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The effects of UVB radiation on temperate southern hemisphere forests

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Solar UVB has a variable but generally modest effect on the morphology and growth of forest trees, but may modify forest community composition.

Abstract

The temperate forests of the southern hemisphere are the most likely forests to be affected by increased levels of ultraviolet-B (UVB) radiation resulting from reduced ozone. The review describes these forests and then discusses the morphological changes, physiological effects, and protection mechanisms, particularly UV absorbing compounds that result from present day and increasing UVB radiation. Possible avenues for future research are explored.

Keywords: UVB; Southern hemisphere; Forest; UV effects; Ozone depletion

1. Introduction

There is little doubt that UVB levels are increasing as a result of stratospheric ozone depletion. A number of studies are now reporting ozone related increased levels of UVB (280–320 nm) in both southern and northern hemisphere sites (review, McKenzie et al., 2003). Forests cover vast areas of the globe and may account for over two-thirds of terrestrial primary productivity (Barnes et al., 1998). Yet studies on the effect of UVB radiation on forest tree species have been few in number, even in northern hemisphere forests, where their economic and ecological significance is recognized (e.g. DeLucia et al., 1994; Schnitzler et al., 1997; Sullivan et al., 2001; and other papers in this volume). Very little work has been done on southern hemisphere forest species, and that which has been published is from New Zealand and South America (e.g. Hunt et al., 1996; Searles et al., 2002; Therburg et al., 2001). There are no southern African forest studies and only one from Australia (Close et al., 1999).

This lack of research effort is unfortunate because the temperate forests of the southern hemisphere region may be more vulnerable to the consequences of stratospheric ozone depletion than forests in northern regions. This is because the ozone hole that forms over Antarctica is much larger than the depletion that forms over the northern polar cap in the northern winter and early spring. The increases in biologically harmful solar UVB radiation that result from this are likely to be of a larger scale than in the northern hemisphere (Madronich et al., 1998). In addition, the earth has a slightly asymmetric orbit around the sun, placing it closest to the sun during the southern hemisphere summer and this results in naturally higher summertime fluxes of UVB radiation (McKenzie et al., 2001).

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Atmospheres over southern latitudes also tend to have lower turbidity and lack the pollution of the industrialized north. Both of these factors lead to the transmission of higher levels of harmful UVB radiation in the south, and have been present since before the Antarctic ozone hole was first reported (Farman et al., 1985). This indicates that the region is already predisposed to higher fluxes of UVB radiation. Perhaps it is fortunate that the lack of suitable land masses and climatic differences prevents the southern hemisphere forests from reaching the same high latitudes as those in the northern hemisphere. Nevertheless, it is important that further research on southern hemisphere forests be undertaken urgently. Global climatologies based on satellite imagery as well as data from ground based measurements are available on the web and in the literature (Cede et al., 2002; McKenzie et al., 2001), which provide essential data for studies on effects of UVB on plant ecosystems.

Since the polar vortex normally confines ozone-depleted air to the Antarctic region, the direct effect of the ozone loss is generally not felt in mid-latitude countries like New Zealand and Australia. In fact ozone levels at these mid-latitudes reach their annual maximum during spring time, when ozone losses are maximal over Antarctica. The ozone poor air from Antarctica is eventually redistributed over the southern hemisphere in summer, and is a contributor to the summertime ozone losses of 10–12% that have occurred over New Zealand in the last two decades (McKenzie et al., 1999). These trends in ozone levels mean that UVB levels are highest in southern hemisphere mid-latitude zones during late summer (Smith et al., 1993; Ryan et al., 1996).

Tierra del Fuego, on the southern tip of South America, is sufficiently far south that ozone-depleted air associated with Antarctic stratospheric ozone depletion is periodically directly overhead (Fig. 1). As a result, Tierra del Fuego experiences more pronounced ozone reduction than any other region in the world where terrestrial plant ecosystems occur (Rousseaux et al., 1999; Abarca and Casiccia, 2002). The area has received the greatest change in solar UVB radiation outside of Antarctica and therefore provides a particularly interesting and useful case study. Rousseaux et al. (1999) note that the frequency and persistence of periods of very low ozone values (<250 DU) has increased noticeably during the last 20 years. During periods of poor ozone cover in spring in Tierra del Fuego, Frederick et al. (1993) have estimated that the increase in UVB is equivalent to shifting the region further north by some 20° latitude and increasing the erythemally effective irradiance by 45%. This area is of particular importance because it is dominated by temperate *Nothofagus* forests.

Rarely, reduced ozone levels resulting from the export of ozone poor plumes can occur during summer. However, the impact of these events on surface UV is generally smaller than the natural day-to-day variability because the perturbation is confined to a small part of the total ozone vertical profile. One example where increased UV occurred as a result of redistributions of ozone poor air was in December 1998. This resulted in an increase in UV over New Zealand of ~10% at a time when UV levels were already extreme (Ajtic et al., 2002, 2003).

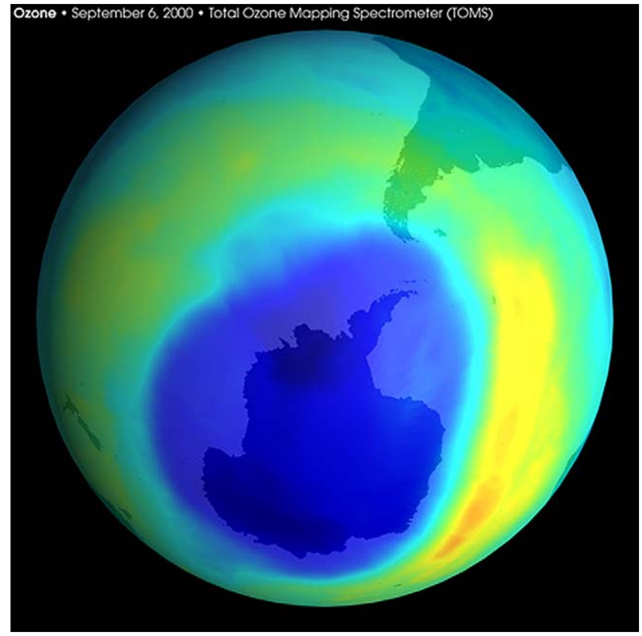

Fig. 1. Total Ozone Mapping Spectrometer (TOMS) image showing the ozone hole on 6 September 2000, extending onto the southern tip of South America.

Many plants grow poorly under enhanced levels of UVB flux (Caldwell et al., 1998) although different species and even different varieties (Hofmann et al., 2000) vary in their sensitivity. This review is limited to the temperate forests of the southern hemisphere as it is these that are the most likely to be affected by increased levels of UVB resulting from reduced ozone. The review will describe these forests and then discuss the morphological changes, physiological effects, and protection mechanisms, particularly UV absorbing compounds that result from present day and increasing UVB radiation.

2. The southern forests

2.1. Australia

Australia is situated between latitudes 10° and 44° S (including Tasmania) and is one of the oldest land surfaces in the world. Much of Australia was subjected to erosion and severe weathering during the Tertiary (20–60 m years ago) and now there are large areas of strongly leached, nutrient poor soils.

Desert, semi-desert and other dry-land vegetation occupy vast areas of central Australia and cover 40% of