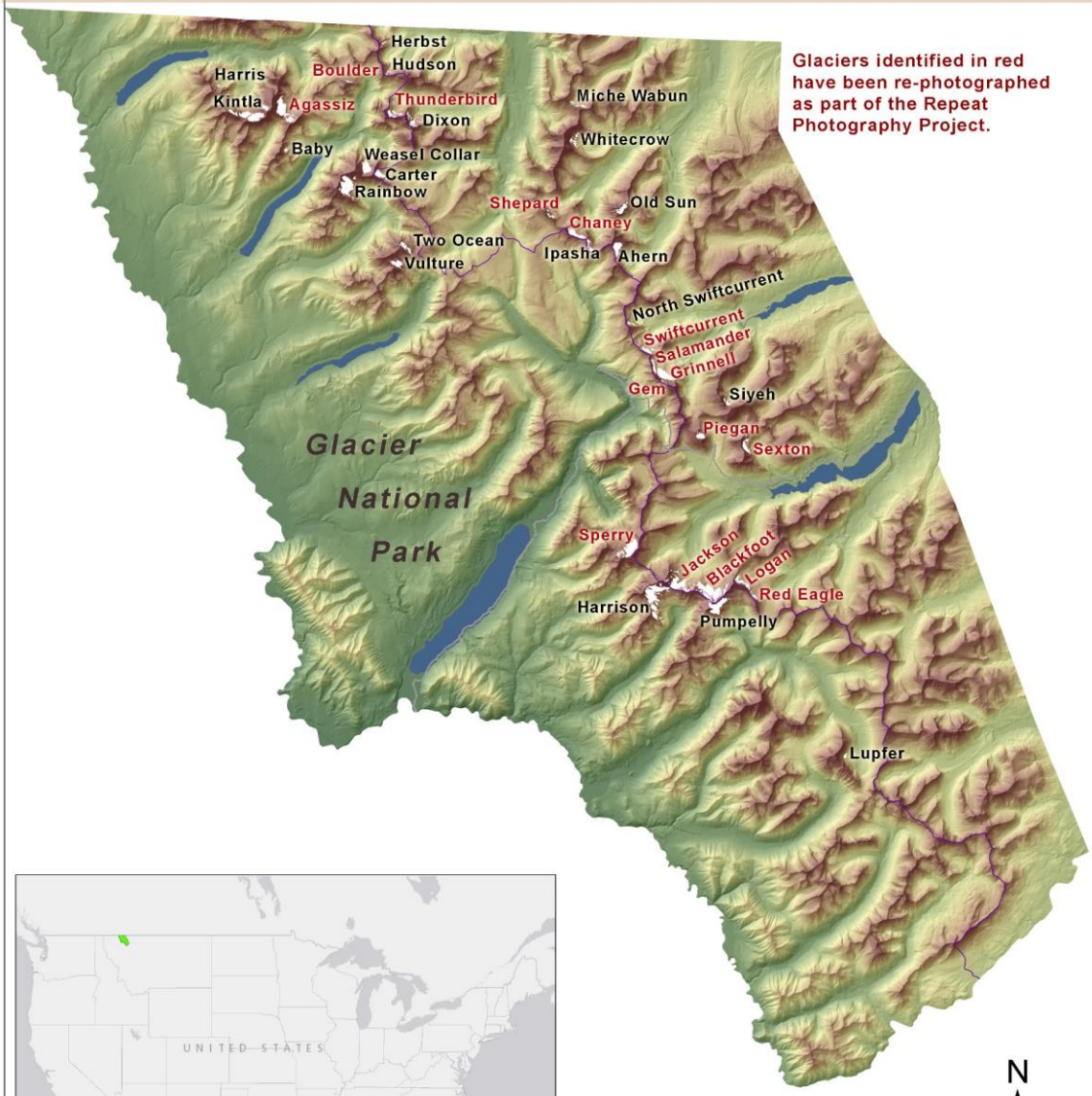
Location of Named Glaciers

Glacier National Park, Montana, USA

USGS science for a changing world



N

0 3.75 7.5 15 22.5 30 Kilometers

https://www.usgs.gov/centers/norock/science/retreat-glaciers-glacier-national-park

