IceCube Polar Science Workshop

Report of Contributions

Contribution ID: **1** Type: **not specified**

LONG-TERM STABILITY OF DEEP BOREHOLES IN ICE FILLED WITH ESTISOL-140 DRILLING FLUID

Tuesday, 19 January 2021 18:00 (20 minutes)

The search for a new environmentally friendly low-temperature drilling fluid for deep drilling in ice is one of the most pressing tasks. ESTISOL 140 was identified as the most suitable fluid and has recently been used in several ice drilling projects, for example, SPICEcore project at South Pole. Unfortunately, no new progress has been made in identifying new drilling fluids. While ESTISOL 140 involves some issues—including high viscosity, strong odor, health hazards, negative effects on many elastomers and plastic materials, convective problems with temperature logging—it will likely be used for future drilling projects until a better fluid is identified. ESTISOL 140 is almost sufficiently dense by itself to compensate for ice overburden pressure, but not completely. In some cases, to provide long-term stability of the borehole walls, two other ESTISOL products, ESTISOL 165 and ESTISOL F2887, added in small quantities (2–6 wt %) could be used as densifiers for ESTISOL 140-based drilling fluids. Tests showed that ESTISOL-140 is miscible with ESTISOL 165 and ESTISOL F2887, and the density–temperature relationship is linear. We present here results of our prediction and estimation of the hydrostatic pressure and borehole deformation in SPICEcore borehole filled with ESTISOL-140. We also present potential deformation in the deeper boreholes filled with pure ESTISOL-140 and with ESTISOL-140 mixed with densifiers.

Primary author: Prof. TALALAY, Pavel G. (Jilin University)

Presenter: Prof. TALALAY, Pavel G. (Jilin University)

Session Classification: Drilling technologies and logistis

Contribution ID: **2** Type: **not specified**

HOW WARM IS THE SOUTH POLE?

Tuesday, 19 January 2021 16:25 (20 minutes)

The Antarctic geothermal heat flux (GHF) has significant influence on the viscosity of basal ice and meltwater content at the ice–base interface. To evaluate GHF under the Antarctic Ice Sheet at South Pole, we used available temperature profile taken by AMANDA and IceCube thermistors installed at depths from 800 m to 2445 m in boreholes produced with hot-water drilling. We applied one-dimensional time-dependent energy-balance equation to model the temperature distribution through the ice as a function of the climate conditions on the surface and the GHF from the bedrock. To overcome model uncertainties, a common genetic algorithm was used to find the optimal global solution of temperature fitting by constraining unknown parameters to a predetermined range. In this report we present GHF estimates at South Pole and analyze the main uncertainty in our fitting model that come from variability of the form factor m.

Primary author: Prof. TALALAY, Pavel G. (Jilin University)

Co-authors: Prof. PRICE, Paul Buford (University of California, Berkeley); BAY, Ryan (University of California, Berkeley); LI, Yazhou (Jilin University)

Presenter: Prof. TALALAY, Pavel G. (Jilin University)

Session Classification: Englacial heterogeneities and stuctures & bedrock properties

Contribution ID: **3** Type: **not specified**

Hot water drilling for the IceCube Upgrade and IceCube Gen2

Tuesday, 19 January 2021 18:20 (20 minutes)

The IceCube Enhanced Hot Water Drill (EHWD) is being refurbished and put back in service to drill holes for the a 7 hole IceCube Upgrade. A preliminary redesign of that system using microturbines, low pressure water heating, high pressure pumping of hot water, and larger sleds is underway to prepare for a potential GEN2 drilling program with 120 holes. Special attention to changes in the architecture of the hot water drill to take advantage of the existing Mobil Heating Plants (MHPs) efficiency, increase the drill radius, increase drill speed, and improve operational flexibility. The Independent Firn Drill (IFD) that uses recirculating polypropylene glycol in copper tubes has been refurbished for use ahead of hot water drilling. The ARA hot water drill that is capable of making dry hole to 200 meters will be retasked to drilling and maintaining a rod well to supply make up water for drill operations. A brief description of each of these drill will be given. There will be a discussion of the general capabilities of the drills and the intended use inthe near future.

