The Alaska Land Carbon Assessment: Baseline and Projected Future Carbon Storage and Greenhouse Gas Fluxes in Ecosystems of Alaska

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USGS Alaska Land Carbon Assessment

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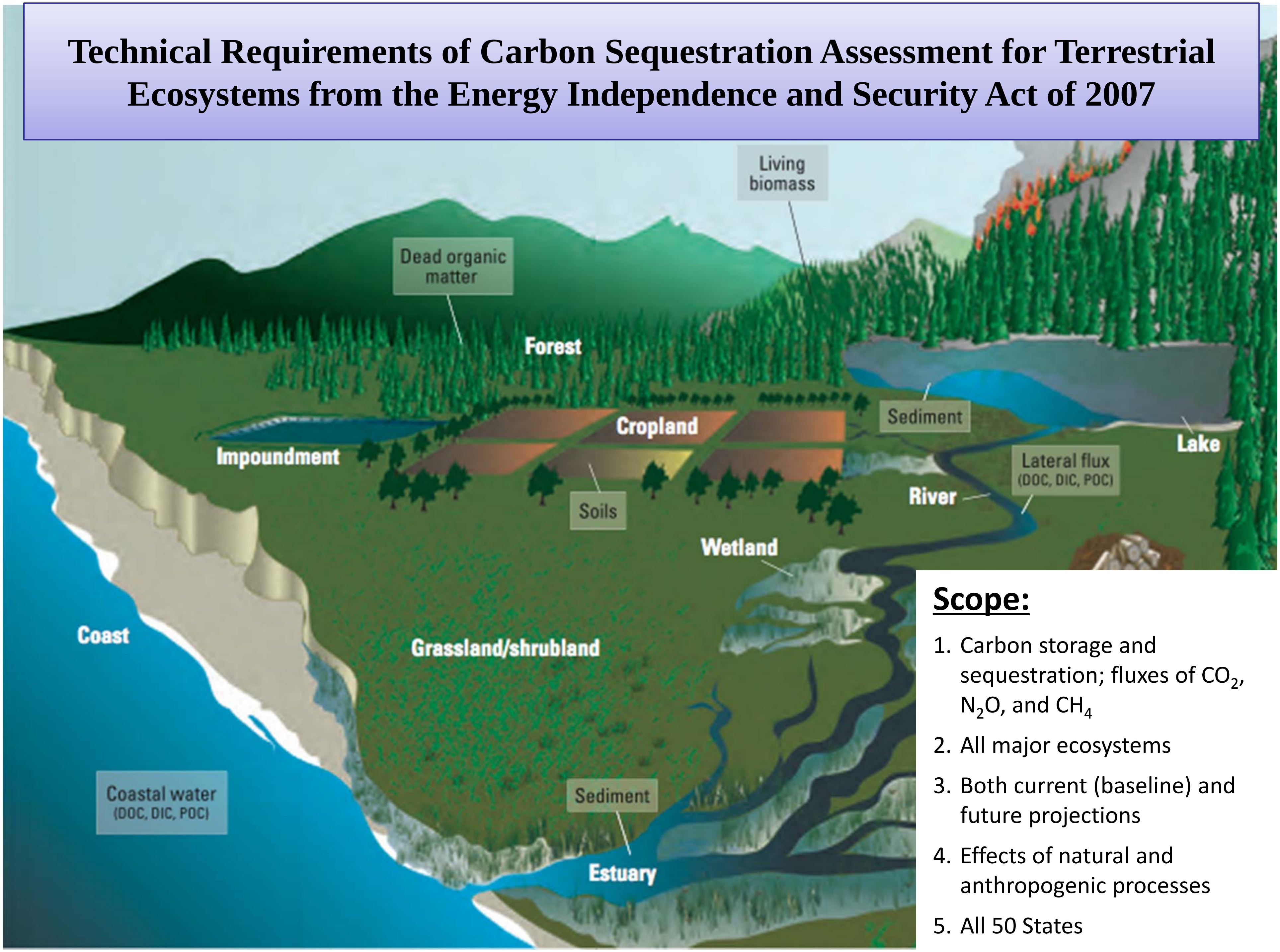
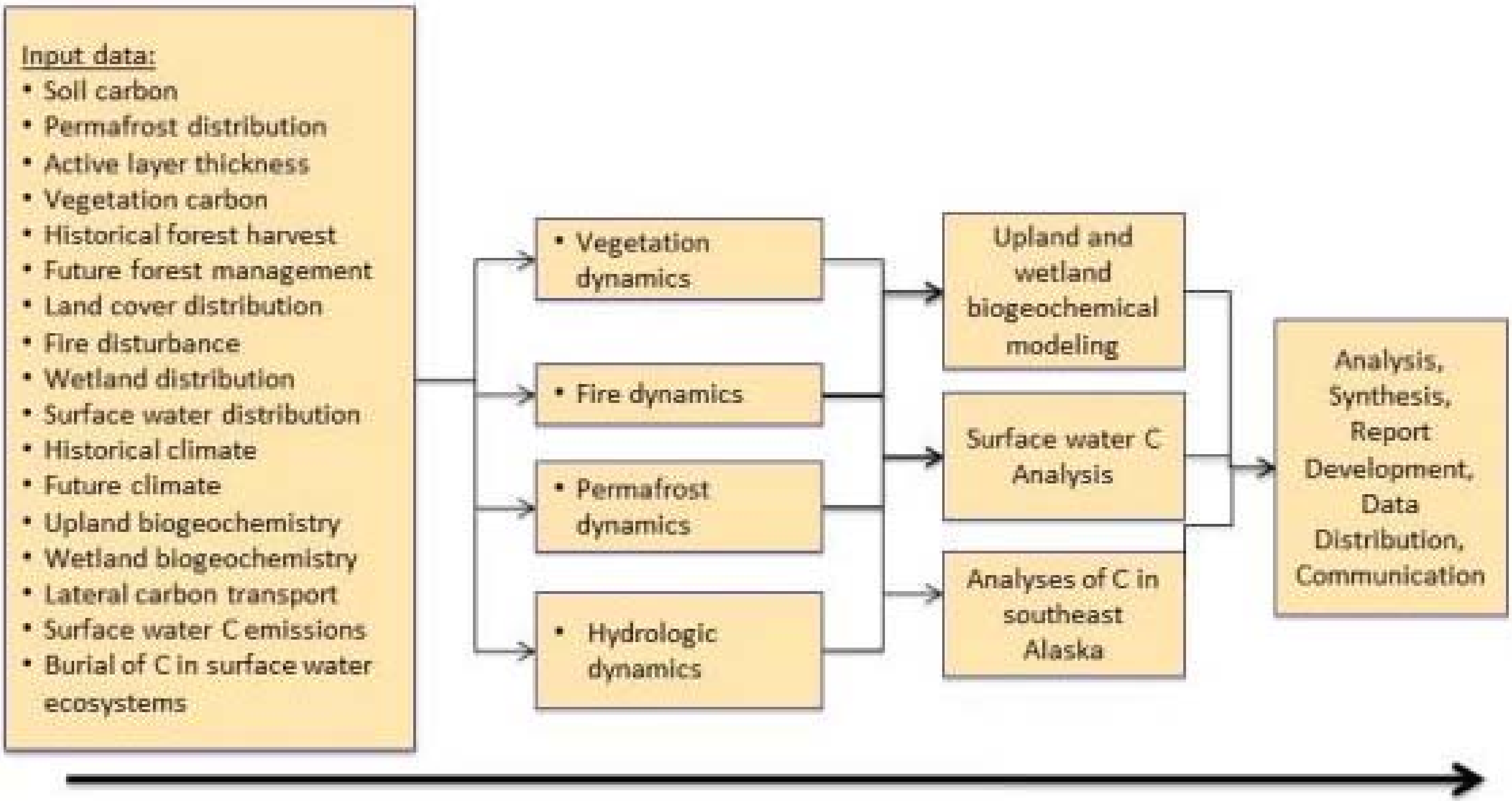
Technical Requirements of Carbon Sequestration Assessment for Terrestrial Ecosystems from the Energy Independence and Security Act of 2007



Scope:

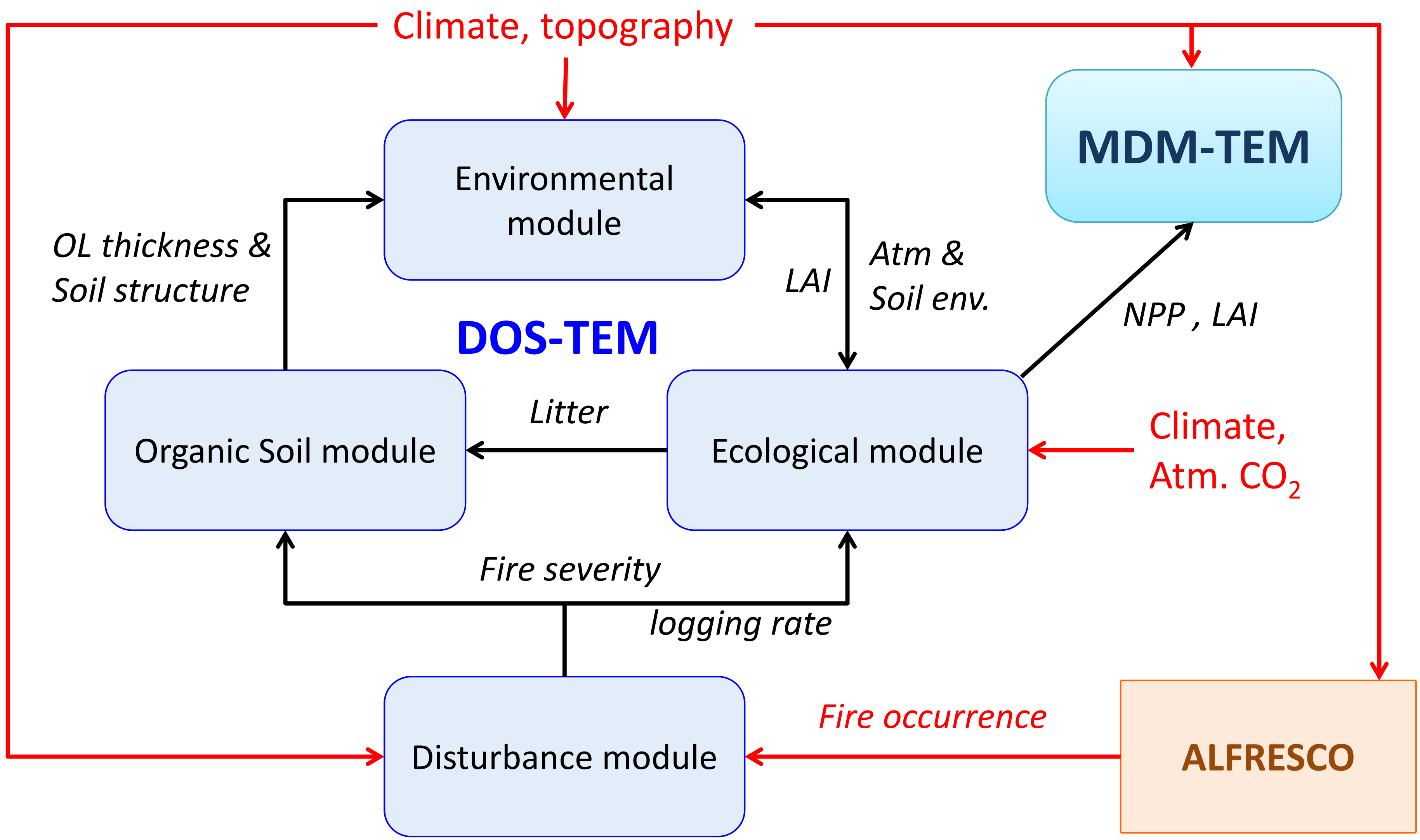
1. Carbon storage and sequestration; fluxes of CO_2, N_2O, and CH_4
2. All major ecosystems
3. Both current (baseline) and future projections
4. Effects of natural and anthropogenic processes
5. All 50 States

