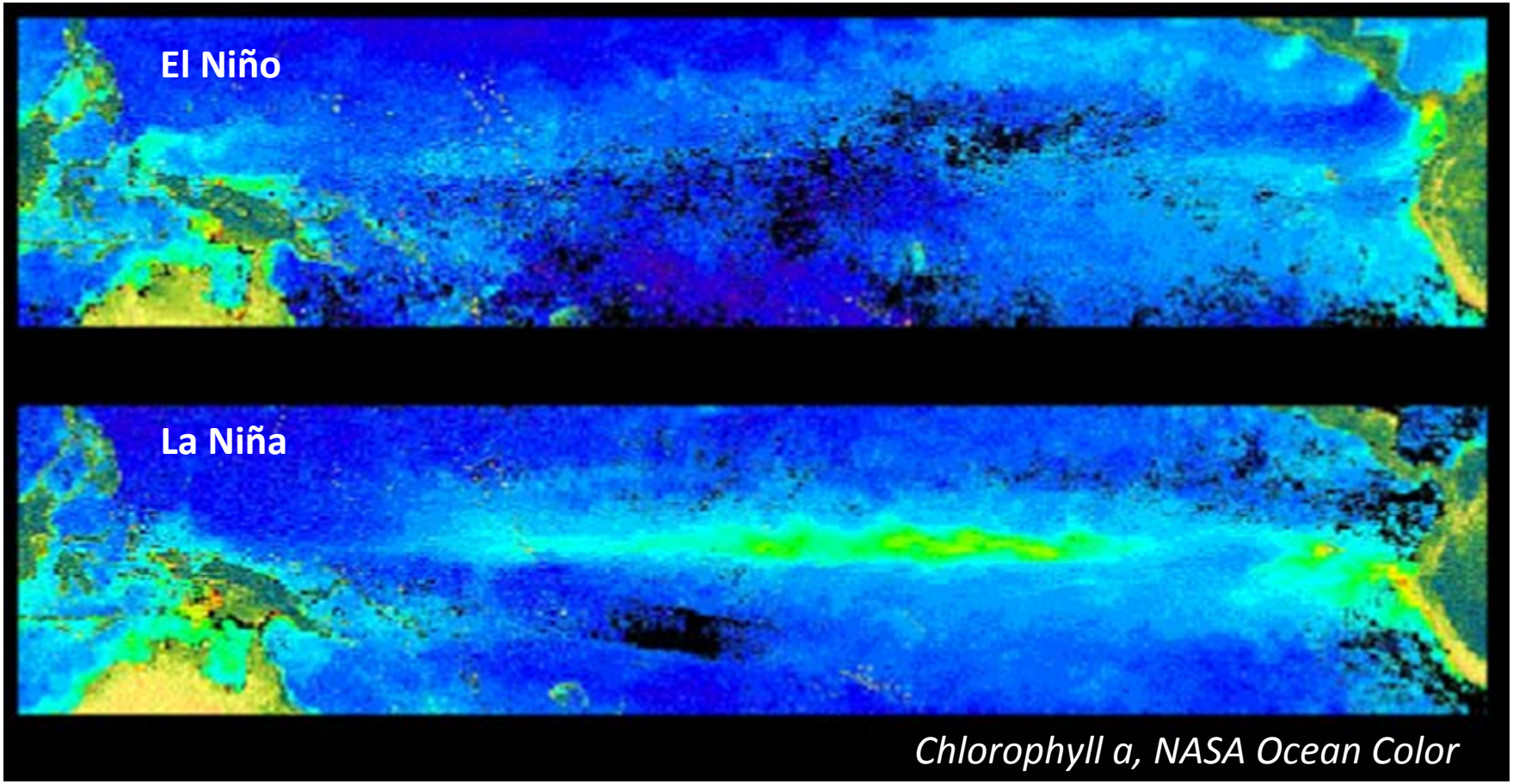
Modeling and forecasting lower trophic impacts

Cecile S. Rousseaux



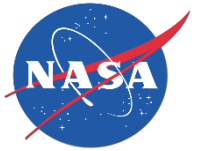
GMAO
Global Modeling and Assimilation Office

US CLIVAR-Forecasting ENSO Impacts on Marine Ecosystems of the US West Coast
August 10-11, 2016

