Alaska Integrated Ecosystem Model

The Pilot Year

A collaborative research project for the
USGS/UAF Alaska Climate Science Center &
USFWS Arctic, Western Alaska and Northwest Interior Forest
Landscape Conservation Cooperatives

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USFWS Arctic, Western Alaska

& Northwest Interior Forest LCCs

Presentation Outline

I. *Introduction*

II. Study system in Alaska

III. Conceptual model framework

IV. Coupling Exercise

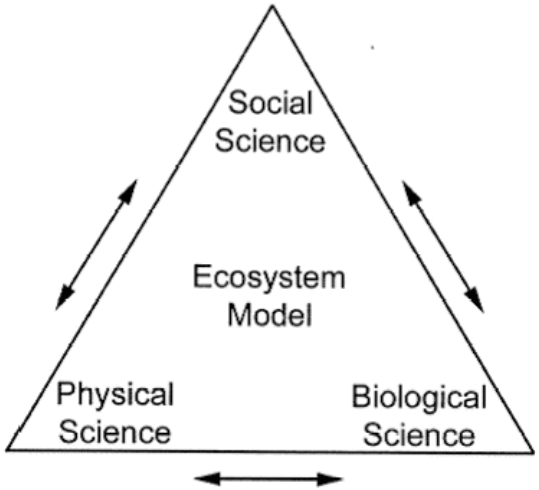
V. Beyond the Pilot Year

VI. Management Implications

Why model ecosystems?

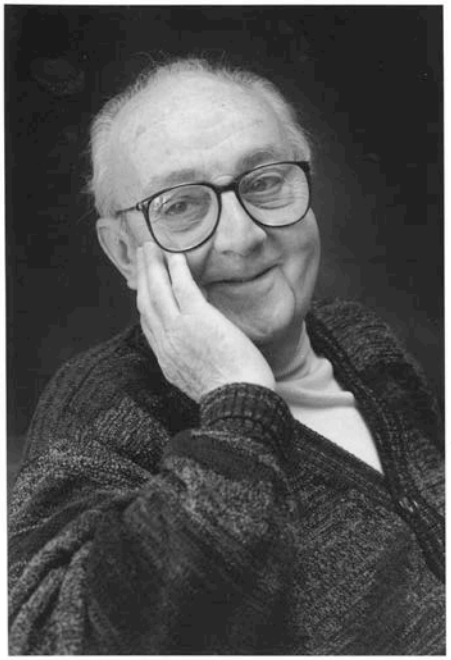
- Better understand complex set of measurements
- Assess behavior in situations and/or at scales beyond which measurements can be made
- Predict potential future conditions and states
- Integrate across space and time
- Inform management and policy decisions

Ivishak Hot Springs in the northern foothills of the Brooks Range in early spring



Sources of model uncertainty

- System complexity
- Model parameters
- Driving input variables
- Temporal and spatial resolution
- Validation data



Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.

Box & Draper (1987) *Empirical Model-Building*

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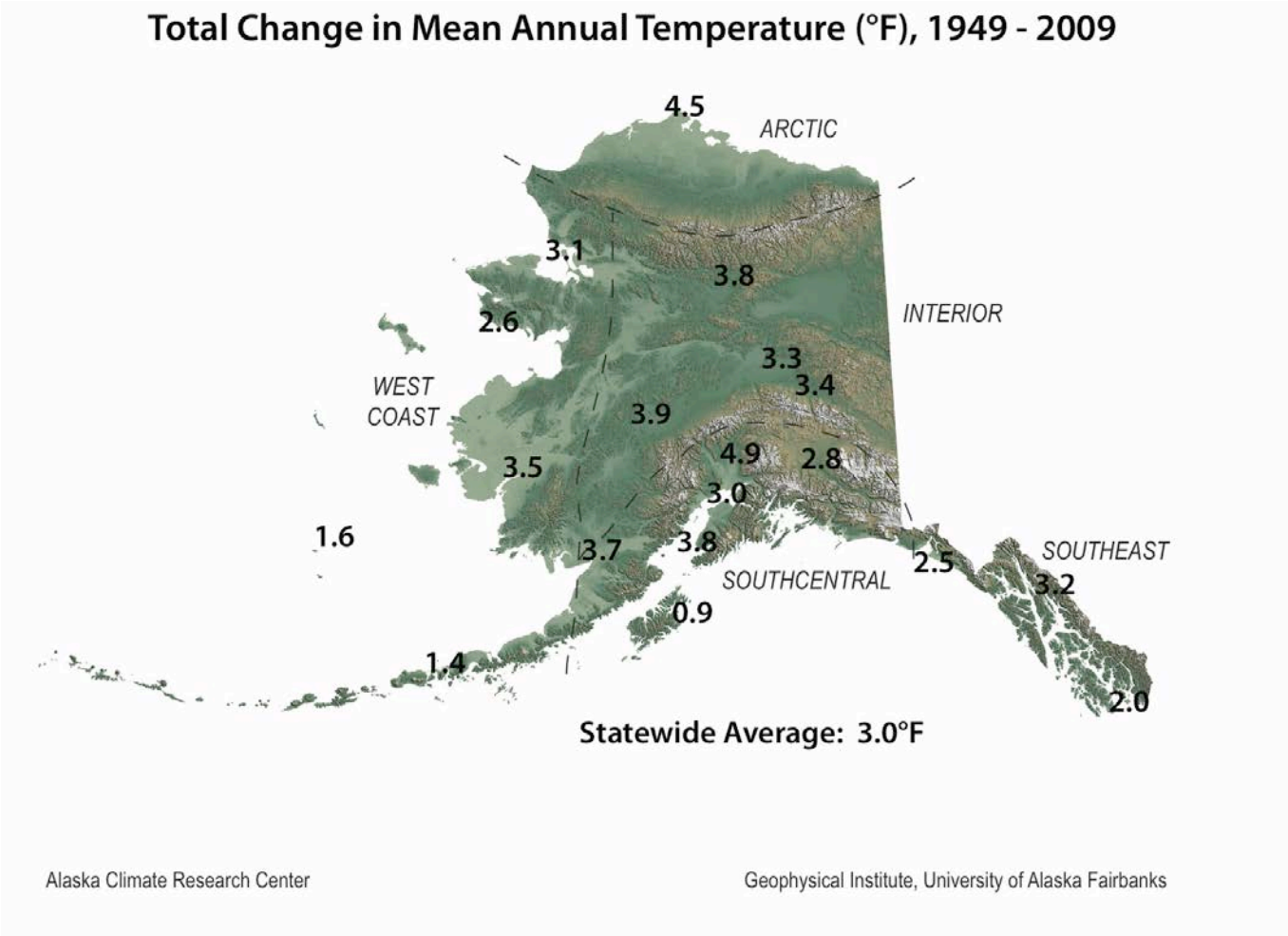
Climate change in Alaska



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 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

Alaska Integrated Ecosystem Model

Objectives for the Pilot Year:

1) 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*

2) Coupling Exercise

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

3) Data Streams & Spatial Layers

To 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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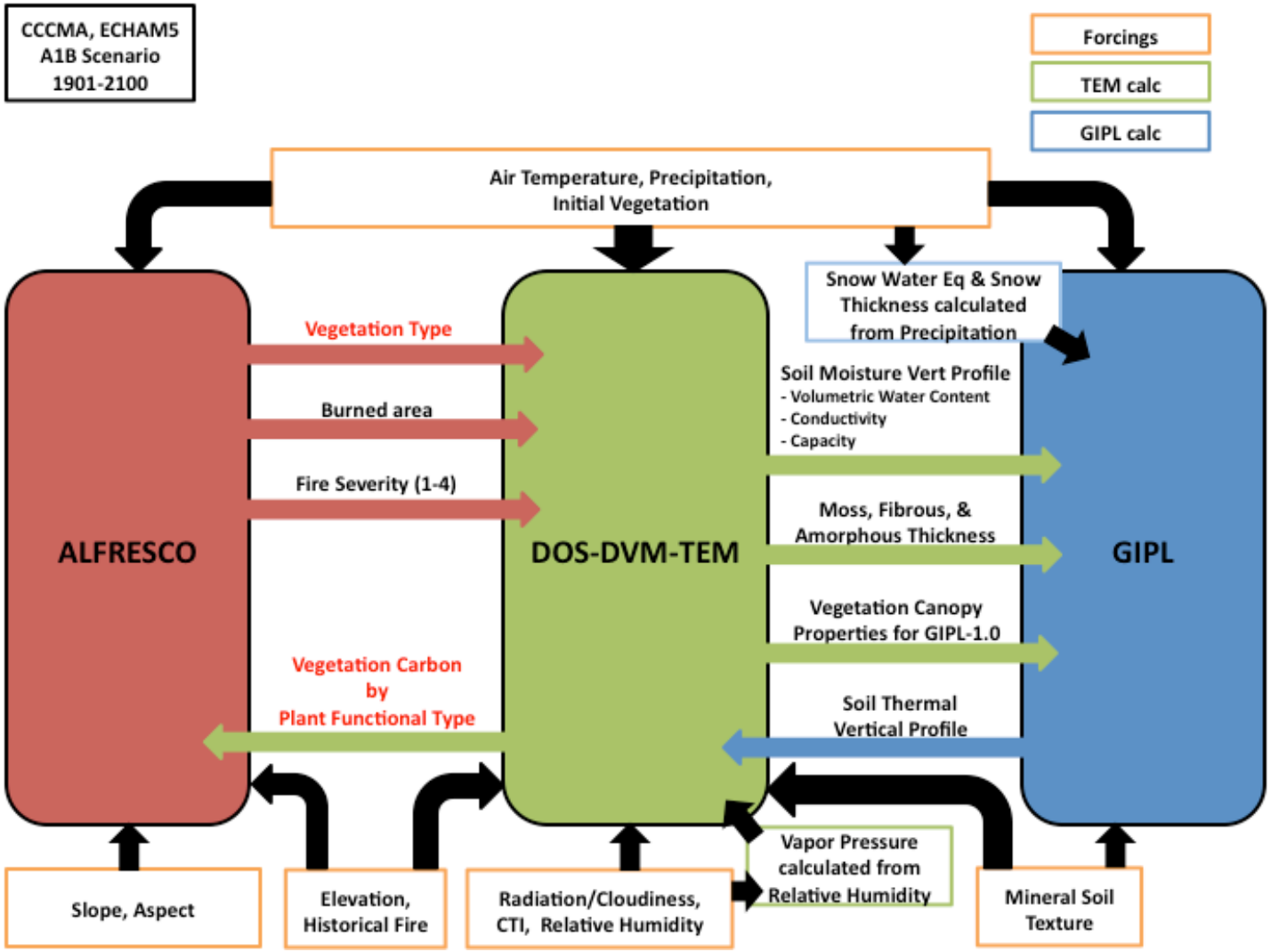
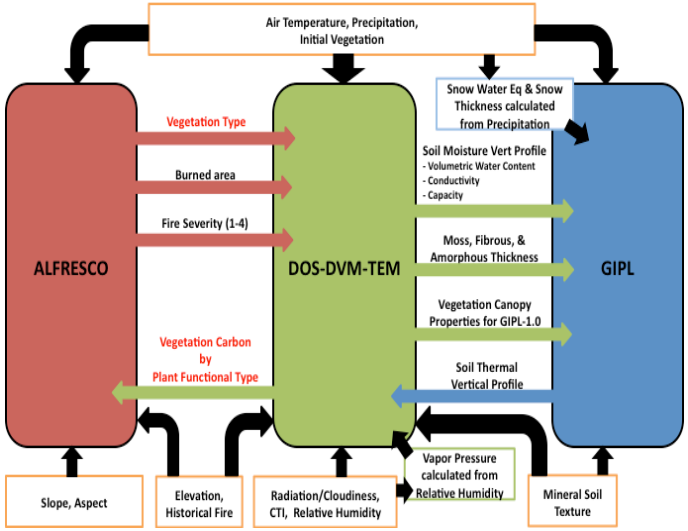
Alaska Integrated Ecosystem Model



