Reviewer #3 Comments

Comment: This is a very interesting study focused on the longwave (LW) signatures of a thick smoke plume from the 2021 Dixie Fire in California. The satellite remote sensing aspects, radiative transfer modeling, and surface station analysis are generally well constructed. The narrative is well-written and organized. My only major comment relates the coarse and giant particles analysis in Section 3.1, which is critical to the conclusions of the paper.

I agree with the comments by other reviewers on incorporating weather radar data to provide a better representation of the horizontal and vertical extents of large smoke debris (ash and other pyrometers). The Dixie Fire plume should have good coverage from radar sites in the region. Adding these data into the current analysis will provide a better constraint on variables driving the observed cooling.

Reflectivity and correlation coefficient (CC) provide a quick and definitive way to examine the presence (or lack thereof) of both hydrometeors (high CC) and pyrometeors (low CC) in the plumes. Smoke plumes examined with radar in previous studies coincided with radar echoes 20+ km downwind, indicative of large particles far from the fire (e.g., McCarthy et al, Lareau et al, Peterson et al.; see example papers below). A quick check of the meteorology on the dates examined here reveal relatively strong winds in the mid-troposphere, which would likely facilitate transport of these larger particles, perhaps as far as the ground station sites. In addition, the analysis period appears to coincide with very intense fire behavior, which would result in higher altitude injections of larger pyrometeors.

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Response: We thank the reviewer for the constructive comments. We further study the potential impacts of large pyrometeors and/or hydrometeors on the observed TIR signal by comparing WSR-88D radar data to the GOES-17 observations. Two nearby NOAA WSR-88D radars, KBBX (Beale Air Force Base, southwest of the Dixie Fire) and KRGX (Reno, Nevada, southeast of the Dixie Fire) provided good coverage of the smoke plume area, so horizontal and vertical cross sections of reflectivity and correlation coefficient at 2021 July 21 00:00:00 UTC are analyzed. Three cross sections of the radar data through the plume region are analyzed, with the cross sections plotted over the GOES-17 visible reflectance, SWIR reflectance, and TIR brightness temperature in Fig 1a, b, and c (below). The PPI of reflectivity from KBBX (Fig. 1d, below) shows regions of high (> 20 dBZ) reflectivity in the regions of the smoke plume immediately downwind of the fire, but extending no more than 20 km downwind of the beginning of the plume. The KRGX PPI reflectivity (Fig 1g, below) shows high reflectivity in similar regions near the fire, but also has regions of low reflectivity extending farther downwind than the KBBX observations show. RHI cross sections of reflectivity through the plume region along the 36 degree azimuth from KBBX (Fig 1e-f, below) show a column of high reflectivity (maximum of 40 dBZ) and very low correlation coefficient (< 0.6) centered about 70 km away from the radar and extending up to 6 km above the radar, with moderate reflectivity and slightly higher (~0.7) correlation coefficient observed at lower heights to about 90 km away from the radar. The high reflectivity and low correlation coefficient suggest the presence of pyrometeors in this region of the plume (although we cannot rule out the impacts of Bragg scattering, for which we have no data to confirm).

However, a cross section of the plume from KRGX very far downwind of the plume, in regions that the GOES-17 visible reflectances show large amounts of smoke and the GOES-17 TIR brightness temperatures show strong cooling, show next to no reflectivity. The same magnitudes of TIR cooling are observed far downwind of the fire, where there are no radar returns, and very close to the fire, where there are significant radar returns. While the KRGX radar is at a much higher elevation than the KBBX radar (2950 m AGL for KRGX, 67 m AGL for KBBX) and thus may not see large ash and/or BB smoke particles below the radar level, even the KBBX radar does not observe any returns far downwind of the fire, as indicated by both the KBBX PPI and RHI diagrams.

While the KBBX and KRGX reflectivity and correlation coefficient observations may suggest the presence of pyrometeors in the plume in close proximity to the fire (and, again, we cannot rule out possible Bragg scattering), the GOES-17 SWIR reflectances do not show significant increases in reflectance in those same regions, which would be expected if large (> 1 um) particles were present in the plume. We thus cannot conclusively state if pyrometeors were present in large amounts near the plume region. Regardless, with the same magnitude of strong TIR cooling being observed in regions with no radar reflectivity and with high reflectivity, we conclude that pyrometeors and hydrometeors are not the primary cause of the TIR cooling signal. Additional factors must be in play.

We have added this analysis to the paper under Section 3.1.

