



NATIONAL WEATHER SERVICE

Building a Weather-Ready Nation

Monitoring/Forecasting Glacier Lake Outburst Floods Along Mendenhall Lake/River & Others Across Alaska

Aaron Jacobs:

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Hydrologist In Charge

NWS APRFC Anchorage Alaska

- Overview of the GLOF Process & Mendenhall Area
- How NWS Generates River Forecasts For Outburst Floods:
 - Forecast Process
 - Tools (hydrograph separation, time/vol scaling)
 - Utilize research findings
 - Forecasts & Challenges in the Future
- Monitoring Program:
 - Near real time data access(visualizations)
 - Future (Improvements)
- Glacier-Dammed Lakes in Alaska

Acknowledgements

Jamie Pierce



Ed Neal



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UNIVERSITY
of ALASKA
SOUTHEAST

Eran Hood

Tom Mattice



Gabriel Wolken



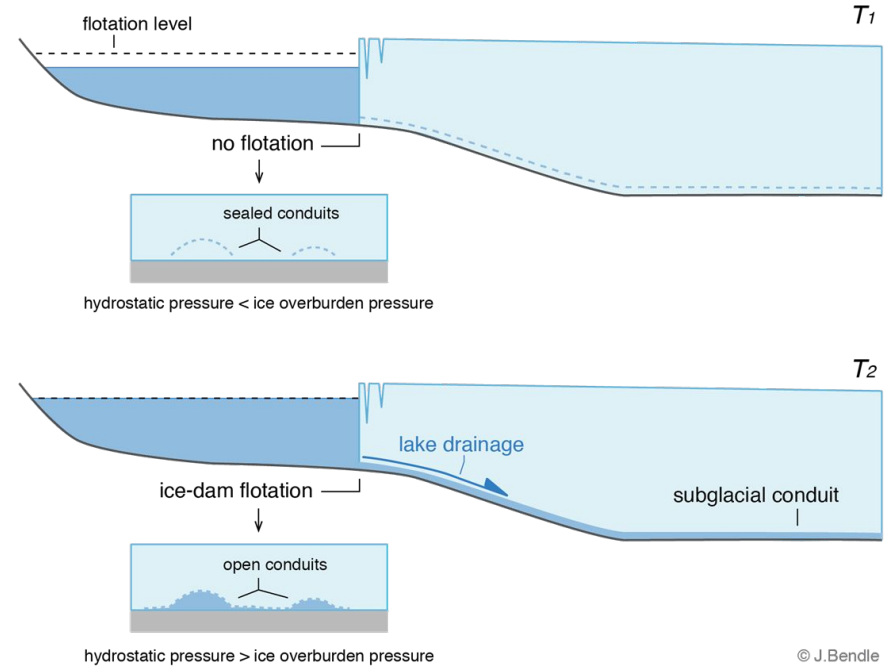
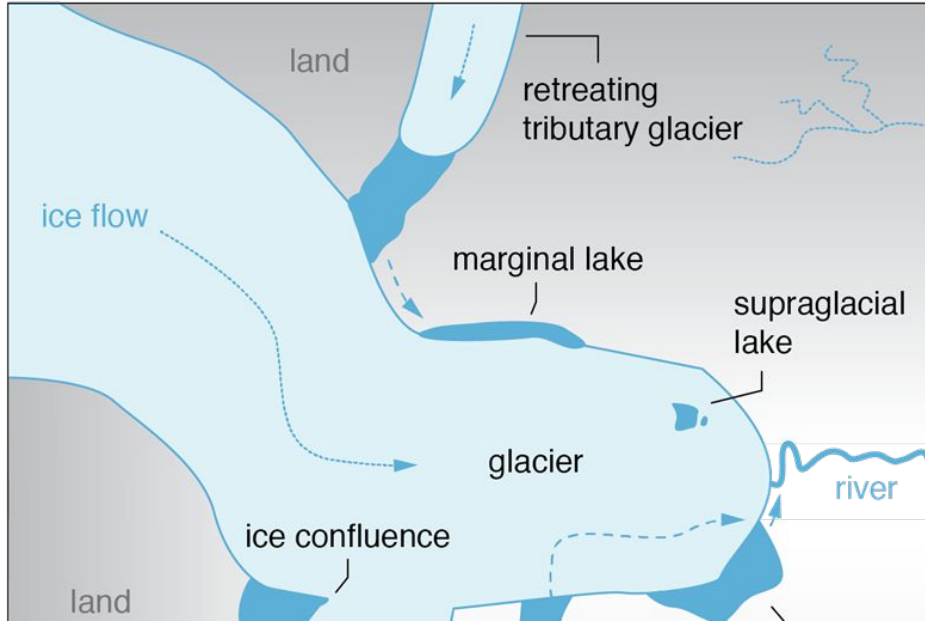
Jason Amundson & Lynn Kaluziensi

UAS students: Abby Watts, Caitlyn
Montalto, Skye Hart, & Ellie
Bretscher



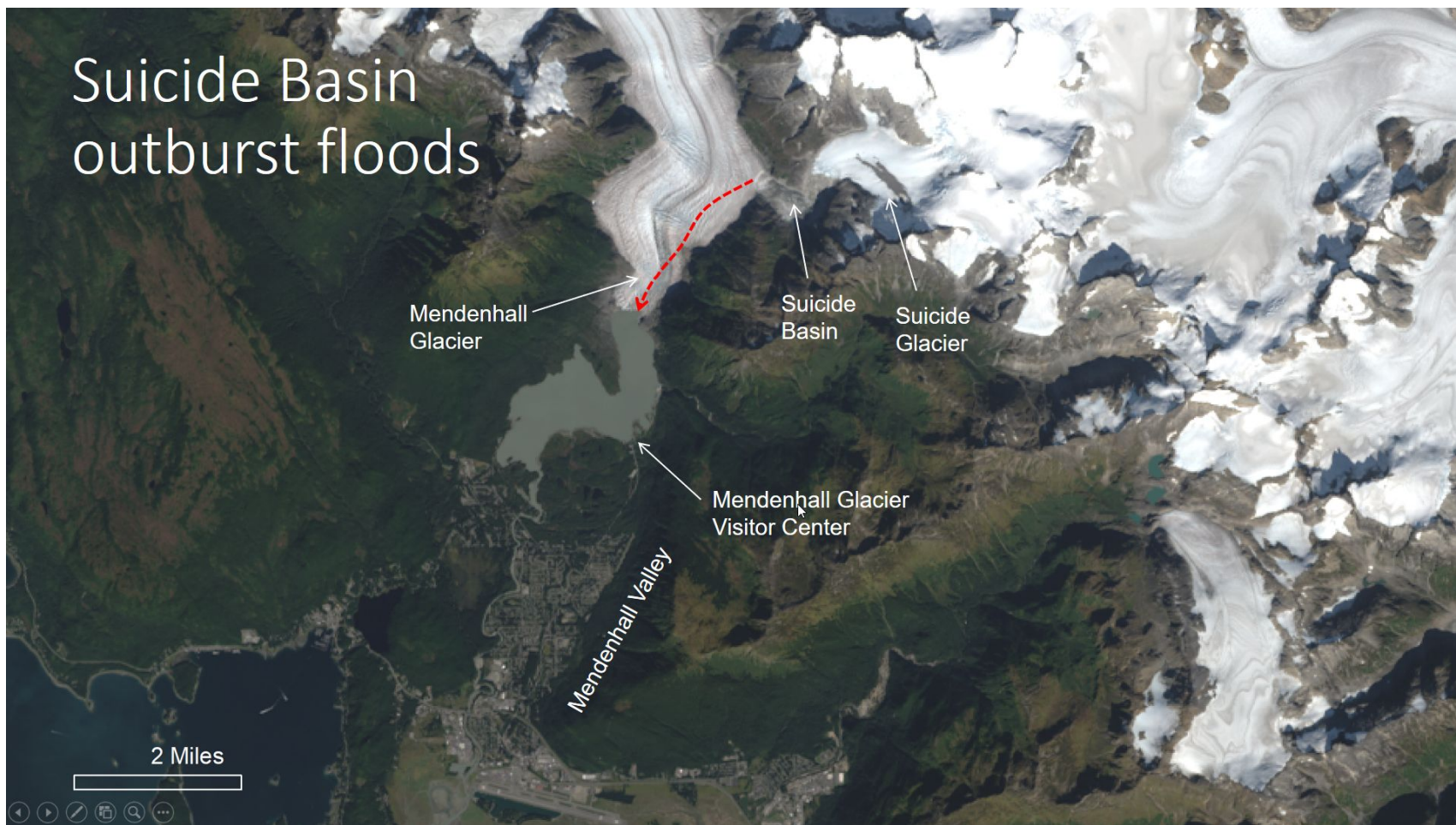
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What are glacier lake outburst floods (GLOFs)?



