Daily, Water-Column Production – Empirical Estimators

Name

dwcpe – empirical estimators of daily, water-column production for a vertically uniform water column

Synopsis

`dwcpe [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 calculates estimates of daily, water-column production for a vertically uniform water column using three empirically-based approximations as compiled by Platt and Sathyendranath (1993). These calculations are provided for their historical interest. For reference, values obtained using a polynomial approximation to the analytic solution of Platt *et al.* (1990) are also provided.

Description

This program computes the dimensionless, scaled, daily, water-column production, $f(I_*^m)$, using four empirically-based methods and, as a benchmark, a method based on the analytic solution. These results may be used to compute total daily, water-column production as described below (see THEORY).

For each input data record, the program computes the photoadaptation parameter, $I_k = P_m^B/\alpha^B$ and the dimensionless irradiance at local noon, $I_*^m = I_0^m/I_k$. The various estimators for the canonical solution, $f(I_*^m)$, for daily primary production are then computed using the current value of I_*^m.

Table 1. Definitions of the three empirically-based estimators of daily, water-column production and the reference method. See Platt and Sathyendranath (1993) for details and references.

Method	$f(I_*^m)$	Domain
Empirical estimators		
Ryther (1956)	$0.701 I_*^m - 0.0954 (I_*^m)^2 + 0.00512 (I_*^m)^3$	$I_*^m \leq 7$
Talling (1957) (i)	$\log_e(I_*^m)$	$I_*^m \geq 1$
Talling (1957) (ii)	$0.9 \log_e(4 I_*^m / \pi)$	$I_*^m \geq \pi/4$
Reference calculation		
Platt et al. (1990)	$\sum_{x=1}^{5} \Omega_x (I_*^m)^x$	$1.6 \leq I_*^m \leq 20$

Theory

The absolute daily, water-column production in the case of uniform biomass is defined by the integral over depth and time:

$$P_{Z,T} = B \int_0^D \int_0^\infty P^B(z,t)\, \mathrm{d}z \mathrm{d}t,$$

where B is the (uniform) biomass concentration (mg Chl m^{-3}), D is the day-length (h), and $P^B(z,t)$ is the primary production rate normalized to biomass (mg C (mg Chl)$^{-1}$ h^{-1}) as a function of depth, z (m) and time, t (h).

Given a value for the canonical function f, an estimate for $P_{Z,T}$ is obtained using the relationship:

$$P_{Z,T} = A \times f(I_*^m),$$

where $A = BDP_m^B/K$ is the scale factor with dimensions of mg C m^{-2}, and K is the vertical attenuation coefficient for irradiance (m^{-1}).

Each of the estimators is characterized by a mathematical formula and the range of values for the argument, I_*^m, for which the formula applies. The definitions used in the program are shown together with the ranges of validity in Table 1. Since I_*^m is always non-negative, the condition $I_*^m \geq 0$ is not stated in Table 1.

Input

The input data file consists of a two-line header followed by one or more data records. Each data record consists of a record identifier followed by values for α^B, P_m^B and I_0^m. The data file corresponding to Figure 1 is:

```
Ident     alphaB     P_mB   I_0m
(a8,x,f8.3,x,f8.3,x,f8.3)
example     0.100    3.000  180.000
```

The fields in each data record are as follows:

1) an arbitrary string (format an) used to identify the record for subsequent processing;
2) initial slope of $P - I$ curve, α^B (mg C(mg Chl)$^{-1}$ h^{-1} (W m^{-2})$^{-1}$), format f$w.p$;
3) assimilation number, P_m^B (mg C (mg Chl)$^{-1}$ h^{-1}), format f$w.p$; and
4) maximum (noon) surface irradiance, I_0^m (W m^{-2}), format f$w.p$.

