Integrated Ecosystem Model for Alaska and Northwest Canada

FAQs and Project Deliverables

What is this document?

The first few pages address Frequently Asked Questions regarding the Integrated Ecosystem Model (IEM) Project. The Appendices (starting on page 4) provide a more detailed description of the Project's methods, products, and timeline of deliverables.

What is the Integrated Ecosystem Model (IEM) Project?

The IEM Project is designed to help resource managers understand the nature and expected rate of landscape change. Maps and other products generated by 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 an understanding of the *uncertainty* in the expected outcomes.

What are the components of IEM?

IEM uses three ecosystem models that link changing climate scenarios to different 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 in arctic and sub-arctic ecosystems - 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 Alaskan and Northwestern Canada landscapes 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.

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 IEM to better forecast landscape changes in western Alaska.
- **Landscape-level thermokarst dynamics.** Thermokarst, the characteristic landscapes formed by thawing of ice-rich permafrost, are the dominant feature of much of the arctic and subarctic and are increasing in those areas and the boreal. 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.

Integrated Ecosystem Model for Alaska and Northwest Canada

What is the area covered by IEM products?

The IEM domain covers most of Alaska, the Yukon Territory, and portions of northern British Columbia (Figure 1), coinciding with the western portion of the Arctic, Northwest Boreal, northern portion of the North Pacific, and Western Alaska LCCs[1].
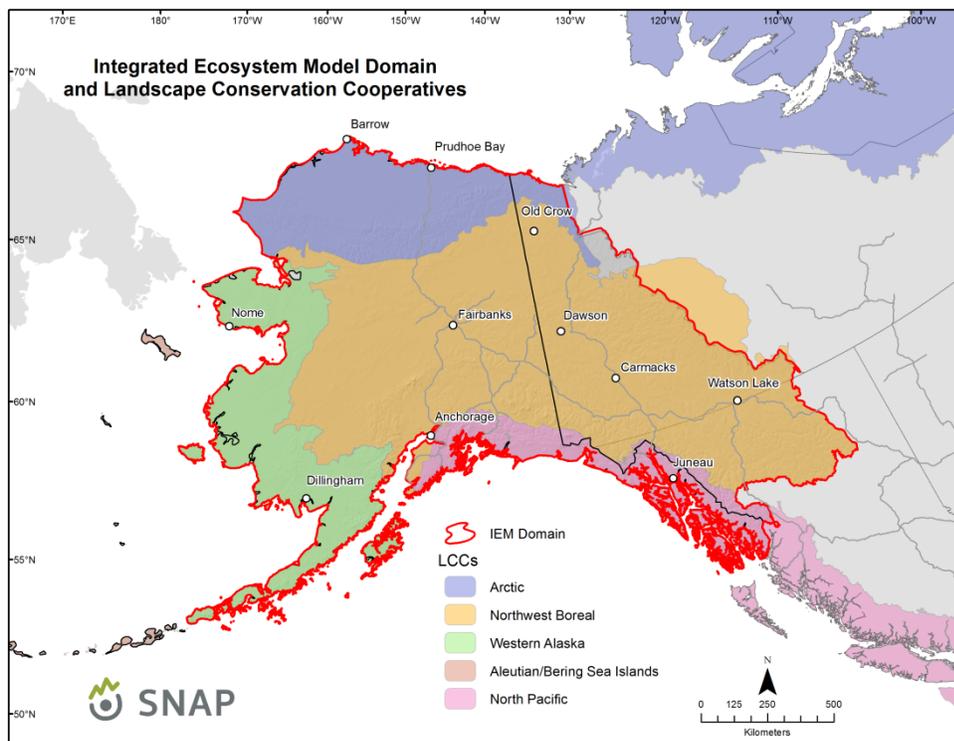

Figure 1. The Alaska and Northwest Canada geographic domain for the IEM and location of Landscape Conservation Cooperatives (LCCs). Graphic created by Scenarios Network for Alaska and Arctic Planning (SNAP).

What type of data products will IEM generate?

IEM will generate a broad variety of datasets for use by land and resource managers as well as researchers. The geographic domain of 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. **See Appendix A for details on IEM data products.**

How will the accuracy of IEM be evaluated?

The outputs from IEM will be compared to historical observations 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.

---

[1]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.

Integrated Ecosystem Model for Alaska and Northwest Canada

What has been accomplished?

