Dynamic Modeling of Global Arctic and Subarctic Vegetation

Simulating Land Cover Change and Biogeochemical Cycles

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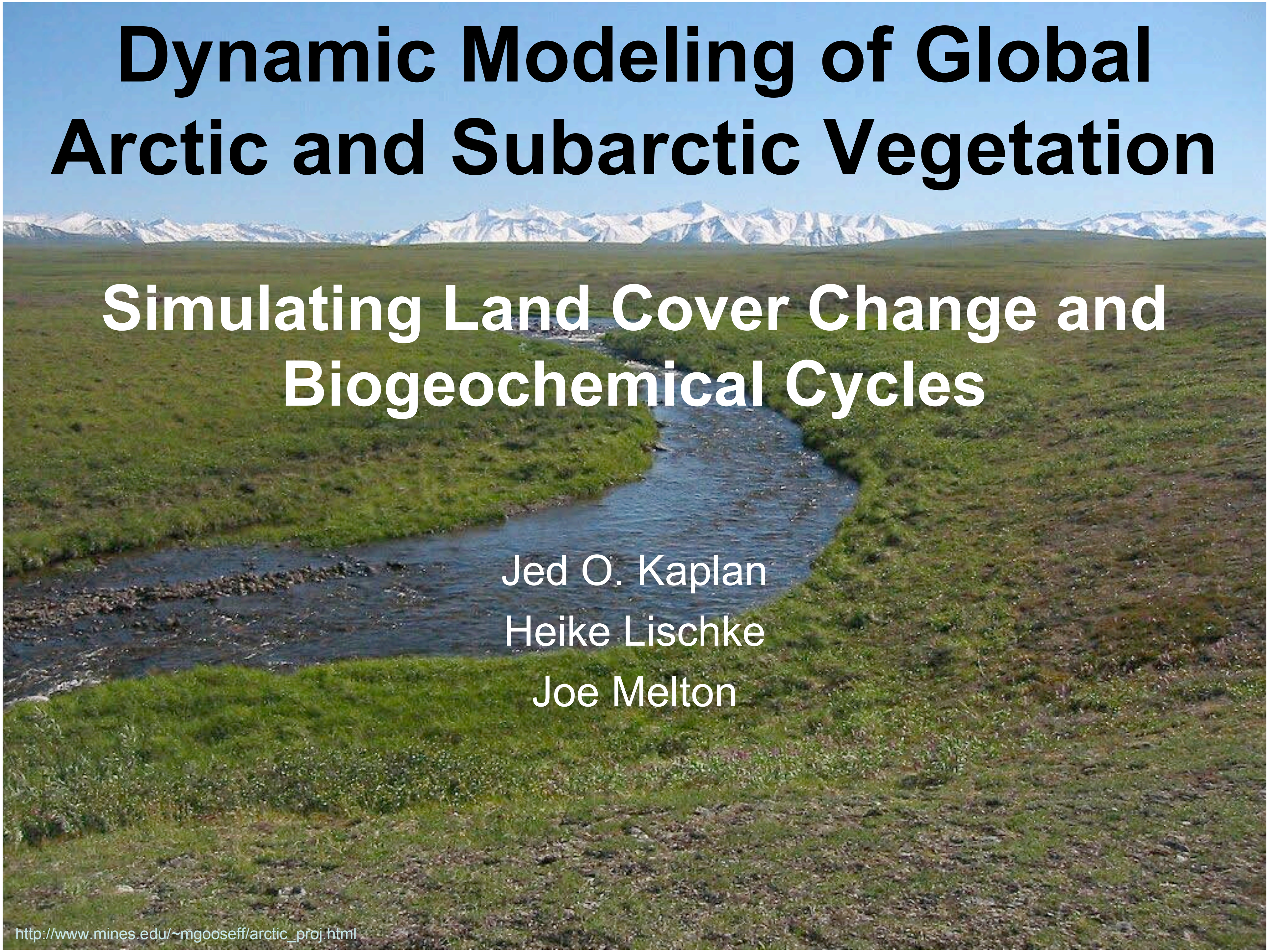


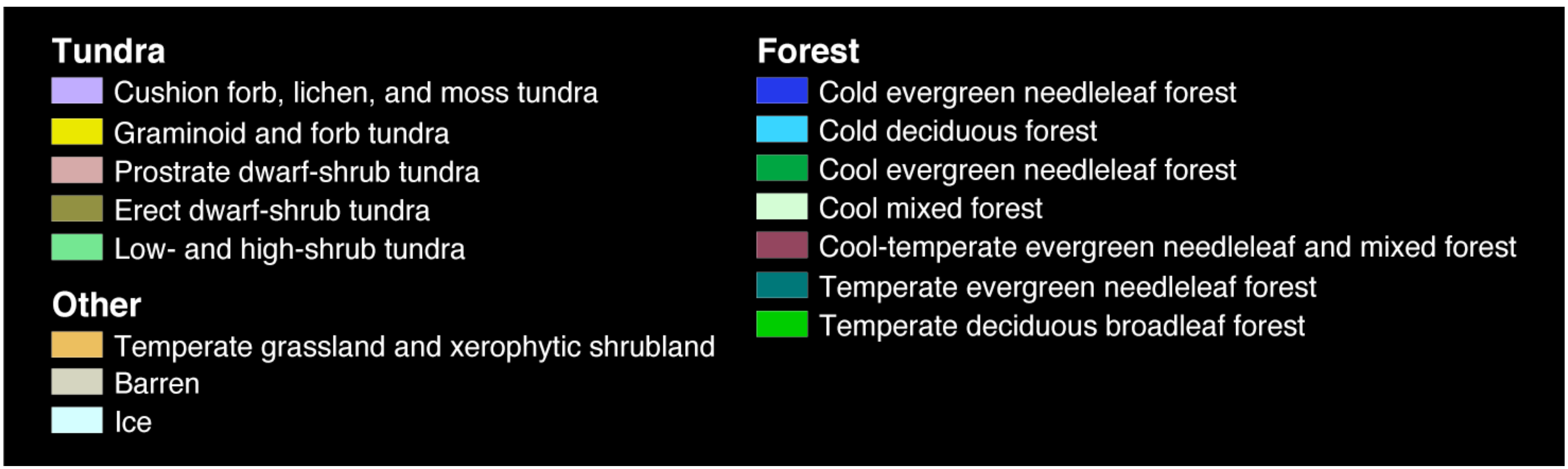
http://www.mines.edu/~mgooseff/arctic_proj.html

Outline

- Description of past activities in developing circumarctic vegetation model
- Current activities
- Future activites
- Needs from other project members

