Estimating underwater planar and scalar solar fluxes in the ultraviolet to the visible from EPIC/DSCOVR observations

Robert Frouin[1], Jing Tan[1], Emmanuel Boss[2]
[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla, California
[2]School of Marine Sciences, University of Maine, Orono, Maine

-Distribution (spectral, spatial, and temporal) of ultraviolet and 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.

-EPIC observations of the Earth's surface lit by the Sun made from the first Lagrange point several times during the day can be used to estimate daily averaged downward planar and scalar irradiance and average cosine for total light just below the ice-free ocean surface in the EPIC spectral bands centered on 317.5, 325, 340, 388, 443, 551, and 680 nm, as well as integrated values over the PAR and UV-A spectral ranges.

-EPIC advantages: Cloud diurnal variability is properly accounted for (unlike with polar-orbiting sensors), and spatial coverage is maximized. EPIC can do the job of several geostationary sensors and spatial resolution at high latitudes is less an issue.

Algorithm

a) ***Planar irradiance (0^+ and 0^-):*** Budget approach; Clear and cloudy regions within a pixel are not distinguished. The instantaneous solar flux reaching the ocean surface is given by:

$$E_d(0^+) = E_{d0}(1 - A)/(1 - A_s)/(1 - S_a A); \qquad E_d(0^-) = E_{d0}(1 - A)/(1 - S_a A)$$

where A is the albedo of the cloud/surface layer, A_s is the albedo of the ocean surface. Daily mean values, $\langle E_d(0^+)\rangle$ and $\langle E_d(0^-)\rangle$, are obtained by integration from sunrise to sunset.

b) ***Scalar irradiance and average cosine (0^-):*** Obtained from daily mean planar flux using a reduced set of parameters, i.e., location, cloud influence, and wind speed. Approach is to use observed cloud factor $\langle CF\rangle = \langle E_d(0^+)\rangle / \langle E_{d\text{-}clear}(0^+)\rangle$ and linearly interpolate between clear sky and overcast conditions using LUTs for $\langle CF_{overcast}\rangle$, $\langle E_{o\text{-}clear}(0^-)\rangle$, $\langle E_{o\text{-}overcast}(0^-)\rangle$, $\langle \mu_{clear}(0^-)\rangle$, and $\langle \mu_{overcast}(0^-)\rangle$:

$$S_1 = [\langle E_{o\text{-}clear}(0^-)\rangle - \langle E_{o\text{-}overcast}(0^-)\rangle] / [1 - \langle CF_{overcast}\rangle]$$

$$S_2 = [\langle \mu_{clear}(0^-)\rangle - \langle \mu_{overcast}(0^-)\rangle]/[1 - \langle CF_{overcast}\rangle]$$

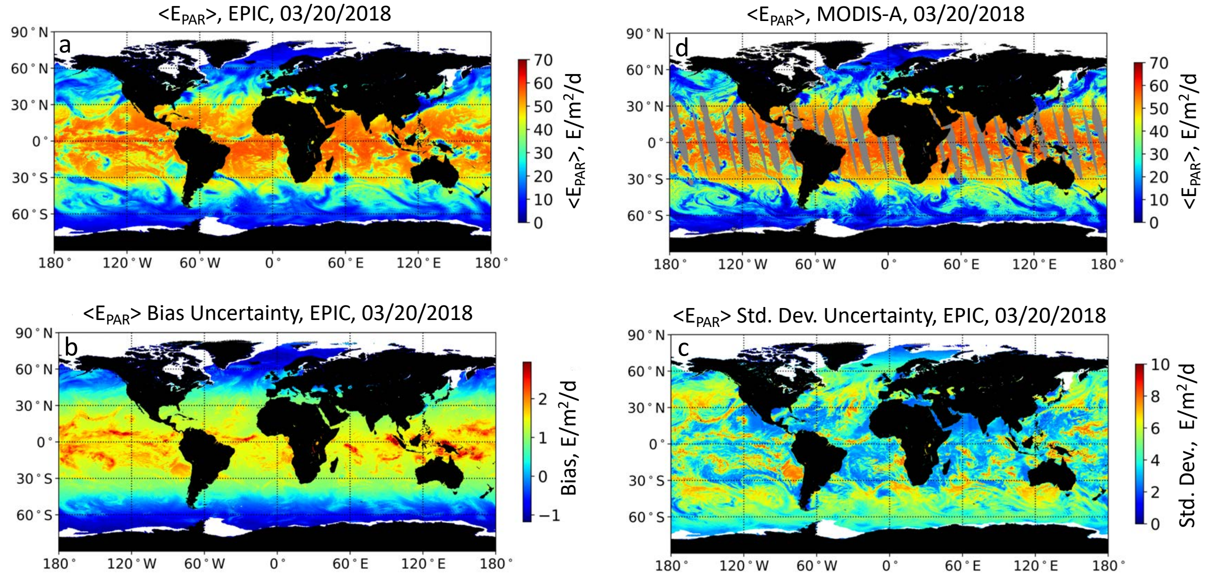
$$E_o(0^-) = S_1 [\langle CF\rangle - \langle CF_{overcast}\rangle] + \langle PAR_{o\_overcast}(0^-)\rangle$$

