Evaluating ELA models for use in paleo-glaciology

Hess
Wagner

Introduction

Importance of ELA and paleo-glaciers…

Geomorphic features such as terminal moraines and cirque basins often provide reliable estimates of the max length, head-elevation, toe-elevation, slope, area, and aspects of paleo-glaciers.

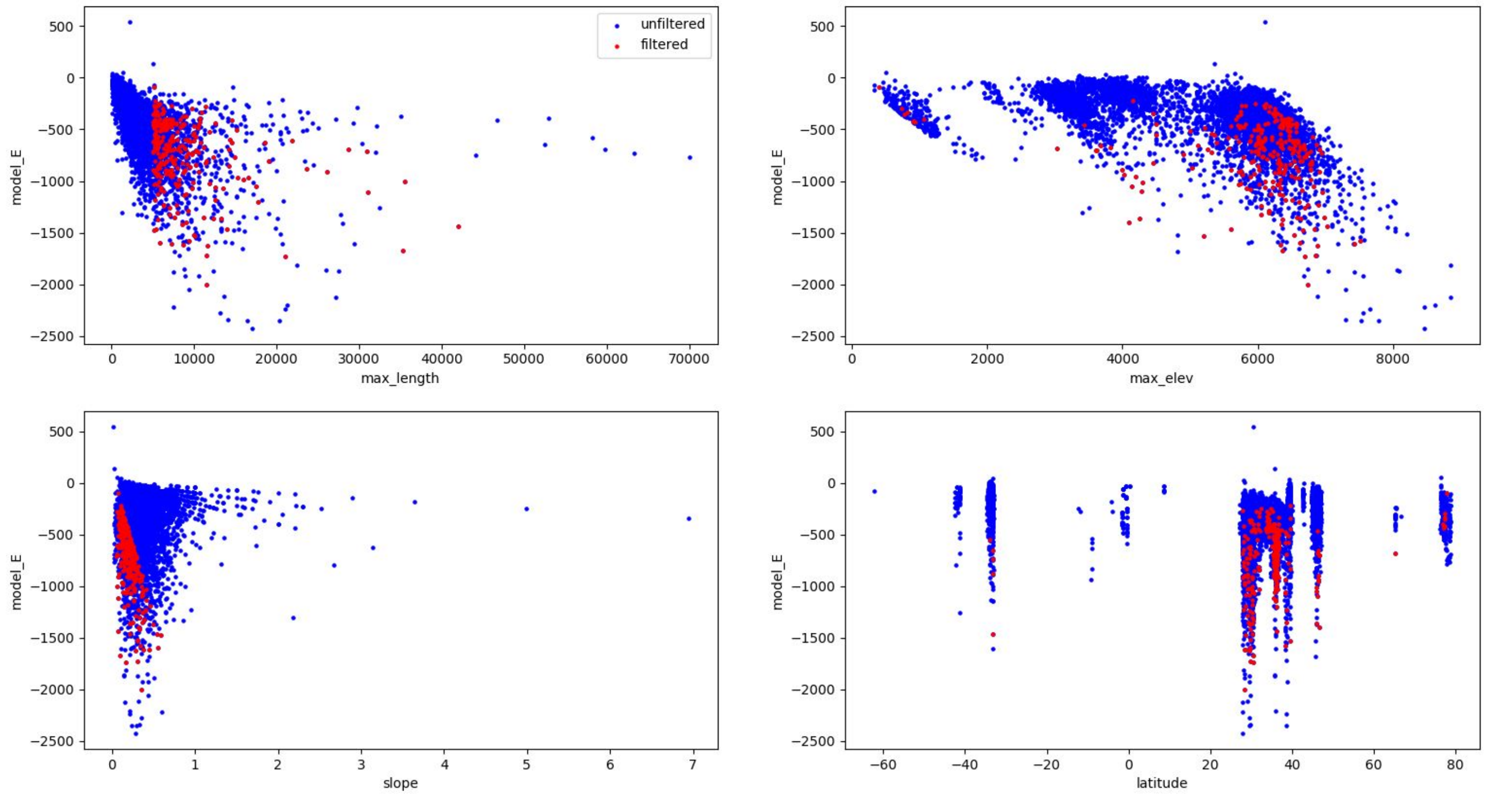
We can use simple models to estimate ELA, which may provide insight into regional paleo-climate.

In this study we evaluate several ELA models by comparing observed ELAs with modeled ELAs in a subset of the World Glacier Inventory (WGI).

