Ocean Surface radiation products from MODIS and VIIRS data

Robert Frouin and Jing Tan, SIO/UCSD, La Jolla, California, USA

1. INTRODUCTION

-Knowing the spatial and temporal distribution of visible solar radiation in the upper ocean is critical to understanding biogeochemical cycles of carbon, nutrients, and oxygen, to addressing climate and global change issues, such as the fate of anthropogenic atmospheric carbon dioxide, and to making future climate projections.

-A simple yet efficient and fairly accurate algorithm was developed to estimate daily mean PAR at the ocean surface from SeaWiFS data (Frouin et al., 2003) and adapted to other sensors in polar orbit, including MODIS-T and -A (Frouin et al., 2012), VIIRS-NPP and -JPSS1.

-Global PAR time series from MODIS and VIIRS data have been routinely produced by the NASA Ocean Biology Processing Group (OBPG) and made available to the user community. The standard Level-2 and -3 PAR products have been used extensively in the science community.

-However, current radiation products, despite their utility, do not fit significant needs of the oceanography community. Other products are required, i.e., sub-surface planar and scalar fluxes, average cosine, spectral fluxes (ultraviolet to visible), diurnal fluxes, fraction of PAR absorbed by live phytoplankton, surface albedo, vertical attenuation, and heating rate, and for associating uncertainties to any product on a pixel-by-pixel basis (Frouin et al., 2018). The requirements are also for consistent time series across sensors and products with no spatial or temporal gaps.

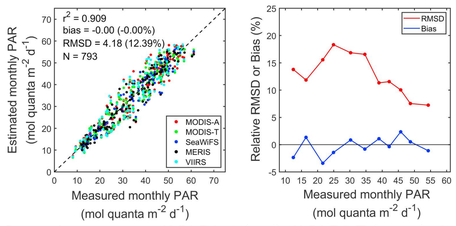
2. GENERATION of CONSISTENT TIME SERIES

- First, a reference time series using the PAR data from SeaWiFS, MODIS-A, and MODIS-T was generated by averaging the monthly estimates from theses three instruments which were selected because they cross the equator at different local times (i.e., 10:30, 12:00, and 13:30, respectively); i.e., cloud diurnal variability is considered (at least partly).

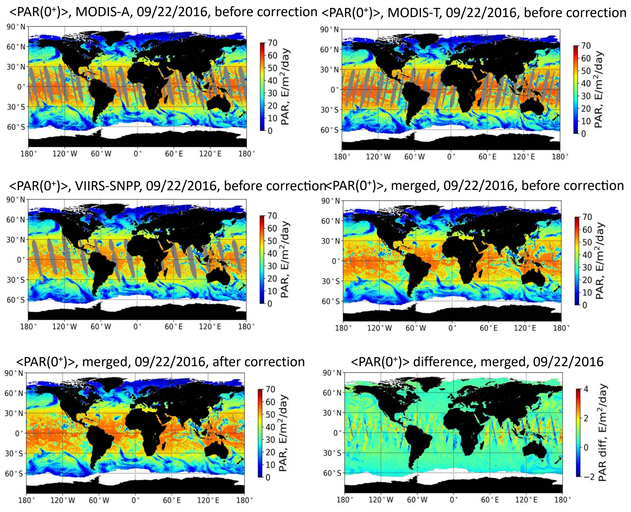
- Secondly, these monthly maps were used to correct the estimates from each individual instrument.

- Finally, the PAR values from other sensors (MERIS and VIIRS) were compared to the corrected PAR from SeaWiFS, MODIS-A, MODIS-T, or their combinations, and the biases were removed.

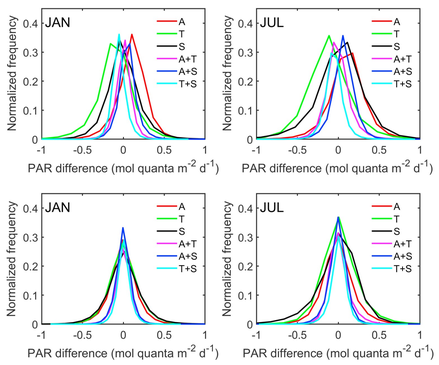
- The adjusted PAR for all sensors is then compared with in-situ measurements and corrected for possible biases.



