Global Ocean Warming

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Teacher Guide Lesson Matrix

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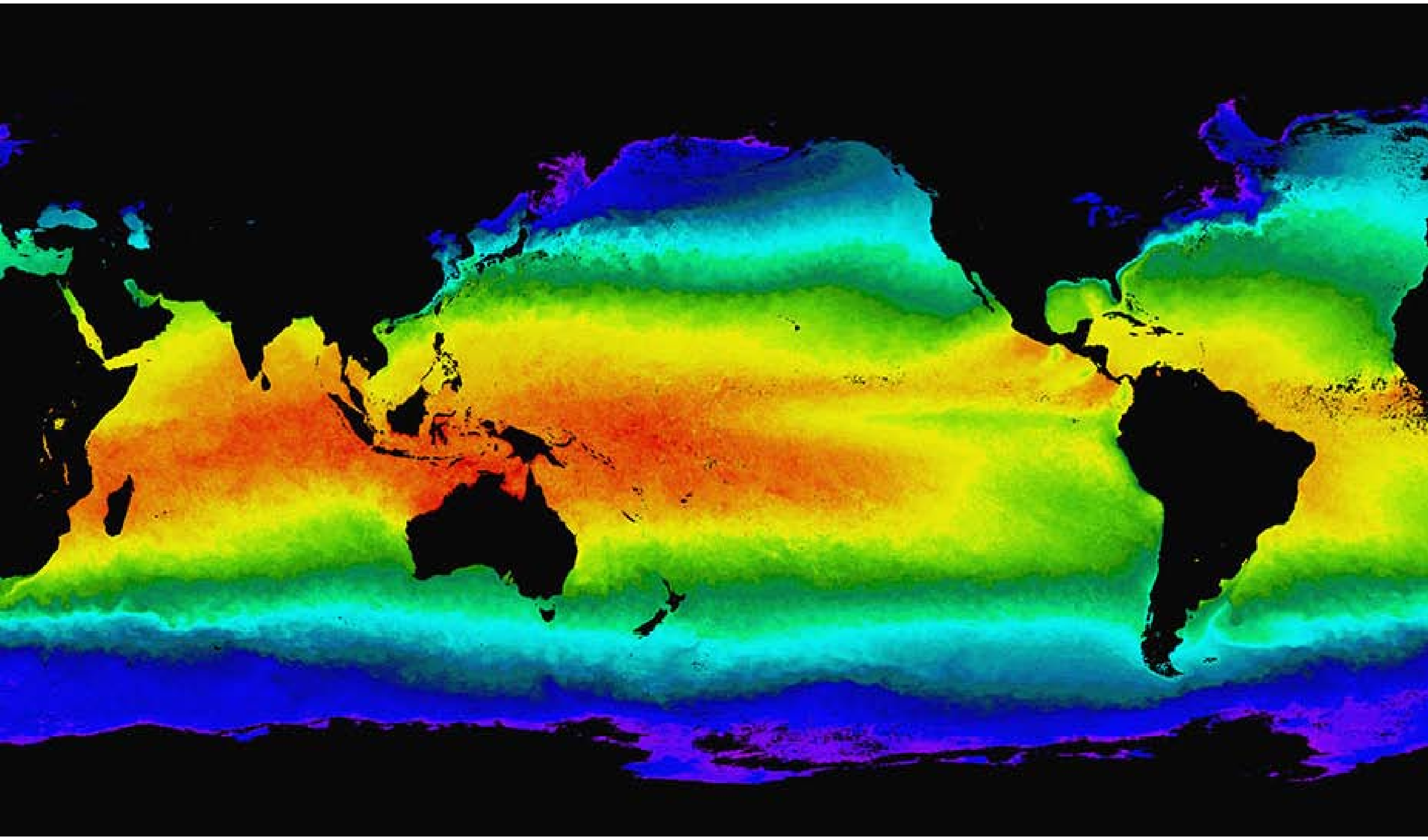


Sea Surface Temperature, MODIS satellite data, NASA, GSFC

Lesson Objectives	Performance Tasks
To demonstrate an understanding of scientific models.	Describe how scientific models used.
To develop an understanding of models and how they illustrate ocean surface energy transfer and storage processes.	Identify similarities and differences between simple, concrete, everyday models and weather-related, target elements.
To identify motion patterns of ocean surface currents in the tropical Pacific.	Manipulate a computer model and accurately read near real-time data collected from the OSCAR project.
To explore how energy transfers and seasonal changes at the ocean surface affect temperatures in the mixed and upper ocean layers.	Predict how energy released by the ocean surface will affect layer temperatures and compare predictions with a computer model.

