



Glacier Monitoring in the Central Alaska Network

Data Quality Standards, Version 1.0



A guest scientist in the Geoscientist-in-the-Parks program uses a steam drill to prepare for ablation stake measurements on Kennicott Glacier, Wrangell-St. Elias National Park and Preserve, Alaska.

NPS

Glacier monitoring in the Central Alaska Network: Data quality standards, version 1.0

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Abstract

The purpose of this report is to document the standards used by the National Park Service (NPS) Central Alaska Network (CAKN) Inventory and Monitoring Program for activities related to the collection, processing, analysis, and publication of glacier monitoring data as described in *Glacier Monitoring in the Central Alaska Network: Protocol Narrative* (Loso 2025). This plan also serves as a guide for CAKN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Acknowledgments

The format and content of this document borrow from Wilson and Shepherd (2017) and Rattenbury and Schmidt (2017). Thanks to them, and to Maggie MacCluskie and Scott Miller, for their guidance in developing these standards. Funding for this project was provided through the National Park Service, Inventory and Monitoring Program. The creation of the accompanying protocol narrative involved the contributions of numerous individuals acknowledged more completely in that document.

Revision Log History

All edits and amendments made to this document since its inception should be recorded in Table 1. Users of this protocol should promptly notify the project managers of recommended edits or changes. The project managers will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes.

Table 1. Revision History Log. ^A

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
None	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–

^A This is the first version of this data quality effort, so there is no information about previous versions yet.

1. Introduction

Glaciers are abundant in the parks of the National Park Service Inventory and Monitoring Program's Central Alaska Network (CAKN: Wrangell-St. Elias National Park and Preserve [WRST], Denali National Park and Preserve [DENA], and Yukon-Charley Rivers National Preserve [YUCH]), but they are not uniformly distributed. The coastal ranges of southern WRST are heavily glaciated, while the more interior glaciers of WRST and DENA are more modestly glaciated, though they still contain many large glaciers in comparison with most other national park units. YUCH, though quite cold, contains no glaciers at all. Still, the CAKN parks collectively contain over 4,000 glaciers covering nearly 12,741 square miles (33,000 km²; Loso et al. 2014). This glacier cover dwarfs the approximately 260 square miles (675 km²) combined coverage of *all* glaciers in the contiguous 48 United States (Pfeffer et al. 2016) and speaks directly to the landscape importance of glaciers in these Alaska parks. These glaciers exert substantial control over physical and ecological processes in WRST and DENA and justify establishment of the CAKN glacier monitoring program.

The glacier monitoring program is formulated as a protocol, as documented by a Protocol Narrative (Loso 2025), by Data Quality Standards (this document), and by Standard Operating Procedures (SOPs) that provide detailed instructions for protocol implementation. Collectively, these documents describe how monitoring data will be collected, managed, and reported as part of the NPS Inventory and Monitoring program and as described in the CAKN Vital Signs Monitoring Plan (MacCluskie et al. 2005).

As part of the glacier monitoring protocol, this report documents the standards used by the CAKN Inventory and Monitoring Program for activities related to the collection, processing, analysis, and publication of glacier monitoring data as described in *Glacier Monitoring in the Central Alaska Network: Protocol Narrative* (Loso 2025). The policies and procedures documented in this quality-assurance plan follow the quality-assurance plan for other monitoring activities conducted by CAKN and supplement the national Inventory & Monitoring Division Quality Management Plan. This plan also serves as a guide for CAKN and other personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

2. Protocol Overview

2.1 Objectives

The CAKN glacier monitoring protocol was designed to provide measurable indications of seasonal and interannual change in glacier extent. The protocol balances traditional mass balance measurements on two glaciers with newer remote sensing-based measurements of long-term glacier change on many, or even all, park glaciers (Table 2).

Table 2. Overview of proposed activities for the CAKN glacier monitoring program.