Alaska IEM Conceptual Framework

Alaska IEM



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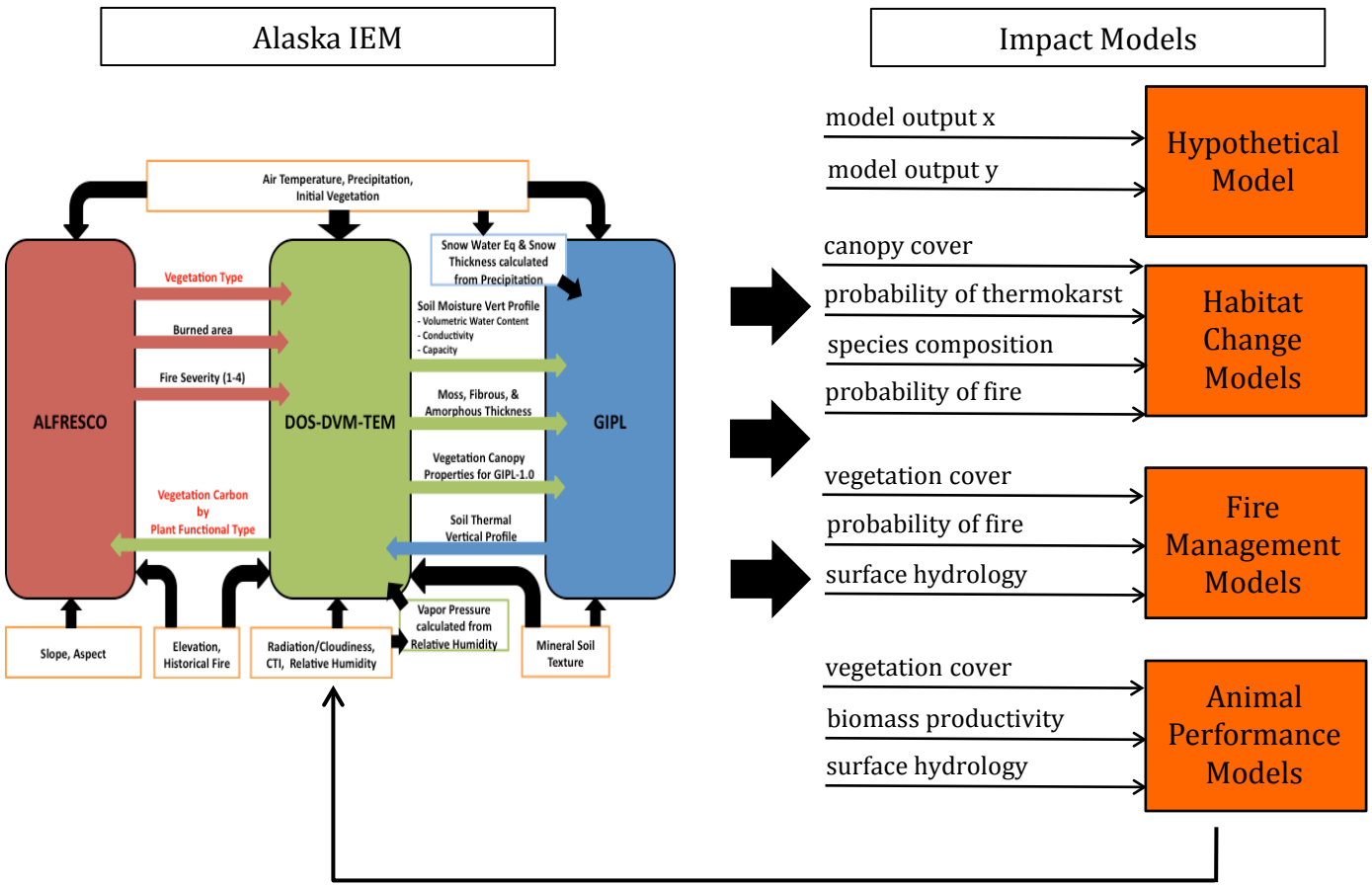

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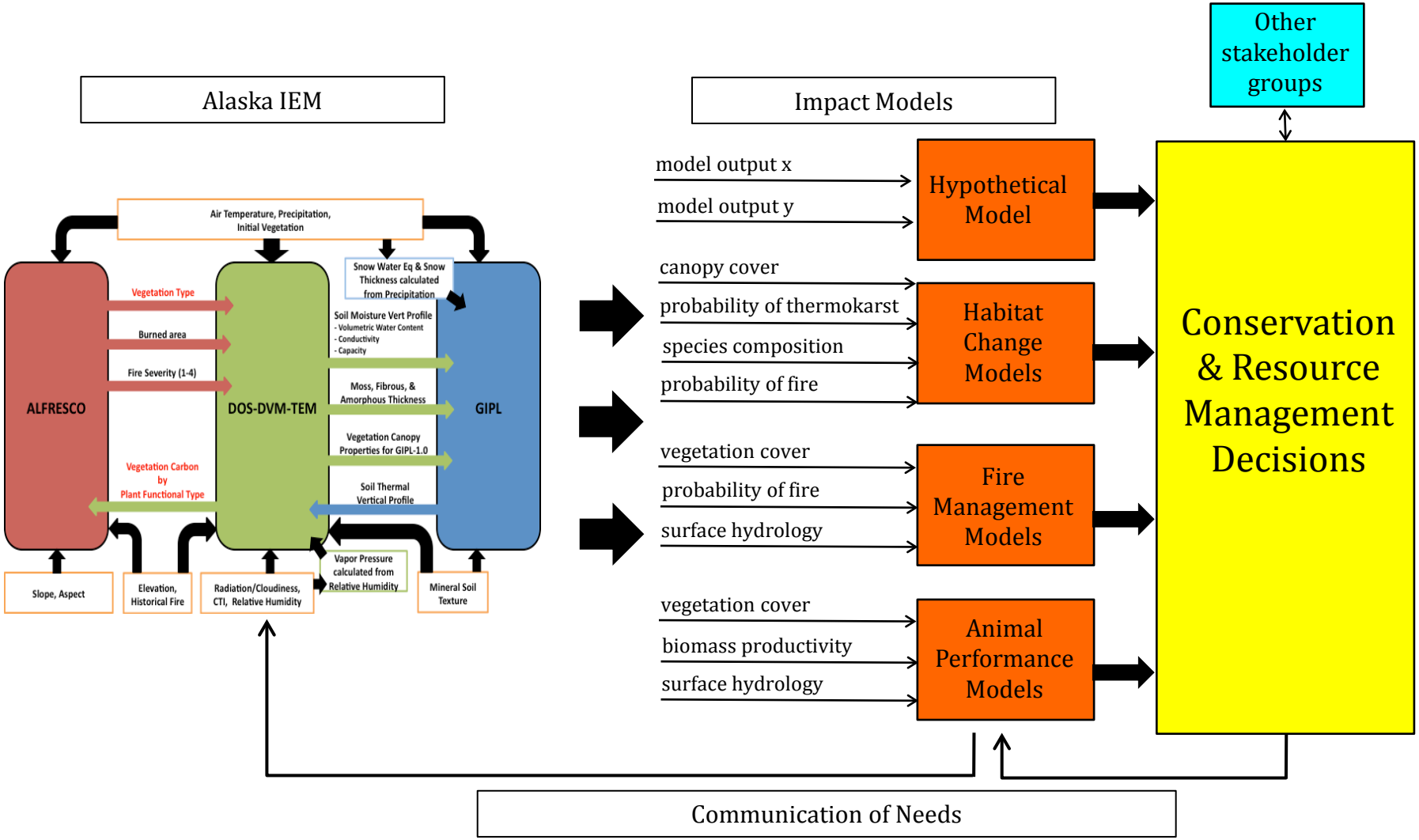
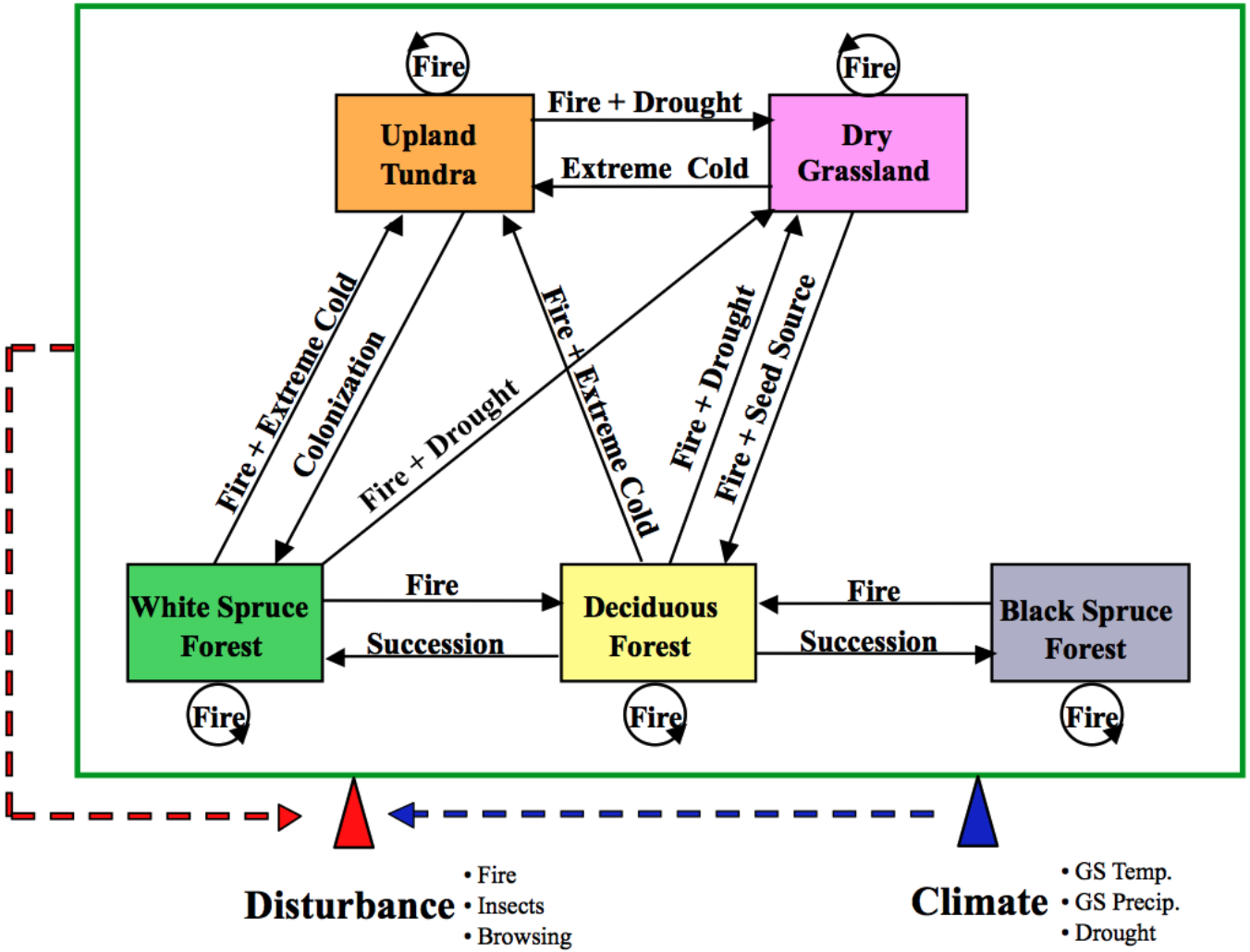


ALFRESCO Alaska Frame-based Ecosystem Code

- 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 Alaska Frame-based Ecosystem Code



DOS-TEM Dynamic Organic Soil Module-Terrestrial Ecosystem Model

- Simulates soil organic layer thickness and carbon dynamics
- Soil profile is multiple-layered and contains four soil organic matter components of different decomposition rates
- Litter fall inputs coarse materials into ground and root death puts them into soil layers according to root distribution
- Soil organic matter in the upper layer can be moved or blended with the lower layer
- Fire removal of soil organic layers is determined by fire size, occurrence season, vegetation type, and landscape position

