

Workshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research

- PROGRAM AND ABSTRACT VOLUME -

27-29 September, 2004

Days Hotel and Conference Center, Herndon, VA

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BYRD POLAR RESEARCH CENTER



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- WORKSHOP AGENDA -

**Days Hotel and Conference Center
Herndon Virginia**

Monday, 27 September 2004 (Salon AB)

- 08:00 - 08:10 *David Bromwich*, Overview and Objectives of the Workshop
08:10 - 08:30 *Scott Borg*, Remarks from NSF/OPP Perspective
08:30 - 08:45 *Waleed Abdalati*, NASA's Perspective on Polar Remote Sensing
08:45 - 09:45 **Session 1: Solid Earth** Chair: Michael Studinger
 08:45 – 09:15 *Carol Finn*, REVEAL Overview
 09:15 – 09:45 *Terry Wilson*, Geology and Geophysics Science Goals
09:45 - 10:45 **Session 2: Glaciology** Chair: Bea Csatho
 09:45 – 10:15 *Waleed Abdalati* and Mark Fahnestock, Glacial Dynamics
 10:15 – 10:45 *Ted Scambos*, Remote Sensing for Ice Sheet Mapping
10:45 - 11:00 COFFEE BREAK
11:00 - 12:00 **Session 3: Atmospheric Science** Chair: Dave Bromwich
 11:00 – 11:30 *Tom Parish*, Antarctic Airborne Atmospheric Science
 11:30 – 12:00 *Fred Eisele*, Airborne Atmospheric Chemistry
12:00 - 13:00 **Session 4: Oceanography/Sea Ice** Chair: Robin Muench
 12:00 – 12:30 *Don Perovich*, Sea Ice Studies
 12:30 – 13:00 *Jamie Morison*, Polar Physical Oceanography
13:00 - 14:00 LUNCH BREAK, lunch on-site
14:00 - 15:00 **Poster Session**
15:00 - 17:30 **Break-Out Discussion** (Solid Earth, Glaciology, Atmospheric Science, Oceanography)
 Science Objectives, Sensors, Instrumentation, Data Collection (Sampling)
18:00 – 20:00 ICEBREAKER – Hotel Prefunction Area/Salon A (cash bar)

Tuesday, 28 September 2004 (Salon AB)

- 08:00 - 09:40 **Break-Out Group Reports** (15 min report + 10 min. discussion each)
 Solid Earth: *Michael Studinger*
 Glaciology: *Bea Csatho*
 Atmospheric Sciences: *Dave Bromwich*
 Oceanography, Sea Ice: *Robin Muench*
09:40 - 10:00 COFFEE BREAK

- 10:00 – 13:00 **Session 5: Capabilities and Opportunities of Research Aircraft** Chair: Robin Muench
- 10:00 – 10:30 *Jeff Stith*, NSF NCAR/RAF C-130Q and Candidate Aircrafts, HIAPER
 - 10:30 – 10:45 *Bill Krabill*, NASA/WFF, Ice Sheet Mapping with Long Range Aircraft
 - 10:45 – 11:00 *John Brozena*, NRL, Long-Range Wheeled Aircraft for Antarctic Science
 - 11:00 – 11:15 *John Holt*, UTIG, Comparison of Airborne Platforms for Aerogeophysical Research in Antarctica
- 11:15 – 11:30 COFFEE BREAK
- 11:30 – 11:45 *Dave Braaten* et al., Univ. of Kansas, Advanced Radar Systems for Airborne Ice thickness Measurements and Near-Surface Internal Layer Mapping
 - 11:45 – 12:00 *Christopher Zappa*, LDEO, Toward a Modular Airborne Observing System for Antarctic Research
 - 12:00 – 12:15 *Terry McConnell*, Magnetic Gradiometry
 - 12:15 – 12:30 *Tom Farr*, NASA/JPL, Airborne Remote Sensing of Mars Analogue Sites in Antarctica
- Followed by Discussion
- 13:00 - 14:00 LUNCH BREAK
- 14:00 - 15:30 **Session 6: Overview of Existing Aircraft Facilities: Models for Management Structure** Chair: Carol Finn
- 14:00 – 14:30 *Gary Shelton*, Overview on Existing Models
 - 14:30 – 15:00 *Heinz Miller*, Alfred-Wegener-Institute Aircraft Operations: Case Studies and Lessons Learned
- Followed by Discussion about Operation, Data Policies and Instrumentation
- 15:30 - 15:45 COFFEE BREAK
- 15:45 - 17:00 **Session 7: Desired Facility Model and Instrumentation.** Chair: Robin Bell
- 15:45 – 16:00 *Jerry Mullins*, Research Applications of Airborne Digital Sensors and LIDAR systems
 - 16:00 - *Carol Finn*, Summary and Opening of Discussion:
Configuration,
Instrument Maintenance
Operations
Data Reduction/Products

Wednesday, September 29, 2004

- 08:00 - 09:00 **Session 8: Aircraft Operations and Safety Considerations for Polar Research Aircrafts (Education of Scientists)**
- 08:00 – 08:30 Overview by *Mike Scheuermann* and *Brian Stone*
Alternate Landing Sites, Weather Constraints, Range, Altitude, Payload,
Conversion: Roll-on/Roll-off, Power
Discussion
- 09:00 - 10:00 **Session 9: Data Policies, Data Management, Data Archiving**
Richard Dirks and *Jim Moore* (NCAR), Data Management Considerations for the Dedicated Polar Research Aircraft
Ted Scambos (NSIDC), Science Data Management for Antarctic Aerogeophysical Data from the Proposed Airborne Platform
Discussion
- 10:00: 11:00 **Panel Discussion:** Develop Road Map, Implementation Plan, Proposal Writing
Closing remarks, *Bea Csatho*

POSTER PRESENTATIONS:

Behlke, Rico (Uppsala Univ., Uppsala, Sweden), Airborne remote sensing campaign over Svalbard

Behrendt, John (Univ. of Colorado, Boulder, CO), Use of LC-130 “Science” aircraft for long range aerogeophysical surveys in Antarctica, experiences from the late 1970s

Blankenship, Donald (Univ. of Texas, Austin, TX) et al., Investigating the crustal elements of the central Antarctic Plate (icecap): How long-range-aerogeophysics is critical to understanding the evolution of the East Antarctic ice sheet

Braaten, David (Univ. of Kansas, Lawrence, KS), Advanced radar systems for airborne ice thickness measurements and near-surface internal layer mapping

Fahnestock, Mark (Univ. of New Hampshire, Durham, NH), The use of ice penetrating radar profiles for large area mapping of long-term accumulation and vertical strain rates: an example covering 10,000 line kilometers in Greenland

Kim, Edward (NASA/GSFC, Greenbelt, MD), The Airborne Earth Science Microwave Imaging Radiometer (AESMIR)

Lazzara, Matthew (AMCR/Univ. of Wisconsin, Madison, WI), The use of existing instrumentation on a long-range science aircraft for Antarctica

Lubin, Dan (Scripps Institution of Oceanography, La Jolla, CA), Aircraft remote sensing of Antarctic cloud microphysical and radiative properties

Matsuoka, Kenichi (Univ. of Washington, Seattle, WA), Polarimetric radar measurements of the interior ice to reveal ice-flow induced features

Powers, Jordan (NCAR, Boulder, CO), Numerical weather prediction in Antarctica and a long-range aircraft for Antarctic research

