Central Asia Deep Ice-Coring Project (CADIP)

A Proposal for International Multi-Institutional Ice-Coring Project in Central Asia (2005-12)

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The high elevation snowfields of the Pamir and Tien Shan contain robust records documenting: moisture advection into central Asia from the Atlantic and Arctic; dynamics of the westerly jet stream, the Siberian High, and Asian monsoon; and naturally and humanly forced environmental change over central Asia.

***Figure 1**. Large accumulation plateau at a head of the Fedchenko Glacier (Pamir)*

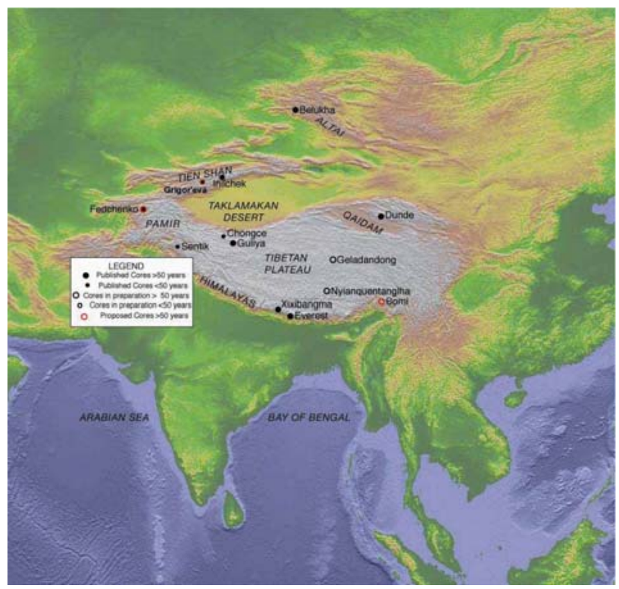

***Figure 2**. Note scarcity of data in the Pamir compared to much of the rest of Asia. See references for research conducted in the regions depicted.*

The current spatial coverage of ice-core records from the Altai, Tibet and the Himalaya is inadequate to document climatic and environmental changes over the northern region of central Asia through the Holocene.

The proposed deep Pamir ice core will be the deepest non-polar ice core record ever recovered.

There are several accumulation basins in the Pamir and Tien Shan located over 5500 m with ice thicknesses greater than 500 m and reaching to 1,000 m. These areas are suitable for the recovery and development of ice core climatic and environmental records extending back at some sites over 100,000 years. In addition, the central Asia long-term meteorological, synoptic, aerosol, and dust storm records provide an ideal platform for ice-core data calibration, validation and interpretation.

<u>The CADIP ice cores have the potential to accomplish several major scientific objectives</u>

The Pamir and Tien Shan are located in a region that influences hemispheric scale climate and is expected to experience major environmental change as a consequence of warming. Little past climate information exists from the Pamir, Tien Shan and central Asia in general. Asia has a long history of diverse civilization and a large potential for dramatic impact by humans in the near future related to demand for land use, water demand, and general development of society.