Sperry Glacier

Glacier National Park, Montana

1908, F Liebig, GNP Archives

09-25-2015, A Clark, USGS

Grinnell Glacier

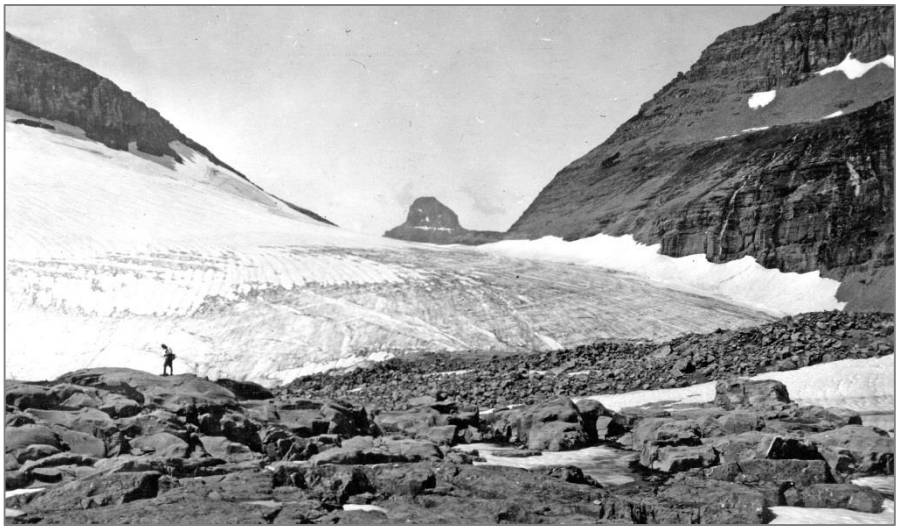
Glacier National Park, Montana

1911, TW Stanton, USGS Photographic Library

09-20-2016, L McKeon, USGS

Boulder Glacier

Glacier National Park, Montana

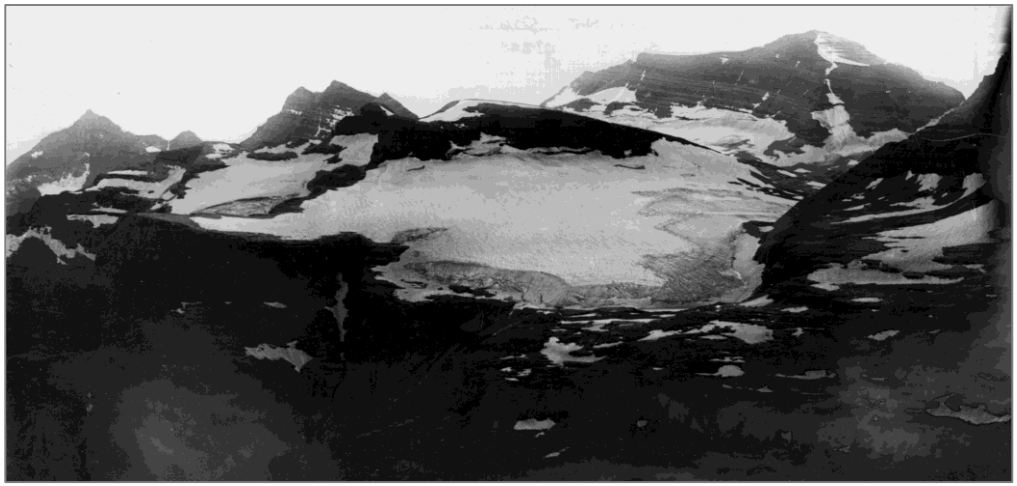


1913, WC Alden, USGS Photographic Library

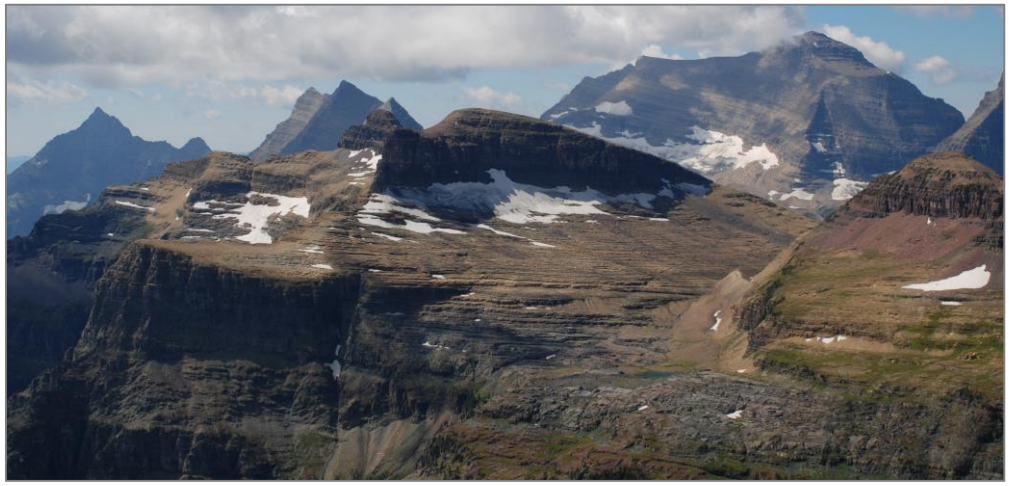
2012, K Jacks, USGS

Boulder Glacier

Glacier National Park, Montana



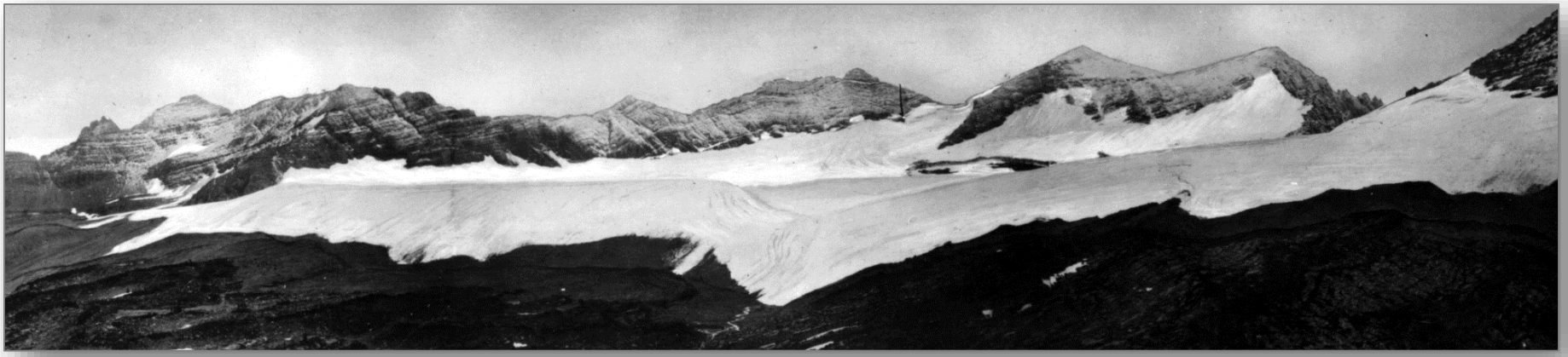
Circa 1910, Morton Elrod, GNP Archives



2007, D Fagre / G Pedersons, USGS

Sperry Glacier

Glacier National Park, Montana

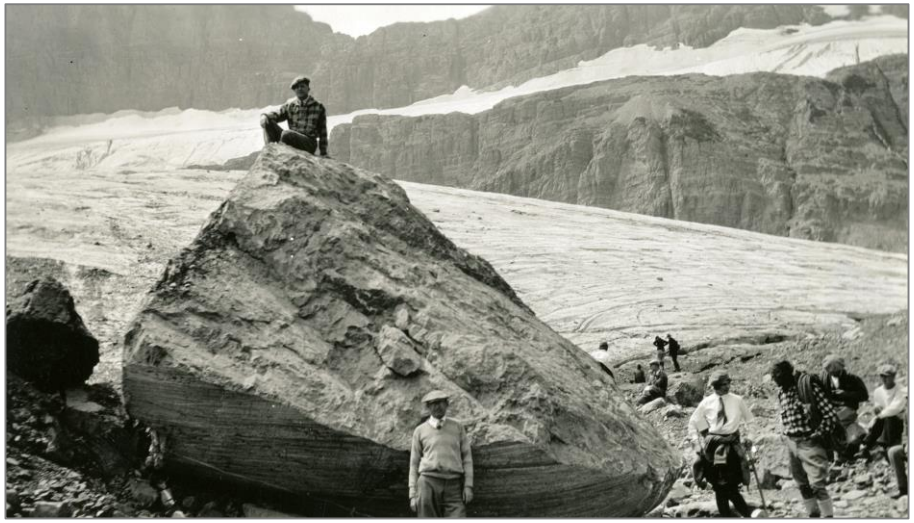


1913, Alden, GNP Archives

2008, L McKeon, USGS

Grinnell Glacier

Glacier National Park, Montana



August 1926, M Elrod, University of Montana

2008, L McKeon, USGS

Shepard Glacier

Glacier National Park, Montana

1913, Alden, USGS Photographic Library

2005, B Reardon, USGS

Jackson Glacier

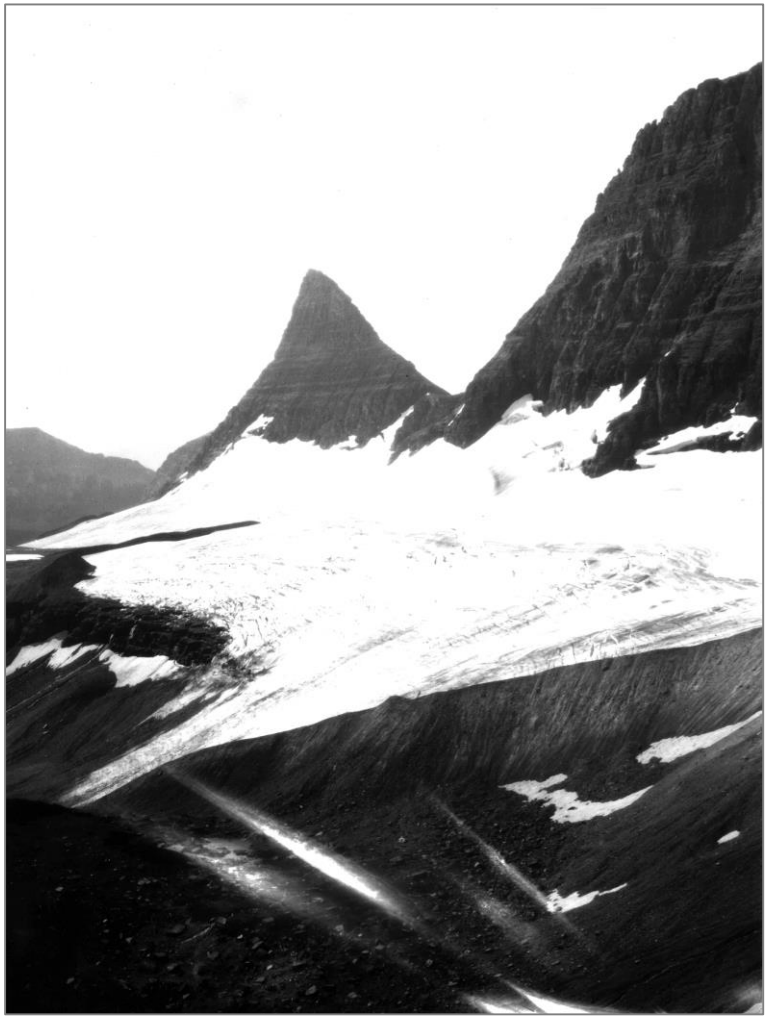
Glacier National Park, Montana

1911, M Elrod, University of Montana

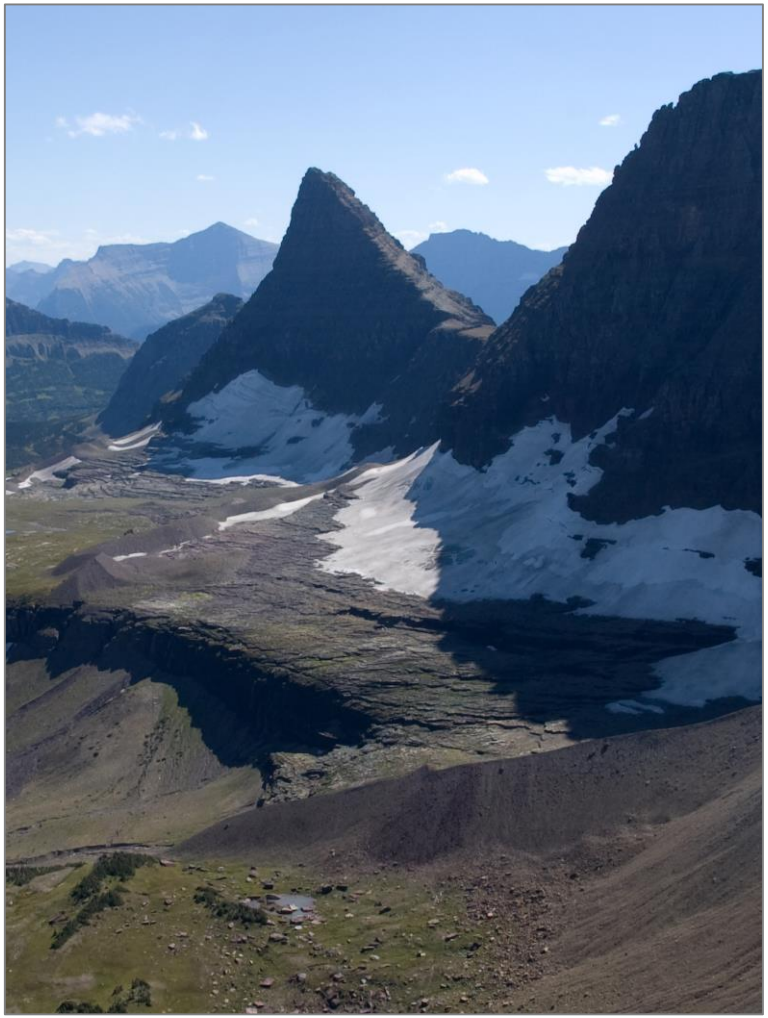
2009, L McKeon, USGS

Red Eagle Glacier

Glacier National Park, Montana



1914, EC Stebinger, USGS Photographic Library



2009, L McKeon, USGS

Blackfoot & Jackson Glaciers

Glacier National Park, Montana

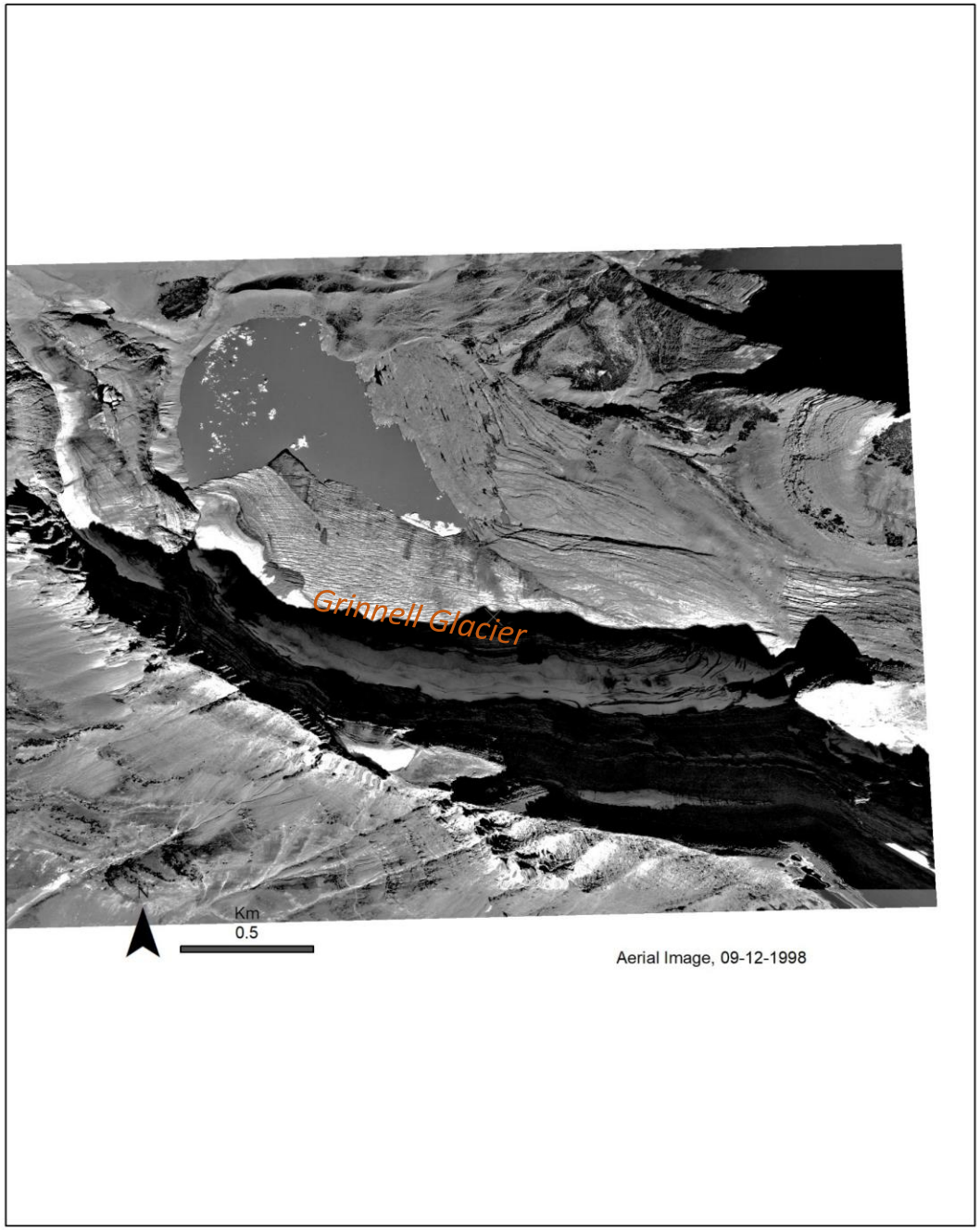
Aug. 1, 1914, EC Stebinger, USGS Photographic Library

Sept. 9, 2009, L McKeon, USGS

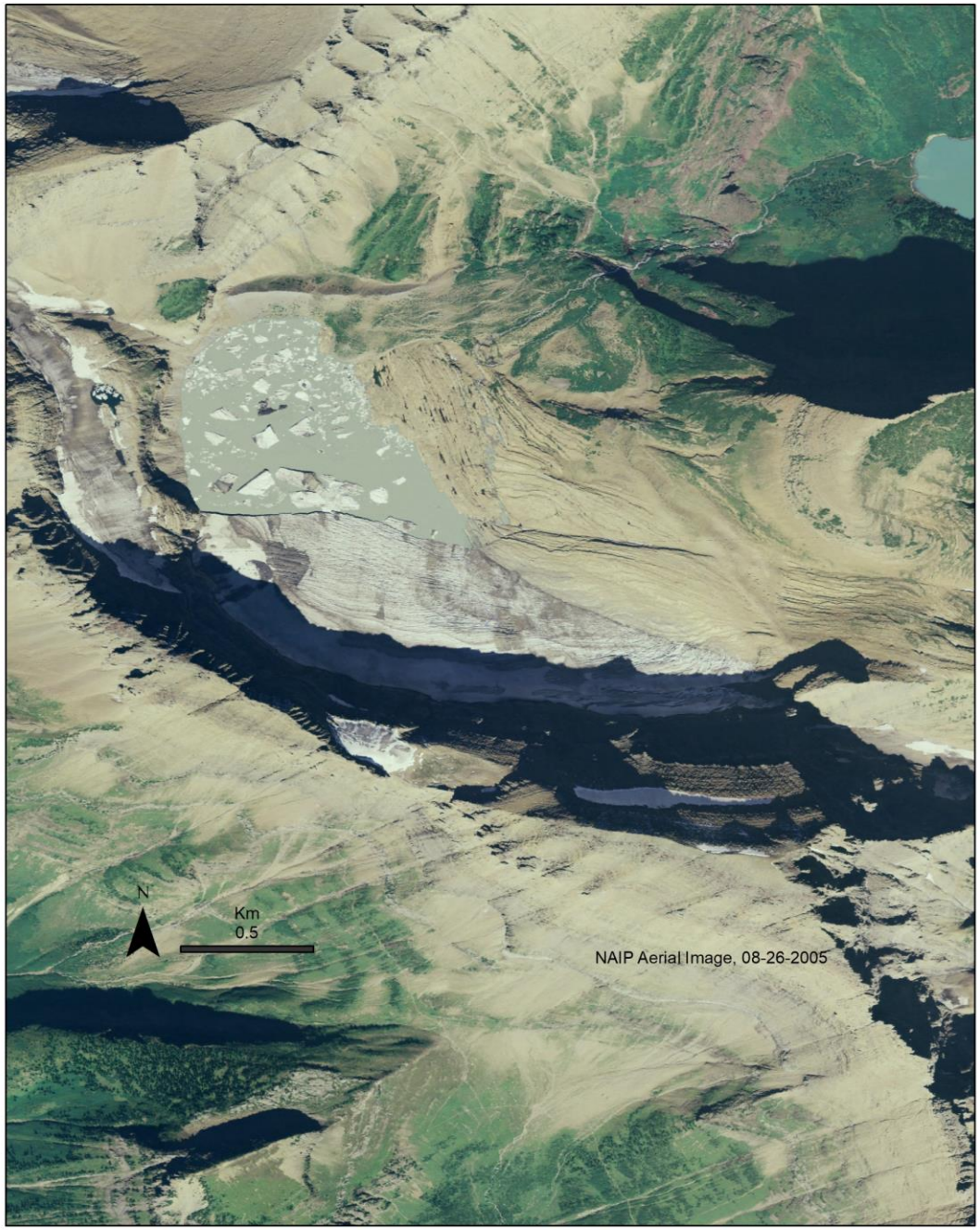
Repeat Photo Observation Form				name:
				date:
Glacier Name	Years Photos WereTaken	Number of Years Between Photos	**Similarities** Between Photos	**Differences** Between Photos

1) Place plastic sheet over page and trace the scale bar to help align images in this lesson.

