A Buffer from the Storms

In recent years, many hurricanes have made landfall in the United States, with the 2004 and 2005 hurricane seasons being particularly active. In 2004, five named storms made landfall in the United States: Bonnie, Charlie, Frances, Ivan, and Jeanne. All of them made landfall in Florida. Two of the storms, Frances and Jeanne, made landfall in virtually the same location within three weeks of one another. The storms caused over 3,132 deaths and $50 billion in damages. The next year, seven hurricanes made landfall in the United States causing over 2,280 deaths and $128 billion in damage. Most of the deaths and destruction in 2005 resulted from five of these storms: Dennis, Emily, Katrina, Rita, and Wilma. Hurricane Katrina and its 30-foot storm surge devastated southeast Louisiana while Wilma was the most powerful hurricane ever recorded in the Atlantic Basin. The 2006 hurricane season was milder than expected and no hurricanes made landfall in the United States, while the 2007 hurricane season saw the development of two category 5 storms, Dean and Felix. Dean made landfall on Mexico's Yucatan Peninsula while Felix made landfall in Central America.

Over half of the United States' population lives within fifty miles of the coast and much of our coastline is being developed to support its growing population. In Louisiana, a complex network of levees and canals, built to protect New Orleans from being flooded by the Mississippi River, and to improve the river as a shipping channel, prevented silt from replenishing the coastal marshes. These same marshes would have partially protected New Orleans from Hurricane Katrina.

During a storm event, coastal marshes, wetlands, and barrier islands serve as the first line of defense against hurricanes. The vegetation and sediments can slow down the storm surge and absorb some of the storm's energy and water. While sturdy vegetation, such as shrubs and cypress trees offer more protection than grasses against high winds, marsh grasses can absorb increased water levels, if the storm hits when the grasses are exposed (e.g., not at high tide). Scientists estimate that for every square mile of wetlands lost in an area, storm surge rises by one foot.

Exploring Hurricanes along the East Coast

- Launch My World GIS. Open the project file name **Hurricanes.m3vz**. The project should open displaying the **U.S. States** and **Countries** layers.

- Turn on the **Atlantic Hurricane Tracts 1851-2006** layer. To turn a layer on, click the **Show/Hide Layer** box located on the far right side of the layer's control panel. When the layer is on, an eye, , will appear in the checkbox.

  - Use the , , and tools to explore the **Atlantic Hurricane Tracts 1851-2006** layer.

Tip: If you zoom in too far, use ◀ the **Zoom-to-the-Previous** button or ⊞, the **Zoom-to-All** button.

Hurricanes are large tropical storms with heavy winds (greater than 74 mph). They generally begin in areas of warm moist air near the Equator. If atmospheric conditions are favorable and water temperatures are above 79 F, a storm will intensify and may become a hurricane.

*Qn. 1. Describe the shape of most of the tracts. Where do they begin? Where do they end?*

Qn. 2. How far west might the effects of Atlantic Coast hurricanes be felt?

- Explore the **Atlantic Hurricane Tracts 1851-2006** data table.

  - First make the **Atlantic Hurricane Tracts 1851-2006** layer active. To activate a layer, click anywhere on its control panel except the **Show/Hide Layer** box; when active, the panel will turn white with a yellow border.

  - Open the **Atlantic Hurricane Tracts 1851-2006** data table by clicking⊞, or by choosing **Layer/Show Layer Table…**. A message will appear telling you that this is a large data table and may take a while to open. Click **OK**, when asked if you still want to open the table.

  - Use the scroll bars to scroll across or down through the data table so you can see what categories of data it contains and what the data looks like.

  - Sort the data table by clicking on a column header. Try clicking **WINDKTS** (wind speed in knots), **PRESSURE**, or **YEAR**. On the first click, the data will be displayed in ascending order ≙ ; on the second click, it will be displayed in descending order ≡ ; and on the third-click, it will return to its original order.
    Note: The sorting takes several seconds, so click only once and wait for the results.

Qn. 3. What information is provided for each storm tract?

*Qn. 4. Does each record represent a single hurricane? Explain.*

  - Close the **Table of Layer "Atlantic Hurricane Tracts 1851-2006"** window.

