Constraining Paleoclimate Estimates Using a Combination of Paleo Glacial and Terminal Lake Shoreline Evidence

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Abstract:

The arid Southwest US recently experienced some of the worst droughts in recorded history and future climate predictions suggest that these events may be more severe in the future. Glacier moraine and terminal lake shoreline evidence from the last deglaciation indicate that the southwest U.S. underwent a series of rapid temperature and precipitation changes. The ability for the southwest climate to suddenly transition between these different hydrological states is alarming, and emphasizes the need to understand the mechanics behind these transitions. The focus of this work is to use computer models of glacier and terminal lake systems in the Eastern Sierra Nevada, CA with existing moraine and terminal lake shoreline evidence to estimate changes in climate during the last deglaciation. The modeling approach for each individual system results in a set of non-unique climate (air temperature and precipitation) solutions that support the paleo climate evidence (i.e., glacier moraine or terminal lake shoreline). The range of possible climate solutions are significantly reduced when the results for multiple systems are combined for a single point in time.

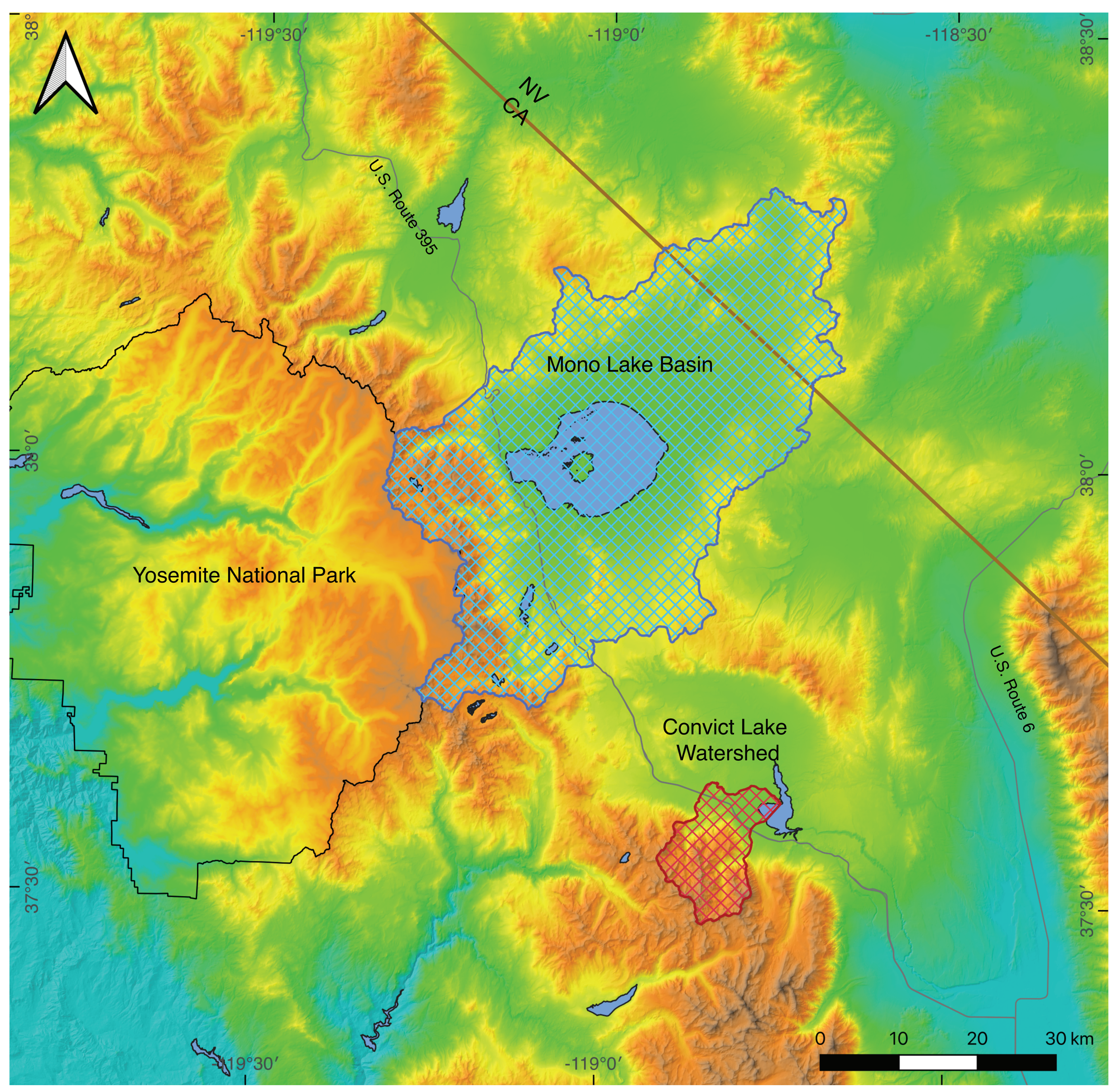

Figure 2. Both Mono Lake and Convict Lake are found on the Eastern Slopes of the High Sierra Nevada, just east of Yosemite National Park. The two study sites are approximately 40 km apart in similar valleys on the Leeward side of the Sierra Nevada and thus are assumed to have experienced nearly identical climate variations in the glacial and deglacial past.