Materials:
Teacher and Student Guide (PDF)
Internet access

Number of Pages: 17
Grade Level: Level 1, high school
Courses supported:
Earth Science, Physics, and Math

Glossary: eddy, hurricane, turbulence, climate, weather, model, advection, latitude, longitude, energy flux, isothermal layer

Introduction: Earth's Weather Machine

The ocean plays a major role in our planet's weather machine. Water covers 73% of the planet's surface and absorbs a high percentage of solar energy. Wind and currents mix solar energy into the ocean depths and circulate surface water between the Equator and the Poles. Powered by the Sun and influenced by Earth's rotation, the unceasing flow and turbulence of circulating fluids on the thin outer skin of our planet affects temperature, clouds, precipitation, humidity and wind speed, resulting in our weather.

Consider the 2005 hurricane season, which riveted the nation's attention as cities along the Gulf of Mexico were swept away and lives changed forever. Scientists monitoring ocean heat and circulation in the Gulf during Hurricanes Katrina and Rita used data gathered from satellites and buoys to learn how these tropical storms can suddenly intensify. A major contributor to the intensification of these hurricanes may have been the Gulf of Mexico's "Loop Current". The Loop Current is a clockwise flow that passes through the Yucatan Channel between the Yucatan Peninsula and Cuba. It follows a U-shaped path northward into the Gulf and then curves southeastward to join the Florida Current. It is likely that hurricanes intensify when passing over eddies of warm water that spins off the Loop Current. Learn how scientists study and predict climate and weather patterns when you interact with the data visualizers in the following investigation.

Image credit: http://earthobservatory.nasa.gov/Newsroom/BlueMarble/BlueMarble_2002.html

Engage: **Preconceptions Survey, "What do you know?"**

Students are asked to take an online Quiz consisting of ten questions. When they submit their responses online, a pop-up window appears that shows the correct response to each question and provides additional, clarifying information for all ten questions. The correct responses, and additional information are provided below. Engagement activities such as this one are typically *not graded*.

True or False	Statement
1 FALSE	**Heating an object always increases its temperature.** *False. Heat is a process of energy transfer that naturally occurs between objects with different temperatures. The heat flow transfers energy from the higher temperature object to the lower temperature object. Temperature is proportional to the average thermal kinetic energy of the molecules in a substance. Ice at zero degrees Celsius can absorb heat from warm surroundings and become water at zero degrees Celsius. Steam (water vapor) at 100 degrees Celsius can lose heat to cooler surroundings and become water at 100 degrees Celsius. In both these cases where there is a change of phase of a substance, energy absorbing or releasing processes occur that do not affect the molecular thermal motion. So the temperature of the ice/water/steam remains the same.*
2 FALSE	**A hot cup of coffee absorbs cold from the room.** *False. Cold (as well as heat) is not a substance that is transferred between objects. Heat is a process that occurs naturally. Energy is transferred from a higher temperature system to a lower temperature system. A warm object has more molecular thermal (random kinetic) energy than the same object is cold. Over time, the hot cup of coffee loses energy as it transfers some of its energy to the cooler surroundings. It will continue to transfer heat until it reaches equilibrium: the temperature of the coffee and room become the same.*
3 FALSE	**Ice made from fresh water always has a temperature of zero degrees Celsius.** *False. At standard atmospheric pressure, fresh water freezes at zero degrees Celsius. The temperature of the ice can drop below zero degrees Celsius if it is exposed to a surrounding environment where temperatures are below zero degrees Celsius.*
4 TRUE	**Melting snow cools the nearby air.** *True. To change from solid (ice) to liquid (water), the snow has to increase its thermal energy by absorbing heat from its surroundings including the air. The changes from solid to liquid, liquid to gas and solid to gas are phase changes that require added energy. The opposite processes (liquid to solid, gas to liquid, gas to solid) are phase changes that release energy. Water vapor (gas) condensing to water droplets (liquid) forms clouds and can release energy.*
5 FALSE	**Consider a sample of water at 20 degrees Celsius. If its temperature decreases by a few degrees, its volume will increase.** *False. Reducing the temperature of water will reduce the average thermal energy of its molecules. Slowing this random, jiggling motion will slightly reduce the volume of the water.*
6 TRUE	**Consider a sample of water at 20 degrees Celsius. If its temperature increases by a few degrees, its density will decrease.** *True. The density of a substance is the mass of the substance divided by its volume. Raising the temperature has no effect on mass. But the increased thermal energy will cause the sample to expand. The higher temperature is an indicator of increased, thermal molecular movement. If volume*

