

CLIMATE CHANGE INSTITUTE

15th J. Louis Agassiz Symposium

May 10 - 11, 2007

Doris Twitchell Allen Village
University of Maine - Orono

15th J. Louis Agassiz Symposium – Program

Thursday, May 10

8:00 – Coffee and Pastries

8:25 – **Gordon Hamilton** "Welcome and introduction"

8:30 – **S.A. Norton, I.J. Fernandez, G.C. Evans, W. Shotyk** "Holocene Atmospheric Deposition Rates for Hg in Maine"

8:45 – **Jasmine Saros** "The Influence of Ultraviolet Radiation on the Structure of Alpine Lake Ecosystems"

9:00 – **Alan D. Wanamaker Jr., Karl J. Kreutz, Bernd R. Schöne, Harold W. Borns, and Douglas S. Introne** "Gulf of Maine Bivalve Shells Reveal Regional North Atlantic Onset of the Little Ice Age at ~ 1400 AD"

9:15 – **Debra Kenneway, Aitbala Sargent, James Fastook** "Better physics using full momentum solver in 2D vertical slice domain, where does longitudinal stress really matter? Application to the Thwaites Glacier flowline"

9:30 – **Kevin Jones, Eunice Smith** "Calculating the Floating Fraction of Basal Ice Along Byrd Glacier, Antarctica, Using the Force Balance and the Mass Balance Connected by the Flow and Sliding Laws of Ice"

9:45 – **Roger LeB. Hooke, James Fastook** "Modeling the retreat of the Laurentide Ice Sheet in Maine: Implications for esker formation"

10:00 – BREAK

10:30 – **Audrey Bamberg** "Waves, wind and ice"

10:45 – **Daniel Dixon, Paul Mayewski, Susan Kaspari, Sharon Sneed, Mike Handley, Kirk Maasch, Karl Kreutz, Gordon Hamilton, Andrew Carleton, Ted Scambos** "An East Antarctic Anthropogenic Pollution Signal from South Pole Station"

11:00 – **Daniel Breton** "The MADGE prototype: Density gauging on ITASE 2007"

11:15 – **Nicole Spaulding, Debra Meese, Ian Baker** "Determination of polar firn/ice core physical properties using scanning electron microscopy"

11:30 – **Elena Korotkikh, Gordon Hamilton, Paul Mayewski, Michael Handley, Sharon Sneed** "High resolution records of Eemian interglacial from Mount Moulton (West Antarctica)"

11:45 – **Paul Andrew Mayewski, Kirk Maasch, Gordon Hamilton, John Turner, Mike Meredith, Peter Barrett, Nancy Bertler** "State of the Antarctic and the Southern Ocean Climate System (SASOCS)"

12:00 – **Karl Kreutz** "The Churchill Exploration Fund"

12:10 – **Paul Mayewski, Sharon Sneed** "And the winning t-shirt is...?"

12:15 – LUNCH

1:00 – **L.L. Brothers, J.T. Kelley, D.F. Belknap, W.A. Barnhardt** "New Insights into the Stratigraphy and Activity of a Nearshore Pockmark Field, Belfast Bay, ME"

1:15 – **Gordon Bromley, Kurt Rademaker, Claire Todd** "Late Quaternary glaciations of Nevado Coropuna, Perú"

1:30 – **Kurt Rademaker, Gordon Bromley, Claire Todd, David Reid, and Louis Fortin** "Terminal Pleistocene Landscapes and Early Foragers in Southern Peru: Recent Investigations"

1:45 – **David Reid, Kurt Rademaker, Taylor Kelley, Dan Sandweiss, Daniel F. Belknap** "Peruvian Beach Ridges: Records of Human Activity and Climate Change"

2:00 – **Alice R. Kelley, Dan Sandweiss, Joseph T. Kelley, Daniel F. Belknap, Kurt Rademaker, David Reid, Anna K. Kelley, Taylor F. Kelley** "Ground-Penetrating Radar at Los Morteros, Peru: More than Meets the Eye"

2:15 – **Sudarshan Chawathe** "Integration and Exploration of Climate-Change Datasets"

2:30 – BREAK

3:00 – **Debra Meese** "The GISP2 chronology"

3:15 – **J. L. Fastook, J. W. Head, and D. R. Marchant** "Tharsis Montes Ice Sheet models at high obliquity driven by GCM results"

3:30 – **Vladimir Smorodin** "Atmospheric Block of the Earth Environment-Climate System in a Context of Global Climate Change: From Problems towards Conceptual Solutions"

3:45 – **Peter Koons, Scott Johnson, Chris Gerbi** "Model Northern Environment and Silicate Earth GCM"

4:00 – **Leigh Stearns, Gordon Hamilton** "Improved ice velocity measurements for several East Antarctic outlet glaciers"

4:15 – **Nathan W. Vogan, Karl J. Kreutz, Cameron Wake, Christian Zdanowicz, Luke Copeland, Dave Fisher, Erich Osterberg, Alan Wanamaker, Kaplan Yalcin** "ENSO Moisture Transport in the North Pacific for the Past Millenium from the Eclipse Icefield, St Elias Mounatins, Yukon Territory"

4:30 – **Erich Osterberg, Paul Mayewski, Karl Kreutz, David Fisher, Sharon Sneed, Mike Handley, and Andrei Kurbatov** "Regional Patterns and Forcing of the Little Ice Age and Medieval Climate Anomaly in the Northern Hemisphere"

4:45 – **Benjamin Gross, Karl Kreutz, Erich Osterberg, Paul Mayewski, Dan Lux, Peter Koons, and Mike Handley** "A multi-isotope study of atmospheric transport and stratification in the North Pacific"

5:00 – **Terry Hughes** "Ice sheets in North Carolina"

Friday, May 11

8:00 – Coffee and Pastries

8:15 – **Daniel F. Belknap** "Transition from ice shelf to tidewater margin in the Gulf of Maine, 23 – 14 cal. ka"

8:30 – **Peter Leach** "GPR investigations of the Glidden Point midden"

8:45 – **Holly Theriault** "What is the effect of sea-level rise on Maine's coastal wetlands?"

9:00 – **Joseph T. Kelley, Daniel F. Belknap, Peter Leach, Walter A. Barnhardt, Emilia G. Pintado** "Preservation of Submarine Moraines off Wells, Maine"

9:15 – **D.S. Introne, A. Wanamaker, K. Kreutz, D. Sanger** "Assessing the Historical Distribution of Swordfish in the Gulf of Maine based on Stable Isotope and Archeological Evidence"

9:30 – **Sean Birkel** "Investigating the role of atmospheric circulation in the anomalous formation, growth and decay of the Laurentide Ice Sheet"

9:45 – **Coen Hofstede** "The uncoupling of Jacobshavn Isbrae between 1993 and 2003"

10:00 – BREAK

10:30 – **Jennifer Ort, Brian Robinson** "Artifact distribution at the Bull Brook paleoindian site: preliminary observations"

10:45 – **Brian Robinson, Martin Yates** "The Identification of Atlantic Salmon on Interior Archaeological Sites"

11:00 – **Kirk Maasch, Paul Mayewski** "Statistical Detection of Holocene Rapid Climate Change Events"

11:15 – **KEYNOTE SPEAKER: David Smith** "A Historian Among the Scientists"

12:00 – LUNCH

1:00 – **William Sneed, Roger Hooke, Gordon Hamilton** "Thinning of the south dome of Barnes Ice Cap, arctic Canada, over the past two decades"

1:15 – **Sam Belknap, Kristin Sobolik, Vaughn Bryant, Tim Riley, Hendrik Poinar, Kirsti Box** "Prehistoric Diet at Hinds Cave, Texas: Evidence from 34 Paleofeces"

1:30 – **Juan Luis Garcia** "Glacial History and Paleoclimate in Patagonia (Southern South America) during the LGM and Termination of the Last Glacial Cycle"

1:45 – **Brenda Hall, Audrey Bamberg, Paul Koch, Rus Hoelzel, and Mark de Bruyn** "Holocene distribution of southern elephant seals along the Victoria Land Coast, Antarctica"

2:00 – **Karl Kreutz, Paul Mayewski, Sharon Sneed, Mike Handley, Andrei Kurbatov** "Comparison of observed and modeled LGM sea salt deposition in Antarctica"

2:15 – **Bruce Williamson, Karl Kreutz, Paul Mayewski, Benjamin Gross, Sharon Sneed, Mike Wasckiewicz** "Connections between meteorology and chemistry in surface snow: Clark Glacier, Antarctica"

2:30 – BREAK

3:00 – **Susan Kaspari, Paul Mayewski, Mike Handley, Shichang Kang** "A High-Resolution Record of Atmospheric Dust Variability Since 1650 AD from a Mt. Everest Ice Core"

3:15 – **B. Grigholm, P. Mayewski, S. Kaspari, S. Sneed, M. Handley, S. Kang, Y. Qinghua, Q. Zhang, Y. Zhang, Z. Cong, F. Chen** "Mt. Geladaindong Dust Record: Relationships between Local and Regional Atmospheric Dust Loading, Circulation, and the PDO"

3:30 – **Andrei V. Kurbatov, Carmelo Ferlito, Paul A. Mayewski, Douglas C. Introne, Sharon B. Sneed, Michael J. Handley** "Searching for the new Northern Hemisphere climate proxies"

3:45 – **Katelyn Michaud, Andrea Nurse, Drew Barton** "Species classification of fossil pinus (pine) pollen from species endemic to Maine, USA"

4:00 – **Ann Dieffenbacher-Krall** "Ecology of chironomid (midge fly) larval head capsules in Maine: increasing understanding of a temperature proxy and developing a robust Holocene temperature inference model for the northeastern United States"

4:15 – **Andrea Nurse, Ann Dieffenbacher-Krall, Molly Schauffler, Lisa Doner** "Late-glacial and Holocene vegetation changes in northern Maine: a multi-proxy approach to evaluating shifting forest patterns"

4:30 – **Louis Fortin, Martin Yates, Gregory Zaro** "Geoarchaeological Investigations along the Tambo-Ilo Coast, Peru"

4:45 – **Gregory Zaro** "Agricultural Landscapes Past and Present: Long-term Thinking along the Peruvian South Coast"

ABSTRACTS APPEAR IN ORDER OF PRESENTATION

Holocene Atmospheric Deposition Rates for Hg in Maine

S.A. Norton, I.J. Fernandez, G.C. Evans (Maine Department of Environmental Protection), W. Shotyk (University of Heidelberg)

Trends and absolute values for the accumulation rate for Hg deposited from the atmosphere have been estimated by three methods: repeated soil surveys at high elevation sites across the northeast, including Maine; ²¹⁰Pb-dated lake sediment cores from lakes in Maine and adjacent areas; and ²¹⁰Pb- and ¹⁴C-dated cores from ombrotrophic Caribou Bog, west of Orono, Maine.

Sub-alpine forest litter data suggest ~50% decline in Hg deposition between 1979 and 1995. Data from drainage lakes suggest accumulation rates (assumed parallel to atmospheric deposition rates) starting increasing just before 1900 AD, increased to maximum values by 1970, and decreased since 1970 to 1975. Data from seepage lakes indicate a more dramatic decrease since 1970 to values less than 50% of maximum. The bog core, dating from about 10,000 BP, indicates variable accumulation rates (10x), depending on vegetation type (lake → wooded fen → ombrotrophic bog), with a persistent increase starting ~500 years ago, a peak in the 1970s at unprecedented accumulation rates, and then a decline of ~50% by 2002.

