Prediction and Measurement of Thermal Exchanges within Pyranometers

Amie M. Smith

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Dr. J.R. Mahan, Chair
Dr. Martial P. Haeffelin
Dr. Karen Thole

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(ABSTRACT)

The Eppley Precision Spectral Pyranometer (PSP) is a shortwave radiometer that is widely used in global networks to monitor solar irradiances at the earth's surface. Within the instrument, a blackened surface is in intimate thermal contact with the hot junction of a thermopile. The cold junction of the thermopile communicates thermally with the large thermal capacitance of the instrument body, which acts as a heat sink. Radiation arrives at the blackened surface through one or two hemispherical dome-shaped filters that limit the instrument response to the solar spectrum. The voltage developed by the thermopile is then interpreted in terms of the incident irradiance.

Measurements taken with the pyranometer are compared with results from theoretical models. Discrepancies between model results and measurements are used to isolate inaccuracies in the optical properties of the atmosphere used in the models. As the accuracy of the models increases, the reliability of the measurements must be examined in order to assure that the models keep up with reality. The sources of error in the pyranometer are examined in order to determine the accuracy of the instrument.

Measurements obtained using the pyranometer are known to be influenced by environmental conditions such as ambient temperature, wind, and cloud cover [Bush, et al., 1998]. It is surmised that at least some of the observed environmental variability in these data is due to parasitic thermal exchanges within the instrument [Haeffelin et al., 1999]. Thermal radiation absorbed and emitted by the filters, as well as that reflected and re-reflected among the internal surfaces, influences the net radiation at the detector surface and produces an offset from the signal that would result from the incident shortwave radiation alone. Described is an ongoing effort to model these exchanges and to use experimental results to verify the model.

The ultimate goal of the work described is to provide reliable protocols, based on an appropriate instrument model, for correcting measured shortwave irradiance for a variable thermal radiation environment.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

Symbols:

C	Instrument sensitivity ($V \bullet m^2$ /W)
c_1,c_2,k	Constants for the Albrecht and Cox pyrgeometer offset model
E	External shortwave irradiance of the instrument (W/m^2),
	Desired measurement quantity of the pyranometer
E_L	Corrective measurement offset for Philipona pyrgeometer model (W/m^2)
ΔF	Corrective measurement offset for Bush pyranometer model (W/m^2)
F	Corrected measurement for Albrecht and Cox pyranometer model (W/m^2)
k_1,k_2,k_3	Constants for the Bush pyranometer offset model
S	Seebeck coefficient of thermopile (μV/K)
T	Temperature (K)
U_{emf}	Thermopile signal (V)
$T_d(\phi)$	Temperature gradient represented by T_d (K)

Greek:

α	absorptivity
ε	emissivity
ρ	reflectivity
σ	Stefan-Boltzmann constant
τ	transmissivity

Subscripts:

b	Body, instrument heat sink
d	Dome, location to be determined
s	Sensor, location to be determined
net	Total
dome	Dome, as defined by Bush et al.
detector	Sensor, as defined by Bush et al.
0	Effective sensor properties, as defined by Albrecht and Cox

Superscripts:

L	Longwave, >3.0 μm wavelength
S	Shortwave, <3.0 μm wavelength