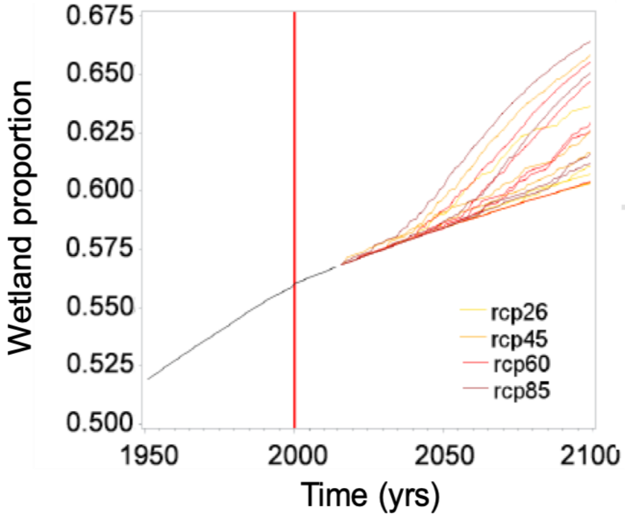
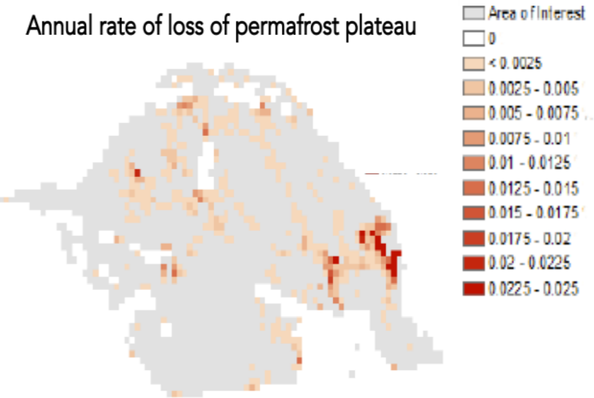
Task CF1 – Modify the integrated model framework to incorporate information developed in sections I & II to the effects of intermediate-scale patterning and processes

Rupp, McGuire, Genet, Turetsky, Romanovsky

Summary of findings:

- In general these efforts are just beginning and progress is limited due to linkages to activities in Sections I & II, as well as a heavy dependency on new leveraged funding mechanisms materializing
- Testing of the integrated model is ongoing for tundra ecosystems with boreal forest next in line – this work to date does not however include intermediate-scale representation
- Ongoing efforts to model thermokarst dynamics; At the local scale, massive landscape change is possible due to abrupt permafrost thaw – e.g., the proportion of wetlands in the Tanana Flats increased by 26.5% from 1950 to 2100



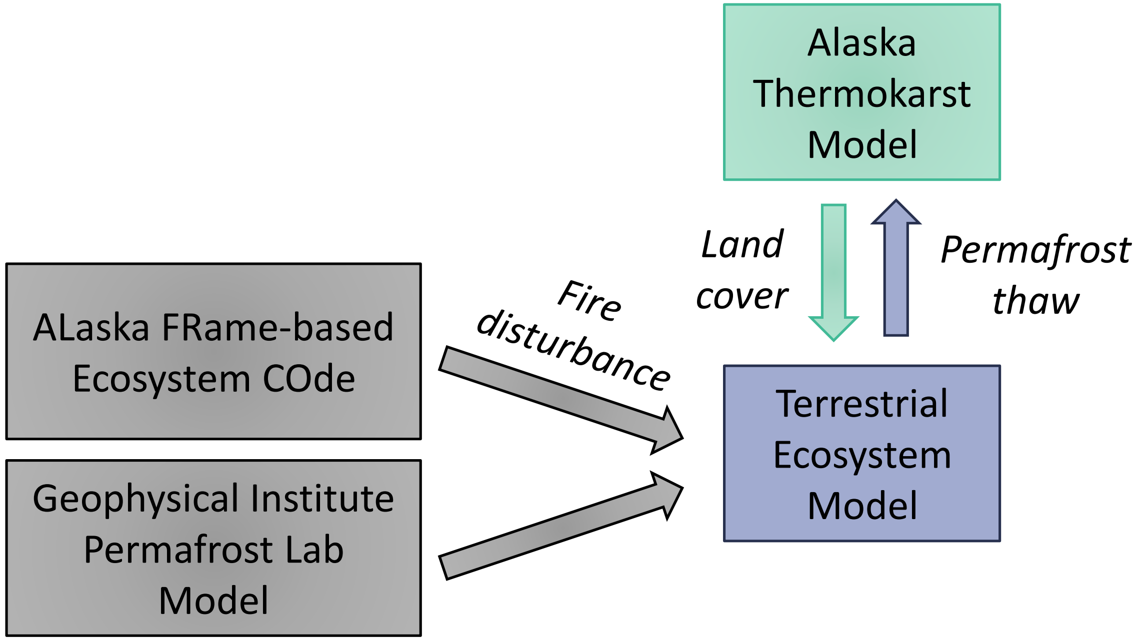


(Genet et al. in prep)

Task CF1 – Modeling intermediate scale patterning and processes

Future directions:

- What are your plans moving forward?
  - Primary focus on wildfire and thermokarst dynamics
  - Assess opportunities to include an individual tree-based landscape and disturbance model (iLand; W. Hanson)
- What is limiting your efforts?
  - These activities require significant leveraged funding, which in the past came primarily from the linked research efforts of the Integrated Ecosystem Model (IEM) and the Alaska LandCarbon program (both USGS funded).
  - These projects have ended (LandCarbon) or are winding down (IEM) and there is not currently a replacement mechanism on the horizon.
  - Changing career paths of McGuire and Rupp provides additional considerations/challenges moving forward



Task CF1 – Modeling intermediate scale patterning and processes

How do your findings inform understanding cross-scale interactive effects?

- TBD – model modification activities are either still in the planning phase or initiated but ongoing
- Our hypothesis (3a) is that vegetation distribution will shift towards increased deciduous forest cover in uplands and towards increased wetland cover in lowlands, with the rate and degree of these shifts being influenced by intermediate-scale patterns and processes

Task CF1 – Modeling intermediate scale patterning and processes

Publications:

- Euskirchen, E.S., K. Timm, A. Breen, S.T. Gray, T.S. Rupp, P. Martin, J.B. Reynolds, A. Sesser, K.A. Murphy, Jeremy.S. Littell, A.P. Bennett, W.R. Bolton, T.B. Carman, H. Genet, B. Griffith, T.K. Kurkowski, M.J. Lara, S. Marchenko, D.J. Nicolsky, S. Panda, V.E. Romanovsky, R. Rutter, C. Tucker, A.D. McGuire. 2018. Co-production of knowledge: Developing the Integrated Ecosystem Model to inform resource management decisions in Arctic Alaska. Frontiers in Ecology and the Environment. In press.
- Pastick N., Duffy P., Genet H., Rupp S.T., Wylie B.K., Johnson K., Jorgenson M.T., Bliss N., McGuire A.D., Jafarov E., Knight J.F. 2017. *Historical and Projected Trends in Landscape Drivers Affecting Carbon Dynamics in Alaska.* Ecological Applications 27: 1383–1402. doi:10.1002/eap.1538
- McGuire, A.D., H. Genet, Z. Lyu, N.J. Pastick, S. Stackpoole, R. Birdsey, D.V. D'Amore, Y. He, T.S. Rupp, R.G. Striegl, B.K. Wylie, X. Zhou, Q. Zhuang, Z. Zhu. 2018. Assessing historical and projected carbon balance of Alaska: A synthesis of results and policy/management implications. Ecological Applications 28(6). pp. 1396-1412. doi: 10.1002/eap.1768

Datasets:

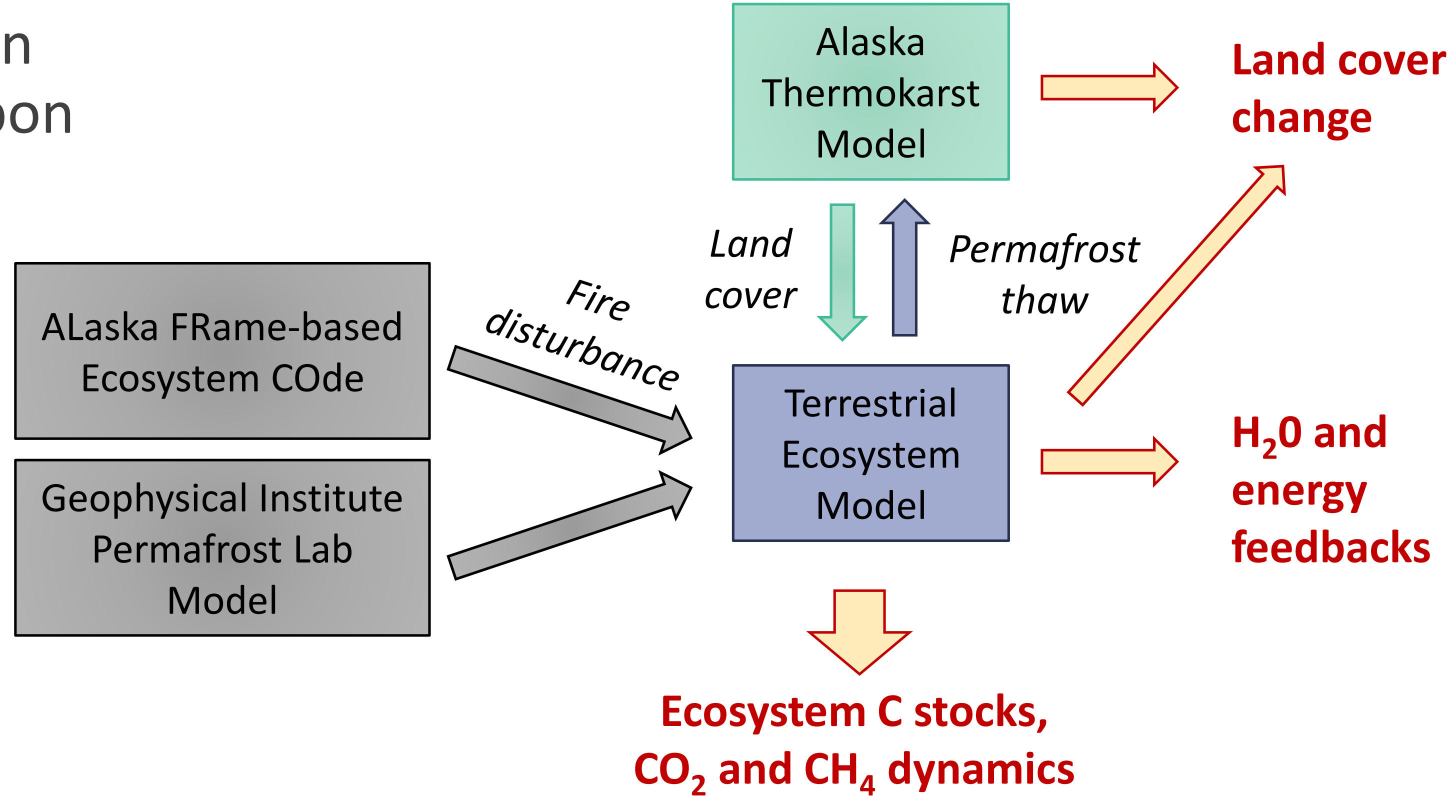
- IEM Generation 2 datasets - http://ckan.snap.uaf.edu/dataset?tags=IEM

Task CF2 – Compare changes in ecosystem structure between model frameworks with and without consideration of intermediate-scale patterning and processes

Rupp, Euskirchen, Genet, Turetsky, McGuire, Romanovsky

Summary of findings:

- No results to date - Activities still in planning phase and dependent upon progress to be made in Task CF1



Task CF2 – Comparing modeling frameworks

Future directions:

- What are your plans moving forward?
  - Complete an initial sensitivity analysis of model versions with and without intermediate-scale patterning and processes that quantifies differences and identifies the most sensitive mechanisms, processes, and parameters
  - Consider exploring the importance of model representation of intermediate-scale patterns and processes with respect to abrupt change and the role of ecological memory and legacy
- What is limiting your efforts?
  - Dependent upon significant progress in Task CF1, which is further dependent upon results coming from Sections I & II
  - Like Task CF1, this task requires significant funding leverage for both integrated model development (CF1) as well as model comparison and analysis (CF2)

Task CF3: Evaluate if simulated future changes in boreal ecosystems are unprecedented in the context of natural variability at decadal to millennial timescales

Hu, Rupp, McGuire, Mack

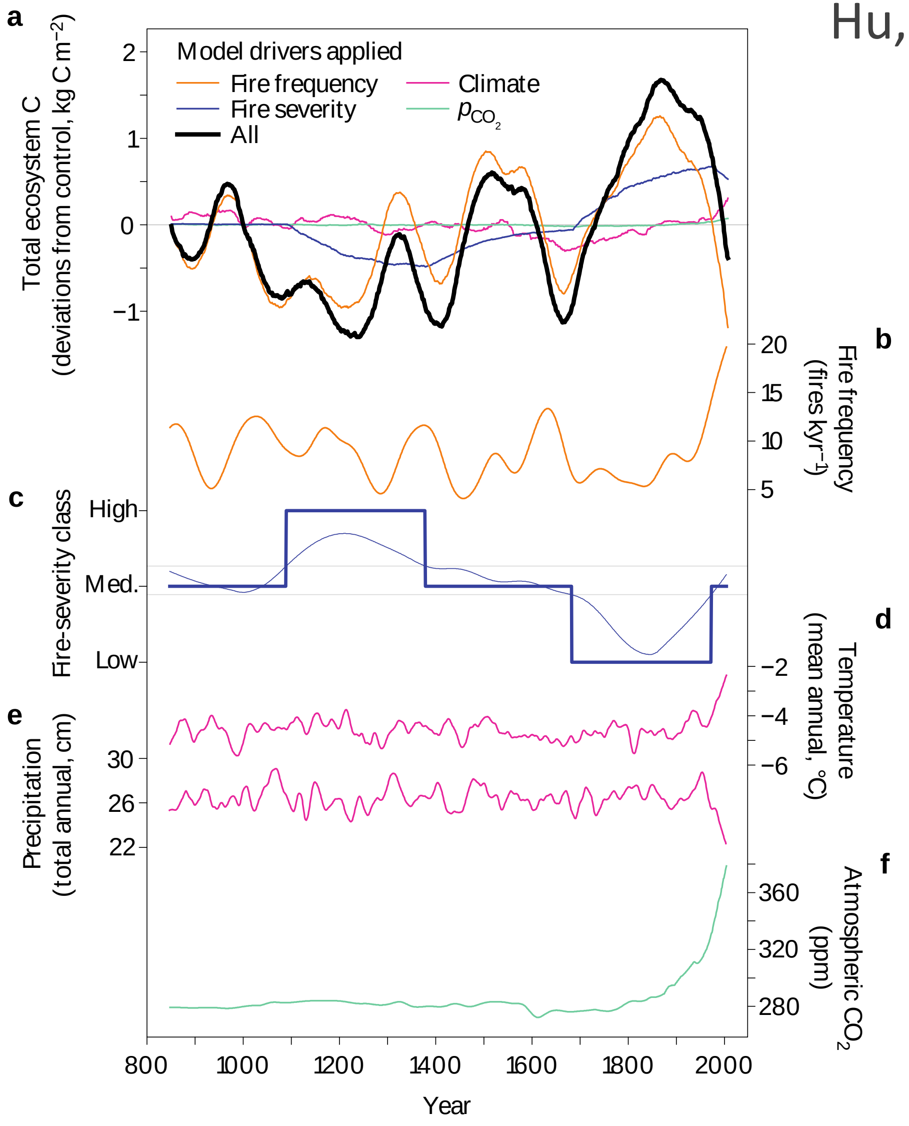


Figure 1 | Carbon dynamics of the past millennium. **a**, Simulated carbon stocks in response to model drivers (**b**–**f**) applied in combination (black) or individually (colours; see legend). Results are plotted as deviations from a control simulation with stationary inputs. **b**, Fire frequency estimated from palaeorecords. **c**, Fire-severity class (thick line) derived by stratifying a proxy variable (thin line) at its upper and lower quartiles (grey lines). **d**,**e**, Simulated palaeoclimate, summarized as trends in annual temperature and precipitation (actual inputs were monthly and included additional variables). **f**, Atmospheric CO_2 concentration from ice-core records. All lines are means over the study area.

