Integrated Ecosystem Model for Alaska

A collaborative research project for the
Arctic Landscape Conservation Cooperative

Presentation to the Arctic LCC & their partners
December 3, 2010

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Presentation Outline

I. *Introduction to the study system*

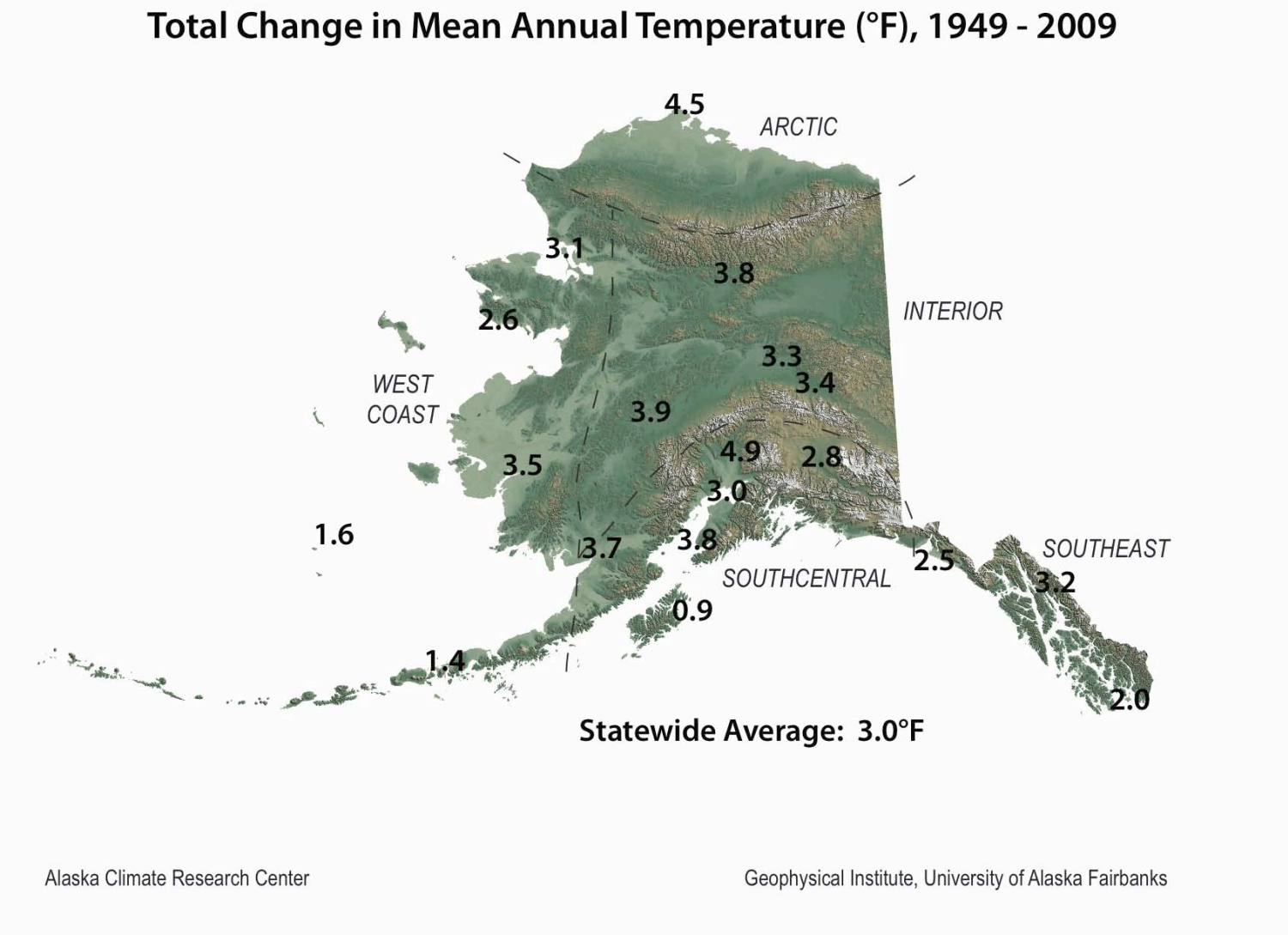
II. Conceptual model framework

III. Coupling exercises

IV. Data streams & spatial layers

V. Broader impacts & significance

Climate change in Alaska



Climate change in Alaska

Total Change in Mean Seasonal and Annual Temperature (°F), 1949 - 2009

Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	6.7	4.5	3.0	3.7	4.5
Interior	Bettles	8.1	4.3	1.8	1.1	3.8
	Big Delta	8.9	3.4	1.2	0.0	3.4
	Fairbanks	7.4	3.6	2.3	-0.2	3.3
	McGrath	7.4	4.6	2.7	0.8	3.9
West Coast	Kotzebue	6.3	1.8	2.6	1.4	3.1
	Nome	4.2	3.3	2.5	0.4	2.6
	Bethel	6.6	4.8	2.3	0.0	3.5
	King Salmon	7.9	4.5	1.7	0.6	3.7
	Cold Bay	1.5	1.6	1.7	0.8	1.4
	St Paul	0.8	2.1	2.6	1.1	1.6
Southcentral	Anchorage	5.8	3.3	1.6	1.5	3.0
	Talkeetna	8.4	5.2	3.1	2.4	4.9
	Gulkana	7.7	2.4	1.0	0.1	2.8
	Homer	5.9	3.8	3.3	1.8	3.8
	Kodiak	0.7	2.1	1.2	-0.4	0.9
Southeast	Yakutat	4.6	2.8	1.8	0.4	2.5
	Juneau	6.2	2.9	2.2	1.4	3.2
	Annette	3.4	2.3	1.8	0.3	2.0
	Average	5.7	3.3	2.1	0.9	3.0

Alaska Climate Research Center Geophysical Institute, University of Alaska Fairbanks

Slope Mountain in the northern foothills of the Brooks Range in late winter

Climate change in Alaska

Projected climate changes for terrestrial landscapes in Alaska will affect:

- temperatures
- rate of snowfall during winter
- frequency of rain on snow events
- length of ice-free season
- length of the growing season
- permafrost integrity
- stream flow patterns
- wildfire patterns
- coastal erosion
- glaciers

Musk ox herd on a hillslope near Nome, Alaska

Climate change in Alaska

One of the recommendations of the interagency and partnership WildREACH workshop was to develop predictive models of habitat change, including:

Fire regime as a function of interactions among climate, permafrost and vegetation

Anaktuvuk River Fire
September 2007
Photo courtesy of Ben Jones/USGS

IEM for Alaska: Phase 1

Objectives:

Conceptual model framework

To develop a conceptual framework for integrating important components of an ecosystem model for Alaska including: *fire, vegetation succession, permafrost dynamics and hydrology*

Coupling exercises

To conduct initial static coupling exercises between some model components as a proof-of-concept for this approach

Deliverables:

Data streams & spatial layers

Produce and deliver data streams and spatial layers to be made available to the broader research and management communities for use in their research efforts

