Reconstruction and Prediction of Variations of Total Ozone and Associated Variations of UV-B Solar Radiation for Subarctic Regions Based of Dendrochronologic Data

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Introduction

Variations of dendrochronologic parameters, especially annual ring density, significantly reflect the physiological tree response to systematic variations of solar UV-B radiation. These responses take place on monthly timescales that are longer during growing season. Such variations of UV-B radiation are totally governed by variations of total ozone (TO). Thus, in any dendrochronologic signal, especially for coniferous trees, there is also a recorded response to TO variations, characterizing variations of UV-B radiation.

Because global TO distribution has been regularly monitored since 1979 using total ozone mapping experiment spectrometer (TOMS) satellite instrumentation, it is possible to reconstruct past TO behavior at practically any point on the dendrochronologic monitoring network. Reconstruction is performed using linear regression based on significant correlation of annual ring density of coniferous trees and TO for coordinates of the denrochronologic signal (Zuev and Bondarenko 2002, 2003). The present report considers the subarctic latitudes, which are characterized by considerable TO variations in the second half of twentieth century.

We analyzed a set of dendrochronologic data for the subarctic regions and selected chronologies according to the maximum density of annual tree rings of coniferous species. We focused on the Siberian spruce and ordinary pine, which grow in plain terrain 25-300 m above sea level (26 chronologies in all). Statistical analysis of dendrochronologic and TO data for the warm period between May and September has shown a significant correlation for a sample of 13-16 points. Unfortunately, dendrochronologic data that are available on the Internet for the chosen region end in 1992-1994. Higher correlation coefficients between TO and annual ring density were obtained for the Siberian spruce (0.8-0.96) and at a significance level for the pine (0.5-0.66).

The results of TO reconstruction for certain coordinates, namely 61°3 N/59°3 E (North Urals) and 65°35 N/69°5 E (Lower Reaches of Ob), are in Figure 1.

