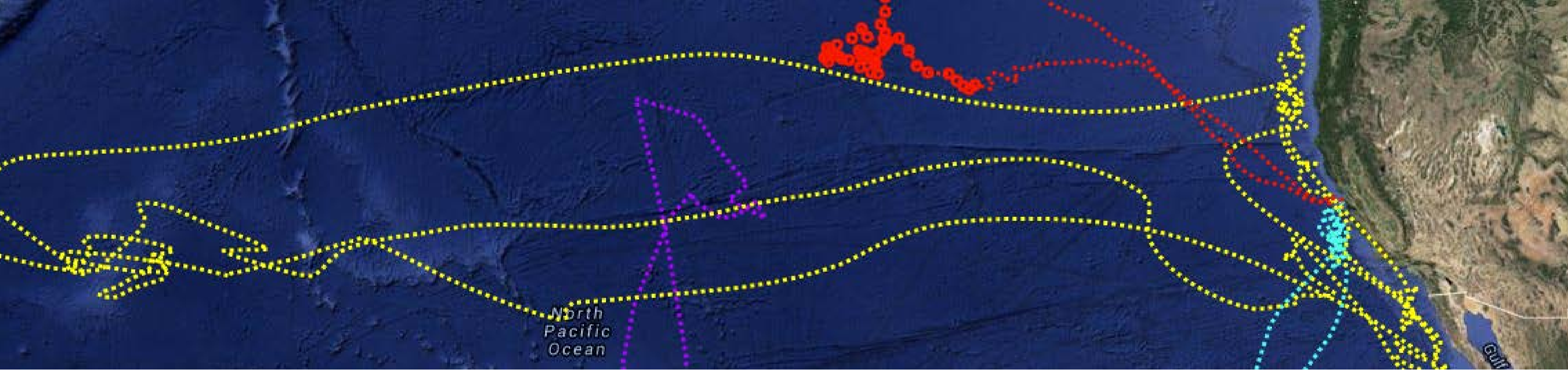


Faster, Farther, Deeper

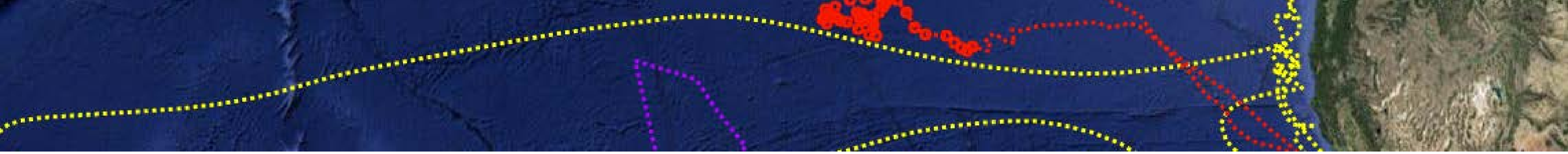
Exploring the Physiology of Highly Migratory Ocean Predators

In this module, you will explore marine habitat usage in three dimensions and design an experiment to explore in greater depth how physiology influences the ways in which different species use the ocean environment.

Learning Objectives

- Understand limitations of a data set and identify additional data required to answer a research question
- Propose a research question and experiment to study adaptations of a marine animal

OceanTracks

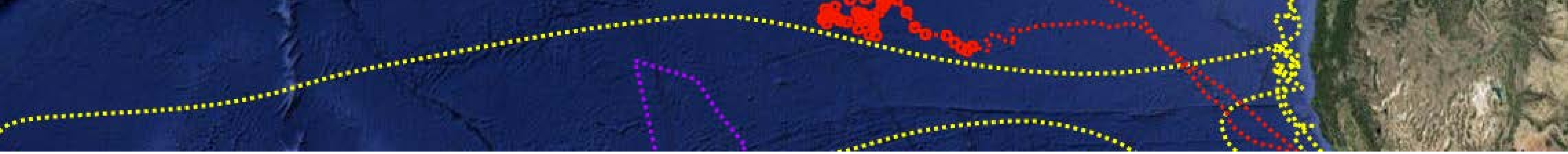


Pre-Lab Assignment

ADAPTING TO SURVIVE

All plant and animal species have developed their own unique set of adaptations for survival in a specific range of environmental conditions. Some of these conditions are so harsh that they can leave us asking, “How do they survive that?” For example, desert-dwelling animals must be equipped to withstand extreme heat and scarce water. Some marine animals must be able to tolerate low light and high pressure, or have the endurance to migrate thousands of miles to feed or breed. The Laysan albatross, with its impressive wingspan of up to almost 7 feet, a bill that can accurately measure flight airspeed, and the ability to travel hundreds of miles without beating its wings, is another example of how animals are uniquely adapted to their environments.

- Read about the albatross and its amazing adaptations for nearly effortless long-distance flight: http://oceantracks.org/library/species/laysan-albatross/
- Now, look at an albatross track in Ocean Tracks. Go to http://oceantracks.org/map.
- Open the **Data & Tools** tab and click + to expand the **Tracks** menu. Hide the default track, Elephant Seal #302.
- **Show** and **Graph** Laysan Albatross #281.
- Click + to expand the **Tools** menu and explore the **Speed** graph.
- Click on any of the active track points on the map to open a track stats window.
- Click on the **Track Summary** tab to get the statistics for the full track.

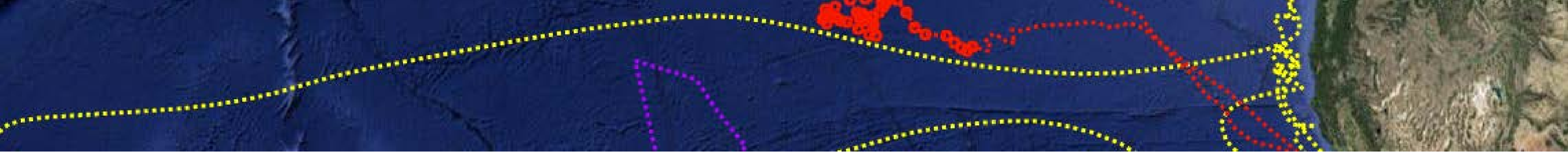


Pre-Lab Assignment

PRE-LAB QUESTIONS

1. *Use the Speed graph and Track Summary for Albatross #281 to answer the following:*
   a. *What was the average speed of Albatross #281 over its entire track?*
   b. *What was the fastest speed recorded for this bird?*
   c. *What was the total distance traveled by Albatross #281?*
   d. *What was the track duration?*
   e. *What was the average distance Albatross #281 traveled each day?*
2. *The distance from Washington, D.C., to San Francisco is approximately 2,800 miles (4506 km).*
   a. *How does this distance compare with the total distance traveled by Albatross #281?*
   b. *If you were to drive from Washington, D.C., to San Francisco at an average speed of 60 miles per hour (96.5 km/h), how long would it take you?*
   c. *If you were to drive at an average speed of 60 miles per hour (96.5 km/h), how long would it take to travel the total distance covered by Albatross #281?*
3. *What adaptation(s) does the albatross have for endurance?*

