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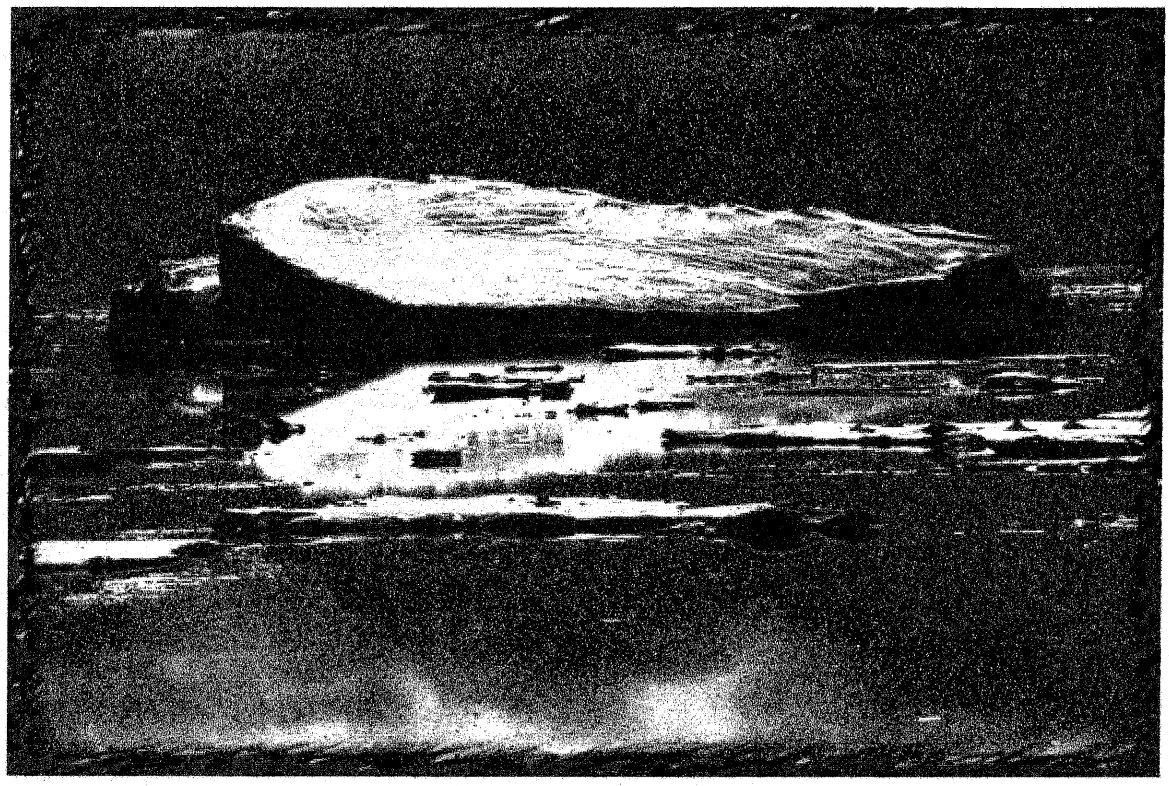
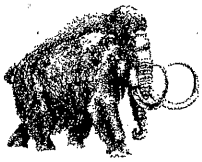


Program with Abstracts for the

10th J. Louis Agassiz Symposium

20 - 21 May 2002

Doris Twitchell Allen Center, University of Maine



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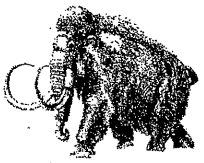


Monday, May 20

HOLOCENE CLIMATE CHANGE

8:30 Kirk Maasch, George Jacobson *"Welcome"*

8:45 Nancy Bertler, Paul Mayewski, P. Barrett, J. Shulmeister, and Karl Kreutz *"Solar Forcing of the McMurdo Dry Valleys Climate"*

9:00 Andrei Kurbatov, Greg Zielinski, N. Dunbar, Paul Mayewski, Eric Meyerson, and Sharon Sneed *"Explosive Volcanism Recorded in Siple Dome Ice Core, Antarctica"*

9:15 Kirk Maasch, Steve Houk and Dan Sandweiss *"Mid-to-late Holocene evolution of El Niño conditions in coastal Peru"*

9:30 Colby Smith *"A Little Ice Age Chronology for the Southern Alps of New Zealand"*

9:45 Fei Chai *"Biological Productivity and Air-Sea CO_2 Flux in the Pacific Ocean: Implications for Paleo-oceanography and Paleo-climatology"*

10:00 BREAK

GLACIAL CLIMATE CHANGE

10:30 Dave Smith, Hal Borns, and Kirk Maasch *"What Did Scientists Know About the Ice Age in 1875?"*

10:45 Hal Borns *"The Younger Dryas glacial fluctuation in northern Maine"*

11:00 George Denton *"Glacial Record of New Zealand"*

11:15 Brett VandenHeuvel *"Surficial Geology and Geomorphology of the Western Olympus Range, Antarctica: Implications for Ice-sheet Stability"*

11:30 Drew Lorrey *"The paleoclimate significance of the debris-covered glaciers in Beacon Valley, Antarctica"*

12:00 LUNCH

ATMOSPHERIC CIRCULATION I

1:00 Greg Zielinski *"Anatomy of the 'Mega-Bomb' "*

1:15 Paul Mayewski, Kirk Maasch, Eric Meyerson, Karl Kreutz, and Ian Goodwin *"Predictable Decadal Scale Climate Variability?"*

1:30 Shichang Kang, Paul Mayewski, and Yuping Yan *"Relationships between dust records from three ice cores and atmospheric circulation over the Northern Hemisphere: atmospheric transport patterns of spring dust aerosols during the last century"*

1:45 Yuping Yan, Shichang Kang, and Paul Mayewski *"Atmospheric transport patterns of sea-salt aerosols over Northern Hemisphere revealed by relationships between ice core sodium records and sea level pressure"*

POSTERS

2:00 Andrea Nurse and Ann Dieffenbacher-Krall *"Asynchroneity of Major Holocene Lake-level Changes Across Maine"*

2:00 Geneva Chase *"Is There Chironomid Evidence for the Killarney Oscillation in Maine?"*

2:00 Jim Fastook and Jesse Johnson *"Predicting the Locations of Lakes beneath Antarctica"*

KEYNOTE SPEAKER

2:30 Karl Turekian *"Cosmogenic nuclides as environmental and climate tracers"*

Tuesday, May 21

ARCHAEOLOGY

8:30 Dan Sandweiss, Steve Houk, Jim Richardson, and Alejandro Chu *"The 2001 Excavations at Siches, a Mid-Holocene Fishing Site near Talara, Peru"*

8:45 Kris Sobolik *"Children's Health in the Prehistoric Southwest"*

9:00 Brian Robinson *"Palaeoindian Studies at Bull Brook, Ipswich Massachusetts"*

9:15 Adrian Burke *"Red Metal (Copper) Use in the Maritime Peninsula during Late Prehistoric and Early Contact Times"*

9:30 Robert Lore *"Faunal Analysis of the Lawrie Farmstead: Insights on Subsistence Strategies in Colonial New Jersey"*

9:45 BREAK

SEA LEVEL CHANGE

10:15 Dan Belknap, Joe Kelley, and Allen Gonz *"Gulf of Maine Inner Shelf Sand Bodies: Relationship to Sea-level Changes and Onshore Pleistocene Sources"*

10:30 Brenda Hall and C. Baroni *"Relative Sea-Level Changes along the Victoria Land Coast, Antarctica"*