Glacier(s)	Objective	Unit	# sites WRST	# sites DENA	Frequency
Kahiltna	Glaciological mass balance	meters weq	–	6	annual
	Climate	air temp, precip, etc.	–	2	daily
	Surface elevation	meters asl	–	1	every 2–3 yr
	Boundary and area	polygon, km ²	–	1	every 2–3 yr
Kennicott	Glaciological mass balance	meters weq	6	–	annual
	Climate	air temp, precip, etc.	1	–	daily
	Surface elevation	meters asl	1	–	every 2–3 yr
	Boundary and area	polygon, km ²	1	–	every 2–3 yr
Many	Surface elevation	meters asl	30	12	every 4–6 yr
	Surface velocity	meters per day	30	12	every 4–6 yr
All	Boundary and area	polygon, km ²	3121	881	every 10 yr

2.2 Sampling Design

Kahiltna and Kennicott Glaciers were chosen for the intensive field-based mass balance measurements because each is (1) large, (2) relatively accessible, and (3) receives high visitation. Measurement sites within those glaciers (shown in Figure 1 and Figure 2) were chosen to maximize spatial coverage while minimizing the costs, safety hazards, and logistical demands of access. The larger number of glaciers chosen for measurements of surface elevation and surface velocity may evolve over time, but presently is chosen to match the selection of the NASA Operation IceBridge program. Their selection of glaciers focused on the largest glaciers in each park so that the number of measured glaciers measured is small, but the cumulative area large, in comparison with the total population of glaciers in both parks. Of all the measurements that can be made of individual glaciers, delineation of glacier boundaries and consequent surface area are the simplest, and for this reason we choose to make these measurements on all glaciers in both parks. Though relatively straightforward, we note that there are nonetheless over 4,000 individual glaciers and that the workload associated with this measurement is substantial. For this reason, such measurements are slated for completion only once every 10 years.

