Atmospheric monitoring for the H.E.S.S. project

K.-M. Aye, P.M. Chadwick, C. Hadjichristidis, M.K. Daniel[1], I.J. Latham, R. Le Gallou, J.C. Mansfield, T.J.L. McComb, J.M. McKenny, A. Noutsos, K.J. Orford, J.L. Osborne, and S.M. Rayner for the H.E.S.S. Collaboration

Dept. of Physics, University of Durham, DH1 3LE Durham, United Kingdom
(1) now at Department of Physics and Astronomy, Iowa State University, Ames, IA 50011-3160, USA.

Abstract and Overview

Several atmospheric monitoring devices have been installed at the H.E.S.S. site in Namibia. Firstly, Heitronics KT19 infrared radiometers, aligned paraxially with the H.E.S.S. telescopes, measure the infrared radiation of the water in clouds crossing the telescope field of view. Correlations between the trigger rate of the telescope and these IR measurements are shown in this paper. For a general judgment of the atmosphere's transmittance, i.e. the detection of any light-attenuating aerosols, a ceilometer – a LIDAR with built-in atmospheric data reduction code -- is being used [1]. The overall status of the weather is monitored by a fully automated weather station.

The main causes of extinction of Cherenkov light are absorption and Rayleigh scattering by molecules, and Mie scattering by aerosols. The H.E.S.S. photomultipliers and mirrors are sensitive to light between 250 and 700 nm. In this range the only light *absorbing* molecule is ozone, but the most significant loss of Cherenkov light in the case of a `clear' sky is caused by Rayleigh *scattering* off all atmospheric molecules dominant at lower wavelengths due to its λ^{-4} dependence, and Mie scattering on aerosols which becomes dominant above approximately 400 nm [2].
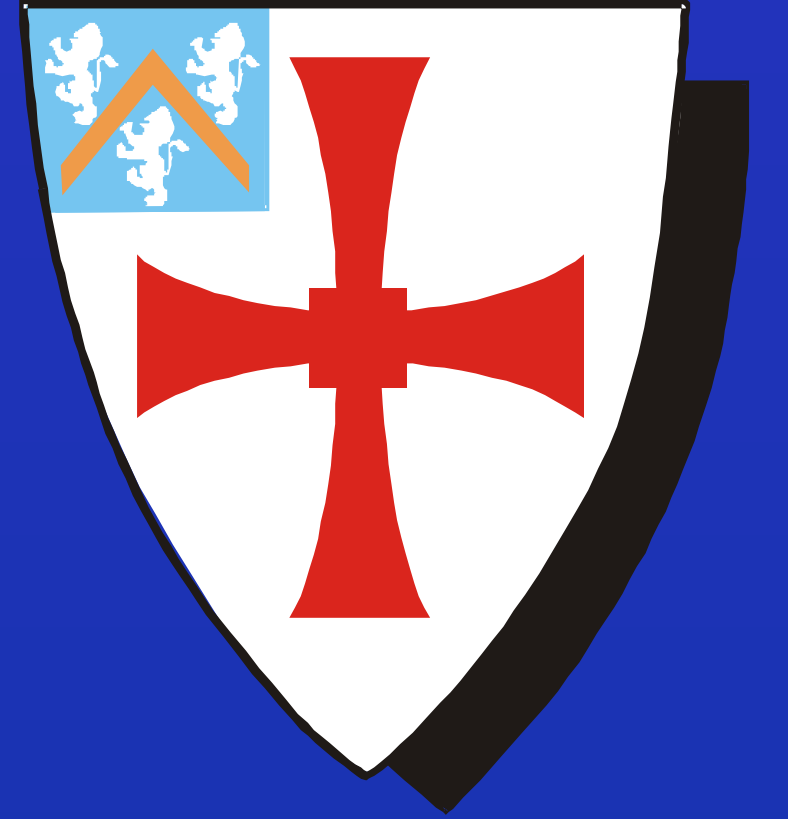
Weather Station

