The colour of natural twilight at Auckland, New Zealand

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ABSTRACT

The purpose of this work is to obtain comparisons of global exterior colour temperature and illuminance measured under twilight conditions at two widely-separated locations in the Southern hemisphere, in the cities of Durban (South Africa) and Auckland (New Zealand). Measurements were taken in Durban during 1991–93, and in Auckland in 2004–05. It is found that there is significant agreement in the data from the two sites.

Subsidiary objectives were to provide information of use to designers of photoelectric switching systems, and also to assess the possible benefits of undertaking a more extensive project in the future. It is found that, at both sites, the colour temperature is between 3600 and 4000 K at an illuminance of 55 lux (a commonly-chosen level for automatic switching). A brief assessment is included of the merits of possible future spectral measurements of twilight.

1. INTRODUCTION

This work follows on from an earlier investigation undertaken by the author in southern Africa over a period of 21 months, some twelve years ago [1]. It was decided that there would be merit in a repeat series of measurements at a location remote from the first – particularly since the author has access to the same two instruments used in the earlier investigation – and to attempt to assess the extent to which the earlier figures may or may not be specific to the geographical locality.

It was felt that the results will also be of interest to designers and manufacturers of photoelectric control units (PECUs) who wish to calibrate their products to switch at a specific value of twilight horizontal illuminance. Photoelectric switching is widely used in the control of exterior lighting systems operated during the hours of darkness and, in certain situations, numbers of separately-switched light-sources need to be activated in synchronism in order to provide an aesthetically pleasing effect – and this means that effective calibration is essential. One of the problems is that the majority of cost-effective photo-detectors are supplied without $V(\lambda)$-correction, and so the calibration of the PECU is dependent on the spectral response function $\Re(\lambda)$ of the specific type of photodetector selected by the circuit designer – and the calibration process becomes highly sensitive to the spectral power distribution (SPD) of the calibration source.

It has to be made clear at this point that, because of cost factors, this work does not attempt to address the question of the SPD of twilight, and the assumption is made that the shape of the SPD curve for twilight approximates that of a Planckian distribution, so that a knowledge of the ***chromaticity*** of twilight alone will give a reasonably complete description of the SPD. This has been based on the measurement of global daylight at Durban during the 1970s [2] which showed daylight SPDs that approximate the Planckian shape – although it is recognized that the assumption may not be entirely valid in view of the greatly increased air mass during twilight, together with the possibility that local geographical and environmental conditions may also modify the received spectrum.

Based on this assumption, the calibration of a PECU can be regarded as effective if the calibration light source possesses the same colour temperature as natural twilight at the illuminance corresponding to the desired switching level. It is therefore necessary to establish the relationship between colour temperature and illuminance under twilight conditions – and our measurements will permit this data to be extracted.

Finally, it is planned that this work will allow an assessment to be made of a proposal to undertake future measurements of the SPD of twilight.

2. GEOGRAPHICAL DETAILS

The earlier measurements [1] were performed at a site, about 100 m above sea level, at Durban, on the South African east coast, with approximate coordinates of 30° south and 30° east. In Durban, the sun rises over the Indian Ocean and sets over the (sometimes arid and dusty) southern African interior and the Drakensberg mountain range.

The new data have been collected at a site in Auckland, New Zealand, about 10-20 m above sea level, with geographic coordinates of approximately 37° south and 175° east. Auckland is located on a narrow isthmus, running roughly north-to-south, and with a maximum land mass of about 70 km width in the general vicinity of the measurement site. Climatic conditions in Auckland are largely dictated by the maritime weather on the neighbouring Tasman Sea to the west, and the Hauraki Gulf and Pacific Ocean to the east.

The measuring site in each instance was at the home of the author. Like the site in Durban [1], the Auckland site provides a clear view of the sky overhead, but the horizon is partially obscured by trees and the roofs of neighbouring dwellings. Because these features are generally low (roughly 10° - 20° above the horizon), and the measuring sensors have a cosine response, it is unlikely that they will have had a significant effect on the measurements.

3. METHOD

The colour temperature of the twilight sky was read with the use of a Gossen™ "Sixtycolor" photographic colour-temperature meter, which has been found to give a reliable indication of the colour temperature of a wide range of different light sources, over a wide range of illuminance levels. Illuminance was measured on a calibrated illuminance meter with custom-built display electronics, and making use of a fully V(λ)-corrected and cosine corrected photo-sensor supplied by LMT™ Berlin.

For each set of readings, measurements were taken of global horizontal illuminance and colour temperature, as well as vertical colour temperature with the sensor surface normal to the direction of the sun's position, at 5-minute intervals, for 30 minutes before and 30 minutes after the published [3] sunrise or sunset time. The timing of each set of measurements was fixed by reference to a set of sunrise and sunset tables for Auckland. The times for recording the readings were read off an electronic wristwatch set according to the national broadcast time signal. Cloud cover on different occasions ranged from zero to total. Some instances of partial cloud were accompanied by considerable cloud movement during the twilight period.

