Estimating Photosynthetically Available Radiation at the Ocean Surface from GOCI Data

Robert Frouin

Scripps Institution of Oceanography
University of California San Diego, La Jolla, USA

IOCS Meeting, 6-8 May 2013, Darmstadt, Germany

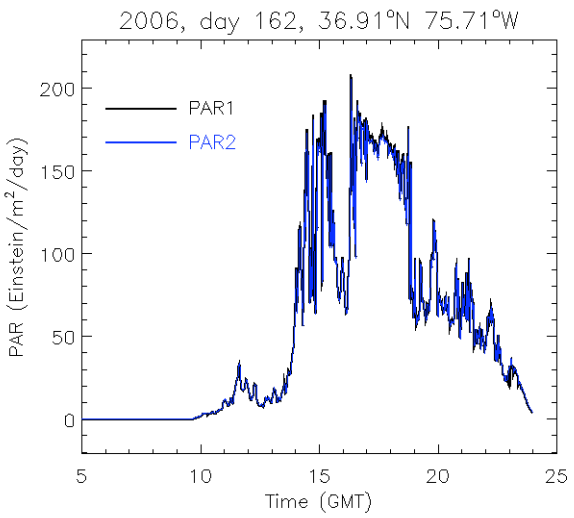
Introduction

-Photosynthetically Available Radiation (PAR), the quantum energy flux from the Sun in the spectral range 400-700 nm, controls the growth of phytoplankton and, therefore, the development of crustaceans, fish, and other consumers. It ultimately regulates the composition and evolution of marine ecosystems.

-GOCI data can be used to generate surface PAR imagery over the East Asia Seas and Northwest Pacific at a 0.5 km resolution and a daily temporal scale for studies of aquatic photosynthesis.

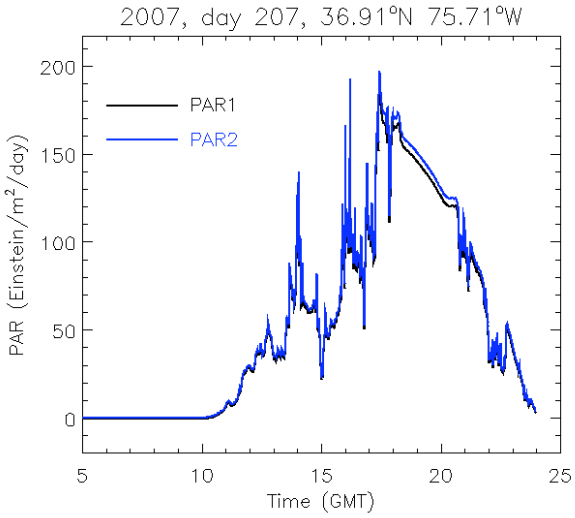
-GOCI is adapted to the problem, since it measures at visible wavelengths and does not saturate over clouds, and the measurements provide adequate temporal sampling to handle diurnal cloud variability.

PAR diurnal variability, COVE site



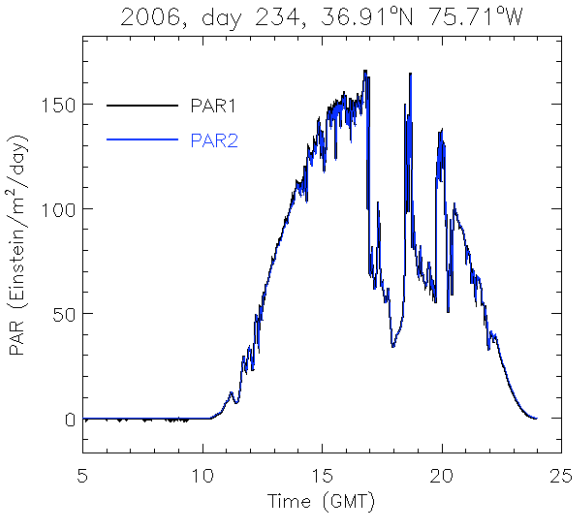
MODIS-T: 16.25 GMT
MODIS-A: 17.83 GMT
SeaWiFS: 18.19 GMT