- Create a histogram displaying the number of Atlantic Hurricane tracts by month.
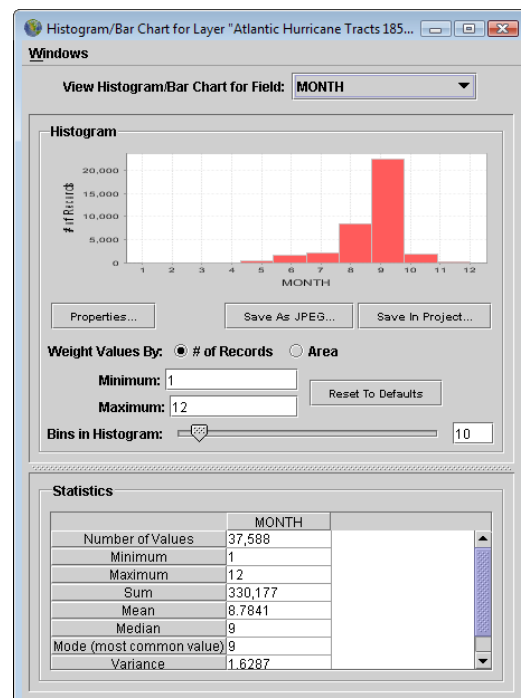
o   Click ⊞ to open the **Histogram/Bar Chart** window, and update it as shown on the right.

o   Choose the variable to be charted by using the **View Histogram/Bar Chart for Field**: pull-down window. Change it to: **MONTH**.

o   Make sure the **Minimum**: value is set to **1** (January) and the **Maximum**: value is set to **12** (December).

o   Set the number of **Bins in Histogram:** to **12**.

o   Study the resulting histogram and the **Statistics** window.

Qn. 5. a) Which month has the most tropical cyclone activity (hurricanes, tropical storms, and tropical depressions)? b) Why do you think that is?

Qn. 6.   According to your histogram, when is hurricane season? (Hint: Hurricane season is the period during which 97% of tropical storms occur .)
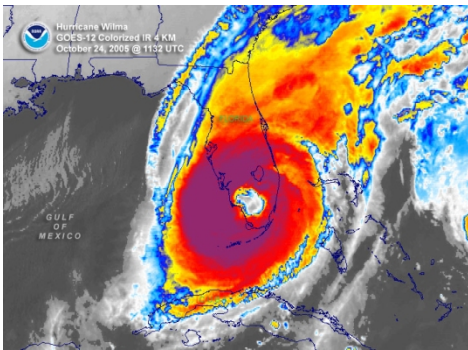
Tropical cyclones are organized, rotating systems of clouds and thunderstorms with a defined circulation pattern and are associated with low barometric pressure. In the Northern Hemisphere, the winds blow counterclockwise; in the Southern Hemisphere, they blow clockwise. As the wind speed increases, the classification changes from a *tropical depression* (winds up to 38 mph) to a *tropical storm* (winds between 39-73 mph) to a *hurricane* (winds greater than 74 mph). As the cyclone strengthens, the associated winds cause greater amounts of damage and storm surge. The size of the storm surge value also depends upon the slope of the continental shelf and the shape of the coastline in the landfall region. A *Category 1 Hurricane* causes minimal damage with wind speeds of 74-95 mph and a storm surge of 4-5 feet. A *Category 5 Hurricane* causes catastrophic damage with wind speeds of more than 155 mph and storm surges of greater than 18 feet. Category 3 Hurricanes and higher are considered to be major hurricanes.

•   Change your histogram to display the records by **CAT** (Category).   Use the scroll bar to move down to see the number of tropical depressions (**TD**) and tropical storms (**TS**).

Qn. 7. What does this histogram tell you about tropical cyclone activities? a) Compare the number of tropical storms and tropical depressions with the number of hurricanes. b) How does the number of Category 1 and 2 Hurricanes compare with the number of major hurricanes (Category 3 and higher)?

- Change your histogram to display the records by **Pressure**. Notice that a "0" is used as the *null value*; it indicates that no data exists about the air pressure inside a specific storm tract (as you can see, there are a large number of these.) Air pressure is measured in millibars.

  - Adjust the **Minimum:** and **Maximum:** values to focus on pressure differences between cyclones with recorded barometric pressures. Set the **Minimum:** value to **900** and the **Maximum:** value to **1050**.

  - Use the slider bar to increase the number of **Bins in Histogram**. (Try sliding it to **100** the maximum number of bins allowed.)

  - Study the resulting histograms.

  Qn. 8. Describe the pattern you see. Are powerful hurricanes associated with higher or lower air pressures?

  - Close the **Histogram/Bar Chart** window.

With a GIS, you can select only those records within a dataset that you are interested in. This technique is called *querying*.

- Query **the Atlantic Hurricane Tracts 1851-2006** layer to select the records that are associated with Category 3 or higher hurricanes. Switch to **Analyze** mode, by clicking the **Analyze** tab above the **Layer List**. Choose**: Select…** ▤ **by Value** and update the window as shown on the next page.

  - Set **Select Records from**: to **Atlantic Hurricane Tracts 1851-2006**.