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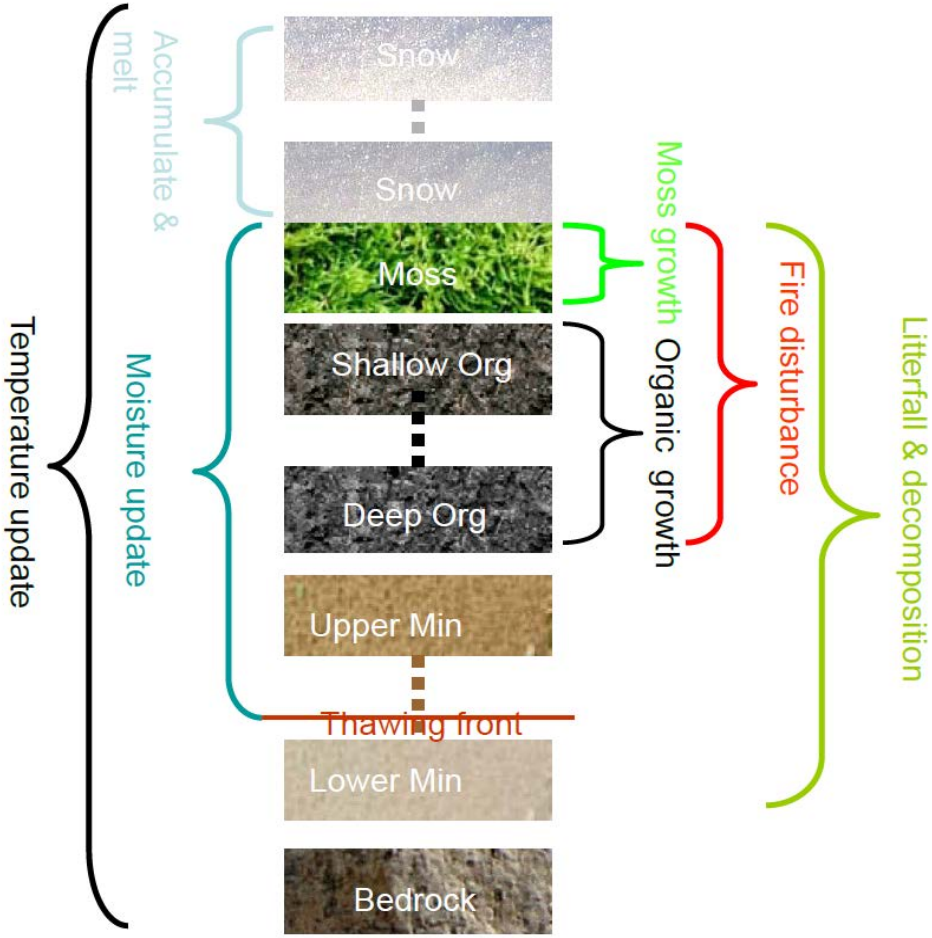
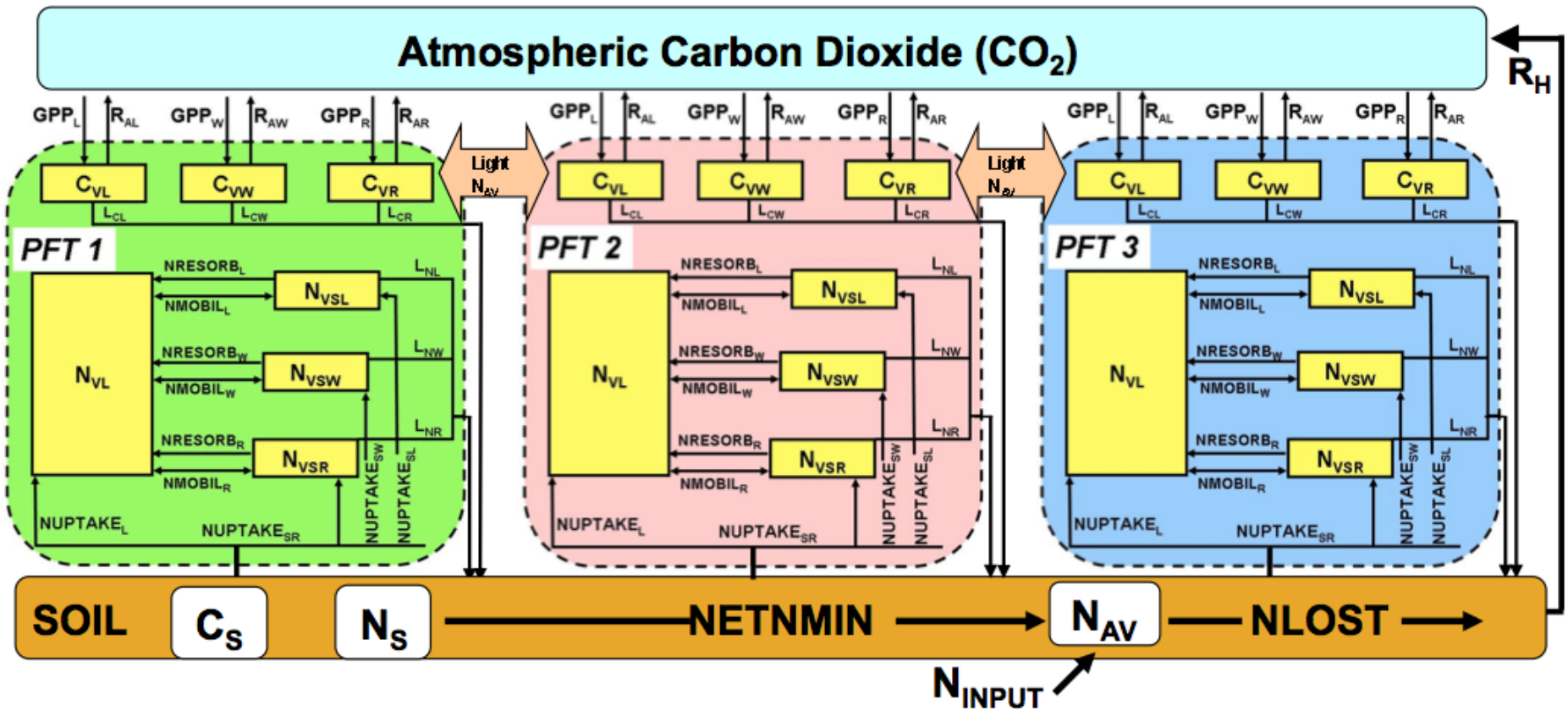


DVM-TEM Dynamic Vegetation Module-Terrestrial Ecosystem Model

- 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 five major ecosystem types

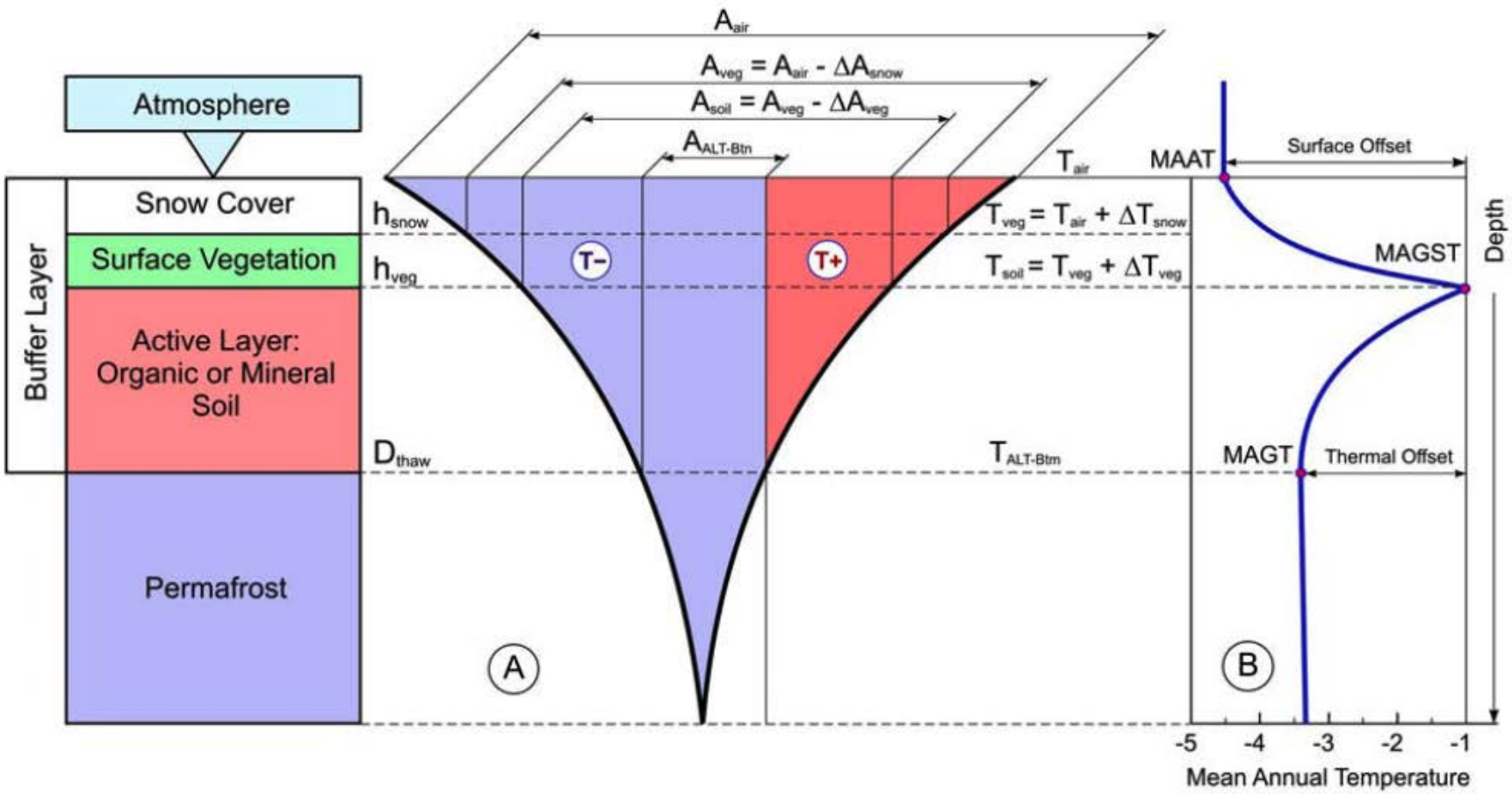
DVM-TEM Dynamic Vegetation Module-Terrestrial Ecosystem Model



GIPL Geophysical Institute Permafrost Lab Model

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

GIPL Geophysical Institute Permafrost Lab Model



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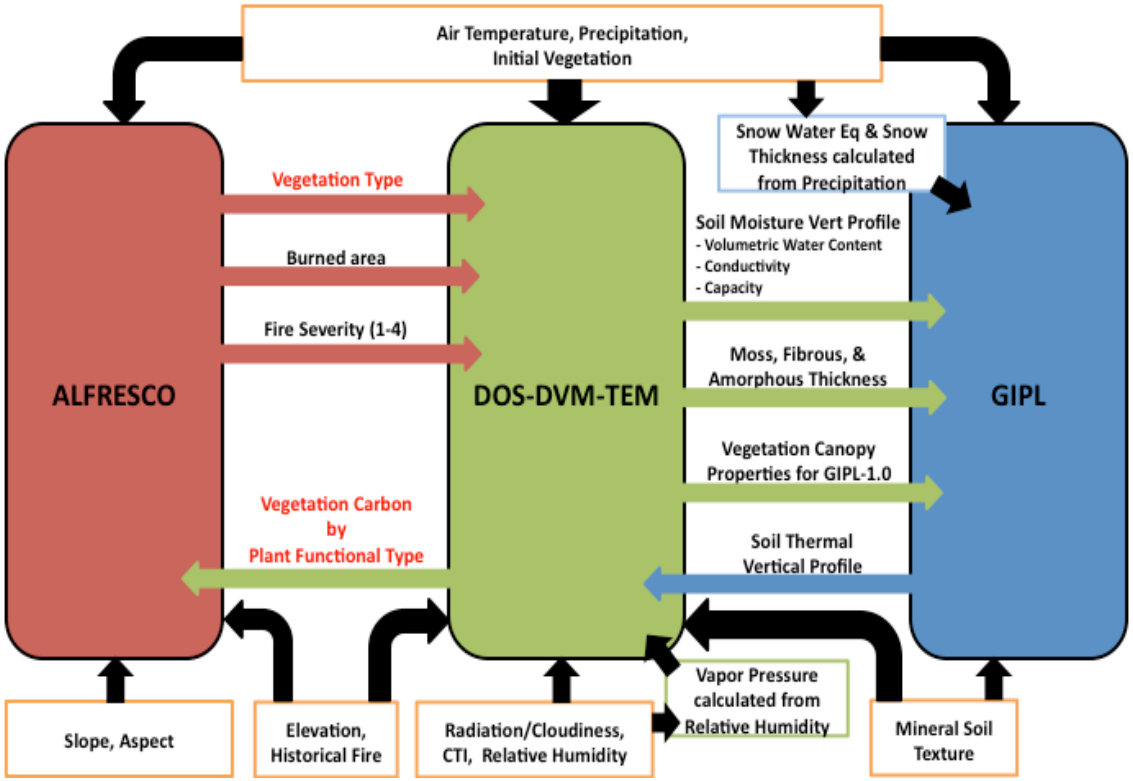
Coupling Exercise

Designed to clarify issues related to:

- forcing data
- exchange of data between models



Coupling Exercise

Simulation Protocol

Boundary: Alaska Yukon River Basin (AKYRB)

