Tide Talk - Research Guide #3

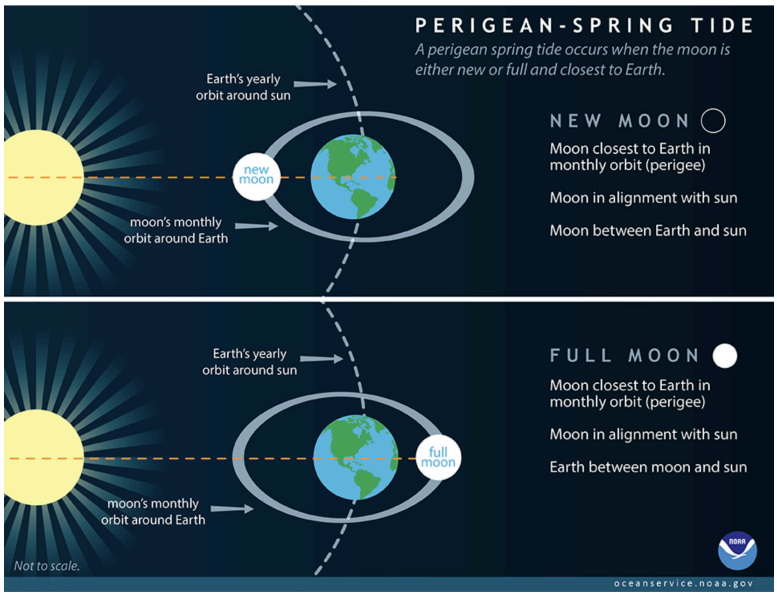
Perigean Spring Tides (aka “King Tides”)

Short video explaining high-tide flooding:

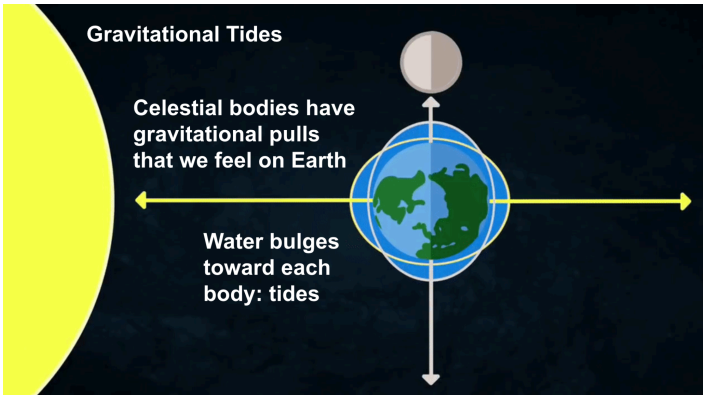
Check out this video from the National Oceanic and Atmospheric Administration (NOAA) on why flooding occurs during some of the highest tides of the year.

What are perigean spring tides or “King Tides”?

“King Tides” is a non-scientific term that describes some of the highest tides of the year. The exact definition of a “King Tide” can vary from place to place. In North Carolina, the term is typically used to refer to a perigean spring tide, that is when the moon is either New Moon or Full Moon AND the moon is closest in its orbit to Earth. Before we explain the concept of perigee and spring tides, and why together these cause some of the highest tides of the year, we need some basic understanding of what causes variations in tides.



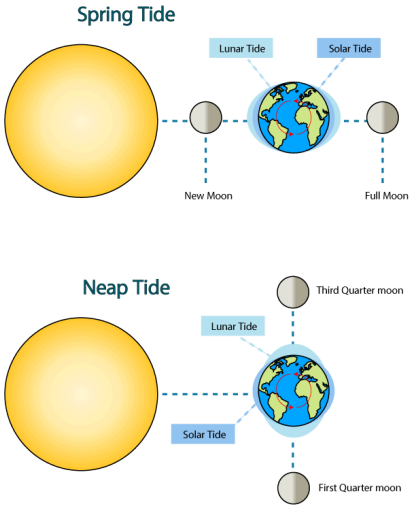
Tides are caused by celestial bodies, the moon and Sun, which have gravitational pulls that we feel on Earth. As shown in the idealized earth-moon-sun schematic below, these gravitational pulls produce bulges toward each celestial body which are the tides. (There is also a bulge generated away from the celestial bodies due to inertia.) We spin on our axis every 24 hours (relative to the sun), so the solar tidal period is 12 hrs. But the Moon is also orbiting Earth (travels some distance everyday). The “Lunar Day” is 24 hours and ~50 minutes and therefore the lunar tidal period is 12.42 hrs.

