

# Global surface ocean phytoplankton community structure determined from co-variability in phytoplankton pigment concentrations

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## Abstract

High performance liquid chromatography (HPLC) remains one of the most widely applied methods currently available for estimation of phytoplankton taxonomy from ocean samples. This method measures the concentrations of phytoplankton pigments, some of which are useful chemotaxonomic markers that can be used to diagnose the relative abundance of phytoplankton groups. Here, we use HPLC phytoplankton pigment concentrations measured on surface water samples from 38 field surveys for a total of over 3,000 distinct samples that cover every major ocean basin and represent a wide range of ecological regimes. The data compilation has been quality controlled to remove measurements below pigment detection limits and outliers from the linear regression of total chlorophyll-a concentration with total accessory pigment concentrations and only samples from labs that have participated in round-robin quality assurance experiments (e.g. NASA SeaHARRE) have been included. We assess the environmental and spatial drivers controlling the global distribution and co-variability of individual phytoplankton pigments. Preliminary results of hierarchical clustering show strong differentiation in phytoplankton pigments following known relationships between phytoplankton size class and relative pigment concentration, partitioning their contributions by micro-, nano-, and pico-phytoplankton size classes. However, the exact clusters relationships change when the data are divided by ocean basin or latitude. We also use statistical techniques, including EOFs and network-based exploration, to examine the associations between groups of pigments over a range of environmental conditions on local to global scales and diagnose the main controls on these associations.

# Global surface ocean phytoplankton community structure determined from co-variability in phytoplankton pigment concentrations

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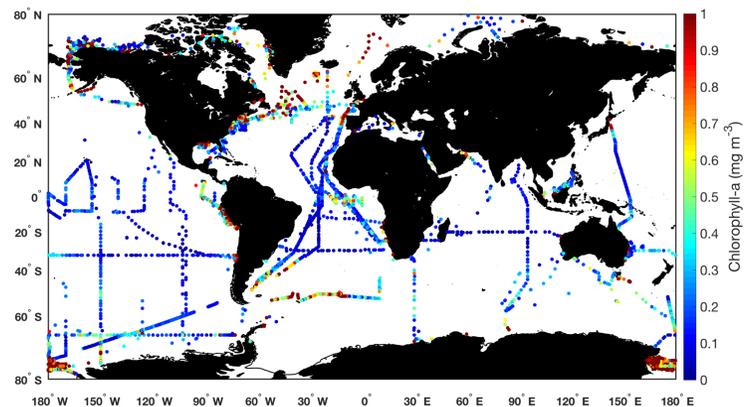
## Research Goals

- Describe the global distribution and co-variability of phytoplankton pigments
- Use **associations between groups of phytoplankton pigments** to distinguish between groups of phytoplankton
- Explore the global patterns of groups and size classes of phytoplankton based on the results of **clustering, EOF, and network analyses** on varying spatial scales

## Data & Methods

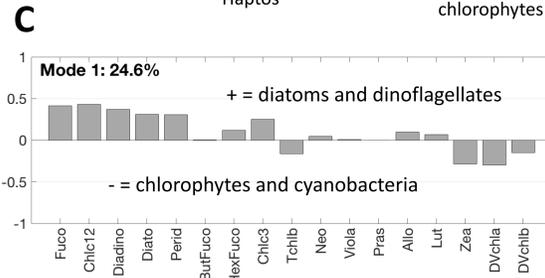
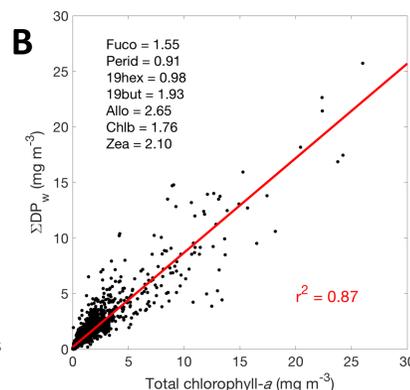
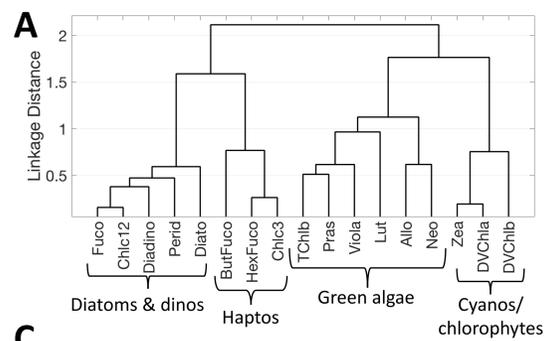
### Data summary:

