

The effects of UVB radiation on southern temperate forests

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Abstract. Although forests cover vast areas of the globe, there are few studies on the effects of changing UVB radiation on forest growth or ecosystem function. Data on southern hemisphere trees are sparse but when combined with northern hemisphere studies they suggest that: the productivity of trees is generally not substantially reduced by a modest increase in UVB, especially where trees are already under some sort of physiological stress. The more subtle ecosystem effects, such as changes in species composition and herbivore interactions, are yet to be studied.

Introduction

Increases in solar UVB levels are now well documented in both the southern and northern hemispheres (McKenzie *et al.* 2003). Plants respond to UVB in a variety of ways and not surprisingly, most studies have been carried out on annual agricultural species. Studies of the effects of UVB on tree species are sparse considering they account for two thirds of terrestrial primary productivity, are important for carbon cycling and storage, and cover vast areas of the globe. Most studies are of northern hemisphere trees and there are only a few southern hemisphere (SH) species have been investigated (Ryan and Hunt 2005).

UV in the Southern Hemisphere

UVB intensities in the SH are higher than from similar latitudes in the northern hemisphere. These differences are predominantly due to a lower amount of ozone and increased atmospheric clarity in the SH. Peak levels of UV in New Zealand have increased by 10-15% in the last 2 decades (McKenzie *et al.* 1999). Temperate forests in the SH may be more vulnerable than northern hemisphere forests to a decrease in stratospheric ozone due to the higher UV doses and their proximity to the Antarctic ozone hole. Since the polar vortex confines the ozone depleted air to the Antarctic region, the direct effect of ozone loss is not felt in most mid-latitude countries. However, during the breakdown of the polar vortex, this ozone poor air is redistributed across the SH. The beech forests of Tierra del Fuego are sufficiently far south to be directly effected by the ozone hole (Figure 1). Dramatic short-term fluctuations in ozone can occur resulting in an increase of up to 45% in UVB.

The southern forests

The four main temperate, forested land masses in the SH are Australia, New Zealand, southern South America and

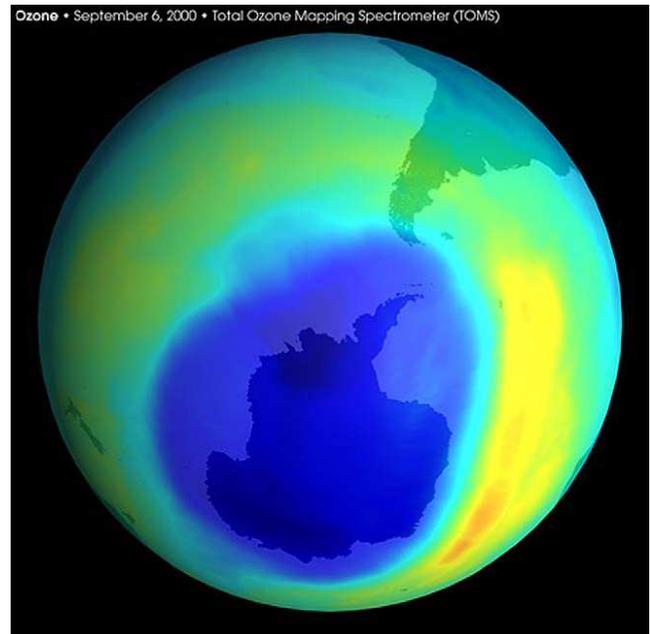


Figure 1. Total Ozone Mapping Spectrometer (TOMS) image showing the ozone hole on 6 September 2000, extending onto the southern tip of South America.

South Africa. The landscapes of Australia and South Africa are very old and in stark contrast to the recently glaciated and tectonically active landscapes of New Zealand and South America. Although all four countries were formally part of Gondwanaland, South Africa separated before the evolution of the southern beeches (*Nothofagus*) and, although it is a major centre of biodiversity, it has only a few tree genera in common with the other three countries. In Australia, *Eucalyptus* and *Acacia* species dominate 95% of the forests biomes, while the cool moist southern forests are dominated by *Nothofagus* species.

