NEW ZEALAND

OBSERVATIONAL ACTIVITIES

In New Zealand, most ozone and UV related research is undertaken by the National Institute of Water and Atmospheric Research (NIWA), a Crown Research Institute (CRI), at research centres at Lauder and Wellington. The site at Lauder is the southern hemisphere mid-latitude charter site in the Network for Detection of Stratospheric Change (NDSC). Several other CRIs have programmes to monitor changes in biologically damaging UV radiation (e.g., Industrial Research, LandCare, AgResearch), some of which are conducted in collaboration with NIWA. The Physics and Astronomy Department at the University of Canterbury also contributes to ozone related research while the Department of Preventive and Social Medicine at the University of Otago researches epidemiological aspects of excess UV radiation exposure. This research is funded primarily through the Foundation for Research Science and Technology (FRST), but with considerable funding coming from international contracts and also from commercial activities such as providing research products and instrument development.

Column measurements of ozone and other gases/variables relevant to ozone loss

Dobson Spectrophotometer Ozone measurements were made using a Dobson spectrophotometer (no. 17) located at Invercargill (46.4°S, 168.3°E) from 3 July 1970 to 30 September 1987. The instrument was then re-located to Arrival Heights in Antarctica (77.8°S, 166.7°E), another NDSC site, where it has been operated since. Another Dobson spectrophotometer (no. 72) has been operated at NIWA Lauder (45.0°S, 169.7°E, alt 370m) since the beginning of 1987 in collaboration with NOAA. A satellite measurement based climatology of total column ozone differences between Lauder and Invercargill has been used to geographically shift the Invercargill measurements to Lauder (Figure 1). The large downward step in ozone during the mid-1980s, which occurred throughout the southern mid-latitudes, remains unexplained. The Dobson spectrophotometers are also used to make Umkehr observations to estimate the vertical profile of ozone in the stratosphere.

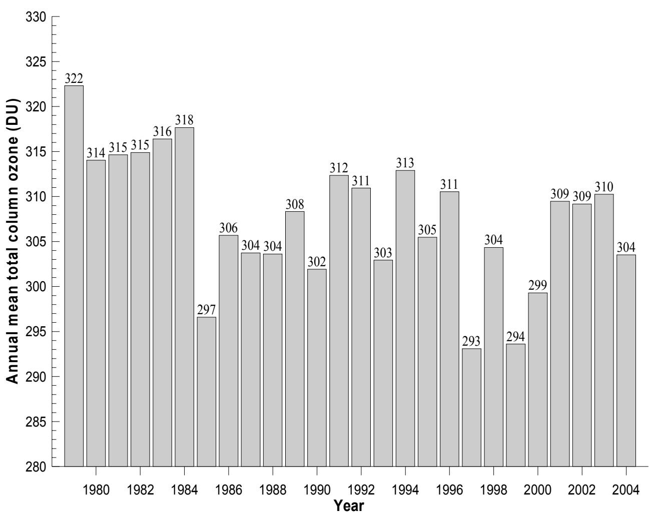

Figure 1: Annual mean total column ozone at Lauder from the combined Lauder and Invercargill Dobson spectrophotometer measurements.

UV-visible spectrometers UV-visible spectrometers at Arrival Heights, Macquarie Island (54.5°S, 159.0°E), Lauder, Mauna Loa (19.5°N, 155.6°W), Tarawa (1.5°N, 173°E), and Kiruna (67.8°N, 21.1°E) measure total column ozone. These spectrometers are also used to measure slant column NO_2 over Kiruna, Japan, Hawaii, Tarawa, Lauder, Macquarie Island and Arrival Heights, BrO over Kiruna, Lauder and Arrival Heights, and OClO over Kiruna and Arrival Heights.

FTIR High resolution Fourier transform infrared (FTIR) interferometers at Lauder and Arrival Heights are used to determine column amounts of O_3, HCl, HNO_3, CH_4, N_2O, HF, COF_2, CO, C_2H_6, $ClONO_2$, CFC-11, CFC-12, NO_2, OCS, and CO_2. For some of these species, 2 to 4 vertical partial column amounts can also be retrieved from the FTIR spectra.

Profile measurements of ozone and other gases/variables relevant to ozone loss

Ozonesondes Vertical ozone profiles over Lauder have been measured weekly since August 1986 using ECC ozonesondes. Until 1996 flights were made twice weekly during the last four months of the year, a time when remnants of the Antarctic ozone hole may be advected over New Zealand. The flights are made to an average altitude of ~33 km. A summary of the data from these flights is presented in Figure 2.

