Stratospheric and Upper Tropospheric Aerosols over 22 Years at 45° South

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Australia and New Zealand Aerosol Workshop

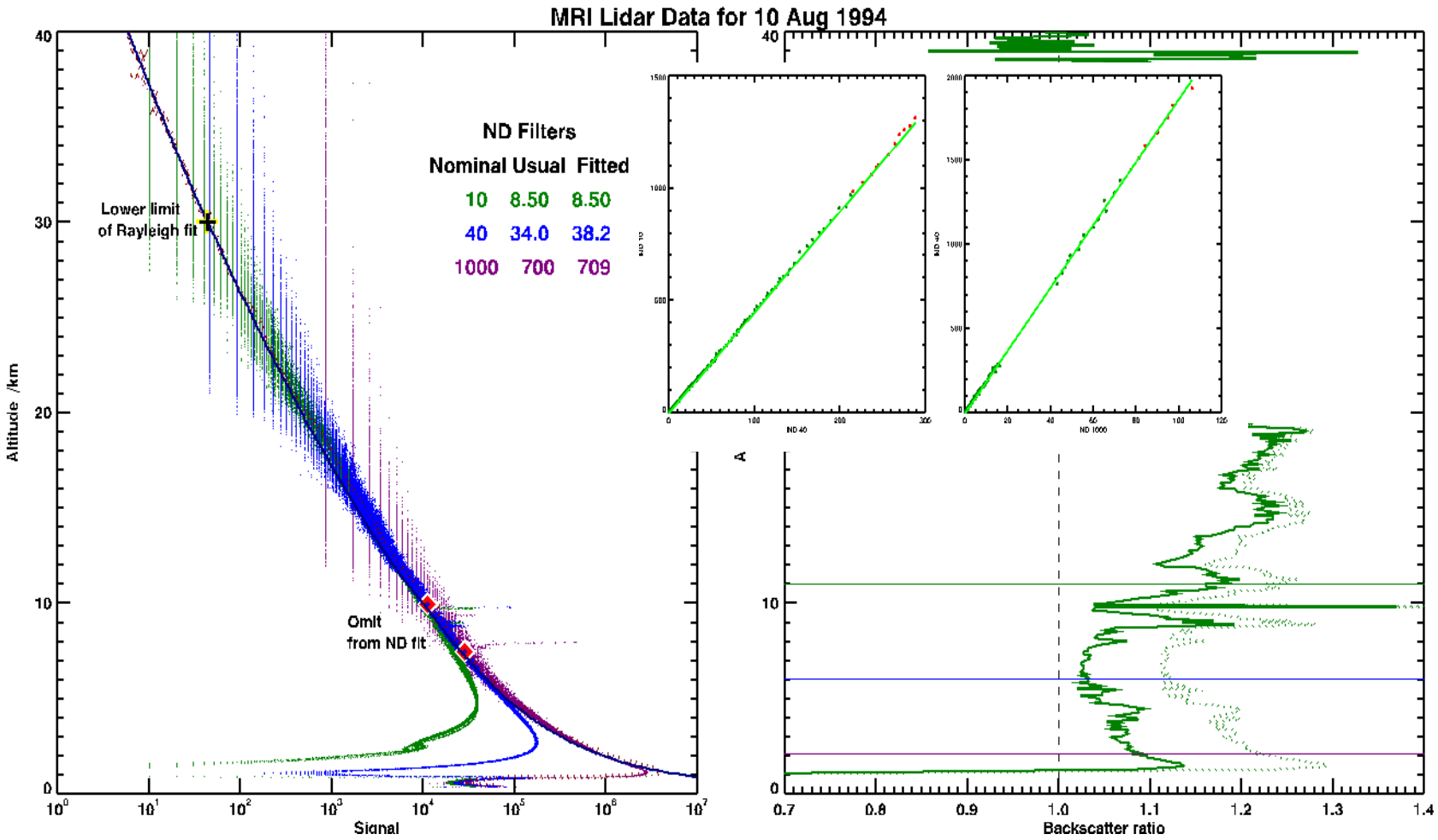
NIWA, Wellington

10-11 July 2014

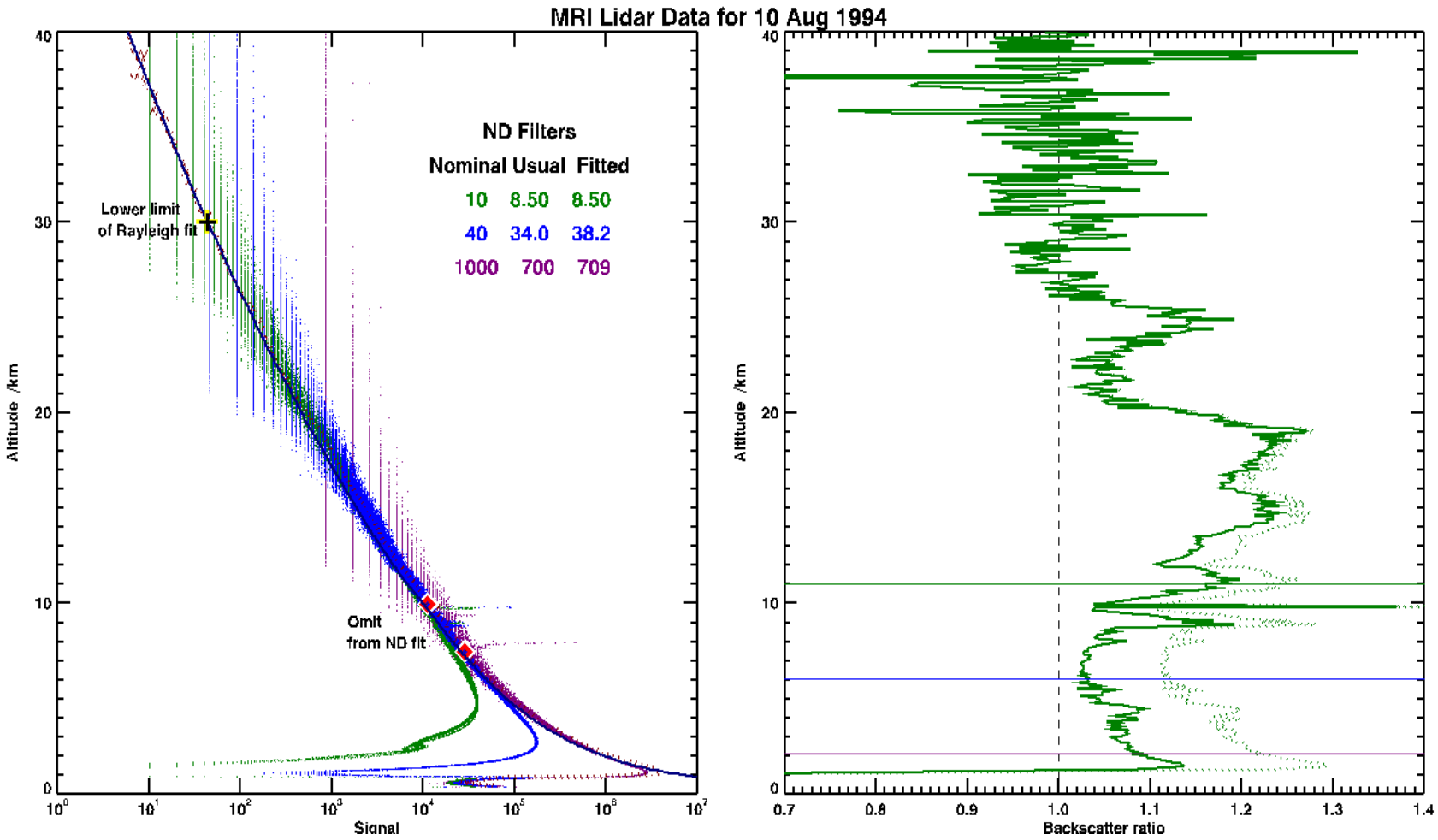
Lauder (45.0° S, 169.7° E, 370 m), in Central Otago, New Zealand, is the southern hemisphere mid-latitude charter site for the NDACC (formerly NDSC).

As a component of the NDSC measurement suite, the Meteorological Research Institute of Japan installed a Nd:YAG lidar system at Lauder in November 1992.