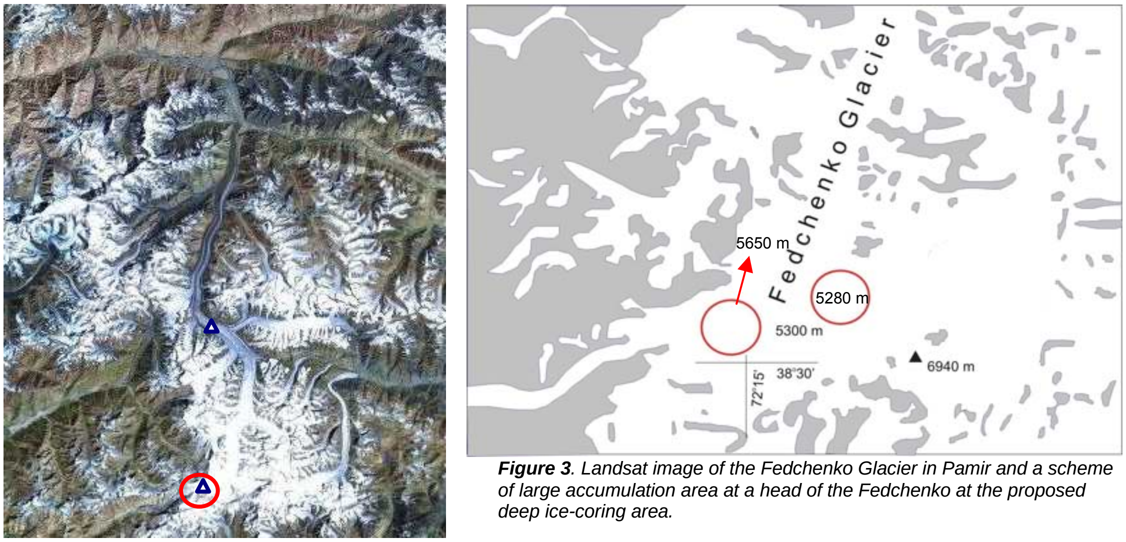

Figure 3*. Landsat image of the Fedchenko Glacier in Pamir and a scheme of large accumulation area at a head of the Fedchenko at the proposed deep ice-coring area.*

<u>Fedchenko Glacier drilling site characteristics:</u>

Glacier type	Valley
Altitude	5200 and 5800 m
Useful square	15 km^2
Latitude	38°30'
Longitude	72°15'
Accumulation	80 g cm^{-2}/yr
Ice depth varies	500 to 1,000 m
Temperature at 12 m depth	-8°C (5280 m)

<u>Grigoriev Glacier drilling site characteristics:</u>

Glacier type	Ice-cap
Altitude	4600 m
Useful square	1 km^2
Latitude	41°58'
Longitude	77°55'
Accumulation	25 g cm^{-2}/yr
Ice depth varies	120 m
Temperature at 10 m depth	-6°C (4600 m)

Figure 4*. Landsat image of the Grigoriev Glacier in central Tien Shan, the proposed deep ice-coring site and operated automatic weather station*

<u>Zuoqiupu Glacier drilling site characteristics</u>:

Glacier type	Ice-cap
Altitude	6200 m
Useful square	1 km^2
Latitude	29°30'
Longitude	97°00'
Accumulation	190 g cm^{-2}/yr
Ice depth varies	140 m
Temperature at 20 m depth	-10°C (6200 m)

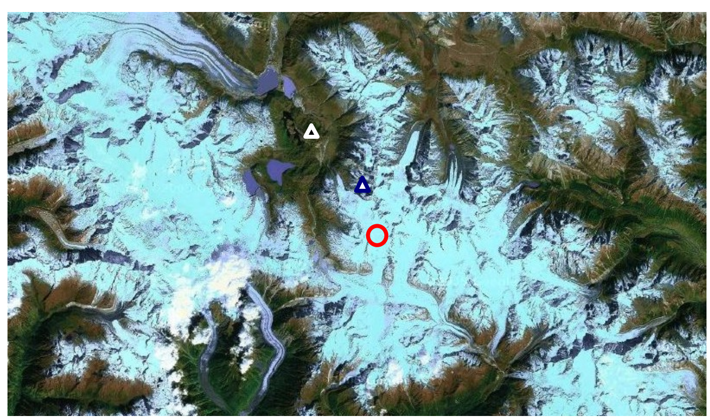

Figure 5*. Landsat image of the Zuoqiupu Glacier in southeastern Tibet, the proposed ice-coring site and operated automatic weather stations.*

<u>Major scientific objectives for CADIP are:</u>

(1) Extract and evaluate climate signals recorded in Fedchenko Glacier (Pamir), Grigoriev Glacier (Tien Shan) and Zuoqiupu Glacier (southeastern Tibet) ice through examination of glaciochemical and isotope time-series to provide inter-annual/decadal to centennial/millennial –scale climate change, atmospheric dynamics, and water cycle variability over north-central and south-eastern Asia in detail through the Holocene.

(2) Reconstruct past changes in: air temperature, snow accumulation, precipitation origin, regional to local scale atmospheric dynamics (western-jet stream, Siberian and Tibetan Highs, eastern and western limbs of the Indian and Pacific monsoon), and regional to global scale teleconnections with ENSO and the polar cell in a region and compare to past and modern climate records.

(3) Investigate naturally and humanly forced environmental changes over central Asia including: evolution of major and trace elements (eg., carbonaceous particles, Sc, Pb, Hg, Cd, Sb), establish natural background concentrations anthropogenic impact on the geochemical cycle of the elements, determine dust emissions and source regions over central Asia during major periods of climate change during the Holocene.

(4) Reconstruct past environmental changes for the last hundreds (Grigoriev and Zuoqiupu glaciers) and several thousand (Fedchenko Glacier) years in order to interpret impact upon human history, particularly because of the long record of human occupation in this region and the availability of records of human history in central Asia.

