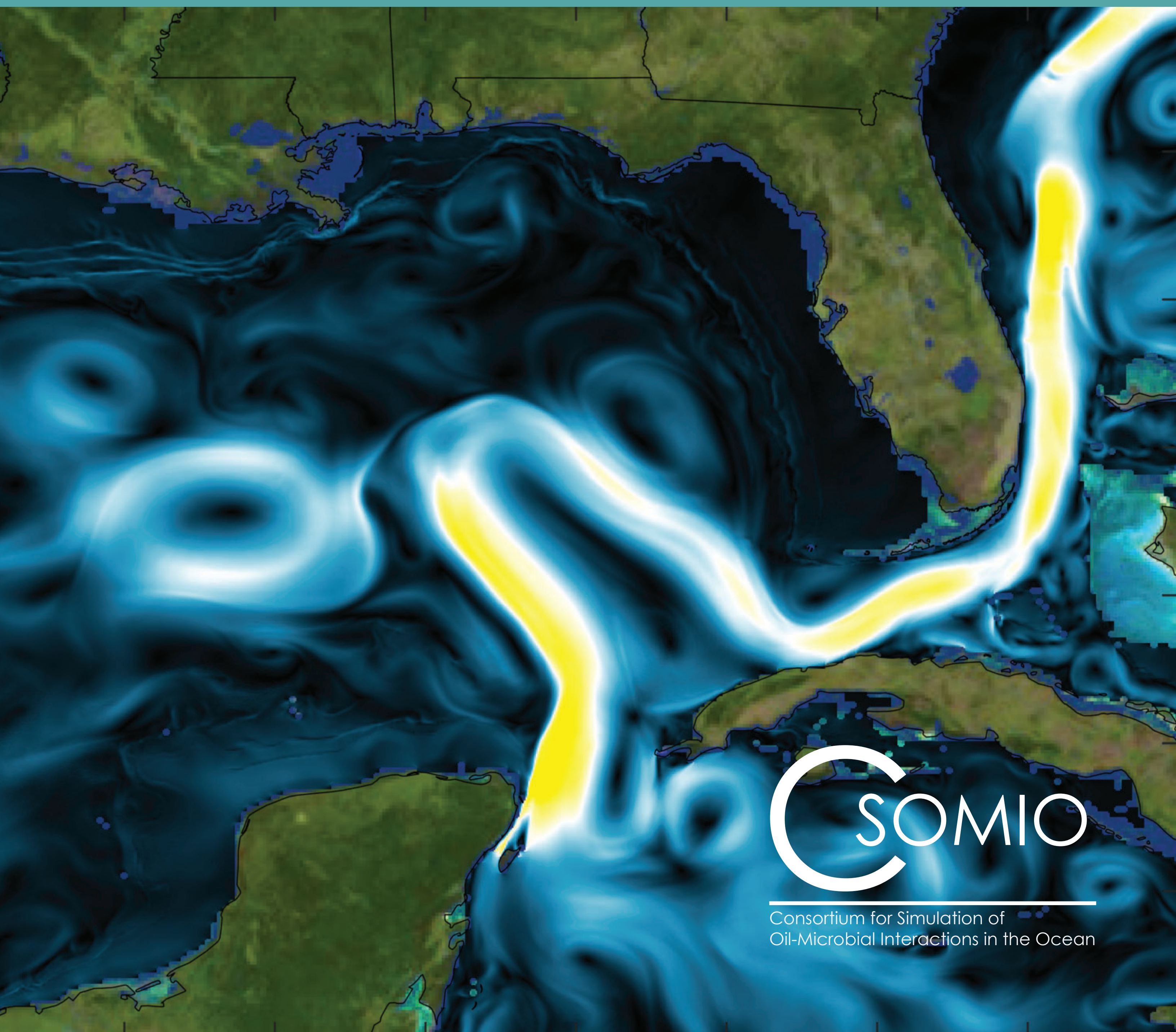
Modeling the Gulf of Mexico

Using scientific research to help students make connections between the theoretical nature of science and real-world applications

A Middle School Science Curriculum

produced by the
Consortium for Simulation of Oil-Microbial Interactions in the Ocean (CSOMIO)



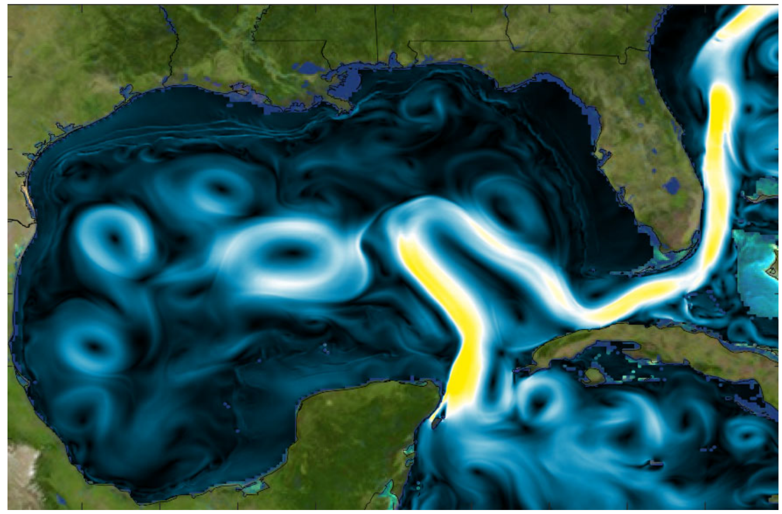
Special thanks and appreciation to our educators for bringing their expertise and passion for science to this project: Karen Metcalf, whose desire to bring a level of critical thinking, inquiry, and practical application of science to classrooms established the curriculum's framework including the development of lessons tailored to the Consortium's research areas; and to Karolyn Burns, whose energy and expertise brought the project to fruition, by writing grade-level texts to accompany lessons, soliciting feedback from teachers and students, developing scaffolds and accommodations for diverse learners, and aligning lessons with the Florida science standards – ensuring the curriculum is a comprehensive educational tool for educators and students.

Eric P. Chassignet, CSOMIO Principal Investigator
Tracy A. Ippolito, Project and Outreach Coordinator

Acknowledgments

Contributing experts are listed throughout curriculum. Many thanks to these researchers and educators who edited, authored content, or assisted with development of the lesson plans. Special thanks the Ocean Conservancy for use of content and maps from *The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas*

About this Curriculum



The “Modeling the Gulf” middle school science curriculum was compiled and developed to align with research being conducted by the Consortium for Ocean-Microbial Interactions in the Ocean (CSOMIO). The CSOMIO project is working to fill critical gaps in our ability to numerically model the transport and fate of oil in coastal waters. CSOMIO is funded by the Gulf of Mexico Research Initiative (GoMRI), a research institute established in 2010 with the stated goal to improve society’s ability to understand, respond to, and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems.

This middle school science curriculum contains five lesson plans related to ocean modeling, including the fields of biogeochemistry, fluid dynamics, and microbiology. This curriculum will be developed using the “5-E” instructional framework. Each of the 5 “E”s describes a phase of learning: **E**ngage, **E**xplore, **E**xplain, **E**laborate, and **E**valuate (see page 3 for more information). The 5E instructional framework allows students and teachers to experience common activities, to use and build on prior knowledge and experience, to construct meaning, and to continually assess their understanding of a concept.

Each of the curriculum activities are aligned with Florida science standards in order to provide the most value to teachers and each focuses on the Gulf of Mexico and Florida’s water system. As this is highly tailored to a particular geographic area so students residing in Florida as well as other Gulf states will find relevance in science and have a better understanding of how these sometimes esoteric and technical fields directly impact their own lived experiences, which can shift their perception of what science is used for, and how they can participate and understand these topics in a meaningful way.

In addition to teacher guides that provide material lists and lesson plans, this curriculum includes student worksheets, maps, articles, and answer keys with rubrics. The answer keys offer possible answers to the questions but are meant for use at the teacher’s discretion. There are accommodations and additional resources in the appendices. The contents of this curriculum may be copied and shared for educational purposes with credit.

This curriculum is available online at
https://csomio.org/education-and-outreach/modeling-the-gulf-middle-school-curriculum

Table of Contents

Using the 5E Instructional Framework

This set of lessons will provide an entry into the world of computer-based scientific modeling. Using an online application that employs block based programming, students will develop these models by engaging with the science behind water movement and the dynamics of oil in the marine environment. The lessons use a 5E learning cycle progression first developed in 1987. The theory underlying the framework views learning as dynamic and interactive. Individuals redefine, reorganize, elaborate, and change their initial concepts through interaction with their environment, other individuals, or both. The learner “interprets” objects and phenomena and internalizes the interpretation in terms of the current experience encountered (Bybee, 2015). Using the 5E Learning Cycle, the order of the activities engages students, gives them a reason to want to learn and explain the concepts, and allows them to apply what they learn prior to the evaluation.

Engage. This phase sparks students' interest and gets them thinking about the desired concept or skill. Engagements can elicit students’ prior knowledge about the subject and collect information on what students know, which can be used to guide instruction. In Lesson 1, students examine the fate of bathtub toys that fell off a cargo ship and examine about a very simple computer model.

Explore. During this phase, students grapple with a problem, task, or situation in an attempt to understand the material on their own or in groups. Students can identify what they are confused about, where their ideas conflict, and what unanswered questions they may have. This phase can generate students' “need to know,” and thus motivate them to find information on their own or listen more attentively and ask more targeted questions during a short lecture. In Lesson 2, students explore the properties of oil and how oil spills can be modeled. In Lesson 3, students explore the causes of ocean currents.

Explain. During this phase, students become more familiar with new ideas, terms, or ways of thinking. This can involve a short lecture, reading, or peer instruction. The aim is not just for instructors to explain, but for students to explain their understanding of a concept. In Lesson 4, students examine the features of organisms within the Gulf of Mexico ecosystem. They think about systems and how models can help us solve problems.

Elaborate. This phase requires students to apply what they have learned to novel problems or contexts. This follows the Explain phase because students' confusions and questions should have been addressed, and students need to try out their new knowledge. In Lesson 5 students work to edit a computer-based model, taking into account the new knowledge gained in lessons 2-4.

Evaluate. During this phase, students reflect on and demonstrate their understanding or mastery of concepts and skills, and instructors have opportunities to evaluate student progress toward achieving learning objectives. In Lesson 5 students collaborate to develop a computer-based scientific model that incorporates new parameters.

Bybee, R. W. (2015). *The BSCS 5E instructional model: Creating teachable moments*. NSTA Press, National Science Teachers Association.

Addressing Florida’s Science Standards

The activities contained in these lessons are aligned with Florida science standards.

6th Grade Standards

SC.6.E.7.1: Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through Earth's system.
The thermohaline circulation in the ocean is driven by differences in density, which are caused by gradients of temperature and salinity. This is the global conveyor belt, moving heat from the equator to the poles, and as warm water rises and cold water sinks, this is a large-scale example of convection.

SC.6.E.7.3: Describe how global patterns such as the jet stream and ocean currents influence local weather in measurable terms such as temperature, air pressure, wind direction and speed, and humidity and precipitation.
Ocean currents being modeled in these lessons are warm-water currents coming from the Gulf of Mexico and are carrying not only warm water, but also warm, moist air.

SC.6.E.7.4: Differentiate and show interactions among the geosphere, hydrosphere, cryosphere, atmosphere, and biosphere.
The oil spill is a result of extraction of fossil fuels from underground, which is part of the geosphere (and was once part of the biosphere, as it is composed of carbon stored by ancient plants). The interactions with plankton link it to the biosphere, and the exposure of oil to sun, wind, and rain, which both break it down and disperse it, are coming from interactions in the atmosphere.

SC.6.E.7.5: Explain how energy provided by the sun influences global patterns of atmospheric movement and the temperature differences between air, water, and land.
Surface currents in the ocean are driven by wind, which is moving between areas of high and low pressure, generated by differential heating of the earth’s surface. Deep-water currents are driven by thermohaline circulation, and the warmth of equatorial water comes from absorption of solar radiation.

SC.6.N.1.1: Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
All of the activities in these lessons center on modeling, or creating a simplified version of a complex system to help understand it. In order to build models, students will need to identify the issues facing the Gulf of Mexico and Florida’s natural environment, do their own research, and use data to help create a representation of the system.

SC.6.N.1.3: Explain the difference between an experiment and other types of scientific investigation, and explain the relative benefits and limitations of each.
SC.6.N.3.4: Identify the role of models in the context of the sixth grade science benchmarks.
Students will need to understand why we use models, and how they are different from experiments. A controlled experiment cannot be done in a large and complex system, such as ocean circulation, so scientists collect data and create models to understand the underlying principles that govern the natural world. In this area, models are advantageous because an experiment is not feasible, but as they are always simplistic when compared to the entirety of the process, they are always limited in their ability to make predictions.

SC.6.N.1.4: Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.
When students are placed into groups to construct models based on data, they will inevitably have some differences in methods and results. They should be able to justify why they chose a particular approach and explain why and how it affected their conclusions.

7th Grade Standards

SC.7.N.1.1: Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
All of the activities in these lessons center on modeling, or creating a simplified version of a complex system to help understand it. In order to build models, students will need to identify the issues facing the Gulf of Mexico and Florida’s natural environment, do their own research, and use data to help create a representation of the system.

SC.7.N.1.3: Distinguish between an experiment (which must involve the identification and control of variables) and other forms of scientific investigation and explain that not all scientific knowledge is derived from experimentation.
SC.7.N.3.2: Identify the benefits and limitations of the use of scientific models.
Students will need to understand why we use models, and how they are different from experiments. A controlled experiment cannot be done in a large and complex system, such as ocean circulation, so scientists collect data and create models to understand the underlying principles that govern the natural world. In this area, models are advantageous because an experiment is not feasible, but as they are always simplistic when compared to the entirety of the process, they are always limited in their ability to make predictions.

SC.7.N.1.5: Describe the methods used in the pursuit of a scientific explanation as seen in different fields of science such as biology, geology, and physics.
Oceanography is unique in that observational methods are often remote sensing. While a student can visually observe or measure laboratory experiments, collecting data from offshore requires satellites, drifters, SONAR, and many more examples of technology which extend our ability to sense phenomena that are hidden or inaccessible.

SC.7.L.17.3: Describe and investigate various limiting factors in the local ecosystem and their impact on native populations, including food, shelter, water, space, disease, parasitism, predation, and nesting sites.
The interactions of plankton with the marine environment fluctuate with access to sunlight, dissolved nutrients, and dissolved organic carbon. The limiting factors for phytoplankton in the ocean include limited penetration of sunlight for photosynthesis, lack of iron for chlorophyll, predation by zooplankton and forage fish, and pollution.

SC.7.P.11.4: Observe and describe that heat flows in predictable ways, moving from warmer objects to cooler ones until they reach the same temperature.
The thermohaline circulation in the ocean is driven by differences in density, which are caused by gradients of temperature and salinity. Warm water flows to cooler areas, but the ocean does not reach temperature equilibrium due to unequal heating of the earth’s surface by the sun. However, the constant movement toward equilibrium drives both wind and water on a global scale.

8th Grade Standards

SC.8.N.1.5: Analyze the methods used to develop a scientific explanation as seen in different fields of science.
SC.8.N.1.6: Understand that scientific investigations involve the collection of relevant empirical evidence, the use of logical reasoning, and the application of imagination in devising hypotheses, predictions, explanations and models to make sense of the collected evidence.
SC.8.N.3.1: Select models useful in relating the results of their own investigations.
In the field of oceanography, modeling is often used to develop a scientific explanation due to the difficulties of running controlled experiments on a large and complex system. In order to create a model, empirical evidence in the form of observations and measurements must be collected and organized in such a way that it has descriptive and predictive abilities.

SC.8.E.5.10: Assess how technology is essential to science for such purposes as access to outer space and other remote locations, sample collection, measurement, data collection and storage, computation, and communication of information.
Oceanography is unique in that observational methods are often remote sensing. While a student can visually observe or measure laboratory experiments, collecting data from offshore requires satellites, drifters, SONAR, and many more examples of technology which extend our ability to sense phenomena that are hidden or inaccessible. Students have access to real-world datasets through CSOMIO and this will include information on how that data was collected and how it was stored and processed.

SC.8.L.18.1: Describe and investigate the process of photosynthesis, such as the roles of light, carbon dioxide, water and chlorophyll; production of food; release of oxygen.
As students model the behavior of phytoplankton in the ocean and while interacting with the oil spill, they will need to incorporate light levels, carbon dioxide/dissolved organic carbon, and the rate of photosynthesis. The biological processes of plankton both affect, and are affected by, the introduction of petrochemicals into the Gulf of Mexico.

SC.8.L.18.3: Construct a scientific model of the carbon cycle to show how matter and energy are continuously transferred within and between organisms and their physical environment.
The natural carbon cycle is out of equilibrium due to the use of fossil fuels. In order to understand the current state of carbon transfer, students must first model and observe the process as it occurs without human interference. The introduction of additional carbon through the oil spill further complicates the carbon cycle and plankton are key to our comprehension of how it enters the food chain and moves within and between marine organisms.

Middle School Computer Science Standards

SC.68.CS-PC.2.8: Identify interdisciplinary careers that are enhanced by computer science.
Oceanography research is greatly enhanced by an understanding of computer modeling, which relies on computations and physics to create a simplistic representation of a large-scale natural system.

SC.68.CS-PC.3.1: Answer research questions using digital information resources
SC.68.CS-PC.3.5: Identify resources such as city, state, and federal government websites and explain that these resources can be used for communication between citizens and government.
Students will need to conduct online research to gather background information and context about the problems in the Gulf of Mexico, as well as use resources such as simulations and data sets from online sources. Many of these sources will be state and federal government websites which share the work of publicly funded researchers with the citizens.

SC.68.CS-CS.1.2: Create or modify and use a simulation to analyze and illustrate a concept in depth (i.e., use a simulation to illustrate a genetic variation), individually and collaboratively.
SC.68.CS-CS.1.4: Interact with content-specific models and simulations to support learning, research and problem solving (e.g., immigration, international trade, invasive species).
SC.68.CS-CS.2.2: Solve real-life issues in science and engineering (i.e., generalize a solution to open-ended problems) using computational thinking skills.
Students will create a simple computer simulation of currents in the Gulf of Mexico, with both individual components and a collaborative finished product. They will first use a simulation that has already been created in order to learn how they work in the context of oceanography. The problem of how best to address oil spills is best solved when there is an understanding of current movement, wind forcing, and biological factors which can be put into a computational model.

SC.68.CS-CS.1.3: Evaluate what kinds of real-world problems can be solved using modeling and simulation.
SC.68.CS-CP.3.1: Select appropriate tools and technology resources to accomplish a variety of tasks and solve problems.
Any process that takes place on a scale that is too large or small for humans to easily manipulate is best understood via modeling and simulation. Additionally, physics-based problems, such as fluid dynamics, rely heavily on computations and are best handled by computer modeling, as humans are far slower and more error-prone.

SC.68.CS-CS.2.4: Organize and display information in a variety of ways such as number formats (e.g., scientific notation, percentages, and exponents), charts, tables and graphs.
As students are introduced to accessing and using real-world data sets from NOAA and CSOMIO, they will be asked to display it in a visual format that best conveys their results. This can include tables, graphs, charts, and maps.

SC.68.CS-CS.2.11: Predict outputs while showing an understanding of inputs.
As students test their models, they will need to predict the output based on the data that they input.

SC.68.CS-CS.6.3: Identify novel ways humans interact with computers, including software, probes, sensors, and handheld devices.
Oceanography is unique in that observational methods are often remote sensing. While a student can visually observe or measure laboratory experiments, collecting data from offshore requires satellites, drifters, SONAR, probes, and many more examples of technology which extend our ability to sense phenomena that are hidden or inaccessible.

The Lesson Plans

Lesson 1: Go With the Flow

Students will be introduced to the concept of models, including physical, mathematical, and computer-based. After watching an example of a real-life scenario that created a physical model (rubber duck spill), They will learn the basics of a coding application then see how it can be used to approximate that process.

Lesson 2: Oil Remediation

In this lesson, students explore the fate of oil released into a body of water using an online simulation. This discussion and reading is designed to help students think through the fate of oil in the environment. They will learn about the properties of oil and natural weathering processes. This is followed by a reading about oil spill remediation.

Lesson 3: Visualizing Ocean Currents

In this lesson, students will use a rheoscopic fluid to simulate ocean currents. They will observe convection, density-driven flow, wind-driven flow, and model an ocean basin system. In observing the fluid, students will see turbulence and eddies.

Lesson 4: The Gulf of Mexico Ecosystem

In this lesson, students will learn about the physical features, species distribution, and human impacts on the Gulf of Mexico system. In reviewing maps and plotting positions, students will predict the potential impacts of oil spills or other events on the members of this system and create an argument to support their claim using the claim-evidence-reasoning (CER) framework.

Lesson 5: Refining an Ocean Model

Students will work in pairs to apply their knowledge of the Gulf of Mexico system to the model seen in Lessons 1 and 2. They will incorporate new parameters to demonstrate the effects of wind, evaporation, degradation, microbial interactions, and sinking. Note: This lesson has a higher level of difficulty than the previous four and may be more appropriate as enrichment or an additional challenge for advanced students.

LESSON 1: Go With The Flow!

Teacher's Guide

Objective: In this lesson, students will be introduced to a case study that helped scientists understand ocean currents, as well as how these can be modeled. After a discussion on what models are, students will see how computational models work using a basic programming language.