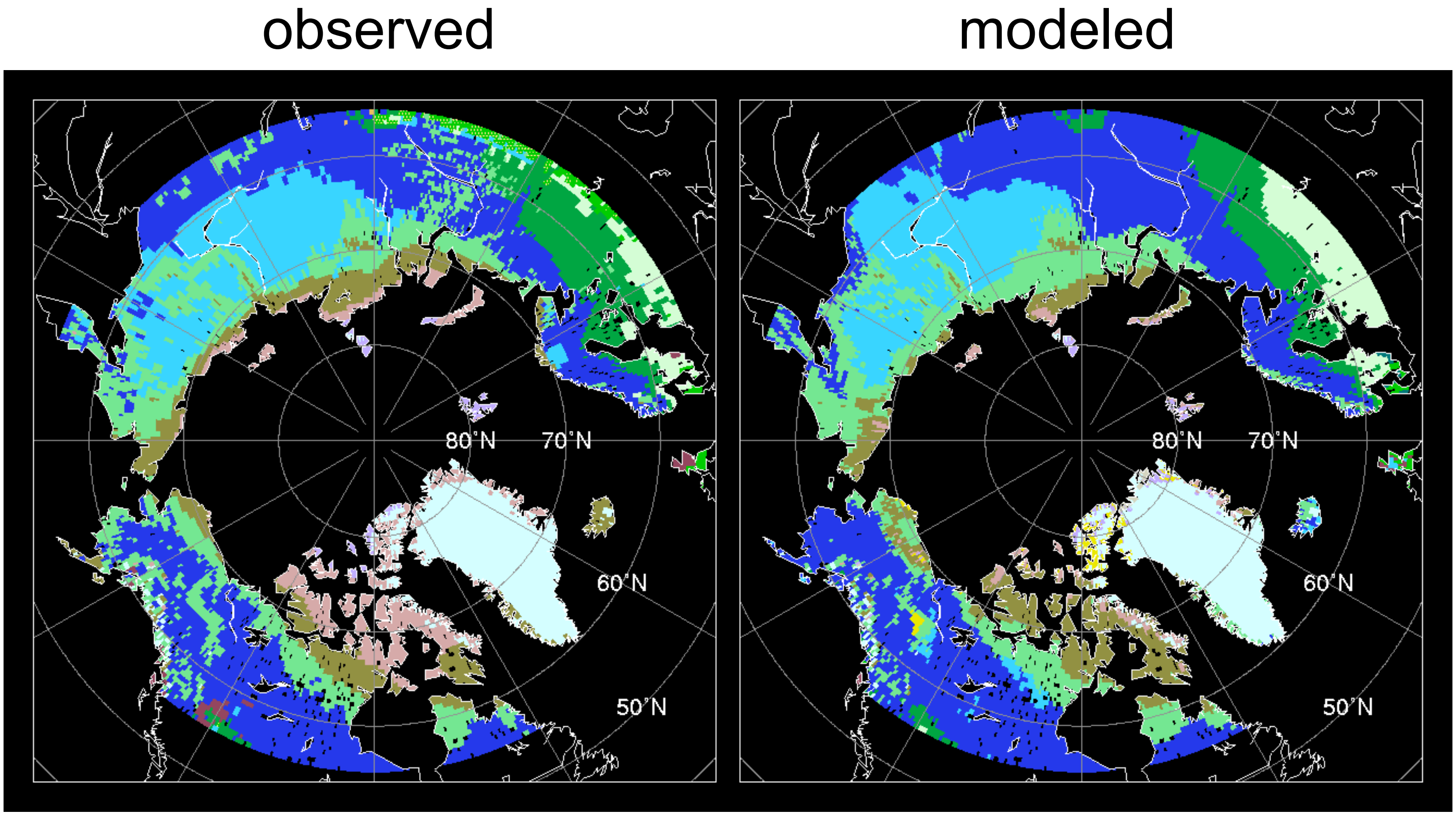
1998: A simplified approach to classifying circumarctic vegetation

- Botanically and biogeographically justifiable according to expert knowledge of vegetation in Europe, North America and Asian Arctic
- Distinctive in paleoecological archives
- Possible to adapt in a large-scale vegetation model using a plant functional type approach



1998-2003: Pan-Arctic INitiative (PAIN)

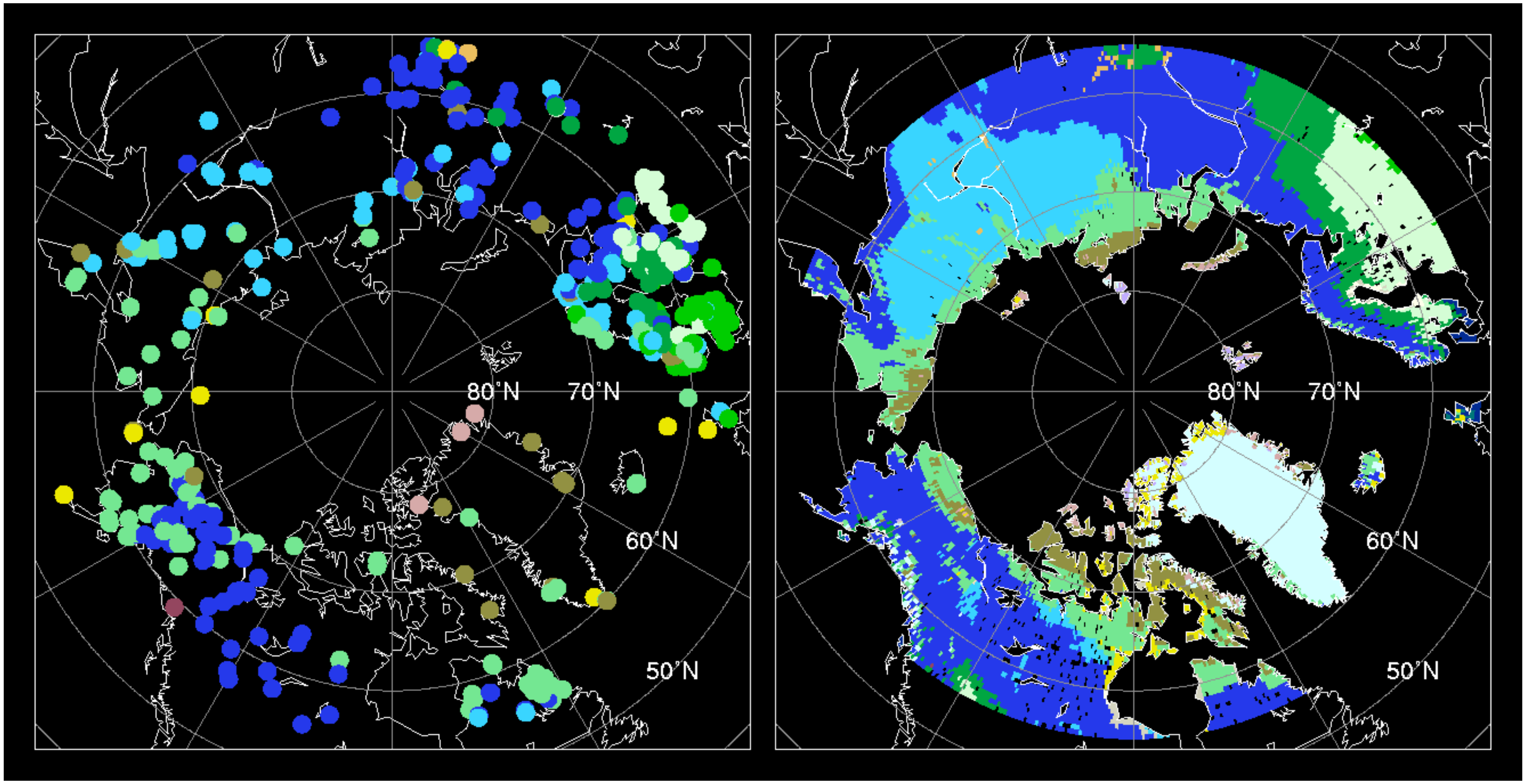
- Development of a prototype circumarctic vegetation map at 0.5° resolution based on existing vegetation maps and remote sensing, etc.
- First modeling results using the BIOME4 equilibrium vegetation model, driven by long-term mean temperature, precipitation and solar radiation



