New Zealand's "World Avoided" by the success of the Montreal Protocol

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Abstract. We present an estimation of the consequences of unrestrained, market-driven growth in ozone-depleting substances post-1975 on ozone, ultra-violet radiation, and skin-cancer occurrence in New Zealand. In agreement with other modelling studies, we find substantial year-round depletion of the ozone layer, corresponding increases of UV such that by 2060, even wintertime UV becomes similar to present-day summer UV, and increases in the occurrence of skin cancer. The actual increase in skin cancer occurrence in New Zealand due to historic and expected ozone depletion is relatively small compared to what would have also happened in the absence of man-made ozone depletion, due to a variety of other factors that dominate the skin cancer risk in New Zealand. Hypothetical large depletion of the ozone layer could have further increased the occurrences of skin cancers, although by 2030 this is still not substantial because of the long time lag between exposure to UV and skin cancer occurrence. However, post-2030 we predict a very substantial increase caused by historically unprecedented high UV in the World Avoided scenario.

Introduction

The World Avoided describes what would have happened to the ozone layer, and consequently to ultraviolet radiation and skin cancer occurrence world-wide, had ozone-depleting substances been allowed to grow unrestrained by regulation under the Montreal Protocol (Prather et al., 1996; Velders et al., 2007). In such a market-driven world, one assumes that these substances would have grown exponentially. World-Avoided scenarios have been simulated using chemistry-climate models (Morgenstern et al., 2008; Newman et al, 2009; Garcia et al., 2012; Egorova et al., 2013); the results illustrate the wide-ranging success of the Montreal Protocol, not only in saving the ozone layer, but also in protecting climate and the hydrological cycle (Morgenstern et al., 2008; Garcia et al., 2012; Wu et al., 2012). All of these would have been affected by aggravated ozone depletion. The extreme ozone depletion characterizing this scenario (figure 1) causes a corresponding increase in ultra-violet radiation (Newman and McKenzie, 2011). As for the health effects, Van Dijk et al. (2013) calculate that by 2030, world-wide 14% of skin cancer cases have been avoided by the Montreal Protocol world-wide, corresponding to millions of cases. Here we assess what the World Avoided scenario would have meant for New Zealand, regarding ozone, UV, and skin cancer.

Results

The "World Avoided" scenario considered here involves a 3% per year increase of ozone depleting substances starting in 1975 and running up to 2065. Figure 2 show projected changes in ozone and the UV index, respectively, at 40°, using a coupled-chemistry climate model forced with this scenario (Newman et al., 2009). The relatively unperturbed ozone layer of the 1980s had, in this simulation, a thickness of 300-380 Dobson Units (DU), depending on season. In the World Avoided scenario, this drops to 80-150 DU; these ozone levels would year-round and globally satisfy a commonly used definition of an "ozone hole". Correspondingly, the UV index would increase, under summer solstice noontime conditions, by a factor of 2.5 in the Northern Hemisphere, and by more than a factor of 3 in the South. It would then exceed the global maximum found today in the most UV-exposed populated region on Earth, the Altiplano region of South America. Most of this increase occurs after 2040. Winter UV indices in 2065 would be more typical of summer values today.

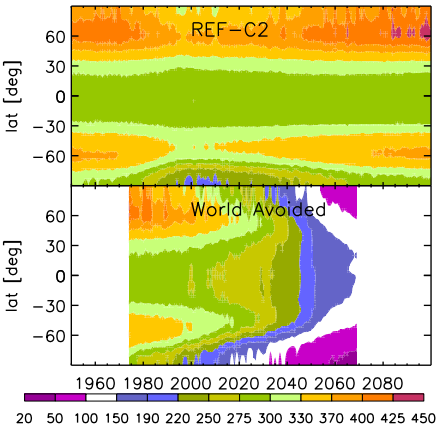

Figure 1. Zonal- and annual-mean total-column ozone (Dobson Units) simulated using the NIWA-UKCA model. Top: Average of 4 reference simulations, each spanning 1950 to 2100, assuming compliance with the Montreal Protocol. Bottom: World-avoided simulation spanning 1974 to 2070.