© J. Bendle

Suicide Basin outburst floods



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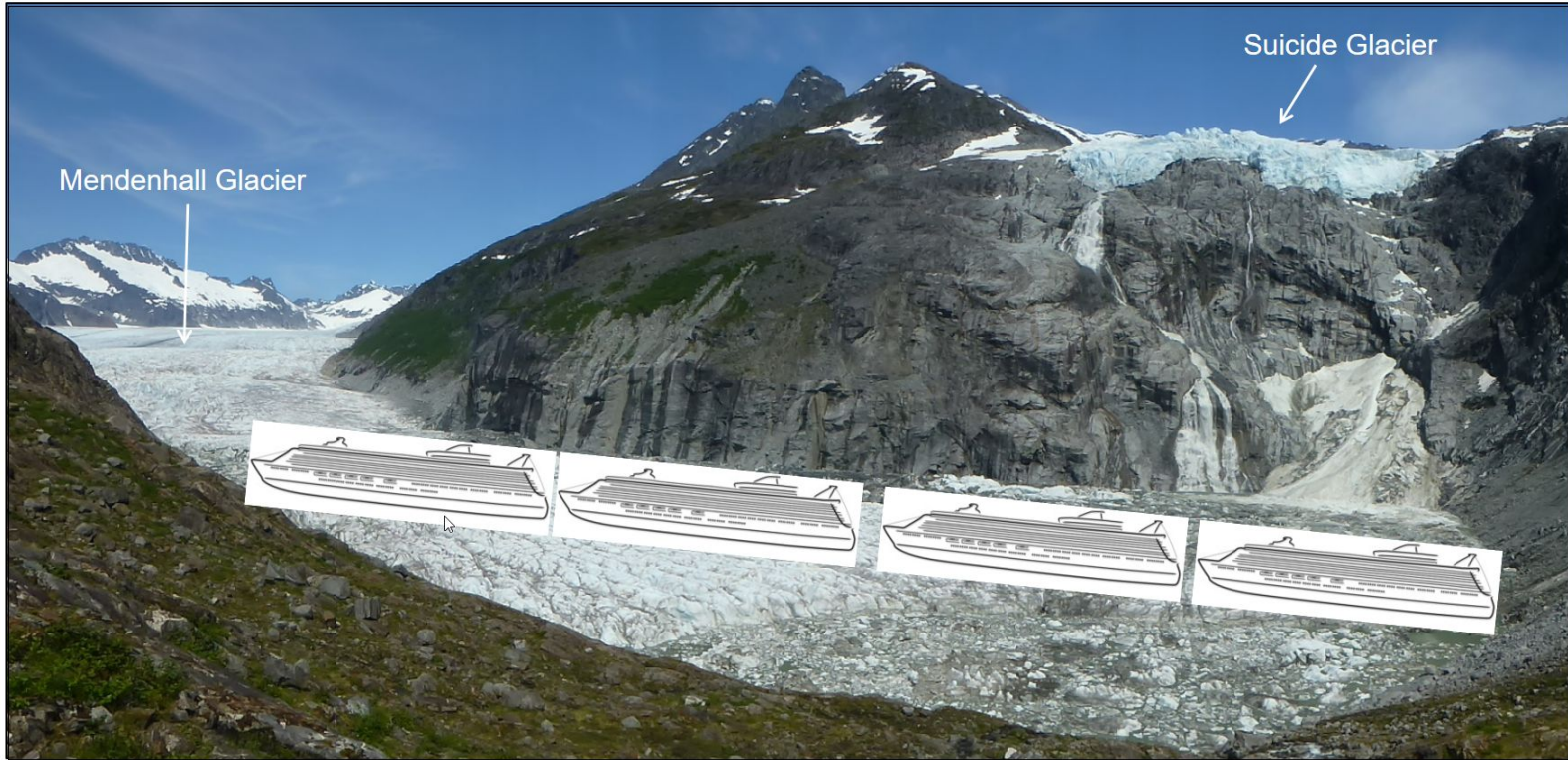
2018



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Building a Weather-Ready Nation // 6

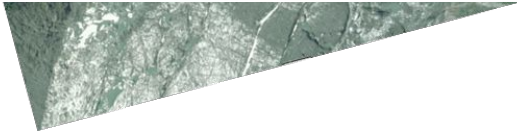
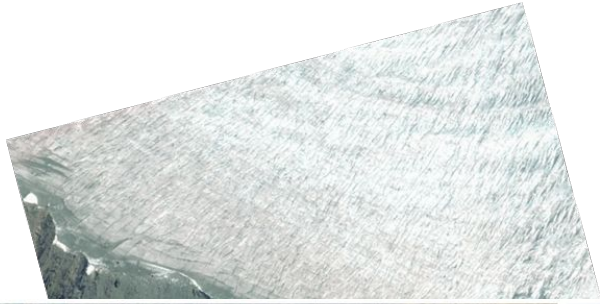
The Basin