Shum, C.K., Chris Jekeli (OSU, Columbus, OH), *Bea Csatho* et al., Interdisciplinary Antarctic Research in Geodesy Using an Instrumented, Long-Range Aircraft

Vogel, Stefan (BPRC, OSU, Columbus, OH) et al., Investigating the subglacial environment and geology of Antarctica by direct means, a new frontier in Antarctic research

Von Frese, Ralph (OSU, Columbus, OH), Aerogeophysical Polar Explorer (Apex) for bi-polar lithospheric investigations

Wilson, Doug and Bruce Luyendyk (UCLA, Santa Barbara, CA), Aerogeophysical survey of the continent-ocean transition of Pacific West Antarctica

- ORAL PRESENTATION ABSTRACTS -

REVEAL OVERVIEW

Carol Finn

U. S. Geological Survey, Denver, CO

Antarctica is a key element in Earth's climatic and geodynamic systems, yet on the eve of the 50th anniversary of the International Geophysical Year, we lack fundamental geologic and geophysical data from the deep interior of this vast continent. Antarctic geological processes are the driving forces for ice sheet dynamics and global environmental change that affect current and long-term large-magnitude sea level changes. Meager exposures record the 3500 million-year history of a continent that continues to be tectonically active today, although its kinematic relation to the global plate circuit and its role as substrate to the world's major ice sheets remain in question. Despite the central role that Antarctica has played in shaping the present global environment, fundamental, first-order parameters such as bedrock elevation, lithology, structure, age, tectonic history and ice volume remain poorly known over large portions of the continent. Given the extensive ice cover, airborne geophysical data, constrained by field-based geologic mapping, ground-based geophysics, and petrologic, geochemical and geochronological analysis of outcrop and drill-hole samples, is the best way to characterize broad areas of the Antarctic lithosphere. However, the U.S. Antarctic program currently lacks an effective means to collect and integrate airborne geophysical data with other datasets under broad science objectives defined by the earth science community. Regional high-resolution aerogeophysical coverage is also required by other national Antarctic research programs. In order to address scientific and logistical issues, the National Science Foundation sponsored an international workshop attended by 45 geologists, geophysicists and glaciologists in Denver, CO in August, 2002. The REVEAL workshop framed a set of key issues in Antarctic research that require airborne gravity, magnetic, laser altimetry and ice-penetrating radar measurements from long- and mid-range fixed-wing and helicopter platforms. Science goals and potential target areas were developed in the context of three major themes: (1). geology and ice sheet dynamics; (2). crustal architecture of the East Antarctic shield, and (3). geodynamics of rifting in an ice-covered environment. Investigations directed at these themes will form the basis for an integrated, multidisciplinary initiative to study the relationship between Antarctic geodynamic processes, ice sheet dynamics and global environmental change. The target areas for airborne geophysical data collection include much of the East Antarctic shield from the Gamburtsev Mountains to the Wilkes Land and the Prince Charles Mountains and selected areas in West Antarctica.

AIRBORNE CAPABILITIES FOR ICE SHEET RESEARCH: A PERSPECTIVE BASED ON NASA'S EXPERIENCES IN GREENLAND

Waleed Abdalati¹ and Mark Fahnestock²

¹NASA Goddard Space Flight Center, Greenbelt, MD

²CSRC, University of New Hampshire, Durham, NH

Since the early 1990s, NASA has made significant investments in developing airborne measurement capabilities for glaciological research. These investments focused primarily on precise repeat airborne altimetry measurement capabilities, for elevation change detection, and ice penetrating radar, for ice sheet thickness measurements. These capabilities formed the core of NASA's Program for Arctic Regional Climate Assessment (PARCA), which has been a focused effort to assess and understand the mass

balance of the Greenland ice sheet. This coordinated effort has led to many advances in ice sheet remote sensing capabilities, and resulted in the first large-scale observational assessment of the mass balance of the Greenland ice sheet, the most comprehensive measurement of ice sheet and outlet glacier thicknesses, detailed representation of the internal layering structure of the ice sheet, and means of estimating long-term accumulation rate, and basal melt rates. In addition, it has led to the development of more advanced capabilities for airborne measurements. A summary of what has been learned from NASA's investment in airborne remote sensing of Greenland will be presented along with a view toward how our experiences can inform our approach to airborne glaciological observations of Antarctica.

ANTARCTIC AIRBORNE ATMOSPHERIC SCIENCE

Thomas R. Parish

Department of Atmospheric Science, University of Wyoming, Laramie, WY

Airborne observing platforms have been used extensively in atmospheric science studies for decades. Significant findings in the fields of physical and dynamical meteorology have taken place based on aircraft studies. Field experiments typically are heavily dependent on one or more research aircraft in pursuit of scientific objectives. Availability of research aircraft has also prompted development of novel instrumentation to enhance the measurement possibilities for a wide range of atmospheric research applications. Perhaps more than any other discipline, atmospheric science has relied on the research aircraft platform to advance the frontiers of knowledge.

The potential of using aircraft in Antarctica has long been recognized. A C-130 platform has previously been used in a limited number of research studies in Antarctica, including studies of boundary layer dynamics. Proposed polar airborne platforms will allow measurements of basic state parameters to support kinematic/dynamic studies of boundary layer and tropospheric processes. Long-endurance platforms will allow sampling of a broad environment, thereby allowing detailed mapping of wind, temperature and pressure fields associated with atmospheric events that currently are only sampled via surface-based sensing. Scientific issues to be addressed include the role of cyclones on modulating atmospheric transports to and from the Antarctic continent, the role of topography in forcing the observed atmospheric circulation systems and spatial and temporal variation of the tropospheric vortex. Such studies are integral components of the proposed Antarctic Regional Meteorology Interactions Experiment (RIME) that aim to better understand the interaction between Antarctic and middle latitude processes. Dropsonde capabilities will allow an unprecedented and highly detailed cross-sectional view of the Antarctic atmosphere in support of process studies. High-rate sensors will allow turbulence studies and enable flux measurements. The aircraft should be configured to permit cloud microphysical, air chemistry and radiation measurements. Few cloud physics studies have been conducted in the Antarctic and knowledge of the microphysical nature of clouds is lacking. Aside from an understanding of polar precipitation processes, such studies will enable development of more accurate parameterization schemes for use within numerical models and help with validation of algorithms formulated for satellite-based retrievals.

Remote sensing capabilities should be incorporated into the basic airborne platform. An example that currently is available for deployment on other NSF-funded aircraft is the Wyoming Cloud Radar. The radar operates at 95 GHz and provides high-resolution measurements of reflectivity, velocity and polarization fields. Coupled with the in-situ observations of hydrometeors and air motions from the same aircraft these data yield unique information for analysis of cloud and precipitation processes.

