10 year plan for Shallow Coring Capabilities (1-400 m deep)

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Introduction

Variability in climate variables such as temperature and precipitation at regional scales is much greater than global or hemispheric averages. This regional variability can be characterized by patterns, such as the Pacific Decadal Oscillation, Arctic Oscillation and the Indian and South Asian Monsoons, which provide useful measures of both the pattern of unforced and forced climate variability. Variability in the proxy data is used in ice cores to infer past climate varies on similar scales. In addition, atmospheric aerosols, particles, and pollutants, show strong regional gradients related to variable source emissions and atmospheric transport pathways. In order to understand how climate and air quality have changed in the past, and to understand the forcing mechanisms responsible, we must first resolve past changes in climate and pollution at the regional scale. Furthermore, few data exist on the particulate and dissolved biological matter in ice cores. When collected in concert with other parameters, biological data can provide new and corroborative information regarding these regional patterns as well as on the abundance and diversity of microbes in ice.

To address this need, the International Partnership in Ice Core Science (IPICS) and U.S. Ice Drilling Program Office (IDPO) have highlighted a 2000-year ice core array as a key long-term scientific goal for the ice drilling community. The 2000 year interval includes the Little Ice Age and Medieval Climate Anomaly, both natural climate fluctuations with global and regional signatures, as well as the initiation of widespread anthropogenic modification of the climate and atmosphere over the past 100-150 years. Recent studies have demonstrated the value of collecting 200-2000 year records from alpine, sub-polar glaciers both in the dry snow and percolation zones. Core collection in such regions poses logistical and technological challenges that must be met to increase the spatial density of 200-2000 year-long records beyond the polar ice sheets. These sites often have the added importance of being situated close to population centers where an understanding of regional climate change has broader societal impacts. In addition, emerging research avenues in glacial and sub-glacial microbiology and ultra-trace element ice chemistry, among others, require adaptations and modifications of existing drilling technology.

Research Objectives

- Increase the density of 200- to 2000-year ice core arrays around the globe (polar ice sheets and ice caps, sub-polar alpine, tropical alpine) to constrain late

Holocene regional climate variability and forcing mechanisms;
- Constrain the relationship between regional climate patterns (AO, ENSO, Monsoons) and the Little Ice Age and Medieval Climate Anomaly;
- Develop regional-scale climate anomaly maps that can be compared to climate model hindcasts for model evaluation purposes;
- Determine the sensitivity of alpine glaciers and ice sheet margins to past warm periods, with implications for the impact of future warming on water resource availability and sea level rise;
- Relate glacial chemical, physical and biological properties to remotely sourced data (satellite, airborne, surface, and borehole-based measurements);
- Develop a global inventory of intra-glacial and sub-glacial ecosystems;
- Increase our inventory of the density, diversity and physiological state of microbes in ice;
- Improve our understanding of the role of microbes in ice related to geological, chemical and climatological changes.
- Investigate relationships between microbiological communities/metabolisms (intra- and sub-glacial) and ice and substrate chemistry;
- Investigate post-depositional physical and chemical processes and constrain their controls;
- Determine the time-variable sources and transport pathways for atmospheric pollutants (e.g. Hg and Pb), dust and aerosols;
- Develop regional records of biomass burning;
- Understand the air-snow exchange of aerosols and gases in alpine regions, and the processes influencing their preservation in ice core records;
- Develop regional records of volcanic emissions for climate model forcing;

Shallow Ice Drilling Scientific Requirements

In order to achieve the scientific objectives briefly outlined above, improvements and modifications are needed to the existing IDDO shallow coring capabilities. The following scientific requirements are differentiated between those for (1) hand augers capable of 30 m cores, and (2) electromechanical or thermal drills capable of 300-400 m cores:

*(1) **Hand Augers (1-30 m depth):***

a) **<u>Add the Stampfli Swiss 2-inch "Backpack Drill" to the IDDO arsenal.</u>**
This drill has performed well in the field and would add a lightweight, highly portable option for coring to 15 m depth. This 2" drill is not applicable for all science purposes, so an improved hand auger is also necessary. See http://www.icedrill.ch/ for more information and contact Margit Schwikowski for assistance in purchasing this drill system.

b) **<u>Improve the current inventory of PICO hand augers as described below.</u>**
- **Improved ability to drill through solid ice**: There is a need to drill efficiently through both blue ice from the surface, and through any major ice layers within percolation zone firn.

- **Horizontal coring capability of up to 2 m deep**. One proposed design is a simple adaptable support to allow collection of horizontal cores from glacier sides that can be integrated with the auger by a single drill operator. The goal is to enable the collection of cores by small teams with backpack capabilities traveling several kilometers.

- **Improved core and borehole quality** with minimal core breaks, gouges, cracks, and other core disturbances. Intact core in 1 m-long sections is needed to prevent chemical and biological contamination.

