Moderate Resolution Imaging Spectroradiometer (MODIS) Downward Shortwave Radiation (MCD18A1 and MCD18C1) and Photosynthetically Active Radiation (MCD18A2 and MCD18C2) User Guide

Collection 62

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Nov 2022

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1. Introduction

Incident solar radiation over land surfaces, either photosynthetically active radiation (PAR) in the visible spectrum (400-700nm) or downward shortwave radiation (DSR) in the shortwave spectrum (300-4000nm), is a key variable to address a variety of scientific and application issues related to climate trends, hydrologic, bio-physical and bio-chemical modeling, solar energy applications, and agriculture management.

Data sets of DSR and PAR are required by almost all land models, such as driving photosynthesis, modeling carbon cycling, analyzing hydrological and energy balance, weather and climate prediction. The DSR and PAR data sets also find their use in many application areas, including agricultural management, ecological forecasting, reusable energy production, public health and so on. The current global satellite products of surface radiative fluxes usually have rather coarse spatial resolutions, such as the Clouds and the Earth's Radiant Energy System (CERES) product at a spatial resolution of 1° from 1997 to present, the International Satellite Cloud Climatology Project (ISCCP) product on a 280 km equal-area global grid from 1983-2008, the Global Energy and Water Cycle Experiment (GEWEX) surface radiation budget (SRB) product at a spatial resolution of 1° x 1° from 1983-2007. Besides, few land surface global PAR products exist so users have to empirically convert DSR to PAR. The conversion itself is a source of uncertainties.

Funded by NASA, a suite of high resolution global DSR and PAR products over land surfaces have been generated from MODIS data. The first version of MODIS DSR and PAR products was released in 2017 as Collection 6. The C6 DSR and PAR products are available at the spatial resolution of 5km. The updated C61 DSR and PAR product was released in 2017, which improved the spatial resolution of the products from 5km to 1km and fixed the programming errors found in the earlier version of the C6 DSR and PAR software. The latest C62 version implemented two major improvements over the previous collections: 1) a new multispectral retrieval algorithm to replace the blue band retrieval algorithm and 2) use of updated climatology of surface spectral and broadband albedo.

The MCD18 C62 product adapts the same file structure of the C61 precedent. MCD18A1 (Downward Shortwave Radiation) and MCD18A2 (Photosynthetically Active Radiation) are 1km combined Aqua and Terra MODIS products. The two products are also aggregated to a spatial resolution of 0.05˚ and re-projected to geographic map projection as CMG products (MCD18C1 and MCD18C2). This user guide will document the technical details of data files and scientific data sets of the products. It will also briefly describe the theoretical basis and practical consideration of the retrieval algorithm.

2. Algorithm summary

The look-up table (LUT)-based algorithm is used to generate the MODIS DSR and PAR products (Wang et al. 2020). The LUT approach uses the satellite TOA signature as the main information source to estimate atmospheric radiative properties and does not rely on additional products of aerosol or cloud optical parameters. By using TOA data, the LUT approach has the advantage of performing at the native resolution of the satellite data and producing fewer data gaps. The LUT approach was initially developed by Liang et al. (2006) to estimate instantaneous PAR from MODIS data. A temporal scaling scheme was added in a following study so that it can estimate temporally averaged or integrated quantities (Wang et al. 2010). The absorption effects of water vapor in shortwave broadband radiation was later incorporated to extend the LUT approach capability in estimating DSR. In its initial version, surface reflectance was estimated from time series of MODIS TOA reflectance data with minimal blue reflectance approach. This approach was later replaced by the direct use of surface reflectance product for simplicity and as well as to avoid the issue of cloud shadow contamination.

The LUT approach consists of two major steps: estimation of atmospheric optical depth and calculation of DSR and PAR. A simple optimization algorithm is used in the first step to estimate atmospheric optical depth. The reflectance data of Band 3 was used to optimize atmospheric condition in the MCD18 C6.1 algorithm. Data of two additional bands (Band 5 and 7) are used in the C6.2 code. Surface irradiance can then be calculated in the second step with surface reflectance and the atmospheric optical depth from the first step.

