Satellite-Measured Net Primary Production in the Chesapeake Bay

SeungHyun Son[1,2], Menghua Wang[1], and Lawrence W. Harding Jr.[3]

[1]NOAA/NESDIS/Center for Satellite Applications & Research, College Park, MD, USA; [2]CIRA, Colorado State Univ., Fort Collins, CO, USA; [3]Dept. of Atmospheric & Oceanic Sciences, Univ. California, Los Angeles, CA, USA

ABSTRACT

The Chesapeake Bay (CB) contains some of the most productive waters along the U.S. East Coast. Standard satellite algorithms for net primary production (NPP) for the open ocean are generally not applicable for the CB. In this presentation, we show NPP estimates from MODIS-Aqua by applying a new regional NPP model to satellite products. This NPP model for the CB incorporates an improved prediction of the photosynthetic parameter, Pbopt, as a function of sea surface temperature (SST). These MODIS-Aqua NPP estimates agree well with in-situ measurements. NPP time series for CB using MODIS-Aqua data (2002-2011) with the new model are used to characterize spatial and temporal variability of NPP in CB. Spatial distributions show high NPP in the southern upper Bay and northern middle Bay, and low NPP values in the northern upper Bay, the eastern middle Bay, and the lower Bay. Lowest NPP occurred during winter over the entire Bay, and highest NPP occurred in late spring to summer. These results are consistent with NPP dynamics ascertained by shipboard studies. We conclude by demonstrating NPP derived using VIIRS products for CB. This study has been documented in our recent paper (*Son et al.*, 2014).

DATA & METHODS

- In situ Primary Production and ancillary data (Chl-a, P^B_{opt}, Z_{eu}, PAR, SST, etc.) are obtained in the Chesapeake Bay by Harding et al.
- Total data number is 558 from April 1989 to November 2003 (data before April 1989 are excluded due to suspected data quality).
- MODIS-Aqua Level-2 ocean color data from July 2002 to December 2011 were generated using the NIR-SWIR combined atmospheric correction algorithm (*Wang & Shi*, 2007) with MODIS-Aqua Level-1B data from the NASA MODAPS website. MODIS PAR and SST data were obtained from the NASA OBPG website.
- Those Level-2 data were remapped and then processed to generate NPP composite images.
- Three regions in Chesapeake Bay are defined, i.e., the lower Bay, middle Bay, and upper Bay (shown as boxes, A, B, & C in Fig.1, respectively), following salinity gradients.

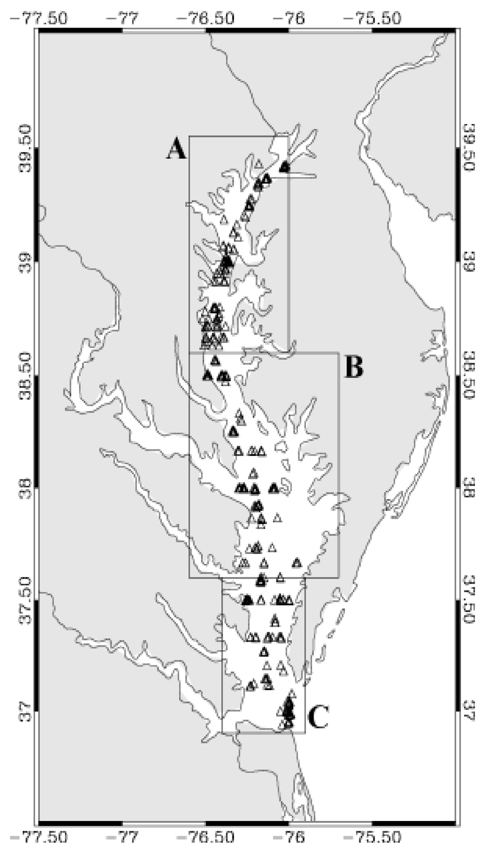

Fig. 1. Map of the Chesapeake Bay with locations of in situ PP data (triangles).

