Monitoring And Prediction Of Hazardous Convective Cloud Object Properties

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With Contributions From
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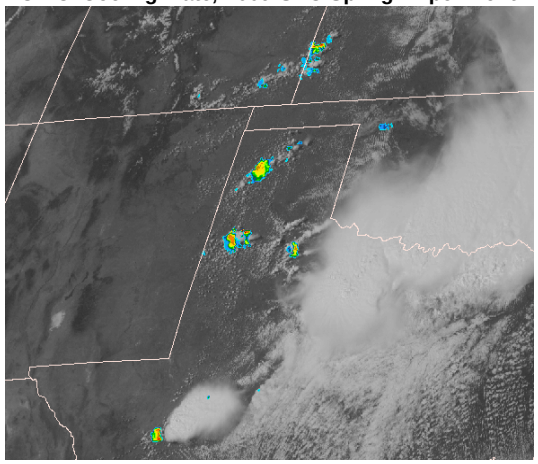
Pixel-Based vs. Cloud Object Tracking

UWCI Cooling Rate, 2009 SPC Spring Experiment

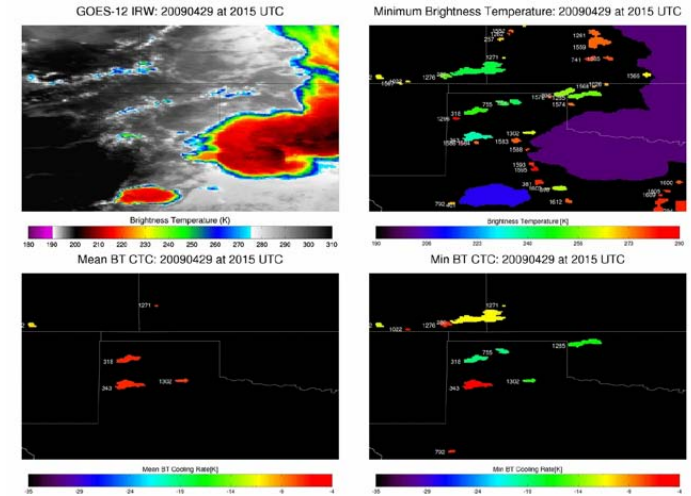


- **Current convective initiation (CI) nowcast methods attempt to monitor cloud top time trends at the pixel scale**
  - Proper handling of cloud movement between images and product validation are significant challenges for these pixel-based frameworks (UWCI and SATCAST)
  - Each 15-30 min sequence of images is an independent event, no "memory" of past cloud behavior
  - These methods "shut off" after CI has occurred, what about mature convection nowcasting?

- **Efficient methods such as the NSSL/OU-CIMMS Warning Decision Support System (WDSS-II, Lakshmanan et al. 2007) are now available for clustering cloud pixels into coherent objects**
  - Objects can be tracked from initial development to storm decay and cloud trends are accurately monitored over time
  - This object-based framework offers significant advantages in that the full spectrum of satellite-derived cloud property information, NWP fields, and validation datasets can be carried along with the object to produce or assess:

1. **Convective Initiation Nowcast**
2. **Storm Lifetime Forecast**
3. **Mature Storm Intensification/Decay**
4. **Storm Future Position Forecast**
5. **Storm Severity Potential**
6. **Turbulence Potential**