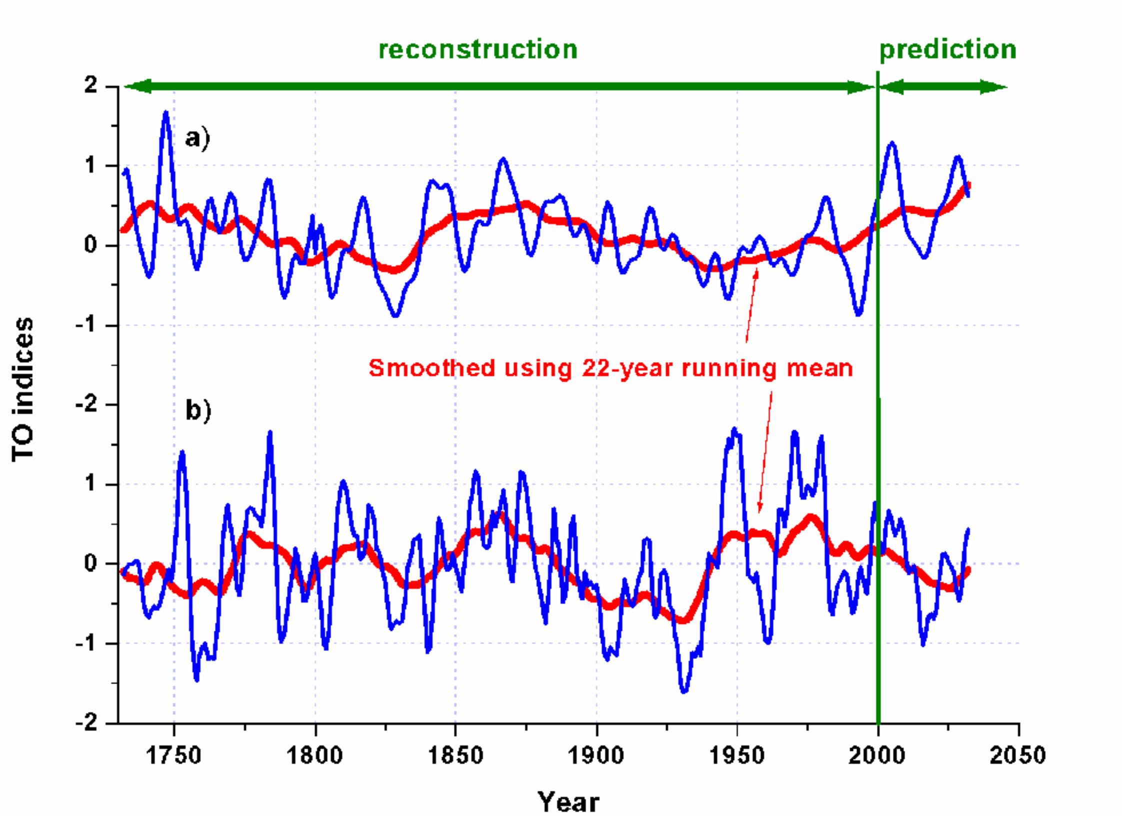

Figure 1. Results of long-term prediction of ozonosphere variations from reconstructed data for the regions of (a) North Urals and (b) West Siberia.

Figure 1 also shows predicted TO behavior for these coordinates; the confidence of this prediction is determined by the length of the reconstructed time series. As seen from Figure 1, for neighboring regions of North Urals and Lower Reaches of Ob, the behavioral tendencies of TO indices are almost 180° out of phase for the aforesaid regions. This is due to spatiotemporal inhomogeneity of the TO field, caused by atmospheric circulation. This is clearly seen in Figure 2, which is based on instrumented TOMS data obtained for meridional variations along subarctic latitude 63°.

Because of such TO behavior, it is difficult to obtain a generalized TO chronology for long-term UV-B radiation variations in entire subarctic latitudinal belt. For this purpose, the studied sample of reconstructed TO chronologies was differentiated into groups using cluster analysis.

Figure 3 presents a clustering of a studied sample of 26 chronologies for different coordinates. Numbers identify groups for averaging reconstructed TO chronology; we used 7 (1), 12 (2), and 7 (3) chronologies.

These three generalized TO chronologies in absolute values for the subarctic, smoothed using a 50-year running mean, are presented in Figure 4. They reflect the most typical UV-B radiation behavior for much of the subarctic Eurasian region.

