Conceptualization and Application of the Alaska Thermokarst Model

Poster Session: A.03

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I. Introduction:

Thermokarst topography forms whenever ice-rich permafrost thaws and the ground subsides due to the volume loss when ground ice transitions to water. The Alaska Thermokarst Model (ATM) is a large-scale, state-and-transition model designed to simulate transitions between landscape units affected by thermokarst disturbance. The ATM uses a frame-based methodology to track transitions and proportion of cohorts within a 1-km2 grid cell. In the arctic tundra environment, the ATM tracks thermokarst-related transitions among wetland tundra, graminoid tundra, shrub tundra, and thermokarst lakes. In the boreal forest environment, the ATM tracks transitions among forested permafrost plateau, thermokarst lakes, collapse scar fens and bogs. The spatial distribution of cohorts [landcover] is required to initialize and run the ATM. The initial landcover distribution is based upon analysis of compiled remote sensing data sets (SPOT-5, Inferometric Synthetic Aperture Radar, and LandSat8 OLI) at 30-m resolution. Remote sensing analysis and field measurements from previous and ongoing studies are used to determine the ice-content of the soil, the drainage efficiency (or the ability of the landscape to store or transport water), the cumulative probability of thermokarst initiation, distance from rivers, lake dynamics (increasing, decreasing, or stable), and other factors which help determine landscape transition rates. Tundra types are allowed to transition from one type to another (for example, wetland tundra to graminoid tundra) under favorable climatic conditions.

II. Model Description:

The ATM is a state-and-transition model designed to simulate transitions among landscapes caused by thermokarst disturbance. The ATM uses a frame-based methodology to track transitions among landscape units, or cohorts. Although the ATM does not track cohorts in a spatially explicit fashion, initial information on the proportion of each cohort in every model element is required. The probability of initiation and the rate of transition is based upon logical rule sets. The logical rule sets consider factors such as climate, topography, fire, land use, hydrology, soil texture and soil ice content.

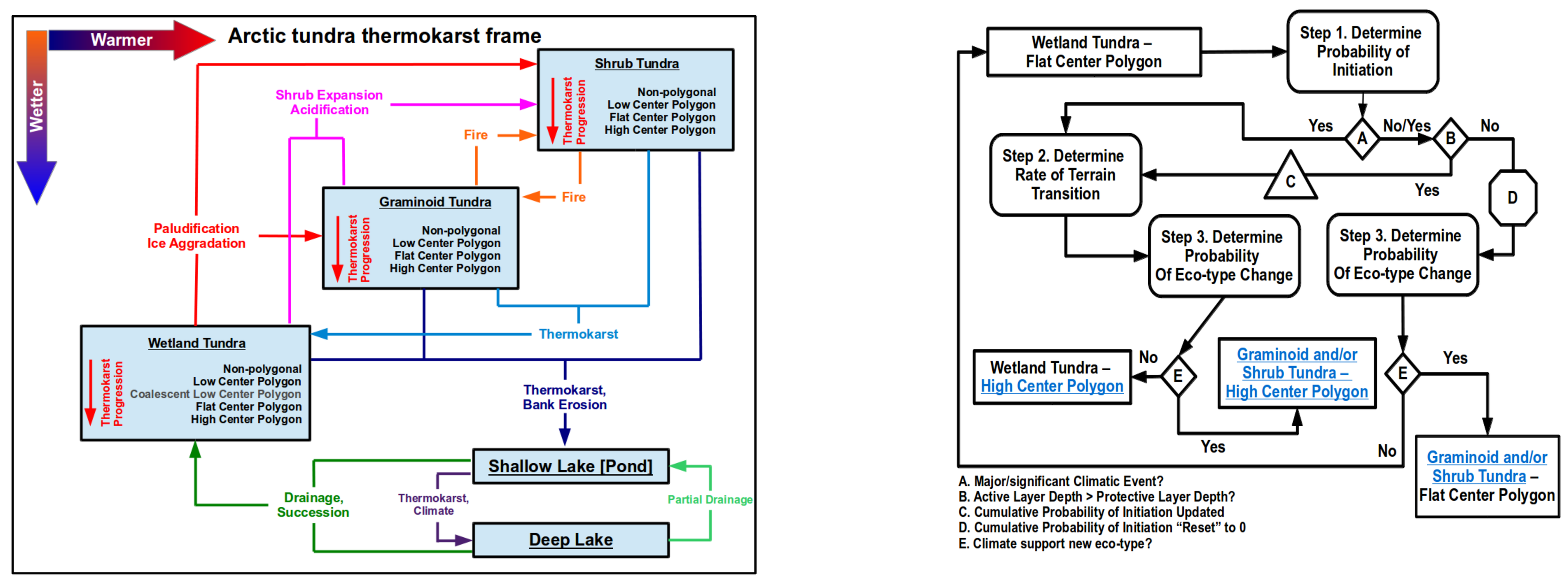
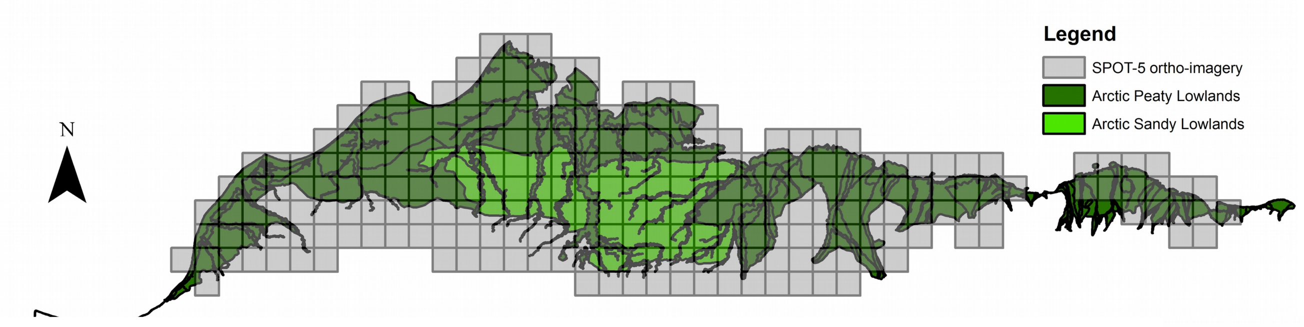