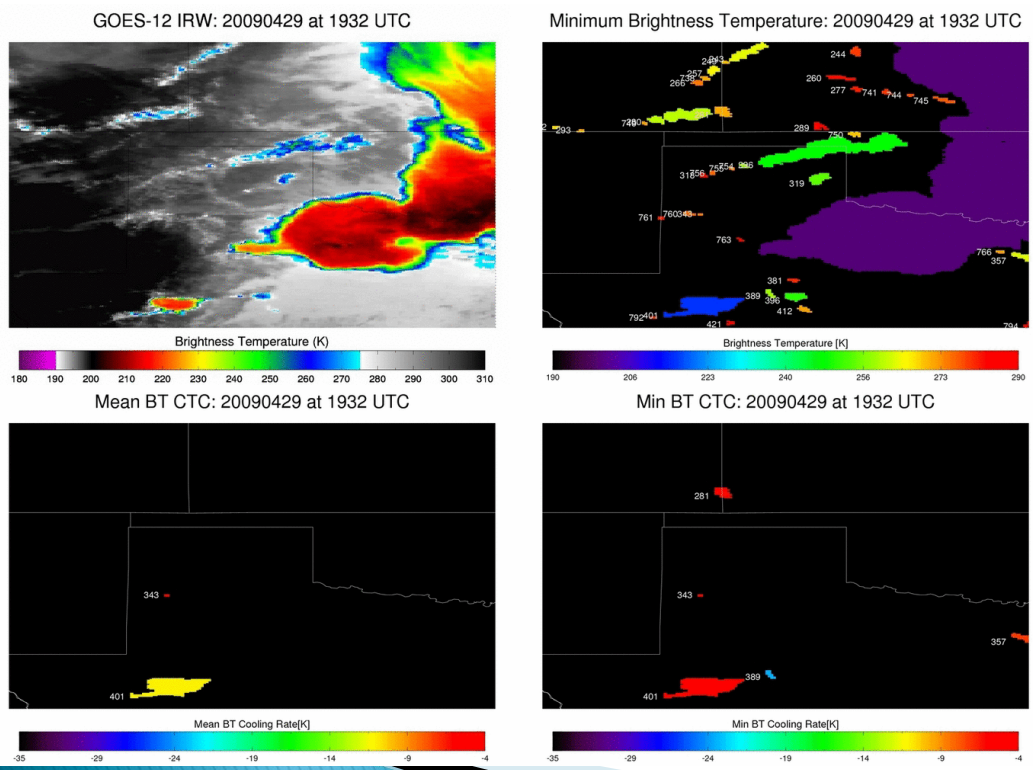
WDSS-II Objects and Cloud Top Cooling Rates For the Above Case



How And Why Cloud Object Tracking?

- A wealth of ***individual*** satellite-derived interest fields have been identified as indicators of a hazardous convective storm.

- An object-based framework provides an opportunity to ***combine*** these fields into a satellite-based best estimate diagnostic of convectively-induced aviation weather hazards



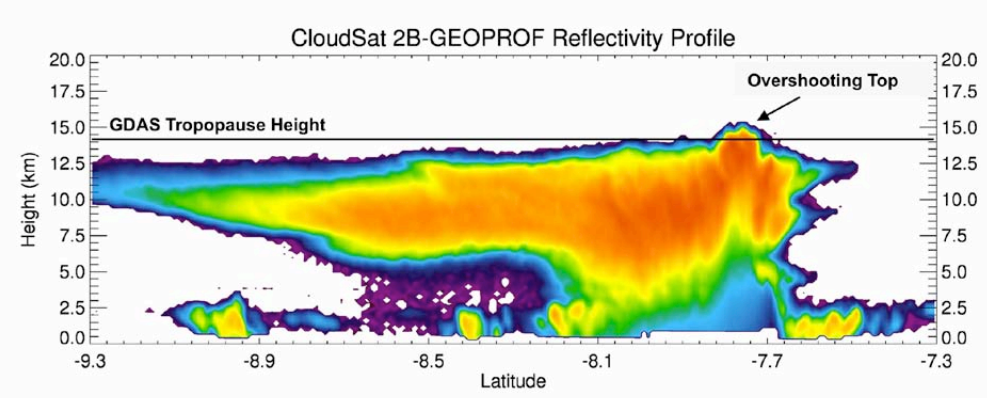
- Cloud objects are assigned an ID number

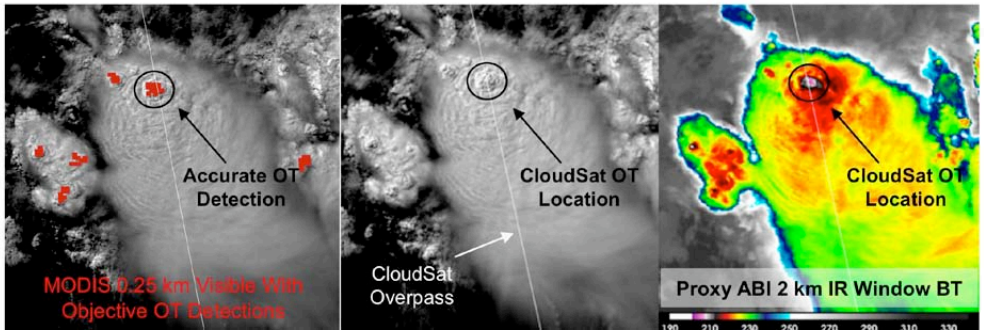
- The ID number persists until the object decays or merges with another object

