

Navigating the Hurricane Highway

Understanding Hurricanes With Google Earth

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Images and data courtesy hurricanetracking.com, oceanweather.com, guiweather.com

Getting Started

Open Google Earth and follow the instructions in Figure 1 (on the next page) to maximize the performance and utility of Google Earth for this exercise.

Then download this file- http://www.stevekluge.com/geoscience/ges/Hurricane_Highway.kmz - and open it in Google Earth.

The Hurricane Highway file will appear in the Temporary Places folder of the Places sidebar. Right click on it, and select "Save to My Places". Once again, turn off all the content in My Places. The 3D display should not contain anything but the default image of the earth in space.

Introduction

Seasonal and individual hurricane predictions can help mariners, aviators, and coastal communities prepare for the high winds, rain, and storm surges associated with tropical storms. Part of the prediction process involves examination of the conditions influencing the formation, strengthening, and weakening of the storms, and paths they follow. Recent advances in the collection and visualization of various oceanic and atmospheric data have made the study of tropical storms easier and more efficient, though the science of prediction is still far from perfected.

In this lab, you'll explore data and imagery collected by satellites, aircraft, and buoys, and displayed in Google Earth, to develop a basic understanding of the nature and behavior of these huge storms.

Part One - Hurricane Dean: a case study.

Hurricane Dean began as a tropical depression off the coast of Africa on August 13, 2007. The next day, Dean had strengthened to a tropical storm, and on August 16, 2007 Dean became the first hurricane of the Atlantic Tropical Season of 2007.

During the next 8 days, Dean traveled westward across the tropical Atlantic, entering the Caribbean Sea on August 17, passing just south of Jamaica on the 19th, and making landfall as a strong Category 5 hurricane on the Yucatan Peninsula on August 21.

Refer to Figure 2 to (1) expand and (2) display the contents of the Hurricane Dean folder in the Places sidebar. Make sure that the remainder of the content in the places folder remains 'turned off'.

Questions marked with a "☆" require you to use the answers to previous questions to develop your understanding of how hurricanes work and behave, and are key to your understanding of hurricanes.

1. On the 3D display, use the ruler tool (click Tools > Ruler) to measure the entire length of the path of Dean, from Advisory 1 (at the eastern end of the storm track) to his end near Mexico, and report that distance here:

_____ miles
_____ nautical miles
_____ kilometers

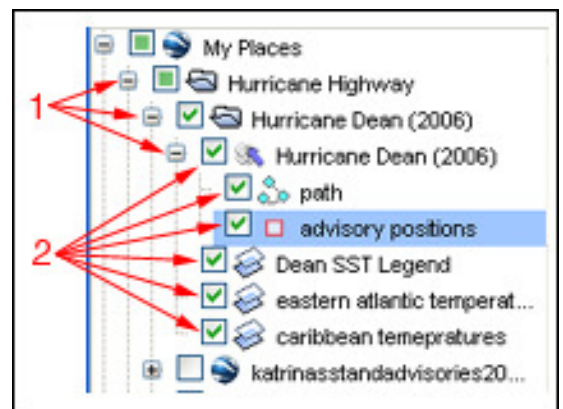


Figure 2. Expand the Hurricane Dean folders (1) and make sure they are all displayed, or 'turned on'. (2)

2. On the 3D display click on every 3rd or 4th storm position, starting at Advisory 1. Working your way westward to longitude 87W, describe how the "maximum sustained wind speed" changes over time.

1. Click here to minimize the Search sidebar.

2. Click here to turn off all the content in your Places sidebar. Note that the content of your Places will be different than what appears here.

3. Click here to turn off all the layers that come with Google Earth. This will 'unclutter' your display and allow the program to run faster and more smoothly.

