April 2015

The Integrated Ecosystem Model for Alaska and Northwest Canada

A. Breen

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.

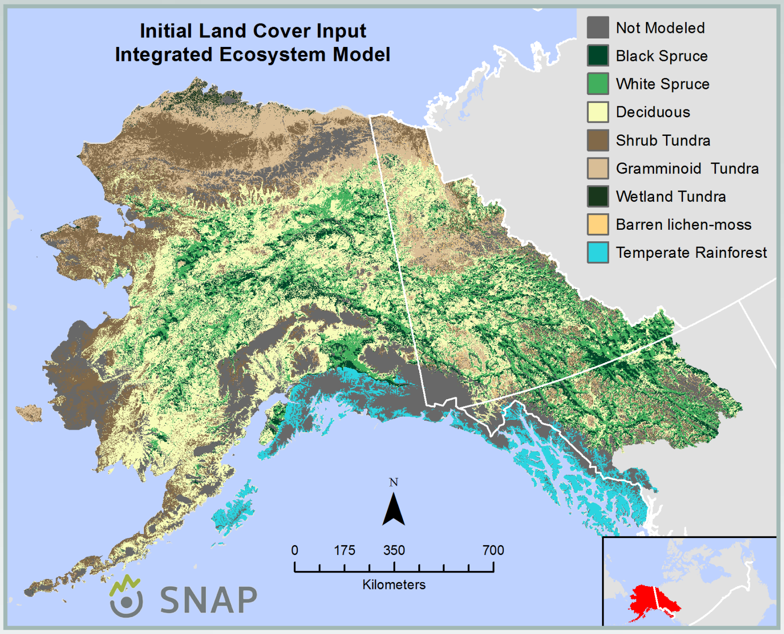
The IEM is also developing new functionality so it can better simulate additional ecosystem dynamics:

Tundra fire and treeline dynamics: Representing tundra succession and disturbance dynamics will allow the IEM to better forecast landscape changes in western Alaska.

Landscape-level thermokarst dynamics: Thermokarst, the characteristic landscapes 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 will generate 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 will be 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. *(Left) The initial land cover input to the IEM. This input is modified from the North American Land Change Monitoring System (NACLMS) and was created by SNAP for use in landscape scale modeling studies. Graphic created by SNAP.*

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) and the Max Planck Institute for Meteorology European Centre Hamburg Model 5 (ECHAM5) 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. ECHAM5 climate produces the greatest burned area, while the CCCMA climate produces the lowest estimates of burned area.

Starting in 2015, 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 and projections that 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.

