Spatial Distribution of Ice in the North Cascades: Using GIS to Determine the Effect of Topography and Climate on Glacier Distribution

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Introduction

Deglaciation, and the overall receding distribution of glaciers in alpine ecosystems, is a pressing concern to the world at large.

Glaciers are:

- Climate indicators
- Sources of water and modulate ablation season streamflow
- Sources of sea level rise
- Can affect the surrounding ecosystems

Previous research has both supported the effects of elevation, aspect, and slope on glacier mass and distribution (Tangborn et. al., 1990; Dick, 2013), while other studies have found little correlation between topography and glacier size (Granshaw and Fountain, 2006).In order to better create accurate models of glacier mass and retreat, more comprehensive work needs to be done on the contributing factors to glacier distribution.

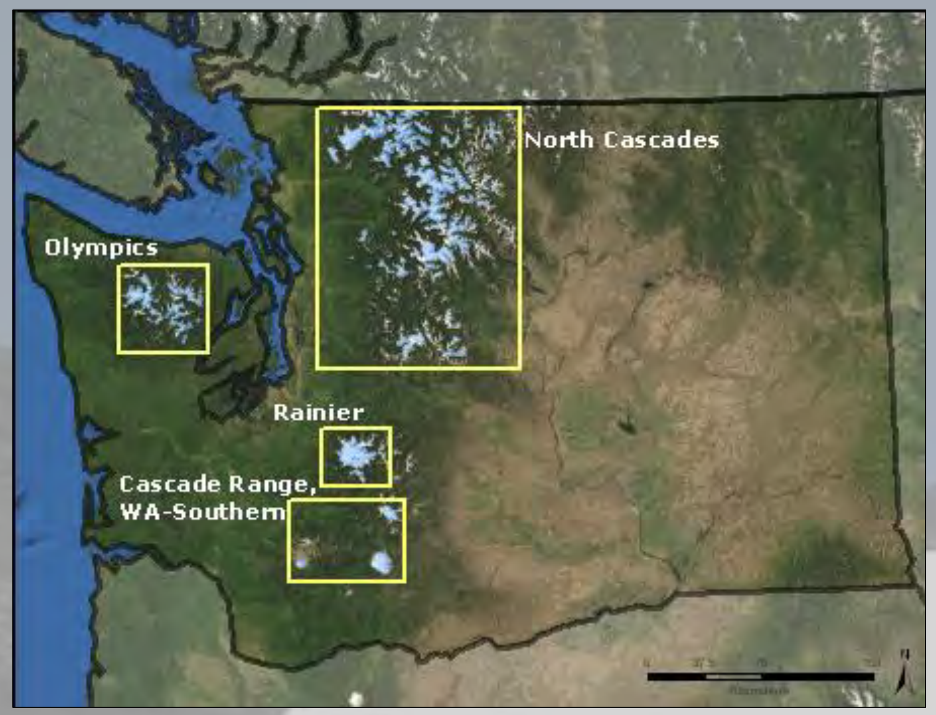
Background

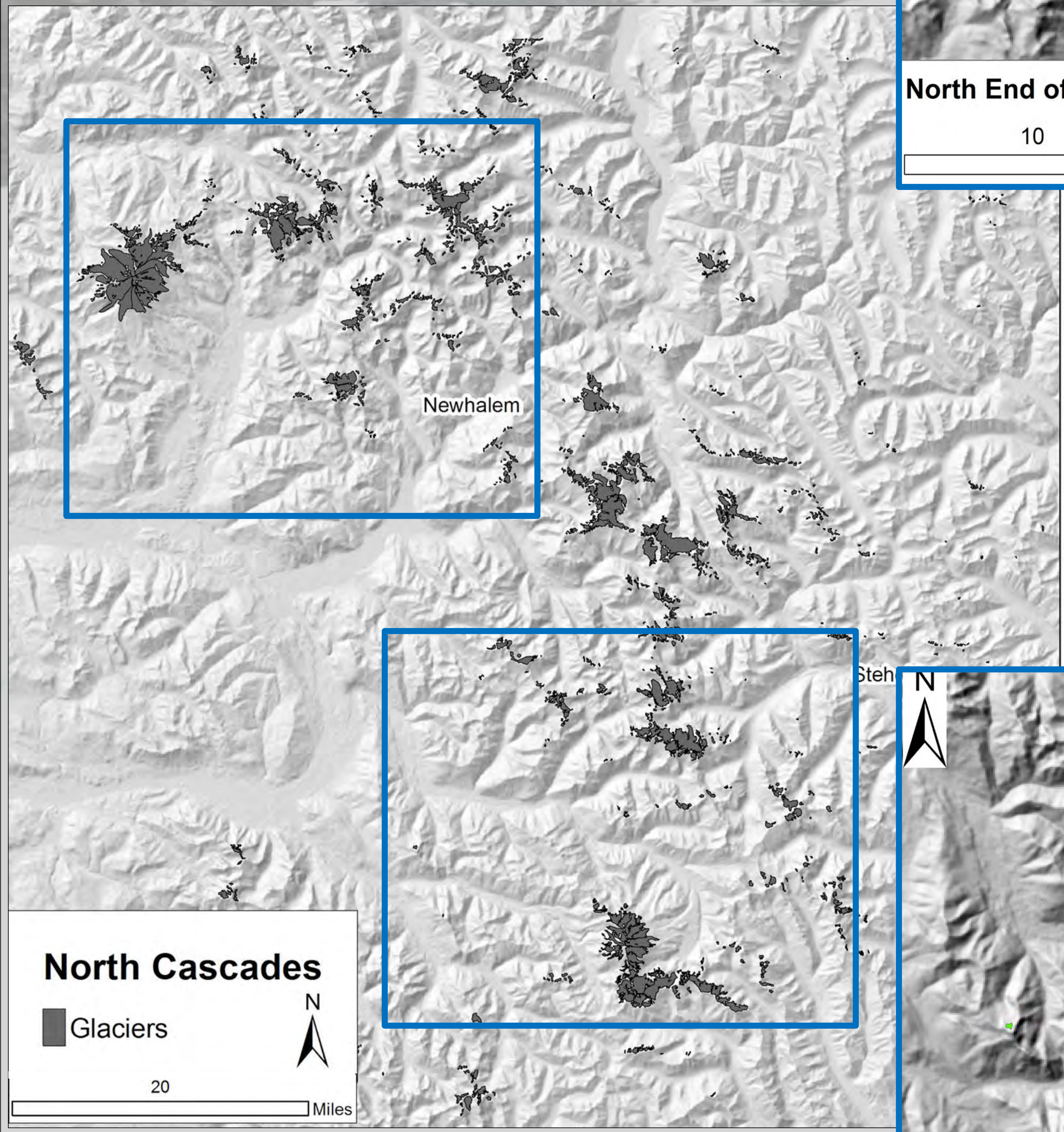
- Ice area of 288.4 ± 0.26 km^2, the largest concentration of ice in the American West
- Temperate, maritime glaciers, very vulnerable to climate change.
  - The ice is at melting point and,due to proximity to the Pacific Ocean, glaciers receive large amounts of precipitation.
  - Increasing spring and fall temperatures can shift the timing of the melt season and the phase of winter precipitation.

