Referee comment on “Thermal infrared shadow-hiding in GOES-R ABI imagery: snow and forest temperature observations from the SnowEx 2020 Grand Mesa field campaign” by Pestena et al.

The authors analyzed satellite, airborne, and ground-based observations of thermal infrared brightness temperature over a snow- and forest-covered area to investigate the dependence of measured brightness temperature on forest coverage and observation angle. A warm bias in GOES surface brightness temperatures was found compared to nadir-looking airborne and satellite-based ASTER observations. This bias is particularly pronounced when the warmer sunlit sides of the trees were observed, which the authors refer to as the "thermal infrared shadow-hiding effect."

Overall, the manuscript is well suited for publication in The Cryosphere. However, some comments might be considered before.

General Comments

For their study, the authors use different thermal infrared sensors, some of which measure in different wavelength bands. Further, atmospheric correction to derive the surface temperature is not applied. Potential effects were shortly discussed. However, I would recommend performing additional radiative transfer simulations to quantify these effects. What I definitely miss is a detailed discussion of the effects of emissivity on the measured brightness temperature. Please take a look at the paper by Hori et al (2006). There, the authors show the dependence of emissivity on wavelength, snow type, and viewing angle.

Specific Comments

1. Please make sure that you specify the temperature term in the text. Use "brightness temperature" consistently if that is the quantity you mean. "Surface temperature" should be corrected for atmospheric contribution and emissivity. Sometimes I wasn't sure what quantity the text was referring to.
2. P1,L15: “observations collected as part of the NASA SnowEx field campaign in February 2020 provided a rich dataset for comparison. Observations over the course of two cloud-free days spanned the entire study site.”: I would not call a study consisting of two days of measurements a "rich" data set. Rather, it is a case study.
3. P2,L36: “as GOES-R ABI”: Introduce the abbreviation ABI here.
4. Introduction: The introduction is quite long and should end with the outline of the manuscript. Here, two subsections follow the outline. Think about including a reduced content of subsections 1.1 and 1.2 in the main body of the introduction. Figure 1 would fit in section 2.
5. P4,L99: “At much smaller spatial scales, similar effects can occur with off-nadir daytime TIR observations of scenes containing forests. Solar illumination, especially at low sun angles, will warm up one side of individual trees or clusters of trees more than the other shaded side. These trees will also cast shadows onto the underlying snow surface, and the snow surface temperature in these shadows can be much colder than snow in sunlight (Figure 2).” This already anticipates some of the results of the study. If this is already known, then point out what is still missing from these previous publications and what you can contribute to close some gaps. Think about to use figure 2 for illustration of your results in a later section.
6. P6,L131: “The high emissivities of both snow and conifer trees provide us with a scene where surface brightness temperatures are close to true surface temperatures (Kim et al., 2018; Warren, 2019).” Please elaborate the dependence of the measured brightness temperature on the emissivity (see general comments).
7. Figure 6: Where does the dark stripe in Fig. 6a come from? Is this from overlapping both sensor measurements? A map showing the phase angles would be nice to see here.

8. P8,L165: “Images from the Advanced Baseline Imager (ABI) onboard GOES-16 and GOES-17 were retrieved …” Mention explicitly that the measured brightness temperature at top of atmosphere is used.
9. P11,L275: “The mean and root mean squared difference between GOES ABI brightness temperatures and the ground-based snow and air temperatures were also computed.” Is it really the air temperature you want to look at or is it more the surface skin temperature?
10. P14,L316: “This may explain some of the temperature gradient seen in the east-west flight images.” The explanation is quite vague. Figure would fit here for illustration.
11. P14,L320: “Snow surface temperatures observed by the airborne IR and ASTER imagers were biased warm in comparison with the ground-based snow surface temperature observations at snow pit #2S10.” Again, is it the brightness temperature or the surface skin temperature what is meant here?
12. Table 3: “Airborne IR Ts”: Why is this not a brightness temperature? Did you consider the atmospheric contribution between aircraft and surface?
13. P20,L415: “The thermal infrared brightness temperatures observed by ABI are likely to be colder than the actual surface brightness temperature due to atmospheric absorption of infrared radiation.” This could be elaborated further. I encourage the authors to use radiative transfer simulations to investigate the sensitivity more deeply and to make more quantitative statements.
14. P20,L422: “Absorption by water vapor along the atmospheric path between the snow surface and the radiometer mounted < 2 m above the snow surface is negligible; however, for the airborne IR observations with a path length of ~1 km…”. Flight altitude should be given earlier.

Technical Comments

1. Y-axis: Specify the “temperature”. Is it the brightness temperature or the surface temperature what is displayed here?
2. Table 1: “Ground-based observations” not fully legible.
3. Figure 5: Enlarge the color bar. “Temperature” → “Brightness temperature”
4. Table 2: Give the unit of the differences.
5. P17,L378,L379: “fveg” → “f_{veg}”
6. Figure 8 and figure 9: Give temperature differences in units of Kelvin.

References:

Hori, Masahiro & Aoki, Teruo & Tanikawa, Tomonori & Motoyoshi, Hiroki & Hachikubo, Akihiro & Sugiura, Konosuke & Yasunari, Teppei & Eide, Hans & Storvold, Rune & Nakajima, Yukinori & Fumihiro, Takahashi. (2006). In-situ measured spectral directional emissivity of snow and ice in the 8–14 µm atmospheric window. Remote Sensing of Environment. 486-502. 10.1016/j.rse.2005.11.001.