Alaska Land Carbon Assessment Methodology

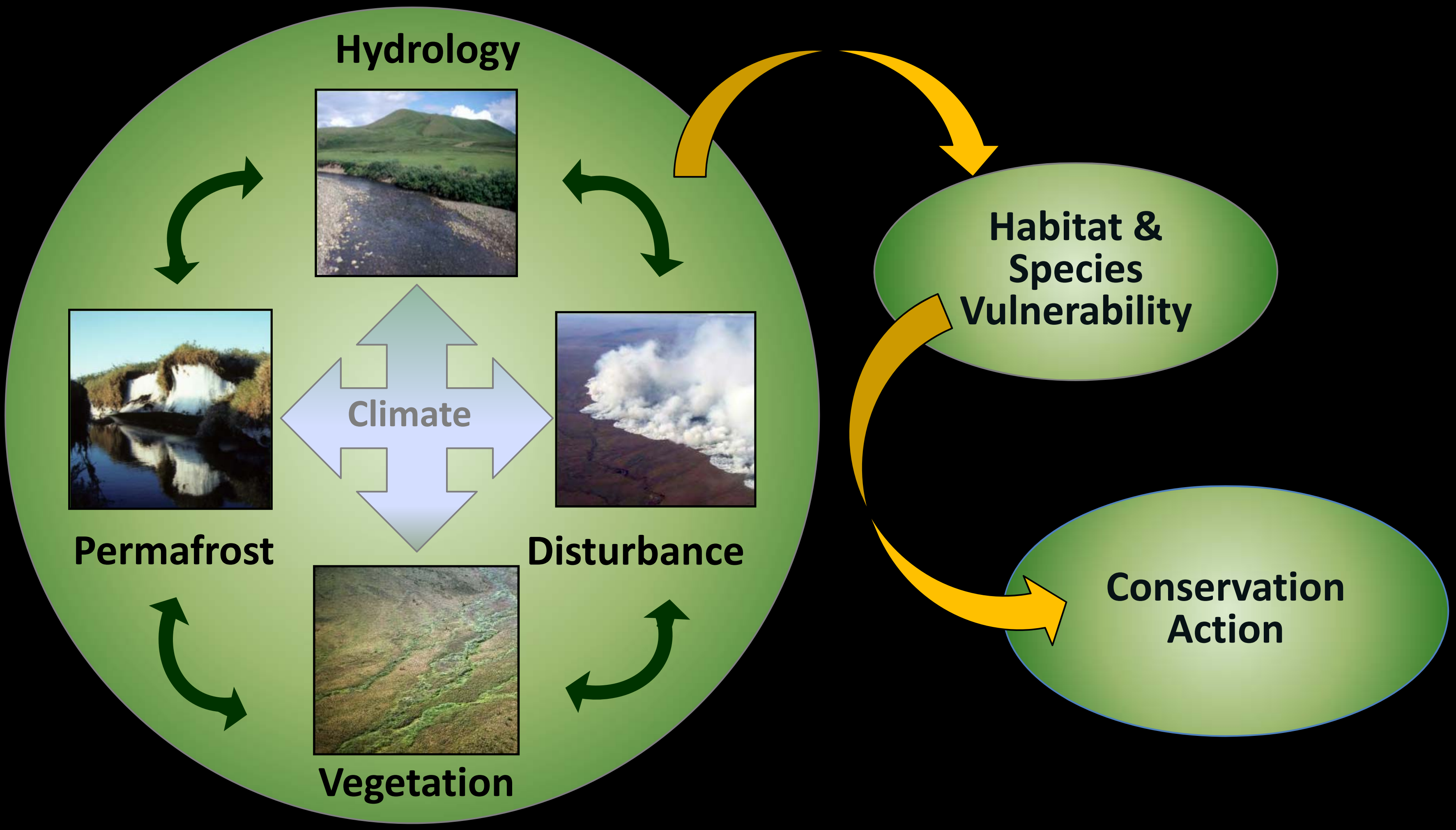


Models Run Annually from 1950 to 2099
Information Products for Historical Period (1950-2009)
Information Products for Projection Period (2010-2099)

Modeling Framework: Uplands and Wetlands



What is the Integrated Ecosystem Model (IEM) for Alaska and Northwest Canada?



What is the IEM?

Air Temperature, Precipitation, Initial Vegetation

Snow Water Equivalent

ALFRESCO

DOS-TEM

GIPL

What is the IEM?

Air Temperature, Precipitation, Initial Vegetation

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DOS-TEM

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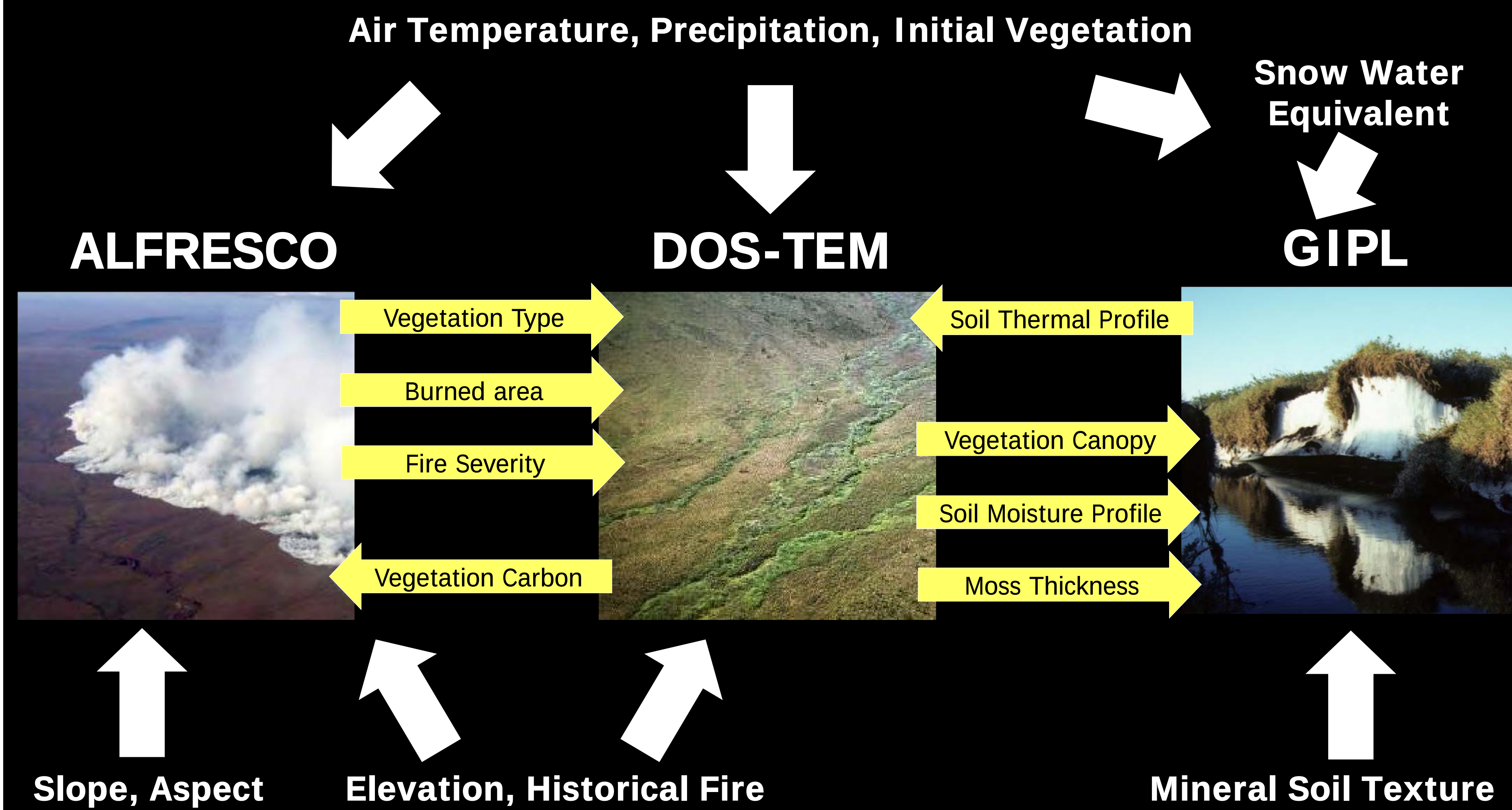
Slope, Aspect