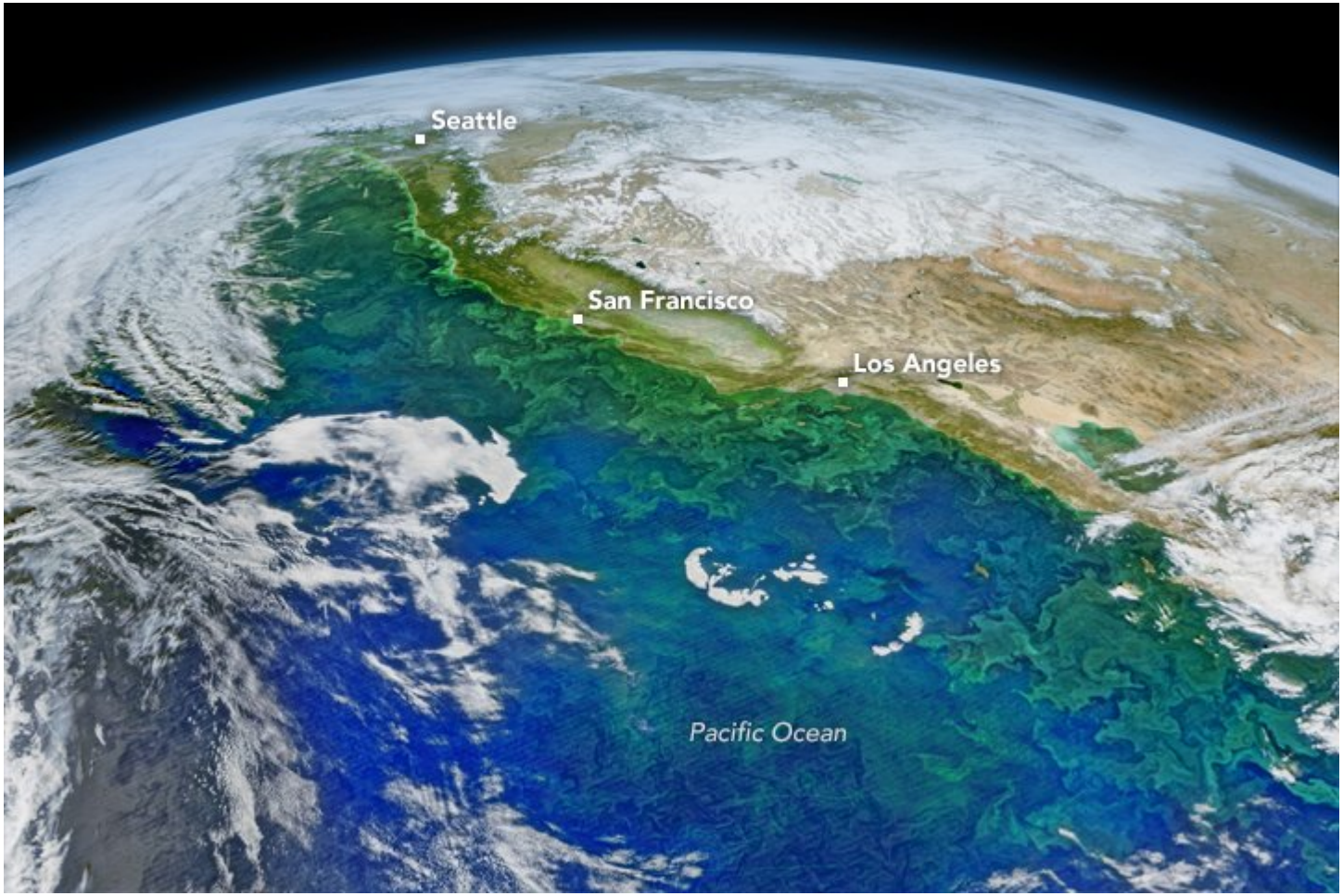
USRA

Overview of talk:

1. Satellite ocean color and ocean biogeochemical (dynamical) models
2. Existing seasonal forecast of atmospheric and ocean (physical) variables
3. From forecast of atmospheric and ocean physical variables to forecast of ocean biogeochemistry
4. Applications of ocean biogeochemical forecast



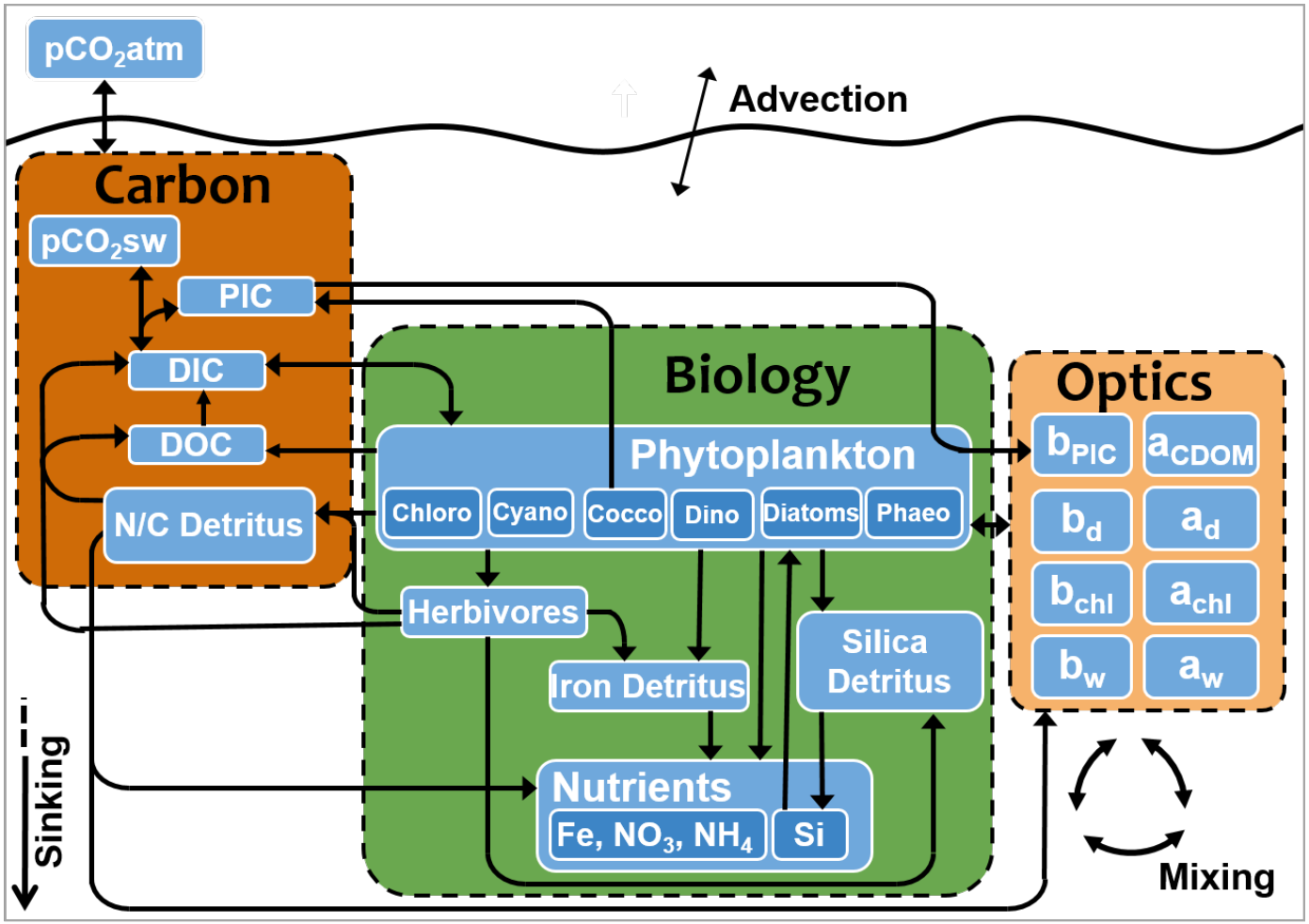
1. Satellite ocean color and ocean biogeochemical (dynamical) models