The Basin

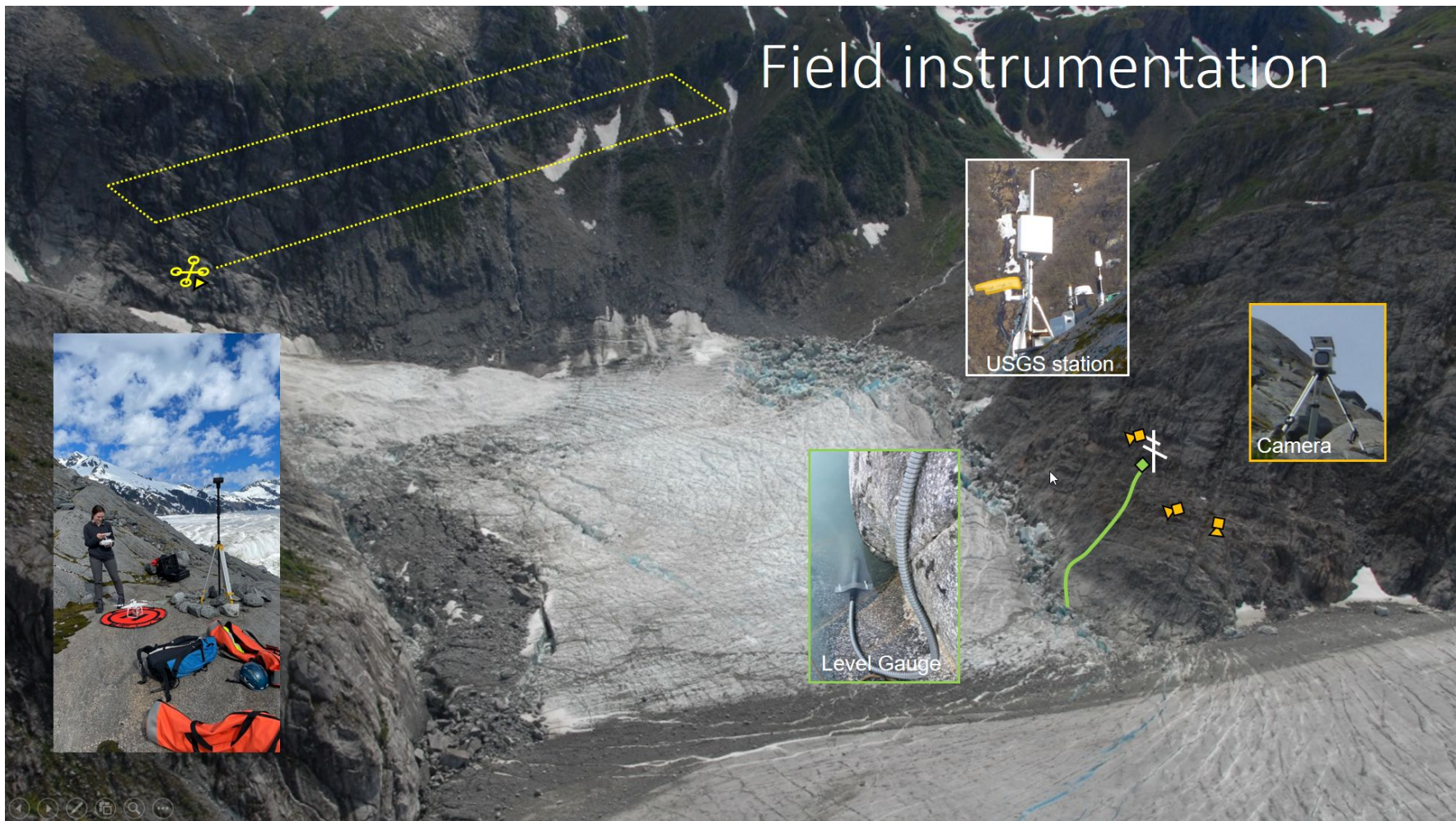


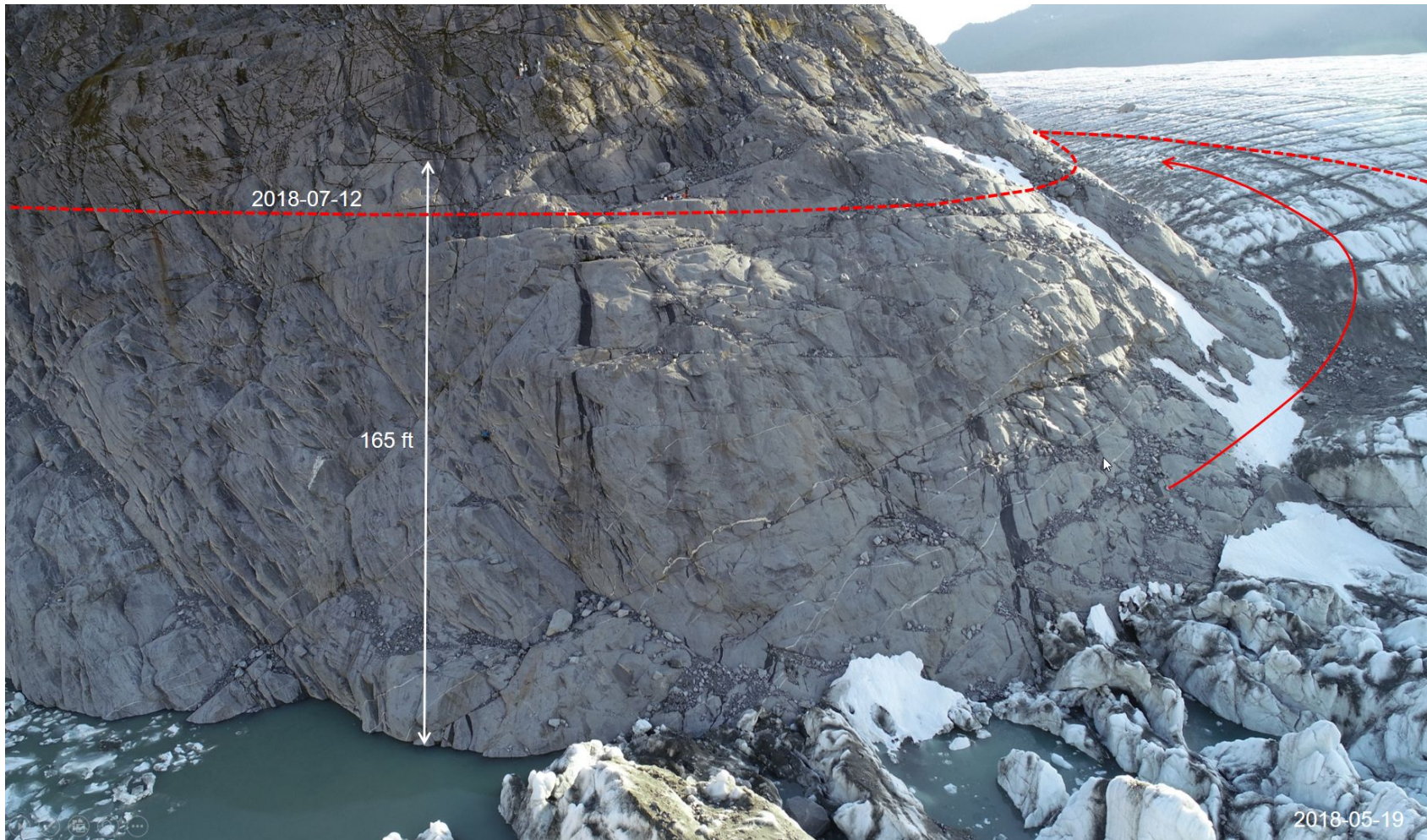
The Basin



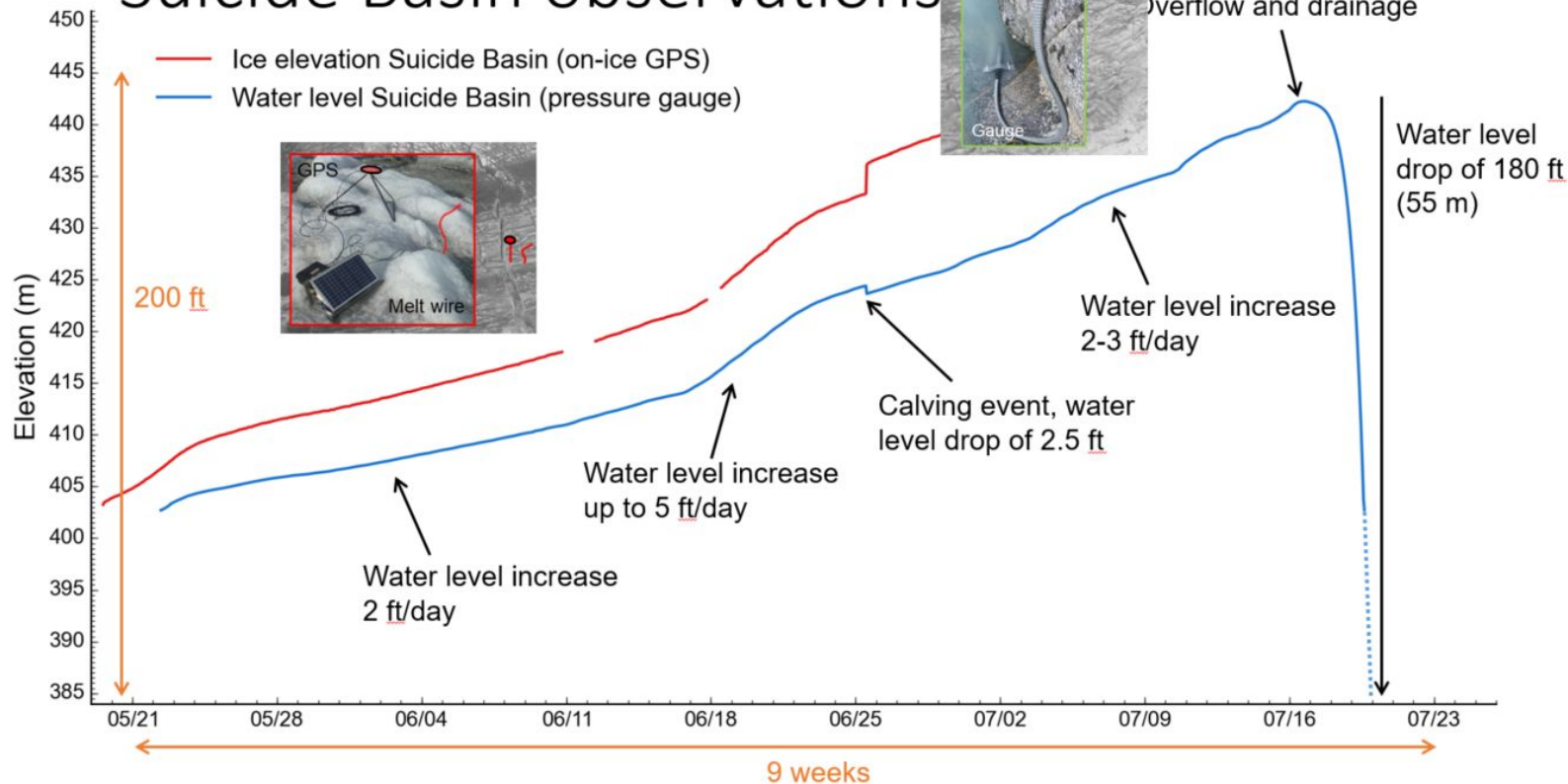
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Field instrumentation

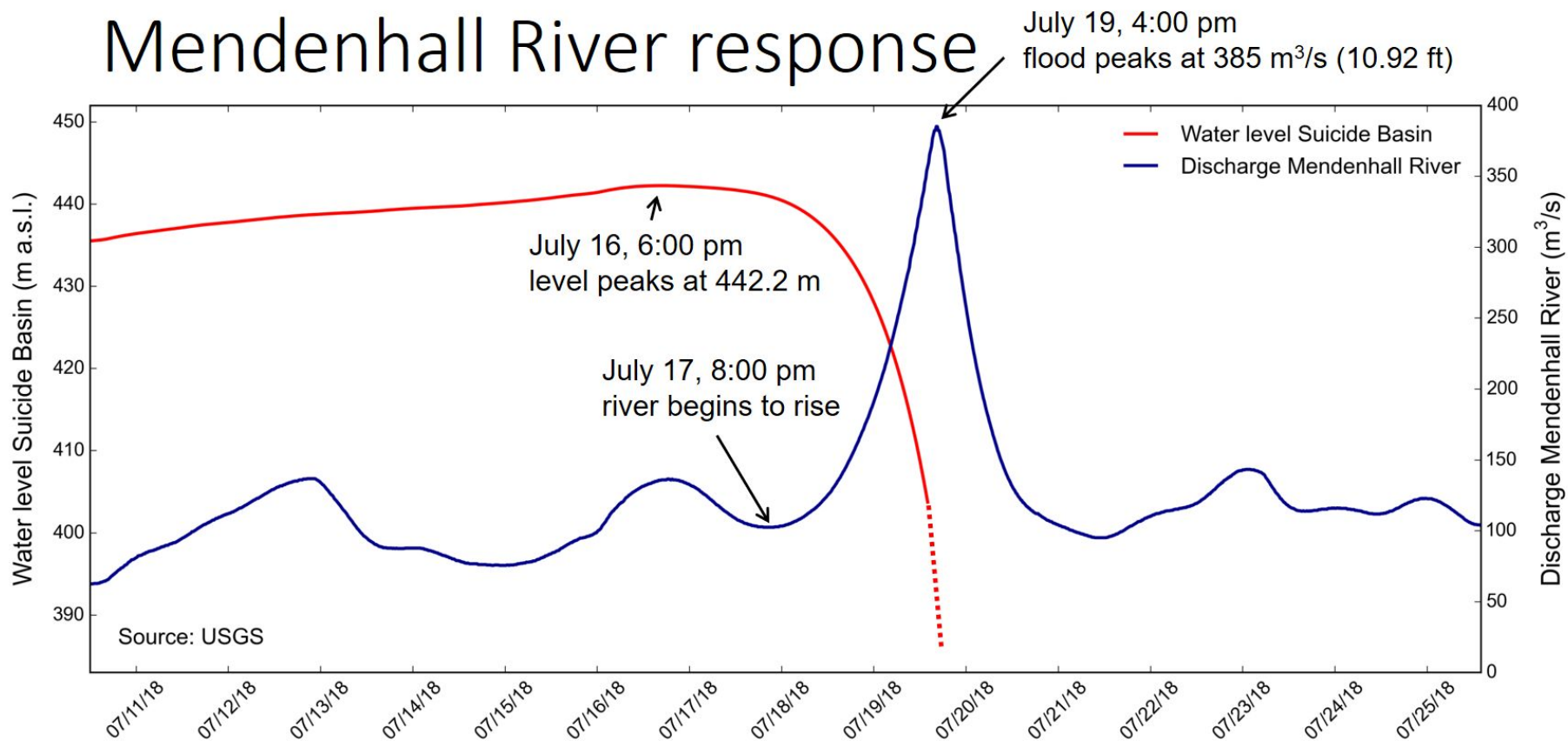




Suicide Basin observations



Mendenhall River response



How NWS Generates River Forecasts For Outburst Floods

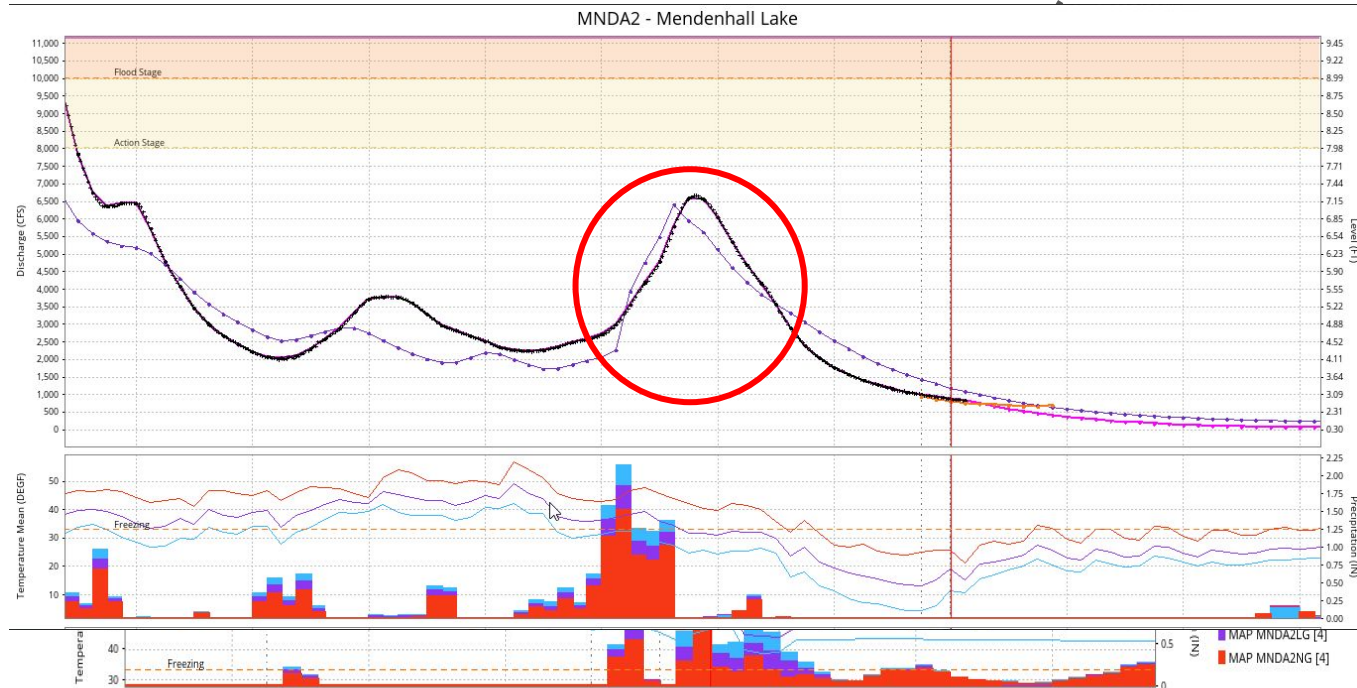
Forecast Process:

Model with concurrent rainfall

Early Event Detection

1. Observed data
2. Camera verification
3. Hydrologic model during periods of concurrent rainfall

Caveat - rainfall is an estimate, no precipitation observations in the basin.



