PICES annual meeting, 2017.9.24-29, Vladivostok, Russia
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What was the Major Factor that has Caused Declines in Coccolithophores Abundance in the North Pacific Subtropical Gyre Since 2005?

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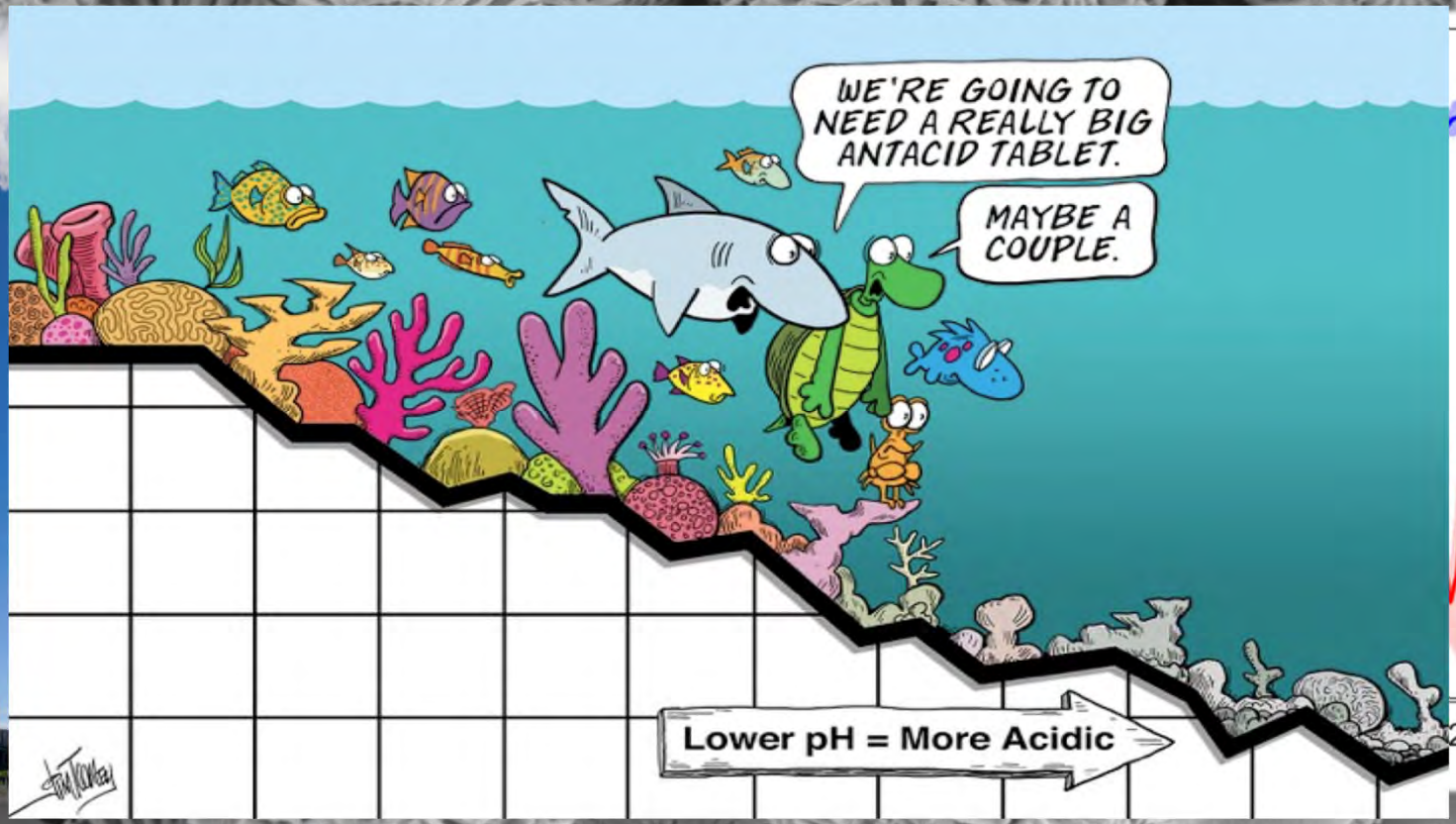
Ocean Acidification

$$\uparrow CO_2 + H_2O + \downarrow CO_3^{2-} \rightarrow \uparrow 2HCO_3^-$$



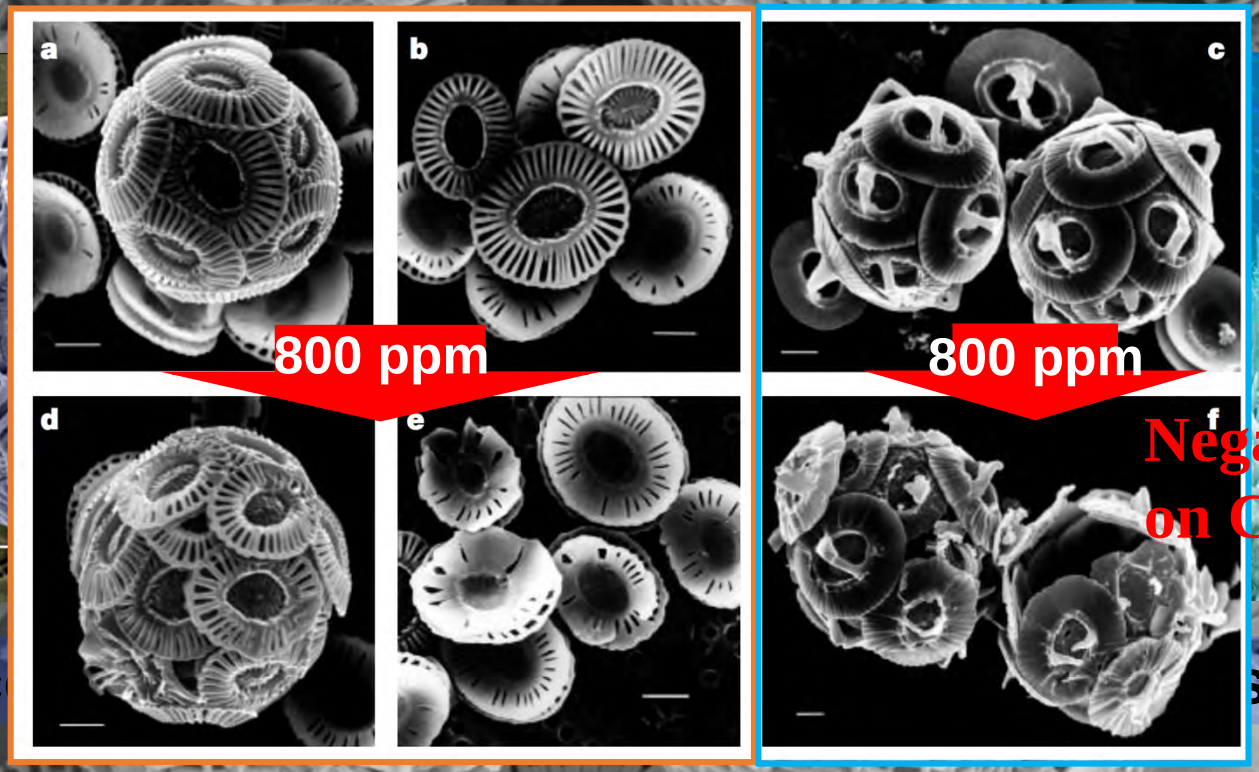
https://indiansnews.com/environment/ocean-acidification-save-marine-ecosystem/

