Assessing the skill of chlorophyll forecasts: latest development and challenges ahead using the case of the Equatorial Pacific

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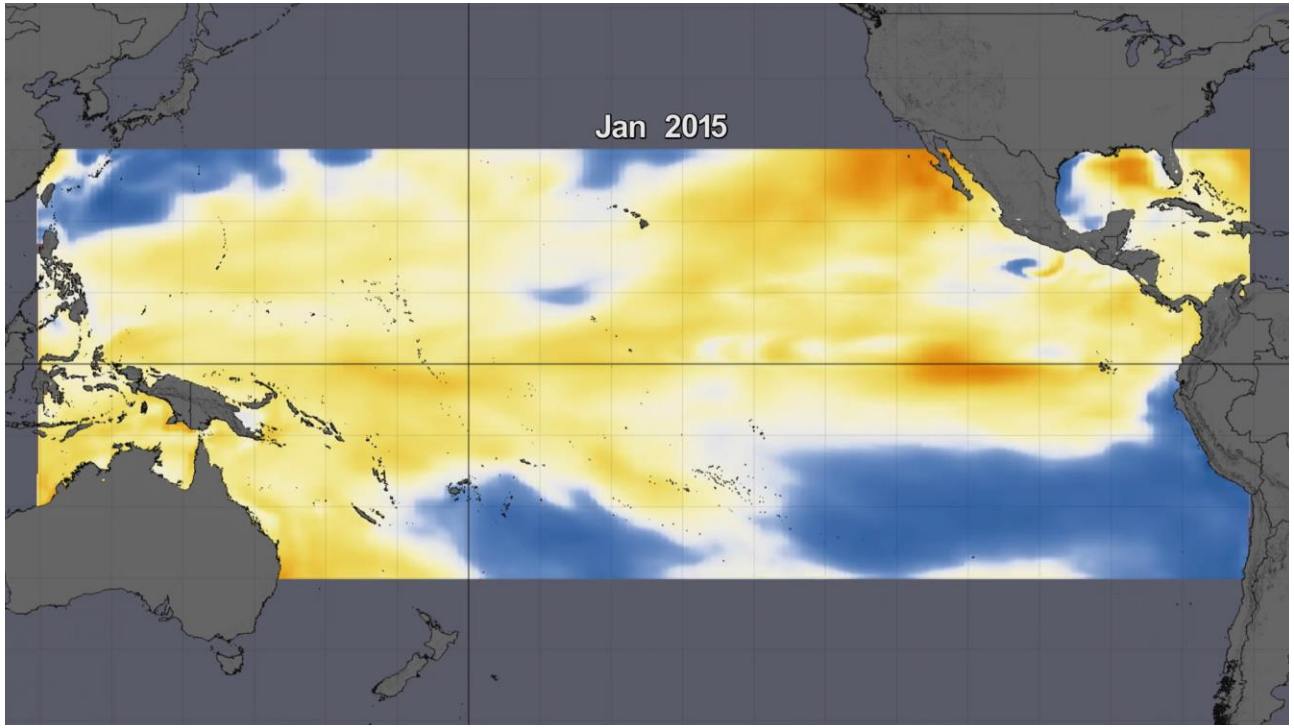
Ocean Sciences Meeting 2018
February 14, 2018

1. Why the Equatorial Pacific: El Niño events

- Impact weather pattern, alter path of storm, cause severe floods and disrupt marine ecosystems (cost of the 1997 El Nino in fisheries lost: $26.3 million)
- Forecasting these events has become a major aim of several large modeling groups
- Forecasting largely focused on SST anomalies
- 2015 El Nino event peaked in late December and the positive temperature anomalies were located in the central Equatorial Pacific

