Charting the Tides:

Exploring the causes and effects of the tides

Lesson plan developed by:

North Carolina KING TIDES PROJECT

Summary

This three-part lesson plan will provide information about tides, the relationships between tides and water levels, and the impacts that high water levels can have on coastal communities. The first part of the lesson will explain how the moon and sun's gravitational pull on the Earth create tides. The different types of tides (Spring, Neap, high, low) will also be reviewed. The second part of the lesson will require the students to graph real tidal data and complete an analysis from their resulting graphs. The last part of the lesson will be a discussion about the influence that high water levels caused by extreme tides can have on coastal communities. This lesson was inspired by the North Carolina King Tides (NCKT) Project, a citizen science project initiated to raise community awareness about the potential impacts of sea-level rise. The extension activity will explain how students can contribute to the NCKT Project as a classroom activity or on their own.

Materials

- Low tide and high tide photos (Appendix)
- 5 white foam balls on a stick (1 per group) – **6th Grade Only**
- 5 flashlights (1 per group) – **6th Grade Only**
- 30 bags of Mini Oreos (1 per student) – **4th Grade Only**
- 30 popsicle sticks (1 per student) – **4th Grade Only**
- Laptops – necessary for 6th grade; optional for 4th grade
- Tidal Chart (Appendix)
- Activity Worksheets and Keys for 4th & 6th grade (included)

Duration

- 45 minutes – 1 hour

Grade Levels

- 4th & 6th

Setting

- Indoors/Classroom

Vocabulary

Tides (High and Low)
Gravitational pull
Lunar phases - New, First Quarter, Full, and Third Quarter
Neap tides
Spring tides
Mean
Range

Objectives

- Explain the difference between high and low tides and how they are created
- Demonstrate how the moon and sun's gravitational pull on the Earth creates tides
- Sketch the alignment of celestial bodies and identify the resulting tide
- Analyze real tidal data and construct plots of the data
- Interpret tidal graphs to determine mean and range of data
- Propose an explanation of how water level is influenced by tides

North Carolina Essential Standards

- 4.E.1: Explain the causes of day and night and phases of the moon
    - 4.E.1.1: Explain the cause of day and night based on the rotation of Earth on its axis.
    - 4.E.1.2: Explain the monthly changes in the appearance of the moon, based on the moon's orbit around the Earth.
- 6.E.1: Understand the earth/moon/sun system, and the properties, structures, and predictable motions of celestial bodies in the Universe.
    - 6.E.1.1: Explain how the relative motion and relative position of the sun, Earth and moon affect the season, tides, phases of the moon, and eclipses.

Common Core Mathematics Standards

- CCSS.Math.Content.4.MD.B.4: Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Solve problems involving addition and subtraction of fractions by using information presented in line plots.
- CCSS.Math.Content.6.SP.B.4: Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
- CCSS.Math.Content.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by:
    - CCSS.Math.Content.6.SP.B.5.a: Reporting the number of observations.
    - CCSS.Math.Content.6.SP.B.5.b: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
    - CCSS.Math.Content.6.SP.B.5.c: Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
    - CCSS.Math.Content.6.SP.B.5.d: Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

Common Core English Language Arts Standards

- CCSS.ELA-Literacy.W.4.1: Write opinion pieces on topics or texts, supporting a point of view with reasons and information.
    - CCSS.ELA-Literacy.W.4.1.a: Introduce a topic or text clearly, state an opinion, and create an organizational structure in which related ideas are grouped to support the writer's purpose.
    - CCSS.ELA-Literacy.W.4.1.b: Provide reasons that are supported by facts and details.

    - CCSS.ELA-Literacy.W.4.1.c: Link opinion and reasons using words and phrases (e.g., *for instance*, *in order to*, *in addition*).
    - CCSS.ELA-Literacy.W.4.1.d: Provide a concluding statement or section related to the opinion presented.
- CCSS.ELA-Literacy.SL.4.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.
    - CCSS.ELA-Literacy.SL.4.1.a: Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
    - CCSS.ELA-Literacy.SL.4.1.b: Follow agreed-upon rules for discussions and carry out assigned roles.
    - CCSS.ELA-Literacy.SL.4.1.c: Pose and respond to specific questions to clarify or follow up on information, and make comments that contribute to the discussion and link to the remarks of others.
    - CCSS.ELA-Literacy.SL.4.1.d: Review the key ideas expressed and explain their own ideas and understanding in light of the discussion.
- CCSS.ELA-Literacy.SL.4.4: Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
- CCSS.ELA-Literacy.W.6.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1-3 above.)
- CCSS.ELA-Literacy.SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- CCSS.ELA-Literacy.SL.6.2: Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.
- CCSS.ELA-Literacy.SL.6.4: Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

Next Generation Science Standards:

- MS-ESS1: Earth's Place in the Universe
    - MS-ESS1-1.: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Background Materials for Teachers