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How NWS Generates River Forecasts For Outburst Floods

Forecast Process:

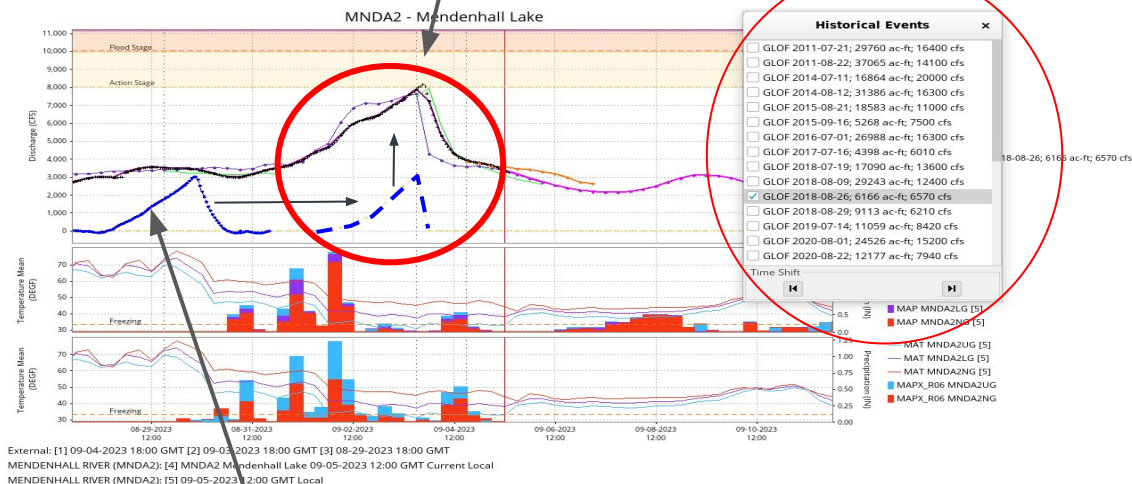
Forecast = Runoff + Glacier Dammed Lake (GDL) Hydrograph

Based on a collaborative process between the River Forecast Center & the Forecast Office in Juneau an analog historical GDL event is selected to 'add' to the hydrologic model

The analog event is chosen based on estimated lake elevation/volume (**not measured**)

GDL Addition

Event Library



Event from GDL Library



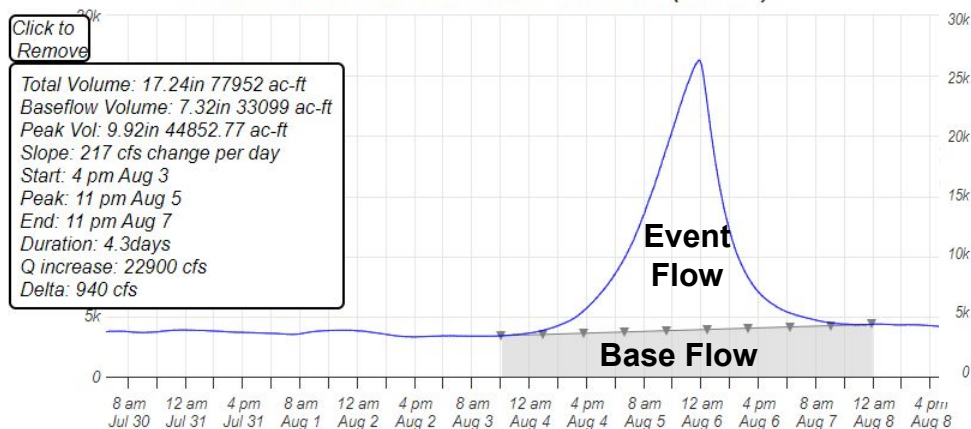
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How NWS Generates River Forecasts For Outburst Floods

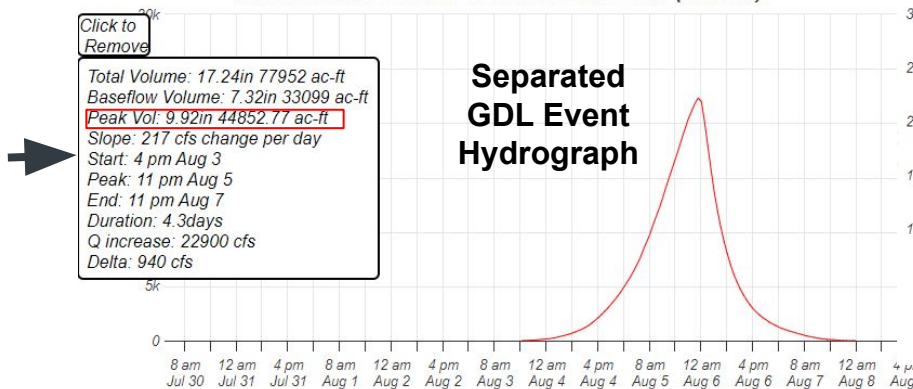
NWS River Forecast
Center Tool to perform
hydrograph separation

Forecast Process:

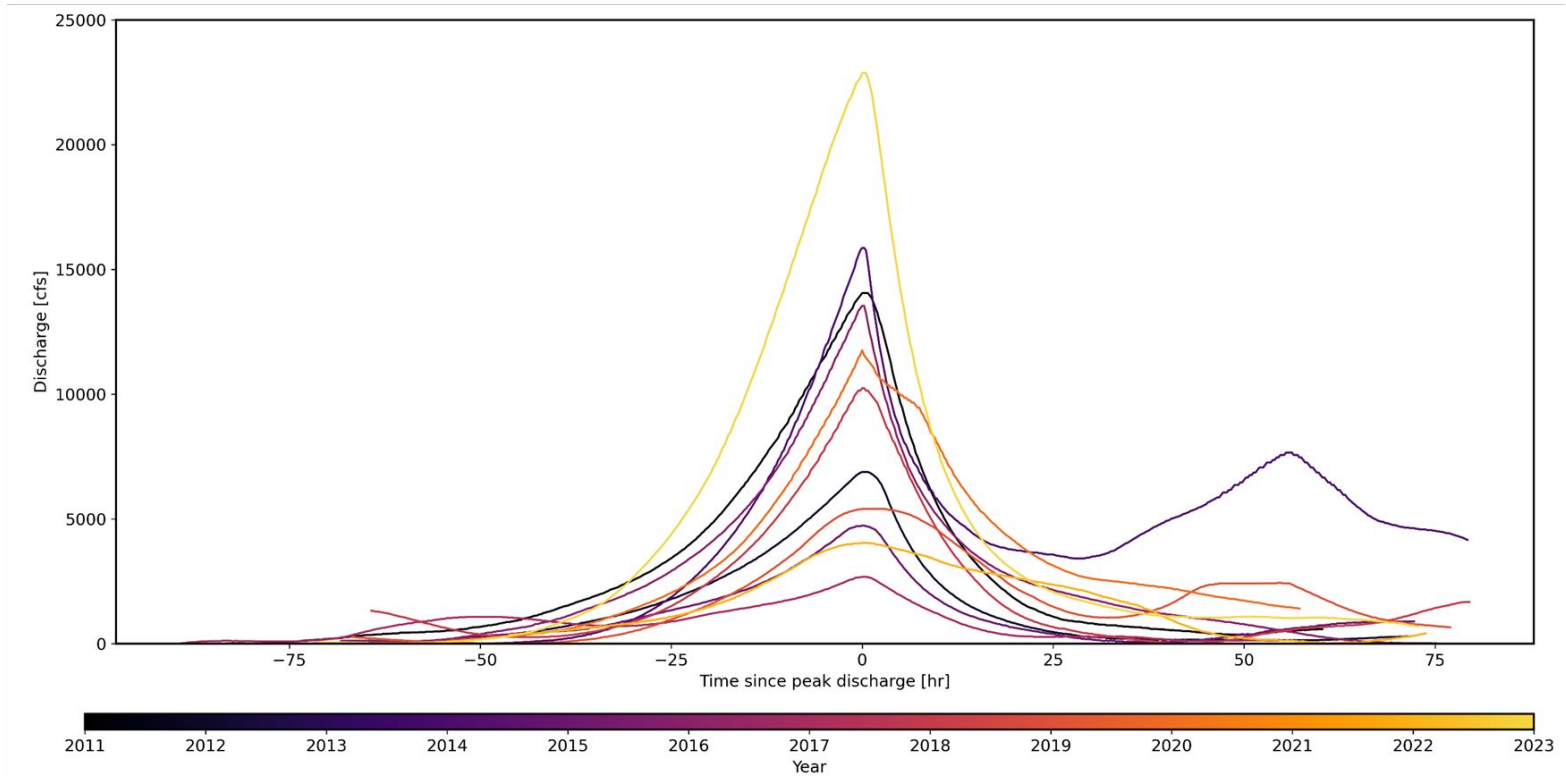
MENDENHALL LAKE 4 NE Mendenhall Lake (MND A2)



MENDENHALL LAKE 4 NE Mendenhall Lake (MND A2)

