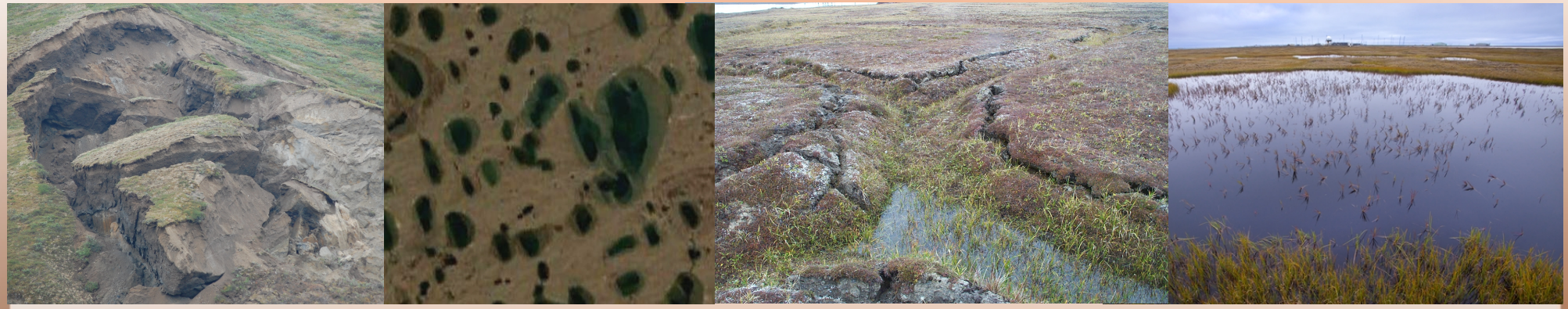


Arctic Tundra Landscape Evolution:

Conceptualization and Initial Application of the Alaska Thermokarst Model

Bob Bolton

International Arctic Research Center

26 October 2015

ATM Research Team

David McGuire,
ATM Lead

Vladimir Romanovsky
Arctic Tundra TK

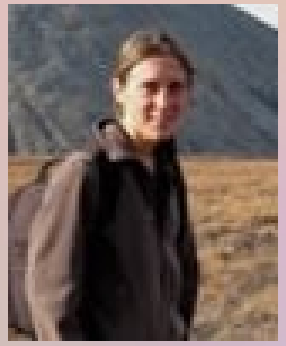
Guido Grosse
Arctic TK Lakes

Yugin Zhang
Boreal TK

Janjiao Mi
Boreal TK
Processes

Bob Bolton
ATM Development &
Application

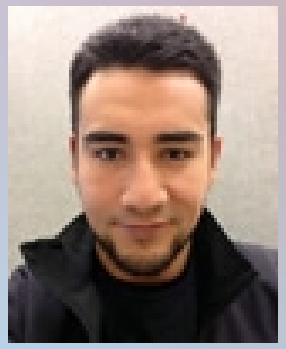
Amy Breen
Eco-type Transitions



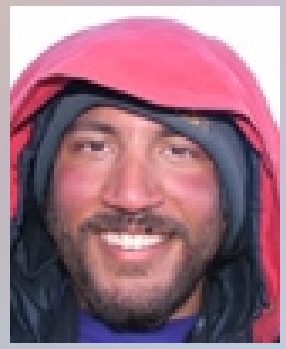
Helene Genet
Boreal TK

Jennifer Roach
Boreal TK Lake
Transitions

Mark Lara
Landscape Analysis



Louise Farquharson
Lake & TK Classification

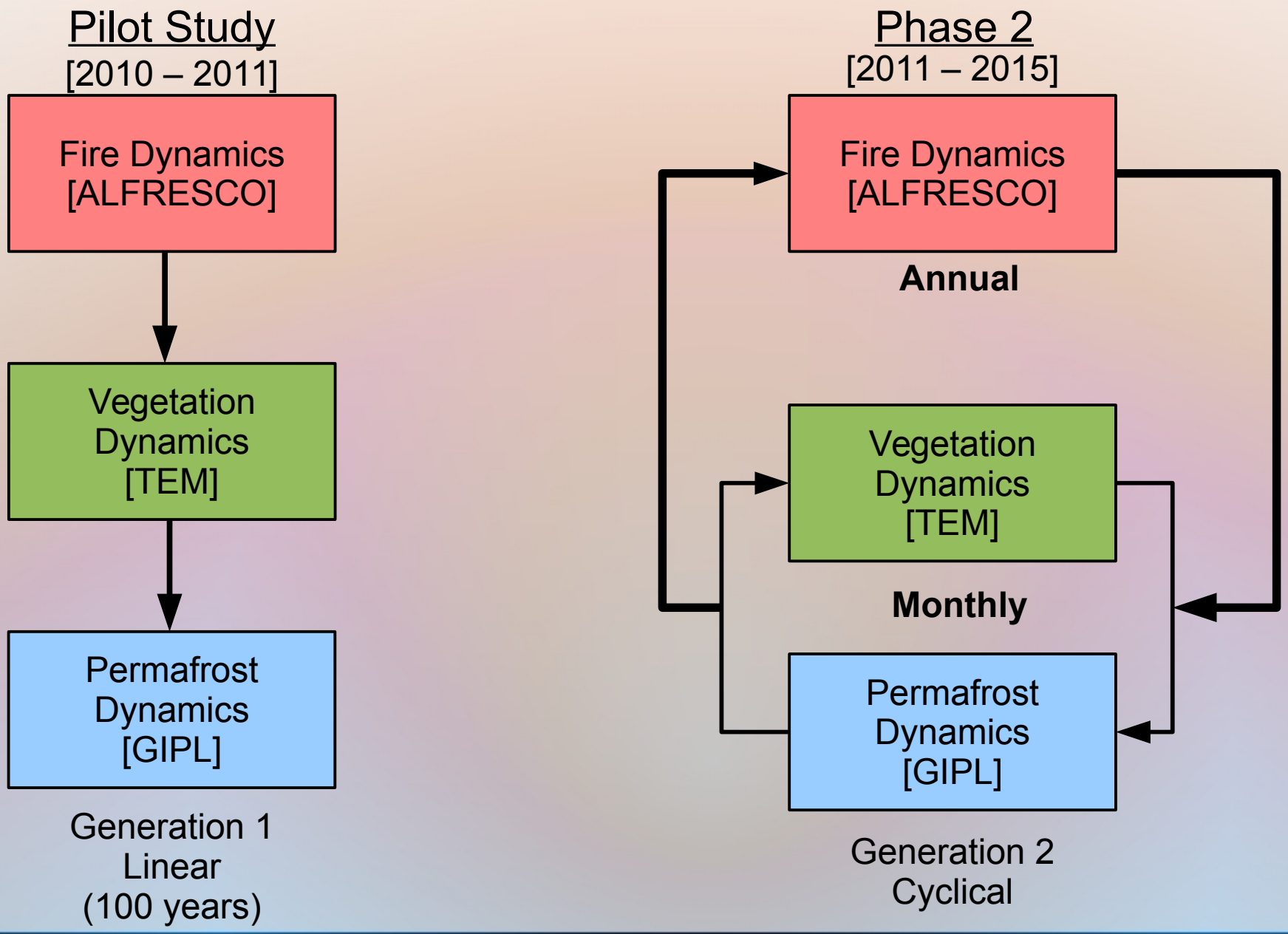


Vijay Patil
Boreal TK Lakes

Integrated Ecosystem Model (IEM) for Alaska and Northwest Alaska

- Goal of this project is to ***develop and apply an ecosystem model*** for Alaska and NW Canada that is ***capable for forecasting how landscape structure and function might change*** in response to how climate change influences interactions among disturbance regimes, permafrost integrity, hydrology and vegetation succession and migration.
- ***The IEM is a tool for forecasting ecosystem change and informing natural resource management [decisions].***

Components of the IEM



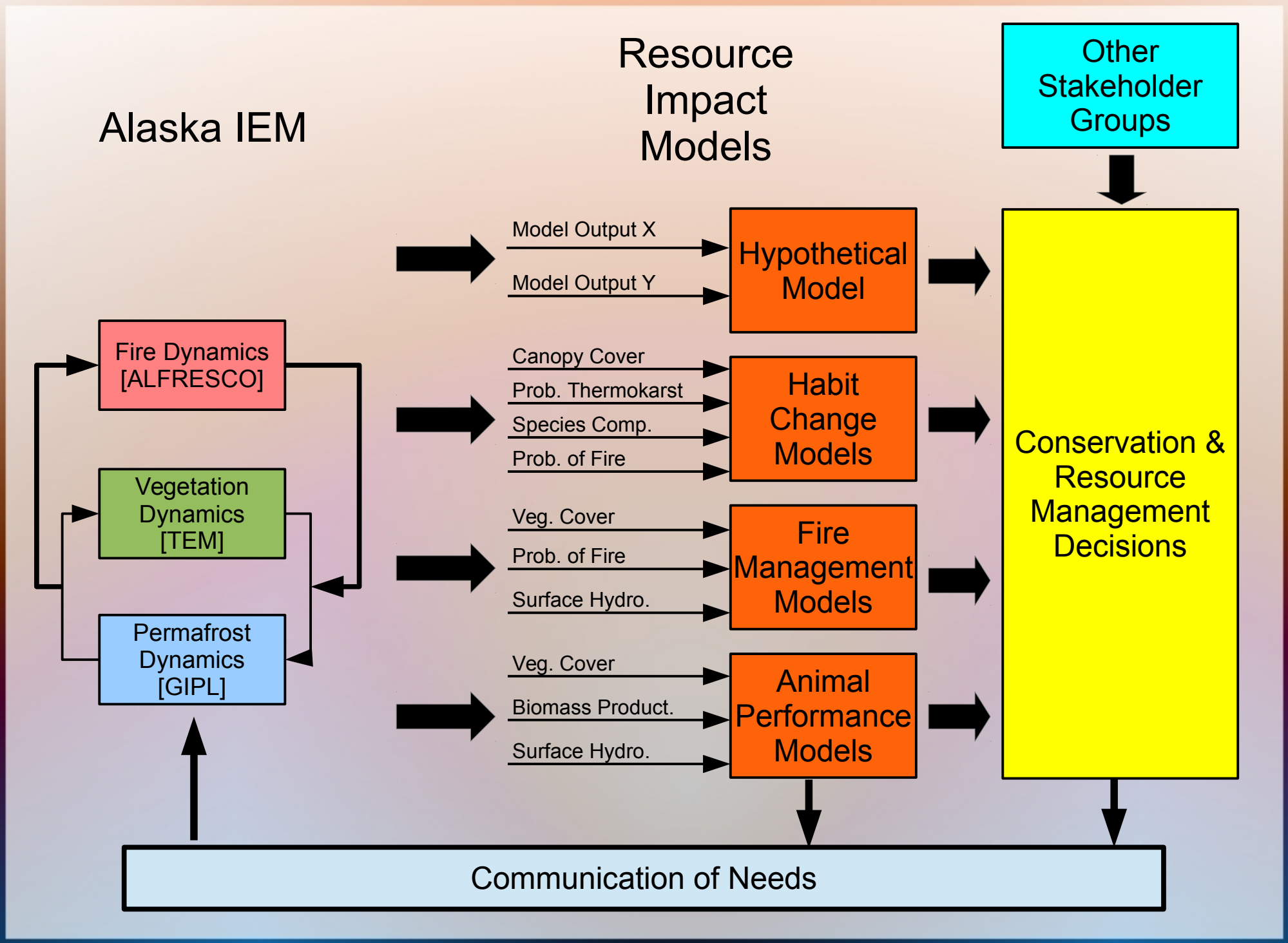
Components of the IEM

- Model Inputs
  - Air Temperature, RH
  - Precipitation
  - Initial Vegetation
  - Slope, Aspect, Elevation
  - Radiation/Cloudiness
  - Mineral Soil Texture

