Effects of Natural Ventilation and Solar Radiation on the Performance of Pyrgeometers

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30 October 1997 and 18 March 1998

ABSTRACT

In this work the authors present the results of field experiments carried out in Almería (36.83°N, 2.42°W), a seashore location in southeastern Spain, in order to evaluate the performance of Eppley precision infrared radiometer (PIR) pyrgeometers. The authors estimate the systematic errors in the measurements of downward longwave radiation caused by solar heating of the pyrgeometer's dome. Pyrgeometer measurements have been obtained in a series of experiments in which the dome of the pyrgeometer has been, alternately, exposed to the solar beam and shaded by a disk. These measurements have been completed with solar direct irradiance and wind velocity measurements. This study confirms previous assessments about the magnitude of this effect and its possible estimation in terms of global horizontal solar irradiance. Additionally, the authors have quantified the influence of natural ventilation on the solar heating effect. The experiments have confirmed the reduction of the solar heating effect with an increase of natural ventilation rates on the pyrgeometer. Nevertheless, this reduction reaches a limit, indicating that the effect cannot be fully eliminated, as has been already pointed out for mechanically driven ventilated pyrgeometers. A formula for the correction of the solar heating effect considering the wind velocity influence is proposed. It estimates the necessary correction as a function of solar irradiance and wind velocity, thus allowing the suppression of systematic errors, which could represent up to $+47$ W m^{-2} for the worst situation (no wind, high irradiation), and providing experimental measurements that are affected by a random error of about ± 5 W m^{-2}.

1. Introduction

An accurate prediction of the surface radiation budget, consisting of downward and upward fluxes of shortwave and longwave radiation, is important because of its contribution to the energy exchange between the atmosphere and the land surface. Among the surface radiation budget components, the thermal atmospheric radiation, due to instrumental constraints, is the only one that is not measured routinely. The importance of downward atmospheric radiation in meteorological and climatological studies—as well as in certain applications, ranging from agrometeorological studies to the design of radiative cooling systems—has led to the development of different radiometric devices and the analysis of their performance.

One of these specific devices, which is used commonly for the direct measurement of thermal incoming irradiance, is the so-called pyrgeometer. Several companies manufacture the pyrgeometer. In essence, it consists of a thermopile covered by a dome that ideally reflects all irradiance with wavelengths fewer than 4 μm, allowing thermal radiation emission from sources at sky and air temperatures.

In our experiments, we have employed a pyrgeometer model PIR that is manufactured by Eppley Laboratory, Inc. The pyrgeometer uses a silicon dome with a vacuum-deposited interference filter. The overall transmission characteristics of the dome offered by the manufacturer vary from 0 in the shortwave range to 0.5–0.3 in the wavelength range of interest (4–50 μm). Testing the complete transmittance spectra of eight Eppley (silicon) domes, Miskolczi and Guzzi (1993) have demonstrated that there are individual variations that reach 20% between specimens, making the recalibration of the thermopile necessary when the dome is substituted.

In regard to the thermal flux emitted by the sensor surface, the pyrgeometer has a thermistor–battery resistance circuit (in addition to a circuit employed to correct the temperature of the radiometer response) that compensates for the thermal emission of the detector surface. This circuit presents some problems (for details, see Albrecht and Cox 1977). Therefore, Berdahl and Fromberg (1982), Alados-Arboledas et al. (1988), and

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Philipona et al. (1995) have suggested that the temperature at the cold junction of the thermopile should be measured in order to analytically compensate for the thermal flux emitted by the sensor surface.

To account for the other thermal fluxes present at the pyrgeometer—namely, the thermal flux that is emitted by the dome to the sensor surface and the small part of the solar spectrum ($\lambda > 4$ μm) that is included in the longwave region—several authors have proposed different expressions, with physically based parameters, for the entire radiative balance of the pyrgeometer. Alados-Arboledas et al. (1988) have proposed the following expression:

$$L\downarrow = (c_1 + c_2 T_B^3)V + \sigma T_B^4 - [(\alpha_0 + 4\varepsilon_o \varepsilon \sigma T_B^3)/\varepsilon_o \tau](T_D - T_B), \quad (1)$$

