Abstract for Digital Terrain Analysis Project

Examining Ice Volume Change in the Northern Cascades, Washington

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Glaciers are important sources of water for their surrounding localities. Because of their dependence on temperature and precipitation, they also are good indicators of shifts in climate. This study will apply the Regional Glaciation Model (RGM) to the North Cascades, Washington. The RGM is a distributed 2-dimensional model that incorporates a Positive Day Degree (PDD) melt model and calculates the volume change of the glacier at one-year time intervals. Using future climate projections, the change in ice volume between 1970 and 2050 will be estimated at a 100m resolution. To refine the resolution to 10m, a tension spline interpolation was applied to the original model output. We find that the RGM predicts ice volume to decrease by ~8.63 km3 and that an interpolated raster of increased resolution predicts less than a 0.03 km3 difference in volume change.

The observed glacier extents circa 1970 are also used to determine the accuracy of the model output by checking ice location misfit and the difference between volumes. We find that there is a 31.0% volume difference between the observed and modeled ice. With this uncertainty, the model predicts -8.63 +/- 2.58 km3 in ice loss between 1970 and 2050, indicating that there could be anywhere between 1.59 km3 to 6.75 km3 left in the North Cascades in 2050 of the modeled 12.80 km3.

Keywords: North Cascades, Glaciers, regional glaciation model, positive day degree, volume change, Washington

Mt Baker’s Easton Glacier

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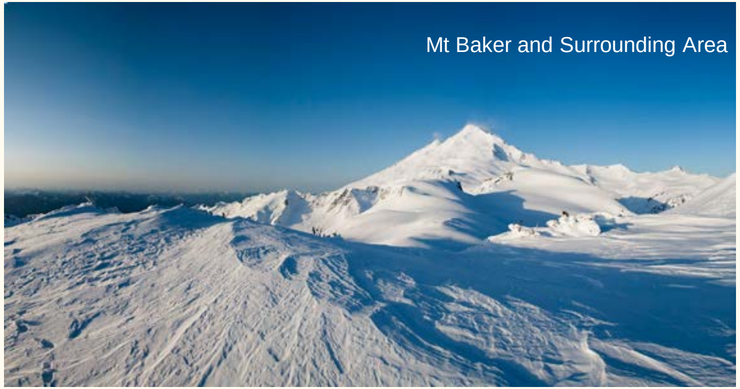
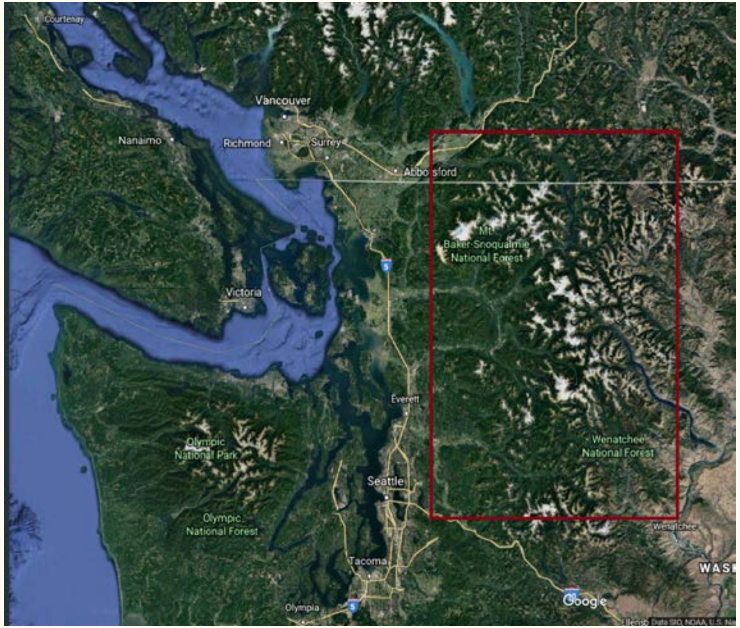
Background

- Ice is melting. This is a problem. We need to know by how much (Dick, 2013; Granshaw, 2006)!
- Hydroelectric energy, water supply, fish habitats (Khalsa 2004, Dick 2013).
- Using a Regional Glaciation Model (RGM) to estimate volume change
- The North Cascades contains a lot of ice and is important for the surrounding localities
  - Also, the RGM works best in regions with a lot of ice