	increases and mass stays the same, the density of the substance will decrease.
7 FALSE	**Increasing temperature causes all substances to expand (increase volume).** *False. Many substances follow this rule but not all. Some substances do contract when their temperature increases within a range of temperatures. One of the most important (and common) example of this behavior happens when water is near its freezing temperature of zero degrees Celsius. As the temperature of heated water rises from zero to 4 degrees Celsius, it contracts. As water cools from 4 degrees Celsius to zero degrees Celsius and becomes ice, it expands. The ice is therefore less dense than water floats. This volume change explains why ice first forms on the surface and not the bottom of bodies of water.*
8 TRUE	**Sometimes when you step out of a shower or rub alcohol on your skin, your skin feels cool. This is mostly due to liquid evaporating from the skin.** *True. Evaporation is a process where molecules escape from the surface of a substance. Since the higher speed molecules are more likely to have enough energy to escape, evaporation reduces the average thermal energy of a substance and thus its temperature. Slow molecules are less able to escape because they lack the kinetic energy to overcome the effects of weak molecular attractive forces at the surface. The human body's mechanism for controlling its temperature is sweat. On a hot day, you sweat more and this helps to cool the body. This mechanism works best when the air is dry (low humidity). On a very humid day, the air is nearly saturated with water vapor and evaporation of liquid water from the skin is slowed.*
9 FALSE	**Life preservers help people to float because they make them weigh less.** *False. The lightweight material of the life preserver (perhaps foam, cork or air) has a low density - relatively small mass distributed over a relatively large volume. This large volume means that the density of the life preserver and person will be significantly less that the density of the person alone in the water. The increased volume (with little increase in mass) is capable of displacing more water and so the person plus life preserver can float on the surface. To float, the weight of water displaced by an object must equal the weight of the object. The life preserver increases the amount of water that the person can displace.*
10 TRUE	**Seawater is denser than fresh water. A boat sailing from fresh water to salt water will float higher in the water.** *True. The seawater is denser so the boat has to displace less seawater than fresh water in order to equal its weight. So the boat will float higher in seawater.*
100	**Overall Score (%)**

Explore: Scientific/Mathematical Models In Your Backyard

What, When and Why?

Models impact our lives everyday. They are developed to represent important features of a target system. Engineers might develop a model airplane to test a new wing or tail design they plan to use for a full size airplane. By studying, manipulating or practicing with a model, investigators can gain expertise and experience that they can apply to the target system. Practicing on models instead of with the target system can offer important practical advantages. It may save time, effort, money, and resources and reduce environmental impact. Investigators can test a wider range of possibilities than they can by using the target system. Since the models are not the real thing, investigators must make sure they understand and compensate for their models' limitations. A model provides an idea or vision that helps investigators simplify and study reality. The following bullets describe models we might use to help organize our lives.

• If you want to build a boat or building, you may begin by constructing a small-scale model, or drawing a virtual object on a computer.

• If you want to look stylish and follow trendsetters, you might look at pictures of fashion models and movie stars to learn how to update your wardrobe, lifestyle and appearance.

• If you earn money on your first job, you may make a budget (a mathematics model) to help you decide how you might spend your money.

• If you play a computer game, you are using a computer model to simulate worlds in which you can play unusual, important roles.

Using the research tools available to you, respond to the three questions below so that you may better understand the implication of using models to explain ocean heating and cooling.

1. What is a scientific model?

Models can be physical replicas of objects or systems. Representational systems, such as maps or diagrams, and mathematical algorithms or formula, are also types of models. Excerpted from "The Nature and Structure of Scientific Models" NCISLA/Wisconsin Center for Education Research. The PDF file of this document can be found at *http://www.wcer.wisc.edu/ncisla/publications/reports/Models.pdf*

A scientific model is simply an idea or working hypothesis that scientists use to create explanations of how a part of the world works.

2. When are models used in science?

Scientists use models whenever they are trying to explain or test the behavior of a system or object. All models are based on a set of assumptions, rules and/or laws. Therefore, a scientific model represents a simplification of reality. Some aspects of reality will be judged important and will be included in the model. Others will be judged unimportant and will be excluded.

3. What are some assumptions you might make when building a model airplane? What basic parts should it have?

The model airplane should have (1) wings that can provide lift (2) a means of propulsion like a propeller or a jet engine (3) a tail to stabilize the airplane and (4) landing gear to cushion and protect the plane when landing.

Explore: A Model In A Cup

A cup of hot water is a model that illustrates some facts about ocean water.

To understand the complexities of the ocean and how it heats, cools and interacts with the atmosphere, compare and contrast heat and energy transfer using a simple model—a cup of hot water. How is a cup of hot water similar to the ocean? How is it different?

For each of the following questions about a cup of water heated in a microwave oven, write a corresponding statement, in the box under "Ocean," that compares and contrasts this model to the ocean.

