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Collaborative Research: Asian Ice Core Array (AICA)--Reconstruction of Past Physical and Chemical Climate over Asia

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Principal Investigator: Mayewski, Paul A.
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Mayewski, Paul - Principal Investigator
Title:
Collaborative Research: Asian Ice Core Array (AICA)--Reconstruction of Past Physical and Chemical Climate over Asia

Project Participants

Senior Personnel

Name: Mayewski, Paul
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kreutz, Karl
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kurbatov, Andrei
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Kaspari, Susan
Worked for more than 160 Hours: No
Contribution to Project:
Susan Kaspari completed her PhD under P. Mayewski working on our Everest ice core in the early stages of AICA. She then went on to do her post-doctoral research at the Paul Scherrer Institute (Switzerland) under M. Schwikowski and is now an assistant professor at Central Washington University with strong links to the Climate Change Institute and AICA.

Graduate Student

Name: Grigholm, Bjorn
Worked for more than 160 Hours: Yes
Contribution to Project:
Ice core recovery team member, core processing, core analysis, interpretation (for PhD project).

Undergraduate Student

Technician, Programmer

Name: Sneed, Sharon
Worked for more than 160 Hours: Yes
Contribution to Project:
Ion chromatography (major ion) lab manager

Name: Introne, Douglas
Worked for more than 160 Hours: Yes
Contribution to Project:

Mass spectrometer (isotopes) lab manager

Name: Handley, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
Ion coupled plasma mass spectrometer (trace elements) lab manager

Other Participant

Name: Aizen, Vladimir
Worked for more than 160 Hours: Yes
Contribution to Project:
Collaborating PI

Research Experience for Undergraduates

Organizational Partners

University of Idaho
Collaborating institution for grant. Primary responsibilities include stable isotope measurements, organization of Pamir field project, hydrologic interpretations.

Tibetan Plateau Institute
TPI has been instrumental in the joint recovery of several of the ice cores utilized in this project.

Lanzhou Institute of Glaciology and Geoc
LIGG has been instrumental in the joint recovery of several of the ice cores utilized in this project.

China Meteorological Administration
CMA has been instrumental in the joint recovery of several of the ice cores utilized in this project.

Japan Institute for Humanity and Nature
IHN has been instrumental in the joint recovery of several of the ice cores utilized in this project.

Tomsk State University, Russia
Planning and logistics for Pamir ice core recovery.

Institute of Water Resources and Hydropo
Planning and logistics for Pamir ice core recovery.

Institute of Water Problems, Hydroenergy
Planning and logistics for Pamir ice core recovery.

University of Nebraska Lincoln
Dr. R. Oglesby and staff provide advice and computer time for WRF modeling of Asian climate.

IGNS
Dr. Uwe Morgenstern and staff provide high precision tritium analyses for AICA.

Maine State Laboratories
Provide beta radioactivity analyses for AICA cores.

Columbia University Lamont Doherty Earth Observatory
Provide 137Cs analyses for AICA cores.

Universidade do Estado do Rio de Janeiro
Dr. Heitor Evangelista and staff provide high precision tritium analyses for AICA cores.

Paul Scherrer Institute, Switzerland
Dr. Margit Schwikowski and staff provide 210Pb for AICA cores.

Central Washington University
Susan Kaspari, assistant professor CWU provides black carbon measurements.

Other Collaborators or Contacts

All listed in previous sections of this report.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
Much of the first two years of AICA has been dedicated to the processing and analysis of the array of ice cores that comprise AICA. The attached spreadsheet summarizes the status of core collection, core processing, and analysis.

AICA 2nd Annual Findings 2009-2010

Altai ice core (175m deep)
Melted and completed 125 m of Altai. Top 50 m melted previously
Isotopes (dD and dO18): currently be analyzed at UIdaho.
Ions: Completed (CCI)
ICP-MS: awaiting final analysis

Tien Shan ice core (160m deep)
Continued Processing down to 120m (40m left) scheduled to be complete by June 2010
Continued isotopes analysis: down to 45 -75m. Samples awaiting analysis (CCI/UIdaho)
Continued Ions analysis: data complete from 45 - 90m. Final samples ready for analysis (CCI).
Continued ICP-MS analysis: Analyzed down to 90m (CCI).
Beta (0-40m): melted/filtered/analyzed (Maine State Lab).
137Cs: Processed and melted 80m-160m (currently being analyzed at Lamont).

Geladaindong ice core (147m deep)
Isotopes: Completed (Lanzhou)
Ions: Completed (CCI)
ICP-MS analysis: 0-60 m completed (CCI).
Beta (0-40m) (Maine State Lab/Lanzhou)
Tritium- 10 m analyzed at Universidade do Estado do Rio de Janeiro.
Tritium ? currently being analyzed in NZ (IGNS)
Pb210 - sampling to take place May 2010 in Lanzhou, China- analysis at Universidade do Estado do Rio de Janeiro.

Fedchenko ice cores
2005 Cores (12 and 9m)
Completed (Isotopes, Ions, ICPMS) (UIdaho, CCI, Univ. of Heidelberg)

Fechenko Glacier Field Season (July/August 2009)

2009 Cores
Completed (ICP-MS) (CCI)
Isotopes (currently being analyzed at UIdaho)
Ions (at CCI)
2009 cores: Annual signals present in trace elements

Nyainquentanghla ice core (124m deep)
Isotopes (dO18): completed (Lanzhou)
Ions: completed (CCI)
ICP-MS: awaiting analysis (CCI).
Pb210 (PSI, Switzerland)
Tritium (NZ IGNS)

WRF climate model runs in collaboration with R. Oglesby, University of Nebraska (Lincoln):

Years 1970, 1986 completed 1st year.
Past year: 1985, 1987 completed. Running 1971-1972 currently

Findings: (See PDF version submitted by PI at the end of the report)

AICA 2008-2009

(1) Atmospheric Soluble Dust Records from a Tibetan Ice Core: Possible Climate Proxies and Teleconnection with the PDO (Grigholm et al., in review): In the autumn of 2005 a joint-expedition between the University of Maine and the Institute of Tibetan Plateau Research recovered three ice cores from Guoqu Glacier (33o34?37.8??N, 91o10?35.3??E, 5720 m a.s.l.) on the northern side of Mt. Geladaindong, central Tibetan Plateau. Isotopes (δ18O), major soluble ions (Na+, K+, Mg2+, Ca2+, Cl-, NO3-, SO42-), and radionuclides (β-activity) measurements from one of the cores revealed a 70-year record (1935-2005). Statistical analysis of major ion time series suggests that atmospheric soluble dust species dominate the chemical signature and that background dust levels conceal marine ion species deposition. The dust time-series have inter-species relations and common structure (EOF 1) suggesting a similar soluble dust source or transport route. Annual and seasonal correlations between the EOF 1 time-series and NCEP/NCAR reanalysis climate variables (1948-2004) suggests that the Mt. Geladaindong ice core record provides a proxy for local and regional surface pressure. A ~ three-fold decrease of soluble dust concentrations in the mid/late 1970s accompanied with regional increases in pressure and temperature 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 soluble dust loading and the PDO. Analysis of temporally longer ice cores from Mt. Geladaindong may enhance understanding of the relationship between the PDO and central Asian atmospheric circulation and subsequent atmospheric soluble dust loading.

(2) WRF Climate Modeling Update: The Weather Research and Forecasting (WRF) model was designed for high-resolution applications and is an ideal tool for assessing the value of high-resolution regional climate modeling. High-resolution allows for a more precise description of regional topographic forcings due to orography, land-sea contrasts and vegetation characteristics. WRF simulations may be particularly beneficial to the alpine regions of Asia (e.g. Himalayas and the Tibetan Plateau), where topography is very complex and has impacts on monsoonal circulation. Two WRF model simulations have been conducted for the years 1970 and 1986 (forced by initial boundary conditions from the NCEP/NCAR Reanalysis) for comparison with ice core reconstructions developed using AICA data. Two nested domains were used in the simulations. An outer domain (48 km grid-spacing) covering roughly the Asian continent and an inner domain (12 km grid-spacing) centered on the Tibetan Plateau. These domains offer much higher resolution than NCEP/NCAR Reanalysis, which uses 2.5 degree grid spacing. Preliminary temperature comparisons between WRF grids and observation weather station data suggest that the WRF domains better simulate the temperature variability and magnitude than NCEP/NCAR Reanalysis. Future evaluation of the WRF model will include comparisons to synoptic weather maps along with comparisons to additional weather station data (e.g. precipitation, pressure, wind velocity).

Examples of papers and findings in preparation (2009-2010):

~350 year dust record from the central Tibetan Plateau

The 147 m ice core soluble ion record from Mt. Geladaindong provides a ~350 year proxy for atmospheric dust concentrations. These dust records reveal that atmospheric dust concentrations during the past 30 years are the lowest of any previous 10-30 year period in the core. The recent decline in atmospheric dust is consistent with observational dust records for regional weather stations. The ~350 year ice core record

suggests that current atmospheric concentrations are unusually low for the region as preceding years display much higher dust concentrations. Implications from this study include identification that the current weakening of the Northern Hemisphere westerlies is a unique event relative to the last ~350years. This contrasts with the current strengthening of the Southern Hemisphere westerlies reported using our Antarctic ice core array in response to forcing by lower tropospheric greenhouse gas rise and the Antarctic ozone hole. In the Northern Hemisphere lower tropospheric warming and decay of Arctic sea ice is resulting in a weakening of the pole-equator thermal gradient hence decrease in strength of the westerlies. Implications for future climate change are immense.

Seasonal influx of potential anthropogenic Pb at Inilchek Glacier, Kyrgyzstan.