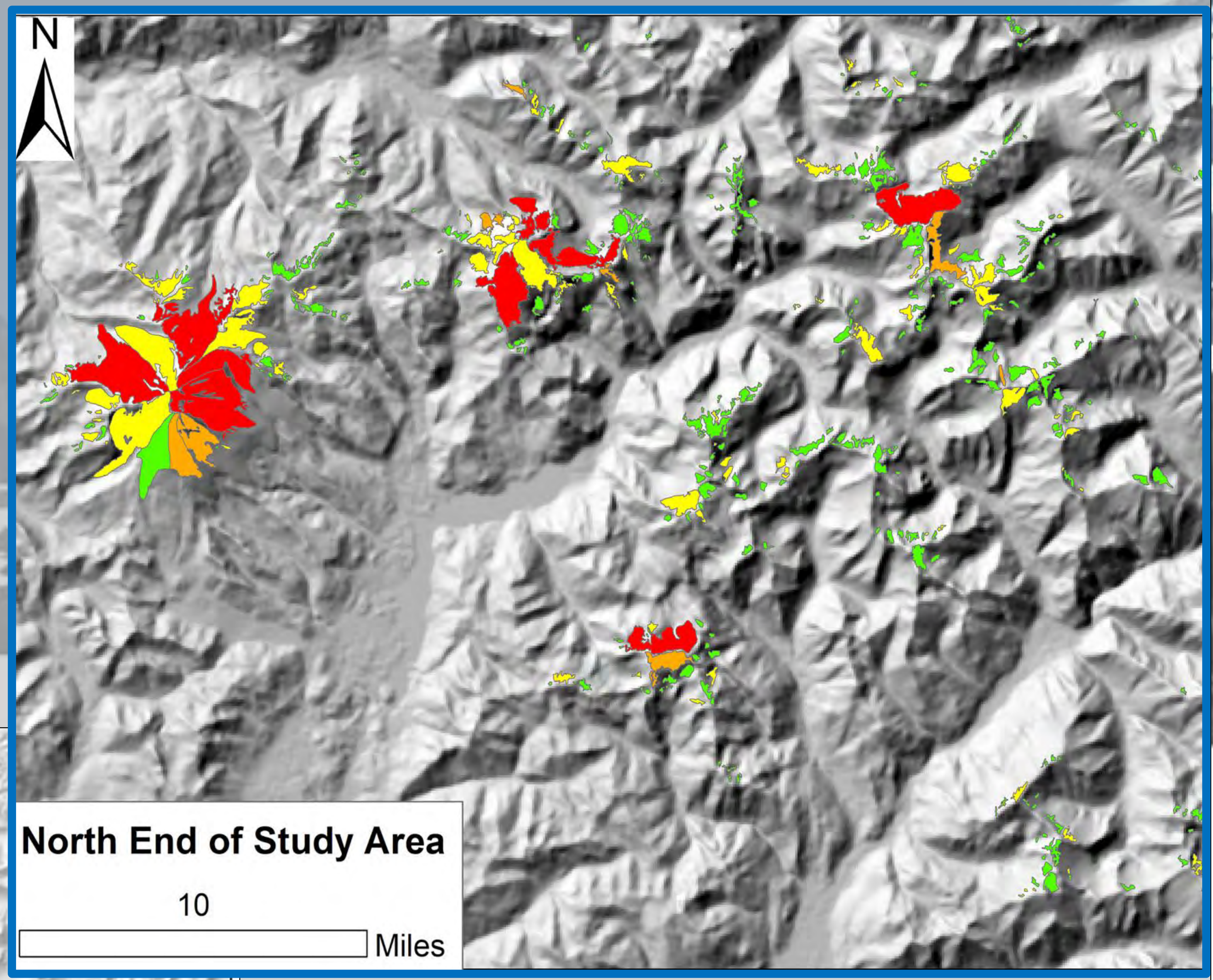
Methods

- The data is processed using the 24K outlines for the North Cascades (USGS, 1998) and zonal statistics is used to summarize topographic data derived from ArcMap and 1960-1969 annual and seasonal climate averages from the PRISM dataset (Daly et al., 2008).
- An Exploratory Regression that employs Ordinary Least Squares Regression (OLS) is used.
  - This determines statistical relationships in the data which is used to determine which parameters are likely to best describe ice distribution and redundancy in the variables.
- A Geographically Weighted Regression (GWR) is used to determine if spatial autocorrelation has an effect on the chosen variables.

