Sea Grant
University of Southern California

Lesson: Sea Level Rise and King Tides

The purpose of this lesson is to increase student understanding of sea level rise impacts on our coastline and to increase student contributions to community citizen science efforts on sea level rise education.

Introduction

Two of the important environmental issues of our time are how to slow the rate of climate change and how to protect and sustain the health of coastal ecosystems. Coastal systems are especially vulnerable to climate change impacts such as ocean acidification, changes in ocean temperatures and sea level rise. The coast attracts people because of its beauty, environmental richness and economic values. It supports those near and far from the shores by providing food and other resources, trade and transportation, nurtures our souls and our need for outdoor recreation.

Global sea level rise is primarily attributed to changes in ocean volume due to two factors: melting of land-based ice and thermal expansion of seawater. The changes in air temperature have increased the melting of glaciers; land ice and continental ice masses contribute significant amounts of freshwater to the Earth's oceans. In addition, the increase of global air temperature creates an expansion of saltwater molecules, thereby increasing ocean volume. Planning for both the present and the future health and safety of our coastlines requires understanding long term trends in sea level and the relationship between global and local sea level changes.

Goals

1. Students will demonstrate increased knowledge about the impacts of sea level rise due to climate change and gain an understanding of the science and methods used to predict future sea level rise.

2. Students will engage in community science as volunteers by collecting and contributing photographic evidence of tidal heights during tidal extremes.

3. Students will effectively communicate their observations to King Tides Initiative and to members of their community.

4. Students will be able to explain the impacts of climate change caused sea level rise on environmental, biological and social systems and give examples of strategies used in adaptation efforts.

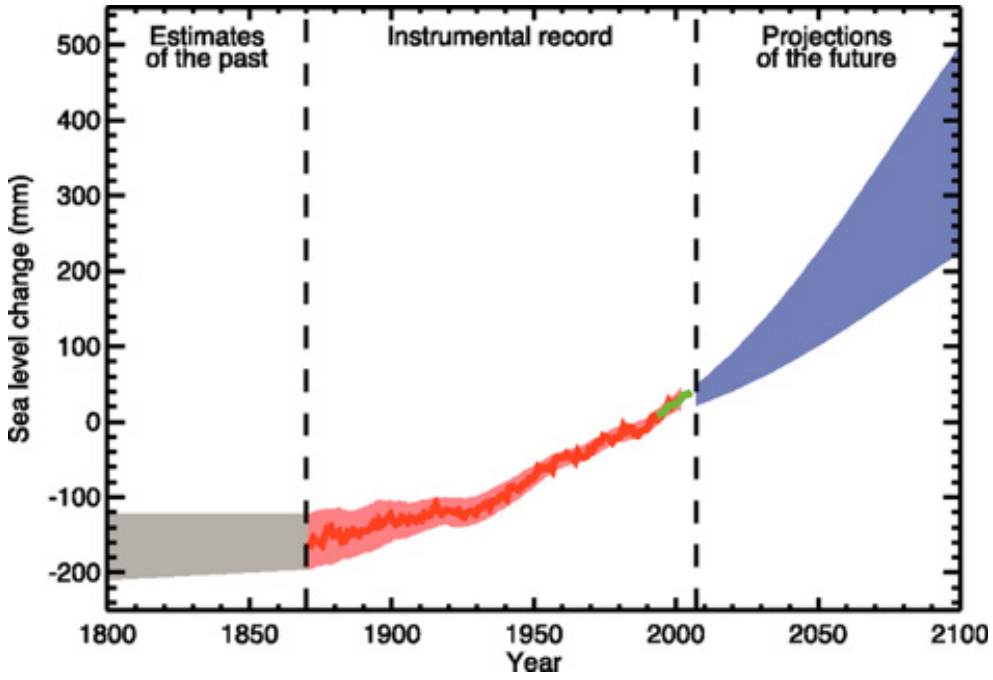
Background

The rate of sea level rise has continued to increase over the past two centuries, impacting coastal communities economically, environmentally, ecologically or culturally, and placing coastal communities on the front lines of climate change. While coastal areas only represent 17% of the continental land in the United States, over half of the population resides and works in coastal areas. These communities are on the front line and will directly experience the impacts of sea level rise in addition to other climate change impacts.