Chesapeake Bay Production Model

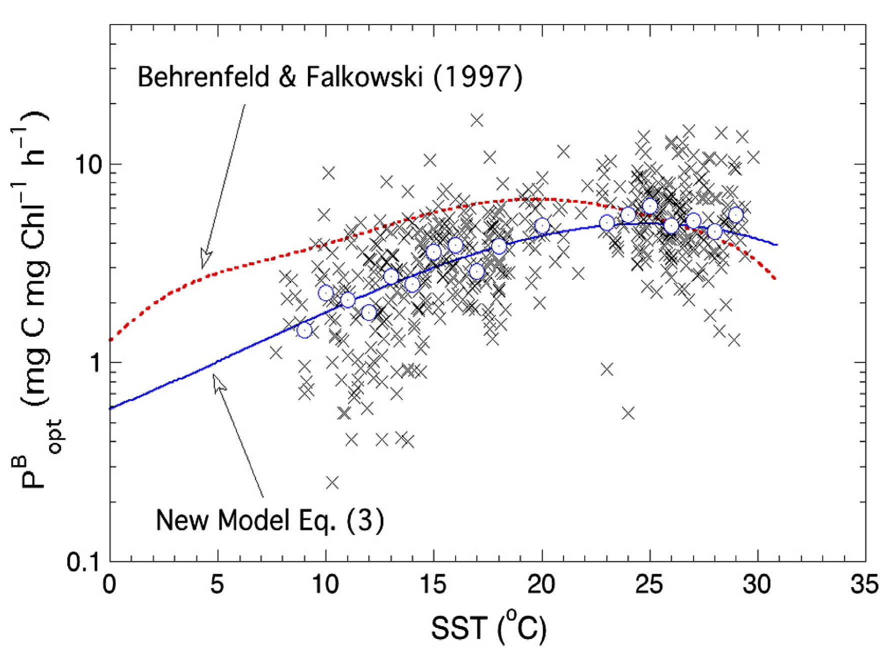

Fig. 2. Optimal photosynthetic carbon fixation rate (P^B_{opt}) as a function of SST for CB.

- The daily-integrated NPP model for CB, CBPM, (*Harding et al.*, 2002) is described as:

$$\mathrm{Log}_{10}(\boldsymbol{NPP}) = 0.1329 + 0.964\cdot\log_{10}P^B_{opt} + 1.0265\cdot\log_{10}Chl\text{-}a + 0.9710\cdot\log_{10}Z_{eu} + 1.4260\cdot\log_{10}[E_0/(E_0+4.1)] + 0.6645\cdot\log_{10}DL,$$

where Zeu is euphotic depth, Eo is surface PAR, and DL is day length.

- A third polynomial regression relationship between P^B_{opt} and SST was derived to parameterize P^B_{opt}:

$$\log_{10}P^B_{opt} = -2.32\times10^{-1} + 4.34\times10^{-2}\,SST + 1.00\times10^{-3}\,SST^2 - 5.00\times10^{-5}\,SST^3$$