Enrichment Factor (EF) calculations of the Pb element record from a Inilchek Glacier in the Tien Shan reveal a possible spring/summer influx of anthropogenic pollution. PbEF signals display spring/summer peaks ranging from 50?250 (EF values >10 suggest anthropogenic influences). The seasonal patterns of PbEF may be a result of: 1) seasonal source emission of anthropogenic activity and/or 2) varying seasonal transport paths and strength. NOAA Hysplit Back-trajectory and NCEP/NCAR Reanalysis are implemented to determine potential source regions.

Late 20th century decline in accumulation at Inilchek Glacier, Kyrgyzstan.

An accumulation record derived from an Inilchek Glacier ice core suggests a potential
~ 40-50% decline in precipitation 1969 ? 1999. Comparison with local weather stations in the Tien Shan show similar overall declines in precipitation. The continued collection of glaciochemical data from the Inilchek ice core will allow for the potential reconstruction of annual accumulation over the past 100-150+ years. Results will lead to a better understanding of decadal-scale precipitation variability in central Asia, a region with growing water demands and limited water resources.

Synoptic comparisons between atmospheric dust records from the Asian Ice Core Array (AICA) sites.

The Asian Ice Core Array (AICA) provides several high resolutions dust records (major soluble ions and trace elements) from the glaciated regions of central Asia (i.e. Himalayas, Tibetan Plateau, and the Tien Shan). A synoptic spatial and temporal comparison between local ice core dust records (e.g. chemical concentrations and composition) reveals larger regional patterns of atmospheric circulation over the past several hundred years throughout Asia. AICA sites vary temporally (depending on the glacier thickness and site accumulation rate) with the longest possible multi-core comparison covering ~350 years. In addition, to direct ice core dust record comparisons, instrumental records (e.g. atmospheric dust, wind velocity, pressure, and precipitation) will be used to elucidate potential driving mechanisms of the spatial and temporal variability in atmospheric dust concentration displayed in ice cores since the mid-20th century.

WRF Model update
The Weather Research and Forecasting (WRF) model was designed for high-resolution (12km x 12km) applications and is an ideal tool for assessing the value of high-resolution regional climate modeling. High-resolution allows for a more precise description of regional topographic forcings due to orography, land-sea contrasts and vegetation characteristics. WRF simulations are of particular value in the mountainous regions of Asia (e.g. Himalayas and the Tibetan Plateau), where topography is very complex and has impacts on monsoonal circulation. Four WRF model simulations have been conducted thus far as part of our project for the years 1970, 1985, 1986, and 1987 (forced by initial boundary conditions from the NCEP/NCAR Reanalysis). Two nested domains were used in the simulations. An outer domain (48 km grid-spacing) covering roughly the Asian continent and an inner domain (12 km grid-spacing) centered on the Tibetan Plateau. These domains offer much higher resolution than NCEP/NCAR Reanalysis, which uses 2.5 degree grid spacing. Preliminary temperature comparisons between WRF grids and observation weather station data suggest that the WRF domains better simulate the temperature variability and magnitude than NCEP/NCAR Reanalysis, especially in regions with more complex topography. Wind velocity comparisons show that WRF reproduced seasonal wind variability is much better than NCEP/NCAR Reanalysis. Precipitation comparison between observational data and model output shows similar seasonal variability with higher precipitation during the summer months coinciding with the summer monsoon. Specific precipitation comparisons between WRF and NCEP/NCAR Reanalysis reveal significant differences between monthly averages (e.g. NCEP/NCAR Reanalysis estimating much larger precipitation averages during the summer months (June and July)). The two final years of the simulations are in progress (1971-1972). Future evaluation of the WRF model will include continued comparison for the two 3-year periods (1970-1972; 1985-1987) with NCEP/NCAR Reanalysis, ERA-40, and synoptic weather maps along with comparisons to additional weather station data (e.g. precipitation, pressure, wind velocity).

Training and Development:
2008-2009
Bjorn Grigholm (AICA PhD student) has been actively involved in all aspects of AICA research (field, processing, analyses, interpretation, and modeling).

He has thus far:
(1)submitted one paper for publication (see Grigholm et al., in review under publications);
(2)presented posters at AGU 2008 San Francisco, USA
'Asian Ice Core Array (AICA): Climate and Environmental Reconstruction of Asia, Grigholm, B., Mayewski, P.A., Aizen, V., Kang, S., Kaspari, S., and Maasch, K.A
(3) given talks at meetings:
3rd CADIP Workshop in San Francisco, December 13, 2008
Title: Asian Ice Core Array (AICA): Ice Core Status
Grigholm, B., Mayewski, P.A., Aizen, V., Kang, S., and Kaspari, S.,
17th Annual Harold W. Borns Jr. Symposium, Climate Change Institute, University of Maine, Orono, ME.
Title: Evaluation of high-resolution regional climate model (WRF) in Asia
Grigholm, B: Mayewski, P.A.; Maasch, K.A.; Oglesby, R.J.; Hays, C.J.

2009-2010
Papers:
Published: Grigholm, B., P. A. Mayewski, S. Kang, Y. Zhang, S. Kaspari, S. B. Sneed, and Q. Zhang (2009), Atmospheric soluble dust records from a Tibetan ice core: Possible climate proxies and teleconnection with the Pacific Decadal Oscillation, J. Geophys. Res., 114.

Talks:
17th Annual Harold W. Borns, Jr. Symposium. May 2009. University of Maine
Evaluation of high-resolution regional climate model (WRF) in Asia

18th Annual Harold W. Borns, Jr. Symposium. May 2010. University of Maine
Asian Ice Core Array (AICA): Climate and Environmental Reconstruction of Asia

INT500 Seminar:
Climate and Environmental Reconstruction in central Asia.? Oct 14th 2009. University of Maine.

Final:

(1) PhD student (Susan Kaspari) completed her PhD under P. Mayewski during the early stages of the current AICA project. She continued her involvement with AICA through her post-doctoral research at Paul Scherrer Institute (Switzerland) under M. Schwikowski and is now an assistant professor at Central Washington University.
(2) PhD student Bjorn Grigholm was supported by AICA and participated in the recovery of ice cores from Mt. Geladaindong, Fedchenko and Nyianquentanglha. He has been integrally involved in all AICA ice core processing, chemical analysis, climate modeling and paper writing. He is expected to complete his PhD in Spring 2012.
(3) Several undergraduate students participated in AICA laboratory activities.
(4) AICA data is regularly used in several courses (INT 652, selected topics, f=graduate seminar).

Outreach Activities:
AICA research is routinely presented as part of a series of national and public lectures given by Paul Mayewski, AICA data is included in ERS542 taught by Mayewski and Maasch, and AICA field activities are made available to the public in the form of student reports (www.climatechange.umaine.edu).

Journal Publications

Kaspari, S., Hooke, R., Mayewski, P.A., Kang, S., Qin, D., and Hou, S, "Changes in the snow accumulation rate at Mt. Everest based on ice core annual layering and a numerical model", Jour. Glaciology, p. 343, vol. 54, (2008). Published,

Grigholm, B., P. A. Mayewski, S. Kang, Y. Zhang, S. Kaspari, S. B. Sneed, and Q. Zhang, "Atmospheric soluble dust records from a Tibetan ice core: Possible climate proxies and teleconnection with the Pacific Decadal Oscillation", Jour. Geophys. Res., p. D20118, vol. 114(D20, (2009). Published, . Doi: 10.1029/2008JD011242

Kaspari, S., P. A. Mayewski, M. Handley, E. Osterberg, S. Kang, S. Sneed, S. Hou, and D. Qin, "Recent increases in atmospheric

concentrations of Bi, U, Cs, S and Ca from a 350-year Mount Everest ice core record", Jour. Geophys. Res., p. , vol. 114, (2009). Published, doi:10.1029/2008JD011088

Aizen, V. B., Mayewski, P.A., Aizen, E., Joswiak, D., Kaspari, S., Surazakov, A., Grigholm, B., and Finaev, A.,, "Stable isotope and chemical time series from Fedchenko Glacier firn core, Pamir", Jour. Glaciology, p. 275, vol. 55, (2009). Published,

Kaspari, S., Mayewski, P.A., Handley, M., Kang, S., Hou, S., Sneed, S., Maasch, K., and Qin, D.,, "A high resolution record of atmospheric dust composition and variability since AD1650 from a Mt. Everest ice core", Jour. Climate, p. 391, vol. 22, (2009). Published,

Pang, H., Hou, S., Kaspari, S., Mayewski, P.A., Masson-Delmotte, V., Jouzel, J., Li, Z., He, Y., Hong, S., and Qin, D, "Atmospheric circulation change in the central Himalayas indicated by a high resolution ice core deuterium excess record", Climate Research, p. , vol. , (2011). Submitted,

Kang, S., Zhang, Q., Kaspari, S., Qin, D., Cong, Z., Ren, J., and Mayewski, P.A., "Spatial and seasonal variations of elemental composition in Mt. Everest snow", Atmospheric Environment, p. 7208, vol. 41, (2007). Published, 10.1016/j.atmosenv.2007.05.024

Xu, J., Hou, S., Qin, D., Kaspari, S., Mayewski, P.A., Petit, J.R., Delmonte, B., Kang, S., Ren, J., Chappellaz, Hong, S.,, "An 108.83 m ice core record of atmospheric dust deposition at Mt. Qomolangma (Everest), central Himalayas", Quaternary Research, p. 33, vol. 73, (2010). Published, 10.1016/ j.yqres.2009.09.005

