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# Comparison of the Response of the UV and Visible Cherenkov Telescopes to the Atmospheric Conditions

**H. M. Badran**

*Department of Physics, Faculty of Science, Tanta University, Tanta 31527, Egypt*

*Present address: Whipple Observatory, P.O.Box 97, Amado, AZ 85645-0097*

**Abstract**

With atmospheric Cherenkov telescopes the experiment is totally at the mercy of the environment; particularly the atmospheric conditions. The effect of the atmospheric conditions on the Cherenkov light flashes is closely investigated for UV and visible cameras. The telescope response for light generated at different altitudes does not have the same variation with the wind speed or cloud thickness. For both cameras measurements can be carried out up to wind speed ~17 m/s without much change of the atmospheric transmittance from light generated close to the observing level and up to 12 m/s for higher elevation and higher zenith angles. The suggested limit for cloud thickness for both cameras is around 0.5 km. A cloud thickness of ~0.9 km can be tolerated for zenith angles less than 30°. The suggested limits are particularly important whenever the spectrum is to be determined from the data. No real change of the response function with the air pressure and temperature was found. The seasonal variation has a slight effect on the telescope response.

## 1 Introduction

The response function (H) characterizes the response of the photomultiplier (pmt) tube in the Cherenkov telescope. It depends on the Cherenkov light spectrum generated by charged particles in the air shower, the atmospheric conditions, the atmospheric transmittance, mirror reflectivity and the pmt quantum efficiency (Badran, 1997). The atmospheric transmittance for light generated at different elevations and observed at altitude 2.3 km are calculated using LOWTRAN 7 (Kneizys *et al*., 1988). Two types of photomultiplier tubes (pmt) have been implemented in the calculations; visible (Bi alkali) and UV solar-blind (CsTe photocathod on quartz window) pmts. The variation of the relative response function with the zenith angle is discussed elsewhere (Badran, 1999).

## 2 Atmospheric Effects

This work is mainly aimed at a study of the effect of different atmospheric conditions on the amount of light received by the atmospheric Cherenkov telescope. The decrease of the atmospheric transmission causes a reduction of the average amount of light detected by a pmt and this leads to an increase in the energy threshold as well as reducing the ability of estimating the energy spectrum from a source due to the variation of the atmospheric condition from one run to the other. Such effects increase with increasing number of pixels in the image. Therefore, it is of utmost importance to VHE $\gamma$-ray observation to determine a range for the atmospheric conditions at which the average response of the camera is not subjected to a considerable variation. To set a limit on each atmospheric parameter, the value at which the response function drops to 85% of its original value at standard atmosphere due to the effect of this parameter is chosen to be a reasonable limit for that parameter.

Apart from the effect of the wind speed on the telescope's stability, it is also important to examine its effect on Cherenkov light collection efficiency. The relative change of H for the visible camera with respect to the wind speed ($S_w$) is shown in Fig. 1 for different elevations and zenith angles 0 and 60°. Each curve is normalized to zero wind speed. The corresponding curves for a UV camera is very similar to those shown in Fig. 1. Table 1 list the values of the limit on the wind speed; $S_W$(85%). High elevation measurements ($\theta$<30°) can be carried out up to wind speed ~17 m/s without much change of the atmospheric transmittance for light generation levels up to 9km. For large zenith angles, 12 m/s is the limit. Therefore, 12 m/s seems to be the best limit for the wind speed without a considerable loss in the overall response (≤15% in most cases) in both cameras.