Regional Glaciation Model (RGM)

- Includes:
    - Surface mass balance (accumulation-ablation over the glacier and land surfaces)
        - Can differentiate between rain and snow precipitation, and ice and snow on the glacier face.
    - Ice dynamics to simulate ice flow.
        - Shallow Ice Approximation equations
        - Assumes isothermal ice
- Inputs:
    - DEM from the shuttle radar topography mission ~1970
    - Subglacial bed topography DEM, estimated from the 1970 DEM.
    - Spatial climate data (PRISM)
    - Global Circulation model (CMIP5, RCP8.5)
- Spun up from year 0, then uses the GCM to add monthly and yearly variation to the PRISM data

Methods: Volume Change and Interpolation

- To interpolate or not to interpolate
  - Original DEM had coarse resolution (100m)- resulting model output also has coarse resolution
  - Used spline - tension type to get finer resolution (10m)
  - Created a finer resolution output- smoothed data
- Volume change in ArcMap
  - Calculated volume change between 1970 and 2050
    - Model output- ice depth layer
    - Raster Calculator: volume = depth x cell size
    - Ice volume-
      - all pixel values x count (# of times that value occurs)
      - Calculate Statistics- Sum
- Spline vs. original model output comparison
  - Hypothesis- Spline interpolation to increase cell resolution would create a surface that more accurately captured changes in ice volume through time than the original low resolution output.
  - Reality- Not a lot of difference

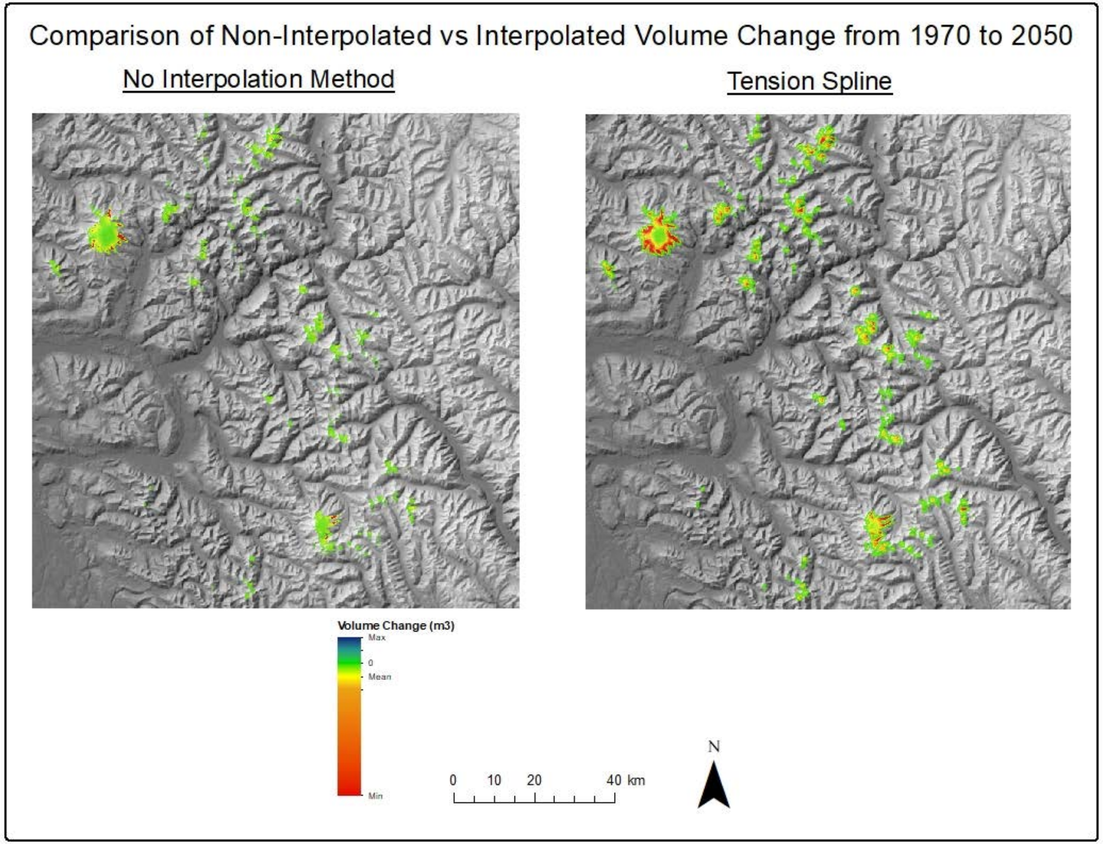
Methods: Model Accuracy

- Model input DEM from ~1970 compared to the model output DEM compared to 1970
  - Look at volume of both to get volume uncertainty range
- Percentages are based on the percent of observed area.