- WDSS-II computes an object motion field to identify past object locations and to project the future object position. No object overlap between images is required
  - The method is best suited for 5 min GOES-R ABI temporal resolution, but also provides good tracking results using current 15-30 min imagery

- Infrared cloud temperature and other NWP, radar, or satellite algorithm output can be carried along with the object over time to objectively identify hazardous storms

Objective Overshooting Convective Cloud Top Detection





- **Overshooting tops (OTs) are the product of deep convective storm updrafts with sufficient strength to rise above the storms' equilibrium level and penetrate into the lower stratosphere**

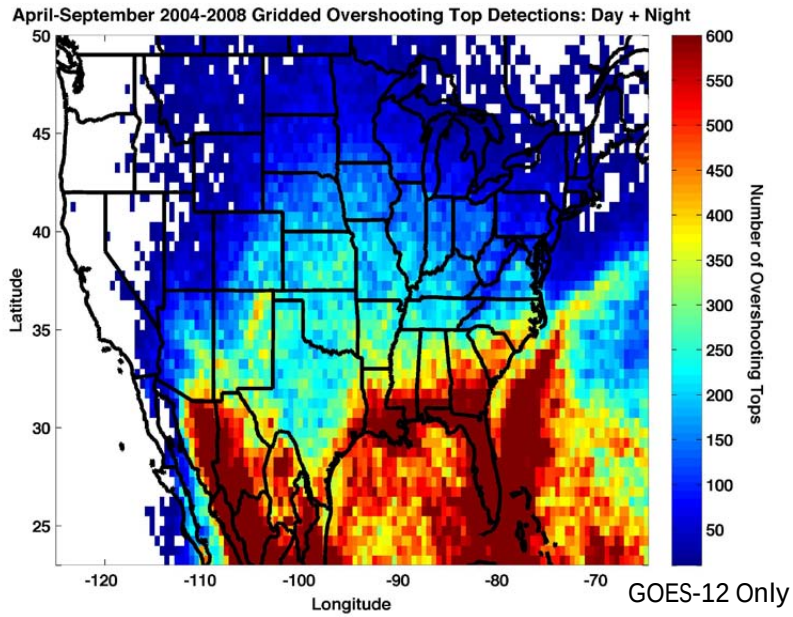
- **OTs appear as small clusters of very cold pixels relative to the surrounding thunderstorm anvil**
  - Infrared (IR) temperature gradients (i.e. texture) are combined with NWP information to accurately detect OTs during day/night using current and future satellite sensors (Bedka et al. 2010)

- **OT detection product being used or evaluated within:**
  1)The 2010 SPC Spring Experiment via the GOES-R Proving Ground
  2)The NCAR Global Atmospheric Turbulence Decision Support System for Aviation
  3)The CERES Cloud Algorithm Package

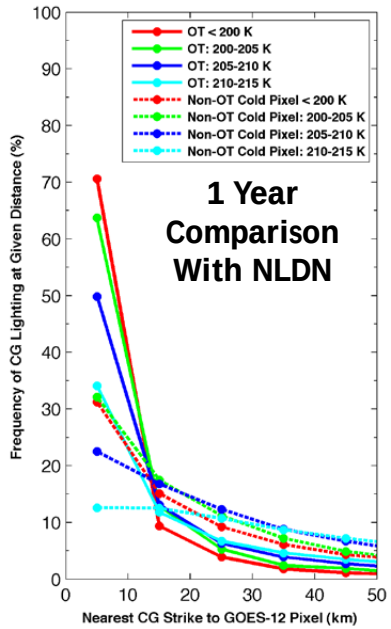
OT Detection Method	OT Pixel FAR ABI Requirement: 25%	OT Top Region POD	Number of OT Detection Pixels Along CloudSat Track
IR-Texture (Applied to Synthetic ABI)	16.1%	74.6%	**940** *(114 Global OT Events)*
IR-Texture (Applied to Current GOES and SEVIRI)	18.3%	57.6%	**252** *(59 OT Events Viewed By GOES/SEVIRI)*
WV-IR BT Diff > 0 K (Currently Operational At Aviation Weather Center)	81.2%	99.1%	**15079** *(114 Global OT Events)*

