Documentation and description of surface solar irradiance data sets produced for SeaWiFS

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Synopsis:

This is a brief description of the solar irradiance products produced for SeaWiFS using data from the International Satellite Cloud Climatology Project (ISCCP). Data sets are now available through the Goddard DAAC. Published descriptions of the algorithm used, algorithm verification, and results of data analysis are found in Bishop and Rossow [1991] and Bishop, Rossow and Dutton [1997]. A recent evaluation of these data for 1991 - 1993 is published by Waliser et al. [1999].

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ISCCP D1 and DX Data:

The major input data set is the International Satellite Cloud Climatology Project DX data, which contains, at nominal 30 km resolution (4-8 km pixel size, randomly subsampled at 30 km resolution) and every 3 hours for the globe, information about clouds, the atmosphere, and surface [Rossow and Schiffer, 1999]. Some parameters are at 280 km (~2.5 degrees) spatial resolution and are are obtained from D1 data. DX data are used to produce a 0.5 by 0.5 degree gridded product.

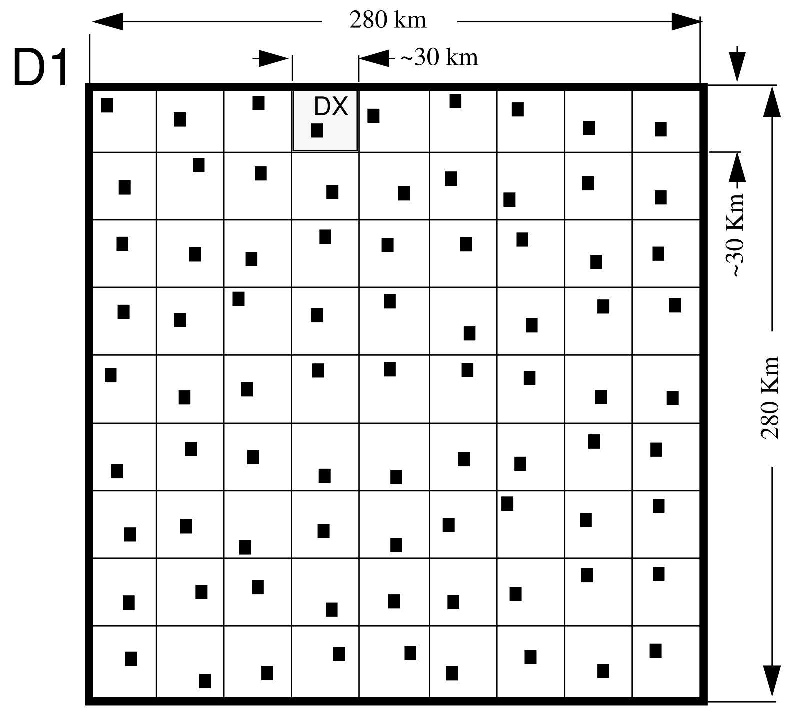


Figure 1. Schematic of ISCCP DX and D1 pixels. D1 pixels represent the average values of cloud properties in approximately 80 30km sized DX pixels. The DX pixel represents data ramdomly subsampled from a single 4-8 km area within that region.

Specific parameters used are: (1) solar zenith angle, (2) atmospheric ozone column abundance, total precipitable water, and surface pressure (daily for each 2.5 degree region on the globe; from TIROS Operational Vertical Sounder (TOVS) data), (3) surface visible (at 600 nm) reflectance (every 3 hours for each 0.5 degree region), and (4) cloud parameters for a single layer: cover fraction, and optical thickness (at 600 nm) (every 3 hours for each 30 km region). A limitation is that visible radiative retrievals of cloud optical properties are performed only when the solar zenith angle is less than 78.5 degrees. Filling schemes are used to over come this limitation. Additional data sets employed are (5) land-water fraction, and (6) snow and sea ice cover (every 5 days for each 1 degree region). Although the ISCCP data are available eight times per day for most of the globe, regions not covered by geostationary satellite are observed less frequently by polar orbiters, leading to occasional gaps in the data.

