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Information Note on the use of Microtops sunphotometer data

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MICROTOPS II sun photometers are specialised narrow field-of-view, hand-held radiometers designed to measure direct solar irradiance. They typically have 5 well-defined spectral bands with full width at half maximum of 10 nm in the visible range. At the time of purchase, the user can select 5 channels from a range of 8 standard wavelengths λ_i =340, 380, 440, 500, 675, 870, 936, or 1020 nm. MICROTOPS II measures aerosol optical thickness (AOT) of the vertical atmospheric column $\tau(\lambda_i)$. The instrument is extremely simpleto use and has a powerful internal microprocessor to store recorded data into internal memory. The construction and the operational principles of MICROTOPS II are reported in detail in Morys, M., F.M. Mims III, and S.E. Anderson, 2001. *Design, calibration and performance of MICROTOPS II hand-held ozonometer*. J. Geophys. Res., Vol. 106, No. D13, 14573-14582.

If the aerosol particles can be modelled to a sufficient degree of accuracy by an equivalent ensemble of homogenous spheres with known and constant index of refraction over the entire radii range then Mie theory of diffraction on spherical particles leads to

(1) $$\tau(\lambda_i) = \int_0^\infty \pi r^2 Q_{\text{ext}}(2\pi r/\lambda_i, m)\, n_c(r)\, dr \; .$$

Here, $Q_{\text{ext}}(2\pi r/\lambda, m)$ is the Mie extinction efficiency factor, $m = n - i \times k$ is the known complex index of refraction and $n_c(r)$ is the aerosol columnar size distribution. The later is usually related with altitude-dependent aerosol size distribution $n(r, z)$ by

(2) $$n_c(r) = \int_0^\infty n(r, z)\, dz \; .$$

A comprehensive review of the methods used to retrieve aerosol size distributions based on measured AOT is given in Mather, T.A., V.I. Tsanev, D.M. Pyle, A.J.S. McGonigle, C. Oppenheimer, and A.G. Allen, 2004. *Characterization and evolution of tropospheric plumes from Lascar and Villarrica volcanoes, Chile*. J. Geophys. Res., VOL. 109, D21303, doi:10.1029/2004JD004934.

The retrieval of the aerosol distributions is based on the solution of the Fredholm integral equation (1). One of the best algorithms is that proposed by Michael King (King, M.D., D.M. Byrne, B.M. Herman and J.A. Reagan, 1978. *Aerosol Size Distribution Obtained by Inversion of Spectral Optical Depth Measurements*. J. Atm. Science, Vol. 35, No. 11, 2153-2167). The Fredholm equation is replaced by simultaneous equations and the solution is obtained by an effective iteration process with imposed constraints for positive and smooth solutions. King's algorithm allows solutions for up to ten particle radii (geometrical means within 10 equal length radii intervals in logarithmic scale).

A software package for inverting measured AOT and estimating aerosol number distributions and aerosol particle columnar amounts in the corresponding radii intervals is available

from http://www.geog.cam.ac.uk/research/projects/microtopsretrieval/ and http://fsf.nerc.ac.uk/resources/software/MicrotopsInverse.shtml
As a by product of the calculations, particle surface and volume distributions and a few types of effective mean radii can also be evaluated.

The next figures show results obtained from measurements of Mt. Etna's volcanic plume.

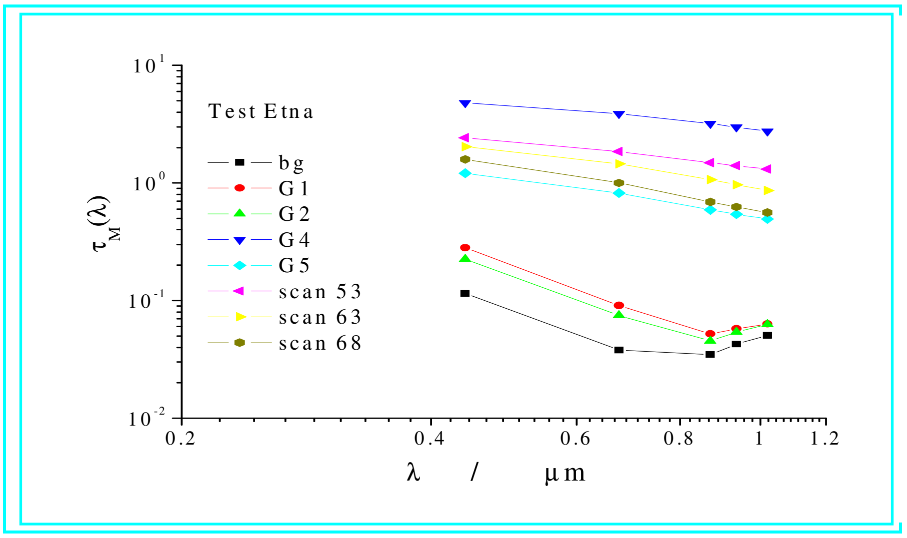

Figure 1. Measured AOTs at different locations.