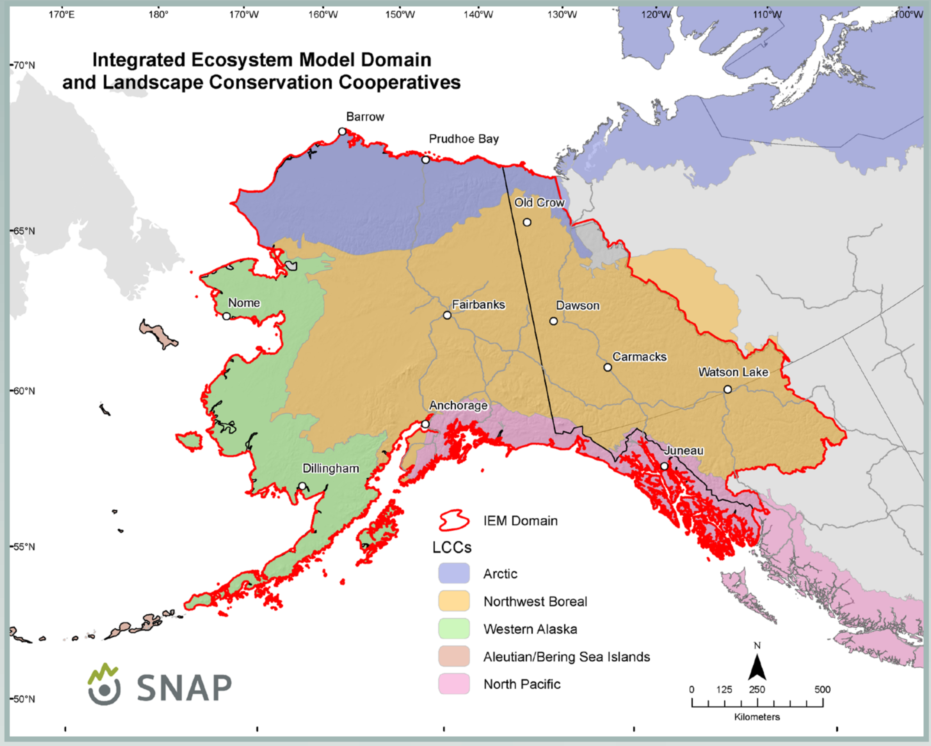


Figure 2. *(Left) The Alaska and northwest Canada geographic domain for the IEM and location of Landscape Conservation Cooperatives (LCCs). Note that a portion of the Northwest Boreal LCC (Mackenzie and Selwyn Mountains) is not included in the IEM domain due to the lack of PRISM data used for downscaling 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.*

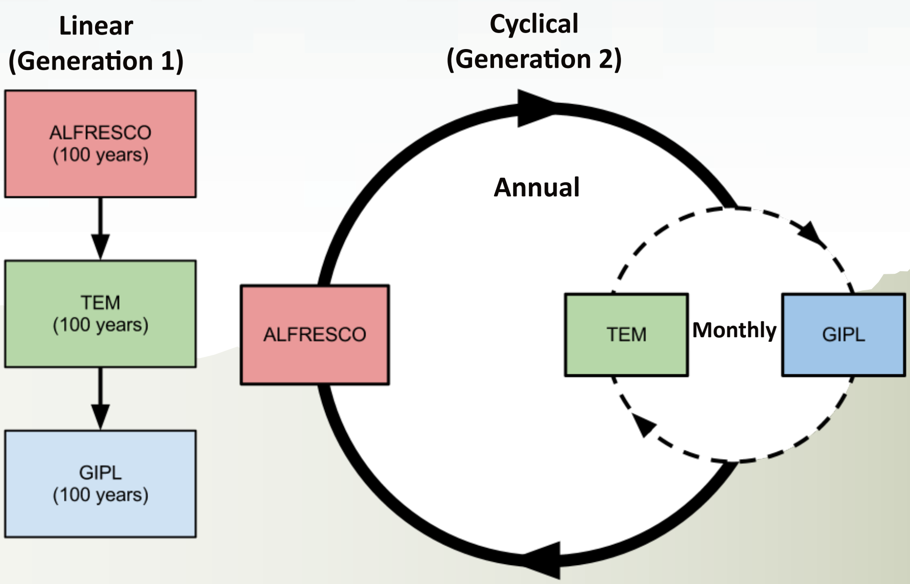
What area is covered by the IEM?

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).

Figure 3. *Diagram showing the linear and cyclical coupling methods used to link the three models that comprise the IEM. Graphic created by SNAP.*



How will the accuracy of the IEM be evaluated?

The outputs from the IEM will be compared to historical observations from Alaska and Northwest Canada. Comparisons will 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.

References:

Commission for Environmental Cooperation (CEC). 2010. 2005 North American Land Cover at 250 m spatial resolution. Produced by Natural Resources Canada/Canadian Centre for Remote Sensing (NRCan/CCRS), United States Geological Survey (USGS); Insituto Nacional de Estadística y Geografía (INEGI), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and Comisión Nacional Forestal (CONAFOR).

