Antarctic Science Symposium 2011

Wednesday 27 April 2011 - Thursday 28 April 2011

Monona Terrace

Book of Abstracts

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Particle Astrophysics in Ice chaired by Buford Price / 1

DeepCore upgrades: A phased approach toward precision megaton neutrino detectors

Author: Darren Grant[1]

[1] *U of Alberta*

Darren Grant

The DeepCore detector, the low-energy extension to the IceCube Neutrino Observatory, instruments a fiducial volume of up to 35MT with an energy threshold as low as about 10 GeV. Much of the success of the achieving a pure neutrino sample in the detector is the use of the IceCube array as the world's largest active veto for cosmic ray muons. It is possible to further infill the DeepCore array to achieve lower detector energy thresholds and higher precision measurements in the deep ice. We discuss here a two phase approach to such an infill array. The first phase detector we consider is similar in design to DeepCore, has goals of 10MT with sub-GeV energy sensitivity, providing improved sensitivity for indirect WIMP searches, atmospheric neutrinos, Galactic Center point sources and a first step towards proton decay searches. The potential second phase would seek to achieve a few MT fiducial volume with an approximate 10 MeV energy threshold for a large-scale physics program that includes proton decay, supernova neutrinos and potential future long baseline efforts. Presented will be the current status of the ongoing physics feasibility studies for these new arrays buried in the ice.

Particle Astrophysics in Ice chaired by Buford Price / 2

Detecting supernova neutrinos in the ice of the South Pole

Author: Marek Kowalski[1]

[1] *Bonn University*

Current supernova detectors will deliver a tremendous neutrino statistics for a core collapse supernova (SN) within our Galaxy or slightly beyond. However, with a rate of 2 SNe per century, awaiting the next discovery requires patience. The perspective changes instantly, once the sensitivity of neutrino detectors reaches a scale allowing the detection of SNe in neighboring galaxies. A low-energy neutrino detector of 10 Mton mass would deliver several SN detections per year, thereby opening enormous new scientific opportunities. In this talk we describe the motivation, along with detector concepts, that utilizing the clear ice at the South Pole and have the potential to reach the required sensitivity in a cost effective manner. More scientific motivation for a low-energy extension will be discussed in the talk by Darren Grant.

Welcome to the Conference / 3

Welcoming remarks

Author: Buford Price[1]

[1] *U. C. Berkeley*

I will explain the logo for the workshop and say a bit about the opportunities for discovery made possible by interdisciplinary efforts.

Ice Cores (Part 1) chaired by Jeff Severinghaus / 4

Ice Cores as a Repository of Ancient Oceanic Cyanobacteria that Contain a Frozen Record of Microbial Evolution

Author: Buford Price[1]

Co-author: Ryan Bay [2]

[1] *U. C. Berkeley*

[2] *University of California, Berkeley*

Oxygen-producing cyanobacteria originated on Earth around two billion years ago. Two genera of oceanic submicrometer-size cells – the Synechococcus and the Prochlorococcus – account for as much as half of the air that we breathe. Winds transport them from polar oceans onto Arctic and Antarctic glacial ice. We find that they are present in the glacial ice at all seven sites and all depths we have examined. Advances in biology instrumentation, especially in single-cell genomics, may enable us to decipher the record of their molecular evolution over millions of generations by nondestructively extracting them from future cores of ice samples more than 150,000 years old at South Pole and other polar sites.

Subglacial Lakes chaired by Ryan Bay / 6

Drilling towards Lake Vostok and accretion ice studies

Author: Vladimir Lipenkov[1]

[1] *Arctic and Antarctic Research Institute*

It is now recognized that subglacial water has been playing significant role in many processes that have shaped the Antarctic continent and its ice sheets today and in the past. Lake Vostok is an essential element of the Antarctic subglacial hydrological system and the largest known subglacial lake on Earth (with an area of about 16,000 km2 and the water volume exceeding 6,000 km3). The Russian Vostok Station sits at the southern end of the lake where the sub-ice water freezing onto the base of the Antarctic ice sheet has formed a 200-250 m thick layer of accreted lake ice separating the ice sheet from the 600 m deep water body underneath. In 1998, deep hole 5G-1 drilled at Vostok by the Russian Antarctic Expedition (RAE) penetrated into accreted ice at 3,539 mbs. The study of the ice samples extracted as a core from the hole has provided first information on the geochemical conditions and potential biological residents of the lake.

