SnowEx20 APL-UW CASIE Brightness Temperatures, Thermal Infrared Imagery (TIR), and Visible-Band Imagery (RGB), Version 1

1 INTRODUCTION

1.1 Data Set Overview

This data set contains long-wave infrared radiometer data, thermal infrared (TIR) imagery, and visible-band (RGB) imagery from the February 2020 NASA SnowEx field campaign flights over the Grand Mesa, CO. These data are from the center, nadir-viewing radiometer; center, nadir-viewing, TIR camera; or nadir-viewing, visible-band camera. Data were collected from the NASA SWESARR flights onboard the Navy CIRPAS Twin Otter. The measurements were to document the snow, forest, and land surface temperatures over targeted points of the mesa coincident with ground survey stations and can be used to study snow remote-sensing of signatures, small-scale temperature variability (sub-satellite resolution), diurnal snow temperature variability, effects of forest cover, and thermal snow budgets.

1.2 File Information

1.2.1 Format

The data are available as NetCDF-4 (.nc) files.

1.2.2 Naming Convention

The data are named according to the following convention:

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SNEX20_CASIE_TIR_[parameter]_YYYYMMDD[THHMM]_V01.0.nc
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Where:

- SNEX20_CASIE_TIR is the short-name for the data set title, SnowEx20 APL-UW CASIE Brightness Temperatures, Thermal Infrared Imagery (TIR), and Visible-Band Imagery (RGB)
- Parameter is either TBT (brightness temperatures), TIR (thermal infrared imagery), RGB (visible band imagery), or MOSAIC (mosaicked TIR imagery)
- YYYYMMDD is the year, month, and day of observation
- THHMM is the Time in hours and minutes of the observation (NOTE this notation is only applicable for the TIR imagery)

1.3 Spatial Information

1.3.1 Coverage

Northernmost latitude: 39.07° N

Southernmost latitude: 38.88° N

Easternmost longitude: 108.01° W

Westernmost longitude: 108.26° W

1.3.2 Resolution

Varies by parameter – approximately 50m (brightness temperatures), approximately 1 to 2m (TIR imagery), approximately 5m gridded (RBG imagery and TIR mosaic)

1.3.3 Geolocation

UTM MGRS 13S WGS84 horizontal, NAVD88 vertical

1.4 Temporal Information

1.4.1 Coverage

08 February 2020 to 12 February 2020

1.4.2 Resolution

Daily flights, approx. 10 minute revisit time

2 DATA ACQUISITION AND PROCESSING

2.1 Sensor and Data Collection Methods

The Compact Airborne System for Imaging the Environment (CASIE), a suite of three thermal infrared (TIR) cameras (DRS model UC640-17), longwave radiometer (Heitronics KT15.85D), and visible-band (RGB) camera, were flown on the CIRPAS Navy Twin Otter aircraft, in cooperation with NASA's SWESARR data flights. The cameras and radiometer were deployed in the rear photo bay and were nadir viewing, with the three TIR cameras oriented to span an approximately 85 degree-wide swath. The radiometer was sampled at 30 Hz. The TIR cameras were recorded at 5 Hz The visual-band camera was recorded at 2 Hz. The aircraft followed flight lines that covered part of the Grand Mesa study site at an altitude of approximately 4000 ft AGL. GPS and IMU (inertial motion unit, Novatel SPAN system) were recorded simultaneously at 5 Hz with the image and radiometer data for accurate inter-sensor timing and later mapping.

2.2 Algorithms

Data were mapped to ground locations using the standard photogrammetric techniques (e.g. Holland et al., 1997). The radiometer data wasn't otherwise altered (i.e. the effect of atmospheric transmission loss and path radiance was not considered), apart from a running average of the original data stream. EO image data were otherwise unaltered, except that they were linearly combined where they overlapped, in the mosaicking, to reduce. TIR images were vicariously calibrated using the linear calibration:

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I_radiometer = Gr*R_camera + Gc*T_camera + Ge*T_external + I_offset
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Where I radiance, R is the camera response, T is temperature and G are gain coefficients. The G parameters and the I_offset are determined through a linear least-square fit to the observed radiometer radiance. In practice, this calibration is computed any [me a non-uniformity correction (NUC) was performed, and in this experiment that was between every transect.