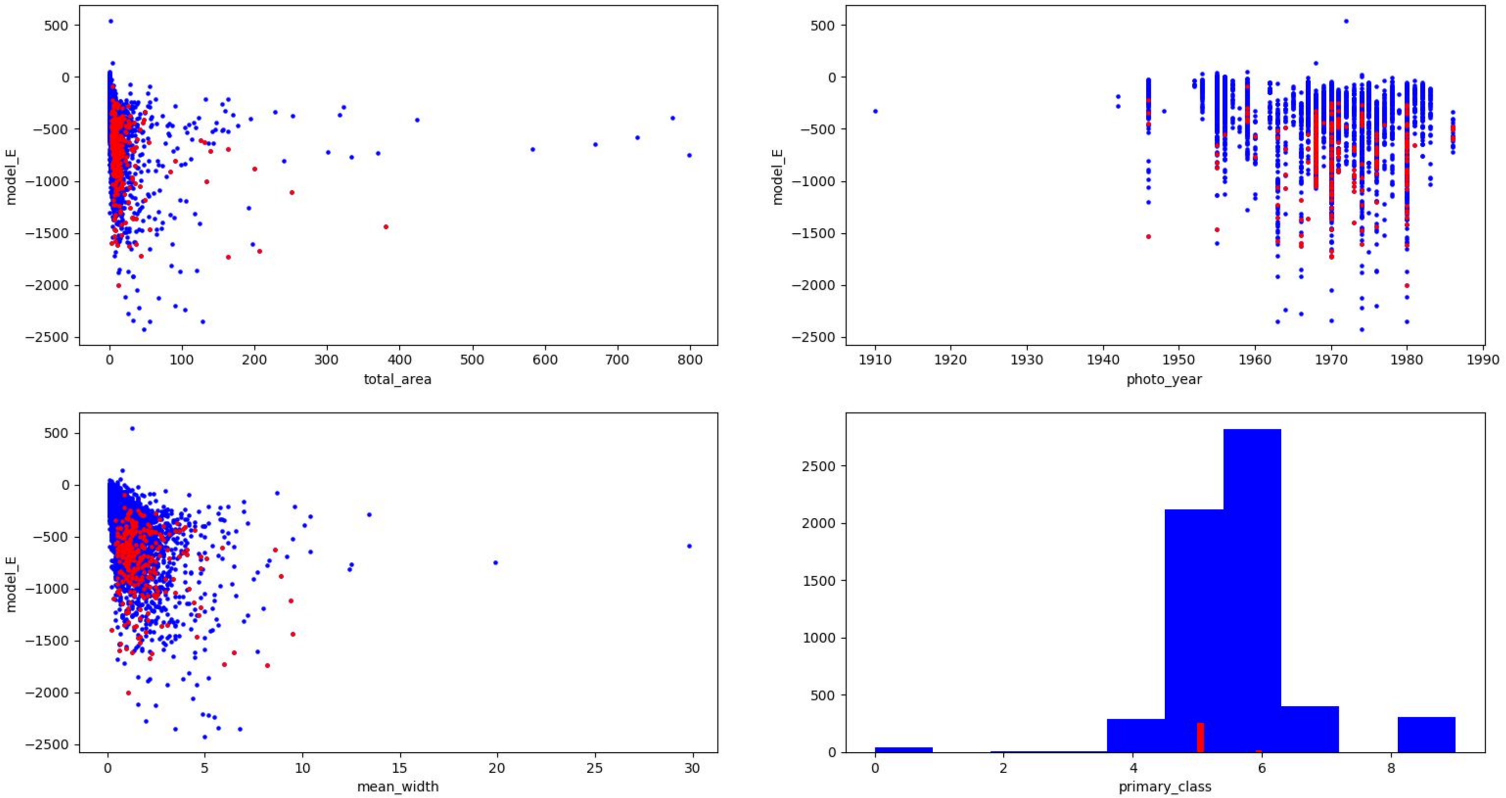
We also attempt to quantify the error of our simplest models.