Materials:
- Interactive whiteboard or projector with internet access and a StarLogo Nova account
- Individual copies of the Student Guide (on page 9 of this curriculum)

Inquiry Question: How do computers let us predict changes in systems?

Time Required: One class period. Extra time may be required for students to become acquainted with the StarLogo Nova program.

Science Standards Addressed:

6th Grade: SC.6.E.7.5, SC.6.N.1.3, SC.6.N.3.4
7th Grade: SC.7.N.1.3, SC.7.N.3.2, SC.7.N.1.5
8th Grade: SC.8.N.1.5, SC.8.N.1.6, SC.8.N.3.1, SC.8.E.5.10
Middle School Computer Science: SC.68.CS-PC.2.8, SC.68.CS-CS.1.2, SC.68.CS-CS.1.4, SC.68.CS-CS.1.3, SC.68.CS-CS.2.11

PROCEDURES

Step 1

Duck Drifters

To spark interest in this series of lessons, begin with a viewing of this video about a container of bathtub toys lost at sea that inadvertently became ocean current tracking devices. Students can also read the article about the bathtub toys on page 11.

Discuss answers to questions 1-6 in the student guide before moving on to Step 2.

YouTube video on bathtub ducks lost at sea
https://www.youtube.com/watch?v=eLMSMs6AYYc
(Note: this is a 6:25 video, but you can stop at 2:17)

Step 2

Computer-based mathematical models

Begin by asking students what a model is and how they are used in science. A concept map or word association activity may be useful to gauge levels of prior knowledge. When generating examples, encourage students branch out from the current subject to examples from their own experience or previous coursework.

Examples of physical models include many science demonstrations (cloud in a bottle, water tables, scale models and dioramas). Conceptual models could be many illustrations in a textbook, ball-and-stick models of molecules, or food chain/food web. Mathematical models include many scientific laws/equations, such as Newton's Laws and growth equations for bacteria populations. As mathematical models become more complex, such as ones that describe a large system with many parts, it becomes more practical to have a computer run the equations, which is where computer models come in.

Making observations with the StarLogo Nova application

This part of the lesson requires a free account with StarLogo Nova, which you can sign up for at http://www.slnova.org.

1. Load the sample model and show the class how it runs. Students will have a chance to edit models in a later lesson.
2. On a digital whiteboard, view a simple model by opening the ***Model Floating Ducks Ver1*** after logging into StarLogo Nova. This model includes 300 randomly moving ducks and no other variables. The model is two-dimensional, representing only surface waters. When setup is clicked, 300 ducks are dropped in the center. When run model is clicked, the ducks wiggle randomly. The result is an ever widening cluster of ducks. The graph shown as the code runs indicates the density of ducks (by showing the number of ducks with nearby neighbors).
3. Show students the code behind the model by scrolling down below the model workspace. They will see that there are "ducks" generated when setup is clicked and run program causes the ducks to move randomly.
4. After students have answered questions 10-13, use the ***think-pair-share*** approach to discuss answers with a partner and as a class.
5. Next, students will fill in the two-column chart in the student guide showing members of the ocean system such as plankton, fish, and sediment in the left-hand column. They should think about the variables (environmental conditions) that influence of the ocean system, such as water temperature, wind speed, salinity, etc.). Save a class list of student ideas about the members of the system and the variables on chart paper or a digital whiteboard to refer back to during these lessons. Students will notice that this simple model does not represent the flow of ocean currents.
6. Finally, open the ***Model Floating Ducks Flow Ver1*** (on a digital whiteboard for the class to see). This model has "widgets" that can be used to represent current speed and direction. Ask students to tell you which way the current moves where the bathtub toys were dropped. Change the setting in the model and test. If time permits, students can go to workstations and view the model and experiment with altering the code to represent the system.

Step 3

Introducing Students to StarLogo Nova

While many students will have been exposed to basic programming/coding, not all will be familiar with the concept. Coding is a way to give a computer commands, so that it "knows" what to do in a given program. Programming languages are used to "translate" commands humans can understand to ones that make sense for computers. Traditional coding involves lines of text that are typed by the programmer, and can be difficult to learn, especially for those without a computer science background.

Block-based coding, sometimes known as block based-programming, is coding within a programming language where instructions are mainly represented as blocks. Students put the blocks in a certain order, and, while this approach is more limited in its applications, it presents a lower barrier to entry and is commonly used to teach the basics of code at the K-12 level.

You may want to go through the **Student Guide to StarLogo Nova** first (which can be found in the Appendices), or between Lessons 1 and 2. Students should be given time to explore the program and try some of the functions before moving on to the next stage of the unit.

Name ______________________________ Class ______________________ Period ____________

QUESTION: How do computers help us predict changes in systems?

ACTIVITY 1

Duck Drifters

Watch the video and answer these questions.

YouTube video on bathtub ducks lost at sea

1. How many ducks were in the container lost at sea?
2. What made the ducks move?
3. Where would you go today if you wanted to find one of the ducks?
4. What factors are important in determining where a duck will wash ashore?
5. What is the value of collecting data about the ducks' locations?
6. Show what the ducks revealed about ocean currents by adding arrows to this map:

Source: *https://commons.wikimedia.org/wiki/File:ColoredBlankMap-World-162E.svg*

ACTIVITY 2

Computer-based mathematical models

Scientific models are representations of the natural world. Models can be ***physical*** (a larger or smaller copy of an object). Models can be **conceptual** (representing a phenomenon with an illustration or system of organization). Models can also be ***mathematical*** (applying mathematical formulas and data to show events and make predictions about outcomes). These mathematical models often employ computers to make calculations and show results.

1. Give an example of a physical model ________________________________
2. Give an example of a conceptual model ______________________________
3. Give an example of a mathematical model ____________________________

In order to represent what happens to rubber ducks, or other materials in the ocean, we will use a computer-based mathematical model. Start by running a model of rubber ducks dropped in the ocean.

StarLogo Nova

Run the Model Floating Ducks Ver1 on StarLogo Nova (www.SLNova.org).

1. What things are shown in this model?
2. How does this model show a system (a group of related parts that make up a whole)?
3. Does this model show what really happens in the ocean system? Tell your evidence.
4. What other things could you add to make a better model to show the fate of ducks dropped into the ocean?

Members of the ocean system: the actual things in the ocean system (living and non-living)	**Variables**: environmental conditions that can vary and influence the system (such as currents and water temperature)

One way to refine this model would be to add code that takes into account wind direction and speed.

- Test out ***Model Floating Ducks Flow Ver1***. Does this do a better job of modeling the ducks?
- Examine the code. What is different about how this is programmed?

Reading: The Rubber Duckie Map – How Children's Toys Help Chart the Ocean

Reprinted with permission from Luke Hollomon, M.S.

The power of the storm was inescapable. The noise, unimaginable. Waves smashed into the sides of the 1,000-foot long ship, splashing freezing water over the deck and slamming into many of the 3,000 containers the ship carries on board. Most containers are held down by their own mass. Millions of car parts, floor tiles, and processed metals weather the storm in silent comfort. Waves like this are rare in the North Pacific, but not unheard of. Containers and the ships that carry them regularly endure conditions like this. Today though, there are an unlucky few containers stacked near the top of the 50ft. tall piles of metal. They became unbalanced and toppled into the ocean. As the containers plummeted into the deep, they struck each other and the ship, bursting open and spilling almost 29,000 rubber duckies and frogs into the ocean.

These *Friendly Floatees* brand toys were on their way from Hong Kong to Tacoma, Washington, but barely made it halfway. 12 containers were washed off the ship, spilling into the ocean and breaking open in the sea. After the waves died down and the huge metal containers slipped to the bottom of the sea, 29,000 rubber toys were left behind, silently bobbing up and down in the middle of the Pacific.

In the harsh environment of the North Pacific, the cardboard rapidly broke down and was either eaten by fish or thrashed apart by the waves. This released the rubber cargo into the wilds of the ocean and to the mercy of its currents. It also piqued the interest of a couple of oceanographers from Seattle.

Ocean currents are incredibly difficult to map. They don't appear on normal satellite images, they cover thousands of miles, and they're driven by invisible forces: wind, water density, and tides. Through the years, oceanographers have developed a toolkit that lets them map these invisible forces. Today, that toolkit includes advanced satellite imagery, mathematical models, and machine learning. In the past, this type of oceanographic work required a different type of tool. The drift bottle.

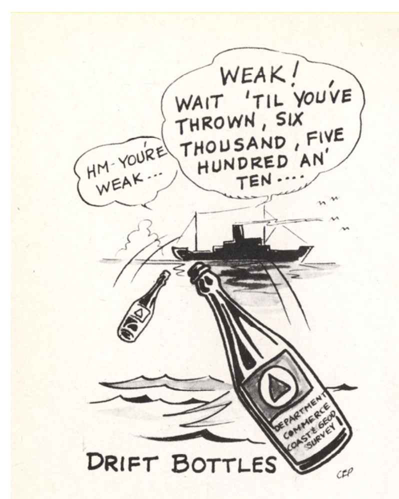
A 20th-century drift bottle found in Martha's Vineyard in 2013. From NOAA http://oceanservice.noaa.gov/news/apr14/message-in-bottle.html

The idea of a drift bottle is the same that's behind messages in bottles that have been dropped in oceans for thousands of years. Seal a message into a glass bottle, cap it tightly, drop it into the ocean, and hope.

Eventually, if you're lucky, someone will find the bottle washed up on a coastline, pop it open, and follow the instructions inside. Bottles beseech their finders to contact the researchers and send both the location and date where the bottle was found. With this information and the location of the original drop site, oceanographers can develop ideas about the direction and speed of ocean currents in the area.

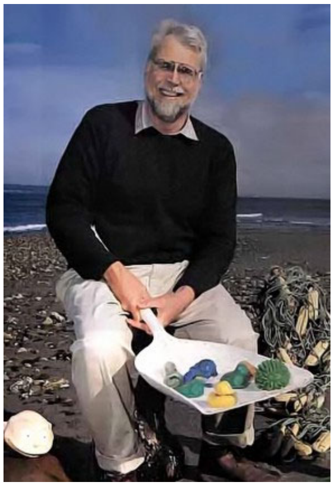
The earliest known usage of this technique occurred in 310 BCE when Theophrastus, an ancient Greek philosopher, dropped his bottles into the Atlantic in order to prove that the Mediterranean is filled by oceanic inflow. Unfortunately, no records indicate if he received a response to his messages. We'll never know if Theophrastus was able to prove his hypothesis. He likely wasn't the first to use this technique, and certainly wasn't the last. Scientific messages in bottles have been used in this way ever since. The oldest message in a bottle ever discovered was scooped up in 2012, 98 years after a Scottish researcher dropped 1,900 into the North Sea.

This old-fashioned method is even occasionally used today. Though inefficient due to bottle loss, breakage, and sinking (a 2012 drop of 2000 bottles has recovered only 70 so far), the message in a bottle method is still an effective way to map unknown ocean currents in an inexpensive manner. The National Oceanic and Atmospheric Administration, NOAA, still maintains maps and records from many of their bottle drops conducted in the last century.



Cartoon from Clarence E. "Pete" Pedersen, a cartoonist and former member of the Coast and Geodesic Survey team at NOAA. From NOAA

Due to the attrition rate in bottle drops, the practice has been used more out of necessity than idealism. There aren't many practices in science where losing 95% of your apparatus is considered an effective method. That's where the rubber duckies reenter the story.



A photo of Oceanographer Curtis Ebbesmeyer with flotsam he uses to monitor ocean currents. From http://vos.noaa.gov/MWL/dec2001.pdf

29,000 rubber toys floating in the Pacific Ocean are a perfect stand-in for drift bottles. They float smoothly, they're recognizable, and they're free. They could only be more effective if each had a researcher's phone number printed on the side. Curtis Ebbesmeyer and James Ingraham, oceanographers who have devoted their lives to mapping ocean currents, saw their opportunity. Instead of releasing 1,000 bottles and retrieving 20–30, the researchers had 29,000 vectors to work with, giving them an expected return of over 600. No ethical researcher could dump this much flotsam into the ocean, but a natural experiment like this could not be missed.

After the first Floatees washed up in Alaska in November 1992, the oceanographers contacted fishermen, beachcombers, and residents of the area to put them on alert for the missing toys that could wash up throughout the region. Over the next year, hundreds more washed up along the Alaskan coastline, contributing data to Ebbesmeyer and Ingraham's ocean current model. With this information, they were able to make predictions about what could happen to the rest of the duck armada, predicting their roundabout paths in the Pacific Ocean and indicating that some could reach the coasts of the United Kingdom. One intrepid little Floatee did hit the coast of Scotland on its own back in 2003, but many more are expected to replicate its journey in the coming years. The company that made them, First Years, Inc. are even offering a £50 bounty to anyone who recovers a Floatee in the United Kingdom.

If you're on the northern coasts of Asia, North America, or Europe this year, keep your eyes open for faded rubber bath toys nestled into the rocks. If you do find one, be sure to contact the researchers involved. You can find Curtis Ebbesmeyer and his writings on the subject at *flotsametrics.com* and *Beach Comber's Alert*.

In their 26 years of drifting the ocean, these little ducks have been frozen in sea ice, smashed into rocks, and hurled about in storms, but they continue their silent contributions to science and the world.

Ebbesmeyer and Ingraham's model, called Ocean Surface Currents Simulation (OSCURS), was partially built with data collected from the duck's movements around the ocean. OSCURS was developed and implemented at the Alaska Resource Ecology and Fisheries Management Division. They used the model to help fishing vessels navigate and fish the Gulf of Alaska for years. The current data could predict fish patterns, flotsam drift, and weather events. Eventually, the project ended and the data was folded into other models, but it continues to inform our knowledge about the ocean today. Even some of the crab trap drop sites used on *Deadliest Catch* could be inspired by the rubber duckie data.

You can get an idea of the complex ocean currents the ducks have ridden and helped map by watching this beautiful visualization NASA put together a few years ago. Billions of data points go into a model like this one, and these rubber ducks provided a few thousand of their own. Our knowledge of the ocean wouldn't be the same without them.

I like to imagine one resolute rubber duckie being frozen into arctic ice and swept toward the pole. Trapped in its frost-bound home, the toy sits deep beneath the ice, spending hundreds (or even thousands) of years in suspended animation. Eventually, polar researchers investigating climate change from our era take an ice core to inspect it for microbes and carbon dioxide content, and are left scratching their heads at the find. An ancient, bright yellow rubber toy staring back at them from ten feet below the ice. What a find that would be.

Source: https://medium.com/@lukehollomon/the-rubber-duckie-map-how-childrens-toys-mapped-the-ocean-bc13290ee3fc

LESSON 2: Oil Remediation

Teacher's Guide

Objective: In this lesson, students will begin by learning about oil spills, their effects on the environment, and how they can be cleaned up by both human effort and natural forces. They will read a passage about these methods and discuss further ideas, then use the modeling software to simulate the spread of oil in the ocean after a spill.

Inquiry question: What happens to oil in the ocean?

Time Required: One class period

Materials:
- Interactive whiteboard or projector with internet access and a StarLogo Nova account
- Individual copies of the *Lesson 2 Student Guide* on page 19 of this curriculum
- Individual copies of Oil Spill Remediation and Cleanup reading on page 17
- A closed jar or bottle containing ¼ cooking oil and ¾ water

Standards Addressed:

6th Grade: SC.6.E.7.5, SC.6.N.1.3, SC.6.N.3.4
7th Grade: SC.7.N.1.3, SC.7.N.3.2, SC.7.N.1.5
8th Grade: SC.8.N.1.5, SC.8.N.1.6, SC.8.N.3.1, SC.8.E.5.10
Middle School Computer Science: SC.68.CS-PC.2.8, SC.68.CS-CS.1.2, SC.68.CS-CS.1.4, SC.68.CS-CS.1.3, SC.68.CS-CS.2.11

PROCEDURES

In this lesson, students explore the fate of oil released into a body of water. This discussion and reading is designed to help students think through the fate of oil in the environment. They will learn about the properties of oil and natural weathering processes. This is followed by a reading about oil spill remediation.

Step 1

Begin the lesson with a demonstration using the jar of water and cooking oil. Note how the two substances separate, and the oil floats to the top. Students may already be aware of the insolubility of oil, and it may be appropriate to discuss polarity and/or density, depending on the science background of the students and the goals of the lesson.

NOAA's Office of Response and Restoration has a web page that summarizes what happens to oil in the environment without human intervention (*https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/oil-types.html*).

Step 2

Use think-pair-share after this reading to answer the first question- what are the properties of various oils, and how do they impact how the oil acts in an ecosystem as well as its impacts on the ecosystem. Encourage students to use examples from their own lives, such as proper disposal of cooking oil and motor oil, and why there are special instructions for storm drains. For additional connections to local government and civics, emphasize the relationship between the responsibilities of citizens and the responsibilities of petrochemical companies.

The student guide on page 15 includes a graphic from NOAA and a matching exercise to familiarize students with these processes. The class will read through the descriptions of each process as they examine the graphic. Have them explain their reasoning for choosing each type of weathering to go in the blanks. Again, it may be helpful to use think-pair-share to ensure that all students have understood the vocabulary before moving on to the next step.

Step 3

Once the class has discussed the weathering processes, have them develop a class list of ways that humans can intervene to remove accidental spills of oil from the environment.

Step 4

Next, students will read the passage on pages 17-18 of this curriculum about oil spill remediation methods. It may be beneficial to pass these out only after the brainstorming session to ensure that students are using prior knowledge and original ideas rather than copying directly from the text. For advanced students or for further enrichment, you can find a detailed report about the Deepwater Horizon oil spill and how it was affected by microbes at *http://archive.gulfcouncil.org/docs/Microbes_and_Oil_Spills.pdf*.

Step 5

After reading, follow up with "Can Microbes Clean Up Our Oily Mess? - Instant Egghead #58" episode from Scientific American (see link at right).

YouTube video on bathtub ducks lost at sea
https://www.youtube.com/watch?v=a_HWlFzgQiM

Application of learning

1. Ask students if the duck model in StarLogo Nova would be a good program to start a model of an oil spill. Why or why not?
2. Which members of the system or environmental variables will be important to a scientist modeling an oil spill?

Step 6

Revise the ***Model Oil Ver1*** in StarLogo Nova. The model shows the dispersal of oil. The first StarLogo Nova Model will be modified to add in a rate of oil loss to the system (e.g., 1 % lost per time interval) to show that we can program this into the model.

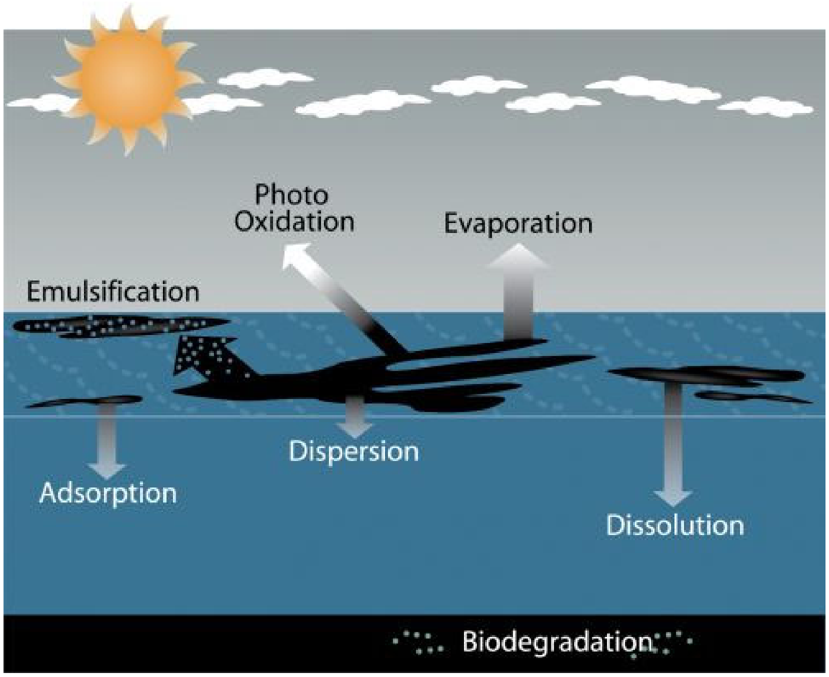
NAME_____________________________**Class** ____________________ **Period**______________

QUESTION: What happens to oil in the ocean?

Activity 1

With a partner, talk about some properties of oil (cooking oil, motor oil, gasoline, etc.). How do these properties affect how oil acts in the environment and how it impacts ecosystems? Be prepared to share at least one idea with the class.

Match the descriptions below with the processes named in the diagram from NOAA's Office of Response and Restoration.



Source NOAA: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/weathering-processes-affecting-spills

1. _________________________ is the process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure (includes sedimentation).

2. _________________________ is the degradation of substances resulting from their use as food energy sources by certain microorganisms including bacteria, fungi, and yeasts.

3. _________________________ is the distribution of spilled oil into the upper layers of the water column by natural wave action or application of chemical dispersants.

4. _________________________ is the act or process of dissolving one substance in another.

5. _________________________ is the process whereby one liquid is dispersed into another liquid in the form of small droplets.

6. _________________________ is the process whereby any substance is converted from a liquid state to become part of the surrounding atmosphere in the form of a vapor.