TROPOSPHERIC CHEMISTRY IN ANTARCTICA

Fred L. Eisele

National Center for Atmospheric Research and Georgia Tech, Boulder, CO

The tropospheric chemistry of the Antarctic continent remains largely unexplored, but the few studies that have taken place have resulted in major surprises. The evolution of atmospheric gases is largely determined by photochemical oxidation initiated by the hydroxyl radical (OH). This radical is primarily produced by the interaction of UV solar radiation with ozone and the subsequent reaction of one of the products with atmospheric water vapor. Air above the Antarctic plateau contains very little water vapor, only modest amounts of ozone, and receives direct sunlight at very high zenith angles causing most UV to be lost. Thus, the production of OH radicals was expected to be very low, so low that photochemistry over the poles was typically considered unimportant. Hydroxyl radical concentrations can be enhanced in the presence of NO, which increases the catalytic cycling between hydroperoxyl and hydroxyl radicals, but NO concentrations in Antarctica were expected to be negligible as well. In fact, Polar plateau boundary layer concentrations of NO are not low, but are up to 2 orders of magnitude higher than expected. As a result, near surface OH concentrations are nearly an order of magnitude higher than predicted, with 24 hour average concentrations equal to those observed in the tropical marine boundary layer, often considered the most photochemically active region of the earth. These findings have many ramifications. Since the observed NO comes from previous unknown nitrate photochemistry in the snow, the previous interpretation of nitrate snow chemistry and nitrate measurements in ice cores must change. Also, the polar plateau has been thought to be a region in which only ozone loss took place and now it appears that it sometimes becomes an ozone source region. Perhaps more importantly, the whole understanding of sulfur chemistry over the plateau and the interpretation of methane sulfonate/sulfate ratio in ice cores needs to be examined. Recent observations of reactive sulfur gases have shown that they are largely depleted before reaching the South Pole, thus changing present understanding of the processes that control ice core sulfur ratios. Ground based observations at an Antarctic coastal site have only added to the presumed complexity of these sulfur oxidation processes.

While these initial studies have demonstrated how poorly the chemistry of the Antarctic troposphere is understood, this chemistry is probably much simpler than that studied and fairly successfully modeled in other areas of the globe. The major bottleneck to understanding Antarctic tropospheric chemistry is the inability to make extensive vertical and horizontal chemical measurements in most regions of the Antarctic. This could clearly change if a research LC-130 was to be made available.

NSF/NCAR/RAF C-130Q AND CANDIDATE AIRCRAFTS, HIAPER

Jeff Stith

National Center for Atmospheric Research, Boulder, CO

The NSF/NCAR C130 is a heavy-lift, long-range aircraft that has been used to support the NSF lower atmospheric research mission for more than 10 years. A wide variety of airborne instruments for chemistry, turbulence, remote sensing, and cloud studies have all been deployed successfully on this platform. HIAPER (High Performance Instrumented Platform for Environmental Research), a Gulfstream V aircraft, is now being modified to support the spectrum of NSF airborne geosciences applications and will begin research operations in 2005. We describe the capabilities of these aircraft and how they were/are being modified to support airborne research. We also describe the types of activities that are needed to support multi-investigator deployments. These activities include flight operations, guest scientist support and project management, support for aircraft modifications and instrument

installations, in-house airborne measurements and research, data system development, analysis of airflow around instrumentation, and software support. We also describe the characteristics of existing LC 130 aircraft that might be candidate aircraft for possible conversion to a research platform.

LONG-RANGE WHEELED AIRCRAFT FOR ANTARCTIC SCIENCE

John Brozena

Naval Research Lab, Washington DC

There are several possible models for airborne science operations in Antarctica. We believe that long-range wheeled aircraft based in McMurdo provides a promising addition to the more traditional ski-equipped small aircraft or LC-130 operations for at least some categories of science requirements. Our concept is to utilize one of the Naval Research Laboratory's research configured P-3 Orion aircraft from the sea-ice runway at McMurdo. The speed and range capabilities of these aircraft would provide access for large payload science missions to more than half of the continent without the difficult logistic support of remote field camps and fuel caches. NRL's P-3's have been employed for numerous long-range aerogeophysical surveys, and are excellent gravity, magnetics, radar/laser, and imagery platforms. Additionally, discussions are currently underway to modify one of the aircraft for interagency (NASA, NSF and DOD) atmospheric research applications.

NRL has devoted a great deal of time and effort over the past five years to determining the viability of P-3 operations from McMurdo. These efforts included: visits of our P-3 group to the 109th ANG squadron in Schenectady for briefings; a site visit of three of our Navy flight and maintenance personnel to Christchurch and McMurdo to observe and participate in flight operations and procedures; extensive historical weather analysis with the help of SPAWAR Charleston personnel; a safety and logistics analysis by our military operations group; approval of the project by the NRL Commanding Officer and Chief Staff Officer; and finally development of a CONOPS (concept of operations) for Antarctica that has been approved by the Air Force office that control flight operations in Antarctica. We believe that in the course of this work we have produced a safe and achievable plan for P-3 operations that can support many science objectives. My talk will address some of the potential capabilities, limitations and trade-offs of this method of operations.

A COMPARISON OF AIRBORNE PLATFORMS FOR AEROGEOPHYSICAL SURVEYS IN ANTARCTICA

John W. Holt

University of Texas Institute for Geophysics, John A. and Katherine G. Jackson School of
Geosciences University of Texas at Austin, Austin, TX

Given the perceived desire for a long-range aircraft for research in Antarctica, and the assumption that this desire is based on scientific objectives, a specific platform type will need to be chosen to best accomplish the science goals that are agreed upon. The options for such a platform are few, but are greater than one. It is also not likely that a single platform is the whole solution. The different science communities have different needs, and their specific requirements may not imply the same platform needs. This presentation will evaluate the differences in airborne platforms and the corresponding logistical support required for example aerogeophysical surveys in support of glaciology and geology.

There are science justifications for a wide variety of survey designs. Surveys for airborne geophysics in support of geology or glaciology have ranged in the past from dense grids spanning several hundred

kilometers on a side to highly linear corridors over 1000 km long, to precisely-located lines targeting relatively small features.

In terms of instrumentation, the geology-glaciology community's aerogeophysical needs have been fairly well developed over the past few decades. The basic suite is ice-penetrating radar, laser altimeter, gravimeter, and magnetometer. This suite has been operated successfully on a Twin Otter platform for nearly a decade. Modifications to this suite could include imaging radar, cameras, and more sophisticated versions of the techniques already employed, such as gradiometry for potential fields. The payload requirements for an aerogeophysics platform can therefore be estimated fairly closely.

Ski-equipped platforms that are suitable for such work include the Twin Otter, Dornier DO-228, Basler BT-67, LC-130, and possibly the Casa 212. Other, non-ski-equipped platforms could be considered for operations from ice runways; however, it is most useful to compare platforms of small, intermediate, and large payload capacity and range. I will therefore compare the Twin Otter, the Basler BT-67, and the LC-130 since their capabilities span the range of available platforms. Their payload, range, and other pertinent specifications will be used to estimate logistical support requirements (fuel needed, experiment duration, the need for field camps, crews, maintenance, etc.) for examples spanning the range of past, present, and proposed survey designs for airborne geophysics in support of geology and glaciology. This exercise should help determine the optimal airborne platform(s) for use by the geology-glaciology community and in which circumstances a long-range, heavy-lift aircraft is desirable.

ADVANCED RADAR SYSTEMS FOR AIRBORNE ICE THICKNESS MEASUREMENTS AND NEAR-SURFACE INTERNAL LAYER MAPPING

D. Braaten, S. Gogineni, T. Akins, P. Kanagaratnam, R. Parthasarathy and C. Allen
The University of Kansas, Lawrence, KS

We have been operating and regularly upgrading an airborne 150-MHz coherent radar depth sounder that has provided excellent data over the Greenland ice sheet. A recent upgrade to the radar has incorporated an arbitrary waveform generator (AWG), a dual-channel receiver, and a data acquisition sub-system for directly digitizing received signals using an undersampling technique. The AWG can be programmed to correct for system imperfections to obtain low-range sidelobes and generate the chirp pulse width. The dual-channel receiver eliminates the need for a sensitivity time control circuit, which must be adjusted frequently to optimize receiver settings. The undersampling eliminates image responses associated with generation by analog circuits of in-phase and quadrature signals. These recent modifications have allowed us to collect better quality data, particularly over the margins of the ice sheet. We have also developed a wideband radar that operates over the frequency range from 600 to 900 MHz to map near-surface internal layers. We have successfully operated it on a NASA P-3 aircraft and demonstrated that it can map internal layers with fine resolution in the dry, percolation and melt zones of the ice sheet.