The Effect of Elevated CO_2 on Coccolithophore species

Marine Calcifiers: $Ca^{2+} + \downarrow CO_3^{2-} \rightarrow \downarrow CaCO_3$

Control: 300 ppm CO_2

Treatment: 800 ppm CO_2



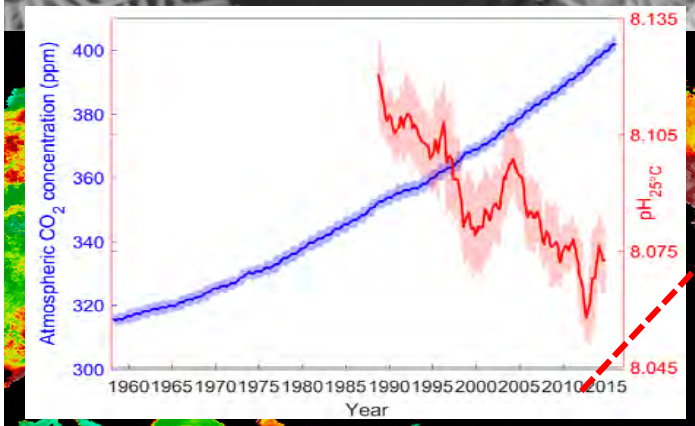
Emiliania huxleyi

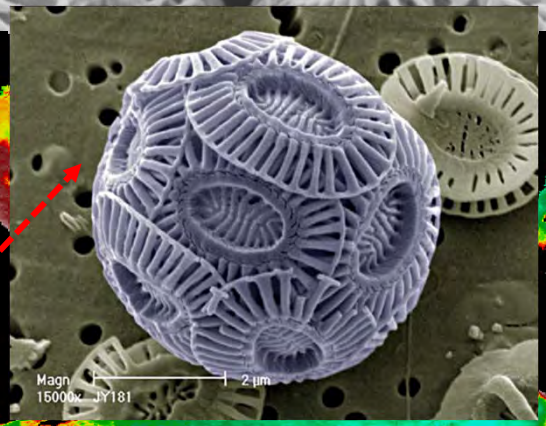
Gephryocapsa oceanica

Negative Effect on Calcification

Riebesell et al. [2000]

Recent Studies in North Atlantic Subtropical Gyre





ALOHA

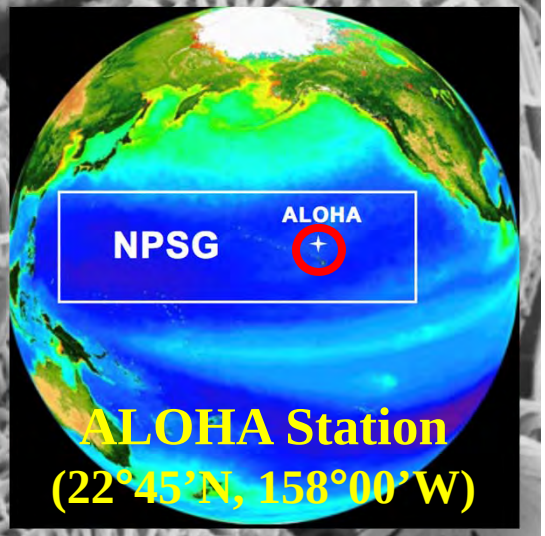
BATS

Increasing??

2015 Annual CHL-a (MODIS 4 km)

Low — High

In the North Pacific Subtropical Gyre (NPSG)



★ To investigate

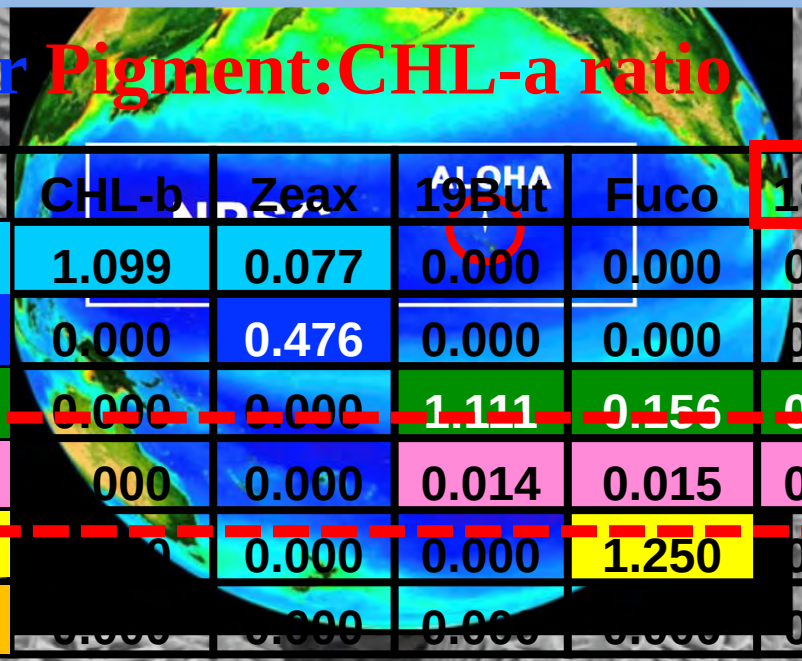
Long-Term Trends in Coccolithophores Abundance

★ To determine

the Relative Importance of Various Environmental Factors on Trends in Coccolithophores Abundance

ALOHA Station (22°45'N, 158°00'W) from 1988 to 2015

Abundances- CHL-a Concentrations by group (Mackey et al., [1996])
Pigment data extracted by HPLC entered into CHEMTAX



Input marker Pigment:CHL-a ratio

Input ratios	CHL-b	Zeax	19But	Fuco	19Hex	Perid	CHL-a
Prochlorococcus	1.099	0.077	0.000	0.000	0.000	0.000	1.000
Cyanobacteria	0.000	0.476	0.000	0.000	0.000	0.000	1.000
Chrysophytes	0.000	0.000	1.111	0.156	0.156	0.000	1.000
Haptophytes	000	0.000	0.014	0.015	0.769	0.000	1.000
Diatoms		0.000	0.000	1.250	0.000	0.000	1.000
Dinoflagellates					0.000	0.667	1.000

* Abbreviations include prasinoxanthin (prasino), zeaxanthin (zeax), 19′-butanoyloxyfucoxanthin (19′-but), 19′-hexanoyloxyfucoxanthin (19′-hex), fucoxanthin (fuco), and peridinin (perid).

