Comment: The phenomenon on which the manuscript focuses, TIR cooling in apparently "dry" smoke, has been of particular interest to me and others studying energetic fire behavior. I have a few questions and observations to consider.

If I understand the manuscript, the conclusion is that the bulk of TIR cooling is attributable to large AOD of submicron particles. Cooling is characterized remotely with satellite brightness temperature data and in situ with surface weather stations. The satellite-based TIR cooling is as large as 25°C, and the onset is sudden. The in-situ surface-temperature observations show a 1-2C initial cooling followed by a leveling off and thereafter a slow rise until about dusk. Is that a fair characterization? If my understanding is accurate, a question I have pertains to the physical reason ascribed to a supposed sudden surface cooling of up to 25°C. I.e. what would make the surface cool well below its pre-smoke condition? Like any sunny day that is interrupted by a cloud or plume, one might expect an interruption in surface warming, but what mechanism would drive the temperature significantly lower than before the plume started inhibiting insolation. Could you clarify the proposed mechanism for such a dramatic cooling as inferred from the satellite data?

Response: Thank you for the comment. The drop in temperature as shown in this study is mostly related to the significant reduction in surface downward solar radiation. This is because downward solar radiation is a key component in maintaining surface energy balance. With the significant reduction of surface downward solar radiation due to the smoke plume, it is not a surprise that we can expect a drop in surface temperature. As with a significantly reduced surface downward SW radiation, and a plausible reduced surface downward LW radiation due to the cooling effect of the atmospheric column above the surface layer due to smoke (as found in this study), to maintain a surface/near surface energy balance, surface upward LW emission, hence surface /or near surface air temperature, must be reduced to maintain the energy balance.

Note that after further analysis of the GOES-17 imagery (and as shown in the figure below), we identified a pyrocumulus cloud that formed over the southeastern side of the fire at approximately 22:30 UTC 20 July 2021, about the same time as that sudden, extreme dip in brightness temperature observed at the orange point (see the bright, white spot in the VIS imagery, as well as the bright spot in the SWIR imagery and the especially cold spot in the TIR imagery above the fire, which is indicated by the bright pixels in the SWIR and TIR). We suspect that this pyrocumulus cloud is likely responsible for the sudden, extreme drop in TIR brightness temperature below the pre-dawn TIR brightness temperature at that point. From the SWIR and TIR observations over the next 15 – 30 minutes (not shown), this pyrocumulus cloud dissipated very quickly after formation, which could explain why the rapid cooling below 280 K was observed at the orange point at about 22:30 UTC and not at the green point farther downwind. Thus, while there was brief pyrocumulus contamination near the fire, strong cooling is still observed at both the orange point and the green points even after the pyrocumulus dissipates, so we can still conclude that pyrocumulus clouds are not primarily responsible for the strong, widespread cooling signal in the plume.

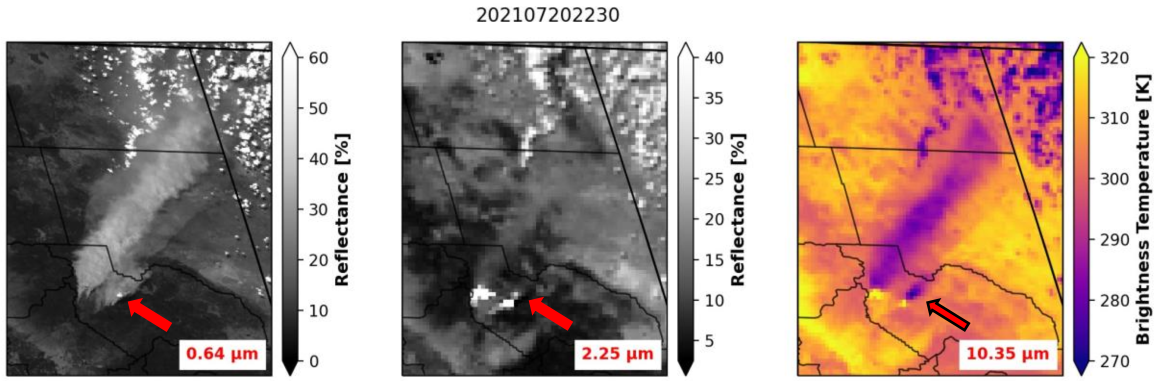

Figure 1. Comparison of GOES-17 observations (visible reflectance (a), short-wave IR reflectance (b), and thermal IR brightness temperature (c)) at 22:30 UTC 20 July 2021. Red arrows point to pyrocumulus cloud in the smoke plume and above the fire.