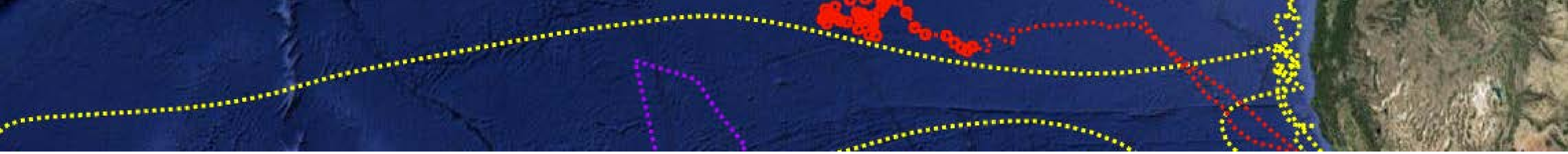
OCEANTRACKS



Engage

Electronic-tagging technologies provide scientists with information not only about where animals go in the open ocean, but also about how deep they dive and the complex environmental conditions they encounter along their journeys, creating a more complete three-dimensional picture of how these animals use their ocean habitats. With Ocean Tracks, you can explore some, but not all, of these kinds of data. In this section, you will look at tracking data available through the Ocean Tracks interface for three different species to lay the foundation for additional research into their physiology and adaptations for survival.

- Go to http://oceantracks.org/map. By default, Elephant Seal #302's track is displayed on the map.
- Open the **Data & Tools** tab and click **+** to expand the **Tracks** menu. In addition to Elephant Seal #302, also **Show**:
  - o Bluefin Tuna #508400
  - o White Shark #501600
- Zoom out on the map so you can see all 3 tracks at once.
- Click **+** to expand the **Tools** menu and explore data graphs for Elephant Seal #302. In particular, look at the **Depth** and **Speed** graphs to get an initial broad sense of how this animal uses the ocean.
- Click the **Graph** button next to Bluefin Tuna track #508400 in the **Tracks** menu to explore the data graphs for this animal. Then, look at the graphs for White Shark #501600.



Engage

ENGAGE QUESTIONS

1. *What did you notice about where each animal traveled? Do they all use the same or different parts of the Pacific? How did the shapes of the three tracks compare?*

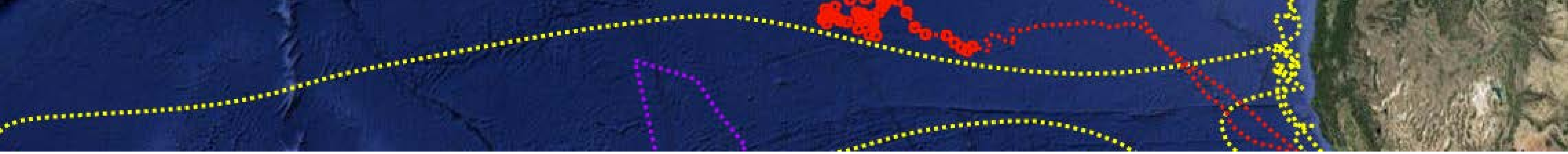
2. *Compare the depth and speed data for these three animals. Answer the following questions about the entire duration of their tracks:*

    a. *Which animal had the deepest average depth? the deepest individual depth measurement? How deep?*

    b. *Which animal had the fastest average speed over its entire track? the fastest individual speed measurement? How fast?*

3. *What aspects of an animal's physiology might limit its ability to go farther, faster, or deeper?*

4. *Sea lions are mammals and breathe air. How did the average diving depth of this air breather compare with the other animals? Do you think it would need to have special physiological adaptations to dive deeper? If so, brainstorm what those might be.*



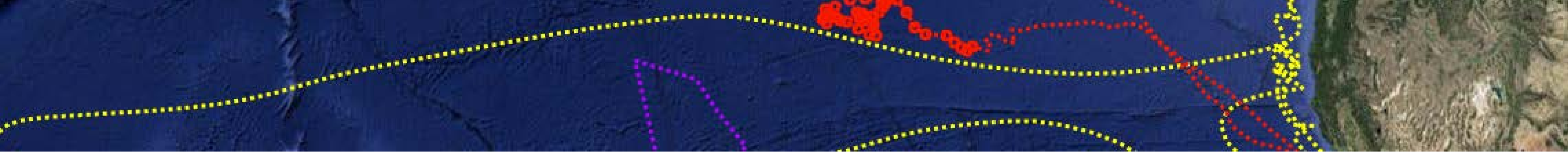
Explore

PART 1: COMPARING SPECIES

In this section, you will look at tracking and oceanographic condition data to explore the biological adaptations of a single species. Looking at data from multiple tracks from within the same species can help us better understand the environmental conditions and limits in which these animals are adapted to survive.

- Choose one species to explore further: elephant seals, bluefin tuna, or white sharks.
- Go to http://oceantracks.org/map. Turn off all tracks for animals that are not of your chosen species.
- Open the **Data & Tools** tab and click **+** to expand the **Tracks** menu. Select and **Show** five tracks for the species you have chosen. Select different years if possible.
- On the map, use the **Add Marker** tool to label your map with the name of the species you chose. Save a screenshot of your map showing all of the tracks you explored for your chosen species. (See Slide 7 for how to add a marker in Ocean Tracks.)
- Make and complete a table like Table 1 on Slide 10 to record depth, speed, and temperature data for all five animals. When gathering data for each animal, remember to select **Graph** to activate the track and generate data plots under **Tools**. When a track is active, track points on the map will be highlighted for the selected time range (see Slide 8).
- Use the annotated images on Slides 8 and 9 for additional tips on how to use the Ocean Tracks interface to find and gather all the data you need for your table.

