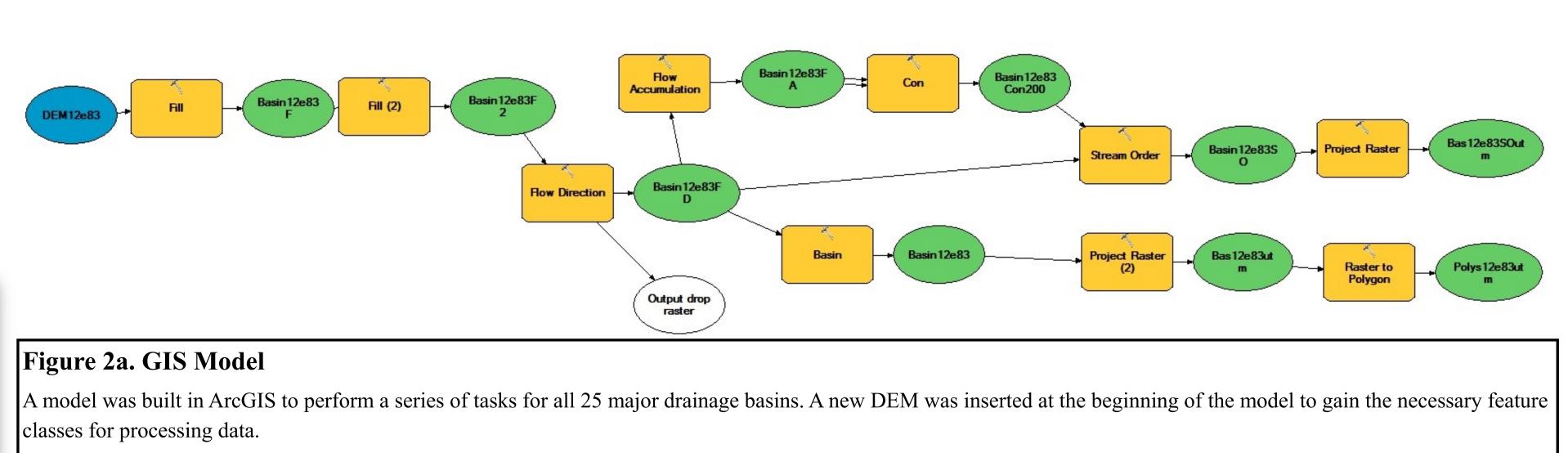




### Abstract:

Topographic indices for quantifying tectonic tilt are used to determine the extent and cause of possible range tilting of the Teton Mountain Range, WY and ID. The Teton Range is a young, asymmetric range on the eastern edge of the Basin and Range and the southern edge of the thermally uplifted Yellowstone region. The thermal uplift, attributed to the Yellowstone hot spot, has caused regional tilt north of the Yellowstone area, and it may also cause regional tilt south of Yellowstone. The Teton Range is ideally situated to test this hypothesis. To determine the magnitude and direction of possible tilt we analyzed the transverse topographic symmetry (TTS) in 25 major basins within the Teton Range (13 on the western side and 12 on the east). The basins and their major streams were identified using ArcGIS basin and stream order algorithms to 10 m USGS Digital Elevation Models (DEMs). The algorithms defined the basins based on drainage divides; the stream analysis defined water flow through the basins. The TTS equals Ds/Dm where Ds is the distance from the midpoint of the basin to the midpoint of the stream meander and Dm is the distance from the ridge to the basin midpoint. Dm was determined by drawing transects, with equal elevation start and end points, from ridge to ridge. The TTS is evaluated for each transect and a vector is used to visualize the magnitude and direction of TTS for each transect. TTS was determined at approximately 100 m intervals in the primary E-W trending basins. If tilting of a basin has occurred, the stream will show a general pattern of down-tilt migration. Thermal uplift of the Yellowstone hotspot, if it influences tilt of the Tetons, will cause a general north-south, down-tilt trend. Understanding tectonic tilt in the Teton Range and evaluating the influence of the Yellowstone hotspot on it will help determine, temporally and spatially, past interactions between passage of the hotspot and Basin and Range faulting.