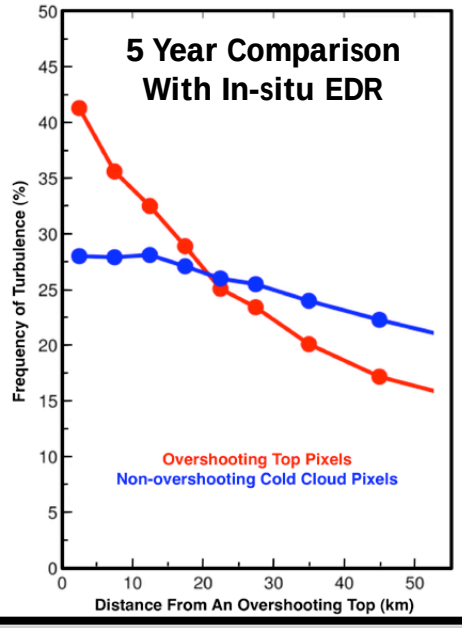
Overshooting Cloud Tops: Why Are They Important?

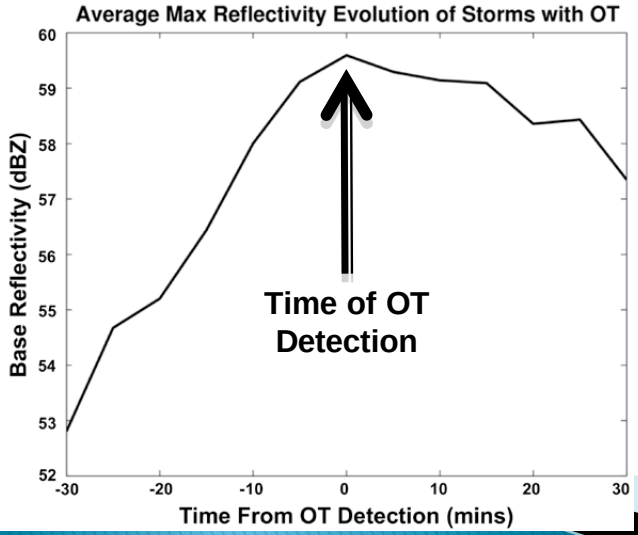
Overshooting Tops Occur Frequently Across Much Of The Airspace System



Aircraft Turbulence And Cloud-To-Ground Lightning Is Concentrated Near The Overshooting Top Region







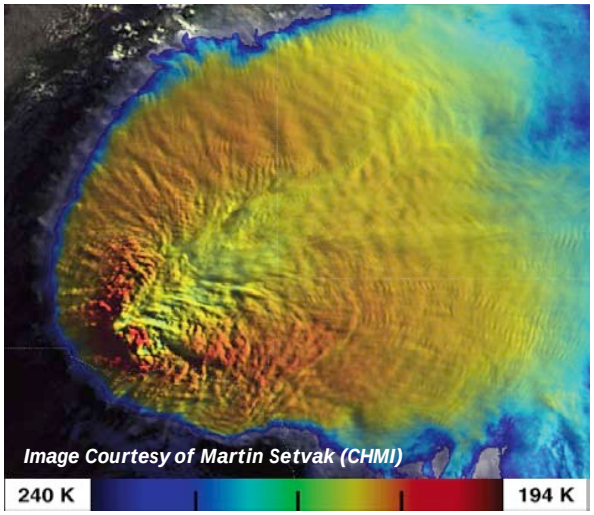
Overshooting Tops Indicate A Relative Maximum In Radar Reflectivity And Are A Strong Indicator Of A Severe Storm

Severe Wx Type	# Of Severe Wx Events Produced By A Storm With Detected OT (GOES-12 Only, 2004-2008)	Frequency Of Total Severe Events
Tornado	2358	56%
Severe Wind	26529	58%
Large Hail	25013	51%
All Types	53900	54%

