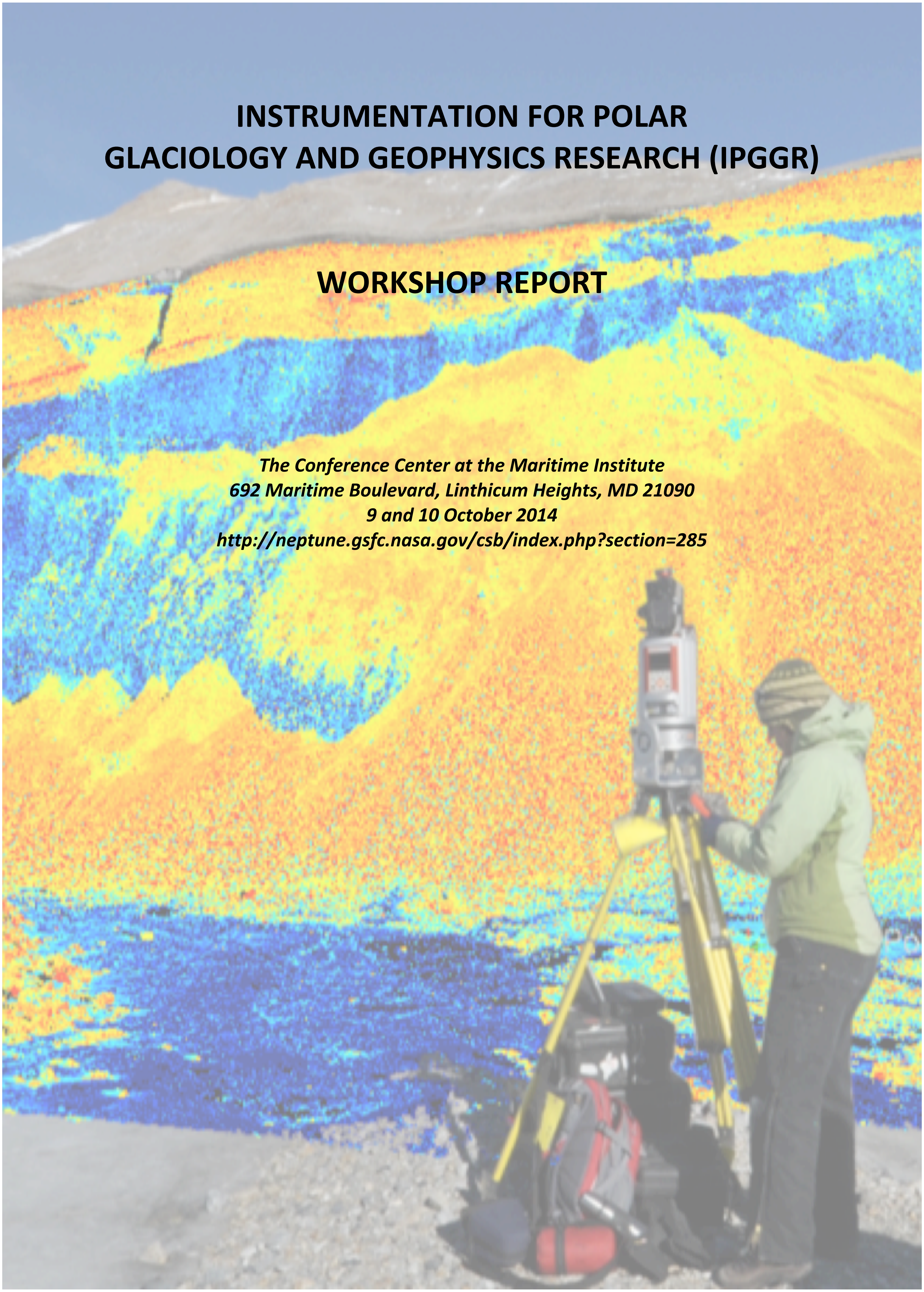

INSTRUMENTATION FOR POLAR GLACIOLOGY AND GEOPHYSICS RESEARCH (IPGGR)

WORKSHOP REPORT

The Conference Center at the Maritime Institute
692 Maritime Boulevard, Linthicum Heights, MD 21090
9 and 10 October 2014
http://neptune.gsfc.nasa.gov/csb/index.php?section=285