where ε_o is the sensor surface longwave emissivity, ε is the silicon dome longwave emissivity, τ is the silicon dome longwave transmissivity, and T_D and T_B are the dome and pyrgeometer body temperatures, respectively. The constants c_1 and c_2 depend on different coefficients involved in the different heat transfer processes that affect the instrument (Alados-Arboledas et al. 1988). The thermal compensating circuit included in the pyrgeometer reproduces this calibration coefficient dependency. The third term takes into account the contribution of the energy budget of the sensor surface caused by the temperature difference between the sensor surface and the dome. The term α_0 represents the contribution associated with the radiative and sensible fluxes. The measurement of T_D is available because, after an earlier assessment of this effect, the manufacturer has upgraded the design of the pyrgeometer to include an additional thermistor to estimate the dome temperature.

There is a solar effect on the pyrgeometer performance that arises mainly from the nonideal spectral response of the dome to incident solar irradiance. The response causes a temperature difference between the dome and the body of the instrument. The temperature difference is minimized by natural or forced ventilation of the dome, approaching T_D and T_B to T_{air}. The shadowing of the dome's external surface, through which solar radiation influence is avoided, can also help to reduce this temperature difference. These two methods, mechanical ventilation and dome shadowing, can be used individually or in combination. The order of magnitude of error removed by these two methods reaches approximately 30%–40% in the worst environmental conditions—that is, clear sky and no wind. The two proposed solutions imply the addition of no foreseen hardware to the pyrgeometer. In the case in which a shading disk is used to make routine measurements, some calibration/repair guidelines will be needed for the normal operation and maintenance of the disk.

In this work we present the results of an in situ evaluation of errors related to the dome heating effect of an Eppley PIR pyrgeometer. We provide some conclusions for practical applications. In addition, we have researched other scientists' findings on the relation of external wind to the dome heating effect of an Eppley PIR pyrgeometer, and thus, this paper is an extension of the work of Alados-Arboledas et al. (1988).

The problem of the dome heating effect by solar radiation and the related temperature difference $T_D - T_B$, can be fully avoided by an accurate calibration. This calibration procedure must include a reference blackbody source and the capability of setting different values of T_D and T_B on the pyrgeometer. Albrecht et al. (1974) proposed the following expression for the sensor energy budget:

$$L\downarrow = V/K + \varepsilon\sigma T_B^4 - k\sigma(T_D^4 - T_B^4). \quad (2)$$

This balance expression differs from that shown in Eq. (1). It includes a generic calibration coefficient, K, to be applied to the voltage output of the instrument and an empirical coefficient, k, to account for the thermal flux provoked by the difference of the temperature between the dome and the pyrgeometer body. The more accepted value for this coefficient is $k = 4$ (Oliveri 1991; Shiobara and Asano 1992; Philipona et al. 1995). Equation (2) has been obtained assuming that the differences between the dome and the base temperature lead only to additional radiative fluxes. Nevertheless, the suggested value for the parameter k, and its explanation in terms of the radiative characteristics of the pyrgeometer's dome (Philipona et al. 1995), is not physically consistent, unless one also considers the contribution of sensible fluxes to this term. Effectively, if $k = 4$ represents the ratio between the dome emissivity, ε, and the transmissivity, τ, as it is proposed, the use of τ in the order of 0.4 (Miskolczi and Guzzi 1993) leads to ε greater than unity. Shiobara and Asano (1992) and Philipona et al. (1995) have also studied the development of sophisticated calibration procedures. Nevertheless, their results are limited because of the lack of representative measurements of the dome temperature. This fact is due to thermistor positioning on the dome and the nonuniformity of the dome temperature distribution when direct solar radiation is present (Foot 1986; Philipona et al. 1995).

Developments in the pyrgeometer-measuring principle proposed by Lorenz et al. (1996) are also very suitable for the elimination of the dome heating effect. However, the complexity of the required hardware increases the cost of the instrument, making it difficult to be an immediate substitute for conventional pyrgeometers.

