Appendix 1:
Supporting Information and Supplemental Figures

Introduction

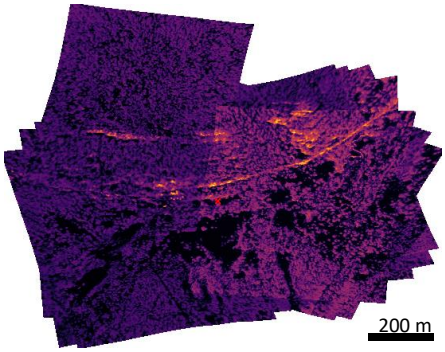
The following supplemental information provides technical specifications of the TIR systems and airborne platforms used, information about the in situ surface temperature observations, photographs of the Sagehen Creek field site in California, USA, and figures to illustrate some of the additional points discussed in the main text.

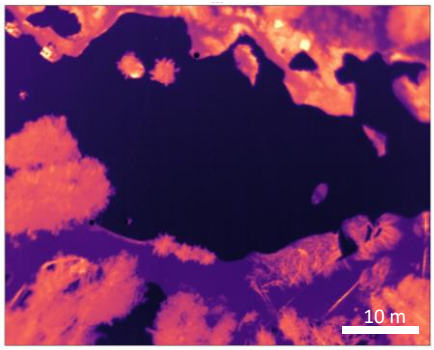
Sample code for implementing the snow-based bias correction method is available at:
https://github.com/spestana/forest-snow-tir

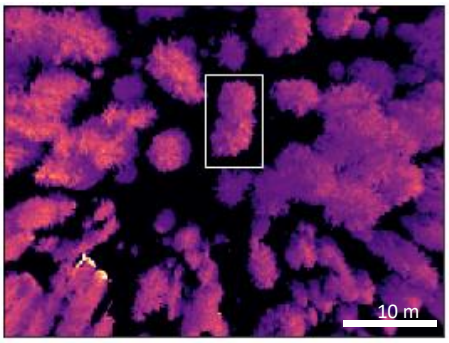
Table of Contents

Sagehen (4/21/2017) | **Davos** (3/27/2017)

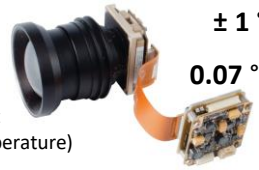
Aircraft/UAS:	**Cessna 172**	**Tarot 650**	**DJI S1000**
Time:	**13:16 – 13:52**	**14:11 – 15:25**	**13:58 – 14:15**
Altitude (AGL):	**1000** m	**20 - 70** m	**40 - 110** m
Spatial Resolutions:	**1.0 – 2.0** m	**0.03 – 0.1** m	**0.07 – 0.2** m







TIR Camera:	**DRS UC640-17**	**ICI 8640P**	**Optris PI450**
Detector Size:	**640** x **480** px	**640** x **512** px	**382** x **288** px
Spectral Response:	**8 – 14** µm	**7 – 14** µm	**7.5 – 13** µm
Accuracy:	**± 1** °C	**± 1** °C	**± 2** °C
NEdT: (Noise Equivalent Differential Temperature)	**0.07** °C	**0.02** °C	**0.04** °C



IR Radiometer:	**KT15.85D**
Field of View:	**1.9°** FOV
Spectral Response:	**9.6 – 11.5** µm
Accuracy:	**± 0.5** °C
NEdT:	**0.02** °C