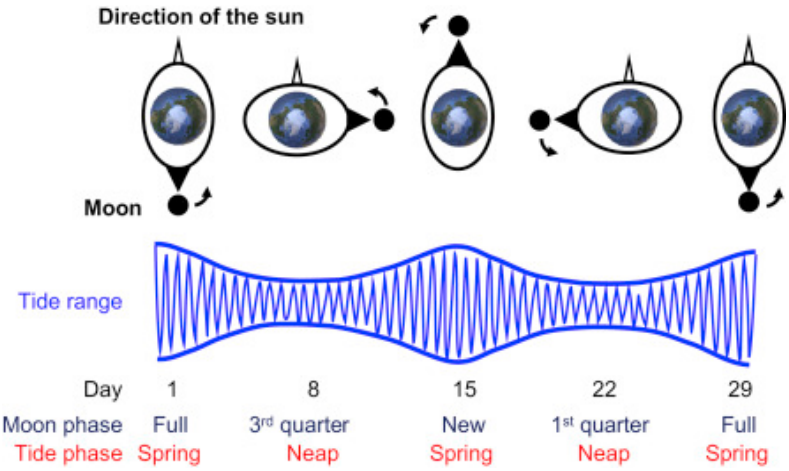


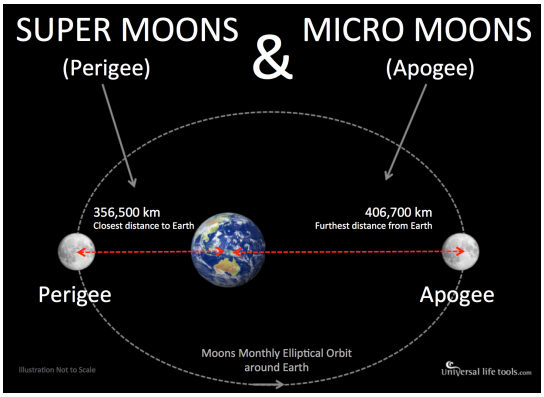
The moon exerts a larger tide-generating force on the Earth than the Sun. If it was just the moon that was exerting a force on Earth’s water bodies (and assuming the Earth was covered in a uniform layer of water), we would have two high tides and low tides a day that are the same height. But due to the Sun and many other complexities (e.g., the moon’s orbit, differences in ocean depth, the presence

of continents), how big the tides are can vary based on where you are located on Earth and they change throughout the month and year.

The first complexity that we will discuss stems from the celestial bulges interfering with each other. Spring tides occur when the solar & lunar bulges are in phase (Earth, moon, and Sun are in alignment), that is during a New Moon or Full Moon. During a neap tide, the bulges are out of phase. As shown in the figure on the right below, there are two spring and neap tidal cycles per month which correspond to the phases of the moon. Spring tides are the largest tides in the month and neap tides are the smallest.







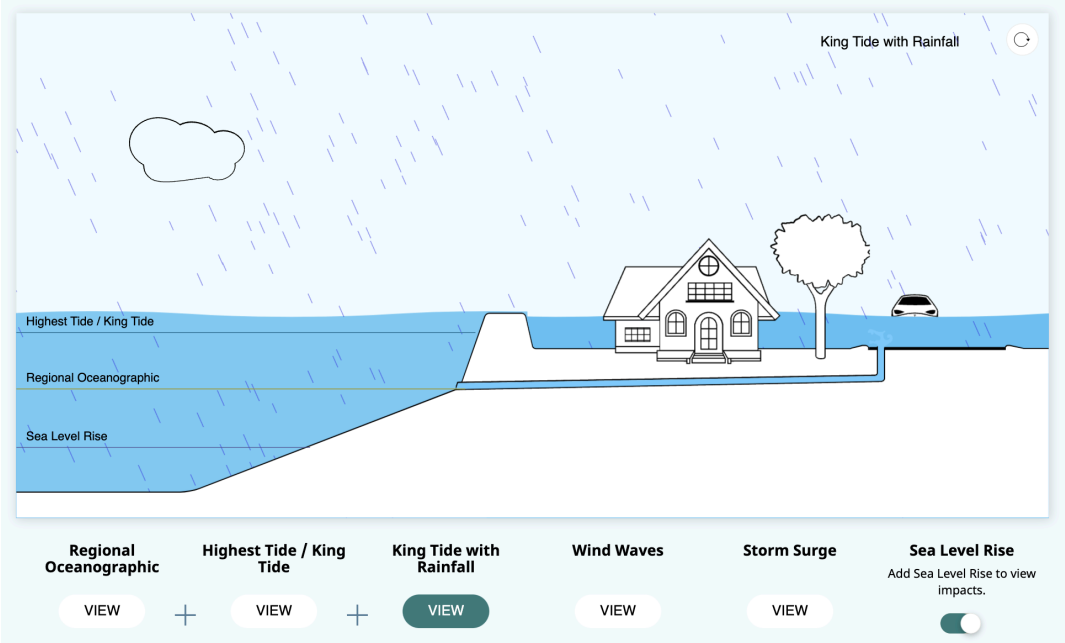
The second complexity we will discuss stems from the fact that the moon's orbit is elliptical and asymmetric. During perigee, the moon is closest in its orbit to Earth and therefore exerts the greatest tidal force. We call the moon during perigee a "Super Moon" and during this time, we see an increase in the average range of the tides.

