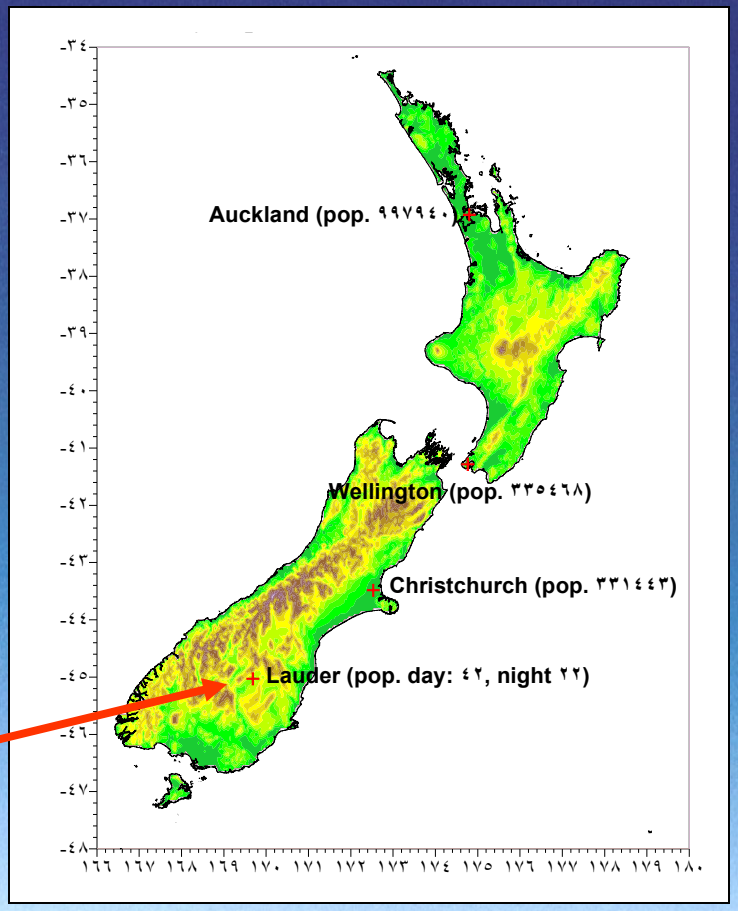
Lauder, New Zealand within Network for Detection of Atmospheric Composition Change (NDACC)

Presented at

Meeting on Implementation of GCOS Reference Upper Air Network (GRUAN)
Lindenberg, Germany, 26-28 February 2008



NIWA's Lauder Site

45.0°S, 169.7°E
370m a.s.l.

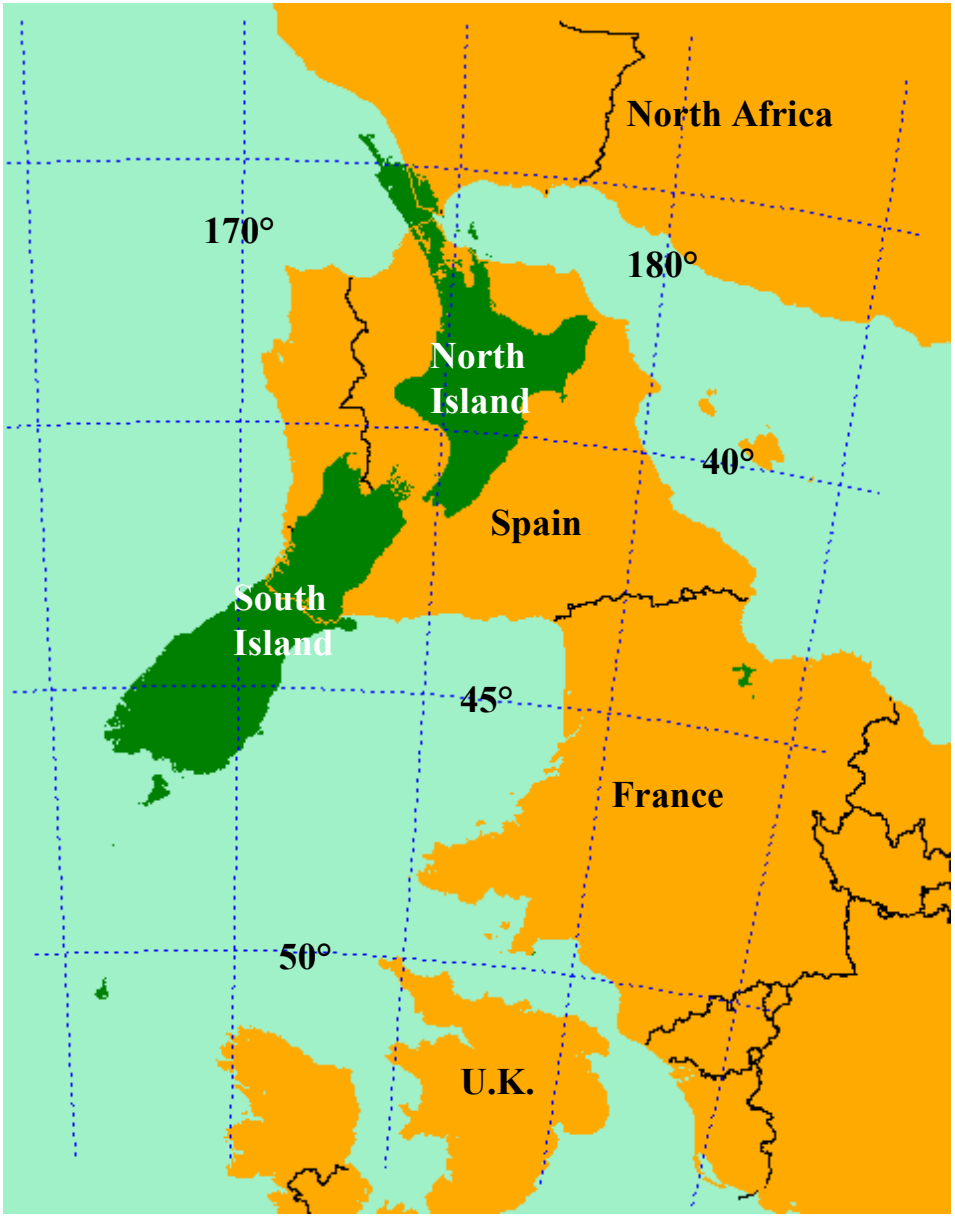
“Lauder Within the NDACC” – we will look at:

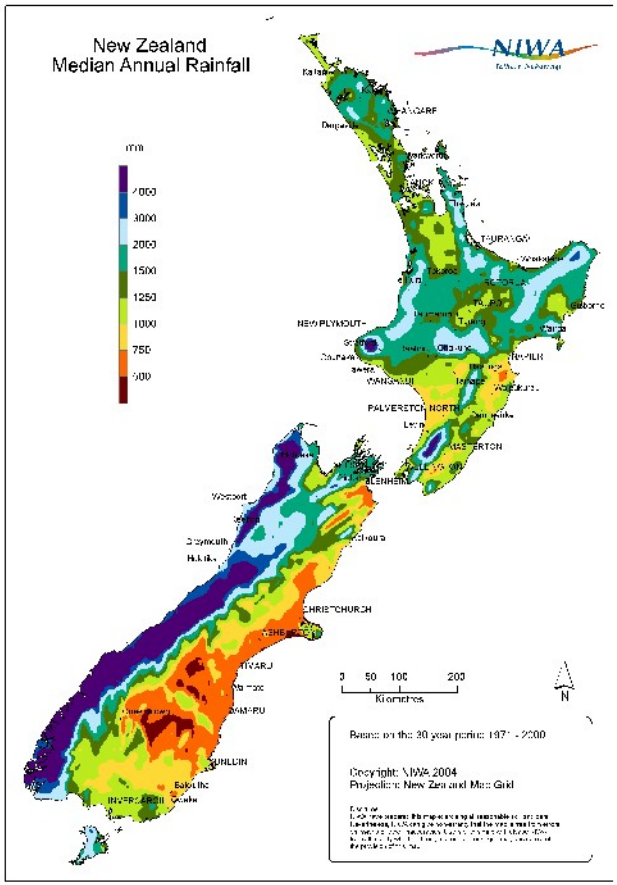
1. Location – Geography and Climate
2. NDACC Measurements
3. Links with GRUAN goals:
   - Measurements
   - Climate Modelling
   - Research Outputs

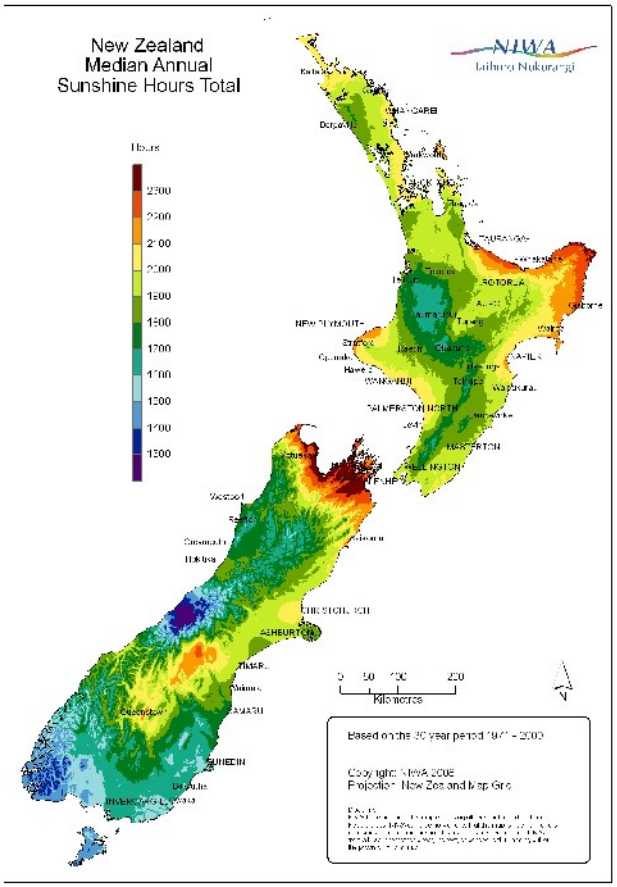
New Zealand, a small country close to Australia and Antarctica