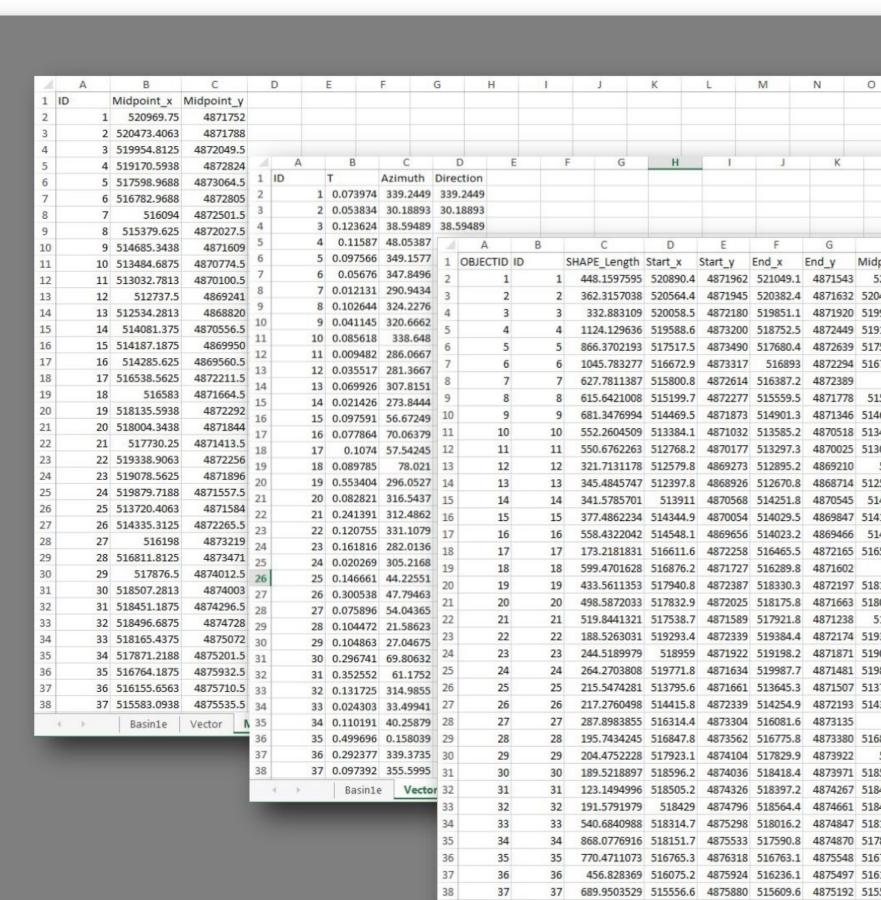
To determine the direction of tilt occurring in the Teton Range, we applied the ArcGIS 'Contour,' 'Basin,' and 'Stream Order' spatial analyst tools to 10-m USGS Digital Elevation Models (DEM's). All data were projected into Universal Transverse Mercator (UTM) coordinates for more accurate analysis. To perform this series of steps, model builder was used in ArcGIS for a more efficient work flow (Figure 2a). The transverse topographic symmetry factor (TTS) was then calculated using the equation Ds/Dm (Figure 2b). Ds represents the distance from the midpoint of the drainage basin to the stream, and Dm represents the distance from the midpoint of the drainage basin to the ridge. Calculations of the TTS were completed on all tributaries, excluding first order streams based on the Strahler method. Transects were drawn at approximately 100-m intervals in ArcGIS using 20-m contours to define the starting and ending points. The start and endpoints of these transects have an equal elevation allowing the midpoint of each transect to be used as the midpoint of the drainage basin for each tributary. XY coordinates of start and endpoints, midpoints, and stream-transect intersections were calculated in ArcGIS using 'calculate geometry' tools. Distances to find Ds and Dm were calculated using the XY coordinates in Microsoft Office Excel (Figure 2c). The calculated TTS gives a value of the magnitude of the vector within a range from 0 to 1 with 0 meaning that the stream has not migrated at all from the midpoint and 1 implying that the stream has migrated to the edge of the basin. Trigonometric functions applied on the drawn transects find the azimuth of the line and the direction in which the stream has moved from the midpoint. Vectors were then created at each stream-transect intersection of each drainage basin (Figure 3d). Inverse distance weighting was applied to better visualize and predict direction of tilt throughout the entire range (Figures 3-6).