2) Trace the perimeter of Grinnell Glacier on 9-12-1998. It may be helpful to look at the color image from 2005 to help determine the basic shape of the glacier in the shaded areas.

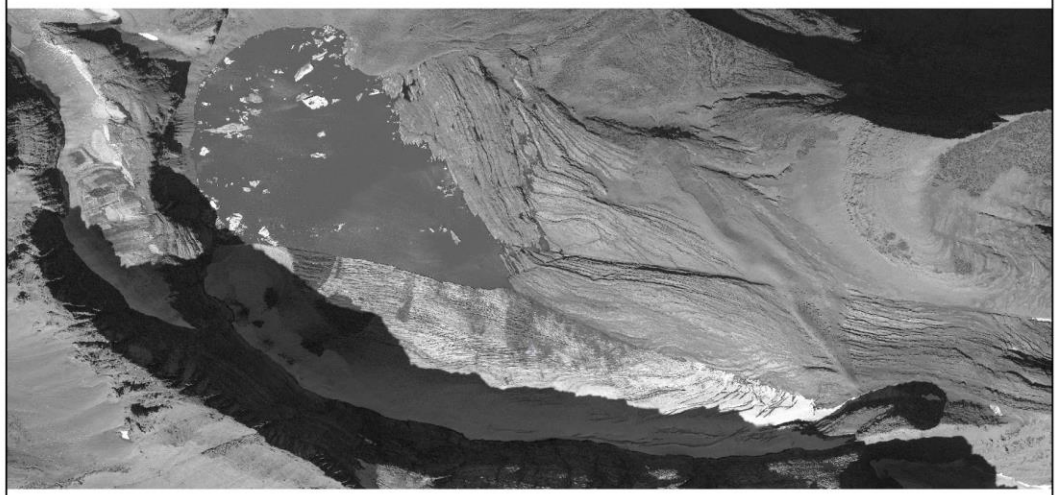


Activity #2:
Trace glacier perimeter



Align plastic sheet with scale bar and trace the perimeter of Grinnell Glacier on 8-26-2005.

Activity #2:
Trace glacier perimeter



N

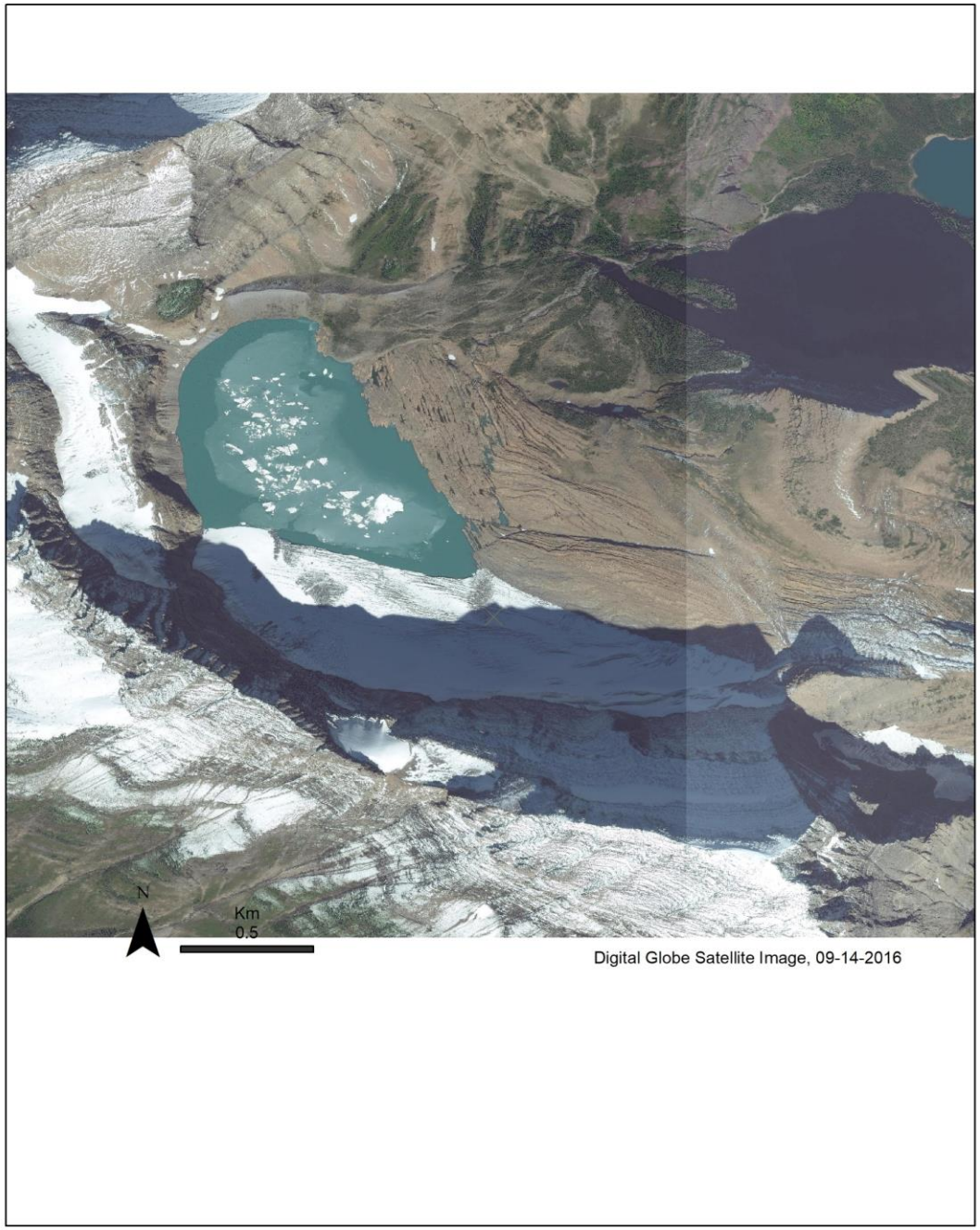
Km
0.5

Digital Globe Satellite Image, 08-22-2015

Align plastic sheet with scale bar and trace the perimeter of Grinnell Glacier on 8-22-2015.

1) Align plastic sheet with scale bar and trace the perimeter of Grinnell Glacier on 9-14-2016.

2)Locate the portions of the moraine visible in this image and trace the size of the glacier around 1850, based on the moraines left behind.



MORAINE:
a mass of rocks and sediment carried down and deposited by a glacier, typically as ridges at its edges or extremity.

Unnamed glacier near Split Mountain, Glacier National Park, MT

Oblique view:

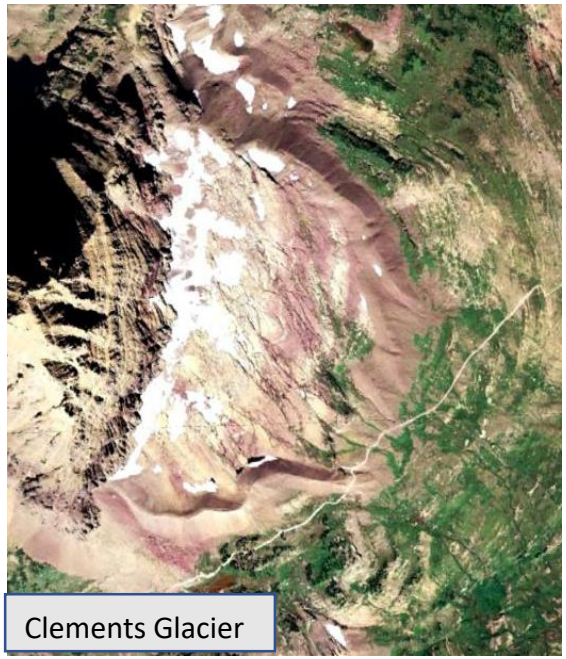
moraine

Aerial view:

moraine

Identifying glacier moraines from the air

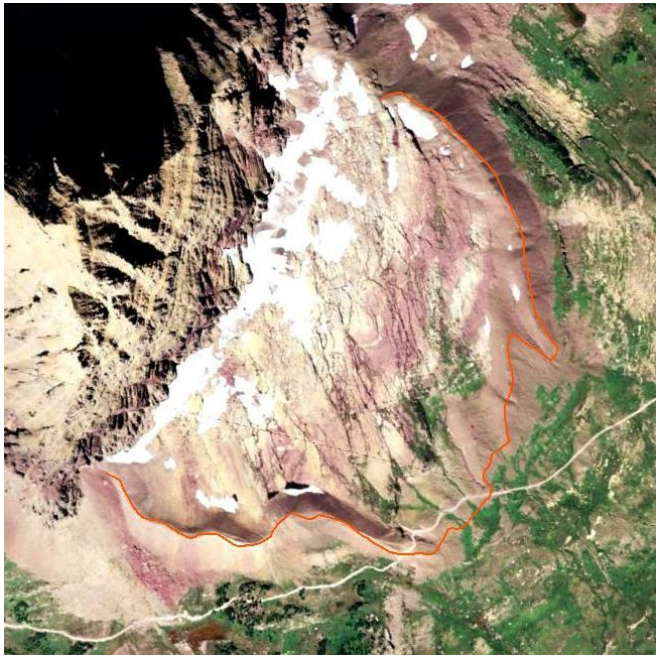
Fold the paper in half along dotted line and practice identifying the moraines, deposits of gravel made by glaciers at their largest size. Unfold to compare your moraine lines.

