High-Latitude Climate Change Experiments: Model uncertainties, needed improvements, and limitations

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Modeling priorities

- Make the best possible prediction of CO$_2$ and other greenhouse gas concentrations on decadal and century timescales.
- Include best possible representation of processes connecting ecosystems and climate.
- Challenge models against observations and experimental results.
- Provide testable hypotheses to guide observation and experimentation.
Modeling uncertainties
(short list)

• Physical climate – ecosystem feedbacks
• Climate – biogeochemistry feedbacks
• Carbon – nutrient interactions
• Carbon – nutrient – water interactions
• $\text{CH}_4$ dynamics
• Distribution of organic matter and biological activity with depth
  – temperature, water, oxygen saturation, pH, other controls…
• Controls on pre-industrial distribution of organic matter
Model results: 1850-present

• Fully-coupled simulation with CCSM4, including prognostic carbon cycle and land C-N dynamics.
• Focus on Alaskan arctic and boreal forest zones
  – Temperature and precipitation
  – Radiation and energy budgets
  – Ecosystem structure and function
Some global results from coupled simulation…

Model **overestimates** present-day $\text{CO}_2$ concentration by $\sim 20$ ppmv.

Model **accurately** predicts recent rate of warming ($\sim 0.7$ K since 1980).
Some global results from coupled simulation...

Some evidence of recent acceleration of hydrological cycle

Higher CO₂, warmer temperatures, increased water availability: higher GPP
Some global results from coupled simulation…

Increased temperature leads to faster N cycling…  
…but increased CO$_2$ still leads to an increase in relative N-limitation
Some global results from coupled simulation...

In spite of increased productivity, total vegetation C stocks declined due to LU/LCC.

Increasing stocks in soil C, but total global estimates much lower than obs: missing permafrost soil C dynamics.
Some global results from coupled simulation…

Low soil C at high latitudes… but better than we’ve done with this model in the past.
Highlighted regions

arctic

boreal
Temperature and precipitation

**AK arctic**
- ~2.0 K increase since 1980, limited impact on snow depth

**AK boreal**
- ~2.0 K increase since 1980, noticeable recent impact on snow depth
Radiation budget

AK arctic

Increase in net radiation, decrease in albedo

Alaskan Arctic (66.5-72N, 170-140W)

AK boreal

Increase in net radiation, decrease in albedo

Alaska (59-66.5N, 170-140W)
Ecosystem structure and function

AK arctic

Alaskan Arctic (66.5-72N, 170-140W)

Increased productivity, LAI, sink strength

AK boreal

Alaska (59-66.5N, 170-140W)

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