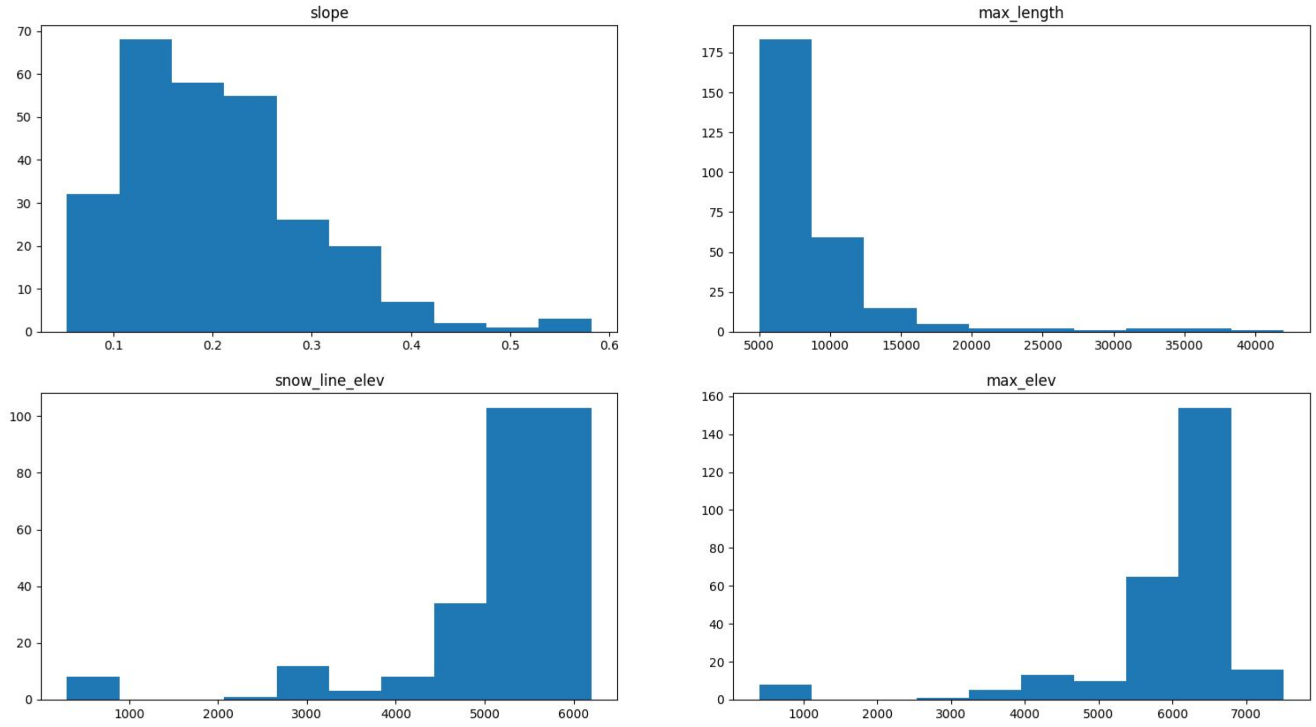
WGI dataset

1. Filter World Glacier Inventory (WGI) dataset
   a. Lengths between 5 km and 45 km (similar to Uinta paleo-glacier lengths)
   b. Slopes between 0 and 1 (rise/run)
   c. Mountain and valley glaciers
   d. Glaciers where the modeled length is within 15% of observed length
      i. L = (2/s) * ((tao/(rho*g*s)) + b_0 - E)
      ii. Glaciers where snowline close to ELA (assume: steady state, equation will get us close)
   e. Drop all remaining Nan
2. Data Validation
   a. Applied WGI variables to Oerlemans Eq. 2.1.4 for data validation--how well measured snowlines agree with modeled ELAs
      i. Slope calculated from WGI variables--((Z_max-Z_min)/Length)
      ii. Hm calculated using Tau/Rho*g*slope

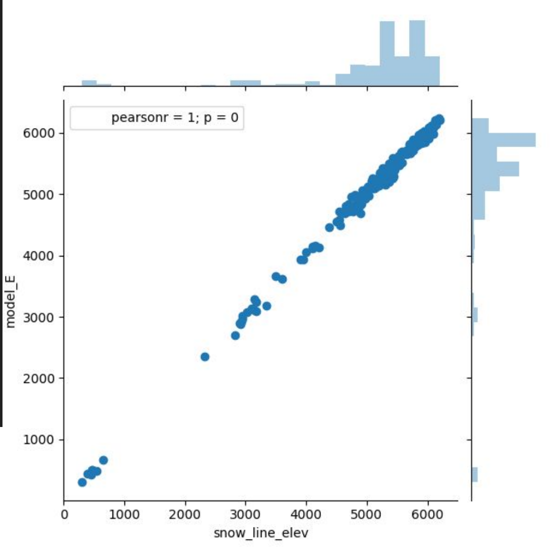


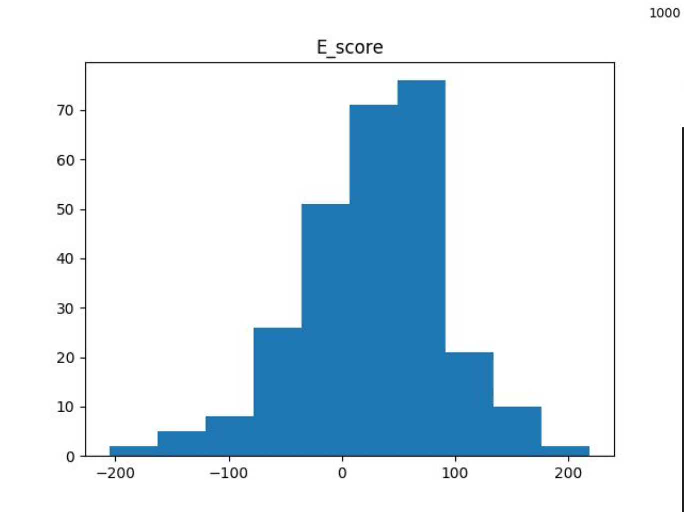
unfiltered
filtered
model_E
max_length
max_elev
slope
latitude

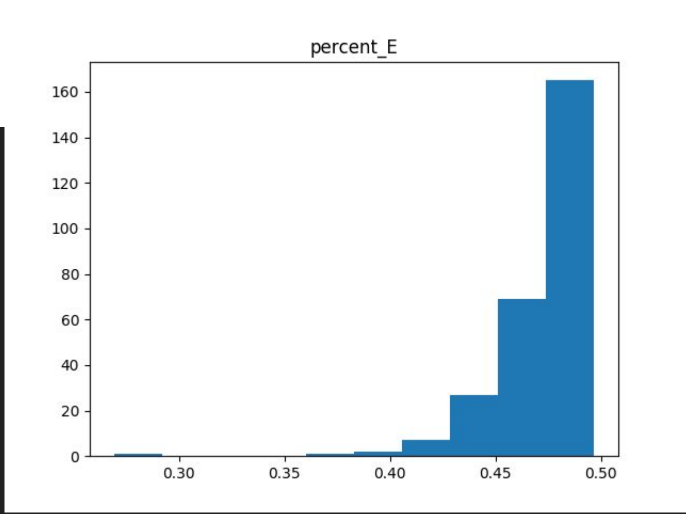

model_E
total_area
model_E
photo_year
model_E
mean_width
primary_class
500
0
−500
−1000
−1500
−2000
−2500
0 100 200 300 400 500 600 700 800
1910 1920 1930 1940 1950 1960 1970 1980 1990
0 5 10 15 20 25 30
2500
2000
1500
1000
500
0
0 2 4 6 8