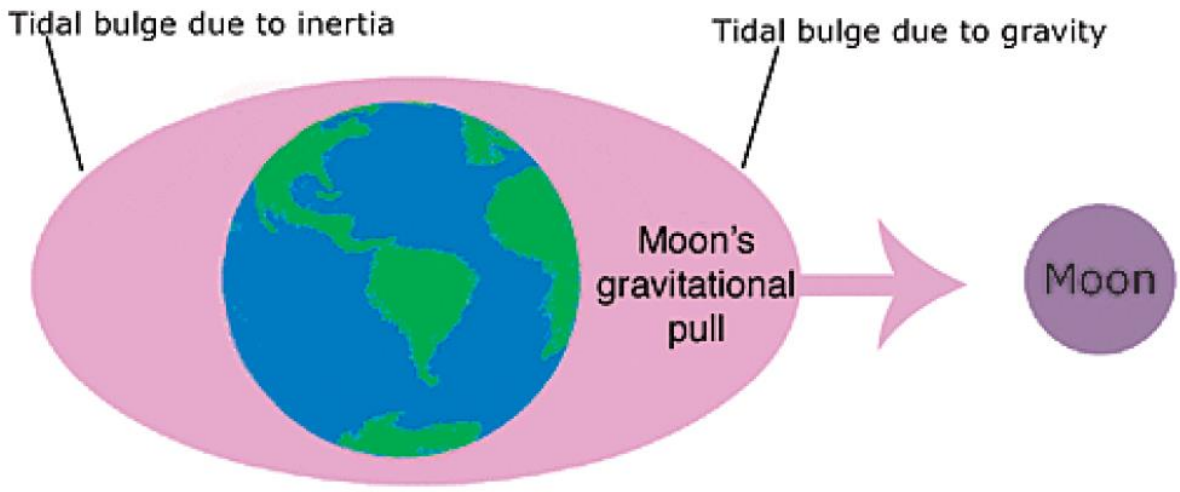
Video “How Do Tides Work?”: https://www.youtube.com/watch?v=5ohDG7RqQ9I

Video “Moon Phases Demonstration”: https://www.youtube.com/watch?v=wz01pTvuMa0

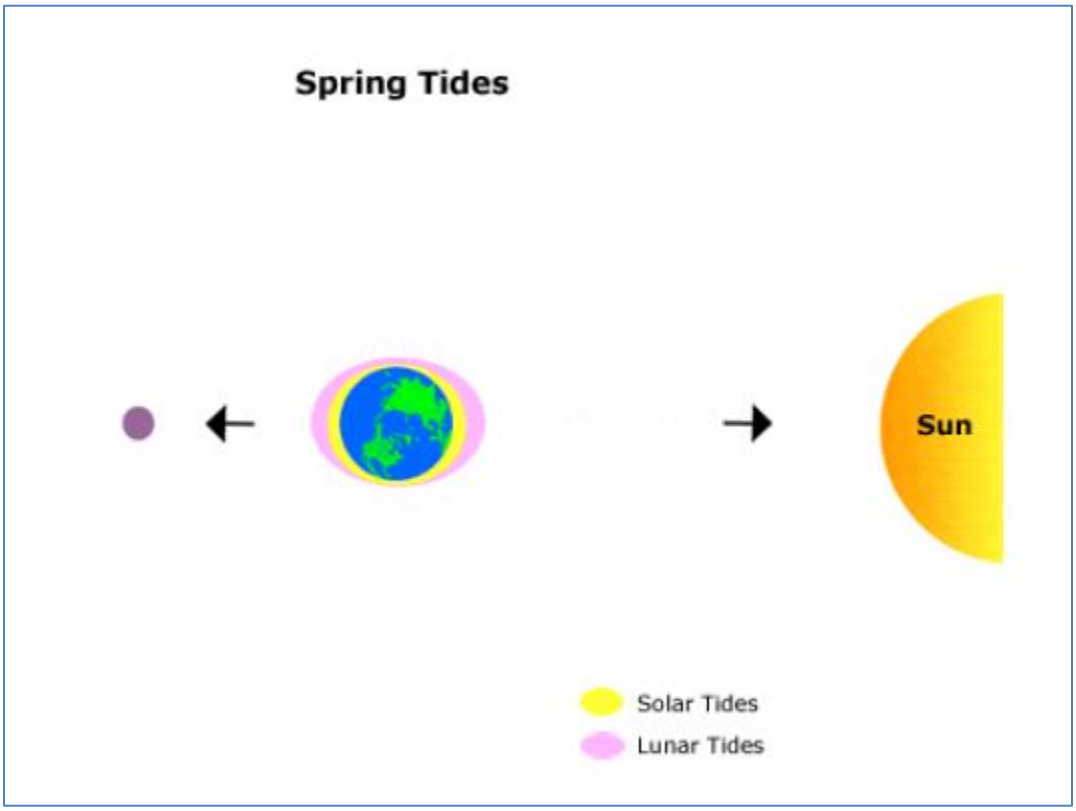
What are tides?