Validation of the CB NPP Model

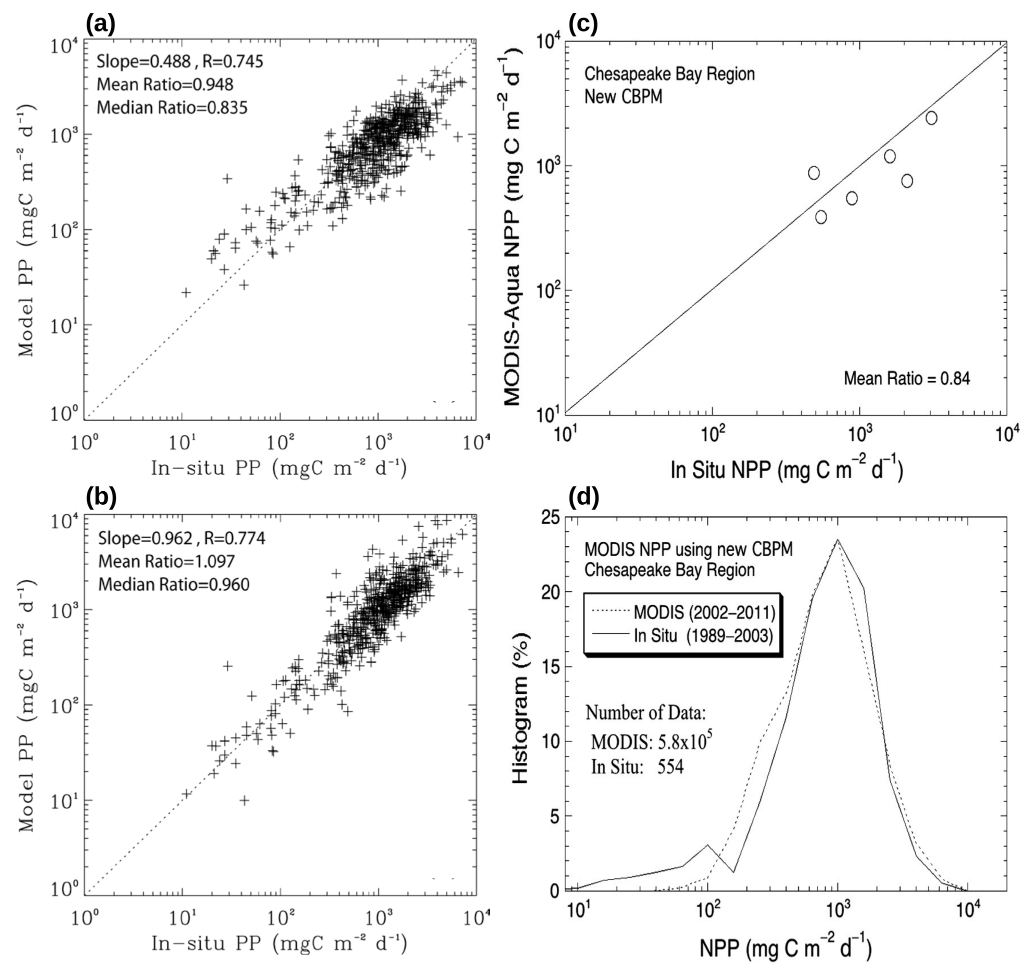

Fig. 3. Comparison of model-derived NPP with in situ NPP using (a) the original CBPM (*Harding et al.*, 2002) and (b) the new CBPM, (c) matchup comparisons of MODIS-Aqua-derived NPP using the new CBPM with in situ NPP, and (d) histogram results for the MODIS-Aqua-derived and the in situ NPP measurements in the entire CB.

- Comparisons of model-derived and in situ NPP show the new approach to generate PBopt significantly improves retrievals for the Bay.
- The original CBPM-derived NPP are biased low by ~20%, while the new CBPM shows better agreement with NPP by ~4% for the median.
- Match-up analyses show that MODIS-derived NPP compares favorably with in situ NPP, despite limitations of sample size due to a short temporal overlap.
- Histogram results show MODIS-derived NPP is similar to in situ NPP. But there is decadal difference between MODIS-Aqua and in situ NPP measurements.

