

Name:

Date:

TEACHER VERSION: Suggested student responses are included.

Seasonal Cycles: the North Atlantic Phytoplankton Bloom

Guiding Question:

What are the factors that control the patterns/cycles of phytoplankton growth in the North Atlantic Ocean?

Introduction

Phytoplankton are microscopic ocean plants that form the base of the marine food chain. Though they are small, the energy they capture from the sun through photosynthesis (aka their **productivity**) helps to sustain almost all life in the ocean. In order to photosynthesize, phytoplankton contain a pigment called **chlorophyll-a** (the same as in land plants), which also gives the microscopic plants a greenish color. Phytoplankton are also crucial to life on land as they produce more than half of Earth's oxygen supply. Like all plants, phytoplankton productivity requires sunlight, water, carbon dioxide, and nutrients.

A **phytoplankton bloom** occurs when phytoplankton respond to favorable environmental factors by initiating heightened photosynthetic activity, leading to an explosive growth of the phytoplankton population. The North Atlantic phytoplankton bloom is the largest seasonal occurring biological event in the oceans, and corresponds with seasonal changes in sunlight and temperature. Scientists use chlorophyll-a concentrations detected by satellites to estimate the extent of a phytoplankton bloom.

Spring brings warmer temperatures and increased sunlight or **photosynthetically available radiation** (PAR), and nutrients become trapped at the ocean surface. This allows phytoplankton to absorb energy and take in the nutrients they need to photosynthesize and multiply. The warming of the surface layer keeps this water less dense, so it stays afloat. As phytoplankton continue thriving in the nutrient-rich surface zone where they receive sunlight, they may become so plentiful that the ocean waters often turn green, brown, or red from the chlorophyll they contain. As the phytoplankton use up the available nutrients however, they begin to die and drift to the bottom, reducing the bloom in the summer. As autumn begins, cooler days cause some vertical mixing that may bring nutrients up from below resulting in a relatively smaller fall bloom. Blooms do not occur in the winter because plummeting temperatures and frequent storms cause heavy ocean mixing, which prevents ready access to sunlight by keeping phytoplankton away from the surface water.

Part 1. Reading Questions

1. What factors are important to phytoplankton growth?

Sunlight, water, CO₂, and nutrients influence phytoplankton growth.

2. What is a phytoplankton bloom and when does it generally occur in the North Atlantic?

A phytoplankton bloom is when good conditions lead to more photosynthesis and an explosion of phytoplankton growth. This usually occurs in the spring, with a smaller bloom in autumn.

3. What might cause a phytoplankton bloom to halt?

A bloom may halt when phytoplankton use up most of the available nutrients, or when heavy Ocean mixing occurs in the winter, due to storms.



Part 2. How does chlorophyll concentration change over one season?

1. From the Student Climate Data website (<http://studentclimatedata.unh.edu>), click on the ‘Ocean Data’ tab at the top of the page.
2. Under ‘Tools and Data’ in the left panel, click ‘DICCE Portal’ to bring you out to the NASA DICCE data portal.
3. In the **Area of Interest** section (below the map), type in the coordinates for the North Atlantic as shown below.

Area of Interest: West: North: South: East:

4. Click ‘Update Map.’ This should create a yellow bounding box in the northern part of the Atlantic Ocean.
5. Under the ‘**Ocean Biosphere**’ parameter section, click the box next to ‘Chlorophyll a concentration.’

Ocean Biosphere(1997/09/01 - 2014/12/31)		
Parameter	Data Product Info	
<input checked="" type="checkbox"/> Chlorophyll a concentration	SWFMO_CHLO.CR	SeaWiFS
<input type="checkbox"/> Chlorophyll a concentration	MAMO_CHLO_9km.CR	MODIS-Aqua

6. In the ‘**Temporal**’ section, set the Begin Date to Jan 2005 and the End Date to Aug 2005.

Begin Date Year Month
End Date Year Month

7. Using the ‘**Select Visualization**’ drop-down menu, select ‘Animation.’
8. Click
9. It may take a few minutes for DICCE to create the animation. Once the map loads, take some time to observe the patterns in chlorophyll by pressing the play button  or using the forward  and back  buttons to move through the animation. (**The highest chlorophyll concentrations are in red)
10. What is the range of chlorophyll concentration over the North Atlantic for the month of February?

The range is 0.1 mg/m³ to 10 mg/m³, with the highest concentration off the coast of the US.

11. Which month has the highest overall chlorophyll concentration value? Which month has the lowest?

The highest chlorophyll values are in April, the lowest are in August.

12. How does the spatial extent of the phytoplankton bloom change over the months?

The bloom increases from January to April, with the highest concentration at the coasts of the US and Europe. By April it covers most of the Northern Atlantic. It then decreases from May to August with very low concentrations (< 0.08 mg/m³) in the lower latitudes.

Part 3. How does chlorophyll concentration change over many years?

1. Return to the data portal page by clicking the [Home](#) tab on the top-left of the page.
2. Rescale the yellow bounding box by typing in the coordinates below and clicking 'Update Map.'

