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

Sasha Kramer\(^1\) and David Siegel\(^2\)

\(^1\)Affiliation not available
\(^2\)University of California Santa Barbara

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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.
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Sasha J. Kramer1* and David A. Siegel2

1Interdepartmental Graduate Program in Marine Science and 2Earth Research Institute, University of California, Santa Barbara

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-α 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-α concentration
  - Empirical orthogonal function analysis

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

Ocean basins:

- Mode 1 of empirical orthogonal function 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.

Coastal vs. Open ocean:

- 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.)

Conclusion & Future Work

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Acknowledgements

This project was made possible through funding support from NASA. SJK is supported by the Department of Defense through the National Defense Science and Engineering Graduate Fellowship. We acknowledge the contributions of all our data sources for each cruise: MAB (Colónia, NSO, AWI); CMOS (Bratlund, DiTullio, Hatteras); G08 (AOA); MAB (Colónia, NODC); SeaBASS (SeaBASS, JAMSTEC, Shimizu); Biogeo-IT (AADC); GOMEX, Cape Hatteras (SeaBASS; Tim Malina, pers. comm.); and David A. Siegel.

Indian

Indian Ocean basin:
- Variance explained by EOF modes 1-6: 72.19%
- Mode 1+temp. r² = 0.14, Mode 1+sal. r² = 0.12

Atlantic

Atlantic Ocean basin:
- Variance explained by EOF modes 1-6: 71.24%
- Mode 1+temp. r² = 0.008, Mode 1+sal. r² = 0.52

Pacific

Pacific Ocean basin:
- Variance explained by EOF modes 1-6: 77.36%
- Mode 1+temp. r² = 0.21, Mode 1+sal. r² = 0.34

Southern

Southern Ocean basin (within 100 km of coastline):
- Variance explained by EOF modes 1-6: 81.77%
- Mode 1+temp. r² = -0.17, Mode 1+sal. r² = -0.61

Arctic

Arctic Ocean basin:
- Variance explained by EOF modes 1-6: 79.93%
- Mode 1+temp. r² = 0.06, Mode 1+sal. r² = 0.30

Variance explained by modes 1-6: 82.93%
- Mode 1+temp. r² = 0.21, Mode 1+sal. r² = 0.0009

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

Coastal (within 100 km. of coastline):
- Variance explained by modes 1-6: 75.67%
- Mode 1-temp. r² = -0.24, Mode 1+sal. r² = 0.008

Open ocean:
- Variance explained by modes 1-6: 70.96%
- Mode 1-temp. r² = -0.48, Mode 1+sal. r² = -0.06

Bloom in coast dominated by micros; blooms in open ocean dominated by pico.

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, aij = [cor(r(xj), r(yi))].

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.

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