3. Product description

The DSR and PAR products are available in two separate datasets: MCD18A1 or MCD18C1 (DSR) and MCD18A2 or MCD18C2 (PAR). MCD18A1 and MCD18A2 are gridded L3 products in MODIS sinusoidal map projection with 1km resolution. MCD18C1 and MCD18C2 are global 0.05˚ CMG products in geographic map projection.

For gridded L3 products, one product file is produced for one day over one MODIS sinusoidal land tile. Names of MCD18A1 and MCD18A2 follow file naming convention of standard MODIS products:

```
MCD18AX.AYYYYDDD.hHHvVV.062.PPPPPPPPPPPPP.hdf
where
X =1: DSR, 2: PAR
YYYY = year
DDD = day of year
HH = horizontal tile coordinate
VV = vertical tile coordinate
PPPPPPPPPPPPP = production date
```

For 0.05˚ CMG products, one single global product file is produced for one day. Names of MCD18C1 and MCD18C2 follow file naming convention of standard MODIS products:

```
MCD18CX.AYYYYDDD.062.PPPPPPPPPPPPP.hdf
where
X =1: DSR, 2: PAR
YYYY = year
DDD = day of year
PPPPPPPPPPPPP = production date
```

3.1 MCD18A1 DSR product

MCD18A1 files are archived in Hierarchical Data Format V4 - Earth Observing System (HDF-EOS) format files. Each file contains global attributes (metadata) and scientific data sets (SDSs, data layers).

3.1.1 Metadata

MCD18A1 contains several global metadata attributes. The attributes include some basic information, such as `HDFEOSVersion`, `identifier_product_doi`, `identifier_product_doi_authority`. They also contain three global attributes used by standard MODIS products, known as EOS Data Information System (EOSDIS) Core System (ECS), namely, `CoreMetadata.0`, `ArchiveMetadata.0` and `StructMetadata.0`.

Besides, there are two attributes specifically used by MCD18A1: `Orbit_amount` and `Orbit_time_stamp`. Orbit_amount stores the count of the MODIS overpass covering the current day and tile. Orbit_time_stamp contains time information of each overpass in the format of `YYYYDDDHHMM`:

```
where YYYY = year
DDD = day of year
HH = hour
MM = minute
```

3.1.2 Data layers

Each MCD18A1 file contains two major types of scientific data sets: instantaneous DSR array for each individual MODIS overpass and 3-hour DSR array. Users should use “filling value” to check if DSR is successfully retrieved or not. No additional quality flag information is provided. The data sets are archived in 11 SDSs (Table 1).

Table 1. Summary of scientific data sets (data layers) in MCD18A1

Name	**Content**	**Dimension**	**Data type**	**Unit**	**Fill value**	**Valid range**
DSR	Instantaneous total DSR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-1400
Direct	Instantaneous direct DSR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-1400

Diffuse	Instantaneous diffuse DSR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_0000_DSR	Total DSR at GMT 00:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_0300_DSR	Total DSR at GMT 03:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_0600_DSR	Total DSR at GMT 06:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_0900_DSR	Total DSR at GMT 09:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_1200_DSR	Total DSR at GMT 12:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_1500_DSR	Total DSR at GMT 15:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_1800_DSR	Total DSR at GMT 18:00	1200*1200	32bit floating	W/m^2	-1	0-1400
GMT_2100_DSR	Total DSR at GMT 21:00	1200*1200	32bit floating	W/m^2	-1	0-1400
DSR_Quality	Quality flag	1200*1200	8bit unsigned integer	N/A	4	0-2

n: the count of MODIS overpass, available from global attribute “Orbit_amount”

SDSs directly store DSR values. Scale and offset factors are not needed.

DSR_Quality is currently used to indicate the input source of surface reflectance data. 0: no valid surface reflectance data; 1: from the MCD43 product, 2: from the climatology data; 4: non land pixel.

3.2 MCD18A2 PAR product

MCD18A2 files are organized in a manner similar to MCD18A1. The difference is that MCD18A2 contains PAR values instead of DSR values (Table 2).