Question	Hot Water in a Cup	Ocean
How is the water heated?	Microwave radiation penetrates the water surface and heats the water on top and through all sides of the cup.	*The ocean is heated from above by visible and infrared radiation from the sun. The surface water becomes hottest.*
Does the water circulate?	The less dense hot water rises up to the top and the more dense colder water sinks to the bottom where it is heated. These rising and sinking flows set up a natural circulation of the water that will heat it throughout.	*As the surface seawater heats up, it becomes less dense and remains at the surface. The cold water stays below. It is a stable dynamic and there will be no vertical circulation*
What happens to the heat in the water?	If the surrounding environment (the room) is cooler than the water, heat will conduct through the sides and bottom of the cup and energy will radiate outwards. The hottest water (least dense) will remain at the top and the coldest (most dense) will stay at the bottom of the cup. At the top of the cup, evaporating steam rises, transferring heat to the air.	*If the air is cooler than the water, energy will be lost at the surface. Since the surrounding waters are at similar temperature, little heat is lost to surrounding seawater. The hottest water will remain on top (assuming uniform salinity, evaporation will make the surface saltier). Evaporation will transfer latent heat in the form of water vapor into the atmosphere.*
How does the temperature of the surroundings affect the rate of heat loss?	If we put the cup in the freezer, it will lose heat more rapidly.	*If the ocean is warm and the air is cold (warm current flows into higher latitudes), the rate of heat loss will be greater (i.e., more evaporation, more sentient heat loss).*
How does the water interact with the air?	If we blow air over the top of the cup, the moving air will drive away the energetic, evaporating water molecules and prevent them from remixing in the liquid. This speeds cooling. Blowing air over the top of the cup, or stirring the water in the cup, causes waves and turbulence that mixes the water and distributes heat more uniformly. This slows cooling.	*Winds do the same to the ocean. The higher energy water molecules evaporate from seawater and are carried away from the surface by the winds. This cools the surface and warm water rises from below to repeat this process. Winds also cause waves and currents, which tend to mix the water in the upper ocean layers. This will decrease surface temperatures and slow heat loss.*

Explore: Weather Models

Additional models to better understand weather elements

In this next activity, you will find five weather-related models that we'll call targets. These targets are matched with a concrete, everyday object. *Choose at least three targets* and describe how they are similar to, and different than, their corresponding concrete objects

Target	Concrete Object	Similar	Different
Wind	Breeze from an electric fan	*Similar to wind in that the fan causes air to be transported.*	*Airflow from a fan is steady powered by electricity; wind is variable driven by atmospheric pressure.*
Rain	Spray from a lawn sprinkler	*Similar to rain in that water sprayed upward falls back to Earth in small droplets.*	*Spray from the sprinkler is steadier than rain falling from the atmosphere.* *Water from a sprinkler carries chemicals (e.g., chlorine) introduced at a water processing plant; rain picks up chemicals (e.g., sulfur dioxide) suspended in the atmosphere.*
Ocean Current	Moving walkway or baggage conveyor belt	*A moving walkway is similar to an ocean current because it transports objects. An ocean current carries heat, organisms, and drifting material.*	*A moving walkway follows the same path and moves at a steady speed. Ocean currents, on the other hand change flow rate and direction and form turbulent, swirling patterns.*
Sunlight	A 120W light bulb	*The light bulb provides heat and light just like the sun.*	*The light bulb is less intense and steadier than sunlight. The light bulb does not produce the same spectrum of radiation as the sun.*
Clouds	White mist of water droplets produced by condensing steam from boiling water	*The mist and clouds are both formed from condensing water vapor. The vapor is produced from heated water.*	*Clouds, which are formed in a colder environment, are typically more dense and composed of droplets of water and ice crystals that vary in size.*

Note: The point of doing the last two exercises, using everyday items to better understand more complex concepts/processes, is to stimulate your thinking. In science, when you learn something new it is good to ask, "How is this similar to, or different from, something else I know"? Too often facts are learned in isolation and are not integrated with or connected to the real world.

Elaborate: # Advection In The Ocean

Looking for patterns in movement of ocean surface water

The cup of water that we used to model the ocean surface was static. One could make the model more interesting by using a bathtub and employing a fan to generate surface waves and currents. Increasing the size of the model 10-100 times still does not capture the complexity and dynamic of the ocean currents that act as efficient conveyors for our terrestrial solar-powered heat engine.

Advection

Earth's oceans contain currents that move water across the globe. *Advection is the transfer of mass, heat, or other properties by the movement of the ocean water.* The dominant movement of the ocean is horizontal. We refer to this lateral motion as currents. Vertical movement of water is typically much slower than the horizontal movement.

Click the picture of Dr. Kelly to play a movie in which she describes advection in the Gulf Stream.

Transcript – Text
QuickTime – High Resolution / Low Resolution
Windows Media – High Resolution / Low Resolution

To better understand the dynamic nature of advection in the ocean you will manipulate the online Ocean Surface Current Visualized, a computer model created from OSCAR data.

Click Ocean Surface Current Visualizer (OSCAR) to explore the computer model. See what it contains; take note of the calibrations; and determine how it can be manipulated. When you have a fair idea of how it works, go to the next step.

Set the following variables to the following parameters.

Year – **1992**
Month – **October**
Parameter – **Speed**
Tropical Pacific Region – **North West**

After the values are set, click on the **Pop-Up-Map** button and use it to answer the following questions.

