The Integrated Ecosystem Model for Alaska and Northwest Canada: An interdisciplinary decision support tool to inform adaptation to Arctic environmental change

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Integrated Ecosystem Model (IEM) for Alaska and Northwest Canada

The IEM is a decision support tool designed to:
- Aid in understanding the nature and rate of landscape change
- Illustrate how landscapes are expected to respond to climate driven changes
- The Alaska Thermokarst Model (ATM) is being developed as part of the IEM project
Components of the IEM

**Pilot Study: 2010 - 2011**

- **Fire Dynamics**
  - [ALFRESCO]
  - 100 yrs

- **Vegetation Dynamics**
  - [TEM]
  - 100 yrs

- **Permafrost Dynamics**
  - [GIPL]
  - 100 yrs

**Phase 2: 2011 - current**

- **Fire Dynamics**
  - [ALFRESCO]
  - Annual

- **Vegetation Dynamics**
  - [TEM]
  - Monthly

- **Permafrost Dynamics**
  - [GIPL]
  - Monthly

**Generation 1 - Linear Coupling**

**Generation 2 - Cyclical Coupling**
## Components of the IEM

### Model Inputs
- Air temperature, relative humidity
- Precipitation
- Initial vegetation distribution
- Slope, aspect, elevation
- Radiation, cloudiness
- Soil properties

### Variables Passed Between Models
- Vegetation distribution
- Area burned, fire severity
- Vertical soil temperature, soil moisture content
- Organic layer thickness
- Biomass
Spatial Domain of the IEM
Example output - Initial Land Cover
Example output - Changes in Treeline

Projected Changes in Treeline

ALFRESCO Model | MPI ECHAM 5 | A1B Scenario

[Map showing changes in treeline with different colors and labels for 2014 Forest, 2100 Forest, IEM Domain, and Tundra Cells with Spruce Present in Year 2100 with basal area categories 0.1 - 5, 5.1 - 10, 10.1 - 20, and CAVM Treeline.]
IEM Products and Deliverables

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 (Figure 1) will illustrate how landscapes are expected to shift due to climate-driven changes to vegetation, disturbance, hydrology, and permafrost. The following tables describe the anticipated products and deliverables for the IEM over the 2012–2016 period.

The IEM links three different models, including the Alaska Frame-Based Ecosystem Code (ALFRESCO), the Geophysical Institute Permafrost Lab model (GIPL), and the Terrestrial Ecosystem Model (TEM) [which includes the Dynamic Vegetation (DVY) and Dynamic Organic Soil (DOS) models]. The Alaska Thermokarst Model (ATM) is also being developed and will be integrated into the IEM at a later date.

In Generation 1 (Gen 1), the models are linked linearly (Figure 2), which allows for the exchange of information between models to occur in series. For example, data generated by the first model is used as input for a second model, and that output is the input for the next model. In Generation 2 (Gen 2), the models are linked cyclically, which allows data outputs to be exchanged among all the models and incorporates the outputs into the next time step.

The models 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 (Figure 3), and provided on an annual time-step unless otherwise indicated.

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

Figure 1. Product Definitions

<table>
<thead>
<tr>
<th>Spatial</th>
<th>GIS data (generally in raster, geotiff format or occasionally shape files)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tables</td>
<td>A summarization of a metric over specific region (generally in .csv format for ease of use in spreadsheet or statistical programs).</td>
</tr>
<tr>
<td>Graphs</td>
<td>A time series of a metric across a region (generally in .png image file).</td>
</tr>
<tr>
<td>Code</td>
<td>Programming code of the models.</td>
</tr>
</tbody>
</table>

Climate Products (e.g., temperature, precipitation, radiation, vapor pressure)

<table>
<thead>
<tr>
<th>Dataset Name</th>
<th>Data Type</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projected average monthly temperature and precipitation</td>
<td>Spatial</td>
<td>Downscaled projections of monthly temperature, precipitation, radiation and vapor pressure from the Max Planck Institute for Meteorology, European</td>
<td>2012</td>
</tr>
</tbody>
</table>

- [https://www.snap.uaf.edu/projects/iem](https://www.snap.uaf.edu/projects/iem)
- Climate Products
- Ecosystem Dynamics Products
- Disturbance Products
- Landcover and Landscape Products
- Soil Properties Products
- Model Code and Documentation
- Indication of availability (date)
Alaska Thermokarst Model
“Black brant have increased dramatically in number on the North Slope...sags in permafrost are changing hydrology and favoring the salt-tolerant plants that are most beneficial to brant...”
Alaska Thermokarst Model

- State-and-transition model
- Framed-based methodology to track cohorts
  - Unique representative landscape unit
  - Tracks cohorts by fractional area of a model element (NOT spatially-explicit)

- 1 km² resolution, annual time step
- Simulation period ~100 years from present
- Landscape transitions for the arctic tundra, boreal forest, and lakes
Predisposition Model

Proportion of the landscape where thermokarst could initiate and expand.

- Presence of permafrost
- Ice content of the soils
- Physiography (upland vs lowland)
- Presence of histels (organic layer > 40 cm overlying permafrost)

http://ckan.snap.uaf.edu/dataset/thermokarst-formation
Initiation and Expansion Modules

Arctic Tundra Frame

Boreal Forest Frame
Landscape Examples

- Drained lake / Meadow
- Low Centered Polygon
- High Centered Polygon
- Gradient of Fen → Young Fen → Permafrost Plateau
- Old Bog

Authors:
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- J. Boike
- L. Hinzman
- M. Lara
Cohort Frame Example

- **Step 1. Determine Probability of Initiation**
  - Yes: Continue
  - No/Yes: Continue
  - No: Continue

- **Step 2. Determine Rate of Terrain Transition**
  - Yes: Continue
  - No: Continue

- **Step 3. Determine Probability Of Eco-type Change**
  - Yes: Continue
  - No: Continue

A. Major/significant Climatic Event?
B. Active Layer Depth > Protective Layer Depth?
C. Cumulative Probability of Initiation Updated
D. Cumulative Probability of Initiation “Reset” to 0
E. Climate support new eco-type?
Expected Output (examples)
Discussion

- **IEM Phase 3**
  - Focus on code completion/coupling
  - Application of IEM to address specific resource manager needs

- **ATM**
  - Arctic Coastal Plain
  - Yukon & Tanana Flats
  - Yukon-Kuskokwim Delta
  - Seward Peninsula

- **Alaska Climate Science Center Pilot Project**
  - Co-production of science framework
  - Working with resource managers to ensure useful science / products

https://www.snap.uaf.edu/projects/iem
Acknowledgements