2.3 Processing Steps – Brightness Temperature

After data collection, the processing followed these steps:

1. Radiometer data collected at 20 Hz was block-averaged to 2 Hz.
2. IMU (inertial measurement unit) and GPS data were interpolated to correspond to the 2Hz radiometer recording times.
3. Radiometer data ground locations were determined from GPS and IMU data and a DEM (NAVD88, National Map, http://coloradohazardmapping.com/lidar) to map to UTM MGRS 13S WGS84 using standard photogrammetric techniques.
4. Data files were created for each mission day.

2.4 Processing Steps – Thermal Infrared Imagery

1. Radiometer brightness temperature data were used to calibrate the co-aimed central camera (both nadir viewing) to produce the best linear calibration during each flight transect.
2. The TIR camera images were geo-rectified per image and per pixel to retain the highest ground mapping possible. Data were mapped to UTM MGRS 13S WGS84 using standard photogrammetric techniques incorporating attitude and position from the GPS/IMU and a DEM (NAVD88, National Map, http://coloradohazardmapping.com/lidar).
3. Data files were created for each transect, with few exceptions where transects were aborted or rerouted.

2.5 Processing Steps – Thermal Infrared Imagery Mosaics

After data collection, the processing followed these steps (see Lundquist et al., 2018 WRR):

1. Radiometer brightness temperature data were used to calibrate the co-aimed central camera (both nadir viewing) to produce the best linear calibration during each flight transect.
2. The lateral (of-nadir) cameras temperatures were adjusted (grain and offset) to match the calibrated center camera on an image-by-image basis.
3. All TIR cameras were geo-rectified and mosaicked for each transect to UTM MGRS 13S WGS84 using standard photogrammetric techniques incorporating attitude and position from the GPS/IMU and a DEM (NAVD88, National Map, http://coloradohazardmapping.com/lidar).
4. Data files were created for each mission day.

2.6 Processing Steps – Visible-band Imagery

After data collection, the processing followed these steps:

1. IMU and GPS data were interpolated to correspond to the EO (RGB visible) image recording times.
2. Candidate images were separated by individual flight transects, removing data taken during turns.
3. EO images were geo-rectified and mosaicked for each transect to UTM MGRS 13S WGS84 using standard photogrammetric techniques incorporating attitude and position from the GPS/IMU and a DEM (NAVD88, National Map, http://coloradohazardmapping.com/lidar).
4. Data files were saved for each mission day.

2.7 Data Quality and Errors

The KT-15 radiometer used for vicarious calibration has a 0.5 K accuracy, as per the manufacturer specifications (see https://www.heitronics.com/wp-content/uploads/KT15.85-IIP-Data-Sheet-EN.pdf for more). Error propagation through the calibration provides an estimate of about 1.1K standard accuracy error for the calibrated TIR imagery.

Empirical error analysis outlined in:

Pestana, S., Chickadel, C. C., Harpold, A., Kostadinov, T. S., Pai, H., Tyler, S., et al. (2019). Bias correction of airborne thermal infrared observations over forests using melting snow. Water Resources Research, 55, 11331– 11343. https://doi.org/10.1029/2019WR025699

and discussed in:

Lundquist, J. D., Chickadel, C., Cristea, N., Currier, W. R.,Henn, B., Keenan, E., & Dozier, J. (2018). Separating snow andforest temperatures with thermal infrared remote sensing. Remote Sensing of Environment, 209, 764-779. https://doi.org/10.1016/j.rse.2018.03.001

show that theoretical error analysis is likely a lower estimate for accuracy, and that it is important to consider bias and spatial variability in radiative estimates of snow, land, and forest temperatures. No error analysis is provided for the RGB imagery; they are offered as a visual reference only.