A weather station from Campbell Scientific has been installed at the H.E.S.S. site. It records air temperature, relative humidity, atmospheric pressure, wind speed, wind direction and will soon record rainfall too 24 hours a day. The data acquisition (DAQ) is integrated in the standard DAQ scheme for the camera data and therefore allows efficient cross-checking of atmospheric conditions and camera data. These data are important for providing input values for atmospheric models constructed with the commercially available MODTRAN package in connection with radiometer and LIDAR data.
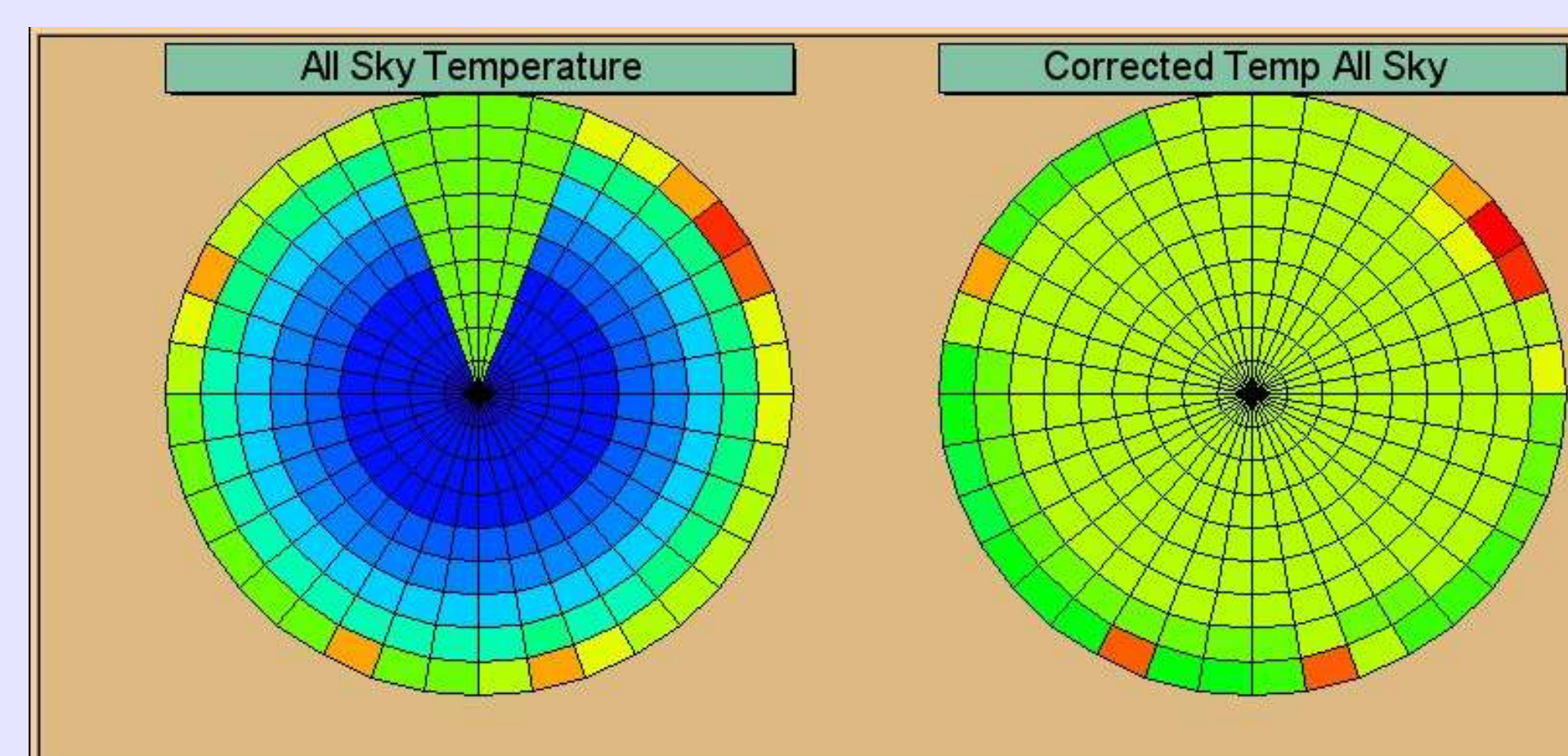
Paraxial Radiometer

The Heitronics KT19.82A Mark II is a radiometer designed for measuring the infrared radiation in the transmission window between 8 and 14 μm [4]. We use it to measure the infrared radiation from the sky in its field of view of 2.9°. By comparing the observed quantity to a blackbody spectrum, the radiometer then calculates the "radiative" temperature of the sky. It has been shown [3] that the measured sky temperature is very sensitive to the presence of clouds and water vapour which is crucial for determining the cause of a variation in the count rate of an IACT. Although clouds are not significantly warmer than the surrounding atmosphere, they are more effective emitters of blackbody radiation than the atmosphere in this wavelength range. If there are no clouds, the temperature still can vary from night to night due to relative humidity and temperature changes which may induce ice crystallisation on aerosols and therefore change the scattering phase function of Mie scattering.

