Montgomery Blair High School
Matthew Casertano
Malcolm Maas
Heerok Das
Jason Liu

Tornado Predictability with GOES-R: A Case Study of April 23, 2021

Abstract

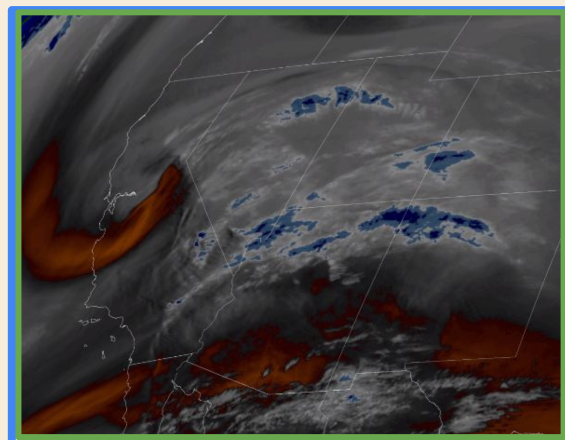
Though tornadoes attract chasers from all over and may even seem eerily beautiful from a distance, their destructive power is immense. A single tornado, such as the 1925 Tri-State tornado or the 2011 Joplin tornado, can kill hundreds, injure thousands, and cause billions of dollars in damage in just hours. With hundreds of tornadoes hitting the U.S. alone every year, it is critical that tornadoes are forecasted accurately for citizens and municipalities to adequately prepare. The GOES-R series satellites are an essential tool for this, offering more spectral data, higher spatial resolution, and faster temporal coverage than the previous generations. By analyzing GOES-16 ABI imagery leading up to a tornadic severe weather event on April 23, 2021, we measured how far in advance various ingredients for tornado formation could be detected. Different bands revealed unique key atmospheric properties or phenomena, and we highlighted the significance of these in our project. Ultimately, a few tornadoes were produced on April 23, which damaged farms and homes; fortunately, no one was injured. Our research will provide useful information to anyone trying to forecast future tornadoes with satellite observations, potentially saving lives by giving people more lead time for tornado threats.

Image of April 23rd tornado, via Will Leverett

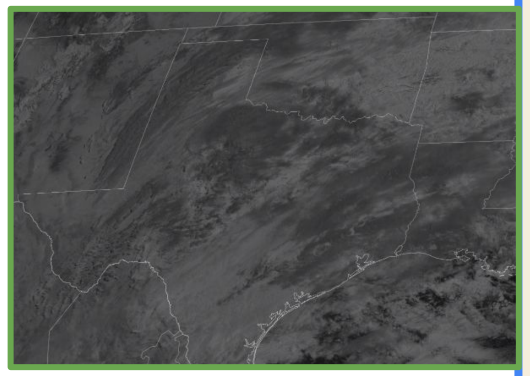
Research question

How far in advance can features affecting tornadogenesis be detected using the GOES-R ABI?

Methods

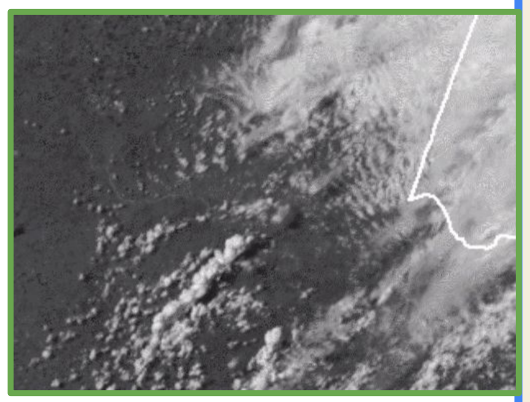


- Trough evident off the Californian coast several days prior, on 6.95 µm mid-level water vapor band
- Band used because higher water vapor content indicates lift, which can indicate a trough
- Motion of trough was towards central Texas

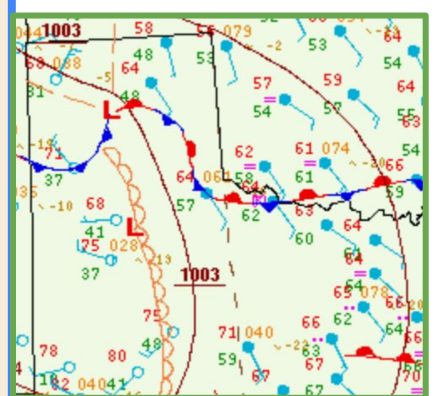


- 15 UTC: 1.61 µm snow/ice band shows widespread stratus clouds, indicating ample low-level moisture
- Band differentiates well between low and high clouds

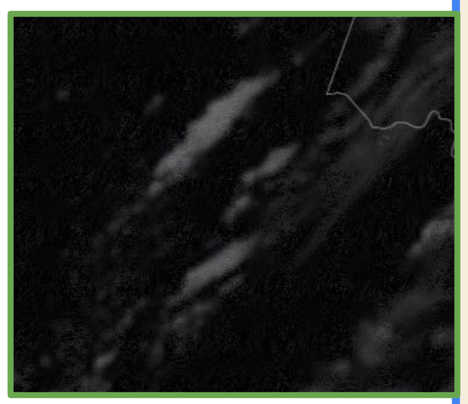
- 18:20 UTC: cumulus development on 0.64 µm red band reveals dryline; area for storm development
- Band used because it has the highest spatial resolution of any band (0.5km)
- Good for detecting small features



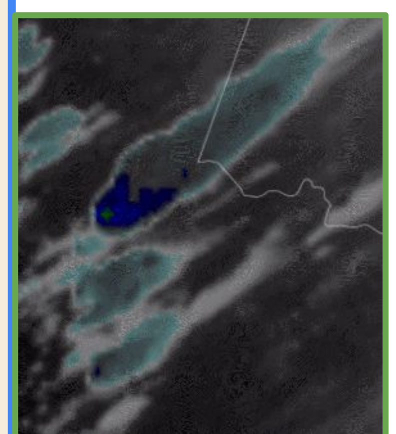
- 18:20 UTC: low-level gravity waves on red band instead of bubbling cumulus indicate cold surface air, limited instability
- Storms less likely there



- 18 UTC surface analysis from WPC confirms satellite observations: low pressure in Texas panhandle with dryline and stationary front, colder air in southwest Oklahoma



- 19 UTC: 1.38 µm Cirrus band shows formation of storm anvils, deep convection beginning
- Band used because it elucidates glaciation of cloud tops



- 21:20 UTC: 11.2 µm longwave infrared band shows three storm cells
- Band used because cloud top temperature is a good proxy for storm height and therefore intensity
- Northernmost storm is strongest (cloud top temperature less than -60 °C); this one went on to produce tornadoes

- On the red band, rotation of the other two storm cells was visible
- However, updrafts of other storms were obscured so detection of this is unreliable

Results and conclusions

- "Lead time" is measured from detection of feature to first tornado report
- The surface cold pool was the most unexpected of the features, resulting in the tornado threat being further south than predicted
- Generally, the larger the features were, the earlier they were detected
- This leads to the conclusion that larger features are more persistent, as if they have more "inertia"

Feature	Lead time
Trough	4 days
Moisture	7.5 hours
Dryline	4.2 hours
Surface cold pool	4.2 hours
Storm initiation	3.5 hours
Storm maturity	1.2 hours
Supercell rotation	Unreliable

- Overall, confidently predicting a specific threat area was only possible about 2 hours in advance
- The above table can be used as a guide for forecasters so they can know when to expect each feature to appear
- Future research could involve more case studies over a more geographically diverse set of storms
- Potential for satellite imagery analysis to be performed more efficiently by a computer

References

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