

## **Tree Waves Upward Migration in the Altai Mountains, Siberia**

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The phenomenon of “tree waves” (hedges and ribbons) formation within the alpine ecotone in Altai Mountains and its response to observed air temperature increase was considered. At the upper limit of tree growth Siberian pine (*Pinus sibirica*) forms hedges on windward slopes and ribbons on the leeward ones. Hedges were formed by prevailing winds and oriented along winds direction. Ribbons were formed by snow blowing and accumulating on the leeward slope and perpendicular to the prevailing winds, as well as to the elevation gradient. Hedges were always linked with microtopography features, whereas ribbons were not. Trees are migrating upward by waves and new ribbons and hedges are forming at or near tree line, whereas at lower elevations ribbons and hedges are being transformed into closed forests.

Time series of high-resolution satellite scenes (from 1968 to 2010) indicated an upslope shift in the position ribbons averaged  $155 \pm 26$  m (or  $3.7$  m yr<sup>-1</sup>) and crown closure increased (about 35–90%). The hedges advance was limited by poor regeneration establishment and was negligible. Regeneration within the “ribbon zone” was approximately 2.5 times (5060 vs 2120 ha<sup>-1</sup>) higher than within the “hedges zone”.

During the last four decades, Siberian pine in both hedges and ribbons strongly increased its growth increment and recent tree growth rate for 50 year old trees was about twice higher than recorded for similarly aged trees at the beginning of the 20th century. Growth increment increase was strongly correlated with CO<sub>2</sub> concentration in the ambient air ( $R^2 = 0.9$ ), which may indicated CO<sub>2</sub>- fertilization. Hedges and ribbons are phenomena that are widespread within the southern and northern Siberian Mountains