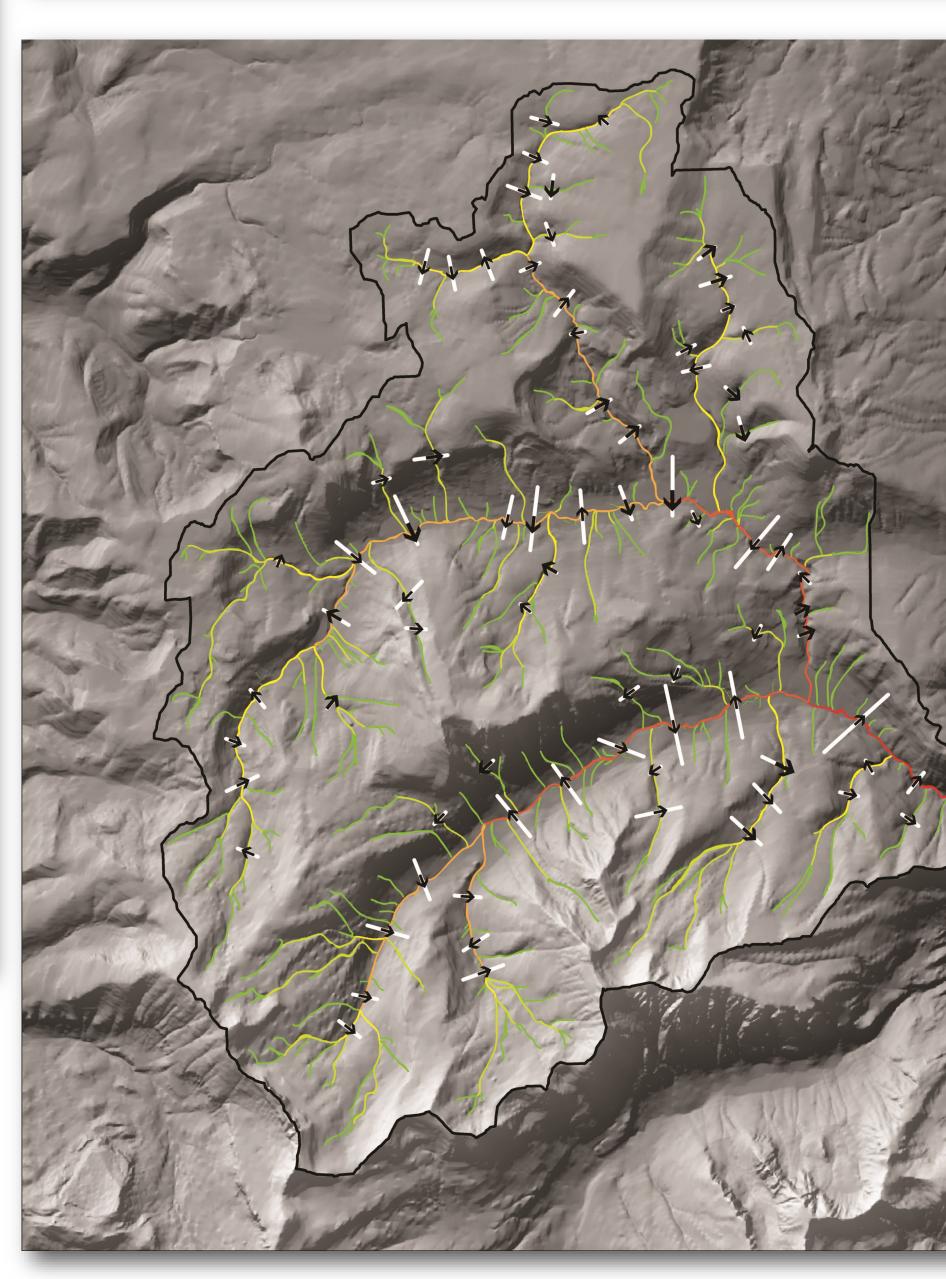


# Peaks S Drainage Basins

### Figure 1. Study Area

Data was collected and analyzed across the entire Teton Mountain Range which sits on the border of Idaho and Wyoming. It is located just south of the Yellowstone hotspot and west of the Teton fault which makes this range an ideal location to test for possible causes of regional tilt using stream order analysis.