Primary author: CHERWINKA, Jeff (University of Wisconsin-Madison)

Presenter: CHERWINKA, Jeff (University of Wisconsin-Madison)

Session Classification: Drilling technologies and logistis

Contribution ID: **4** Type: **not specified**

A very broadband seismometer in the IceCube Upgrade

Wednesday, 20 January 2021 18:15 (20 minutes)

Seismograms from the South Pole have been important for seismological observations for over six decades by providing (until 2007) the only continuous seismic records from the interior of the Antarctic continent. The station SPA (South Pole, Antarctica) has undergone many updates over the years including being converted to a digitally recording station as part of the Global Seismographic Network (GSN) in 1991 and being re-located to multiple deep (> 250 m) boreholes 8 km away from the station in 2003 (and renamed to QSPA, Quiet South Pole, Antarctica). Notably, QSPA is the 2nd most used GSN station by the National Earthquake Information Center (NEIC) to pick phases used to rapidly detect and locate earthquakes globally and has been used for a variety of glaciological and oceanography studies. Additionally, it is the only seismic station on the Earth where low-frequency (< 5 mHz) normal-mode oscillations of the planet excited by large earthquakes can be recorded without influence from Earth's rotation and the direct effects of the solid earth tide vanish. However, the current sensors are largely a 1980s technology and, while able to make some lower-frequency observations from earthquakes, the borehole sensors appear unable to resolve ambient ground motions at frequencies lower than 25 mHz due to instrument noise and contamination from magnetic field variations. Recently developed borehole sensors offer the potential to extend background noise observations to below 3 mHz, which would substantially improve the fidelity and scientific value of seismic observations at South Pole. Through collaboration with the IceCube Neutrino Observatory, the opportunity exists to emplace a modern, very broadband seismometer near the base (> 2 km depth) of the Antarctic ice cap, which could lead to unprecedented seismic observations at long-periods and facilitate a broad spectrum of earth science studies.

Primary author: Dr ANTHONY, Robert (United States Geological Survey)

Presenter: Dr ANTHONY, Robert (United States Geological Survey)

Session Classification: Future glaciological instrumentation at the South Pole (IceCube Upgrade, RAID and beyond)

Contribution ID: **5** Type: **not specified**

The IceCube ice anisotropy

Wednesday, 20 January 2021 16:35 (20 minutes)

The IceCube Neutrino Observatory instruments about 1 km3 of deep, glacial ice at the geographic South Pole with 5160 photomultipliers to detect Cherenkov light of charged relativistic particles. The experiment pursues a wide range of scientific questions ranging from particle physics such as neutrino oscillations to astronomy with the search for sources of astrophysical neutrinos. Most of these efforts rely heavily on an ever more precise understanding of the optical properties of the instrumented ice. A largely unexplained light propagation effect is an anisotropic attenuation, which is aligned with the local flow of the ice. In this talk, the micro-structure of ice as a birefringent polycrystal is explored as the cause for this anisotropy.

Primary author: RONGEN, Martin (RWTH Aachen University)

Co-author: Mr CHIRKIN, Dmitry (University of Wisconsin-Madison)

Presenter: RONGEN, Martin (RWTH Aachen University)

Session Classification: Modeling and measurements of optical and radio propagation in birefringent ice

Contribution ID: **6** Type: **not specified**

Observation of an optical anisotropy in the deep glacial ice at the geographic South Pole using a laser dust logger

Wednesday, 20 January 2021 16:55 (20 minutes)

We report on the observation of a directional anisotropy in the recorded intensity of back-scattered light as measured using an oriented laser dust logger. The measurement has been performed in a drill hole at the geographic South Pole, about a kilometer away from the IceCube Neutrino Observatory. The drill hole was preserved for logging access, after the SPICEcore collaboration had retrieved a 1751 meter ice core. We find the measured, optical anisotropy axis of 126° to be compatible with the local flow direction. The observation is discussed in comparison to a similar anisotropy observed by the nearby IceCube Neutrino Observatory. The measurement principle, when combined with a full-chain simulation, may in the future be used to provide a continuous record of fabric properties along the entire depth of a drill hole.