slope
max_length
snow_line_elev
max_elev

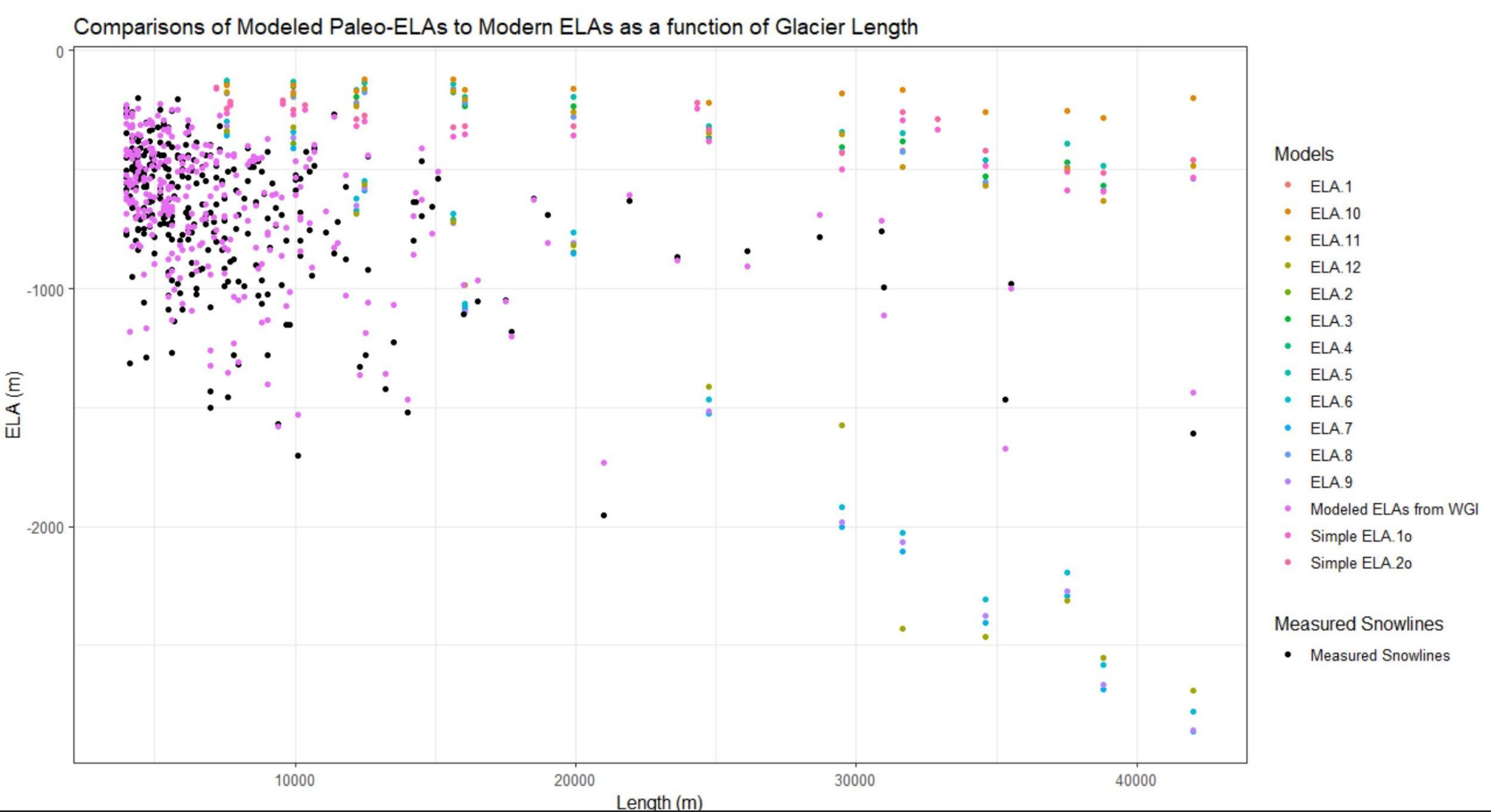

pearsonr = 1; p = 0
model_E
snow_line_elev
0
1000
2000
3000
4000
5000
6000

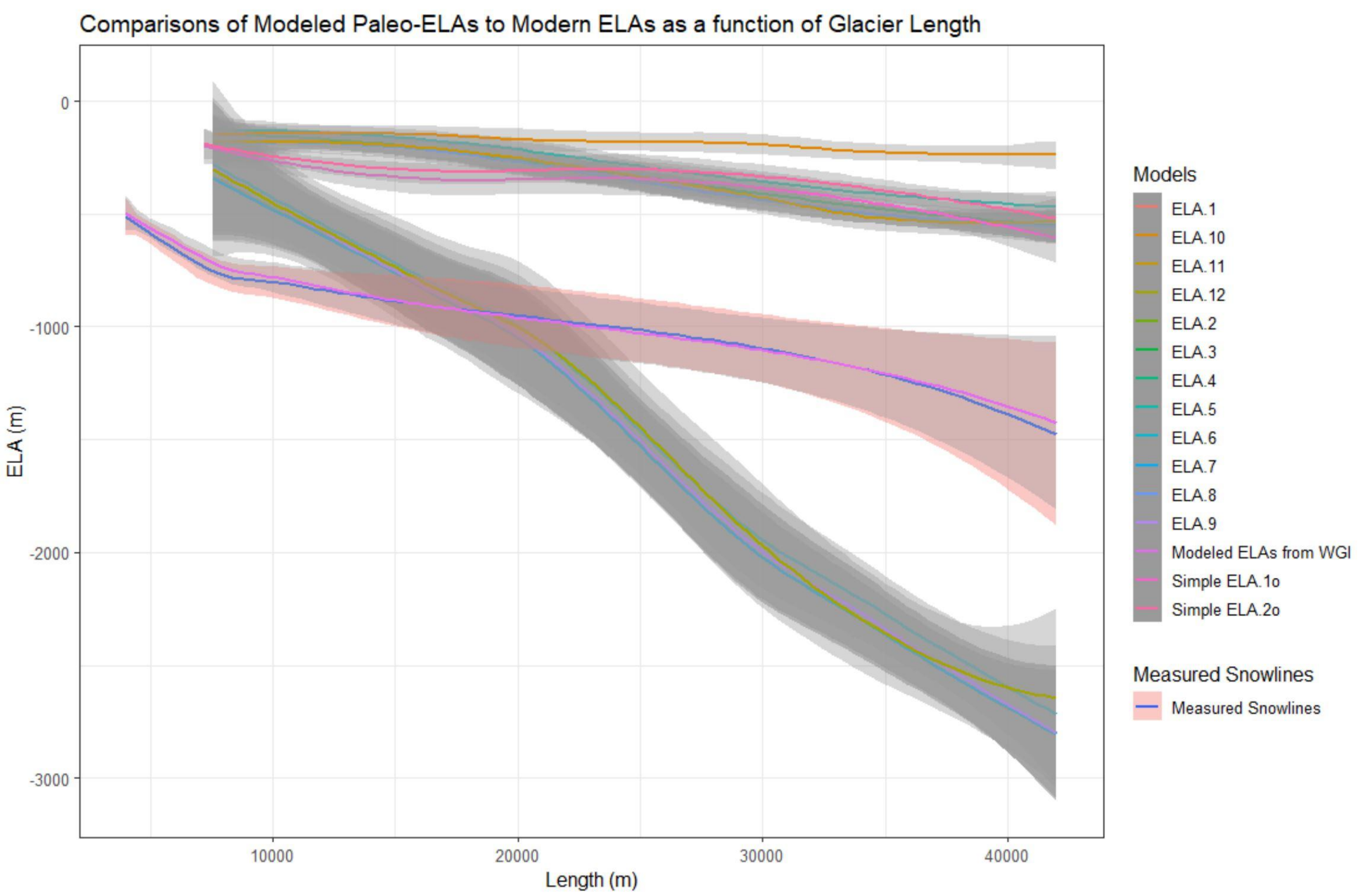

E_score
−200
−100
0
100
200
0
10
20
30
40
50
60
70


percent_E
0.30
0.35
0.40
0.45
0.50
0
20
40
60
80
100
120
140
160

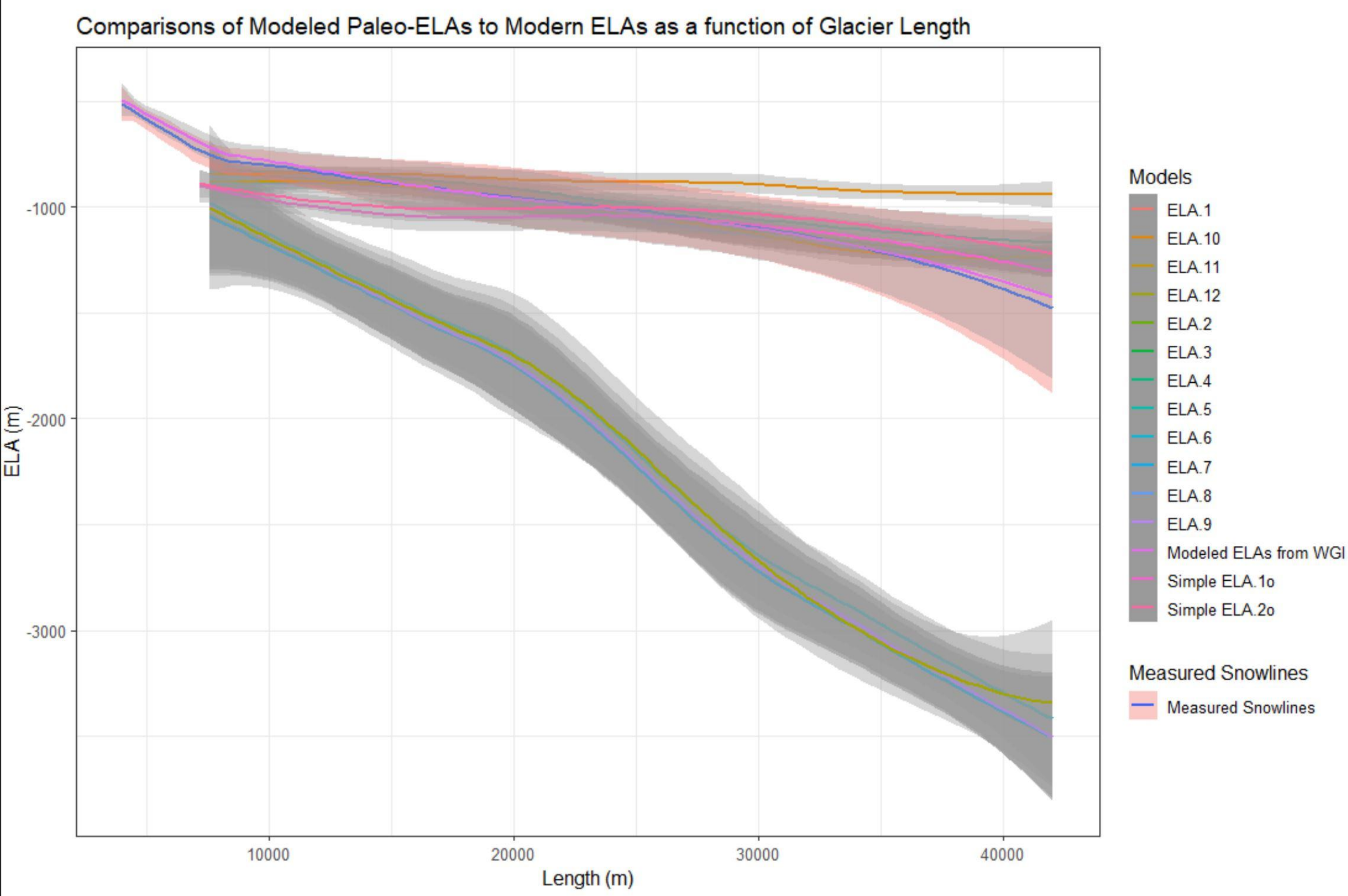