SeaWiFS DX Production data:

SeaWiFS irradiance product information is summarized below and in Tables 1 and 2.. The data are readable using NCSA's HDF software and may be examined displayed and animated using NCSA's Collage. One year of daily averaged data (all fields) totals 2 GB; The 3 hourly data total 18 GB (3 compressed).

Data format and description:

ISCCP DX data source data is on an equal area grid with a an effective 30x30 km pixel size. For SeaWiFS production, the data have been mapped on a 720 x 360 (0.5 x 0.5 degree) rectangular grid, with:

```
[  1,  1]    centered on 179.75W 89.75N
[  1,360]    centered on   "     89.75S
[720,  1]             on 179.75E 89.75N
[720,360]             on    "    89.75S
```

Some variables are updated only once per day (e.g. 'TOVS' data for H_2O, O_3). Owing to sparseness of coverage, some of the D1 input variables were replaced with climatology (e.g. surface pressure from NOAA GFDL monthly climatological data), with theoretical estimates (e.g. ocean surface reflectances, see above) or with bulk parameterizations (e.g. sulfate aerosols and visibilities were assumed constant). Total irradiance is given for both the full spectral range and for Photosynthetically Active Radiation (PAR, 400-700 nm). Standard deviations of total irradiance for both the full and PAR ranges are also included.The model output consists of 3-hourly, averaged daily (over 24 hours), and averaged monthly fields of clear-sky and total (i.e. including effects of clouds) irradiance.

The 3 hourly data correspond to 3 hour periods centered on GMT’s 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100. Monthly and daily data are representative of the actual number of days of the month. February data represent 29 days in leap years.

The NAMING SCHEME for files is as follows:

```
example file name: dxqclddp2.199103.sds.
                          namex n yyyymm
```

where

`dx`: means ISCCP DX data were used.

`name`: is the 4-letter code *NAME* for the variable (see Tables 1-2 below).

`x`: data *TYPE* is 8, d, or m - for 3-hourly, daily or monthly data, respectively.
The three data types in uncompressed from occupy 128, 16, and 0.5MB, respectively.
The ’8’ and ’d’ file sizes depend on the number of days in the month.
(Note that the 3-hourly and daily data fall into two categories: for most fractional data and state variables, such as cloud cover and ozone, the data represents an average over the period in question; however for cumulative variables such as irradiance the 3-hourly data represent time-integrated averages. By contrast daily

and monthly values always represent averages of 3 hourly and the daily data, respectively)

`p2`: means this is the 2rd version of the DX production

`yyyy`: is year, e.g. 1993

`mm`: is the month and year; all files for March 1991 are designated 199103.

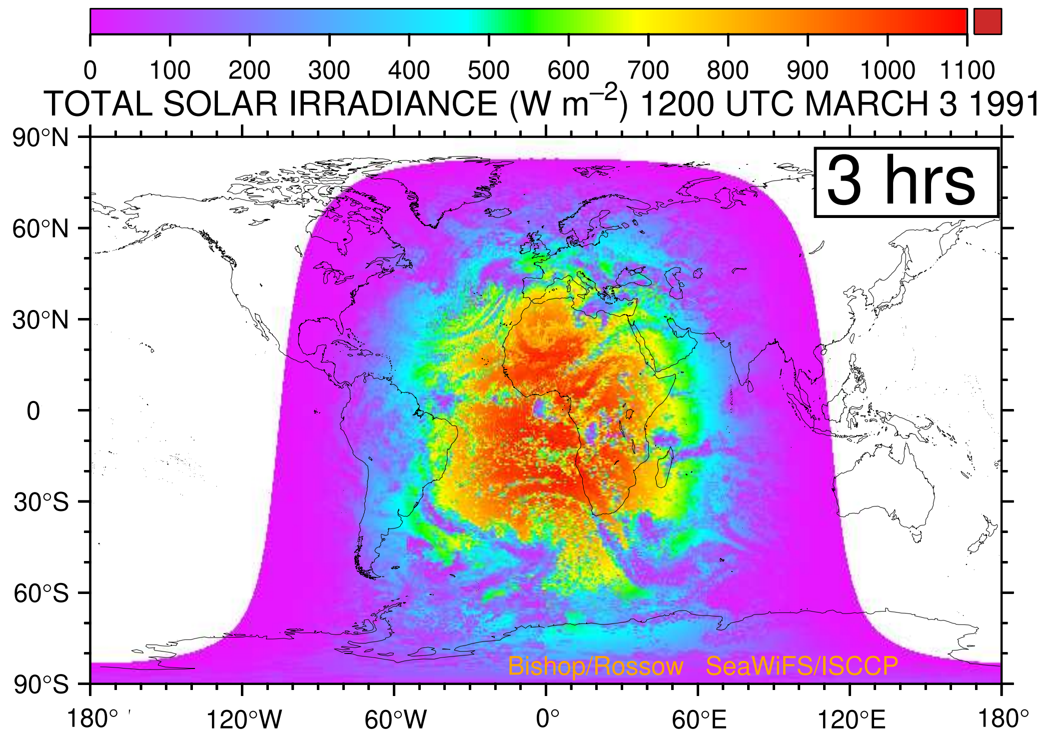
`sds`: identifies the data as being in HDF Scientific Data Set format

