

UK



EUROPEAN SPACE EDUCATION RESOURCE OFFICE
A collaboration between ESA & national partners



Tracking Hurricane Matthew

A scheme of work to develop earth observation skills in geography



Contents

	Introduction	3
	Aims and Background	4
Activity 01	Estimating when and where Hurricane Matthew started and ended using satellite images	8
	Answers to Activity 01	14
Activity 02	Tracking the path of a hurricane using Google Earth	15
	Hurricane Matthew Quiz	25
	Extension	26
	Answers to activity 02	27
	Hurricane Matthew Quiz Answers	29
	Differentiating activity 02	30
Activity 03	Plotting rainfall and wind speed data in Google Earth	31
	Answers to Activity 03	36
	Tropical storms mock exam questions	37
Activity 04	Viewing satellite images	42
	Activity 4: Alternative (active learning)	44
	Answers to Activity 04	52
Activity 05	Adding moving satellite imagery to Google Earth	54
	Differentiating Activity 05	68
Activity 06	Using satellite images to view the impacts of Hurricane Matthew	69
	Answers to Activity 06	74

A satellite image of Earth from space, showing a large hurricane with a distinct eye over the ocean. The landmasses are visible in shades of green and brown, and the ocean is a deep blue. The curvature of the Earth is visible at the top right.

Introduction

2017 was a year of extreme hurricane activity. From Typhoon Noru in the Pacific Ocean to the devastation of Hurricane Harvey and Irma that made landfall over the USA and Caribbean, 2017 became the seventh most active hurricane season since records began in 1851. As news updates were produced across the globe, fuelling public interest, it was no surprise that images taken by astronauts and cosmonauts on board the International Space Station would soon begin circulating through social media sites such as Twitter. This was, after all, the perfect place from which to spot the eye of the storm.

Whilst the ubiquitous satellite images that we see within the media whenever a tropical storm such as Noru, Irma or Matthew become breaking news are not a new technique, photographs such as this remind us of the incredible innovations being made within the field of science and technology. Earth observation is now far more advanced meaning that our understanding of geographical phenomena is better than it has ever been. No longer are teachers limited to static, isolated images of hurricanes but instead, we can engage in earth observation first hand, offering a curriculum that stimulates the minds of our pupils and inspires them to understand more by providing practical lessons utilising a combination of space based data and GIS skills.

Indeed, students can now actively seek out developing tropical storms across the oceans of the world, utilise layers to correlate the formation of tropical storms with sea temperature data to assess their cause, employ technology to measure the size of a cyclone, create video footage using NASA images to show changing cloud density as hurricanes progress through the Saffir-Simpson scale, examine the impacts of events using historical data and photographs within Google Earth, use satellite imagery to assess which areas are most in need of humanitarian aid as well as comparing and contrasting different tropical storm paths plotted by the students themselves onto digital maps.

Yet the potential for earth observation within geography lessons doesn't stop at tropical storms. Websites such as Sentinel Playground allow us to utilise satellite images and remote sensing to compare vegetation types in contrasting ecosystems, see how deforestation impacts an area such as the Amazon Rainforest, examine seasonal variations in cold environments, look at the impacts of volcanic activity upon the atmosphere or climate change upon sea ice, survey geohazards, plan pipeline routes, examine the impacts of coastal defence schemes upon erosion rates, correlate climate and disease within sub-Saharan Africa, use satellite images to observe food security and sustainable farming practices as well as urban planning and resource management across the world.

Overall, earth observation offers students a clearer visualisation of the world in which they live. In evaluating its potential, it is therefore perhaps worth considering the well-known phrase "a picture says a thousand words". If that holds even an element of truth, imagine how broad students' vocabulary will become from the thousands of pieces of visual data available to them through earth observation.

Elizabeth Hayward, Geography Teacher | Resource Author

Aims and Background

Aims

This pack of resources is based upon Hurricane Matthew and is designed as a complete Scheme of Work on GIS skills that teachers can use with geography classes from KS3 to KS5, using the differentiation ideas to target students of different age ranges and abilities. Alternatively, teachers can select individual activities as standalone lessons to merge with existing teaching practice.

Background

Activity 1

Estimating when and where Hurricane Matthew started and ended using satellite images

This provides a basic introduction to using Google Earth. Students will familiarise themselves with both the [NASA Worldview](#) website and [Google Earth](#) which they will utilise in later activities to greater depth. The focus here is on learning how to read satellite images and learn how to drop pins in Google Earth to locate features.

Resources needed



Activity 1 worksheet



[Google Earth](#)



[NASA Worldview](#)



Activity 1 answer sheet

Activity 2

Tracking the path of a hurricane using Google Earth

Students will begin to develop their familiarity with Google Earth in this activity and the layer that they generate will be used throughout future tasks. It begins with background information about the Saffir-Simpson Scale and then extends the technique of dropping pins by using custom icons as well as using basic KML code to generate a legend. Students also develop their skills by using the ruler function to begin calculating distances.

Extension activities in the form of a quiz and further questions will target thinking skills and could be offered as stretch and challenge or as homework activities. A completed KMZ file is also offered with the teaching pack should teaching staff wish to opt out of this activity but still use the layer for future activities. Differentiation ideas have also been provided. All additional files can be found on the ESERO-UK resource library.

Resources needed



Activity 2 worksheet



Hurricane Matthew quiz



Set of hurricane symbols saved to the school network. The location of these symbols should be given to your students for step 10 and beyond.



Extension activities



Activity 2 answer sheet (including quiz answers)



Legend saved to the school network



Differentiation ideas



[Google Earth](#)



KMZ file of answers

Activity 3

Plotting rainfall and wind speed data in Google Earth

Activity 3 develops the use of layers in Google Earth and examines weather patterns. The task starts with a basic skill of adding layers, though students should be encouraged to develop their skills of comparison to stretch their geographical thinking. It then develops to the more complex skill of using located proportional bar graphs in Google Earth to show wind speed data. A set of examination style questions has also been offered with the activity. This is aimed at GCSE students but could be used for further stretch and challenge at KS3 or adapted slightly to meet the needs of A Level students.

Resources needed



Activity 3 worksheet



KMZ file of Hurricane Matthew path (if activity 2 has not been completed)



[Rainfall Watch](#)



Tropical storms examination questions



[Google Earth](#)



Activity 3 answer sheet








GE Graph

Activity 4

Viewing satellite images

This activity uses satellite images to develop students' earth observation skills. The activity could be completed either in an ICT suite in which students complete independent learning about the images or could be taught using a more active learning style in the classroom. Here, students work in pairs/small groups using packs of laminated colour satellite images and a card sort activity. The task is to sequence the images correctly and then match the cards to each image.

Resources needed









- | | | | |
|---|--|---|--|
|  | Activity 4 worksheet |  | Cards for card sorting activity (two levels of difficulty available) |
|  | ICT suite (if independent student learning) |  | Activity 4 answer sheet |
|  | Laminated colour copies of satellite images A-E (one pack per group) | | |

Activity 5

Adding moving satellite imagery to Google Earth

This activity offers a significant extension in Google Earth skills by using KML code to time stamp images and create an animation. Students use the skill of acquiring satellite images and then layer these in Google Earth. The code has been simplified as much as possible to make it accessible to lower key stages. Ideas are offered for how the activity could be differentiated further though with an additional sample of images and KML codes available should teachers wish to use it.

Resources needed

- | | | | |
|---|---|---|--|
|  | Activity 5 worksheet |  | Zip file of images taken from GOES Project |
|  | NASA Worldview |  | KMZ file (answers) |
|  | Google Earth |  | Differentiation ideas for activity 5 |
|  | Zip file of images taken from Worldview |  | KMZ file (for student use) |

Activity 6

Using satellite images to view the impacts of Hurricane Matthew

The final activity in the pack is based upon remotely sensed data and encourages students to investigate how earth observation can be used to examine the impacts of natural disasters such as Hurricane Matthew. Students begin by examining images of Haiti in Google Earth and then examine false colour satellite images using [EO Browser](#). By annotating images and identifying contrasts, students will develop their geographical skills of observation and analysis.

Resources needed



Activity 6 worksheet



Microsoft PowerPoint/Word



[Google Earth](#)



Activity 6 answer sheet



[Sentinel Hub](#)

Credits

All images and websites have been sourced throughout the activity pack. In addition, the following helped to inspire ideas for activities 2 and 3:

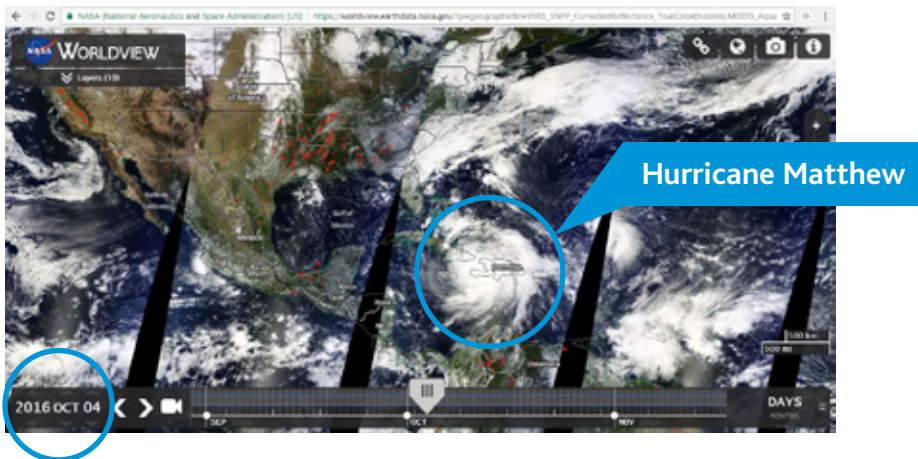
[Chasing Hurricane Andrew A Google Earth Exploration](#)

[Chase the Typhoon](#)

Activity 01

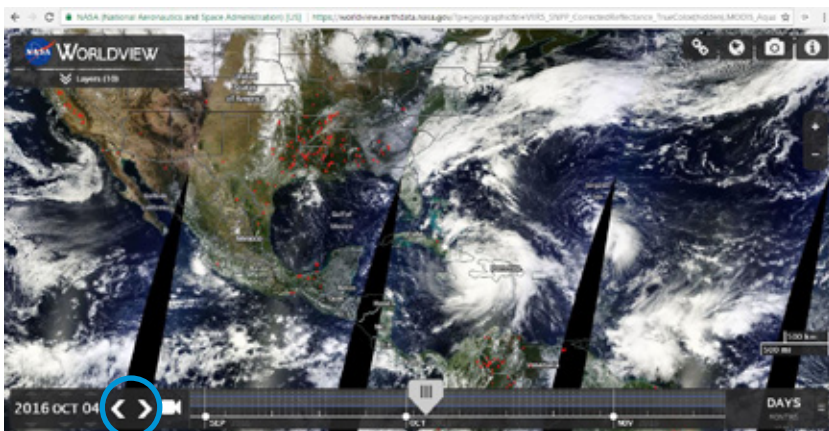
Estimating when and where Hurricane Matthew started and ended using satellite images

1. Visit <https://worldview.earthdata.nasa.gov>
2. Change the date at the bottom of the screen to 4th October 2016 (using the arrows above and below each part of the date) and pan over to the USA to get a view similar to that below:



Here, you can see Hurricane Matthew positioned over Haiti.

3. Use the arrows to move back one day at a time and see if you can estimate on which day you think Hurricane Matthew started and where.

