

Parallels and contrasts between the science of ozone depletion and climate change

W Andrew Matthews

AM-NZ Services, Khandallah, Wellington, New Zealand. Contact: wa.matthews@gmail.com

Richard L McKenzie

National Institute for Water and Atmospheric Research (NIWA), Lauder, Central Otago, New Zealand

Abstract

In a recent paper in *Science*, Kerr, [2006] quoting Oppenheimer and Alley referring to the issue of climate change and resulting sea level rise for the melting of high latitude ice sheets stated “the ice sheet problem today very much resembles the ozone problem of the early 1980s, before researchers recognized the Antarctic ozone hole”. There are certainly a number of parallels that can be drawn between these two important human induced changes to the atmosphere of our planet. Table 1 highlights some of these similarities and differences.

Intergovernmental Panel on Climate Change (IPCC) as his stance was perceived to be against the oil industry, and in a memo sent to the White House in February 2001 raised the issue: ‘Can Watson now be replaced at the request of the US?’, [Randol, 2001). Watson lost his position in the ensuing elections in April 2002.

This action strongly parallels with the very proactive role played by DuPont, ICI, Hoechst and Allied Chemicals in the early 1970’s attempting to discredit the professionalism of the scientists who had predicted that chlorofluocarbons that were released into the lower atmosphere would destroy ozone in the stratosphere. This maneuvering can now be understood as an attempt to delay the imposition of controls on the release of CFCs into the atmosphere while the industry developed alternatives. With alternatives developed some 10 years later, industry moved to the front of those promoting the restriction on the use of CFCs and the promotion of the use of the more environmentally friendly alternatives at up prices 100 times that of the original chemicals.

It is ironic that only in 1972, 2 years before the scientific theory was announced on the danger of CFCs, that the US had led the call for the restriction of supersonic aircraft over concerns that their exhaust gases would destroy ozone. This was at a time when considerable pressure for extra investment was being exerted on the US Government by the US aircraft industry.

However, there are very close relationships and links between the science of ozone depletion science and that of enhanced greenhouse gas warming. Both of these phenomena involve the absorption of solar radiation and a change in energy distribution. Ozone is the predominant absorber of incoming ultraviolet radiation from the sun which it traps in the stratosphere and hence is responsible for most of the consequent heating of the stratosphere. The greenhouse gases, particularly water vapour and carbon dioxide, trap the outgoing (infrared) radiation from the Earth, as the Earth attempts to maintain a thermal balance and therefore results in habitable temperature that we enjoy. Decreasing the amount of ozone in the stratosphere results not only in a local cooling which exacerbates the ozone loss processes, but an increase in the amount of UV radiation reaching the earth’s surface. This results in increasing the damage to the skin of humans, animals and plants.

However, increasing greenhouse gases into the atmosphere traps additional outgoing radiation from the earth and results in additional warming close to the earth’s

Ozone Depletion	Global Warming
<ul style="list-style-type: none"> • Global problem • Man-made (over 50% by DuPont) • Developing world is key • <i>Developed world at risk</i> • Multi-decadal • Some culprit gases in common (e.g., O₃, H₂O, CFCs) • <i>Caused by CFCs (ClO, BrO)</i> • Initial scepticism by big business • <i>Replacements available</i> • <i>International agreement (eventually)</i> • Clouds influence • Aerosols influence • Surface albedo influence • Solar cycle influence • Dynamical influence • International response: <i>Montreal, ++</i> • Developing world treated separately • Further amendments were needed • <i>Maybe past the worst</i> 	<ul style="list-style-type: none"> • Global problem • Man-made (approx. 24% from US alone) • Developing world is key • <i>Developing world at risk</i> • Multi-decadal • Some culprit gases in common (e.g., O₃, H₂O, CFCs) • <i>Caused by CO₂, CH₄, N₂O</i> • Initial scepticism by big business • <i>No replacements available</i> • <i>USA and Australia refuse to co-operate</i> • Clouds influence • Aerosols influence • Surface albedo influence • Solar cycle influence • Dynamical influence • International response: <i>Kyoto +?</i> • Developing world treated separately • Further amendments will be needed • <i>Worst is still to come</i>

Table 1. Similarities and *differences* between the issues of ozone depletion and enhanced greenhouse gas warming.

Trying to remedy these changes has engendered a vigorous response from the industries that are implicated. The world’s largest oil company ExxonMobil lobbied the Bush Administration to remove the Chair of the

surface. This is the enhanced greenhouse effect and is driven through the addition of carbon dioxide through the burning of fossil fuels and through anthropogenic methane, particularly belched by ruminant farm animals and from nitrous oxide through the application of excess nitrogen fertilizers in agriculture.