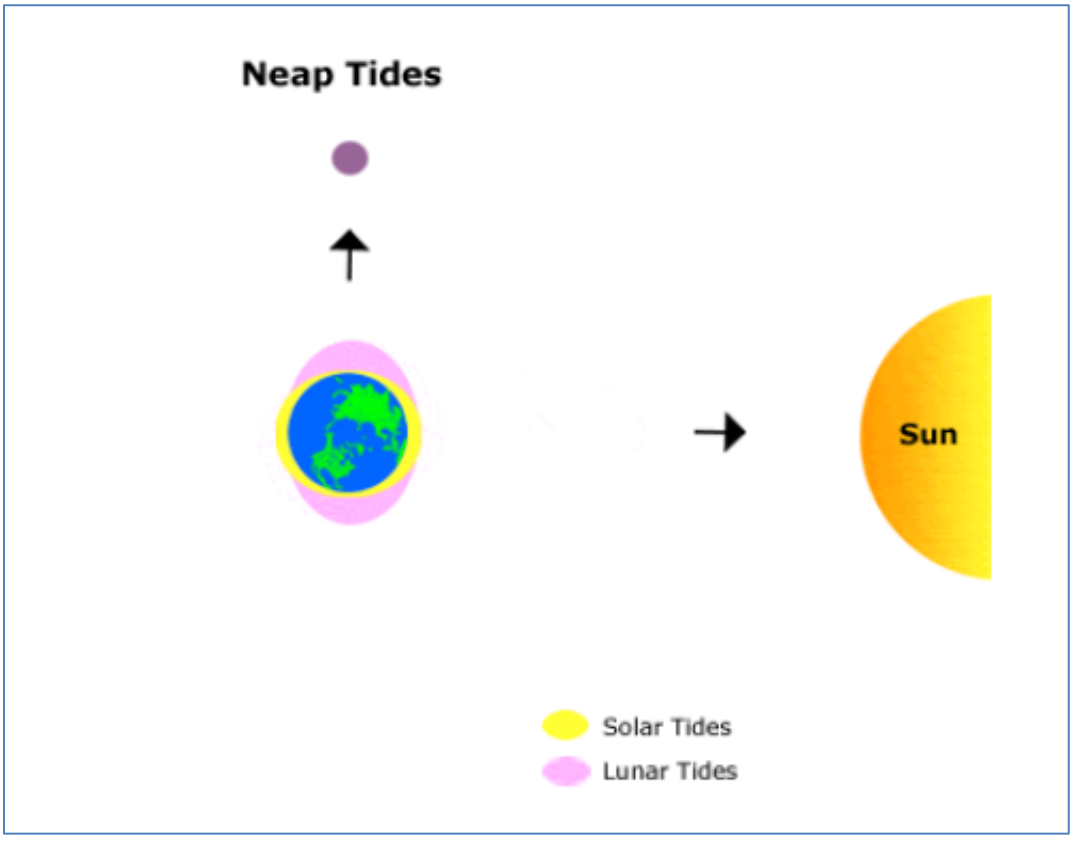
Tides are a period wave that move through the oceans causing the seas surface to rise and fall. When the crest of the “tidal wave” reaches a particular location this is known as high tide, and the trough of the wave is known as low tide. This pattern is most noticeable along the coastline where the shifting of water can be seen in reference to the water’s height on the beach or coastal structure.

Tides are generated by the gravitational attraction of the moon and Sun on the Earth. Distance is a more highly weighted variable than mass when concerning tidal generation, therefore the moon has the greatest effect on the ocean’s tides than the sun. The gravitational pull of the moon is greatest on the side of the Earth that is facing the moon, which causes the water on that side to be pulled toward the moon. Inertia counterbalances the pull of gravity and “attempts” to keep the water in place. On the side of the Earth where the moon is closest, gravity exceeds inertia causing a “bulge” of water on the near side toward the moon. On the opposite side of the Earth inertia exceeds the gravitational pull and keeps the water moving in a straight line creating another bulge.

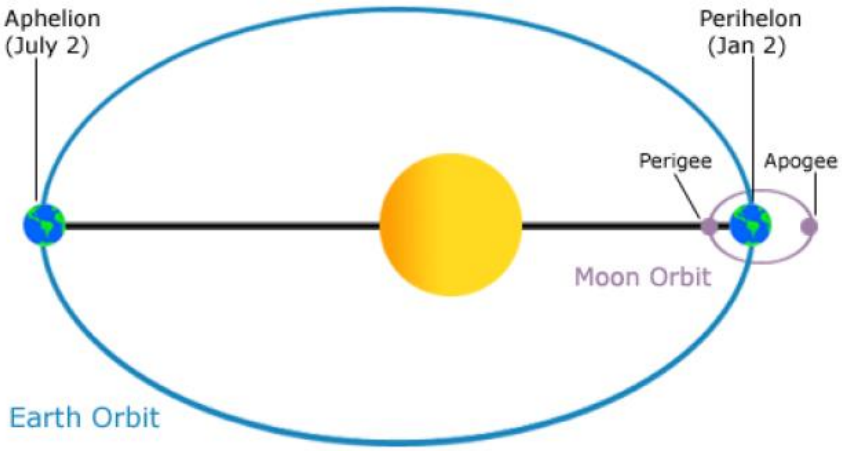


When the Sun, moon, and Earth are all in alignment the “solar tide” has an additive effect on the lunar tide. This creates higher high tides, and lower low tides, both are often referred to as spring tides. When the sun and moon are at right angles to each other the solar tide has an opposing effect on the lunar tide leading to a moderate tidal levels, often referred to as neap tides.


