# Estimating the proportion of diffuse photosynthetically active radiation from satellite measured cloud fraction: a test under humid temperate conditions

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## 1. Introduction

The proportion of diffuse photosynthetically active radiation (PAR) reaching the ground is an important factor in plant growth, but this is difficult to measure using remote sensing. Butt et al. (2010) showed how diffuse PAR in Amazonian rainforest could be estimated from remotely sensed measurements of cloud fraction, but the validity of this method was not tested in other areas. In this study, a similar methodology was used to test whether diffuse PAR in a humid temperate area could be estimated from cloud fraction derived from data provided by the International Satellite Cloud Climatology Project (ISCCP). The research took place at the Chilbolton Facility for Atmospheric and Radio Research (CFARR), southern England (latitude 51.14 N, longitude 1.44 W) and used solar irradiation data collected between May 2003 and June 2008 using a broadband (305-2800 nm) pyranometer.

## 2. Data and methodology

- Data in this study were collected at CFARR, southern England (1.44 W, 51.14N), as shown in Fig. 1.
- Collected data from two types of measurement at CFARR were used in this study. First equipment for global and diffuse PAR measuring in this study is a Delta-T Devices, BF-3 Sunshine Sensor. The second equipment is a Kipp & Zonen CM-21 pyranometer, broadband solar radiation measurement. Equipments are shown in Fig. 2.

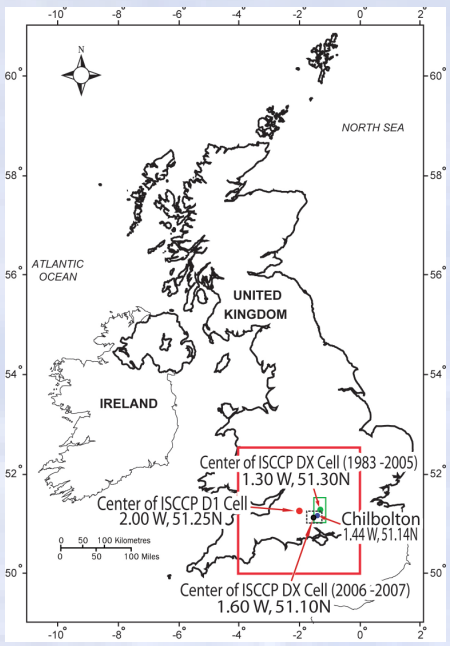


Fig. 1 Area of interest over southern part of England

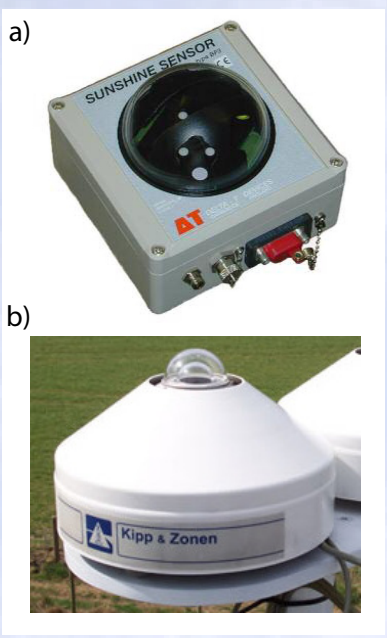


Fig. 2 a) Delta-T Device Sunshine Sensor model BF-3 for global and diffuse PAR measuring, b) Kipp & Zonen pyranometer model CM 21 for global broadband radiation measuring

- The 5-minutely instantaneous variation of global and diffuse solar radiation in PAR wavelength (400-700 nm) from the BF-3 Sunshine Sensor are shown in Fig. 3.
- The 10-secondly instantaneous variation of calculated extraterestrial solar radiation and measured global broadband solar radiation (305-2,800 nm) from Kipp & Zonen CM21 pyranometer are shown in Fig. 4.
- The variation of PAR diffuse proportion and proportion between global broadband per extraterestrial solar irradiation have been plotted in Fig. 5. This graph shows the nature of the fluctuation between two of them.
- Measured data during 1st October - 6th November 2009 were used for 3 hourly relation of PAR diffuse proportion and proportion of global broadband solar radiation per extraterstrial solar radiation.
- Measured data during 10th - 30th September 2009 were used for testing the relation between measured diffuse proportion and the calculated diffuse proportion using the empirical equation with the measured global broadband data.

