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Examining Pyrocumulonimbus Clouds with GOES-17: A Case Study of the 2021 Bootleg Fire

ABSTRACT

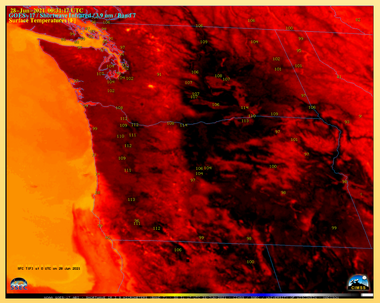
Although an essential part of nature, wildfires are becoming increasingly destructive and causing extreme weather in the form of powerful, dangerous fire clouds. These clouds, known as pyrocumulonimbus clouds (pyroCbs), are fire-generated convective clouds that can reach the lower stratosphere. Not only can pyroCbs create powerful downbursts that spread embers, they can also generate lightning and fire tornadoes that intensify wildfires and cause widespread damage. The Geostationary Operational Environmental Satellite (GOES) fleet may assist with the identification and understanding of pyroCbs, with their continuous imagery, highly-detailed spatial resolution, and atmospheric measurements across many wavelengths of the electromagnetic spectrum. Using imagery from several GOES-17 ABI bands and information from the CIMSS satellite blog, I examined pyroCbs from the Bootleg wildfire of summer 2021. GOES-17 was able to capture key features of these pyroCbs, such as very cold cloud-top temperatures and origination from very intense wildfire activity. GOES-17 also highlighted an earlier severe heatwave that may have contributed to the subsequent formation of the Bootleg pyroCbs. Smoke lingering in the stratosphere following the Bootleg pyroCbs was also visible via GOES imagery. Implications of these findings, as well as the increasing importance of further satellite study of pyroCbs, are discussed.

RESEARCH QUESTION

Does GOES imagery assist with the identification, understanding, and prediction of wildfire-generated pyroCbs?

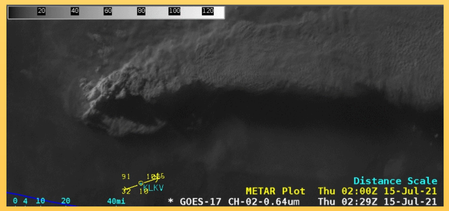
Bootleg Fire, via Washington Post

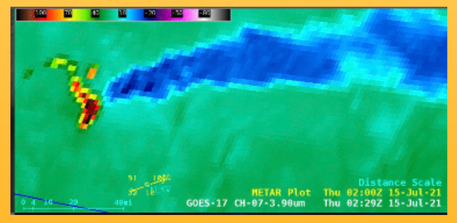
METHODS



- A heat wave with record-breaking surface temperatures occurred in late June 2021 in the Pacific Northwest, just prior to start of the Bootleg fire on July 6
- Extremely elevated surface temperatures were detected with ABI Band 7 (shortwave infrared, 3.9 μm), which captures emitted terrestrial and reflected solar radiation

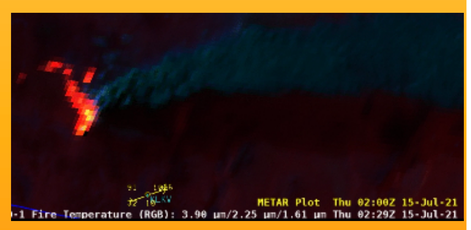
- Late on July 14 (2:00 UTC, July 15), red visible band (ABI Band 2, 0.64 μm) revealed overshooting cloud top and smoke plume in great detail
- This band used because it has highest degree of spatial resolution compared to other bands (0.5 km)

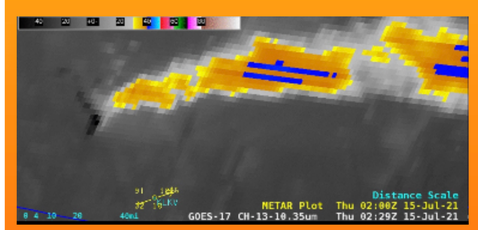




- Surface temperatures reached the saturation temperature of ABI Band 7 (3.9 μm) (shown by black pixels) at 138.7° C (281.7° F)

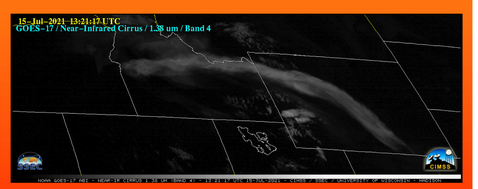
- Fire temperature RGB (a product of ABI imagery) showed the location of the most intense fire activity (yellow = hot, white = very hot, up to 1400 K) and ice clouds (green) that also pointed to the presence of pyroCb





- Cloud-top brightness temperatures reached -40° C and colder (dark blue pixels), an indication of pyroCb formation
- The longwave infrared window (ABI Band 13, 10.35 μm) was used because it is less sensitive to water vapor absorption, helps with cloud identification

- Smoke & aerosols projected into lower stratosphere/upper troposphere by energy from Bootleg pyroCb, seen above Idaho and farther east
- Cirrus Band (ABI Band 4, 1.37 μm) used because it shows location, formation of daytime cirrus clouds



RESULTS & CONCLUSIONS

- Features of pyroCb clouds can be identified using GOES imagery, as shown in the case of the Bootleg Fire
- Identifiable relevant features include overshooting cloud tops accompanying a smoke plume over intense wildfire area, high surface and fire temperatures, and very cold cloud temperatures of -40° C
- Prior to the Bootleg fire, a heat wave with extremely high surface temperatures likely raised the risk for wildfires and a pyroCb outbreak, particularly as it affected the large forested Bootleg fire region and dried out fuel
- Extreme heatwaves in forested areas may be a risk factor for future pyroCb outbreaks
- The Bootleg pyroCbs released smoke into the stratosphere, visible via GOES imagery
- Stratospheric smoke from pyroCbs lingers and spreads great distances, potentially affecting weather systems and leading to a possible cooling effect, as in the case of volcanic eruptions
- Meteorologists can use GOES imagery to quickly detect and monitor potential pyroCb outbreaks, which can aid fire management and public safety efforts
- Global warming linked to climate change may increase the number and intensity of wildfires and pyroCbs, thus, future research, including with GOES-18, is vital to help with more comprehensive understanding and earlier prediction of pyroCbs

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