10:45 Roger LeB. Hooke *"Irreversible widening of a small estuary: a delayed anthropogenic effect?"*

ICE DYNAMICS

11:00 Terry Hughes *"Is the 'Jakobshavns Effect' in effect in Greenland?"*

11:15 Gordon Hamilton *"Glaciology of Siple Dome and the case for a minimally enlarged West Antarctic Ice Sheet at LGM"*

11:30 Blue Spikes, Bea Csathó Gordon Hamilton, and Ian Whillans *"Mass Balance of Antarctic Ice Streams Derived from Laser Altimeter Measurements"*

11:45 Tom Kellogg *"Are Deformable Basal Sediments Necessary for Fast Glacier Flow?"*

12:00 George Jacobson *"The Future of the Institute"*

12:15 LUNCH

ATMOSPHERIC CIRCULATION II

1:45 Dan Dixon *"Soluble ion characteristics over West Antarctica from U.S.ITASE ice cores"*

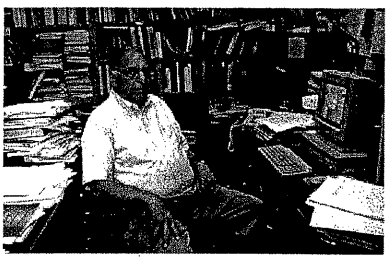
2:00 Eric Meyerson, Paul Mayewski, and Sharon Sneed *"The Holocene-Glacial History of Siple Dome, West Antarctica"*

2:15 Lee Pruett, Karl Kruetz, M Wadleigh, E Sholkovitz, and Paul Mayewski *"Stable sulfur isotope ratios ($\delta^{34}S$) in a West Antarctic firn core: Assessment of sulfate source and deposition"*

2:30 Susan Kaspari, Paul Mayewski, Sharon Sneed, Eric Meyerson *"Chemical Signature of an Extreme Storm Event in West Antarctica"*

KARL K. TUREKIAN
Silliman Professor of Geology
& Geophysics, Yale University

"Cosmogenic nuclides as environmental and climate tracers"



Keynote speaker for the10th IQCS Agassiz Symposium is Karl K. Turekian, Silliman Professor of Geology & Geophysics, Yale University. Professor Turekian also holds the titles of Director, Yale Institute for Biospheric Studies, Editorial Board, Proceedings of the National Academy of Sciences(1996-), Member, National Academy of Sciences, and Fellow, American Academy of Arts and Sciences.

His research interests are centered on radioactive, radiogenic and isotope measurements in Earth materials. Such measurements provide a useful approach to the study of terrestrial and cosmic processes. His laboratory has used these tools to address problems as diverse as the circulation of Long Island Sound and the cosmic dust flux to Earth. A few recent projects are listed below:

1. Air samples and atmospheric precipitation are analyzed for ^{222}Rn (radon) daughters such as ^{210}Pb and ^{214}Pb as well as cosmogenically produced ^{7}Be and ^{35}S to determine: (a) the residence times of aerosols in different layers of the troposphere via ^{214}Pb, ^{210}Pb and ^{7}Be, (b) the sources of ozone found in the troposphere based on correlations with ^{7}Be and ^{210}Pb, and (c) the oxidation and precipitation kinetics (including dry deposition) of SO_2 based on cosmogenic ^{35}S measurements.
2. The radioactive decay of ^{187}Re (half-life $\sim$4.6x10^{10} years) produces ^{187}Os. The ratio of ^{187}Os to non-radiogenic Os(nominally represented by ^{186}Os) in rocks undergoing weathering is determined by the Re/Os of the rock and its age. The variation in the relative sources of weathered material (high ^{187}Os/^{186}Os from continental crust, low ^{187}Os/^{186}Os from mantle-derived rocks) is sensed by contemporary sea water osmium and ultimately recorded in accumulating marine sediments. The tectonic history of the past 100 million years is inferred from Os isotope measurements in deep-sea deposits.
3. The measurement of ^{222}Rn (3.4 d), ^{226}Ra (1620 y), ^{228}Ra (5.7 y) and ^{224}Ra (3.6 d) in Long Island Sound water profiles provides information on the mean residence time of water in the Sound as well as the flux of nutrient-rich water from the New York City area. The radium isotopes also indicate the horizontal mixing rates in the Sound.
4. The ^{222}Rn and radium isotopes measured in groundwaters also indicate the retardation factors affecting the movement of cations, some of interest in nuclear waste disposal studies.
5. The cosmic dust flux to Earth is determined from the Os flux of the unique ^{187}Os/^{186}Os. Comparison with another cosmic dust tracer, ^{3}He, provides information on the transport of different size components of the dust through the atmosphere and the oceans before reaching the ocean floor.
6. ^{87}Sr/^{86}Sr of sea water and streams have been shown by others to be a way of translating this ratio into the salinity of coastal waters. Applications to environments of the Mesozoic provide the possibility of working out the life habitats of ancient coastal organisms.
7. Planetary degassing as seen through the study of radiogenic ^{40}Ar provides clues to the rates of recycling of carbon and water through the mantle. These evaluations depend on understanding the composition of the crust and direct measurements of ^{40}Ar flux from the solid earth to the atmosphere.
8. Oxygen isotope signatures preserved in seawater phosphate and phosphatic deposits such as fish debris provide information on the sites of enzymatic equilibration in the water column, and consequently paleothermometry of ancient marine fish habitats.

Abstracts

HOLOCENE CLIMATE CHANGE

Solar Forcing of the McMurdo Dry Valleys Climate

Nancy Bertler, Paul Mayewski, P. Barrett, J. Shulmeister, and Karl Kreutz

Major ion analyses and oxygen isotope data from snow and firn from Victoria Lower Glacier (VLG) in the McMurdo Dry Valleys (MDV) indicate that variations in solar activity have a measurable influence on local air mass trajectories.

Centered between the Ross Sea, the East Antarctic Ice Sheet (EAIS), and the Transantarctic Mountains (TAA), the MDV combine some of the greatest climatic contrasts found in Antarctica. The three distinct climatic environments - the ocean, ice sheet, and mountain range - interact in the MDV and alter the dry valley climate system.

These different environments exhibit large contrasts in surface albedo, with values ranging from 98% at the EAIS and VLG, and 10-80% at the Ross Sea to 25% in Victoria Valley, the northern most ice-free area of the MDV. The resulting albedo gradients are indicative for the dissimilar energy budgets of the four systems that make the MDV sensitive to radiation variations.

A comparison between the historical solar activity record and the chemical signal in shallow firn cores from VLG shows a relationship for at least the last 75 years between the alternation of marine and continental airmass input to the glacier in phase with solar radiation output.

A climate model is presented to explain this relationship.

Explosive Volcanism Recorded in Siple Dome Ice Core, Antarctica

Andrei Kurbatov, Greg Zielinski, N. Dunbar, Paul Mayewski, Eric Meyerson, and Sharon Sneed

More than one hundred volcanic signals were identified over the Holocene period using non-sea salt sulfate and non-sea salt chloride time series from the Siple Dome ice core. 108 volcanic peaks were identified as those having a concentration of 2σ above the mean positive residual of the spline fit, as was done for the GISP2 volcanic record. The largest sulfate signal (389 ppb) over the time period evaluated occurs 2223 yr B.P. Large signals of volcanically enhanced sulfate in the ice core record also occur around 685 yr B.P. (1265 C.E.; 283 ppb), 4775 yr B.P. (271 ppb), 7690 yr B.P. (365 ppb) and 11,225 yr B.P. (239 ppb). Ages for large equatorial or southern hemisphere volcanic eruptions are synchronous with identified sulfate peaks in the reconstructed volcanic record

Geochemical fingerprinting of glass shards analyzed using microprobe suggests correlation with local, Antarctic volcanic centers: Mt. Melbourne, Buckle Island, Mt. Berlin and provide an opportunity independently confirm age time scale developed by layers counting and linking measurements with marine records for older part of the core. Source of rhyolitic volcanic glass is compositionally close to Andean volcanic centers. It is consistent with the nature of the Antarctica vortex that could provide possible transport pathways from Antarctica, South America and New Zealand regions.

