A Synthesis of Terrestrial Carbon Balance of Alaska and Projected Changes in the 21st Century: Implications for Climate Policy and Carbon Management

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Assessment Objectives and Organization

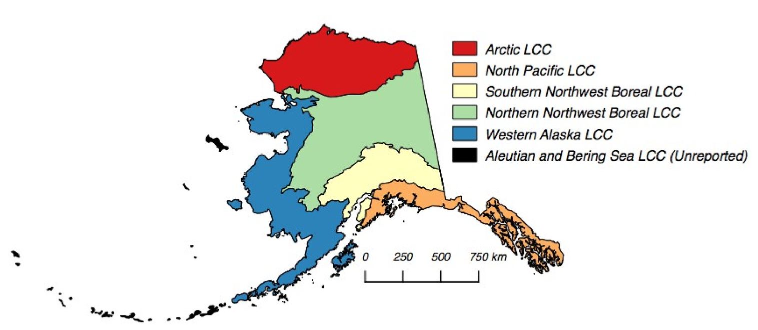

Fig. 1. The terrestrial reporting regions of the Alaska Land Carbon Assessment are based on the spatial domains of the Landscape Conservation Cooperatives (LCC) in Alaska..

To better understand how carbon responses to changes in climate and other drivers in Alaska might influence national climate and carbon management policies, the U.S. Geological Survey, in collaboration with the USDA Forest Service and university scientists, has conducted a comprehensive assessment of the historical (1960-2009) and projected (2010-2099) carbon balance for Alaska. This assessment of carbon dynamics in Alaska includes (1) syntheses of soil, vegetation, and surface water carbon stocks and fluxes in Alaska, and (2) state of the art models of fire dynamics, vegetation change, forest management, permafrost dynamics, and upland, wetland, and surface water ecosystem carbon dynamics. Here we report on progress in the soils synthesis, fire and vegetation dynamics synthesis, and syntheses of upland, wetland, and inland waters components.

The terrestrial reporting regions for soil, upland, and wetland components of this assessment are based on the four large terrestrial Landscape Conservation Cooperatives (LCC) in Alaska: (1) the Arctic, (2) the Western Alaska, (3) the Northwest Boreal, and (4) the North Pacific (Fig. 1). The reporting regions for the inland waters' component of this assessment are based on the six main hydrologic regions of Alaska: the Southeast, the South-Central, Southwest, Yukon, Northwest and Arctic Slope (Fig. 2).

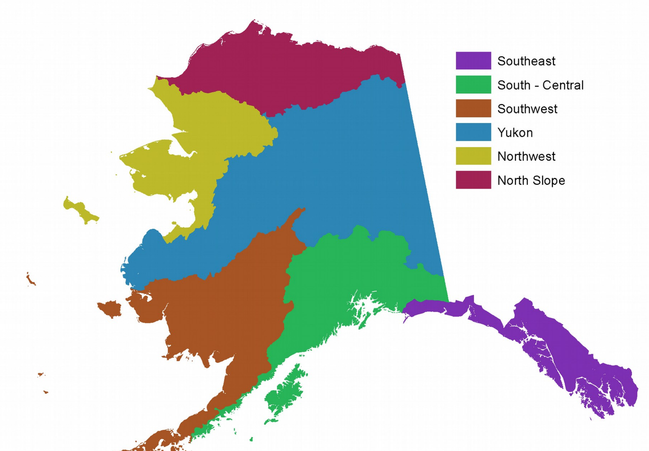

Fig. 2 . The reporting regions for the inland waters component of the Alaska Land Carbon Assessment..