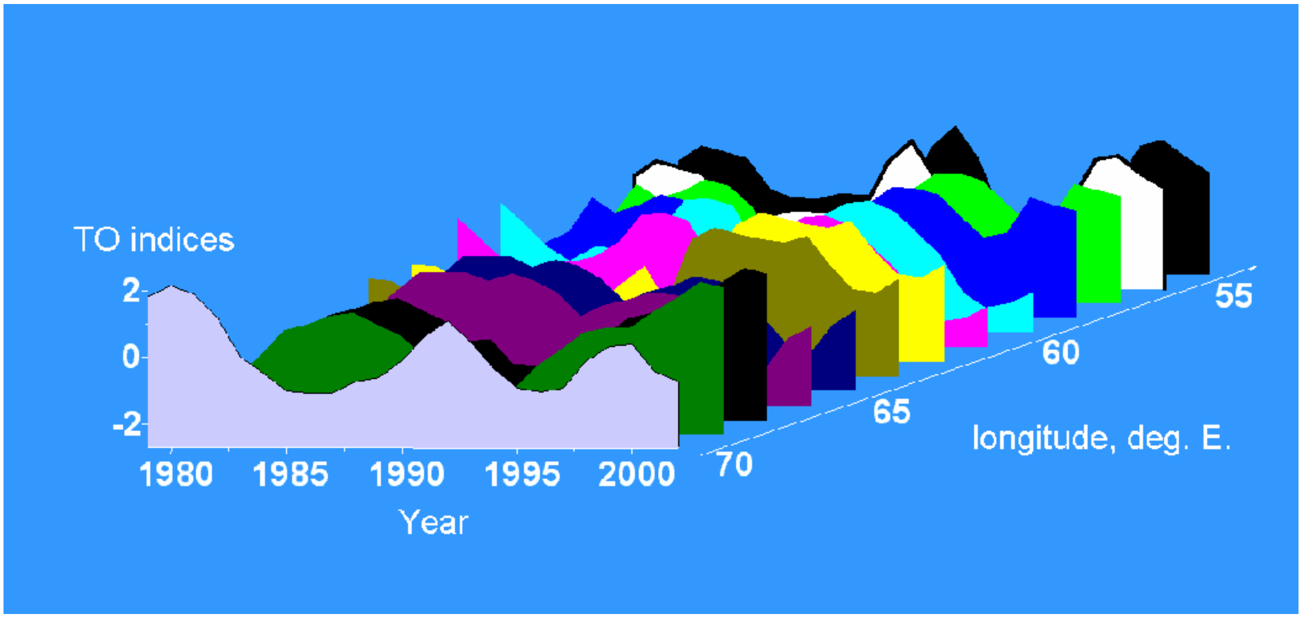

Figure 2. Spatiotemporal inhomogeneity of the TO field from TOMS data for the Subarctic.

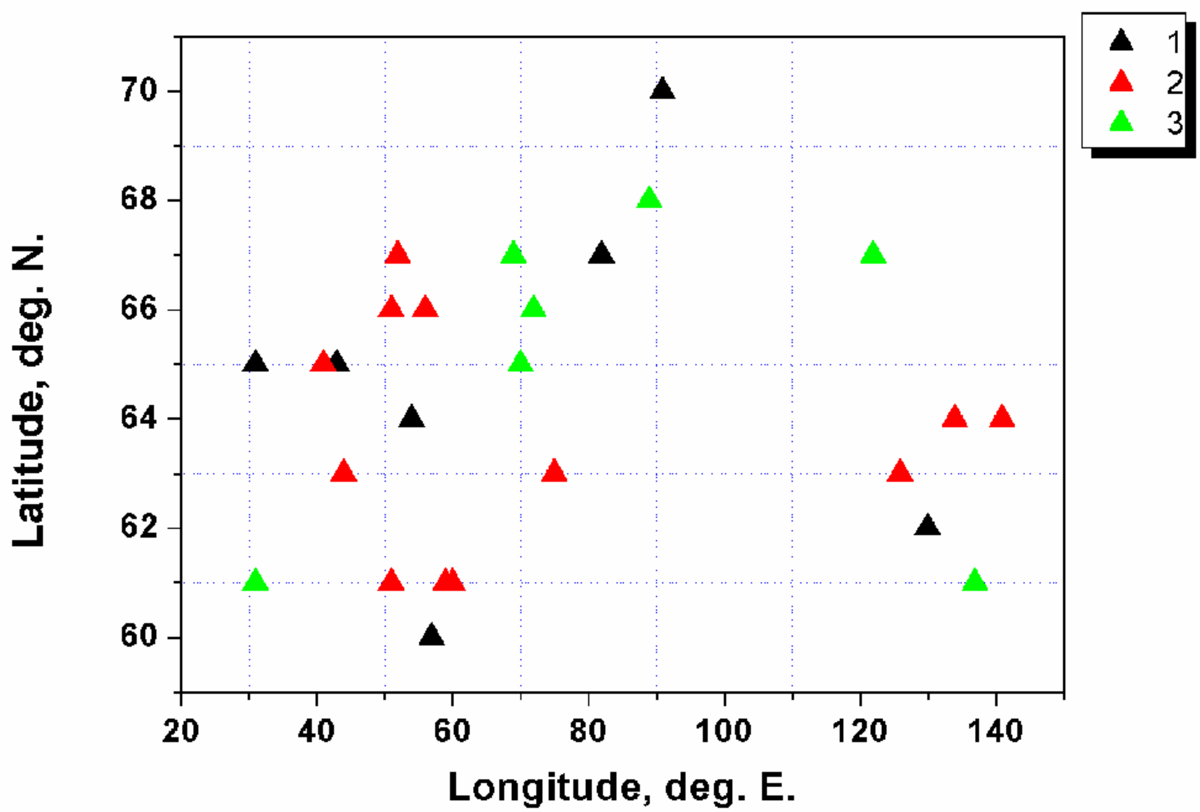

Figure 3. Three groups of TO chronologies after cluster analyses.

