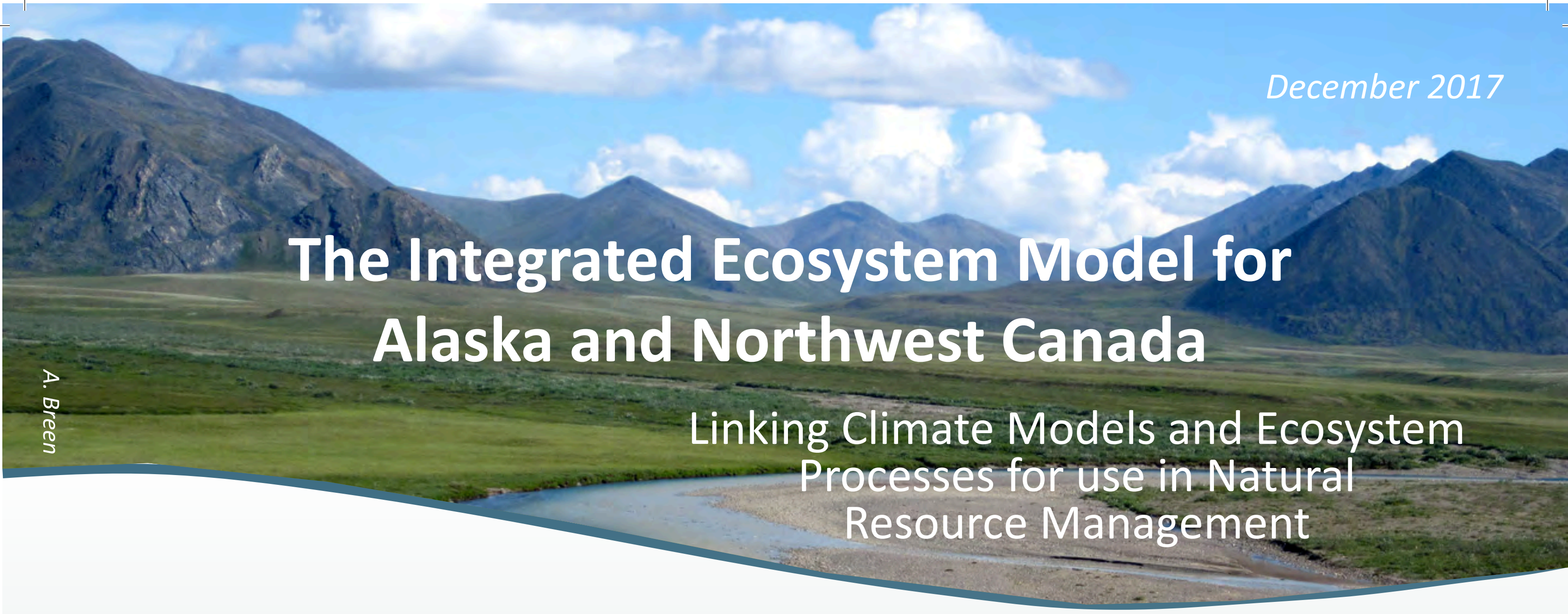

December 2017

The Integrated Ecosystem Model for Alaska and Northwest Canada

Linking Climate Models and Ecosystem Processes for use in Natural Resource Management

The Integrated Ecosystem Model is designed to help resource managers understand the nature and expected rate of landscape change. Maps and other products generated by the IEM will illustrate how arctic and boreal landscapes are expected to alter due to climate-driven changes to vegetation, disturbance, hydrology, and permafrost. The products will also provide resource managers with an understanding of the uncertainty in the expected outcomes.

Fire, vegetation, and permafrost are a few of the many factors that will be considered in the IEM.

The Integrated Ecosystem Model—also known as the IEM—is a project that links changing climate scenarios and three different models of ecological processes:

The Alaska Frame-Based Ecosystem Code (ALFRESCO)

ALFRESCO simulates wildland fire, vegetation establishment, and succession. These are the dominant landscape-scale ecological processes in boreal ecosystems and potentially of increasing importance in tundra ecosystems as well.

The Terrestrial Ecosystem Model (TEM)

TEM simulates characteristics of organic and mineral soils, hydrology, vegetation succession, plant community composition, biomass, and carbon balance in soil. These characteristics have important influences on ungulate populations and other resources important for subsistence by people in Alaska and northwest Canada. Resource managers want to better understand how these dynamics may change due to climate change.