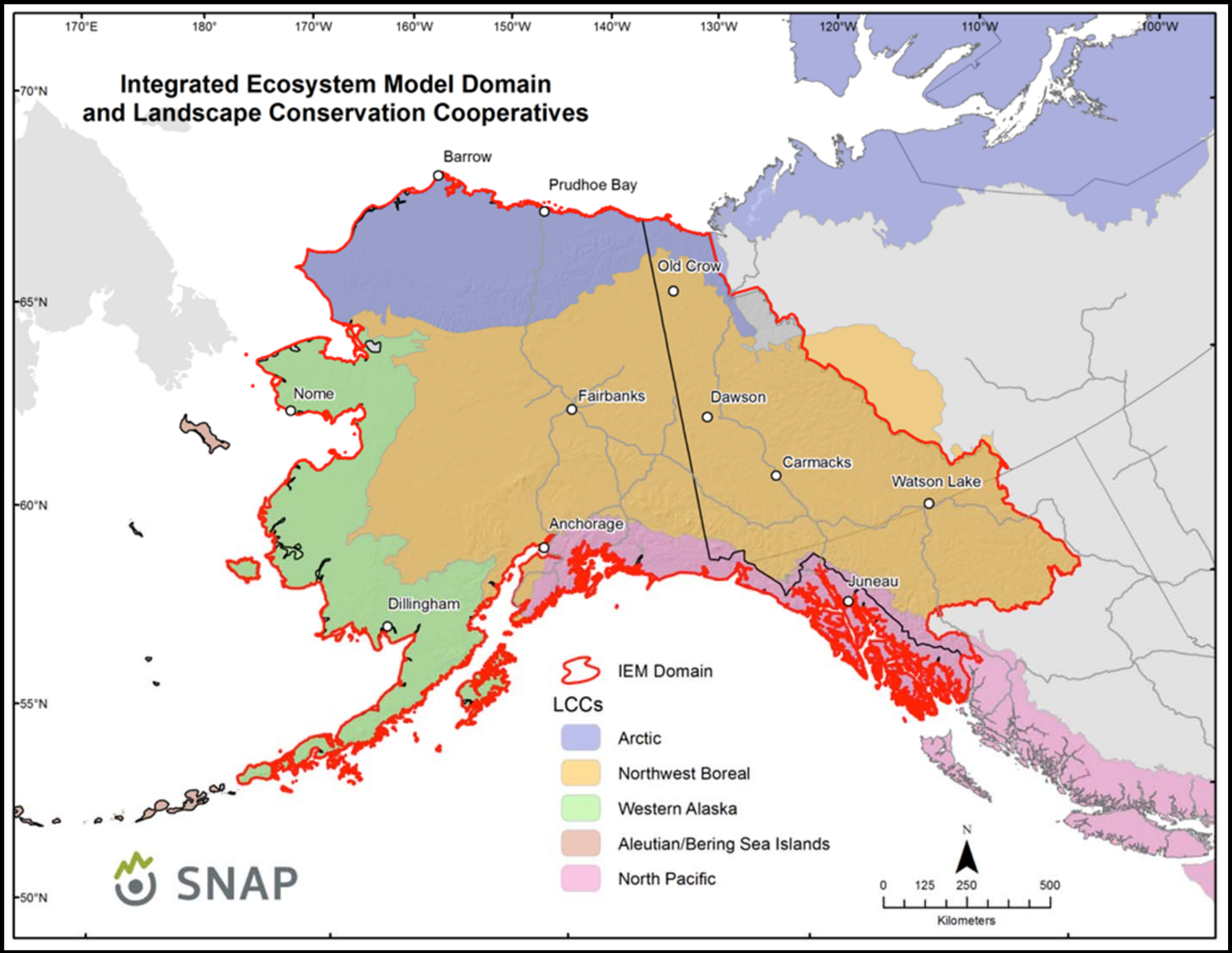
Elevation, Historical Fire

Mineral Soil Texture

What is the IEM?

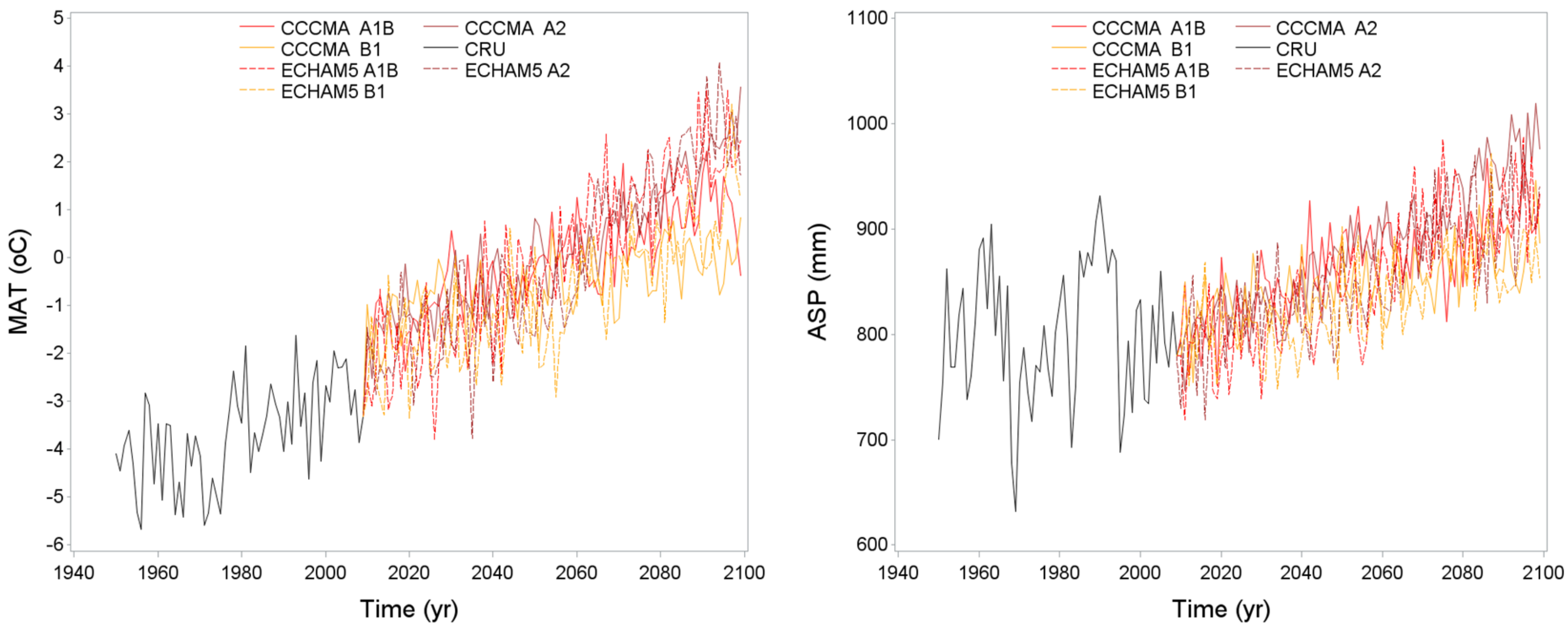


What is the IEM?



ALF TEM GIPL

Climate Drivers



Mean Annual Temperature (MAT) and Annual Sum of Precipitation (ASP) from 1950 to 2100 summarized for the simulation extent. The black line represents the CRU data for the historical period and the colored lines represent the CCCMA (solid) and ECHAM5 (dotted) projections for the 3 emission scenarios.

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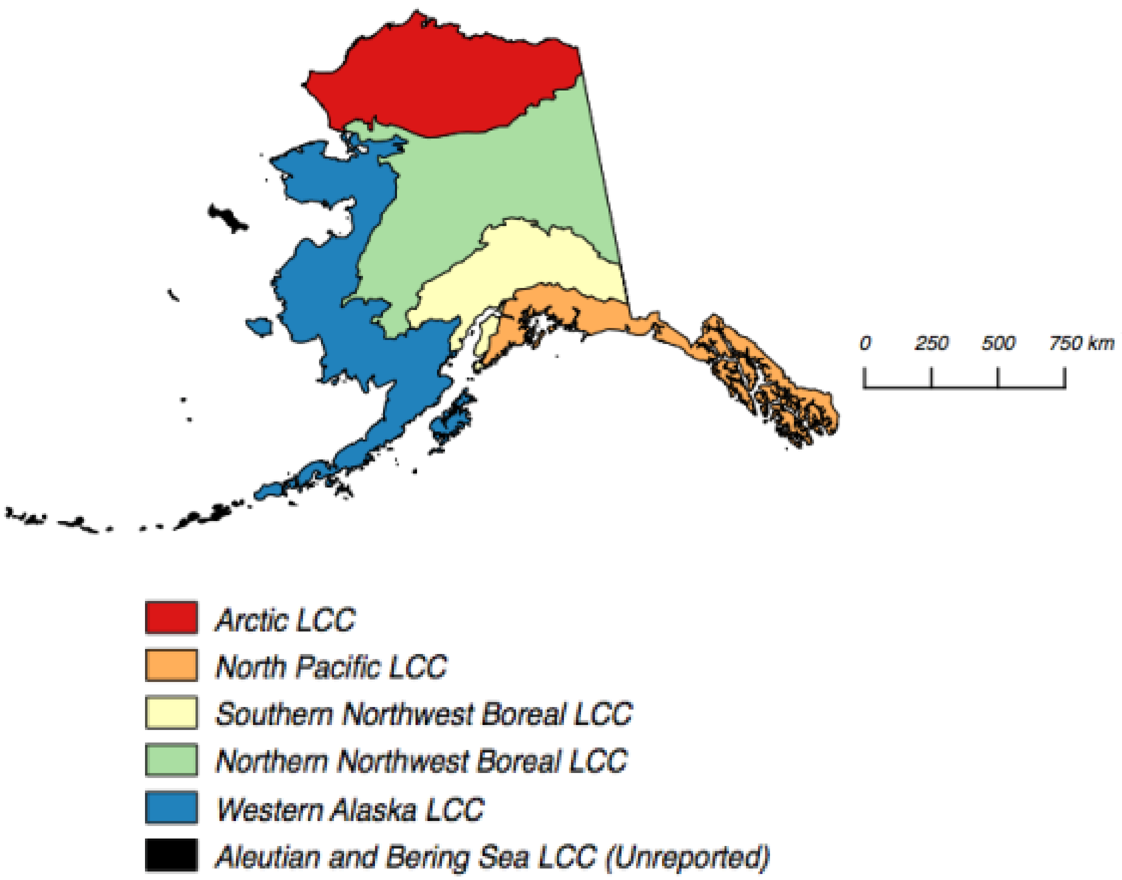
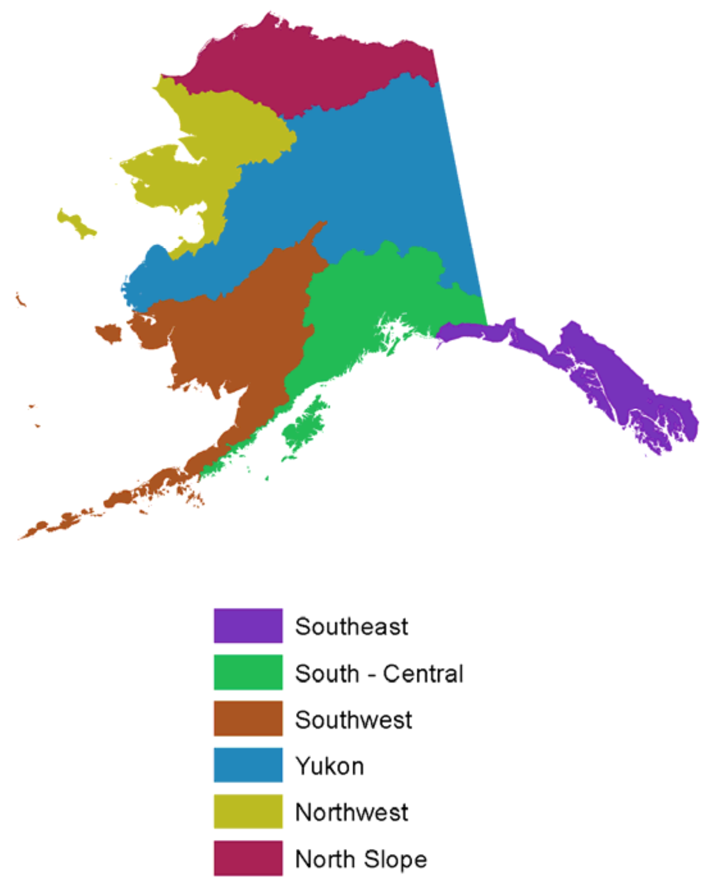
Reporting Regions in Alaska