$$\mu(0^-) = S_2 [[\langle CF\rangle - \langle Cf_{overcast}\rangle] + \langle \mu_{overcast}(0^-)\rangle$$

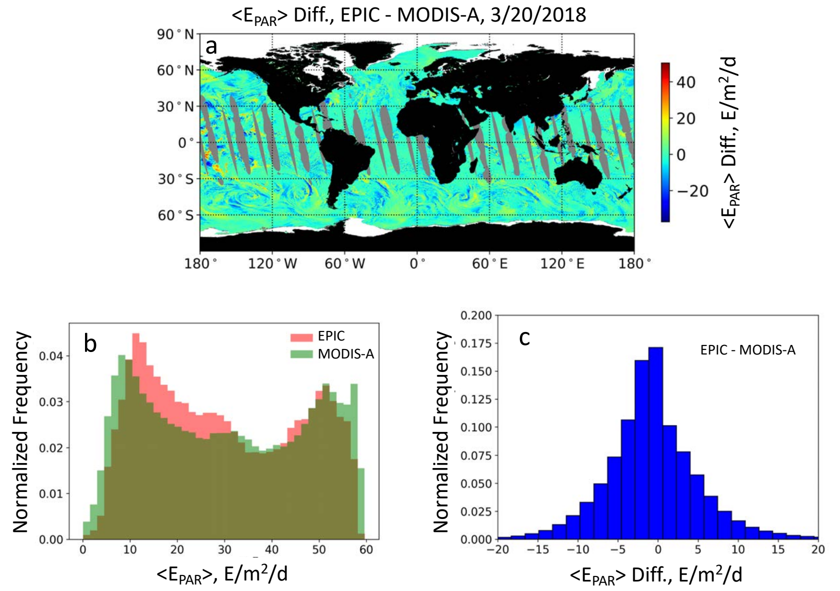
Uncertainty

-LUTs are generated from several years of global hourly MERRA-2 data that relate algorithm uncertainties (bias, standard deviation) to clear sky PAR, $\langle E_{d\text{-}clear}\rangle$, and cloud factor, $\langle CF\rangle$.