The Geophysical Institute Permafrost Lab model (GIPL)

GIPL simulates permafrost dynamics—such as active layer thickness (the depth of summer seasonal thaw in perennially frozen ground), changes in soil temperature and changes in permafrost extent. Changes in permafrost can trigger substantive changes in hydrology, carbon cycling, and landscape structure, impacting both the ecosystems and the built environment (infrastructure).

The individual models simulate key processes influencing how the landscapes of Alaska and northwest Canada may respond to climate change. However, these processes do not act in isolation—each influences processes in the other component models. Thus linking ALFRESCO, GIPL, and TEM together should produce a more realistic picture of potential future landscape conditions by more accurately simulating known interactions of ecosystem components and physical processes.

The IEM is also developing new functionality so it can better simulate additional ecosystem dynamics:

Tundra fire and treeline dynamics: Representing tundra succession and disturbance dynamics will allow the IEM to better forecast landscape changes to vegetation and wildlife habitat.

Landscape-level thermokarst dynamics: Thermokarst, the characteristic landscape formed by thawing of ice-rich permafrost, is the dominant feature of much of the arctic and subarctic and are increasing in those areas. The dynamics of these landscapes are associated with subsidence and can result in substantial shifts in vegetation and habitat.

Wetland dynamics: Wetland dynamics are important to represent because of their prevalence and importance in northern landscapes.

Forecasting changes in vegetation structure and composition can help resource managers understand ecosystem connections and make decisions about subsistence species, such as caribou.

What type of data products will the IEM generate?

The IEM generates a broad variety of datasets for use by land and resource managers as well as researchers. The geographic domain of the IEM is based on ecological rather than political boundaries, so its products are a valuable resource for entities focusing on landscape issues that do not necessarily stop at the Alaska-Canada border. Different categories of data products include: climate, disturbance, landcover and landscape, ecosystem dynamics, soil properties, and model code and documentation. A detailed description of the IEM data products is available in the supplemental insert that accompanies this fact sheet (see back page for more information).

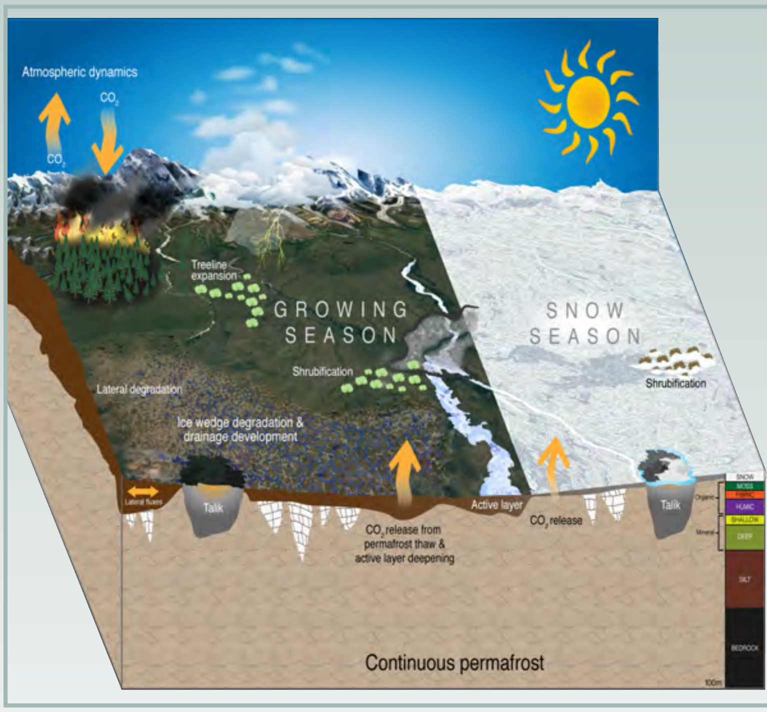

Figure 1. *The Arctic Alaska landscape showing the coupled nature of disturbance, biochemistry, permafrost and vegetation dynamics that are included in the IEM.*

What climate models and scenarios are used by the IEM? Why were they selected?

