FIRST RESULTS FROM CAELI – CESAR WATER VAPOUR, AEROSOL AND CLOUD LIDAR

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ABSTRACT

The current state of the art in climate research cannot adequately reconstruct or predict climate change. Part of the gap arises from the lack of information about the vertical structure of the atmosphere in general, and in particular for the three dimensional distribution of water vapour, aerosols and clouds, and their evolution over time. New instrumentation is needed to provide these data and the data should be gathered in monitoring programmes and across networks [1].
The Light Detection and Ranging technique plays a key role in atmospheric profiling. For routine, operational measurements required for monitoring of water vapour, aerosols and clouds, the Raman lidar technique offers the unique possibility to perform these measurements simultaneously and in exactly the same atmospheric volume, which enables the study of their interrelationships without having to deal with the ambiguities of differences in space and time.
A test system was built at RIVM based on a small receiver and a powerful laser system. The test system is now under development into an operational system and has been designed for simultaneous measurement of vertical profiles of the water vapour mixing ratio, aerosol properties and cloud properties, including a polarisation channel for detection of particle non-sphericity.
The operational system, when finished, will be deployed at the Cabauw Experimental Site for Atmospheric Reseach (CESAR) where a whole suite of advanced instruments for atmospheric measurements is operated, with emphasis on atmospheric profiling [2]. The lidar will be embedded in networks such as the European Aerosol Research Lidar Network (EARLINET) [3] and will take part in satellite validation and correlative measurements. The system is called Caeli† (Cesar water vapour, Aerosol and cloud LIdar).

† Latin: cælum (1) -i n. [the heavens , sky, air, climate]. Esp. [heaven] as the home of the gods; fig., [heaven] as the height of joy, renown, etc., cælum (2) -i n. [the burin or engraving tool].

Fig.1. Aerial view of CESAR (Cabauw Experimental Site for Atmospheric Research) with the 213m meteorological tower. Site coordinates: (51.97 N, 4.92 E). Site link: http://www.cesar-observatory.nl/

1. TEST SYSTEM

New equipment was purchased to carry out the experiments. Since the aim was to develop the test system further into an operational system, major components were selected with re-use in the operational system in mind. The laser was selected on power, laser line width, stability and maintenance criteria to be able to address a wide range of measurements. This included:

- Applicability of high level optical and microphysical aerosol retrieval algorithms using the 3ß+2α approach [4]. Three laser wavelengths should be emitted simultaneously.
- Water vapour measurements during daytime. In order to accomplish this efficiently, the laser should have high emitted energy per pulse as well as high average power.
- Pure rotational Raman temperature measurements, requiring narrow linewidth and wavelength stability which is accomplished with a seeder.

A Nd:YAG laser with second and third harmonic generators is most suitable for this. This laser emits at 1064 nm (fundamental wavelength), 532 nm (second harmonic) and 355 nm (third harmonic). Further, in the pulse energy/average power trade-off it was decided to use a 30 Hz pulse/sec. configuration. This configuration does not yield the highest possible energy per pulse optimal for water vapour measurements, but gives the possibility for high time resolution aerosol and cloud measurements. High time resolution is favoured in situations with high cloud cover, frequently occurring in the Netherlands. A Continuum PL9030 with seeder was finally selected. The critical wavelength is 355 nm that will be used to measure water vapour. This laser emits about 12 W at 355 nm. It is expected that water vapour concentration profiles can be measured at night time well into the free troposphere using this laser and a 60 cm diameter or larger telescope [5]. During daytime the maximum range will be less, but extending above the boundary layer.

It was decided to build the test system with a relatively small receiver of 15 cm diameter for close range measurements in the boundary layer. This would be cost effective and a full-scale receiver could be dimensioned on the basis of experience gained with the small telescope. Additionally, the small telescope could be re-used as the second receiver for close range. The 6 channel receiver, show schematically in Fig. 2 is fiber coupled to the near-field telescope (NFR).

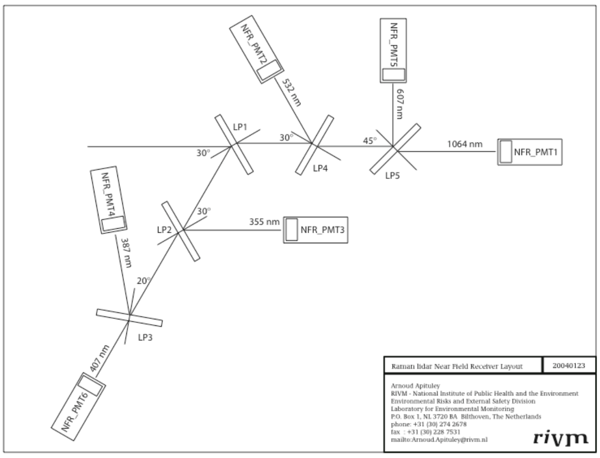

Fig.2. Schematic layout of the detection system. The light from the telescope is enters from the left by way of an optical fiber and is first split into a short wave branch and a long wave branch by the mirror indicated by LP1.