Mid-to-late Holocene Evolution of El Niño Conditions in Coastal Peru

Kirk Maasch, Steve Houk and Dan Sandweiss

Many independent lines of evidence indicate that El Niño was absent or significantly different between 8.8 and 5.8 (ka=calendar years BP). In northern Peru mollusk assemblages from archaeological sites are indicative of the presence of stable warm-tropical water as far south as 10°S during this time, suggesting that El Niño did not function for these millennia when global and regional climate was slightly warmer than today. Mollusk assemblages from more recent archaeological sites on the north and central coasts of Peru indicate that between around 5.8 and $\sim$ 3 ka, El Niño events were less frequent than today, with modern, rapid recurrence intervals achieved only after that time. This shift correlates with climate records throughout the Pacific basin indicating that fully modern conditions were not achieved until about that time. These changes had apparent cultural consequences: the onset of El Niño at 5.8 ka is temporally correlated with the beginning of monumental construction on the Peruvian coast, while the increase in ENSO frequency after $\sim$ 3 ka is correlated with the abandonment of monumental temples in the same region.

Climate records constructed from growth increment and stable isotope analyses of modern and fossil mollusks from the north coast of Peru can provide a high-resolution proxy for interannual sea surface temperature (SST) oscillations. Oxygen isotopes were measured in

fossil and modern mollusk shells along the axes of maximum growth. Acetate peels of shell cross-sections record daily and semi-daily growth increments. The locations of drilled samples taken for oxygen isotope analyses are visible in the acetate peels. SST time series are constructed by counting the number of growth increments between and contained in each drilled sample.

Thus far, 17 shells have been analyzed; 6 modern, 11 mid-Holocene (6-7 ka). Modern shells include *Trachycardium procerum* (2), *Chione subrugosa* (2), and *Anadara tuberclosa* (2). The fossil shells were *C. subrugosa* (4), *A. tubersulosa* (2), and *Protothaca ecuatoriana* (5). The age of the mollusks at time of death ranges from 3 to 5 years. Short time series with 3 to 5 annual SST cycles can be used to test the hypothesis that prior to 5.8 ka, El Niño cycles did not occur as they do today. This hypothesis suggests that warm-tropical waters of the Panamanian biogeographic province extended 500 km south of the modern boundary with the Peruvian biogeographic province prior to 5.8 ka. Collections of warm-tropical mollusks from archaeological shell middens in what is today the Peruvian biogeographic province support this hypothesis. High-resolution records can detect changes in SST attributable to a single El Niño event. It is our hope that the method presented here might establish variations in interannual SST cycles during a time of changing climate boundary conditions.

A Little Ice Age Chronology for the Southern Alps of New Zealand

Colby Smith

The glacial geologic record of New Zealands Southern Alps is an important tool in determining the synchrony or non-synchrony of climate change between the Northern and Southern Hemispheres. The Little Ice Age, a recent period of climatic cooling culminating around 1860 AD, is well documented in Europe by historical records. However, this is not the case in New Zealand due to late European colonization.

Relative chronologic relationships of glacial landforms were determined in order to make glacial geomorphic maps of the Tasman, Murchison, and Hooker glacier valleys. An intensive lichenometric study was then carried out on the glacial deposits to determine the existence and magnitude of the Little Ice Age. Initial results indicate that glacial advances in New Zealand correspond chronologically to glacier expansions in Europe during at least the latest stages of the Little Ice Age.

Biological Productivity and Air-Sea CO_2 Flux in the Pacific Ocean: Implications for Paleo-oceanography and Paleo-climatology

Fei Chai

The Pacific Ocean exhibits strong variations at interannual to decadal time scales, and the changing Pacific climate has direct impacts on global carbon cycle. The biological productivity and sea-to-air CO_2 flux decrease in the equatorial Pacific during the onset of El Niño events, which may lower atmospheric CO_2 concentration slightly. The Pacific Decadal Oscillation (PDO) is a low-frequency pattern of Pacific climate variability, the PDO tends to stay in phase (negative or positive) for decades at a time (18-30 year period). The warm phase of the PDO is characterized by warmer sea surface temperature (SST) in the equatorial region and colder SST in the central North Pacific. Recent studies of decadal changes in ocean circulation in the tropical and subtropical Pacific have demonstrated a slowdown in the meridional overturning in the upper Pacific Ocean during the past 25 years, that resulted in an increase of 0.8°C in tropical SST and a reduction of CO_2 outgassing from the equatorial Pacific Ocean. Using a three-dimensional ocean physical-biogeochemical model, I will present the evidence on interannual and decadal variability of physical processes, marine ecosystem response and carbon flux in the Pacific Ocean.

Biological productivity plays an important role in regulating air-sea CO_2 flux. One of the modeled results is that the diatom population of the equatorial Pacific upwelling system is limited by $Si(OH)_4$ supplied in a low $Si(OH)_4$:NO_3 ratio from the Equatorial Undercurrent (EUC). Increased $Si(OH)_4$ results in increased diatom productivity, suppression of non-diatom populations and decreased surface pCO_2. The deficiency in EUC $Si(OH)_4$ results from low $Si(OH)_4$:NO_3 water originating in the vicinity of the Antarctic polar front, a consequence of the extraordinary trapping of silica by the Southern Ocean. In glacial periods this silica trapping is reduced several fold and likely results in increased $Si(OH)_4$ transport to the north, increased biogenic silica production and deposition at the equatorial Pacific which can be expected to reduce surface pCO_2. Atmospheric CO_2 concentration varies in step with glacial cycles with lower values (by 80 - 100 ppm) during glacial periods. Although these cycles are driven by orbital parameters, the changes in radiation are insufficient to drive the large amplitude of the CO_2 changes. The interaction between the equatorial Pacific biological production and Southern Ocean silica trapping may provide a major biogeochemical feed-

back system capable of amplifying the orbital signals to glacial/interglacial values.

GLACIAL CLIMATE CHANGE

What Did Scientists Know About the Ice Age in 1875?

Dave Smith, Hal Borns, and Kirk Maasch

After publication of the views of L. Agassiz on the probable role of glaciers in changing many of the earth's features, geological thinking focused on the questions raised by this comment. This paradigmatic change in thinking was also intensified by the intellectual bombshell created by C. Darwin in *The Origin of Species.* Among the observers who were involved in this new research was John De Laski, (1814-1874) of Rockland, Maine. Here we attempt to place De Laski in the sequence of research conducted from around 1850 to 1875, the time in which he was actively pursuing answers to the mystery of the Ice Age. We have begun this udertaking with a careful review of the research done in the 19th century on climate and related subjects that was published in the *American Journal of Science.*

The Younger Dryas glacial fluctuation in northern Maine

Hal Borns

Clear evidence of the most intense cold reversal during the general warming following the Last Glacial Maximum, the Younger Dryas event (11,000 10,000 14C yrs B.P.) now well documented in both hemispheres, has long been elusive in Maine. However, the event has now been identified in both the lacustrine and glacial records in northern Maine. Our current research to describe the Younger Dryas event is focused upon deriving the temperature and precipitation parameters during the event from both lacustrine sediment core records and documentation of the dynamic response of the glacier remnants in northern Maine. The evidence of a glacier readvance in Maine during Younger Dryas time was first reported in 1984 based upon a stratigraphic exposure in the town of Oxbow. Current research, focused upon the documentation of the chronology and changes in glacier configuration and geography before and after the readvance, is now the focus of the glacial geologic research by the University of Maine team.

