VIIRS Ocean Color Data and Global Modeling: Extending the Time Series of Ocean Biology from Space

Cecile S. Rousseaux
Watson W. Gregg
NASA Global Modeling and Assimilation Office
USRA

MODIS/VIIRS Science Team Meeting, Silver Spring, June 9th 2016

Use of Ocean Color in global numerical models

- Maximize use of satellite data via data assimilation into global models

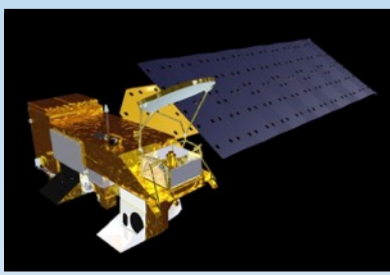
    1. Improve the representation of past and present variability and change
    2. Detection of trends in ocean biogeochemistry
    3. Forecast seasonal to decadal variability

- Use Ocean Color Chlorophyll Data; assimilate into the NASA Ocean Biogeochemical Model (NOBM)

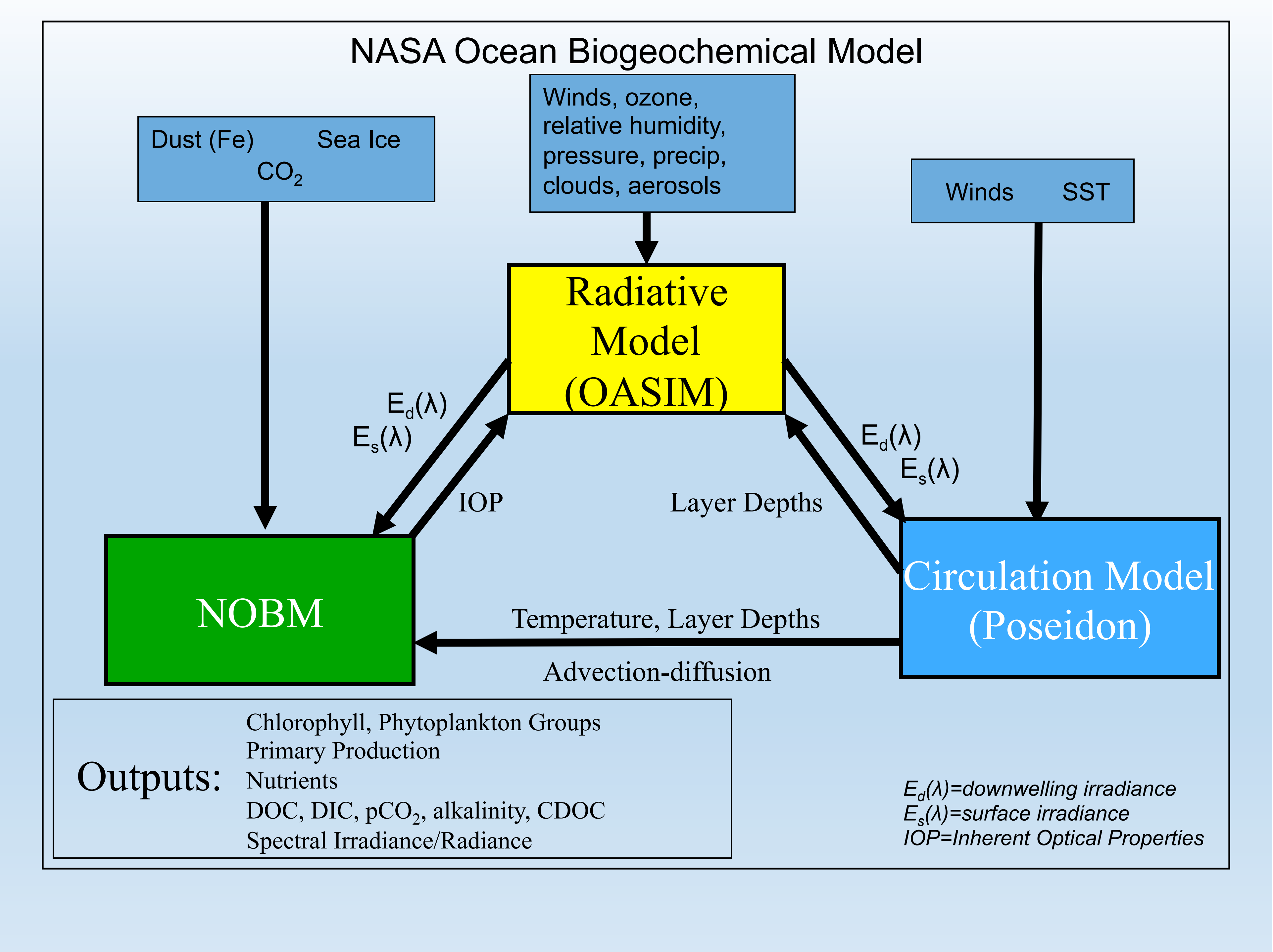
1997 SeaWiFS

2010

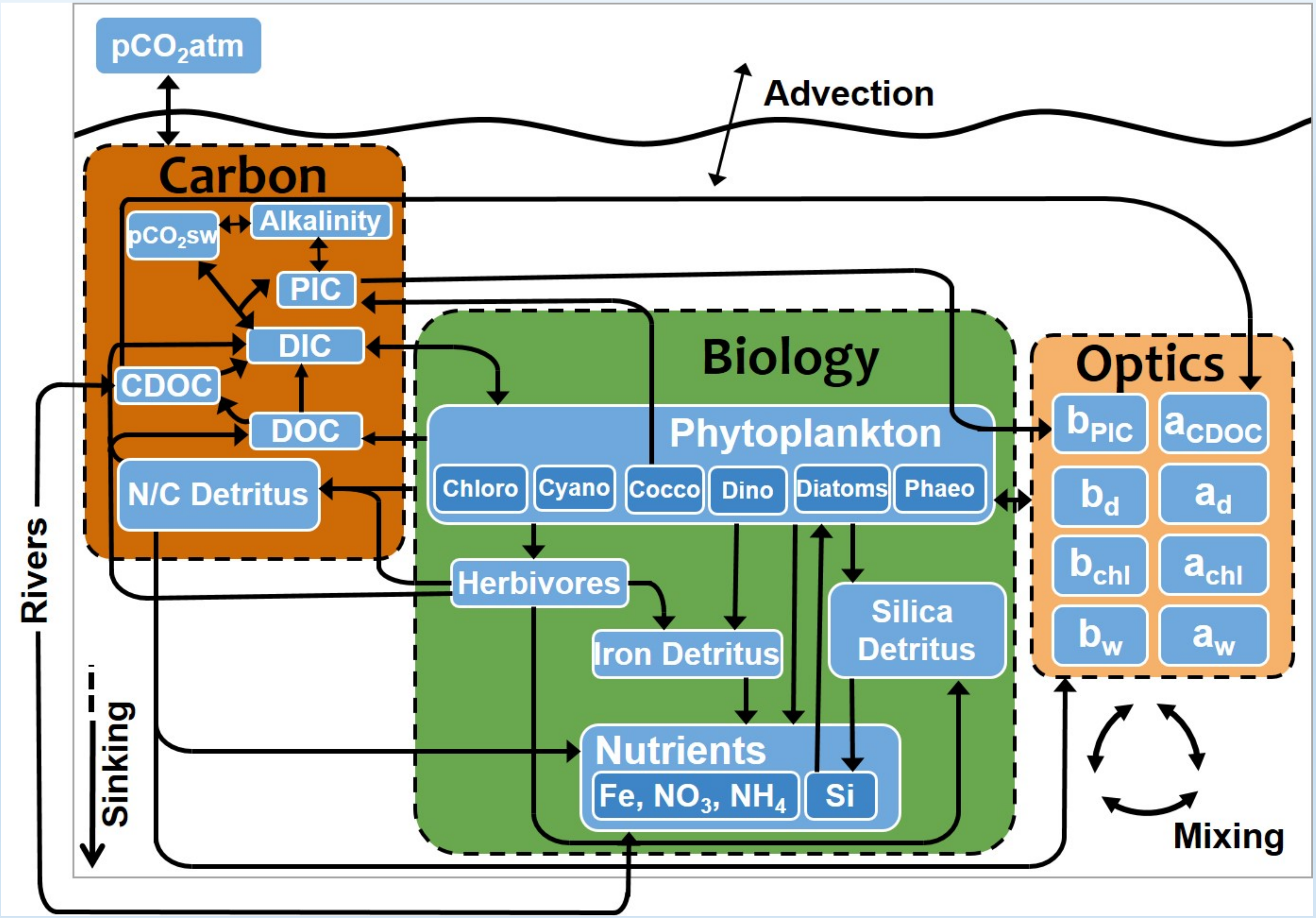
2002 MODIS-Aqua



2011 S-NPP VIIRS


NASA Ocean Biogeochemical Model
Dust (Fe) Sea Ice
CO_2
Winds, ozone, relative humidity, pressure, precip, clouds, aerosols
Winds SST
Radiative Model (OASIM)
$E_d(\lambda)$
$E_s(\lambda)$
IOP
Layer Depths
$E_d(\lambda)$
$E_s(\lambda)$
NOBM
Circulation Model (Poseidon)
Temperature, Layer Depths
Advection-diffusion
Outputs:
Chlorophyll, Phytoplankton Groups
Primary Production
Nutrients
DOC, DIC, pCO_2, alkalinity, CDOC
Spectral Irradiance/Radiance
$E_d(\lambda)$=downwelling irradiance
$E_s(\lambda)$=surface irradiance
IOP=Inherent Optical Properties

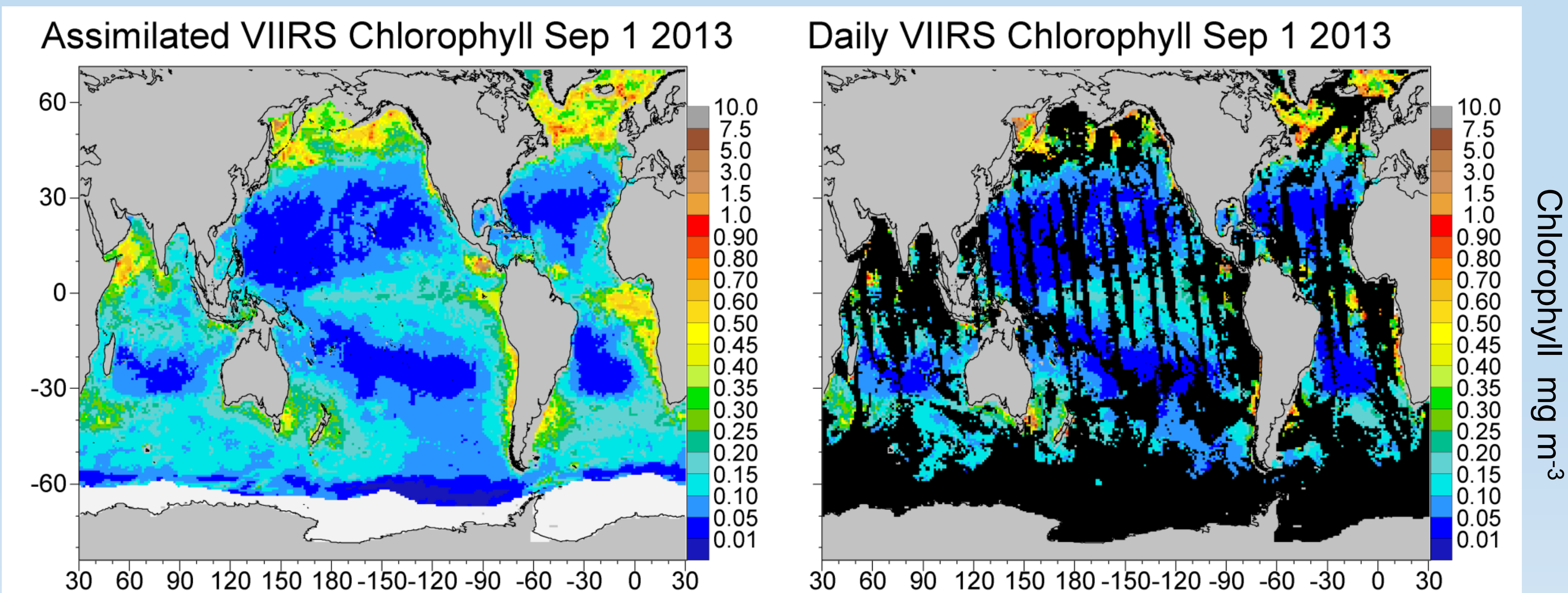
NASA Ocean Biogeochemical Model



1. Improve the representation of past and present variability and change

It is widely known that data assimilation improves model results.
It is less widely known that data assimilation also improves data representations
Global mean chlorophyll representations are distorted by gaps in sampling. Ocean color missions typically observe only about **15%** of the ocean per day
Due to:

- **inter-orbit gaps**
- **insufficient light for detection at high latitudes**
- **sun glint**
- **clouds**
- **aerosols**

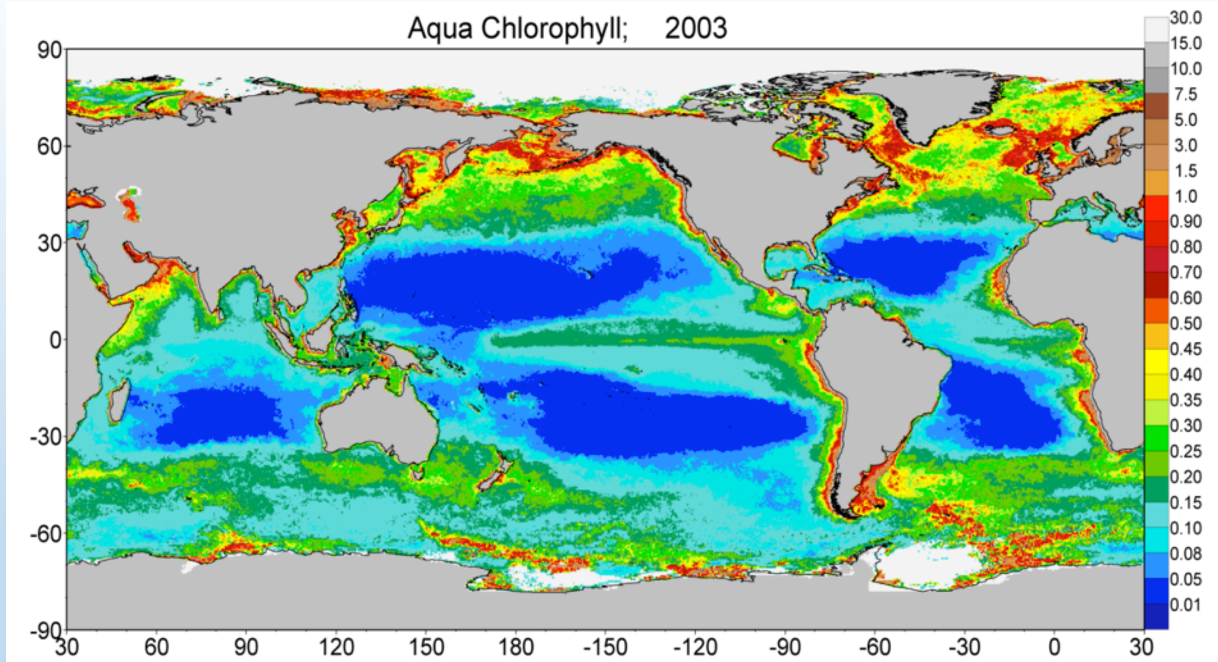


Ice fields are shown in white.

