Measurements of Downwelling Infrared Irradiance

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1 Background

Nocturnal minimum temperatures have increased three times faster than daytime maximum temperatures, an effect observed worldwide. The difference between day and night temperature ranges has notably decreased over the past sixty years but the cause for the trend is unknown. A possible explanation is an increase in nocturnal downwelling (infrared) radiation due to nocturnal trapping of aerosols and condensational growth in aerosols in the boundary layer. The specific study of downwelling radiation and its effect on hygroscopic aerosol growth and overall increase in nocturnal temperatures is a topic that is not well understood in the scientific field. Exploratory boundary layer models applied to nocturnal conditions have shown the growth in hygroscopic aerosols and trapped aerosol emissions can increase downwelling radiation by 13-20 watts per meter squared. An increase of 10 watts per meter squared is considered significant, and anything more than this should be given special attention.

2 Components

2.1 Atmospheric Observations

2.1.1 Downwelling Longwave Radiation

In order to understand downwelling longwave radiation effects on hygroscopic aerosols, two upward-looking pyrgeometers are being used to make a direct measurement of downwelling longwave radiation. The measurements will be used to accomplish two main objectives: (1) to detect, isolate, and quantify the nocturnal warming signal at the earth surface; and simultaneously (2) to quantify the contribution of aerosol trapping and aerosol hygroscopic growth to that climatic signal. The radiative measurements will also be used for verification into the exploratory models.

2.1.2 Aerosol Backscatter

Aerosol backscatter measurements will be obtained with a ceilometer and will be used to evaluate diurnal changes in aerosol characteristics. A ceilometer, located in the same area as the pyrgeometers, will provide the aerosol backscatter measurements. The measurements can be used to compare diurnal changes in aerosol characteristics to diurnal changes in downwelling longwave radiation.

3 Previous Work

Previous work for the DEPSCOR project entailed developing a detailed project plan after acquiring one CR232X datalogger and two CG4 pyrgeometers. This plan included two phases: intercalibration and experiment.

During the intercalibration phase, the two CG4 units would operate side by side for an extended period of time, viewing the sky over a wide range of air temperatures, sky temperatures, cloud cover, and solar irradiance. Detailed analyses would be performed on the temporal and statistical trends in the case temperature offsets, net IR irradiance offsets, and downwelling IR irradiance offsets. The intercalibration phase was designed to accomplish several interrelated objectives:

- Diagnosing the sources and quantifying the statistics of measurement errors;
- Isolating measurement errors from scene irradiance changes;
- Correcting for instrument-induced offsets; and, if possible,
- Reducing absolute irradiance errors.

During the experiment phase, the two pyrgeometers would operate in any of several modes: separated horizontally, separated vertically, or separated in viewing direction (one looking upward, the other looking downward). The raw data from these experiments would be processed using the intercalibration results, to provide high-quality data sets for comparisons of measured and modeled infrared irradiance.

4 Progress

4.1 Instrumentation

4.1.1 Pyrgeometer

4.1.1.1 Implementation

Two Kipp and Zonen CG4 pyrgeometers were integrated with the datalogger system and installed on a roof tower specifically designed for the DEPSCOR instrumentation. A 12-foot tower was designed and implemented on the laboratory roof (Figure 1) as a temporary location for the two ventilated CG4 pyrgeometers. The tower provides secure quarters for the instrumentation and creates an unobstructed view of the sky and horizon. The CG4 pyrgeometers (Figure 2) were installed in March 2007, and began providing routine data in early April. The datalogger is currently programmed to run one second data for the pyrgeometers.

Figure 1 Roof tower with pyrgeometers and relative humidity sensor installed.

Figure 2 Kipp and Zonen CG4 pyrgeometer installed on roof tower.

4.1.1.2 Calibration

Calibration programs were developed in Mathcad in order to quantify measurement errors and to derive an absolute downwelling longwave radiation measurement. The pyrgeometer sensors are currently undergoing an intercallibration period (Figure 3), expected to last until August 2007, comparing air temperatures, sky conditions, and sky temperatures. The relative offsets between the two sensors (Figure 4) rarely exceed 1-2 watt/m^2 with the largest errors occurring on clear, hot days and/or rapid changes in air or sky temperatures. These offsets are expected to significantly reduce after corrections in the calculations are made for temperature dependence and non-linearity in the thermopile response. The current noise levels in the pyrgeometer one second data are about 0.1 watt/m^2 at night and about 0.2-0.5 watt/m^2 in sunlight but will become negligible after averaging to the one minute BSRN standard.