Haptophytes: Source Coccolithophores ('*Emiliania Huxleyi*')

Letelier et al. [1993]

ALOHA Station (22°45'N, 158°00'W) from 1988 to 2015

Environmental Parameters

★ 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_2SYS software (Mehrbach et al. [1973])

★ Physical Parameters

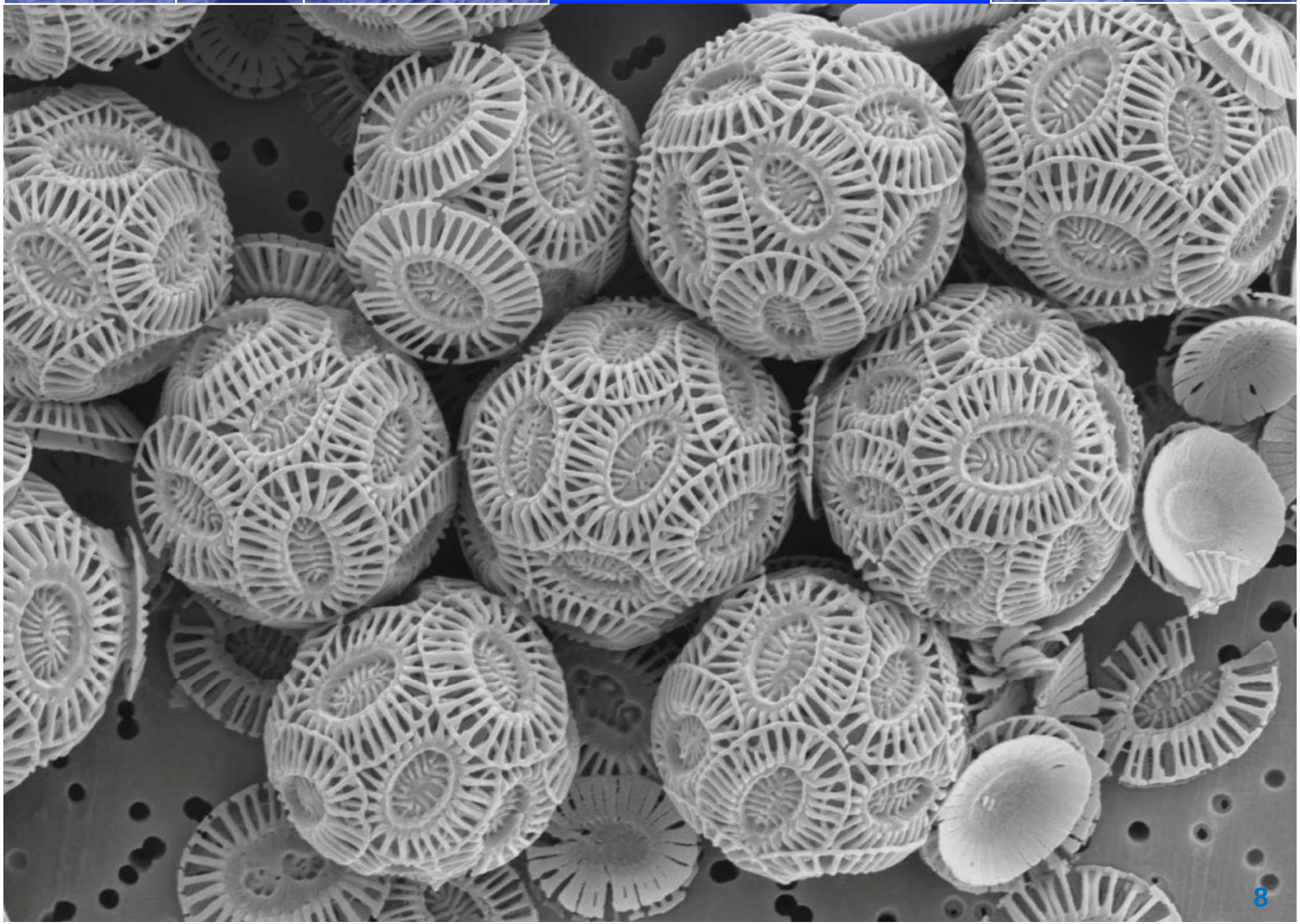
- Temperature, Salinity, Euphotic Depth (Zeu)
- Mixed Layer Depth (potential density- 0.125 kg m^{-3} from surface waters)

★ Nutrients Parameters

- DIN (Nitrate + Nitrite), Phosphate, Silicate

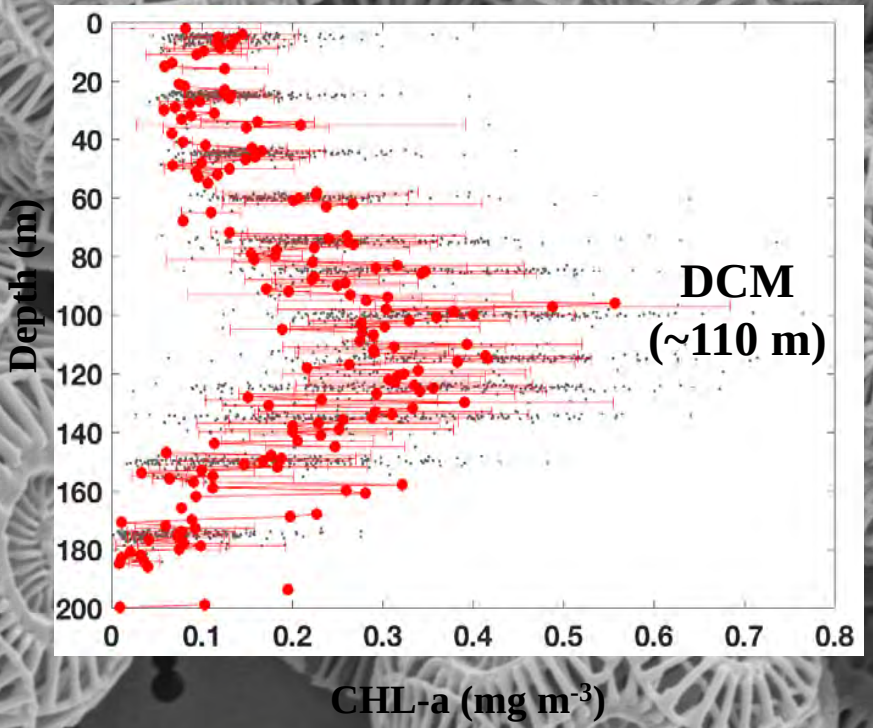
★ Climate indices

- Pacific Decadal Oscillation (PDO, Mantua et al. [1997]),
- North Pacific Index (NPI, Trenberth and Hurrell [1994]),
- North Pacific Gyre Oscillation (NPGO, Di Lorenzo et al. [2007])