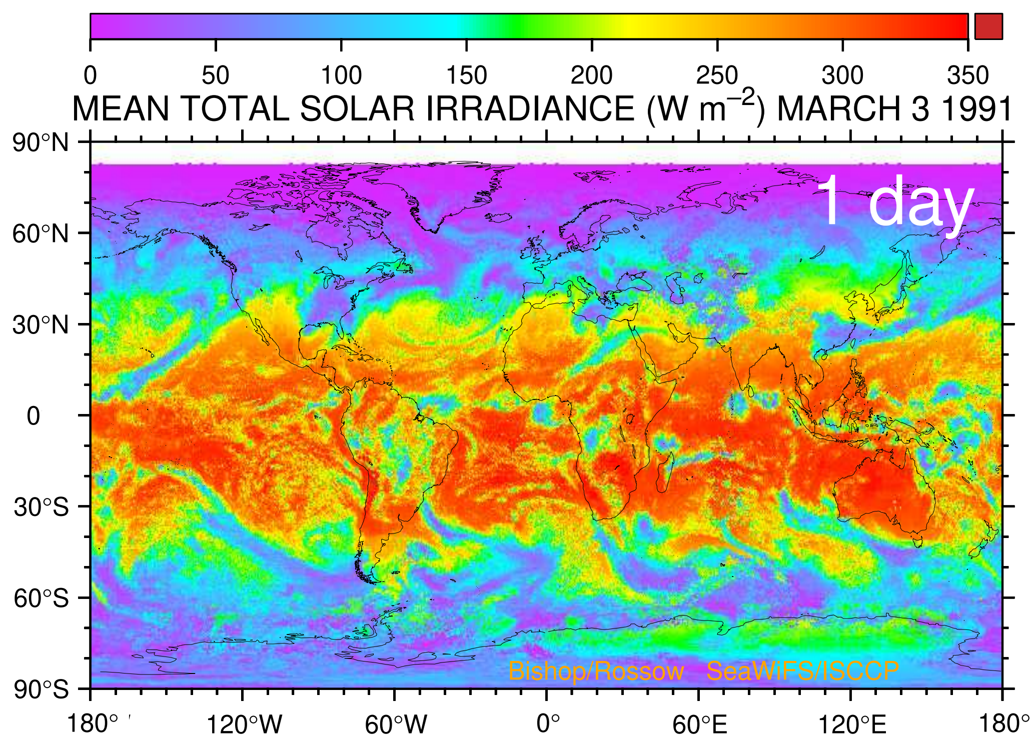
The four-letter variable code names and corresponding data descriptions are summarized in tables below. The main rationale for saving clear-sky (qclr) and gridded input data fields is to permit recalculation of aerosol effects (now assumed constant) at a later date.

Data File Names for the month of March 1991. File size is in bytes.