Primary author: BLOT, Summer (DESY Zeuthen)

Co-authors: RONGEN, Martin (RWTH Aachen University); BAY, Ryan (University of California, Berkeley)

Presenter: BLOT, Summer (DESY Zeuthen)

Session Classification: Modeling and measurements of optical and radio propagation in birefringent ice

Contribution ID: **7** Type: **not specified**

The IceCube optical ice model

Tuesday, 19 January 2021 15:30 (20 minutes)

Modeling of optical properties of ice at the South Pole, as it applies to neutrino detectors AMANDA and IceCube, has a long history of incremental improvements and unexpected surprises, starting in the early 90s, with significant breakthroughs still happening within the last couple of years. The ice model is used by the IceCube collaboration in both simulating and reconstructing of the IceCube data, and the accuracy in the ice description directly impacts the science results of our experiment. The larger optical model array of IceCube with its more precise data capture, as well as faster computing methods and GPU resources that became available over the last decade were indispensable to our progress. I will briefly outline the history of South Pole ice model development, touching upon the key turning points, and describing the latest state-of the art model in more detail.

Primary author: CHIRKIN, Dmitry (University of Wisconsin-Madison)

Co-author: RONGEN, Martin (RWTH Aachen University)

Presenters: CHIRKIN, Dmitry (University of Wisconsin-Madison); RONGEN, Martin (RWTH Aachen University)

Session Classification: Available instrumentation at the South Pole (IceCube, SPICEcore, GPS stake field and other)

Contribution ID: **8** Type: **not specified**

The IceCube Neutrino Observatory and the IceCube Upgrade

Tuesday, 19 January 2021 15:10 (20 minutes)

The IceCube Neutrino Observatory is the largest neutrino detector in the world, located at the geographic South Pole. The detector consists of 86 cables called "strings", each instrumented with 60 sensors. IceCube has observed high energy neutrinos from beyond the solar system, including the highest energy neutrinos ever observed and a neutrino in coincidence with a flaring blazar. IceCube also probes fundamental neutrino oscillation properties, using the constant flux of cosmic ray-induced atmospheric neutrinos. IceCube has observed the disappearance of muon neutrinos and the appearance of tau neutrinos from the atmospheric neutrino sample. The near future of IceCube will be the recently approved IceCube Upgrade, which will add 7 additional strings to the detector with upgraded sensor designs and new calibration devices. The upgraded detector will make world-leading measurements of tau neutrino appearance from the atmosphere, and generate new calibration data which will be applied to the entire archival IceCube data set. The IceCube Upgrade will serve as the first step to the next generation neutrino observatory at the South Pole, called IceCube-Gen2. This talk will discuss the status of the IceCube Upgrade and its science goals.

Primary author: WILLIAMS, Dawn (University of Alabama)

Presenter: WILLIAMS, Dawn (University of Alabama)

Session Classification: Available instrumentation at the South Pole (IceCube, SPICEcore, GPS stake field and other)

Contribution ID: **9** Type: **not specified**

BigRAID

Tuesday, 19 January 2021 18:40 (20 minutes)

The British Antarctic Survey (BAS) has developed a larger diameter (~285mm) version of the record-breaking Rapid Access Isotope Drill (RAID) known as BigRAID. The increase in size brings new design challenges but also new opportunities. The drill is described alongside the modifications to the RAID design, data from increased diameter drilling and the pre-deployment testing regime.

BigRAID is intended to rapidly drill dry holes to depths of 350m, which will be used as boreholes for detectors in the Radio Neutrino Observatory – Greenland (RNO-G) at Summit, starting summer 2021. Other uses include rapid and efficient pilot hole drilling of the firn layer, which will be exploited for hot water drilling in the upcoming attempt to sample subglacial Lake CECs in West Antarctica. The vast array of holes required by RNO-G requires automation of the drilling system. New automation features and developments are outlined.

