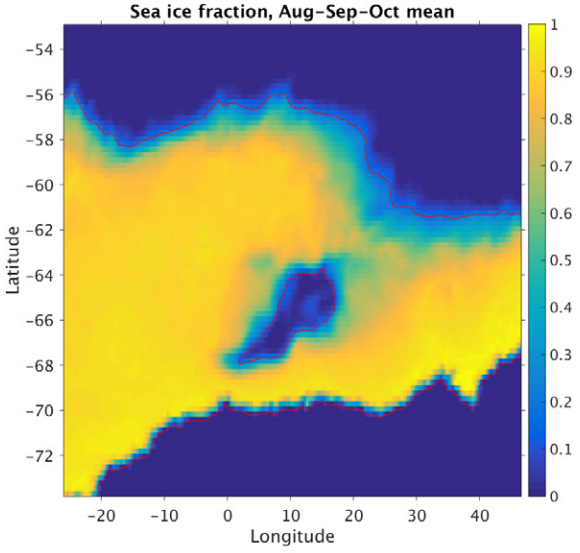
# HIGH-LATITUDE APPLICATION AND TESTING OF EARTH SYSTEM MODELS (HiLAT)

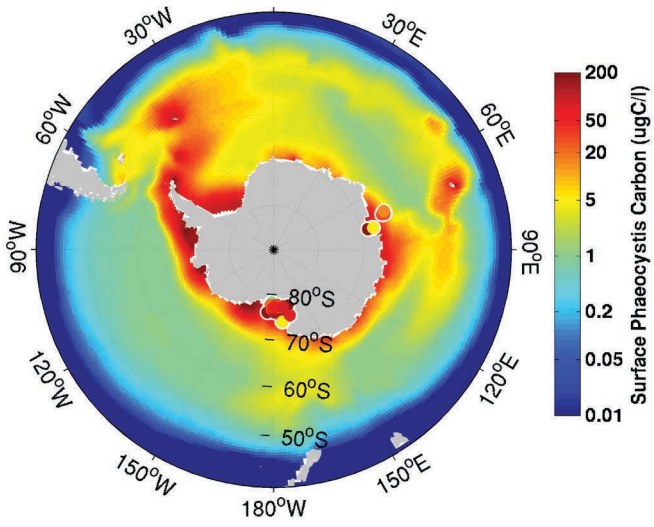
Polar regions are changing faster than anywhere on Earth. Thawing permafrost, melting ice sheets, disintegrating ice shelves, and retreating sea ice have all made headlines in recent years. These changes not only pose challenges, but also provide opportunities for the nation, and in particular the U.S. Department of Energy (DOE).

While thawing permafrost and rising sea levels threaten coastal and Arctic energy infrastructures, a seasonally ice-free Arctic may open up new areas for commercial shipping and fossil fuel exploration. A thorough understanding of the fine-scale processes of high-latitude environments is critical for addressing these challenges and opportunities.

Key is improving scientists' understanding of the impacts that high-latitude changes have on polar and global systems, such as the exchange of carbon between the atmosphere, land, and oceans. The High-Latitude Application and Testing of Earth System Models (HiLAT) project applies state-of-the-science global modeling and analysis capabilities to answer questions regarding environmental changes in the Arctic and Antarctic regions of importance to DOE and the nation.




*High-resolution earth system model of a polynya (area of open water enclosed by pack ice) shown in the Weddell Sea, Southern Ocean. Polynyas are important for the formation of the densest water masses in the world's ocean.*




*Simulated distribution of the plankton species Phaeocystis Antarctica is displayed in the Southern Ocean (observations in dots). This high-latitude species is an important source of cloud-brightening aerosols.*

## *INTEGRATIVE APPROACH*

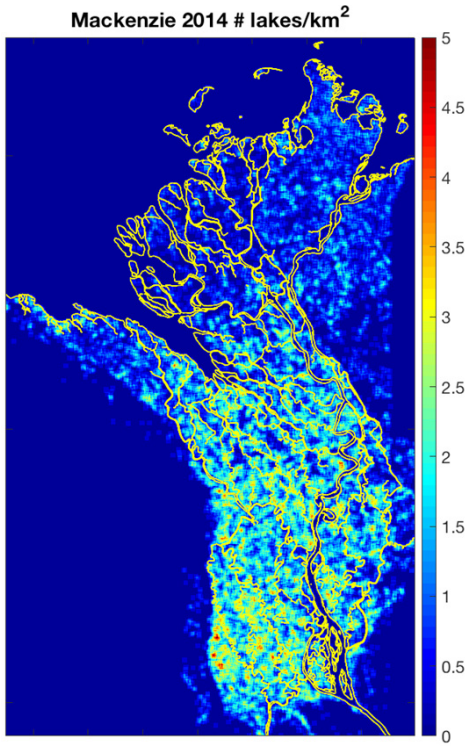
High-latitude regions (between 60 and 90 degrees latitude in the northern and southern hemispheres) are very cold with low humidity. These polar regions behave in complex ways due to the strong interactions between ocean, atmosphere, land, sea ice, land ice, and associated ecosystems. The multidisciplinary HiLAT team is taking an integrative approach to tackling some of the toughest climate problems.

Project researchers will use earth system models to quantify feedbacks between the cryosphere—regions covered by ice and snow—and Earth's heat and water budgets. They perform computer model simulations to help identify changes near the poles and implications to the planet at lower latitudes.

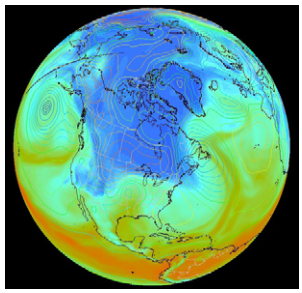
Several component studies will help improve regional and global projections of Arctic sea-ice and delta changes and Greenland ice sheet behavior in a warming environment.

Science questions include:

- Are changes in Arctic sea-ice cover influencing mid-latitude weather extremes?
- How do recent changes in Arctic and Antarctic sea ice impact marine ecosystems, aerosol production, and the brightness of polar clouds?
- How do freshwater and nutrient inputs from ice sheets (e.g., Greenland and Antarctica) and Arctic rivers affect marine ecosystems and carbon sequestration?
- Does enhanced freshwater input from the Antarctic ice sheet play a role in the recent Southern Hemisphere sea-ice expansion?
- Will changes in Arctic Ocean circulation impact the Atlantic Meridional Overturning Circulation (AMOC) and affect decadal variability of the climate system?
- How will the Southern Ocean overturning and Antarctic bottom water formation respond to competing changes in atmospheric wind forcing, upwelling, sea-ice changes, and freshwater inputs from ice sheets?
- Is polar amplification weaker in the Antarctic due to water vapor transport and lapse rate feedbacks resulting from changes in land mass and sea-ice distribution?




*Deltas play an important role in the Arctic earth system, as they modify the discharge of the major Arctic rivers before they reach the ocean. This is important for the timing of sea-ice retreat in spring. Shown here is an analysis of lake coverage of the arctic Mackenzie River delta.*



*Water vapor and sea-level pressure (contours) show the strong connectivity between the high and mid latitudes.*

## FUTURE DIRECTION

Research from the HiLAT project will inform scientists' understanding of the complex interactions between polar ocean, atmosphere, and land systems, and how they will affect the high-latitude environments under various scenarios.

These HiLAT components will increase the level of understanding and the reliability of DOE's next-generation Energy Exascale Earth System Model (E3SM), which will help solve energy and earth system challenges. At the same time, the progress being made in improving model accuracy will allow researchers to better use models in real-world applications.

## ACKNOWLEDGEMENT

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