Soils Assessment

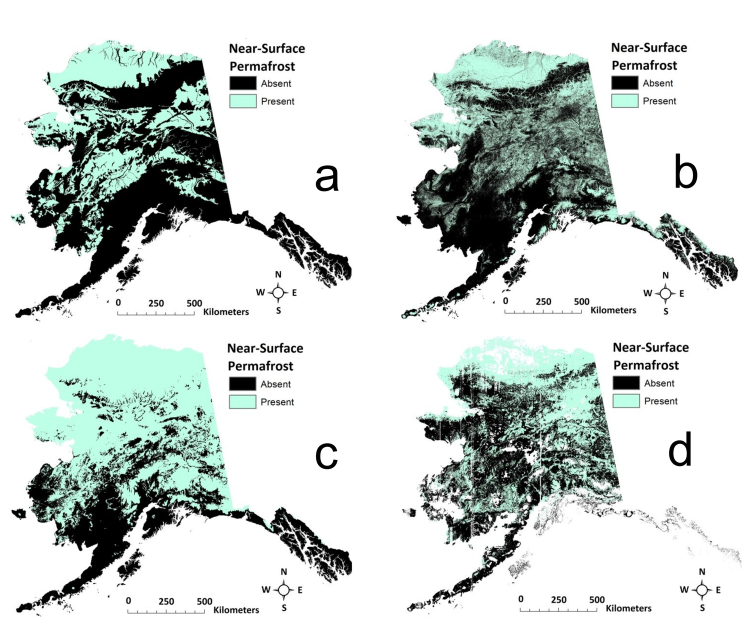

Fig. 3. Presence-absence of near-surface (within 1 m) permafrost for Alaska: a) STATSGO; b) Pastick et al., (in-prep); c) Geophysical Institute Permafrost Lab (GIPL) 2.0, and; d) DOS-TEM.

The soils component of the Alaska Land Carbon Assessment focused on (1) documenting uncertainties in the contemporary distributions of permafrost and soil C in Alaska, and (2) evaluating the simulations of permafrost and soil C in Alaska by the dynamic organic soil version of the Terrestrial Ecosystem Model (DOS-TEM), the processed based model used to make projections of changes in permafrost and soil C in this assessment. Several new soil property products were created as part of this study to help improve and refine soil property predictions by assimilating new field observations and remote sensing analyses, and to better quantify and assess landscape-scale map uncertainties.

Near surface permafrost (NSP) was estimated to underlay a large portion of Alaska with a wide range of estimates (36% - 67%) among the different numerically based products (Fig. 3). The mean NSP frequency of DOS-TEM outputs (44%) falls within this range.

The total carbon storage for soils in Alaska was estimated to be between 31.5 and 72.1 Pg C among empirical estimates, and the DOS-TEM estimate of 45.2 Pg C was within this range. DOS-TEM estimates generally agreed with mean organic carbon estimates for each ecotype, falling within the range of estimates for 78% of the ecotypes (Fig. 4).

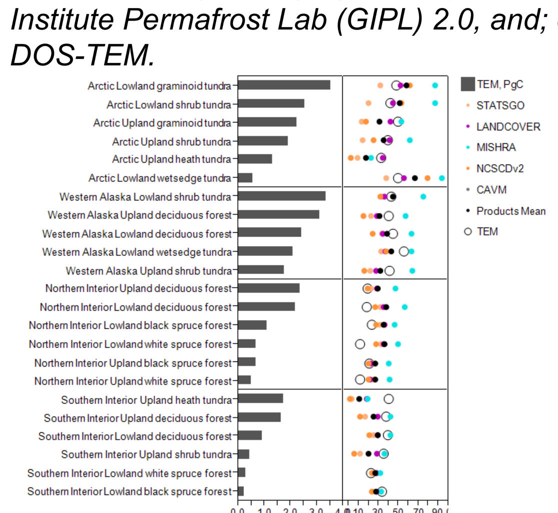

Fig. 4. Soil organic carbon characterization by Landscape Conservation Cooperative (LCC) and land cover class.