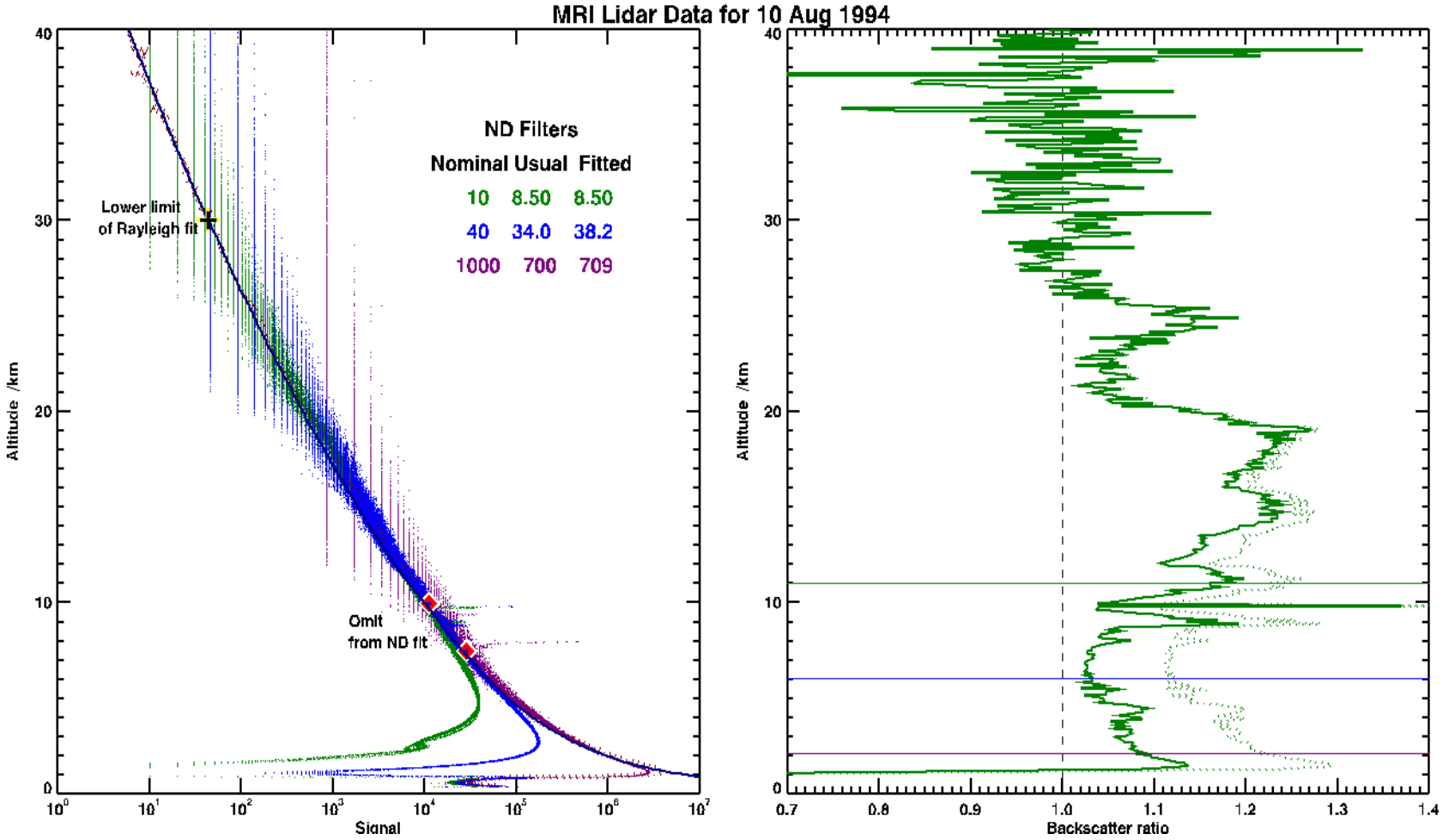
Laser	Nd:YAG (SHG)
Wavelength	532.07 nm
Pulse energy	135 mJ
Repetition rate	10 Hz
Divergence	0.2 mrad
Telescope	Schmidt Cassegrain
Diameter	254 mm
Field of view	2.0 mrad
Polarisation	P & S
Gate width	6 m min, 96 m nom.
Detector	PMT (Hamamatsu R1332)
ND filters	**1**,2,4,**10**,20,**40**,100,200,400,**1000**,10000
Signal processing	Photon counting



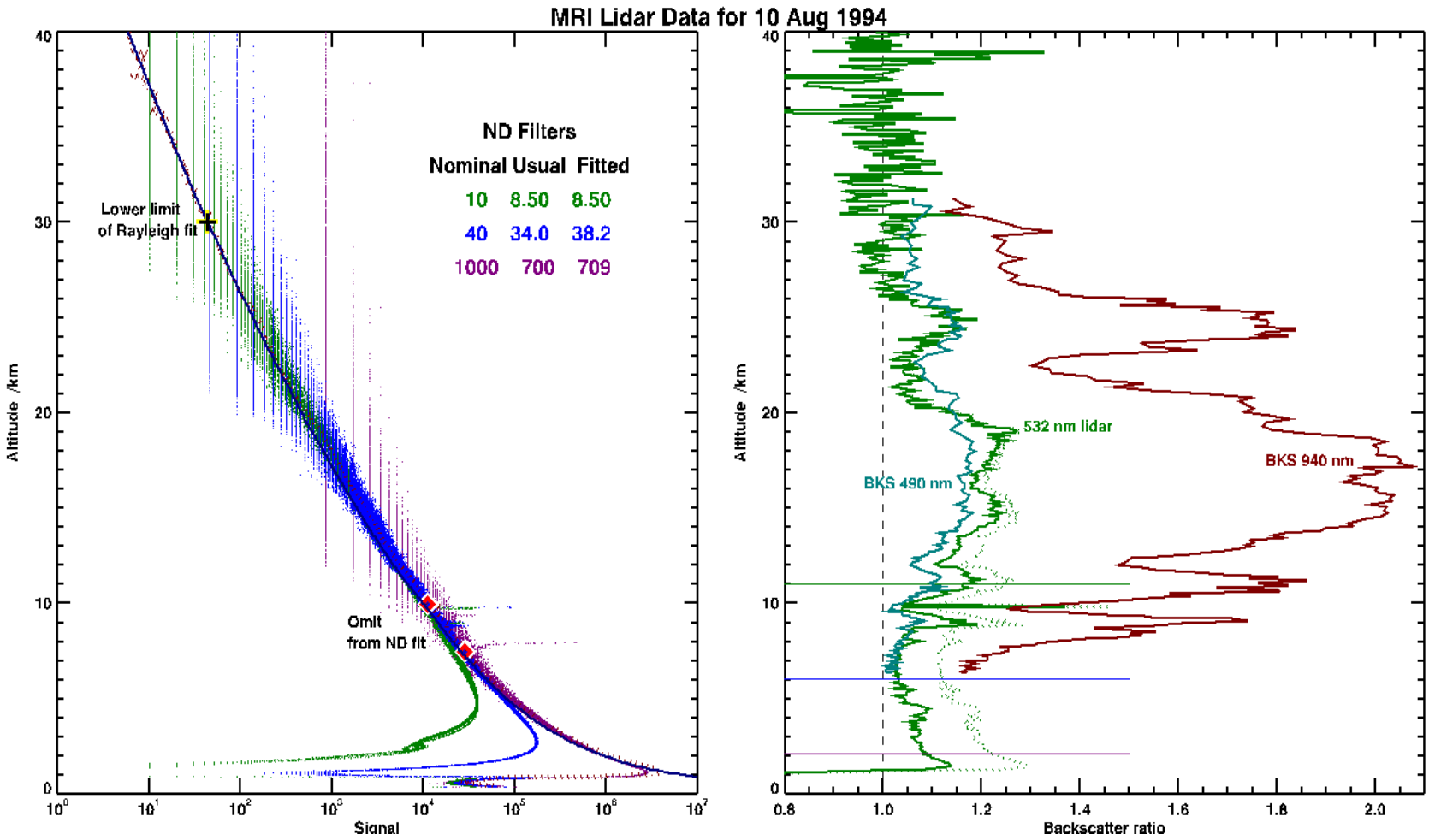
Neutral density filters were changed manually, with typically 3000 shots (5 min) per file, and ~30 files accumulated over 2-3 hours.
Varying laser power and tropospheric clarity are accommodated by fitting the ND ratios in respective overlap regions. Horizontal lines in RH plot show join heights.



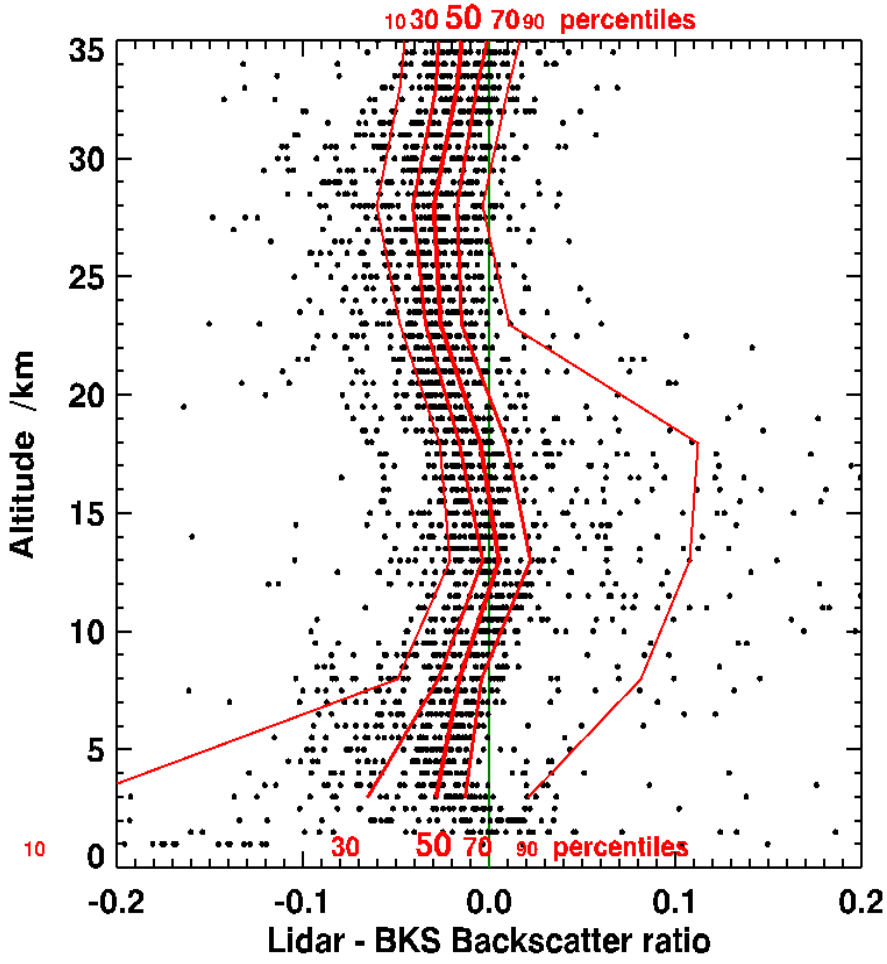
Atmospheric density has been calculated from Rosen backscattersonde (Lauder, 30+ km, night), ECC ozonesonde (Lauder, 30+ km, day), or radiosonde (Invercargill, 20+ km, twice daily), according to availability, extended with NMC data above sonde height.



