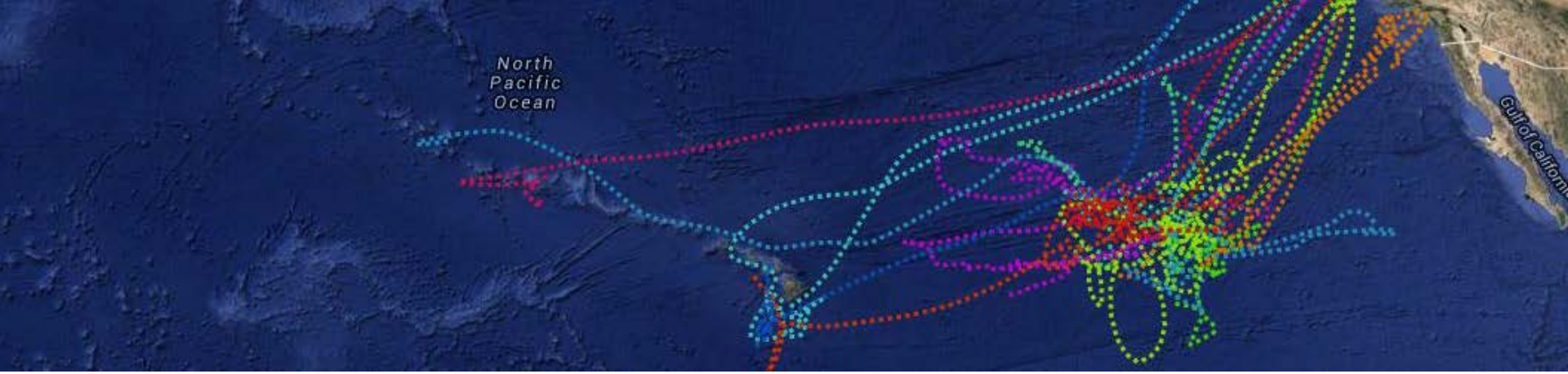


Fact or Artifact?

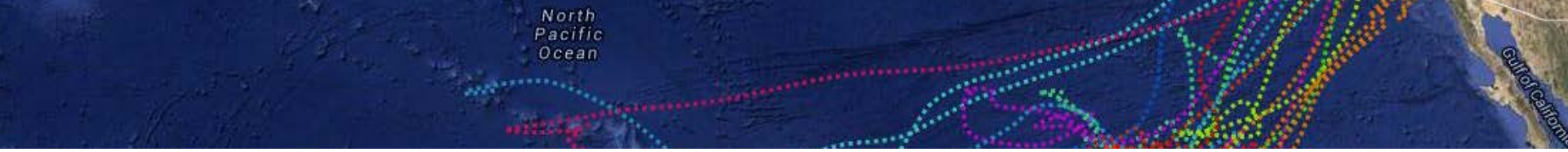
Interpreting Patterns in Ocean Tracks Data

The tracking data in Ocean Tracks have been a powerful tool for scientists, revealing animal behaviors never before understood. You'll use these data to develop your own new insights about these animals, but beware—to extract meaningful patterns and separate facts from artifacts, you need to take a critical look at the data. You should assess the quality and accuracy of measurements, understand how the data are collected and represented in the Ocean Tracks interface, and apply background information about tagging technologies and animal behaviors.

Learning Objectives

- Recognize how animal movement is represented in the Ocean Tracks interface
- Decode track features in the context of data collection techniques and technologies
- Identify, extract, and interpret meaningful patterns in tracking data
- Critically evaluate data/limitations of data

OCEANTRACKS



Pre-Lab Assignment

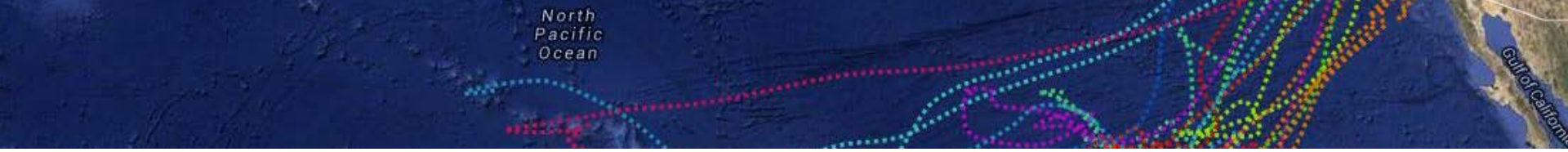
Ever wonder where marine animals go? How fast they swim? How deep they dive? Electronic tagging has opened a new window into the world of the open ocean. Ocean Tracks gives you access to data collected by tags on real live migrating marine animals, as well as data from drifting buoys and satellites. Ocean Tracks also has tools that allow you to display and analyze these data to investigate current and important scientific questions about how these animals interact with the ocean environment.

HOW ARE MARINE ANIMALS TAGGED AND TRACKED?

When you collect your own data, you already know a lot about how those data were collected—what methods you used, the accuracy of the instruments, what technical malfunctions (if any) may have occurred, or if any artifacts resulting from data processing may be present. When using data collected by someone (or something) else, you might need to do a little background research to find that information. Before we dive into Ocean Tracks, it's important to understand where the data come from and how they are displayed in the Ocean Tracks interface. These understandings will help you better discern data patterns and identify potential errors in data sampling and processing.

- Watch the video *From Tags to Tracks:* http://oceantracks.org/library/tags/tags-tracks
- Make a table like **Table 1** on the following slide to record information about the accuracy of the tagging technologies used to track the marine animals in the Ocean Tracks interface.
- As you watch the video, pay special attention to how each type of animal is tagged and how their movements are represented as data points on the Ocean Tracks map. Use your observations to answer the questions on the following slide.

More information about how each species is tagged and tracked is available in the **Ocean Tracks Library:** http://oceantracks.org/library



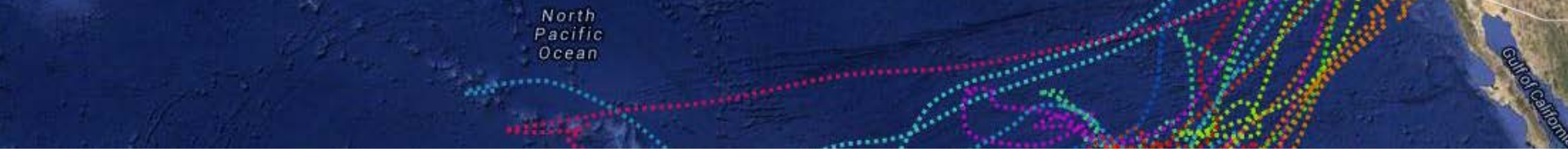
Pre-Lab Assignment

Table 1.