The Influence of Ultraviolet Radiation on the Structure of Alpine Lake Ecosystems

Jasmine Saros

Due to their high elevation and low concentrations of dissolved organic material, alpine lakes are often highly transparent to ultraviolet radiation (UVR). Furthermore, the late ice-out dates at high elevations lead to low water temperatures near the time of peak ambient UVR at summer solstice, potentially reducing the ability of planktonic organisms to repair UVR-induced damage. This has led to the suggestion that UVR plays a major role in controlling algal production and community structure in alpine lakes. I will present results from a variety of studies in the central Rocky Mountains that suggest that the relative importance of UVR in structuring the base of the food web in these lakes varies. Specifically, I will present data from these lakes that suggest that UVR has little effect on the location of the chlorophyll maximum, as well as the total level of algal production. In contrast, results from several experiments indicate that UVR may play an important role in determining algal community structure, as species respond differently to UVR exposure at different temperatures. The different responses of diatom species in these experiments will be related back to changes observed in sedimentary diatom profiles from these lakes. The implications of changes in UVR transparency as a result of recent episodic acidification events will also be discussed.

Gulf of Maine Bivalve Shells Reveal Regional North Atlantic Onset of the Little Ice Age at ~ 1400 AD

Alan D. Wanamaker Jr., Karl J. Kreutz, Bernd R. Schöne (University of Mainz), Harold W. Borns, and Douglas S. Introne

The onset of the Little Ice Age (LIA) at ~ 1400 AD in the North Atlantic is well documented in Greenland ice core records, while other terrestrial-based proxy archives indicate regional differences both in onset magnitude and timing. The LIA is characterized by enhanced atmospheric circulation (stronger westerlies) in the North Atlantic, greater storminess, and generally cooler air temperatures punctuated by warm intervals. Currently, few high-resolution (annual), marine-based records exist in the North Atlantic that reveal the regional onset of the LIA. Here, we present subannual to annual oxygen isotope data ($\delta^{18}\text{O}$) from the shells of the long-lived bivalve *Arctica islandica* L. from the Gulf of Maine that support a significant shift in mean ocean conditions coincident with known atmospheric changes in the North Atlantic. Using high-resolution microsampling techniques for oxygen isotopes (~ 1200 samples from two shells) we show a rapid (within 6 years), large isotopic shift (1.86 to 0.93 per mil [‰]) in shell aragonite values at ~ 1400 AD. Prior to ~ 1400 AD the mean annualized $\delta^{18}\text{O}$ values were 1.57 (± 0.21 ‰), while after ~ 1405 AD mean $\delta^{18}\text{O}$ values were 1.38 (± 0.22 ‰). The shift in mean $\delta^{18}\text{O}$ values indicate a substantial change in hydrographic conditions in the Gulf of Maine, and may reflect a warming of seawater by ~ 0.9 °C. We suggest that increased strength in westerlies coupled with North Atlantic Oscillation (NAO) dynamics remotely forced slope water properties and deepwater exchange with the Gulf of Maine.

Better physics using full momentum solver in 2D vertical slice domain, where does longitudinal stress really matter? Application to the Thwaites Glacier flowline

Debra Kenneway, Aitbala Sargent, James Fastook

The shallow-ice approximation neglects all stresses except basal drag, a good assumption for inland ice but poor for fast-flowing, low-surface slope ice streams, where longitudinal stresses are important, even dominant [2]. A higher-order approach couples mass- and momentum-conservation equations and solves with no neglected stresses. In developing such a full-momentum solver for the University of Maine Ice Sheet Model (UMISM) [1], we test a simplification which models a vertical slice through the ice sheet. This allows us to: 1) implement and test complex boundary conditions, and 2) evaluate longitudinal stresses

There are two types of boundary conditions [4]: 1) Dirichlet, state variable (velocity) specified, and 2) Neumann, conserved flux (force applied on the boundary) specified. With frozen beds, Dirichlet boundary conditions are specified, since velocity is zero. With sliding, the force exerted on the ice by the bed is specified. This resistive force cannot equal or exceed the driving stress. A fraction of the driving stress does produce the characteristic concave profile, but is hard to define. A boundary-layer is a better approach. We preserve Dirichlet-type zero velocity on the boundary, and allow greater deformation within the boundary-layer to simulate sliding. This soft layer can be interpreted as deformable till or slush. Either way its thickness is negligible compared to ice thickness.

We apply this to a flowline along the Thwaites Glacier in the Amundsen Sea sector using excellent new data from the Airborne Geophysical survey of the Amundsen Sea Embayment by University of Texas [3] and British Antarctic Survey [5] teams.

[1] J.L. Fastook. Computational Science and Engineering, 1(1):55-67, 1993.

[2] J.L. Fastook and A. Sargent. 11th Annual WAIS Initiative Workshop, Virginia, 2004.

[3] Holt et al. Geophys. Res. Lett., L09502(doi:10.1029/2005GL025561), 2006.

[4] T.J.R. Hughes. Prentice-Hall, Inc., New Jersey, 1987.

[5] Vaughan et al. Geophys. Res. Lett., doi:10.1029/2005GL025588, 2006.

Calculating the Floating Fraction of Basal Ice Along Byrd Glacier, Antarctica, Using the Force Balance and the Mass Balance Connected by the Flow and Sliding Laws of Ice

Kevin Jones, Eunice Smith

A geometrical force balance that links floating fraction ϕ of basal ice to basal and side shear and to longitudinal tension and compression along an ice stream was combined with the mass balance along the ice stream using the flow law of ice and a sliding law of ice that incorporates the floating fraction of basal ice. This establishes the dependence of floating fraction ϕ on all the major stresses in an ice stream, the mass balance, the flow law, and the sliding law. The result is a second-order model that calculates how ϕ changes with the change of ice thickness upslope from the grounding line of an ice shelf supplied by the ice stream, and improves the first-order calculation of ϕ based on the force balance alone. The model is applied to a radio-echo flightline up Byrd Glacier, Antarctica, from the Ross Ice Shelf to converging flow in the East Antarctic Ice Sheet. The separate contributions of basal shear, side shear, and longitudinal tension/compression to floating fraction ϕ are presented along the flightline to show how these stresses change as flow changes from converging sheet flow to linear stream flow, to diverging shelf flow.

Modeling the retreat of the Laurentide Ice Sheet in Maine: Implications for esker formation

Roger LeB. Hooke, James Fastook

We used the University of Maine Ice Sheet Model to simulate retreat of the Laurentide Ice Sheet in Maine during the last deglaciation, focusing principally on basal conditions.

Pauses in retreat occurred at ~15.5 and 16.4 (cal) ka, at times of brief cold swings in the $\delta^{18}\text{O}$ temperature record from the GISP2 core. At these times, the model margin was near the locations of the Pineo Ridge and Pond Ridge moraines, respectively, in downeast coastal Maine, suggesting a direct relation between the cold swings and construction of these moraines.

Within 150 km of the margin, basal melt rates average ~5 mm a⁻¹ during retreat. They decline over the next 100 km, so areas of frozen bed develop in northern Maine during retreat. Such melt rates would not have supplied enough water to build the esker in the time available. Additional input of water from the glacier surface was required. Sedimentological evidence, however, indicates that the Katahdin esker was constructed in segments, averaging 5 to 10 km in length, in the marginal zone of the glacier. If this was the case, how did the segments become aligned in such a way as to produce a continuous esker?

Between ~50 and ~250 km from the margin, temperature gradients in the basal ice average ~0.2 K m⁻¹. Such gradients can conduct upward into the ice all of the heat produced by viscous dissipation in water flowing in a developing conduit less than a few centimeters high. This inhibits enlargement of the conduit to a size in which an esker could form. Basal temperature gradients are lower within a few kilometers of the margin. This may explain why eskers commonly seem to form near the margin and are typically segmented, with later segments lapping onto earlier ones.

Waves, wind and ice

Audrey Bamberg

Antarctic beaches are formed by three basic geologic agents: waves, wind and ice, that produce diverse coastal environments. The great variety of polar shorelines is determined by the amount of time each agent has to leave its distinctive mark on the geologic record. The southern Scott Coast in the Ross Sea, Antarctica, provides a great example for this diversity. The numerous flights of raised beach ridges on this coast preserve the geologic record of Holocene glacial isostatic rebound. This presentation will report how these relict beaches can be examined to reconstruct past environmental conditions in the Ross Sea. This analysis comprises relief and slope angle measurements as well as orientation of the beach ridges and grain-size and shape analysis. This investigation will allow me to determine the relative importance and time-frame that each geologic agent had to leave their imprint on each individual beach ridge. Based on these findings, I will be able to present a chronology of changing environmental conditions in the Ross Sea during the Holocene.

An East Antarctic Anthropogenic Pollution Signal from South Pole Station

Daniel Dixon, Paul Mayewski, Susan Kaspari, Sharon Sneed, Mike Handley, Kirk Maasch, Karl Kreutz, Gordon Hamilton, Andrew Carleton, Ted Scambos.

Over-snow traverses, such as those conducted by the International Trans-Antarctic Scientific Expedition (ITASE), provide us with the opportunity to collect a large number of shallow cores from broad geographic areas. These large arrays of shallow cores provide the data needed, at a high enough spatial and temporal resolution, to form a more accurate assessment of the regional climate differences between deep core sites. Here we present chemistry data from shallow ice core tops and surface snow samples collected along the US ITASE-2002 (Byrd To South Pole Station), and Light Ground Traverse-2003 (LGT-03 - South Pole Station to Taylor Dome) traverses to determine the spatial and temporal variability of chemical deposition over extensive and highly inaccessible inland areas of the Antarctic continent.

The US ITASE 2002 traverse (ITASE-02) started from Byrd Station, West Antarctica (80S 120W), and progressed southward, passing through the Transantarctic Mountains at the Bottleneck, ultimately ending at the South Pole, East Antarctica (90S 0W). The LGT-03 traverse began at the South Pole and preceded over the interior of East Antarctica to the Automated Geophysical Observatory #4 (AGO4, 82S 96.76E). From AGO4 the traverse traveled northward along the Transantarctic Mountains Seismic Experiment (TAMSEIS) sensor line, passing through the area known as Megadunes (80.78S 124.49E), and finishing up at Taylor Dome (77.78S 158.73E). Eight shallow cores were collected along the ITASE-02 traverse and seven shallow cores and several snowpits were collected along the LGT-03 traverse. Surface snow samples were collected every ~30-50 km along both traverses. All surface snow samples and core tops are analyzed using an Ion Chromatograph (IC) for

their soluble major ion content (Na⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, NO₃⁻, SO₄²⁻). The surface snow samples are additionally analyzed for their δO₁₈, H/D, and trace element content (Sr, Cd, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Pb, Bi, U, As, Ti, Al, S, Ca, Ti, V, Cr, Mn, Fe, Co, Cu, Zn). Relative to the seasonal variability of Na⁺ and SO₄²⁻ concentrations in the core tops, the majority of surface snow concentrations are low and high, respectively, suggesting a summer chemical signature. Most of the observed chemistry within the surface samples can be explained by naturally occurring physical phenomena such as proximity to chemical source area, chemical transport pathway, and surface ablation. However, surface snow samples >200km upstream from the South Pole Station exhibit very high, and in some cases the highest, concentrations of Cd, Cs, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Pb, Bi, U, As, Mn, Fe, and Cu.