When perigee coincides with a New Moon or a Full Moon, we call it a perigean spring tide. Depending on your location on Earth, this occurs 6-8 times per year, and can be some of the highest (and lowest) tides of the year.

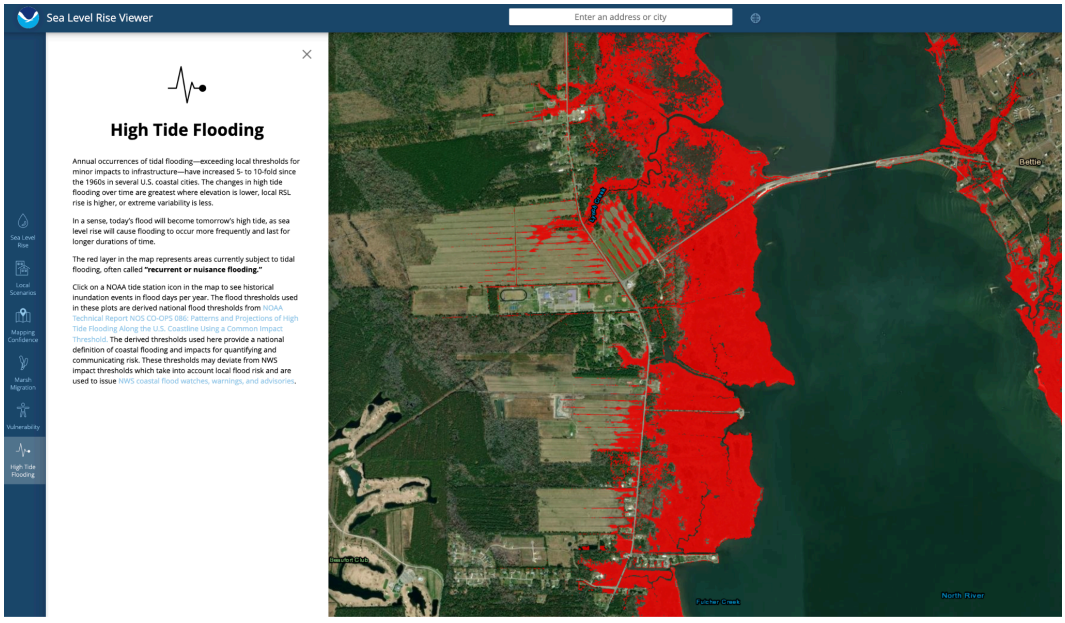
Why does it often flood in NC during perigean spring tides?

Coastal flooding has not historically always occurred during perigean spring tides in North Carolina, but with sea-level rise, flooding is becoming more and more common during these times of year. With sea-level rise, tides now rise higher and extend more landward than they used to.

You can use [this tool by]NOAA (also shown below) to better understand how high tides can combine with other factors, including rainfall (Research Guide #4), and lead to flooding of low-lying coastal areas.



The [NOAA Sea-Level Rise Viewer,] which is described in detail in Research Guide #2, also shows areas vulnerable to high tide flooding and how flooding has changed over time. If you navigate to the “High Tide Flooding” tab on the left side of the webpage, it displays a red layer that outlines areas that may be affected by tidal flooding (including the roads around ECHS!). As detailed in the legend on the webviewer, you can navigate to the Beaufort tide gauge on the map and click to see how tidal flooding has changed over time.