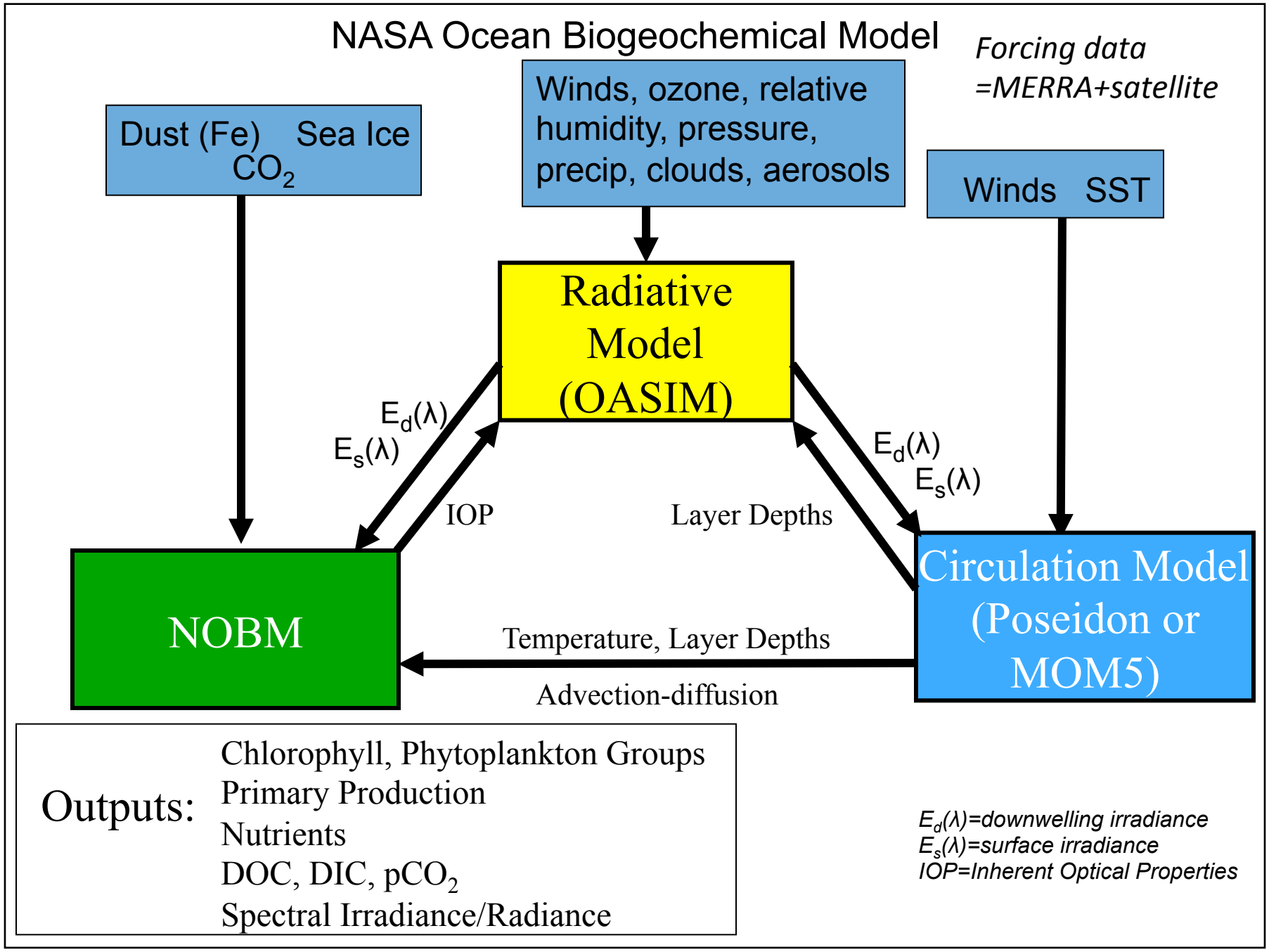
Global Ocean Color Satellite: SeaWiFS-MODIS-VIIRS
Present here one way to (a) model lower trophic levels and (b) produce a global ocean biogeochemical forecast

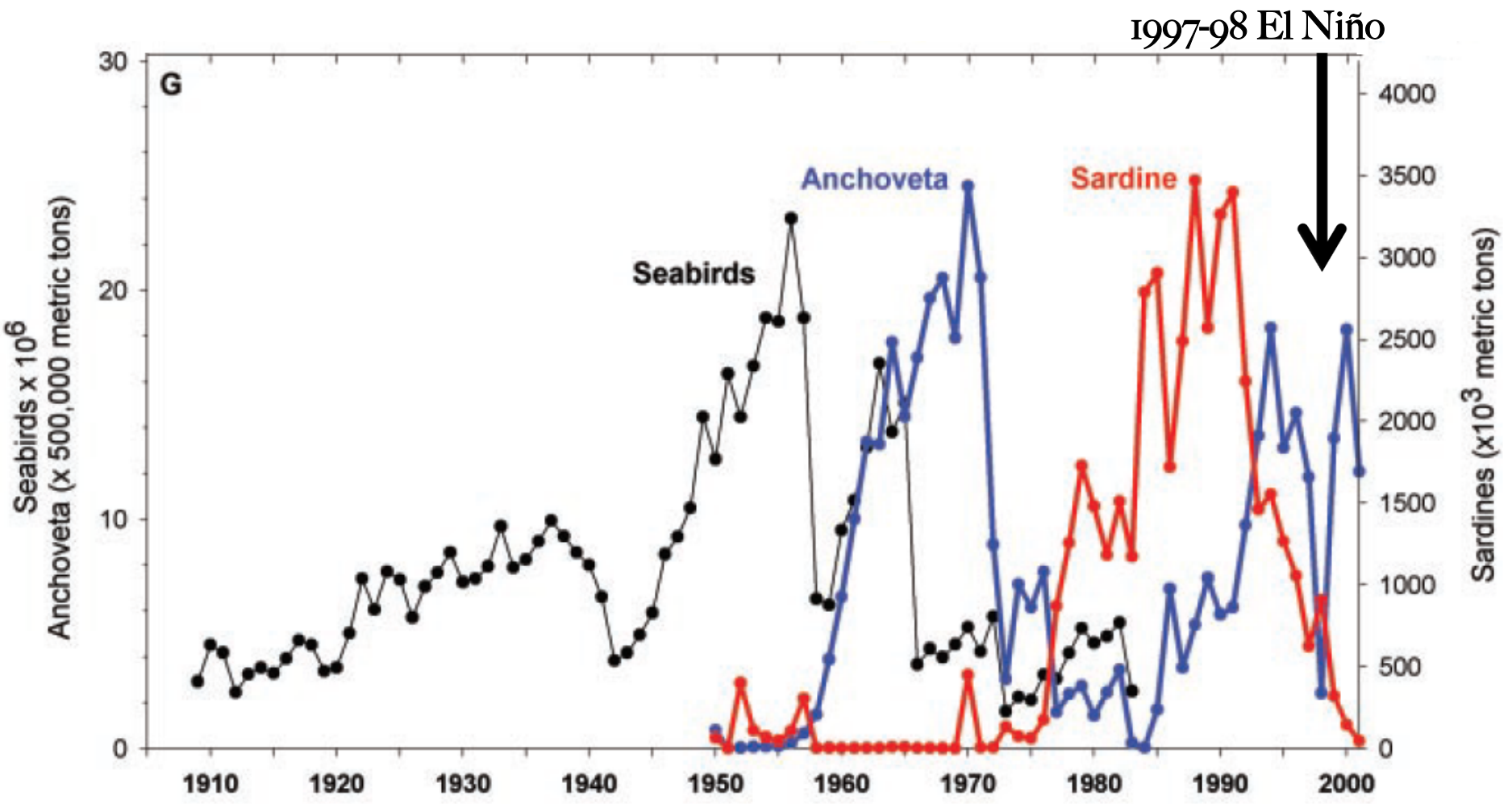
1. Satellite ocean color and ocean biogeochemical (dynamical) models

