Impacts of Soil Freeze/Thaw Dynamics on the North American Carbon Cycle

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Introduction: There is a strong positive correlation between winter soil temperature and annual net carbon fluxes. Field measurements show a sharp transition from carbon release to carbon uptake coinciding with spring soil thaw. 80% of North America experience annual freeze/thaw (Fig. 1). Realistic representation of soil freeze/thaw processes would improve the simulation and understanding of the carbon cycle.

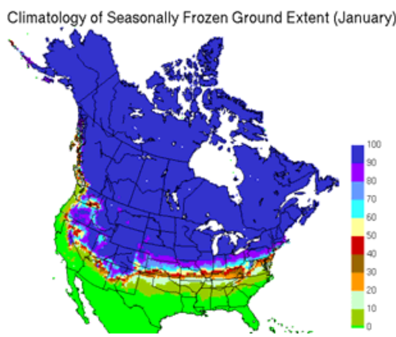

Fig. 1. Area extent of seasonally frozen ground in North America. 80% of North America experiences soil freeze/thaw, ranging from a few days in the south to longer than eight months in the Arctic.

Objective: To understand the role of soil thermal regime and freeze/thaw processes in determining seasonal and inter-annual variability in terrestrial biomass, photosynthesis, and respiration over the North America. We will (i) assess spatial and temporal variability in seasonal snow cover, soil freeze-thaw depth, and soil temperature; (ii) investigate the impacts of soil temperature and freeze-thaw on net carbon fluxes; (iii) relate changes in season snow cover, frozen ground, and soil temperature and carbon fluxes to large-scale climate forcing; (iv) estimate uncertainty in our estimated carbon fluxes; (v) assess the sensitivity of cryosphere/biosphere system to changes in climate; (vi) generate datasets of seasonal snow cover, frozen ground, soil temperature, biomass, and carbon flux over North America.

Approach *(i) Satellite remote sensing:* use SMMR, SSM/I, and AMSR-E data to detect snow depth/snow water equivalent, and near-surface soil freeze/thaw status. We will use AVHRR and MODIS data to detect snow cover extent, LAI, NDVI, and surface temperature; *(ii) Ground-based measurements:* collect snow depth, SWE, soil temperature, freeze/thaw depth, permafrost distribution, carbon fluxes from all available sources over NA; *(iii) Modeling:* Frozen Soil Algorithm (Fig. 2) will simulate soil temperature and soil freeze-thaw depth; SiBCASA (Fig. 3) will simulate biomass and carbon fluxes.

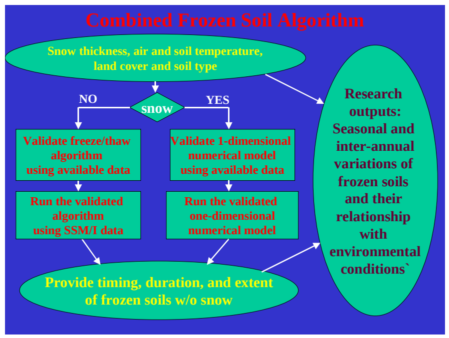

Fig. 2. The NSIDC Frozen Soil Algorithm, which was used to detect soil freeze/thaw in the Arctic with good results.

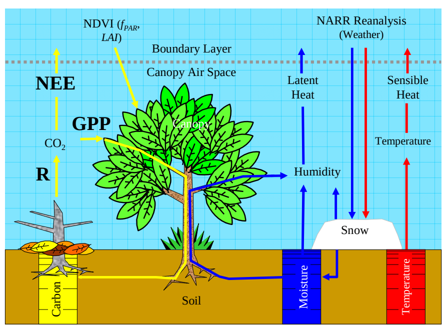

Fig. 3. The SiBCASA biogeochemical Model to simulate biomass and carbon fluxes.

Data: We will combine satellite remote sensing data of snow extent from visible sensors and SWE from passive microwave sensors with ground-based measurements (Fig. 4) to generate daily snow cover from 1981 to present over North America. Fig. 5 shows the combined product over the Arctic region.

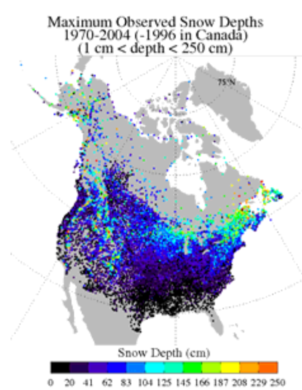

Fig. 4. Distribution of stations and sites of snow cover data over North America.

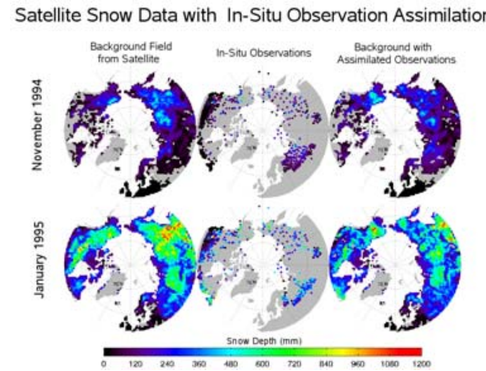

Fig. 5. Combined snow cover products from satellite and ground-based measurements over the Arctic. Similar snow cover products will be produced for North America.

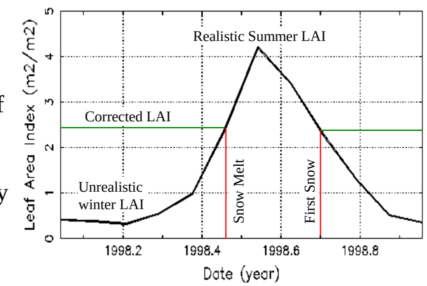

Fig. 6. NDVI snow cover bias: snow burial is interpreted as a false loss of Leaf Area Index (LAI), which we will correct by combining NDVI with daily snow cover data (Fig. 5).

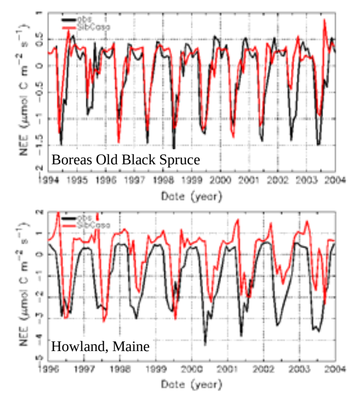

Fig. 7. Observed (black) and SiBCASA simulated (red) monthly average NEE at Boreas old black spruce (top) and at Howland sites (bottom). Boreas is a mature boreal forest with a snow bias correction. Howland is a nearly mature mixed evergreen-deciduous forest.

Expected Products: (i) daily soil temperature, snow and soil freeze/thaw depth, generated from in-situ measurements, satellite remote sensing, FSA modeling (1981-present). (ii) monthly average biomass from SibCASA (1981-present). (iii) daily and monthly carbon fluxes and uncertainties (1981-present).