Final Report

High Resolution Solar Radiation Data for Biogenic Emissions Modeling for 1998 Ozone Episodes in the Houston Area

Work Order No. 31984-14
TNRCC Umbrella Contract No. 582-0-31984

Prepared for:

Texas Natural Resources Conservation Commission
12118 Park 35 Circle
Austin, Texas 78753

Prepared by:

Rachel T. Pinker
Department of Meteorology
University of Maryland
College Park, MD 20742
August 29, 2001
Table of Content

Abstract

1. Introduction

2. Work Accomplished

2.1 Input and Output Information

2.2 Methodology

2.2.1 Tasks Performed
2.2.2 Version 1.4-Application of CLAVR to GOES-8

3. Deliverables

3.1 Detailed description of par-8.tar.gz
3.2 Detailed description of par-16.tar.gz

4. Quality Control

5. Time Line

References
Abstract

The purpose of this work assignment is to produce high-resolution fluxes of photosynthetically active radiation (PAR) over the Houston/Galveston region, at hourly time intervals, for the July 28-August 5 and August 23-30, 1998 ozone episodes. This, in support of the development of an emission control plan for the Houston/Galveston (H/G) area, by the Texas Natural Resource Conservation Commission (TNRCC).

In this report described will be the development of the high-resolution solar radiation data, appropriate support information, and a discussion of the data sources, analysis and QA procedures.

The data, graphics, and files used in the preparation of this documents and work files needed to document results and conclusions, or developed as work products under this contract are being supplied via the following ftp site:

ftp.environ.org

1. Introduction

The Texas Natural Resource Conservation Commission (TNRCC) is currently developing an emissions control plan for the Houston/Galveston (H/G) area that demonstrates compliance with the Federal 1-hour standard by 2007. Information on Photosynthetically active Radiation (PAR) is also needed as input to the biogenic emissions inventory. At the University of Maryland, under the direction of R. T. Pinker, capabilities were developed to derive such information from observations made from the geostationary satellite GOES-8 (Pinker and Laszlo, 1992; Pinker et al., 1995; Tarpley et al., 1996). The methodology is currently implemented operationally at NOAA/NESDIS, at 0.5-degree resolution, at hourly time intervals. The PAR inputs for the air quality modeling are required at higher spatial resolution than currently available. Under this Work Plan, we have produced a high resolution PAR product for two high ozone episodes that occurred during July 28-August 5 and August 23-30, 1998 in the Houston/Galveston and Beaumont/Port-Arthur ozone non-attainment areas (Harris, Galveston, Brazoria, Fort Bend, Liberty, Chambers, Montgomery, Waller, Hardin, Jefferson and Orange counties).

The inference scheme that has been used for producing the high-resolution PAR data is similar to the one used to produce the NOAA/NESDIS operational product, as distributed to the users in support of the GEWEX Continental–scale International Project (GCIP) activity, via:

http://metosrv2.umd.edu/~srb/gcip/gcipsrb.htm

However, the cloud screening procedures used here are different than the ones currently in use at NOAA/NESDIS, which are based only on the visible channel on GOES-8. The procedures used here are based on observations from all five channels on the GOES-8
satellite, and therefore, there is a need for large data storage. At NOAA/NESDIS, the
original satellite input data are discarded after the model is run; only the processed cloud
information is stored. Since the saved cloud products are gridded to 0.5 degree
resolution, any subsequent runs are restricted to this resolution, and no modification to
cloud processing or producing a higher resolution product are possible. To obtain
information at a higher spatial resolution requires availability of the original satellite data,
and development of new interfaces between the model, the satellite input data, and
information on the state of the atmosphere.

2. Work accomplished

2.1 Input and Output Information

Goes-8 satellite data in five channels, at highest available resolution were used. They
were available to us from independent sources in the McIdas format. For this work the
PAR data that are produced from the inference scheme are at 1/8th of a degree, for the
entire United States, and at 1/16th for an extended area over Texas, that includes the
primary areas of interest: the Houston/Galveston and Beaumont/Port-Arthur ozone non-
attainment areas (Harris, Galveston, Brazoria, Fort Bend, Liberty, Chambers,
Montgomery, Waller, Hardin, Jefferson and Orange counties) as well as the area of East
Texas covering Houston, Corpus Christi, Dallas and Longview. Data cover the time
periods July 28-August 5, 1998 and August 23-30, 1998. Data were prepared in the
“Little Endian” binary format and instructions were prepared to transfer the data into
formats compatible with the TNRCCs Unix computers (SGI and IBM), IEEE “Big
Endian” binary format (see section 3.1).

