GRSLE Archaeology

Iowa State University Anthropology

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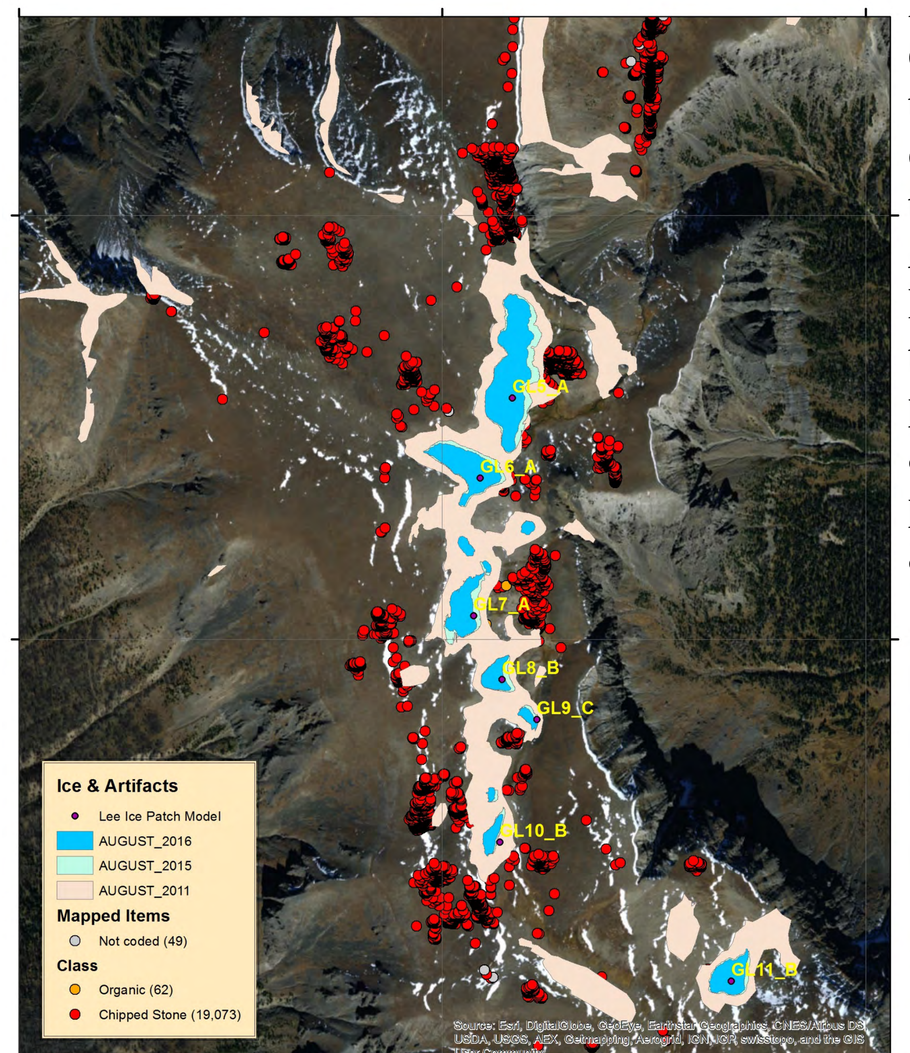
Quantifying Ice Patch Variability Using GIS Functionality

