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# IODP Expedition 377: Arctic Ocean Paleoceanography (ArcOP) – Toward a Continuous Cenozoic Record from a Greenhouse to an Icehouse Earth

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## Abstract

Investigations of both short-term natural climate variability, and long-term, large-scale changes in climate state are advanced by scientific ocean drilling at globally-distributed locations. Despite its global importance as both a contributor to climate change and a region that is most affected by global warming, the Arctic Ocean is the last major region on Earth where the long-term climate history remains poorly known. While many major advances in understanding were achieved in 2004 with the successful completion of IODP Expedition 302: Arctic Coring Expedition (ACEX), the record was hampered by generally poor recovery and by a 26-myri hiatus (or condensed interval depending on the age model) spanning the global transition from the Greenhouse to Icehouse climate states. In August-September 2022, IODP Expedition 377: Arctic Ocean Paleoceanography (ArcOP) will enable another step in reconstructing the detailed history of climate change in the Arctic over the last 50-million years. The overall goal of the ArcOP drilling campaign is the recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet the highest priority paleoceanographic objective: the continuous long-term Cenozoic climate history of the central Arctic Ocean. Key scientific themes and questions to be addressed by ArcOP are summarized in this poster. The expedition goals can be achieved through 1) careful site selection, 2) the use of appropriate drilling technology and ice management supported by two ice breakers, and 3) applying multi-proxy approaches to paleoceanographic, paleoclimatic, and age-model reconstructions. The expedition will complete one primary deep drill hole (LR-11B) to 900 meters below seafloor (mbsf; twice as deep as the ACEX core depth). This will be supplemented by a short drill site (LR-10B) to 50 mbsf, to recover an undisturbed Quaternary sedimentary section to ensure complete recovery for construction of a composite section spanning the full age range through the Cenozoic. Expected sedimentation rates two to four times higher than those of ACEX will permit higher-resolution studies of Arctic climate change. More information on ArcOP can be found at the expedition website accessible via the QR code.

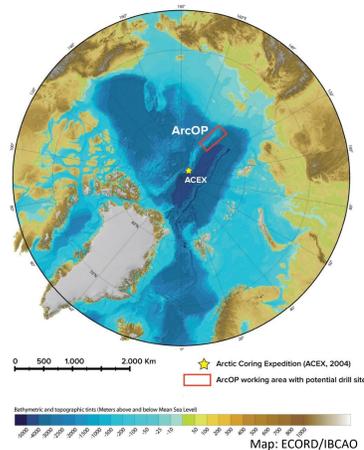
## Expedition Operations



ArcOP is an expedition of the International Ocean Discovery Program (IODP), an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms.



One of the three platform providers for IODP is the European Consortium for Ocean Research Drilling (ECORD). ArcOP is funded, managed, and operated by ECORD, in partnership with the Swedish Polar Research Secretariat (SPRS) and Arctic Marine Solutions (AMS).



ArcOP is a two-part expedition.

### Part 1: Offshore Phase

#### Lomonosov Ridge, Arctic Ocean

- 16 scientists will participate offshore
- Aug.-Sept. 2022, ~50 days
- Cores are not split at sea
- On-deck container 'labs'
- Measurement of ephemeral properties, pore water
- Measurements/observations required to guide drilling
- Multi-sensor core-track scanner
- Downhole logging
- Time-sensitive sampling (e.g. microbiology)



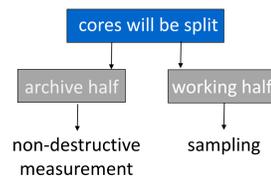
Images of ArcOP fleet superimposed on image of 2004 ACEX operations to illustrate anticipated ArcOP sea ice conditions and operations.

- **Drilling vessel: Dina Polaris.** This Norwegian ice class A1 vessel provided by Geoquip Marine can operate in cold climates in ice thickness up to 0.8m.
- **Icebreakers:** The Swedish *Oden* will be deployed as the near field icebreaker, and the Russian *Viktor Chernomyrdin* will be deployed in the far field. By managing the ice, the drill ship can remain on station to conduct the coring.

### Part 2: Onshore Phase

#### IODP Bremen Core Repository & MARUM Laboratories at the University of Bremen

- All 36 scientists will participate onshore
- Cores are split
- Late 2022/early 2023, ~30 days
- All other IODP measurements, description and sampling



Thermal conductivity -- Core splitting -- Core description -- Digital imaging -- Color reflectance -- P-wave velocity -- Moisture and density on samples -- Smear slide sampling -- Biostratigraphy -- Inorganic geochemistry -- Organic geochemistry -- Paleomagnetic measurements -- Core sampling for individual post-expedition research



Photo credit: MARUM

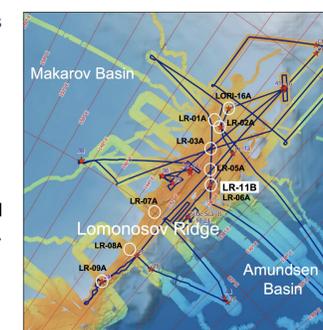
## Expedition Science Objectives

**Overall Goal: Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest-priority objective - reconstructing the long-term Arctic Ocean climate history over the last 50-60 million years.**

