

Antarctic Sciences Division GPRA highlights, FY2009

Basic research in Antarctica applied to assessment of Yucca Mountain

Highlight ID: 16815, Version: AC/GPA

The outcomes of fundamental research on igneous rocks in Antarctica were used to assess volcanic hazards to the proposed Yucca mountain nuclear waste repository. An earlier report speculated that magma intersecting the repository would generate a shock wave, fill multiple storage tunnels, and expose a large proportion of the nuclear waste containers. Research supported under this NSF award showed that such a scenario is unlikely. Based on observations of dikes in Antarctica, the panel concluded that if a dike penetrated the tunnels, it would not generate a shock wave, and would likely clog the area with rapidly solidifying magma, so a much smaller number of waste packages would be affected. This assessment is reported in NUREG-1890 *Evaluating Igneous Activity at Yucca Mountain: Technical Basis for Decision Making*, a report of the United States Nuclear Regulatory Commission released in February 2008. The scientific research is reported in various journal articles.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

This research supports NSF's strategic goal of discovery. Frontier research led to advances in both basic earth sciences and had the societal benefit of helping constrain the hazards associated with storage of nuclear waste at Yucca Mountain.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Fundamental research on Antarctic geology led to a societally relevant outcome of constraining hazards at the Yucca Mountain repository.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

Fundamental research on Antarctic geology led to a societally relevant outcome of constraining hazards at the Yucca Mountain repository.

OPP/ANT 2009

Program Officer: Thomas Wagner

NSF Award Numbers:

[0440718](#)

Award Title: 3-D Dynamics of the Ferrar Magmatic Mush Column, McMurdo Dry Valleys, Antarctic

PI: Bruce Marsh, bmarsh@jhu.edu
Institution Name: Johns Hopkins University
State Code: MD
PE Codes: 5112

NSF Contract Numbers:
NSF Investments: None Applicable

Interpreting the glacial history of Mars from research in Antarctica

Highlight ID: 16816, Version: AC/GPA

Based on their experience working in the McMurdo Dry Valleys of Antarctica, researchers were able to interpret images of the Martian landscape to show that Mars has experienced varied glaciation. These include large ice sheets followed by small scale alpine glaciers in a single location. They also showed that some areas may harbor icy remnants of the final glacial episode, some hundreds of meters thick. These would be prime targets for future exploration for both life and climate records. These results were the cover story for the journal *Geology*, which is the third most cited journal in earth science. The reference is:

"Late Amazonian glaciation at the dichotomy boundary on Mars: Evidence for glacial thickness maxima and multiple glacial phases"

Authors: James L. Dickson; James W. Head; David R. Marchant
Geology, May 2008; v. 36; no. 5; p. 411-414; doi: 10.1130/G24382A.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

This outcome demonstrates how NSF's investment in basic research helps another agency in its mission. In this case, a scientist working in Antarctica--Dr. David Marchant of Boston University--teamed up with a planetary scientist--Dr. James Head of Brown University--to interpret Antarctic landscapes, especially ancient buried ice. Subsequently, they applied their findings to photographs of the Martian landscape. They found that they could interpret these images to describe Mars' glacial history, and identify debris covered glacial remnants--areas where ice might be found today. This ice may hold important records of Mars' climate history as well as harbor microbial life, as it does on Earth. These are critical goals of NASA's Mars exploration program. This research meets NSF's strategic goal of discovery.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

This project involved the education of graduate students in both terrestrial and planetary science.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)
No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

No

OPP/ANT 2009

Program Officer: Thomas Wagner

NSF Award Numbers:

[0338291](#)

Award Title: Collaborative Proposal: Age, Origin and Climatic Significance of Buried Ice in the Western Dry Valleys, Antarctica

PI: David Marchant, marchant@bu.edu

Institution Name: Trustees of Boston University

State Code: MA

PE Codes: 5112

NSF Contract Numbers:

NSF Investments: None Applicable

Antarctica was once connected to the US

Highlight ID: 16969, Version: AC/GPA

Central to all earth science is determining the past configurations of the continents. These records serve many purposes, from helping locate natural resources to modeling past climates to understanding evolution. We currently have a good understanding of the last amalgamation of continents into Pangea, which existed from 545 to 180 million years ago and allowed land-dwelling organisms to proliferate across the globe. However, we have poor information on the previous amalgamation--Rodinia--which formed about 1.3 billion years ago. Rodinia's characteristics are key to understanding the origins of complex life on earth, as well as understanding the snowball earth period, when the entire globe froze over. This study shows that a rock from Antarctica is identical to a band of rocks in western North America, and implies that the two continents were adjacent to one another. It had previously been suggested that China or Siberia had been adjacent to this coast, which requires radically different plate reconstructions. Paper was published in *Science*, 11-July 2008: Vol. 321. no. 5886, pp. 235 - 240

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

The results are applicable to 1) fundamental questions of plate tectonics; 2) basic geologic interpretations of ancient rock units; 3) understanding ancient climates and ocean circulation; and 4) potentially useful to natural resource extraction

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

First award to an early career woman who is the lead PI on the collaborative project.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

First award to an early career woman who is the lead PI on the collaborative project.

What may be the benefits of the proposed activity to society?

No

OPP/ANT 2009

Program Officer: Thomas Wagner

NSF Award Numbers:

[0440885](#)

Award Title: Collaborative Research: Integrated Study of East Antarctic Ice Sheet Tillis (ISET): Tracers of Ice Flow and Proxies of the Ice-covered continental shield

PI: Kathy Licht, klicht@iupui.edu

Institution Name: Indiana University

State Code: IN

PE Codes: 5112

NSF Contract Numbers:

NSF Investments: None Applicable

The last vestiges of life in Antarctica

Highlight ID: 16970, Version: AC/GPA

A major question about the Antarctic ice sheet is when and how it came into its current configuration of stable, cold-footed ice sheets as opposed to more dynamic, warmer glacial systems. This project discovered a fossilized lake that indicates rapid cooling of Antarctica 14 million years ago. The cooling event--roughly 8 degrees centigrade--killed off the last vestiges of tundra life that included plants, insects, and other microscopic fauna. This event is the single most important climatic event in Antarctica since the formation of the ice sheet 34 million years ago. Understanding its cause will help us develop predictive models for our warming world. The paper was published in PNAS 105:31; August 5, 2008; p 1067-10680.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

This research dates the most important change in the character of the Antarctic ice sheet. When correlated with climate and CO2 records from the rest of the globe, the results will help us with long term predictions on the fate of the Antarctic ice sheet in a warming world.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

A movie--Ice People directed by Anne Aghion--was made about the project and has been released worldwide. Two undergraduate students, including one woman, had exciting research experiences in Antarctica. This award established Adam Lewis--co Investigator--as an independent researcher and led to tenure track position.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)
No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)
No

What may be the benefits of the proposed activity to society?
No
OPP/ANT 2009

Program Officer: Thomas Wagner
NSF Award Numbers:
[0440711](#)

Award Title: Collaborative Research: Deducing Late Neogene Antarctic Climate from Fossil-Rich Lacustrine Sediments in the Dry Valleys
PI: David Marchant, marchant@bu.edu
Institution Name: Trustees of Boston University
State Code: MA
PE Codes: 5112

NSF Contract Numbers:
NSF Investments: None Applicable

West Antarctic Ice Sheet (WAIS) Divide Ice Core Program Completed a Successful Season by Drilling through the Brittle Ice Using the New Deep Ice Sheet Coring (DISC) Drill

Highlight ID: 17962, Version: AC/GPA

The U.S research community is conducting a deep ice coring project in West Antarctica for studies of climate, ice sheet history and cryobiology. This project is collecting a deep ice core from the West Antarctic Ice Sheet (WAIS) ice flow divide and integrating approximately 20 separate but synergistic projects to analyze the ice and interpret the records. The most significant characteristic of the WAIS Divide project is the development of climate records with an absolute, annual-layer-counted chronology for the most recent ~40,000 years. Lower temporal resolution records will extend to ~100,000 years before present. These records will enable comparison of environmental conditions between the northern and southern hemispheres, and the study of greenhouse gas concentrations in the paleo-atmosphere, with a greater level of detail than previously possible. This information will be used to improve the models that are used to predict how climate will change in the future.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Polar Facilities & Logistics

In terms of intellectual merit, why is this outcome notable and/or important?

The goal for this field season (2008/09) was to drill through the portion of the ice sheet where the ice was known to be brittle. In this brittle ice zone in an ice sheet (typically between about 800-1500 m depth the ice must be carefully handled and stored in place for a year without significant movement so that it can "relax" and decompress. Drilling was completed for the 2008-2009 field season at depth of 1511.9 meters, which included all the brittle ice and an additional 100 m of non brittle ice. A total of 931.9 meters of core was processed during the close to 3 month field season and is stored on site. Electrical measurements on the core identified the annual layers and indicate that the last ice drilled this season is approximately 7693 years before present in age.

Ice cores collected from the brittle zone typically have numerous fractures that can reduce the scientific value of the ice. Several new methods were used this year that greatly improved the core quality and scientific value of the cores from the brittle zone. These methods included, innovative drilling procedures, improved alignment and rigidity of the core handling equipment, encasing the core in a plastic net to provide a compressive force, and reducing the thermal shock to the core by keeping the air temperature of the core handling area at -30 C.

Another significant aspect of this field season is that it was the first complete field season using the new Deep Ice Sheet Coring (DISC) drill. The drill was designed and built by Ice Coring and Drilling Services (ICDS) a contractor of the National Science Foundation. Several years were spent designing and testing the drill. Last field season was the first season that the drill had been used in Antarctica and this field season was the first complete field season where the drill was put into production mode drilling.