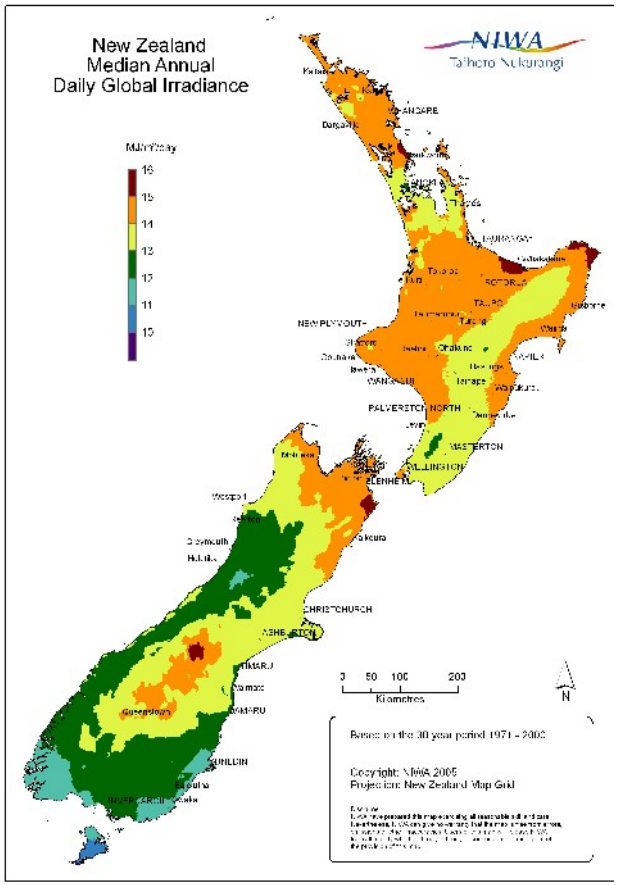
McKenzie et al., JGR 103, D22, pp28,785-28,792, 1998. Image from J Descloitres, MODIS Rapid Response Team at NASA GSFC, as published in NIWAClimate Update No. 50

New Zealand and its Antipodes

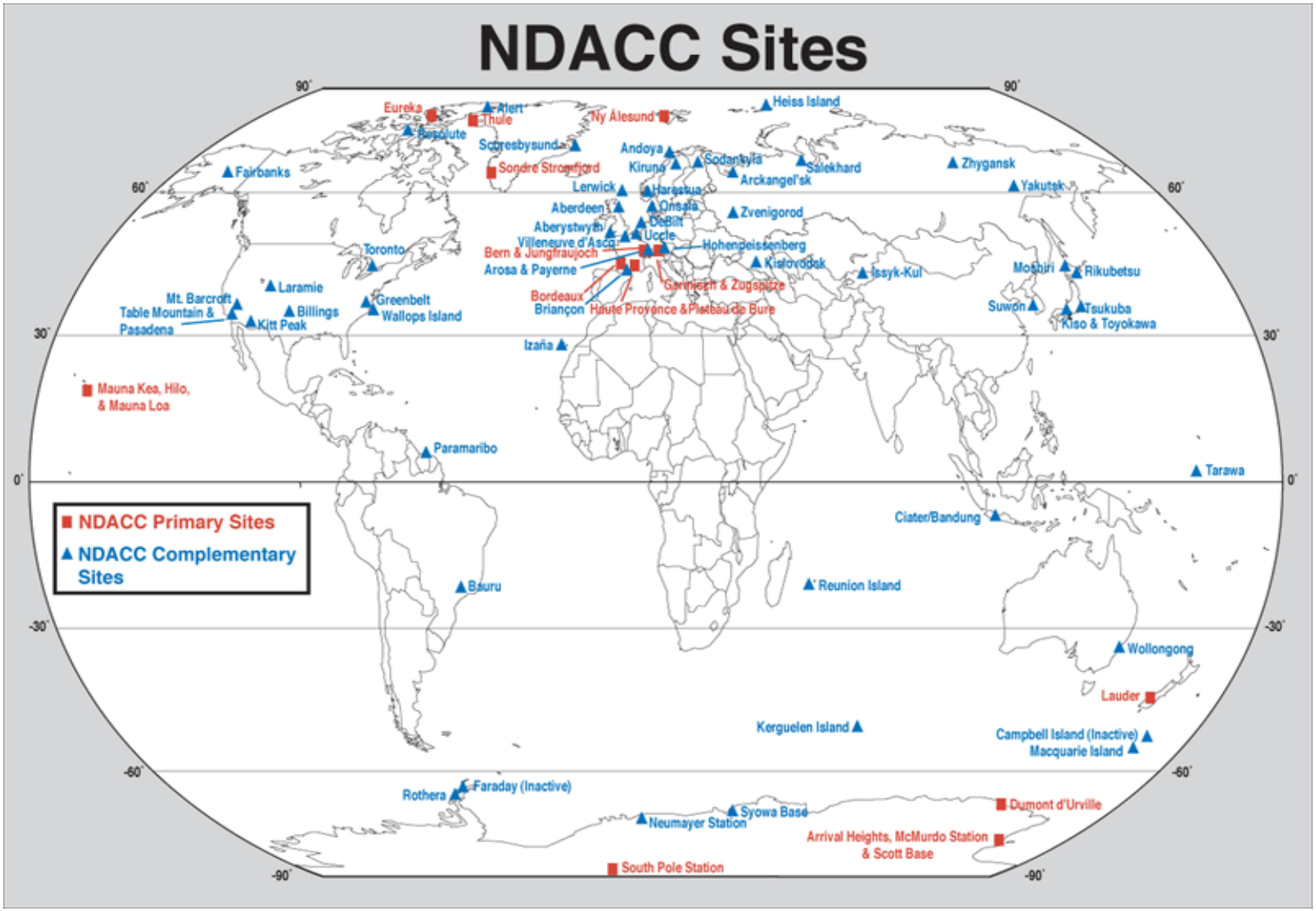



New Zealand
Median Annual Rainfall
NIWA
Taihoro Nukurangi
mm
4000
3000
2000
1500
1250
1000
750
500
0 50 100 200
Kilometres
N
Based on the 30 year period 1971 - 2000
Copyright: NIWA 2004
Projection: New Zealand Map Grid

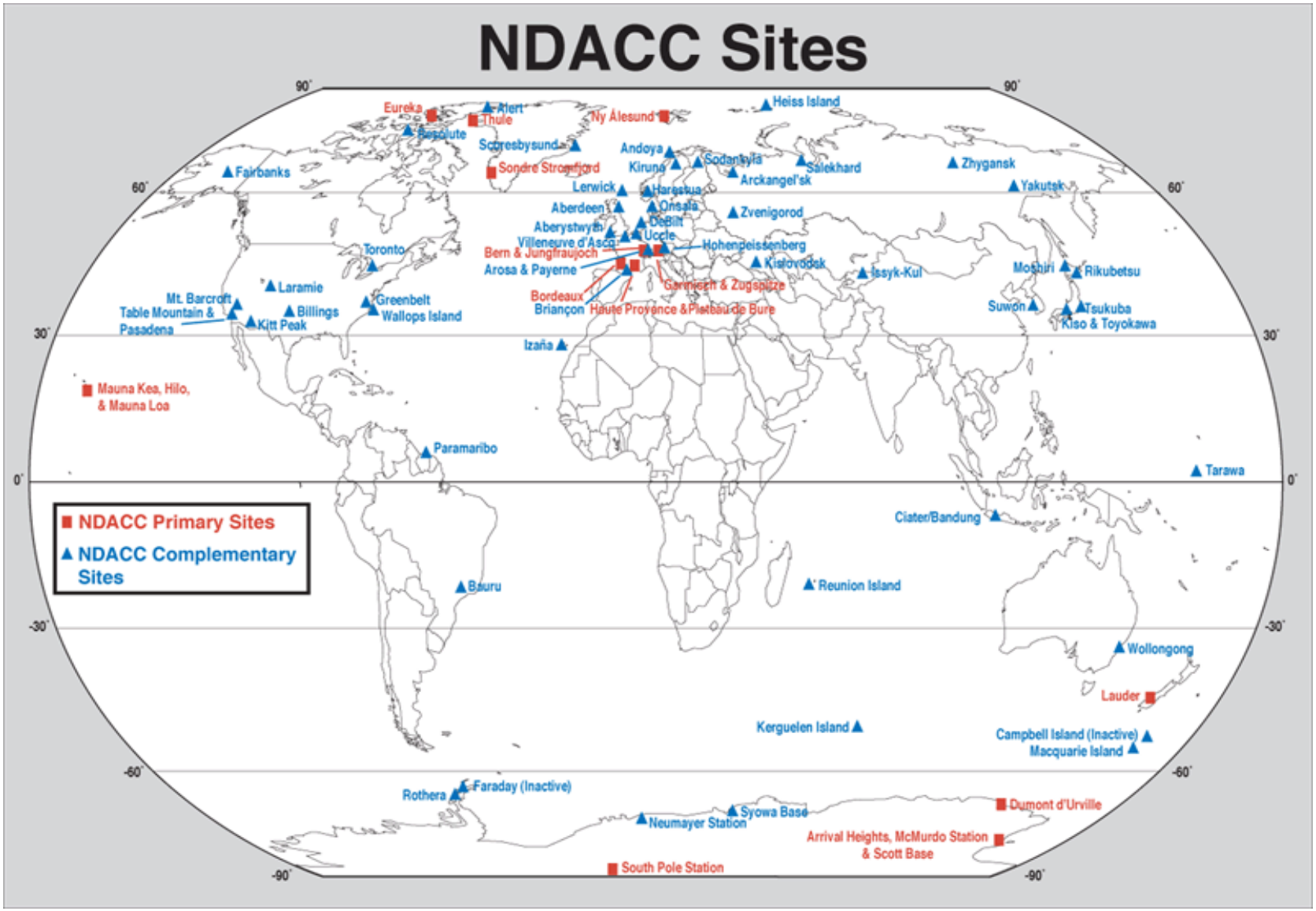

New Zealand
Median Annual
Sunshine Hours Total
NIWA
Taihoro Nukurangi
Hours
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
0 50 100 200
Kilometres
N
Based on the 30 year period 1971 - 2000
Copyright: NIWA 2005
Projection: New Zealand Map Grid


New Zealand
Median Annual
Daily Global Irradiance
NIWA
Taihoro Nukurangi
MJ/m²/day
16
15
14
13
12
11
10
0 50 100 200
Kilometres
N
Based on the 30 year period 1971 - 2000
Copyright: NIWA 2005
Projection: New Zealand Map Grid

The international Network for the Detection of Stratospheric Change (NDSC) was formed to provide a consistent, standardised set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites.