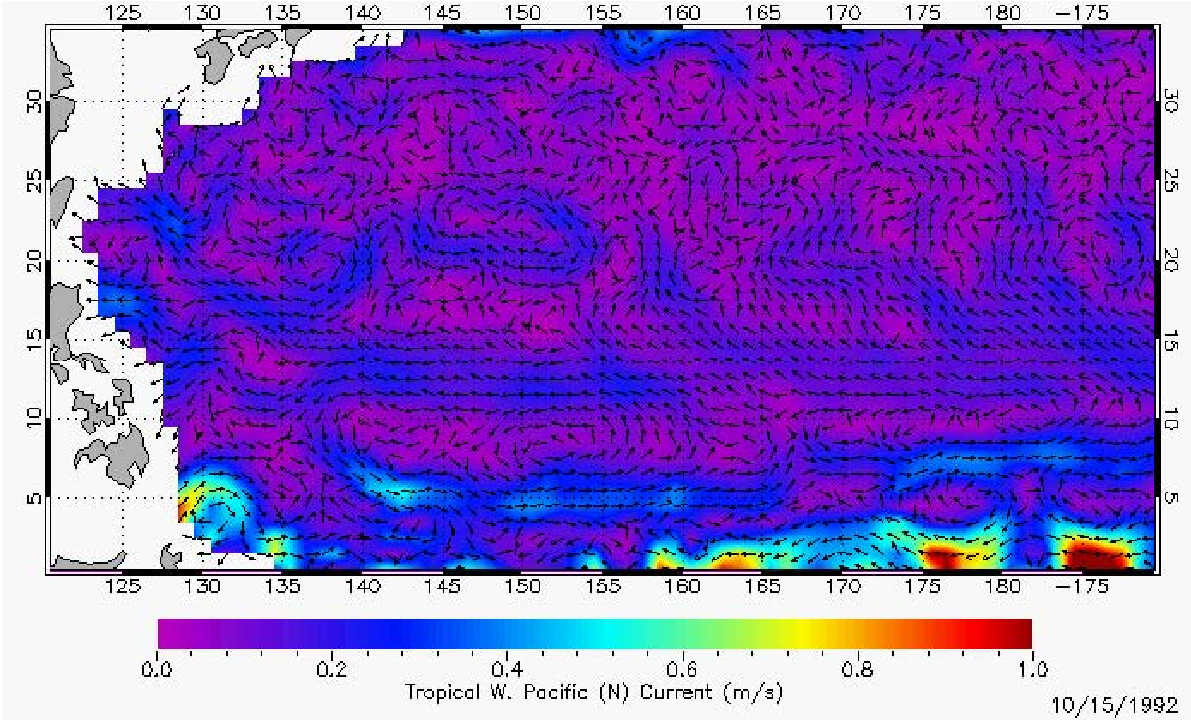
5. What latitude range does the map cover?
0^o to 35^o North

6. What longitude range does the map cover?
170^o East to 120^o West

7. What do the colors on the map represent?
Speed of the current on the ocean's surface

8. What do the arrows on the map represent?
Direction the ocean surface current is moving

9. How many degrees do the horizontal, dotted bands cover?
5^o latitude



Beginning at the Equator, observe each 5° latitude band across the entire map. (It may help to take two pieces of paper and section off each individual band as you examine it.) You will determine the variables: dominant speed and dominant current direction for each band.

- To determine the dominant speed, observe the entire band and decide what color makes up the majority of the band. Then, using the color key below the map, determine the speed of the current and record the speed in the table below. Repeat this step for each of the latitude bands. Note: If there are many colors in the band, it is acceptable to conclude that the dominant speed varies.

- To determine the dominant direction of the current, observe each band again and examine the direction of the arrows. What direction are most arrows pointing—east or west?

Record your results in the data table below. Note: If you are unable to find that a majority of arrows point one direction or another, it is acceptable to conclude that the dominant current direction varies.

Data Collected from the Tropical Surface Current Computer Model		
Latitude Bands	**Dominant Speed (meter/sec)**	**Dominant Current Direction**
0–5 N	*Varied*	*Varied*
5–10 N	*0.3*	*Eastward*
10–15 N	*0.3*	*Westward*
15–20 N	*Varied*	*Varied*
20–25 N	*Varied*	*Varied*
25–30 N	*0.0*	*Varied*
30–35 N	*0.0*	*Varied*

10. Most people walk at a speed of about 1 meter/sec. Using the data you just collected, would you describe the ocean surface currents as slower or faster than a person walking?
Slower

11. If you wanted to travel across the Pacific Ocean from Asia to the Americas using surface currents, at what latitude would you start to go eastward (assuming currents do not change with time)?
Eastward: 5^o -10^oN

At what latitude would you start to go westward?
Westward: 10^o – 15^oN

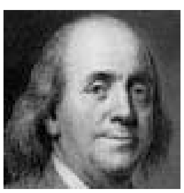
12. Estimate how many days it would take to cross the Pacific Ocean (about 13 million meters) floating along on the surface currents?
Time = Distance/Speed = 43 million seconds
*Days = 43 million/(3600 sec/hr * 24 hr) = 43000000/86400 = almost 500 days!*
Each day has 86400 seconds

The ocean surface shows large-scale patterns of surface flow. The speed and direction of the flow is of interest to scientists. Currents at the Equator in the tropical Pacific (as well as in the Atlantic and Indian Oceans) show patterns in current speed and direction.