7. _________________________ is sunlight-promoted chemical reaction of oxygen in the air and oil.

List the ways oil might be “removed” from an ecosystem. What are some advantages and disadvantages to each method?

Read the passage “Oil Spill Removal and Cleanup.” Are any of your ideas being used in real-life oil spills?

Activity 2

Apply What You Learned

Log into StarLogo Nova (use the StarLogo Nova guide if you need help). Open Model Oil Ver1 in StarLogo Nova.

1. How well does this model show what happens during an ocean oil spill?

2. What could we add to this model to make it more accurate?

3. How could we add the unused blocks on the right-hand side of the coding workspace to model how microbes act on oil in the ocean?

Reading: Oil Spill Removal and Cleanup

By Karolyn Burns, M.S.

The ocean is the largest ecosystem on earth, but it is still vulnerable to pollution and contamination by human activities, especially close to shore. Oil spills are the one of the most common sources of marine pollution. According to the U.S. Department of Energy, 1.3 million gallons (4.9 million liters) of petroleum are spilled into U.S. waters from vessels and pipelines in a typical year (https://fas.org/sgp/crs/misc/RL33705.pdf). A major oil spill could easily double that amount, such as the Deepwater Horizon oil spill in the Gulf of Mexico in 2010. Oil spills vary in severity and in the amount of damage they cause due to variables like the type of oil, location of the spill, weather, and interactions with microbes.

Regardless of severity, all oil spills damage the ocean environment. The oil doesn't stay where it is spilled from a well or tanker, but spreads out across the surface of the water and can negatively impact shorelines and habitats for many miles. Oil is less dense than water, so it floats to the surface. This means that, while it is easier to clean up from the surface than it would be on the bottom, it is much more likely to affect marine mammals that must come up to breathe as well are seabirds that land on the ocean's surface.

Oil Booms

Since oil floats to the top, one of the most popular methods of containing an oil spill is the oil boom. Booms are floating, physical barriers to oil, made of plastic, metal, or other materials, which slow the spread of oil and keep it contained. They are most useful when the oil is confined to a single location, as they will keep it from spreading outward. They can also be placed around areas that would be severely damaged by oil, such as shellfish beds and reefs. Oil booms are not helpful when the oil has already spread out over a large area, or if there are large waves or storms that would make them ineffective.

Source: https://commons.wikimedia.org/wiki/File:Pensacola_NAS_oil_boom_4_May_2010_100504-N-6268N-039.jpg

Oil Skimmers

While booms can confine the oil to one area, they do not remove it from the water. This is where skimmers come in. A skimmer is a device for recovering spilled oil from the surface of the water. They can be used from boats or from shore, depending on where the oil spill is. There are several types of skimmer that can be used depending on the type of oil and the conditions on the water. Like oil booms, they are not very effective under rough sea conditions.

Source: https://en.wikipedia.org/wiki/File:Self_adjusting_weir_type_oil_skimmer,_Ultraspin.jpg

Oil Absorbers

Certain materials (called sorbents) are very good at soaking up liquids, and can be placed on top of the oil spills so that the oil can be recovered, and this prevents wastage and further pollution. As they need to be collected after taking up the oil this can be expensive and time consuming, so they are most often used in small spills or to remove the final traces of a large spill. There are natural sorbent materials such as peat moss, straw, sawdust, clay, glass wool, and even volcanic ash. There are also synthetic or man-made sorbents that are more effective at soaking up oil, but cost more to use.

In Situ Burning

In situ means on-site, so in situ burning involves igniting the layer of oil on the surface of the water to burn it off. If the layer is thick enough, this can be very effective and remove up to 98% of a spill, though it does come with risks to wildlife and people from toxic fumes. This method works best on a fresh spill, before the oil spreads out over a large area and degrades.

Dispersants

Image source: https://commons.wikimedia.org/wiki/File:C-130_support_oil_spill_cleanup.jpg

Once the spilled oil has spread out over a large area, it cannot be contained with booms, picked up by skimmers, or burned. The only remaining option is to deal with the oil and try to break petroleum oil into small droplets. Planes spray the oil spill with chemicals called dispersants over a large area, which break up the heavy oil into smaller droplets. These are easier for sun, waves, and microbes to break down, and are more likely to disperse into the water column. This helps to clear oil from the water's surface, making it less likely that the oil slick will reach the shoreline. Different types of oil respond differently to chemical dispersants, and the effectiveness is also impacted by temperature. Disadvantages to this method include creating tar balls from the denser parts of the oil which float to shore, and poisoning marine organisms.

Bioremediation

Bioremediation is the process of using microbes to break down or remove harmful and toxic substances from the environment. These microbes can be bacteria, fungi, or algae and they degrade petroleum products by metabolizing and breaking them into simpler and non-toxic molecules. This is often done after as much oil as possible has already been collected from the surface. This is a process that will happen naturally, as there are oil-eating bacteria that live in the ocean and “eat” the oil that seeps from cracks in the earth’s crust. These naturally occurring microbes need lots of oxygen and warm water as well as a food source, and there may not be enough of them to handle a large-scale oil spill, or all of the components of the oil itself.

LESSON 3: Visualizing Ocean Currents

Teacher's Guide

Materials:

- Individual copies of Student Guide (on page 21)
- Straight-sided bottle with cap filled completely with rheoscopic fluid (no air space at the top)
- Small flashlight (optional)
- Shallow container larger than the bottle
- Hot water
- Shallow tray or dish (about 7” across)
- Drinking straw
- Food coloring (red, yellow)
- Salt
- Ice cube tray
- 2 plastic containers (at least 9”x9”)
- Small funnel
- Clear flexible rubber tubing
- Air stone diffuser (used in aquariums)

Objective: In this lesson, students will use a rheoscopic fluid to simulate ocean currents. They will observe convection, density-driven flow, and wind-driven flow. In observing the fluid, students will see turbulence and eddies.

There is a short reading included at the end of the student guide.

Inquiry question:
What causes oceanic currents?

Time Required: One class period

Standards Addressed:
6th Grade: SC.6.E.7.1, SC.6.E.7.3, SC.6.E.7.4, SC.6.E.7.5, SC.6.N.3.4
7th Grade: SC.7.N.1.3, SC.7.N.3.2, SC.7.N.1.5, SC.7.P.11.4
8th Grade: SC.8.N.1.5, SC.8.N.3.1

PREPARATION

Convection. Rheoscopic fluid can be either purchased or made cheaply and easily, although the DIY version will settle more quickly. Cosmetic mica powder can be purchased online or at a craft store and is very safe. ¼ tsp in a liter of water yields a very nice flow visualization and suspension of particulate. After several minutes it will settle to the bottom, but any movement will maintain a swirling pattern. Food dye can be added to the water or it can be left undyed. As the bottle should be filled to the top with no air pocket, it is advisable to glue the top onto the bottle to prevent leaks.

Wind-Driven Flow. The rheoscopic fluid can be used in a shallow tray to show wind-driven flow.

Density-Driven Flow. Mix the red food dye with water and freeze it in the ice cube tray to produce red ice cubes. Mix the salt with water and yellow dye. 35 grams of salt in 1 liter of water will produce a 35ppt salinity, which is the global average for seawater. Fill one container all the way with fresh water and fill the other container 1/3 with fresh water.

PROCEDURES

Students will work through each of the items and record their observations in the data table on the student guide.

Step 1: Convection

A smooth-walled bottle containing rheoscopic fluid (with no air space) is placed in a larger dish of warm water. Students observe the flow of the fluid at the edge of the bottle. Students will see the fluid submerged in the warm water is rising and the fluid at the top that is not submerged sinking.

Step 2: Wind-driven flow

Using a shallow tray of fluid and a drinking straw, students blow gently parallel to the fluid surface to observe changes in flow of the rheoscopic fluid.

Step 3: Density-driven flow

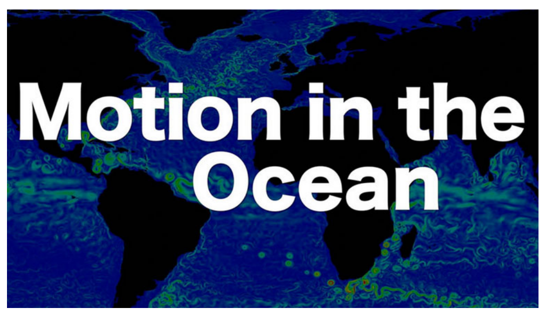
1. Connect the tubing to the air stone diffuser and place the diffuser in the bottom of the partially filled container (below the fresh water). Connect the funnel to the other end and slowly pour the salt-dye-water mixture into the container. It should layer below the fresh water layer with minimal mixing. Fill it to the same level as the first container.
2. Put the red ice cubes in both containers and watch where the melt water goes. This melt water represents the cold/salty dense water in the poles. The top layer of fresh water is the surrounding surface waters; the bottom salty layer represents the deep dense ocean layers.

Step 4: Coriolis Effect

Students will read "Motion in the Ocean" (on page 23) and watch the video "Why Do Hurricanes Spin?" to learn more about the Coriolis Effect (see URL link to the video below left).

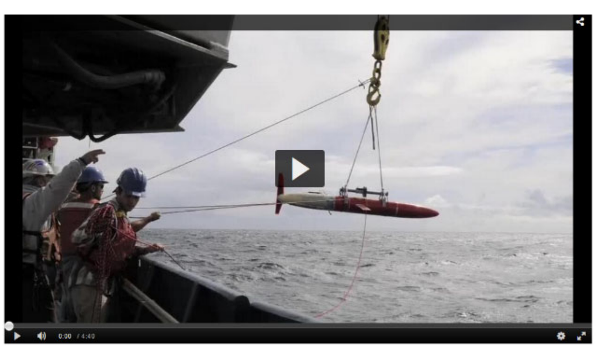
After the data collection, students will read about and watch a video on the NOAA website showing the ocean conveyor belt and, specifically, the Gulf Stream current (see URL link to "Motion in the Ocean" at right).

https://www.youtube.com/watch?v=6L5UD240mCQ



https://oceanservice.noaa.gov/podcast/apr14/mw123-currents.html

Finally, students will watch the video "Science in a Time of Crisis: Tracking the Currents" to learn more about how scientists reacted to the BP oil spill on the Gulf of Mexico.



https://ocean.si.edu/planet-ocean/tides-currents/science-time-crisis-tracking-currents

NAME______________________________**Class**______________________ **Period**______________

QUESTION: What causes oceanic currents?

These activities will help you understand the phenomena that drive ocean currents. Rheoscopic fluids will be used. The prefix ***rheo-*** means flow and the root ***-scopic*** means see. The fluids we will use will help us see the movement of water.

Each group needs to follow teacher instructions for obtaining: safety goggles, one smooth-walled bottle of rheoscopic fluid, several straws, a stirring rod or metal utensil, one ice cube, dishes of saltwater and freshwater, a shallow dish with room temperature water

© Can Stock Photo - csp36629120

Wear safety goggles for all of these procedures.

First pass the bottle of rheoscopic fluid to all of your lab partners to examine. Discuss with your partners what you observe. For the remainder of these procedures, try to make sure you keep the fluid as still as possible as you begin each activity.

Activity 1

Warm water bath. Leave the rheoscopic fluid bottle on the table for 1 minute to allow the movement of particles to slow. Carefully place the bottle containing room temperature rheoscopic fluid into a larger dish of very warm water. Observe the flow of the fluid in the bottle (use a flashlight, if available).

Activity 2

Blowing across surface. Once you and your lab partners have recorded observations for procedure 1, pour rheoscopic fluid into a shallow tray. The fluid should not fill more than half of the tray. Use a drinking straw (do not share a straw with your partners) to very gently blow a full breath of air parallel to the fluid surface. Describe what you observe in the data table. Repeat blowing and observing using a slightly stronger and then a stronger force. Observe how blowing affects movement of water in the dish.

Activity 3

Salt and freshwater mixing. Put the red ice cubes in both containers and watch where the melt water goes. This melt water represents the cold/salty dense water in the poles. The top layer of fresh water is the surrounding surface waters and the bottom salty layer represents the deep dense layers in the ocean.

Step/Procedure	Treatment	Process we are modelling?	Observations
1. In a warm water bath	Initially placed in water		
	After 2 minutes		
2. Blowing across surface	Gentle blowing		
	Medium blowing		
	Strong blowing		

Step/Procedure	Treatment	Process we are modelling?	Observations
3. Salt and freshwater mixing	As colors start to flow		
	After 3 minutes		

Activity 4

Coriolis Effect. Watch the video “Why Do Hurricanes Spin?” and discuss. How does the Coriolis Effect influence the movement of water in the ocean?

https://www.youtube.com/watch?v=6L5UD240mCQ

Activity 5 - Coriolis Effect

Now read about ocean currents and watch the “Motion in the Ocean” video from NOAA.

1. What is an eddy?

2. What is the Loop Current?

3. Name three factors that put the motion in the ocean.

https://oceanservice.noaa.gov/podcast/apr14/mw123-currents.html
How much do you know about ocean currents? Watch our three-minute video podcast to learn what puts the motion in the ocean.

Next, go to https://earth.nullschool.net/#current/ocean/surface/currents/orthographic to see current wind, weather, ocean, and pollution conditions as forecast by supercomputers on an interactive animated map. The Earth Nullschool maps are updated every three hours.

Zoom in to the Gulf of Mexico and answer these two questions.

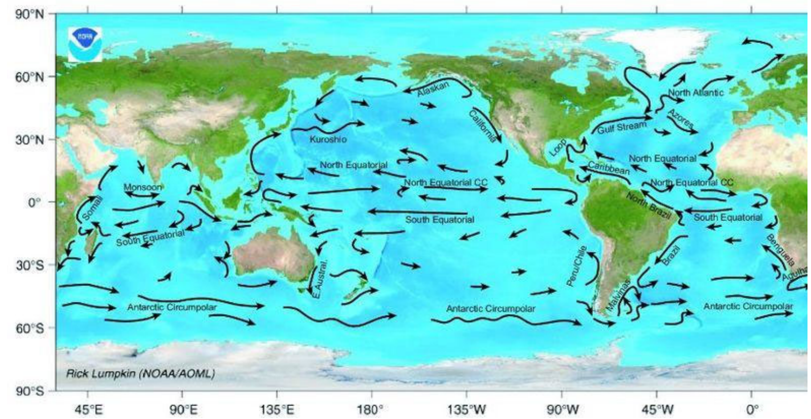
1. What was happening in the Gulf of Mexico? How is it connected to the rest of the Atlantic Ocean?

2. How do you think understanding currents can help us when oil spills happen?

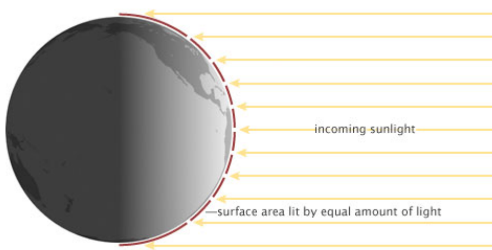
Reading: Motion in the Ocean

By Karolyn Burns, MS, Yana Bebieva, PhD, and Cathrine Hancock, PhD.

Although it can take thousands of years, the world's oceans are interconnected and communicate with each other. They do this through water movement, from one ocean basin to another. Energy is what makes the water move. There are different types of energy that affect the ocean in different ways, but the two most important forces are the wind, which provides kinetic energy, or the energy of motion. The other is the sun, which provides heat. Ultimately, the air movement that creates wind is also powered by the sun, and the sun is the source of energy for the Earth. Surface currents are driven by the wind, as the friction between air and water pushes the surface water around.



https://commons.wikimedia.org/wiki/File:Ocean_surface_currents.jpg



https://earthobservatory.nasa.gov/features/EnergyBalance/page2.php

There are also currents that move under the ocean's surface, and these are driven by heat. The earth is round, and the axis is at an angle. The sun shines directly on the equator, and less light and heat make it to the poles.

This creates a temperature difference between these surface waters. Think of a cold room, with a fire place on one side. If you start a fire in the fireplace, right by the fireplace it is hot. As you move away from the fire it gradually gets colder and colder. The heat travels from the fireplace to the other side of the room, but it takes time.

Surface water at the equator can move in two directions, downward (towards the ocean floor) and poleward. For water to sink, it needs to be denser than its surroundings. Water density is affected by heat and salt. Warm/fresh water is less dense than cold/salty water. So, warming the waters at the equator will decrease their density, forcing them to stay at the surface. Therefore, the only place this warm surface water can move is poleward.

https://commons.wikimedia.org/wiki/File:Ocean_circulation_conveyor_belt.jpg

Surface waters move poleward to redistribute the heat energy from the equator to areas that are colder. On their way to the poles this water encounters colder air above it, removing heat and increasing the density of the surface water. At the poles the air is freezing, which forces even more heat out of the surface waters. Eventually sea ice will form. When sea ice forms out of salt water, most of the salt is expelled into the remaining water. Now the remaining water is cold and salty, which means it is denser than the surrounding water. This dense water will sink until it reaches a water mass with the same density as itself. At this point, the water will spread out moving toward the equator. The equatorward flow will mix with surrounding water masses, decreasing its density. Thus, the equatorward flow will slowly rise in the water column until it reaches the surface once more. Then the cycle will start all over again.

The sinking of dense waters at the poles is called convection; and the entire circulation is commonly referred to as that thermohaline circulation. (***thermo*** – heat, ***haline*** – salt).

LESSON 4: The Gulf of Mexico Ecosystem

Teacher's Guide

Objective: In this lesson, students will learn about the physical features, species distribution, and human impacts on the Gulf of Mexico system. In reviewing maps and plotting positions, students will analyze the potential impacts of oil spills or other events on the members of this system.

Inquiry question:
How is the Gulf of Mexico a system?

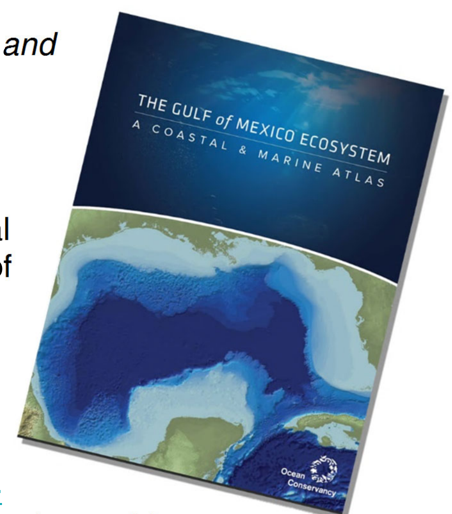
Time Required: One class period

Science Standards Addressed:
6th Grade: SC.6.E.7.3, SC.6.E.7.4
7th Grade: SC.7.N.1.3, SC.7.N.1.5, SC.7.L.17.3
8th Grade: SC.8.N.1.5, SC.8.N.1.6, SC.8.E.5.10
Middle School Computer Science: SC.68.CS-PC.3.1, SC.68.CS-CS.2.2, SC.68.CS-CP.3.1, SC.68.CS-CS.2.4, SC.68.CS-CS.6.3

Materials:
- The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
- Color copies of select maps from the Atlas (one of each unless noted below)
    - Project Area Map (p. 11) - 10 copies
    - Bathymetry Map (p. 15)
    - Sea Surface Currents Map (p. 26)
    - Seagrasses Map (p. 44)
    - Hydrocarbon Seeps & Communities Map (p. 63) - 2 copies
    - Whale Shark Map (p. 86)
    - Red Snapper Map (p. 98)
    - Kemp's Ridley Sea Turtle Map (p. 140)
    - Atlantic Bottlenose Dolphin Map (p. 148)
    - Hazardous Materials Spills Map (p. 187)
    - Oil and Gas Drilling Platforms & Boreholes Map (p. 200) - 3 copies
    - Selected Oil and Gas Pipelines Map (p. 201) - 2 copies
- Individual copies of the Lesson 4 Student Guide (pages 32-33 of this curriculum)
- One set of the correspondence items for distribution to the student teams
- One poster-sized whiteboard or a piece of chart paper per group, with markers

PROCEDURES

Step 1



Introduce students to *The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas* published by the Ocean Conservancy (a pdf can be downloaded here - https://oceanconservancy.org/wp-content/uploads/2017/05/gulf-atlas.pdf). This document is a compilation of many different data sets and provides an overall picture of the Gulf of Mexico ecosystem. The Atlas includes physical features, habitats, animals, stressors, and human uses in the Gulf of Mexico. The maps and brief summaries make a good jumping off point for understanding the Gulf ecosystem.

The Ocean Conservancy Atlas provides many maps that could be used in classrooms. However, only 13 mapped features are used for this lesson. To print **only the maps used in this lesson**, go to: https://csomio.org/education-and-outreach/modeling-the-gulf-middle-school-curriculum. Ideally, you will want to print the maps in color on 11 x 17 inch paper for the group work, and laminate them for repeated use.

Step 2

Use a projector or digital whiteboard to display the Atlas. Show the "project area" map or provide a copy for individuals or pairs of students. Have students tell you what they observe on this map (land and water geographical areas, states and countries, lines of latitude and longitude, shading differences, a key, etc.). Be certain to note the scale of the map and let students know that all other maps used in this activity will show the same area at the same scale. Ask students how they think scientists obtained this data- examples may include satellite imagery, sonar, human observers, commercial fisheries, and research expeditions taking samples of water, plankton, and vegetation. If covering standard SC.8.E.5.10, this would be a logical place to introduce Geographic Information Systems (GIS) and the use of computers, satellites, and location-tagged data to produce the maps.