The total area of Alaska considered in this assessment was 1,474,844 km^2, which is composed of 84 percent “uplands”, 12 percent wetlands, and 4 percent inland waters.

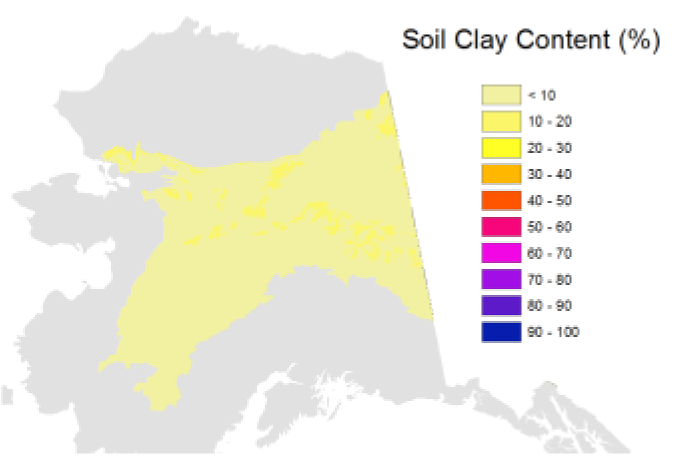
Landscape Conservation Cooperatives

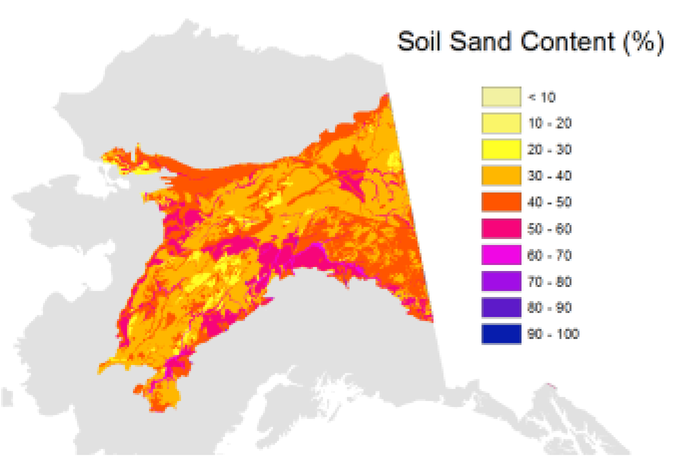


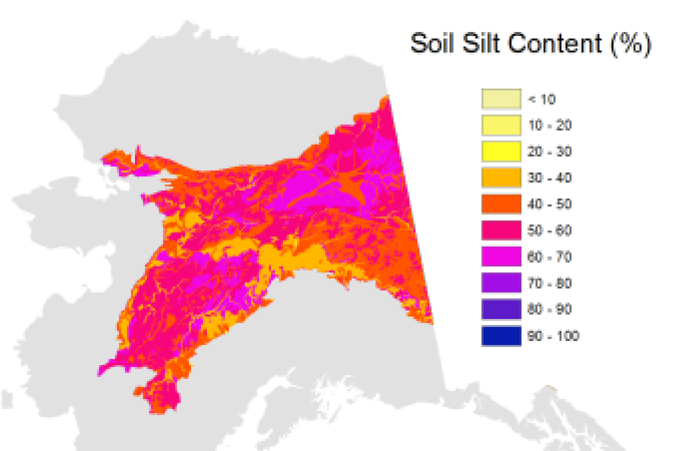
Main Hydrologic Units

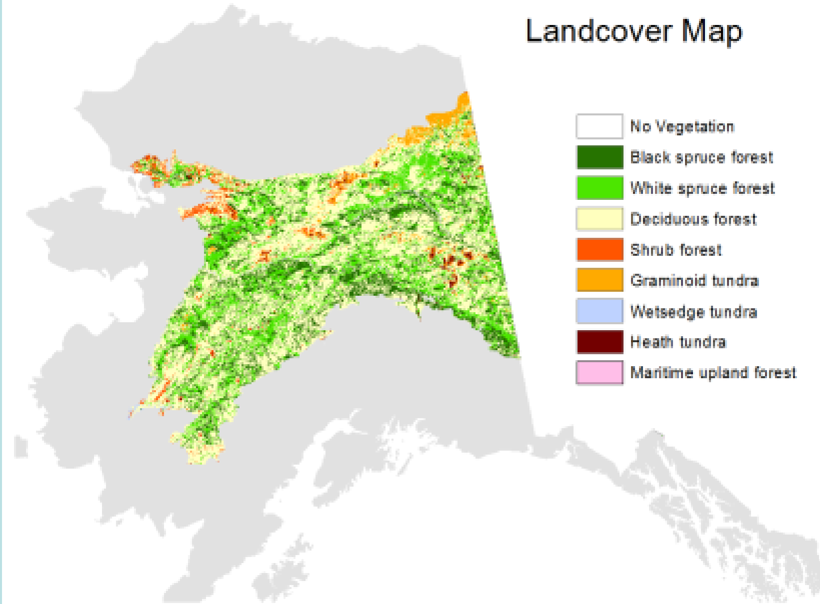


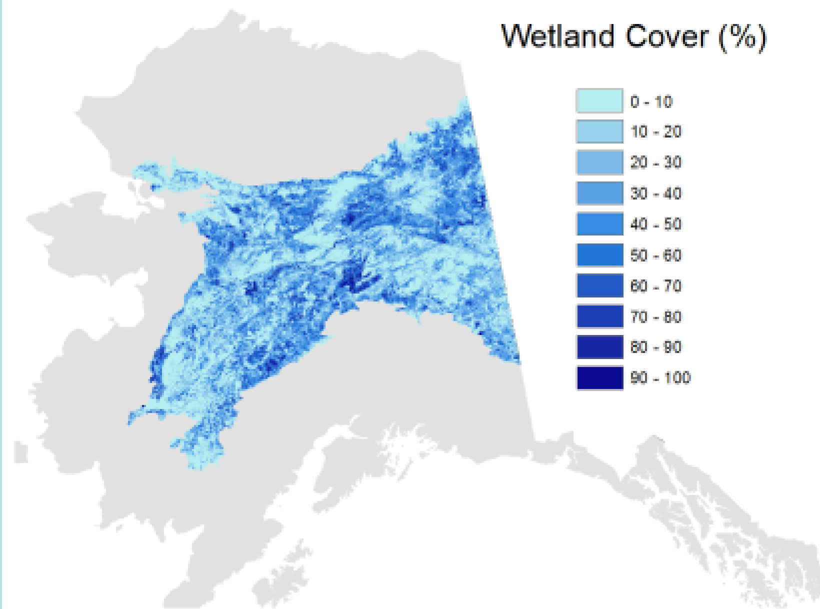
Environmental Drivers



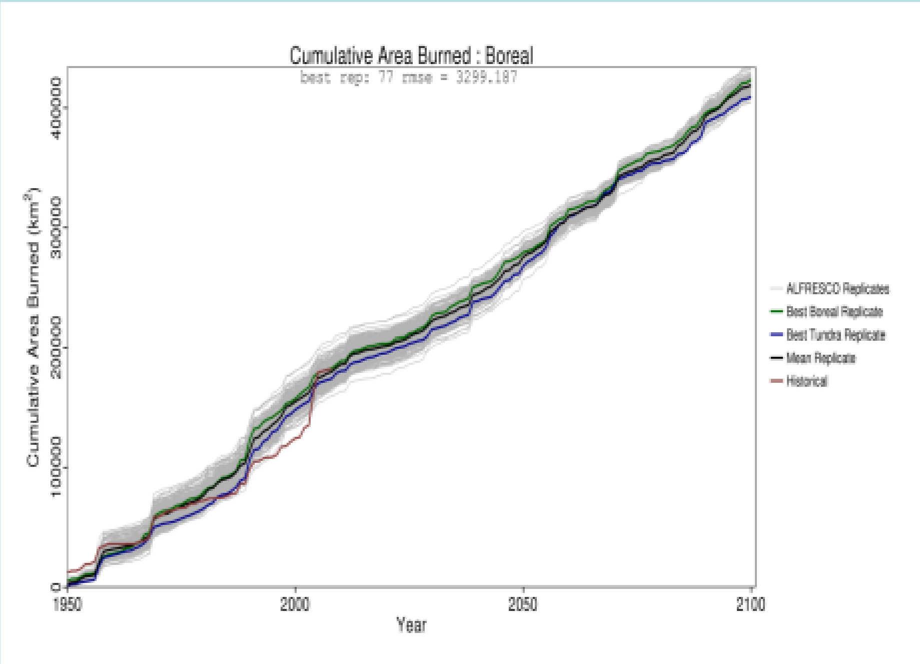


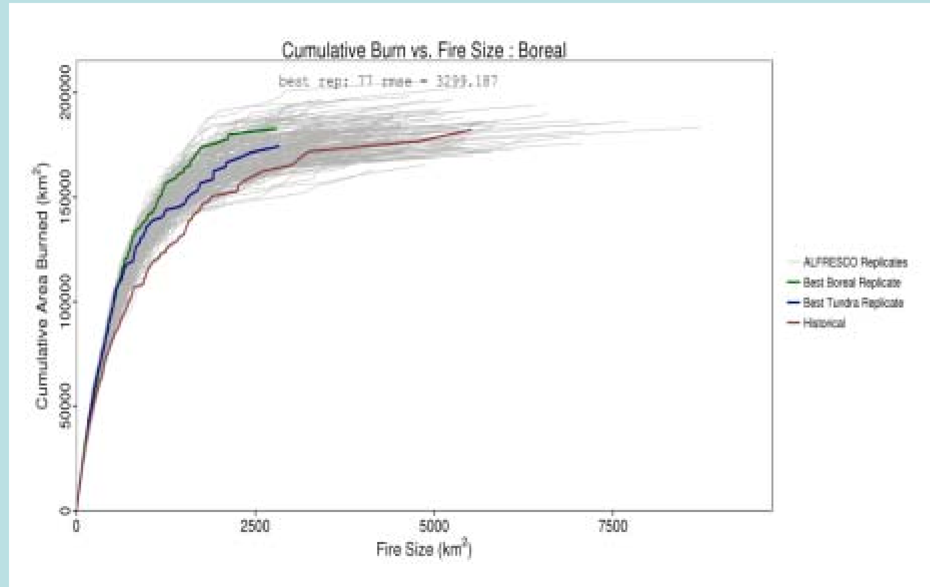






Evaluation of ALFRESCO Simulations of Fire Dynamics





Cumulative area burned (km^2) through time (left) and vs. individual fire size (right). Record of observation 1950-2010 indicated by the red line. Individual model simulations (n=200) indicated by gray lines. Projections through 2099 are for the CCCMA A1B climate scenario.