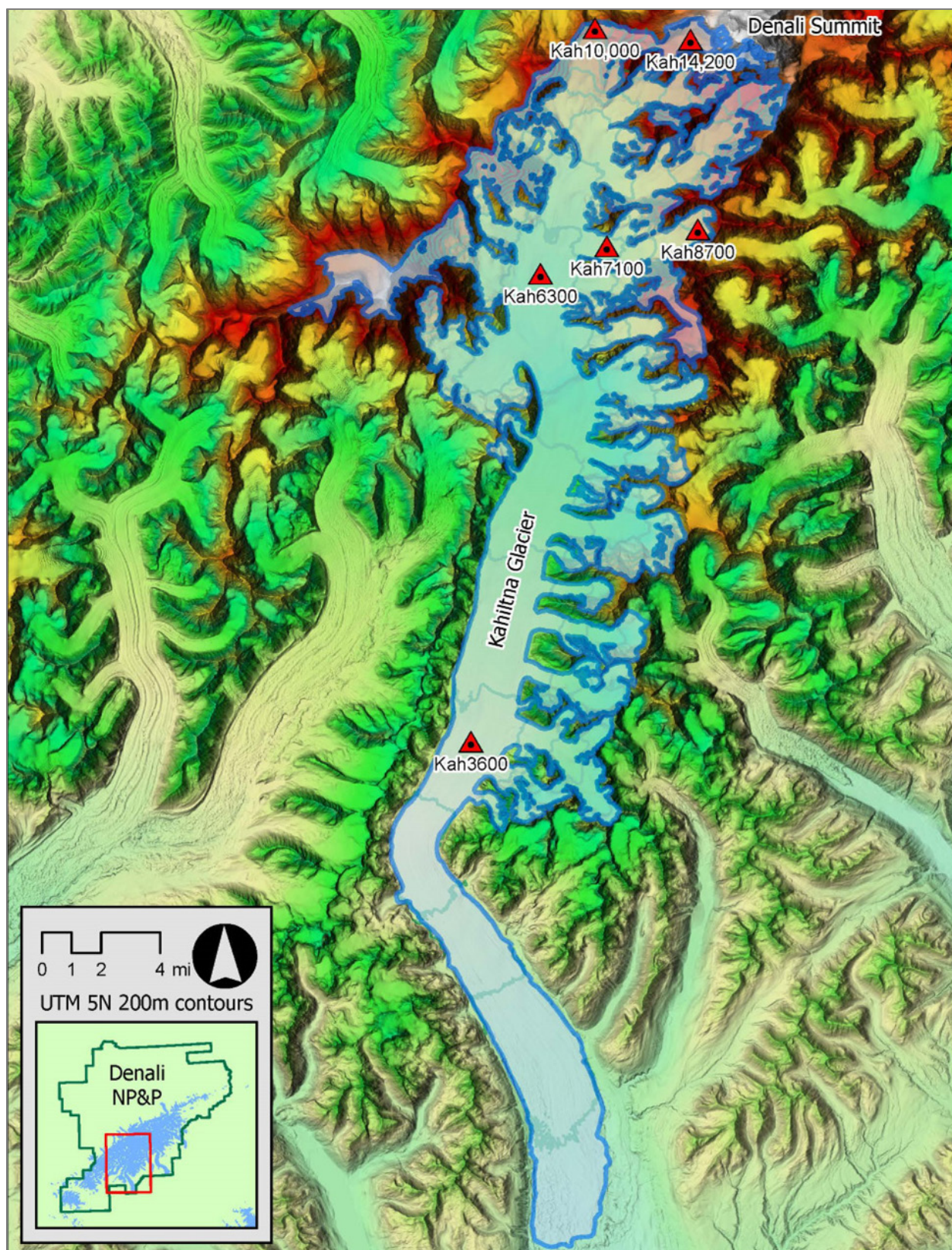


Figure 1. Current (2025) monitoring sites on Kahiltna Glacier. Lowest of the 200-meter contours is at 400 m asl. Equilibrium Line Altitude is generally just below Kah 6300. NPS

