GOES-R Risk Reduction Research on Satellite-Derived Overshooting Tops

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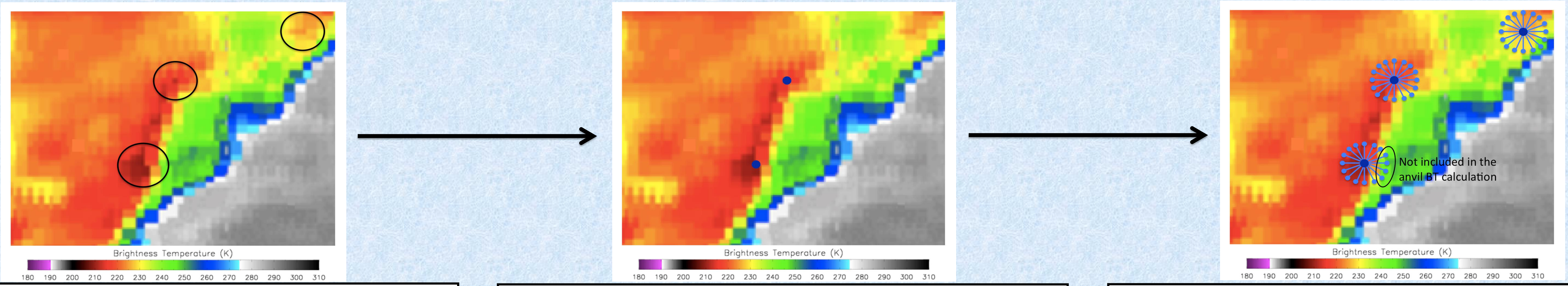
Introduction

- Satellite-derived overshooting tops are presented as temperature anomalies, which can be converted to altitude for practical applications, such as aviation.
- Two branches of an IR-based overshooting top detection algorithm exist and have been improved. Future work includes fusing them into one algorithm.
- GOES-R will allow even better detection due to improved spatial and temporal sampling.

Satellite-Based Objective Overshooting Top Detection Algorithm



Using geostationary satellite imagery, find minima in the 11 µm brightness temperature (BT) field colder than 215 K.

Sample the surrounding anvil at an ~8 km radius in 16 radial directions.
At least 5-of-16 anvil cloud pixels must be colder than 225 K.
Compute the mean BT of these anvil pixels.

Overshooting tops are identified as either:
1. Having a BT colder than the tropopause temp. and 6.5 K colder than the surrounding anvil BT
2. Having a BT 9 K colder than the surrounding anvil BT. (9 anvil pixels required)

Calculating the Height of Overshooting Tops

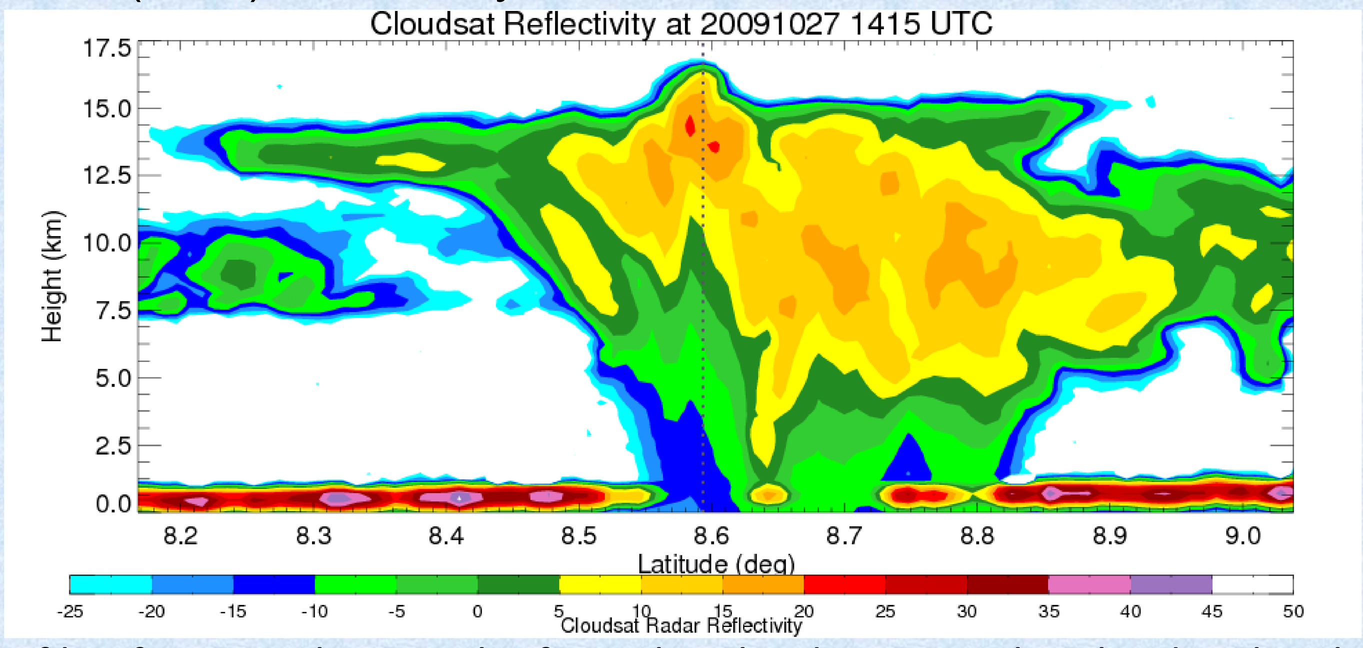
***Motivation*: Overshoots are calculated in temperature space but applications, such as aviation, desire overshoots in a height/altitude reference.**

