9-25-2013

Collaborative Research: Exploring A 2 Million + Year Ice Climate Archive-Allan Hills Blue Ice Area (2MBIA)

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Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	0838843
Project Title:	Collaborative Research: Exploring A 2 Million + Year Ice Climate Archive-Allan Hills Blue Ice Area (2MBIA)
PD/PI Name:	Andrei V Kurbatov, Principal Investigator Paul A Mayewski, Co-Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	07/01/2009 - 06/30/2013
Reporting Period:	07/01/2012 - 06/30/2013
Submitting Official (if other than PD\PI):	Andrei V Kurbatov Principal Investigator
Submission Date:	09/25/2013
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Andrei V Kurbatov

Accomplishments

*** What are the major goals of the project?**

Our research focus was absolutely influenced by the uniqueness of the Allan Hills Blue Ice Area (AH BIA). The AH BIA is located near the northwest corner of the McMurdo Dry Valleys in South Victoria Land, East Antarctica. The

oldest age of ice exposed at the surface at AH BIA is bracketed by 2.2 Ma terrestrial meteorite ages systematically collected on the surface by previous investigators. Remarkable glaciology of the area provided advantageous conditions for obtaining the oldest ice on Earth with relatively modest field work logistics. As a consequence the overall project goals were:

1) Demonstrate the possibility of reconstructing a paleoclimate record from the Allan Hills Blue Ice Area (AH BIA) that extends beyond the longest available 0.8 Ma EPICA Dome C ice core record;

2) Confirm that concentrations and isotopic composition of argon and oxygen isotopes extracted from trapped air in ice samples can be used to develop an absolute timescale for the Allan Hills BIA;

3) Investigate the suitability of stable water isotopes and glaciochemistry of ice within the AH BIA for reconstructing environmental signal and confirming the developed age model;

4) Reevaluate the feasibility of developing a “paleoclimate park” with virtually unlimited supply of samples that can be collected from different ages of ice near the surface of AH BIA;

5) Fill in details of rapid climate change events using potentially unlimited sample volumes from trenching;

6) Contribute to the existing terrestrial meteorite age data set by dating additional meteorites collected from the Allan Hills Main Ice field blue ice area using the latest instrumentation and methods.

Below we briefly discuss how project goals are relevant to broader aspects of paleoclimate and glaciology research. According to deep-sea sediment records, at around the 0.9 Ma time interval named the Mid-Pleistocene Transition (MPT), a 40 kyr cycle of Earth’s climate was replaced by a 100 ka cycle. A 100 ka cycle was used to tune the Vostok and recent EPICA Dome C records. Everything that we know about the 40k world was learned from marine records, but our understanding of atmospheric conditions during this period is incomplete because only ice core records directly capture atmospheric gas concentrations. Many unresolved questions exist about the relationship between greenhouse gas concentrations and temperature changes. The association of precipitation and aridity variations with radioactively forced climate change and atmospheric circulation patterns is not well understood either. The importance of recovery of ice samples that overlap the100 to 40 ka cycle MPT transition around 0.9 Ma ago is widely accepted by the scientific community. Unfortunately, the majority of the old ice is probably hidden below the surface of the Antarctic ice sheet at a depth of more than 4 km, with complex logistical demands. It was reported several times in the literature that terrestrial ages of meteorites systematically collected over the last several decades from Allan Hills BIA scattered systematically with increased age near the BIA. During the first two field seasons we expanded previously conducted measurements of ice flow and for the first time determined a vertical component of ice flow that is based on more than a decade of observations (see Spaulding et al., 2012).

We used new argon isotope dating method, developed by our collaborators from Princeton. The large uncertainties in age in this method can be refined by matching timing of variations of paloatmospheric oxygen isotopes measured from trapped air in ice samples or stable water isotopes. Both trapped air and stable water isotopes variations are reasonably well characterized from a number of Antarctic deep ice cores and provide a means to correlate ages and develop and compare time scales of two independently measured properties: trapped air (well mixed global signal that can only be impacted by firn densification processes) and stable water isotopes record (driven by major shifts in climate but sensitive to changes in air moisture sources). Fortunately, another independent method, glaciochemistry of snow, provides means to evaluate major shifts in climate, moisture and airmass sources and is less dependent on firn densification pathways. We tested ice samples collected from drilled ice cores and surface samples and demonstrated that preserved paleoclimate record provides new high quality information from the ice samples collected near the surface of AH BIA.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities: To successfully accomplish major project goals during the final year, the University of Maine team continues to work in close research cooperation with Michael Bender, Laura Chimiak, and John Higgins from Princeton University. We also