The international Network for the Detection of Atmospheric Composition Change was established to provide a consistent, standardised set of long term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites.



The primary NDACC instruments and measurements are:

- **Ozone Sondes and Dobson/Brewer** (Profiles to > 30km & total column ozone)
- **Ozone lidar** (vertical profiles of ozone from the tropopause to at least 40 km altitude; in some cases tropospheric ozone will also be measured)
- **Temperature lidar** (vertical profiles of temperature from about 30 to 80 km)
- **Aerosol lidar** (vertical profiles of aerosol optical depth in the lower stratosphere)
- **Water vapor lidar** (vertical profiles of water vapor in the lower stratosphere)
- **Ozone microwave** (vertical profiles of stratospheric ozone from 20 to 70 km)
- **H_2O microwave** (vertical profiles water vapor from about 20 to 80 km)
- **ClO microwave** (vertical profiles of CLO from about 25 to 45 km, dep. on latitude)
- **Ultraviolet/Visible spectrograph** (column abundance of ozone, NO_2, and, at some latitudes, OClO and BrO)
- **Spectral UV Radiometer** (irradiances to track effects of Atmospheric Change)
- **Fourier Transform Infrared spectrometer** (column abundances of a broad range of species including ozone, HCl, NO, NO_2, $ClONO_2$, and HNO_3)

Measurements at the Lauder NDACC Station, Dec 2007

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Instrument & Period	Parameter	Cooperating Institutions	Comments

Ozone Dobson/Sonde, Lauder

Dobson Ozone 1987 Jan -	Column ozone	NOAA/GMD, Boulder, USA	
Balloon sonde (ECC) 1986 Aug -	Ozone, T/P, humidity and wind profiles	NOAA/GMD, Boulder, USA	Weekly throughout the year. 0 – 32 km

FTIR Trace Gas Spectroscopy, Lauder

Mid IR Interferometer (Bruker) 1990 -	Column HCl, HNO_3, $ClONO_3$, HF, CFCs, CO & GHGs		Mid-IR (windows in 2-12µ region). SFIT2 profiles

Total Column Carbon Observing Network, Lauder

Near IR Interferometer (Bruker) 2003 -	Column CO_2, CO, CH_4, N_2O	NASA, JPL, UC, Univ. Woolongong	Total Column Carbon Netw. OCO Validation

UV-Vis Trace Gas Spectroscopy, Lauder

UV-Vis DOAS spectrometers 1980 Dec -	Column NO_2 Column BrO Zen (1994) + Sun (2001) + Off-axis (04)	NOAA, Univ. Nagoya, Swedish IRF Aus. Ant. Div.	6 Lauder systems 4 O/Seas systems

Instrument & Period	Parameter	Cooperating Institutions	Comments

Ozone/Aerosol Lidars, Lauder

Aerosol & temperature lidar. 1993 Dec -	Aerosols 5-30 km Temp. 30-70 km	IROE, Florence, Italy University of Lyon, France	Nd-YAG 532 nm, 355 nm
Aerosol lidar. 1992 Nov -	Aerosol profile 3-30 km	Met. Research Instit., Tsukuba, Japan	Nd-YAG 532 nm
Ozone lidar 1994 Dec -	Ozone profiles 8-45 km	RIVM, Bilthoven, Netherlands	Excimer laser plus Raman cell

Microwave Radiometers, Lauder

microwave radiometer 1993 -	Ozone profiles 20-65 km	University of Massachusetts, USA	110 GHz and 6 hour integration
Microwave radiometer 1994 -	H2O 40-80 km profiles	NRL, Washington DC, USA	22 GHz and 1 week integrat. times

Spectral UV, Lauder

UV Spectrometer 1980 & 1988 obs. 1989 Nov -	Global and scattered UV Spectral irradiance	NOAA/GMD, Boulder, USA. BOM, Australia	285-450 nm 3 Lauder systems 5 O/Seas systems

NDACC Measurement Intercomparisons

A fundamental requirement of NDACC operation is involvement in regular intercomparisons of instruments and processing algorithms. These ensure measurement consistency across the global network as well as providing close interaction of experimenters from all organisations making NDACC measurements. Considerable improvements in accuracy and stability have been gained as a result.

Recent Intercomparisons by Working Group, are:

Dobson: Lauder, 2001

Lidar: Ozone Lidar, Lauder, 2002

Ozone Sondes: Balloon Experiment on Standards for Ozone Sondes (BESOS), 2004

FTIR: Kiruna, ?????

UV/Visible: Andoya, Norway, 2003

Spectral UV: Table Mountain, Boulder, 2003

Ozone and Hygrometer Sonde measurements + Dobson Ozone

Weekly Sonde measurements are made using two different systems on alternate weeks:

- RS92-SGP Radiosonde with ECC-1Z Ozone Sensor (1986 on). NOAA copy.
- RS80-15H Radiosonde with ECC-1Z Ozone Sensor and NOAA Frost Point Hygrometer.

Both use a GPS to record winds.

Total Column ozone is measured up to 5 times/day in clear sun conditions. The Lauder Dobson Spectrophotometer of the part of International Dobson Network run by NOAA.

Lauder Sonde with RS92-SGP and NOAA Hygrometer Specifications
(GRUAN Requirements in Red)

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Pressure	Type:	Barocap silicon sensor
	Range:	1080 to 3 hPa
	Resolution:	0.1 hPa **0.01 hPa**
	Total Uncertainty in Sounding[1]	1.5 hPa (1080 – 100 hPa) **0.1 hPa** 0.6 hPa (100 – 3 hPa)
	Repeatability[2]	0.4 hPa (1080 – 100 hPa) 0.3 hPa (100 – 3 hPa)
	Reproducibility[3]	0.5 hPa (1080 – 100 hPa) 0.3 hPa (100 – 3 hPa)
Temperature	Type:	F-Thermocap capacitive wire
	Range:	+60°C to -90°C
	Resolution:	0.1°C
	Accuracy:	
	Total Uncertainty in Sounding[1]	0.5°C **Accuracy: 0.1°K Tropo 0.2°K Strato**
	Repeatability[2]	0.15°C **Long term stab: 0.05°K**
	Reproducibility[3]	0.2°C (1080 – 100 hPa) 0.3°C (100 – 20 hPa) 0.5°C (20 – 3 hPa)
	Lag:	< 0.4 s (1000 hPa) < 1 s (100 hPa) < 2.5 s (10 hPa)

Wind	Type:	Code-correlating GPS receiver, 12 channels
	Accuracy:	
	- Horizontal position	10m
	- Vertical position	20m **Vert Res. 50 m tropo 250 m strato**
	- Wind velocity	0.2m/s **0.5 m/s**
Water Vapour	Type:	Chilled Mirror Hygrometer (NOAA)
	Accuracy	Approx 10% **2%**
Ozone Sonde	Type:	Coulometric, employing a electrochemical concentration cell with platinum electrodes, and a Teflon gas sampling pump
	Estimated accuracy:	< 10% **5%**
	Noise:	< 1% of full scale
	Sensitivity:	2 to 3 parts per billion by volume

Radiation and Aerosol Lidar

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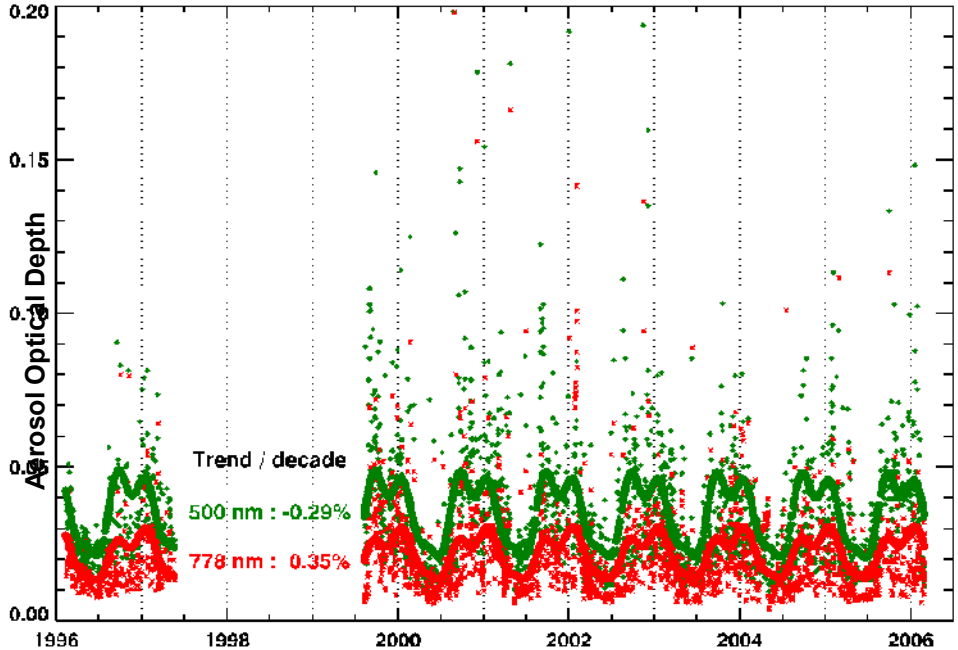
Lauder is a BSRN site in collaboration with Bureau of Meteorology, Melbourne.