Primary author: RIX, Julius (British Antarctic Suvey)

Presenter: RIX, Julius (British Antarctic Suvey)

Session Classification: Drilling technologies and logistis

Contribution ID: **10** Type: **not specified**

A Gen-2 calibration borehole with the U.S. Rapid Access Ice Drill (RAID)?

Wednesday, 20 January 2021 19:15 (20 minutes)

Ice boreholes have been shown to be stable for several decades, if filled with a non-freezing fluid that has the same density as ice. This enables repeated observations and occupations by instrumented probes, making long time-series measurements possible. We recently learned that Gen-2 is exploring the possibility of such a long-term access hole for calibration purposes.
Our new Rapid Access Ice Drill (RAID) could make such a hole in 2-4 days at South Pole, producing only ice chips (no ice core) and having a borehole diameter of 89 mm. However,
the drill is designed for speed, not for making perfectly-vertical boreholes, so the hole may deviate from the vertical by up to 10 degrees. The stabilizing fluid would be Estisol-140, which
has nearly the exact same density as ice at South Pole temperature, and would be expected to keep the borehole open for use for several decades

Primary authors: SEVERINGHAUS , Jeff (University of California); GOODGE , John (University of Minnesota)

Presenter: SEVERINGHAUS , Jeff (University of California)

Session Classification: Future glaciological instrumentation at the South Pole (IceCube Upgrade, RAID and beyond)

Contribution ID: **12** Type: **not specified**

The Ice Diver Dust Logger

Wednesday, 20 January 2021 18:35 (20 minutes)

IceCube showed that dustloggers deployed in freshwater boreholes provide highly detailed Antarctic histories for mapping chronology across the continent and Southern Ocean. Developed over the same time, the Ice Diver cryobot has proven potential for realizing a deep Philberth probe to explore ice anywhere with a small logistic footprint. The two technologies can be united naturally, and an Ice Diver Dust Logger would enable searches for the oldest pristine ices on earth.

Primary author: BAY, Ryan (University of California, Berkeley)

Co-authors: WINEBRENNER , Dale (University of Washington); BROOK , Edward (Oregon State University)

Presenter: BAY, Ryan (University of California, Berkeley)

Session Classification: Future glaciological instrumentation at the South Pole (IceCube Upgrade, RAID and beyond)

Contribution ID: **13** Type: **not specified**

Climatic imprint in the mechanical properties of ice sheets and its effect on ice flow. Observations from South Pole and EPICA Dome C ice cores

Wednesday, 20 January 2021 17:35 (20 minutes)

The climatic conditions over ice sheets at the time of snow deposition imprint distinctive crystallographic properties to the resulting ice. As it gets buried, its macroscopic structure evolves due to vertical compression and horizontal extension but retains traces of the climatic imprint that generate distinctive mechanical, thermal and optical properties. Because climate alternates between glacial periods, that are colder and dustier, and interglacial periods, the ice sheets are composed from layers with alternating mechanical properties. Here we compare ice core dust content, crystal orientation fabrics, borehole temperature and englacial vertical velocity, measured with phase-sensitive radar (ApRES), at South Pole and EPICA Dome C ice cores. Similarly to previous observations, we show that ice deposited during glacial periods develops stronger crystal orientation fabrics. In addition, we show that ice deposited during glacial periods ice is harder to vertically compress and horizontally extend but softer to shear. These variations in mechanical properties are ignored in ice-flow modelling but they could be critical to interpret ice core records. Also, we show that the changes in crystal orientation fabrics due to transitions from interglacial to glacial conditions can be detected by radar. This information can be used to constrain age-depth in future ice-core locations. Finally, we give our perspective on how radar-detected crystal orientation fabric and englacial vertical velocity can be used to investigate the mechanical properties of ice, its rheology, that are the core of every ice flow model.