  - Set **Whose:** to **CAT**.

  - Click the check boxes after **H3**, **H4**, and **H5**.

  - Click the check box in front of **Make Selection a New Layer**.

 - After **Result Name:** type **Atlantic Hurricanes Cat 3, 4, and 5**.
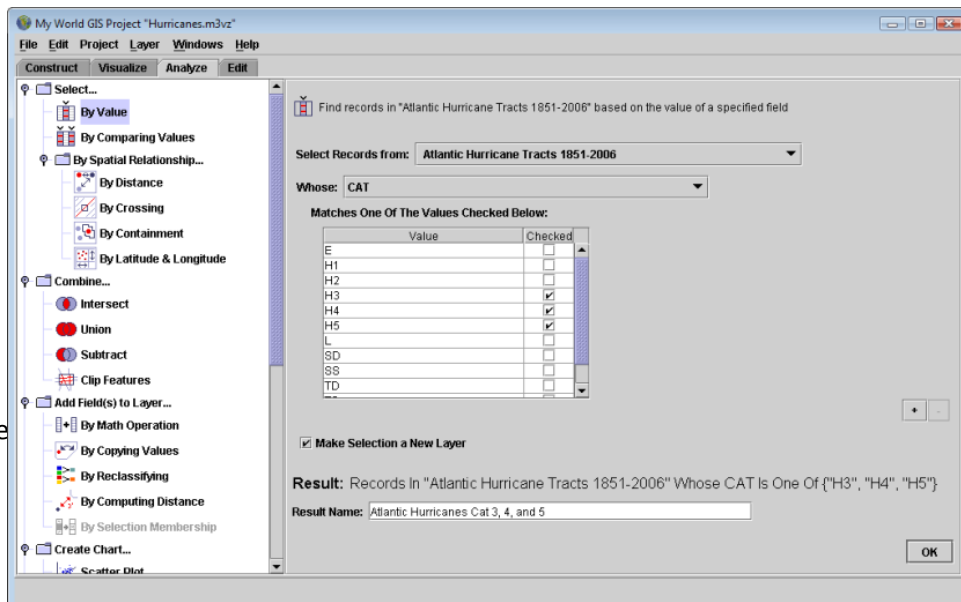
- Click **OK**.

- Return to **Visualize** mode. Study the new layer showing **Atlantic Hurricanes Cat 3, 4, and 5**.

    Qn. 9. How does the number of Category 3, 4, and 5 storms compare to the total number of storms?
   *Hint: Open the data table to see how many Category 3, 4, and 5 storms are selected.*

Exploring Hurricanes in southern Florida

- Query **the Atlantic Hurricane Tracts 1851-2006** layer to select hurricanes that made landfall in (crossed over) Florida.

    - Switch to **Analyze** Mode, and then choose: **Select by Spatial Relationship…** **By Crossing**.

    - Update the **Analyze** window as shown below.

    - Be sure to set **Select Records from**: to **Atlantic Hurricane Tracts 1851-2006**.)

    - Select all records that cross **Florida (boundary).**

    - Name the layer **Hurricanes that Cross Florida**.

