david.kienle@web.de

Mass elevation effect, continentality and isolation - drivers of global treeline elevation?

David Kienle[1], Severin D.H. Irl[1], Carl Beierkuhnlein[1]

[1] Department of Biogeography, University of Bayreuth

www.biogeo.uni-bayreuth.de

Background

Treelines are one of the few fundamental borders in ecology, separating forests from treeless alpine systems. Their physiological implications have been widely investigated, however their implications on global patterns are rarely analyzed.

Treeline elevation has been described to be positively influenced by both mass elevation effect (MEE) and continentality. MEE decreases cloudiness and increases local air temperatures in the interior of large mountain chains, while continenatility (distance to ocean) increases temperatures during the growing season. Comprehensive quantifications of both MEE and continentaility are missing.

Leuschner (1996) proposed treeline elevation to decrease with isolation on islands. How isolation influences treeline elevation in general, is currently unknown.

We hypothesized that globally treeline elevations i) **increase with increasing MEE**, ii) **increase with increasing continentality** and iii) **decrease with increasing isolation** (by decreasing probability that a high elevation-adapted tree species occur).

Methods

We sampled the currently largest dataset of global treeline elevations (672 treeline sample points, 1051 absence points) by using GoogleEarth images, enabling a global coverage of treeline elevations (74° N to 66° S).

MEE was calculated based on nearest distances to outlines of mountain chains. These outlines were defined as lowest contour polygons of a coarsened digital elevation model (50 x 50 km raster cells, 1000 m elevation levels). Continentality was measured with nearest distances to the coastline.

A global isolation map has been calculated for each elevation based on nearest distances to locations with similar elevations (elevational levels of 100 m).

To consider the global relationship of treeline elevation on latitudes all linear regressions were calculated based on the residuals of a quadratic regression which explains treeline elevations with latitudes ($p < 0.001$, $R^2 = 0.66$). Continentality and isolation were illustrated in quartiles to emphasize variance heterogeneities.

Results

The global latitudinal pattern showed a distinct double hump with highest treelines around 20° S and 30° N (fig. not shown). In the equatorial tropics only few treeline samples were found.

With increasing distances to mountain chain outlines treeline elevations increased significantly (Fig. 1).

Treelines increased with increasing continentality (Fig. 2). The effect was measurable independent of the MEE (not shown, $p < 0.001$).

Treeline elevations decreased with increasing isolation distances (Fig. 3). With decreasing latitude (except for the equitorial tropics) the differentiation of latitudinal bands showed an increasing variance between isolation classes due to a higher isolation potential.

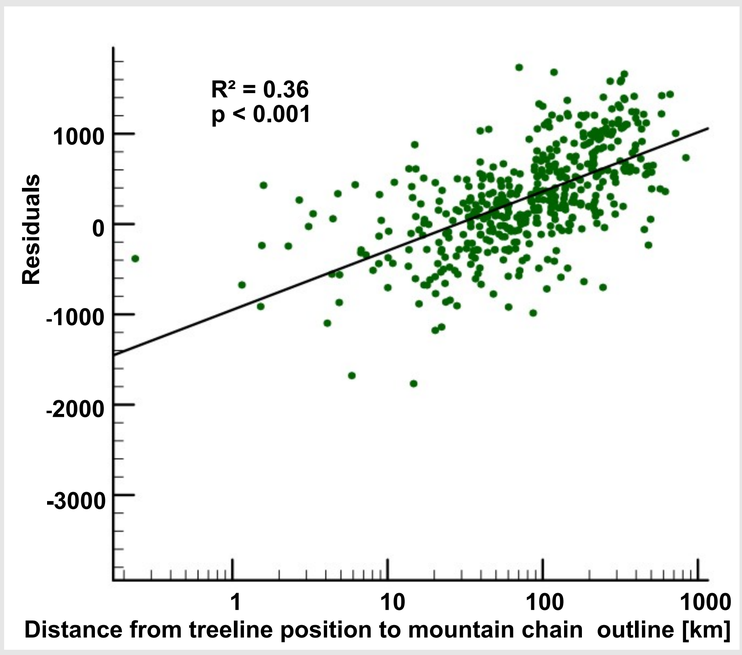

Fig. 1. Treeline elevations increase with increasing **mass elevation effect**.

