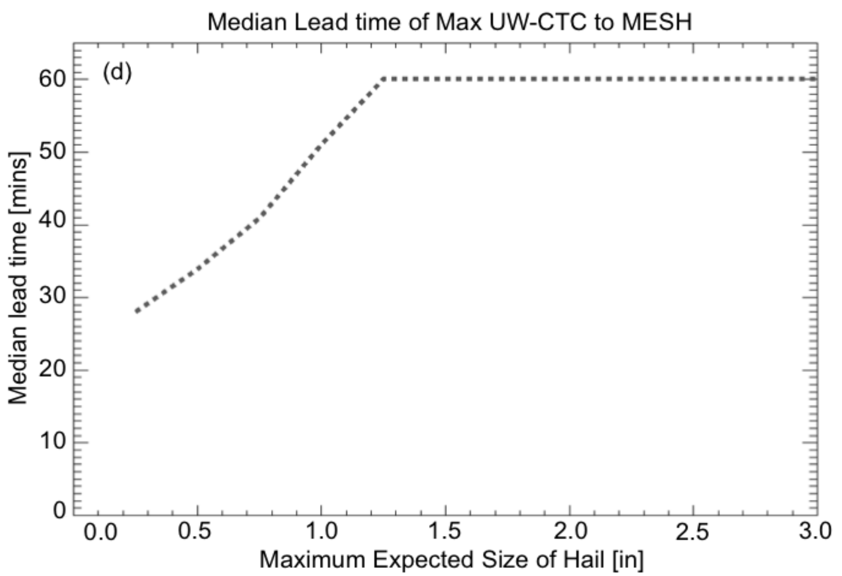
- POD of storms with severe hail MESH (1.00”) is 0.71 (0.72 for 2.00” MESH)

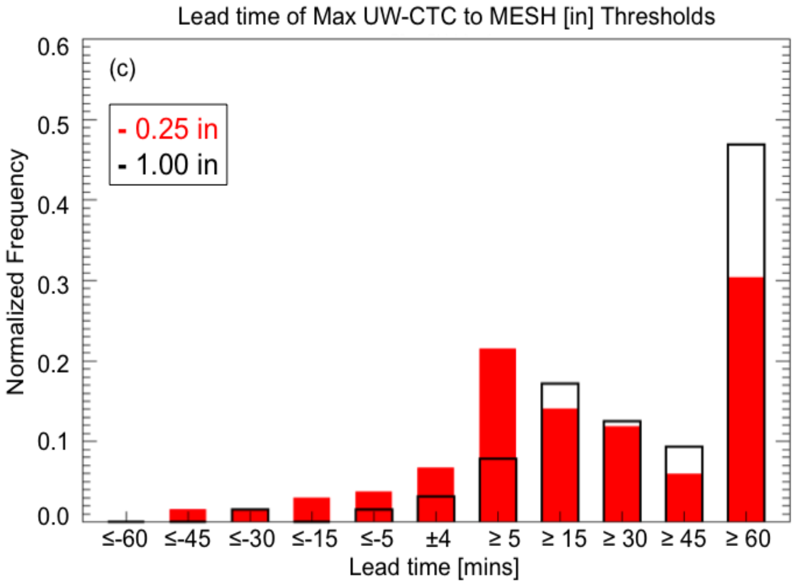


Lead Time: UW-CTC to Max Hail Size

- Median lead-time of maximum UW-CTC rate to various MESH thresholds :
  - ~28 min to 0.25” MESH
  - ~33 min to 0.5” MESH
  - ~45 min to 1.0” MESH
  - ~60+ min to 1.25+” MESH

- Distribution lead-times for 0.25” and 1.00” MESH show significant increase of lead-time due for severe hail versus small hail. The lead-time is attributed to the time necessary for organization of convective updrafts to produce severe hail

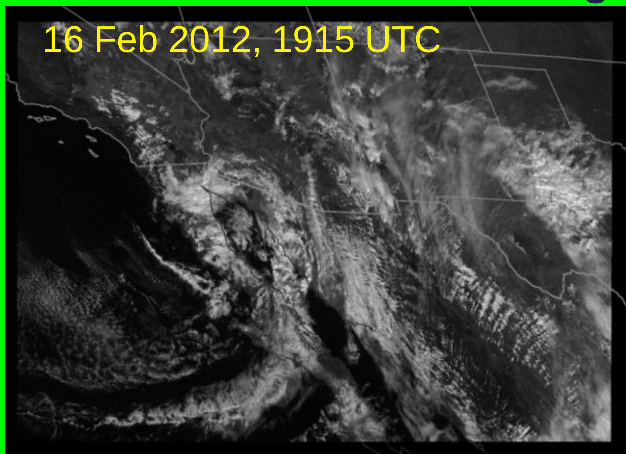




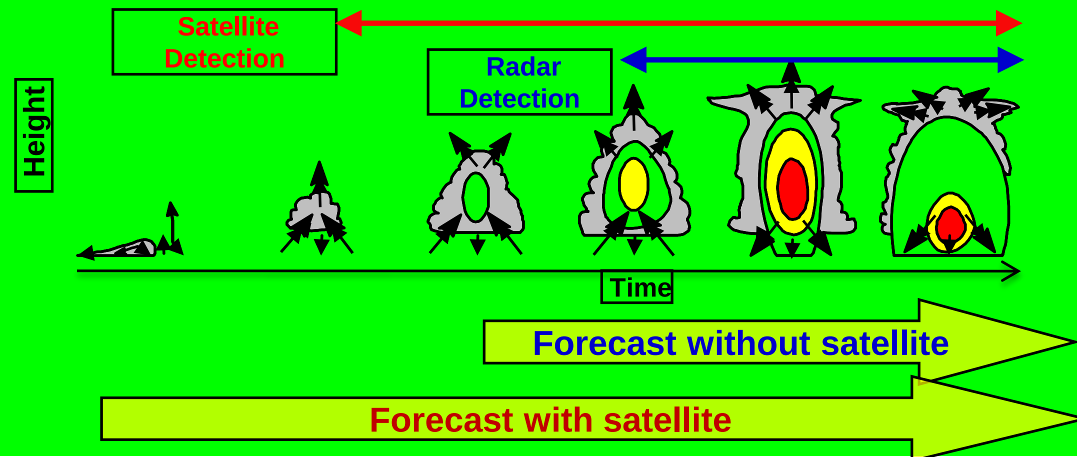
UAH-SATCAST 0-1 hr Convective Initiation

SATCAST-Convective Initiation Flowchart

Download latest satellite imagery…



Monitor Cumulus Cloud Development



Make Cloud Mask

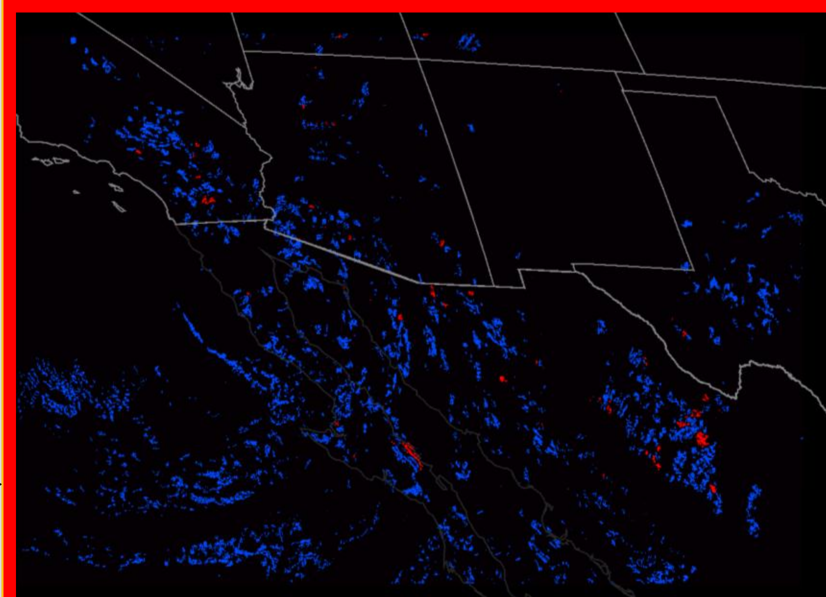
Produce MAMVs

Track "Cloud Objects" from 'T1' to 'T2' (Similar to "Cb-TRAM" Zinner et al. 2008)

Determine CI forecast for each tracked Cloud Object using 6 spectral/temporal differencing tests (aka: "Interest Fields")