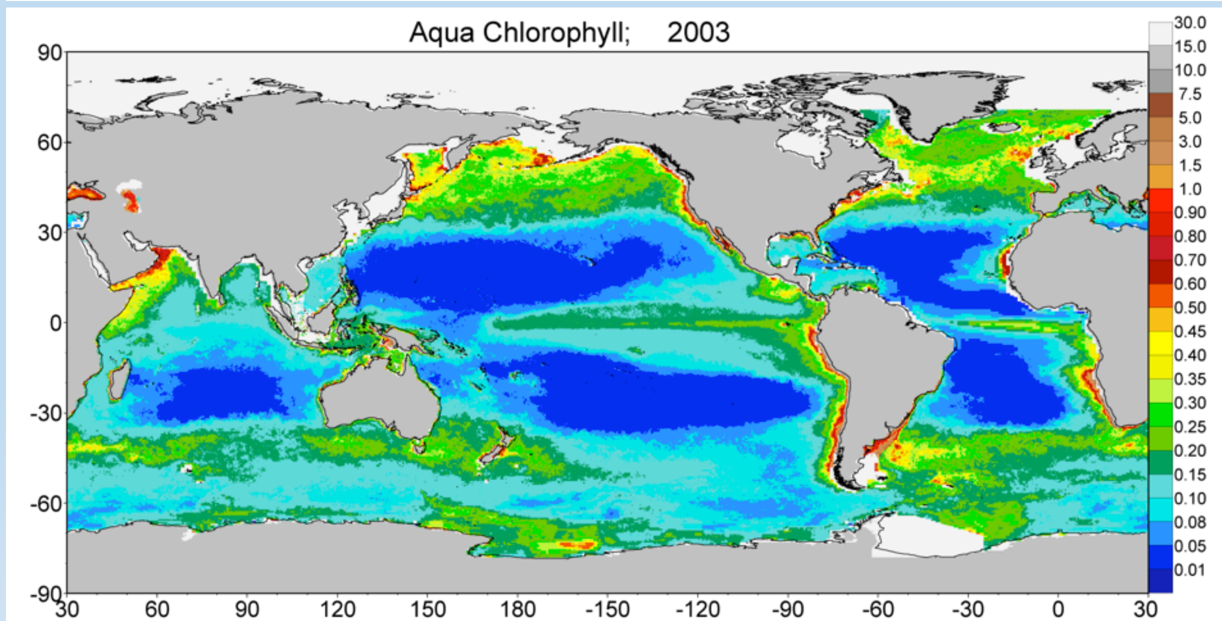
Missing data is shown in black.