Kang, S., Zhang, Y., Zhang, Y., Grigholm, B., Kaspari, S, Qin, D., Ren, J. and Mayewski, P.A., "Variability of atmospheric dust loading over the central Tibetan Plateau based on ice core glaciochemistry", Atmospheric Environment, p. 298, vol. 44, (2010). Published, 10.1016/j.atmosenv.2010.05.014

Kaspari S., M. Schwikowski, M. Gyse, M. G. Flanner, S. Kang, S. Hou, P. A. Mayewski, "Recent increase in black carbon concentrations from a Mt. Everest ice core spanning 1860???2000 AD", Geophysical Research Letters, p. , vol. 38, (2011). Published, 10.1029/2010GL046096

Xu J., S. Kaspari, S. Hou, S. Kang, D. Qin, J. Ren, P. Mayewski, "Records of volcanic events since AD 1800 in the East Rongbuk ice core from Mt. Qomolangma", Chinese Science Bulletin, p. , vol. 54, (2009). Published, 10.1007/s11434-009-0020-y

Zhang Q., *S. Kang, S. Kaspari, C. Li, D. Qin, P. A. Mayewski, S. Hou, "Rare earth elements in an ice core from Mt. Everest: Seasonal variations and potential sources", Atmospheric Research, p. 300, vol. 94, (2009). Published, 10.1016/j.atmosres.2009.06.005

Hou S., J. Chappellaz, J. Jouzel, P. C. Chu, V. Masson-Delmotte, D. Qin, D. Raynaud, P. A. Mayewski, V. Y. Lipenkov, S. Kang, "Summer temperature trend over the past two millennia using air content in Himalayan ice", Climate of the Past, p. 89, vol. 3, (2007). Published,

Kang S., D. Qin, P. A. Mayewski, S. Kaspari, J. Ren, S. Hou, "Annual accumulation in the Mt. Nyainqentanglha ice core, southern Tibetan Plateau, China: relationships to atmospheric circulation over Asia", Arctic, Antarctic, Alpine Research, p. 663, vol. 39, (2007). Published,

Kang S., Y. Zhang, Qin D., Ren J., Zhang Q., B. Grigholm, P. Mayewski, "Recent temperature increase recorded in an ice core in the source region of Yangtze River", Chinese Science Bulletin, p. 825, vol. 52, (2007). Published, 10.1007/s11434- 007-0140-1

Kaspari, S., P. Mayewski1, S. Kang, S. Sneed, S. Hou, R. Hooke, K. Kreutz, D. Introne, M. Handley, K. Maasch, D. Qin, J. Ren, "Reduction in northward incursions of the South Asian monsoon since ~1400 AD inferred from a Mt. Everest ice core", Geophysical Research Letter, p. , vol. 34, (2007). Published, 10.1029/2007GL030440

Zhang Y., S. Kang*, D. Qin, B. Grigholm, P. A. Mayewski, "Changes in annual accumulation recorded in a Geladaindong ice core and its relationship to atmospheric circulation over the Tibetan Plateau", Chinese Science Bulletin, p. 3261, vol. 52, (2007). Published,

Books or Other One-time Publications

Web/Internet Site

URL(s):

(1) http://climatechange.umaine.edu/pamir_2009
(2) http://climatechange.umaine.edu/Research
/projects/CADIP2.html

(3)Data sharing - see urls below

Description:

(1) Pictures and notes related to "Ice Cores and Glaciological Surveys at Fedchenko Glacier, Pamir Mountains, Tajikistan".
(2) Description of international research effort that includes AICA.

Other Specific Products

Product Type:

Data or databases

Product Description:

Data sharing:
Mt. Geladaindong A
http://www.ncdc.noaa.gov/paleo/icecore/trop/guoqu/guoqu.html

Everest
http://www.ncdc.noaa.gov/paleo/icecore/trop/rongbuk/rongbuk_data.html

Fedchenko Glacier 2005
Submitted. Awaiting url

Geladaindong B
to be submitted by Spring 2012

Inilchek Glacier
to be submitted by Spring 2012

Belukha Glacier
to be submitted by Spring 2012

Nyainqentanglha
to be submitted by Spring 2012

Sharing Information:

Data has or will be made available through:
http://www.ncdc.noaa.gov/paleo/icecore/trop/

Contributions

Contributions within Discipline:

AICA will more than double the number of ice core records over central Asia.
AICA records provide new perspective concerning the current state of atmospheric circulation, water resources and air quality over Asia.

Contributions to Other Disciplines:

AICA ice core results and climate modeling will enhance understanding of past natural climate variability, assessment of the role of human activity in forcing climate, and prediction of future climate change at regional to continental scales over Asia and for global climate change.

Massaging raw data to interpretable results using *P301dx*.

Sudarshan S. Chawathe, Andrei V. Kurbatov, Paul A. Mayewski, Mark Royer.

P301dx is a workbench for managing scientific datasets related to climate-change research, with an emphasis on data from ice cores. A primary objective of P301dx is enhancing and accelerating the process of transforming raw datasets, such as those emerging from instruments, into meaningful representations that allow data to be easily interpreted. This process of transforming the data includes sub-tasks such as data cleaning, data integration, data mining, end-user programming, visualization, and provenance management. P301dx enables these tasks to be performed iteratively and with interactive response times, in a context that is tailored to the specific needs of climate-change researchers. We demonstrate these ideas using a few representative examples drawn from our recent and ongoing work with a group of CCI researchers (faculty, staff, and students).

AICA records provide new perspective concerning the current state of atmospheric circulation, water resources and air quality over Asia.

Contributions to Human Resource Development:

Asia contains more than half of the world's population. Water availability and quality is of prime concern to the Asian population. AICA is providing a framework for assessing past, present and future physical and chemical climate change.
AICA records provide new perspective concerning the current state of atmospheric circulation, water resources and air quality over Asia.

Contributions to Resources for Research and Education:

AICA will provide the basis for one PhD student's (Bjorn Grigholm) research at the Climate Change Institute, University of Maine.

AICA has provided an important focus for the analytical and climate modeling activities of several major national and international climate change research institutions and organizations.

Contributions Beyond Science and Engineering:

The Eurasian continent is the largest landmass in the World, exerting substantial influence on atmospheric and terrestrial systems and the 2.5 billion people living in the region. Changes in climate over this region have dramatic impacts on humans and ecosystems. Further changes in water resources and desertification over this heavily populated region may cause unpredictable consequences all over the World. However, instrumented records of climate and environmental variability over the region are sparse. Ice cores from Asian glaciers provide a proven source of high-resolution records of past climate dynamics and chemistry of the atmosphere extending back at seasonal resolution centuries to millennia. AICA will provide: unprecedented understanding of physical and chemical climate variability; a baseline for assessing modern climate variability in the context of human activity; and a contribution to the prediction of future climate variability for Asia.

Conference Proceedings

Categories for which nothing is reported:

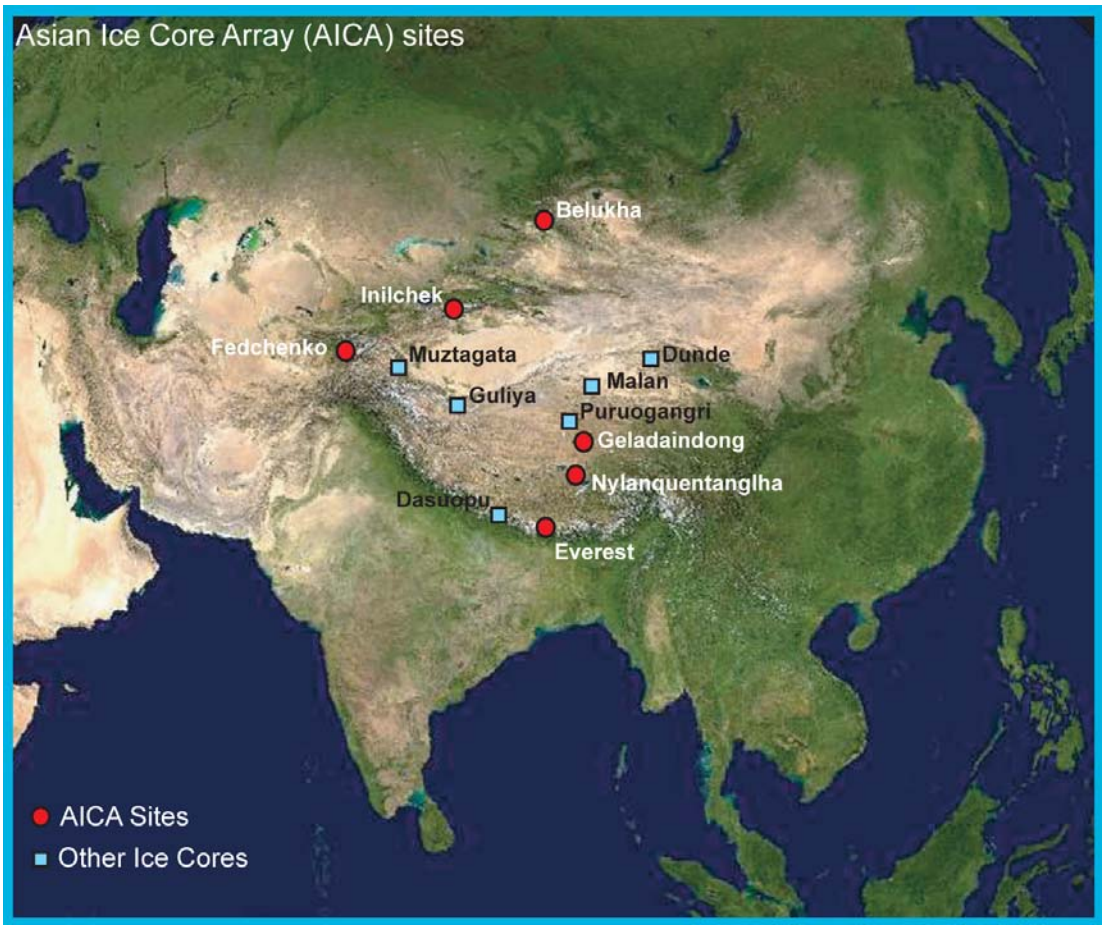
Any Book

Any Conference

Final Research and Education Activities 2011

Research –

(1) AICA doubled the number and expanded the N-S and E-W range of ice core records currently available from the Tibetan Plateau and northern Himalayas as demonstrated in the following figure.