All three models within the IEM require information about air temperature, precipitation, and other climate-related variables (e.g. vapor pressure deficit and cloudiness). The source of this information can either be historical data or future climate scenarios generated by General Circulation Models (GCMs). Two GCMs, operating under the moderate A1B (i.e., mid-range) emissions scenario, were chosen to represent the range of warming and precipitation expected to occur across Alaska. The Canadian Centre for Climate Modeling and Analysis General Circulation Model 3.1 - t47 (CCCMA-CGCM3.1(T47)) and the Max Planck Institute for Meteorology European Centre Hamburg Model 5 (MPI-ECHAM5/MPI-OM)) were chosen among a suite of 15 IPCC Fourth Assessment Report (AR4) GCMs ranked among the top five for performance across Alaska and the Arctic (Walsh et al., 2008). These two climate models were selected specifically because they bound the uncertainty associated with ALFRESCO simulations for future fire regime. MPI-ECHAM5/MPI-OM climate produces the greatest burned area, while the CCCMA-CGCM3.1 (T47) climate produces the lowest estimates of burned area.

Starting in 2017, the IEM will transition from using climate projections based on the AR4 models and the A1B scenario to a new generation of IPCC Fifth Assessment Report (AR5) GCMs. The AR5 models selected include NCAR-CCSM4 and MRI-CGCM3. Projections use representative concentration pathways, or RCPs. RCPs (i.e. RCP4.5, RCP6.0, and RCP8.5) are defined by varying degrees of “radiative forcing,” or the balance between incoming and outgoing radiation. A positive forcing (more incoming radiation) tends to warm the system, while a negative forcing (more outgoing energy) tends to cool the system. Increasing concentrations of greenhouse gases, such as carbon dioxide, cause a positive forcing. The RCP 8.5 scenario is the most extreme case, where radiative forcing reaches 8.5 W/m^2 (watts per meter squared) by 2100 and continues to rise (Moss et al. 2010). RCP’s 4.5 and 6.0 are mid-range scenarios where radiative forcing reaches 4.5 W/m^2 or 6.0 W/m^2 by 2100, but subsequently stabilizes at that level. The RCP selected for the IEM is RCP 8.5, although model results for all three RCPs will be available by request.

Figure 2. (Left) The Alaska and northwest Canada geographic domain for the IEM and location of Landscape Conservation Cooperatives (LCCs). Note that a portion of the Northwest Boreal LCC (Mackenzie and Selwyn Mountains) is not included in the IEM domain due to the lack of PRISM data used for downscaling GCM projections. The Aleutian and Bering Sea Islands are also not included because the dominant ecosystem processes at work in this maritime environment are not well represented by the IEM. Graphic created by SNAP.*

What area is covered by the IEM?

The IEM domain covers most of Alaska, the Yukon Territory, and portions of northern British Columbia (Figure 2), coinciding with the western portion of the Arctic, Northwest Boreal, northern portion of the North Pacific, and Western Alaska LCCs.

How are the models linked together?

There are two different methods used to link the components of the IEM together. One method, referred to as linear coupling, allows for the exchange of information between models to occur in series. For example, data generated by the first model in the series is used as input for a second model, and output from the second model is subsequently used as input for the next model. The second method, referred to as cyclical coupling, allows data outputs to be exchanged among all models and incorporates the output for the next time step. The IEM output generated by linear coupling mode is identified as Generation 1 and data generated by cyclical coupling is called Generation 2 (Figure 3).

How will the accuracy of the IEM be evaluated?

The outputs from the IEM are compared to historical observations from Alaska and Northwest Canada. Comparisons assess the accuracy of modeled vegetation distribution, historical burned area, fire size distribution, forest age class distribution, vegetation biomass, thickness of soil organic horizons, soil carbon stocks, leaf area index, soil temperature, soil moisture, snow water content, and distribution. Other accuracy assessments will be added as new data sets become available.