Seasonal Variability of MODIS-derived NPP

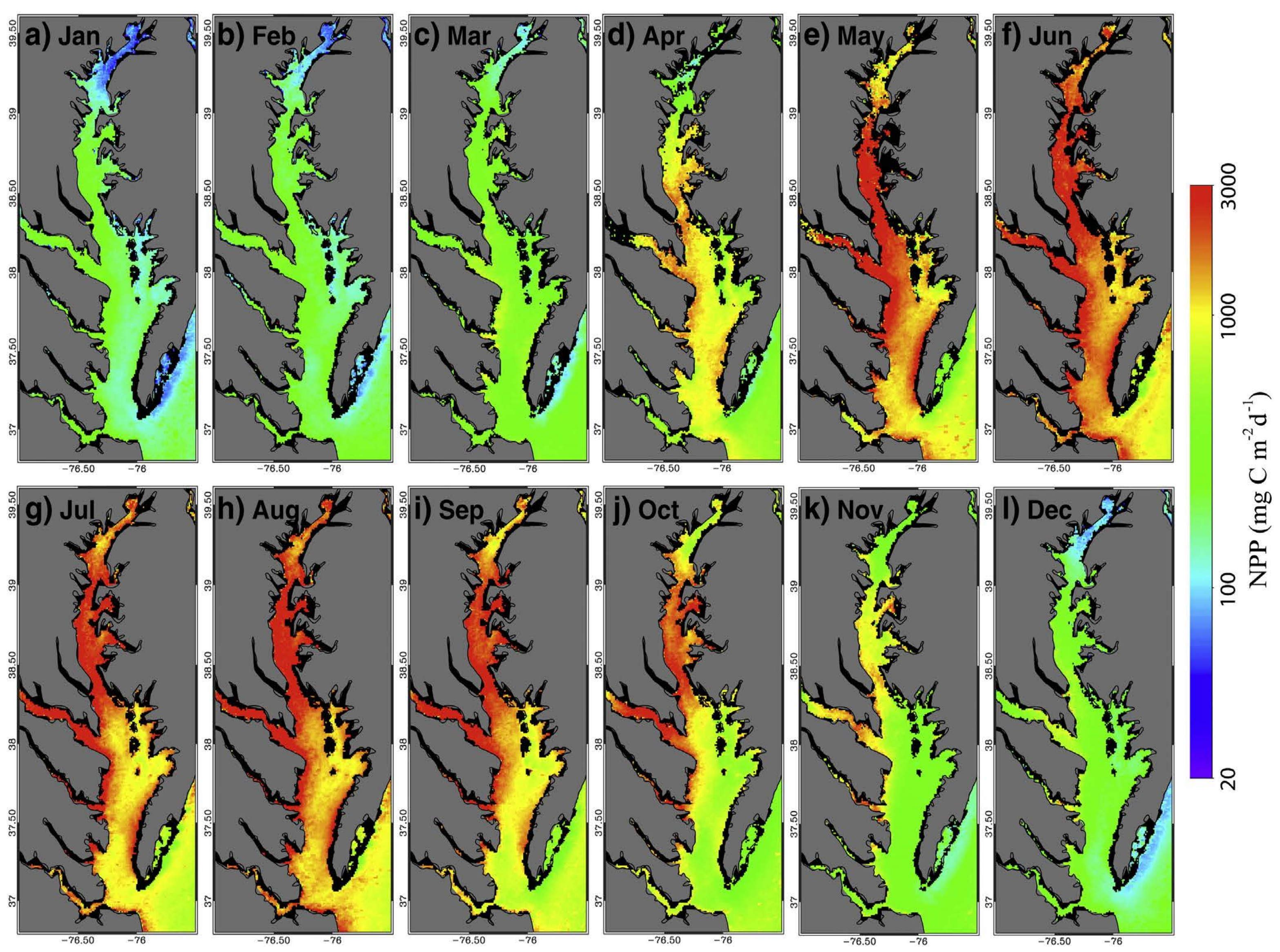

Fig. 4. MODIS-Aqua-measured (2002-2011) monthly NPP climatology images for the Chesapeake Bay for months of January to December.

- General spatial distributions from MODIS-Aqua NPP images are similar over most of months, showing high values in the southern upper Bay and the northern middle Bay, while relatively lower NPP values are in the northern upper ay, the eastern area of the middle Bay, and the lower Bay.
- MODIS-derived NPP are lowest in winter (Dec–Feb) for the entire Bay, due to limited light availability. NPP is highest in late spring to summer (May–Aug), depending on location. In autumn, NPP decreases with seasonal reduction of solar energy.