Mono Lake Model

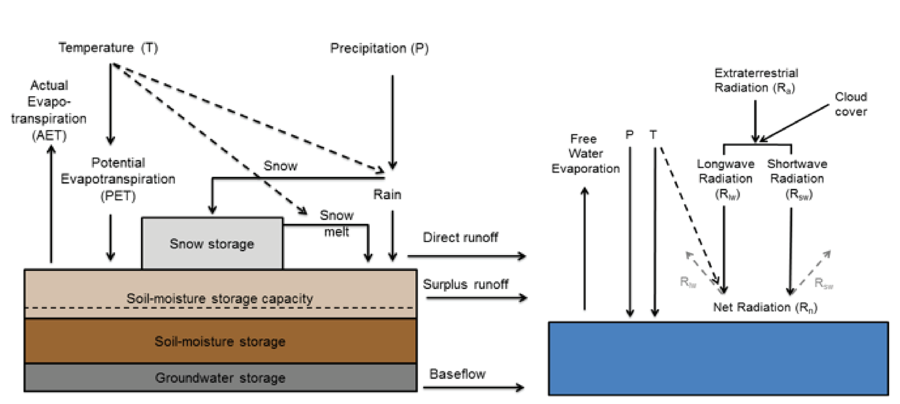

Figure 3. Shows all the processes contributing to the Mono Lake mass balance in the Mono Lake Model both in a land runoff and lake component.

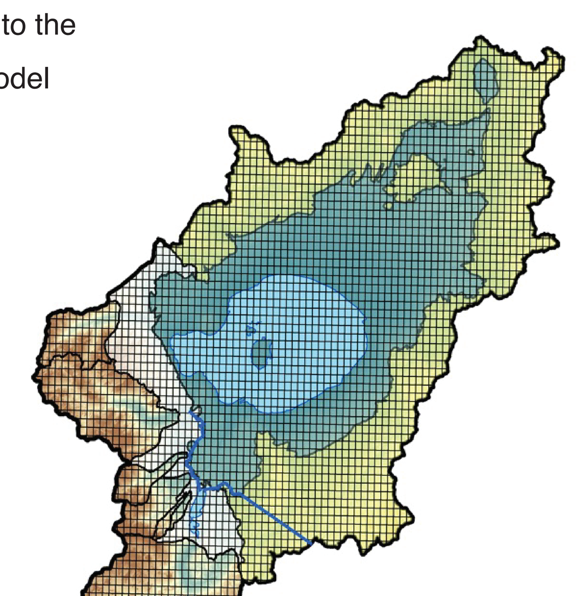

Figure 4. Each grid cell covering the Mono Lake watershed composing the Mono Lake model domain.

Main Takeaway: Modeling Paleo Glacial and Lakes together reduces the range of paleoclimate solutions specific to each system to a unique paleoclimate solution.