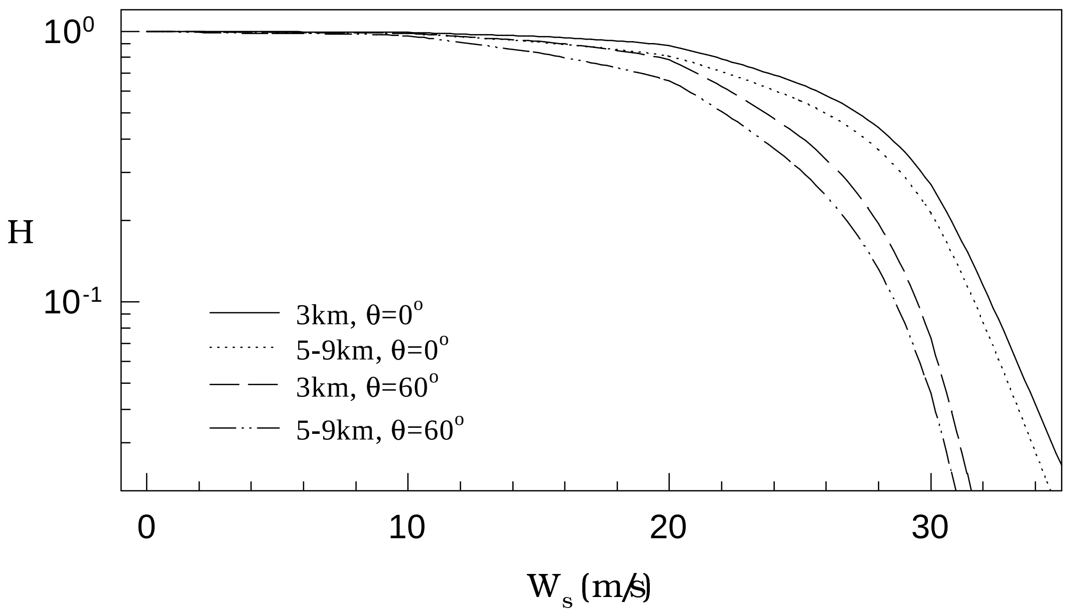


**Fig. 1**. Variation of the relative response function of the visible photomultipliers with the wind speed for light generated at 3, 5, 7, and 9 km and detected at 2.3 km. The zenith angles are 0 and 60°.

The base and top of infinite (in two dimensions) cirrus cloud is defined as the region where the air is considered saturated with 100% relative humidity. The overall telescope response has been calculated for cirrus clouds with base at 2.6 km altitude (300 m above the observation level) and with different thicknesses ($T_C$). Fig. 2 shows the results of these calculations for the two cameras. The atmospheric transmission decreases with increasing cloud thickness until the top of the cloud exceeds the altitude where the light is generated. When the top of the cloud extends above the light emission level, the transmission declines with a lower rate with increasing cloud thickness. This is because of the humidity elevated around the cloud, which affects the transmission for light paths that pass in or near the cloud. The calculated limits $T_C$(85%) are given in Table 1. A reasonable limit for operating the Cherenkov telescope depends on the zenith angle. In case if the measurements have to be carried out at low elevation ($\theta$~75°), the limit should be around 0.5 km for cloud thickness. Clearly, if the cloud is above certain elevation where the Cherenkov light is generated, then the transmission will be affected only with the humidity around the cloud.

**Table 1**. The calculated limit of the wind speed, $S_W(85\%)$ m/s, cloud thickness, $T_C(85\%)$ km, for atmospheric Cherenkov telescope with visible or UV cameras.

| θ (degree) | $S_W(85\%)$ m/ | | $T_C(85\%)$ km | |
|---|---|---|---|---|
| | 3km | 5, 7, and 9km | 3km | 5, 7, and 9km |
| 0 | 21 | 18 | 2.7 | 1.1 |
| 30 | 20 | 17 | 2.4 | 0.9 |
| 60 | 18 | 14 | 1.4 | 0.7 |
| 75 | 15 | 12 | 0.7 | 0.5 |

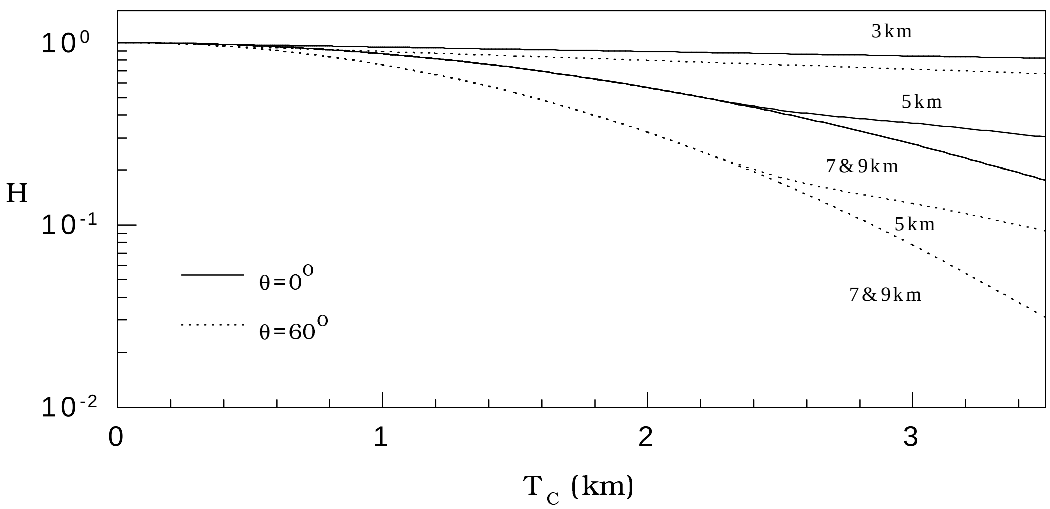


**Fig. 2**. Variation of the relative response function of the visible or UV photomultipliers with the cirrus cloud thickness for light generated at 3, 5, 7, and 9 km and detected at 2.3 km. The zenith angles are 0 and 60° and the cloud base is at 2.6 km.

