Observing and Modeling Drainage Networks from Supraglacial Lakes on Russell Glacier, West Greenland (Honors Capstone)

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Introduction

- During the summer, meltwater accumulates in lakes (supraglacial lakes) on top of the Greenland Ice Sheet (GrIS)
- Meltwater can be removed from the GrIS via holes in the ice sheet (moulins) and by lakes overtopping and draining off the ice sheet

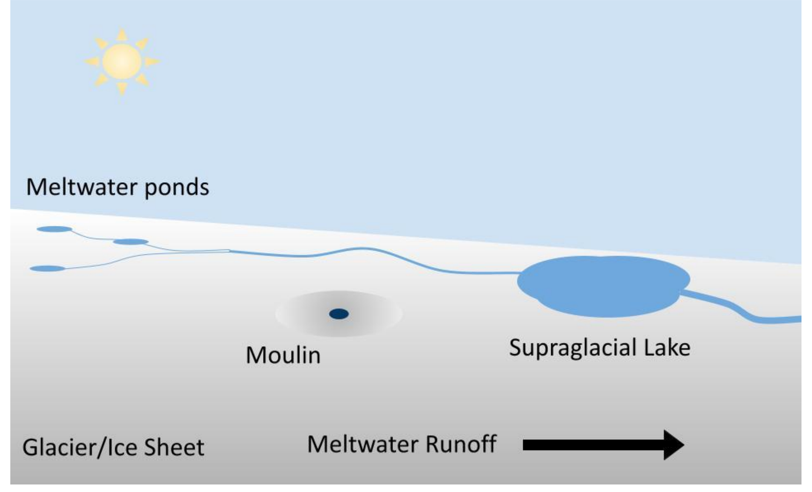


Figure 1. Diagram detailing supraglacial lake formation and dynamics.

- Supraglacial lakes and meltwater dynamics impact meltwater runoff calculations and ice dynamics in climate models and sea level rise estimates
- This study aims to understand and predict the processes associated with supraglacial lakes by analyzing satellite observations and constructing a meltwater dynamics model for a section of the GrIS near Russell Glacier

Methods

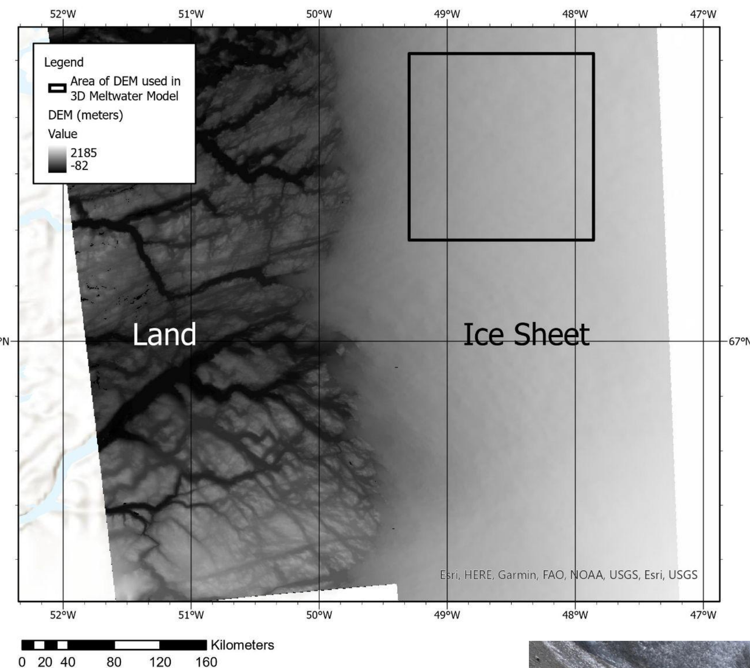
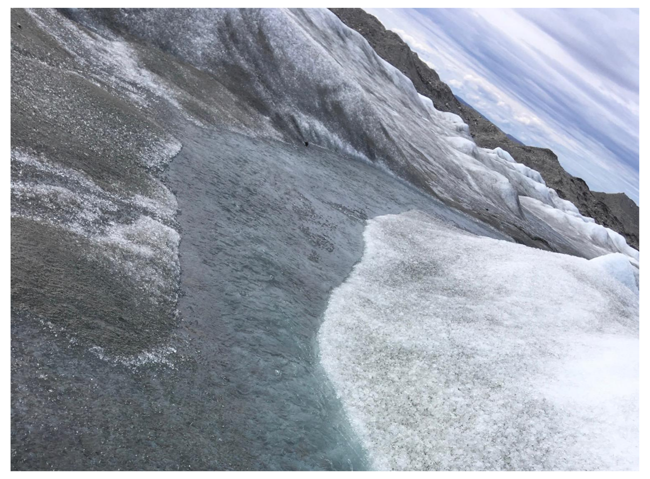


Figure 2. (Left) Study area on western GrIS highlighted in the bound box. Area covers approximately 25,000 km^2.