4. Finally, click here to minimize the Layers sidebar.

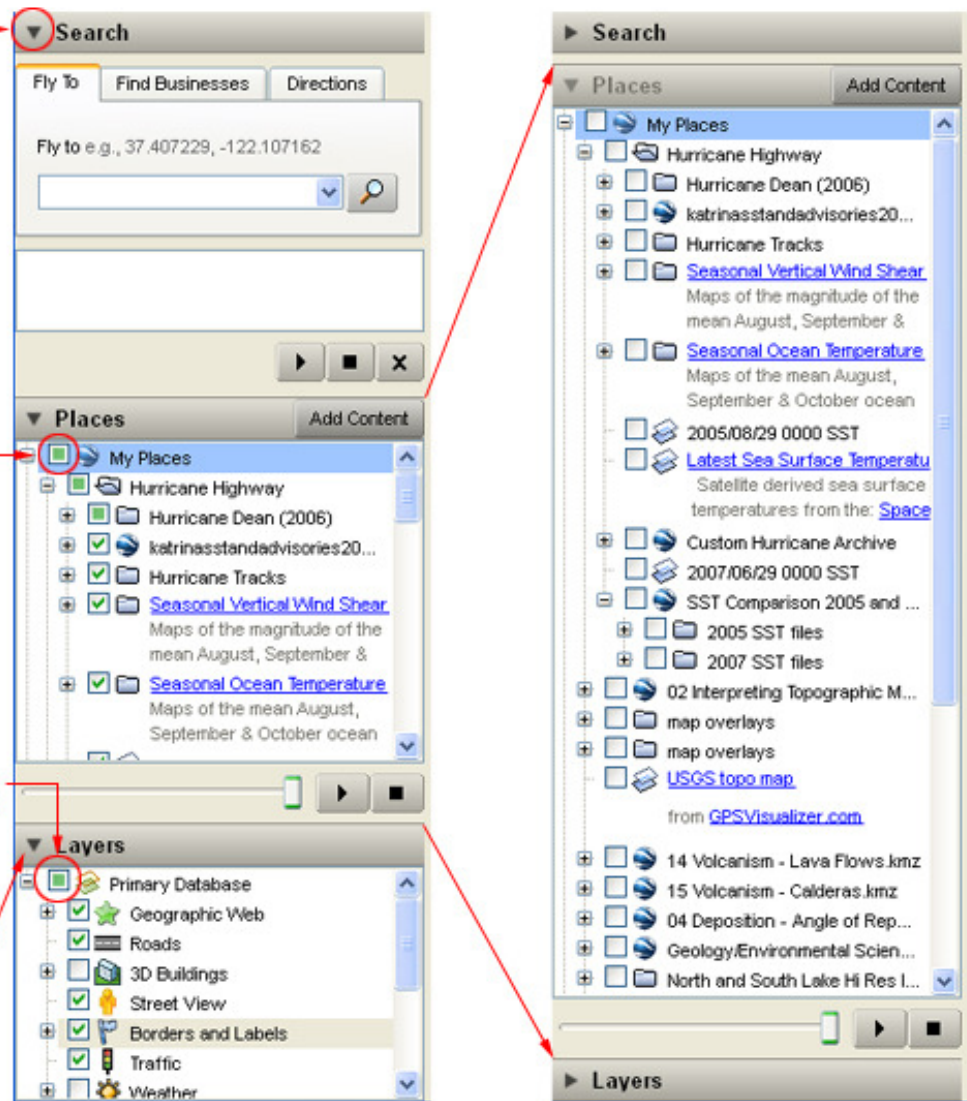


Figure 1. Follow the instructions in red – in order – to maximize the performance and utility of Google Earth for this exercise. The sidebar should look like the image on the right when you're ready to begin the lesson.

3. Citing actual temperatures, describe how the sea surface temperature changes as you travel westward across the Atlantic on the 15th parallel of latitude.

4. What was the approximate sea surface temperature as Dean became a tropical storm?

5. What was the approximate sea surface temperature as Dean became a hurricane?

6. What was the approximate sea surface temperature as Dean reached Category 5 strength?

☆ 7. Describe the relationship between sea surface temperature and the strengthening of tropical storms and hurricanes. Use specific temperatures in your description.

8. What is the range of forward speeds of the storm (referred to as “tracking” in the Google Earth advisories) during it’s lifetime?

Slowest: _____ Fastest: _____

☆ 9. What is the average tracking speed of the storm? (you don’t need to calculate it, just look for the most frequently appearing tracking value)

10. What was the maximum sustained wind speed, and what was the Saffir Simpson Category, as Dean came ashore on the Yucatan Peninsula?