Wildfire and Vegetation Dynamics

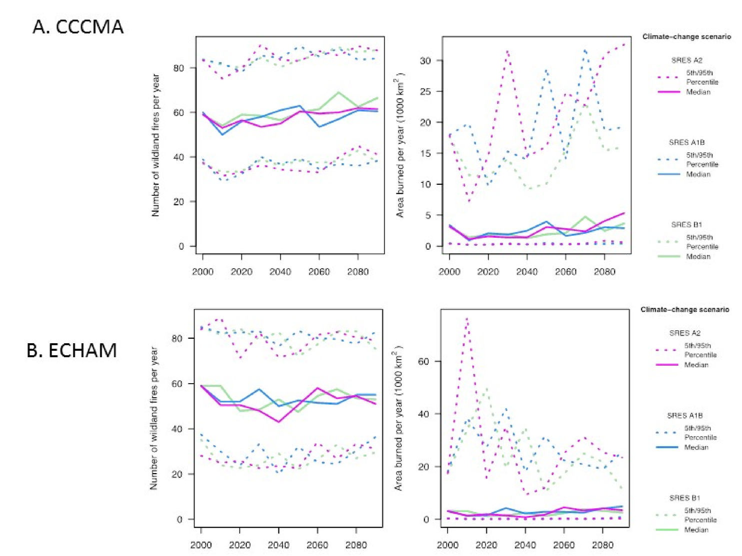

Fig. 5. Simulated fire activity across the full assessment domain showing summaries of projected wildland-fire ignitions and area burned for each decade for (A) CCCMA and (B) ECHAM. Median, 5th and 95th percentiles reported across 200 simulations.

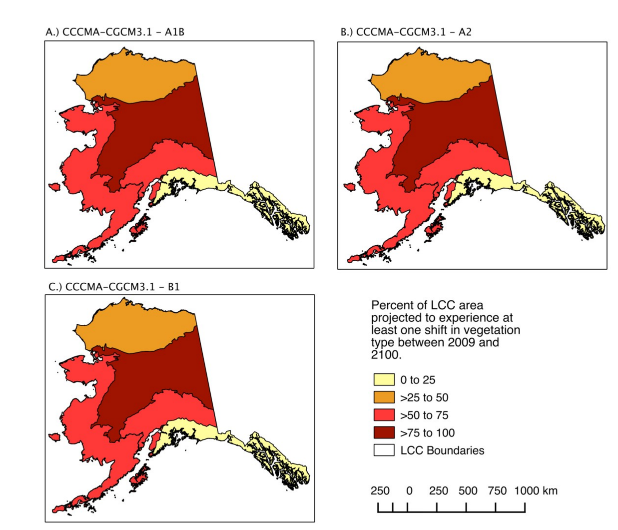

Fig. 6. Projected land cover change (%) footprint visualized by LCC subregions for the CCCMA simulations; the ECHAM model produces the same results for the binned categories depicted.

We used the Alaska Frame Based Ecosystem Code (ALFRESCO) to simulate changes in wildfire and vegetation dynamics in the 21st Century. ALFRESCO estimates that median annual area burned will range between a decrease of 24% for the A2 ECHAM climate to an increase of 78% for A1B CCCMA climate (Fig. 5). Statewide vegetation change is projected to affect approximately 60% of the landscape across all climate scenarios, with the largest changes predicted for the Northern Northwest Boreal LCC Region, where fire activity is the most intense (Fig. 6).