Kelley, Genet, McGuire and Hu 2015

Task CF3: Evaluate if simulated future changes in boreal ecosystems are unprecedented in the context of natural variability at decadal to millennial timescales

Future directions

- What are your plans moving forward?
  - E.g., field/lab work, modeling, synthesis activities
- What is limiting your efforts?
  - E.g., money, personnel, time

Task CF3: Evaluate if simulated future changes in boreal ecosystems are unprecedented in the context of natural variability at decadal to millennial timescales

How do your findings inform understanding cross-scale interactive effects?

- In our proposal, we outlined a program "to understand the cross-scale interactive effects of changing climate and disturbance regimes on the Alaska boreal forest, study associated consequences for regional feedbacks to the climate system, and identify vulnerabilities and explore adaptation opportunities to social-ecological change with rural Alaskan communities and land management agencies."
- The site review team will be interested to understand how our collective research is addressing this broad goal

Task CF3: Evaluate if simulated future changes in boreal ecosystems are unprecedented in the context of natural variability at decadal to millennial timescales

RESEARCH PAPER

WILEY Global Ecology and Biogeography A Journal of Macroecology

Consequences of climatic thresholds for projecting fire activity and ecological change

Adam M. Young[1,2] | Philip E. Higuera[2] | John T. Abatzoglou[3] | Paul A. Duffy[4] | Feng Sheng Hu[5,6]

Landscape Ecol (2016) 31:1781–1793
DOI 10.1007/s10980-016-0361-2
CrossMark

RESEARCH ARTICLE

Land cover influences boreal-forest fire responses to climate change: geospatial analysis of historical records from Alaska

Carolyn Barrett Dash · Jennifer M. Fraterrigo · Feng Sheng Hu

Research

Ecography 40: 606–617, 2017
doi: 10.1111/ecog.02205

Subject Editor: Jessica Blois. Editor-in-Chief: Miguel Araújo. Accepted 30 March 2016

Climatic thresholds shape northern high-latitude fire regimes and imply vulnerability to future climate change

Adam M. Young, Philip E. Higuera, Paul A. Duffy and Feng Sheng Hu

A. M. Young, Dept of Forest, Rangeland, and Fire Sciences, Univ. of Idaho, Moscow, ID, USA. – P. E. Higuera (philip.higuera@umontana.edu), Dept of Ecosystem and Conservation Sciences, Univ. of Montana, Missoula, MT, USA. – P. A. Duffy, Neptune and Company, Lakewood, CO, USA. – F. S. Hu, Dept of Plant Biology, Univ. of Illinois, Urbana, IL, USA, and Dept of Geology, Univ. of Illinois, Urbana, IL, USA.

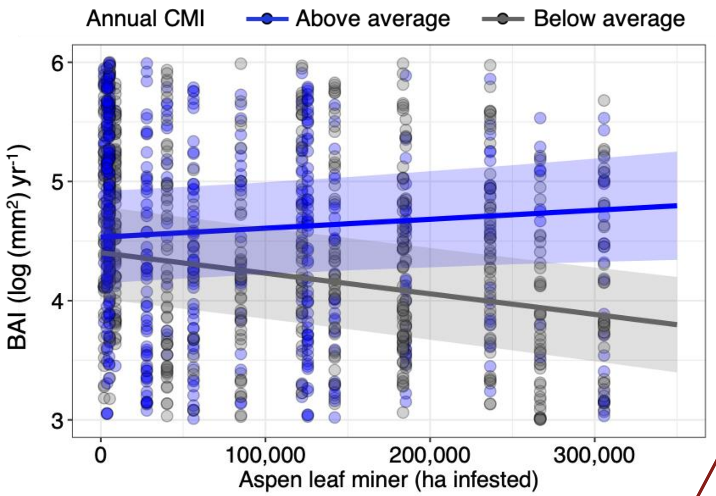
nature climate change
LETTERS
PUBLISHED ONLINE: 19 OCTOBER 2015 | DOI: 10.1038/NCLIMATE2832

Palaeodata-informed modelling of large carbon losses from recent burning of boreal forests

Ryan Kelly[1], Hélène Genet[2], A. David McGuire[3] and Feng Sheng Hu[1,4]*

Results

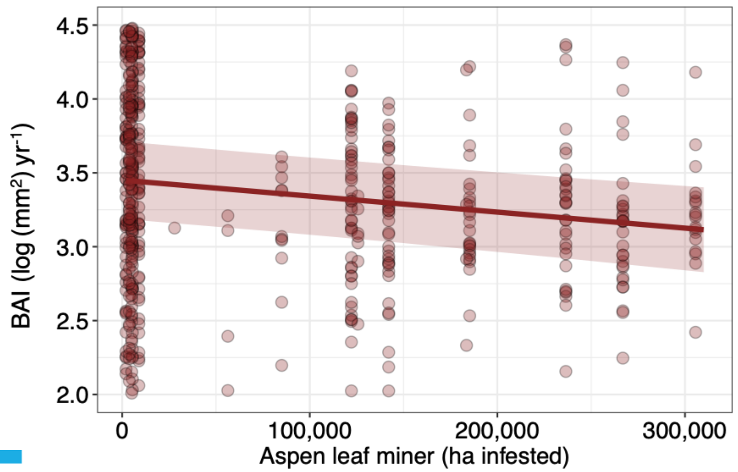
Aspen mortality and decreased productivity: drivers and NDVI trends



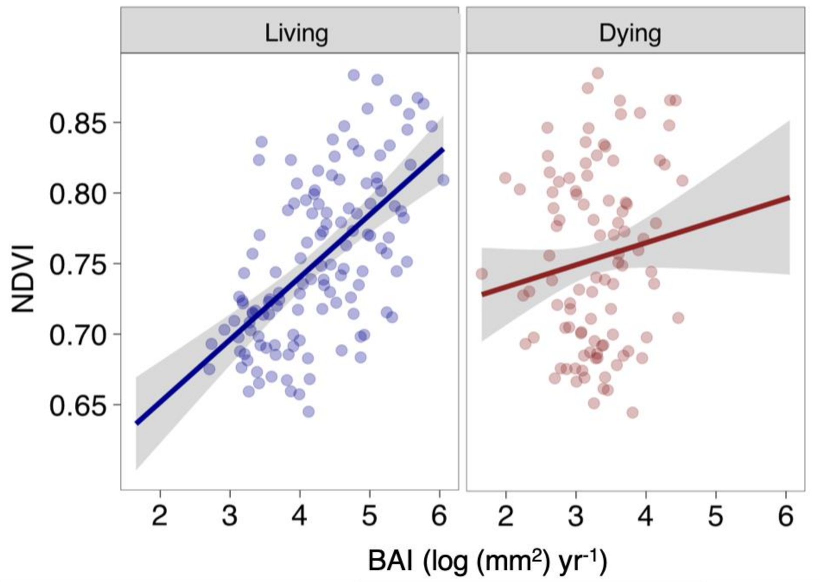
During the *P. populiella* outbreak (1997-2013), productivity of:

(a) living trees negatively affected by leaf mining only when moisture availability was low

(b) dying trees always negatively affected by leaf mining



Productivity of living trees more strongly reflected in NDVI signal than dying trees



Climate Feedbacks Task CF4

Task CF4: Analyze water and energy feedbacks to future change in climate for interior Alaska between applications of the model that do and do not consider intermediate-scale patterning and processes

(Euskirchen, Turetsky, Genet, Rupp, McGuire, Romanovsky).