NASA Ocean Biogeochemical Model (NOBM)

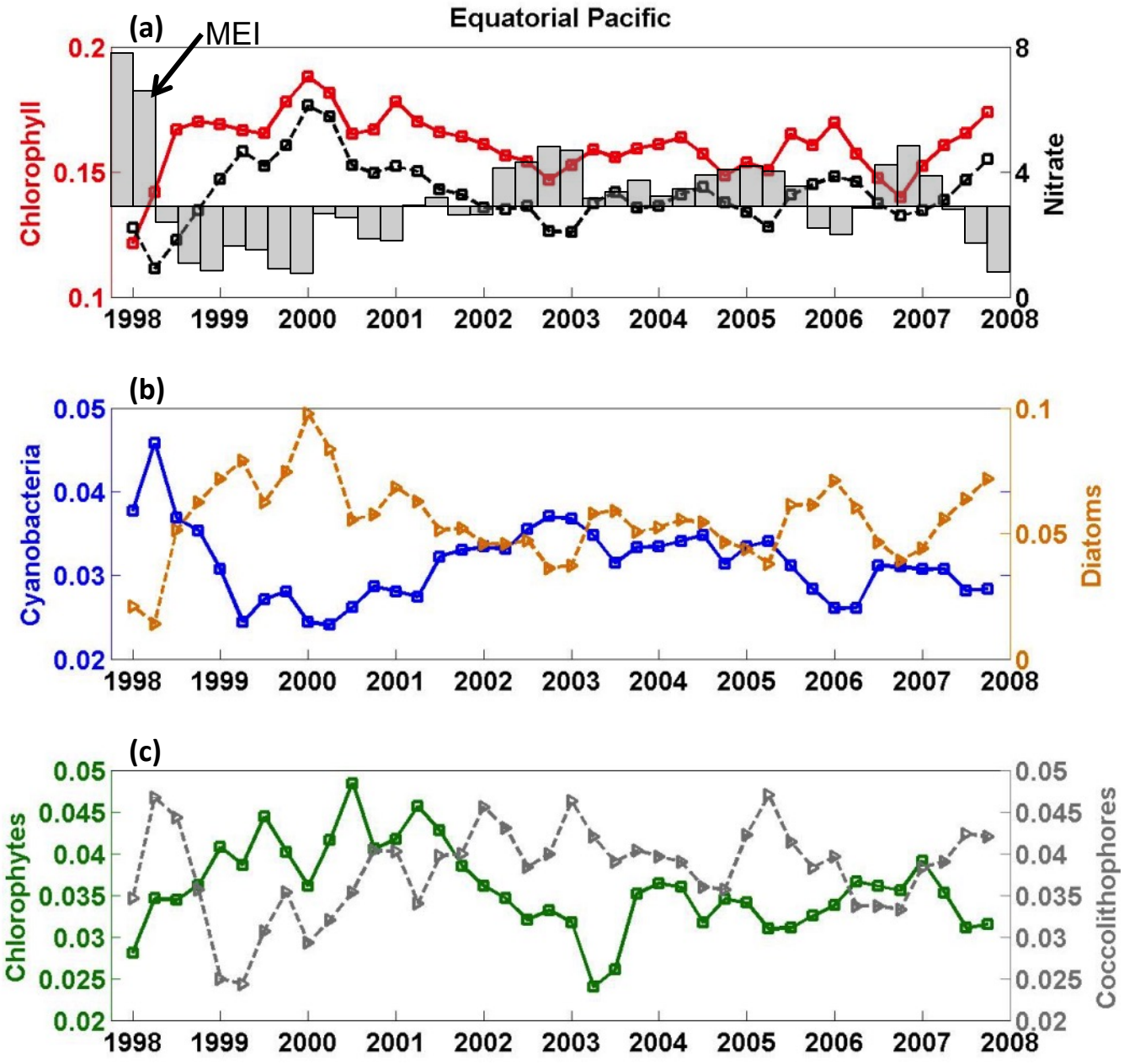


- Interactions among the carbon, biological and optical components of NOBM
- Assimilation of satellite chlorophyll, PIC and aCDOM (SeaWiFS, MODIS and VIIRS)
- Force the model using MERRA data (Reanalysis product)


NASA Ocean Biogeochemical Model
Forcing data
=MERRA+satellite
Winds, ozone, relative humidity, pressure, precip, clouds, aerosols
Dust (Fe) Sea Ice
CO_2
Winds SST
Radiative Model (OASIM)
$E_d(\lambda)$
$E_s(\lambda)$
IOP
Layer Depths
$E_d(\lambda)$
$E_s(\lambda)$
NOBM
Circulation Model (Poseidon or MOM5)
Temperature, Layer Depths
Advection-diffusion
Outputs:
Chlorophyll, Phytoplankton Groups
Primary Production
Nutrients
DOC, DIC, pCO_2
Spectral Irradiance/Radiance
$E_d(\lambda)$=downwelling irradiance
$E_s(\lambda)$=surface irradiance
IOP=Inherent Optical Properties

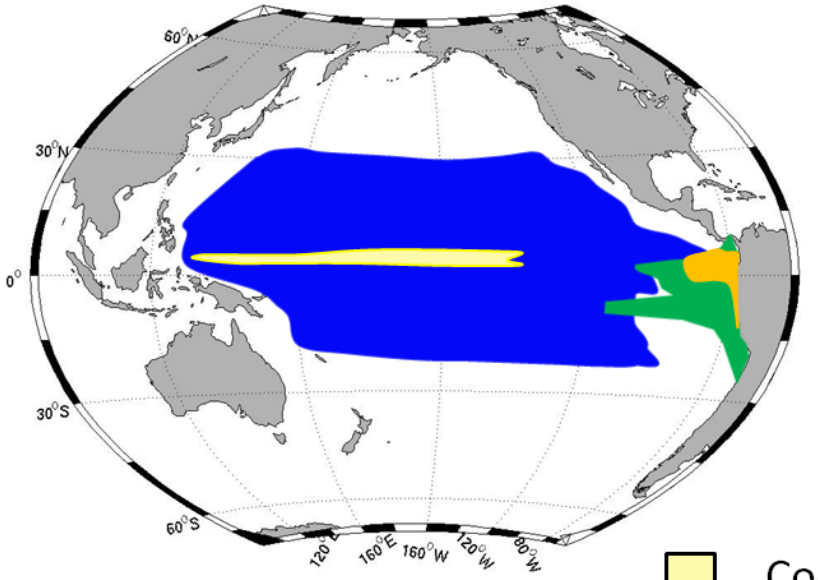


Seabird abundance and anchoveta and sardine landings from Peru (Chavez et al. 2003)