Additionally, as seen in the figure below, we plotted three new time series of the GOES-17 multi-channel observations for points much farther down the plume, and the green point in this figure (which encounters smoke starting at about 23:00 UTC) still sees cooling of about 20 K without the rapid, extreme, and short-lived cooling seen at the orange point in the original figure.

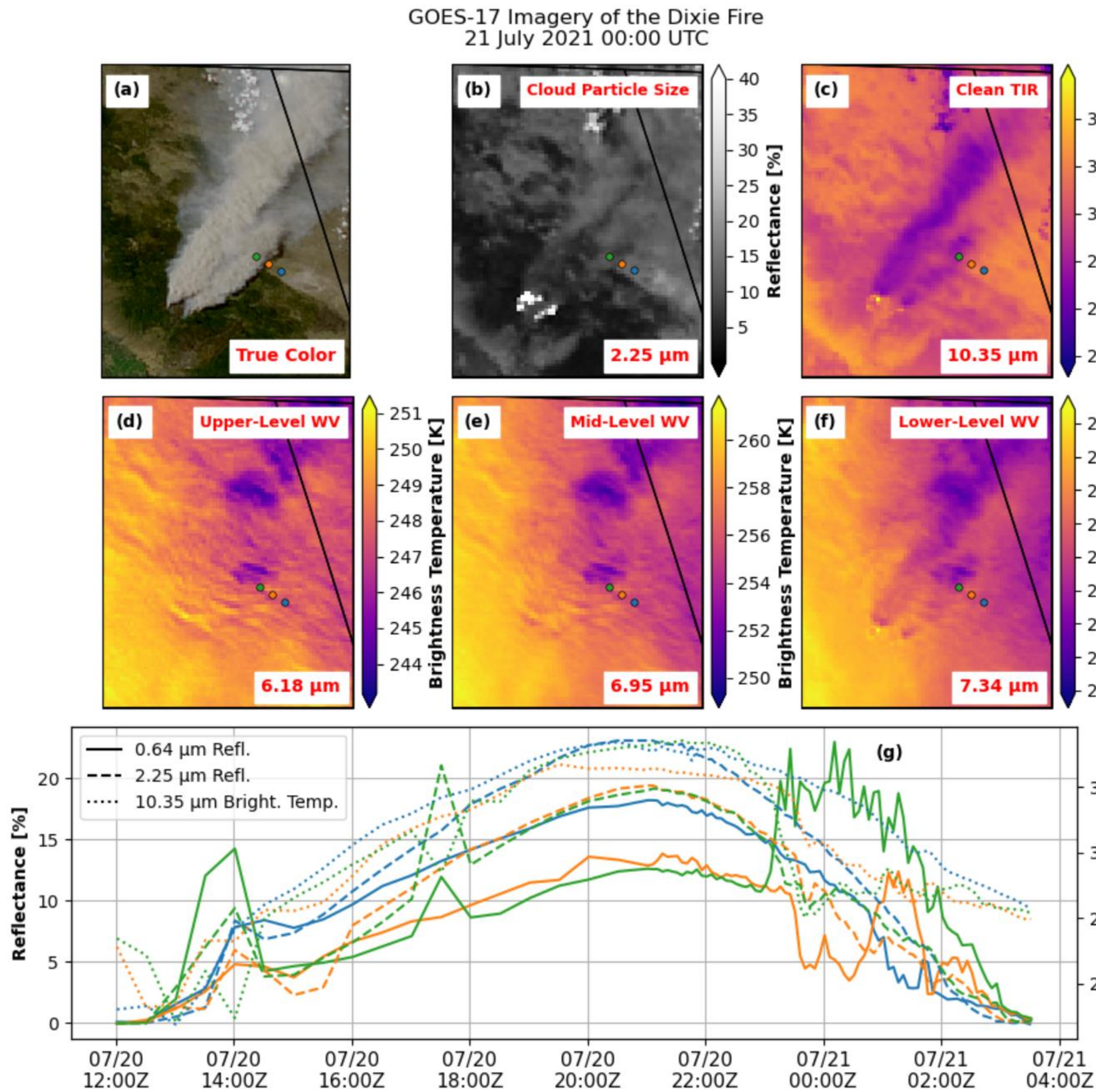

Figure 2. GOES-17 true color (a), shortwave infrared (2.25 µm, (b)), thermal infrared (10.35 µm, (c)), upper-level water vapor (6.18 µm, (d)), mid-level water vapor (6.95 µm, (e)), and low-level water vapor (7.34 µm, (f)) imagery of the Dixie Fire at 21 July 2021, 00:00 UTC. Third row: Time series of GOES-17 0.64 µm visible reflectance (solid), 2.25 µm shortwave infrared reflectance (dashed), and 10.35 µm brightness temperature (dotted) for points outside of the Dixie Fire smoke plume (blue and orange) and inside the plume (green) downwind of the fire.

<u>Comment</u>*:* There is excellent NEXRAD coverage of the Dixie fire and downwind area. These data bear directly on this case study. A review of these data reveals that there were radar echoes in the smoke plume far downwind of the fire itself. This indicates large enough particles to impact TIR brightness temperature. The radar data suggest that pyrometeors (a term coined by McCarthy et al., https://doi.org/10.1029/2019GL084305) and/or hydrometeors were in play both on 20-21 and 22 July instances.

Response: Thank you for the suggestion. We have compared GOES-17 visible (0.64 micron) reflectance, SWIR (2.25 micron) reflectance, and TIR (10.35 micron) brightness temperature to composite reflectivity derived from the Reno (KRGX) and Beale Air Force Base (KBBX) NEXRAD radars at the same time as the GOES-17 observation, with the comparison for 00:00 UTC 21-07-2021 shown below. Clear returns can be seen in areas just downwind of the Dixie fire, suggesting the existence of pyrometeors and/or hydrometeors in the plume very near to the fire (or may be an indication of Bragg scattering). However, strong GOES-17 TIR cooling signals can still be observed in regions far downwind of the fire, where no returns are shown in the NEXRAD composite reflectivity fields. Thus, we suspect that while pyrometeors and/or hydrometeors may contribute to the TIR cooling signal in regions very close to the fire, they are not primarily responsible for the observed TIR cooling.