Moss, R.H. et al. 2010. The next generation of scenarios for climate change research and assessment. Nature 463: 747-756. Available at: http://dx.doi.org/10.1038/nature08823

Rupp, T.S. et al. 2012. Integrated Ecosystem Model for Alaska: a collaborative project for the Arctic Landscape Conservation Cooperative. Final report 20 January 2012. 30 p. CESU agreement #701817K403, FWS #0002/701819T060 Task Order #2. Available at http://arcticlcc.org/assets/products/ARCT2010-05/reports/AIEM_Final_Report_20Jan2012.pdf

Walsh, J.E. et al. 2008. Global climate model performance over Alaska and Greenland. Journal of Climate 21:6156-6174, doi:10.1175/2008JCLI2163.1

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. Since 2012, the IEM project has conducted a Generation 1 application, 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. The new version of ALFRESCO represents more sophisticated tree line and tundra dynamics. Highlights of these simulations include:

Fire: In the boreal sub-region, 1.58 times more area burned under the warmer and drier ECHAM5 than CCMA. In the tundra sub-region 1.89 times more area burned under ECHAM5 than CCMA.

Vegetation Change: The more moderate CCCMA-driven fire regime led to an approximately 12% conversion of tundra to forest and a decrease of both graminoid and shrub tundra through the 21st century. The greater fire activity of the ECHAM5 scenario led to an approximately 6% conversion of tundra to forest, a loss of graminoid tundra (~24%) and an increase in shrub tundra (~11%) through the 21st century.

Vegetation Productivity: In the boreal forest, productivity increased by about the same amount under the two projections. In contrast, tundra productivity increased considerably more under the ECHAM5 projection than under the CCCMA projection.

Soil Carbon Storage: During the 21st century, soil carbon stocks increased in both forest and tundra ecosystems, but the increase in soil C stocks was greater under the CCCMA projection than under the ECHAM5 projection.

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?

Work will continue toward completing Generation 2 simulations. Applications of the Alaska Thermokarst Model for the Barrow Peninsula and for Interior Alaska wetland complexes (the Tanana and Yukon Flats) are being conducted. The IEM group will continue to work with the projects making use of the IEM outputs to assess the impacts of climate change on natural resources and their management.

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 (https://csc.alaska.edu/resource/integrated-ecosystem-model) and in the IEM Interim Progress Report (https://csc.alaska.edu/resource/interim-progress-report-IEM).

Contact Information:

David McGuire, Principal Investigator
Integrated Ecosystem Model for Alaska and Northwest Canada
admcguire@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

This research is funded by the Arctic, Western Alaska, and Northwest Boreal Landscape Conservation Cooperatives and the Alaska Climate Science Center. The AK CSC was established in 2010 by the U.S. Department of the Interior to bring together the expertise of federal and university scientists to address the priorities of federal, state, and tribal resource managers.

UAF is an affirmative action / equal opportunity employer and educational institution.

The project described in this publication is supported by Grant/Cooperative Agreement Number GIOAC00588 from the United States Geological Survey. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USGS.

IEM PRODUCTS & DELIVERABLES

MARCH 2015

The Integrated Ecosystem Model (IEM) is designed to help resource managers understand the nature and expected rate of landscape change. Products generated by the IEM will illustrate how landscapes are expected to shift due to climate-driven changes to vegetation, disturbance, hydrology, and permafrost. The following tables provide a detailed description of the IEM's anticipated products and deliverables for the 2012–2016 period.

IEM products are specified as Generation 1 (Gen 1) if produced by the linear coupled model and Generation (Gen 2) if produced by the cyclical coupled model. They are driven by the ECHAM-5 and CCCMA climate models for the mid-range A1B emissions scenario. The IEM products are developed for the full geographic extent of the IEM domain, and provided on an annual time-step unless otherwise indicated.

For questions about data, please contact the IEM data manager, Tom Kurkowski at takurkowski@alaska.edu.

PRODUCT DEFINITIONS

Spatial: GIS data (generally in raster .geotiff format or occasionally shape files)

Tables: A summarization of a metric over specific region (generally in .csv format for ease of use in spreadsheet or statistical programs).

Graphs: A time series of a metric across a region (generally in .png image file).

Code: Programming code of the models.

