Storm Interrogation

IC 3 Lesson 3

Updraft location of a sheared cell by satellite

Storm Interrogation, Updraft location of a sheared cell by satellite

This lesson is 17 slides long and should take 20 minutes to complete.

Sheared storm updraft location via satellite

- Objective
  - As a compliment to, or without radar data, use satellite data to locate an updraft to deep, moist convection in a sheared environment
    - Be able to use satellite data during the day or night

This lesson looks at how to interpret storm top brightness temperature information from GOES to locate the storm top in an environment with significant vertical wind shear. This process may seem straightforward if there is a unique relationship between storm height and brightness temperature. However, that is often not the case. We will look at how you can locate a storm top even if cloud height and brightness temperature are not colocated.

Sheared storm updraft location via satellite

- Motivation
  - Uncertain radar presentation of storm structure requires interpretation from independent sources
  - No radar data available
  - No spotters
  - No web cams

Why do you want to use satellite to locate a storm top? Satellite data can compliment radar in cases where the radar data are poor in quality or you just need some confirming piece of evidence as to the location of a storm. More likely than not, poor radar data, or even lack of radar data provides a strong incentive to use satellite data as a backup.

Sheared storm updraft location via satellite

- Locating updraft summits with GOES 0.6 and 10.7 μm data
  - Assume that the updraft location is at the summit of an overshooting storm top
  - Most of the time, cloud height and brightness temperature are related
  - However, not always, and this complicates locating the updraft summit

In this lesson, we will assume that the upper-level updraft is near the location of an overshooting top that is depicted well in visible imagery. As we mentioned before, the cloud top summit and the brightness temperature minimum can be occasionally displaced from each other, especially in sheared storm environments.

Sheared storm updraft location via satellite

- Brightness temperature can be uncorrelated from storm top height because
  - Elevated cirrus over storm top
  - **Resolution of IR imagery**
  - **Mixing warm air above the tropopause**

Research has theorized three possible contributions for why brightness temperature and storm top summits may be uncorrelated.

1. There could be a plume of elevated cirrus over and downwind of the storm top. If the temperature at the elevated cirrus is warmer than the storm top summit, as may be the case in an inversion, then the storm top may appear warm.
2. The storm top summit may be too small to be adequately resolved.
3. The most likely scenario is that the storm summit cloud boundary contains strong mixing resulting in the cloud edge taking on the properties of the environment around it, including its temperature.

Let’s examine the bottom two possibilities in more detail

Sheared storm updraft location via satellite

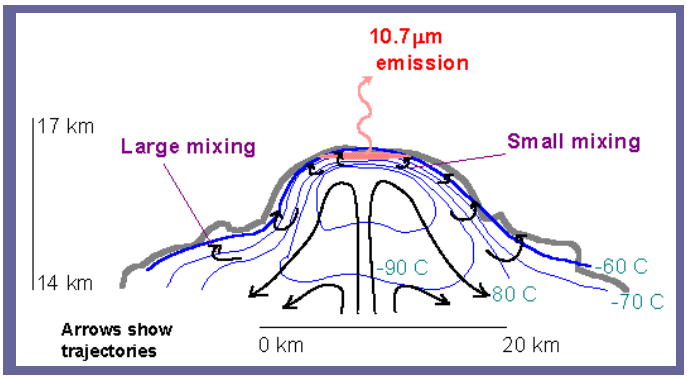
- IR Resolution
  - 2 X 4 km Instantaneous Field of View (IFOV) at nadir is too large to resolve small overshooting tops.
  - Downwind anvil Tb may be lower than at updraft summit.

Most overshooting storm tops are large enough to be resolved even by the GOES IR imager. But a significant minority of storm tops may be too small for detection compared to the surrounding anvil brightness temperature. The result is that the anvil brightness temperature may be lower than the storm summit, since the anvil is a large, relatively flat expanse much larger than the Instantaneous Field Of View or IFOV from the GOES satellite. In order to properly resolve any overshooting top, the GOES IR imagery will need to decrease this size of its IFOV to about 1 km. This requirement will be met by the time GOES-R is launched within the next several years.

The 2X4 km IFOV at nadir refers to the point directly below the satellite. If you want to figure out the resolution for any area of your choice, consider reviewing the lesson on satellite data quality in the section on data quality in AWOC. We show you a simple method to determine the satellite resolution anywhere within view of a GOES satellite.