In January 2009, the drilling of hole 5G-1 was abandoned at a depth of 3,667 m due to a drill accident. The new branch-hole 5G-2 was started by deviation from 5G-1 at 3,585 m depth so that to allow replicate coring of the ice layer bedded between 3,606 and 3,607 m that comprises large mineral inclusions of lake sediments. In the austral season of 2010-2011, RAE resumed drilling of the 5G-2 hole and with an electromechanical drill adapted for "warm ice" reached a depth of 3,720 m thus leaving less than 50 meters of undrilled ice between the hole and the lake.

The advance in drilling of 5G-2 in 2009-2011 yielded 120 m of new ice core (66 m of the replicate core and 54 m of core representing uninvestigated so far thickness of lake ice). The studies of the fresh ice core performed in the field allowed to continuously document the evolution of the accretion ice fabric and texture with depth as the hole approached the ice-water interface. At the beginning of the new hole deviation the replicate 5G-2 core reveals textural and fabric properties which are

clearly distinct from those observed in the overlapping section of the 5G-1 core. This distinction has been attributed to a modification of original ice texture by rotation recrystallization occurred in ice in proximity of the 5G-1 hole wall in the course of rapid hole closure caused by the high ice-fluid pressure difference (up to 1 MPa) that has been allowed in 5G-1 at the time of the drilling accident.

Logging and Remote Sensing chaired by Dorthe Dahl-Jensen / 7

Peering into deep blue ice using radar

Author: Kenny Matsuoka[1]

[1] *Norwegian Polar Institute*

TBA

Particle Astrophysics in Ice chaired by Buford Price / 8

DM-Ice: A direct dark matter search at the South Pole

Author: Reina Maruyama[1]

[1] *University of Wisconsin–Madison*

I will describe DM-Ice, a direct detection dark matter experiment to be deployed at the South Pole co-located with the IceCube/DeepCore Neutrino Telescope. This experiment will use roughly 250 kg of low-background NaI detectors to search for the DAMA/LIBRA annual modulation in the southern hemisphere where many of the environmental backgrounds associated with seasonal variations present in experiments in the northern hemisphere are either reversed in phase or absent altogether. A 15-kg prototype was deployed in December 2010 at the South Pole at the depth of ~2200 m.w.e. as a feasibility study: it is now taking data. I will report on the status of the prototype and the plans for the full-scale experiment.

Subglacial Lakes chaired by Ryan Bay / 9

IceMole – Prototype Development and Testing of a Subsurface Icecraft

Author: Bernd Dachwald[1]

Co-authors: Changsheng Xu [1]; Engelbert Plescher [1]; Marco Feldmann [1]

[1] *FH Aachen University of Applied Sciences*

We present the novel concept of a combined drilling and melting probe for subsurface ice research. This "subsurface icecraft", named "IceMole", is currently developed, built, and tested at the FH Aachen University of Applied Sciences' Astronautical Laboratory. Here, we describe the IceMole's first prototype design and report the results of its first field tests on the Morteratsch glacier in Switzerland.
We have developed the combined drilling and melting concept to surpass the limited controllability and penetration capability of traditional melting probes, which have been used since the 1960s. The IceMole has the shape of a rectangular tube (15cm x 15cm cross section) with a ~3kW melting head