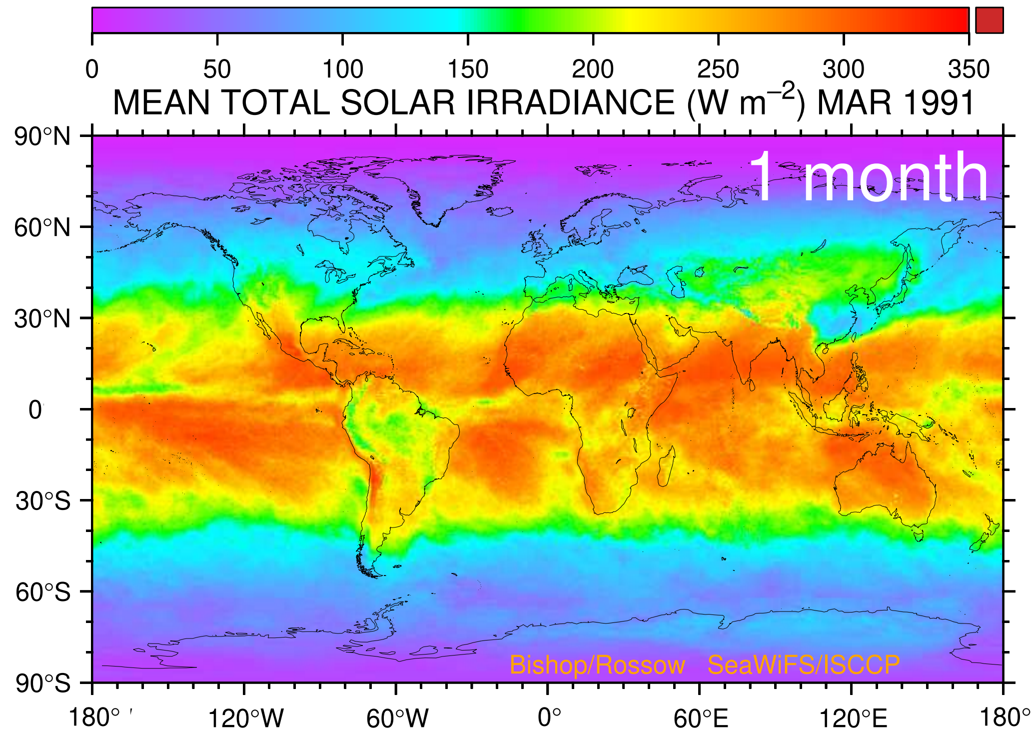
```
128575726 Apr 03 1998  dxaicc8p2.199103.sds
 16072369 Apr 03 1998  dxaicedp2.199103.sds
257151015 Apr 03 1998  dxaics8p2.199103.sds
128575726 Apr 03 1998  dxclfr8p2.199103.sds
 16072372 Apr 03 1998  dxclfrdp2.199103.sds
128575726 Apr 03 1998  dxclfs8p2.199103.sds
128575726 Apr 03 1998  dxcosz8p2.199103.sds
 16072372 Apr 03 1998  dxcoszdp2.199103.sds
257151015 Apr 03 1998  dxctau8p2.199103.sds
257151016 Apr 03 1998  dxdalb8p2.199103.sds
128575726 Apr 03 1998  dxdffr8p2.199103.sds
 16072372 Apr 03 1998  dxdffrdp2.199103.sds
 16072382 Apr 03 1998  dxfilldp2.199103.sds
   518895 Apr 03 1998  dxlwcomp2.199103.sds
128575723 Apr 03 1998  dxqcld8p2.199103.sds
 16072370 Apr 03 1998  dxqclddp2.199103.sds
128575723 Apr 03 1998  dxqclr8p2.199103.sds
 16072370 Apr 03 1998  dxqclrdp2.199103.sds
128575723 Apr 03 1998  dxqpar8p2.199103.sds
 16072370 Apr 03 1998  dxqpardp2.199103.sds
 16072372 Apr 03 1998  dxratidp2.199103.sds
128575726 Apr 03 1998  dxrsfb8p2.199103.sds
 16072372 Apr 03 1998  dxrsfbdp2.199103.sds
128575728 Apr 03 1998  dxsati8p2.199103.sds
```