Effects of assimilation

Global Annual
Median Chlorophyll
for MODIS-Aqua

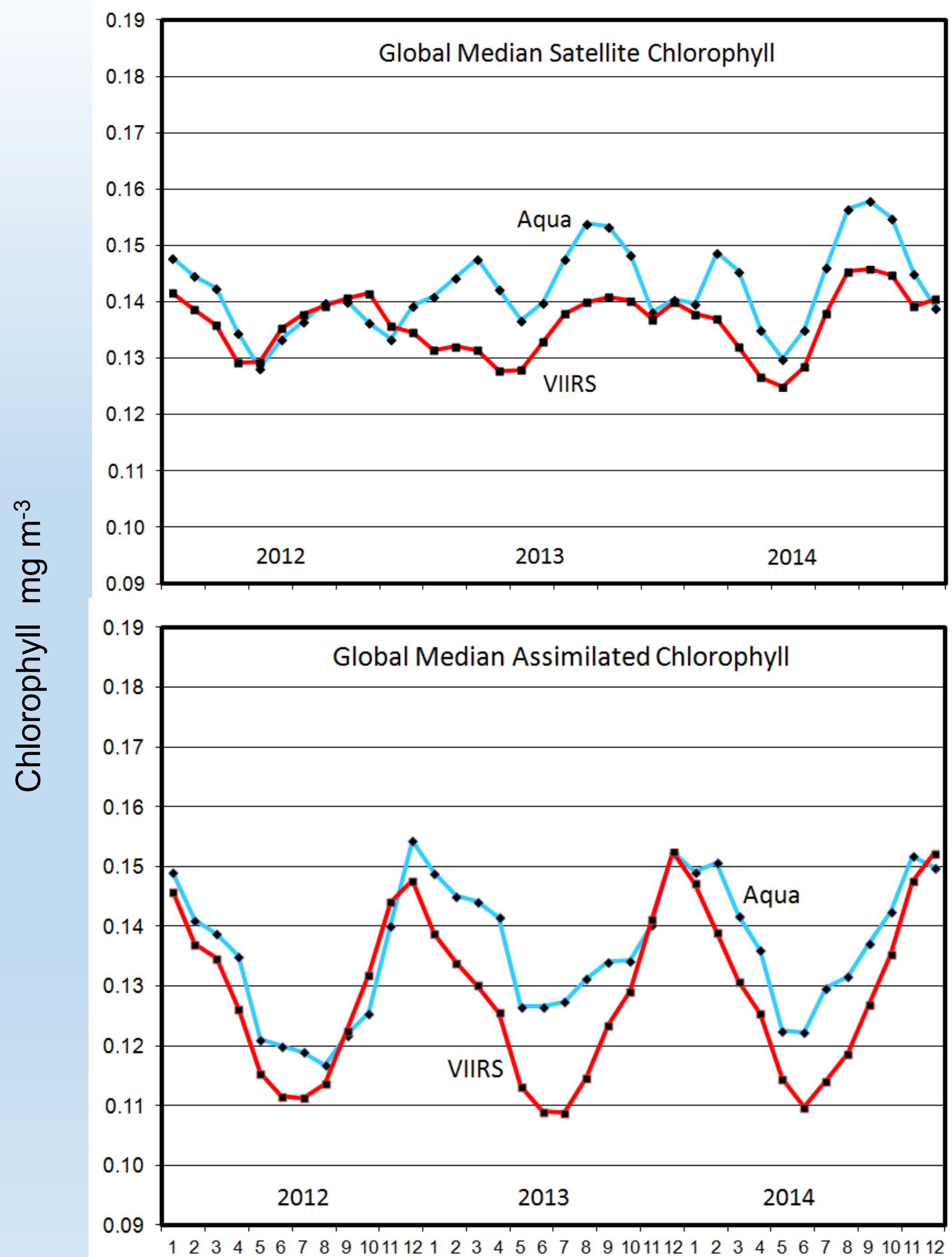


Assimilated
Global Annual
Median Chlorophyll
for MODIS-Aqua

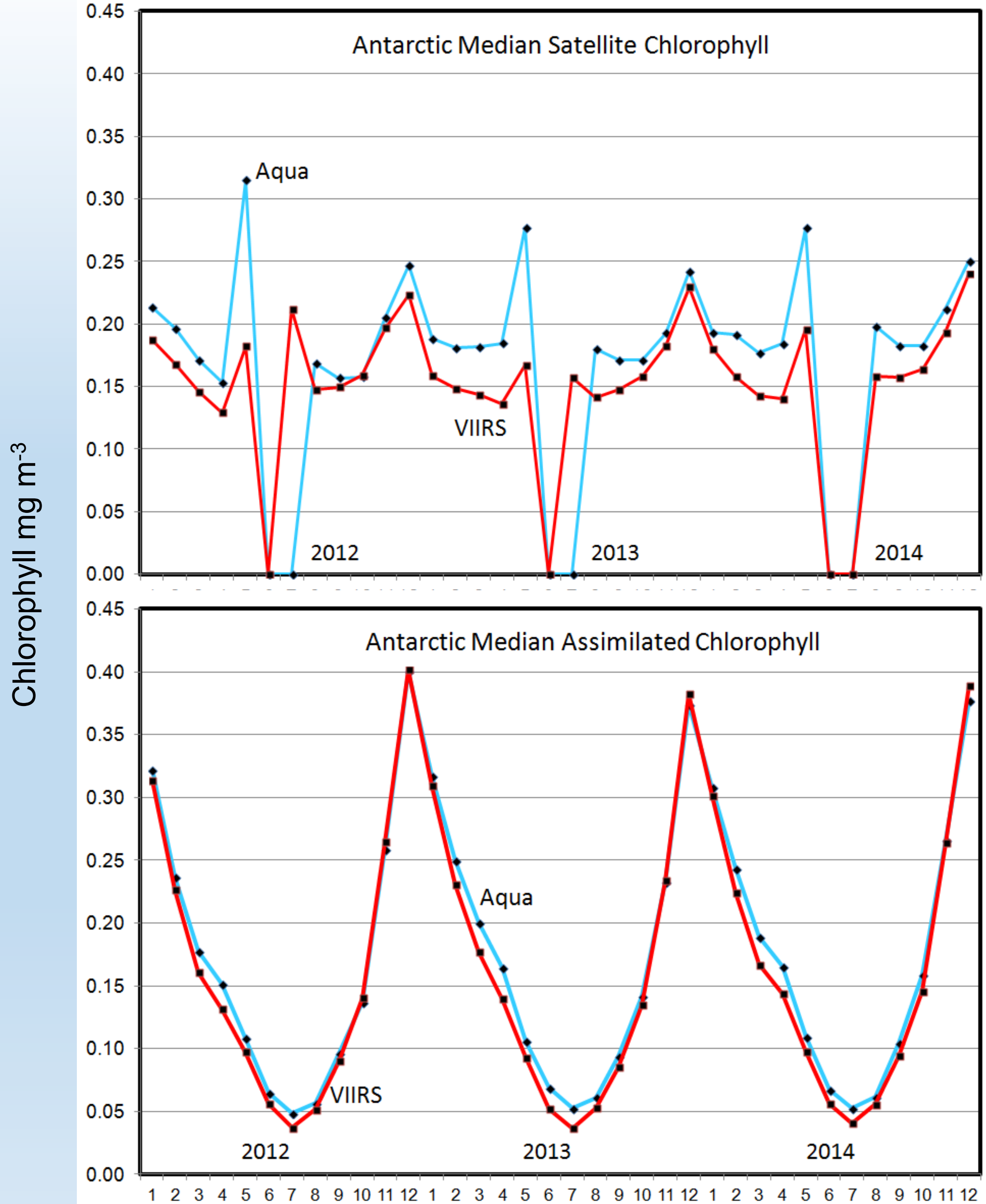


Chlorophyll mg m^{-3}

Note the plumes of high chlorophyll in the Southern Ocean that are artifacts of sampling. Missing data along some continental shelves, which is due to the underlying model domain.

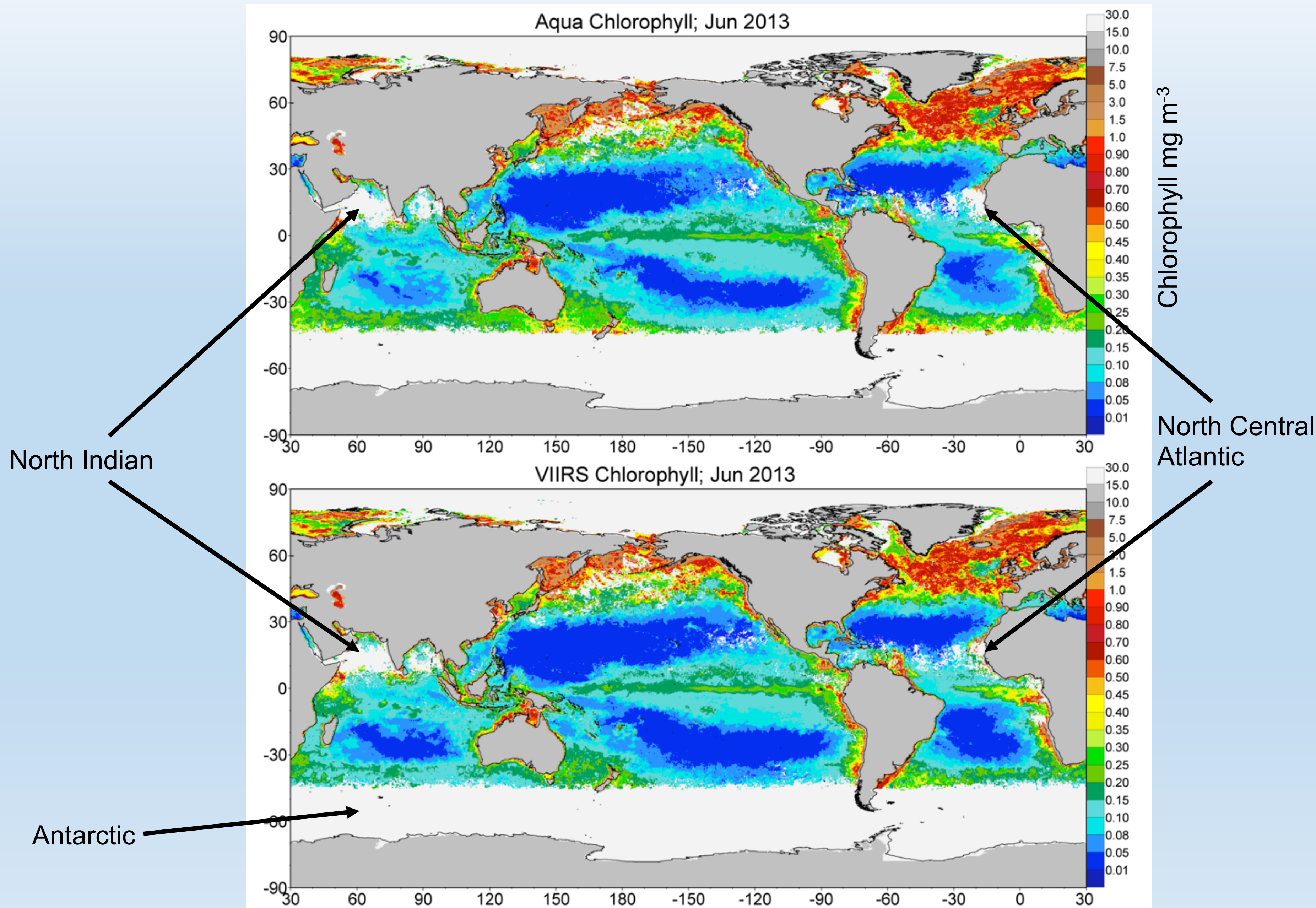