2.2 Methodology

2.2.1 Tasks performed

We used an improved cloud screening methodology for inferring model cloud input
parameters, using the available GOES-8 4 km data. The following was done:

1. prepared the satellite data base for the selected periods
2. prepared information on precipitable water, for input to model
3. gridded the precipitable water that is available at 0.5 degree resolution into
   1/8th and 1/16th resolution grids
4. ozone was obtained from climatology
5. the cloud screening algorithm was run for the designated region and selected
time period; 4 types of pixels are obtained from this procedure:
   a. clear
   b. cloudy
   c. clear mixed
d. clear cloudy

A procedure has been developed to allocate the mixed categories into clear and cloudy; **Version 1.4** of this procedure was applied here.

6. processed the satellite data into cloud parameters, as required by the inference scheme
7. run the inference scheme (this is usually done after the cloud parameters are gridded at 0.5 degree); requires building a new interface to the higher resolution data
8. the product is instantaneous satellite estimates at selected resolutions; these values were integrated, to obtain hourly averaged data.

### 2.2.2 **Version 1.4-Application of CLAVR to GOES-8**

In the past, cloud information was obtained on the basis of a cloud-screening algorithm based on the visible channel alone. It was demonstrated, that while under “average” conditions this approach is yielding satisfactory results, the one channel algorithm has difficulty to detect sub-pixel clouds and clouds over snow. Therefore, it was decided to adopt the Clouds from AVHRR (CLAVR) algorithm, which was developed for the AVHRR sensor, to GOES observations.

The CLAVR algorithm has several tests based on the following principles:

- **Contrast signature**
- **Spectral signature**
- **Spatial signature**

The output from CLAVR is a “cloud mask” and a “cloud type”, as follows:

Cloud mask output: Clear; mixed clear; mixed cloudy; cloudy

Cloud type output: Clear; partly cloudy; liquid cloud; mixed phase cloud; glaciated cloud; cirrus

There is a need for a redistribution of the mixed pixels into clear and cloudy categories. It is based on the assumption that the relationship between the visible channel reflectance and the cloud amount is linear.

Before model implementation, there is a need to redistribute the mixed pixels, and determine the clear sky composite. Since there is no “objective” way to derive this information, several experiments have been performed, to identify the best approach. One of the experiments, which seemed to get best results when inferred fluxes were compared with ground observations, is labeled **Version 1.4**, and was used here.
3. **Deliverables**

The data are provided in an electronic data appendix to the report and also transferred via ftp at:

[ftp.environ.org](ftp.environ.org)

Two directories were created at the ftp site, to match the data files in the electronic appendix:

1) **par-8**
2) **par-16**

The first one includes the results at the 1/8th resolution, while the other includes the 1/16th resolution data. Both files include selected figures.

The files in these two directories are:

**par-8.tar.gz**
and
**par-16.tar.gz**

To unpack these files, use following commands:

1) The command "ungzip par-8.tar.gz" for uncompressing
2) The command "tar -xvf par-8.tar" for unpacking

3.1 **Detailed description of par-8.tar.gz**

Satellite estimates of PAR for the periods July 28-31 and August 1-31, 1998 at 1/8th of a degree resolution can be found in directory par-8.tar.gz. The data are provided at hourly and daily time scales and cover all of the contiguous United States.

The floating-point binary data conform to the **Little Endian** specification, and were written on a DEC workstation.

To read the data on a **Big Endian** machine, the bytes must be swapped around the middle. The FORTRAN compiler on your machine may have an option for doing the conversion between the two formats. Alternatively, you may want to try the Fortran program (read_d_bigend.f). This is a **Big Endian** version of read_d.f. It has a subroutine to swap the bytes.

The sample code assumes that the record length is given in 4-byte words. If your compiler requires bytes for the record length, you should uncomment the line "Lrec=4 * Nlon" and comment out the line "Lrec =Nlon" in the read programs.
Filenames:

    hourly: yymmpar.h
    daily:  yymmpar.d

where

yy: year (two digits)
mm: month (two digits)
par: photosynthetically active radiation

File structure:

Data for the parameter PAR at hourly and daily time resolutions for each month are contained in a single file. Hourly average files contain all 24 hours for a day, and all days for a month, even if data are missing. The hours for the hourly average files is local standard time (1-24). The hourly average flux is an estimate of the flux averaged for an hour ending at the hour in local standard time. It is obtained from the instantaneous flux by normalizing it to the average solar zenith angle for the hour.

For August 1998, there are 31 days included in the file. For July 1998, there are 4 days (from July 28 to July 31) included in the file. Please use the GrADS data descriptor files, 9808parh.ctl, 9807parh.ctl, 9808pard.ctl, 9807pard.ctl to view the data under GrADS interface.

Unit of measurement: Fluxes are given in Wm-2.

Special data values: Missing data are represented by -999.

Grid structure:

Each file has information for 88641 (0.125 by 0.125 degree, equal-angle) cells (441 latitudes and 201 longitudes). All cells are present, even when data are missing. The cells are written sequentially, proceeding eastward through the latitude zone, then northward to the next latitude zone. The center lat/lon coordinates of the first cell are 25 N, 125 W, and those of the last cell are 50 N, 70 W.