Spatial resolution: 1 x 1 km for all models

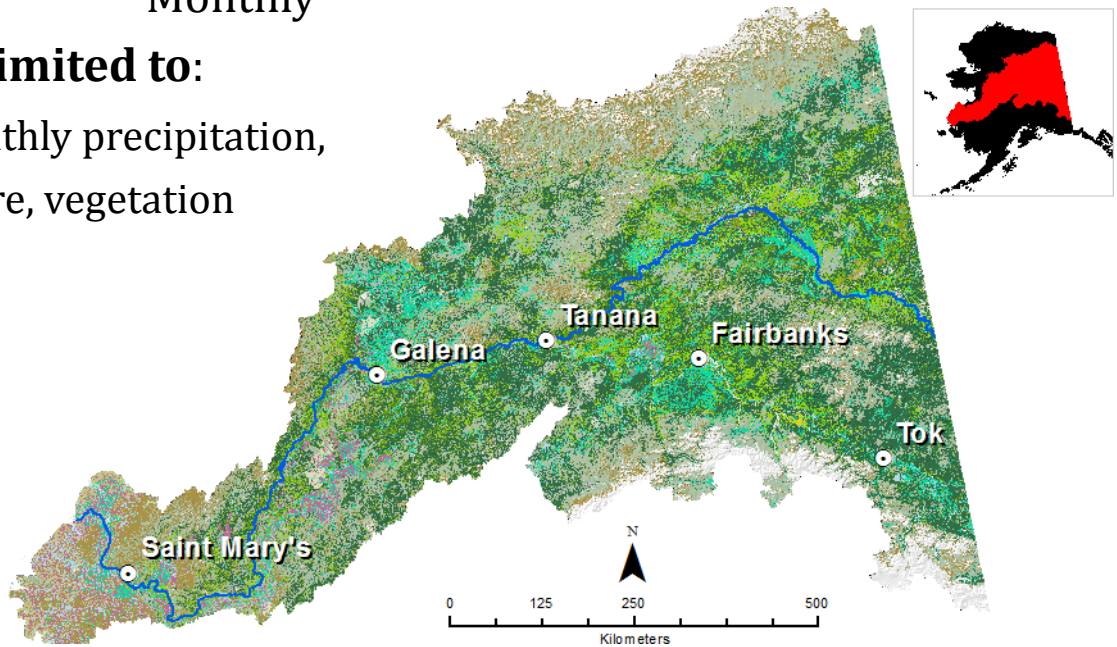
Historical extent of model outputs: 1950-2006

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



Coupling Exercise

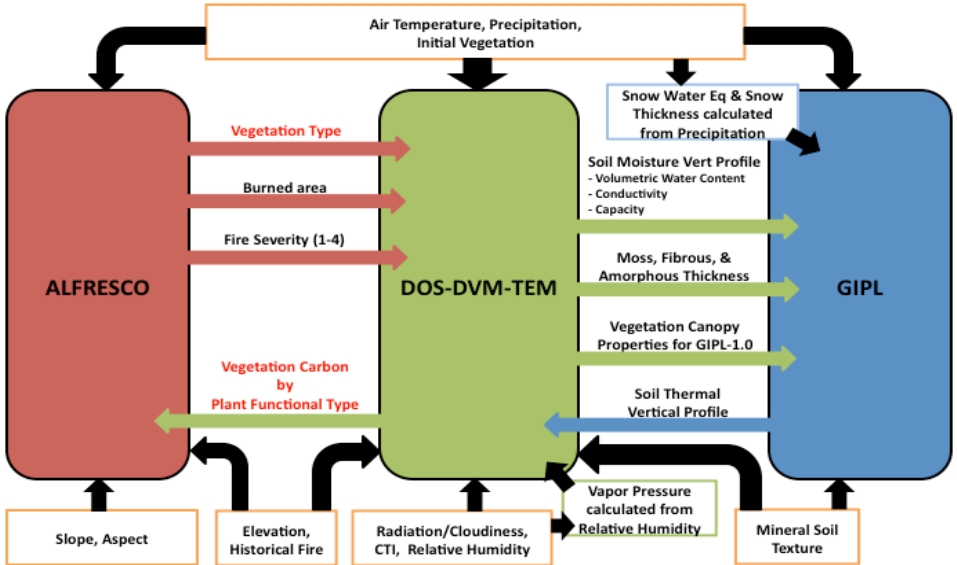
Simulation Series

- 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 regime outputs *drive*

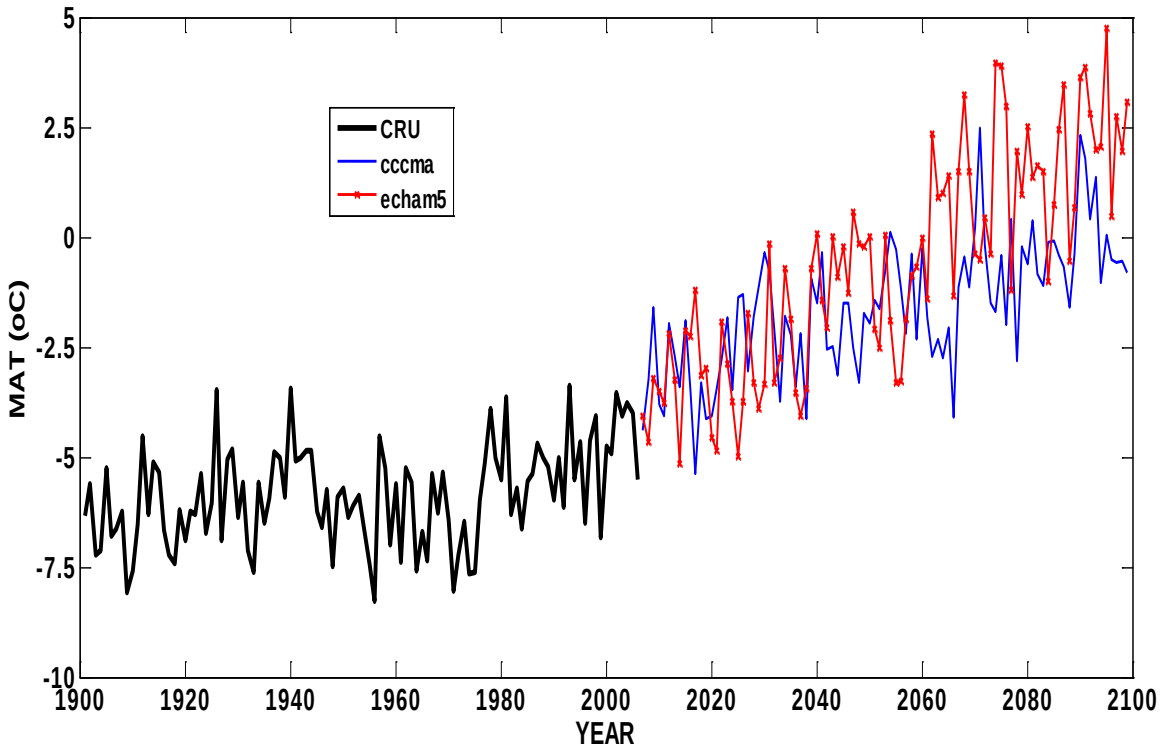
  Stage 2: DOS-DVM-TEM which produces moss and and organic layer thickness outputs to *drive*