Chlorophyll mg m-3
Global Median Satellite Chlorophyll
Aqua
VIIRS
2012
2013
2014
Global Median Assimilated Chlorophyll
Aqua
VIIRS
2012
2013
2014
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12



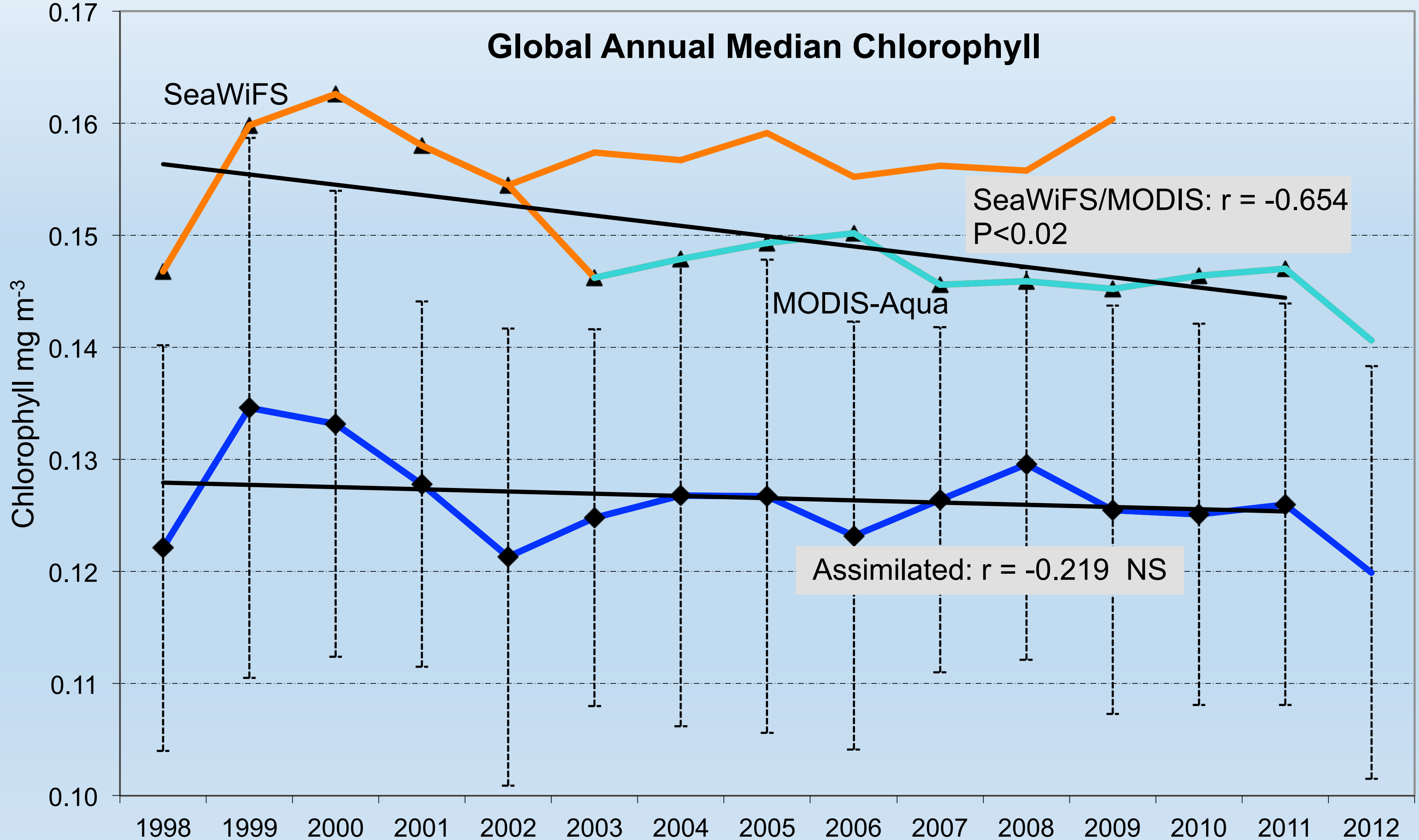
Chlorophyll mg m-3
Antarctic Median Satellite Chlorophyll
Aqua
VIIRS
2012
2013
2014
Antarctic Median Assimilated Chlorophyll
Aqua
VIIRS
2012
2013
2014
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