The ultimate goal of the project is to complete the drilling of the main ice core over the next two years to a depth of about 3500 m. The project is off to a good start and will no doubt yield significant results.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The WAIS Divide ice core will provide the first Southern Hemisphere climate and greenhouse gas records of comparable time resolution and duration to the Greenland ice cores enabling detailed comparison of environmental conditions between the northern and southern hemispheres, and the study of greenhouse gas concentrations in the paleo-atmosphere, with a greater level of detail than previously possible. The WAIS Divide ice core will also be used to test models of WAIS history and stability, and to investigate the biological signals contained in deep Antarctic ice cores. Unlike the Greenland ice cores, an excellent atmospheric CO₂ record is expected to be obtained from the WAIS Divide ice core since Antarctic ice has more than an order of magnitude less dust than Greenland ice. Many other gases (both greenhouse and non-greenhouse) and their isotopes will be measured at unprecedented precision and resolution.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

This will be the first ice core to result in a highly resolved carbon dioxide record which will enable scientists to study the lead-lag relationships between atmospheric gases and climate forcing.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

Numerous young women scientists participated in the field work and are students supported as part of this program. This field has seen a dramatic increase in the number of women who are interested in ice core science. This is a direct result of the importance the program has placed on broadening participation of under-represented groups.

What may be the benefits of the proposed activity to society?

Yes

Global climate change has important societal relevance. This project will result in better information about past climate change and how the future will be impacted if greenhouse gases continue to rise in the atmosphere.

OPP/ANT 2009

Program Officer: Julie Palais

NSF Award Numbers:

[0440817](#)

Award Title: Investigation of Climate, Ice Dynamics and Biology using a Deep Ice Core from the West Antarctic Ice Sheet Ice Divide
PI: Kendrick Taylor, Kendrick.Taylor@dri.edu
Institution Name: University of Nevada Desert Research Institute
State Code: NV
PE Codes: 5140, 5116

[0440819](#)

Award Title: Investigation of the Stratigraphy and Time Scale of the WAIS Divide Ice Core Using Electrical Methods
PI: Kendrick Taylor, Kendrick.Taylor@dri.edu
Institution Name: University of Nevada Desert Research Institute
State Code: NV
PE Codes: 5116

[0230396](#)

Award Title: Preparation for a Deep Ice Coring Project in West Antarctica
PI: Kendrick Taylor, Kendrick.Taylor@dri.edu
Institution Name: University of Nevada Desert Research Institute
State Code: NV
PE Codes: 5140, 5116

NSF Contract Numbers:
0003289

NSF Investments: Climate Change, International Polar Year (IPY)

New Data Reveal Recent Antarctic Warming

Highlight ID: 17984, Version: AC/GPA

New results published in the journals *Nature* and *Proceedings of the National Academy of Sciences* reveal that parts of Antarctica, especially West Antarctica, have been warming for the last 50 years. These results are based on a statistical blending of satellite data and temperature data from weather stations. There is separate evidence from ice cores that Antarctica has been warming for most of the 20th century, but this is complicated by the strong influences of El Niño events in West Antarctica. These results suggest that the climate of West Antarctica is affected by both atmospheric and oceanic changes that occur many miles to the North, perhaps in the tropics. What is novel about this work is that the scientists have shown that the warming is greater in West Antarctica than in East Antarctica. Although it has been known for some time that the Antarctic Peninsula is warming, this is the first time that anyone has examined the climate over the rest of the West Antarctic ice sheet. While it is well accepted that the East Antarctic ice sheet has cooled in recent years (due to an increasing trend in the strength of the circumpolar Westerlies resulting from changes in the stratosphere, mostly due to losses of stratospheric ozone), the scientists say that these new results do not contradict or change those conclusions. However, they believe that this effect is probably smaller than previously thought, relative to other influences. The scientists conclude that warming exceeded one tenth of a degree Celsius per decade over the last 50 years which more than offsets the cooling estimated to have occurred over the last 20-30 years over East Antarctica.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research (AC/GPA selected)

Secondary Strategic Outcome Goals:

- National Center for Atmospheric Research (NCAR)
- Polar Facilities & Logistics

In terms of intellectual merit, why is this outcome notable and/or important?

The intellectual merit of this work is that scientists are beginning to better understand the reasons that the climate over the West Antarctic behaves the way it does. Because the Antarctic Peninsula and West Antarctica are both lower in elevation than the East Antarctic ice sheet there seems to be enhanced meridional flow and it is easier for warm, moist air masses to penetrate over West Antarctica than it is over the higher, more isolated East Antarctic ice sheet.

Another effect of this penetration of air masses from farther North is the fact that in recent years there has been less sea ice in the region off the coast of West Antarctica (despite increases in the average sea ice around the Antarctic continent as a whole). In fact there seems to be a positive feedback, with less sea ice leading to warmer water and rising air creating lower pressure and enhanced storminess which helps to limit the amount of sea ice which forms off the coast of the West Antarctic ice sheet.

In addition to the satellite work and analysis of limited weather station data, the studies of ice cores provide an excellent means to study the climate in the past over an area where little or no data exist prior to 1950. These results help to put the recent climate trends in the Antarctic in a more long-term, global context.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The broader impacts of this work relate to both the societal relevance of climate changes studies as well as the training of a new generation of polar scientists.

The societal relevance of the work relates to the fact that the West Antarctic ice sheet is particularly vulnerable to changes in climate because it is a marine-based ice sheet grounded below sea level and fringed by floating ice shelves. If, due to atmospheric warming or oceanic temperature increases, these ice shelves were to disappear, it is thought that the ice sheet could be vulnerable to partial collapse or decay. If the fringing ice shelves were to disappear and no longer buttress, or hold back, the glaciers flowing out to the sea then the ice sheet could disappear, thus raising sea level by 5-6 m.

A number of students were trained as part of this work. Two undergraduates and two graduate students have gained experience as part of this research. Graduate students obtained significant field experience as well as laboratory and instrumentation experience. A post doc who is now employed at the National Center for Atmospheric Research also has gained experience in modeling and publishing his results. A female student received her PhD as part of this work.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

The societal relevance relates to the importance of understanding the climate over the Antarctic ice sheet and how it might be affected by global warming. The ice core work helps to put the results into context since the ice cores provide a record of the pre-industrial climate and therefore the natural variability of climate in the region.

OPP/ANT 2009

Program Officer: Palais Julie

NSF Award Numbers:

[0440414](#)

Award Title: Stable Isotope Studies at East Antarctic US ITASE Sites

PI: Eric Steig, steig@ess.washington.edu

Institution Name: University of Washington

State Code: WA

PE Codes: 5116

[0126161](#)

Award Title: Collaborative Research: Remote Observations of Ice Sheet Surface Temperature: Toward Multi-Proxy Reconstruction of Antarctic Climate Variability

PI: Dale Winebrenner, dpw@apl.washington.edu

Institution Name: University of Washington

State Code: WA

PE Codes: 5113

NSF Contract Numbers:

NSF Investments: Climate Change, International Polar Year (IPY)

Gas from the past gives clues about the relationship between climate and ocean circulation

Highlight ID: 17987, Version: AC/GPA

Analysis of the global carbon cycle and climate for a 70,000 year period in the most recent Ice Age shows a remarkable correlation between carbon dioxide levels and abrupt changes in climate. The findings shed further light on the fluctuations in greenhouse gases and climate in Earth's past, providing data that match well with computer models of earth's carbon cycle, ocean circulation, and climate.

The work identifies a consistent and coherent pattern of carbon dioxide fluctuations from the past and observes a strong correlation of this to temperature in the northern and southern hemispheres, demonstrating that the carbon dioxide variations are part of a global, interconnected ocean-atmosphere system. The analysis was made by studying the levels of carbon dioxide and other trace gases trapped as bubbles in ancient ice cores from Greenland and Antarctica. Researchers who study ice cores have found that Greenland underwent repeated abrupt warming and cooling during the last ice age (between 10,000 and 110,000 years ago). In Antarctica, the pattern is reversed, and that continent warms when Greenland cools. This is thought to be due to changes in how the ocean transports heat between the hemispheres. The new work clearly shows that carbon dioxide rose each time that Antarctica warmed significantly. This pattern is predicted by computer models that simulate the climate "see-saw" between Greenland and Antarctica. These models predict that carbon dioxide is released from the deep ocean when the see-saw switches to warm Antarctica.

The carbon dioxide data were obtained by post doctoral researcher Jinho Ahn and Professor Edward Brook at Oregon State University, by carefully crushing ice under vacuum, releasing the small amounts of ancient air trapped in bubbles. Careful sample handling and analysis is needed to obtain results from such small samples. The results shed light on how climate and the carbon cycle are linked, and suggest that future changes in ocean circulation should affect carbon dioxide levels in the atmosphere.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research (AC/GPA selected)

Secondary Strategic Outcome Goals:

- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

This study provides new data that provide a much better understanding of the timing of natural CO₂ variations with respect to climate change in other parts of the world. The results reveal a very consistent pattern that helps explain why CO₂ varies naturally, and reveals a strong link between CO₂ variations and abrupt climate change. The data provide a strong target or climate models that are used to predict past and future climate change, and therefore are important for validating such models.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Because carbon dioxide is the most important greenhouse gas that humans are directly increasing in the atmosphere, it is very important to understand how carbon dioxide and climate are linked.

This study suggests that one aspect of the natural cycle, the link between ocean circulation and carbon dioxide, functions in such a way that when North Atlantic circulation is altered and heat transport to the North Atlantic region is reduced, carbon dioxide rises and Antarctica warms. It is quite possible that this link will function in the future if human activities change ocean circulation, thereby causing an additional CO₂ increase.

This study also contributed to the infrastructure for science, through funding of the construction of the lab instrumentation used to extract air from ice, and the training of a post doctoral researcher and lab technicians. The PI has also been active in many outreach activities, including the Leopold Leadership Fellowship (<http://leopoldleadership.org/content/index.jsp>).

