Multi-decadal variability in coccolithophore abundance in the North Pacific Subtropical Gyre

Joo-Eun Yoon and Il-Nam Kim
Department of Marine Science
Incheon National University
1. Introduction
Ocean Acidification

**Ocean acidification**

$$\text{(CO}_2\text{↑ + H}_2\text{O + CO}_3^{2-} \rightarrow 2\text{HCO}_3^-)$$

**Marine Calcifiers**

$$\text{(Ca}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CaCO}_3)$$

[300 ppm CO$_2$, 800 ppm CO$_2$]

[Riebesell et al., 2000]
Recent Studies

Rivero-Calle et al. [2015]

Krumhardt et al. [2016]

Coccolithophores

68%

20%

"Average pH ~8.1"

Atlantic Large Observing Array (ALOHA) Station

BATS

"Precipitation of CaCO3" "Negative impact below pH 7.7"

(Bach et al. 2013)

Other Parameters?

Ocean Acidification

68%

or

"Precipitation of CaCO3" "Negative impact below pH 7.7"

(Bach et al. 2013)
Study Purpose

ALOHA Station
(22°45’N, 158°00’W)

1. To investigate Long-Term Trends in Coccolithophores Abundance

2. To determine the Relative Importance of Various Environmental Factors on Trends in Coccolithophores Abundance
2. Data & Methods
Phytoplankton Functional Groups (PFGs)

Abundances- CHL-a Concentrations by Group [Mackey et al., 1996]

Pigment Data extracted by HPLC entered into CHEMTAX

Input Marker Pigment:CHL-a Ratio

<table>
<thead>
<tr>
<th>Input Marker Pigment</th>
<th>CHL-b</th>
<th>Zeax</th>
<th>19But</th>
<th>Fuco</th>
<th>19Hex</th>
<th>CHL-a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prochlorococcus</td>
<td>1.099</td>
<td>0.077</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>0.000</td>
<td>0.476</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Chrysophytes</td>
<td>0.000</td>
<td>0.000</td>
<td>1.111</td>
<td>0.156</td>
<td>0.156</td>
<td>1.000</td>
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<tr>
<td>Haptophytes</td>
<td>0.000</td>
<td>0.000</td>
<td>0.014</td>
<td>0.015</td>
<td>0.769</td>
<td>1.000</td>
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<tr>
<td>Diatoms</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.250</td>
<td>0.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

From 1988 To 2016
ALOAHA Station (22°45’N, 158°00’W)

HPLC Pigment Data
CHL-b, Zeax, 19But, Fuco, 19Hex, CHL-a

CHL-a Concentrations by Group
Prochlorococcus, Cyanobacteria, Chrysophytes, Haptophytes, Diatoms

* Abbreviations include prasinoxanthin (prasino), zeaxanthin (zeax), 19'-butanoyloxyfucoxanthin (19'-but), 19'-hexanoyloxyfucoxanthin (19'-hex), fucoxanthin (fucox), and peridinin (peri).
Environmental Parameters

From 1988 To 2016
ALOHA Station (22°45’N, 158°00’W)

- **Physical Parameters**
  - Temperature, Salinity, Sigma-t
  - Mixed Layer Depth (Sigma-t- 0.125 kg m⁻³ from surface waters)

- **Nutrients Parameters**
  - DIN (Nitrate + Nitrite), Phosphate, Silicate

- **Carbon Chemistry Parameters**
  - Dissolved Inorganic Carbon, Total Alkalinity data
  - $pCO_2$, HCO$_3^-$, CO$_3^{2-}$, pH, $\Omega_{aragonite}$, $\Omega_{calcite}$ (in situ temperature)
  - CO$_2$ system calculations with CO$_2$SYS software [Mehrbach et al., 1973]
3. Results & Discussion
Vertical Patterns of CHL-a and PFGs

3. Results & Discussion

CHL-a

Surface

DCM ~110 m

PFGs

Surface (0–60 m)

"2nd Dominant Group"

DCM (90–150 m)
Trend in Coccolithophore

Haptophytes

Total CHL-a = 1
Relative Ratio

Surface
(0–60 m)

DCM
(90–150 m)

3. Results & Discussion

4th Climate and Oceans Symposium

11
3. Results & Discussion

Trend in Coccolithophore

Linear Trend
(For a Range of Start and End Years)

(☆: p<0.05)

Surface
(0–60 m)

DCM
(90–150 m)
Correlation with Environmental Factors and other PFGs

### Surface
(0–60 m)

<table>
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<th>PFGs</th>
<th>Physical Factors</th>
<th>CO₂ parameters</th>
<th>Nutrients</th>
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<tbody>
<tr>
<td>Diatom</td>
<td>Prochl</td>
<td>Cyano</td>
<td>Chryso</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>-</td>
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### DCM
(90–150 m)

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3. Results & Discussion

Correlation with Environmental Factors and other PFGs

**DCM** (90–150 m)

Environmental Factors

**T** (+) **DIN** (+)

Correlation between Prochlorococcus & other factors

T (+) DIN (+)

**Prochlorococcus**

**Haptophytes**

**Sigma-t** **T** **Sal** **MLD**

DIC Alk pH pCO₂ HCO₃⁻

P DIN Si
4. Unresolved Question

Why are NPSG and NASG trends different?

1. Non-linear relationship?
2. Relationship between Prochlorococcus and climate indices?
5. Summary

1) Haptophytes (Coccolithophores) are 2nd Dominant Phytoplankton Group.

2) Maximum occurs at ~ 110 m depth.

3) Haptophytes rapidly increased until ~2000 and then decreased. This trend was related to Changes in Prochlorococcus.

4) Future study is needed to understand Factors Driving the Decrease in Haptophytes Since ~2001.
Q & A

Thank You for Your Attention!!

jeyoon@inu.ac.kr