Uinta Paleo-glaciers

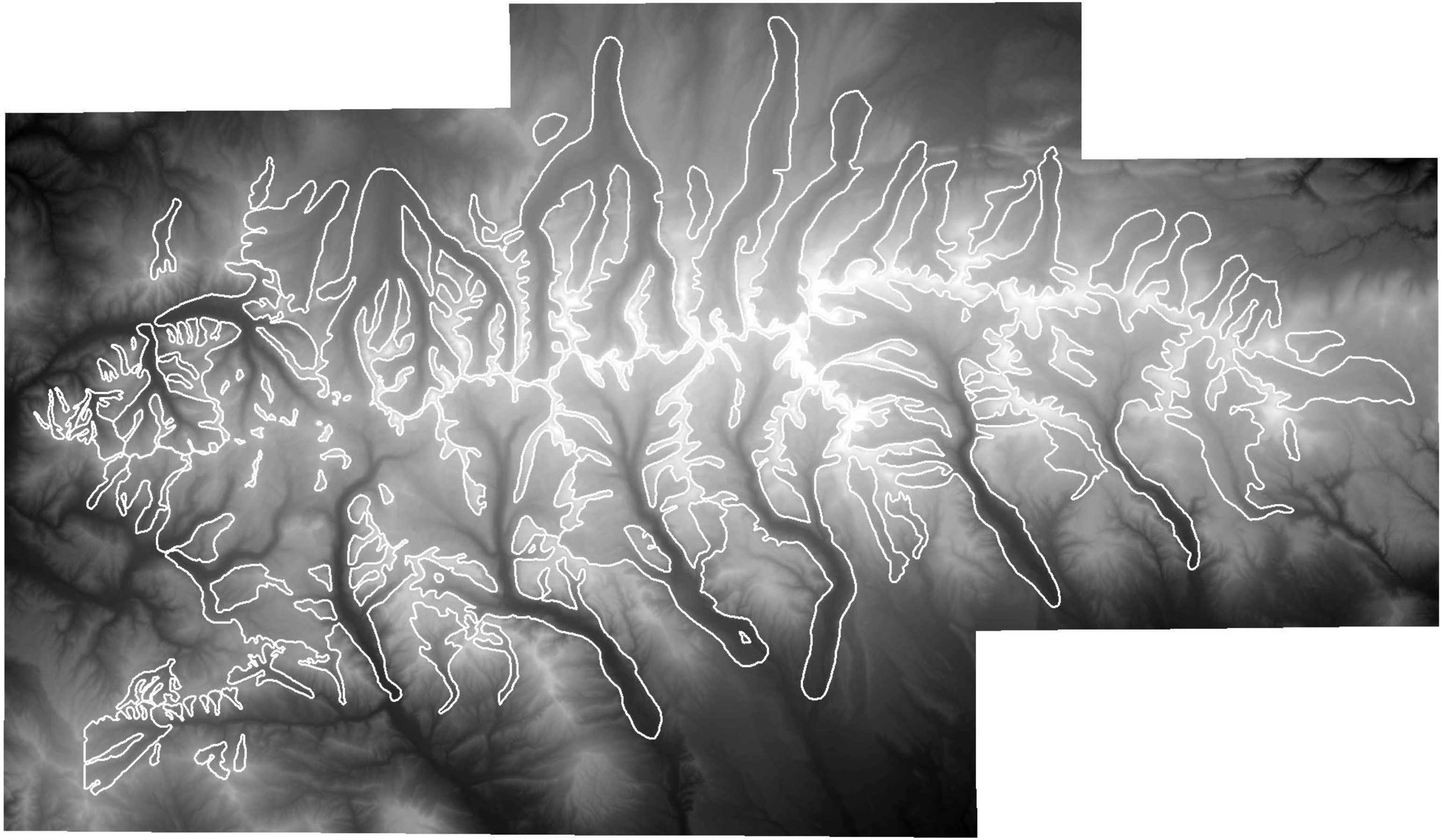
1. Analysis of DEMs and Ice Surface shapefile
    a. Created interpolated glacier surface according to polygons
    b. Split glaciers into upper basins and tongues
    c. Derived glacier model variables by calculating glacier volume, surface area, mean ice thickness, surface slope, bedrock slope, upper basin and lower basin widths from DEMs
2. Model Variations
    a. Ran model using equations from Oerlemans (2.1.4) and (2.2.3)
        i. Several iterations included changing variables such as using bedrock slope versus ice surface slope, glacier thickness derived from DEM and glacier thickness, etc.