Regression Results



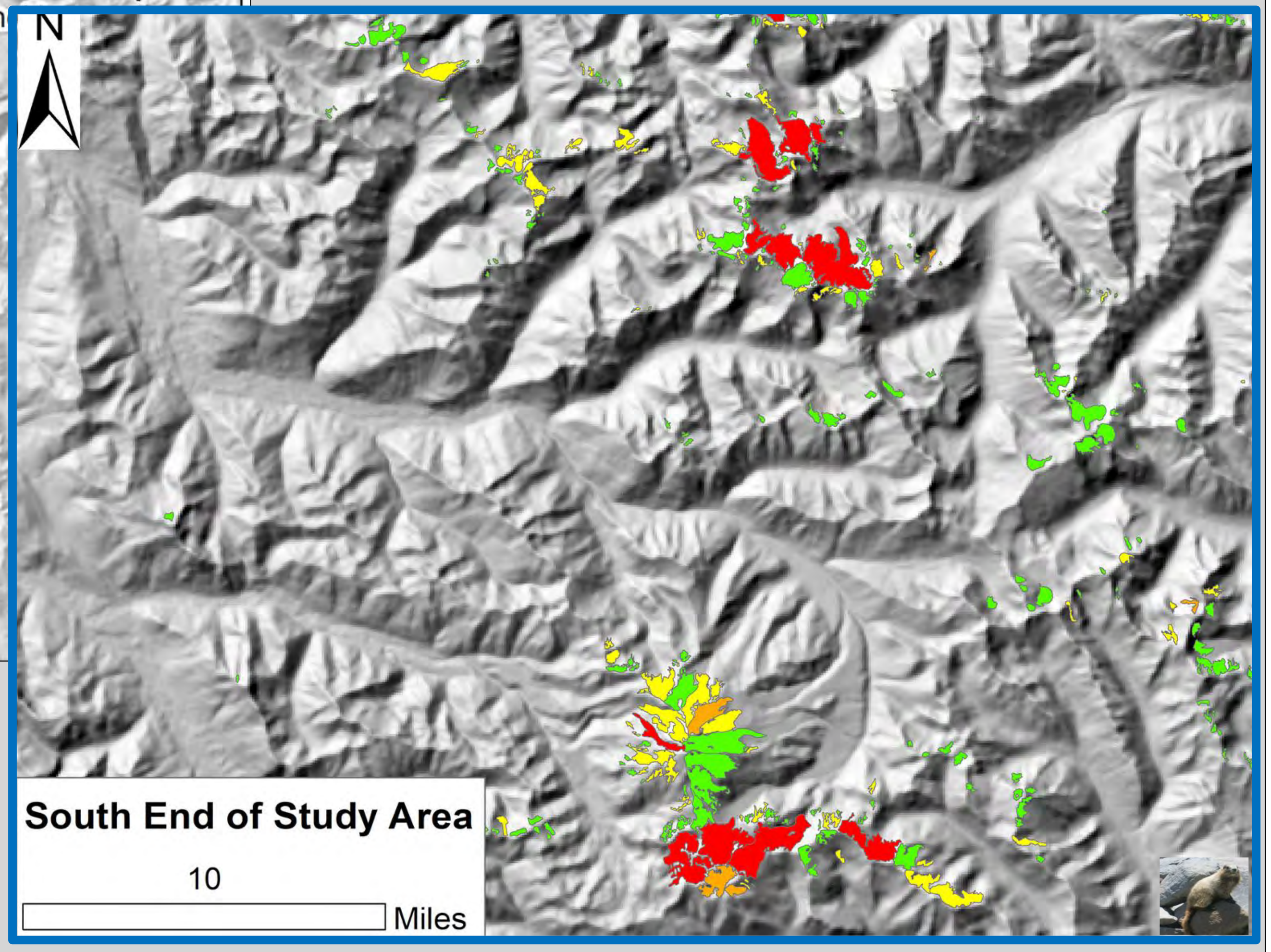




North and South Study Areas

Standard Deviation of Residuals

- < -2.5 Std. Dev.
- -2.5 - -1.5 Std. Dev.
- -1.5 - -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- 1.5 - 2.5 Std. Dev.
- > 2.5 Std. Dev.



OLS Regression

Area = (-0.0172)*Slope + (0.0004)*Precip + (-0.0166)*Temp + (0.0017)*ElevRange + (0.0365)* Northing + 0.2398

Regression Results

After conducting the OLS, it was determined that seasonal and annual climate values were redundant with each other. Therefore only annual temperature and annual precipitation for the 1960-1969 time period were used.

- Topographic factors of elevation range, means slope, and northing were determined to explain most of the ice distribution.
- These variables were used in our GWR and we found that our Adjusted R^2 increases from 0.5703 to 0.6956, indicating that ice distribution is spatially dependent.
  - Randomly oriented residuals indicate that the GWR model is good for the entire region.

Discussion

- Larger glaciers are not captured well in the GWR
  - This could be because the small glaciers are easier to predict since their existence is more dependent on topography (Kuhn, 1995).
    - If the models were fit to the smaller ice bodies, which make up most of the region, which are more dependent on topography, then a greater contribution of topography of glacier distribution makes sense.
    - Conversely, larger glaciers are more exposed to the elements, and topography is less important
      - Possibly this region should have been divided into large and small ice bodies to better constrain each type of ice.
- It is possible that other important variables were necessary to raise the Adjusted R^2 value.
  - These include but are not limited to latent and sensible heat, insolation, wind redistribution of snow, and avalanching.
- The climate data was also very coarse, and the choice of time scale could reduce the effectiveness of climate.
- It is possible that normalization of the data by calculating correlations of variables to ice area or z-scores could create a more accurate model.

Conclusions

- OLS and GWR results indicate that topographic variables are the best describers of ice distribution, and climate is secondary.
- Appling a GWR to the data increases the Adjusted R^2 Values, indicating that ice does vary spatially.
- Larger ice bodies are poorly constrained in the GWR model, possibly because they are related more strongly to climate and less so to topography.

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