Primary author: Dr MARTIN, Carlos (British Antarctic Survey)

Co-authors: Dr RITZ, Catherine (Institut des Géosciences de l'Environnement); Prof. CONWAY, Howard (University of Washington); Dr KOUTNIK, Michelle (University of Washington); Mr ERSHADI, Mohammadreza (University of Tubingen); Dr DREWS, Reinhard (University of Tubingen); Dr MULVANEY, Robert (British Antarctic Survey); Dr BAUSKA, Thomas (British Antarctic Survey)

Presenter: Dr MARTIN, Carlos (British Antarctic Survey)

Session Classification: Modeling and measurements of optical and radio propagation in birefringent ice

Contribution ID: **14** Type: **not specified**

Radio neutrino detection and the required ice calibration

Wednesday, 20 January 2021 17:55 (20 minutes)

The IceCube-Gen2 radio array is an ambitious augmentation to IceCube-Gen2, seeking to extend the ultra-high energy neutrino detection reach above 10 PeV. Consisting of 200 multi-channel 'stations' deployed over a surface area of ~500 km^2, such an array also offers significant radio-glaciological science. We'll summarize plans to calibrate South Polar radio ice properties necessary for neutrino reconstruction.

Primary author: BESSON, David (University of Kansas)

Presenter: BESSON, David (University of Kansas)

Session Classification: Modeling and measurements of optical and radio propagation in birefringent ice

Contribution ID: **15** Type: **not specified**

Ice-dynamic implications of geophysical studies upstream of South Pole

Tuesday, 19 January 2021 16:45 (20 minutes)

The South Pole is at least 180 km from an ice-flow divide. Thus, the annual-equivalent layer thicknesses in the area are affected by spatial variations in accumulation upstream in addition to temporal variations in regional accumulation. We use a new method to compare the accumulation record from the South Pole Ice Core (SPICEcore), derived by correcting measured layer thicknesses for thinning, with an accumulation record derived from new GPS and radar measurements upstream. When ice speeds are modeled as increasing by 15% since 10 ka, the upstream accumulation explains 77% of the variance in the SPICEcore-derived accumulation (versus 22% without speedup). This result demonstrates that the ice-flow direction and spatial pattern of accumulation were stable throughout the Holocene. The 15% speedup in turn suggests a slight (3–4%) steepening or thickening of the ice-sheet interior and provides a new constraint on the evolution of the East Antarctic Ice Sheet following the glacial termination.

We also report briefly on other results from our studies of conditions upstream of South Pole, which included assessing ice-dynamic effects upon the climate record in SPICEcore and measurements of firn compaction.

Primary author: LILIEN, David (University of Washington)

Co-authors: STEVENS, C. Max (University of Washington); FERRIS, David (Dartmouth College); WADDINGTON, Edwin (University of Washington); OSTERBERG, Erich (Dartmouth College); CONWAY, Howard (University of Washington); Dr KOUTNIK, Michelle (University of Washington); FUDGE, TJ (University of Washington)

Presenters: BESSON, David (University of Kansas); LILIEN, David (University of Washington)

Session Classification: Englacial heterogeneities and stuctures & bedrock properties

Contribution ID: **16** Type: **not specified**

Polarimetric radar-sounding methods to characterise ice birefringence, fabric anisotropy, and flow history

Wednesday, 20 January 2021 17:15 (20 minutes)

Ice-penetrating radar is able to detect anisotropy through exploiting the birefringence of ice crystals, and this technique has aided quantification of the horizontal properties of the ice crystal orientation fabric (COF) at multiple sites across the Antarctic Ice Sheet. These techniques have not only been verified through multiple comparisons with ice cores, but also have been subsequently applied at sites with more dynamic and complex ice flow that are unsuitable for drilling operations. Because the bulk COF of ice sheets records the past history of ice sheet deformation and influences present-day ice flow dynamics, radar observations of ice anisotropic properties provide an opportunity for accurate and widespread mapping of bulk COF across a diverse range of flow regimes. The applications for radar measurements of ice anisotropy are diverse and important. Accurate measurements of ice fabric strength and orientation not only places constraints on present and past ice flow history, but also aids in the incorporation of anisotropic rheology in ice flow models. Separately, the characterisation of ice birefringence, as previously applied in radar-sounding, shows promise for application in radio neutrino experiments.

