Trends in productivity in the Canary upwelling system
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Outline

• A global warming context

• Trends from Ocean Color observations

• Trends from biogeochemical modelling

• Implications in Ecosystem-based management
Worldwide context

• global warming : how much ?
Just... an unprecedented global warming context

global effect on air and sea temperatures (1995-2004 increase):
SST trend 1960 – 2007 (ICOADS data, 48 years)
1985 – 2007 SST trend (AVHRR pathfinder)

\(-0.2\) \(-0.1\) \(0\) \(0.1\) \(0.2\) \(\text{°C year}^{-1}\)

[Map of SST trend with color scale indicating temperature changes from 1985 to 2007.]

[Histogram showing global SST anomaly from 1880 to 2000.]
To match the satellite ocean color era

AVHRR Pfv5 data

SST trend 1998 - 2007
Trend in Chlorophyll concentration  1998 – 2007

Trend in Production - Vertically Generalized Production Model (absolute values)
Classification of the biomass response

- SST+ Chl -
- SST- Chl +
- SST++ Chl – (except coastal)
- SST- Chl -
- SST+ Chl -

not significant
Trend of the Equatorward wind

SST Trend
Trends by upwelling systems
\[ \Delta \text{chl} = 0.4 \Delta \text{wind} + 0.07 \]
\[ r = 0.57 \text{ (0.66 without Calif. N)} \]
Combinations of trends by sensor (SeaWiFS / MODIS)

see Demarcq and Benazzou 2015 6.4 Trends in phytoplankton and primary productivity off northwest Africa, in Oceanographic and biological features in the Canary Current Large Marine Ecosystem2015 Progress.
Average overestimate of the full area 5°N-25°N: **30.7%**
(1.932/1.478)

Shelf only: **42.3%**
Both are probably correct... but difficult to merge.
Chlorophyll trend from 1998 to 2014 (SeaWiFS + uncorrected MODIS data)

Spurious trend...
Comparison of chlrophyll trends from SeaWiFS and MODIS for their common period (2003 --> 2010)

Quite similar...
Empirical correction are made with spline functions to match the (better calibrated) SeaWiFS series.
Check of the remaining bias between MODIS Corrected data and SeaWiFS data

Average of the monthly MODIS-SeaWiFS raw differences (60 months from 2003 to 2007)

Difference:
0.191 (5-25N)
0.793 (shelf)

Idem, with monthly corrected data

Difference:
5-25°N: -0.053 (0.7%)
Shelf: -0.121 (2%)

Seasonal differences are higher than the global average but still acceptable
Effect of the corrections for the four years 2003 to 2007: **Stable in time**

<table>
<thead>
<tr>
<th>Year</th>
<th>raw data</th>
<th>Corrected MODIS data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-25°N</td>
<td>5-25°N shelf only</td>
</tr>
<tr>
<td>2003</td>
<td>0.157</td>
<td>0.696</td>
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<tr>
<td>2004</td>
<td>0.146</td>
<td>0.682</td>
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<td>2005</td>
<td>0.132</td>
<td>0.800</td>
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<tr>
<td>2006</td>
<td>0.140</td>
<td>0.585</td>
</tr>
<tr>
<td>2007</td>
<td>0.184</td>
<td>0.780</td>
</tr>
<tr>
<td>average</td>
<td>0.152</td>
<td>0.709</td>
</tr>
</tbody>
</table>

Conclusion: the climatological seasonal correction is fully adequate when separately applied on each year from 2003 to 2007, with a null average bias that do not show any significant trend during the five common years. Nevertheless, slightly spatialized patterns persist in the average bias (previous figure) due to intrinsic differences between atmospheric corrections.
1998-2014 (spurious) Trend
SeaWiFS + MODIS raw data

1998-2014 Trend
SeaWiFS + MODIS-corrected data
Evolution in time: rather coherent in space and intensity

1998-2007 Trend
(SeaWiFS data only)

1998-2014 Trend
SeaWiFS + MODIS-corrected data
Now check if something has changed with the new R2014 MODIS reprocessing

R2013 (=R2012+R2013)  

R2014 (NetCDF data) (just a bit higher)

Differences are very weak (R2014 is 0.5 % higher) and far bellow the MODIS-SeaWiFS differences from 2003 to 2007
Improvements from the last reprocessing « R2014 » (June 2015)

Differences are moderate and do not affect trends computation.
Conclusion:
Trends are almost identical (as expected)
Conclusion:
Quite close, except at small scale and south of Senegal

 MODIS data are used for the 2011-2014 period only
1998-2014 Trend

SeaWiFS + MODIS-corrected

Slightly decreasing trends

Variable and spatially dependent trends...
Trends in the 2 phytoplankton groups from ROMS-PISCES model from 1980 to 2009

Surface wind stress: from satellite winds (ERS + QuikSCAT from 1999)
Trend in the total chlorophyll from the ROMS-PISCES model (run 1980-2009) with real winds (ERS + QuikSCAT)

1998-2007 Trend
(SeaWiFS data only)

1996-2009 Trend
(ROMS, total Chla)
Implications in Ecosystem-based management?

• Not for now...
• The length of the time series is still short (17 years)
• Trends represent only a part of the variability!
• Seasonal/phenological variability (including shifts) is also pronounced (and well estimated from sat. data)

• NPZ models AND satellite observations must be better evaluated from in situ measurements
  – Still approximations in satellite atmospheric corrections
  – Difficult to generate intrinsic variability in phytoplankton groups from NPZ models
  – But... this is an interesting way to go since satellite obs. can be splitted into 4 groups or more...