$$\text{Overshoot Height} = \text{Overshoot Anvil Height} + \frac{\text{Overshoot BTD}}{\text{Lapse Rate}}$$

- *Overshoot Anvil Height:* the height of the anvil BT in a NWP model profile of temperature and height
- *Overshoot BTD*: Overshoot BT – Anvil BT
- *Lapse rate*: median of 107 MODIS overshoot lapse rates.

$$\text{Overshoot Lapse Rate} = \frac{\text{Overshoot BTD}}{\text{CloudSat height} - \text{Overshoot Anvil Height}}$$

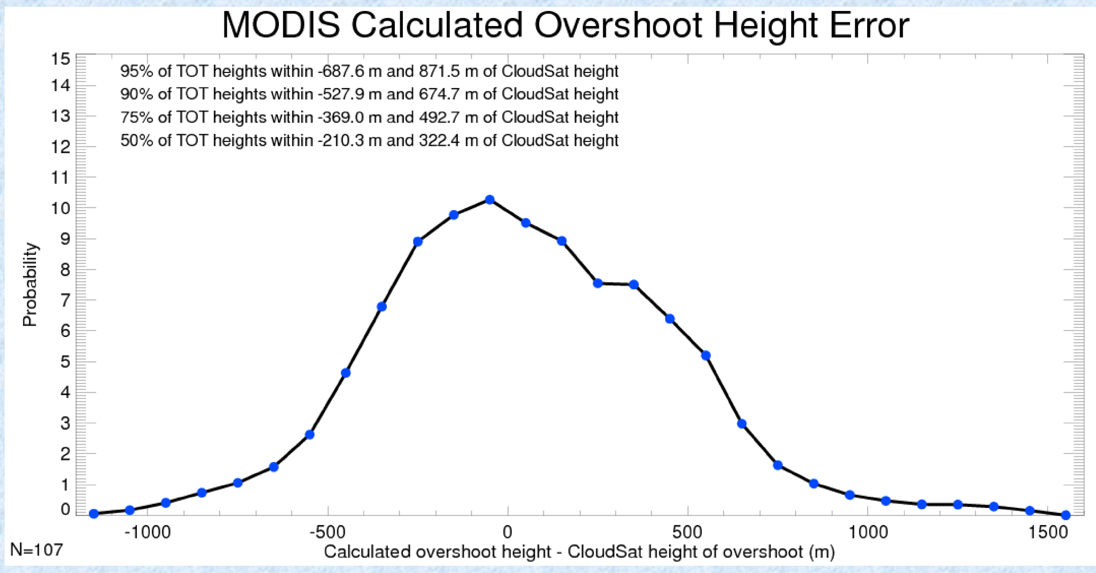
CloudSat height: highest-in-atmosphere CloudSat Cloud Profiling Radar (CPR) Reflectivity ≥ -25 dBZ for the overshoot.



Profile of an overshoot in the from the CloudSat CPR. The CloudSat height is the height of the -25 dBZ contour at the dotted line.