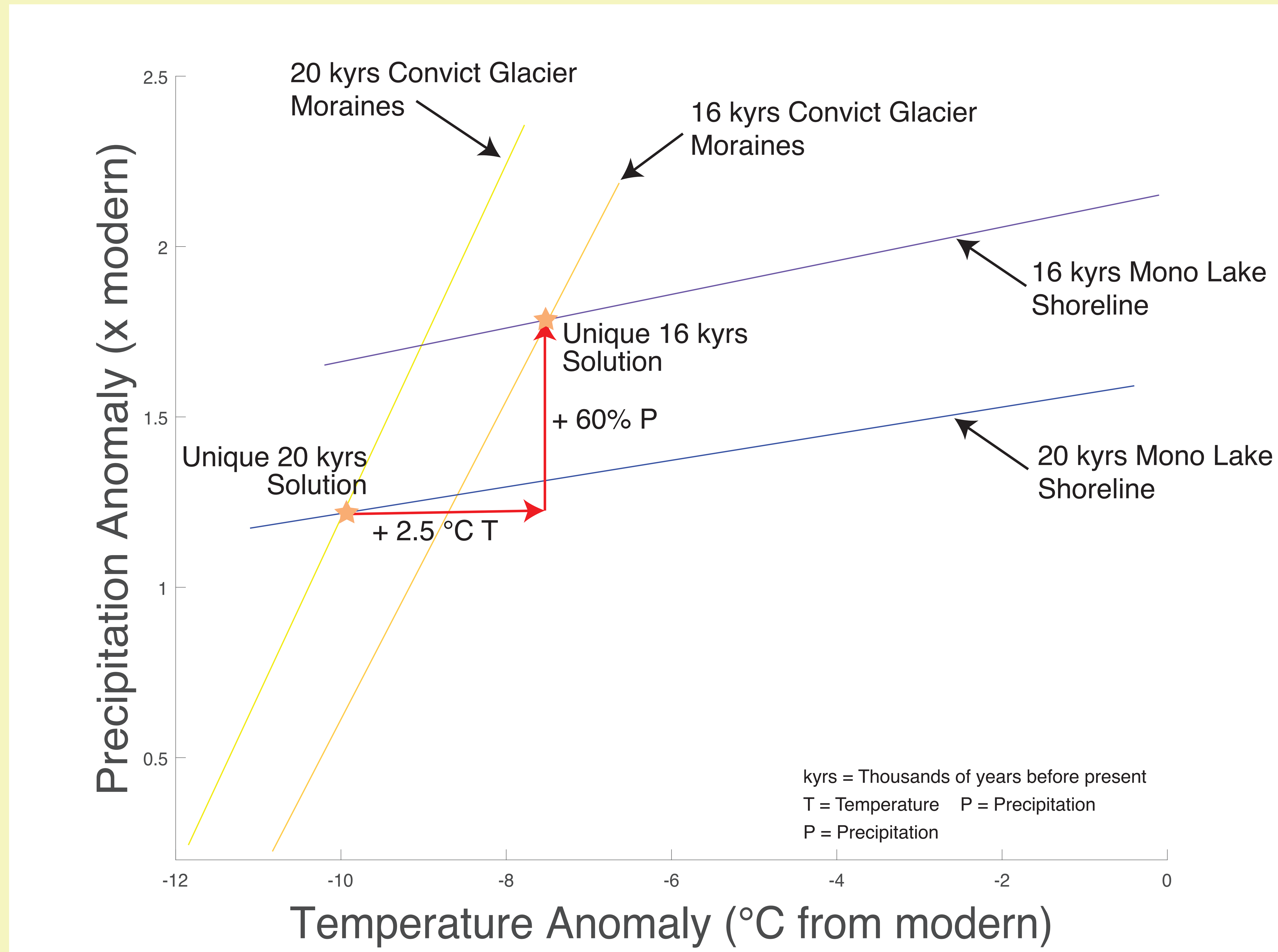

Figure 1. Mono Lake and Convict Lake Modeling Solutions.

Key Figure Points and Results:

1. Paleo-glaciers and lake modeling results suggest there is no unique solution for changes in T & P without prior knowledge of either the T or P solution.

2. Modeling results suggest the glacial system is more sensitive to changes in T than P. Modeling results also show that the watershed lake system is more sensitive to changes in P than T.

3. Combining the modeling results allows for the identification of a unique solution.

4. Modeling the glacier and lake at both 20 kyrs and 16 kyrs and obtaining a unique paleoclimate solution for each allows the change in T and P to be calculated between each period.

Conclusion and Future Work

1. Previous methods of determining a unique paleoclimate solution involved using another proxy to constrain either temperature or precipitation. However, signals in these other proxies are not always related to climate. Pairing two sets of physical proxy records that respond to the same two climate variables simplifies the number of assumptions required to obtain a paleoclimate solution.
2. This work lays a foundation for similar paleoclimate reconstructions in other locations with clear records of adjacent closed basin lakes and glaciers that responded primarily to temperature and precipitation changes.
3. It also provides paleoclimate estimates and that can be independently compared to paleoclimate reconstructions from other proxy records.
4. By finding paleoclimate solutions for a sequence of dated lake and glacier records, we can use this method to reconstruct a timeline of paleoclimate variations. Such a timeline will be important in efforts to test hypotheses of the causes of local and global climate change during the Pleistocene glacier cycles.