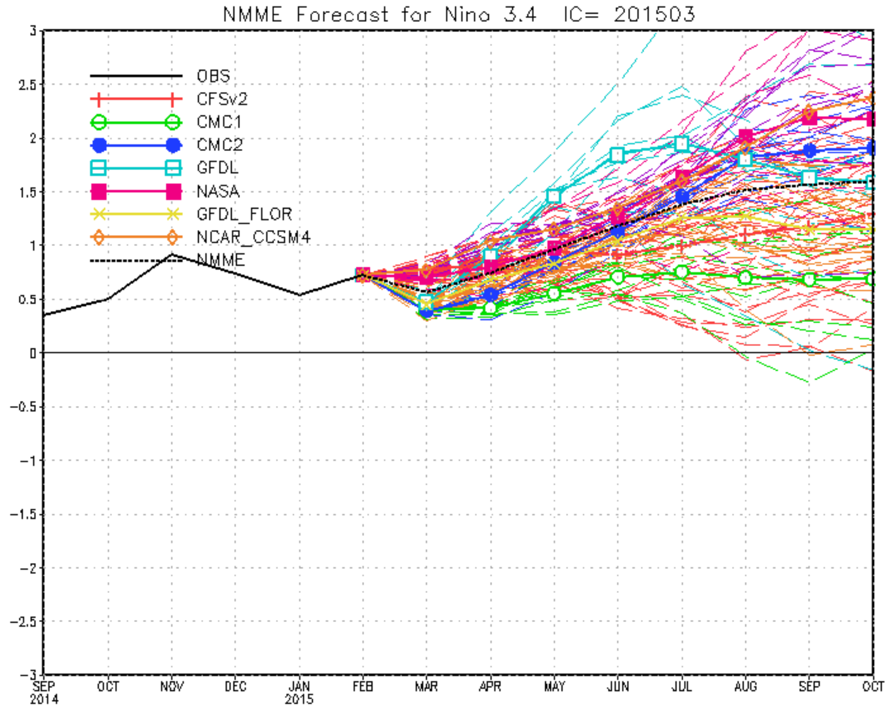


1. **NASA Global Modeling and Assimilation Office (GMAO) seasonal forecast**

- 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

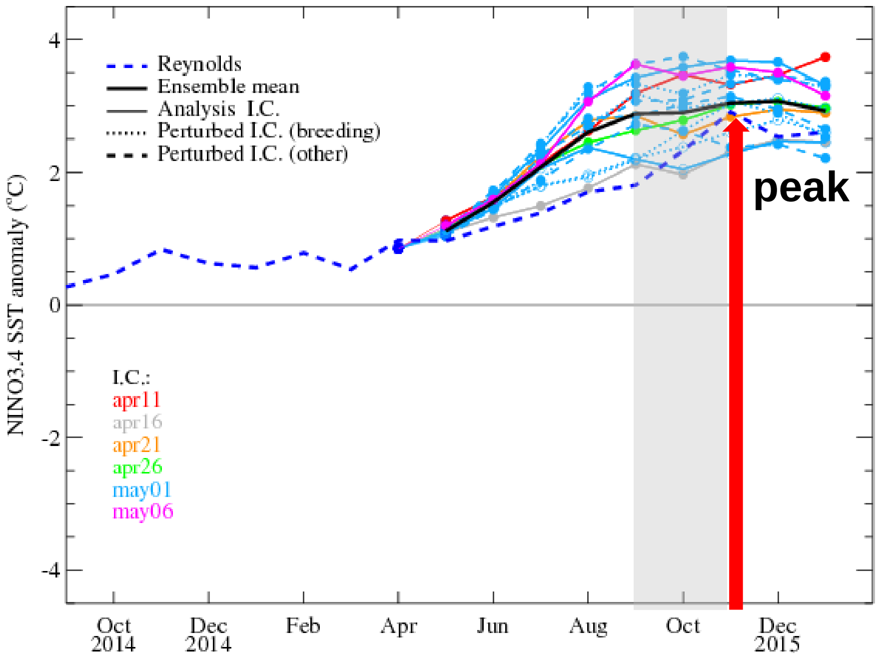
- Ocean initial conditions for temperature and salinity are provided to the Real Time Multiple Ocean Reanalysis Intercomparison project to help assess the uncertainties in the subsurface ocean analyses