were finally able to provide our subcontractor from Berkley with meteorite samples that we requested from the repository several years ago. During this final year of the 2MBIA research project we focused on synthesizing multidisciplinary data collected up to date from the Main Ice Field (see attached Fig.1) Allan Hills, Antarctica. The ice cores recovered during the two field seasons were sampled for trapped gas and stable water isotopes during two sampling campaigns organized by the University of Maine team in our Orono cold room laboratory in the Fall of 2012 and the Spring of 2013. Additional sampling during the last year of the project was driven by the discovery of very old 990 +/- 70 ka ice at the site BIT-58. Ar isotope dating of the BIT-58 ice core showed that its age was about 300 ka in the upper 116 m with a very sharp transition observed within several meters to about 1.0 +/- 0.1 Ma. The rest of the samples between 116 - 126 m below surface show that this ice predates the oldest continuous ice samples in the deep Antarctic ice cores (Dome C and Dome Fuji, dating to about 800 ka). M. Bender provided three ~ 1Ma samples to E. Brook who measured CO2 concentrations 245, 264, and 273 ppm. These numbers are very fascinating because, before 400 ka, the highest CO2 concentration observed in Dome C ice is 264 ppm. Unfortunately, the glaciology of the site BIT-58 where a 2.8 Ma extra terrestrial debris layer at the ice surface was reported is not well understood even today. Our limited attempts to improve glaciological understanding of the area with shallow GPR radar measurements, reevaluation of ice flow movement, stable water isotopes surface sampling and reevaluation of information on embedded volcanic layers was not very successful. In addition, the quality of the ice core collected from site BIT-58 was not very good. We were able to obtain several continuous sections with careful drilling and sampling but in general the ice is very brittle, with several unexplained stratigraphic transitions that prohibit us from developing a continuous environmental record from the site BIT-58. Princeton collaborators and Paul Mayewski submitted a proposal in the Spring of 2013 that focuses on collecting and measuring more samples from the deepest part of the BIT-58 ice core for trapped gas, glaciochemistry and stable water isotope measurements. We anticipate that the ice flow near the site BIT-58 may be disturbed and there is a possibility that the oldest ice is trapped near the bottom in small pockets. Fortunately the site BIT-58 is not far away (Fig. 1) from a well-established flow line (see Spaulding et al., 2012, 2013). We utilized ice flow, trapped air in ice, stable water isotopic composition, glaciochemical, meteorite terrestrial ages, and tephra measurements within the AH BIA. To develop the climate archive of the AH BIA, we interpreted the age of water stable isotope composition (delta D) from 5-10 cm depth along a 5 km transect through the AH BIA and correlated with stable water isotopes data a 225 m core (S27) at the midpoint of the transect. Comparison of delta D of the surface chips and S27 show that both records contain the same signal. Once we found that the climate record has not been altered in the surface ice we began to constrain the ages of the ice using measurements of air argon and oxygen isotopes that were taken from S27 and 8 additional shallow ice cores. We found that determining the age of ice exposed within the AH BIA is particularly challenging. Traditionally, ice flow models are used to provide a first approximation of the age of ice at the surface and at depth. The required input for such models includes accumulation rates, high-resolution bedrock topography, and horizontal velocities. At the AH BIA, high-resolution (< 100 m resolution) bedrock data is not available and modern and paleo accumulation rates are not well constrained. In the absence of a flow model, the terrestrial ages of meteorites collected at the ice surface have been used to estimate the age of the ice. Several teams of researchers have collected meteorites in the Allan Hills and hundreds of these meteorites have been dated. The majority of meteorite terrestrial ages for the Allan Hills are between 100 and

