Remote Sensing of the Cryosphere

AT A GLANCE

Why the cryosphere?

The U.S. Navy needs snow depth and sea ice forecasting capabilities that meet stringent year-round spatial resolution and coverage requirements for polar operations.

What are we doing?

Understanding the physics behind how snow and ice are viewed by passive microwave and visible/infrared (Vis/IR) sensors (e.g. AMSR, VIIRS, and SMAP satellites or ship-based sensors) and modeling these phenomena.

What are the goals?

This basic research will lead to both (1) operational algorithms exploiting passive microwave and visible/IR satellite data with the ultimate goal of operational sea ice concentration and sea ice thickness forecasting algorithms in the polar regions, and (2) sensors for increased Arctic battlespace awareness.

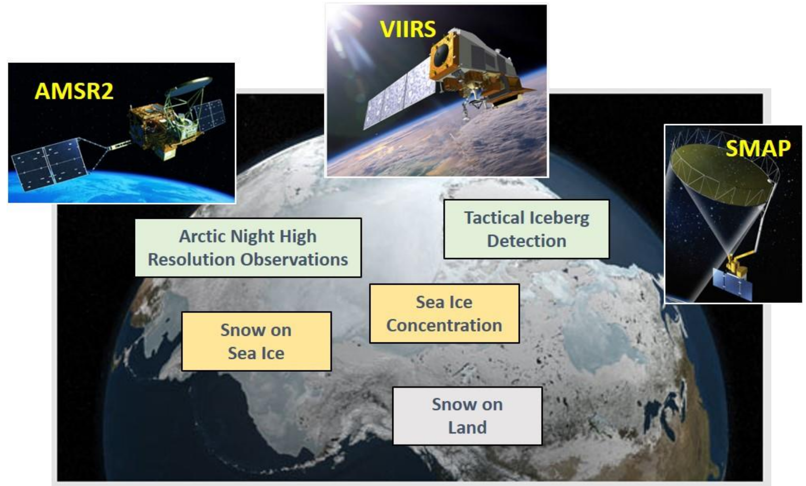
R&D Sponsor

Office of Naval Research (ONR)

Points of Contact

Dr. Elizabeth Twarog
202.767.9130
Elizabeth.Twarog@nrl.navy.mil

Dr. Li Li
202.767.0849
Li.Li@nrl.navy.mil



Cryosphere and Spaceborne Cryosphere-Imaging Sensors

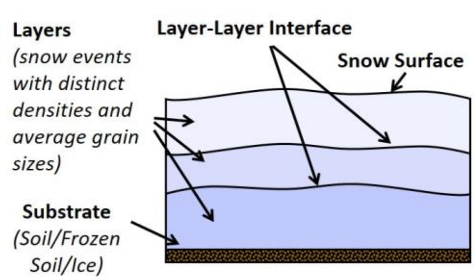
Code 7223 has a cryosphere research focus on understanding and utilizing the phenomenology of passive microwave and Vis/IR signatures of snow and sea ice in the Arctic. Radiative transfer modeling and satellite-based spectral analysis are vital tools for this research. The programs highlighted here build the theoretical basis for future operational algorithms and sensors.

Snow depth and snow water equivalent on both land and ice are vitally important to cold weather tactical mobility and gap-crossing capabilities, as well as for numerical weather prediction. High-resolution Arctic sea ice concentration data is vital for the safe transport of ships and submarines year round. Knowledge of iceberg location increases battlespace awareness in the Arctic Ocean and provides greater operational flexibility for non-ice-hardened vessels.

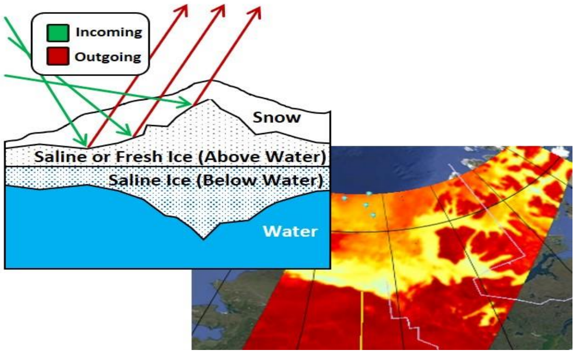
Snow on Land

Objective: Create a novel algorithm for snow depth and snow water equivalent estimates on land by combining passive microwave and Vis/IR observations with dense media radiative transfer and snowpack morphology model predictions.