The project's pilot phase (2010-2011) focused on the Alaska Yukon River Basin. A proof-of-concept model run linking ALFRESCO, TEM, GIPL was completed during this pilot phase and researchers evaluated the degree to which feedbacks between forest type and fire regime may alter organic soils and permafrost under a scenario of warming climate (Rupp et al., 2012).

The significant progress made during 2012 is summarized below by research activity:

Input Data: Prepared downscaled data sets of climate drivers and various other model inputs for the entire project domain and developed a new modeled vegetation input based on the North America Land Change Monitoring System's 2005 North American Land Cover at 250 m spatial resolution (CEC 2010).

Model Coupling: Cyclically coupled the ALFRESCO, TEM, and GIPL models by assembling all of the models on a common computer platform and set up communication among the models so they exchange data at appropriate time steps.

Tundra Fire & Treeline Dynamics: Developed a conceptual framework and new algorithm, and incorporated these processes into ALFRESCO.

Thermokarst Dynamics: Developed a conceptual approach to representing permafrost dynamics appropriate to the landscape scale of IEM.

Wetland Dynamics: Conducted field studies that provide insight into carbon and vegetation dynamics for boreal fens and collapse-scar bogs.

Where can I learn more about IEM?

Appendix B details how the IEM component models are linked together, the climate models and scenarios used by IEM, and the research plan for 2013-2016.

Further information is available at http://www.snap.uaf.edu/project_page.php?projectid=15 and http://arcticlcc.org/projects/landscape/integrated-ecosystem-model-iem-for-alaska/

Integrated Ecosystem Model for Alaska and Northwest Canada

APPENDIX A: Anticipated data products from IEM for 2012 – 2014. Data products for 2015 and 2016 are largely to be determined and therefore omitted from this table.

Climate (e.g., temperature, precipitation, radiation, vapor pressure)			
Dataset name	Data type	Description	Year available
Projected average monthly temperature, precipitation, radiation, and vapor pressure (ECHAM5-A1B scenario)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation, and vapor pressure from the Max Planck Institute for Meteorology European Centre Hamburg Model 5 (ECHAM5).	2012
Projected average monthly temperature, 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 temperature, precipitation, radiation, and vapor pressure (CRU)	Spatial	Downscaled historical simulations of monthly temperature, precipitation, radiation, and vapor pressure, from Climatic Research Unit (CRU) at the University East Anglia time series (TS) datasets CRUTS 3.1 or CRUTS3.1.01.	2012
Projected average monthly temperature, precipitation, radiation, and vapor pressure (AR5 models and RPCs)	Spatial	Downscaled projections of monthly temperature, precipitation, radiation, and vapor pressure for AR5 climate models that perform well in the Arctic.	2014

Integrated Ecosystem Model for Alaska and Northwest Canada

Disturbance (e.g., area burned, burn severity, stand age, thermokarst)			
Dataset/ Data Collection Name	Data Type	Description	Year Available
Area burned and burn severity (ECHAM5 and CCCMA -A1B scenario)	Spatial; Tables/graphs	Maps and graphs that depict simulations of area burned and burn severity.	2014 (Gen 2)*
Historical area burned/ stand age	Spatial	Historical area burned (Gen 1: 1917-2011, Gen 2: 1901-2012) and modeled historical stand age (Gen 2: 1901-2011).	2013 (Gen 1) 2014 (Gen 2)
Area burned and burn severity (AR5 models and RPCs)	Spatial; Tables/graphs	Maps and graphs that depict simulations of area burned and burn severity.	2014 (Gen 2)
Thermokarst disturbance	Spatial; Tables/graphs	Maps and graphs for depicting changes in (1) low-center, high-center, and transitional polygons in tundra, (2) fen and bog area in boreal forest, (3) soil moisture due to thermokarst (4) vegetation due to thermokarst and (5) proportion of shallow and deep thermokarst lakes. This dataset will also include maps identifying areas susceptible to massive subsidence caused by thermokarst.	2014
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.	2014

*See APPENDIX B: "How are the models linked together?" for information on the difference between Generation 1 (Gen 1) and Generation 2 (Gen 2) datasets.