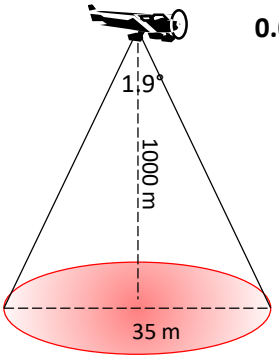
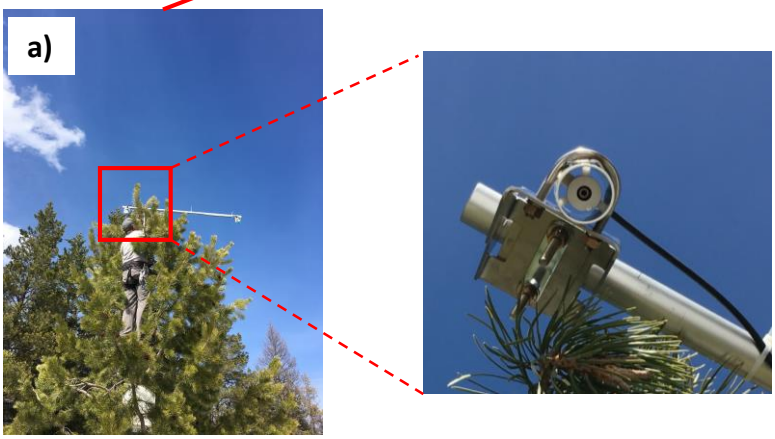


Figure S1. Aircraft/UAS (top row) and TIR systems (bottom row) used in this project: a) University of Washington Applied Physics Lab TIR camera and IR radiometer system on a light aircraft, and b) Center for Transformative Environmental Monitoring Program (CTEMPs) UAS used at Sagehen Creek Field Station, California, USA.; c) WSL Institute for Snow and Avalanche Research SLF UAS used at Laret, Davos, Switzerland.



Canopy & Snow Surface Temperature
Apogee SI-111 IR Radiometers

Field of View: **44°**

Spectral Response: **8 - 14** µm

Photo: waterdata.usgs.gov

Water Temperature
USGS #10343500
National Water Information System

Figure S2. In situ temperature data collection at Sagehen Creek Field Station, California, USA included a) IR radiometers pointing nadir (forest canopy temperature) and at 45° (snow surface temperature) and b) water temperature data accessed from the USGS National Water Information System (USGS, 2016)