Spring Tides
Sun
Solar Tides
Lunar Tides

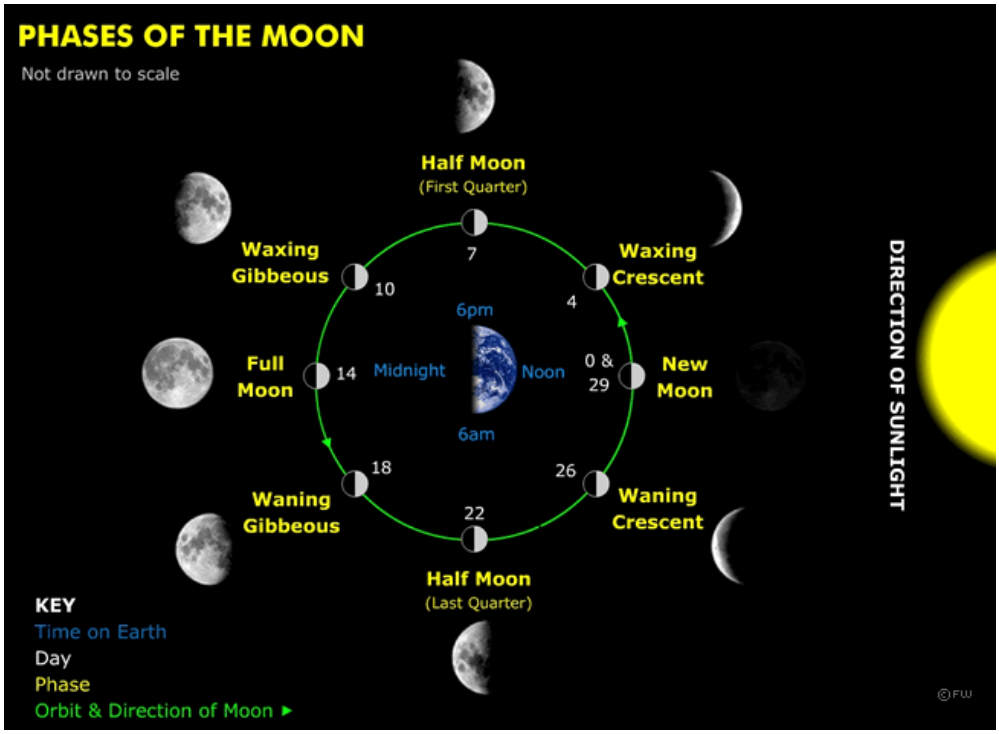

Neap Tides
Sun
Solar Tides
Lunar Tides

In addition, the sun and moon follow elliptical orbits around the Earth, which also affects tide levels. When the moon is closest to the Earth (perigee) tide generating forces are the greater than usual, and when it's farthest from the Earth (apogee) tidal forces are smaller than usual.



This causes higher and lower than normal tidal ranges. Similarly, when the Earth is closest to the sun tides (perihelion) are higher, and when it's farther from the Earth (aphelion) tides are lower.

Most coastal areas experience two high, and two low, tide events every lunar day. A lunar day is the time it takes for a specific point on Earth to complete a full rotation in relation to the moon. Unlike the 24-hour solar day that we are all familiar with, a lunar day is 24-hours and 50-minutes. This means that high tides occur every 12-hours and 25-minutes.



Activity Overview

Engage

Show students the picture to the right and prompt them to think about the following questions:

- What is the difference between the two pictures?
- What might be causing the difference between the two pictures?
- How might tides affect the coastal community?

Additional questions to ask the students could include:

- Have you ever witnessed a very high or low tide?
- Have you ever driven, walked, or biked through flooded streets during a high tide?

Explore

Show the "How do Tides Work" video:
https://www.youtube.com/watch?v=5ohDG7RqQ9I&t=45s

You may either break the students up in to groups to do this activity or you may do it all together as a class:

1) Form a tight circle while standing and have students interlock their elbows and face inward. *This circle is a very simplistic model of the Earth if it were covered with water at a consistent depth.*
2) One student will remain on the outside of the circle and will represent the moon by walking slowly around the outside of the circle. As the moon passes by, the students in the circle who are nearest the moon lean toward it. The students the opposite side of the circle also bulge out, representing differential gravitational forces. If necessary, the teacher can stand in the middle of the circle and point to where students should lean outward. After the moon passes by, the students return to an upright position.
3) Have the moon stop at several points in the circle and let the class see where high and low tides are in relation to the moon's orbit. *High tides are the areas where the students*

are leaning out away from the center of the circle. Low tides are at the sides of the circle, halfway between the high tides.

4) In addition to the moon, have another student play the sun. Students can then repeat the previous activity with the combined gravitational pull of the moon and the sun. Remember the sun's gravitational pull is not as strong as the moon's.
5) Demonstrate the areas where the sun is in alignment with the moon (spring tide) and where the sun, Earth, and moon form a 90-degree angle (neap tide). *When the sun, Earth, and moon are in alignment, the tides are more extreme. When the sun, Earth, and moon form a 90-degree angle, the gravitational pull of the sun and moon mostly cancel each other out.*

Have students return to their seats and fill out Section 1 of the Activity Worksheet.

Explain

Prior to starting either of the following activities, you may wish to go over phases of the moon with your students so that they have some context.

4th Grade: Oreo Moon Phases: https://www.youtube.com/watch?v=xTmWltNgnx8

Students will use popsicle sticks to shape and cut the icing on Mini Oreos to represent the different phases of the moon. They can then fill out Section 2 of the Activity Worksheet by placing the Oreos on their paper in the proper location and labeling the different phases.