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

Because carbon dioxide is the most important greenhouse gas that humans are directly increasing in the atmosphere, it is very important to understand how carbon dioxide and climate are linked. It is quite possible that this link will function in the future if human activities change ocean circulation, thereby causing an additional CO₂ increase. This study also contributed to the infrastructure for science, through funding of the construction of the lab instrumentation used to extract air from ice, and the training of a post doctoral researcher and lab technicians. This infrastructure enhancement would have supported the companies providing the equipment and jobs were provided to the students and technicians that were supported by the work.

OPP/ANT 2009

Program Officer: Julie Palais

NSF Award Numbers:

[0337891](#)

Award Title: Developing Dry Extraction of Ice Core Gases and Application to Millennial-Scale Variability in Atmospheric CO₂

PI: Edward Brook, brooke@geo.oregonstate.edu

Institution Name: Oregon State University
State Code: OR
PE Codes: 5116

[0602395](#)

Award Title: Collaborative Research: Project PALEOVAR -- Past Climate Variability: Understanding Mechanisms and Interactions with the Mean State
PI: Nicklas Piasias, npisias@coas.oregonstate.edu
Institution Name: Oregon State University
State Code: OR
PE Codes: 1530

NSF Contract Numbers:
NSF Investments: Climate Change

Uplift of Ice Sheet Surface Reveals Dynamic Circulation of Subglacial Water

Highlight ID: 18015, Version: AC/GPA

On the surface Antarctica is dry and frozen. However, beneath the Antarctic ice sheet scientists find the largest wetland on Earth. Vast expanses of wet subglacial mud surround lakes and rivers lying under thousands of meters of ice. Where there is liquid water, there is life, so microbiologists are interested in this subglacial 'water world' because its isolation from light and atmosphere makes it a potential analogue for life on Mars and Europa, as well as for evolution of life on early Earth.

Changes in subglacial water flow can accelerate the rate of ice sheet sliding, which makes studies of subglacial lakes and rivers important in evaluating future contribution of Antarctica to global sea level changes.

A team of US researchers from the University of California-Santa Cruz, University of Washington, and University of California-San Diego, together with international collaborators from University of Northumbria (UK) and Uppsala University (Sweden) are using sensitive geophysical sensors, such as GPS, seismometers, and ice-penetrating radar to quantify dynamics of subglacial water flow beneath the West Antarctic ice sheet.

Dr. Slawek Tulaczyk, professor of Earth Sciences at the University of California-Santa Cruz and the lead PI on this project, reports that GPS units placed in December 2007 above two subglacial lakes captured a transition from lake drainage to fast lake filling during 2008 (Figure 1). As the lakes fill, water pressure increased enough to push up the overlying ice sheet by several meters. The fastest ice uplift rates observed by the GPS are equivalent to almost 6m of uplift per year, or nearly 2.5 cm per day.

Once all of the geophysical data are processed, the science team will be able to answer the question: Does dynamic water flow between subglacial lakes induce changes in the sliding rate of the overlying ice sheet? In effect, the scientists are using the natural phenomenon of subglacial water transfer between lakes as a large-scale experiment to test the traditional model of ice sliding being highly sensitive to changes in subglacial water pressure and volume.

Primary Strategic Outcome Goal:

- International Collaborative Research
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Undergraduate Education and Undergraduate Student Research
- Graduate Education and Graduate Student Research
- Broadening Participation to Improve Workforce Development

In terms of intellectual merit, why is this outcome notable and/or important?

Scientists estimate that more than 10% of lake water on Earth is trapped in lake basins beneath the Antarctic ice sheet Priscu et al. (2008). These lake basins have been isolated from light, atmosphere, and the other parts of the biosphere for hundreds of thousands to millions of years. A large fraction of all the subglacial water generated beneath the Antarctic ice sheet passes through subglacial lakes. The lakes, and the aquatic subglacial environments associated with them provide an important scientific target for several disciplines. This includes the glaciology community, which is interested in quantifying the effect of variable subglacial water conditions on the movement of the Antarctic ice sheet. Polar microbiologists want to understand if microbes live beneath the Antarctic ice sheet, and if yes, how they adapted to these unique conditions. Finally, subglacial lakes will hold sedimentary sequences, which will enable reconstruction of long-term records of paleoclimate and paleoenvironmental changes.

Priscu, J.C., S. Tulaczyk, M. Studinger, M.C. Kennicutt II, B.C. Christner and C.M. Foreman. 2008. [Antarctic Subglacial Water: Origin, Evolution and Ecology](#). In: W. Vincent and J. Laybourn-Parry (eds.), Polar Lakes and Rivers. Oxford University Press. Pp. 119-135.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

During the first field season of our project we were joined in the field by Douglas Fox, a freelance journalist from San Francisco, CA. In 2008 Douglas Fox published several articles in Discover Magazine and Science News for Kids about our project:

<http://www.sciencenewsforkids.org/articles/20080723/Feature2.asp>

<http://www.sciencenewsforkids.org/articles/20080723/Note3.asp>

<http://discovermagazine.com/2008/sep/08-the-ground-zero-of-climate-change>

In addition, he used his time in McMurdo to interview other scientists and published other Antarctic stories in ScienceNOW Daily News, Science, and The Christian Science Monitor.

We also established collaboration with the NSF-funded IPY project Ice Stories, headed by Mary Miller of the SF Exploratorium. Ice Stories maintain a website for our project that has been populated by materials submitted by us from the field.

<http://icestories.exploratorium.edu/dispatches/antarctic-projects/under-the-glaciers/>

This project is providing Antarctic field research experience for three UCSC doctoral students, one REU undergraduate student, as well as non-field experience to one postdoctoral fellow (UW) and several undergraduate research assistants at UCSC.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

The project team is diverse. At UCSC we have three PIs, one glaciologist, Slawek Tulaczyk, and two female seismologists (Susan Schwartz, Emily Brodsky). The UCSC participants also included graduate students: Nadine Quintana-Krupinski (female, Latino/Caucasian ethnic background) and Jake Walter. One undergraduate student from University of Chicago spent six months at UCSC as an REU student funded by this project (Saffia Hossainzadeh, female, Persian ethnicity). At UCSD the unfunded collaborator is Dr. Helen Fricker. At UW the funded collaborators include Drs. Ian Joughin and Ben Smith. International collaborators include Dr. John Woodward (University of Northumbria, UK) and Dr. Rickard Pettersson, University of Uppsala, Sweden).

What may be the benefits of the proposed activity to society?

Yes

This project will contribute to the ongoing effort by the US scientific community to understand climate change and its various impacts, including the potential rise of global sea level due to increased discharge of ice from Antarctica. The project is providing background information, which will guide planned efforts to drill into West Antarctic subglacial lakes to study their microbiology and paleoclimate records contained within them. Understanding of microbiology and biochemistry of organisms adapted to cold and dark conditions may bring future economic benefits and may guide US efforts to search for evidence of life on other planets.

OPP/ANT 2009

Program Officer: Palais Julie

NSF Award Numbers:

[0636970](#)

Award Title: COLLABORATIVE RESEARCH: Elevation Change Anomalies in West Antarctica and Dynamics of Subglacial Water Transport Beneath Ice Streams and their Tributaries

PI: Slawek Tulaczyk, tulaczyk@pmc.ucsc.edu

Institution Name: University of California-Santa Cruz

State Code: CA

PE Codes: 5116

[0636719](#)

Award Title: COLLABORATIVE RESEARCH: Elevation Change Anomalies in West Antarctica and Dynamics of Subglacial Water Transport Beneath Ice Streams and their Tributaries

PI: Ian Joughin, ian@apl.washington.edu

Institution Name: University of Washington

State Code: WA

PE Codes: 5116

NSF Contract Numbers:

NSF Investments: Climate Change

New galaxy clusters discovered with the 10m South Pole Telescope

Highlight ID: 18588, Version: AC/GPA

The South Pole Telescope (SPT) is a 10-meter-diameter radio telescope deployed in February 2007 at the U.S. Amundsen-Scott South Pole Station operated by the National Science Foundation (NSF). The telescope is designed for conducting large-area millimeter and sub-millimeter wave surveys of faint, low contrast emission, as required to map primary and secondary anisotropies in the Cosmic Microwave Background (CMB) radiation.

A major goal of the SPT project is to measure the abundance of massive galaxy clusters throughout the history of the Universe. The SPT will detect galaxy clusters through the Sunyaev-Zel'dovich (SZ) effect (named after two Russian scientists who first predicted it), measuring CMB photons scattered to slightly higher energies by electrons in the hot intracluster gas. Because this technique for finding clusters uses the CMB as a backlight, it can find clusters out to arbitrarily large distances. The SPT survey will find all clusters above a certain mass limit in the ~10% of the sky targeted by the survey, and this cluster sample will have the power to greatly increase our understanding of mysterious *Dark Energy* that fills the Universe. *Dark Energy* affects the expansion rate of the

Universe, influencing both the growth of structure and the volume of the Universe. Thus, the abundance of massive structures (such as above galaxy clusters) is a sensitive probe of the nature of *Dark Energy*.

Prof. John Carlstrom and his team at the University of Chicago and other collaborating institutions have released the first major scientific results from the SPT's initial survey (<http://arxiv.org/abs/0810.1578v1>). The paper submitted to the *Astrophysical Journal* describes the detection of four distant, massive clusters of galaxies in an initial analysis of SPT survey data. Three of these galaxy clusters were previously unknown systems and, therefore, represent the first clusters detected using observations of the interaction between the hot gas in the cluster and CMB photons. These first four galaxy clusters are the most significant SZ detections from a subset of the ongoing SPT survey. As such, they serve as a demonstration that SZ surveys, and the SPT in particular, can be an effective means for finding galaxy clusters.