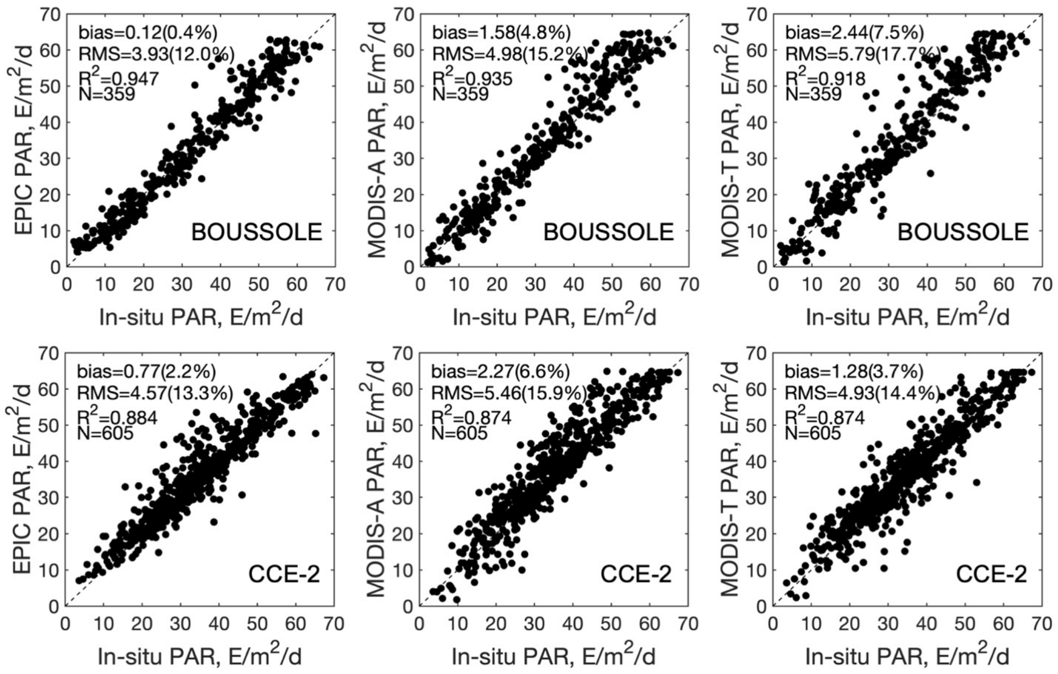
Daily mean PAR Product, 03/20/2018



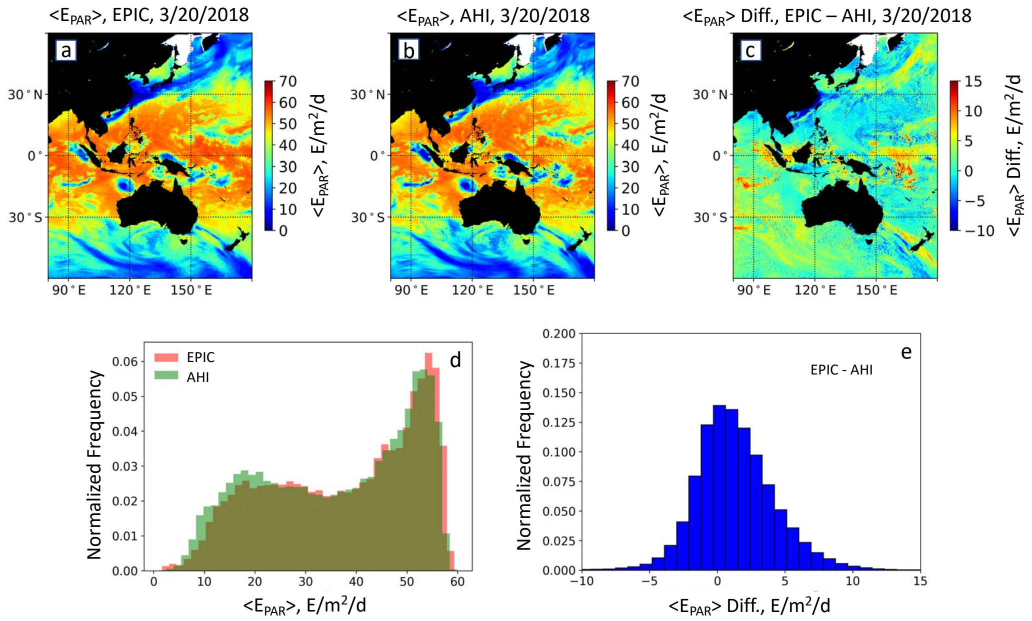
Comparison with MODIS/Aqua



Comparison with in-situ measurements



Comparison with AHI/Hiwamari-8



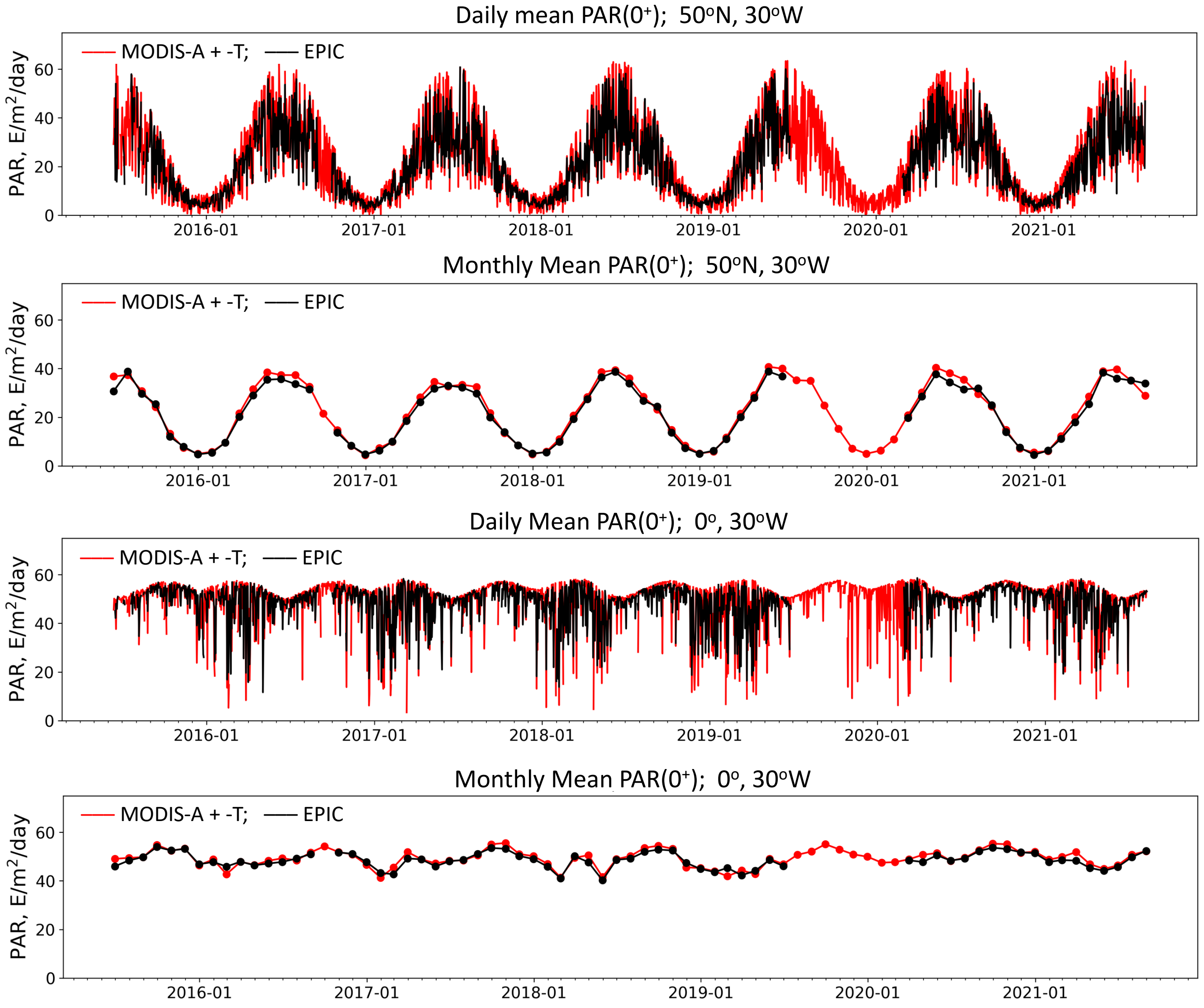
•EPIC daily mean PAR estimates agree with in situ measurements and estimates from other satellite sensors.

•Statistical performance at the mooring sites, i.e., biases of -1.5 to 2.2% and RMSDs of 10.0 to 13.3%, is satisfactory for primary production studies from space.

