PERMAFROST PATHWAYS

Connecting science, people, and policy for Arctic justice and global climate

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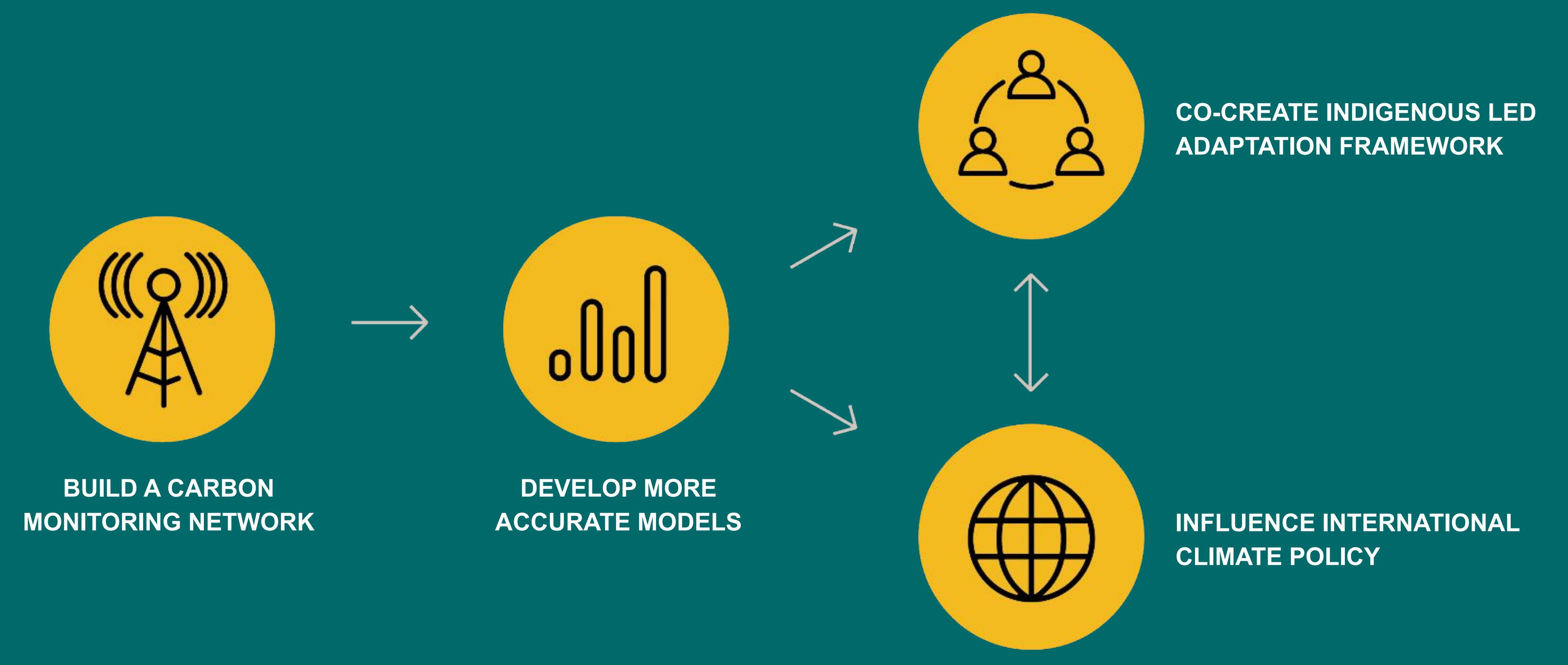
Background

The arctic and boreal regions are warming at more than twice the global rate, with temperatures already greater than 2°C above preindustrial levels. Rapid warming is intensifying wildfires and thawing permafrost, both of which are transforming northern ecosystems and creating hazardous conditions that are forcing arctic communities to make difficult and urgent adaptation decisions. These changes can also impact global climate through carbon feedbacks, and thus there is an urgent need to reduce the uncertainties that observational and modeling gaps create in understanding the current and future state of permafrost feedbacks. Despite this need, at present, not even current scientific understanding of future emissions from a warming Arctic is reflected in most climate policy planning.