(Modeled-observed)/Observed

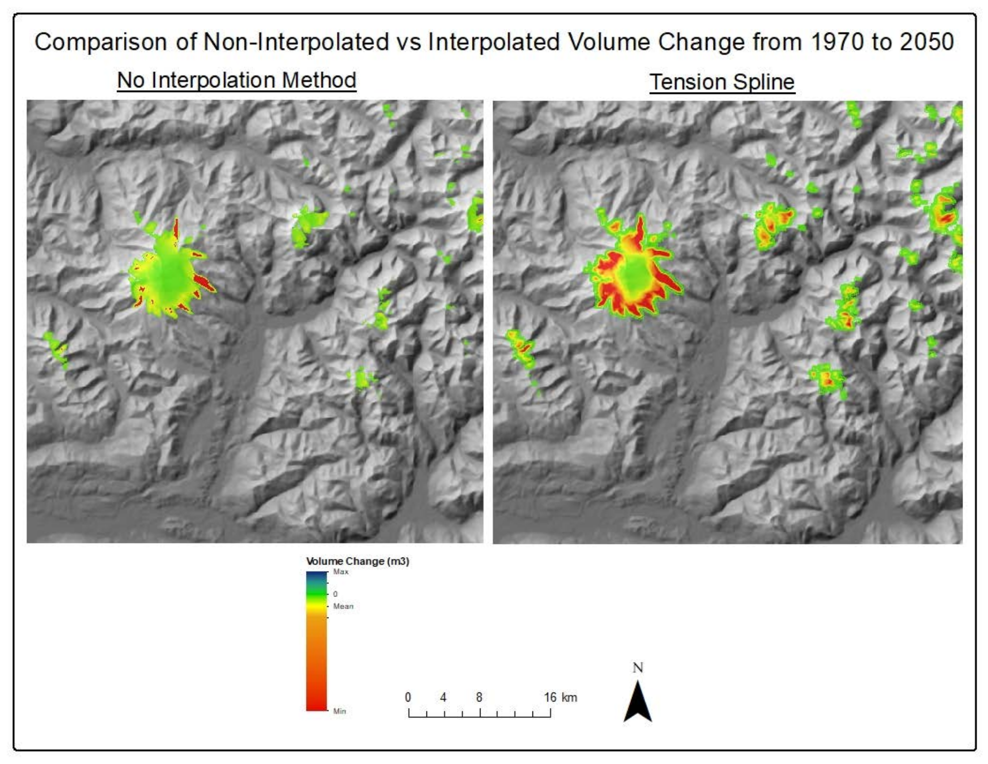
Results: Volume Change (1970-2050)

- The ice is melting!
- Original Model Output Volume Change: ~ -8.63 km3
- Interpolated Volume Change: ~ -8.66 km3
- Difference: 0.03 km3
  - This is a huge amount of ice (9200 olympic swimming pools), but only ~0.35% of the total observed volume in the North Cascades



Results: Interpolation

- Comparison of the original model output (100mx100m) to the new interpolated raster (10mx10m)
- We can see that the coarser raster shows more dramatic change throughout the region than the interpolated raster
- Interpolated model captures small changes better.
    - More yellow and orange cells captures small changes in mid range values better.