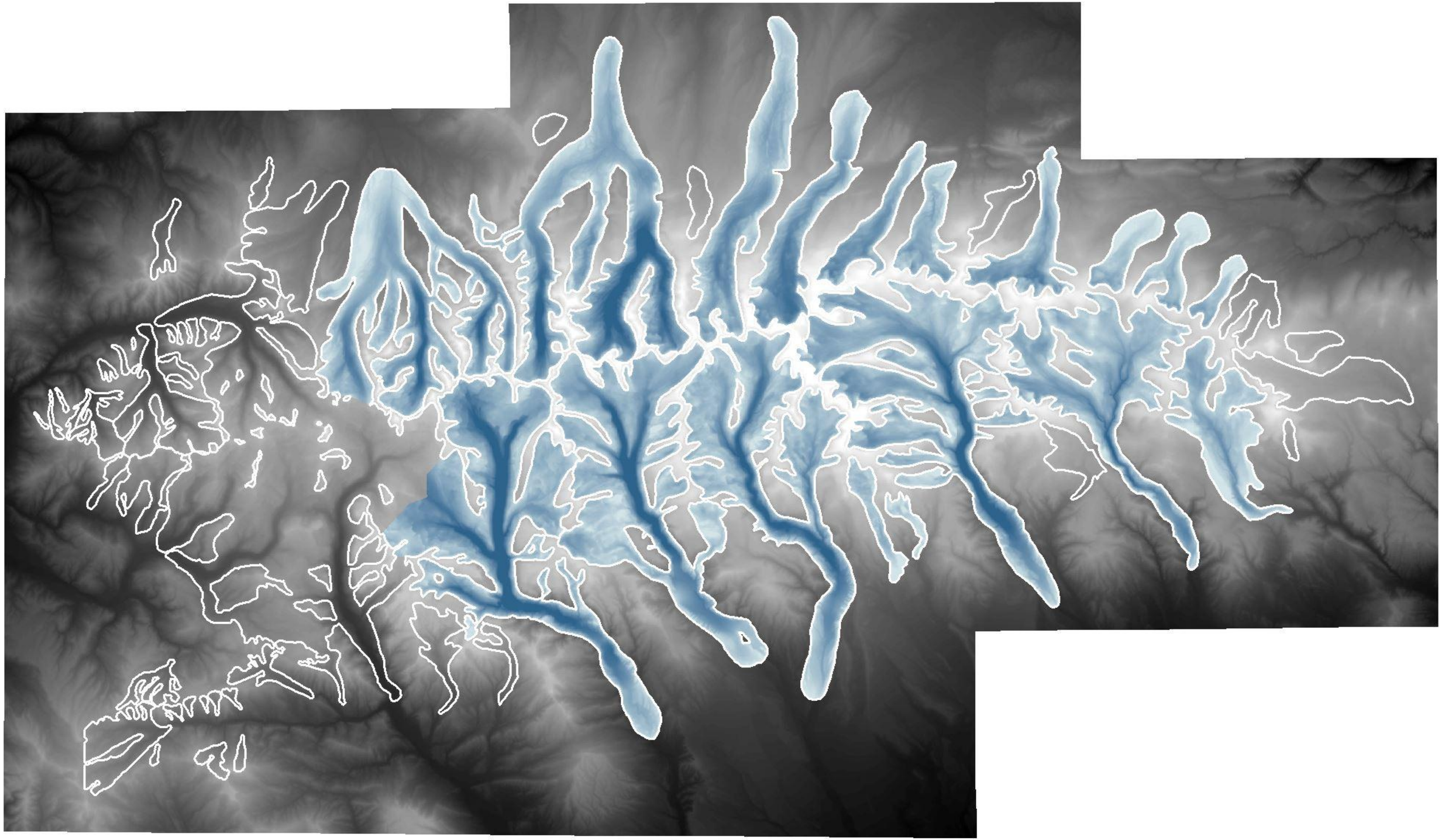

Comparisons of Modeled Paleo-ELAs to Modern ELAs as a function of Glacier Length
ELA (m)
Length (m)
0
-1000
-2000
10000
20000
30000
40000
Models
ELA.1
ELA.10
ELA.11
ELA.12
ELA.2
ELA.3
ELA.4
ELA.5
ELA.6
ELA.7
ELA.8
ELA.9
Modeled ELAs from WGI
Simple ELA.1o
Simple ELA.2o
Measured Snowlines
Measured Snowlines



Comparisons of Modeled Paleo-ELAs to Modern ELAs as a function of Glacier Length
ELA (m)
0
-1000
-2000
-3000
10000
20000
30000
40000
Length (m)
Models
ELA.1
ELA.10
ELA.11
ELA.12
ELA.2
ELA.3
ELA.4
ELA.5
ELA.6
ELA.7
ELA.8
ELA.9
Modeled ELAs from WGI
Simple ELA.1o
Simple ELA.2o
Measured Snowlines
Measured Snowlines