Differences in sampling between MODIS-Aqua (top) and VIIRS (bottom)



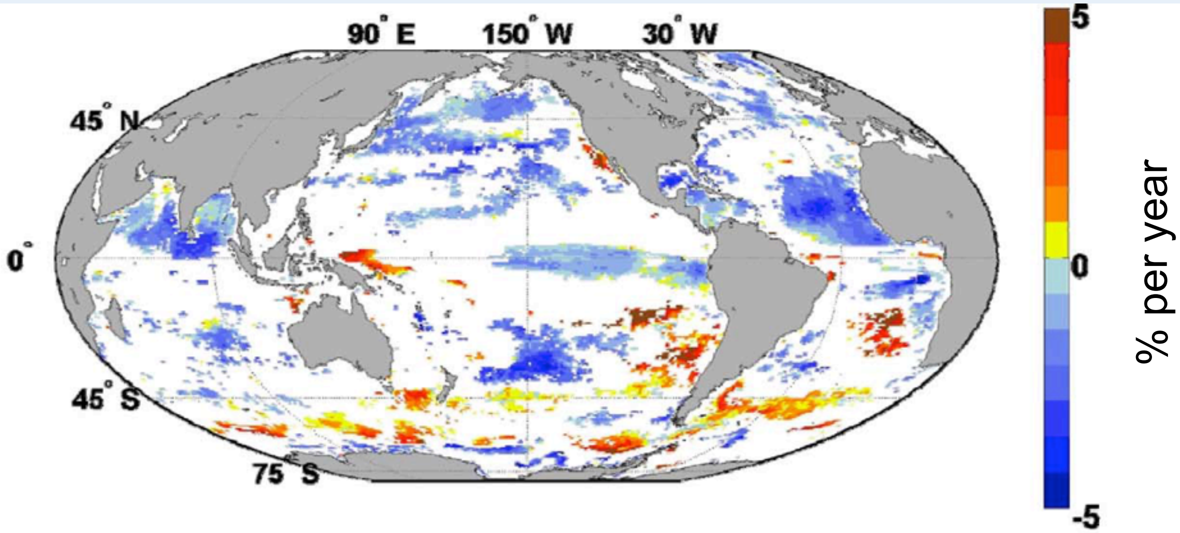
2. Detection of trends in ocean biogeochemistry

