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The south Siberian mountain treeline ecotone response to climate change

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Models predict climate-driven changes of vegetation pattern. The most significant climate-induced air temperature increase is observing in Siberia. Tree response to climate trends is most likely observable in the forest-tundra ecotone, where temperature limits tree growth.Here we show that trees in the forest-tundra ecotone of the south Siberian Mountains responded strongly to warmer temperatures during the past three decades. There was growth increment increase, stand densitification, regeneration propagation into the alpine tundra, and transformation of prostrate Siberian pine, larch and fir into arboreal forms.

A temperature increase of 1Ñº allows regeneration to occupy areas 40 - 100 m higher in elevation, depending on site. Siberian pine and larch regeneration and arboreal forms now occur at elevations up to 200 m higher in comparison with the known location of the former tree line. These species surpass its upper historical boundary on 10-80 m in elevation.

Tree stands occupies slopes with small (up to 10º) and high ($>$20º) steepness mainly. Stand distribution with respect to azimuth is north-oriented for the heights $<$2000 m, which is cased by water limit on the southern slopes. At heights $>$ 2300 m. the wind direction becomes the dominating factor of a tree survival: azimuth distribution corresponds to a wind rose.

Regeneration is propagating into the alpine tundra with the rate of 0.5 – 2.0 m/yr. Observable winter temperature increases is significant for regeneration survival.

Measurements of the radial and apical growth increments indicates an acceleration of krummholz transforming into arboreal forms in the mid - 1980's. Larch surpasses Siberian pine in cold resistance, and has arboreal growth form where Siberian pine is in krummholz form.

Dendrochronology analysis of fossil trees showed that during last millennium tree mortality was mainly in 17^{th}-18^{th} centuries, following period of cooling. During more than two hundred years there were no trees in the present forest-tundra ecotone (elevation belt about 2300-2600 m a.s.l.). The new wave of tree establishment refers to begin of XX century.

Improving climate provides competitive advantages to Siberian pine in the areas with sufficient precipitation amount. Larch, as a leader in hush environment resistance, received an advantage at upper front tree line, and in the areas with low precipitation.

Observed tree migration into alpine stony tundra will decrease albedo, which may provide positive feedback for warming at regional level.