

# MEETINGS

## Science Opportunities for a Long-Range Antarctic Research Aircraft

The polar regions play a critical role in the geodynamic and climate system of the Earth. Although located far from the main centers of human civilization, the polar atmosphere and oceans have strong global connections and therefore directly affect global weather, climate, and the world's population, living mostly in tropical and midlatitude environments. Antarctic geodynamic processes are the driving forces for ice sheet dynamics and global environmental change that affect current and long-term, large-magnitude sea level changes.

The importance of the polar regions for our natural environment has long been recognized. Many nations around the world are currently planning the International Polar Year 2007–2008 (IPY), an intense, coordinated effort of novel and comprehensive observations combined with multidisciplinary research, analysis, and educational activities (<http://www.ipy.org>).

Our present understanding of the polar environment is far more advanced for the Arctic than for the Antarctic. This imbalance results largely from ease of accessibility, in particular Arctic landing facilities for wheeled aircraft. Landing sites for wheeled aircraft in Antarctica are extremely limited, and the vast interior of the Antarctic continent currently can only be reached by ski-equipped aircraft because most existing wheeled aircraft do not satisfy the necessary safety and operational requirements for such an extreme environment.

We have a physically based, conceptual understanding of many of the significant interactions that affect climate and the Antarctic environment. Our observationally based knowledge, however, is inadequate in many cases to quantify these interactions or to predict their net impact.

To pursue key goals in Antarctic science and transform our conceptual understanding of the processes of interest into quantitative knowledge, it is necessary to acquire geographically diverse sets of fundamental observations at high spatial and often temporal resolution. We currently lack the data sets to build a comprehensive picture of the Antarctic environment because of a long-standing gap in our observational capabilities.

On the one hand, satellite-borne instruments provide continent-wide coverage, but often

have limited spatial resolution and essentially no ability to penetrate beneath the surface. On the other hand, instruments deployed from remote field camps, seagoing vessels, and small aircraft can provide the necessary high spatial and temporal resolution, but lack the capability to operate over continent-wide scales.

The growing need for a long-range research aircraft in the solid Earth, glaciology, atmospheric science, and oceanography communities over the past several years resulted in a September 2004 workshop at Herndon, Virginia, that brought together Antarctic scientists in order to formulate a science justification for a long-range research aviation facility.

The overall goal of the workshop was (1) to identify the key scientific questions in Antarctic science that currently cannot be addressed because of a gap in our observational capabilities, and (2) to develop a strong science justification for the required new research tools. A primary objective of the workshop was to provide the U.S. National Science Foundation (NSF) with recommendations on the requirements for a long-range research aviation facility.

The key science questions are targeted at understanding the elements of the Antarctic environment: the bedrock, the cryosphere, the ocean, and the atmosphere. These questions also focus on the interactions among these key elements and how the Antarctic environment is connected to the global environment.

The large overlap between the key questions of each discipline shows that only an interdisciplinary approach can solve the outstanding questions.

### *Geology and Geophysics*

- What is the role of subglacial sediments, volcanoes, and other geologic features on ice sheet dynamics?
- What are the interactions between tectonic and climate evolution of Antarctica?
- What is the geologic and tectonic setting of subglacial lakes?
- What was the role of East Antarctica in the Precambrian continental growth process?
- What is the magnitude and timing of Mesozoic to Cenozoic extension and its effect on the global plate motion circuit?

### *Glaciology*

- What are the interrelationships between climate change and the ice sheet system?
- What are the controls and interactions governing ice sheet dynamics?
- What are the distribution, nature, and interconnection of subglacial lakes?
- What are the current dynamics of coastal areas?

### *Oceanography*

- What is the interannual variation in sea ice thickness on a basin-wide scale?
- What is the role of water densification in polynyas and beneath ice shelves for the global ocean meridional overturning circulation?
- What is the temperature variability of the deep ocean waters over interannual scales?
- What is the large-scale drift of sea ice in the Antarctic Zone from its formation to melt?
- What is the role of marginal ice zones for physical and biological activity?