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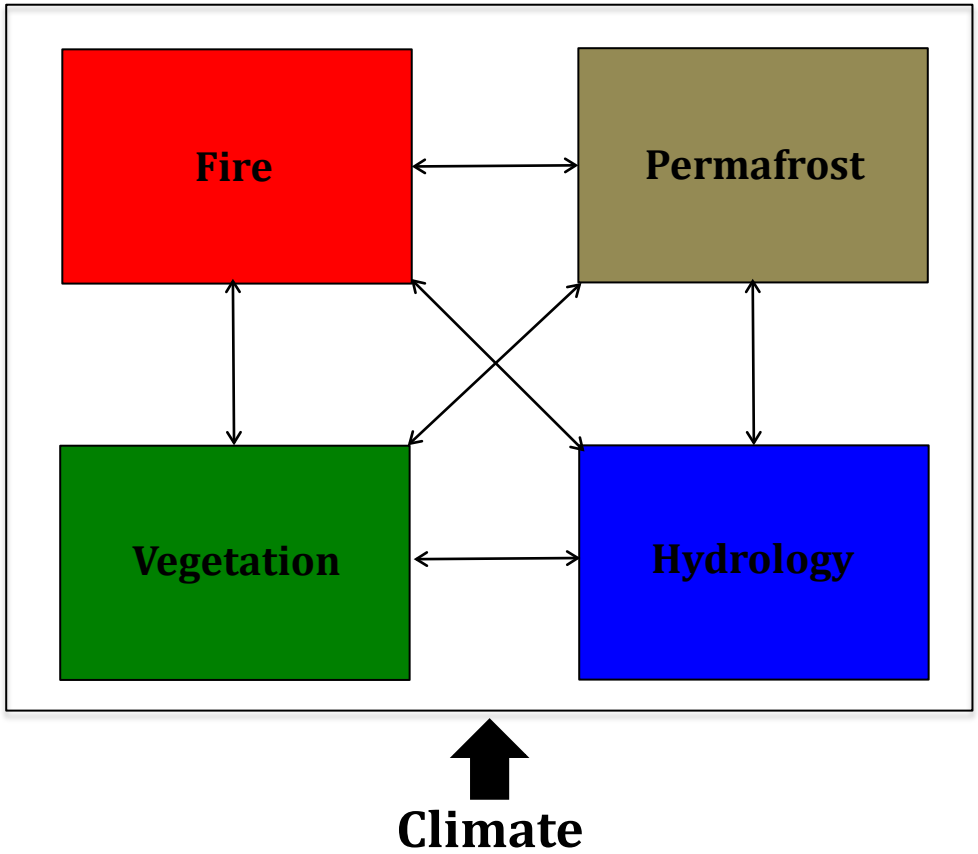
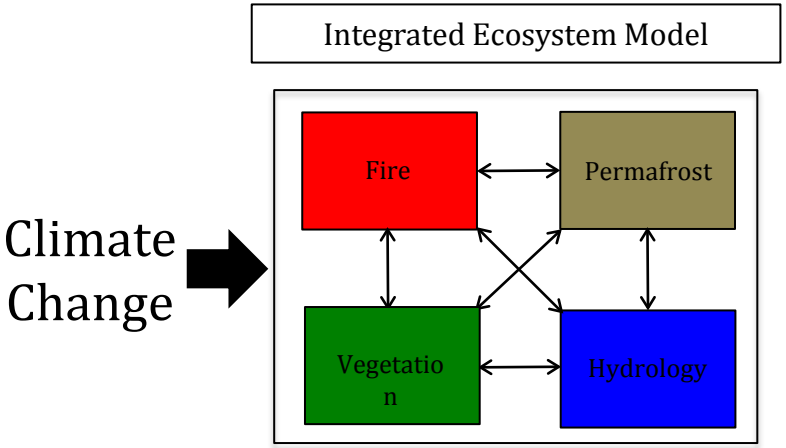


IEM for Alaska Conceptual Framework



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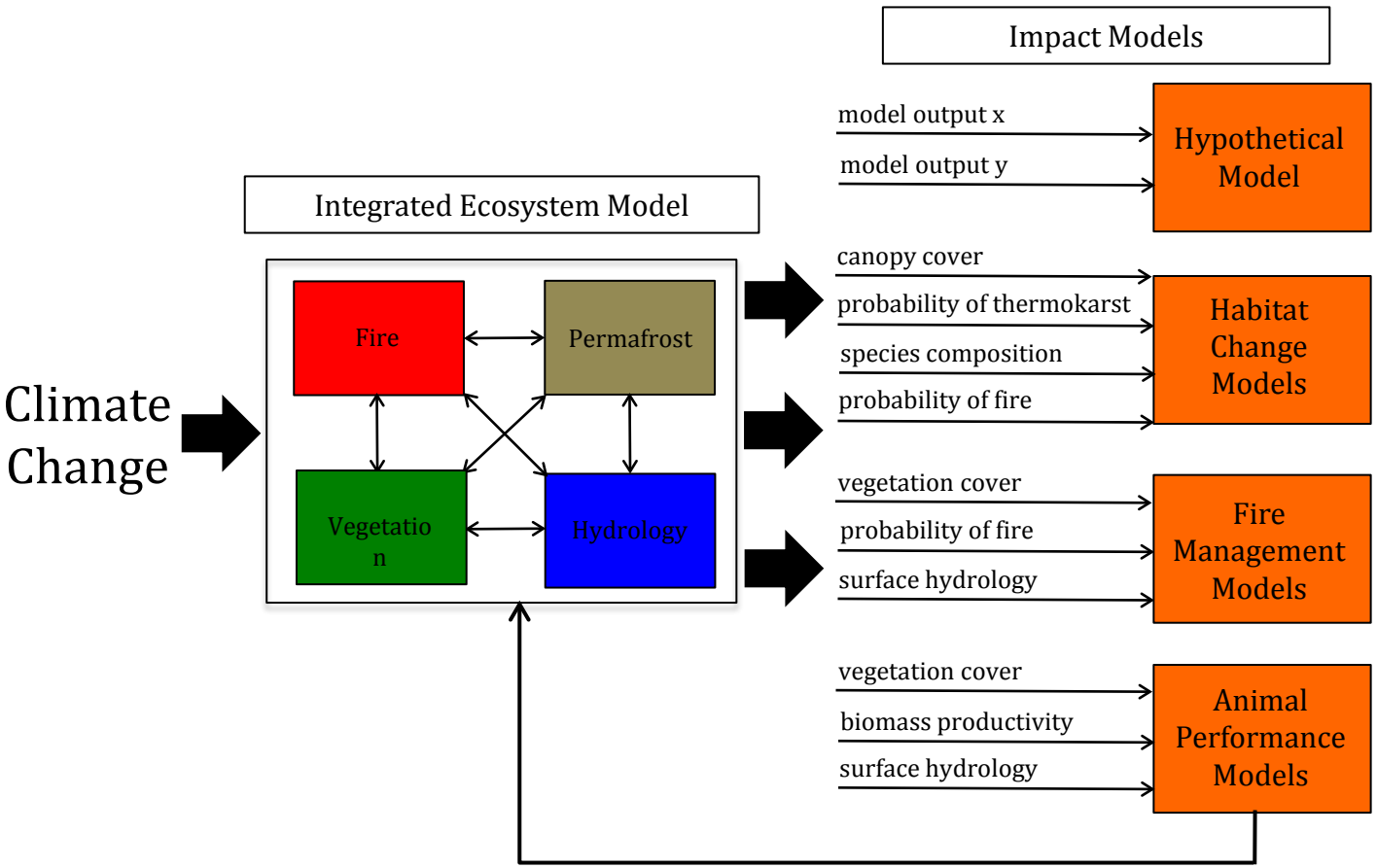