In general terms, the instrument produces an output contaminated by a process governed by the difference between dome temperature, T_D, and sensor surface temperature, T_B, which is, moreover, determined by the solar radiation and the natural ventilation around the dome. Direct measuring of T_D and T_B with the help of specific calibration can reduce this undesired effect. However, some uncertainties remain because of the lack of representative measurements of T_D, due to the positioning of the temperature sensor and the physical interpretation of calibration factors. Mechanical ventilation and shading of the pyrgeometer also can contribute to the reduction of this undesirable effect. Therefore, any correct measuring of incoming longwave irradiance by Eppley PIR pyrgeometers will require either a supplementary channel in the measuring system or the installation of additional hardware not supplied by the pyrgeometer manufacturer.

However, an alternative method will be proposed in this paper. The method is based on the estimation of a subtractive correction term as a function of accessible meteorological parameters related to the dome heating effect. That is the case of solar irradiance and local wind velocity, which can be immediately introduced in the pyrgeometer output instead of measuring instrumental temperatures.

For the derivation of both methods, two simultaneous values have to be compared. The first one is the directly measured longwave incoming irradiance $L\downarrow_{meas}$ affected by the error we are trying to evaluate. The other is the true longwave irradiance undisturbed by the dome heating effect $L\downarrow_0$. We obtain the latter by shading the dome with a small disk that obscures the direct sun irradiance, minimizing the solar influence in $T_D - T_B$ (apart from the diffuse one). The excess of the pyrgeometer signal provoked by the dome heating $L\downarrow_{meas} - L\downarrow_0$ must be related to the dome–base temperature difference or, alternatively, it must be correlated with solar irradiance or wind velocity, or both, by simple expressions.

There are many expressions (Enz et al. 1975; Albrecht and Cox 1977; Yamanuchi et al. 1981; Alados-Arboledas et al. 1988; Heitor et al. 1991; Culf and Gash 1993) and indirect procedures (Ineichen et al. 1984) that reduce the magnitude of the provoked error. Most of them are based on shading disk experiments, in which the considered variable is solar irradiance. There are, however, some correction procedures with an explicit reference to the effect of wind velocity in the dome heating effect (Halldin and Lindroth 1992; Duchon and Wilk 1994). Halldin and Lindroth (1992) parameterized shortwave interference error for a nonventilated pyrgeometer as a linear function of global solar irradiance. The correction was 7.3% of the total irradiance for calm conditions, decreasing to 2.6% at wind speeds of 2 m s^{-1} and greater. Duchon and Wilk (1994) have proposed a formula including wind velocity after regression on data gathered in an 8-h period. The corrected daytime values were compared also with values obtained by pyrradiometer measurements:

$$L\downarrow_{meas} - L\downarrow_0 = 0.099\ G/(\upsilon + 1)^{1/2}. \qquad (3)$$

After this revision of the literature, we found that different expressions have been proposed for the correction of the solar heating effect on the pyrgeometers. Additionally, we have seen that there is no general agreement with reference to the magnitude of the involved coefficients. In the next sections, we will show our results obtained in a set of field campaigns.

2. Experimental setup

The experiments for field evaluation of the dome heating effect on the pyrgeometer performance were carried out from April to July 1996. The experimental site was the radiometric station at the rooftop of the EPS building of the University of Almería (36.83°N, 2.42°W) in a seashore location. This period was selected because of the coincidence of clear sky and a variety of winds condition.

A shading disk (80 mm in diameter) was used to protect the pyrgeometer dome from direct sun irradiance. The shading disk was mounted on a circular frame, at a 5° angle subtended from the disk. Shading of the pyrgeometer dome was performed in 5-min alternating consecutive intervals. The shaded–unshaded simultaneous measurements were generated by cubic spline interpolation.

Five-minute integrated values of T_D, T_B, external wind velocity, global and diffuse irradiance, and thermopile output were analyzed. The pyrgeometer used was an Eppley PIR pyrgeometer, serial number 27457F3. (The original calibration constant was checked with the reference blackbody.) Global and diffuse (shading band method) horizontal irradiances were measured by two Kipp and Zonen CM-11 pyranometers. Wind velocity values were gathered on a 10-m-high meteorological tower in a station at the Fundación para la Investigación Agraria de la Provincia de Almería (FIAPA) Center, 400 m from the EPS building. Since no large obstacles lay between the meteorological tower and the radiometric station, measured wind speeds are considered representative. The solar diffuse irradiance values have been corrected for shadow band effects using the method proposed by Batlles et al. (1995). By computing the corrected diffuse irradiance values and the corresponding global horizontal irradiances, the direct solar irradiance was obtained.