Wind speed: _____ Category: _____

11. What happened to the maximum sustained wind speed and Category as Dean crossed the Yucatan Peninsula? Use specific times, wind speeds, and categories in your description.

☆ 12. What caused the wind speed changes you’ve noted in question 11. In your answer, list the factors involved, and explain **how** and **why** they affect wind speed.

- ☆ 13. Notice the water temperatures along the Louisiana, Mississippi, Alabama, and Florida panhandle coast (around 30N, 88W) and describe how and why those water temperatures might affect a storm making landfall there.

- ☆ 14. Describe **how** and **why** the water temperatures along the east coast of Florida (29N, 80W) might affect the intensity of a storm moving up the coast there, or making landfall there?

Part Two – Hurricane Katrina: the costliest hurricane in US history

Much has been written about incredible human, cultural, and economic costs of Hurricane Katrina, just one of a record breaking number (27!) of tropical storms and hurricanes of the 2005 Atlantic tropical season. Currently the costliest hurricane in US history (and the third deadliest), Katrina grew from tropical disturbance in the Bahamas into a major category 5 hurricane in the Gulf of Mexico in just four days. On the fifth day, hurricane induced flooding had paralyzed and nearly destroyed the port city of New Orleans in the Mississippi delta as Katrina made landfall.

Turn off the Hurricane Dean layers and folders, and turn on the Hurricane Katrina folder (you do not have to expand the Hurricane Katrina folder). See Figure 3. A sea surface temperature (SST) display appears, along with a temperature legend.

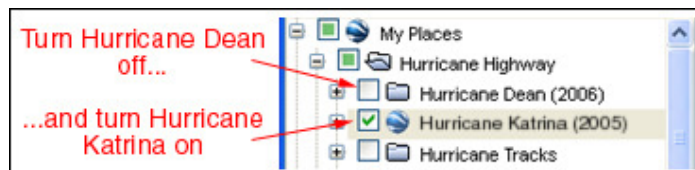


Figure 3

Notice also that a time scale is now displayed across the top of the 3D display. As you work through Part Two, you will want to play a looping image of sea surface temperatures and storm location and data. See Figure 4 and take a minute to play with the time line.



Figure 4.

You can (1) change the speed of the looping image, (2) drag the slider to select a specific date, and (3) stop and start the automatic looping of the display.

Run the loop a few times, and then stop it and drag the display to August 26 at 9:30 AM. Now mouse over, and then click, any of the points along Katrina's path to reveal the date and other information regarding the progress of the storm.

1. Describe how the wind speed and pressure changed as Katrina moved over the southern tip of Florida on August 26.

- ☆ 2. In Part One, we learned that hurricanes lose energy over land. Explain why Katrina was still intensifying as she moved over Florida.

3. Use the slider to set the time to August 28 at about 10:30 PM. Citing Categories and specific wind speeds and air pressures, describe the changes in Hurricane Katrina from August 26 to August 28.

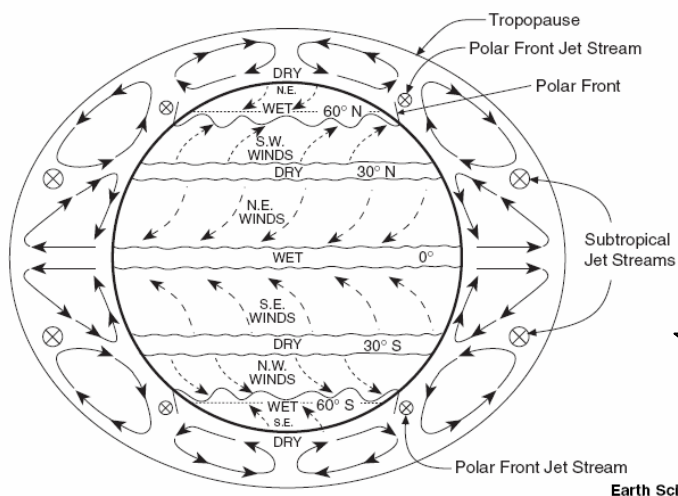
- ☆ 4. Explain why your answer to question 3 above is not surprising.

