Responses of subalpine tree recruitment to warming within and above current altitudinal ranges

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Objectives: High latitude and high elevation forests are globally important contributors to carbon storage and release, and have strong regional leverage on surface energy balance and water fluxes. Highly uncertain feedbacks to climate change from dynamic shifts in forest distributions are increasingly incorporated into Earth system models, but lack data for parameterizations and quantitative benchmarks. We established the Alpine Treeline Warming Experiment at Niwot Ridge, CO, to examine effects of climate warming on tree seedling establishment near the lower limit of subalpine forest, at upper treeline, and in the alpine. We use infrared heaters to increase surface temperatures, and to lengthen the growing season. The warming treatment is crossed with a soil moisture manipulation to distinguish effects due to higher temperatures from those due to drier soil. Each plot is a common garden sown with two populations each of three species. We are asking: Will subalpine trees move into current alpine habitat and/or be impaired in their existing range as a result of climate change? And how do ecophysiological and population genetic factors influence changes in subalpine species success?

Results: During 2010-2013, heating elevated soil temperatures, with larger increases (~4.5 °C) in forest, than in alpine and treeline (1.5-2 °C) sites, reflecting differences in wind speed and heater efficiency. Heating alone tended to slightly reduce soil moisture, while heated and watered plots were not systematically wetter or drier than controls, as intended. In 2012, heating advanced snowmelt dates by 10-40 days. Preliminary analyses show that heating reduced germination for two species and, in most years, had no or negative effects on survival to 2 years in the forest, while watering increased demographic rates, consistent with expectations of reduced recruitment at lower elevations with warming and drying. At treeline, heating also reduced germination, but had year-dependent effects on survival to 2 years. In the alpine, contrary to expectations, experimental heating did not increase germination or survival, while watering increased survival to two years. In alpine and treeline sites, ecophysiological and microclimate measurements indicate increased exposure of seedlings to summer water stress with warming, resulting in lower net carbon assimilation that offset increased assimilation due to reduced cold stress. Observed differences among species in temperature and moisture thresholds may explain differences in response to treatments. Meta-population models offer an opportunity to bridge experimental results to landscape scales and establish benchmarks for shifts in forest tree distributions with climate change.