Climate Feedbacks Task CF4

Vegetation Albedo – Climate Feedbacks

- Treeline migration
- Shrubs
- Reduced growth of spruce forests under drought stress
- Fire

Snow Season Albedo – Climate Feedbacks

May alter the reflectance, energy balance, and carbon cycling of a given ecosystem, resulting in a climate feedback

Biogeochemical – Climate Feedbacks

- Greater CO_2 uptake by plants
- Increases in heterotrophic respiration

Building off Previous Work

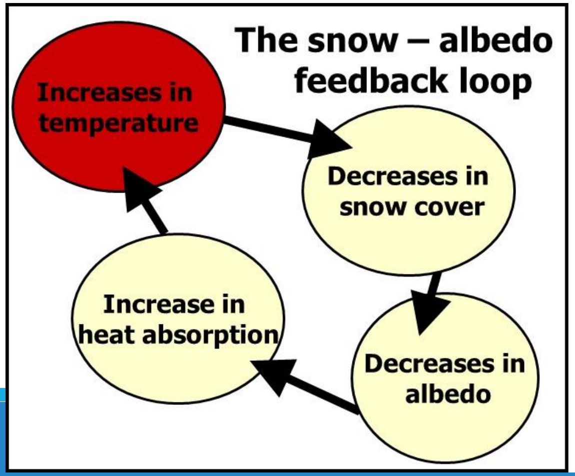
Examined energy feedbacks to climate due to changes in:

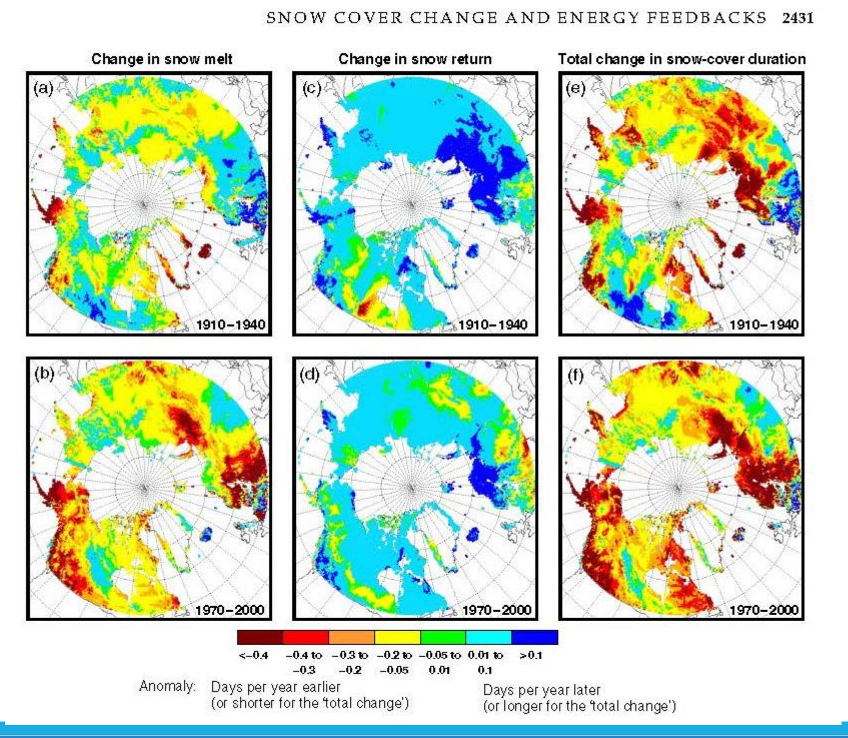
(1) Snow cover at the pan-Arctic scale (Euskirchen et al., 2007)

(2) Both snow cover and vegetation due to shifts in the fire regime across boreal Alaska and northwest Canada (Euskirchen et al., 2009a) and,

(3) Increased shrub growth and changes in snow cover in arctic Alaska (Euskirchen et al., 2009b).

***Bottom Line*: Changes in snow cover exert a stronger feedback to warming than shifts in vegetation type (Euskirchen et al., 2010).**