As a part of a large Information Technology Research (ITR) project, funded by NSF and NASA, we have developed a wideband radar sounder that operates over the frequency range 50 to 200 MHz, and an ultra wideband radar that operates over the frequency range from 500 to 2000 MHz. These systems have been developed such that they can be programmed to operate over a narrow-frequency band within their broad operating frequency range. They are also designed to be compact, and are housed along with the data acquisition system in a compact PCI case with dimensions (width x height x depth) of 19" x 18" x 24" and weight of about 100 lbs. Both radars have been field tested at the Summit Camp in Greenland during July 2004. The results show that the wideband depth sounder can measure more than 3 km of ice with a high signal-to-noise ratio and map deep internal layers with about 1 m resolution. The ultra wideband radar results show that near-surface internal layers can be mapped to a depth of 150 meters with about 0.1 m

resolution. We developed these systems such that they can be easily adopted for airborne ice thickness measurements from either a twin-engine or long-range aircraft.

This paper will provide an overview of existing radar systems and show sample results from airborne and surface-based experiments over the Greenland ice sheet.

TOWARDS A MODULAR AIRBORNE OBSERVING SYSTEM FOR ANTARCTIC RESEARCH

Christopher J. Zappa and Arnold L. Gordon
Lamont-Doherty Earth Observatory, Palisades, NY

A group at LDEO has been working to acquire and integrate a compact, portable, modular, multi-sensor airborne package that incorporates three applications of airborne remote sensing using a Thermal InfraRed (TIR) imager, a hyperspectral Visible/Near-InfraRed (VNIR) mapper, and laser altimeter technology to provide complementary observational imaging capabilities in conjunction with micrometeorological and radiative flux measurements. Airborne imaging systems cover large areas synoptically, while at the same time achieve high spatial and temporal resolution with the ability to generate two-, and in some cases, three-dimensional "snapshots" of measured phenomena. The TIR, VNIR, and laser systems described here all have sub-meter spatial resolution, and will allow us to examine features that span from scales of 1 meter, driven, for example, by wave processes, to scales of 1 km, driven by processes in the atmospheric boundary layer. Presently, there is no instrument package that combines all the components of the proposed Modular Airborne Coastal Observing System (MACOS). Our focus is on integrating a portable suite of instrumentation with precise geo-correction capability that can be operated from a variety of aircraft, as well as additional plug-in flexibility depending upon the scientific objective. The integration of these remote sensing applications into a complete system will constitute a revolutionary observational capability for airborne remote sensing of the Antarctic (from over ice, through the coastal margins, and out to the open ocean).

Our science objectives motivating this system include the study of coastal polynyas around the Antarctic continent, the tidal impacts on sea ice and lead formation, and the surface heat budget and characteristics of ice-covered oceans. Aircraft measurements of collocated micrometeorological fluxes and surface forcing are necessary to understand the myriad of processes controlling the flux at meso- and regional scales. It has proven extremely difficult to study these processes with the requisite spatial and temporal resolution using conventional shipboard, moored, or fixed-platform observing technology. The measurements from the MACOS will constitute a significant advance in the scientific understanding and interaction of the physical, chemical, and biological processes they represent. For example, coastal polynyas around the Antarctic continent produce much of the dense shelf water that ultimately feeds Antarctic Bottom Water (AABW) formation and thus affects both the thermohaline circulation and the ventilation of the deep ocean. The remote location and episodic nature of the opening of coastal polynyas has not allowed quantitative study of the atmospheric forcing by measurement of the air-sea-ice fluxes. Airborne remote sensing would allow for the measurement of the ocean-atmosphere fluxes of heat and momentum as well as the spatial and temporal variability of the ice cover and sea surface temperatures over coastal polynyas. These remotely-sensed aircraft measurements would greatly enhance the understanding of the processes of Antarctic polynya formation, their maintenance, and overall quantitative role in deep-water formation. Ultimately, MACOS will have an important impact on the larger issues of, among others, the uptake of CO₂ by the ocean, the horizontal patchiness of organisms and nutrients in the photic zone, and the formation of dense shelf water in the Antarctic.

AIRBORNE REMOTE SENSING OF MARS ANALOG SITES IN ANTARCTICA

Tom G. Farr

Jet Propulsion Laboratory and California Institute of Technology, Pasadena, CA

In 2001, the U.S. National Research Council, at the request of NASA, initiated a broad community survey of the current state of solar system exploration seeking recommendations for the coming decade. One of the studies was on Terrestrial Analogs to Mars. Recommendations from the Terrestrial Analogs to Mars community panel included: process studies at analog sites, field workshops, instrument and operations tests, and laboratory measurements. Coordinated deployment of airborne, spaceborne, and field instrumentation, and personnel to several sites to test instruments and technology intended for Mars and to provide data for ongoing studies of terrestrial geologic processes relevant to Mars was the most important area recommended for support. On this basis, we have begun planning for the deployment of several NASA airborne instruments to Antarctica in order to collect data similar to current and planned Mars orbital instruments. The instruments being discussed are the Airborne Visible-InfraRed Imaging Spectrometer (AVIRIS), the MODIS-ASTER Airborne Simulator (MASTER), and the Airborne SAR (AirSAR).

AVIRIS collects image data in 224 spectral bands between 0.4 and 2.5 microm, similar to the CRISM instrument on Mars Reconnaissance Orbiter (MRO) to be launched in 2005. Imaging spectrometry provides detailed reflectance spectra for every pixel in an image, allowing identification of materials in the scene. Much work has been accomplished in calibration and interpretation of imaging spectrometry data through work with AVIRIS and laboratory studies. MASTER is a multi-spectral imager, obtaining images in 50 bands, thus not fully sampling the spectrum. Its range, however, extends from visible wavelengths to the thermal IR (0.4 - 13 microm) and thus is similar to the Themis instrument orbiting Mars aboard Mars Odyssey. In addition, the Earth-orbiting ASTER satellite collects images in 14 bands through the same spectral range. Extension into the thermal IR provides additional compositional information as well as determination of bulk thermophysical properties (e.g. dust and rock cover). AirSAR obtains radar images at 3 wavelengths (5.5, 25, 67 cm) and multiple polarizations. There are also Earth-orbiting satellites which operate at the shorter wavelengths. Imaging radars have been proposed for Mars, but so far none have flown. Much longer wavelength sounders will be operating at Mars on Mars Express and MRO.

Antarctica's Dry Valleys and ice fields provide a geologically and climatically similar environment to Mars and so provide an ideal test-bed for these technologies and the interpretation of similar data from Mars. The types, rates, and magnitudes of surficial modification processes in this cold environment are different than in warmer, wetter environments on Earth so it is important to evaluate the capabilities of visible-near IR, thermal IR, and imaging radar to collect data for identification of the processes and products. Ice and its impurities may also be studied with these techniques. An important additional capability of longer wavelength radar is the potential for penetration of dry surface materials and cold ice, yielding information on the subsurface up to many wavelengths depth.

