Tôhoku Geophys. Journ. (Sci. Rep. Tôhoku Univ., Ser. 5), Vol. 36, No. 4, pp. 380–381, 2003

Land-Atmosphere-Ice Interactions (LAII): An Interdisciplinary Study of Changes in the Terrestrial Climate System (Extended Abstract)

F. STUART CHAPIN, III

Institute of Arctic Biology, University of Alaska, Fairbanks, AK 99775, USA

(Received January 5, 2003)

1. Introduction

The program objectives of the LAII program have been the detection and analysis of change in the land-atmosphere system at regional and pan-Arctic scales, projections of these changes into the future, and implications of these changes in terms of the sustainability of the Arctic System under global change. Our approach has been the measurement of key processes over a range of temporal and spatial scales, the development of process-based models, use of these models to extrapolate in time and space, and to test these predictions in new locations.

The land-atmosphere system of the Arctic is changing. Temperatures are increasing more rapidly than at lower latitudes. This has implications for thaw depth, which correlates closely with air temperature, and for permafrost, which has warmed significantly in the last decade. In zones of discontinuous permafrost, this is causing thermokarst and the shrinkage of lakes in the Seward Peninsula. These changes are mediated by interactions among air temperature, snow, and vegetation. The consequences of these changes could be profound and may have contributed to the large increases in discharge of the major arctic rivers over the past 70 years.

Arctic vegetation is also changing dramatically. The arctic treeline is extending into tundra, and the density of trees in this transition zone is increasing. Within treeless tundra, repeat photography demonstrates that the density and extent of shrubs is increasing. Replicated experiments conducted throughout the circumpolar Arctic by ITEX (International Tundra Experiment) demonstrate that warming leads to increased shrub growth within 5–8 years. The resulting changes in community composition result from interactive changes in environment, physiological processes, and population processes. The increased shrub abundance observed in the field is consistent with satellite measures of increased NDVI (Normalized Difference Vegetation Index), a measure of plant greenness. The observations demonstrate that the transitions in the land surface have been highly nonlinear and are leading to new community assemblages.

The vegetation changes have pronounced effects on the arctic system. Some of the most important changes involve winter processes. Shrubs lead to increased depth and insulative capacity of the winter snow, which warms the soil, leading to more mineralization of carbon and nutrients and greater nutrient availability to plants the following spring, a factor that promotes the growth of shrubs. The stimulation of winter decomposition also contributes to high rates of winter respiration observed in shrublands. The positive feedback between shrubs, snow, temperature, and nutrients provides one potential explanation for the large magnitude of vegetation change that has occurred in the last half-century.

The vegetation change also feeds back to climate. Shrub tundra absorbs more radiation than moist tundra and transfers more of this energy to the atmosphere as sensible heat, creating a positive feedback to regional warming. The warming has also had substantial affects on carbon budgets, initially increasing carbon efflux and subsequently bringing carbon uptake and loss more nearly into balance. It has become increasingly clear that carbon exchange during winter plays a large role in determining whether the tundra is a net source or sink of radiatively active trace gases.

We have scaled our observations of land-atmosphere exchange to large areas in several ways. By making measurements at multiple scales (chambers, towers, aircraft), we can determine the important sources of variability at different scales. Based on these observations, maps of vegetation and soils, and models derived from them, we have extrapolated carbon fluxes to the Kuparuk Basin in northeast Alaska, the North Slope of Alaska, and the circumpolar Arctic.

The development of the LAII program has changed the way terrestrial ecologists and climatologists do science in the Arctic. Through the LAII program, the science has become increasingly interdisciplinary and has placed greater emphasis on integrating processes across temporal and spatial scales through modeling and through interactions with paleoecologists. There has also been greater emphasis on data archival in electronically accessible forms, and an increased emphasis on synthesis at all phases of the research. The program has placed substantial emphasis on outreach, for example, involving local residents and providing real-time climate data to remote communities. These advances lay the groundwork for a more integrated approach to study of the entire Arctic System and its interaction with the rest of the globe.