(2) Status of glaciochemical analyses produced by the Climate Change Institute as part of AICA summarized in table below. Ice cores were melted using Continuous Melter System or Discrete Sampling (hand-cut) techniques in clean room conditions. IC (major soluble ions: Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}) and ICPMS (major and trace elements: e.g. Al, Fe, Zn, Pb, Cd, Cu, Co, Ti, Ba, Cr, Sr, V, U, Cs, Mn, As, Mg, and REE suit) were analyzed at the Climate Change Institute. Other AICA measurements were conducted by the University of Idaho (δD and $\delta^{18}O$), the Institute of Tibetan Plateau Research, ($\delta^{18}O$), the Paul Scherrer Institute (^{210}Pb), Lamont Doherty Earth Observatory (^{137}Cs), Central Washington University (black carbon) and GNS Science in New Zealand (^{3}H).

Asian Ice Core Array

Site	Year Drilled	Lat (N)	Long (E)	Elev (m)	Length (m)	Sample Resolution (cm)	Analyzed IC	Analyzed ICPMS
Belukha	2003	49.4	86.32	4117	175	5	4252	in progress
Inilchek	2000	42.21	80.2	5120	160	10	1510	1510
Mt.Geladain-dong A	2005	33.58	91.18	5750	70	3	1600	n/a
Mt.Geladain-dong B	2005	33.58	91.18	5750	147	4	3500	3500
Nyianquent-anglha	2003	30.40	90.57	5860	124	3	2400	n/a
Fedchenko Glacier (site 1)	2005	38.55	72.26	5650	12	10	105	105
Fedchenko Glacier (site 2)	2005	38.55	72.26	5280	9	10	89	89
Fedchenko Glacier	2009	38.61	72.43	4950	10	10	n/a	105
Everest East Rongbuk	2002	27.98	86.92	6518	108	3	3123	3123

A total of n = 24,922 (IC and ICPMS) samples were analyzed by the Climate Change Institute as part of AICA. Samples listed as in progress will be completed in the coming months.

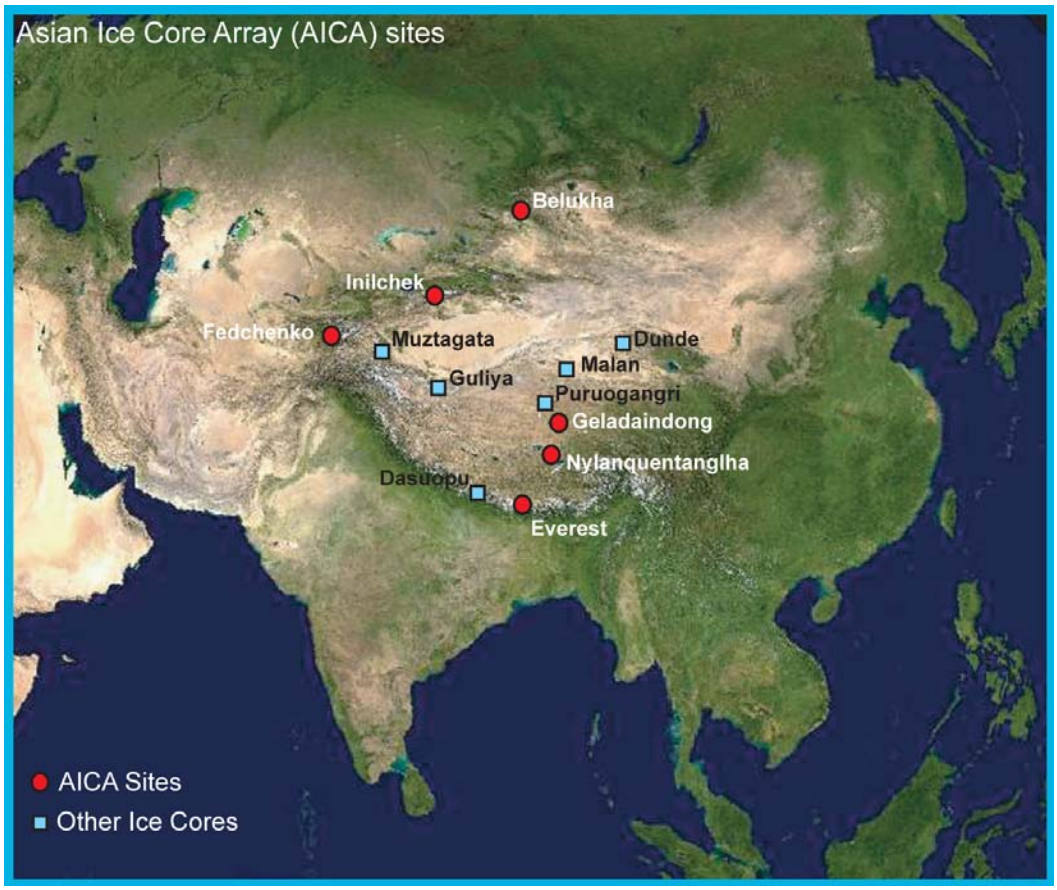
Education –

(1) PhD student (Susan Kaspari) completed her PhD under P. Mayewski during the early stages of the current AICA project. She continued her involvement with AICA through her post-doctoral research at Paul

Scherrer Institute (Switzerland) under M. Schwikowski and is now an assoistant professor at Central Washington University.

(2) PhD student Bjorn Grigholm was supported by AICA and participated in the recovery of ice cores from Mt. Geladaindong, Fedchenko, and Nyianquentanglha. He has been integrally involved in all AICA ice core processing, chemical analyses, climate modeling and paper writing. He is expected to complete his PhD in Spring 2012.

(3) Several undergraduate students participated in AICA laboratory activities.



Synthesis of Major Findings:

The following figures provide a synthesis of AICA major findings. Some of the results have already been published, but the full synthesis will be submitted for publication no later than spring 2012 as part of B. Grigholm's PhD dissertation.