PAR (in situ): 41.7 E/m²/d
PAR (SeaWiFS): 58.9 E/m²/d
PAR (MODIS-T, MODIS-A, SeaWIFS): 53.6 E/m²/d



MODIS-T: 15.25, 16.83 GMT
SeaWiFS: 18.34 GMT
MODIS-A: 18.50 GMT

PAR (in situ): 43.53 E/m²/d
PAR (SeaWiFS): 56.87 E/m²/d
PAR (MODIS-T, MODIS-A, SeaWIFS): 41.28 E/m²/d



MODIS-T: 15.42 GMT
MODIS-A: 18.67 GMT
SeaWiFS: 19.13 GMT

PAR (in situ): 40.9 E/m²/d
PAR (SeaWiFS): 34.9 E/m²/d
PAR (MODIS-T, MODIS-A, SeaWIFS): 42.4 E/m²/d

Measured surface PAR in typical cloudy situations at the COVE site. Combining estimates from three satellite instruments measuring at different times accounts for diurnal variability of clouds, therefore reduces differences with in situ measurements.

Approach

-Instantaneous PAR is computed for each GOCI pixel as the difference between the incident 400-700 nm solar flux (known) and the reflected flux (measured), taking into account atmospheric absorption (modeled).

-Instantaneous estimates (8 GOCI observations per day) are combined to compute daily PAR.

-Knowledge of pixel composition is not required, eliminating the need for cloud screening and arbitrary assumptions about sub-pixel cloudiness.

Model

-The solar flux reaching the ocean surface is given by

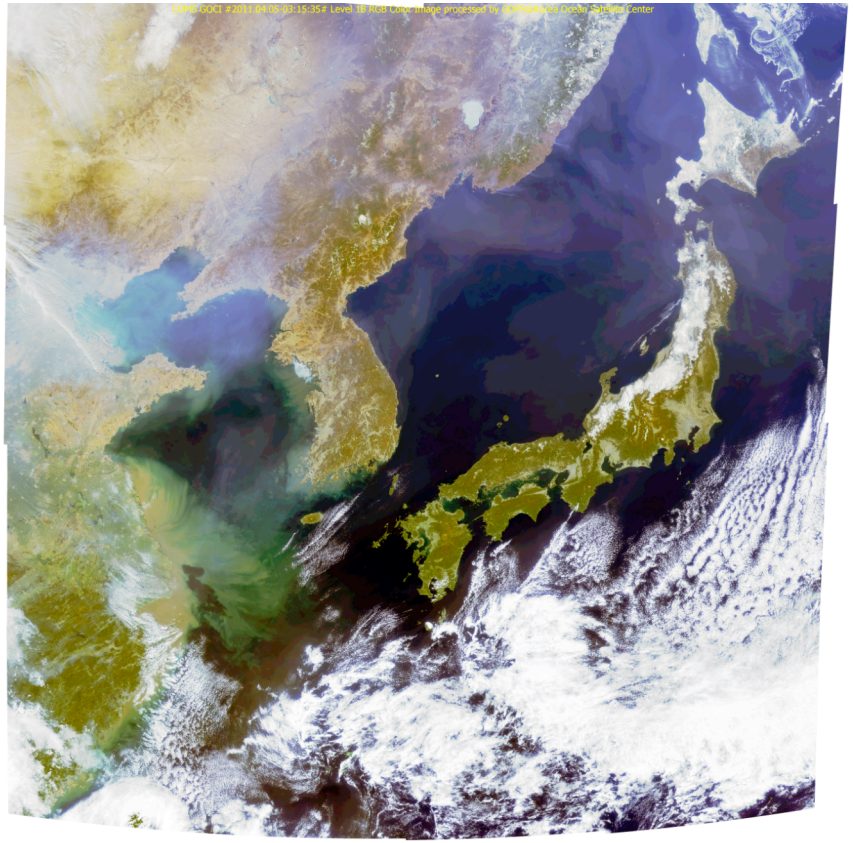
$$E = E_{clear}(1 - A)(1 - A_s)^{-1}$$

where A is the albedo of the cloud-surface system and A_s the albedo of the surface, and E_{clear} is the clear sky solar flux.