Integrated Ecosystem Model for Alaska and Northwest Canada

Landcover and landscape (e.g., vegetation type, treeline extent, topography)			
Dataset/ Data Collection Name	Data Type	Description	Year 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
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. http://www.climatesource.com/ or http://www.prism.oregonstate.edu/	2012
Growth dynamic 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).	2013 (Gen 1)* 2014 (Gen 2)
Treeline extent (ECHAM5 and CCCMA-A1B scenario)	Spatial	Maps depicting projected treeline migration.	2013 (Gen 1) 2014 (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 showing changes in area of vegetation types through time.	2014 (Gen 2)
Growth dynamic of vegetation (AR5 models and RPCs)	Spatial; Tables/graphs	Maps and graphs showing changes in biomass over time of different plant functional types within the four vegetation types.	2014 (Gen 2)
Treeline extent (AR5 models and RPCs)	Spatial	Maps depicting projected treeline migration.	2014 (Gen 2)
Vegetation distribution (AR5 models and RPCs)	Spatial; Tables/graphs	Modeled distribution of six vegetation types (white spruce, black spruce, deciduous forest, graminoid tundra, shrub tundra, wetland tundra). Graphs showing changes in area of vegetation types through time.	2014 (Gen 2)

*See APPENDIX B: "How are the models linked together?" for information on the difference between Generation 1 (Gen 1) and Generation 2 (Gen 2) datasets.

Integrated Ecosystem Model for Alaska and Northwest Canada

Ecosystem dynamics (e.g., carbon flux)			
Dataset/ Data Collection Name	Data Type	Description	Year Available
Data from wetland field component of IEM	Site specific spatial data; Text; 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, CH4 flux, and CH4 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; Text; 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. These data will be made available by request.	2013 (Gen 1)* 2014 (Gen 2)
Carbon fluxes and pools (RCP 4.5, RCP 6.0, and RCP 8.5) †	Spatial; Text; 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. These data will be made available by request.	2014 (Gen 2)

†Data available by request. Please submit requests by completing the 'Contact Us' form at http://www.snap.uaf.edu/people.php#contact
*See APPENDIX B: "How are the models linked together?" for information on the difference between Generation 1 (Gen 1) and Generation 2 (Gen 2) datasets.

Integrated Ecosystem Model for Alaska and Northwest Canada

Soil properties (e.g., permafrost, active layer, soil temperature)			
Dataset/ Data Collection Name	Data Type	Description	Year Available
Permafrost distribution, active layer thickness, and mean annual ground temperature (ECHAM5 and CCCMA-A1B scenario)	Spatial; Text; Tables/graphs	Maps and graphs depicting modeled permafrost distribution, simulated active layer thickness (m), and simulated mean annual ground temperature (°C).	2013 (Gen 1)* 2014 (Gen 2)
Soil characteristics (ECHAM5 and CCCMA-A1B scenario) †	Spatial; Text; 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.	2013 (Gen 1) 2014 (Gen 2)
Permafrost distribution, active layer thickness, and mean annual ground temperature (AR5 models and RPCs)	Spatial; Text; Tables/graphs	Maps and graphs depicting modeled permafrost distribution, simulated active layer thickness (m), and simulated mean annual ground temperature (°C).	2014 (Gen 2)
Soil characteristics (AR5 models and RPCs) †	Spatial; Text; 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.	2014 (Gen 2)

*See APPENDIX B: "How are the models linked together?" for information on the difference between Generation 1 (Gen 1) and Generation 2 (Gen 2) datasets.
†Data available by request. Please submit requests by completing the 'Contact Us' form at http://www.snap.uaf.edu/people.php#contact

Model code and documentation			
Dataset/ Data Collection Name	Data Type	Description	Year Available
IEM program code	Source Code	The **IEM Generation 2*** (i.e., cyclical coupling) will be made available as source code (available through the Github.com source management tools) and also packaged in installable Linux packages.	2013
Alaska Thermokarst Module program code	Source Code	The Alaska Thermokarst Module will have source code available via a Github.com repository, and will also be bundled with the **IEM Generation 2** installable Linux packages.	2014

*See APPENDIX B: "How are the models linked together?" for information on the difference between Generation 1 (Gen 1) and Generation 2 (Gen 2) datasets.

Integrated Ecosystem Model for Alaska and Northwest Canada

APPENDIX B: How the IEM component models are linked together, the climate models and scenarios used by IEM, and the research plan for 2013-2016

How are the models linked together?

