Conditions at Sea

Below is an overview of the activity Conditions at Sea: Background, Making Waves, and Data Activity (NANOOS) to incorporate information learned from Dr. Herrington's presentation and subsequent discussion.

Lesson Overview

Students learn about the process of wave formation and the forces that cause waves, access real-time data to make predictions about sea conditions, and analyze the relationship between the ocean and the atmosphere.

Lesson Rationale

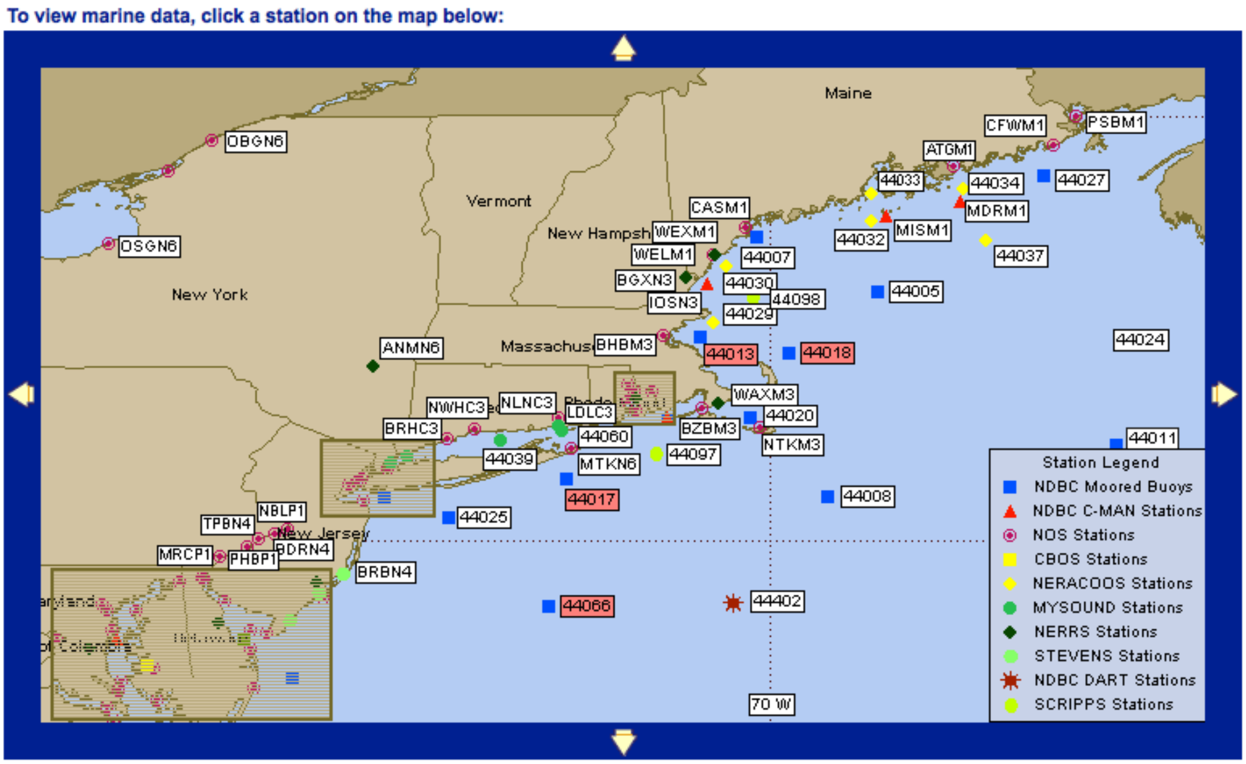
Forecasting the conditions at sea is an important tool for sailors, fishermen, maritime transportation, anyone on the water. Students gain an understanding that wave formation is primarily caused by wind and that the characteristics of waves can be forecasted from wind data. Through participating in a forecasting activity students learn how it happens and the importance of forecasting for anyone on the water. Through the activities, students learn about the concepts of wave formation and forecasting, conduct an in-class wave-making activity, and access near real-time and real-time data from ocean observing buoys to investigate the relationship between wind and wave height, and predict the actual conditions out at sea using the Beaufort scale.

Key Concept

Students learn about wave formation and forecasting of waves, and access real-time data to predict actual conditions at sea.

