Title: Natural and anthropogenic changes in atmospheric greenhouse gases over the past 2 millennia

Presenter: David Etheridge
Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research

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Abstract

Millennial changes in atmospheric trace gas composition are best determined from air enclosed in ice sheets. Air extracted from the open pores in firn and the bubbles in ice is measured to derive the past concentrations and isotopic ratios of the long lived trace gases. The significant increases in CO2, CH4 and N2O since about 1750 and the more recent appearance of synthetic gases such as the CFCs in the atmosphere are a key feature of the anthropocene.

The millennia preceding the anthropocene, the Late Pre-Industrial Holocene (LPIH), show evidence of natural changes in trace gases that can be used to constrain models and improve their ability to predict future changes under scenarios of anthropogenic emissions and climate change. Precise measurements and ice core air samples that are accurately dated and highly resolved in time are required to record the small and rapid trace gas signals of this period.

The atmospheric composition records produced by CSIRO and collaborators using the Law Dome, Antarctica ice cores are widely used in models of climate, atmospheric chemistry and the carbon cycle over the anthropocene and the LPIH. Results from these studies have been influential in informing global policies, including the Montreal and Kyoto Protocols.

We will present the recently revised trace gas records from Law Dome and new measurements of tracers from these and other ice sites that reveal the causes of atmospheric changes over the anthropocene and the LPIH.

Title: Roosevelt Island Climate Evolution (RICE), West Antarctica: Report on Field Results and Challenges, Solutions and Successes

Presenter: Alex Pyne
Antarctic Research Centre, Victoria University of Wellington

Authors: Alex Pyne[1], Darcy Mandeno[1], Nancy A.N. Bertler[1, 2], Howard Conway[3]

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Abstract

RICE is a 9-nation collaboration (New Zealand, Australia, Denmark, Germany, Italy, People's Republic of China, Sweden, UK and USA), which aims to document the retreat of the Ross Sea sector in West Antarctica. The overarching goal is to improve understanding of the stability of West Antarctica in a warming world. Roosevelt Island, a 140-km long ice rise in the eastern Ross Sea, is ideally situated for investigating histories of climate and deglaciation of the region. With ice thickness H=745m, accumulation rate b=0.18m/yr, the characteristic timescale at the divide H/b is about 4kyr; we expect to be able to infer histories of climate and ice dynamics over the past 40kyr.

Dry coring at Roosevelt Island began on 8 December 2011; 129.6m depth of dry core was recovered and firn casing was set later in the 2011-12 season. Drilling with fluid began on 20 November 2012 and reached 'bedrock' at 763.5m depth in 31 days. Core processing is now underway.

Many technical and operational challenges had to be overcome. The project required both a new drill, and development of light-weight services and drilling infrastructure that could be transported by DC6-T airplane and could winter over on site. Air support to the site was also challenging; the long distance from McMurdo (1500km round trip) and extended periods of bad flying conditions (primarily fog) made for irregular flights. Maintaining recovered ice cores below -18°C (for gas analysis) for extended periods between flights required active refrigeration because mid-summer air temperatures were often above 0°C.

Title: Modeling the isotopic composition of snow for synoptic storm events at Roosevelt Island, Antarctica

Presenter: Lana Cohen
Antarctic Research Centre, Victoria University

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Abstract

Understanding the stable isotope-temperature relationship in snow is critical for reliable use of ice core isotope records as temperature proxies. Though stable isotopes ($\delta^{18}O$ and δD) show a strong relationship with temperature on annual and longer timescales, they are also known to be influenced by moisture trajectory, source region conditions, and cloud micro-physical processes, which can change the δ-T relationship both spatially and temporally. This research investigates these secondary influences by modeling the isotopic fractionation on sub-storm timescales for three storms that occurred at Roosevelt Island, a coastal Antarctic site on the Ross Ice Shelf. The modeled results are compared to measured isotope values from snow collected at the site throughout the three storms. By collecting snow samples during storm events, uncertainties involving post-depositional effects (diffusion and re-distribution) and determination of the exact timing of precipitation are eliminated. This study uses a Rayleigh distillation mixed cloud isotopic model (MCIM) with air-mass pathways determined using European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis data and the National Oceanic and Atmospheric Administration (NOAA) HYSPLIT back-trajectory model. The model is able to reproduce significant intra-storm variability in $\delta^{18}O$ due to changes in air mass trajectory as well as identifying the effects of mixing (isotopic recharge) on isotopic ratios. The d-excess parameter, which is often used as an indicator of source region changes, is shown to be very sensitive to changes in both source region and air mass trajectory.