-A is expressed as a function of the radiance measured by the satellite sensor in the PAR spectral range, i.e., at 412, 443, 490, 510, 660, and 680 nm.

Application to GOCI Imagery

GOCI, 05 April 2011, 03:16 GMT, True color



(Provided by KORDI.)

-05 April 2011, 8 images (00:16, 01:16, 02:16, 03:16, 04:16, 05:16, 06:16, 07:16 GMT).

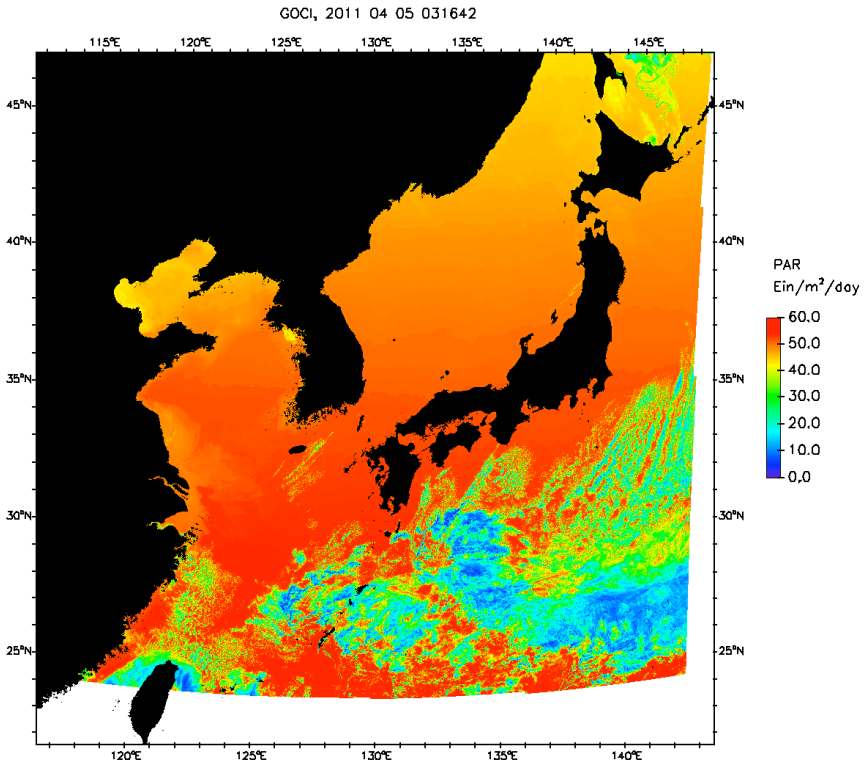
-Acquisition time assumed constant for entire image.

-Ozone and water vapor amount taken from climatology.