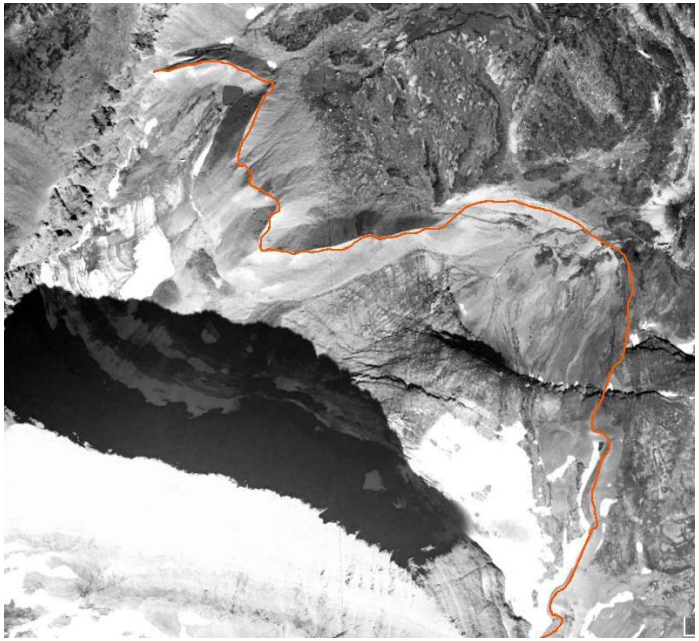


Clements Glacier

Logan Glacier

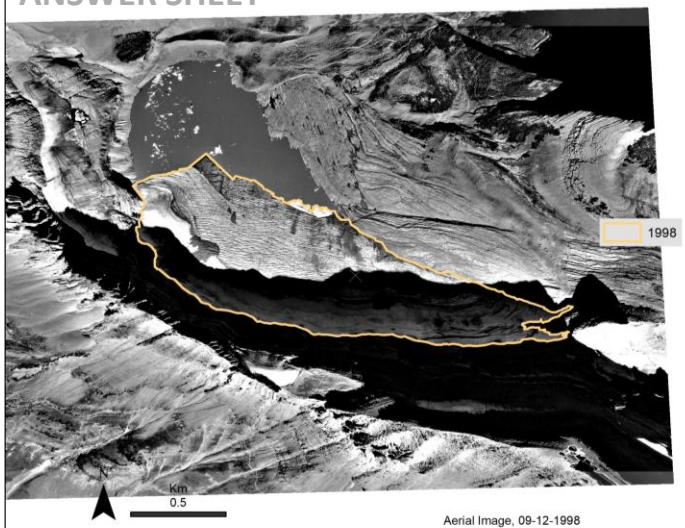
Fold Here

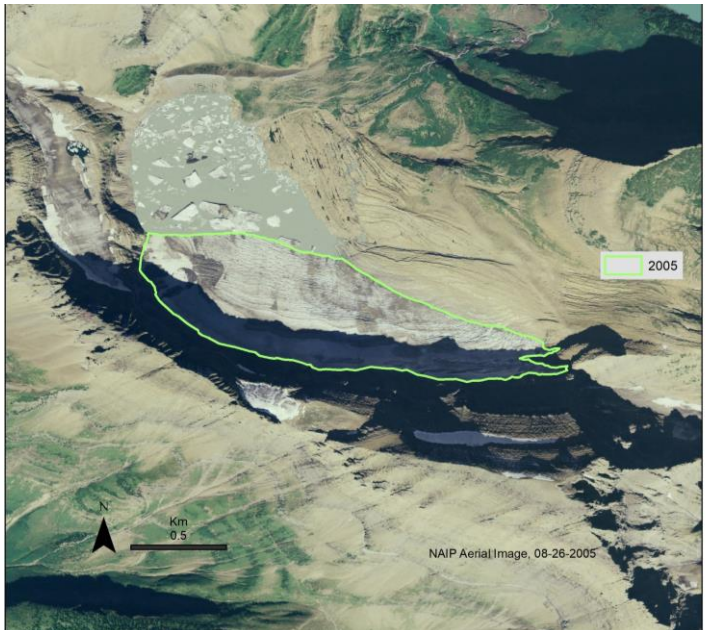


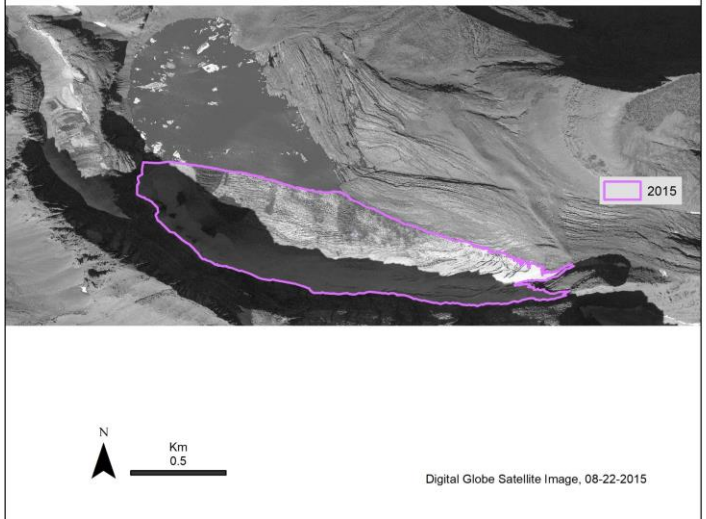


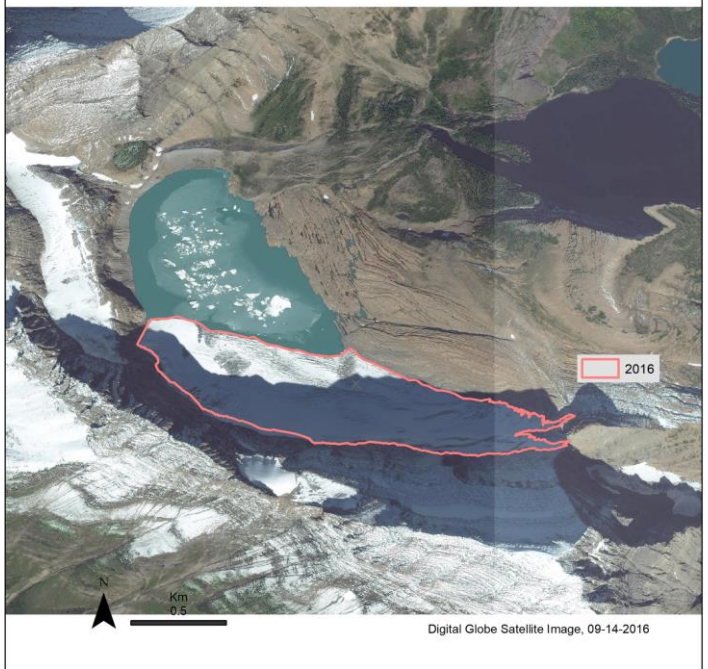
moraine

Activity #2: Trace glacier perimeter
ANSWER SHEET



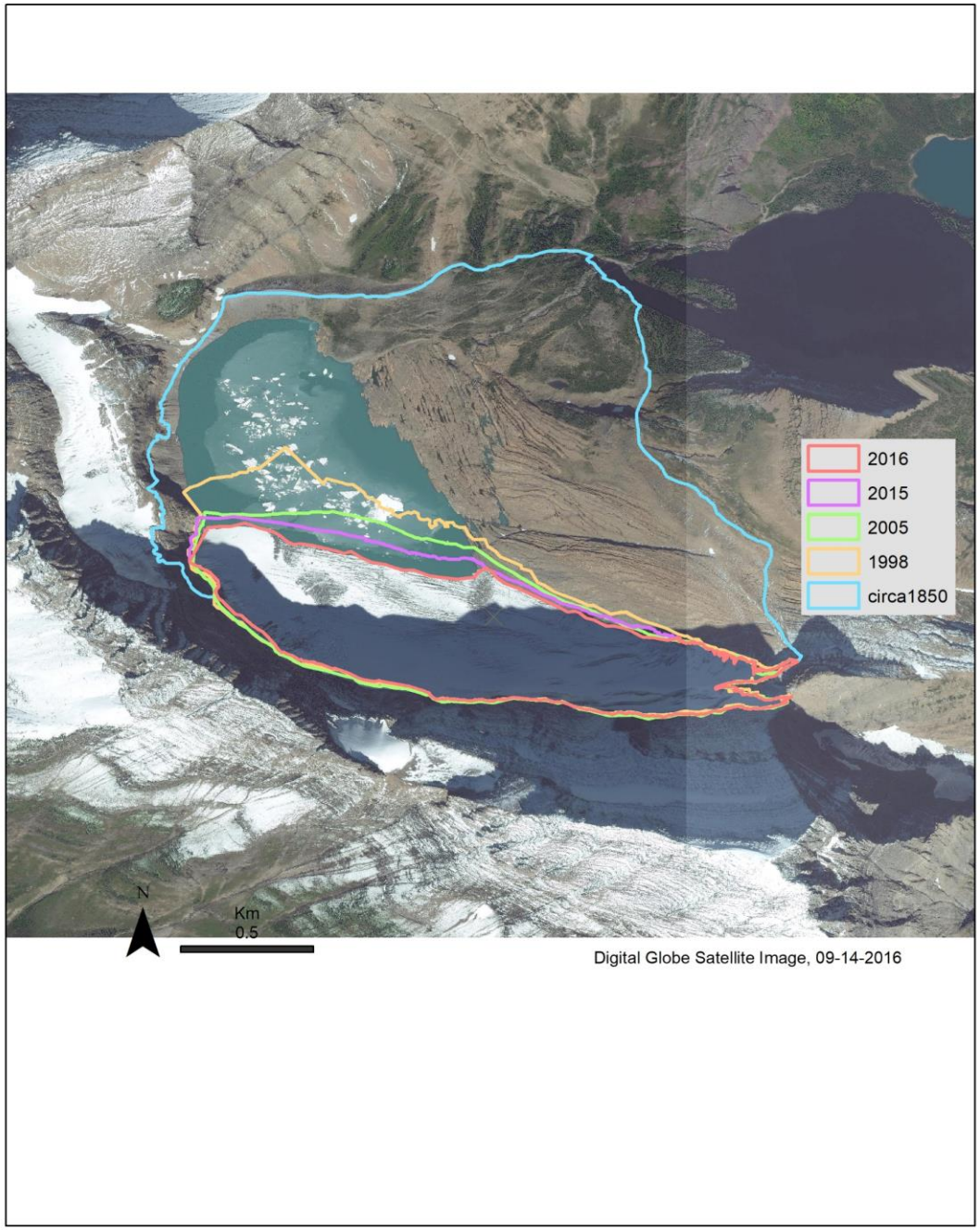






Activity #2:
Trace glacier perimeter

ANSWER SHEET



Glacier Area Table – named glaciers of Glacier National Park, MT

Glacier Name	Area LIA (m²)	Area 1966 (m²)	Area 1998 (m²)	Area 2005 (m²)	Area 2015 (m²)	% Decrease 1850-2015
Agassiz Glacier	4,246,977.56	1,600,559.73	1,174,485.68	1,039,612.34	736,669.75	82.65
Ahern Glacier	765,116.39	589,185.63	516,658.66	511,939.47	511,589.79	33.14
Baby Glacier*	136,133.57	117,171.13	80,880.38	76,006.47	75,562.60	44.49
Blackfoot Glacier	4,970,064.26	1,832,451.35	1,625,124.38	1,630,173.41	1,498,505.92	69.85
Boulder Glacier*	829,577.99	231,017.73	48,774.13	45,803.63	35,298.01	95.75
Carter Glacier	708,091.34	355,743.44	269,013.88	234,414.36	224,773.89	68.26
Chaney Glacier	1,078,922.83	563,819.03	430,372.02	359,686.58	334,484.90	69.00
Dixon Glacier	671,001.22	291,142.05	166,983.60	162,669.91	125,831.13	81.25
Gem Glacier*	24,364.74	29,140.12	23,756.51	23,527.27	22,156.68	9.06
Grinnell Glacier	1,976,494.97	1,020,200.39	715,907.79	615,568.81	563,720.29	71.48
Harris Glacier*	79,286.24	148,501.60	40,263.73	38,969.10	34,260.89	56.79
Harrison Glacier	3,470,484.89	2,059,376.84	1,846,232.52	1,697,714.47	1,661,456.75	52.13
Herbst Glacier*	343,244.32	170,234.16	50,794.78	40,856.01	31,886.02	90.71
Hudson Glacier*	132,164.98	90,213.45	55,762.11	52,269.76	52,167.62	60.53
Ipasha Glacier	594,065.79	328,608.60	228,254.45	195,800.97	194,738.75	67.22
Jackson Glacier	3,094,285.19	1,280,508.24	811,857.45	803,342.15	756,864.10	75.54
Kintla Glacier	2,780,343.02	1,309,016.20	972,884.73	931,213.70	877,726.05	68.43
Logan Glacier	694,335.54	503,361.09	387,547.07	367,936.17	219,016.92	68.46
Lupfer Glacier*	171,200.25	126,375.83	66,661.16	63,843.53	73,274.68	57.20
Miche Wabun	263,262.30	204,468.79	111,127.26	107,464.55	103,616.92	60.64
North Swiftcurrent*	227,306.21	116,675.97	84,546.10	90,181.52	86,305.30	62.03
Old Sun Glacier	499,662.38	421,347.41	349,137.54	346,751.63	341,077.95	31.74
Piegan Glacier	311,173.34	280,151.62	265,084.78	250,768.05	244,307.08	21.49
Pumpelly Glacier	1,978,996.13	1,006,469.53	910,631.86	908,834.15	902,787.30	54.38
Rainbow Glacier	1,910,417.47	1,430,411.36	1,120,814.92	1,089,977.46	1,053,376.03	44.86
Red Eagle*	477,070.90	134,709.82	77,923.58	77,923.53	63,685.24	86.65
Salamander Glacier	250,056.48	229,028.19	181,688.65	173,617.99	176,108.77	29.57
Sexton Glacier	528,179.20	400,493.53	324,011.87	312,762.43	298,681.73	43.45
Shepard Glacier*	497,244.16	250,678.82	91,584.19	75,248.66	70,739.49	85.77
Siyeh Glacier	378,010.17	306,295.75	214,597.44	214,663.20	205,386.48	45.67
Sperry Glacier	3,793,322.12	1,339,531.54	953,104.43	888,095.13	801,670.14	78.87
Swiftcurrent Glacier	594,231.70	221,786.00	188,681.39	176,239.36	170,348.10	71.33
Thunderbird Glacier	1,075,097.51	135,074.71	121,885.69	115,978.22	107,012.09	90.05
Two Ocean Glacier*	1,076,919.16	429,001.73	193,677.91	189,199.44	75,172.89	93.02
Vulture Glacier	811,528.41	408,034.38	336,924.77	329,180.45	296,786.09	63.43
Weasel Collar Glacier	809,813.09	558,088.21	507,418.42	506,575.45	499,734.76	38.29
Whitecrow Glacier	741,530.93	242,488.01	124,759.84	112,799.23	103,824.86	86.00
Total	**39,550,185.16**	**20,761,361.98**	**15,669,815.67**	**14,857,608.56**	**13,630,605.96**	**65.54**

https://www.usgs.gov/data-tools/area-named-glaciers-glacier-national-park-gnp-and-flathead-national-forest-fnf-including