Tag Type	Animals Tracked	Accuracy
Satellite telemetry tags		
Archival tags		

PRE-LAB QUESTIONS

1. *When viewing a track in the Ocean Tracks interface, what do the larger dots represent? What do the smaller dots represent?*
2. *How many position estimates are recorded for each animal in the Ocean Tracks interface per day?*
3. *Referring back to the* From Tags to Tracks *video, describe the differences in how daily positions are estimated using each of the two tagging technologies.*



Engage

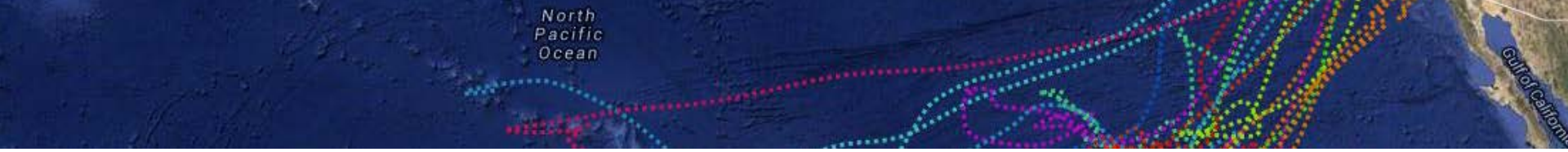
In this module, you'll explore tracks of several marine animals using the Ocean Tracks interface. One of the most important things to ask yourself when looking at data is, "Does this make sense?" Sometimes you will immediately know the answer, and other times you might have to investigate further to find out. Your challenge is to take a critical look at these tracks to learn how to identify and extract meaningful patterns from the data.

MAKING MEANING OF DATA

Tracking data can be a powerful tool for helping scientists gain insight into marine animals' migratory behaviors and what influences the ocean environment might have on the animals' movements. However, it is important to remember that there are limitations to what we can conclude from the data alone.

Interpreting data requires a critical eye. Animals can be unpredictable. Technology isn't perfect. Data processing can sometimes introduce **artifacts** (false signals in the data). These are just a few things to keep in mind when working with data. In this module, you will learn valuable techniques for separating fact from artifact, as you investigate the question:

What can the use of electronic tagging technologies reveal about the movement and behavior patterns of large marine animals?



Engage

WHAT WOULD YOUR TRACK LOOK LIKE?

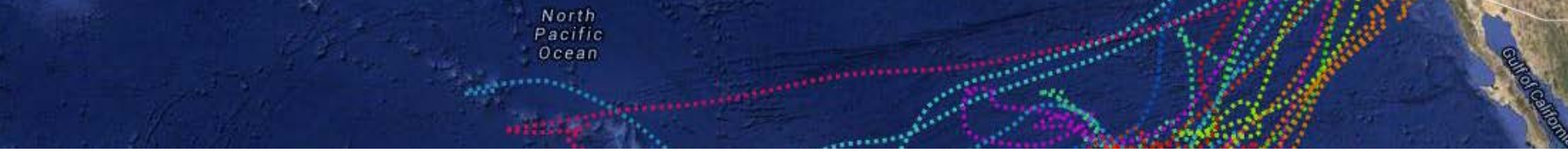
If you were wearing a location tracker, what would a map of your movements look like over the course of a day? a week? a year? What patterns would you see in the data? What stories could you tell with these data? How close to reality would those stories be?

CLASS DISCUSSION

Look at the campus map on Slide 7 showing the location of a college student, Jane, every 30 minutes over the course of a day. Suppose Jane's tracker is accurate within 10 yards in the vertical and horizontal directions. As a class, discuss the following questions:

1. *How accurately do you think this simplified representation depicts what Jane was doing?*
    - *How is Jane moving between each of the locations? Is she necessarily moving in a straight-line path or perhaps taking a more circuitous route?*
    - *Considering how Jane may be entering and exiting the various buildings around her campus, does this track path depict her using doorways? Explain why or why not.*

(CONTINUED ON NEXT SLIDE)



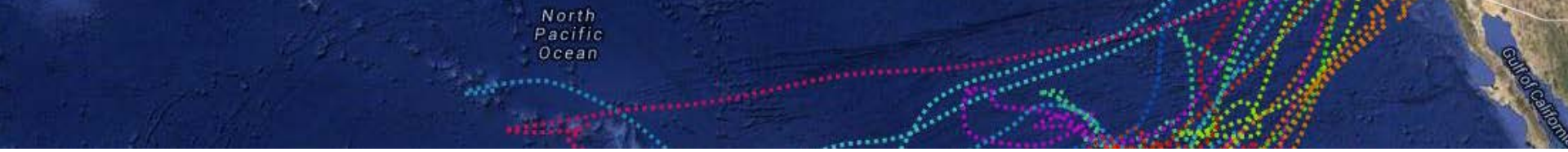
Engage

CLASS DISCUSSION (CONTINUED)

2. What can you infer about what Jane was doing at each point along her path?
    - Which track points may be logical start and stop locations?
    - When Jane is at the corner of Building J, is she inside or perhaps at a bench in the adjoining quad? Based on the accuracy of her tracker, how confident are you in your assertion of an indoor or outdoor location?
3. What other information would help you tell a more complete story?
4. How might the track look different if:
    - You increased or decreased the time resolution (e.g., location was plotted every 5 minutes or every 4 hours instead of every 30 minutes)?
    - You tracked this student during a vacation week rather than a regular school week?
    - Jane accidentally left her tracker in her dorm room for a few hours?
5. What other activities or changes in data collection may affect the representation of this track?
6. Is Jane's path indicative of the larger student population?
    - How might her track compare with that of another student with a different major? to a student in a different graduating class?

A. Student Union
B. Theater Bldg.
C. History Bldg.
D. Dorm
E. Math Bldg.
F. Science Bldg.
G. Gym
H. English Bldg.
I. Library
J. Coffee Shop
K. Dining Hall

Figure 1. Map displaying the path of Jane around her college campus, with locations recorded every 30 minutes by her tracker, over the course of approximately one day.



Explore

PART 1: INTERPRETING INTERPOLATION

Tracks plotted on an Ocean Tracks map, like the one shown below, are simplified representations of what animals were actually doing during the time they were being tracked. In the case of Ocean Tracks, a single track point represents the daily position estimate for the animal on a given day. Sometimes these simplifications result in track features or patterns that don't quite make sense based on what we know about these animals and how they are tagged and tracked, but that doesn't mean we can't still learn from them. Let's look at an example.

- Go to http://oceantracks.org/map.
- Click on the **Data & Tools** tab**.**
- Click + to expand the **Tracks** menu and the **White Shark** tracks.
- **Show** and **Graph** the track for White Shark #502800. **NOTE**: You may want to turn off the default track (Elephant Seal #302) so that only the white shark track appears on the map.
- Click **Show Animal Movement** in the **Tools** menu to animate the track on the map. See Slide 9.
- Look for patterns in the track that might tell you something about what the shark is doing along its journey. For example, you might look for sections of the track that are particularly straight or curvy, or where the shark is traveling faster or slower.