400 ka; however a continuous range of ages up to 1 Ma and a single 2.2 Ma specimen have also been reported. The continuous sequence of meteorite terrestrial ages, the lack of evidence for offsetting of layers and the low surface ice velocity indicate that the AH BIA has old ice that can be accessed with horizontal trenches and shallow ice cores to be used for paleoclimate reconstruction.
Argon isotope dating of Core S27 established an age of 100 +/-90 ka from three samples collected between 110 and 215 meters depth. The resulting correlations with the EPICA Dome C core are shown in Fig. 2 and 3, where the record from Core S27 is aligned with the EPICA timescale. It is clear from these data that we have a record of paleoclimate including the coldest part of Marine Isotope Stage 6 (about 140 ka), glacial termination 2, the Eemian, and on to the subsequent cooling. In Fig. 4, we show that the low-resolution glaciochemical data captured major shifts between glacial and interglacial climate. Major ion and trace element chemistry analyzed in sections from core S27 correspond to MIS-5e and MIS-6 time intervals in deep sea cores. Ice chemistry data appears to capture changes during MIS-6, when atmospheric circulation is intensified and source area aridity is enhanced. We observed the concentrations during MIS-6 at S27 are as much as 30 times higher than during MIS-5e (Fig. 4). This is true for sea salt species as well as elements associated with terrestrial dust, such as Al, which is transported to Antarctica from primarily distal sources. The association of element concentrations with climate changes suggests that both dust and marine - sourced aerosols potentially can be used to reconstruct atmospheric circulation patterns. To positively identify dust-sourced elements, we calculated enrichment factors. In Site 27, Al, Ca, Fe and many of the rare earth elements are crustal. In previous studies the pattern of rare earth element enrichment has been used to identify dust provenance. Applying this technique we found that, during MIS-6, the pattern at S27 is consistent with a primarily South American dust source, as observed in ice cores from central East Antarctic Plateau (Spaulding et al., 2013 submitted).

With regard to marine sourced species, the increased sea salt concentrations during MIS-6 are indicative of increased cyclonic activity resulted in fast air mass transport over open water. Although absolute concentrations are higher during MIS-6, the percent of the total ion budget attributable to sea salt sodium (ssNa ions) is greater during MIS-5e. No depletion of sulfate relative to Na ions is observed in the sodium/sulfate ratios indicating that ssNa ions are sourced from the open-ocean rather than from frost flowers on the sea ice surface. The total ion budget during MIS-5e can be used to reconstruct variability in sea ice extent and primary productivity. Glaciochemical data confirms that the established flow line (Spaulding et al., 2012) covers the period 86-254 ka. No ice core drilled in West Antarctica has yet reached this time. It is clear that the ice archive of the Allan Hills, although located in East Antarctica, contains a history of climate change in the Ross Embayment and future work could extend our knowledge of West Antarctic Ice Sheet stability under warmer climate scenarios.

Specific Objectives: Develop a “climate park” of mapped locations of ice samples ranging from present time to at least 1 Ma in the Main ice field area of the Allan Hills.

Significant Results: Our results already have implications for documenting major events in Earth’s paleoclimate history from unique time intervals older than 1 Ma. New data also suggest that an environmental signal is preserved at the surface ice of the AH BIA. We also confirmed that the “ice climate park” archive exposed at the surface provides a unique opportunity to investigate, relatively inexpensively, selected intervals of past climate in great detail if needed.

Key outcomes or Other achievements: We have begun studying the paleoclimate significance of the 1 Ma section. This work is yielding the first measurements of Antarctic temperature, greenhouse gas concentrations, and other properties from the 40k world (or the Mid-Pleistocene Transition). Our work established the presence of ice in the Allan Hills BIA going back to at least 1 Ma, a result that will likely be of interest to other glaciologists. A paper on the flow line is published (Spaulding et al., 2012), paper on flow line time scale development is accepted for publication (Spaulding et al., 2013), and paper on changes in atmospheric circulation patterns is in review (Spaulding et al., 2013). Finally, a paper on the argon dating of the BIT-58 core that has 1 Ma old ice is in preparation by John Higgins. It will report our discovery of million year-old ice at the site BIT-58.

*** What opportunities for training and professional development has the project provided?**

During the course of the project Kurbatov mentored the project graduate student, Nicole E. Spaulding, who just defended her Ph.D. dissertation and now is a postdoctoral fellow at the Climate Change Institute. Kurbatov was promoted to Associate Research Professor level. A number of undergraduate students and one high school student incorporated project research topics into their classes and reports during this year.

