PML | Plymouth Marine Laboratory

Marine Matters

Remote sensing of assimilation number for marine phytoplankton

Stéphane Saux Picart, Shubha Sathyendranath, Mark Dowell, Trevor Platt

3rd Coastcolour user consultation meeting - October 2011

Challenge: Estimate phytoplankton primary production from space

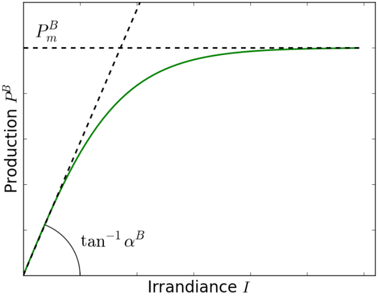
Primary production can be computed using a photosynthesis-light model:
$P^B(z) = P^B(I(z); \alpha^B, P^B_m)$

Superscript B indicates normalisation to chlorophyll biomass B.

P^B Normalised production; z: depth; I: irradiance;

α^B **: initial slope**;

P^B_m **: assimilation number**



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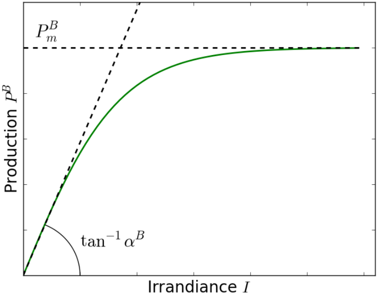

Specific objective of the study:
Estimate the assimilation number globally from remote sensing data

- If no photo-inhibition, maximum primary production $P_{max} = BP_m^B$
- Maximum primary production is also given by $P_{max} = \frac{dC_p}{dt}|_{max}$ where C_p is the phytoplankton carbon concentration
- Maximum growth rate: $\mu_{max} = \frac{1}{C_p}\frac{dC_p}{d_t}|_{max}$

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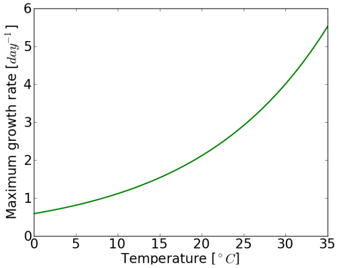
Eppley (1972) defines the maximum growth rate as a function of temperature:

$$\mu_{max} = 0.851(1.066^T)\frac{\ln 2}{24}$$



Two ways of estimating carbon-to-chlorophyll ratio:

1. Sathyendranath et al. 2004: $\chi^s = \frac{10^{(1.81+0.63*log_{10}(Chl))}}{Chl}$
   (gives an upper limit of χ)
2. Cloern et al. 1995: $\chi^c = \left[0.003 + 0.0154\exp(0.05T)\exp(-0.059I)\frac{[N]}{K_N+[N]}\right]^{-1}$
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Combining these two model and the maximum growth rate formulation from Eppley (1979), we can approach computation of assimilation number as follows:

- **Model 1**: $P_m^B = f(Chl, T) = \chi^s \mu_{max}$
- **Model 2**: $P_m^B = f(I, N, T) = \chi^c \mu_{max}$
- **Model 3**:
  $P_m^B = f(I, N, Chl, T) = \left[(\chi^s)^{-1} + 0.0154\exp(0.05T)\exp(-0.059I)\frac{[N]}{K_N+[N]}\right]^{-1} \mu_{max}$

Model applied to a large database (> 700 measurements): P_m^B, Chl, T, mixed layer depth, surface PAR, nitrates

$\Longrightarrow$ Gaps filled with climatological data (for surface PAR and nitrates)

$\Longrightarrow$ North West Atlantic, subtropics (Gulf of Mexico and Arabian Sea), Middle Atlantic

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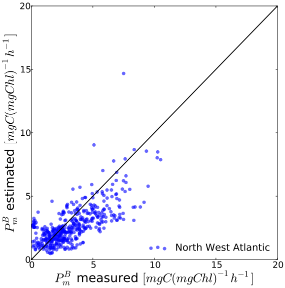
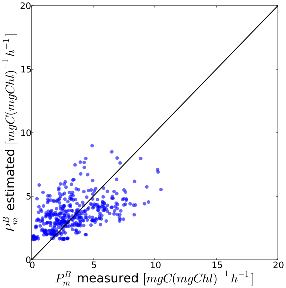
North West Atlantic

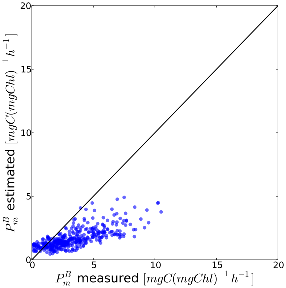
Model 1
$f(Chl, T)$



Model 2
$f(I, N, T)$



Model 3
$f(I, N, Chl, T)$



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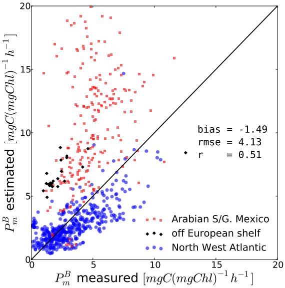

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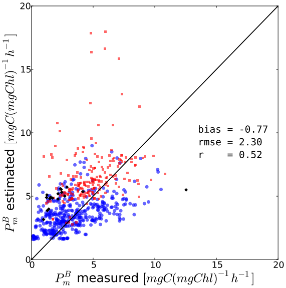