- ☆ 5. What conditions at that time led forecasters to suggest that Katrina might make landfall on the Gulf coast as a strong Category 5 storm?

- ☆ 6. Set the slider to August 29 at around 5:30 AM. While Katrina was still a strong Category 5 storm and seemed to be heading straight for New Orleans, forecasters began to think the storm might weaken before making landfall. Why?

- ☆ 7. Drag the slider ahead to September 1, and describe what happens to the temperatures in the Gulf as and after the storm crosses it.

- ☆ 8. Describe as many mechanisms as you can think of to explain the cooling of the sea surface in the wake of Hurricane Katrina. Think, "Where did the heat go?"



9. Refer to the chart of planetary winds to the left, and do/answer the following:

A. At what latitude did Katrina's track turn to the northeast?

B. Trace the path of Katrina on the diagram to the left.

- ☆ C. Does the forward motion of the hurricane seem to be at least in part driven by the planetary winds?

Part Three – Looking at Hurricane Seasons over the years

By now you should be able to make some predictions about hurricane activity. Collapse and turn off the Hurricane Katrina folder, and expand the Hurricane Seasons folder and subfolders. Turn on the 2005 data as shown in Figure 5. Click on 2005 Animated Tracks in the sidebar to display the timeline in the 3D display. Click play button on the timeline, and notice in particular the seasonal SST and the corresponding number of tropical storms and hurricanes.

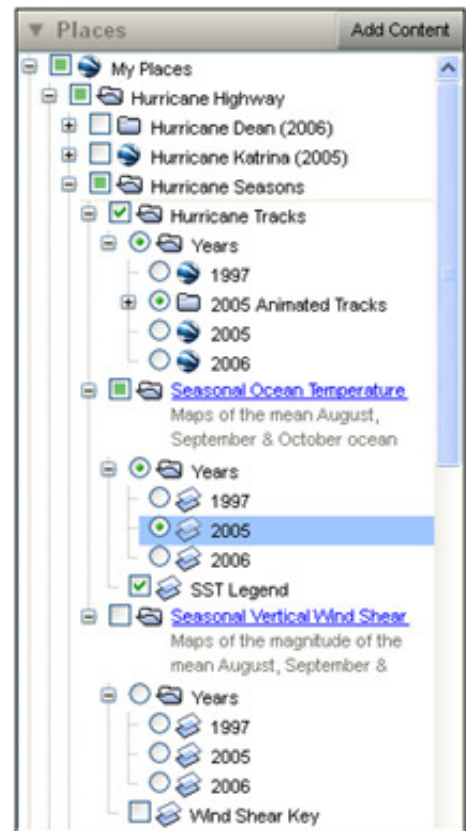


Figure 5

Now turn off the Hurricane Tracks, and toggle the 1997 and 2005 SST's back and forth (See Figure 6).

1. How do the seasonal SST's in those 2 years compare?

2. Based on the observed seasonal SST, predict the relative number and intensity of storms in 1997 compared to the number of storms in 2005.



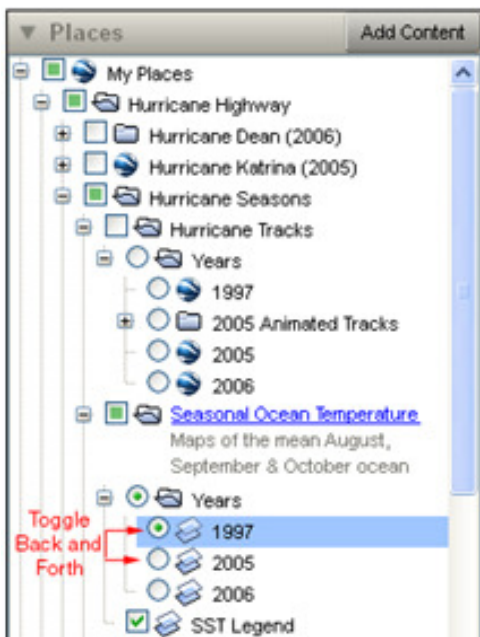


Figure 6

Turn on and toggle back and forth between the 2005 and 1997 tracks to confirm your answer to question 2 above (See Figure 7).