Glacier Area Table – Six of the named glaciers of Glacier National Park, MT

Glacier Name	Area LIA (m^2)	Area 1966 (m^2)	Area 1998 (m^2)	Area 2005 (m^2)	Area 2015 (m^2)	% Decrease 1850-2015
Agassiz Glacier	4,246,978	1,600,560	1,174,486	1,039,612	736,670	83
Chaney Glacier	1,078,923	563,819	430,372	359,687	334,485	69
Grinnell Glacier	1,976,495	1,020,200	715,908	615,569	563,720	71
Jackson Glacier	3,094,285	1,280,508	811,857	803,342	756,864	76
Old Sun Glacier	499,662	421,347	349,138	346,752	341,078	32
Sperry Glacier	3,793,322	1,339,532	953,104	888,095	801,670	79

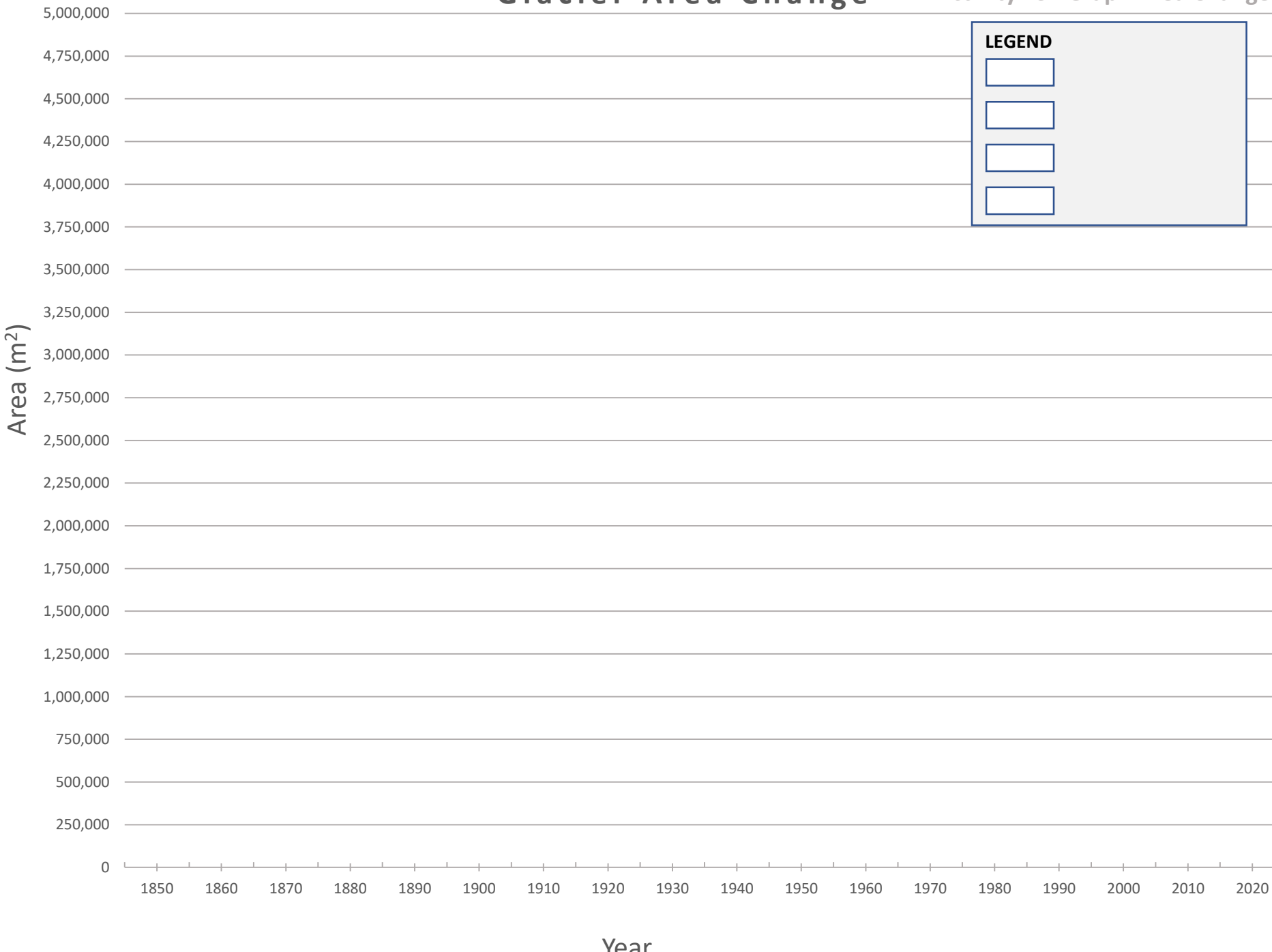
* Sub-set of full data table, Area of the Named Glaciers of Glacier National Park

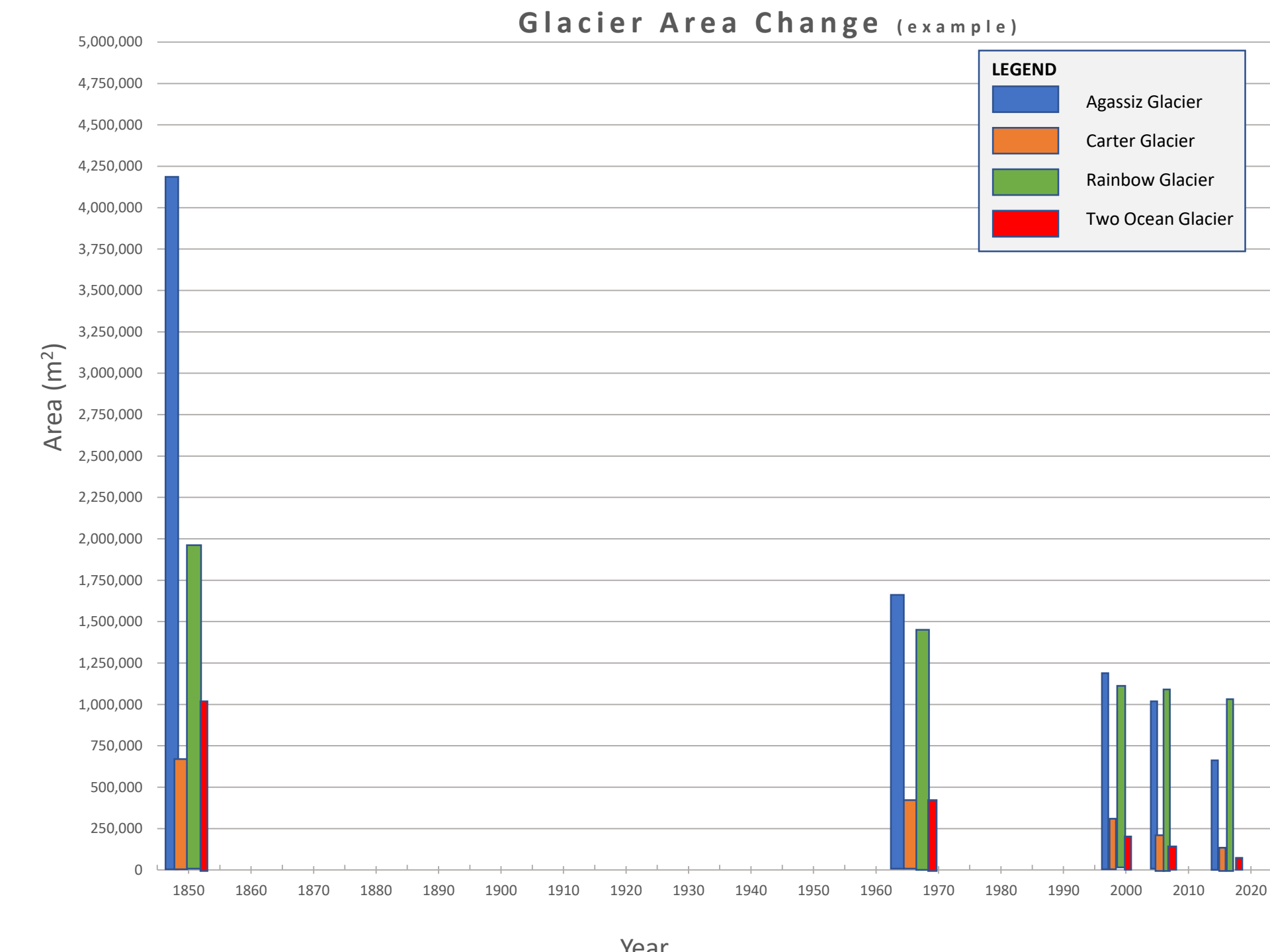
https://www.usgs.gov/data-tools/area-named-glaciers-glacier-national-park-gnp-and-flathead-national-forest-fnf-including

USGS science for a changing world

Glacier Area Change

Activity #3: Graph Area Change



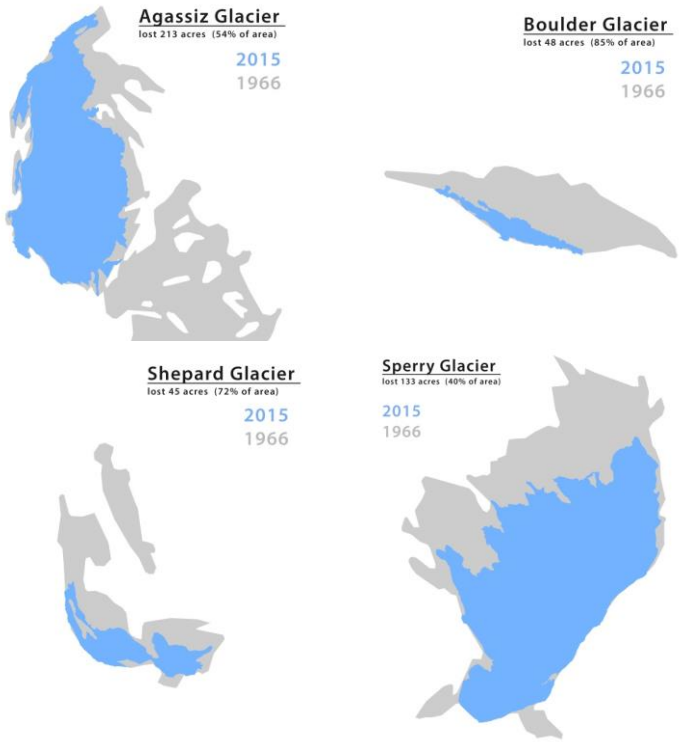

Glacier Area Change (example)
LEGEND
Agassiz Glacier
Carter Glacier
Rainbow Glacier
Two Ocean Glacier
Area (m2)
5,000,000
4,750,000
4,500,000
4,250,000
4,000,000
3,750,000
3,500,000
3,250,000
3,000,000
2,750,000
2,500,000
2,250,000
2,000,000
1,750,000
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