- Benefited previous mission planning (e.g. NASA Arctic Radiation, IceBridge Sea & Ice Experiment (ARISE) 2014, 2015 Operation IceBridge)

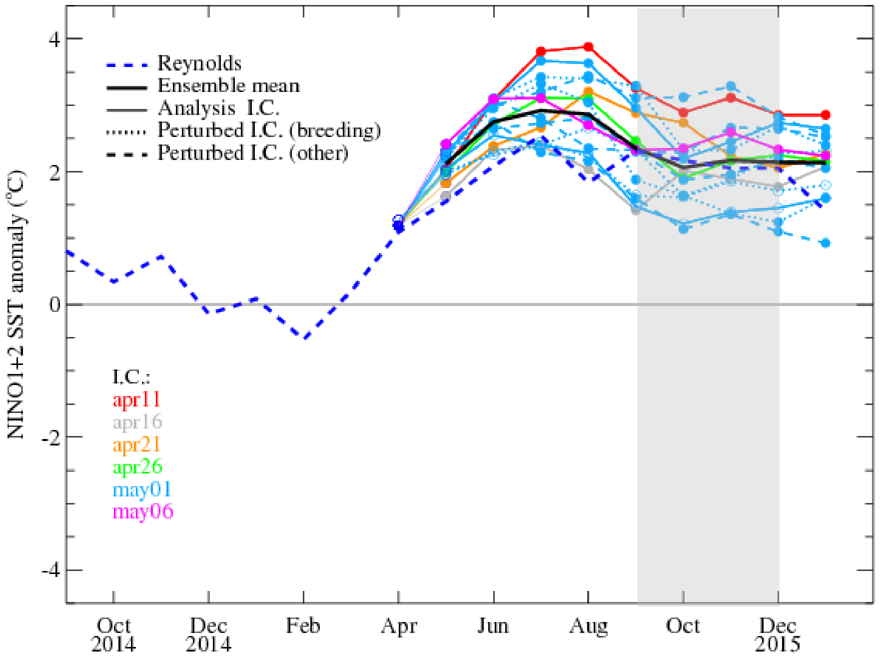


- The GMAO May 2015 forecast for the November 2015 peak in SST anomaly was in excellent agreement with the real event, even though it was still one of the outliers in the NMME and IRI multi-model ensemble prediction plumes.
- The GEOS-5 May 2015 forecast also correctly predicted the weakening of the Eastern Pacific (Niño1+2) anomalies for the Fall.