Step 3

Begin the lesson by sharing the "U.S. Gulf of Mexico Marine Ecosystem" video from NOAA Fisheries (see web address at right).

Have your students share to develop a definition for the Gulf of Mexico ecosystem. Be certain they understand that this system includes non-living components (abiotic features) and that it is influenced by things that happen outside the ecosystem. Ask students to share the types of people who are involved in the system.

https://www.fisheries.noaa.gov/southeast/ecosystems/gulf-mexico-regional-ecosystem

Students will work in groups of four to complete an analysis of the ecosystem. They will take on the role of a research team from the National Oceanic and Atmospheric Administration, the federal scientific agency that focuses on areas such as the Gulf ecosystem. Specific roles will be assigned to them after they have answered the initial questions.

Before investigating a specific issue, each research team will collaborate to find answers to questions about the system. This activity should familiarize students with the Atlas and some main features of the Gulf.

Step 4

After submitting their responses to the initial questions, each group will receive a correspondence from someone expressing a concern about the Gulf. Each indicates a specific location (longitude and latitude) and the nature of the writer's concern.

Correspondence Items Addressed to the NOAA Ecosystem Science Team

(letters, tweets, emails, a ship-to-shore radio transcription, and a telegram)

Longitude	Latitude	Correspondence item assigned to the research team	Map(s) needed to address the correspondence
91.1°W	28.4°N	 *Greetings from Alabama,* *I was out on a fishing trip this weekend and saw 2 whale sharks. What an amazing experience that was! I've spent my whole life of 67 years on the water and never seen a single whale shark. The fishing spot is at 91.1°W 28.4°N.* *The reason for my letter is to let you know that I'm very concerned about the oil platforms in that area. What would happen if these whale sharks are exposed to oil? Will that interrupt any part of their life history? I know that your team has lots of data available from years of study. Should I be concerned about this very special species?* *Also, I'm wondering about the reproduction of whale sharks. Do they have egg cases like those I've seen washed up on the beach from other species of sharks and rays?*	• Project Area Map • Whale Shark Map • Oil & Gas Drilling Platforms and Boreholes Map • Hazardous Materials Spills Map • Oil & Gas Pipelines Map

Longitude	Latitude	Correspondence item assigned to the research team	Map(s) needed to address the correspondence
81.3°W	24.8°N	*Distressed now due to the Tampa Bay red tide. Will this impact my favorite seagrass bed for snorkeling and fishing? #redtide #seagrass4life 81.3°W 24.8°N*	• Project Area Map • Seagrasses Map • Surface Currents Map Note: For ecosystem level analysis, you may want to also introduce this team to the Sea Surface Temperature Map (p. 22) and the Salinity and Riverflow Map (p. 23), but these are optional.
93.7°W	24.4°N	*I regret that I must inform you that our cargo ship has lost a container of wholesale shampoo bottles. These bottles with sealed caps are packaged in cardboard boxes. There were 144 boxes each containing 200 bottles. The accident happened at 93.7°W 24.4°N.* *My shipping company has access to 4 large workboats with crews. Can you please help me know where I should send each crew so that we can collect as many of these bottles as possible? The cargo was lost yesterday. The crews can be on-site in 3 days.* *How far do you think these bottles could travel in the next month?*	• Project Area Map • Surface Currents Map
97.8°W	22.2°N	*Hola, I went to the beach this week with my class. We noticed lots of plastic and are concerned. Should the government do something about the litter that washes up onshore? 97.8°W 22.2°N are the longitude and latitude of the beach we visited.*	• Project Area Map • Surface Currents Map • Kemp's Ridley Turtles Map
82.4°W	26.3°N	*I just read an article on Huffingtonpost.com. I know that I need to be careful about checking facts online, so I wanted to ask the experts.* *The military has a need for sonar devices to help protect the country during times of war. Since they need to train the sailors, they do testing in the ocean. These tests involve very loud soundwaves that are much higher than what's healthy for humans.* *The article I read said that tests will be happening at these coordinates: 82.4°W 26.3°N. Do you think that there are any marine mammals who might be impacted by the tests? When and where would be best for these testing events?*	• Project Area Map • Bottlenose Dolphin Map
86.1°W	23.6°N	*Cheers science team,* *I'm an investor from Fiji. My fellow investors and I have developed a new technology that uses recycled materials to make floating "islands" in large shallow bodies of water. There is an area off the Yucatan Peninsula that we think would be a great spot for a new floating resort. The coordinates are 86.1°W 23.6°N.* *Our resorts are completely solar-powered and self-sufficient. We only use biodegradable materials (except for the "island") and have containment systems that compost all waste.* *Water quality is a very important consideration for our resort. The construction material for the "island" can breakdown when exposed to petroleum products like oil. As you might imagine, siting will be very critical. We would like to water depth to be less than 100 feet for scuba divers to safely access the bottom. If neither of these sites will work for our criteria, where do you suggest we locate the resort?* *I hope you will be able to travel to the new Sun-stainable Gulf Resort once it opens. Thanks for your assistance.*	• Project Area Map • Hydrocarbon Seeps & Communities Map • Bathymetry Map

Longitude	Latitude	Correspondence item assigned to the research team	Map(s) needed to address the correspondence
88.9°W	29.5°N	*Science team,* *My friends and I were on a scuba diving trip to an abandoned oil drilling platform at 88.9°W longitude 29.5°N latitude. While we were there, we think we found an invasive species of algae, Caulerpa taxifolia.* *I know that this species can reproduce from just fragments that float to a new location. I've also heard that this algae produces a poison that is toxic to fish.* *I hope your team will be able to make a plan to investigate and control the spread if you find it is actually an invasive species. We dive on old platforms all over the Northern Gulf. Where can we expect to see this algae in the future? What would happen to the recreational red snapper fishery?* *Could you also let me know how much of the United States' oil and gas supply comes from the Gulf? Thanks*	• Project Area Map • Surface Currents Map • Red Snapper Map • Oil & Gas Drilling Platforms and Boreholes Map
84.1°W	28.0° N	T *FROM W J JACKSON-(STOP)-WATER SHEEN EIGHTY FOUR POINT ONE DEGREES WEST TWENTY EIGHT POINT ZERO DEGREES NORTH -(STOP)- DEAD FISH FLOATING-(STOP)- PLEASE ADVISE-(STOP)*	• Hydrocarbon Seeps & Communities Map • Selected Oil and Gas Pipelines Maps • Oil & Gas Drilling Platforms and Boreholes Map • Surface Currents Map

NOTE: Printable versions of these correspondence examples are provided on pages 28-31 of this curriculum. Print and assign one to each of your student teams.

Step 5

The team will investigate the issue presented in their correspondence item using the maps from the Atlas. Once the work is completed, each team will complete (as a team) the ***Claim-Evidence-Reasoning (CER)*** chart (page 35) and present to the class. Poster-sized whiteboards, chart paper, or a whiteboard or projector can be used to display the appropriate information to the class.

Step 6

The presentation is the reply to original query. Presenters must include a claim (state whether the team thinks there may be an issue of concern or not), evidence (actual data that supports this claim), and reasoning (a scientific explanation of the scientific principles that justify using this data to make the claim). ***Claim-Evidence-Reasoning*** is a framework for constructing a scientific argument and can be used in any and all content areas that involve empiricism and qualitative or quantitative data. It involves an initial question, with the claim being a proposed answer to that question. If this is not familiar to the students, it may be helpful to go over an example, science-based or not, before independent or group work. The CER structure is as follows:

<table>
<tr><td colspan="2">Question: What do you want to know?</td></tr>
<tr><td colspan="2">CLAIM: A statement that answers your question</td></tr>
<tr><td>EVIDENCE for the claim:
• Scientific data that support the claim
• Data need to be appropriate (pictures, graphs, table)
• Observation</td><td>REASONING (How the evidence justifies the claim):
• Based on scientific principles
• Each piece of evidence may have a different justification for why it supports the claim</td></tr>
<tr><td colspan="2">Teams should also answer any other questions posed in the correspondence. The answers can be found in the text description that precedes each map in the Atlas.</td></tr>
</table>

Step 7

In closing the lesson, emphasize that the members of the Gulf ecosystem can all have effects on other parts of the system.

Letter

To: NOAA Ecosystem Science Team

From: Kathryn Williams

Greetings from Alabama,

I was out on a fishing trip this weekend and saw 2 whale sharks. What an amazing experience that was! I've spent my whole life of 67 years on the water and never seen a single whale shark. The fishing spot is at 91.1° W 28.4°N.

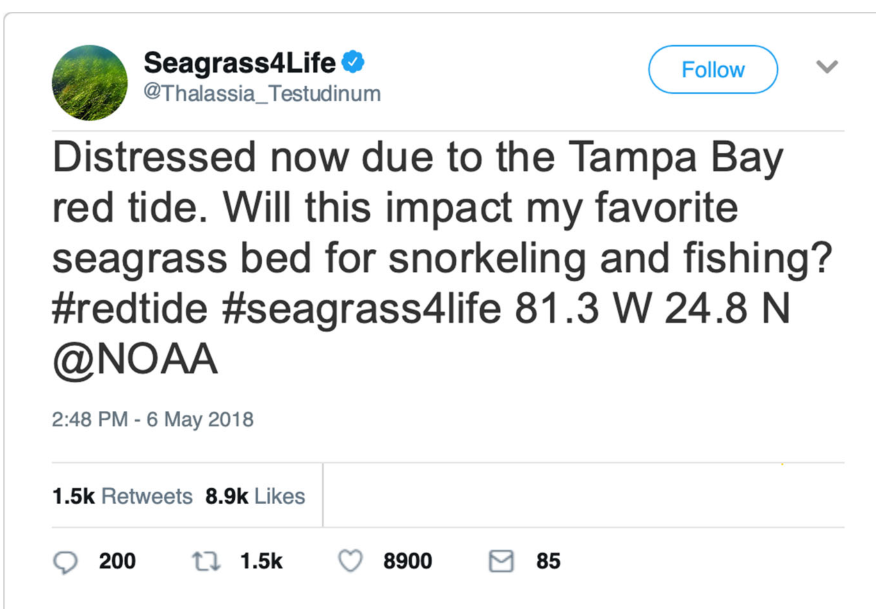
The reason for my letter is to let you know that I'm very concerned about the oil platforms in that area. What would happen if these whale sharks are exposed to oil? Will that interrupt any part of their life history? I know that your team has lots of data available from years of study. Should I be concerned about this very special species?

Also, I'm wondering about the reproduction of whale sharks. Do they have egg cases like those I've seen washed up on the beach from other species of sharks and rays?

Thank you,

Kathryn Williams

Tweet



Seagrass4Life
@Thalassia_Testudinum

Follow

Distressed now due to the Tampa Bay red tide. Will this impact my favorite seagrass bed for snorkeling and fishing? #redtide #seagrass4life 81.3 W 24.8 N @NOAA

2:48 PM - 6 May 2018

1.5k Retweets **8.9k** Likes

200 1.5k 8900 85

Ship-to-Shore Radio Transmission

SHIP-TO-SHORE RADIO TRANSMISSION FROM MV HALOPHILA
TRANSCRIBED MAY 20 7:22PM

HALOPHILA: COME IN COAST GUARD

COAST GUARD: GO AHEAD

HALOPHILA: I REGRET THAT I MUST INFORM YOU THAT OUR CARGO SHIP HAS LOST A CONTAINER OF WHOLESALE SHAMPOO BOTTLES. THESE BOTTLES WITH SEALED CAPS ARE PACKAGED IN CARDBOARD BOXES. THERE WERE 144 BOXES EACH CONTAINING 200 BOTTLES. THE ACCIDENT HAPPENED AT 93.7°W 24.4°N.

MY SHIPPING COMPANY HAS ACCESS TO 4 LARGE WORKBOATS WITH CREWS. CAN YOU PLEASE HELP ME KNOW WHERE I SHOULD SEND EACH CREW SO THAT WE CAN COLLECT AS MANY OF THESE BOTTLES AS POSSIBLE? THE CARGO WAS LOST YESTERDAY. THE CREWS CAN BE ON-SITE IN 3 DAYS.

HOW FAR DO YOU THINK THESE BOTTLES COULD TRAVEL IN THE NEXT MONTH?

OVER

Tweet

ScienceTeacher
@EarthScienceRocks
Follow

Hola, I went to the beach this week with my class. We noticed lots of plastic and are concerned. Should the government do something about the litter that washes up onshore? 97.8 W 22.2 N are the longitude and latitude of the beach we visited. #plasticocean @NOAA

2:48 PM - 6 May 2018

1.2k Retweets **2.3k** Likes

12 1.2k 4353 24

Email

From:	jacoblee2012@gmail.com
Subject:	Sonar testing and marine mammals
To:	ecosystemscienceteam@noaa.gov

I just read an article on the Internet. I know that I need to be careful about checking facts online, so I wanted to ask the experts.

The military has a need for sonar devices to help protect the country during times of war. Since they need to train the sailors, they do testing in the ocean. These tests involve very loud soundwaves that are much higher than what's healthy for humans.

The article I read said that tests will be happening at these coordinates: 82.4°W 26.3°N. Do you think that there are any marine mammals who might be impacted by the tests? When and where would be best for these testing events?

Thank you,

Jake Lee

Letter

Elenoa Katalou
14 Viria St
Vatuwaqa, Fiji
(679)-272-3858
Ekatalou@sunstainableislands.com.fj

Cheers science team,

I'm an investor from Fiji. My fellow investors and I have developed a new technology that uses recycled materials to make floating "islands" in large shallow bodies of water. There is an area off the Yucatan Peninsula that we think would be a great spot for a new floating resort. The coordinates are 86.1°W 23.6°N.

Our resorts are completely solar-powered and self-sufficient. We only use biodegradable materials (except for the "island") and have containment systems that compost all waste.

Water quality is a very important consideration for our resort. The construction material for the "island" can breakdown when exposed to petroleum products like oil. As you might imagine, siting will be very critical. We would like to water depth to be less than 100 feet for scuba divers to safely access the bottom. If neither of these sites will work for our criteria, where do you suggest we locate the resort?

I hope you will be able to travel to the new Sun-stainable Gulf Resort once it opens. Thanks for your assistance.

Elenoa Katalou
Sun-stainable Islands, Inc.

Email

From:	prodiver850@outlook.com
Subject:	Oil and gas supply from the Gulf of Mexico?
To:	ecosystemscienceteam@noaa.gov

Science team,

My friends and I was on a scuba diving trip to an abandoned oil drilling platform at 88.9° W longitude 29.5°N latitude. While we were there, we think we found an invasive species of algae, *Caulerpa taxifolia*.

I know that this species can reproduce from just fragments that float to a new location. I've also heard that this algae produces a poison that is toxic to fish.

I hope your team will be able to make a plan to investigate and control the spread if you find it is actually an invasive species. We dive on old platforms all over the Northern Gulf. Where can we expect to see this algae in the future? What would happen to the recreational red snapper fishery?

Could you also let me know how much of the United States' oil and gas supply comes from the Gulf? Thanks

Earl Johnson

Telegram

TELEGRAM

TO: NOAA ECOSYSTEM SCIENCE TEAM
FROM: W.J. JACKSON

FROM W J JACKSON-(STOP)-WATER SHEEN EIGHTY FOUR POINT ONE DEGREES WEST TWENTY EIGHT POINT ZERO DEGREES NORTH -(STOP)- DEAD FISH FLOATING-(STOP)-PLEASE ADVISE-(STOP)

TIME RECEIVED: 4:13AM

NAME________________________ **Class**_____________ **Period**____________

QUESTION: How is the Gulf of Mexico a system?

For this activity, you will use information from *Gulf of Mexico Ecosystem: A Coastal and Marine Atlas*. This document used a variety of scientific sources to compile data about many parts of the Gulf of Mexico ecosystem.

Activity 1

Look at the cover of the Atlas and note who created it and when. It was produced by the Ocean Conservancy after the Deepwater Horizon oil disaster to be a resource for people interested in restoring the Gulf of Mexico. Before beginning your task, look at the project area map in the Atlas.

1. Write down five things you observe:
    1.
    2.
    3.
    4.
    5.
2. Approximately how far does one centimeter on this map represent?

3. What kinds of data do you think will be shown in the Atlas?

Activity 2

Define the Gulf of Mexico ecosystem. Watch the video "U.S. Gulf of Mexico Marine Ecosystem." Your teacher will pass out some maps for you and your classmates to look at. Examine each map and be ready to share something that you notice.

Activity 3

Now that you are familiar with the area, you will be working in a team to conduct an analysis of the ecosystem. Your group is a research team from universities around the Gulf of Mexico coast. The team includes a physical oceanographer, marine biologist, resource manager, and communications coordinator. Groups like this are *interdisciplinary*. By having a team with expertise in many areas, your group can get the big picture about what is happening in a system. Your teacher will assign your team and role.

Physical oceanographers are experts in the physical properties and changes in the ocean. They may study currents, salinity, dissolved oxygen and carbon dioxide, or other chemicals.

Marine biologists study the living things in the ocean. This can include the very largest fish or the tiniest bacterium and everything in between.

Resource managers have the job of assessing the abundance of all the types of resources in the ocean and advising lawmakers and other agencies. They plan for the long-term sustainability of ocean resources.

Communications coordinators help scientists share information with the public in a way that they can understand. Communications coordinators help us understand why scientific research is relevant to our lives.

Your team has received correspondence from a member of the public. It is your job to investigate, using data from the Atlas, so you can respond to the inquiry. Your team should use the maps and accompanying text related to different parts of the ecosystem. Once your team has come to a conclusion, you will prepare a response to the person. This will be presented to the class as a poster or single slide using the format below. Presenters must include:

1. A summary of **the problem**.
2. **A claim** (state whether your team thinks there may be an issue of concern or not) and what should be done about it.
3. **Evidence** (scientific data that support your claim).
4. **Reasoning** (a scientific explanation of the principles that justify using this data to make the claim).

You and your team should also answer any other questions posed in the correspondence. Answers to these can be found in the text description that comes before each map in the Atlas. Below is a space for your notes. Your team submission will include all member ideas.

Team Submission Form

1. The Problem	2. Group Members and Assigned Roles

3. Our Claim

4. Evidence	5. Reasoning

Other Information to Answer the Person's Question or Problem

LESSON 5: Refining an Ocean Model

Teacher's Guide

Materials:
- Internet-connected devices for student pairs
- Individual copies of the Lesson 5 Student Guide

Objective: In this lesson, students will apply what they learned about computer modeling by modifying existing code to reflect more complex ocean processes. In this partnered activity, they will develop a deeper understanding of how computers can be used to make predictions and recreate natural systems

Inquiry question: How do scientists refine computer-based mathematical models?

Time Required: One-two class periods

Science Standards Addressed:
6th Grade: SC.6.E.7.4, SC.6.N.1.1, SC.6.N.1.3, SC.6.N.3.4, SC.6.N.1.4
7th Grade: SC.7.N.1.1, SC.7.N.1.3, SC.7.N.3.2, SC.7.N.1.5, SC.7.L.17.3
8th Grade: SC.8.N.1.5, SC.8.N.1.6, SC.8.N.3.1, SC.8.E.5.10, SC.8.L.18.1, SC.8.L.18.3
Middle School Computer Science: SC.68.CS-PC.2.8, SC.68.CS-PC.3.1, SC.68.CS-PC.3.5, SC.68.CS-CS.1.2, SC.68.CS-CS.1.4, SC.68.CS-CS.2.2, SC.68.CS-CS.1.3, SC.68.CS-CP.3.1, SC.68.CS-CS.2.4, SC.68.CS-CS.2.11, SC.68.CS-CS.6.3

PROCEDURES

Step 1

Orientation to StarLogo Nova

Individual students or student pairs will need web-enabled devices (PCs, laptops, tablets).

Using instructions on the **StarLogo Nova Student Guide** (page 41 of this curriculum), students should register, login, and load a model. After examining the code underlying the model, student pairs will alter the model. To edit a model, have them click "Remix" at the top of the page to add it to their gallery and allow changes to be made. For this first run, the modification does not have to be realistic for the model, just a chance to practice making changes.

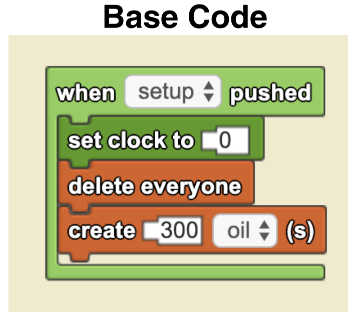
Each student pair should show a neighbor once they have successfully edited the *Model Floating Ducks Ver1*. Groups should show the new model workspace and explain the code.

Step 2

Model modification

Using the suggested items on the student guide, pairs will edit models to include other variables using pair programming. You can learn more about pair programming here: https://www.youtube.com/watch?v=vgkahOzFH2Q.

Base Code



If students work on models showing different components (evaporation, microbes, sinking) these can be combined into a single model (groups can share the coding blocks from their separate models so that each group can come up with a combined model).

A series of screenshots for each of the modifications is included in the answer key. This can be used to help students get to a working model, but they should not be shown the example code. Note that this is not the only correct answer, and if students are able to create a working model with a different set of code, that may also be correct. To get students started, the base code can be used as a starting point.