Table 2. Summary of scientific data sets (data layers) in MCD18A2

Name	Content	Dimension	Data type	Unit	Fill value	Valid range
PAR	Instantaneous total PAR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-700
Direct	Instantaneous direct PAR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-700
Diffuse	Instantaneous diffuse PAR at MODIS overpass	n*1200*1200	32bit floating	W/m^2	-1	0-700
GMT_0000_PAR	Total PAR at GMT 00:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_0300_ PAR	Total PAR at GMT 03:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_0600_ PAR	Total PAR at GMT 06:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_0900_ PAR	Total PAR at GMT 09:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_1200_ PAR	Total PAR at GMT 12:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_1500_ PAR	Total PAR at GMT 15:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_1800_ PAR	Total PAR at GMT 18:00	1200*1200	32bit floating	W/m^2	-1	0-700
GMT_2100_ PAR	Total PAR at GMT 21:00	1200*1200	32bit floating	W/m^2	-1	0-700
PAR_Quality	Quality flag	1200*1200	8bit unsigned integer	N/A	4	0-2

n: the count of MODIS overpass, available from global attribute “Orbit_amount”

SDSs directly store PAR values. Scale and offset factors are not needed.

PAR_Quality is currently used to indicate the input source of surface reflectance data. 0: no valid surface reflectance data; 1: from the MCD43 product; 2: from the climatology data; 4: non land pixel.

3.3 MCD18C1 DSR CMG product

MCD18C1 is aggregated from MCD18A1 files, including eight global 3-hour DSR layers at 0.05˚ spatial resolution and in geographic map projection.

Table 3. Summary of scientific data sets (data layers) in MCD18C1

Name	Content	Dimension	Data type	Unit	Fill value	Valid range
GMT_0000_DSR	Total DSR at GMT 00:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_0300_DSR	Total DSR at GMT 03:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_0600_DSR	Total DSR at GMT 06:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_0900_DSR	Total DSR at GMT 09:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_1200_DSR	Total DSR at GMT 12:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_1500_DSR	Total DSR at GMT 15:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_1800_DSR	Total DSR at GMT 18:00	3600*7200	32bit floating	W/m^2	-1	0-1400
GMT_2100_DSR	Total DSR at GMT 21:00	3600*7200	32bit floating	W/m^2	-1	0-1400

3.3 MCD18C2 PAR CMG product

MCD18C2 is aggregated from MCD18A2 files, including eight global 3-hour PAR layers at 0.05˚ spatial resolution and in geographic map projection.

Table 4. Summary of scientific data sets (data layers) in MCD18C2

Name	Content	Dimension	Data type	Unit	Fill value	Valid range
GMT_0000_PAR	Total PAR at GMT 00:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_0300_ PAR	Total PAR at GMT 03:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_0600_ PAR	Total PAR at GMT 06:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_0900_ PAR	Total PAR at GMT 09:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_1200_ PAR	Total PAR at GMT 12:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_1500_ PAR	Total PAR at GMT 15:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_1800_ PAR	Total PAR at GMT 18:00	3600*7200	32bit floating	W/m^2	-1	0-700
GMT_2100_ PAR	Total PAR at GMT 21:00	3600*7200	32bit floating	W/m^2	-1	0-700

4. Obtaining MODIS DSR and PAR products

The MODIS DSR (MCD18A1) and PAR (MCD18A2) products are available to users free of charge. The products are archived at the Land Processes Distributed Active Archive Center (LP-DAAC). They can be ordered and downloaded through Earthdata Search (https://search.earthdata.nasa.gov/).

5. References

Wang, D., Liang, S., Li, R., & Jia, A. (2021). A synergic study on estimating surface downward shortwave radiation from satellite data. *Remote Sensing of Environment*, 264, doi:10.1016/j.rse.2021.112639

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Liang, S., Zheng, T., Liu, R., Fang, H., Tsay, S.C., & Running, S. (2006). Estimation of incident photosynthetically active radiation from Moderate Resolution Imaging Spectrometer data. *Journal of Geophysical Research-Atmospheres*, 111