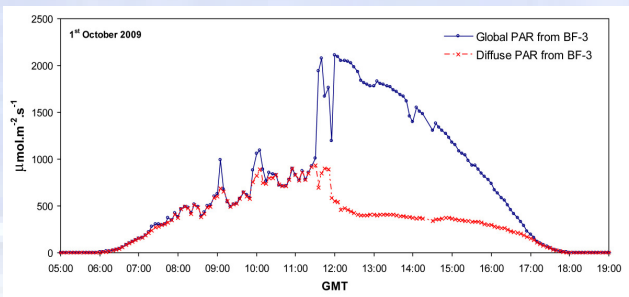


Fig. 3 An example on 1st October 2009 of variation of diffuse and global irradiation at CFARR

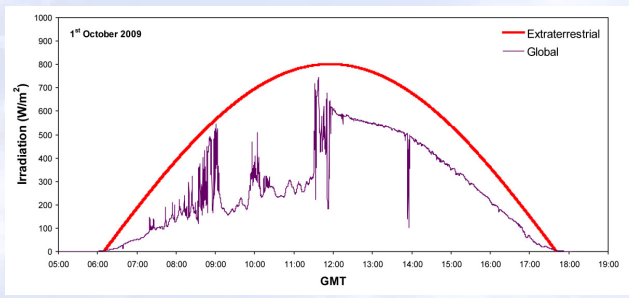


Fig. 4 Extraterrestrial solar radiation and global broadband solar radiation on 1st October 2009

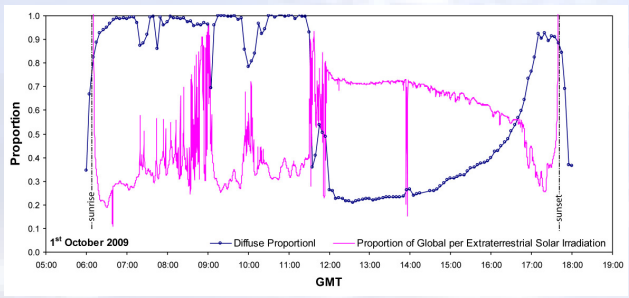


Fig. 5 Comparison between diffuse proportion and proportion of global per extraterestrial broadband solar irradiation, example on 1st October 2009

## 3. Results

The relation and accuracy between diffuse proportion and proportion of Global per extraterrestrial solar irradiation, from measured data at CFARR are shown in Fig. 6 and Fig. 7. The relation of diffuse proportion and cloud fraction from ISCCP DX data during May 2003 - June 2008 were then estimated as shown in Fig. 7.

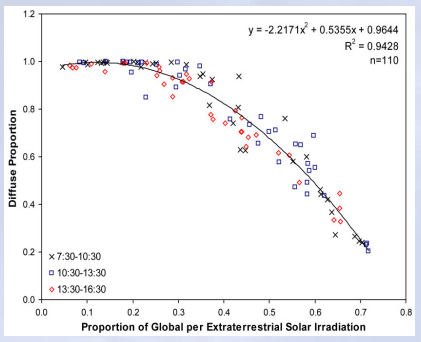


Fig. 6 3-hourly relation of diffuse proportion and global per extraterestrial solar irradiation (1st October - 6th November 2009)

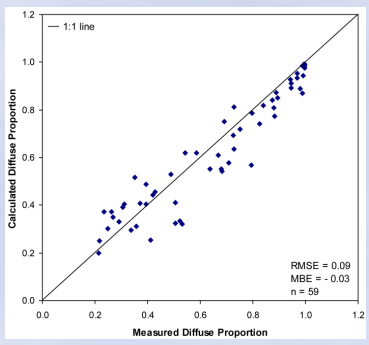


Fig. 7 Comparison of 3-hourly measured and calculated diffuse proportion (10th - 30th September 2009)