The impacts of climate change induced sea level rise include but are not limited to:

- increased storm frequency and flooding
- erosion and damage to man made structures
- loss of natural habitats, that impact jobs such as fisheries and tourism
- damage to structures such as roads and residences
- saltwater intrusion into drinking water supplies and agriculture areas

What is sea level rise and why does it matter? Sea level is the measure of height of the Earth's ocean. There are global, regional and local sea level measurements, which may differ as there are many factors that effect these measurements including tides, currents, seasonal, and decadal changes. Ice melt and thermal expansion of the ocean are the two main contributors to the sea level rise that has occured over the last century. While there was very little change in sea level over the two thousand years proceeding the end of the 19th century, since then the height has risen on average 1.7 mm/ year according to the IPCC report. This trend has increased over the last two decades where sea level has risen at a rate of more than 3 mm/year. Both coastal tidal gauges and satellite telemetry demonstrate these findings.



source: IPCC fourth Assessment on Climate Change 2007

Local sea level is a measure of the height of the ocean relative to a vertical point on land; typically a tide station measures local sea level. The land-water interface changes with subsidence (sinking of the Earth's surface) and in other cases land being pushed slowly upward, thus time must also be defined.

Daily sea level heights change with tides, storms, wind and melting or flooding. Long-term variations can include seasonal and decadal changes such as El Nino/La Nina conditions and Pacific Decadal Oscillation. Sea Level trends are measured over multiple decades to reduce errors and to account for these influences.

The IPCC report indicates with very high confidence that coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding and coastal erosion due to relative sea level rise over the next century. The report also indicates with high confidence that beaches, sand dunes and cliffs currently eroding will continue to do so under increasing sea level.

Additional explanation can be found at: http://climate.nasa.gov/key_indicators/

Thermal expansion explained http://ed.ted.com/featured/3KsJMLba

Materials

- Chart paper and pens
- Melting Ice, Rising Seas video animation
  http://pmm.nasa.gov/education/videos/melting-ice-rising-seas
- Internet access

** Prior knowledge: basic understanding of tides. NOAA's tides tutorial can be found at
http://oceanservice.noaa.gov/education/kits/tides/tides01_intro.html

Procedures

Engage

What do we know about climate change and sea level rise?

1. Ask the students what do they already know about sea level rise?

2. Create list of what they know, what they want to know, and what information they question or they would list as a misconception they've heard. These lists will be modified throughout this lesson.

3. Explain that sea level rise is one climate change impact. Ask students why is the issue climate change so prevalent in the news?

4. Assign students to review and share with the class an article or video on climate change; specifically sea level rise if possible. (Help students to define what is a trusted or credible source.)

Note to teacher: guide students to think about whether sea level rise will impact them individually.

5. Look at and update the established lists from the previous session based upon the student shared articles.

6. Have students view Melting Ice, Rising Seas NASA video:
http://pmm.nasa.gov/education/videos/melting-ice-rising-seas

7. Discuss what we know and what is still challenging for scientists studying sea level rise. Have students discuss how they think that these questions might be answered.

Explore

What evidence can we use to see potential and current changes in sea level rise?

King tides are the very highest tides that occur at each place. They:
- occur naturally and regularly
- are predictable and expected
- are not an every day occurrence

During extreme high tide events, we can get an idea of what a permanent rise in sea level might look like in our communities in the future.

Have students in small groups review the previously captured images of king tides from the list found in the Photo Links section or from other sources, and discuss the following questions in preparation to share their observations with the rest of the group.