Primary Strategic Outcome Goal:

- Mathematical & Physical Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

Until recently, the technique of finding galaxy clusters through the SZ effect was only a promising idea; no clusters had been actually discovered this way. The SPT team has now reported the first galaxy clusters discovered in an SZ survey, and images of the discovery are shown at right. The four clusters shown are the highest-significance detections in the first 40 square degrees of the SPT survey, and three of the clusters are new discoveries. The distance between these clusters and us is estimated to range from roughly one quarter to over one-half of the size of the visible Universe.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The SPT is collaboration among several institutions including the University of Chicago/KICP, Cardiff University, Case Western Reserve University, Harvard-Smithsonian Astrophysical Observatory, McGill University, University of California at Berkeley, University of California at Davis, University of Colorado at Boulder, and University of Illinois at Urbana-Champaign. This research project represents discovery across the frontier of cosmology and astrophysics, connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and serve to society.

<http://pole.uchicago.edu/>

<http://kicp.uchicago.edu/research/highlights/>

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

The SPT conducts sensitive survey of 10% of the Southern sky in three wavelength bands and with unprecedented angular resolution. As shown in this highlight, the SPT's potential for discovery of new astronomical objects is enormous. The SPT investigation of the nature of *Dark Energy* through its impact on the growth of large cosmic structure (when compared with measurement through other techniques such as the brightness of distant supernova) could lead to transformative shifts in our understanding of the Dark Energy and of the Universe evolution.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

Basic research in understating of the nature of *Dark Energy* may lead to advances in general physics of the Universe's birth and evolution.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0638937](#)

Award Title: Cosmological Research with the 10 meter South Pole Telescope

PI: John Carlstrom, jc@kicp.uchicago.edu

Institution Name: University of Chicago

State Code: IL

PE Codes: 5115, 1217

[0750083](#)

Award Title: Science Coordination Office for Astrophysical Research in Antarctica - Phase 2

PI: John Carlstrom, jc@kicp.uchicago.edu

Institution Name: University of Chicago

State Code: IL

PE Codes: 5115

NSF Contract Numbers:

NSF Investments: None Applicable

IceCube Neutrino Telescope at South Pole began providing scientific data while still under construction

Highlight ID: 18631, Version: AC/GPA

The IceCube MREFC project recently exceeded its 2008/09 seasonal goal by deploying 19 detector strings, each instrumented with 60 digital optical modules (DOMs), at the U.S. Amundsen Scott South Pole Station. Fifty-nine strings laced with 3540 digital optical modules now comprise the IceCube Neutrino Telescope that will be completed in 2011. Drilling the 2500-meter deep ice holes with the Enhanced Hot Water Drill began without delay this season and with a new, optimized drilling procedure the drilling season ended one week ahead of the planned 16-hole schedule.

The efficiencies also led to less fuel consumption for the planned 16 strings. Consequently, IceCube received permission to drill three more ice holes than scheduled. One of the strings installed this year is a prototype for a potential six-string deep core array that will be proposed soon. This deep core array would, if approved, continue the detection of lower energy events (in the giga-electronvolts range, GeV) now provided by the AMANDA detector, IceCube's predecessor. The IceTop detector array continues to keep pace with IceCube with 19 new stations installed.

As Prof. Francis Halzen and his team at the University of Wisconsin-Madison and other collaborating institutions report, the IceCube Neutrino Telescope was taking data for 349 days in 2008 with nearly 99% of the DOMs operational. The system triggered over 3.4×10^{10} events, sending 13 TB of data by satellite and 50 TB of preprocessed data by magnetic tape north for further processing. Results from data taken with 22 strings for less than one year bettered the AMANDA detector with seven years of data taking. Both detectors have accumulated more than 5000 neutrinos, but the angular resolution of IceCube is superior. The final sample of 5114 neutrino events agrees well with the expected background of atmospheric neutrinos. No evidence of a cosmic source has been found

yet, with the most significant excess of events in the sky at 2.2 standard deviations after accounting for all trials. The IceCube team looks forward to the results from data collected in 2008 with 40 strings deployed by the end the previous season 2007/08.

Among many analyses, one was performed to search for muon neutrinos from the annihilation of Dark Matter particles trapped in the Sun. No signal was observed. The limits obtained on the annihilation rate were converted to limits on the cross-section for Dark Matter particles interacting with ordinary matter. The results are especially noteworthy in the case of Dark Matter particles with spin-dependent interactions with ordinary matter - they improve by two orders of magnitude the sensitivity previously obtained by direct experiments.

The International Polar Year (IPY) featured IceCube as one of the projects in its "Above the Poles" day December 4, 2008. IceCube researchers participated in an IPY-related webcast from the South Pole Station as part of the San Francisco Exploratorium's "Dispatches from Polar Scientists" on December 18, 2008. IceCube team members shared their South Pole experiences via websites and blogs, being interviewed by their hometown newspapers, and visiting schoolrooms and participating in various science fairs and exhibitions after the field season. Working with another NSF sponsored program, PolarTrec, and the Knowles Science Teaching Foundation, IceCube selected a high school teacher to be trained to take part in IceCube construction at the South Pole in 2009/10.

<http://www.ipy.org/index.php?ipy/detail/abovethepoles>

<http://www.exploratorium.edu/>

<http://icecube.wisc.edu/>

<http://www.expeditions.udel.edu/antarctica/>

Primary Strategic Outcome Goal:

- MREFC Projects: ALMA, Earthscope, IceCube Neutrino Observatory, SODV (Scientific Ocean Drilling Vessel), South Pole Station Modernization, NEON, OOI, ARRV, ATST

Secondary Strategic Outcome Goals:

- Mathematical & Physical Sciences
- Polar Sciences: Arctic and Antarctic Research
- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships
- International Research Experiences for Undergraduate & Graduate Students

In terms of intellectual merit, why is this outcome notable and/or important?

The research represents discovery across the frontier of cosmology and astrophysics, connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and serve to society.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

IceCube scientists and staff eagerly shared the excitement of their experiences at the South Pole Station and of the discovery potential of this project with people of all ages, genders, and underrepresented groups. The mystique of the South Pole environment and the transformative science are an alluring mix.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

The IceCube Neutrino Telescope opens a new window for extragalactic astronomy and astrophysics, exploring a range of neutrino energies that are not available from any terrestrial source built by nuclear and particle physicists. IceCube discoveries have the potential for an improved understanding of the Universe content and evolution, for instance, discovering the nature of Dark Matter. In addition, IceCube has made or will make contributions to solar physics, glaciology, and geology.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

IceCube scientists and staff eagerly shared the excitement of their experiences at the South Pole Station and of the discovery potential of this project with people of all ages, genders, and underrepresented groups. The mystique of the South Pole environment and the transformative science are an alluring mix.

What may be the benefits of the proposed activity to society?

Yes

The research represents discovery across the frontier of cosmology and astrophysics, connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and serve to society.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0639286](#)

Award Title: IceCube Neutrino Observatory Maintenance and Operations

PI: Francis Halzen, halzen@icecube.wisc.edu

Institution Name: University of Wisconsin-Madison

State Code: WI

PE Codes: 006F

[0236449](#)

Award Title: IceCube Startup and Construction Project

PI: Francis Halzen, halzen@icecube.wisc.edu

Institution Name: University of Wisconsin-Madison

State Code: WI

PE Codes: 5281, 005F

[0653266](#)

Award Title: High Energy Neutrino Astronomy with IceCube

PI: Spencer Klein, srklein@lbl.gov

Institution Name: University of California-Berkeley

State Code: CA

PE Codes: 5115, 1643

NSF Contract Numbers:

NSF Investments: None Applicable

NSF Sponsored Film Nominated for Academy Award

Highlight ID: 18644, Version: AC/GPA

ANT- 0538072

Werner Herzog, under an Antarctic Artists and Writer's Award from NSF/OPP/ANT, created a film about the US Antarctic Program and Antarctic science in general. The film is titled "Encounters at the End of the World" and it has been won praise at several film festivals. It was recently nominated for an Academy Award.

Primary Strategic Outcome Goal:

- Public Understanding of Science and Lifelong Learning

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

Public awareness of the US Antarctic Program - a US national program managed by NSF - via an Oscar-nominated film is notable.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The film captures the human side of Antarctic science along with the excitement of discovery and the relevance of science to society.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

It shows a diverse array of people involved in science.

What may be the benefits of the proposed activity to society?

Yes

Greater public understanding of science.

OPP/ANT 2009

Program Officer: Kim Silverman

NSF Award Numbers:

[0538072](#)

Award Title: Documentary Film - ANTARCTICA: THE INNER LANDSCAPE

PI: Werner Herzog, hkaiser@mindspring.com

Institution Name: Herzog Werner

State Code: CA

PE Codes: 5130

NSF Contract Numbers:

NSF Investments: International Polar Year (IPY)

BICEP Telescope at South Pole makes first maps of CMB Polarization on the angular scales which probe the physics of Inflation

Highlight ID: 18761, Version: AC/GPA

Observations of the Cosmic Microwave Background (CMB) radiation from telescopes at high-altitude sites and on satellites have produced a wealth of information about our Universe on its largest scales, precisely measuring the Universe's age, composition, and the seeds of its structure. BICEP is a novel mm-wave telescope designed by Prof. Andrew Lange and his team at the California Institute of Technology and deployed at the U.S. Amundsen-Scott South Pole Station to test theories of the very origin of the Big Bang by probing the earliest times and highest energies accessible to physics using precise measurements of the CMB polarization. In the course of these observations, however, BICEP also measured polarization that originates much closer to home, mapping out the polarized emission from dust and free electrons which trace our own Galaxy's magnetic fields.

Between March 2006 and December 2008, BICEP has been observing nearly continuously, mainly targeting CMB polarization in an 800 square-degree region of the Southern sky that is uniquely free of Galactic emission, but also dedicating 15% of its time to mapping out polarized emission from our Milky Way Galaxy. The resulting maps like the one shown at right uniquely trace the large-scale magnetic fields essential to understanding the dynamics of star formation in our Galaxy. They also provide feedback to models which predict levels of Galactic foreground emission and their impact on future CMB missions like the Planck satellite. Finally, because BICEP's polarization response has been precisely referenced to artificial sources, these maps offer a unique astronomical calibration standard, and will ultimately specify the orientation of polarized Galactic emission at three frequencies (100, 150, and 220 GHz) to the level of precision required for Planck to use this emission for in-flight calibration.