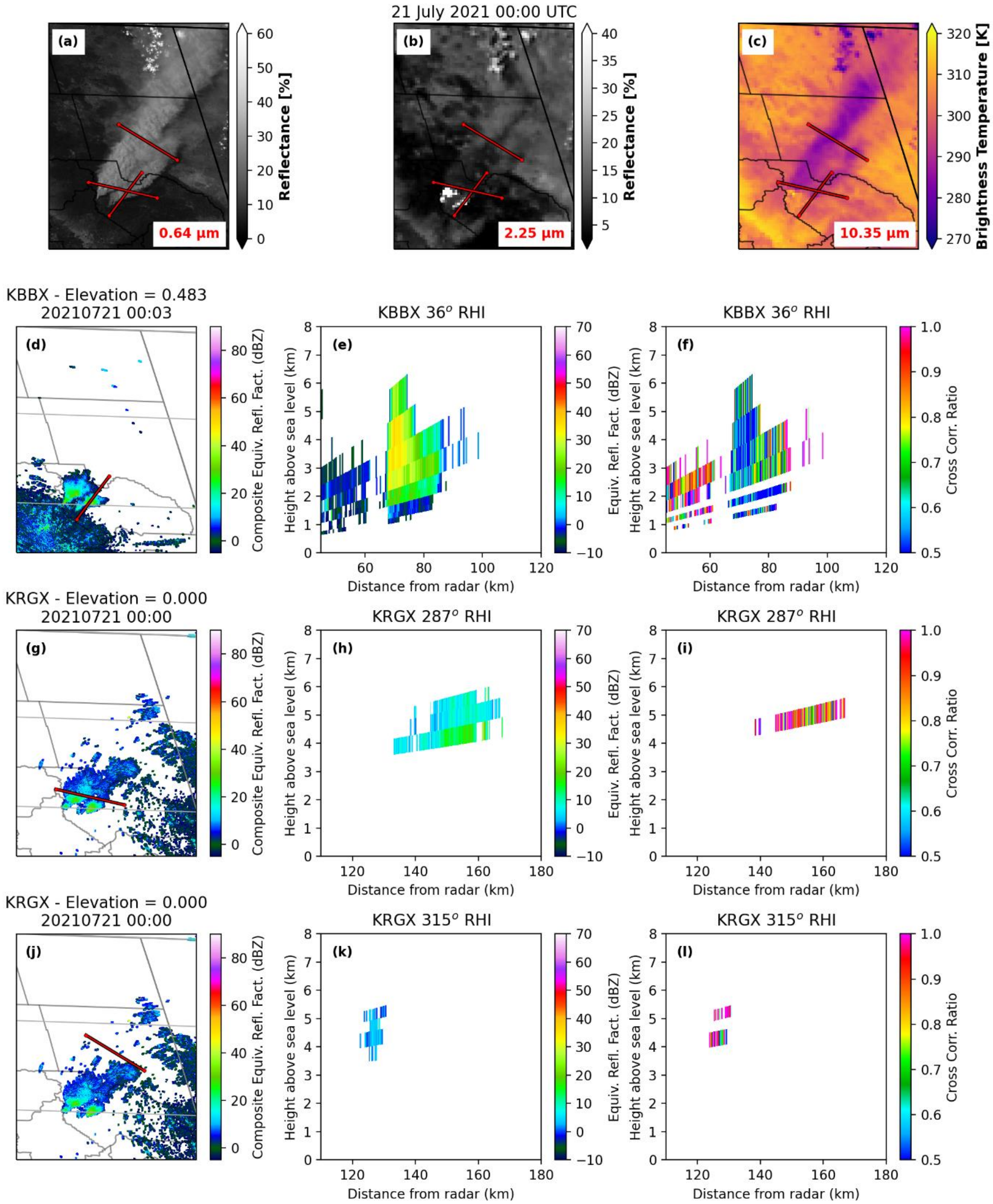

Figure 1. Comparison of GOES-17 and NEXRAD radar observations derived from the Beale AFB radar (KBBX, southwest of figure) and Reno, NV NWS radar (KRGX, southeast of figure) at 00:00 UTC 21 July 2021. First row: GOES-17 visible reflectance (a), shortwave IR reflectance (b), and thermal IR brightness temperature (c), with radar cross section locations added as red lines along azimuths from KBBX and KRGX. Second row: KBBX plan position indicator (PPI) of composite reflectivity (d), and range-height indicator (RHI) of reflectivity (e) and correlation coefficient (f). Third row: as in the second row, but for KRGX. Fourth row: as in the third row, but for a cross section much farther downwind of the fire.