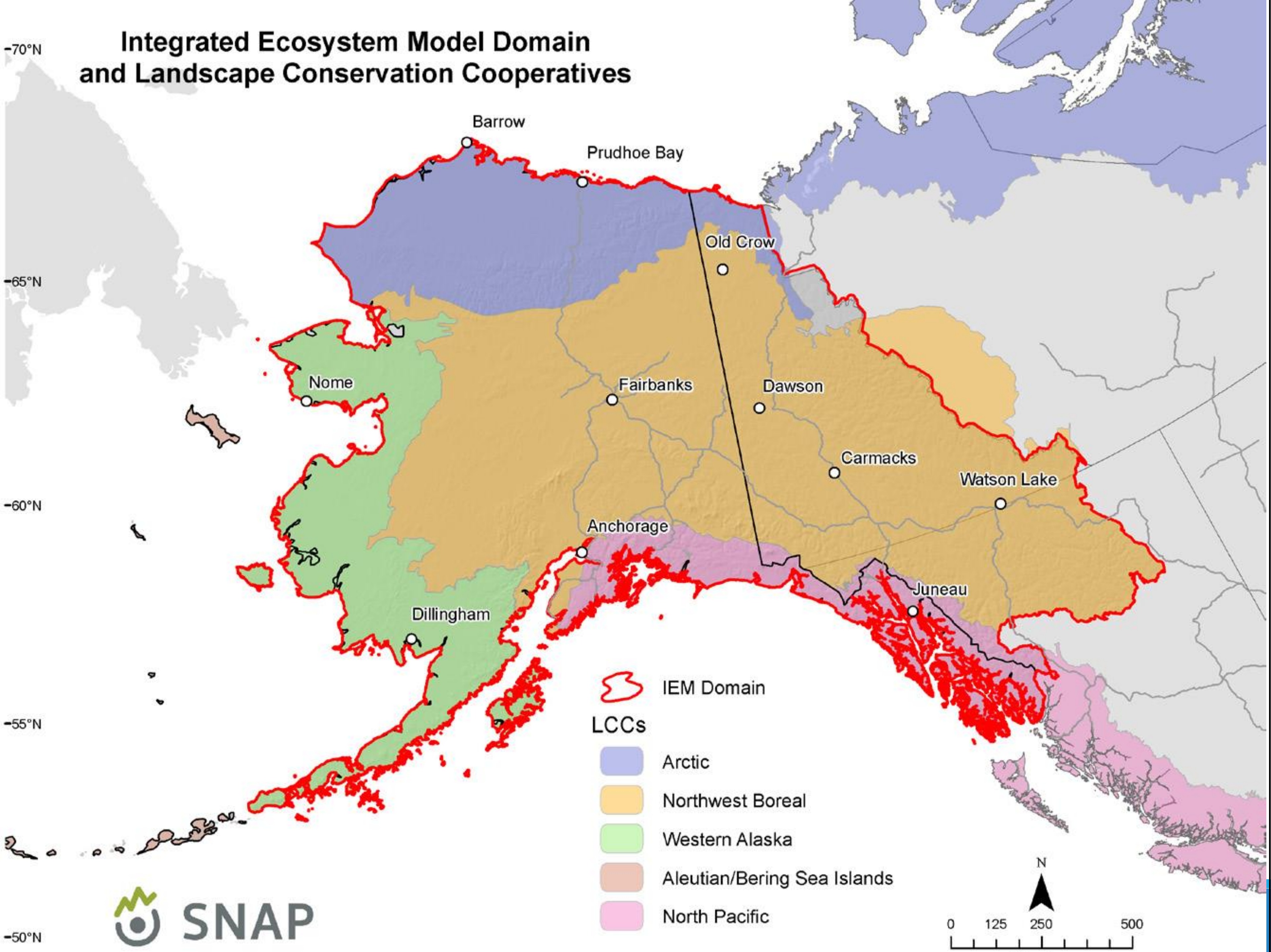
Euskirchen et al., GCB, 2007

Climate Feedbacks Task CF4

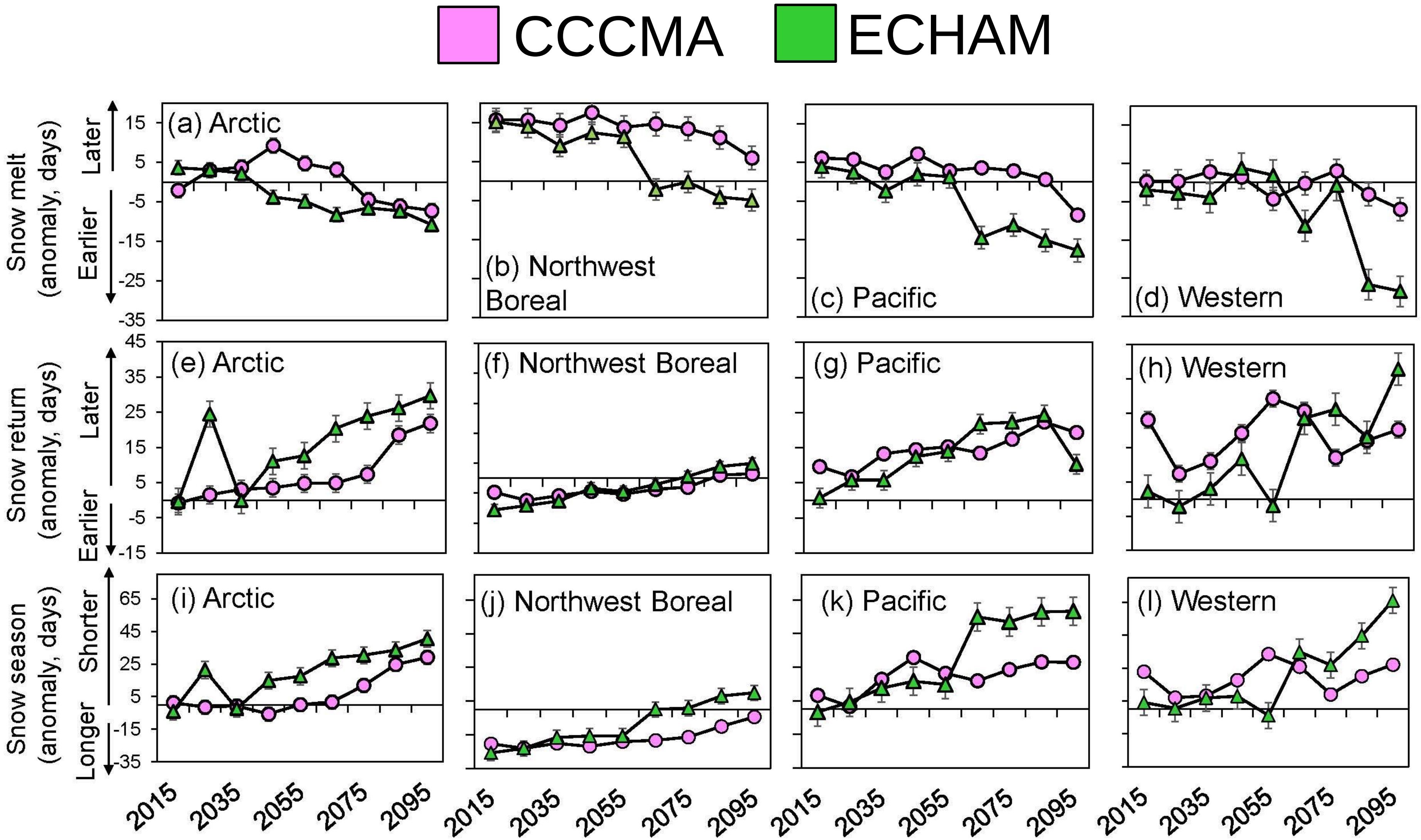
Include a more comprehensive suite of the types of vegetation change

- Changes in shrub distribution and growth
- Tundra fires (in addition to boreal fires)
- Advances in treeline
- Reduction in forest cover due to drought.