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Kelly Brunt	Co-Convener, ESSIC, University of Maryland; NASA GSFC Cryosphere
Joseph MacGregor	Co-Convener, University of Texas, Institute for Geophysics
Carlton Leuschen	Steering Committee, University Kansas
Duncan Young	Steering Committee, University of Texas, Institute for Geophysics
Kirsteen Tinto	Steering Committee, Lamont-Doherty Earth Observatory
Knut Christianson	Steering Committee, NYU, Courant Institute of Mathematical Sciences
Marianne Okal	Steering Committee, UNAVCO

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SUMMARY

Scientists are studying the Earth's ice sheets and their connections to other Earth systems using a variety of instrumentation. However, many scientists are unfamiliar with other instrument capabilities that are complementary to their research goals. A workshop was organized to bring together scientists to assess current polar instrumentation and identify a means of communicating the nature and value of this instrumentation to the broader research communities. The workshop, titled Instrumentation for Polar Glaciology and Geophysics Research (IPGGR), was held 9–10 October 2014, in Baltimore, Maryland.

The goals of the IPGGR workshop were to: 1) assess the current state of instrumentation; 2) identify instrument limitations; and 3) develop a means of communicating these technologies to the broader scientific community. To achieve these goals, invited IPGGR workshop participants included: 1) scientists with a deep understanding of the current instrumentation; 2) instrument designers and operators, of both current and emerging instrumentation; 3) scientists involved in multi-disciplinary platform development; and 4) federally-funded program managers.

The IPGGR Steering Committee organized the workshop into sessions associated with ground-based, airborne, and satellite-borne instrumentation. Each session included a series of presentations, followed by a discussion. Notes from these discussions form the basis of this report and an instrumentation summary document. The IPGGR workshop website is hosted by NASA Cryospheric Sciences Laboratory, and includes the participant list, agenda, this report, and a summary document of the instruments presented (http://neptune.gsfc.nasa.gov/csb/index.php?section=285).

Areas of improvement were discussed and were often unique to specific instruments. All identified challenges are detailed further in this report, but a few common themes were identified.

- Instrument weight and size
A transition from heavy, lead-acid batteries to lighter, more expensive lithium-based batteries could help reduce logistics requirements associated with ground-based instrumentation. Reducing the weight and size of airborne instruments creates more space on aircraft, increases aircraft range and increases the feasibility of instrument deployment as part of an unmanned aerial system.

- Data archiving
There is a large expense associated with proper data archiving (including standardization and documentation) and data accessibility (e.g., a geo-referenced, searchable viewer). However, this effort could facilitate integration of numerous types of datasets, which would accelerate interpretation of geophysical properties measured by several platforms.

- Communication of concentrated logistics

Large-scale surveys often require a concentration of deep-field logistics, which needs to be communicated to the scientific community to identify synergistic activities. The research-cruise model (where schedules are decided well in advance) should be applied to other research platforms, such as traverses or airborne missions, allowing groups to share logistics with minimal additional cost.

Finally, discussions included methods of updating the instrumentation document (Instrumentation for Polar Glaciology and Geophysics Research) as technologies evolve. A regular poster session that focuses on instrumentation for polar research should be convened at the AGU Fall Meeting. Input from the conference session could be appended to the existing document.

The workshop was supported by both NSF, Division of Polar Programs, and by NASA, Cryospheric Sciences.

WORKSHOP GOALS

Due to the vast and often inaccessible nature of the polar ice sheets, many fundamental research topics in the fields of glaciology and geophysics require remote-sensing techniques. There are many specialists addressing these topics and these studies involve numerous specialized instruments. Polar researchers are often limited by this specialization, even though instrumentation may be complementary to their science. Thus, there is a critical need to bring together interested parties to assess current polar instrumentation and to establish a means of disseminating information about this instrumentation to the broader community, with a specific goal of reaching researchers new to polar research.

