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LIDAR MEASUREMENTS OF STRATOSPHERIC TEMPERATURE

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The radiative budget of the stratosphere and mesosphere is mainly influenced by ozone and carbon dioxide and thus directly sensitive to the variations of these trace species which can be induced by anthropogenic activities. Temperature distribution will thus vary at various temporal and spatial scales related to dynamical processes such as planetary waves activity or radiative effects induced by trace species or aerosols fluctuations. Long term variations or trends either related to solar variability or to anthropogenic perturbations have not yet been detected and will constitute part of the rationale to implement a monitoring programme. Furthermore, systematic observations of the temperature profile will provide a data base of particular value for the establisment of Reference Model of the Middle Atmosphere. Use of ground based systems which can provide a high accuracy and vertical resolution is also important for the validation of satellite data including temperature measurements and trace species concentration retrievals from IR and microwave passive sensors.

Rayleigh backscattering of a laser beam by atmospheric molecules has been observed by most of the first lidar researchers but the first tentative determination of stratospheric temperature was only performed in the late 1970s. In 1980 a lidar system devoted to that type of measurements has been set up at the Observatoire de Haute Provence and operated on a quasiroutine basis from this time (Hauchecorne and Chanin, 1983). Several systems are presently under development in various countries (RFA, USA, UK, France,...) which might provide the basis of a future global network.

When a monochromatic laser beam, at a wavelength which does not coincide with any absorption or resonant feature of atmospheric species, is sent in the atmosphere, two processes can provide a backscattered signal : Rayleigh scattering by atmospheric molecules and Mie scattering by aerosol particles. At the height above 30 to 35 km where the aerosol content is very low, if any, the atmosphere can be considered as purely molecular and the lidar backscattered signal is proportional to the

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atmospheric density. The temperature profile can then be computed from the density profile assuming that the atmosphere obeys the perfect gas law and is in hydrostatic equilibrium. This second assumption implies that atmospheric turbulence does not affect the mean air density, which is the case considering the temporal and spatial resolutions of the lidar data. The constant mixing ratio of the major atmospheric constituents (N_2, O_2 and Ar) and the negligible value of the H_2O mixing ratio justify the choice of a constant value for the air mean molecular weight. Details of the analysis are given in Annex. It should be pointed out that the only assumption to be made to compute the temperature profile is that of a pressure boundary at the top of the atmosphere. the accuracy of which can be evaluated to be of the order of 15 %. Its contribution to the temperature uncertainty decreases rapidly with altitude and is smaller than 2 % at 15 km from the top, and smaller than 1 %, 5 km lower. It is important to note that only the ratio of experimental density values is taken into account and that consequently any constant of normalization in the return signal disappears. The temperature determination can then be considered as absolute as soon as one can neglect the term due to the pressure at the top, even though the density is only measured on a relative way.

The characteristics of the "Rayleigh" lidar in operational use at the Observatoire de Haute Provence are given in the Appendix. Such a system will include a powerful Nd Yag laser emitting at the second harmonic wavelength (532 nm). The choice of the emitter is obviously a function of the state of the art of laser development and particular attention should be brought to the new sources such as exciplex lasers (XeF) at 355 nm. The receiver is a large diameter (– 1 m) telescope required for high altitude measurements. Due to the large dynamics of the signal two acquisition modes are used, i.e. analogical time sampling for the lower attitude ranges and photon counting in the upper levels. All the experiment is computer controlled and can be run efficiently for many hours without an operator assistance. Typical accuracy on the measurements can be quoted as follows for the OHP system :

- $\Delta T =$; 1 K at 40 km for a 1 hour integration time and 1 km height resolution

- $\Delta T =$; 5 K at 70 km for a 3 hours integration and a 0.5 km height resolution.

With the performances already available, the advantages of a Rayleigh lidar, in terms of atmospheric needs, are mainly due to three characeristics :

- The possibility of making absolute temperature determination without requiring an external calibration, and this with an accuracy better than a few K in the stratosphere.

- The availability of good vertical resolution (– 1 km)

- The continuity of the survey in altitude, from 30 to 80 km, and in time. The observations are only limited by meteorological conditions which implies a good choice of the site and at the present time restricted to nighttime.

These three characteristics make the Rayleigh lidar a powerful tool mostly for two types of studies based either on the knowledge of the absolute temperature and its eventual evolution, or on the description of the temporal and spatial fine structure of both density and temperature. For both approaches it is a necessary complement of satellite observations.

CHARACTERISTICS OF THE RAYLEIGH LIDAR IN OPERATIONAL USE AT THE OBSERVATOIRE DE HAUTE PROVENCE

Laser

type	Neodymium - Yag (Quantel Model 408)
Energy per pulse	400 mj at 532 nm (150 mj at 355 nm)
Repetition rate	10 Hz
Pulse width	15 ns
Divergence	4.10^{-4} rad
Divergence	10^{-4} rad (with a beam expander)

Receiver

Telescope diameter	80 cm
Telescope area	$0.5\ m^2$
Field of view	10^{-3} to 10^{-4} rad
Band pass filter	0.8 nm (FWHM)
P.F. interferometer	20 pm (FWHM)
Gate width	4 µm (0.6 km)

REFERENCES

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