MODIS Overshoot Height Error

Monte Carlo approach:
1. Divided into 2 groups
2. Calculate the lapse rate for first group, use to calculate the overshoot height for second group.
3. Repeat 50 times

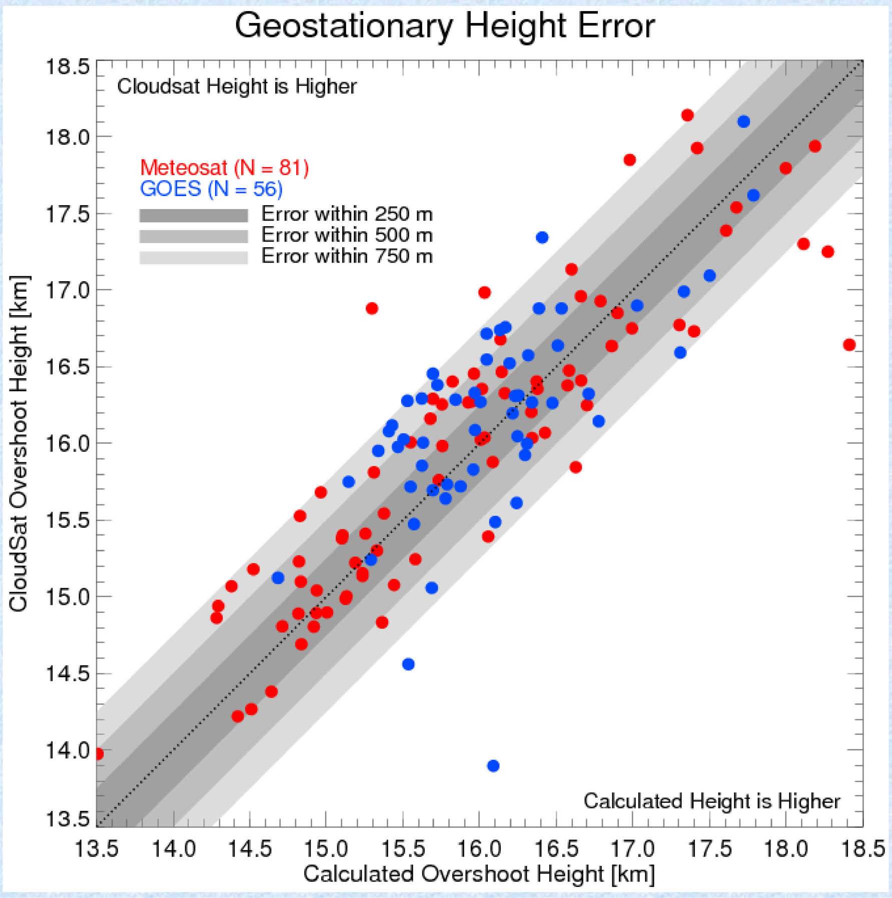


Nearly 50% (75%) of MODIS calculated overshoot height are within 300m (500m) of the CloudSat height.

Geostationary Overshoot Height Error

Approach:
1. Convert geostationary overshoot and anvil BT to be more "MODIS-like".
   - Linear regression equations based on 514 (351) collocated Meteosat (GOES) and MODIS overshoots.
2. Find height of new anvil BT using NWP.
3. Calculate overshoot height using median MODIS lapse rate.

About 51% (68%) of Meteosat and 39% (59%) of GOES calculated overshoot heights are within 300m (500m) of the CloudSat height.

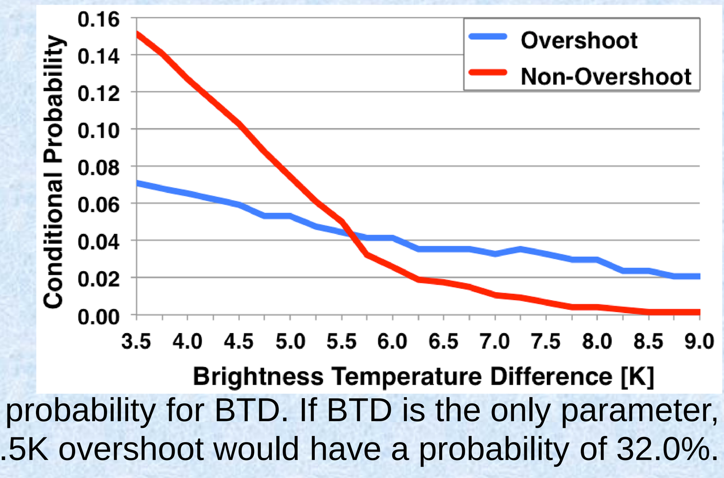


Increasing Overshoot Detection in Tropical Cyclones

***Motivation*: Dense clouds in tropical cyclones (TCs) can reduce overshoot BTD. *Goal*: Allow overshoots with a BT > the tropopause temp. and BTD < 9 K to be identified if within 150 km of the TC center.**