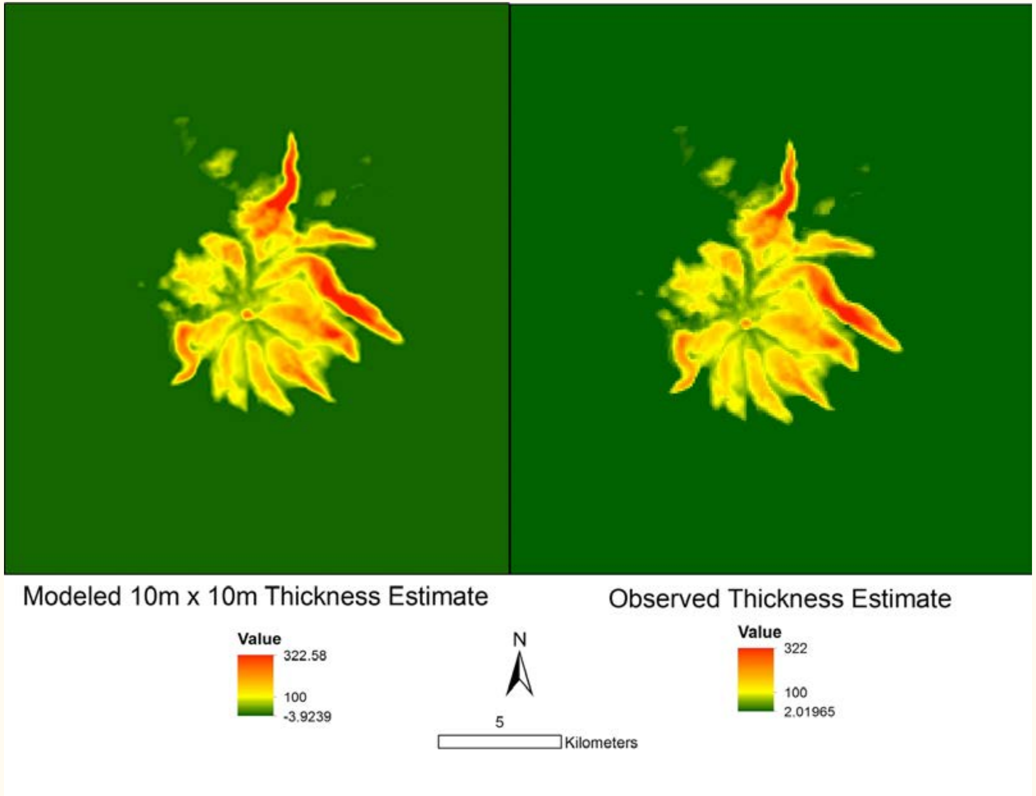
Model Accuracy: Volume

Observed Volume: ~8.49 km3

Model Volume: ~12.80 km3

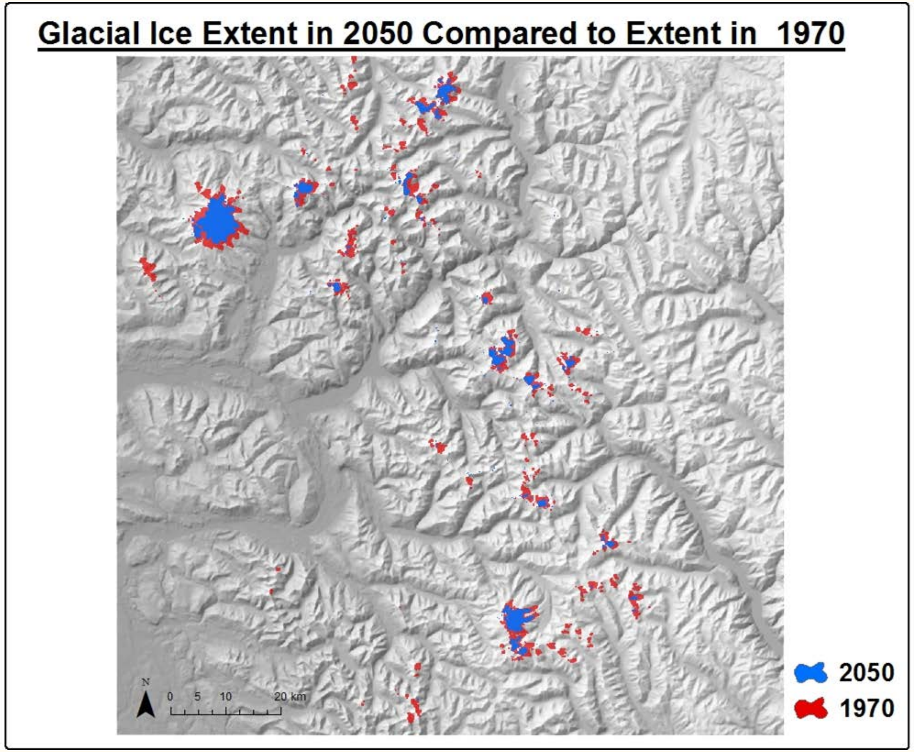
Difference: 4.01 km3, or ~31%

While this is a large difference, because the model is overestimating the volume it could indicate a conservative estimate in volume change.