Adjustments to Data Activity: Procedure

In step 2, have the students visit http://www.ndbc.noaa.gov/maps/Northeast.shtml to access buoy data for the Northeast (Virginia to Maine). If you are interested in having the students look at buoy data from throughout the world and/or United States, have the students visit http://www.ndbc.noaa.gov/rmd.shtml.



Rather than limiting the students to choosing a region of the Pacific Coast, Pacific Ocean, or Great Lakes either have the students look in the Northeast region or open the activity to the entire world. * Note – a good extension would be to have students compare wind and wave heights in the Pacific and Atlantic Ocean.

In the acknowledgements, the data lesson is based on "Sea State" which is one of the Ocean Observing Systems lesson plans (http://www2.vims.edu/bridge/search/oosarchives.cfm).

Lesson Plan: Conditions at Sea
Background

Summary

Forecasting the conditions at sea is an important tool for sailors, fishers, maritime transportation, anyone on the water. In Conditions at Sea, a three-part series, students first learn about the concepts of wave formation and forecasting, conduct an in-class wave-making activity, and access near real-time and real-time data from ocean observing buoys to investigate the relationship between wind and wave height, and predict the actual conditions out at sea using the Beaufort scale.

Subject Area

Physical Science/ Earth science

Grade Level

6-12

Key Concepts

- Ocean wave formation is primarily caused by wind.
- Wave characteristics can be forecasted from wind data.
- Forecasting is an important tool for mariners

Objectives

- Explain the process of wave formation and the forces that cause waves.
- Access and use near real-time data to make predictions on sea conditions.
- Analyze the relationship between the ocean and the atmosphere.

Background Information

Ocean waves are most commonly caused by wind. As wind moves across the water, it "pushes" the ocean water ahead of it. The wind actually transfers some of its energy into the water. The water is able to "gain" energy from the wind because of the

friction between the wind and the water. As wind pushes the water, wrinkles form on the surface. The stronger the wind is, the rougher the water surface. As the surface of the water gets rougher the surface area of the water increases, and thus the more surface area is available for the wind to catch, creating larger and larger waves as the wind travels across the water's surface.

The size of a wave created by wind is determined by three things:

- ~ distance the wind blows over open water, known as the **fetch**
- ~ the length of time the wind blows, the **duration**
- ~ And the speed of the wind, the **wind speed**

The greater any one of these three conditions, the larger the wave. Often, a wave's size and shape can give clues to its origin. A steep, choppy wave out at sea is probably fairly new and formed by a local storm. Slow, steady waves near shore probably come from storms far away.

A wave's characteristics can be described and quantified. A wave's highest point is called its **crest**. The low point between two waves is called a **trough**. The vertical distance between crest and trough is called the **wave height**. The distance between two waves is called the **wavelength** and it is usually measured either from one crest to the next or from one trough to the next. The time it takes for waves to pass is called the **wave period**. It can be measured by counting the seconds it takes for two crests or troughs to pass by a specific point. The number of wave crests passing a specific point each second is the **wave frequency**.

Understanding the wind and wave conditions, or **sea state**, out on the water is an invaluable tool for anyone out on the water, including mariners, fishers, and travelers. In 1805, British Admiral Sir Francis Beaufort (1774-1857) created a wind speed estimation system based on the conditions at sea. Consisting of a 0-12 scale, the **Beaufort Wind Force Scale** ranged from calm to hurricane force winds (which are then measured by the **Saffir-Simpson Scale**; tornadoes are measured by the **Fujita Scale**). Despite many different forms, Sir Beaufort's Scale is still recognized as the standard and is used all over the world for describing wind conditions both at sea and on land.