Figure 1. Description of the arctic tundra frames, trajectories, and example frame. The arctic tundra component of the ATM considers landscape transitions between the following eco-types: wetland tundra, graminoid tundra, shrub tundra, and lakes. Within each terrestrial eco-type, the landscape position defines the state of thermokarst degradation. The boreal forest component (not shown) of the ATM describes transitions between a permafrost plateau, fens, bogs, and lakes. Frames are being developed for both the arctic tundra and boreal forest modules. Frames contain the logic needed to determine the fate of each cohort present in each model element.

III. Initialization & Data Requirements:



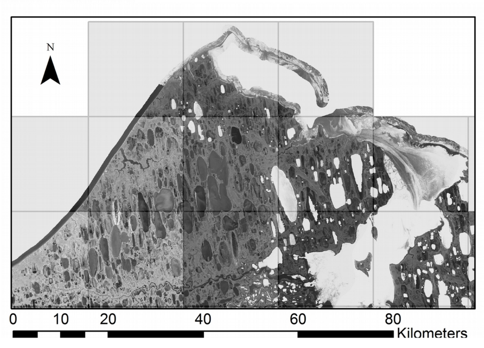
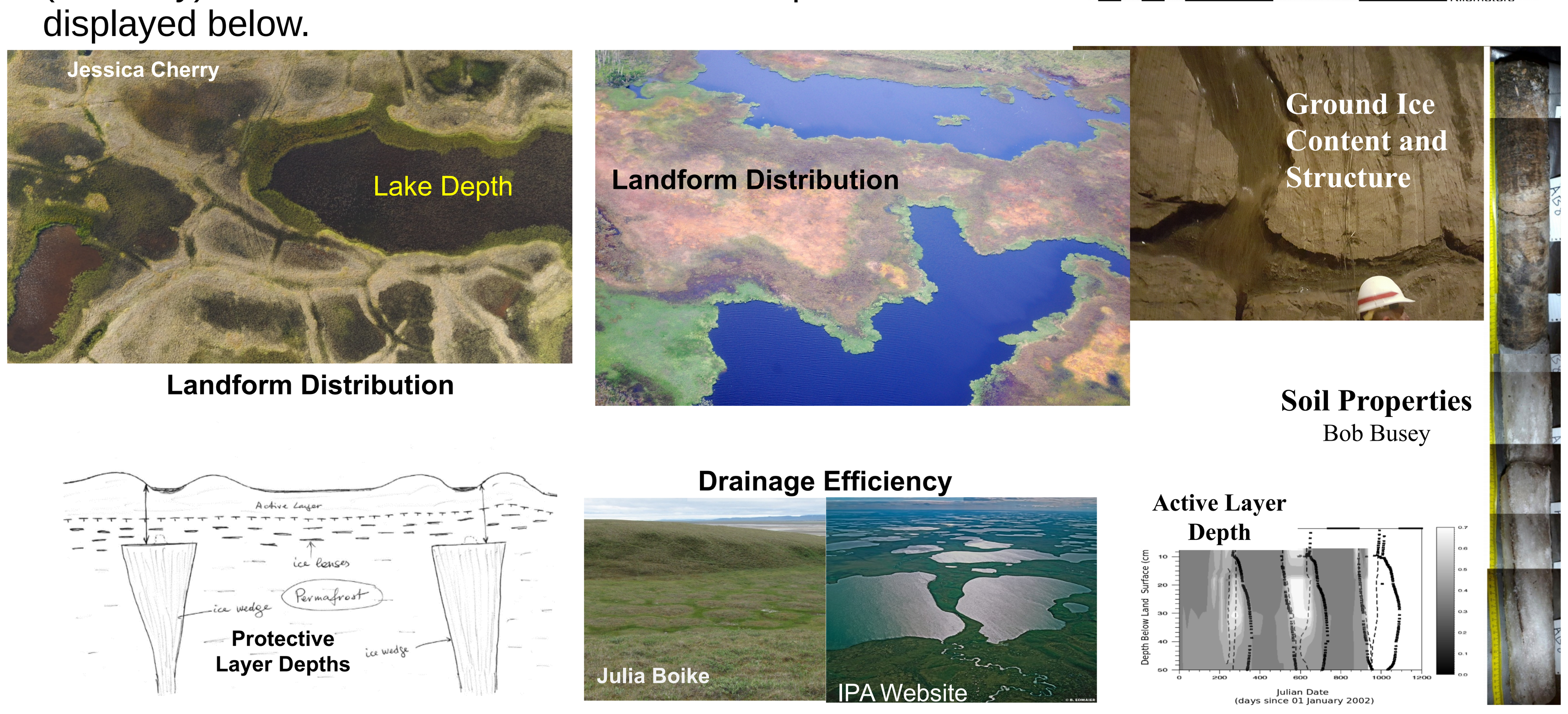