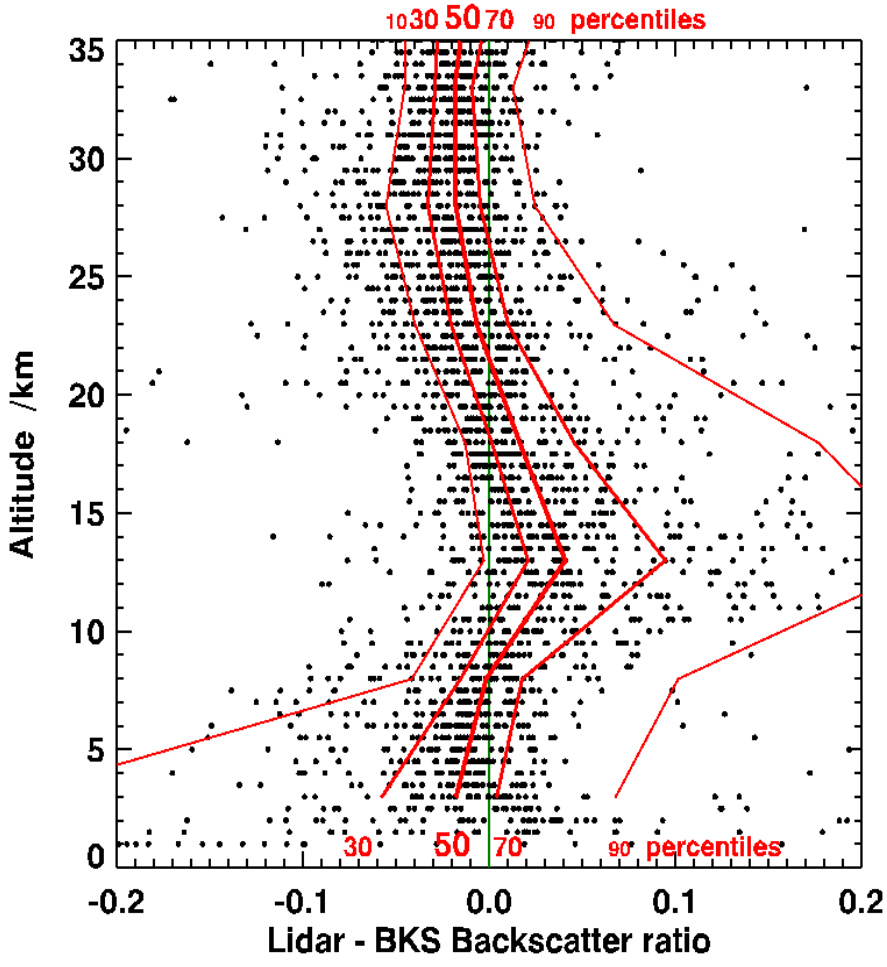
The solid line in the LH plot shows Rayleigh backscatter fitted down to the marked altitude (usually 30 km). After correction for Rayleigh extinction and ozone absorption in the Chappuis band, the aerosol extinction is calculated by the Klett method, with an extinction-to-backscatter ratio of 35 sr.



The backscattersonde (BKS) data are directly comparable, though the spectral regions (490 nm & 940 nm) are broad (~120 nm FWHM), as is the scattering angle, centred on 173° . The BKS has the advantage of no extinction, smaller dynamic range to measure, and concurrent sounding of temperature and ozone.



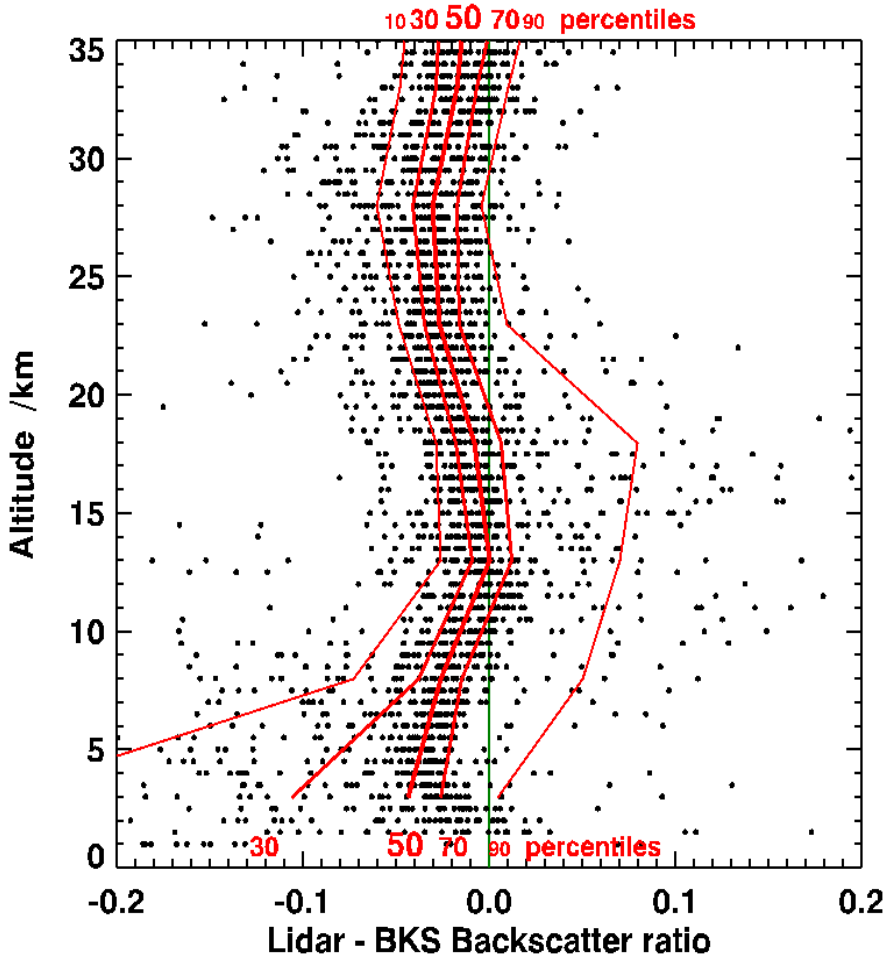
Over the period 1992 - 1999, 76 BKS were launched monthly. Of these, 40 were coincident in time with lidar measurements. The figure shows the differences on a 0.5 km vertical grid, between the lidar backscatter ratio at 532 nm and a weighted sum ($0.93\ R_{490} + 0.07\ R_{940}$) of the BKS data.



No ozone absorption

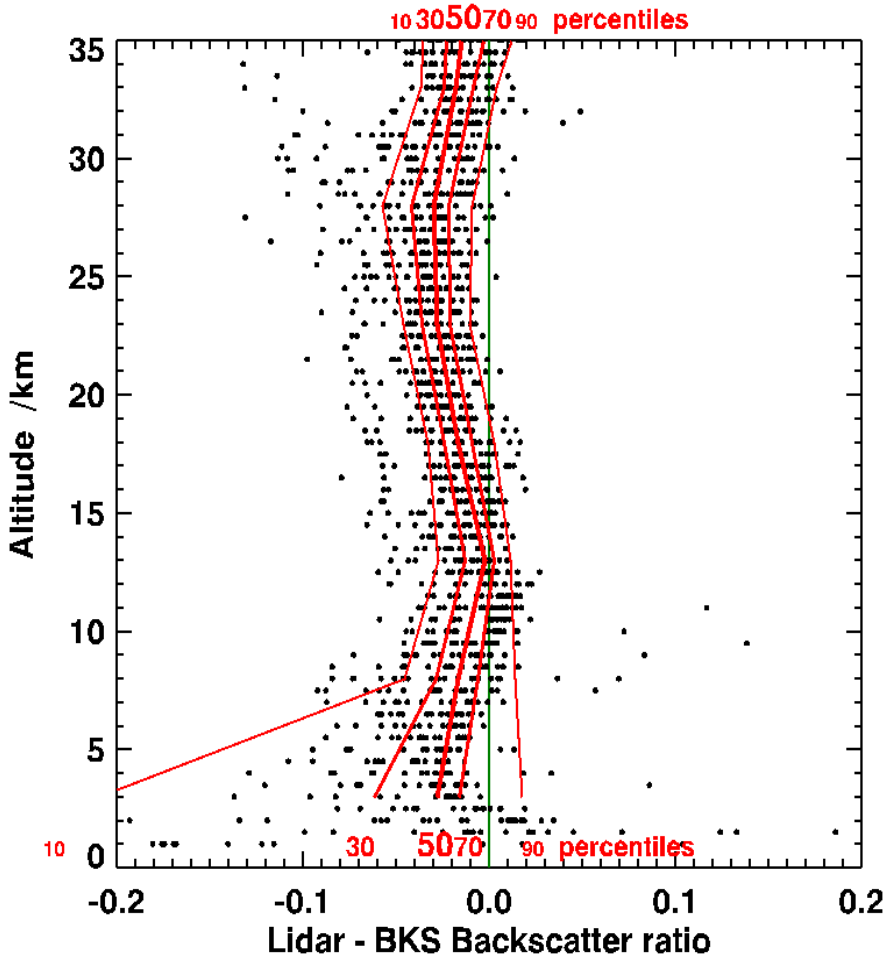
Some bias is apparent, with a downward trend from lower- to mid-stratosphere.