The MADGE prototype: Density gauging on ITASE 2007

Dan Breton

A brief overview of the theory and physical construction of the Maine Automated Density Gauge Experiment is given, followed by data collected on its first journey to Antarctica on ITASE 2007. The density gauge is designed to provide high precision and high vertical resolution density profiles of ice cores using a fast gamma-ray counting system, electronic calipers and a stepper motor controlled actuator, all of which are controlled by a field programmable microcontroller.

Determination of polar firn/ice core physical properties using scanning electron microscopy

Nicole Spaulding, Debra Meese, Ian Baker (Dartmouth College)

Because of its fragile nature, firn is a very difficult material to work with and obtain accurate physical property measurements. Measurements of various microstructural parameters using traditional methods require a pore filler that, despite its utility, disrupts the microstructure. The fillers that have traditionally been used are also toxic and undesirable to work with. The utility of scanning electron microscopy in gaining an understanding of the physical characteristics of the U.S. International Trans Antarctic Scientific Expedition (U.S. ITASE) firn and ice cores will be discussed. Use of the SEM allows high-resolution images of both grain and pore geometry to be obtained even in shallower sections where porosity is high. Imaging of shallow sections suggests that firn sections prepared using a pore filler, a technique embraced by the scientific community as a whole, provides too simplistic a view of grain geometry.

Grain-size measurements from Antarctic and Arctic firn/ice cores based on traditional cross-sectional area measurements of two dimensional thin sections largely fall along a temperature grain growth curve, thus this methodology has the potential to redefine this curve and how physical properties are determined on firn cores, in particular. This technique allows a re-evaluation of the assumptions made about grain geometry and therefore the validity of the temperature grain-growth curve. Some consideration may also be given to other aspects of my thesis project.

High resolution records of Eemian interglacial from Mount Moulton (West Antarctica)

Elena Korotkikh, Gordon Hamilton, Paul Mayewski, Michael Handley, Sharon Sneed

Developed earlier from the Mt. Moulton blue ice area (MLT), West Antarctica, horizontal ice core low resolution glaciochemistry record, demonstrated that trend in sodium concentrations is similar to trend observed in Vostok ice core. Available methane measurements of Eemian section of MLT record from air bubbles trapped in ice by Todd Sowers (Penn State University) confirmed that it is well preserved. The Eemian interglacial is the most recent analog for the Holocene period. Because only low resolution records of the Eemian interglacial are available from other Antarctic ice cores it is valuable to understand in details the post Eemian transition in order to understand present climate trends.

We conducted high resolution sampling of ~40 meters long section of the trench A (MLT) using Climate Change Institute continuous melter system. Melted section is overlapping with the Eemian part of the record based on ⁴⁰Ar/³⁹Ar radiometric dates of 4 englacial tephra layers. Samples were examined for their major ions (Na⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, NO₃⁻, SO₄²⁻) and trace elements (Sr, Cd, Cs, Ba, La, Ce, Pr, Pb, Bi, U, As, Al, S, Ti, V, Cr,

Mn, Fe, Co, Cu, Zn). The developed data set will be used to investigate in detail the last interglacial-glacial transition in context of changes in atmospheric circulation patterns.

State of the Antarctic and the Southern Ocean Climate System (SASOCS)

Paul Andrew Mayewski, Kirk Maasch, Gordon Hamilton, John Turner (British Antarctic Survey), Mike Meredith (British Antarctic Survey), Peter Barrett (Victoria University of Wellington), Nancy Bertler (Victoria University of Wellington) and others

Modern climate over the Antarctic and the Southern Ocean results from the interplay of the ice sheet – ocean – sea ice – atmosphere system to past and present climate forcing. This system first established itself with the first big ice sheets 34 Ma as global CO₂ levels fell, but developed into a well established “icehouse” world just 14 Ma ago, with extreme glacial-interglacial oscillations only in the last million years. Ice cores and geological studies show how temperature and greenhouse gases have oscillated within a well-defined band through out this time, though atmospheric CO₂ levels have now risen above the normal limit. Distinguishing between naturally forced non greenhouse gas Antarctic climate events and those responding to CO₂ forcing, and projecting future responses are the twin key challenge for Antarctic climate scientists.

In addition to gradual CO₂-forced change, this climate system can experience abrupt change on the order of decades and shorter, as seen from both past climate records recovered from ice cores and modern observations such as the rapid near-surface warming observed across the Antarctic Peninsula and the massive calving of ice shelves in West Antarctica. A climate change event commencing ~1000 years ago is the most significant abrupt change event of at least the last 5000 years. It was characterized by intensification of major circulation features such as the westerlies and the Amundsen Sea Low and in general cooler temperatures over East Antarctica. The most recent, pre-instrumental era, abrupt climate change events are characterized by reorganization in temperature and atmospheric circulation starting ~AD1700 and ending ~AD1850 that are generally coincident with a period of increased solar output throughout this period and close with the onset of the modern rise in CO₂.

New Insights into the Stratigraphy and Activity of a Nearshore Pockmark Field, Belfast Bay, ME

L.L. Brothers, J.T. Kelley, D.F. Belknap, W.A. Barnhardt

Biogenic natural gas deposits and circular seafloor depressions, or pockmarks, are a global phenomena recognized in a variety of continental settings including deltas, shelf basins, and areas of petroleum production. Pockmarks are also widespread in mid-latitude estuaries, especially in formerly glaciated regions, such as the Gulf of Maine. In different regions of the world methane-sourced pockmark fields actively vent and create new craters. In some locations, the methane escape resulting from pockmark formation is of significant quantity to impact the calculation of greenhouse gas emissions. Despite their ubiquity, pockmarks are one of the least understood underwater landforms on the coast of northeastern North America. Pockmarks are sourced by methane escaping from organic-rich sediments in the deep Holocene sections of Belfast Bay, Maine and similar settings in the region. We hypothesize that the source beds are early Holocene terrestrial (bog or lake) or estuarine (salt marsh, tidal flat, or bay) sediments that accumulated at a time of lower-than-present sea level. Recently gathered high resolution Chirp seismic profile data, in conjunction with interferometric sidescan sonar remapping of Belfast Bay's bathymetry, show a distinct seismic facies above the Pleistocene/Holocene unconformity. This unit ranges in thickness from 0 m to 3 m, and has layered bedding. We speculate that this reflector represents the Holocene source bed and/or the pathway for gas escape pock mark formation. A comparative analysis of the swath bathymetric survey and a previous bathymetric survey conducted by NOAA in 1999 indicates the dynamics of the Belfast Bay Pockmark differ from previous interpretations and may involve low-scale venting activity for field maintenance and episodic, catastrophic events for pockmark formation.

Late Quaternary glaciations of Nevado Coropuna, Perú

Gordon Bromley, Kurt Rademaker, Claire Todd (University of Washington)

Nevado Coropuna is a sprawling, glaciated stratovolcano in arid southwest Perú. Surrounding the peak is a well-

preserved sequence of lateral and end moraines, drift sheets, and glacial-erosional landforms formed during repeated advances of Coropuna's glaciers. In summer 2006 we undertook glacial geologic fieldwork on the northern, western, and south-western flanks of the mountain with the aim of deciphering the last c. 20 Ka glacial history of this relatively unknown climate zone. Specifically, we are interested in the timing of glacial maxima at Coropuna, the extent of temperature depression, the existence of any late-glacial climate reversal, and the nature of tropical glaciation during the Holocene. On a larger scale, Coropuna is the western datum of an east-west transect across the Andes that, when complete, should provide insight into the role of the tropics in climate change.

Terminal Pleistocene Landscapes and Early Foragers in Southern Peru: Recent Investigations

Kurt Rademaker, Gordon Bromley, Claire Todd (University of Washington), David Reid, and Louis Fortin

Ongoing interdisciplinary research in southern Peru provides an increasingly clear picture of how local Andean climate, ecology, and human settlement patterns changed at the end of the last ice age. We integrate data from previous studies, our recent glacial geologic field work at the Firura and Coropuna ice caps, and continuing archaeological survey of a ~155 km-long coast-highland corridor within a Geographic Information Systems (GIS) model. Our model highlights important connections between early Andean foragers and their paleoenvironments and in turn is used to refine the search for additional early human settlements in this and other coast-highland corridors.

Peruvian Beach Ridges: Records of Human Activity and Climate Change

David Reid, Kurt Rademaker, Taylor Kelley, Dan Sandweiss, Daniel F. Belknap

Among the many unusual features of the desert coast of northern Peru are the five major beach ridge sets: Santa (9°S), Piura (5° S), Colán (5°S), Chira (4°50' S), and Tumbes (3°40' S). These features of the landscape began forming after 5800 cal yr B.P., initiated by severe El Niño and seismic events. Archaeological remains on the beach ridge sets of Santa, Colán, and Chira provide evidence of local prehistoric peoples. The extent of prehistoric occupation and utilization varied due to environmental limitations influenced by beach ridge material, local paleoenvironments, and climate change events.

Ground-Penetrating Radar at Los Morteros, Peru: More than Meets the Eye

Alice R. Kelley, Dan Sandweiss, Joseph T. Kelley, Daniel F. Belknap, Kurt Rademaker, David Reid, Anna K. Kelley, Taylor F. Kelley

Archaeological excavations in the 1970s at Los Morteros in the Salinas de Chau of northern Peru identified a pre-ceramic-age site dating to ca. 4000 radiocarbon years BP. The remains of small, rock-walled structures, marine fauna and numerous groundstone mortars were discovered at the site, as was evidence of human burials. This material was found at the top of a large geomorphic feature, identified by the excavator as a sand dune, located on a raised marine terrace, 4.7 km [2.81 mi] from the present day shoreline. At present, the landform is the largest, non-bedrock feature in the area. Smaller barchan dunes are common below the raised marine terrace. The area is part of the Peruvian coastal desert and is devoid of vegetation.

In July 2006, the University of Maine field party conducted a reconnaissance level ground-penetrating radar survey of the landform in an effort to understand the formation processes associated with this anomalous feature. Transects of the site produced evidence of large, highly reflective material inconsistent with the fine-grained, aeolian deposits associated with sand dunes. The placement and orientation of these reflectors is consistent with walls and stairs that are characteristic of other pre-ceramic monumental structures identified in coastal Peru. This work suggests that the Los Morteros site is located on the apex of a large, human-constructed mound, not a sand dune or bedrock-cored feature. Construction of the mound pre-dates the age of the archaeological material sampled from the mound surface, placing the building of this feature at the very beginning of monumental architecture in Peru.

Future research must determine the chronology and details of construction, understand the geographic setting of

the site in relation to the paleoshoreline and other features, reconstruct the paleoclimatic and environmental conditions that permitted an early human group to construct this massive structure in what today is stark desert, and suggest the uses and purpose of the mound.