    - Click **OK.**
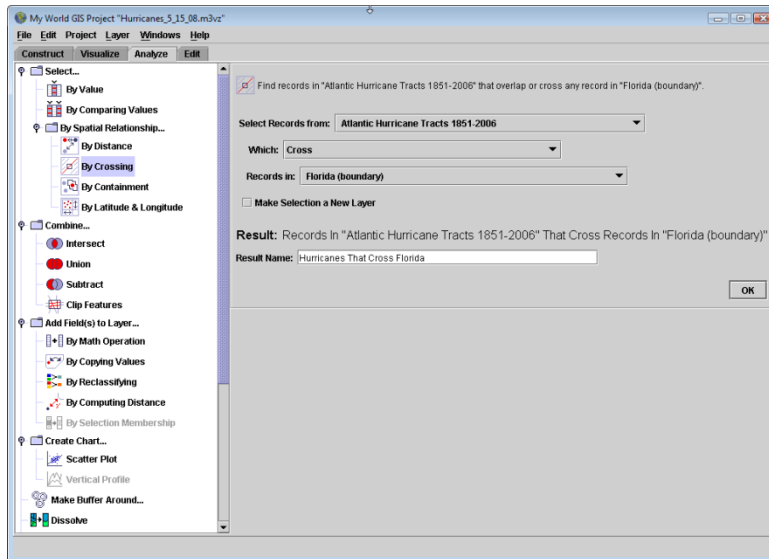
- Now perform a query on the **Hurricanes that Crossed Florida** layer. This time **Select…** by **Value,** and select the subset of records from **CAT H3**, **H4**, and **H5** storms.
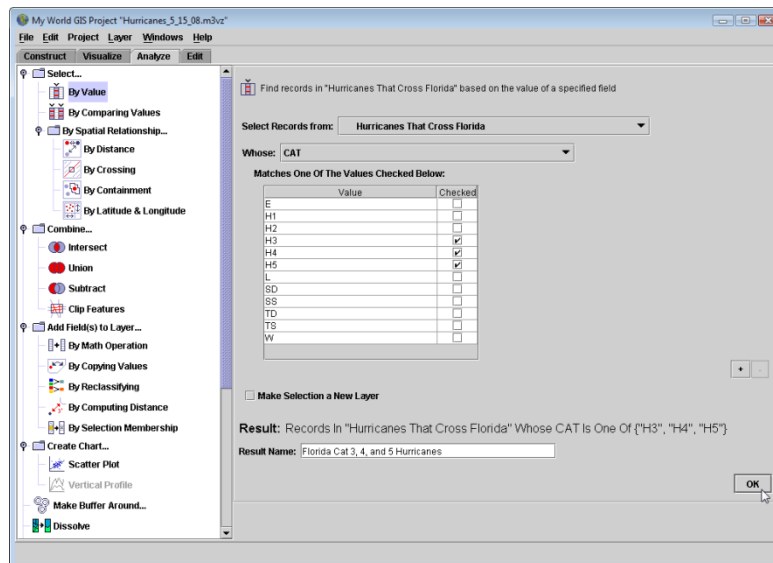
- Turn off the other hurricane layers (except for **Florida Cat 3, 4, and 5 Hurricanes**) and zoom in on Florida.

  Qn. 10. In Florida, where do most of the Category 3, 4, and 5 hurricanes make landfall?

  rtyrgdcx

  Qn. 11. a) How many Category 3, 4, and 5 hurricanes have made landfall in Florida? b) In what years did they hit? Hint: Open the layer table and count hurricanes. Be careful—some hurricanes are listed more than once. Check the names and/or dates of the storms to ensure you count each hurricane only once.

Hurricane Wilma (October 15-25, 2005)

Hurricane Wilma was one of the most intense hurricanes ever recorded in the Atlantic Basin. It developed as a tropical depression on October 15, 2005, and quickly intensified into a Category 5 hurricane. It made landfall several times: first on Mexico's Yucatan Peninsula, next in Cuba, and finally in southern Florida. It then moved northward across the Atlantic Ocean before dissipating on October 25, 2005. At its peak, Hurricane Wilma had winds of 185 mph (300 km/hr) and an internal pressure of 882 mbar. Hurricane Wilma killed at least 63 people and caused $29.1 billion in damage, most of it in southern Florida. The Florida Keys were flooded twice during the storm, once as it crossed the state and again as water pushed into the Everglades by the storm retreated into Florida Bay. In recognition of the severity of the storm, the name *Wilma* has been retired from the list of storm names.

- Turn off **Florida Cat 3, 4, and 5 Hurricanes** layer.

- Query the **Atlantic Hurricane Tracts 1851-2006** layer for **Hurricane Wilma's** storm tract. Update the **Select…** By Value window as shown below. Make the selection a new layer named **Hurricane Wilma 2005**.
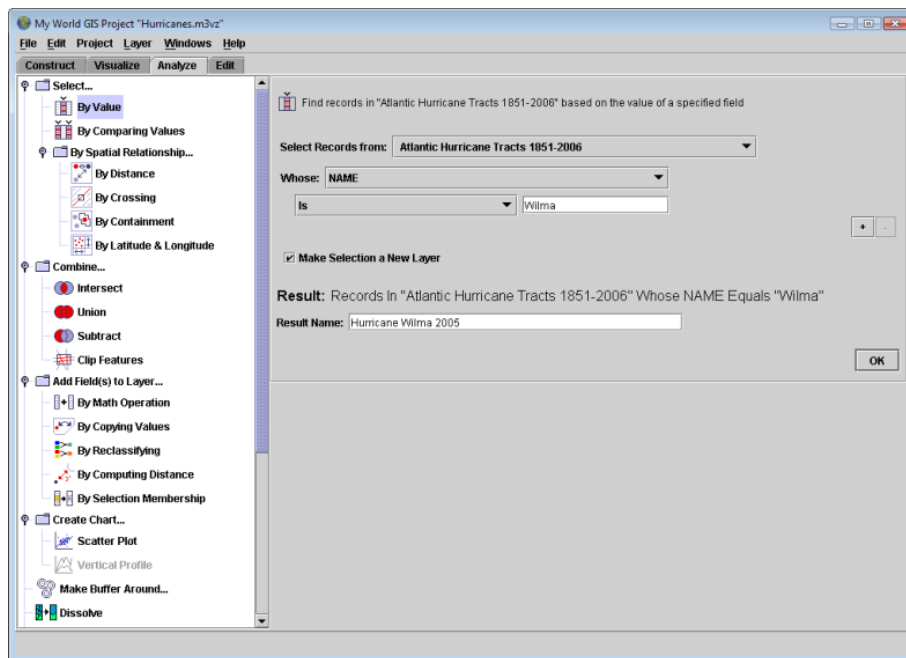