PAIN: Application to paleo time slices

- Synthesis of paleoecological data (pollen and macrofossils) followed by the “biomisation” technique to identify the arctic biomes
- Simulation of vegetation driven by climate model (GCM) output for paleoclimate simulations

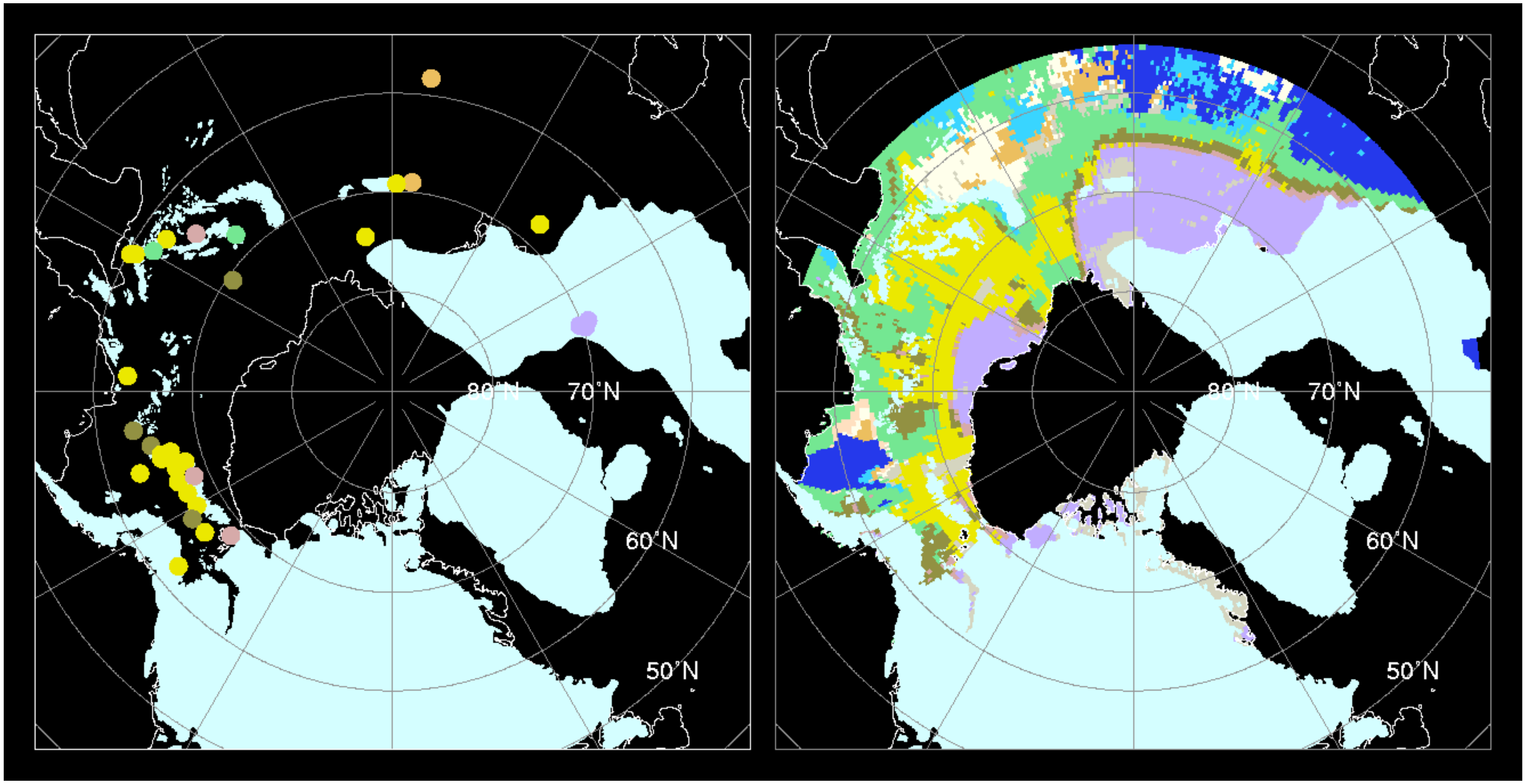
Middle Holocene (6 ka) modeled



PAIN: Application to paleo time slices

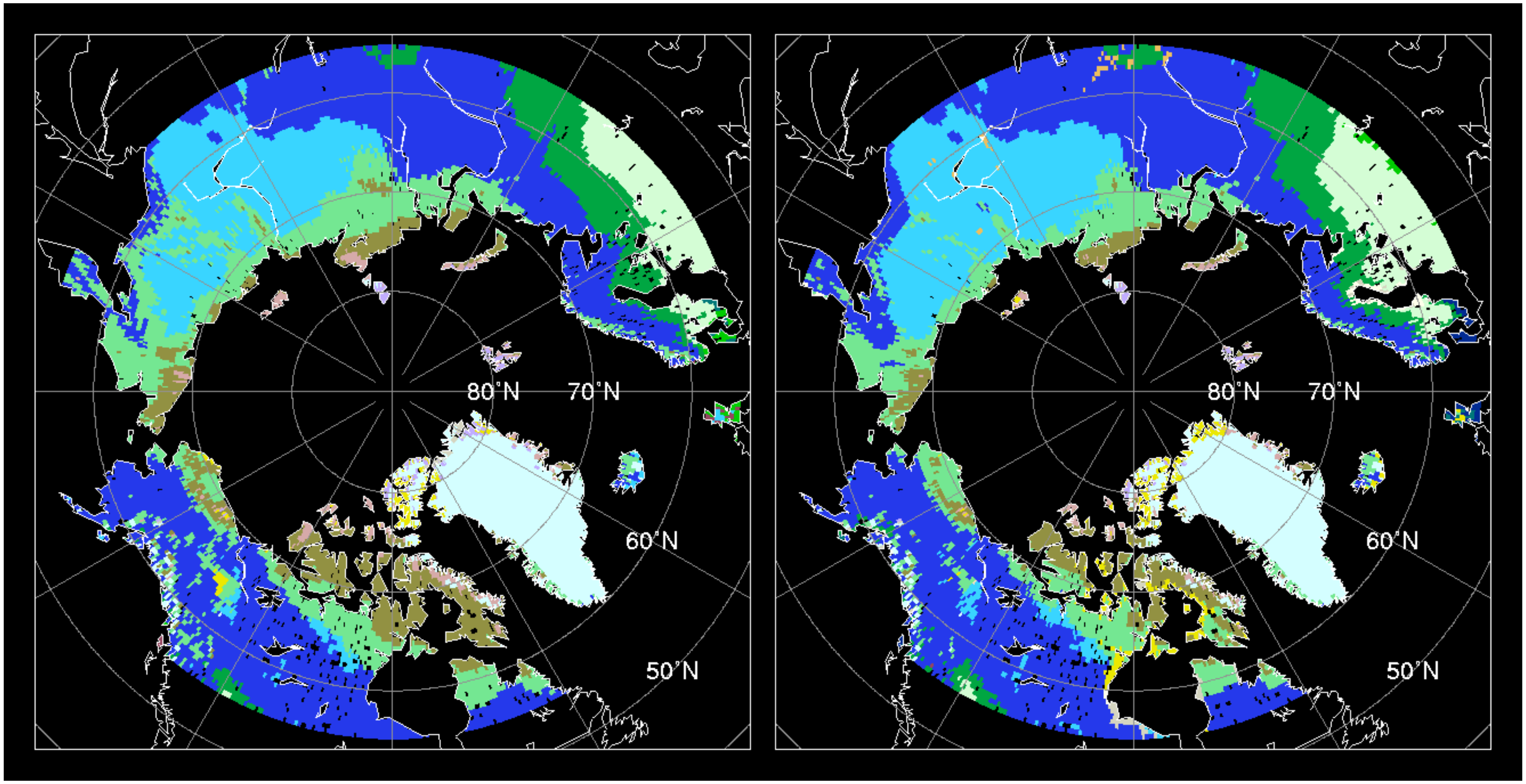
- The glacial maximum graminoid and forb tundra (“tundra steppe”) is diifcult to reproduce with models - we know we need to improve model hydrology