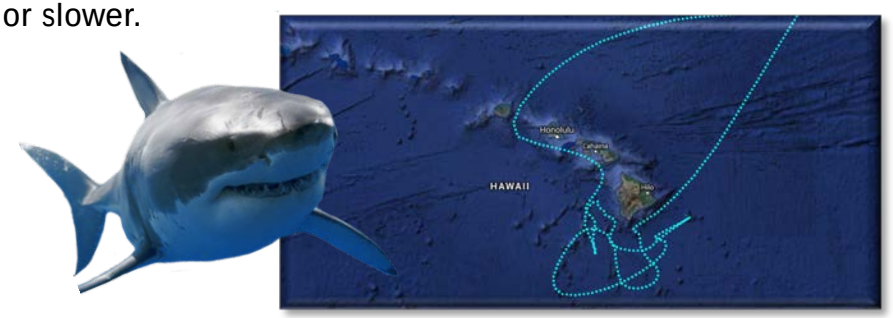


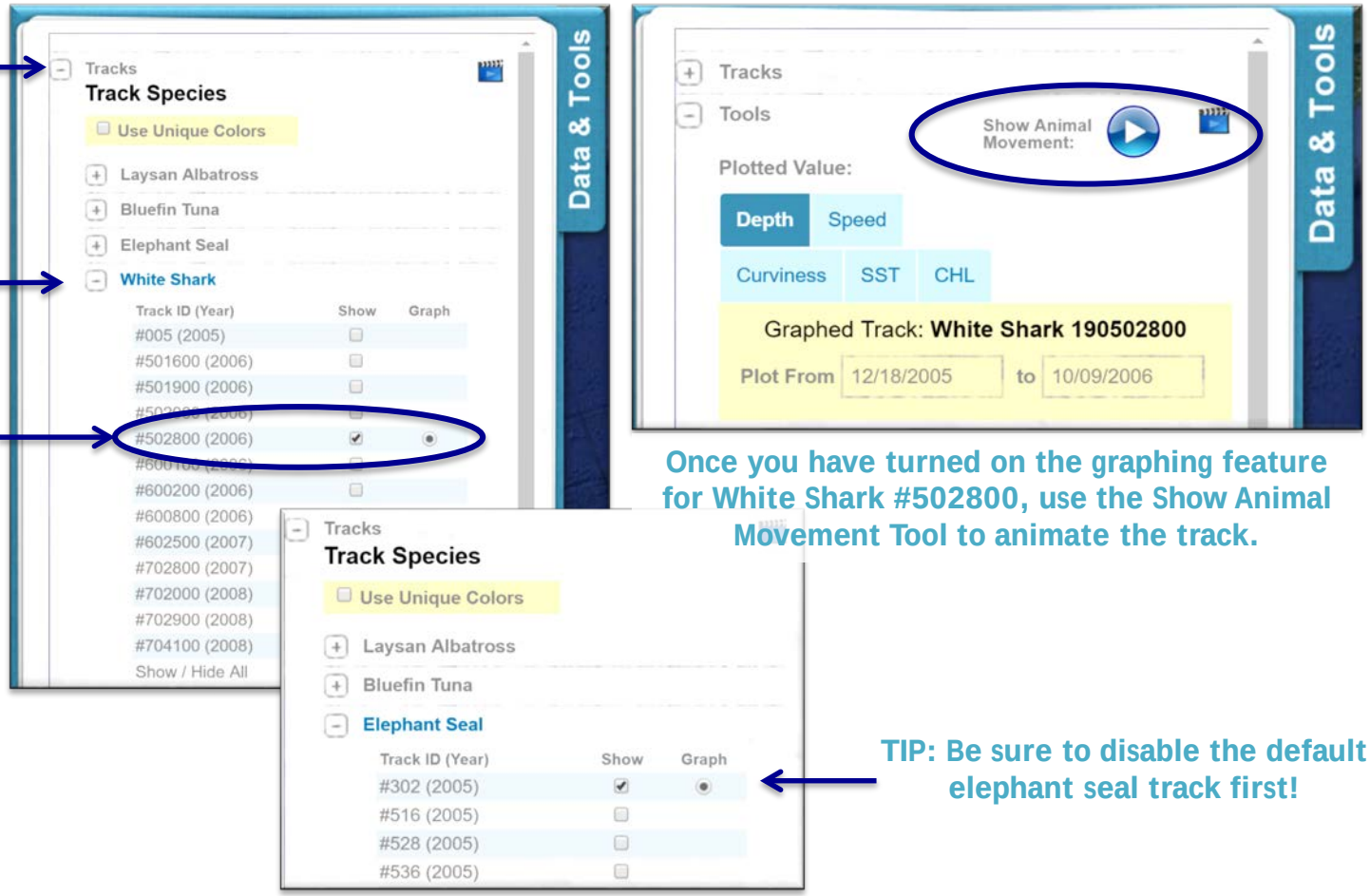
Figure 2. White Shark #502800's path around the Hawaiian Islands

Explore

Expand the Tracks dropdown.

Select White Shark from the species list.

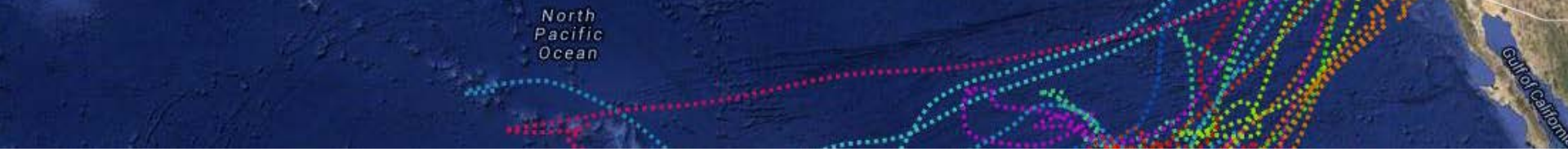
Show and Graph White Shark #502800.



Once you have turned on the graphing feature for White Shark #502800, use the Show Animal Movement Tool to animate the track.

TIP: Be sure to disable the default elephant seal track first!

Figure 3. Screenshots showing how to display animal tracks and access the "Show Animal Movement" tool



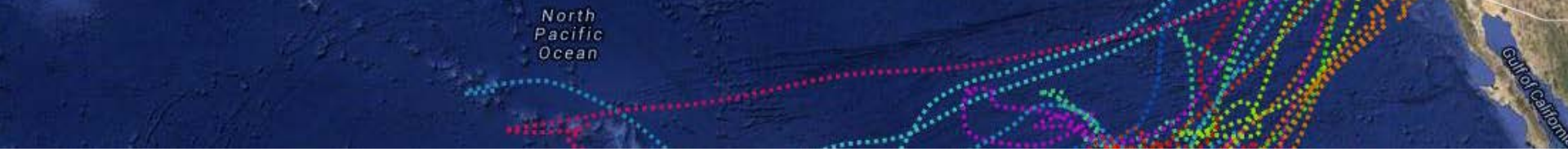
Explore

Throughout this module, you will work to develop a set of strategies to investigate the interesting track features and data patterns you will encounter in Ocean Tracks modules. These critical-thinking strategies extend beyond your work in Ocean Tracks, however. Data are everywhere. You'll likely come across interesting data more than once, whether it be in future schooling, a career, or even in your day-to-day life. As you work through this module, consider how the investigatory strategies you use can extend beyond Ocean Tracks.

As you encounter interesting track features, like those in the track of White Shark #502800 you're about to investigate, think critically about the data by asking yourself the following questions to help guide your exploration:

- ***Inspect:*** *Look closely at the track and graph. What stands out? What feature(s) should I investigate further?*
- ***Compare:*** *Do these feature(s) show up anywhere else along this animal's track? in tracks of other animals of this species? in tracks of animals of a different species within Ocean Tracks?*
- ***Be Skeptical:*** *Do these features make sense? Is it consistent with what I know about these animals? Are data values within reasonable limits?*
- ***Consider Limitations and Artifacts:*** *If you see a pattern somewhere along the track that doesn't seem to make sense, how might the tagging technologies and their accuracy limits explain this pattern? What aspects of data collection, processing, and representation might explain this pattern?*
- ***Identify Additional Sources of Information:*** *What known behaviors, background information, and/or outside research might help explain this pattern?*
- ***Extract Meaningful Patterns:*** *Even if a data artifact has been identified, what meaningful patterns in this animal's movements and behaviors may tagging technologies still reveal? What information can you learn from the track as a whole?*

The nature of the track feature or pattern you identify will determine which of these questions apply to your data investigation. Now apply this framework to an interesting feature in the track of White Shark #502800.



