Department of Meteorology

Measuring cloud properties from meteorological radiosondes

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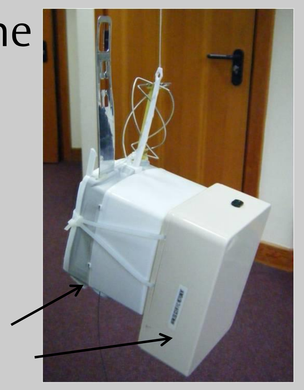
1. Introduction

Observations of in-situ cloud properties are an essential aspect of cloud microphysics studies. Meteorological balloons and small unmanned aerial vehicles readily provide a platform from which high resolution cloud measurements can be made, in both vertical and horizontal directions. Currently, however, one limiting factor in the use of these platforms for cloud studies is the lack of availability of lightweight, low power sensors. This work describes a number of small, inexpensive and disposable instruments for cloud detection, which are designed for use alongside conventional meteorological radiosondes such as the Vaisala RS92 radiosonde. Cloud properties measured with these sensors include solar radiation, visual range, supercooled liquid water content and electric charge. This work will described each of these sensors in turn and present data from a number of in-cloud flights demonstrating their operation.

2. Radiosonde data transfer

The sensors described here are all low cost, lightweight (50-200g) and disposable. They are intended to be flown alongside standard meteorological radiosondes, currently the Vaisala RS92. Measurements from the extra sensors are sent across the existing UHF radio link synchronously with the radiosonde temperature, pressure, RH and GPS data, using the specially designed PANDORA interface[1]. No extra hardware at the ground station is required, thereby allowing the use of standard operational flights carrying the extra sensors.



Vaisala RS92 radiosonde

PANDORA interface

3. Solar radiation

A rapid response solar radiation sensor has been developed to provide an optical measurement of cloud location, capable of higher resolution measurements of cloud edges than the thermodynamic methods employed by the radiosonde. A semiconductor photodiode sensitive to wavelengths from 300 to 720 nm (peak response at 580 nm) is used[2]. Fig1 shows a flight carrying the sensor through stratocumulus cloud. Beneath and inside the cloud, the solar radiation is small with no variability (as the radiation is mostly diffuse and isotropic). Outside the cloud the variability in the radiation measured increases, resulting from the swing and spin of the balloon, varying the sensor orientation with respect to the sun in the anisotropic radiation field. The sharp transition in variability between clear and cloudy air gives an accurate determination of the cloud edge location.

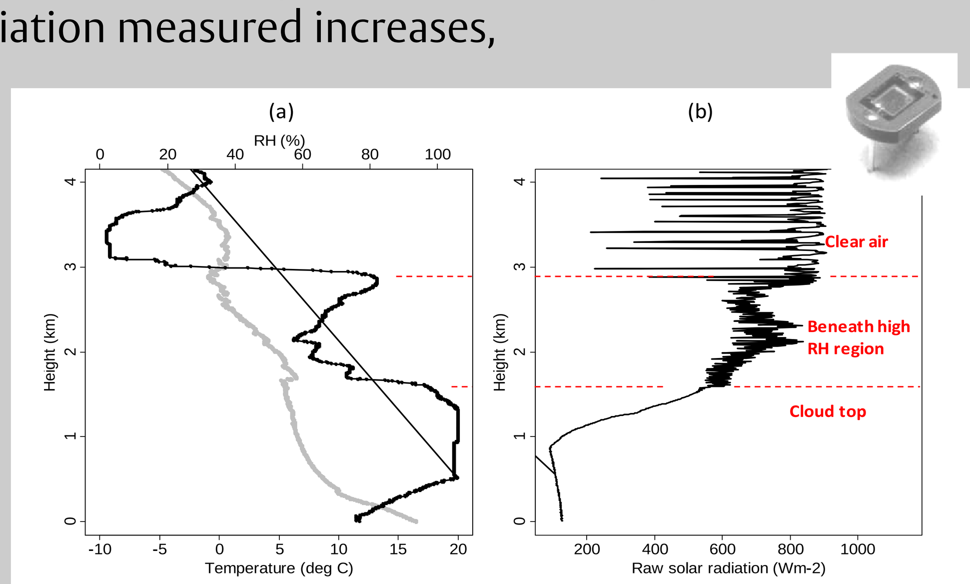


Figure 1. Vertical profiles from a radiosonde descent through stratocumulus cloud layer. (a) Temperature (grey) and RH (black) measured by the RS92 radiosonde, (b) solar radiation measured by the photodiode sensor. From [2]