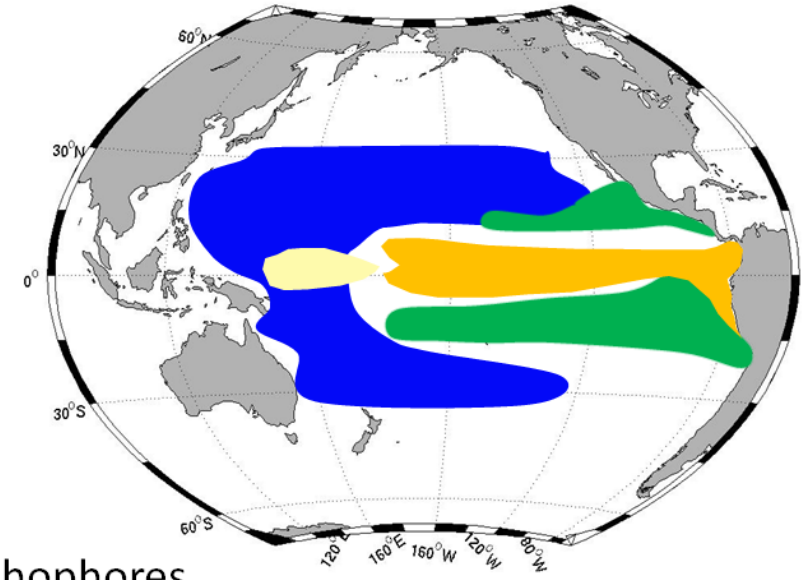


Rousseaux and Gregg 2012

El Niño



La Niña



Coccolithophores

Chlorophytes

Diatoms

Cyanobacteria

Rousseaux and Gregg 2012

How well does the NOBM compare to in situ data?

	North Central Pacific	Equatorial Pacific	South Pacific
Diatoms	-3.50 (3)	-0.87 (21)	25.58 (7)
Chlorophytes	-19.40 (2)	-18.01 (17)	-33.32 (7)
Cyanobacteria	10.67 (24)	-13.47 (20)	3.20 (2)
Coccolithophores	1.99 (3)	36.77 (15)	-2.11 (7)

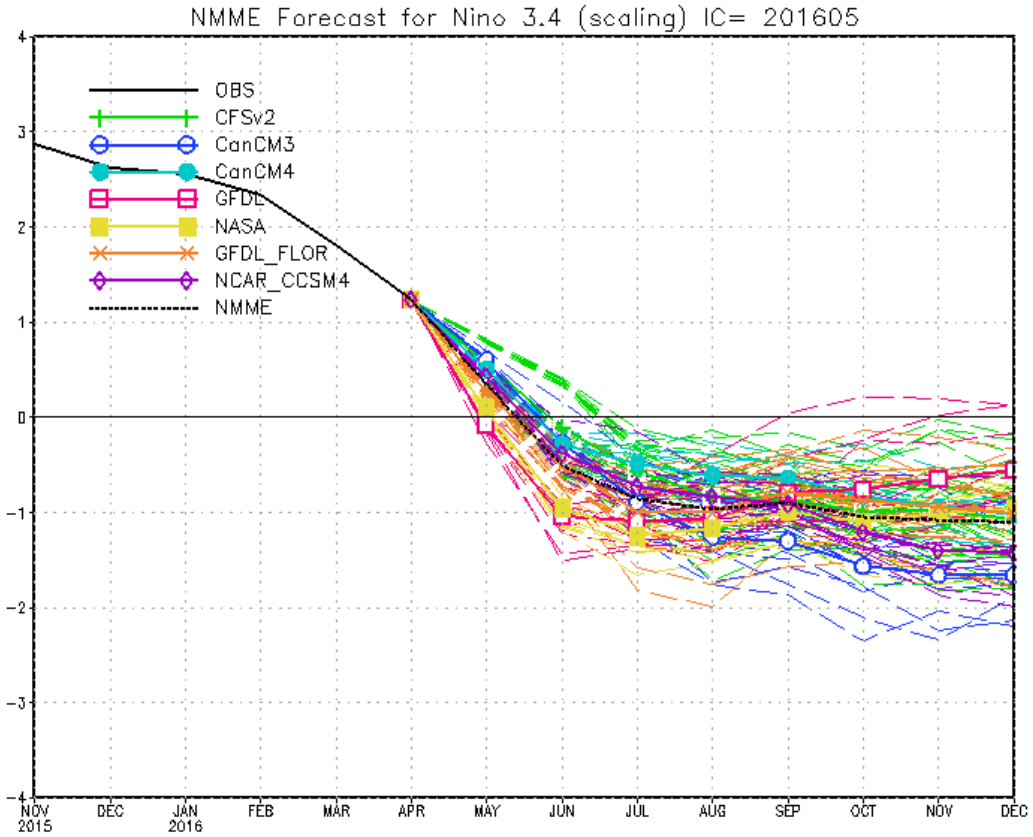
Percentage difference between the NOBM and the in situ data. The number of observations used for the comparison is between parenthesis

Only >20% in 3 cases

2. Existing seasonal forecast of atmospheric and ocean (physical) variables

NASA Global Modeling and Assimilation Office (GMAO) experimental seasonal forecast

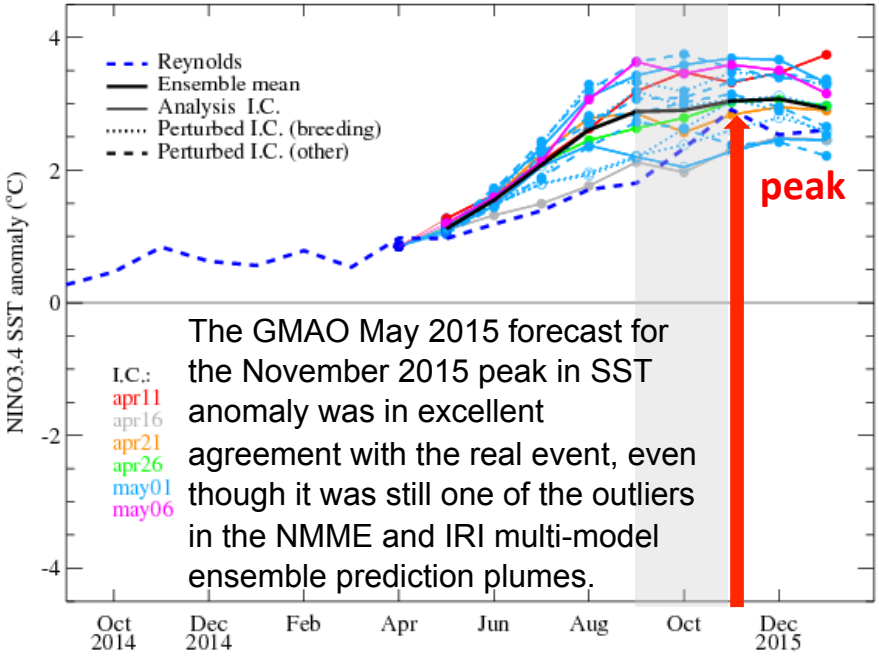
- Physical (atmospheric and ocean) variables currently provided to the North American Multi-Model Ensemble (NMME) prediction project, as well as to other national (IRI) and international (APCC) ensemble seasonal forecasting efforts
- Benefited previous mission planning (e.g. NASA Arctic Radiation, IceBridge Sea & Ice Experiment (ARISE) 2014, 2015 Operation IceBridge)