Data products described in the following tables are available at:

WWW.SNAP.UAF.EDU/PROJECTS/IEM

Climate Products (e.g., temperature, precipitation, radiation, vapor pressure)			
Dataset Name	Data Type	Description	Date Available
Projected average monthly temperatures, precipitation, radiation and vapor pressure (ECHAM5-A1B scenario)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation and vapor pressure from the Max Plank Institute for Meteorology, European Centre Hamburg Model 5 (ECHAM5).	2012
Projected average monthly temperatures, precipitation, radiation and vapor pressure (CCCMA-A1B scenario)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation and vapor pressure from the Canadian Centre for Climate Modeling and Analysis, General Circulation Model 3.1-t47 (CCCMA).	2012
Historical average monthly temperatures, precipitation, radiation and vapor pressure (CRU)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation and vapor pressure from the Climatic Research Unit (CRU) at the University of East Anglia time series (TS) datasets CRUTS 3.1 or CRUTS 3.1.01.	2012
Projected average monthly temperatures, precipitation, radiation and vapor pressure (AR5 models and RCPs)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation and vapor pressure for AR5 climate models that perform well in the Arctic.	June 2015

Ecosystem Dynamics Products (e.g., carbon flux)			
Dataset Name	Data Type	Description	Date Available
Data from wetland field component of the IEM	Spatial (Site specific) Tables Graphs	Observational data such as net ecosystem exchange (NEE), Ecosystem Respiration, (ER), Gross Primary Productivity (GPP), soil temperature, soil moisture, air temperature, solar radiation, CH_4 flux, and CH_4 isotopes. In later years, additional datasets, including soil carbon and nitrogen storage values, modeled rates of permafrost carbon loss, and wetland carbon accumulation will be added.	2013 2014
Carbon fluxes and pools (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Model output data related to carbon fluxes (GPP, Net Primary Productivity, decomposition, carbon released by fire) and carbon pools in soil and vegetation.	March 2015 (Gen 1) December 2015 (Gen 1) August 2016 (Gen 2)

Landcover and Landscape Products (e.g., vegetation type, treeline extent, topography)			
Dataset Name	Data Type	Description	Date Available
Model input land cover	Spatial	Model input landcover for the IEM domain. This data layer is a greatly modified product derived from the “2005 Land Cover of North America at 250 meters, Edition 1.0” dataset produced as part of the North America Land Change Monitoring System (NALCMS). This data was developed as, and focused solely on, model input data requirements, which is a simplification of the landscape.	2012 (Version 0.5) 2015 (Version 1.0)
Elevation, aspect, and slope	Spatial	Modeled elevation (m), aspect, and slope derived from elevation data developed by the PRISM climate group and distributed by ClimateSource via www.climatesource.com or www.prism.oregonstate.edu.	2012
Treeline extent (ECHAM5 and CCCMA-A1B scenario)	Spatial	Derived product depicting projected treeline migration.	March 2015 (Gen 1) August 2016 (Gen 2)
Vegetation distribution (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Modeled distribution of six vegetation types (white spruce, black spruce, deciduous forest, graminoid tundra, shrub tundra, wetland tundra). Graphs and tables showing changes in area of vegetation types through time.	March 2015 (Gen 1) August 2016 (Gen 2)
Relative vegetation change (ECHAM5 and CCCMA-A1B scenario)	Spatial	Derived product depicting relative vegetation change, which is the likelihood of a pixel to transition among vegetation classes, summarized for three time periods (1900-2100, 1900-1999, and 2000-2099).	January 2015 (Gen 1) August 2016 (Gen 2)
Growth dynamics of vegetation (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Maps and graphs showing changes in biomass over time of different plant functional types within six vegetation types (white spruce, black spruce, deciduous forest, graminoid tundra, shrub tundra, wetland tundra).	March 2015 (Gen 1) December 2015 (Gen 1) August 2016 (Gen 2)
Tanana Flats vegetation map	Spatial	Model input landcover for the ATM domain. The developed product is derived from both Landsat 7 ETM+ and JERS1 satellite imagery, at 30 m resolution.	January 2015
Barrow Peninsula geomorphology map	Spatial	Model input landcover for ATM and DVM-DOS-TEM domains. The developed product was derived from the following data products: Landsat-7 ETM+, Quickbird, and IFSAR/LIDAR Digital Elevation Models. Map resolution is at 30 m.	January 2015
Yukon Flats vegetation map	Spatial	Model input landcover for the ATM domain. The developed product is modified from the National Land Cover Database 2001 for Alaska, at 30 m resolution.	June 2015