Glacial Record of New Zealand

George Denton

Glacial geologic maps of the Southern Alps of New Zealand have been constructed for 15 quadrangle sheets at a scale of 1:50,000. About 300 radiocarbon and 20 exposure dates afford a chronology for glacier fluctuations. Ten pollen diagrams register past changes in vegetation west of the Alpine Fault. Overall, the structure, magnitude, and timing of climatic changes in New Zealand during the last glacial cycle seem to be similar to those in the North Atlantic region. The source of these climate changes may thus lie in the atmosphere rather than in a North Atlantic thermohaline switch.

Surficial Geology and Geomorphology of the Western Olympus Range, Antarctica: Implications for Ice-sheet Stability

Brett VandenHeuvel

A widespread erosion surface passes across bedrock and sedimentary deposits in the western Dry Valleys sector of the Transantarctic Mountains (TAM), southern Victoria Land, Antarctica. The surface includes stoss-and-lee slopes, channels, potholes, scoured basins, and corrugated bedrock. These features have been taken to represent subglacial meltwater erosion beneath a greatly expanded East Antarctic Ice Sheet (EAIS) in the mid-Miocene (Denton et al. 1984, Marchant et al. 1993). By this hypothesis, the nearly perfect preservation of mid-Miocene geomorphic features on the erosion surface suggests that the Dry Valleys region has been locked in polar desert conditions since the carving of the erosion surface. The adjacent EAIS probably remained stable under such climate conditions. An alternate hypothesis suggests that the erosional features are the product of wind-deflation and chemical weathering of the land surface under present-day polar desert processes. Chronology is one means of discriminating between these hypotheses.

Small, theater-shaped cirques in the western Olympus Range contain Alpine moraines that record minor fluctuations of small alpine glaciers. The moraines are undissected and rest on the erosion surface. Therefore, the age of the moraines provides a minimum age of the carving of the erosion surface. The preliminary 3He cosmogenic surface exposure ages of twelve boulders from three moraines range from 300 ka to 1 Ma. These are minimum ages because surface weathering of the boulders was not considered in the exposure age calibrations.

The erosion surface has not been active in at least 1 Ma. The dates constitute an argument against the wind-deflation hypothesis.

The second part of this talk will focus on unanswered questions and propose future research. The erosional surface is not well understood. A detailed analysis of the morphology of the features in the Dry Valleys region may provide data to understand better the erosional process. In addition, a regional synthesis of the erosion surface in southern Victoria Land is needed.

Additional chronology of the erosion surface is will help to assess the stability of the EAIS. The lack of overlying sediments in most areas limits the opportunity to obtain bracketing ages. Therefore, detailed ages of the Alpine till in the Olympus Range are important. Volcanic ash was discovered in the Alpine moraines. The age of the ash will provide a minimum age of moraine and, thus, the erosion surface.

The paleoclimate significance of the debris-covered glaciers in Beacon Valley, Antarctica

Drew Lorrey

Beacon Valley is located in the western Dry Valleys, Antarctica, adjacent to the East Antarctic Ice Sheet (EAIS). Three Wilsonian shallow-core glaciers are prominent features contained at the heads of Beacon Valley tributaries. This type of glacier, covered with a boulder and sediment armor, may represent a possible modern terrestrial analog to similar ice bodies seen on Mars. Polygons cover the surface of a debris-covered glacier that fills part of upper Beacon Valley and Mullins Valley. A survey of the polygons indicates that they mature with distance from the equilibrium line. The polygon morphology is a result of the transport path of buried glacier ice from Mullins Valley to upper Beacon Valley.

A gray diamicton is draped over the buried ice in Mullins Valley and upper Beacon Valley. It has textural and weathering characteristics akin to englacial, buried ice sediment. This diamicton is classified as a till that formed from sublimation of buried ice. The sublimation till (28% sand, 69% gravel, and 3% mud) is sorted by narrow contraction cracks in the buried ice. The sorting of the resulting sand wedge deposits (83% sand, 11% gravel, and 6% mud) indicate that supraglacial sediment is first derived from sublimation of the buried ice.

Deep polygon trenches develop over thermal contraction cracks in the buried ice, and create traps for wind-blown sediment (reworked sublimation till, sand wedge sediment and volcanic ash.) The tops of some contraction cracks were void of sediment, indicative of a sediment starvation. In this case, any primary volcanic ash-fall could descend directly into active sand wedges. As sublimation occurs, sand wedges containing volcanic ash can slump over the sublimation till and buried ice.

The stratigraphy of massive weathered sand, with stringers of volcanic ash, resting on sublimation till and buried ice is widespread in upper Beacon Valley. Because the contraction cracks, sand wedges, and polygons are secondary to the buried ice, the ashes contained in them can afford a minimum age for the buried ice. This study supports the concept of the ash chronology previously used (Sugden et al., 1995) to date the buried ice at late Miocene age, and argues for persistent polar conditions in Beacon Valley since that time.

ATMOSPHERIC CIRCULATION I

Anatomy of the "Mega-Bomb"

Greg Zielinski

A storm is considered to be a meteorological "bomb" when its central low pressure drops at an average rate of 1 mb hr^{-1} over a period of 24 hours. Such storms are said to have very rapid deepening when the central pressure drops by 3 mb over a 3 hour period at any time during the deepening phase. Two very powerful nor'easters, one in January of 2000, the other in January of 2002, moved through the Gulf of Maine with deepening rates that far exceeded these average values. These storms thus deserve to be classified as "mega-bombs", that is, average deepening rates exceed 1.5 mb hr^{-1}.

Central pressure of the 20-21 January 2000 storm dropped from 1008 mb on 0600 UTC 20 January to 948 mb on 1800 UTC 21 January, (i.e., -60 mb over a 36-hour period). Rapid deepening occurred at rates of about -4 to -8 mb 3 hr^{-1} for 33 of those 36 hours. These numbers produced an average deepening rate of 1.82 mb hr^{-1} (for the 33 hours of rapid deepening) or 1.67 mb hr^{-1} for the entire 36-hour period of deepening. Highest average deepening rates for other strong nor'easters (after Kocin and Uccellini, 1990) are on the order of 1.24 to 1.27 mb hr^{-1} with an average value of 0.93 mb hr^{-1}.

The 13-14 January 2002 storm deepened at an even more increadible rate. Central pressures in that storm dropped from 1012 mb on 0000 UTC 13 January 2002 to 956 mb on 0000 UTC 14 January 2002 or 64 mb in 24 hours. This produced an average deepening rate of 2.67

mb hr^{-1}. Rapid deepening rates in this storm reached 12 mb 3 hr^{-1}.

Several specific factors appear to be responsible for the exceptional development of January 2000 storm. An extensive trough at the 500 mb level initially extended from the U.S.-Canada border northward to the highest latitudes of the Canadian Arctic. The axis of this trough eventually rotated from a N-S position to a negatively tilted NW-SE position at the same time that it "dug" well into the mid-Atlantic and southeastern states. Amplitude of the 500 mb surface increased significantly with this process. Both an isolated low pressure vortex (geopotential height of 4970 m) and an area of low pressure circulation eventually became established northwest and north of the surface cyclone, respectively. Maximum wind speeds in the jet streak entering the base of the trough at the 500 mb level were on the high side of those often found in the development of other "bombs".