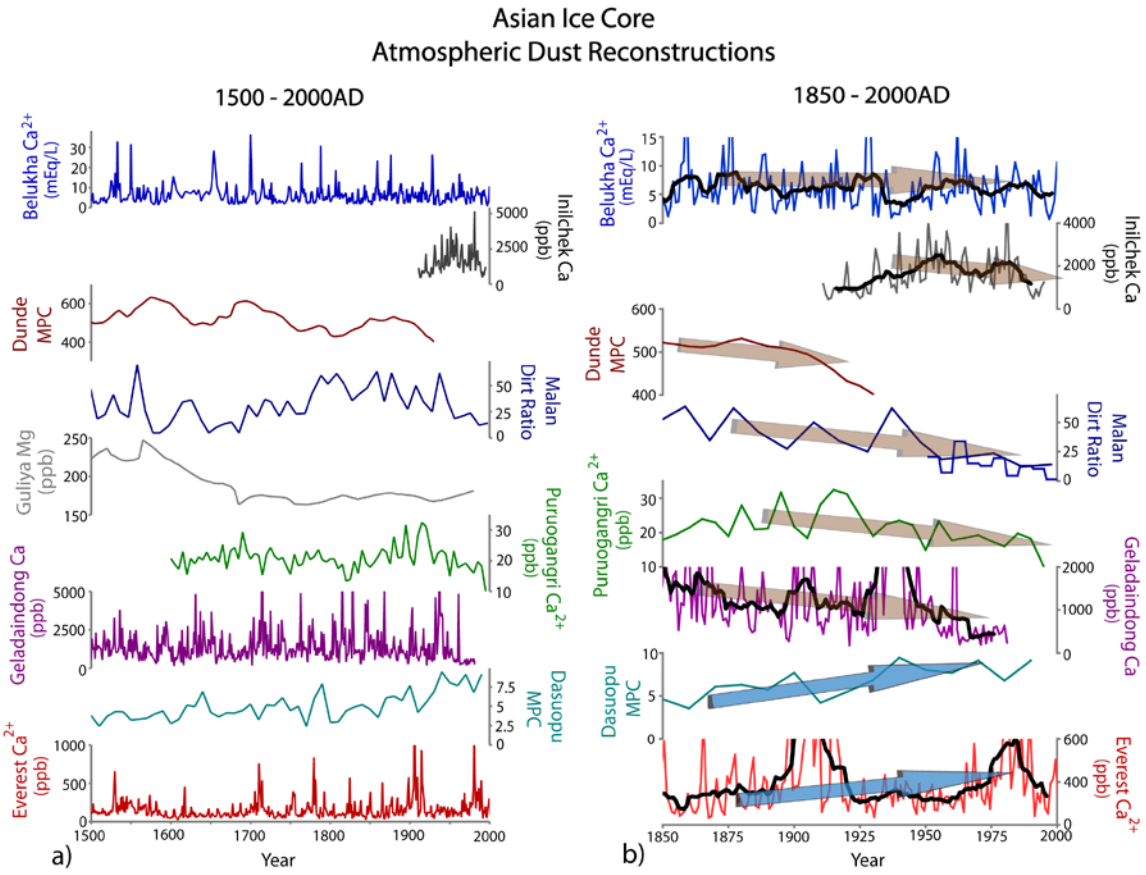


Figure 1. Asian Ice Core Dust Reconstructions: AICA sites provide new high-resolution glaciochemical data sets (10-26 samples/yr), expanding the spatial and temporal coverage of past climatological conditions in Asia. Comparisons with existing lower-resolution Asian ice core dust reconstructions have allowed insight to past variability of atmospheric dust concentrations and provided context to modern atmospheric conditions. **a)** Asian dust records 1500-2000AD: The spatial and temporal array of cores reveal local variability and regional trends between sites over the past 500 years. Local and regional variability of dust concentrations may reflect shifts in atmospheric dust entrainment variables (e.g. wind velocities and precipitation) associated with westerly and monsoonal circulation dynamics. Comparison between sites suggest that northern and central Tibetan Plateau atmospheric dust concentrations were generally higher prior to 1950. However, southern sites (Dasuopo and Everest) in the Himalayas suggest that atmospheric concencentrations have generally increased over the past few hundred years. *AICA sites (Belukha, Inilchek, Geladaindong, and Everest) calcium records are smoothed at annual resolution. Dunde Microparticle concentration (MPC) (10-yr r-mean)* (Yang et al., 2006)*; Malan Dirt Ratio (10-yr means)(Wang et al., 2006); Guliya Mg (10-yr r-mean)(Yang et al., 2006); Puruogangri Ca^{2+} (5-yr means)(Thompson et al., 2006); Dasuopu MPC (10-yr means)(Thompson et al., 2000).* **b)** Dust records between 1850-2000AD reveal general declining trends in the central Tibetan Plateau (Malan,

Puruogangri, and Geladaindong). These regional trends may reflect declines in winter/spring westerly circulation strength or increases in precipitation reducing atmospheric dust entrainment and transport on the central Tibetan Plateau. Conversely, southern ice core sites in the Himalayas (Dasuopo and Everest) display increases in dust concentrations, which have been associated with a reduction in summer monsoon incursions by *Kaspari et al. (2007). AICA sites (Belukha, Inilchek, Geladaindong, and Everest) calcium records are smoothed at annual resolution and black lines represent 11-yr r-means. Dunde Microparticle concentration (MPC) (10-yr r-mean)* (Yang et al., 2006)*; Malan Dirt Ratio (dark blue line (10 yr means); light blue line (5-yr means)) (Wang et al., (2005 and 2006); Guliya Mg (10-yr r-mean) (Yang et al., 2006); Puruogangri Ca^{2+} (5-yr means) (Thompson et al., 2006); Dasuopu MPC (10-yr means) (Thompson et al., 2000).*

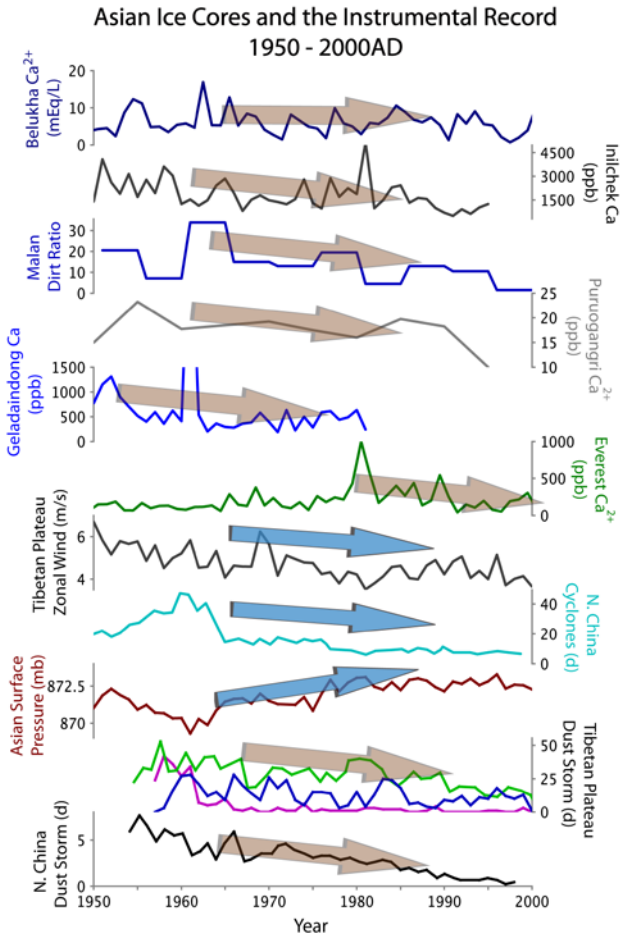


Figure 2. Asian ice core records (Inilchek, Malan, Puruogangri, and Geladaindong) reveal general declines in atmospheric dust concentrations over the north/central Tibetan Plateau (1950-2000AD). Comparison to instrumental records reveal a corresponding regional weakening of atmospheric circulation marked by reductions in zonal winds, cyclone days, and increases in pressure; elucidating potential driving mechanisms of atmospheric dust entrainment and transport. Recent reductions in atmospheric dust concentrations suggested by ice core records are supported by regional dust storm day observations in northern China and the Tibetan Plateau. *AICA sites (Belukha, Inilchek, Geladaindong, and Everest) calcium records are smoothed at annual resolution. Malan Dirt Ratio (5-yr means); Puruogangri Ca^{2+} (5-yr means); Tibetan Plateau surface zonal winds (NCEP/NCAR:30-35 °N;80-90 °E); North China Cyclone days (Qian et al., 2002); Asian Surface Pressure (NCEP/NCAR:35-60 °N;60-110 °E). Tibetan Dust Storms (Wang et al., 2004 and Chinese Meteorological Adminstation); North China dust storm days (Qian et al., 2002).*

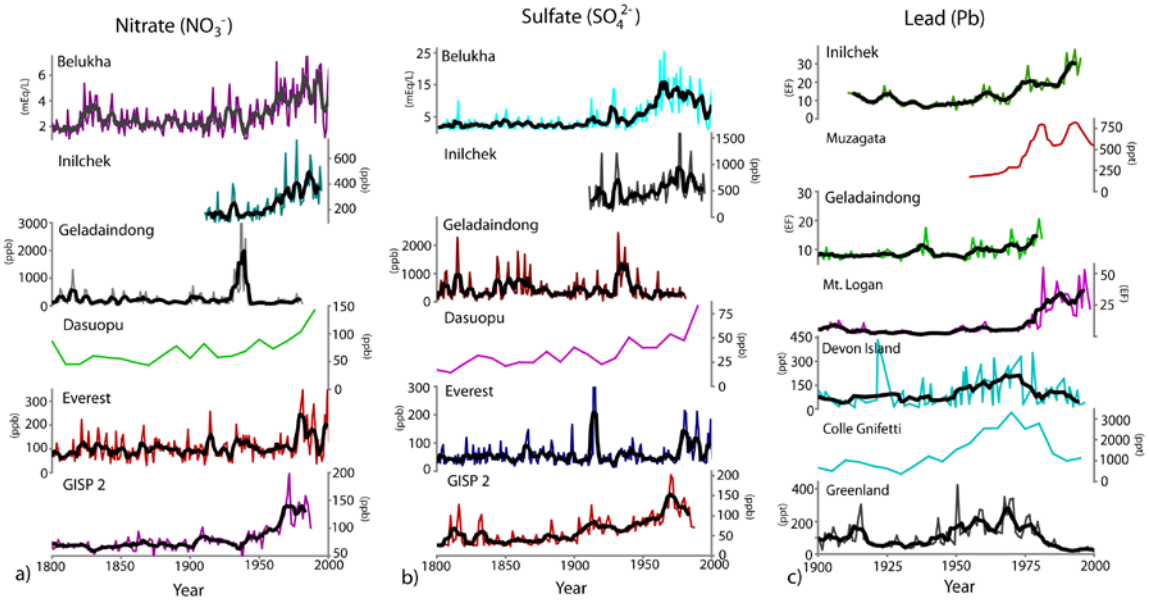


Figure 3. AICA sites provide records to help access the spatial and temporal impact of anthropogenic pollutants (e.g. NO_3^-, SO_4^{2-}, and Pb). **a) and b)** Northern AICA sites (Belukha and Inilchek) reveal similar rises in nitrate and sulfate concentrations as Dasuopu (in the Himalayas) and GISP2 (central Greenland) coinciding with hemispheric increases in anthropogenic pollutants. Geladaindong and Everest reveal different trends suggesting that nitrate/sulfate concentrations are locally variable within Asia and perhaps masked by natural sources. *AICA sites (Belukha and Inilchek) are smoothed at annual resolution and black lines represent 5-yr r-mean); Dasuopu (*NO_3^- and SO_4^{2-}*) (10-yr means)(Thompson et al., 2000); GISP 2 (*NO_3^- and SO_4^{2-}*); (Mayewski et al., 1990).* **c)** AICA records have added to the limited available Pb records. Inilchek Pb enrichment factor value trends are similar to Pb

records in central Asia and the North Pacific (i.e. Mt. Logan), displaying increases throughout the late 20th century corresponding to local and regional increases in Asian industrial emissions. However, comparisons to Pb records from Greenland, Devon Island (Canadian Arctic), and Colle Gnifetti (European Alps) reveal opposite trends since the early 1970s, most likely resulting from North American and European air quality policies that have only recently been adopted in Asia. *AICA sites (Inilchek and Geladaindong), Mt. Logan (Osterberg et al., 2007), and Greenland (McConnell et al., 2006), are smoothed at annual resolution and black lines represent 5-yr r-mean); Devon Island (Shotyk et al., 2005) (~1-yr mean and black lines represent 5-yr r-means); Colle Gnifetti (5-yr mean) (Schwikowski et al., 2004).*

Published Papers:

Kang S., Y. L. Zhang, Y.J. Zhang, B. Grigholm, S. Kaspari, D. Qin, J. Ren, P. Mayewski. (2010) Variability of atmospheric dust loading over the central Tibetan Plateau based on ice core glaciochemistry. Atmospheric Environment, 44(25): 2980-2989. Doi:10.1016/j.atmosenv.2010.05.014.