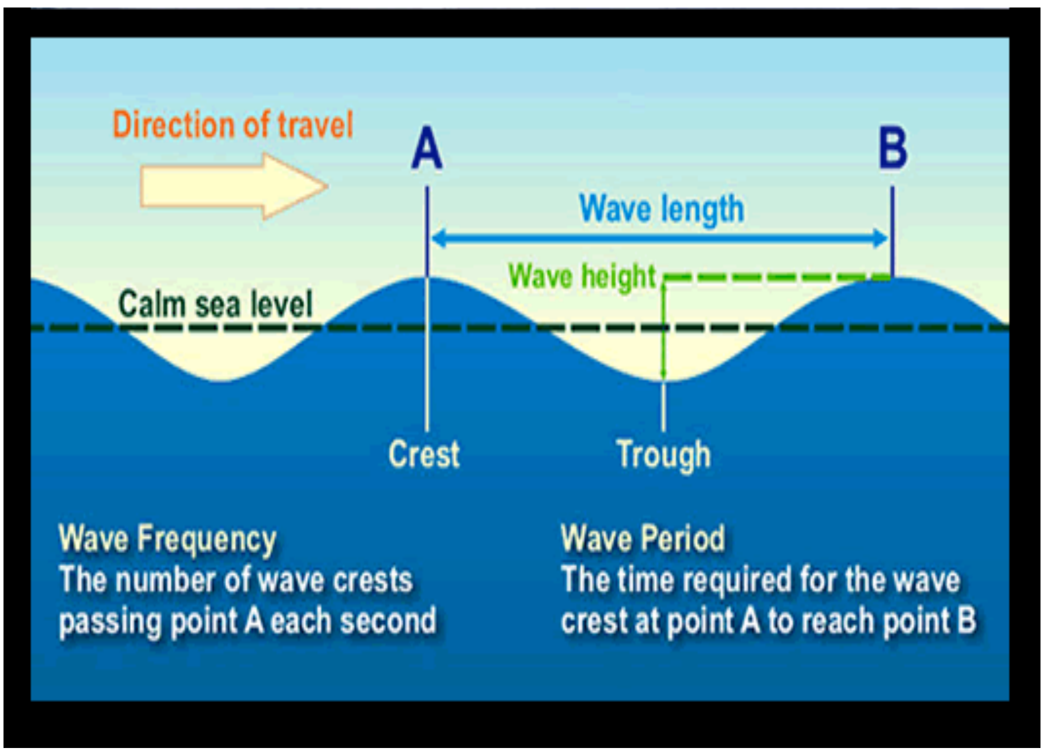


Image from: http://www.windows.ucar.edu/tour/link=/earth/Water/ocean.html

Ocean observing systems maintain buoys along our coasts and offshore to record conditions out on the ocean, and are able to transmit this information, via satellite, in real- time or near real-time. Many of these buoys measure parameters including wind speed, and wave height, which can provide valuable information on sea conditions to anyone who is considering being out on the water.

Lesson Plan: Conditions at Sea
Introductory Activity, Making Waves

Summary

Forecasting the conditions at sea is an important tool for sailors, fishers, maritime transportation, anyone on the water. In Conditions at Sea, a three-part series, students first learn about the concepts of wave formation and forecasting, conduct an in-class wave-making activity, and access near real-time and real-time data from ocean observing buoys to investigate the relationship between wind and wave height, and predict the actual conditions out at sea using the Beaufort scale.

Subject Area

Physical Science/ Earth science

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6-12

Key Concepts

- Ocean wave formation is primarily caused by wind.
- Wave characteristics can be forecasted from wind data.
- Forecasting is an important tool for mariners

Objective

- Explain the process of wave formation and the forces that cause waves.

Materials

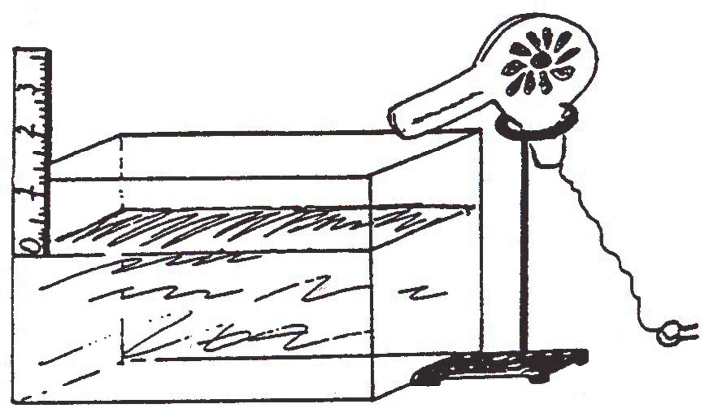
- hair dryer
- aquarium, clear glass or plastic rectangular container
- ring stand or doll stand (to hold and position hair dryer)

- erasable markers
- ruler
- water
- tape
- clock or watch

Safety note: do not let any part of the dryer touch the water!!!