Primary authors: Dr MARTÍN, Carlos (British Antarctic Survey); Dr JORDAN, Thomas M. (Plymouth Marine Laboratory); Dr YOUNG, Tun Jan (Cambridge University)

Presenter: Dr YOUNG, Tun Jan (Cambridge University)

Session Classification: Modeling and measurements of optical and radio propagation in birefringent ice

Contribution ID: **17** Type: **not specified**

Physical properties of the South Pole Ice Core, SPC14

Wednesday, 20 January 2021 15:40 (20 minutes)

Analyses of the physical properties of the 1751-meter long South Pole ice core (SPC14) have been carried out on 82 vertically-oriented samples cut from the core below the firn-ice transition on a 20-meter sampling interval. Analyses include bubble-number density, grain orientation and fabric, grain-size distributions, and grain-shape characteristics derived from the grain statistics.

We find mean grain sizes to be small and grain-growth rates to be slow in comparison to other, warmer sites that have been drilled for climate records. We also find that the grain-shape anisotropy is first observed at a somewhat shallower depth than that observed in other cores. With increasing depth, we observe the development of a strong girdle fabric in the ice, with the deepest sample from 1739 meters having eigenvalue ratios values comparable to those found in deeper ice at other sites. The fabric shows no signs of disturbance of the ice stratigraphy in SPC14 by folding, boudinage or other processes acting at a large enough scale to affect the paleoclimatic records. These results are commensurate with the mean-annual temperature and ice-flow regime at South Pole.

Primary authors: VOIGT, Donald (Pennsylvania State University); FITZPATRICK, Joan (U.S. Geological Survey); FEGYVERESI, John (Northern Arizona University); ALLEY, Richard (Pennsylvania State University)

Presenter: ALLEY, Richard (Pennsylvania State University)

Session Classification: SPICEcore physical properties, hole lifetime and logging

Contribution ID: **18** Type: **not specified**

Assessing the utility of dynamic particle imaging in South Pole Ice Core dust analysis

Wednesday, 20 January 2021 16:00 (20 minutes)

Microparticle measurements from Antarctic ice cores provide valuable information on past climate dynamics (e.g., atmospheric circulation, dust source area conditions) and ice physical properties. Microparticle concentration and size distributions can be measured using coulter counter techniques on discrete samples, and/or high-resolution laser-based (Abakus) particle counters paired with continuous flow analysis (CFA). While the coulter counter technique (electrical resistance) provides the most accurate measurement of particle volume, it is limited to low resolution analysis. The laser-based approach provides high resolution, continuous, and accurate concentration data by measuring maximum particle length which is assumed to be particle diameter. At the South Pole, correlation between centennially resolved South Pole Ice Core (SPICEcore; 1751m, 54,000 years) Abakus dust concentration data and South Pole IceCube laser dust logger data is statistically significant (r = 0.85, p-value = <0.01). Recent evidence suggests that the spherical particle shape assumption may be incorrect due to variations in particle shape (i.e., aspect ratio). Dynamic particle imaging methodologies (i.e., FlowCAM) have been used by the biological community recently to measure physical properties of micro-sized phytoplankton (i.e., length, width, aspect ratio). We use the dynamic particle imaging technique to measure aspect ratios of microparticles over the past 54,000 years and compare to Abakus and Coulter Counter measurements collected from the SPICEcore during CFA melting. Discrete samples (~25 years/sample in the Holocene and ~120 years/sample in the LGM) were collected during CFA melting and measured via Coulter Counter and dynamic particle imaging techniques during three time periods; Termination I (n = 19, 10-18,000 years ago), LGM (n = 20, 18-26,000 years ago), and Heinrich Stadials 4 and 5 (n = 16, 36-50,000 years ago). Using a student's t-test, coarse (5.1-6.4μm) size dependent aspect ratio distributions are statistically similar during the LGM and Heinrich Stadials 4 and 5 but are different (p-value < 0.01) during Termination 1. Our results suggest that coarse particle shape is temporally variable. Volume metrics used for coarser particle interpretations must account for temporal variability as the changing particle shape during Termination I will have an impact on particle refractive indices. Climatically, particle shape variability suggests a possible introduction of a new dust source(s) and/or change in mineralogical composition.