Primary Strategic Outcome Goal:

- Mathematical & Physical Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

The research represents discovery across the frontier of cosmology and astrophysics, connected to learning, innovation, and education. The BICEP conducts sensitive survey of 800 square degrees of the Southern sky in two wavelength bands and with unprecedented sensitivities and angular resolution.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

While the BICEP project produces CMB polarization maps of unprecedented sensitivity, it remains a small-scale experiment driven largely by the efforts of the graduate and post-doctoral students it trains. So far this has included eight PhD students at Caltech, Berkeley, and UC San Diego and over a dozen undergraduates whose combined efforts have built the telescope, taken it to the South Pole, commissioned and calibrated it, and continue to analyze its science data. In the past three years, they have shared their enthusiasm with dozens of school groups and public lecture audiences, explaining to each how their careers in science have led them to study the beginning of time from the bottom of the Earth. This enables people who work at the forefront of discovery to

make important and significant contributions to science and engineering knowledge, and serve to society.

http://www.astro.caltech.edu/~lgg/bicep_front.htm

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

The BICEP's investigation to test theories of the very origin of the Big Bang by probing the earliest times and highest energies accessible to physics could lead to transformative shifts in our understanding of the Universe origin and evolution.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

Basic research in understating of the nature of early Universe's gravitational waves may lead to advances in general physics of the Universe's birth and evolution.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0230438](#)

Award Title: Background Imaging of Cosmic Extragalactic Polarization (BICEP): An Experimental Probe of Inflation

PI: Andrew Lange, ael@astro.caltech.edu

Institution Name: California Institute of Technology

State Code: CA

PE Codes: 5115

[0742818](#)

Award Title: Collaborative Research: BICEP2 and SPUD - A Search for Inflation with Degree-Scale Polarimetry from the South Pole

PI: John Kovac, jmkovac@caltech.edu

Institution Name: California Institute of Technology

State Code: CA

PE Codes: 5115, 1217

[0742592](#)

Award Title: Collaborative Research: BICEP2 and SPUD - A Search for Inflation with Degree-Scale Polarimetry from the South Pole

PI: Clement Pryke, pryke@oddjob.uchicago.edu

Institution Name: University of Chicago

State Code: IL

PE Codes: 5115

NSF Contract Numbers:

NSF Investments: None Applicable

Dan David Prize is split between the U.S. and Italian astrophysicists

Highlight ID: 18792, Version: AC/GPA

Prof. Andrew Lange of Caltech is sharing the 2009 Dan David Prize for the Past Time Dimension (<http://www.dandavidprize.org/>) with his BOOMERanG and MAXIMA co-investigators Prof. Paolo de Bernardis of University La Sapienza (Italy) and Prof. Paul Richards of University of California at Berkeley.

The prize, awarded annually, covers three time dimensions - Past, Present and Future - that represent realms of human achievement, recognizing and encouraging innovative and interdisciplinary research that cuts across traditional boundaries and paradigms. The Past Time Dimension specifically refers to scientific fields that expand knowledge of former times.

Prof. Lange is known for the discovery of the large-scale spatial geometry of the Universe being spatially flat, of its total mass-energy density having a "critical" value and for major by-products of this discovery. He confirmed the existence of a negative-pressure Dark Energy pervading the Universe; provided evidence for an Inflationary epoch at the beginning of the Universe, and measured the Universe's mean density, matter density and other cosmological parameters.

Together with Paolo De Bernardis (and parallel with Paul Richards' MAXIMA experiment) Prof. Lange led the BOOMERanG experiment which measured the angular sizes and amplitudes of the first few acoustic peaks in the afterglow of the Big Bang - the Cosmic Microwave Background (CMB) radiation. These results led Lange and colleagues to deduce the Universe's geometry and to make other discoveries.

The publication of the BOOMERanG and MAXIMA data in 2000 provided the first undisputed evidence that the Universe has a flat geometry. Additional analysis of the data implied that ordinary matter makes a small fraction of the cosmic mass density (5% at the present time). These results have been confirmed subsequently and carry important implications for fundamental physics. The nature of most of the cosmic matter (known as Dark Matter) is actively being explored, and the flat geometry of the Universe is believed to have originated from an early epoch of Inflation, during which space curvature was erased by a prolonged period of vast expansion.

The BOOMERanG and MAXIMA projects were milestones in a series of experiments to study the CMB radiation properties. Now Prof. Lange leads a new experiment at the U.S. Amundsen-Scott South Pole Station called BICEP (Background Imaging of Cosmic Extragalactic Polarization), which is designed to measure the CMB's polarization to unprecedented precision. Prof. Lange hopes to answer crucial questions about the beginnings of the Universe through the potential detection of primordial gravitational waves imprint in his experimental observations.

The Dan David Prize is 1M U.S. dollars, and there is a stipulation that its laureates donate 10% of their prize money to graduate students in their respective fields, thereby contributing to the community and fostering a new generation of scholars

Primary Strategic Outcome Goal:

- Mathematical & Physical Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

Prof. Lange's discoveries go across the frontier of cosmology and astrophysics being connected to learning, innovation, and education.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Prof. Lange fosters research that advances the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit, and establishing the nation

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

Lange's investigations test theories of the very origin of the Big Bang by probing the earliest times accessible to physics that could lead to transformative shifts in our understanding of the Universe origin and evolution.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

Basic research in understating of the nature of early Universe's gravitational waves may lead to advances in general physics of the Universe's birth and evolution.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0230438](#)

Award Title: Background Imaging of Cosmic Extragalactic Polarization (BICEP): An Experimental Probe of Inflation

PI: Andrew Lange, ael@astro.caltech.edu

Institution Name: California Institute of Technology

State Code: CA

PE Codes: 5115

[0742818](#)

Award Title: Collaborative Research: BICEP2 and SPUD - A Search for Inflation with Degree-Scale Polarimetry from the South Pole

PI: John Kovac, jmkovac@caltech.edu

Institution Name: California Institute of Technology

State Code: CA

PE Codes: 5115, 1217

NSF Contract Numbers:

NSF Investments: None Applicable

Multi-instrument geospace observations on Antarctica

Highlight ID: 18986, Version: AC/GPA

The Polar Experiment Network for Geospace Upper-atmosphere INvestigations (PENGUIn) project supports a number of autonomous geophysical observatories (AGO) deployed across the Antarctic

continent, which are instrumented to measure various ionospheric and magnetospheric parameters with low-powered magnetometers, riometers, very low frequency (VLF) and high frequency (HF) receivers, optical and other related instruments (more information, including data, are available at <http://www.antarcticsspace.org>).

One of the main objectives of this observing network is to study the evolution of *magnetospheric substorms* - an intense phenomena occurring roughly every 3 hours, where energy from the solar wind is first stored within Earth's magnetic field and then suddenly released in a spectacular display of aurora and various other phenomena on the nightside of Earth. The most classic signature of this substorm is a sudden increase in the flux of energetic particles observed by satellites at geosynchronous orbit. During strong geomagnetic storms, these particles could damage satellites' electronic equipment.

Although this particle injection signature has been studied extensively, a new paper published by the PENGUIn team in the *Journal of Geophysical Research* shows that energetic particles can sometimes be observed at much higher latitudes than previously expected. The critical observations during the March 23, 2007 substorm were acquired by the AGO network operating remotely at high latitudes on the Antarctic Plateau.

Using fluxgate magnetometer data, supported by numerical modeling, the science team determined that the locations of the observatories straddle the open-closed magnetic field boundary. Near these locations (on closed field lines), VLF and riometer signatures show effects of energetic particle precipitation in the morning sector (extending to the post-dawn region), confirmed by observations at geosynchronous orbit. In the VLF data, both the initial injections as well as echoes are observed. The mechanism responsible for such high-latitude injections is thought to be a combination of dynamics of the injection process and drift-shell splitting processes not yet incorporated into current injection models.

Understanding magnetospheric substorm dynamics is the main objective of the THEMIS satellite mission (http://www.nasa.gov/mission_pages/themis/) and persists as one of the more difficult problems in space science. The PENGUIn results described here take advantage of the THEMIS data and, by comparing THEMIS to ground observations, provide new results that can only be achieved by comparisons of ground- to satellite data.

Lessard, M. R., et al. (2009), PENGUIn multi-instrument observations of dayside high-latitude injections during the 23 March 2007 substorm, *J. Geophys. Res.*, 114, A00C11, doi:10.1029/2008JA013507.

Primary Strategic Outcome Goal:

- Geosciences: Earth, Atmosphere, and Ocean Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Undergraduate Education and Undergraduate Student Research
- Graduate Education and Graduate Student Research

In terms of intellectual merit, why is this outcome notable and/or important?