OCEANTRACKS



Explore

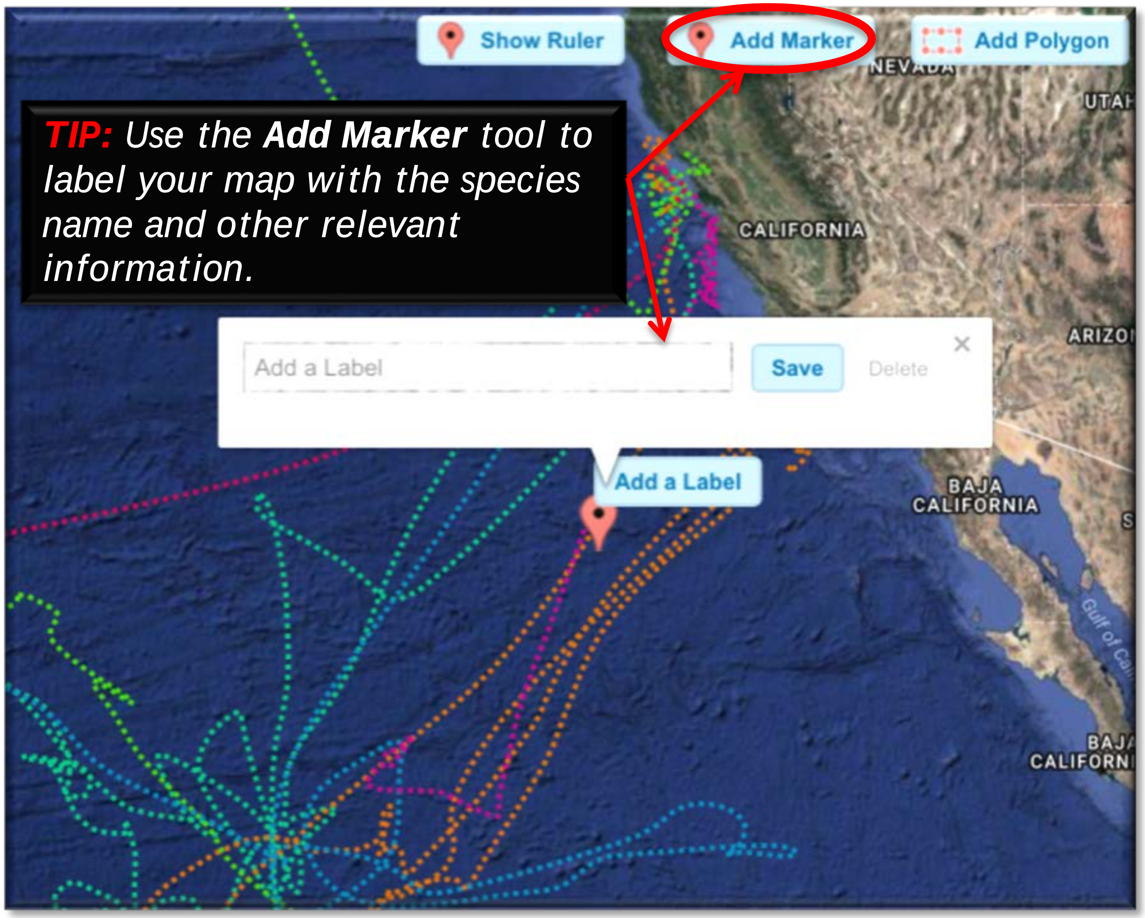
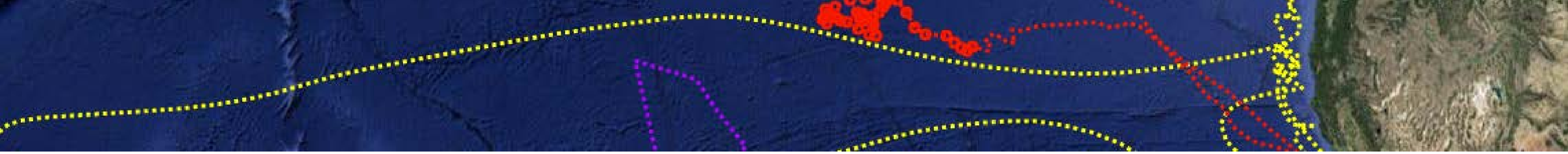