Per-Object CI forecast

16 Feb 2012, 1945 UTC

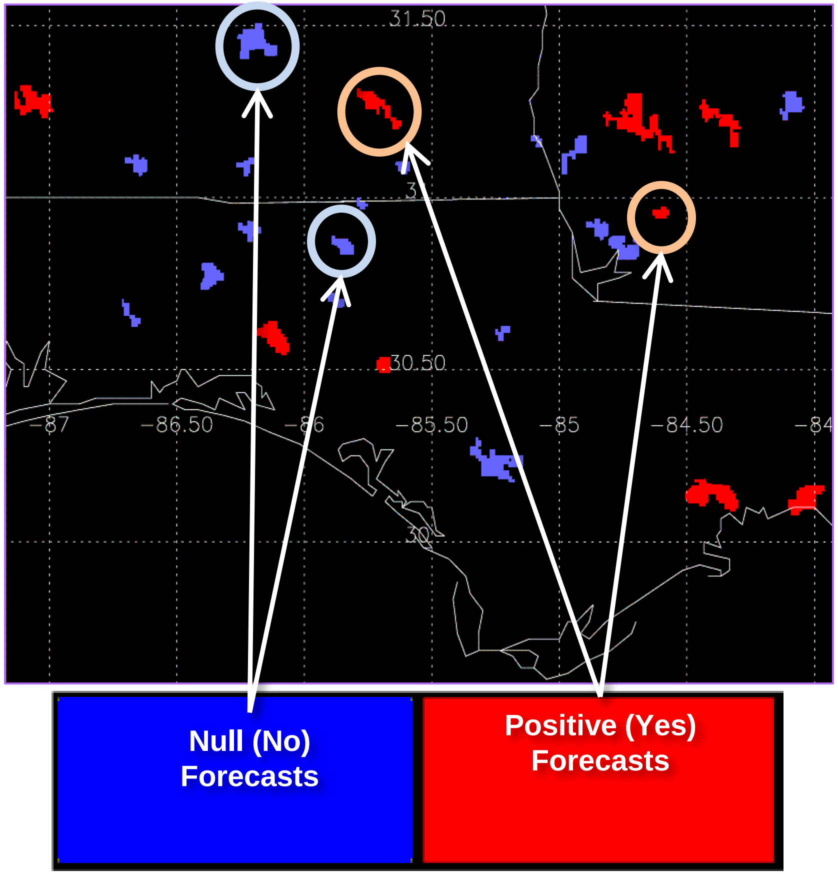


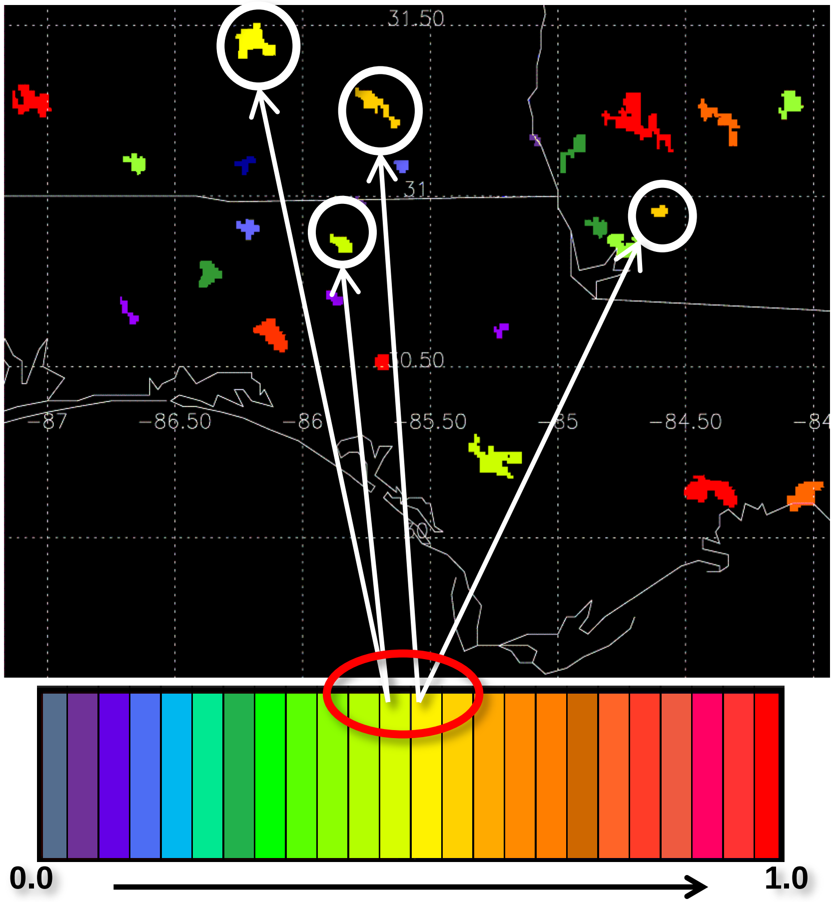
CI Definition: 1st ≥35 dBZ echo at ground, or at –10 ºC altitude

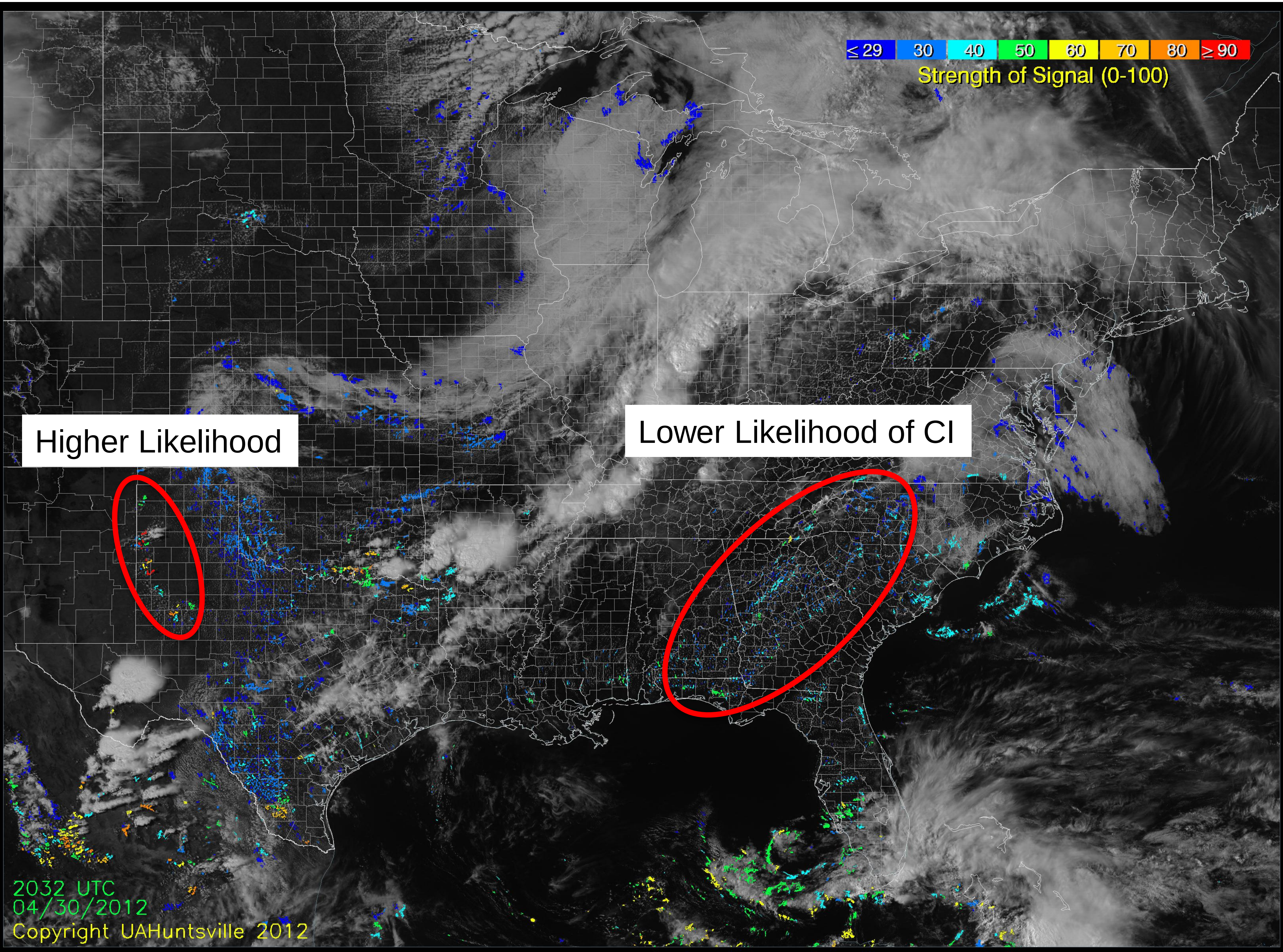
Data Fusion: Current Indicators being sampled in SATCAST-CI

- **SATCAST:**
  - 10.7 µm TB
  - 15 min 10.7 µm Trends
  - 6.7–10.7 µm TB difference & 15-min trend
  - 13.3–10.7 µm TB difference & 15-min trend
- **Environmental (NWP)**
  - Surface and most unstable convective available potential energy (CAPE)