Sheared storm updraft location via satellite

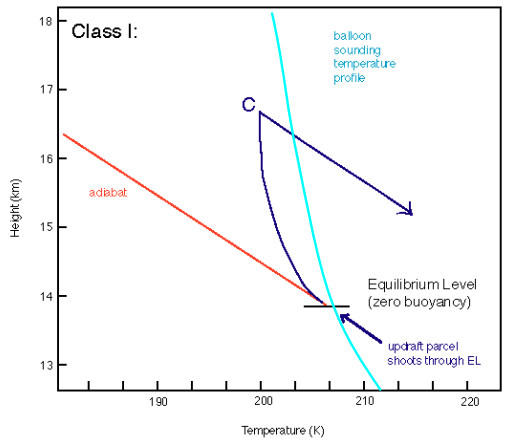
- Mixing along the top of the updraft dome mixes environmental air with cloud air



The most likely explanation for decorrelating storm top height and brightness temperature involves mixing the edges of the overshooting top with the relatively warm environmental air. Note that the 10.7 µm radiation is emitted mostly right at the cloud top edge in the region of thermal gradient between the extremely cold undiluted updraft air and the environment. The stronger the mixing along this edge, the more diluted the temperature gradient, and the more likely the thermal IR emissions are closer to that of the environment. Now imagine that the overshooting top is penetrating into a thermal inversion. It is quite conceivable that the mixing may cause the cloud edge to actually warm with height. This is the most likely explanation available and it seems to fit the conditions required, that is a thermal inversion. Let's go on and explore this some more.

Sheared storm updraft location via satellite

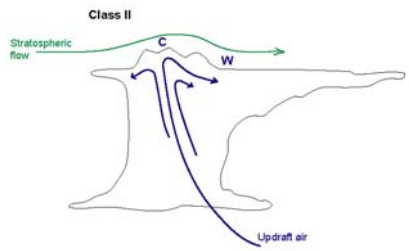
- If the temperature keeps falling above the EL, the brightness temperature (T_b) minima and cloud top height are correlated

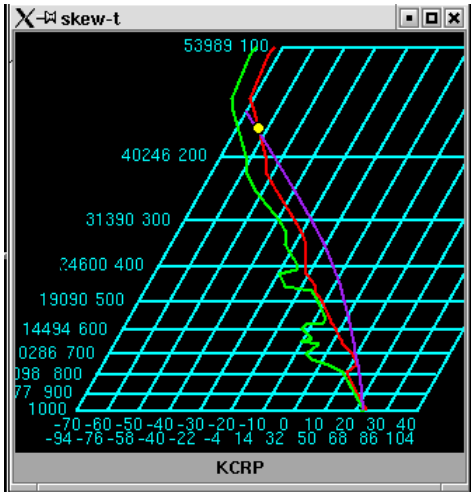


The figure to the right shows the temperature vs. height track of a theoretical air parcel marked as a blue curve as it passes above its equilibrium level, reaches its maximum altitude and descends. In this case, the temperature lapse rate is still positive (temperature decreasing with height) across the equilibrium level as shown by the cyan line. Therefore, as the parcel continues its slowing ascent, the parcel cools. The rate of cooling decreases as mixing commences with the environment but temperature still cools with height until it reaches its maximum altitude located at “C”. This is the case where the overshooting top and brightness temperature minimum are colocated.

Sheared storm updraft location via satellite

- The EL is below the tropopause
- This means good correlation most likely between updraft summit and T_b minimum





Here is a case from South Texas from a cool season severe weather event with supercells. The nearby Corpus Christi sounding showed that the equilibrium level is below the tropopause and positive lapse rates exist above it. This environment suggests that we stand a good chance of picking out the storm top location at its cold point “C”. Any warm wakes “W” may lie downwind of the storm top.