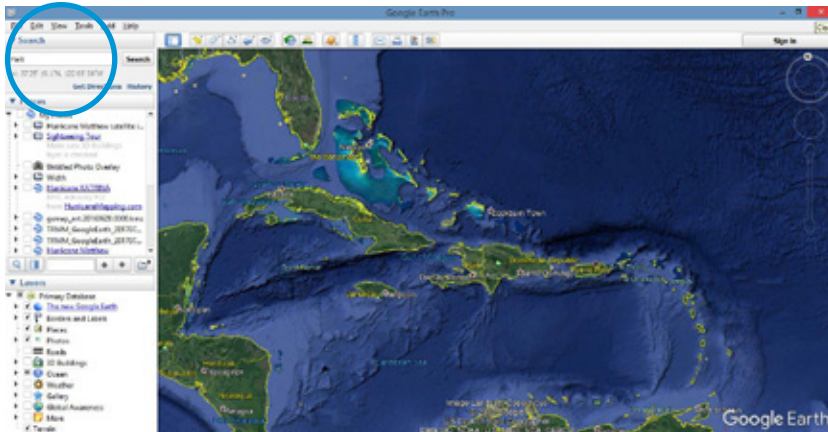


4. Once you have a position and date in mind, open up Google Earth.

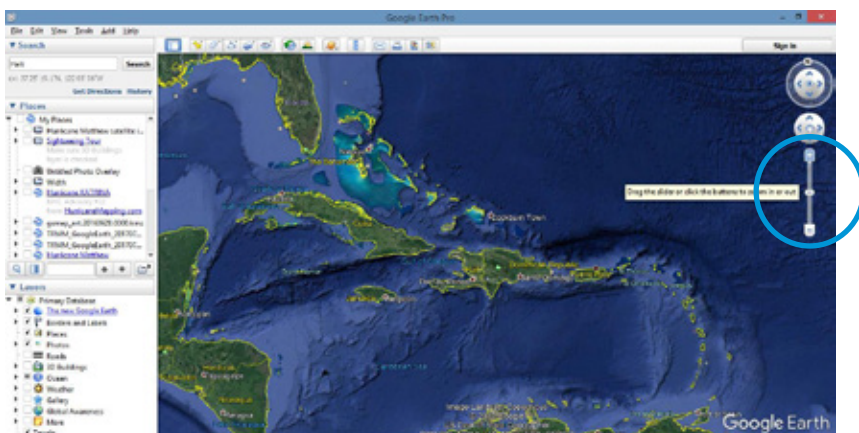
Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

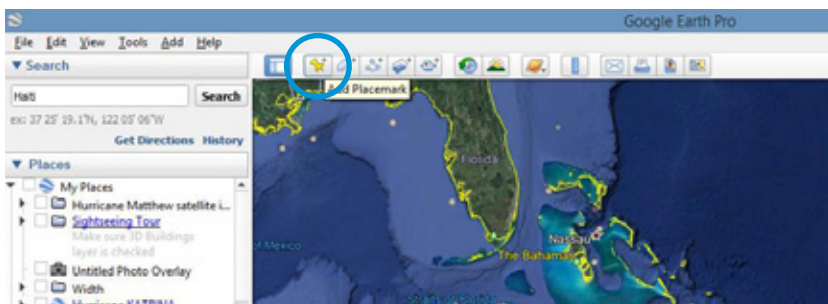
5. In the search box, type in Haiti and press the search button which will orient your map.



You may like to zoom out a little so that you get a better view. This can be done using the slider to the right of your screen:



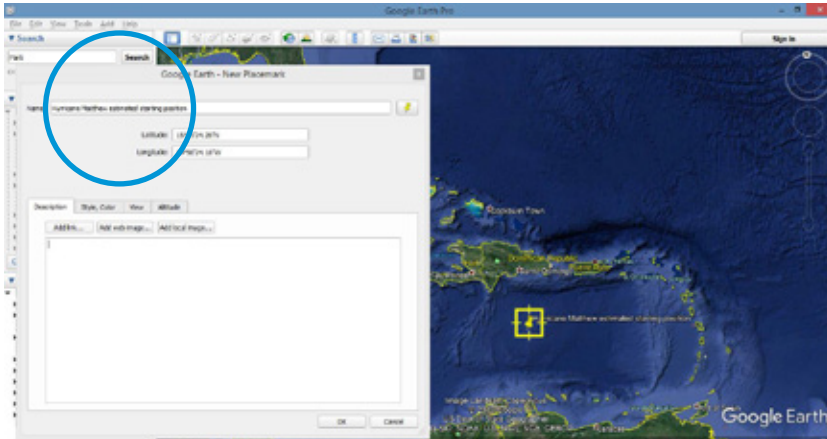
6. Now, drop a pin in the location you think that Hurricane Matthew started by clicking the “add placemark” icon (📌) at the top of the screen as shown below:



Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

7. In the box that appears on your screen, change the name to "Hurricane Matthew estimated starting position" but **do NOT select OK or press enter just yet.**



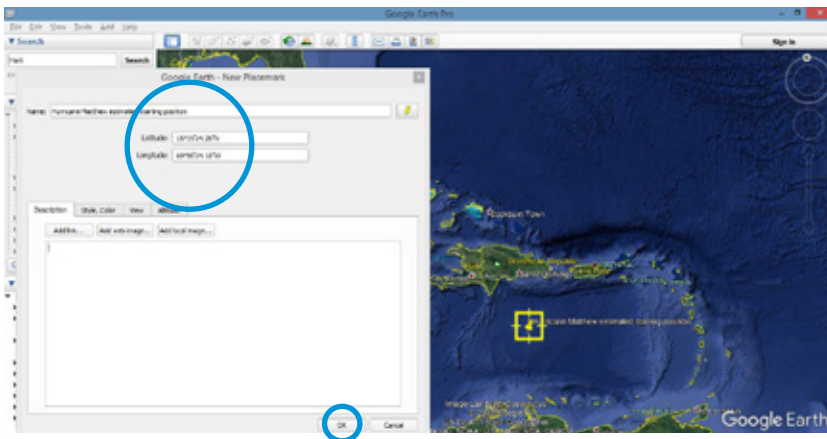
8. Drag the pin to the location that you think is correct from the <https://worldview.earthdata.nasa.gov> website, thinking about the position of nearby countries to help you.

9. When you've located what you think is the correct position, write in the table below the latitude and longitude for your estimated starting point of Hurricane Matthew. This can be found in the placemark information screen.

I think Hurricane Matthew started on

Latitude	Longitude

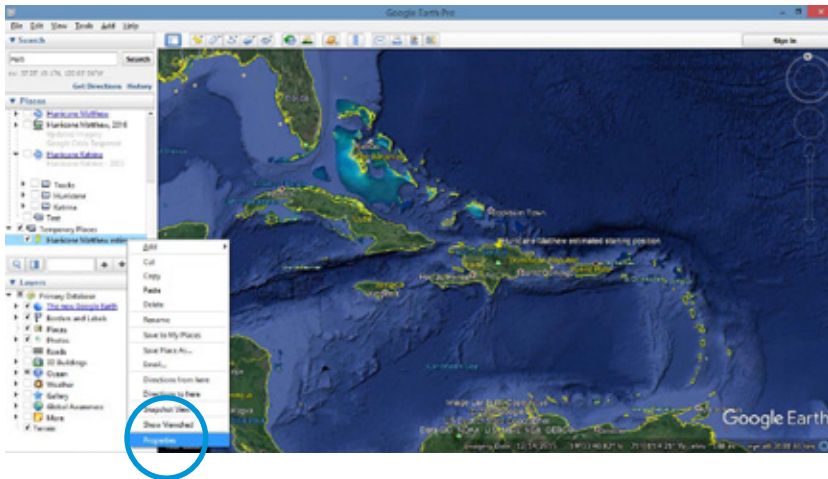
10. Now select OK.



Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

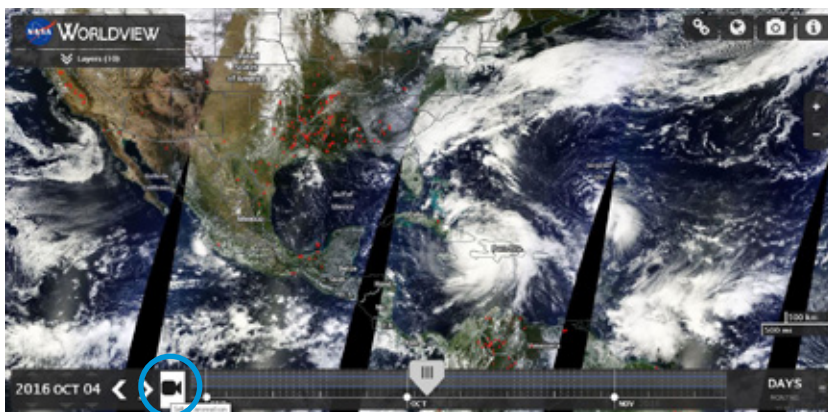
NOTE if you accidentally select OK too early, you will see the pin in your places to the left of your screen. If you right click this and select "Properties" you will be able to revert to moving the pin as shown below:



11. Return to <https://worldview.earthdata.nasa.gov>

You're now going to look at the path that Hurricane Matthew took to try and estimate the end date and location.

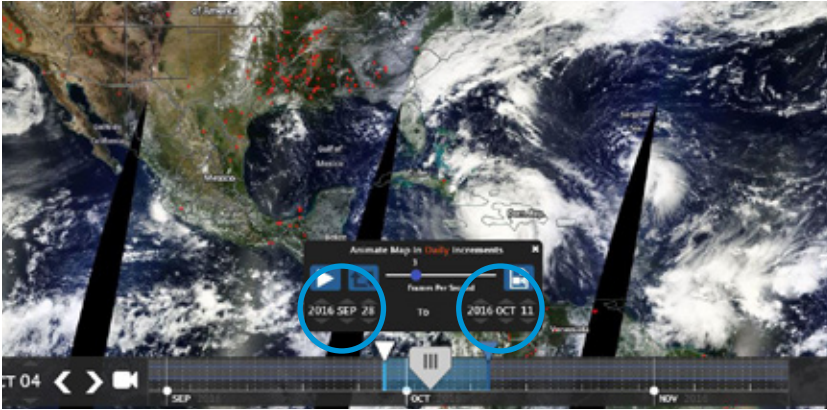
12. Select the "Setup animation" icon at the bottom of the screen.



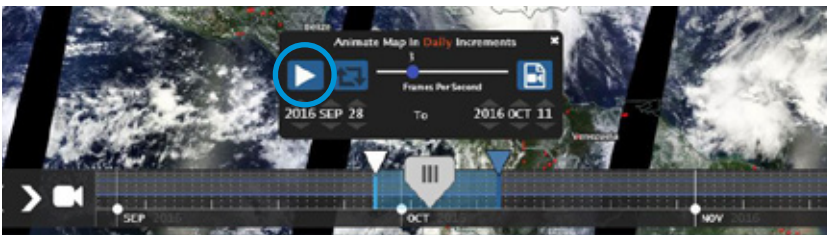
Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

13. Change the date to cover 28th September to 11th October (this covers a slightly broader period than the hurricane itself so you can see how the cloud changes).



14. Press play to watch the movement of the hurricane.



15. Name four countries that were affected by Hurricane Matthew in the table below:

1	2	3	4

16. Repeat steps 2-10 but this time, you need to work on the end date of Hurricane Matthew.

17. When you've located what you think is the correct position, write in the table below the latitude and longitude for your estimated finishing point of Hurricane Matthew.

I think Hurricane Matthew ended on

Latitude	Longitude

Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

18. Check the answer sheet and write in the correct latitude and longitude for Hurricane Matthew's starting and finishing points.

	Latitude	Longitude
Starting point date =		
Finishing point date =		



Activity 01

Estimating when and where Hurricane Matthew started and ended using satellite images

Answers to Activity 01

Name four countries that were affected by Hurricane Matthew. Most likely options are as follows:

1	2	3	4	5	6
Haiti	Jamaica	Cuba	USA	Dominican Republic	The Bahamas

Latitude and longitude




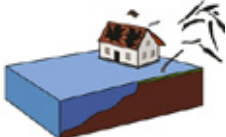
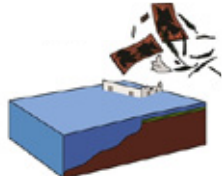
	Latitude	Longitude
Starting point date = 29th September (category 1 storm)	14°11'60.00"N	66°54'0.00"W
Finishing point date = 9th October (category 1 storm)	34°42'0.00"N	76° 0'0.00"W

Data based on actual coordinates as stated in the National Hurricane Centre Tropical Cyclone Report:
http://www.nhc.noaa.gov/data/tcr/AL142016_Matthew.pdf

Activity 02

Tracking the path of a hurricane using Google Earth

Topical storms are measured using the Saffir-Simpson Scale which categorises the hurricane using numbers from 1-5 depending upon the wind speed. This is shown in the table below:

Category	Wind speed	Category	Image
1	74-95mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles and gutters. Large branches of trees will snap and shallowly rooted trees may topple. Extensive damage to power lines and poles will likely result in power outages that could last a few to several days.	
2	96-110mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.	
3	111-129mph	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.	
4	130-156mph	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.	
5	157mph+	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.	