Student questions:

1. What risks do you see from increased tidal levels?

2. How would you categorize the impact of the tide shown? (it may effect more than one area)
   a. effects public recreation and access
   b. effects coastal habitats
   c. effects coastal agriculture
   d. effects cultural resources
   e. effects coastal development
   f. effects groundwater aquifers - freshwater sources

3. Identify where and when the photo was taken and what the tide height was on that date. Have students report out to the group their findings.

- Why do they think that there are limited photos for each of the areas?
- Why would people want to take photos and contribute them to the project?

Discuss how scientists might use this array of photos including:

1. Document current flood risk in coastal areas
2. Visualize the impacts of future sea level rise in their community
3. Ground-truth and validate climate change models by comparing model predictions with the high-tide reality
4. Serve as a living record of change for future generations

See King Tides Initiative: http://california.kingtides.net/how-are-king-tides-photos-used/

Explain

How can we forecast sea level rise for the future?

The steady rise in sea levels has been attributed to both a warming expansion of the oceans and contributions from melting glaciers and land-based ice sheets. Climate modeling combined with direct observations from tidal gauges and satellites suggest sea level rise will continue well into the future with significant implications for California's coastal communities.

Satellites provide a measure of the sea surface height. To gain an understanding of how satellites have built our knowledge watch the Sea Level Viewer Overview at: http://climate.nasa.gov/interactives/sea_level_viewer

Some environments will be squeezed out or eroded with sea level rise; other terrestrial environments and populations will need to retreat from the coast to survive both economically and ecologically. Ascertaining how far to retreat to better ensure long-term success is difficult to determine without modeling.

Scientists use models to understand the universe. A model is a physical or mathematical representation that helps to explain a phenomena that cannot be directly observed due to scale or time. Models are critical to scientists being able to communicate their work. They serve as simplified illustrations and enable predictions of future conditions. Scientists use current and past data in testing their models to see if the model works with the available data; they are then able to predict what is likely to happen. Sometimes there are several models for the same question, so that scientists can test their ideas. Inaccuracy in a model sometimes results from not having enough data. Climate models are often computerized and need to be continually tested and revised as we gain new data, thus continuing to refine our knowledge about climate.

Together with the class look at sea level predictions found here http://coast.noaa.gov/digitalcoast/tools/slr, and discuss the following questions:

- What is expected to happen in your larger community?
- Which areas or surrounding areas are especially vulnerable?
- How will sea level rise effect recreation, infrastructure and residences?
- How will sea level rise effect you?
- If you plan to photograph for the King Tides Initiative, where would be the best location near you to photograph, and why?

More information on models can be found at:
- Scientific modeling and why scientists use models: http://sciencelearn.org.nz/%20Contexts/The-Noisy-Reef/Science-Ideas-and-Concepts/Scientific-modelling
- How do climate models work? http://www.epa.gov/climatechange/science/future.html

Elaborate — Contributing to Community Science

Join the King Tides Initiative by selecting areas in your region to take photos not only during the highest high tides of the year but also when there are extremely high waves or storm surge. Check your local tide chart for the tidal prediction. First of all be safe. Take extra precautions before you step on slippery surfaces and watch sets of waves to ensure where you are photographing will not put you in harm's way.

Some extraordinary images taken in coastal areas are in those areas subject to flooding and erosion, including places where high water levels can be gauged against familiar landmarks (such as buildings, breakwaters, roads, bridge supports, sea walls, staircases, dikes, and piers). A listing of recommended places to take pictures that contribute to specific projects can be found at http://california.kingtides.net/when/

Once you have taken pictures, submit your photos. Recommendations are found at: http://california.kingtides.net/share-pictures/

The pictures you take may help scientists better understand which areas are most at risk of flooding and future sea level rise. Researchers will compare your photos of the high tide against computer simulations of flooding to see how well these simulations match reality. This is a fun, easy way for you to provide important information that will help future sea level rise adaptation planning efforts.