Figure 3 shows corresponding projected changes in skin cancer incidence rates (from Van Dijk et al., 2013) for New Zealand (35-45°S), where the current mortality rates from melanoma skin cancer are the highest in the world. Incidence rates for all forms of skin cancer are expected to increase markedly over the remainder of the 21st century, due mainly to changes in demographics (i.e., an aging population). The difference between the grey and black curves show the impact of past ozone depletion. Due to the success of the Montreal Protocol, the effect is small and peaks around the middle of the century, about 50 years after the maximum ozone depletion occurred. The brown symbols (circles) show the estimated total skin cancer rates that would have occurred in 2030 in the "World Avoided". While much bigger than the impact of the actual ozone depletion, the effect is only a minor fraction of what is anyway expected in current projections. Note that because of the long time lag between exposure and diagnosis, this represents the effects of relatively modest ozone depletion early on (around year 2000) in the World Avoided scenario.

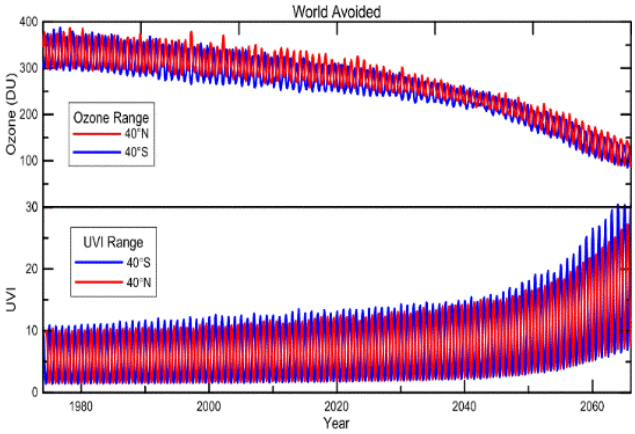

Figure 2. (top) Predicted zonal-mean ozone layer thickness and (bottom) UV indices for local noon under cloud-free conditions at (red) 40°N and (blue) 40°S.

However, in this scenario ozone depletion accelerates rapidly after 2050 (Newman and McKenzie, 2011; see figure 2), which would lead to much more extreme incidence rates by 2100.

The lower panel in figure 3 shows the equivalent results for the south-western United States, identified by Van Dijk et al. (2013) as the region with the largest projected increase in all forms of skin cancer. Apart from the overall larger rates of skin cancer occurrence (to do with the high altitude and demographics of this region) and a somewhat larger impact of the Montreal Protocol, the results are similar to those for New Zealand.

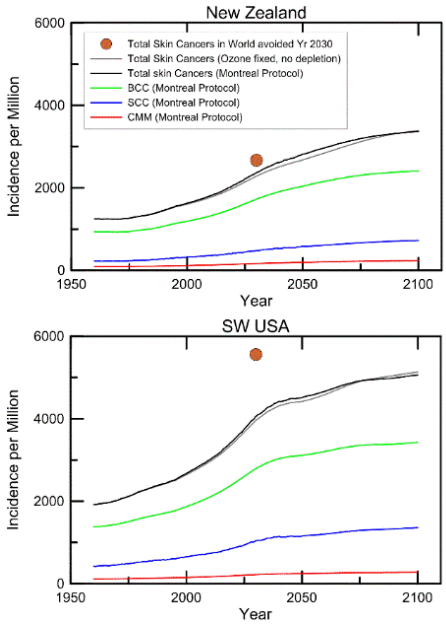

Figure 3. Incidence of skin cancers by type in New Zealand and the south-western United States. Black: Total predicted skin cancer occurrence assuming compliance with the Montreal Protocol. Grey: Skin cancer occurrence in a no-anthropogenic ozone depletion scenario. Colours: Difference skin cancer types. Orange dot: Projected skin cancer occurrence in 2030 in a World-Avoided scenario (Van Dijk et al., 2013).

Conclusions

Simulations assuming a "World Avoided" scenario of market-driven growth of ozone-depleting substances would lead, particularly in the second half of this century, to much more severe ozone loss than experienced hitherto. By 2065, roughly two thirds of global ozone would have been lost (Newman et al., 2009); over New Zealand, there would be a permanent ozone hole and a 3-fold increase of UV. However, by 2030 this only leads to relatively small increases of skin cancer, due to the long lead times of skin cancer and the relatively modest increases of UV caused by ozone depletion early on in the simulation. However, towards the end of the century, very substantial increases of skin cancer would have been avoided thanks to the Montreal Protocol. Other avoided impacts not discussed here include extreme sunburns, cataracts, and disruption of food production due to crop failures caused by the high UV. An ageing population in New Zealand means that substantial increases of skin cancer incidence are still expected which are however largely unrelated to ozone depletion.

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