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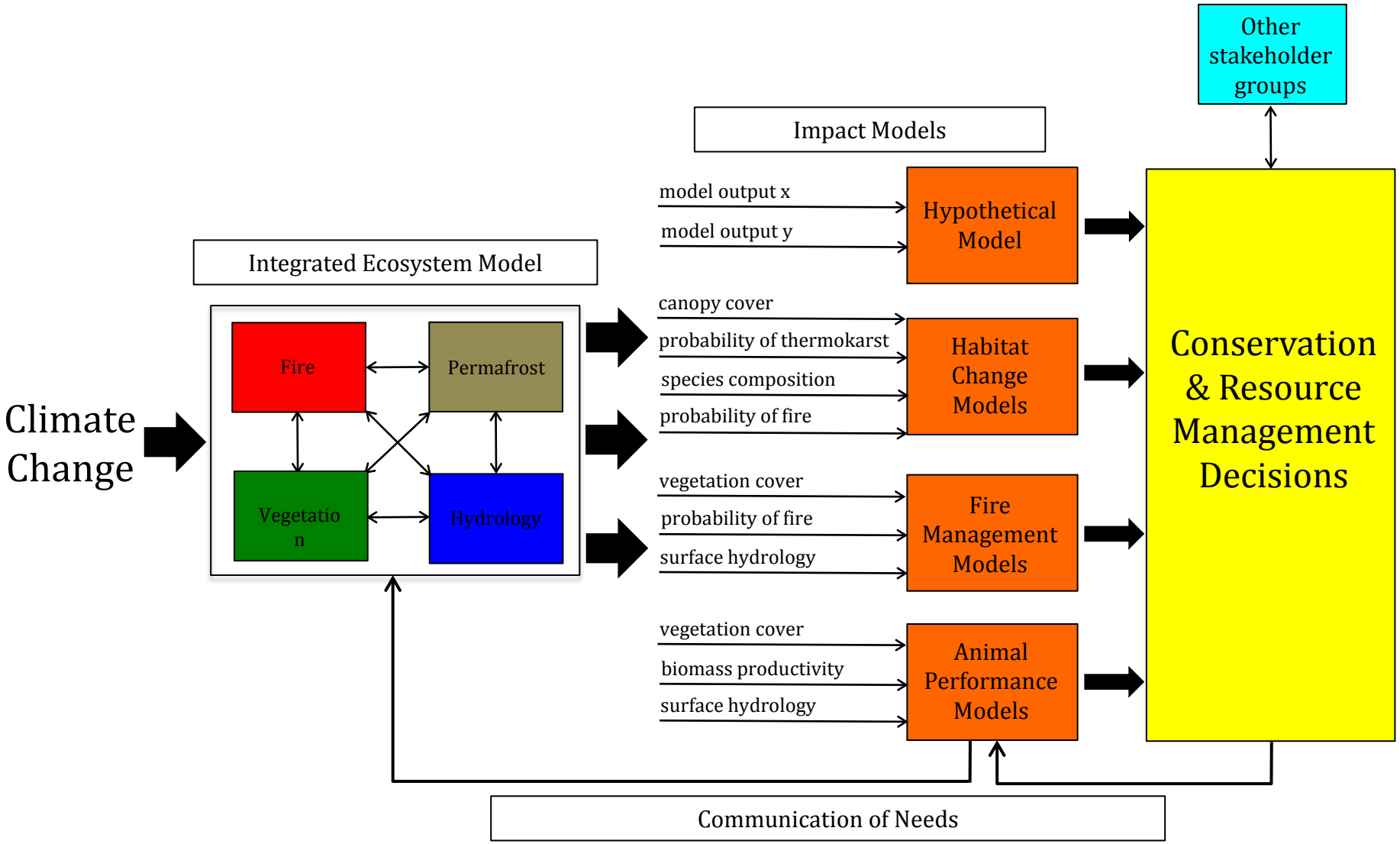
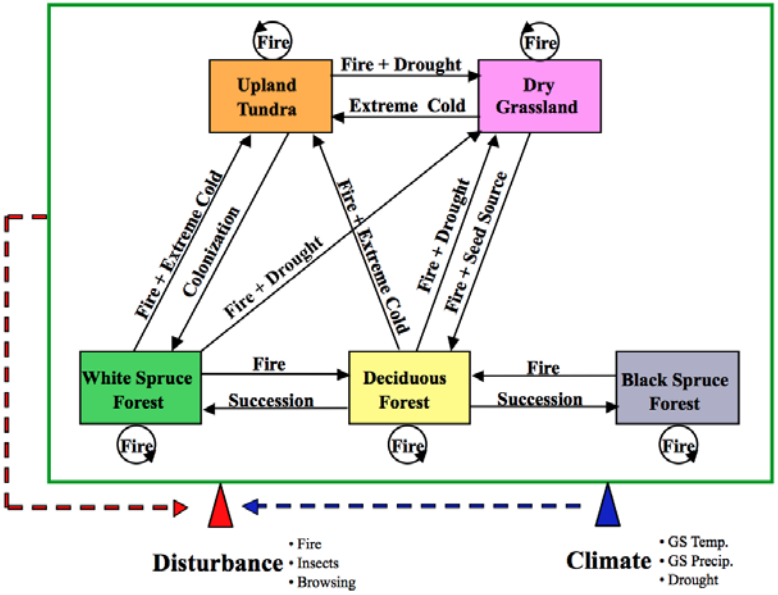
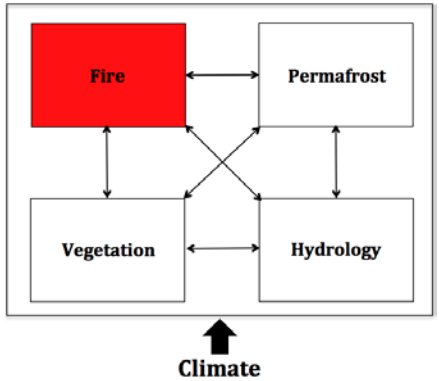


ALFRESCO

Alaska Frame-Based Ecosystem Code

- State-transition type vegetation succession model
- Developed to simulate the response of subarctic and boreal vegetation to climate change
- Focuses on system interactions and feedbacks
- Model assumptions reflect the hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation
- Model simulates five major ecosystem types