Integration and Exploration of Climate-Change Datasets

Sudarshan S. Chawathe

(joint work with Andrei Kurbatov and Pául Mayewski)

The integration of diverse datasets not only improves the efficiency and impact of research but also leads to scientific insights that are otherwise difficult to achieve. I outline a framework for such data integration in the context of cyber-infrastructure for climate-change research. I briefly describe some research challenges related to syntactic and semantic integration, flexible data access, efficiency, provenance, and archival. I highlight the importance of semi-structured datasets: those that are not easily rendered into a consistent tabular format or its variations. I describe methods for the mining and high-throughput interactive exploration of rich, integrated datasets. I also report on some early work on building a testbed for these ideas using on the ice-core and old-weather datasets. I suggest strategies to avoid a database version of "You can't get there from here" and hint at why some obvious ideas based on increasing flexibility are unlikely to work.

The GISP2 Chronology

Debra Meese

In determining the timing of paleoclimatic events, a highly-resolved continuous chronology is required. In glaciers and ice sheets, annual layers can be counted in a manner similar to tree rings and varves, including visual, chemical and physical techniques. Depending on the accumulation rate and flow history it is possible to obtain continuous annually (and in some cases seasonally) resolved histories. At the time the GISP2 core was drilled, it provided the most highly-resolved chronology of any geologic material, and therefore, was the chronology to compare to and improve on. Extensive work attempting to improve the accuracy has been published, including data from deep sea cores, stalagmites and other ice cores. A review of some of this work and potential revisions to the chronology will be discussed.

Tharsis Montes Ice Sheet models at high obliquity driven by GCM results

J. L. Fastook, J. W. Head (Brown University), and D. R. Marchant (Boston University)

Introduction: Fan-shaped deposits on the flanks of the Tharsis Montes volcanoes [1-3] have been interpreted to be glacial in origin, and are likely Amazonian in age [4]. The deposits contain three distinct facies [5], each of which can be associated with different glacial processes [1]. Earth analogs to these three facies have been identified in the Dry Valleys of Antarctica and their climatic implications described [6-7]. In previous work we have shown that fundamental differences between the atmospheric snow accumulation environments on Earth [8] and Mars [9-10], combined with the University of Maine Ice Sheet Model (UMISM) [8,11-12] constrained by geological observations [1-5], allowed us to characterize the mass balance of the Martian ice sheet by two equilibrium lines, and that glacial accumulation is favored on the flanks of large volcanoes, not their summits as seen on Earth. In addition, we have shown that coupling this mass balance parameterization to sample spin-axis obliquity histories [13-14] leads to chronologically reasonable glacial episodes with a maximum configuration that is in accord with the geological observations [15]. However, we found this to be true only for repeated advance and retreat during multiple 100 Ka obliquity cycles where the mean value is in excess of 45o.

In our past reconstructions, we used UMISM constrained by the geological record to define the parameterization of mass balance. While this approach gave a good fit to the geologic record, it yielded little information about how the atmospheric circulation of Mars was actually changing during the periods of high obliquity. In this contribution we describe the use of results from a focused run of an atmospheric general circulation model (GCM) for Mars at high obliquity [16-17]. This GCM, run for a high-obliquity climate, favors deposition of snow on the northwest flanks of the Tharsis Montes due to upwelling and adiabatic cooling of moist polar air as it rises up the slopes of the volcanoes. Predicted, rather than parameterized, accumulation rates are used to drive UMISM,

and the resulting ice sheets are compared to the geological evidence. This allows us to assess the validity of the GCM results, and also to assess both the spatial geometry in terms of areal extent and ice volume, and the temporal response in terms of how long such a high obliquity climate must exist to create ice sheet imprints that are in agreement with observed landforms.

Modeling: UMISM uses the well-tested shallow-ice approximation [8,11-12], which is suitable for modeling ice sheets on Mars because the cold temperatures and low accumulation rates make wet-bed sliding unlikely. In the shallow-ice approximation, a combination of mass and vertically-integrated momentum conservation yields a time-dependent partial differential equation for the ice thickness that requires as source the net mass balance (the difference between a positive deposition of ice and any negative removal over an annual cycle) at each point in the domain. In this simulation, the mass balance distribution is obtained from the results of a GCM run for a high-obliquity climate.

Mass Balance Distribution: The GCM used was the Martian Global Climate Model of the Laboratoire de Meteorologie

Dynamique [18-19], a well-tested model able to adequately simulate present Martian climate. A high-obliquity climate was simulated for 45 degrees obliquity (near the most probable value of 41.8 [13]) with a spatial resolution of approximately 2 degrees. The simulation showed net accumulation of 30-70 mm/yr on the western flanks of Olympus, Ascreus, Arsia, and Pavonis Montes, largely due to adiabatically cooled westerlies blowing upslope. The model was relatively insensitive to obliquity, as long as it was greater than 40 degrees, but mildly sensitive to atmospheric dust load, an unknown at high obliquity.

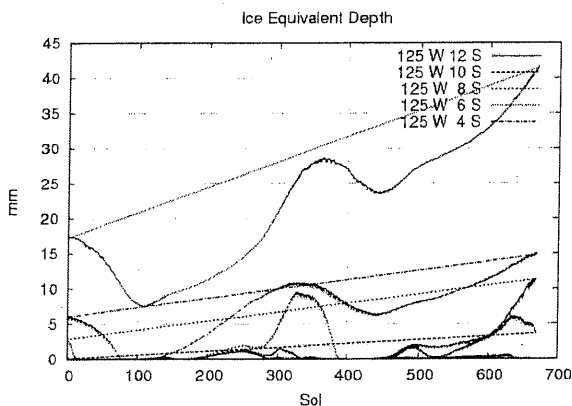


Figure 1: Ice-equivalent depth as a function of Sol.

The GCM results yield ice-equivalent depth (IED) as a function of Sol (Fig. 1). We can use this to separate positive accumulation from negative sublimation in our quest for the net mass balance at each point. For each point the IED may rise and fall throughout the year. As it rises, we sum up total annual accumulation (Fig. 2a), and as it falls, we sum up total annual sublimation (Fig. 2b). The difference represents the net annual mass balance, which is needed for the source in UMISM (Figure 3a). By separating these two components of the mass balance, we allow ourselves the opportunity to shift the balance between accumulation and sublimation. For instance, we generated Fig. 3a by scaling sublimation by a factor of two to more closely match the geologic record. This method also allows for the specification of a "climate knob" that can be connected to signals such as obliquity variations. Also generated by the GCM and required as an input boundary condition for UMISM is the surface temperature at each point in the domain (Fig. 3b).

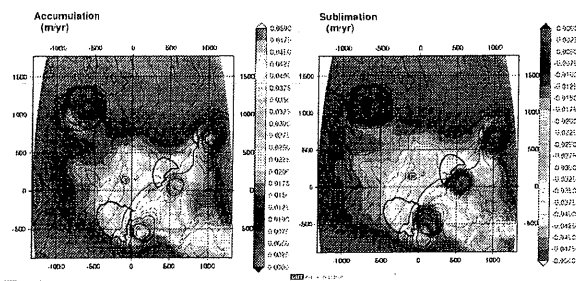


Figure 2: (a:left) Ice-equivalent Accumulation, (b:right) Ice-equivalent Sublimation.

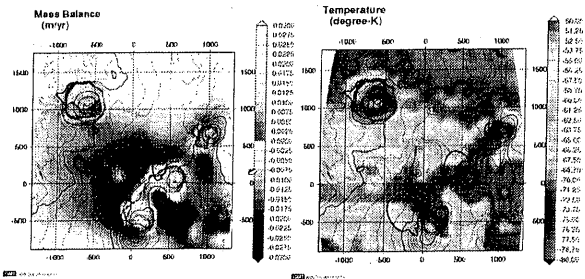


Figure 3: (a:left) Ice-equivalent Net Mass Balance, and (b:right) Surface Temperature.

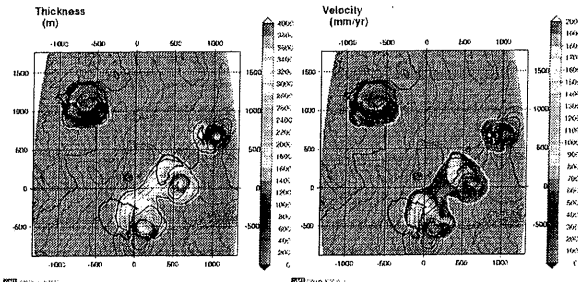


Figure 4: (a:left) Ice Thicknesses and (b:right) Velocities with surface elevations after 500 Ka.

Simulations: The simulation uses constant, fixed input (mass balance and surface temperatures) from the GCM. Figs. 4a,b show the ice thicknesses and column-averaged flow velocities with surface elevations superimposed as contours at the end of 500 Ka of model time. While artificial in the sense that these fixed climatic conditions likely did not hold steady for more than a 100 Ka, the resulting pattern of glaciation is compelling. Approach to steady state is indicated in Fig. 5, showing volume as a function of time. Interestingly, the volume attained after 500 Ka is within 15% of the estimate for the volume of the North Polar Ice Cap, which in the GCM is the source of moisture for the Tharsis precipitation. The ice thicknesses and velocities (Figs. 4a,b) show moderate agreement with [1]. The Olympus ice sheet is too large and extends too far to the south. The Arsia ice sheet extends too far up the flanks and at the same time does not go far enough to the west. The Pavonis ice sheet engulfs its peak, but matches the northern margin well. Also, the area of maximum velocity where the geologic imprint would be strongest matches the deposits. The Ascreus ice sheet, while slightly too large and with some ice on the peak, matches the deposits reasonably well.

Given the extraordinary topographic relief (> 20 km) of features with lateral extents of just a few hundreds of km, and that the resolution of the simulation is ~15 km, while that of the GCM is ~120 km at the equator, these results are in remarkably close agreement. A very good Earth-based GCM, Polar MM5 [20], produces a mass balance distribution that would yield similar inconsistencies with the current Greenland Ice Sheet, especially along its margin.

We are currently using a variety of predicted spin-axis obliquity histories [13] during the period when the glacial deposits were forming [2-4] to further refine our understanding of the history of the Tharsis tropical mountain glaciers.

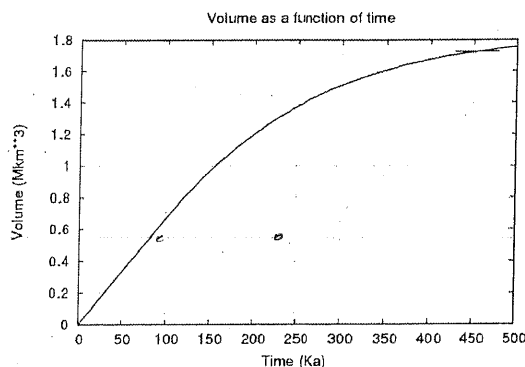


Figure 5: Volume in millions of km³ versus time.

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Atmospheric Block of the Earth Environment-Climate System in a Context of Global Climate Change: From Problems towards Conceptual Solutions

Vladimir Smorodin

I am going to present a brief review of some essential "still remaining" problems in the atmospheric block of the planetary environment-climate system in a context of Global Climate Change (GCC), both (1) particular (experimental and theoretical) and (2) general (methodological).