  Stage 3: GIPL



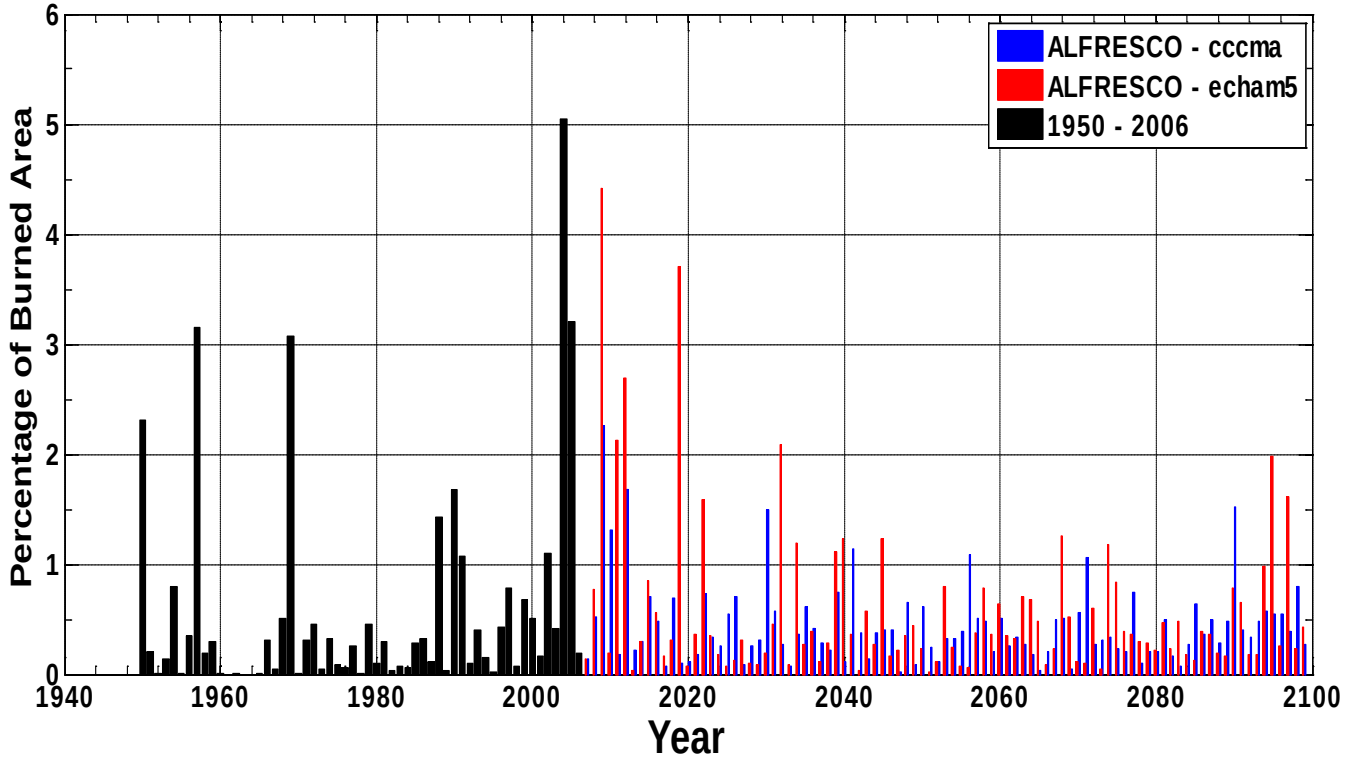
Coupling Exercise

Mean Annual Temperature and its projection for the AKYRB



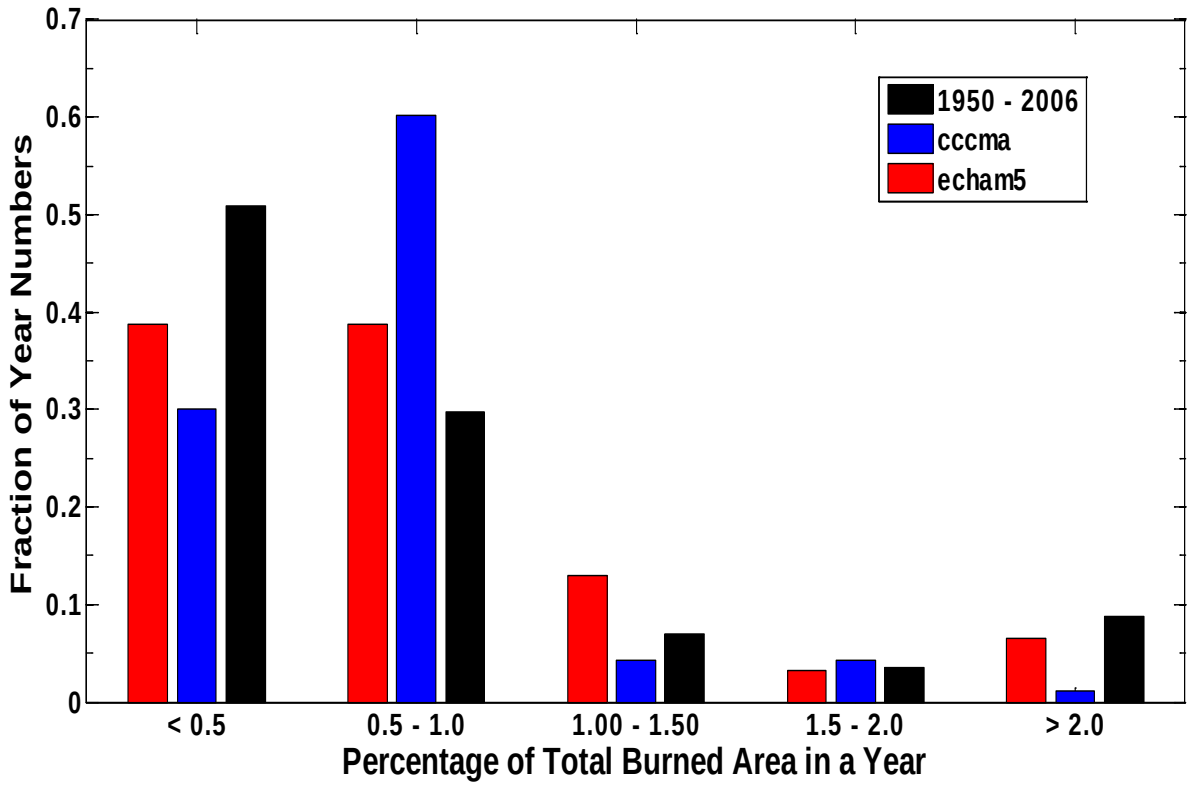
Coupling Exercise

Historical and projected annual burned area over the AKYRB



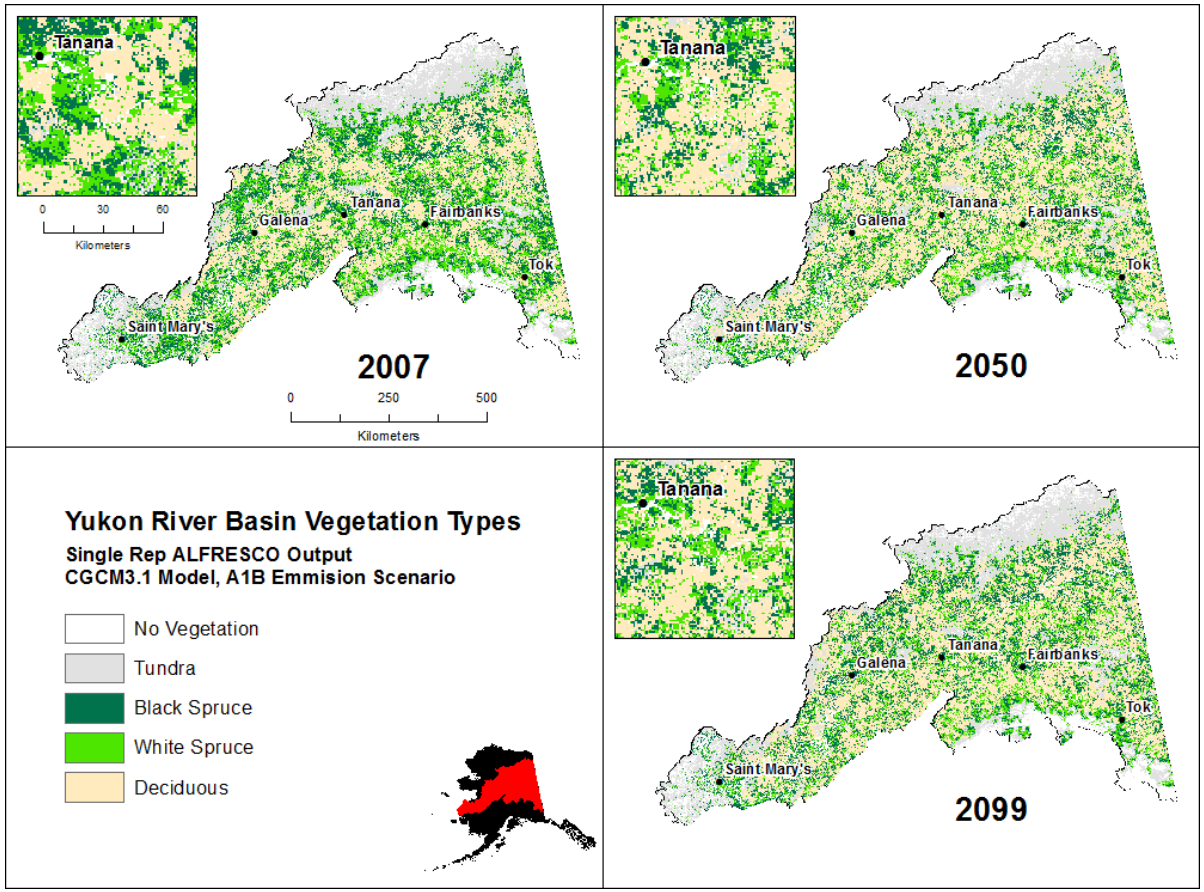
Coupling Exercise

Relative frequency of annual burned area over the AKYRB



Coupling Exercise

Modeled ALFRESCO vegetation dynamics for the AKYRB



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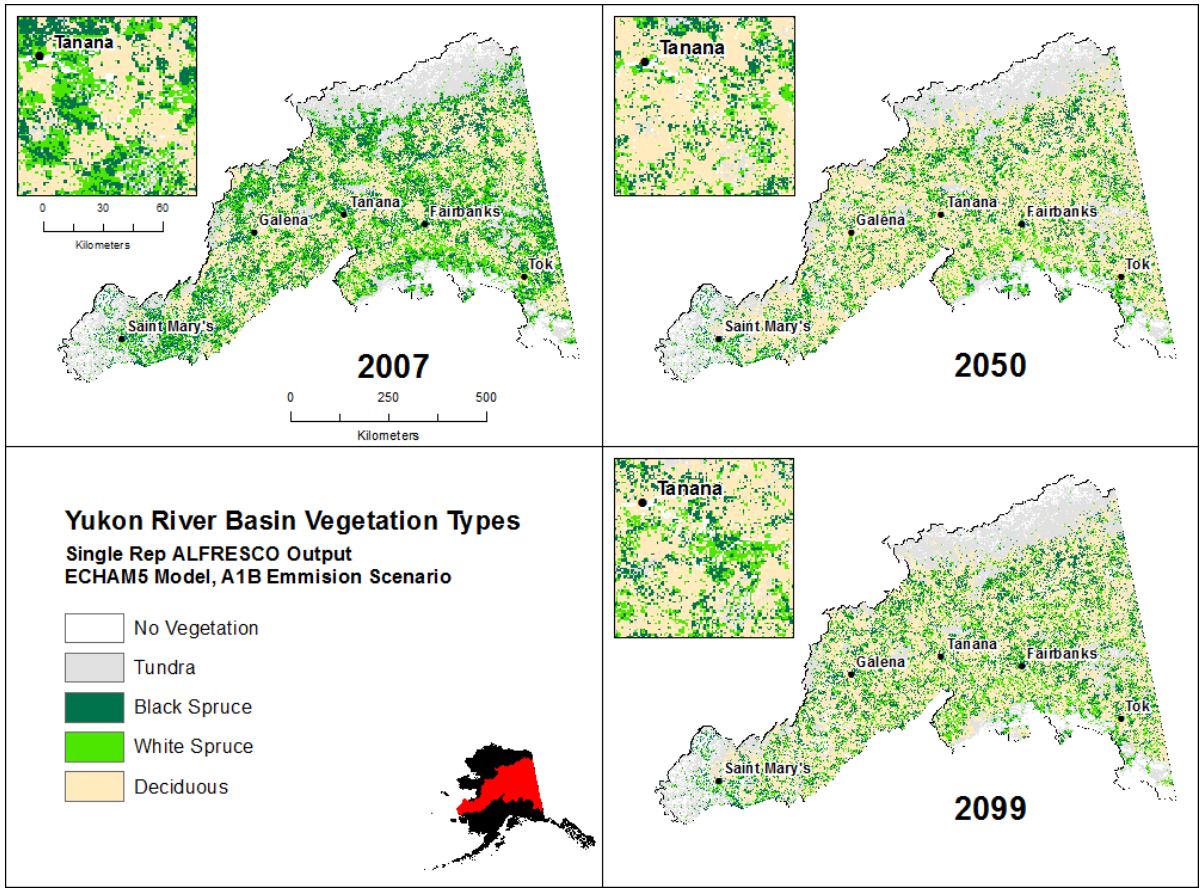
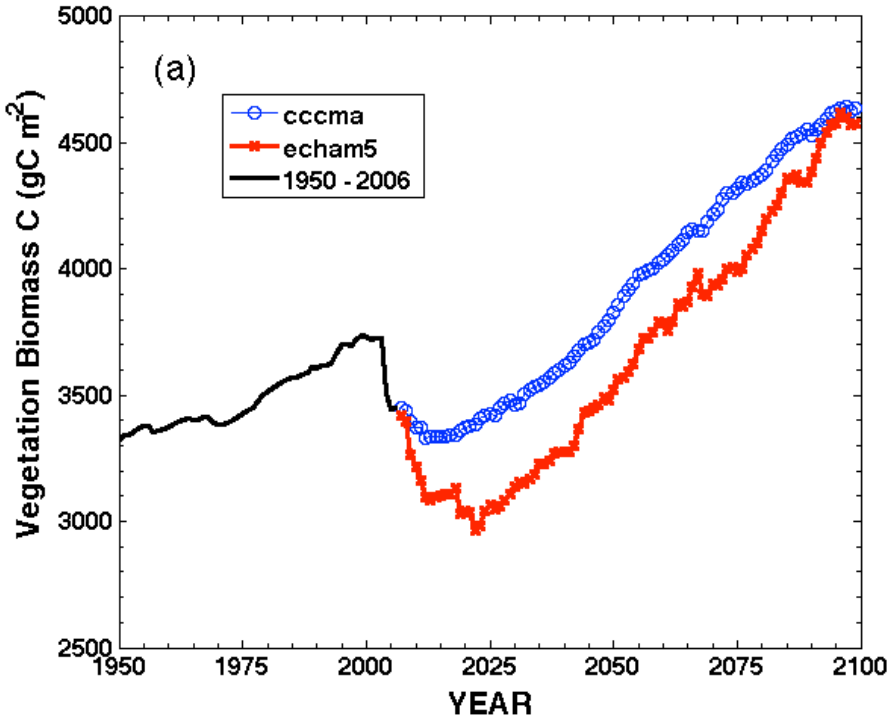
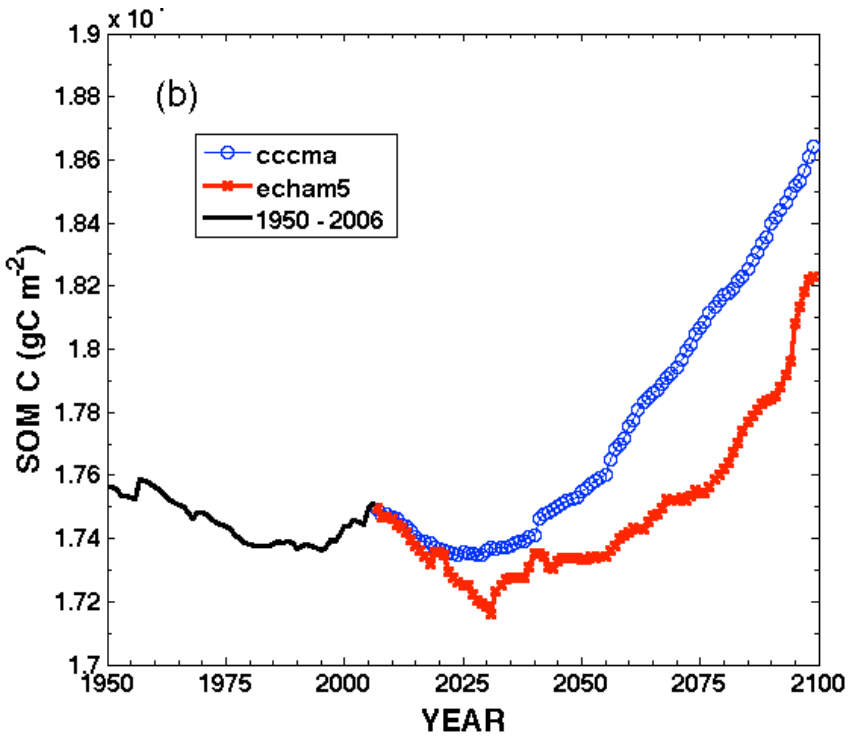