- Adjust the **Hurricane Wilma 2005** legend so it displays storm strength (category). To do this, activate the **Hurricane Wilma 2005** layer and open the **Legend Editor** clicking on the tool bar, or choosing **Layer/Edit Layer Appearance**.

- Set **the Choose Color by**: window to **CAT**. Don't worry about what **Colorscheme**: has been assigned to the categories—we're going to change it to colors that indicate the severity of the storm.

- Double click on the colored symbols to the left of each category to open the **Edit Value Color…** window. Use the color picker to change the colors to those listed below and shown in the screenshot.
    - E: black
    - H1: light green
    - H2: yellow
    - H3: orange
    - H4: red
    - H5: dark red
    - TD: dark blue
    - TS: light blue
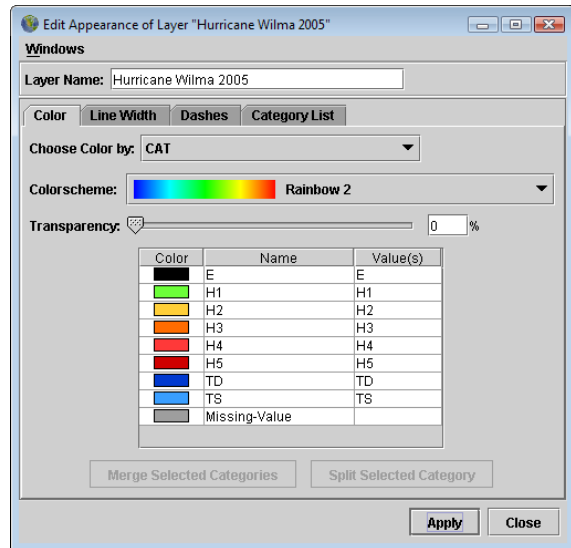
- Click the **Line Width** tab and change the **Line Width**: to a thicker line.

- Click **Apply** and then **Close**.

- Study Hurricane Wilma's tract. Use the 🛈 tool to obtain information about specific segments of the storm tract, including wind speed (WINDKTS) and pressure.

*Qn.   12. How strong was Hurricane Wilma **before** it made landfall in a) the Yucatán Peninsula, b) Cuba, and c) southern Florida? Note Wilma's intensity (category), wind speed, and pressure, then complete the chart on your Data Sheet.*

Strength of Hurricane Wilma Before Making Landfall

Location	Category	Wind Speed (knots)	Pressure (mbar)
Yucatan Peninsula			
Cuba			
Southern Florida			

- Turn on the following layers: **Everglades National Park**, **Canals – south Florida**, **Rivers – Florida (line)**, **Rivers – Florida (polygon)**, **Lakes – South Florida**, and **Counties -100 K – Florida** and **Population vs. Hurricane Strikes**.

- Make the **Population vs. Hurricane Strikes** layer active and zoom in to it using either 🔍 or 🔲, the **Zoom to Active Layer** tool.

- Pick a county in southern Florida that lies along the tract of Hurricane Wilma and explore the graph that has been linked to it.

  - Click 👆 , the **Link** tool. Flags will appear on the square red symbols in each county. With the tip of the cursor (the pointer finger), click on the center of the symbol in the county you picked.

  - The name of the image linked to that symbol will appear below the flag. Click on the image's name to open the linked graph.

    Population vs Hurricane Strikes: Collier County

A graph will open that shows the population by decade, and the number of tropical storms/hurricanes that impacted the county, what category each storm was, and whether the storm entered into or exited through the county. (Image Source: NOAA Coastal Service Center, Coastal Population Tool, http://maps.csc.noaa.gov/hurricanes/download.jsp).

> *Qn. 13. a) What county did you pick? b) Describe how the county's population changed from 1900 to the present and the impact of hurricanes on your county. c) Describe the impact of hurricanes on your county. Include the following information in your description: How many storms impacted your county? What was/were the strongest storm(s)? When did it/they occur? Did your county receive any indirect hits from hurricanes? How does the population of the county affect the amount of damage it may sustain?*

- Turn off the **Population vs. Hurricane Strikes** layer.