SeaWIFS: R2010.0
MODIS: R2013.1
OCX

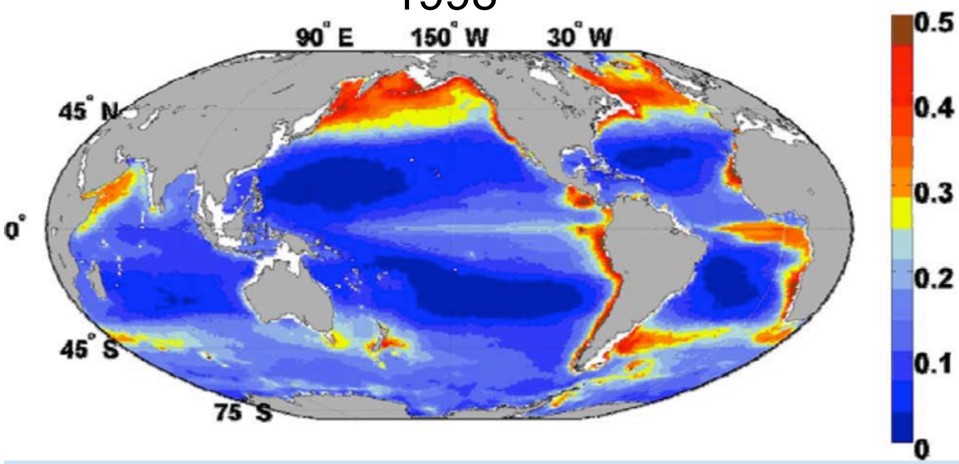


Gregg and Rousseaux 2014; JGR Oceans

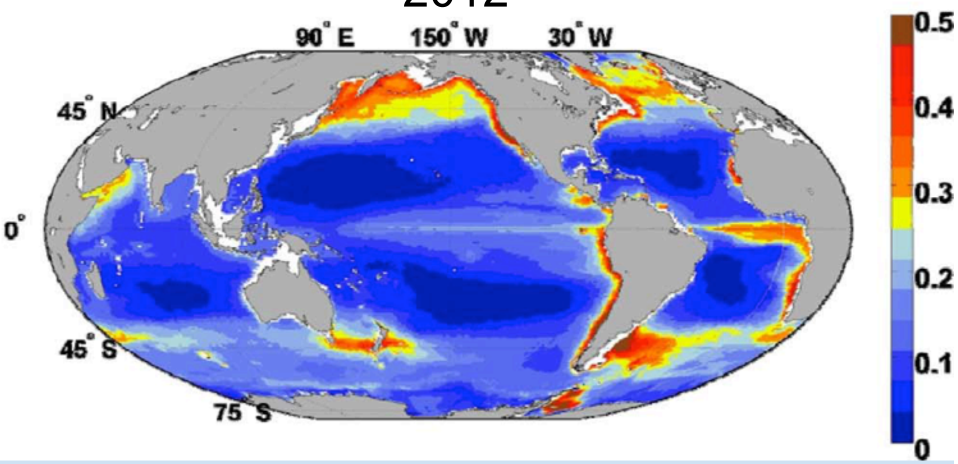
Significant Trends 1998-2012



1998



2012

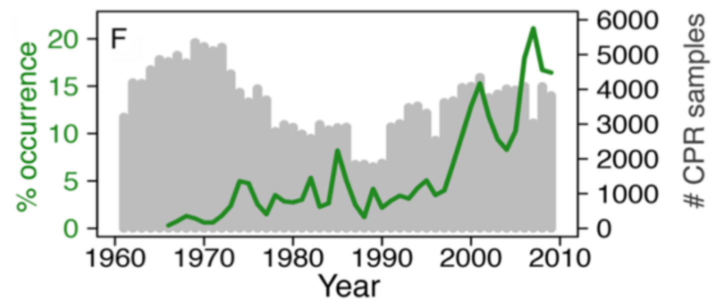


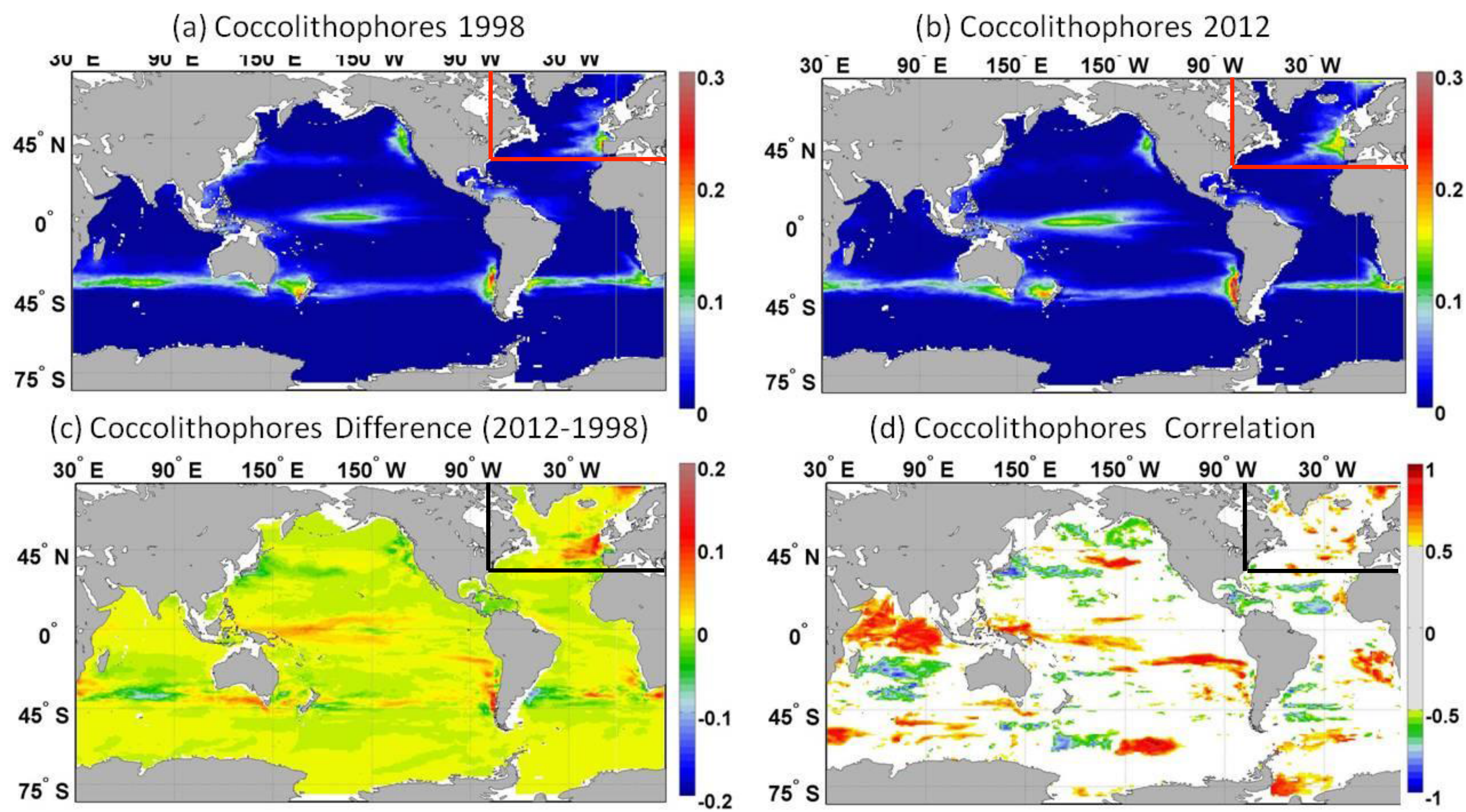
Chlorophyll mg m^{-3}

Gregg and Rousseaux 2014; JGR Oceans

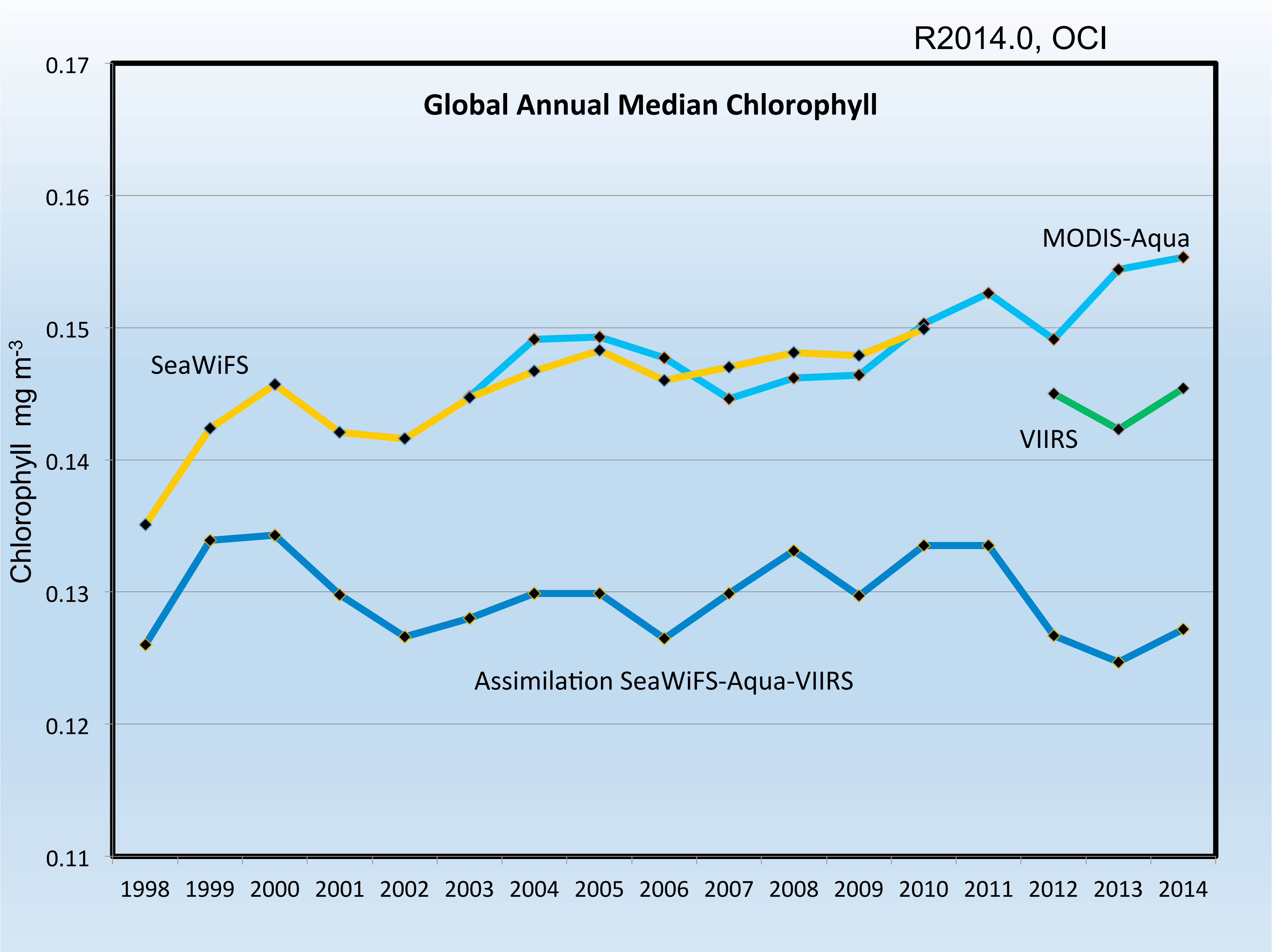
Increasing occurrence of coccolithophores
In North Atlantic

