Recent dynamics of arctic tundra vegetation: Remote sensing, field observations, and simulation modeling

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CIRCUMPOLAR TUNDRA BIOMASS DYNAMICS

Numberous studies have explored the dynamics of arctic tundra vegetation throughout the past several decades, using remotely sensed proxies of vegetation, such as the Normalized Difference Vegetation Index (NDVI). While extremely useful, these coarse-resolution products give us minimal information with regard to how these changes are being expressed on the ground. In terms of tundra structure and function, we used a strong regression model between NDVI and aboveground tundra biomass, developed from extensive field-harvested measurements of vegetation biomass, to estimate the biomass dynamics of the circumarctic tundra over the past several decades (over the records of MODIS from 1981-2010). We found that the tundra biomass (C-E) dominates in the biomass increase, ranging from 20-36%, although there is a high degree of heterogeneity across regions, floristic provinces, and vegetation types. The estimated total sequestration of 0.40 Pg C over the past three decades is quantitative, albeit scale relative to anthropogenic C emissions. However, a 19.8% average increase in aboveground biomass has major implications for nearly all aspects of tundra ecosystems including hydrology, active layer depth, permafrost regime, wildlife, and human use of arctic landscapes. While spatially extensive on-the-ground measurements of tundra biomass were conducted in the development of this analysis, validation is still impossible without more repeated, long-term monitoring of arctic tundra biomass in the field.

SHRUB EXPANSION IN NORTHEASTERN SIBERIA

Numerous experimental and simulation modeling studies have indicated that expansion of deciduous shrubs is one of the most likely land-cover changes to accompany climate warming in Low Arctic tundra. Observational studies have corroborated these findings, particularly in the North American Arctic. However, the Eurasian Arctic has received less attention. Here, we show that the introduction of tundra-dominated regions has the potential to strongly enhance a range of biophysical attributes of arctic ecosystems, including vegetation structure, albedo, surface energy balance, and decomposition. We used a combination of in situ observations (vegetation density, height, and biomass), biophysical model simulations, and satellite data (MODIS, AVHRR, and GIMMS) to quantify changes in shrub distribution in the Russian Arctic. We found that the period of our study 1981-2005 indicated a strong "greening" across much of the site, especially in association with alder shrublands. We were primarily interested in identifying important soil- and geomorphic site characteristics related to recent alder proliferation and increases in vegetation productivity at Kharp.

We established a series of transects in alder shrublands of varying stand age to test if alder expansion is facilitated by circle microsites, and to evaluate likely impacts of shrubland development on permafrost thermal regime. We recorded soil organic depth, mineral horizon thickness, soil temperature profiles, and Leaf Area Densities (LAD) systematically along the transects and at alders. We found that alders are positively related to circle microsites, and that the soil conditions and distribution of alders in older shrublands and circle microsites are obscured by vegetation—was consistent with initial recruitment on circles.

Simulation models for High Arctic sites and declined in Low Arctic sites. Understanding the responses of the arctic tundra biome to a changing climate requires knowledge of the complex interactions among climate, soils, and the biological system. This study investigates the individual and interactive effects of climate change and reindeer grazing across a variety of climate zones and soil texture types on tundra vegetation community dynamics using an arctic vegetation model that incorporates reindeer diet area, where grazing is a function of both forage nitrogen concentration and reindeer forage preference. We found that climate is important in addition to the latitudinal and vegetation types and structural differences in tundra vegetation community composition, comprising about 13% of the total variance in model simulations for all arctic tundra subzones. The decrease in biomass of causes by grazing such as lichens, deciduous shrub and graminoid plant functional types (PFTs) is potentially dampened by climate warming. "Soil" biomass had a nonlinear response to increased grazing intensity, and such responses were stronger when warming was present. Our results suggest that ecosystem productivity may be increased by increased grazing intensity due to their low nutrient availability. Further inter-calibration between the sensors is needed to resolve the inconsistency and to better understand long-term trends of vegetation growth in the Arctic.

SEASONALITY OF CIRCUMPOLAR TUNDRA VEGETATION

RN: Phenology of vegetation is a sensitive and valuable indicator of the dynamic responses of terrestrial ecosystems to climate change. Therefore, it is important to reduce uncertainties in detecting phenological changes under a changing climate. Remote sensing and field observations have been widely used to study vegetation phenology. However, most previous studies have focused on the northern high-latitude region (LaM). Here, we use a strong regression model between NDVI and aboveground tundra phenology, developed from extensive field-harvested measurements of vegetation biomass, to estimate the biomass dynamics of the circumarctic tundra over the past several decades (1981-2010). We found that the tundra biomass (C-E) dominates in the biomass increase, ranging from 20-36%, although there is a high degree of heterogeneity across regions, floristic provinces, and vegetation types. The estimated total sequestration of 0.40 Pg C over the past three decades is quantitative, albeit scale relative to anthropogenic C emissions. However, a 19.8% average increase in aboveground biomass has major implications for nearly all aspects of tundra ecosystems including hydrology, active layer depth, permafrost regime, wildlife, and human use of arctic landscapes. While spatially extensive on-the-ground measurements of tundra biomass were conducted in the development of this analysis, validation is still impossible without more repeated, long-term monitoring of arctic tundra biomass in the field.

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