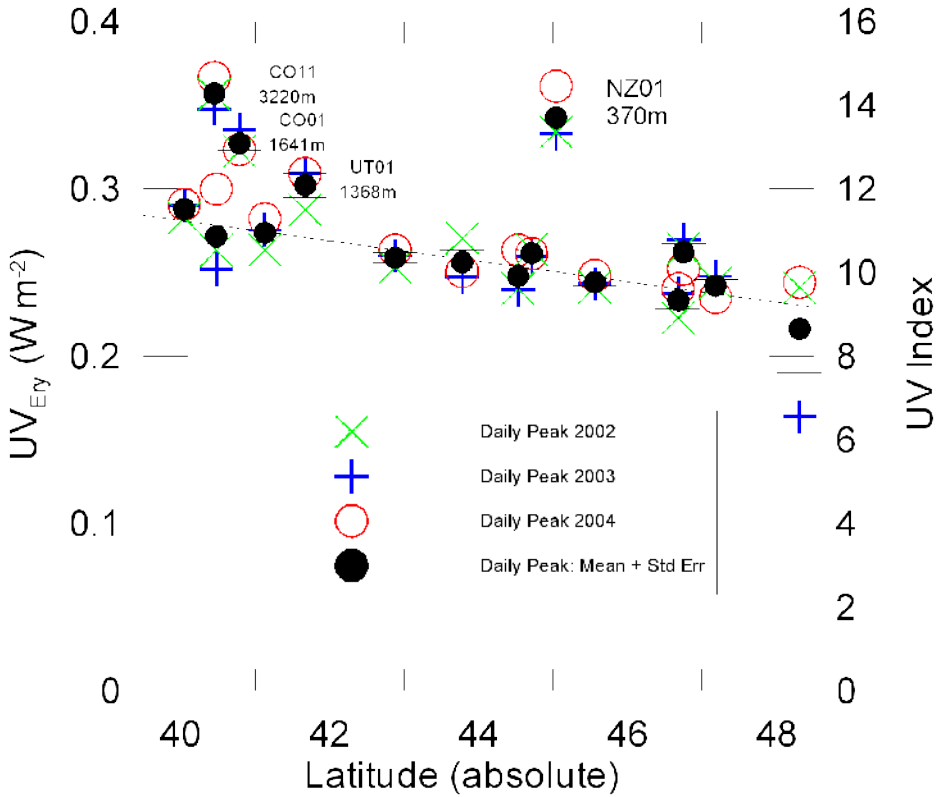
- BSRN measures the downward components of solar and Thermal irradiance from a globally distributed surface based network of 35 sites.
- Ancillary BSRN data at Lauder is: meteorological observations, aerosol optical depth and Spectral UV.
- Clean atmosphere at Lauder shown in AOD record:

Lauder Aerosol Optical Depth at 500 and 778 nm



Spectral UV Measurements

Peak UV at 45 S (Lauder, NZ) compared with sites in North America of comparable latitude.

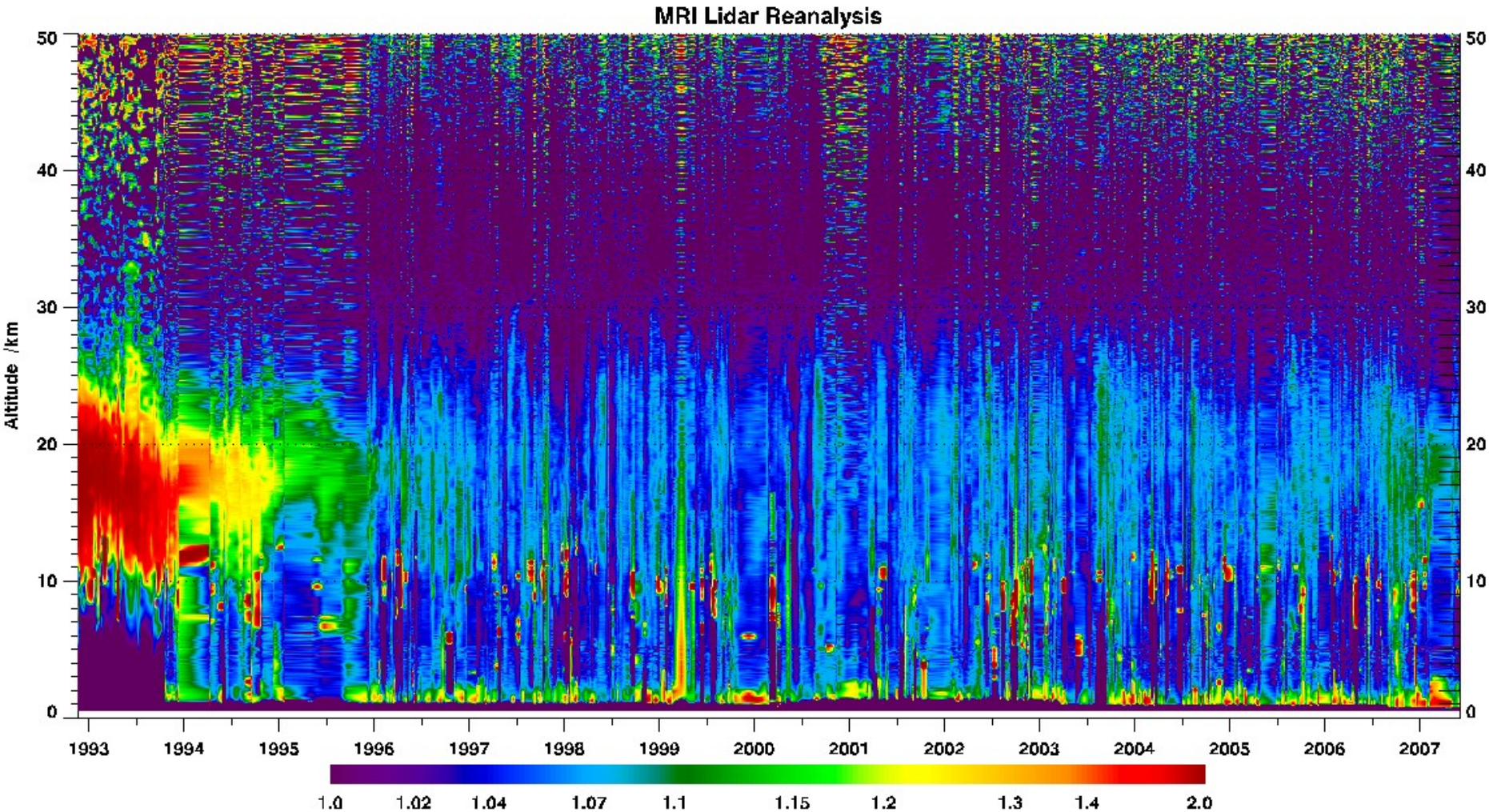


NIWA UV Radiometer measuring Spectral Irradiance, 285 – 450 nm. Accuracy ±3%, traceable to NIST.

Aerosol Lidar Measurements

The results shown are from the MRI Japanese Lidar processed using algorithms developed at Lauder.

The Lauder analysed backscatter ratio is shown, interpolated between measurements.



Tropospheric Carbon Column Observing Network (TCCON)

NIWA
Taihoro Nukurangi

Synopsis

- **Future climate predictions uncertain, in part because the carbon budget cannot be balanced.**
- **A new generation of satellite measurements (OCO, GOSAT) will be coupled with high precision, ground-based column density measurements, to determine the surface to atmosphere flux of CO_2 and CH_4.**
- **Carbon flux presently inferred from a network of surface measurements, interpreted within atmospheric transport models, but surface measurements alone have limited success in inferring carbon flux to the atmosphere.**
- **Column measurements are much less sensitive to uncertainties in vertical mixing, but respond similarly to surface flux. Thus the combination of column and surface measurements is a powerful constraint on model transport, and enables confident determination of flux.**
- **Satellite column measurements complement ground-based observations by providing dense global coverage.**
- **Measurement and modeling capabilities have now advanced to the point that it is possible to exploit this synergy between surface, column, and satellite measurements.**

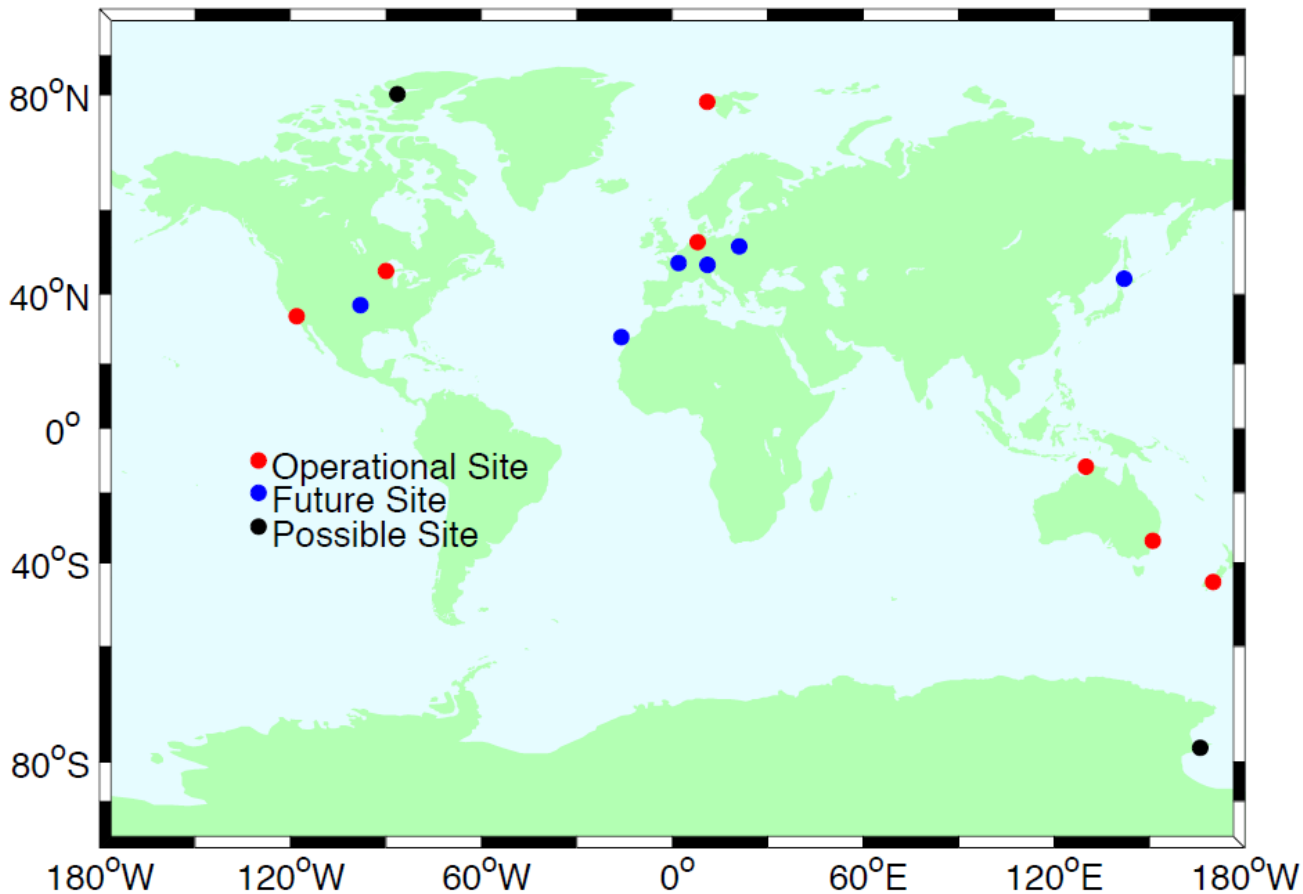
•Hi-resolution FTS in near-IR solar absorption making precision column measurements of CO_2, CH_4, CO & N_2O.