Regional and local governments rely upon scientific data to help plan the best solutions and approaches to adapt to future sea level rise. Adaptation planning takes into account shifting environments and incorporates strategies to reduce economic and social risks. These strategies may include planned retreat, moving back from the coast, alternative building materials, installing more permeable surfaces, protective structures, increased flood proofing, identifying and protecting vulnerable populations, and much more.

More on the need for adaptation planning:
http://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate

Evaluate

How do you share what you have learned?

1. Have students serve as stewards and outreach to others by sharing a presentation about sea level rise for their chosen audience. This could include other classes at the school, a school newspaper article, students in another school, to community panels or others.

2. In the presentation, include an overview of what sea level rise is, how it is caused and what is the evidence we have for this, what are some of the risks to your community, and what can be done to reduce risks.

Student Worksheet

As a group discuss the risks from increased tidal level depicted in the photo and prepare to share your observations with the group.

1. Which risks from sea level rise apply to the area shown in your photo?

YES	NO	IMPACTS:
____	____	Effects coastal habitats
____	____	Effects coastal agriculture
____	____	Effects coastal resources
____	____	Effects coastal development
____	____	Effects groundwater aquifers – freshwater sources
____	____	Effects public recreation and access
____	____	Other:

2. What is the tidal variation and how high was the tide when your photo was taken? You may need to look up the tides for the date the photo was taken on line.

Photo location: _____
Date of photo: _____
Time of high tide: _____
Time of low tide: _____

3. Why do you think people would want to volunteer to take photos documenting extreme tidal heights?

4. Why do you think the photos we viewed were selected as examples?

5. Plan what you will report out to your group.

Photo Links

Marine Stadium, Long Beach, CA, January 31, 2014, 3:45 pm
https://www.flickr.com/photos/92644156@N07/12295409536/in/pool-cakingtides

Marine Stadium, Long Beach, CA, January 31, 2014, 8:45 am
https://www.flickr.com/photos/92644156@N07/12294841175/in/pool-cakingtides/

Tiberon, CA, Elephant Rock, December 31, 2013, 5:30 pm
https://www.flickr.com/photos/92644156@N07/12241300585/in/pool-cakingtides/

Tiberon, CA, Elephant Rock, December 31, 2013, 11:58 am
https://www.flickr.com/photos/92644156@N07/12241300245/in/pool-cakingtides/

Embarcadaro, San Francisco, January 2, 2014, 11:45 am
https://www.flickr.com/photos/92644156@N07/12091681333/in/pool-cakingtides/

Campus Point, Santa Barbara, CA, January 29, 2014, 8:48 am
https://www.flickr.com/photos/clairefackler/12213513974/in/pool-cakingtides/

Campus Point, Santa Barbara, CA, January 29, 2014, 8:44 am
https://www.flickr.com/photos/clairefackler/12213114965/in/pool-cakingtides/

Campus Point, Santa Barbara, CA, January 29, 2014, 2:51 pm
https://www.flickr.com/photos/clairefackler/12213513314/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, -1.26 tidal height
https://www.flickr.com/photos/tmikkphoto/12225141366/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, +7.75 tidal height
https://www.flickr.com/photos/tmikkphoto/12225142546/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, +7.75 tidal height
https://www.flickr.com/photos/tmikkphoto/12224962584/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, -1.26 tidal height
https://www.flickr.com/photos/tmikkphoto/12224962464/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014
https://www.flickr.com/photos/tmikkphoto/12225143436/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/12225143586/in/pool-cakingtides/

Bay Trail Sausalito, CA, January 1, 2014
https://www.flickr.com/photos/tmikkphoto/11700807984/in/pool-cakingtides/

Meeker Slough from Bridge at Marina Bay on Pt. Isabel Trail, December 30, 2013
https://www.flickr.com/photos/tmikkphoto/11680363763/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680113305/in/pool-cakingtides/

Buchanan Street Marsh, CA, December 30, 2013
https://www.flickr.com/photos/tmikkphoto/11680896956/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680896836/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680894606/in/pool-cakingtides/

