Averting Climate Catastrophes

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Abstract. New Zealand research on ozone had very early beginnings, and it increased with concern that stratospheric ozone could be depleted by manufactured chemicals. The Antarctic ozone hole catalysed a concerted global response so that global ozone destruction was largely averted. Research on UV in NZ arose from the threat to ozone. Changes in UV have been small, but the need to drive action led to several misconceptions about NZ's UV. Even so, peak UV intensity here is about 40% higher than at equivalent northern latitudes, contributing to extreme rates of melanoma and other skin cancers. It could have been massively worse but for the Montreal Protocol; UV intensity in 2065 could have been up to four times higher. From the same era as the first ozone warnings, global warming has been a similar threat, but there have been decades of inactivity because there were no ready technological solutions. At last there are, and our response now has even greater urgency.

Ozone and UV

The chemistry of ozone formation and removal was formulated by Chapman (1930). At about the same time, measurement pioneer Gordon Dobson sited one of his instruments in Christchurch for two years. In the 1950s, Bates and Nicolet showed that ozone destruction could be catalysed by other stratospheric gases. In NZ, Edith Farkas began regular column ozone measurements in Wellington, later continued at Invercargill.

Crutzen (1970) showed that NO from stratospheric aircraft could contribute to ozone destruction, and like Rowland and Molina (1975) found the much greater concern from chlorofluorocarbons (CFCs). Wofsy and McElroy showed that bromine from halons was worse still. Measurements of NO_2 at Lauder began in 1980 alongside a global effort to understand ozone chemistry, but it was the unexpected Antarctic ozone hole that induced prompt global action.

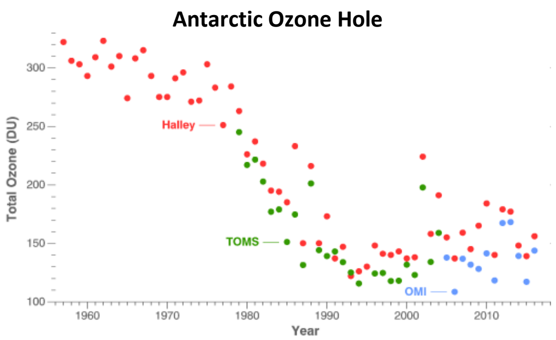

Figure 1. Ground-based (Halley) and satellite (TOMS, OMI) measurements of column ozone over Antarctica in October. (https://ozonewatch.gsfc.nasa.gov/facts/history.html)

The 1985 Vienna Convention for the Protection of the Ozone Layer, with 28 signatories, led to the 1987 Montreal Protocol (46), progressively strengthened in nine Amendments and now ratified by 197 parties. It required intensive monitoring of emissions, and globally-coordinated research on ozone chemistry and its effects. New Zealand's contribution has involved both Lauder and Arrival Heights as heavily-instrumented sites of the Network for the Detection of Atmospheric Composition Change.

The Montreal Protocol is often cited as a model for such international agreement, and indeed there are several lessons. One is that the Amendments were, as shown in Fig. 2, even more important than the original, which was a critical first step but would have been very inadequate on its own.

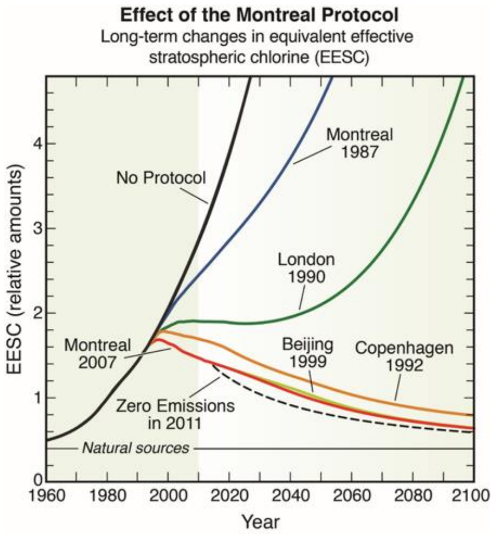

Figure 2. Expected change in ozone-depleting substances without the Montreal Protocol and its Amendments. (https://www.esrl.noaa.gov/csd/assessments/ozone/2014/)

A second lesson was how long it takes Earth's systems to recover. After halocarbon use reached a level that triggered the annual Antarctic ozone hole, it grew to full size over a decade, but recovery is expected at least seven decades later.