Generation 1
Linear
(100 years)

- Variables Passed Between Models
  - Vegetation Type/Carbon
  - Area Burned/Fire Severity
  - Vertical Soil Temp/SMC
  - Organic Layer Thickness

Generation 2
Cyclical


Alaska IEM
Resource Impact Models
Other Stakeholder Groups
Fire Dynamics [ALFRESCO]
Vegetation Dynamics [TEM]
Permafrost Dynamics [GIPL]
Model Output X
Model Output Y
Hypothetical Model
Canopy Cover
Prob. Thermokarst
Species Comp.
Prob. of Fire
Habit Change Models
Veg. Cover
Prob. of Fire
Surface Hydro.
Fire Management Models
Veg. Cover
Biomass Product.
Surface Hydro.
Animal Performance Models
Conservation & Resource Management Decisions
Communication of Needs

Alaska Dispatch News

Wildlife

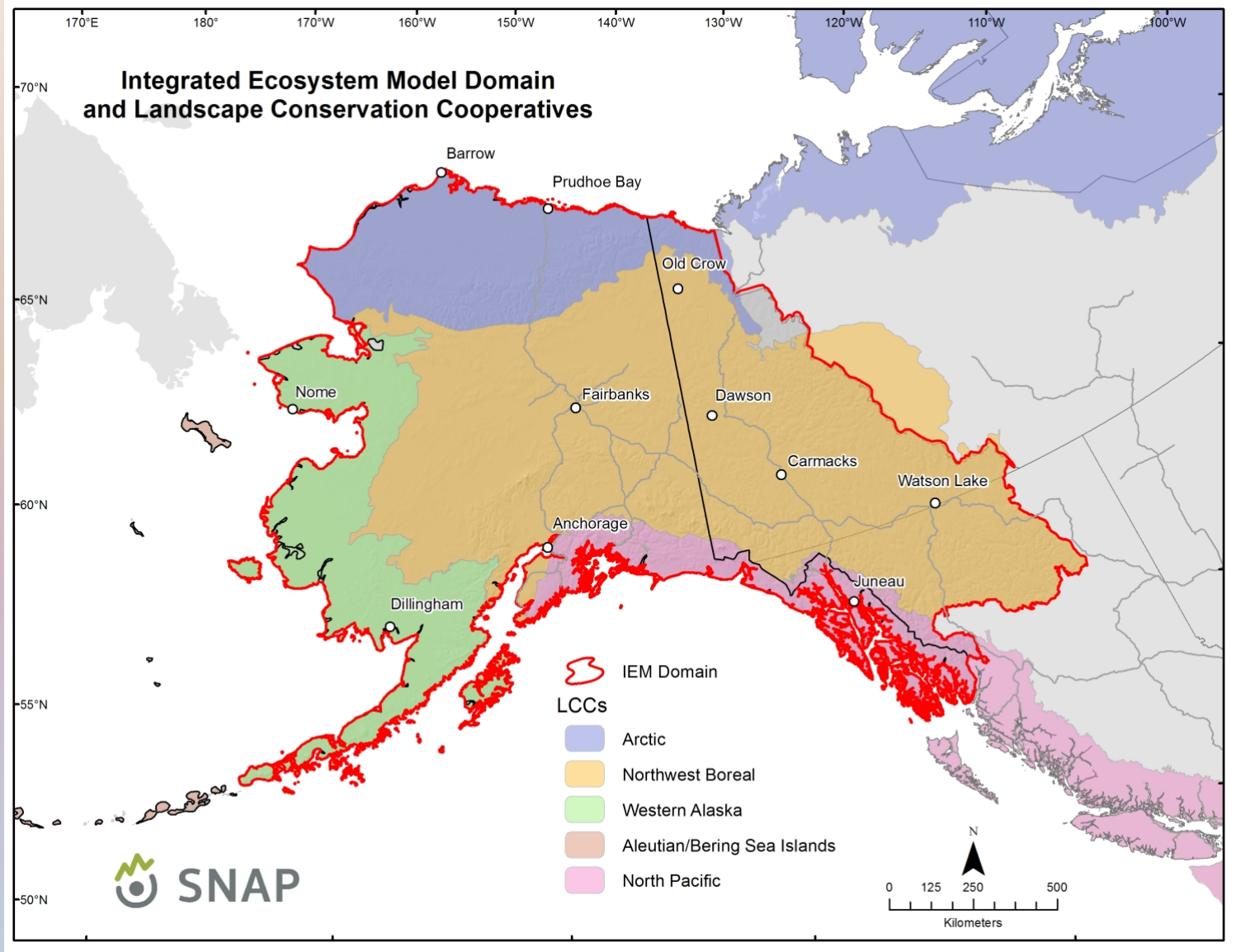
As spring comes sooner, geese arriving earlier to Colville River Delta nesting sites

Yereth Rosen | Alaska Dispatch News | October 23, 2015

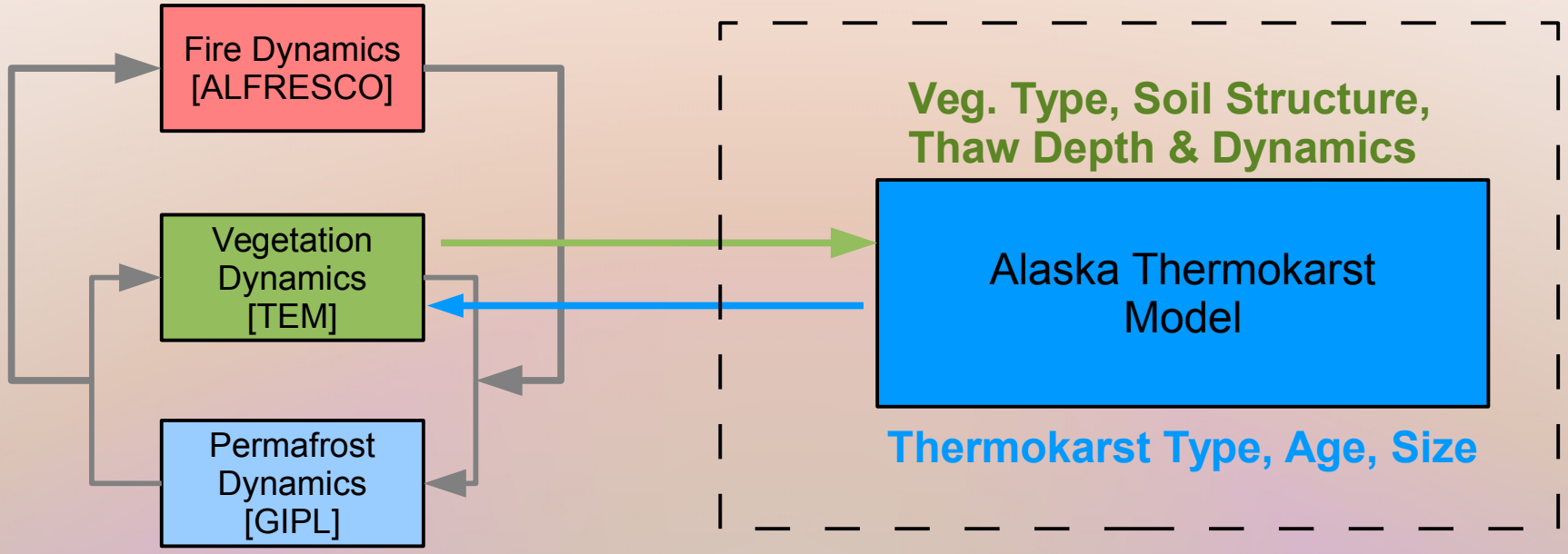
Black brant have increased dramatically in number on the North Slope, thanks to some changes brought about by the warming climate. Sags in thawing permafrost are changing hydrology and favoring the salt-tolerant plants that are most beneficial to brant, according to research by the scientists from the USGS and University of Alaska Fairbanks.

www.imgneed.com

Spatial Domain of the IEM



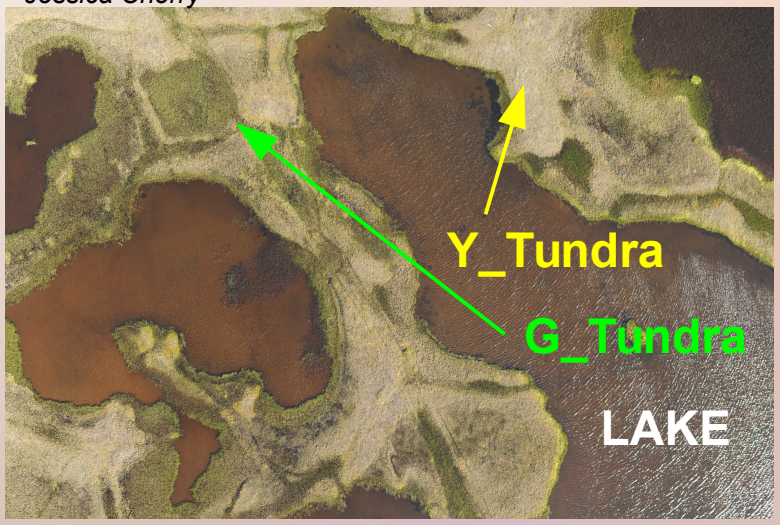
Alaska Thermokarst Model [ATM]

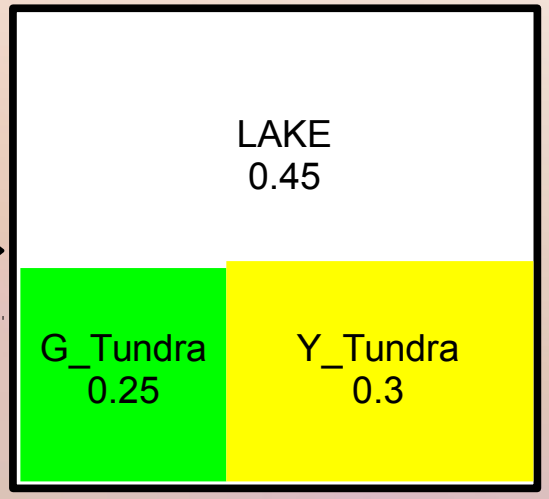


- State-and-transition model
- Frame-based methodology to track cohorts
  - Unique, representative landscape unit
- The ATM tracks cohorts by fractional area of model element (NOT spatially-explicit)
- 1 km^2 resolution, 1-year time step
- Simulation period ~100 years from current
- Landscape transitions include: arctic tundra, boreal forest, and lakes