The 2015 El Niño peaked in November 2015 with the Equatorial Pacific sea-surface-temperature (SST) anomalies higher than 2.0 °C in the Central Pacific Niño3.4 region. These very strong temperature anomalies began in Sep/Oct/Nov (SON) of 2015 and persisted through Dec/Jan/Feb (DJF) of 2016. The GEOS-5 system began predicting this strong El Niño for SON starting with the March 2015 forecast.

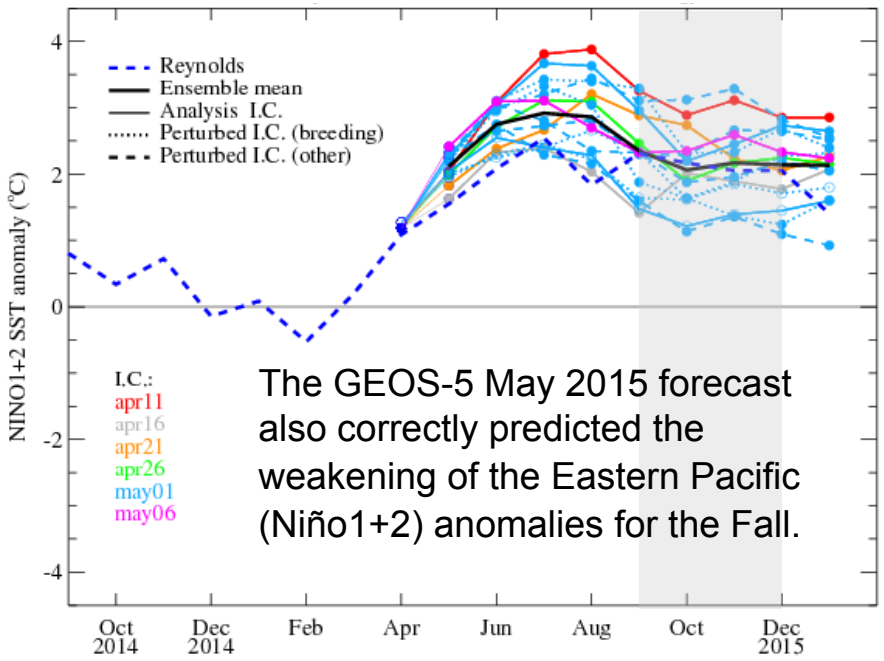
GMAO GEOS-5 May 2015 Experimental Forecasts

Niño3.4: Central Pacific



The GMAO May 2015 forecast for the November 2015 peak in SST anomaly was in excellent agreement with the real event, even though it was still one of the outliers in the NMME and IRI multi-model ensemble prediction plumes.

Niño1+2: Eastern Pacific



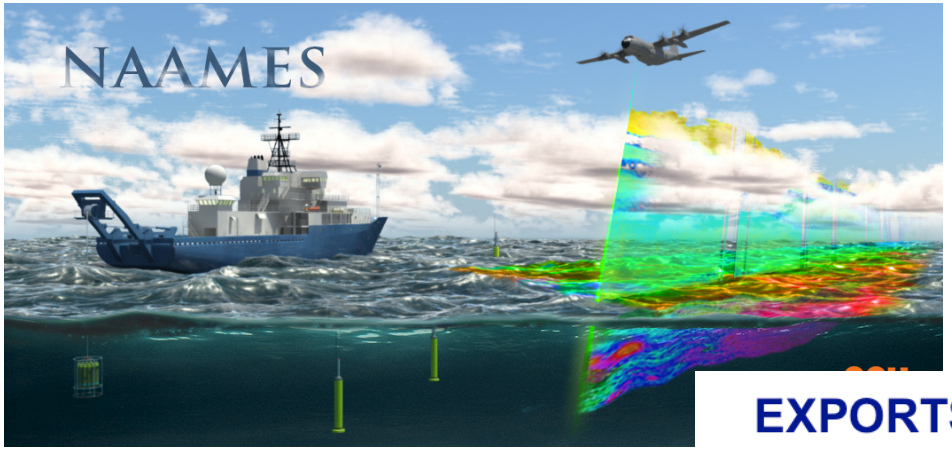
The GEOS-5 May 2015 forecast also correctly predicted the weakening of the Eastern Pacific (Niño1+2) anomalies for the Fall.

Slide courtesy of Robin Kovach (NASA GMAO)

- Current forecast focus mostly on weather, harmful algal blooms, regional forecast
- Need to include ocean biogeochemistry in forecast:
    - recruitment of higher trophic levels (strategic versus reactive marine resource management)
    - prediction of harmful algal blooms
    - improved ocean heat content estimate could lead to improve atmospheric forecast (i.e. hurricanes)
    - Field campaign planning
    - …etc

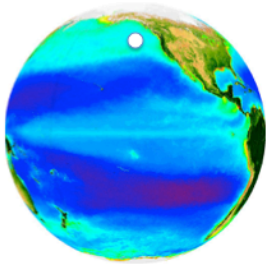
3. Applications of ocean biogeochemical forecast (2)

- Provide up-to-date representation of the spatial and temporal changes in ocean biogeochemistry for sampling purposes