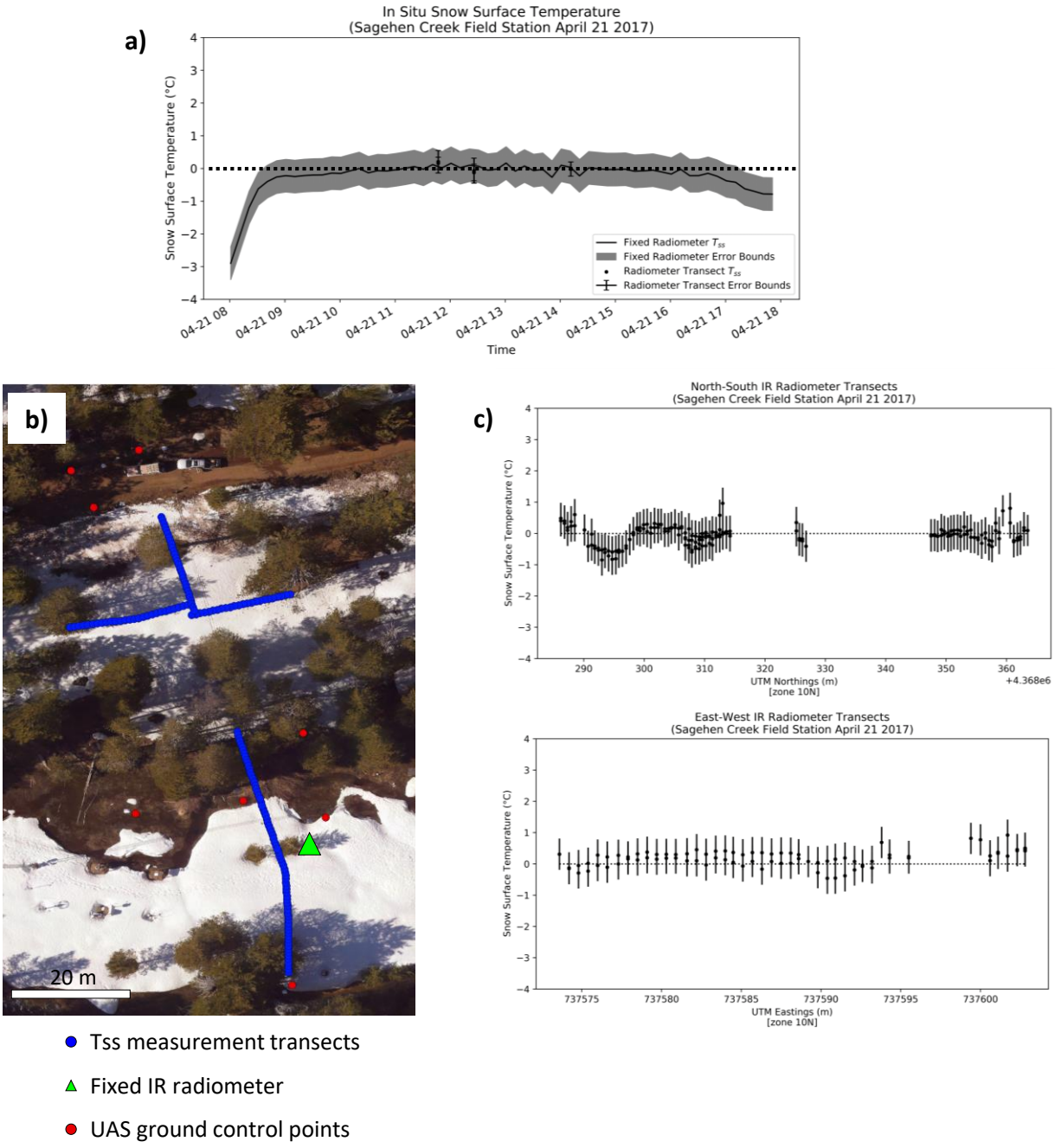


Figure S3. a) Timeline of snow surface temperature measurements from the fixed radiometer and radiometer transects. b) Radiometer transect paths (blue) across the Sagehen study site, and c) their snow surface temperature measurements.