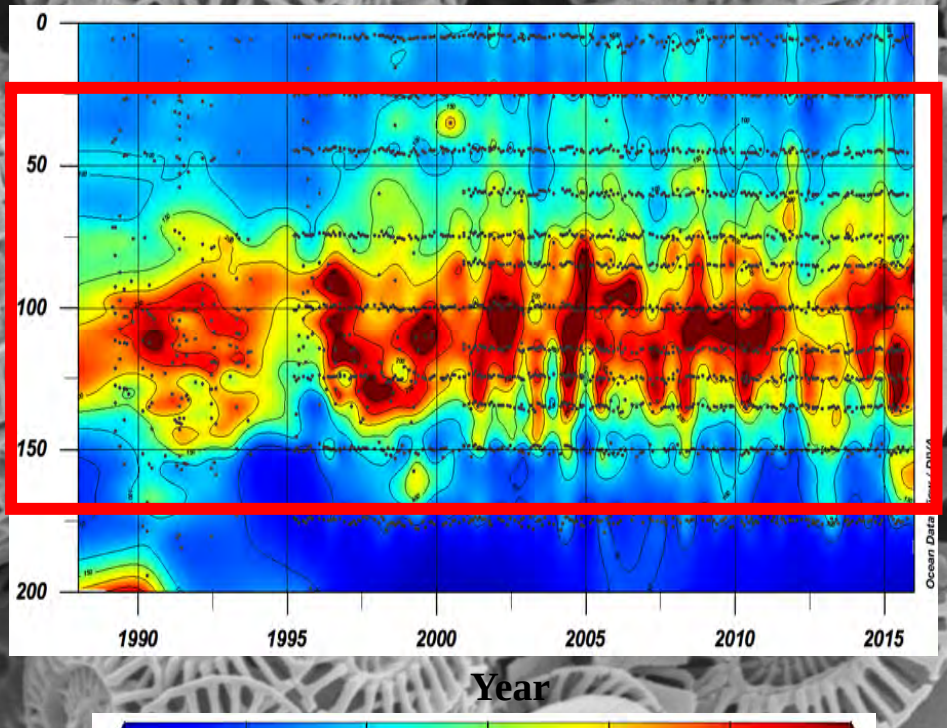


Vertical and Temporal Patterns of CHL-a

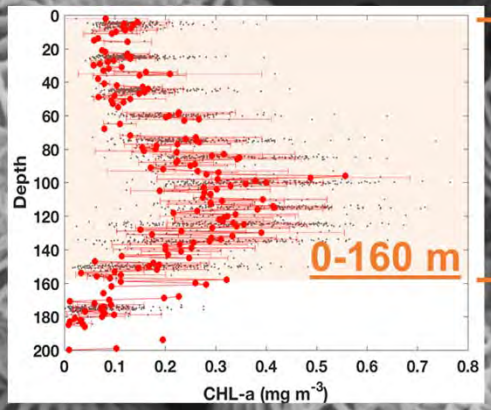
Vertical Profile

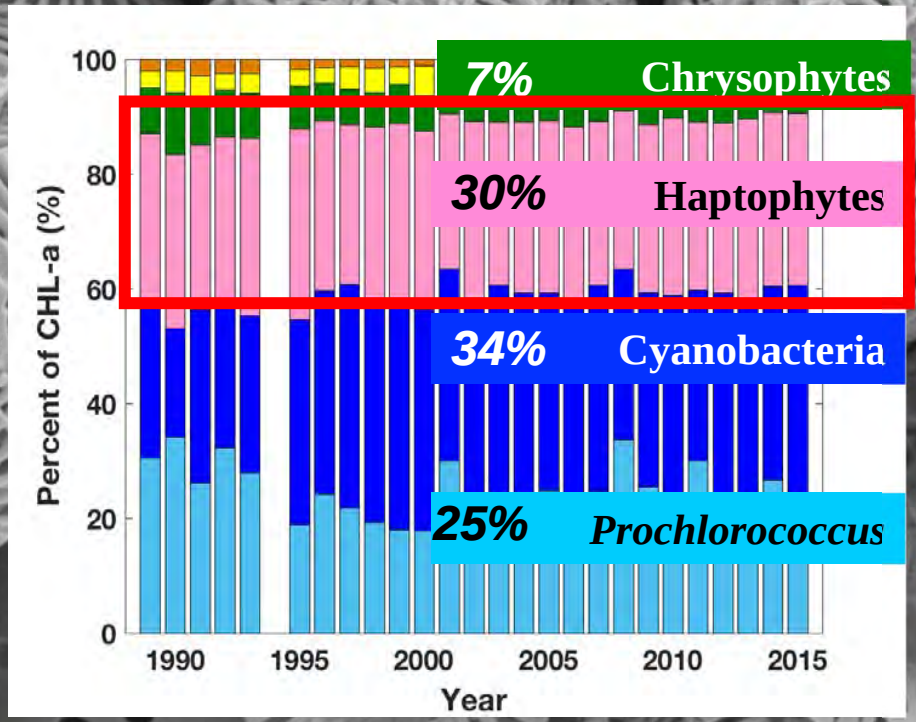


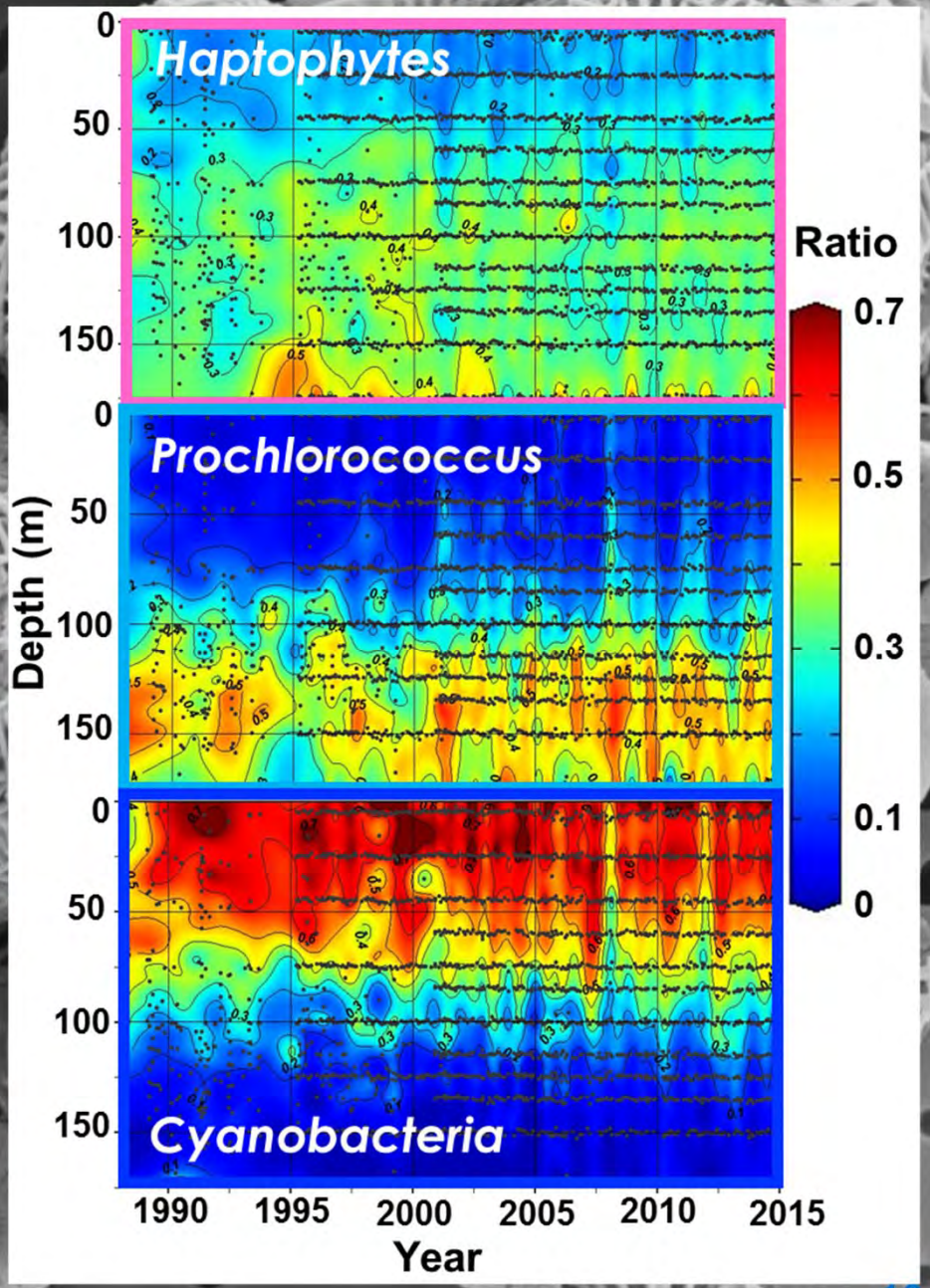
Temporal Distribution