The rapid deepening of the January 2002 storm appears to be a function of the continual rotation of short waves toward the northeast at all levels of the atmosphere during the time of surface low deepening. In addition, the central pressure of the primary surface cyclone (988 mb) is uncommonly low when compared to the primary low in other cases of nor'easter development.

These two examples fail to identify a distinct factor or distinct multiple factors that contribute to such rapid deepening. It appears that the magnitude of the many parameters contributing to the development of a typical meteorological "bomb" is much greater when a "mega-bomb" forms.

Predictable Decadal Scale Climate Variability?

Paul Mayewski, Kirk Maasch, Eric Meyerson, Karl Kreutz, and Ian Goodwin

Basic assumptions

1. Cyclic patterns underpin a significant amount of the climate variability during the last Glacial and the Holocene.
2. Climate cycles that range from multi-millennial to multi-annual are associated with a wide range of climate forcings.
3. Most of the heat transported to the poles from north and south of 30^o is transferred by the atmosphere.
4. The global atmosphere is teleconnected through major features such as the Arctic Oscillation (AO), the Antarctic Oscillations (AO), ENSO and the Pacific Decadal Oscillation (PDO).

Questions

1. Are there predictable decadal scale patterns in the AO, AAO, ENSO, and PDO?
2. Are these decadal scale patterns similar?
3. What causes decadal scale patterns?

Relationships between dust records from three ice cores and atmospheric circulation over the Northern Hemisphere: atmospheric transport patterns of spring dust aerosols during the last century

Shichang Kang, Paul Mayewski, and Yuping Yan

The arid and semi-arid regions of central Asia are a major source area for wind-blown dust in the Northern Hemisphere (Gao et al. 1992). The peak in dust-storm activity throughout central Asia occurs from mid-February to late-May, with a strong maximum in late April-early May (Merrill et al., 1989). High-resolution ice core records provide a convenient means to measure the depositional flux of atmospheric dust, which is related to the changes in dust sources and transport pathway and strength, as well as spatial variability.

Relationships between non-sea-salt Mg (nssMg: a index of atmospheric dust from ice core records) from three Northern Hemisphere sites (Mt. Everest, Himalayas; Mt. Logan, Yukon territory; and 20D, southern Greenland) and instrumental sea-level pressure (SLP) series of spring (March-April-May) are investigated for the last century (1899-1996 AD), in order to get an insight of atmospheric transport patterns of dust aerosols over the Northern Hemisphere during the spring season. Mt. Everest nssMg concentrations are positively correlated with SLP of the Tibetan High, Arctic High, and Azores High in spring. The 20D nssMg concentrations are positively correlated with Siberian High and Azores High SLP, while negatively correlated with Arctic High and Icelandic Low SLP in spring. Mt. Logan nssMg concentrations have a negative relationship with SLP of the Aleutian Low and Arctic High, and a positive relationship with Tibetan High SLP in spring.

On a hemispheric scale, an enhanced springtime Arctic High is unfavorable for dust aerosol transport from central Asia to subarctic regions (e.g., southern Greenland and Yukon territory), while favorable for transport

to the Himalayas (e.g., Mt. Everest). An enhancing of the Siberian High may strengthen transport of atmospheric dust to Greenland, and an enhancing of the Tibetan High strengthens transport to Himalayan and Yukon regions in spring. A stronger springtime Azores High favors dust transport to both Himalayas and South Greenland. On a regional scale, a deepened springtime Icelandic Low and Aleutian Low boosts transport of dust aerosols to Greenland and the Yukon territory, respectively. Understanding of these transport patterns is significant for the interpretation of ice core records and reconstruction of atmospheric circulation over the Northern Hemisphere using these records.

Atmospheric transport patterns of sea-salt aerosols over Northern Hemisphere revealed by relationships between ice core sodium records and sea level pressure

Yuping Yan, Shichang Kang, and Paul Mayewski

Atmospheric circulation reconstructions based on glaciochemical records require knowledge of chemical concentration controls (sources, transport pathway and strength) and spatial variability. To gain insight into these processes, the relationships between glaciochemical records from two Northern Hemisphere sites (Mt. Logan and 20D) and instrumental sea level pressure (SLP) series of Northern Hemisphere are investigated. Calibrations between Mt. Logan sea-salt sodium (ssNa+) concentration and SLP series show that ssNa+ concentrations are closely correlated with the autumntime (SON) Aleutian Low and the summertime (JJA) North Pacific High. Both the deepened Aleutian Low in autumn and enhanced North Pacific High in summer strengthen the transport of sea-salt aerosols from the North Pacific to the Mt. Logan region. Calibration between 20D ssNa+ concentrations and SLP series show that ssNa+ concentrations are closely correlated with the wintertime (Jan.) Icelandic Low. A deepening of the Icelandic Low strengthens winter storms and increases cyclogenesis over the North Atlantic Ocean, this pushes more sea-salt laden air masses to the Greenland ice sheet. Therefore, ice core ssNa+ records from the Mt. Logan region can be considered as a proxy for reconstructing the autumntime Aleutian Low and Summertime North Pacific High, and the ssNa+ records from Greenland ice cores may provide a proxy for reconstructing the wintertime Icelandic Low.

POSTERS

Asynchroneity of Major Holocene Lake-level Changes Across Maine

Andrea Nurse and Ann Dieffenbacher-Krall

Numerous studies indicate relative consistency in major Holocene lake-level changes in the Midwest. However, a survey of lake-level studies from sites across New England, Mid-Atlantic states, and neighboring Canada shows significant variability in both timing and direction of water-balance changes. Using methods refined by Almquist, et al., in their study of Mansell Pond, Central Maine, we are developing Holocene lake-level curves for two lakes in Maine. These studies, along with the Mansell Pond study, will provide a comprehensive picture of lake-level changes across northern and eastern portions of Maine. While preliminary results indicate that the magnitude and trend of water-balance changes are consistent across the region, the timing of these fluctuations is asynchronous.

Is There Chironomid Evidence for the Killarney Oscillation in Maine?

Geneva Chase

Evidence for the Killarney Oscillation, a late-glacial cold event, was originally detected in the Atlantic Provinces of Canada. The geographic extent of this short-lived episode has not yet been determined. However, multiple lines of evidence exist for late glacial cooling events across the North Atlantic region, of which the Killarney Oscillation may, or may not be, synonymous. The analysis of non-biting midge (Diptera: Chironomidae) remains from two Maine lakes may provide further evidence for the occurrence, timing, and extent of the Killarney Oscillation.

Predicting the Locations of Lakes beneath Antarctica

Jim Fastook and Jesse Johnson

Lakes beneath the Antarctic Ice Sheet form in basins of a potential field derived from the bedrock topography and the ice thickness. Lakes endure where the temperature regime is capable of supporting liquid water at the bed. An ice sheet model predicts the occurrence of lakes, subject to these conditions. Predicted lakes are compared with known existing lakes, and regions where undiscovered lakes might occur are described.

Lakes have been recognized beneath the Antarctic ice sheet since the early 1970's. The presence of lakes beneath thick ice sheets has important consequences for the understanding the dynamics of currently existing ice sheets, as well as for the interpretation of the glacial landforms that inform us about the timing and behavior of paleo-ice sheets. For example, one interpretation of particular landforms from the Laurentide Ice Sheet of North America requires the presence of extensive meltwater that can be released catastrophically to shape and erode the landscape. In addition, the lakes' potential for harboring life in a most extreme environment is quite important for the understanding of exotic biologies.