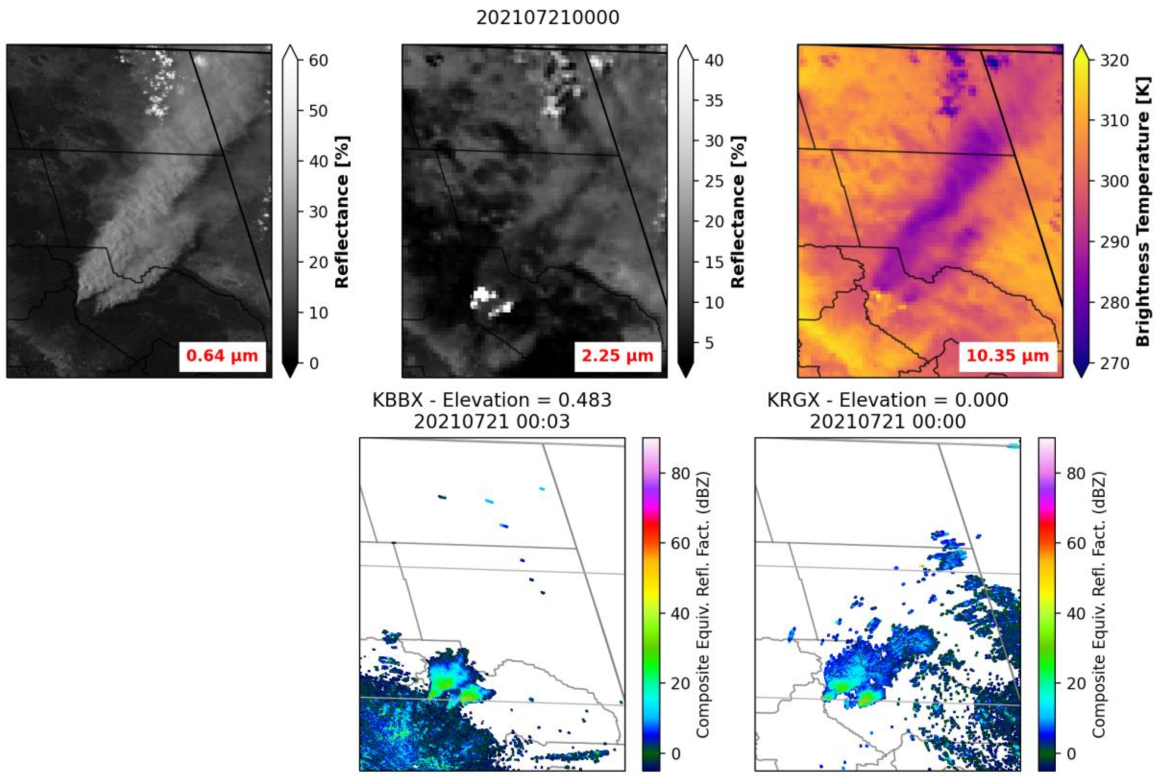

Figure 3. Comparison of GOES-17 observations (visible reflectance (a), short-wave IR reflectance (b), and thermal IR brightness temperature (c)) to composite reflectivity derived from the Beale AFB radar (KBBX, d, southwest of figure) and Reno, NV NWS radar (KRGX, e, southeast of figure) at 00:00 UTC 21 July 2021.

Comment: Although GOES West data were not available for the 22 July case study, GOES East data are. These might offer an opportunity to compare the remotely sensed TIR brightness temperature with radar echoes and the surface station temperature.

Response: Thank you for the suggestion. In the figure below, cross sections of the plume as observed from KBBX and KRGX are shown in relation to the GOES-16 VIS, SWIR, and TIR observations at 21:10 UTC 22 July 2021. Note that, due to the very high viewing angle of GOES-16 to the Dixie Fire plume, the visual positions of the station points relative to the smoke plume will vary slightly compared to the GOES-17 and MODIS images, which have smaller viewing angles. The blue dots in the spatial images show the location of the O05 ASOS site while the orange dot shows the location of the AAT ASOS site. The red dot in the RHI plots indicates the location (distance from the radar and height above sea level) relative to either the KBBX or KRGX radars. From the KBBX PPI and RHI plots, we can see that the O05 ASOS site was located beneath a zone of high reflectivity (> 30 dBZ) and low correlation coefficient (< 0.6). Additionally, the VIS and SWIR imagery show a pyrocumulus cloud located over the western side of the Dixie Fire (see the bright, white cloud in panel A below). Due to its close proximity to the fire, the large region of reflectivity located above the site, and the potential impacts of nearby pyrocumulus at the observation time, additional factors could be influencing the stronger TIR cooling at the O05 site. However, as seen in the KBBX RHI and PPI, the regions with radar reflectivity are primarily close to the fire, while strong TIR cooling is still observed far downwind of the fire, where no reflectivity signals are observed. Thus, this supports our conclusion that pyrometeors and hydrometeors are not primarily responsible for the TIR cooling observed extending far downwind of the fire. We have added some NEXRAD/GOES-17 comparison analysis to Section 3.1 and NEXRAD data description to Section 2 of the paper.