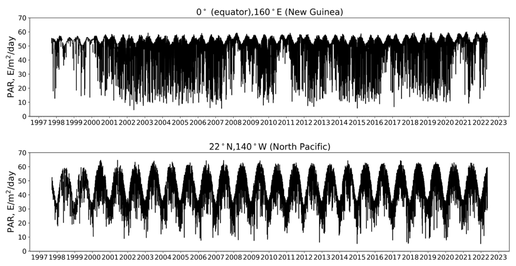
(left) Comparison between MODIS-A (red), MODIS-T (green), SeaWiFS (blue), MERIS (black), and VIIRS (cyan), monthly PAR and field measured monthly PAR at four sites (BOUSSOLE, CCE1, CCE2, and COVE). (right) Bias (blue line) and RMSD (red line) of satellite-derived monthly PAR as a function of field measured monthly PAR.



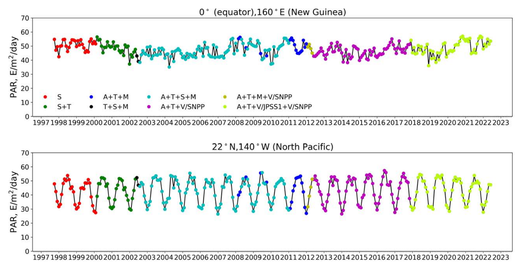
Global maps of daily mean PAR for September 22, 2016 (equinox), obtained from MODIS-A, MODIS-T, and VIIRS-SNPP without bias correction (top left, to right, and middle left, respectively), merged product before and after bias correction of estimates from individual sensors (middle right and bottom left, respectively) and the difference after bias correction (bottom right). Land is in black, sea ice in white, and missing values in gray. Missing values at low latitudes are almost filled in the merged product.



(top row) Histograms of January and July differences (left and right, respectively) between monthly mean PAR derived by SeaWiFS (S), MODIS-AQUA (A), MODIS-TERRA (T), or two of the instruments (A + T, A + S, and T + S), and PAR derived by the three instruments (A + T + S). (bottom row) Same as the top row but after correction of biases. The histograms are computed using PAR estimates in the tropical ocean from July 2002 to December 2010, when estimates from SeaWiFS, MODIS-AQUA, and MODIS-TERRA all exist.



Time series of satellite-derived daily mean PAR) in the western equatorial Pacific (0°, 160°E) and the northeast Pacific (22°N, 140°W) from September 1997 to April 2022. Values are averages over areas of about 46x46 km2. The PAR estimates obtained from SeaWiFS (S), MODIS-A (A), MODIS-T (T), MERIS (M), and VIIRS (V) are corrected for biases and averaged depending on data availability. Seasonal cycle is pronounced at 22oN and small at the Equator; short term variability dominates at the Equator.



Same as above, but monthly mean PAR

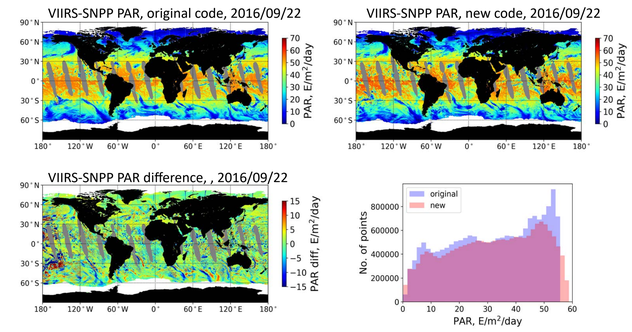
3. ALGORITHM IMPROVEMENT

-Instead of using the single-scattering approximation to estimate atmospheric reflectance in the retrieval of the reflectance of the cloud/surface layer, which becomes inaccurate at large Sun and view zenith angles, Look-Up Tables (LUTs) are constructed for the various aerosol models considered in the algorithm.

-The satellite climatology of aerosol optical thickness and Angstrom coefficient arereplaced by hourly 0.65ox0.5o MERRA-2 data (Gelaro et al., 2017) interpolated to the source grid.