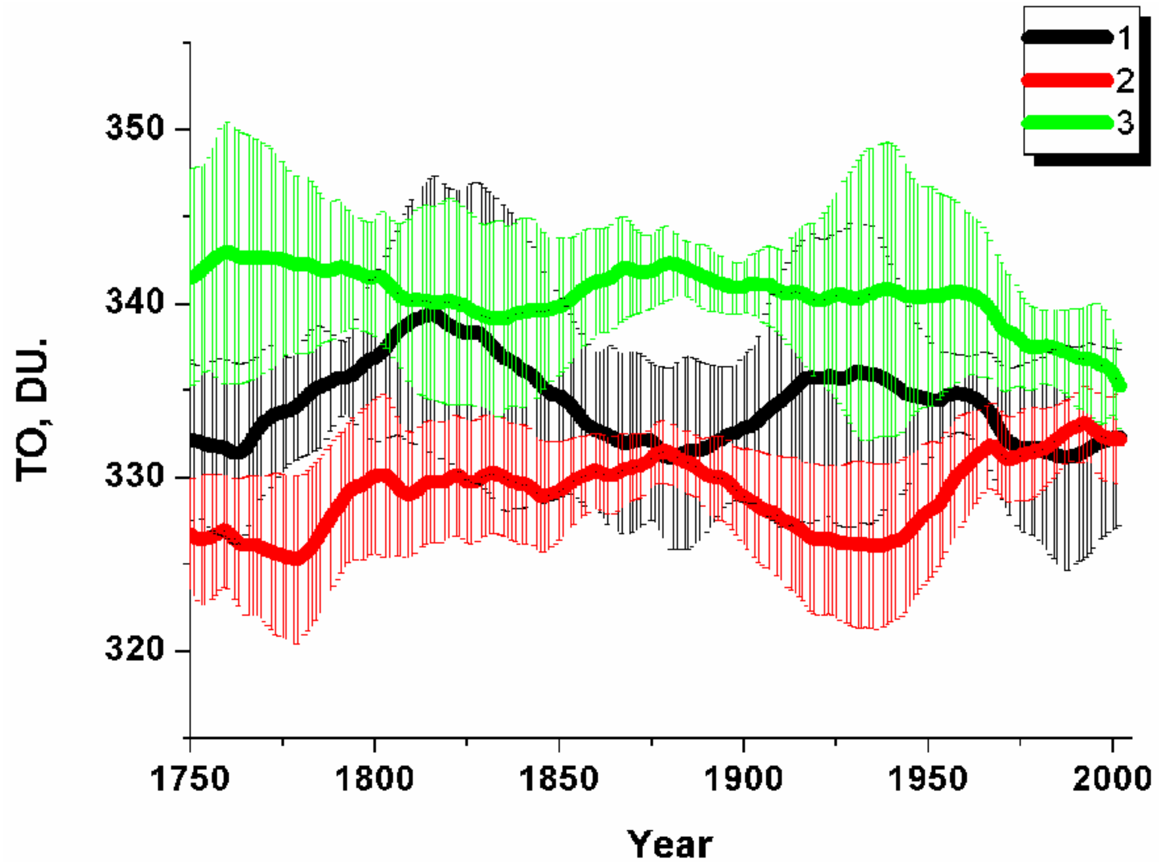

Figure 4. Three generalized TO chronologies.

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References

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