Figure 1. How to add a marker



Explore

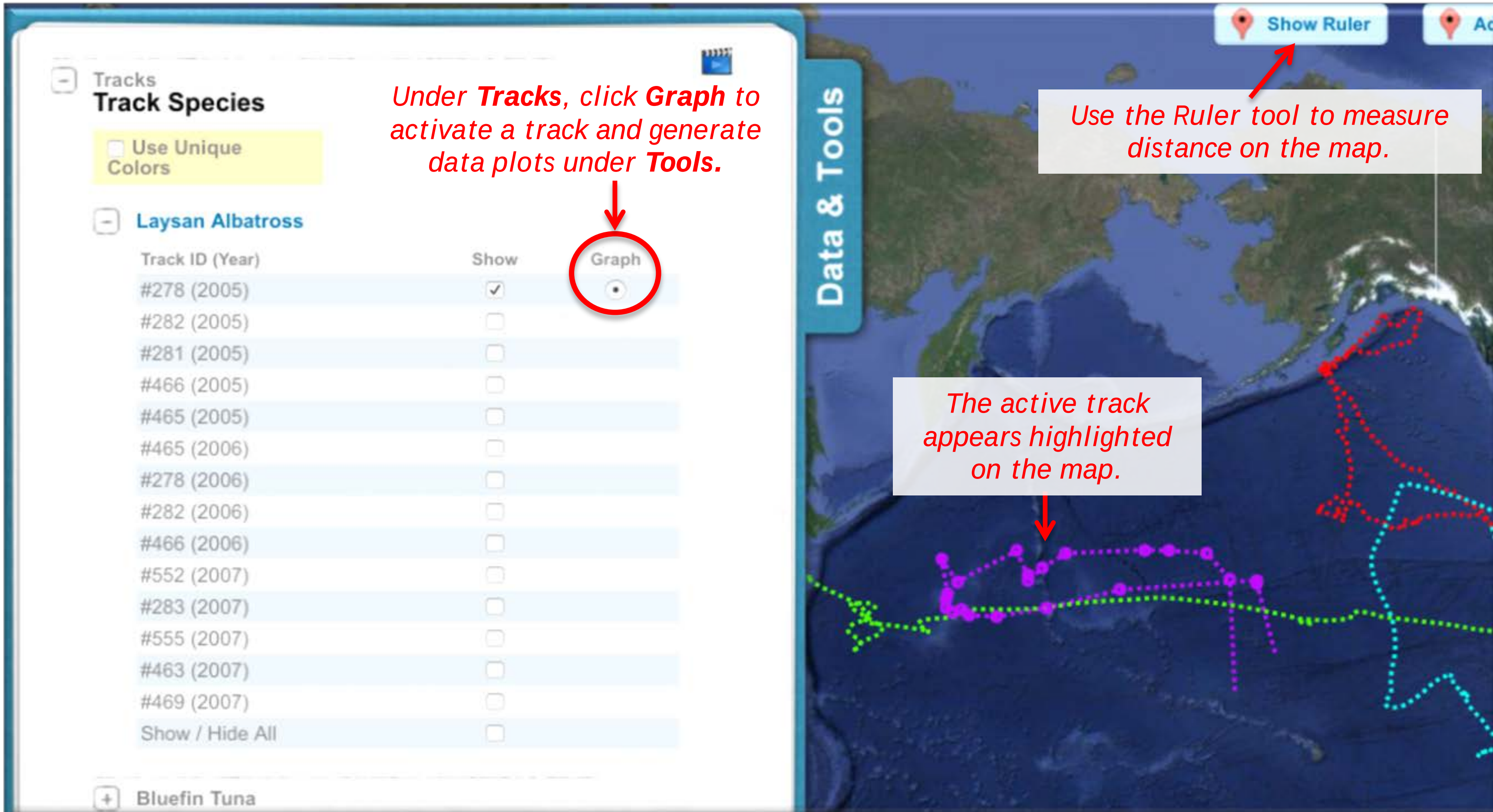
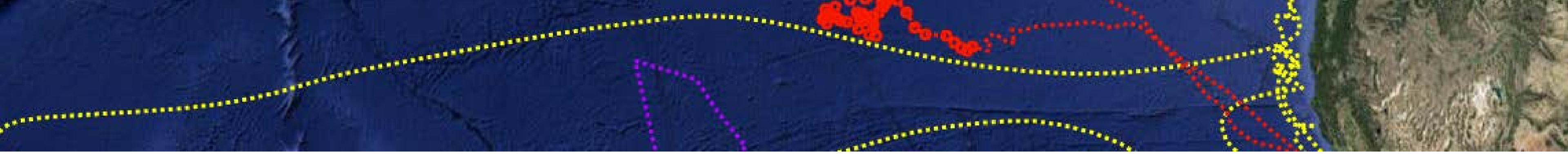


Figure 2. How to graph/activate a track



Explore

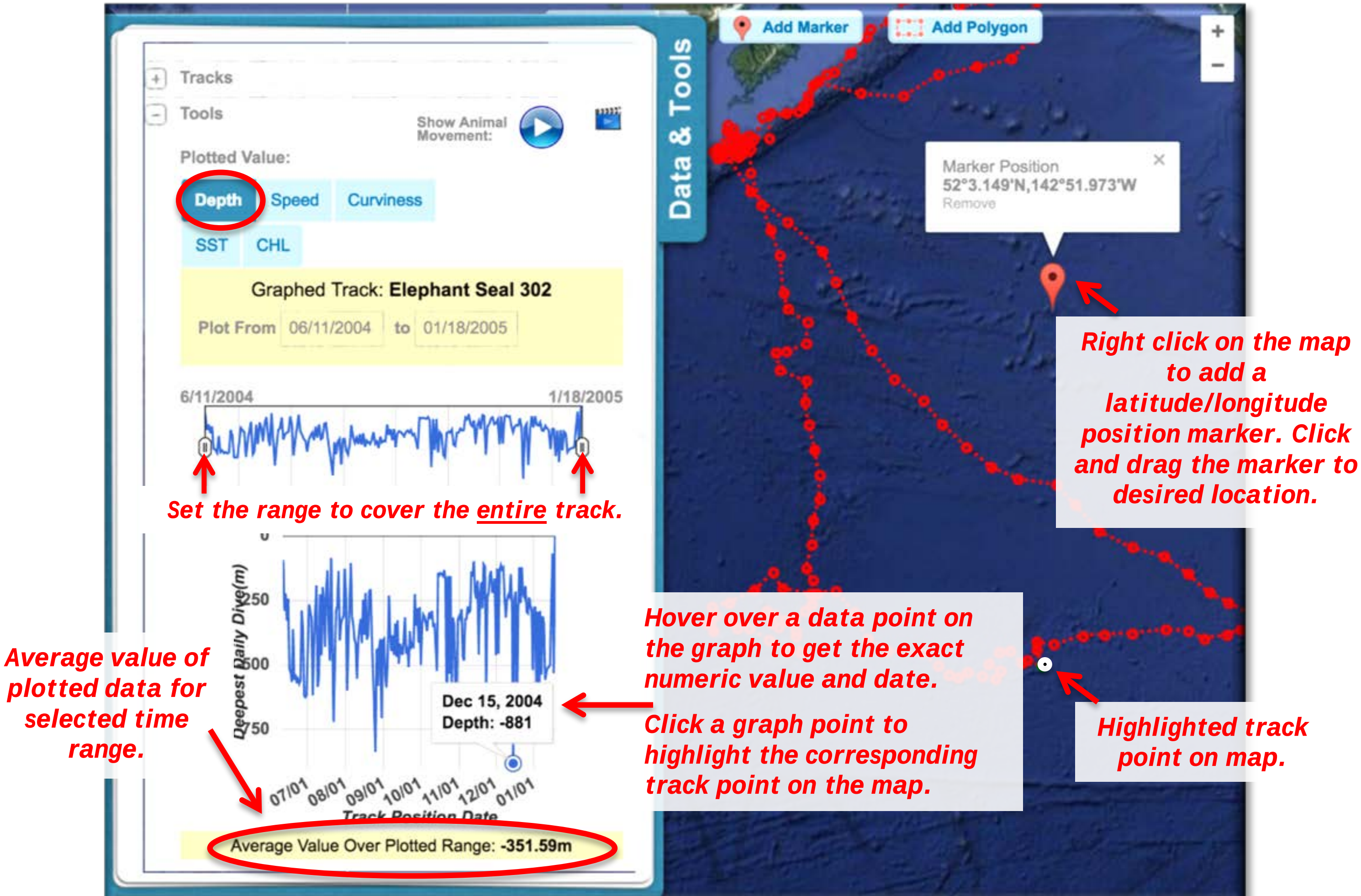
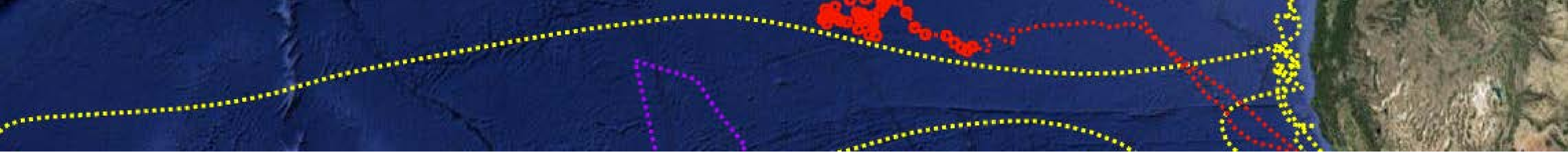