Introduction

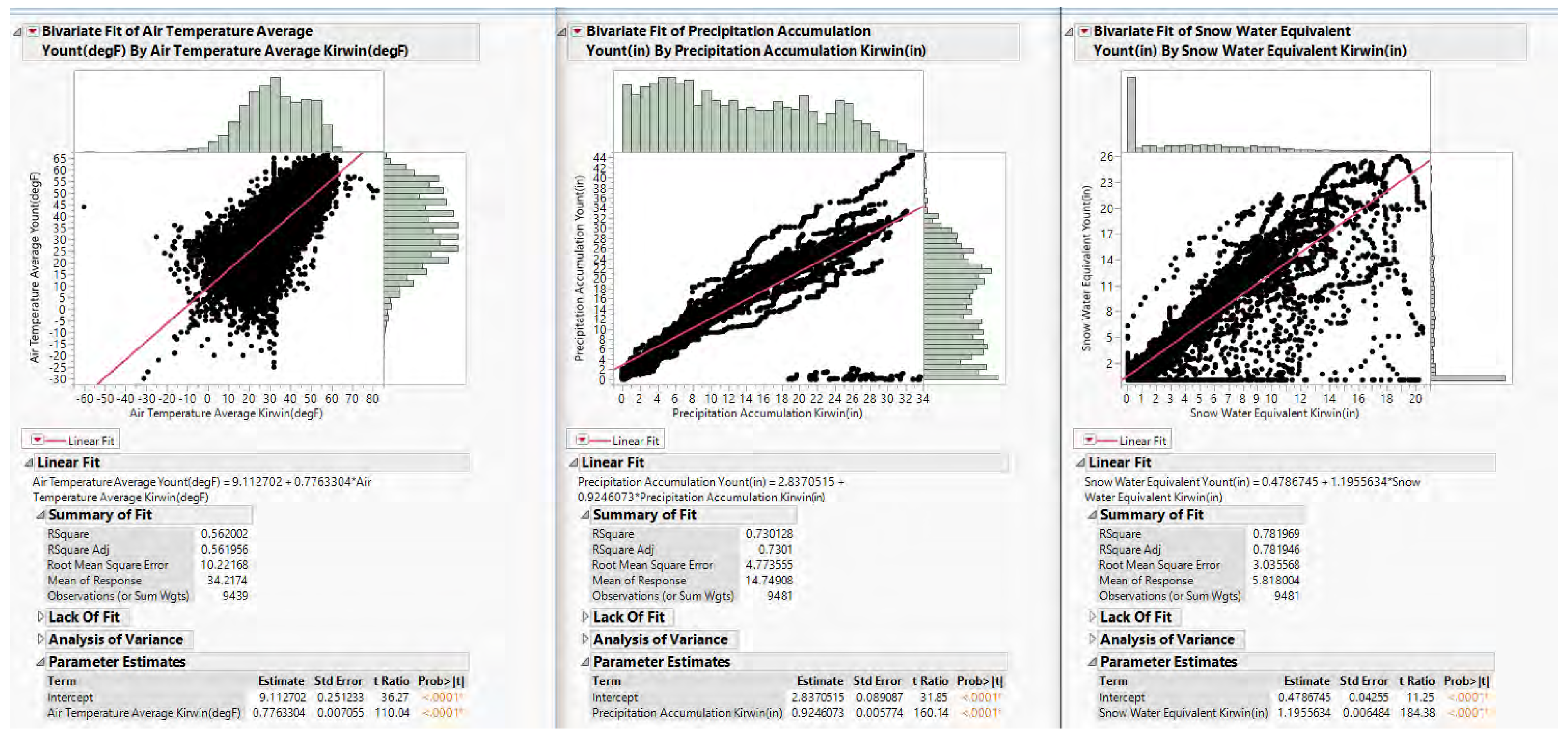
Recently, data recorded by the GRSLE project provide attributes regarding the sizes and areas of ice patches in the Cougar Pass region of north western Wyoming. By relating the change in ice patch areas to conditions, such as rainfall, temperature, and snow water equivalents, a regression equation can be derived that calculates the change ice patch areas relative to key environmental variables. Using this regression equation, a dynamic model may be constructed in GIS to quantify the alteration in ice patch size and area with the change in the respected variables. The model provides insight into how ice patches may have responded to past climatic variation and help to develop more refined hypotheses about the role that ice patch locations played in prehistoric cultural systems. This model can be expanded to evaluate ice patches existing across the Absaroka mountain region, and to identify locations where they once persisted. Predicting the locations of past ice patches would be a powerful tool for locating archaeological sites among the Absaroka mountain range, and could potentially expand into other mountain archaeological research.