and a rotating (hollow) ice screw at the tip. The required electric power is generated by a surface aggregate and transmitted via a cable that is uncoiled from the probe. Communications and data transfer to the surface is also via the power cable. The ice screw generates a driving force that presses the melting head against the ice, thus leading to a good conductive heat transfer. The IceMole can change direction by differential heating of the melting head (in the next prototype, also side heaters will be implemented), which generates a torque that forces the IceMole into a curve. The IceMole design philosophy is that of rapid prototyping. The first IceMole prototype was build in 2009/10 and was tested on the Swiss Morteratsch glacier in September 2010. Three penetration tests have been successfully performed: 1) melting 45° upwards for ~1.5m, against gravity; 2) melting horizontally for ~5m; 3) melting 45° downwards for ~3m, thereby penetrating three obstructing non-ice layers (mud and sand found on the glacier) and driving a curve with a radius of ~10m. The penetration velocity was ~0.3m/h (but will be increased for the next prototype). The test results show that the IceMole concept is a viable approach to deliver scientific instruments into deep ice and to recover them afterwards. An advantage with respect to drilling is that biological contamination can be minimized and the process can be made highly autonomous, so that there is no need for an operator on the surface.

Logging and Remote Sensing chaired by Dorthe Dahl-Jensen / 10

Future Directions in Antarctic Paleoclimate and Glaciology Research

Author: Jeff Severinghaus[1]

[1] *University of California at San Diego*

Several "big" questions include: (1) Did the West Antarctic Ice Sheet collapse 125,000 years ago, a time when our climate was several degrees warmer than today? and
(2) Why did Earth's ice ages oscillate within a 41,000-year period between 1.5- and 1.3-million years ago?
These questions require multiple access holes to the deep ice, to map the spatial dimension in a rapid-access mode that is an order of magnitude faster than traditional ice coring, in which a project can take 5 to 10 years to execute. Potential enabling technologies are discussed.

Ice Cores (Part 1) chaired by Jeff Severinghaus / 11

The influence of subglacial processes on ice-sheet dynamics in the vicinity of the South Pole: A modeling study

Author: Frank Pattyn[1]

[1] *Laboratoire de Glaciologie, U Libre Brussels*

Subglacial conditions of large polar ice sheets remain poorly understood, despite recent advances in satellite observation. Major uncertainties related to basal conditions, such as the temperature field, are due to an insufficient knowledge of geothermal heat flow. We use a hybrid method that combines numerical modeling of the ice sheet thermodynamics with a priori information, using a simple assimilation technique. Additional data are essentially vertical temperature profiles measured in the ice sheet at selected spots, as well as the distribution of subglacial lakes. In this way, geothermal heat-flow datasets are improved to yield calculated temperatures in accord with observations in areas where information is available. Although the whole Antarctic ice sheet is modeled, the analysis essentially focuses on the area around the South Pole, where IceCube is installed. A nearby subglacial lake may influence the dynamics of the ice sheet on longer time scales. We evaluate the effect of subglacial discharge on the behavior of the ice sheet in the vicinity of the South Pole.

Particle Astrophysics in Ice chaired by Buford Price / 12

The Askaryan Radio Array - a new instrument for the detection of highest energy neutrinos.

Author: Albrecht Karle[1]

[1] *UW Madison*

Building on the expertise gained by RICE, ANITA and IceCube's radio extension in the use of the Askaryan effect in cold Antarctic ice, we are currently developing an antenna array known as ARA (The Askaryan Radio Array) to be installed in boreholes extending 200 m below the surface of the ice near the geographic South Pole.
The cold and deep glacial ice at the South Pole is transparent to radiowaves, which allows to use relatively shallow radio detectors to observe highest energy neutrino interactions in the ice sheet.
With the planned area of 80 square kilometers and effective detection volume of 200km^2 ARA is large enough to reliably detect of the flux of neutrinos that are inevitably produced when highest energy cosmic rays interact with the microwave background. First instruments were deployed in the Austral season 2010/2011.
I will describe the detector and the science goals, and give the current status of the project.

