Surface Irradiance

Name

I0 – total clear-sky surface irradiance

Synopsis

`I0 [filename]`

The program has two operating modes, depending on whether a filename is provided on the command line. If no filename is provided, the program will provide an interactive data entry screen (Figure 1).

If the name of a suitable data file (extension "`.dat`") is provided, the program will run in "batch" mode and will create two new files (overwriting any existing files of the same name). The names of the new files are obtained by first removing any extension to obtain the "basename". The program will read data from "`basename.dat`", and will write the results on "`basename.out`". A processing log will be written on "`basename.log`".

Purpose

This program employs a spectral model of irradiance to determine the direct and diffuse components of the light energy available at the ocean surface. The program described here simply summarizes these results in two variables: a) total daily clear-sky surface irradiance, I_T (Watts $\cdot m^{-2} \cdot d^{-1}$) and b) the maximum (noon) clear-sky surface irradiance, I_0^m (Watts $\cdot m^{-2}$) for a given location (latitude) and day number. The sections of the program used to compute spectral irradiances are similar to those employed by other programs in this series.

Description

The spectral irradiance field at the sea surface is required for many oceanographic computations. This program computes spectral values of the direct and diffuse components of surface irradiance and integrates these numerically over the photosynthetically-active range to obtain the output variables.

Total surface irradiance is calculated using the clear-sky, spectral irradiance model of Bird (1984). This model determines diffuse and direct components of the downwelling irradiance $I_0(t)$ (Watts$\cdot m^{-2}$) at the surface as a function of time, t (h), for a given location (latitude) and date. Adjustments for seasonal variations in extraterrestrial solar irradiance and for surface reflectance are made as described by Sathyendranath and Platt (1988).

```
                Select variable, press [Enter] to edit:

** Exit (accept current values)
Latitude: 24.800 (decimal degrees, [-90 .. 90])
Longitude: 61.600 (decimal degrees, [-180 .. 180])
Day number: 305 [1=Jan 1st .. 365]

                                  results
Status code: 0 (0=OK, ...)
Day length: 11.110 (h): 6.450 (h)
Total daily surface irradiance: 2244.100 (Watts/m^2/d)
Noon (maximum) surface irradiance: 341.000 (Watts/m^2)
```

Figure 1. Interactive data entry screen for surface irradiance calculations.

Theory

Day-length, D, is a function of the latitude and day number. For a given day, time, t, is measured with the origin at sunrise. Given the surface irradiance as a function of time, $I_0(t)$, the total daily irradiance is defined by the integral:

$$I_T = \int_0^D I_0(t)\,\mathrm{d}t\,. \tag{1}$$

The function $I_0(t)$ is assumed to be symmetric about noon ($t = D/2$), allowing the integral to be expressed in a form that is advantageous for numerical evaluation:

$$\begin{aligned} I_T &= \int_0^{D/2} I_0(t)\,\mathrm{d}t + \int_{D/2}^{D} I_0(t)\,\mathrm{d}t \\ &= 2 \times \int_0^{D/2} I_0(t)\,\mathrm{d}t \quad . \end{aligned} \tag{2}$$

Note that the maximum, I_0^m, of $I_0(t)$ occurs at local noon (*i.e.*, $I_0^m = I_0(D/2)$).

Input

When the program is run without naming a data file, a data entry screen will be displayed (Figure 1). The cursor keys can be used to select one of the four input lines (`** Exit ...` to `Day number ...`). If "Exit" is selected, the user is given the choice of either using the current values in a calculation (the new results will be displayed in the above format) or exiting from the program. If one of the input variables is selected, the user will be asked to enter a new value. If the user enters a value that is outside the indicated range, the value will be reset to the nearest endpoint. When a new input value is entered, the output values shown under "`results`" are no longer valid and will be changed to "`*`".

When the program is run interactively, a data file called `I0.dat` will be created together with the output file `I0.out` and a log file `I0.log`. These are simple ASCII text files that can be viewed with any editor. Each time the program is run these files will be overwritten, so the files must be copied to another location or renamed if the results are to be saved for future use.

The program runs in batch mode if a data file is named on the command line. The data file must provide a location and day number. The input data file has two header records followed by one or more data records. The fields in a data record are:

1) latitude, decimal degrees;
2) longitude, decimal degrees (not used for the calculations); and
3) day number, an integer between 1 and 365.

Note that the longitude is not required by the calculations, but is included for convenience when relating the file to other data sets. The input file is ASCII text with one record per line. The first line of the file is not used by the program, and may be used to describe the data set or to list the variables. The second line gives the FORTRAN format required to read the data records. This format must use only `f`$w.p$, `i`n, or `x` specifiers. The data file corresponding to Figure 1 is:

```
Latitude Longitude Day
(f8.3,2x,f8.3,x,i3)
  24.800    61.600 305
```

OUTPUT

The program produces a single output data file and a file containing a log of the processing. The first two records are a list of the variables and a FORTRAN format suitable for reading the file. The remaining records contain the data. The first three fields are the same as the first three fields of the input data. The fourth field is a code indicating the status of the calculation. The fifth field is the time t_0 of sunrise, or dawn, in hours local apparent time. The sixth and seventh fields are I_T, the total clear-sky irradiance, and the maximum irradiance, I_0^m. Missing value codes are given when a value for I_0^m could not be computed (*e.g.*, due to a large, noon, zenith angle). The output corresponding to the input file given above is:

```
Latitude Longitude Day status   D   I_T    I_0m
(f6.2,x,f7.2,5x,i3,5x,i2,x,f5.2,x,f6.1,x,f6.2)
 24.80   61.60     305      0 11.11 2244.1 341.00
```