C and CH4 Dynamics in Uplands and Wetlands

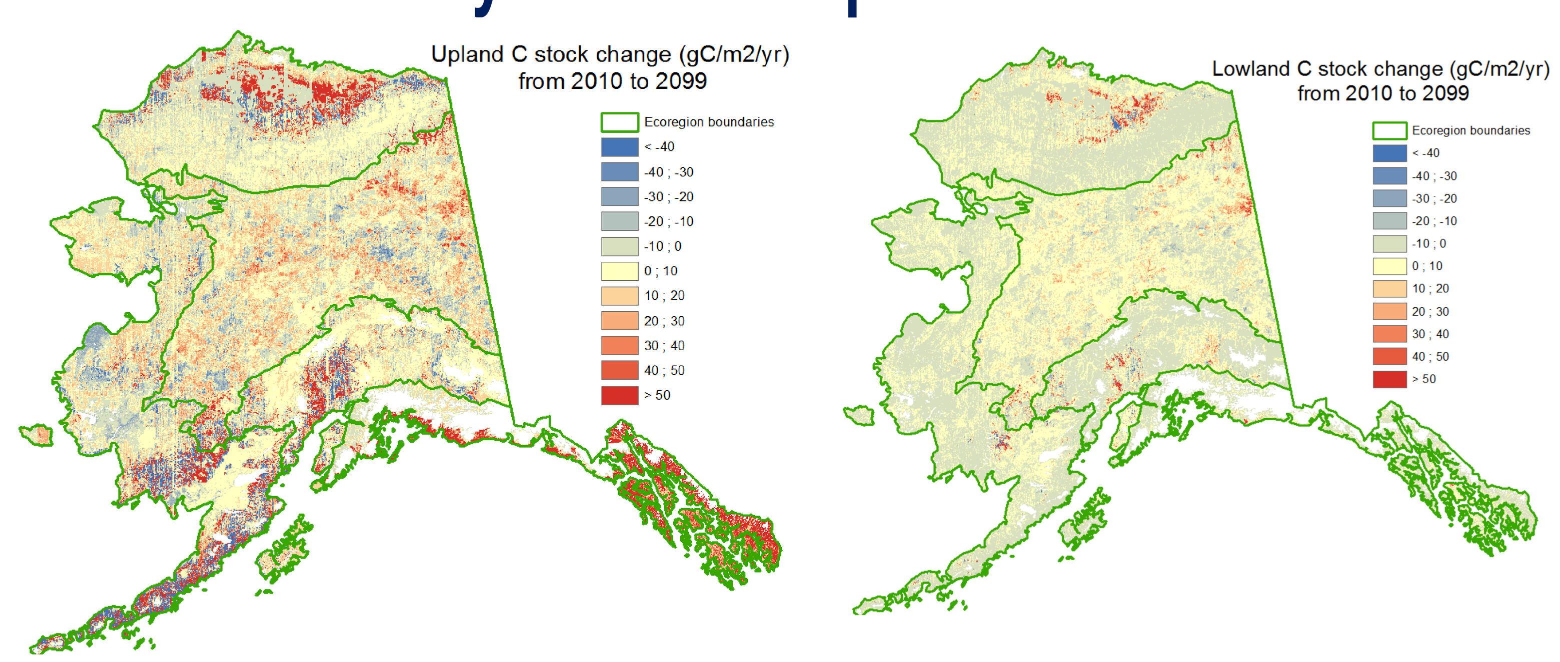

Fig. 7. Changes in carbon stocks simulated by DOS-TEM for the CCCMA A1B climate for upland and lowland/wetland land cover types in Alaska.

We used DOS-TEM to simulate C dynamics in Alaska from 1960 – 2100. For historical climate the model estimates that the annual change is C storage for uplands and wetlands was -7.11 Tg C from 2000-2009 (-2.95 Tg C in vegetation and -4.16 Tg C in soils) associated with substantial wildfie activity in the decade. There is substantial spatial variability in the projected changes in C storage between 2010 and 2099 (e.g., Fig. 7). The estimated annual changes in C storage for uplands and wetlands between 2010 and 2099 ranged from 20.3 Tg C for the scenario with the least warming (CCCMA-B1) to 20.7 Tg C for the scenario with the steepest warming trend (ECHAM-A2). The similar C gain for the most extreme scenarios was related to the fact that larger C gains from increases in productivity in the warmest scenario were offset by more C lost from increases in burned area.