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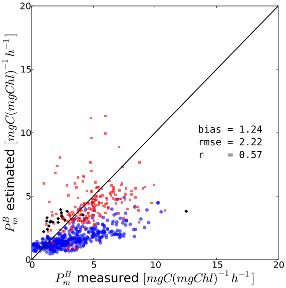

Results: remote sensing application

Data used (all monthly composites), 2004:

- SeaWiFS cholophyll-a concentration
- MODIS sea surface temperature
- SeaWiFS surface PAR
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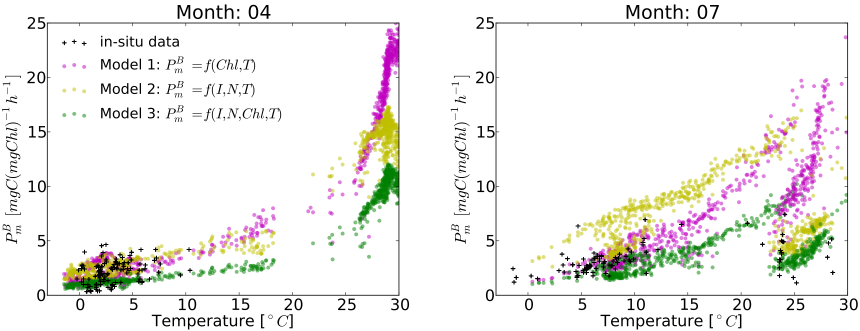

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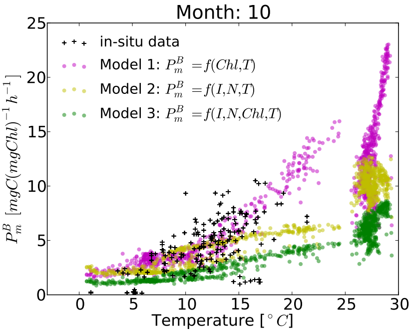

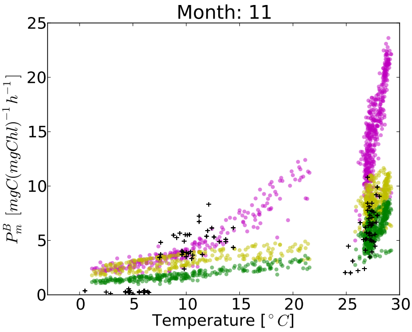

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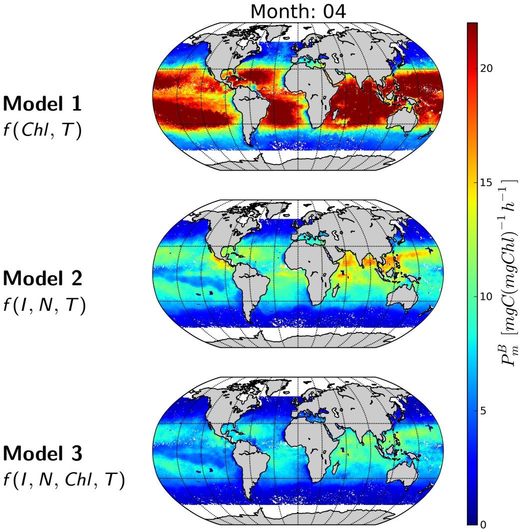

- Model 1 ($f(Chl, T)$) overestimates P_m^B in oligothrophic waters
- Model 2 and 3 have stronger latitudinal seasonal variations because of the light
- Model 3: estimates of P_m^B are too low

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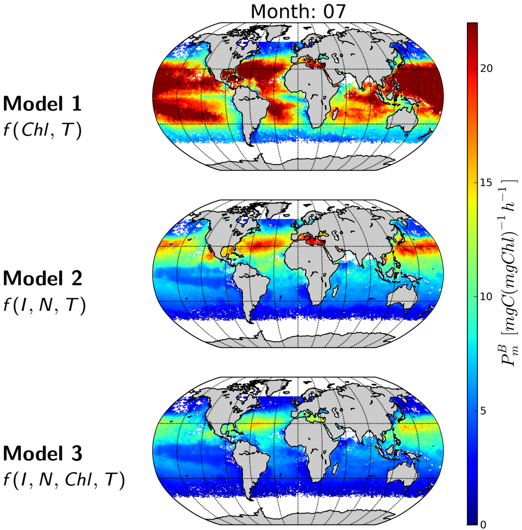

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Implementation in coastal waters

Assimilation number: $P_m^B = f(B, T, N, I)$

B	$\Longrightarrow$	Coastcolour product (case 2 water)
I	$\Longrightarrow$	$I(z) = I(0)\exp(-Kz)$
$I(0),\ K$	$\Longrightarrow$	Coastcolour products (case 2 water)
T	$\Longrightarrow$	Satellite sea surface temperature
N	$\Longrightarrow$	Climatological data (World Ocean Atlas)

Conclusion

- We have tested three different models for estimating P_m^B
- Comparison with in-situ data has shown three contrasting results, and each model has skill in a different region of the globe
- Overall **Model 2** ($f(I, N, T)$) seems to be able to estimate the assimilation number reasonably well at global scale

Future work:

- Develop a model to estimate the initial slope of the photosynthesis-light curve (α^B)
- Estimate primary production

Aknowledgments

CoastColour - ESA project

NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS)

Thank you

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