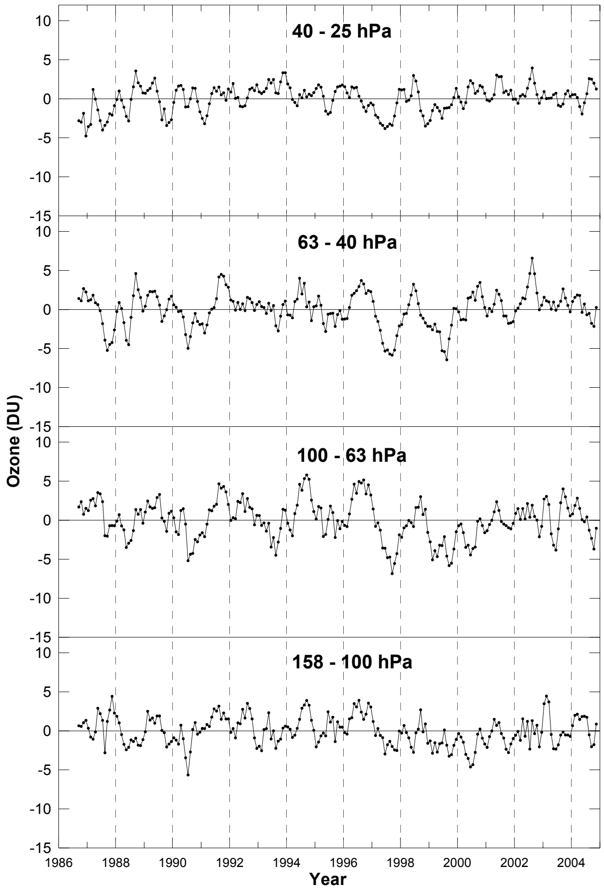

Figure 2: Deseasonalized monthly mean ozone partial columns from the ozonesonde ozone profiles measure at Lauder, New Zealand.

Microwave radiometer A microwave radiometer has been used to make daily measurements of ozone profiles at Lauder since November 1992 over the altitude range 20-70 km. A second instrument is used to make water vapour profile measurements in the upper stratosphere and lower mesosphere. A microwave radiometer is also operated at Arrival Heights for monitoring the ClO vertical profile.

Ozone lidar In collaboration with RIVM, The Netherlands, vertical ozone profiles measurements have been made using a UV DIAL system since November 1994 over the altitude range 8-50 km.

Frost point hygrometer flights In a new collaborative effort with NOAA/CMDL, frost point hygrometer flights have been made from Lauder every second week since August 2004 to measure stratospheric water vapour. The programme is co-funded by the NOAA GCOS office.

Surface ozone measurements

Surface ozone measurements have been continuously monitored at Lauder since December 2003. Measurements are made with a TEI in-situ spectrophotometer. Similar measurements have been made at Arrival Heights since December 1996. These measurements were made with a Dasibi in-situ spectrophotometer until it was replaced with a TEI monitor in December 2003.

UV measurements

Spectroradiometers Since late 1990, surface spectral UV irradiance has been measured routinely at Lauder. Scans are made at 5 degree steps in solar zenith angle, and at 15 minute intervals over the midday period. The spectral resolution is 0.6-0.8 nm, and data cover the range 285 to 450 nm in 0.2 nm steps. Similar spectral measurements have been undertaken in collaboration with NOAA/CMDL at two sites in the USA (Mauna Loa Observatory, Hawaii, and Boulder, Colorado); with the Australian Bureau of Meteorology at three sites in Australia (Melbourne, Alice Springs and Darwin); and with the University of Tokyo at one site in Japan using weatherproof, temperature-controlled spectrometers. In addition to the measurements of spectral irradiance, measurements of actinic fluxes, more relevant for atmospheric chemistry, are now available from Lauder and Tokyo.

Broadband measurements The spectral measurements are complemented by a wide range of broadband measurements and by all-sky images taken at 1 minute intervals to quantify the effect of cloud distribution and type on UV radiation. Broadband instruments which measure integrated

UV with a response close to the erythemal action spectrum, are operated by NIWA at several sites in New Zealand (Invercargill, Lauder, Leigh, Paraparaumu, Christchurch) and in the Pacific (Cook Islands – Rarotonga and, Fiji). Because of mismatch between instrument sensitivity and erythemal response, corrections which depend on solar elevation and ozone are applied to these broadband instruments.