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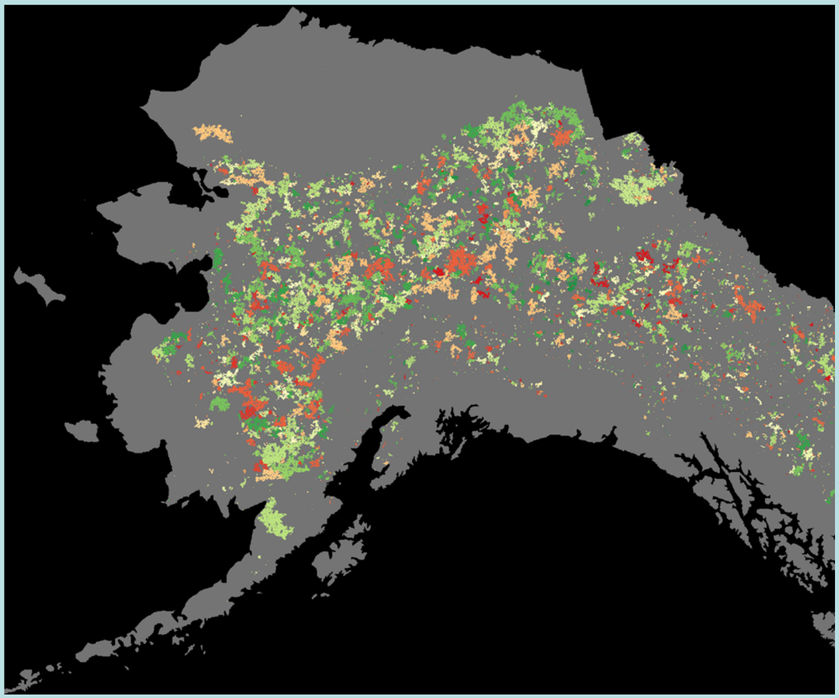
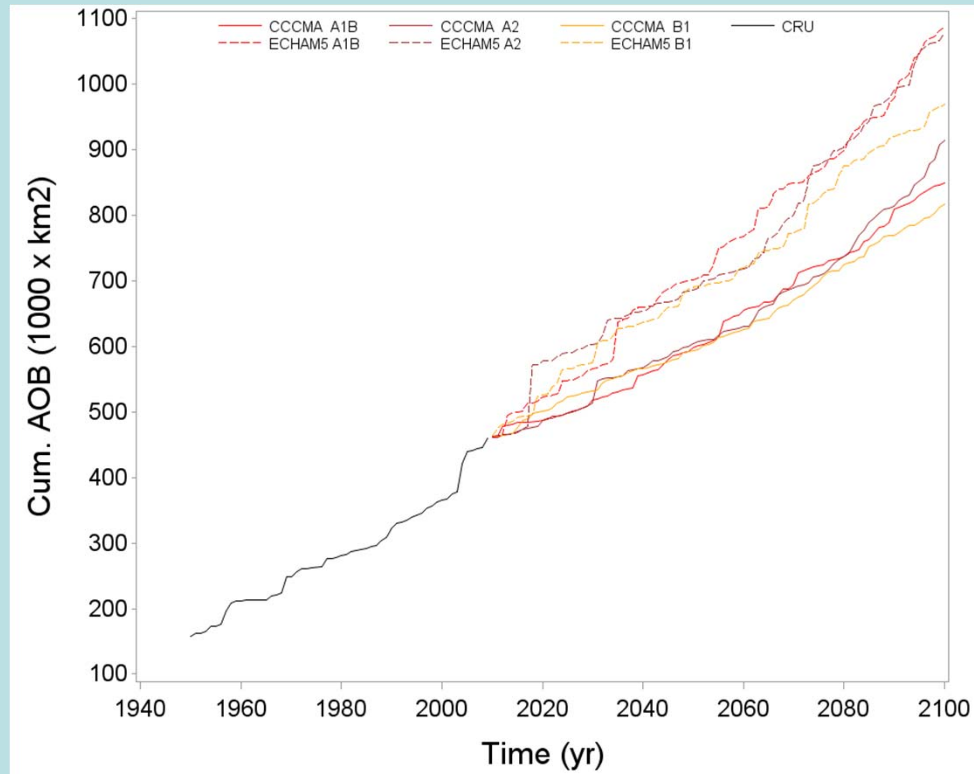
Disturbance regimes : Fire

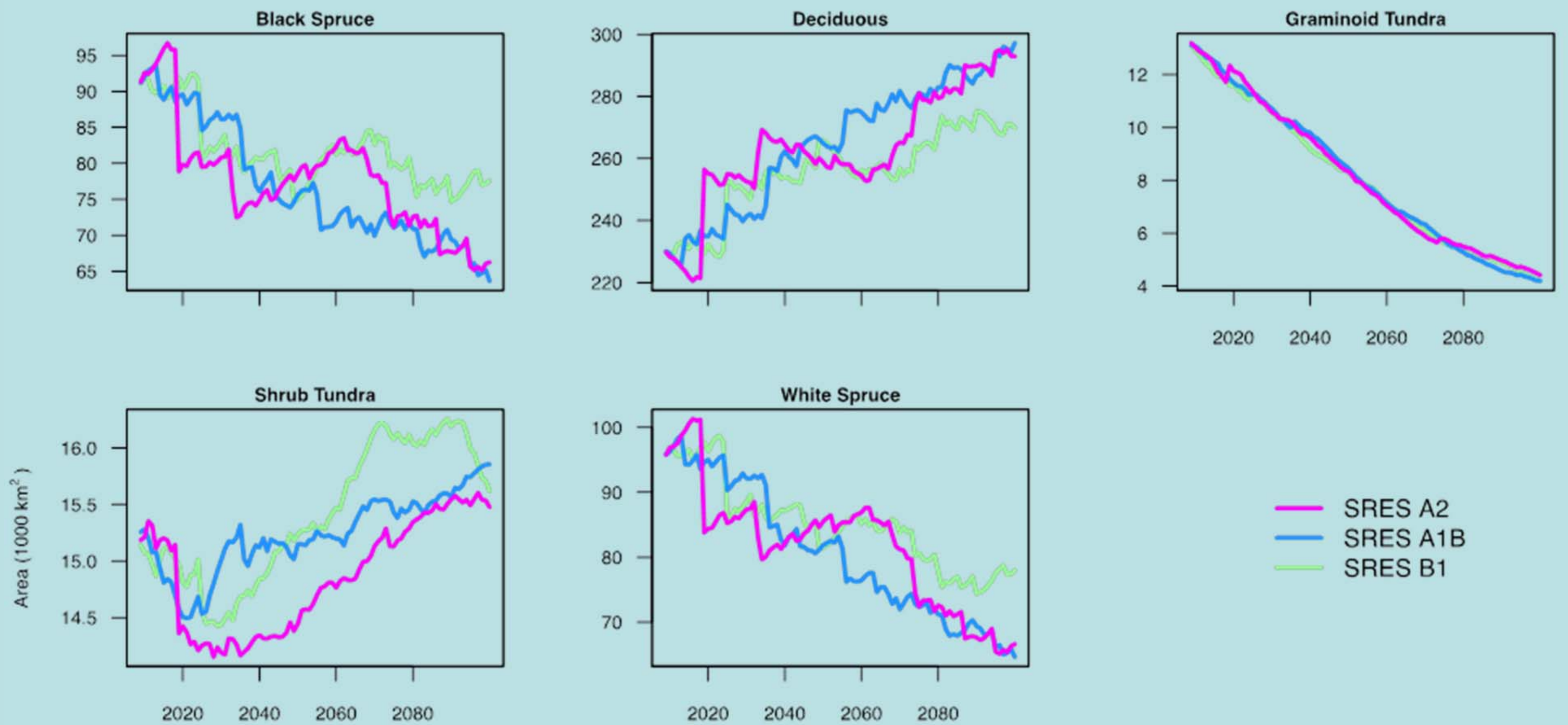


Simulated fire scars for the historical period 1950-2009. Individual fire scar colors indicate age of burn from oldest (red) to youngest (green).



Cumulated area burned for the historical period (black line) are estimated from the Alaskan Large Fire Database. Projections from 2009 to 2100 are simulated by ALFRESCO for the 6 climate scenarios.

Vegetation Change: Northern Northwest Boreal LCC



Projected land cover type change (in 1000 square km) across the NW Boreal North LCC subregion under the ECHAM5 climate model for three emission scenarios.