Relative Abundances (%) of Coccolithophores







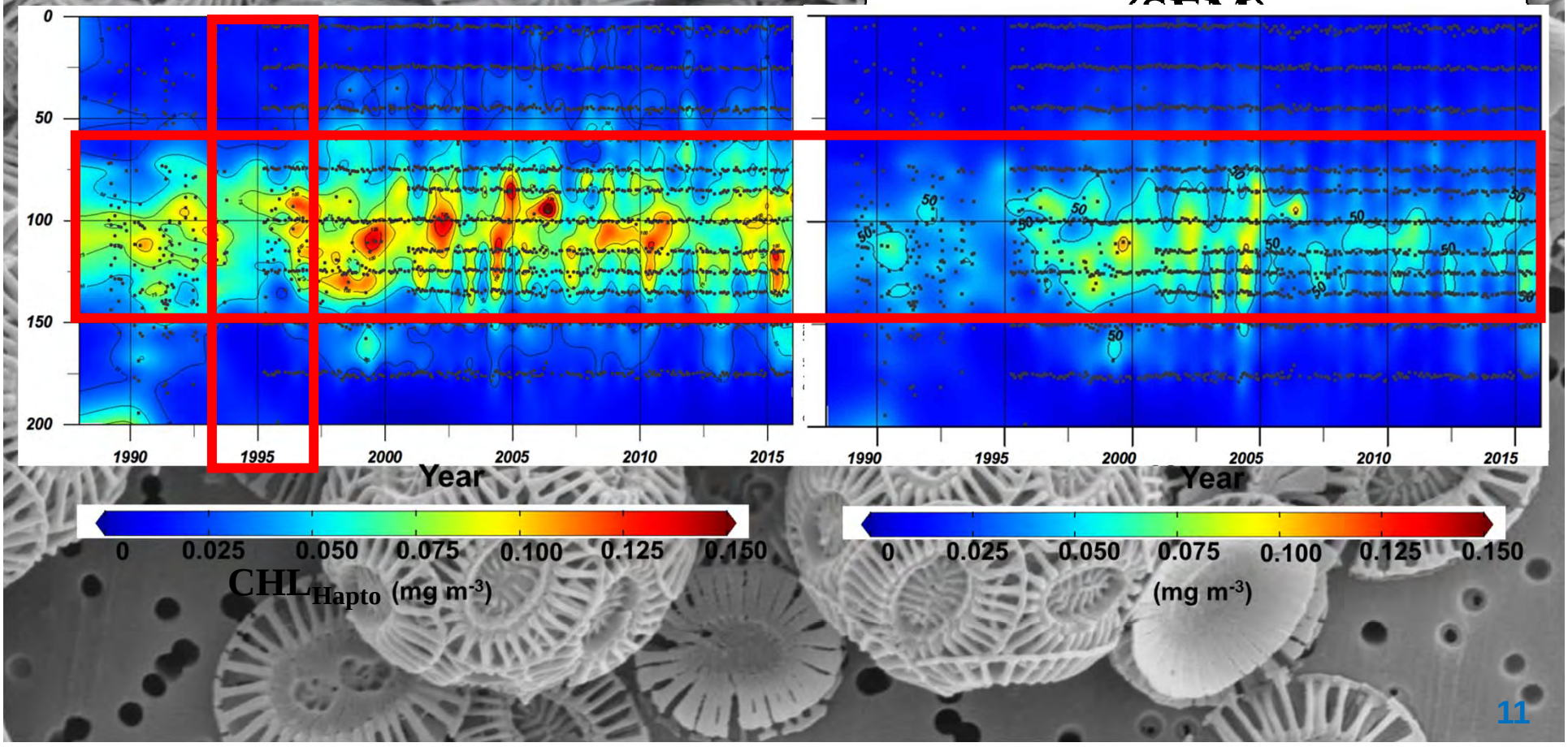
Coccolithophores Abundance

Input ratios	CHL-b	Zeax	19But	Fuco	19Hex	Perid	CHL-a
Haptophytes	0.000	0.000	0.014	0.015	0.769	0.000	1.000