A thorough cataloging of known lakes reveals at least 70 lakes of various sizes and locations, the largest and best documented of which is Lake Vostok. In the inventory process, lakes are recognized by the presence of a strong and spatially uniform bottom reflection accompanied by very low surface slopes. Estimates of size and occasionally water thickness are available for some of the lakes.

Modeling work predicts basal melting within the known boundaries of Lake Vostok. Known boundaries also match a basin in the generalized potential field. We repeat the comparison of these criteria with other lakes listed in the Siegert inventory, in order to provide criteria for predicting the location of as yet unrecognized lakes beneath Antarctica.

Within the limitations of the measured topography, several lakes currently not in the inventory are proposed, the most likely being near a feature in the radar map that is similar to the expression of Lake Vostok. These proposed lakes are comparable in size to Lake Vostok, and are located approximately 200 km grid-east and 800 km grid-north of the pole at 82.5S, 15W.

ARCHAEOLOGY

The 2001 Excavations at Siches, a Mid-Holocene Fishing Site near Talara, Peru

Dan Sandweiss, Steve Houk, James B. Richardson III, and Alejandro Chu

First discovered in the 1920s, the Siches site was rediscovered by James B. Richardson III in the 1960s. Richardson collected and tested the site on several occasions, and with Dan Sandweiss carried out the first formal test excavations in 1995. At the time, they divided the site into two areas: Area I (ca. 5000 14-C BP) and Area II (ca. 6500-7500 14-C BP). Effort focused on Area I, where faunal remains reflected the 5000 BP climate transition marked by the onset of El Niño. Sandweiss, Richardson, and colleagues returned to Siches last summer to expand work in Area II, where they had found several post holes. Deposits proved complex, with multiple postholes, hearths, and possible storage units, all embedded in midden. Area II may be a mid-Holocene village site contemporary with late Las Vegas on the Ecuadorian coast. This talk details the features uncovered in Area II and discusses preliminary analyses of site contents.

Children's Health in the Prehistoric Southwest

Kris Sobolik

Children's health in the prehistoric southwest is a subject that a number of researchers have examined, particularly given the relative abundance of well-preserved human skeletal remains that have been excavated from the region. Most researchers, however, have addressed the question of children's health from a very local, site specific perspective rather than from a broader, southwestern perspective. In this paper, I synthesize data from previously analyzed human skeletal remains in different cultural contexts (Anasazi, Mogollon, Hohokam, and Sinagua), site sizes (small and large), and time periods (AD 1 - protohistoric) to address the issue of children's health from a broader, southwestern perspective. The intent of this research is to review and discuss the main health indicators observable on human skeletal material, and to ascertain patterns of children's health through time and across cultural boundaries in the prehistoric southwest.

Palaeoindian Studies at Bull Brook, Ipswich Massachusetts

Brian Robinson

The Bull Brook site was among the first Palaeoindian sites discovered in the Northeast in 1951. After a decade of excavation by a dedicated group of amateurs the site yielded one of the largest Palaeoindian settlement patterns and artifact assemblages in North America. Further analysis of the Bull Brook site is in progress at the University of Maine as an extension of the ongoing Alaska Project, in cooperation with the Peabody Essex Museum. Problems and prospects will be discussed.

Red Metal (Copper) Use in the Maritime Peninsula during Late Prehistoric and Early Contact Times

Adrian Burke

The prehistoric inhabitants of the Maritime Peninsula (Maine, Canadian Maritime Provinces, and easternmost Quebec) used native copper to fashion a limited number of utilitarian and decorative items during the Ceramic period. Geological sources of pure native copper were known from New England and Nova Scotia. European copper and brass were introduced into aboriginal society starting in the sixteenth century. Archaeometric analyses (x-ray fluorescence and neutron activation analysis) of copper based artifacts from late prehistoric and early contact period sites in the region are used to distinguish sources of copper. These data help us to better understand how the meanings and roles of the red metal in aboriginal life changed over time in the Maritime Peninsula.

Faunal Analysis of the Lawrie Farmstead: Insights on Subsistence Strategies in Colonial New Jersey

Robert Lore

Recent archaeological investigations at the Lawrie Farmstead (28MO257), Upper Freehold Township, Monmouth County, New Jersey have uncovered several features, including the remains of two residential structures. Occupation of the farmstead spans from the early18th century, as evidenced by artifacts associated with an earthfast structure, and a later brick and stone foundation. Zooarchaeological analysis of each discrete feature allows for an assessment of dietary subsistence strategies associated with an early self-sufficient colonial farmstead, and its transition to a more stable market based economy. Preliminary documentary research has provided data on ethnicity and socioeconomic status, which may be elucidated through analysis of taxa and butchering units present at the farmstead.

SEA LEVEL CHANGE

Gulf of Maine Inner Shelf Sand Bodies: Relationship to Sea-level Changes and Onshore Pleistocene Sources

Dan Belknap, Joe Kelley, and Allen Gonz

The inner shelf of the northern Gulf of Maine has evolved since deglaciation 15 ka through coastal and fluvial processes during rapidly changing sea level. Glacial erosion of bedrock left complex bays, peninsulas and islands as the well-known "rock-bound coast of Maine." Till and outwash provided coarse sediment throughout the Holocene transgression. Glaciomarine mud, the Presumpscot Fm., was an abundant source of fine sediments. Relative sea-level change was driven by submergence 70-130 m above present SL, contemporaneous with marine-based ice-sheet retreat 15-13 ka, emergence during rapid isostatic rebound 13-11 ka to 60 m below present, and submergence and transgression 11 ka to present as isostatic rebound was overtaken by eustatic sea-level rise. Reworking during emergence and lowstand at around 10.8 ka brought sand and gravel to the present coast and inner shelf, building paleodeltas at the mouth of the large Merrimack and Kennebec rivers. Wells embayment, Saco Bay, Pleasant Bay and Machias Bay received lesser amounts of sand, and have a mixture of beaches, tidal flats and rocky headlands. Other rivers drained landscapes with fewer coarse-grained sources, and have primarily mud-filled estuaries, such as Penobscot Bay. Inland and coastal Pleistocene sand and gravel deposits played an important role in building beaches and paleodeltas, and continue to influence modern coastal systems. Detailed seismic reflection profiling and sidescan sonar mapping provide data for a model of inner-shelf evolution based on principles of sequence stratigraphy. The lower sequence boundary is the unconformity created on top of the Presumpscot Formation and other glacial sediments during emergence. Lowstand systems tracts are best recognized in paleodeltas. Transgressive systems tracts are thin, but interrupted by parasequences of prograding deltaic and estuarine facies in some estuaries. Significant examples such as the newly discovered Penobscot Paleodelta (8-9 ka, 30 m below present sea-level) may relate to a slowing of relative sea-level rise. Highstand systems tracts formed in the late Holocene as the rate of sea-level rise slowed and continued fluvial and littoral sediment supply allowed stabilization and progradation of barriers and tidal deltas. Preservation potential of these features is controlled by the open coast ravinement unconformity, and by tidal ravinement unconformity and bluff ravinement unconformity in embayments. Variability in preservation potential results from paleotopography and energy of modern processes. Understanding this evolutionary system has importance for coastal land-use planning, geological archaeology, stratigraphy and sedimentary processes that may apply widely on paraglacial (formerly glaciated) coasts.