(5) Reconstruct temporal variations in vegetation and supra-glacial biological activity to assess impact of climate change on ecosystems in high altitude environments.

(6) Model the effects of changes in aerosol concentrations in snow and ice as consequences of the magnitude and temporal distribution of precipitation, temperature, and hydrological cycle and the impact of climatic change on desertification over central Asia.

(7) Simulation of glacier mass balance over the late Holocene to study implications for future changes in glacier/ water resources.

CADIP Science Plan

Field Activities:
Summer 2005 reconnaissance (***completed***)
Summer 2006, reload AWS on the Grigoriev and Fedchenko glaciers.
Summer-Fall 2007 Grigoriev Glacier (~120 m ice core, Japanese drill)
Summer-Fall 2008 Fedchenko Glacier (~200 m two cores, Swiss drill)
Deep drilling 2009+ Fedchenko Glacier (~800-1000 m core)
Fall or Spring 2010 Zuoqiupu Glacier (~140 m ice core, Chinese drill)
Lab and analytical research 2010-2012+

Ice Core Examinations:

Methods	**Measurements**	**Sample Volumes**
Cr-red	δD	50µL
CO_2-equilib.	$\delta^{18}O$	0.5µL
IC	MS, Cl^-, NO_3^-, SO_4^{2-} Na^+, NH_4^+, K^+, $Mg^{2+,}$ Ca^{2+}	4mL
ICP-MS	Sr, Cd, Cs, Ba, REE,, Bi, U As, Ti, Al, S, Ti, V, Cr, Ne, Fe, Co, Cu, Zn, Pb, Pb isotopes, Sc, Ag, Cd, Te, Sb	4mL
Particle	size, distribution	
α-Spectroscopy	^{210}Pb	100-200mL
AMS	^{14}C	1kg
Thermal Combustion	OC/EC	100mL
AFS	Hg	10mL
AMS	$^{10}Be/^{36}Cl$	1kg
Microscopy	algae, bacteria, pollen	1~20mL
DNA Sequence	algae, bacteria	1~20mL
Stable Isotope	particulate organic, C, N	1~20mL
Stratigraphy	ice layer, bubble density grain size (thickness width)	10*40mm
Meteorological	air temperature, air humidity wind speed, wind direction, atmospheric pressure, solar radiance characteristics,	
Glaciological	accumulation, ablation, evaporation,	

surface velocity, ice thickness, snow
and firn stratigraphy

A Collaborative Agreement for CADIP.

Based upon discussion undertaken during a meeting in Orono, Maine on 23-24 May 2005 and Nagoya on 28-29 January 2006, representatives from the following countries intend to participate in ice coring activities in the Tien Shan, Kyrgyzstan and Pamir, Tajikistan as part of CADIP. The south-eastern Tibet site will be discussed in 2008 or 2009 after the drilling accomplishment in Tien Shan and Pamir:

China
China Meteorological Administration (Qin Dahe)
Cold and Arid Environmental Engineering Research Institute, Chinese Academy of Sciences (Shugui Hou, Ren Jiawen)
Tibetan Plateau Institute (Yao Tandong, Shichang Kang)

France
Laboratoire de Glaciologie et Géophysique de l'Environnement, Domaine Universitaire (Jerome Chappellaz)

Germany
Kommission fur Glaziologie der Bavarischen Academie der Wissenschaften, Munchen (Ludwig Braun, Christoph Mayer)
Institute for Environmental Physics, University of Heidelberg (Dietmar Wagenbach)
Institute of Environmental Geochemistry, University of Heidelberg (Michael Krachler, Bill Shotyk)

Japan
Research Institute for Humanity and Nature (Masyoshi Nakawo, Jumpei Kubota, Nozomu Takeuchi)
Graduate School of Environmental Studies, Nagoya University (Koji Fujita)

Kyrgyzstan
Zenralasiatisches Institut für Angewandte Geowissenschaften in Bischkek (Wasili Michajljow)

Switzerland
Paul Scherrer Institut, Labor fur Radio- und Umweltchemie (Margit Schwikowski)
ETH Institute for Particle Physics (Hans-Arno Synal)
EAWAG (Jurg Beer)

Tajikistan
Institute of Water Problems, Hydroenergy and Ecology, Tajik Academy of Science (Alexander Finaev)
Soil Science Research Institute, Tajik Academy of Science (Peter Sosin)