Logistical Regression: Strength of Signal







≤ 29
30
40
50
60
70
80
≥ 90
Strength of Signal (0-100)
Higher Likelihood
Lower Likelihood of CI
2032 UTC
04/30/2012
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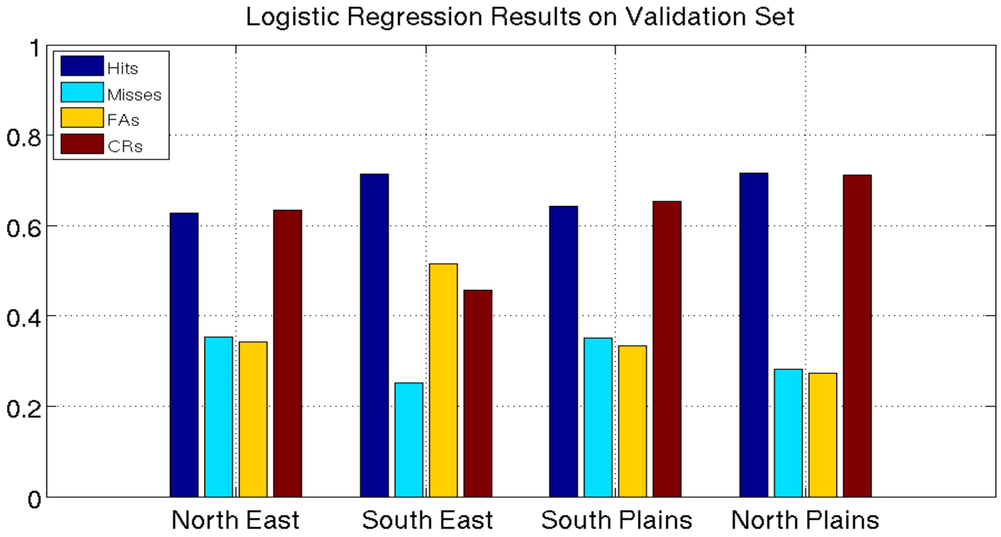
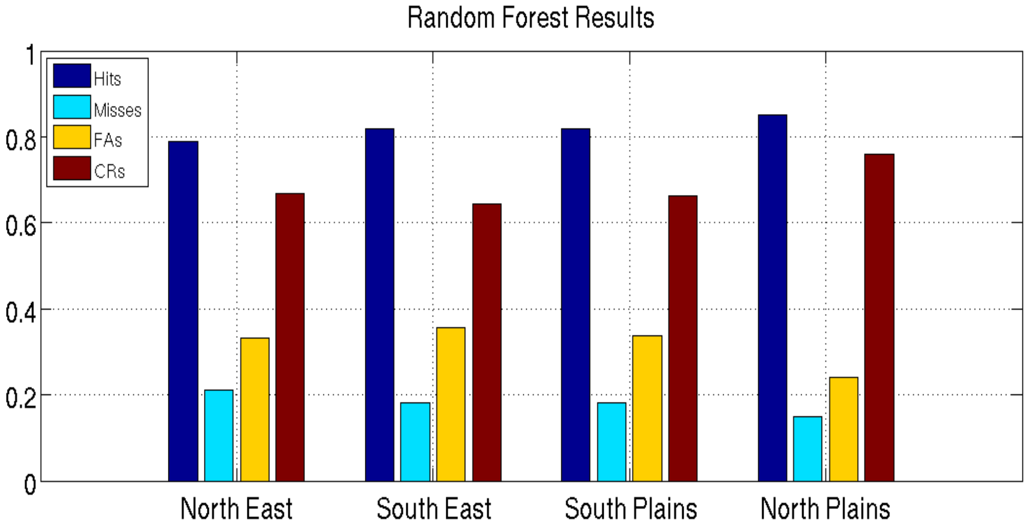
Alternative Approaches – SATCAST CI False Alarm Reduction



Logistic Regression Method

- Produced PODs of 63-73%
- False Alarms at 40-50%
- Results have no strong regional bias



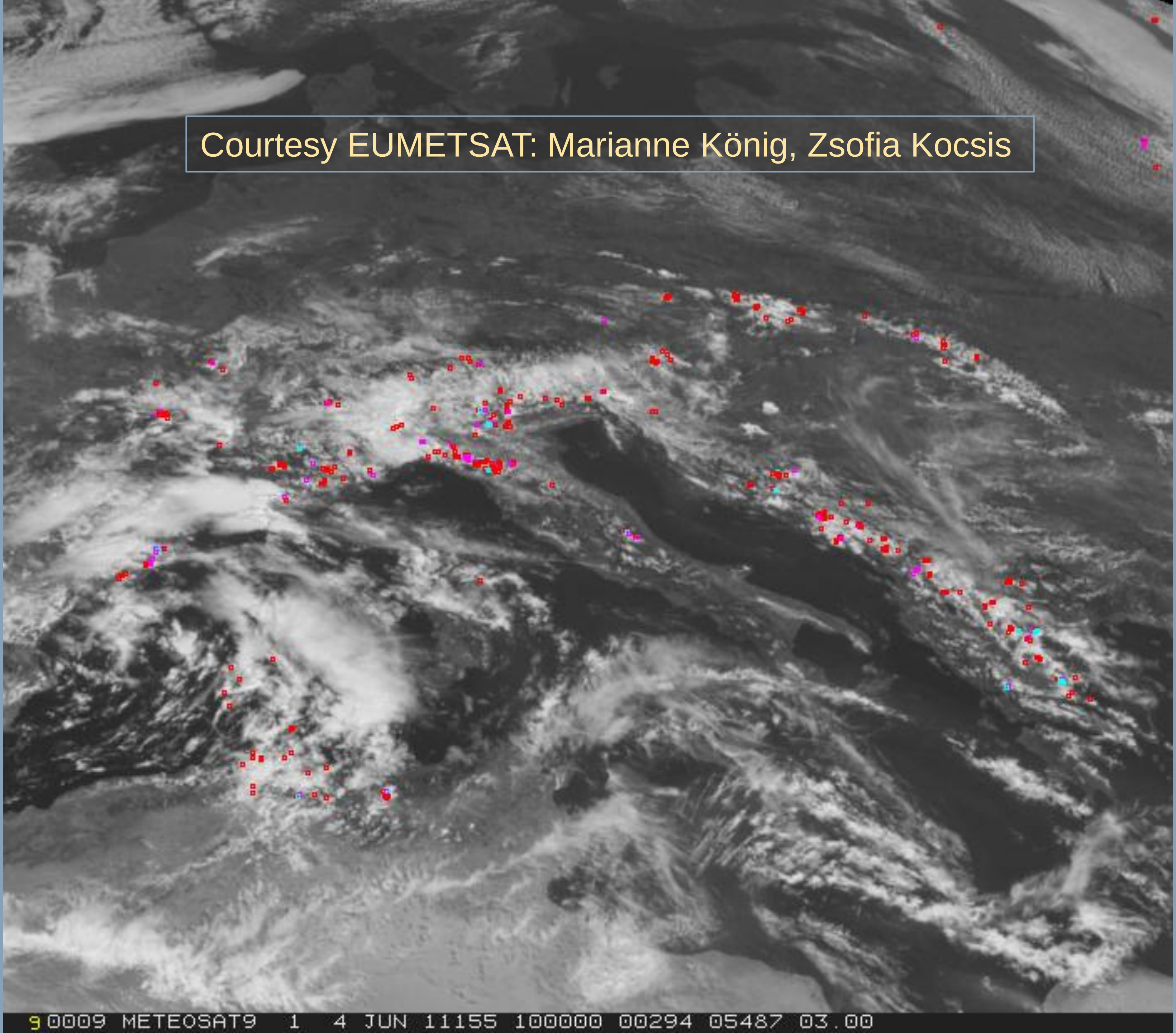
Probabilistic Method

- Increased POD to **≥80%**
- False Alarms reduced to **25-35%**
- Results have no regional bias

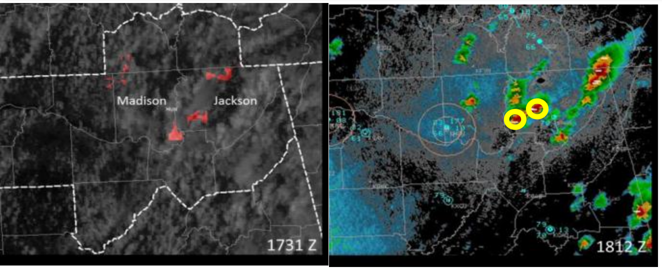
Indicators being sampled in SATCAST-CI for 2012

- SATCAST:
  - 10.7 µm TB
  - 15 min 10.7 µm Trends
  - 6.7–10.7 µm TB difference & 15-min trend
  - 13.3–10.7 µm TB difference & 15-min trend
  - Convective cloud mask at t1 and t2
  - Convective cloud mask change (i.e., cumulus to towering cumulus, cumulus staying cumulus, etc.)
  - Object size at t1 and t2
  - Change in object size for t1 and t2
  - Geographical locations (latitude/longitude)
  - Solar time

- Environmental (NWP)
  - Surface and most unstable convective available potential energy (CAPE)
  - Surface and most stable convective inhibition (CIN)
  - Surface and best lifted index (LI)
  - Lifted Condensation Level (LCL)
  - Level of Free Convection (LFC)
  - Convective Condensation Level (CCL)
  - Bulk Wind Shear and Low Level Wind Shear
  - Height of Freezing Level

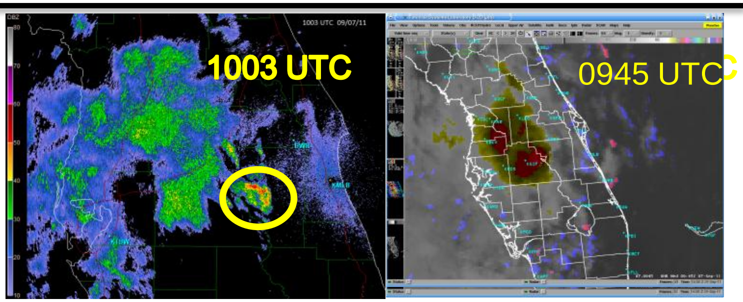

Courtesy EUMETSAT: Marianne König, Zsofia Kocsis
9 0009 METEOSAT9 1 4 JUN 11155 100000 00294 05487 03.00

