Normalized Fluorescence Line Height

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Key Points:

- nFLH estimates chlorophyll fluorescence from satellite nLw measurements near 683 nm.
- Tracks phytoplankton physiology and stress, and helps detect harmful algal blooms.
- Implemented for MODIS and PACE-OCI using a line-height interpolation of nearby bands.

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Abstract

This algorithm returns the fluorescence line height (nflh) in mW cm^{-2} μm^{-1} sr^{-1}, calculated using a simple line height approach from the normalized water leaving radiances (nLw). The implementation is contingent on the availability of bands in the region of the peak of chlorophyll fluorescence (683 nm), making it applicable only to selected missions (e.g. MODIS and PACE). The nflh product is included as part of the NASA standard Level-2 OC product suite (Level-2 AOP suite for PACE) and as a Level-3 product.

Plain Language Summary

We use this algorithm to calculate the fluorescence of chlorophyll in aquatic environments. Chlorophyll, a green pigment present in all phytoplankton, absorbs light across all colors, and a portion of that light is then emitted back as fluorescence visible in ocean color. This product can be used to estimate the health of the phytoplankton community, its capability to photosynthesize, and in some cases serve as a marker for the detection of harmful algal blooms from space.

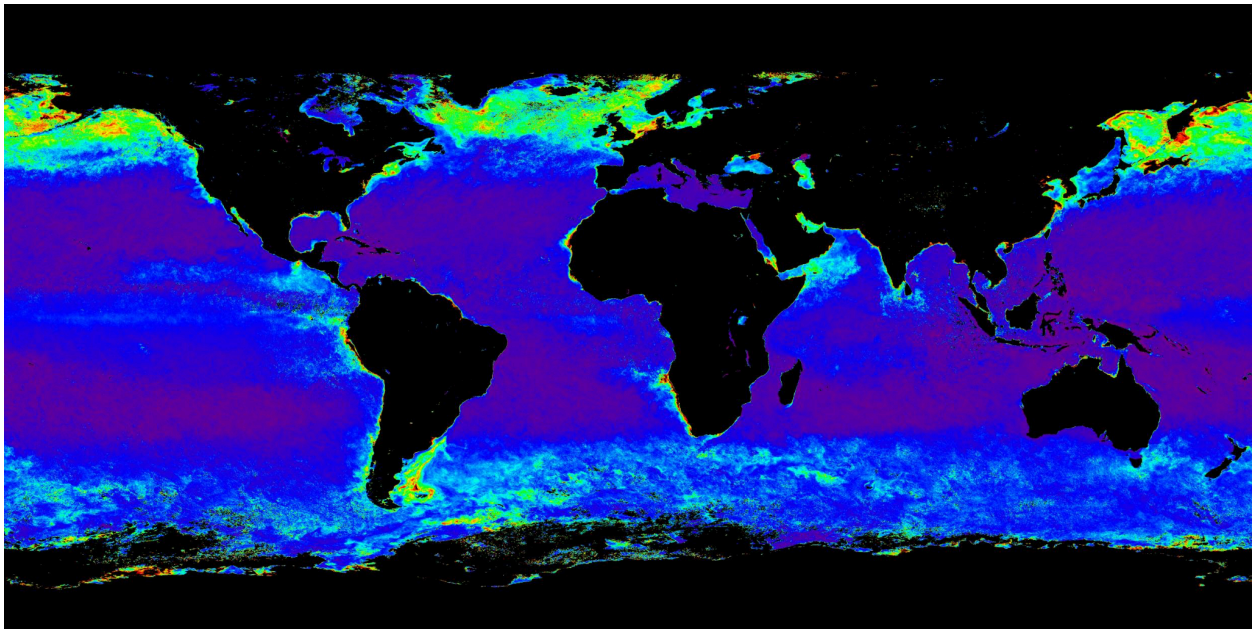
Keywords: EARTH SCIENCE > BIOSPHERE > ECOSYSTEMS > AQUATIC ECOSYSTEMS, EARTH SCIENCE > BIOSPHERE > VEGETATION > SOLAR INDUCED FLUORESCENCE, EARTH SCIENCE > BIOSPHERE > ECOSYSTEMS > AQUATIC ECOSYSTEMS > PLANKTON > PHYTOPLANKTON, EARTH SCIENCE > OCEANS > OCEAN OPTICS > FLUORESCENCE

Version Description

This is an updated version of the normalized fluorescence line height algorithm for MODIS. This new version includes application adaptation to PACE-OCI.

1 Introduction

This algorithm returns normalized fluorescence line height (nflh) in mW cm^{-2} μm^{-1} sr^{-1}, calculated as the difference between the observed nLw(678) and a linearly interpolated nLw(678) from surrounding bands, quantifying the amount of radiance leaving the sea surface, which is presumably a result of chlorophyll fluorescence. This product is available from MODIS, where linear interpolation is done with two neighboring bands (Abbott & Letelier, 1999), and from PACE OCI, where the baseline is calculated by fitting a line through a group of neighboring bands. Fluorescence line height is a product that allows for tracking of the physiological aspects of the phytoplankton community (Letelier et al., 1997), and giving insight into the nutrient stress, light limitation and other aspects important for better understanding of the oceanic primary production (Behrenfeld et al., 2009, Westberry et al., 2023). Additionally, nflh is used in conjunction with other products to track harmful algal blooms, especially massive red tide blooms (e.g., Soto et al., 2015).



MODIS Aqua nFLH seasonal composite for Autumn 2022.