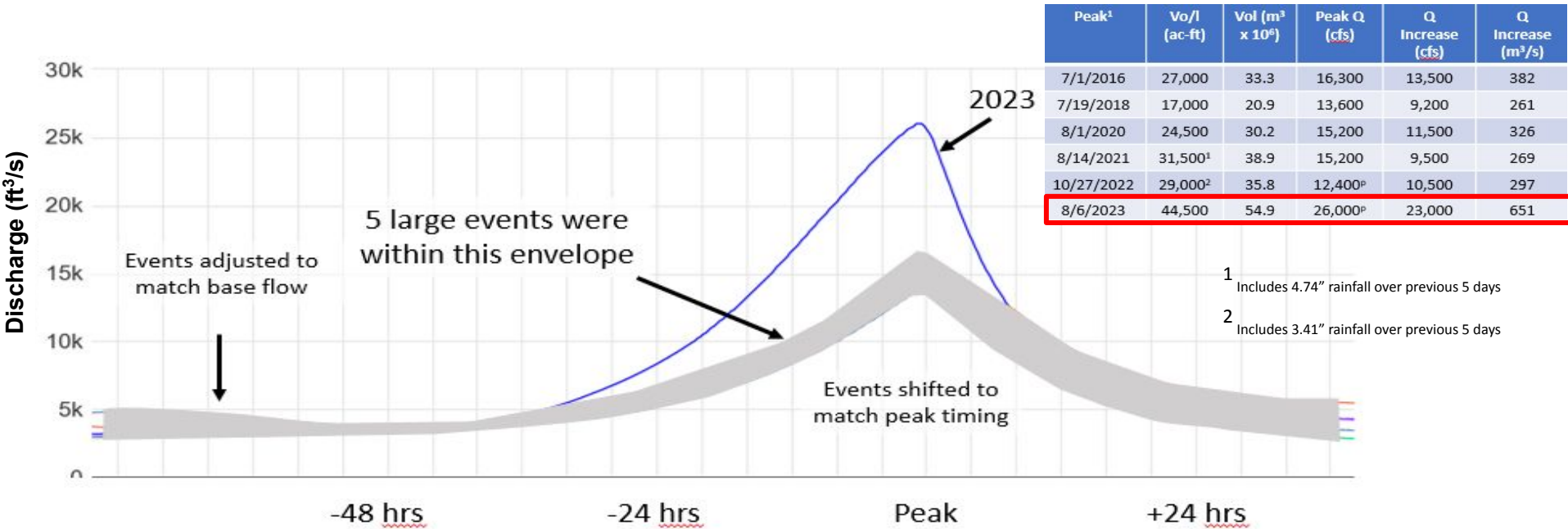


Outburst flood hydrographs



How NWS Generates River Forecasts For Outburst Floods

Forecast Process:



How NWS Generates River Forecasts For Outburst Floods

Tools: Hydrograph Scaling

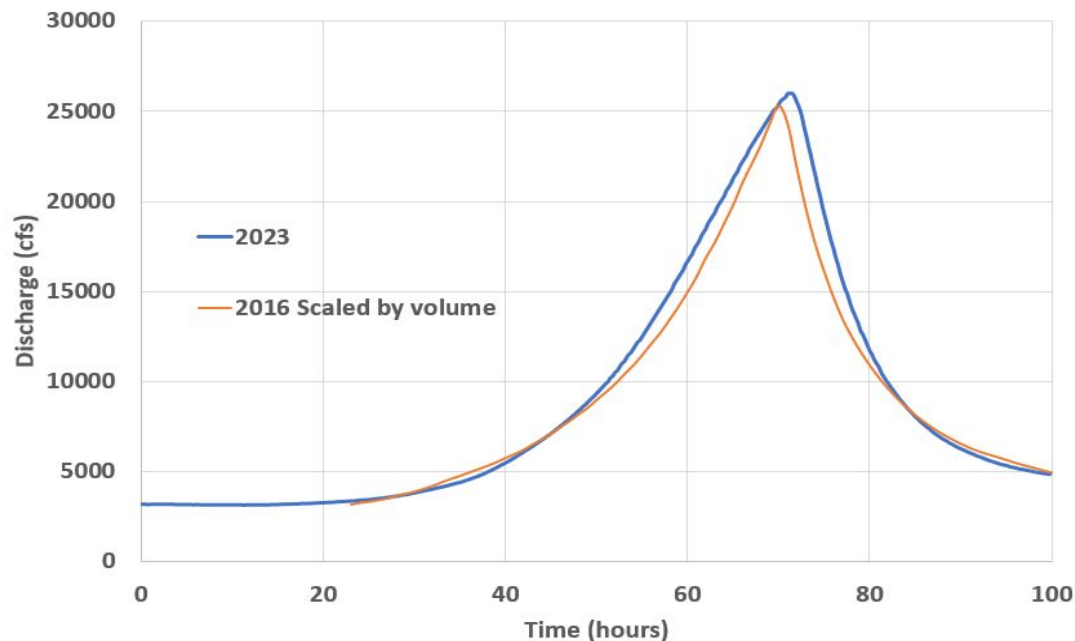
Hydrograph Scaling at the Gage

Inputs:

- Previous reference event
 - Ordinate scaling to match volume
- **Released volume**

Plot shows 2016 event scaled by up by volume

27,000 acre-ft -> 44,500 acre-ft



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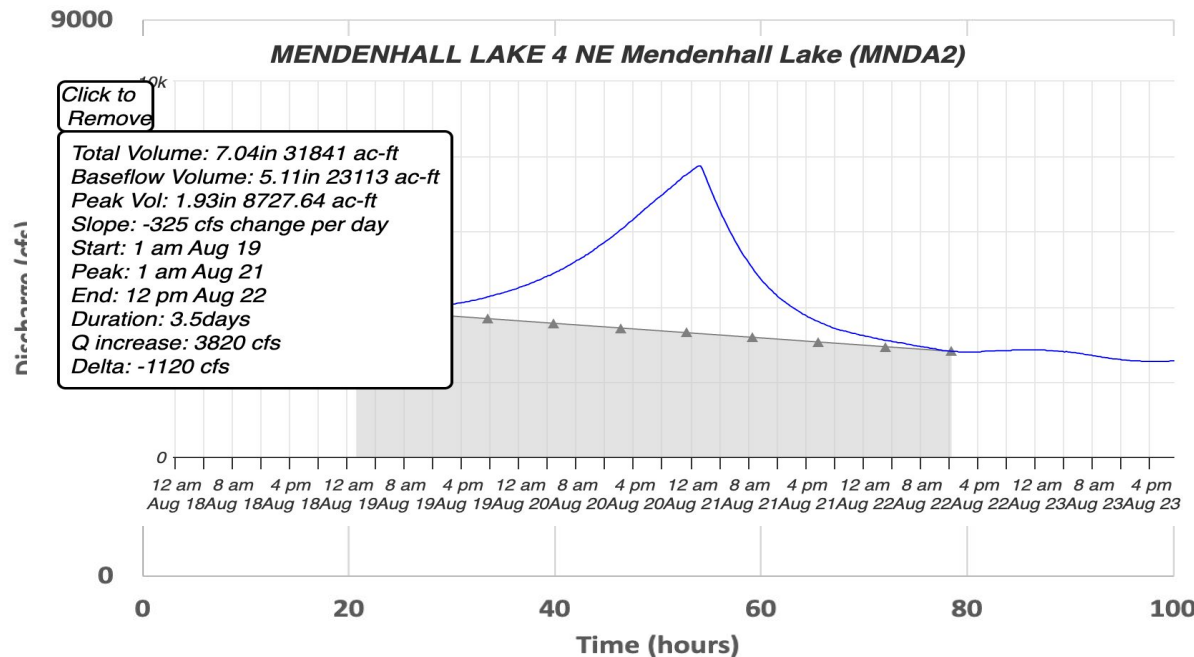
How NWS Generates River Forecasts For Outburst Floods

Tools: Hydrograph Scaling

Hydrograph Scaling at the Gage

2023 2nd Event

- Measured volume ~8700 acre-ft
- 2016 scaled down to match volume
 - From 27,000 acre-ft -> 8700 acre-ft
- Baseflow decreasing - overpredicts



How NWS Generates River Forecasts For Outburst Floods

Utilize UAS Research Findings

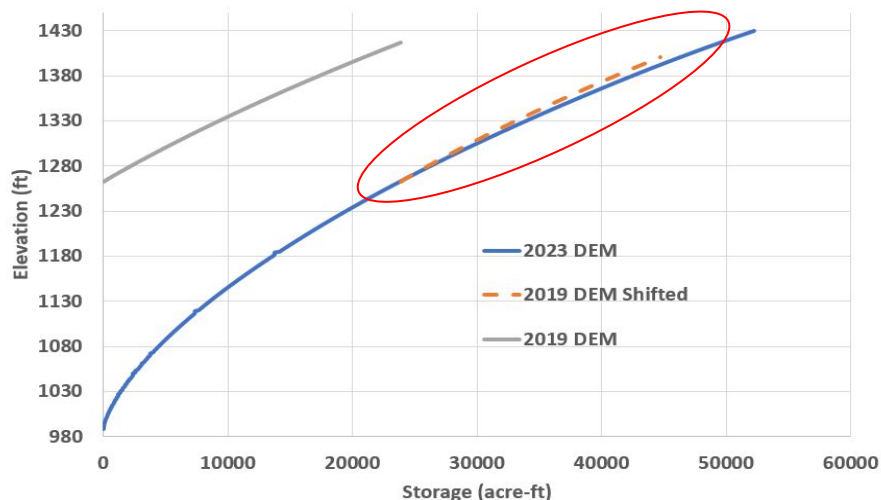
- Generate Storage to elevation curves from drone survey generated digital elevation model (DEM)
 - To improve a total basin release forecast scenario from current water levels (worst case)
- Changes within the basin from year to year to account for ice loss to produce more water storage
 - Be able to add a % of increased water storage as conditions continue to evolve in the basin



How NWS Generates River Forecasts For Outburst Floods

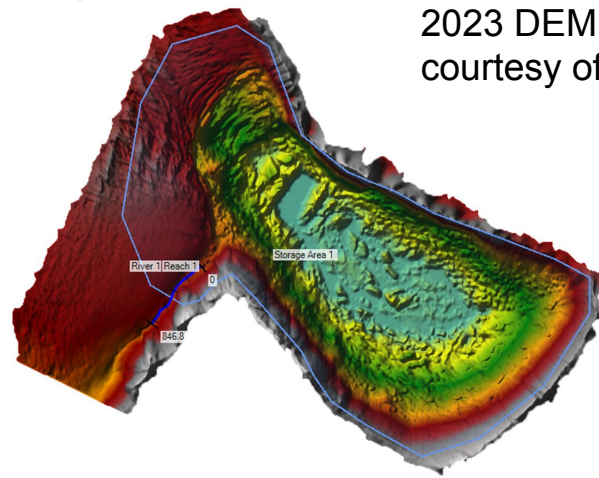
Storage-Elevation

Elevation vs. Storage



2019 DEM - Truncated at 1263' msl

2023 DEM - A more complete picture with data down to 988' msl



2023 DEM (Data courtesy of UAS)

2023 draft post event write up concluded that some basin expansion occurred, comparison of storage elevation curves from 2019 and 2023 (NWS) support this conclusion.

Additional volume was likely from **ice loss** and more **complete drainage** (2020 Kienholz).