Ice Patches and Prehistoric Archaeology
Basemap Image Date: 9/23/2015

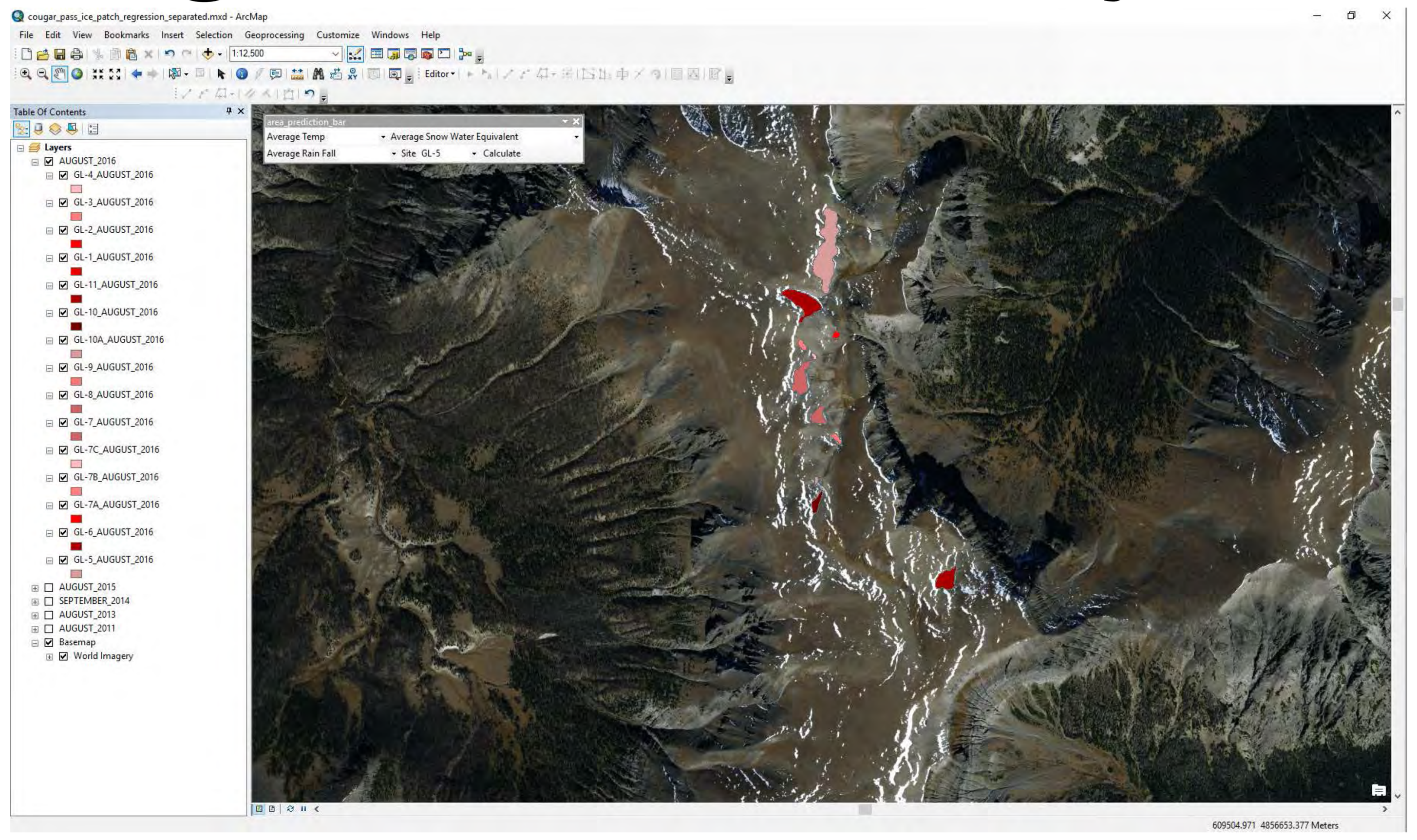
Procuring Data

The Natural Resources Conservation Service (NRCS) provides an open access database retaining SNOTEL records dating back to 1980. Temperatures, precipitation, and snow water equivalents data are all recorded daily at weather stations and stored into downloadable csv. files. Relative to Cougar Pass, there are three weather stations within feasible proximity, Yount's Peak [19.8 km], Kirwin [27.5 km], and Borough Creek [20.1 km]. Though Yount's Peak is the nearest station there is a significant gap in the data where no records of temperature, precipitation, or snow water equivalence were able to be recorded from October 1st 2013 to August 12th 2015 due to forest fires. In concurrence, Borough Creek, the next nearest weather station, is missing data from October 1st 2013 to July 9th 2014. Therefore, the Kirwin weather station is the nearest complete dataset. Comparing the data between Kirwin an Yount's Peak show the variation to be minimal, temperature has the greatest variation 0.7763, while precipitation and snow water equivalence have the lease 0.9240 and 1.1955 respectively.