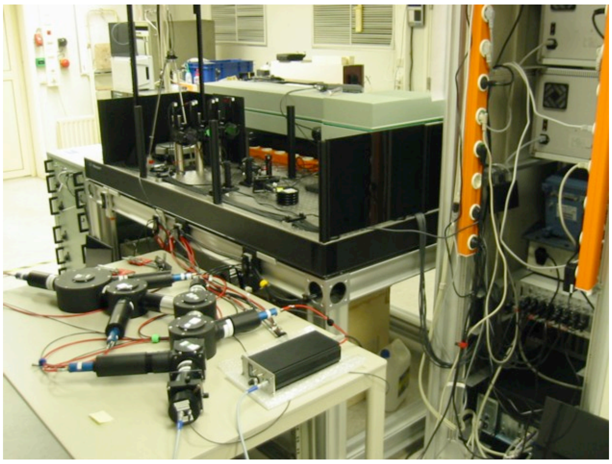

Fig.3. Laboratory test setup for Caeli in Bilthoven. Site coordinates: (53.33 N, 6.27 E).

Currently, test measurements are ongoing with the test system shown in Fig. 3. Optimizations are being made to the optical alignment and signal conditioning. A measurement example along with preliminary retrieval results is shown in Fig.5.

2. OPERATIONAL SYSTEM CONCEPT

The test system was set-up with a small 15 cm diameter receiver, sufficient only for the lower 2-3 km for the Raman channels. In order to reach higher altitudes, up to the top of the troposphere, the power-aperture product of the lidar needs to be scaled up by using a large aperture receiving telescope. A constraining factor is the total physical size of the system that is determined by the requirement that the lidar system will be operated in the field in a 20ft sea container. This conainer will hold the entire lidar system, including the primary control systems of the lidar, a small operator booth and support systems for power supply, temperature and humidity control. The sea container also allows the lidar to be easily and cost effectively transported to other locations for dedicated field experiments and intercomparisons. All this means that the lidar can be scaled up with a large telescope up to about 70 cm diameter. This should be sufficient to meet the most stringent scientific requirements for this system: water vapour measurements during daytime up to altitudes extending substantially above the boundary layer. A conceptual drawing of the layout of the system is shown in Fig.4.

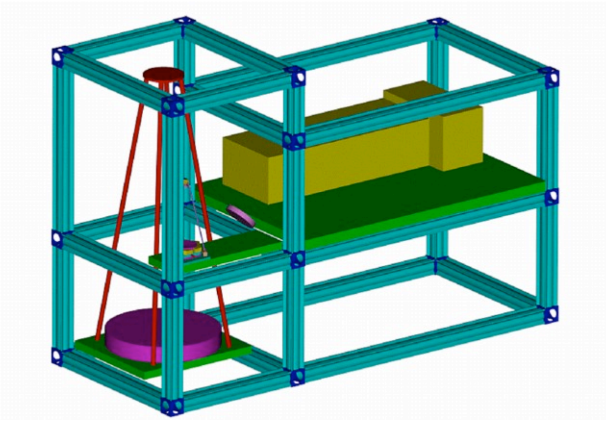

Fig.4. Conceptual layout of the operational lidar system. The middle deck holds the laser, beam conditioning optics and the sub-system for beam alignment. This level also holds the small, near-field receiver. The large telescope primary mirror sits at the bottom of the support structure, while the secondary mirror is at the top. The detection optics will be at the top level of the box. Below the laser is room for electronic equipment. The surrounding container space is not shown. The intention is to have the frame holding the lidar in the middle of the container space, so that it can be accessed from all sides for maintenance and repair.

3. Conclusions and Outlook

A test system was built for a three wavelength Raman lidar with detection channels for sultaneous 3ß+2α aerosol retrievals and water vapor measurements. Based on a 15 cm diameter receiver and a powerful laser system the near-field receiver part of the operational lidar can now be used for actual measurements. With this system experience was gained for Raman lidar techniques. An initial validation has been done for water vapour measurements that show favourable results. At night, water vapor profiles can be measured up to 5 km at a 10-minute time resolution. The aerosol retrieval algorithms will be validated following the EARLINET protocol [6].