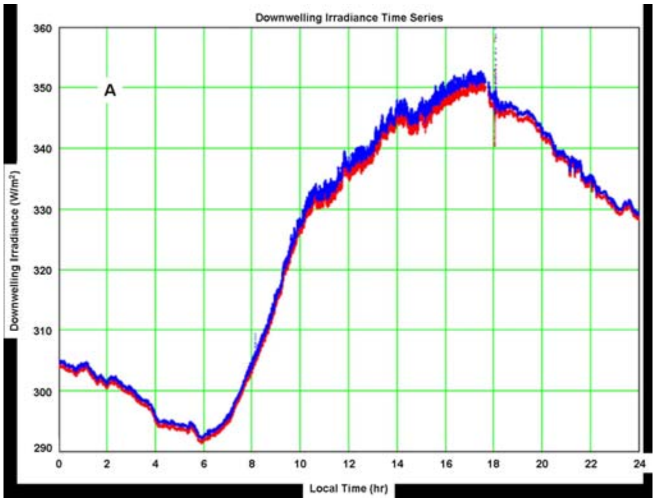

Figure 3 Time series of downwelling infrared irradiance for May 21, 2007. A clear sky was present from midnight-midnight local time.

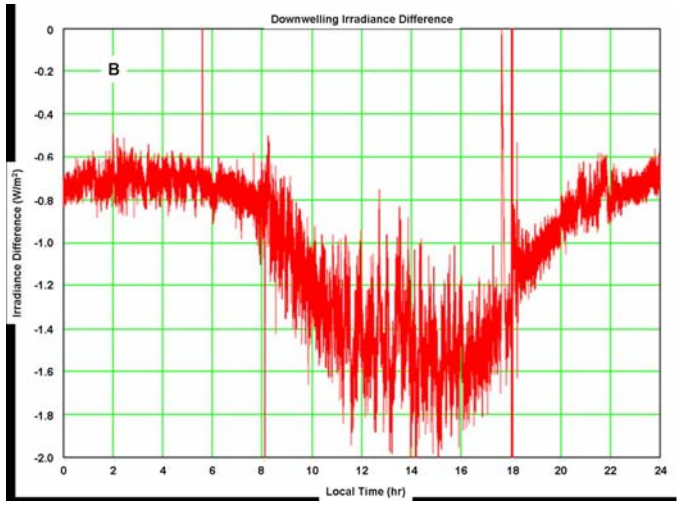

Figure 4 Time series difference in downwelling infrared irradiance for two collocated pyrgeometers for the same conditions as in Figure 3.

4.1.2 Temperature and Humidity Sensor

4.1.2.1 Implementation

A Vaisala HMP45C temperature and relative humidity probe (Figure 5) was acquired and integrated with the datalogger system on the roof tower. The probe was ordered and received in February 2007 and installed on the roof tower in March 2007. The temperature and relative humidity probe is operated by the datalogger and is programmed to accumulate data with one-minute averaging.

Figure 5 Relative humidity sensor installed on roof tower.

4.1.3 Datalogger

4.1.3.1 Programming

In order to operate all DEPSCOR instruments, Loggernet was used to program controls and operations of the instruments through the CR23X datalogger. The datalogger is programmed to store the time, battery voltage, and all pyrgeometer data every second and stores temperature and relative humidity data every minute. All data is moved into final storage within the datalogger every second or minute, and is automatically moved onto an Intranet-connected computer for storage and copied over to a server for backup daily.

4.1.3.2 Implementation

The datalogger (Figure 6, Figure 7) was implemented on the roof tower in conjunction with all other DEPSCOR instrumentation. It was mounted on the side of the tower for easy access and optimum protection from weathering. A power box (Figure 8) was also installed on the tower to provide power to the pyrgeometer ventilators, the datalogger, and the Lantronix device server. The datalogger box and power box are both designed to provide protection for the electronics from the external environment.

Figure 6 Datalogger box and power box installed on roof tower.

Figure 7 Inside of datalogger box.

Figure 8 Interior of power box.

4.1.4 Sonic Anemometer

A Vaisala WMT50 sonic anemometer was selected and ordered with plans for installation on the roof tower. It will be operated with the datalogger using the same data storage procedure as the other instruments. The sonic anemometer will supplement the wind measurements provided for two and ten meters above the surface from the Mobile Integrated Profiling System (MIPS) station in the same area.

4.2 Meteorological Data Integration

Solar radiation data from the BIRM pyranometer and aerosol backscatter data from the MIPS ceilometer are being used for calibration of the pyrgeometers and understanding aerosol characteristics, respectively. The BIRM and MIPS stations are located near the roof tower providing desirable meteorological data for interaction and comparison studies.

5 Publications and Presentations

None during this reporting period.

6 Future Work

In order to actively continue the progression of the project, the instrumentation team will maintain the instruments and develop analysis programs that can be used to understand the effects of longwave downwelling radiation on hygroscopic aerosols and trapped aerosol emissions. Several analysis programs are being developed and will be enhanced in order to achieve optimum understanding of the science driving the experiment.

7 Student Involvement

UAH students are making vital contributions to the pyrgeometer project. Danielle Nuding, Junior in Physics, has been working on the project since July 2006. Danielle programmed the data logger, installed the tower with its instruments, and now serves a Junior Scientist for project coordination. Stephanie Long, also a Junior in Physics, has been working on the project since March 2007. Stephanie serves as an Instrument Technician, with responsibility for maintaining the instrumentation, constructing the database, and developing Mathcad programs for quality control and analysis. Both students are participating in the radiometer/ceilometer analyses.

8 Additional Federal Support and Collaboration

None during this reporting period.