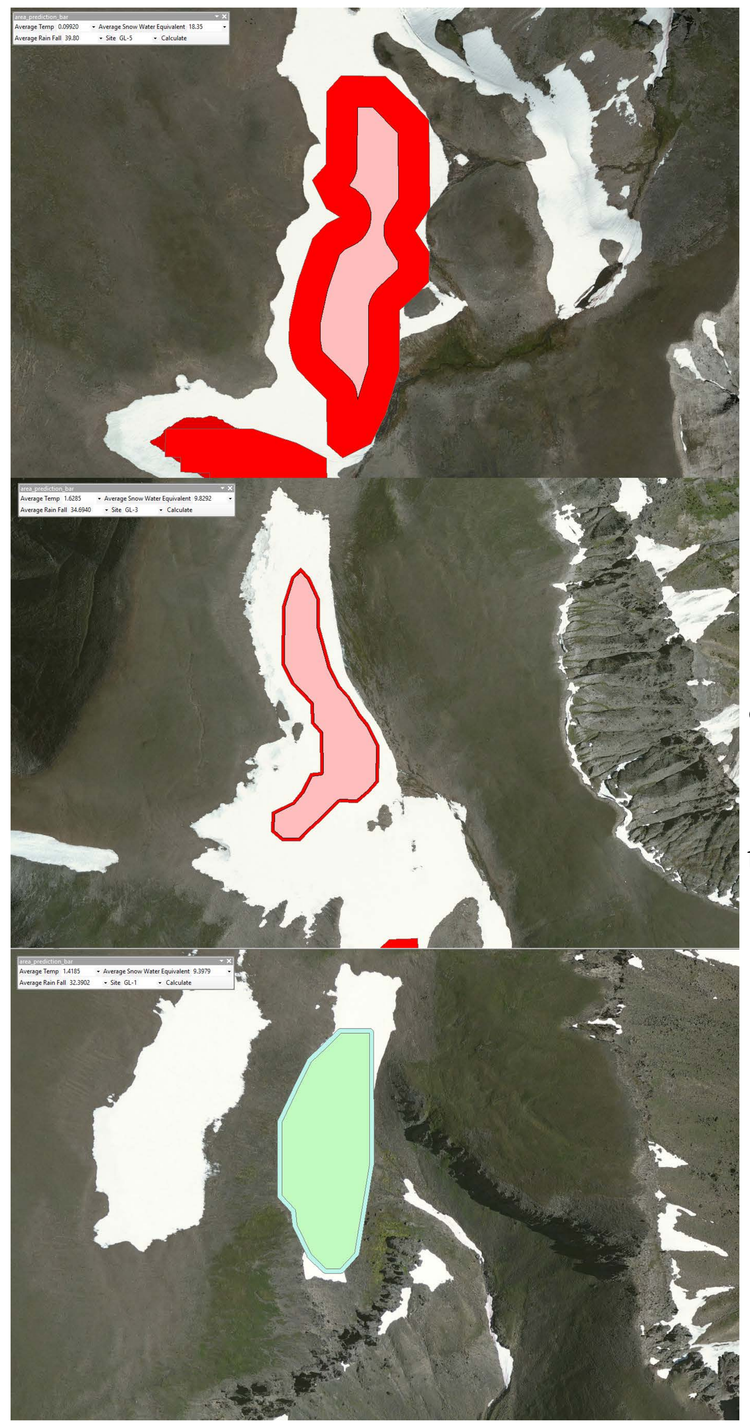
Data Sources

"EarthExplorer," United States Geological Survey: Reston, Virginia. Web. < http://earthexplorer.usgs.gov/>
"Snow Telemetry (SNOTEL) and Snow Course Data and Products," Natural Resource Conservation Service, *United States Department of Agriculture:* Washington D.C. Web < http://www.wcc.nrcs.usda.gov/snow/>



Obtaining Ice Patch Areas

Ice Patch area data was procured using a variety of different methods. Areas from 2015 and 2016 were recorded by GRSLE researchers who encircled individual ice patches while recording GNSS positions, thereby producing high resolution polygons with 40cm accuracy, in addition to areas from 2011 which where digitized on a high resolution image by Larry Todd. Other data are available from the USGS open access satellite imagery database. Using the ArcMap digitizing functionalities, areas from 2014 and 2013 were constructed using Landsat 8 data LC80370302014268LGN00 and LC80370302013217LGN00 taken in September 26, 2014 and August 26, 2013. The accuracy of these digitization's is limited by the Landsat images' 30m resolution. Satellite imagery of the Cougar Pass region from 2012 are not available in feasible resolution from the USGS databases.