Sheared storm updraft location via satellite

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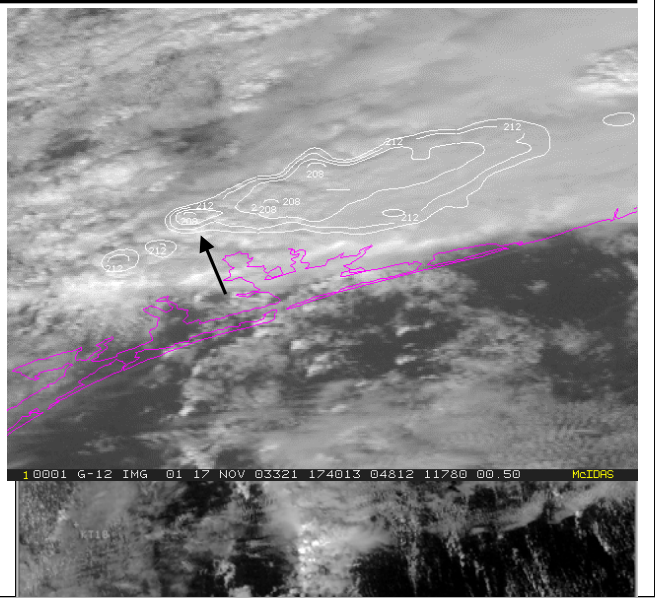
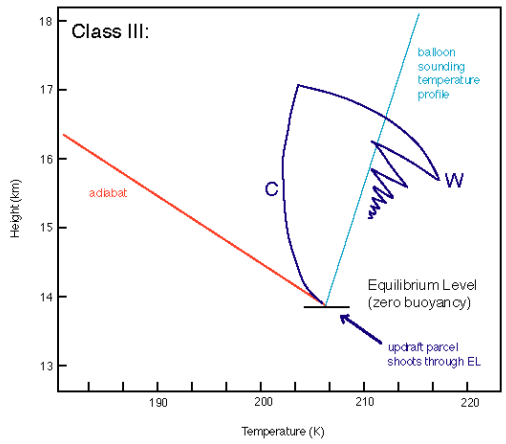
- This means good correlation most likely between updraft summit and T_b minimum



Comparing the visible imagery with the IR, we see that the brightness temperature minima just northwest of the black arrow is right where the brightest cumuliform cloud top shows up in the visible imagery.

Sheared storm updraft location via satellite

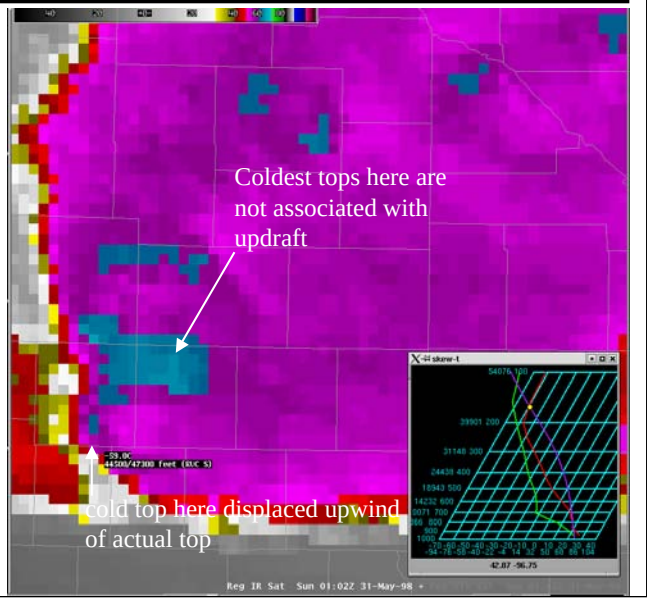
- If the temperature rises above the EL, the brightness temperature (Tb) minimum and cloud top height become displaced



When the EL is in an inversion, mixing causes the cloud top to actually start warming with height. This causes a displacement between the highest cloud and the coldest temperature. The cold spot is displaced upwind of the highest point. The cloud sinks downwind of the highest point warming nearly adiabatically until it settles to a level closer to the environmental EL.

Sheared storm updraft location via satellite

- Displaced cold top example
- Cold Tb top is displaced upwind of physical top
- or little relation between Tb and cloud height



The Spencer, SD tornadic storm on 31 May 1998 exhibited a typical upwind displacement of the coldest tops. In fact, the overshooting top was warmer than the rest of the anvil. The coldest top visible here is actually a collision of two anvils between two storms and has nothing to do with updraft.

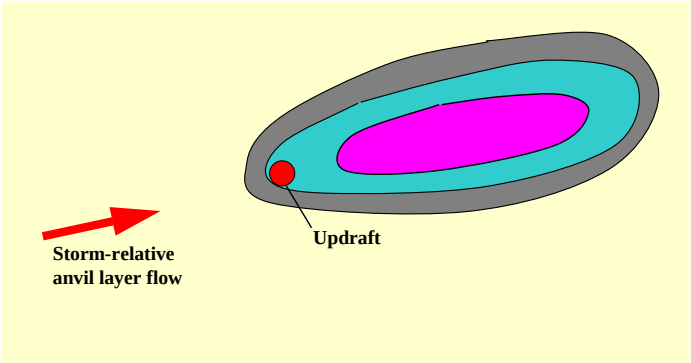
Sheared storm updraft location via satellite summary

- If the EL is in a positive or neutral lapse rate, the Tb minimum is located over the updraft summit
- If the EL is in an inversion, the updraft summit may lie between the Tb minimum and the warm wake
- You may compare to visible imagery during the day

To summarize, if the EL is in a positive lapse rate, the T_b minimum is well correlated with cloud height. Once the EL becomes embedded in a neutral or inverted lapse rate, the cloud actually begins to warm with height creating features such as the warm wake, the enhanced-V, and decorrelating the relationship between T_b and cloud height.