The same method and the same two instruments were used in the earlier measurements [1]. Because the Durban readings were taken for the 15 minutes either side of sunrise/sunset, the Auckland data are presented here for the corresponding time interval.

4. RESULTS

The results of the two sets of measurements are summarized in Figures 1 and 2 in terms of the horizontal-colour-temperature transients at the two sites. In the case of the Auckland data, the 'sunrise' and 'sunset' curves are each plotted from the averages of twelve individual measured transients. The 'mean' is the average of the two (sunrise and sunset) curves. For the Durban measurements, the 'sunrise' curve is the average of seven data sets, and the 'sunset' curve the average of eleven sets. Otherwise, the treatment of the data is the same for the two sites.

Figure 3 shows the horizontal colour temperature plotted as a function of horizontal illuminance for the two measurement sites. In each case, a power curve has been fitted to the measured data points using least-squares regression. It is noted that, in the case of the Durban results, there is a considerably larger scatter of data points around the fitted curve.

Because of space limitations, we have not included any plots of vertical colour temperature. It can be noted, however, that there was an almost linear relationship between vertical and horizontal colour temperatures at both sites, with the vertical colour temperatures being lower than the horizontal by amounts in the range 500–1500 K.

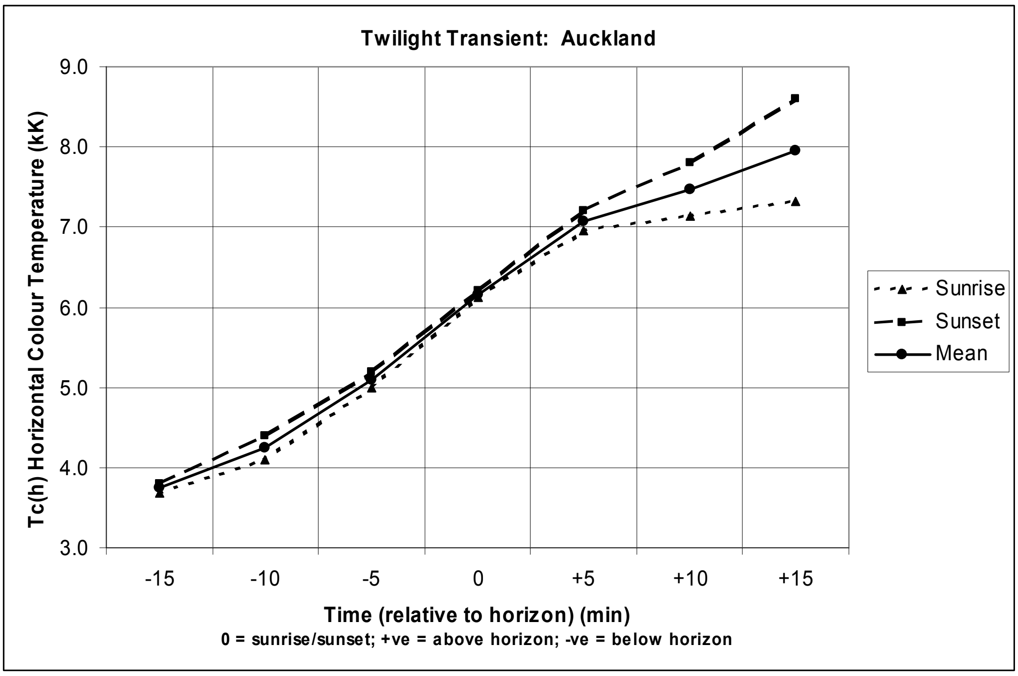


Figure 1: Horizontal colour temperature twilight transient measured at Auckland, 2004–05: Averages of 12 sunrise and 12 sunset data sets..
Note: Relative time used as abscissa to permit sunrise and sunset data to be combined.