Primary author: CHESLER, Aaron (University of Maine)

Co-authors: PUTNAM, Aaron (University of Maine); KOFFMAN, Bess (Colby College); FERRIS, David (Dartmouth College); WINSKI, Dominic (University of Maine); OSTERBERG, Erich (Dartmouth College); DAI, Jihong-Cole (South Dakota State University); KREUTZ, Karl (University of Maine); ANDERSON, Katherine (Dartmouth College); WELLS, Mark (University of Maine); HANDLEY, Michael (University of Maine); HARMON, Natalie (University of Maine); THUNDERCLOUD, Zayta (Dartmouth College)

Presenter: CHESLER, Aaron (University of Maine)

Session Classification: SPICEcore physical properties, hole lifetime and logging

Contribution ID: **19** Type: **not specified**

Borehole deformation at the South Pole

Wednesday, 20 January 2021 15:20 (20 minutes)

An acoustic televiewer, which collects tilt, azimuth, and
high-resolution caliper measurements, was deployed to measure the 3D shape of the 1751m SPIceCore Borehole in December 2019. We will present the results of this data collection including analysis of borehole shape and inclination, evidence of drilling artifacts on
the borehole wall, and lessons learned for optimal data collection with the acoustic televiewer.

Our ultimate goal is an improved understanding of ice flow laws to contribute to ice flow models. We assume an initially smooth, circular hole of consistent diameter, and provide preliminary analysis of the effects of impurities, grain size, and crystal fabric on deformation from observed borehole shape. We show how a future second log of the borehole will provide an improved assessment of the effects of ice
properties on ice flow.

Primary author: SINKLER, Emilie (University of Alaska Fairbanks)

Co-author: PETTIT, Erin (Oregon State University)

Presenter: SINKLER, Emilie (University of Alaska Fairbanks)

Session Classification: SPICEcore physical properties, hole lifetime and logging

Contribution ID: **20** Type: **not specified**

Optical televiewing of ice-mass boreholes

Wednesday, 20 January 2021 18:55 (20 minutes)

Developed and applied to ice masses over the past decade, borehole optical televiewing (OPTV) is a logging technique that records a geometrically accurate, full-colour (radial) image of the complete borehole wall at a typical resolution of 1 mm. Borehole OPTV has been successfully deployed at temperate and polythermal valley glaciers, at Antarctic ice shelves, and at the Greenland Ice Sheet – both inland and at a fast-moving outlet glacier. The resulting OPTV logs have imaged numerous visibly contrasting ice types and inclusions, and allowed their scale and geometries to be reconstructed. Applications to date have included:

- `Revealing the 3D internal ice and debris structure of valley glaciers in Svalbard and Nepal H`
- `Characterizing ice deformation structures, including crevasses to depths of \~{}300 m in the`
- `Imaging ice types present at the base of an Antarctic ice shelf rift.`
- `Recording annual layering and allowing age-depth scales to be reconstructed for contrasting l`
- `Providing a proxy for snow, firn and ice density, including characterization of refrozen ice`
- `Reconstructing former surface melting and melt-pond formation on an Antarctic ice shelf.`
- `Revealing aspects of the internal structure of the Greenland ice sheet, including ash layers.`

This presentation will summarize the technique and applications noted above and outline the potential ways in which OPTV logging might usefully be applied to IceCube boreholes.

Primary author: HUBBARD, Bryn (Aberystwyth University)

Presenter: HUBBARD, Bryn (Aberystwyth University)

Session Classification: Future glaciological instrumentation at the South Pole (IceCube Upgrade, RAID and beyond)

Contribution ID: **21** Type: **not specified**

Inclination data from sensors in the South Pole ice

Wednesday, 20 January 2021 15:00 (20 minutes)

In 2013 the dust logger was equipped with a precision orientation sensor to study ice anisotropies. This sensor can be used to monitor SPICE borehole deformation by comparing data taken over multiple seasons between 2015 and 2019. We will also re-examine data from inclinometers installed in the IceCube array in order to develop a fuller picture of ice flow at South Pole.

