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Key Points:

- Geostationary measurements reveal phytoplankton photoacclimation
- Cholorophyll fluorescence yields phytoplankton light saturation index (Ek)
- Phytoplankton photoacclimation is tuned to median mixed layer light level

Supporting Information:

- Readme
- Figures S1–S28
- Text S1

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Geostationary satellite observations of dynamic phytoplankton photophysiology

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Abstract Since June 2010, the Geostationary Ocean Color Imager (GOCI) has been collecting the first diurnally resolved satellite ocean measurements. Here GOCI retrievals of phytoplankton chlorophyll concentration and fluorescence are used to evaluate daily to seasonal changes in photophysiological properties. We focus on nonphotochemical quenching (NPQ) processes that protect phytoplankton from high light damage and cause strong diurnal cycles in fluorescence emission. This NPQ signal varies seasonally, with maxima in winter and minima in summer. Contrary to expectations from laboratory studies under constant light conditions, this pattern is highly consistent with an earlier conceptual model and recent field observations. The same seasonal cycle is registered in fluorescence data from the polar-orbiting Moderate Resolution Imaging Spectroradiometer Aqua satellite sensor. GOCI data reveal a strong correlation between mixed layer growth irradiance and fluorescence-derived phytoplankton photoacclimation state that can provide a path for mechanistically accounting for NPQ variability and, subsequently, retrieving information on iron stress in global phytoplankton populations.

1. Introduction

Every day, the ocean emits light of a biological origin: the fluorescence of chlorophyll *a* in phytoplankton. This signal has been globally monitored from space by the Moderate Resolution Imaging Spectrometer (MODIS) on NASA's Aqua satellite since July 2002. The distribution of solar-induced (i.e., natural) fluorescence reflects, to first order, patterns in surface chlorophyll concentration [*Behrenfeld et al*., 2009; *Letelier et al*., 1997]. However, physiological factors also have a strong impact on fluorescence variability. Pigment packaging effects [*Bricaud et al*., 1995], for example, cause chlorophyll-normalized fluorescence to decrease with increasing chlorophyll concentration [*Behrenfeld et al*., 2009]. Another critical process impacting MODIS fluorescence data is nonphotochemical quenching (NPQ). NPQ encompasses a variety of specific mechanism within photosynthetic membranes that thermally dissipate absorbed sunlight energy that is in excess of requirements for light-saturated photosynthesis [*Muller et al*., 2001]. Because MODIS ocean retrievals are only collected under clear-sky, high light conditions, observed fluorescence is strongly dampened by near-maximal NPQ levels [*Behrenfeld et al*., 2009; *Morrison and Goodwin*, 2010]. A third factor influencing fluorescence yields, which is of great ecological interest, is biologically available iron in the ocean surface layer. Iron stress in phytoplankton causes a significant increase in fluorescence emission, in part, owing to the associated synthesis of photosynthetically inactive chlorophyll pigment complexes [*Ryan-Keogh et al*., 2012; *Schrader et al*., 2011]. Resolving this latter physiological signature can allow global monitoring of surface ocean iron status, but achieving this goal first requires an accurate characterization of the NPQ effects.

In June 2010, the first Geostationary Ocean Color Imager (GOCI) was launched into space [*Ryu et al*., 2012]. GOCI provides daily retrievals of ocean properties in the northwestern Pacific at hourly resolution between 9:15 A.M. and 4:15 P.M. local time. These temporally resolved daily measurements offer an unprecedented opportunity to evaluate physiological variability in natural phytoplankton populations. The current study represents the first GOCI-based investigation of fluorescence variability. Our focus is on evaluating and constraining an earlier conceptual model of NPQ variability and its relation to photoacclimation states in phytoplankton [*Behrenfeld et al*., 2009]. While refinements are still needed in GOCI ocean radiance retrieval algorithms and data processing, our results strongly suggest that these unique observations will be highly valuable for further understanding the photophysiological properties of surface ocean phytoplankton populations.