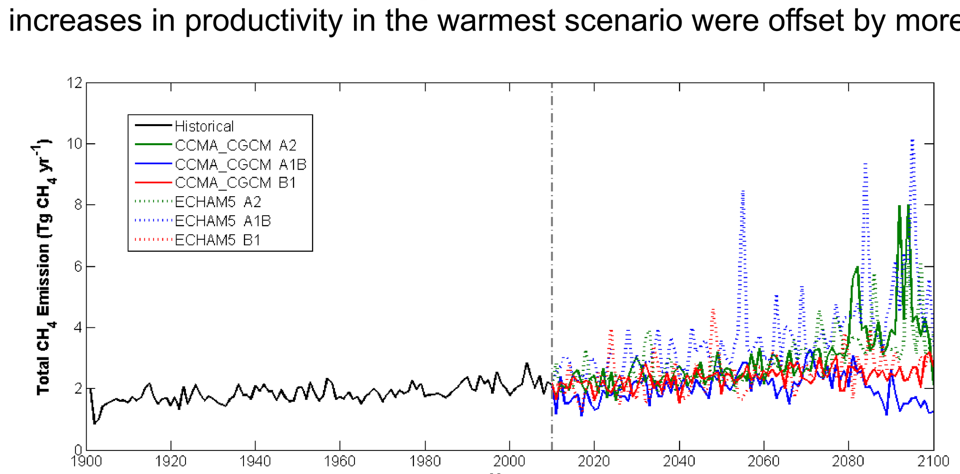

Fig. 8. Simulated net methane emissions for Alaska for the historical period through 2009 and the projected period (2010-2099) by the methane dynamics module of the Terrestrial Ecosystem Model..

We used the methane dynamics module (MDM) of TEM to simulate methane dynamics in uplands and wetlands for Alaska. For historical climate the MDM estimates that net methane emissions for Alaska are approximately 2 Tg CH_4 per year from uplands and wetlands (Fig. 8). By the last decade of the 21st Century, Methane emissions from upland and wetland soils Alaska are projected to range from 2.0 Tg CH_4 for the CCMA-A1B climate to 5.1 Tg CH_4 for the ECHAM-A1B climate.