Calculate Overshoot Probability: $P(C_{\text{overshoot}}|\mathbf{F}) = \frac{\prod_{i=1}^{N} P(F_i|C_{\text{overshoot}})}{P(\mathbf{F})}$

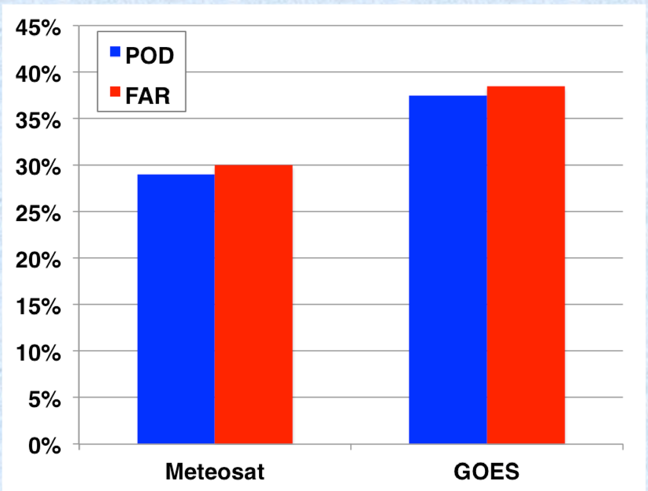
Potential Parameters (**F**):
1. Overshoot BTD
2. Overshoot BT – Tropopause Temp.
3. Water vapor BT – Overshoot BT
4. 12.0 µm BT – Overshoot BT (Meteosat Only)
5. 13.3 µm BT – Overshoot BT
6. Number of overshooting pixels
7. Number of anvil pixels



Conditional probability for BTD. If BTD is the only parameter, a BTD=3.5K overshoot would have a probability of 32.0%.

Optimal parameters/probability have highest Critical Success Index, based on visibly-identified overshoots in 250m-resolution MODIS imagery.

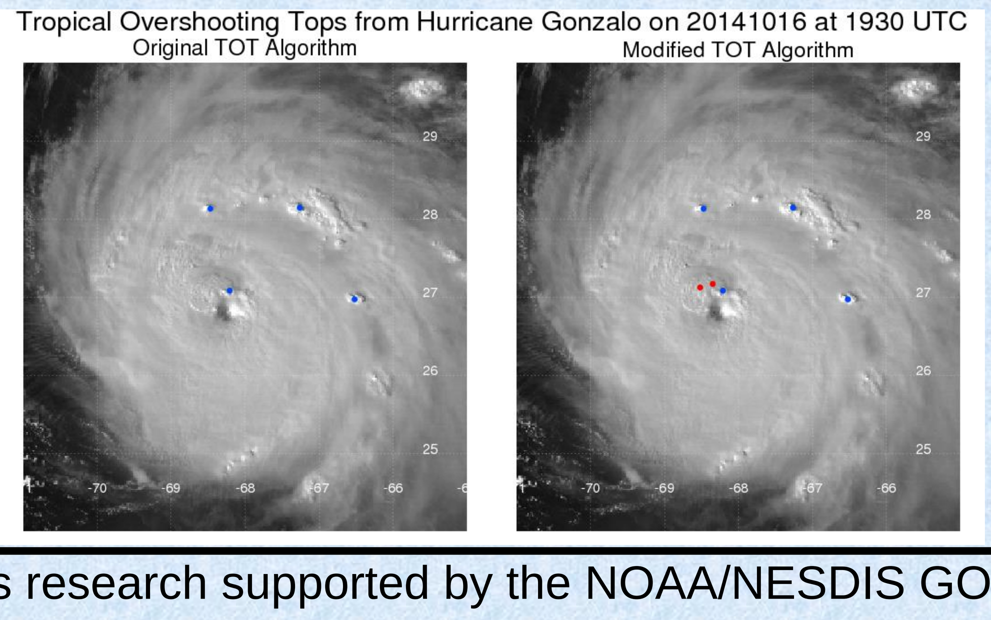
Independent results:



29.0% (37.5%) POD and 30.0% (38.5%) FAR for Meteosat (GOES).