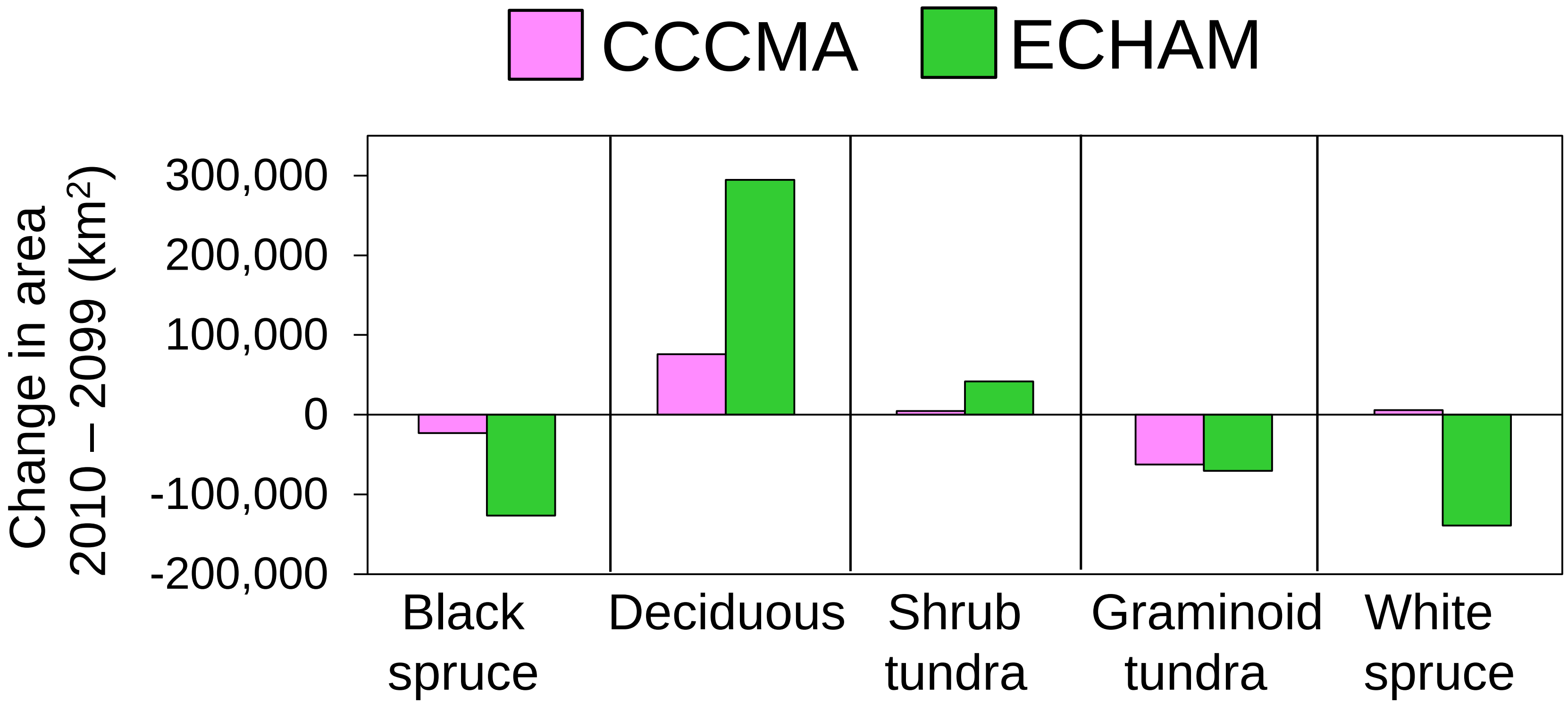


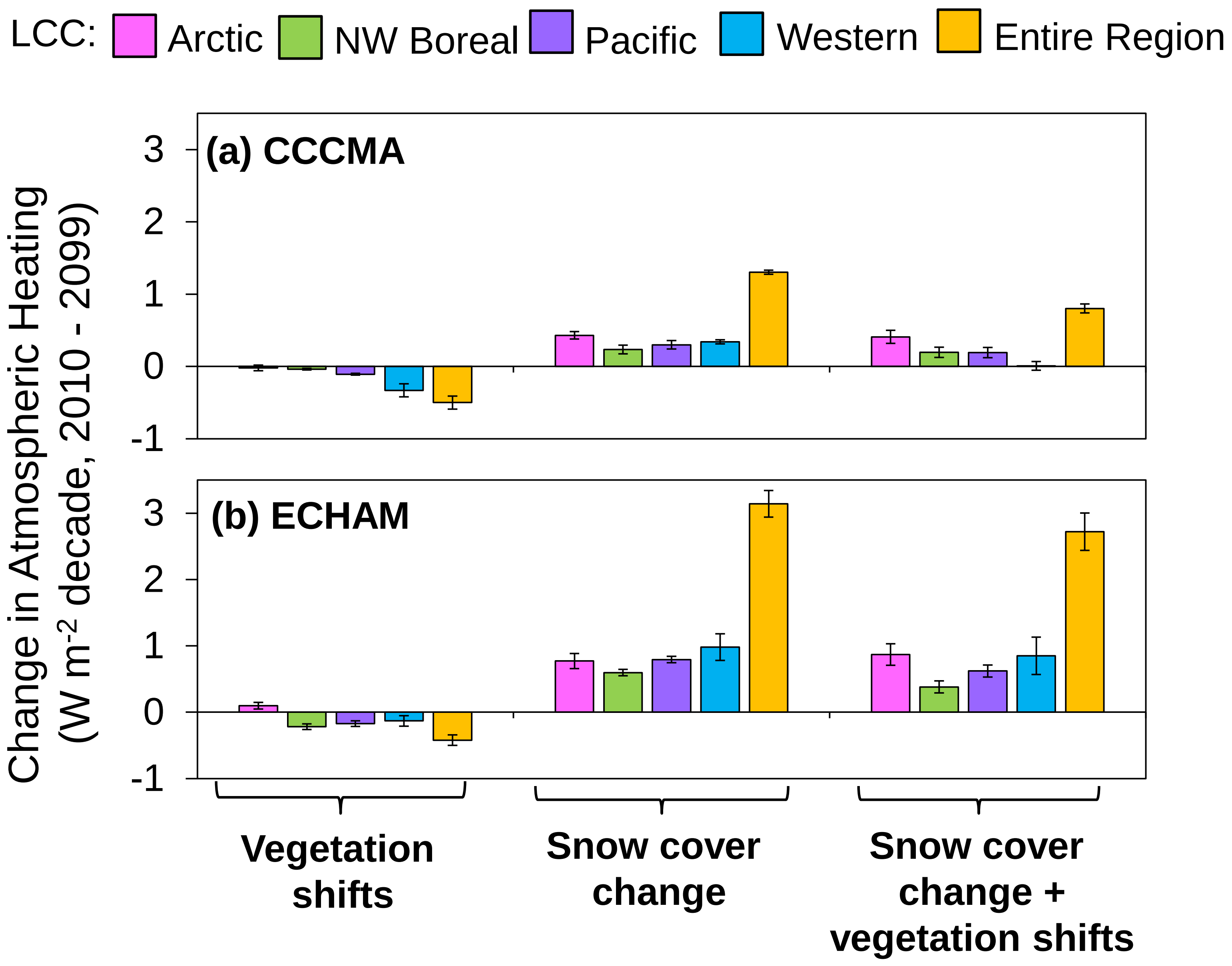


Integrated Ecosystem Model Domain
and Landscape Conservation Cooperatives
70°N
65°N
60°N
55°N
50°N
Barrow
Prudhoe Bay
Old Crow
Nome
Fairbanks
Dawson
Carmacks
Watson Lake
Anchorage
Juneau
Dillingham
IEM Domain
LCCs
Arctic
Northwest Boreal
Western Alaska
Aleutian/Bering Sea Islands
North Pacific
N
0
125
250
500
SNAP

Changes in the duration of the snow season, 2010 - 2099



Region-wide changes in vegetation due to fire, treeline advance, shrubification, and drought, 2010 - 2099





Euskirchen et al., 2016, Environmental Research Letters

Climate Feedbacks Task CF4

- Greatest overall negative climate feedback from changes in vegetation cover: fire in spruce forests in the Northwest Boreal LCC and fire in shrub tundra in the Western LCC.

- Treeline advance = negligible impact on atmospheric heating

- Vegetation shifts only partially outweighed the positive feedback from changes in snow cover

- Overall, increases in C storage in the vegetation and soils across the study region acted as a negative feedback to climate.

Climate Feedbacks Task CF4

Future directions

- Would be important to bring in changes in C storage more formally to this assessment
- Need to more carefully consider heterotrophic respiration and shoulder season dynamics
- Requires a radiative transfer model or possibly some other methodology our group previously has not employed

- What is limiting your efforts?
  - Need to identify the most straight-forward, defensible approach to this
  - May need additional funding sources
  - Would make a great project for the right graduate student or postdoc

Climate Feedbacks Task CF4

How do your findings inform understanding cross-scale interactive effects?

- In our proposal, we outlined a program "to understand the cross-scale interactive effects of changing climate and disturbance regimes on the Alaska boreal forest, study associated consequences for regional feedbacks to the climate system, and identify vulnerabilities and explore adaptation opportunities to social-ecological change with rural Alaskan communities and land management agencies."
- **In the process to directly quantifying the climate feedbacks, we determined which regions may be most vulnerable to changes in snow cover, which impacts rural Alaskan communities**
- **Also identified important changes and shifts in vegetation cover (and areas that are susceptible to fire) across the landscape, which is key for animal habitat**

Task description (from proposal)

Publications and datasets

Euskirchen, ES., A. Bennett, A.L. Breen, H. Genet, M. Lindgren, T. Kurkowski, A.D. Mcuire, T.S. Rupp. 2016. Consequences of changes in vegetation and snow cover for climate feedbacks in Alaska and northwest Canada. *Environmental Research Letters.* **11**:105003, doi:10.1088/1748-9326/11/10/105003

Datasets:

Available through SNAP:

http://ckan.snap.uaf.edu/dataset?q=euskirchen&sort=score+desc%2C+metadata_modified+desc

Analyze carbon feedbacks to the climate system to future change in climate for interior Alaska.

Genet H., Turetsky T., McGuire A.D., Romanovsky V.

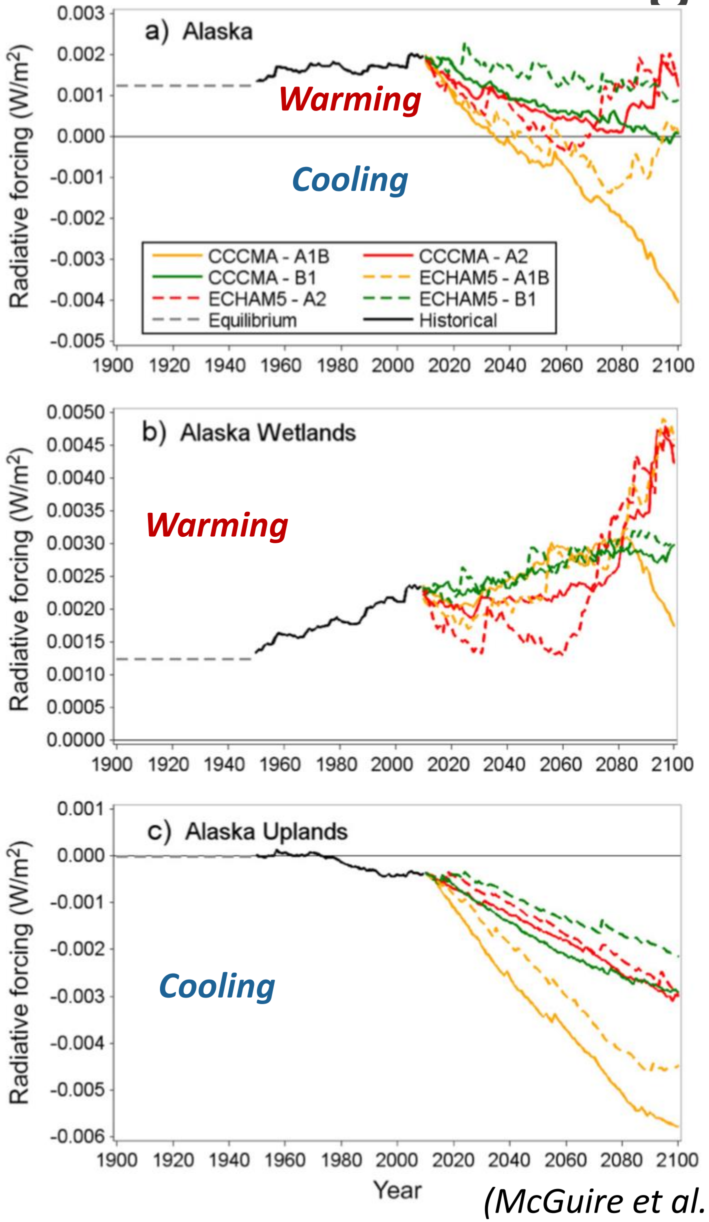
The Terrestrial Carbon Balance of Alaska and Projected Changes in the 21st Century

Between 1950 and 2009, upland and wetland ecosystems of Alaska sequestered **0.4 Tg C yr^{-1}**.

