Name of research institute or organization:

MeteoSwiss, Payerne

Title of project:

Global Atmosphere Watch Radiation Measurements

Project leader and team:

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Project description:

In the framework of establishing long-term series of radiation measurements, MeteoSwiss continued its operation at the Jungfraujoch as part of the Swiss Atmospheric Radiation Monitoring program (CHARM). The program includes short-wave (solar spectrum) and long-wave (Earth and atmosphere spectrum) broadband measurements as well as UV broadband measurements. Short- and long-wave measurement series are important for climate research, while UV measurements are of interest for both public health and exploring the relationship between the evolution of the ozone layer and radiation. Broadband radiation is measured both as global downward hemispheric irradiance and as direct sun irradiance. In addition, direct spectral irradiance is also measured, which allows the total column of several atmospheric constituents to be determined. The list of parameters measured at the Jungfraujoch as part of the CHARM program is summarized in Table 1.

Table 1: Parameters measured at the Jungfraujoch as part of the CHARM program.

Parameter	Instrument	Since	Remarks
Downward global visible irradiance at 2 meters above ground	Pyranometer CM21 (K&Z)	07/1996	Redundant measurement available
Downward infrared irradiance at 2 meters above ground	Pyrgeometer PIR (Eppley) upgraded by WRCD	07/1996	Redundant measurement available
Direct irradiance	Pyrheliometer CH1 (K&Z)	07/1996	“On-line” calibration by absolute radiometer PMO6
Pressure, Temperature, Humidity	Thygan	07/1996	Redundant measurement available by Rotronic
2-D Wind	SIAP	07/1996	Redundant measurement available by Rosemount
Sun duration	Heanni	07/1996	
Downward global UVA irradiance at 2 meters above ground	Solar Light Biometer 512A	07/1996	
Downward global UVB irradiance at 2 meters above ground	Solar Light Biometer 512A	07/1996	Redundant measurement available
Direct UVB irradiance at 2 meters above ground	Solar Light Biometer 512A	07/1996	

Direct spectral measurements	Precision Filter Radiometer WRCD	03/1999	368, 412, 500, 862 nm
Direct spectral measurements	Precision Filter Radiometer WRCD	03/1999	778, 817, 946, 1024 nm
Direct spectral measurements	Precision Filter Radiometer WRCD	03/1999	450, 610, 675, 719 nm
Direct spectral measurements	Precision Filter Radiometer WRCD	04/2000	305, 311, 318, 332 nm

The CHARM measurement activities at the Jungfraujoch are completely automated. Thanks to a rugged apparatus design developed in part by MeteoSwiss and careful maintenance and operation, data availability in 2002 reached 93% for direct solar irradiance measurements and 98% for other measurements.

Since MeteoSwiss aims at establishing long-term time series of radiation parameters, special care has to be devoted to instrumental stability in order to avoid drift that could be misinterpreted as a trend. In 2002, spectral direct irradiance measurements from the Precision Filter Radiometers (PFR) were analyzed to check for stability. These PFR were developed at the World Radiation Center Davos (WRCD), and four such radiometers, each equipped with four channels at different wavelengths (see Table 1) are being operated by MeteoSwiss at the Jungfraujoch. In total, spectral direct irradiance is measured at 16 wavelengths from λ = 305 to 1024 nm. An important advantage of such spectro-photometers is the ability to conduct in situ calibrations using the Langley plot method, which avoids the time-consuming use of laboratory-based methods and the ensuing loss of measurement data.

The Langley plot method is based on the relationship between the direct solar intensity and the slant path through the atmosphere. When conditions are favorable (the atmosphere remains stable), the signal measured can be expressed as a function of the amount of atmosphere traversed (air mass) and be extrapolated to the signal V_0 that would be measured for zero air mass. This extrapolated signal can be compared to the known extra-terrestrial solar irradiance, providing a point of calibration (for example, see Schmid and Wehrli, 1995 and Schmid et al., 1998).