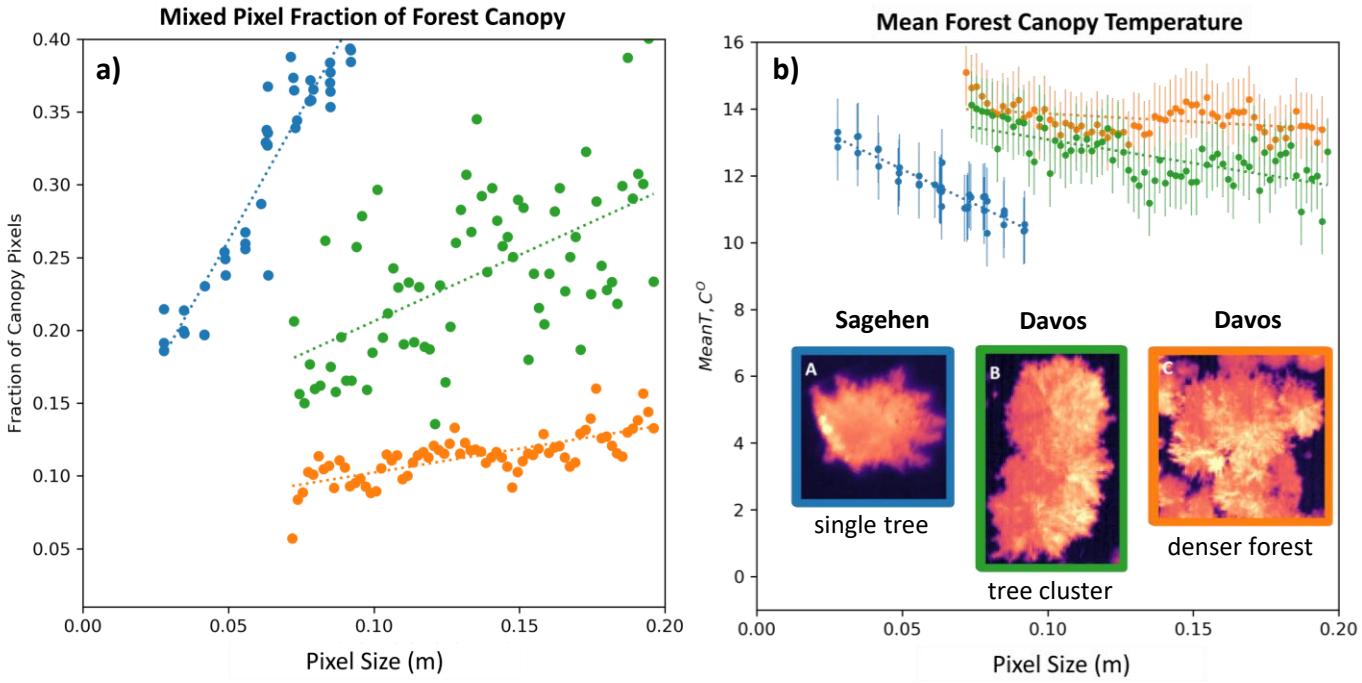


Figure S4. Trends for three different forest canopy configurations: a) Increasing fraction of the forest canopy represented by mixed pixels as pixel sizes increase (image resolutions decrease). b) Mean forest canopy temperature decreasing with increasing pixel sizes.

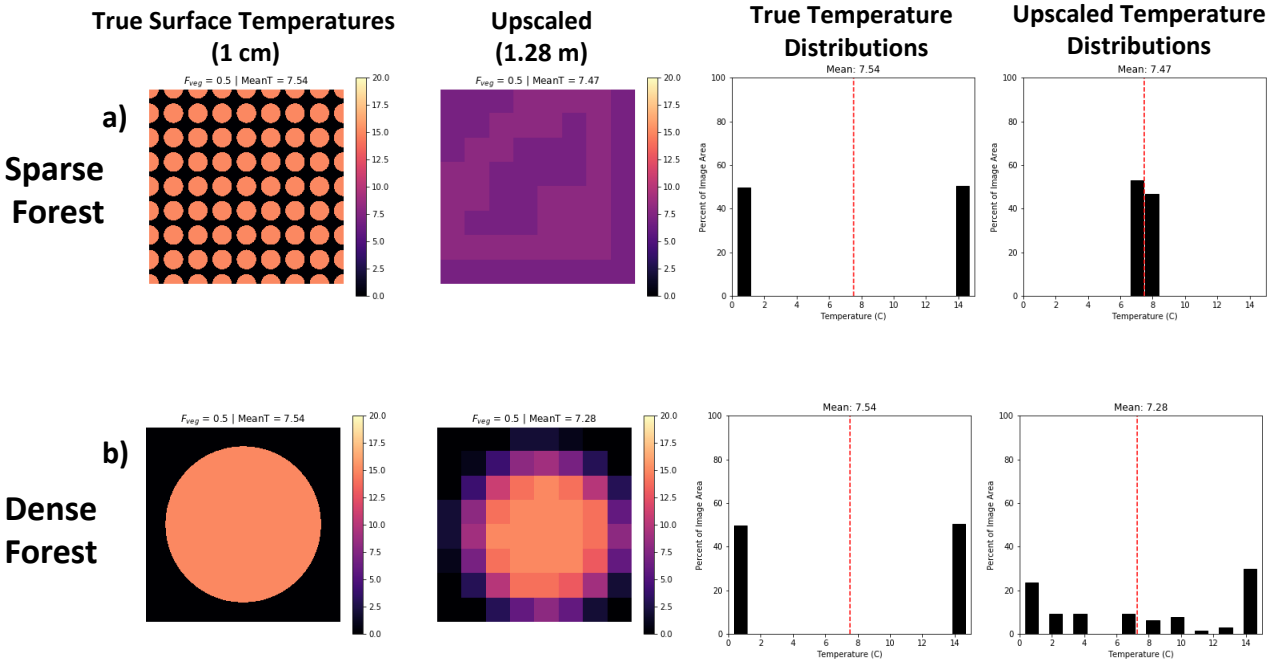


Figure S5. Two simulated forest scenes with f_{veg}=0.5 shown at their original resolution (1 cm) and an upscaled resolution (1.28 m), as well as their corresponding temperature distributions: a) uniformly distributed sparse forest with small 2 m diameter canopies, and b) a single dense tree cluster.