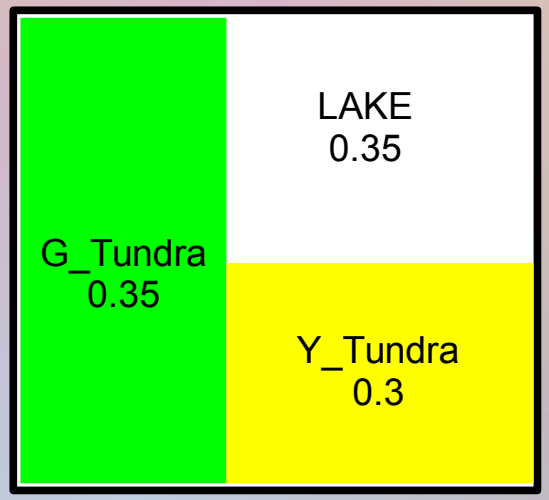
Alaska Thermokarst Model

Jessica Cherry



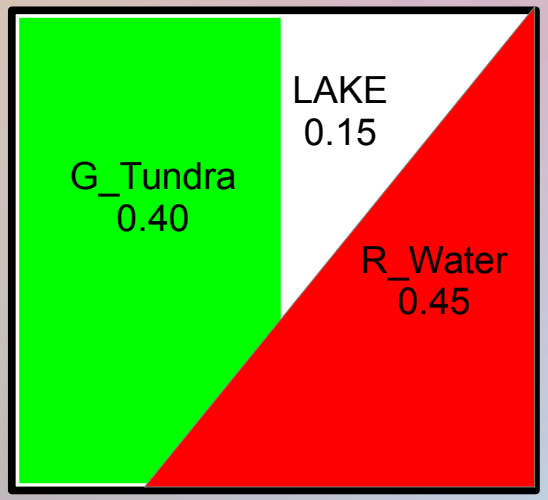


Time = t_0



Time = t+1

....



