Slide 1: Title slide. This training details work to detect Overshooting Tops and Thermal Couplets (OTTC) as part of GOES-R Readyness training

Slide 2: Definitions of Overshooting Tops. (Thermal couplets are discussed later in the training). Why do we want to know where they are? Some reasons are listed on this slide. Take especial note of the small size of OTs – you should immediately ask yourself: Can they be resolved by GOES? The MODIS 1-km IR image clearly shows OTs; they are a lot less distinct in the (nominal) 4-km GOES IR image. The reduced resolution hinders the detection of the features.

Slide 3: OTs correlate well with severe reports – especially wind damage – as shown in these slides.

Slide 4: One benefit of autodetection: it tells you where to focus your attention. In this loop, the IR imagery is fairly complex. Can you tell at a glance where the likelihood of severe weather or turbulence is highest? You can if you know where the overshooting tops are.

Slide 5: Severe weather reports from animation period in Slide 4. That's where most of the OT detection was occurring as well.

Slide 6: Another example showing the OTs and TCs for a strong MCS that moved through Iowa. Again, great spatial correlation between OTs and severe weather reports.

Slide 7: Excellent image of OT in a thunderstorm over Cote d'Ivoire (Ivory Coast) and the MSG image at the same time, showing the overshooting top in the infrared, in the visible, and showing the pixels that are identified as OTs.

Slide 8: How does the detection algorithm work, and what does it focus on? Note that IRW (IR window channel – around 11 micrometers) data are used, and tropopause information from a numerical model (usually the GFS) are used. Look for clusters of cold pixels. Code is rapid – takes about 45 seconds to run once the image is in. Code is flexible – works for standard scanning or for RSO for GOES, and works for Polar Orbiters are well. Better accuracy than the operational OT detection algorithm based on the 6.7 – 11 micron brightness temperature differences.

Slide 9: Guts of algorithm: Read the 10.7 micron brightness temperature and the NWP Tropopause temperature. OTs **must** have a brightness temperature colder than 215 K (-58 C). This threshold temperature was determined by examining 450 storms with OTs in May through July. The cold pixels must be *isolated*. You don't want to detect a cold cirrus shield. Look at the temperatures surrounding the candidate point in 16 directions with a radius of 8 km. The second frame shows "good" OTs (white pinwheels) and "bad" OTs (black). The "bad" OTs in general are not isolated. Pixels must be 6.5 K than the surrounding anvil – and a last test is there to identify all the OT pixels – you don't want just one center pixels, you want all the pixels that define the OT.

Slide 10: A cumulative frequency diagram that was used to determine the threshold for the OT temperature. Again, note that the 450 storms in the climatology used to determine the threshold occurred between 1 May and 1 July. You might ask yourself if this will hinder OT detection in months when CAPE values aren't quite so strong, but dynamical forcing is stronger.

Slide 11: Threshold temperature determined in a similar way – note that you could change this threshold temperature – the difference between the OT temperature and the surrounding anvil, but that could lead underdetection, or false detections of marginal OTs.

Slide 12: AWIPS displays. OTs are designated by a Severe Thunderstorm symbol, and they draw your eye to a region of interest.

Slide 13: Examples of relationships between radar imagery and OT detection. OTs are detected where the lines are solid. Nice correlation with Max Echo Top. Shortly after the OT detection, increase in area of heavy rain – so the impulse up that generates the OT collapses and brings a whole bunch of precip down with it

Slide 14: Frames in this slide show when OTs are detected near Severe Weather events, and when severe weather occurs near any OT (Two sides to detection test). OTs are detected near Severe Weather events most frequently in the southern states. Two factors might be in play: Storm morphology is difference over the Southeast/Southern Plains/Northern Plains compared to the Midwest and Northeast. There are also resolution differences – best over the Southeast, worst over the Northern Plains. Note that when OTs are detected, severe weather is present about ¼ of the time. (In comparison, if there is severe weather, an OT is present about ½ the time). The ¼ detection is likely influenced by under-reporting of severe weather in underpopulated areas

Slide 15: Why is OT detection important? Note the relationship between OT and frequency of severe weather – especially as the OT temperature gets colder and colder. Better relationship in warm season than in cold – but OT detection was 'tuned' to warm months. Is that a factor here? Maybe.

Slide 16: Limitations and dependencies of OT detection. That is, things to keep in mind. The big dependency is on NWP availability. No GFS model, no OT detection, because OT has to be colder than tropopause. It's a rare occurrence that the GFS is missing.