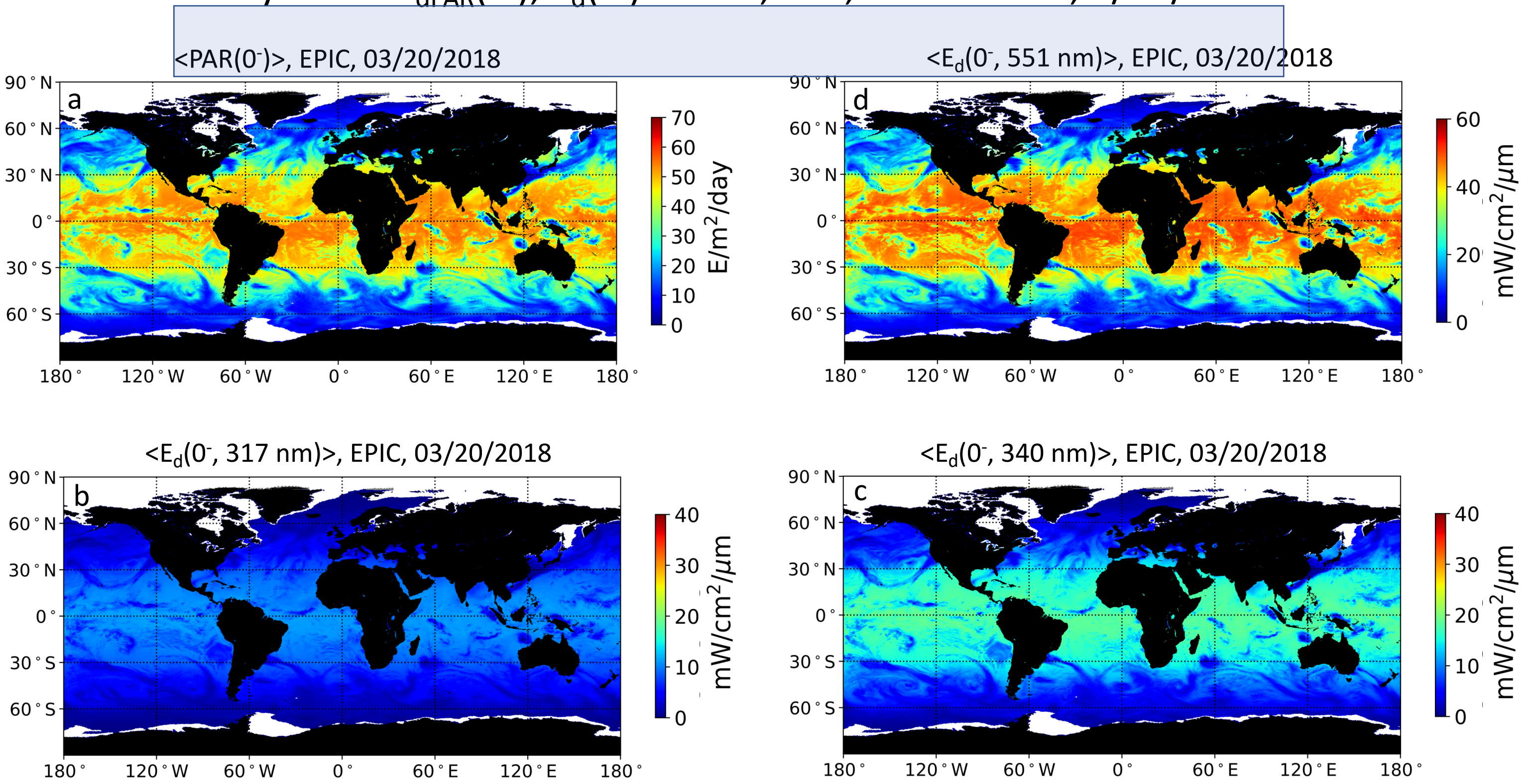
•EPIC PAR is less biased than MODIS PAR, and EPIC PAR imagery less noisy with no gaps at low/middle latitudes, which is explained by using multiple observations during the day.