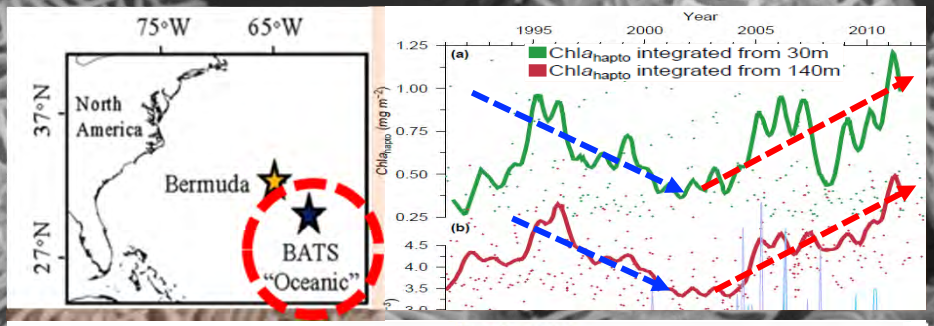
Haptophytes

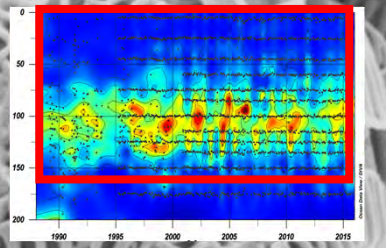
Hitachi 2300
Scanning Electron Microscope
(SEM)

19'-Hexanoyloxyfucoxanthin



Trends in Coccolithophores Abundance

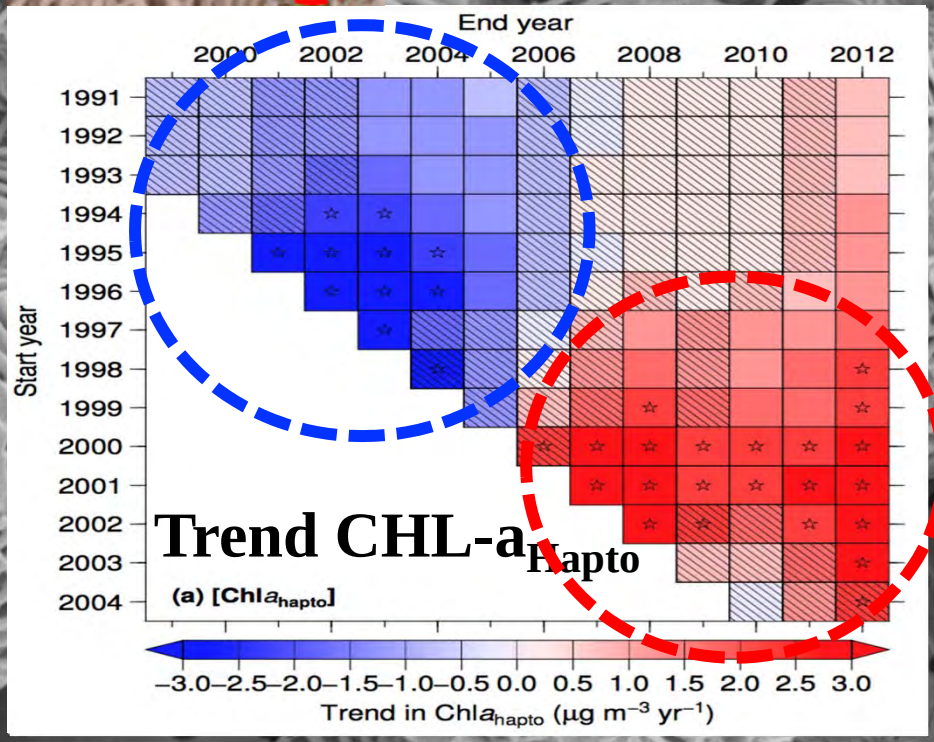


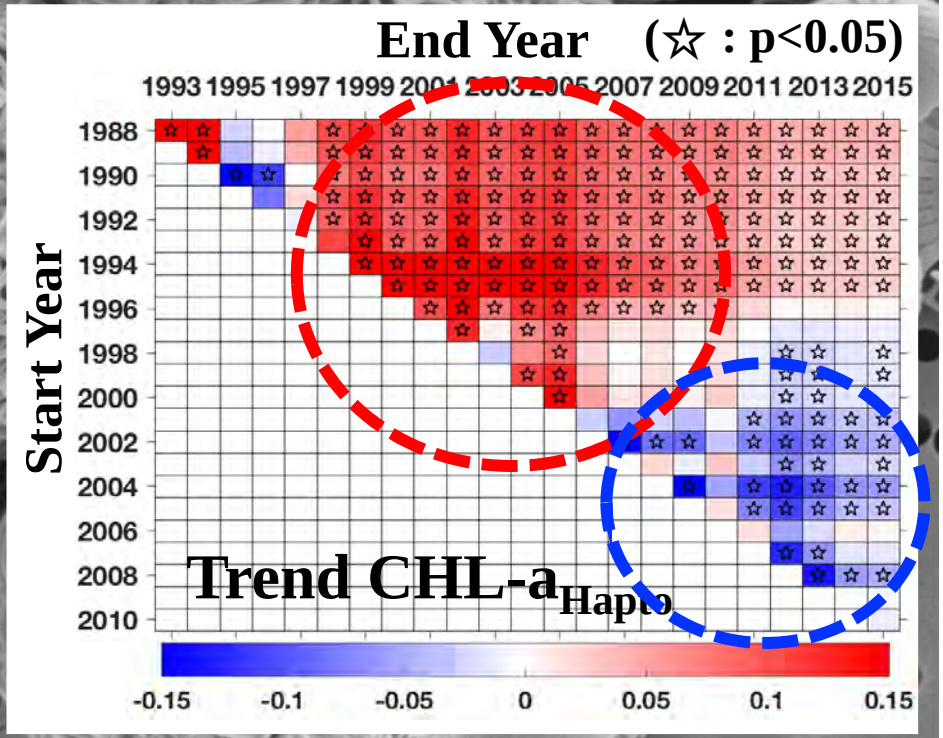


Integrated for 0-160 m

Linear Trends

For a Range of Start and End Years

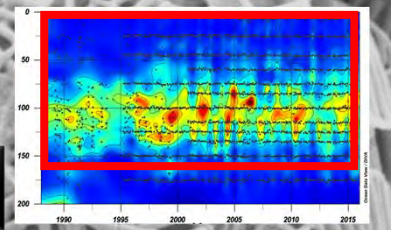




North Atlantic Subtropical Gyre

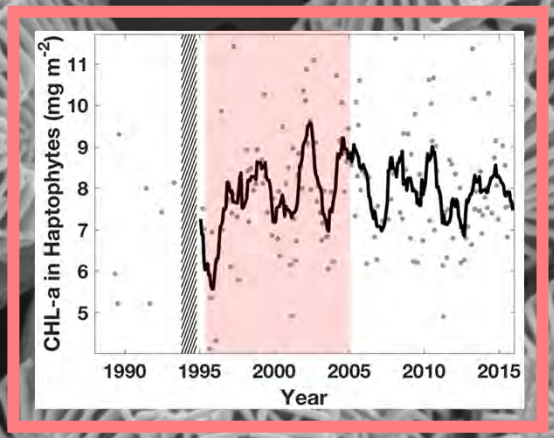
Krumhardt et al. [2016]

