Suomi-NPP and JPSS-1 VIIRS Downward Shortwave Radiation (VNP18A1/VJ118A1) and Photosynthetically Active Radiation (VNP18A2/VJ118A2) User Guide

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1. Introduction

Downward shortwave radiation (DSR) designates solar radiation with a wavelength from 300 to 4000 nm received at the Earth's surface. It is the driving force of many global ecological, hydrological, biophysical, and biochemical processes and is a key variable in modeling weather and climate systems. Photosynthetically active radiation (PAR) is particular in the spectral range of solar radiation from 400-700 nm and is one of the main input variables of terrestrial ecosystem modeling, carbon cycle modeling and agriculture applications. Direct and diffuse radiation are also two important variables and needed to be separated from the total radiation for various studies, as they present diverged efficacies on the evapotranspiration and net ecosystem exchange process (Wang, Dickinson, & Liang, 2008). Long-term data records of DSR/PAR and their direct and diffuse partitions are thus essential for global environmental and climate monitoring.

Few surface radiation products contain PAR, direct and diffuse radiation information, which will impose difficulties and bring uncertainties to users when they try to convert DSR to PAR or separate diffuse and direct radiation from the total. Besides, the existing global satellite products of surface radiative fluxes have comparatively coarse spatial resolutions and most of them have not been updated since the 2000s, such as 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.

The high-quality DSR and PAR products with finer spatial and temporal resolution are consequently needed for a better understanding of critical Earth science processes and applications. The MODerate resolution Imaging Spectroradiometer (MODIS) 1km DSR and PAR products (MCD18) have been released in 2017. With the aging of MODIS sensors, continuous and consistent DSR and PAR product retrieved from the Visible Infrared Imaging Radiometer Suite (VIIRS), onboard on the Suomi-NPP and JPSS-1 satellites is needed for long-term remote sensing environmental data records. Therefore, the same algorithm is applied to the VIIRS data to generate DSR (VNP18A1 and VJ118A1) and PAR (VNP18A2 and VJ118A2) product. Instantaneous, 3hour, daily DSR and PAR, and their corresponding direct and diffuse radiation are derived at 1 km resolution globally. This user guide aims to provide a brief description of the retrieval algorithm and the technical details about data files and scientific data sets.

2. Algorithm summary

The VIIRS DSR/PAR algorithm adapted the narrowband look-up table (LUT) approach used to produce the MODIS DSR and PAR product (MCD18). Two parameterization schemes are used to simplify the radiative transfer process and the parameters calculated are simulated offline and

saved as two LUT. The first scheme is to parameterize TOA spectral reflectance R(λ) at wavelength λ from surface spectral reflectance r(λ):

$$x = R_0(\lambda) + \frac{r(\lambda)}{1-r(\lambda)\rho(\lambda)}\cos(\theta_s)\gamma/\pi \qquad (1)$$

where θ_s is solar zenith angle (SZA). $R_0(\lambda)$ and $\rho(\lambda)$ are path reflectance, atmospheric spherical albedo for the spectral band at wavelength λ. γ is the transmittance. After retrieving the transmittance γ, surface broadband downward radiation fluxes (F) can be calculated as:

$$F = F_0 + \frac{r\rho}{1-r\rho}E_0\cos(\theta_s)\gamma \qquad (2)$$

where r is surface broadband reflectance, E0 is extraterrestrial solar broadband irradiance, θ_s is SZA, F0 is path irradiance, and ρ is atmospheric spherical albedo.

VIIRS TOA reflectance, geolocation, VIIRS surface albedo, MERRA2 water vapor, GTOPO30 DEM, and surface reflectance climatology data are used as the input data. The major steps are summarized as:

1) TOA radiance is calculated for each atmospheric condition from the clearest condition to the cloudiest conditions (high cloud extinction coefficient) based on the TOA LUT in Figure 2. Then, the actual observed TOA radiance is compared to the series of the radiance calculated for different atmospheric conditions to retrieve the atmospheric index.
2) Both instantaneous DSR and PAR, as well as the direct and diffuse radiation, are estimated by searching the surface LUT using the estimated surface reflectance, atmospheric index, elevation, water column data.
3) The instantaneous values are interpolated to produce 3-hour values and thus to aggregate to daily mean values.