Third, rapid action on ozone depletion was possible because the chemical industry, even as it disputed culpability, worked quickly to find alternatives.

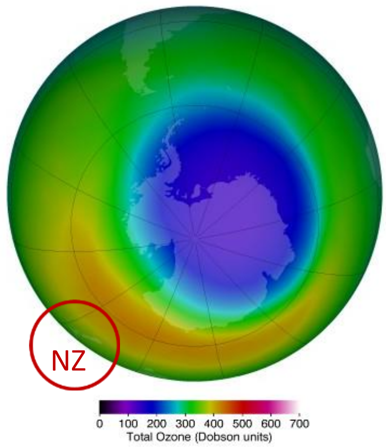

Figure 3. A typical Antarctic ozone hole in October.

A fourth lesson is the risk of public misperceptions, perhaps accentuated by repeated calls to action. Two very persistent and widespread errors are the idea that NZ is under the Antarctic ozone hole, and that our UV intensity is (consequently) extreme. As illustrated in Fig. 3, the ozone hole is confined within about 30° of the pole, though often displaced toward South America. In October, an ozone ridge south of and sometimes over NZ gives our highest annual ozone amounts at that time.

Figure 4 shows that UV intensity is extreme (UVI > 10) at times for nearly 90% of the world's population, and half of them experience higher UVI than anywhere in NZ.

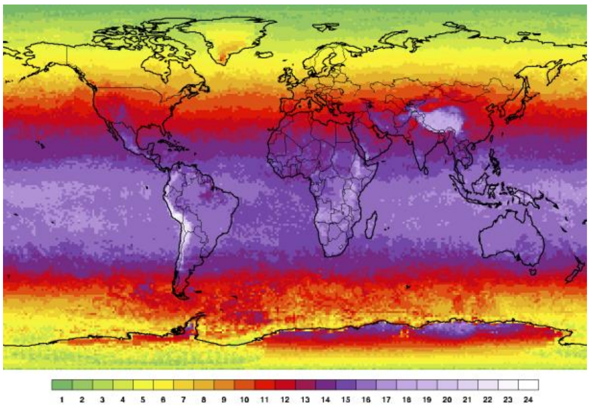

Figure 4. Global peak UV Index from TOMS.

Notwithstanding this comparison, UV intensity in NZ is extreme in the summer months, with peak amounts around 40% higher than at equivalent latitudes in Europe (Seckmeyer & McKenzie 1992) and North America (McKenzie et al. 2006). More important, NZ now leads the world in the death rate from malignant melanoma, and the incidence rate of all skin cancers is extreme. On top of more intense UV, the most probable causes are our predominantly wrong skin types for these latitudes and outdoor lifestyle in a temperate climate.

Ozone, both stratospheric and tropospheric, accounts for perhaps a third of the hemispheric difference. Measurements of UV in NZ started in the 1980s, and greatly advanced in both spectral precision and coverage in the 1990s. The impetus was concern about chemical destruction of ozone, but that has been minor. New Zealand's melanoma status, the characteristics of our UV climate, and the wide-ranging application of results show that NZ UV research was vital whatever happened to ozone.

But for the Montreal Protocol and Amendments, it might have been very different, as shown in Fig. 5 where the annual cycle of ozone and UV is projected for the 'No Protocol' scenario of Fig. 2. In 2065, the summer UV index would have increased by a factor of 3 since 1975, and winter UV in 2065 would have been comparable to summer UV in 1975.