Please see FORTRAN code cread_h.f code for reading hourly data and cread_.f for reading daily data.

List of images:
To ensure that the user is reading the files correctly, several images were created, and are included. The images also include results from evaluation against ground observations. Used were observations of PAR as well as of downward surface short-wave solar radiation. Specifically, the following are included:

1) YYMMDD_par_d_deg1_8_ver1_4.gif:

Daily mean surface downward PAR at 1/8th of a degree resolution

where:

YY: year
MM: month
DD: day

An example for the daily mean values of PAR for August 25, 1998 is given in Figure 1.

2) compYYMMDDHH_par_i_ver1_4.gif:

Upper: instantaneous surface downward PAR at 1/16th of a degree resolution;
Lower: 1/8th of a degree resolution

where:

YY: year
MM: month
DD: day
HH: hour

An example for the instantaneous values of PAR at the two resolutions for August 1, 1998 at 19:15Z is given in Figure 2.

3) 9808m_model_ver1_4_deg1_8_par.gif:

Comparison of monthly mean hourly satellite estimates (at 1/8th of a degree resolution) and observed surface PAR

4) 9808m_model_ver1_4_deg1_8_sw.gif:

Comparison of monthly mean hourly satellite estimates (at 1/8th of a degree resolution) and observed surface SW

5) 9808h_model_ver1_4_deg1_8_par.gif:
Comparison of hourly mean satellite estimates (at 1/8th of a degree resolution) and observed surface PAR

6) 9808h_model_ver1_4_deg1_8_sw.gif:

Comparison of hourly mean satellite estimates (at 1/8th of a degree resolution) and observed surface SW

7) 9808d_model_ver1_4_deg1_8_par.gif:

Comparison of daily mean satellite estimates (at 1/8th of a degree resolution) and observed surface PAR

8) 9808d_model_ver1_4_deg1_8_sw.gif:

Comparison of daily mean satellite estimates (at 1/8th of a degree resolution) and observed surface SW

Most of this information can be also found at the ftp site, with the data.

3.2 Detailed description of par-16.tar.gz

Satellite estimates of PAR for the periods July 28-31 and August 1-31, 1998 at 1/16th of a degree resolution can be found in directory par-16.tar.gz. The data are provided at hourly and daily time scales. The area covered is between 25-37 degrees N and 125-70 W.

The floating-point binary data conform to the Little Endian specifications, and were written on a DEC workstation.

Filenames:

hourly: yymmpar.h
daily: yymmpar.d

where

yy: year (two digits)
mm: month (two digits)
par: photosynthetically active radiation
**File structure:**

Data for the parameter par at hourly and daily time resolutions for each month are contained in a single file. Hourly average files contain all 24 hours for a day, and all days for a month, even if data are missing. The hours for the hourly average files are local standard time (1-24).

For August 1998, there are 31 days included in the file. For July 1998, there are 4 days (from July 28 to July 31) included in the file. Please use the GrADS data descriptor files, 9808parh.ctl, 9807parh.ctl, 9808pard.ctl, 9807pard.ctl to view the data under GrADS interface.

Unit of measurement: Fluxes are given in Wm-2.

Special data values: Missing data are represented by -999.

**Grid structure:**

Each file has information for 49601 (0.0625 by 0.0625 degree, equal-angle) cells (193 latitudes and 257 longitudes). All cells are present, even when data are missing. The cells are written sequentially, proceeding eastward through the latitude zone, then northward to the next latitude zone. The center lat/lon coordinates of the first cell are 25 N, 105 W, and those of the last cell are 37 N, 92 W.

Please see FORTRAN code cread_h.f code for reading hourly data and cread_.f for reading daily data.

**List of images:**

YYMMDD_par_d_deg1_16_ver1_4.gif:

Daily mean surface downward PAR at 1/16th of a degree resolution

where:

YY: year
MM: month
DD: day

An example for the daily mean values of PAR for August 25, 1998 at 1/16th resolution is given in Figure 3.
4. Quality control

In the past, the satellite-based estimates of the surface SW fluxes have been evaluated against ground truth as available from projects, such as SURFRAD (Hicks et al., 1996), the DOE Atmospheric Radiation Measurement ARM/CART/SGP observations of SW fluxes, obtained from the central facility (36.605° N, 97.485° W), the AZMET network (Brown, 1989) and the Illinois State Water Survey (Hollinger et al., 1994). The data produced under this project have been evaluated against ground observations as available from the SURFRAD network. Both SW and PAR fluxes were used. Selected results have been placed on the ftp site, with the database. The results indicate improvements in agreement with ground truth, as compared to results obtained using the old cloud screening methods.

5. Time line

The work reported on in this document was completed under a highly compressed schedule due to funding cycle constraints at the TNRCC. The project began on July 26, 2001 and the final report and data products were provided on August 31, 2001.

References


