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Tropospheric ozone dial for air quality and climate monitoring, and validation studies

A Differential Absorption Lidar (DIAL) called *tropO3* for routine profiling of tropospheric ozone is presented (Fig. 1 and 2). The instrument is located at RIVM in Bilthoven, The Netherlands (52°07' N, 5°12' E). The instrument was built for routine observations and validation purposes in 1992 . Recently, the system was modernised and upgraded for a study to validate tropospheric ozone products from AURA/OMI and to analyse the temporal and spatial variability and representativeness of satellite measurements of tropospheric ozone. Under clear sky conditions, a full ozone profile from below 0.5 km up to 12 km can be now created in about 30 min., which enables high-resolution time series of tropospheric ozone profiles needed for the variability and representativeness study. Operation under low-level cloud conditions with coverage up to 4 octa is possible. A description of the modernised system is given and a reassessment of the instrument performance is shown utilizing ozone sonde data from the nearby station in de Bilt (NL). This work is performed within a project aimed at strengthening the satellite validation potential of CESAR (Cabauw Experimental Site for Atmospheric Research).

System modernisation summary

Recent modernisations were aimed at instrument improvement and automation and also to better cover of the near range to within the boundary layer. Hardware modernisations included installation of new lasers, detectors, optical filters and filter wheels and the installation of a second, near range telescope. The data processing software was also revised. Semi-automated removal of clouds from a measurement is amongst the implemented features. Quicklooks from this instrument can be publicly accessed at http://cerberus.rivm.nl/lidar/Bilthoven/TropO3/

Raman conversion optimisation

With the new lasers installed, experiments were performed to optimise the mixtures and pressures in both Raman cells. High first Stokes conversion in combination with good beam quality was aimed at. Optima were found for 289 nm at 32.5 bar D_2 with 2.5 bar Ar and for 289 nm at 22.5 bar H_2 with 10 bar Ar. Results are depicted in Fig. 3.

Automated overlap scans

An improved routine performing automated scans of the laser-telescope geometrical overlap has been developed. When the scan completes, Gaussian fits of the observed beam profiles provide the optimal overlap positions and estimates for the beam divergence (Fig. 4, left). A quick-scan mode is available, in which half the scan points are skipped in a checkerboard pattern. Because of the robustness of the fit, the laser beams can still be aligned (Fig. 4, right).

Cloud clearing

A semi-automated cloud clearing routine was developed, based on the derivatives of the backscatter signals that are scanned for peaks, which are often due to clouds. Cloud contaminated data is subsequently ignored, as shown in Fig. 5.

	Old	New
Emitter		
Lasers	Quanta-Ray DCR-3	Spectron SL852
Beam profile	Doughnut	Table top
Rep. rate / Energy	10 Hz / 80 mJ	30 Hz / 67 mJ
Receiver		
Detectors	Thorn-EMI 9817QA	Hamamatsu R7400P
Optical filters	Barr Associates	Barr Associates
Wavelength	289 nm / 299 nm	289 nm / 299 nm
Bandwidth	3 nm	1 nm
Out-of-band blocking	$>10^3$ / $>1.5\times10^3$	$>10^5$ / $>10^6$
Transmission at 289 nm and 299 nm	43 % / 60 %	16 % / 29 %
Digitiser	LeCroy TR6810	Licel TR20-160
Frequency	5 MHz	20 MHz

Tab. 1. Summary of the recent modifications.

Fig. 1. An impression of the instrument 'tropO3'.

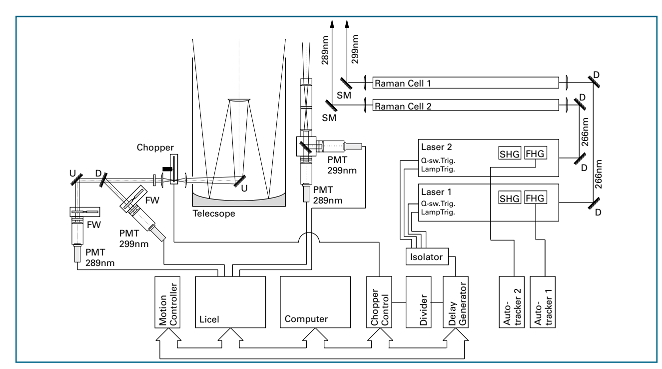

Fig. 2. Schematic layout of tropO3.

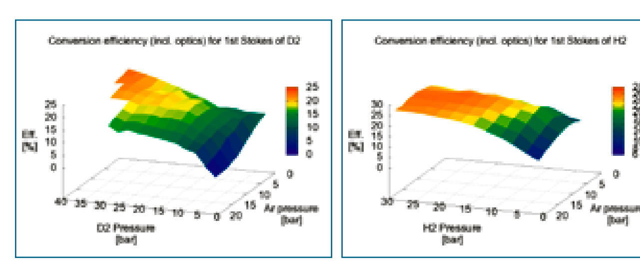

Fig. 3. Conversion efficiency graphs for the 1st Stokes of 266 nm in D_2/Ar (289 nm), and H_2/Ar (289 nm) mixtures.