Russian Federation
Tomsk State University (Stanislaw Nikitin)

United States
University of Idaho (Vladimir Aizen, Elena Aizen, Daniel Joswiak, Arzhan Surazakov, John Marshall)

Climate Change Institute, University of Maine (Paul Mayewski, Karl Kreutz, Andrei Kurbatov, Sharon Sneed, Michael Handley, Susan Kaspari, Bjorn Grigholm)

CADIP members agree to the following as part of our collaborative efforts:

(1) Data will be made accessible to all CADIP researchers with the understanding that the use of this data for presentation and publication will only be allowed with the permission of the institution that generated the data.
(2) Data will be released to the scientific community through international data centers immediately upon publication and no later than two years following final analyses.
(3) For purposes of developing an annually resolved depth/age scale all necessary data will be made available and published in a commonly constructed paper. CADIP researchers will agree to one common depth/age scale.

(4) All papers intended for publication by a CADIP researcher will be shared with representatives from other CADIP institutions in order to insure the highest possible collaboration and quality of science. Wherever possible papers will be co-authored by a combination of CADIP researchers from several institutions.
(5) A series of annual workshops will be held starting in 2006 for purposes of project planning and scientific exchange. The first Workshop will be planed in spring 2007 in PSI in Switzerland or at University of Heidelberg.
(6) CADIP researchers will conduct inter-calibrations between laboratories (Joint KEY Laboratory of Cryosphere and Environment, University of Heidelberg, NIPR, PSI, CCI, University of Idaho).
(7) CADIP institutions will be open to personnel exchange with other CADIP institutions.
(8) A reconnaissance field program in summer 2005 has been acomplished in Tien Shan and Pamir and data recovered demonstrate well-preserved climatic signals. This information will be made available to all CADIP institutions for incorporation in proposals seeking support for CADIP activities.
(9) A field trip will be undertaken in 2006 to reload automatic weather stations in Tien Shan (Grigorieva Glacier) and Pamir (Fedchenko Glacier).
(10) One-two surface to bottom ice-cores in Tien Shan (Grigorieva Glacier) will be recovered in summer 2007 and two 150-200 m core(s) in Pamir (Fedchenko Glacier) in following summer 2008. The cores and logistic costs will be shared by CADIP researchers and their institutions.
(11) A field program dedicated to the recovery of a core to bedrock in Pamir in 2008 will be undertaken once funds are realized.
(12) Organization of this program including science and logistics will be undertaken as a joint effort by CADIP institutions. Vladimir Aizen will be the Chief Scientist for CADIP. The CADIP steering committee includes: Paul Mayewski, Margit Schwikowski, Nozomu Takeuchi, Koji Fujita, Michael Krachler, Hou Shugui, Alexander Finaev.
(13) CADIP is open to other institutions that can contribute to the scientific and logistic goals of CADIP.

Appendix

Tien Shan and Pamir reconnaissance 2005

Japanese / Russian /Kyrgyzstan /Tajikistan/ USA joint team have carried out first reconnaissance trip to Central Tien Shan (Kyrgyzstan) and Central Pamir (Tajikistan) in July-August 2005. The Grigorieva Ice-Cap in Central Tien Shan (4600 m a.s.l.) and Fedchenko Glacier snow/firn plateau (5280 -5650 m a.s.l.) have been investigated for potential ice-core drilling. A detailed radio-echo sounding survey conducted over 60 GPS-surveyed sites on the top of Grigorieva ice-cap where ice thickness reaches 110-120 m at the area selected for ice drilling. Two automatic weather stations have been assembled near the potential drilling sites on the Grigorieva ice-cap (4600) m, and on the Fedchenko Gl rock knob (5800 m) 150 m above the drilling site. These stations will record the following parameters: hourly air temperature, humidity, wind speed, wind direction, atmospheric pressure, solar radiance duration, short and long wave radiation. Two snow pits were dug out in each site to determine the annual accumulation depth: 1m at the Grigorieva ice-cap and 2.5 m at the Fedchenko Gl. Three shallow ice cores (6, 9 and 12 m) were recovered at