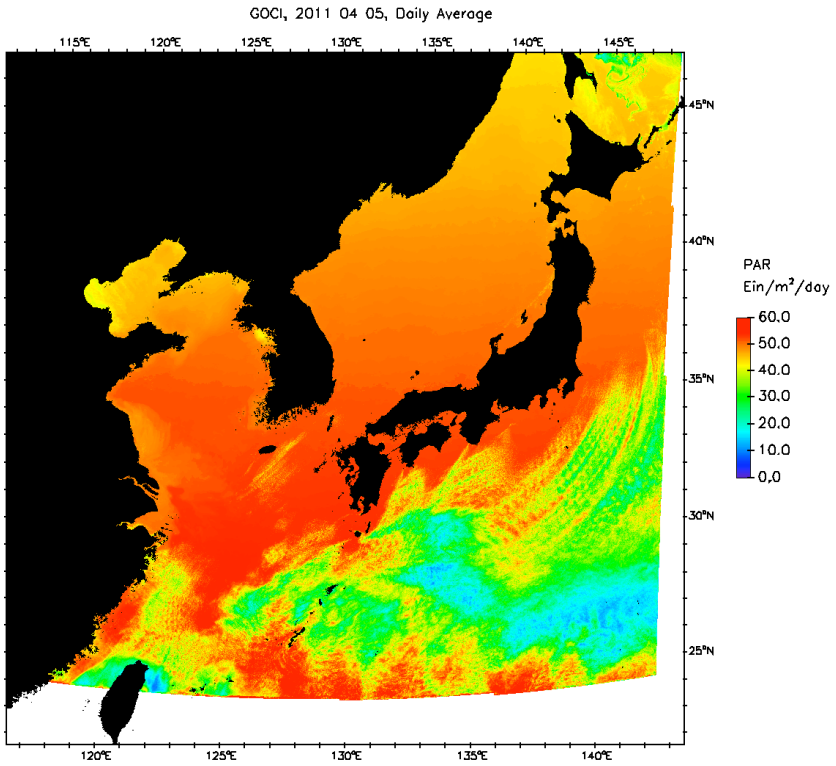
-Aerosol optical thickness at 865 nm and Angstrom coefficient taken from MODIS April climatology.

-Ocean albedo parameterized according to Jin et al. (2004).