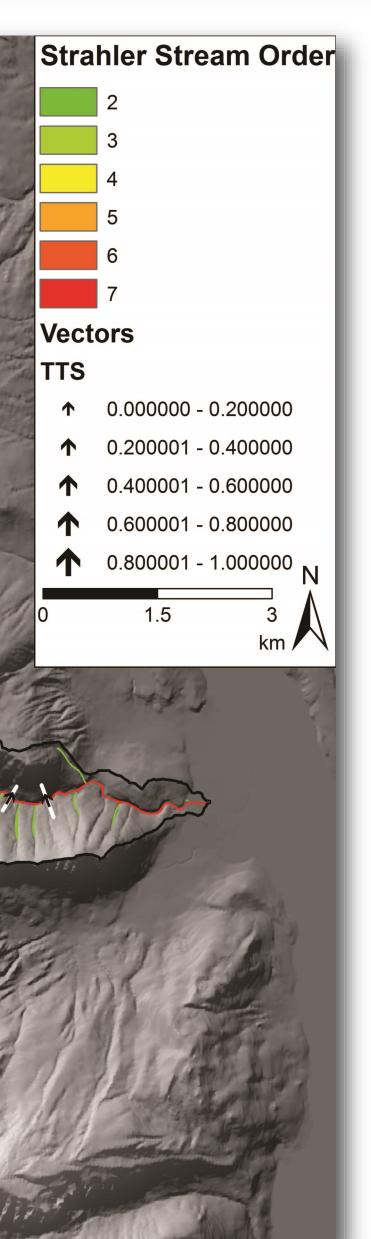


# Assessing Tectonic Tilt of the Teton Range, Wyoming and Idaho, Using Stream Topographic Analysis

# Walk, Cory J., Day, Troy W., Willis, Dr. Julie B.

### **Methods:**

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		-	Y	X	W	V	U	Т	S	R	Q	P	0	N	M	L
													1			
V	U	T	S	R	Q	P	0	N		M	L	K	J	0.015	1	H
Direction		stream_y-mid_y			and the second second	change_x		Mid_length							Midpoint_y	dpoint_x
339.2449	5.5 N			-20.7551		158.75		224.07988	505577				1		1	520969.75
30.1889	8.5 N			30.18893	and the second se	-182.031		181.157852	453618			520478.1875				0473.4063
38.5948	16 N 3.5 N			38.59489 48.05387		-207.438 -836.094	0.123624	166.441554 562.064818			4872065.5	519967.75	3			9954.8125
48.05387	1.5 N			-10.8423		-836.094		433.18511			4872867.5				100000000	9170.5938
349.1577	-29 S		349.1577		-850.9	220.125	0.05676	522.891638	405092 907775		4873106	517590.9688 516789.2813		and a	700 800 10	7598.9688 6782.9688
110.943	-29 S		290.9434	and the second sec	-224.4			313.890569	886553		4872500	516097.5	7	1177.00		516094
324.227	5.5 N		324.2276		-499.4			307.82105	597544	-	4872053	515360.9688				15379.625
320.666	11 N			-39.3338	-526.9			340.67385	587042		4872600	514676.6563				4685.3438
158.64	-22 S			-21.352	-514.4	19101		276.130225	171449			513493.3438				3484.6875
106.066	0.5 S			-73.9333	-152.4			275.338113	S		4870100	513035.3438				3032.7813
101.366	-1 S			-78.6333	-63.4	315.375		160.856559					12			512737.5
127.815	7.5 S			-52.1849	-211.9	273.0313		172.742287		-			13		10000353	2534.2813
93.8444	0.5 S		273.8444	-86.1556	-22.9	340.7813	0.021426	170.789285	320292	3.6593	4870556	514085	14	6.5	4870556.	14081.375
236.672	-10 S	-10	56.67249	56.67249	-207.4	-315.406	0.097591	188.743112	961527	18.419	4869940	514171.7188	15	950	486995	4187.1875
70.0637	7.5 N	7.5	70.06379	70.06379	-190.4	-524.938	0.077864	279.216102	086105	21.740	4869568	514306.0313	16	0.5	4869560.	14285.625
237.542	-5 S	-5	57.54245	57.54245	-92.9	-146.063	0.1074	86.6090915	850034	9.3018	4872206.5	516530.7188	17	1.5	4872211.	6538.5625
78.02	5.5 N	5.5	78.021	78.021	-124.4	-586.313	0.089785	299.735081	176628	26.911	4871670	516609.3438	18	4.5	4871664.	516583
116.052	-53 S	-53	296.0527	-63.9473	-190.4	389.4688	0.553404	216.780568	572481	119.96	4872239	518243.2188	19	292	487229	8135.5938
136.543	-15 S	-15	316.5437	-43.4563	-361.9	342.9063	0.082821	249.293602	567422	20.646	4871829	518018.5313	20	344	487184	8004.3438
132.4862	2.5 S	-42.5	312.4862	-47.5138	-350.9	383.125	0.241391	259.922066	272399	62.742	4871371	517776.4063	21	3.5	4871413.	517730.25
331.1079	10 N	10	331.1079	-28.8921	-164.9	91	0.120755	94.2631515	272403	11.382	4872266	519333.4688	22	256	487225	9338.9063
102.013	-4 S	-4	282.0136	-77.9864	-50.9	239.1875	0.161816	122.259499	359485	19.783	4871892	519097.9375	23	396	487189	9078.5625
125.216	1.5 S	-1.5	305.2168	-54.7832	-152.4	215.9063	0.020269	132.13519	217983	2.6782	4871556	519881.9375	24	7.5	4871557.	9879.7188
224.225	1.5 S			44.22551		-150.281		107.773714	523023			513709.5625		584	487158	3720.4063
227.7946	-22 S			47.79463		-160.875		108.638025				514311.1875				4335.3125
234.043	6.5 S			54.04365		-232.844		143.949193				516189.2188				516198
201.586	9.5 S			21.58623		-71.9688		97.8717123				516808.0313				6811.8125
207.046	9.5 S			27.04675		-93.125		102.237611				517871.5313				517876.5
69.8063	10 N			69.80632	10000	-177.813		94.7609449		100000000		518533.5625				8507.2813
61.175	0.5 N		61.1752		-59.4			61.5747498				518470.1875				8451.1875
314.985	9 N			-45.0145		135.4688		95.789599	792035			518487.8438				8496.6875
33.4994 220.258	5.5 N 6.5 S			33.49941 40.25879	Warman And	-298.438 -560.938		270.342049 434.038846				518169.0313 517840.3125		211-		8165.4375 7871.2188
180.15		-30.3		0.158039		-2.125		385.235554				516763.6563				6764.1875
159.373	2.5 S		339.3735		-427.4	160.875						516179.1875				6155.6563
355.599	3.5 N			-4.40054	10.000	The second second		344.975176				515580.5313	1200			5583.0938