Figure 3. Tips for exploring Ocean Tracks data

OCEANTRACKS

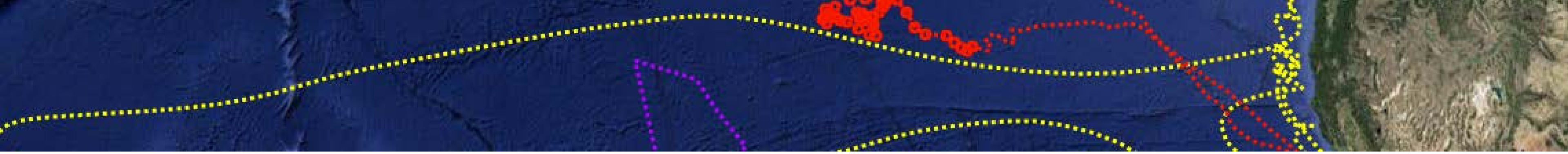


Explore

Table 1. Depth, Speed, and Temperature Data

Animal Species/ID	Avg. Deepest Daily Dive (m)	Deepest Dive (m)	Date and Lat./Long. of Deepest Dive	Avg. Speed over Entire Track (km/h)	Fastest Recorded Speed (km/h)	Avg. SST along Track (°C)	Max. SST along Track (°C)	Min. SST along Track (°C)

OCEANTRACKS



Explore

EXPLORE PART 1 QUESTIONS

Using data from tracking tags helps us understand the environmental conditions that animals' bodies have adapted to withstand.

1. *Answer the following questions about data recorded in your table:*
   a. *What was the range of deepest dives recorded in your data table (largest value in third column minus smallest value in third column)?*
   b. *What was the fastest speed recorded?*
   c. *What was the total range (max – min) of SST encountered by these animals?*
   d. *Compare measurements down each column of your table. What values stand out to you as being noticeably different from others? What about those values caught your attention? What questions do they raise?*

2. *Some animals must dive deep in search of food. Pressure at the surface of the ocean (atmospheric pressure) is 14.5 pounds per square inch (psi) or 1 atmosphere (atm). Pressure below the ocean surface increases by 14.5 psi (1 atm) for every 10 m of depth.*
   a. *Professional (human) divers typically don't go deeper than about 400 ft (~120 m) so as not to risk collapsing their lungs. How does the deepest dive recorded in your data table compare?*
   b. *Calculate the greatest pressure in psi and atm experienced by each of the five animals in your data table. Add a column to your data table to record these values.*
   c. *Elephant seals can dive as deep as 2,500 m in search of prey. What adapations do these animals have that allow them to withstand such extreme pressure? How do these values compare with the deepest dive and greatest pressure recorded in your data table? (See http://oceantracks.org/library/species/elephant-seal/ for more information about elephant seals.)*

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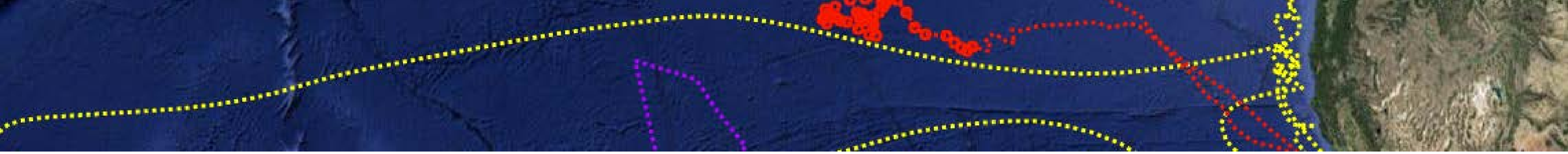


Explore

EXPLORE PART 1 QUESTIONS (CONTINUED)

3. *Sunlight keeps the top layer of the ocean relatively warm compared with deeper water. As animals dive deep below the surface, they typically encounter colder temperatures than at the surface. How cold does it get? Use the World Ocean Atlas (http://tinyurl.com/oceanatlas) to find the temperature at the approximate location and depth of the deepest dive recorded in your data table. (See Slides 13 and 14 for information about how to use the World Ocean Atlas.) How does the temperature at this depth compare with the minimum SST recorded in your data table?*

4. *How might temperature affect an animal? What adaptations do elephant seals, white sharks, and bluefin tuna have for surviving a wide range of temperatures?*