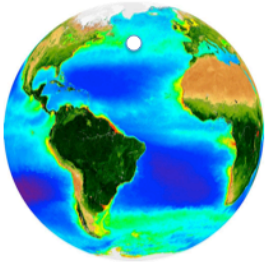


EXPORTS: *Notional* Implementation

Station P



North Atlantic



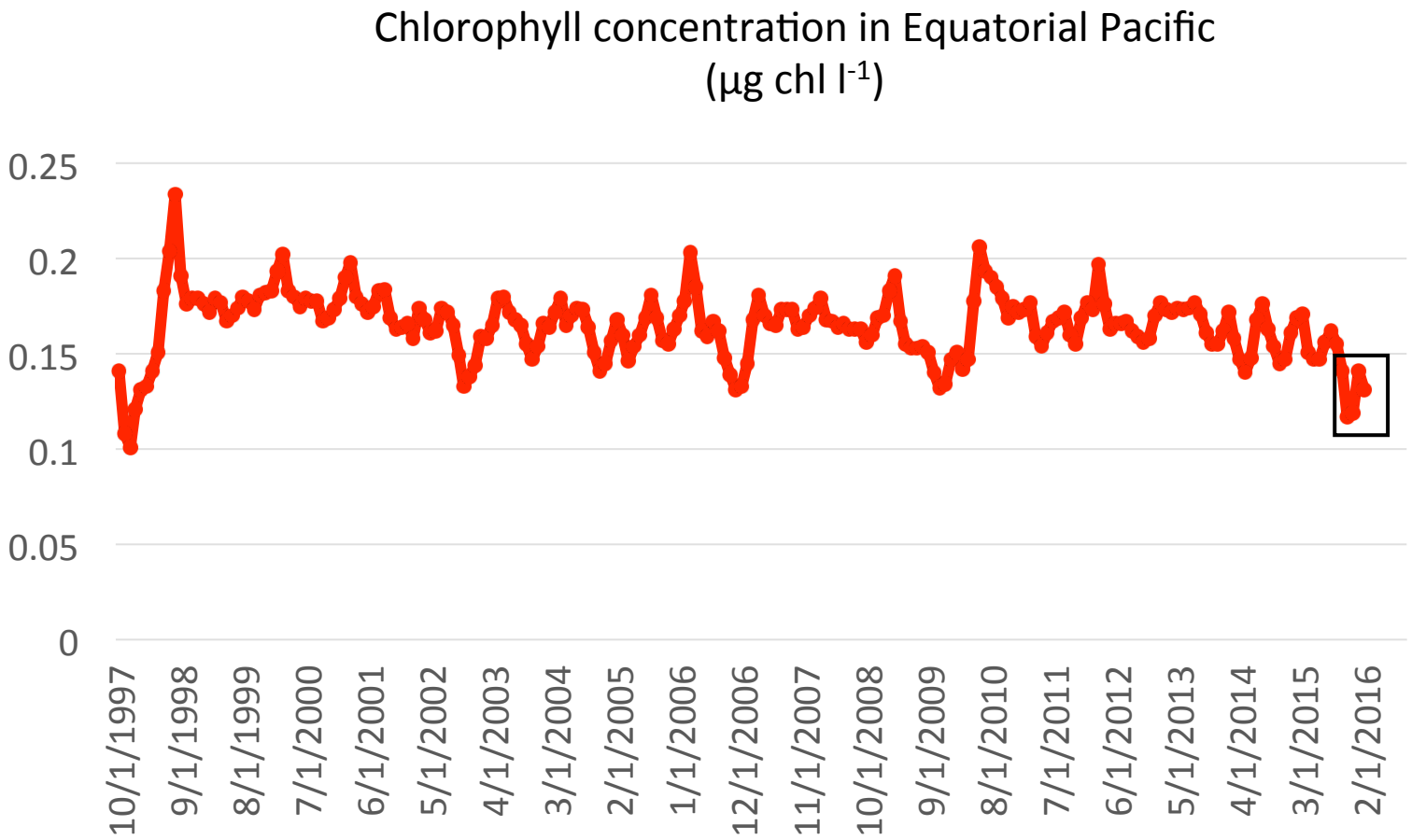
Cruise 1: April/May 30/45d
Cruise 2: Aug, 30d
Leverage: OOI node, LineP

Bloom: April/May 45 d
Non-bloom: Aug, 30d
Leverage: Internationals

Will collect ~8 ecosystem / C cycling states
Supplement by data mining existing results

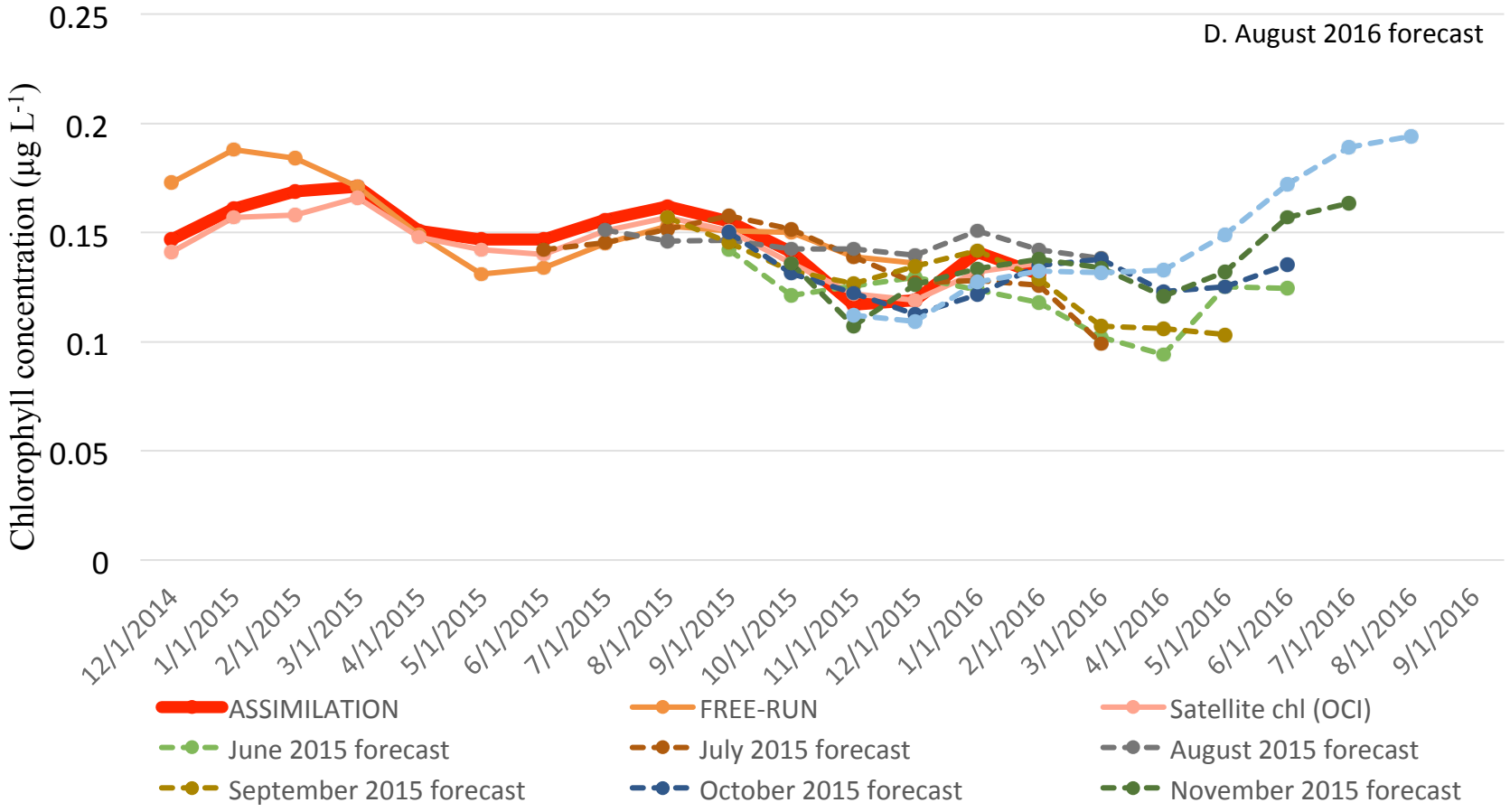
4. Next step: From forecast of atmospheric and ocean physical variables to forecast of ocean biogeochemistry

