Aerobot-based Measurements of the Profile of Downwelling Shortwave Irradiance

D. Hagan, J.-F. Blavier, and D. Crisp
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

L. Di Girolamo
University of Chicago
Chicago, Illinois

T. P. Ackerman
The Pennsylvania State University
College Park, Pennsylvania

Summary

Using a helium plus reversible fluid balloon system as the observing platform, multiple profiles of shortwave irradiance between 4 km and 10 km were recently obtained over the Los Angeles basin. Measurements of downwelling hemispheric broadband irradiance were made over a period of 6 hours in conditions that could be characterized by a mid-latitude, summer model atmosphere. These data are described and compared to model computations using a spectrum-resolving, plane-parallel, multiple-scattering model. The systematic difference between model and observations (10%) at high altitudes is discussed in terms of possible factors that affect the instrument measurement response under cold temperature conditions. The measurements and calculations of downwelling irradiance agree to better than 5% in the lower troposphere.

Observations and Results

On September 29, 1996, an aerobot carrying an up-looking Eppley pyranometer and radiometer orientation sensors was released at the Jet Propulsion Laboratory (JPL) in Pasadena, California. The Eppley instrument was mounted on a styrofoam plate, attached to the top of the helium balloon. The pyranometer measures global solar radiation, which includes the direct beam of incoming sunlight and the diffuse component due to scattering. Attitude sensors, which included a flux gate compass and dual-axis clinometer, were placed near the pyranometer. The pyranometer measurements and attitude information were transmitted by radio frequency to ground-based receivers using a commercial radiosonde as the data link. The radiosonde also made measurements of atmospheric pressure, temperature and relative humidity.

The aerobot was launched from JPL around 9:30 a.m. local time, and performed three full cycles between 4 km and 10 km over a horizontal distance of about 200 km. Two of the cycles were completed during daylight hours. The stability of the platform can be characterized by the platform orientation information. The mean tilt of the platform remained near 2° for the duration of the flight. The platform rotated equally in both directions at a typical azimuthal rate of about $5° s^{-1}$. The variation in the irradiance due to larger, instantaneous tilt changes could be significantly reduced using the platform orientation measurements in a geometrical correction procedure. The geometrical correction accounts primarily for changes in the irradiance resulting from platform tilt relative to the direction of the sun.

The observations have been compared to model calculations using a spectrum-resolving, plane-parallel, multiple-scattering model and best guesses for the gas and aerosol contributions, and found to agree to within 5% over much of the lower altitude range (Figure 1). The best agreement occurs where the diffuse or scattered component of the total irradiance is the largest. The larger systematic differences at high altitudes could be attributed to known pyranometer measurement errors along with cooling of the instrument hemispheric dome.

Significance of the Results

To our knowledge, this is the first time that the same instrument and observing platform have been used to obtain

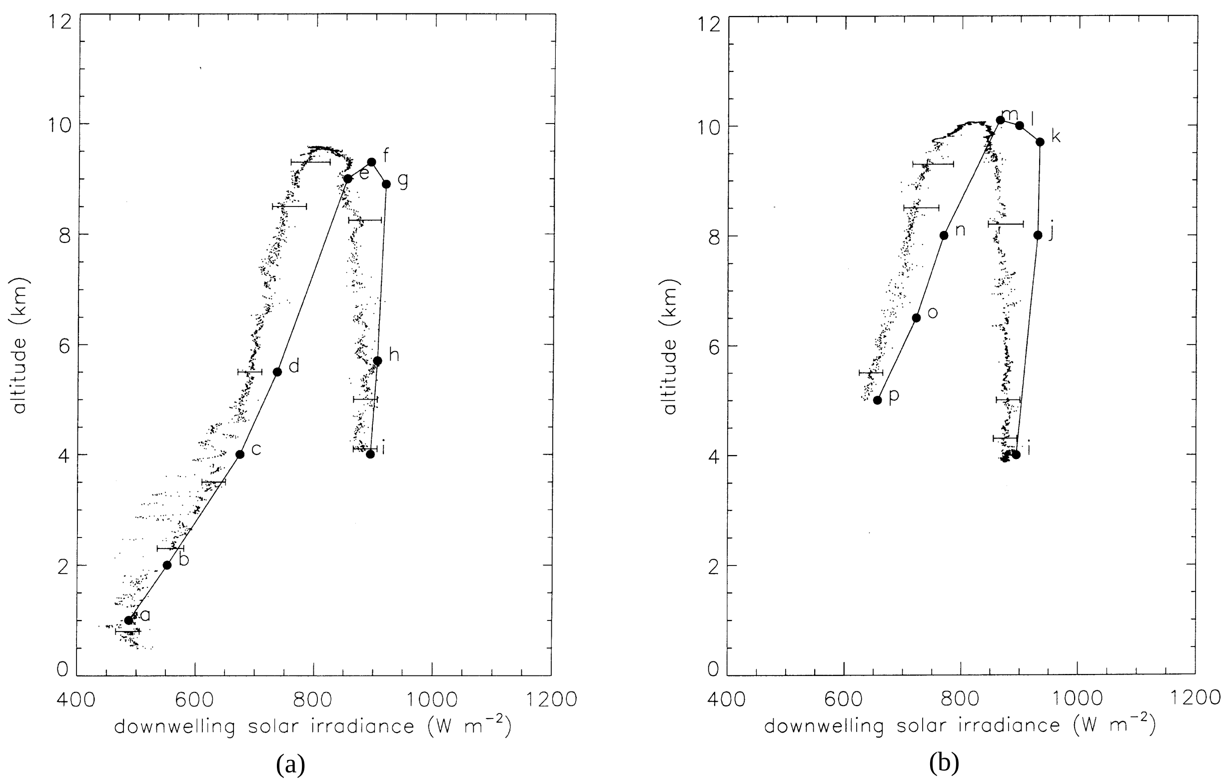

Figure 1. Irradiance profiles obtained during the aerobot test flight on September 29, 1996. The measurements are compared to modeled values, for the (a) morning and (b) afternoon ascent-descent cycles of the aerobot. The model was evaluated at the points, labeled by letters a through p. Point *a* corresponds to a measurement time at 9:30 a.m., and point *p* corresponds to a measurement time at 3:00 p.m., local time. The bars show the percentage of known instrument uncertainty, not including effects of temperature inhomogeneity (from Hagan et al. 1998).

precise, multiple, tropospheric profiles of downwelling solar irradiance by method of continuous vertical profiling. This is an especially relevant problem in light of many recent papers that provide evidence for anomalies in the absorption of cloudy and clear-sky shortwave radiation. The discrepancy between models and observations, which varies from 5% to 30%, is often attributed to errors in measuring and modeling the diffuse component of the incoming shortwave radiation. However, our results do not suggest a significant error in the modeling of clear-sky solar radiance (at least within the instrument measurement error).

Recently, intensive experiments have been undertaken to measure the variables needed to compute the vertical profile of shortwave fluxes (Wielicki et al. 1995; Charlock et al. 1996). One remaining challenge is to obtain high quality in situ measurements of the vertical fluxes to validate the radiative transfer models. This was demonstrated in the aerobot test flight. The results show that downwelling shortwave irradiance in cloud-free conditions can be measured and calculated to within 5% in the lower region of the troposphere. Clearly, however, the accuracy of the measurements can be improved in future profiling experiments. These needed improvements in instrument measurement technique are described in Hagan et al. (1998).

References

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