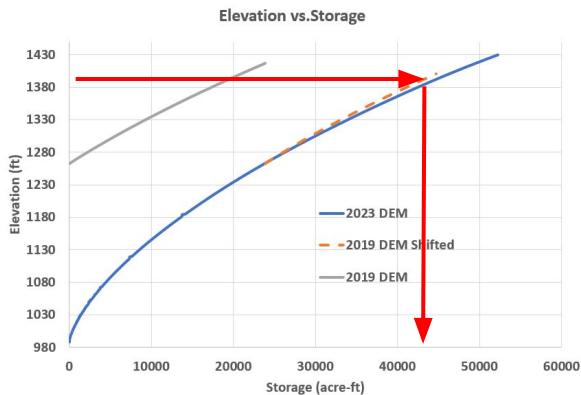
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How NWS Generates River Forecasts For Outburst Floods

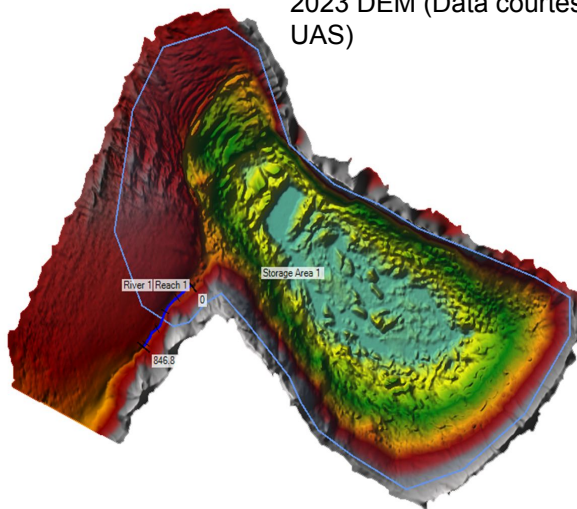
Storage-Elevation

2023 Event

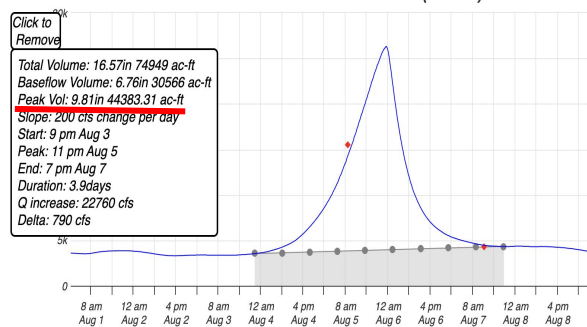
- Hydrograph separation volume ~ 44,500 acre-ft
- Storage-elevation volume ~ 43,000 acre-ft



2023 DEM (Data courtesy of UAS)



MENDENHALL LAKE 4 NE Mendenhall Lake (MND A2)

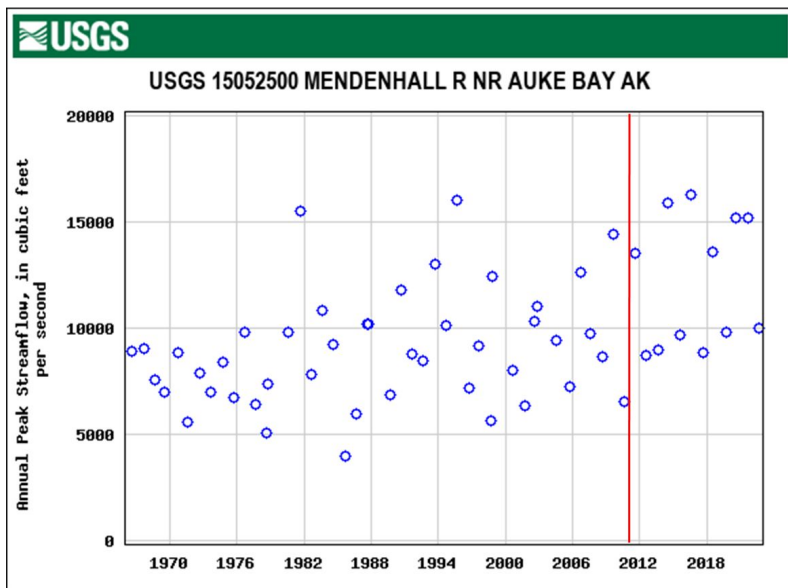


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How NWS Generates River Forecasts For Outburst Floods

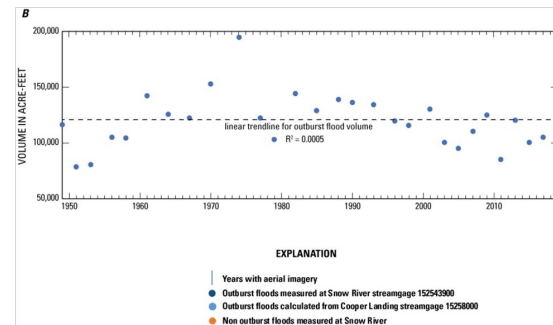
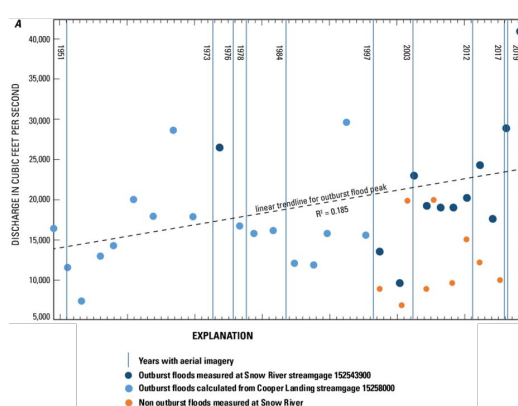
Forecasts & Challenges in the Future

2023 Event



What can we learn from other outburst floods?

Snow River, Kenai Peninsula



Beebe, 2022



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How NWS Generates River Forecasts For Outburst Floods

Forecasts & Challenges in the Future

- **“THERE IS ALWAYS UNCERTAINTY”** from the vast amounts of unknown factors...BUT
- From expanded storage elevation curves, improved forecasts for a near total basin release.
 - No way to confidently say of a partial release.
- From latest studies peak streamflow events have not occurred due to ice remaining in the basin but there is a linear relationship between peak GLOF discharge and vol. released from basin.
(Jenson, A 2022)
- Continue support/collaborate with researchers to better understand this complex and dynamic system.



Monitoring Program

Near real time data access(visualizations)

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Local forecast by 6:36 AM on 09/24/2023

News Headlines
• Showers diminishing into the weekend with colder and drier conditions developing. Latest forecast discussion can be found here.

Suicide Basin
Weather Map • July 2023 • Suicide Basin

Current Hazards Current Conditions Radar Forecasts Rivers and Lakes Climate and Past Weather Local Programs

Suicide Basin Monitoring and Current Conditions

Suicide Basin is a side basin of the Mendenhall Glacier above Juneau, Alaska. Since 2011, Suicide Basin has released glacier lake outburst floods that cause inundation along Mendenhall Lake and Mendenhall River.

Current Status 09/25/2023: Suicide Basin released water for the 5th time this season from September 24th through the 25th which produced a 1.58 rise on Mendenhall Lake/River. The basin is filling again after the recent release with the current water levels much lower than the major release at the beginning of August. Monitoring of Suicide Basin will continue into the fall for additional releases through the fall season.

UAS performed a drone survey of the basin on 08/02 to capture post-release imagery and elevation data. UAS, USGS, and NWS are in the process of evaluating the data from the major flooding event on the Mendenhall Lake and River. Here is the [NWS summary report](#) from the major flooding event from the Suicide Basin glacier lake outburst flood in early August. More information will be available here in the coming months.

Images from the entire 2023 season can be viewed [here](#).

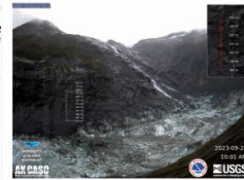
Additional Information available:

- Mendenhall River/Inundation Maps
- Alaska Climate Adaptation Science Center (AK CASC) Story Map
- Suicide Water: The Suicide Basin Outburst Flood
- 2022 Season Time-Lapse Animations ([image](#) and [video](#))
- 2021 Season Time-Lapse Animations ([image](#) and [video](#))



Last Two Week Time-Lapse

Animated time-lapse sequence, combining 15 daily images. Click [here](#) to step through the images from the entire season.



2023 Last Two Week Time-Lapse Sequence With Vectors

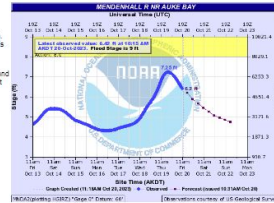
Animated time-lapse sequence including velocity field with maximum height from 2022 (red line) and 2021 (yellow line). Color-coded arrows represent motion of the floating ice in the basin. [Largest image with vectors.](#)



Mendenhall Lake Stage Level

Graph showing the current (blue) and predicted (purple) stage level at Mendenhall Lake. Stage levels are annotated on the left y-axis on the graph. The graph also shows the Mendenhall River discharge (right y-axis), which is derived from the Mendenhall Lake stage level via rating curve.

Once an outburst flood event begins, water levels rise at Mendenhall Lake and Mendenhall River. Drainage initiation at Suicide Basin and water level rise at Mendenhall Lake and River can be offset by several hours.

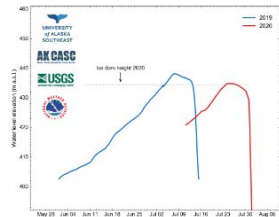


Latest Basin Image

Most recent image of the basin, updated at daily to sub-daily intervals (see time-stamp bottom right). The camera is placed at the basin entrance and faces northeast, into the basin. Click on image to enlarge and read basin levels.

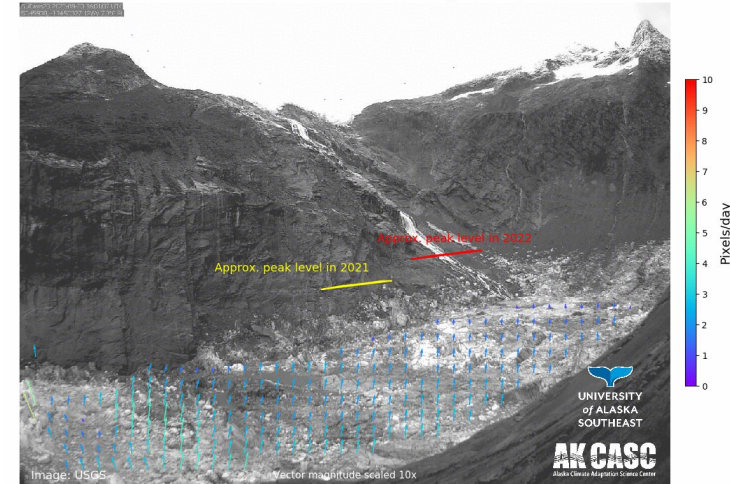
Suicide Basin Lake Level - UNDER DEVELOPMENT

Daily updated graph tracking the lake level at Suicide Basin over the 2020 season (red line). The water level from the 2019 season is included for reference (blue line).