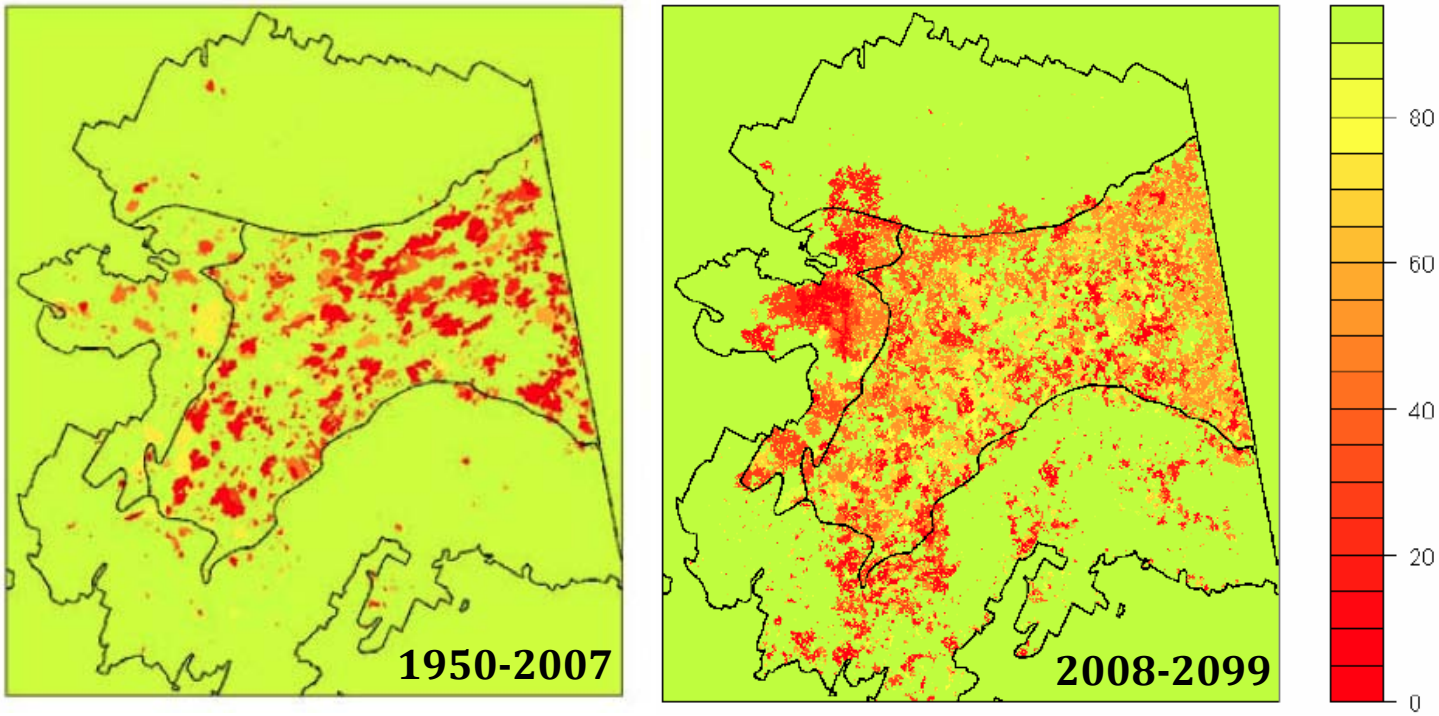




ALFRESCO

Example Output

Time since last fire



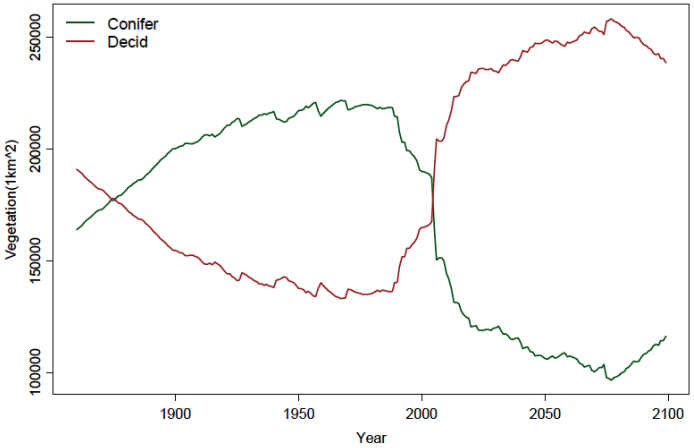
Observed

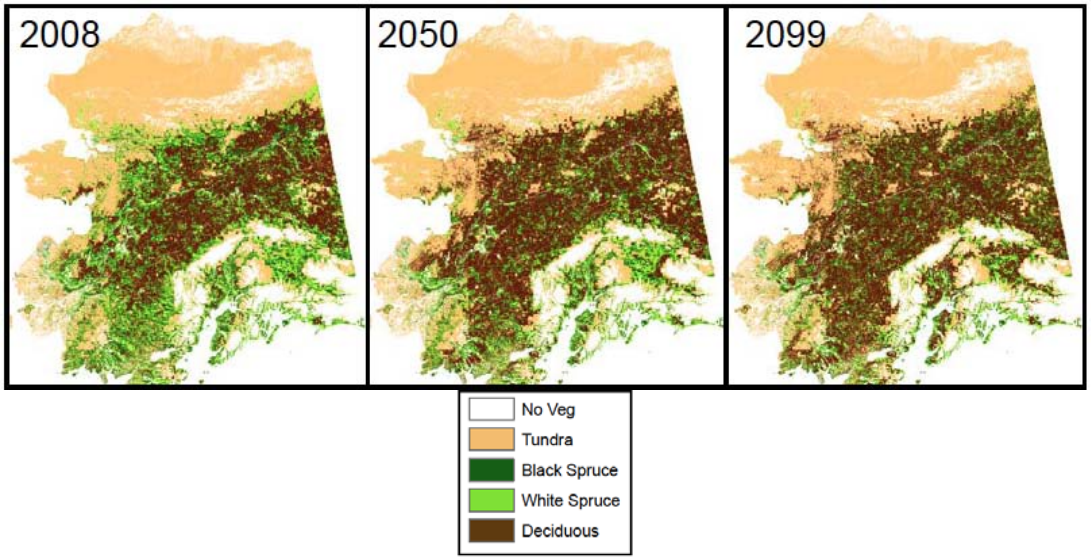
Projected

ALFRESCO

Example Output

Simulated changes in the distribution of vegetation types

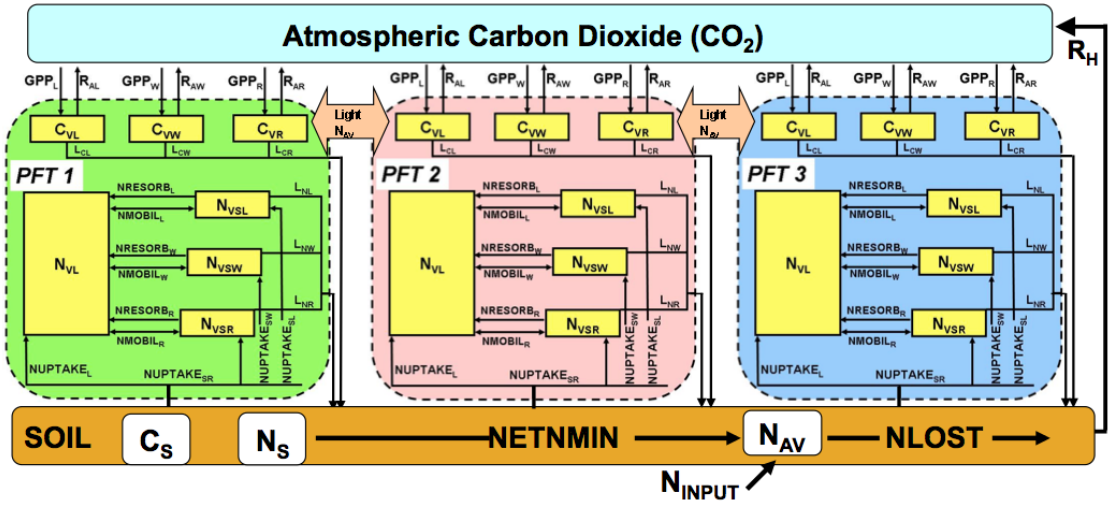


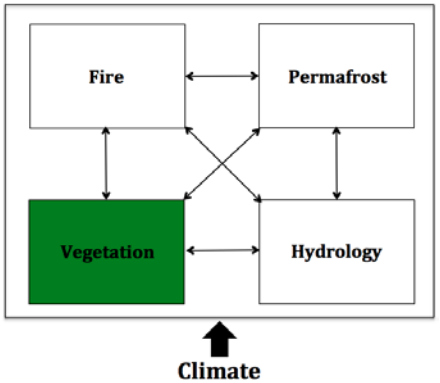


TEM-DVM

Terrestrial Ecosystem Model-Dynamic Vegetation Module

- Calculates the pools and fluxes of carbon and nitrogen for a given set of plant functional types
- Developed specifically to take into account high-latitude vegetation and processes (e.g., permafrost dynamics)
- Includes competition among the plant functional types for light and nitrogen
- Can be used at different spatial scales
- Model simulates three major ecosystem types