Dosimeter badges for measuring personal exposures of UV have been developed in collaboration with the University of Canterbury. Similar sensors have been used in UV displays which have been deployed in public places and outdoor sporting events.

Narrowband filter instruments Since late 2002, the US Department of Agriculture have been undertaking complementary measurements of UV radiation at Lauder using multi-filter rotating shadow band radiometers. This pro-vides a direct linkage between the UV climatologies of New Zealand and the USA.

Calibration activities

The Lauder Dobson spectrophotometer was last calibrated in a Dobson intercomparison at Lauder in November and December 2001, which included the world standard instrument no. 83. The next intercomparison will occur in January 2006 in Melbourne. The Arrival Heights Dobson spectrophotometer was intercompared against the world standard in Melbourne in early 2004.

An intercomparison of vertical ozone and temperature profile measurements, the TOPAL (Temperature and Ozone Profiler Assessment at Lauder) campaign, was conducted from 8-20 April 2002 and included measurements from ozonesondes, the RIVM ozone lidar, a NASA/GSFC ozone lidar and the microwave radiometer.

The NIWA UV spectrometers represent the state-of-the-art, and have participated with distinction at an international intercomparison campaign in the USA, and have been used to certify instruments for acceptance by the Network for Detection of Stratospheric Change. During a measurement campaign at Lauder, the NIWA spectrometers were cross calibrated against a European reference instrument that measured spectral radiances as well as irradiances.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The NIWA assimilated total column ozone data base

The NIWA assimilated total column ozone data base combines satellite-based measurements of total column ozone from 4 Total Ozone Mapping Spectrometer (TOMS) instruments, 4 Solar Backscatter Ultra-Violet (SBUV) instruments, and three different retrievals from the Global Ozone Monitoring Experiment (GOME), and compares these against ground-based measurements made by the global network of Dobson spectrometers to create a homogeneous data base that combines the advantages of global satellite measurements with the advantages of the stability of ground-based measurements. This data base was used extensively in the WMO/UNEP ozone assessment in 2002 and is planned for use in the next ozone assessment in 2006. The use of this data base to track the long-term evolution of the Antarctic ozone hole is shown in Figure 3.

Analysis of UV measurements

Data from NIWA UV spectrometers have been used to identify problems with satellite-derived UV and have led to improvements in retrieval algorithms. Studies have quantified the effects of clouds on UV at Lauder and at sites in Antarctica. A detailed intercomparison between calculated and measured UV for clear skies at several sites has identified deficiencies in the aerosol parameters which are used as inputs to the model. The same analysis quantified errors due to a recently-discovered temperature-dependence in PTFE, which is the material used in the diffusers of the spectrometers. Instruments and retrieval algorithms have now been improved to properly take these into account. Studies have identified the importance of the altitude distribution of ozone and temperature in modulating UV radiation received at the surface. We have also shown that while UV intensities are relatively high in the New Zealand summer, they are relatively low in the New Zealand winter, and this has serious implications for human health (contributing to skin damage in summer, and vitamin-d deficiency in winter). A study has quantified the increased UV exposure experienced during skiing.

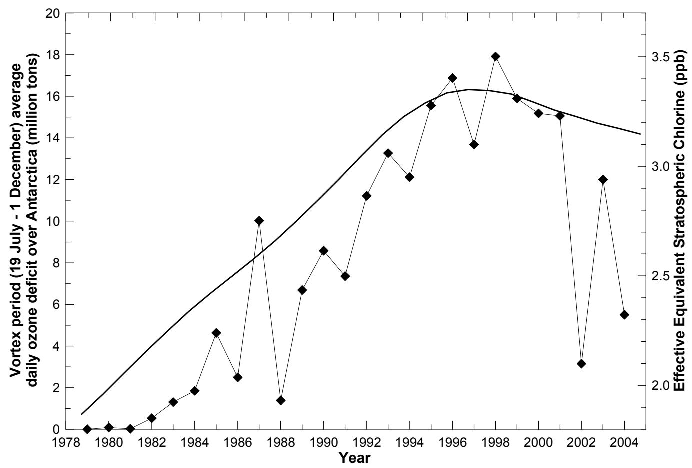

Figure 3: Daily ozone mass deficit (the mass of ozone required to restore ozone levels to 220 DU over Antarctica) averaged over the Antarctic vortex period (thin line with symbols plotted against left axis) together with effective equivalent stratospheric chlorine (thick line plotted against right axis).

