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Scoping Completed for an Experiment to Assess Vulnerability of Arctic and Boreal Ecosystems

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Over the past 100 years, high northern latitude regions have experienced more rapid warming than elsewhere on Earth. This trend is expected to continue over the next century. Arctic tundra, boreal forests, and peatlands are already undergoing major changes, reinforced by the cascading effects of thawing permafrost, increasing disturbance (particularly fire and insect pests), and altered surface hydrology. These changes influence processes at the ecosystem and landscape scales, including energy balance and vegetation productivity, which feed back to regional and global climate in addition to affecting wildlife habitat and ecosystem resources available to local communities.

While there is a considerable legacy of research on the nature and effects of climate change in the Arctic, major gaps remain in understanding the vulnerability and response of Arctic and boreal ecosystems to continued warming. These knowledge gaps and associated uncertainties provide the basis for an integrated, multidisciplinary field campaign.

To facilitate the development of this campaign, and in response to a solicitation from NASA's Terrestrial Ecology program, a scoping study was recently completed for an international Arctic-Boreal Vulnerability Experiment (ABOVE). As proposed, ABOVE will focus on terrestrial ecosystems of Alaska and western Canada (see Figure 1), providing opportunities to expand and coordinate interdisciplinary research to better understand drivers and consequences of climate change. The objective of the scoping study was to engage the science community in formulating ABOVE's research strategy by indentifying critical knowledge gaps and priorities and outlining possible organizational plans and operational resources. This was accomplished in a number of ways, as described in a report posted on NASA's Terrestrial Ecology Web site (http://cce.nasa.gov/terrestrial_ecology/scoping.html). The scoping study's coordinators are now soliciting community feedback on proposed activities, which will lead to a decision on whether and how to proceed with implementation.

ABOVE Themes

The scoping study helped identify research goals for ABOVE, which will be organized in seven themes: disturbances, ecosystem dynamics, permafrost, surface hydrology, soil carbon, land-atmosphere feedbacks, and human dimensions.

Disturbances influence ecosystem vulnerability (susceptibility to change), resilience (resistance to change), and associated feedbacks to climate. ABOVE will focus on three categories of disturbance agents: physical (such as fire), biological (such as insects and pathogens), and anthropogenic (such as mining, drilling, and forestry). Satellite observations will be used to map and monitor disturbance patterns and frequencies, and models will be used to analyze factors influencing the susceptibility of landscapes to disturbance, as well as how natural disturbance regimes are likely to change in the future.

Ecosystem dynamics, including changes to species composition and range distribution, have important effects on ecosystem functioning and can modify feedbacks to climate. Spatial and temporal variations in satellite observations of vegetation dynamics, including productivity, composition, and structure, will be investigated through comparisons with ecosystem models representing similar properties and processes. Modeling studies will explore magnitudes, directions, and change rates of ecosystem dynamics over the past 30–100 years and their relation to longer records established from regional climate proxies. A focus will be assessing whether some ecosystem components (e.g., vegetation types and specific fauna) are more vulnerable or resilient than others to change as well as the degree of plasticity in responses.

Permafrost is widespread in all high-latitude regions, and its characteristics control surface hydrology, ecosystem dynamics, and soil carbon. Surface characteristics that can be derived from satellite observations (freeze/thaw status, surface hydrology, vegetation and snow cover, and disturbances) will be used with field measurements to further develop, refine, and assess models that explain the current distribution of permafrost and to predict how future variations in land-atmosphere exchanges of energy will influence permafrost degradation and the associated release of carbon stored in deeper layers of soil.

Surface hydrology interacts with permafrost, disturbances, vegetation, and soil carbon processes and is influenced by complex landscape features ranging from microscale patterning of tundra to vast expanses of small lakes and ponds that link to coastal ocean processes via river discharges. Remote sensing and field observations will capture spatial and temporal variations in surface water extent and soil moisture, providing the basis for modeling factors controlling extreme events (flooding and ice breakup) as well as water storage, surficial flow regimes, and controls on transitional phenomena.

Soil carbon reservoirs in the high northern latitudes are extremely large as a result of cold or frozen and poorly drained ground layers. ABOVE will focus on the vulnerability of deep carbon pools to changes in climate, disturbance regimes, ecosystem dynamics, permafrost, and surface hydrology. Uncertainties in the distribution of soil carbon and factors controlling its cycling will be addressed, drawing upon observations and modeling conducted for other science themes, particularly the effects of disturbances.

