PAR and Insolation

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Incident solar radiation product, either photosynthetically active radiation (PAR) in the visible spectrum (400-700nm) or insolation in the total shortwave spectrum (300-4000nm) is needed to address a variety of scientific questions and applications, such as climate trends, hydrologic and biogeophysical modelling, solar energy applications, and agriculture.

1. Scientific rationale and importance of products and expected end users

1.1 What are the science questions or applications drivers that the product will be used to address?

- *How is the global Earth system changing?*
- *How will the atmospheric contribution to the land surface change with the effects of global warming?*
- *What are the evaporative flux rates and partitioning between sensible heat and latent heat at the land surface of the Earth and how are they spatially distributed and how are they changing?*
- *How is land use changing and what are the consequences of any changes on the water, energy, and carbon cycles?*
- *What role does the land surface play in determining the dependence of the large-scale atmospheric circulation?*
- *How well can we predict the changes in the Earth system that will occur in the future?*

1.2 Why is the product important to a NASA Earth Science Focus Areas?

Carbon Cycle and Ecosystems Focus Area: Incident PAR is a critical forcing of photosynthesis. Many ecosystem models calculate biomass accumulation linearly proportional to incident PAR. Different terrestrial ecosystem models, including models of terrestrial biogeochemistry, global vegetation biogeography, dynamic vegetation and land-atmosphere exchange processes have been developed for the function and dynamic nature of ecosystems, along with their role in the global carbon, nutrition, and water cycles. Almost all these models contain the physiological processes involved in photosynthesis and stomatal regulation that control the exchange of water vapor and carbon dioxide (CO_2) between vegetation canopies and the atmosphere. Incident PAR is a critical variable to initiate, calibrate and validate these models,

Climate Variability and Change Focus Area: In climate research, radiative processes are central to the climate's energy cycle: climate is determined by the imbalances of solar radiative heating and longwave radiative cooling. Radiation is a central process of the climate system to be understood, and a critical tool to obtain that understanding. Modulations of the radiation budget associated with changing surface and atmospheric conditions, including clouds, give rise to significant climate feedbacks that are considered to be among the most uncertain aspects in our understanding of climate and climatic change.

Water and Energy Cycle Focus Area: Understanding water and energy cycles and how they are affected by climate change.

Application Areas: Agricultural productivity and sustainability, Ecological Forecasting, Energy Management, Public Health, Water Management.

1.3 Which user communities need the product?

Hydrologists/Ecologists for characterizing surface fluxes, managing water and carbon resources;

Agronomists for monitoring crops, estimating water requirements and predicting yields at farm to continental scales;

Federal Agencies involved in water resource allocation, crop yield assessment and drought monitoring;

Urban and regional planners for mitigating heat island effects.

2. Scientific requirements for the products

Requirements vary depending on science questions being answered. The MODIS science team is currently generating the official MODIS global terrestrial gross and net primary production (GPP and NPP) product with Data Assimilation Office (DAO) as an input. Zhao et al. (2006) examined European Centre for Medium-Range Weather Forecasts (ECMWF) (ERA-40) and National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis by comparing these meteorological reanalysis data with the observations from weather stations. They found that the biases in meteorological input data can introduce substantial error into MODIS GPP and NPP estimations, and emphasized the need for more accurate incident solar radiation product.

For supporting MODIS GPP/NPP production, it requires 1km spatial resolution and 8 day temporal resolution. For climate studies, coarser spatial resolutions (e.g. >1° * 1°) and higher temporal resolutions (e.g., 3 hours and daily) are needed.

Record length varies depending on science or application requirement. Climate change studies would need the record length of 6+ years.

3. Approach to generating the products

There are roughly two types of algorithms for calculating incident solar radiation. The first approach is to use the retrieved cloud and atmosphere parameters from other sources, with measured top-of-atmosphere (TOA) radiance/flux acting as a constraint. The Clouds and the Earth's Radiant Energy System (CERES) algorithm (Wielicki, Barkstrom et al. 1998) uses the cloud and aerosol information from MODIS, and TOA broadband fluxes as a constraint, to produce both insolation and PAR at the spatial resolution of 25km with the instantaneous sensor footprint. The International Satellite Cloud Climatology Project (ISCCP) has produced a new 18-year (1983-2000) global radiative flux data product called ISCCP FD, every three hours on a 280 km equal-area global grid (Zhang, Rossow et al. 2004). ISCCP FD has been calculated using a radiative transfer model from the Goddard Institute for Space Studies (GISS) General Circulation Model (GCM) with the atmosphere and surface properties primarily from the TIROS Operational Vertical Sounding (TOVS) data.

The second approach is to establish the relationship between the TOA radiance and surface incident insolation or PAR based on extensive radiative transfer simulations. This method was first applied to analyze Earth Radiation Budget Experiment (ERBE) data. Liang et al. (2006) generated the PAR and insolation products at 1km from MODIS data directly using the similar approach. The Global Energy and Water Cycle Experiment (GEWEX) surface radiation budget (SRB) Release 2 product has a spatial resolution of 1° x 1° and high temporal resolutions mainly from GOES data (Pinker, Tarpley et al. 2003).

4. Intended sources for the products

Different satellite sensors can be used to produce incident PAR or insolation at different spatial and temporal resolutions. For climate studies, CERES broadband sensors are needed at the global scale, and geostationary sensors (e.g., GOES) are needed at the continental scale. For ecosystem, carbon cycle and hydrological studies, polar-orbiting narrowband sensors, such as MODIS, AVHRR, will be used. In the future, after Terra is out of commission, the next generation of instruments, NPOESS/VIIRS, will be the primary instrument. Other instruments, such as SPOT-VEGETATION can be used as an alternative data source to generate incident PAR and insolation if both MODIS and VIIRS fail.

PAR and insolation products generated from satellites can be validated against surface-based measurements such as those currently provided by several global networks: the

World Climate Research Program (WCRP) Baseline Surface Radiation Network (BSRN), NOAA's SURFRAD and ISIS , FLUXNET, Atmospheric Radiation Measurement Program (ARM) Cloud and Radiation Testbed (CART).

5. Relationships to other products and programs

PAR or insolation will be inputs to generate the MODIS GPP /NPP products and surface hydrology products. Mapping these variables also makes a significant contribution to other large international and regional projects, such as the Global Carbon Project, the Global Terrestrial Observing System, the North American Carbon Program, the Atmospheric Radiation Measurement Program, the Global Energy and Water Cycle Experiment, and the Global Climate Observing System.

6. Key references

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