The legend also describes how NOAA uses measurements from tide gauges as a proxy for flooding on land (similar to the National Weather Service (NWS) as described in Research Guide #1). When we say "proxy" we mean that because tide gauges are located over marine water bodies, and not directly over land, they are not intended to measure or predict "flooding". Both NOAA and the NWS have developed thresholds, or elevations, that can be used to estimate when flooding might occur on land. When measurements at tide gauge exceed this threshold, it is inferred that flooding occurs. For example, using historical tide gauge measurements in Beaufort and a flood threshold, NOAA reports that there were a total of 9 flood days from 1982 to 2002 and a total of 58 flood days from 2002 to 2023. These flood days did not only occur because of tides, but also include extreme storms (Research Guide #5). The increasing frequency of flood days in recent years is largely attributed to rising sea levels.

Can we predict flooding from tides?

Tides are remarkably predictable and we use tide gauges to estimate when perigean spring tides will occur each year, as well as the number of potential high tide flood days. You can use both of the resources featured below to be better informed about when high tide flooding may occur in your community. Importantly, because these resources are developed using tide gauge measurements, your personal flood risk may be higher or lower due to other land-based factors (outdated stormwater pipes, high groundwater, rainfall runoff) or marine based factors (wind, high river flows).

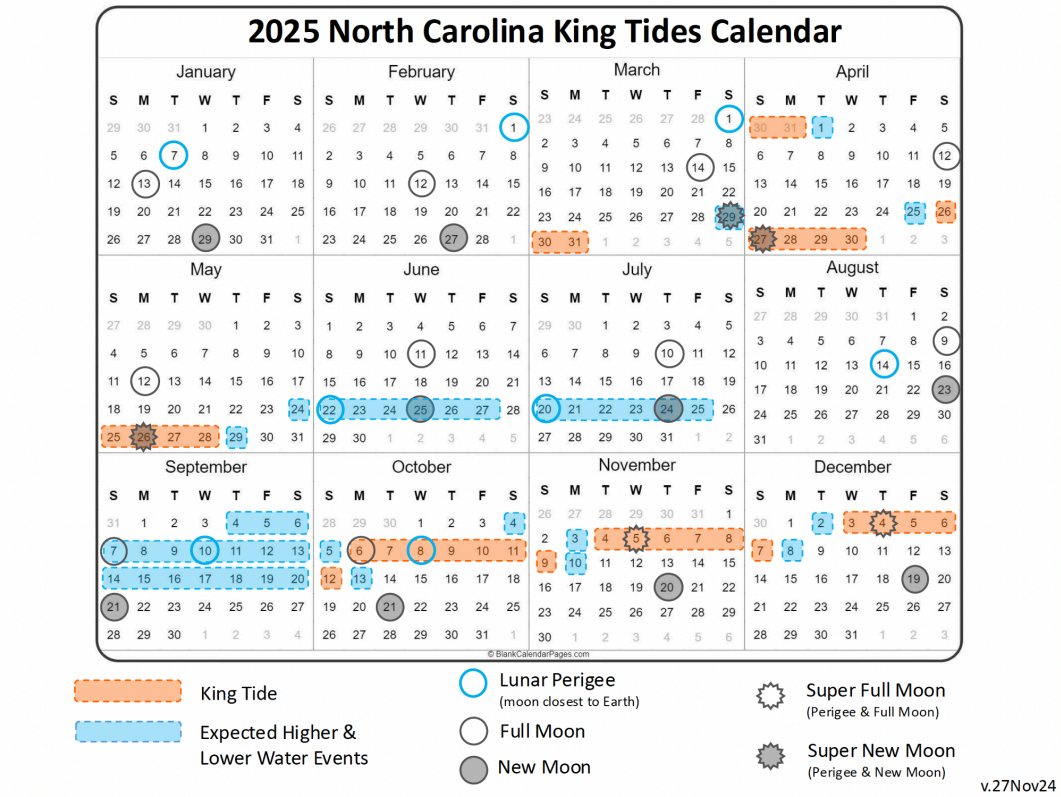
⭐*Featured Data Resources*⭐

North Carolina King Tides Calendar: The NC King Tides calendar is developed by researchers at UNC Chapel Hill and NCSU as part of the NC King Tides Project to track the occurrence of perigean spring tides each year. Although "King Tides" is a non-scientific term, the NC King Tides Project has adopted the following definition for consistent identification of perigean spring tide events from year-to-year as part of the King Tides calendar:

*"King tides are some of the highest predictable water levels of the year, occurring during the perigean spring tides – that is, when the moon is either new or full and closest to Earth – and exceeding a local risk-based threshold of **4 ft MLLW** (for NOAA Beaufort Duke Marine Lab NC Gauge #8656483)."*

As part of the calendar, the NC King Tides project also states the following regarding usage of the calendar to predict flooding:

"The NC King Tides calendar does not predict coastal flooding. The occurrence of coastal flooding can be influenced by non-tidal factors, including meteorological forcing (e.g., wind and pressure), seasonal changes in sea level, and land-based factors (e.g., high groundwater, rainfall, infrastructure). We direct the reader to the NOAA Monthly High Tide Outlook for predictions of coastal flooding."



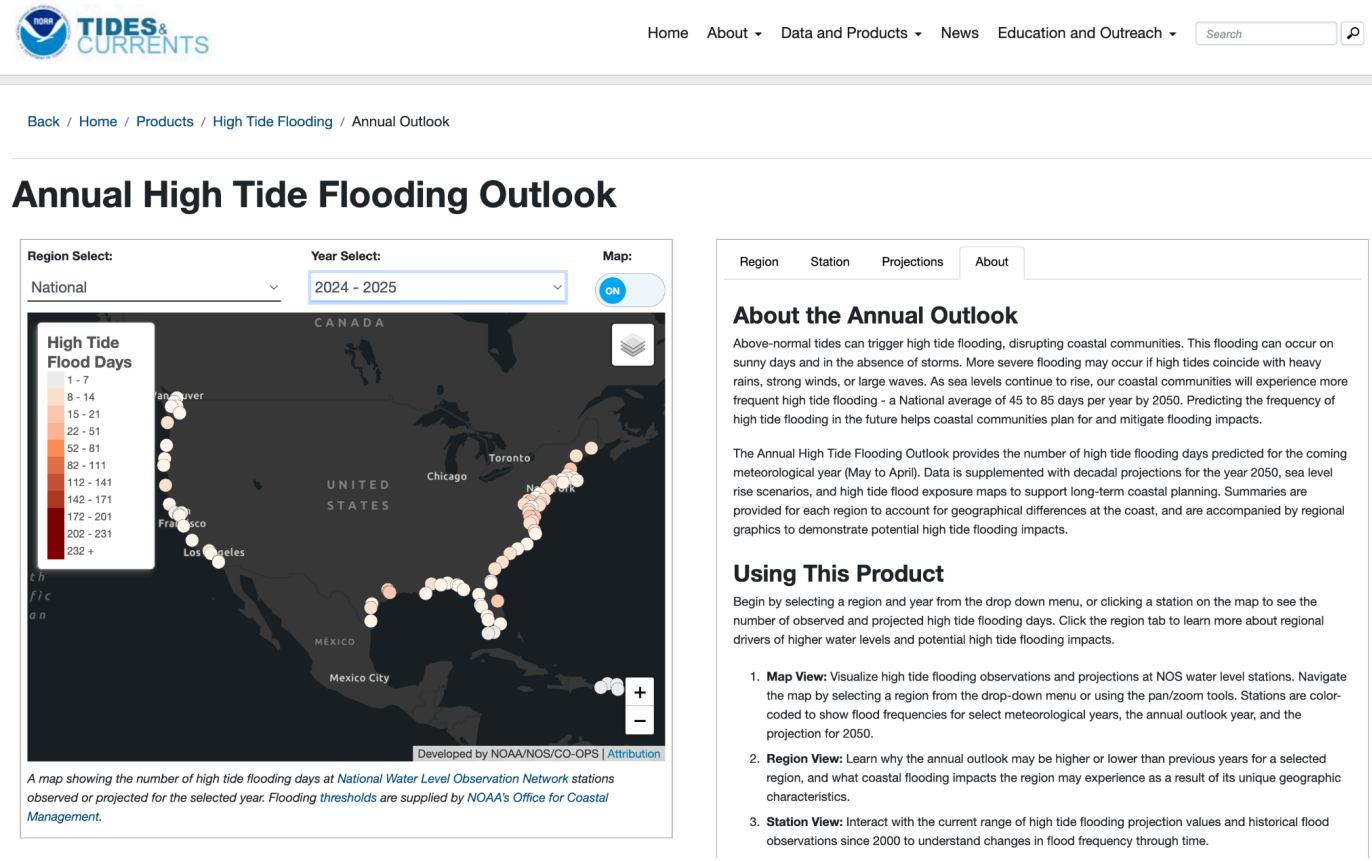
Importantly, you can make this calendar too as all of the data you need is publicly available! Because the moons and tides are predictable, you can follow the instructions below to make the calendar for future years.