3. Product description

The product IDs of the VIIRS DSR product is VNP18A1 or VJ118A1 for SNPP and JPSS1 respectively. The product ID for PAR is VNP18A2 or VJ118A2. All the VIIRS DSR and PAR products are gridded L3 data sets in sinusoidal map projection with 1km resolution. The details of sinusoidal map projection can be found at https://modis-land.gsfc.nasa.gov/MODLAND_grid.html. Each file is produced for one day over one sinusoidal land tile. The filenames follow the naming convention:

```
VSS18AX.AYYYYDDD.hHHvVV.CCC.PPPPPPPPPPPPP.h5
Where
SS =NP: SNPP, J1: JPSS1
X =1: DSR, 2: PAR
```

```
YYYY = year
DDD = day of year
HH = horizontal tile coordinate
VV = vertical tile coordinate
CCC = version number
PPPPPPPPPPPPP = production date
```

The products are archived in Hierarchical Data Format V5 - Earth Observing System (HDF-EOS5) format. Both global attributes (metadata) and scientific data sets (SDSs) are stored.

3.1 Metadata

Beside the general information shared by VIIRS standard products, there are two orbit-related attributes saved in the metadata: `Orbit_amount` and `Orbit_time_stamp`. Orbit_amount represents the number of the VIIRS overpass covering the current day and tile. Orbit_time_stamp stores the UTC time of each overpass.

3.2 Science datasets (SDS)

Both VNP18A1/VJ118A1 and VNP18A2/VJ118A2 are archived in 6 SDSs. Users should use "filling value" to check if DSR/PAR is successfully retrieved or not. Table 1 summarizes the 6 SDSs of VNP18A1/VJ118A1. Sample images illustrating the 3hour DSR and daily DSR of one tile are shown in Figure 1.

Table 1. Summary of scientific data sets (data layers) in VNP18A1/VJ118A1

SDS long name	Content	Dimension	Data type	Unit	Fill value	Valid range
Instantaneous DSR at VIIRS overpass	Instantaneous total DSR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-1400
Instantaneous direct portion of DSR at VIIRS overpass	Instantaneous direct DSR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-1400
Instantaneous diffuse portion of DSR at VIIRS overpass	Instantaneous diffuse DSR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-1400
3-hour mean DSR	Total DSR averaged between UTC 00:00-03:00, 03:00-06:00, 06:00-09:00, 09:00-12:00, 12:00-15:00,	8*1200*1200	32bit floating	W/m^2	-1	0-1400

	15:00-18:00, 18:00-21:00, 21:00-24:00					
Daily mean DSR	Daily averaged total DSR	1200*1200	32bit floating	W/m^2	-1	0-1400
DSR quality flag	Quality flag	1200*1200	8bit unsigned integer	N/A	N/A	0-4

n: the count of VIIRS 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 ; 01: from the VNP43/VJ143 product, 10: from the climatology data (1-4).