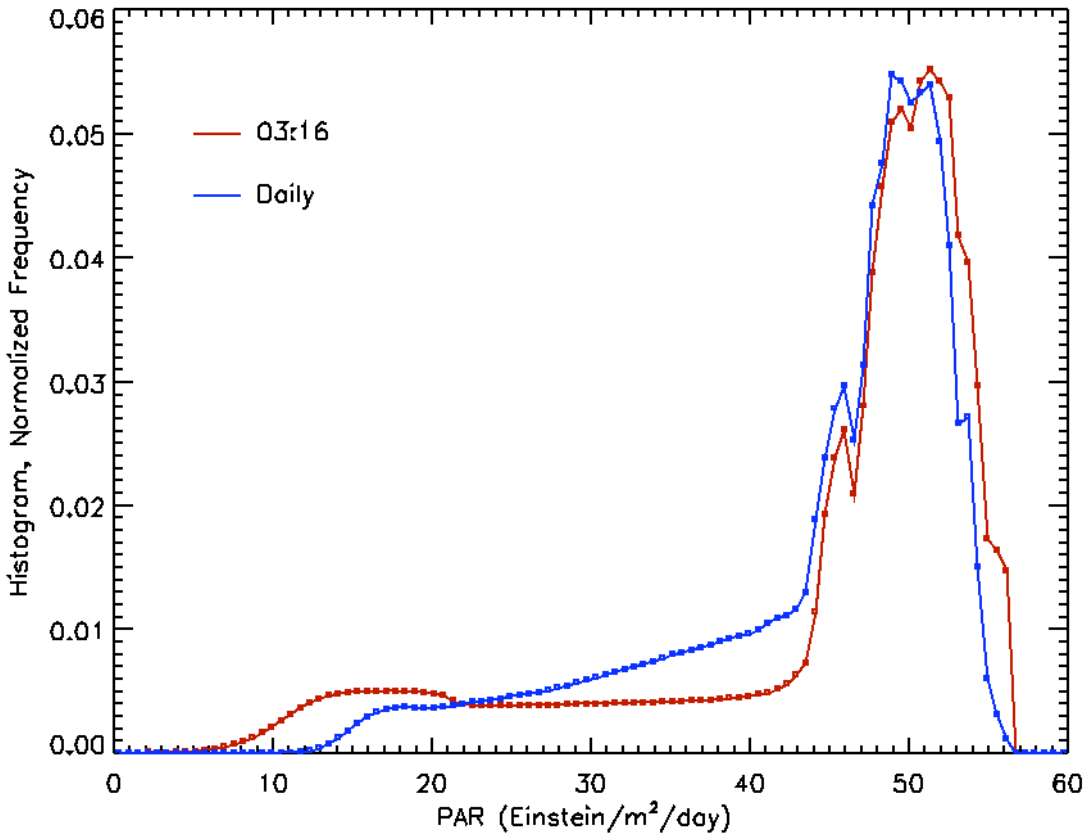
Daily PAR from 03:16 GMT image



Daily PAR from 8 images



Daily PAR imagery for April 5, 2011 obtained from eight GOCI observations at 00:16, 01:16, 02:16, 0.3:16, 04:16, 05:16, 06:16, and 07:16 GMT (right) and a single GOCI observation at 03:16 GMT (left).



Comparison Statistics

N = 16676030

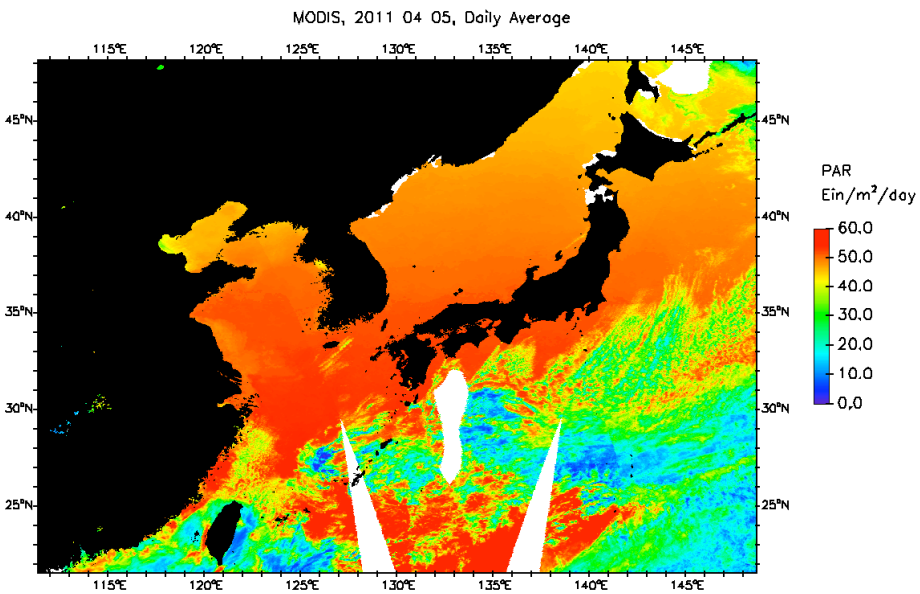
R^2 = 0.759

Bias = 0.09 E/m²/day (0.2%)

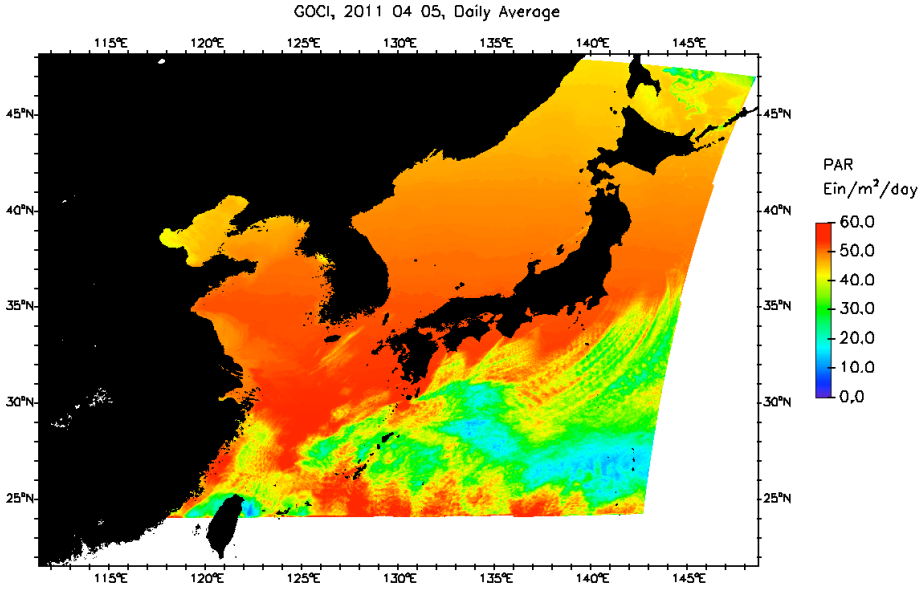
RMS Difference = 5.94 E/m²/day (13.6%)