ABSTRACT. A Mt. Geladaindong (GL) ice core was recovered from the central Tibetan Plateau (TP) spanning the period 1940–2005 AD. High-resolution major ion (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-) time-series are used to investigate variations in atmospheric dust loading through time. The crustal source ions vary seasonally with peaks in dust concentrations occurring during the winter and spring which are consistent with atmospheric dust observations at local meteorological stations. However, both similarities and dissimilarities are displayed between the decadal variation of atmospheric dust in the GL core and dust observation records from meteorological stations, which can be attributed to local environmental effects at the stations. This paper compares the 1980s and 1970s as case periods for low and high atmospheric dust loading, respectively, two periods reflecting shifts in spring atmospheric circulation (a weakening of zonal and meridional winds) from the 1970s (a period of enhanced dust aerosol transportation to central TP) to the 1980s (a period of diminished dust aerosol transportation to central TP), especially a significant decrease of meridional wind speeds in the 1980s. GL ice core dust proxies (Ca^{2+} and K^+) are correlated with Total Ozone Mapping Spectrometer (TOMS) Aerosol Index (AI) data in spring over the TP and in the northwestern China (especially for K^+). Thus variability of crustal ions in central TP ice core provides a proxy for reconstructing a history of atmospheric dust loading not only on the TP, but also in northwestern China.

Aizen, V. B., P. A. Mayewski, E. M. Aizen, D. R. Joswiak, A.B. Surazakov, S. Kaspari, B. Grigholm, M. Krachler, M. Handley, A. Finaev. (2009) Stable-isotope and trace element time series from Fedchenko glacier (Pamirs) snow/firn cores. Journal of Glaciology, Vol. 55, No. 190.

ABSTRACT. In summer 2005, two pilot snow/firn cores were obtained at 5365 and 5206ma.s.l. on Fedchenko glacier, Pamirs, Tajikistan, the world's longest and deepest alpine glacier. The well-defined seasonal layering appearing in stable-isotope and trace element distribution identified the physical links controlling the climate and aerosol concentration signals. Air temperature and humidity/precipitation were the primary determinants of stable-isotope ratios. Most precipitation over the Pamirs originated in the Atlantic. In summer, water vapor was re-evaporated from semi-arid regions in central Eurasia. The semi-arid regions contribute to non-soluble aerosol loading in snow accumulated on Fedchenko glacier. In the Pamir core, concentrations of rare earth elements, major and other elements were less than those in the Tien Shan but greater than those in Antarctica, Greenland, the Alps and the Altai. The content of heavy metals in the Fedchenko cores is 2–14 times lower than in the Altai glaciers. Loess from Afghan–Tajik deposits is the predominant lithogenic material transported to the Pamirs. Trace elements generally showed that aerosol concentration tended to increase on the windward slopes during dust storms but tended to decrease with altitude under clear conditions. The trace element profile documented one of the most severe droughts in the 20th century.

Grigholm B, P. A. Mayewski, S. Kang, Y. Zhang, S. Kaspari, S. Sneed, Q. Zhang, Z. Cong. (2009) Atmospheric soluble dust records from a Tibetan ice core: Possible climate proxies and teleconnection with the Pacific Decadal Oscillation. Journal of Geophysical Research, 114(D20), D20118. Doi: 10.1029/2008JD011242.

ABSTRACT. In autumn 2005, a joint expedition between the University of Maine and the Institute of Tibetan Plateau Research recovered three ice cores from Guoqu Glacier (33°34037.800N, 91°10035.300E, 5720 m above sea level) on the northern side of Mt. Geladaindong, central Tibetan Plateau. Isotopes (d18O), major soluble ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-) and radionuclide (B-activity) measurements from one of the cores revealed a 70-year record (1935–2005). Statistical analysis of major ion time series suggests that atmospheric soluble dust species dominate the chemical signature and that background dust levels conceal marine ion species deposition. The soluble dust time series have interspecies relations and common structure (empirical orthogonal function (EOF) 1), suggesting a similar soluble dust source or transport route. Annual and seasonal correlations between the EOF 1 time series and National Centers for Environmental Prediction/National Center for Atmospheric Research reanalysis climate variables (1948–2004) suggest that the Mt. Geladaindong ice core record provides a proxy for local and regional surface pressure. An approximately threefold decrease of soluble dust concentrations in the middle to late 1970s, accompanied by regional increases in pressure and temperature and decreases in wind velocity, coincides with the major 1976–1977 shift of the Pacific Decadal Oscillation (PDO) from a negative to a positive state. This is the first ice core evidence of a potential teleconnection between central Asian atmospheric soluble dust loading and the PDO. Analysis of temporally longer ice cores from Mt. Geladaindong may enhance understanding of

the relationship between the PDO and central Asian atmospheric circulation and subsequent atmospheric soluble dust loading.

Kaspari S., M. Schwikowski, M. Gyse, M. G. Flanner, S. Kang, S. Hou, P. A. Mayewski. (2011) Recent increase in black carbon concentrations from a Mt. Everest ice core spanning 1860–2000 AD. Geophysical Research Letters, 38 (L04703), Doi: 10.1029/2010GL046096.

ABSTRACT. A Mt. Everest ice core spanning 1860–2000 AD and analyzed at high resolution for black carbon (BC) using a Single Particle Soot Photometer (SP2) demonstrates strong seasonality, with peak concentrations during the winter-spring, and low concentrations during the summer monsoon season. BC concentrations from 1975–2000 relative to 1860–1975 have increased approximately threefold, indicating that BC from anthropogenic sources is being transported to high elevation regions of the Himalaya. The timing of the increase in BC is consistent with BC emission inventory data from South Asia and the Middle East, however since 1990 the ice core BC record does not indicate continually increasing BC concentrations. The Everest BC and dust records provide information about absorbing impurities that can contribute to glacier melt by reducing the albedo of snow and ice. There is no increasing trend in dust concentrations since 1860, and estimated surface radiative forcing due to BC in snow exceeds that of dust in snow. This suggests that a reduction in BC emissions may be an effective means to reduce the effect of absorbing impurities on snow albedo and melt, which affects Himalayan glaciers and the availability of water resources in major Asian rivers.

Xu J., S. Hou, D. Qin, S. Kaspari, P. Mayewski, J. Petit, B. Delmonte, S. Kang, J. Ren, J. Chappellaz, S. Hong. (2010). An 108.83 m ice core Record of atmospheric dust deposition at Mt. Qomolangma (Everest), Central Himalaya. Quaternary Research, 73, 33-38. Doi: 10.1016/ j.yqres.2009.09.005.

ABSTRACT. The central Himalaya can be regarded as an ideal site for developing a long-term ice core dust record to reflect the environmental signals from regional to semi-hemispheric scales. Here we present a dust record from segments of a 108.83-m ice core recovered from the East Rongbuk (ER) Glacier (27°59′N, 86°55′E; 6518 m a.s.l.) on the northeast slope of Mt. Qomolangma (Everest) in the central Himalaya, covering the period AD 600–1960. Due to rapidly layer thinning and coarse sampling, we primarily discuss the changes in the dust record since AD 1500 in this paper. Results show a significant positive relationship between the dust concentration and reconstructed air temperatures during this period, suggesting a likely cold–humid and warm–dry climatic pattern in the dust source regions, namely Central Asia. This is associated with the variability in the strength of the westerlies and its corresponding precipitation.

Kaspari S., P.A. Mayewski, M. Handley, S. Kang, S. Hou, S. Sneed, K. Maasch, D. Qin. (2009). A high-resolution record of atmospheric dust composition and variability since

1650 AD from a Mt. Everest ice core. Journal of Climate, 22: 3910-3925. DOI: 10.1175/2009JCLI2518.1.

ABSTRACT. A Mount Everest ice core analyzed at high resolution for major and trace elements (Sr, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb, Lu, Bi, U, Tl, Al, S, Ca, Ti, V, Cr, Mn, Fe, Co) and spanning the period a.d. 1650–2002 is used to investigate the sources of and variations in atmospheric dust through time. The chemical composition of dust varies seasonally, and peak dust concentrations occur during the winter–spring months. Significant correlations between the Everest dust record and dust observations at stations suggest that the Everest record is representative of regional variations in atmospheric dust loading. Back-trajectory analysis in addition to a significant correlation of Everest dust concentrations and the Total Ozone Mapping Spectrometer (TOMS) aerosol index indicates that the dominant winter sources of dust are the Arabian Peninsula, Thar Desert, and northern Sahara. Factors that contribute to dust generation at the surface include soil moisture and temperature, and the long-range transport of dust aerosols appears to be sensitive to the strength of 500-mb zonal winds. There are periods of high dust concentration throughout the 350-yr Mount Everest dust record; however, there is an increase in these periods since the early 1800s. The record was examined for recent increases in dust emissions associated with anthropogenic activities, but no recent dust variations can be conclusively attributed to anthropogenic inputs of dust.