<https://www.weather.gov/ajk/suicideBasin>

2023-09-22 02:01 PM - 2023-09-23 08:01 AM (18.0 hours)



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Monitoring Program

Future (Improvements)

- USGS to add another camera to increase the situational awareness of conditions within the basin and interaction with the main trunk of Mendenhall Glacier (caving events, extent of overflow of ice dam)
- USGS will reinstall pressure gauge to get water level within the basin & laser for increased redundancy.
- Lower latency of Mendenhall Lake data from USGS to NWS and public from once an hour to twice an hour at 15 min increments.

Public Resources:

Google Search-“NWS Suicide Basin”

- NWS Suicide Basin Monitoring page:
<https://www.weather.gov/ajk/suicideBasin>
- NWS Mendenhall Valley Inundation Maps:
<https://water.weather.gov/ahps2/inundation/index.php?gage=mnda2>
- Alaska Climate Adaptation Science Center (AK CASC) Story Map "Hidden Water: The Suicide Basin Outburst Flood":
<https://www.arcgis.com/apps/Cascade/index.html?appid=ad88fd5ccd7848139315f42f49343bb5>



Recent Research

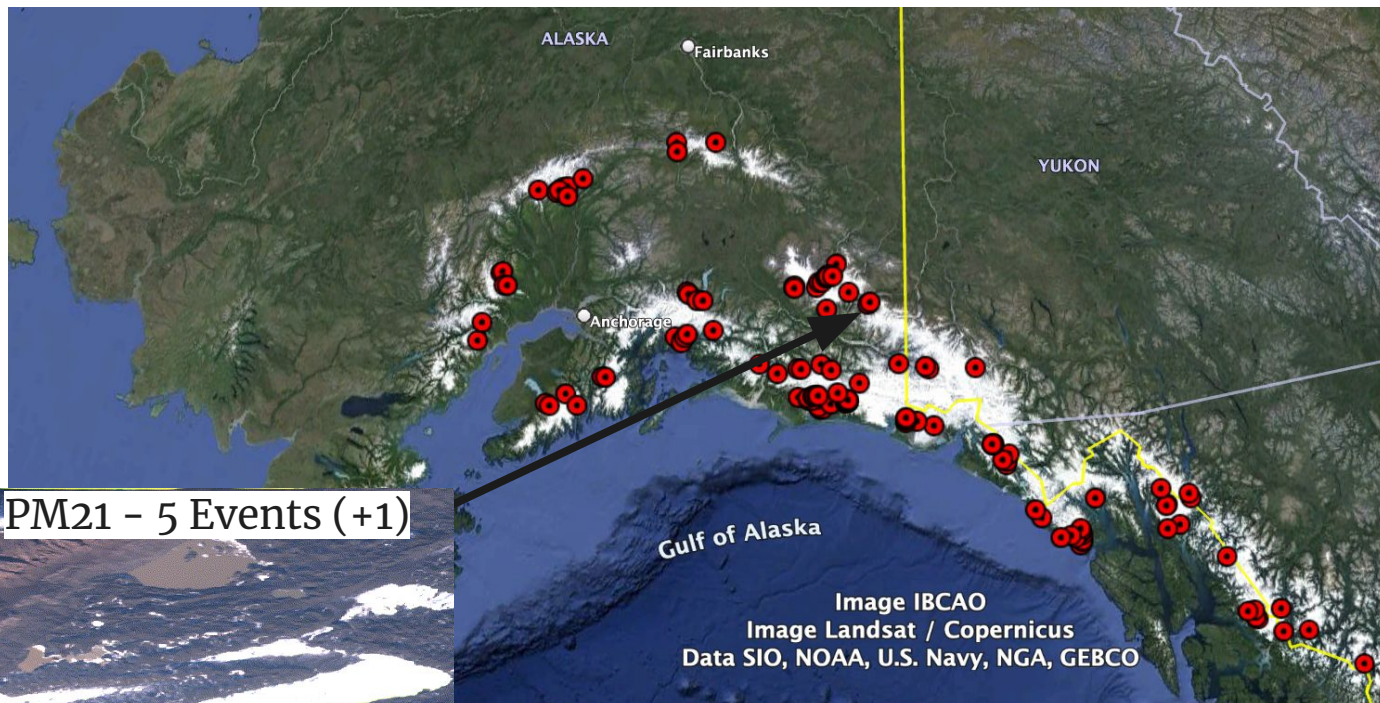
- Kienholz, C., Pierce, J., Hood, E., Amundson, J., Wolken, G., Jacobs, A., Hart, S., Jones, K. W., Abdel-Fattah, D., Johnson, C., and Conaway, J.: **Deglacierization of a marginal basin and implications for outburst floods, Mendenhall Glacier, Alaska**. Front. Earth Sci., 8, 137, <https://doi.org/10.3389/feart.2020.00137>, 2020
- Jenson, A., Amundson, J. M., Kingslake, J., and Hood, E.: **Long-period variability in ice-dammed glacier outburst floods due to evolving catchment geometry**, The Cryosphere, 16, 333–347, <https://doi.org/10.5194/tc-16-333-2022>, 2022 (Published: 25 Jan 2022). <https://doi.org/10.5194/tc-16-333-2022>

NWS Alaska Monitors and Messages (IDSS) for Glacier Lake Outburst Floods

120 glacier-dammed lakes in Alaska

106 of which have drained at least once since 1985

(Brianna Rick et al, 2023)

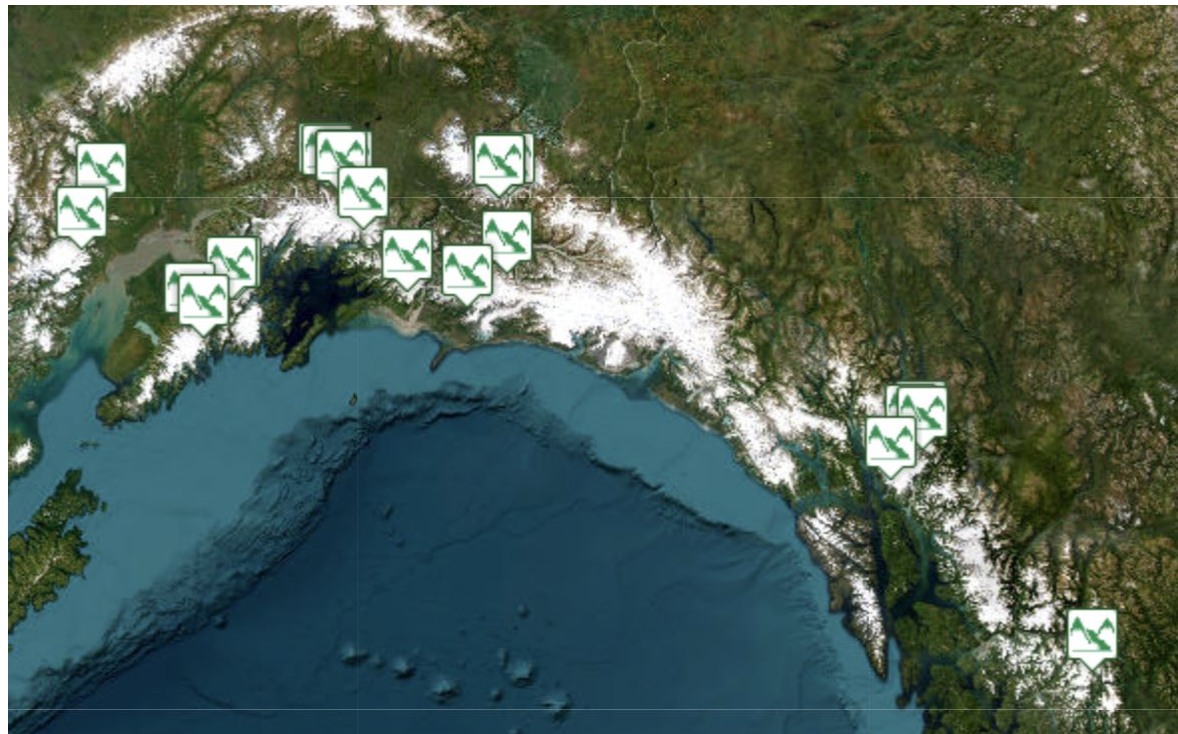


PM21 - 5 Events (+1)

Google Earth Engine Tools

NWS Alaska Monitors and Messages (IDSS) for Glacier Lake Outburst Floods

- Kenai River
 - **Snow**
 - **Skilak**
- Bear Glacier
- Berg Glacier
- Kennicott River
 - **Hidden Lake**
- **Valdez Glacier**
- Taku River
 - **Lake No Lake**
- Salmon River
 - **Summit Lake**
- + Others



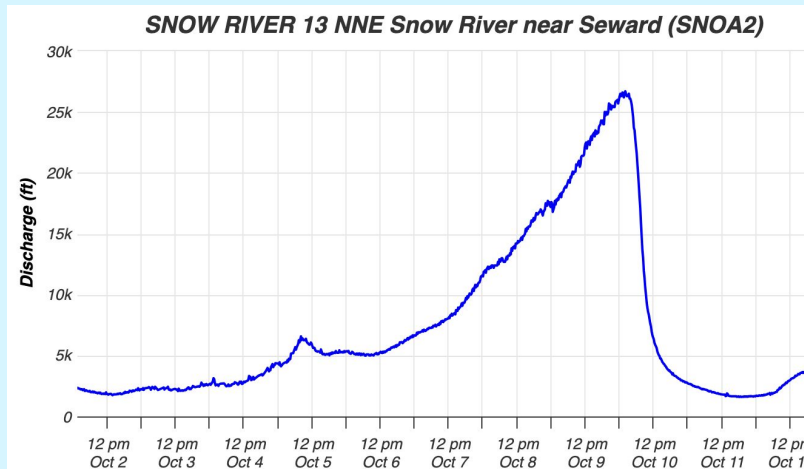
NWS Glacier-Dammed Lakes

- Monitor
- Event Detection
- Flood Forecast/Flood Routing
- Messaging and Impact Based Decision Support
 - Flood Watches
 - Flood Warnings
 - Special Weather Statements (less impactful)
 - Marine Weather Statements (debris and ice)
- Track and Document GLOF Events and Impacts
- Support Researchers
 - USGS, University of Alaska, Alaska Division of Geological & Geophysical Surveys, Ohio State, NASA and others

