A Recipe for Ocean Productivity, with Variations

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What I’m going to talk about

- An alternate (sort of) algorithm for remotely-sensed primary productivity
- Absorption and Pigments in phytoplankton, and in the algorithm
- Variations caused by mesoscale phenomena
An alternate (non-B&F) model of remotely-sensed primary productivity

\[ P(z) = \Phi(E,N) \cdot a_{ph} \cdot [\text{Chla}(z)] \cdot E(z) \]

- Agreement found between pigment and irradiance and $^{14}$C uptake in several studies
- Coupled: based on absorption properties of the ocean, and has some stability
- Allows for physiological adaptation
- Challenge is to understand how quantum yield and absorption vary with environmental properties

Agreement found between calculations based on pigment and irradiance, with $^{14}$C uptake in different areas
Productivity Algorithm: What we need to know, minimum

- Variability in Quantum Yield?
- Chlorophyll-a as a function of depth?
- Chlorophyll-specific absorption as a function of depth?
- Spatial variability of Chlorophyll-specific absorption?

Current version of the model

- Function of irradiance: constant maximum
  - Gaussian (sub-surface max)
    - up to a threshold
- Assumed constant with depth:
  - averaged over λ
- Varies with SST?

How the algorithm is (somewhat) stabilized and coupled.

...but basing an algorithm on absorption means also knowing absorption from water and other components
Phytoplankton Absorption and Environmental Variables

Objective is to create rules for the geographic and temporal variability in $a_{ph}^*$ (sensu Hoepffner and Sathyendranath, 1992).

Avoid using relationships based on the [Chl-a] (e.g., Bricaud et al., 1995; Cleveland, 1995)

- Up to now it seems that $a_{ph}^*$ ($\lambda$) is only considered in terms of the biological effects: pigment packaging and species composition, cell size.
- Chlorophyll-a: as biomass, as an adaptable property, as a trophic indicator?
- Assume that $a_{ph}^*$ does not vary within the first two optical depths (literature supports, but not unanimous)

Absorption in Phytoplankton

- Objective is to create rules for the geographic and temporal variability in $a_{ph}^*$ (sensu Hoepffner and Sathyendranath, 1992)
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  - Up to now it seems that $a_{ph}^*$ ($\lambda$) is only considered in terms of the biological effects: pigment packaging and species composition, cell size.
  - Chlorophyll-a: as biomass, as an adaptable property, as a trophic indicator?
  - Assume that $a_{ph}^*$ does not vary within the first two optical depths (literature supports, but not unanimous)
How we might expect absorption properties to vary with SST

(Not a physiological relationship)

Chlorophyll-specific absorption and SST

(Marra and Trees, submitted)
$P^{\text{Bopt}}$ and Temperature?

(Based on physiology)

(thanks to J. Cullen's presentation at the Bangor Productivity Conference, March 2002)

A Sample View of Algorithm Output:
January, 1998
The Oceanic Mesoscale and Phytoplankton Variability

- Two studies, two anti-cyclonic eddies, both hemispheres
- Eddy Haulani off the island of Hawaii
- An eddy spawned by the Leeuwin Current (off W. Australia)

The birth of the eddy, Haulani, near Hawaii I in Fall, 2000
Eddy Haulani as Ocean Color

SeaWiFS image, courtesy NASA GSFC and Orbital Sciences Corp.

19 November, 2000
(Dotted line indicates SST feature for same date)

Community composition in and out of the Hawaii eddy

Larger forms are found in greater numbers inside the eddy. (Population do not change much.)
Eddies in the Leeuwin Current

See the movie → Leeuwin.mov
(required a QuickTime plug-in)

The anti-cyclonic ("convergent") eddy with the ocean color signal
We then compared the pigment composition of coastal water and that in the eddy...

From Moore et al., 2001

Pigment analysis of coastal (Sta 52) and eddy (Sta 62) samples

- Total quantity of pigment is the same
- Pigment composition nearly the same (loss of alloxanthin, fucoxanthin, Chl c1+c2)

From Moore et al., 2001
So, in conclusion...

- The Productivity Algorithm: promising, but needs work
  - How does phytoplankton absorption vary with environmental properties?
  - What about other absorbing components?
  - Quantum yield parameterization?
    - Non-absorption based observations (e.g., FRRF)
    - Environmental determinants to $\Phi_{\text{max}}$
- Instead of PvsE parameters (like $P^\text{opt}_{\text{opt}}$), focus on $a_{\text{ph}}$ and pigments
- Go from satellite reflectances -> productivity?
- We need to understand the differences caused by vertical as opposed to horizontal processes in eddies