Six of the 16 PFR wavelengths cannot be analyzed with this so-called simple Langley method because of the influence of either ozone or water vapor, and need more refined analysis. Analysis of the data at the remaining 10 wavelengths is presented below. An algorithm based on the work of Harrison and Michalsky (1994) was used to select data points that can be used for Langley analysis from the dataset measured at the Jungfraujoch from March 1999 or April 2000 (see Table 1) to the present. The selected data were grouped in morning or afternoon subsets for each day, and the half-day subsets were used to determine the extrapolated V_0 values. Figure 1 shows the V_0 time series at four selected wavelengths. Since the extra-terrestrial irradiance is relatively stable after correction for the annual variation in Earth-Sun distance, the V_0 time series can be used to check PFR stability.

Two of the 10 analyzed channels exhibited clear trends and are shown in Figure 1a and 1c (λ = 332 and 778 nm, respectively). Note that the discontinuity in Figure 1a was due to an instrument replacement on 9 April 2002. The other eight channels gave results similar to those in Figure 1b and 1d (500 and 862 nm), with no obvious trend. The trend at λ = 332 nm has already been observed in other PFR instruments equipped with the same filter (Wehrli, 2002), and is probably due to filter degradation, as is the trend at λ = 778 nm. In order to test more rigorously for trends and scatter, a linear regression was performed at each wavelength (black line in Figure 1). However, data from the second half of 2002 in Fig. 1b-d appear to be consistently low due to presently unknown reasons. Hence, the fit was computed solely on data before 1 June 2002, except for 332 nm, where two fits were computed (before and after 9 April 2002).