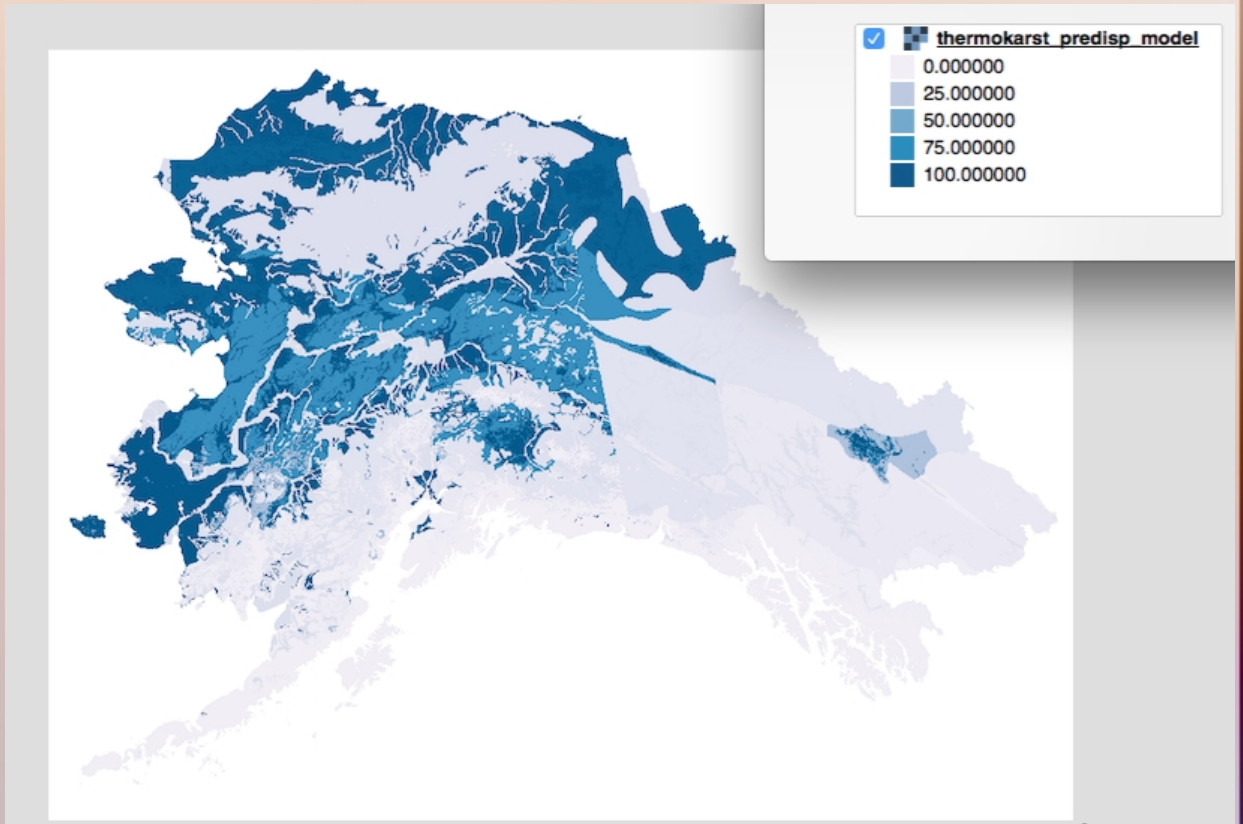
Time = t+1+n

Alaska Thermokarst Model

Initiation & Expansion Module

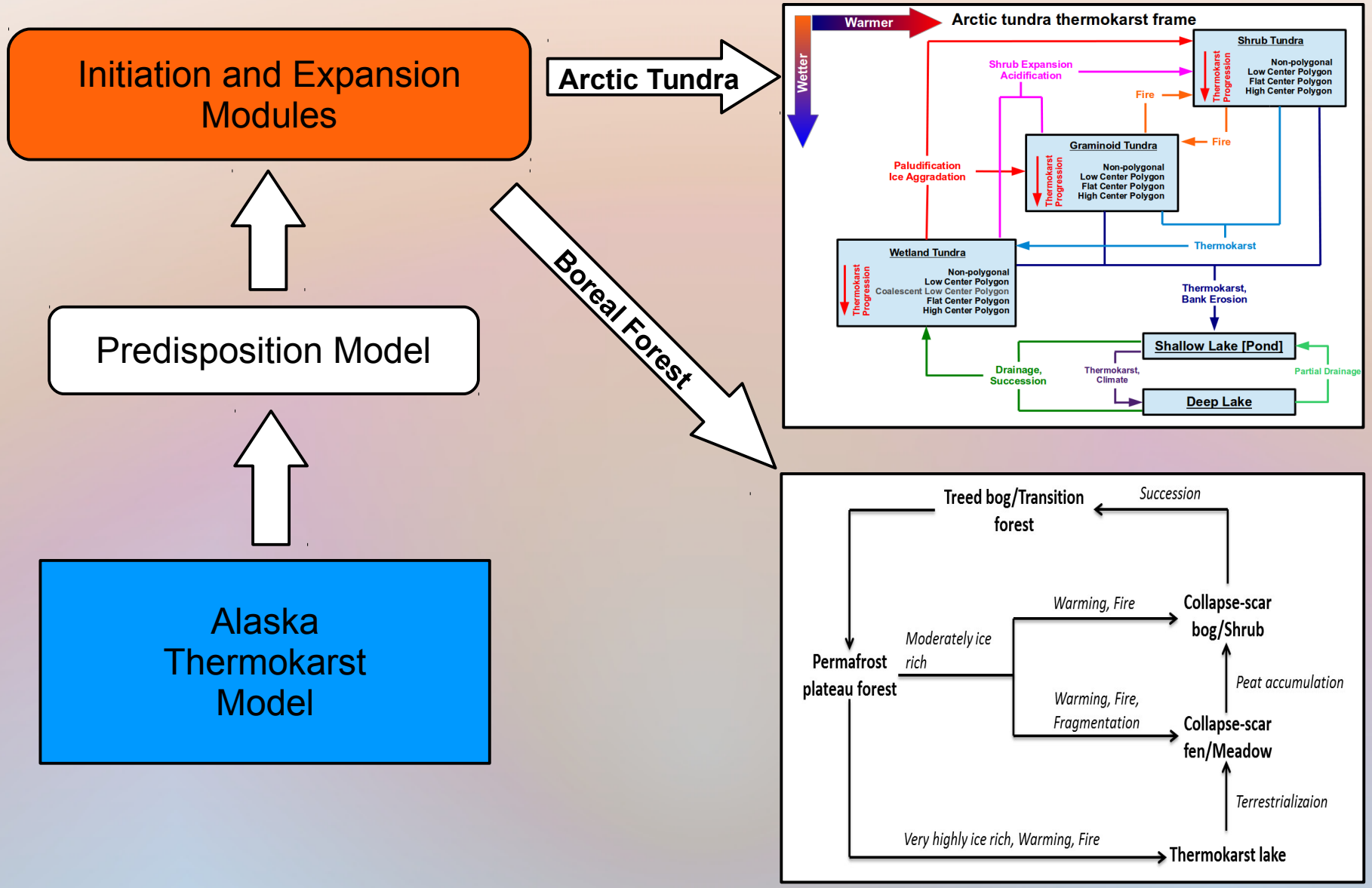
Predisposition Module

Alaska Thermokarst Model

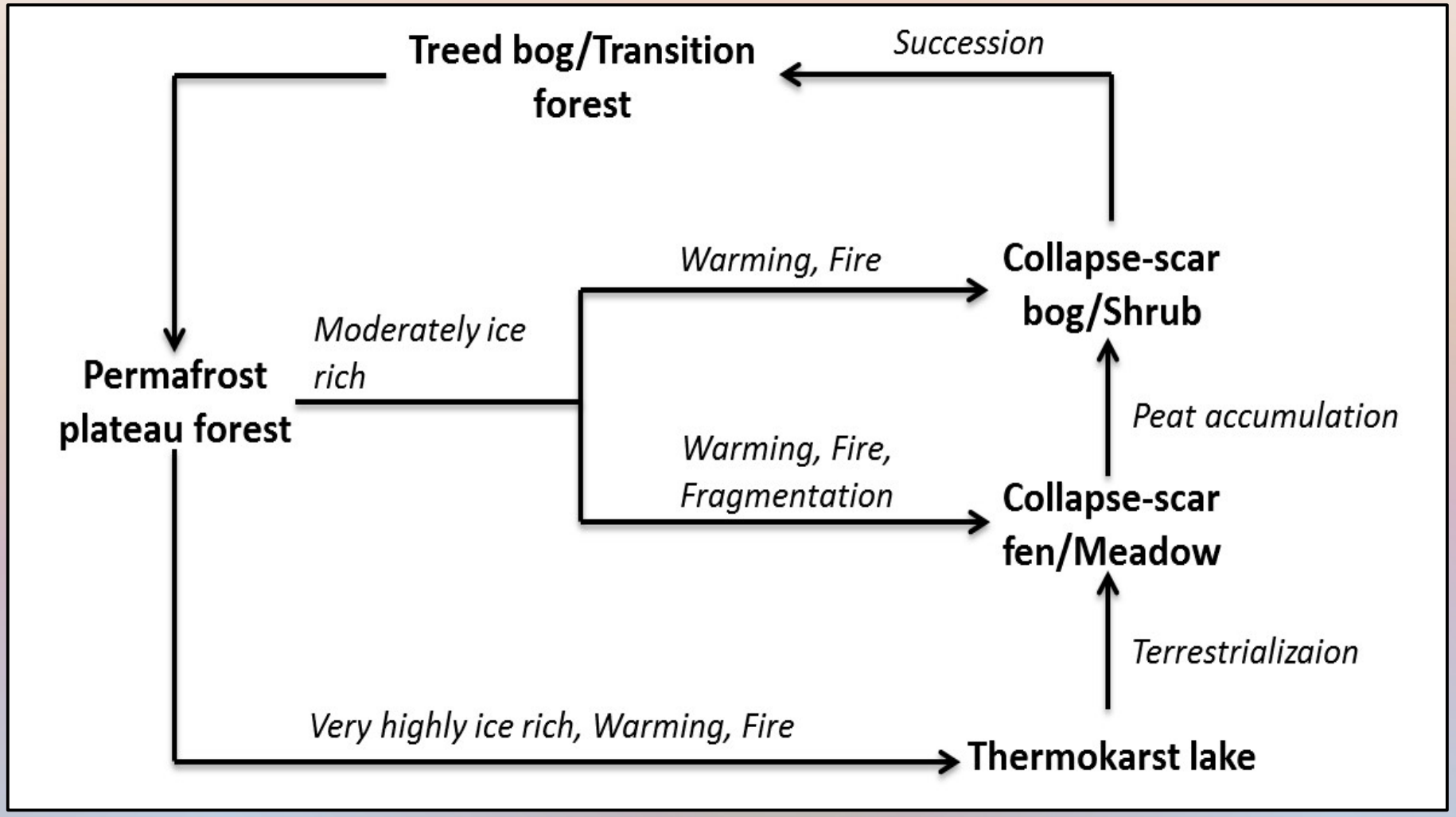


Helene Genet

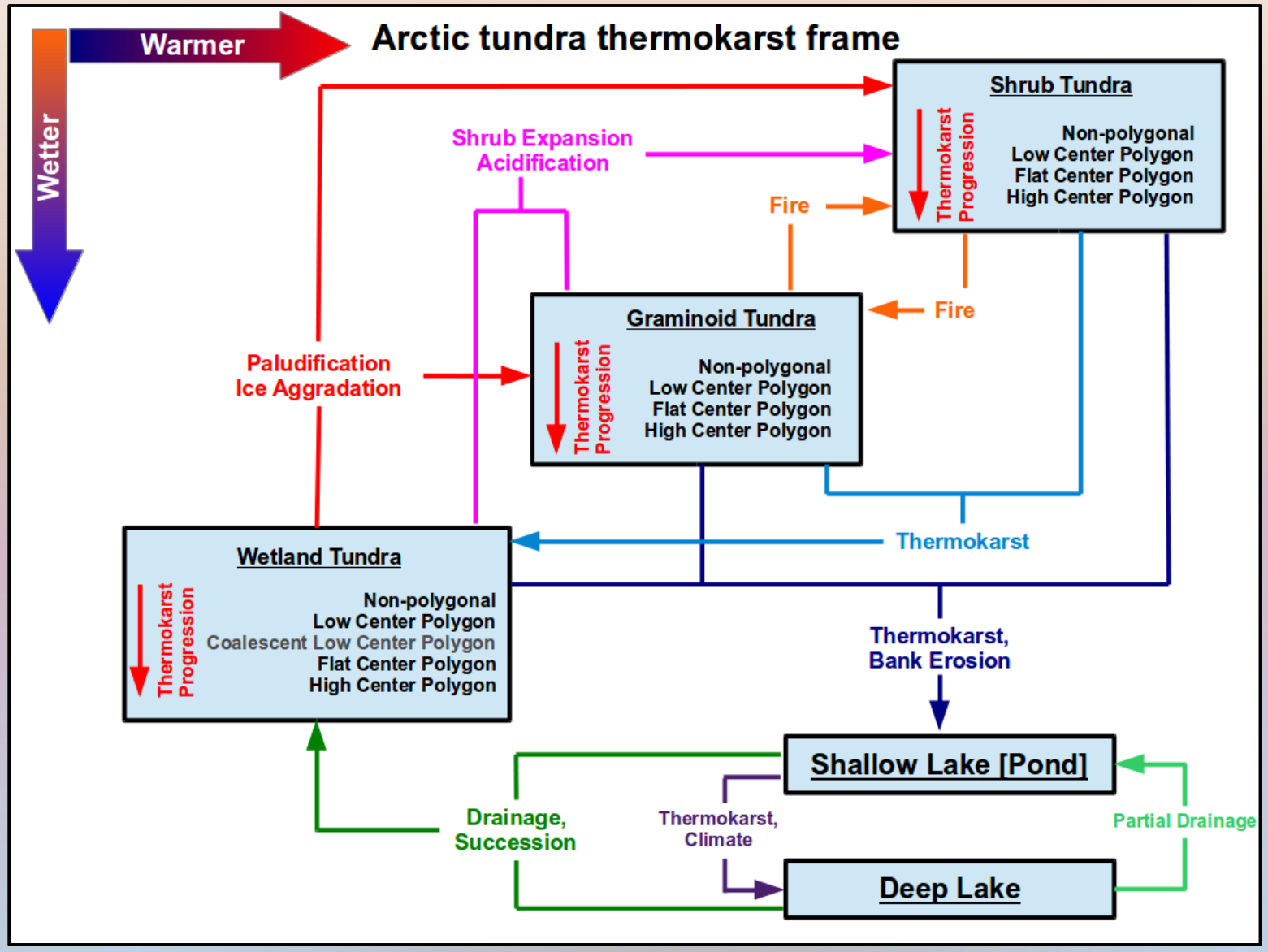
Alaska Thermokarst Model



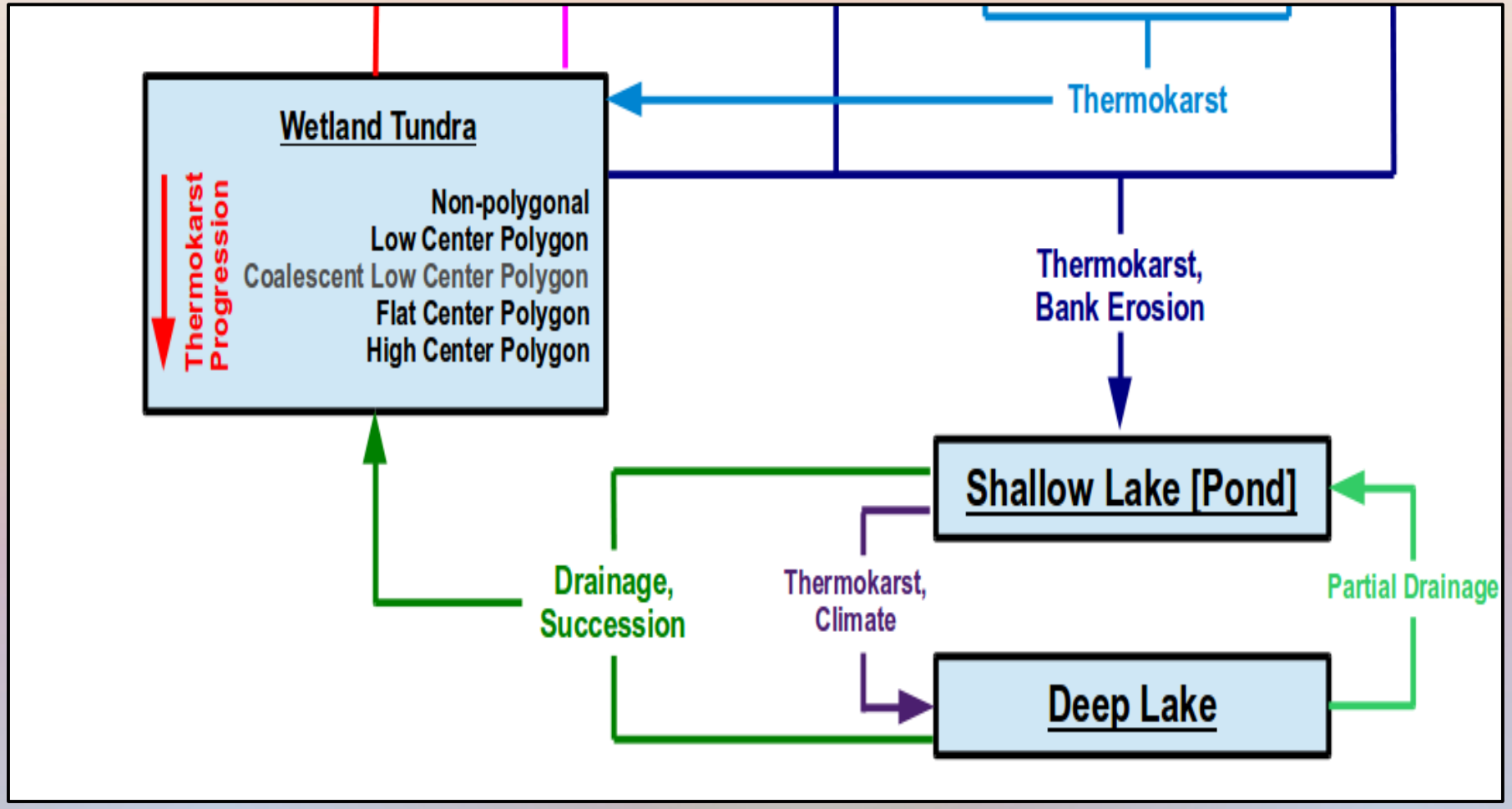
Alaska Thermokarst Model: Boreal Forest



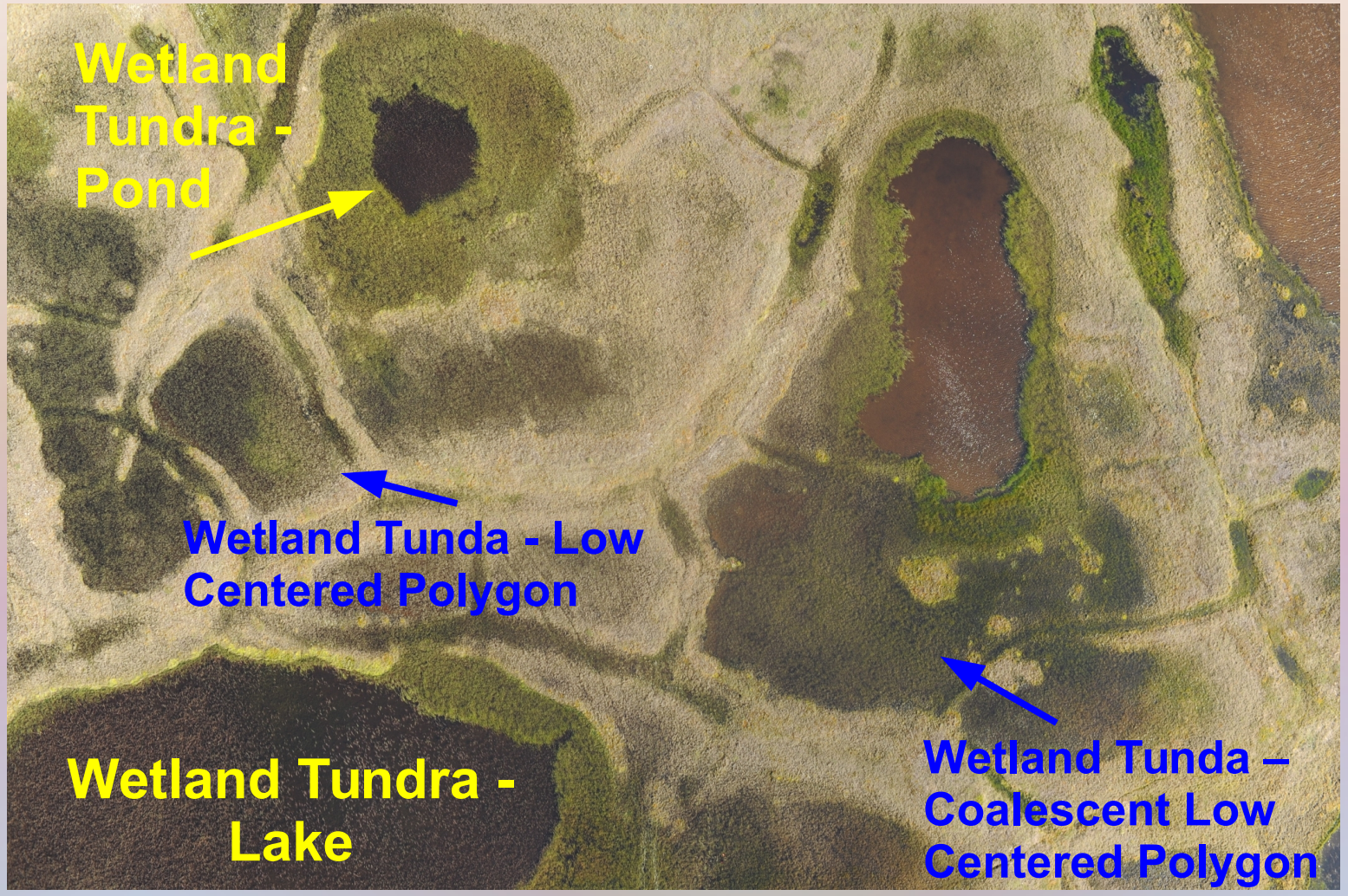
Alaska Thermokarst Model: Arctic Tundra



Arctic Tundra Thermokarst Model