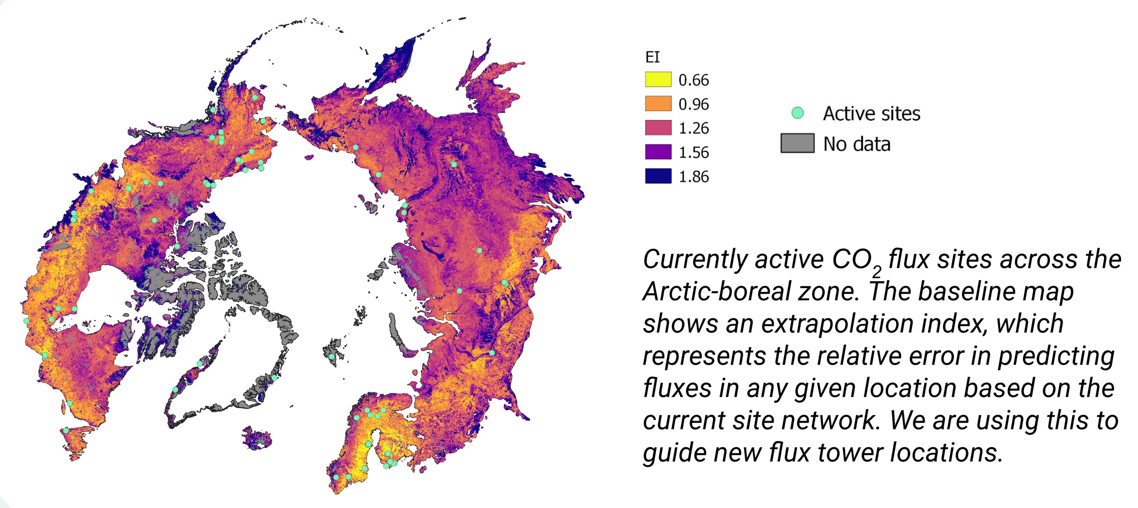
Here we present our strategy to address these issues through a six-year science and policy project, Permafrost Pathways. Our scientific approach includes coordinating and expanding the network of CO_2 and CH_4 eddy covariance sites across the permafrost zone, remote sensing of landscape disturbances, and developing a data assimilation ecosystem model to project carbon-climate feedbacks under various policy scenarios. We will work in partnership with local leaders and national policymakers to harness these data to support Arctic community adaptation and appropriate climate mitigation policy. We plan to work closely with members of the ABoVE community and contribute to ABoVE objectives regarding permafrost thaw, carbon cycling, disturbances, hydrology, modeling, climate feedbacks, knowledge co-production, and mitigation and adaptation solutions.



Monitoring & Modeling

Flux Networks

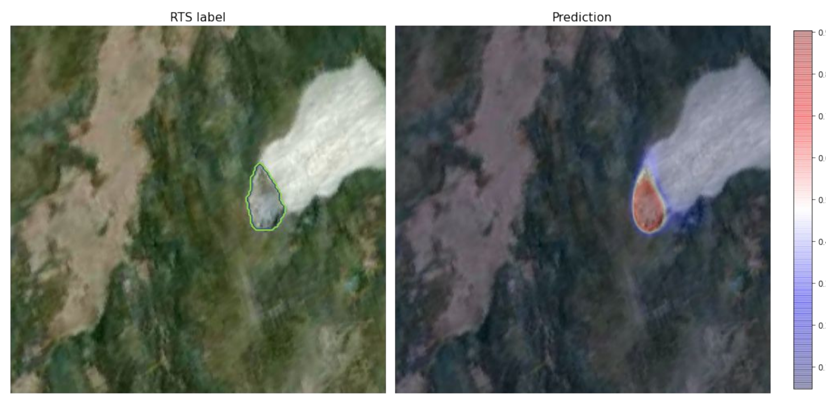
In collaboration with members of the international flux community, we are working towards a more comprehensive ground network of CO_2 and CH_4 eddy covariance sites across the Arctic-boreal zone. This includes collating and synthesizing past observations, supporting and augmenting current towers, and establishing new sites.



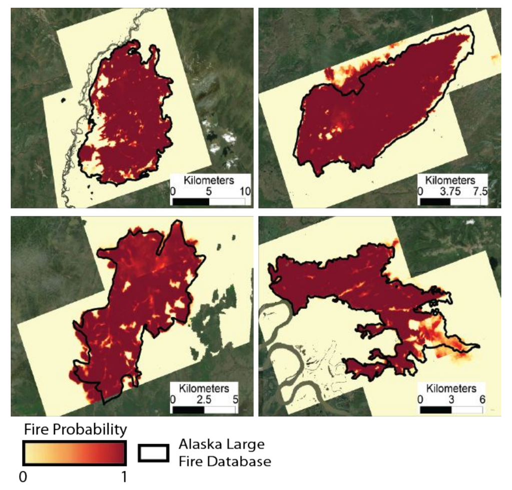
Currently active CO_2 flux sites across the Arctic-boreal zone. The baseline map shows an extrapolation index, which represents the relative error in predicting fluxes in any given location based on the current site network. We are using this to guide new flux tower locations.