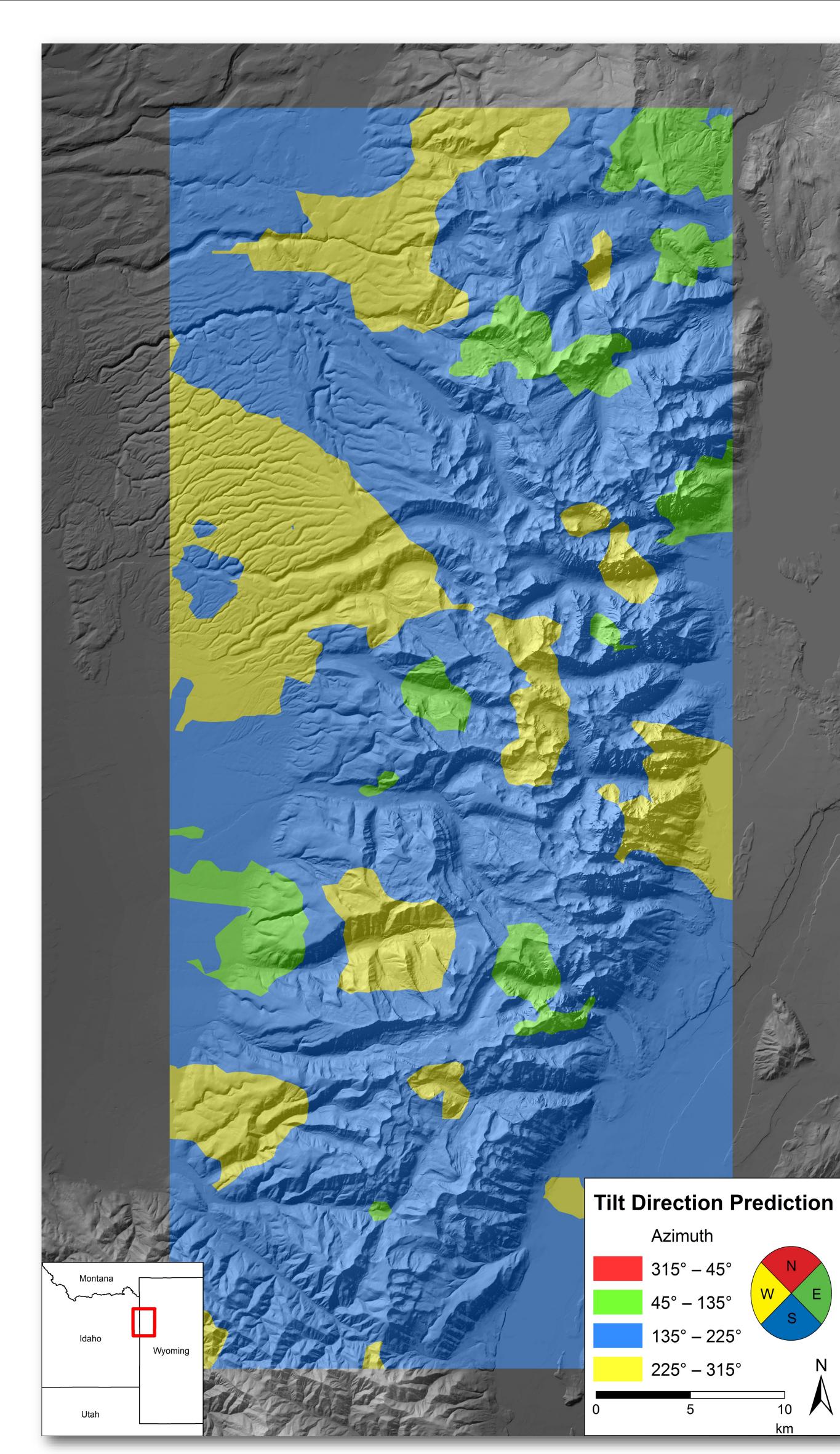


### Figure 2b. Using Excel Spreadsheets

XY coordinates of transect start and endpoints, midpoints, and stream-transect intersections were calculated in ArcGIS and exported into Microsoft Excel. Ds and Dm values were calculated in Excel along with the azimuth of the transect and the direction in which the stream has migrated using trigonometric functions.