The ocean surface is in motion and the simple water-in-a-cup model is too limited to include larger scale ocean features like advection.

Elaborate: Energy Flow and Sea Surface Temperatures

Temperature is a measure of the energy content of the water.



One of the measurements made by early sea travelers, including Benjamin Franklin, is the surface temperature of the ocean water. Significant changes in surface water temperature could indicate warm western boundary currents that could speed up a journey or cold, nutrient-rich waters upwelling from the depths that could support varieties of marine life. Today, patterns of sea surface temperatures help scientists identify ocean surface currents and track energy fluxes. These fluxes may relate to regional weather or short-term climate change.

The surface of the ocean is dynamic and continuously exchanges energy with the environment through the following processes:
• Absorption of Electromagnetic Radiation from the Sun: This energy varies with the season and depends on cloud cover and the albedo (reflectivity) of the ocean's surface. The ocean's albedo depends on various factors including wind speed and chlorophyll concentration of the seawater.

• Emission of Infrared Radiation: Water emits electromagnetic radiation that depends strongly on its Kelvin temperature. This is affected by the emissivity of seawater and by the cloud cover.

• Sensible Heat Transfer: This is the energy that air and the water exchange through their contact at the air-ocean boundary. This depends on wind speed as well as the air-sea temperature difference.

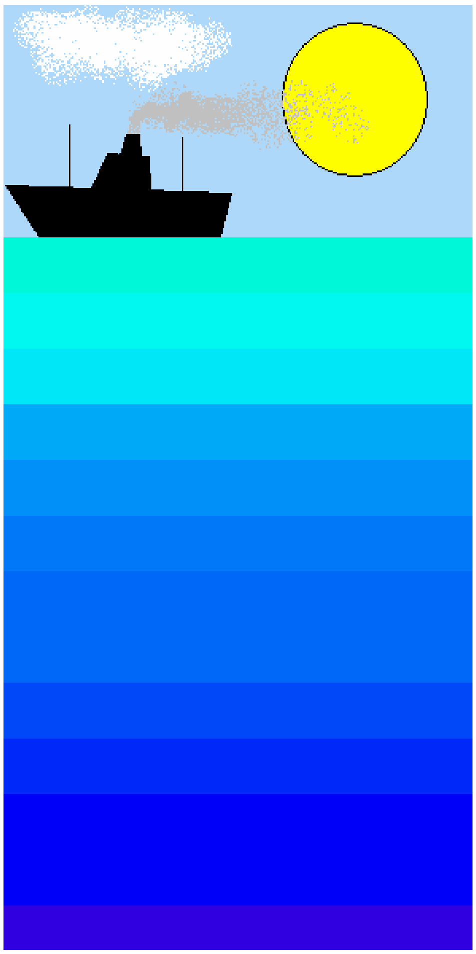
• Latent Heat Transfer: The ocean loses energy when some of its water evaporates and becomes water vapor in the atmosphere. The amount of energy lost depends on wind speed, and the humidity of the air.

Explore: The Energy Flow Model

How does the ocean store energy over time?

In this investigation, you will explore the energy flow at the ocean's surface using a simple computer model, Energy Flow Model , to track energy exchanges. Exploring this model will help you develop a better understanding of how the ocean's surface responds to solar heating and how the ocean stores energy over time.

You will need to know the following parameters to understand energy flow at the ocean's surface.



Parameter	Relevance
Solar Energy (SE)	Energy emitted from the Sun
Heat Transfer (HT)	Energy transfers happen between the sea and the air by evaporation, sensible heat and long-wave radiation. A cool atmosphere absorbs heat from a warm ocean and vice-versa. Heat transfer determines how fast the ocean surface loses or gains heat energy through the surface.
Water Transparency (WT)	Indicates the depth that sunlight energy penetrates below the surface of the water.
Wind Speed (WS)	Wind causes turbulence that mixes water in the surface layers.
Water Diffusion (WD)	Water undergoes diffusion (spread of water molecules) and conduction (energy transfer between water molecules) that tend to equalize temperatures in the layers.
Air Temperature (AT)	Air temperature above the ocean's surface determines the temperature threshold that affects whether heat transfers from ocean to atmosphere or vice-versa.

To explore the energy flow at the ocean's surface and track changes, you will complete four trials. In each trial, you will alter four parameters in the Energy Flow model and determine their impacts on temperatures and the isothermal layer (i.e., a vertical column of water that has a constant temperature with depth).