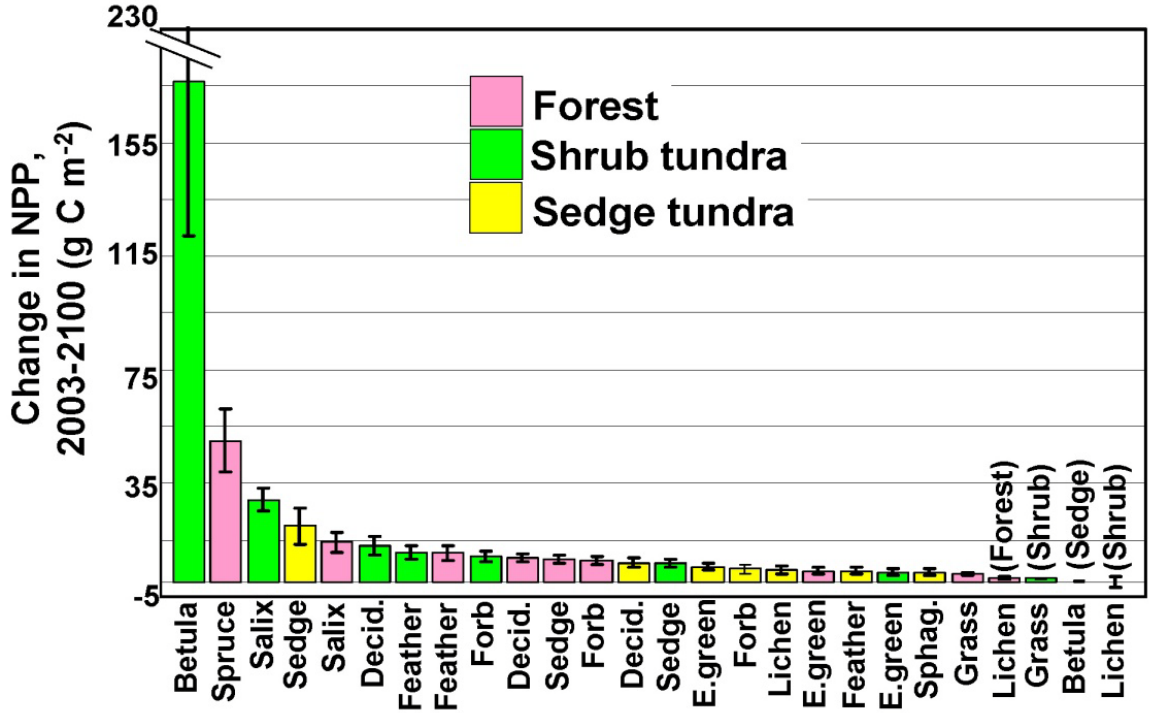




TEM-DVM

Example Output

Changes in productivity of arctic vegetation

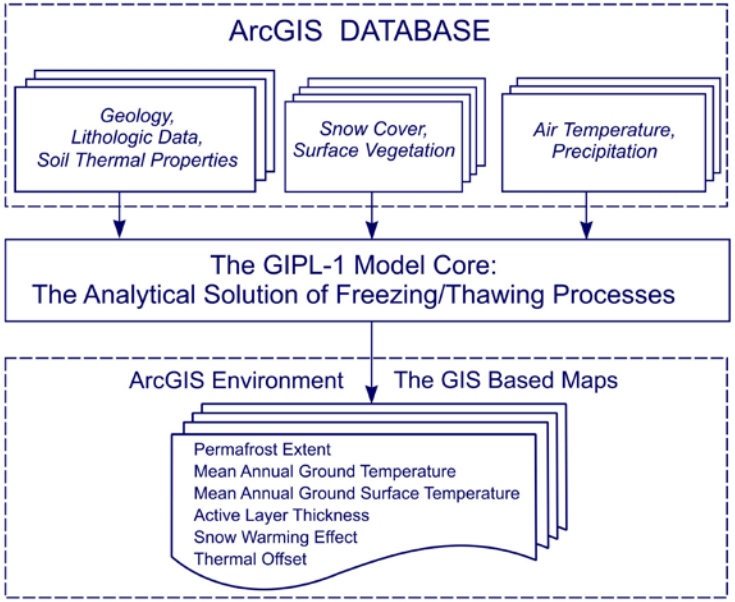


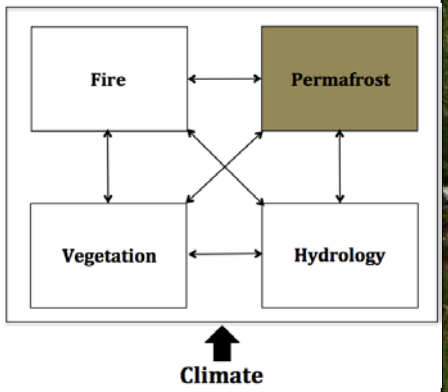
Looking west toward the Sadlerochit Mountains

GIPL

Geophysical Institute Permafrost Lab Permafrost Dynamics Model

- Assesses the effects of a changing climate on permafrost
- Quasi-transitional, spatially distributed, equilibrium model for calculating active layer thickness and mean annual ground temperature
- Input parameters to the model are spatial datasets of mean monthly air temperature and precipitation, vegetation, soil thermal properties and water content