- **4,124** distinct data points from **40+** cruises in **5** major ocean basins
- **6** labs performed analysis: Horn Point, NASA GSFC, LOV, CSIRO, AWI, DiTullio



### Methods:

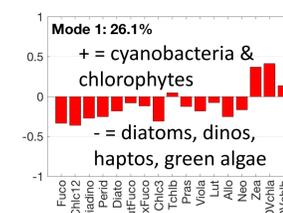
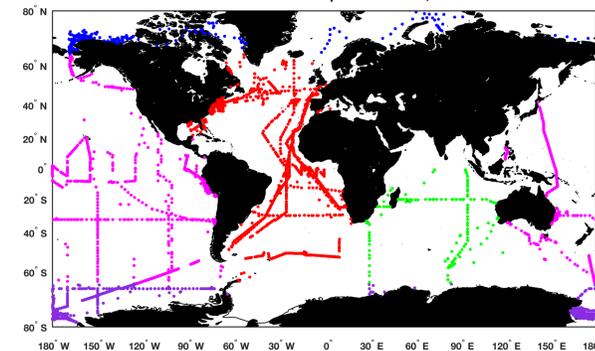
- All pigment values below NASA GSFC detection limit set to zero; pigments normalized to total chlorophyll-*a* concentration for all analyses
- Hierarchical cluster analysis using correlation distance & Ward's linkage
- Optimized coefficients for diagnostic pigment analysis (Vidussi, Uitz): weighted sum of 7 pigments to equal total chlorophyll-*a* concentration
- Empirical orthogonal function analysis



(A) Hierarchical clustering analysis results. (B) Mode 1 of empirical orthogonal function analysis: loadings show the strength of the correlation between each pigment and Mode 1. Sum of first six modes explains 72% of total variance in the dataset. (C) Re-optimized diagnostic pigment analysis.

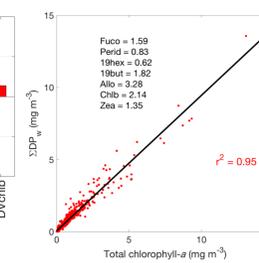
## Results of Cluster, EOF, and DPA Analyses on Varying Spatial Scales

**Ocean basins:** Variance explained by EOF modes 1-6: **72.19%**  
Mode 1+temp.  $r^2 = -0.14$ , Mode 1+sal.  $r^2 = 0.12$

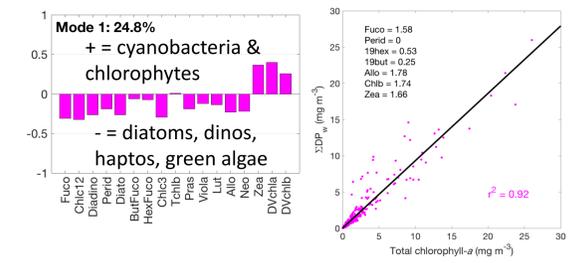


Variance explained by modes 1-6: **71.24%**  
Mode 1+temp.  $r^2 = 0.008$ , Mode 1+sal.  $r^2 = 0.52$

**Atlantic**

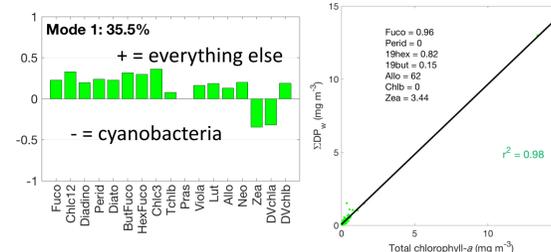


**Pacific**



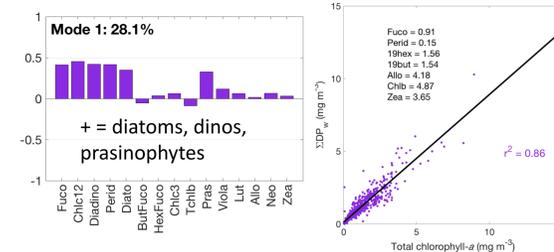
Variance explained by modes 1-6: **77.36%**  
Mode 1+temp.  $r^2 = -0.21$ , Mode 1+sal.  $r^2 = 0.34$