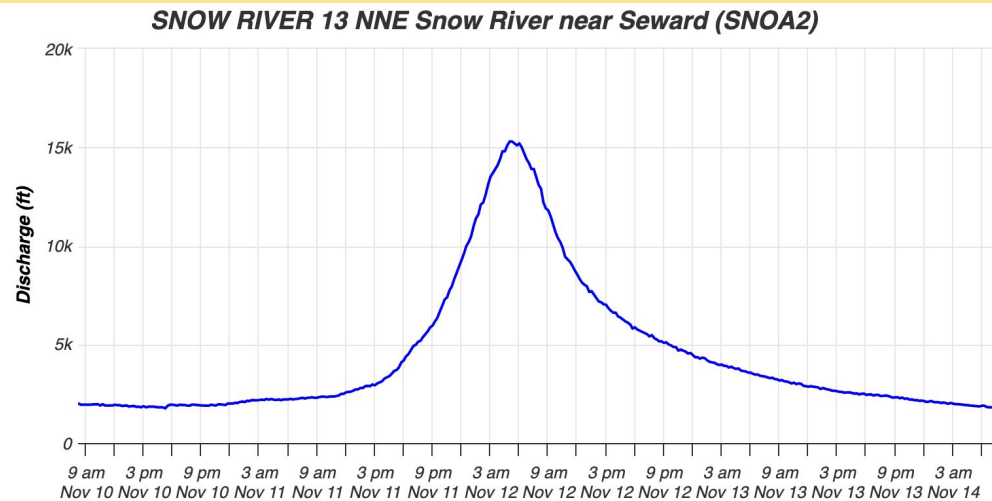


Monitoring for Early Detection - Gages

Glacier Lake Outburst Flood Hydrograph



Rainfall Flood Hydrograph



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Valdez Glacier River

USGS AK - 15227090

The chart displays discharge levels in feet over a period of time, with specific years labeled: 2017, 2020, 2019, 2018, and 2022. The y-axis represents Discharge (ft) from 0 to 40k. The x-axis shows time in 12-hour increments. A blue box highlights the period around 2022, and a blue line connects the peaks of 2017, 2022, and 2018.



2022 Event

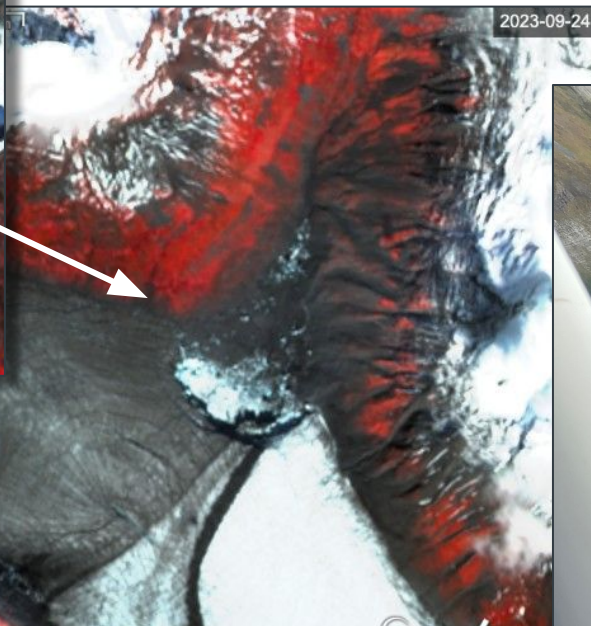
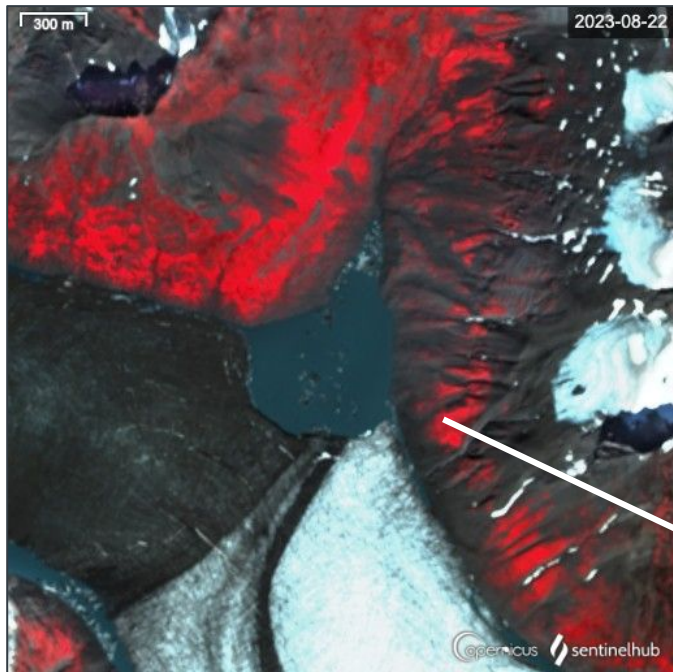
Building a We

Monitoring - Satellites & Aerial Imagery

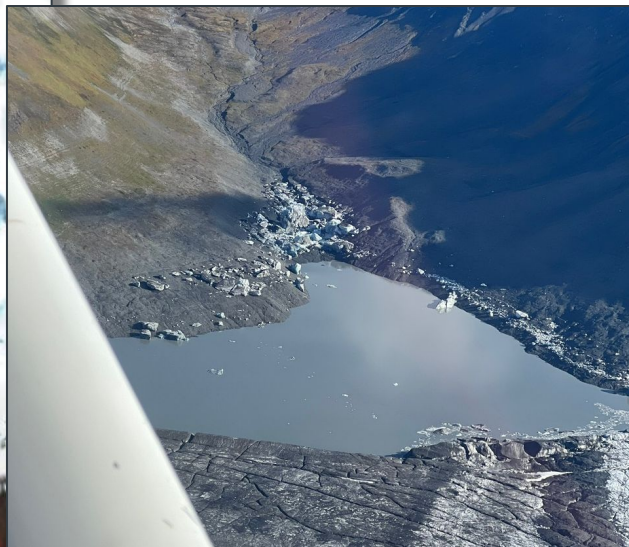
Skilak Glacier-Dammed Lake

Sentinel-1 and Sentinel-2 EO Browser,

<https://apps.sentinel-hub.com/eo-browser/>, Sinergise Ltd.



Civil Air Patrol



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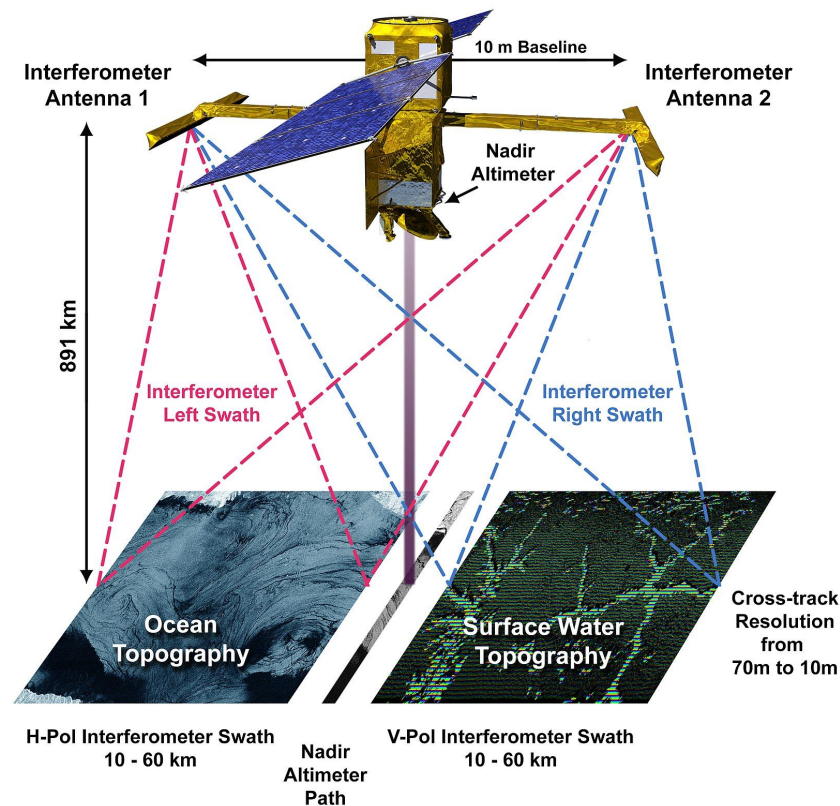
Snow GDL
(released Wed-Sat)



Future Satellite Monitoring

Surface Water and Ocean Topography

- SWOT is expected to observe Alaskan river points 4–7 times per 21-day repeat cycle with 120-km swath coverage
- Over land, produce a water mask able to resolve 100 meter wide rivers and lakes of 250x250 m in size, wetlands, or reservoirs. Associated with this mask are water level elevations with an accuracy of 10 cm and a slope accuracy of 1.7 cm/1



Recent Research

- Rick, B., McGrath, D., Armstrong, W., and McCoy, S. W.: **Dam type and lake location characterize ice-marginal lake area change in Alaska and NW Canada between 1984 and 2019**, The Cryosphere, 16, 297–314, <https://doi.org/10.5194/tc-16-297-2022>, 2022.
- Rick, B., McGrath, D., McCoy, S.W. et al. **Unchanged frequency and decreasing magnitude of outbursts from ice-dammed lakes in Alaska**. Nat Commun 14, 6138 (2023). <https://doi.org/10.1038/s41467-023-41794-6>
- Lützow, N., Veh, G., and Korup, O.: **A global database of historic glacier lake outburst floods**, Earth Syst. Sci. Data, 15, 2983–3000, <https://doi.org/10.5194/essd-15-2983-2023>, 2023.
- Beebee, R.A., 2022, **Recent history of glacial lake outburst floods, analysis of channel changes, and development of a two-dimensional flow and sediment transport model of the Snow River near Seward, Alaska**: U.S. Geological Survey Scientific Investigations Report 2022–5099, 39 p., <https://doi.org/10.3133/sir20225099>.
- AK DGGS - **Monitoring Glacial Lake Outburst Floods** - various <https://dggs.alaska.gov/hazards/climate/glacier-change.html>

Questions??

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Extra Slide:



What's next?