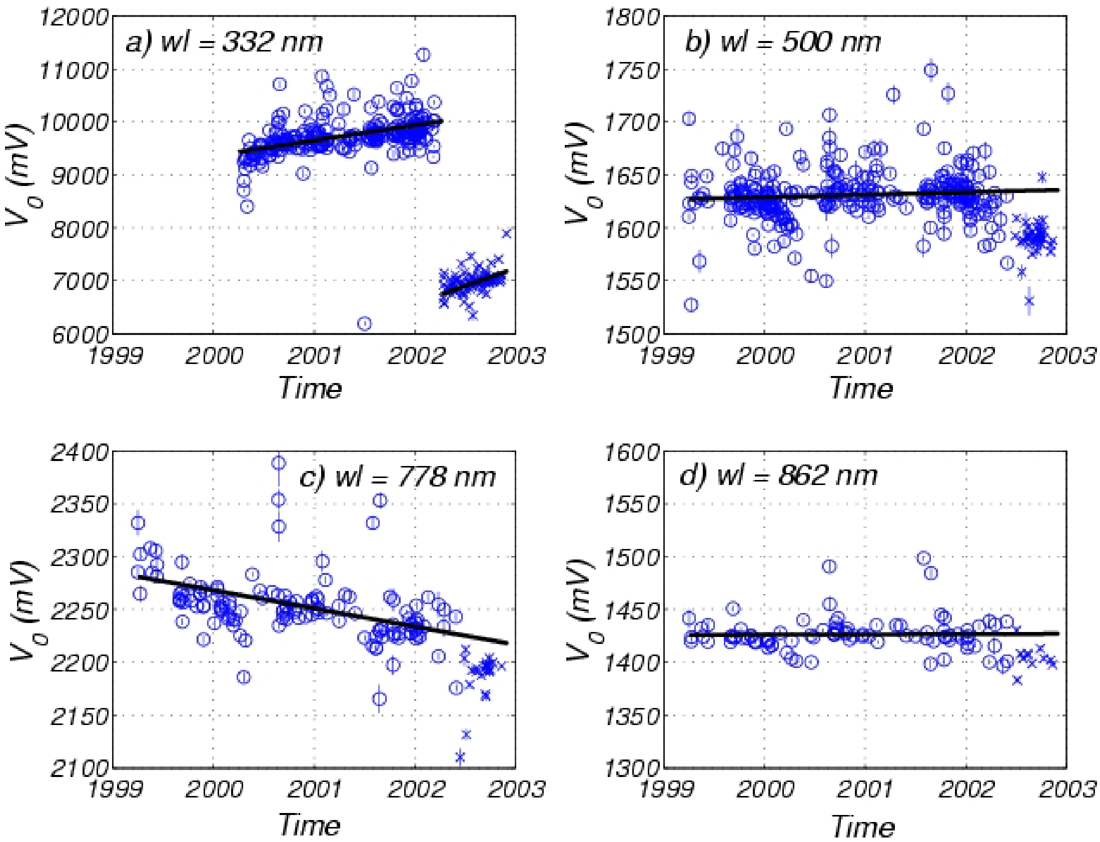

Figure 1: V_0 signal extrapolation to top-of-atmosphere from PFR measuring spectral direct irradiance at four wavelengths. Fig. 1a) Open circles represent data before an instrument change on 9 April 2002 and crosses represent data thereafter. Fig 1b-d) Open circles represent data before 1 June 2002, and crosses represent data thereafter (see text). Bars indicate the error in V_0 extrapolation. Black lines represent linear regression fits.

According to linear regression, the instrumental drift at the 332 nm channel was 585 mV between 01/04/2000 and 08/04/2002 at an average value of 9724 mV, and was 436 mV between 10/04/2000 and 30/11/2002 at an average value of 6958 mV. Such drift is important and needs to be compensated for, which is possible with the Langley plot method. At 778 nm, the drift is 54 mV between 01/04/1999 and 01/06/2002 at an average value of 2254 mV. This represents less than one percent per year; however, compensating this drift still allows a significant reduction of uncertainty. At other wavelengths, e.g. Figure 1b and 1d, the drifts are negligible (~ 0.1 % per year or less).

Significant scatter is visible in Figure 1, and mainly depends on atmospheric stability during the half-days selected for Langley plot analysis. The main condition for allowing Langley plot analysis to succeed is that the atmosphere should be stable during the length of time considered. The Harrison and Michalsky (1994) selection algorithm is tuned to select half-day subsets fulfilling this condition. The more stable the atmosphere is during a half-day, the more precise the corresponding V_0 extrapolation will be. In Figure 1, most outliers exhibit error bound estimates (from the Langley analysis) that are larger than error bounds for other V_0 values. It is an indication that most outliers result from Langley analysis less successful than average. Further analysis will be conducted to explore whether the selection criteria from the Harrison and Michalsky algorithm can be further tuned so that such subsets are rejected.

In order to estimate the uncertainty in the Langley plot analysis, the residuals between the V_0 values and the linear regression were computed. Figure 2 shows the cumulative distribution of the residuals on a normal probability plot for the 500 nm channel. The residuals are compatible with a normal distribution between approximately the 20th and the 80th percentile (they follow a straight line on a normal probability plot). It is seen that the residual distribution departs from the normal distribution beyond the above limits, and is due to outliers. Most probably, these outliers are due to selection of half-days that are not suitable for Langley plot analysis, and lead to erroneous V_0 values. In any case, 80% of the residuals (from the 10th to the 90th percentile) are within ±25 mV from zero. Given that the average V_0 at 500 nm is 1631 mV, this represents a ±1% scatter. This is representative of the dispersion of the residual distribution, but the linear regression fit value, which is the result of an averaging process, is much more accurate, depending on the number of V_0 values considered for the fit.