Hurricane Wilma's Impact on the Florida Everglades

As Hurricane Wilma passed across Florida, it left millions of people without electricity, blew roofs off buildings, and left neighborhoods filled with debris. It also impacted the natural environment. Heavy rains and winds stirred up bottom sediments in Lake Okeechobee and the Southern Florida Water Management District (SFWMD)'s Storm Water Treatment Areas. The *Storm Water Treatment Areas* are man-made, wetlands and containment areas that remove excess nutrients from surface waters. Nutrients that had accumulated for decades from storm water runoff entered into the Storm Water Treatment Areas and the Everglades. Along the southwest coast of Florida, mangrove forests faced the brunt of the storm. Trees were down, the canopy defoliated, and salt water was pushed far up the Shark River Slough and Taylor Slough watersheds.

- Display the **Hurricane Wilma Images** layer. Use the 👆 tool to explore images of damage caused by Hurricane Wilma.

> *Qn. 14. Describe the impacts of Hurricane Wilma on the Everglades that you observed in the images.*

- Display the **SRS TN TP Salinity**, **TS/Ph 6a – 7a TN TP Salinity**, **Taylor Slough** and **Shark River Slough** layers.

Sampling stations at the Florida Coastal Everglades (FCE) Long Term Ecological Reserve (LTER) sites automatically sample and record water quality every 3-6 days depending upon the site and when it was established. The stations record the salinity, total nitrogen (TN) and total phosphate (TP) levels. The **SRS TN TP Salinity** layer includes water quality data from FCE LTER sites SRS 1 through SRS 6 located along the Shark River Slough watershed, while the **TS/Ph 6a-7a TN TP Salinity** layer has water quality data from FCE LTER sites TS/Ph 6a and TS/Ph 7a located along the Taylor Slough/PanHandle watershed.

- Activate the **SRS TN TP Salinity** layer.

- Open the **SRS TN TP Salinity** data table by clicking ▦, the **Show Table of Active Layer** button. Determine the temporal coverage of the dataset – when did it begin? When does it end?

  - Sort the records in chronological order by clicking once on the top of the **Date** column. A ≣ symbol will appear after the column heading. Click again to sort the data in reverse chronological order (most recent first) ≣ , and again to return to the original order.

  - Use the scroll bar to move up and down the table if necessary.

- Query the **SRS TN TP Salinity** layer to determine the impacts of Hurricane Wilma on the water quality within the Everglades. Select the records by date to include from October 1, 2005 - November 30, 2005. (Hurricane Wilma made landfall on October 25, 2005.)

  - Switch to **Analyze** mode.

  - Choose **Select…** ▤ **By Value** and update the window as shown below.
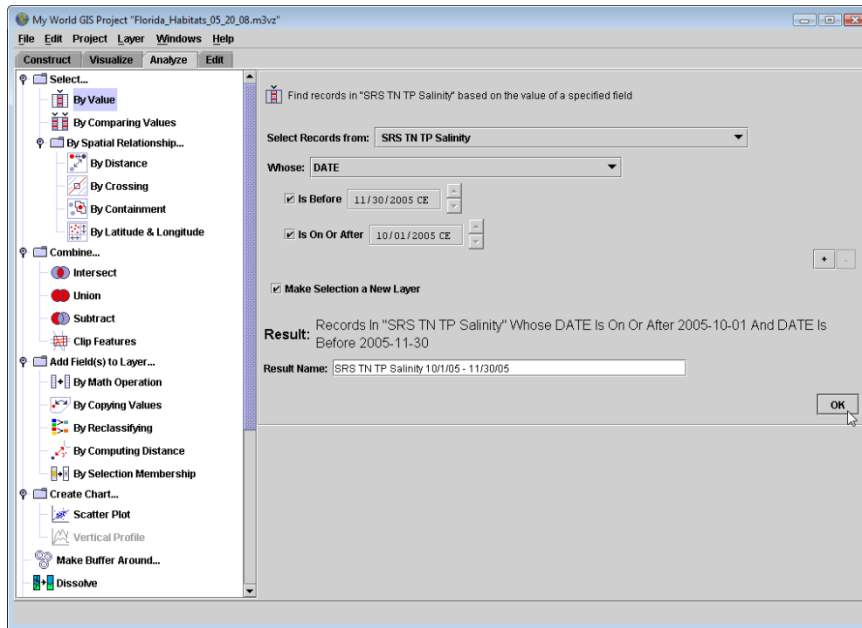
- Switch back to **Visualize** Mode and open the **SRS TN TP Salinity 10/1/05 – 11/30/05** data table. Study the salinity levels at each site before, during and after Hurricane Wilma passed through the area.