Higher POD and FAR for GOES than Meteosat result of optimal parameters used.

Low POD is a result of spatial resolution, as about 40% of visible MODIS TOTs are not identified by the geostationary overshoot top detection algorithm.

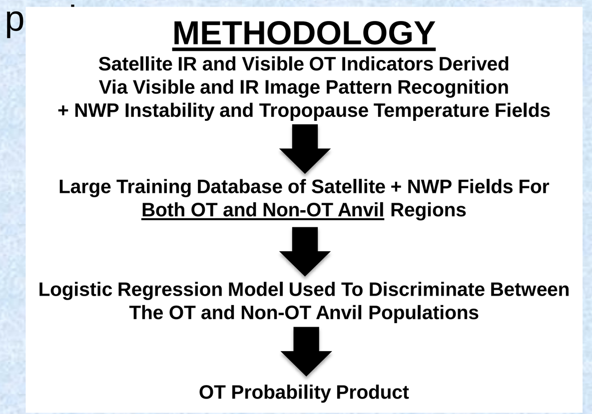


Example: original (left) and new (right) tropical overshooting top detection for Gonzalo (2014). The blue dots represent overshoots detected by the original algorithm and the red represent additional overshoots detected with the modified algorithm.

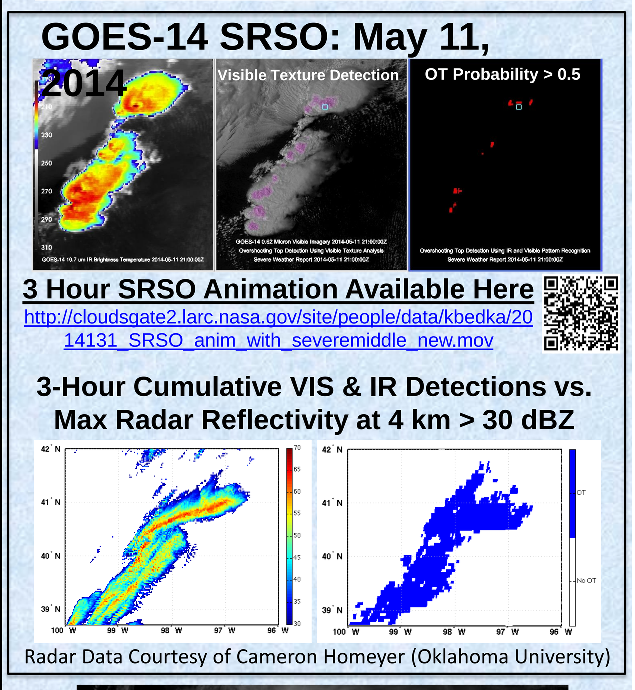
Probabilistic Overshooting Top Detection Using Multi-Spectral Satellite Imager Data

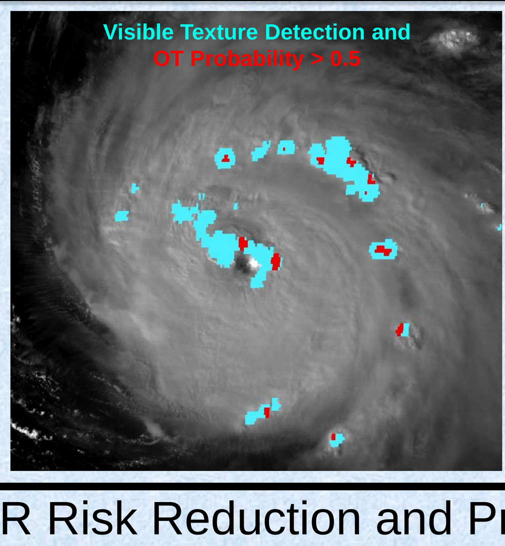
PROBLEM: Though the Bedka et al. (2010) OT detection product has been widely used for weather analysis/forecasting, climate research, and by private industry, fixed detection thresholds and lack of sophisticated pattern recognition can reduce overall detection accuracy. Issues such as these can 1) inhibit identification of trends in hazardous storm activity associated with climate change and 2) cause some severe weather events to be missed, reducing the product's utility for severe weather forecasting.