Alaska Thermokarst Model - Cohorts

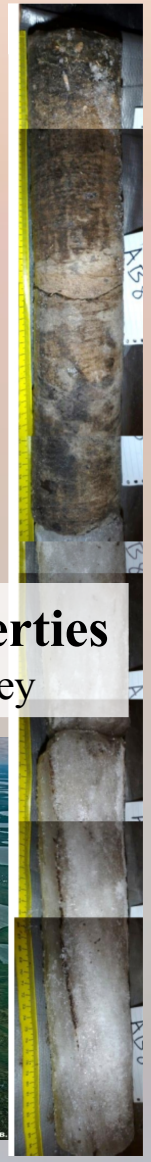


Jessica Cherry

Eco-Type + Landform

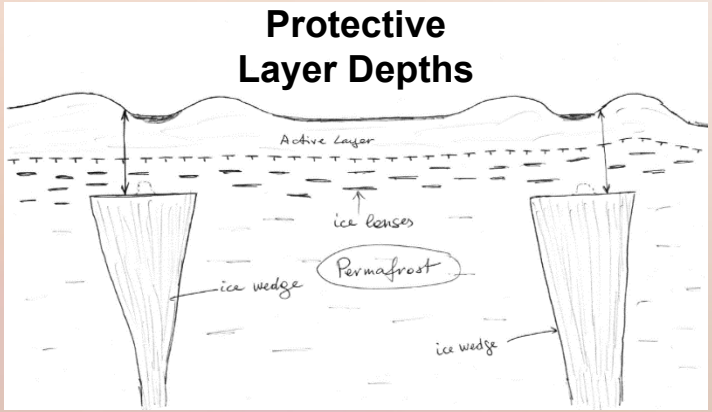
Alaska Thermokarst Model - Initialization

Landform Distribution

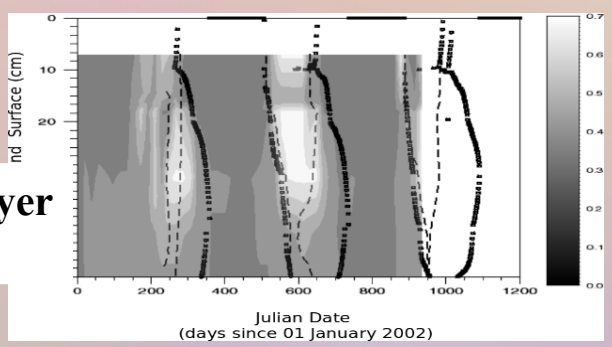


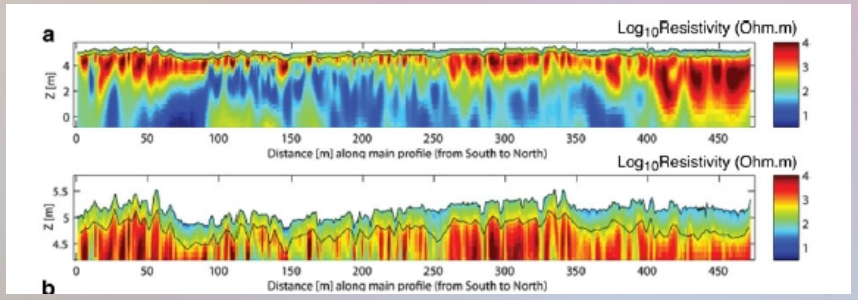
Soil Properties
Bob Busey

Drainage Efficiency



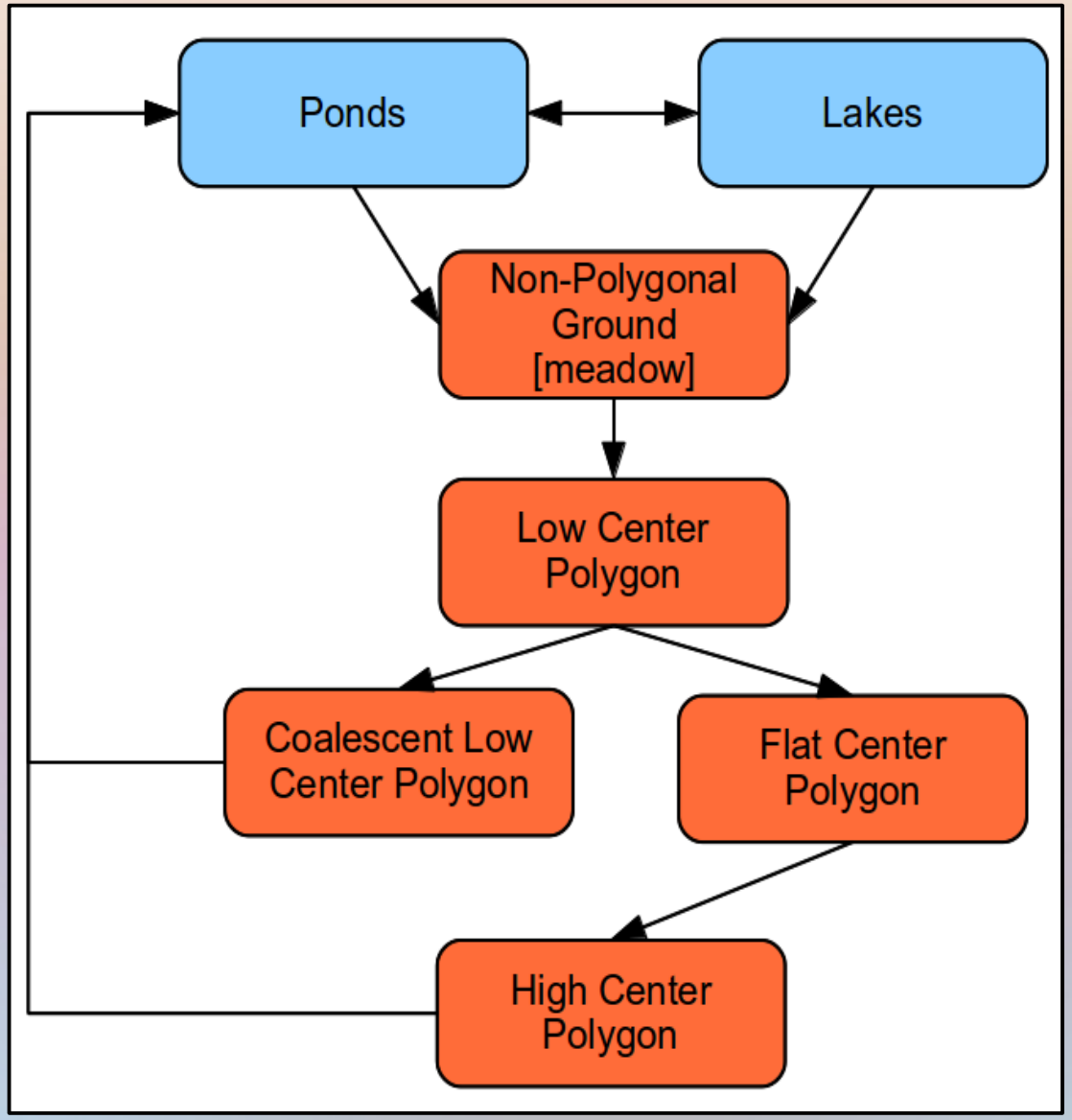
Active Layer Depth





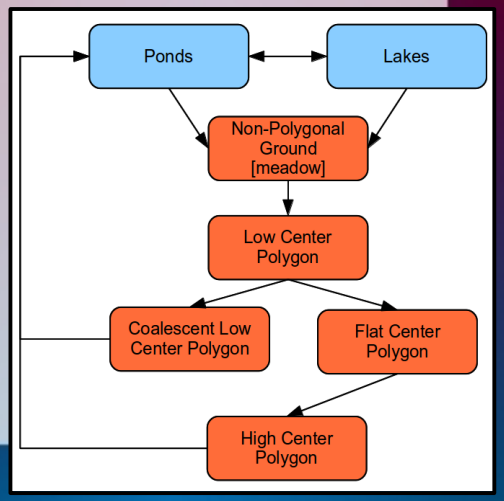
Ice Content and Structure
Hubbard et al [2013]