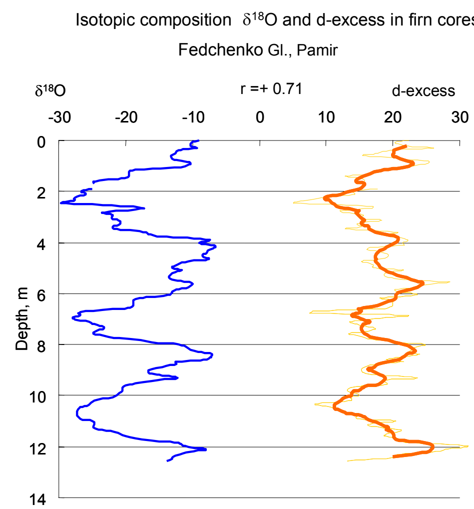

Figure. 6. *Distribution in $\delta^{18}O$ and δD records from the Pamir snow/firn cores show well-preserved seasonal variations (*paper in process*).*

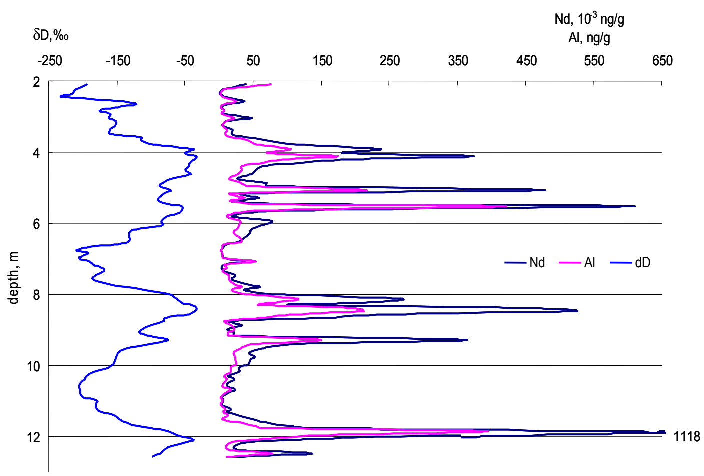

Figure 7. *Distribution of some major element concentration in the Pamir firn core. There are two maximum in stable isotope and mineral dust distribution during warm season each year that could be explained by intrusions of western originated cyclones or Indians monsoons (paper in process)*

elevations: 4600 m a.s.l. (Grigorieva Gl.), 5280 m and 5650 m a.s.l. (Fedchenko Gl.). The surface topography of the Fedchenko Gl. snow/firn plateau (10x5 km) has been measured by GPS and coordinated top the benchmarks on the rock surface. Data on this survey will be used the plateau high-resolution map, ice thickness, and ice flow velocity measurements. Twenty GPS coordinated wooden stakes 4 m high each established on the plateau. Data of this survey will be used to develop High-resolution stable isotope and chemical (ISPMS) data recovered from three shallow snow/firn cores and snow pits shows very clear preserved seasonal signal (Fig.6). The Pamir's ice core has better signal than Tien Shan ice core with a little more depleted amplitudes. During winter/ spring season, when maximum precipitation is observed in Pamir, the d-excess records are ranging from 8‰ to 11‰, with about the same intercept as for the GMWL. Western (Atlantic) air masses bring precipitation to the Pamir. For summer/autumn seasons, d-excess increased up to 28.5‰ and reflect complicated sources of precipitation, e. g., the air masses originated over warm oceanic waters (Indian Ocean or/and Mediterranean Sea) and modification of air masses during passage over relatively warm continental waters. The central Asia arid and semi-arid areas are the world's second largest source of atmospheric mineral dust. There is substantial seasonal variability in the deposition of mineral dust as illustrated by the depth profile of Al, Fe (not shown), Nd and even Ca displaying identical to $\delta^{18}O$ and δD stable isotope down core changes with several maximum peaks in summer and background minimum dust conditions in winter (Fig. 7). The major and REE elements concentration (average, maximum, background) from the Fedchenko (Pamir) firn core is ~1 magnitude (20 times) lower than a concentration from the Tien Shan cores but greater than from Greenland and Antarctic samples (Fig. 8).

The -8.2°C temperature has been recorded at 9 m of ice-hole at 5280 m Pamir's drilling site. Snow/firn samples from the cores and snow pits will be analyzed for microbiological at the RIHN by Nozomu Takeuchi team.

The Pamir drilling sites showed minimal snowmelt caused by solar radiation under air temperatures below 0°C. The radiation melt is negligible and form only thin ice crusts on the snow surface. We did not find a sign of water percolation in the Pamir cores. At the same time an effect of evaporation/sublimation from snow surface and at a depth of 0 -3 m is required special attention. Our collaborators in Kyrgyzstan and Tajikistan will collect the long-term meteorological and synoptic data necessary for ice-core data calibration and validation.