Glacier Area Change Data Table

Area of Named Glaciers of Glacier National Park: 1966, 1998, 2005, 2015

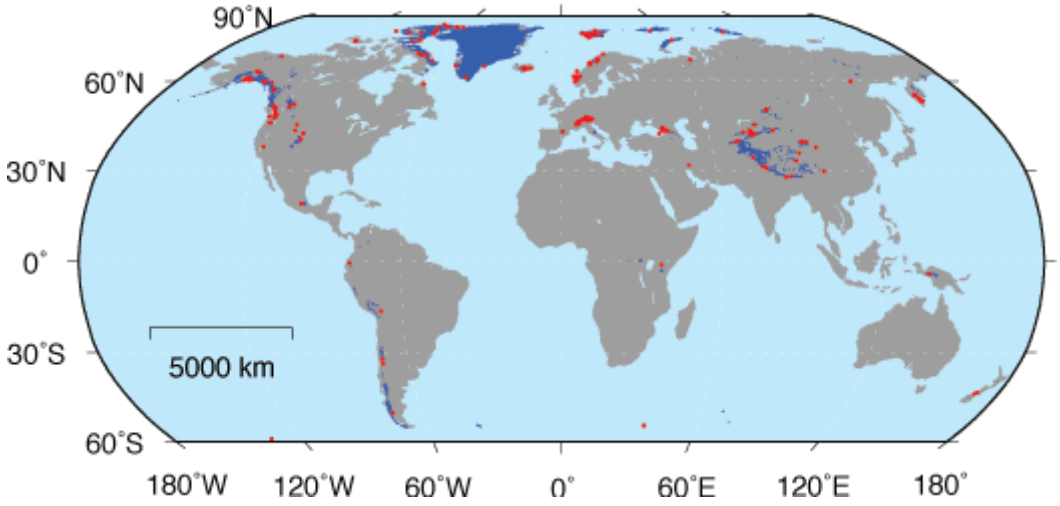
Glacier Name	Area1966 (m²)	Area1998 (m²)	Area2005 (m²)	Area2015 (m²)	% Change 1966-2015
Agassiz Glacier	1,600,559.73	1,174,485.68	1,039,612.34	736,669.75	-53.97
Ahern Glacier	589,185.63	516,658.66	511,939.47	511,589.79	-13.17
Baby Glacier	117,171.13	80,880.38	76,006.47	75,562.60	-35.51
Blackfoot Glacier	1,832,451.35	1,625,124.38	1,630,173.41	1,498,505.92	-18.22
Boulder Glacier	231,017.73	48,774.13	45,803.63	35,298.01	-84.72
Carter Glacier	355,743.44	269,013.88	234,414.36	224,773.89	-36.82
Chaney Glacier	563,819.03	430,372.02	359,686.58	334,484.90	-40.68
Dixon Glacier	291,142.05	166,983.60	162,669.91	125,831.13	-56.78
Gem Glacier	29,140.12	23,756.51	23,527.27	22,156.68	-23.97
Grinnell Glacier	1,020,200.39	715,907.79	615,568.81	563,720.29	-44.74
Harris Glacier	148,501.60	40,263.73	38,969.10	34,260.89	-76.93
Harrison Glacier	2,059,376.84	1,846,232.52	1,697,714.47	1,661,456.75	-19.32
Herbst Glacier	170,234.16	50,794.78	40,856.01	31,886.02	-81.27
Hudson Glacier	90,213.45	55,762.11	52,269.76	52,167.62	-42.17
Ipasha Glacier	328,608.60	228,254.45	195,800.97	194,738.75	-40.74
Jackson Glacier	1,280,508.24	811,857.45	803,342.15	756,864.10	-40.89
Kintla Glacier	1,309,016.20	972,884.73	931,213.70	877,726.05	-32.95
Logan Glacier	503,361.09	387,547.07	367,936.17	219,016.92	-56.49
Lupfer Glacier	126,375.83	66,661.16	63,843.53	73,274.68	-42.02
Miche Wabun	204,468.79	111,127.26	107,464.55	103,616.92	-49.32
N. Swiftcurrent Glacie	116,675.97	84,546.10	90,181.52	86,305.30	-26.03
Old Sun Glacier	421,347.41	349,137.54	346,751.63	341,077.95	-19.05
Piegan Glacier	280,151.62	265,084.78	250,768.05	244,307.08	-12.79
Pumpelly Glacier	1,006,469.53	910,631.86	908,834.15	902,787.30	-10.30
Rainbow Glacier	1,430,411.36	1,120,814.92	1,089,977.46	1,053,376.03	-26.36
Red Eagle	134,709.82	77,923.58	77,923.53	63,685.24	-52.72
Salamander Glacier	229,028.19	181,688.65	173,617.99	176,108.77	-23.11
Sexton Glacier	400,493.53	324,011.87	312,762.43	298,681.73	-25.42
Shepard Glacier	250,678.82	91,584.19	75,248.66	70,739.49	-71.78
Siyeh Glacier	306,295.75	214,597.44	214,663.20	205,386.48	-32.95
Sperry Glacier	1,339,531.54	953,104.43	888,095.13	801,670.14	-40.15
Swiftcurrent Glacier	221,786.00	188,681.39	176,239.36	170,348.10	-23.19
Thunderbird Glacier	135,074.71	121,885.69	115,978.22	107,012.09	-20.78
Two Ocean Glacier	429,001.73	193,677.91	189,199.44	75,172.89	-82.48
Vulture Glacier	408,034.38	336,924.77	329,180.45	296,786.09	-27.26
Weasel Collar Glacier	558,088.21	507,418.42	506,575.45	499,734.76	-10.46
Whitecrow Glacier	242,488.01	124,759.84	112,799.23	103,824.86	-57.18
Total	**20,761,361.98**	**15,669,815.67**	**14,857,608.56**	**13,630,605.96**	

Glacier Area Change Graphic



SOURCE: USGS, https://www.usgs.gov/data-tools/area-named-glaciers-glacier-national-park-gnp-and-flathead-national-forest-fnf-derived

Location of Glaciers on Earth



How are glaciers responding to climate around the world?

The data for the reference glaciers is shown in the lower graph. Describe what is happening in the graph:

_____
_____
_____
_____
_____
_____
_____
_____

Average cumulative mass balance* of "reference" glaciers worldwide 1945- 2015

Are these data based on quantitative or qualitative data? How do you know?

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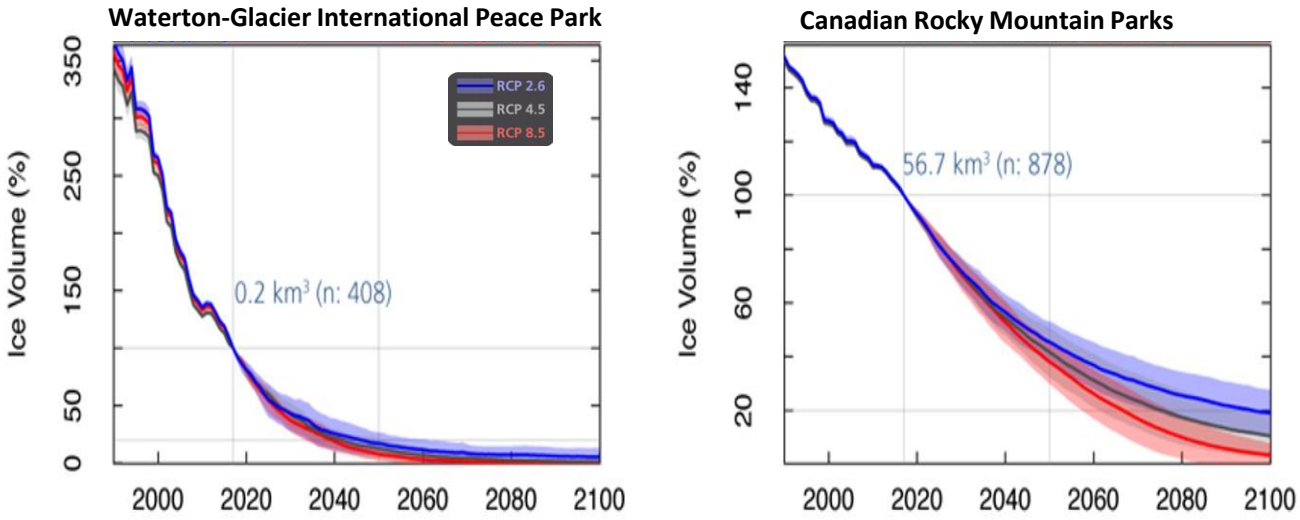
***Mass balance** *is the difference between the accumulation of new ice and the melting of old ice – in other words, is the glacier adding ice or losing ice?*

Projections of Glacier Retreat in Glacier National Park, MT, and Canada



The 21st century evolution of glaciers located in natural World Heritage sites according to different CO2 emission scenarios (RCP2.6, RCP4.5, and RCP8.5). Ice volume variations (multimodel mean of 14 general circulation models ±1 standard deviation) are relative to the 2017 ice volume (in cubic kilometer with the number of glaciers and their mean area considered in each panel). RCP = Representative Concentration Pathways;

Bosson, J.-B., Huss, M., & Osipova, E. (2019). Disappearing World Heritage glaciers as a keystone of nature conservation in a changing climate, Earth's Future, Volume: 7, Issue: 4, Pages: 469-479, First published: 29 April 2019, DOI: (10.1029/2018EF001139)

What will happen to glaciers in Glacier National Park and Canada the future?

Does the amount of carbon in the atmosphere influence the loss of glaciers in Glacier National Park?

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Does it influence the loss of glaciers in Canada?

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Why? Explain your answers:

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*__RCP__=represented carbon pathway, or how much CO2 is projected to be in the atmosphere

Worldwide Projections of Glacier Retreat at World Heritage Sites

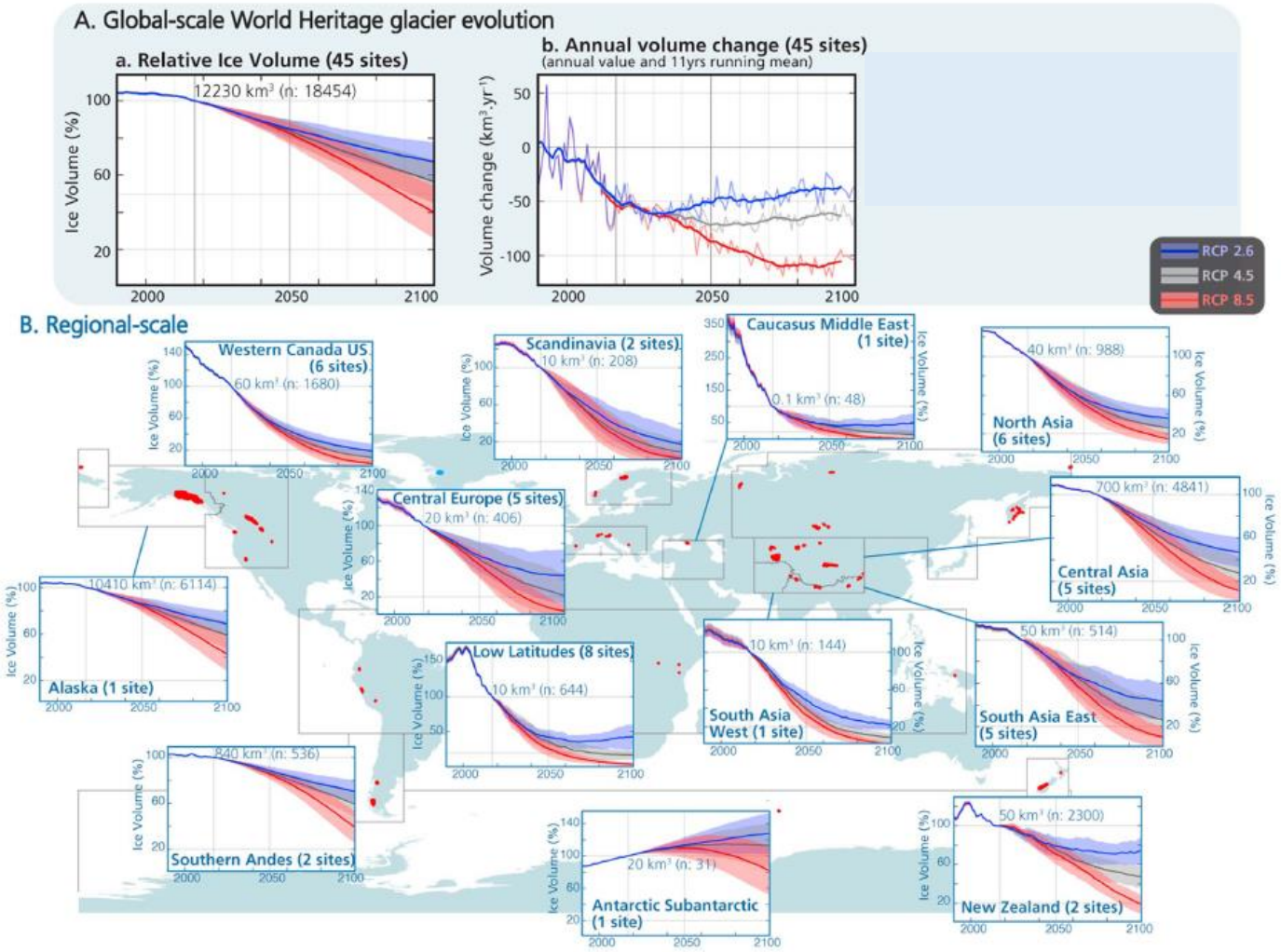

Figure 3. (a) Global and (b) regional 21st century evolution of glaciers located in natural World Heritage sites according to different CO_2 emission scenarios (RCP2.6, RCP4.5, and RCP8.5). Ice volume variations (multimodel mean of 14 general circulation models ±1 standard deviation) are relative to the 2017 ice volume (in cubic kilometer with the number of glaciers considered in each evolution diagram). On the map, the red dots correspond to the modelled World Heritage glaciers. RCP = Representative Concentration Pathways.

What will happen to glaciers around the world in the future?

Describe what is happening in the graph:

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How does the amount of carbon in the atmosphere influence the loss of glaciers?