Source: <http://www.nhc.noaa.gov/aboutsshws.php>

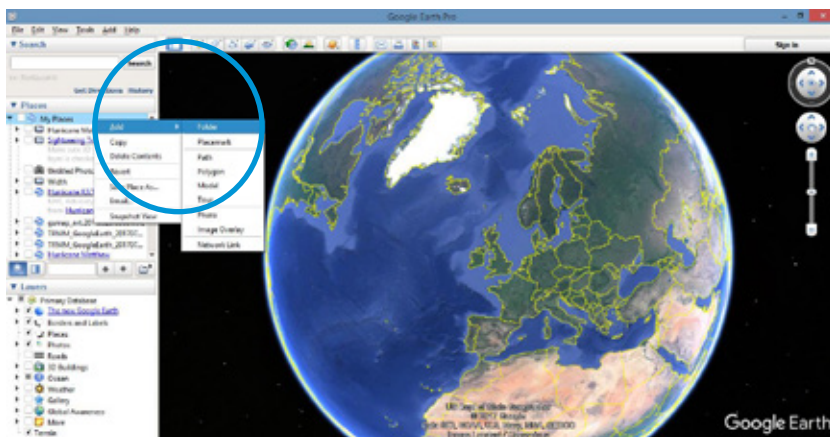
Activity 02

Tracking the path of a hurricane using Google Earth

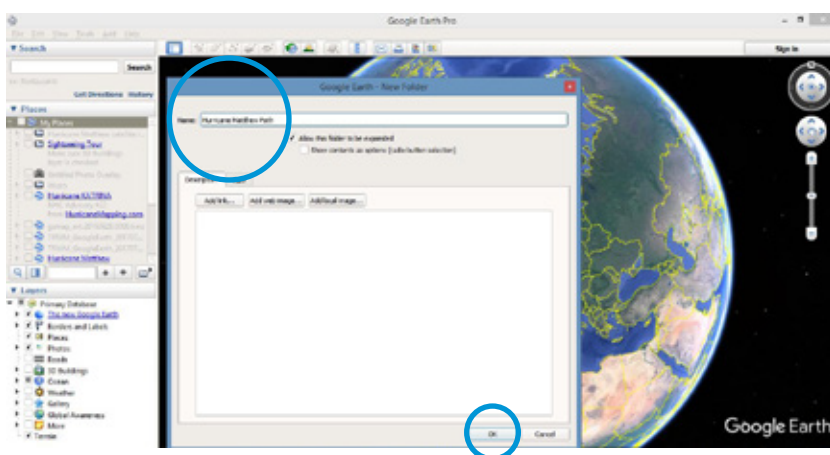
Before hurricanes reach category 1 though, they start off as a tropical depression.

Hurricane Matthew was classed as a category 5 hurricane at its most intense level but it wasn't like this from start to finish. Your task is to plot the path of Hurricane Matthew in Google Earth to see how it changed from a tropical depression and to see which areas experienced the most catastrophic wind speeds.

1. Open up Google Earth
2. Click once on My Places on the left of the screen so that it is highlighted blue



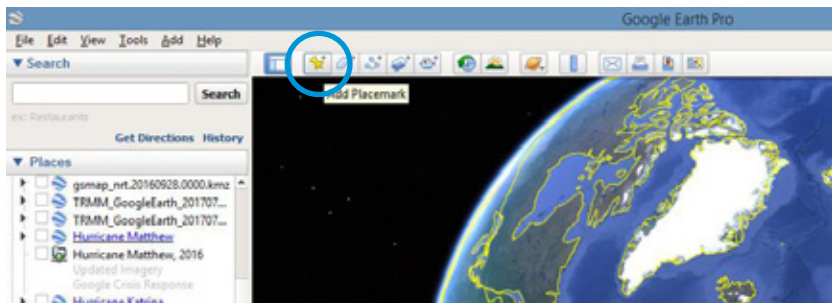
3. Right click and select Add and then Folder
4. Change the name to "Hurricane Matthew path" and select OK



Activity 02

Tracking the path of a hurricane using Google Earth

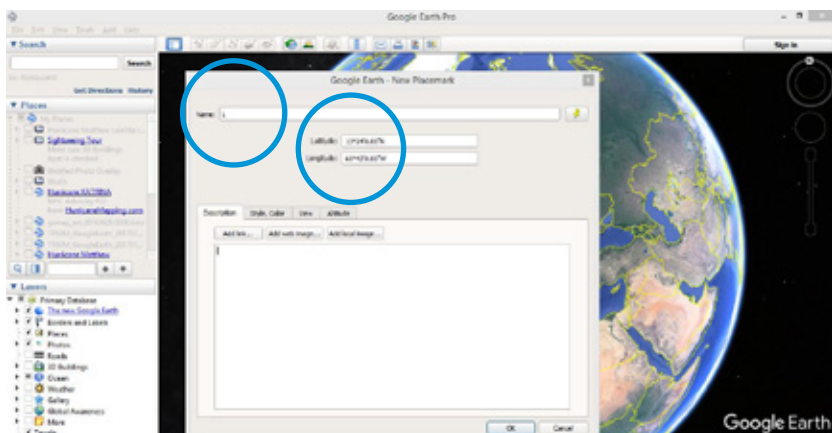
5. Make sure that this folder is now highlighted blue under My Places and click the "add placemark" icon (📌) at the top of the screen as shown below:



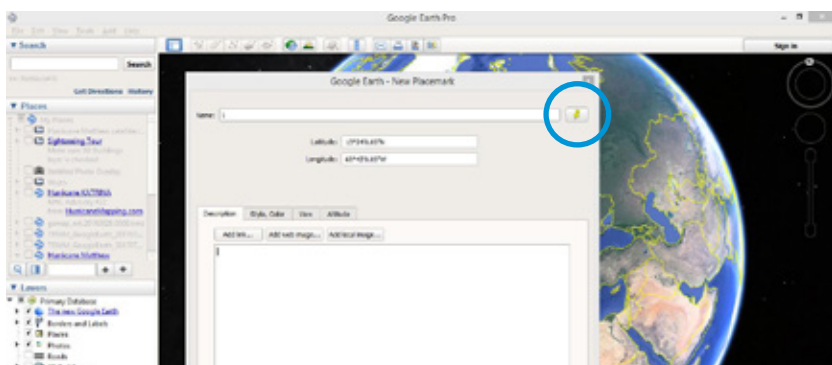
6. In the box that appears on your screen, delete the "untitled placemark" name and change it to "1" to represent the first point. **Do NOT select OK or press enter just yet though.**

7. Change the latitude to 13.4 and the longitude to -60.7 but again, **do NOT select OK or press enter just yet.**

Note that Google Earth will change the format of the latitude and longitude values automatically so don't worry if these look different when you change to the next box.



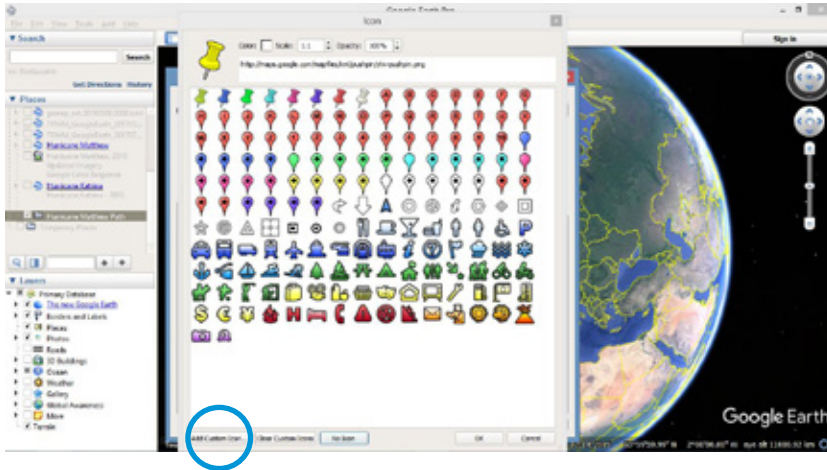
8. Click on the pin icon to the top right of the New Placemark screen



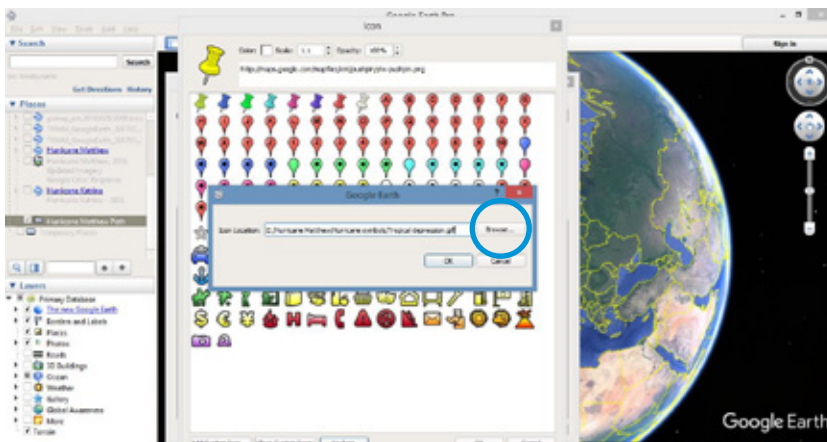
Activity 02

Tracking the path of a hurricane using Google Earth

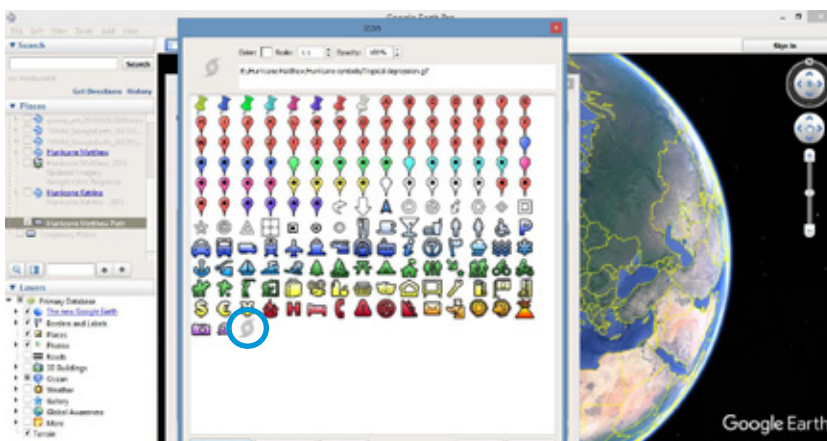
9. Click on "add custom icon" from the bottom of this new window.



10. A set of hurricane icons have been saved for you on the school network. Use the browse button to find the location of the icon named Tropical storm and select OK.



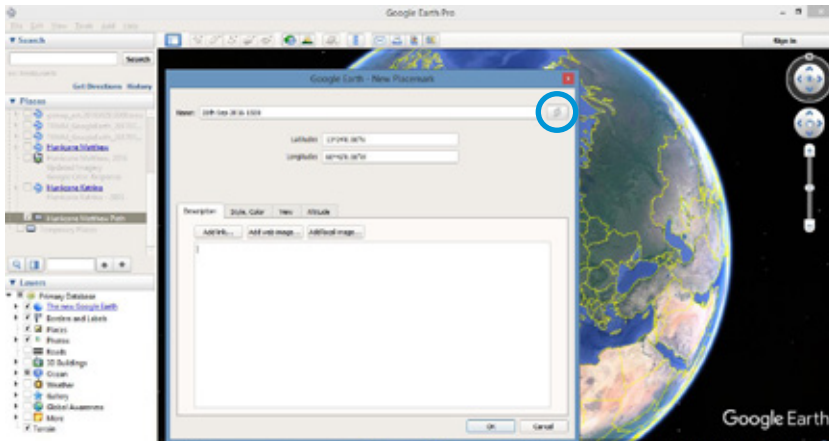
You should find that this symbol has now appeared in the list of icons



Activity 02

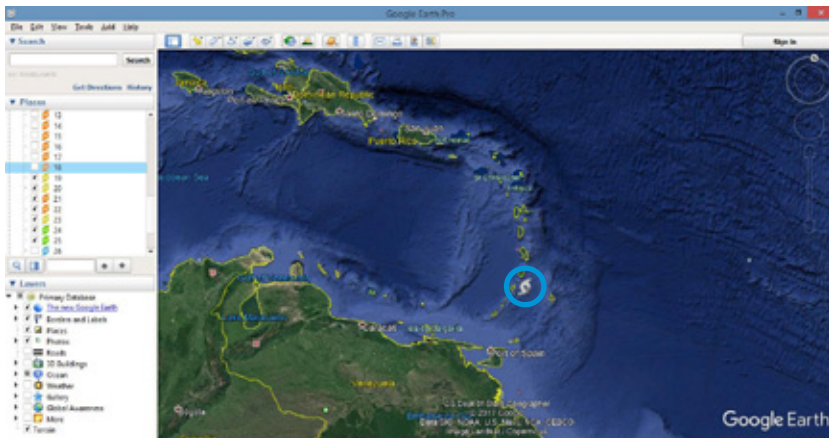
Tracking the path of a hurricane using Google Earth

11. Select OK which should return you to the screen below (which now displays the hurricane icon rather than the pin):



12. Select OK.

13. If you zoom into this location on Google Earth, you will now see the icon has been added.



14. Repeat for the following pieces of data being careful to change icons as the category of storm changes (NOTE the first data set has been greyed out as this point has just been plotted):

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
28th Sep 2016	1500	13.4	-60.7	60	Tropical storm
28th Sep 2016	2100	13.8	-62	60	Tropical storm
29th Sep 2016	0300	13.9	-63.1	65	Tropical storm
29th Sep 2016	2100	14.1	-67.8	75	Category 1
30th Sep 2016	0300	14.1	-68.8	80	Category 1

Activity 02

Tracking the path of a hurricane using Google Earth

15. Repeat for the next set of data:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
30th Sep 2016	0600	14.1	-69.3	100	Category 2
30th Sep 2016	0900	14.0	-69.9	100	Category 2
30th Sep 2016	1500	13.7	-70.8	115	Category 3
30th Sep 2016	2100	13.5	-71.6	140	Category 4
1st Oct 2016	0300	13.3	-72.3	160	Category 5

16. Based on the progress of Hurricane Matthew so far, which country or countries do you think are most in need of weather warnings?