*** How have the results been disseminated to communities of interest?**

The Maine Climate Change Institute has a long history of incorporating research into graduate and undergraduate education, and presenting scientific findings to the wider community through activities at local schools and museum displays (American Museum of Natural History, Boston Museum of Science). CCI also has exposure in radio (e.g. NPR Fresh Air, Diane Rhem Show), TV (e.g. CBS 60 Minutes, Good Morning America), film (e.g. NOVA, BBC) and print (e.g. Downeast Magazine, LA Times). Special sections of the CCI website are dedicated to scientific and field highlights and this format will be maintained for this project.
Data and ideas developed in this project and associated work were used in several courses taught at UMaine by Mayewski and Kurbatov. CCI has outreach efforts on several levels as noted above, including K-12 school interaction, university tours, public speaking, public media and popular non-fiction books [Mayewski and White, 2002; Mayewski and Morrison, 2011]. One of the many CCI innovations to attract youth into science is our annual Climate Change Science Day to which we invite K-12 for a special set of tours and presentations at CCI and collaborating academic units such as Anthropology and Earth Sciences.
We integrated ice core experiences into podcast and web-based courses for high school students and teachers that are posted on the 2MBIA project web site.
Mayewski has included Allan Hills products in his classes and numerous scientific and public lectures. Mayewski Speaking engagements 2012-2013
(1) 14 July - SCAR Portland, Oregon (by Skype) – Antarctic and SH climate variability
(2) 16 July – Camden, Keynote for BIOGEOMON – Climate variability and ice core records
(3) 21 July – Bangor, Maine – Forbidden America interview climate change
(4) 24 July Castine, Maine, Castine Yacht Club – Journey Into Climate Change Institute
(5) 5 October – Punta Arenas, Chile – Universidad de Magallanes
(6) Antarctic and SH climate variability
(1) 13 October – King Edward Point British Antarctic Survey Station, South Georgia Island – Antarctic and SH climate variability
(2) 2 Nov – Stanley, Falkland Islands Government House - Antarctic and SH climate variability
(3) 28 Nov – Harvard – First millennium Climate Change Institute
(4) 19 Dec – Deerfield academy, Mass – Lambert Fellow Annual Talk – Journey Into Climate Change
(5) 24 Jan 2013 – MPBN – Journey Into Climate Change
(6) 5 February – Santiago, Chile – Climate variability and ice cores
(7) 1 April – Harvard – Climate and ice core record
(8) 2 April – Texas AandM (Skype) – Journey Into Climate Change

(9) 4 April – Bowdoin College, First Parish Church Brunswick, Unitarian Universalist Church, Bowdoin, St. Paul's Episcopal Church Brunswick, United Nations Association of Maine – Journey Into Climate Change
(10) 16 April – Keynote 75th Anniversary American Polar Society at Wood's Hole, Mass – Journey Into Climate
(11) 23 April (Earth Day) – appeared in 230 venues as part of movie "Thin Ice"
(12) 13 June – Webnar for Explorers Club – Journey Into Climate Change Institute
(13) 18 June – Andover, NH – Keynote Gordon Conference – Climate and ice cores

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Fig1.pdf	Figure 1	Andrei Kurbatov	09/21/2013
Fig2.pdf	Figure 2	Andrei Kurbatov	09/21/2013
Fig3.pdf	Figure 3	Andrei Kurbatov	09/21/2013
Fig4.pdf	Figure 4	Andrei Kurbatov	09/21/2013

Products

Books

Book Chapters

Conference Papers and Presentations

Inventions
Nothing to report.

Journals
N. Spaulding, A. Kurbatov, M. Bender, H. J.A., P. Mayewski, S. Arcone, S. Campbell, N. Dunbar, and D. Introne (2013). Climate archives from 80-250 ka in horizontal and vertical ice cores from the Allan Hills Blue Ice Area, Antarctica. *Quaternary Research*. N/A N/A. Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; OTHER: accepted

N. Spaulding, V. Spikes, G. Hamilton, P. Mayewski, N. Dunbar, R. Harvey, J. Schutt, and A. Kurbatov (2013). Ice motion and mass balance at the allan hills blue ice area, antarctica, with implications for paleoclimate reconstructions. *Journal of Glaciology*. 58 (208), 399--406. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3189/2012JoG11J176

Licenses
Nothing to report.