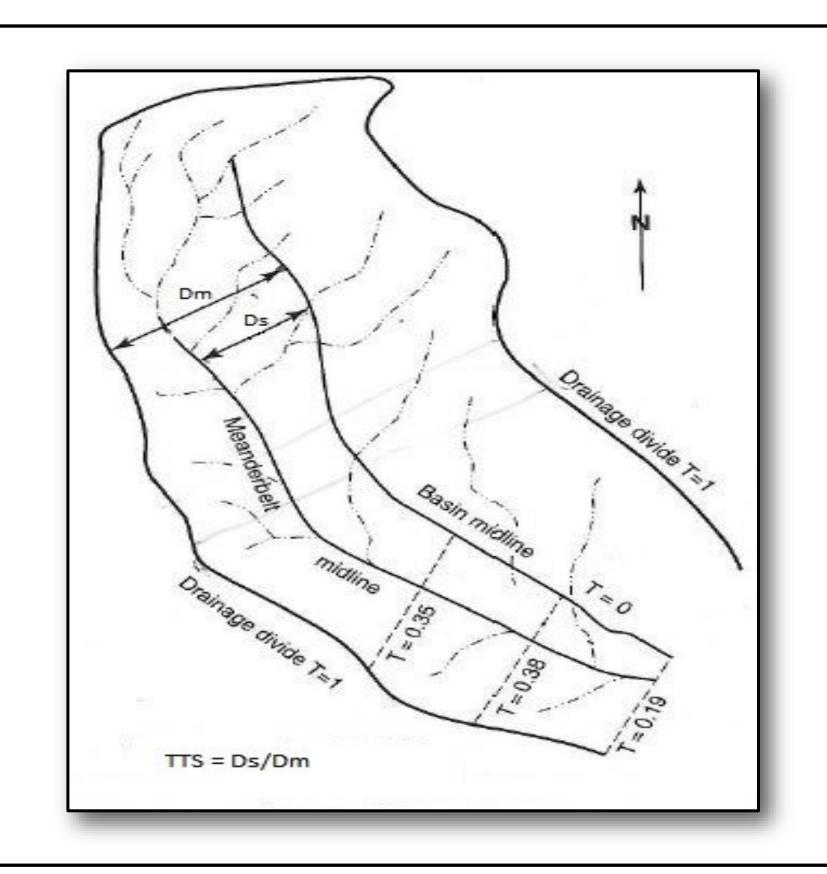
### Figure 2c. Vectors

Vectors were created at stream-transect intersections by using the data calculated in exce with the vector pointing in the direction in which the stream is moving and the size of the arrows based upon the calculated TTS value. The most north-eastern basin contains an anomaly found owhere else in the entire mountain range. This basin contains a stream capture that cut across the drainage divide. For a stream capture to cut across basin divide a lake needed to have formed. Field work performed earlier this year found previously undocumented lake deposits in the area. These deposits provide evidence for the presence of a long lived lake. Upon further review of the area a mapped landslide or a glacial moraine could have been the cause of the lake formation. Further research into the Quaternary geology of the area is needed to determine the actual cause of the lake and the unusual drainage patterns.



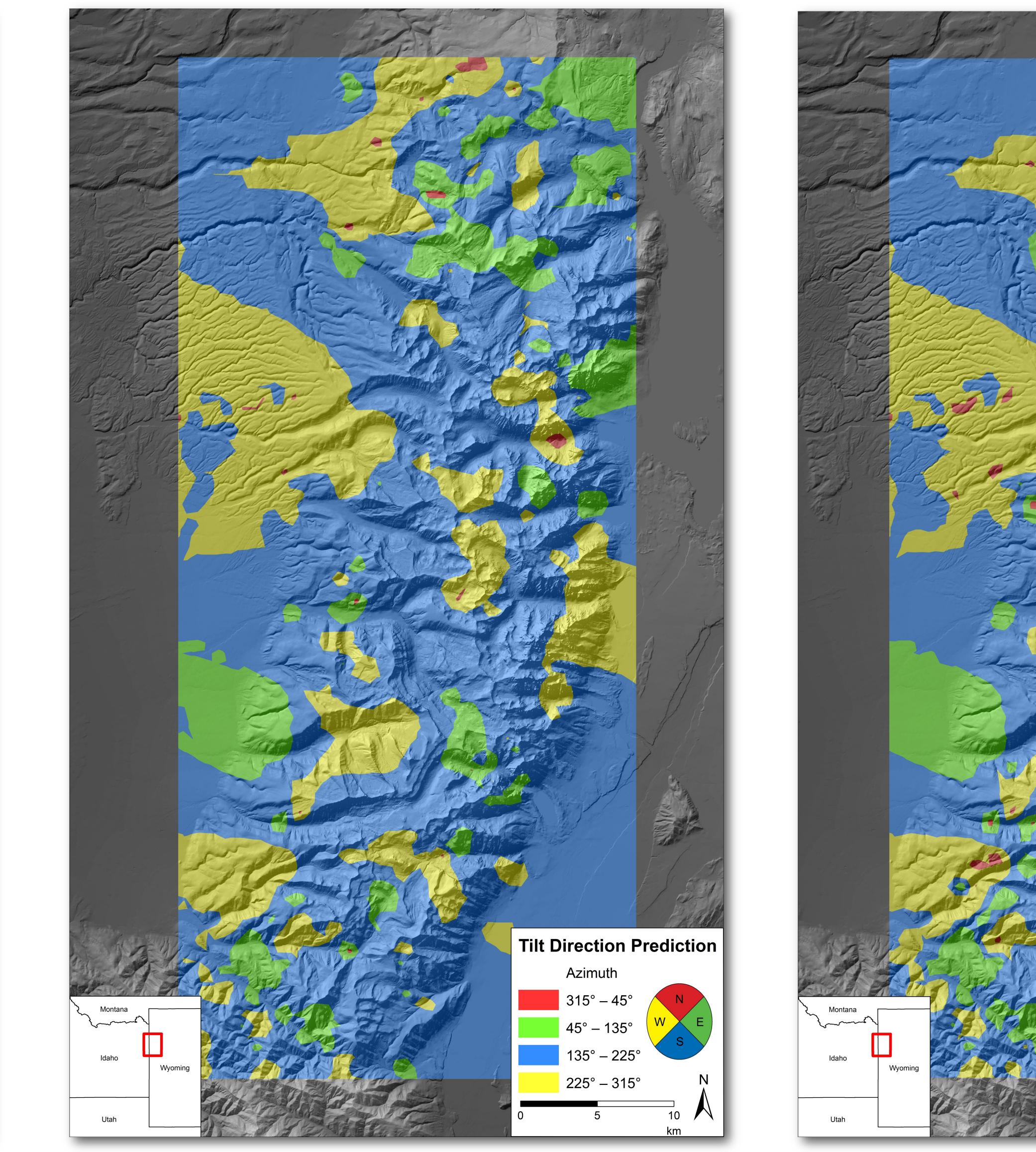
### Figure 3. Inverse Distance Weighting using First Order Polynomial Analysis

is representation of tilt data is a first order polynomial analysis using inverse distance weighting of the transect data with a minimum 10 nearest neighbors. The representation suggests that no northward tilt occurs in the Teton Range in neasureable quantities. This result led to the further use of statistical tools to determine if using higher order polynomials would give to different results (Figures 2 & 3).