6th Grade: Moon Phases Demonstration: https://www.youtube.com/watch?v=wz01pTvuMa0

Using the foam moons and flashlights, have students get in to groups and demonstrate how the moon orbits around the Earth and causes different moon phases according to the video above. It might help to turn off the lights in the classroom so that the students can more clearly see the phases. Have students fill out Section 2 of the Activity Worksheet by coloring in the blank circles on the Moon Phases diagram to represent each phase of the moon and labeling each phase.

Elaborate

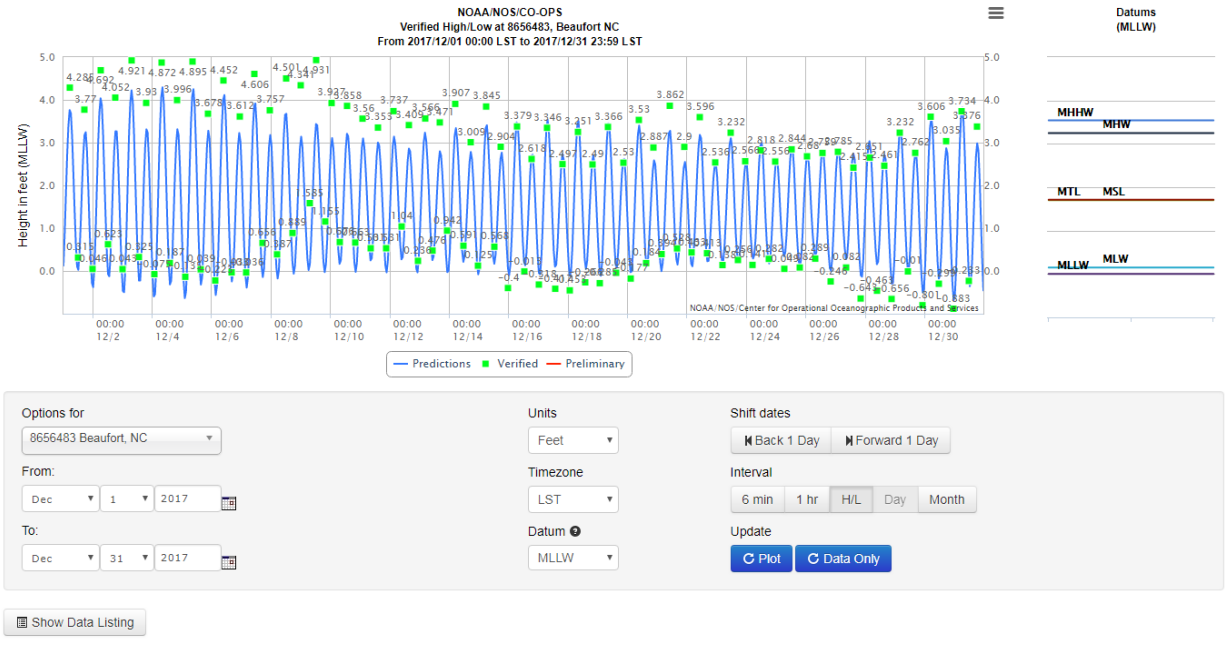
4th Grade: For this activity, students will be interpreting a tide chart from a North Carolina waterfront area. Show students how the tides and phases of the moon coincide to create different tidal extents and have them answer the questions on Section 3 of their worksheets. They can do this individually or as a group. Review the correct answers to this activity as a class.

The tide charts created by US Harbors are well suited for this activity and you may choose any month or location you like. You can either print out the tide chart, project it on a screen or have students navigate to the website on laptops. An example of a tide chart from January 2018 in Beaufort, NC is included in the Appendix.

6th Grade: For this activity, students will be interpreting real tidal data from North Carolina collected by the National Oceanic and Atmospheric Administration (NOAA) water level stations. On laptops, have students navigate to the NOAA Tides and Currents website: https://tidesandcurrents.noaa.gov/ .