17. Repeat for the next set of data:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
1st Oct 2016	0900	13.3	-72.8	155	Category 4
1st Oct 2016	2100	13.5	-73.4	150	Category 4
2nd Oct 2016	0300	13.8	-73.6	150	Category 4
2nd Oct 2016	2100	14.6	-74.8	145	Category 4
3rd Oct 2016	0300	14.7	-75.0	145	Category 4

18. Which country or countries do you now think are in need of weather warnings?

Activity 02

Tracking the path of a hurricane using Google Earth

19. Keep plotting the next set of data:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
3rd Oct 2016	2100	16.3	-74.7	140	Category 4
4th Oct 2016	0300	16.9	-74.6	145	Category 4
4th Oct 2016	2100	19.8	-74.3	140	Category 4
5th Oct 2016	0300	20.4	-74.4	135	Category 4
5th Oct 2016	2100	22.5	-75.7	120	Category 3

20. And again for this set of data:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
6th Oct 2016	0300	23.4	-76.4	115	Category 3
6th Oct 2016	2100	26.2	-78.6	140	Category 4
7th Oct 2016	0300	27.1	-79.2	135	Category 4
7th Oct 2016	1500	29.4	-80.5	120	Category 3
7th Oct 2016	2100	30.2	-80.7	110	Category 2

21. And finally, this set of data:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
8th Oct 2016	0300	31.2	-80.5	105	Category 2
8th Oct 2016	2100	33.8	-78.2	75	Category 2
9th Oct 2016	0300	34.1	-76.5	75	Category 1
9th Oct 2016	0900	34.9	-75.1	75	Post-tropical cyclone
9th Oct 2016	2100	35.4	-72.0	75	Post-tropical cyclone

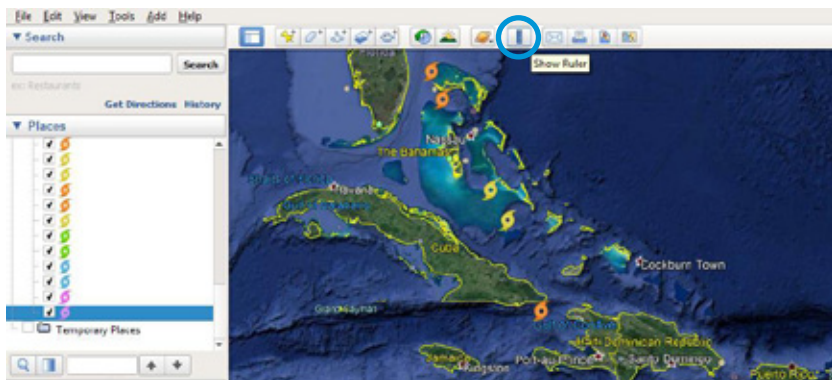
(Data obtained from: <https://www.wunderground.com/hurricane/atlantic/2016/Post-Tropical-Cyclone-Matthew>)

Activity 02

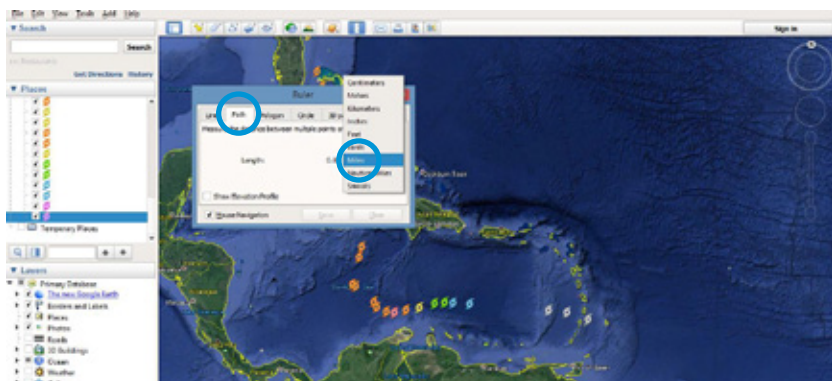
Tracking the path of a hurricane using Google Earth

Your next task is to measure the path of Hurricane Matthew.

22. Select the "Show ruler" icon () at the top of the screen as shown below:



23. In the menu, change the tab to "Path" and select miles as the units of measurement.



24. You should find that when you move your mouse over the map, you get a square outline. Place this over the first hurricane marker point that you plotted, left click once, move to the next marker, left click again and keep going until you reach the first category 1 point. This is the distance it took for Hurricane Matthew to go from being a tropical storm to a hurricane.

25. Write this value below:

_____ miles

Activity 02

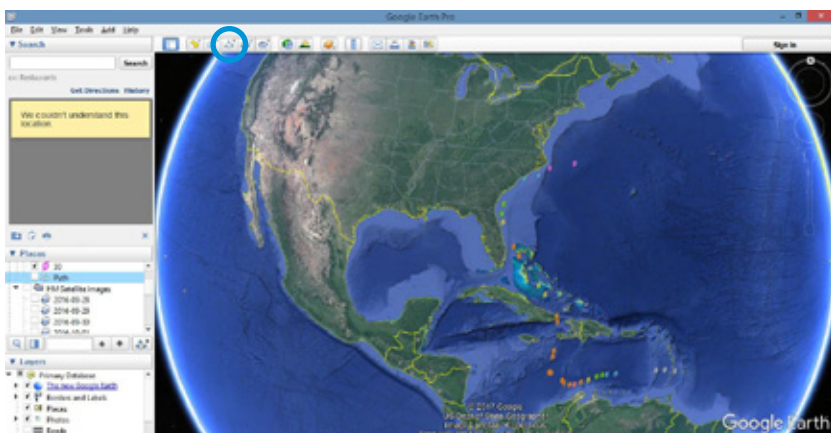
Tracking the path of a hurricane using Google Earth

26. Now keep plotting until you reach the end of your points.

27. What is the total distance?

_____ miles

28. To connect the points that you have created to give a clear path, choose the Add Path option ().



29. Change the name and click once on each of your points. When you have finished, select OK.

30. To add a legend, we need to use KML code. This can be seen below:

```
<ScreenOverlay>
<name>Legend: Hurricane Key</name>
<Icon> <href>E:/Hurricane Matthew/Hurricane symbols/Legend.gif</href>
</Icon>
<overlayXY x="0" y="0" xunits="fraction" yunits="fraction"/>
<screenXY x="25" y="95" xunits="pixels" yunits="pixels"/>
<rotationXY x="0.5" y="0.5" xunits="fraction" yunits="fraction"/>
<size x="0" y="0" xunits="pixels" yunits="pixels"/>
</ScreenOverlay>
```

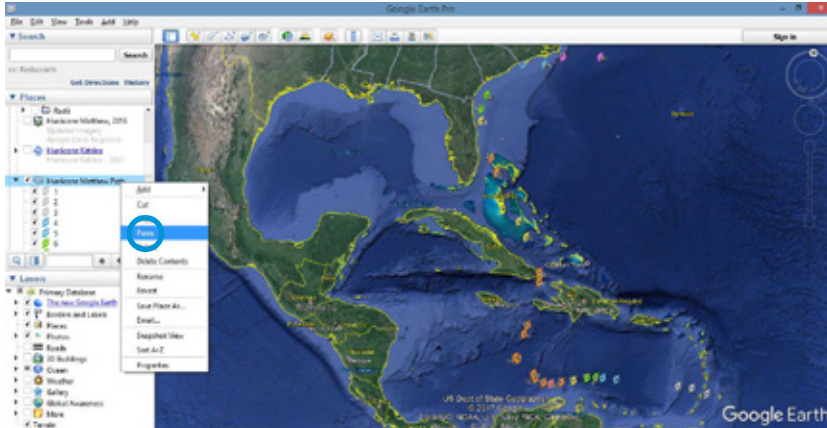
31. Change the section highlighted bold to the location of the saved image, making sure that the location is typed exactly.

32. Highlight the entire KML code, right click and select copy.

Activity 02

Tracking the path of a hurricane using Google Earth

33. Go to Google Earth and right click on the folder name.



34. Select paste and your legend should appear. You are now ready to print screen your work.

35. Now answer the quiz questions using your work from this activity to help you.

Activity 02

Tracking the path of a hurricane using Google Earth

Hurricane Matthew Quiz

- 1 On what date did Hurricane Matthew officially become classed as a hurricane?

- 2 On what date did Hurricane Matthew get downgraded from a hurricane to a tropical storm?

- 3 On what date did Hurricane Matthew reach a category 5 storm?

- 4 What was the wind speed recorded on this date?

- 5 In which sea was Hurricane Matthew at its most catastrophic?

- 6 Which was the first major country to be hit by Hurricane Matthew?

- 7 Put the following countries in order in terms of the date that Hurricane Matthew affected them:
Bahamas | Cuba | Haiti | Jamaica | USA

- 8 Which four US states were most affected by Hurricane Matthew?

- 9 What significant event happened on 3rd October 2016 between 0300 and 2100?

- 10 In which compass direction did the tropical storm move between the 5th and 7th October?

Activity 02

Tracking the path of a hurricane using Google Earth

Extension

Describe the path that Hurricane Matthew takes. Try and refer to place names including countries and bodies of water that it passes over, the change in the Saffir-Simpson scale as well as using the ruler function to refer to distances.

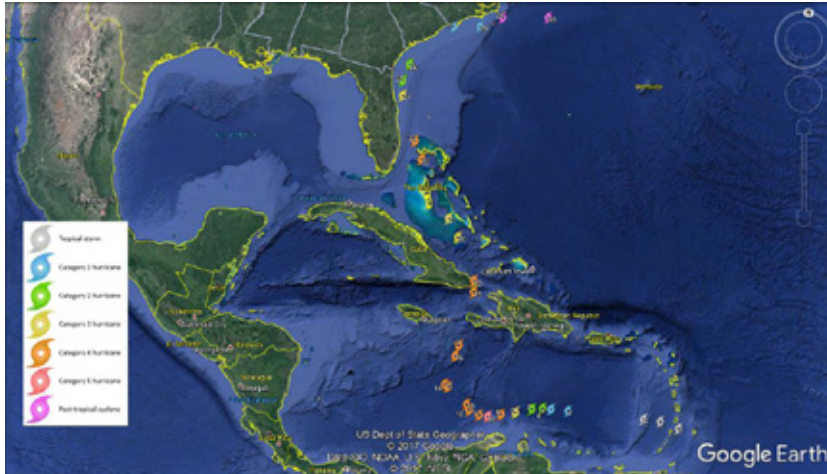
Hurricane Matthew was a category 4 storm when it hit Cuba. It then decreased to a category 3 storm prior to hitting the Bahamas and then increased again to a category 4 storm off the coast of Florida. Using your knowledge of the causes of tropical storms, explain this pattern.

