# Acclimation in the Coccolithophorid *Emiliana Huxleyi* in Response to Variable Light in Photosynthesis

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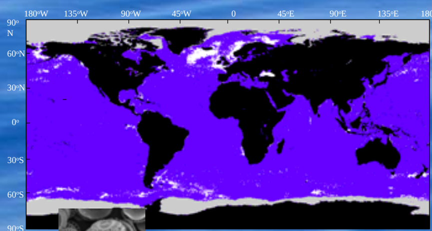
## Motivation

**Phytoplankton make up at least 8 phylogenetic divisions. They also significantly contribute to the largest reservoir of carbon on Earth, the carbonates. Coccolithophorid species, such as *Emiliana Huxleyi* convert the largest amount of dissolved inorganic carbon and calcium to calcium carbonate[1]. Important to biogeochemical and ecological processes, it is vital to understand the optimal conditions for their growth and efficiency. Figure 1 shows a Sea WiFS image mapping the global distributions of an *Emiliana Huxleyi* bloom in white[1]. Satellite images show that *E. huxleyi* blooms primarily in the polar regions, which are known as highly turbulent ocean environments.**



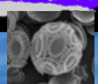



**Figure 1: Satellite imagery shows coccolithophorid blooms primarily occurring in the polar regions.**

## Our Goal

Mixing can alter the photosynthetic efficiency and growth of phytoplankton due to changing the ambient light levels. This project will attempt to evaluate how changing light levels impact *Emiliana huxleyi*. Specifically, our goals are:

- **Assess how the photosynthetic efficiency varies with light level.**
- **Determine the time it takes for *Emiliana huxleyi* to acclimate when light levels change.**
- **Assess the potential impact of these light induced changes in nature.**

## Methods

To determine the effects of varied light intensities on *Emiliana huxleyi*, we made a series of measurements on laboratory cultures acclimated to 100 µmol photons $m^{-2}$ $s^{-1}$. Cultures where then transferred to three different levels (low light = 25µmol photons $m^{-2}$ $s^{-1}$, control light = 100 µmol photons $m^{-2}$ $s^{-1}$, and high light = 500 µmol photons $m^{-2}$ $s^{-1}$). The fluorescence of these samples was monitored over a period of five days using a Fast Repetition Rate Fluorometer (FRRF). Fluorescence is the light emitted from Photosystem II (PSII) and is an expression of the photosynthetic efficiency, or health, of an organism (Figure 2). The maximum quantum yield during PSII is calculated from the minimum ($F_0$) and maximum ($F_m$) fluorescence levels as $(F_m-F_0)/F_m$. The $F_o$ is when all PSII systems are open. The $F_m$ is when all PSII systems are closed. The difference between the two is called $F_v$ (Figure3). After following the acclimation, the $F_v/F_m$ for each culture was measured at 14 different irradiances. Measurements were also taken for cell number and total absorption.

What is fluorescence?

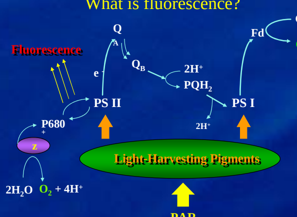



Figure 2: Cells use light from PSII and emit what light energy they cannot use in the form of fluorescence.

What we measure?

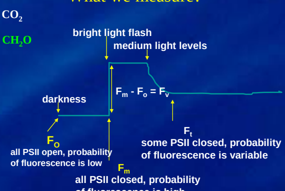
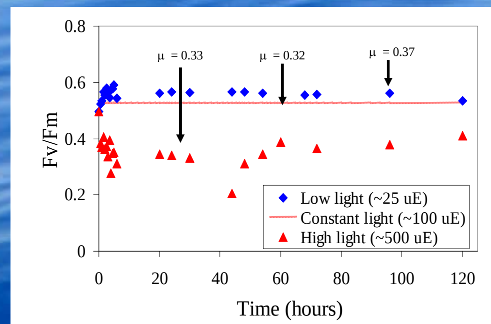



Figure 3: The FRRF measures maximum quantum yield, or $F_v/F_m$, using the $F_o$ and $F_m$ values.

## *E. Huxleyi* and changing light

In the presence of changing light, it is apparent that *E. Huxleyi* is most vulnerable to a change from low light to high light (Figure 4). Figure 4a illustrates the $F_v/F_m$ readings taken over 5 days after a light shift. Relative to the control, the low light culture increased slightly (~17%) and appeared to be acclimated to a relatively steady state after 1 day. In comparison, the high light culture decreased significantly (~30-50%), reached a low steady state after 2 days, and never recovered to the control efficiencies (Figure 4). The photosynthetic efficiency is much more variable in the high light culture. Results suggest that it takes longer to acclimate to high light. This is in contrast to diatoms[2,3] and dinoflagellates[4,5].