Knowledge of snow depth and snow water equivalent has strategic (mobility) and climatological (land surface modeling) importance to the Navy. We model snowpack using the Snow Microwave Radiative Transfer (SMRT) framework and evolve it using a morphology model. We have investigated model responses to variations in different snowpack bulk properties to lay the groundwork for a future snow retrieval algorithm.



Snowpack modeling



Layered snow and ice modeling with satellite validation

Snow on Sea Ice

Objective: Develop a radiative transfer model to accurately characterize upwelling passive microwave emissions from snow on sea ice.

Uncertainty in the depth of snow on sea ice is one of the largest sources of error in sea ice forecast models and is also the largest source of error in satellite estimates for sea ice thickness. The goal of this research is to provide accurate global retrievals of snow in order to improve satellite-based sea ice thickness measurements and medium/long term sea ice forecasting. We aim to build a physically-based dense media radiative transfer model to investigate and accurately characterize upwelling microwave emission signatures from bulk properties (e.g. depth, salinity, density, grain size) of sea ice and the snowpack.

We are extending the SMRT modeling from the Snow on Land project to include the ice substrate and incorporate an ice surface roughness model with a new NRL sea ice surface spectrum. The SMRT model inputs are physical ground truth parameters from Arctic field campaign in situ ice cores and snow pits, and will be validated with AMSR satellite data.

Glacial Ice Warning System

Objective: Design a shipboard passive microwave radiometric system to enhance tactical awareness during near-ice navigation for Navy vessels with emphasis on small iceberg detection (< 60 m length).

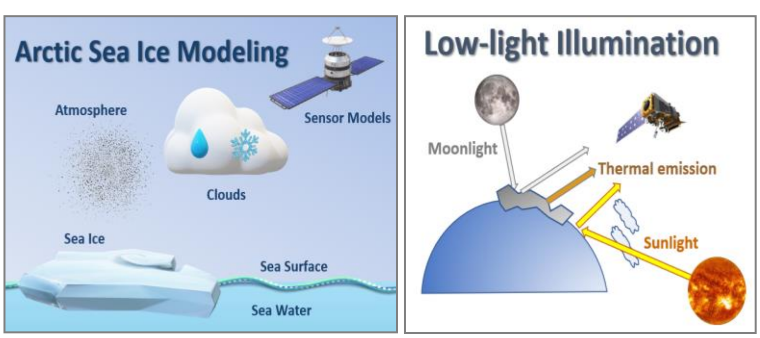
Passive microwave shipboard small iceberg detection sensor

Arctic icebergs are usually freshwater remnants of the Greenland ice sheet and are hazardous due to their high density and the large proportion of mass below the sea surface. They have low radar cross sections and are difficult to detect from space. We will combine established models into a simulation tool to evaluate radiometric sensitivity in polar conditions from a ship-board geometry, incorporate empirical data, quantify system performance metrics and design a radiometric system for ice navigation.

Arctic Nighttime Sea Ice Remote Sensing

Objective: Investigate the spectral signatures of visible to long-wave IR of the Arctic sea ice under the previously-unstudied low-light conditions of twilight, moonlight, and cloud shadow.

Current operational Vis/IR sea ice concentration algorithms have no high-resolution forecast capability during the Arctic winter due to the lack of understanding of the physics of the input satellite data acquired under low-light conditions.



3D radiative transfer modeling of low-light Arctic illumination

This project investigates and models the physical processes observed by satellites in Arctic low-light conditions using 3D radiative transfer modeling of clouds and below-horizon twilight illumination. This will result in an understanding of both the physical processes associated with the interaction between twilight illumination and sea ice and clouds as well as the phenomenology of Vis/IR sensors that produce high resolution sea ice observations during the Arctic winter.