CO$_2$ Sensitivity to Chl-a Data assimilation

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Contents

• Introduction to data assimilation
• The model GOTM-ERSEM-CO$_2$
• Data Assimilation setup
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  – Reference
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• Future Work

- Observations are snapshots of 3D processes
- Model makes explicit assumption of one dimensional processes
Satellite data

Time (day)

Chlorophyll (µg/l)

Model forecast

“True state”

(Re)analysis

Satellite data

Observed ecosystem variable

In situ data

Better simulation
Total particulate carbon (mg C m$^{-3}$)

Covariance with assimilated variable

Unassimilated variable/parameter

Unassimilated data

Better understanding
LTL biogeochemical model
PFT model
Processes based model
C, N, P, Si dynamics completely decoupled
Benthic-pelagic coupled model
Coupled with several hydrodynamic model:
• 1D (e.g. GOTM)
• 3D (POLCOMS, NEMO, FVCOM)

Artioli et al., 2012 JMS
Reference simulation

Temperature [deg C]

Chlorophyll [mg/m$^3$]

T and S are relaxed to weekly CTD profiles
Reference simulation

Temperature [deg C]

Chlorophyll [mg/m³]

Spring bloom
Autotrophy
Summer deep chla
Heterotrophy
Autumn bloom
Reference simulation

Winter over-estimation

Autumn under-estimation

Chlorophyll $[\text{mg/m}^3]$

Nitrate $[\text{mmol/m}^3]$
Reference simulation

Winter over-estimation

Chlorophyll [mg/m$^3$]

Autumn under-estimation

Nitrate [mmol/m$^3$]

Good seasonal cycle but...

over

over
<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Chlorophyll</td>
<td>0.24</td>
</tr>
<tr>
<td>Silicates</td>
<td>0.56</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.75</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.84</td>
</tr>
<tr>
<td>TotC</td>
<td>0.32</td>
</tr>
<tr>
<td>pH</td>
<td>0.22</td>
</tr>
<tr>
<td>DIC</td>
<td>0.14</td>
</tr>
<tr>
<td>pco2</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Overall good model seasonality

Poor short-time skill

Carbonate variables lack the daily variations present in observations
Chlorophyll

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>T and S vertical structure</td>
<td>Kz and vertical fluxes</td>
</tr>
<tr>
<td>Surface Irradiance</td>
<td>Light availability at depth</td>
</tr>
<tr>
<td>Background SPM</td>
<td>Light availability at depth</td>
</tr>
<tr>
<td>ALL Initial Conditions</td>
<td>Model trajectory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tbody>
<tr>
<td>Nº Ensembles</td>
<td>100</td>
</tr>
<tr>
<td>Observations Error</td>
<td>30%</td>
</tr>
<tr>
<td>Irradiance Error</td>
<td>25%</td>
</tr>
<tr>
<td>SPM Error</td>
<td>25%</td>
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</tbody>
</table>
 EO chlorophyll with 30% errors

*In-situ*
HPCL

**EO**

Over-estimation

Month 2009
Chl-a assimilation Experiment

Strong reduction in ensemble spread
i.e. in “simulation error”

And improved correlation
0.24 → 0.33

Reduces winter blooms
Captures autumn blooms
Non-assimilated variables

Chlorophyll [mg/m$^3$]

Correlations Total chl vs variables [surface]
Chl-a assimilation Experiment

Effect on pCO$_2$

0.22  ➔  0.30

Assimilation

Observations

Reduces winter blooms

Captures autumn blooms

Air-Sea flux pCO$_2$

Cumulative sum
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</table>
Monthly Chla assimilation
Chl-a assimilation 3D

Air-sea flux [mol C m$^{-2}$ yr$^{-1}$]
Reanalysis-Reference

1998-2005
Conclusions

- Chla assimilation can improve simulations system-wide
- Improvements in Total Chla cascade to carbonate system variables
- This results in a significant change in the Air-Sea fluxes, specially at times of high production
Future Work

• Introduce seasonality in SPM at L4 in model
• Model evaluation against zooplankton data
• Perform more sensitivity analysis to covariance matrix
• Assimilate on different years (2009 to 2010)
• Remove sub-daily observations from correlations.
Thank you
Twin Experiment simulation

Observations

Assimilation step

Forecast step

Biomass corrected

Shaded area represents mean ± one standard deviation
Twin Experiment simulation

Observations

Assimilation step

Forecast step

Biomass corrected

Nutrients…
Significant differences with reference simulation
$\frac{dC}{dt} = \text{photosynthesis} - \text{respiration} - \text{excretion} - \text{lysis} - \text{grazing}$

$\frac{dN}{dt} = \text{nutrient uptake} - \text{excretion} - \text{lysis} - \text{grazing}$
Twin Experiment simulation
Model setup

- Boundary region between coastal and open-shelf
- Straddles biogeographical provinces;
- Considerable fluctuation of flora and fauna over the past century;
- Easily accessible from PML (within 30 km)