**Indian**



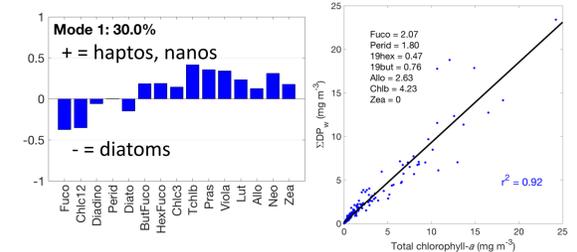
Variance explained by modes 1-6: **81.77%**  
Mode 1+temp.  $r^2 = -0.17$ , Mode 1+sal.  $r^2 = -0.61$

**Southern**



Variance explained by modes 1-6: **79.93%**  
Mode 1+temp.  $r^2 = 0.06$ , Mode 1+sal.  $r^2 = 0.30$

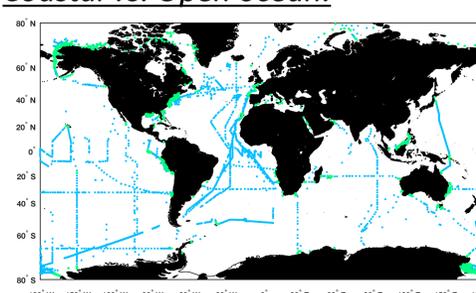
**Arctic**



Variance explained by modes 1-6: **82.93%**  
Mode 1+temp.  $r^2 = 0.21$ , Mode 1+sal.  $r^2 = 0.0009$

Mode 1 of EOF analysis generally more highly correlated with salinity than with temperature: water mass seems to dictate pigment assemblage.

### Coastal vs. Open ocean:



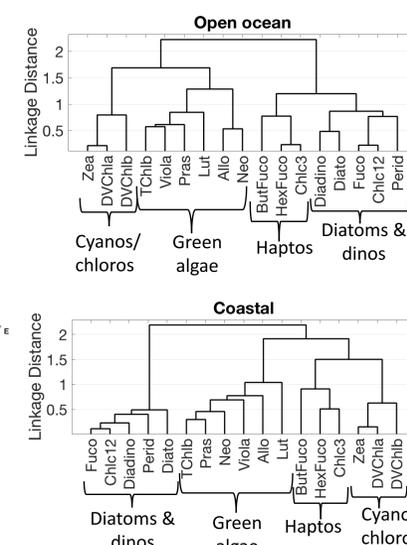
#### Coastal (within 100 km. of coastline):

Variance explained by modes 1-6 = **75.67%**  
Mode 1+temp.  $r^2 = -0.24$ , Mode 1+sal.  $r^2 = 0.008$

#### Open ocean:

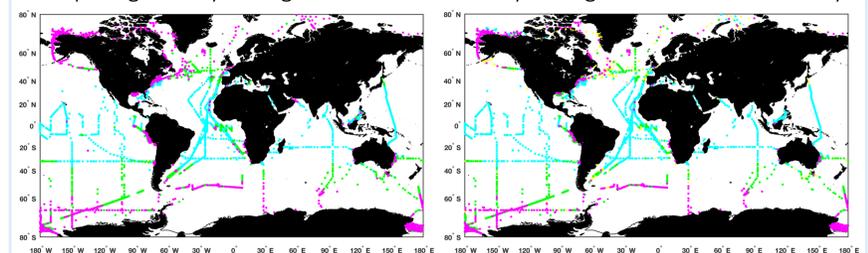
Variance explained by modes 1-6 = **70.96%**  
Mode 1+temp.  $r^2 = -0.48$ , Mode 1+sal.  $r^2 = -0.06$

Blooms in coast dominated by micros; blooms in open ocean dominated by picos.



### Preliminary network results:

Generalized Louvain network for community detection: groups nodes by comparing density of edges inside a community to edges outside a community.



**Louvain network results:** Algorithm balances speed with performance. 3 communities detected based on the modularity of the weighted correlation adjacency matrix,  $a_{ij} = |\text{corrcoeff}(x_i, x_j)|^\beta$

**Optimized diagnostic pigment analysis:** Phytoplankton size classes as a fraction of chl-*a* where pink >50% micro, green >50% nano, cyan >50% pico, and yellow = multiple groups but no dominant group.

Lucas G. S. Jeub, Marya Bazzi, Inderjit S. Jutla and Peter J. Mucha, "A generalized Louvain method for community detection implemented in MATLAB," <http://netwiki.amath.unc.edu/GenLouvain> (2016).

## Conclusion & Future Work

- **Size** emerges as a dominant source of variation in the assemblage of phytoplankton pigments across all analyses (cluster, EOF, DPA, and networks) on both global and basin/coastal scales
- Plan to determine local communities within global dataset of pigments using **random walks**
- Compare other phytoplankton community metrics (absorption, genomics, IFCB imagery, etc.)

## Acknowledgements

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