The research represents discovery across the frontier of geosciences and geospace sciences connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and to serve society.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The PENGUIn project is a collaboration among several institutions including the University of New Hampshire, Siena College, Augsburg College, Dartmouth College, New Jersey Institute of

Technology, Stanford University, Virginia Tech University, University of California-Berkeley, and University of Maryland-College Park. This research project represents discovery across the frontiers of geospace and space sciences, connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and serve to society.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)
Yes

Existing models of energetic particle injections have, to date, not taken drift shell splitting effects into account, in spite of the fact that these models do not adequately explain substorm injection signatures. The results acquired in this study demonstrate the importance of this effect.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)
No

What may be the benefits of the proposed activity to society?
Yes

This study directly supports studies of substorm injections, which are thought to provide seed particles for Earth's radiation belts. By understanding the injection process in more detail, scientists will be able to understand better the radiation belt dynamics. Radiation belts can provide hazardous environments for astronauts and satellites.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili
NSF Award Numbers:
[0636874](#)

Award Title: Collaborative Research: Polar Experiment Network for Geospace Upper Atmosphere Investigations (PENGUIn) - Advancing the Vision for Global Studies
PI: Marc Lessard, marc.lessard@unh.edu
Institution Name: University of New Hampshire
State Code: NH
PE Codes: 5115

[0636790](#)

Award Title: Collaborative Research: Polar Experiment Network for Geospace Upper-atmosphere Investigations (PENGUIn) - Advancing the Vision for Global Studies
PI: Allan Weatherwax, aweatherwax@siena.edu
Institution Name: Siena College
State Code: NY
PE Codes: 5115

[0636927](#)

Award Title: Collaborative Research: Polar Experiment Network for Geospace Upper atmosphere Investigations (PENGUIn) - Advancing the Vision for Global Studies
PI: Umran Inan, inan@nova.stanford.edu
Institution Name: Stanford University
State Code: CA
PE Codes: 5115

NSF Contract Numbers:

NSF Investments: None Applicable

British-American cooperation in observational studies of EMIC waves during geomagnetic storms

Highlight ID: 19006, Version: AC/GPA

As a result of over a decade of cooperation between NSF and the British Antarctic Survey (BAS), an 8-year data base of electromagnetic ion cyclotron (EMIC) waves, which covers over 2/3 of an 11-year solar cycle, has been accumulated at auroral latitudes in Antarctica. Such waves (with frequencies between 0.1 and 5 Hz in the ultra-low-frequency range of the electromagnetic spectrum) play a significant role in the increase and decay of the populations of energetic ions and electrons that make up Earth's radiation belts. EMIC waves are frequently observed by research spacecraft and by ground-based induction magnetometers.

In 1994, BAS invited Prof. Mark Engebretson of Augsburg College and Prof. Roger Arnoldy of the University of New Hampshire to supply a set of 3-axis induction magnetometers as part of the instrumentation for an array of Automatic Geophysical observatories (AGOs). The first of these NSF-funded induction magnetometers, constructed at UNH and calibrated at Augsburg, was installed in 1996. During the combined life of these BAS AGOs, from 1996 through 2003, data were available from at least one site for 2648 of the possible 2922 days, for a 91% coverage ratio.

These AGOs provide a unique data set in an electromagnetically quiet region of Earth supplying large statistics of the occurrence of EMIC waves as a function of the phase and characteristics of the many geomagnetic storms that occurred during this 8-year interval. Many previous theoretical and observational studies of the EMIC wave effects focused exclusively on intervals near the "zero epoch" of storms and during their aftermath. Superposed epoch analysis of the data collected by induction magnetometers at BAS' AGOs provides a reality check, suggesting that such waves are in fact more prominent during non-storm times, and occur predominantly during near-noon hours in all phases of geomagnetic storms. These observations of increased wave activity during non-storm times are consistent with published studies, but more work is needed to characterize further variations in wave occurrence as a function of the various drivers of geomagnetic storms.

Murphy, M. T., M. J. Engebretson, J. L. Posch, M. R. Lessard, M. Denton, and R. B. Horne, Occurrence patterns of magnetospheric EMIC waves during geomagnetic storms: Ground-based observations at auroral and subauroral latitudes, presented at the Fall Meeting of the American Geophysical Union, December 16, 2008.

Primary Strategic Outcome Goal:

- Geosciences: Earth, Atmosphere, and Ocean Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Undergraduate Education and Undergraduate Student Research
- International Research Experiences for Undergraduate & Graduate Students

In terms of intellectual merit, why is this outcome notable and/or important?

Understanding geomagnetic storms is important both for the intrinsic value of better understanding the fundamental plasma processes that accelerate and/or destabilize highly energetic charged particles in Earth's space environment, and for the practical ability to better forecast and respond to such storms and thus avert deleterious consequences to both space-based and ground-based technological systems.

Studies of near-Earth space continue to be hampered by lack of sufficient *in situ* coverage by the few properly equipped research spacecraft in orbit. Ground-based magnetometers provide data that greatly extend and complement data from such spacecraft.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The task of analyzing naturally occurring waves is uniquely accessible to talented undergraduate researchers. Undergraduates have played a major role in Augsburg's space research activity for over 30 years; over 85% of those involved have gone on to further study in graduate or professional programs. Michael Murphy, who carried out this analysis while an undergraduate physics major at Augsburg College, is now completing a dual-degree program in Civil Engineering at the University of Minnesota in Minneapolis.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)
No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

Exposing undergraduates to front-line research at Augsburg College has provided students with both the motivation and key skills needed to continue their education in science and engineering beyond the undergraduate level.

What may be the benefits of the proposed activity to society?

Yes

Better understanding of the development of geomagnetic storms can lead to improved predictions that can safeguard both space-based and ground-based technological systems.

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0442648](#)

Award Title: Collaborative Research: Using Ground-based Observations of ULF Waves at Auroral and Subauroral Latitudes in Antarctica to Probe Earth's Space Environment

PI: Mark Engebretson, ENGBRET@AUGSBURG.EDU

Institution Name: Augsburg College

State Code: MN

PE Codes: 5115

[0442787](#)

Award Title: Collaborative Research: Using Ground-based Observations of ULF Waves at Auroral and Subauroral Latitudes in Antarctica to Probe Earth's Space Environment

PI: Marc Lessard, marc.lessard@unh.edu

Institution Name: University of New Hampshire

State Code: NH

PE Codes: 5115

NSF Contract Numbers:

NSF Investments: None Applicable

Research and Education Opportunities in Antarctica for Minorities (ROAM)

Highlight ID: 19135, Version: AC/GPA

In the winter of 2007/2008, the International Polar Year (IPY) Research and Education Opportunities in Antarctica for Minorities (ROAM) project went on a field trip to Antarctica. The culmination of this field research experience included individual student research projects to be presented at national conferences. At the Society for the Advancement of Chicano and Native Americans in Science (SACNAS) conference in 2008, three undergraduate students won awards for their original research. IPY-ROAM provided a comprehensive mentoring program before and after the field research expedition that took 15 undergraduate, five graduate and one postdoctoral student and five K-12 teachers to Antarctica for a research experience focused on increasing minority participation in research. Online coursework and a field visit to Washington D.C. prior to the field experience united the participants from across the U.S. and introduced the research theme "***How is Antarctica responding to global change and why is change in Antarctica important to the rest of the globe?***"

Primary Strategic Outcome Goal:

- Teacher Education and In-service Professional Development
- Undergraduate Education and Undergraduate Student Research
- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships
- International Research Experiences for Undergraduate & Graduate Students
- Public Understanding of Science and Lifelong Learning
- Broadening Participation to Improve Workforce Development

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

Key drivers of the project are that hands-on field-based instructional and research experiences provide students and teachers with transformational educational and life experiences; minority groups are severely under-represented in engineering and science and most university study abroad programs - especially in the polar sciences; the International Polar Year (IPY) provides a unique opportunity to educate the next generation of scientists and the general public about the Polar Regions and their importance to the global system. To address these issues, the objectives of this proposal are to 1) increase the number of underrepresented minorities continuing on to higher degrees or careers in science and 2) increase public awareness and knowledge about the Polar Regions. To this end, the educators and students took a novel and life-changing trip to Antarctica to acquire first-hand experience in field-based research and system science. The experienced team of lead investigators recruited participants from across the U.S. focusing on minority applicants. Participants earned course credit for preparatory work done through web-casting to understand more about the Antarctic environment, climate change and explore concepts relating to the importance of advancing the representation of minorities in science and engineering. During a field trip to Washington D.C. the participants interacted with experts in the polar sciences and organizations affiliated with international policy and tourism in Antarctica. The capstone 3-week field trip was aboard an Antarctic tourist vessel from Tierra del Fuego to the Antarctic Peninsula where participants were mentored in the design, implementation, documentation and dissemination of hands-on field based research.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Broadening participation of underrepresented groups in polar science is the focus of this project. The participants were mainly from underrepresented groups: Teachers: five women, two from underrepresented minorities; Students: 16 women, 20 of 24 from underrepresented groups. While in the field, the project shared interviews, text and photos via live satellite feeds to public radio, a project web site with question/answer interactivity and journals from students and teachers. Curriculum materials and an educational documentary of the Antarctic field experience are in post-production for release in 2009. Field data course materials, and evaluations related to the formal assessment of the success of the project will go into the archive at the National Snow and Ice Data Center (NSIDC). This project celebrates the IPY through a field experience that will improve public awareness of the Polar Regions and contribute to the recruitment of minorities to polar science.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)
No

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

This project involved 22 minority participants in a group of 29 in a field research experience in Antarctica. The student participants are more likely to pursue academic careers in polar science. The teachers will mentor hundreds of students each year in K-12 classrooms while the student participants reach positions in academia where they too will be role models for minorities in science. In addition, the project has engaged the public through radio, newspaper and a museum exhibit at the University of Texas El Paso where hundreds of families and school groups visit each day.

What may be the benefits of the proposed activity to society?

No

OPP/ANT 2009

Program Officer: Renee Crain

NSF Award Numbers:

[0632360](#)

Award Title: IPY-ROAM: International Polar Year Research and Educational Opportunities in Antarctica for Minorities

PI: Craig Tweedie, ctweedie@utep.edu

Institution Name: University of Texas at El Paso

State Code: TX

PE Codes: 7494, 7179, 5208, 5130

NSF Contract Numbers:

NSF Investments: American Competitiveness Initiative (ACI), Climate Change, International Polar Year (IPY), Environment (including the importance of fresh water and dynamics of water processes)

New CMB Polarization Results from QUaD

Highlight ID: 19160, Version: AC/GPA

The Cosmic Microwave Background (CMB) radiation is "light" that comes to us from the "fireball" phase of the infant Universe, only 400,000 years after the Big Bang itself. Due to the subsequent expansion of the Universe, this light is detected today as a faint glow of microwaves over the entire sky, which can be measured with specialized radio telescopes. To obtain the best possible view of this ancient light the QUaD Telescope was located at the U.S. National Science Foundation's

Amundsen-Scott South Pole Station, and operated through three six-month-long Antarctic nights, where temperatures plunge to -75°C .