There are two different methods used to link the components of 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. IEM output generated by linear coupling mode is identified as Generation 1 and data generated by cyclical coupling is called Generation 2 (Figure 2).
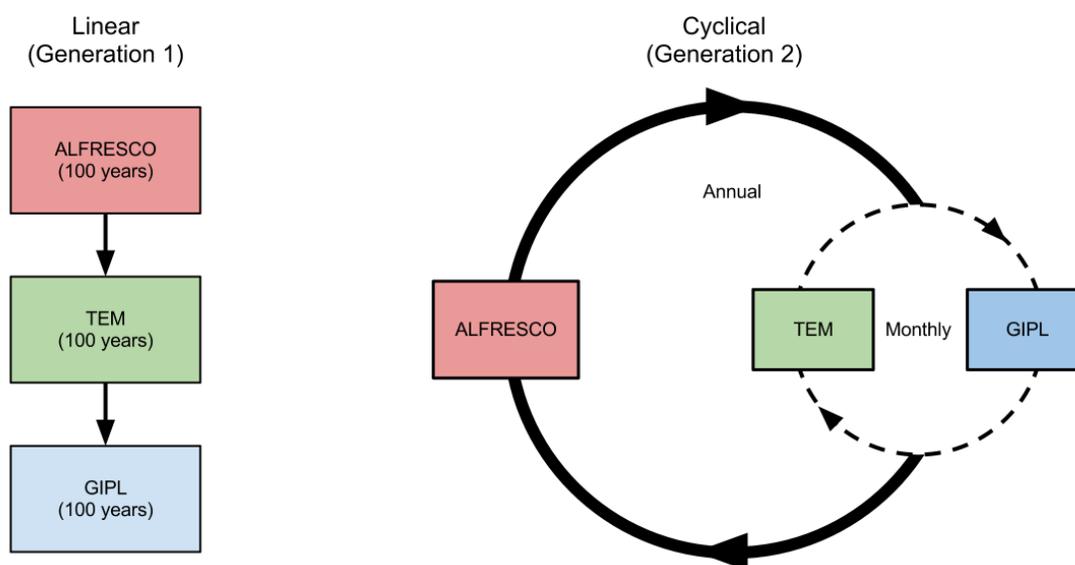

Figure 2. Diagram showing the linear and cyclical coupling methods used to link the three models that comprise the IEM. Graphic created by SNAP.

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 Global Climate 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 2014, 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 Wm^{-2} 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 Wm^{-2} or 6.0 Wm^{-2} by 2100, but subsequently stabilizes at that level.

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

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

Year	Activities			
	Model Coupling	Tundra Fire & Treeline Dynamics	Thermokarst Dynamics	Wetland Dynamics
2013	Full assessment IEM 2.0 over the IEM domain. Models driven by A1B emission scenario.	Development of IEM 2.1 by incorporation of tundra fire & treeline dynamics program code into IEM 2.0; proof-of-concept study.	Development of new program code; testing of landscape-scale thermokarst dynamics module.	Development of new program code for wetland dynamics.
2014	Full assessment of IEM 2.1 (IEM 2.0 with tundra fire & treeline dynamics) over the IEM domain. Transition from AR4 models A1B scenario to AR5 models and RCPs,	Assessment of IEM 2.1 across the IEM domain.	Development of IEM 2.2 by incorporation of thermokarst dynamics program code into IEM 2.1; proof-of-concept study.	Testing and evaluation of wetland dynamics module.
2015	Full assessment of IEM 2.2 (IEM 2.1 with thermokarst dynamics) over the IEM domain. Models driven by RCP4.5, RCP6.0, and RCP8.5.	Identification and development of resource impact models that can be coupled to IEM 2.1 (tundra fire & treeline dynamics), e.g., caribou energetic models.	Assessment of IEM 2.2 across the IEM domain.	Development of IEM 2.3 by incorporation of wetland dynamics program code into IEM 2.2; proof-of-concept study.
2016	Full assessment of IEM 2.3 (IEM 2.2 with wetland dynamics) over the IEM domain. Models driven by RCP4.5, RCP6.0, and RCP8.5.	Identification and development of resource impact models that can be coupled to IEM 2.2 (e.g., waterbird habitat models.	Identification and development of resource impact models that include thermokarst dynamics.	Assessment of IEM 2.3 across the IEM domain.

Integrated Ecosystem Model for Alaska and Northwest Canada

Citations

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., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Keywan, R., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P., and T.J. Wilbanks. 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., McGuire, A.D., Romanovsky, V., Euskirchen, E., Marchenko, S., Loya, W., Breen, A., Yuan, F.M., McAfee, S., Muskett, R., and T. Kurkowski. 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., Chapman, W.L., Romanovsky, V., Christensen, J.H, and M. Stendel. 2008. Global climate model performance over Alaska and Greenland. Journal of Climate 21:6156-6174, doi:10.1175/2008JCLI2163.1.