With this need in mind, the objective of the IPGGR workshop was to bring together the glaciology and geophysics communities to review ground-based, airborne, and satellite-borne instrumentation (e.g., radar, lidar, seismics, GPS, etc.) that either exists or is in development that is suitable for Arctic and Antarctic research. The specific goals of the IPGGR workshop were to: 1) assess the current state of both in-development and mature instrumentation; 2) identify limitations within existing instrumentation; 3) develop a means of communicating, and updating, the broader community (especially researchers that are new to polar science) of these technical capabilities; and 4) provide advice to funding agencies (e.g., NSF and NASA) on how to regularly communicate the available instrumentation to the broader community.

Ultimately, the IPGGR workshop brought together: 1) researchers that use existing and complementary datasets, who have a deep understanding of the strengths and weaknesses of specific current instrumentation; 2) instrument designers and operators, of both current and emerging instrumentation; 3) researchers involved in multi-disciplinary platform development, which integrates suites of instruments that are applied to diverse glaciological and geophysical investigations; and 4) program managers, including funding managers, Science and Technology Center (STC) managers, and Distributed Active Archive Center (DAAC) managers, to help formulate a means of communicating results to the broader community.

Notes from the IPGGR workshop formed the basis of: 1) this report, which summarizes the workshop and addresses the four goals; 2) an instrumentation document (Instrumentation for Polar Glaciology and Geophysics Research), which summarizes the technologies presented; and 3) a publication of the highlights of this report in EOS, to inform the broader geoscience community.

The IPGGR workshop documents are intended to aid researchers, especially early-career researchers or those new to polar sciences, in the preparation of NSF or NASA proposals for Arctic and Antarctic research. A key outcome of the workshop is this instrumentation document, which will be valuable to researchers throughout the duration of their research projects. Specifically, this report and the instrumentation document will assist researchers during the proposal development phase, by informing those new to polar science of the technological capabilities available to polar researchers. Many of these tools have been developed over the last decade; therefore the workshop was intended to update the community on what is available (e.g., the tools, the capabilities of the instruments and the groups that have developed and who are operating them). The instrumentation document will also assist researchers with the field-site selection phase, particularly when research goals or safety concerns are strongly linked to glacial dynamics. Finally, these documents will assist researchers during the data analysis and publication phase, by linking researchers with complementary datasets.

WORKSHOP OUTCOMES

- Instrument weight and size

With respect to ground-based instruments, increased weight is often associated with increasing power requirements. Scientists simultaneously want both sufficient power to operate stations continuously through the polar winter and lightweight power options that reduce logistical costs associated with deep-field deployment. A transition from heavy, lead-acid batteries to lighter, more expensive lithium-based batteries could help meet both power requirements and logistical constraints. With respect to airborne instruments, reducing both the weight and size of instruments creates more space on aircraft, increases aircraft range, and increases the feasibility of instrument deployment as part of an unmanned aerial system.

- Data archiving and discovery

Participants recognized the large expense associated with proper data archiving (including standardized format and documentation) and data accessibility (e.g., in a geo-referenced, searchable viewer). The combination of uniformly archived data and a suitable data-discovery tool will facilitate integration of ground-based, airborne and satellite-borne datasets from numerous types of instrumentation. This could accelerate interpretation of the same geophysical property measured by several platforms (e.g., surface elevation) and simplify the integrated interpretation of difficult-to-reach regions (e.g., subglacial environments). Over the last several years, the Norwegian Polar Institute developed Quantarctica, an add-on package for QGIS, an open-source, multi-platform geographic information system. Quantarctica contains many of the most commonly needed data products for Antarctica (e.g., Bedmap2) and represents a plausible tool for widespread data sharing. The IceBridge Planning Tools developed by the University of New Hampshire are another salient example of the value of numerous georeferenced datasets in a single system.

NetCDF, HDF5 and SEGY were recognized as the established standards for distribution of most polar geophysical data, although some simpler datasets (e.g., depth profiles of ice-core properties) are still commonly made available in ASCII text formats. Modern file formats handle large data volumes better, but outstanding challenges still exist in terms of suitable formats for emerging instruments that generate extremely large data volumes (GB to TB day^{-1}), such terrestrial laser scanning (TLS) or photon counting lidar, and for which data-format standardization has not yet occurred.