Title: Monthly ice core dating using Numerical Weather Prediction (NWP) data

Presenter: Mana Inoue
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Abstract

High resolution climate records from ice cores can be used to calibrate instrumental data and to interpret past climate. The ice core from the high accumulation site at the summit of Mill Island, East Antarctica (100°40' E, 65°30' S) shows potential for retrieval of monthly climate records. The monthly dating can be improved using NWP-derived monthly snowfall totals. Rather than assuming constant snow fall throughout each year. After the hydrogen peroxide (HOOH) mid-summer peak and stable isotope signals were used to annually date the Mill Island ice core, NWP-derived monthly snowfall totals were used to date the core on a monthly basis(i.e., instead of equally dividing annual data into 12, we calculate the proportion of monthly snow fall in each year).

European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim data show large variability in total monthly snow fall (ranging from near-zero to ~8 cm water equivalent), i.e., even at high snow accumulation sites such as Mill Island, there are some months with no accumulating snowfall. The linear accumulation interpretation causes ~2.5 months' error in core date in some years.

Title: "Horizontal Ice Coring": Lessons from the Ice Age for Future Greenhouse Warming

Presenter: Hinrich Schaefer
NIWA

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Abstract

Analyses of gases extracted from ice cores show that throughout the ice ages greenhouse gases and climate have changed in specific patterns. This variability shows how an increase of greenhouse gases in the atmosphere (through burning of fossil fuels) will lead to future warming. Does it also show that this warming is likely to lead to additional greenhouse gas emissions from natural sources?

The rapid climate shifts at the end of the last ice age offer an analogue to study this question. It is possible to constrain the activity of methane sources through analysis of stable isotopes and radiocarbon content of old atmospheric methane. Since these are present in minuscule amounts, large amounts of air must be extracted from ancient ice. Therefore, these studies are only feasible at so-called "horizontal ice core sites" where ancient ice layers are exposed at the glacier surface and offer unlimited access to old ice. Such a site is currently being developed at Taylor Glacier in Antarctica's Dry Valleys. First results from this work and findings from a similar site in Western Greenland show which methane sources are likely to respond to future warming with increased emissions.

Title: Hot rocks in a cool place - sub-glacial heat flow in east Antarctica

Presenter: Chris Carson
Geoscience Australia

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Abstract

Numerical models are the primary predictive tools for understanding the dynamic behavior of the Antarctic ice sheet. But a key boundary parameter – the magnitude of sub-glacial heat flow – is controlled by geological factors and remains poorly constrained. We show that variations in the abundance and distribution of heat-producing elements (U, Th and K) within the Antarctic continental crust give rise to higher (by a factor as much as 2-3), and considerably more variable, regional sub-glacial heat flows than that assumed in many ice modeling studies. Such elevated, and variable, heat flows would fundamentally impact on regional ice sheet behaviour and predict higher localized basal melt production and enhanced ice surging and streaming. We also note that, prior to the breakup of Gondwana, much of the East Antarctic continental crust was contiguous with southern Australia where extensive high heat-producing Proterozoic-aged rocks, and correspondingly elevated regional heat flows, are well documented and such crustal rocks almost certainly extend beneath the modern east Antarctic ice sheet. Such fundamental geological controls on sub-glacial heat flow must be considered to accurately model ice dynamics, and would allow more refined predictions of ice mass balance and sea level change, particularly in the context of anthropogenic climate change.