If it were not for these additional greenhouse gases in the lower atmosphere, some of this emitted infrared radiation would have reached the stratosphere where it would have been absorbed by ozone. Ozone is also an infrared absorber and hence also a 'greenhouse gas'. However, since some of this radiation is trapped near the surface and does not get to the stratosphere where most of the ozone resides, the stratosphere is cooling at a rate of 2°C per decade, a situation that would not have arisen without the addition of these anthropogenic greenhouse gases, [Shine *et al.*, 2003]. The international media focus has been on the current 0.6°C warming of the earth's surface and that warming is just above the noise in terms of natural variability. However, the 2 degree cooling/ decade in the stratosphere is a very measurable effect that has received essentially no media attention.

A cooler stratosphere, as mentioned previously, exacerbates ozone loss in the Polar regions where heterogeneous chemistry on ice surfaces dominates (but may improve matters in other regions, where gas-phase chemistry dominates) and so although the amount of anthropogenic chlorine (from CFCs) is now starting to decrease in the stratosphere, the timing of the commensurate predicted recovery of ozone may be delayed (or accelerated) through the increase of greenhouse gases in the atmosphere.

The science of ozone destruction and the enhanced greenhouse effect is even more intertwined. The warming of the earth's oceans is increasing the bioactivity in the ocean's surface waters. Increased bioactivity means an increase of dimethyl-sulphide, DMS, into the lower atmosphere. This is an exhaust gas from some biological processes. However DMS provides a host site for the formation of atmospheric aerosols. These aerosols, either in liquid or solid form, on reaching the stratosphere, provide sites for increased ozone loss through heterogeneous chemical reactions. So a positive feedback mechanism is formed where increasing temperatures in the lower atmosphere further deplete ozone.

Interactions can work in the opposite direction as well. For example, reductions in Antarctic ozone lead to cooling which affects the strength of winds in the stratosphere, and these changes in winds extend right down to the troposphere and can lead to changes in temperature or precipitation patterns [Gillett and Thompson, 2003]. There can also be interactions between climate change and UV radiation without involving ozone itself. For example, global warming can lead to reduced glaciation, increased run-off, increases or decreases in snow cover and rainfall, and rising sea levels, all of which impact

on the UV exposure of organisms in the transition zones. Consequently, fragile Polar ecosystems, as well as low-lying countries may be particularly at risk. The complexity and extent of these interactions is demonstrated in Figure 1.

Interactions between ozone depletion and climate change have recently been assessed and summarized in the IPCC/TEAP report [IPCC, 2005]. Further details regarding these interactions are given in Chapter 1 of the full IPCC Report [Pyle *et al.*, 2005].

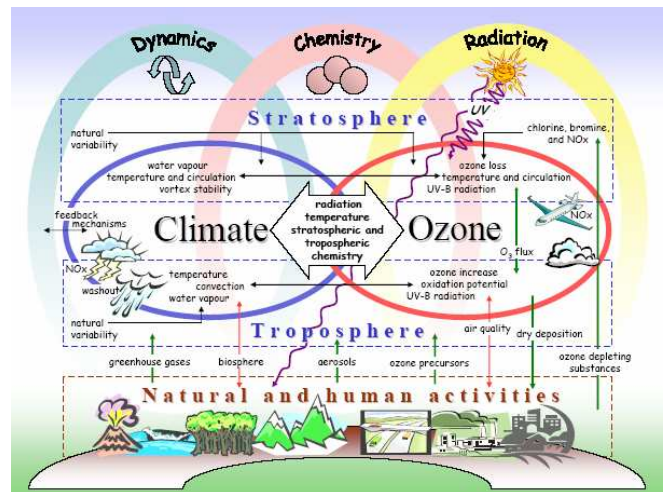


Figure 1. Ozone/climate feedback linkages. From [Isaksen, 2003].

References

Gillett, N.P., and D.W.J. Thompson, Simulation of recent Southern Hemisphere climate change, *Science*, 302 (5643), 273-275, 2003.

IPCC, IPCC/TEAP Special report: Safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons. Summary for policymakers, IPCC, Geneva, 2005.

Isaksen, I.S.A., (Editor) EC Air Pollution Report No. 81: Ozone-Climate Interactions, 2003.

Kerr, R. 2006. Climate Change: A Worrying Trend of Less Ice, Higher Seas. *Science*, 311, 1698-1701.

Pyle, J., T.G. Shepherd, G. Bodeker, P. Canziani, M. Dameris, P. Forster, A. Gruzdev, R. Mueller, J. Muthama, G. Pitari, and W. Randel, Ozone and Climate, in *IPCC/TEAP Special report: Safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons*, edited by IPCC/TEAP, Geneva, 2005.

Randol, R 2001. Bush Team for IPCC Negotiations. <http://www.nrdc.org/media/docs/020403.pdf>

Shine, K. et al. A comparison of model-simulated trends in stratospheric temperatures.. *Q. J. Royal Meteor. Soc.* 129, 1565-1588, 2003.