Niño3.4: Central Pacific



Niño1+2: Eastern Pacific

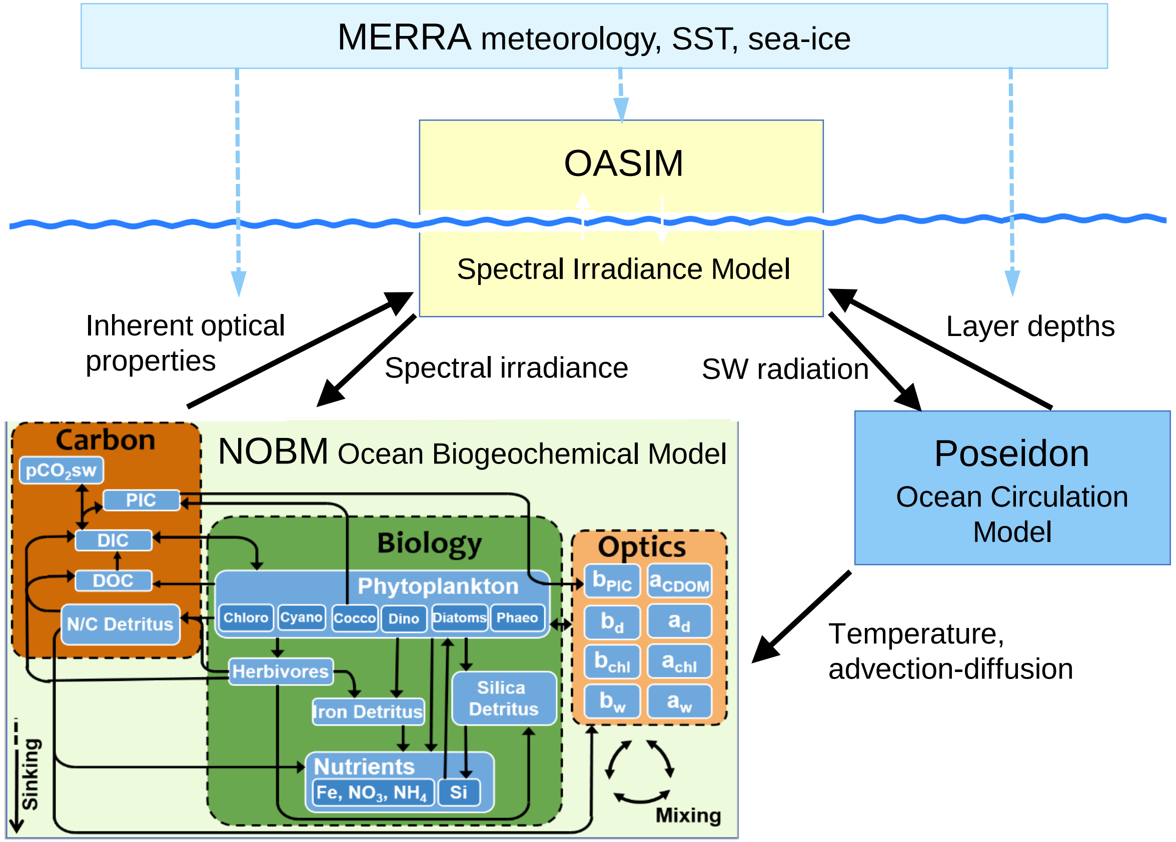


Slide courtesy of Robin Kovach (NASA GMAO)

2. From forecast of atmospheric and ocean physical variables to forecast of ocean biogeochemistry

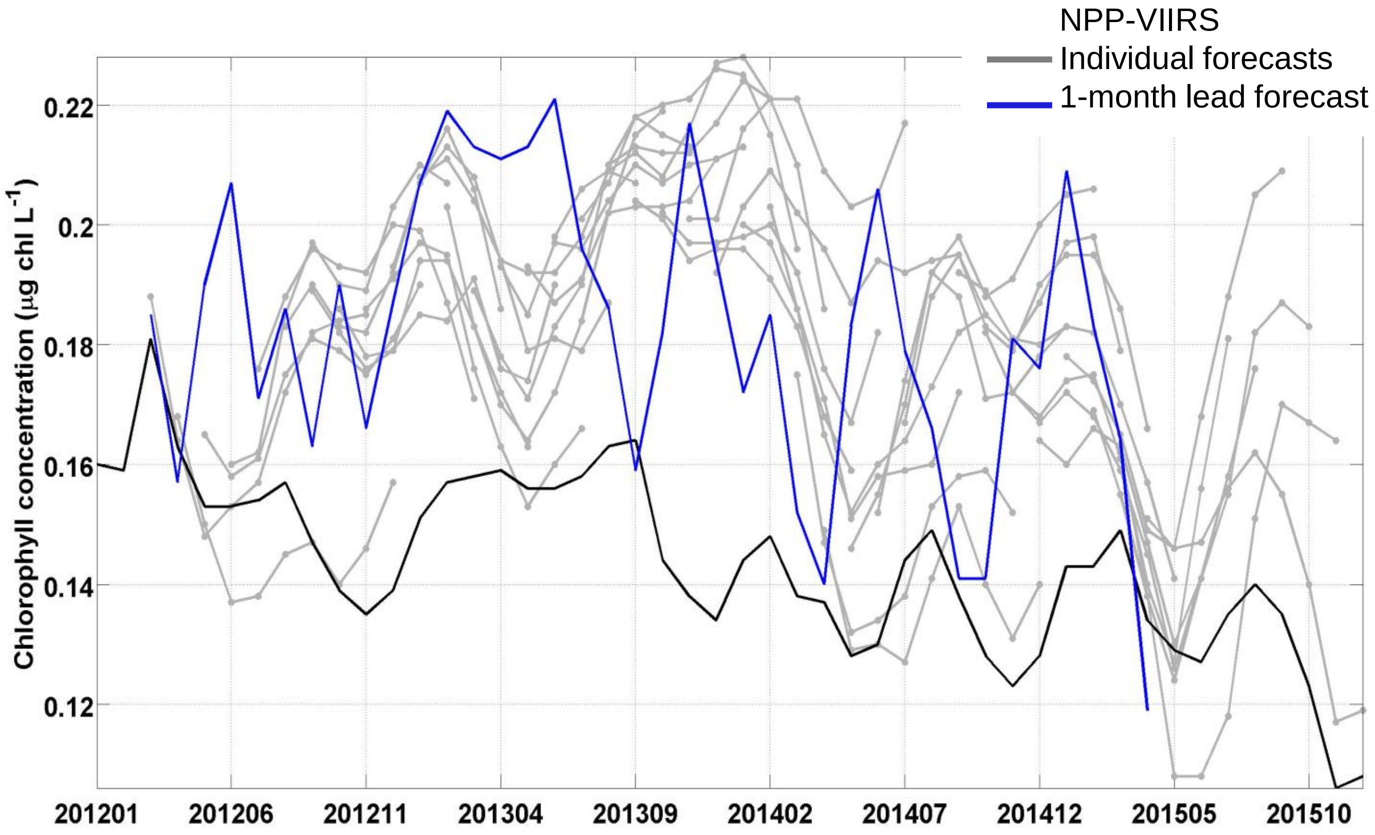
- Use atmospheric and ocean forecasts to force the biogeochemical model (e.g. wind stress, SST, short- and longwave radiation)
- Uncertainties in forecast assessed using retrospective forecasts
- NOBM with Poseidon @1degree spatial resolution with assimilation of satellite ocean color chlorophyll