It corresponds in shape to the ozone absorption correction, but this was already included (O_3 cross-section at 532 nm = 2.8 x 10^{-25} m^2)



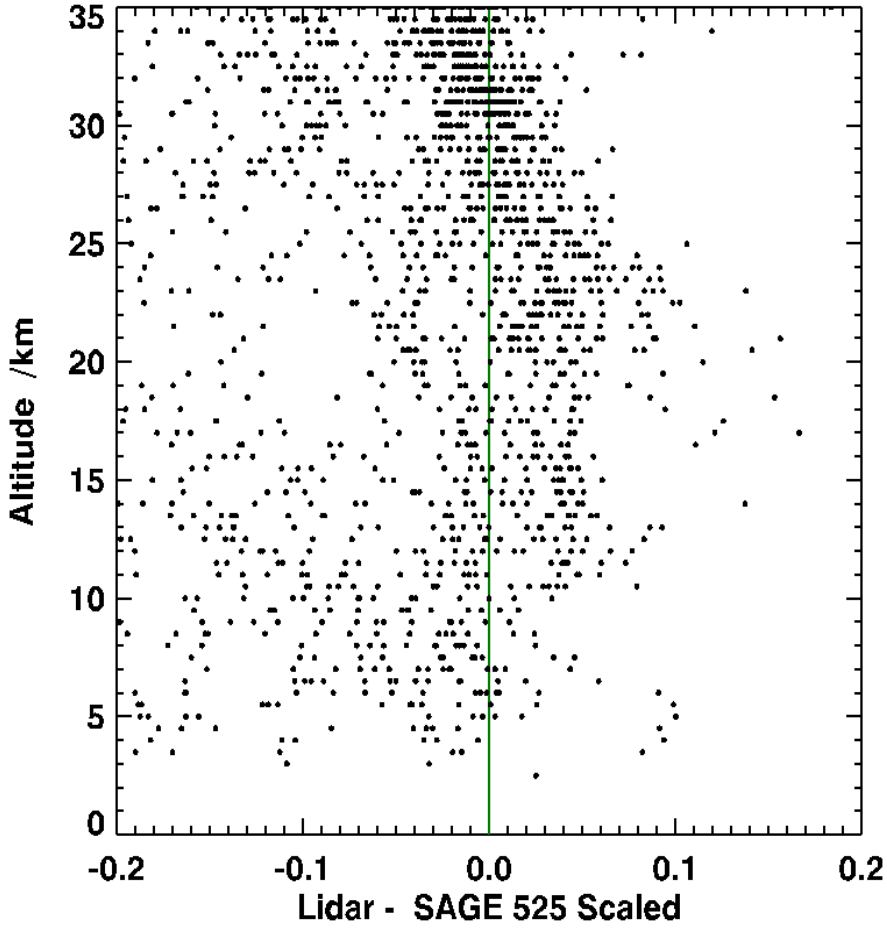
Extinction to backscatter ratio = 50 sr

We also compare the effect of changing the extinction to backscatter ratio, but there is too little aerosol through most of this period for it to have a significant effect.



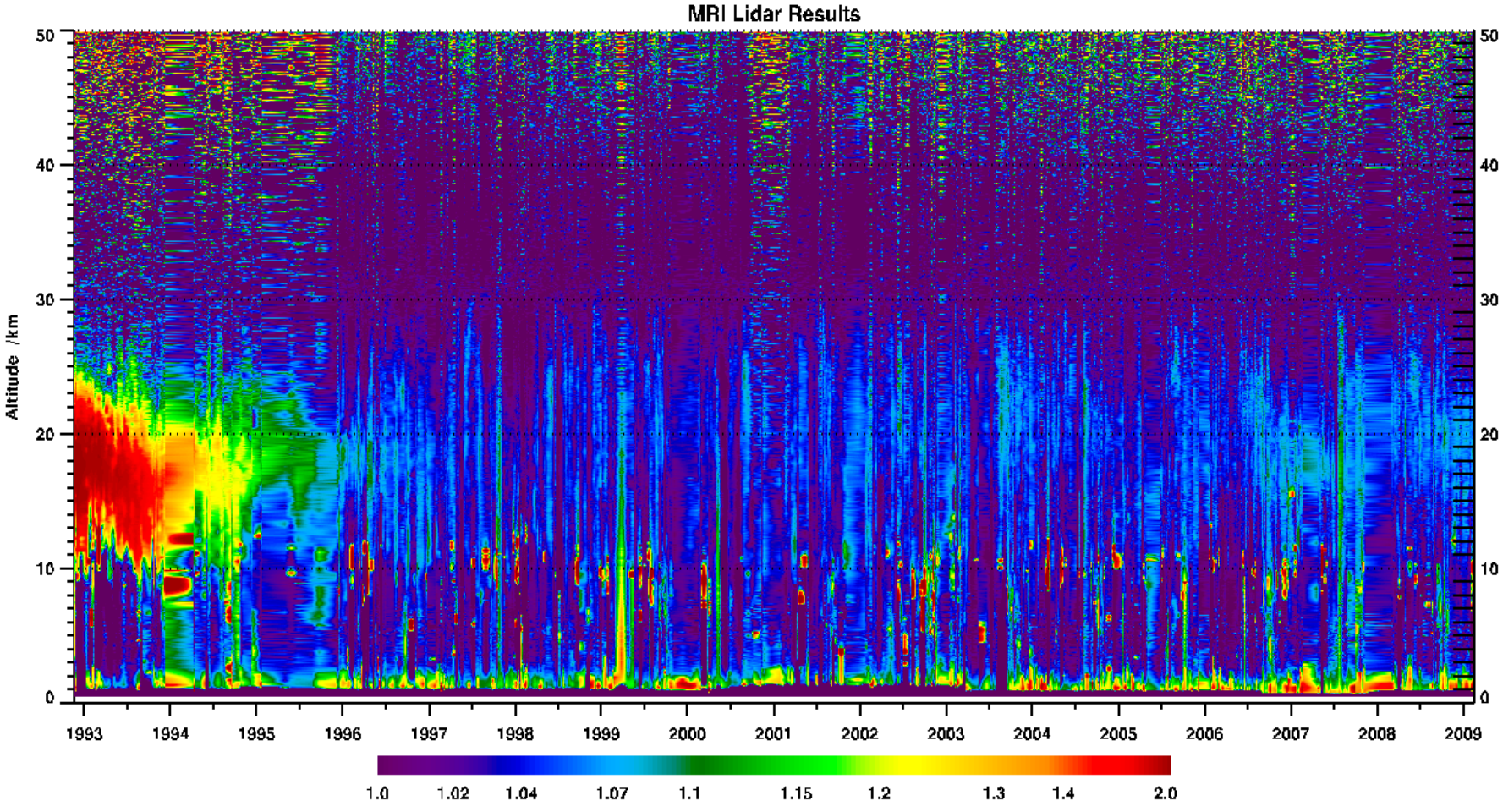
Measurements from 1996 onward

Restricting to only the 21 concurrent profiles after the Pinatubo-affected era shows much closer agreement, with a smaller slope in the apparent bias.



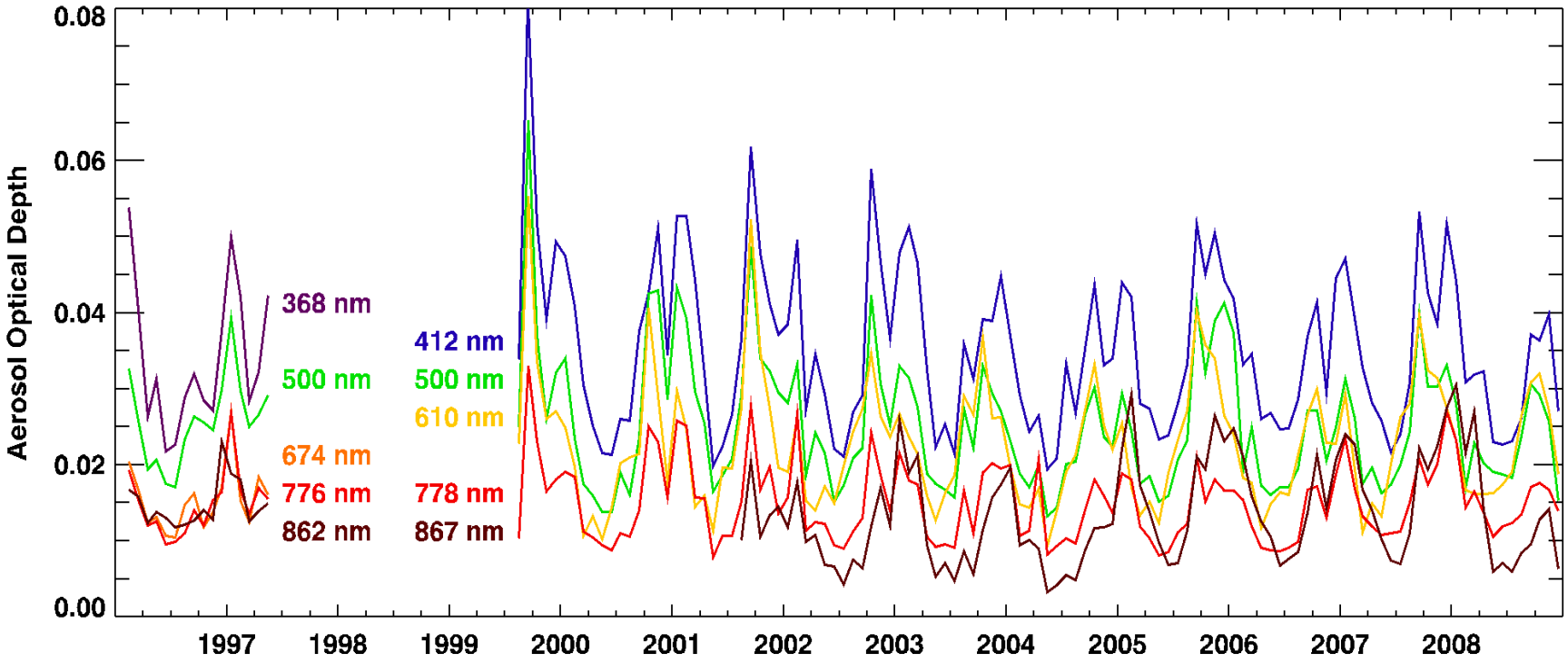
Extinction to backscatter ratio = 50 sr

There are 60 lidar profiles up to July 2005 that were coincident with SAGE II (v6.20) measurements of extinction at 525 nm. Converting SAGE II extinction to backscatter by the assumed backscatter ratio, the SAGE data again show agreement to the BKS data. The spread is much greater, but without an apparent low bias at 25 km.