Innovations in Hot-Water Drilling chaired by Ryan Bay / 13

IceCube's Enhanced Hot-Water Drill

Author: Terry Benson[1]

[1] *IceCube 222 UW-Madison/PSL*

IceCube's construction presented massive challenges; at the core was a drilling campaign to melt over 17 million gallons of ice over the course of 7 short field seasons. The Enhanced Hot Water Drill and its team made this possible. Vast amounts of knowledge and experience were gained, and technological innovations were continuously sought out and implemented to overcome the inherent challenges. A very brief overview of the Enhanced Hot Water Drill system design and performance will be presented, followed by highlights of a few of the dominant lessons learned along the way.

Logging and Remote Sensing chaired by Dorthe Dahl-Jensen / 14

Glaciology in AMANDA and IceCube

Author: Ryan Bay[1]

[1] *UC Berkeley*

While the AMANDA and IceCube experiments have opened a new window on the universe, their use of hot water drills has also opened unique research opportunities by providing recurrent passage to the deep South Pole ice sheet. I will overview how this "fast access" drilling has led to advances in glaciology, climatology, material science and technology development.

Ice Cores (Part 1) chaired by Jeff Severinghaus / 15

What can we learn from deep ice cores?

Author: Jean-Robert Petit[1]

[1] *UJF-Grenoble*

Polar ice sheets and glaciers contain well-ordered archives of ancient ice that fell as snow, from recently to millions of years ago. The ice composition and impurities, along with the gasses entrapped in air bubbles together provide a unique history of past climate changes and environmental and atmospheric composition. The study of deep ice cores revealed the close link between temperature and atmospheric CO2 over the last 700,000 years, pointing out those climate issues caused by increasing anthropogenic emissions of greenhouse gasses. Also, the role of the Atlantic Ocean in distributing heat between the Northern and Southern Hemispheres is now documented by a so-called see-saw phenomenon that occurred at millennial scale during the last glacial period.

Aerosols emitted from continents (dust), from volcanoes (sulfur and glass shards), and from the ocean (sea salts) are measured in ice, and are used to document atmospheric circulation and environmental changes through time. Of interest is 10Be, which is formed by the interaction of cosmic rays with the atmosphere, and its potential for reconstruction of solar activity and documenting short-term variability of the atmospheric circulation.

Subglacial Lakes chaired by Ryan Bay / 16

Where a little water makes a lot of difference - liquid water in Antarctic glaciology and microbiology

Author: Slawek Tulaczyk[1]

Co-authors: Lucas Beem [2]; Saffia Hossainzadeh [1]

[1] *Department of Earth and Planetary Sciences, University of California, Santa Cruz*

[2] *epartment of Earth and Planetary Sciences, University of California, Santa Cruz*

Water is produced at the base of polar ice sheets when geothermal heat and basal shear heating exceed conductive heat escape. Published estimates of subglacial water production rates in Antarctica vary between an average of about 3 and 6 mm per year per unit bed area. This rate of production is almost two orders of magnitude smaller than the mean snow accumulation rate on top of the ice sheet. Yet, these small basal melt rates feed an active subglacial hydrological system, which includes the largest wetland on Earth, subglacial lakes, and streams/rivers. Subglacial water makes fast ice sliding possible and hydrological temporal variability induces changes in the rates of ice discharge into the ocean. Emerging scientific evidence suggests that Antarctic subglacial waters make microbial life possible beneath the ice sheet and produce significant (bio)geochemical fluxes into the Southern Ocean. Funded international drilling projects will provide vital data to further elucidate the surprising role of subglacial waters in controlling physical, chemical, and biological processes in Antarctica.

Innovations in Hot-Water Drilling chaired by Ryan Bay / 17

Production Drilling

Author: Alan Elcheikh[1]

[1] *IceCube*

In order to complete the construction phase of the IceCube project on time and within budget, a very ambitious construction schedule was planned over 7 short field seasons. The critical path of the construction project was the drilling operation, which required 86 2500-meter holes to be made in the ice. The instruments would then be deployed into these drilled holes. Lessons were learned during construction, and changes were made to the drill and the drilling operation in order to achieve the target number of holes on time each season. A brief discussion will be presented of the challenges that were faced in undertaking this production drilling and what was done to overcome these challenges. Based on this experience, recommendations will also be given for any future production drilling operation.