Figure 3. (Below) Photo of meltwater draining off the edge of Russell Glacier. Taken June 21, 2019.



- Observations covered the 2019 melt season (May - August)
- Observed lakes were identified from images by an index (NDWI)
- Lake characteristics (area, elevation) were compared to a measure of radiative forcing, cumulative Positive Degree Days (PDDs)
- 3D meltwater model driven by an elevation model of the GrIS and meltwater approximated from PDDs
  - Only method of meltwater removal is runoff
  - 32 m x 32 m resolution
  - May 1, 2019 to August 31, 2019 in 1 day timesteps

Results

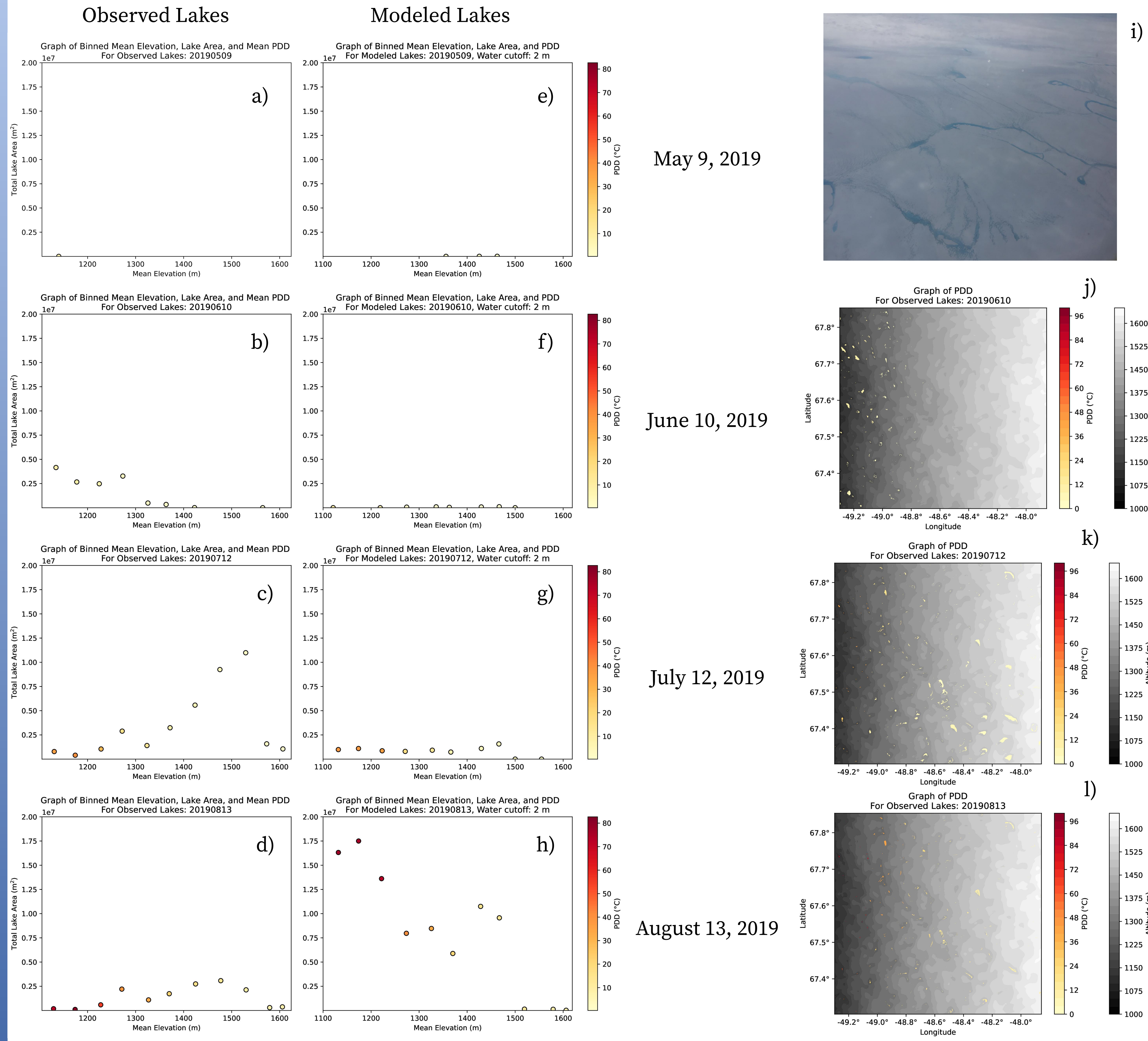


Figure 4. (a-d) Total lake area vs mean lake elevation overlaid with mean cumulative PDD for observed lakes, binned by mean lake elevation (50 m width) for the dates (top to bottom) May 9, June 10, July 12, and August 13 of 2019. (e-h) Total lake area vs mean lake elevation overlaid with mean cumulative PDD for modeled lakes (water depth above 2 m), binned by mean lake elevation (50 m width) for the same dates (top to bottom) as the observed lakes. (i) Picture of supraglacial lakes on the GrIS taken from a plane on June 24, 2019. (j-l) Maps of observed lakes overlaid with cumulative PDD for the dates (top to bottom) June 10, July 12, and August 13 of 2019.