Conclusions

- Original model output volume change: -8.63 km3
- Interpolated volume change: -8.66 km3
- Interpolation doesn't lead to a large difference in volume change values.
- Total Volume uncertainty: 31%
- Based on the original model output, we estimate that volume change between 1970 and 2050 to be -8.63 + /- 2.58 km3, or 6.05 km3 to 11.21 km3.
    - In 2050 only 12.24 - 52.73% of the 1970 ice will remain.
- This is ~3,166,973 Olympic swimming pools of water!
- Ice melt will have a big impact on ecosystems and communities (Dick 2013, Khalsa 2004)



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Model Accuracy: Location Misfit

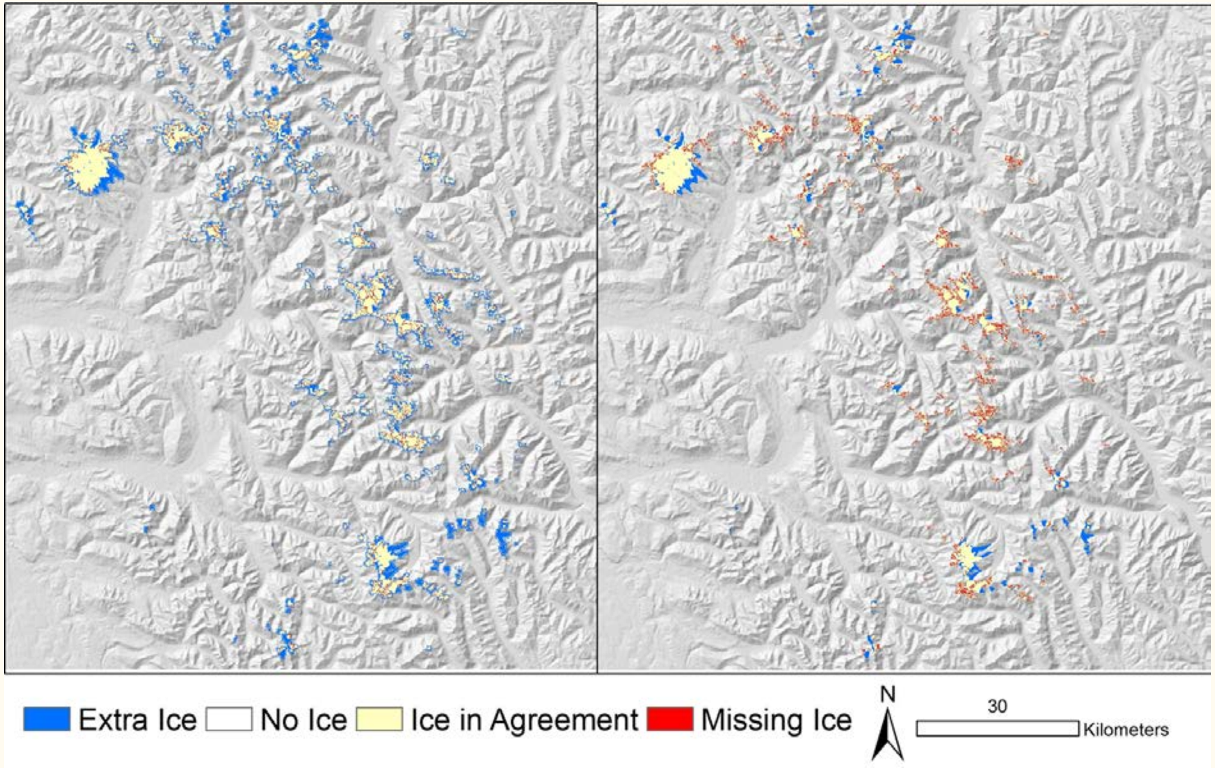
Original model output misfit area: 184.23 km2

Observed Total Area: 349.91 km2

Percent Error: 52.7%

Extra ice: 22.7%

Missing ice: 30.0%



Model output plus interpolation

Original Model output

This missing and extra ice roughly cancel each other out

Model Accuracy: Location Misfit