3. Analysis and discussion

The parameters used in this analysis include the excess of the thermopile signal provoked by the heating of the dome in watts per square meter ($\Delta L\downarrow = L\downarrow_{meas} - L\downarrow_0$) and the temperature difference between the dome and the body, $T_D - T_B$. The latter has been converted into thermal flux by the expression $\sigma(T_D^4 - T_B^4)$. The coincident measurements of solar irradiance allow the study of the relationship between $\Delta L\downarrow$ and the horizontal component of solar direct irradiance, which represents the solar flux excluded by shading the dome with the disk. The analysis of the relations between $\Delta L\downarrow$ and $\sigma(T_D^4 - T_B^4)$ and between $\Delta L\downarrow$ and $(T_D - T_B)$ can be used to obtain the corresponding empirical estimates of

TABLE 1. Statistical results concerning direct measurements of variables influencing the dome heating process.

Variable	Group	Cases	Average	Std dev	Min	Max
$\Delta L\downarrow$ (W m^{-2})	Total	216	21.8	9.3	5.3	47.2
	V1	23	20.6	12.6	5.5	42.5
	V2	35	25.3	10.7	5.3	47.2
	V3	31	23.1	9.6	6.3	41.7
	V4	54	20.0	9.3	6.0	39.3
	V5	27	21.8	7.4	6.8	36.2
	VH	46	21.0	5.7	7.3	32.6
$T_D - T_B$ (°C)	Total	216	0.9	0.3	0.2	1.5
	V1	23	0.8	0.4	0.3	1.4
	V2	35	0.9	0.3	0.4	1.5
	V3	31	0.9	0.4	0.3	1.4
	V4	54	0.8	0.4	0.2	1.5
	V5	27	0.8	0.3	0.2	1.2
	VH	46	0.9	0.2	0.3	1.2
G (W m^{-2})	Total	216	725.6	218.5	217.5	996.2
	V1	23	627.2	205.6	379.7	956.4
	V2	35	727.1	205.5	354.4	996.2
	V3	31	697.3	237.3	239.8	960.3
	V4	51	681.8	255.5	224.3	969.1
	V5	27	797.9	221.2	217.5	959.3
	VH	46	801.7	126.3	560.3	994.3
Dh (W m^{-2})	Total	216	569.6	207.7	144.2	898.5
	V1	23	465.2	235.1	212.3	863.7
	V2	35	587.6	220.4	187.1	898.5
	V3	31	560.8	206.2	165.7	854.4
	V4	54	545.7	227.0	152.6	841.1
	V5	27	656.1	203.3	144.2	836.9
	VH	46	591.2	134.0	377.2	819.1
v (m s^{-1})	Total	216	4.2	2.4	0.7	12.7
	V1	23	1.2	0.2	0.7	1.5
	V2	35	2.0	0.3	1.6	2.5
	V3	31	3.0	0.3	2.6	3.5
	V4	54	4.1	0.3	3.6	4.5
	V5	27	4.9	0.3	4.6	5.5
	VH	46	8.0	1.9	5.6	12.7

the proposed parameters in the energy balance equations of the pyrgeometer [Eqs. (1) and (2)].

Additionally, as one of the objectives is the assessment of natural ventilation influence on the solar heating process, data were grouped into six wind velocity bins from 0.5 to 5.5 m s^{-1} and V1–V5. Occasionally, during the experiments, wind gusts greater than 5.5 m s^{-1} appeared. The corresponding values have been included in a generic group, VH, representing higher wind velocities. Summaries of this study as well as the results for the different wind velocity groups are given in Tables 1 and 2.