(1) Particular ones concern physics and physical chemistry of atmospheric aerosols, heterogeneous condensation, and atmospheric optics in the atmosphere. In part, only recently researchers have realized importance of contribution of mineral desert-derived aerosols into the climate radiative forcing. Earlier dust aerosol effects on climate by scattering and absorption solar radiation have been largely ignored. Today a description of the aerosol forcing in the GCC modeling seems to be as one of the largest uncertainties [1]. As we believe, key points for solving this problem are (a) further developing our concept of particulates with heterogeneous interfaces, and (b) elaborating conceptually new theoretical "tools" for understanding aerosol thermodynamics and dynamics on a nano-scale [2-5]. As we found out, adequate solutions of many remaining interrelated problems in cloud microphysics, homo- and heterogeneous nucleation, and atmospheric "chemistry" (on a large scale) may be revealed from this basic new viewpoint. (It is one of our projects on establishing "nano-science" fundamentals, we are dealing with: "non-equilibrium nano-thermodynamics of systems with finite life-time").

(2) Concerning general conceptual response of science on challenges of global climate change, I believe, we have to employ both "passive" (descriptive) and complementary "active" approaches in formulating climatic-environmental programs. In part, regarding of the atmospheric block in the context of GCC, additionally to (a) research, modeling, and monitoring the atmosphere, we may (b) apply a modern effective atmospheric technology on the regional and global net scale for improving or smoothing environment and climate. Gained purposes are: redistribution and renewal of natural water resources, preventing natural/anthropogenic crises and accidents, maintenance of steady ecological development of planetary biosphere. Realizing such a strategy,

humanity may get a chance to resolve any tragic global problems caused by a global warming, lack of fresh water, floods and droughts, soil erosion and desertification, massive forest fires, and possibly, tornados and hurricanes. (This is our net project "Ecopsphere-3").

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Model Northern Environment and Silicate Earth GCM

P O Koons, SE Johnson, C Gerbi

Our developing research programs seek to link the response of the silicate earth to internal earth dynamics and external perturbations through construction of two linked dynamic models operating at different temporal frequencies. The high frequency ($t < 20\text{kyr}$) Northern Environment model will produce a reference earth surface in time and space for the northern hemisphere by simultaneous solution of the coupled equations for the internal deformation of the earth and for the evolving earth surface influenced by a changing ice/water load and erosion. This high frequency model will embed within a Silicate Earth Global Circulation Model that relates mantle and crustal dynamics for the past 200Myr, the longest period over which the trajectory of a single convective limb, the Pacific Plate, can reliably be traced. Together these models will permit construction of a single rheological framework for the outer 200km of the earth that is constrained both by the low frequency, thermal-gravitational behavior of the deep earth, and by the high frequency glacial isostatic response. Preliminary observations on modern displacement following the removal of well characterized loads in Southeast Alaska and Iceland indicate lateral heterogeneity of the upper mantle and lower crust with local viscosities on the order of three orders of magnitude below those used in global visco-elastic solutions. These viscosities result from long term tectonic processes including mantle convection and crustal deformation, and strongly influence the physical and chemical evolution of the earth's surface in the northern hemisphere.

Improved ice velocity measurements for several East Antarctic outlet glaciers

Leigh A. Stearns, Gordon S. Hamilton

The East Antarctic Ice Sheet (EAIS) is Earth's largest freshwater reservoir, and has the potential to raise global sea level by ~55 meters. Because of its large size and the logistical challenge of conducting measurements, potential regional-scale mass imbalances of the EAIS are difficult to determine with the datasets currently available. ASTER satellite imagery provides coverage farther south than many existing datasets, opening up new possibilities for investigation. Here, we present new ASTER-derived ice velocity maps for several East Antarctic outlet glaciers. These new measurements allow us to compare the current flow dynamics and update our mass balance estimates for large outlet glaciers draining into the Ross Ice Shelf.

Results indicate that Byrd Glacier, one of the largest glaciers in Antarctica, entered a phase of modest acceleration and thinning beginning in 2006-2007. Ice velocity measurements from the 1960s through 2007 indicate that current flow speeds are anomalous in the past ~45 years. An investigation of other East Antarctic outlet glaciers (e.g. Mulock and Nimrod glaciers), using ASTER imaging techniques, indicates that these glaciers are not currently undergoing the same ice dynamics changes as observed on Byrd Glacier.

ENSO Moisture Transport in the North Pacific for the Past Millenium from the Eclipse Icefield, St Elias Mounatins, Yukon Territory

Nathan W. Vogan, Karl J. Kreutz, Cameron Wake, Christian Zdanowicz, Luke Copeland, Dave Fisher, Erich Osterberg, Alan Wanamaker, Kaplan Yalcin

A new ice core (343 m) was collected from the Eclipse Icefield (~30 km northeast of the Logan Massif, 3017 masl) in the St. Elias Mountains in 2002. This new record has been sampled for stable hydrogen isotopes (δD)

on a subannual resolution from 1450 AD forward and on a five-year resolution for the last millennium. The isotope record shows the dominant climate patterns of the last 1000 years with higher values during the Medieval Climate Anomaly (MCA) and lower values during the Little Ice Age (LIA). A standard temperature/isotope relationship implies lower regional temperatures with higher temperature variability during the period of 1250-1700. However, previous work on snow samples and an ice core recovered in 1980 from Mt. Logan (5345 masl) has shown that major discontinuities in the variation of the water stable isotope ratios exist with altitude, which are believed to be derived from a multilayered atmosphere during precipitation events on high altitude glacier sites. This layering in the atmosphere results in a decreasing influence of local water on water isotope fractionation with increasing altitude. Therefore, isotopes at high altitude ice core sites in the St. Elias Mountains will be sensitive to changes in ENSO moisture transport in the North Pacific, rather than to the standard isotope-air temperature fractionation commonly applied to ice cores. We suggest that the Eclipse core is representative of ENSO forcing of moisture in the North Pacific for the past millennium. Using data from the last 50 years, El Niño (La Niña) years correspond to greater (less) isotope fractionation at Eclipse and the St. Elias Mountains. These relationships indicate an apparent shift to El Niño conditions just prior to 1200 AD with depleted δD values coincident with the onset of the Little Ice Age. Eclipse isotope fractionation is still influenced by local water sources. To properly understand the influence of local meteorological conditions on fresh snow isotope chemistry in the St. Elias Mountains a concurrent study of snow pit sampling and weather measurements at the Divide Site (2800 masl) is being carried out. The relationships derived from the Divide Site will be an integral component in determining the role that moisture source plays in the water isotope chemistry of precipitation in the St. Elias Mountains.

Regional Patterns and Forcing of the Little Ice Age and Medieval Climate Anomaly in the Northern Hemisphere

Erich Osterberg, Paul Mayewski, Karl Kreutz, David Fisher, Sharon Sneed, Mike Handley, and Andrei Kurbatov

Recent analyses based on paleoproxies and intermediate-complexity climate models suggest that a quasi-persistent El Niño (La Niña) state was induced during the Little Ice Age (Medieval Climate Anomaly; MCA) by a combination of enhanced (reduced) volcanic activity and minima (maxima) in solar intensity. Teleconnections from the tropical Pacific are also hypothesized to induce conditions similar to the Arctic Oscillation positive state (AO+) in the North Atlantic region during La Niña-like conditions (i.e. during the MCA), and vice versa. A calibrated glaciochemical (sea salt Na+) proxy of the Aleutian Low (ALOW) from the Mt. Logan (Yukon, Canada) ice core reveals a generally weak ALOW from ~500-1300 AD, followed by a more intense ALOW beginning in the 14th century and deepening from ~1690 AD to present, consistent with the hypothesis of El Niño-like (La Niña-like) conditions in the LIA (MCA). A calibrated proxy record of Icelandic Low (ICELOW) intensity from the GISP2 ice core, however, reveals an abrupt (~20-30 years) shift from a weaker ICELOW (AO- like) to a stronger ICELOW (AO+ like) coincident with the Spörer solar minimum at ~1430 A.D, and a persistence of the stronger ICELOW state until the 20th century. The ICELOW shift at ~1430 A.D. is contrary to the modeled response of the North Atlantic region to reduced solar intensity and more El Niño-like conditions during the LIA. We suggest that the ~1430 shift is related to an increase in winter sea-ice extent in the North Atlantic, potentially due to reduced solar intensity. The ~1430 increase in sea-ice appears to overwhelm any signal of ENSO teleconnection in the North Atlantic, but such a signal is apparent in the GISP2 record during the subsequent Maunder solar minimum (~1675 AD) within the expanded sea-ice regime.

A multi-isotope study of atmospheric transport and stratification in the North Pacific

Benjamin Gross, Karl Kreutz, Erich Osterberg, Paul Mayewski, Dan Lux, Peter Koons, and Mike Handley

Atmospheric circulation and stratification exerts a crucial control on alpine-climate, alpine climate variability, and pollution transport. Work in the St. Elias Range (Yukon Territories, Canada) has yielded unexpected altitudinal distributions of stable water isotopes and aerosol pollutant concentrations. For example, the 40-year record from Eclipse Icefield (3100 masl) shows Pb concentrations ranging from 8.96 parts per thousand (ppt) to 536.81 ppt with no apparent long-term trend. When the Eclipse Icefield record is compared to the PR-Col record (5300 masl), differences between the two sites in Pb, SO₄²⁻, and NO₃⁻ suggest that different pollutant sources may be present at different elevations. I propose to return to previously sampled sites on and around Mount Logan to collect: two firn cores (at Eclipse Icefield and King Col [4200 masl]), snowpit samples (at Quintino-Sella [2800

masl], Eclipse Icefield, King Trench Camp [3300 masl], and King Col), and samples from any fresh snow events. All samples will be analyzed for stable Pb isotopes (^{204}Pb , ^{206}Pb , ^{207}Pb , ^{208}Pb), stable water isotopes (H, D, ^{16}O , ^{18}O), and major ions. These geochemical proxies should provide important constraints on the source of Pb pollution in Mount Logan snow and large-scale (Trans-Pacific) and synoptic-scale atmospheric transport and stratification in the North Pacific.

Ice sheets in North Carolina

T. Hughes

During two weeks in June of 2006 I taught a two-week course in glaciology to students attending Elizabeth City State University (ECSU) in North Carolina. ECSU trains Black students for careers in science and technology. Like the University of Maine (UM), ECSU is a collaborating institution in the science and technology center funded by NSF for \$20 million over five years with another \$20 million budgeted for a second five years. The center is called the Center for Remote Sensing of Ice Sheets (CReSIS). It is located at the University of Kansas (KU). Other collaborating institutions are NASA, The Pennsylvania State University (PU), The Ohio State University (OSU), and Haskell Indian Nations University (HINU) which like KU is located in Lawrence, Kansas.

CReSIS has five major components, (1) developing technology for studying the behavior of the Greenland and Antarctic ice sheets by manufacturing surface and air vehicles for collecting standard glaciological data using remote control operation, (2) undertaking field work at specific sites where instabilities have developed in major ice streams that drain these ice sheets, (3) producing computer models that capture the physics responsible for the instabilities so the models can project the extent and duration of the instabilities into the future, (3) including an educational outreach program that targets groups under-represented in science and technology, (4) collaborating with corporate science and technology institutions by way of student internships and cost-sharing, and (5) dispersing scientific and technological data and expertise to the broad scientific and educational communities.