NAME ____________________________ **Class** ____________________ **Period** ______________

QUESTION: How do scientists refine computer-based mathematical models?

Let's use what you've learned to make a more refined oil spill model. Work with a partner for this activity. You will use the ***StarLogo Nova Student Guide*** to create a login on the website. Email addresses are not required. Your programming team will share the login.

Activity 1

1. Load the *Model Floating Ducks Ver1* model.
2. Play around with changing the code to make this model do different things. Troubleshoot as you run into problems. If you get too lost, you can always re-load the original model.

What features did you change in the model and what was the result?

Activity 2

Open the current oil spill model - Model Oil Dispersal with Current Ver2.
Run the model and describe what happens.

Activity 3

Now it's time to include some new information in this model. Choose from one of these options to refine the model. If you are successful, see if you can use two or three of these options.

- **Option 1:** There are oil-consuming microbes present in the area. These microbes must eat 5 units of oil in order to have enough energy to reproduce. To represent this in the model, there is a 20% chance of reproduction after each encounter with an oil particle.
- **Option 2:** Different types of oil evaporate at different rates. Jet fuel evaporates at a rate of .002 percent per time unit. Diesel evaporates at a rate of .001 percent per time unit. Crude oil evaporates at a rate of .0005 percent per time unit.
- **Option 3:** Oil-consuming microbes will reproduce rapidly in the presence of oil, but as oil runs out, the microbes die off. This die-off starts to happen after 100 time units and there is a .005 percent chance of dying per time unit after 100. Once they die, microbes will sink to the bottom.

Now that you and your partner have developed a computer-based mathematical model for the fate of oil, share your work. StarLogo Nova will give you the option of creating a graph from your data. Create your graph!

Activity 4

Conclusion questions:

1. Which option did you choose for your final model?

2. What was the most challenging part of programming?

3. Could you use this model to predict what would happen in the Gulf of Mexico?

4. What other features of the system could be included in this model to make it a more realistic representation of the Gulf of Mexico?

Appendices

Accommodations

In order to help you create an inclusive and accessible classroom, included below are vocabulary lists, modified questions, and alternate procedures for each lesson as suggestions in this unit plan. These accommodations are designed to be useful in assisting students with a 504 plan or an IEP (Individualized Education Plan) or ELL (English language learner) students who might benefit from vocabulary support, small-group instruction, oral vs. written answers, and simplified language.

Lesson 1

Vocabulary List

Part 1 Video

Gyre – any large system of circulating ocean currents, particularly those involved with large wind movements

Vortex – fluid with a whirling or circular motion

Coriolis force – makes things (like planes or currents of air) traveling long distances around Earth appear to move at a curve as opposed to a straight line

Part 1 Article

Mass – a measurement of how much matter is in an object

Beseech – to beg or ask urgently

Attrition – loss over time

Apparatus – the technical equipment or machinery needed for a particular activity or purpose.

Flotsam – the wreckage of a ship or its cargo found floating on or washed up by the sea.

Parts 2 and 3

Computer program – A computer program is a collection of instructions that performs a specific task when executed by a computer

Physical model – a smaller or larger physical copy of an object

Conceptual model – a representation of a system that uses concepts and ideas to form said representation

Mathematical model – a description of a system using mathematical concepts and language

Computer model – a computer program that is designed to simulate what might or what did happen in a situation

Modified Questions

1. How many ducks were in the container lost at sea?
2. What made the ducks move?
3. Where would you go today if you wanted to find one of the ducks?
4. What determines where a duck will wash ashore?
5. Why do scientists collect data about the ducks' locations?

Lesson 2

Vocabulary List

Ocean diagram

Emulsification – when tiny drops of oil are mixed into the water
Photo-oxidation – when the light breaks oil down
Evaporation – when molecules of liquid become gas and enter the atmosphere
Absorption – when a substance clings to the surface of another substance without going inside
Dispersion – when oil becomes tiny drop that mix into the surface layers of the water
Dissolution – when one substance dissolves into another
Biodegradation – when living organisms break down oil

Oil Spill Removal and Cleanup passage

Vulnerable – at risk
Contamination – when a harmful substance goes into the environment
Petroleum – the raw material for oil
Microbes – organisms too small to see without a microscope
Severity – how harmful an event is
Ineffective – not working well
Igniting – setting something on fire
Metabolizing – breaking down or digesting

Modified Questions

1. Think of two ways to remove oil from the ocean. Compare and contrast how they work.
2. Read the passage "Oil Spill Removal and Cleanup". Are any of your ideas being used in real-life oil spills?
3. How well does this model show what happens during an ocean oil spill?
4. What could we add to this model to make it better?

Lesson 3

Vocabulary List

Rheoscopic fluid – liquid with small particles that show movement
Convection – the movement of heat because of the movement of warm matter.
Conduction – Heat energy moves from one area to a cooler area
Thermohaline circulation – movement of water based on temperature and saltiness
Salinity – saltiness
Coriolis effect – curving the movement of water because the earth is spinning

Modified Questions

1. What is an eddy?
2. What is the Loop Current?
3. Name three things that put the motion in the ocean.
4. What was happening in the Gulf of Mexico? How is it connected to the rest of the Atlantic Ocean?
5. How do you think understanding currents can help us when oil spills happen?

Lesson 4

Vocabulary List

Atlas – A book of maps or some type of information that includes pictures and/or tables and charts

Ecosystem – An ecosystem is made up of all of the living and nonliving things in an area

Correspondence – Communication by letters, email, or social media

Observation – Any information collected with the senses

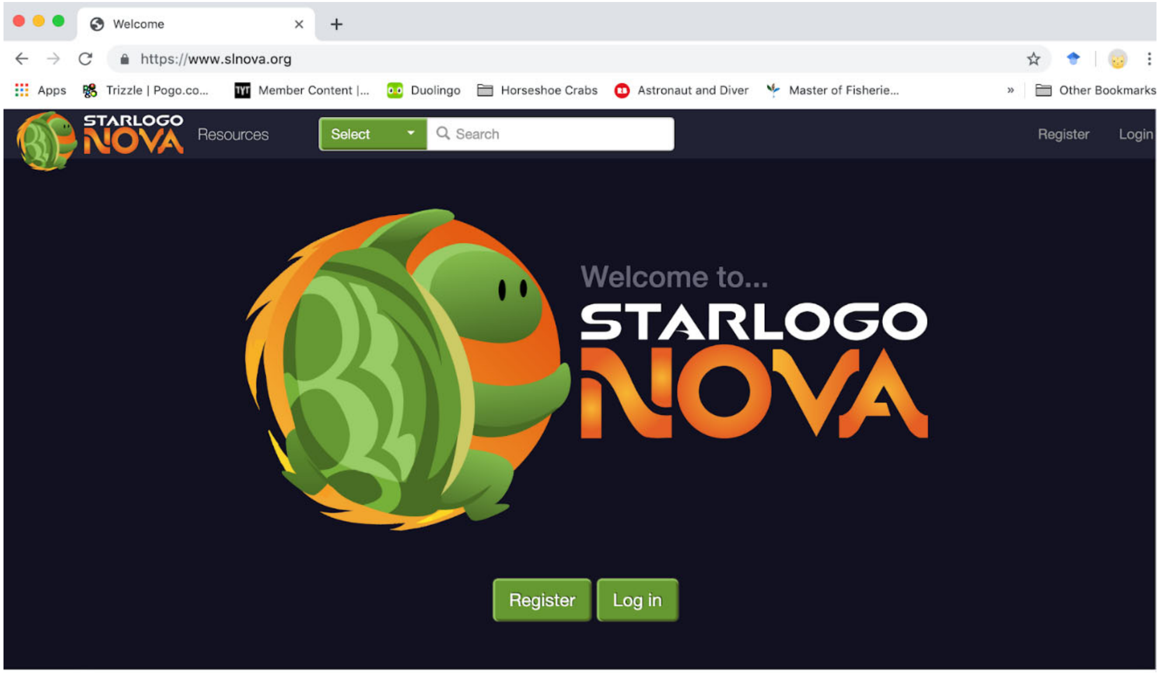
Additional accommodations for this lesson can include pairing students with a buddy, highlighting relevant points on the printed maps, reading the correspondence aloud, and allowing for drawings and oral presentations to take the place of written answers in the claim-evidence-reasoning chart.

Lesson 5

This lesson is advanced and may be difficult for students who do not have background knowledge about computers. It would make an excellent enrichment activity for gifted/talented students as well as early finishers to work on as a longer-term project. The work is generally best as a partnered project, but students can work on their own or in larger groups as needed.

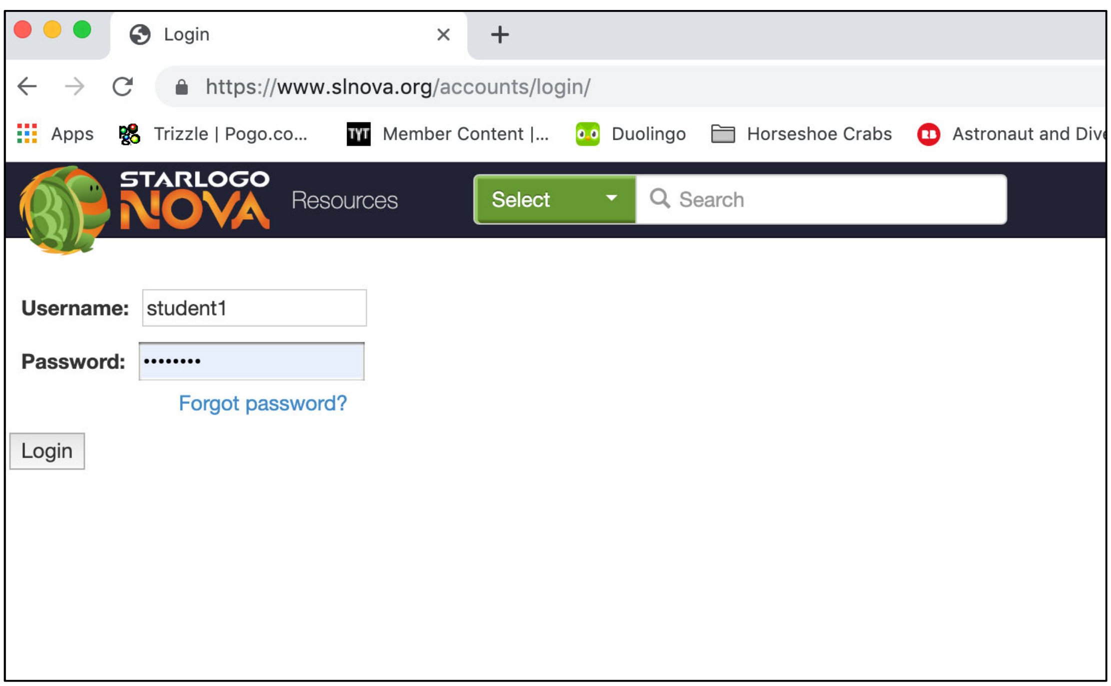
StarLogo Nova Student Guide

StarLogo Nova is an online programming environment for creating games and simulations. For these lessons, we use StarLogo Nova to model ocean systems.



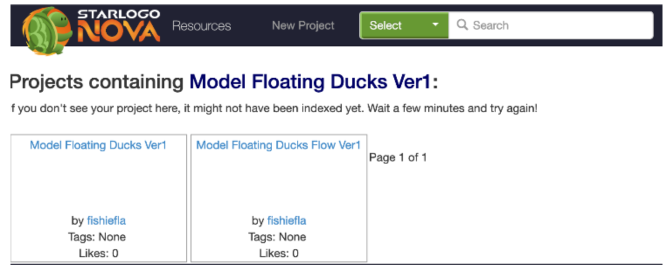
Step 1: Register and Log In

1. Go to http://www.slnova.org/ and click ***Register.***
2. Type in a username __________________________ and password ________________________ then write them here. Email addresses are not required. You will be logged in after your successful registration.
3. To log in and open the first model: Type in your username and password then click ***Login***



Step 2: Open the Model

In the search box at the top, type ***Model Floating Ducks Ver1.*** When the project appears on the screen, click on it to go to begin.



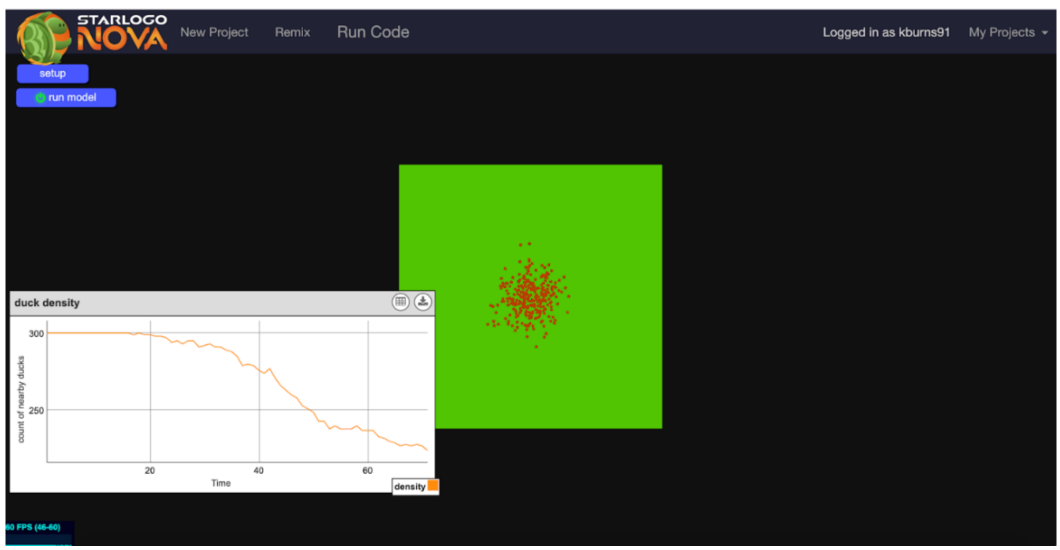
Step 3: Add the Project to Your Gallery

Once you've opened the existing project, make a copy for yourself by clicking add this project to my gallery. Click submit in the pop-up window.

Step 3: Run the First Model

Now that you have the ***Model Floating Ducks Ver1*** open,

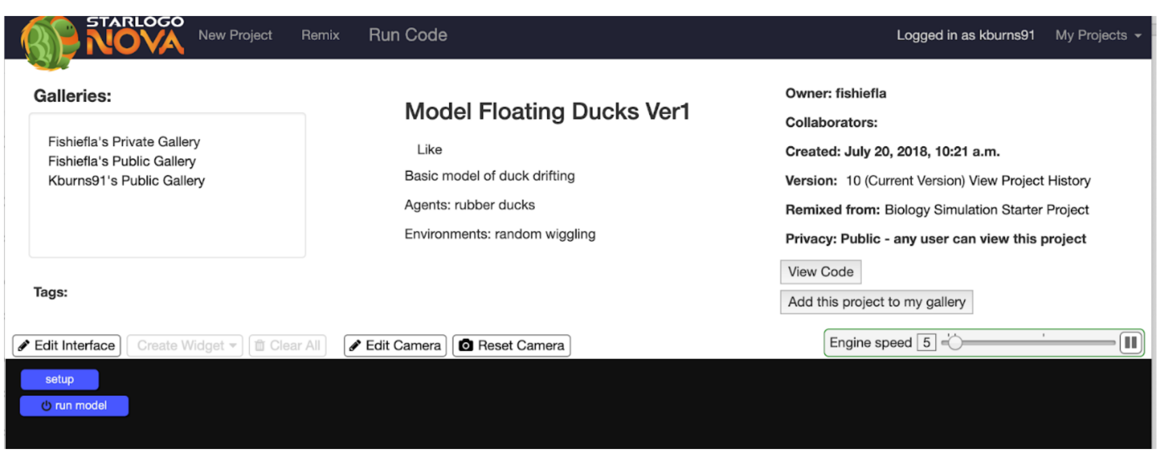
1. Scroll down to the space with the black background. Note: The green *ocean* can be enlarged by clicking *edit camera* and then expanding the green box with the touch screen, touch pad, or scroll wheel. After resizing, click *lock camera* to hold that view for the session (the camera will reset once the model has been closed and re-opened).
2. Click the blue setup box to place 300 ducks in the ocean
3. Click the blue run model box to cause the ducks to randomly move about the ocean



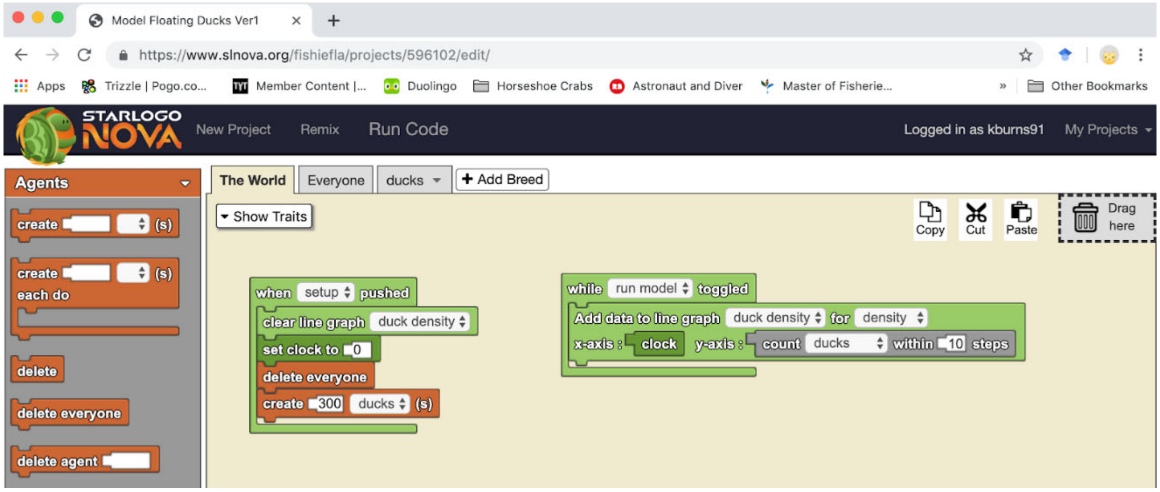
Notice the graph to the left. This shows how close the ducks are to each other. As they drift apart, the line showing the density of ducks will drop.

Step 4: View the code that runs the model:

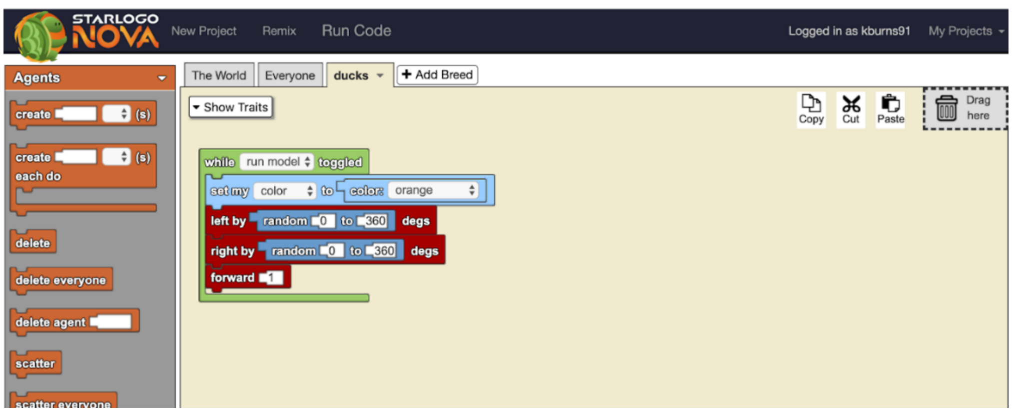
1. Click on the button that says "View Code" in the top right corner.



2. Scroll down below the space with the black background. You will see a beige workspace, tabs on top, graphic coding blocks below the tabs, and commands shown to the left.



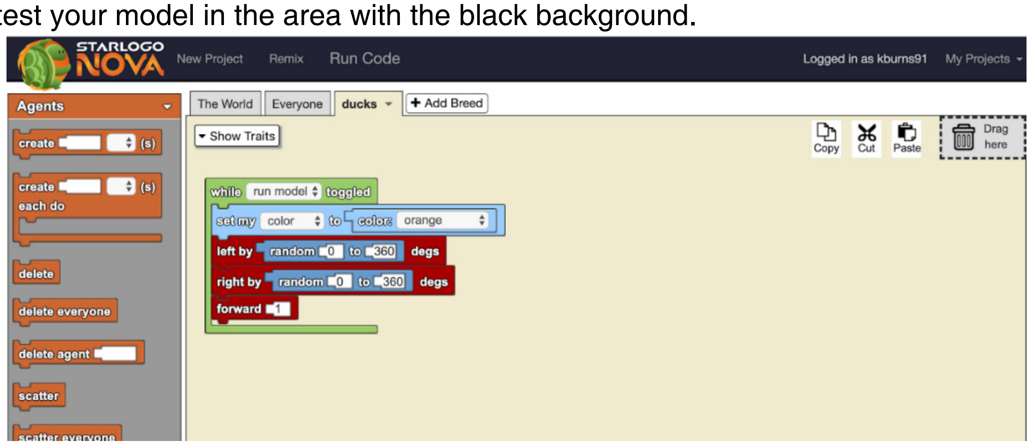
3. Choose “the world” tab. The left coding block clears the space and then creates 300 rubber ducks when setup is clicked in the model.
4. Choose the “ducks” tab. The coding block here shows what happens when the run model button is clicked on. Each duck turns left and right at random and then moves forward one step. This repeats while the button is clicked on.