Correlation with Environmental Factors

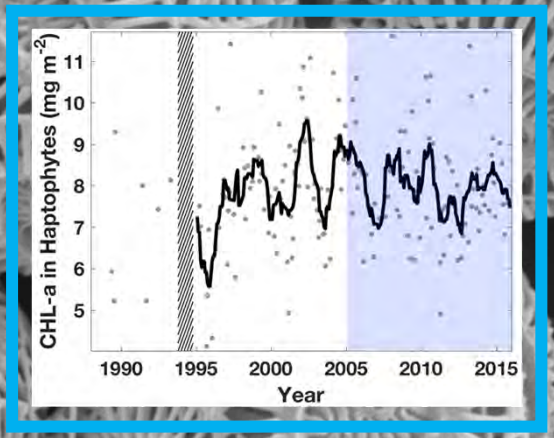


(0-160 m)

1995-2004



2005-2015



r >0.5

**T **S *DIN *P *Si *TA *DIC **pH **pCO2 *HCO3- *CO3 2- **Ωar **Ωcal MLD PDO NPI NPGO Zeu

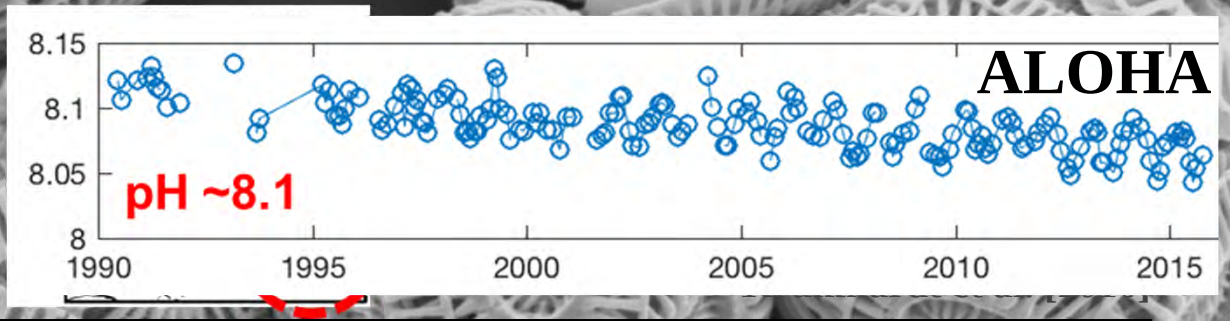
Negative (-) Positive (+)

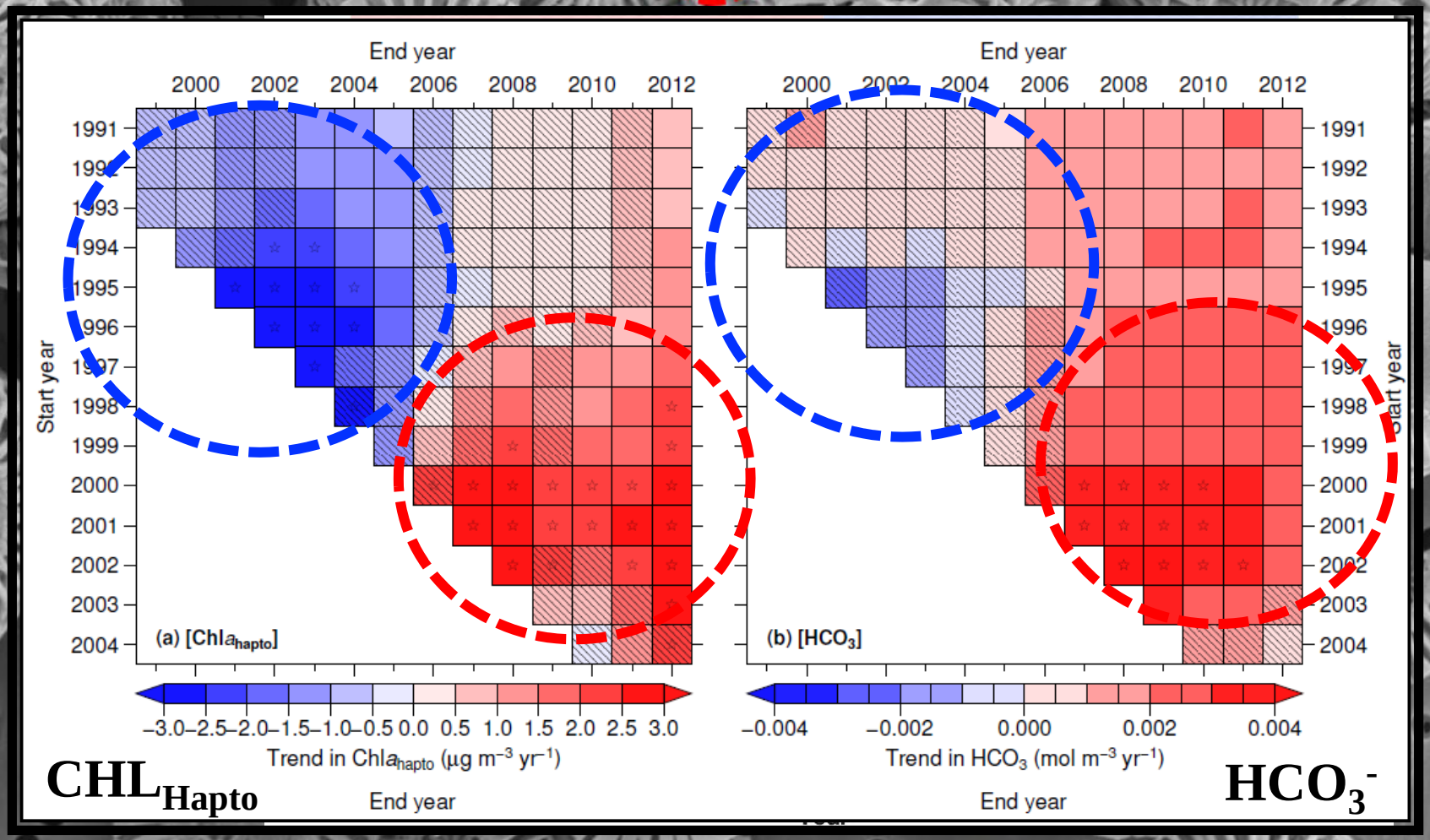
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

☆ : p<0.05

*Integrated value for 0-160 m; **Mean value for 0-160 m;

Relationship with HCO_3^-





What Other Factors?