Explore

- Zoom in and explore the shark's path around the Hawaiian Islands, paying particular attention to the section of the track where the shark passes by the islands near Maui. **NOTE:** You need to zoom way in to see the names of the islands.
- Practice asking yourself the questions on the previous slide as you look at the shark's path around Hawaii.

EXPLORE PART 1 QUESTIONS

1. ***Inspect:*** *Look at the shark's path by the island of Kaho'olawe. What do you notice about the shark's track? What feature(s) stand(s) out?*
2. ***Be skeptical:*** *Are there any features in the track representation that don't make sense given what you know about white sharks?*
3. ***Consider limitations and artifacts:***
   a. *Referring back to the example of Jane in the Engage section, explain how the way tracks are represented in Ocean Tracks might explain the shark's path appearing to cross over the island of Kaho'olawe?*
   b. *Referring back to what you learned about tagging technologies in the Pre-Lab Assignment, explain how the accuracy and limitations of tagging technologies may also explain this shark's path appearing to cross over land?*
4. ***Extract meaningful patterns:*** *Although you may have identified an artifact of the data and/or how the data are represented, it doesn't mean this track isn't useful to study or learn from. For example, electronic tagging technologies reveal migration patterns for this animal. Describe the locations to which this shark travels and the time of year the shark is in these locations.*

Explore

PART 2: STAYING ON TRACK

As you've just seen, sometimes the track paths represented in the Ocean Tracks interface don't quite match our expectations and intuitions for how animals behave. In this section, you will further explore the accuracy in tracking data using Bluefin Tuna track #506600.

- **Show** and **Graph** Bluefin Tuna track #506600. **NOTE:** If you are still zoomed in on the Hawaiian islands, you will need to zoom out or refresh the page to be able to see the whole tuna track.
- Zoom in and explore the tuna's track around the coast of Japan.

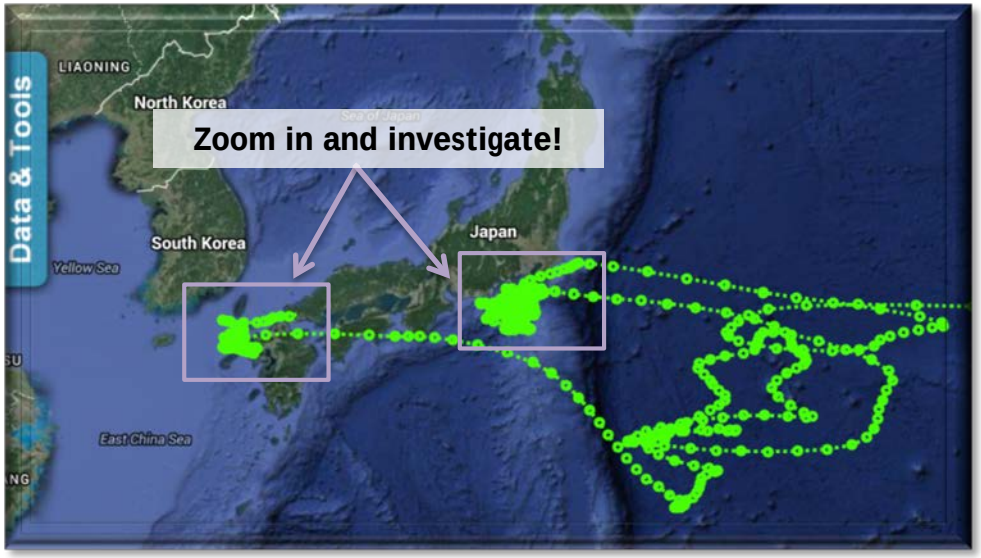
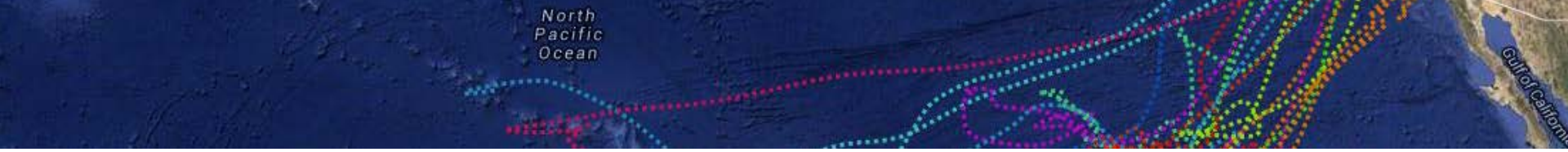


Figure 4. Screenshot displaying the path of Bluefin Tuna #506600 as it travels the waters near Japan



Explore

You may notice that like White Shark #502800 from the previous section, the Bluefin Tuna #506600 track appears to cross over land multiple times during its journey around Japan. Upon inspection, the shark's land-crossing was found to be an artifact of interpolation of data between daily track points. This is also the case for some parts of the tuna track. However, the tuna track also shows multiple data track points (daily position estimates) on land.

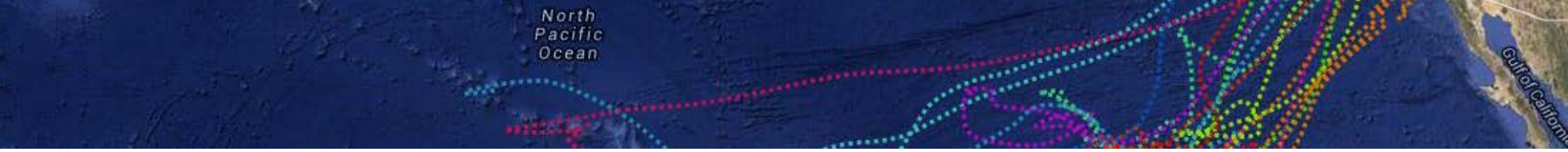
- Zoom in further on Bluefin Tuna #506600's track around Japan.
- Identify a section of the track where 3 or more consecutive daily position estimates appear on land.

EXPLORE PART 2 QUESTIONS

1. ***Inspect:*** *Record the date range and approximate location for the section of track you identified where three or more consecutive daily position estimates appear on land.*

2. ***Consider limitations and artifacts:*** *Referring back to what you learned about tagging technologies in the Pre-Lab Assignment, explain how the accuracy limitations of the archival tags used to track these bluefin tuna might explain this track feature.*

(CONTINUED ON NEXT SLIDE)



Explore

Now that we have identified the limitations associated with tagging technologies and the aspects of data collection, processing, and representation as the likely causes for the appearance of White Shark #502800 and Bluefin Tuna #506600 tracks crossing land, the question still remains: What were these animals doing so close to the land masses of Hawaii and Japan?

Another investigatory strategy is to explore scientific literature to research what is currently known about these animals. Refer to the Ocean Tracks Library to learn more about the bluefin tuna that are tagged and tracked in Ocean Tracks: http://oceantracks.org/library/species/northern-bluefin-tuna.