Remote Sensing

Using remote sensing and machine / deep learning techniques, we will produce pan-Arctic maps of wildfire extent and carbon emissions, changing hydrology, abrupt permafrost thaw, and upscaled CO_2 and CH_4 fluxes. Mapping will be facilitated by ground data collected by project scientists, volunteers, and our partners including Indigenous community members.



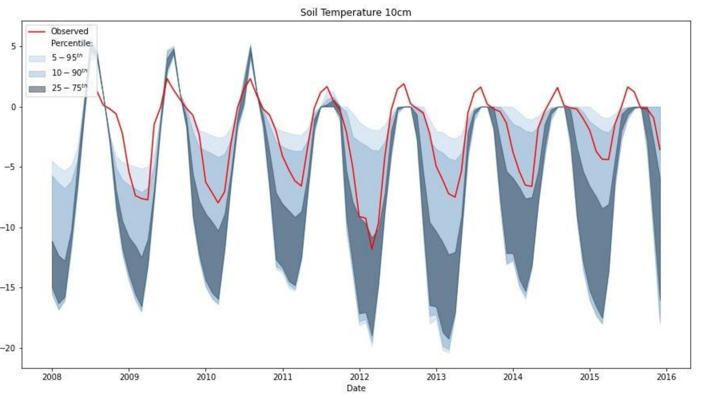
Preliminary model results of mapping retrogressive thaw slumps in the Yamal and Gydan Peninsulas, Siberia. A convolutional neural network is trained using high-resolution imagery from Maxar, the Arctic DEM, and Landsat NDVI.



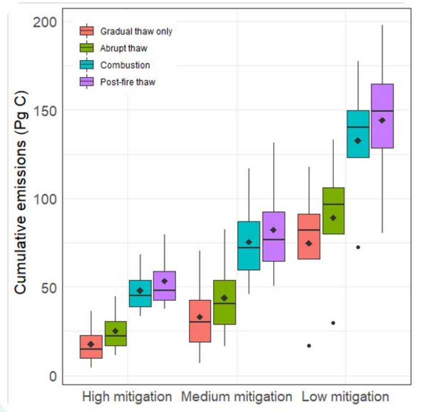
Convolutional Neural Network model predictions of fires in Alaska. The model was trained on fires exclusively in Canada. Differences between model predictions and government fire polygons (shown in black) are largely attributable to unburned patches and inaccuracies in polygon delineation.

Modeling

We are building a data assimilation version of the DVM-DOS-TEM model in order to better constrain parameters and provide accurate initial conditions. We are also further developing the model's capacity to represent wildfire, abrupt permafrost thaw, CH_4 fluxes, and aquatic transport and fluxes. The model will be run at 1-2 km resolution across the Arctic-boreal zone to provide historical assessments, near-term forecasts, and longer-term projections. We will use model outputs to inform policy scenarios using a compact Earth System model (OSCAR).



Model-data comparisons of soil temperature at Toolik Field Station from a comprehensive parameter sensitivity analysis within DVM-DOS-TEM.



Cumulative emissions (Pg C) from 2022 to 2100 under high mitigation effort (low warming; SSP2 - RCP 1.6), medium mitigation (medium warming; SSP2 - 4.5 & SSP4 - 6.0), and low mitigation (high warming; SSP5 - 8.5). Colors indicate model configuration. Processes are incorporated in model configuration in a stepwise manner. Diamond points indicate mean values.

Mitigation

Translating our collective science (in partnership with ABoVE) into impact is one of our primary project goals. With updated data and models that reduce uncertainty in permafrost emissions, we will supply policymakers at varying levels of government with information to incorporate permafrost into international climate mitigation policy, and continually communicate the level of risk associated with permafrost carbon feedbacks.

Adaptation

Permafrost thaw is putting Arctic communities at risk. Working closely with climate scientists, Indigenous knowledge holders and Alaska Native tribes who live on land underlain by permafrost, we are applying our monitoring and modeling tools to assess the current and future impacts of permafrost thaw and co-create equitable adaptation plans that respect and protect the health, well-being, and human rights of Arctic residents.