LGM (21 ka) modeled



PAIN: Analysis of modeled changes

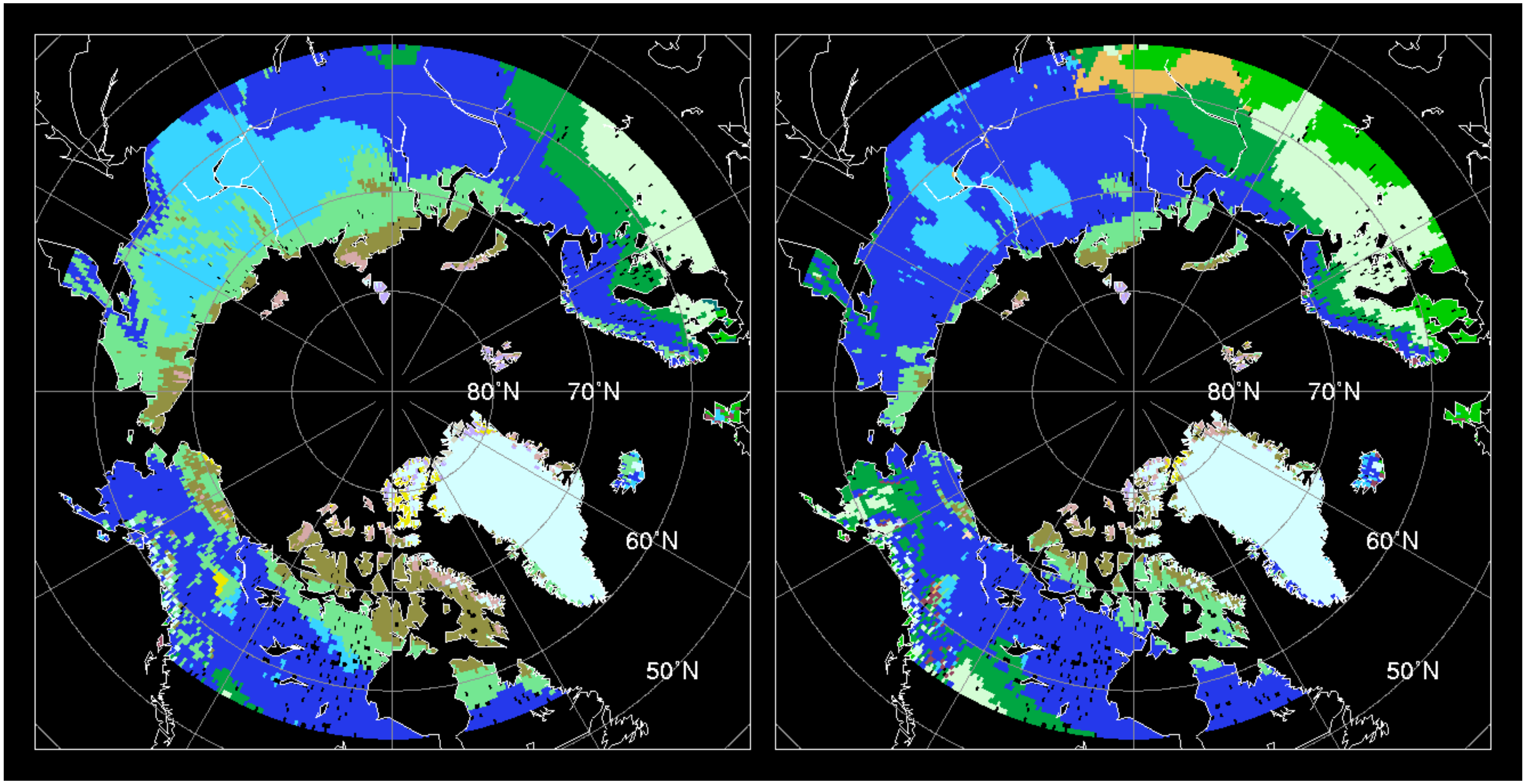
present | 6 ka



PAIN: Analysis of Modeled Changes

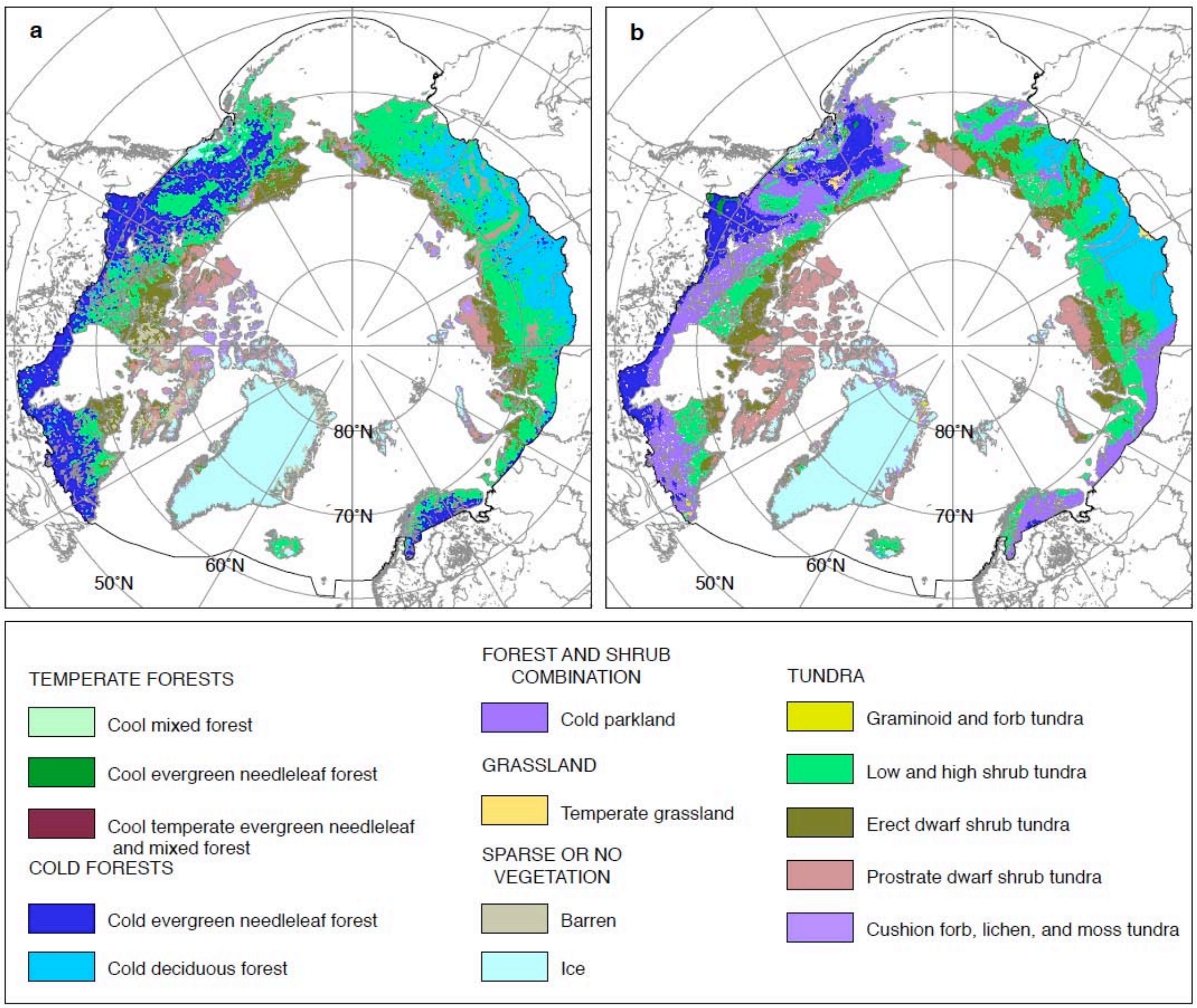
- IPCC IS92a scenario

present 2100