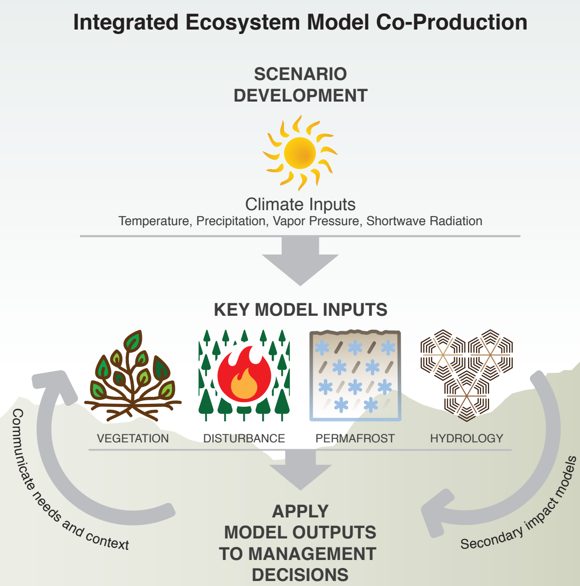

Figure 3. (Right) The Integrated Ecosystem Model co-production process, including model coupling. Examples of IEM outputs include vegetation (land cover, treeline extent, growth and carbon dynamics, growing season length), disturbance (wildfire, secondary succession, thermokarst), permafrost (active layer depth, ground temperature, subsidence), and hydrology (soil moisture, thaw lake dynamics, patterned ground dynamics). Potential secondary impact model applications include habitat assessment, fire risk, access for subsistence, and identifying hotspots of change.*

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What has been accomplished?

The project's pilot phase (2010-2011) conducted a proof-of-concept study linking ALFRESCO, TEM, and GIPL over the Alaska Yukon River Basin. The second phase of the project (2011-2016) resulted in completion of Generation 1 IEM outputs, linking a new version of ALFRESCO, TEM, and GIPL over the entire IEM domain for historical climate and the ECHAM5 and CCCMA model simulations for the A1B scenario. Highlights of these simulations include:

Wildfire & Vegetation Dynamics: Fire frequency and area burned have increased in recent years across the region, and the trend is projected to continue into the future for both climate models. The boreal region is projected to see the highest increase in fire activities, with coniferous forest projected to decline, and deciduous forest projected to increase. In tundra regions, shrub tundra is projected to increase and graminoid tundra to decrease.

Ecosystem Carbon Dynamics and Energy Balance: The IEM region was a small sink for carbon during the historical period and becomes a much stronger sink for carbon in the future. Changes in snow cover duration provided the dominant positive biogeophysical feedback to climate across the region. The greatest overall negative feedback to climate from changes in vegetation cover was due to fire in the coniferous boreal forest, and fire in shrub tundra in western Alaska.

Permafrost Dynamics: Simulations of future changes in permafrost indicate that by the end of the 21st century late Holocene permafrost in the region will be actively thawing and even some Late Pleistocene permafrost will begin to thaw at some locations. Ecosystem types and fire disturbances affect the thermal state of permafrost and their stability. Although the rate of soil warming and permafrost degradation in peatland areas are slower than other ecotypes, a considerable volume of peat within the region is projected to thaw by the end of the current century.

Thermokarst Modeling: We successfully developed a conceptual framework for the Alaska Thermokarst Model (ATM) as a stand-alone state-and-transition module that simulates landscape transitions for thermokarst landforms. We developed transition rules for both tundra and boreal ecosystems, and a land cover map for the Arctic Coastal Plain of Alaska to be used by the ATM.

Scientists collect data in the field to determine how tundra vegetation and soils respond to fire and accumulate fuel over time. A better understanding of post-fire vegetation processes will improve forecasts of future tundra habitats and is important to inform land managers of the implications of a potentially changing fire regime.

What can we expect from the IEM team in the future?

We will complete the Generation 2 coupling of the IEM framework by the end of 2018. We will conduct research to add new functionality to the IEM, including the implementation of herbivory and associated vegetation dynamics in ALFRESCO, with applications focused on caribou and moose. We will also implement successional vegetation and wetland biogeochemical capabilities into DVM-DOS-TEM. The ATM will be applied outside of the original test areas, in all of Interior Alaska and the entire Arctic Coastal Plain. The ATM will also be dynamically coupled to the IEM framework to represent the effect of thermokarst dynamics on ecosystem processes.

Where can I learn more about the IEM?

More detailed information about the research plan, project objectives, and data products for each project year (2013-2016) are available in a supplementary table (v) and in the IEM Interim Progress Report (https://csc.alaska.edu/resource/interim-progress-report-IEM).

Contact Information

Brad Griffith, Principal Investigator
Integrated Ecosystem Model for Alaska and Northwest Canada
dbgriffith@alaska.edu

Steve Gray, Director
Alaska Climate Science Center
sgray@usgs.gov

Amy Breen, Asst. Research Professor
Scenarios Network for Alaska & Arctic Planning (SNAP)
albreen@alaska.edu

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