Area of Interest: West: North: South: East:

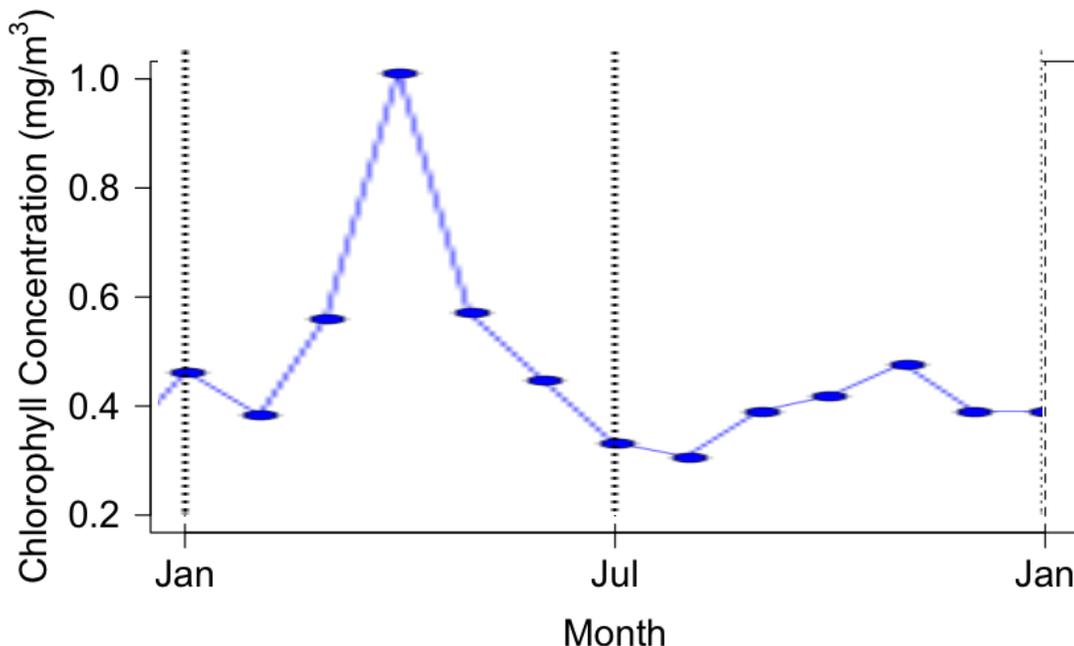
3. Change the End Date to December 2007.
4. Using the 'Select Visualization' drop-down menu, select 'Time series.' This will create a graph of the average chlorophyll concentration for that area.
5. Click
6. Once the graph loads, take a few minutes to observe the patterns in Chlorophyll.
7. In this graph, what is the dependent variable (y-axis) and what is the independent variable (x-axis)?

The x-axis is the Date; the y-axis is the Chlorophyll-a concentrations (in mg/m³)

8. Which year has the largest phytoplankton bloom? How can you tell?

2006 has the largest bloom, because that spring had the highest chlorophyll-a concentrations.

9. On the blank graph below, sketch the chlorophyll concentration for the year 2006.



10. Notice, in the graph, that there is a small peak and a large peak. What do you think is the cause of the taller peak in chlorophyll concentration? The smaller peak? (**Use the information in the Introduction to help you answer this question)

The taller peak is the spring phytoplankton bloom, when conditions are favorable for photosynthesis. The small yearly peak is the fall bloom, which ocean mixing brings more nutrients up to the surface.

Part 4. Is there a relationship between Chlorophyll, Light, and Sea Surface Temperature?

1. Return to the data portal page by clicking the [Home](#) tab on the top-left of the page.
2. In the **Physical Ocean** parameter box, keep Chlorophyll a concentration on.
3. Also select the ‘Photosynthetically Available Radiation’ (PAR) box, under the **Energy and Net Radiation System** parameter box. PAR is a measure of the available sunlight.
4. Keep the ‘**Select Visualization**’ drop-down menu on ‘Time series.’
5. Click [Edit Preferences](#) and set the **Overlay Flag** to ‘Yes’ (this will plot all variables on the same graph).
6. Click [Generate Visualization](#)
7. What is the color of the line displaying the chlorophyll data? The Photosynthetically Available Radiation (PAR) data?

The chlorophyll data are red, the PAR data are blue.

8. Based on the time series graph and your knowledge from the Introduction, what is the relationship between chlorophyll and light? Why don’t the lines for the two variables completely match up? What other factors could help explain the patterns in chlorophyll?

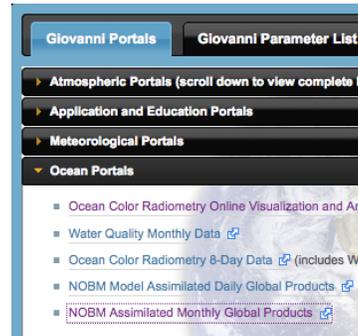
Increased sunlight leads to increased chlorophyll concentration, because more phytoplankton are photosynthesizing. However, the lines don’t completely match up because there are other factors influencing chlorophyll concentration, such as nutrient availability and the amount of ocean mixing. For example, the highest PAR values are in the summer, but this is when a spring bloom has caused low nutrient availability, so phytoplankton (and therefore chlorophyll concentrations) have decreased.