Rivero-Calle, 2015; Science

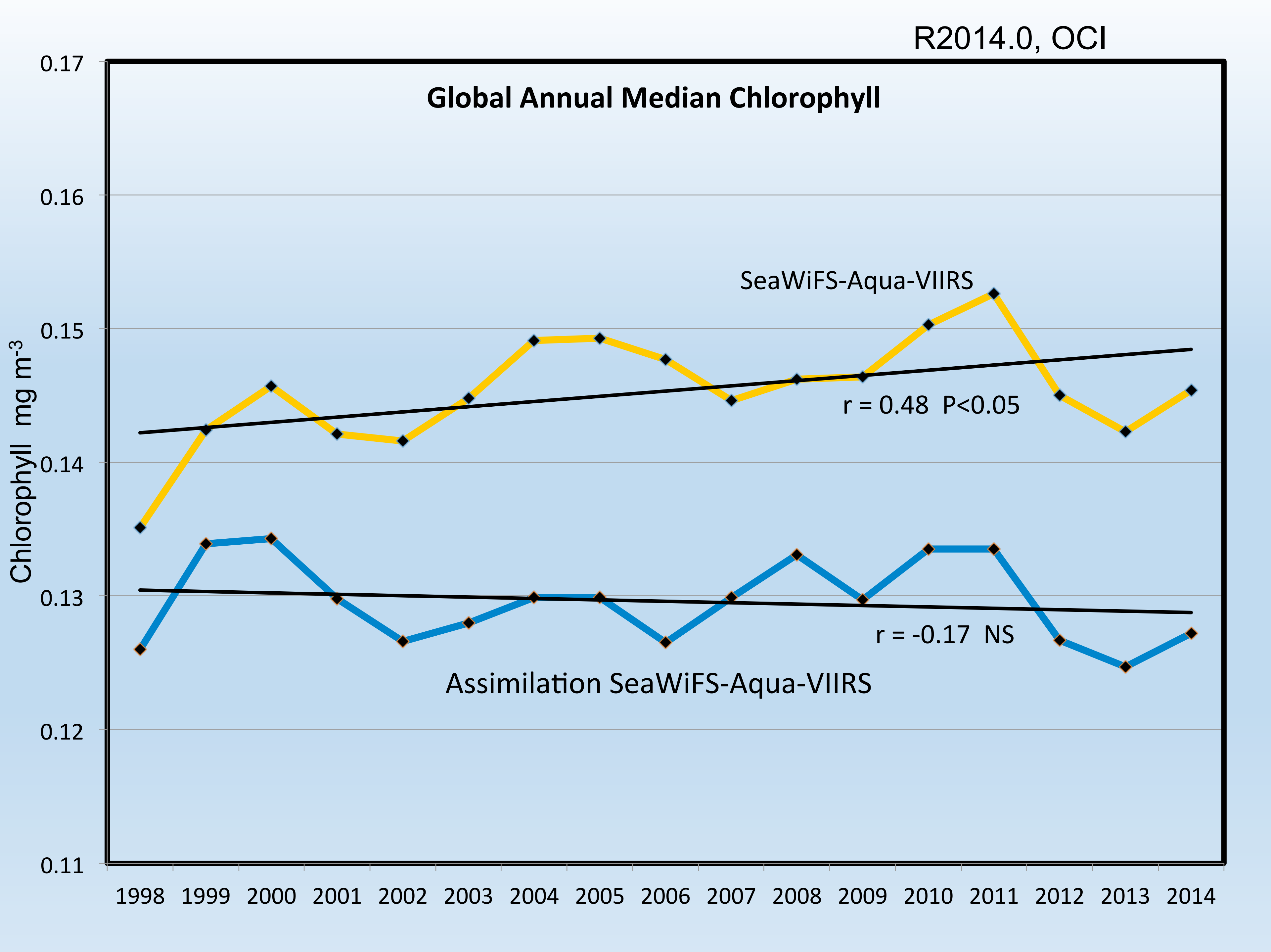




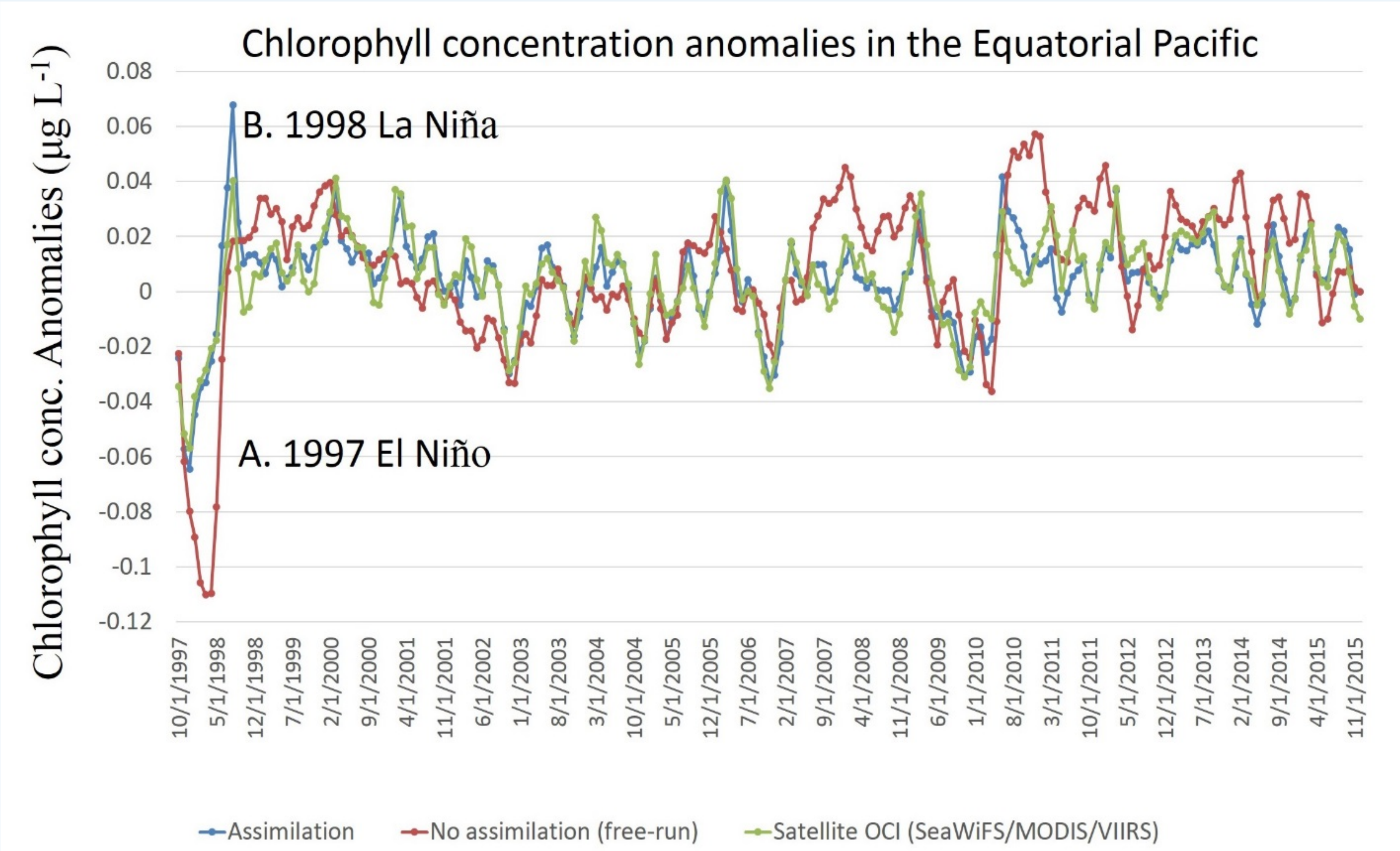
Rousseaux and Gregg, 2015; Global Biogeochemical Cycles



R2014.0, OCI
Global Annual Median Chlorophyll
Chlorophyll mg m-3
0.17
0.16
0.15
0.14
0.13
0.12
0.11
MODIS-Aqua
SeaWiFS
VIIRS
Assimilation SeaWiFS-Aqua-VIIRS
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014


R2014.0, OCI
Global Annual Median Chlorophyll
SeaWiFS-Aqua-VIIRS
r = 0.48 P<0.05
r = -0.17 NS
Assimilation SeaWiFS-Aqua-VIIRS
Chlorophyll mg m-3
0.17
0.16
0.15
0.14
0.13
0.12
0.11
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

3. Forecast seasonal to decadal variability



Significant correlation of model versus satellite:
SeaWiFS (R=0.77), MODIS (R=0.64), VIIRS (R=0.74)

GMAO Seasonal Forecast Data (e.g. wind stress, SST, shortwave radiation)