C Dynamics of Inland Aquatic Ecosystems

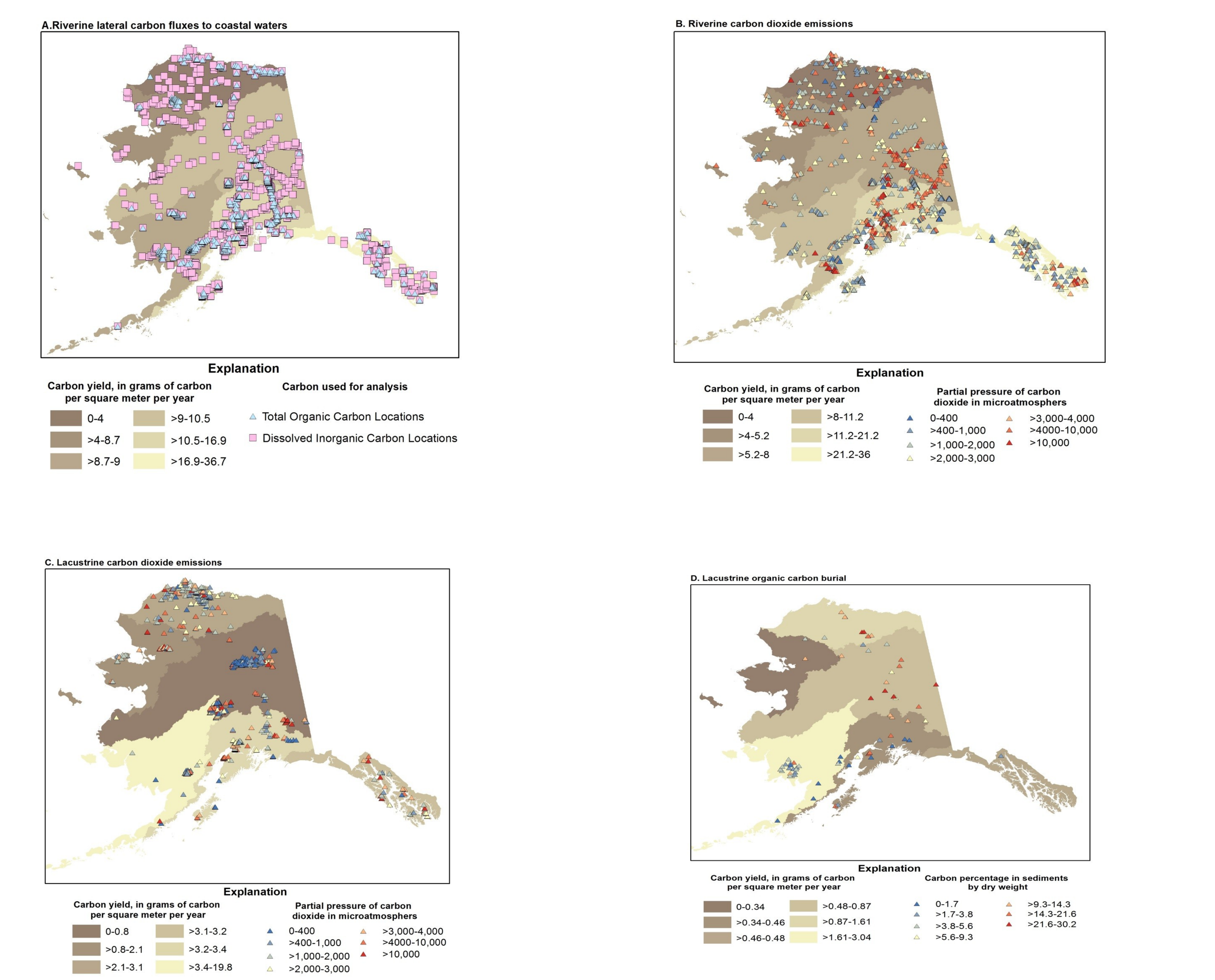

Fig. 9. Estimates of coastal C transport by rivers (upper left), carbon dioxide emission from rivers (upper right), carbon dioxide emissions from lakes (lower left), and C burial in lakes (lower right) for six hydrologic reporting region in Alaska..

The C fluxes estimated for inland aquatic ecosystems for the historical period include lateral C transport by rivers to the coast, vertical CO_2 emissions from rivers and lakes, and C burial in lake sediments (Fig. 9). The sum of these fluxes indicates that approximately 41 +/- 20 Tg C is being lost annually from inland aquatic ecosystems of Alaska (18 Tg C to the coast, 17 Tg C emissions from rivers, 8 Tg C emission from lakes, offset by 2 Tg C burial in lakes).

Highlights and Summary

Contemporary C Dynamics for Alaska:

- The annual change in C storage for uplands and wetlands of Alaska is estimated to be -7.11 Tg C (-2.95 Tg C in vegetation and -4.16 Tg C in soils) because of substantial fire activity.
- Net annual methane emissions for uplands and lowlands are estimated to be ~2 Tg CH_4.
- The C fluxes estimated for inland aquatic ecosystems for the historical period of this assessment include C transport to rivers, CO_2 emissions from rivers and lakes, and C burial in lakes. The sum of these fluxes indicates that approximately 41 +/- 20 Tg C is being lost annually from inland aquatic ecosystems of Alaska.

Projections of Future C Dynamics for Alaska:

- Estimated annual changes in C storage for uplands and wetlands between 2010 and 2099 ranged from 20.3 Tg C for the scenario with the least warming (CCCMA-B1) to 20.7 Tg C for the warmest scenario (ECHAM-A2).
- By the last decade of the 21st Century, methane emissions for Alaska are projected to range from 2.0 Tg CH_4 for the CCMA-A1B climate to 5.1 Tg CH_4 for the ECHAM-A1B climate.

Issues not considered:

- Carbon analyses do not include CH_4 emissions from lakes, insect disturbance, thermokarst disturbance, and thermal erosion processes.

Acknowledgements:

This assessment was funded by the Land Carbon Program of the U.S. Geological Survey.