Effects of dynamic physical processes on phytoplankton production and biomass in the tropical-subtropical North East Pacific Ocean off Mexico

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Phytoplankton uses inorganic carbon in two ways:

- Photosynthesis
- Form shells from calcium carbonate

http://www.xplora.org/

$pCO_{2\text{atm}}$ 150-200 μatm above without phytoplankton (Laws et al. 2000)

Ballantyne et al. (2012)
Production and phytoplankton biomass

Chemical reaction:
\[ n\text{CO}_2 + 2n\text{H}_2\text{O} \rightarrow (\text{CH}_2\text{O})n + n\text{O}_2 + n\text{H}_2\text{O} \]

Diatoms, Synechococcus, Prochlorococcus

Factors:
- Light
- Availability of nutrients

Graph showing irradiance, temperature, chlorophyll, and nutrients.
Availability of nutrients

Klein & Lapeyre (2009)

Shoaling isopycnals:
Nitrate injection stimulates phytoplankton growth

Deepening isopycnals:
No ecosystem response

Modified from Espinosa-Carreón et al. (2012)
Variability of phytoplankton production

Variability in the light-limited (PAR)
Vertical variability in phytoplankton biomass (Chla)
Behrenfeld & Falkwoski (1997)

But... What about ecosystem disturbance processes? (physical dynamic processes!!!)

Not accounted for bio-optical models  Siegel et al. (2001)
How is the effect of the physical dynamic processes on production and biomass of phytoplankton?
Study Area: North East Pacific Ocean off Mexico

Upwellings, eddies and interaction of water masses (Durazo & Baumgartner, 2002; Durazo et al., 2010; Kurczyn et al., 2012; Durazo, 2015)
Methods

**In situ data**

PP and Chla and hydrographic data from three programs:

- IMECOCAL
- ISFOBAC
- PROCOMEX

PP integrated from surface to euphotic zone depth; Chla integrated to 100 m.

**Satellite data**

- ADT (Weekly, $1/3^\circ \times 1/3^\circ$)
- Winds (6 hourly, $1/4^\circ \times 1/4^\circ$)

3052 oceanographic stations from 1997 to 2012

- Mexico
- Pacific Ocean
Methods: Relationship between variables

* Generalized Additive Models (GAMs) → Find nonlinear relationships between variables.

\[
PP = \beta_0 + s(X_1) + ... + s(X_i) + \varepsilon \\
Chla = \beta_0 + s(X_1) + ... + s(X_i) + \varepsilon
\]

The variables tested were:

\[s(X_i) \rightarrow EkP, ADT\]

Where “EkP” is Ekman Pumping and “ADT” is the Absolute Dynamic Topography.

The best model was chosen by means of Akaike’s criterion:

\[AIC = -2\text{Log(likelihood)} + 2p\]
Results

GAMs models
Smooth splines
Effects of EkP and ADT in PP and Chla
Conceptual model
The best models fitted for primary production and Chlorophyll-\(a\) were:

\[
PP = s(EkP_1) + s(ADT)
\]

\[
Chla = s(EkP_2) + s(ADT)
\]

The parameters of the models were statistically significant and the variables have not linear correlation.
The best relationship between the production and phytoplankton biomass with Ekman pumping were at different “lags” because:

Time response of hours because PP is a rate (gCm\(^{-2}\)d\(^{-1}\))

\[
PP = s(EkP_1) + s(ADT)
\]

\[
Chla = s(EkP_2) + s(ADT)
\]

Time response of days, because biomass depends of phytoplankton to growth
Probability that observed data occurs given the models was:

\[ PP \quad D^2 = 13\% \quad Chla \quad D^2 = 12\% \]

In other GAMs studies:

\[ PP = s(PAR) + s(Nitrates) + s(Chla) \quad D^2 = 96\% \quad \text{Lamont et al. (2014)} \]

\[ Chla = s(Phosphates) + s(Nitrates) + s(MLD) + s(Salinidad) + s(SST) \quad D^2 = 70\% \quad \text{Raitsos et al. (2012)} \]
Ekman pumping $> 0 \text{ md}^{-1}$ and ADT $< 60 \text{ cm}$ showed the higher values of PP *in situ* (circles) and PP inferred from the GAM model (colors).
Ekman pumping > 0 md\textsuperscript{-1} and ADT < 60cm showed the higher values of Chla \textit{in situ} (circles) and Chla inferred from the GAM model (colors).
* Chla and PP inferred from GAMs models allow us to observe the effects of both: EkP and ADT on PP and Chla. This tool maybe can be useful to infer the tendency of PP and Chla because of changes in ADT and EkP along the time.

* The relationships found showed that EkP > 0 md\(^{-1}\) and ADT < 62 cm are the optimal conditions for enhance PP and Chla.

* Thermocline inside of euphotic zone could be explaining the enhance of PP and Chla when ADT < 62 cm and EkP~ 0 md\(^{-1}\).
¡¡GRACIAS!!
OBRIGADA!!
THANK YOU!

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