The QUaD collaboration has published new results on the CMB polarization observations with far higher sensitivity than previous measurements [Astrophysical Journal, 692, 2009, 1247-1270]. The plot on the right shows new results from QUaD - the E-mode data are seen to be in accord with the theoretical expectation (blue line), while B-modes are shown to be close to zero as expected. Another way to view this result is to make maps of the sky pattern in E-modes and B-modes as we see in the figures.

These results are perfectly in accord with the prevailing Standard Cosmological Model, lending further support to this highly successful, but equally mysterious, theory of the Universe. This model makes specific predictions about the pattern of the CMB glow, including that it should be polarized in a particular way - there should be no "swirliness". In the jargon of cosmology, "swirls" are called B-modes, and non-swirls are called E-modes.

QUaD is a collaboration lead by scientists at Stanford University, the Kavli Institute of Cosmological Physics at the University of Chicago, and Caltech in the U.S., and Cardiff University in the U.K., and includes more than thirty members from twelve institutions.

Primary Strategic Outcome Goal:

- Mathematical & Physical Sciences
- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Graduate Education and Graduate Student Research
- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

The QUaD results represent a major step forward in the extremely challenging experimental field of CMB measurement.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The Standard Cosmological Model has been rapidly gathering strength in recent years, evolving from the realm of speculation to become a hard scientific theory. Data from a wide range of telescopes around the world all seem to support the model, with few conflicts reported. However, the model also proposes that the Universe is dominated by two components, neither of which we can see directly. The first is dark matter, an entirely new kind of matter that appears to suffuse throughout our galaxy (and others) without interacting with the ordinary matter of which stars, planets, and humans are made. The second new component is even more mysterious - a strange substance known as dark energy that is energy of empty space itself.

By further supporting the Standard Cosmological Model the new results from QUaD have a strong impact on the field of cosmology and physics more generally.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

Because of this contradiction between a theory that makes testable predictions, but contains components that we do not understand, it is essential to conduct every possible test. With the new results from QUaD the Standard Cosmology passes yet another stringent test with flying colors.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

This research project represents discovery across the frontier of cosmology and astrophysics, connected to learning, innovation, and education. This enables people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge, and to serve society.

In addition - and very importantly - cosmological research is a superb vehicle for engaging the public in scientific research. The questions being addressed capture the public imagination like few others - "where did the Universe come from and how will it end."

OPP/ANT 2009

Program Officer: Vladimir Papitashvili

NSF Award Numbers:

[0739413](#)

Award Title: Collaborative Research: Analysis of data from the QUaD experiment

PI: Clement Pryke, pryke@oddjob.uchicago.edu

Institution Name: University of Chicago

State Code: IL

PE Codes: 5115, 1217

[0739729](#)

Award Title: Collaborative Research: Analysis of Data from the QUaD Experiment

PI: Sarah Church, schurch@stanford.edu

Institution Name: Stanford University

State Code: CA

PE Codes: 5115

[0638615](#)

Award Title: Collaborative Research: Next Generation CMB Polarization Measurements with the QUaD Experiment

PI: Sarah Church, schurch@stanford.edu

Institution Name: Stanford University

State Code: CA

PE Codes: 5115

NSF Contract Numbers:

NSF Investments: None Applicable

Postponing life in extreme environments?

Highlight ID: 19162, Version: AC/GPA

The McMurdo Dry Valleys of Antarctica are one of the coldest and driest desert environments on earth. With extreme temperatures and darkness during the austral winter, terrestrial life forms in the salty desert soils are physiologically challenged by lack of water. The dominant metazoans in Dry Valley soils are nematodes, a microscopic worm with a multi-year life cycle that is commonly found in a freeze-dried state called "anhydrobiosis." During anhydrobiosis, 95-99% of body water is shed, and metabolism shuts down, allowing the worms to postpone their life cycle until conditions improve.

A graduate student at Brigham Young University (BYU), Bishwo Adhikari, working collaboratively with McMurdo Dry Valley's Long Term Ecological Researchers Bryan Adams of BYU and Diana Wall of Colorado State University, has conducted experiments that reveal the genes associated with anhydrobiosis. In the study, Antarctic nematodes were desiccated under controlled, laboratory conditions, while a parallel group was maintained in a live state. Genomic analyses were conducted for both sets of organisms. This comparative method, called subtractive hybridization, allows identification of differentially expressed genes. Further evaluation using databases such as GenBank allows scientists to begin the evaluation of what functions these differentially expressed genes control.

Their findings revealed a suite of novel genes, i.e. not previously identified in databases, which may be unique to Antarctic organisms. "Known" genes expressed during anhydrobiosis were associated with metabolic and stress responses that likely facilitate physiological reorganization. A most unusual finding is a gene associated with antifreeze protein production, very similar to one found in Atlantic herring. While many organisms produce antifreeze substances, it is rare that their structures show such a high degree of similarity between such divergent species. The work is published in BMC Genomics (2009) 10:69.

The Antarctic nematodes, although microscopic, are significant drivers of carbon cycling in this unusual cold desert ecosystem. The identification of genes associated with desiccation reveals a fundamental capability to adapt to a harsh and variable climate. Genomic studies such as this enable scientists to look for similar genes in other organisms and environments, further broadening our view of how populations and ecosystems adapt to changing environmental circumstances.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Graduate Education and Graduate Student Research

In terms of intellectual merit, why is this outcome notable and/or important?

As noted in the concluding paragraphs of the highlight, the identification of genes associated with desiccation is like having a key to understanding adaptation from an evolutionary perspective. This key allows scientists to search for similar genes in other populations and ecosystems to determine their adaptive capacity with respect to climate change.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The research embodies the fulfillment of genome-enabled biology, a fundamental goal of IPY. In addition, the discovery of antifreeze proteins and the genes associated with anhydrobiosis may have commercial application (see below).

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

As noted above, the findings are an excellent example of genome-enabled science that has relevance for ecosystem responses to global change, as well as food storage and preservation.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

The research was carried out by a graduate student.

What may be the benefits of the proposed activity to society?

Yes

Antifreeze proteins have commercial application for engineering frost-tolerant plants and fish, and anhydrobiotic response genes may have similar uses for food storage.
OPP/ANT 2009

Program Officer: Roberta Marinelli

NSF Award Numbers:

[0832755](#)

Award Title: The Role of Resource Legacy on Contemporary Linkages Between Biodiversity and Ecosystem Processes in a Cold Desert Ecosystem: The McMurdo Dry Valley LTER Program

PI: Andrew Fountain, andrew@pdx.edu

Institution Name: Portland State University

State Code: OR

PE Codes: 5111, 1195

NSF Contract Numbers:

NSF Investments: Climate Change, Environment (including the importance of fresh water and dynamics of water processes)

Fossils provide clues to the future of Antarctic marine life

Highlight ID: 19214, Version: AC/GPA

Durophagus (shell-breaking) marine predators, which include many decapod and anomuran crustaceans (e.g. blue crabs), are common occupants of nearshore environments but are noticeably absent in coastal Antarctic waters. These absences are related to physiological limitations associated with cold temperatures. Crabs, for example, are unable to eliminate magnesium, a common seawater ion -- in the subzero waters of the Antarctic, magnesium has a narcotizing effect, and becomes lethal. Freedom from predators, over time, has allowed the Antarctic benthos to maintain a rich fauna of primitive life forms such as seastars, crinoids, and brachiopods, as well as modern invertebrates more common to temperate waters.

It wasn't always this way. Richard Aronson of the Florida Institute of Technology, and colleagues working in the Antarctic peninsula, found fossil evidence from the La Meseta Formation at Seymour Island, that shows a shift in benthic fauna with a change in climate. Approximately 40 million years ago, Antarctic coastal seas cooled nearly 10 degrees over several million years. The faunal remains associated with this cooling show a rapid rise in predation-sensitive invertebrates and the development of rich suspension-feeding assemblages, including the echinoderms *Ophiura* and *Metacrinus*. This rise is paralleled by the gradual extinction of durophagous predators. Interestingly, the brachiopod *Bouchardia* was present throughout the cooling period. Morphometric analysis of *Bouchardia* shells indicates that their shape and strength did not change substantially during this time. The evidence suggests *Bouchardia* may be insensitive to breakage by shell crushing predators and is broadly capable of withstanding a variety of stressors (Aronson et al, PLoS ONE 4(2)).

Today, the Antarctic peninsula region is warming. Air temperatures have risen 5 degrees C, and surface water temperatures have risen 1 degree C, over the last 50 years. Accordingly, the peninsula ecosystem is changing - sea ice extent is decreasing, phytoplankton composition is shifting, and plankton tows indicate that crab larvae are making their way across the Drake passage and into Antarctic waters. Using both geologic and modern oceanographic data, Aronson and colleagues are making predictions for the future of Antarctic benthos. They suggest that predation pressure on the benthic fauna will increase; the character and function of the endemic benthos will be altered dramatically, but that some epifauna will survive the predator invasion. They also note that, in the past, climate change has been relatively gradual compared to current temperature trends, and species invasions were not aided by modern transportation. An important question is,

How will the benthos respond to the rapid rates of climate change, and the specter of species invasions, on the horizon?

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Academic Research Fleet
- Polar Facilities & Logistics

In terms of intellectual merit, why is this outcome notable and/or important?

The work is a striking example of geological findings used to infer ecological relationships that have bearing on the future.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Climate change is a pressing issue in polar regions.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

The research will promote new integrative investigations that link ecology, paleobiology, and physiology with global change.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

The research includes young investigators.

What may be the benefits of the proposed activity to society?

Yes

As noted above, the research has important implications for ecological responses to global change.