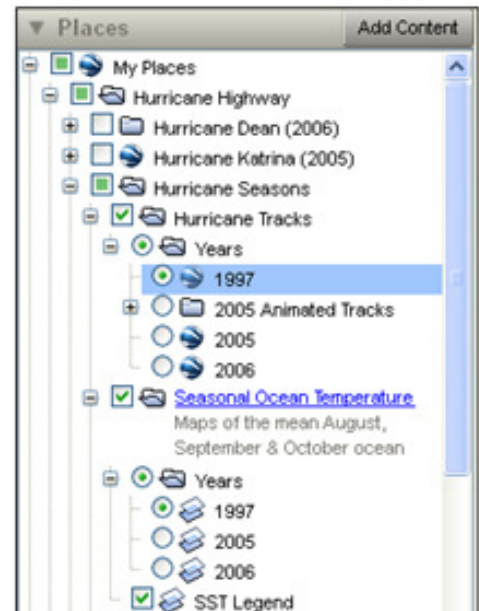


Figure 7

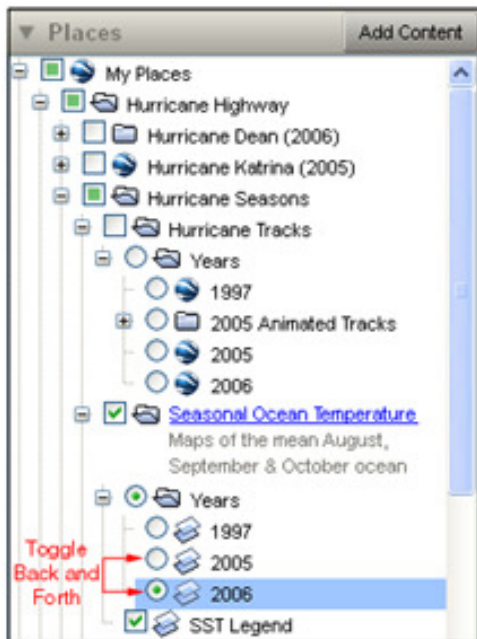


Figure 8

Now turn off the Hurricane Tracks again, and toggle back and forth between the 2005 and 2006 SST's (Figure 8).

3. Would you describe the seasonal temperatures as similar, or very different? _____
- ☆ 4. Predict how the number and intensity of storms in 2006 probably compared to the number of storms in 2005...

... and then turn on the 2006 tracks and toggle back and forth between the 2006 and 2005 tracks to confirm your answer to question 4 (Figure 9).

You probably predicted that 2005 and 2006, with similar SST's, were similarly active. The reality was, however, that in spite of similar SST's there were far fewer and less intense storms during 2006 hurricane season.

Although the 2005 and 2006 SST's were similarly warm, there were far fewer storms in 2006.

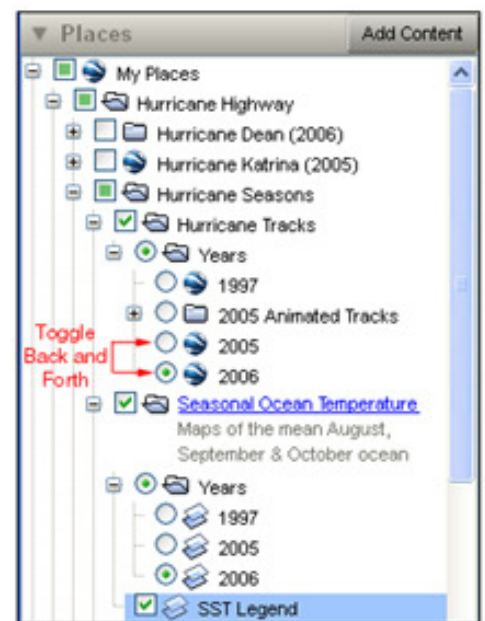
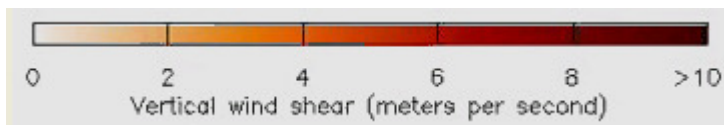