Two of the planned four telescopes of H.E.S.S Phase 1 are presently operational and on each of them a radiometer is installed paraxially to provide an immediate means of cloud detection in the field of view of the camera. The figure on the right shows the detection of the clearance of the sky after a period of high cloud.

Sensitivity range of the radiometer Heitronics KT19.82A

Telescope count rate and temperature measured by the radiometer versus time

clouds   clear sky

References
1. Aye et.al, *Implications of LIDAR observations at the H.E.S.S. site in Namibia for energy calibration of the atmospheric Cherenkov telescopes*, this conference
2. Bernlöhr K. 2000, Astroparticle Physics 12, 255-268
3. Buckley et.al. 1999, Experimental Astronomy 9, p237-249
4. http://www.heitronics.de, Accessed 2003-05-13
5. Idso S.B. 1981, Water Resources Research 17, p295-304
6. Daniel M. 2003, *The attenuation of atmospheric Cherenkov photons*, PhD Thesis, Durham University, UK
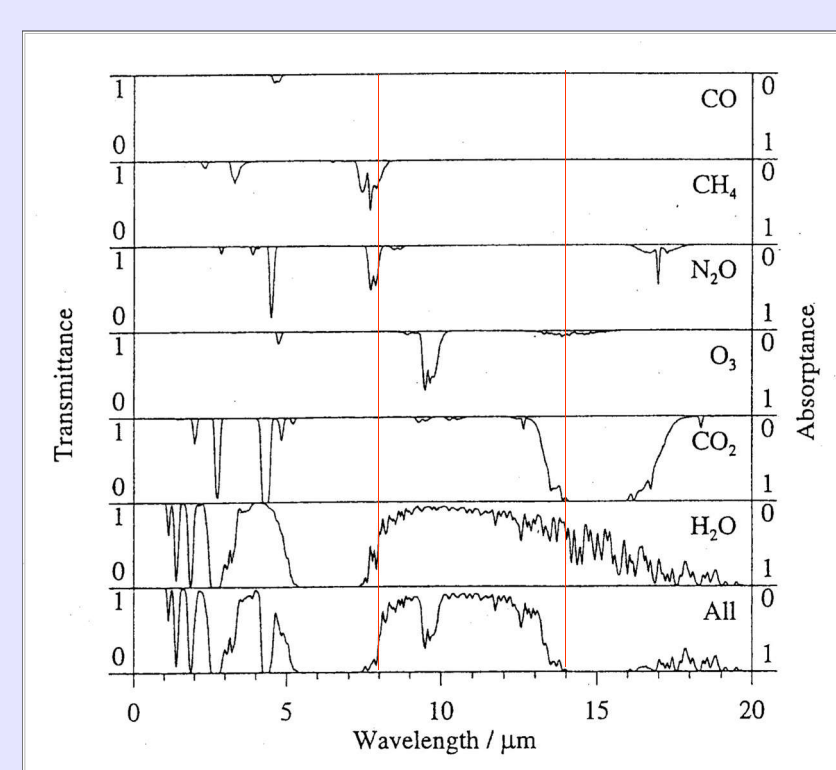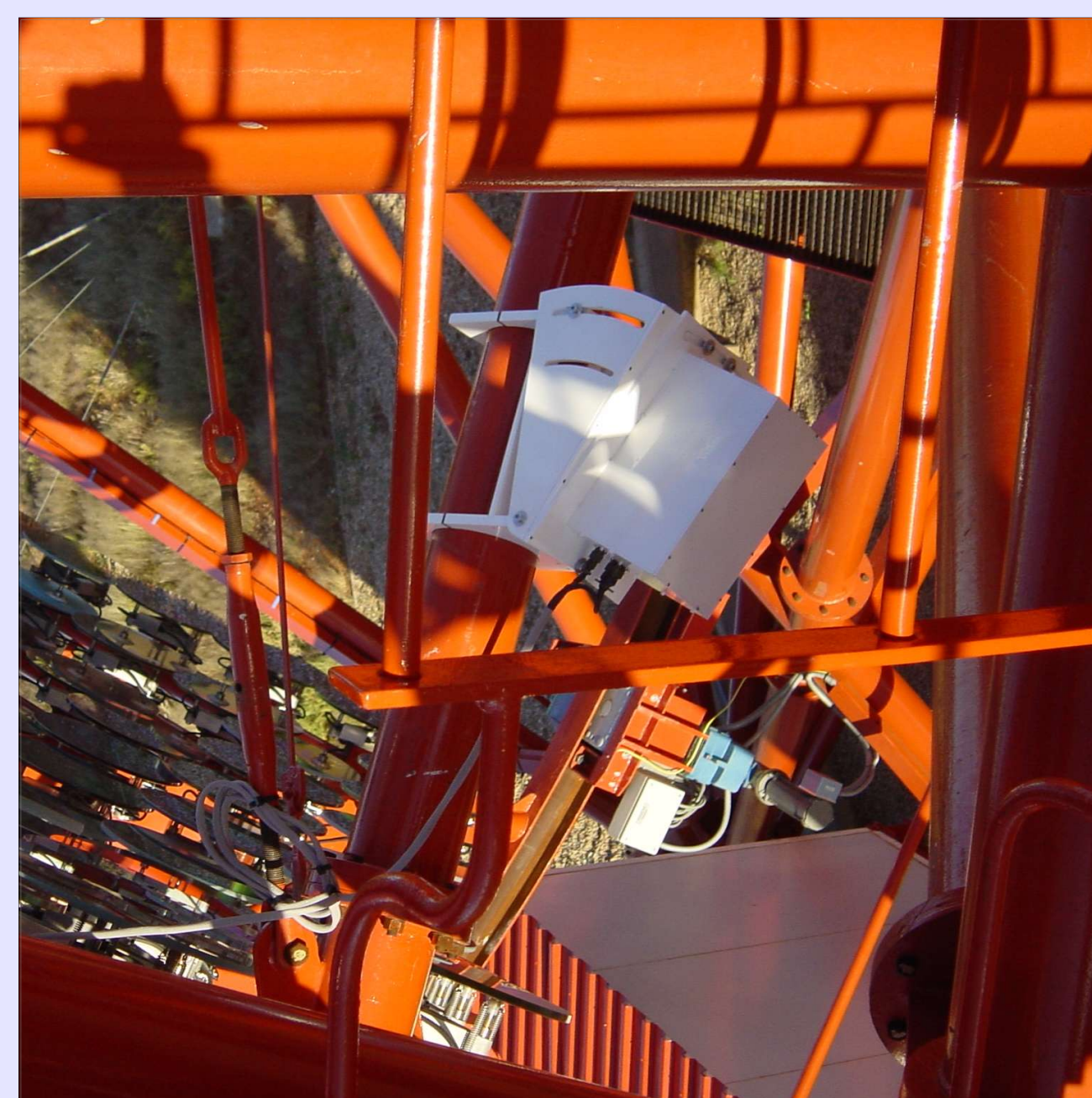
Scanning Radiometer