OPP/ANT 2009

Program Officer: Scott Borg

NSF Award Numbers:

[9908828](#)

Award Title: Global Climate Change and the Evolutionary Ecology of Antarctic Mollusks in the Late Eocene

PI: Richard Aronson, aronson@fit.edu

Institution Name: Marine Environmental Sciences Consortium

State Code: AL

PE Codes: 5112

NSF Contract Numbers:

NSF Investments: Climate Change, Environment (including the importance of fresh water and dynamics of water processes)

Warming ocean's effect on Antarctic marine ice sheets

Highlight ID: 19248, Version: AC/GPA

The West Antarctic ice sheet (WAIS) at its coastal margins is grounded below sea level. The stability of this shelf ice in our warming ocean is a complex balance between upstream ice influx, iceberg discharge into the coastal ocean, and the rate of melting at the base of these floating ice shelves. Ice shelves such as those in the Pine Island Bay region of the Amundsen Sea (see satellite image and insert) appear to be markedly and rapidly thinning, suggesting that West Antarctica is more sensitive to changing climate than is currently believed, or is represented in climate models. During this year's (2009) austral summer cruise of the RV/IB Nathaniel B. Palmer, US and UK scientists have been engaged in extensive measurement of seawater temperature, salinity and currents at the Pine Island Glacier shelf front to determine the thermohaline environment at the base of this ice sheet. As well as profiling the variability of deep ocean water access up onto the continental shelf, the UK Autosub, a submersible robot that can travel under ice, was successfully used to map the dimensions of the seawater cavity under the ice sheet. This will allow a better understanding of the thermal stability of the shelf ice.

[NSF Award 0632282: OPP AOAS]

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research (AC/GPA selected)

Secondary Strategic Outcome Goals:

In terms of intellectual merit, why is this outcome notable and/or important?

The rate of melting of Antarctica's extensive ice shelves is a strong controller of global sea level, and is both an indicator and determinant of global climate change.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

Rising sea-level in this century will force a myriad of human, social and economic change.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

Stability of the West Antarctic ice sheet has been until recently monitored and thought of as a function of the warming atmosphere over the Antarctic continent. The warming effect of the ocean to ice shelves, which serve to buttress upstream ice flows, is potentially a much more dominate term.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

The research cruise that enabled these studies included a full complement of US and UK researchers, and graduate students.

What may be the benefits of the proposed activity to society?

Yes

Mitigation and adaptation to global climate change will be a major determinant and activity of the U.S. economy for the foreseeable future.

OPP/ANT 2009

Program Officer: Peter Milne

NSF Award Numbers:

[0632282](#)

Award Title: IPY/ASEP - Collaborative International Research: Amundsen Sea Influence on West Antarctic Ice Sheet Stability and Sea Level Rise.

PI: Stanley Jacobs, sjacobs@ldeo.columbia.edu

Institution Name: Columbia University

State Code: NY
PE Codes: 5113

NSF Contract Numbers:

NSF Investments: Climate Change, International Polar Year (IPY), Environment (including the importance of fresh water and dynamics of water processes)

Ecosystem Change in the West Antarctic Peninsula Top Down, or Bottom Up?

Highlight ID: 19262, Version: AC/GPA

The West Antarctic Peninsula (WAP) is one of the most rapidly warming regions on Earth. Over the last 50 years, winter temperatures have risen five times faster than the global average and the duration of sea ice coverage has decreased. A warm, moist maritime climate has moved into the northern WAP region, pushing the continental, polar conditions to the south.

Researchers in the Palmer LTER (Long Term Ecological Research) project have uncovered a suite of ecological changes associated with this climatic shift. Species that depend on sea ice, such as the Adelie penguin, Antarctic silverfish, and krill, have decreased in the northern region of the WAP, and accordingly, new species that typically avoid ice, such as gentoo and chinstrap penguins, and lanternfish are moving into the habitat.

Why is the change occurring? Is it because top predators like the Adelie penguin are driven out by climatic factors that directly impact their success? Recently, Palmer scientists showed that a byproduct of the warmer maritime climate is increased ground moisture. The melting snow at Adelie nest sites impedes oxygen exchange in eggs, reducing the number of hatchlings. What other factors are involved in species declines?

Using satellite data on ocean color, temperature, sea ice and winds, substantiated by *in situ* measurements, LTER post doc Martin Montes Hugo and colleagues have shown that primary productivity in the waters of the WAP has changed dramatically over the last 20 years. In the north, where ice-dependent species are disappearing, wind stress has increased. The wind intensity and reduced sea ice causes greater mixing of the surface ocean waters. The result - a deepening of the surface mixed layer that lowers cell size and primary productivity rates, because phytoplankton cells are exposed to less light.

Conversely, in the southern WAP, where ice-dependent species continue to thrive, the situation is reversed. Sea ice is less prevalent but still creates a fresh water lens, the winds are calmer and the waters are highly stratified. These features promote the formation of a stable and shallow mixed layer, with increased light and the development of large phytoplankton cells, such as diatoms. Diatoms form the base of the rich Antarctic food web that includes krill, penguins and whales.

The research shows that climate change is influencing populations and ecological processes including carbon cycling from the bottom up (changing phytoplankton) as well as from the top down (affecting large predators). The Long Term Ecological Research Program enables long term tracking of ecological variables, so that the mechanisms of climate change impact on ecosystems can be revealed. The research has been published in the journal *Science* (Recent Changes in Phytoplankton Communities Associated with Rapid Regional Climate Change Along the Western Antarctic Peninsula, *Science Magazine*, 13 March 2009)

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Postdoctoral Education, including International Postdoctoral Fellowships

In terms of intellectual merit, why is this outcome notable and/or important?

The research reveals the mechanism by which climate change influences ecosystem structure and function

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The paper was published by a post doctoral researcher with the Palmer LTER.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

It demonstrates that climatically-driven, top-down and bottom-up processes impact ecosystems.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

Yes

Yes, it helps to facilitate the introduction of a new investigator into the research pool.

What may be the benefits of the proposed activity to society?

Yes

Climate change has important societal implications.

OPP/ANT 2009

Program Officer: Roberta Marinelli

NSF Award Numbers:

[0823101](#)

Award Title: Palmer, Antarctica Long Term Ecological Research Project

PI: Hugh Ducklow, hducklow@mbl.edu

Institution Name: Marine Biological Laboratory

State Code: MA

PE Codes: 5111, 1195

NSF Contract Numbers:

NSF Investments: Climate Change, Environment (including the importance of fresh water and dynamics of water processes)

What can humans learn from Antarctic fish?

Highlight ID: 19282, Version: AC/GPA

A major challenge for biologists is to understand the genetic and environmental risk factors that underlie human diseases. Surprisingly, animal species in the wild have sometimes evolved the characteristics of a human disease, and yet the 'disease' trait is precisely what allows them to flourish in their natural environment. Writing in the February 2009 issue of *Trends in Genetics* (vol. 25, no. 2, pp. 74-81) Drs. R. Craig Albertson (Syracuse University), William Cresko (University of Oregon), H. William Detrich (Northeastern University), and John Postlethwait (UO) argue that these "evolutionary mutant models" hold important clues for understanding, and eventually treating, human diseases.

Two examples of Evolutionary Mutant Models come from Antarctic fish, many of which have evolved reduced bone density, through the replacement of some bone by connective tissue and decreased mineralization of the skeleton as a whole. This adaptation increases buoyancy, allowing the fish to move easily in the water column for feeding. The trait clearly mimics the detrimental human

condition osteopenia, which is a reduction in bone mineral density that affects ~34 million American women and 12 million American men. Osteopenia can lead to osteoporosis, a disease characterized by low bone mass, bone deterioration and fragility. By studying Antarctic fish, the authors are attempting to identify unknown genes and gene/environment interactions that affect human health and underlie human disease.

Similarly, a subset of Antarctic fish, known as the icefish, don't make hemoglobin, the oxygen-transporting protein of all other vertebrates, and don't produce red blood cells. They are profoundly anemic. The icefishes nevertheless survive and thrive because the cold waters surrounding Antarctica are rich in oxygen. In humans, anemia is deleterious because it greatly reduces delivery of oxygen to the body tissues. Work from Detrich's laboratory on the icefishes has revealed novel genes involved in red cell formation that might be developed as new targets for anemia treatments, providing further support for the role that studies of exotic organisms can play in improving human health.

The researchers argue that evolution and adaptation are instructive tools to learn about the human condition. Oddball creatures, such as cavefish that lack eyes, giraffes with high blood pressure, and Antarctic fishes, are powerful research systems that complement the more traditional models of human disease, like the mouse, but outside the laboratory.

Primary Strategic Outcome Goal:

- Polar Sciences: Arctic and Antarctic Research

Secondary Strategic Outcome Goals:

- Polar Facilities & Logistics

In terms of intellectual merit, why is this outcome notable and/or important?

The research links genes associated with unique adaptations in the wild to disease conditions in humans.

In terms of broader impacts, why is this outcome notable and/or important?

[Merit Review Broader Impacts Criterion: Representative Activities, July 2007](#)

The research findings have important implications for human health.

Does this highlight represent transformative or potentially transformative research? If so, please explain why. For more information, see [Report to Congress: Transformative Research at the National Science Foundation, April 16, 2008](#) and [Important Notice 130: Transformative Research](#)

Yes

The research is transformative because it shows how evolutionary traits are harmful in some senses but beneficial in others.

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc?)

No

What may be the benefits of the proposed activity to society?

Yes

As noted above, the research has implications for human health.

OPP/ANT 2009

Program Officer: Roberta Marinelli

NSF Award Numbers:

[0635470](#)

Award Title: Protein Folding and Function at Cold Temperature: Co-Evolution of the Chaperonin CCT and Tubulins from Antarctic Fishes

PI: H. William Detrich, ICEMAN@NEU.EDU

Institution Name: Northeastern University

State Code: MA
PE Codes: 5111

NSF Contract Numbers:
NSF Investments: American Competitiveness Initiative (ACI)