Beech species form a major element in most New Zealand and southern South America forests. While all the New Zealand beech species are evergreen, over half of the Southern American beeches are deciduous.

General UVB effects on plants

Some 400 plant species have been screened for sensitivity to UVB radiation, with about two thirds showing sensitivity of some parameter (Sullivan and Rozema 1999). Unfortunately, the sheer size of trees makes them difficult subjects to manipulate and study. Most studies used either whole seedlings or just leaves. Generally, UVB is either supplemented using artificial UVB sources, or UVB is reduced using cutoff filters. Each has its own associated

advantages and limitations. Early studies used excessive doses of UVB or radiation sources with inappropriate wavelengths. When combined with low levels of photosynthetically active light, dramatic damage occurred. More realistic lighting techniques are now regularly used.

General plant response to increases in UVB include a reduction in biomass and height, smaller and thicker leaves, an increase in reflective surface waxes, an increase in UVB absorbing compounds and antioxidant defense systems (Searles *et al.* 2001). There are also direct effects on photosynthesis and stomatal conductance. Some species are extremely tolerant and some are sensitive to UVB. Substantial genetic variability within a single species can also affect UVB tolerance. Long-term experiments suggest that accumulation of effects from one year to the next may occur in evergreen trees, but not in deciduous trees, making them generally resistant to increases in UVB. (Julkunen-Titto *et al.* 2005).

UVB studies on SH trees

There have been fewer than 20 papers on the influence of UVB on SH tree species. Most have used UVB filters to investigate the effects of the present-day levels of UVB on plant biomass and secondary leaf compounds. The tree species studied are predominantly from New Zealand and South America, with only one study from Australia and none from South Africa. Most studies have concentrated on *Nothofagus* species. This leaves us with a sparse and biased view to generalize about the effects of UVB on temperate SH forests.

Short-term exclusion of UV had little effect on plant growth of the deciduous South American *N. antarctica* but long-term exposure to UVB reduced branching frequency and some other growth parameters (Robson *et al.* 2003). In a similar experiment on the New Zealand evergreen *N. solandri* UVB reduced height growth and leaf production (Hunt and McNeil 1999). Other experiments on the role of UVB on SH trees using natural gradients in UVB intensity have been complicated by co-varying environmental parameters.

The production of phenolic compounds in leaves exposed to UV is a dynamic process, where an increase in UV leads to a subsequent increase in these UV absorbing compounds. However, this response is not instantaneous and, in *Nothofagus* species, may take a number of weeks to accumulate the required protection (Hunt and McSeveny 2002). This suggests that short-term changes in UVB may be more detrimental to plant growth than their absolute dose would suggest. These conditions are likely when there is a sudden change in forest canopy or cloud cover, or large changes in stratospheric ozone - as can happen in Tierra del Fuego.

Trees growing under some form of stress are generally more tolerant of UVB. This suggests that adaptation to one stress may confer greater resilience to elevated UVB. For instance, trees growing in Mediterranean climates (e.g. dry Australian and South African forests) with prolonged drought are well protected from increases in UV-B (Paoletti 2005). Also, plants growing in mineral deficient

soils are less sensitive to UVB. As yet there are not enough studies of SH trees to look at UVB along evolutionary lines but from NH studies, deciduous woody species in general express quite high resistance to UVB.

Conclusions

Northern hemisphere studies suggest that in general, the productivity of most trees is not substantially reduced by a modest increase in UVB. Therefore, it is unlikely that large-scale changes in biomass or species dominance will occur in the temperate SH forests with a small increase in UVB (< 20%). However, forest trees differ in their response to UVB radiation. The present day levels of UVB can affect the growth and physiology of some important SH tree species. Current levels of UV play an important ecological role in competitive ability of different species and its role in plant/herbivore interactions needs further studies. The ecological effects of increased UVB will most likely occur in well watered, fertile habitats and may have more influence on species and trophic interactions than on productivity and biomass.

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