Acknowledgements: Michael Eastwood and Ian McCubbin provided information on AVIRIS, Simon Hook on MASTER, and Bruce Chapman and Yunling Lou on AirSAR. Chris Jennison and Walter Klein helped with aircraft mission planning. This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

AWI AIRCRAFT OPERATIONS: CASE STUDIES AND LESSONS LEARNED

Heinz Miller

Alfred-Wegener-Institute, Bremerhaven, Germany

Alfred-Wegener-Institute operates two ski equipped aircraft (Dornier 228/100) for scientific and logistic purposes. Both are equipped with identical basic and advanced navigation equipment and can easily be adapted to different science programs. We have available and used

1. aerogeophysical instrumentation (magnetics, gravity, ice penetrating radar, scanning laser altimetry system and since recently a ku band bistatic radar system which is used in conjunction with CRYOSAT ground truthing.
2. meteorological equipment for high resolution studies of atmospheric parameters
3. sensor suite for aerochemistry.

Actual aircraft operation is contracted out as is the oversight and maintenance of scientific equipment. With some case studies I will show what can be done with that or similar type of aircraft and will relate that to what could be done with an appropriately equipped long range aircraft.

RESEARCH APPLICATIONS OF AIRBORNE DIGITAL SENSORS AND LIDAR SYSTEMS

Jerry L. Mullins

US Geological Survey, Reston VA

Modern airborne digital sensors and LIDAR systems provide technology for collecting high-resolution airborne geospatial information in Antarctica. Today's systems are capable acquiring high-resolution data using aircraft with long range and dwell time. These airborne systems can be used to conduct multidisciplinary research as diverse as geology, glaciology, ecosystem studies, hydrology, penguin censuses, digital elevation models, aeromagnetism, geospatial data collection, topographic mapping, and others US Antarctic research disciplines.

DATA MANAGEMENT CONSIDERATIONS FOR THE DEDICATED POLAR RESEARCH AIRCRAFT

James A. Moore and Richard Dirks

UCAR Joint Office for Science Support, Boulder, CO

A multi-user research aircraft facility requires a comprehensive data management strategy. This effort should consider an integrated data management strategy that facilitates easy and timely data access in the field as well as from an archive.

Our recommendations are based on experiences with other polar programs and several research aircraft. An effective data management plan should encourage easy exchange of the data, permit instrument scientists access for quality control, processing and analysis, and assure a place to publish final data. A data policy should include data format and documentation guidelines that will help organize data for investigator analysis, intercomparison and broad community access. Procedures associated with the quality control and processing of standard aircraft data (e.g. navigation, meteorological) will be described.

These processing steps, including the integration of standard data and investigator instrument data will be introduced.

Some particular challenges to address in implementation of data management strategy for multidisciplinary field work includes; (1) the data format and content coming from a diverse suite of airborne instruments, (2) availability of centralized navigation information on the aircraft (e.g. time and position) data system, (3) timely availability of critical data and products (e.g. flight tracks, flight level data, selected products from onboard instruments) during field campaigns to aid real-time decision making (e.g. multiple aircraft coordination, weather updates, mission modifications). The cataloging and archival of all aircraft datasets and associated metadata will require coordination and establishing protocols among the participating investigators and institutions that might provide aircraft instrumentation to be flown.

A data management web site provides a single point of contact for everyone. This site also presents documentation on the instrumentation, data processing methods and available products (e.g. downloadable software for data analysis). Examples of these include the Western Arctic Shelf Basin Interactions (SBI) Project: <http://www.joss.ucar.edu/sbi/> and the Surface Heat Budget of the Arctic (SHEBA) Project <http://www.joss.ucar.edu/sheba/>.

Examples will be provided of useful web pages, real time display capabilities and long term data archive structures that are considered good models. There are unique issues regarding international data archive and exchange that will be mentioned in the context of this facility as a resource for investigators from different nations.

SCIENCE DATA MANAGEMENT FOR ANTARCTIC AEROGEOPHYSICAL DATA FROM THE PROPOSED LC-130 PLATFORM

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Data archival, management, and distribution for the scientific data stream generated by the instruments on the proposed LC-130 aircraft platform will be a key component of engaging the broad polar science community and assuring maximum scientific benefit from the facility. The National Snow and Ice Data Center is well-positioned to support an aerogeophysical data center, and already archives and distributes several related data sets (e.g., ICESat altimetry data, MODIS image data, Landsat data, and the field and compiled data sets from the Antarctic Glaciological Data Center).

A first step would be to establish a Data Advisory Group for the Facility. The LC-130 Data Advisory Group would then shape the data management plan by considering data acquisition, archive, PI proprietary rights, and accessibility/format issues in conjunction with NSIDC staff. The data management plan should define the goals for the LC-130 data management based on the scientific questions in the Science Plan. It should establish which data and data products are needed to meet the scientific goals, and should outline the organizational data structure. This structure must be operational before the start of the field phase. Of primary importance will be the establishment of meta-data descriptors for the data streams, including acquisition parameters for each instrument, calibration information, data format, and time/location information.

We anticipate data streams from the aircraft to include: position and attitude; atmospheric chemistry; laser altimetry; accumulation radar profiling; sounding radar profiling; gravity; and magnetic intensity. It may also include (eventually) digital high-resolution VIS/NIR images, thermal band images, and SAR. We

estimate that roughly 20 data streams will comprise about 10 megabytes per acquisition- kilometer, and approximately 600 gigabytes will be acquired per season. Image data would be additional to this estimate.

- POSTER ABSTRACTS -

SOLID EARTH

USE OF THE LC-130 "SCIENCE" AIRCRAFT FOR LONG RANGE AEROGEOPHYSICAL SURVEYS IN ANTARCTICA - EXPERIENCES FROM THE LATE 1970S

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In 1978 The US Geological Survey (USGS) and the Scott Polar Research Institute (SPRI) carried out long range aeromagnetic and radar ice sounding surveys over the West Antarctic Ice Sheet (WAIS) and the Dufek Massif-Filchner Ice Shelf areas. The "science" LC-130 was built with "hard points" in the wings for radar antennas and a 2-m tail magnetometer "stinger" during initial construction. Applied Physics Laboratory (APL) of Johns Hopkins University installed the data acquisition system and magnetometer. Technical University of Denmark TUD (working closely with SPRI) installed the radar ice sounding system. The aircraft was not demagnetized because of cost (estimated by APL at about \$25 million, 1975). Instead, magnetic compensation was approximately accomplished and heading corrections were applied. Although the magnetic data were approximately accurate for profile use with radar ice sounding profiles, the heading errors precluded accurate contouring. The radar data were recorded photographically and later digitized. The magnetic data were recorded digitally as had been done US Antarctic aeromagnetic surveys since 1963. State-of-the-art 1970s electronics dictated a massive console, which largely filled the aircraft cabin. The associated recording system acquired navigation data from an inertial navigation system.