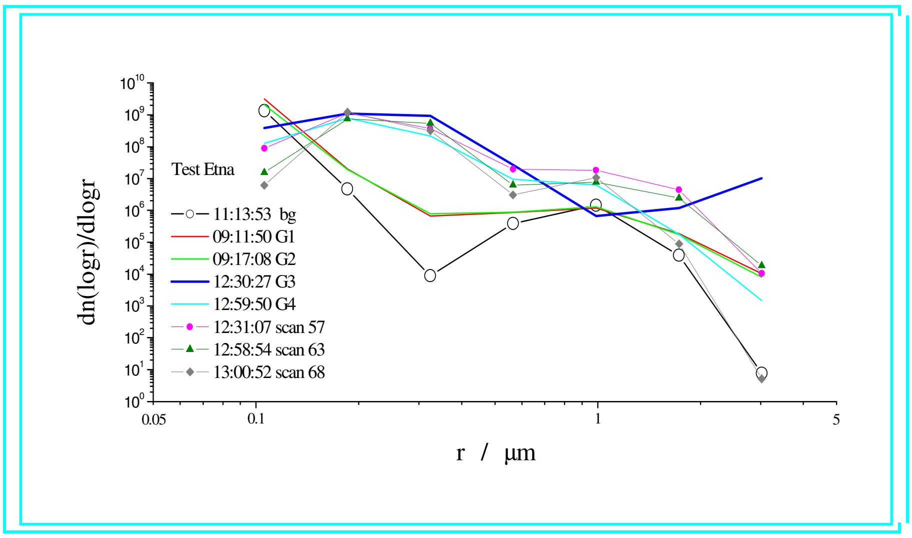

Figure 2. Retrieved columnar number distributions

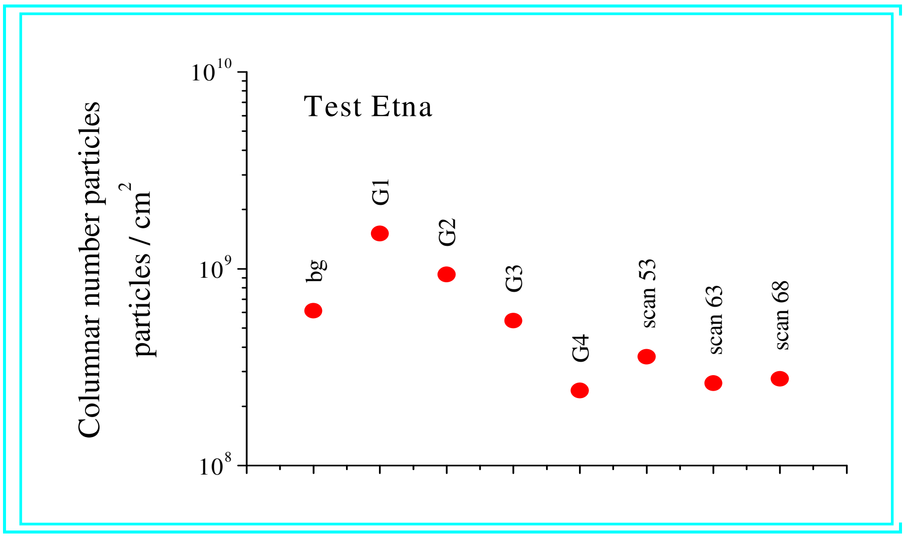

Figure 3. Retrieved columnar number particles

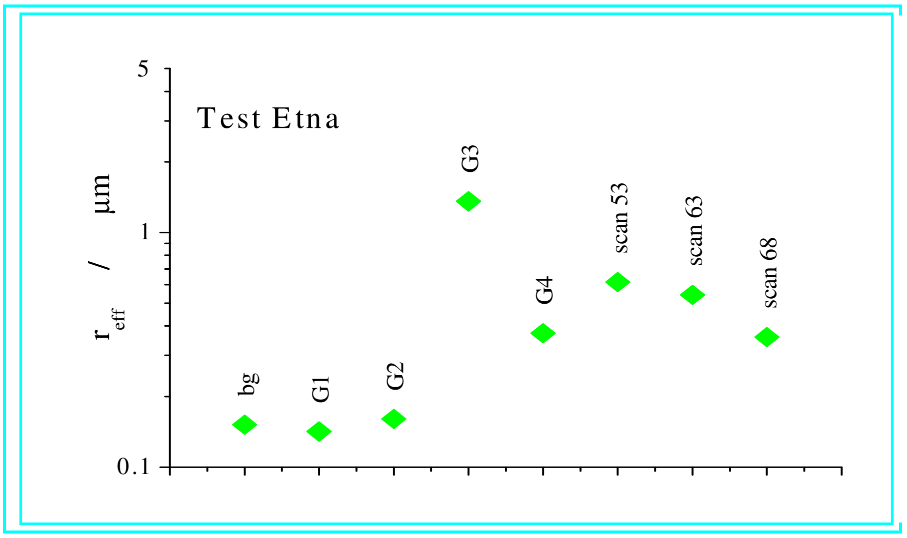

Figure 4. Retrieved effective radii

MICROTOPS II have been applied in the measurement of the explosions and subsequent fire plume at the Buncefield oil depot in December 2005 (Mather, T.A., R.G. Harrison, V.I. Tsanev, D.M. Pyle, M.L. Karumudi, A.J. Bennett, G.M. Sawyer and E.J. Highwood, 2007, *Observations of the plume generated by the December 2005 oil depot explosions and prolonged fire at Buncefield (Hertfordshire, UK) and associated atmospheric changes*. Proceedings of the Royal Society A, 463, 1153-1177, 2007, doi:10.1098/rspa.2006.1810). Near-source measurements suggest that plume particles were ~50% black carbon (BC) with refractive index 1.73- i 0.42, effective radius (R_{eff}) 0.45-0.85 µm and mass loading ~2000 µg×.m^{-3}. About 50 km downwind, particles were ~60-75% BC with refractive index between 1.80-0.52i and 1.89-0.69i, R_{eff} ~1.0 µm and mass loadings 320-780 µg×m^{-3}. Number distributions were almost all monomodal with peak at r<0.1 µm.