- Use atmospheric and ocean forecasts to force the biogeochemical model (e.g. wind stress, SST, short- and longwave radiation)
- GEOS-5= AGCM+MOM5+CICE+GOCART+NOBM (current forecast in Poseidon)
- ¼ degree resolution, 40 vertical levels
- Uncertainties in forecast assessed using retrospective forecasts
- Future developments: use several forecast ensembles


Chlorophyll concentration in Equatorial Pacific
(µg chl l-1)
0.25
0.2
0.15
0.1
0.05
0
10/1/1997
9/1/1998
8/1/1999
7/1/2000
6/1/2001
5/1/2002
4/1/2003
3/1/2004
2/1/2005
1/1/2006
12/1/2006
11/1/2007
10/1/2008
9/1/2009
8/1/2010
7/1/2011
6/1/2012
5/1/2013
4/1/2014
3/1/2015
2/1/2016

5. Applications of ocean biogeochemical forecast (1)

Experimental ocean biogeochemistry forecast

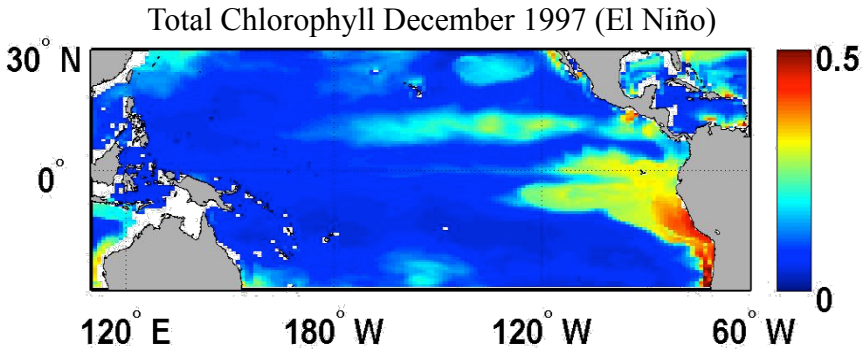


Time series of chlorophyll concentration (µg L^{-1}) from the assimilated run, the free-run and the VIIRS satellite data as well as the 9-month forecast done monthly since June 2015.

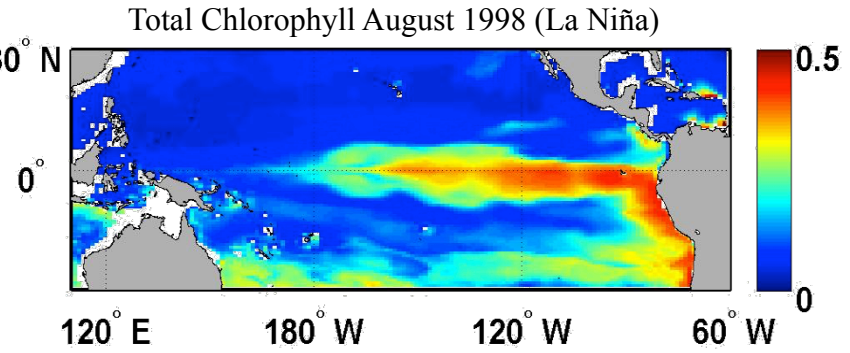
Within 8% if the satellite chlorophyll in the Equatorial Pacific for the first two months of the forecast, within 18-20% for a forecast 3-4 month ahead of time and within 42% for months 5-9 .

NOBM with VIIRS chlorophyll assimilation (except for August 2016 forecast)

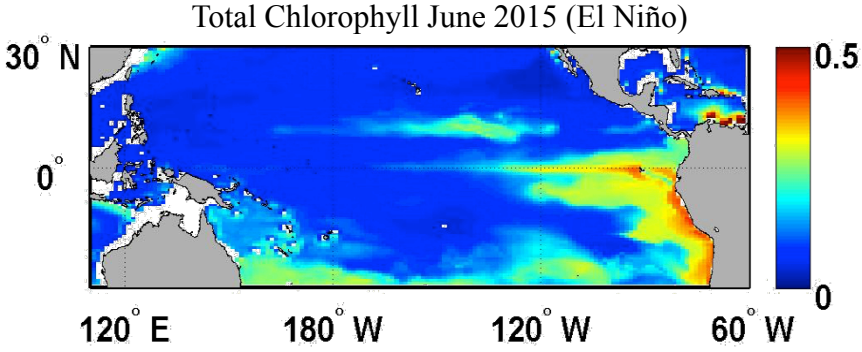
A. 1997 El Niño



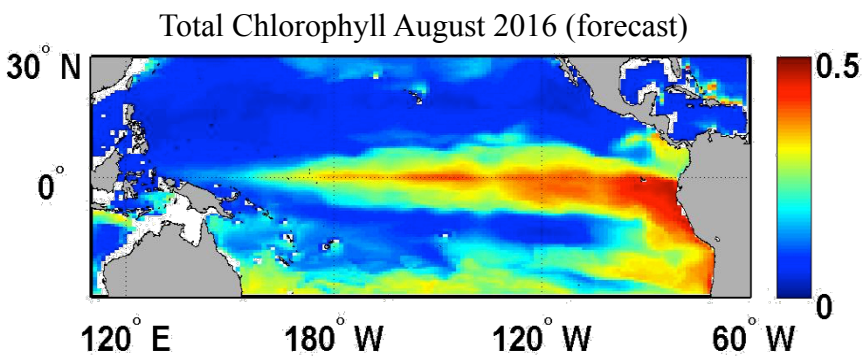
B. 1998 La Niña



C. 2015 El Niño



D. August 2016



Spatial distribution of chlorophyll concentration (µg L^{-1}) in October (A) October 1997, (B) June 1998 and (C) June 2015 and (D) forecast of chlorophyll concentration for August 2016.

Summary

1. Satellite ocean color assimilation in combination with biogeochemical models to provide global coverage of chlorophyll
2. Existing seasonal forecast of atmospheric and ocean (physical) variables can be used to provide the conditions for a forecast of ocean biogeochemistry
3. Initial ocean biogeochemistry forecast is promising but will require work to remove any drift and become operational
4. Numerous applications of this type of forecast from fisheries to sampling planning