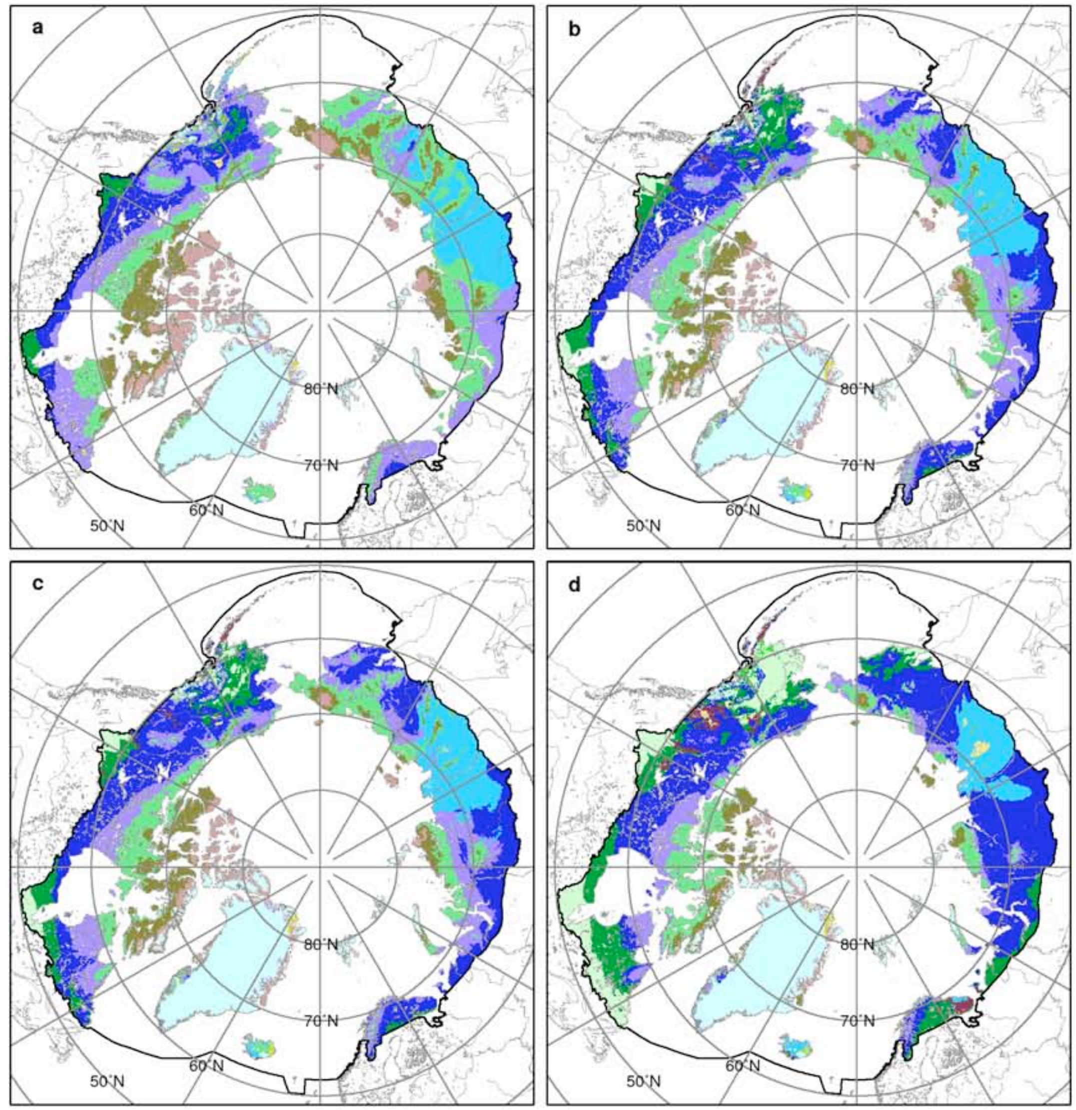
2004-2006: Kaplan & New

- Revisited the circumarctic vegetation map
- Used CAVM (then available) and GLC2000 (for boreal forest)
- Created on 10km equal-area (EASE) grid, reclassified to PAIN legend