My two-week glaciology course at ECSU served the third goal. Students taking my course were part of a larger outreach program at ECSU. Two classes per day were held. The morning classes consisted of slide presentations beginning with historical maps and photographs from the "Heroic Age" of polar exploration, especially in Antarctica, moving to modern research activity in Antarctica under the umbrella of the Antarctic Treaty, and then focusing on my own research activities in Greenland and Antarctica since 1968. These presentations were designed to instill the adventure and challenge of glaciological research conducted in spectacular settings. The afternoon classes consisted in teaching the basic concepts in glaciological research, using as a text my monograph, "Holistic Ice Sheet Modeling: A First-Order Approach" prepared specifically for teaching this course. It began by locating glaciology in the larger enterprise of understanding episodes of rapid climate change during the present Quaternary Ice Age, including present-day trends, and then moved on to derivations of the force balance and the mass balance of ice sheets, linked by the flow law and the sliding law of glacier ice, with applications to Greenland and Antarctica.

As a result of taking this course, three students gave presentations at the NSF-sponsored Thirteenth Annual WAIS Workshop in September of 2006 (WAIS: West Antarctic Ice Sheet Initiative). Two were undergraduate women, one from Jackson State University in Mississippi and one from Jarvis Christian College in Texas. One was a male graduate student at ECSU who had just completed his MS thesis, and who is now my doctoral student at UM. The course has been integrated into a new course being taught this fall at ECSU that deals with how to study dynamic systems, such as ice sheets and global climate.

Transition from ice shelf to tidewater margin in the Gulf of Maine, 23 – 14 cal. ka

Daniel F. Belknap, Department of Earth Sciences, School of Marine Studies and Climate Change Institute

The Gulf of Maine (GoM) during LGM was filled by Laurentide Ice Sheet to Georges and Browns Banks. Basins and margins contain a record of deglaciation accessible to high-resolution seismic reflection profiling and piston coring. Till is overlain by proximal glaciomarine (PGM) with a draped geometry, distinct stratification, and abundant internal hyperbolic reflections from iceberg dump. Distal glaciomarine (DGM) has a draping geometry,

with less distinct reflectors and fewer iceberg dumps. Ice shelves developed ca. 22 cal. ka as warming and sea-level rise led to progressively back-stepping grounding lines. At the grounding lines wedge-shaped till tongues define ice shelf prograding and receding grounding lines exquisitely interbedded with PGM. There is little deformation at the interface, strongly suggesting a grounding line as opposed to ice push or outwash fan. Ice streams draining the Bay of Fundy brought reddish sediments as far west as Wilkinson Basin, and through the eastern basins from Jordan to Crowell into Georges Basin, producing a transitional (TGM) unit, 15.7-16.9 cal. ka, near the time of Heinrich Event 1 (16.5 cal. ka). Coarse dumps and well-stratified reflectors suggest rapid advection and meltout south of Truxton Swell. Central and southern GoM is completely plowed by iceberg furrows to a bathymetric depth of 200 m, with some deeper in Georges Basin. The deglacial sequence in central Jordan Basin, north of and younger than the TGM, records ca. 15 cal. ka transition from red-brown gravelly, sandy mud of Bay of Fundy provenance to gray mud from crystalline basement in New England. No till tongues are found in northern Jordan Basin, suggesting a transition to calving tidewater front also around 15 cal. ka. This tidewater margin was characteristic of the ice sheet front as it retreated across the isostatically depressed coasts of Northeastern New England and New Brunswick, until becoming a terrestrial margin at the marine limit ca. 14-13 cal. ka. The tidewater margin demonstrates short (ca. 1 km) coarse fans interfingering with glaciomarine mud, actively deformed till and stratified sediment, and fossil evidence of shallow environments 14.5 to 12.5 cal. ka. This is one of the world's best-studied examples of termination of a marine-based ice margin, with extensive high-resolution geophysical records and correlative on-land exposures.

GPR investigations of the Glidden Point midden

Peter A. Leach

The famous Glidden Point midden is a massive oyster shell heap located on the western side of the Damariscotta in the town of Newcastle. The midden is conserved by the Damariscotta River Association and by the Hart family who own the site and the surrounding property. A Ground Penetrating Radar (GPR) survey was conducted on the Glidden Point Midden to assess the stratigraphy and basal configuration of the midden, and to evaluate the appropriateness of GPR for shell midden archaeology. The initial results of the GPR survey show that the midden comprises one large, central heap, that was built sporadically. Numerous, stacked reflectors in the central heap show successive periods of shell deposition and abandonment episodes. Steeply dipping clinofolds prograde to the southwest from the central heap, implying later stages of midden building. The midden thins to the northeast and to the west, where the GPR profiles show a glaciomarine basal unit that steepens in these directions. GPR survey is non-invasive and provides a relatively quick and inexpensive means of non-destructive archaeological survey of shell middens.

What is the effect of sea-level rise on Maine's coastal wetlands?

Holly Theriault

Sea-level is rising in Maine at rates of 1.5 to 2.5mm/yr and is predicted to accelerate its rate of rise over the next century or more. The terrestrial environment affected most dramatically by sea-level rise is that with the least topographic relief, freshwater wetlands. With only a slight sea-level rise, extensive freshwater wetlands are at risk of encroachment by the sea. Maine has many freshwater wetlands extending to the coast, and these are the locations in Maine vulnerable to rising sea-level. Previous study suggests that peatlands can collapse when they encounter the sea, but there are few direct observations and little previous work on this topic. I am studying four freshwater wetland settings in Maine where rising sea-level is interacting with the peat deposits. The sites are located along the Downeast Maine coast. Grand Marsh in Gouldsboro demonstrates a gradual transition from broad, high salt marsh to a brackish-to-fresh marsh at the inflow of a minor stream. Hay Creek in Jonesport is an unusual example of a tidal creek and saltmarsh intersecting a raised bog with an abrupt transition. Carrying Place Cove in Lubec is exposed to both a transgressing beach on its seaward side and a rapidly eroding peat bluff on its northern tidal flat margin. At each site, ground-penetrating radar and cores will be used to define the stratigraphic succession that represents the transgression. Time series aerial photography will be used to measure the differing rates of transgression and to predict future land losses. Thus far, ground-penetrating radar over the site in Jonesport provided information about the contact layer below and the relationship of salt water to the freshwater peat. Future transects and cores combined will give data that will determine the longer term rates of transgression and the processes that operate during the change from

freshwater bog to saltmarsh, and whether or not there is the possibility of preservation of past marshes.

Preservation of Submarine Moraines off Wells, Maine

Joseph T. Kelley, Daniel F. Belknap, Peter Leach, Walter A. Barnhardt, Emilia G. Pintado

In 2005, the seafloor off Wells, ME was mapped with interferometric side scan sonar, yielding bathymetry and acoustic images of 102 km² of the seafloor between 20 and 50 m depth. New Chirp seismic records were also added to more than 500 km of "boomer" seismic data. Fields of moraines clustering from 25-35 m depth, observed earlier by Miller (1988), show remarkable preservation despite having experienced both late Pleistocene emergence through the surf zone, and later submergence. Though some moraines are substantially wave-eroded, with apparent drowned spits and inlets, many show little effect from wave exposure. One hypothesis to explain the minimal erosion is that both falling and rising sea-level change rates were extreme (0.5-1 cm/yr) when these features experienced wave exposure. At estimated erosion rates of 0.1 m/yr, < 50 m of till erosion would occur. Some moraines appear to have experienced even less erosion than this, however. It is possible that eroded material remained nearby to armor the features from subsequent erosion. Another hypothesis, that paleobathymetry shielded the moraines from waves at lower sea levels was investigated with the SWAN numerical model. When sea level was 25 m below present, a large exposure of land existed north of the moraines and shielded them from wave energy during northeast storms, the most powerful in the region. Though the moraines were still exposed to the common southwesterly swells, these smaller waves had impact only on some of the moraines in the northern part of the study area. Thus, rapid sea-level change coupled with more protective paleobathymetry, probably led to minimal moraine erosion.

Assessing the Historical Distribution of Swordfish in the Gulf of Maine based on Stable Isotope and Archeological Evidence

D.S. Introne, A. Wanamaker, K. Kreutz, D. Sanger

Swordfish, *Xiphias gladius*, a highly migratory pelagic fish, occur in tropical, subtropical and temperate seas. They can be found in water depths ranging from 180 m to 580 m, but also in water as shallow as 30 m during their shoreward summer migration. Because of their feeding habits and thermoregulation requirements swordfish will only be found in water where sea surface temperatures (SST) reach a minimum of 10 oC, with a preferred temperature optimum of approximately 15 oC to 16 oC. Recent isotopic paleotemperature records derived from long-lived ocean quahog, fossil *Arctica islandica*, show a systematic mean cooling in the Gulf of Maine (GOM) by approximately 2 oC during the last 1000 years. This cooling trend correlates over the same timescale with a 2 oC cooling of northwest Atlantic slope water based on alkenone derived SST estimates from sediment cores. It is believed that there is an oceanographic link between slope water temperature and GOM water temperature. If this coupling persisted back in time, an additional cooling of 5 to 6 oC can be derived for the GOM by extrapolating the historical Scotian Margin and Laurentian Fan SSTs for the Holocene. Calibrated GOM SSTs derived by comparing the isotopic data to measured surface water temperatures suggest a shift in mean values from 10.7 oC at 1000 years BP to 8.6 oC today, and as warm as 17 oC in the past. The mean GOM SST is currently below the threshold for swordfish. However at 1000 years BP, the SST exceeded the 10 oC temperature threshold and even warmer GOM SSTs have persisted for the last 12,000 years. Currently swordfish distribution in the northeastern US is limited to southern New England and Cape Cod, and farther offshore in the Gulf of Maine, where water temperatures today are above 10 oC and approach the optimum temperature range. However, archeological sites in Maine show that aboriginal people were utilizing swordfish since before 5000 years ago and until 3800 BP. Did these native people fish far offshore as fisherman must do today, or were they able to fish closer to shore? These new data suggest that threshold surface water temperatures for swordfish existed within the GOM at least during more recent archaeological times (1000y BP) and by extrapolation well into the past. More optimal swordfish fishing temperatures of 15 oC to 16 oC could have existed 5000 years ago allowing for a near shore aboriginal swordfish fishery to be established. At 3800 years BP, when the aboriginal fishery ceased, derived SSTs although slightly cooler, were still conducive to a swordfish fishery (>10 oC) and these temperatures persisted in the GOM long after aboriginal peoples had abandoned the fishery. The derived SST at 3800 years BP was above the critical threshold temperature for swordfish, therefore the possible collapse of the fishery, most likely was not due to the accessibility or the abundance of the target species, but rather it may have been caused by some other physical or cultural reason.

Did a new people with a different approach to subsistence that did not include swordfishing move into the area? There is abundant evidence to support a migration at that time. If so, cooling SSTs may not be the reason for the absence of swordfish remains in archaeological sites after 3800 BP.