Interannual Variability of MODIS-derived NPP

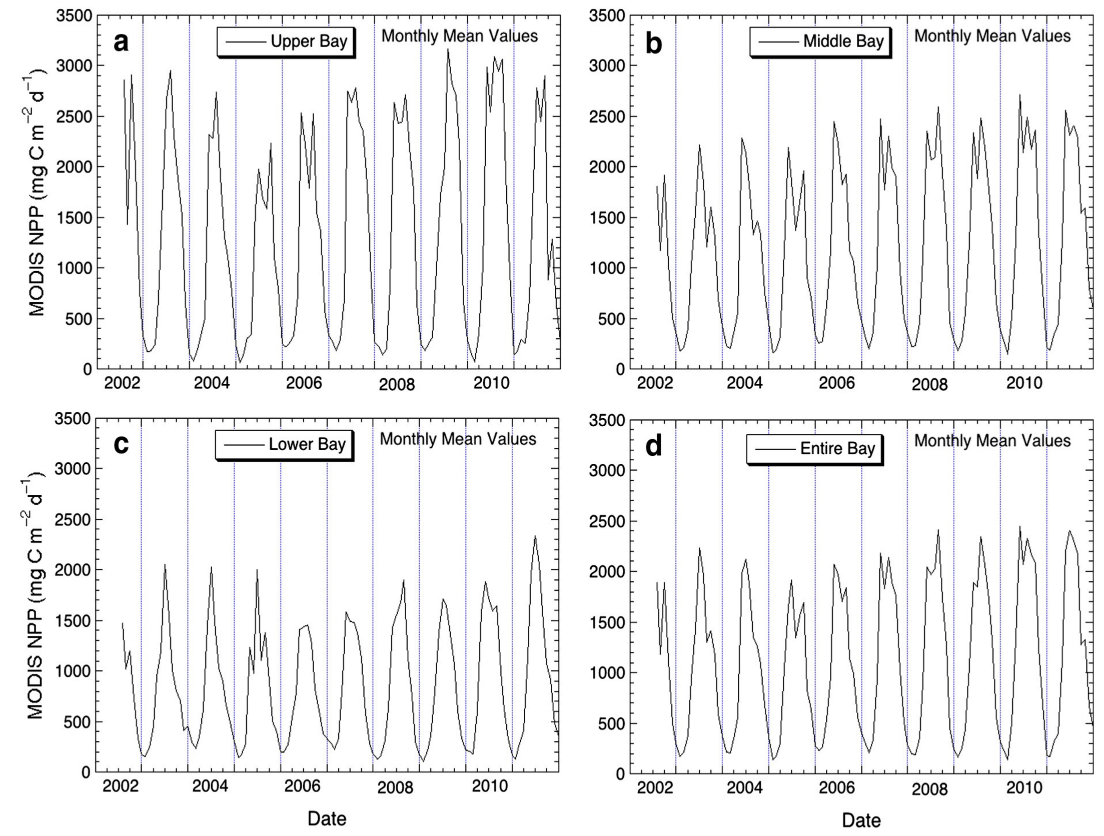

Fig. 5. Time series of MODIS-derived mean monthly NPP in the CB sub-regions of (a) upper Bay, (b) middle Bay, (c) lower Bay, and (d) entire Bay from July 2002 to December 2011.

- There is a strong interannual variability in the NPP for CB. In the upper Bay, highest NPP values appeared in summer of 2009 and 2010, while relatively lower seasonal peaks occurred in 2005 and 2006.
- In the lower Bay, the seasonal peak of NPP generally appears in June. But, an early seasonal peak appeared in 2007 and 2010 (May), and a late seasonal peak in 2008 (August). A relatively higher NPP peak occurred in June 2011.

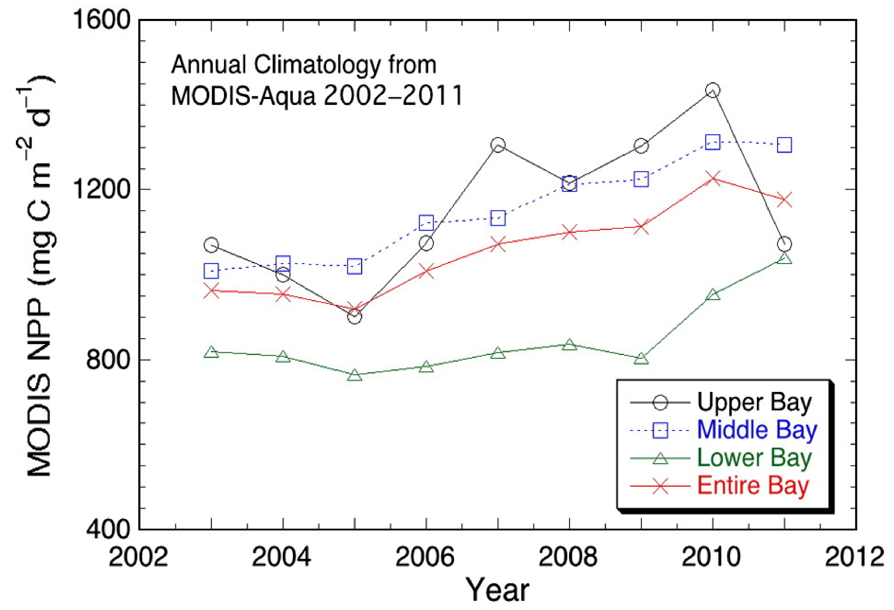

Fig. 6. MODIS-derived annual NPP time series from 2003 to 2011 for the upper Bay, middle Bay, lower Bay, and entire Chesapeake Bay.

- Results from mean values of the MODIS-derived annual NPP show that interannual variability of annual NPP is evident in the three sub-regions, with an apparent increasing trend from 2003 to 2011 in the all Bay regions. The increasing trend in NPP may be related to the increases in nutrient and phytoplankton biomass.
- Interannual variability in NPP in the Chesapeake Bay would be positively (lower Bay) or negatively (upper Bay) related to freshwater flow from the rivers, particularly the Susquehanna River.

CONCLUSIONS

- The regional daily NPP model for the Chesapeake Bay has been improved for use with satellite ocean color data.
- MODIS-derived NPP data correspond reasonably well to in situ measurements.
- MODIS-derived NPP products show that higher NPP values are found in southern upper Bay and northern middle Bay, while relatively low NPP values are in northern upper Bay, the eastern area of middle Bay, and lower Bay. Temporally, lowest NPP in winter over the entire Bay, while high NPP in later spring to summer depending on location.
- There is a strong interannual variability in NPP for CB, and an apparent increasing trend from 2003 to 2011.

Reference:

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