### Figure 2d. Transverse Topographic Symmetry Factor

This technique allows for a quick method of accurate basin analysis. This method utilizes the natural topography to measure the distance that a stream migrates from t center of a basin. The amount and direction of shift of the stream from basin center provides information about the tilt effecting the area.



southward trend seen across the entire mountain range.

Figure 4. Inverse Distance Weighting using Second Order Polynomial Analysis The default second order polynomial suggests further variation in the tilt expressed in the Teton Range than did the first order. The small amount of northward tilt remains eclipsed by the large amount of southward tilt. Areas that tilt both west and east are larger in size and more connected than some of the more isolated areas seen in the third order polynomial tilt map (Figure 3)

### **Conclusions:**

• The data derived from the first second, and third order polynomial inverse distance weighting equations corroborates the hypothesis that the Yellowstone Hotspot is the primary source of the tilt found within the Teton Mountain Range.

• The southern tilt is expressed throughout the entire mountain range, and is not based around the hinge point of the Teton Fault.

## • This research allows for further investigation in the Teton Range of a stream capture in the north-eastern most basin. The further research of this stream capture may lead to new information regarding paleotopography in the area.

• To further support the hypothesis that uplift described in the Tetons is regional rather than local, analysis could be performed in the neighboring Gros Ventre Mountain Range to determine if the same results could be produced.

• The raster data could be converted to vector data to allow for the geometric analysis of the area above and below the streams to be done. If the converted data suggests that the area above the streams is larger than the area beneath them; it corroborates the hypothesis that southward tilt dominates the area.

• Analysis of the Teton fault could determine how the Teton fault affects the mountain range, and the relationship with the Yellowstone hotspot. The analysis of the fault could also explain the reasons why large sections of the Tetons tilt towards the west or east respectively.

• The tectonic tilt mapping could be useful in understanding Quaternary mass wasting scenarios in the parts of the Range prone to these events.

