Estimating Chlorophyll Concentrations using MODIS Fluorescence: A Preliminary Evaluation in Coastal Waters

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Natural (passive) Fluorescence

where $F =$ fluorescence

$[chl] =$ chlorophyll concentration

$PAR =$ photosynthetically available radiation

$a^* =$ chlorophyll specific absorption

$\phi_F =$ fluorescence quantum yield

• Absorbed Radiation by Phytoplankton

$ARP = a^* \times [chl] \times PAR$ (calculated independently from $[chl]$)

• $F/ARP =$ Chl Fluor. Efficiency (CFE) $\propto \phi_F$
If $\Phi_p + \Phi_f + \Phi_h = 1$ & $\Phi_h = \text{const.}$

then $\Phi_p = \text{const.} - \Phi_f$

$\therefore$

$PP = [\text{chl}] \times (\text{PAR} \times \alpha^*) \times (\text{const.} - \Phi_f)$

or $PP \propto ARP \times (\text{const.} - \text{FLH}/ARP)$

$\propto (\text{const.}/ARP) - \text{FLH}$
Can we use FLH to tell us about chlorophyll?

- Absorption-based algorithms fail in waters where there are other materials that absorb and scatter and are not correlated with chlorophyll
  - Sediment
  - Dissolved organic matter
- Chlorophyll fluorescence is specific to chlorophyll
  - But it also depends on physiology
Goddard DACC weekly declouded 36 km starting 12/02/2000 (Quality=0 L2 V 4.2.2)
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Chlorophyll June 25, 2002
Field Approach

- Mesoscale Surveys (Cowles/Barth)
Some Survey Measurements

- Continuous from Flow-through system
  - Temperature/ Salinity
  - Active Fluorometry
  - Fast Repetition Rate Fluorometry
  - Total and dissolved absorption and attenuation

- Discrete
  - Pigments (Fluor/HPLC)
  - Nutrients (autoanalyzer)
  - Particulate absorption

- Other Platforms
  - Optical Drifters, tethered buoys
  - Moorings
  - Satlantic MicroSAS underway reflectance
Comparison between field measurements and Remote Sensing data
(Mesoscale Survey August 2000 And MODIS Image from August 2\textsuperscript{nd})

(In situ chl derived from the calibration of the flow through fluorometer with HPLC chlorophyll determinations)

-Blue = all mesoscale survey data (July 31\textsuperscript{st} - August 7\textsuperscript{th})
-Red = Within 0.5 days of the MODIS Image Time stamp
Range covering most oceanic regions (Gordon, 1979; Carder & Steward, 1985; and others)
Fischer and Kronfeld (1990) Assuming CFE = 0.003
Chlorophyll biomass proxy

Optimum photosynthesis max yield

(From Rachel Sander's work)
August 2000 (Nighttime)

Optimum Absorption Quantum Yield

Absorption Cross-section of Photosystem II
Photoprotective:Photosynthetic pigment ratio

Other alternatives:
- Changes in ARP (We just finished analyzing the filter pad particulate absorption samples)
- Heat dissipation processes not accounted for
However:

- FLH and CFE are very different MODIS products in terms of validation.
  - FLH is based on nLw at 678 nm after baseline correction
  - CFE is a proxy for $\Phi_f$ (a physiological parameter) that requires the previous validation of ARP ([chl] x $a^*$).
  - Further use of $\Phi_f$ to infer $\Phi_p$ requires the characterization of the variability in energy distribution within the photosystem.
Thalassiosira weissflogii
Chemostat results 2001-2002

After 3 days of constant cell counts
After 14 days
Summary

• Fluorescence and chlorophyll
  - Generally a linear relationship between absorption-based estimates and fluorescence-based estimates of chlorophyll
    • Exceptions are apparent, for example near the coast
  - Slope of line relating FLH to chl is related to CFE

• Can we estimate chlorophyll from FLH?
  - Challenge is that many processes affect $\Phi_F$
    • Photoprotective pigments, absorption cross-section
  - Appears, though, that CFE appears to fall into 2 clusters so problem may be tractable
  - High values of CFE appear to be associated with communities far from equilibrium