Land-atmosphere feedbacks are critical to understanding the magnitude of climate warming and how it will be expressed and vary across the globe. ABOVE research will focus on positive feedback processes, such as increased fire emissions, thawing of permafrost, vegetation productivity decline, increases in soil respiration, and reductions in land surface albedo with shorter snow duration and shrub expansion. Negative feedback processes will also be quantified, including increases in net primary production and surface albedo with shifts from coniferous to deciduous vegetation, and increases in cloud cover resulting from sea ice loss and enhanced evapotranspiration. ABOVE will focus on the interactions of these processes and their net trade-offs as climate forcing factors.

The human dimensions theme will explore the role that humans play in altering high-latitude landscapes as well as how climate change may affect communities (particularly native and subsistence cultures) and the ecosystem services on which they depend. The information exchange between these communities and scientists will flow in both directions. Knowledge generated through basic research on causes and effects of climate change will inform policy makers and land managers, who make decisions based on assessments of changes that affect a wide range of migratory fish, bird, and mammal species. Local communities will share their intimate knowledge of the environment with ABOVE scientists and will be actively involved in documenting changes via systematic monitoring in remote regions.

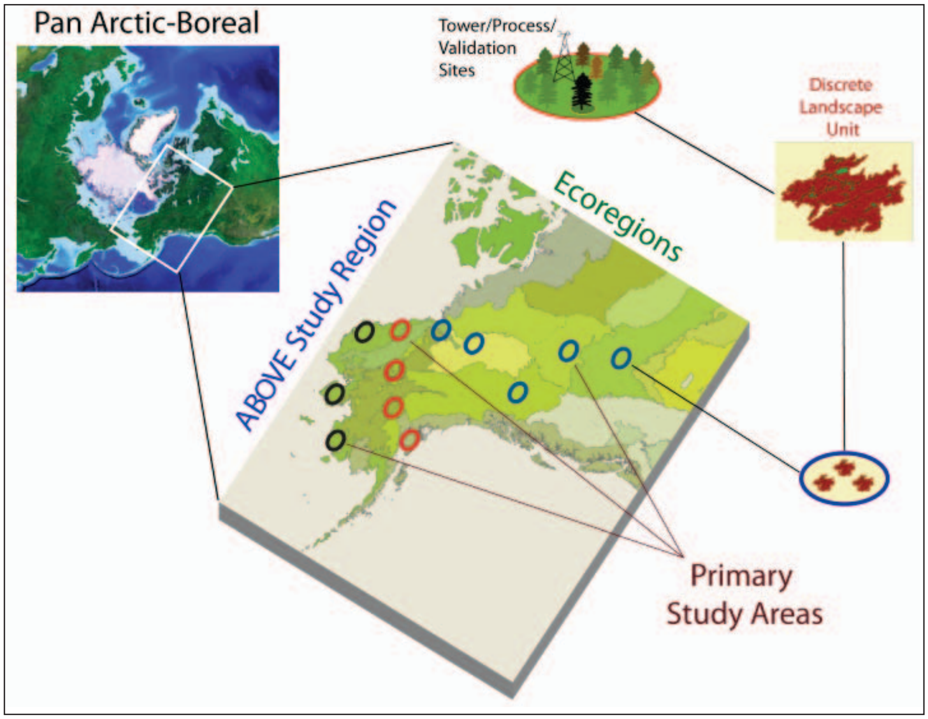

Fig. 1. The Arctic-Boreal Vulnerability Experiment (ABOVE) will have a pan-Arctic scope, but field campaigns will focus on Alaska and western Canada. Within this study region, primary research areas (circles) will be located along three north-south transects (indicated by different colors) covering large gradients arrayed across ecoregions. Nested within each research area will be discrete landscape units (e.g., a disturbed area or a watershed), within which measurements and experiments will be conducted at sites (e.g., flux towers).

Interweaving Themes to Build Better Models

Because processes associated with each ABOVE science theme interact and influence one another, a central focus will be to improve and apply diagnostic and predictive models with improved representation of ecosystem and landscape processes and their responses to climate and disturbance across multiple spatial and temporal scales. By design, ABOVE will incorporate multidisciplinary research and modeling frameworks that address how resilient Arctic and boreal ecosystems are to longer-term changes in environmental drivers, such as climate warming and episodic disturbance events.

ABOVE will also encourage research on the vulnerability of these ecosystems to critical thresholds that may move them into new stable states—beyond “tipping points”—where novel dynamics emerge and persist. These processes and their dynamics can only be addressed when interpreted synergistically with field observations and monitoring, analyses of remotely sensed data, and the use of this information in robust, process-oriented models.

The broad umbrella of ABOVE will ensure that all research themes and modeling efforts are incorporated in a manner that will substantially increase the ability to project realistic scenarios of environmental change and probabilities of risk into the future. Recommendations for the specific design and implementation of ABOVE from the broader scientific community will ideally focus on stimulating innovation and approaches to advance Arctic and boreal research. Participation, comments, and contributions will be essential to moving forward.

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