What are the critical knowledge gaps in arctic and boreal ecosystems?

• Changes in the northern hydrologic cycle, for example soil moisture dynamics in peatlands are not well known
  – ppt may be increasing, but what about net ET balance?
  – We need to know intra and inter annual variability in water spatial extent and water table depths
  – InSAR could help
  – CO2 increase -> stomata closure and increased sensible heat, decreased transpiration

• To what degree does soil moisture modulate response of ecosystems to the strong temperature increases – via respiration?
  – N & P mineralization coupled critically to temperature and precipitation changes
  – There are fundamental tradeoffs between CH4 and CO2 fluxes associated with a change in water table depth

• Eddy flux & climate stations in the Arctic
  - data for model drivers & validation currently limited
  - We need eddy flux towers in areas undergoing active permafrost degradation to improve process level understanding
  - Need chamber measurements to supplement eddy covariance measurement approaches
  - Sub-snowpack monitoring, or full ecosystem chambers are needed, as is support for innovative approaches in measuring fluxes in these extreme environments
  - Lack of flux measurements in the Arctic, especially over full year.
• Soils (observational gaps)
  – How much soil carbon resides in arctic tundra and boreal forest soils?
  – Vertical structure of soil organic matter
  – What is the age of respired soil carbon? More radiocarbon observations
  – **We need FIA soil sampling in Alaska as soon as possible!**
  – We need improved active layer thickness maps, permafrost depths, and time series of permafrost change
  – Circumpolar soil carbon map (down to 2m) does exist – but not outside of the Arctic
  – Maps of peatland ages, carbon content, and depths need to be made available for better assessment of C losses associated with fires

• Soils (model gaps)
  – Current suite of biogeochemical and carbon climate models represent permafrost and peatland soils very poorly – this is a gap
  – Carbon build up mechanisms (like loess deposition and labile C burial and deep freeze) may be different than loss mechanisms
  – Lacking mechanisms for soil carbon formation in permafrost in models.

• Soils (gaps in process-level understanding in permafrost thaw)
  – Changes in nitrogen cycle related to permafrost and soil carbon changes
  – Does the N released from decomposition stimulate NPP
  – How much of the nutrients released from soil thaw will enter aquatic ecosystems and the Arctic Ocean?
  – Do we understand tradeoff between peatland methane and CO₂ fluxes? Between productivity and trace gas production?

• Lakes
  – We need to include lakes in biogeochemical and climate models
  – Are lakes drying out (draining via talik formation) or are lake levels rising via increased PPT?
  – Systematic measurements of lake heights, spatial extent, and impacts on water table
• Gap in basic understanding of bryophytes, carbon uptake capacities, landscape scaling
  – Mosses are not often included in NA bgc or coupled carbon climate models even though they influence, in a fundamental way, C stocks, soil temperatures and permafrost distributions, and the surface energy budget
  – Tundra shift in dominance between shrubs/mosses. Shrubs may be increasing…
  – Importance of lichen, e.g. caribou
  – Need improved remote sensing estimates, improved representation in models

• Movement of pollutants into the Arctic
  – N deposition from fossil fuel plumes
  – Transport of biomass burning emissions is seen clearly from remote sensing observations – MOPITT provides new constraints
  – Deposition of N & P from remote fires – have recent increases in Siberian fires fertilized NA boreal ecosystems?
  – Black carbon from NA fossil fuel emissions is contributing to lower snow and sea ice albedo and is probably contributing to accelerated loss of snow and ice cover
  – We do not well understand the transport of pollutants from Russia into N. America