Procedure

1. Place the aquarium or glass/plastic container on a firm surface.
2. Fill the container about three fourths full of water.
3. Allow the water to settle into a smooth surface
4. Tape a ruler on the outside of the container with the zero mark at the waterline. See illustration.



5. Set the ring stand or doll stand at one end of the container. Attach the hair dryer, so that it is a few inches from the edge of the container and a few inches above the water. (See sample of a data table at the end of this procedure.)
6. With an erasable marker, mark the water level of the still surface, which is at the zero mark on the ruler.
7. With the dryer on low level, note the time you turned the dryer on, and let it blow for three minutes. Describe the waves in your data table. (See a sample of a data table at the end of this procedure.)
8. After three minutes, mark the height of the waves on the outside of the container (label this mark, A). In your data table, record the height of these waves and the distance above the still water level and describe the shape of the waves.

9. Continue to let the dryer blow on the water for 5 minutes, mark the height of the waves on the outside of the container (label this mark, B). Record their height and description in your data table.
10. Describe what happens to the waves as they hit the end and sides of the container. Place this information in your data table.
11. Turn the dryer off and let the water settle.
12. Turn the dryer on medium speed. Describe these waves.
13. After 3 minutes, mark the height of the waves on the outside of the container (label this mark, C). Record the waves' height and description in your data table.
14. After 5 minutes, mark the height of these waves on the outside of the container (label this mark, D). Record the description and height of these waves in your data table.
15. Describe what happens to these waves as they hit the end and sides of the container.
16. Turn the dryer off again and let the water settle.
17. Turn the dryer on high power and observe the waves.
18. Describe these waves.
19. After 3 minutes, mark the height of the waves on the outside of the container (label this mark, E). Record the waves' height and description in your data table.
20. After 5 minutes, mark the height of these waves on the outside of the container (label this mark, F). Record the waves' height and description in your data table.
21. Describe what happens to these waves as they hit the end and sides of the container.
22. Turn dryer off!

Note: Some hair dryers have only low and high speeds. If this is the case, omit steps #12 – 16 in the above procedure. You will also need to modify the Sample Data Table.

Sample Data Table:

Dryer speed	Low	Medium (if available)	High
Description of original waves			
Description of waves after 3 minutes			
Height of waves after 3 minutes			
Description of waves after 5 minutes			
Height of waves after 5 minutes			
Description of what happens to the waves as they strike the end and sides of container			

Have Students use the information in their data table to do the following and answer questions such as:

- Describe how the force or strength of the wind affects the height of the waves.
- How is the wave height affected by the length of time the wind blows?
- Does the strength of the waves have any effect on the movement of the waves? Explain your answer.
- What happens to the waves when they hit the end and sides of the container?
- Compare the behavior of the waves that reach the end of the container with those that reach the sides.

- If your container was twice as long, what effect do you think this extra length would have on the behavior of the waves? (If a larger container is available - try it and see!)

Assessment

Have students write a few paragraphs and draw a diagram to explain how this investigation demonstrates the factors that affect wind waves and how these factors affect wave size.

Resources

- National Geographic wave simulator. Students can adjust wave height, wave period and/or wave length to see how each affects wave formation: http://www.nationalgeographic.com/volvooceanrace/interactives/waves/
- Background information on waves. Windows to the Universe: http://www.windows.ucar.edu/tour/link=/earth/Water/ocean_waves.html&edu=mid&back=/search/search_navigation.html
- Office of Naval Research: http://www.onr.navy.mil/Focus/ocean/motion/waves1.htm

Standards

NSES (National Science Education Standards)

Oregon Science Standards

Washington State **EALRs** (Essential Academic Learning Requirements) and **GLEs** (Grade Level Expectations)