The dome–body temperature difference has an average value of 0.8°C, which provokes an average systematic deviation of +22 W m^{-2} in $L\downarrow$. Our analysis shows that the ratios $k = \Delta L\downarrow/\sigma(T_D^4 - T_B^4)$ and $k' = \Delta L\downarrow/(T_D - T_B)$ do not present any dependency on the wind velocity. The obtained mean value for the coefficient k is coherent with previous findings (Albrecht and Cox 1977; Oliveri 1991; Philipona et al. 1995). Concerning the coefficient k', we obtained a mean value that is approximately twice the one suggested by Berdahl and Fromberg (1982). This shows the difficulties associated with the justification of this experimental coefficient in terms of the physical parameters that control the additional energy exchange between the dome and the base (Alados-Arboledas et al. 1988). The deviations can be explained by problems related to the use of a single thermistor to measure the dome temperature. As Philipona et al. (1995) have pointed out, the nonhomogeneous heating of the dome, especially under cloudless conditions, can provoke new uncertainties in the analysis due to the lack of representative measurements of the dome temperature.

However, we have developed an alternative method for estimating the solar heating effect. For this purpose, we use accessible meteorological parameters related to dome heating—that is, solar irradiance and local wind velocity. The $\Delta L\downarrow$ and dome–base temperature differences are positively correlated with the solar irradiance (Fig. 1). We have analyzed the correlation between the increase in the thermal irradiance, $\Delta L\downarrow$, and the solar irradiance using the horizontal component of direct solar radiation, Dh, as the independent variable. The observed variations in $\Delta L\downarrow$ for each irradiance level are to be related to the effect of natural ventilation; that is, for a given irradiance value, the lower the wind velocity, the

TABLE 2. Statistical results of calculated parameters influencing the dome heating process.

Variable	Group	Average	Std dev	Min	Max
$k = \Delta L\downarrow/\sigma(T_D^4 - T_B^4)$ (−)	Total	4.3	1.1	1.9	6.8
	V1	4.3	1.4	1.9	6.8
	V2	4.5	1.2	2.1	6.8
	V3	4.3	0.9	2.8	6.4
	V4	4.3	1.0	2.5	6.5
	V5	4.6	1.1	2.4	6.8
	VH	4.0	0.9	2.9	6.8
$k' = \Delta L\downarrow/(T_D - T_B)$ W m^{-2}/°C	Total	25.7	5.8	11.0	40.7
	V1	26.1	8.1	11.0	39.5
	V2	26.9	6.7	13.2	39.3
	V3	26.1	4.9	16.8	37.3
	V4	25.6	5.2	14.1	38.2
	V5	26.6	5.5	15.0	40.6
	VH	24.1	5.0	17.7	40.7
$c = \Delta L\downarrow/G$ (−)	Total	0.030	0.007	0.013	0.050
	V1	0.030	0.010	0.014	0.047
	V2	0.034	0.008	0.014	0.050
	V3	0.032	0.005	0.024	0.043
	V4	0.029	0.005	0.016	0.041
	V5	0.028	0.006	0.015	0.039
	VH	0.026	0.005	0.013	0.036
$c' = \Delta L\downarrow$Dh (−)	Total	0.038	0.009	0.019	0.091
	V1	0.042	0.009	0.024	0.055
	V2	0.044	0.012	0.025	0.091
	V3	0.041	0.006	0.031	0.051
	V4	0.036	0.006	0.020	0.047
	V5	0.035	0.008	0.019	0.047
	VH	0.036	0.007	0.019	0.049

higher the increase in thermal irradiance, $\Delta L\downarrow$. The best fit of experimental data corresponds to the relation

$$\Delta L\downarrow = (0.0 \pm 0.9) + (0.038 \pm 0.001)\mathrm{Dh}, \quad (4)$$

with a correlation coefficient of 0.861 and an estimation error of 4.7 W m^{-2}. Analyzing the ratios $\Delta L\downarrow$/Dh by wind velocity groups, a decay of the observed values as wind velocity increases is evident (Fig. 2). If the entire range of wind velocities is considered, the dependence can be set in the form of an exponential decay:

$$\Delta L\downarrow = [0.033 + 0.015 \exp(-v/3.2)]\mathrm{Dh}. \quad (5)$$

The mbe (mean bias error) and rmse (root-mean-square error) associated with the proposed expressions are 0.3 and 4.1 W m^{-2}, respectively.