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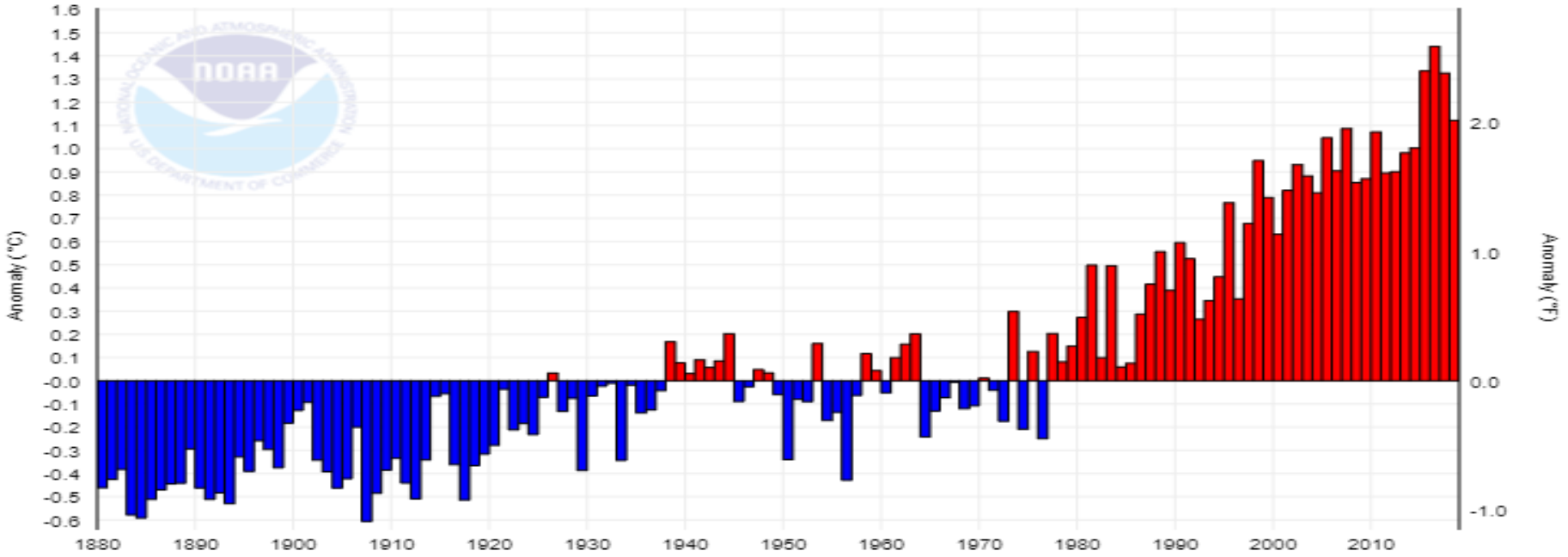
*__RCP__=represented carbon pathway, or how much CO2 is projected to be in the atmosphere

Bosson, J.-B., Huss, M., & Osipova, E. (2019). Disappearing World Heritage glaciers as a keystone of nature conservation in a changing climate, Earth's Future, Volume: 7, Issue: 4, Pages: 469-479, First published: 29 April 2019, DOI: (10.1029/2018EF001139)

Global Land Temperature Anomalies 1850-2018, Jan-Dec



The graph shows average annual global temperatures since 1880 compared to the long-term average (1901-2000). The zero line represents the long-term average temperature for the whole planet; blue and red bars show the difference above or below average for each year.

Anomaly: Deviation from what is normal or expected.

How does this graph relate to the repeat photos and area measurements taken from aerial photos?

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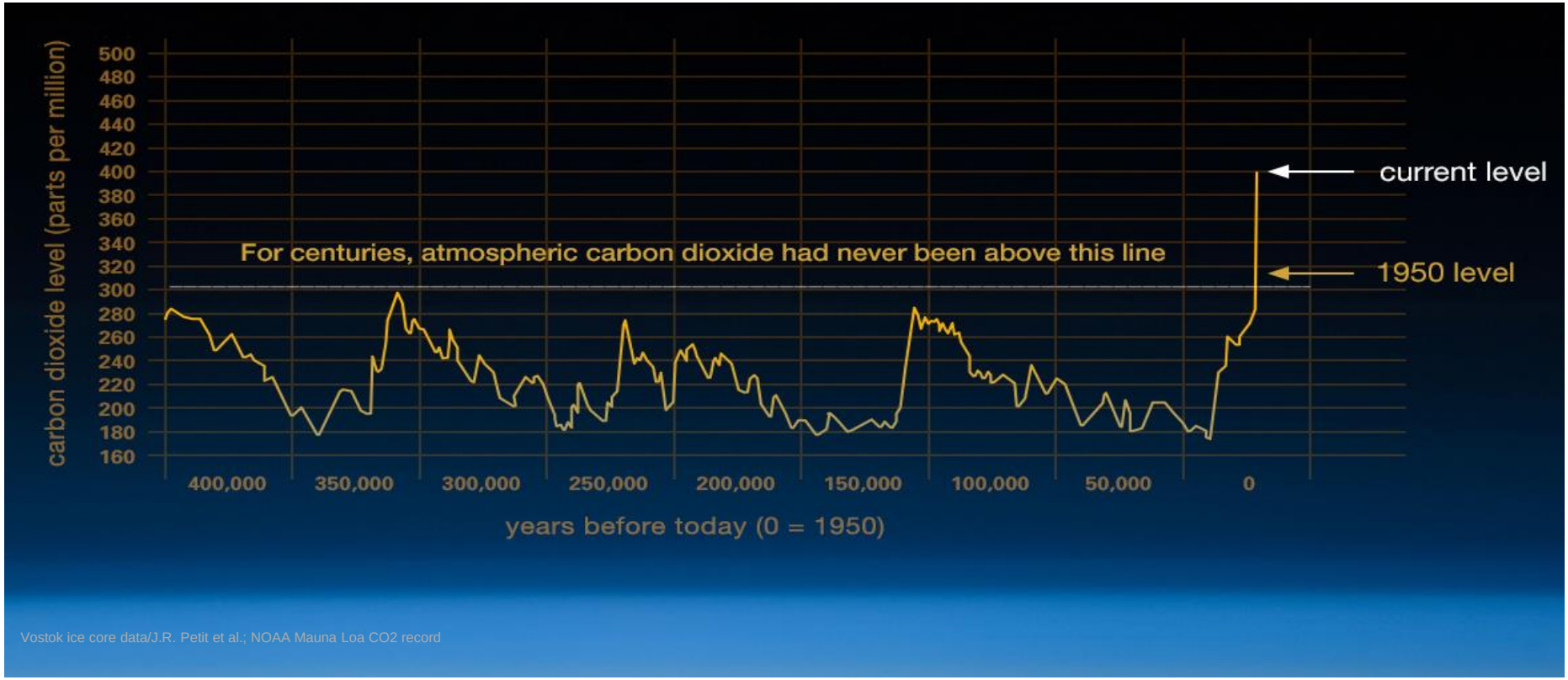
NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published February 2019, retrieved on March 11, 2019 from https://www.ncdc.noaa.gov/cag/

Centuries of CO2 Levels from Ice Core Records and Recent Direct Measurements



This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution.

SOURCE: NASA, https://climate.nasa.gov/evidence/

What trends are shown in the graph?

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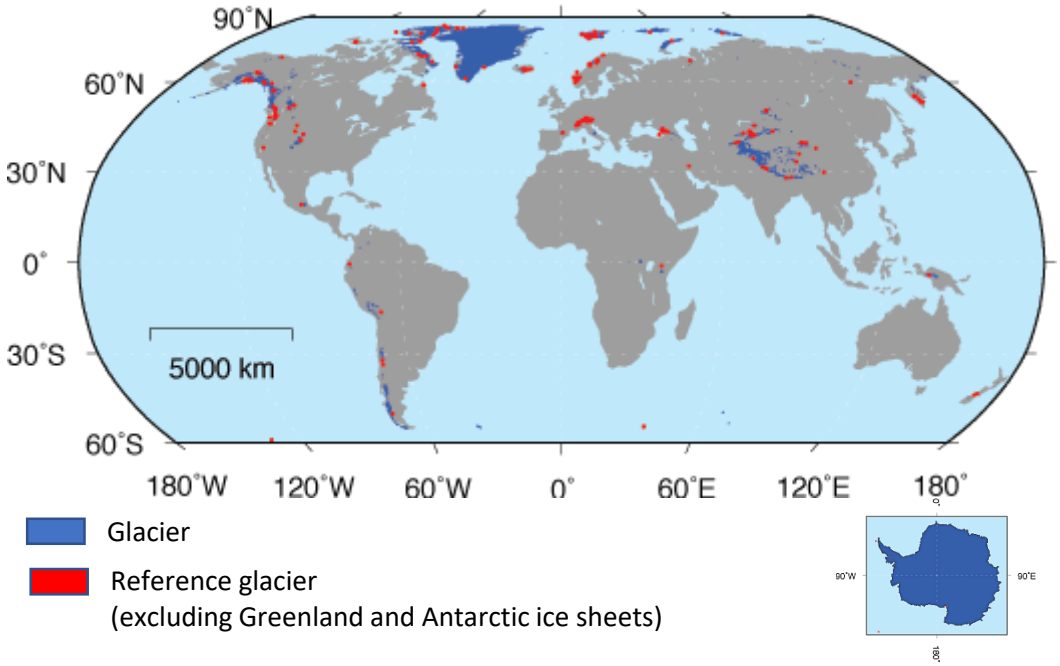
Location of Glaciers on Earth



Average cumulative mass balance* of "reference" glaciers worldwide 1945- 2015

TEACHER VERSION

How are glaciers responding to climate around the world?

The data for the reference glaciers is shown in the lower graph. Describe what is happening in the graph:

glaciers worldwide are melting, losing mass

Activity #4: Evaluate Graphic Data

Are these data based on quantitative or qualitative data? How do you know?

Quantitative, y axis indicates meters of water equivalent which is a numerical measurement

***Mass balance** *is the difference between the accumulation of new ice and the melting of old ice – in other words, is the glacier adding ice or losing ice?*

Worldwide Projections of Glacier Retreat at World Heritage Sites

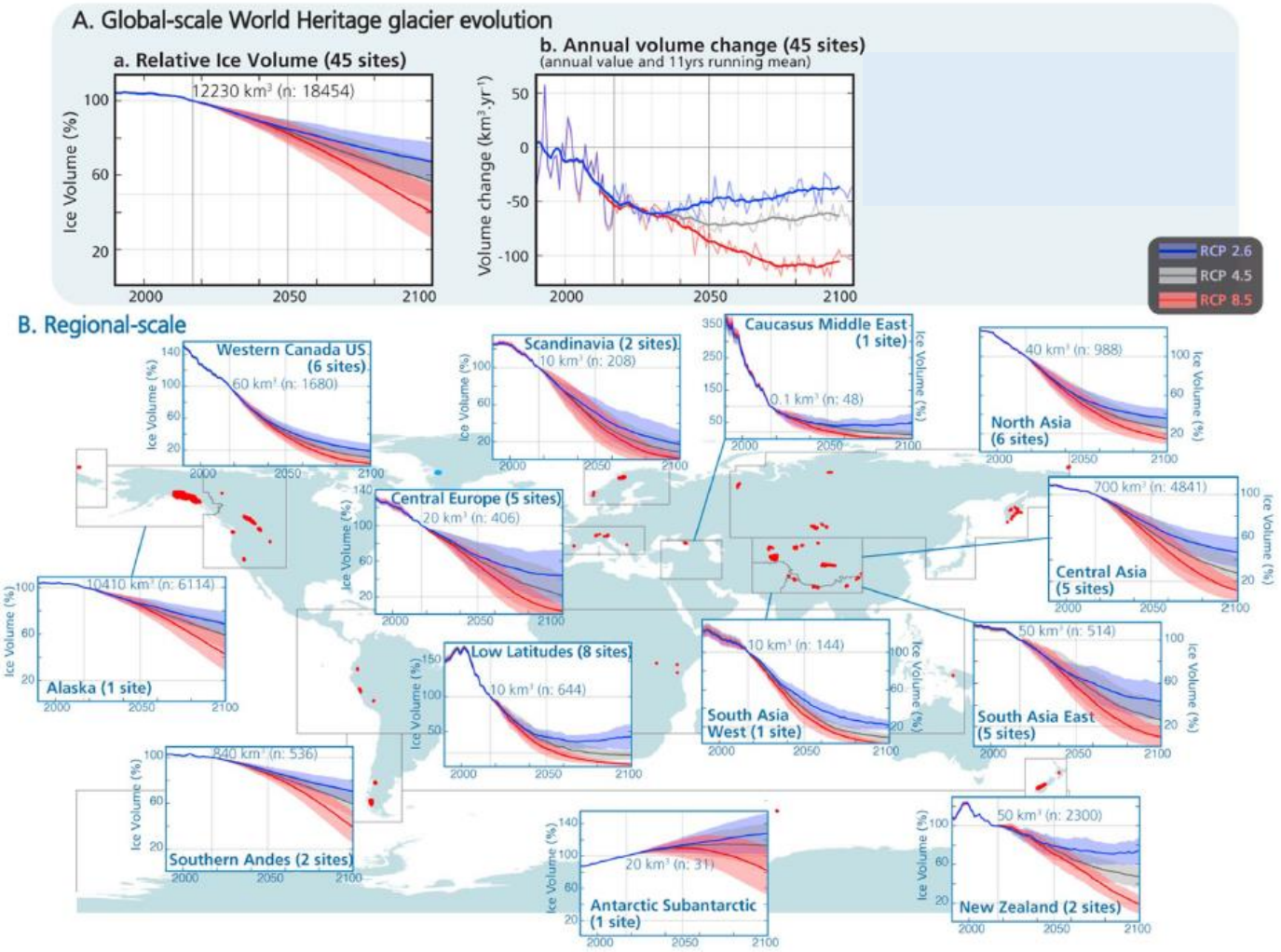


Figure 3. (a) Global and (b) regional 21st century evolution of glaciers located in natural World Heritage sites according to different CO_2 emission scenarios (RCP2.6, RCP4.5, and RCP8.5). Ice volume variations (multimodel mean of 14 general circulation models ±1 standard deviation) are relative to the 2017 ice volume (in cubic kilometer with the number of glaciers considered in each evolution diagram). On the map, the red dots correspond to the modelled World Heritage glaciers. RCP = Representative Concentration Pathways.