Slide 17: Especially in the cold season, OT-looking features may not be ID'ed as OTs because they are too warm.

Slide 18: Here's a storm near Dallas, with what looks to be an OT – not an old glaciated top, however, and it's hard to tell how big it is – how many satellite pixels is the top, cold, part of the OT? Very hard to tell.

Slide 19: Vis imagery shows a shadow, so there is an isolated tower. But IR temperatures are only around -40, so not cold enough for this algorithm. If this is a resolution issue, that problem will be mitigated with the launch of GOES-R and GOES-S, which satellites will have better horizontal resolution. There were OTs detected on this day, but they were farther to the northeast of the Dallas/Fort Worth metroplex.

Slide 20: Reasons to keep track of OTs is aviation-related. OTs are associated with aircraft turbulence. OTs are associated with cloud-to-ground lightning. The last two slides show GOES-12 OT detection climatology, as well as tracks of aircraft that measure EDR – this is just SW and Delta. United and Continental are doing this too. The climatology of OTs is also shown on the last frame. OTs are a night-time phenomena over the northern Plains, but daytime in the southeast and over the Rocky Mountains.

Slide 21: OT detection algorithms have of course been validated, some with CloudSat radars that's on a polar orbiter on the 'A-train'. The CloudSat information pinpoints the OT location in a MODIS image. Frame 3 shows the great advantage to this technique over the WV-IRW brightness temperature difference technique. A total of 114 OT events were found with CloudSat that had been detected also with MODIS. These are used to compute POD and FAR.

Slide 22: Summary slide for OT detection. Work is ongoing to change the thresholds to values that are seasonally dependent.

Slide 23-25: Here's an example of why OT detection is valuable. Two IR animations, one with OT detection on it, one without. The OT detection draws your focus to regions where the most deleterious weather is likely occurring.

Slide 26: How are OTs and Enhanced Vs related? For this training, Enhanced Vs are also termed thermal couplets. *You cannot have a TC without an OT: The OT serves as the vertex of the TC*. The TC is an important indicator of a severe thunderstorm: 92% of storms with enhanced Vs (TCs) produced severe weather during summers 2003 and 2004. There is Visitview Enhanced V teletraining that you can take, as shown on the final frames of this page

Slide 27: This is an excellent series of slides showing how an overshoot – plainly visible in the true color image – you can see the finger of the OT extending up above the anvil cirrus at the SW edge of the storm – relates to the thermal structure…The IR imagery shows an enhanced V signature with the thermal couplet represented as the warm trench between the two cold arms of the V.

Slide 28: This enhanced V – like many – was associated with a lot of severe weather reports. A difficulty in auto-detection of Enhanced-Vs: they come in many different sizes and orientations. This presents a challenge. There are common features to an Enhanced V – the overshooting top, the warm region, and the anvil that is blowing downwind.

Slide 29: There is a difficulty in detection that is related to resolution issues. This GOES-15 image shows something that could be an enhanced V, but it's very difficult to be sure. The MODIS IR image at the same time shows a warm trench downwind of a cold turret. It was accompanied by a lot of lightning and a severe gust.

Slide 30: Validation is a function of resolution…FAR and POD are higher in datasets with ABI-ish resolution compared to GOES-12 resolution.

Slide 31: Steps to finding a TC – OT first, then find the warm area downstream of the OT. Winds are from the GFS, and the TC must be within +- 45 degrees of the wind flow within a 25x50 box downwind of the OT. The downstream warm region must be at 10 K warmer than the OT. Observations of 450 TCs helped to determine the detection criteria. TCs are important because there is a strong relationship between TCs and severe weather. Low FAR. Product is computed quickly. Works with standard and RSO scanning patterns. Covers CONUS east of the Rockies. There are limitations: Warm trench must be 10K warmer. Isolated regions between anvils can be misclassified as ATCs.

Slide 32: TC output helps you focus your attention where the 'interesting' weather is. This image has lots of cirrus shields. Which are the ones you should pay attention to? There are 4 TCs in the image…these were the 4 storms that produced severe weather.

Slide 33: Product output includes OT magnitude. OT position is highly correlated with turbulence, lightning risk. ATC is related to the risk of severe weather. ATC values have a value from -10 to -50 K. Higher couplet magnitudes are better correlated with severe weather.

Slide 34: Product is available in AWIPS as part of the UW CI product.