Frequency histogram of daily PAR values obtained using the 03:16 GMT GOCI image (red) and the 8 GOCI images (blue).

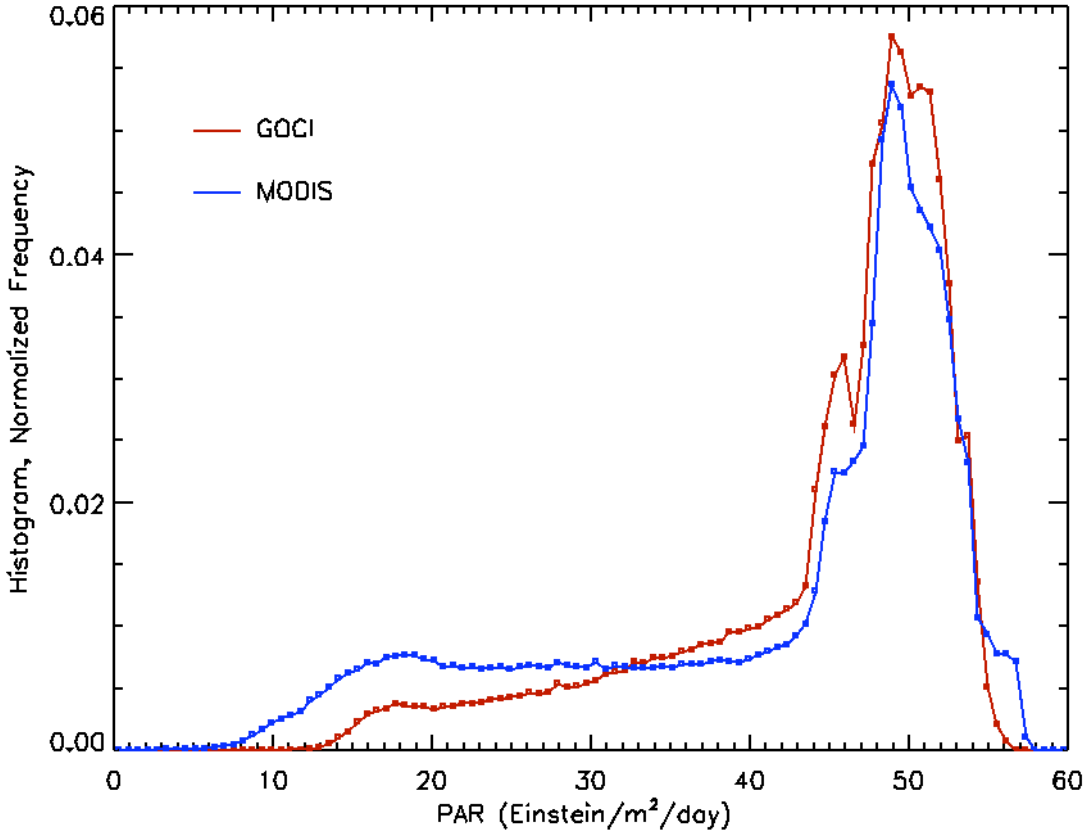
Daily PAR from MODIS-Terra and -Aqua



Daily PAR from GOCI



Daily PAR imagery for April 5, 2011 obtained from GOCI data (right) and MODIS-Aqua and -Terra data (left). The GOCI estimates at 0.5 km resolution are remapped onto the MODIS Level 3 4x4 km grid.