Parameter Estimates — GL-1

Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	14293.213	1.6769e-8	214.22493	<.0001*	.	.
AVG_TEMP_C	5635.4193	4.5384e-9	217.23493	<.0001*	.	.
AVG_SNOW_WATER_CM	1430.4924	1.528e-9	214.9757	<.0001*	.	.
AVG_PRECIP_CM	-1095.051	1.127e-9	215.27324	<.0001*	.	.

Correlation of Estimates

Corr	Intercept	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
Intercept	1.0000	0.9275	0.9645	-0.986
AVG_TEMP_C	0.9275	1.0000	0.9880	-0.974
AVG_SNOW_WATER_CM	0.9645	0.9880	1.0000	-0.995
AVG_PRECIP_CM	-0.986	-0.974	-0.995	1.0000

Parameter Estimates — GL-2

Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	-8088.548	9.3796e-9	7.437e+23	<.0001*	.	.
AVG_TEMP_C	9441.2685	2.5385e-9	1.383e+25	<.0001*	.	.
AVG_SNOW_WATER_CM	1699.8972	8.546e-10	3.956e+24	<.0001*	.	.
AVG_PRECIP_CM	-661.7368	6.303e-10	1.102e+24	<.0001*	.	.

Correlation of Estimates

Corr	Intercept	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
Intercept	1.0000	0.9275	0.9645	-0.986
AVG_TEMP_C	0.9275	1.0000	0.9880	-0.974
AVG_SNOW_WATER_CM	0.9645	0.9880	1.0000	-0.995
AVG_PRECIP_CM	-0.986	-0.974	-0.995	1.0000

Parameter Estimates — GL-3 & GL-4

Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	195659.06	3.8827e-7	210.02036	<.0001*	.	.
AVG_TEMP_C	142173.79	1.0508e-7	217.92147	<.0001*	.	.
AVG_SNOW_WATER_CM	42309.931	3.5378e-8	216.93444	<.0001*	.	.
AVG_PRECIP_CM	-24576.45	2.6093e-8	215.02386	<.0001*	.	.

Correlation of Estimates

Corr	Intercept	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
Intercept	1.0000	0.9275	0.9645	-0.986
AVG_TEMP_C	0.9275	1.0000	0.9880	-0.974
AVG_SNOW_WATER_CM	0.9645	0.9880	1.0000	-0.995
AVG_PRECIP_CM	-0.986	-0.974	-0.995	1.0000

Parameter Estimates — GL-5 through GL-10A

Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	65395.851	1.9823e-7	206.63122	<.0001*	.	.
AVG_TEMP_C	86342.774	5.3649e-8	219.30985	<.0001*	.	.
AVG_SNOW_WATER_CM	23463.491	1.8062e-8	217.59602	<.0001*	.	.
AVG_PRECIP_CM	-12703.65	1.3322e-8	215.12285	<.0001*	.	.