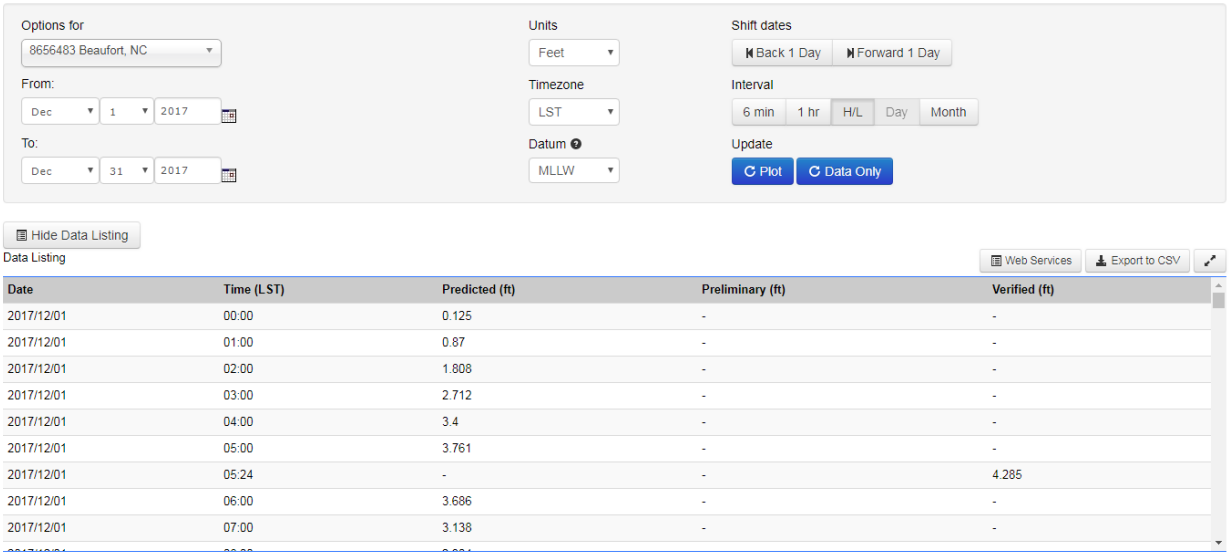
1) Once there, click on the tab labeled "PRODUCTS" → "TIDES/WATER LEVELS" →"Water Levels"
2) Scroll down to the North Carolina water level stations and select one of the six stations.
3) After you select a station, you will arrive at the station's website where all of the data is housed. If there is time, allow the students to explore this page and play with the data before they begin filling out Section 3 of the worksheet.
4) Select a one month time period in the "From" and "To" boxes. *Note: The time period selected needs to be a month at least two months behind the current month (data any sooner will not have been officially "verified" and will not suit the activity).* For the other parameters, select the following settings:
    - Units: Feet
    - Timezone: LST
    - Datum: MLLW
    - Interval: H/L

Click the "Plot" button. You should a screen that looks like the following:



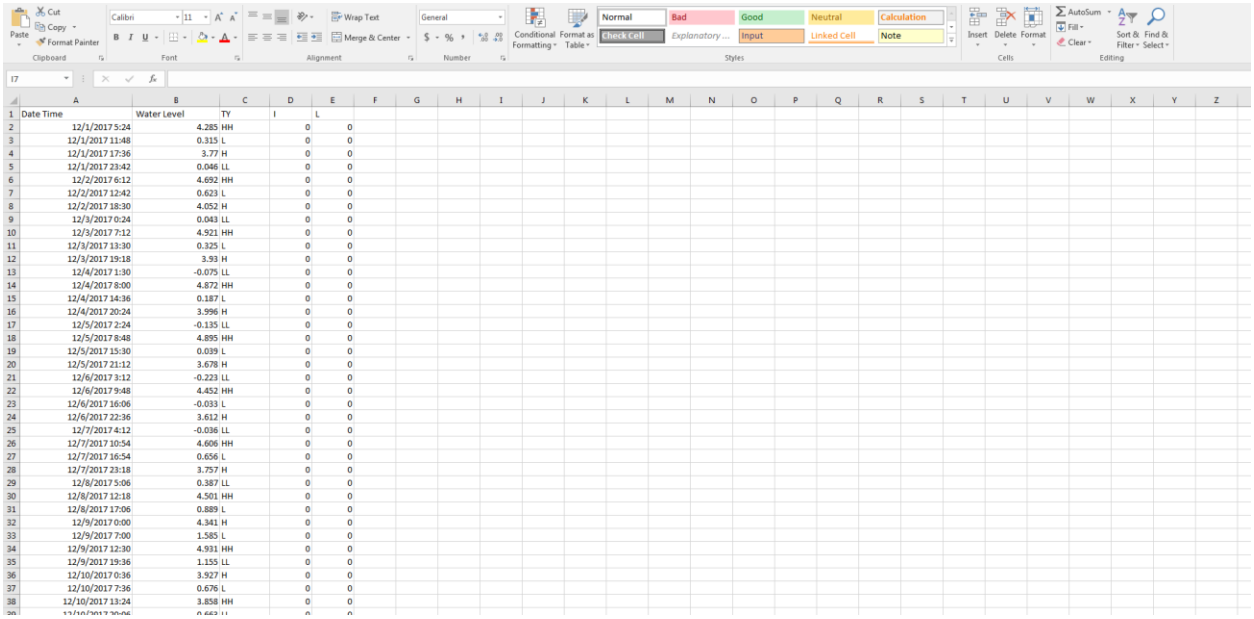
The blue lines show the predicted tides and the green dots (Verified) show the highs and lows that actually occurred each day. If you hover your mouse over any of the points, you should be able to see the date and time of each of the high and low tides.