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TEACHER VERSION

What will happen to glaciers around the world in the future?

Describe what is projected to happen to glaciers:

At most locations, glaciers will be melting away

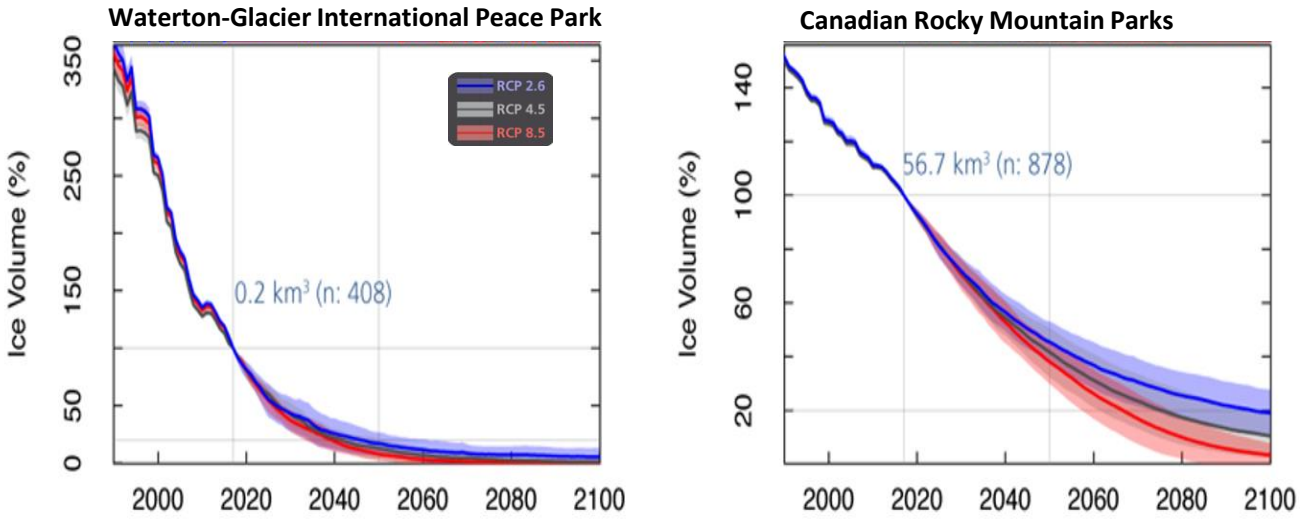
How does the amount of carbon in the atmosphere influence the loss of glaciers?

More carbon (higher RCP number) indicates earlier loss of glaciers

Reducing carbon can help the larger glaciers last longer, but the smaller glaciers are not as influenced by differences in carbon since they won't last long enough (the average glacier size is indicated by the volume in each graph)

***RCP**=represented carbon pathway, or how much CO2 is projected to be in the atmosphere

Projections of Glacier Retreat in Glacier National Park, MT, and Canada



The 21st century evolution of glaciers located in natural World Heritage sites according to different CO2 emission scenarios (RCP2.6, RCP4.5, and RCP8.5). Ice volume variations (multimodel mean of 14 general circulation models ±1 standard deviation) are relative to the 2017 ice volume (in cubic kilometer with the number of glaciers and their mean area considered in each panel). RCP = Representative Concentration Pathways;

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TEACHER VERSION

What will happen to glaciers in Glacier National Park and Canada the future?

Does the amount of carbon in the atmosphere influence the loss of glaciers in Glacier National Park?

No – all three projections lines are very close. Ice volume is projected to be close to zero around 2060 for all carbon scenarios

Does it influence the loss of glaciers in Canada?

Yes – there is a difference in the projected ice volume over time, though the trend is toward ice loss for all scenarios

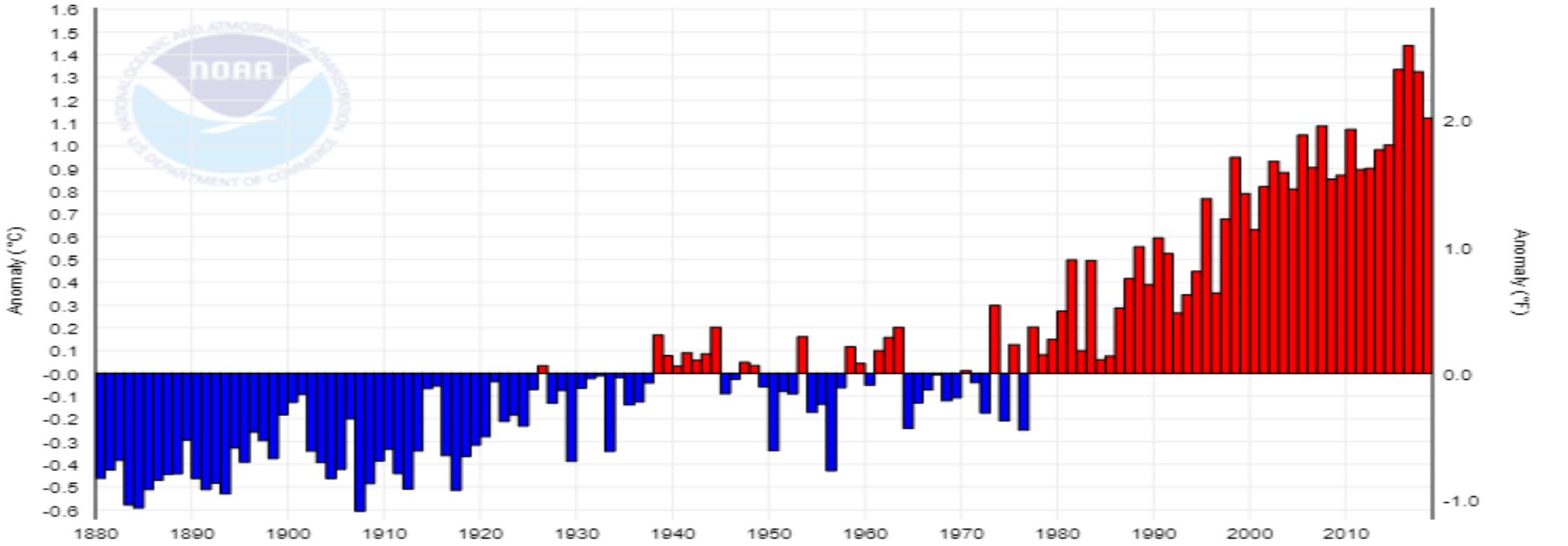
Why? Explain your answers:

Less carbon (blue) shows slower loss of ice volume through time. Canadian glaciers are larger (56.7 km3) and have enough ice to last longer.

Global Land Temperature Anomalies 1850-2018, Jan-Dec

TEACHER VERSION

Activity #5: Evaluate Climate Trends and Impacts



The graph shows average annual global temperatures since 1880 compared to the long-term average (1901-2000). The zero line represents the long-term average temperature for the whole planet; blue and red bars show the difference above or below average for each year.

Anomaly: Deviation from what is normal or expected.

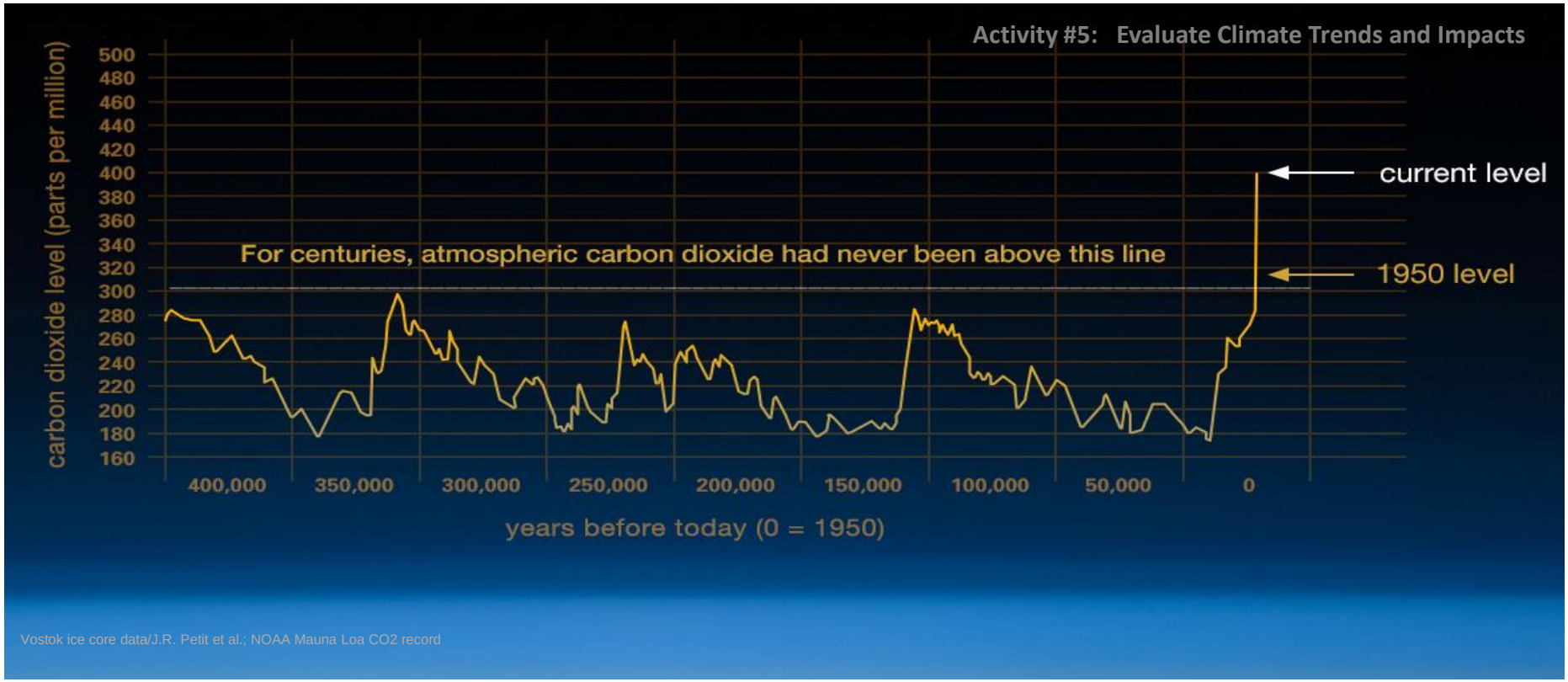
How does this graph relate to the repeat photos and area measurements taken from aerial photos?

This graph shows that land temperature has warmed since the mid-1800s, which would account for the retreat of glaciers around the world. Glaciers retreat when the climate warms.

NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published February 2019, retrieved on March 11, 2019 from https://www.ncdc.noaa.gov/cag/

Centuries of CO2 Levels from Ice Core Records and Recent Direct Measurements

TEACHER VERSION



This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution.

SOURCE: NASA, https://climate.nasa.gov/evidence/

What trends are shown in the graph?

Before 1950 the levels of CO2 in the atmosphere had both decreasing and increasing trends over time all below 300 PPM. The most recent trend is steadily increasing, surpassing the 300 ppm level in which our planet has not experienced in over 400,000 years.