  - Make **SRS TN TP Salinity 10/1/05 – 11/30/05** the active layer.

  - Click , the **Show Table of the Active Layer** button.

  - Scroll through the table. Study the salinity level for each site. Record the values just before Hurricane Wilma, immediately after Wilma, and a few days later on your Data Sheet.

Qn. 15 Record the salinity values for each of the sites on the dates given in the table on your Data Sheet.

FCE LTER Station	10/23 or 10/24	10/26 or 10/27	10/29 or 10/30	Average
SRS 1c				
SRS 2				
SRS 3				
SRS 4				
SRS 5				
SRS 6				
TS/Ph6a (optional)				
TS/Ph 7a (optional)				

A Buffer from the Storm

Qn. 16. a) Which sites show a change in salinity as a result of Hurricane Wilma? b) Why did the salinity increase at these sites? c) At which site was no data recorded?

○ Close the **Table of Active Layer "SRS TN TP Salinity 10/1/05 – 11/30/05"** window.

• Determine the average salinity for each FCE LTER monitoring site along Shark River Slough.

○ Switch to **Analyze** Mode.

○ Choose Σ **Summarize** from the list on the right side of the window.
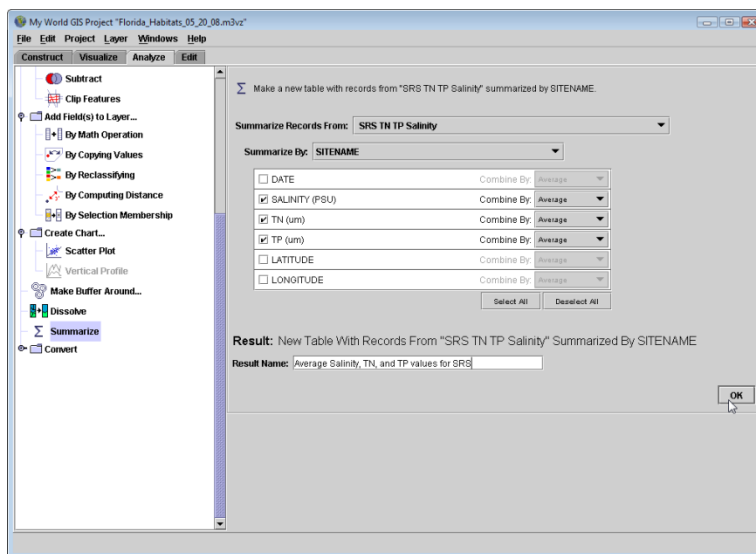
○ Set **Summarize Records From**: to **SRS TN TP Salinity**.

○ Set **Summarize by**: to **SITENAME**.

○ Choose **SALINITY (PSU)**, **TN (um)**, and **TP (um)** and choose **Combine by: Average** for each.

○ Name the table **Average Salinity, TN and TP values for SRS.**

○ Click **OK**.

Qn. 17. a) Record the average salinity value for each site in your Data Table for Qn. 15. b) How do the values you recorded compare to the long-term average values for each site? c) Why is important to study an ecosystem for a long period of time?

To fully understand the spatial and temporal extent of the saltwater intrusion into the Everglades caused by storms such as Wilma, scientists would need water quality data sampled hourly at many more

locations along the study transect. Marine sediment deposits have been found at some of the sample sites. Scientists rely on modeling to complement field datasets.

- If time permits, repeat the above analyses to look at changes in salinity along the Taylor Slough/Pan Handle sites, TS/Ph6a and TS/Ph7a. Activate the **TS/Ph 6a-7a TN TP Salinity** and use the techniques described above to determine salinity before, during and after Hurricane Wilma as well as the average salinity.

Scientists from many organizations, including the FCE LTER site, Everglades National Park and the Southern Florida Water Management District continue to monitor the water quality within the Everglades to determine the impact of natural variation and major storm events on the ecosystem. As fresh water flow through the Everglades system is reduced and salt water is pushed further into estuary system by major storm events, the boundary between freshwater marshes and mangroves slowly moves inland. The introduction of nutrients, such as phosphates and nitrates from either sea water or storm water run-off, affects the plant and microbial communities. The decomposition of organic material (e.g., plant material) is limited in the freshwater marshes and saw grass communities by a lack of phosphorus. The microbial communities need both oxygen and phosphorus to decompose dead plant material and to release the nutrients back into the ecosystem.

Qn. 18. What variables could you look at if you wanted to see what impact freshwater overflow resulting from Hurricane Wilma and its associated rainfall had on the ecosystem?

- Close My World GIS. When asked to save changes to the project, click **No**.