Soil Properties Products (e.g., permafrost, active layer, soil temperature)			
Dataset Name	Data Type	Description	Date Available
Permafrost distribution Active layer thickness Mean annual ground temperature (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Maps and graphs depicting modeled permafrost distribution, simulated active layer thickness (m), and simulated mean annual ground temperature (°C).	June 2015 (Gen 1) December 2015 (Gen 1) August 2016 (Gen 2)
Soil characteristics (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Modeled soil-related output data, such as soil moisture and soil temperature generated by IEM. These data will be made available by request.	June 2015 (Gen 1) December 2015 (Gen 1) August 2016 (Gen 2)

Disturbance Products (e.g., area burned, burn severity, stand age, thermokarst)			
Dataset Name	Data Type	Description	Date Available
Historical area burned	Spatial	Historical area burned.	2013
Area burned and burn severity (ECHAM5 and CCCMA-A1B scenario)	Spatial Tables Graphs	Model output of area burned and burn severity. Graphs and tables showing annual area burned through time.	March 2015 (Gen 1) August 2016 (Gen 2)
Relative flammability (ECHAM5 and CCCMA-A1B scenario)	Spatial	Derived product depicting relative flammability, which is the likelihood of a pixel to burn, summarized for three time periods (1900-2100, 1900-1999, and 2000-2099).	January 2015 (Gen 1) August 2016 (Gen 2)
Potential susceptibility to thermokarst	Spatial	Modeled data used to identify areas susceptible to thermokarst disturbance. Datasets may include contemporary fractional coverage of thermokarst/wetland landforms, distance from surface to ice rich permafrost, amount of ice in the soil column, drainage efficiency (parameter that describes the ability of the landscape to store water), and soil water content.	June 2014
Thermokarst disturbance	Spatial Tables Graphs	Maps and graphs depicting land cover changes in 1) low-center, flat-center, and high-center polygons on the Barrow Peninsula, 2) fen and bog area in the Tanana and Yukon Flats, and 3) proportion of thermokarst lakes on the Barrow Peninsula and the Tanana and Yukon Flats.	December 2015

Model Code and Documentation Products			
Dataset Name	Data Type	Description	Date Available
IEM program code	Source Code	The IEM Generation 2 (i.e. cyclical coupling) will be made available as source code (available through the http://github.com source management tools) and also packaged in installable Linux packages.	December 2015 (Gen 1) August 2016 (Gen 2)
Alaska Thermokarst Module (ATM) program code	Source Code	The Alaska Thermokarst Module will have source code available via a http://github.com repository, and will also be bundled with the IEM Generation 2 installable Linux packages.	December 2015 (Gen 1) August 2016 (Gen 2)
IEM model code	Source Code	The IEM Generation 1 (i.e. linear coupling) will be made available as installable Linux packages and upon request through GitHub. Usage instructions will be provided with the code.	December 2015 (Gen 1)
IEM model code	Source Code	The IEM Generation 2 (i.e. cyclical coupling) will be made available as installable Linux packages and upon request through GitHub. Usage instructions will be provided with the code.	August 2016 (Gen 2)

WHAT CAN WE EXPECT FROM THE IEM TEAM IN THE FUTURE?

Long-term objectives for the IEM team are to develop datasets for the IEM domain and phase in refinements to the model that are necessary to better understand the potential effects of climate change. The table below outlines the 2013-2016 research activities.