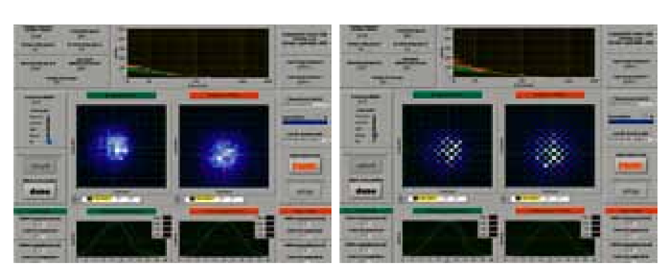

Fig. 4. Screenshots of the overlap scan program. Cross sections of the laser beams at 2.25 km altitude are shown.

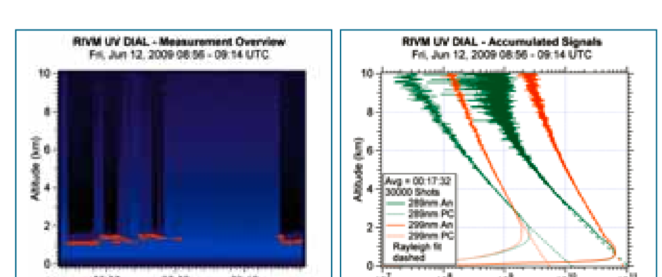

Fig. 5. Results from the cloud clearing routine. In this measurement, approximately 55 % of the data is lost due to clouds.

Measurements

During the CINDI campaign June and July of 2009 (www.knmi.nl/samenw/cindi/) the instrument was operational on 18 days and the measurement data corresponds well to ozone sonde data. In figure 6, data from this campaign is compared to a relevant historic dataset. Figure 7 shows multiple measurements of an ozone intrusion event on June 23rd and 24th.

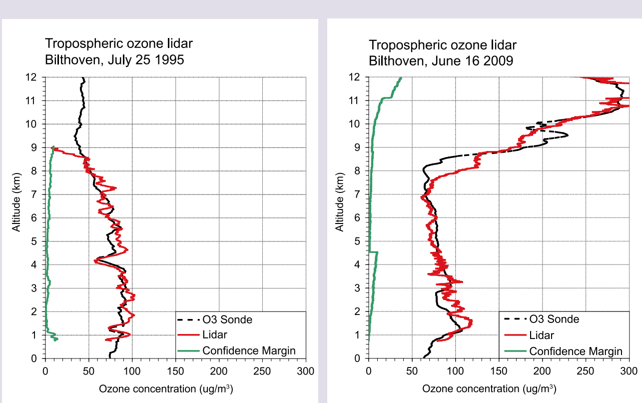

Fig. 6. A historic dataset (left) compared to a recent dataset (right). Note the increased measurement range and the larger deviation in the near field of the 2009 measurement.

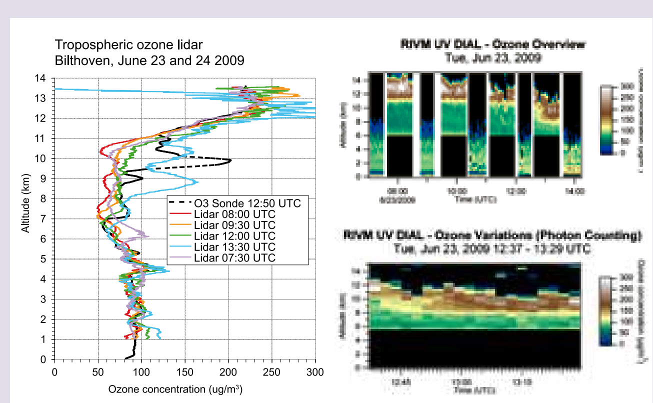

Fig. 7. Multiple measurements of an ozone intrusion event. On the right, a high temporal resolution image consisting of multiple measurements.

Conclusions

- The tropO3 system has been reoperationalised and improved. The measurement range systematically reaches the lower stratosphere. The lower range starting at 300-400 m above ground is also covered.
- Participation in the CINDI campaign showed successful operation of the instrument.
- Multiple measurements per day in combination with high-time resolution profiling shows the capability to measure variability in ozone concentrations during the day.
- Over the full measurement range, lidar and sonde data agree well, confirming that the system is ready to be used for validation of satellite data.

Acknowledgement

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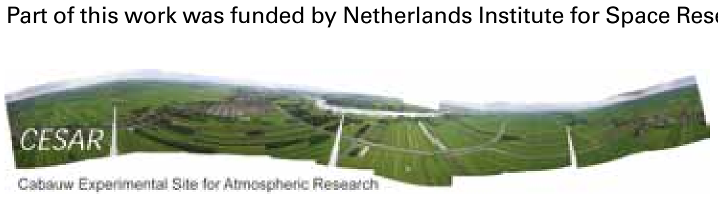

CINDI

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