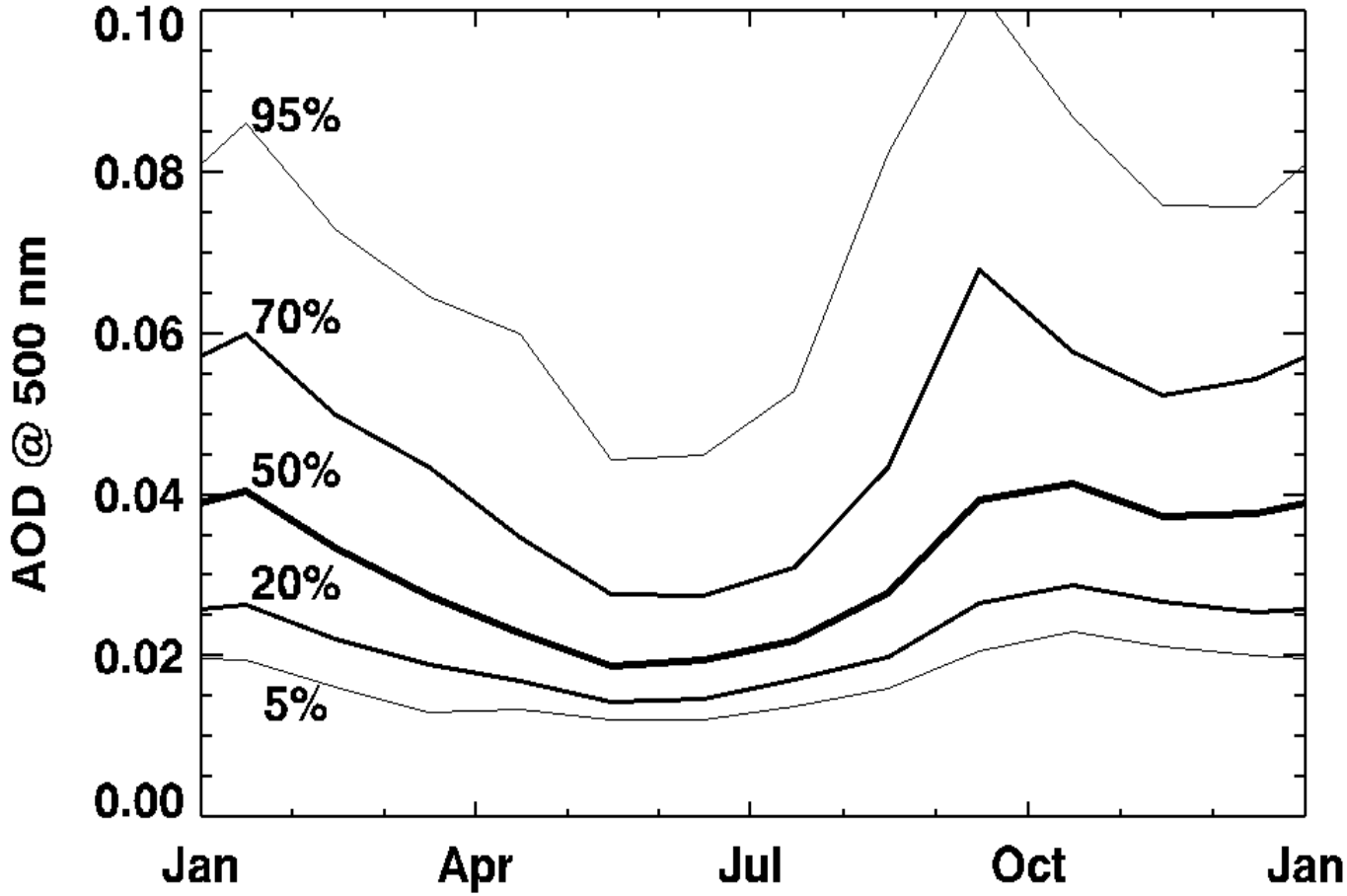
The single-channel Nd:YAG system was very reliable, working for 17 years with little maintenance until its replacement in February 2009.

Aerosol Optical Depth at Lauder - SPO1 & SPO2

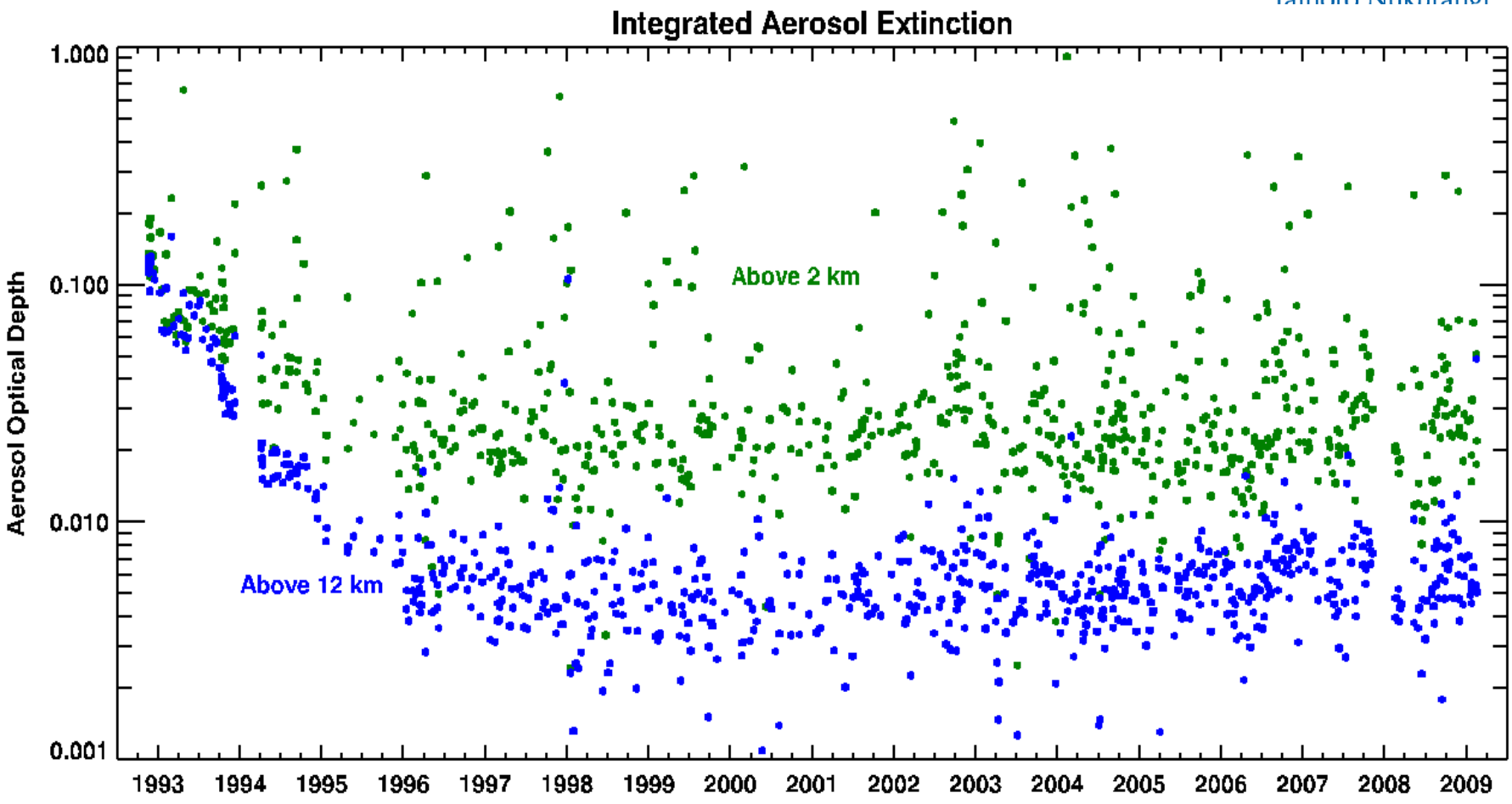


As a station of the Baseline Surface Radiation Network (BSRN), Lauder is instrumented for precision radiometry and aerosol optical depth (AOD) derivation. The AOD dataset now spans 18 years.