Coupling Exercise

ALFRESCO fire scenarios *drive* TEM soil thermal dynamics





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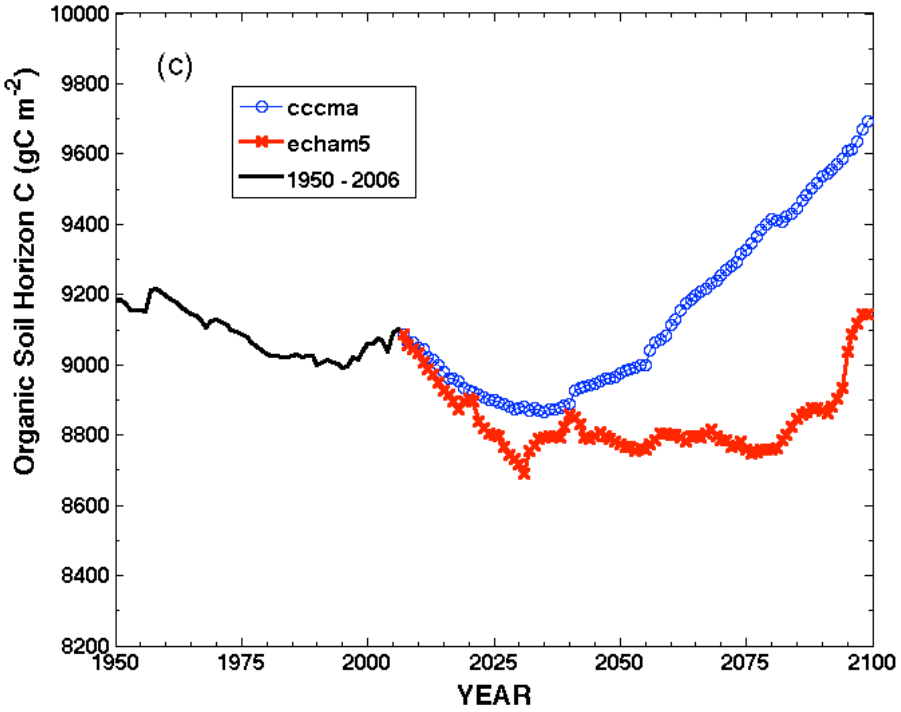

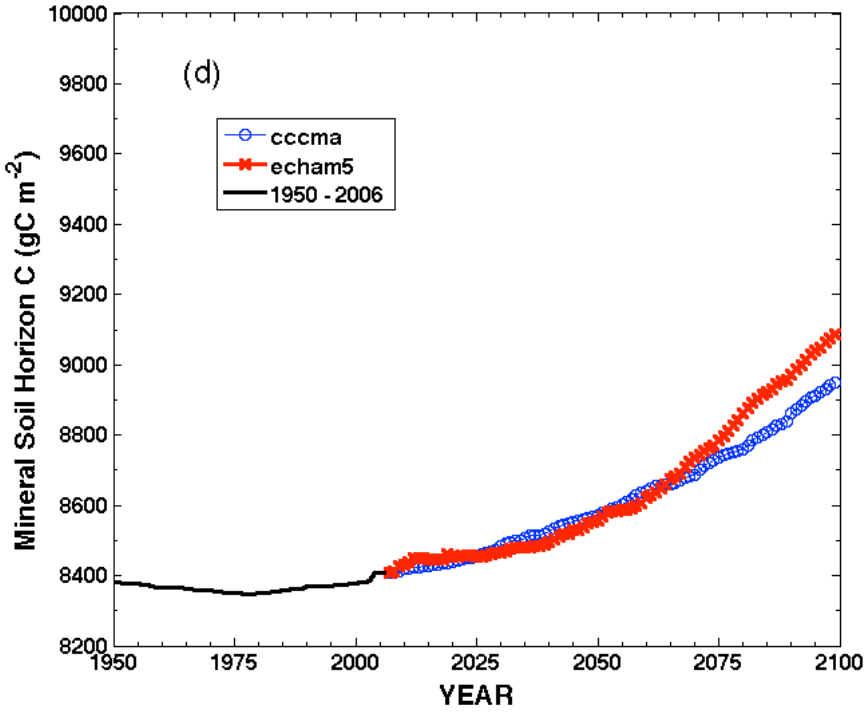

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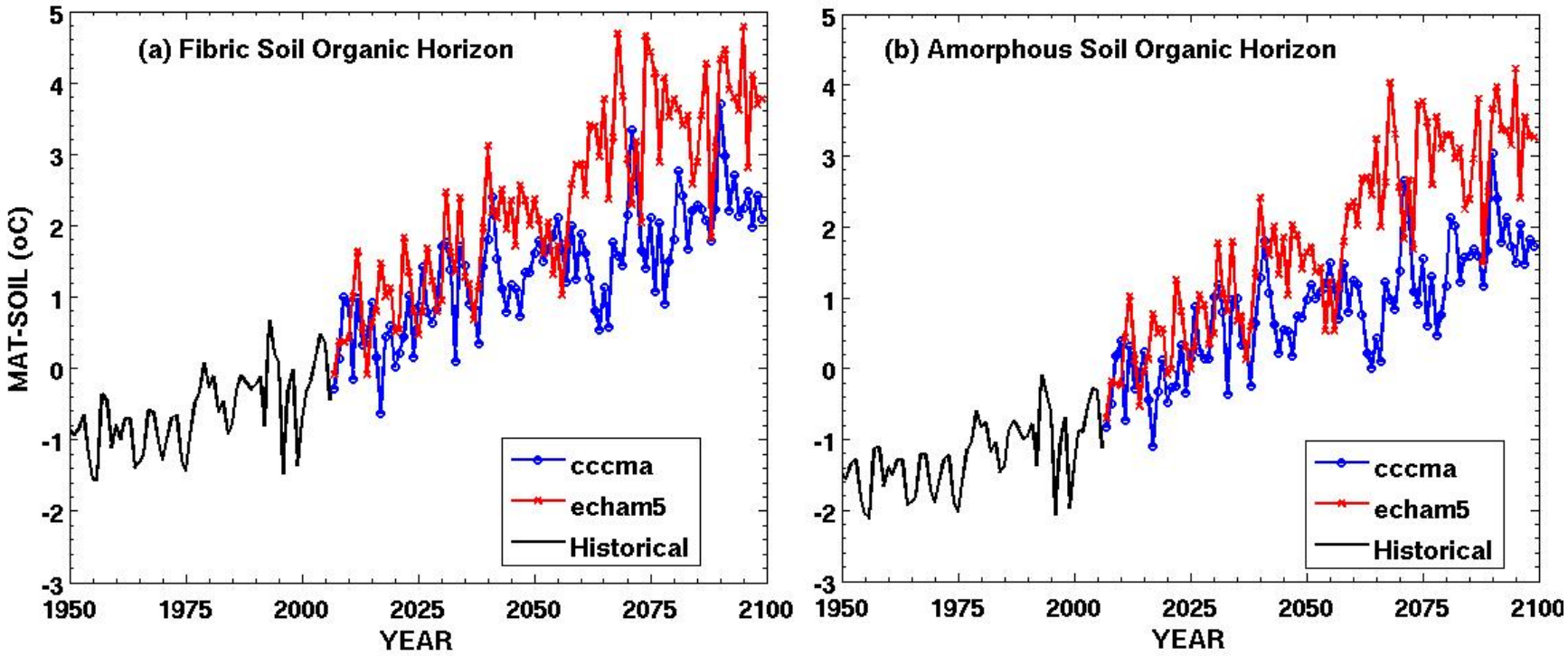

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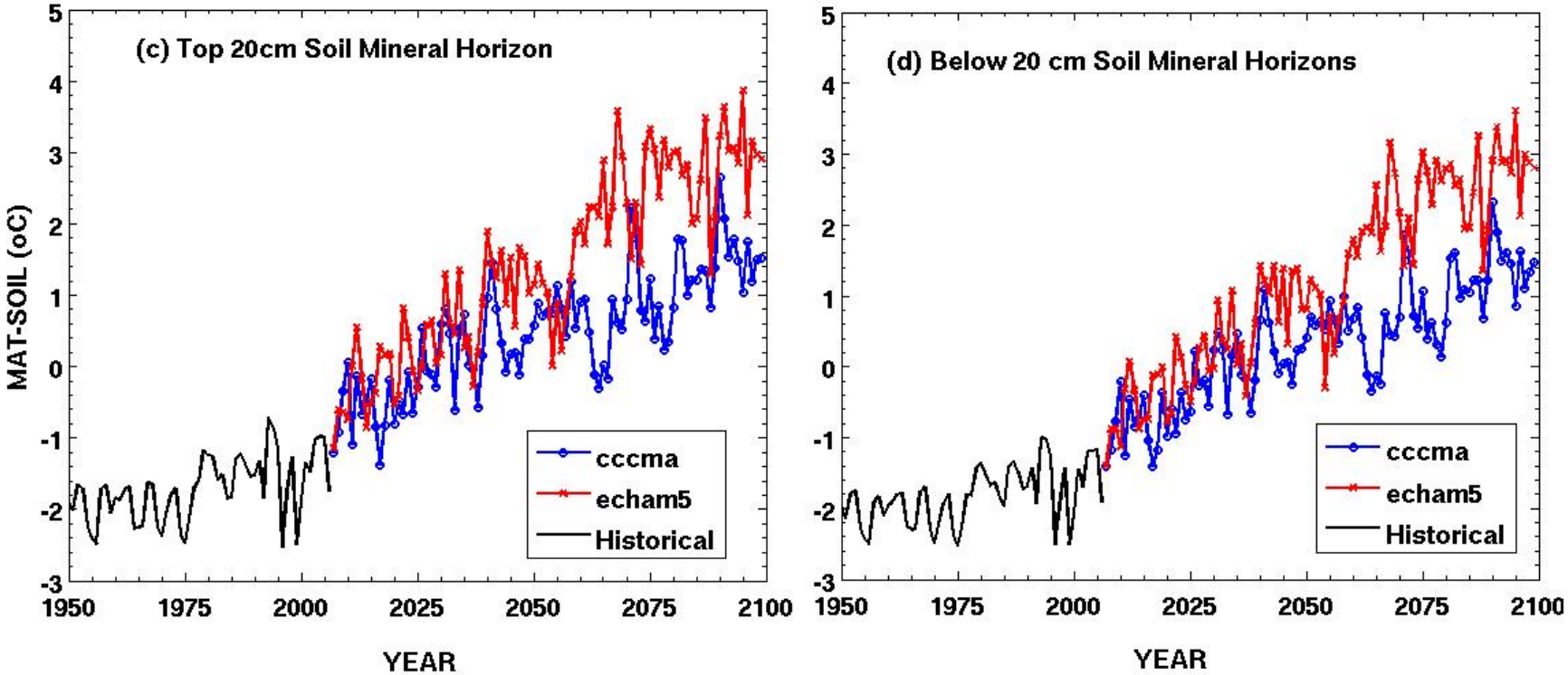

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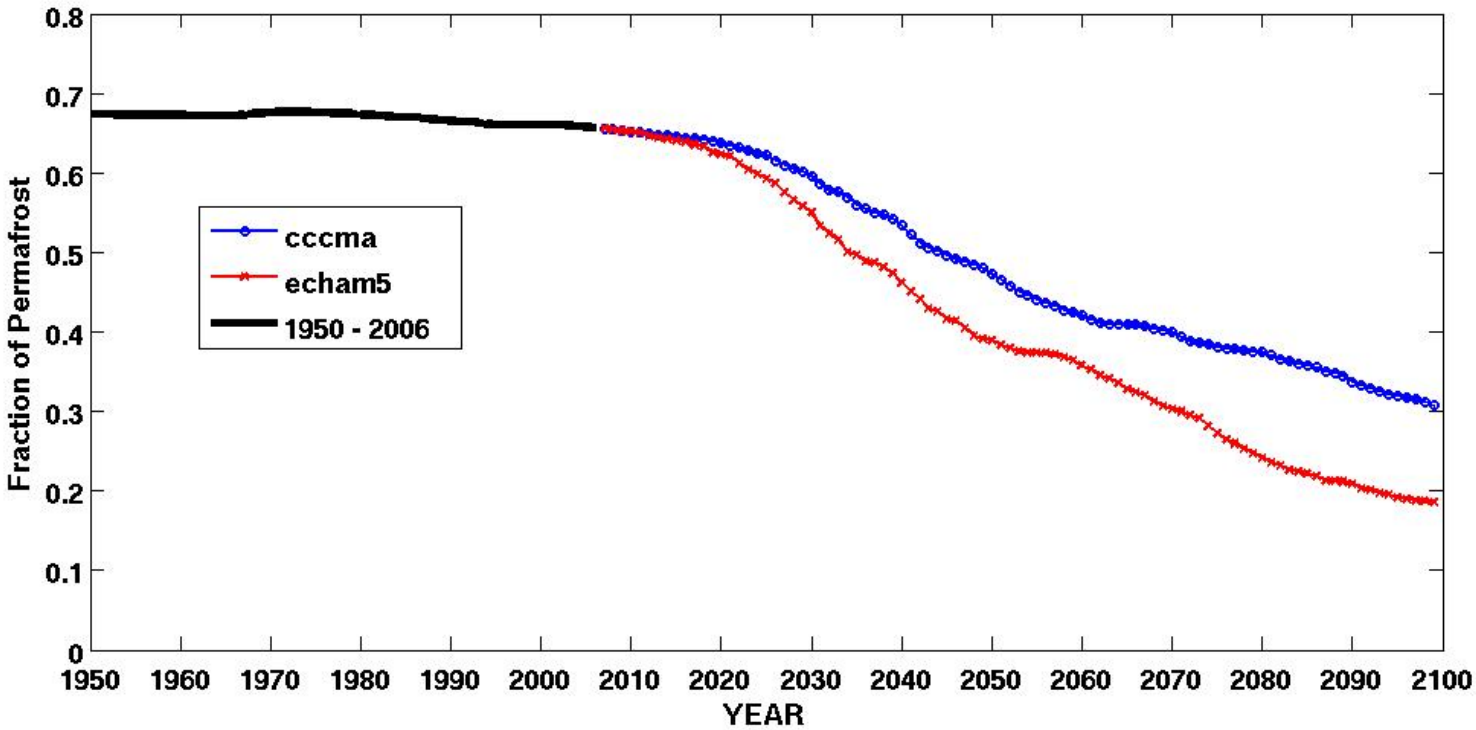