Steps followed for constructing the NCKT Calendars:

1. Download a simple, generic annual calendar online (we have been using Google)
2. Gather data on the moon cycles
   a. Create a table of the moon cycles (scroll to later slides for examples). Times should be converted to local time (EST/EDT).
      i. Lunar Perigee/Apogee & New/Full Moon
         - As of 2024, the Navy is the official US agency responsible for tracking/providing astronomical conditions: https://aa.usno.navy.mil/data/MoonPhases. The Navy does not provide dates of perigee, so we use https://astropixels.com/ephemeris/moon/moonperap2001.html with the following acknowledgement: "Moon Perigee and Apogee Table Courtesy of Fred Espenak, www.Astropixels.com". Calculations based on the text Astronomical Algorithms by Jean Meeus (Willmann-Bell, Inc., Richmond, 1999)
      ii. Super moons
         - Here, we only consider "super moons" to occur when the new/full moon overlaps with lunar perigee within 24 hours. Note, the icon for "super moon" should be placed on the same calendar day as the new or full moon.
   b. Denote these lunar cycles on the calendar using the designated symbology
3. Gather data on predicted tides
   a. Determine the days where we expect to see high-water events
      i. When is the predicted tide (from the NOAA Beaufort Duke Marine Lab NC Gauge #8656483) higher than 4 ft MLLW? This is the local risk threshold that NCKT established in 2015 for flooding in Carteret County. For consistency between calendar years, we continue to use this threshold.
   b. Add the high-water events to the table
   c. Denote on calendar these times of high-water in blue
4. Using the calendar, determine (visually) which of the high-water events are "king tides", meaning there is a co-occurrence of high-water events (tides > 4 ft MLLW, highlighted blue) and perigee + spring tide (i.e., the occurrence of a super moon OR a new moon/full moon and perigee within +-2 days).
   a. Change the color of these days on the calendar from blue to orange to represent a "king tide".
5. For the "Expected High Water Level Events", we use a lower water level threshold: 3.8 ft MLLW at NOAA Beaufort Duke Marine Lab NC Gauge #8656483. Return to the NOAA predicted tides from STEP 4 above and extend any of the "expected high water level events" (highlighted blue) to days that exceed this lower threshold.
6. Add hash marks on the edges of all "orange" and "blue" events. This implies that while we must establish start/end dates to the "king tides" and "expected high water level events", the events may occur earlier/extend later.

NOAA High Tide Flooding Outlook: The NOAA High Tide Flooding Outlook presents predictions for high tide flooding using tide gauge measurements across the United States. As shown below, the outlook provides annual predictions, but also seasonal predictions.

On the annual predictions page, zoom to Beaufort and click the Duke Marine Lab Gauge: how many flood days are predicted for the year 2040? What sea level rise scenario is used to make this prediction? What happens if you change the sea level rise scenario? Importantly, the wide range in predicted flood days (20-40) results from there being several plausible future sea level rise scenarios influenced by factors like greenhouse gas emissions (see Research Guide #2). Remember, predictions of the number of future flood days from high tide flooding are a "best case" scenario because they do not account for non-tidal factors like rain, groundwater, wind, or stormwater infrastructure. These predictions are also made using water levels measured at tide gauges, which are sparsely located along the coast.



Using the tabs at the top of the page, navigate back to the "High Tide Flooding" main page and then "Monthly Outlook". Again, select the Beaufort Duke Marine Lab gauge and then navigate to the "Calendar" tab on the right hand side of the page. How does predicted high tide flooding by NOAA for 2025 compare to the predicted King Tides from the NC King Tide Calendar? Why do they differ? (HINT: look at the thresholds.)

Other Resources:

- NOAA Perigean Spring Tide: This website includes information about perigean spring tides, their cause, and how they contribute to coastal flooding.
- NOAA Gravity and Inertia: Information regarding gravity, inertia, and their impact on tidal bulges.
- NOAA What causes Tides?: This website has information about how tides are formed on Earth.

Want to Get Involved and Learn More about High Tide Flooding?

Are you interested in being a citizen scientist and tracking high tide flooding in your community? Download the Coastal Observer App and follow the instructions on the NC King Tides Project website!