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Extension 1. Nutrients and mixed layer depth

1. Click **+ ABOUT GIOVANNI** at the top of the DICCE page.
2. Under ‘Giovanni Portals,’ click ‘Ocean Portals’ and then ‘NOBM Assimilated Monthly Global Products.’



3. In the **Area of Interest** section (below the map), type in the coordinates for the North Atlantic as shown below and click ‘Update Map.’

Area of Interest: West:	<input type="text" value="-75"/>	North:	<input type="text" value="50"/>	South:	<input type="text" value="30"/>	East:	<input type="text" value="-5"/>	<input type="button" value="Update Map"/>
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4. Under the ‘**Parameters**’ section, click the box next to ‘NOBM Nitrate’. **Nitrate** is one of the nutrients needed for phytoplankton growth.
5. In the ‘**Temporal**’ section, set the Begin Date to Jan 2005 and the End Date to Aug 2005.

Begin Date	Year	<input type="text" value="2005"/>	Month	<input type="text" value="Jan"/>
End Date	Year	<input type="text" value="2005"/>	Month	<input type="text" value="Aug"/>

6. Using the ‘**Select Visualization**’ drop-down menu, select ‘Animation.’
7. Click **Generate Visualization**
8. What happens to surface nitrate from January to August?

Nitrate increases from January to March, and then decreases from April to August.

9. What are the largest and smallest nitrate values? Which month has the highest nitrate values overall?

Nitrate values range from 0.01 micromoles/L to 30 micromoles/L. Nitrate values are highest in March.

10. Return to the data portal page by clicking the **Home** tab on the top-left of the page, and repeat the animation generation for ‘NOBM Mixed Layer Depth’. The **Mixed Layer Depth** is the depth in the water column at which the surface waters are well mixed and considered homogenous in their properties.

11. What happens to the mixed layer depth from January to August?

An increase is seen from January through March, and then it decreases through August.

12. Which month has the most area with a high mixed layer depth? What are the range of values (including units) for that month?

The largest mixed layer depth is in March, with values of 10-150 meters.

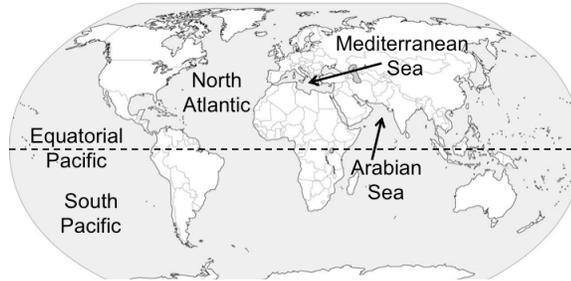
13. Using your knowledge from the Introduction as well as your results from the previous sections (Part 2 through 4) explain how nitrate and mixed layer depth interact with chlorophyll.

Nitrate concentrations increase from winter to spring, likely due to a higher mixed layer depth, bringing up nutrients from lower in the Ocean. This increase in nutrients (along with more available sunlight in the spring) allows for the spring phytoplankton bloom, and therefore more chlorophyll.

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Extension 2. Seasonal Variability Investigation in Other Regions



From the table below, choose a region or regions you would like to investigate.

Table 1. Coordinates for selected regions.

Region	West	North	South	East
Mediterranean Sea	-6	46	30	38
Arabian Sea	50	27	10	75

Which regions did you chose?

Pose a **research question** that focuses on seasonal trends in phytoplankton growth and can be answered using the data available on the DICCE Data Portal page.

A research question should be concise, have a single or limited set of variables, and be answerable using data available on GIOVANNI.

Write a **hypothesis statement** that will either be supported or not supported by the results of your investigation. State your hypothesis:

The hypothesis statement should answer the research question and provide reasoning for their thinking.

What data/information do you need in order to test your hypothesis?

Information should include the variables they wish to study as well as the range of dates they will use in their investigation.

***Student responses on this page depend on the student developed research question.*

Use the coordinates from Table 1, and the data available on the DICCE portal, to investigate research question. Record your results in the table below or create your own table. (***You may not need to use all columns*)

Table 2. Investigation Results

Region	Year	Sea Surface Temp(min)	Sea Surface Temp(max)	PAR (min)	PAR (max)	Chlorophyll (min)	Chlorophyll (max)

Record other observations and findings using graphs, tables, or text below.

Analysis and Discussion

What are some notable outcomes of your investigation? Were the results of your investigation similar or different than the patterns observed in the North Atlantic?

Was your hypothesis supported by the data from your investigation? Why or why not?

Develop one new research questions you have after viewing your results. What information would you need to answer this new question?