Step 5: Edit the Code

There are many more coding blocks that can be used on the left-hand side of the beige coding workspace. Students who have used Scratch or many of the Hour of Code interactives have already used the block coding format.

You can make changes, additions and deletions to the existing code. Once you have made a change, click *run code* at the top of the page. Run code will update from the previous code. You can then test your model in the area with the black background.



Step 6: Test Yourself

1. What happens when you change the number of ducks to 10?

2. What happens when you remove the “left by…” and “right by…” coding lines?

Related models available on StarLogo Nova

- Model Floating Ducks Ver1 (Lesson 1)
- Model Floating Ducks Flow Ver1 (Lesson 1)
- Model Oil Ver1 (Lesson 2)
- Model Oil Dispersal with Current Ver1 (Lesson 5)
- Model Oil and Microbes Ver1 (Lesson 5)

Answer Keys

Lesson 1: Go with the Flow!

Inquiry question: How do computers help us predict changes in systems?

Duck Drifters

Watch the video *https://www.youtube.com/watch?v=eLMSMs6AYYc* and answer these questions.

1. How many ducks were in the container lost at sea?

29,000

2. What made the ducks move?

The ducks were carried across the ocean by surface currents.

3. Where would you go today if you wanted to find one of the ducks?

Today, you can find them all over the world. They have made their way into the North Atlantic and are found in Scotland.

4. What factors are important in determining where a duck will wash ashore?

The speed and direction of ocean currents are most important in determining where a duck will wash ashore.

5. What is the value of collecting data about the ducks' locations?

Collecting data about the ducks' location helps us to understand where the gyres are in the ocean, how the Great Pacific Garbage Patch formed, and where to focus on ocean clean-up.

6. Show what the ducks revealed about ocean currents by adding arrows to this map:

https://commons.wikimedia.org/wiki/File:ColoredBlankMap-World-162E.svg

Computer-based mathematical models

Scientific models are representations of the natural world. Models can be ***physical*** - a larger or smaller copy of an object. Models can be ***conceptual*** - representing a phenomenon with an illustration or system of organization. Models can also be ***mathematical*** - applying mathematical formulas and data to show events and make predictions about outcomes. These mathematical models often employ computers to make calculations and show results.

7. Give an example of a physical model

Examples may include: dioramas, solar system mobile, architectural models/mockups, model airplanes or trains, anatomical skeletons or organs, etc.

8. Give an example of a conceptual model

Examples may include: flow-charts, diagrams and illustrations, verbal or written explanations, etc.

9. Give an example of a mathematical model

Examples may include: Newton's laws, population growth models, gas laws, computer simulations, weather predicting model, etc.

In order to represent what happens to rubber ducks, or other materials in the ocean, we will use a computer-based mathematical model. Start by running a model of rubber ducks dropped in the ocean.

StarLogo Nova

Run the Model Floating Ducks Ver1 on StarLogo Nova (SLNova.org).

10. What things are shown in this model?

In this model, the ocean with currents, the speed and direction of those currents, and the movement of the ducks is included.

11. How does this model show a system (a group of related parts that make up a whole)?

The speed and direction of the currents interact to move the ducks around. This shows how the ducks interact with the ocean as a system.

12. Does this model show what really happens in the ocean system? Tell your evidence.

This does not show what really happens in the ocean system. The currents don't make gyres and there are no land masses for the ducks to wash onto. There isn't wind to direct the currents or any other weather that might affect how and where the ducks go.

13. What other things could you add to make a better model to show the fate of ducks dropped into the ocean?

I would add the shape of the ocean, where the continents are, how deep the water is, and actual currents that show things like the gyres and Great Pacific Garbage Patch.

Members of the ocean system: the actual things in the ocean system (living and non-living)	**Variables**: environmental conditions that can vary and influence the system (such as currents and water temperature)
Water Seafloor Rocks Fish Plankton Whales	Currents Salinity Wind (speed and directions) Weather conditions Depth Water temperature Waves

One way to refine this model would be to add code that takes into account wind direction and speed. Test out Model Floating Ducks Flow Ver1. Does this do a better job of modeling the ducks? Examine the code. What is different about how this is programmed?

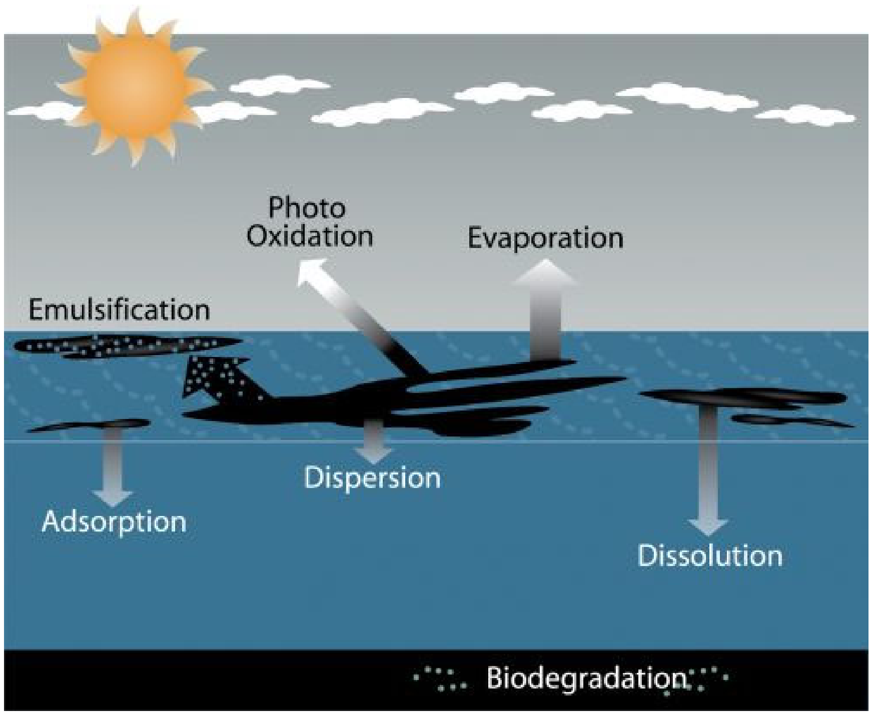
This code is programmed so that instead of the ducks spreading out randomly, the person running the model chooses the direction and speed of the currents. It is more realistic, since the currents do flow in one direction, but they still don't move in circles.

Lesson 2: Oil Remediation

Inquiry question: What happens to oil in the ocean?

With a partner, talk about some properties of oil (cooking oil, motor oil, gasoline, etc.). How do these properties affect how oil acts in the environment and how it impacts ecosystems? Be prepared to share at least one idea with the class.

Match the descriptions below with the processes named in the diagram from NOAA's Office of Response and Restoration.



Source NOAA: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/weathering-processes-affecting-spills

1. Absorption – The process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure (includes sedimentation).
2. Biodegradation – The degradation of substances resulting from their use as food energy sources by certain microorganisms including bacteria, fungi, and yeasts.
3. Dispersion – The distribution of spilled oil into the upper layers of the water column by natural wave action or application of chemical dispersants.
4. Dissolution – The act or process of dissolving one substance in another.
5. Emulsification – The process whereby one liquid is dispersed into another liquid in the form of small droplets.
6. Evaporation – The process whereby any substance is converted from a liquid state to become part of the surrounding atmosphere in the form of a vapor.
7. Photo oxidation – Sunlight-promoted chemical reaction of oxygen in the air and oil.

List the ways oil might be "removed" from an ecosystem. What are some advantages and disadvantages to each method?

Oil skimmers can confine the oil to one area so that it can be removed more easily, but they don't work very well under rough conditions or if the oil has already spread out over a wide area.

Oil absorbers soak up the oil and are good at removing it from the water, but they can be expensive, and also required workers to gather them and take them out of the water. They work best in small spills or to gather the last of a large spill, so they're best when used with other methods.

Burning off the oil can be very effective at removing a thick layer on the surface of the water. This doesn't work very well if a lot of the oil has already evaporated or sunk. It also increases air pollution in the area and can harm wildlife or workers.

Dispersants are good for oil that has already spread out and is in a thinner layer, and they break up the oil so that it is more likely to evaporate or be broken down. Dispersants can be toxic, though, and don't work at all temperatures.

Bioremediation uses microbes to break down the oil. These microbes already exists in the ocean so they are not harmful, but too many of them can use up all the oxygen in the water and kill fish. It's also difficult to get enough of them to clean up a very large oil spill.

Read the passage "Oil Spill Removal and Cleanup". Are any of your ideas being used in real-life oil spills?
Answers may vary.

Applying what you learned
Login to StarLogo Nova (use the StarLogo Nova guide if you need help). Open Model Oil Ver1 in StarLogo Nova.

8. How well does this model show what happens during an ocean oil spill?
This model shows the oil dispersing into the ocean, but it does not include any of the ways in which oil gets broken down and leaves the ocean, like dispersion, dissolution, biodegradation, evaporation, emulsification, etc

9. What could we add to this model to make it more accurate?
We can add any of those natural processes, or some of the human removal efforts, or microbes that eat oil. We can also add real currents to see which way the oil moves.

10. How could we add the unused blocks on the right-hand side of the coding workspace to model how microbes act on oil in the ocean?
Those coding blocks can be used to create the features in question 9.

Lesson 3: Visualizing Ocean Currents

Inquiry question: What causes oceanic currents?

These activities will help you understand the phenomena that drive ocean currents. *Rheoscopic* fluids will be used. The prefix rheo- means *flow* and the root -scopic means *see.* The fluids we will use will help us see the movement of water.

Each group needs to follow your teacher's instructions for obtaining: safety goggles, 1 smooth-walled bottle of rheoscopic fluid, several straws, a stirring rod or metal utensil, one ice cube, dishes of saltwater and freshwater, a shallow dish with room temperature water.

First pass the bottle of rheoscopic fluid to all of your lab partners to examine. Discuss with your partners what you observe. For the remainder of these procedures, try to make sure you keep the fluid as still as possible as you begin each activity.

Procedure 1 - Warm water bath

Leave the rheoscopic fluid bottle on the table for 1 minute to allow the movement of particles to slow. Carefully place the bottle containing room temperature rheoscopic fluid into a larger dish of very warm water. Observe the flow of the fluid in the bottle (use a flashlight, if available).

Procedure 2 - Blowing across surface

Once you and your lab partners have recorded observations for procedure 1, pour rheoscopic fluid into a shallow tray. The fluid should not fill more than half of the tray. Use a drinking straw (do not share a straw with your partners) to *very gently* blow a full breath of air parallel to the fluid surface. Describe what you observe in the data table. Repeat blowing and observing using a slightly stronger and then a stronger force. Observe how blowing affects movement of water in the dish.

Procedure 3 - Salt and freshwater mixing

Put the red ice cubes in both containers and watch where the melt water goes. This melt water represents the cold/salty dense water in the poles. The top layer of fresh water is the surrounding surface waters and the bottom salty layer represents the deep dense layers in the ocean.

Procedure	Treatment	Which process are we modeling?	Observations
1. In a warm water bath	Initially placed in water	Convection	Initially, water moved in all directions.
	After 2 minutes	Convection	After 2 minutes, water starts to rise from the bottom to the top, then sink again. It creates a loop.
2. Blowing across surface	Gentle blowing	Low wind speed, breezes	The water slowly moved in the same direction as the wind blows, but does not make waves.
	Medium blowing	Medium wind speed	The water moves more quickly and there are ripples on the water.
	Strong blowing	High winds, storms, hurricanes	The water moves faster, the ripples start to make waves and it splashes on the sides of the tray.
3. Salt and freshwater mixing	As colors start to flow	Thermohaline circulation	The ice cubes float on top of the water.
	After 3 minutes	Thermohaline circulation	As the ice cubes melt, the red water sinks to the bottom.

Procedure 5 - Coriolis effect

Watch this video https://www.youtube.com/watch?v=6L5UD240mCQ and discuss.

How does Coriolis effect influence the movement of water in the ocean?

Without the Coriolis effect, water would just go north and south. As the earth rotates, water in the Northern hemisphere curves to the right as it goes toward the pole. Water in the southern hemisphere curves to the left as it moves from the equator to the pole.

Wrapping it up

Now read about ocean currents and watch this video from NOAA https://oceanservice.noaa.gov/podcast/apr14/mw123-currents.html.

1. What is an eddy? An eddy is a circular current of water.
2. What is the Loop Current? The Loop Current moves water from the Yucatan peninsula in Mexico, up to the US Gulf Coast and between Florida and Cuba out to the Atlantic Ocean.
3. Name three factors that put the motion in the ocean. Water temperature and salinity, and wind.

View the live current map at https://earth.nullschool.net/#current/ocean/surface/currents/orthographic and zoom into the Gulf of Mexico.

5. What was happening in the Gulf of Mexico? How is it connected to the rest of the Atlantic Ocean?

Answers may vary

6. How do you think understanding currents can help us when oil spills happen?

The currents might carry oil from the Gulf of Mexico out to the Atlantic Ocean. If this happens, the damage will be over a much bigger area. By understanding the currents, scientists can try to prevent this and keep the oil spill confined.

Lesson 4: The Gulf of Mexico Ecosystem

Inquiry question: How is the Gulf of Mexico a system?

For this activity, you will use information from Gulf of Mexico Ecosystem: A Coastal and Marine Atlas (Ocean Conservancy publication) https://oceanconservancy.org/wp-content/uploads/2017/05/gulf-atlas.pdf. This document used a variety of scientific sources to compile data about many parts of the Gulf of Mexico ecosystem.

Take a look at the cover of the Atlas and notice who made it and when. It was produced after the Deepwater Horizon oil disaster to be a resource for people interested in restoring the Gulf of Mexico.

Before diving into your task, take a look at the project area map in the Atlas.

1. Write down 5 things you observe:

Answers may vary.

2. Approximately how far does one centimeter on this map represent?

About 50 kilometers

3. What kinds of data do you think will be shown in the Atlas?

Answers may vary.

4. Watch the following video https://www.fisheries.noaa.gov/southeast/ecosystems/gulf-mexico-regional-ecosystem.

Define Gulf of Mexico Ecosystem:

The Gulf of Mexico ecosystem stretches from the southern coast of the US in the north to Mexico in the south and west, and Cuba in the east. It is a marine ecosystem and includes nonliving factors such as water, temperature, depth, salinity, wind, and weather. It also includes living organisms such as plankton, fish, whales, dolphins, turtles, crabs, and shrimp.

Your teacher will pass out some maps for you to share with nearby students. Examine each map and be ready to share something you notice.

Your task:

Now that you are familiar with the area, you will be working in a team to conduct an analysis of the ecosystem. Your group is a research team from universities around the Gulf of Mexico coast. The team includes a physical oceanographer, marine biologist, resource manager, and communications coordinator. Groups like this are *interdisciplinary*. By having a team with expertise in many areas, your group can get the big picture about what is happening in a system. Your teacher will assign your team and role.

Physical oceanographers are experts in the physical properties and changes in the ocean. They may study currents, salinity, dissolved oxygen and carbon dioxide, or other chemicals.

Marine biologists study the living things in the ocean. This can include the very largest fish or the tiniest bacterium and everything in between.

Resource managers have the job of assessing the abundance of all the types of resources in the ocean and advising lawmakers and other agencies. They plan for the long-term sustainability of ocean resources.

Communications coordinators help scientists share information with the public in a way that they can understand. Communications coordinators help us understand why scientific research is relevant to our lives.

The team has received correspondence from a citizen. It's your job to investigate by using data from the Atlas. Your team should use the maps and accompanying text related to different parts of the ecosystem. Once your team has made a conclusion, you will prepare a response to the citizen. This will be presented to the class as a poster or single slide using the format below.

The presentation is the reply to original correspondence. Presenters must include:

- A summary of the problem
- A claim (state whether the team thinks there may be an issue of concern or not) and what should be done about it,
- Evidence (actual scientific data that supports this claim), and
- Reasoning (a scientific explanation of the principles that justify using this data to make the claim).
- Teams should also answer any other questions posed in the correspondence. Answers to these might be found in the text description that precedes each map in the Atlas.

<table>
<tr><td>The Problem</td><td>Group members and Roles</td></tr>
<tr><td colspan="2">Our Claim</td></tr>
<tr><td>Evidence</td><td>Reasoning</td></tr>
</table>

Answers will vary depending on which maps and prompts are used. Please see the rubric on the following page for grading guide.

	4	3	2	1	0
Claim – a conclusion that answers the original question	• Scientifically accurate • Completely answers the question	• Scientifically accurate • Nearly completely answers the question	• Partially scientifically accurate • Partially answers the question	• Is not scientifically accurate overall • Does not adequately answer the question	No claim
Evidence – scientific data that supports the claim	• The data are scientifically appropriate to support the claim. • At least 2 maps are used to produce detailed data • Proper units are used in data	• The data are scientifically appropriate to support the claim • Data comes from a single map or lacks detail • Evidence may be repetitive	• The data relate to the claim, but are not entirely scientifically appropriate • Data is include but is insufficient and/or not attributed to a map	• There is some evidence provided, but it is not logically linked to the claim or scientifically appropriate	No evidence provided
Reasoning – a justification that links the claim and evidence	• Reasoning clearly links evidence to claim • Shows why the data count as evidence by using appropriate scientific principles • There are at least two examples of relating a data point to the claim	• Reasoning adequately links claim to evidence • Includes related scientific principles, but only passably clarifies why this data count as evidence • There is at least one example of relating a data point to the claim	• Reasoning does not adequately link claim to evidence, or clarify why data count as evidence • Includes non-related scientific principles, and shows little depth of content understanding	• Reasoning is clearly insufficient and relates only tangentially to question and claim at hand • Scientific understanding is very limited	Does not provide reasoning
Language and Vocabulary	• Response expresses ideas in complete sentences with specific examples using vocabulary from the reading	• Response expresses ideas in complete sentences, but examples are generic and/or lack scientific terms	• Response inconsistently and sometimes inappropriately expresses ideas or scientific descriptions and vocabulary	• Scientific language and vocabulary are not precise or appropriate	Not under-standable

Rubric adapted from National Science Teachers Association (NSTA)

Lesson 5: Pair Programming to Refine an Ocean Model

Inquiry question: How do scientists refine computer-based mathematical models?

The final phase of the unit is to use what you've learned to make a more refined oil spill model. Work with a partner for this activity.

1. Use the StarLogo Nova Student Guide to create a login on the website. Email addresses are not required. Your programming team will share the login.
2. Load the Model Floating Ducks Ver1 model.
3. Play around with changing the code to make this model do different things. Troubleshoot as you run into problems. If you get too lost, you can always re-load the original model.

Which features did you change in the model and what was the result?

Answers may vary.

4. Open our current oil spill model - Model Oil Dispersal with Current Ver2.
5. Run the model and describe what happens.

Answers may vary.

6. Now it's time to include some new information in this model. Choose from one of these options to refine the model. If you are successful, see if you can use two or three of these options.

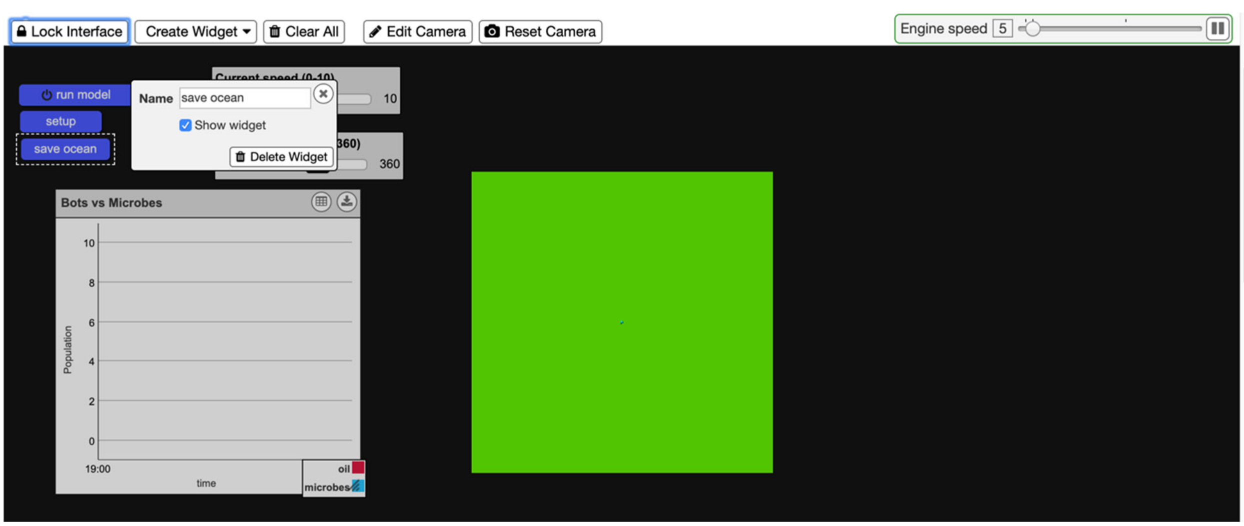
a. There are oil-consuming microbes present in the area. These microbes must eat 5 units of oil in order to have enough energy to reproduce. To represent this in the model, there is a 20% chance of reproduction after each encounter with an oil particle.