Relative Sea-Level Changes along the Victoria Land Coast, Antarctica

Brenda Hall and C. Baroni

Relative sea-level (RSL) curves produced from dated raised-beach ridges afford information concerning glacial isostasy and the timing of deglaciation. Here we present data from Terra Nova Bay (74.5°–75°S, 163.5°–164.5°E) and the southern Scott Coast (76.5° – 78.5°S, 163° – 164°E) that allow us to reconstruct Holocene RSL changes along the western coast of the Ross Sea Embayment, Antarctica.

During the last glacial maximum, the Ross Sea Embayment was filled with an extensive grounded ice sheet. Raised beaches, deltas, and marine sediments associated with retreat of this ice sheet occur up to 32 m elevation and are the subject of this study. Over seventy AMS radiocarbon dates of incorporated shells, seal skin, and seal and penguin remains afford a chronology for RSL curves along the southern Scott Coast. Final unloading of grounded Ross Sea ice occurred there shortly before 6500 ^{14}C yr B.P. (all ages have been corrected for an estimated 1300-yr marine-reservoir effect). This timing is consistent with glacial geologic evidence that places deglaciation of the same area between 5730 and 8340 ^{14}C yr B.P. Farther north at Terra Nova Bay, a new RSL curve, constrained by over sixty AMS radiocarbon dates of penguin guano and remains, seal skin, and shells, intersects the marine limit at about 7000 ^{14}C yr B.P. This age is consistent with other evidence for the timing of deglaciation at Terra Nova Bay, but is several thousand years younger than dates obtained from total organic carbon in marine sediment cores located nearby and from relict penguin rookeries farther south at Cape Hickey.

The timing of deglaciation is critical for isolating the mechanism that forced retreat of the West Antarctic Ice Sheet grounding line to its present position at the Siple Coast. Our data strongly suggest Holocene grounding-line retreat, with much of the ice sheet, at least along the southern Scott Coast, still intact 7000 ^{14}C yr B.P. If correct, then ice recession to the present position may have been due largely to dynamic processes within the ice sheet itself, as other potential forcing (such as deglacial sea-level rise) essentially was accomplished by mid-Holocene time.

Irreversible widening of a small estuary: a delayed anthropogenic effect?

Roger LeB. Hooke

Blocks of fibrous peat have become detached from the banks of a ~5-m wide estuary, informally named Coffin Estuary, in Steuben, Maine. These blocks slump downward and inward, resulting in widening of the estuary. If the present width of the estuary were an equilibrium width under present conditions, there would have to be a complementary process that was actively decreasing the width. Two possible processes are accretion on the opposite bank or sedimentation on top of the slump blocks. The opposite bank is vertical, however, and about a decade of surveys demonstrate that there is no significant aggradation on top of the blocks. Therefore, the estuary must be undergoing irreversible widening.

The upper ~0.7 m of the banks of the estuary are composed of fibrous peat. This is underlain by 0.3 m of muddy peat which is, in turn, underlain by Presumpscot clays. The organic content decreases from ~12% in the fibrous peat to ~6% in the muddy peat (Colby Smith, 2001). The muddy peat erodes faster than the fibrous peat, resulting in undercutting. The undercutting is responsible for the failure of the blocks of fibrous peat. The mud content of the peat presumably reflects clastic input to the system from surrounding uplands. Based on current rates of sea level rise, the muddy peat probably dates from about the time of settlement. This suggests that the mud content may reflect clearing of the land. If this is the case, the present irreversible widening is a delayed response to anthropogenic impacts on the system ~200 years ago.

ICE DYNAMICS

Is the "Jakobshavns Effect" in effect in Greenland?

Terry Hughes

The "Jakobshavns Effect" is a circle of positive feedback mechanisms first perceived to be active on Jakobshavns Isbrae in Greenland, and to be responsible for rapid thinning retreat of the Greenland Ice Sheet during times of climate warming. It takes place in ice streams and generally has proceeded from south to north during the Holocene. The positive feedback mechanisms begin with ubiquitous surface crevassing as sheet flow converges to become stream flow toward the ice-sheet margin and, if ice streams become afloat, as stream flow becomes shelf flow. The Jakobshavns Effect is triggered by episodes of climate warming, with copious amounts of summer meltwater entering the crevasses to both warm interior ice by refreezing and to lubricate the bed if re-

freezing is incomplete. The thermally softened ice is then able to creep more easily and to slide more rapidly over the bed, thereby increasing ice velocity and multiplying surface crevassing. Increased ice thinning and surface crevassing increases the ice calving rate and, if the ice stream becomes afloat, initiates basal crevassing, all of which increasingly frees the floating ice shelf from bedrock pinning points and lateral constraints inside fjords. Removing these constraints permits more rapid calving and further acceleration of the ice stream, with a further increase in crevassing, thereby allowing more thermal radiation to be absorbed by multiple reflections inside crevasses. This produces more summer meltwater and brings the cycle of positive feedbacks full circle to begin another cycle of reinforcement. Four episodes of climate warming may have triggered the Jakobshavns Effect: (i) about 14,000 BP during termination of the last glacial maximum, when the continental shelf of Greenland was deglaciated, (ii) about 8000 BP during the Early Holocene climate optimum, when ice streams began to retreat from fjord entrances, (iii) about 1850 AD when the Little Ice Age came to an end and ice streams retreated to fjord heads, and (iv) today when anthropogenic "greenhouse" warming is thinning ice streams beyond fjord heads. Iceberg outbursts during these episodes have the potential to temporarily slow or halt production of North Atlantic Deep Water in its primary production areas north of Iceland and in the Labrador Sea, and thereby trigger episodes of climate change. Modeling results are presented that allow the amount of thinning now taking place in major Greenland ice streams to proceed to what has taken place in major West Antarctic ice streams. A flowline model is employed in which gravitational thinning induces basal shear, side shear, and longitudinal extension. Thinning retreat is controlled primarily by longitudinal extension for both stream flow and shelf flow. If thinning retreat caused by the Jakobshavns Effect is both rapid and simultaneous for the major Greenland ice streams, the resulting iceberg outbursts could trigger an episode of rapid climate change.

Glaciology of Siple Dome and the case for a minimally enlarged West Antarctic Ice Sheet at LGM

Gordon Hamilton

Snow accumulation rates and rates of ice thickness change (mass balance) are studied at several sites on Siple Dome, an elevated ridge between two ice streams in West Antarctica. Accumulation rates are derived from analyses of gross beta radioactivity in shallow firn cores located along a 60 km transect spanning both flanks and the crest of the dome. There is a northsouth gradient in snow accumulation rate across the dome that is consistent with earlier radar mapping of internal stratigraphy. Orographic forcing of moisture-laden air masses causes this distribution. The similarity between the core-derived accumulation rates (the past few decades) and those inferred from radar profiling (1-10 kyr) implies that orographic processes have operated in this part of West Antarctica since at least the beginning of the Holocene. Mass balance is inferred from the difference between GPS-derived vertical velocities and snow accumulation rates for sites close to the firn core locations. Results indicate that there is virtually no net thickness change at four of the five sites and that the elevation of the dome summit is not currently undergoing significant change. Using the calculated uncertainties (about 0.02 m/yr) as an upper bound implies that the dome was no more than $\sim$ 250 m higher in elevation during LGM. The resulting ice sheet geometry is apparently inconsistent with other reconstructions, and with a postulated West Antarctic source for meltwater pulse 1A at 14 kyr.