Content Standard or Essential Principle	LEARNING GOALS
A: Abilities necessary to do science *NSES*	☐ Use appropriate tools and techniques to gather, analyze, and interpret data. (6-8) ☐ Develop descriptions, explanations, predications, and models using evidence. (6-8) ☐ Think critically and logically to make the relationships between evidence and explanations. (6-8)
B. Motion and Forces *NSES*	☐ The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph. (6-8)
B. Interactions of Energy and Matter *NSES*	☐ Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. (9-12)
Scientific Inquiry *OR*	☐ Collecting and Presenting Data: Conduct procedures to collect, organize, and display scientific data.
Scientific Inquiry *OR*	☐ Summarize and analyze data including possible sources of error. Explain results and offer reasonable and accurate interpretations and implications.
EALR 2: Inquiry Core Content: Questioning and Investigating *WA*	☐ Collecting, analyzing, and displaying data are essential aspects of all *investigations*.
EALR 2: Inquiry Core Content: Questioning and Investigating *WA*	☐ *Models* are used to represent objects, events, *systems*, and processes. *Models* can be used to test *hypotheses* and better understand *phenomena*, but they have limitations.
EALR 4: Physical Science Core Content: Interactions of Energy and Matter *WA*	☐ Energy can be *transferred* from one place to another through *waves*. *Waves* include vibrations in materials. Sound and earthquake *waves* are examples. These and other *waves* move at different speeds in different materials.

Lesson Plan: Conditions at Sea
Data Activity

Summary

Forecasting the conditions at sea is an important tool for sailors, fishers, maritime transportation, anyone on the water. In Conditions at Sea, a three-part series, students first learn about the concepts of wave formation and forecasting, conduct an in-class wave-making activity, and access near real-time and real-time data from ocean observing buoys to investigate the relationship between wind and wave height, and predict the actual conditions out at sea using the Beaufort scale.

Subject Area

Physical Science/ Earth science

Grade Level

6-12

Key Concepts

- Ocean wave formation is primarily caused by wind.
- Wave characteristics can be forecasted from wind data.
- Forecasting is an important tool for mariners

Objectives

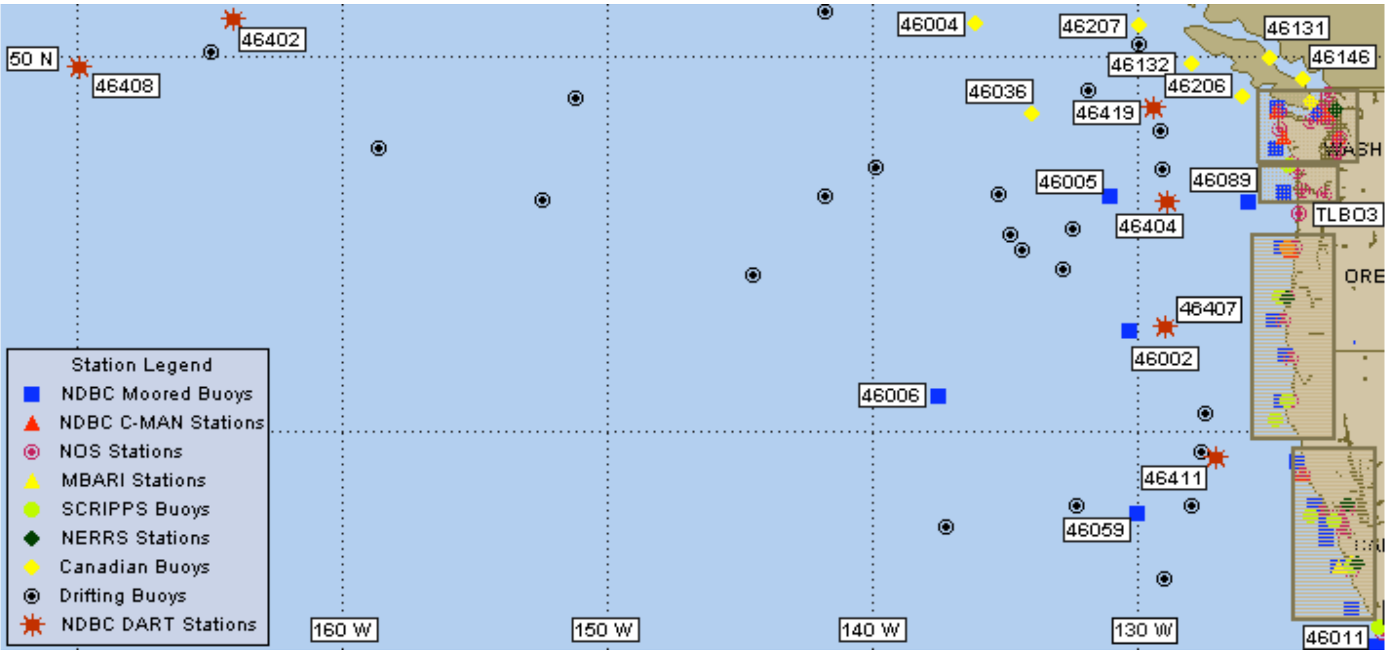
- Access and use near real-time data to make predictions on sea conditions.
- Analyze the relationship between the ocean and the atmosphere.