Output

The output file also consists of a two-line header followed by one output data record for each input record. The output file corresponding to Figure 1 is:

```
Ident,     I_k,      I_*m,   Ry56, Ta57i, Ta57ii, Pl90
(a8,x,f8.3,x,f8.3,x,f6.2,x,f6.2,x,f6.2,x,f6.2)
example    30.000    6.000   1.88   1.79   1.83   1.78
```

Processing

The first two input records form the data header. The first input record is not used in the program, but should, by convention, identify the data set. The second input record provides the Fortran format statement used to read the remaining input (data) records. The portion of this input format up to the first comma character is also used to construct the output format.

The input data records are processed in a loop that reads one input data record, processes the data, and writes the corresponding output record. The record identifier is not used, but is stored as a character string and reproduced unchanged in the output data record.

Once a value for I_*^m has been computed using the current input data record, this value is checked against the domain of each method and, if the domain conditions (Table 1) are satisfied, a value for f is obtained. Polynomials are evaluated using Horner's rule.

The reference method uses the second set of polynomial coefficients from Table A2 of Platt and Sathyendranath (1993).

Special cases

The various methods differ in the range of permissible input values Table 1. A negative value is assigned to f when the value for I_*^m is not in the range for a particular method.

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

** Exit (accept current values)
Record identifier: example
Initial slope of P-I curve, alphaB: 0.100 (mg C/(mg Chl)/h/(W/m^2))
Assimilation number, P_mB: 3.000 (mg C/(mg Chl)/h)
Maximum (noon) surface irradiance, I_0m: 180.000 (W/m^2)

             Results
Adaptation parameter, I_k: 30.000 (W/m^2)
Dimensionless irradiance at local noon I_*m: 6.000

         Canonical value, f(I_*m), for daily, water-Column Production
Empirical estimators:
Ryther (1956) ....................  1.88
Talling (1957) (i) ...............  1.79
Talling (1957) (ii) ..............  1.83

Reference calculation:
Platt et al. (1990) ..............  1.78
```

Figure 1. Interactive data-entry screen for empirical estimators of daily, water-column production. See Platt and Sathyendranath (1993) for details and references.

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 "`dwcpe.dat`" using values entered interactively by the user. In this case, the output files will be "`dwcpe.log`" and "`dwcpe.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 bytes of free memory are required. The `ansi.sys` device driver must be loaded in `config.sys`.

Bugs

None known.

Limits

The program does not impose any limits beyond those imposed by the hardware on which it is run.

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.

References

Platt, T., and S. Sathyendranath (1993), 'Estimators of primary production for interpretation of remotely sensed data on ocean color', *J. Geophys. Res.* **98**, 14,561–14,576.

Platt, T., S. Sathyendranath, and P. Ravindran (1990), 'Primary production by phytoplankton: analytic solutions for daily rates per unit area of water surface', *Proc. R. Soc. Lond. Ser. B* **241**, 101–111.

NOTATION

- α^B initial slope of relationship between photosynthesis and irradiance, $\alpha^B \equiv \partial P^B/\partial I|_{I\to 0}$, mg C (mg Chl)$^{-1}$ h^{-1}(W m^{-2})$^{-1}$.
- B biomass, as concentration of chlorophyll a, mg Chl m^{-3}.
- D day-length, hours.
- f function of I_*^m arising in dimensional analysis and in canonical form, of solution for daily primary production, dimensionless.
- I_0^m maximum surface irradiance at local noon, W m^{-2}.
- I_*^m dimensionless irradiance at local noon, $I_*^m \equiv I_0^m/I_k$.
- I_k photoadaptation parameter in the relationship between photosynthesis and irradiance, $I_k \equiv P_m^B/\alpha^B \equiv P_m/\alpha$, W m^{-2}.
- K vertical attenuation coefficient for irradiance, $K = -I^{-1}(dI/dz)$, m^{-1}.
- P^B primary production rate normalized to biomass, $P^B \equiv P/B$, mg C (mg Chl)$^{-1}$ h^{-1}.
- $P_{Z,T}$ daily primary production for the water column, mg C m^{-2}.
- P_m^B assimilation number, specific production at saturating light, in the absence of photoinhibition, $P_m^B = P^B|_{I\to\infty}$, mg C (mg Chl)$^{-1}$ h^{-1}.
- z depth (origin at surface, positive downwards), m.