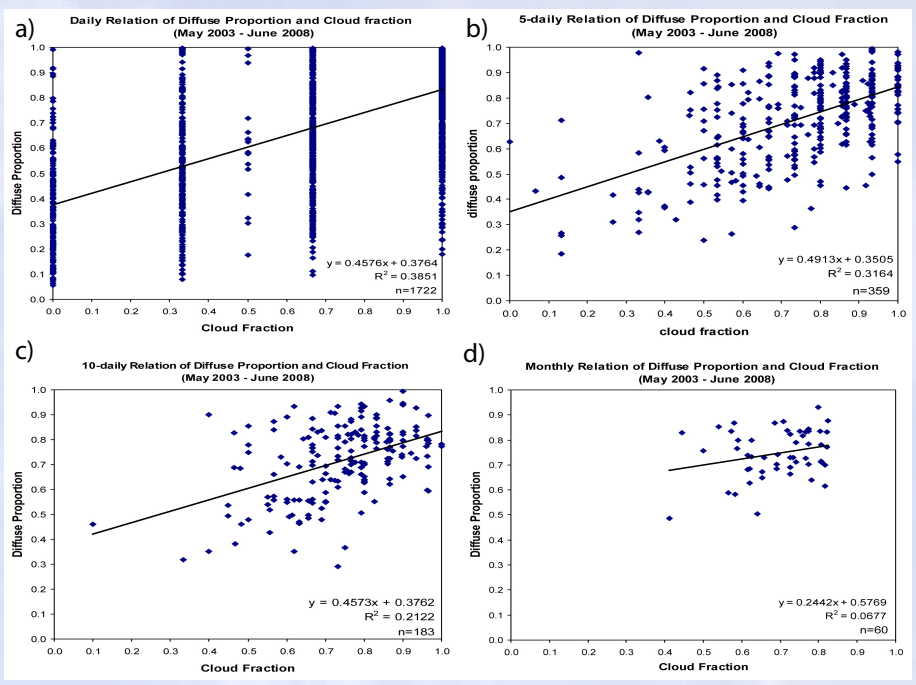


Fig. 8 Relation of diffuse proportion from ground base measuring at CFARR and cloud fraction from ISCCP DX data for a) daily, b) 5-daily, c) 10-daily and d) monthly basis

## 4. Discussion

We found that the relationship between cloud fraction measured from space (ISCCP DX) and the proportion of diffuse PAR measured at ground level was significant, but weaker than that measured in Amazonia. Several factors might explain this:

1. The characteristics of the clouds present. In the UK these are at lower altitude and most commonly cumulus and stratus, whereas in Amazonia are generally higher and thicker than clouds in the UK.
2. The solar environment. The solar elevation angle is much smaller at latitude 50 deg. north than in the tropics. This will cause cloud shadows to be more significant in the UK than in Amazonia and mean that solar radiation has a longer airmass path length through the atmosphere.
3. Aerosol environment. The Amazonian area is dominated by continental aerosols and aerosols from biomass burning are also significant. The UK site is more affected by maritime aerosols and is subject to rapid changes in weather due to the passage of fronts.

## 5. Conclusion

The three-hourly relationship between the diffuse proportion and the cloud fraction was used to test the hypothesis of Butt et al. (2010) that diffuse radiation can be predicted from cloud fraction. Although the results of the analysis supported the hypothesis of Butt et al., the relationship in our study was not as strong as theirs, which were conducted in the Amazonian region. We suggest that the highly variable and ephemeral nature of mid-latitude atmospheric conditions in the UK was the reason for the much weaker relationship.

## Acknowledgements

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## Reference

Butt, N., New, M., Malhi, Y., Lola da Costa, A.C., Oliveira, P. & Silva-Espejo, J.E., 2010. Diffuse radiation and cloud fraction relationships in two contrasting Amazonian rainforest sites. *Agricultural and Forest Meteorology*, 150, pp.361-8.