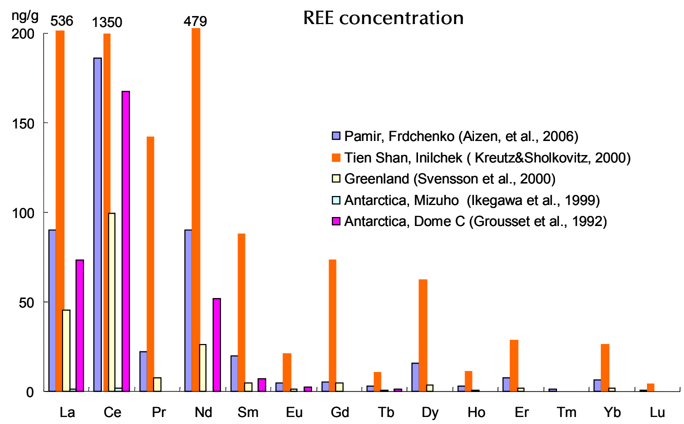

Figure 8. *The average, maximum, background) from the Fedchenko (Pamir) firn core is ~1 magnitude (20 times) lower than concentration from the Inilchek, Tien Shan.*

Southeastern Tibet reconnaissance 2002

The Nyaingen Tanglha massif at southeastern Tibet is the largest glacier covered area (approximately 28,000 km^2) in the low latitudes of the Northern Hemisphere. The location of this area between Tibetan and Himalayas mountain ranges, on the southeastern margin of the Tibetan Plateau provide an excellent opportunity to develop climatic records relating to the major circulation systems such as the tropical and subtropical monsoons, Tibetan high pressure system and the westerly jet stream. Furthermore, the Nyaingen Tanglha massif feed several major Asian rivers: Yangtze, Mekong, Hengduan, Brahmaputra, and play very important role in the water cycle of this region. Detailed radio-echo sounding measurements were completed at over 100 sites throughout at the accumulation area to determine the glacier ice thickness. Two 'Campbell Scientific' automatic weather stations were installed to record hourly measurements in the Zuoqiupu Glacier basin for one year. One station is near the terminus (4,800 m a.s.l.) and the other at the glacier equilibrium level (5,800 m a.s.l.). Both these stations are still operating and maintained by our Chinese

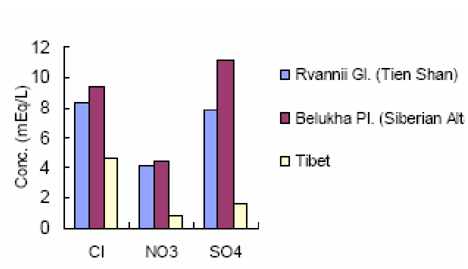

Figure 9. *Anion concentration in snow at different Asian regions.*

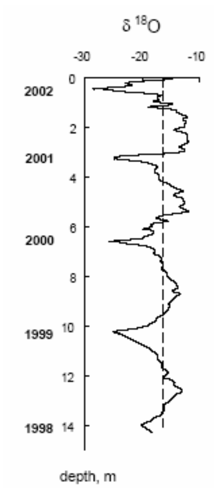

Figure 10. *Southeastern Tibet 14 mshallow core (6120 m a.s.l.)*

colleagues from Lanzhou Institute (CAREERI), Dr. Shiyin Liu.

During three weeks work in the Nyaingen Tanglha massif, hundreds of fresh snow and stream water samples were collected for geochemical analysis. One shallow (14 m) snow-firn core has been drilled at 6100 m elevation and delivered frozen to the University of Idaho ice-core laboratory. The extremely low values of anions (Fig. 9) compared to other Asian sites (Tien Shan, Altai and Pamir) associating with the greatest amounts of precipitation due to the close proximity to moisture sources (Indian Ocean), and location far from terrestrial dust inputs. The low $SO4^{2-}$ and NO^{3-} concentrations point to minimal effects from anthropogenic impact. The elevated Cl levels among other anions is related to the close proximity to a marine moisture source. Small concentrations of Ca2+, Mg2+, K+ and $SO4^{2-}$ are dominate in the fall and winter. Maximum concentrations of Na and Cl were observed in the spring and summer samples when the monsoon periods of maximum precipitation. The snow-firn core samples show well preserved annual isotopic variation (Fig. 10). The low annual range (8.8‰) results from the warmer monsoon climatic conditions and short transport distance of source moisture.

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