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4. Cloud droplet sensor - Visibility

An optical backscatter method of cloud droplet detection, has been developed utilising two ultra-bright LEDs as the light source and a photodiode as the receiver[3]. Scattering of the LED light by cloud droplets generates a small optical signal which is separated from background light fluctuations using a lock-in technique. The signal to noise obtained permits cloud detection using the scattered LED light, even in daytime. The instrument is laboratory calibrated to give visual range (visibility) by simultaneous measurement of optical extinction and backscatter inside an artificially generated water cloud. Fig. 2 shows measurements made by the instrument during a daylight balloon sounding through a layer of stratocumulus cloud about 400 m thick, with cloud base at 1250 to 1270 m.

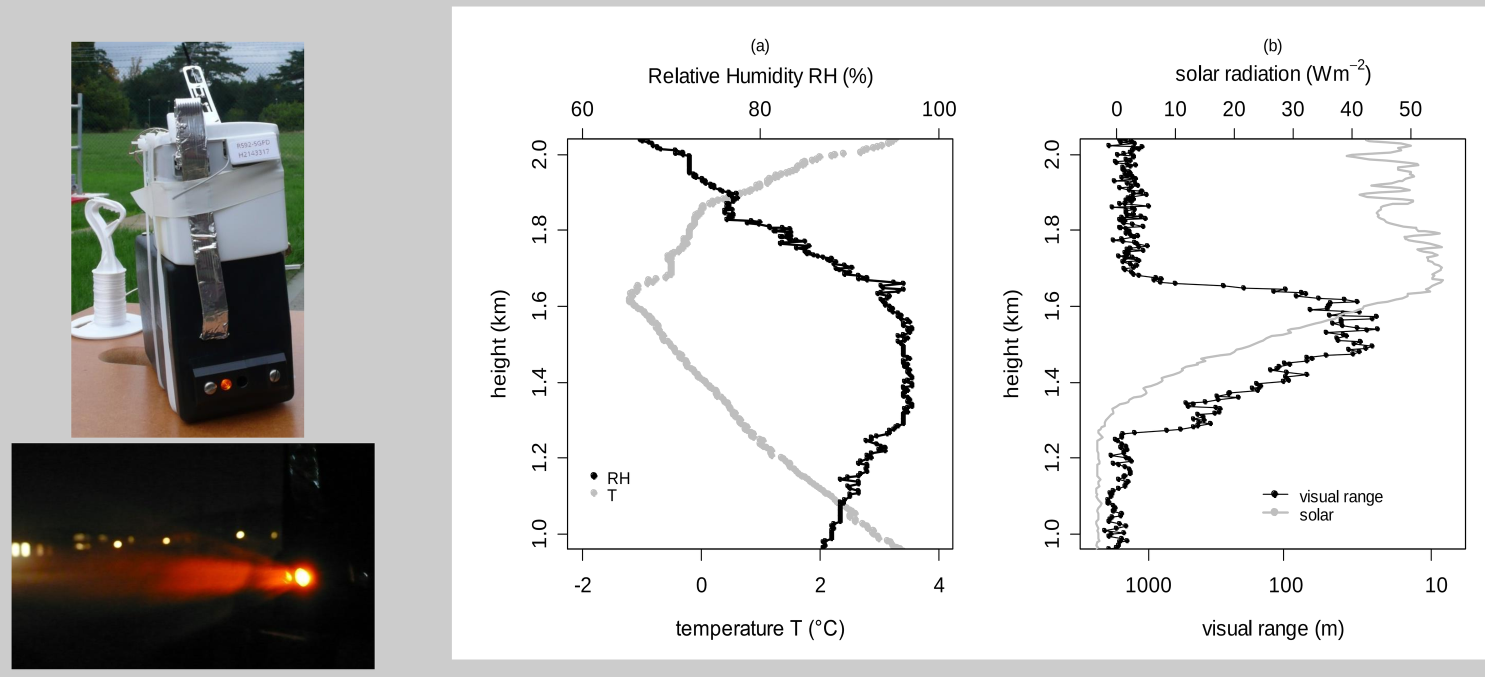

Figure 2. Vertical sounding made from Reading in daylight conditions through a cloud layer showing (a) thermodynamic quantities of Relative Humidity and temperature measured by a Vaisala RS92 radiosonde and (b) visual range measured by the active cloud detector (black) and solar radiation (grey) (from a downward pointing solar radiation sensor). From [3]

5. Supercooled liquid water