(2) Electromechanical and Thermal Drilling (30-400 m depth):

a) **<u>Modifications to the existing Eclipse drilling platform.</u>**

- **Thermal drilling capability for polythermal and temperate ice**. Recent work at Mt. Waddington (BC) and McCall Glacier (Alaska) using old "PICO" 4-inch drill has demonstrated that high quality, annual-layer counted records can be obtained in warm ice, but drilling challenging due to regelation in the borehole. Greater power and/or a different thermal drill design, including the ability to delivery alcohol directly to the drill head, is needed.

- **Ability to interchange thermal and electromechanical sondes in a single drilling platform.** Such a system would need to be easy to interchange by a small field team. This drilling method has been used successfully at several sites (e.g. Zagorodnov et al., 2005).

- **Ability to interchange with a rock or soil coring system to collect basal dirty ice and sub-glacial sediment cores.** Such a sub-glacial coring system would enhance geobiological and glacial substrate (till) studies.

- **"Clean" drill for trace element chemistry, particles, gases, and microbiology analyses:** There is an increasing need to collect core in clean conditions to conduct state-of-the-art chemical and biological analyses. While cores can often be decontaminated after drilling, this results in loss of significant volume of ice and often does not eliminate all contamination. The Geological Survey of Canada and Icefield Instruments "Clean Simon" drill is identified as a potential starting-point for a design. "Clean" coring also includes the use of power supplies with minimal contamination potential.

- **Improved core and borehole quality** with minimal core breaks and gouges. Intact core is needed to prevent chemical and biological contamination.

- **Reduced risk of freezing the drill in the borehole.** Drilling in more temperature and polythermal glaciers will increase the risk drill freezing. One potential scheme would be the ability to deliver alcohol directly to the cutting surface c.f. Zagorodnov et al., 2005.

- **Sealed sonde system**. This is to increase the depth range of the drill, and improve drilling capabilities in wetter ice. Perhaps only one of these sondes is needed per platform.

- **Continued ability to collect 300-400 m of core in a dry hole**. Drilling fluid contaminates chemical and biological analyses and should be avoided if at all possible.

- **Continued ability to transport drill to coring sites via helicopte**r. Twin and turbine single Otter aircraft are not always available and these aircraft cannot access all sites even when available.

(b) <u>Integrated support equipment and facilities</u>

- Integrated core processing lines
- Ice core boxes that can carry some drill components
- Simplified tool kit specific to each platform
- Integrated clean space with the ability to accept core directly from drill and process core cleanly in the field
- Integrated drill shelter

Timeline of Shallow Coring Needs:

- Mt. Hunter – Summer, 2012 – Eclipse Drill: Investigating hydroclimate and alpine glacier response over past 1000 years. Proposal in review by P2C2. Contact Erich Osterberg.
- North Ice Cap, Thule Greenland – Summer 2012 – Hand Auger: Reconnaissance on North Ice Cap to investigate the response of the NW Greenland Ice Sheet to the Early Holocene thermal maximum. Proposal in review by ANS. Contact Erich Osterberg.
- North Ice Cap, Thule Greenland – Summer 2014 – Eclipse Drill: Drilling to bedrock on North Ice Cap to investigate the response of the NW Greenland Ice Sheet to the Early Holocene thermal maximum. Proposal in review by ANS. Contact Erich Osterberg.
- Ilulissat, Greenland - Summer 2012, 2013 – Hand Auger: Spatio-temporal characterization of cryoconite systems in Greenland (Ilulissat). Proposal submitted to NSF OPP/Arctic Natural Sciences
- McMurdo Dry Valleys, Antarctica - Austral summers 2012, 2013 – Hand Auger: Cryoconite holes in McMurdo Dry Valleys, Antarctica: Define areal extent using remote sensing, physical, biological and geochemical characteristics and relate these to a surface energy balance model. Proposal submitted to NASA Exobiology
- Tien Shan – Summer, 2013 – Eclipse Drill: Holocene climate variability and atmospheric pollution in Central Asia. Contact Vladimir Aizen. Proposals in preparation.
- Tien Shan – Summer, 2014 – Eclipse Drill: Holocene climate variability and atmospheric pollution in Central Asia. Contact Vladimir Aizen. Proposals in preparation.

- New Zealand – August-November, 2015 – Combined thermal and electromechanical Eclipse Drill: Climate variability and atmospheric pollution in New Zealand over the pat 200 years. Contact Andrei Kurbatov. Proposal in preparation.
- Northeast Greenland Traverse – Summer, 2014 – Hand Auger and Eclipse Drill: Spatial variability of chemical and physical properties of the neat surface firn over the 20th century. Contact Bob Hawley and Erich Osterberg.