Ice Cores (Part 2) chaired by Jeff Severinghaus / 18

What can we learn from deep ice cores that informs today's changing climate?

Author: Jim White[1]

[1] *University of Colorado at Boulder*

Deep ice cores contain information about past climates that were as warm as, or warmer than, today. These warm times are the nearest analogs for our future climate. This talk will address what key pieces of information are contained in deep ice to inform us about a warmer future, including rates and ultimate fates of sea level rise and abrupt climate change, which is climate change on time scales of human interest with magnitudes that would impact and challenge human adaptation. Ice cores from both Greenland and Antarctica inform this subject, and this talk will interface with others as we discuss where to drill next in both of the world's major ice sheets.

Ice Cores (Part 1) chaired by Jeff Severinghaus / 19

The role of the Greenland Ice Sheet in future sea levels - Based on palaeorecords from ice cores and present observations

Author: Dorthe Dahl-Jensen[1]

[1] *Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen*

A new Greenland ice core has been drilled. The first results from the NEEM ice core are presented and then combined with results from other deep ice cores from the Greenland Ice Sheet.

All of the ice cores drilled through the Greenland Ice Sheets have been analyzed, and the results show that all contain ice from the previous warm Eemian period near the base. Is it thus clear that the Greenland Ice Sheet has existed for over 120,000 years, going back to the previous warm period, when it was 5 deg C warmer over Greenland?

The difference between Eemian and Holocene stable oxygen isotope values has been combined with an ice sheet flow model constrained by the ice core results and internal radio echo sounding layers, to estimate the volume of the Greenland Ice Sheet 120,000 years ago.

The results show that South Greenland has not been ice-free during the Eemian period, and that the sea level contribution from the Greenland Ice Sheet has been 1 to 2 meters.

Subglacial Lakes chaired by Ryan Bay / 20

South Pole ice stream evolution with implications for fabric development and subglacial hydrology

Author: D.D. Blankenship[1]

[1] *Institute for Geophysics, U of Texas*

The evolution of the East Antarctic ice sheet surrounding the South Pole has been complex. Previous work using airborne radar sounding has indicated that the tributaries of major ice streams have reached the South Pole, but details of the position and timing of flow regime change have been unknown. We will present an analysis of internal layering observed in airborne radar sounding data collected over South Pole and time-registered to the local dust record that shows the position of an ice stream margin that was active from about 10,000 to at least 70,000 years ago.

The position of this margin was initially about 10 km grid north of the South Pole, and migrated to the grid south about 40 km before expiring. Significant melting occurred beneath the active portion of this ice stream, causing the ice of Eemian age to reside very near the bed to the grid south of the South Pole, relative to its depth to the grid north. Melting associated with the margin migration pattern observed is consistent with the distribution of subglacial lakes previously identified in the region. Additionally, preferred fabric orientations and associated birefringence can be expected within the former boundaries of the ice stream margin, which includes the IceCube neutrino observatory.

Summary:

Co-authors - S.P. Carter, D.A. Young, M.J. Siegert, R.G. Bingham, C.S. Jackson, M. Cavitte, and G. Gutowski

Ice Cores (Part 2) chaired by Jeff Severinghaus / 21

Does it have to be deep, or can we learn anything from shallow ice cores?

Author: Robert Mulvaney[1]

[1] *British Antarctic Survey*

The deep ice cores from Antarctica have revealed an unparalleled view of the changes in, and linkages between, the climate and the atmosphere over several climate cycles. Further, comparison of the Antarctic cores with the deep ice cores from Greenland has shown the inter-hemispheric exchange of energy, probably via the Meridional Overturning Circulation, has lead to a difference in phasing of climate in the north to that of the south.