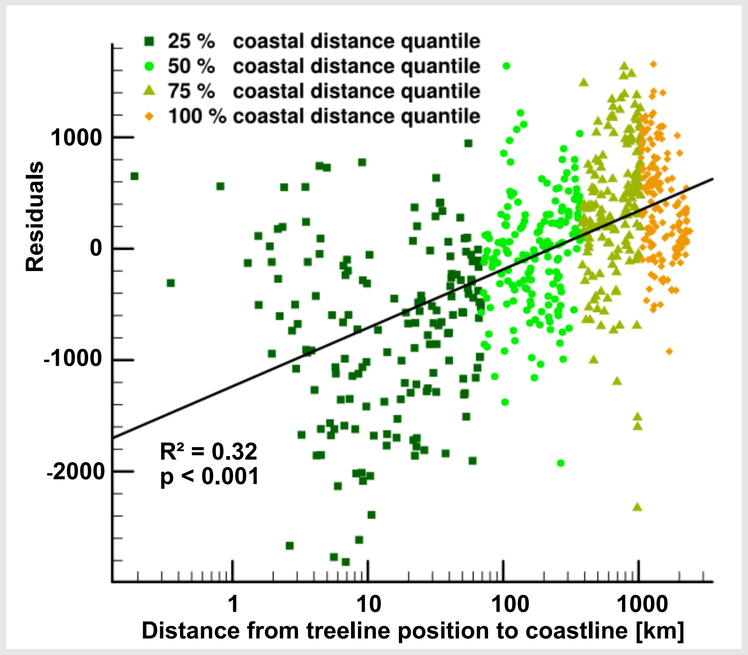

Fig. 2. Treeline elevations increase with increasing **continentality**.

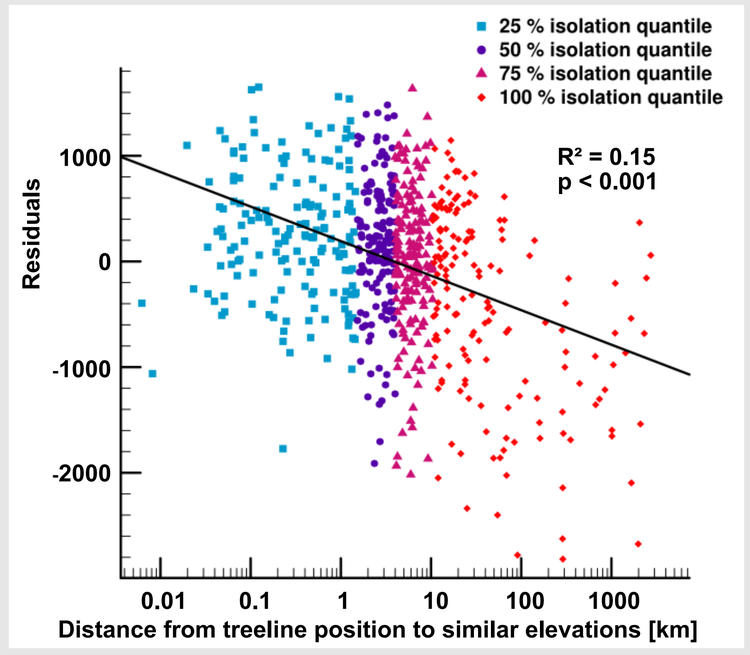

Fig. 3. Treeline elevations decrease with increasing **isolation** between mountain systems.

Discussion & Conclusions

Global treeline pattern showed a marked subtropical double-hump, as described by Troll (1948), who explained the tropical depression with diurnal climate (strong diurnal cloud formation and unpredictable frost events). However, our results suggest that lacking high mountains and the strong isolation between the exisiting tropical mountains drive this pattern.

The **MEE and continentality positively affected treeline elevation**, probably because **increased solar radiation** and **minimum growth temperatures** (which are the most commonly accepted physiological explanations of treelines (Körner, 1998)) lead to better conditions of tree establishment.

It was shown that MEE and continentality are **distinguishable drivers** although they have the same ecological effectiveness on treeline elevations. **Treeline elevations decreased with increasing distance** to areas of equal elevation due to **low rates of immigration of high elevation-adapted tree species**.

In Addition to Körner's (2012) conclusion, MEE, continentality and isolation are global geographic drivers of treeline elevations besides of latitudes.

Further References

Körner C. (1998) A re-assessment of high elevation treeline positions and their explanation. *Oecologia*, **115**, 445-459.

Körner C. (2012), *Alpine treelines*. Springer, Basel.

Leuschner C. (1996) Timberline and alpine vegetation on the tropical and warm-temperate oceanic islands of the world: elevation, structure and floristics. *Vegetatio*, **123**, 193-206.

Troll C. (1948) Der asymmetrische Aufbau der Vegetationszonen und Vegetationsstufen auf der Nord- und Südhalbkugel. *Bericht über das Geobotanische Forschungsinstitut Rübel zu Zürich*, **1948**, 46-83.