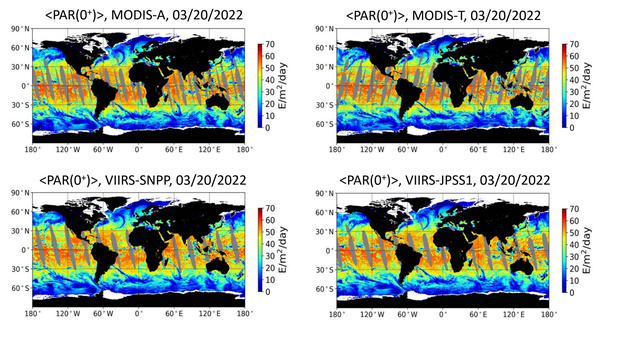
-The surface albedo, *As*, is parameterized according to Jin et al. (2011) as a function of Sun zenith angle, the ratio of direct and total radiation, and wind speed.

-The diurnal variability of clouds, a serious limitation when using a single satellite observation per day, are accounted for using MERRA-2 hourly cloud products

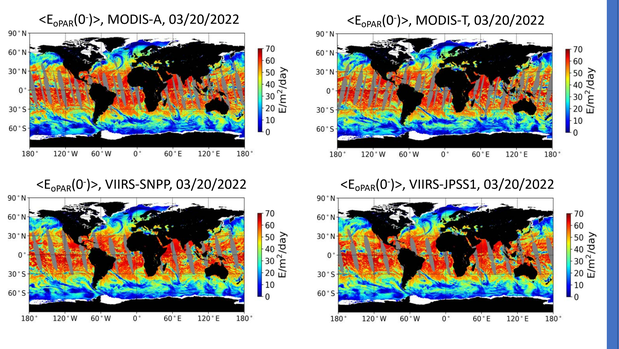


4. EXAMPLE NEW PRODUCT S

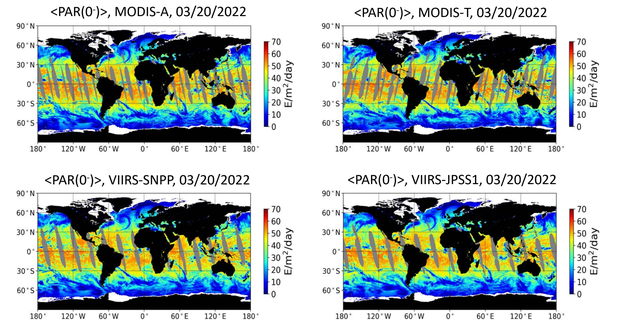
Daily mean planar fluxes just above surface



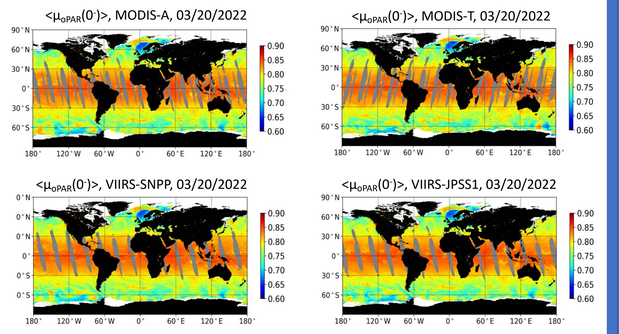
Daily mean scalar fluxes just below surface



Daily mean planar fluxes just below surface



Daily mean average cosine just below surface



5. SUMMARY

- An accurate 20-year record of monthly PAR over the tropical oceans from SeaWiFS, MODIS-AQUA, MODIS-TERRA, MERIS, and VIIRS data was generated. Such time series provides the means to investigate interannual variability of oceanic primary production and allow numerical modeling of biogeochemical impacts of long-term PAR changes.

- The PAR algorithm has been improved, including better quantifying the reflectance of the cloud/surface layer, surface albedo, aerosol optical properties, and cloud diurnal variabilities.

- In addition to the surface radiation products, the subsurface products including daily mean planar and scalar fluxes and average cosine just below surface from MODIS and VIIRS were generated, which are unique yet essential for understanding the global carbon cycle and ocean ecosystem responses to a changing climate.

Acknowledgements

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