•Continuous in-situ measurements of CO_2 at all sites.

•Continuous in-situ measurements of CH_4, CO, N_2O at selected sites (Lauder, Darwin, others TBD).

•An in-situ precision CO_2 analyser (Licor 7000) will be installed at Lauder soon.

Total Carbon Column Observing Network (TCCON) Sites



Operational

Bremen, Germany

Ny-Alesund, Norway

Wollongong, Australia

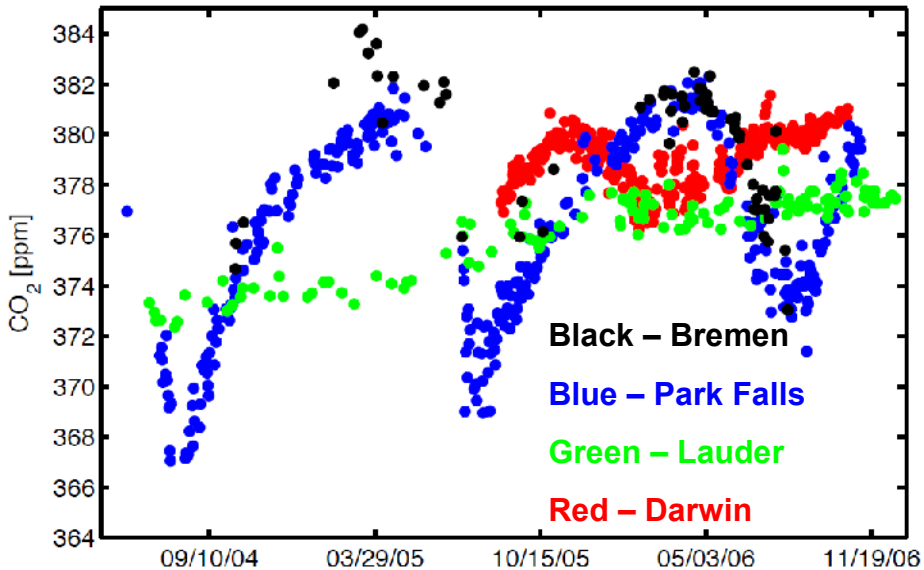
Darwin, Australia

Lauder, New Zealand

Park Falls, Wisconsin, USA

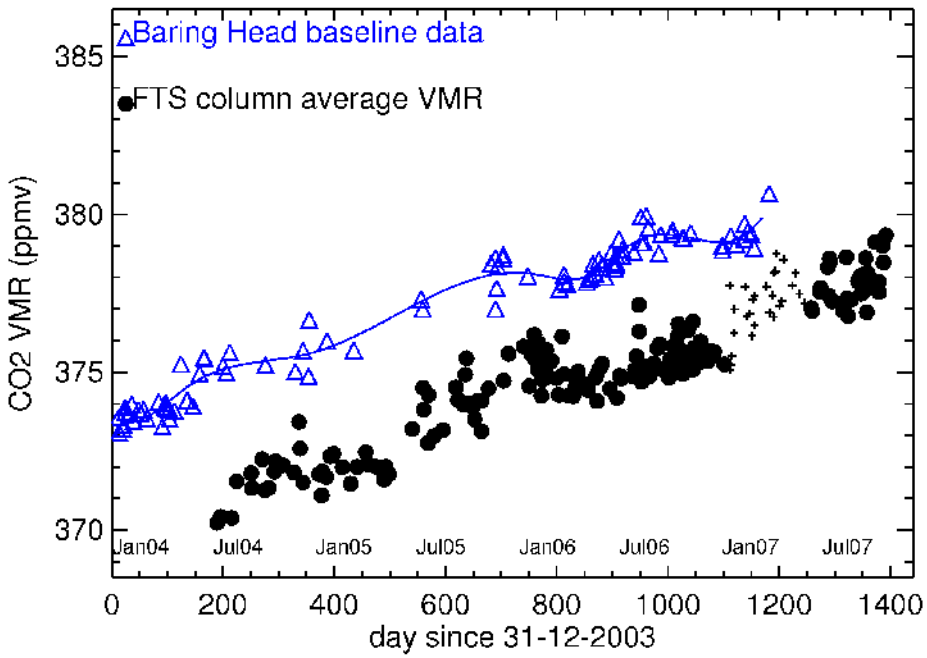
CIT, Pasadena, USA

Examples of TCCON data



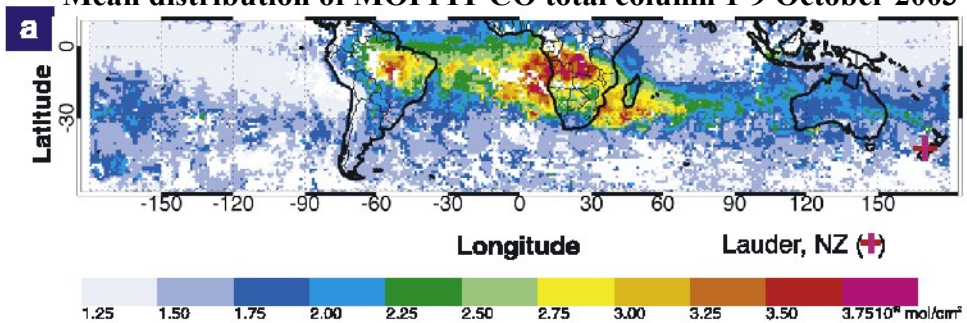
Average Vol. Mix. Ratios are derived from the greenhouse gas column amount and the O_2 column amount, obtained from the same measurement spectra.

The daily average CO_2 precision is <= 0.6 ppm.

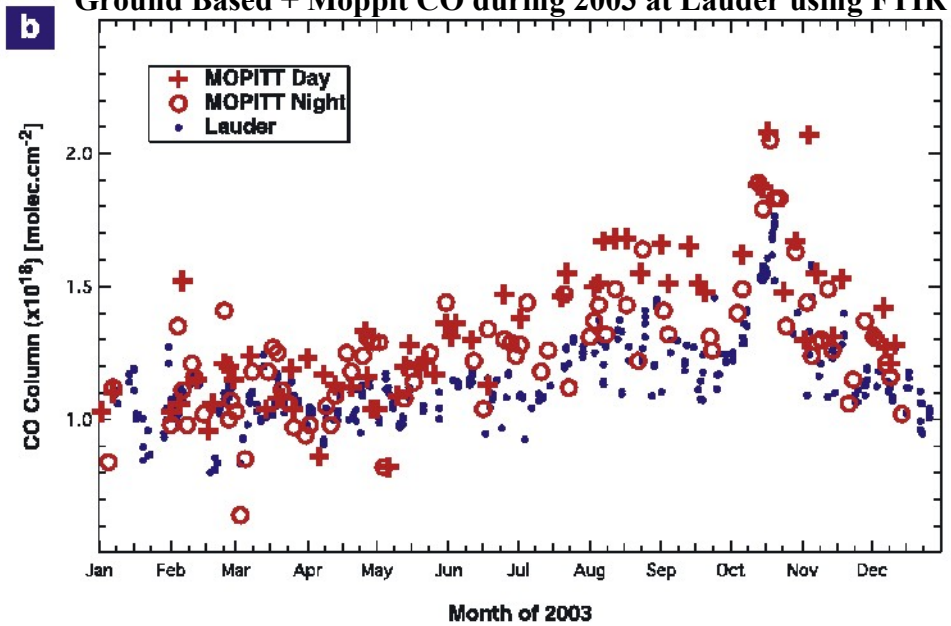


Examples of the use of Mid-IR FT-Spectroscopy to measure atmospheric composition at Lauder and Validate Satellite measurements

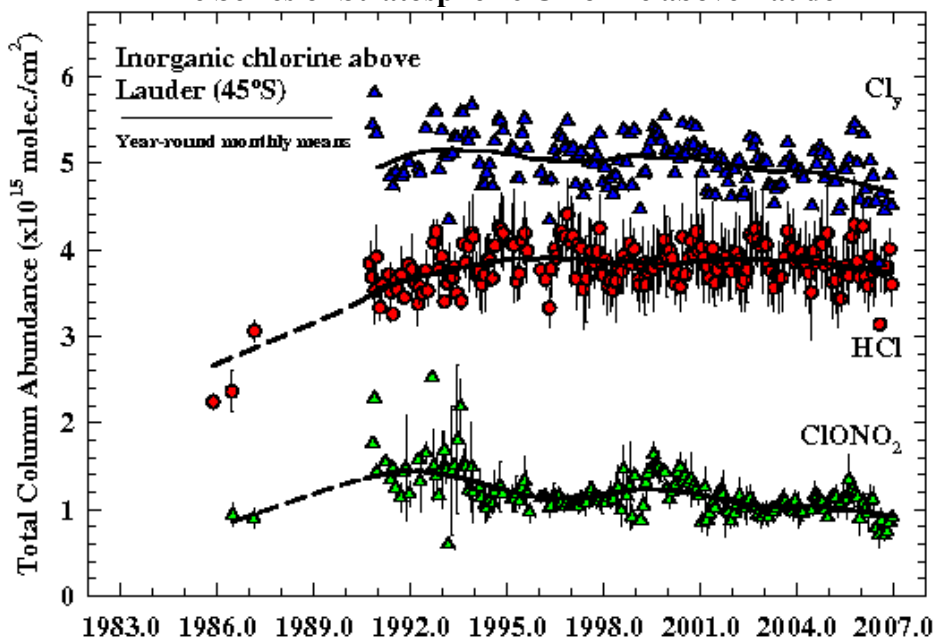
Mean distribution of MOPPIT CO total column 1-9 October 2003