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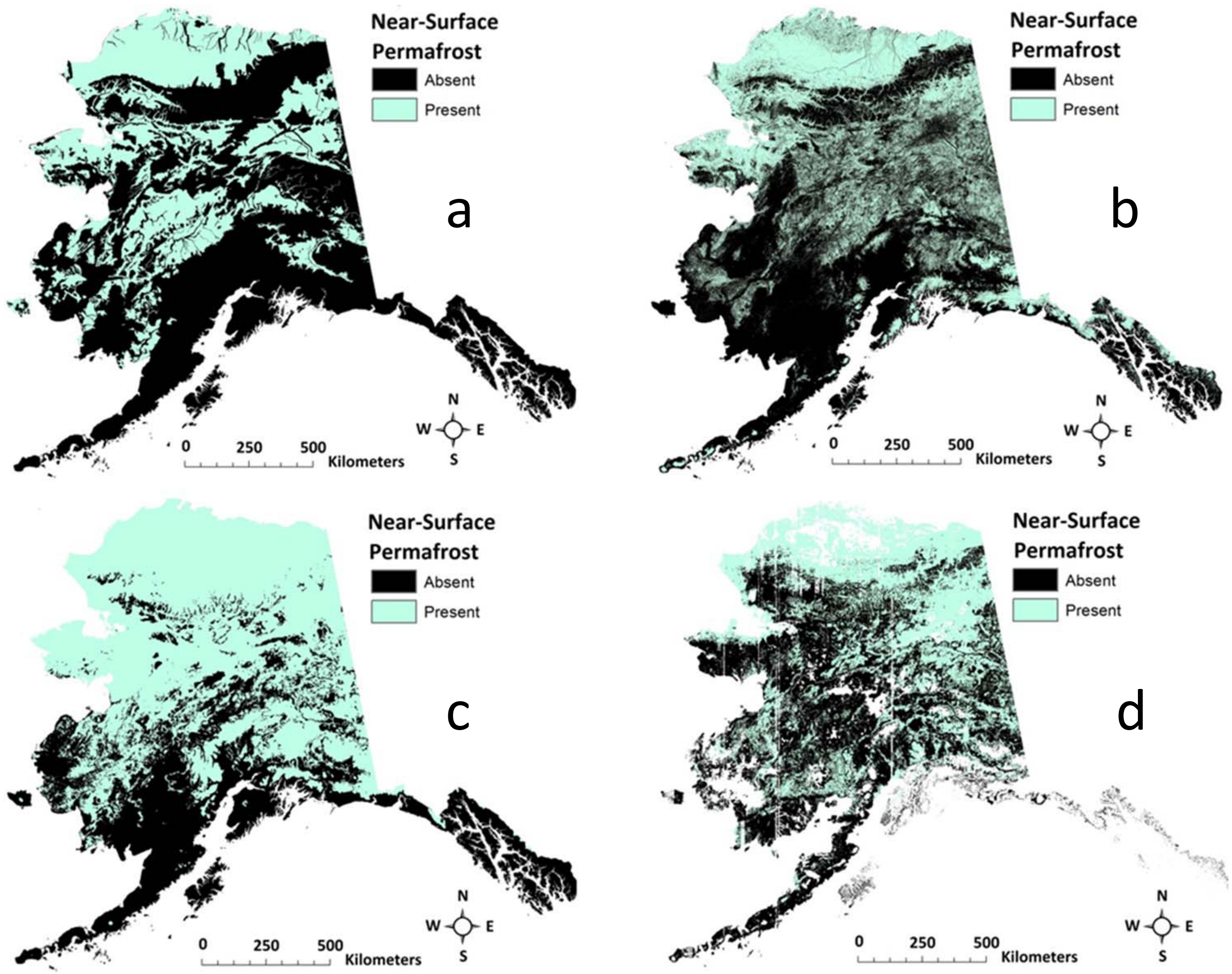
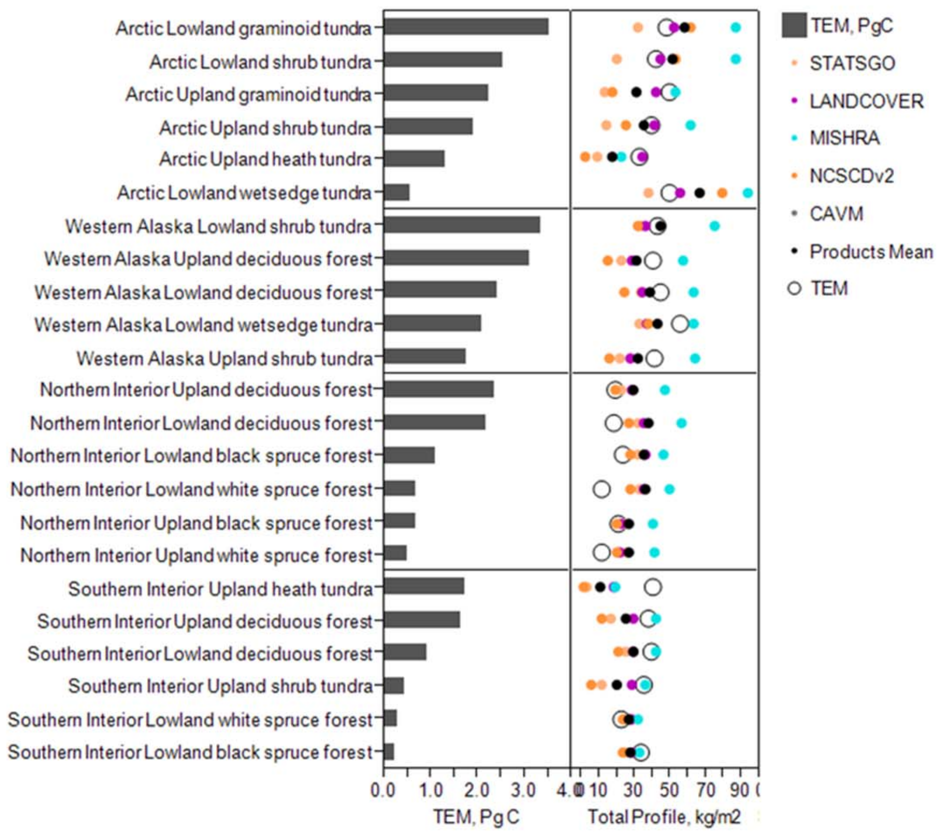
Evaluation of Permafrost Distribution Estimates by DOS-TEM

Presence-absence of near-surface (within 1 m) permafrost for Alaska: a) STATSGO; b) Pastick et al., (2015); c) Geophysical Institute Permafrost Lab (GIPL) 2.0, and; d) DOS-TEM.

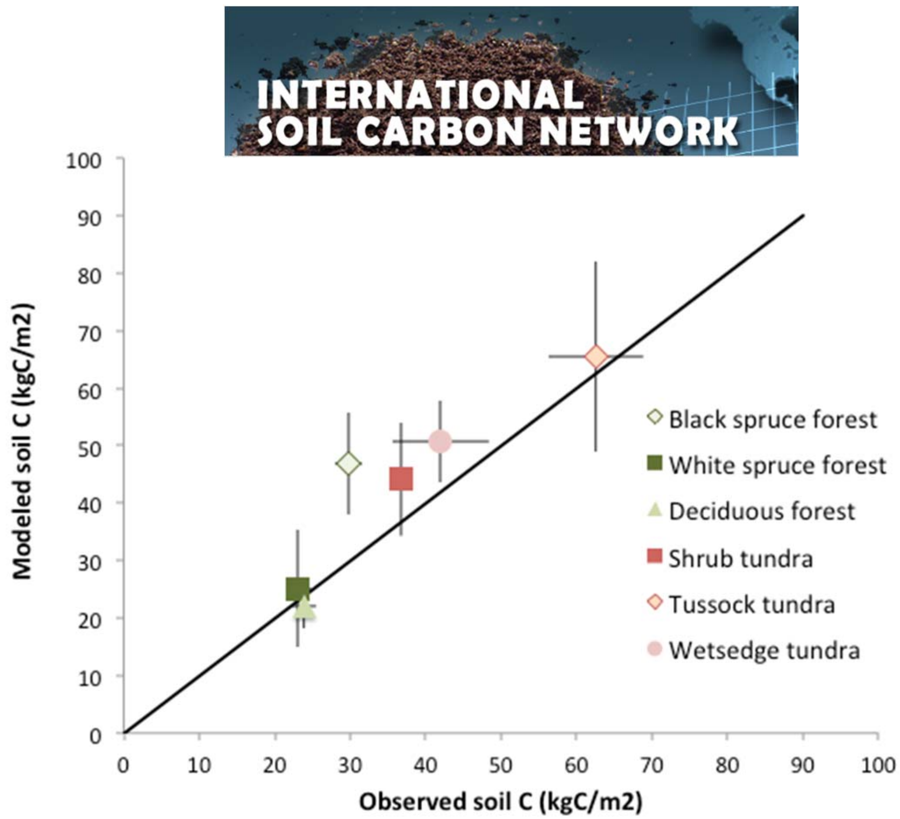


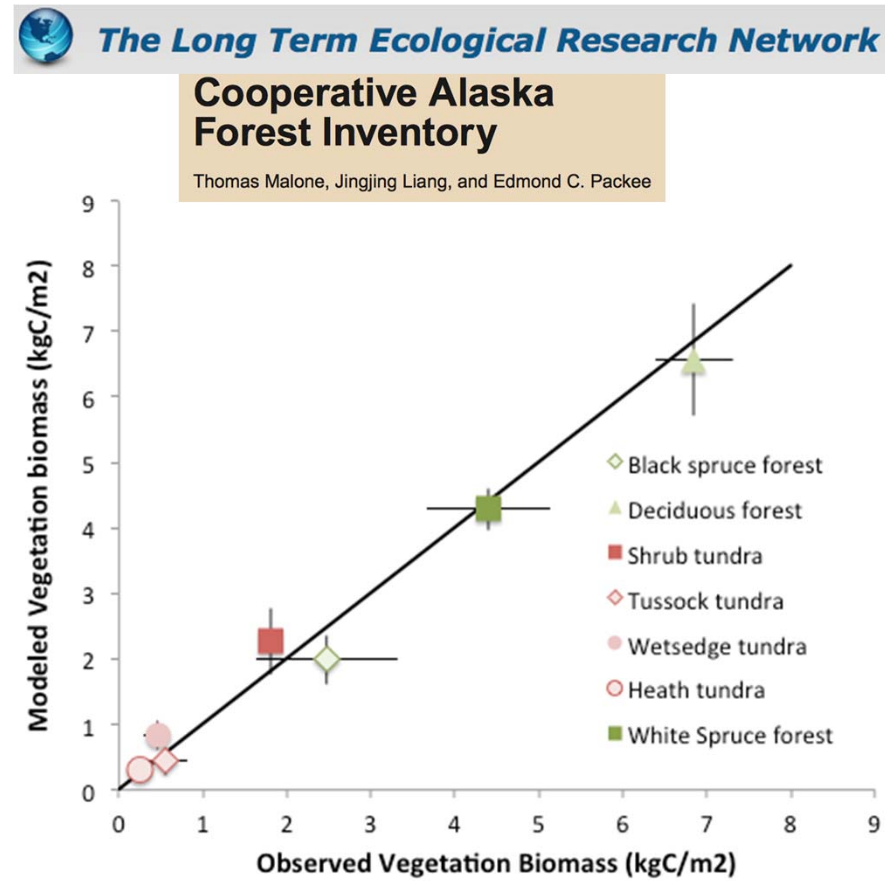
Evaluation of Soil Carbon Estimates by DOS-TEM

Soil organic carbon characterization by Landscape Conservation Cooperative (LCC) and land cover class.