Alaska Thermokarst Model – Landscape Transitions

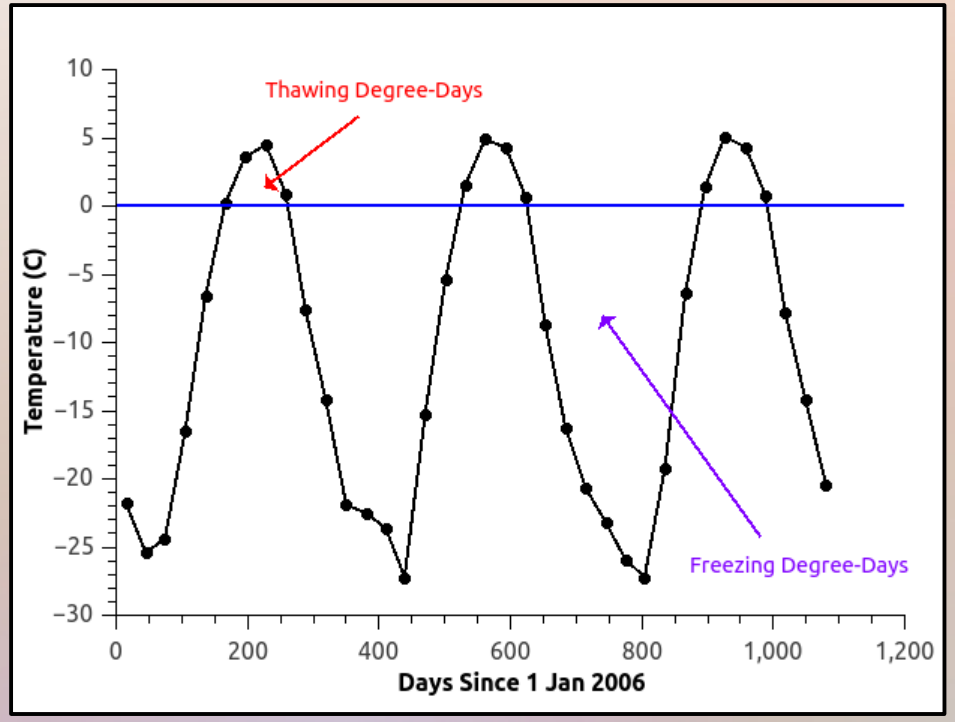


ATM - Arctic Tundra Assumptions

- Lakes and Ponds
  - Thick permafrost ≠ Vertical drainage
  - Lakes and Ponds expand at a prescribed rate (↓ and ↔)
  - Lakes ⇔ Ponds is determined by the Lake/Pond depth : Ice thickness ratio
  - Climatic events → Lateral drainage → Non-polygonal ground [meadows]
- Terrestrial Cohorts
  - 1-directional transitions
  - Transition occurs when the Active Layer Depth > Protective Layer Depth
  - Coalescent Low Center Polygons & High Center Polygons ⇒ Ponds

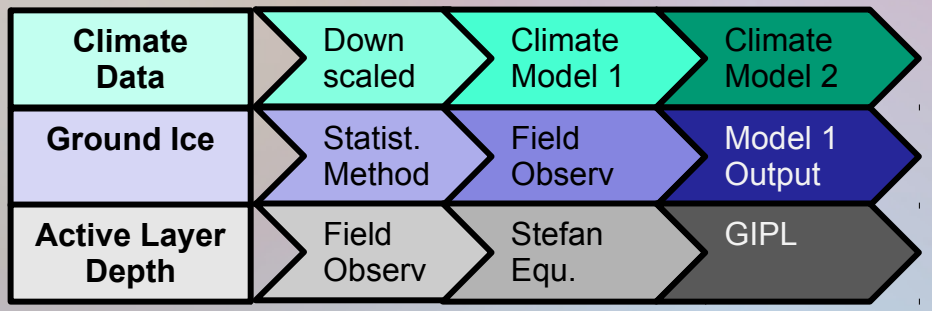


Alaska Thermokarst Model

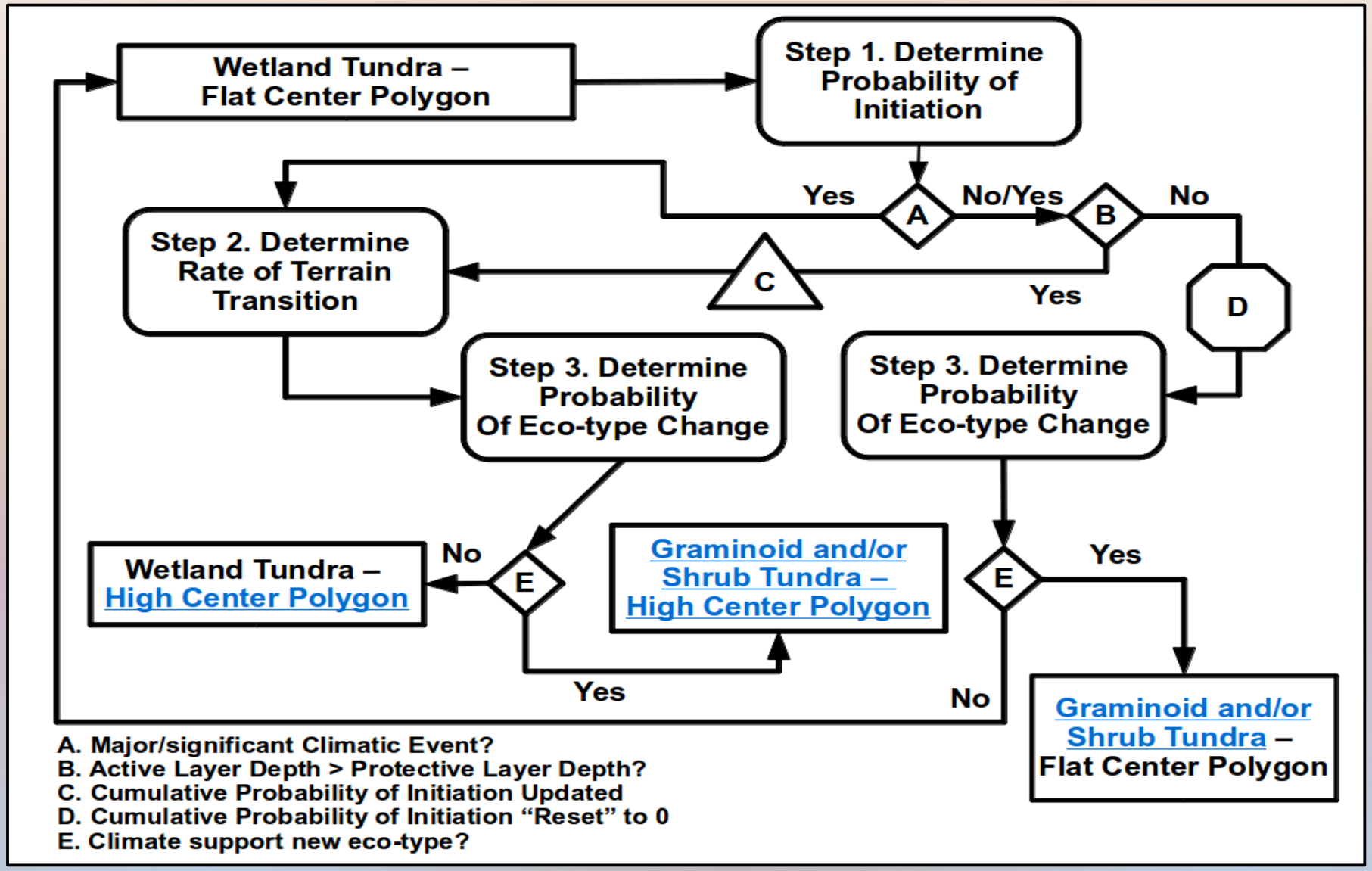


Temperature, converted into Thawing and Freezing Degree-Days, is the primary driver of the ATM. TDD and FDD drives many processes including ice thickness, and active layer depth.

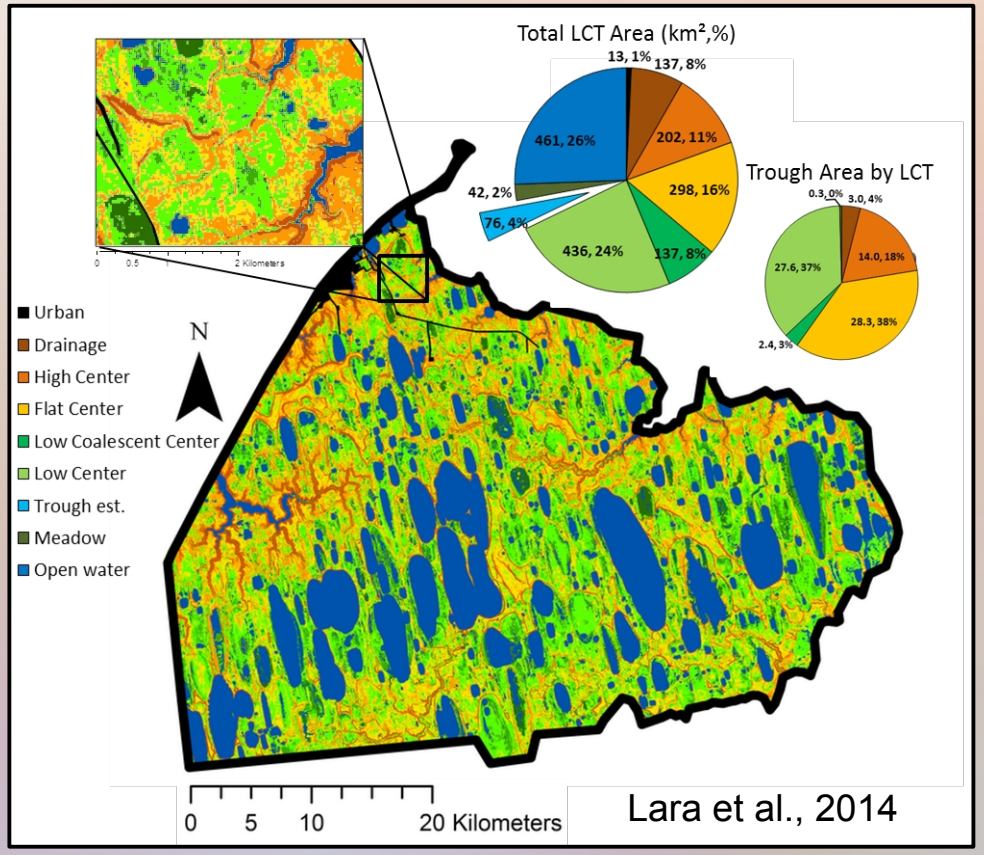
- Initialization
- Main Program Loop
  - Check Climatic Event
  - Pond & Lake Expansion
  - Terrestrial Cohort Frames
  - Pond & Lake Frames
  - Eco-type Transitions
- Output Results