EXPLORE PART 2 QUESTIONS (CONTINUED)

3. ***Extract meaningful patterns:*** *Despite the data artifacts identified, looking at the whole track, what meaningful patterns do electronic tagging technologies reveal about this tuna's movements?*
   - *What locations does it travel to?*
   - *When does it travel to those locations?*
   - *Where does it spend most of its time?*
4. ***Compare:*** *Are these migration patterns consistent with what you read in the Ocean Tracks Library? Why or why not?*
5. ***Identify additional sources of information:*** *What additional information and/or data would be useful for making a more complete interpretation of the tuna's actual path around the coast of Japan?*

Explore

PART 3: DIVE DEEPER INTO OCEAN TRACKS DATA

Map displays aren't the only way to explore data in the Ocean Tracks interface. Under **Tools,** you can graph additional data parameters like speed, depth, and curviness as well as the ocean conditions the animals encounter along their tracks, like sea surface temperature (SST) and chlorophyll concentration (CHL).

In this section, you'll use these data to look for meaningful patterns and to investigate and evaluate the validity of **outliers** (observation points that are abnormally distant from other data points).

- **Show** and **Graph** the track for Bluefin Tuna #704500.
- Click the + to open **Tools**.
- Carefully examine the **Depth** data. Move the sliders to see how the graph looks for different time intervals. Look for patterns that tell you something about the tuna's behavior as well as outlier values or patterns in the data that don't make sense based on what you know about tuna.

Keep in mind that a point on the depth graph represents the deepest dive for that animal on a given day. Lines connecting the data points show change over time, and like the lines connecting track points on the map, are interpolations between daily depth measurements.

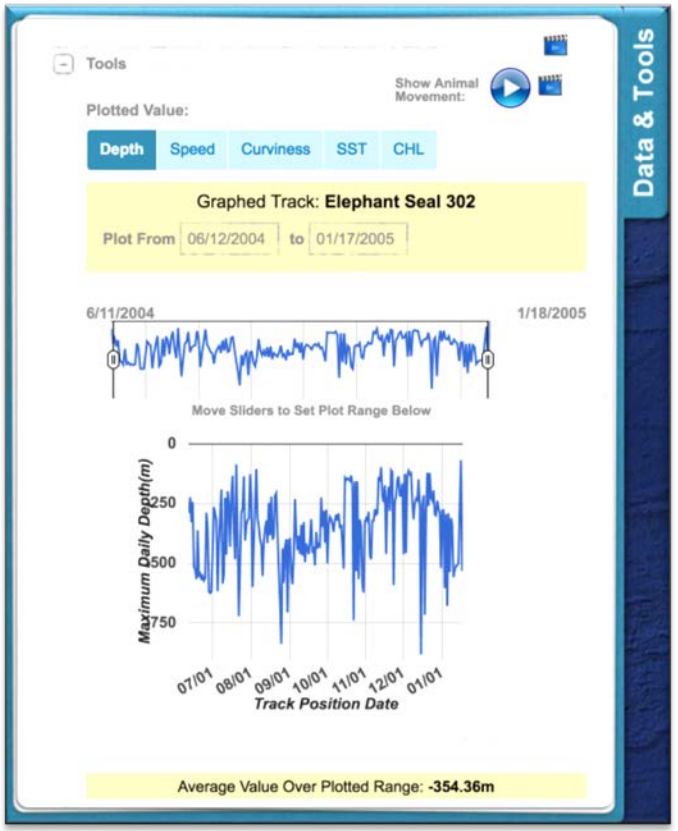
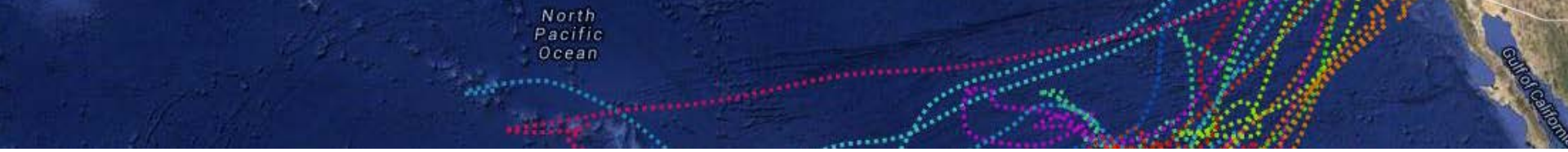


Figure 5. Ocean Tracks graphing tool showing depth data for Elephant Seal #302



Explore

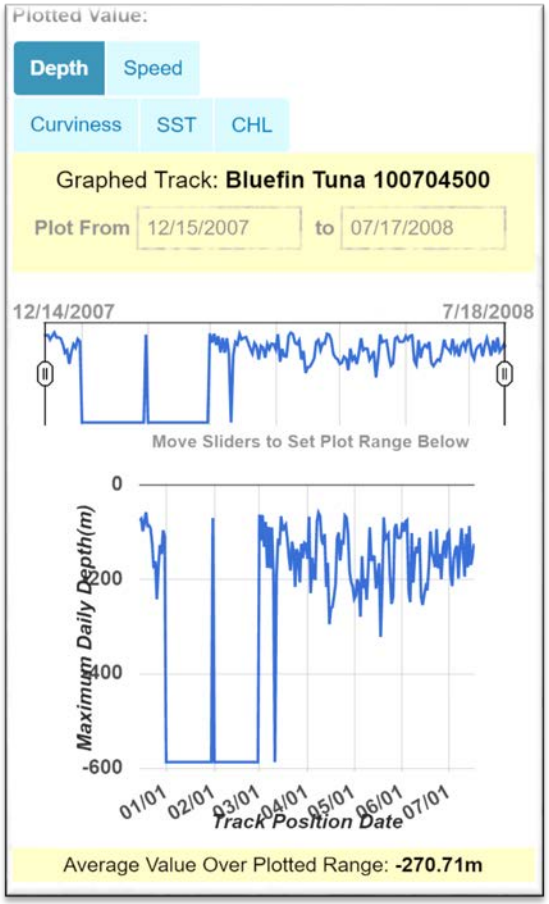
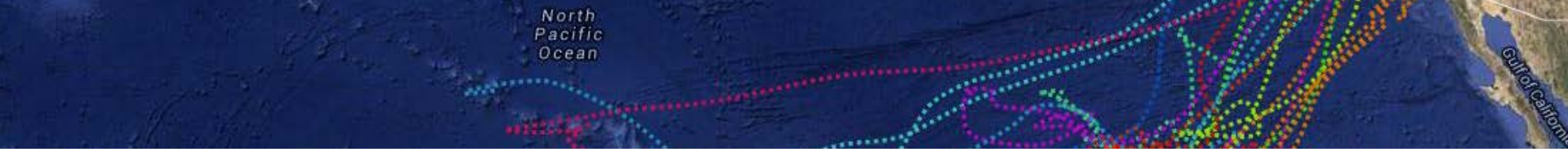


Figure 6. Ocean Tracks graphing tool showing depth data for Bluefin Tuna #704500

EXPLORE PART 3 QUESTIONS

1. ***Consider limitations and artifacts:***
   a) *Upon inspection, you may notice sections of the depth graph have a "jagged" appearance. How might the choice of how the depth data are represented affect this appearance?*
   b) *How might the appearance of the depth graph change if:*
      - *the maximum depth was plotted every 8 hours (a third of a day)?*
      - *the depth was plotted every second for the duration of the track?*
2. ***Extract meaningful patterns:*** *How might the variability in the tuna's day-to-day diving behavior also explain this jagged appearance?*

(CONTINUED ON SLIDE 18)



Explore

- Now focus on the section of the track where the maximum daily depth doesn't change for an extended period of time and the graph appears "flat." Recall the following from the critical-thinking strategies described earlier in the module: Another method to investigate whether a section of track is indicative of typical tuna diving behavior or is instead an artifact of the data collection, processing, and representation process is to compare the track with that of another tuna and see if the pattern shows up there as well.
- Use Figure 7 below to compare the depth data for Bluefin Tuna #704500 (on the left) to that of Bluefin Tuna #604300 (on the right). **NOTE:** It may be helpful to load these tracks in the Ocean Tracks interface to examine the depth graphs in further detail.