Evaluation of DOS-TEM Performance

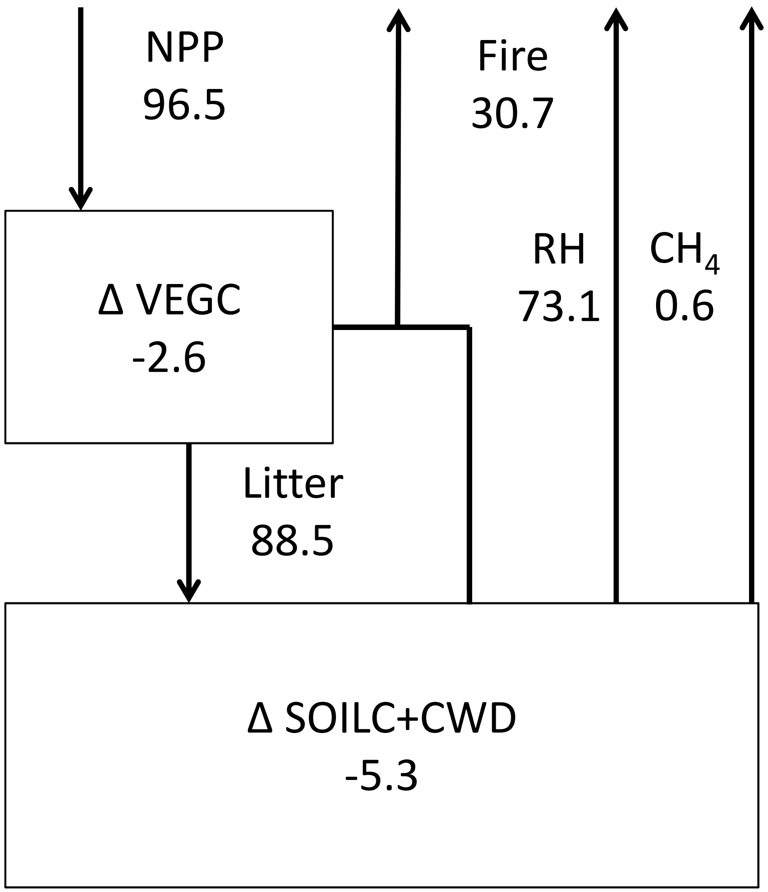




TEM soil C stocks compared with soil C stocks based on 315 samples collected in Alaska (Johnson et al. 2011). Both simulated and observed soil C stock estimates are for the organic and 0-1m mineral horizons.

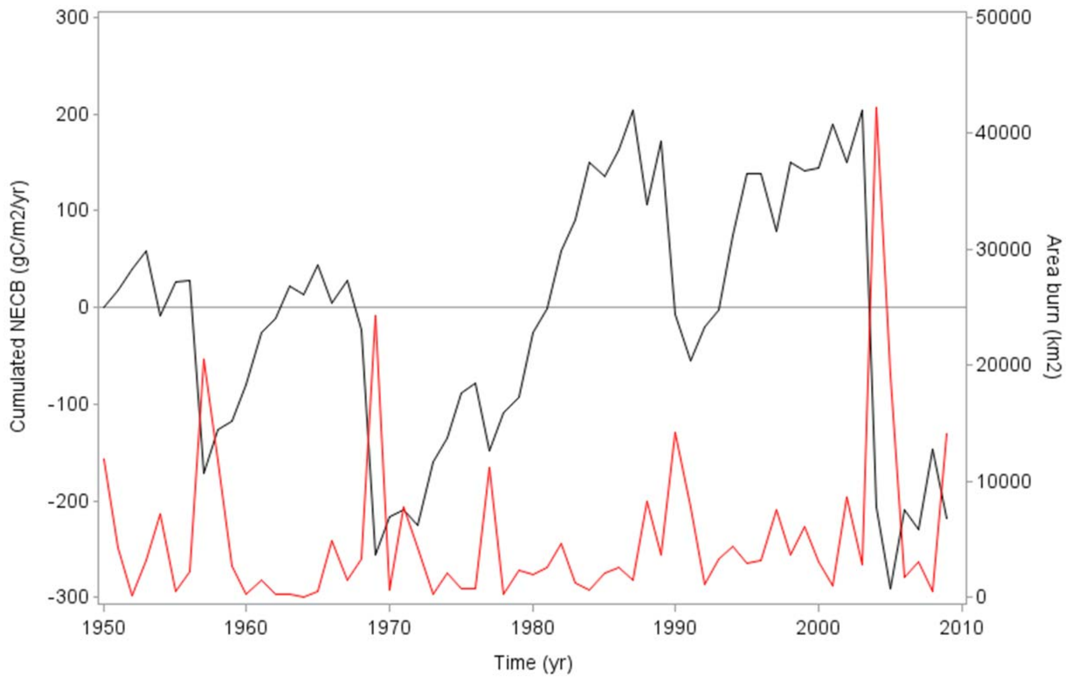
Evaluation of TEM for vegetation biomass using data from 190 permanent study plots of the Cooperative Alaska Forest Inventory (CAFI) for boreal forest communities and LTER data for the arctic tundra communities.

Historical change in Net Ecosystem C balance [1950-2009] in Terrestrial Boreal Alaska



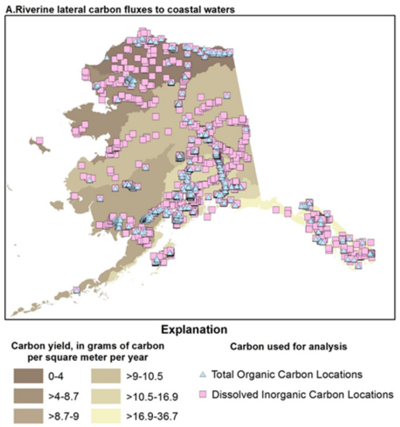
Unit = *TgC*/yr

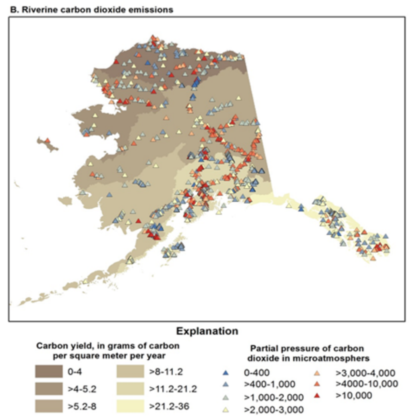
- -7.9 TgC/yr were lost on average between 1950 and 2009 in Interior Alaska.
- The loss over the 60 year period is primarily driven by unprecedented fire emissions during the decade of 2000s (record fire years in 2004 and 2005).

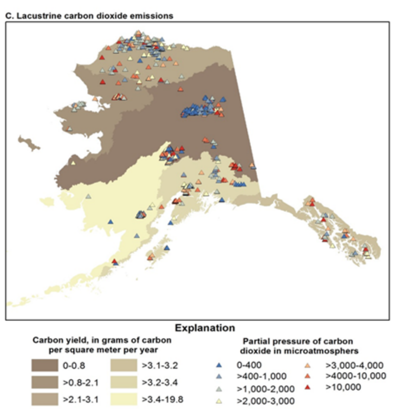


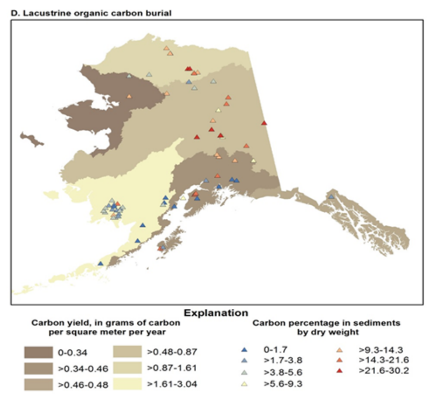
Estimates of Carbon Fluxes from Inland Waters of Alaska

coastal C transport by rivers (upper left), carbon dioxide emission from rivers (upper right), carbon dioxide emissions from lakes (lower left), and C burial in lakes (lower right)