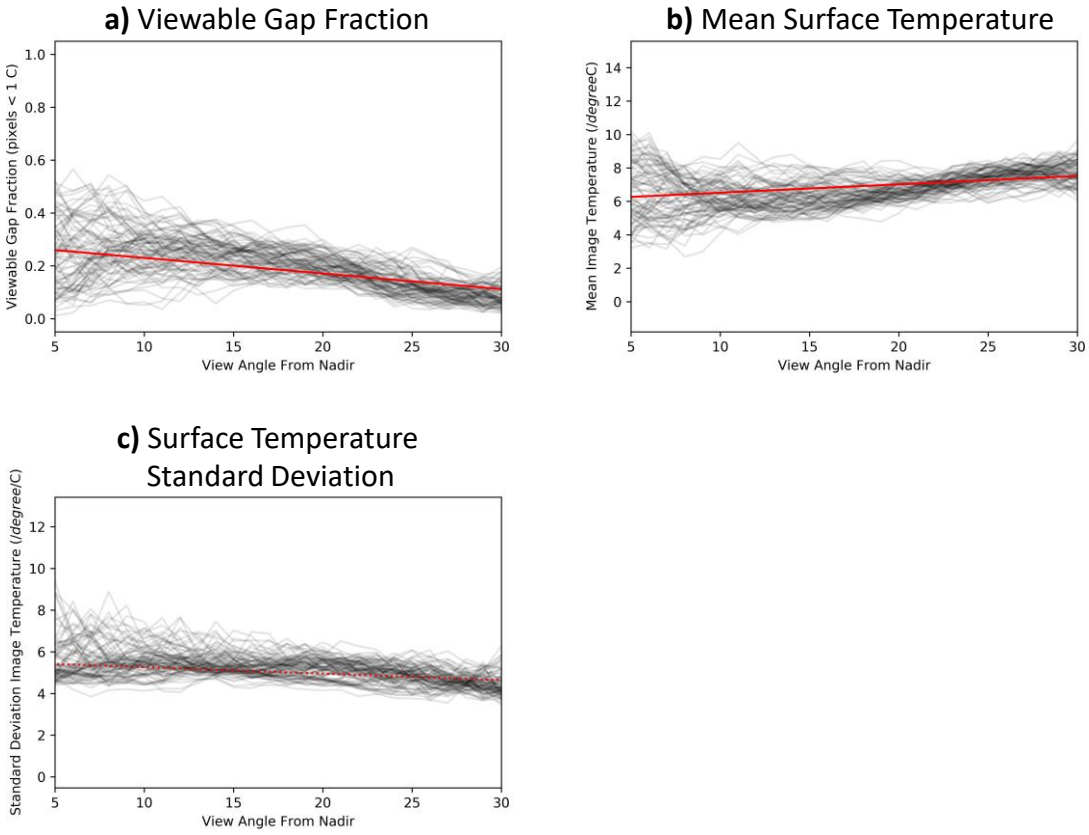


Figure S6. Trends in a) viewable gap fraction, b) mean surface temperature, and c) surface temperature standard deviation, as a function of view angle from the aircraft TIR data over Sagehen. (Computed for 1° concentric rings from 5-30° off-nadir where the number of pixels > 2500.)