GCM2M Glacier Model

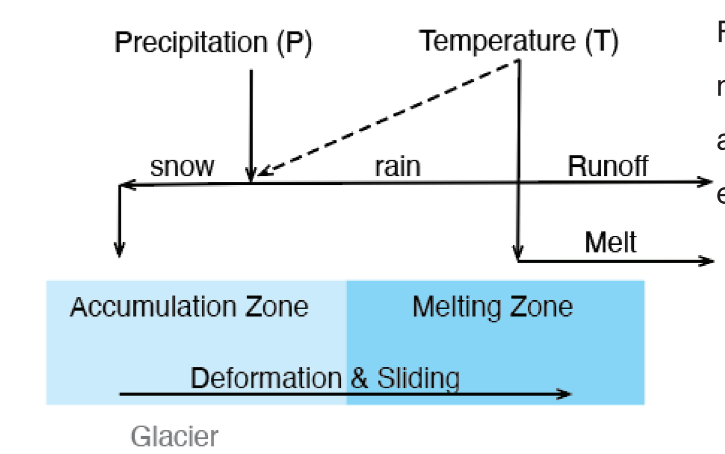

Figure 5. The GCM2m glacier model moves mass into around and out of the glacier via different processes.

Methods

For both modeling Mono Lake & Convict Glacier:

- Identify contemporary dated target glacier and lake landforms.
- Find ΔP, ΔT from 1971-2000 climatology of gridded climate datasets to fit lake level and glacial extents.
- Model lake/glacier allowing the adjusted climate to control the balance of precipitation and evapotranspiration.
- Record optimal [ΔT,ΔP] pair(s) that best allow the modeled lake/glacier to match target landform(s) (lake shorelines and glacier moraines).
- Use optimal [ΔT,ΔP] pairs from each separate system to determine if combining the range of Δ value pairs that solve each system will produce a smaller range of Δ value pairs that simultaneously solve both systems.
- Repeat for target features of different ages.

New Benchmark Method for Glacier Model

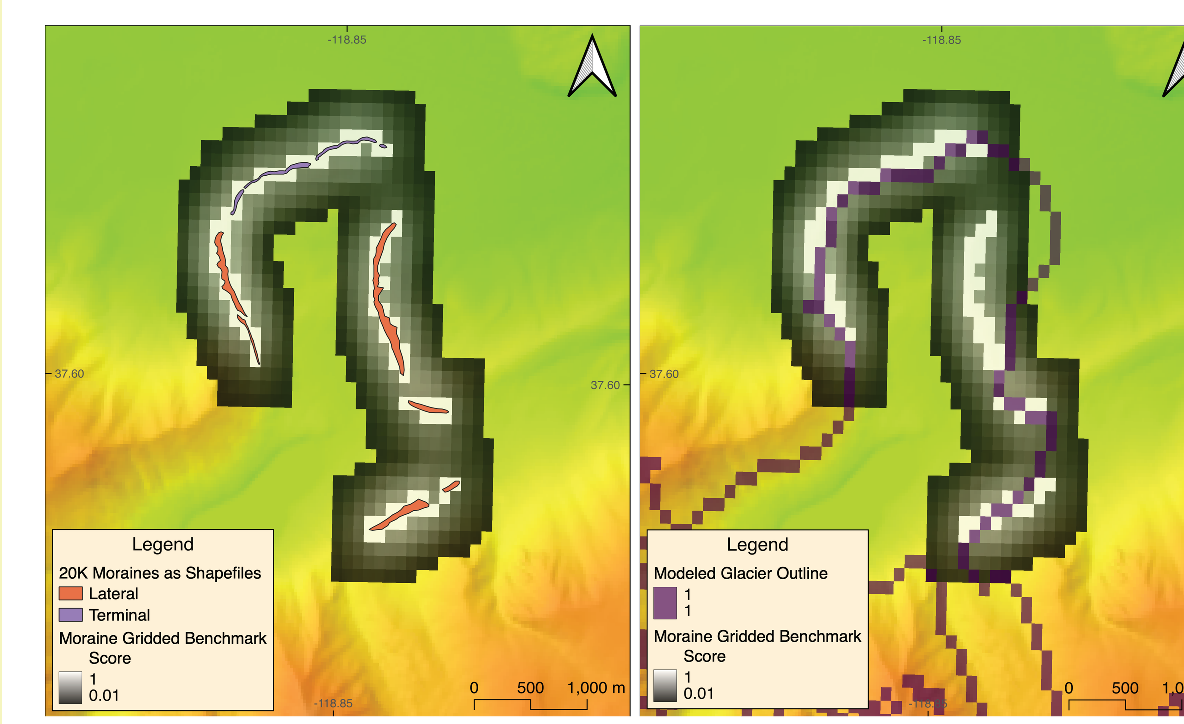

Figure 7. This figure shows how grid cells of values decreasing from 1 are created from shapefiles of the target moraine features and how the glacier outline is scored by its overlap with these grid cells.

- Rasterize shapefile by selecting gridcells on underlying DEM shapefile overlaps with.
- Perform a convolution to create a slope of decreasing scores away from “correct” gridcells.
- Create an outline of the glacier modeled from a certain change to current P and T.
- Tally the score of target cells overlapped by the glacier boundary cells.

References and Acknowledgements

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