Ground Based + Moppit CO during 2003 at Lauder using FTIR



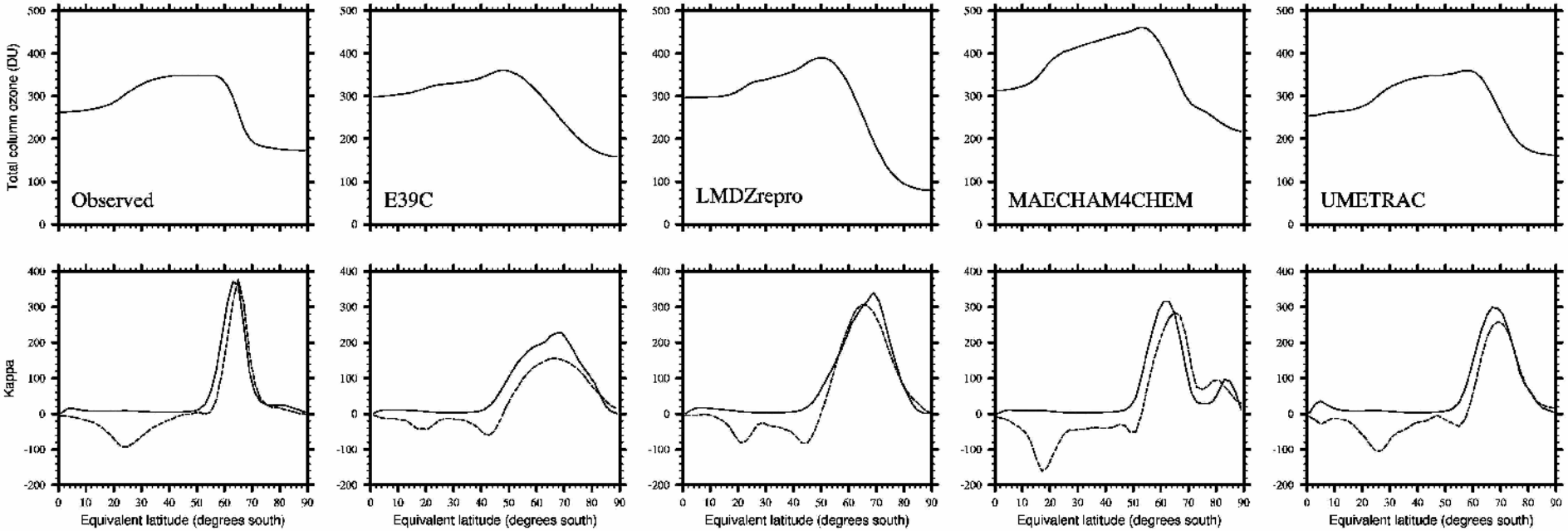
Time Series of Stratospheric Chlorine above Lauder



Coupled Chemistry Climate Modelling at Lauder

NIWA Taihoro Nukurangi

Comparison of equivalent latitude zonal mean ozone total column and meridional impermebility from observations and four coupled chemistry-climate models.



Top plots shows the sharp gradients at the edge of the ozone hole.
Solid line in the bottom plots = kappa (meridional impermeability).
[Kappa is a diagnostic of the strength of the dynamical mixing barrier.]
Dashed lines = the negative of the total column ozone gradient.

EMETRAC: Unified Model with Eulerian Transport and Chemistry

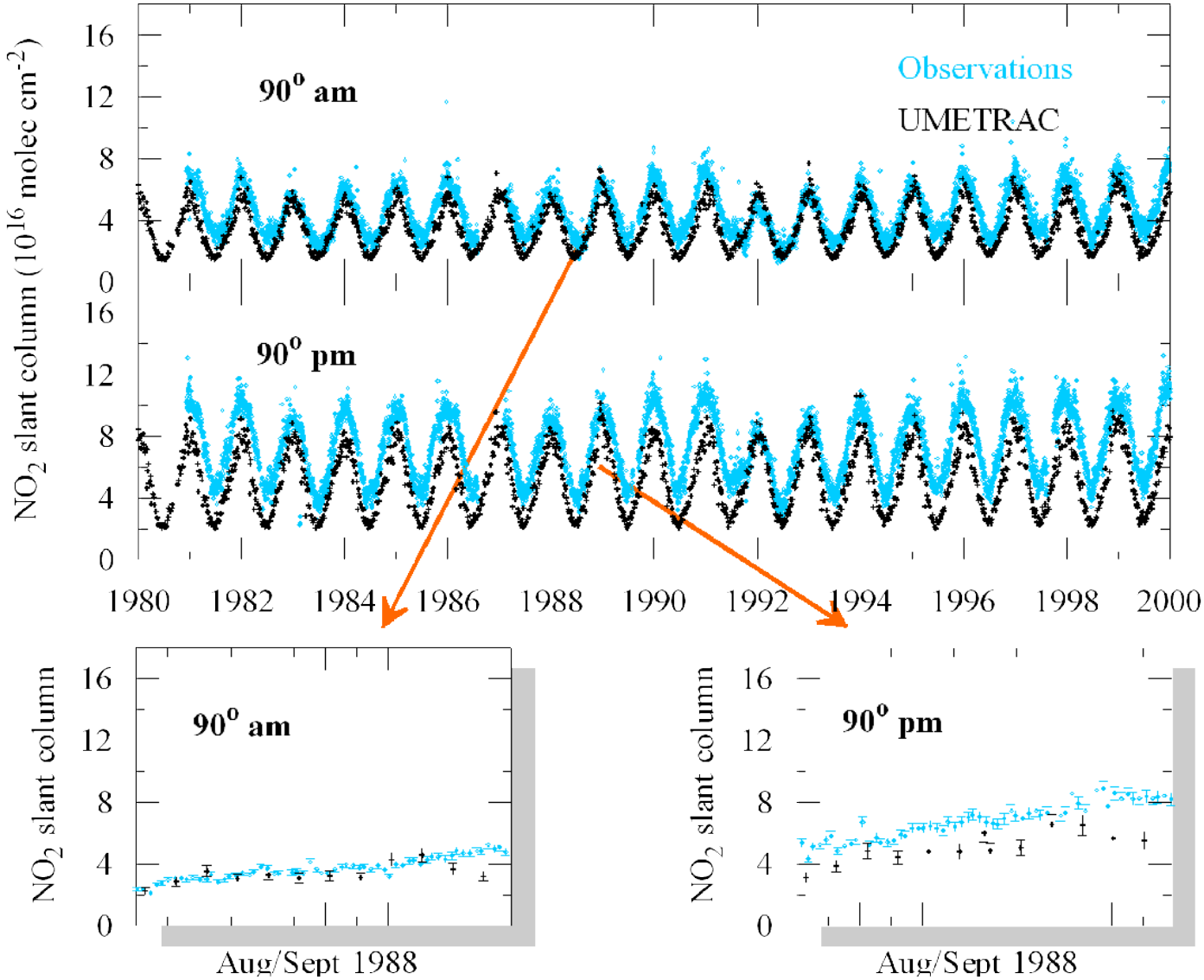
The bottom plots demonstrate that:

(b) there is a narrow mixing barrier at the edge of the polar vortex. All the models produce kappa peaks that are too wide and generally a little too weak.

(b) Gradients in total column ozone are strongly correlated with kappa (both in the real atmosphere and in models).

(c) The models representation of the ozone gradients at the edge of the polar vortex are too weak and this is strongly related to the modelling of dynamics at the vortex edge.

Measured NO_2 v CCM (Unified Model with Eulerian Transport and Chemistry)



Struthers, et. al., Atmos. Chem. Phys., 4, 2227–2239, 2004

Lauder Staff

Scientists: 8

Engineers/Technicians: 6

Administration/Computing: 2

Students: typically 2 PhD students + 2 overseas students gaining practical experience.

Published Research Papers 2003-2007

Lauder First Author: 26

Lauder Co-Author: 91

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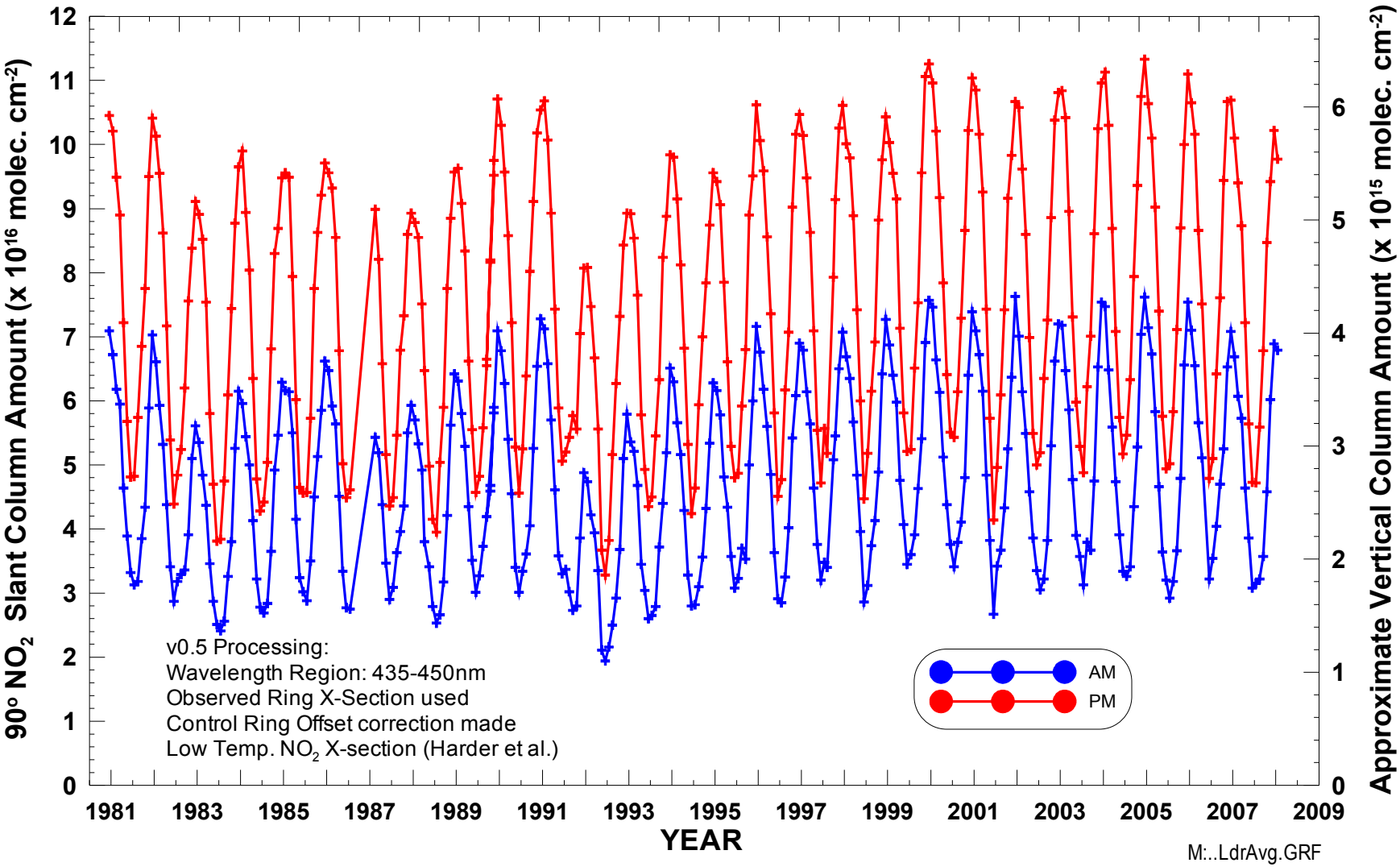
LONG TERM NO_2 MEASUREMENTS OVER LAUDER, NZ (45° S, 170° E)