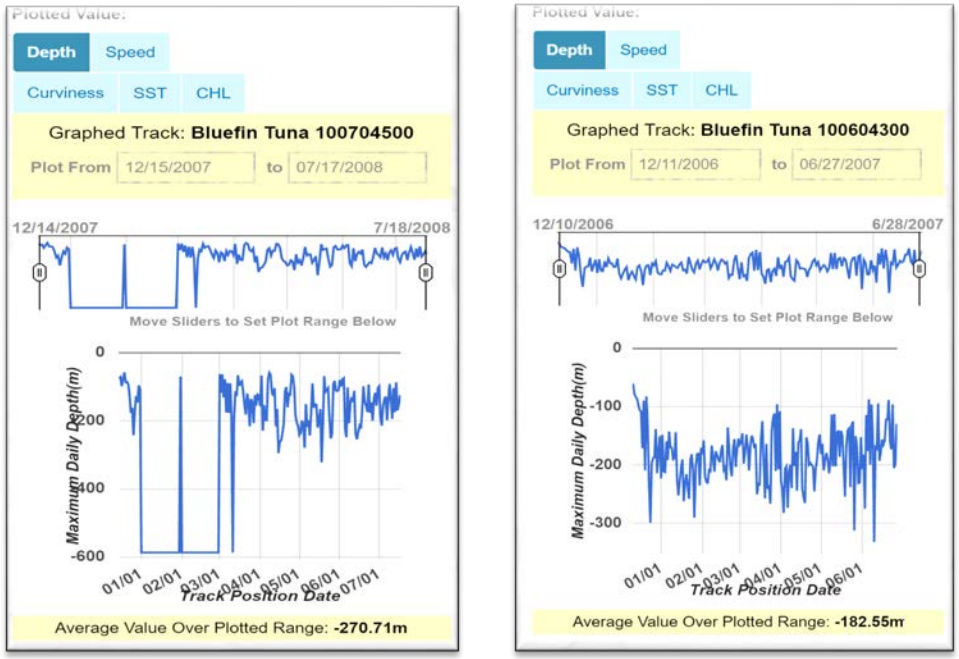
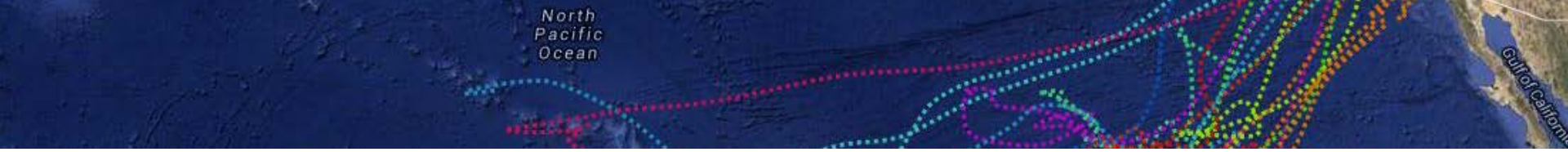


Figure 7. Ocean Tracks graphing tool showing depth data for Bluefin Tuna #704500 (left) and Bluefin Tuna #604300 (right)

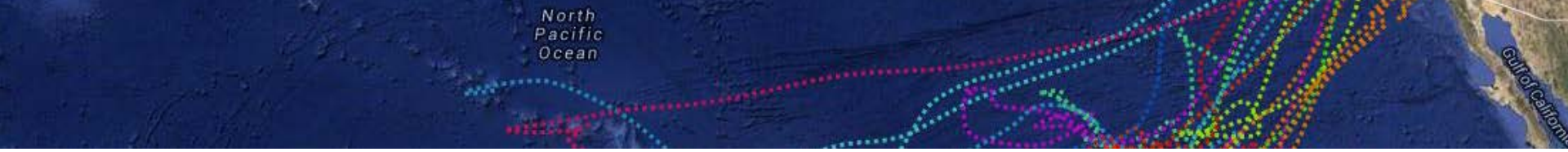


Explore

- After visually inspecting the depth graphs for Bluefin Tunas #704500 and #604300 on the screenshots on the previous slide or in the Ocean Tracks interface, use the following questions to further your analysis:

EXPLORE PART 3 QUESTIONS (CONTINUED):

3. ***Compare:***
   a) *In which sections of Tuna #704500's track do the patterns in the depth graph most closely match those of Tuna #604300? Use the date sliders in the graph tool to provide an accurate date range in your response.*
   b) *Based on your comparison of the two depth graphs, which track section, the one that appears "flat" or "jagged," is more likely to be indicative of typical diving behavior for Bluefin Tuna #704500? Which is more likely an artifact of the data collection, processing, and representation processes?*
4. ***Identify additional sources of information:*** *In this exercise, you used a depth graph and an additional tuna track (Bluefin Tuna #604300) to make inferences about the typical diving behavior of Bluefin Tuna #704500. What additional data, within Ocean Tracks or from external sources, would help you make further inferences about the typical diving behaviors of the bluefin tuna species as a whole?*

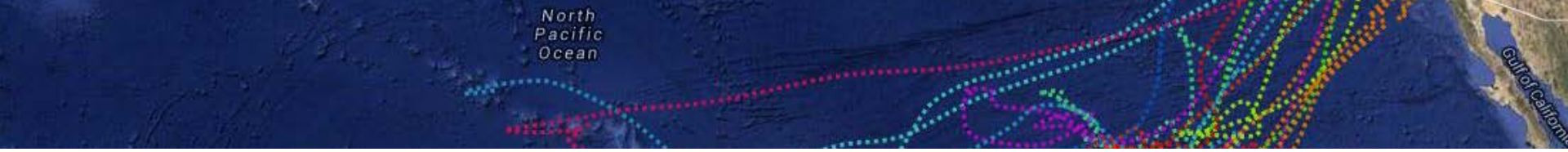


Explore

PART 4: MORE THAN ONE WAY TO LOOK AT DATA

As you saw in Part 2, the **Show Animal Movement** animation tool can be particularly useful for finding patterns in animals' movements. It can also help identify sections of the track that might be worth further investigation. Let's use this tool to see what we can learn about Elephant Seal #1266.