5. *Some animals have a need for speed. Researchers have found that bluefin tuna can swim as fast as 70 km/h (~43 mph) for short periods of time and white sharks can reach speeds of ~40 km/h (25 mph) when attacking prey, whereas elephant seals max out around 10 km/h (6 mph). What physiological adaptations do these animals have that enable them to move so quickly and efficiently through the water? Use information from the Ocean Tracks Library for bluefin tuna (http://oceantracks.org/library/species/northern-bluefin-tuna/), white sharks (http://oceantracks.org/library/species/white-shark/), and elephant seals (http://oceantracks.org/library/species/elephant-seal/) to help you.*

6. *Think about how the data in Ocean Tracks are displayed and what they represent. Are you able to determine exactly how fast, far, or deep each animal actually goes each day? Explain why or why not.*

OCEANTRACKS

Explore

Set all map and data parameters and then click Show Figure *button at bottom left.*

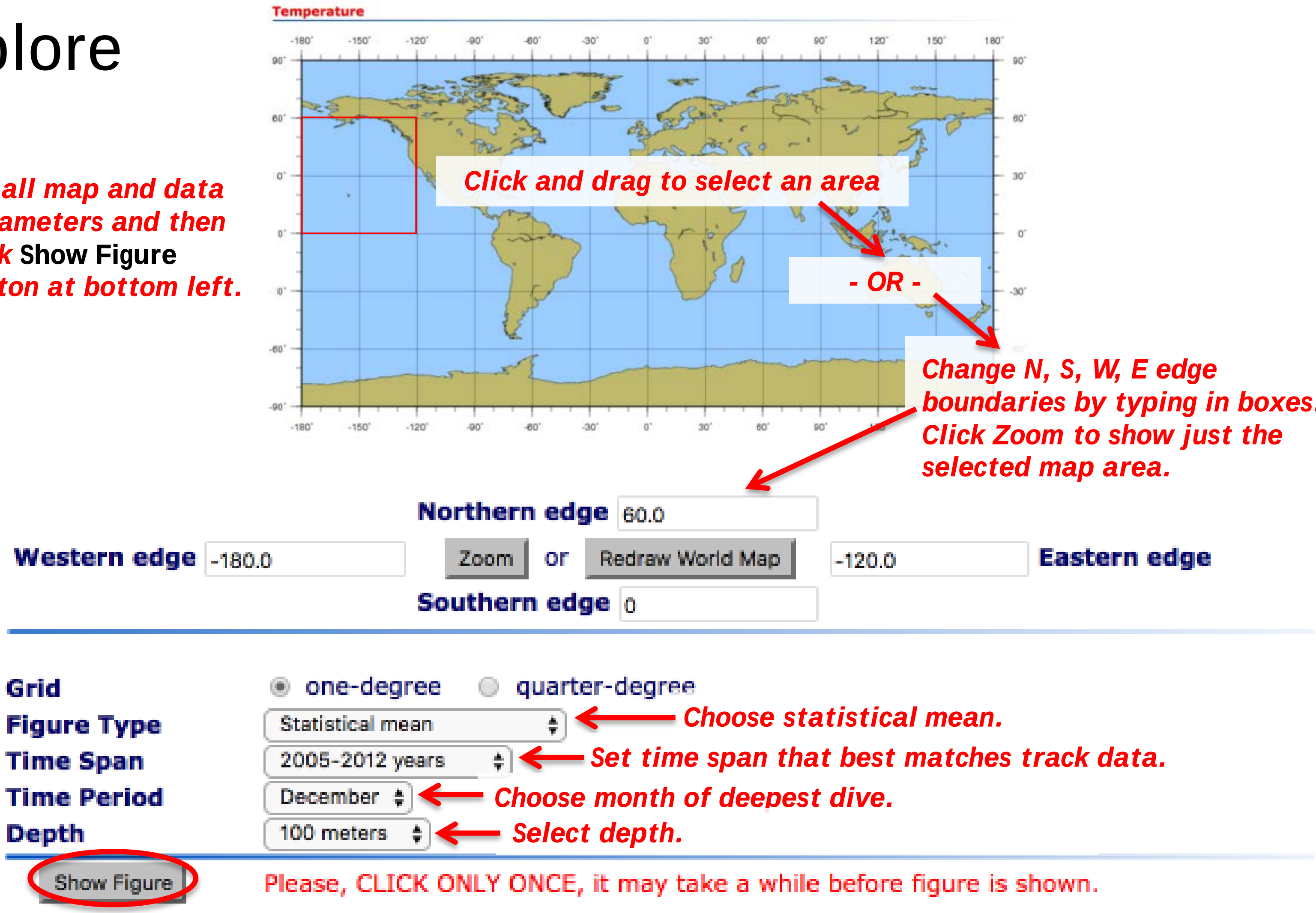
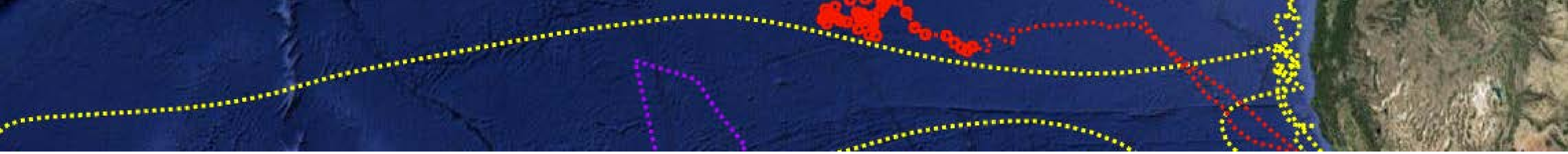