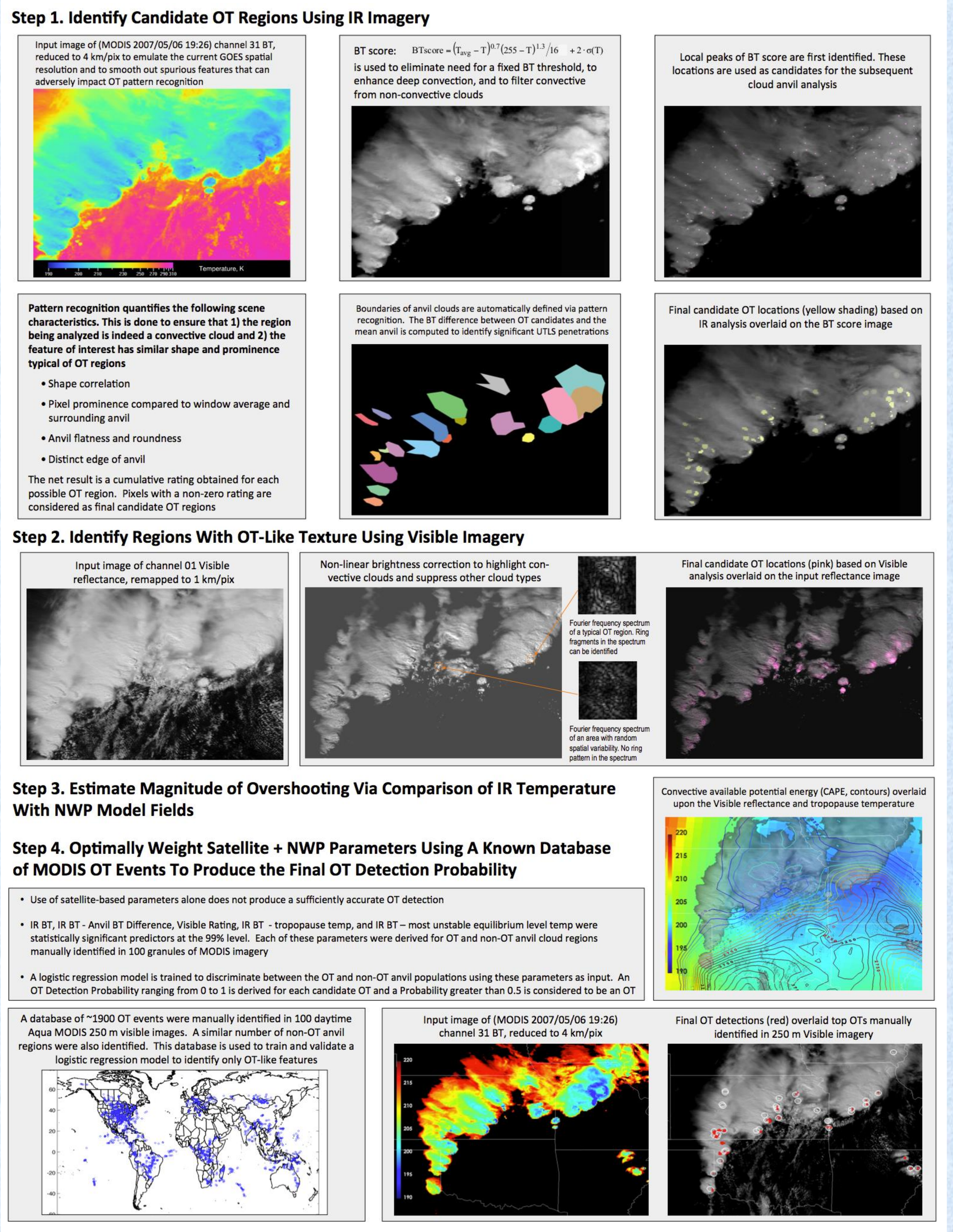
SOLUTION: Mimic the process used by the human mind to identify overshooting cloud tops using visible & infrared satellite imagery and numerical weather prediction (NWP) model data within an automated computer algorithm. This will serve to eliminate fixed thresholds and provide a probabilistic OT detection p



GOES-14 SRSO: May 11, 2014







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