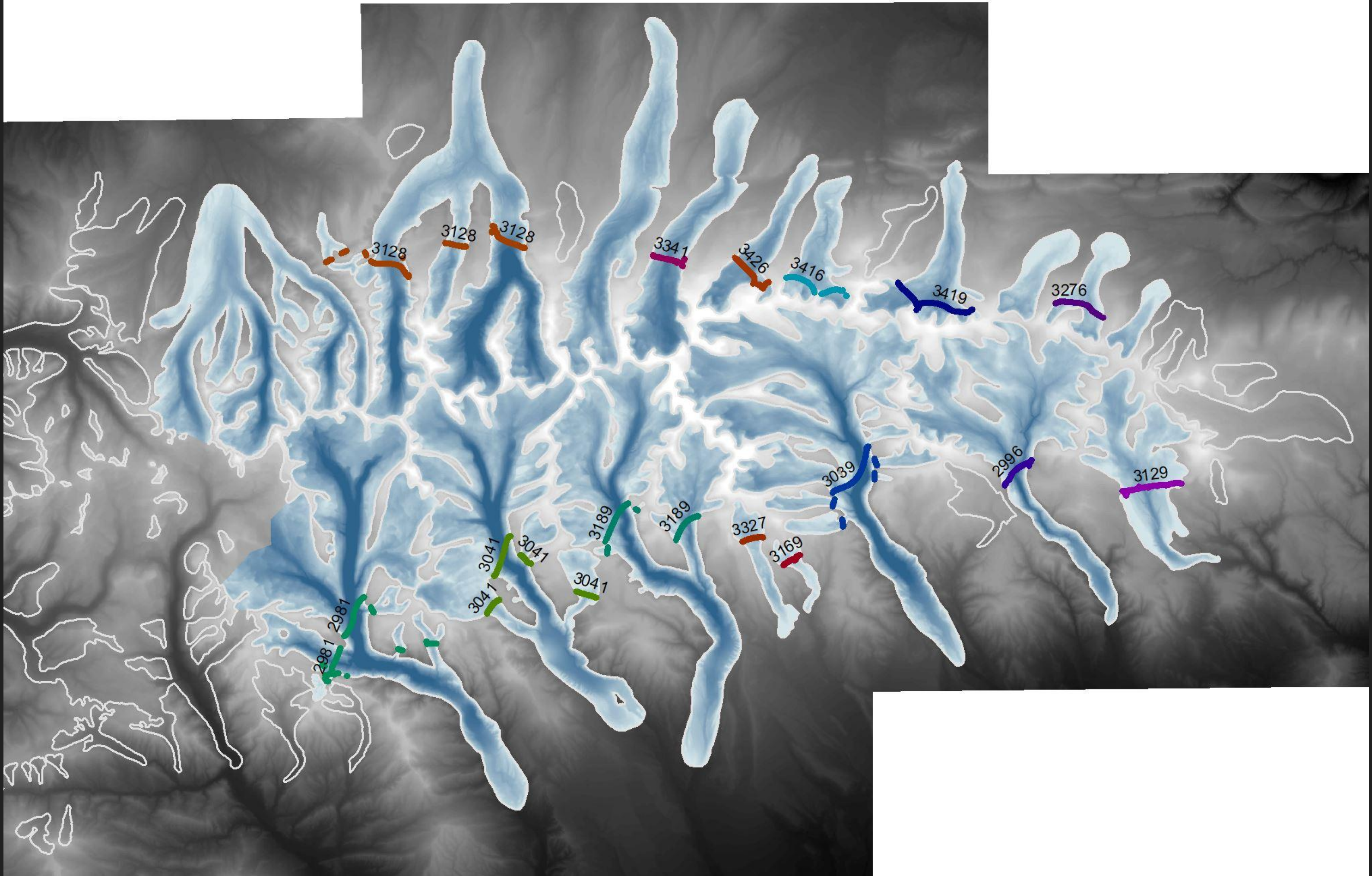

Comparisons of Modeled Paleo-ELAs to Modern ELAs as a function of Glacier Length
ELA (m)
-1000
-2000
-3000
10000
20000
30000
40000
Length (m)
Models
ELA.1
ELA.10
ELA.11
ELA.12
ELA.2
ELA.3
ELA.4
ELA.5
ELA.6
ELA.7
ELA.8
ELA.9
Modeled ELAs from WGI
Simple ELA.1o
Simple ELA.2o
Measured Snowlines
Measured Snowlines





Discussion/Conclusions

- WGI Data
- Uinta Data



3128
3128
3128
3341
3426
3416
3419
3276
2996
3129
3039
3189
3189
3327
3169
3041
3041
3041
3041
2981
2981

References

Eric M. Leonard (1984) Late Pleistocene Equilibrium-Line Altitudes and Modern Snow Accumulation Patterns, San Juan Mountains, Colorado, U.S.A., Arctic and Alpine Research, 16:1, 65-76

Gregory A. Zielinski & William D. McCoy (1987) Paleoclimatic Implications of the Relationship Between Modern Snowpack and Late Pleistocene Equilibrium-Line Altitudes in the Mountains of the Great Basin, Western U.S.A., Arctic and Alpine Research, 19:2, 127-134

Johannes Oerlemans (2008) Minimal Glacier Models, ISBN 978-90-6701-022-1

S. N. Bacon , T. J. Chinn , R. J. van Dissen , S. F. Tillinghast , H. L. Goldstein & R. M. Burke (2001) Paleo-equilibrium line altitude estimates from late Quaternary glacial features in the Inland Kaikoura Range, South Island, New Zealand, New Zealand Journal of Geology and Geophysics, 44:1, 55-67, DOI: 10.1080/00288306.2001.9514922

WGMS, and National Snow and Ice Data Center (comps.). 1999, updated 2012. *World Glacier Inventory, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5/NSIDC-WGI-2012-02. [10/01/2018].