Expectations and Deliverables			
Year	Model Coupling and Data Development	Tundra Fire and Treeline Dynamics	Thermokarst and Wetland Dynamics
2013	▪ Continued development of Generation 1 IEM with new fire and vegetation dynamics. ▪ Continued preparation of all data sets required to drive fully Generation 1 IEM with AR4 climate scenarios. ▪ Begin development of Generation 2 (fully coupled) IEM.	▪ Incorporation of new tundra fire and treeline dynamics program code into the IEM. ▪ Begin study of Generation 1 IEM application to model changing ecosystem services in the Nuiqsut region (collaboration with EPSCoR Northern Test Case). ▪ Support development of Generation 2 (fully coupled) IEM.	▪ Continued development of the Thermokarst Predisposition Model and the Alaska Thermokarst Model. ▪ Recruit postdoctoral scientist for development of wetland dynamics aspects of the IEM.
2014	▪ Complete development of Generation 1 IEM with new fire and vegetation dynamics. ▪ Complete preparation of all data sets required to drive fully Generation 1 IEM with AR4 climate scenarios. ▪ Support assessment using Generation 1 IEM over the complete IEM domain driven by AR4 climate scenarios. ▪ Continued development of Generation 2 (fully coupled) IEM. ▪ Begin preparation of all data sets required to drive Generation 2 IEM with AR5 climate scenarios.	▪ Begin assessment using Generation 1 IEM with new fire and vegetation dynamics over the IEM domain driven by AR4 climate scenarios. ▪ Continued study of Generation 1 IEM application to model changing ecosystem services in the Nuiqsut region. ▪ Support development of Generation 2 (fully coupled) IEM.	▪ Complete development of the Permafrost Predisposition Model. ▪ Continued development of Alaska Thermokarst Model. ▪ Begin proof of concept studies for Alaska Thermokarst Model over the Barrow Peninsula and the Tanana and Yukon Flats driven by AR4 climate scenarios. ▪ Begin development of wetland dynamics model for incorporation into the IEM framework.
2015	▪ Support assessment using Generation 1 IEM over the complete IEM domain driven by AR4 climate scenarios. ▪ Development an operational "beta" version of the Generation 2 (fully coupled) IEM. ▪ Complete preparation of all data sets required to drive Generation 2 IEM with AR5 climate scenarios. ▪ Begin incorporation of Alaska Thermokarst Model into Generation 2 IEM.	▪ Support development of Generation 2 (fully coupled) IEM. ▪ Complete study of Generation 1 IEM application to model changing ecosystem services in the Nuiqsut region. ▪ Begin assessment using Generation 2 IEM over the IEM domain driven by AR4 climate scenarios. ▪ Begin collaboration with the three resource impact models funded by the Alaska Climate Science Center.	▪ Complete development of the Alaska Thermokarst Model. ▪ Complete proof of concept studies for Alaska Thermokarst Model over the Barrow Peninsula and the Tanana and Yukon Flats driven by AR4 climate scenarios. ▪ Support incorporation of Alaska Thermokarst Model into Generation 2 IEM. ▪ Continue development of wetland dynamics model being designed for incorporation into the IEM framework and begin proof-of-concept study. ▪ Feasibility study of automated mapping of Arctic Coastal Plain Surface Land Forms for possible use in an application of the Alaska Thermokarst Model coupled to a shorebird habitat model.
2016	▪ Support assessment using Generation 2 IEM over the complete IEM domain driven by AR4 climate scenarios. ▪ Support applications for the coupling of IEM outputs to resource impact models. ▪ Incorporate an operational "beta" version of the Alaska Thermokarst Model into Generation 2 IEM.	▪ Complete assessment using Generation 2 IEM over the IEM domain driven by AR4 climate scenarios. ▪ Continue collaboration with the three resource impact models funded by the Alaska Climate Science Center.	▪ Support incorporation of Alaska Thermokarst Model into Generation 2 IEM. ▪ Complete proof-of-concept study of wetland dynamics model that is being designed for incorporation into the IEM framework. ▪ Possibly conduct an application of the Alaska Thermokarst Model coupled to a shorebird habitat model.