The **Energy Flow model** represents water at the surface of the ocean as columns of color-coded layers that are each 10 meters thick. The colors represent the water temperature (red = warm, blue = cold). The model assumes that the ocean water is chemically homogeneous (i.e., has the same salinity throughout). In this case, temperature will determine the ordering of layers–warm water (low density) at the top, cold (high density) at the bottom. You will use this to study the effect of solar energy (SE), heat transfer (HT), water transparency (WT), and seasons of the year on temperatures in the water column. As you manipulate the values of the four parameters, you will observe the surface temperature, the average water temperature and the depth of the constant temperature (isothermal or mixed) layer.

Note: The temperature values marked with an asterisk (*) are within 0.8^{o}C of the top layer temperature and are considered to be within the isothermal layer.

Before you begin Trials 1 - 4, make a prediction about how each parameter affects temperatures and the isothermal layer. Enter your predictions in the chart below then go to the exercise in which you will manipulate the parameters of the model. After you complete each trial, you will be prompted to return to this chart and determine if your predictions were correct.

Exploring Parameters That Affect Energy Flow At the Ocean Surface			
Trial	**Parameter**	**Prediction**	**Conclusion**
1	Solar Energy (SE)	*As the solar energy increases:* *• The top layer temperature and average temperature should increase.* *• Greater differences between the layer temperatures will occur so the isothermal layer depth will decrease. The warm water will move to the surface and will not mix with the water below.*	
2	Heat Transfer (HT)	*As the heat transfer increases:* *• The surface temperature and average temperature of the water should decrease. Heat energy and temperature are proportional.* *• The surface isothermal layer depth should increase because heat loss cools the surface and makes it more similar to the deeper layers.*	
3	Water Transparency (WT)	*As water transparency increases:* *• More solar energy will be absorbed deeper in the seawater* *• The surface layer temperature decreases since the total energy is shared with water at lower depths.* *• The average temperature should stay about the same because the solar energy is the same and the heat loss doesn't change.* *• More energy is shared with deeper water and the isothermal layer depth should increase.*	
4	Season of the Year (Cycle)	*• The average temperature will be highest in the summer and lowest in the winter.* *• The isothermal layer depth will be greatest in the winter and lowest in the summer.*	

Trial 1: Solar Energy (SE)

In the first trial, you will explore the impact of changes in ocean energy as the **Solar Energy** parameter is manipulated.

Step 1: Note the values for parameters other than solar energy listed below. You will manipulate the model to show the following settings. *Important: Once set, the values for these parameters will remain constant during trial 1.*

Trial 1 - Constant Settings					
HT	**WT**	**WN**	**ND**	**AT**	**IST**
MEDIUM	MEDIUM	OFF	OFF	OFF	14

Step 2: Connect to the Energy Flow model and set the variables as indicated above.

Step 3: Use the model to manipulate the **Solar Energy** parameter to **Low** then click the START button and read the *Top Layer Temperature* and the *Average Temperature*. Record these temperatures in the table below. Repeat this step two more times changing the SE value to **Medium** then, **High**.

Step 4: Click the "Run Model" button (This button runs the model for a fixed time interval.) until the Average Temperature does not change much. Note the values for *Top Layer Temperature, Average Temperature, and Isothermal Layer Depth* and record them below.

Trial 1 - Solar Energy (SE)					
	Initial (Start Button)		**Final (Step Button)**		
Solar Energy Values	Top Layer Temp	Average Temp	Top Layer Temp	Average Temp	Isothermal Layer Depth (m)
LOW	*14*	*7.92*	*3.34*	*3.16*	*130*
MEDIUM	*14*	*7.92*	*6.66*	*5.64*	*90*
HIGH	*14*	*7.92*	*9.95*	*7.27*	*60*

Step 5: Analyze the data you collected in Trial 1 and determine if your prediction for solar energy was accurate. Record your conclusion(s) in the **Exploring Parameters That Affect Energy Flow At the Ocean Surface** then, proceed to Trial 2.

Trial 2: Heat Transfer (HT)

In this trial, you will manipulate the **Heat Transfer** parameter.

Step 1: Note the values for parameters other than Heat Transfer listed below. You will manipulate the model to show the following settings. *Important: Once set, the values for these parameters will remain constant during Trial 2.*

Trial 2 - Constant Settings					
SE	**WT**	**WN**	**ND**	**AT**	**IST**
MEDIUM	MEDIUM	OFF	OFF	OFF	14

Step 2: Connect to the Energy Flow model and set the parameters as indicated above.

Step 3: Use the model to manipulate the **Heat Transfer** parameter to **Low**. Then click the Start button and read the *Top Layer Temperature and the Average Temperature*. Record these temperatures in the table below. Repeat the step two more times setting the HT to **Medium**, then **High**.