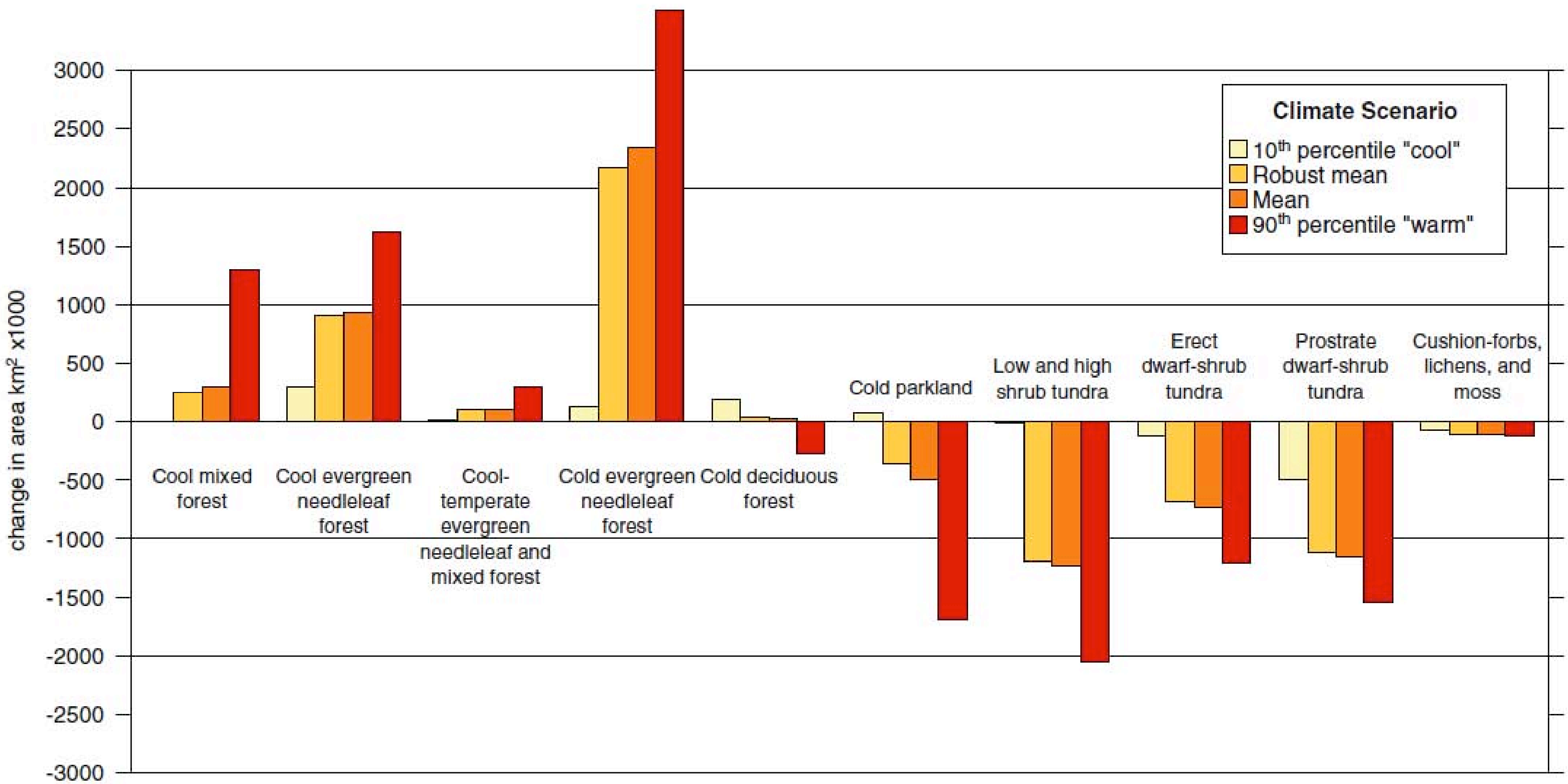
More Future Scenarios

- Synthesized 8 GCM simulations of future climate
- Identified the year in the simulation when 2°C global warming over preindustrial is reached (25-75 years from present)
- Created a series of climate scenarios based on 2°C global warming (arctic warming is much greater, particularly in winter)
- Ran BIOME4 at high resolution for these scenarios



Simulated changes in biome area with 2°C global warming

- Largest changes amount to an afforestation of the Arctic and a disappearance of coldest tundra subtypes
- Questions about how long it might actually take for this change to be realized (migrational lag) and vegetation-permafrost interactions (changes to hydrologic cycle)

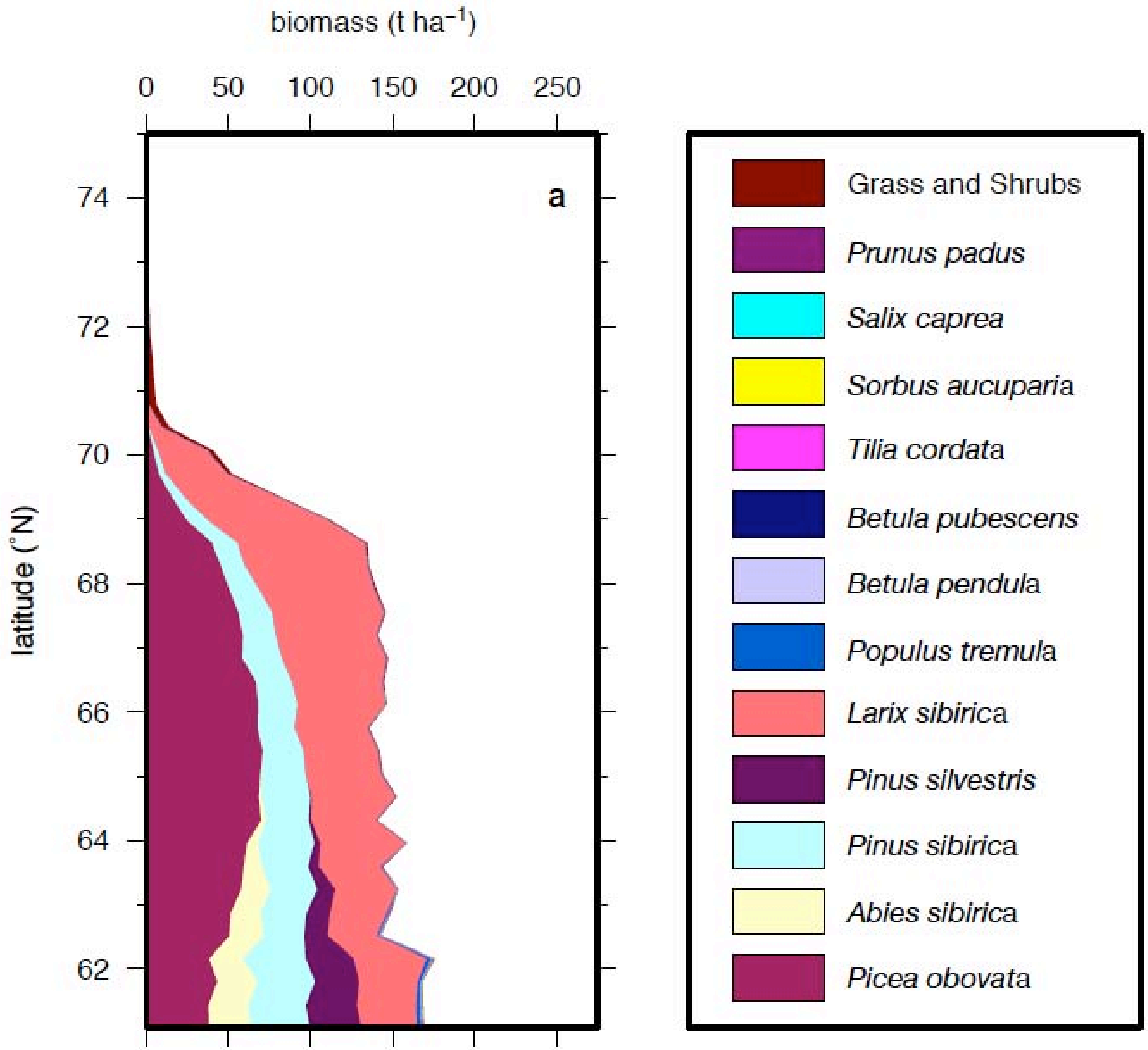


2006-2008: GOA and NEESPI- a multi-part modeling activity

- Dynamic modeling with the TreeMig model
  - Modeling biogeography (species presence) and simple biomass
  - Very useful for investigating lags due to plant migration (seed dispersal)
  - Uses annual climate summaries
- Biogeochemistry-biogeography modeling using the WSL-DGVM
  - Successor model to BIOME4 and LPJ-DGVM
  - To improve soil physics and represent permafrost-vegetation interactions
  - Developed with state-of-the-art soil physics from NCAR-CLM3.5
  - New parameterizations for thermal properties of bedrock (shallow soils)