Activity 02

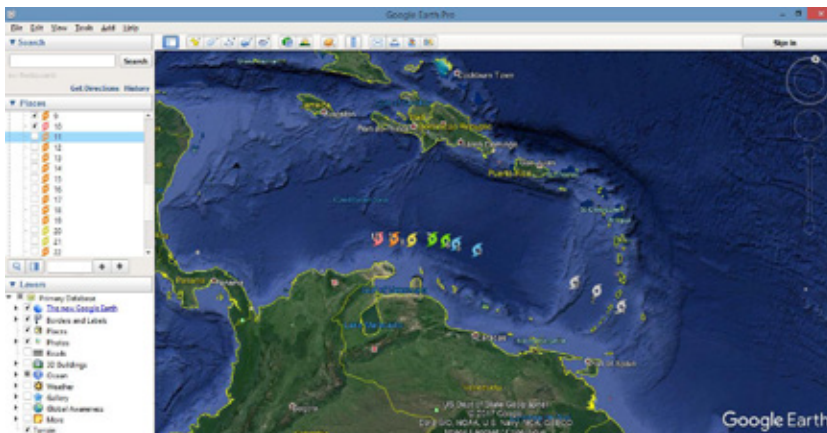
Tracking the path of a hurricane using Google Earth

Answers to activity 02

The completed map should appear as follows:



The map following the first 10 points is below:

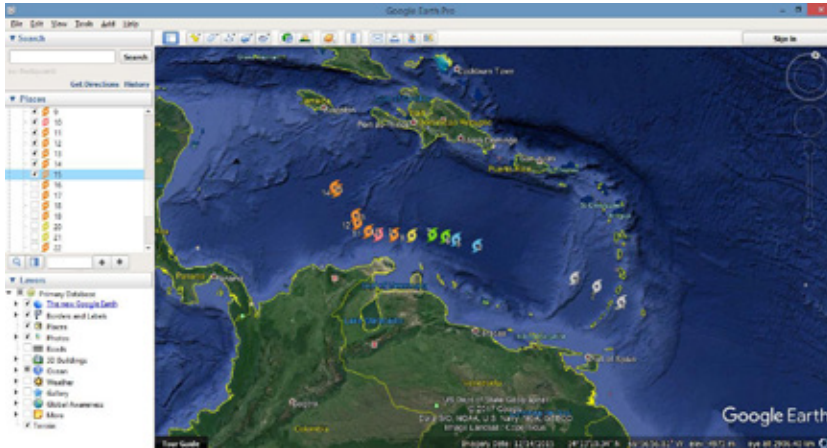


Expect a range of responses from students. Some may see Venezuela and Colombia as expected areas to be hit, others may refer to Haiti, Jamaica and Cuba, especially following activity 1.

Activity 02

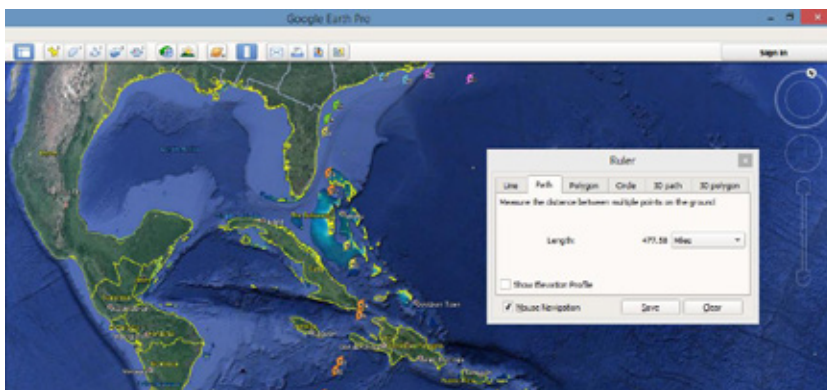
Tracking the path of a hurricane using Google Earth

The map for the first 15 points is below:

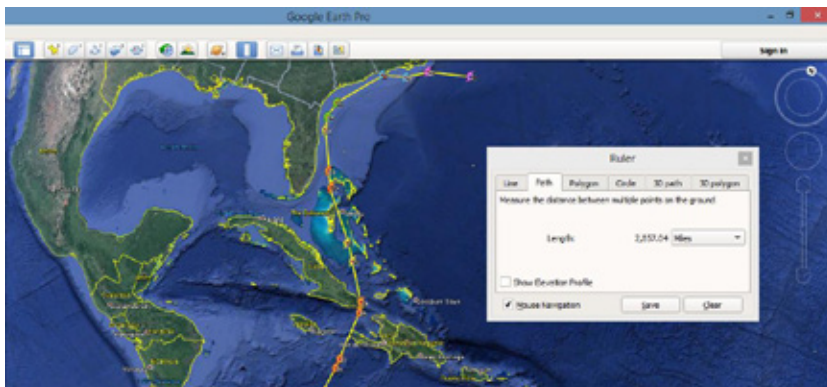


Answers should now be pointing towards Haiti and Jamaica as key areas requiring warnings.

Distance from tropical storm to hurricane status: approximately 480 miles



Total distance: approximately 2860 miles



Activity 02

Tracking the path of a hurricane using Google Earth

Hurricane Matthew Quiz

- 1 On what date did Hurricane Matthew officially become classed as a hurricane?
[29th September 2016](#)

- 2 On what date did Hurricane Matthew get downgraded from a hurricane to a tropical storm?
[9th October 2016](#)

- 3 On what date did Hurricane Matthew reach a category 5 storm?
[1st October 2016](#)

- 4 What was the wind speed recorded on this date?
[160mph](#)

- 5 In which sea was Hurricane Matthew at its most catastrophic?
[Caribbean Sea](#)

- 6 Which was the first major country to be hit by Hurricane Matthew?
[Haiti](#)

- 7 Put the following countries in order in terms of the date that Hurricane Matthew affected them:
Bahamas | Cuba | Haiti | Jamaica | USA
[Haiti](#) | [Jamaica](#) | [Cuba](#) | [Bahamas](#) | [USA](#)

- 8 Which four US states were most affected by Hurricane Matthew?
[Florida, Georgia, South Carolina, North Carolina](#)

- 9 What significant event happened on 3rd October 2016 between 0300 and 2100?
[The hurricane changed direction – began moving NE](#)

- 10 In which compass direction did the tropical storm move between the 5th and 7th October?
[North-west](#)

Activity 02

Tracking the path of a hurricane using Google Earth

Differentiating activity 02

Gifted and Talented students/higher key stages

Remove the completed column for the category of storm and ask students to use the Saffir-Simpson scale to work this out prior to plotting as shown in the example below:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
6th Oct 2016	0300	23.4	-76.4	115	
6th Oct 2016	2100	26.2	-78.6	140	
7th Oct 2016	0300	27.1	-79.2	135	
7th Oct 2016	1500	29.4	-80.5	120	
7th Oct 2016	2100	30.2	-80.7	110	






More data sets are also available – see the following website for more:

<https://www.wunderground.com/hurricane/atlantic/2016/Post-Tropical-Cyclone-Matthew>

Students could also research more about the causes of Hurricane Matthew using independent research and then present their findings to the class.

SEN students

Provide a colour coded version of the category storm so that students use the correct symbol as shown below:

Date	Time	Latitude	Longitude	Wind speed (mph)	Category
6th Oct 2016	0300	23.4	-76.4	115	Category 3 
6th Oct 2016	2100	26.2	-78.6	140	Category 4 
7th Oct 2016	0300	27.1	-79.2	135	Category 4 
7th Oct 2016	1500	29.4	-80.5	120	Category 3 
7th Oct 2016	2100	30.2	-80.7	110	Category 2 

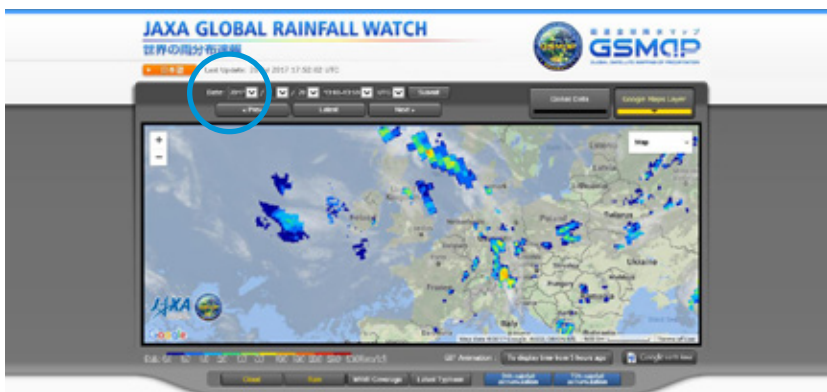
Students could also work with fewer pieces of data, showing the key changes in categories.

Activity 03

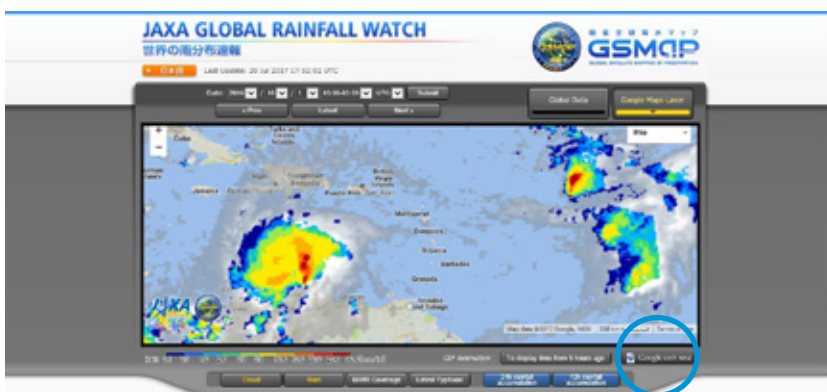
Plotting rainfall and wind speed data in Google Earth

Now that you know the path of Hurricane Matthew, we want to examine the weather associated with it. The first thing you will examine is rainfall.

1. Visit <http://sharaku.eorc.jaxa.jp/GSMaP/index.htm>
2. Change the date at the top of the page to 1st October 2016 and the time to 0300. This is when Hurricane Matthew was classed as a category 5 storm. NB the date format on this web page is year/month/day.



3. Pan over towards USA and zoom in to the area where Hurricane Matthew is found.
4. This data can be added as a layer within Google Earth. To do this, click on the Google Earth KMZ button at the bottom of the screen as shown below:



Activity 03

Plotting rainfall and wind speed data in Google Earth

5. Save the file to your desktop and then open it up. This should automatically add the layer to Google Earth.

6. Expand the folder by clicking the arrow next to the layer name under Places.



7. Deselect Typhoon.

8. Deselect Coverage (MicroWave Radiometer overpasses) (found under 2016-10-01T03:00-59Z) to give yourself a clearer view.

9. Print screen your work and paste it in a Word document.

10. Now repeat this process but this time, examine 8th October 2016 2100.

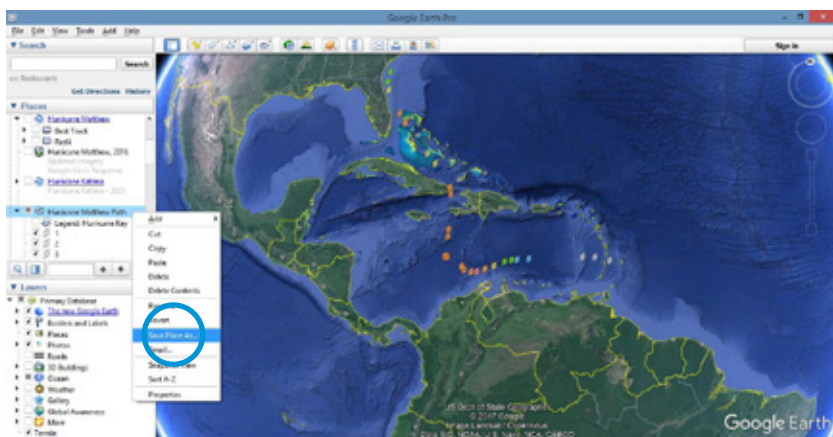
11. Write a paragraph describing the pattern of rainfall shown in both images and comment on any changes that you can see. You should also consider using the ruler tool that you used in activity 2 to measure the area of rainfall in both regions. Think about similarities

Activity 03

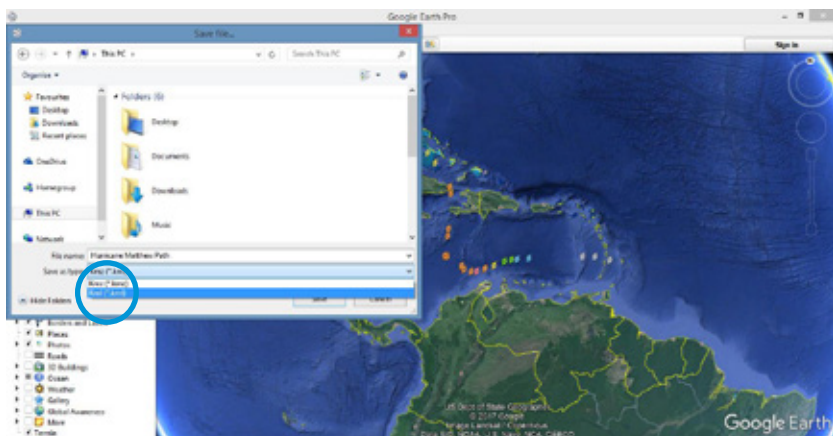
Plotting rainfall and wind speed data in Google Earth

You're now going to plot the wind speed recorded throughout Hurricane Matthew as a bar graph in Google Earth.