Other Products
Physical Collections.

Allocation Status for Antarctic Meteorite Requests
10/12/2010
Principal Investigator: KURBATOV,A

Generic	Classification	Sample Type	Sample Weight	Action	Comments
ALHA81 183	H5 CHONDRITE	1 CP	3.000	PASS	

ALHA81 251	LL3.3 CHONDRITE	1 CP	3.000	PASS
ALHA81 026	L6 CHONDRITE	1 CP	3.000	PASS
ALH 84 167	H5 CHONDRITE	1 CP	3.000	PASS
ALHA80 106	H4 CHONDRITE	1 CP	3.000	PASS
ALH 83 008	L3.4-3.7 CHONDRITE	1 CP	3.000	PASS
ALHA81 025	L3.6 CHONDRITE	1 CP	3.000	PASS
ALHA81 035	H6 CHONDRITE	1 CP	3.000	PASS

Samples send to Kees Welten and Kunihiko Nishiizumi for terrstrial age determinations

Educational aids or Curricula.

The educational resources designed for teachers and students to bring cutting-edge ice core research into the classroom.

Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).

Kurbatov, A, G. Hamilton, V. Spikes and N. Spaulding.. 2011. *GPS Ice Flow Measurements, Allan Hills, Antarctica*. Boulder, Colorado USA: National Snow and Ice Data Center. http://dx.doi.org/10.7265/N5NS0RSX.

AMD portal URL: http://gcmd.nasa.gov/r/d/[GCMD]NSIDC-0507

Data and Research Materials (e.g. Cell lines, DNA probes, Animal models).

Data set submitted to Antarctic Glaciological Data Center at NSIDC (AGDC data submission ticket #24376)

AMD portal url: http://gcmd.nasa.gov/getdif.htm?NSIDC-0541

The main page for data set will be at the following page once paper is published:

http://nsidc.org/data/nsidc-0541.html

The following FTP location is where data are staged:

ftp://sidads.colorado.edu/pub/DATASETS/AGDC/nsidc0541_kurbatov
data set title: Allan Hills Stable Water Isotopes

Data set summary: This data set includes stable water isotope values at 10 m resolution along an ~5 km transect (A-B) through the main icefield of the Allan Hills Blue Ice Area and at 15 cm within a 225 m core drilled at the midpoint of A-B.

Other Publications

J.A. Higgins, A. Kurbatov, N. Spaulding, E. Brook, P. Mayewski, E. Chimiak, M. Bender (2013). *Ar isotope evidence for ~1 Myr old ice from shallow cores in the Allan Hills Blue Ice Area, Antarctica*. AGU, 2013 Fall meeting. Status = SUBMITTED; Acknowledgement of Federal Support = Yes

N. Spaulding, A. Kurbatov, J. Higgins, P. A. Mayewski, M. Bender, and D. Introne (2012). *Insights on WAIS history from a high-resolution Eemian record collected at the Allan hills blue ice area, Antarctica*. Nineteenth Annual WAIS Workshop, Pack Forest Conference Center, Eatonville, Washington, U.S.A.. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patents

Nothing to report.

Technologies or Techniques

Nothing to report.

Thesis/Dissertations

Nicole E. Spaulding. *Exploration and Development of the climate archive of the Allan Hills Blue Ice Area, Antarctica*. (2013). The University of Maine. Acknowledgement of Federal Support = Yes

Websites

Allan Hills Blue 2Ma Ice Area web site (2MBIA)
http://cci.um.maine.edu/2MBIA/

2MBIA web site is developed to help dissiminate results of a blue ice coring and trenching project in East Antarctica sponsored by the National Science Foundation Office of Polar Programs.
The project's primary purpose is to demonstrate the possible recovery of an environmental record as old as 2.5-2.8 million years from the Allan Hills Blue Ice site, located one hour by airplane from U.S. McMurdo Station. With our collections, we hope to generate an absolute timescale for the Allan Hills Blue Ice Area (BIA), and then to reconstruct details of past climate changes and greenhouse gas concentrations for certain time periods back to 2.5 Ma.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Kurbatov, Andrei	PD/PI	4
Mayewski, Paul	Co PD/PI	2
Introne, Douglas	Co-Investigator	1
Handley, Mike	Technician	6
Spaulding, Nicole	Graduate Student (research assistant)	12

Full details of individuals who have worked on the project:

Andrei V Kurbatov
Email: akurbatov@maine.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 4

Contribution to the Project: PI, Project coordination, data processing and interpretation.