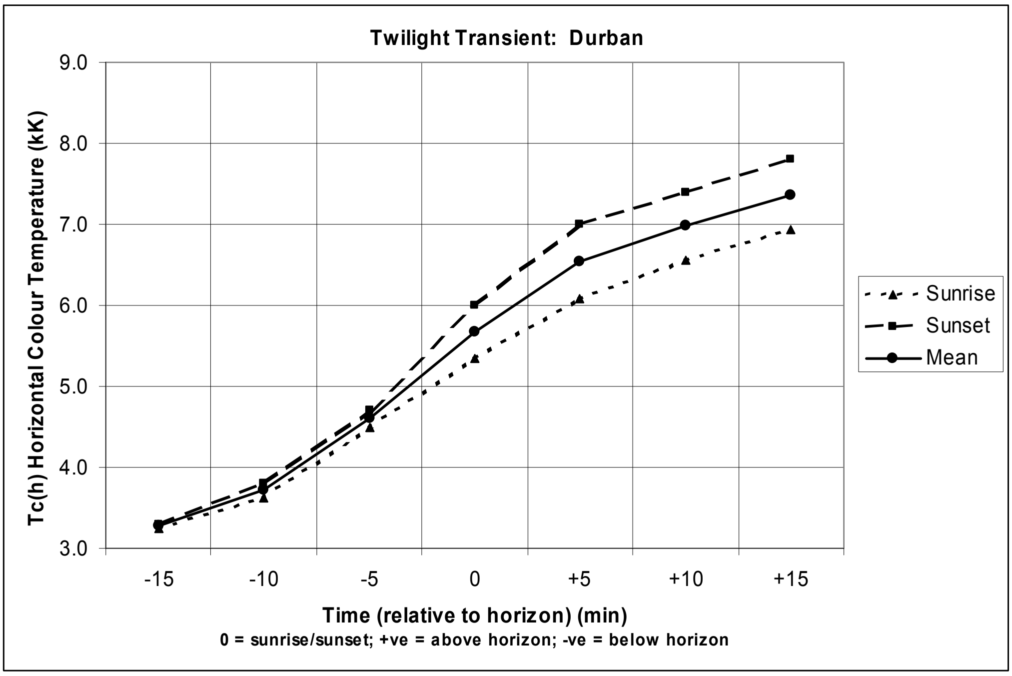
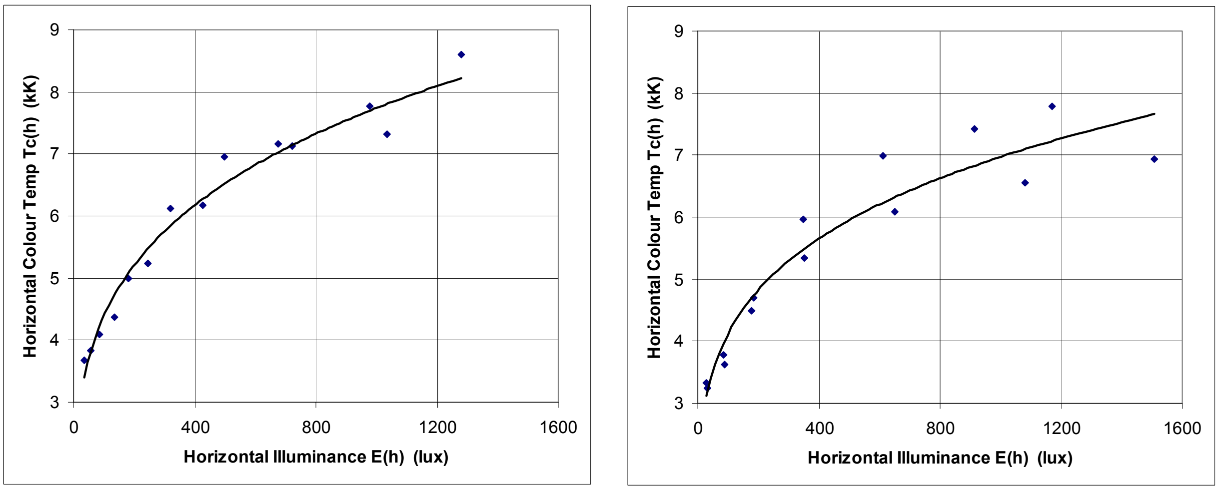


Figure 2: Horizontal illuminance twilight transient measured at Durban, 1991–93: Averages of 7 sunrise and 11 sunset data sets..
Note: Relative time used as abscissa to permit sunrise and sunset data to be combined.

It should be noted that there was significant day-to-day variability in the twilight data gathered at both sites, and that measurements were conducted on random dates that suited the convenience of the investigator. Space limitations preclude a detailed examination of the statistics – suffice to say that the results should be interpreted with these variations in mind.



(a) (b)

Figure 3: Twilight colour temperature vs. illuminance locus for (a) Auckland, 2004-05, (b) Durban, 1991-93.

5. CONCLUSIONS

The graphs presented in the figures show a few obvious but relatively minor differences in the twilight conditions at the two sites. Overall, however, there is a remarkable degree of similarity. Possibly the most interesting difference is the higher colour temperature (exceeding 8,000 K within 15 minutes of sunset) at the Auckland site. A feature that is common to both sites is the change in the slope of the colour-temperature transient (Figures 1 and 2) when the sun is more than 5 minutes above the horizon. Using the fitted curves from Figure 3, it can be deduced that the colour temperatures of twilight at 55 lux at the two locations were 3800 K at Auckland and 3600 K at Durban. The difference of 200 K is well within the variability at each site, and is not considered significant.

It is noted that the published results for twilight SPD measurements in Spain and the USA [4] during 1998–2001 provide evidence of twilight chromaticities at the 'dark' end of the transient that are generally close to the Planckian locus, at colour temperatures that mostly exceed 6,000 K. It is not immediately clear whether these higher colour temperatures are a result of geophysical variations for different parts of the globe, or whether they arise from different measurement techniques. It is considered, however, that they warrant further investigation. Other opinions will be welcomed.

References

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