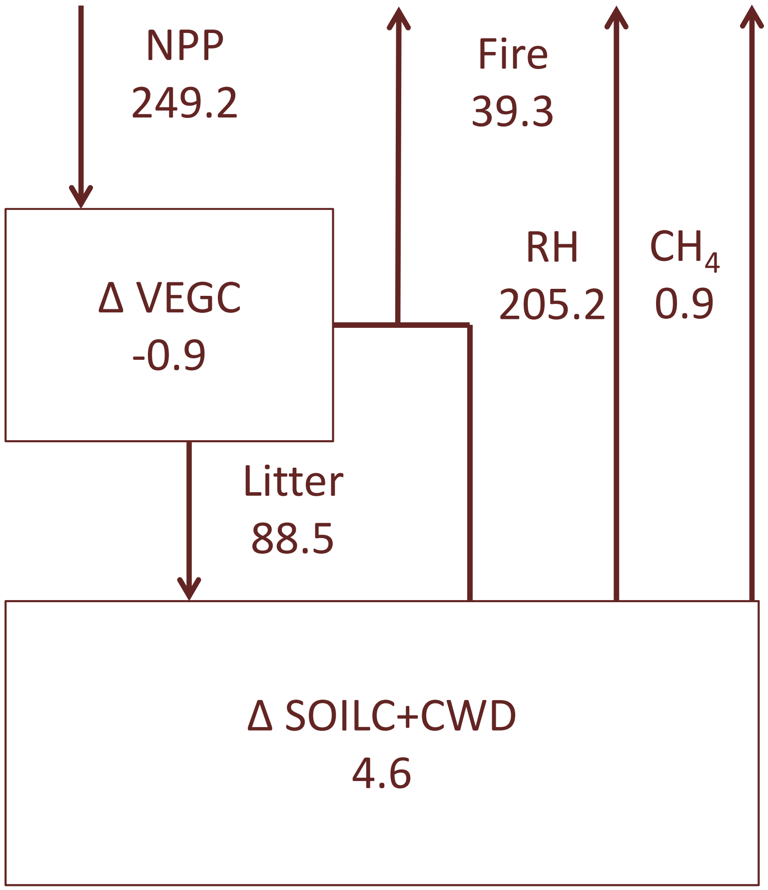






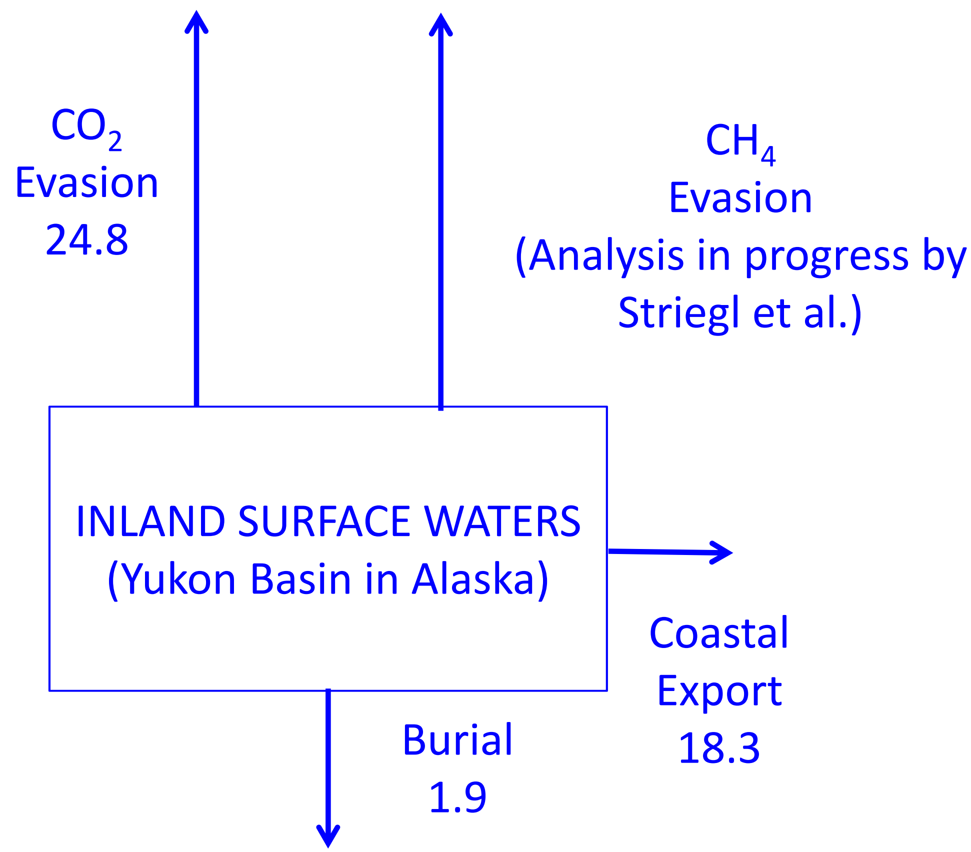


Historical change in Net Ecosystem C balance [1950-2009] Including Inland Surface Waters (Rivers and Lakes)



Unit = *Tg C*/yr

We estimated that 3.7 Tg C per year was sequestrated in terrestrial ecosystems. Analysis of aquatic fluxes suggests that up to an 41.2 Tg C per year could be lost from surface water of Alaska.



Projections of Alaska Future Carbon Storage [2010-2100]

Projected Carbon Balance (Tg C/ yr) and Greenhouse Gas Warming Potential (GWP, Tg CO_2 eq/yr) of Terrestrial Ecosystems in the Northern Northwestern Boreal LCC

Climate Scenario	Delta VEG C	Delta SOIL C	NPP	RH	Fire C	Bio CH_4	NECB	GWP
CCCMA B1	6.2	20.5	278.2	-219.9	-30.4	-1.1	26.8	-62.4
ECHAM5 B1	9.8	8.5	282.3	-222.4	-40.3	-1.3	18.2	-24.5
CCCMA A1B	10.2	21.9	306.6	-168.7	-103.4	-1.9	32.2	-51.0
ECHAM5 A1B	12.5	11.7	323.3	-190.5	-106.5	-1.6	24.3	-31.2
CCCMA A2	6.8	25.6	292.6	-232.0	-25.1	-1.1	34.4	-91.6
ECHAM5 A2	12.6	8.9	324.1	-176.9	-122.7	-2.7	21.4	11.6

Unit = *TgC*/yr

Take home messages on the historical assessment of C dynamics in Alaska

- Upland and wetland Ecosystems of Alaska are estimated to have gained 3.7 Tg C per year from 1950 to 2009, which is ~2% of NPP, but sequestration is spatially variable with the northern Northwest Boreal region losing carbon.
- We estimate that the combined carbon loss through various pathways of the inland aquatic ecosystems of Alaska was 41.2 Tg C per year, or about 17 percent of upland and wetland NPP.
- We estimate that the greenhouse gas forcing potential of upland and wetland ecosystems of Alaska was approximately neutral during the historical period, but that the state as a whole could be a source for greenhouse gas forcing to the climate system from CH_4 emissions from lake ecosystems.
- A major uncertainty of the historical assessment is related to the fact that aquatic inland ecosystems were not able to be integrated with upland and wetland ecosystems.

Take home messages on the projected C dynamics for Alaska

- During the projected period (2010-2099), carbon sequestration of upland and wetland ecosystems of Alaska would increase substantially (18.2 to 34.4 Tg C per year) primarily because of an increase in NPP of 8 to 19 percent associated with responses to rising atmospheric CO_2, increased nitrogen cycling, and longer growing seasons. Although C emissions to the atmosphere from wildfire increase substantially for all of the projected climates, the increases in NPP more than compensate for those losses.

- Our analysis indicates that upland and wetland ecosystems would be sinks for greenhouse gases for all scenarios during the projected period. However, as in the case of the analysis of the historical period, there is uncertainty as whether the state would be a net source for GHG if emissions of CH_4 from lakes in Alaska were considered.

Identifying Indicators of State Change and Forecasting Future Vulnerability in the Alaskan Boreal Forest

- Technical Objective 2: Develop models that can **forecast landscape change** in response to projected changes in climate, fire regime, and fire management.

SERDP Project Modeling Objectives

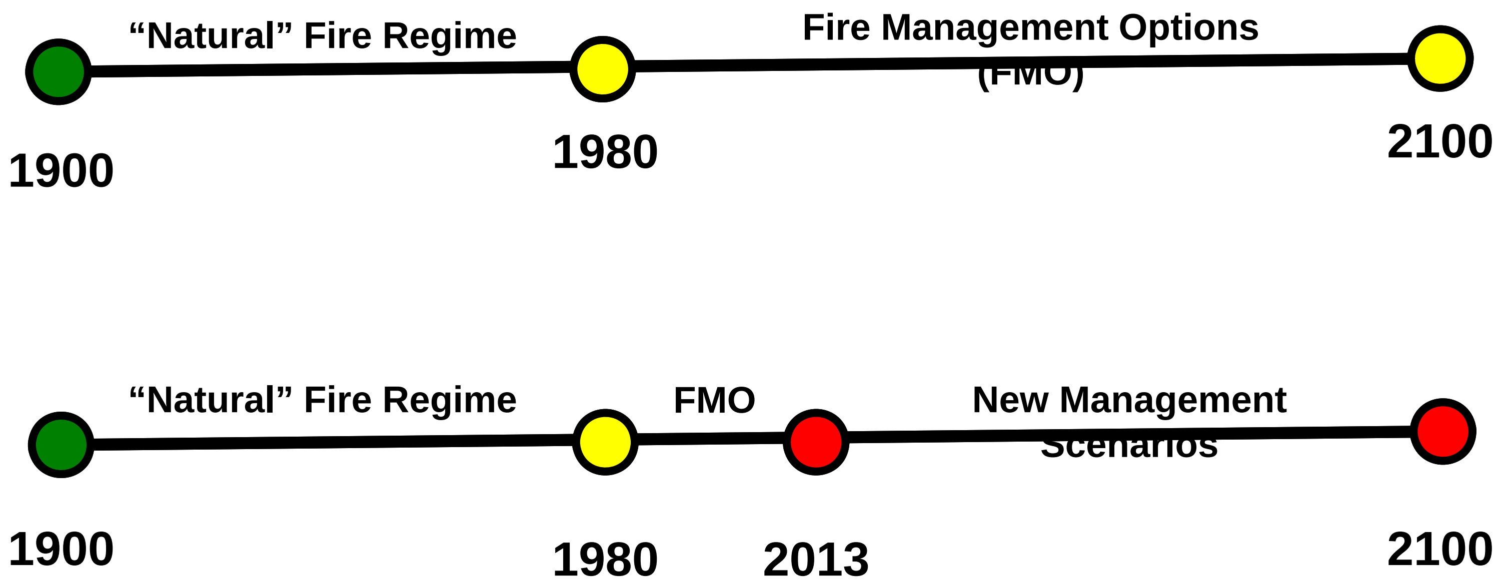
- ***Question 1**: How does simulated fire frequency respond to different climate scenarios during the 21st Century on, and adjacent to, military lands of the Upper Tanana Hydrologic Basin?*
- ***Question 2**: How might changes in the fire management options within military training land boundaries influence the frequency and extent of wildfire activity on, and adjacent to, military lands in the Upper Tanana Hydrologic Basin during the 21st Century?*
- ***Question 3**: How might wildlife (e.g., moose) habitat suitability change on military lands in the Upper Tanana Hydrologic Basin through the 21st Century?*

Mean Annual Area Burned (%) from 1988-2012

	Critical	*Full*	*Modified*	*Limited*
Mean	0.24	0.69	1.43	1.64
Standard deviation	1.14	1.75	4.28	2.88
Median	0	0.03	0.03	0.41

Calef et al. 2015 *Earth Interactions*

Model Simulation Scheme



IEM Acknowledgements

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and Alaska Landscape Conservation Cooperatives