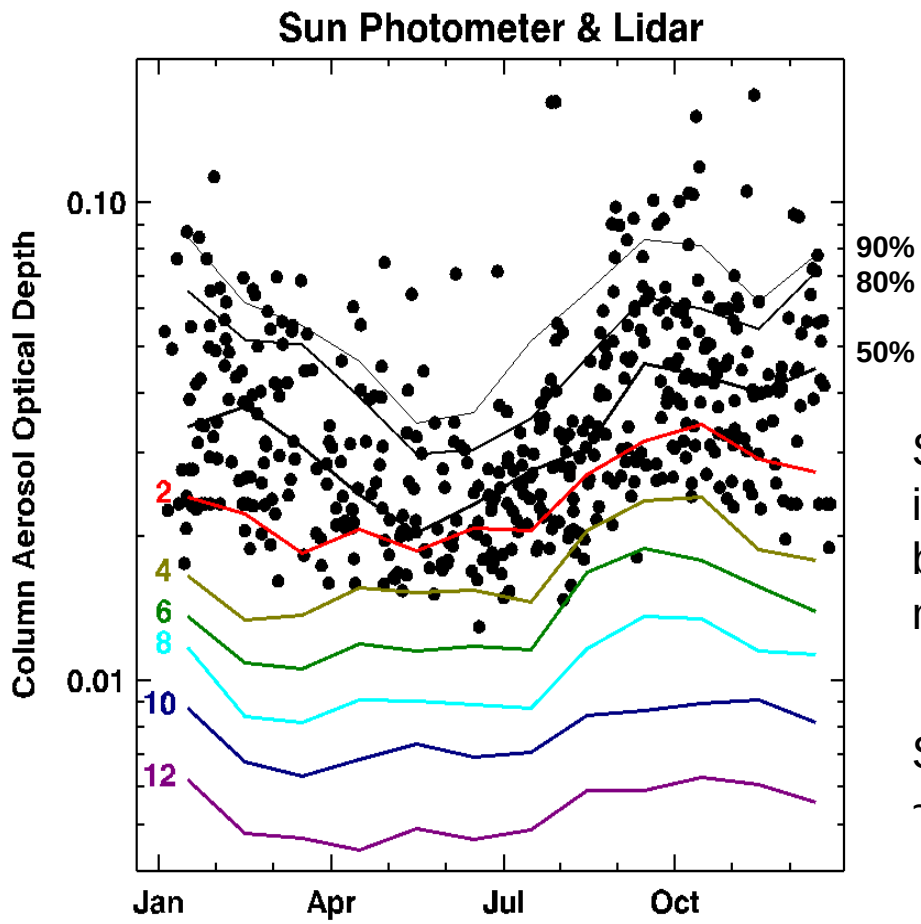
Though the earlier SPO1 instrument record seems to be consistent with the subsequent SPO2 dataset, the following analysis is confined to the latter.



The aerosol optical depth at all wavelengths shows a seasonal cycle, with a minimum in winter (JJA), and summer maximum. There is an additional peak in spring that is more episodic.



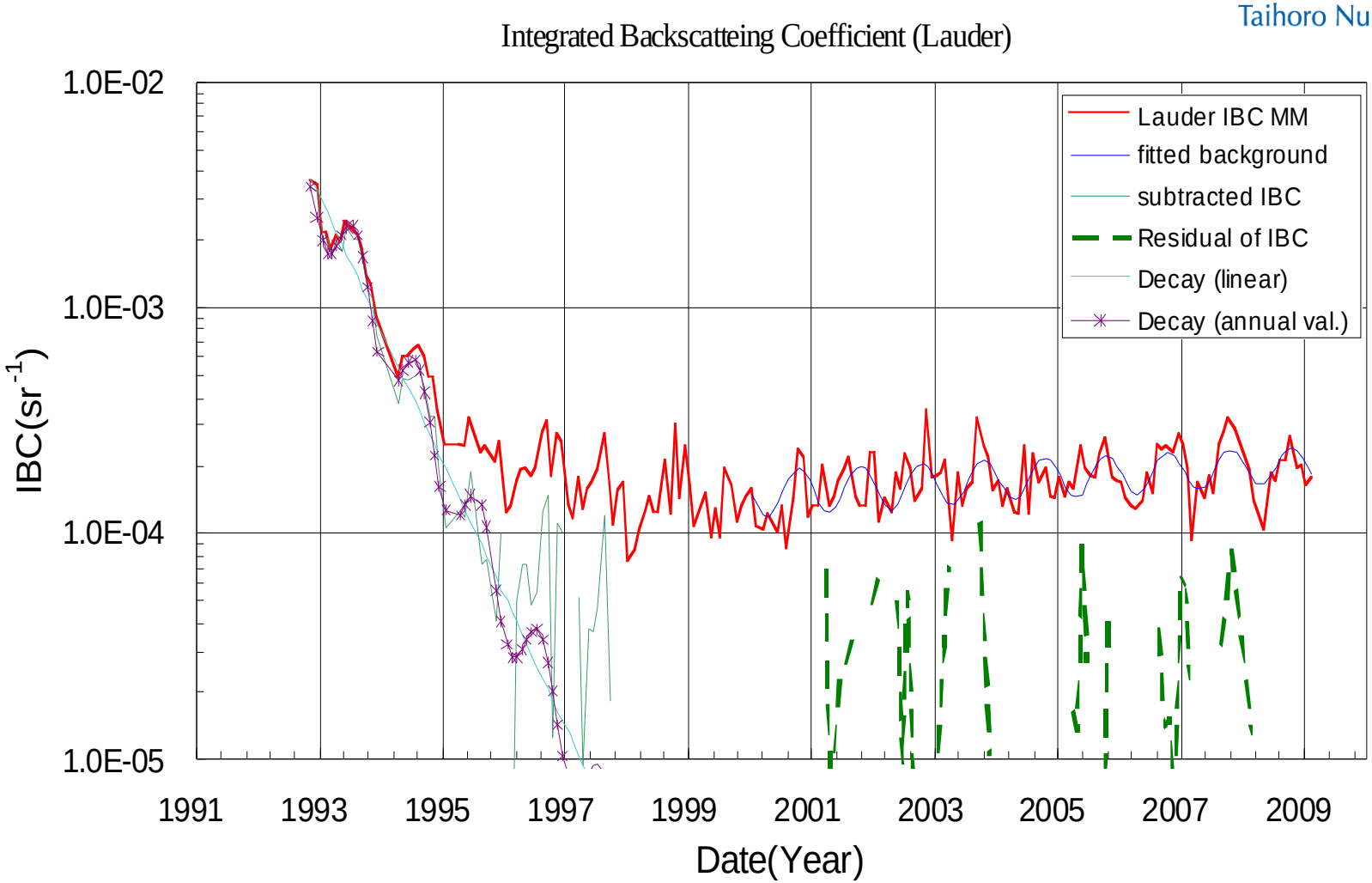
By integrating the aerosol extinction we obtain a measure of AOD (at 532 nm) within a given region of the atmosphere.



Summer peak in AOD is below 2 km altitude, but spring peak is mid-tropospheric

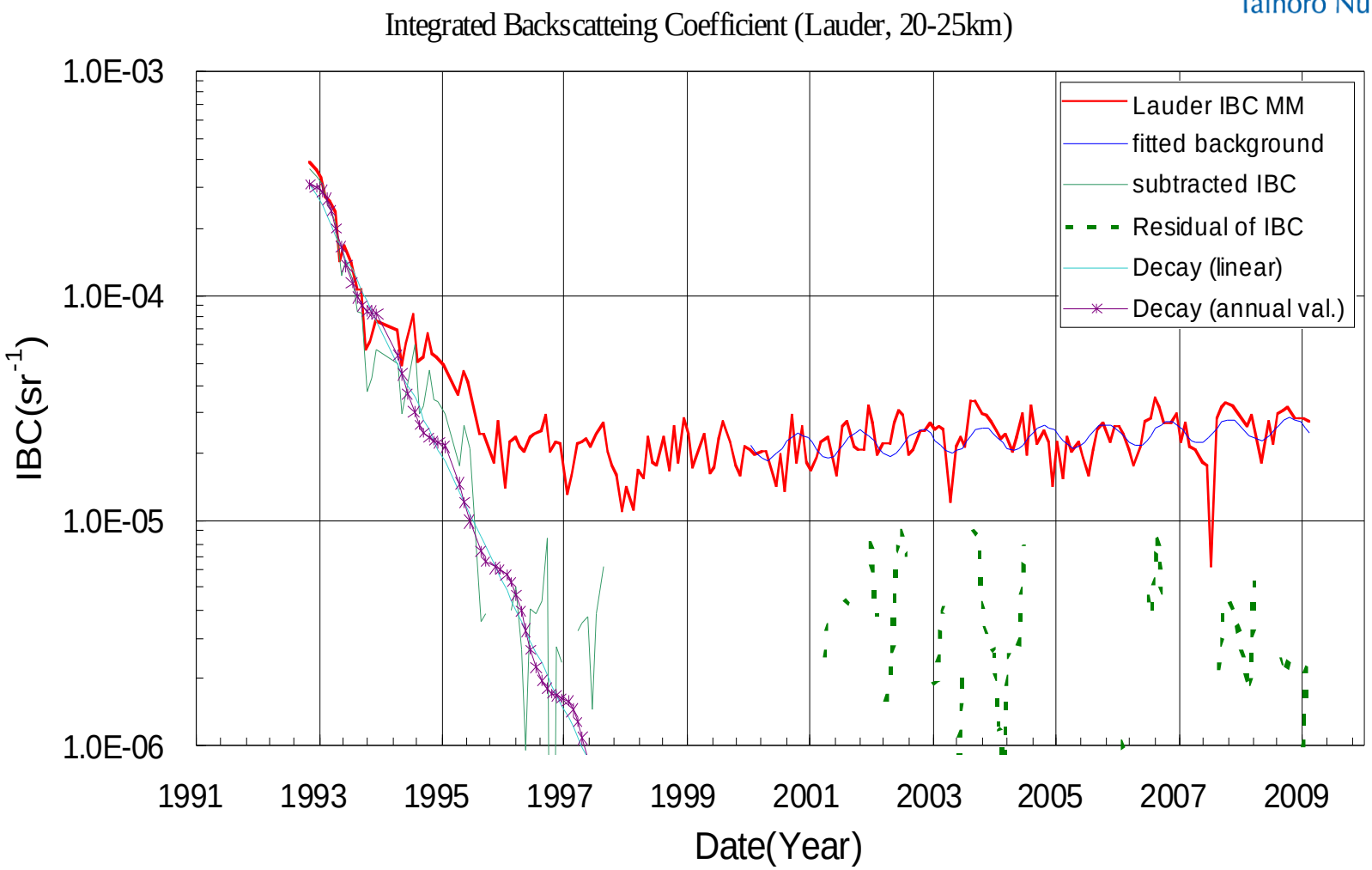
Stratospheric AOD ~ 0.006

Selecting just those SPO2 data (dots) adjacent to night-time lidar observations, we compare median, 80th and 90th percentiles (black lines) of 500 nm AOD with lidar AOD (532 nm) above altitudes as shown (coloured lines).