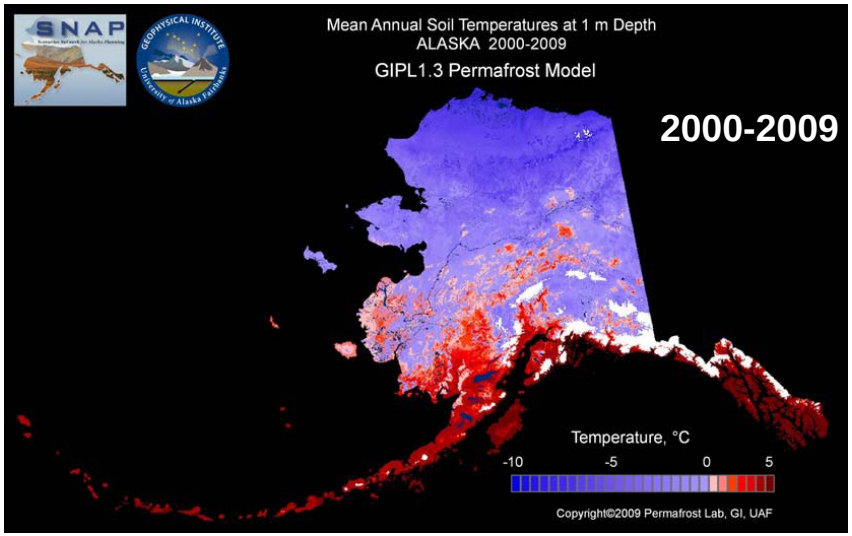


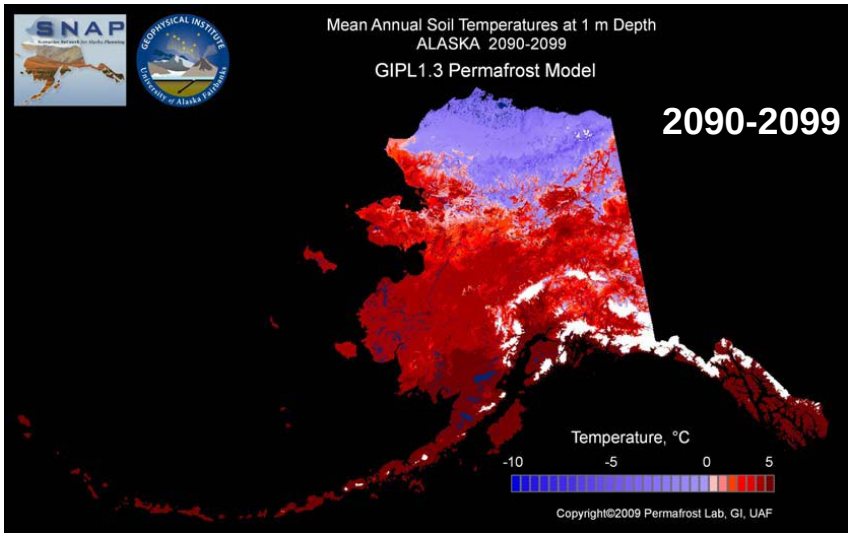


GIPL

Example Output

Simulated ground temperatures at 1 m depth



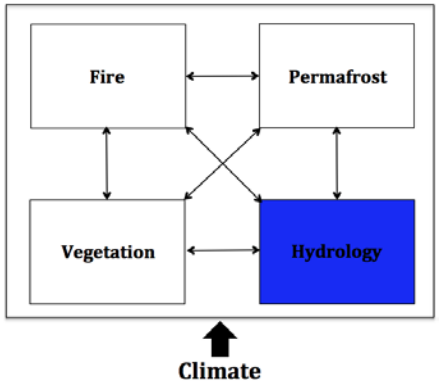


Hydrology

Soil Moisture

Link among the ALFRESCO, TEM and GIPL models and controls:

- land-atmosphere interactions
  - surface energy balance by partitioning of available energy into sensible/latent heat
  - distribution of vegetation
- soil respiration
  - CO_2 vs. CH_4
- permafrost distribution / active layer thickness
  - thermal conductivity of water
- Wildfire
  - distribution, frequency and severity



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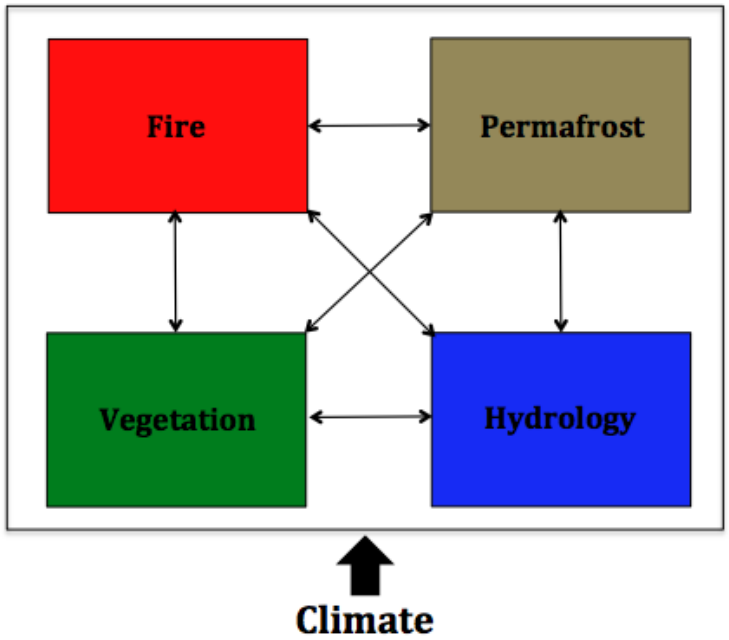
Initial Coupling Exercise

- First set of simulations is underway to develop the IEM for Alaska
- Designed coupling exercise to clarify issues related to:
  - forcing data
  - exchange of data between models
  - potential confounding variables that more than one model simulates



Initial Coupling Exercise

Simulation Protocol

Boundary: Yukon River Basin within Alaska

Spatial resolution: 2 km x 2 km for all models

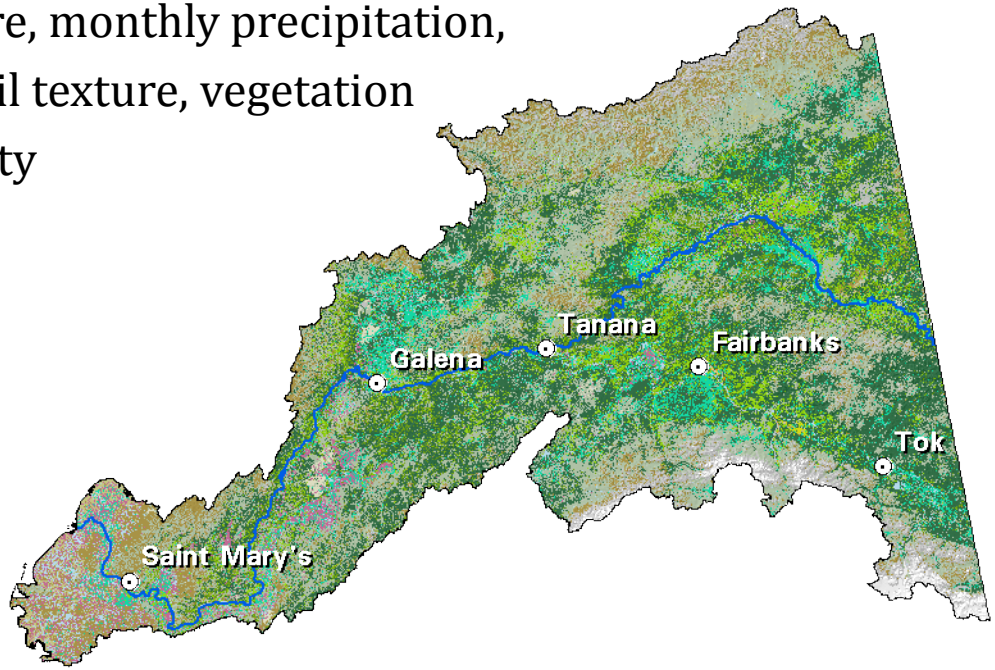
Historical extent of model outputs: 1950-2006

Future extent of model outputs: 2007-2100

Temporal resolution of outputs: Monthly

Driving data include, but are not limited to:

CO_2 record, monthly temperature, monthly precipitation, monthly radiation, elevation, soil texture, vegetation type, fire occurrence, fire severity