- **Show** and **Graph** the track for Elephant Seal #1266.
- Animate the track by clicking the **Show Animal Movement** icon under **Tools**.
- As you've done throughout the module, perform a visual inspection of the track and identify sections you wish to explore in more detail based on patterns that stood out to you in the animation. Watch the data tracker in the upper right corner of the screen while the track is animated or click on individual track points to narrow down the date ranges for the track sections you want to explore in more detail.
- After you have identified sections of the track to explore further, examine the graphs for speed, depth, and curviness under **Tools. NOTE:** If you are unfamiliar with curviness, you can learn more about it here: http://oceantracks.org/library/the-curviness-tool
- In your visual inspection of the track for Elephant Seal #1266, you may have noticed a considerable "jump" in the track. If you missed this, return back to the Ocean Tracks interface, use the Show Animal Movement tool, and watch the entirety of the track animation. Did our seal speed back out into the open ocean? Is this track pattern consistent with the elephant seal's behaviors along other sections of the track?



Explore

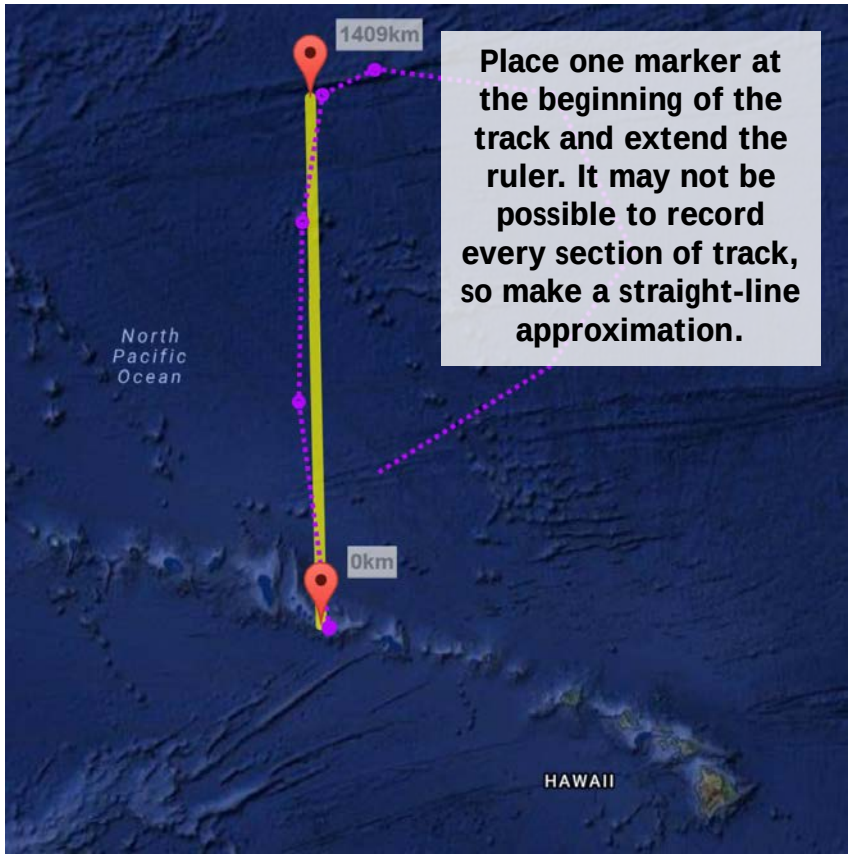
- Let's use another one of our critical-thinking strategies—comparing multiple sections of the same track—to investigate the track jump. Start by creating a table like Table 2 on Slide 22 to record and organize data taken from various sections of Elephant Seal #1266's track. The first row contains data taken from the ~21-day jump from 1/02/2008 to 1/23/2008, and is completed for you.
- Fill in the information in the second and third rows, the sections of track immediately before and after the jump. In the fourth row, choose a different section of track, and fill in the corresponding data for that section.
- Use the ruler tool to approximate the distance traveled for each section of track. If you are unsure how to use the ruler tool, Figure 8 on Slide 21 shows an example of measuring the length of a 10-day section of track for Laysan Albatross #465.

  To use the ruler tool:

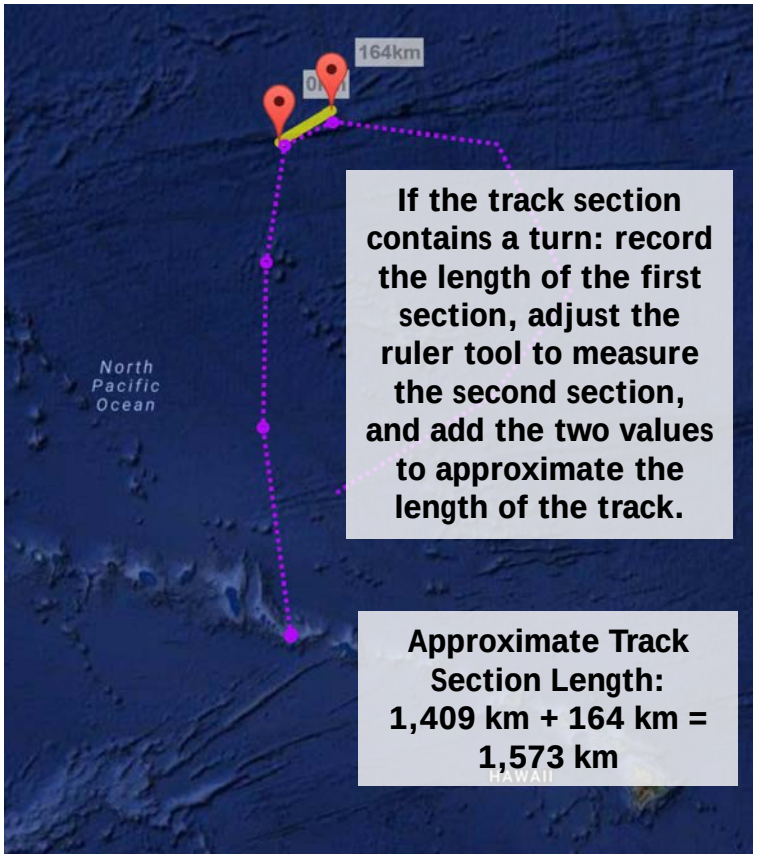
  - Click **Show Ruler** in the top right corner of the map to activate the ruler tool. 

  - Click on the map to place a 0-km marker.
  - Click and drag the marker to extend the ruler; a second marker shows distance between the start and end markers.
  - Click and drag either marker to change the start/end positions of the ruler.
  - Click **Hide Ruler** to remove the ruler from the map.

Explore



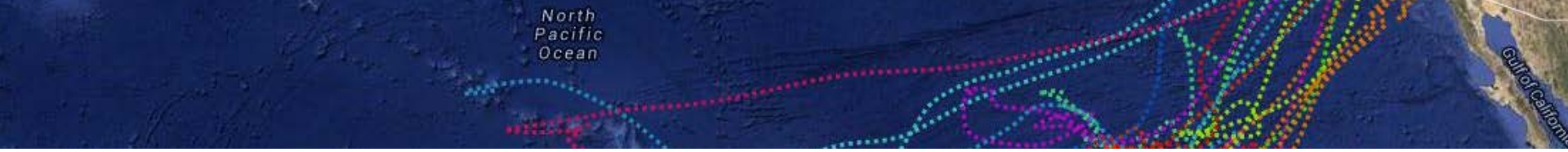
Place one marker at the beginning of the track and extend the ruler. It may not be possible to record every section of track, so make a straight-line approximation.