A scanning radiometer is installed to give the shift crew an immediate overview of the sky for any presence of clouds or approaching weather fronts. See below the display available in the control room.
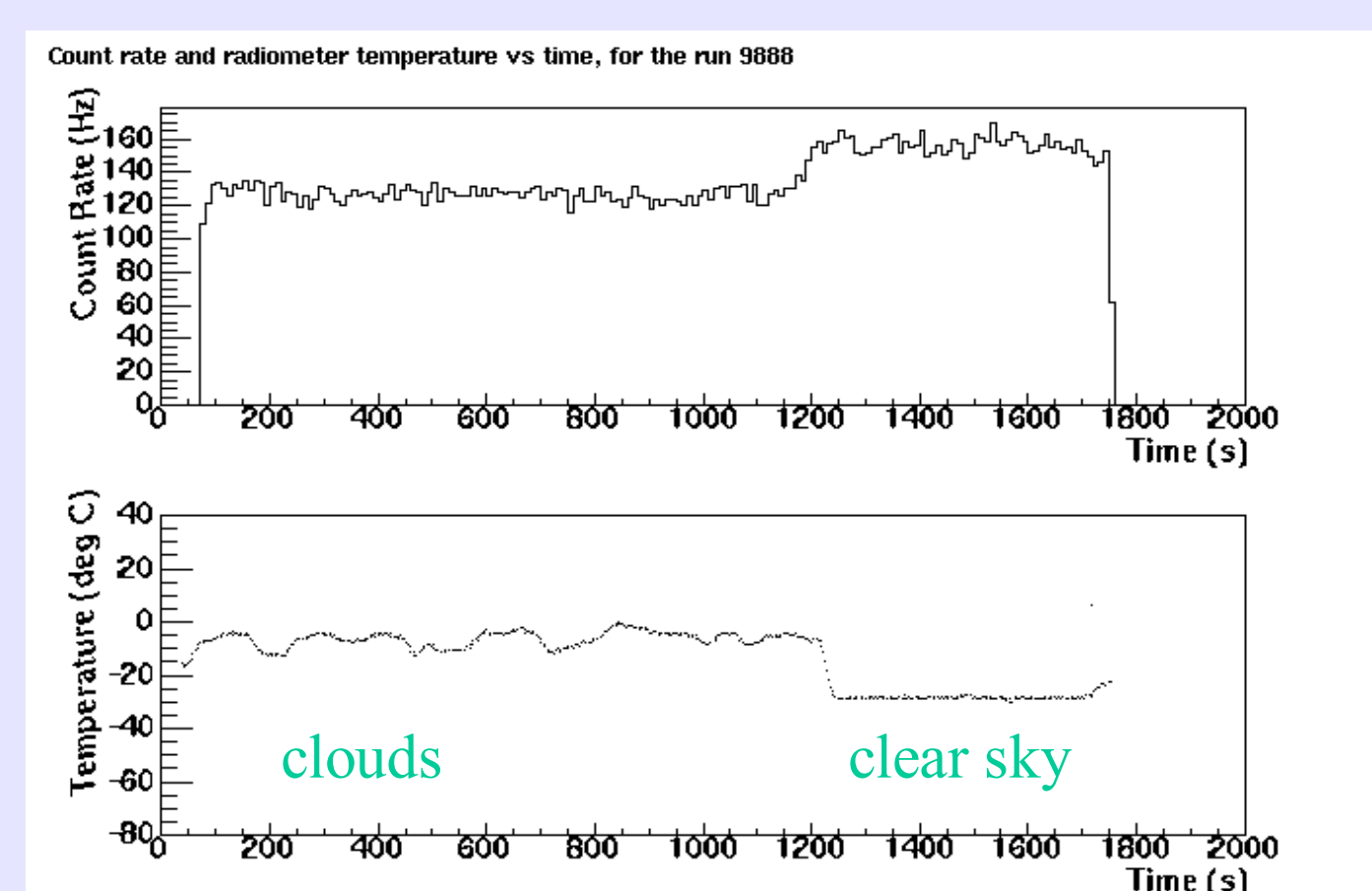
All Sky Temperature   Corrected Temp All Sky