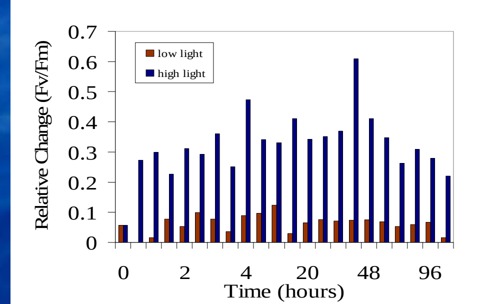




Figure 4: a.) Represents the periods of acclimation for a sample transferred from low light to high light and a sample transferred from high light to low light. b.) Represents the relative change in the $F_v/F_m$ for the high light and low light samples in comparison to the constant light sample.

## *E. Huxleyi* and light gradients

The response in Fv/Fm for all 3 cultures to a light gradient, ranging from 2 to 300 µmol photons $m^{-2}$ $s^{-1}$. Results showed that the overall shape in the curves was similar (Figure 5) with photosynthetic efficiency decreasing with increasing irradiance. The only differences were seen in the $F_v/F_m$ intercepts. There was no significant difference in the inhibitory slopes.

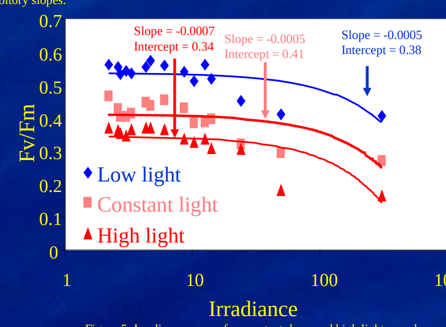
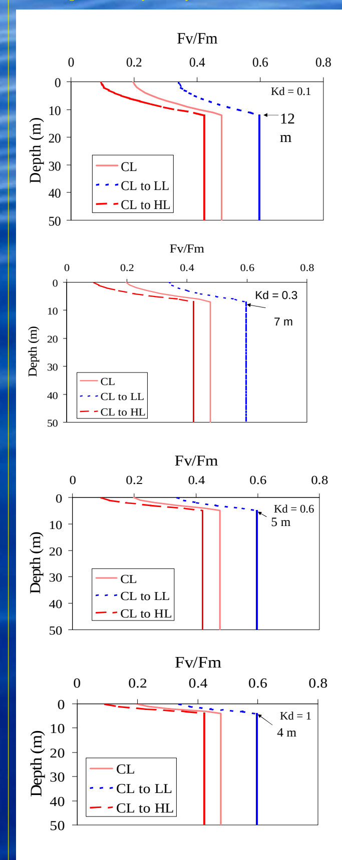



Figure 5: Irradiance curves for constant, low, and high light samples.

## *E. Huxleyi* and natural light gradients

Using typical irradiance profiles from nature (Figure 6) it is possible to estimate the photosynthetic efficiencies in the water column. We estimated the potential curves for the control, low, and high light conditions. Given cells circulate throughout the water column in the upper mixed layer we might expect cellular signatures for low to high light transitions and vice versa. This variability will be expected for populations in nature. We calculated the $F_v/F_m$ profiles over a range of water column turbidities (when Kd is high, the water column is more turbid). Figure 5 shows the range of $F_v/F_m$ profiles that might be encountered. The differences in the Fv/Fm curves for a given Kd reflect only the cellular response to a changing light environments. As readily evident the $F_v/F_m$ profiles are very sensitive to the light history of the cells. This means that data collected in the field includes this variability.

Figure 5: Photosynthetic yields in a water column.



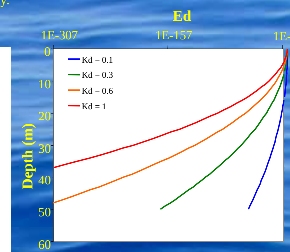




Figure 6: An irradiance profile from nature.

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**1) *Emiliana huxleyi* is sensitive to high light. The acclimation time for high light adaptation is longer than low light acclimation. This is in contrast to diatoms and dinoflagellates.**

**2) $F_v/F_m$ is sensitive to the light history of the phytoplankton.**

**3) The light history will introduce variability into $F_v/F_m$ measurements in nature when cells are mixing and experiencing a constantly changing light environment.**

**4) For *Emiliana huxleyi*, which grows in polar oceans, we predict the light induced variability in $F_v/F_m$ will be significant. Therefore, interpreting declines in $F_v/F_m$ as only due to nutrient limitation will be problematic.**