Investigating the role of atmospheric circulation in the anomalous formation, growth and decay of the Laurentide Ice Sheet

Searl Birkel

The Laurentide Ice Sheet (LIS) which covered North America is commonly thought of as a standard feature of the Ice Age. Surprisingly, the growth of the ice sheet itself constitutes an anomaly. Known from various climate proxies, global mean-summer temperature depression during maximum ice buildup was on the order of 5-6 degrees C. When used as input for a finite-element glaciological model, this temperature departure from modern values yields realistic growth of the Cordilleran Ice Sheet over western North America. In contrast, a much greater cooling of about 18 degrees C is necessary to grow the LIS over the eastern Hudson Bay lowlands. Previous work indicates that this difference is probably real and that it is associated with a southward displacement of the summer Polar Front east of the Rocky Mountains. I expand upon this idea and hypothesize that the position of the Polar Front over eastern North America was depressed southward during the Last Glacial Maximum because of the orographic influence of the LIS. This artificial displacement of upper-level and surface winds in turn shifted the Gulf Stream to a more southerly track, which in turn afforded strong Labrador Current influence offshore of the New England and the Canadian Maritime provinces. Ultimately, these coupled feedbacks caused a drastic regional climatic cooling and led to an expansion of the summer Polar cell which then enabled the LIS to grow well into the mid-latitudes. This hypothesis will be tested using a coupled ocean-atmosphere general circulation model.

The uncoupling of Jakobshavn Isbrae between 1993 and 2003

Coen Hofstede

Most ice sheet models use laminar flow where gravitational forcing is balanced by the basal shear stress. More sophisticated models include thermomechanical coupling so they are able to calculate ice temperatures at each time step. These models are able to reconstruct the present shape of ice sheets or ice sheets in the past accurately. This is mainly done by adjusting the ice hardness parameter. One might assume the models represent ice dynamics properly as they do a good job in ice sheet reconstruction. None of the ice sheet models predicted the quick reaction of the Greenland ice sheet to the present warming period. The dynamic reaction of the Greenland ice sheet is only restricted to the edges at the southern half of the ice sheet. Obviously this relatively small area can not be characterized by laminar sheet flow as laminar flow is too slow in its reaction. The edges of an ice sheet are often characterized by stream flow. Stream flow is quick in reaction to climatic change, it can accelerate and decelerate quickly. I will present a simple flow line model to simulate ice stream dynamics. Ice stream dynamics is treated as a continuous transition between sheet flow and shelf flow by calculating the floating fraction of the ice. The floating fraction really is a measure for the coupling of ice to the bed. Using the flow line model I will show the ice bed uncoupling of Jakobshavn Isbrae from 1993 to 2003. Jakobshavn Isbrae is one of the three larger ice streams that accelerated significantly from 1997 up to present. The uncoupling history of Jakobshavn Isbrae can be used to quantify perturbations in the force balance that may have caused the quick reaction of the ice stream.

Artifact distribution at the Bull Brook paleoindian site: preliminary observations

Jennifer Ort, Brian Robinson

The Bull Brook Paleoindian site has 42 discrete artifact concentrations arranged in a circular pattern measuring over 500 ft. across. Located in Ipswich, Massachusetts the site was excavated between the 1950s and 1960s by avocational archaeologists before its destruction by gravel operations. The site is currently being reanalyzed with NSF support by multiple researchers through the University of Maine. Analysis by the presenter is focused on distributional patterns of artifact classes and lithic materials. This poster will present preliminary observations on patterns and problems of interpreting distributions across the site.

The Identification of Atlantic Salmon on Interior Archaeological Sites

Brian Robinson and Martin Yates

Faunal remains from archaeological sites contribute to reconstruction of past habitats in addition to past diets. Archaeological occurrences of Atlantic salmon are of particular interest related to modern recreation, economics, critical habitats, species restoration and climate change. Identification of salmon on interior archaeological sites has been a problem because: 1) fish bone is preserved in Maine's acid soils only in special circumstances after it has been burned, and 2) different species of salmon and trout are difficult to distinguish in highly fragmented remains. Here we address ongoing efforts to identify Atlantic salmon based on bone morphology and chemistry, using the Electron Microprobe at the University of Maine.

Statistical Detection of Holocene Rapid Climate Change Events

Kirk Allen Maasch and Paul Andrew Mayewski

Statistical methods to quantify the timing of rapid climate change (RCC) events of the late Holocene were applied to high-resolution proxy records of hemispheric scale atmospheric circulation and temperature change spanning the past 2000 years. Climate jumps were detected using the signal-to-noise (S/N) ratio defined by Yamamoto et al. (1986). This method of analysis is similar to a procedure called non-overlapping consecutive epoch analysis (Karl and Riebsame, 1984). Each time series was broken into 150-250 year long segments. The mean for each of these segments, along with its 95% confidence limit, were calculated for the time span before and after a reference year. The S/N ratio was defined as the absolute value of the difference between the mean before and after the reference year divided by the sum of the confidence limits before and after the reference year. The reference year was moved over the data to obtain a S/N time series. Detection of a jump was presumed for a S/N ratio greater than 1.0.

In the Northern Hemisphere temperature record four significant jumps were detected. The largest were a weakening of the westerlies and warming at around AD800 and a strengthening of the westerlies and cooling near AD1440. There was also a slight decrease in circulation and temperature at around AD1100 and a temporary cooling at AD1700.

In the Southern Hemisphere temperature record five significant jumps were detected. The largest were a weakening of the westerlies and warming at around AD500 and a strengthening of the westerlies and cooling at AD1000. There was a smaller amount of cooling at around AD750 and AD1700, and a slight warming at about AD1300.

Karl, T.R., and Riebsame, W.E.: The identification of 10- and 20- year temperature and precipitation fluctuations in the contiguous United States, *Journal of Climate and Applied Meteorology*, 23, 950-966, 1984

Yamamoto, R., Iwashima, T., and Sange, N.K.: An analysis of climate jump, *J. Meteor. Soc. Japan*, 64, 273-281, 1986.

Thinning of the south dome of Barnes Ice Cap, arctic Canada, over the past two decades

William Sneed, Roger Hooke, Gordon Hamilton

Between 1970 and 1984, ground surveys were carried out along a flowline extending from the top of the south dome of Barnes Ice Cap to the margin. Over this time span, the ice cap thinned an average of 1.6 m, or 0.11 m a⁻¹. By comparing the 1984 survey with elevations derived from satellite imagery in 2006 we find that it has now thinned an additional 16.8 ± 0.1 m, or an average of ~ 0.76 m a⁻¹. Laser altimeter profiles show that between 2004 and 2006, the thinning rate was 1.0 ± 0.14 m a⁻¹. A correlation between mass balance and mean summer temperature at nearby weather stations, developed over the period of the ground surveys, permits independent estimates of the thinning rate. These estimates are in excellent agreement with those based on satellite imagery. The acceleration in thinning is consistent with meteorological records documenting an increase in the number of positive degree days (atmospheric warming) in the region.

Prehistoric Diet at Hinds Cave, Texas: Evidence from 34 Paleofeces

Sam Belknap, Kristin Sobolik, Vaughn Bryant (Texas A&M), Tim Riley (Texas A&M), Hendrik Poinar (McMaster Univ.), Kirsti Box (McMaster Univ.)

A thorough examination of 34 human paleofecal samples from Hinds Cave, Texas provides direct evidence of the use of certain plant species as well as the importance of small mammals as a food source for the inhabitants of the Lower Pecos region. This study incorporates the latest palynological, starch grain, and metagenomic analysis, as well as the tried and true macro-botanical and macro-faunal research, to enhance our ability to quantify and interpret paleo-dietary information provided by human fecal remains.

Glacial History and Paleoclimate in Patagonia (Southern South America) during the LGM and Termination of the Last Glacial Cycle

Juan Luis García

This report shows some preliminary results of the first field season in Torres del Paine National Park (50°S) in the Chilean Patagonian district. The aim of this project is to reconstruct the timing of the cold events during the last glacial cycle through exposure dating (i.e. ^{10}Be). This approach should provide a valuable glacial chronology of the region, which in turn will be compared with other paleoclimate chronologies in the Southern and Northern Hemispheres. Main questions this project will answer are: a) The initiation, extent, duration, and termination of the Last Glacial Maximum in Patagonia; b) Glacial history during the transition to the present interglacial (i.e. Last Termination); c) The possible existence of interhemispheric asynchrony of past climate change. The results expected from the project will provide a better comprehension about major global problems, such as the origin of the ice ages and the cause of abrupt climate change.

Holocene distribution of southern elephant seals along the Victoria Land Coast, Antarctica

Brenda Hall, Audrey Bamberg, Paul Koch (University of California–Santa Cruz), Rus Hoelzel, and Mark de Bruyn (University of Durham)

We are reconstructing the Holocene distribution of southern elephant seals (*Mirounga leonina*) in the Ross Sea, based on abandoned colonies along the Victoria Land Coast. The goals of this project, now in its second year, are threefold: first, to determine the timing of elephant seal occupation and its relationship to climate factors, such as sea-ice extent and duration; second, to produce a genetic record of the now locally extinct population, including its diversity over time, rates of mutations, and relationship to extant populations in the Subantarctic; and finally, to document changes in seal ecology, such as feeding strategy, as well as any concurrent oceanographic shifts. Results so far indicate large changes in seal distribution in the mid-to-late Holocene, with two main periods of occupation being 1000-2500 and 4000-~6000 14C yr B.P. The presence of elephant seals along the Victoria Land Coast at these times requires two to six months of ice-free conditions at the shore per year, in an area where the ice does not break out today.

Comparison of observed and modeled LGM sea salt deposition in Antarctica

Karl Kreutz, Paul Mayewski, Sharon Sneed, Mike Handley, Andrei Kurbatov

Temporal variations of sea salt chemistry in any particular area, including ice core sites in Greenland and Antarctica, reflect some combination of aerosol production, transport, and deposition. Recent model results using the NCAR Community Atmospheric Model (CAM3; Mahowald et al., 2006) indicate a <5% change in sea salt response to different climate scenarios (last glacial maximum, preindustrial, current, and $2 \times \text{CO}_2$). These results are at odds with most Antarctic and Greenland ice core data, which have LGM:modern sea salt ratios of ~4-12, however are consistent with previous modeling studies which also fail to reproduce observed LGM sea salt deposition increases. Additionally, model runs that include sea ice processes and aerosol production from frost flowers still fail to reproduce observed LGM concentrations. Therefore, possible reasons for the model/observation discrepancy include: 1) deficiencies in the sea salt aerosol source, assumed size distribution, and deposition in the model, 2) deficiencies in the modeled surface wind changes in high latitudes, or 3) deficiencies in the model transport from the coastal ocean to the high altitude locations of the ice cores. We evaluate these scenarios using the LGM sea salt record from the Siple Dome ice core, which has a different

geographic setting (coastal) than the suite of high elevation Antarctic deep cores. While Siple Dome has likely undergone surface elevation changes over the past ~14kyr due to ice dynamical response to grounding line changes, it still provides a useful test of model performance.