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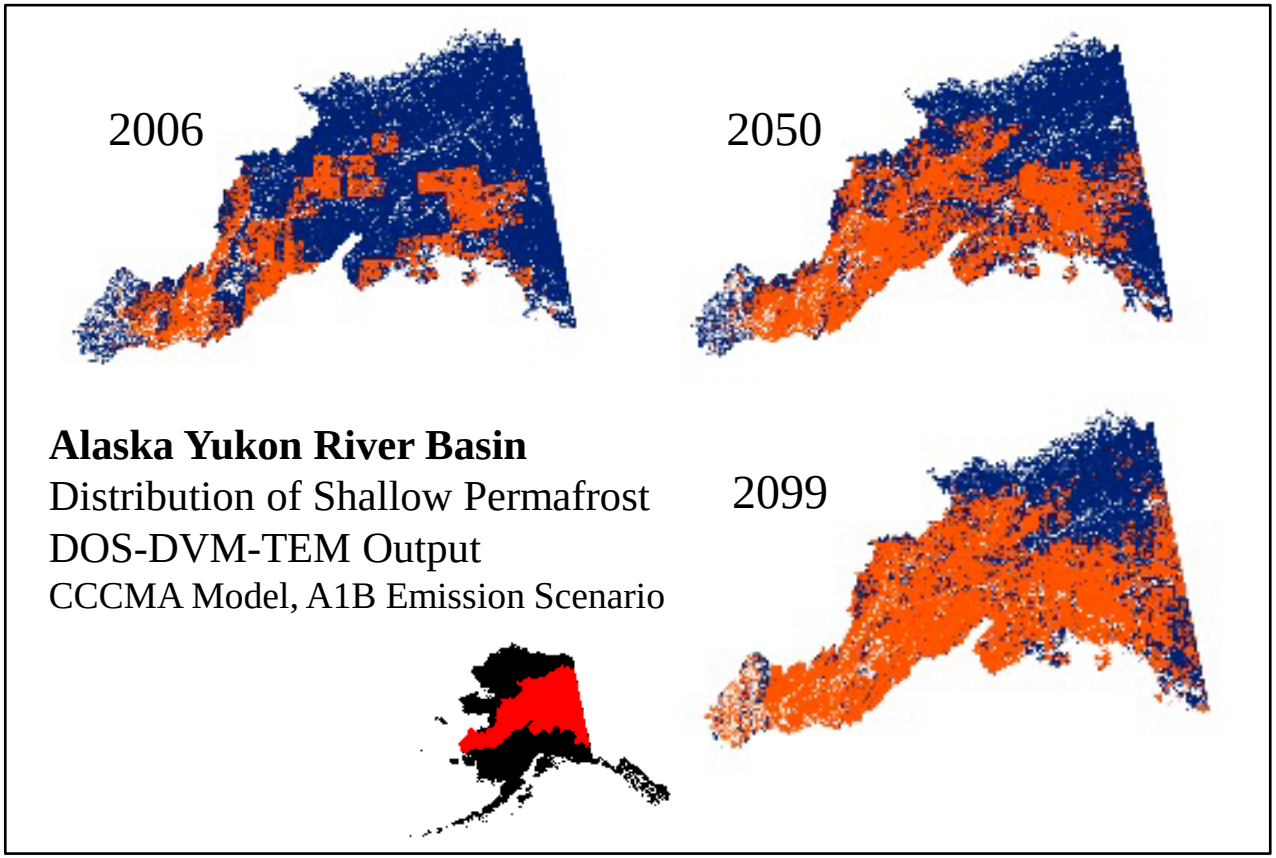
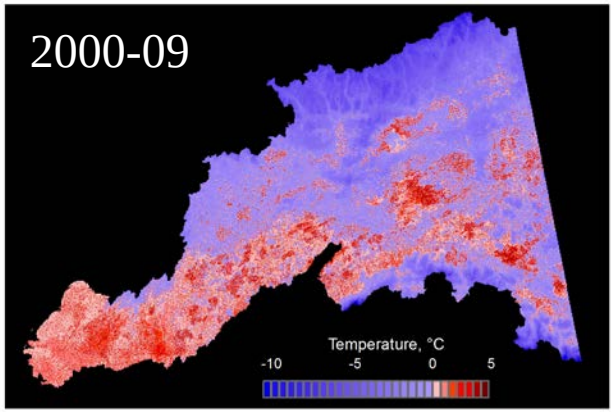
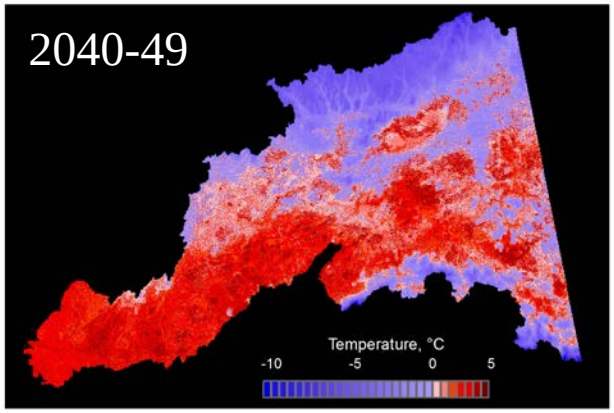


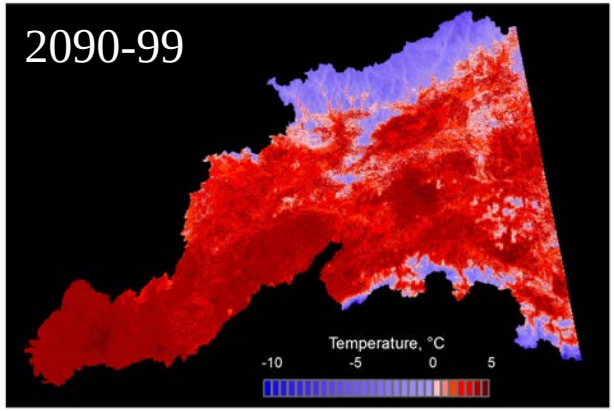
Coupling Exercise

TEM moss and and organic layer thickness outputs *drive* GIPL



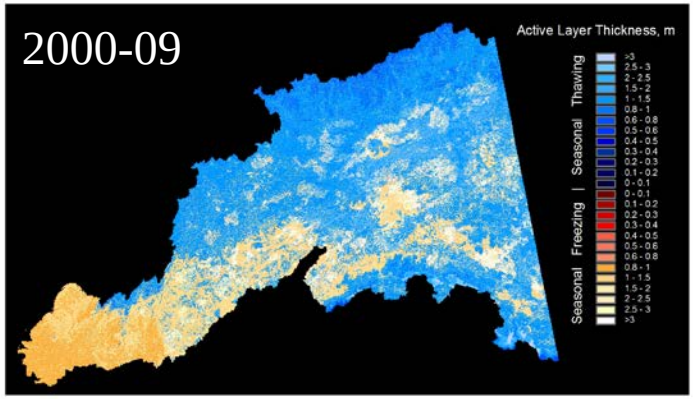


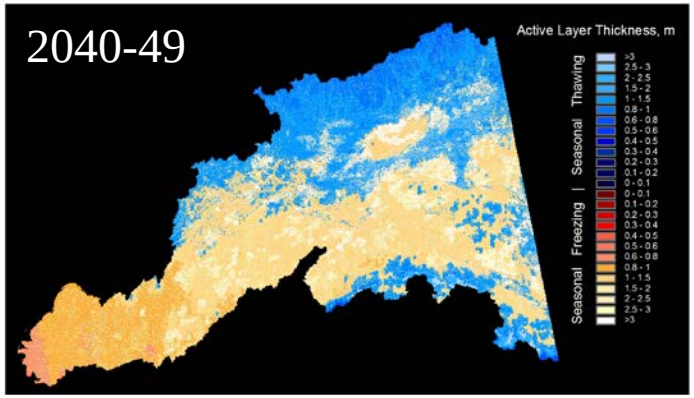
Alaska Yukon River Basin
Mean Annual Ground Temperature (°C)
GIPL-1 Output, Decadal Average
CCCMA Model, A1B Emission Scenario



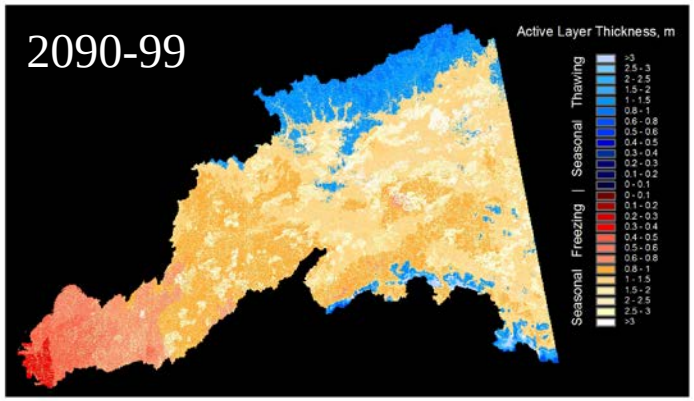
Coupling Exercise

TEM moss and and organic layer thickness outputs *drive* GIPL





Alaska Yukon River Basin
Active Layer Thickness (m)
GIPL-1 Output, Decadal Average
CCCMA Model, A1B Emission Scenario



Coupling Exercise

Summary of Results from the Pilot Study

ALFRESCO

- Fire was enhanced through the mid-21st century after which it reverted to pre-1990 levels because of a shift to low flammability deciduous forest

TEM *driven* by ALFRESCO fire

- Carbon in vegetation and soil organic horizons decreased in response to more frequent fire in the first half of the 21st century; then accumulated after fire became less frequent in the second half of the century
- In contrast, carbon in soil mineral horizons accumulated throughout the century
- Soil temperature warms through the 21st century
- Shallow permafrost decreases from ~70% of the basin to 20-30% of the basin by 2100

Coupling Exercise

Summary of Results from the Pilot Study

GIPL *driven* by TEM moss and and organic layer thickness

- Area with mean annual ground temperatures > 0 °C increases from ~40% in the 2000s to 64% mid-century and 85% by the end of the 21st century
- Active layer thickness switches for most of the basin from seasonal thawing to seasonal freezing
- Permafrost largely confined to the mountainous foothills of the Brooks Range by 2100

What have we learned from the Pilot Year?