The surveys were all made from McMurdo station using the sea-ice runway. A much heavier fuel load could be carried in contrast to ski take-offs from Williams field on the nearby ice shelf. Nonetheless, sufficient fuel could not be carried for the longest missions, and refueling was accomplished at the South Pole using fuel carried there by LC-130. The greatest limitation was the short endurance over the surveyed areas resulting from low flight elevation required for radar ice sounding and acquisition of the aeromagnetic profiles. Hundreds of km of profile were surveyed as heights as low as 15 m above the snow surface, although I suspect that this low clearance was never reported in US Navy records. This low level over the thickest ice of the warm WAIS was necessary for the state-of-the-art radar ice-sounder. Future surveys over cold EAIS could be easily accomplished at 1 km flight height over the ice (as was done in the CASERTZ-SOAR surveys in the 1990s). However, higher elevations would degrade the magnetic data because of the sharp dropoff of amplitude of short-wavelength anomalies with height above sources at the base of the ice. The 1970s survey flights were severely limited in "endurance" over the surveyed areas required by the much higher fuel consumption to the 1970s LC-130 engines at about 2 km elevation in West Antarctica contrasted with the approximately 10 km design elevation for maximum fuel efficiency. Although high elevation flights would be optimal some missions, such as aerial photography, aeromagnetic data acquisition will always require as low as possible flights several-kilometer-thick Antarctic ice.

The "science" LC-130 was lost in a crash on the EAIS, along with 6 lives.

**INVESTIGATING THE CRUSTAL ELEMENTS OF THE CENTRAL
ANTARCTIC PLATE (ICECAP): HOW LONG-RANGE AEROGEOPHYSICS IS
CRITICAL TO UNDERSTANDING THE EVOLUTION OF THE EAST ANTARCTIC ICE SHEET**

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The highlands of the central Antarctic Plate have been the nursery for East Antarctic ice sheets at least since the early Oligocene separation of Antarctica and Australia. Over the last decade, great strides have been made in compiling a marine geological, geophysical and geochemical record of the deposits left by these ice sheets. In addition, enormous resources have been invested in extracting a Pleistocene paleoclimate record from the central reaches of the contemporary East Antarctic ice sheet. Most recently the scientific community has realized the importance of the isolated biome represented by the subglacial lakes that characterize the domes of the central East Antarctic ice sheet and evolve in concert with them. The impact of these research efforts and discoveries has been to spur major international research initiatives to study the evolution of the East Antarctic ice sheet and its subglacial environment.

Critical to understanding these offshore and ice core records, as well as the distribution/isolation of any subglacial lake systems, is developing a comprehensive understanding of the crustal elements of the central Antarctic Plate. A complete understanding of the evolution of East Antarctic ice sheets throughout the Cenozoic requires knowledge of the boundaries, elevation and paleolatitude of these crustal elements through time as well as evidence of their morphological, sedimentological and tectono-thermal history. The basic impediments to gaining this understanding are the subcontinental scale of the central Antarctic Plate and the one to four kilometers of ice cover that inhibits direct access. It is possible however to provide a substantial framework for understanding these crustal elements through a comprehensive program of long-range airborne geophysical observations. Measurements required to characterize this crust in the context of both contemporary and paleo-icesheet evolution include:

- 1) Distribution of gravity and magnetic anomalies to characterize subglacial lithology (e.g., sediments, crystalline basement and volcanics), identify crustal boundaries and estimate lithospheric flexure through potential field modeling.
- 2) Absolute bedrock elevation (from ice sheet surface elevation and thickness) to provide a necessary boundary condition at a scale suitable for models of both contemporary and paleo-ice-sheet (or lake) evolution as well as for potential fields modeling.
- 3) Detailed subglacial morphology and physical character of the ice-rock interface to identify any "preserved" glacial geomorphology and map fault scarps indicative of Cenozoic (or older) tectonic processes as well as to determine the location, properties and connectivity of subglacial sedimentary units (and lakes).
- 4) Contemporary basal melt distribution (from ice sheet layering) to estimate the current distribution of geothermal flux for indications of tectono-thermal history and as a necessary boundary condition for models of ice sheet (and lake) evolution.

We will review the techniques required to obtain these measurements and present a compatible plan for a program of long-range aerogeophysics, including gravity, magnetics, ice-penetrating radar data and laser/radar altimetry, over the Gamburtsev, Vostok and Belgica subglacial highlands beneath Domes A - C of the contemporary East Antarctic ice sheet.

INTERDISCIPLINARY ANTARCTIC RESEARCH IN GEODESY USING AN INSTRUMENTED, LONG-RANGE AIRCRAFT

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During the last few decades, the discipline of *Geodesy* or most appropriately, *Geodetic Science* have evolved into an interdisciplinary science exploiting new technologies to acquire fundamental measurements such as time, positioning, realization of reference frames, gravity, tides, topography, bathymetry, Earth orientation, ocean winds; and inferring climate-sensitive observations including changes in sea level, ice sheet, sea ice, glacier, land cover, solid Earth deformation, glacial isostatic rebound, ocean circulations, tidal dissipation, space weather, geomagnetism, meteorology, atmosphere, and hydrological processes. Advances in the measurement of the gravity with modern free-fall methods reached accuracies of 10^{-9} g (~ 1 μ Gal or 10 nm/s²), allowing the measurement of effects of mass changes in the Earth interior or the geophysical fluids (ocean, cryosphere, atmosphere and hydrosphere), and the commensurate 1 part per billion (ppb) measurement accuracy of height changes at ~ 3 mm relative to the Earth's center of mass. As a result, the role of *Geodesy* primarily as an observational tool has largely been the foundation of many cross-disciplinary research topics in geophysics, glaciology, oceanography, hydrology and atmosphere, including those in Antarctica. Geodesy as a tool for interdisciplinary science in Antarctica via an instrumented, long-range airborne platform provides accurate observations or models including the fine-resolution gravity and magnetic fields, subglacial topography, ice sheet mass balance and ice stream velocities, Antarctic sea level change, ocean tides over seasonally or permanently sea ice covered ocean, sea ice freeboard height change, marine gravity and bathymetry over seasonally or permanently sea ice covered ocean, digital elevation models for ice-covered and land topography, tectonic uplift and postglacial rebound. These observations support Antarctic research and applications including:

- Satellite mission (ICESat, CryoSat, ENVISAT, GRACE, GOCE) calibration and validation
- Geology and ice sheet dynamics
- Lithosphere rifting crustal structures
- Sea ice thickness change
- Antarctica ice sheet mass balance and its role in global sea level change
- Coupled ice-ocean dynamics
- Ocean circulations

This presentation provides some selected examples of potential interdisciplinary research in Geodesy exploiting an instrumented, long-range aerogeophysical platform. Some of our activities will have full support from international organization via partnerships. They include: the International Association of Geodesy (IAG), Commission II (Gravity Field), Project 2.4, entitled *Antarctic Gravity Project*, and the Scientific Committee on Antarctic Research (SCAR), Project 3 entitled *Physical Geodesy* (within the *Geodetic Infrastructure in Antarctica* (GIANT), sub-programme of the SCAR Geoscience Standing Scientific Group (GSSG)).

AEROGEOPHYSICAL POLAR EXPLORER (APEX) FOR BI-POLAR LITHOSPHERIC INVESTIGATIONS

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Our poor knowledge of the geology of the polar regions contributes to significant gaps in our understanding of global tectonic and paleoenvironmental evolution. Recent advances in navigation technology permit us to efficiently map at high resolution the gravity and magnetic anomaly fields over the polar regions using long-range aircraft. For example, during a typical 2-3 month polar field season, an aircraft such as the CASA CN-235 or Fokker F-27 navigated by differential GPS can map over 200,000 sq km (an area about twice the size of Ohio) at a 20 km resolution. These data would provide the needed information to estimate the structure, age and evolution of the polar lithosphere and can be used to locate areas for further study by seismic, drilling, and other surface-based geophysical and geological programs.

