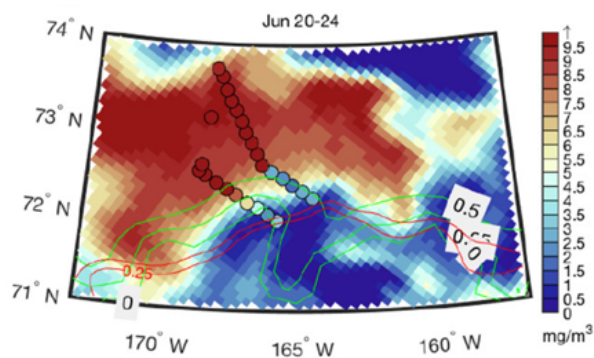


# HILAT-RASM: HIGH-LATITUDE APPLICATION AND TESTING OF EARTH SYSTEM MODELS – PHASE II

The polar regions are changing faster than anywhere else on Earth. Thawing permafrost, melting ice sheets, disintegrating ice shelves, and retreating sea ice have all made headlines in recent years. These changes pose challenges and provide opportunities for the nation and the U.S. Department of Energy (DOE). For instance, permafrost degradation and sea-level rise threaten coastal and arctic energy infrastructures, but a seasonally ice-free Arctic may also open up new areas for commercial shipping. A thorough understanding of the high-latitude environment and its connection to the rest of the planet is important to address these challenges and opportunities.

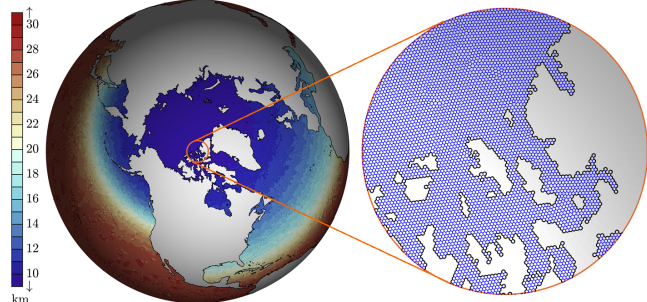
High-latitude changes also have other important effects, through impacts on the uptake of carbon dioxide in the oceans, and release of methane frozen underground and at the ocean bottom, and with dramatic impacts to land and ocean ecosystems.

The High-Latitude Application and Testing of Earth System Models (HiLAT) Science Focus Area, in collaboration with the Regional Arctic Systems Model (RASM) project, addresses questions regarding arctic and antarctic environmental change of importance to DOE and the nation.



Surface chlorophyll distribution in the northern Chukchi Sea during June 20-24, 2011, simulated by the Regional Arctic System Model. The figure shows a plankton bloom underneath the sea ice. The circles represent the observed concentrations during the July 2011 ICESCAPE cruise. The contours represent observed (green) and modeled (red) sea ice concentrations.

E3SM-ARRM-Ocean: Resolution and Grid Structure

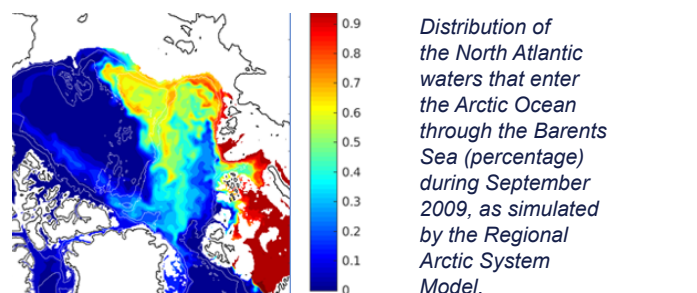


The HiLAT-RASM team uses the variable-resolution capabilities of Energy Exascale Earth System Model to resolve important fine-scale processes in the Arctic Ocean.