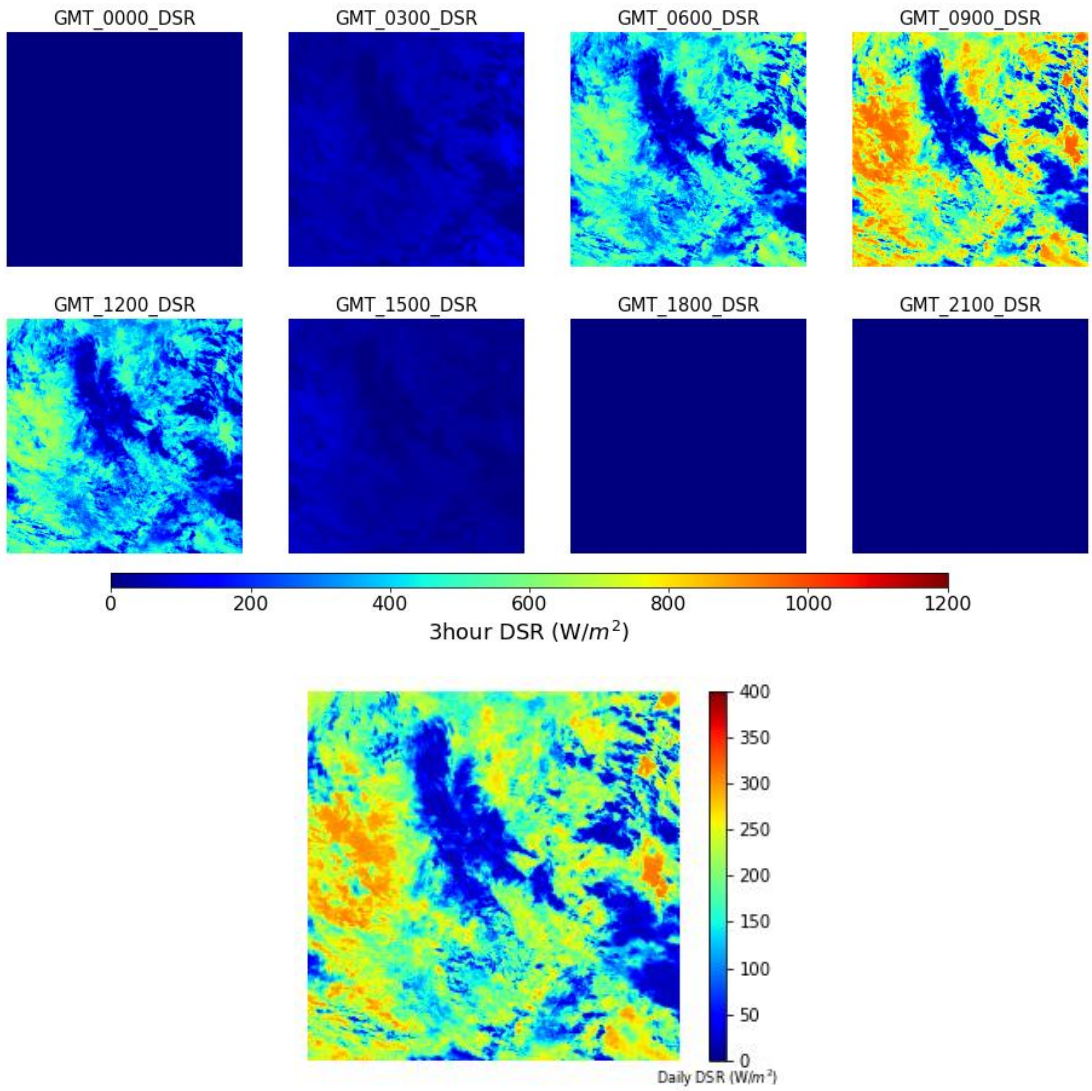

Figure 1. Sample of VNP18A1 3 hour and daily DSR.

VNP18A2/VJ118A2 files are organized in a similar manner with VNP18A1/VJ118A1, but contains PAR values instead of DSR values (Table 2). Sample images of one tile illustrating the 3hour DSR and daily PAR are shown in figure 2.

Table 2. Summary of scientific data sets (data layers) in VNP18A2/VJ118A2

SDS long name	Content	Dimension	Data type	Unit	Fill value	Valid range
Instantaneous PARR at VIIRS overpass	Instantaneous total PAR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-700
Instantaneous direct portion of PAR at VIIRS overpass	Instantaneous direct PAR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-700
Instantaneous diffuse portion of PAR at VIIRS overpass	Instantaneous diffuse PAR at VIIRS overpass time	n*1200*1200	32bit floating	W/m^2	-1	0-700
3-hour mean PAR	Total PAR averaged between UTC 00:00-03:00, 03:00-06:00, 06:00-09:00, 09:00-12:00, 12:00-15:00, 15:00-18:00, 18:00-21:00, 21:00-24:00	8*1200*1200	32bit floating	W/m^2	-1	0-700
Daily mean PAR	Daily averaged total PAR	1200*1200	32bit floating	W/m^2	-1	0-700
PAR quality flag	Quality flag	1200*1200	8bit unsigned integer	N/A	N/A	0-4

n: the count of VIIRS 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. 00: no valid surface reflectance data ; 01: from the VNP43/VJ143 product, 10: from the climatology data.