### **Future Research:**



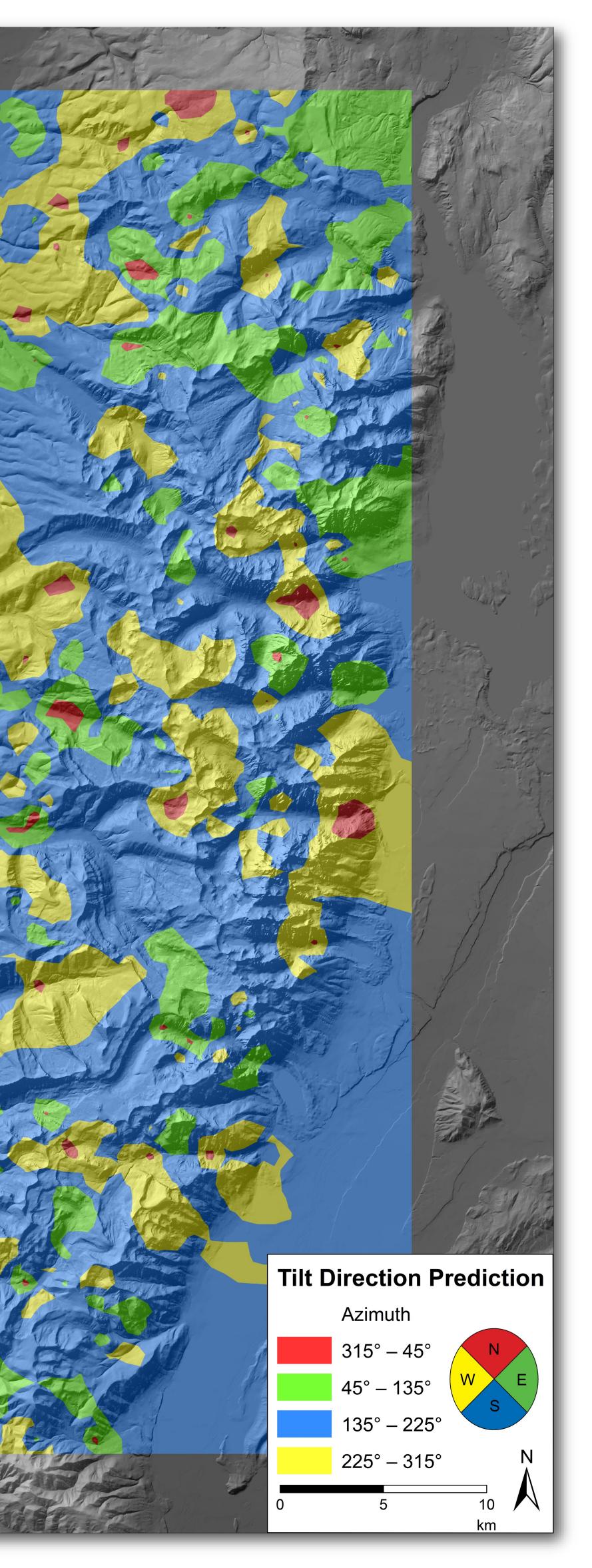
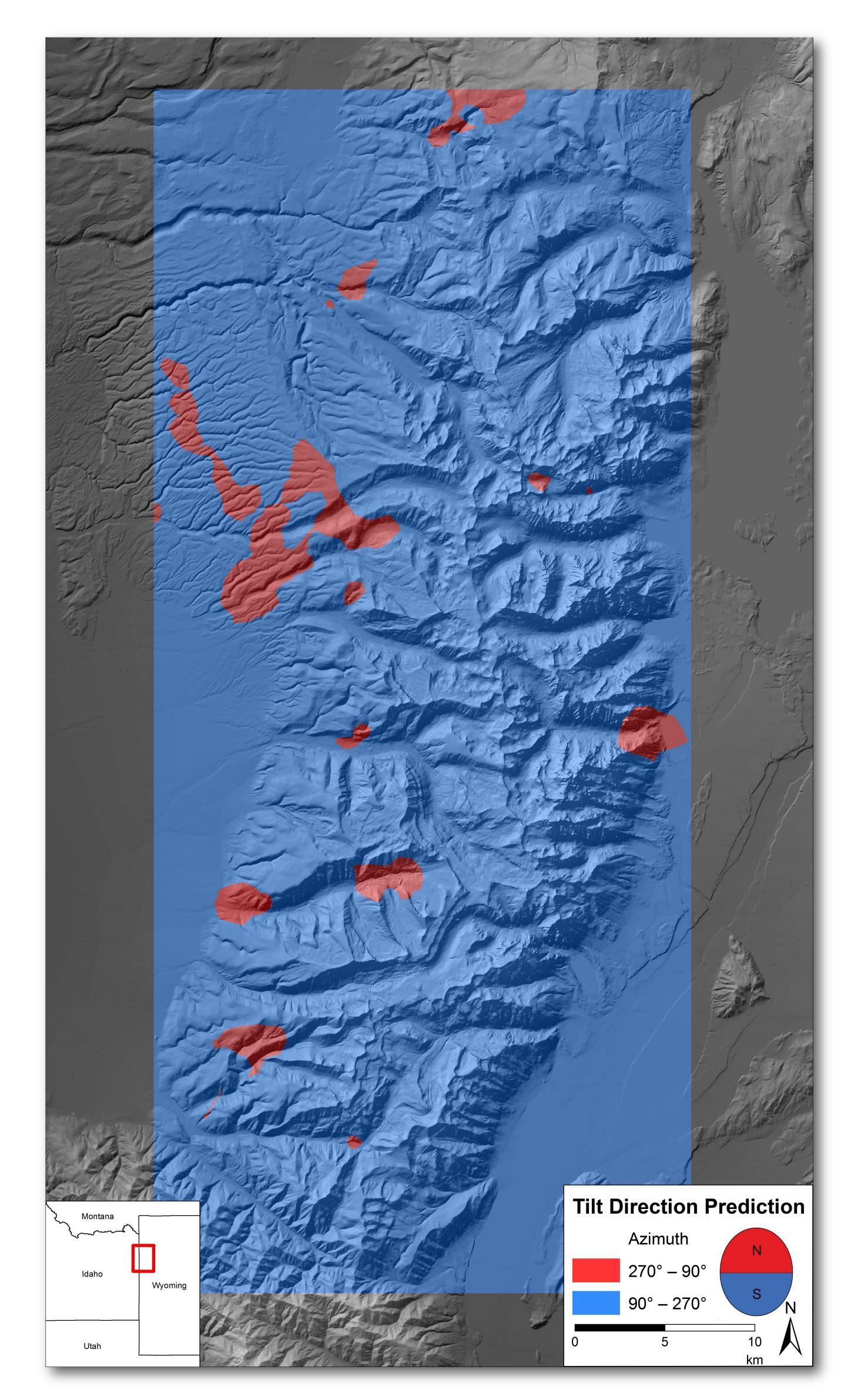


Figure 5. Inverse Distance Weighting using Third Order Polynomial Analysis

To further analyze the data, a third order polynomial analysis suggests more areas that tilt both to the east and the west. Some isolated areas suggest greater northward tilt, however those areas remain small when compared to the general



### Figure 6. North versus South Tilt Directions

In an effort to show the dramatic difference in the tilt seen in the Teton Range, tilt has been categorized to only be north or south facing. By separating the tilt into these two directions the regional southern trend becomes clearly visible. The widespread regional tilt to the south corroborates the hypothesis that the Yellowstone hotspot is the cause of regional

### Acknowledgements:

• The data were collected using the ESRI ArcGis software and the analysis performed could not have been done without the software.

• The help of Dr. Grant Willis, head of the geologic mapping program for the Utah Geological Survey, proved invaluable in determining the areas of future research in the Teton Range and in the interpretation of data found while doing field work.

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