Kaspari, S., P. A. Mayewski, M. Handley, E. Osterberg, S. Kang, S. Sneed, S. Hou, D. Qin. (2009). Recent increases in atmospheric concentrations of Bi, U, Cs, S and Ca from a 350-year Mount Everest ice core record. Journal of Geophysical Research, 114, D04302. Doi: 10.1029/2008JD011088.

ABSTRACT. High-resolution major and trace elements (Sr, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb, Lu, Bi, U, Tl, Al, S, Ca, Ti, V, Cr, Mn, Fe, and Co) quantified in a Mount Everest ice core (6518 m above sea level) spanning the period 1650–2002 AD provides the first Asian record of trace element concentrations from the pre-industrial era, and the first continuous high-resolution Asian record from which natural baseline concentrations and subsequent changes due to anthropogenic activities can be examined. Modern concentrations of most elements remain within the pre-industrial range; however, Bi, U, and Cs concentrations and their enrichment factors (EF) have increased since the □1950s, and S and Ca concentrations and their EFs have increased since the late 1980s. A comparison of the Bi, U, Cs, S, and Ca data with other ice core records and production data indicates that the increase in atmospheric concentrations of trace elements is widespread, but that enrichment varies regionally. Likely sources for the recent enrichment of these elements include mining, metal smelting, oil and coal combustion, and end uses for Bi, and mining and refinement for U and Cs. The source of the synchronous enrichment of Ca and S is less certain, but may be related to land use and environmental change.

Xu J., S. Kaspari, S. Hou, S. Kang, D. Qin, J. Ren, P. Mayewski. (2009). Records of volcanic events since AD 1800 in the East Rongbuk ice core from Mt. Qomolangma. Chinese Science Bulletin 54, Doi: 10.1007/s11434-009-0020-y.

ABSTRACT. Continuous Bi profile of the East Rongbuk (ER) ice core near Mt. Qomolangma reveals nine major volcanic events since AD 1800. Compared with Volcanic Explosivity Index (VEI), it shows that the con-centrations of Bi in the ER ice core can reflect the major volcanic events within the key areas. This provides a good horizon layer for ice core dating, as well as a basis for reconstructing a long sequence of volcanic records from the Qinghai-Xizang (Tibet) Plateau ice cores.

*Zhang Q., *S. Kang, S. Kaspari, C. Li, D. Qin, P. A. Mayewski, S. Hou. (2009). Rare earth elements in an ice core from Mt. Everest: Seasonal variations and potential sources. Atmospheric Research, 94(2): 300-312. Doi:10.1016/j.atmosres.2009.06.005.*

ABSTRACT. Rare earth element (REE) concentrations in ice samples from the upper 8.4 m of a Mt. Everest ice core retrieved from the col of the East Rongbuk Glacier (28.03°N, 86.96°E, 6518 m a.s.l.) on the northeast ridge of Mt. Everest in September 2002 are presented. REEs display large seasonal variations, with high concentrations in the non-monsoon season and low concentrations in the summer monsoon season. This seasonality is useful for ice core dating. When normalized to a shale standard, the Mt. Everest REEs exhibit a consistent shale-like pattern with a slight enrichment of middle REEs during both seasons. However, individual monsoon REE patterns display differences, possibly resulting from diversified sources. Non-monsoon REE patterns are stable and are associated with the westerlies. Investigation of potential sources for the Everest REEs suggests an absence of anthropogenic contributions and minimal input from local provenances. REEs in Mt. Everest samples are most likely representative of a stable well-mixed REE background of the upper troposphere consisting of a mixture of aerosols transported by the atmospheric circulation from the west windward arid regions such as the Thar Desert, West Asia, the Sahara Desert and other uncertain provenances.

Kaspari S., R. L. Hooke, P. Mayewski, S. Kang, S. Hou, D. Qin, (2008). Snow accumulation rate on Qomolangma (Mount Everest), Himalaya: synchroneity with sites across the Tibetan Plateau on 50-100 year timescales. Journal of Glaciology, 54(185): 343-352.

ABSTRACT. Annual-layer thickness data, spanning AD 1534–2001, from an ice core from East Rongbuk Col on Qomolangma (Mount Everest, Himalaya) yield an age–depth profile that deviates systematically from a constant accumulation-rate analytical model. The profile clearly shows that the mean accumulation rate has changed every 50–100 years. A numerical model was developed to determine the magnitude of these multi-decadal-scale rates. The model was used to obtain a time series of annual accumulation. The mean annual accumulation rate decreased from

□□0.8 m ice equivalent in the 1500s to □0.3 m in the mid-1800s. From □1880 to □1970 the rate increased. However, it has decreased since □1970. Comparison with six other records from the Himalaya and the Tibetan Plateau shows that the changes in accumulation in East Rongbuk Col are broadly consistent with a regional pattern over much of the Plateau. This suggests that there may be an overarching mechanism controlling precipitation and mass balance over this area. However, a record from Dasuopu, only 125 km northwest of Qomolangma and 700 m higher than East Rongbuk Col, shows a maximum in accumulation during the 1800s, a time during which the East Rongbuk Col and Tibetan Plateau ice-core and tree-ring records show a minimum. This asynchroneity may be due to altitudinal or seasonal differences in monsoon versus westerly moisture sources or complex mountain meteorology.

Hou S., J. Chappellaz, J. Jouzel, P. C. Chu, V. Masson-Delmotte, D. Qin, D. Raynaud, P. A. Mayewski, V. Y. Lipenkov, S. Kang. (2007). Summer temperature trend over the past two millennia using air content in Himalayan ice. Climate of the Past, 3, 89-95.

ABSTRACT. Two Himalayan ice cores display a factor-two decreasing trend of air content over the past two millennia, in contrast to the relatively stable values in Greenland and Antarctica ice cores over the same period. Because the air content can be related with the relative frequency and inten- sity of melt phenomena, its variations along the Himalayan ice cores provide an indication of summer temperature trend. Our reconstruction point toward an unprecedented warming trend in the 20th century but does not depict the usual trends associated with "Medieval Warm Period" (MWP), or "Little Ice Age" (LIA).

Kang S., D. Qin, P. A. Mayewski, S. Kaspari, J. Ren, S. Hou. 2007. Annual accumulation in the Mt. Nyainqentanglha ice core, southern Tibetan Plateau, China: relationships to atmospheric circulation over Asia. Arctic, Antarctic, Alpine Research, 39(4): 663-670.

ABSTRACT. Annual accumulation records covering the period A.D. 1952-1998 were reconstructed using a 29.5-m ice core from the col of the Lanong Glacier (5850 m a.s.l.) on the eastern saddle of Mt. Nyainqentanglha, southern Tibetan Plateau. Using NCEP/NCAR Reanalysis data, we explore the relationships between this ice-core accumulation record and primary components of the climate system. Linear correlation analysis between annual accumulation and climate components for the 47-yr overlap period indicates that annual accumulation variations are closely correlated with sea-surface and 500-mb air temperature over the North Indian Ocean and atmospheric circulation (surface pressure and geopotential height) over Asia ($r > 0.34$, $P < 0.01$). An intensification of atmospheric circulation and increase of seasurface and air temperatures, resulting in intensified moisture availability and moisture transport, have been a major cause for the increase of ice-core accumulation over the Mt. Nyainquentanglha region since the 1980s.

Kang S., Q. Zhang, S. Kaspari, D. Qin, Z. Cong, J. Ren, P. A. Mayewski. (2007) Spatial and seasonal variations of elemental composition in Mt. Everest (Qomolangma) snow/firn. Atmospheric Environment, 41(34): 7208-7218. DOI: 10.1016/j.atmosenv.2007.05.024.

ABSTRACT. In May 2005, a total of 14 surface snow (0–10 cm) samples were collected along the climbing route from the advanced base camp to the summit (6500–8844 m a.s.l.) on the northern slope of Mt. Everest (Qomolangma). A 108 m firn/ice core was retrieved from the col of the East Rongbuk Glacier (28.031N, 86.961E, 6518 m a.s.l.) on the north eastern saddle of Mt. Everest in September 2002. Surface snow and the upper 3.5 m firn samples from the core were analyzed for major and trace elements by inductively coupled plasma mass spectroscopy (ICP-MS). Measurements show that crustal elements dominated both surface snow and the firn core, suggesting that Everest snow chemistry is mainly influenced by crustal aerosols from local rock or prevalent spring dust storms over southern/central Asia.
There are no clear trends for element variations with elevation due to local crustal aerosol inputs or redistribution of surface snow by strong winds during the spring. Seasonal variability in snow/firn elements show that high elemental concentrations occur during the non-monsoon season and low values during the monsoon season. Ca, Cr, Cs, and Sr display the most distinct seasonal variations. Elemental concentrations (especially for heavy metals) at Mt. Everest are comparable with polar sites, generally lower than in suburban areas, and far lower than in large cities. This indicates that anthropogenic activities and heavy metal pollution have little effect on the Mt. Everest atmospheric environment. Everest firn core REE concentrations are the first reported in the region and seem to be comparable with those measured in modern and Last Glacial Maximum snow/ice samples from Greenland and Antarctica, and with precipitation samples from Japan and the East China Sea. This suggests that REE concentrations measured at Everest are representative of the background atmospheric environment.

Kang S., Y. Zhang, Qin D., Ren J., Zhang Q., B. Grigholm, P. Mayewski. 2007. Recent temperature increase recorded in an ice core in the source region of Yangtze River. Chinese Science Bulletin, 52(6): 825-831. DOI: 10.1007/s11434- 007-0140-1.