A dedicated APEX aircraft can be implemented to service the requirements of both Arctic and Antarctic geoscientists because the two field seasons are complementary. Hence, a decade long APEX program could fulfill long term aerogeophysical objectives for Antarctica while mapping the unexplored and poorly understood regions of the Arctic. The APEX aircraft could be outfitted with radars to map the distribution, thickness and other properties of ice for various geological, glaciological, marine and climatological applications. The APEX could also be equipped with detectors to monitor the environment, and to provide ground truth information for satellite monitors, as well as additional information on atmospheric chemistry, biomass, ice and oceanic processes. The aircraft could also be utilized to deploy buoys and other monitoring devices along the survey route.

These considerations suggest that an APEX could well serve a considerable spectrum of polar interests in academia and the government agencies (e.g., NSF, USGS, NASA, NRL, NIMA, NOAA, EPA, etc.). Accordingly, it is recommended that the bi-polar community of geoscientists contribute to the planning, production, and implementation of an APEX with the goal of mapping the polar geopotential fields as a major contribution towards resolving the structure and evolution of the polar lithospheres.

AEROGEOPHYSICAL SURVEY OF THE CONTINENT- OCEAN TRANSITION OF PACIFIC WEST ANTARCTICA

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With its great range and over-water capabilities, an LC-130 would be uniquely suited to surveys extending from outcrop areas onshore to the continental margin. The rapid mapping rates of aerogeophysics along with access to ice-covered areas are unique advantages to this method of study of the continent-ocean basin transition. Aerogravity anomalies, even if limited to wavelengths of 15-20 km

and longer, will be a valuable addition to reconnaissance mapping by satellite and sparse ship tracks. In areas of ice shelves or persistent fast ice, gravity anomalies can show the trends and approximate amplitudes of major bathymetric features such as glacial troughs. In offshore areas with bathymetric soundings, gravity anomalies would allow mapping of features such as sediment-filled basins with greater control than is available from gravity derived from satellite altimetry. Aeromagnetic data can reveal structures at the margin edge along with those in the ocean basin diagnostic of continental rifting and sea floor spreading kinematics. An aerogeophysics survey conducted by the SOAR project over western Marie Byrd Land (Ford Ranges and Edward VII Peninsula) could be enhanced with additional offshore data from an LC-130 survey. Sub-ice topography shows a basin-and-range structure trending N-S, at a high angle to the continental margin. Similar, nearly parallel structures had been mapped previously by marine geophysics in the adjacent eastern Ross Sea. Studies of outcrop relations show most of the extension dates to 105-90 Ma, shortly prior to rifting between New Zealand and Antarctica. Combined analysis of gravity and topography suggests crustal thickness about 30 km east of the Ford Ranges but about 22 km under the eastern Ross Ice Shelf (stretching factor of at least 1.3). High-amplitude, short-wavelength magnetic anomalies are common in the eastern half of the survey area over the ice sheet, east of about 145°W, suggesting the presence of mafic volcanic rocks, possibly quite young. Using aeromagnetic anomalies to map the relation of the boundary of the volcanic province and the continental margin should help understand the origin of the volcanics. With a mantle-plume source, there should be little correlation between the boundary of the volcanics and the continental margin, but alternative models based on sources in the sub continental mantle would be more compatible with a limit of young volcanics coinciding with the continental margin. Details of a possible survey from the Marie Byrd Land coastal areas to the continent-ocean transition, collecting radar, gravity, and magnetic data will be presented.

GLACIOLOGY

THE USE OF ICE PENETRATING RADAR PROFILES FOR LARGE AREA MAPPING OF LONG-TERM ACCUMULATION AND VERTICAL STRAIN RATES: AN EXAMPLE COVERING 10,000 LINE KILOMETERS IN GREENLAND

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Internal layering in ice penetrating radar profiles, once calibrated at an ice core site, can provide a picture of long-term (several thousand years) accumulation patterns, and can also constrain the vertical strain rates experienced in the upper 1 to 2 kilometers of ice. The relationship between accumulation rate and vertical strain rate, which determines the positions of the internal layers in the profile, also provides information about the ice flow in an area. It is possible to detect strong transitions in basal processes (distinguishing areas that are frozen to the bed from those that are sliding, and detecting areas that are experiencing substantial basal melting). I will discuss the basic ideas, and demonstrate how internal layer tracing has been applied to the extensive network of long radar profiles flow with the University of Kansas radar in Greenland, including a favorable comparison with the best available information on accumulation patterns from other sources.

POLARIMETRIC RADAR MEASUREMENTS OF THE INTERIOR ICE TO REVEAL ICE-FLOW INDUCED FEATURES

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The alignment of crystals in ice, called crystal-orientation fabrics, has an important effect on ice deformation. As ice deforms, nonuniform fabrics are produced, which, in turn, influence further deformation. Consequently, measurements of ice fabrics variations can help reveal the deformation history of the ice and indicate how deformation will continue in the future. Since single ice crystals are uniaxial at radio-wave frequencies, nonuniform fabrics can cause birefringence and anisotropic reflectivities within ice.

Ground-based radar surveys using 60 MHz and 179 MHz radars in East Antarctica found that the radar echoes were highly dependent on the radar polarization plane for ice depths between 40 and 60% of the ice thickness in the lower reaches of the convergent ice-flow sector. When the polarization was perpendicular to the ice flow, echoes were about 10 dB stronger than when the polarization was parallel to the ice flow. This feature was less evident in the upper region of the convergent flow. Farther inland, where ice flow is divergent, the radar echo varied by several decibels with the radar polarization. Dual-frequency data showed that the cause of the reflections was changes in ice fabrics. Multipolarization data identified anisotropic reflectivities and birefringence as causes of the anisotropic radar echoes in the lower and upper reaches, respectively. Principal axes of the anisotropy and birefringence agree well with principal axes of the regional-scale strain field. We argue that ice is composed of stacked layers of single-pole and vertical girdle fabrics in the lower reaches, while changes of single-pole clustering cause isotropic reflectivities in the upper reaches.

To cover a further downstream region towards a fast-flowing glacier, an ice ridge impeded by nunataks, and a parallel sheet-flow region, we analyzed 179-MHz airborne radar data. The former two areas are of

particular interests, because most of ice-sheet ice is discharged through fast-flowing glaciers and ice streams, and nunataks are dominant along the coast (e.g. Transantarctic Mountains). The study area includes the same drainage basin as the ground-based study above, where ice fabrics were identified as the major cause of reflection at 179 MHz. A distinct zone of high radar scattering several-hundred-meters thick was found at middle depths only when the radar polarization plane was parallel to the compression axis in ice suggesting that difference in horizontal strain components developed alternations of ice fabrics among adjacent ice layers. Furthermore, the high-scattering zone was less evident in areas where a tributary of a fast-flowing glacier penetrates. This implies that ice deformation at middle depths are affected by basal conditions.

These ground-based and airborne studies suggest that polarimetric radar measurements at high frequencies have a high potential to map anisotropic ice structures induced by past ice flow. Long-range airplane is the only way to make polarimetric radar measurements over inland and coastal areas in East Antarctica. Low flight height and sharp antenna-beam width are essential to gain better horizontal resolution and prevent mixing reflection from within ice with off-nadir reflections from the ice sheet surface.

INVESTIGATING THE SUBGLACIAL ENVIRONMENT AND GEOLOGY OF ANTARCTICA BY DIRECT MEANS, A NEW FRONTIER IN ANTARCTIC RESEARCH

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Here we present an initiative to directly investigate the subglacial environment and geology of Antarctica representing a new frontier in Antarctic research and a proposal to develop the technology - a hydro-mechanical drill - necessary to obtain rock and sediment samples from beneath deep glacier ice.