Supercooled liquid water (SLW) is an abundant constituent of mid-and high latitude clouds as well as deep convective systems; it strongly influences the clouds' radiative properties and microphysical processes. A balloon-borne vibrating wire sensor for SLW was devised by Hill and Woffinden, 1980 (Fig. 3). This exposed a piano wire (90x0.6 mm, fixed at only one end) to the airflow. As supercooled droplets freeze onto such a wire, the resonance frequency decreases. The rate of frequency decrease is proportional to SLW content.

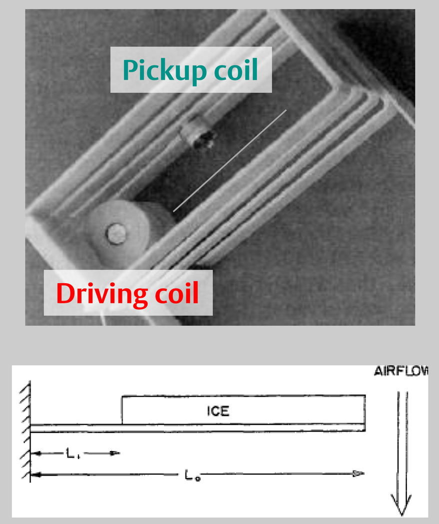

Figure 3. Original SLW sonde design from Hill and Woffinden, 1980.

A miniaturized and modernized version of the vibrating wire sensor is currently under development. By replacing the original coil system by lightweight piezo elements, the sensor's power consumption and weight has been greatly reduced. Furthermore, a microcontroller replaces the original analog feedback loop. The new sensor can be flown in combination with other sensors attached to the PANDORA system without requiring an extra battery. First laboratory tests (Fig. 4) show the high sensitivity of the wire's resonant frequency to changes in the wire's loading. First test flights of the prototype sensor are planned for the end of 2014.

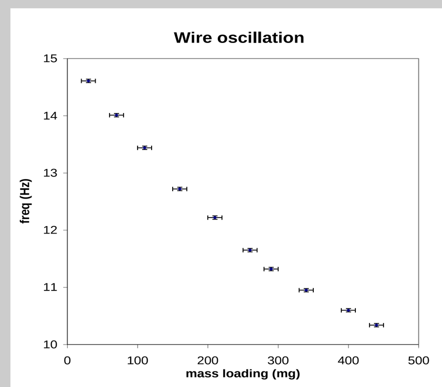

Figure 4. First laboratory tests with the new vibrating wire sensor: Sensitivity of the resonance frequency to mass loading on the vibrating wire.