Processing

The latitude and day number determine the day-length, D. If the computed day-length is less than a defined tolerance, ϵ, it is set to zero. A time increment, Δ_t, is defined as $\Delta_t = D/24$. The zenith angle is computed for the twelve times ($1 \times \Delta_t$, $2 \times \Delta_t$, ..., $D/2$(=noon)). In general, the first $n > 1$ of these time steps may correspond to zenith angles which exceed 80°. The total clear-sky surface irradiance, $I_0(t)$ (Watts $\cdot$m^{-2}) as function of time, t (hours, measured from local sunrise), is computed for times where the zenith angle is less than 80°. Total daily irradiance, I_T, is obtained using the trapezoidal rule and taking advantage of symmetry (Eqn. (2)). Since (when $D < 24$) $I(0) = 0$, the quadrature uses the points: $t = 0$, $(n+1)\Delta_t$, $(n+2)\Delta_t$, ..., $12 \times \Delta_t (= D/2)$.

Special cases

Two cases require special handling: a) the case where the noon zenith angle exceeds 80°, and b) the case of twenty-four hour darkness (*i.e.*, day-length is zero). In the latter case, total irradiance and noon irradiance are set to zero. In the case where day length is not zero but the noon zenith angle exceeds 80°, the values of I_T and I_0^m are set to missing value codes.

Files

In addition to the binary executable program, one input data file is required. Two new files will be created, an output data file and a log file containing a record of the processing (previously existing files having the same names will be destroyed without warning). Each file is identified by its extension (the three letters following the "`.`" character):

1) the program (executable) itself (`.exe` extension);
2) input data (ASCII text, `.dat` extension);
3) processing log (ASCII text, `.log` extension); and
4) output data (ASCII text, `.out` extension).

All the names are determined from the command line at run time (*i.e.*, the program does not rely on any "hard-coded" file names). When no file name is given on the command line, the program creates the file "`I0.dat`" using values entered interactively by the user. In this case, the output files will be "`I0.log`" and "`I0.out`".

Requirements

The numerical calculations are not demanding. An effort has been made to ensure that the results will remain consistent across a range of hardware platforms. It is assumed that double precision variables conform to the IEEE floating point arithmetic standard. This is the most efficient data type for floating point computations on modern microprocessors with hardware floating point support.

To run the program under MS-DOS, approximately 400k of free low DOS memory and 1M bytes of extended memory are required. The `ansi.sys` device driver must be loaded in `config.sys`.

Bugs

It is difficult to protect against all possible combinations of input parameters that generate run-time errors due to floating point underflow or overflow.

Limits

No results are computed when the noon zenith angle exceeds 80°.

The parameter ϵ (used in the test: $D > \epsilon$) is set at compile time. The current value is shown in the log file.

Diagnostics

The following messages may occur:

`** error in get_files **`

An error occurred in the `get_files` subroutine. This message will be preceeded by a message indicating the type of error that occurred.

`** error ** file I/O`

An error occurred while reading or writing a file. This could indicate a missing or corrupted file, a disk problem such as lack of space, or a program which uses more files than the operating system configuration allows (many systems limit the number of files a program can use; in some cases the user may be able to increase this number via a configuration option).

`** error ** getarg`

The system function used to obtain the command line parameters returned an error. This may indicate lack of memory, an incompatible command processor, or a command line that is too long.

`** error ** name too long:  ...`

A program or file name was too long.

`** error ** limit exceeded:  too many files to read`

This is an internal program error which should not occur. The list of input file extensions passed to the subroutine has more entries than the number of files requested.

`** error ** limit exceeded:  too many files to write`

This is an internal program error which should not occur. The list of output file extensions passed to the subroutine has more entries than the number of files requested.

`** error ** opening file ...`

The indicated file could not be opened. The file name may have been entered incorrectly or the file may have a hidden, read-only, or system attribute.

`** I/O error **`

An error occurred while reading from or writing to a file or the console. This could indicate a missing or corrupted file, a disk problem such as lack of space, a buffer overflow, or a control character inadvertently entered from the keyboard.

`-- End of file --`

This is not always an error, but may indicate a file that has been truncated or damaged.

`** error:  input file(s) **`

A problem occurred with an input file. The file name passed to the program may be incorrect, or the file may have a hidden or system attribute.

`** error:  output file(s) **`

A problem occurred with an output file. The file name passed to the program may be incorrect or the file may have a hidden, system, or read-only attribute.

`** error:  input record format **`

The input record format (obtained from the second line of the input file) did not have the required number and types of fields.

The following warning messages are issued when a non-zero status code is set for the output record:

`warning:  could not determine noon irradiance`

The noon zenith angle exceeded 80°. The output status code is 1.

`warning:  24 hour darkness`

The surface irradiance is set to zero. The output status code is 2.

`warning:  missing data`

The input record was incomplete or a variable was entered with a missing value code. The output status code is 3.

References

Bird, R. E. (1984), 'A simple, solar spectral model for direct-normal and diffuse horizontal irradiance', *Solar Energy* **32**, 461–471.

Sathyendranath, S., and T. Platt (1988), 'The spectral irradiance field at the surface and in the interior of the ocean: A model for applications in oceanography and remote sensing', *J. Geophys. Res.* **93**, 9270–9280.

Notation

D	day-length, h.
$I_0(t)$	total clear-sky surface irradiance, as a function of time, Watts $\cdot \mathrm{m}^{-2}$.
I_0^m	maximum (noon) clear-sky surface irradiance, Watts $\cdot \mathrm{m}^{-2}$.
I_T	total daily clear-sky surface irradiance, Watts $\cdot \mathrm{m}^{-2} \cdot \mathrm{d}^{-1}$.
t	time measured from local sunrise, h.
Δ_t	time interval for values of $I_0(t)$, h.
ϵ	tolerance for test $D > \epsilon$, h.