12. In Google Earth, right click the folder that you created in activity 2 plotting Hurricane Matthew's path and select "Save Place As"



13. In the window that appears, set the name to Hurricane Matthew Path and change the "Save as type" option to a KML file. This is important.



14. Choose your file location and select Save.

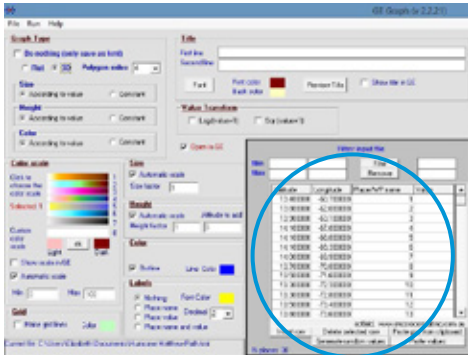
15. Now open GEGraph

16. Select File>Open File and then retrieve the KML file that you've just saved.

Activity 03

Plotting rainfall and wind speed data in Google Earth

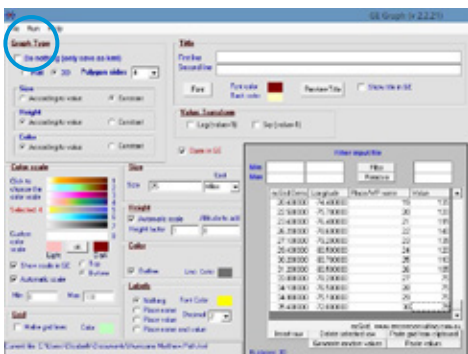
You should find that all of your points now appear in the box to the bottom right of your screen as highlighted below:



17. Insert the wind speed values that relate to each point as shown below:

Point	Wind speed (mph)	Point	Wind speed (mph)	Point	Wind speed (mph)
1	60	11	155	21	115
2	60	12	150	22	140
3	65	13	150	23	135
4	75	14	145	24	120
5	80	15	145	25	110
6	100	16	140	26	105
7	100	17	145	27	75
8	115	18	140	28	75
9	140	19	135	29	75
10	160	20	120	30	75

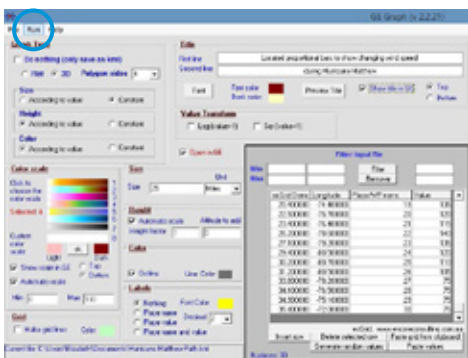
18. Under Graph Type, make sure that the 3D option is ticked and Polygon sides is set to 4.



Activity 03

Plotting rainfall and wind speed data in Google Earth

19. Change Size to Constant and leave height and colour as According to value.
20. Under Colour scale, choose the option that you would like to use. This will be the shading used for the bars in Google Earth. Alternatively, you could create a custom scale if you prefer.
21. Tick the box that says Show scale in GE.
22. Under Size, choose 25 and change the units to miles.
23. Change the colour of the line colour if you wish.
24. Under the title heading, write "Located proportional bars to show changing wind speed during Hurricane Matthew". NOTE split this into two lines so that you can read it clearly.
25. Change the font colour and background if you wish or leave as the automatic option.
26. Select Show title in GE.
27. Select Run



28. In the window that appears, save your new KML file. It should now automatically open in Google Earth.
29. Change the orientation so that you can view the bars clearly.
30. Print screen your work and write a paragraph describing what it shows. Remember to refer to data and place names within your answer.

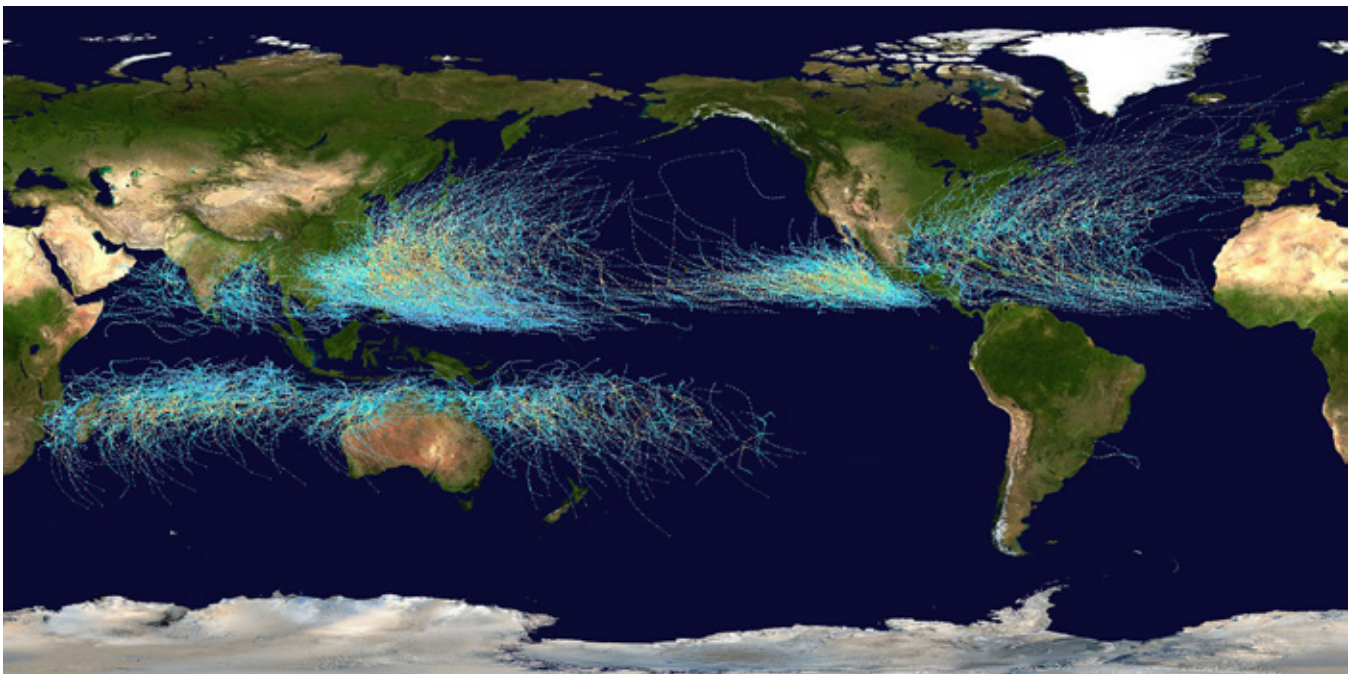
Extension: Write a weather report for Haiti describing the weather conditions that they can expect in the 24 hour period from 0300 on 4th October 2016 to 0300 on 5th October 2016.

Activity 03

Plotting rainfall and wind speed data in Google Earth

3. State whether the tropical storm shown in **Figure 1** is located in the northern or southern hemisphere. Justify your choice. (3 marks)

Figure 2 shows the global distribution of tropical storms.



Source: https://en.wikipedia.org/wiki/Tropical_cyclone#/media/File:Global_tropical_cyclone_tracks-edit2.jpg

4. Using **Figure 2** and your own knowledge, describe the location of tropical storms. (4 marks)

Activity 03

Plotting rainfall and wind speed data in Google Earth

5. Explain reasons for the distribution shown in **Figure 2**.

(4 marks)

Figure 3a shows the amount of rainfall dropped by Hurricane Matthew over the life and track of the storm.

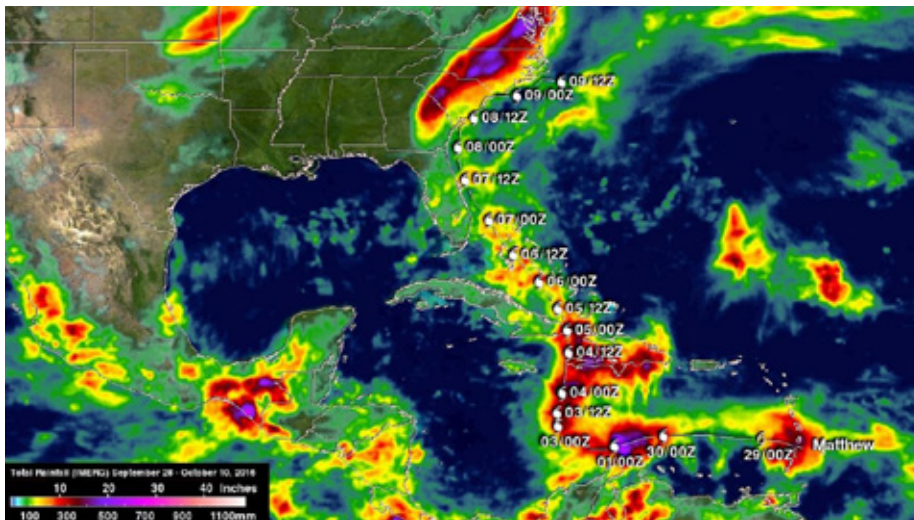
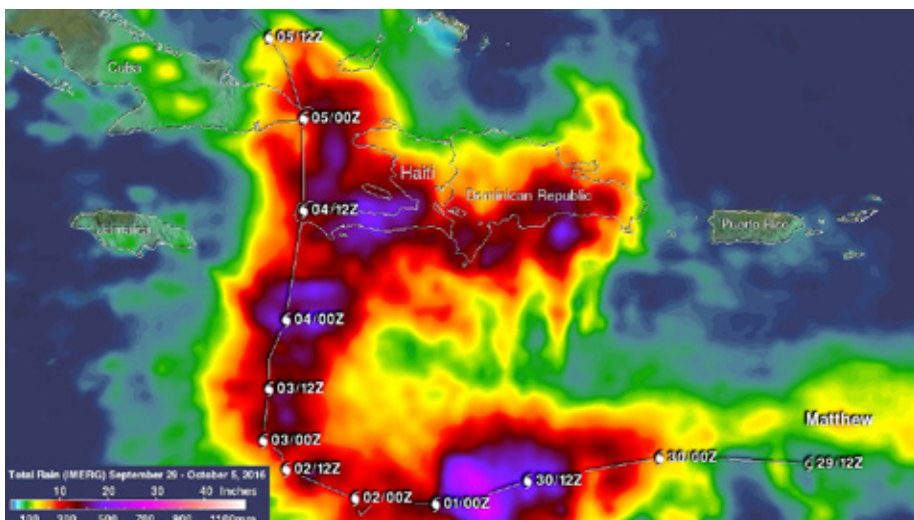


Figure 3b is a close-up over the area of Haiti, the Dominican Republic and Cuba.



Source: <https://www.nasa.gov/feature/goddard/2016/matthew-atlantic-ocean>

Activity 03

Plotting rainfall and wind speed data in Google Earth

6. Describe the weather shown in **Figures 3a** and **3b**.

(5 marks)

Figure 4 shows a satellite image of Hurricane Matthew taken on 4th October 2016 by NASA's Terra satellite.



7. Label three features of a hurricane onto **Figure 4**.

(3 marks)

Activity 03

Plotting rainfall and wind speed data in Google Earth

8. Describe the likely weather conditions that Haiti will experience over the next 24 hours as Hurricane Matthew passes over it. (4 marks)

Total - 25 marks

Activity 04

Viewing satellite images

The following satellite image shows Hurricane Matthew moving north towards the west coast of Haiti.