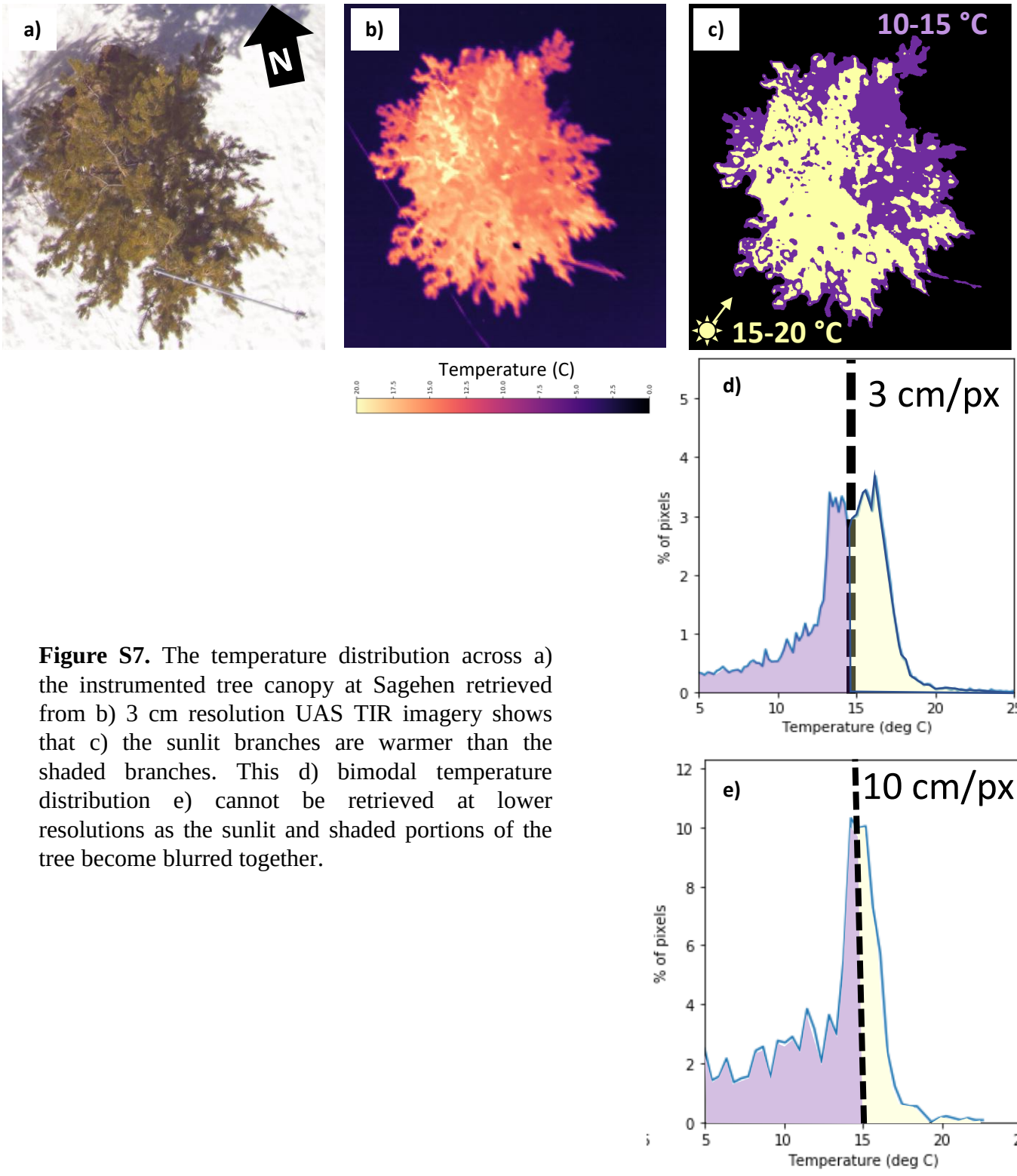


Figure S7. The temperature distribution across a) the instrumented tree canopy at Sagehen retrieved from b) 3 cm resolution UAS TIR imagery shows that c) the sunlit branches are warmer than the shaded branches. This d) bimodal temperature distribution e) cannot be retrieved at lower resolutions as the sunlit and shaded portions of the tree become blurred together.