Correlation of Estimates

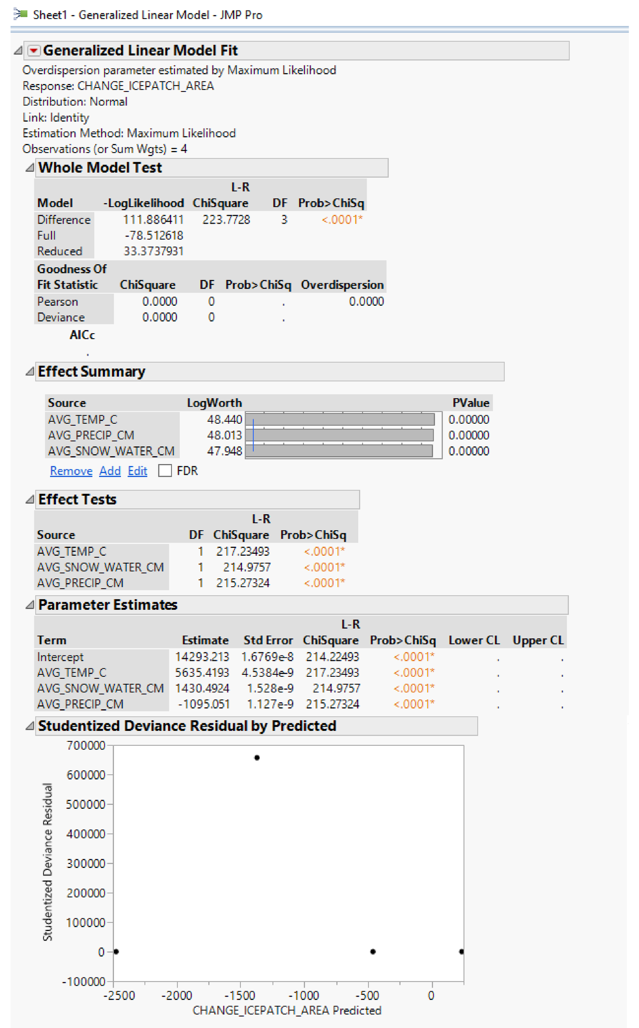
Corr	Intercept	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
Intercept	1.0000	0.9275	0.9645	-0.986
AVG_TEMP_C	0.9275	1.0000	0.9880	-0.974
AVG_SNOW_WATER_CM	0.9645	0.9880	1.0000	-0.995
AVG_PRECIP_CM	-0.986	-0.974	-0.995	1.0000

Parameter Estimates — GL-11

Term	Estimate	Std Error	L-R ChiSquare	Prob>ChiSq	Lower CL	Upper CL
Intercept	7032.702	2.7519e-8	204.5886	<.0001*	.	.
AVG_TEMP_C	12560.618	7.4477e-9	219.68427	<.0001*	.	.
AVG_SNOW_WATER_CM	3250.2223	2.5074e-9	217.57872	<.0001*	.	.
AVG_PRECIP_CM	-1719.298	1.8494e-9	214.91955	<.0001*	.	.

Correlation of Estimates

Corr	Intercept	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
Intercept	1.0000	0.9275	0.9645	-0.986
AVG_TEMP_C	0.9275	1.0000	0.9880	-0.974
AVG_SNOW_WATER_CM	0.9645	0.9880	1.0000	-0.995
AVG_PRECIP_CM	-0.986	-0.974	-0.995	1.0000



Regression Analysis

JMP statistical analysis software provides a fit by model functionality where a dependent variable **y** (the change in ice patch area) is calculated on a generalized linear model against three **x** variables (average annual temperature, precipitation, and snow water equivalence). Using environmental data from the Kirwin weather station and ice patch area data from GRSLE and LANDSET digitization provides all the necessary variables to construct this model.

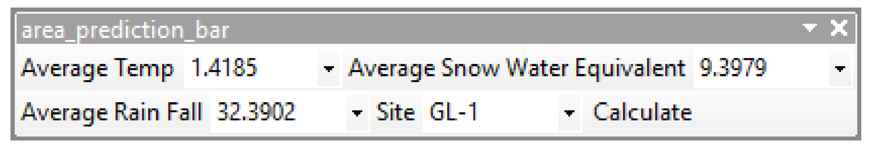
GL-1	CHANGE_ICEPAT	AVG_TEMP_C	AVG_SNOW_WATER_CM	AVG_PRECIP_CM
AVG_2016	236.3887045	1.418569254	9.379906849	32.39021918
AVG_2015	-460.5224428	1.628510379	9.829241758	34.69402747
AVG_2014	-2476.729253	0.099206349	18.35568681	39.80333516
AVG_2013	-1370.340043	0.741758242	9.189357143	30.12551648
AVG_2011		0.467032967	15.88128022	37.95834615
AVG_2010		-0.246575342	10.0945863	29.46191233

Four intervals for the change in annual ice patch area are derived for each individual ice patch, resulting in a total of 20 data sets. In 2011, the ice patch area data showed that multiple ice patches did not melt enough to separate into independent areas, particularly GL-3 and GL-4, and GL-5 through GL-10A. As such, the change in areas of these ice patches are evaluated in whole relative to their corresponding annual change.