The National Snow and Ice Data Center (NSIDC) was recognized as the most common data-archiving center for polar data products, while the Polar Geospatial Center (PGC) archived high-resolution satellite imagery. The range of data types that these centers archive increased in recent years, particularly for the NSIDC during the course of Operation IceBridge (OIB). However, some data types had no clear archive.

For advanced analysis of particularly rich datasets, such as airborne radar-sounding data or laser-altimetry waveforms, participants recognized that L0 or L1A data is sometimes required but rarely publicly archived. This situation slows the development of novel results from such data.

While NSIDC archives some software (e.g., IMCORR), no official archive exists for most software used in polar glaciology and geophysics. As for many disciplines, such software is often task-specific and not always robust, although that is starting to change (e.g., the use of the R environment in statistics). Many tools are proprietary (e.g., Landmark), while others are semi-proprietary (e.g., MATLAB) and others are fully open-source (e.g., Python). Github was recognized as a popular online solution for software archiving and sharing, and it was recognized that increased use of such platforms would accelerate analysis and discovery in polar research.

- *Communication of concentrated logistics*

Large-scale surveys often require a concentration of deep-field logistics, which needs to be communicated to the scientific community to identify synergistic activities. The research-cruise model, where schedules are decided well in advance, should be applied to other research platforms. The U.S. Ice Drilling Program Office and the Ice Drilling Design and Operations Office (IPDO-IDDO) coordinate the development and deployment of ice-drilling operations and offer an example of community-driven decision-making in the use of limited resources in the polar regions. The call of opportunity for the recent TAM Camp in the Transantarctic Mountains is another salient example of community-driven logistics coordination. Planned ground-based traverses or airborne surveys could be shared through QGIS or the IceBridge Planning Tools, allowing groups to share logistics with minimal additional cost.

- *Communication of available polar instrumentation*

Discussions included methods of updating the instrumentation document as technologies evolve. Two options were preferred: 1) A regular poster session that focuses on instrumentation for polar research should be convened at the AGU Fall Meeting. Input from the conference session could be appended to the existing document; 2) A website that sorts links to relevant instrumentation webpages, specific data archives and organizes this information coherently.

- *Instrument lifecycle*

Workshop participants were concerned with the cost associated with maintaining aging infrastructure; participants wanted to ensure that instrument lifecycles were being evaluated and that instruments were being retired when appropriate.

- *Science not represented at this workshop*

Due to scheduling conflicts, some instruments were not represented at this workshop. Examples included GRACE, structure from motion (SFM), and automatic weather stations (AWS). To stay focused, workshop organizers limited instrument discussions to tools used on the ice sheets (i.e., oceanographic instruments were generally not discussed). The meeting organizers suggest the inclusion of these as the document is updated.

APPENDIX A1: WORKSHOP AGENDA

Day 1:

08:00
Welcome
Co-conveners – Kelly Brunt and Joseph MacGregor
NSF – Julie Palais and Scott Borg
NASA

08:30
Session 1: Ground-based instrumentation
08:30 - GPS – Joseph Petit
08:45 - GPS and ice-sheet motion – Lucas Beem
09:00 - Terrestrial laser scanning – Marianne Okal
09:15 - Terrestrial laser scanning – Joseph Levy (remote)
09:30 - Terrestrial radar interferometry – Timothy Dixon
09:45 - GPR and ice structure – Knut Christianson
10:00 - Chemistry/temperature from Spectral Induced Polarization – David Stillman
10:15 - Active source seismics – Sridhar Anandakrishnan
10:30 - Break
10:45 - Passive seismics – Jacob Walter
11:00 - Long-term arrays for passive seismic monitoring – Richard Aster
11:15 - Seismic reflection imaging – Marvin Speece
11:30 - Broadband seismics/crustal structure – Paul Winberry
11:45 - Repeat/time-lapse photography – Timothy Bartholomaus (remote)
12:00 - Lunch
13:00 - Ice drilling and subglacial coring (RAID) – John Goodge
13:15 - Ice drilling (PIG) – Martin Truffer
13:30 - Ice drilling (Antarctic and other planetary bodies) – Britney Schmidt
13:45 - Session discussion