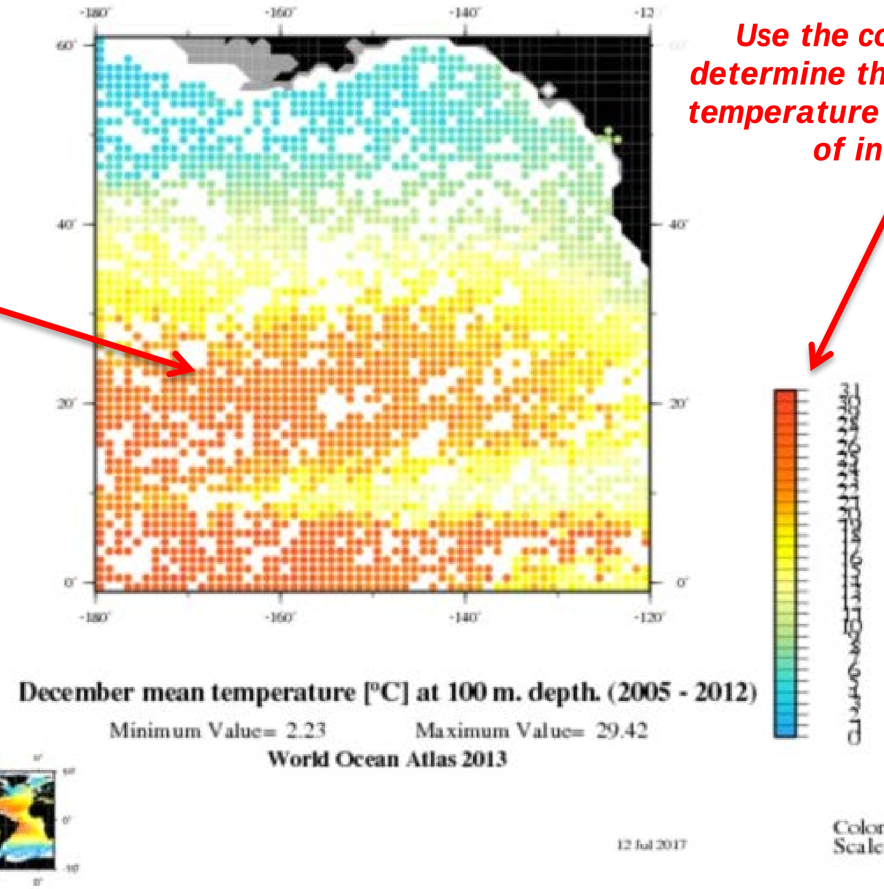
Figure 4. How to use World Ocean Atlas



Explore

Find the location closest to the location of the track point for which the animal recorded its deepest dive.

Use the color scale to determine the approximate temperature at the location of interest.



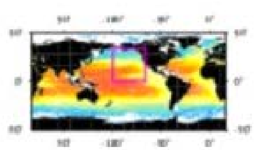
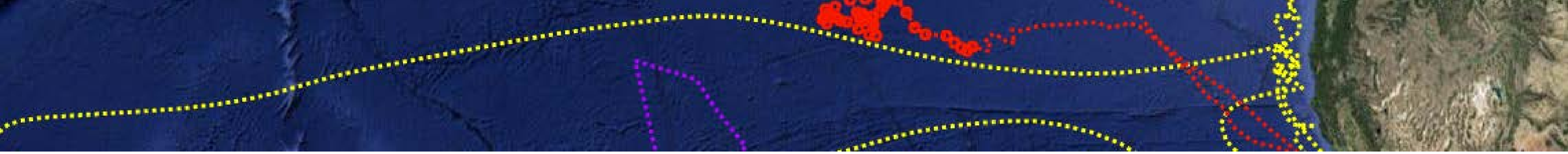


Figure 5. Interpreting World Ocean Atlas temperature data



Explore

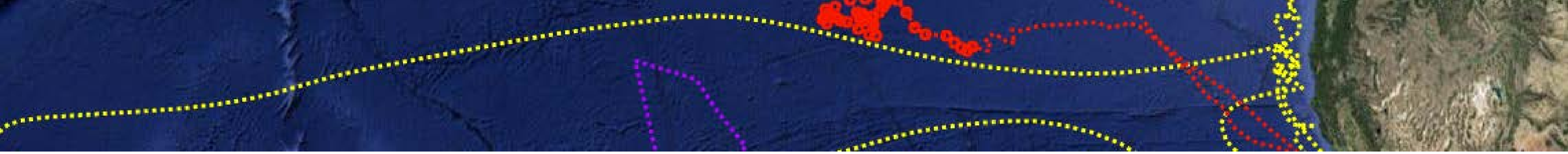
PART 2: COMBINING MULTIPLE SOURCES OF INFORMATION

Tracking data is only one piece of the puzzle. Multiple sources of data and information are needed to more fully understand how animals use the ocean environment and how their bodies are adapted to survive. In this section, you will discover and explore more about your chosen species as you begin to ponder its adaptations.

- Research adaptations of the species you chose to investigate further using the Ocean Tracks Library (http://oceantracks.org/library/), the Additional Resources below, and/or the internet.

ADDITIONAL RESOURCES

- **Elephant Seal:**
    - Friends of the Elephant Seal: http://www.elephantseal.org/
    - Le Boeuf, B. J., Naito, Y., Huntley, A., & Asaga T. (1989). Prolonged, continuous, deep diving by northern elephant seals. *Canadian Journal of Zoology, 67*(10), 2514–2519. http://mirounga.ucsc.edu/leboeuf/pdfs/LeBoeuf.1989.prolongeddiving.pdf
- **Bluefin Tuna:**
    - Graham, J. B., & Dickson, K. A. (2004). Tuna comparative physiology. *Journal of Experimental Biology*, *207*(23), 4015-4024. http://jeb.biologists.org/content/207/23/4015.full
- **White Shark:**
    - Del Raye, G., Jorgensen, S. J., Krumhansl, K., Ezcurra, J. M., & Block, B. A. (2013). Travelling light: White sharks (Carcharodon carcharias) rely on body lipid stores to power ocean-basin scale migration. *Proceedings of the Royal Society of London B: Biological Sciences*, *280*(1766), 20130836. http://rspb.royalsocietypublishing.org/content/280/1766/20130836



Explore

EXPLORE PART 2 QUESTIONS

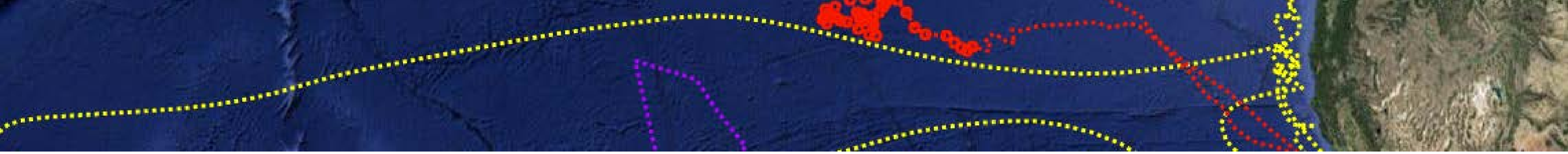
1. *Compare the data in your data table to the information you read in the Ocean Tracks Library and Additional Resources about your chosen species. What behavioral patterns identified or explained in the literature do you see evidence of in your data table?*

2. *Consider what we can and can't learn about animals' biology from tracking data.*

    a. *How can tracking data inform us about animals' biology? What are the limitations of these data with regard to investigating animal biology?*

    b. *What questions do the tracking data raise for you about these animals' biology? What additional data/information do you need to explore these questions further?*

3. *How can tracking data help researchers understand the relationship between animals and their environments and protect them from change?*



Synthesize

WRITE A RESEARCH PROPOSAL

Your assignment is to write a hypothetical research proposal to obtain the data you would need to explore a question you have about your chosen species and its adaptations for survival in the ocean.