NASA Ocean Biogeochemical Model (NOBM)



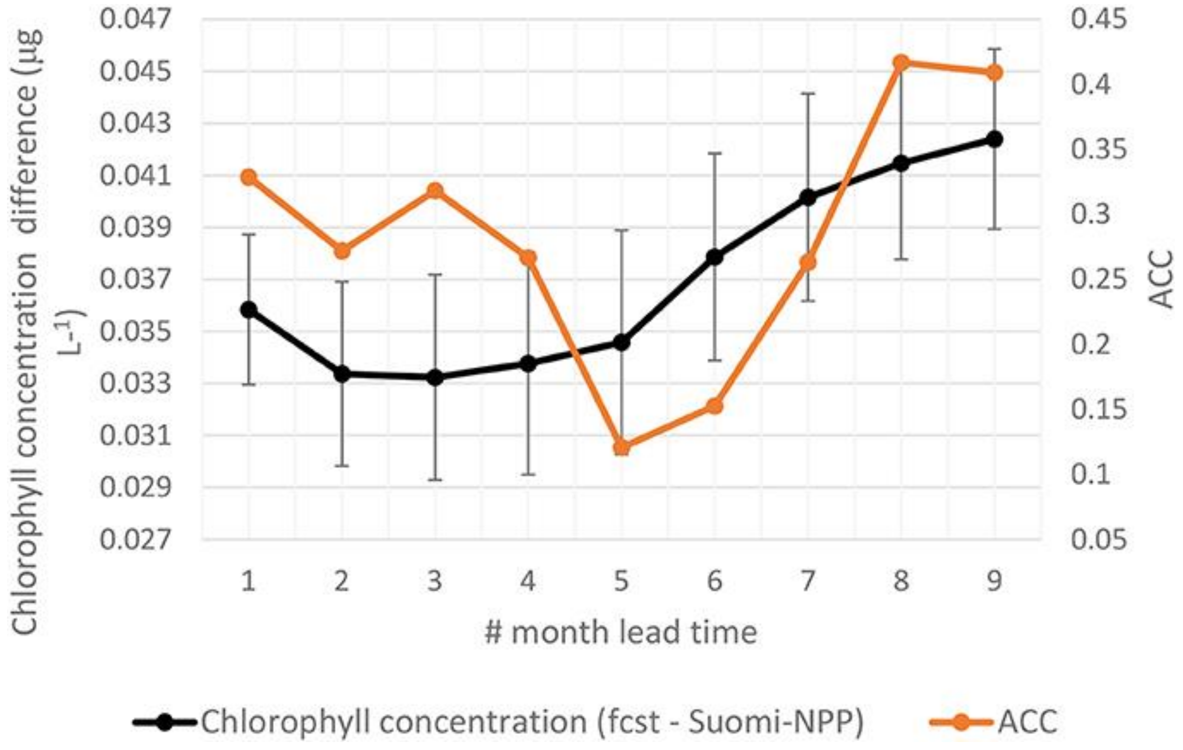
Assimilates chlorophyll, absorption of colored dissolved organic matter (CDOM), and particulate inorganic carbon (PIC) from SeaWiFS, MODIS and VIIRS

