Assessing Small Scale Variability in Surface Snow and Landscape Temperature using Drone-Based Thermal Observations

Jeremy Johnston, Paul Houser, Viviana Maggioni
George Mason University, Fairfax, VA

MOTIVATION & BACKGROUND

- **Goal to observe the evolution of snow surface temperature (SST) and freeze/thaw (FT)** throughout a **single day**
- Provide information on **landscape surface temperature variability** for **high-resolution (spatial/temporal) process modeling**
- **Investigate the potential uses of emerging drone technology for applications in SST and FT processes**
  - **Drone PROS: affordable, repeatable flights, rapid deployment, high-resolution (cm scale), relatively simple acquisition process, minimal atmospheric effects on imagery, ability to fly below cloud deck**
  - **Drone CONS: limited areal coverage, limited sensor precision/characterization, flight highly dependent on weather conditions**

METHODOLOGY/CALIBRATION

DJI Inspire 2 – Dual Gimbal-Mounted Thermal and RGB Cameras

FLIR Vue Pro R (left), DJI Zenmuse X4S (middle), sUAS 2-axis gimbal w/ FLIR (right)

Calibration Target (+/- 0.5 °C accuracy)

Data Collection and Processing Workflow

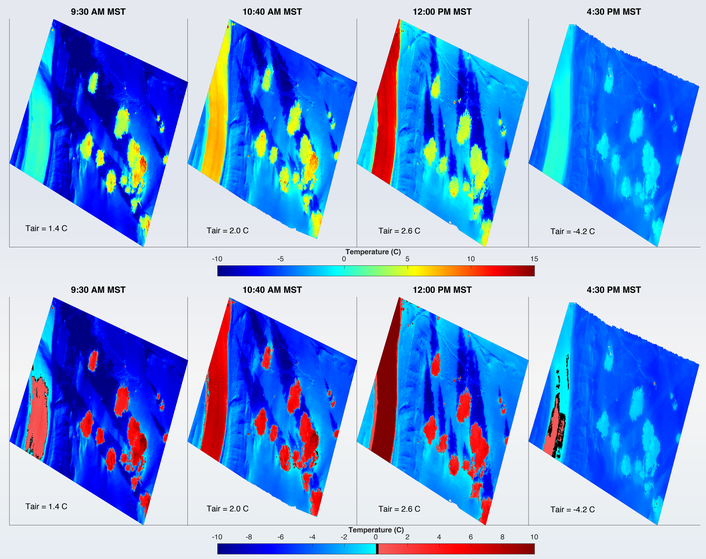
Flight Planning → Data Collection → Vignette & Movement Corrections → Drift Correction → Develop Calibration Curve → Orthomosaic Creation → Error and Image Analysis

- **Study Area:** Grand Mesa, Colorado [~3,200 m, 108.065° W 39.042° N]
- **Data Collection Period:** February 2, 2020 (9:30 AM, 10:40 AM, 12 PM, 4:30 PM - MST)
- **System Specifications**
  - DJI Inpsire 2: Weighs 2.4kg w/ payload capacity ~1kg, up to 30 min flight time
  - Zenmuse X4S: 20-megapixel RGB camera, mounted on DJI built in gimbal
  - FLIR Vue Pro R: Radiometric thermal camera [7.5 – 13.5 µm], uncooled microbolometer, 640 x 512 pixels, stated accuracy +/- 5 °C (or 5% of measurement)
  - Thermal Vision 2-axis gimbal w/ GPS and data logging
- **Data Resolution (TIR):** 6.5 cm GSD (@ 50 m flight altitude)
- **Image Collection and Flight Planning:** Pix4D auto-pilot flight plan, FLIR automated image capture at 2 second intervals, Zenmuse RGB capture automated in Pix4D software
- **Ground Observations:** Contact and IR measurements of ground targets (snow, vegetation) continuous measurement calibration targets, and meteorological station w/ weather and soil temperature data (Skyway meteorological tower ~1 km NE)