Comparison Statistics

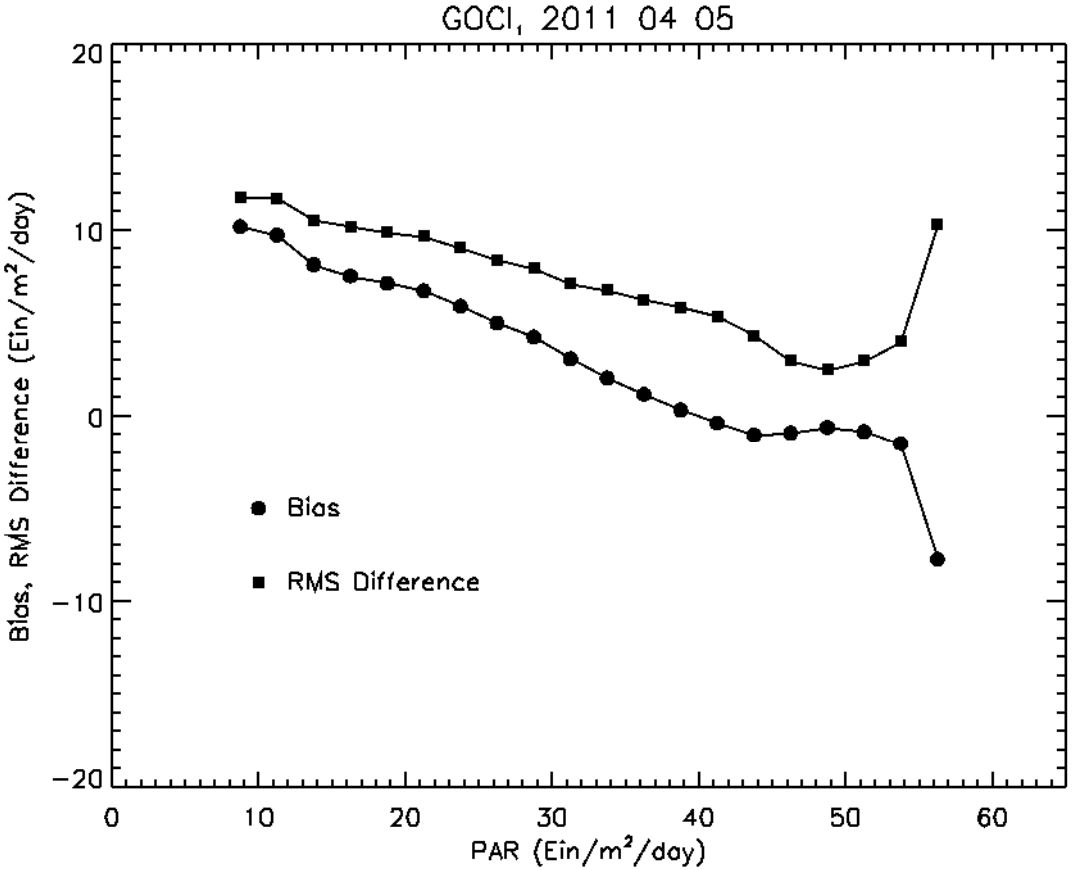
N = 2328200

R^2 = 0.778

Bias = 0.22 E/m²/day (0.5%)

RMS Difference = 5.00 E/m²/day (11.2%)

Frequency histogram of daily PAR values obtained using GOCI data (red) and MODIS data (blue).



Bias and RMS difference between GOCI and MODIS daily PAR values versus PAR level for April 5, 2011.

Conclusions

-An algorithm has been developed to estimate daily PAR from GOCI data and tested on actual GOCI imagery.

-Comparison with the MODIS PAR product shows good agreement, i.e., R^2 of 0.78 and RMS difference of 5.0 $E/m^2/day$ (12%), with little bias.

-Improvements include using the exact time of GOCI observations, actual values of ozone amount, and a climatology of marine reflectance.

-The methodology can be easily extended to compute PAR over land, and to generate UV-A and UV-B irradiance, and other products (e.g., Absorbed Radiation by Algae, ARA).