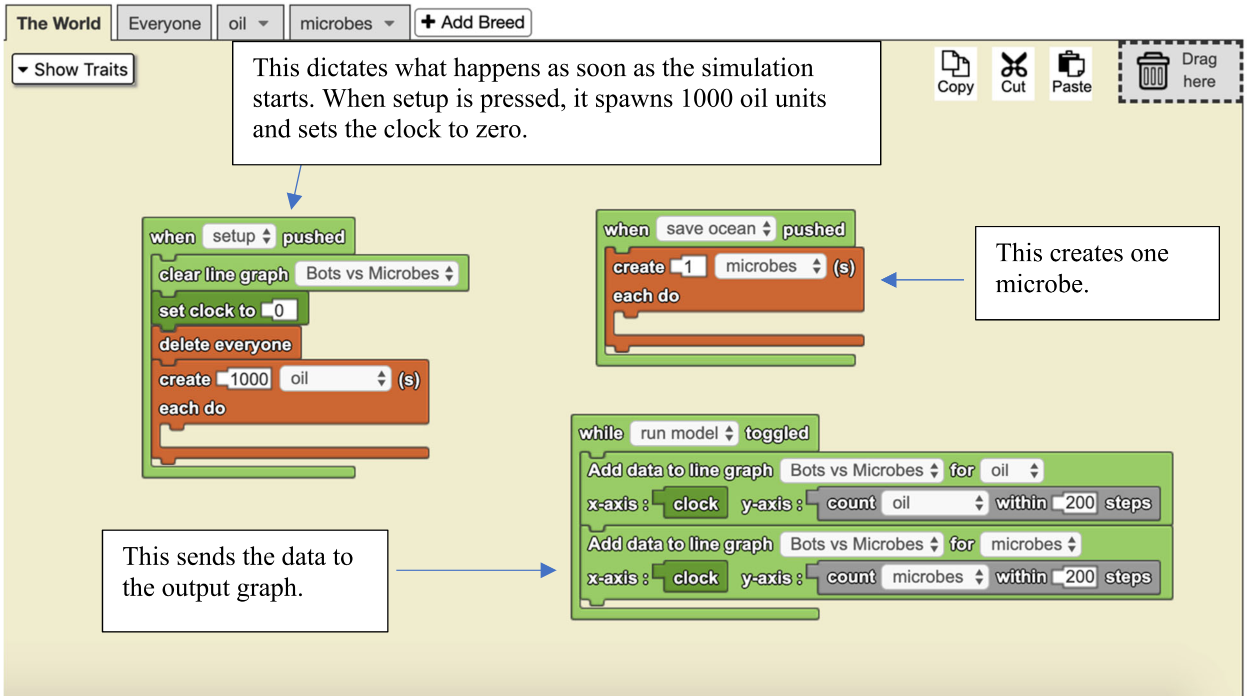
The change percentage is used here because in this software, a counter variable cannot be attached to a collision event.

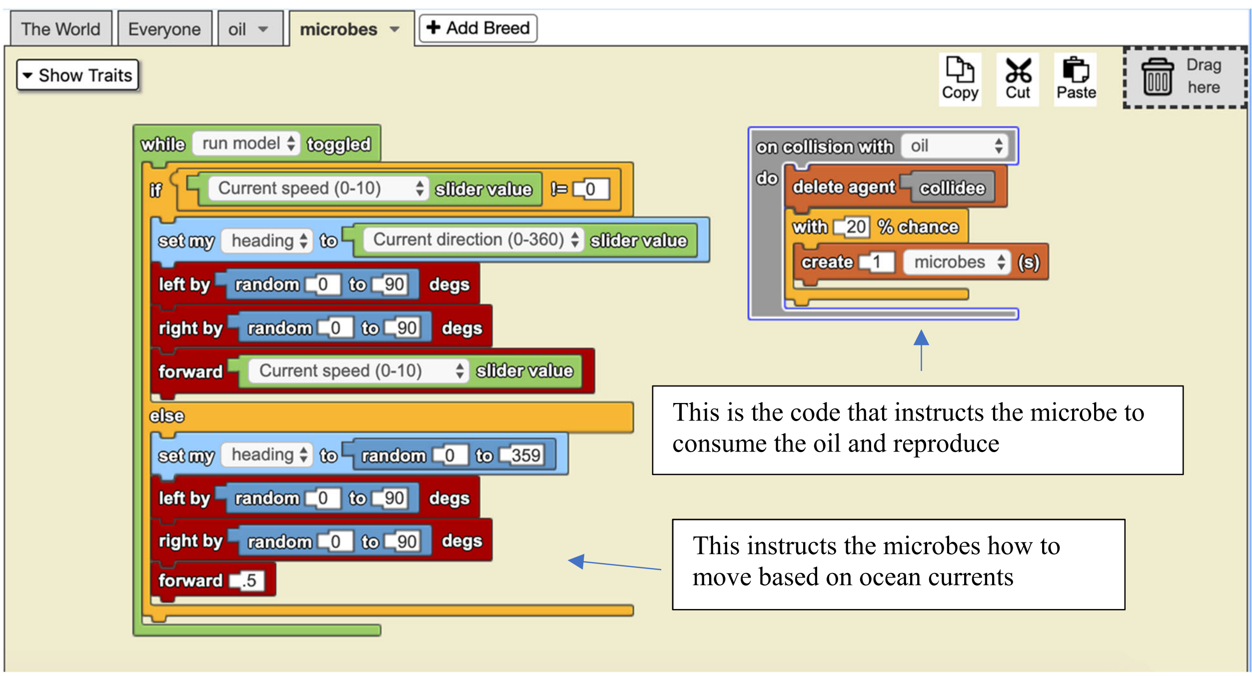
The following screenshots show an example of how this can be set up. Note that there are several pages that can be toggled between, displayed at the top.

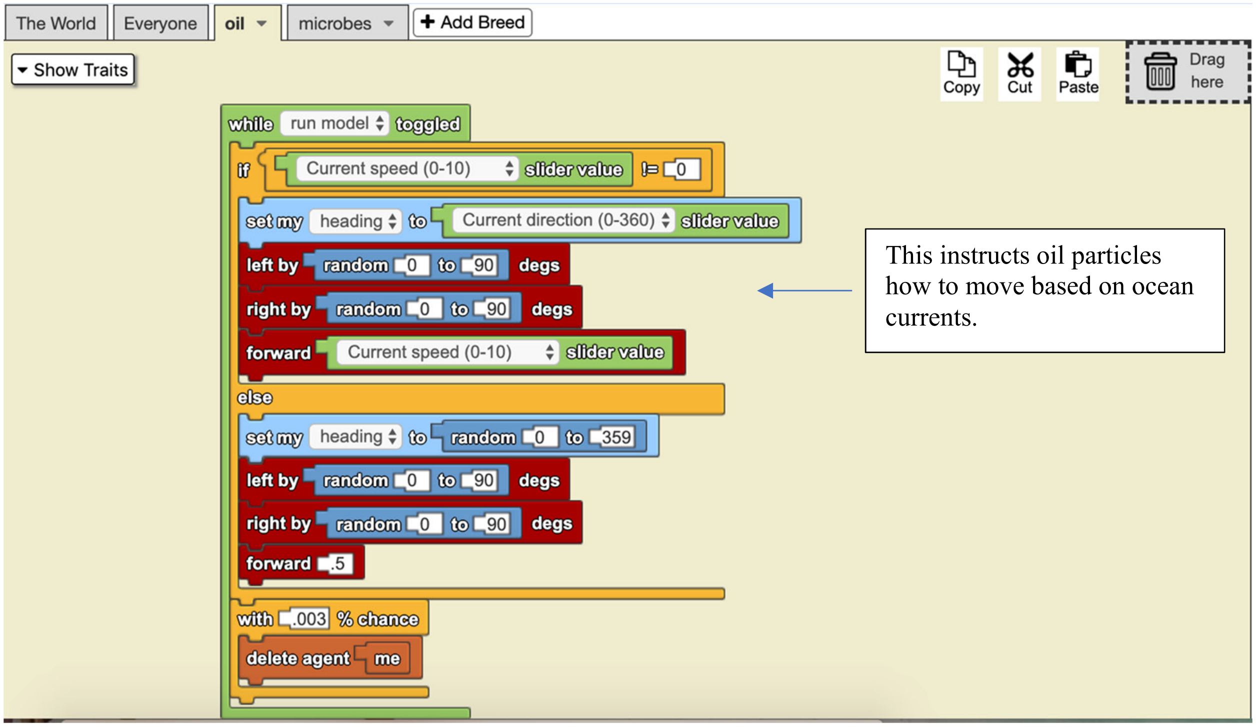
First, the interface needs to be created. "Run model" and "setup" are there as default options.

In order to later introduce the microbes to the simulation, a third button needs to be added. To add a new button, click "Edit Interface" (the text on the button will then change to "Lock Interface". Click on "Create Widget" and scroll down to "Push button", which will appear in the interface. Students can name this whatever they feel is appropriate for their model. This example uses "save ocean".

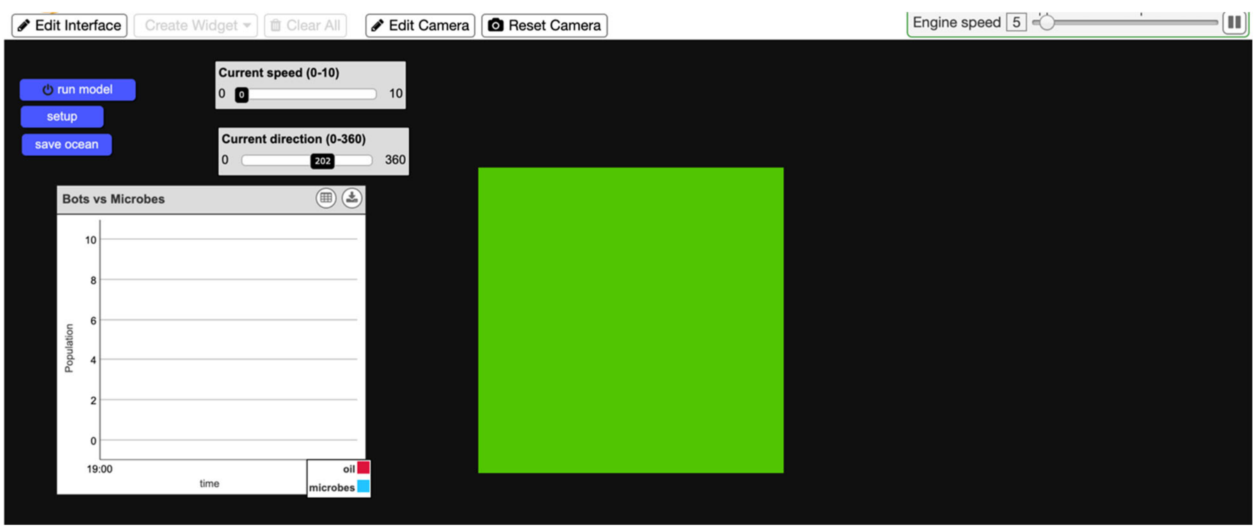



The World
Everyone
oil
microbes
Add Breed
Show Traits
This dictates what happens as soon as the simulation starts. When setup is pressed, it spawns 1000 oil units and sets the clock to zero.
Copy
Cut
Paste
Drag here
when setup pushed
clear line graph Bots vs Microbes
set clock to 0
delete everyone
create 1000 oil (s)
each do
when save ocean pushed
create 1 microbes (s)
each do
This creates one microbe.
while run model toggled
Add data to line graph Bots vs Microbes for oil
x-axis : clock y-axis : count oil within 200 steps
Add data to line graph Bots vs Microbes for microbes
x-axis : clock y-axis : count microbes within 200 steps
This sends the data to the output graph.


The World
Everyone
oil
microbes
Add Breed
Show Traits
Copy
Cut
Paste
Drag here
while run model toggled
if Current speed (0-10) slider value != 0
set my heading to Current direction (0-360) slider value
left by random 0 to 90 degs
right by random 0 to 90 degs
forward Current speed (0-10) slider value
else
set my heading to random 0 to 359
left by random 0 to 90 degs
right by random 0 to 90 degs
forward .5
on collision with oil
do
delete agent collidee
with 20 % chance
create 1 microbes (s)
This is the code that instructs the microbe to consume the oil and reproduce
This instructs the microbes how to move based on ocean currents



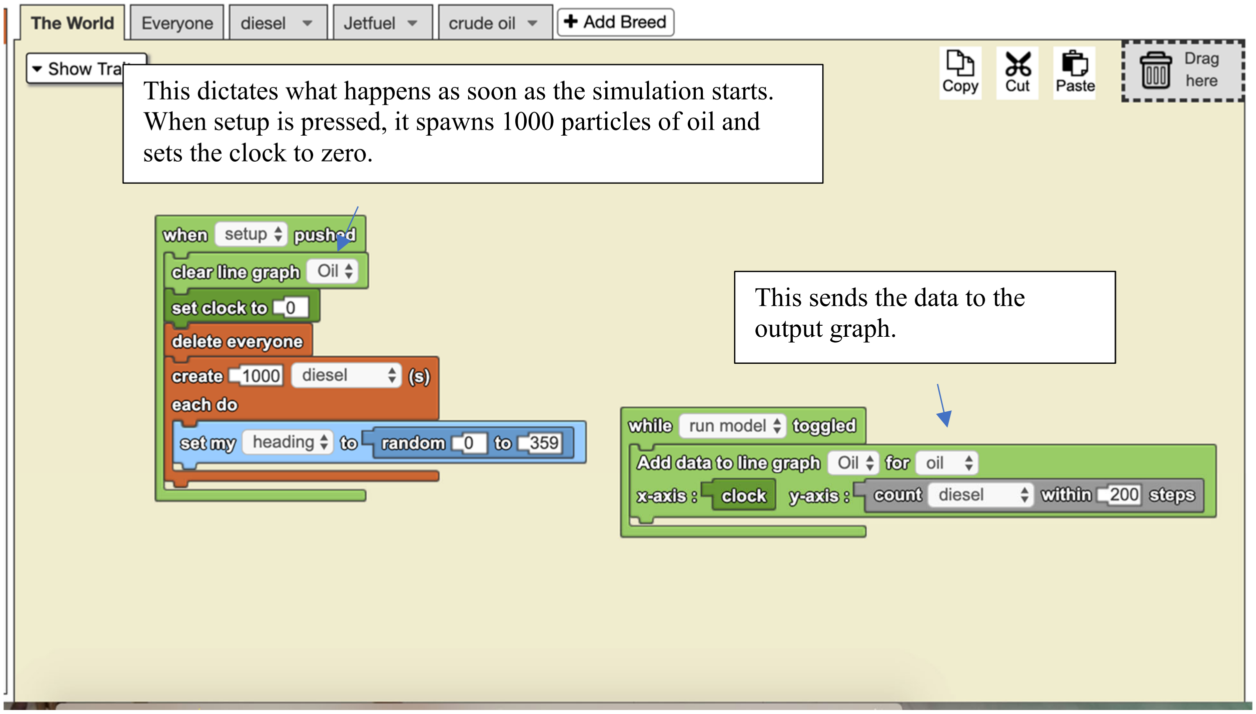
To run the model, click “run model” and ensure that the off/on button is green. Next, click “setup” to add oil to the simulation. It’s recommended to let the model run for 5-10 seconds to observe the movement and behavior of oil particles before clicking “save ocean”, which introduces oil-eating microbes.

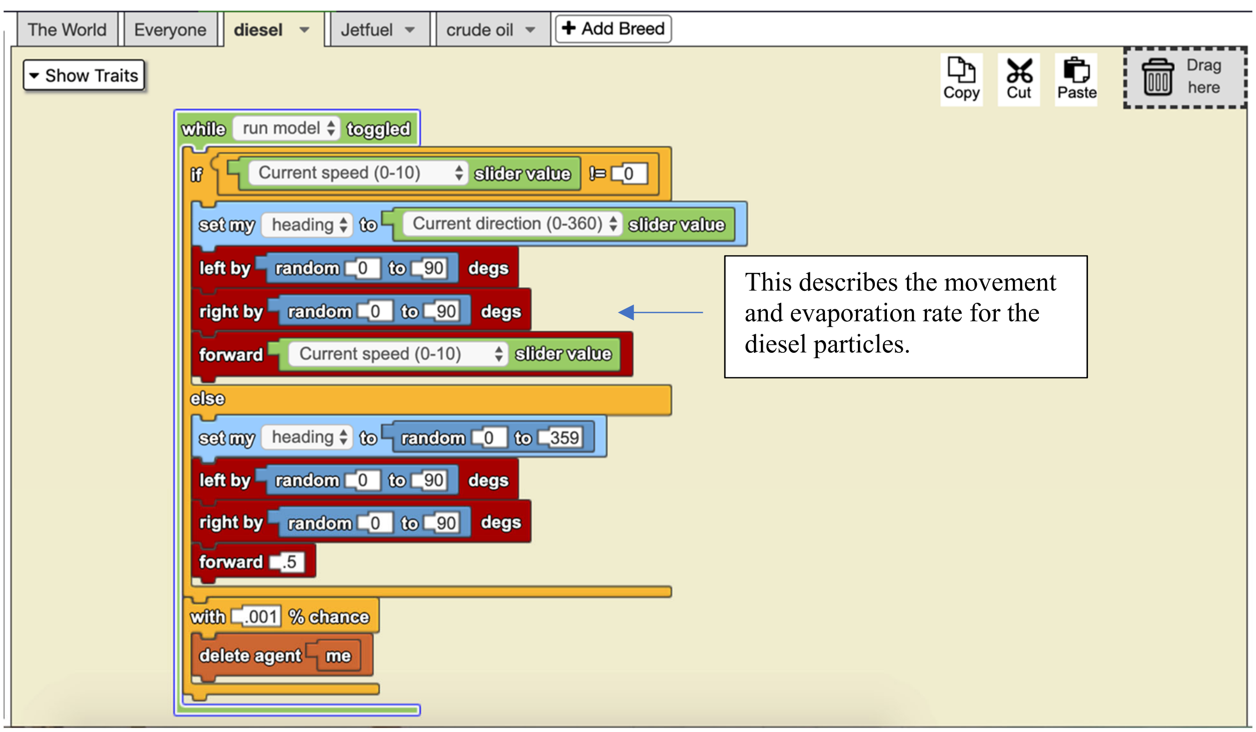


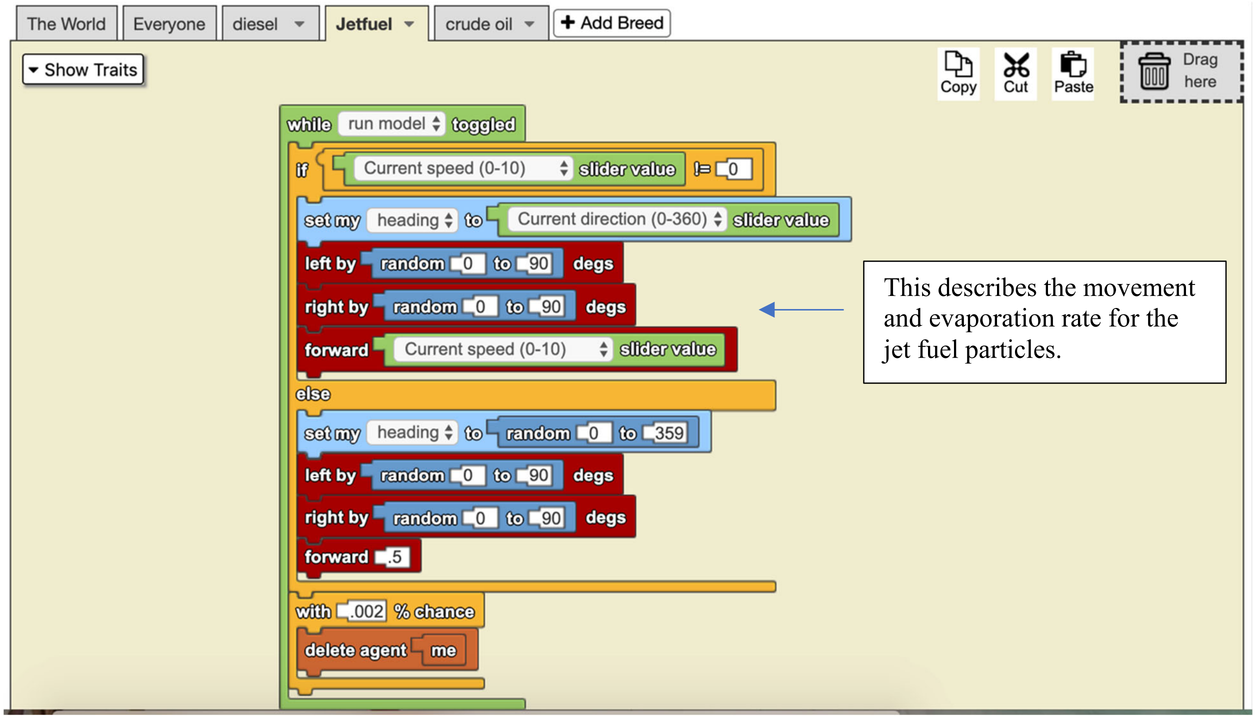
b. Different types of oil evaporate at different rates. Jet fuel evaporates at a rate of .002 percent per time unit. Diesel evaporates at a rate of .001 percent per time unit. Crude oil evaporates at a rate of .0005 percent per time unit.