Figure 2. The initial landcover distribution is based upon analysis of compiled remote sensing data sets including SPOT-5, Inferometric Synthetic Aperture Radar, and LandSat8 OLI at 30-m resolution. The examples shown above and to the right are of the Alaska Arctic Coastal Plain and the Barrow Peninsula, Alaska. See Lara poster (Tuesday) for more information. Other data requirements are displayed below.



IV. Initial Results:

The Barrow Peninsula is the test region for development and evaluation of thermokarst dynamics of the arctic component of the ATM. The Barrow Peninsula is located in a polygonal tundra landscape under varying degrees of thermokarst degradation. For the boreal component of the ATM, the Yukon and Tanana Flats are the test regions selected for development and evaluation of the landscape evolution in the boreal forest.

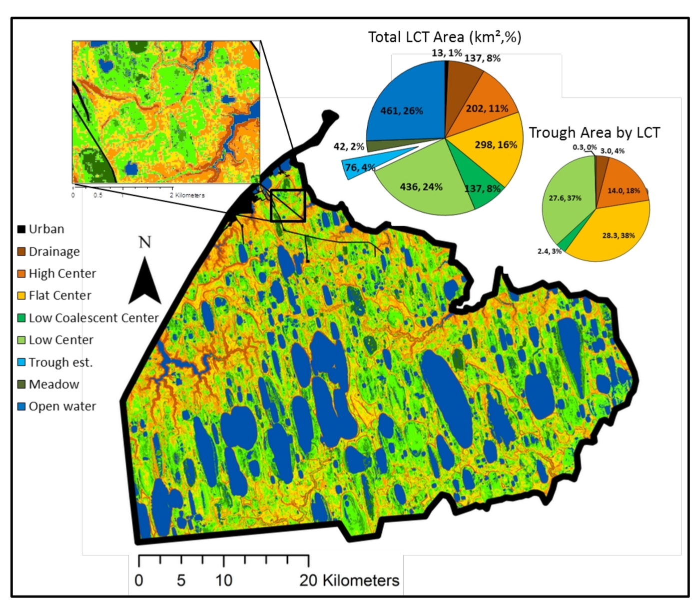


Figure 3. (Left) Initial cohort distribution for the Barrow Peninsula at 30m resolution derived from remote sensing products. Image courtesy of M. Lara (2015).