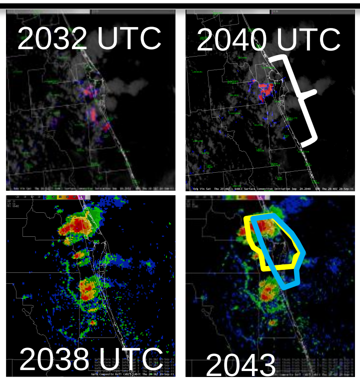
UAH SATCAST-CI Product in Operational Use



- WFO-HUN on 22 September 2011
- Used for threat of CI, lightning, and impacts to aviation and outdoor activities in Madison and Jackson Counties
- Courtesy Christina Crowe and Kris White, NWS-HUN

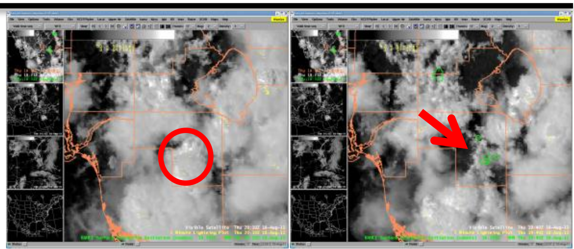
- WFO-MLB on 07 September 2011
- Nocturnal thunderstorm event in rapid scan mode: would CI occur ahead of a system moving toward Orlando metro and impact Brevard County?
- Courtesy Jonathan Guseman and David Sharp, NWS-MLB

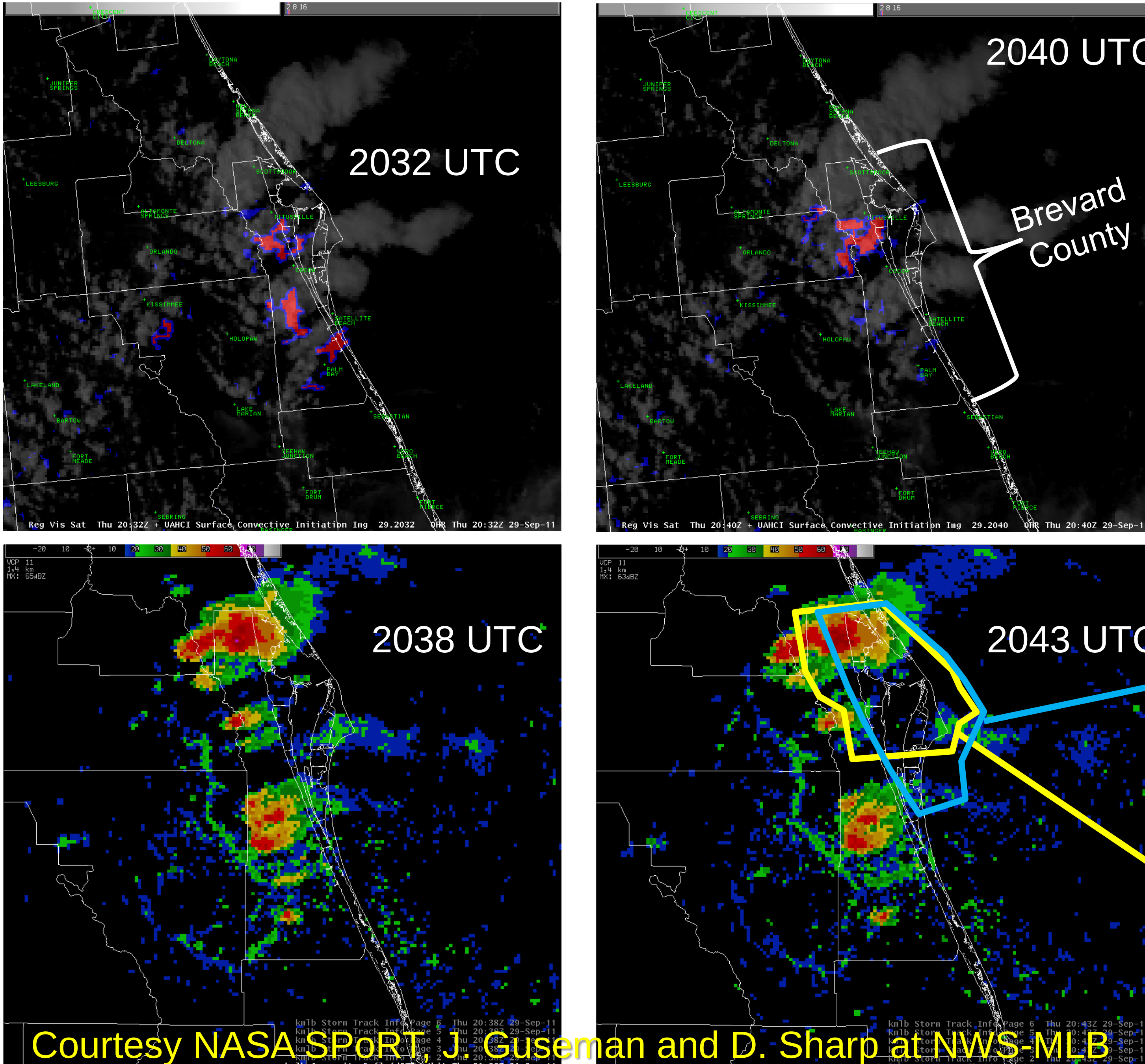




- WFO-MLB on 29 September 2011
- From MLB/SPoRT training module for warning decision-making with experimental products: “You Make the Call”
- Used to determine if all or part of Brevard County needed to be under Severe Thunderstorm and Marine Warnings
- Courtesy NASA SPoRT; J. Guseman, and D. Sharp, NWS-MLB

- WFO-MIA on 18 August 2011
- Evaluating CI and 5-min lightning coincidence
- Courtesy Jeral Estupinan, NWS-MIA





<u>Forecaster Question</u>: *How large should the warning polygon be?*

Less projected CI at 2040 UTC in S. Brevard helps forecasters decide.

Special Marine Warning
(34+ knot gusts)

Severe Thunderstorm Warning
(50+ knot gusts & 1.0 inch hail)

Proposal

- Combine UAH-SATCAST/UW-CTC Rate (and relationships with NEXRAD) into *OU-Probabilistic Hazards Information* (PHI) for improving 0-1 hr Nowcasts
- OU-Probabilistic Hazards Information System will fuse a variety of meteorological data to produce Probabilistic Nowcasts for hail, tornado, and lightning

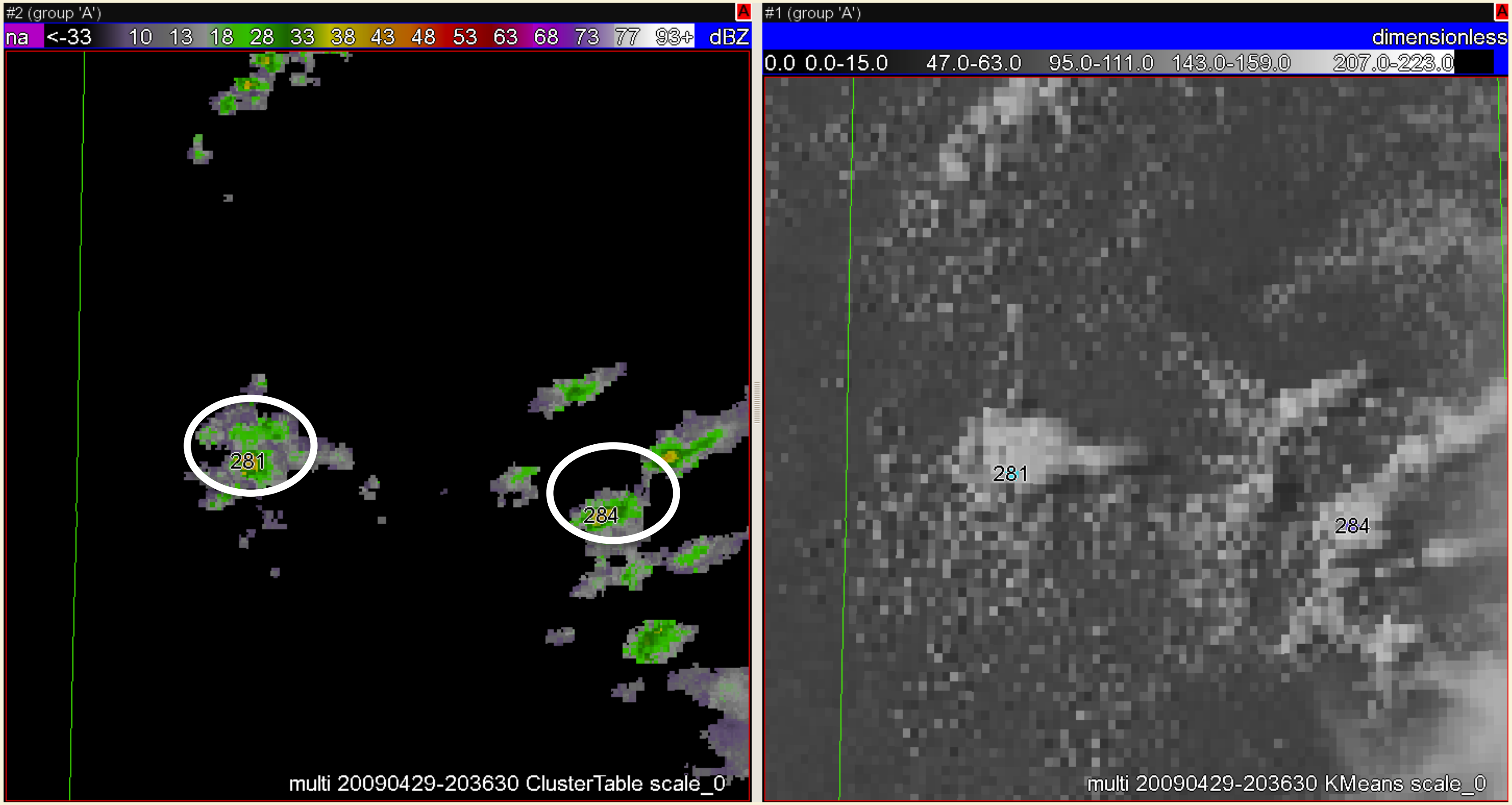
OU-Probabilistic Hazards Information Goals