The Antarctic continent is 98% ice covered and thus the subglacial environment is inaccessible to the geologist, glaciologists and biologist as well as other scientists. Aero-geophysical observations in combination with interpolation from surrounding outcrops are currently the only information about the underlying bedrock geology in East or West Antarctica. While several higher resolution data sets are available for West Antarctica data-coverage for East-Antarctica is in some areas more than sparse.

Since most of the Antarctic continent is covered with ice and geologically unknown, almost any borehole through the ice will encounter rocks of interest, enlarging the observational base of Antarctic geology. However such observation need to be placed into a regional/continental context. Therefore the drilling will be guided by detailed aero-geophysical surveys, necessary to find the best and most representative drill site, for addressing a specific high-ranking scientific question. In return interpretation of aero-geophysical data need to be validated by analyses of actual rock specimen. Aero-geophysical data than further allow it to draw conclusion from such analyses in a regional or global context.

SEA ICE

AIRBORNE REMOTE SENSING CAMPAIGN OVER SVALBARD

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We present data from an airborne campaign over Svalbard (78° N, 11°E) using a Dornier 228 airplane equipped with a spectral imager. An overview over the equipment used is given. The routines for selecting, planning and following a selected route are presented and discussed. We also give an overview over additional parameters such as the read-out time of the camera and the resulting overlap of the obtained spectral images and spatial resolution. The purpose of the experiment was to measure the reflective properties of seawater, ice and snow from an altitude of 10.000 ft. Using the Bayes classification method, the imager successfully classified snow, leads, and new and rafted ice. Furthermore, a comparison study between airborne measurements of ocean color and in-situ measurements of optical properties of surface waters is presented. Here, e.g., different substrates and kelp forest distributions in shallow waters are visible.

THE AIRBORNE EARTH SCIENCE MICROWAVE IMAGING RADIOMETER (AESMIR)

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The Airborne Earth Science Microwave Imaging Radiometer (AESMIR)---a versatile new airborne imaging radiometer developed by NASA---recently completed its first flights on a NASA C-130. The AESMIR design is unique in that it performs dual-polarized imaging at all standard passive microwave frequency bands (6-89 GHz) using only one sensor head/scanner package, providing an efficient solution for Earth remote sensing applications (snow/ice, sea ice, soil moisture/land parameters, precipitation, ocean winds, sea surface temperature, water vapor, etc.), particularly when combined with other synergistic instruments. The microwave radiometers themselves incorporate state-of-the-art receivers, with particular attention given to instrument calibration.

Parallel filter banks allow AESMIR to simultaneously simulate the exact passbands of multiple satellite radiometers: SSM/I, TMI, AMSR, Windsat, SSMI/S, and the upcoming GPM/GMI and NPOESS/CMIS instruments—a unique capability among aircraft radiometers. And, all receivers except the 23 GHz sounding channels are configured for 4-Stokes polarimetric operation.

The single-package design of AESMIR makes it compatible with a variety of aircraft. The arbitrary 2-axis gimbal can perform conical and cross-track scanning, as well as fixed-beam staring.

Ice sheet & sea ice science investigations have recently been discussed for which AESMIR would be ideal. And, potential C-130 based configurations have been considered. Potential science investigations, and the requirements & considerations for Antarctic & polar observing with AESMIR will be presented. Companion instruments that would expand frequency coverage to 1-600 GHz will also be briefly described.

ATMOSPHERIC SCIENCES

AIRCRAFT REMOTE SENSING OF ANTARCTIC CLOUD MICROPHYSICAL AND RADIATIVE PROPERTIES

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In addition to current high latitude scientific questions, the study of Antarctic clouds has global relevance because of the Antarctic atmosphere's unique attributes as a "cloud physics laboratory." Over Antarctica and the Ross Ice Shelf, one can observe dynamical and thermodynamic mixed phase cloud processes in a pristine atmosphere, that are relevant to such issues as cirrus formation in tropical deep convection, but at from flight altitudes accessible from an LC-130 or similar aircraft, as opposed to much more expensive and challenging ER-2 flights. It therefore makes sense to outfit an Antarctic research aircraft with a suite of shortwave and long-wave spectral radiometric instruments that can provide data over cloud during every flight. These passive sensors simply "go along for the ride" and can provide useful data even when the main flight mission might be dedicated to something else entirely. This paper discusses the potential utility of shortwave dispersive spectrometers, and long-wave Fourier Transform Infrared (FTIR) spectroradiometers, for aircraft-based remote sensing of Antarctic cloud properties.

THE USE OF EXISTING INSTRUMENTATION ON A LONG-RANGE SCIENCE AIRCRAFT FOR ANTARCTICA

Matthew Lazzara

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With the research aircraft widely used in the mid-latitudes, several cloud detection, surface features, and vertical profile instruments have been developed and flown for a variety of field experiments and validation campaigns. Among these instruments includes Scanning High-resolution Interferometer Sounder (S-HIS), Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS), National Polar-orbiting Operational Environmental Satellite System (NPOESS) Aircraft Sounding Testbed (NAST) for both imaging (NAST-I) and microwave (NAST-M) platforms. These instruments have been flown on the NASA ER-2 or in some cases the Proteus or DC-8 aircraft. None have flown over the Antarctic due to the limited reach of these aircraft platforms and logistical challenges of deployment. This presentation will make the case to have any long-range science aircraft for Antarctica be equipped with the avionics to host these instruments. This allows these instruments the first chance for them to fly over and observe the Antarctic, as well as potentially saving money in the development of new instrumentation. Some critical issues will need to be addressed, as the altitudes and conditions these instruments have been tested and designed for may not match that of the candidate long-range science aircraft. This presentation will also propose an additional instrument that would be a valuable asset for the proposed long-range science aircraft, namely the High Spectral Resolution LIDAR (HSRL).

**NUMERICAL WEATHER PREDICTION IN ANTARCTICA
AND A LONG-RANGE AIRCRAFT FOR ANTARCTIC RESEARCH**

Jordan Powers

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Numerical weather prediction (NWP) efforts are crucial for science and operations in Antarctica. Mesoscale forecast models, such as in the Antarctic Mesoscale Prediction System (AMPS), provide vital guidance to flight forecasters responsible for long-range aircraft operations on the ice. While AMPS has been developed to support and facilitate such activity, including LC-130 traffic for the United States Antarctic Program, long-range aircraft (such as the LC/C-130) offer an avenue for improving polar modeling and forecasting.

A long-range aircraft for Antarctic research could serve as a platform for the gathering of atmospheric measurements that may be exploited in a number of ways for both research modeling and real-time forecasting. For specific field programs such as RIME, LC-130 data would be invaluable for verification and evaluation of simulations of targeted events. These in-situ observations would permit unequalled assessment of the model-generated, three-dimensional atmospheric structures and dynamics. In addition, the aircraft measurements would be useful in data assimilation. They would support studies to explore the impacts of their ingest in case-study simulations as well as in real-time mesoscale forecasting. The latter may demonstrate the benefits of equipping Antarctic LC/C-130's with MDCRS-like equipment.

The aircraft data are expected to be of benefit to the real-time AMPS effort by enhancing the accuracy of initializations. The improved forecasts would, in turn, increase the safety and efficiency of both scientific and logistical activities in Antarctica. This presentation will address the ways in which Antarctic NWP would benefit from a long-range aircraft for Antarctic research.

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