Further Explorations:

- Current hurricane tracts can be obtained from the National Hurricane Center; instructions for using their data sets in a GIS are available online: http://www.nhc.noaa.gov/aboutgisproducts.shtml.

- Explore the **Hurricane SLOSH Layers** (entering and exiting).

- Explore the water quality data provided in *the A Matter of Inches* activity. Determine the impact Hurricane Wilma had on the turbidity, salinity, total nitrogen and total phosphate levels within Everglades National Park. Additional datasets are available on the Florida Coastal Everglades LTER site Web page: http://fce.lternet.edu/ .

Resources:

- FEMA for Kids—Hurricanes: http://www.fema.gov/kids/hurr.html

- Journey to El Yunque: http://elyunque.net/english/introduction/hurricane.html

- National Hurricane Center: http://www.nhc.noaa.gov/

- NOAA Hurricane Portal: http://hurricanes.noaa.gov/

- Saffir-Simpson Hurricane Scale:
  http://www.nyc.gov/html/oem/html/hazards/storms_saffirsimpson.shtml and
  http://www.nhc.noaa.gov/aboutsshs.shtml

- Southern Florida Water Management District : After Hurricane Wilma
  https://my.sfwmd.gov/portal/page?
  _pageid=2814,19613308,2814_19613546&_dad=portal&_schema=PORTAL

- USGS Responds to Hurricanes (Katrina, Rita, and Wilma):
  http://www.usgs.gov/hazards/hurricanes/kat_rit_wil/

A Buffer from the Storms: Data Sheet

Qn. 1.   Describe the shape of the storm tracts. Where do they begin? Where do they end?

Qn. 2.   How far west might the effects of Atlantic Coast hurricanes be felt?

Qn. 3.   What information is provided for each storm tract?

Qn. 4. Does each record represent a single hurricane? Explain.

Qn. 5. a) Which month has the most tropical cyclone activity (hurricanes, tropical storms, and tropical depressions)?

b) Why do you think that is?

Qn. 6. According to your histogram, when is hurricane season? (Hint: 97% of tropical storms occur during hurricane season.)

Qn. 7. What does this histogram tell you about tropical cyclone activities? a) Compare the number of tropical storms and tropical depressions with the number of hurricanes.

b) How does the number of Category 1 and 2 Hurricanes compare with the number of major hurricanes (Category 3 and higher)?

Qn. 8. Describe the pattern you see. Are powerful hurricanes associated with higher or lower air pressures?

Qn. 9. How does the number of Category 3, 4, and 5 storms compare to the total number of storms? Hint: Open the data table to see how many Category 3, 4, and 5 storms are selected.

Qn. 10. In Florida, where do most of the Category 3, 4, and 5 hurricanes make landfall?

Qn. 11. a) How many Category 3, 4, and 5 hurricanes have made landfall in Florida?

b) In what years did they hit? Hint: Open the layer table and count hurricanes. Be careful—some hurricanes are listed more than once. Check the names and/or dates of the storms to ensure you count each hurricane only once.

Qn. 12. Complete the chart below.

Strength of Hurricane Wilma Before Making Landfall

Location	Category	Wind Speed (knots)	Pressure (mbar)
Yucatan Peninsula			
Cuba			
Southern Florida			

Qn. 13. a) What county did you pick?

b) Describe how the county's population changed from 1900 to the present and the impact of hurricanes on your county.

c) Describe the impact of hurricanes on your county. Include the following information in your description: How many storms impacted your county? What was/were the strongest storm(s)?

When did it/they occur? Did your county receive any indirect hits from hurricanes? How does the population of the county affect the amount of damage it may sustain?

Qn. 14. Describe the impacts of Hurricane Wilma on the Everglades that you observed in the images.

Qn. 15 Record the salinity values for each of the sites on the dates given in the table below.

Salinity Values at SRS LTER Sites

FCE LTER Station	10/23/2005 or 10/24/2005	10/26/2005 or 10/27/2005	10/29/2005 or 10/30/2005	Average
SRS 1c				
SRS 2				
SRS 3				
SRS 4				
SRS 5				
SRS 6				
TS/Ph 6a (optional)				
TS/Ph 7a (optional)				

Qn. 16. a) Which sites show a change in salinity as a result of Hurricane Wilma?

b) Why did the salinity increase at these sites?

c) At which site was no data recorded?

Qn. 17. a) Record the average salinity value for each site in your Data Table for Qn. 15.

b) How do the values you recorded compare to the long-term average values for each site?

c) Why is important to study an ecosystem for a long period of time?

Qn. 18. What variables could you look at if you wanted to see what impact freshwater overflow resulting from Hurricane Wilma and its associated rainfall had on the ecosystem?