Particle Backscatter and Relative Humidity in and around Cirrus Clouds Measured with a Lightweight Balloon Sonde

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1. Introduction

Dehydration mechanisms driven by the formation of visible and subvisible cirrus clouds ***determine the atmospheric water vapor budget*** and thus the ***chemical and radiative properties of the upper troposphere and the stratosphere***. In contrast to previous understanding ***recent in situ observations*** have revealed ***high supersaturation with respect to ice of several 10%*** [e.g.: Gierens et al., 1999; Spichtinger et al., 2004; Peter et al., 2006] occurring ***not only in clear air surrounding cirrus clouds but also inside the cirrus*** themselves, and apparently also in large interconnected regions where they ***cannot be explained easily*** in terms of local upwelling. ***Precise and frequent measurements of cirrus properties and relative humidity using independent instrumentation are required to obtain a better understanding of dehydration processes and of their influence on the global atmospheric radiation budget. To further investigate these findings a radiosonde payload combining frost point water and aerosol backscatter measurements was developed.***

2. Instrument Description

The lightweight balloon sonde **COBALD** (**C**ompact **O**ptical **B**ackscatter **A**eroso**L** **D**etector) was designed and tested at our institute (IACETH). It is currently working with SnowWhite (pTu-sonde by MeteoLabor).

Weights:
COBALD + SnowWhite = **540 g** + 1010 g = 1550 g

It is based on similar principles as the sonde of Rosen and Kjome [1991] which has been used extensively in field studies.

Optics:

- 2 high-power LEDs each ≈250 mW optical power (Figure 1)
- Emitted light is collimated to cones of less than 4° beam divergence
- The backscatter is collected by a fast lens and focused onto a silicon detector yielding a field of view of ±6° oriented into the same direction as the LED emission.

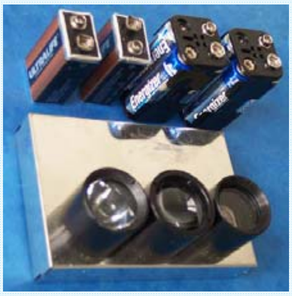

Figure 1: Picture of the Backscatter sonde **COBALD**.

Signal Treatment:

Backscatter sonde signals obtained at the optical wavelength λ are usually expressed as:

1) Backscatter ratio:
BSR = Total signal / Rayleigh signal

2) Aerosol backscatter ratio:
ABSR = Aerosol signal / Rayleigh signal

3) Color Index (indicates particle size):
$CI = ABSR_{\lambda 1} / ABSR_{\lambda 2}$

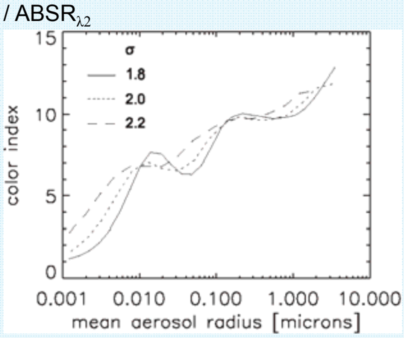

Fig. 2: Color index. The color index of a lognormal aerosol distribution as measured by COBALD. Smaller particles have a CI near 1 and large particles can exceed a CI of 14.

3. Applications:

Backscatter sondes are a valuable tool to ***characterize in-situ aerosol*** or ***cloud particles*** on balloon soundings.

References

- Rosen JM, Kjome NT, Appl. Opt., 30 (12): 1552-1561, 1991.
- Gierens K, Schumann U, Helten M, Smit H, Marenco A, Ann. Geophysicae, 17, 1218-1226, 1999.
- Spichtinger P, Gierens K, Wernli H, Atmos. Chem. Phys., 5, 973-987, 2005.
- Peter T, Marcolli C, Spichtinger P, Corti T, Baker MB, Koop T, Science, 314, 1399-1400, 2006.

4. Results

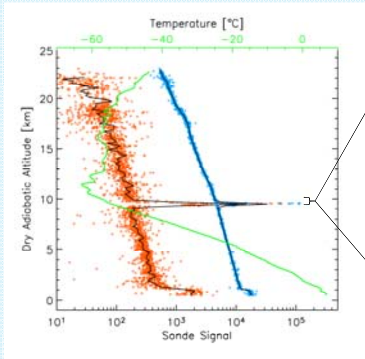

Figure 3: The temperature profile is provided in green. It shows the raw data of the 455 nm (blue) and 870 nm (red) channels. The black lines denote averages over 200 m altitude bins.

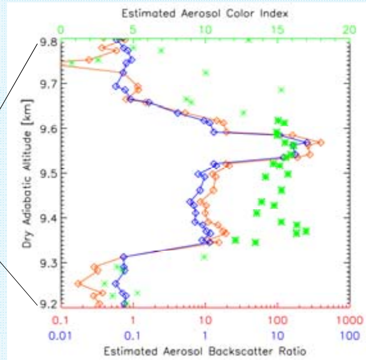

Figure 4: Estimated aerosol backscatter data. Data integrated over 1 s. The color index is given by green symbols. Bold symbols indicate color index values found inside the cloud.

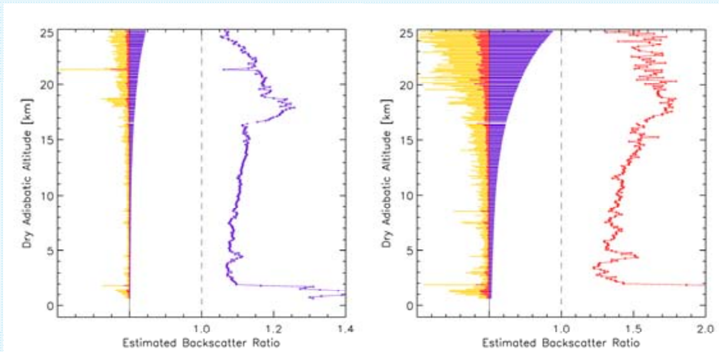

Figure 5: Analyses of a flight over Zurich. The left panel shows the blue and the right panel the red channel. The „harp" left of the Backscatter Ratio profiles show the noise expected for the 1 s data from laboratory measurements and compares it to the flight data standard deviation of the bin (yellow) and to the bin standard error (red).

5. Conclusion and Outlook

- First observations with COBALD show the new backscatter sonde can robustly ***provide parameters of the aerosol and hydro particle size distributions*** in the troposphere and stratosphere.
- Combined with a pTu sonde and an accurate hygrometer it will give ***new insight into the water vapor budget and cloud-physical processes*** especially in cirrus clouds.
- Due to the ***small weight*** of the backscatter sonde, the sonde can be launched with ordinary pTu-sondes.
- Through an ***attractive pricing*** and the widespread ***deployment a new climatology of cirrus clouds, their cloud particle densities and sizes and the relative humidity in and around midlatitude cirrus*** clouds can be ***derived from regular measurements***.
- **Ongoing activities:**
  a) 2 deployments during SOWER (Philipines)
  b) Regularly launches in Payerne
  c) field campaign in Niger (SCOUT)
  d) Participance in Lindenberg (LUAMI-campaign)

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