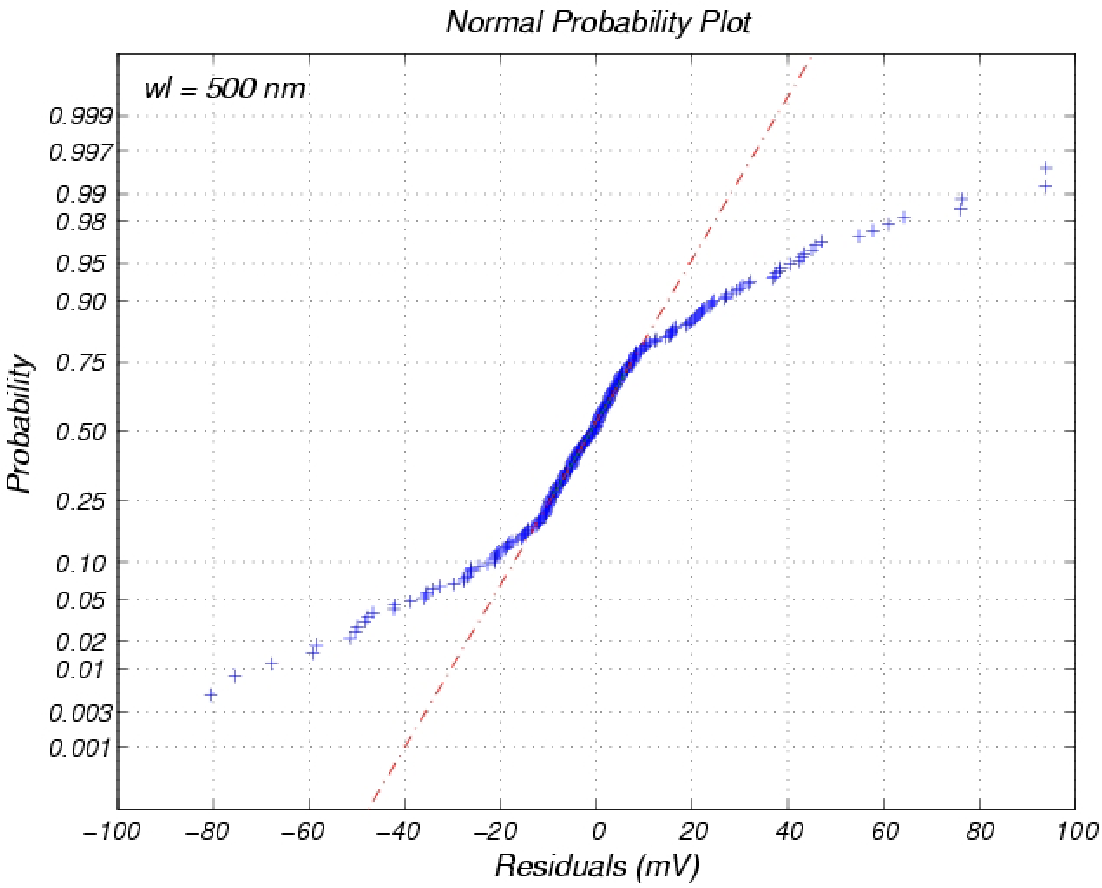

Figure 2: Cumulative probability distribution of residuals for channels at 500 nm.

The analysis applied to 10 wavelengths showed that the CHARM PFR at the Jungfraujoch exhibited good stability for the majority of channels. In two cases where drift was present, corrections using Langley calibration can be conducted. The fact that a subset of V_0 values from the second half of 2002 seems to be consistently lower than the rest of the values at many wavelengths remains to be explained. During the next year, such analysis will be continued and improved. First, we will check whether such lower values continue to be seen. Second, refinements will be introduced that can decrease the uncertainty of Langley analysis (reducing the scatter of V_0 values) and allow consideration of wavelengths influenced by ozone or water vapor.

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Key words:

Solar irradiance, ultraviolet, visible, infrared, spectral irradiance, precision filter radiometer (PFR), pyranometer, pyrheliometer, UV biometer, total aerosol optical depth (AOD), total column water vapor (CWV), total ozone column.

Internet data bases:

Collaborating partners/networks:

Data responsibility of the Word Radiation Center/Physikalisch-Meteorologisches shared with the Alpine Surface Radiation Budget network under the Observatorium Davos.

Scientific publications and public outreach 2002:

Philipona, R., C. Wehrli, A. Heimo, and L. Vuilleumier, Radiation Measurements and Climate Change in the Alps, Proc. Workshop on 'Atmospheric Research at the Jungfraujoch and in the Alps', Davos, Switzerland, 20 September 2002, Swiss Academy of Sciences SAS, 54-55, 2002.

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