Source: <https://www.nytimes.com/2016/10/05/world/americas/hurricane-matthew-caribbean.html>

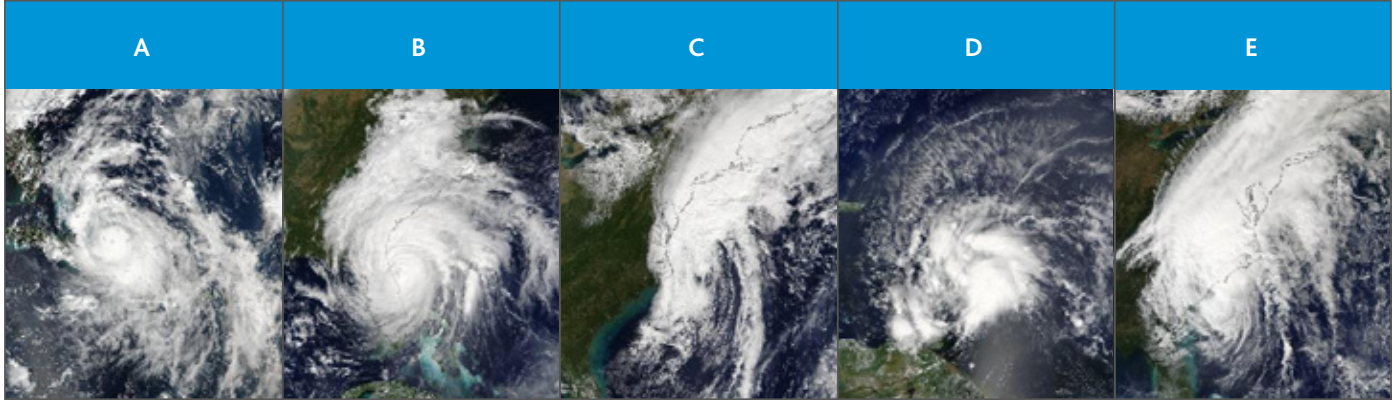
Add labels onto the image to show the following:

- Eye
- Eyewall
- Spiral rainbands
- Cirrus clouds
- Anticlockwise direction
- Haiti
- Dominican Republic
- Jamaica
- Cuba
- Caribbean Sea

Activity 04

Viewing satellite images

The following satellite image shows Hurricane Matthew moving north towards the west coast of Haiti.



Images from NASA: <https://www.nasa.gov/feature/goddard/2016/matthew-atlantic-ocean/>

Cut out and stick the images into the table below in the correct sequence and write a description of what each image shows. This should include the cloud movements, density, weather conditions and countries affected.

28th Sep 2016 1430	5th Oct 2016 1830	7th Oct 2016 1600	8th Oct 2016 1820	9th Oct 2016 1545
Description	Description	Description	Description	Description

Activity 04

Viewing satellite images

Activity 4: Alternative (active learning)

Lower ability set of cards:

Tropical storm evident

Movement = west in the direction of Haiti

Location = centre of circulation just east of the Lesser Antilles.

Weather = Strong thunderstorms surrounding the center with heavy clouds in the Caribbean Sea. Wind speeds are around 70mph.

Hurricane Matthew become a post-tropical cyclone with a visible change in structure

Movement = north-easterly direction along the SE coast of the USA.

Location = off the coast of North Carolina.

Weather = winds of around 75mph with some stronger gusts and heavy rainfall. Conditions will begin to improve over the next 48 hours though.

Hurricane now visible

Movement = north-west direction towards the Bahamas

Location = eye is visible north of Cuba and heading through the Bahamas

Weather = the anticlockwise spiralling of cloud is visible. This produces high winds, gusts and heavy downpours for the areas affected. Haiti, the Dominican Republic, Jamaica and Cuba continue to be affected. Weather warnings issued for the Bahamas.

Post-tropical cyclone

Movement = now being absorbed by a cold front along the US Eastern Seaboard as evidenced by the decreased cloud density.

Location = around 200 miles east of North Carolina.

Weather = winds beginning to weaken.

Category 3 hurricane

Movement = north-west direction heading along the US coast

Location = central vortex is visible off the coast of Florida. Here, there is high density cloud and a clear hurricane structure

Weather = strong winds of around 115mph affecting Florida and Georgia.

Activity 04

Viewing satellite images

Higher ability set of cards:

Movement = now being absorbed by a cold front along the US Eastern Seaboard as evidenced by the decreased cloud density.

Location = centre of circulation just east of the Lesser Antilles.

Movement = north-easterly direction along the SE coast of the USA.

Weather = the anticlockwise spiralling of cloud is visible. This produces high winds, gusts and heavy downpours for the areas affected. Haiti, the Dominican Republic, Jamaica and Cuba continue to be affected. Weather warnings issued for the Bahamas.

Location = central vortex is visible off the coast of Florida. Here, there is high density cloud and a clear hurricane structure.

Tropical storm evident.

Hurricane Matthew become a post-tropical cyclone with a visible change in structure.

Movement = north-west direction towards the Bahamas.

Weather = winds of around 75mph with some stronger gusts and heavy rainfall. Conditions will begin to improve over the next 48 hours though.

Location = around 200 miles east of North Carolina.

Activity 04

Viewing satellite images

Higher ability set of cards:

Movement = north-west direction heading along the US coast.

Location = off the coast of North Carolina.

Weather = winds beginning to weaken.

Post-tropical cyclone.

Movement = west in the direction of Haiti.

Weather = strong winds of around 115mph affecting Florida and Georgia.

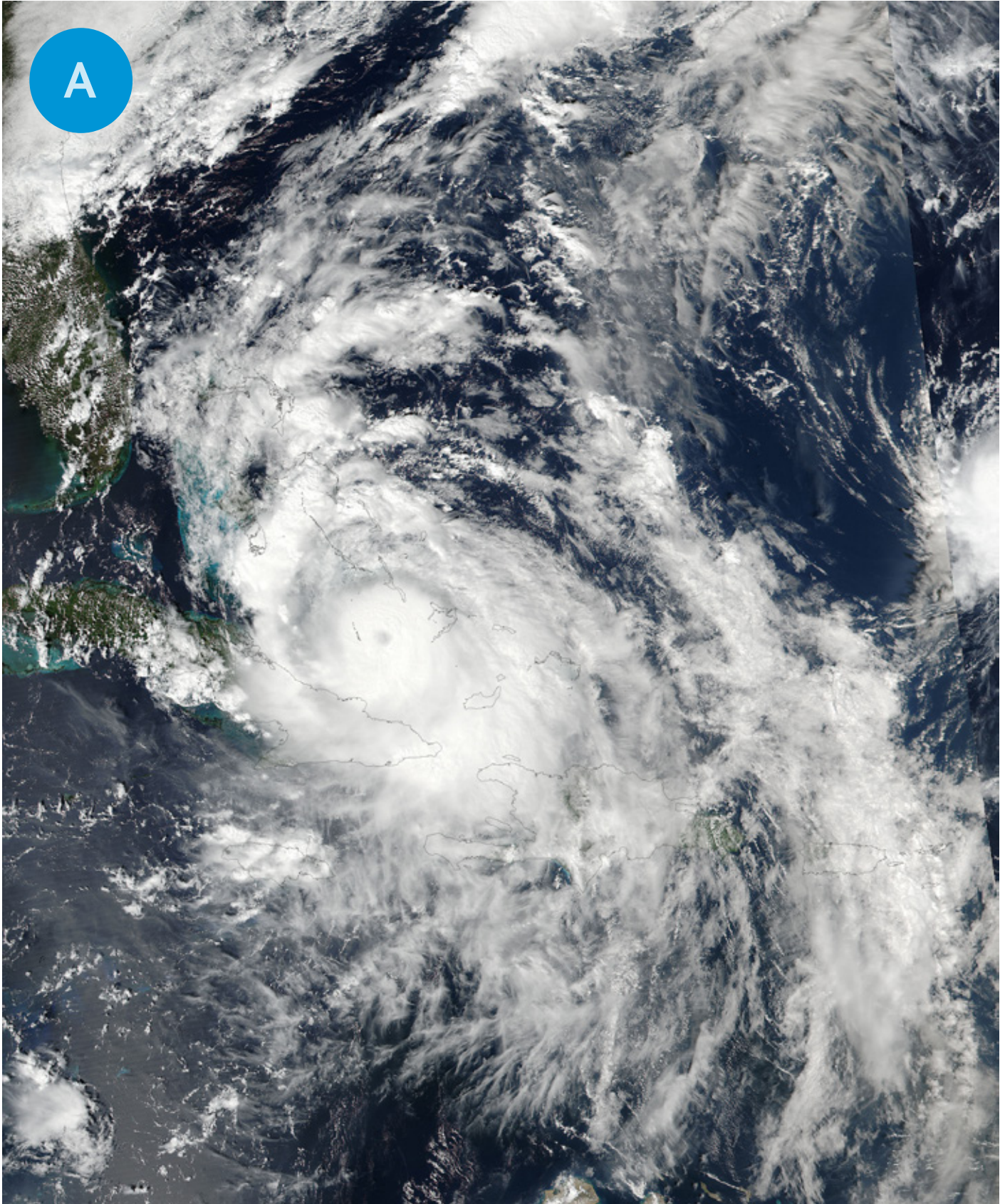
Category 3 hurricane.

Hurricane now visible.

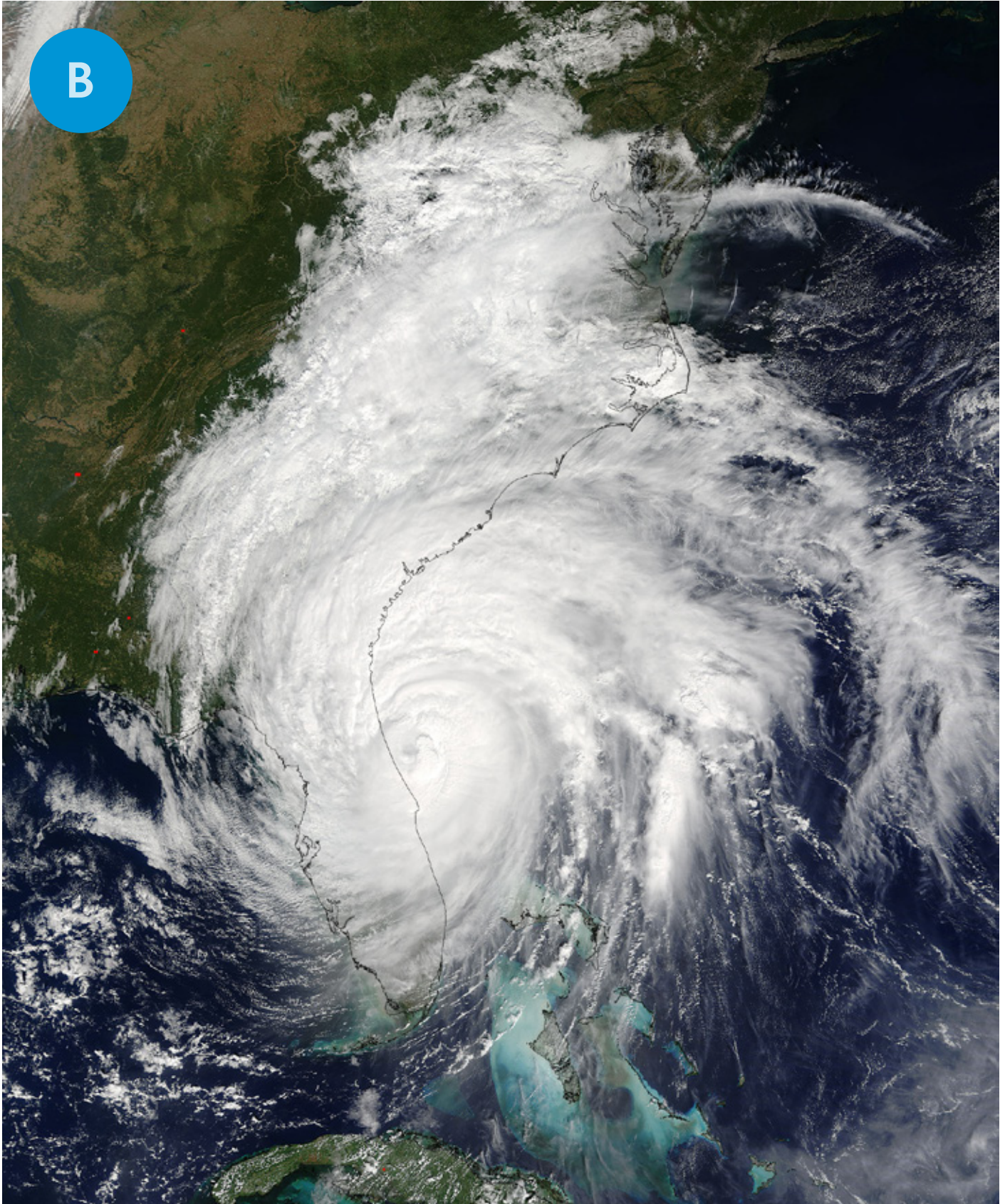
Weather = Strong thunderstorms surrounding the center with heavy clouds in the Caribbean Sea. Wind speeds are around 70mph.