Outputs chlorophyll, nutrients, phytoplankton groups, primary production, nutrients, carbon components and fluxes, spectral irradiance/radiance



Of the 38 forecasts, the average percent difference between the forecasted chlorophyll and the SNPP VIIRS chlorophyll varied between 23% (3 months lead time, the equivalent of 0.033 μg chl L^{-1}) and 30.7% (9 months lead time, the equivalent of 0.042 μg chl L^{-1})

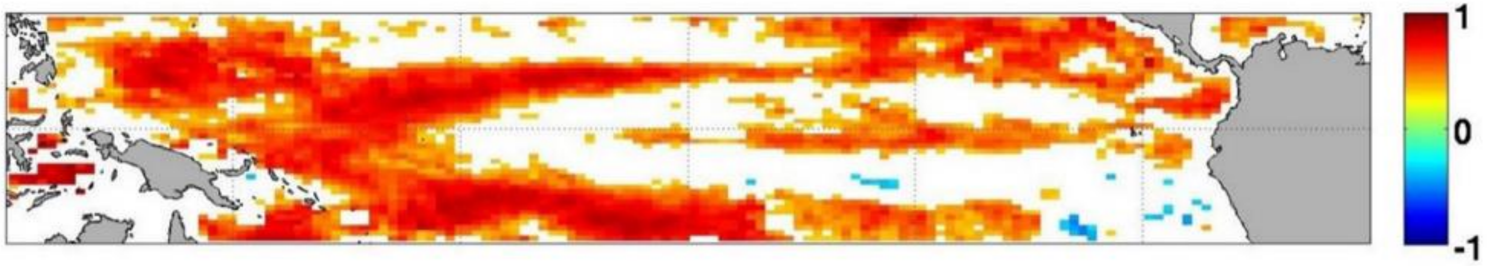
Rousseaux, C. S., and W. W. Gregg (2017), Forecasting Ocean Chlorophyll in the Equatorial Pacific, *Frontiers in Marine Science, 4(236).*