Primary authors: TOSI, Delia (University of Wisconsin-Madison); BAY, Ryan (University of California, Berkeley)

Presenter: TOSI, Delia (University of Wisconsin-Madison)

Session Classification: SPICEcore physical properties, hole lifetime and logging

Contribution ID: **22** Type: **not specified**

BedMachine: mapping the bed under the Antarctic ice sheet by combining sparse radar data and mass conservation

Tuesday, 19 January 2021 17:05 (20 minutes)

Despite major advances in subglacial bed topography mapping over the past decades using nadir-looking radar sounding profiles, significant sectors remain poorly known and critical spatial details are missing, especially in the proximity of grounding lines. We present a novel, high-resolution, physical description of Antarctic bed topography and ice thickness that uses a mass conservation approach combining all available ice thickness data with high-resolution ice velocity mapping to alleviate the spatial resolution limitations of prior products. In the interior, where this method is not applicable due to larger errors in surface velocity data, we rely on simpler methods, such as Kriging or streamline diffusion. We enforce a smooth, seamless transition in ice thickness at the grounding line to match ice shelf thickness reconstructed using a calibrated firn depth correction. The results reveal significant basal topographic features not known previously, at a resolution of 500 m, with major implications for glacier stability.

Primary author: MORLIGHEM, Mathieu (University of California)

Presenter: MORLIGHEM, Mathieu (University of California)

Session Classification: Englacial heterogeneities and stuctures & bedrock properties

Contribution ID: **24** Type: **not specified**

South Pole Ice Core (SPICEcore) - What has been accomplished, what is below 1751 m, and synergies with the new Hercules Dome project

Tuesday, 19 January 2021 15:50 (15 minutes)

It has been 4 years since the completion of the SPICEcore project in the field. The SPC14 ice core was drilled to a final depth of 1751 m and the measurements funded with the first wave of science proposals have already been completed. More than half of the SPC14 ice core is archived at the NSF ice core facility in Denver and will be available for future measurements for years to come. The age of the SPC14 ice core at 1751 m is 54.3 ky BP (thousand years before 1950 CE). The bedrock at the SPICEcore site is close to 2850 m and modeling suggests there is undisturbed ice through the Last Interglacial Period (130 ky BP). The recently funded Hercules Dome project aims to collect an ice core to bedrock which contains LIG ice from the intersection of East and West Antarctica (86°S, 105°W). Hercules Dome is on the edge of the Transantarctic Mountains overlooking the West Antarctic Ice Sheet, which heavily influences the meteorology and the climate signal at Hercules Dome. In this talk, we briefly review the scientific potential of a deep ice core near the SPICEcore site and potential synergies with the Hercules Dome project within the context of possible future collaborations in ice coring at the South Pole.

Primary authors: STEIG, Eric Julian (University of Washington); ROOP, Heidi (University of Washington); SOUNEY, Joseph (University of New Hampshire); TWICKLER, Mark (University of New Hampshire); AYDIN, Murat (University of California-Irvine); FUDGE, TJ (University of Washington)

Presenter: AYDIN, Murat (University of California-Irvine)

Session Classification: Available instrumentation at the South Pole (IceCube, SPICEcore, GPS stake field and other)

Contribution ID: **25** Type: **not specified**

TRIPLE-IceCraft - A Retrievable Melting Probe for Transporting Scientific Payloads

Tuesday, 19 January 2021 19:00 (20 minutes)

Primary author: HEINEN, Dirk (RWTH Aachen University)

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Presenter: HEINEN, Dirk (RWTH Aachen University)

Session Classification: Drilling technologies and logistis

Contribution ID: **26** Type: **not specified**

Analysis of Surface Motion with South Pole Campus

Tuesday, 19 January 2021 17:25 (20 minutes)

Given the vast distance to bedrock and to the nearest outcrop, it seems justified to assume that the ice shelf flow regime at South Pole is uniform within the footprint of the Station. However, survey suggest otherwise.

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Session Classification: Englacial heterogeneities and stuctures & bedrock properties

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Characterising the regional glaciological context for relevance for IceCube-Gen-2

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