If the track section contains a turn: record the length of the first section, adjust the ruler tool to measure the second section, and add the two values to approximate the length of the track.

Approximate Track Section Length: 1,409 km + 164 km = 1,573 km

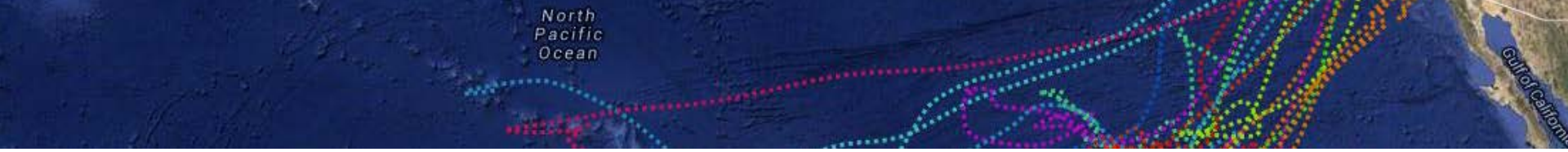
Figure 8. Example of measuring the approximate length of a 10-day section of track (1/14/2006-1/23/2006) for Laysan Albatross #465



Explore

Table 2.

Date Range	Track Section Description	Duration of Section (Days)	Length of Section (km)	Avg. Depth (m)	Avg. Speed (km/h)	Avg. Curviness
1/2/2008–1/23/2008	*Track appears to jump ahead more than 20 days between track points.*	*21 days*	*~1,882 km*	*372.50 m*	*23.55 km/h*	*1.22*
12/04/2007–12/25/2007	*During time preceding jump, seal is traveling southeast toward the California coast in a relatively straight path.*				*2.48 km/h*	
1/26/2008–2/12/2008	*During time following jump, seal loops back on its path out into the North Pacific. Periods of lower speeds and higher curviness may indicate foraging.*			*326.00 m*		



Explore

Use the data you collected in Table 2 to help interpret the ~21-day jump in Elephant Seal #1266's track, and infer what the seal may have been doing during this time period.

EXPLORE PART 4 QUESTIONS

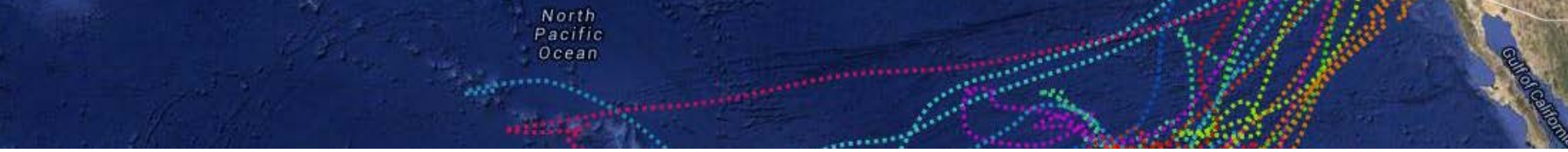
1. ***Compare:*** *Compare the data you collected for the four sections of the track. How strongly do the data support the claim that the section of track containing the ~21-day jump from 1/02/2008 to 1/23/2008 is typical behavior for this elephant seal? (You may consider: How far does the seal typically travel in that amount of time in other parts of the track? What is a typical curviness for this animal?)*

2. ***Consider limitations and artifacts:***

    a) *Referring back to the example of Jane in the Engage section, explain how the way the tracks are represented in Ocean Tracks might explain the section of the track containing the jump.*

    b) *Referring back to what you learned about tagging technologies and data representation in the Pre-Lab Assignment, explain how the various aspects of data collection, processing, and representation might also explain the jump in the seal's track.*

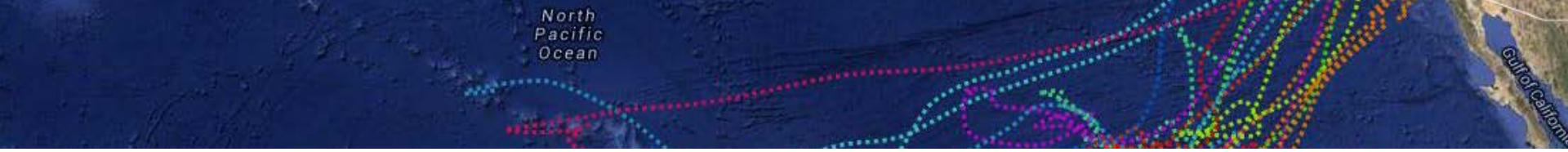
3. ***Extract meaningful patterns:*** *Though this section of the track contains a data artifact, Elephant Seal #1266 was still moving about the North Pacific Ocean, and it is still useful to infer what this seal may have been doing during this timeframe. Hypothesize and draw (on a screenshot or in your notebook) what you think the seal's actual track might have looked like during the ~21-day "jump" from 1/02/2008 to 1/23/2008.*



Synthesize

- The tracks you explored throughout this module demonstrate that tracking data can help us learn a great deal about animal behavior, but they also highlight the importance of interpreting those data with a critical lens rather than just accepting them as fact.

- Your Synthesize activity for this module is a class discussion. To prepare for your discussion, reflect on the analytical tools and strategies you used throughout the module to investigate the various data artifacts encountered. It may be helpful to return back to the Ocean Tracks map, explore a new track, and ask yourself the following questions to help guide your exploration:
  - ***Inspect:*** *Look closely at the track and graph. What stands out? What feature(s) should I investigate further?*
  - ***Compare:*** *Do these features show up anywhere else along this animal's track? in tracks of other animals of this species? in tracks of animals of a different species within Ocean Tracks?*
  - ***Be skeptical:*** *Do these features make sense? Is it consistent with what I know about these animals? Are data values within reasonable limits?*
  - ***Consider limitations and artifacts****: If you see a pattern somewhere along the track that doesn't seem to make sense, how might the tagging technologies and their accuracy limits explain this pattern? What aspects of data collection, processing, and representation might explain this pattern?*
  - ***Identify additional sources of information:*** *What known behaviors, background information, and/or outside research might help explain this pattern?*
  - ***Extract meaningful patterns:*** *Even if a data artifact has been identified, what meaningful patterns in this animal's movements and behaviors may tagging technologies still reveal? What information can you learn from the track as a whole?*
- Compile your notes and use these to inform your responses to the class discussion questions on the following slide.



Synthesize

CLASS DISCUSSION

As a class, discuss your answers to the Synthesize Questions below. Also, think about the challenge question you have explored throughout this module: ***What can the use of electronic tagging technologies reveal about the movement and behavior patterns of large marine animals?***

SYNTHESIZE QUESTIONS

1. *Summarize patterns you've seen in the Ocean Tracks data that might not make sense. What artifacts will you look for in the data as you do other Ocean Tracks modules (and other data analysis activities)?*
2. *What are some of the strategies and resources you will use to separate fact from artifact?*
3. *How do the tracks in Ocean Tracks resemble the actual movements of marine animals? Give two or more examples of the types of things you can you learn about these animals from the data available in Ocean Tracks?*
4. *Give two or more examples of ways in which the tracks differ from the actual movements of marine animals? What are some questions this module raised for you about the animals' behaviors?*
5. *Describe and discuss some examples of other kinds of data you've seen (outside of Ocean Tracks) that you would need to look at critically. What strategies will you use to try to better understand what is meaningful and what is not?*