Atmos. Chem. Phys., 4, 2227–2239, 2004
www.atmos-chem-phys.org/acp/4/2227/
SRef-ID: 1680-7324/acp/2004-4-2227
European Geosciences Union

Atmospheric Chemistry and Physics

NIWA
Taihoro Nukurangi

Past and future simulations of NO_2 from a coupled chemistry-climate model in comparison with observations

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Received: 8 June 2004 – Published in Atmos. Chem. Phys. Discuss.: 20 August 2004
Revised: 15 November 2004 – Accepted: 15 November 2004 – Published: 22 November 2004

Abstract. Trends in NO_2 derived from a 45 year integration of a chemistry-climate model (CCM) run have been compared with ground-based NO_2 measurements at Lauder (45° S) and Arrival Heights (78° S). Observed trends in NO_2 at both sites exceed the modelled trends in N_2O, the primary source gas for stratospheric NO_2. This suggests that the processes driving the NO_2 trend are not solely dictated by changes in N_2O but are coupled to global atmospheric change, either chemically or dynamically or both. If CCMs are to accurately estimate future changes in ozone, it is important that they comprehensively include all processes affecting NO_x ($NO+NO_2$) because NO_x concentrations are an important factor affecting ozone concentrations. Comparison of measured and modelled NO_2 trends is a sensitive test of the degree to which these processes are incorporated in the CCM used here. At Lauder the 1980–2000 CCM NO_2 trends (4.2% per decade at sunrise, 3.8% per decade at sunset) are lower than the observed trends (6.5% per decade at sunrise, 6.0% per decade at sunset) but not significantly different at the 2σ level. Large variability in both the model and measurement data from Arrival Heights makes trend analysis of the data difficult. CCM predictions (2001–2019) of NO_2 at Lauder and Arrival Heights show significant reductions in the rate of increase of NO_2 compared with the previous 20 years (1980–2000). The model results indicate that the partitioning of oxides of nitrogen changes with time and is influenced by both chemical forcing and circulation changes.

Correspondence to: H. Struthers
(h.struthers@niwa.co.nz)

1 Introduction

It has been recognised for some time that the reactive species NO_x are important in the altitude range from approximately 20 km to 35 km in determining the concentration of stratospheric ozone (Crutzen, 1970). NO_x destroys ozone through the catalytic cycle shown in Reactions (1) and (2).

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (1)$$

$$NO_2 + O \rightarrow NO + O_2 \quad (2)$$

$$\text{(net)}\ O_3 + O \rightarrow 2\,O_2 \quad (3)$$

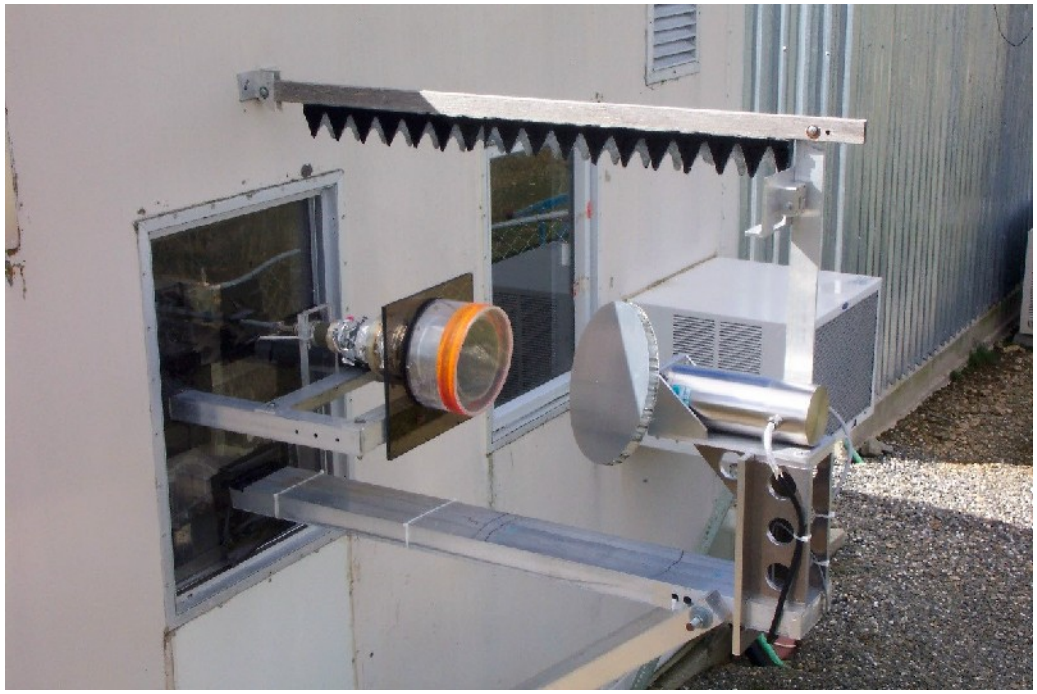
In the lower stratosphere (approximately 10 km to 20 km) the most significant influence of NO_x is its interaction with the ClO_x and BrO_x ozone loss cycles via the formation of reservoir species $ClONO_2$ and $BrONO_2$. NO_2 also reacts with OH (Eq. 4), reducing the HO_x concentration and thus inhibiting the HO_x catalysed destruction of ozone.

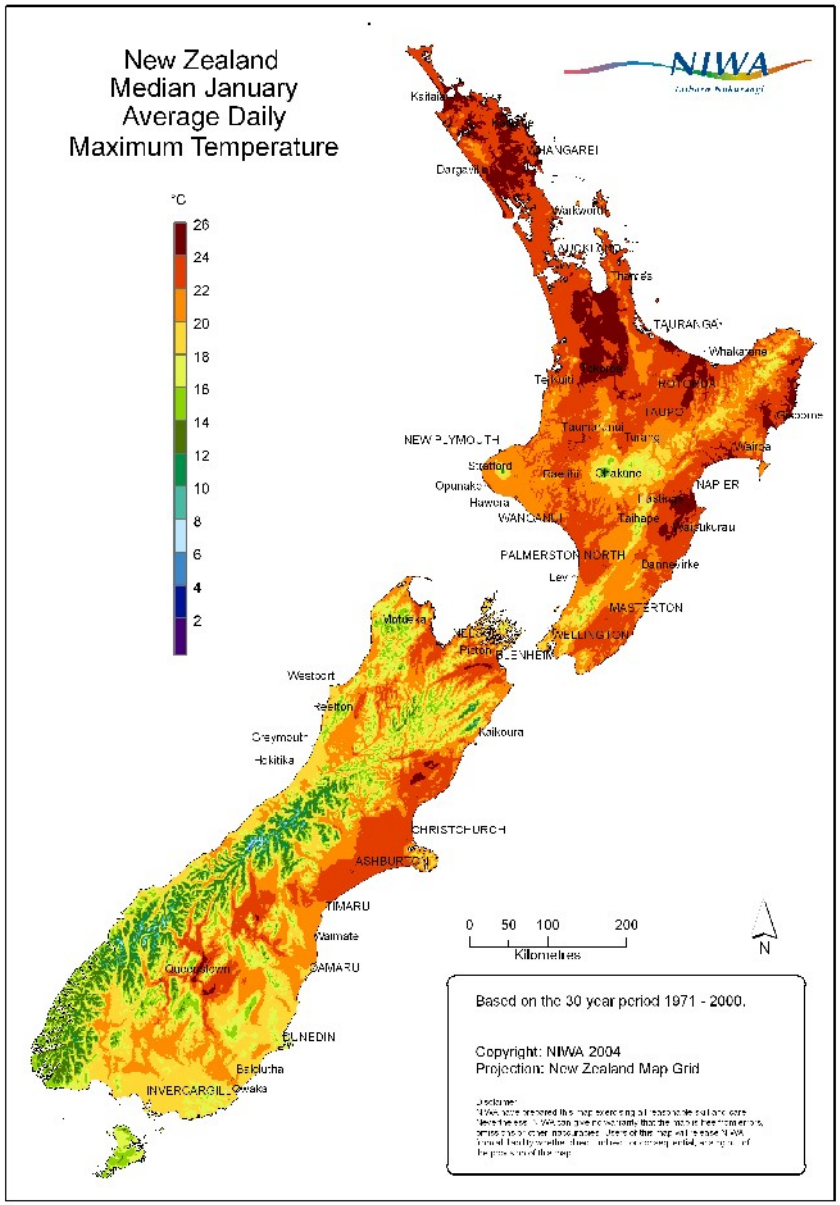
$$NO_2 + OH + M \rightarrow HNO_3 + M. \quad (4)$$