If you continue to scroll down, you will see a button labeled “Show Data Listing”. If you click on this button, you should see the following:



Date	Time (LST)	Predicted (ft)	Preliminary (ft)	Verified (ft)
2017/12/01	00:00	0.125	-	-
2017/12/01	01:00	0.87	-	-
2017/12/01	02:00	1.808	-	-
2017/12/01	03:00	2.712	-	-
2017/12/01	04:00	3.4	-	-
2017/12/01	05:00	3.761	-	-
2017/12/01	05:24	-	-	4.285
2017/12/01	06:00	3.686	-	-
2017/12/01	07:00	3.138	-	-

This will show you a table of the data from the graph above. The values in the “Verified (ft)” column are the verified lows and highs that occurred (usually two highs and two lows per day). If you click on the “Export to CSV” button, you can download the data from the chart into an Excel Spreadsheet that should look like the following:



Date Time	Water Level	TY	I	L
12/1/2017 5:24	4.285	HH	0	0
12/1/2017 11:48	0.315	L	0	0
12/1/2017 17:36	3.77	H	0	0
12/1/2017 23:42	0.046	LL	0	0
12/2/2017 6:12	4.692	HH	0	0
12/2/2017 12:42	0.623	L	0	0
12/2/2017 18:30	4.052	H	0	0
12/3/2017 0:24	0.043	LL	0	0
12/3/2017 7:12	4.921	HH	0	0
12/3/2017 13:30	0.325	L	0	0
12/3/2017 19:18	3.93	H	0	0
12/4/2017 1:30	-0.075	LL	0	0
12/4/2017 8:00	4.872	HH	0	0
12/4/2017 14:36	0.187	L	0	0
12/4/2017 20:24	3.996	H	0	0
12/5/2017 2:24	-0.135	LL	0	0
12/5/2017 8:48	4.895	HH	0	0
12/5/2017 15:30	0.039	L	0	0
12/5/2017 21:12	3.678	H	0	0
12/6/2017 3:12	-0.223	LL	0	0
12/6/2017 9:48	4.452	HH	0	0
12/6/2017 16:06	-0.033	L	0	0
12/6/2017 22:36	3.612	H	0	0
12/7/2017 4:12	-0.036	LL	0	0
12/7/2017 10:54	4.606	HH	0	0
12/7/2017 16:54	0.656	L	0	0
12/7/2017 23:18	3.757	H	0	0
12/8/2017 5:06	0.387	LL	0	0
12/8/2017 12:18	4.501	HH	0	0
12/8/2017 17:06	0.889	L	0	0
12/9/2017 0:00	4.341	H	0	0
12/9/2017 7:00	1.585	L	0	0
12/9/2017 12:30	4.931	HH	0	0
12/9/2017 19:36	1.155	LL	0	0
12/10/2017 0:36	3.927	H	0	0
12/10/2017 7:36	0.676	L	0	0
12/10/2017 13:24	3.858	HH	0	0

The values in the “Water Level” column show the highs and lows that occurred (in feet) and the “TY” column tells you whether the value was the highest high (HH), high (H), low (L) or lowest low (LL) tide that occurred that day. Viewing the Data Listing table and downloading the CSV are not necessary steps for the students to be able to answer the questions on Section 3 of the worksheet. However, this step could allow students the chance to manipulate the data in Excel and produce their own graph. This may also be useful to you as you check their work.

Evaluate

4th Grade: Have students complete Section 4 of the Activity Worksheet. For the graphing activity, you may want to pre-select the four dates you want the students to graph.

6th Grade: Have students click on PRODUCTS → METEOROLOGICAL/OTHER → Astronomical Data. Then have them select the year and month on the left side of the page that coincides with their tidal data and click "Submit". This page will tell them when the different phases of the moon occurred during the month of their tidal data. Have them complete Section 4 of the worksheet using this astronomical data and the tidal data.

Both Grades: If there is time, you could have the students think about the possible impacts of higher water levels on coastal communities. You could do this by initiating a group discussion or have students write a paragraph about how higher water levels could affect the coast, specifically what/who it would impact.

Extension Activity (optional)

The mission of the international King Tides Project is to help people better understand the impacts of climate change on their local communities by looking at abnormally high tides. A king tide is a non-scientific term used to describe the predicted highest high-tide and lowest low-tide events of the year. King tides occur during a perigean (when Moon is closest to Earth) spring tide (full and new moon); in other words, a full or new moon must co-occur when the Moon is closest to Earth in its elliptical orbit. Due to their astronomical nature, king tides are regular and predictable events, reoccurring multiple times a year (click here to see the 2018 NC King Tides Calendar).

These king tide events are frequently associated with flooding, especially when accompanied by a storm. While these events are completely natural, they can help us visualize and forecast what our coastal communities may look like with sea-level rise. Therefore, these king tide events can help coastal planners and developers understand what actions we may need to take within our communities to prepare for the effects of sea-level rise. There are King Tides citizen science projects throughout the world and in many US states. In the fall of 2015, UNC Institute of Marine Sciences began the North Carolina King Tides Project.

We are asking citizen scientists, like you, to go out and take pictures at certain times of the year when we are expecting high tide events. These photos need to include a vertically stable benchmark that we can later measure to collect data on how high the water level was during the high tide event. Students and their parents, or teachers and the class (this would make a great field trip activity), can use their cameras or smartphones to take photos of high water events and then upload them to the Water Level Reporter GeoForm on the "What's your water level? app.