2 Context/Background

2.1 Historical Perspective

A variable portion of the sunlight, absorbed by the cellular photosystems, gets emitted in the form of chlorophyll fluorescence. This signal, gaussian in shape, can be detected in the water leaving radiance (Lw) (Behrenfeld et al., 2009). If measured from space, sun-induced fluorescence peak height, as well as the shape of the signal, is a function of the incoming sunlight, chlorophyll concentration, chlorophyll specific absorption, and quantum yield of fluorescence as well as the position of the position of the phytoplankton in the water column (Behrenfeld et al., 2009, Erickson et al., 2019). These vary with phytoplankton physiological state and offer insight into functionality of the biological carbon pump.

The first measurements of sun induced fluorescence date back to the 1970s, where measurements of upwelling radiance across aquatic systems demonstrated the presence of the peak centered at 683 nm (see Abbott & Letelier, 1999 and references within). Early measurements of the remote sensed fluorescence peak indicated a highly variable correlation with chlorophyll which was impacted by the fluorescence yield (inherent to the system). These were also crucial for understanding of the impact that atmospheric oxygen and water vapor absorption have on the retrieval of the FLH from remote sensing platforms.

With the launch of MODIS, nFLH has become a product distributed by OB.DAAC, thanks to the dedicated bands on MODIS-Aqua and MODIS-Terra instruments.

3 Algorithm Description

3.1 Scientific Theory

Solar induced fluorescence is a signal highly specific to chlorophyll containing organisms, in this case phytoplankton. A portion of the light absorbed by the phytoplankton is converted to energy that is released at higher wavelengths (while rest is utilized for photosynthesis and released as thermal energy). Hence, solar induced fluorescence is a function of the incident light, chlorophyll concentration, chlorophyll-specific phytoplankton absorption coefficient, and quantum yield of fluorescence (BABIN et al., 1996, Behrenfeld et al., 2009).

This sun induced fluorescence will add a weak, gaussian shaped signal, to water leaving radiance, peaking at 673 nm. Shape of the gaussian curve, and height of the peak are a function of the above mentioned parameters, plus the position of the phytoplankton in the watercolumn (e.g., Erickson et al., 2019).

3.1.1 Scientific Theory Assumptions

In order for this weak signal to be detected from satellite based observations, instruments used should have the ability to measure at least several specific wavelengths in that spectral area, and a relatively high signal to noise ratio to ensure detection.

3.2 Mathematical Theory

Fluorescence line height algorithm that is used for MODIS returns normalized fluorescence line height (nflh) in mW cm^{-2} μm^{-1} sr^{-1}, calculated as the difference between the observed nLw(678) and a linearly interpolated nLw(678) from two surrounding bands, where:

$$nflh = nLw(678) - \frac{70}{81}nLw(667) - \frac{11}{81}nLw(748)$$

Fluorescence line height algorithm that is used for PACE OCI returns normalized fluorescence line height (nflh) in mW cm^{-2} μm^{-1} sr^{-1}, calculated as a difference between observed nLw(678) and a linearly interpolated nLw(678) from surrounding bands of nLw(650, 660, 710, and 720).

3.3 Algorithm Input Variables

Fluorescence line height algorithm uses the normalized water leaving radiances (nLw) as input. Data sources are provided in Section 8.

Table 2. *Input variable used in the algorithm*

Name	Long name	Unit
nLw (λ)	normalized water leaving radiance	μW cm^{-2} nm^{-1} sr^{-1}

3.4 Algorithm Output Variables

Fluorescence line height algorithm returns normalized fluorescence line height (nflh) in mW cm^{-2} μm^{-1} sr^{-1} as the output variables.

Table 3. *The output products from the algorithm*

Name	Long name	Unit
nflh	fluorescence line height	mW cm^{-2} μm^{-1} sr^{-1}

4 Algorithm Usage Constraints

The fluorescence line height product can be made only from instruments that measure bands in the spectral regions of the fluorescence peak. Currently, this product is made and distributed for MODIS and PACE-OCI, but the algorithm can be applied on MERIS and OLCI data as well.

5 Performance Assessment

5.1 Validation Methods

While no validation for nflh has been done yet, future validation will be done using in situ collected radiometry measurements archived in the NASA SeaWiFS Bio-optical Archive and Storage System - SeaBASS.

5.2 Uncertainties

The uncertainties for the nflh can be quantified using the first order approach described in McKinna et al., 2019, and have been implemented in L2gen code (uflh) but are not distributed.

6 Algorithm Implementation

6.1 Algorithm Availability

URL

https://git.smce.nasa.gov/oel/ocssw/-/blob/develop/src/l2gen/fluorescence.c

DESCRIPTION

This is the source code of NASA's Ocean Color Science Software (OCSSW). nflh product could be obtained from satellite remote sensing data via command line processing or using the graphical user interface to OCSSW known as SeaDAS https://seadas.gsfc.nasa.gov). The following instructions provide guidance on processing data with SeaDAS: https://seadas.gsfc.nasa.gov/help-8.3.0/processors/ProcessL2gen.html#PRODUCTS_TAB.

6.2 Input Data Access

URL

https://oceancolor.gsfc.nasa.gov/data/download_methods/

DESCRIPTION

Input data can be accessed following the directions described on the above linked website.

6.3 Output Data Access

URL

https://oceancolor.gsfc.nasa.gov/data/download_methods/

DESCRIPTION

nflh is a L2 and L3 product under the MODIS - Aqua, MODIS - Terra, and PACE mission, and as such can be accessed through the sources described on above linked website.

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