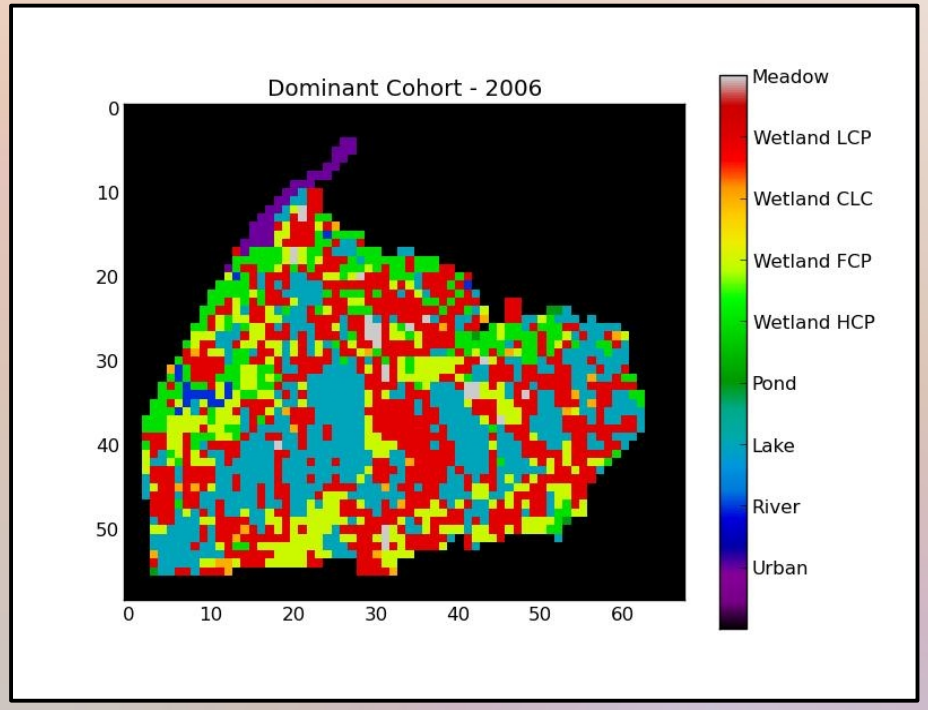
Cohort Frame Example



ATM Test Area: Barrow Peninsula

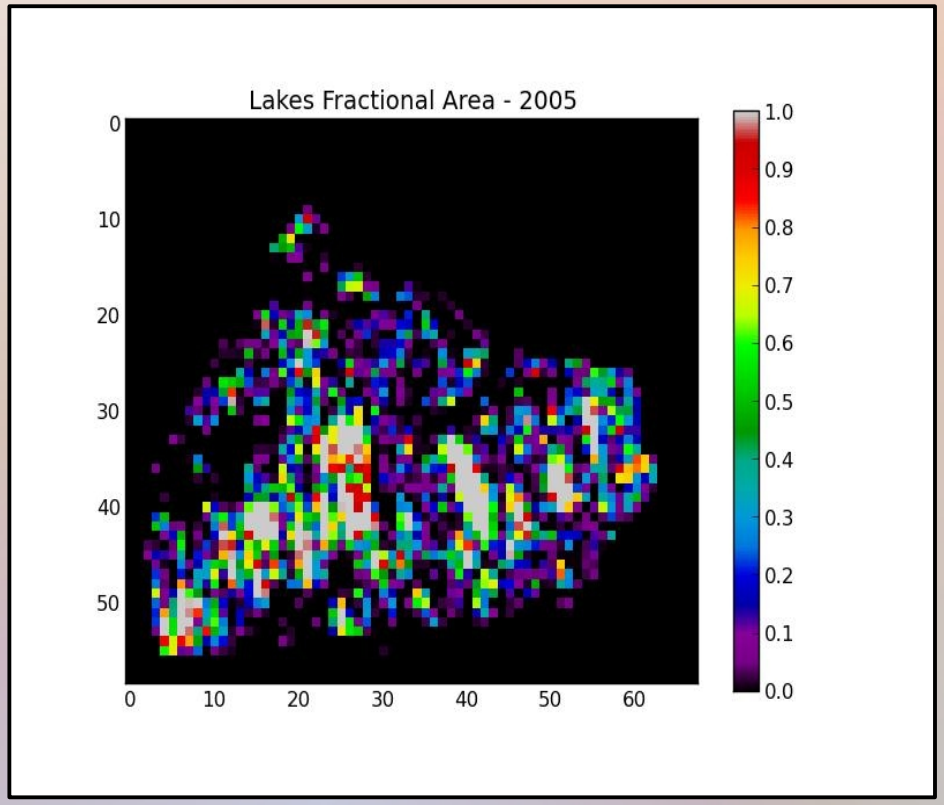


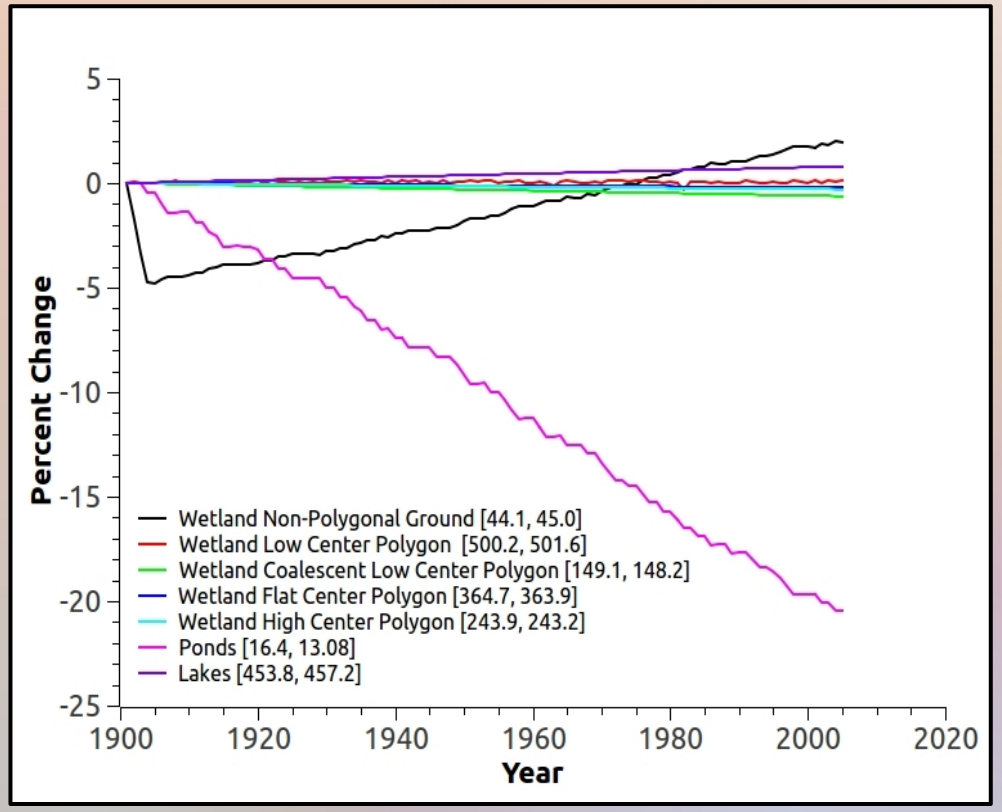
Lara et al., 2014



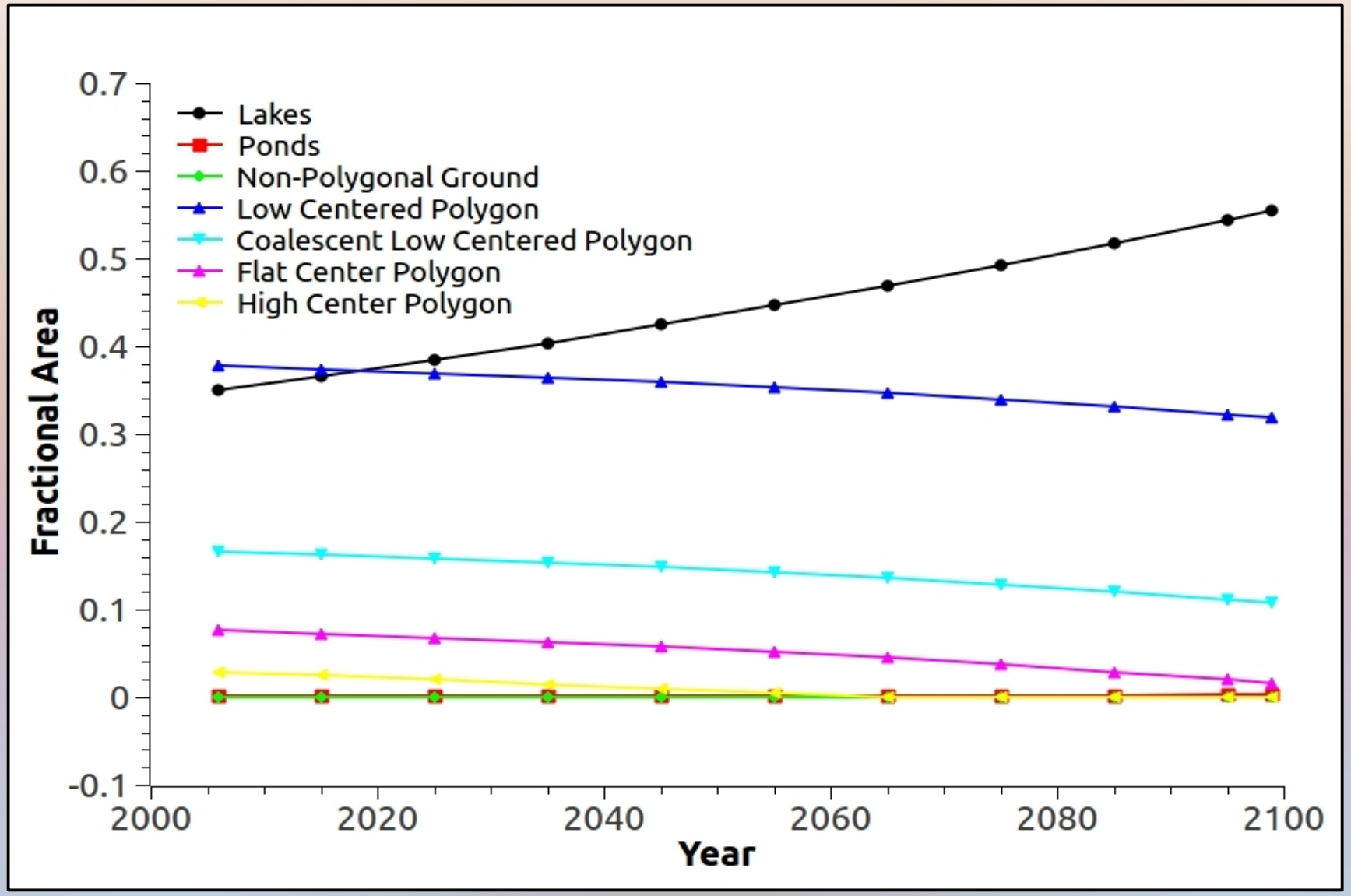
The Barrow Peninsula (1972 km^2) is being used to develop transition rates for all of the Wetland Tundra cohorts, Lakes and Ponds.