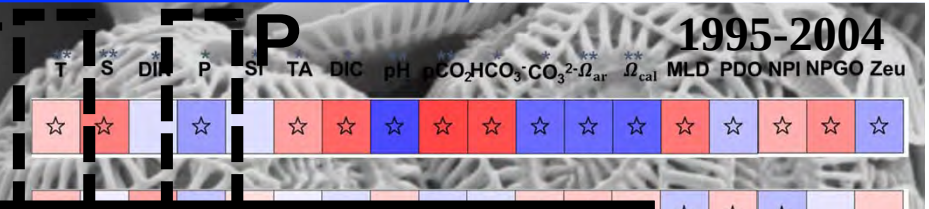
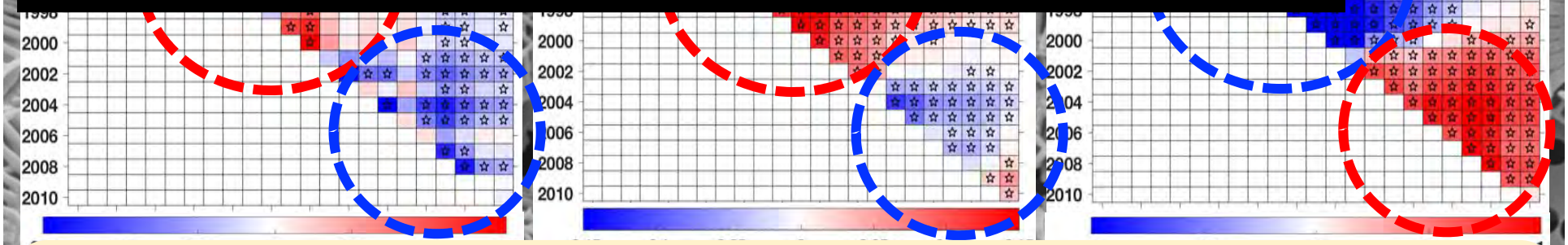


Table 2
Environmental parameters controlling the variability of the dominant coccolithophore taxa as obtained by multiple correlation analyses[a]

ALOHA Station: Cortes et al. [2001]

Largest proportion of the variation in coccolithophore cell density

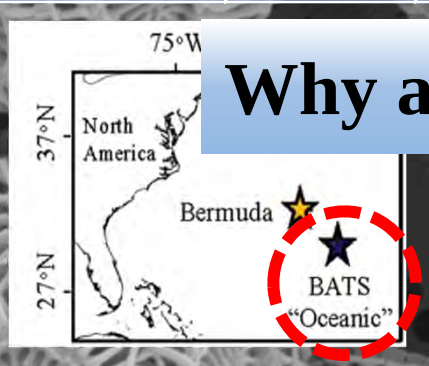
Species	Environmental parameters						
	T Temperature	Salinity	Light	Nitrate	**P** Phosphate	R^2_{adj}
E. huxleyi	x				o	0.67

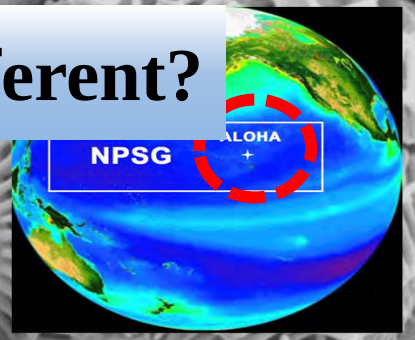


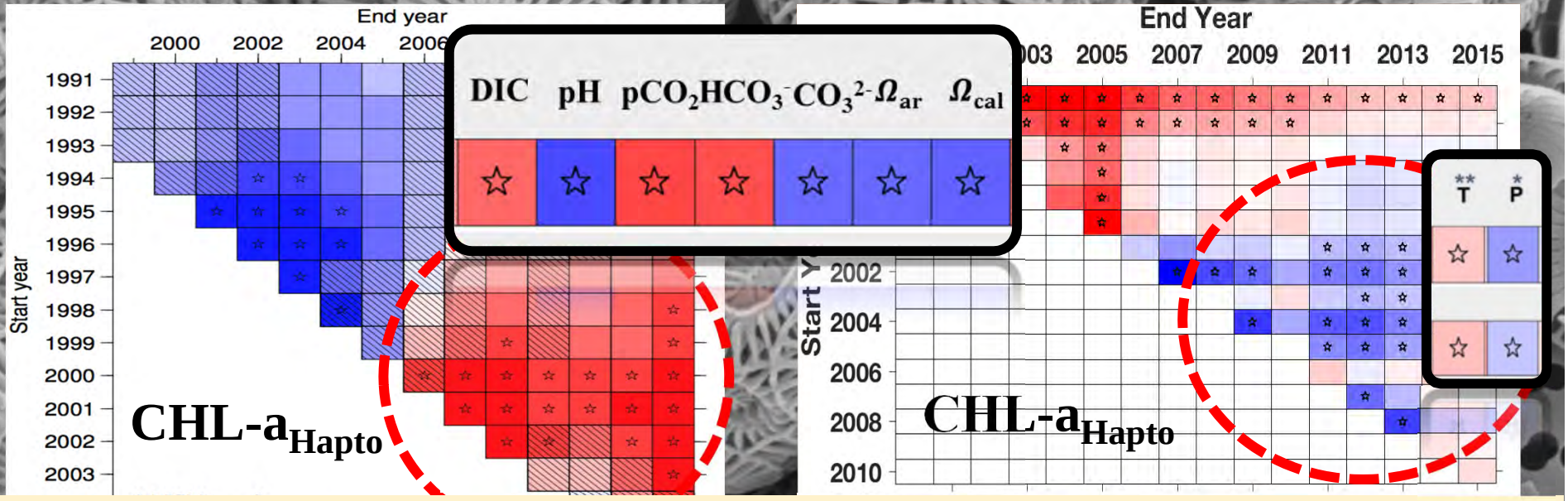
T ↓ & P ↑ ⇨ Haptophytes ↓ ????

Multiple correlation analyses are needed.

Why are NPSG and NASG trends different?







1. Influence of T and P?
2. Relationship with other phytoplankton groups?
3. Non-linear relationship?

Krumhardt et al. [2016]

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