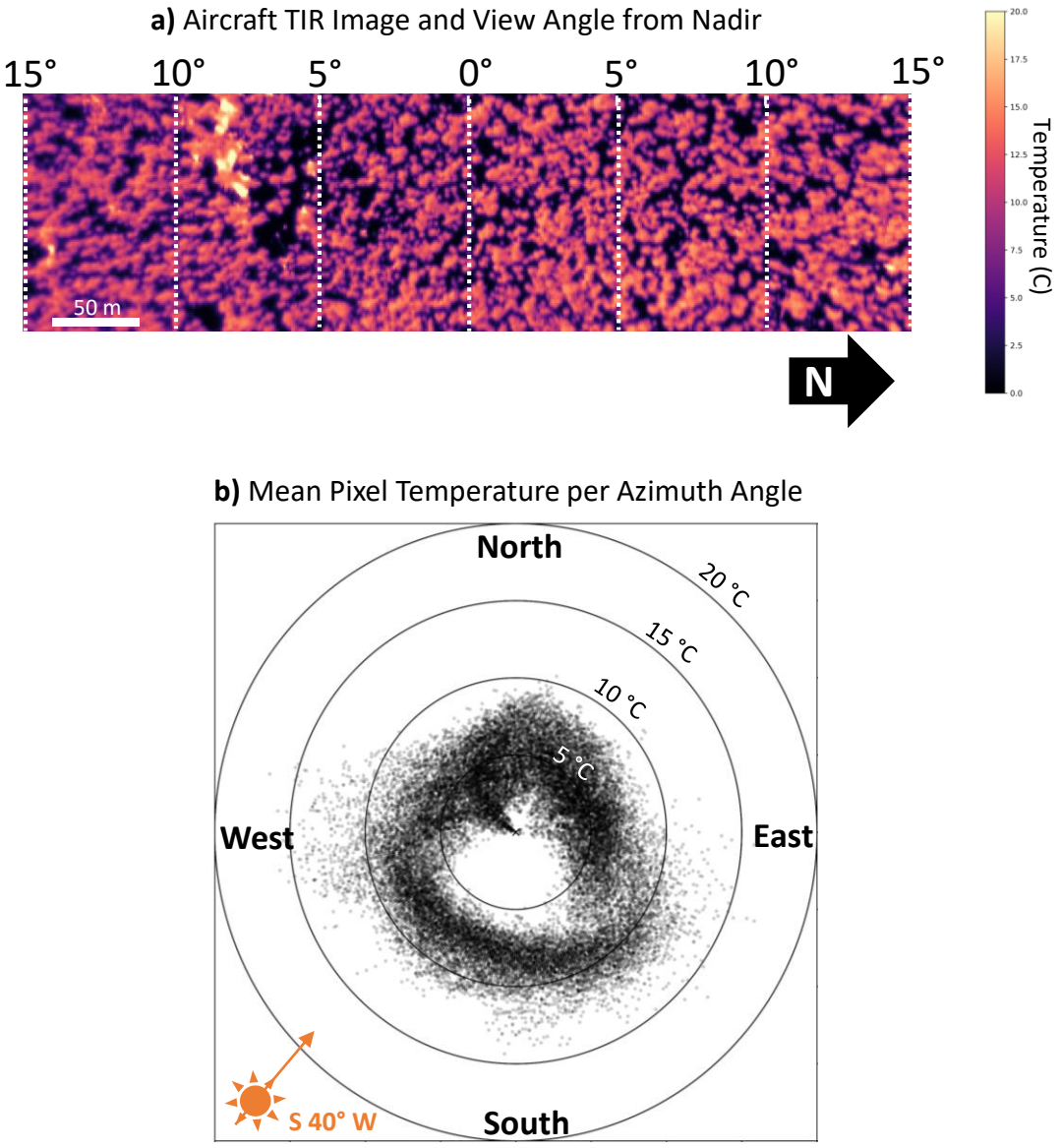


Figure S8. Forest canopy temperature variations due to incident sunlight visualized a) across a single TIR image, and with b) the mean pixel temperature per azimuth angle as viewed from the aircraft TIR system. This shows that across all images, temperatures viewed from the south were biased higher than those viewed from the north, corresponding to solar heating of south-facing tree canopies.