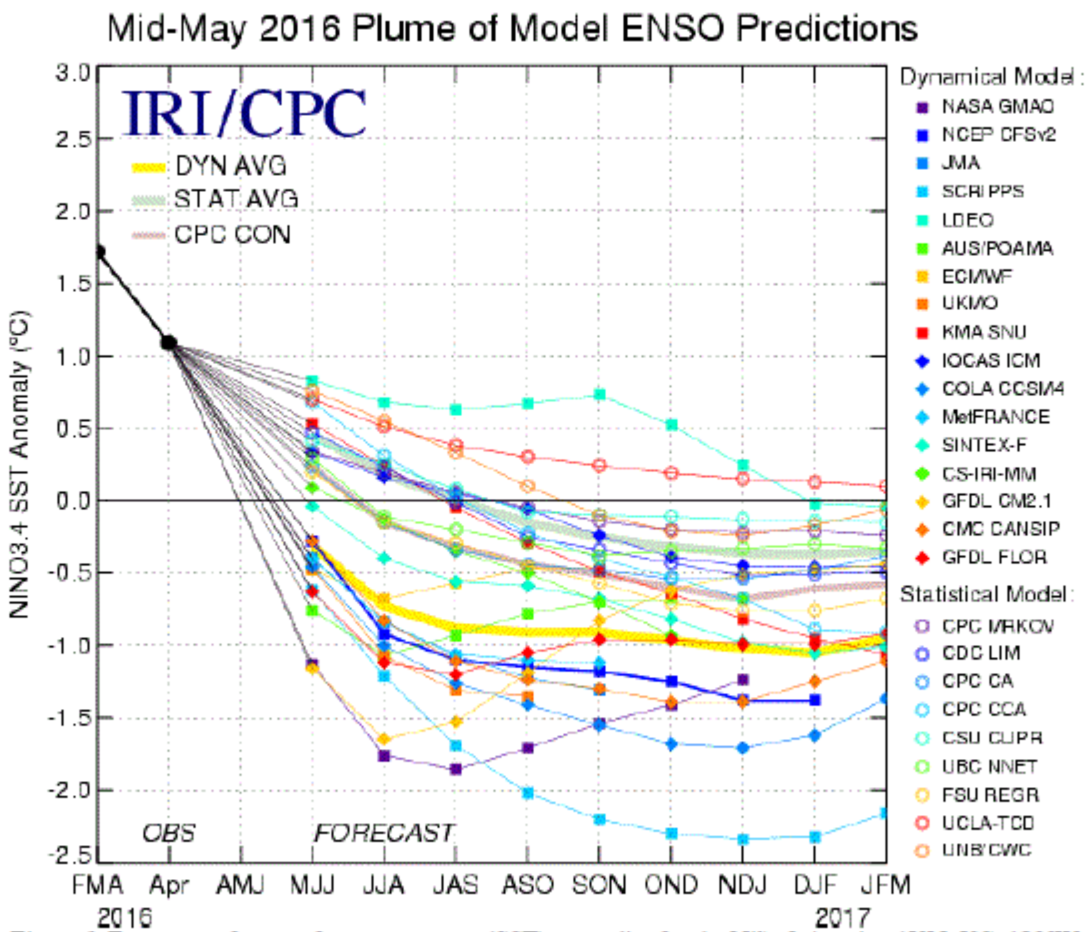
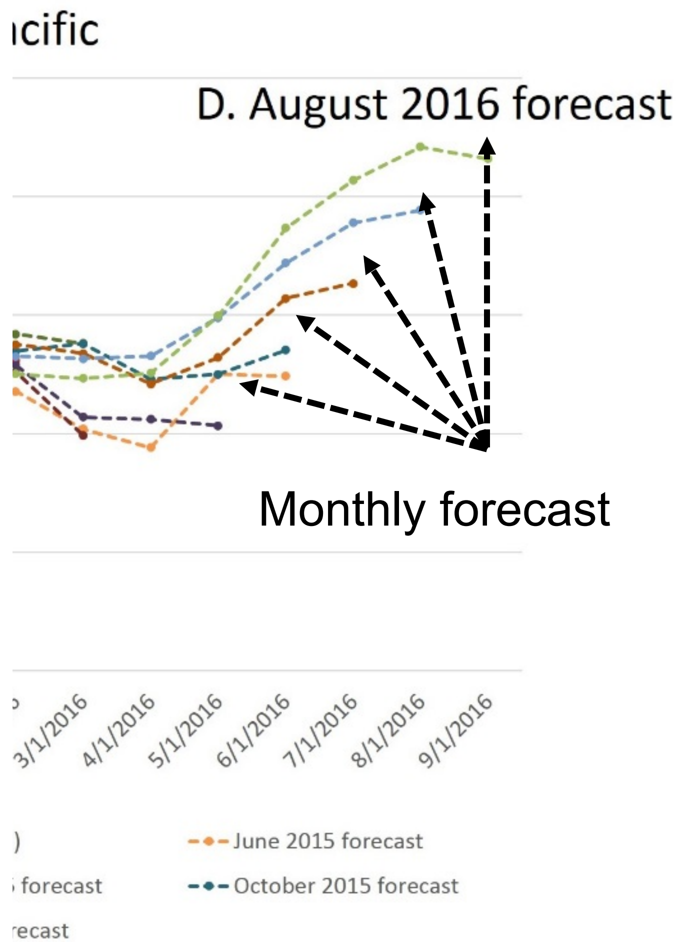
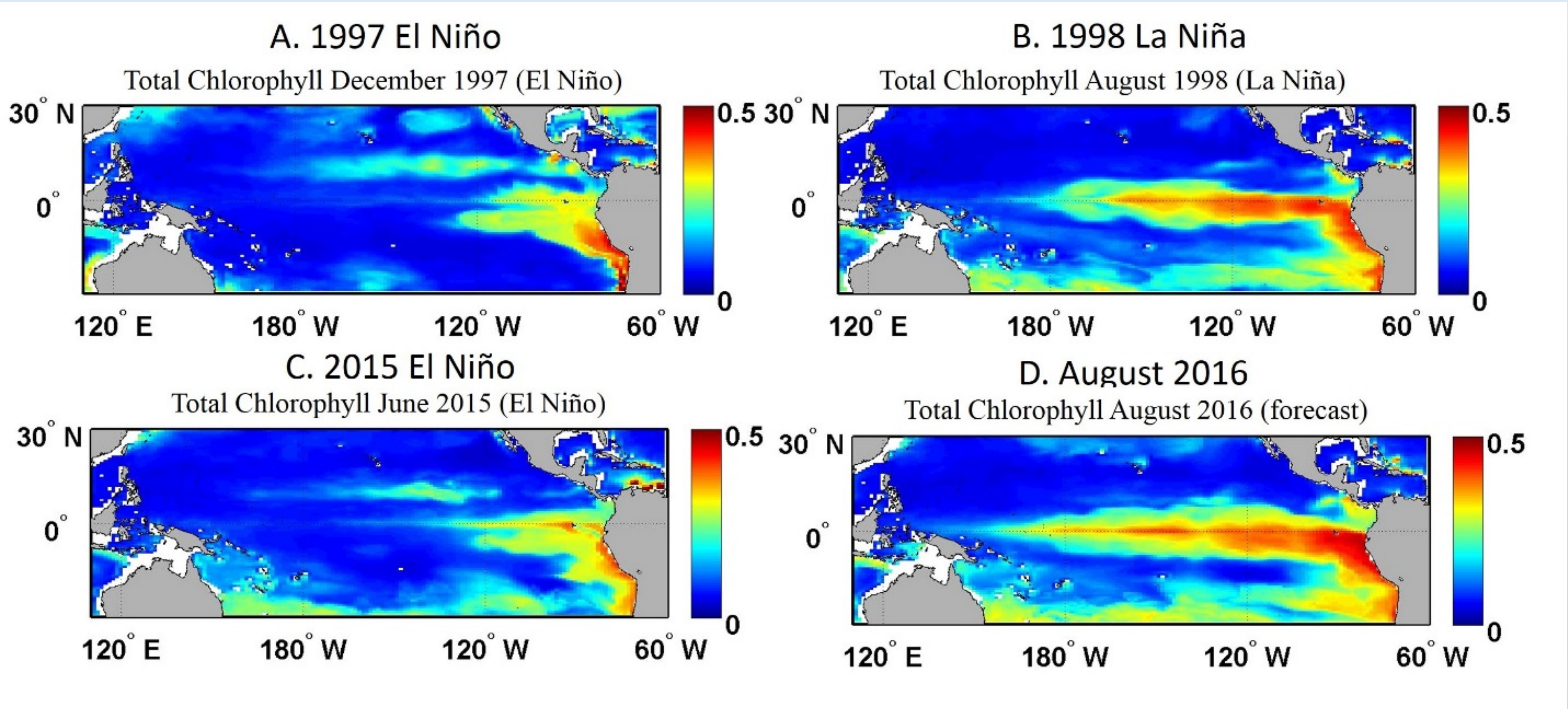


Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure updated 17 May 2016.

Source: NOAA Climate Prediction Center



Forecasting Chlorophyll in the 2015-2016 El Niño using VIIRS



Application for ENSO but also HABs, heat content, etc

Summary

- A rigorous integration of satellite data and models via data assimilation shows
    - Reduction of inconsistencies between chlorophyll observed by different satellites/sensors
    - Reduction of sampling biases among the sensors
    - Provide a global coverage and information on products that cannot (currently) be derived from ocean color
- Enables trend detection over decades with multiple satellites
- Next step: Use of VIIRS in improving and evaluating forecast chlorophyll in ENSO events is promising