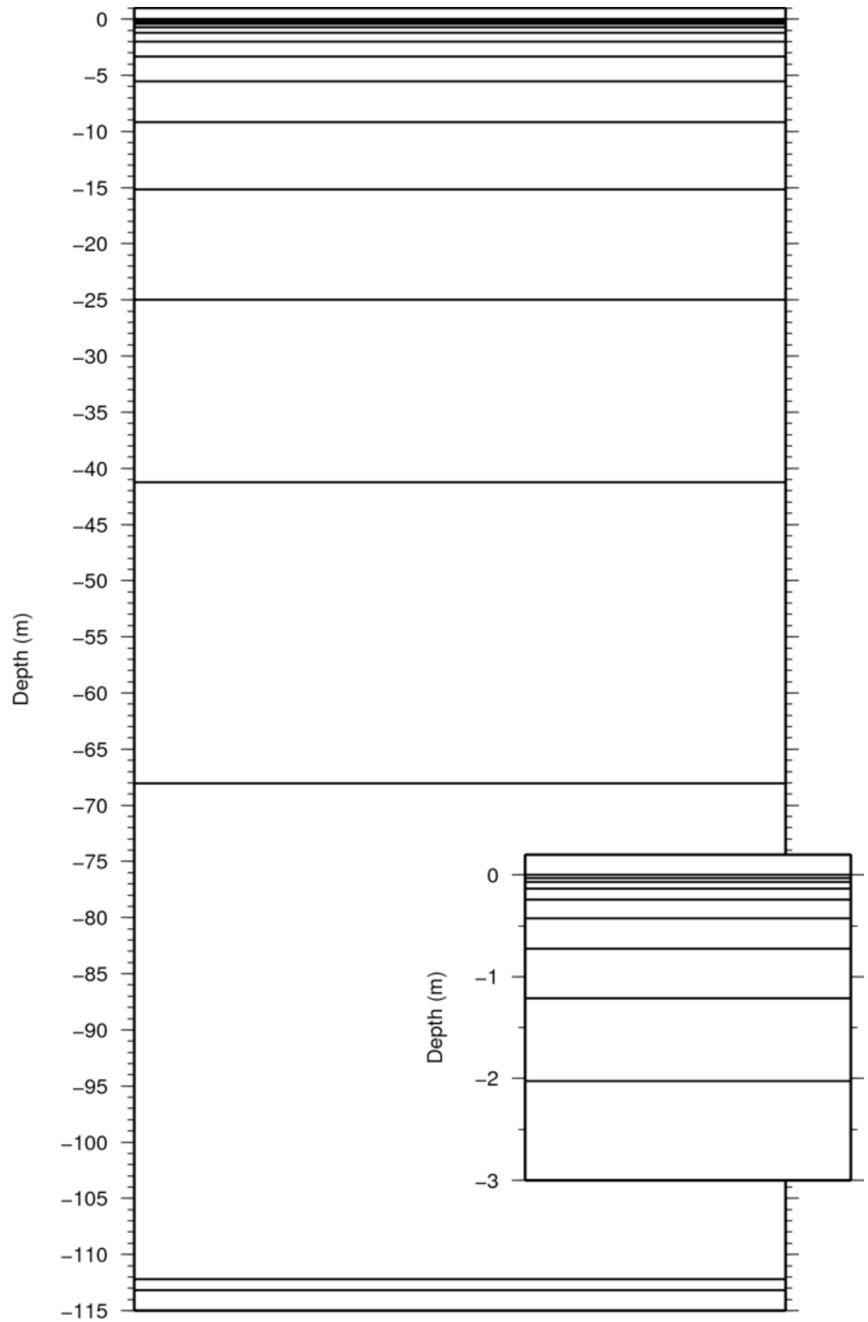
TreeMig modeling on latidudinal transect

- Show PDF images



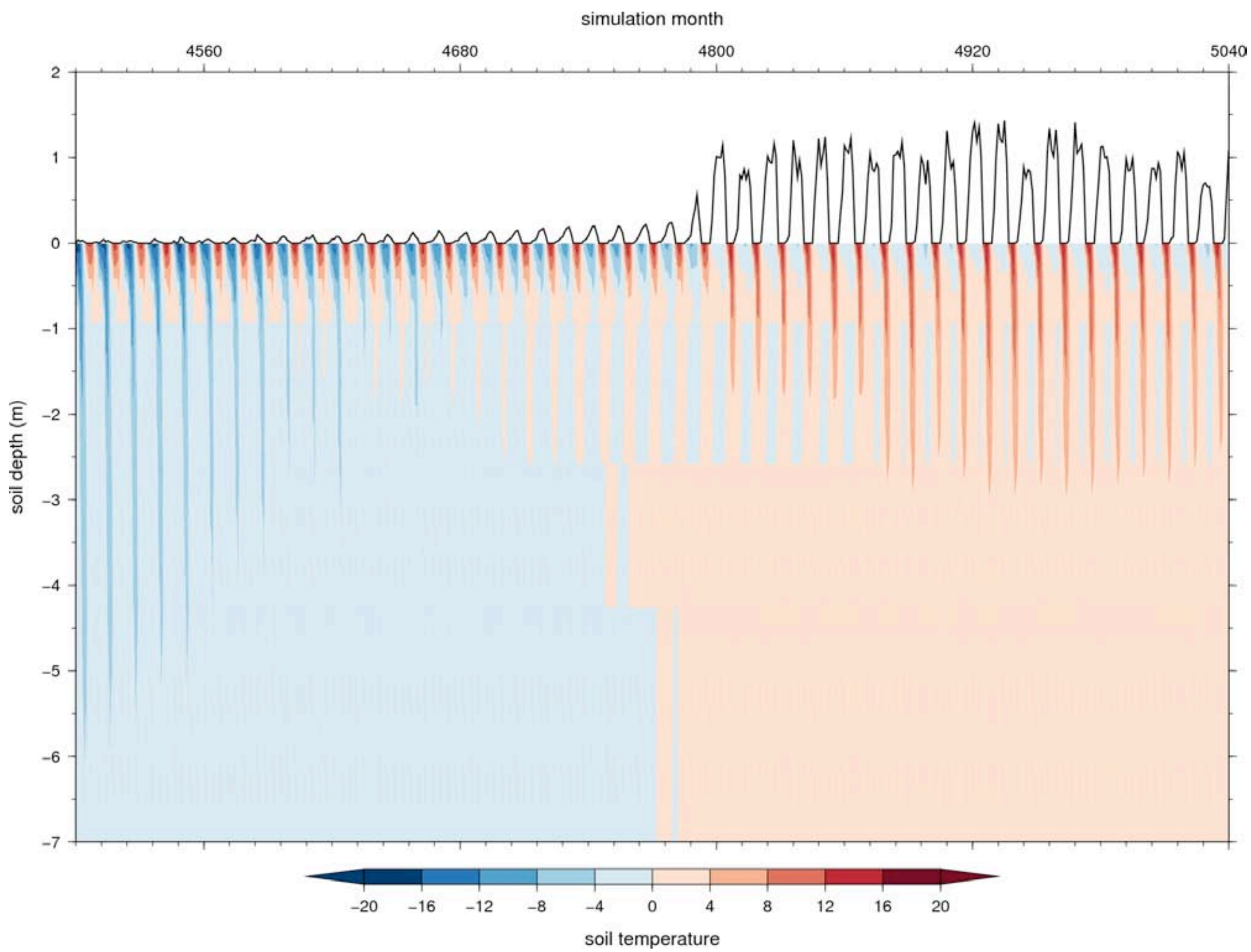
The new WSL-DGVM soil model

- Modified NCAR CLM3.5 soil scheme
- 17 layers of soil, exponentially increasing in thickness to ~70m, followed by 30m thick slab, then 1m bottom layer
- Total soil layer thickness ~115m
- Top layers are much thinner because that is where most energy exchange takes place
- Simulates permafrost, perched and trapped water tables, etc.