Left: sky temperature; blue means cold hence clear ; red would mean warm hence cloudy. The four green sectors looking up is the dead angle of the instrument. Right: difference between a scan and the averaged previous one. Green means no difference, hence stable conditions. Clouds or haze would show up in red.
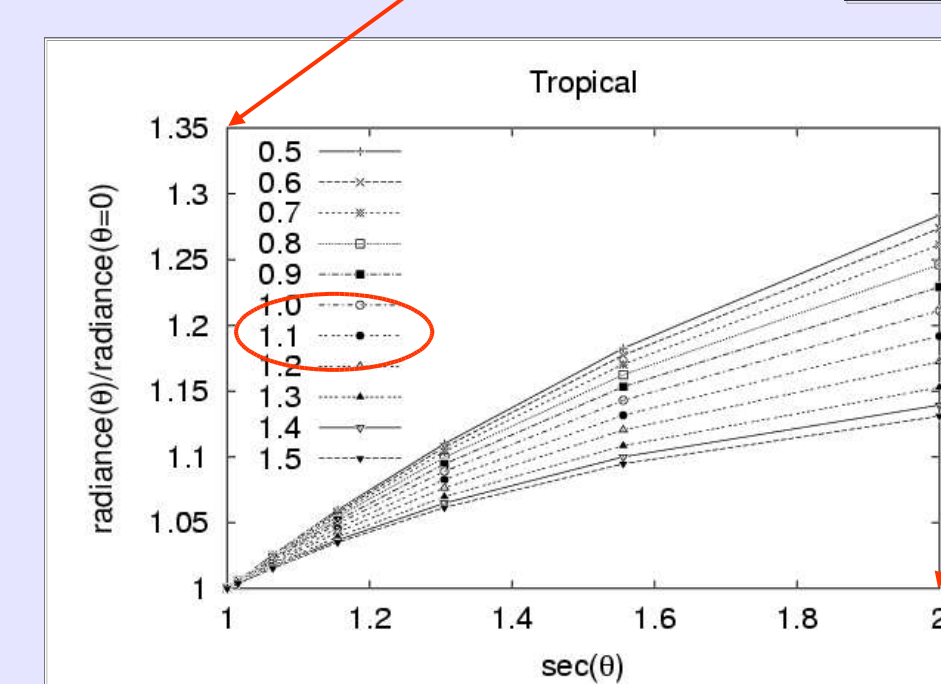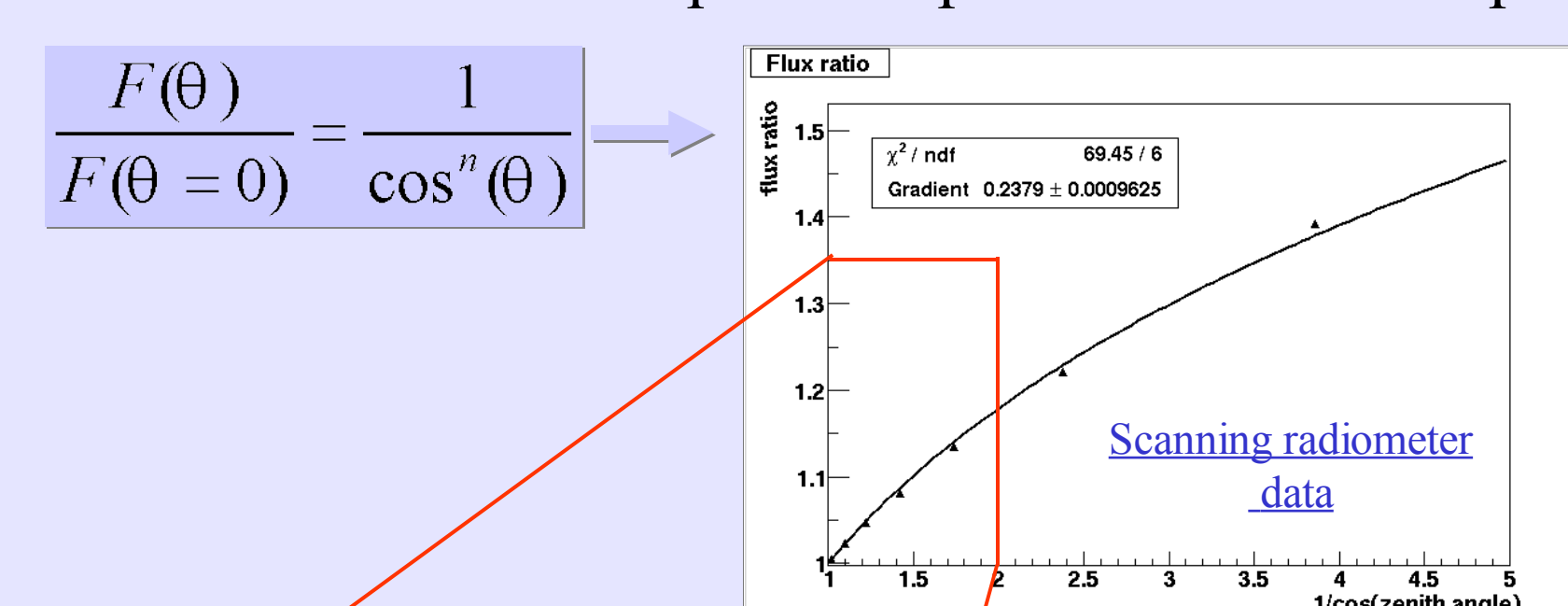
In addition to detecting clouds, the radiometer data can be used to determine the amount of water vapour contained in the atmosphere, a quantity on which the transmissivity of the latter for Cherenkov light depends. Such a measurement is not trivial. The temperature measured by the radiometer depends on several parameters: the temperature and water vapour profile of the atmosphere, the observing zenith angle, and the material of the window used to protect the instrument from the weather. Semi-empirical models like the one from Idso [5] try to relate the infrared flux detected by the radiometer to the temperature and the water vapour pressure measured at ground level in a quantitative way. Indeed, we have measured such a correlation in our data, but nevertheless this model is not satisfactory and a suitable one has yet to be found. The temperature measured with the radiometer for a clear sky increases with the zenith