Trend analysis

Regression analysis models have been developed to quantify trends in ozone and the trace gases affecting ozone.

Detection of the peak in stratospheric chlorine loading

Measurements of HCl and $ClONO_2$ at Lauder can be used to monitor stratospheric chlorine loading, which appears to have reached a peak in the mid-1990s but not to have significantly decreased since then.

THEORY, MODELLING, AND OTHER RESEARCH

The Dilution Effect

The effect on mid-latitude ozone of the mixing of ozone depleted air from within the Antarctic vortex over southern mid-latitudes following the breakup of the vortex has been quantified for 1998, 1999, and 2000 by calculating the trajectories of ensembles of ozone-depleted air parcels. The results suggest that dilution of the ozone hole is the major source of summertime southern mid-latitude ozone loss, amounting to as much as 4-5% of the total ozone even after allowing for photochemical recovery. This is the first time the large-scale dilution has been quantified. This work was done in collaboration with the University of Canterbury.

Chemistry-climate modelling

Since 2001 NIWA has been operating a coupled chemistry-climate model (CCM) to investigate the feedbacks of stratospheric change on climate change, and the effects of climate change on the ozone layer. This work has been undertaken in close collaboration with the UK Met Office and with the NOAA Geophysical Fluid Dynamics Laboratory. The Unified Model with Eulerian Transport And Chemistry (UMETRAC) is run on NIWA's cray T3E supercomputer. This modelling programme will contribute to the SPARC (Stratospheric Processes And their Role in Climate) initiated activity to conduct an internationally coordinated validation of CCMs.

Use of satellite data

Data from satellite programmes of the USA, European and Japanese space agencies have been used in ozone and UV related research in New Zealand. In turn we have contributed to a number of satellite measurement validation activities. Total column ozone measurements from a variety of instruments have been used to generate an assimilated total column ozone data base (see Section 2.1). Ozone profile measurements from the SAGE II, POAM II and POAM III instruments have been used to diagnose ozone loss rates over Antarctica.

UV effect studies

Scientists from NIWA and the University of Otago have been working in close collaboration to understand the factors affecting excess UV exposure in New Zealand schoolchildren. Over the summer of 2004/2005 UV exposure of 491 school children at 28 schools over 14 one-week periods were measured and combined with data from activity diaries maintained by the children and data from questionnaires to create a data base that can be used to answer many questions related to UV exposure of school children. For each participating child, the UV exposure over a one week period was logged using electronic UV monitors specifically developed for this project. The monitors were programmed to log UV exposure at 8-second intervals throughout the day. The resultant data base is now been analyzed to quantify the most important factors affecting UV exposure in schoolchildren. This work was co-funded by NIWA and the Cancer Society of New Zealand.

DISSEMINATION OF RESULTS

Data reporting

Measurements from the following sites are regularly submitted to the NDSC data base: From Lauder: ozonesonde and lidar ozone profiles, Dobson spectrophotometer O_3, NO_2 columns, UV weighted irradiances (Erythema, UVA, UVB), vertical columns of HCl and HNO_3; from Arrival Heights: vertical columns of HCl and HNO_3, Dobson spectrophotometer O_3, NO_2 columns; from Kiruna: NO_2 columns; from Moshiri (Japan): NO_2 columns; from Boulder (USA): UV weighted irradiances (Erythema, UVA, UVB); from Mauna Loa Observatory (Hawaii): NO_2 columns, UV weighted irradiances (Erythema, UVA, UVB); from Macquarie Island (Australia): NO_2 columns.

Measurements from the following sites are regularly submitted the WOUDC data base: From Lauder: Ozonesonde ozone profiles; from Arrival Heights: Dobson spectrophotometer O_3.

Aerosol Measurements from Lauder are regularly submitted to the BSRN data base.

Information to the public

Data from NIWA's broadband instruments and radiative transfer calculations are used to provide the public with information on UV radiation levels via the Internet. Data are also provided to the public via the Cancer Society of New Zealand’s web pages, and via contracts with New Zealand Met Service.