Provide probabilities of hail, tornadoes and lightning, etc. from pre-initiation through decay

Multi-sensor data fusion:

- Satellite cloud-top cooling objects (UW-CTC; UAH-SATCAST)
- Radar echoes (NEXRAD: including dual-pol variables)
- Data assimilation into WRF for vorticity, etc.
- Nowcast of trends from NWP + statistics
    - Statistics being created from long-term analysis of radar archives (“MYRRORS” project at NSSL)
    - Also from relationship between satellite pre-CI objects and MESH, etc. (UW-CTC)

Integrating Satellite Observations into the OU-PHI System



Example: OU-PHI (WDSS-II based) application of radar reflectivity features. In this case, strong radar reflectivity features are first identified at 2036 UTC – **30-60 minutes after the initial identification of the storm objects in the satellite data.** Note the continuity of object ids between radar and satellite – this indicates temporal trends of satellite gets carried over to radar-based signals.

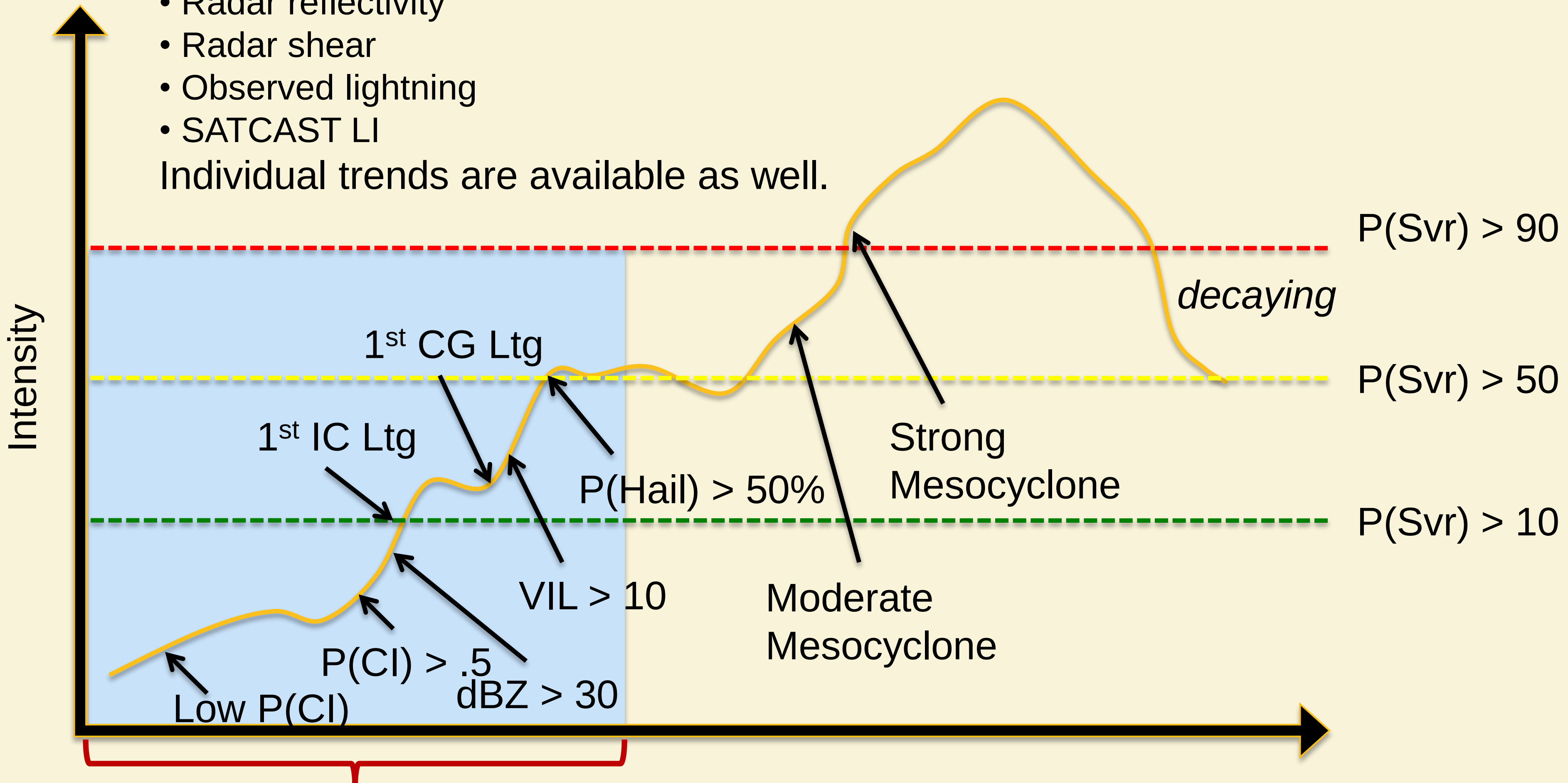
OU-PHI Composite Severity Trend

Synthetic parameter based on (e.g.):

- Sat CI / Cooling
- Sat IR temp
- Radar reflectivity
- Radar shear
- Observed lightning
- SATCAST LI

Individual trends are available as well.

Multi-sensor-based trend of storm severity.



Improved nowcast by including satellite growth (UW-CTC rates; UAH-SATCAST nowcasts)

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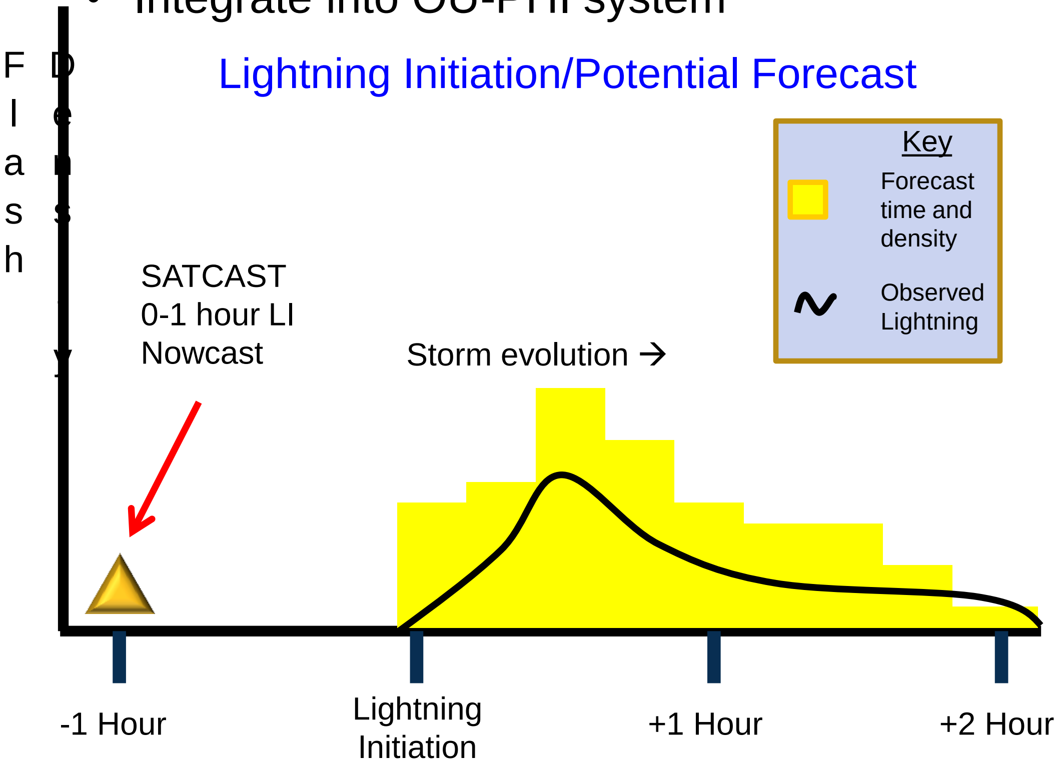
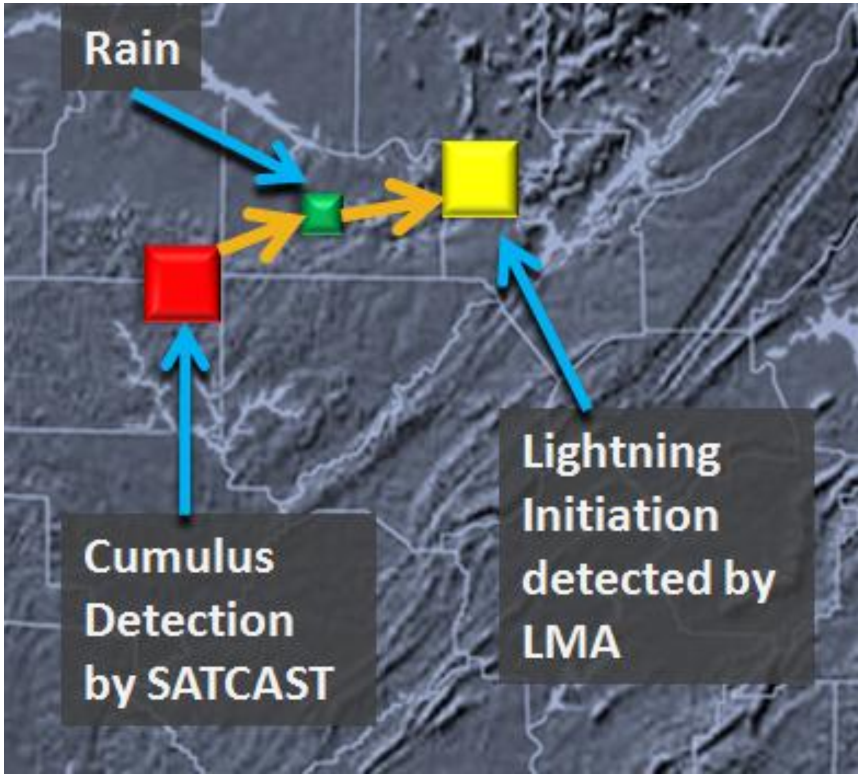
   - UAH-SATCAST CI integrated into NOAA/ERSL HRRR (High Resolution Rapid Refresh)