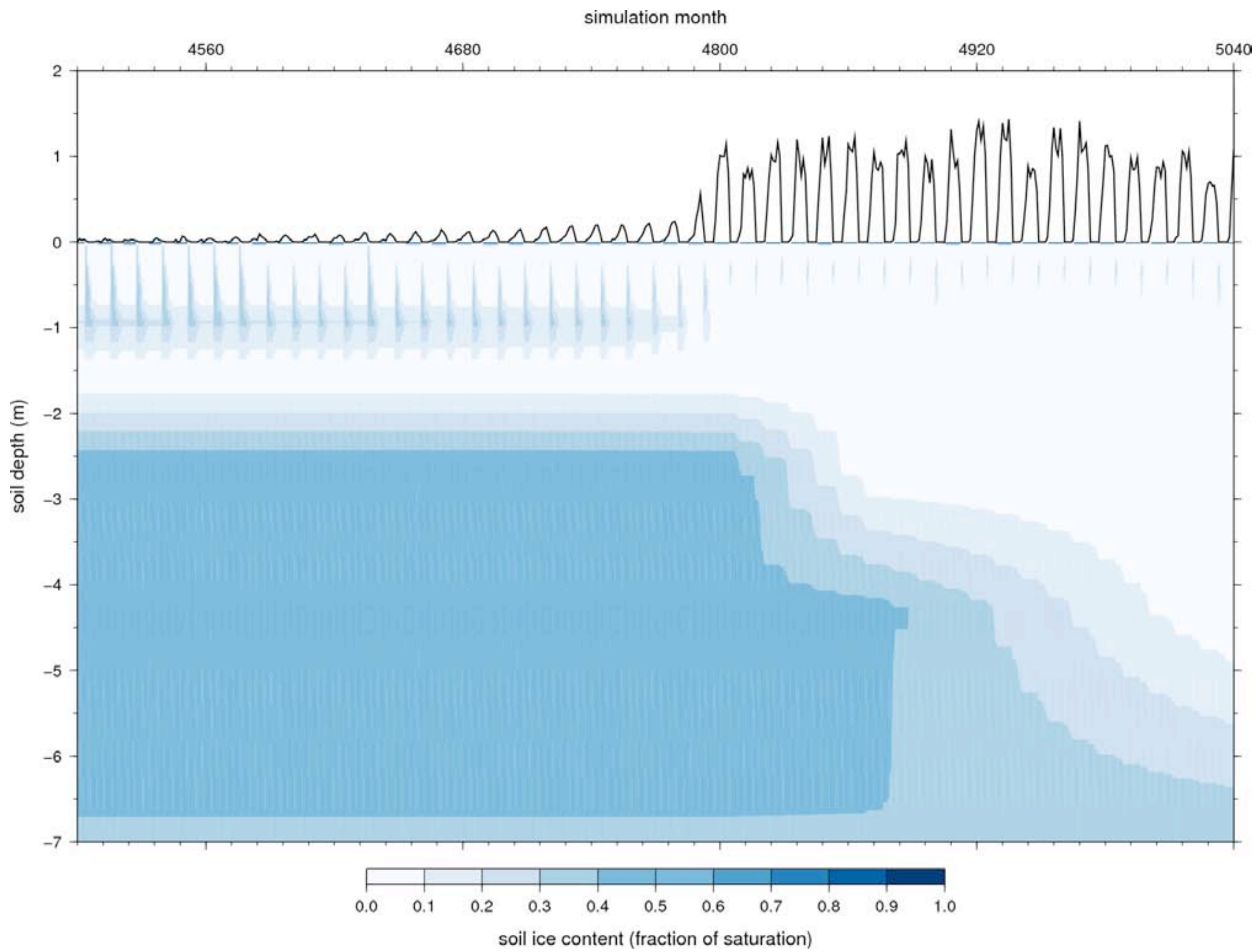
New soil model: preliminary results

- Soil temperature responds strongly to snow depth



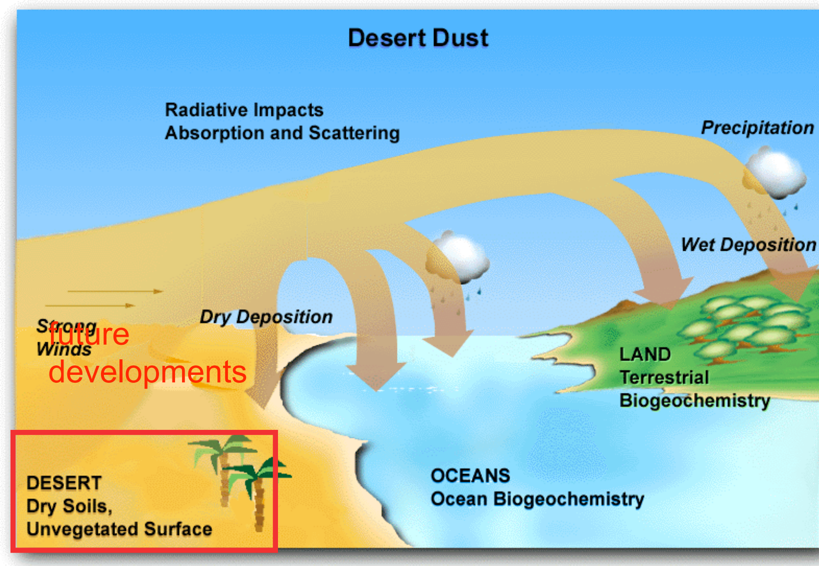
New soil model: Preliminary results

- Soil ice content in permafrost regions with deep relic permafrost and floating frozen layer



Future activities…

- Introduction of shrub, moss and lichen plant functional types for the WSL-DGVM, following the ArcVeg scheme
- Refinement of the soil physical model
- Simulation of CH_4 and $\delta^{13}C$-CH_4 from tundra soils (Yedoma?)
- Development of a scheme for soil development and erosion with the goal of simulating dust fluxes to atmosphere
- Implementation of the N-cycle in the model (some years off)
- Development of a simple parameterization for grazers (?)



…and what we would like from the project

- Soil texture
- Soil depth to bedrock
- Lithology
- Soil temperature profiles for comparison to modeled values
- Typical snow depth
- Solar radiation, precipitation (Arctic has the problem of very low station density)
- Biomass data (living biomass, litter, soil organic matter) from a variety of subzones
- Data on canopy density (FPAR, LAI)
- Emissions of trace gases from vegetation and soils (CO_2, CH_4)