FUTURE PLANS

The International Polar Year (IPY)

New Zealand researchers are included on a number of IPY proposals, including proposals on air-ice chemical interactions (AICE) and ultraviolet radiation in polar environments. The eventual extent of New Zealand participation in these programmes will depend on how much IPY targeted funding will be made available through New Zealand funding agencies.

NEEDS AND RECOMMENDATIONS

The following needs and recommendations require attention:

- The contribution of very short-lived compounds to stratospheric species abundances, and in particular BrO, needs to be better quantified.
- The inability of state-of-the-art atmospheric chemistry models to reproduce the inter-hemispheric differences in the response of ozone to the Mt. Pinatubo volcanic eruption suggests that our knowledge of the aerosol chemistry driving ozone changes is incomplete.

- We need better quantification of how management of banks of ozone depleting substances may affect the recovery of the global ozone layer.
- In depth assessment of when and where the ozone layer is likely to recover is required. Is any observation of the onset of recovery observed to date consistent with our best understanding of atmospheric chemistry and dynamics? The importance of attribution in the analysis of ozone recovery must be stressed.
- The effects of stratospheric change on surface climate change, and the mechanisms involved, need to be better quantified. In particular forcing of the southern annular mode through Antarctic ozone depletion, and its effect on southern middle and high latitude surface climate, needs to be better understood.
- A better understanding of the drivers of southern hemisphere mid-latitude ozone changes is required. Current models are unable to reproduce changes in southern mid-latitude ozone observed over the past 25 years.
- We need to confirm that ground- and satellite-based measurements of bromine and chlorine containing compounds are in agreement and that the stratospheric loading of these trace gases is consistent with our understanding of their surface source emissions.
- Working with health sciences to improve our understanding of both the positive and negative effects of UV exposure.

RELEVANT SCIENTIFIC PAPERS

A list of selected key scientific papers from New Zealand ozone and UV research over the past 3 years, is provided below:

Ajtic, J., B.J. Connor, B.N. Lawrence, G.E. Bodeker, K.W. Hoppel, J.E. Rosenfield, and D.N. Heuff, Dilution of the Antarctic ozone hole into southern midlatitudes, 1998–2000, Journal of Geophysical Research, 109, D17107, doi:10.1029/2003JD004500, 2004.

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Liley, J.B., D. Baumgardner, Y. Kondo, K. Kita, D.R. Blake, M. Koike, T. Machida, N. Takegawa, S. Kawakami, T. Shirai, and T. Ogawa, Black carbon in aerosol during BIBLE B, Journal of Geophysical Research, 108 (D3), 8399, doi:10.1029/2001JD000845, 2003.

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McKenzie, R.L., J. Badosa, M. Kotkamp, and P.V. Johnston, Effects of the temperature dependence in PTFE diffusers on observed UV irradiances, Geophysical Research Letters, 32, L06808, doi:10.1029/2004GL022268, 2005.

Nichol, S.E., G. Pfister, G.E. Bodeker, R.L. McKenzie, S.W. Wood, and G. Bernhard, Moderation of cloud reduction of UV in the Antarctic due to high surface albedo, Journal of Applied Meteorology, 42, 1174-1183, 2003.

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Schofield, R., K. Kreher, B.J. Connor, P.V. Johnston, A. Thomas, D. Shooter, M.P. Chipperfield, C.D. Rodgers, and G.H. Mount, Retrieved tropospheric and stratospheric BrO columns over Lauder, New Zealand, Journal of Geophysical Research, 109, D14304, doi:10.1029/2003JD004463, 2004.

Struthers, H., K. Kreher, J. Austin, R. Schofield, G.E. Bodeker, P.V. Johnston, H. Shiona, and A. Thomas, Past and future simulations of NO_2 from a coupled chemistry-climate model in comparison with observations, Atmospheric Chemistry and Physics, 4, 2227–2239, 2004.

Wood, S.W., G.E. Bodeker, I.S. Boyd, N.B. Jones, B.J. Connor, P.V. Johnston, W.A. Matthews, S.E. Nichol, F.J. Murcray, H. Nakajima, and Y. Sasano, Validation of version 5.20 ILAS HNO_3,CH_4 ,N_2O, O_3, and NO_2 using ground-based measurements at Arrival Heights and Kiruna, Journal of Geophysical Research, 107 (D24), 8208, doi:10.1029/2001JD000581, 2002.

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