- Identified and obtained all variables needed to drive and couple the individual models
- How to modify outputs from one model so that they are meaningful to another model
- How to downscale driving variables
- How to compare similar output variables between models to understand differences and/or uncertainties in these outputs

Perhaps most important -- we provided the full research team with experience that will be valuable as we enter Phase II and synchronously couple the Alaska IEM

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Alaska IEM: Phase II

Objectives for Phase II:

1) Model coupling

To develop and apply a fully **synchronous** coupled model over the Western Arctic integrating important components of an ecosystem model for Alaska including: *fire, vegetation succession and permafrost dynamics*

2) Tundra fire and treeline dynamics

To evaluate, test and incorporate tundra fire and treeline and shrub dynamics into the Alaska IEM

Alaska IEM: Phase II

Objectives for Phase II:

3) Thermokarst dynamics

To develop a conceptual model of thermokarst dynamics at a landscape scale and to evaluate, test and incorporate thermokarst dynamics into the Alaska IEM

4) Wetland dynamics

To design wetland field dynamics program to support the Alaska IEM and develop, evaluate, test and incorporate wetland dynamics into the Alaska IEM

Alaska IEM: Phase II

The steps to develop a fully coupled Alaska IEM include:

- Bring individual models into a common computer platform
- Set up communication between models so exchange data at appropriate time steps
- Test the application of the fully coupled model in a retrospective context
- Assess response to future climate change scenarios across the Western Arctic
- Incorporate future climate change scenarios for:
    - Tundra fire and Treeline and Shrub dynamics
    - Thermokarst and wetland dynamics

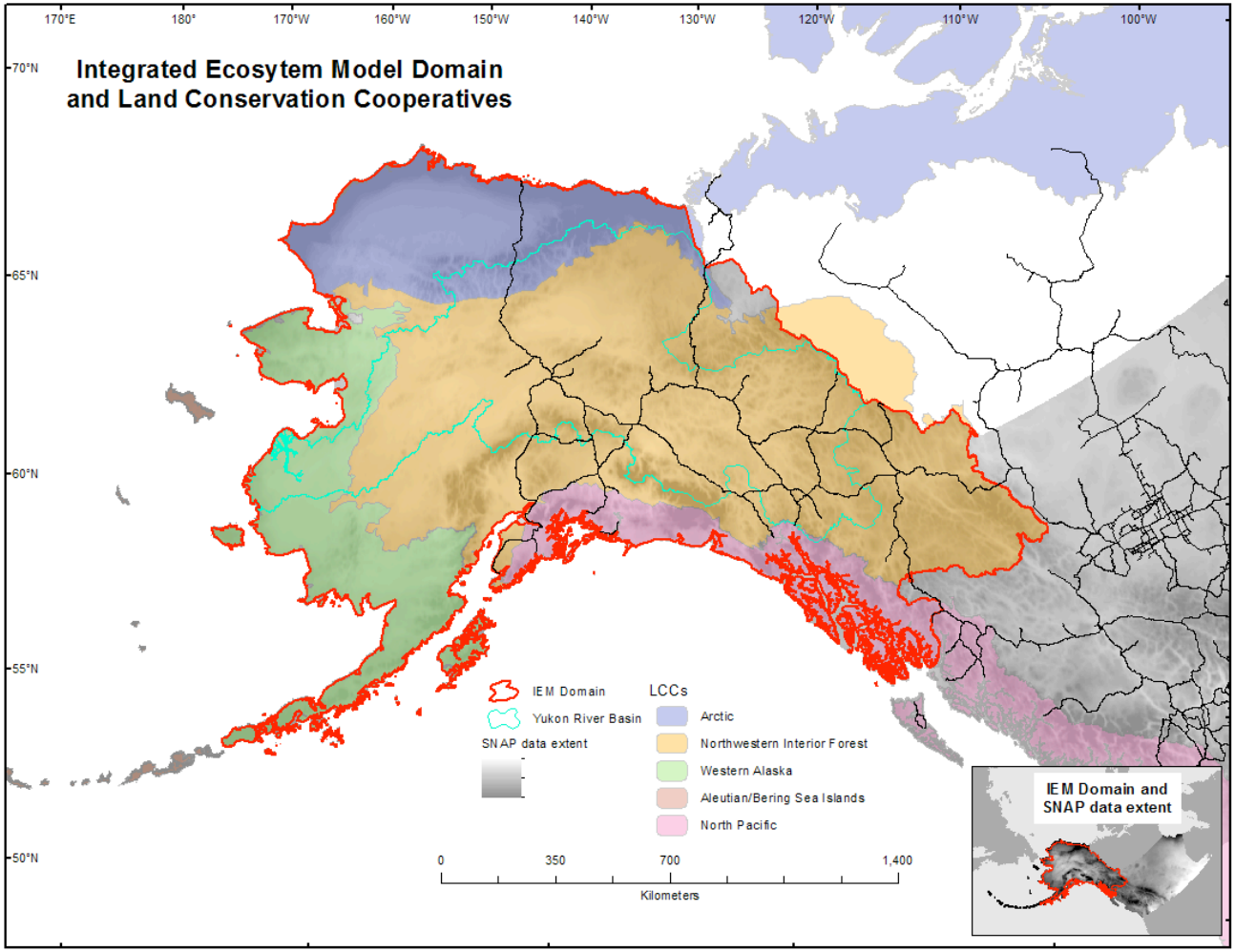
Alaska IEM: Phase II

Simulation Protocol

Boundary:	Western Arctic
Spatial resolution:	1 x 1 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 as in Pilot Year.

Alaska IEM: Phase II



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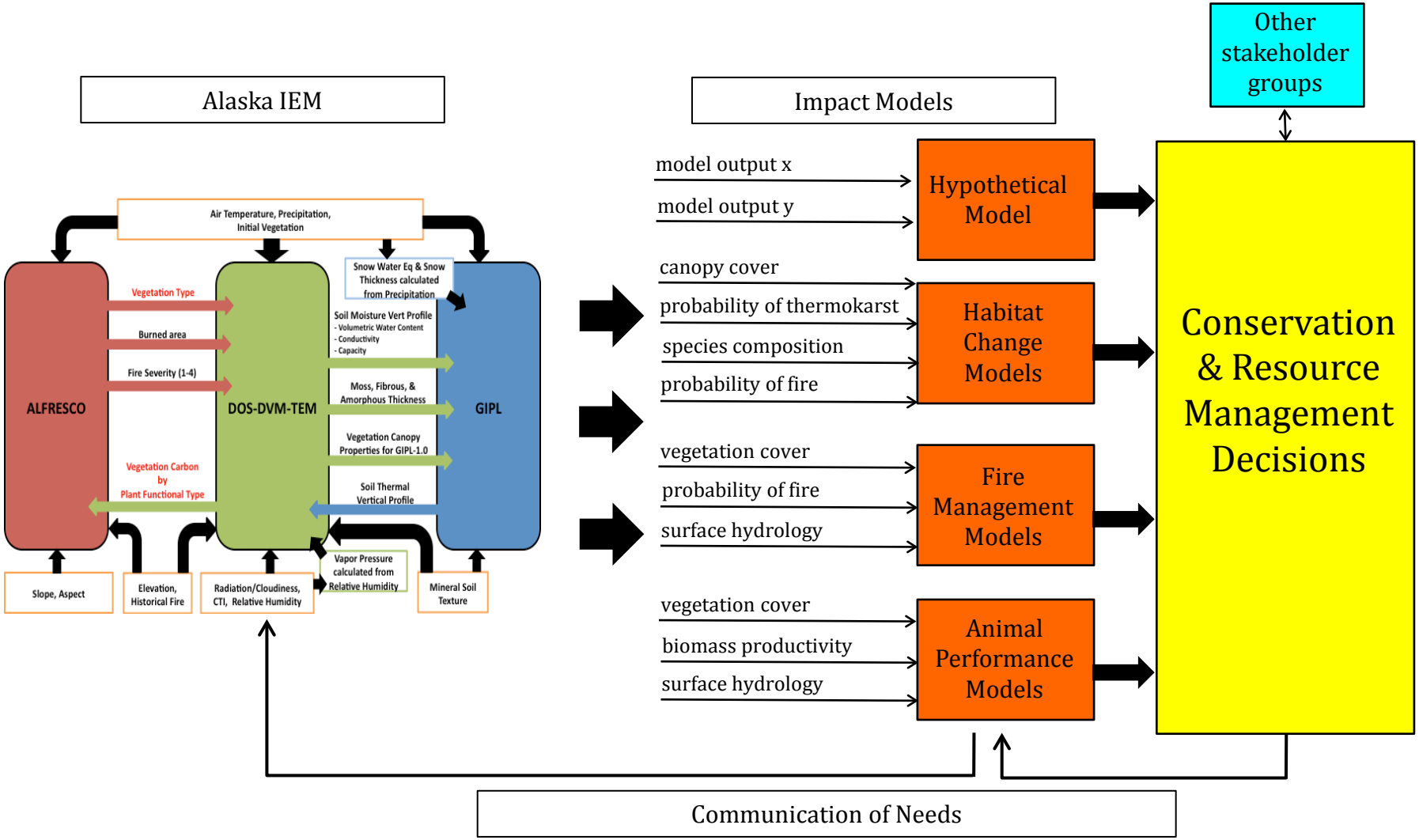
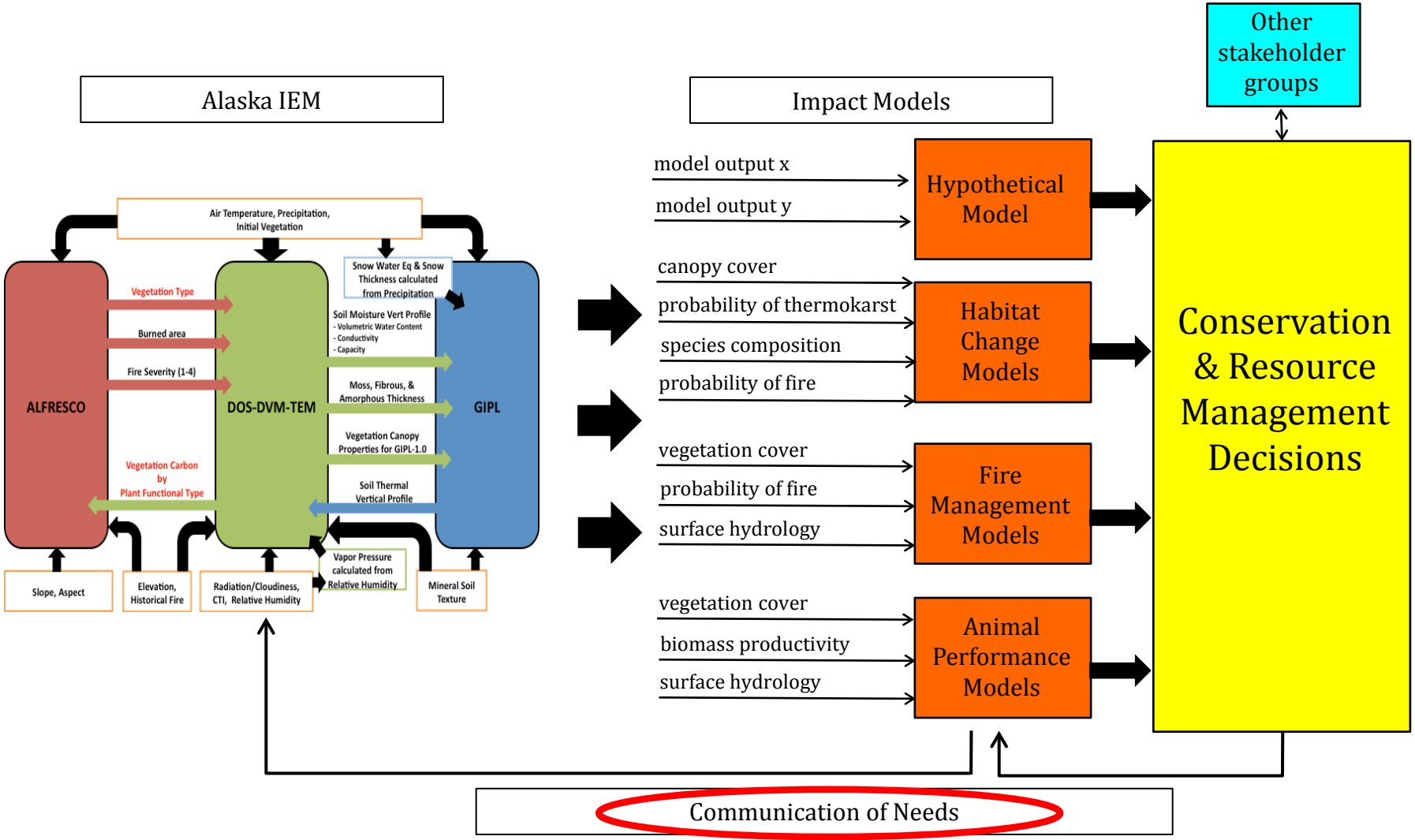
VI. Management Implications

Alaska IEM Conceptual Framework



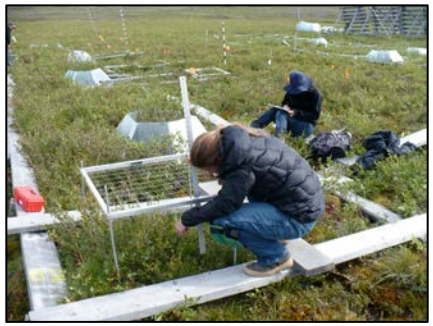
Alaska IEM Conceptual Framework



Management Implications

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

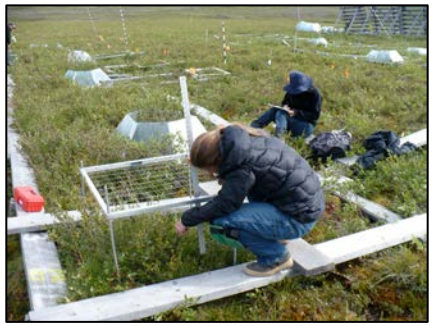
- Improve our understanding of the potential response of ecosystems to climate change
- Identify processes by which climate change will most likely affect species and habitats



Management Implications

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

- 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



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