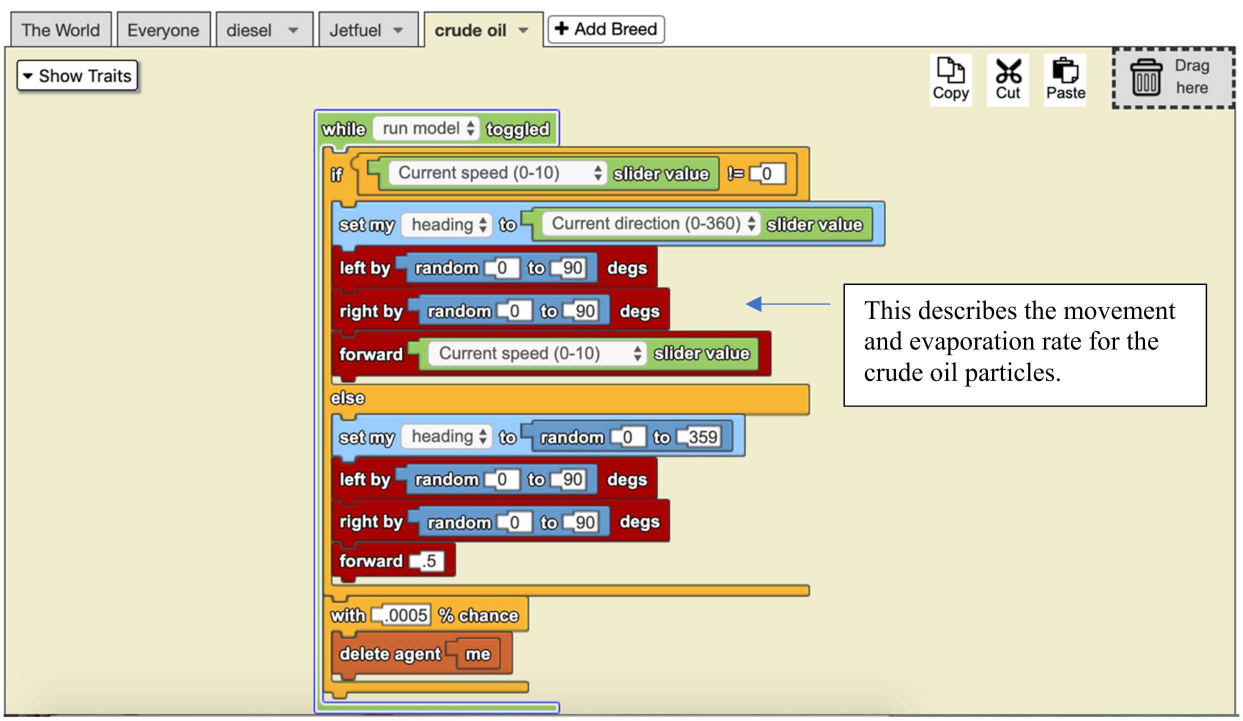
In real life, there comes a point where oil stops evaporating and either sinks or goes into the food chain. Due to limitations of the modeling software, this is difficult to include in the model.

The following screenshots show an example of how an oil evaporation model can be set up. Note that there are several pages that can be toggled between, shown at the top.

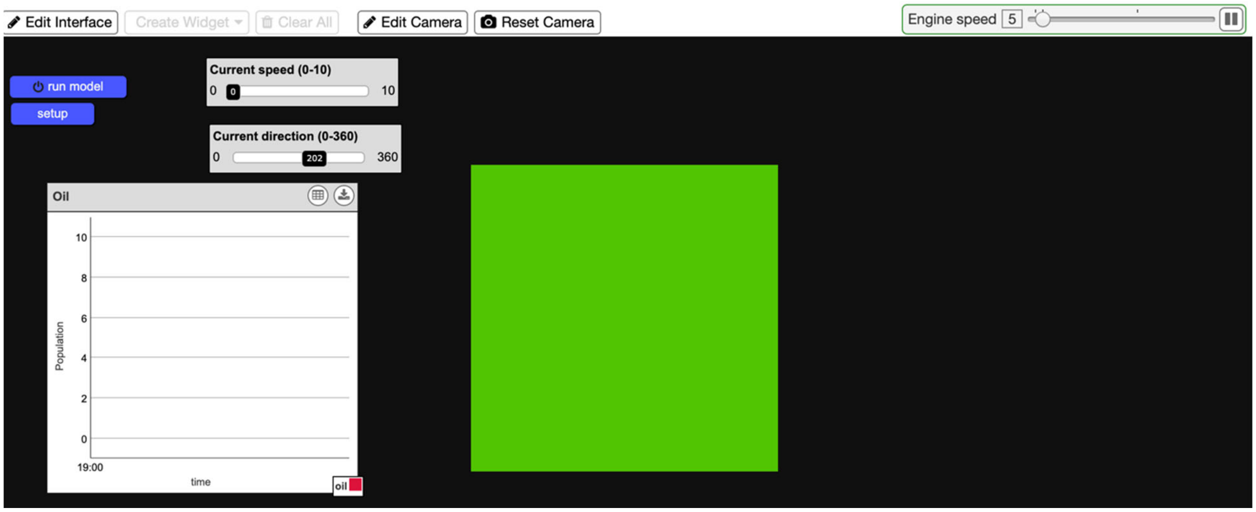

The World
Everyone
diesel
Jetfuel
crude oil
+ Add Breed
Show Traits
Copy
Cut
Paste
Drag here
This dictates what happens as soon as the simulation starts. When setup is pressed, it spawns 1000 particles of oil and sets the clock to zero.
when setup pushed
clear line graph Oil
set clock to 0
delete everyone
create 1000 diesel (s)
each do
set my heading to random 0 to 359
This sends the data to the output graph.
while run model toggled
Add data to line graph Oil for oil
x-axis : clock y-axis : count diesel within 200 steps


The World
Everyone
diesel
Jetfuel
crude oil
+ Add Breed
Show Traits
Copy
Cut
Paste
Drag here
while run model toggled
if Current speed (0-10) slider value != 0
set my heading to Current direction (0-360) slider value
left by random 0 to 90 degs
right by random 0 to 90 degs
forward Current speed (0-10) slider value
else
set my heading to random 0 to 359
left by random 0 to 90 degs
right by random 0 to 90 degs
forward .5
with .001 % chance
delete agent me
This describes the movement and evaporation rate for the diesel particles.



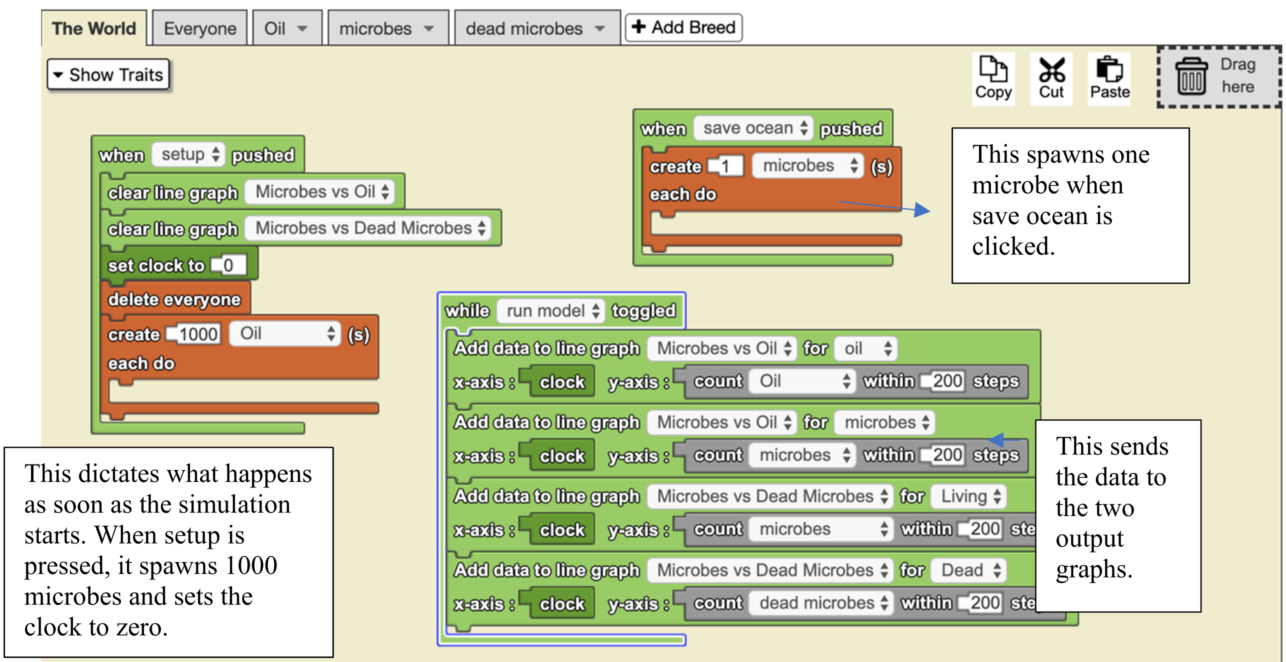


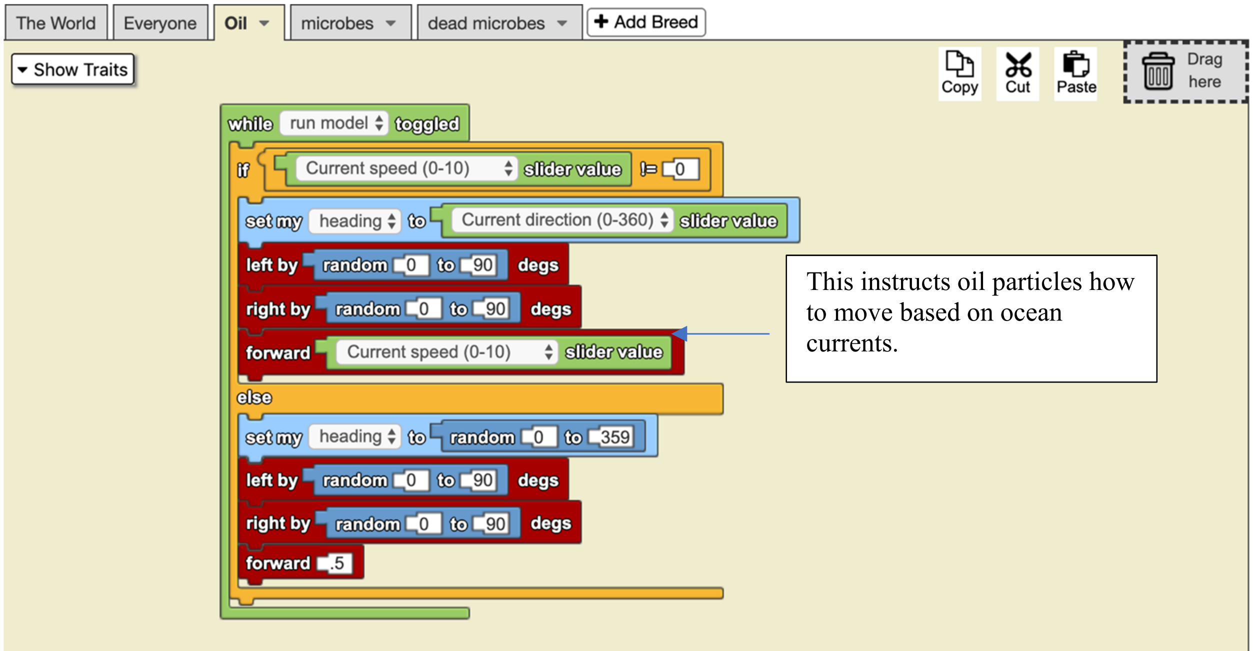
To run the model, click “run model” and ensure that the off/on button is green. Next, click “setup” which will add the oil particles to the model which will then start to evaporate.



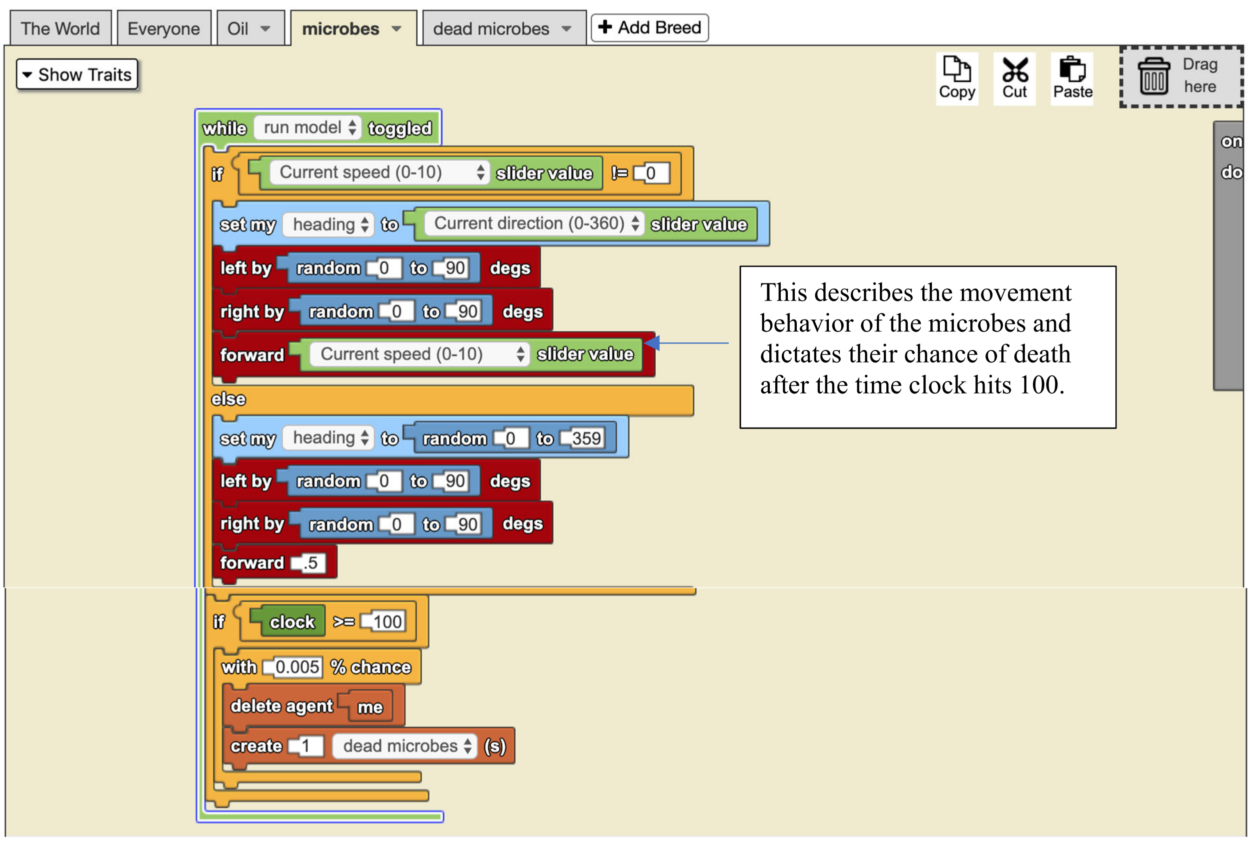
c. Oil-consuming microbes will reproduce rapidly in the presence of oil, but as oil runs out, the microbes die off. This die-off starts to happen after 100 time units and there is a .005 percent chance of dying per time unit after 100. Once they die, microbes will sink to the bottom.

The counter for time units begins when the first microbe is created, as that starts the process of using up the oil as a food source.

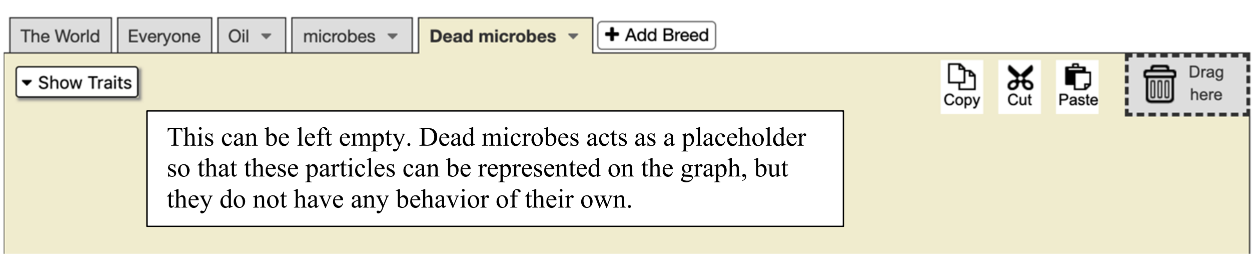




This instructs oil particles how to move based on ocean currents.



This describes the movement behavior of the microbes and dictates their chance of death after the time clock hits 100.



This can be left empty. Dead microbes acts as a placeholder so that these particles can be represented on the graph, but they do not have any behavior of their own.

Now that you and your partner have developed a computer-based mathematical model for the fate of oil, share your work.

StarLogo Nova will give you the option of creating a graph from your data.

Conclusion questions:

1. Which options did you choose for your final model?

   Answers may vary.

2. What was the most challenging part of programming?

   Answers may vary.

3. Could you use this model to predict what would happen in the Gulf of Mexico?

   This model can be used to predict what would happen in the Gulf of Mexico, because it includes many ways for the oil to leave the system. However, it is still incomplete.

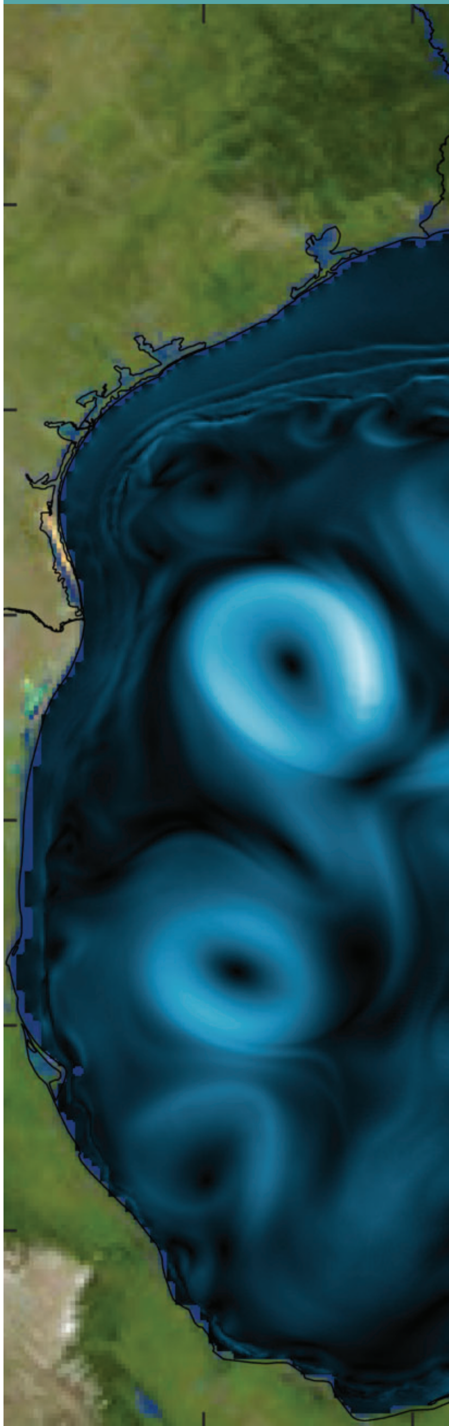
4. What other features of the system could be included in this model to make it a more realistic representation of the Gulf of Mexico?

   Examples may include: human oil removal efforts, wind and waves, rough weather, movement in the Loop Current, ocean bathymetry and interaction with landmasses/shorelines, continued leaking of oil, reactions with chemical dispersants, etc.

This page intentionally left blank

The Deepwater Horizon oil spill resulted in an unprecedented commitment to study and better understand different aspects of the fate of oil released in northeast region of the Gulf of Mexico in 2010. Countless research teams have spent considerable resources developing modeling tools, collecting and analyzing measurements, and performing scientific studies to understand different aspects governing the eventual fate of the oil. Together, these data have provided the basis for development of vastly improved modeling tools for tracking the distribution and chemical evolution of oil. But one area where our understanding remains quite limited is the role that microbes play in determining the eventual fate of oil and its impact on ecosystems, and how these processes depend on environmental conditions (hydrographic and biogeochemical properties of the water and circulation), hindering predictive capability.

The CSOMIO project is working to synthesize the technology, tools, and scientific knowledge of a group of individual investigators some of whom, since the Deepwater Horizon event, have immersed themselves in this study. The Consortium also brings to the study investigators who can fill critical gaps in our ability to numerically model the transport and fate of oil in coastal waters. The goal is to produce a comprehensive framework for simulating and understanding the role that microbes play in mitigating the impacts of oil spills. This model system will be an open source product that can potentially be run in a variety of locations with different physical forcing models. Expected outcomes include the ability to predict the impact of oil spills occurring under different temperature, hydrodynamic, and biogeochemical regimes, a consistently annotated synthesis of genomic and transcriptomic data for the Gulf of Mexico, and the elucidation of mechanisms relating hydrocarbon degradation to microbial community dynamics, flocculation, and sediment transport processes.



CSOMIO

Consortium for Simulation of
Oil-Microbial Interactions in the Ocean