C sequestration increased substantially during the projected period, from 2010 to 2100 (**22.5 to 70.0 Tg C yr^{-1}**).

Wetland biogenic methane emissions increased by 47.7% on average across the projections, compare to the historical period.

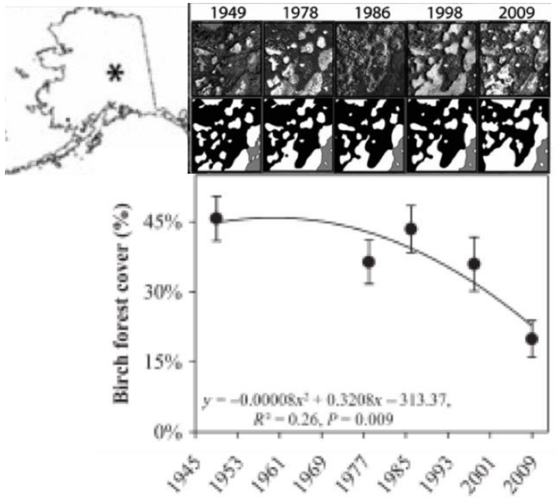
The decreasing sensitivity of NPP to atm. CO_2 and the linear sensitivity of heterotrophic respiration and wetland methane emissions to air/soil temperature, in addition to the increase in C loss from wildfires **weakens the C sink** from Alaska ecosystems beyond 2100.



(McGuire et al. 2018)

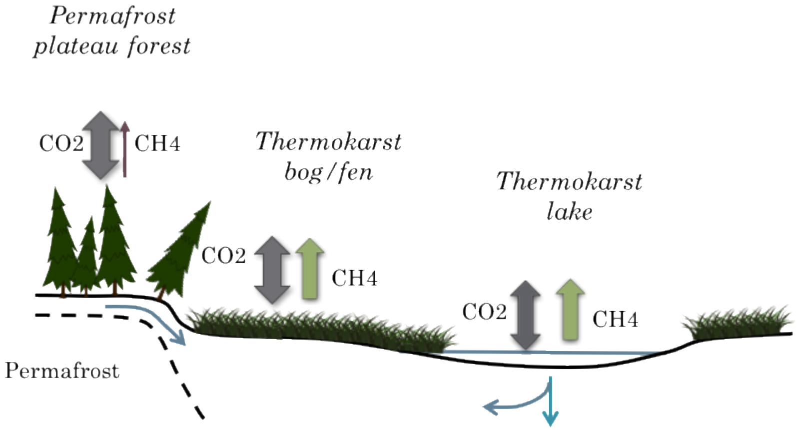
Quantify the importance of intermediate-scale patterning and processes on the carbon feedbacks to the climate system

Genet H., Turetsky T., McGuire A.D., Romanovsky V.



(Lara et al. 2016)

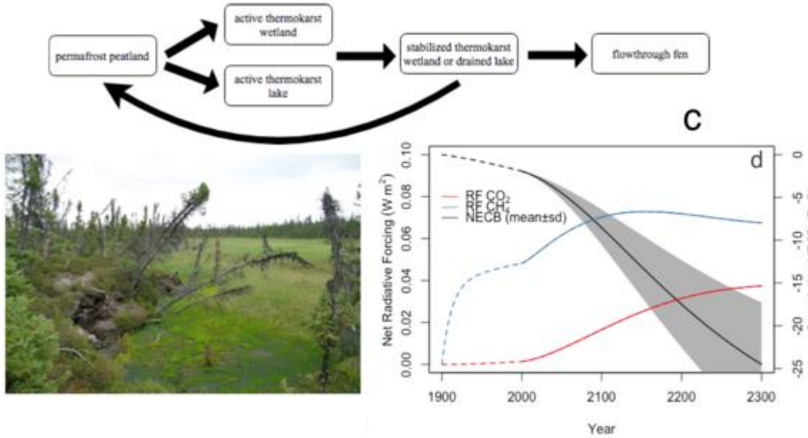
A large part of the boreal permafrost region in Alaska is vulnerable to thermokarst and thermal erosion disturbances as a result from rapid permafrost degradation. Repeated imagery analysis suggest an acceleration of permafrost plateau degradation in lowlands.



Increases in abrupt thaw due to climate warming trigger a change in carbon behavior from net uptake to net release.

Hillslope erosional features increase in area from 0.1% to 3% of abrupt thaw terrain, but these active features have the potential to emit ~ 1/3 of abrupt thaw carbon losses.

Thaw lakes and wetlands act as methane hot spots but their carbon release is partially offset by slowly regrowing vegetation.

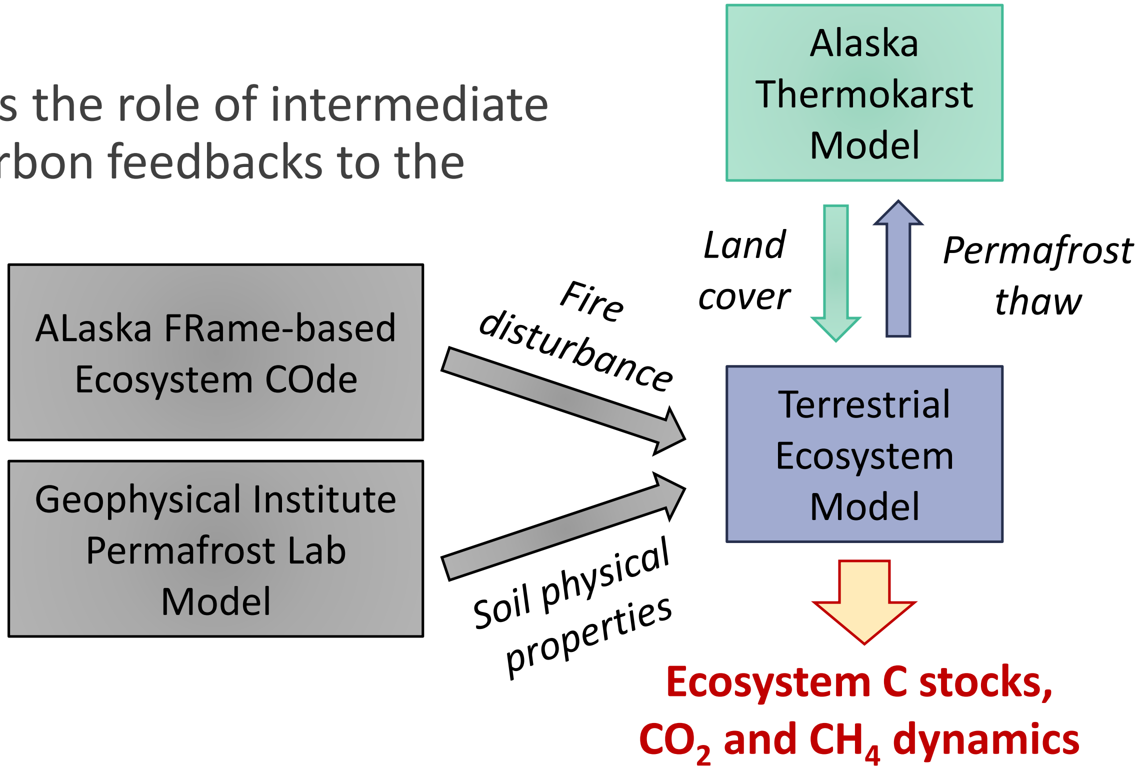


(Turetsky et al. in prep)

Integrating intermediate-scale patterning and processes in ecosystem models to assess the carbon feedbacks to the climate system