6. Charge

Charge is ubiquitous in the atmosphere, resulting from galactic cosmic ray ionisation and, near the Earth's surface, natural radioactivity. Away from the strong electrification of thunderstorms, space charge is generated at the upper and lower boundaries of stratiform layer clouds due to the vertical gradient in electrical conductivity and current flow in the global electric circuit. Charge has been suggested to influence cloud microphysical processes such as the collection of charged particles by droplets, and droplet-droplet collisions[4]. A balloon-borne charge sensor has been developed, utilising an electrode connected to a sensitive electrometer circuit, which measures the current flowing to the electrode[5]. Figure 5 shows an example of a charge sensor flight through a layer of stratocumulus cloud over the UK, demonstrating the presence of negative charge in the cloud base, and positive charge at cloud top. Multiple charge sensor flights have demonstrated that charge is always present in such layer clouds, providing an additional cloud detection method beyond thermodynamic or optical methods.

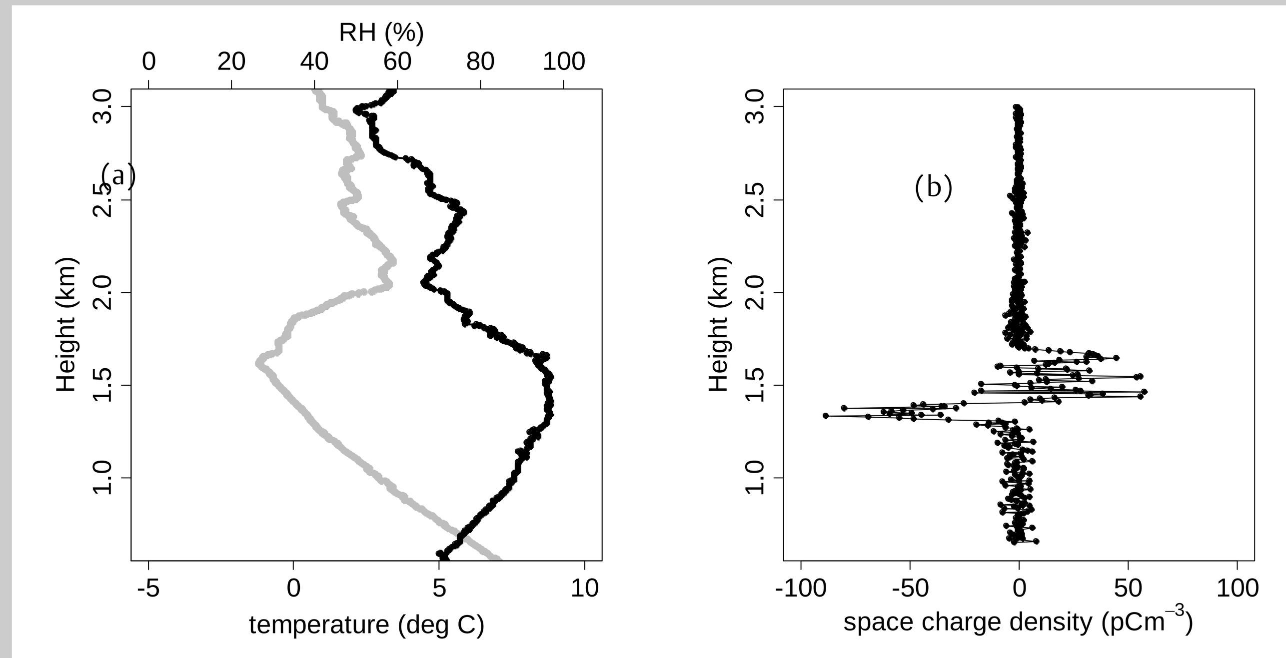

Figure 5. Vertical sounding through the same cloud layer in Fig2 showing (a) temperature (grey) and RH (black) as well as (b) charge measured by the balloon-borne charge sensor.

7. Summary

A suite of small disposable sensors and instruments has been developed to measure a variety of different cloud properties including **solar radiation, cloud visibility, supercooled liquid water and charge**. The sensors have been flown extensively alongside standard meteorological radiosondes, with no additional hardware required to receive the extra sensor data. The cloud sensors can be combined with others previously described, such as a **Geiger counter[6], turbulence sensor[7], and aerosol counter[8]**. Addition of such sensors can enhance and further exploit standard operational radiosonde flights or those used in field campaigns, providing additional scientific data for little extra cost.

References
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