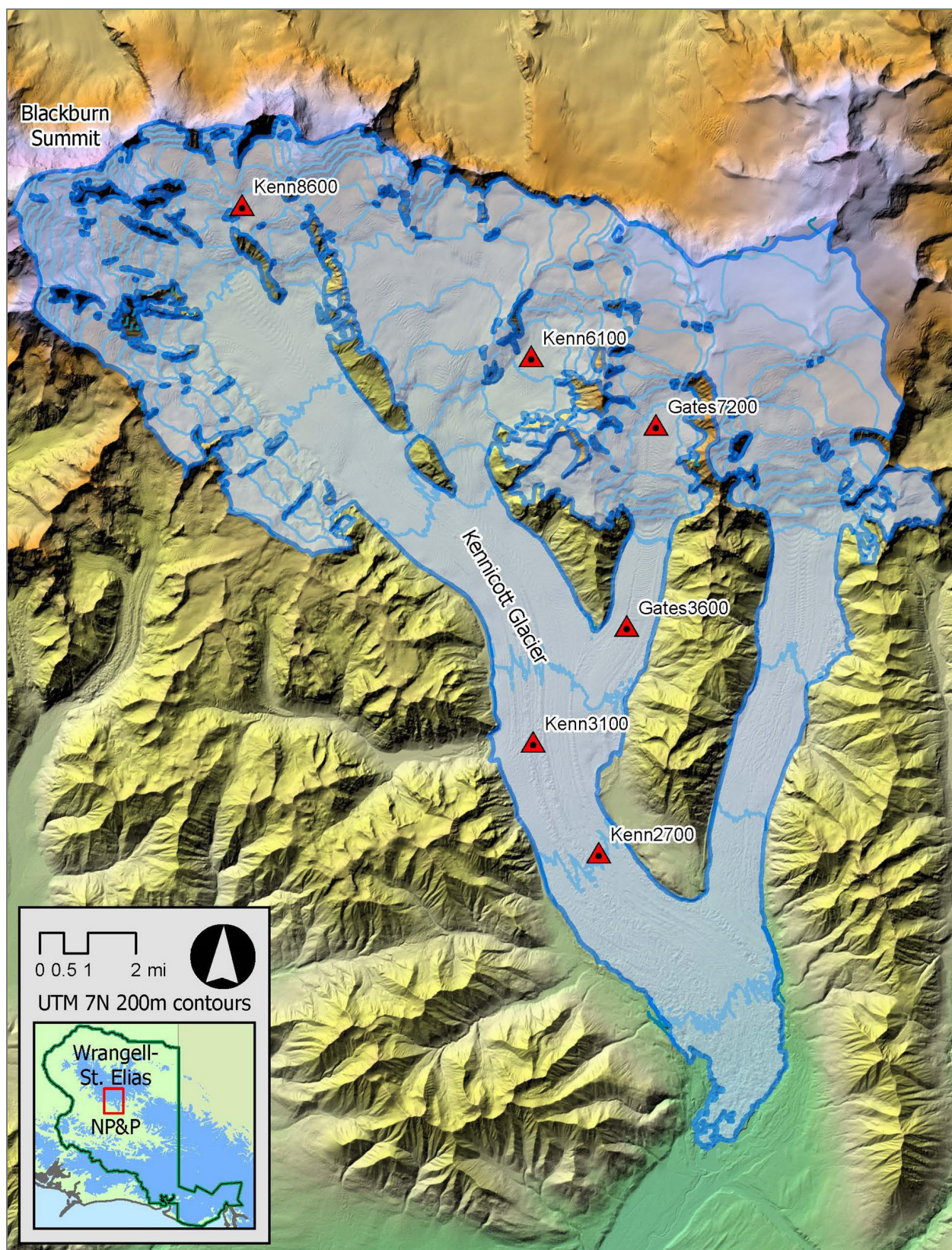


Figure 2. Current (2025) monitoring sites on Kennicott Glacier. Lowest of the 200-meter contours is at 600 m. Equilibrium Line Altitude is generally just below Kenn6100. NPS

3. Data Quality Objectives

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information.

3.1 Representativeness and Data Comparability

Because of the sample design described above, most of these measurements are not randomly distributed through space. Like many comparable studies, the two glaciers selected for mass balance field measurements were not selected randomly and are not expected to be statistically representative of the entire population of glaciers in DENA and WRST. The larger group of glaciers selected for surface elevation and velocity measurements is also not randomly selected. The present group of glaciers was selected by the Operation IceBridge team to capture most of the very large glaciers within the parks (and outside the parks as well). As such, they capture the dynamics of a large fraction of the total glacier ice in the parks. That sample cannot be understood to be representative of all the glaciers in the parks, however, because small glaciers are underrepresented. Only the glacier area measurements can be understood as truly representative for they are aimed at including the entire population of park glaciers. For the other measurements, interpretation of results will need to be done carefully to avoid conveying an impression of statistical representativeness. These measurements are best interpreted using a time series approach where the focus is on trends—at each sampling site—over time.

That said, all of the glacier measurements proposed within this protocol are being collected using techniques and equipment that are directly comparable to (and in many cases identical to) those used for measurements elsewhere in Alaska and in glaciated regions throughout the world. This protocol will therefore significantly expand the existing global network of glacier monitoring sites with new datasets that can be analyzed more broadly in direct comparison with other areas.

3.2 Data Completeness and Quality

If measurements are unable to be completed in a scheduled year due to funding or logistical issues, they will be attempted in the next year if possible. In the case of automated weather station measurements or satellite-derived measurements, this delay will not result in any lost data but may delay the posting of certified datasets. For the other (field-measured) variables, a skipped data collection season could not be recovered, but data collection at a later date would still allow calculation of long-term trends, albeit with reduced temporal resolution for that epoch. Climate station records can be used to estimate values from unmeasured glacier monitoring stakes, but because of unknown extrapolation errors such a practice is in general avoided.

Target data quality objectives for each measurement type are summarized in Table 3. Equipment and techniques required to meet these objectives are described in the Standard Operating Procedures. These objectives are aspirational and confidence intervals derived from actual data will always be presented with data reports and publications, regardless of whether they meet or exceed the data quality objectives. Quality standards for the field measurements on Kahiltna and Kennicott Glaciers

are based on years of field experience and reflect the PIs' best estimate of reasonable measurement standards given current techniques and technology.

Table 3. Target data quality standards for the glacier monitoring protocol.