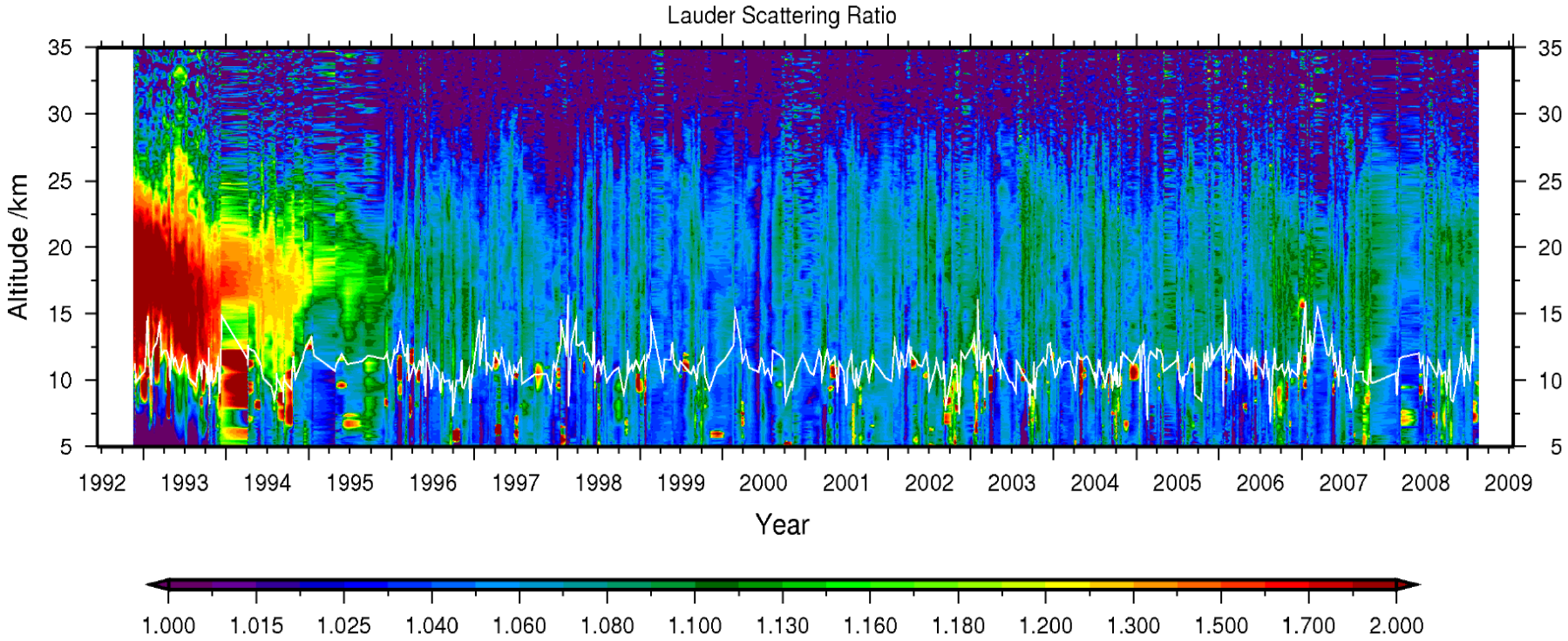
Stratospheric IBC has been increasing since 2000 at a rate of 3.8% per year.
Stratospheric AOD has increased from ~0.005 to ~0.007 in that time.

*T. Nagai, B. Liley, T. Sakai, T. Shibata, O. Uchino, SOLA **6**, 69 (2010).*



Upward trends in stratospheric aerosol has been observed at Mauna Loa (4.8% yr^{-1}) and Boulder (6.3% yr^{-1}), with a maximum at 20-25 km altitude, whereas the Lauder trend is only 2.6% yr^{-1} in this altitude range.

*T. Nagai, B. Liley, T. Sakai, T. Shibata, O. Uchino, SOLA **6**, 69 (2010).*



The upward trend is readily apparent in this plot, especially in the 15 - 20 km altitude range. The increase of stratospheric optical depth at 532 nm by 0.002 over the decade represents a 10% increase in total AOD in winter.

Hofmann et al. (2009, GRL **36**, L15808) suggested that increased stratospheric aerosol could be from increased coal burning since 2002, mainly in China.

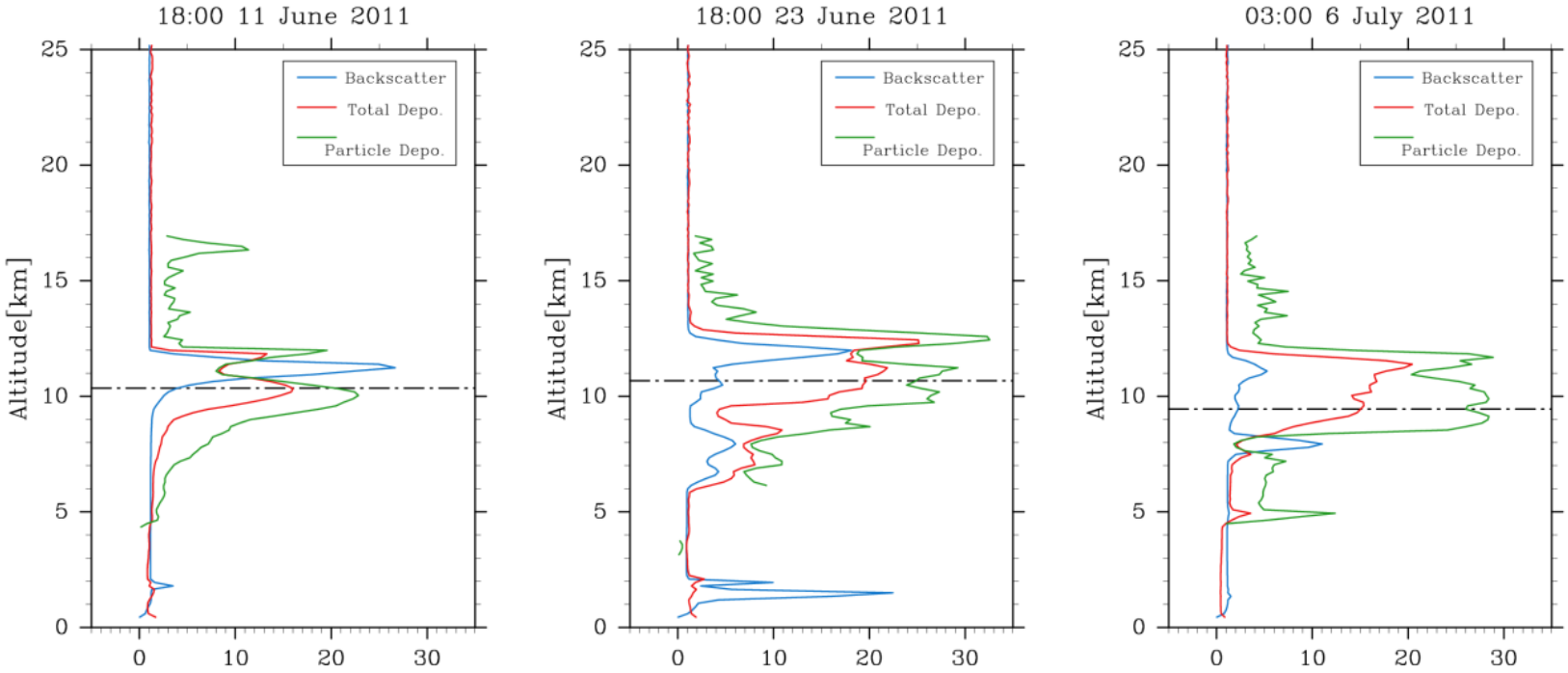
Instead, space-borne CALIOP lidar data show several small volcanic injections.