Materials

- Computer lab with internet access or projection screen
- Science journal or similar for each student

Procedure:

1. Engage students in a class discussion, considering the following questions:
   - What factors influence wave formation?
   - What information on wind and waves would be useful for forecasting sea conditions?
   - Given wind data, could you predict wave conditions? How?
2. Have students work in small groups to explore buoy data on the internet. If computers are not available, you can use a digital projector to display the computer screen for entire class, or gather data on buoys before class and disseminate to the students.
   - Go to the NANOOS Home page, www.nanoos.org. Under left menu item, "Data Explorer," click "Products," scroll down to "NOAA Buoys," and click.
   - Have students explore this map, zooming in to their state, and/or an area of interest, and clicking on buoys to bring up the most recent data from that buoy.



Interacive Map of West Coast buoys. Clicking a symbol will pull up data from that buoy.

- NDBC Moored Buoys: wind and wave data
- NDBC C-MAN Stations: wind data
- NOS Stations: wind data
- SCRIPPS Buoys: wave data.
- NERRS Stations: wind data
- Canadian Buoys: wind and wave data

- Have students choose a region of the Pacific Coast, Pacific Ocean, or Great Lakes, and gather data from buoys in the region. Include date and time of the latest observation, wind speed, and wave height from buoys. (Alternative: to groups of students assign a geographic area from which to gather data.)
- Post or pass around a Beaufort Scale to all students. Students should use their data to determine the Beaufort Wind Force Scale at each of their buoy

locations, and whether or not they expect it to be safe to travel in the area of the buoy.

- Have each group compile a report to mariners based on this information.

MAREP or MAriner REPort:

MAREPs are messages about weather and sea conditions that you and other mariners have observed at sea. They are used to inform other mariners about actual sea conditions, helping mariners decide where they may or may not travel on the water. They can also be used by weather forecasters to update marine warnings and forecasts.

Information for your reports to mariners includes:

- Radio call sign
- Time of observation
- Location
- Wind direction and speed
- Seas
- Swell direction and height
- Visibility
- Present weather
- Barometer (air pressure) – inches (in) or millibars (mb), if rising or falling
- Air temperature
- Sea water temperature
- Wind gusts – seas higher than average, heavy rain, dense fog, etc.
- Any other conditions you feel are important

Resources from NOAA:
MAREP user guide:
http://www.nws.noaa.gov/om/marine/marepreport.pdf

Guide to Mariner Reports (MAREPs)
http://www.nws.noaa.gov/om/marine/marep.pdf

- If students would like more information to include in their forecast, they can access the National Weather Service, at : http://www.nws.noaa.gov/ to find information on temperature, precipitation, and cloud cover.
- As a class, students can come together to determine the best and worst places to be out on the water based on their data. They can use the sample Data Table below.

Sample Data Table:

Buoy #	Location	Obs. Date	Obs. Time	Wind speed	Wave Height	Beaufort #	Expected Conditions	Safe to travel?

- In class or small groups have students graph wind and wave data from their data table. What do students expect the relationship to be between wind and waves, based on their experience in the introductory activity? Does their graph meet their expectations? If not, have a class discussion on reasons this may be.
- For an explanation on this, direct students to these education pages on the National Buoy Data Center:

http://www.ndbc.noaa.gov/educate/pacwave.shtml . Make sure students read through the page and click "Answer" at the bottom to get the explanation of why wind and wave data may not correlate as nicely as they might expect.