Future directions:

1. Evaluate parameter **uncertainty** of thermokarst disturbance and its impact of ecosystem C projections
2. Finalize the **integration** of thermokarst disturbance in our modeling framework
3. Finalize ecosystem model **parameterization** to represent wetland C, CO_2 and CH_4 dynamic in the Terrestrial Ecosystem Model
4. Conduct an **attribution analysis** to assess the role of intermediate scale permafrost disturbances on the carbon feedbacks to the climate system in boreal Alaska

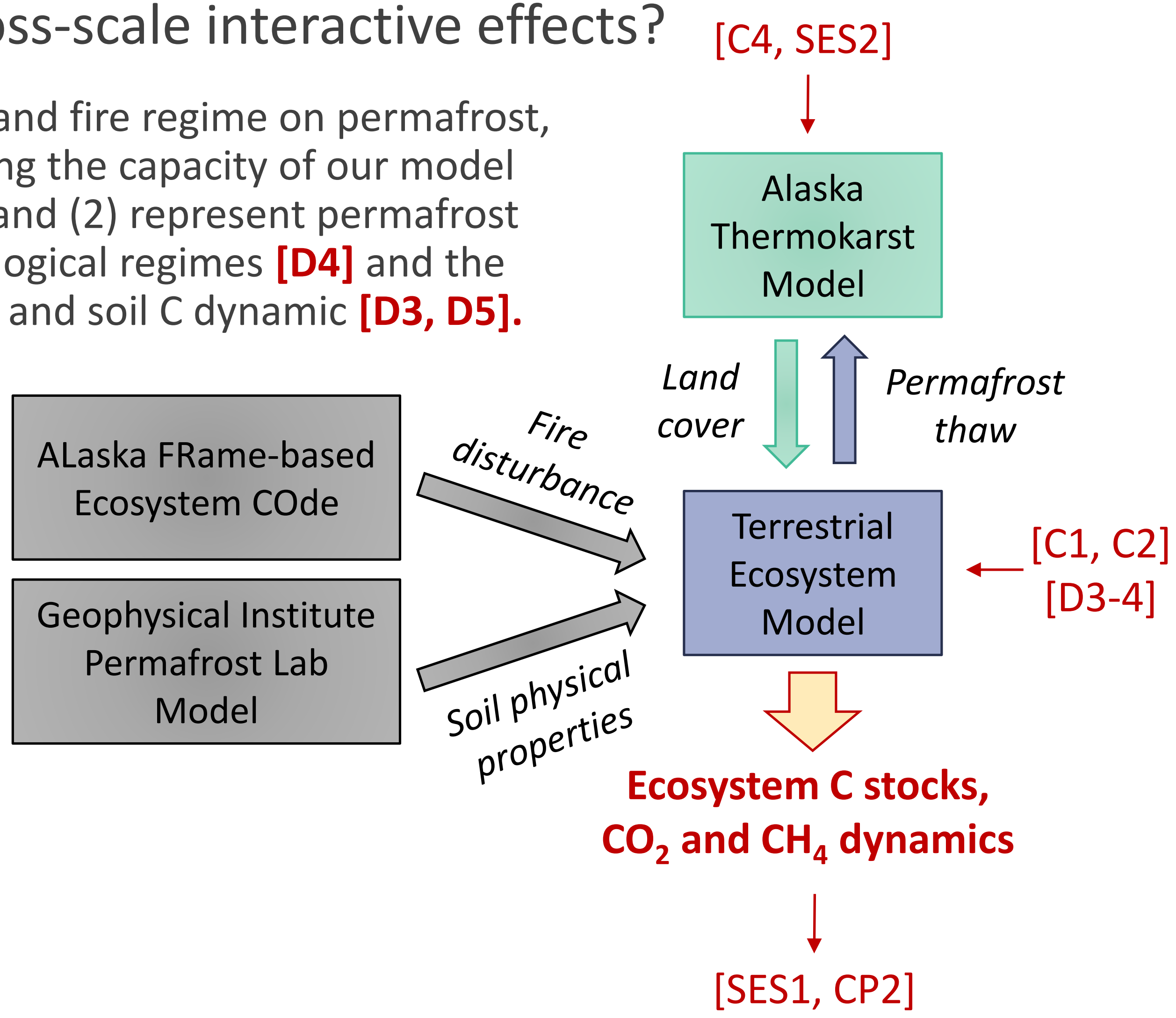


Integrating intermediate-scale patterning and processes in ecosystem models to assess the carbon feedbacks to the climate system

How do your findings inform understanding cross-scale interactive effects?

New understanding on the consequences of changing climate and fire regime on permafrost, vegetation and hydrology will be used for developing and testing the capacity of our model framework to (1) predict thermokarst disturbances **[C4, SES2]** and (2) represent permafrost dynamic, the associated changes in the soil thermal and hydrological regimes **[D4]** and the consequences of vegetation dynamic and productivity **[C1, C2]** and soil C dynamic **[D3, D5].**

Improving the representation of intermediate scale disturbances and processes in our modeling framework allows for a better understanding of local scale carbon dynamic and the influence of local changes in boreal Alaska on the regional carbon feedbacks to climate in boreal Alaska. This multi-scale evaluation can serve as a baseline to inform local resource management **[SES1]** and regional forest and, fire management **[CP2].**



Integrating intermediate-scale patterning and processes in ecosystem models to assess the carbon feedbacks to the climate system

Accepted publications

- Lyu Z., Genet H., He Y., Zhuang Q., McGuire A. D., Bennett A. *et al.* 2018. *The role of environmental driving factors in historical and projected carbon dynamics of wetland ecosystems in Alaska.* Ecological Applications, *28*(6). doi:10.1002/eap.1755
- Genet H., He Y., Lyu Z., McGuire A.D., Zhuang Q., Clein J., D'Amore D., Bennett A., Breen A., Biles F., S. Euskirchen E.S., Johnson K., Kurkowski T., Schroder S., Pastick N., Rupp S.T., Wylie B., Zhang Y., Zhou X., Zhu Z. 2017. *The role of driving factors in historical and projected carbon dynamics of upland ecosystems in Alaska.* Ecological Applications: doi/10.1002/eap.1641
- McGuire, A. D., Genet, H., Lyu, Z., Pastick, N., Stackpoole, S., Birdsey, R., Zhu, Z. 2018. *Assessing historical and projected carbon balance of Alaska: A synthesis of results and policy/management implications.* Ecological Applications, 28(6). https://doi.org/10.1002/eap.1768
- Pastick N.J., Jorgenson M.T., Goetz S.J., Jones B.M., Wylie B.K., Minsley B.J., Genet H., Knight J.F., Swanson D.K., Jorgenson J.C. 2018. *Spatiotemporal remote sensing of ecosystem change and causation across Alaska.* Global Change Biology. doi: 10.1111/gcb.14279
- Lara M.J., Genet H., McGuire A.D., Euskirchen E.S., Zhang Y., Brown D.R.N., Jorgenson M.T., Romanovsky V., Breen A., Bolton W.R. 2016. *Thermokarst rates intensify due to climate change and forest fragmentation in an Alaskan boreal forest lowland.* Global Change Biology, doi: 10.1111/gcb.13124

Publications in review

- Turetsky M.R., Abbott B.W., Jones M.C., Walter Anthony K., Olefeldt D., Schuur E.A.G., Grosse G., Kuhry P., Hugelius G., Koven C., Lawrence D.M., Gibson C., Britta A., Sanneli K., McGuire A.D. *Abrupt thaw amplifies the permafrost carbon feedback through upland erosion and methane hotspots.*

Publications in preparation

- Genet H., McGuire A.D., Jorgenson T., Greaves H., Rutter R., Romanovski V., Turetsky M., Douglas T., Euskirchen E.S., Bolton W.R., Lara M. *Modeling the importance of thermokarst disturbance on the regional carbon balance in boreal Alaska and the consequences on the carbon feedback to the climate.* In preparation.
- Greaves H., Genet H., Rutter R., Carman T., Euskirchen E.S., McGuire A.D. *Evaluation of the importance of change precipitation and permafrost thaw on soil moisture using an integrative approach.*