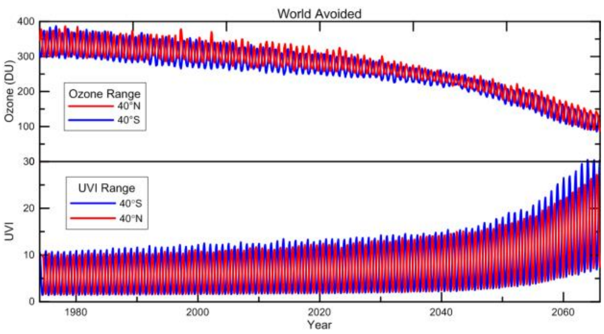

Figure 5. Projected ozone and UV for cloud-free solar noon at 40° latitudes without Montreal Protocol and Amendments (Morgenstern et al. 2014).

Climate Change

Paul Crutzen, Mario Molina, and Sherwood Rowland were awarded the 1995 Nobel Prize in Chemistry for their work on stratospheric ozone. In 1979, Rowland was already saying that another trend receiving little attention might in time prove to be a much larger threat; global warming from CO_2.

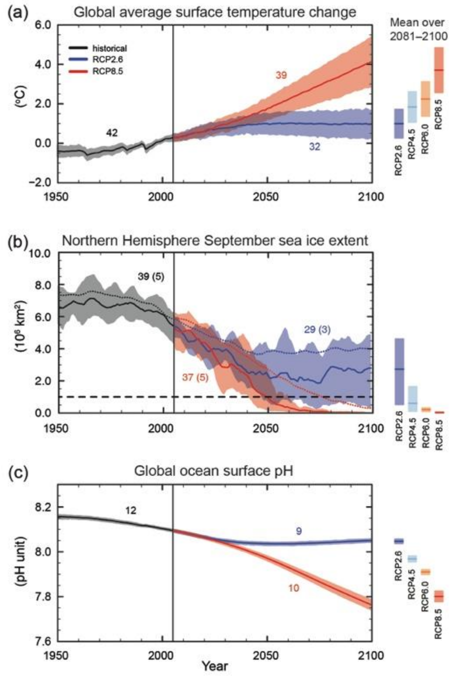

Figure 6. Simulations of temperature change, sea ice, and ocean surface pH for standard IPCC scenarios. (http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/)

The anticipated trends shown in Fig. 6 are not unlike of those of Figs. 2 and 5 in severity. They prompt the question of what hope there is of a solution, and whether the lessons of the Montreal Protocol apply.

The 1997 Kyoto Protocol was supposed to be a first step, but it applied to a minority of global emissions, and the 2012 Doha Amendment was not adopted. The separate 2015 Paris Agreement offers much greater hope, albeit 18 years later.

That bears on the second lesson; that of timescales. Emissions from fossil fuels have built over 150 years, and the effects will last for thousands even after the world acts.

The biggest difficulty has been third consideration, what technologies exist to mitigate emissions. Remarkably, after four decades of little apparent progress, the last few years have shown that a solution is possible. Wind and solar photovoltaic generation now undercut all other generation in cost, and electric vehicles will far surpass fossil-fuelled vehicles in both performance and cost-effectiveness once battery prices fall as expected.

For example, Jacobson et al. (2017) provide 'roadmaps' for 139 countries for all electricity, transport, heating/cooling, industry, and primary industries from wind, water, and sunlight by 2050 (e.g., Table 1). Total energy consumption and air pollution would reduce, employment would increase, and global temperature would rise less than 2 °C.

Table 1. A possible profile of 100% renewable energy for NZ in 2050, from Jacobson et al., using current technology.

Source	%
Onshore wind	19.1
Offshore wind	15.9
Hydroelectric	13.6
Residential solar PV	13.9
Commercial/Government PV	10.1
Concentrated solar	8.7
Utility PV	4.8
Geothermal	9.3
Wave	4.6
Tidal	0.3

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