ABSTRACT. Interests on climate change in the source region of Yangtze River have been raised since it is a region with the greatest warming over the Tibetan Plateau (TP). A 70-year history of precipitation $\delta^{18}O$ has been recovered using an ice core record retrieved in a plat portion of the firn area in the Guoqu Glacier (33°34′37.8″N, 91°10′35.3″E, 5720 m a.s.l.), Mt. Geladaindong (the source region of Yangtze River), in November, 2005. By using a significant positive relationship between ice core $\delta^{18}O$ record and summer air temperature (July to September) from the nearby meteorological stations, a history of summer air temperature has been reconstructed for the last 70 years. Summer temperature was relatively low in 1940s and high in 1950s to the middle of 1960s. The lowest temperature occurred in the middle of 1970s. Temperature was low in 1980s and dramatically increased

since 1990s, keeping the trend to the beginning of the 21st century. The warming rate recorded in the ice core with 0.5°C/10 a since 1970s is much higher that that in the central TP and the Northern Hemisphere (NH), and it becomes 1.1 °C/10 a since 1990s which is also higher than these from the central TP and the NH, reflecting an accelerated warming and a more sensitive response to global warming in the high elevation region.

Kaspari, S., P. Mayewski1, S. Kang, S. Sneed, S. Hou, R. Hooke, K. Kreutz, D. Introne, M. Handley, K. Maasch, D. Qin, J. Ren. (2007). Reduction in northward incursions of the South Asian monsoon since ~1400 AD inferred from a Mt. Everest ice core. Geophysical Research Letter, 34(L16701). Doi: 10.1029/2007GL030440.

ABSTRACT. A highly resolved Mt. Everest ice core reveals a decrease in marine and increase in continental air masses related to relatively high summer surface pressure over Mongolia, and reduction in northward incursions of the summer South Asian monsoon since □1400 AD. Previously published proxy records from lower sites south of the Himalayas indicate strengthening of the monsoon since this time. These regional differences are consistent with a south – north seesaw in convective activity in the Asian monsoon region, and reflect a southward shift in the mean summer position of the monsoon trough since □1400 AD. The change in monsoonal circulation at 1400 AD is synchronous with a reduction in solar irradiance and the onset of the LIA. This demonstrates a hemispheric scale circulation reorganization at this time, and the potential for future large shifts in monsoonal circulation.

Zhang Y., S. Kang, D. Qin, B. Grigholm, P. A. Mayewski. (2007). Changes in annual accumulation recorded in a Geladaindong ice core and its relationship to atmospheric circulation over the Tibetan Plateau. Chinese Science Bulletin, 52(23): 3261-3266.*

ABSTRACT. Annual accumulation records covering 1935 to 2004 were reconstructed using Geladaindong ice core in the source of Yangtze River. A significant positive correlation between annual accumulation and precipitation from nearby meteorological stations was found suggesting ice core accumulation could be taken as a precipitation proxy in the region. In the past 70 years, precipitation in the Geladaindong region was low from 1930s to early 1960s, and the lowest value occurred in the later 1950s. Since 1960s, precipitation increased dramatically and reached the maximum around 1980s, then decreased slightly in 1990s. By using Mann-Kendall rank statistical test method, a change point for precipitation was de- termined in 1967. Analysis of the atmospheric circulation over the Tibetan Plateau suggested that, compared with the southwest wind during the low precipitation period (before 1967), it extended about 2 latitudes northward during high precipitation period (after 1967). Moreover, during the high precipita- tion, the trough over the Bal Karshi Lake was also enhanced, and both the meridional wind and vapor transporting displayed a remarkable aggrandizement.

Papers Near Press

Pang, H., Hou, S., Kaspari, S., Mayewski, P.A., Masson-Delmotte, V., Jouzel, J., Li, Z., He, Y., Hong, S., and Qin, D., in review, Atmospheric circulation change in the central Himalayas indicated by a high resolution ice core deuterium excess record, Climate Research.

ABSTRACT. Continuous measurements for both δD and δ^{18}O along a 108.8 m ice core recovered from the East Rongbuk (ER) Glacier on the northeast saddle of Mt. Qomolangma (Everest) (28.03º N, 86.96º E, 6518 m above sea level) in September 2002 provide the first high-resolution historical record of deuterium excess (*d*) in the central Himalayas. In this paper, we focus on *d* record during the period 1951-2001 and its association with changes in atmospheric circulation. The *d* record exhibits a significant seasonal variation, with low values in summer and high values in winter, reflecting the atmospheric circulation shift between the winter westerlies and the Indian Summer Monsoon (ISM). The interannual *d* variation is primarily controlled by the ISM moisture transportation. Nevertheless, the abnormally high *d* value during the period 1960-64 is due to the strengthening of the winter westerlies. And the anomalously low *d* value during the period 1965-68 is primarily a result of migration of the ISM moisture source region, and secondly to surface sublimation. The results in this paper demonstrate that the ice-core *d* record retrieved from the high Himalayas is a good proxy for atmospheric circulation.

Papers in Progress (for B. Grigholm PhD to be completed by Spring 2012)

Grigholm et al., ~500-year Synoptic comparisons between Asian ice core atmospheric dust records.

TENTATIVE ABSTRACT. The Asian Ice Core Array (AICA) has provided new high-resolution glaciochemical records (major soluble ions and trace elements) from the glaciated regions of central Asia (i.e. Himalayas, Tibetan Plateau, and the Tien Shan), expanding the spatial and temporal coverage of past climatological conditions in Asia. Comparisons with existing lower-resolution Asian ice core dust reconstructions allow greater insight into past variability of atmospheric dust concentrations and provide greater context for understanding modern atmospheric conditions. The spatial and temporal array of cores reveal local variability and regional trends between sites over the past 500 years. Local and regional variability of dust concentrations may reflect shifts in atmospheric dust entrainment variables (e.g. wind velocities and precipitation) associated with westerly and monsoonal circulation dynamics. Comparison between sites (Belukha, Malan, Puruogangri, and Geladaindong) suggest that northern and central Asian atmospheric dust concentrations were higher prior to 1950. Examination of dust records between 1850-2000AD reveal general declining trends in the central Tibetan Plateau (Malan, Puruogangri, and Geladaindong), while southern sites in the Himalayas (Dasuopo

and Everest) display increases. These regional trends may reflect declines in winter/spring westerly circulation strength or increases in precipitation, reducing atmospheric dust entrainment in the central Tibetan Plateau. Increase in dust concentrations in the Himalayas (Dasuopo and Everest) may be a result of a reduction in summer monsoon incursions producing dustier conditions as suggested by Kaspari et al. (2007).

Comparison between Asian ice core dust records and the instrumental record offer the potential to elucidate the potential driving mechanisms of atmospheric dust entrainment and transport. Asian ice core records (Inilchek, Malan, Puruogangri, and Geladaindong) reveal general declines in atmospheric dust concentrations over the north/central Tibetan Plateau between 1950-2000AD. The instrumental records reveal a corresponding regional weakening of atmospheric circulation marked by reductions in dust entraining variables (i.e. zonal winds, cyclone days, and increases in surface pressure). The recent reductions in atmospheric dust concentrations suggested by ice core records are supported by regional dust storm day observations in northern China and the Tibetan Plateau.

Grigholm et al., Spatial and temporal variability of anthropogenic pollutants over Central Asia.

TENTATIVE ABSTRACT. AICA sites yield records that reveal the spatial and temporal impact of anthropogenic pollutants (e.g. NO_3^-, SO_4^{2-}, and Pb). Northern AICA sites (Belukha and Inilchek) reveal similar rises in nitrate and sulfate concentrations as Dasuopu (in the Himalayas) and GISP2 (central Greenland) corresponding to hemispheric increases in anthropogenic pollutants. Geladaindong and Everest reveal nitrate/sulfate concentration trends that are locally variable within Asia and are partly masked by natural sources. AICA records have also added to the limited available Pb records. Inilchek Pb enrichment factor value trends are similar to available Pb records in central Asia and the North Pacific (i.e. Mt. Logan), displaying increases throughout the late 20th century corresponding to local and regional increases in Asian industrial emissions. However, comparison to Pb records from Greenland, Devon Island (Canadian Arctic), and Colle Gnifetti (European Alps) reveal opposite trends since the early 1970s most likely resulting from North American and European air quality policies that have only recently been adopted in Asia.

Grigholm et al., 20th century accumulation record from Inilchek Glacier, Kyrgyzstan.

TENTATIVE ABSTRACT. A high-resolution ice core record derived from Inilchek Glacier provides an accumulation record from 1915-1995. Early portions of the record (1915-1934) reveal strong annual variability in accumulation followed by a steady rise from the 1940s to mid-1970s. Accumulation begins to decline in 1976/77 and declines steadily ~ 40-50% from 1975 to 1999. Although weather stations are limited in the Tien Shan, records show similar overall declines in precipitation from 1975 to 1999. The high-accumulation rate and precise annual signals make the Inilchek ice core one of the most best-dated precipitation proxy

records in the region. Records will be compared to regional ice core accumulation records as well as additional available regional precipitation proxy records and climate indices (e.g. PDO)

Grigholm et al., 20th century dust record from Inilchek Glacier

TENTATIVE ABSTRACT. Trace element concentrations of Ca^{2+}, Na^{+} and S provide a ~85 year proxy for atmospheric dust concentrations at Inilchek Glacier. Spatial correlations to NCEP/NCAR (1948-1995) summer (MJJA) surface pressure (indicative of storm activity) reveal significant negative correlations to Ca^{2+}, Na^{+} and S. Enhanced convective activity during summer is responsible for vertical transport of dust aerosols to the upper troposphere transported by westerly circulation over the evaporite-rich Caspian/Aral Sea Region to the west of Inilchek. Trace element records show similar declines to available regional dust storm observations.