Resources

- National Geographic wave simulator. Students can adjust wave height, wave period wave length. http://www.nationalgeographic.com/volvooceanrace/interactives/waves/
- Background information on waves: http://www.windows.ucar.edu/tour/link=/earth/Water/ocean_motion.html
- NDBC Science Education Page: http://www.ndbc.noaa.gov/educate/pacwave.shtml

Standards

OLEP (Ocean Literacy Essential Principles)

NSES (National Science Education Standards)

Washington State **EALRs** (Essential Academic Learning Requirements) and **GLEs** (Grade Level Expectations)

Oregon Science Standards

Content Standard or Essential Principle	LEARNING GOALS
A: Abilities necessary to do science *NSES*	- Develop descriptions, explanations, predications, and models using evidence. (6-8) - Think critically and logically to make the relationships between evidence and explanations. (6-8)
7: The ocean is largely unexplored. *OLEP*	- Understanding the ocean is more than a matter of curiosity. Exploration, inquiry, and study are required to better understand ocean systems and processes. - New technologies, sensors, and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on

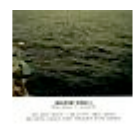
	satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Scientific Inquiry *OR*	Summarize and analyze data including possible sources of error. Explain results and offer reasonable and accurate interpretations and implications.
EALR 2: Inquiry Core Content: Questioning and Investigating *WA*	Collecting, analyzing, and displaying data are essential aspects of all investigations.
EALR 3: Application Core Content: Science, Technology, and Society *WA*	The ability to solve problems is greatly enhanced by use of mathematics and information technologies.

Acknowledgements

- Introductory lesson modified from lesson by Margaret Olsen, SouthEast COSEE
- Data lesson based on "Sea State" lesson from the Bridge: http://www2.vims.edu/bridge/search/archives.cfm

MODERN BEAUFORT SCALE

Beaufort Number	Wind Speed (mph)	Description	Wave height (ft)	Sea Conditions	Land Conditions	Sea State Photo
0	<1	Calm	0	Flat. Sea like a mirror	Calm. Smoke rises vertically.	

1	1-5	Light air	0.33	Ripples, without crests	Smoke drifts in the wind.	
2	6-11	Light breeze	0.66	Small wavelets. Crests have glassy appearance, not breaking	Wind felt on exposed skin. Leaves rustle.	
3	12-19	Gentle breeze	2	Large wavelets. Crests begin to break; scattered whitecaps	Leaves and smaller twigs in constant motion.	
4	20-28	Moderate breeze	3.3	Small waves. Numerous whitecaps	Dust, leaves, and loose paper raised. Small branches move.	
5	29-38	Fresh breeze	6.6	Many whitecaps. Some foam and spray.	Branches of a moderate size move. Small trees sway.	
6	39-49	Strong breeze	9.9	Large waves with foam crests and some spray. Whitecaps everywhere	Large branches move. Whistling in overhead wires. Umbrella use becomes difficult.	
7	50-61	High wind, Moderate Gale, Near Gale	13.1	Sea heaps up and foam begins to be blown in streaks in wind direction.	Whole trees in motion. Effort needed to walk against the wind. Swaying of skyscrapers may be felt.	

8	62-74	Fresh Gale	18	Moderately high waves with breaking crests forming spindrift. Streaks of foam.	Twigs broken from trees. Cars veer on road.	
9	75-88	Strong Gale	23	High waves with dense foam. Sea begins to roll. Considerable spray.	Larger branches break off trees, and small trees uprooted. Temporary signs and barricades blow over.	
10	89-102	Whole Gale/Storm	29.5	Very high waves with overhanging crests. Foam gives the sea a white appearance. Airborne spray reduces visibility.	Trees are broken off or uprooted, saplings bent and deformed, Shingles in poor condition peel off roofs.	
11	103-117	Violent storm	37.7	Exceptionally high waves. Foam covers much of the sea surface. Airborne spray severely reduces visibility.	Widespread damage. Damage to most roof surfaces, older curled/fractured asphalt tiles may break away completely.	

12	≥118	Hurricane-force	≥46	Huge waves. Sea is completely white with foam and spray. Air filled with spray, visibility greatly reduced	Considerable widespread damage, windows broken, structural damage to mobile homes, sheds and barns. Debris may be hurled about.