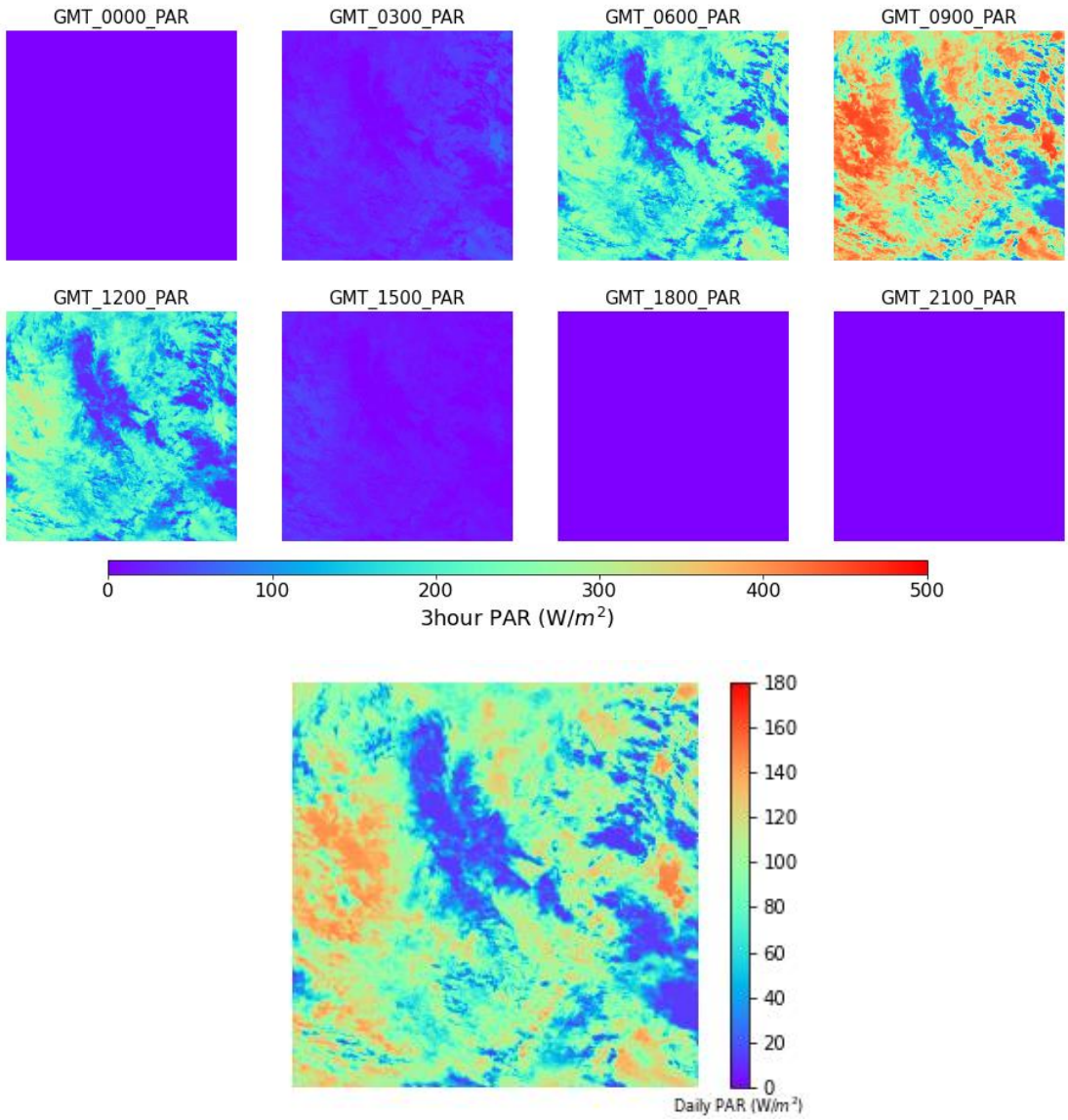

Figure 2. Sample of VNP18A2 3 hour and daily PAR.

3.3 VNP18C1/VJ118C1 DSR CMG product

VNP18C1/VJ118C1 is aggregated from VNP18A1/VJ118A1 files, including one set of global 3-hour DSR layers and one set of daily mean DSR at 0.05˚ spatial resolution and in geographic map projection. One example of the gobal maps of 3-hour and daily mean DSR is whon in Figure 3.