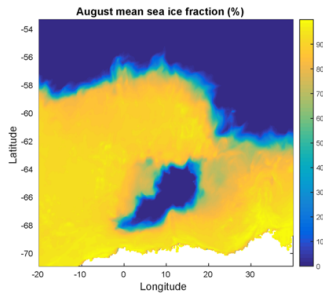
## REGIONAL AND GLOBAL CHANGES

The high-latitude earth systems are strongly coupled to the lower latitudes through exchange processes. For instance, the atmospheric storm systems that transport heat from the tropics to the pole are also responsible for the outbreaks of cold air and snow reaching lower latitudes that can have a big impact on society. Similarly, the ocean's overturning circulation affects arctic sea ice by transporting heat poleward, but affects weather at lower latitudes as well. In turn, these exchange processes are strongly influenced by high-latitude processes that amplify environmental change compared to other places on the planet.

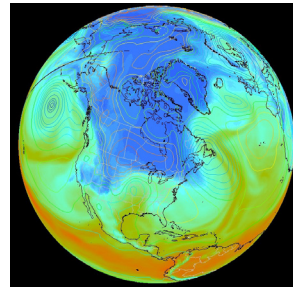
The HiLAT-RASM team is a multidisciplinary group taking an integrative approach to understand these processes and their impact on the planet to improve next-generation earth system models (ESMs), and to better understand how these processes affect the predictability of the high-latitude environmental features. The group uses ESM simulations to explore four themes.



Distribution of the North Atlantic waters that enter the Arctic Ocean through the Barents Sea (percentage) during September 2009, as simulated by the Regional Arctic System Model.



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



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

**Theme 1: The role of sea ice in mediating meridional heat transports in the ocean and atmosphere.**

Heat transport from low to high latitudes is a central component of the Earth’s heat budget, but the processes that control this heat exchange, and the partitioning of transport between the ocean and atmosphere, are not well understood. This theme investigates how changes in sea ice cover affect that partitioning, and what the consequences are for the earth system if heat transport changes as sea ice decreases.

**Theme 2: The role of fine-scale and transboundary transport processes in arctic change**

The transport of heat, water, and aerosols into the Arctic depends on processes that are not well represented in ESMs. Examples are processes that are relatively short-lived and small scale (like the filamentary streams of water vapor called atmospheric rivers that are important in delivering water to the Arctic), or that are very complex and involve interactions between several earth system components (such as the volume and composition of river outflow into the Arctic Ocean, and its impact on marine ecosystems). This topic investigates the sensitivity of arctic environmental change to improved representation of these fine-scale processes.

**Theme 3: Extra-polar impacts of arctic change**

With the arctic environment changing so dramatically, how does this influence weather and climate at lower latitudes? Does arctic sea ice decline affect the frequency and intensity of winter storms in the United States? Is it affecting the strength of the ocean’s overturning circulation, and possibly the strength of tropical hurricanes? Theme 3 will address such questions.

**Theme 4: Decadal predictability of high-latitude environmental change**

Finally, how can we use this improved understanding of exchange processes and their impacts to improve predictions of high-latitude environmental change? Are there opportunities for improving the description of changes that may occur over the next five to 10

years? Researchers plan a combination of approaches to understand how to better use observations and models to improve this kind of prognosis of high-latitude environmental change.

**OUTLOOK**

The team’s research aims to improve understanding of the complex interactions among the high-latitude earth system components, and how component interactions shape the evolution of the high-latitude environment in the presence of increasing greenhouse gases and land use change. The development of a new generation of ESMs with flexible meshes under DOE’s Energy Exascale Earth System Model (E3SM) project provides opportunities to address these complicated issues with increasing levels of detail. At the same time, developments in statistical approaches help researchers to interpret results more rigorously.

HiLAT-RASM is a collaborative effort of scientists at Los Alamos National Laboratory, Pacific Northwest National Laboratory, the Naval Postgraduate School, University of Washington, and University of Colorado, Boulder. It is funded by the DOE Office of Science, Regional and Global Model Analysis (RGMA) program.

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