Materials

- Cameras or smartphones
- Ruler or measuring stick
- Clipboard
- Pen & paper
- Computers, access to internet

Procedure

1. **Check the calendar.** Click here to view the most recent NC King Tides Calendar to see when the next high water level event will be.
2. **Let us know!** Send us an email at nckingtides@gmail.com to tell us that you will be photographing a king tide or high water level event so that we can be on the lookout for your photos.
3. **Provide examples.** Prior to going in the field, show students examples of photos taken for the King Tides project (Click here to see previous photos).
    a. What evidence is present in the photos that suggest high or low tide events?
    b. Why do you think these sites were chosen?
    c. What types of sites do we want to choose that represent water level change over time?
4. **Plan your photo shoot.** Visit our website for tips on how to plan your photo shoot.
5. **Get in the field.** When out in the field, identify locations where high or low tide can be examined. We are particularly interested in photos of public places, but are open to all locations! ***Remember, safety is the number one priority! Be aware of slippery surfaces, currents, and waves.***
    a. Why might a particular location be a good place to observe tides over time?
    b. What might it look like if high tide conditions occurred more often in these locations?
6. **Send us your photos and reports!** Please visit our YouTube page for a video tutorial on how to upload your photos and reports using the Water Level Reporter GeoForm. You can look at all previous submissions (including your own) on the "What's you water level?" Web App.

References

https://www.teacherspayteachers.com/FreeDownload/Phases-of-the-Moon-Assessment-1080735

https://www.teacherspayteachers.com/Product/Phases-of-the-Moon-Cut-and-Paste-Phases-of-the-Moon-Calendar-2694832

https://naturebridge.org/sites/default/files/Gravity%20and%20Tides.pdf

https://homeschoolclipart.com/science/solar-system-clipart/phases-of-the-moon/

Tide chart from January 2018 in Beaufort, NC:

DATE		HIGH				LOW						
		AM	ft	PM	ft	AM	ft	PM	ft	RISE	SET	MOON
1	Mon	6:48	4.0	7:07	3.0	12:14	-0.8	1:16	-0.5	7:12	5:08	
2	Tue	7:41	4.1	8:01	3.1	1:09	-0.9	2:08	-0.6	7:12	5:09	
3	Wed	8:34	4.0	8:55	3.1	2:03	-0.9	2:58	-0.6	7:12	5:10	
4	Thu	9:26	3.9	9:50	3.1	2:55	-0.9	3:48	-0.6	7:13	5:11	
5	Fri	10:19	3.7	10:46	3.1	3:49	-0.7	4:41	-0.5	7:13	5:11	
6	Sat	11:11	3.4	11:41	3.0	4:47	-0.4	5:36	-0.4	7:13	5:12	
7	Sun			12:02	3.2	5:49	-0.2	6:32	-0.3	7:13	5:13	
8	Mon	12:35	3.0	12:52	2.9	6:53	-0.0	7:26	-0.2	7:13	5:14	
9	Tue	1:30	2.9	1:44	2.7	7:56	0.1	8:18	-0.2	7:12	5:15	
10	Wed	2:29	2.9	2:42	2.5	8:56	0.2	9:07	-0.1	7:12	5:16	
11	Thu	3:29	2.9	3:40	2.4	9:50	0.2	9:53	-0.1	7:12	5:17	
12	Fri	4:23	3.0	4:34	2.4	10:41	0.2	10:38	-0.2	7:12	5:18	
13	Sat	5:11	3.1	5:22	2.4	11:29	0.1	11:22	-0.2	7:12	5:19	
14	Sun	5:56	3.2	6:07	2.5			12:16	0.0	7:12	5:20	
15	Mon	6:38	3.3	6:49	2.5	12:06	-0.2	12:59	-0.0	7:11	5:20	
16	Tue	7:18	3.3	7:30	2.5	12:49	-0.3	1:38	-0.1	7:11	5:21	
17	Wed	7:57	3.3	8:10	2.5	1:29	-0.3	2:13	-0.1	7:11	5:22	
18	Thu	8:35	3.2	8:49	2.5	2:06	-0.3	2:47	-0.1	7:10	5:23	
19	Fri	9:13	3.2	9:28	2.5	2:43	-0.3	3:22	-0.1	7:10	5:24	
20	Sat	9:51	3.1	10:09	2.5	3:20	-0.2	3:57	-0.1	7:10	5:25	
21	Sun	10:30	3.0	10:51	2.6	4:00	-0.1	4:36	-0.1	7:09	5:26	
22	Mon	11:10	2.9	11:35	2.7	4:48	0.0	5:20	-0.1	7:09	5:27	
23	Tue	11:53	2.8			5:45	0.1	6:10	-0.1	7:08	5:28	
24	Wed	12:23	2.8	12:40	2.7	6:49	0.1	7:05	-0.2	7:08	5:29	
25	Thu	1:18	2.9	1:37	2.5	7:56	0.1	8:03	-0.3	7:07	5:30	
26	Fri	2:25	3.0	2:46	2.5	9:02	0.0	9:02	-0.4	7:06	5:31	
27	Sat	3:36	3.2	3:56	2.5	10:04	-0.1	10:01	-0.6	7:06	5:32	
28	Sun	4:40	3.4	4:59	2.7	11:05	-0.2	11:00	-0.7	7:05	5:33	
29	Mon	5:38	3.6	5:57	2.8			12:03 11:59	-0.4 -0.9	7:05	5:34	
30	Tue	6:33	3.8	6:52	3.0			12:59	-0.6	7:04	5:35	
31	Wed			7:45	3.1					7:03	5:36	

http://nc.usharbors.com/monthly-tides/North%20Carolina-South%20Shore/Beaufort/2018-01