The effect of air pressure (P), temperature (T), and the ratio P/T on the relative response function has also been investigated. Almost no real change was found in the ranges T= -10–40°C, P= 800–1000 mb. The seasonal dependence has also been investigated assuming no other effect is affecting the measurements; e.g. wind or cloud. The telescope response is almost independent of the seasonal variation with a few exceptions. This is clearly illustrated in Fig. 3. The visible camera has the highest response (~11%) at the mid-latitude summer. The UV camera has the lowest response at the mid-latitude summer (~4%) and the highest response at both tropical model and subarctic winter (~3%).

The nearly equal variation of the visible and UV pmt with different atmospheric conditions does not mean that they are identical. A major difference between the response of visible and UV pmt is that the response of the UV camera drops faster with increasing zenith angle and/or the altitude at which Cherenkov light is generated. This is mainly due to the rapid attenuation of the UV component by increasing the path of the light in the atmosphere.

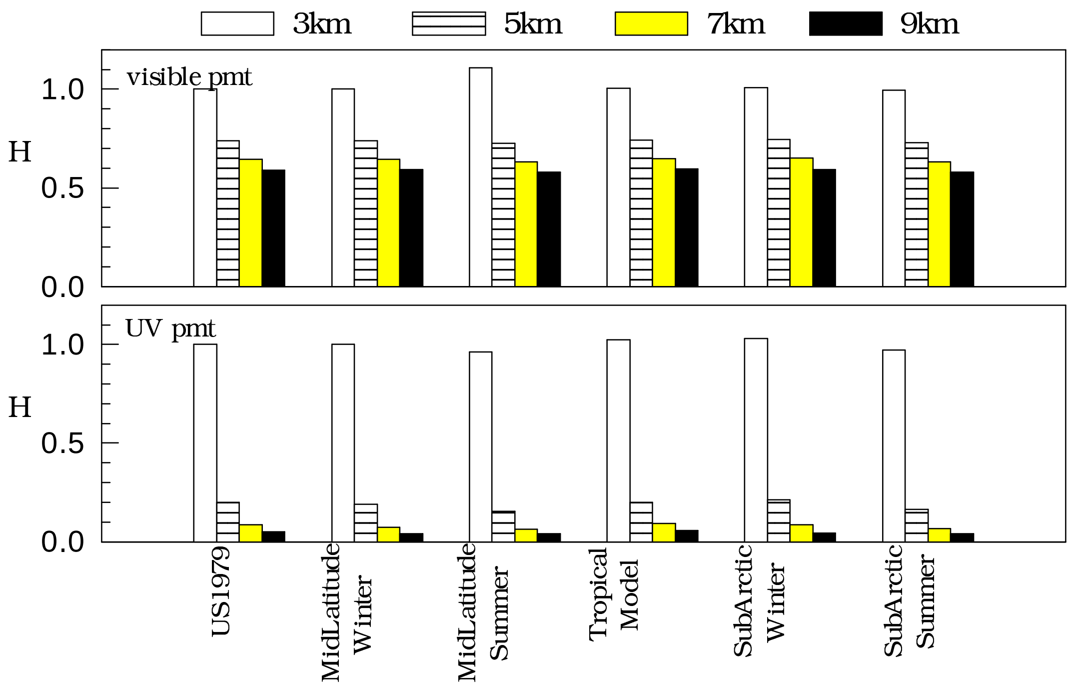


**Fig. 3**. Seasonal dependence of the response of atmospheric Cherenkov telescope with visible and UV cameras.

## 3 CONCLUSION

Among the atmospheric parameters investigated here, the wind speed and the cirrus cloud represent the important parameters that affect the Cherenkov light collected by the ACT. Generally, 12m/s seems to be an acceptable limit for the wind speed. As for the cirrus cloud, the response of ACT decreases with the increase of the air humidity and/or the increase of the vertical thickness of the air with that humidity. An important point has to be made here that choosing a safe limit for the measurements does not mean the observed energy spectrum is still the same. On the contrary, the energy spectrum is affected from run to run if the wind speed or the cloud thickness are changing. The response of the telescope becomes more biased toward light generated at close elevations; and therefore towards higher energy events; as either the wind speed or the cloud thickness increases. The same effect is also expected if the base of the cloud moves to higher elevation. Therefore, special care has to be given to this effect in estimating the energy threshold or the energy spectrum. It has to be noted that a simultaneous increase of wind speed and the existence of clouds together should reduce the suggested limits.

## References

Badran H.M. 1993, *Proc. 23rd ICRC* (Calgary) 4, 327.
Badran H.M. 1997, *Proc. 23rd ICRC* (Calgary) 5, 165.
Kneizys *et al*. F. X. 1988, *Users Guide to LOWTRAN 7*, Air Force Geophysics Lab., AFGL-TR-88-0177.