Sheared storm updraft location via satellite summary

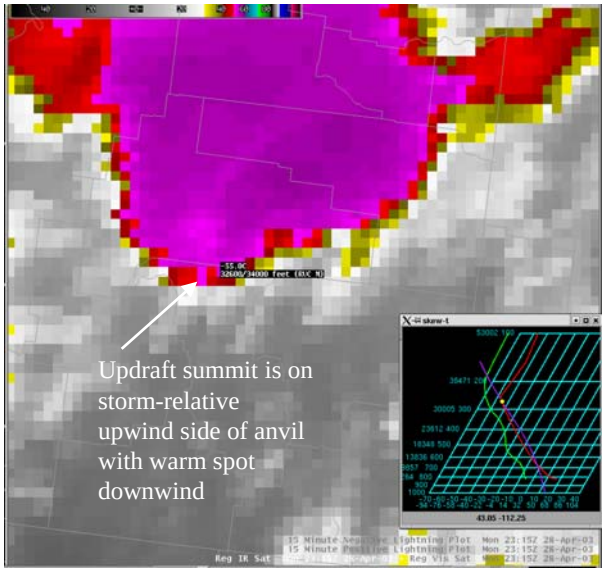
- For small storms, the updraft summit will be at upwind edge or point



Small overshooting tops from small storms may be completely unresolved by GOES. Or a storm struggling in high wind shear will have no overshooting top. The result is an anvil whose lowest T_b is in the flat anvil well downwind from the updraft. In these cases, the updraft will be at the extreme upwind location of the cold anvil.

Sheared storm updraft location via satellite

- Resolution problems
- 28 Apr 2003 - PIH
- Small updraft overshooting top in visible is lost in IR



On 28 April 2003, a supercell southwest of Pocatello, ID exhibited a very small overshooting top that was unresolved by the GOES satellite. However, there is a warm wake since the EL is in a near isothermal layer. Both of these factors contribute to difficulty in finding the updraft summit by satellite. Two things help to make an educated guess as to where the updraft is located:

1. Look to the upwind wide of the anvil with respect to the storm-relative anvil-layer flow.
2. Upwind of the warm wake.

Sheared storm updraft location via satellite

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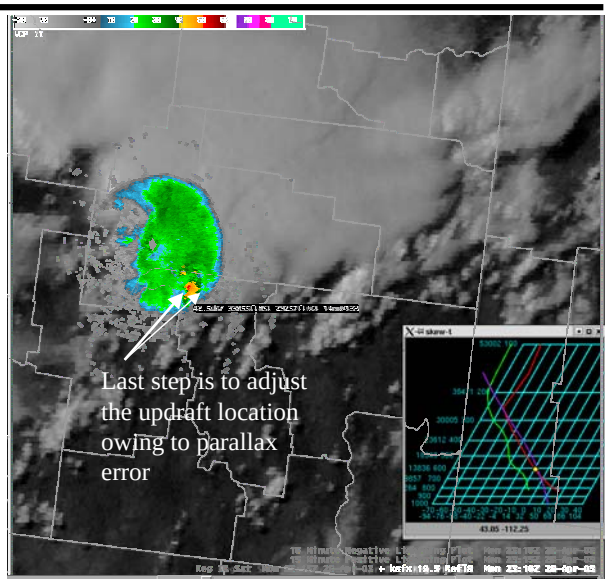

Overlaying the high level reflectivity core shows good agreement between satellite educated guess and the radar observed location of the upper-level updraft. Note the parallax correction.

Summary: Sheared updraft detection by satellite

- Positive lapse rate above EL
  - Updraft summit height and IR brightness temperature well related
- Negative lapse rate above EL (inversion)
  - Updraft summit height and IR brightness temperature may **not** be well related
- Small overshooting tops will be poorly resolved by 4km GOES IR
- Parallax correction needed

When there are positive lapse rates above the EL, there is good agreement between updraft summit height and IR Tb.

When the lapse rates become negative (inversion), the Tb minimum gets displaced upwind. In some cases, there might not be a Tb minimum.

Small overshooting tops are likely to be unresolved by satellite and therefore, you need to look at the upwind side of the anvil relative to the storm-relative anvil layer flow.