angle due to a thicker section of the warm atmosphere being sampled [3]. In the figure below, one can see the zenith angle dependence for different window materials. Influence of the radiometer lens: This window, depending on one of the radiometer lenses, one can see it not only increases the measured temperatures, but also alters the sensitivity $T(\theta_{max})-T(\theta_{min})$. For this reason, the thin polyethylene film, whilst less robust than Cleartran™, is the chosen material for the protective window.
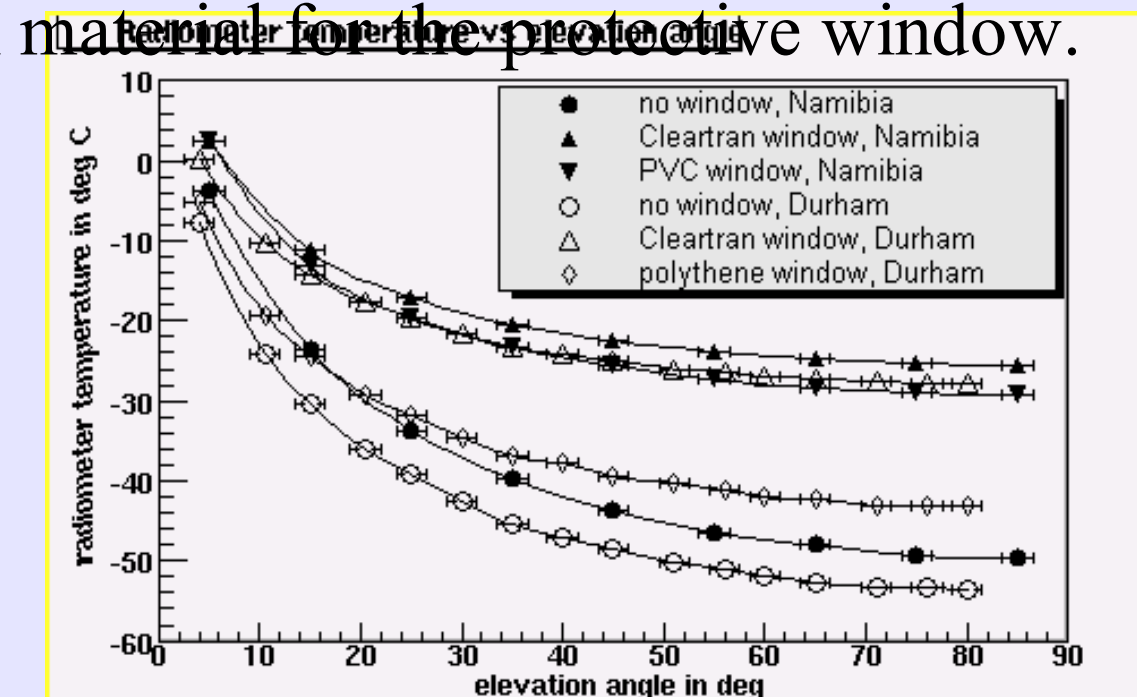
The relation between sky temperature and elevation angle of the radiometer with different window materials. Ambient conditions in Namibia: night time, T=16°C, rel.Humidity 41%; Durham: afternoon, T=5° C, rel.Humidity 70±10%.

The parametrization of the zenith angle dependence of the radiometer measurement can in principle provide, following [6], an estimate of the water vapour content of the atmosphere. However, studies have yet to be made in order to exclude biases coming from the window material and the temperature profile of the atmosphere.

$$\frac{F(\theta)}{F(\theta = 0)} = \frac{1}{\cos^n(\theta)}$$

Scanning radiometer data

Prediction from MODTRAN, for the tropical model atmosphere and different water vapour column density scale factors. (Plot from [6])