Berkeley Pier, CA, December 30, 2013
https://www.flickr.com/photos/tmikkphoto/11680365373/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680475174/in/pool-cakingtides/

Embarcadaro, Pier 14, San Francisco, CA, January 29, 2014, 7:40 am
https://www.flickr.com/photos/tomhilton/12225011886/in/pool-cakingtides/

Tomales Bay Resort, Inverness, CA, December 31, 2013, 11:30 am
https://www.flickr.com/photos/113781824@N04/11830514475/in/pool-cakingtides/

Inverness Store Parking Lot, CA, 11:50 am, December 31, 2013
https://www.flickr.com/photos/113781824@N04/11830951314/in/pool-cakingtides/

Inverness Yacht Club, Tomales Bay, CA, December 31, 2013, 11:55 am
https://www.flickr.com/photos/113781824@N04/11830815193/in/pool-cakingtides/

Pacifica Pier, Pacifica, CA, December 1, 2012
https://www.flickr.com/photos/tmikkphoto/11700807984/in/pool-cakingtides/

Agriculture Building, Embarcadaro, San Francisco, CA, February 14, 2011
https://www.flickr.com/photos/daver6/5469222223/in/pool-cakingtides/

Kirby Park Nature Trail, August 8, 2013
https://www.flickr.com/photos/97276503@N02/9465737901/in/pool-cakingtides/

South Marsh, Elkhorn Slough Reserve, August 8, 2013,
https://www.flickr.com/photos/97276503@N02/9465712967/in/pool-cakingtides/

Tijuana River Estuary, August 6, 2013
https://www.flickr.com/photos/97276503@N02/9457519342/in/pool-cakingtides/

Common Core Standards

- CCSS.ELA-LITERACY.SL.6TH – 12TH GRADES.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. 6TH – 12TH GRADES.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. 6TH – 12TH GRADES.4

Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

- CCSS.ELA-LITERACY.SL. 6TH – 12TH GRADES.5

Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.

- CCSS.ELA-LITERACY.RST.9-10.7

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Climate Literacy Principals

- 5 Our Understanding of the Climate System is Improved through Observations, Theoretical Studies and Modeling - C

- 6 Human Activities are impacting the climate system

B, C, D

- 7 Climate Change will Have Consequences for the Earth System and Human Lives

A and D

Principles and concepts of climate literacy: http://www.cleanet.org/cln/climateliteracy.html

Ocean Literacy Principals

- 2 The ocean and life in the ocean shape the features of the Earth
- 6 The ocean and humans are inextricably interconnected

Principles and concepts can be found at: http://oceanliteracy.wp2.coexploration.org/

Resources

- Oceans climate dance poster and associated activities: http://sealevel.jpl.nasa.gov/education/posters/jason1poster/
- Tips and tricks for using NASA's global climate change website: http://climate.nasa.gov/education/TipsandTricks/
- Windows to the Universe climate and sea level rise: http://www.windows2universe.org/earth/climate/cli_sea_level.html
- Windows to the Universe: How Climate Models Work: http://www.windows2universe.org/earth/climate/cli_models3.html
- Common misconceptions about climate change: http://cires.colorado.edu/education/outreach/climateCommunication/CC%20Misconceptions%20Handout.pdf
- NOAA's frequently asked questions about sea level: http://tidesandcurrents.noaa.gov/sltrends/faq.htm#q1
- NASA 2-minute video role of carbon in climate change - The Carbon Crisis in 90 seconds: https://www.youtube.com/watch?v=nm8jat5VI_g
- NASA video - Oceans of Climate Change: http://climate.nasa.gov/climate_reel/
- NASA video - Melting Ice Rising Seas, includes scientist interviews: http://pmm.nasa.gov/education/videos/melting-ice-rising-seas
- Sporadic Events: Monterey Bay: Sanctuary Integrated Monitoring Network: http://sanctuarysimon.org/news/index.php/2013/01/2012-california-king-tides/