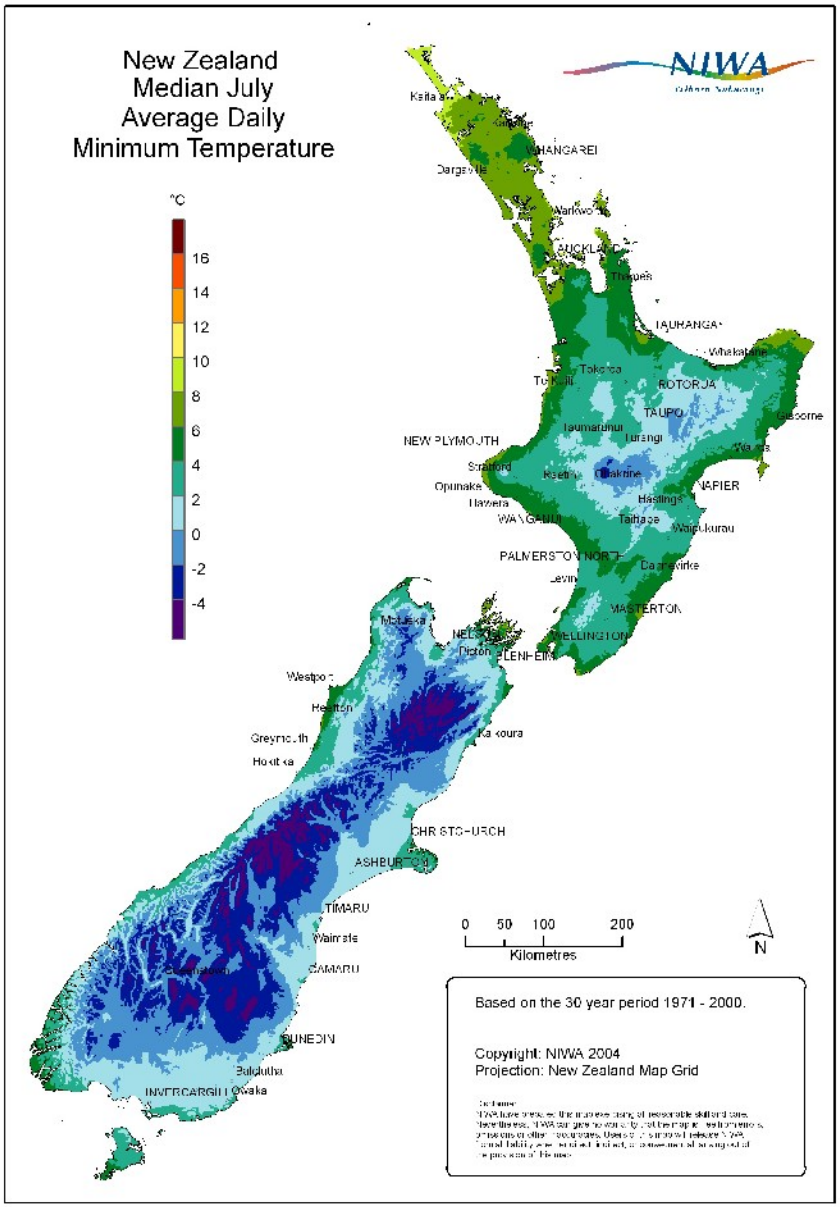
Oxidation of N_2O (Reaction (5)) is the major source of stratospheric NO_y ($NO+NO_2+NO_3+HNO_3+2N_2O_5+HNO_4+ClONO_2+BrONO_2$) and hence NO_x (Minschwener et al., 1993).

$$N_2O + O(^1D) \rightarrow 2NO. \quad (5)$$

N_2O concentrations are predicted to continue to increase over the coming century due to anthropogenic surface emissions, mostly attributed to agricultural nitrogen fixation (IPCC, 2001; WMO, 1999). Trends in the concentration of atmospheric N_2O for the period 1980 to 1988 have been estimated to be +0.25±0.05% per year (IPCC (2001), p253). Zander et al. (1994) quote a trend in N_2O of +0.33±0.04 %




New Zealand
Median January
Average Daily
Maximum Temperature
°C
26
24
22
20
18
16
14
12
10
8
6
4
2
NIWA
Taihoro Nukurangi
WHANGAREI
Dargaville
Warkworth
AUCKLAND
Thames
TAURANGA
Whakatane
Tokaroa
ROTORUA
TAUPO
Gisborne
NEW PLYMOUTH
Taumarunui
Turangi
Wairoa
Stratford
Opunake
Hawera
WANGANUI
Taihape
NAPIER
Wairarapa
PALMERSTON NORTH
Dannevirke
MASTERTON
WELLINGTON
Motueka
Picton
BLENHEIM
Westport
Reefton
Greymouth
Hokitika
Kaikoura
CHRISTCHURCH
ASHBURTON
TIMARU
Waimate
Queenstown
OAMARU
DUNEDIN
Balclutha
INVERCARGILL
Owaka
0 50 100 200
Kilometres
N
Based on the 30 year period 1971 - 2000.
Copyright: NIWA 2004
Projection: New Zealand Map Grid


New Zealand
Median July
Average Daily
Minimum Temperature
°C
16
14
12
10
8
6
4
2
0
-2
-4
NIWA
Taihoro Nukurangi
WHANGAREI
Dargaville
Warkworth
AUCKLAND
Thames
TAURANGA
Whakatane
Tokaroa
ROTORUA
TAUPO
Gisborne
NEW PLYMOUTH
Taumarunui
Turangi
Wairoa
Stratford
Opunake
Hawera
WANGANUI
Taihape
NAPIER
Hastings
Waipukurau
PALMERSTON NORTH
Dannevirke
MASTERTON
WELLINGTON
Motueka
Picton
BLENHEIM
Westport
Reefton
Greymouth
Hokitika
Kaikoura
CHRISTCHURCH
ASHBURTON
TIMARU
Waimate
OAMARU
DUNEDIN
Balclutha
INVERCARGILL
Owaka
0 50 100 200
Kilometres
N
Based on the 30 year period 1971 - 2000.
Copyright: NIWA 2004
Projection: New Zealand Map Grid

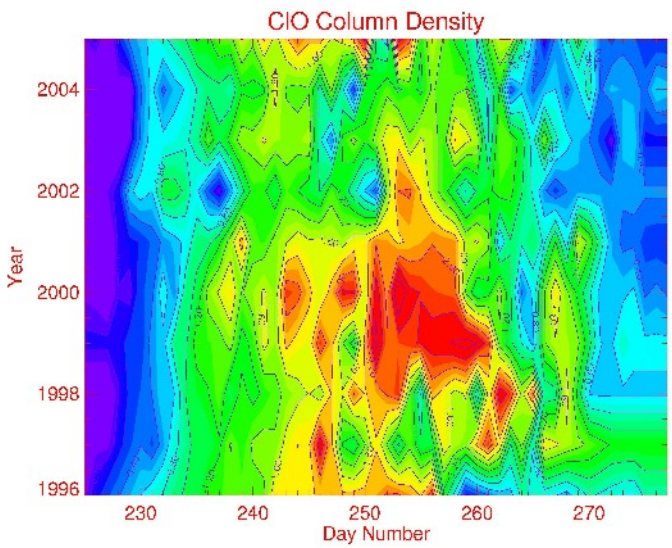
Lauder Measurements at the Antarctic NDACC Station, Dec 2007

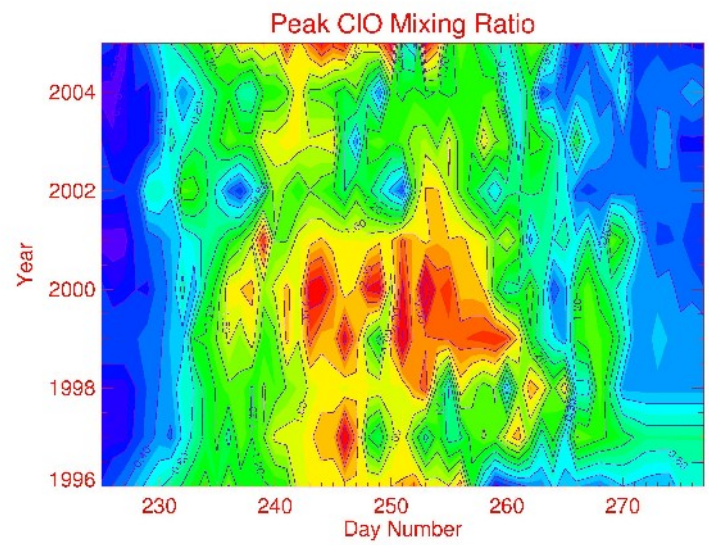
Instrument & Period	Parameter	Cooperating Institutions	Comments
Dobson Ozone 1987 -	Column ozone	NOAA/GMD, Boulder, USA	Direct sun obs. Winter moon obs. (when visible)
IR Interferometer (Bomem FTIR) 1992 - 96 (Bruker FTIR) 1997 -	Column HCl, HNO_3, $ClONO_3$, HF, CFCs, CO & GHGs, etc	University of Denver, Denver, USA	Mid-IR (windows in 2-12μ region). SFIT2 profiles
UV-Vis DOAS spectrometers 1982 -	Column NO_2 Column OClO Column BrO Column ozone Off-Axis BrO	University of Heidelberg	340-490 nm Halogens start 1993, Off-axis 1998.
ClO microwave radiometer 1996 -	ClO	SUNY, Stony Brook, New York, USA	278 GHz and 1 Day integration time

ClO Time Series, 1996-2005. Measured with the Stonybrook Microwave Radiometer at Scott Base

Contour plots of column density and peak mixing ratio vs. year and day of year

The Figures below show ClO column density and peak mixing ratio as a function of time, with day of year on the x-axis and year on the y-axis. The maximum values of ClO occur during the period of days 240-260, and the onset of ClO is less variable than its annual decline. The multi-year record shows that the highest values of ClO occurred in 1999-2000, that values were consistently low in 2002-2004, but rebounded significantly in 2005. In addition, there is a hint of the annual decline occurring earlier over the course of the 10 years.





The peak mixing ratio plot shows essentially the same features as the column density.