Step 4: Click the "Run Model" button (This button runs the model for a fixed time interval.) until the Average Temperature does not change much. Note the values for *Top Layer Temperature, Average Temperature, and Isothermal Layer Depth* and record them below.

Trial 2 - Heat Transfer (HT)					
	Initial (Start Button)		**Final (Step Button)**		
Heat Transfer Values	Top Layer Temp	Average Temp	Top Layer Temp	Average Temp	Isothermal Layer Depth (m)
LOW	*14*	*7.92*	*19.3*	*10.8*	*40*
MEDIUM	*14*	*7.92*	*6.66*	*5.64*	*90*
HIGH	*14*	*7.92*	*3.62*	*4.00*	*130*

Step 5: Analyze the data you collected in Trial 2 and determine if your prediction for Heat Transfer was accurate. Record your conclusion(s) in the **Exploring Parameters That Affect Energy Flow At the Ocean Surface** then, proceed to Trial 3.

Trial 3: Water Transparency (WT)

In this trial, you will manipulate the **Water Transparency** parameter.

Step 1: Note the values for parameters other than Water Transparency listed below. You will manipulate the model to show the following settings. *Important: Once set, the values for these parameters will remain constant during Trial 3.*

Trial 3 - Constant Settings					
SE	**HT**	**WN**	**ND**	**AT**	**IST**
MEDIUM	MEDIUM	OFF	OFF	OFF	14

Step 2: Connect to the Energy Flow model and set the parameters indicated above.

Step 3: Use the model to manipulate the **Water Transparency** parameter to **Low**. Then click the Start button and read the *Top Layer Temperature and the Average Temperature.* Record these temperatures in the table below. Repeat the step two more times to **Medium**, then **High**.

Step 4: Click the "Run Model" button (This button runs the model for a fixed time interval.) until the Average Temperature does not change much. Note the values for *Top Layer Temperature, Average Temperature, and Isothermal Layer Depth* and record them below.

Trial 3 - Water Transparency (WT)					
	Initial (Start Button)		**Final (Step Button)**		
Water Transparency Values	**Top Layer Temp**	**Average Temp**	**Top Layer Temp**	**Average Temp**	**Isothermal Layer Depth (m)**
LOW	*14*	*7.92*	*6.67*	*5.72*	*80*
MEDIUM	*14*	*7.92*	*6.69*	*5.65*	*90*
HIGH	*14*	*7.92*	*6.64*	*5.71*	*100*

Step 5: Analyze the data you collected in Trial 3 and determine if your prediction for Water Transparency was accurate. Record your conclusion(s) in **Exploring Parameters That Affect Energy Flow At the Ocean Surface** then, proceed to Trial 4.

Trial 4: Season Of The Year (Cycle)

In this trial, you will manipulate the **Season of the Year** parameter.

Step 1: Note the values for parameters other than **Season of the Year** listed below. You will manipulate the model to show the following settings.

Trial 4 - Constant Settings					
HT	**WT**	**WN**	**ND**	**AT**	**IST**
MEDIUM	MEDIUM	OFF	OFF	OFF	14

Step 2: Next, connect to the Energy Flow model and set the parameters as indicated above.

Step 3: Next, click the **Cycle** button then observe the data printed out in the Data Logger box under the model. Record the data in the table below.

Trial 4 - Season of the Year (Cycle)				
Season of the Year	**Average Temperature in Data Logger**		**Isothermal Layer Depth in Data Logger**	
	Minimum Average Temperature	Maximum Average Temperature	Minimum Isothermal Layer Depth	Maximum Isothermal Layer Depth
Winter	*6.33*	*8.01*	*20*	*80*
Spring	*6.90*	*7.96*	*10*	*30*
Summer	*8.76*	*10.2*	*10*	*30*
Fall	*8.89*	*9.59*	*20*	*40*

Step 5: Analyze the data you collected in Trial 4 and determine if your prediction for Season of the Year was accurate. Record your conclusion(s) in the Exploring Parameters That Affect Energy Flow At the Ocean Surface.

Elaborate: Energy Exchange

The pattern of temperatures near the ocean surface determines the energy that the ocean has available to exchange with the atmosphere. You have used a computer model to test your hypotheses about how some simple processes can affect surface layer water temperatures.

Explore: Additional Trials for Further Investigation

Create additional trials by manipulating the three parameters in the model not used in the four trials above, including:

- Wind Speed (WS),
- Water Diffusion (WD), and
- Air Temperature (AT).

Follow the same steps described in each trial of this lesson.

Evaluation: Matrix for Grading Lesson 4

Performance List	**Points**	**Student Evaluation**	**Teacher Evaluation**
Shows evidence of understanding models and their uses to explain scientific concepts and processes.			
Proficiently manipulates a computer model to explore near real-time data collected from satellites.			
Form predictions and follows through to determine accuracy of prediction.			
Collects data from computer models accurately.			
Analyses of data are accurate.			
Total Points			