The offset is related to the solar heating effect for calm situations, and the asymptotic behavior is consistent with conclusions by Enz et al. (1975). Enz et al. (1975) remark that the solar heating effect could not be totally reduced by increasing air velocity in mechanically driven pyrgeometer ventilation systems. It is also worth noting that the observed value of the coefficient of the global irradiance for high wind conditions (group VH) is quite similar to that recommended for constant correction in ventilated pyrgeometers (Dehne et al. 1993). Dehne et al. (1993) use previous conclusions obtained by Wardle and McArthur (1987).

Nevertheless, it is interesting to note that the correct procedure is to initially correlate $\Delta L\downarrow$ with the horizontal component of direct solar irradiance and wind velocity. Since, during the shading experiences, the differences in the pyrgeometer output correspond only to the existing contribution when the solar direct radiation is excluded, the final expression should account for the diffuse irradiance. This is possible since the solar heating effect due to the solar diffuse irradiance follows the same relationship as that obtained for the solar direct component (Enz et al. 1975). Therefore, it can be proposed that Eq. (5) should be used for the entire solar flux impinging on the dome, estimated in terms of the solar global horizontal irradiance, G.

For wind velocities in the range of 2–5 m s^{-1}, we observed a decay in the heating effect by 1.6 W m^{-2} per m s^{-1}, caused by the natural ventilation of the pyrgeometer dome, for solar irradiance values of approximately 500 W m^{-2}. This result is close to the findings of Heitor et al. (1991).

In comparison with previous results, including the influence of wind speed, we can see that the approaches based on global irradiance are coincident for high wind velocities, though minor differences exist in the remaining asymptotic behavior. Greater differences appear, however, for calm situations. The expressions of Duchon and Wilk (1994) and Halldin and Lindroth (1992) produce higher correction terms—99 and 76 W m^{-2}, respectively—than those encountered in this study—48 W m^{-2}—for a global irradiance level of 1000 W m^{-2}. These differences in the lower range of wind velocity could be the result of differences in

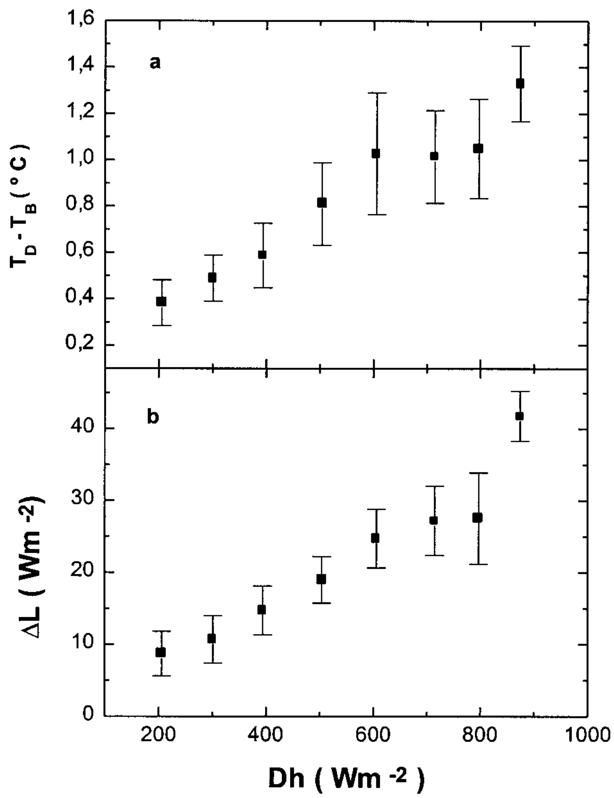

FIG. 1. Pyrgeometer solar heating effect as a function of the direct solar irradiance projected onto the horizontal, Dh. (a) Temperature difference between the pyrgeometer's dome and base, $T_D - T_B$. (b) Difference between shaded and unshaded simultaneous pyrgeometer outputs, $\Delta L\downarrow = L\downarrow_{meas} - L\downarrow_0$. The points correspond to mean values evaluated for direct solar irradiance classes that are 100 W m^{-2} in width. The error bar size corresponds to one standard deviation.