•EPIC PAR 2015-2021 time series at selected oceanic locations demonstrate ability to capture variability for investigating ocean response to changes in available light over wide range of temporal scales.

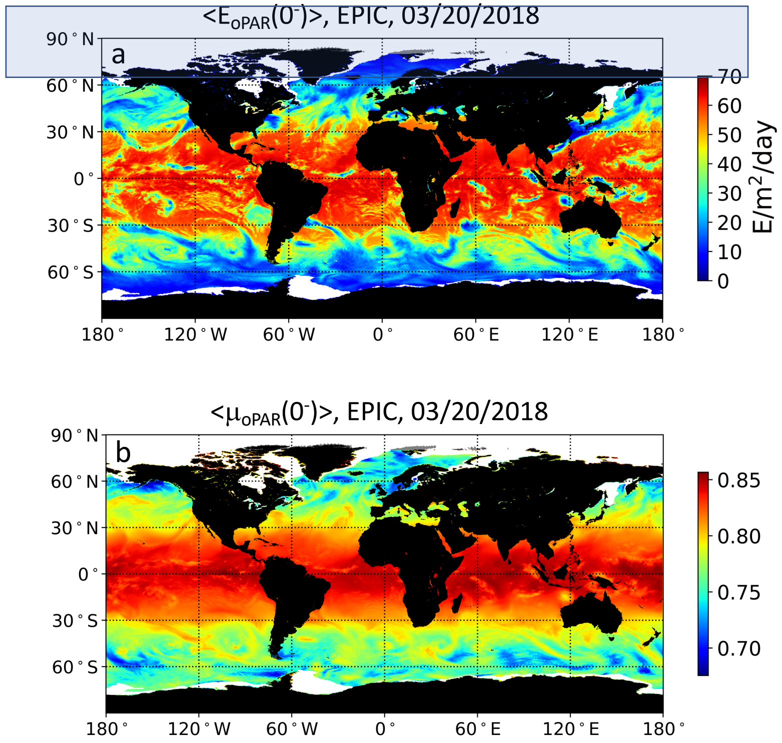
Time series of daily and monthly mean PAR, EPIC and MODIS



Daily mean $E_{dPAR}(0^-)$, $E_d(0^-)$ at 317, 340, and 551 nm, 3/20/2018



Daily mean $E_{oPAR}(0^-)$, $\mu_{oPAR}(0^-)$, 3/20/2018



Conclusion

-EPIC-derived global fields of spectral and integrated *$E_d(0+)$, $E_d(0^-)$, $E_o(0^-)$*, and *$\mu(0^-)$* in the ultraviolet and visible are useful in many research applications, such as primary production and carbon export modeling, ecosystem dynamics and mixed-layer physics, and photochemical transformations of dissolved organic matter. They complement existing *$\langle E_{dPAR} \rangle$* datasets and may bring about consistency across sensors, allowing a better description of biological phenomena/variability.

Knowledge gaps and priorities

-EPIC observations contribute to describing the light field just above and below the surface and its variability at daily to interannual scales. Algorithms are applicable to future PACE, GLIMR, and SGB missions. But our view of the underwater light field is still limited from space.

-Issues of diurnal variability, spatial coverage/gaps exist with current satellite products and need to be addressed. Combining data from polar orbiters and satellites in geostationary and L1 orbits may be necessary.

-No information is retrieved below sea ice, and vertical structure is not currently accessible (only an average diffuse attenuation coefficient for the surface layer is retrieved).

-Near-term priorities should focus on improving existing algorithms, associating uncertainties, eliminating gaps (important for assimilation in climate models), evaluating the various radiation products, and preparing for upcoming ocean color missions.

-In the mid-term, focus should be on estimating average mixed layer PAR, diurnal fluxes, and the fraction of PAR or spectral irradiance absorbed by live phytoplankton, a variable at the top of the community needs according to 2018 and 2021 surveys.

-In the long-term, space lidars that can resolve the vertical distribution of material in the upper ocean should be considered to improve the description of sub-surface light fields.