Figure 9

Part Four – Vertical Wind Shear

Obviously, there must be another factor involved in the development of tropical storms. **Vertical wind shear** (the rate of change of wind speed or direction with a given change in height) is another critical factor in determining whether severe weather will develop. Significant wind shear will disrupt the 'organization' of a tropical depression, limiting or even preventing the formation of rotating cyclonic storm or hurricane.

Turn off the Seasonal Ocean Temperature layer, and turn on the 2005 wind shear layer. Also turn on the 2005 Animated Tracks layer. Run the time line loop again, and answer the following questions:



1. The wind shear legend to the left matches the images on the 3D display. Which end/color of the legend will correspond with the greatest likelihood of tropical storm development? (the left/white end, of the dark red/right end?) Explain!

☆ 2. Describe any relationship you see between tropical storm origin areas and vertical wind shear in 2005.

☆ 3. Turn on the 1997 seasonal wind shear layer and the 1997 Hurricane Tracks layer. Describe the 1997 season wind shear, and explain how it influenced tropical storm development that year.

☆ 4. Turn on the 2006 seasonal wind shear layer, and comment on the apparent extent to which vertical wind shear affected the number and intensity of tropical storms that year. (Toggle the 2005 and 2006 wind shear layers back and forth.

Part Five – Storm Precipitation and Energy Calculation

In Part Two you were asked to speculate on the reasons for the cooling of the sea surface in the wake of Hurricane Katrina.

The amount of energy in tropical storms is enormous, and it is possible to make rough calculations of just how much energy is involved in generating and maintaining them. The total precipitation can be used as a proxy for those calculations. Follow the instructions in Figure 10 to set up the Google Earth display and work through the following questions.

1. Adjust the opacity of the Total Rainfall overlay up and down, noticing the relationship between cloud cover and rainfall amounts. Describe the relationship.

2. Maximize the opacity of the Total Rainfall layer, and use the ruler tool to estimate the diameter and radius of the area of maximum precipitation associated with Katrina on August 26. Report your answer in km and miles

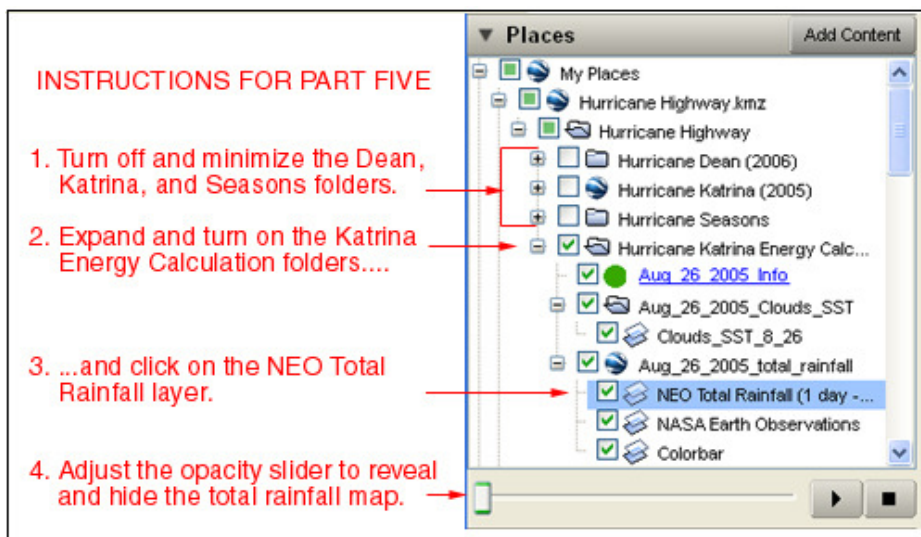


Figure 10

3. Calculate the surface area of the region of Total Rainfall in Katrina on August 26. Report your answer in km^2 and miles^2

Area = _____ km^2 _____ miles^2