Thermal Offset Errors in Solar Diffuse Measurements with Some Commercial Pyranometers

E. G. Dutton
National Oceanic and Atmospheric Administration
Climate Monitoring and Diagnostics Laboratory
Boulder, Colorado

T. L. Stoffel
National Renewable Energy Laboratory
Golden, Colorado

J. J. Michalsky
State University of New York
Albany, New York

Introduction

Fundamental heat budget analysis of the thermal detector system used in many commercial pyranometers reveals a zero offset error term accounting for the infrared (IR) exchange between the protective dome-filter and the detector (Gulbrandsen 1978; Wardle and Barton 1988). This term exists for thermal radiometer detectors if the entire detector is black at solar and IR wavelengths and if the detector has any fore-optics. This error is especially problematic for clear-sky diffuse irradiance measurements because it becomes large relative to the measured values. To correct for this term, the alternatives are 1) to design the instrument to minimize the related temperature and emissivity differences and then use the radiometer within its error range, 2) determine the respective temperatures and emissivities and compute the error term, or 3) develop a quantitative surrogate for the error term using available data. Since the designs of many instruments in use are fixed, and since proper determination of actual glass dome temperature is difficult and illusive, we have developed or implemented various methods for estimating the instantaneous dome temperature error in diffuse irradiance measurements. We have tested these various methods for consistency and their ability to produce a realistic Rayleigh-limiting lower bound in clear skies.

Three independent methods for determining the dome temperature error in diffuse measurements using black detectors were developed. The first, and most widely recommended operational procedure, is to establish a relationship between nighttime offsets and a measure of the net IR irradiance, which is a major factor influencing the differential temperature of the exposed glass dome. Such a relationship can be justifiably applied to daytime conditions for diffuse measurements because the dome is typically exposed to similar heat budget influences during day and night. Six different formulations of the net-IR relationship have been tested. A second method of determining the offset error is a dome-capping procedure whereby the dome/detector system is instantaneously blocked from all solar irradiance while exposing it to a neutral IR environment. Because of the relatively long thermal *e*-folding time constant of the glass dome (several minutes) compared to that of the detector (2 to 10 seconds), the capped instruments briefly register the offset caused by the differential dome temperature. The third method examined is a comparison of observed diffuse irradiances with those from black-and-white detector instruments, which because of their alternating black and white exposed detector surface are essentially unaffected by the differential dome temperature error. Several commercial pyranometers of both the black and black-and-white designs were tested and the dome offset error evaluated by these different methods. The results show that black-and-white instruments produce satisfactory clear-sky diffuse measurements, within 5 Wm^{-2}, without any offset corrections, and that the black detectors with ventilation and optimal corrections applied produce similar diffuse irradiances. Additionally, the effects of detector cosine response errors are also shown to be typically less than 4% (2 Wm^{-2}) for Rayleigh and Modtran rural aerosol cases.

References

Gulbrandsen, A., 1978: On the use of pyranometers in the study of spectral solar radiation and atmospheric aerosols. *J. Appl. Meteoro.*, **17**, 899-904.

Wardle, D. I., and D. V. Barton, 1988: Zero offsets in pyranometer signals related to longwave radiation, temperature change and ventilation and some implications regarding measurement uncertainty. Atmospheric Environmental Services, Canada, Internal Report ARPD 129X52, February 1988, 36 pp.