South Pole Solar Radiation Data

Introduction

The FMQ-19 surface observing system was installed at the South Pole in January of 2004. A solar radiometer was procured as part of the observing system and was installed on the 3-meter tower in the Clean Air Sector. This is the same tower that holds the two temperature/relative humidity sensors and the FDCU enclosure. It is located about two meters from the 10-meter tower that holds the wind monitor. This document consists first of a summary of the instrument and what it measures, then a discussion of a preliminary analysis of a year's worth of radiation data.

Instrument

The radiometer that is part of the FMQ-19 observing system is an LI-200SZ Pyranometer manufactured by LI-COR, Inc. It is designed for field measurement of global solar radiation. The LI-200SZ is a WMO class two pyranometer that compares very well with class one thermopile pyranometers in clear, unobstructed daylight conditions.

Global solar radiation is defined as the solar irradiance received on a horizontal surface from the combination of direct solar radiation and diffuse solar radiation (scattered and reflected from the sky). Irradiance is the radiant flux incident on a receiving surface from all directions per unit surface area, and is expressed in units of watts per square meter (W/m^2). Pyranometers are also sometimes described as "short wave" radiometers, as they measure the short wave radiation from the sun and not the long wave (infrared) atmospheric and terrestrial radiation. Pyranometer readings relate to the intensity of sunshine received in a particular location and thus represent only part of the overall radiation balance picture.

The LI-200SZ is factory calibrated against an Eppley Precision Spectral Pyranometer under natural daylight conditions, with a typical error in these conditions of +/- 5%. The stability error is +/- 2% per year and recalibration is recommended every two years. There is a small temperature coefficient error of up to 0.15% per °C. The sensor is cosine-corrected, meaning that the error related to beams coming from different angles is minimized: for the worst-case scenario of totally diffuse radiation the cosine error is approximately 2.5%.

A current resistor that goes with the LI-200SZ is mounted on the FDCU interface board. The sensor has a calibration coefficient of 66992.7 that is programmed into the Zeno datalogger as a negative number (-66992.7).

The instrument is essentially maintenance-free. If it gets covered with snow or frost then the readings will not be accurate, but the small surface area of the sensor and nearly constant winds of the South Pole tend to keep this from being an issue.

Available Data

The LI-200SZ was first installed on January 19, 2004. It was taken down and stored for the winter from March 10th through October 25th, 2004, after which it has been left installed continuously. The sensor is polled once per minute and an irradiance reading in W/m^2 is recorded by the FMQ-19 database.

Monthly files of all one-minute data from the Clean Air Met tower are produced as part of the department's month-end process. These files are available from February 2004 onward. These files are currently the only place where the solar radiation data gets saved.

Data Analysis

This discussion refers to the Excel file called "2005 Solar Data and Graphs." A year's worth of irradiance values were imported into Excel and reduced to hourly averages. The year 2005 was used, except that due to a large amount of missing data in the December 2005 file, values from December 2006 were used instead. This should not change the qualitative results.

Annual Global Solar Radiation

The Excel file has six tabs, three containing datasets and three containing graphs. The tab on the far right contains hourly data for the whole year. The corresponding graph is on the tab labeled "Annual Solar Graph." As expected, the irradiance data for one year at the South Pole looks quite similar to how a plot of one day's worth of data from a mid-latitude location would appear. The highest values, a bit over 450 W/m^2, occur in the weeks around the summer solstice. Daily and hourly variations due to changing cloud cover are apparent, but overall the solar radiation values decrease steadily as the sun lowers in the sky during January, February, and March. The instrument reads values of 1 W/m^2 for about a week after sunset and a week before sunrise; otherwise the value is zero for the six-month-long polar night.

Solar Radiation and Cloud Cover

The tab labeled "Solar vs. Cloud Graph" demonstrates how the solar radiation data varies with cloud cover. Since the solar insolation changes only a minute amount in a day's time at the Pole, changes in measured irradiance on this timescale must correspond to changes in cloud cover and/or other atmospheric obscurations. For this example plot, a four-day period with variable cloud cover was chosen and the solar radiation was graphed along with the hourly observations of sky cover in oktas (8ths). As expected, an inverse relationship is evident, with the radiation values lowest as the cloud cover is at its maximum and vice-versa. It is worth noting however, that during a period of constant overcast on the 10th of January the solar radiation values still showed considerable variation. This alludes to one of the possible uses of this instrument: to quantify the degree of opacity of cloud cover. The pyranometer offers more information than the department's Campbell-Stokes sunshine recorder that is used to determine hours of sunshine per day. In evaluating the Campbell-Stokes cards the observer must determine a simple "yes" or "no" for sunshine in each time interval. Due to the frequent occurrence of thin clouds at the Pole, a day with 100% sunshine can have considerable cloud cover. It is expected that the pyranometer can distinguish these thin clouds from a truly clear sky and that its readings could be used to say something about the opacity of clouds over the station. Note that this potential use only applies to the months when the sun is up.

An Interference Issue

The final graph, on the tab labeled "Clear Sky Graph," illustrates a sensor placement issue that was not known of prior to this analysis. Three consecutive days of essentially clear skies (zero or 1 okta sky cover every hour) were selected for this example and the hourly-averaged solar radiation was plotted. The resulting line is not as straight as should be expected! In particular there is a very conspicuous dip in the values each day at 06Z. The hours immediately before and after the dips exhibit daily peak values of about 460 W/m^2. It is assumed that these variations are primarily due to interference caused by the proximity of the 10-meter tower: at 06Z part of the sunbeam is blocked by the tower, causing the dip in measured irradiance. The maxima on either side of 06Z are possibly due to reflected or diffracted sunlight off the 10-meter tower that is directed toward the pyranometer. However, it is also noted that the maxima appear to be at the top of a diurnal sinusoidal curve. This curve is most likely the effect of the sensor being slightly out of level. A more recent data sample from January 2007 revealed the same pattern. These variations indicate that if this data is to be used for analysis on the timescale of hours then some corrective smoothing will need to be applied. Ideally, the sensor will be re-positioned at some point so that there is no longer an interference problem.

Conclusion

The LI-200SZ pyranometer gives fairly accurate readings of global solar radiation, with an irradiance value in W/m^2 recorded every minute. The data is archived along with other one-minute data from the Clean Air tower in monthly text files. Possible applications of this information include long-term monitoring of solar radiation at the South Pole and determination of cloud thickness or opacity. This instrument measures only a portion of the surface radiation budget; it does not measure reflected solar radiation or any long wave (infrared) radiation. **Note:** NOAA maintains a complete suite of radiometers at the Atmospheric Research Observatory, including pyranometers, pyrheliometers, and pyrgeometers. Any researcher interested in radiation balance calculations for the South Pole should refer to their datasets.

Users of data from this instrument should be aware of an interference issue that causes spurious readings at around 06Z each day. If practicable, the sensor should be re-positioned so that it is sufficiently far from any obstructions that could cause interference. The sensor should also be periodically re-leveled.