Glacier(s)	Objective	Unit	Quality Target
Kahiltna / Kennicott	Glaciological mass balance	meters weq	+/- 0.1 m weq
	Climate—air temperature	degrees C	+/- 2° C
	Climate—snow depth	meters	+/- 0.1 m
	Climate—wind speed	meters per second	+/- 1.0 m/s
	Climate—wind direction	degrees	+/- 5°
	Climate—shortwave radiation	watts per square meter	+/- 5 w/m ²
	Climate—relative humidity	percent	+/- 2%
	Surface elevation	meters asl	+/- 0.2 m at individual stakes
	Boundary and area	polygon, km ²	+/- 2%
Many	Surface elevation	meters asl	+/- 0.5 m for median elev per 10 m bin
	Surface velocity	meters per day	+/- 0.05 m/d
All	Boundary and area	polygon, km ²	+/- 5% of area for all glaciers > 10 km ²

Quality standards for the remotely sensed measurements (surface elevation, velocity, and glacier areas) are based on recent practice but are expected to vary as technologies evolve. In Table 2, target qualities for glacier area and surface elevation are based upon more detailed error analyses in Loso et al. (2014). Target velocity errors are aspirational, and in any case dependent on data sources, but the largest errors in cross correlation-based flow estimates like ITS-LIVE occur with short time-interval image pairs. By using annual mosaics, we can minimize errors in all but the slowest moving glacier areas (Gardner et al. 2024). We note that the quality standards will not always decrease over time. As an example, the apparent confidence intervals in glacier area have risen since the measurement technique changed from human delineation to computer-assisted algorithms (Loso et al. 2014, Roberts-Pierel et al. 2022).

3.3 Data Archival, Closeout, and Certification Procedures

Data archival, closeout, and certification procedures will generally follow the guidelines established in Miller (2017) and presented more specifically in the accompanying protocol narrative. All protocol associated data will be uploaded to the IRMA Data Store within Dataset References that correspond to the rows of Table 4.

Table 4. CAKN glacier monitoring data deliverables references. Types raw and processed are uploaded to IRMA as internally viewable data records. Certified records are intended to be publicly viewable.

Identifier	Deliverable	Type	Format	Schedule
GM-MB notes	Field notebooks and data sheets	raw	Scans, *.pdf	Annual
GM-MB photos	Field photographs	raw	Photos, typically *.jpg	Annual
GM-MB gps_logger	GPS datalogger files (raw)	raw	Evolving	Annual
GM-MB positions	Corrected, QC'd GPS records and exported shapefiles	processed	Evolving	Annual
GM-MB met_logger	Met station datalogger files	raw	Table, *.csv	Annual
GM-MB weather	Corrected, QC'd met station records	processed	Table, *.xlsx	Annual
GM-MB legacy_stakes	Mass balance records (pre-2016)	processed	Table, *.xlsx	Complete
GM-MB stakes	Mass balance records (2016-modern)	processed	Table, *.xlsx	Annual
GM-MB database	Certified mass balance records	certified	SQL database engine	Annual
GM-MB outlines	Glacier outlines for Kahiltna and Kennicott Glaciers	certified	Arc, *.shp or other	2–3 yr
GM-MB elevations	Surface elevations for Kahiltna and Kennicott Glaciers	certified	Raster, *.tif	2–3 yr
GM-LTC elevations	Surface elevations for a subset of DENA/WRST glaciers	certified	Raster, *.tif	4- 6 yr
GM-LTC velocities	Surface velocities for a subset of DENA/WRST glaciers	certified	Raster, *.tif	4–6 yr
GM-LTC outlines	Glacier outlines for all DENA/WRST glaciers	certified	Arc, *.shp or other	10 yr

This is a “file based data management system,” per Miller (2017), and it consists fundamentally of two different types of data: internal and public references. Internal references include raw and processed data files that will be archived in the IRMA Data Store but are not viewable to the general public. These files are not considered “certified.” Public references are based upon the internal references but will have been quality-controlled by the PI prior to publication. Quality control safeguards applied, as appropriate, to all deliverables described in Table 3 include:

- Immediate (within 48 hours) checking of collected/downloaded data for completeness,
- Regular collection, scanning, and archiving of field notes to maintain a record of data collection abnormalities,
- Double data entry in the rare case of manually entered data,
- Regular checking of data for extreme or impossible values,
- Regular calibration of sensors on manufacturer recommended schedules,
- Graphical and visual exploratory data analysis, and

- Statistical error or outlier identification.

This quality control, followed by posting as public references, constitutes “implied certification.” All files posted in this way will include “certified” in their titles and are considered to be developed to analytical quality. All certified data products will be presented in human and machine-readable formats and presented with metadata in FGDC (spatial; FGDC 1998)) or Ecological Metadata Language (tabular; Knowledge Network for Biocomplexity 2015) language.

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