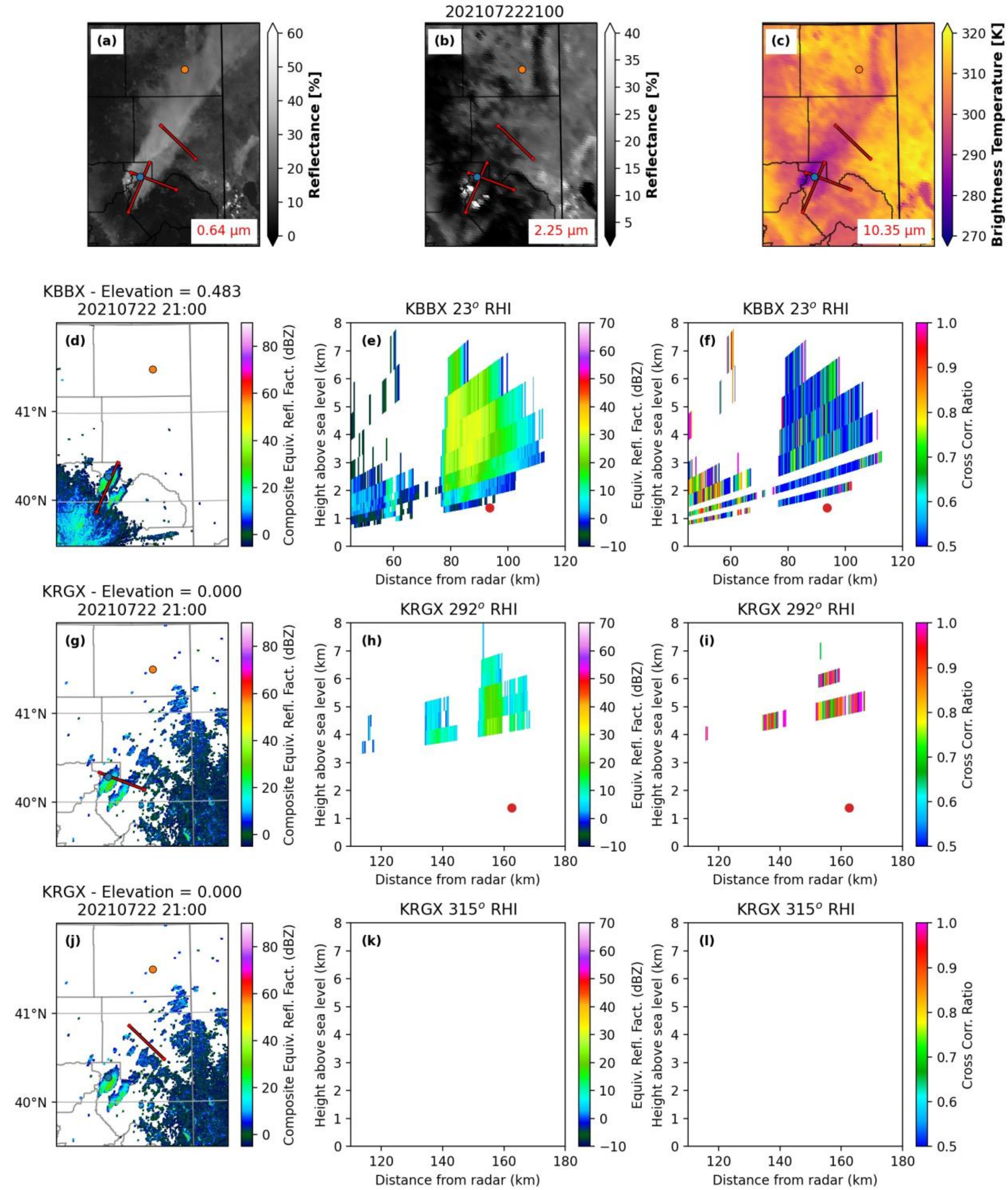

Figure 4. Comparison of GOES-16 and NEXRAD radar observations derived from the Beale AFB radar (KBBX, southwest of figure) and Reno, NV NWS radar (KRGX, southeast of figure) at 21:00 UTC 22 July 2021. First row: GOES-16 visible reflectance (a), shortwave IR reflectance (b), and thermal IR brightness temperature (c), with radar cross section locations added as red lines along azimuths from KBBX and KRGX and the O05 and AAT ASOS sites indicated by blue and orange dots, respectively. Second row: KBBX plan position indicator (PPI) of composite reflectivity (d), and range-height indicator (RHI) of reflectivity (e) and correlation coefficient (f), with the red dot in (e) and (f) indicating the location of the O05 ASOS site relative to the radar cross section. 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.