ICE PATCH AR	SITES	AUGUST_2011	CHANGE IN AREA 2011-2013	AUGUST_2013	CHANGE IN AREA 2013-2014	AUGUST_2014	CHANGE IN AREA 2014-2015	AUGUST_2015	CHANGE IN AREA 2015-2016	AUGUST_2016
	GL-1	5397.565216	-1370.340043	4027.225174	-2476.729253	1550.495921	-460.5224428	1089.973478	236.3887045	1326.362182
	GL-2	9218.560081	-5399.609732	3818.950349	-2288.465543	1530.484806	1037.04147	2567.526276	-184.3774586	2383.148818
	GL-3			4574.634584		9186.68777		3656.566562		2849.024627
	GL-4	59207.83967	-50459.61599	4173.589095	8166.673327	7728.209236	-9591.023874	3667.306571	-1831.043298	2643.805208
	GL-5			8761.566492		11514.99582		8844.625061		7116.066421
	GL-6			4168.83481		3993.003208		3947.78432		3227.374537
	GL-7			4127.109042		3752.047897		2649.316877		2146.456139
	GL-7A			890.2935448		486.15151		215.666642		242.2919312
	GL-8			2431.301654		1461.789135		1350.306825		1032.8559
	GL-9			590.8520385		342.3427125		458.5762785		344.5118304
	GL-10			1090.544268		443.7128216		797.5005564		670.3307175
	GL-10A	61188.64495	-37648.24447	1479.898625	-997.4655575	548.8918154	-4106.434032	172.7243233	-3509.529054	147.0843538
	GL-11	8491.221304	-5577.653285	2913.568019	-494.9503657	2418.617653	-214.3646906	2204.252962	-350.8594912	1853.393471
	GL-7B			619.2081738	-167.922004	451.2861698	-112.2786492	339.0075206		
	GL-7C				0			114.0228027		

ArcPlugin

A Plugin tool that takes three inputs, average annual temperature, precipitation, and snow water equivalence, and has the user select the ice patch they wish to manipulate, generates a predicted ice patch layer which abides by the regression equation relative to the users designated variables. This Plugin (version 0.2) was programed in Python and currently serves as a preliminary framework for constructing more powerful tools. Particularly, an ice patch predictability model that takes multiple variables and assess various data for locations with the necessary conditions for ice patches to reside.



Refining the Algorithm

Several factors greatly effect the capabilities and accuracy of this model. Unfortunately, the nearest weather station to Cougar Pass, Yount's Peak, is missing a portion of significant data, thereby rendering it an inapplicable data source for models incorporating areas from 2013 to 2015. The data from Kirwin are certainly useable in place of Yount's Peak, yet are less ideal. The most ideal data would require exact variable readings between individual ice patches, which currently do not exist. In addition to better variable readings, higher resolution satellite imagery would allow for more accurate measurements of the change in area. The data from 2015 and 2016 are exceptionally accurate (40 cm accuracy), as well as 2011 which was digitized over a much higher resolution image than 2014 and 2013 (30m resolution).

Conclusion

This ArcPlugin serves as a preliminary framework for more capable ice patch models. Currently, the Plugin is limited to only three variables, average annual temperature, precipitation, and snow water equivalence, and assumes that the said variables are responsible for 100% of an ice patch's change in area. Other variables such as elevation, ice patch thickness, wind direction, slope, ground material, and the ratio of ice to foreign materials, all certainly effect the change in ice patch area relative to time. By incorporating a greater array of variables, the regression equation can provide insight into both, the variation between ice patch sizes, and work towards a model for predicting past of ice patch locations. Implementing this plugin into the 2017 GRSLE Archaeology field season at Cougar Pass could prove to be an effective tool in locating archaeological material left behind by extinct ice patches and determining the accuracy of the predictability algorithm.

Thanks to the 2016 GRSLE field team for recording ice patch area data. Special thanks to GRSLE archaeology for sharing GIS data and providing project assistance. Funding provided by Wyoming CLG grant to PCHPC and Shoshone National Forest.

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