Initial Coupling Exercise

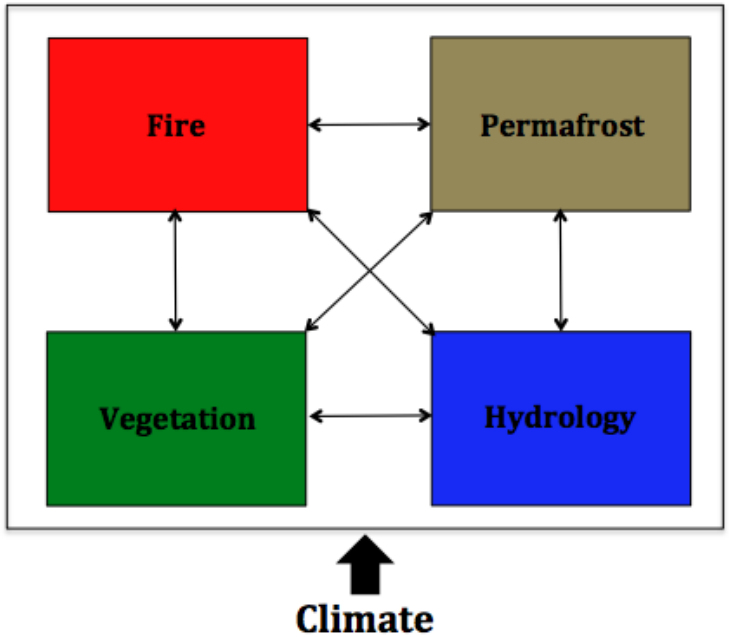
Simulation Series

- Series requires coordination of driving data sets, data exchange format and output variables between models
- Each stage of the simulation in the initial coupling exercise depends upon the previous stage in the following order:

  Stage 1: ALFRESCO fire scenarios *drive*

  Stage 2: TEM which will produce soil organic layer thickness outputs to *drive*

  Stage 3: GIPL-1



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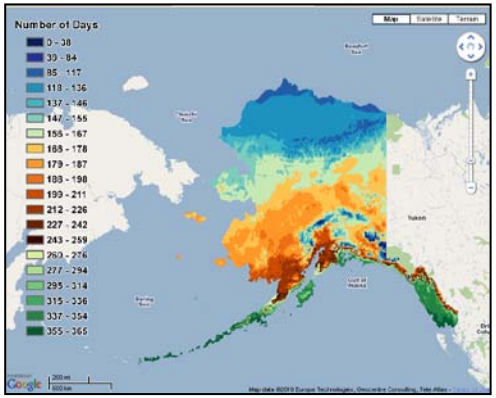
Spatial layer data products

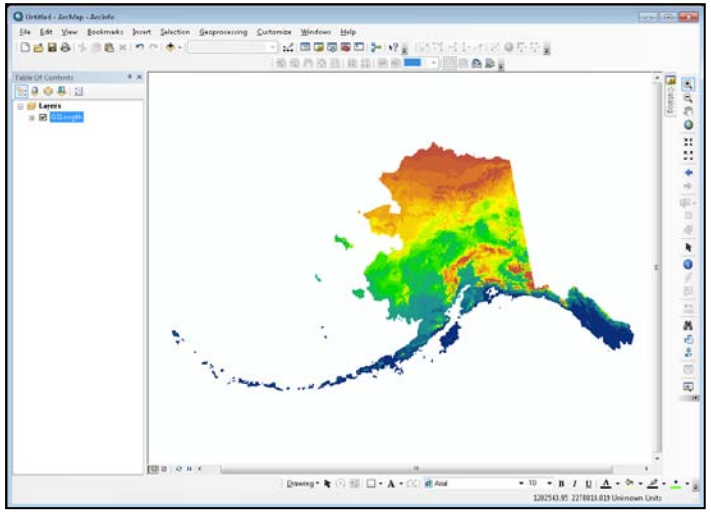
Deliverables	Group	Temporal Resolution
Historical evaporative demand	SNAP	Jan 1901 - Dec 2006
Historical burned area	SNAP	Jan 1950 - Dec 2006
Projected mean annual ground temperature	GIPL	Jan 2007 - Dec 2099
Projected active layer thickness	GIPL	Jan 2007 - Dec 2099
Projected burned area	SNAP	Jan 2007 - Dec 2099
Projected evaporative demand	TWS-SNAP	Jan 2007 - Dec 2099
Historical snow water equivalent	GIPL	Jan 2005 - May 2010
Historical snow water equivalent	GIPL	Jan 2000 - May 2007
Historical land surface temperature	GIPL	March 2000 - May 2010
Projected growing season length	TEM	Jan 2007 - Dec 2099
Projected plant productivity (NPP/NEP)	TEM	Jan 2007 - Dec 2099
Projected snow cover duration (snow melt/return)	TEM	Jan 2007 - Dec 2099

Spatial layer data products

Protocol

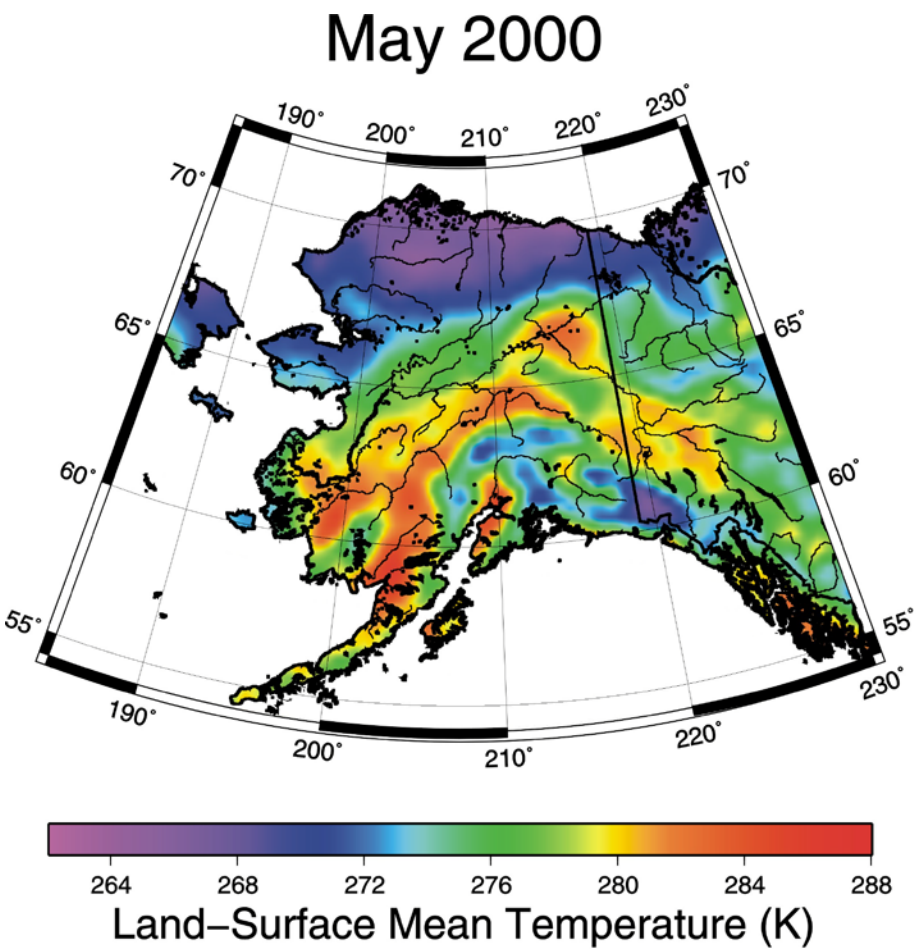
- Statewide data
- Will deliver historical period and all decades: 2010's, 2020's … 2090's
- Geotiff format
  - ➢ Standardized format which can be directly used in most analytical/GIS programs
- Served as a web mapping service (WMS) for use on web
- Monthly data made available as needed