RUC/HRRR SATCAST Field Assimilation

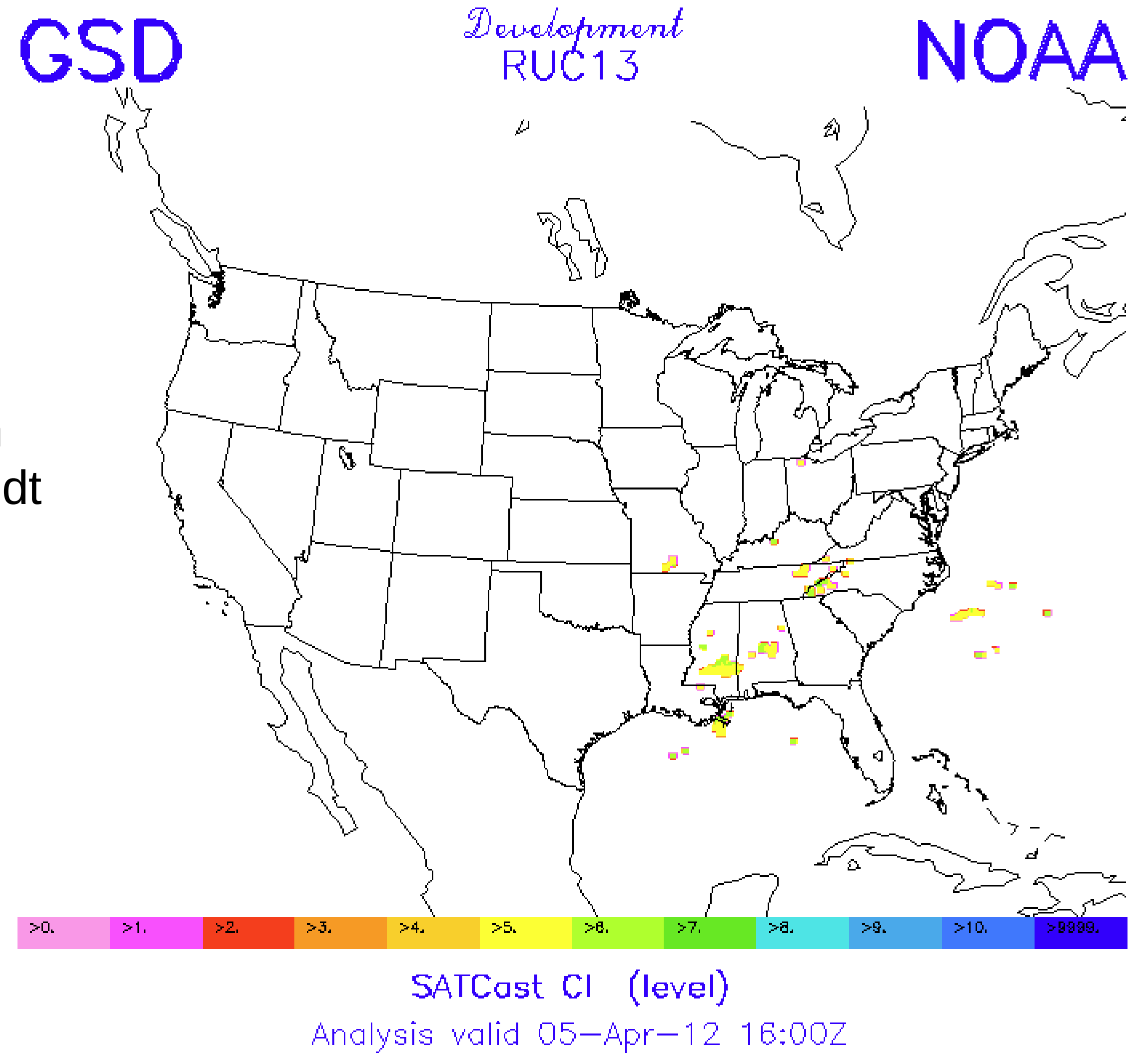
WRF/SATCAST Lightning Initiation & Threat Forecast

- Created an algorithm that links 0-1 hour lightning initiation to forecast of a short-term lightning threat (density), or potential amounts per storm.
- Explore distance-weighted method to account for expected differences in lightning/storm initiation location and WRF-based lightning threat forecasted storms.
- Validate using LMA for truth flash density.
- Refine GOES lightning initiation method.
- Preparing for GLM
- Integrate into OU-PHI system