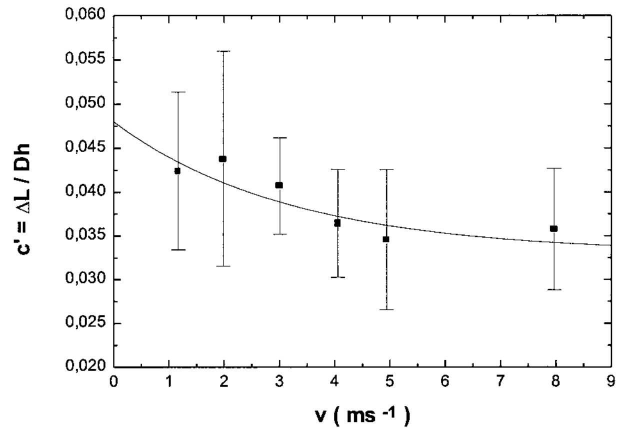

FIG. 2. Dependence of $c' = \Delta L\downarrow$/Dh on the wind velocity.

the experimental procedure and particularities of the devices (Miskolczi and Guzzi 1993). Furthermore, under low wind speed, the solar heating of the dome reaches its higher values, and any fluctuation of wind velocity could be responsible for the marked changes in this effect. High wind velocities around the dome mask these influences, making all the approaches coincident in this region. Averaging for all wind intervals also reduces this variability, although a loss of information occurs.

Concerning simple expressions containing only solar irradiance dependence, the expression of Alados-Arboledas et al. (1988) is consistent with the model on solar irradiance and wind velocity proposed here. This is interesting, considering that Alados-Arboledas et al. (1988) used instantaneous measurements acquired in a different location with an earlier version of the pyrgeometer that did not measure dome temperature. However, Alados-Arboledas et al. calculated wind measurements at instrument level, although the shading procedure they used is similar to the one we used in this study.

4. Conclusions

We have analyzed a series of field experiments carried out in order to estimate the systematic errors in the measurements of downward longwave radiation by an Eppley PIR pyrgeometer, caused by solar heating of the pyrgeomter's dome. Shaded–unshaded pyrgeometer measurements have been obtained in combination with solar direct irradiance and wind velocity values.

The excess in pyrgeometer output can be estimated from the measurements of dome–base temperature differences. We have obtained experimental estimates of the coefficients necessary for this computation. In this way, we can approach the correction of the solar heating effect. Nevertheless, the nonhomogeneous heating of the dome, especially under cloudless conditions, can provoke certain uncertainties in this computation due to the lack of representative measurements of the dome temperature.

The results of field experiments demonstrate the reduction of solar influence in dome heating effect caused by an increase in natural ventilation rates on the Eppley PIR pyrgeometer. We found that with solar irradiance values of about 500 W m^{-2} there is decay in the heating effect of 1.6 W m^{-2} per m s^{-1}. This is a direct result of the natural ventilation of the pyrgeometer dome. A correction term for stations with nonventilated pyrgeometers is proposed as a function of solar irradiance and wind velocity. The existence of an asymptotic solar effect for high wind velocities has also been verified. The developed model allows for the suppression of systematic errors, which could represent up to 40 W m^{-2} for the worst situation (no wind, high irradiation), and provides experimental measurements affected by a random error of about $\pm$5 W m^{-2}.

It must be pointed out that any expression of the correction term obtained by shading experiments should include an additional influence of diffuse irradiance. This influence could be estimated by the use of solar global irradiance instead of solar horizontal direct irradiance. In that case, it is assumed that an equal amount of diffuse and direct solar irradiance incident on the dome has nearly the same effect on pyrgeometer output.

The results obtained in this study are coherent with the simple correction method proposed by Alados-Arboledas et al. (1988), which is based only on solar irradiance.

Acknowledgments. This work was supported by La Dirección General de Ciencia y Tecnología from the Education and Research Spanish Ministry through Project No. CLI95-1840. The wind velocity data have been kindly supplied by FIAPA Center. The authors are indebted to the anonymous referees, who read the manuscript and made several valuable suggestions.

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