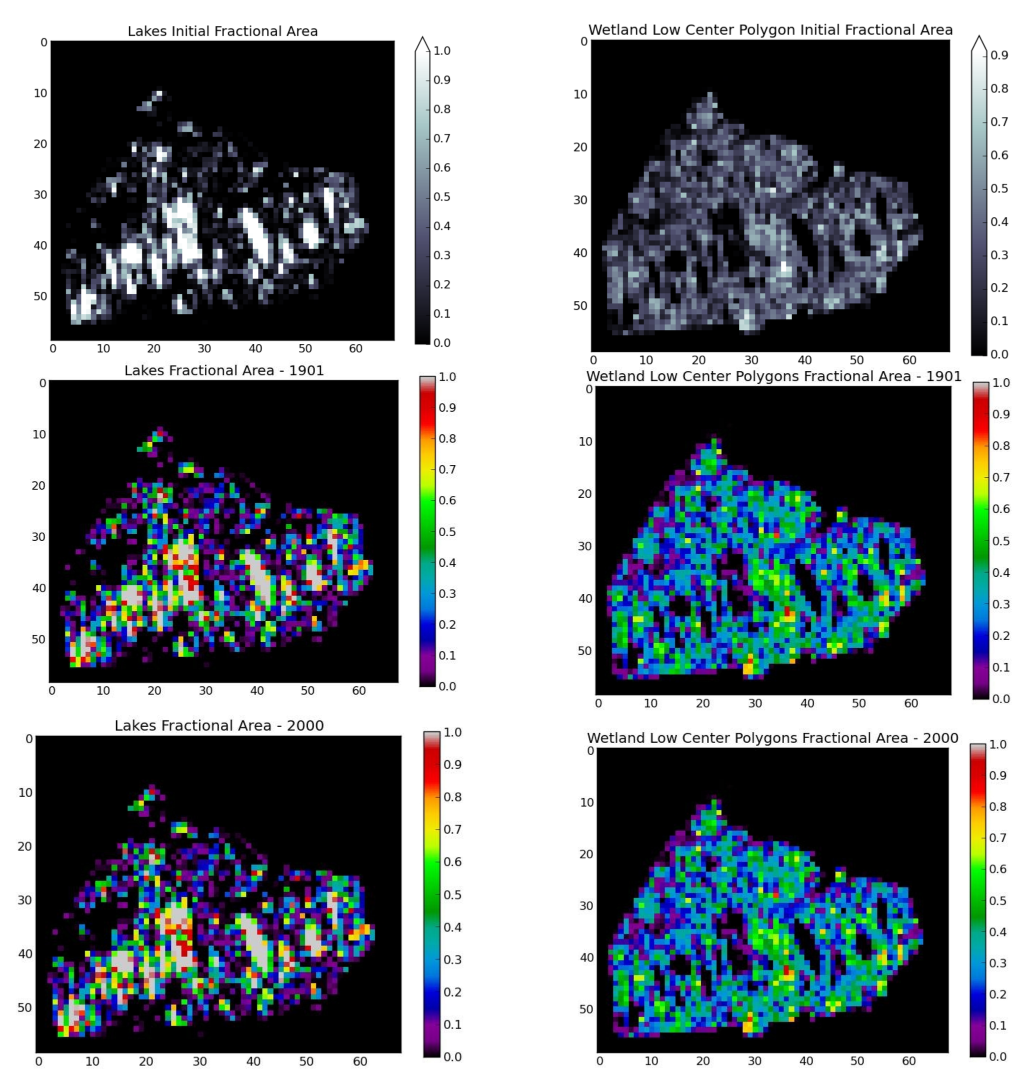


Figure 4. Results from the model development process. Presented here are the fractional area for the Lake and Low Center Polygon cohorts at initialization, 1901, and 2000.

V. Future Work:

- Function development/parameterization to describe probability of initiation and transition rates from field observation and fine-scale numerical experiments for the Alaskan Arctic Coastal Plain, the Yukon and Tanana Flats
- Develop functional responses of landscape transitions to be integrated into climate-scale modeling efforts.
- Robust sensitivity analysis
- Conduct scenario simulations in order to predict future landscape evolution
- Planned development for the Seward Peninsula and Yukon-Kuskokwim River Delta

VI. ACKNOWLEDGEMENTS:

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AK CSC Alaska Climate Science Center
Arctic Landscape Conservation Cooperative
Western Alaska LCC
Northwest Boreal Landscape Conservation Cooperative