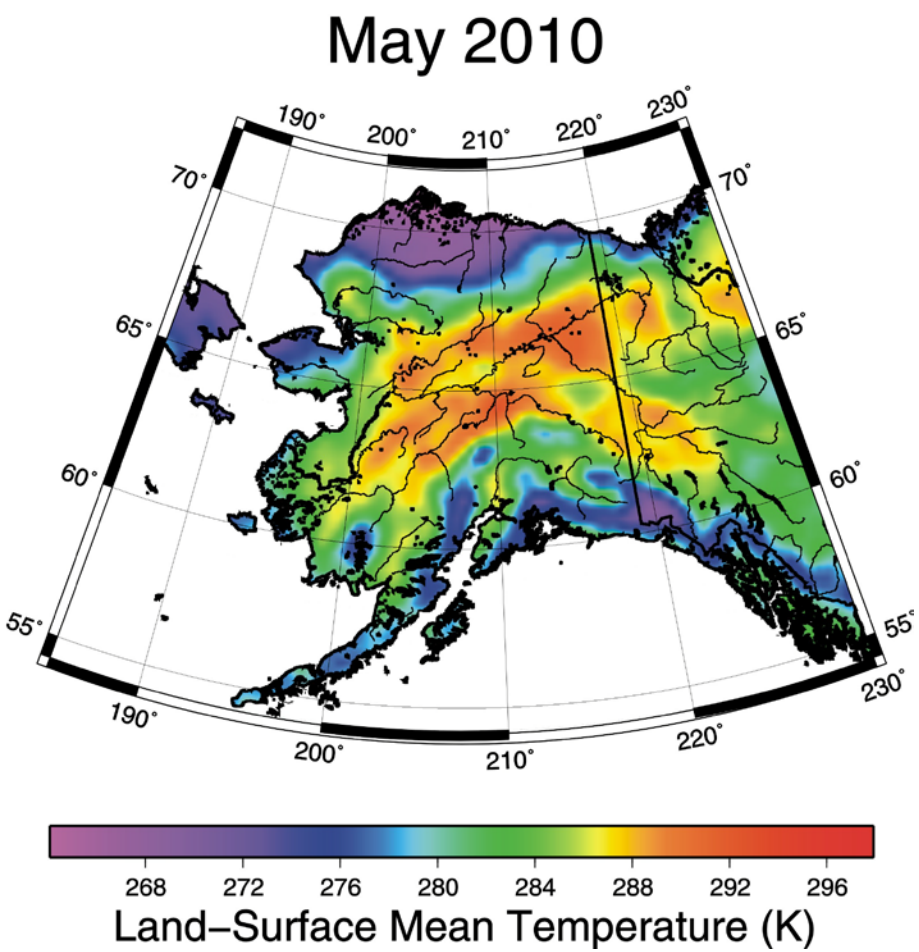




Spatial layer data products

Example Deliverable





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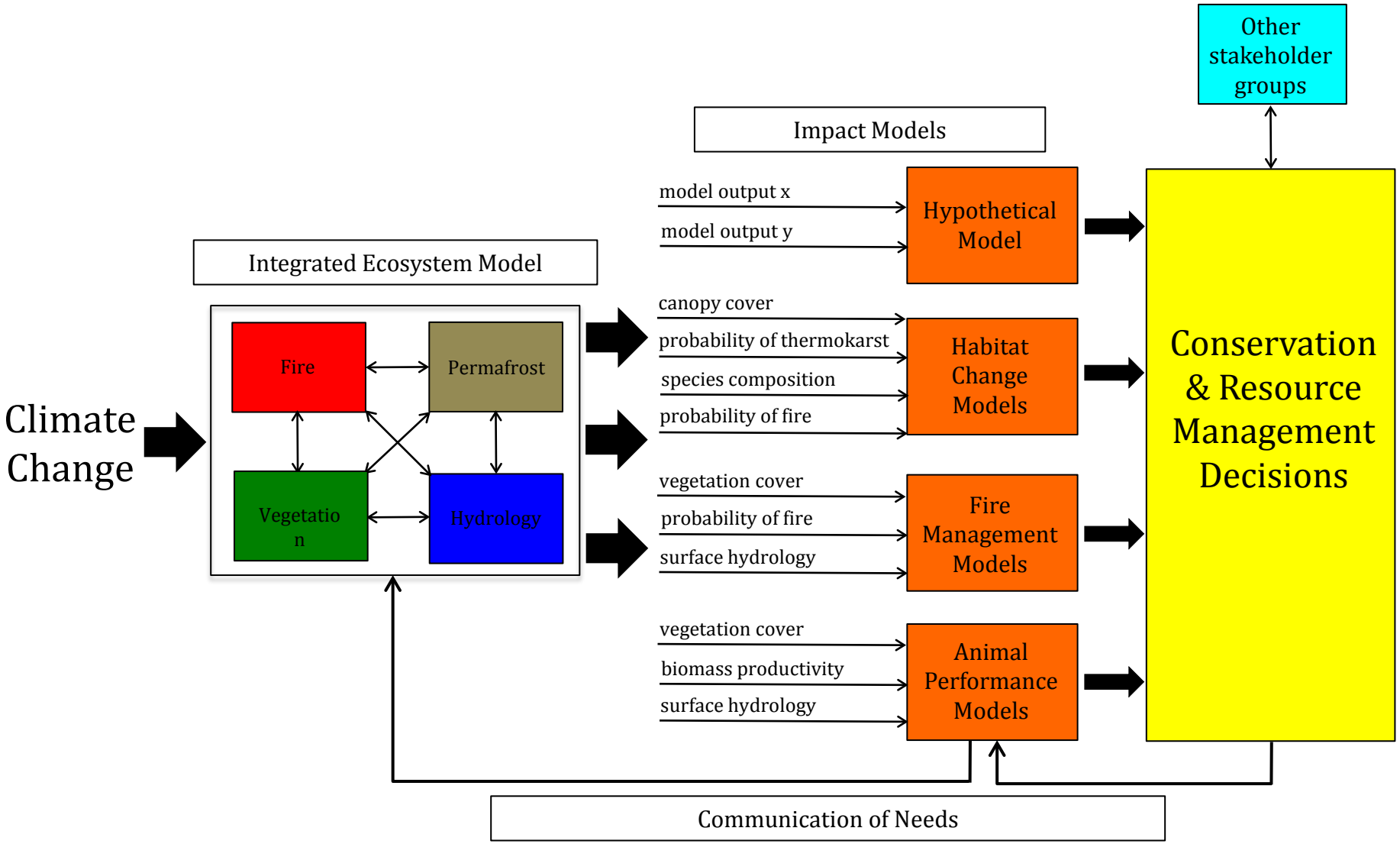

Broader Impacts & Significance

The Integrated Ecosystem Model for Alaska will provide a *decision support tool* which will:

- Improve our understanding of the potential response of ecosystems to climate change
- Identify processes by which climate change will most likely affect species and habitats
- Serve to inform the structure and design of inventory and monitoring activities
- Serve to broadly inform societal issues that will be affected by climate change such as human health, agriculture, engineering and subsistence sustainability