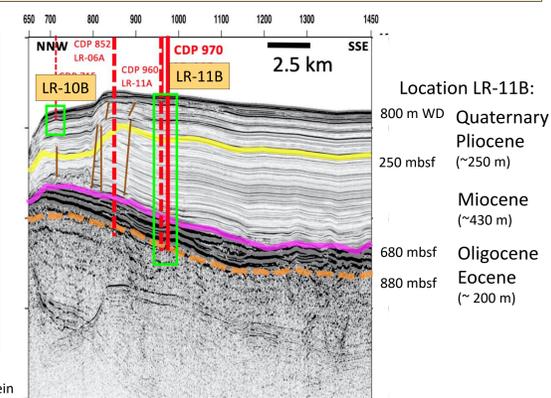
ArcOP will build on the successes and learn from the challenges of the ACEX expedition.

### Two Primary Sites

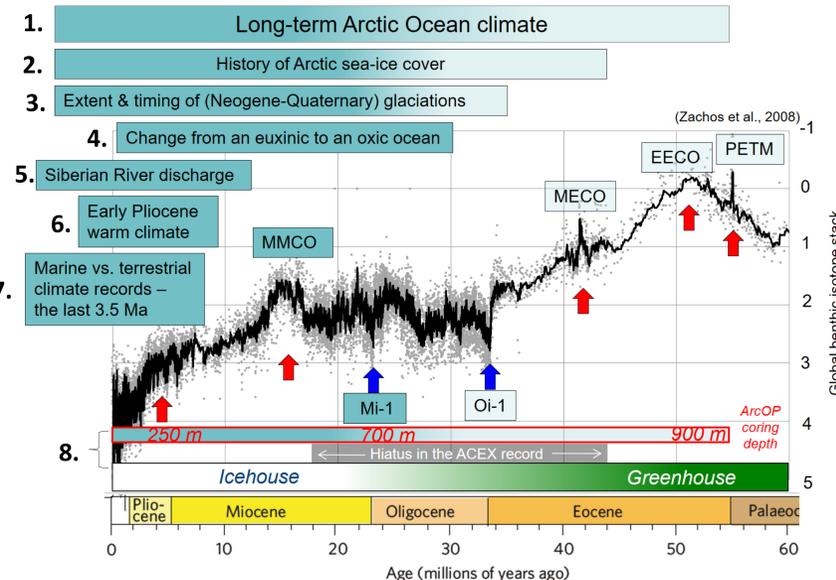
- **LR-11B:** primary deep drill site to 900 mbsf.
- **LR-10B:** short drill site to 50 mbsf to recover an undisturbed uppermost Quaternary section.
- Sedimentation rates: 2-4X higher than ACEX.
- Drill depth: 2X deeper than ACEX.



Stein, 2019, Paleoceanography & Paleoclimatology; based on a 2018 Polarstern site survey expedition (Stein 2019 and Weigelt et al 2019)



## Key Scientific Themes and Questions to be addressed by ArcOP:



1. **Did the Arctic Ocean climate follow the global climate evolution during its course from early Cenozoic Greenhouse to late Cenozoic Icehouse conditions?**
  - Are the Early Eocene Climate Optimum (poor recovery in the ACEX record) and the Oligocene and Mid-Miocene warmings also reflected in Arctic Ocean records?
  - Did extensive glaciations (e.g., the Oi-1 and Mi-1 glaciations) develop synchronously in both the Northern and Southern Hemispheres?
  - What are the related scale and timing of short- and long-term sea level changes?
2. **What is the history of sea-ice cover since its onset in the Eocene?**
  - When did the transition from seasonally open waters to perennial sea ice occur?
3. **What is the extent and timing of glaciations?**
  - How extensive was the Siberian ice sheet during Pleistocene glaciations?
  - What impact did broad, thick ice shelves and low sea level have on Arctic ocean circulation and salinity?

4. **When and how did the change to oxygenated bottom waters typical for the Neogene and Quaternary Arctic Ocean occur?**
  - Was it in the early mid-Miocene or the late Eocene?
  - What are the implications for the gateway configurations of the Arctic and its connection to the Earth's oceans?
5. **What is the history of Siberian river discharge and how critical is it for sea ice formation, water mass circulation, and climate change?**
6. **How did the Arctic Ocean evolve during the Pliocene warm period and succeeding cooling?**
7. **How does the Arctic marine record correlate with terrestrial records obtained from Siberian Lake Elgygytyn?**
8. **What is the cause of the major hiatus discovered in the ACEX record?**
  - Does this hiatus in fact exist or is it rather an interval of extremely reduced sedimentation rate?
  - If there is a major hiatus, is it related to the subsidence history of Lomonosov Ridge, a phase of uplift and exposure of the ridge, or a response to increased bottom water currents during the opening of the Fram Strait?

More Information at  
the Expedition Website