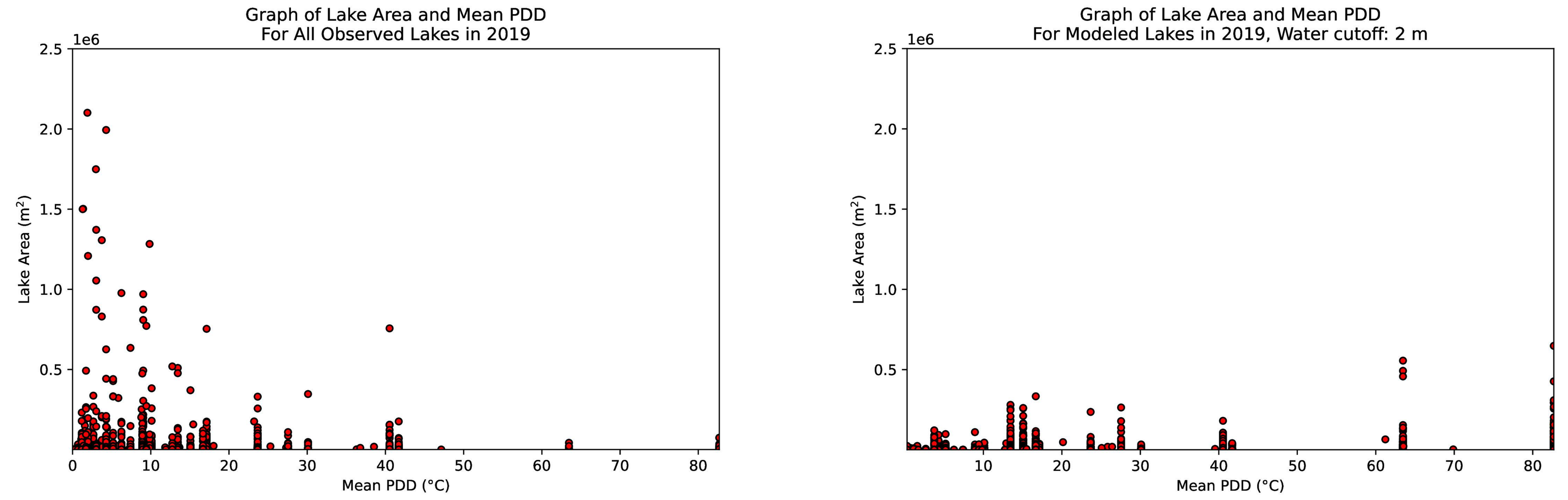


Figure 5. (Left) Lake area vs mean cumulative PDD for observed lakes, with all four dates (May 9, June 10, July 12, and August 13 of 2019) plotted on the same graph. (Right) Lake area vs mean cumulative PDD for modeled lakes, with all four dates (May 9, June 10, July 12, and August 13 of 2019) plotted on the same graph.

Conclusions

- Observations
  - Lakes form at low elevations early in the melt season and form at increasingly higher elevations as the season progresses and the cumulative radiative forcing increases
  - Once new lakes reach a large enough size, they seem to shrink or disappear entirely, likely due to moulins forming
- Meltwater Model
  - The model reproduces some of the spatio-temporal patterns in the observations and overestimated lake coverage at low elevations
  - The control mechanism on patterns of lake area and elevation is not solely meltwater runoff
  - Moulins must be responsible for lake coverage reduction at low elevations
- Results from observational and model analyses suggest that moulins are a critical mechanism for meltwater drainage off of the ice sheet and reduction in lake area
- Future work should involve adding moulin parameterization to observe how that changes the meltwater model results

References

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Acknowledgements

DEMs provided by the Polar Geospatial Center under NSF-OPP awards 1043681, 1559691, and 1542736. Geospatial support for this work provided by the Polar Geospatial Center under NSF-OPP awards 1043681 and 1559691. Landsat 8 data available from the U.S. Geological Survey.

Thank you to Jeremy Bassis for his enthusiasm and mentorship the past 3 years on this project.