1. Based on the data you explored in Ocean Tracks and the reading you did on the species of your choice, come up with a research question about your chosen species that cannot be answered with Ocean Tracks data alone. To do this, ask yourself the following questions:

    - What do I already know about this species from reading/research I have done or things I have learned in class?
    - What did I see in my data that I am curious about that cannot be answered with Ocean Tracks data or analysis tools?
    - What phenomena or adaptations did I see in the data or read about that I want to know more about? What questions remained for the researchers who wrote the papers I read?
    - What questions do I have about this species and how it is adapted to the ocean environment?
    - What additional data would you need to answer these questions? How could those data be collected?

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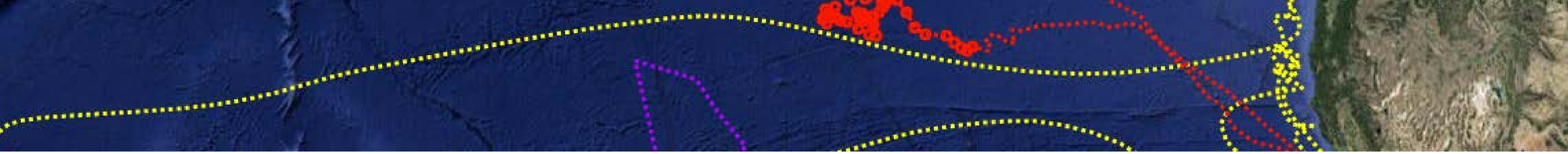

Synthesize

2. Assemble a short research proposal to describe how you would pursue an answer to your research question. See an example on Slide 19 using a species not included in Ocean Tracks.

PROPOSAL GUIDELINES

Your proposal is not intended to be a fully realized research proposal but, rather, a summary that includes the following key components, which can be captured in one well-focused paragraph (or PowerPoint slide) per section:

- **Title**: What is the research question you want to answer?
- **Background**: Why is your research question important or interesting? What did you observe in the Ocean Tracks data that led to your research question? What else would someone reading your proposal need to know to understand your proposed research idea? Include relevant screenshots, Ocean Tracks data, and/or citations.
- **Data Needed:** What data will you collect? What analyses will you perform? How will these data and analyses help answer your research question? Why would these data be better to collect than another potential source?

EXAMPLES OF TOPICS YOU MIGHT CONSIDER:

Having trouble coming up with a question of your own? Here are a couple ideas that might help spark an idea:

- Differences in diving behavior between males and females of your species based on physiological differences.
- How time of year influences metabolic rates/energy needed to survive.

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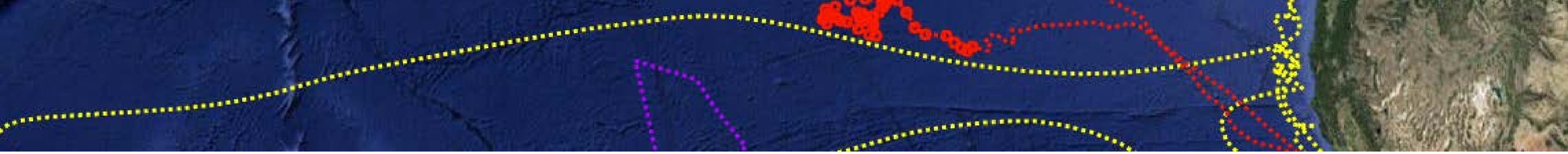
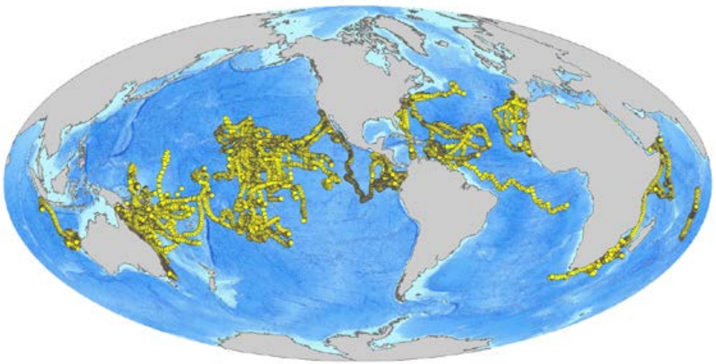
OCEANTRACKS



Synthesize

EXAMPLE: ***How do body temperature and water temperature affect the heart function of marlins*?**



EXAMPLE: Marlin tracks. Image courtesy of Stanford University and IGFA

From tagging data, a marlin researcher observed that the marlins in her data set were never found in water warmer than 23°C, and she would like to know why. She wonders what adaptations these animals have for survival in cooler water and whether the upper limit of the the water temperature measured by the tracking tags is a biological limit for marlins or if it is simply a limitation of her tracking data set. She recently read a research paper outlining a hypothesis that marlins' hearts can't function properly above a certain temperature, so she proposes to test this with her own study in which she will measure the external water temperature the marlins experience and see how it relates to their internal temperature. Additionally, she will collect heart rate data from the animals to serve as a proxy for the marlin's proper heart function and to see if it fluctuates with changing external and internal temperature conditions.

By collecting internal temperature data and heart rate data rather than just looking at more marlin tracks and examining maximum water temperature, this researcher will be able to learn more about marlins' adaptations and how efficiently their bodies work under different environmental conditions. If she just looked at more temperature data, she would still be missing a key component for understanding the animals' biology.

OceanTracks