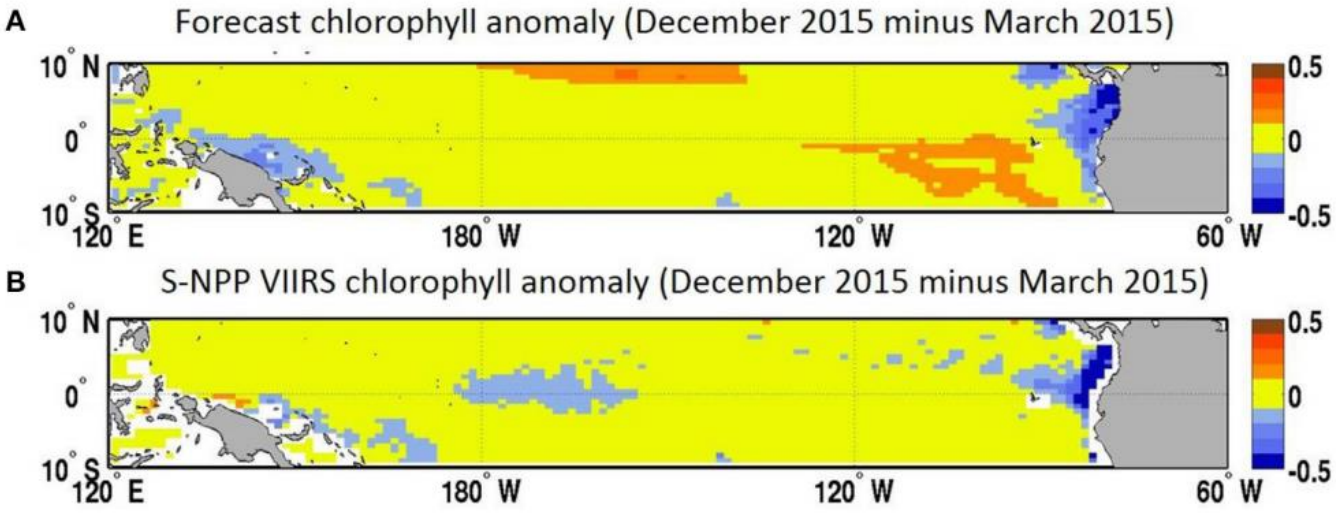
No. months lead time	ACC	RMSE
1	0.329*	0.0399
2	0.272	0.0397
3	0.318	0.0411
4	0.267	0.0427
5	0.121	0.0435
6	0.153	0.0450
7	0.263	0.0470
8	0.417*	0.0471
9	0.409*	0.0472

**indicates that the anomaly correlation coefficient was significant ($p < 0.05$).*

Anomaly correlation coefficient at 1-month lead time (2012-2015, VIIRS)



white = not significant (p > 0.05)



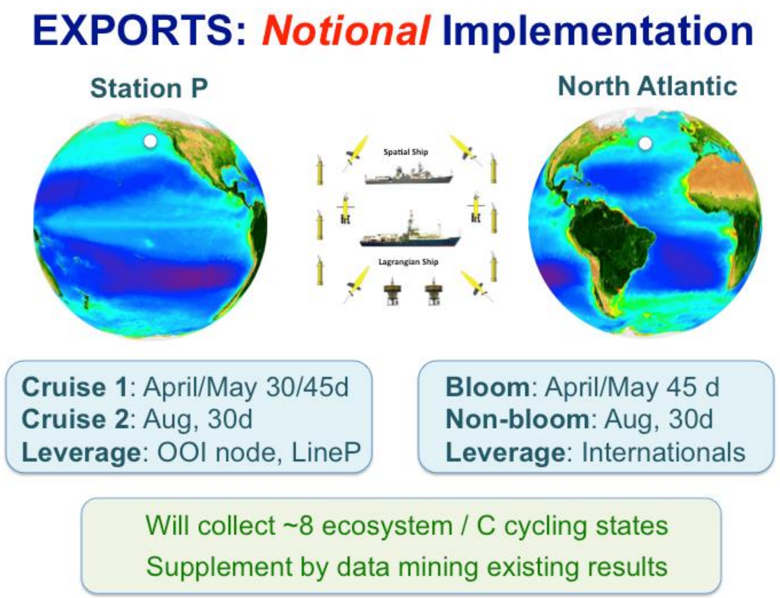
3. Applications of ocean biogeochemical forecast

EXPORTS
EXport Processes in the Ocean from RemoTe Sensing

The three Science Questions are:
1. How do upper-ocean ecosystem characteristics determine the vertical transfer of carbon from the well-lit surface ocean?

2. What controls the efficiency of vertical transfer of carbon below the well-lit surface ocean?

3. How can the knowledge gained be used to reduce uncertainties in contemporary and future estimates of the export and fates of global ocean NPP?



Support of field campaign by:
(1) Conduct Observing System Simulation Experiments (OSSEs) for field sampling design
(2) Provide updated forecast in the months leading up to field sampling

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

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