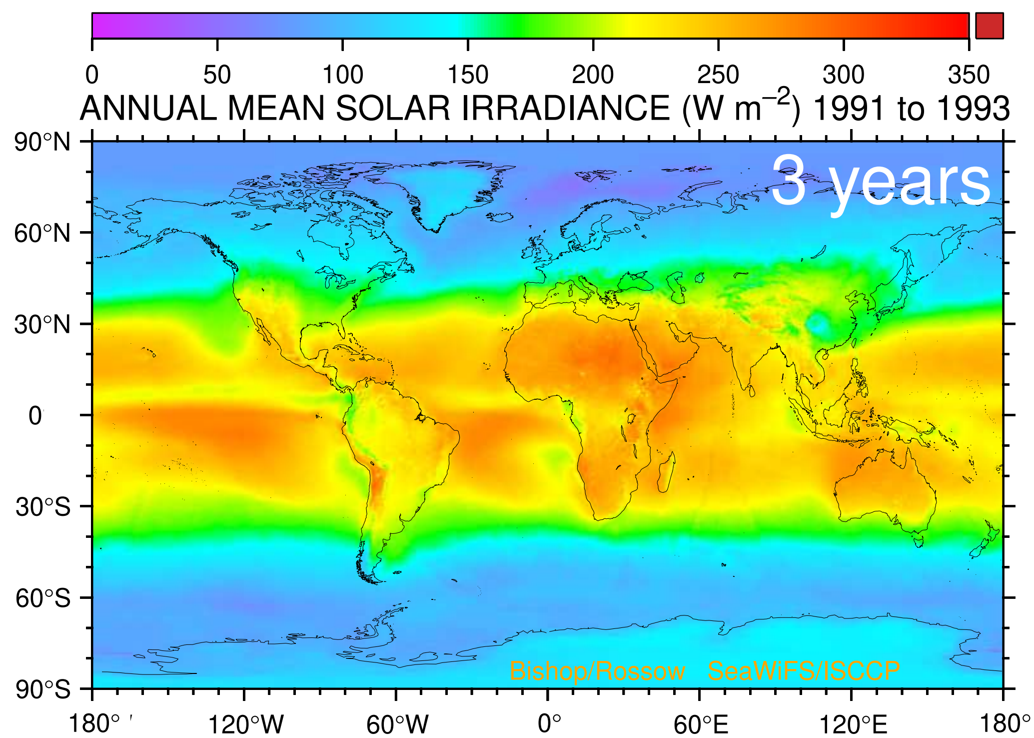
Example: total solar irradiance at 3 hourly (qcld8) and daily (qcldd) resolutions:





Example: total solar irradiance at monthly (qcldm) and annual resolutions:





SUMMARY

We have implemented and modified a fast computational scheme that reproduces the average and temporal fluctuations of surface solar irradiance and PAR on time scales relevant to marine phytoplankton physiology using ISCCP cloud data. Beyond the validation reported by Bishop and Rossow [1991] and Bishop, Rossow and Dutton [1997], the data set has been tested against records from ocean weather station climatology and from the contemporaneous BioWatt and MLML optical moorings and from selected Base Line Surface Radiation Network (BSRN) stations. Waliser et al. [1999] evaluated DX data for 1991-1993 by comparing our results to contemporaneous mooring data from the subtropical NE Atlantic and found generally excellent agreement.

References:

Bishop, J.K.B., Rossow W.B. and E.G. Dutton. Surface Solar Irradiance from the International Satellite Cloud Climatology Project 1983-1991, *J. Geophys. Res*., 102, 6883-6910, 1997.

Bishop, J.K.B. and Rossow W.B., Spatial and temporal variability of global surface solar irradiance, *J. Geophys. Res*., 96, 16839-16858, 1991.

Rossow, W.B. and R.A. Schiffer (1999) Advances in understanding clouds from ISCCP. *Bull. Am. Met. Soc.* 80, 2261-2287.

Waliser, D.E., R.A. Weller, and R.D. Cess (1999) Comparisons between buoy-observed, satellite-derived, and modeled surface shortwave flux over the subtropical North Atlantic during the Subduction Experiment. *J. Geophys. Res.* (Atmospheres), 104 No. D24, 31,301-31,320

Appendix

Table 1: DX 0.5 degree Variables produced for SeaWiFS

name	type 'x'	multiplier	description	Units	Size* Mb

`clfr`	`8`
	`d`
	`m`
		1000
		1000
		1000
			cloud fraction	-	129 (*7*)
					16 (*2*)
					0.5

`dffr`	`8`
	`d`
	`m`
		1000
		1000
		1000
			Diffuse fraction PAR (including clouds)	-	129 (*16*)
					16
					0.5