Alaska Thermokarst Model Output

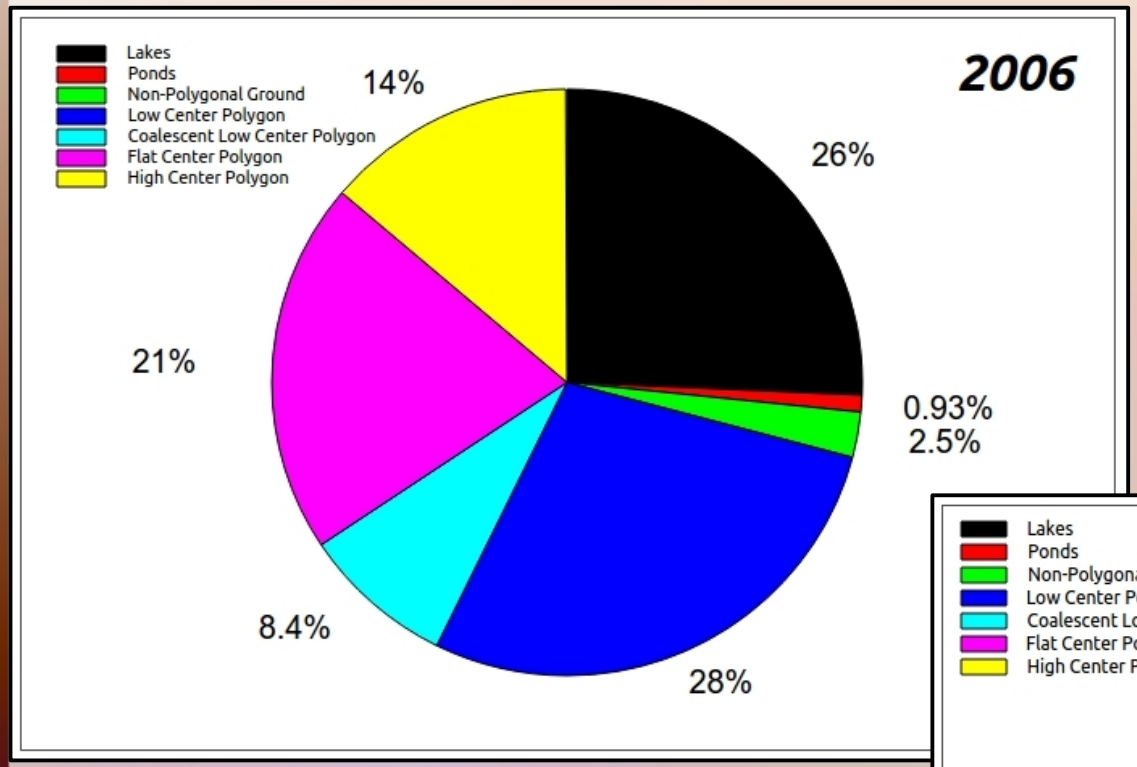


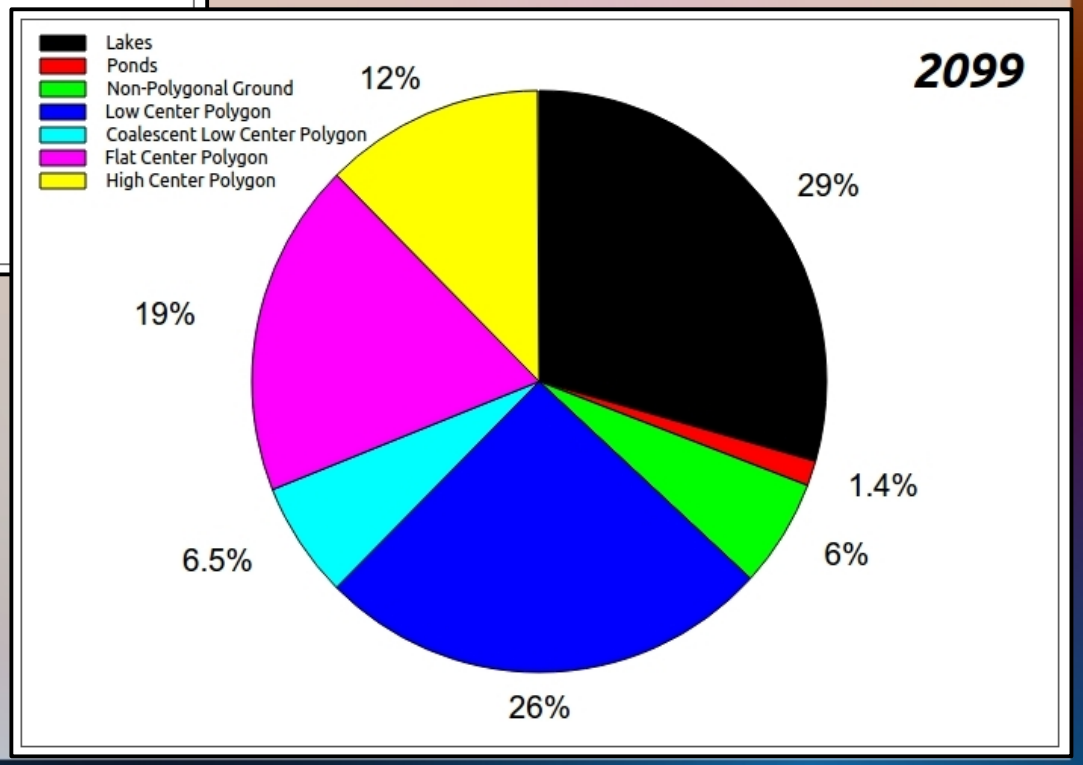


Alaska Thermokarst Model Output



Alaska Thermokarst Model Output

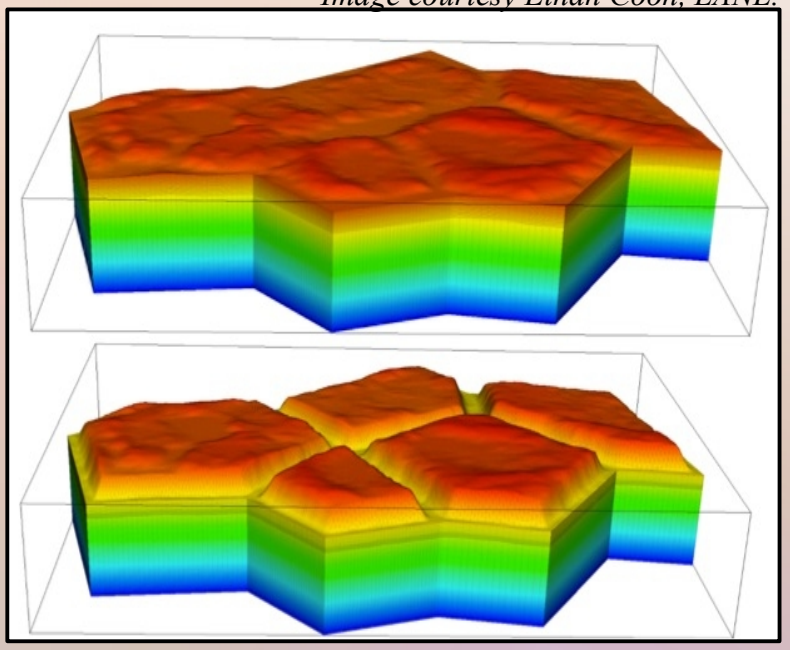


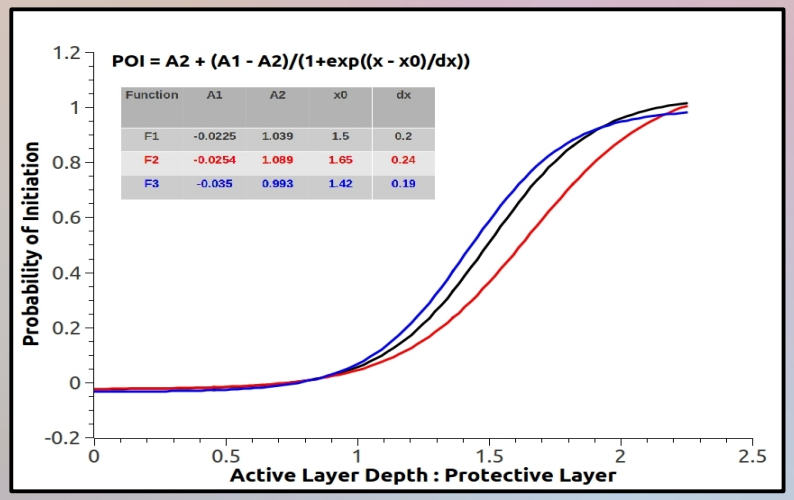


Moving Forward

- Function development/ parameterizations for each cohort to describe landscape transition rates from field observation, fine-scale numerical experiments, and literature.
  - Develop parameterizations & calibrate: 1901-2006
  - Scenario simulations: 2006-2100
- Development of frames & data sets for application:
  - Arctic Coastal Plain
  - Boreal forest (Tanana/Yukon Flats)
  - Seward Peninsula
- Couple ATM with the IEM

Image courtesy Ethan Coon, LANL.





Acknowledgements

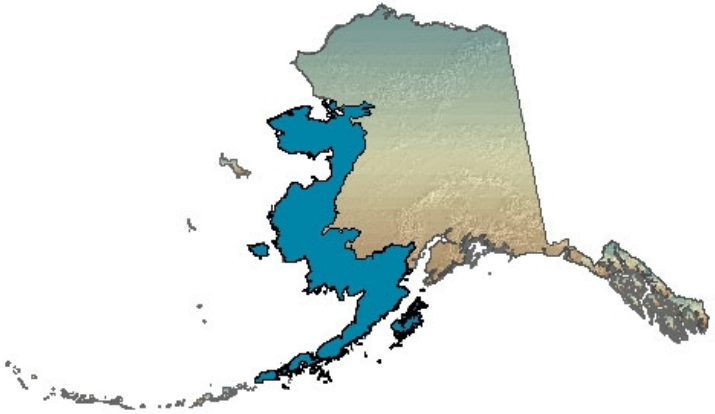
AK CSC
Alaska Climate Science Center

ALF TEM GIPL

Arctic Landscape Conservation Cooperative

Northwest Boreal Landscape Conservation Cooperative

Western Alaska LCC



Next-Generation Ecosystem Experiments: Arctic
Ecosystem Processes
Modeling, Prediction
Systems Understanding