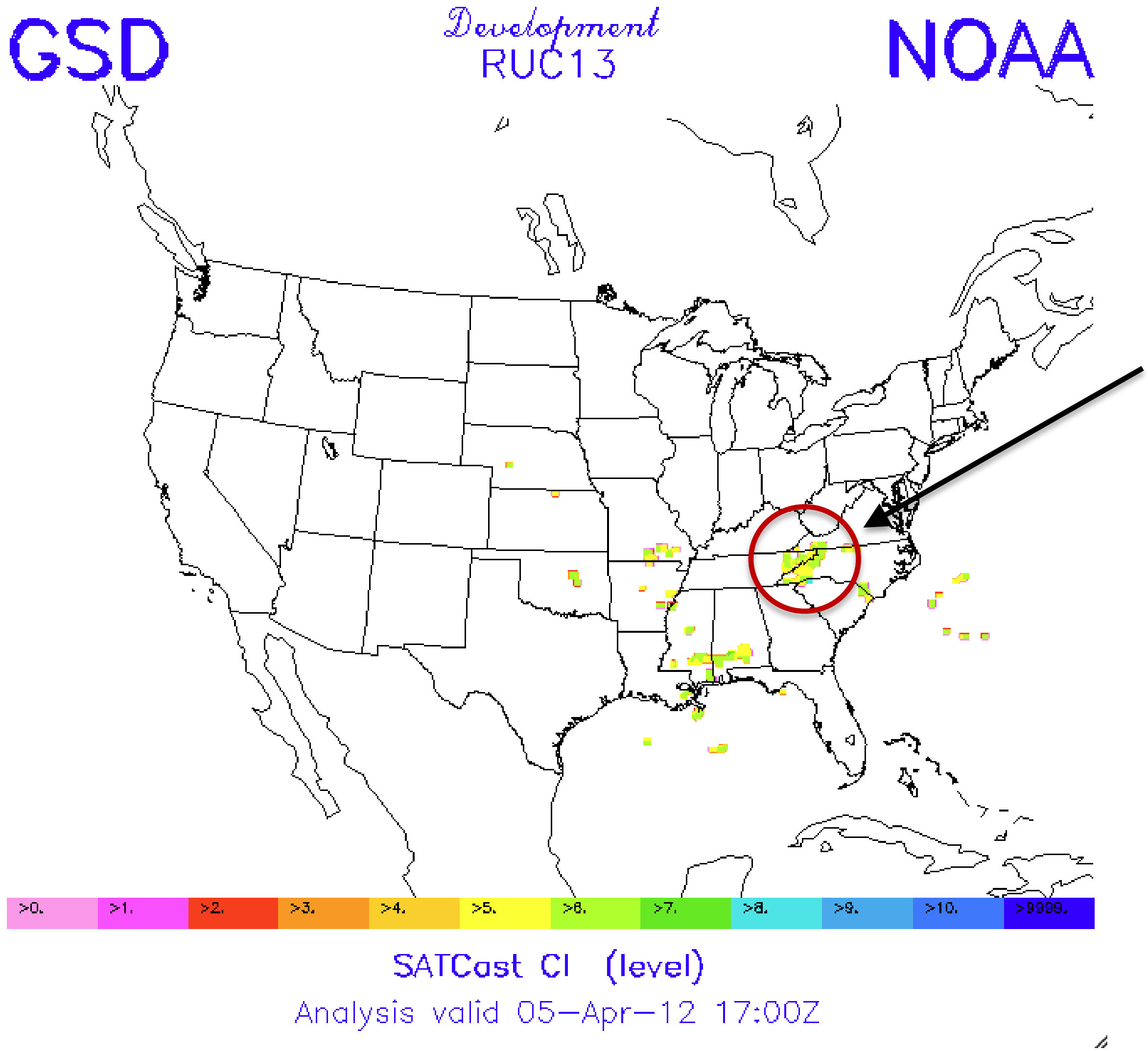


SATCAST data on RUC grid for 1600 UTC 5 April 2012



Courtesy:
Tracy Smith
Stan Benjamin
Steve Weygandt

SATCAST data on RUC grid for 1700 UTC 5 April 2012

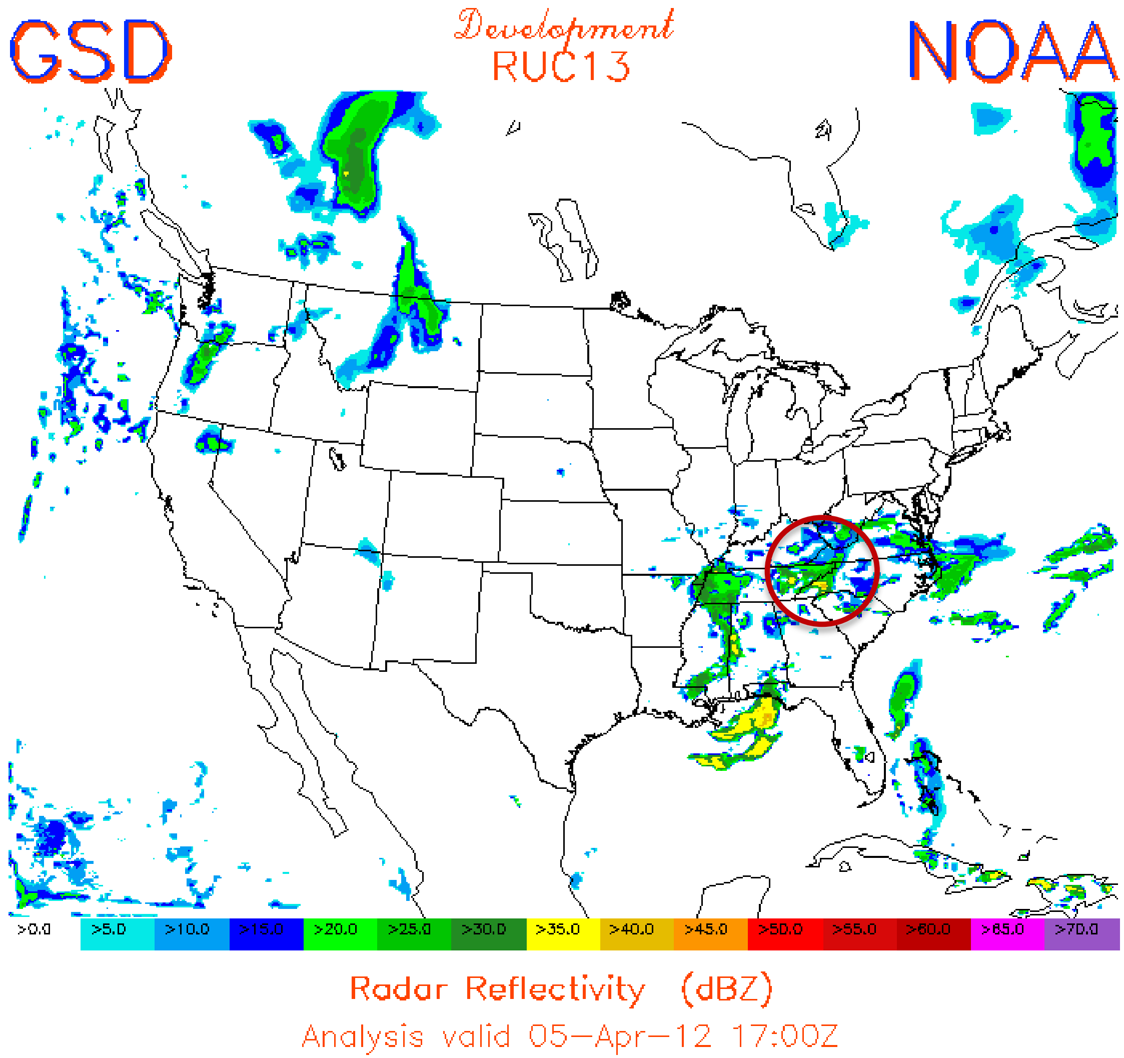


SATCAST data assimilation led to higher reflectivities in RUC:

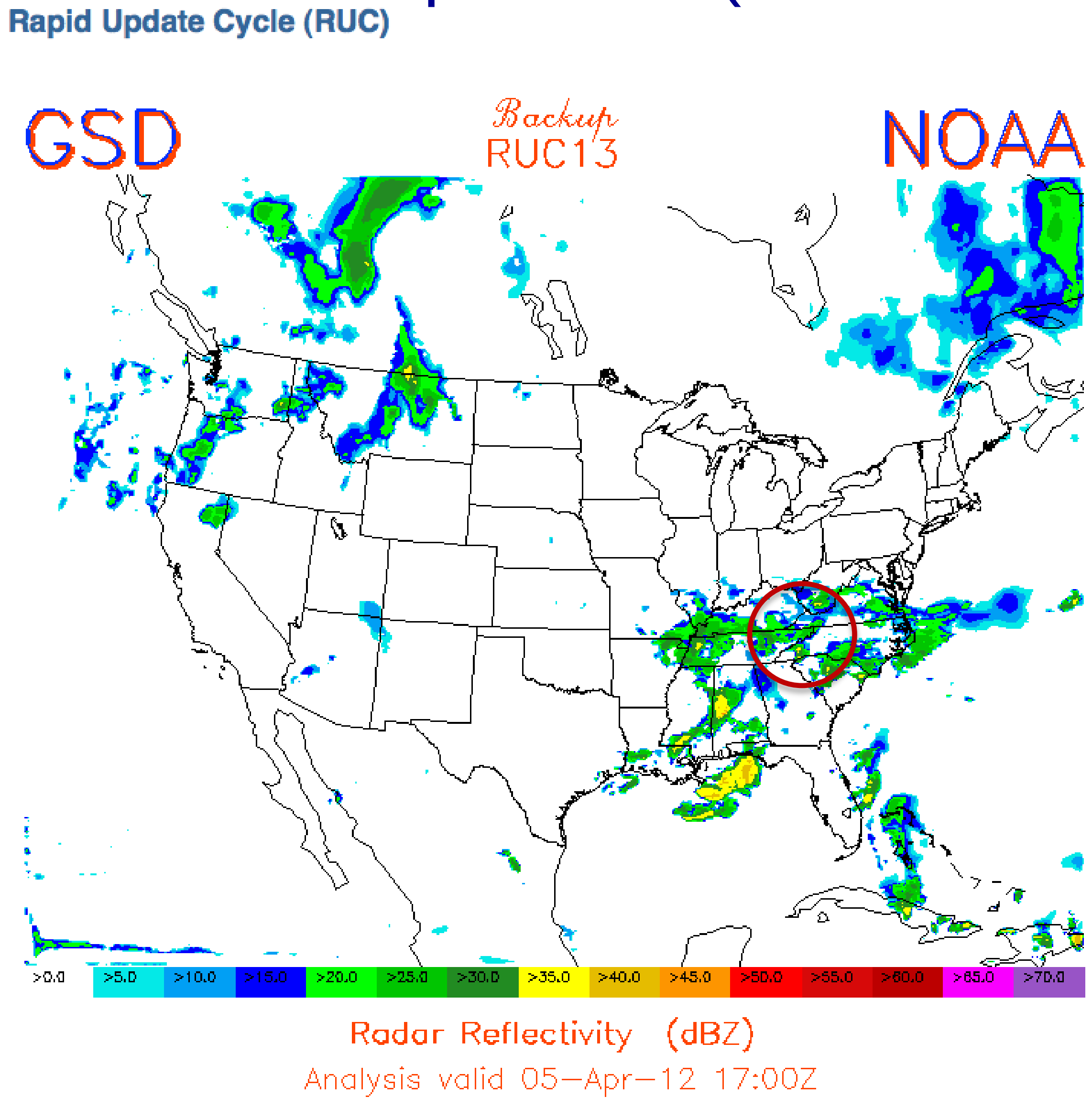
Positive impact on the forecast

Developmental RUC reflectivity field for 1700 UTC 5 April 2012 (+SATCAST)