### *Atmospheric Sciences*

- What is the role of the Antarctic atmospheric heat sink in global climate?
- What impacts do the mountainous topography of Antarctica have on the global atmospheric circulation?
- What is the role of the Antarctic ice sheets in global sea level variations?
- What is the nature of the air-sea interactions over the Southern Ocean?
- How is the atmospheric chemistry of the high southern latitudes tied to the atmospheric circulation?

New observational capabilities are needed to gather the necessary data sets. For the geology and geophysics community, a long-range research aircraft could map the subglacial topography, gravity, and magnetic anomalies that can be used to derive a structural tectonic framework in ice-covered regions. For the glaciology community, an instrumented long-range aircraft could provide a comprehensive survey of the surface and bedrock topography and the internal structure of the ice sheet, as well as monitor changes over the most dynamic parts of Antarctica.

The key oceanographic questions require measurements of sea ice thickness and transport, surface heat fluxes and ocean wave conditions, and the structure of the upper ocean from expendable conductivity-temperature-depth (XCTD) probes.

For atmospheric sciences, measurement of the atmospheric state variables (temperature, pressure, winds, and atmospheric moisture), turbulent fluxes, cloud microphysical parameters, and radiative fluxes will be required. For upper tropospheric flights, extensive use of dropsondes to monitor the atmospheric structure below flight level will be necessary.

In order to address the key science questions, an order of magnitude improvement in data

quality and quantity is urgently needed. The target areas are widespread and extend over both continental and oceanic regions. In order to acquire the needed data, different survey designs and sensor configurations are required for each key question or science discipline.

The workshop defined several generic mission profiles. These mission profiles outline typical operational requirements that are needed to achieve the vast majority of the science goals for each science discipline. What is common to all mission profiles is the need for an aircraft that is capable of carrying an integrated payload of remote sensing and in situ measurements over long distances.

Almost all mission profiles require acquisition of data in remote regions more than a thousand nautical miles away from existing landing sites for wheeled aircraft in Antarctica. Getting to the target area and being able to survey for several hours require aircraft endurance of at least 10 hours or the ability to refuel in remote locations.

The primary advantage of a ski-equipped long-range aircraft, as opposed to a wheeled aircraft, would be its capability to operate from remote field camps. Existing wheeled long-range P-3 aircraft have an operational radius from McMurdo of approximately 1800 km. There are many scientific targets more than 1800 km from McMurdo, and the accessibility of these targets provides perhaps the greatest

scientific incentive for building a dedicated ski-equipped long-range research aircraft.

The advantage of a ski-equipped aircraft derives from (1) support of deep field operations (beyond the 1800-km radius); (2) a longer field season; and (3) a lower weather-related abort rate and an additional margin of safety provided by lower ceiling/visibility minimums and the possibility of diverting away from McMurdo to land elsewhere in Antarctica.

In addition to long-range and remote refueling requirements, flights from a few hundred meters above the surface to at least 7 km are required. Atmospheric physics and chemistry research requires a heavy aircraft with long-range endurance and significant load-carrying capability. The payload requirements range from 2500 lbs for solid Earth and glaciology missions to 12,000 lbs for atmospheric chemistry missions.

#### *Recommendations and Conclusions*

The geology, geophysics, glaciology, atmospheric, and oceanographic communities represented at the workshop need a multi-disciplinary, instrumented long-range Antarctic research aircraft (LARA). The projected use by varied disciplines requires a large number of different sensors and measurements that creates operational complexity, which requires a central management and operations facility.

Existing research aviation facilities generally do not span such a broad range of disciplines

and sensors as envisioned for the long-range Antarctic research aviation facility. The development and operation of such a facility would be a unique undertaking.

The final report will be posted on the workshop Web site: <http://polarmet.mps.ohio-state.edu/lara/>.

The workshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research was held 27–29 September 2004, at the Days Inn Hotel and Conference Center, Herndon, Virginia.

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