Connections between meteorology and chemistry in surface snow: Clark Glacier, Antarctica

Bruce Williamson, Karl Kreutz, Paul Mayewski, Benjamin Gross, Sharon Sneed, Mike Wasckiewicz

Many studies have examined snow and ice chemistry in polar regions with the purpose of extending our knowledge of climate through the thousands of years captured in seasonal ice stratigraphy. Variation in major ions, stable isotope ratios, trapped gas composition, trace metal contents, and physical properties of the ice, among other studies, have provided information interpreted to yield a picture of the state of the atmosphere in the Holocene period. Sometimes, however, these studies are calibrated in the modern period against instrumental records not from the immediate vicinity of the site of the firn or ice core collected. In 2004-2005, a meteorology station was active on the surface of the Clark Glacier, collecting instrumental information for one full year on surface barometric pressure, temperature, wind speed and direction, and snow depth. In 2005, a snowpit was excavated and sampled directly below this meteorology station. Samples from this pit were analyzed for major ion composition using ion chromatography at the Climate Change Institute. The results demonstrate the precise correlations between the chemistry of the snow pack and the weather conditions active at the time of precipitation. Major ions are shown to react in a variable fashion, with some (Na⁺, Ca²⁺, Mg²⁺) demonstrating reaction to multiple individual snow deposition events, while MS⁻ shows a more clearly annual signal, with only one peak shown for the period of meteorology collected. The stable isotopic record, meanwhile, appears to record the most recent year with a reasonable annual signal, but the signal becomes increasingly muted with increasing depth in the snowpack (also representing increasing time after deposition). These results confirm the potential for such records in snow and ice to record not only annual but potentially sub-annual time series in several chemical proxies related to climate study.

A High-Resolution Record of Atmospheric Dust Variability Since 1650 AD from a Mt. Everest Ice Core

Susan Kaspari, Paul Mayewski, Mike Handley, Shichang Kang

The arid and semi-arid regions of Asia are a major source of atmospheric dust over the Northern Hemisphere. Dust aerosols have a large impact on the climate system by altering the Earth's radiative balance, are important for biogeochemical cycles, and affect human respiratory health. We investigate atmospheric dust variability in Asia since 1650 AD using a high resolution Mt. Everest ice core record analyzed for a suite of dust related elements (Sr, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Bi, U, Th, Al, S, Ca, Ti, V, Cr, Mn, Fe, Co, Mg and Na,) via inductively coupled plasma mass spectrometry (ICP-MS). Dust concentrations peak during the late winter and spring due to unstable atmospheric conditions. The chemical composition of dust varies seasonally between low dust and high dust periods, indicating differences in source material and atmospheric circulation. Large dust events occur throughout the 350-year record, however atmospheric dust loading is slightly higher since 1850. We do not observe an increase in the frequency or intensity of dust events in recent decades, suggesting that human activities are not affecting the atmospheric dust loading of the remote atmosphere in Asia.

Mt. Geladaindong Dust Record: Relationships between Local and Regional Atmospheric Dust Loading, Circulation, and the PDO

B. Grigholm, P. Mayewski, S. Kaspari, S. Sneed, M. Handley (Univ. Maine), S. Kang, Y. Qinghua, Q. Zhang, Y. Zhang, Z. Cong, F. Chen (Institute of Tibetan Plateau Research)

In the fall of 2005 a joint-expedition between the University of Maine and the Institute of Tibetan Plateau Research recovered three ice cores from Guoqu Glacier (33°34'37.8"N, 91°10'35.3"E, 5720 m a.s.l.) on the northern side of Mt. Geladaindong. High-resolution analysis of a 45m ice core section based on isotopes ($\delta^{18}O$), major ions (Na⁺, K⁺, Mg²⁺, Ca²⁺, Cl⁻, NO₃⁻, SO₄²⁻), and radionuclides (Beta) established a 70 year record. Statistical analysis of major ion time series suggests that atmospheric dust species (all ions) dominate and that background dust levels conceal marine ion species deposition. Annual and seasonal correlations between the dust chemistry time series and NCEP Reanalysis variables (1948-2004) suggests that the Mt. Geladaindong record may present local and regional surface pressure and wind velocity proxies. The ~ three-fold decrease of dust baseline concentrations in the mid/late 70s accompanied with regional increases in surface pressure and decreases in wind velocity coincide with the major 1976-1977 shift of the Pacific Decadal Oscillation (PDO) from a negative to positive state. This is the first ice core evidence of a potential

teleconnection between central Asian atmospheric dust loading and the PDO. Analysis of temporally longer ice cores from Mt. Geladaindong may enhance understanding of the relationship the PDO and regional central Asian atmospheric circulation and subsequent atmospheric dust loading.

Searching for the new Northern Hemisphere climate proxies

Andrei V. Kurbatov, Carmelo Ferlito (University of Catania, Italy), Paul A. Mayewski, Douglas C. Introne, Sharon B. Sneed, Michael Handley

In September 2006 we conducted exploratory sampling of the ice layers formed in the cave "Grotta del Gelo", Mt. Etna, Sicily, Italy. The major goal of this pilot project was to evaluate potential recovery of the environmental signal from ice accumulated in the cave. The cave entrance was formed during roof collapse of one of the lava tunnels that was formed during the 1614 eruptions of Mt. Etna. In the winter months snow normally accumulates near the cave entrance. During melting season water propagates into the deeper part of the cave and refreezes, forming visible layers. Data from IC, isotope and ICP-MS show complex, potentially seasonal patterns in the sampled layers. Preliminary results concerning the significance of these potential climate records will be presented.

Species classification of fossil pinus (pine) pollen from species endemic to Maine, USA

Katelyn Michaud (UM Farmington), Andrea Nurse, Drew Barton (UM Farmington)

Because of the difficulty of separating red pine (*Pinus resinosa*) and jack pine (*Pinus banksiana*) in the pollen record, little is known about their paleoecological history and distribution. These species co-occur in Maine, along with white pine (*Pinus strobus*) and pitch pine (*Pinus rigida*). Because *P. strobus* pollen is distinguished by the furrow membrane sculpturing and *P. rigida* pollen is distinguished by its large grain size, this study focused on character separation between the remaining two species. In preliminary analysis (2005), we analyzed modern pollen collections of the four pine species (800 grains from 12 collections) using six qualitative and three quantitative pollen grain characters. During the summer of 2006, red pine and jack pine pollen was collected from 12 additional Maine sites and was analyzed using the same six qualitative and three quantitative characters as the preliminary study. Classification and regression-tree (CART) analysis allowed statistically robust separation of the two species using morphologic characters such as grain size, furrow sculpturing, and bladder width. Binary classification trees for each species give the probability of focal species identification in a given end node. First run data strongly suggest that *P. resinosa* and *P. banksiana* can be distinguished on the basis of over-all grain size.

Ecology of chironomid (midge fly) larval head capsules in Maine: increasing understanding of a temperature proxy and developing a robust Holocene temperature inference model for the northeastern United States

Ann C. Dieffenbacher-Krall

Since Ian Walker pioneered the chironomid-temperature inference model sixteen years ago, nearly two dozen studies have attempted to develop similar models for locations throughout the world, including both northeastern and northwestern North America, Fennoscandia, the Swiss Alps, Siberia, Greenland, and New Zealand. Criticism of Walker's initial model has led most researchers to conduct multivariate ecological analyses of chironomid and environmental data to demonstrate strong control of temperature over chironomid assemblages and validate their inference models. However, nearly half of these studies find that non-climatic factors have greater influence on chironomid assemblage variability than does temperature.

The proposed ecological analysis of chironomid larval head capsules in surface sediment from 410 Maine lakes will provide a data set 3-20 times more extensive than that used in any previous study. The large sample number will permit statistically valid subsetting of the data to allow examination of questions such as the extent to which the results of ecological statistical tests replicable, the climatic scale at which temperature ceases to be the primary driver of chironomid distribution, and if chironomids respond differently to temperature along different portions of the trophic gradient. By determining which chironomid taxa are most sensitive to temperature, and which lakes have adverse effects on inference model performance statistics, an improved

model may be developed using only a portion of taxa and a select subset of lakes. The addition of Maine and southern New England surface samples to the current eastern Canada training set will permit robust Holocene temperature reconstructions from chironomid data.

Late-glacial and Holocene vegetation changes in northern Maine: a multi-proxy approach to evaluating shifting forest patterns

Andrea Nurse, Ann Dieffenbacher-Krall, Molly Schaffler, Lisa Doner (Plymouth State)

Pollen records from five sites located in two regions of northern Maine provide a continuous and well-dated record of shifting vegetation patterns from late-glacial to present-day landscape. Integration of these pollen stratigraphies with the additional proxies of lake-level change, charcoal, plant macrofossils, chironomid assemblages, and magnetic susceptibility reveal a number of regional and local events:

1. Red and white spruce declined following with the advent of Holocene warming, but black spruce persisted throughout the Holocene. Spruce pollen declined at a time when both summer temperatures and regional moisture balance increased suggesting that red and white spruce may be more sensitive to temperature variances than to moisture balance.
2. Terrestrial pollen concentrations declined and lake levels were low at a time coincident with the 8200 year event suggesting cooler temperatures and decreased precipitation.
3. Hemlock declined across northeastern North America at 4800 14C years BP – the start of an abrupt decline in lake levels that heralded a 1000 year drought period.
4. Periods of fire (indicated by increased charcoal deposition) are followed by subtle increases in lake level and by spikes in birch pollen.
5. Lack of Younger Dryas-aged sediment deposition in a number of northern Maine ponds and the persistence of cold-tolerant vegetation around Whitehead Lake suggest cooler than average microclimates in the lowlands between the Boundary Mountains to the west and the New Brunswick highland plateau to the east. Differences in pollen and macrofossil assemblages at the various sites indicate patchy distribution of upland plants and provides further evidence for cold microclimates.

Geoarchaeological Investigations along the Tambo-Ilo Coast, Peru

Louis Fortin, Martin Yates, Gregory Zaro

Since the arrival of the Spanish in the 16th century, much has been learned about the coastal desert and highland's people of Peru. Through the analysis of ceramics, architecture, and textiles, archaeologists have gained knowledge about the local inhabitants, how they lived and how they interacted with their environment. However, little work has been completed in the area of stone tools just prior to Spanish contact and during the subsequent colonial period. How were local coastal inhabitants using stone tools? Can a stone tool typology be generated from coastal artifacts? Were local geological sources in the area exploited or were people trading or traveling long distances to obtain such materials? This summer's lithic survey along the Tambo-Ilo Coast, Peru is designed to increase our current understanding of lithic tool use during the late prehispanic and early Spanish colonial periods on the southern coast of Peru. In particular, I will investigate the role these stone tools played within the realms of trade and interaction at the archaeological site designated TI-185 and its immediate hinterland along the Tambo-Ilo coast of southern Peru.

Agricultural Landscapes Past and Present: Long-term Thinking along the Peruvian South Coast

Gregory Zaro

The Peruvian south coast between the Tambo and Ilo rivers is today a dry and desolate landscape. The lomas among the inland hills are considerably diminished, while agriculture in the area has been reduced to only a few surviving farmsteads. However, recent archaeological investigations provide evidence that farming was once a significant and viable activity along this intervalley coastline, and the lomas provided some opportunities for both dry farming and herding. These results suggest that contemporary patterns of land use, resource distribution, and sustainability are best understood when contextualized within long, historical trajectories of landscape transformation and human-environment dynamics. To better understand the role of human agency in landscape evolution in southern Peru, our current research will investigate changes in agricultural technology, the impact of agriculture on soil chemistry and nutrients, and long-term shifts in subsistence strategies at an abandoned agricultural complex between the Tambo and Ilo rivers.