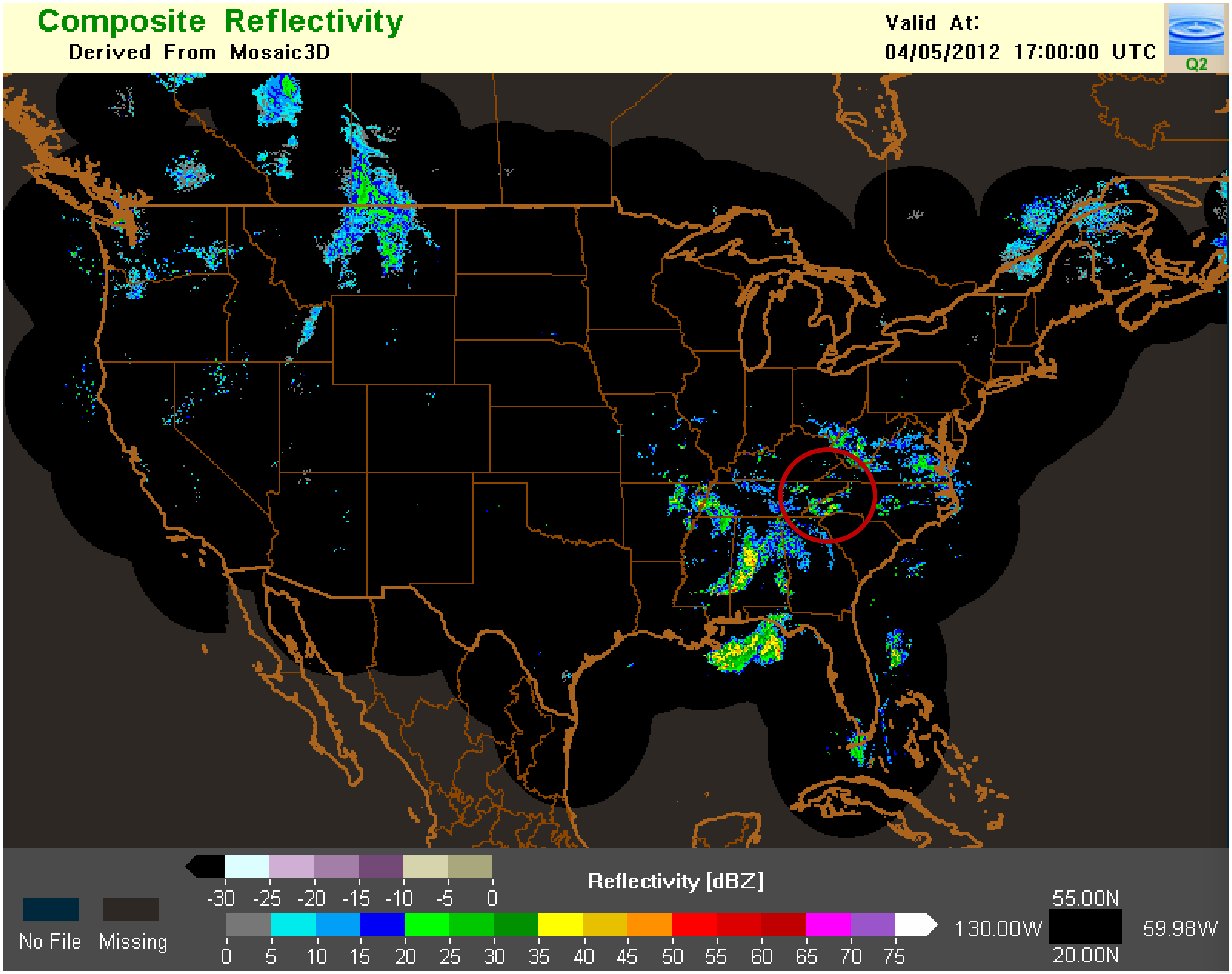
Rapid Update Cycle (RUC)



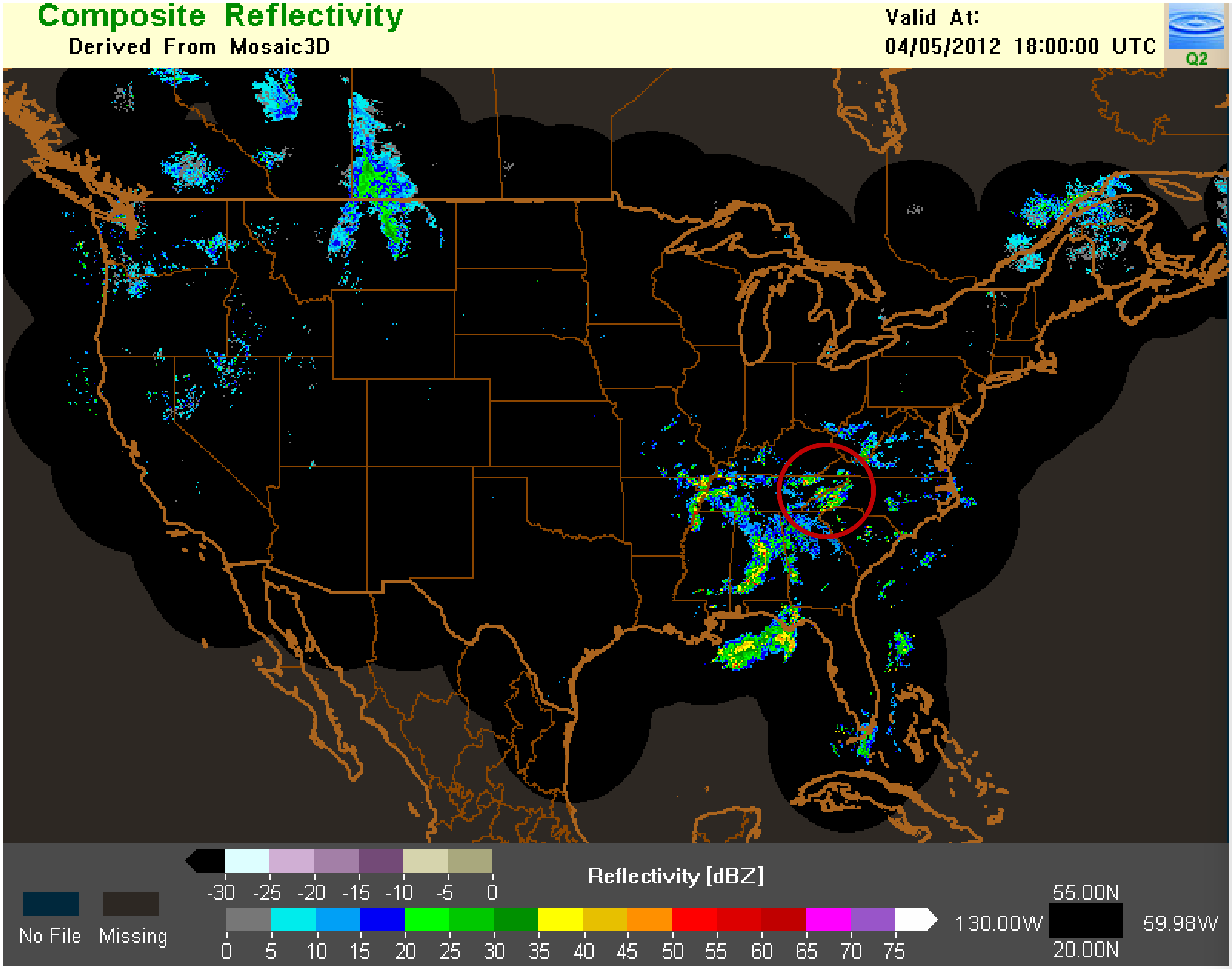
Backup RUC reflectivity field for 1700 UTC 5 April 2012 (no SATCAST)



Q2 radar reflectivity for 1700 UTC 5 April 2012



Q2 radar reflectivity for 1800 UTC 5 April 2012



Conclusions

Fuse satellite-based convective initiation and growth algorithms to:

- Improve storm nowcasts (0-1 hr)
  - Integrate UW-CTCR/UAH-SATCAST cooling intensity into OU-Probabilistic Hazards Information
  - OU-PHI already fuses radar, NWP, and lightning data to make probabilistic nowcasts of hail, tornadoes, and lightning from pre-initiation through decay
  - Leverage on UW-CTC rate vs NEXRAD (reflectivity, hail size, etc.) study and UAH-SATCAST probabilistic forecasting techniques

- Improve storm forecasts (0-6 hr)
  - Integrate SATCAST CI into RUC/HRRR model
  - Assimilating SATCAST CI into the RUC to improve the forecast of radar reflectivity compared to the control RUC radar reflectivity

Satellite-based ingredients are an essential piece in the data fusion solution of the convective nowcast/forecasting problem:

- UAH-SATCAST-CI and UW-CTC rates are being used in NWS operations
- Both satellite-based methodologies have been improved based on forecaster feedback
  - Adding the capability to operate in areas of non-opaque cirrus clouds
  - Increased lead times for both convective initiation and

Related Posters

Wednesday #23 Sieglaff, Cronce, Feltz, Hartung – *An Inter-Comparison of UWCI-CTC Algorithm Cloud-Top Cooling Rates with WSR-88D Radar Data*

Thursday #9 Mecikalski, Walker, Jewett, Schultz – *Future Capability for Monitoring and Nowcasting Convective Initiation within the GOES-R Era using a Data Fused Approach*