Other Satellite Signatures Indicative Of A Hazardous Storm

Enhanced-V Signature

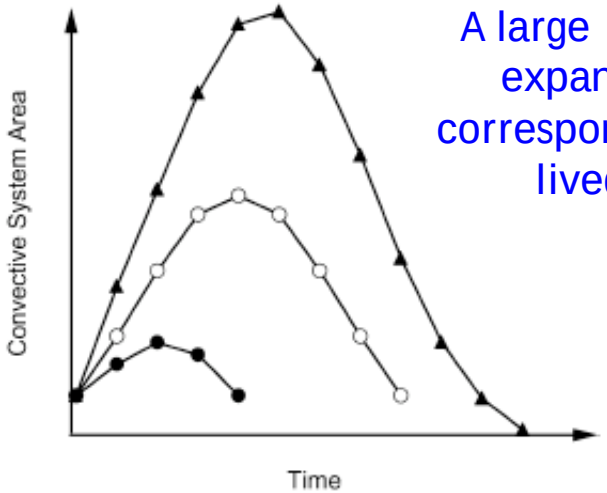
- A storm with an enhanced-V is thought to be caused by strong winds aloft being diverted around the OT region
- Enhanced-V storms are likely to produce severe weather within the next 30 mins (Brunner et al. 2007)
- Objective enhanced-V signature detection is also an aviation product requirement for GOES-R
- The GOES-R enhanced-V detection product can be applied to current satellite data and is being evaluated within the 2010 SPC Spring Experiment



V-Detection FAR	V-Detection POD	Frequency of V-Detections With Severe Wx	# of Events
24%	62%	72%	203

Rapid Anvil Cloud Expansion

- Rapid lateral anvil cloud expansion implies the presence of a strong updraft and an outflow environment supportive of continued storm intensification
- Studies have shown that the initial anvil expansion rate is a key predictor of storm lifetime
- Rapid expansion is often associated with the development of transverse cirrus bands. Turbulence was observed via in-situ EDR in 93% of transverse band events during 2006.



A large initial anvil expansion rate corresponds to a long lived storm

FIG. 6. Schematic diagram of the convective system size evolution for different initial area expansions.

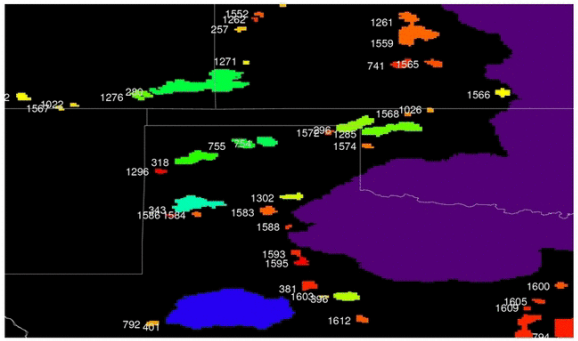
Use Of Satellite Derived Diagnostics And Trends To Identify Hazardous Convective Storms Via Object Tracking

Satellite-Derived Convective Cloud Properties/Trends

Multispectral IR Temperature
Cloud Top Height
Cloud Top Phase and Microphysical Characteristics
Enhanced-V/Overshooting Top Detection
Deep Convective Region Areal Coverage
High Resolution NWP Wind and Thermodynamic Fields

Object Identification and Tracking

Sequential Imagery of Normalized Infrared Temperature



Machine Learning

(Random Forest,
Neural Network,
Decision Trees,…?)

Relevant Aviation Weather Products

- Convective Initiation Nowcast
- Storm Lifetime Forecast
- Mature Storm Intensification/Decay
- Storm Position Forecast
- Storm Severity Potential
- Turbulence Potential

Validation Datasets

(Where Did The Hazardous Weather Actually Occur?)

In-Situ EDR and/or PIREPS
Radar Reflectivity
Severe Storm Reports
NLDN / LMA / GLM
NASA A-Train

Contributors And References

Primary Contributors

- Wayne Feltz, Justin Sieglaff, Jason Brunner, Lee Cronce, and Richard Dworak (UW-CIMSS)
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- Robert Rabin (NSSL/UW-CIMSS)
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- Martin Setvak (CHMI)

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