Mass Balance of Antarctic Ice Streams Derived from Laser Altimeter Measurements

Blue Spikes, Bea Csathó Gordon Hamilton, and Ian Whillans

Airborne laser altimetry has been used to determine whether surface elevations on the Whillans Ice Stream and Ice Stream C in Antarctica are changing with time. Laser altimeter data was initially collected in 1997 by the United States National Science Foundations Support Office for Aerogeophysical Research. Repeat surveys were conduced two years later using the same facility. Results show that the surveyed portions of two major tributaries of the Whillans Ice Stream are thinning almost uniformly. Ice Stream C has a complicated elevation change pattern, but is generally thickening. An approach to using short-term elevation measurements to infer changes in mass balance is presented. Mass balance results are used to estimate the possible contribution of each surveyed region to global sea level rise.

Are Deformable Basal Sediments Necessary for Fast Glacier Flow?

Tom Kellogg

Over the past 15 years, studies of West Antarctic ice streams on the Siple Coast have led to a new paradigm,

that fast glacier flow typical of ice streams requires the presence of deformable sediments at the base of ice streams. New multibeam and seismic data from the Amundsen Sea sector shows the presence of rugged bedrock topography beneath Pine Island and Thwaites glaciers, two of the fastest ice streams in Antarctica. An argument is presented suggesting that the "new paradigm" results from an overly restrictive definition of "ice streams" which precludes large outlet glaciers that display basal roughness and lack sediments at their beds. Broadening the definition to include these large glaciers as ice streams is actually a return to the original definition by Swithinbank, and allows for streaming flow where rugged bedrock is present. The most important condition required for streaming flow is a well lubricated (wet) bed.

ATMOSPHERIC CIRCULATION II

Soluble ion characteristics over West Antarctica from U.S.ITASE ice cores

Dan Dixon

Ice cores have been successfully used to reconstruct past weather patterns and climate characteristics over the Antarctic continent. A subsample of the 21, 60 to 115m-deep, ice cores collected thus far on the U.S.ITASE traverses are used to investigate recent characteristics of the major air masses that affect West Antarctica. The ice cores were analyzed at sub-annual (8-10 samples per year), continuous resolution, and examined for their soluble major ion content (Na, K, NH_4, Mg, Ca, Cl, NO_3, SO_4). The peaks and troughs in many of the ion time series exhibit a clear seasonal signal throughout the length of the record that is used to identify and date extreme events that have occurred over the last 200+ years, such as the Tambora volcanic event.

Empirical Orthogonal Function (multi-dimensional principal component) analysis is employed to assess and interpret the differences and relationships in chemical loading over time and from site to site. The results provide an understanding of the characteristics of the air masses affecting West Antarctica and of the physical controls (such as topography, elevation, accumulation rate, and distance inland) on chemical species deposition. The spectral properties of the time series are analyzed for periodicities ranging from 3-50 years. The spectral data will confirm whether the climate signals in these ice cores are associated in any way with phenomena such as the solar cycle, El Nino, or the Pacific Decadal Oscillation.

The Holocene-Glacial History of Siple Dome, West Antarctica

Eric Meyerson, Paul Mayewski, and Sharon Sneed

We use a ~98ky glaciochemical record recovered from Siple Dome that was collected as part of the WAIS Initiative to understand West Antarctic climate variability. This glaciochemical record reveals strong source signals from the ocean (seasalt (ssNa, ssK, ssMg, ssCa, ssCl, ss-sulfate) and biogenic non-ss-sulfate), volcanism (excess-sulfate), remote continental dust (nssK, nssCa), and katabatic flow (nitrate, biogenic nss-sulfate). This Siple Dome ice core climate proxy has a strongly calibrated seasonal (Sept-Nov) signature in seasalt species that is dominated by strength (SLP) of the Amundsen Sea Low (ASL). This calibration has predicated a record of the Antarctic Oscillation (AAO): specifically the ASL (West Antarctica) and the East Antarctic High (EAH), East Antarctica. The well-preserved Siple Dome Holocene structure is similar to the GISP2 Holocene suggesting a strong association between ASL behavior and that of GISP2 proxies for the Icelandic Low (Na) and the Siberian High (K). The pre-Holocene climate record from Siple Dome is quite different from other Antarctic records because the glacial age ASL (the major source for marine air) is significantly north of its Holocene position as a consequence of changes in boundary conditions (e.g., size of EAH, sea ice extent, ice sheet configuration, grounding line retreat in Ross Sea at ~75OO years before present). The Little Ice Age expansion and deepening of the ASL is the most dramatic event in the full Siple Dome Holocene-Glacial atmospheric circulation record.

Stable sulfur isotope ratios ($\delta^{34}S$) in a West Antarctic firn core: Assessment of sulfate source and deposition

Lee Pruett, Karl Kruetz, M Wadleigh, E Sholkovitz, and Paul Mayewski

Stable sulfur isotopes can be a useful tracer of atmospheric sulfate sources, if the isotopic signature of each source is distinct. In Antarctica, there are assumed to be only three possible sources of sulfate (marine biogenic activity, sea-salt, and volcanic eruptions), with the marine and volcanic contributions having $\delta^{34}S$ values of approximately 16-21% and 2-5%, respectively. Therefore, $\delta^{34}S$ data may be useful for estimating the relative contribution of marine and volcanic sulfate both spatially across Antarctica, and temporally in firn and ice core records. Here we present $\delta^{34}S$ data from a firn core in

West Antarctica (RIDSA, 78°44' S, 116°20' W, 1804 m) covering the years 1935-1976, including the 1963 Agung eruption. The $\delta^{34}S$ value from the section of core including the 1963 Agung period is 4%, consistent with a volcanic sulfur signature. The range of $\delta^{34}S$ data from core sections on either side of the Agung eruption is 3-10%, suggesting that the contribution of volcanic sulfate on the West Antarctic polar plateau was significant not only during the Agung eruption, but during other times as well. Our results from the Agung layer are consistent with published data from the Vostok core (East Antarctica; 78°S, 115°E, 2850m), where a $\delta^{34}S$ value of 2.7% was reported. However, Vostok data display a significant marine influence, with $\delta^{34}S$ values of 15% to 22% on either side of the Agung eruption. Possible explanations for the discrepancy between West Antarctic and East Antarctic $\delta^{34}S$ values include: 1) different spatial patterns of sulfate deposition related to upper tropospheric/lower stratospheric circulation, and 2) regional-scale influence of sub-Antarctic volcanic island chains. We will discuss these possibilities in the context of new samples collected during recent ITASE traverses.

Chemical Signature of an Extreme Storm Event in West Antarctica

Susan Kaspari, Paul Mayewski, Sharon Sneed, Eric Meyerson

Glaciochemical analysis (Na, K, NH_4, Mg, Ca, Cl, NO_3 and SO_4) of fresh surface snow samples collected during an extreme storm event in the Pine Island catchment in West Antarctica is used to identify the chemical signature of the marine source for this storm. In order to capture variations in the chemical composition of the storm sixteen surface snow samples were collected throughout the forty-four hours of this event.

Empirical orthogonal function (EOF) analysis is used to determine the primary aerosol sources and atmospheric transport pathways for the storm. Further, a comparison of storm event EOF analysis with EOF analysis of chemistry from other West Antarctic samples is used to assess the impact of chemical loading during storm events compared to seasonal and annual loading.

Pine Island catchment is in a region of West Antarctica where storm events have not previously been sampled. This study therefore improves the overall understanding of the influence of chemical loading from storm events on the glaciochemistry of snow in West Antarctica.