14:30
Session 2A: Airborne instrumentation
14:30 - Aerogravity and magnetic operations – Kirsteen Tinto
14:45 - Aerogravity and magnetic operations – Jamin Greenbaum
15:00 - Operation IceBridge altimetry – Benjamin Smith (remote)
15:15 - ATM altimetry – William Krabill
15:30 - MCoRDS and ultra-wideband, microwave radars – Carlton Leuschen
15:45 - MCoRDS analysis – Joseph MacGregor
16:00 - HiCARS radar – Dustin Schroeder
16:15 - Airborne Synthetic Aperture Radars – Delwyn Moller
16:30 - IcePod instrument suite – Robin Bell
16:45 - Session discussion

Day 2:

08:30

Session 2B: Airborne platforms

08:30 - Current and future plan for Operation IceBridge – Lora Koenig
08:45 - Unmanned aircraft operations and development – Richard Hale
09:00 - IcePod platform – Nicholas Frearson
09:15 - ICECAP platform – Duncan Young
09:30 - Session discussion

10:15

Session 3: Spaceborne instrumentation

10:15 - ICESat-2 – Thomas Neumann
10:30 - Cryosat-2 – Nathan Kurtz
10:45 - Space-based SAR and InSAR – Mark Fahnestock
11:00 - Satellite magnetic applications – Michael Purucker
11:15 - Planetary seismometers (Antarctic and other planetary bodies) – Nicholas Schmerr
11:30 - Commercial imagery – Paul Morin
11:45 - Commercial imagery applications – David Shean
12:00 - Review of other NASA platforms (airborne and satellite) – Kelly Brunt

12:15 - Lunch
13:15 - Session discussion

2:00

Session 4: Workshop summary discussion:

- Overall summary discussion
- What tech should have been included?
- How do we update community annually without having a workshop?

3:30
Adjourn

APPENDIX A2: WORKSHOP PARTICIPANTS

Kelly Brunt	Co-Convener, University of Maryland, ESSIC; NASA, GSFC Cryosphere
Joseph MacGregor	Co-Convener, University of Texas, Institute for Geophysics
Carlton Leuschen	Steering Committee, University Kansas
Duncan Young	Steering Committee, University of Texas, Institute for Geophysics
Kirsteen Tinto	Steering Committee, Lamont-Doherty Earth Observatory
Knut Christianson	Steering Committee, NYU, Courant Institute of Mathematical Sciences
Marianne Okal	Steering Committee, UNAVCO
Julie Palais	NSF-ANT
Lisa Clough	NSF-ANT
Mark Kurz	NSF-ANT
Nature McGinn	NSF-PLR
Benjamin Smith	University of Washington, APL (*remote)
Britney Schmidt	Georgia Institute of Technology
Cara Sucher	Lockheed
David Shean	University of Washington
David Stillman	Southwest Research Institute
Delwyn Moller	NASA, JPL
Dustin Schroeder	NASA, JPL
Jacob Walter	University of Texas, Institute for Geophysics
Jamin Greenbaum	University of Texas, Institute for Geophysics
Joseph Levy	University of Texas, Institute for Geophysics (*remote)
Joseph Pettit	UNAVCO
John Goodge	University of Minnesota
John Rand	Lockheed
Judy Shiple	Lockheed
Lora Koenig	NASA, GSFC Cryosphere
Lucas Beem	California Institute of Technology
Mark Fahnestock	University of Alaska, Fairbanks
Martin Truffer	University of Alaska, Fairbanks
Marvin Speece	Montana Tech
Michael Purucker	NASA, GSFC
Nathan Kurtz	NASA, GSFC Cryosphere
Nicholas Frearson	Lamont-Doherty Earth Observatory
Nicholas Schmerr	NASA, GSFC
Paul Morin	PGC
Paul Winberry	Central Washington University
Richard Aster	New Mexico Tech
Richard Hale	University Kansas
Robin Bell	Lamont-Doherty Earth Observatory
Sridhar Anandakrishnan	Pennsylvania State University
Thomas Neumann	NASA, GSFC Cryosphere
Thorsten Markus	NASA, GSFC Cryosphere
Tim Dixon	University of South Florida
Timothy Bartholomaus	University of Texas, Institute for Geophysics (*remote)
William Krabill	NASA, GSFC Cryosphere