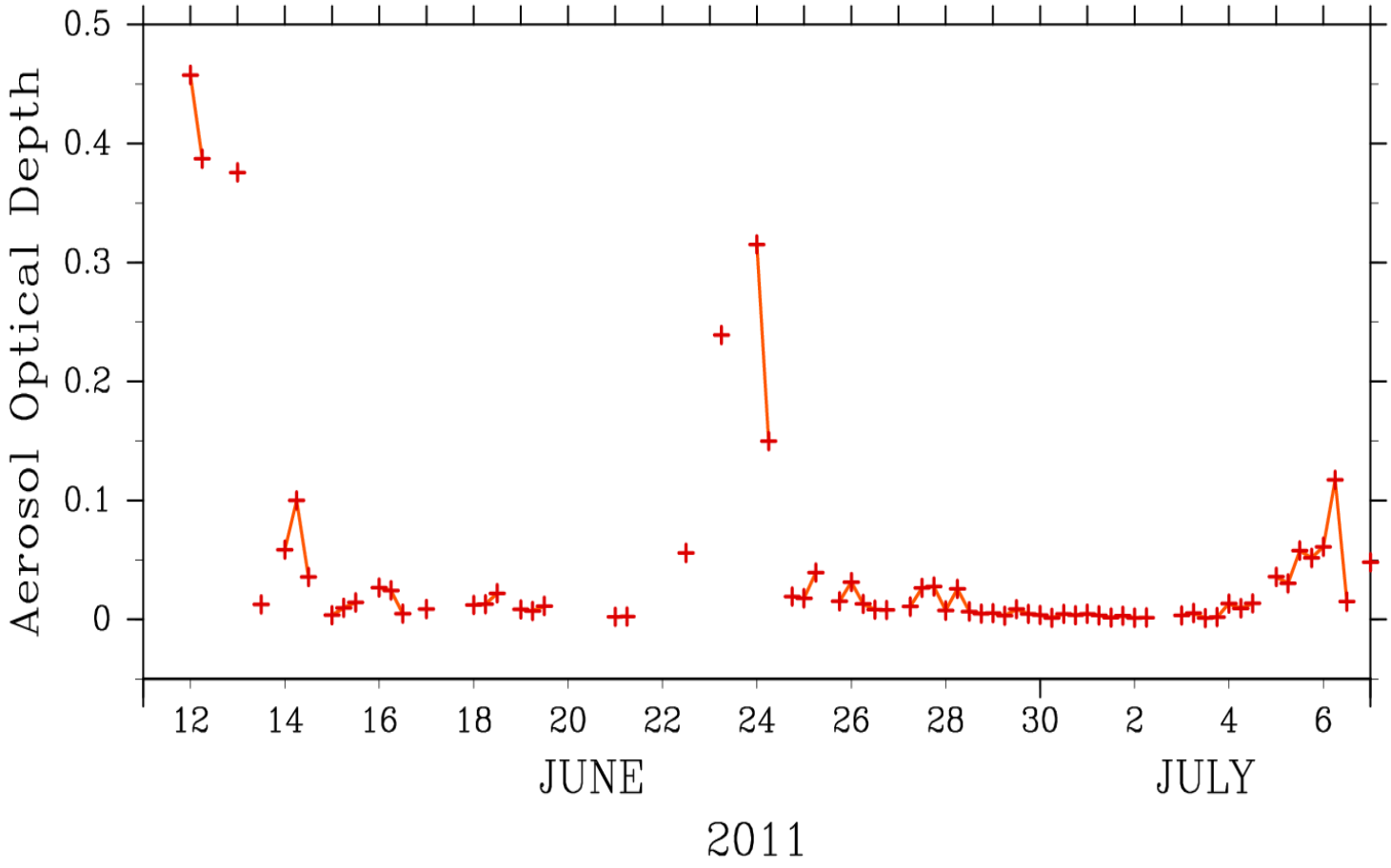
In conjunction with Near-Infrared Fourier Transform Spectroscopy in the Total Column Carbon Observing Network, the National Institute of Environmental Studies (NIES) and MRI upgraded the aerosol lidar at Lauder in February 2009.

Laser	Nd:YAG (SHG & primary)
Wavelength	532 nm & 1064 nm
Pulse energy	150 mJ
Repetition rate	10 Hz
Divergence	0.2 mrad
Telescope	Ritchey-Chrétian
Diameter	305 mm
Field of view	1.0 mrad
Polarisation	Parallel & Perp. @ 532
Gate width	7.5 m min., 120 m nominal
Detectors	3 x PMT, 1 x APD
Far & near channels @ 532	~93% & ~7% of parallel perpendicular, far only
Signal processing	Analog & PC for Photomultipliers Analog for Avalanche Photodiode

On 4 June 2011, eruption of the Puyehue-Cordón Caulle Volcanic Complex (PCCVC, 40.59° S, 72.11° W) in Chile injected large amounts of volcanic ash into the lower stratosphere.

The Volcanic Ash Advisory Centre (VAAC) in Wellington forecast that the volcanic plumes would come over New Zealand. For the safety of civil aviation, aerosols were continuously observed with lidar at Lauder for a month from 10 June, and the observations were provided to the VAAC.

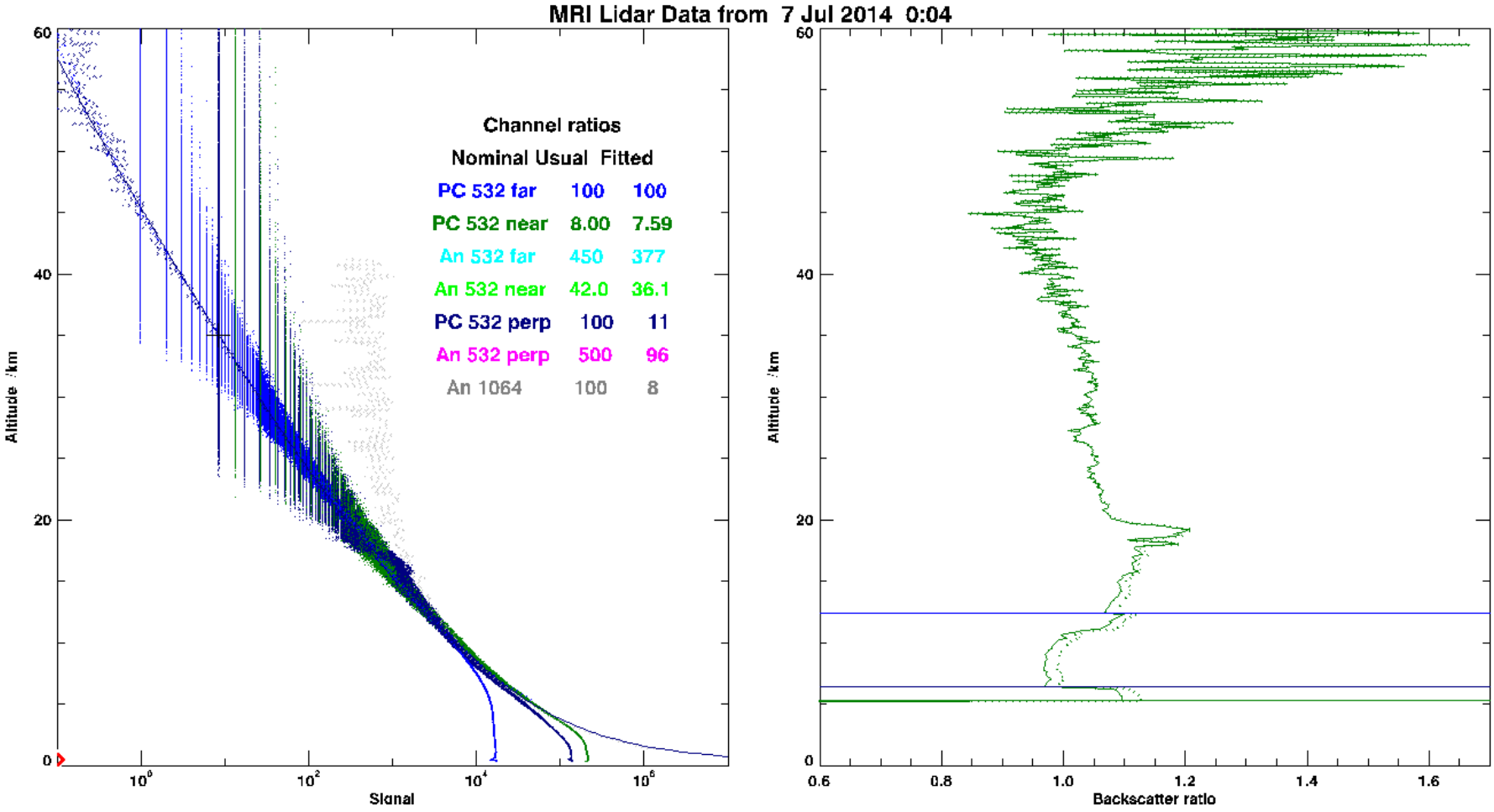




Over the course of a month, the PCCVC aerosol circled the globe three times, passing over Lauder at 12-day intervals. It produced peaks in lidar-derived AOD at 532 nm of 0.45 on 11 June, 0.31 on 23 June, and 0.12 on 5 July.

ACP Discussion until 18 July 2014: http://www.atmos-chem-phys-discuss.net/14/13465/2014/

NIWA
Taihoro Nukurangi



Summary

Aerosol measurements with the single channel (532 nm) lidar compare well with data from Rosen backscattersondes (~490 & ~940 nm), and with SAGE II aerosol extinction at 525 nm, with a possible low bias around 25 km altitude.

Optical depths calculated for the lidar data are comparable to the (very low) AOD at 500 nm measured by sun-photometer at Lauder, though the lidar measurements are at night and the AOD by day. The summer peak in AOD appears to be in the planetary boundary layer, but the spring peak is in the free troposphere.

Stratospheric AOD at 532 nm increased by ~40% over the decade from 1998.

A new dual wavelength (532 and 1064 nm) lidar, with depolarisation detection, weatherproof window, and narrowband filters for daytime operation, was installed in February 1998. It has contributed to GOSAT validation and volcanic aerosol observations. More work to analyse these data is needed before they can be used to extend the NDACC time-series.

Acknowledgements

The authors gratefully acknowledge the work of Julian Orange, Brian McNamara, Andrew Cunningham, Hisako Shiona, and Hamish Chisholm, who maintained and operated the lidar over 17 years; Michael Kotkamp, who did this and also launched the backscattersondes and maintained the sun photometer; and Bruce Forgan who supplied, calibrated, and analysed data from the sun photometer.