Funding Support: UMAINE

International Collaboration: Yes, New Zealand
International Travel: No

Paul A Mayewski
Email: paul.mayewski@maine.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: Co-PI. Involved in data interpretation with a focus on associations of developed ice chemistry and stable isotope records with climate change cycles.

Funding Support: UMAINE, NSF, Keck foundation

International Collaboration: No
International Travel: No

Douglas S Introne
Email: introne@maine.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Stable Isotope Laboratory Technician. Was involved in preparation and analyses of stable water isotopes samples.

Funding Support: UMaine

International Collaboration: No
International Travel: No

Mike Handley
Email: handley@maine.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6

Contribution to the Project: ICPMS Laboratory Technician. Mike is in charge of ICP-MS analyses of trench and ice core samples.

Funding Support: UM

International Collaboration: No
International Travel: No

Nicole Elizabeth Spaulding
Email: Nicole.Spaulding@maine.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Project Ph.D. student. Started her degree program, at the Department of Earth Sciences, University of Maine in September 2009 and works as a Research Assistant on the project. The data collected during the project provide the basis for her Ph.D. dissertation. She participated in the first and second field seasons, processed all GPS and GPR data, collected ice core and trench samples, participated in glaciochemical analyses. Defended her Ph.D. in April 2013 and currently publishing results.

Funding Support: N/A

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Géosciences Environnement Toulouse	Academic Institution	France

Princeton University	Academic Institution	Princeton, NJ
Space Sciences Laboratory, University of California Berkeley	Academic Institution	Berkeley CA
WSL Institute for Snow and Avalanche Research SLF	Academic Institution	Switzerland

Full details of organizations that have been involved as partners:

Géosciences Environnement Toulouse

Organization Type: Academic Institution
Organization Location: France

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: LA-ICP-MS and SEM work to test tephra based correlations

Princeton University

Organization Type: Academic Institution
Organization Location: Princeton, NJ

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Collaborative research

Space Sciences Laboratory, University of California Berkeley

Organization Type: Academic Institution
Organization Location: Berkeley CA

Partner's Contribution to the Project:
Other: subcontract

More Detail on Partner and Contribution: Dr. Kunihiko Nishiizumi and Kees Welten received from Linda Welzenbach, Smithsonian number of Allan Hills meteorite samples for terrestrial age determination.

WSL Institute for Snow and Avalanche Research SLF

Organization Type: Academic Institution
Organization Location: Switzerland

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: X-ray measurements of embedded bubbles

What other collaborators or contacts have been involved?

NO

Impacts

What is the impact on the development of the principal discipline(s) of the project?

During the course of the project we were able to confirm vertical ice transport that is crucial to the mechanism of formation of blue ice areas in Antarctica proposed earlier. We established and dated ice along the flow line and found the oldest ice on Earth.

What is the impact on other disciplines?

The developed “climate park” could be utilized by a variety of disciplines (i.e. biology, geology, paleoclimatology) to answer questions requiring sample volumes impossible to attain with traditional ice coring techniques.

What is the impact on the development of human resources?

The project significantly contributes to the development of the academic career of a female Ph.D. student who, at the present time, is a Postdoctoral scholar working in close cooperation with several European institutions and Harvard University on developing a paleoclimate record from the Swiss Alps.

What is the impact on physical resources that form infrastructure?

We contributed to improving blue ice drilling and ice trenching techniques. We also established several new ice sampling laboratory protocols that utilized our work experience with large trenched ice samples.

What is the impact on institutional resources that form infrastructure?

Two project PIs are members of the newly established School of Earth and Climate Sciences at the University of Maine. Our involvement in the 2MBIA project was very positively rated by an independent review committee that recommended the University form the new school to focus on improved training of undergraduate students in Climate science.

What is the impact on information resources that form infrastructure?

Most of the project data are already uploaded on public data repositories. Once papers are published all data will be immediately available to the scientific community. We developed several software modules that will be released on 2MBIA project web site by the end of the year.
Project data formats were used to improve the capability of our cyberinfrastructure, specifically spatial attributes of the collected datasets.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.