• Rates of shrub expansion
  – Coupling between biophysical and carbon consequences of shrub expansion. What effects dominate?
  – Where is shrub expansion occurring?! We need to map this
• Disturbances (Gaps in understanding)
  – How are disturbances linked with contemporary and future climate variability? (e.g., fire and insects)
  – For example, what will future increases in temperature and growing season length do to these disturbance types
• Top-down modeling potential e.g. seasonal tropospheric changes in CO₂ concentrations.
  – Transport-driven meridional variation could be a problem
  – Need to resolve atmospheric motion over the Arctic with respect to arctic oscillation (?)
• Climate Impacts on ecosystems
  – Influence on arctic climate of changes in deep water formation.
  – What is the effect of arctic growing season length if sea ice is gone in 50 years?
• Disturbances (Gaps in understanding - continued)
• Fires
  – In good shape for mapping fires in N. am. Perimeter is OK
  – Majors limits on fire emissions certainty come from limited understanding of burn
    severity, depth of burning, and the distribution of forest soils
• Insects – Major gap- Need better maps of insect disturbance.
  – Species differences, Alaska DNR has a monitoring program. Western Canada
    and Eastern Canada mapping underway.
  – Concern that with changing winter climate, could jump to jack pine.
  – Socio-economic dimension – e.g. making use of the dead wood from infestations
    for power production in Canada.
  – U.S.F.S. has annual insect mortality density survey.
  – Potential for greenness monitoring in real time. Needs to be based in the ecology
    and biology of the disturbance processes. Get this at 1 km resolution (LAC).
• Also improved predictive models (fire, insects, occurrence and effects)
• This could be a good topic for a workshop
• What are the processes for insect spread, effects on productivity and
  mortality
• Plans in place (Goward) to do N.Am. wall-to-wall disturbance mapping,
  yearly repeat, with landsat. Need more liberal access to Landsat archive
To what degree are arctic and boreal systems driving the N.Am. C-cycle?

- Most likely place to expect significant biogeography dynamics over 100 year time frame.
- Spatial scales of disturbance dwarf what we see in lower 48.
  - Contributes substantially to interannual variability.
  - Potential for rapid catastrophic events – from interactions of drought, insects, and fires
  - Interactions (some non-linear) between drought, temperatures, insects, and fires not well understood
- Ecosystems are experiencing very large changes in temperature and growing season length – with important consequences for endangered species and C fluxes
- Bering Sea ecosystem will be impacted by effects from transport of freshwater and sediment from Yukon
- No consensus on the sign of boreal and arctic ecosystem fluxes in terms of contribution to a N. Am. sink
- Important driver of seasonal atmospheric CO$_2$ variability in N. Hem.
- Contributions of nutrients from arctic land surface to Arctic Ocean are substantial
- Large C pools – and thus large impact on long-term trends
What synthesis and integration activities can help address knowledge gaps?

- Bring together the multiple existing groups with regional focus. Boreal and arctic studies.
  - Compare and contrast water, carbon, nitrogen, and energy budget drivers in different regions of northern ecosystems
  - Identify knowledge gaps
  - NEESPI connection (meeting sept 07). IPY (return to this).
  - Create a metadata record of datasets, investigations
  - Can we balance fire emissions with accumulation rates within air mass trajectory?
  - Reconcile the various approaches, including post-fire eddy covariance estimates with carbon accumulation estimates and top-down estimates of fire emissions
  - Develop estimates of uncertainties
Ideas for synthesis, cont’d

• Bring researchers together to study a single sub-region to improve process level understanding
  – Close budgets
  – Consider all the process questions relevant to that area
  – USGS leading planning effort for Yukon Basin
  – Other studies starting to coordinate with this effort.
  – Coordination with Canada
  – Would be a good link for satellite validation like OCO
Synthesis ideas, cont’d

• IPY/NACP interaction
  – Make existing datasets available to IPY
  – Creation of metadata index would be a big contribution to IPY
  – GeoNorth 07? Yellowknife.
Synthesis ideas, cont’d

• Fuel consumption and emissions from fires: coordination between U.S. and Canada.
  – Get this started soon.
  – Reconcile inventories with top-down estimates.
  – Not just area burned, need detailed understanding of intensity – bring together modelers and ecologists to get this knowledge into current models.
  – Eric Kasischke and Nancy French are working on this with Canadian colleagues

• Insect disturbance working group and meeting
  – Bring entomologists, forestry experts, ecosystem ecologists, and modelers together to move from diagnostic to prognostic capability.
  – Currently biogeochemical and climate models do not adequately represent insect mortality
  – Do this for a few of the major insect species (perhaps focus on 5 or 6 species)
  – Include fire interactions, community ecology, remote sensing, Alaska DNR, Forest Service, Canadian provincial gov (Rich Flemming).
  – Hyp: warming increases range of spruce bud worm due to changes in food quality
  – Post-insect carbon trajectory.
  – Historical disturbance included in Canada’s Kyoto accounting model, but diagnostic, not prognostic.
  – How do insect, fire, and post-disturbance harvest interact.
  – What can remote sensing approaches offer with respect to mapping these disturbance types?

• Extensive model evaluation – comparison against the highest-quality datasets.
Synthesis ideas, cont’d

• Are we comfortable with current SOCCCR structure?
  – Put together a SOCCCR team to improve treatment of boreal/arctic regions.

• Interaction with carbon studies and thermokarst, thaw lakes, in tundra and boreal regions