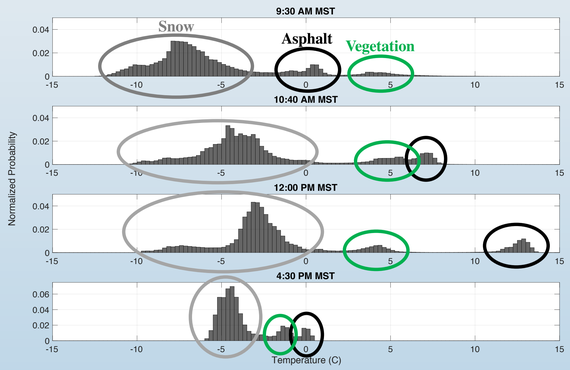
TAKEAWAYS

- **No snowmelt was observed over the focus study location even as temperatures approached 4 °C (~40 °F)**
- **Image calibration improved accuracy to around +/- 2 °C (from +/- 5 °C)**
- **High-resolution imagery allowed identification of small-scale processes: i.e. warming of SST on sun facing side of trees, shadow cooling, and showed consistency of vegetation temperature throughout the day**

RESULTS



Top – Resulting calibrated surface temperature map over study focus region (90 m x 80 m section of full flight domain), Bottom – Thermal imagery over focus area in which red indicates temperatures above freezing (trees/roadway) and blue indicates temperatures below freezing (snow surface)

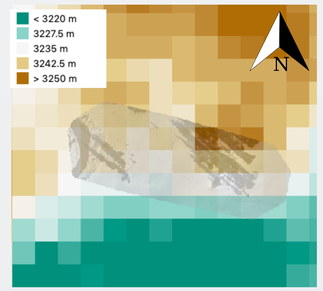


Temperature (°C) Mean	SD	Error (°C) Bias	RMSE
-5.41	4.07	-0.54	1.83
-2.40	4.44	-2.11	2.84
-1.03	5.37	-1.38	2.02
-3.70	1.62	0.59	1.78

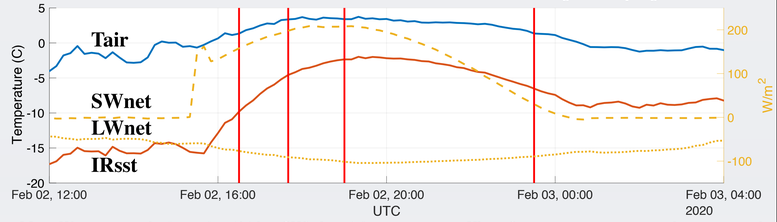
Temperature histograms from project focus area (cropped portion of the region shown in the above figure), with temperature (average, standard deviation), and error metrics (bias, RMSE)

STUDY PLOT CONDITIONS

Study site RGB imagery with calibration target locations indicated



Elevation from ASTER 30-m DEM with full visible RGB image of study region overlaid



Mesa West meteorologic station (14 km SW) data (air temperature, IR surface snow temperature, shortwave and longwave net radiation). Flight times indicated by red lines, awaiting QC met data from nearby Skyway met. site

DISCUSSION & CONCLUSIONS

- **TIR observations appeared to match well with nearby meteorologic station IR measurements of the snow surface**
- **Standard deviation of SST shown to decrease throughout the day**
- **Trees maintain consistent temperature throughout daytime (~ 4 °C)**
- **Patterns observed in SST due to influences of vegetation, shading**
- **SST did not climb above freezing** during flights, **even as air temperatures climbed above freezing** for an extended period
- **Clear thermal drift and vignette effects were observed in the collected imagery requiring non-trivial calibration to correct**
- **Next Steps**
  - Modeling small scale surface temperature processes, including snow melt
  - Comparing drone mapped TIR to satellite- based thermal and microwave observations
  - More flights and equally spread out flights, beginning earlier to capture more complete picture of warm up and cool down
  - Apply knowledge to downscaling of FT processes

RELEVANT PUBLICATIONS & ACKNOWLEDGEMENTS

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For more information contact Jeremy Johnston: jjohns60@gmu.edu