`qclr`	`8`
	`d`
	`m`
		1
		10
		10
			clear-sky irradiance (full spectrum)	W m^{-2}	129
					16
					0.5

`qcld`	`8`
	`d`
	`m`
		1
		10
		10
			irradiance including effects of clouds (full spectrum)	W m^{-2}	129 (*48*)
					16 (*13*)
					0.5

`qpar`	`8`
	`d`
	`m`
		1
		10
		10
			Photosynthetically active radiation. PAR [400-700 nm].	W m^{-2}	129 (*48*)
					16
					0.5

`sqcl`	`m`	10	std dev of daily `qcld` values over one month	W m^{-2}	0.5
`sqpa`	`m`	10	std dev of `qpar` including clouds	W m^{-2}	0.5

*size ( ) indicates file size in Mb after compression.

Table 2: DX 0.5 degree diagnostic quantities produced for SeaWiFS

name	type 'x'	multiplier	description	Units	Size* Mb
aicc	8	1000	ice cloud fraction of clouds	-	129 *(7)*
aice	d	1	ISCCP ice/snow/mixed code 0-3 0 -water 1 - ice 2 - snow 3 - partial ice/snow	-	129
cosz	8 d m	1000 1000 1000	cosine solar zenith angle - includes seasonal variation in earth - sun distance.	-	129 *(21)* 16 (*1*) 0.5
ctau	8	1000	Cloud Optical Thickness (Tau) count values from ISCCP DX data. Data fields alternate between those for water drop clouds and those for ice drop clouds.	-	258 *(23)*
dalb	8	1000	Diffuse Albedo for clouds. Data fields alternate between those for water drop clouds and those for ice drop clouds.	-	258 *(37)*
fill	d	1	fill method: 0 = normal (no data filled) +10 = TOVS data filled (H_20, O_3) +50 = glint or missing land reflectance +100 = missing cloud opt thickness, cloud fraction data present. or no clouds +190 = missing cloud opt thickness, cloud fraction data filled. 255 = no daylight entire day	-	16
lwco	m	1	land water coast ocean mask 1 = land 2 = coast 3 = non-ocean water (includes seas) 4 = Atlantic 5 = Indian 6 = Pacific NOTE: This field never changes but is repeated in data to facilitate analysis.	-	0.5
rati	d	1000	fraction of ISCCP daytime irradiance sampled.	-	16
rsfb	8 d	1000	surface albedo used in irradiance calculations.	-	129 *(24)* 16 *(5)*
sati	8	1	Satellite id. See ISCCP documentation	-	129 *(4)*

***notes on methods**:*

rsfb: Ocean points are the sum of theoretical reflectance after Cox and Munk [1956] (function of zenith angle and cloud fraction) and irradiance back-scattered from below the surface, after Morel and Gentili [1991] (function of diffuse fraction of PAR using uniform backscattering parameters).

qpar: Photosynthetically Active irRadiance (PAR) [400-700 nm]. PAR is computed using the Frouin et al. [1989] clear-sky formulation and the Bishop and Rossow [1991] approach.

diffr: The diffuse fraction of PAR including clouds is calculated from the parameterization of the clear sky formula, and assuming Rayleigh optical thicknesses [Hoyt, 1977] and a uniform aerosol optical thickness of 0.04.

***References for methods**:*

Cox, C. and W. Munk, Slopes of the sea surface deduced from photographs of sun glitter. Bull. Scripps Inst. Oceanogr., Univ. Calif, 6, 401-488, 1956.

Frouin, R., D.W. Lingner, C. Gautier, K.S. Baker, and R.C. Smith, A simple analytical formula to compute clear sky total and photosynthetically available solar irradiance at the ocean surface, J. Geophys. Res., 94, 9731-9742, 1989.

Hoyt, D. V., A redetermination of the Rayleigh Optical Depth and its application to selected solar radiation problems. J. Appl. Meteorol, 16, 432-436, 1977.

Morel A. and B. Gentili, Diffuse reflectance of oceanic waters: its dependence on sun angle as influenced by the molectular scattering contribution. Appl. Opt, 30, 4427-4438, 1991

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