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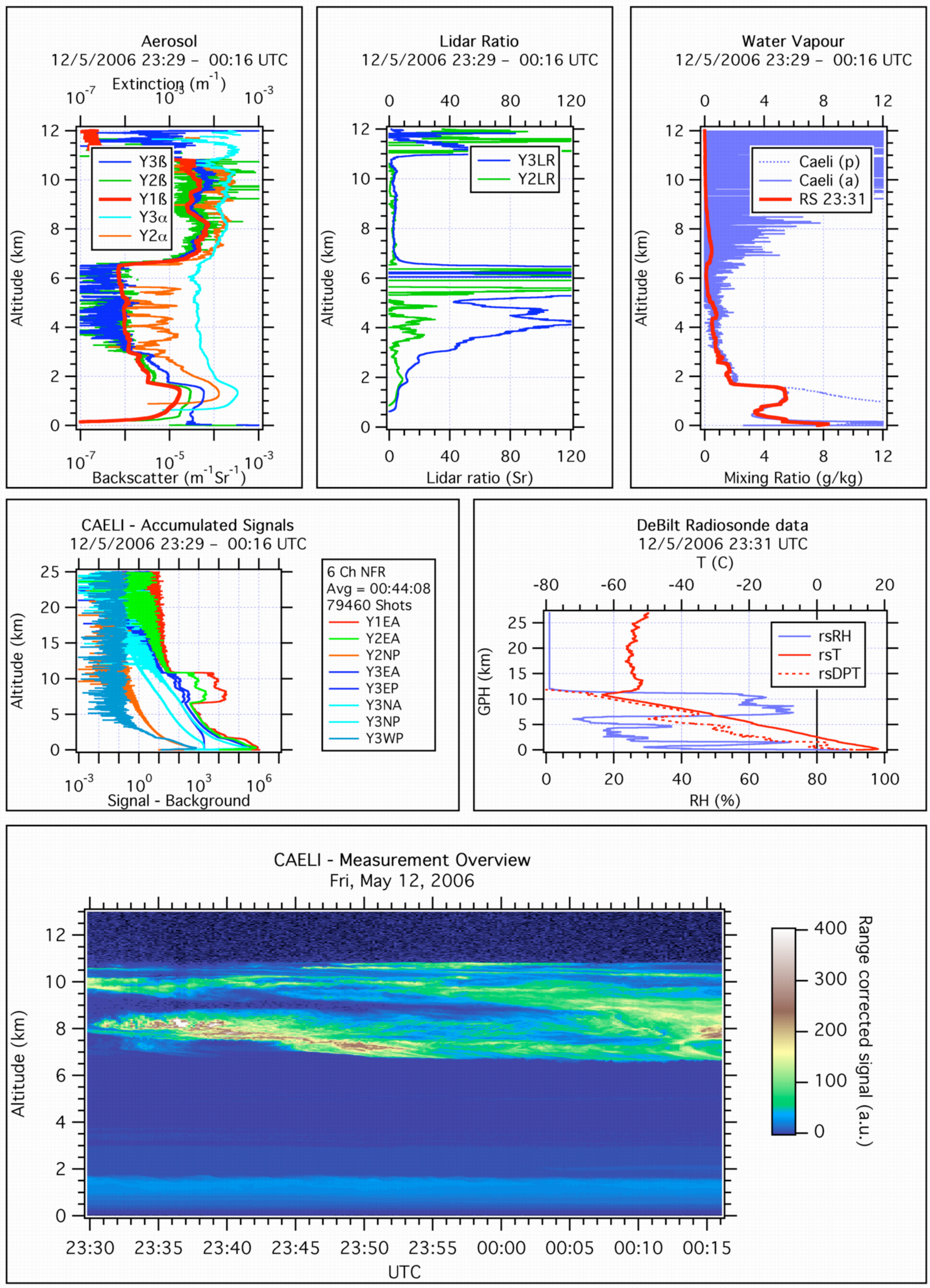

Fig.5. Caeli test data for 12 May 2006, with 15 cm receiver at nominal FOV of 1.3 mrad. The overview shows the 1064 nm range corrected signal at 10 seconds time resolution and 7.5 m vertical resolution. The water vapour mixing ratio profile, derived from the averaged signals over the shown measurement interval, was calibrated against the radiosonde, launched simultanously from De Bilt, at 2 km distance from the lidar site. The particle extinction and backscatter profiles and the lidar ratio were obtained from preliminary (unvalidated) processing software.