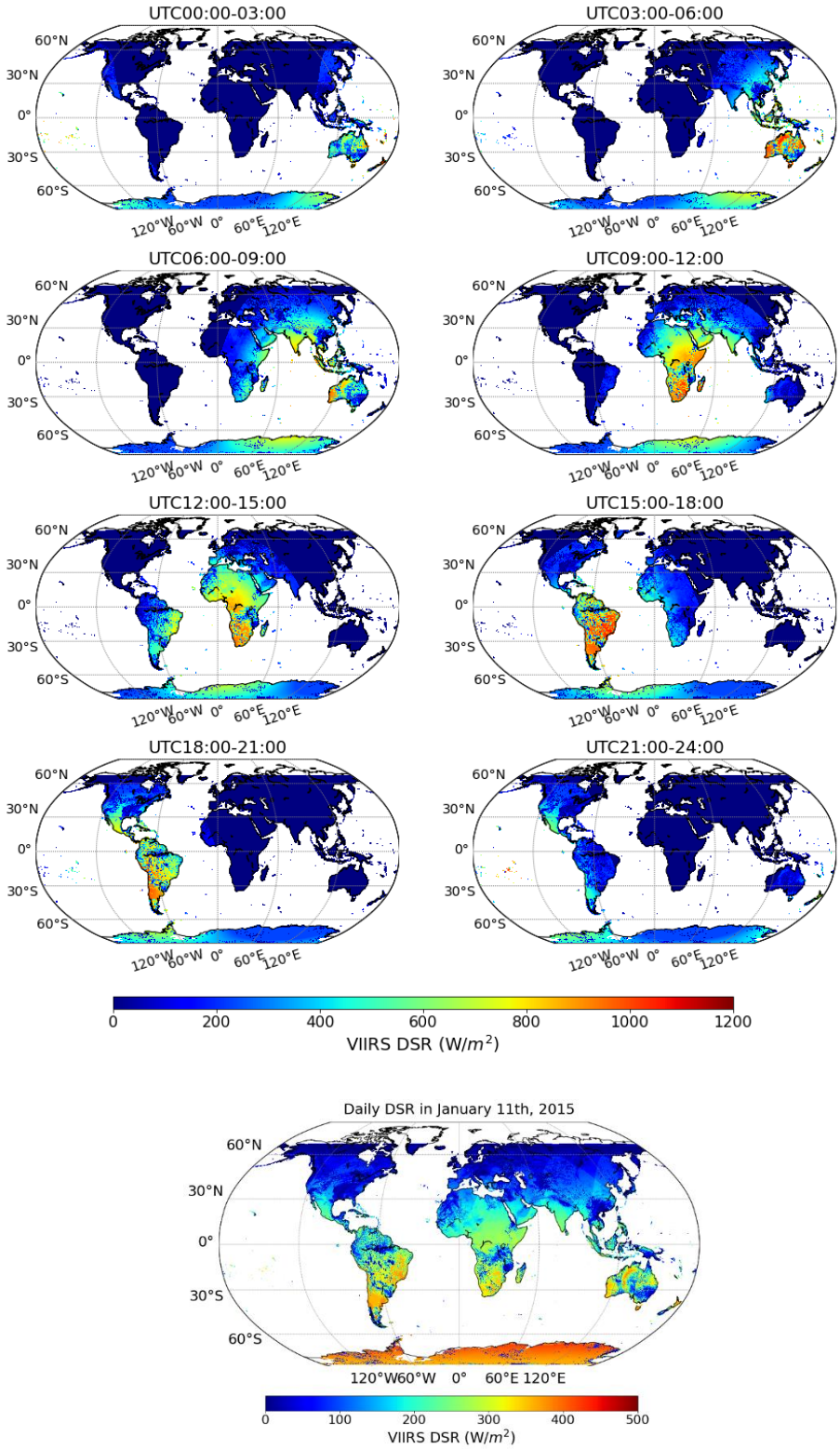

Figure 3. Global maps of 3-hourly DSR and daily DSR on January 11th, 2015 from VNP18

Table 3. Summary of scientific data sets (data layers) in VNP18C1/VJ118C1

SDS long name	Content	Dimension	Data type	Unit	Fill value	Valid range
3-hour mean DSR	Total DSR averaged between UTC 00:00-03:00, 03:00-06:00, 06:00-09:00, 09:00-12:00, 12:00-15:00, 15:00-18:00, 18:00-21:00, 21:00-24:00	8*3600*7200	32bit floating	W/m^2	-1	0-1400
Daily mean DSR	Daily averaged total DSR	3600*7200	32bit floating	W/m^2	-1	0-1400

3.4 VNP18C2/VJ118C2 PAR CMG product

VNP18C2/VJ118C2 is aggregated from VNP18A2/VJ118A2 files, including one set of global 3-hour PAR layers and one set of daily mean PAR at 0.05˚ spatial resolution and in geographic map projection.

Table 4. Summary of scientific data sets (data layers) in VNP18C2/VJ118C2

SDS long name	Content	Dimension	Data type	Unit	Fill value	Valid range
3-hour mean PAR	Total PAR averaged between UTC 00:00-03:00, 03:00-06:00, 06:00-09:00, 09:00-12:00, 12:00-15:00, 15:00-18:00, 18:00-21:00, 21:00-24:00	8*3600*7200	32bit floating	W/m^2	-1	0-700
Daily mean PAR	Daily averaged total PAR	3600*72 00	32bit floating	W/m^2	-1	0-700

4. Obtaining VIIRS DSR and PAR products

The VIIRS DSR (VNP18A1/VJ118A1) and PAR (VNP18A2/VJ118A2) products are available to users free of charge. The products are archived at the Land Processes Distributed Active

Archive Center (LP-DAAC), and can be ordered and downloaded through Earthdata Search (https://search.earthdata.nasa.gov/).

5. References

Wang, D., Liang, S., Zhang, Y., Gao, X., Brown, M. G., & Jia, A. (2020). A new set of MODIS land products (MCD18): Downward shortwave radiation and photosynthetically active radiation. *Remote Sensing*, 12(1), 168, doi:10.3390/rs12010168

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