These deep ice cores have justifiably become the 'gold standard' for studying long-term climate change. So is there any value to be obtained from drilling shallow ice cores (which I define here as including cores ranging from around 100 to 1000 m deep)? With a few chosen examples, I will examine how Antarctic shallow ice cores can help fill in the regional picture of climate change, and also whether they have adequately captured the most recent 'anthropogenic' warming trends.

Innovations in Hot-Water Drilling chaired by Ryan Bay / 22

Ice Shelf Access Drilling - ANDRILL's Recent Experience at Coulman High

Author: Frank Rack[1]

[1] *University of Nebraska-Lincoln, ANDRILL*

The ANDRILL Coulman High (CH) Project Site Surveys, which were conducted from November 2010 through January 2011 using the ANDRILL hot water drill system, achieved all primary and secondary objectives. We demonstrated a safe traverse route from McMurdo Station across the Ross Ice Shelf to CH and established safe operating areas using ground-penetrating radar supplemented by airborne radar. A series of combined US-NZ field camps on the RIS were occupied, and the ANDRILL hot water drill (HWD) system was used to melt numerous holes through 250-275 meters of ice shelf.

Oceanographic inductive moorings were deployed through the RIS at two sites and were recovered to the ice surface after two months. We acquired video camera observations of the interior and basal surface of the ice shelf, and these observations were integrated with conductivity-temperature-depth (CTD) measurements through the ice shelf to the seafloor at each site. The Submersible Capable of under-Ice Navigation and Imaging (SCINI) underwater remotely operated vehicle (ROV) was deployed through 260 meters of ice to explore the underside of the ice shelf while conducting operational testing. Lateral and vertical ice motions were monitored by GPS stations installed at four sites to provide data that will contribute to the development of a tidal model that will be used to evaluate the potential impacts on the drill riser for planned geological drilling. The ANDRILL hot- water drill system operated well throughout the field season and allowed all of the science and operational goals of the project to be met.

Innovations in Hot-Water Drilling chaired by Ryan Bay / 23

Panel Discussion with the 3 speakers

Author: Ryan Bay[1]

[1] *UC-Berkeley*

Panel

Particle Astrophysics in Ice chaired by Buford Price / 24

Panel Discussion with the 4 speakers

Author: Buford Price[1]

[1] *UC-Berkeley*

Panel

Subglacial Lakes chaired by Ryan Bay / 25

Panel Discussion with the 4 speakers

Author: Ryan Bay[1]

[1] *UC-Berkeley*

Panel

Logging and Remote Sensing chaired by Dorthe Dahl-Jensen / 26

Panel Discussion with the 3 speakers

Author: Dorthe Dahl-Jensen[1]

[1] *Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen*

Panel

Ice Cores (Part 2) chaired by Jeff Severinghaus / 27

Panel Discussion with the 7 speakers

Author: Jeff Severinghaus[1]

[1] *UC-San Diego*

Panel

Ice Cores (Part 2) chaired by Jeff Severinghaus / 28

Ultra-Trace Gases in Polar Ice Cores

Author: Eric Saltzman[1]

[1] *UC-Irvine*

TBD

Particle Astrophysics in Ice chaired by Buford Price / 29

Beyond-IceCube – IceCube++

Author: Christopher Wiebusch[1]

Co-author: David Altmann

[1] *RWTH-Aachen University*

We present initial results from simulations of possible large optical extension of IceCube additional strings optimized for neutrino-astronomy in the TeV-PeV range.

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High energy neutrino sources

Author: Eli Waxman[1]

[1] *Weizmann Inst.*

The completed IceCube detector achieves the minimum sensitivity required for the detection of high energy extra-Galactic sources of neutrinos. I will discuss the prospects for detecting such sources, and the outstanding astrophysics and physics open questions that may be resolved by their detection. These open questions include the origin of ultrahigh energy cosmic, the underlying physics of models describing high energy astrophysical sources, and neutrino properties (e.g. flavor oscillations and coupling to gravity).