Location = eye is visible north of Cuba and heading through the Bahamas.

Activity 04
Viewing satellite images

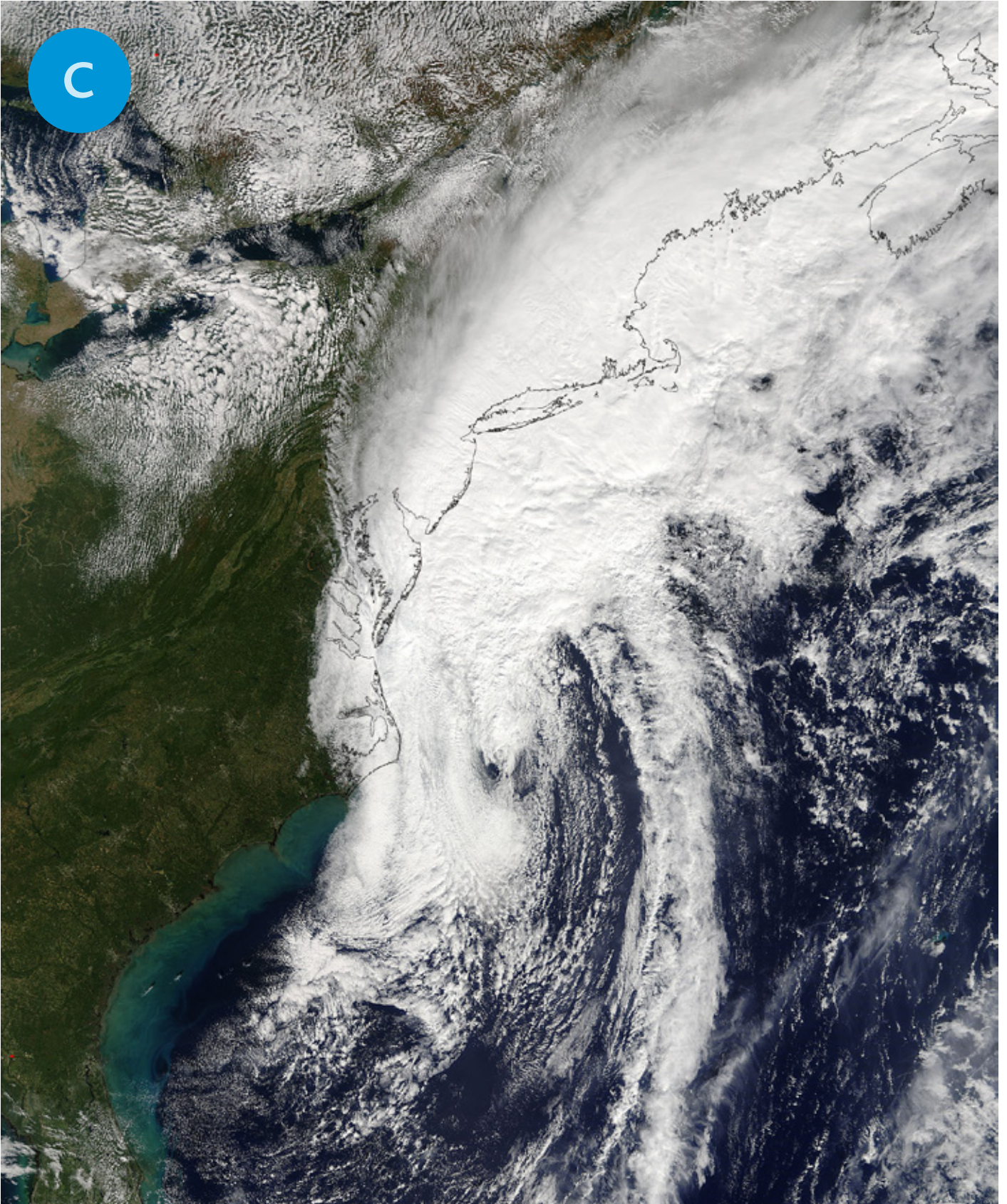


Activity 04
Viewing satellite images

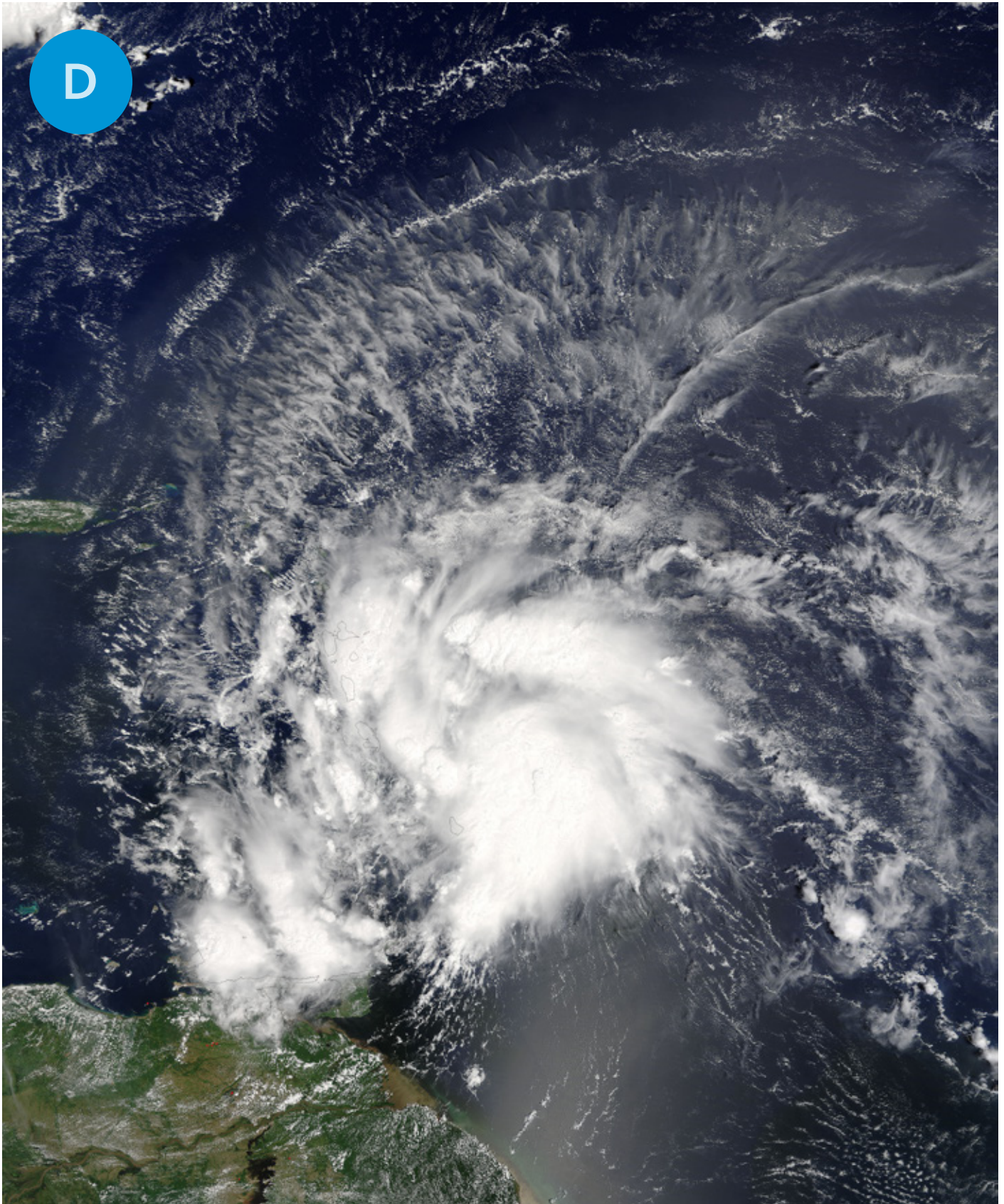


Activity 04

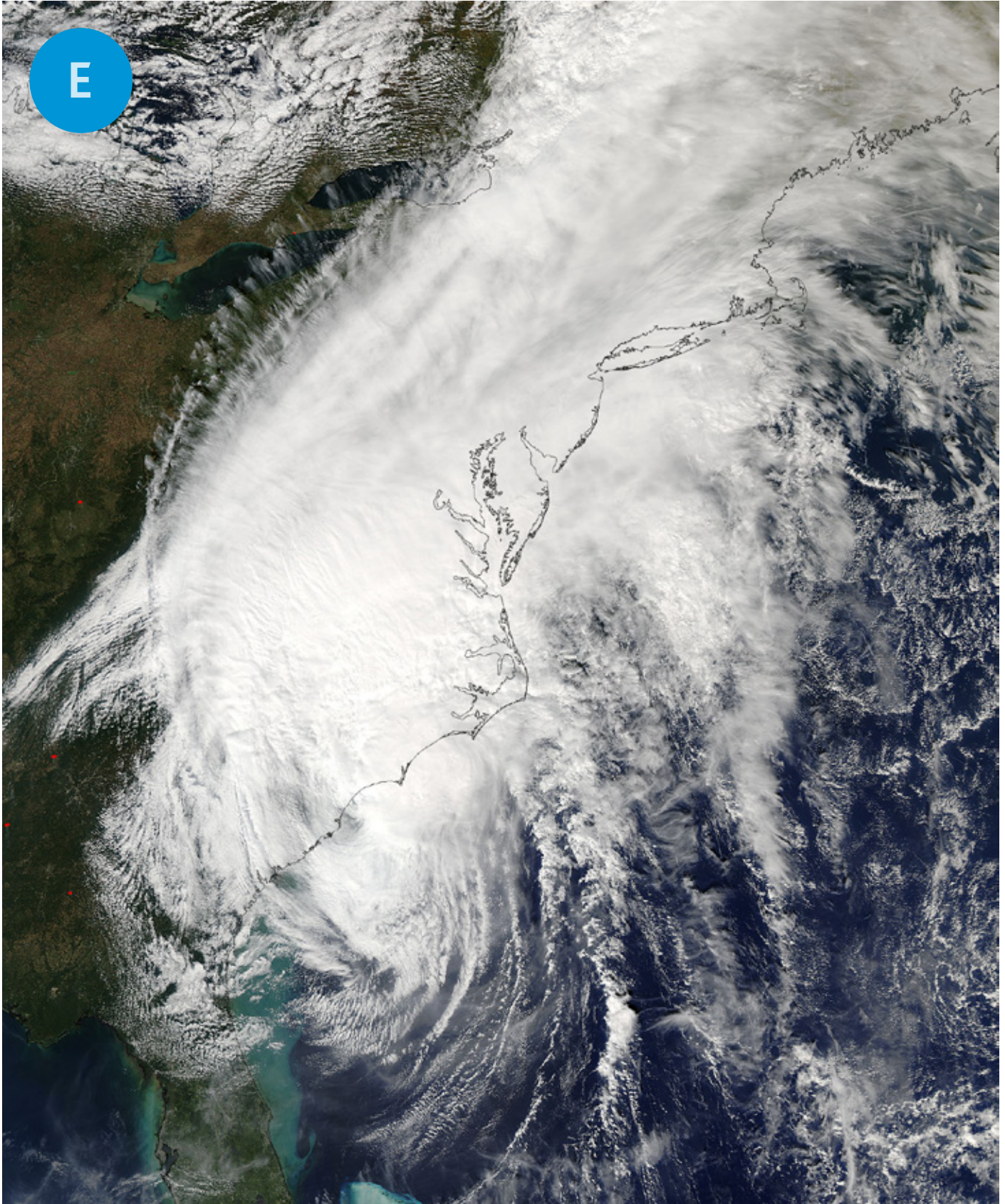
Viewing satellite images



Activity 04
Viewing satellite images

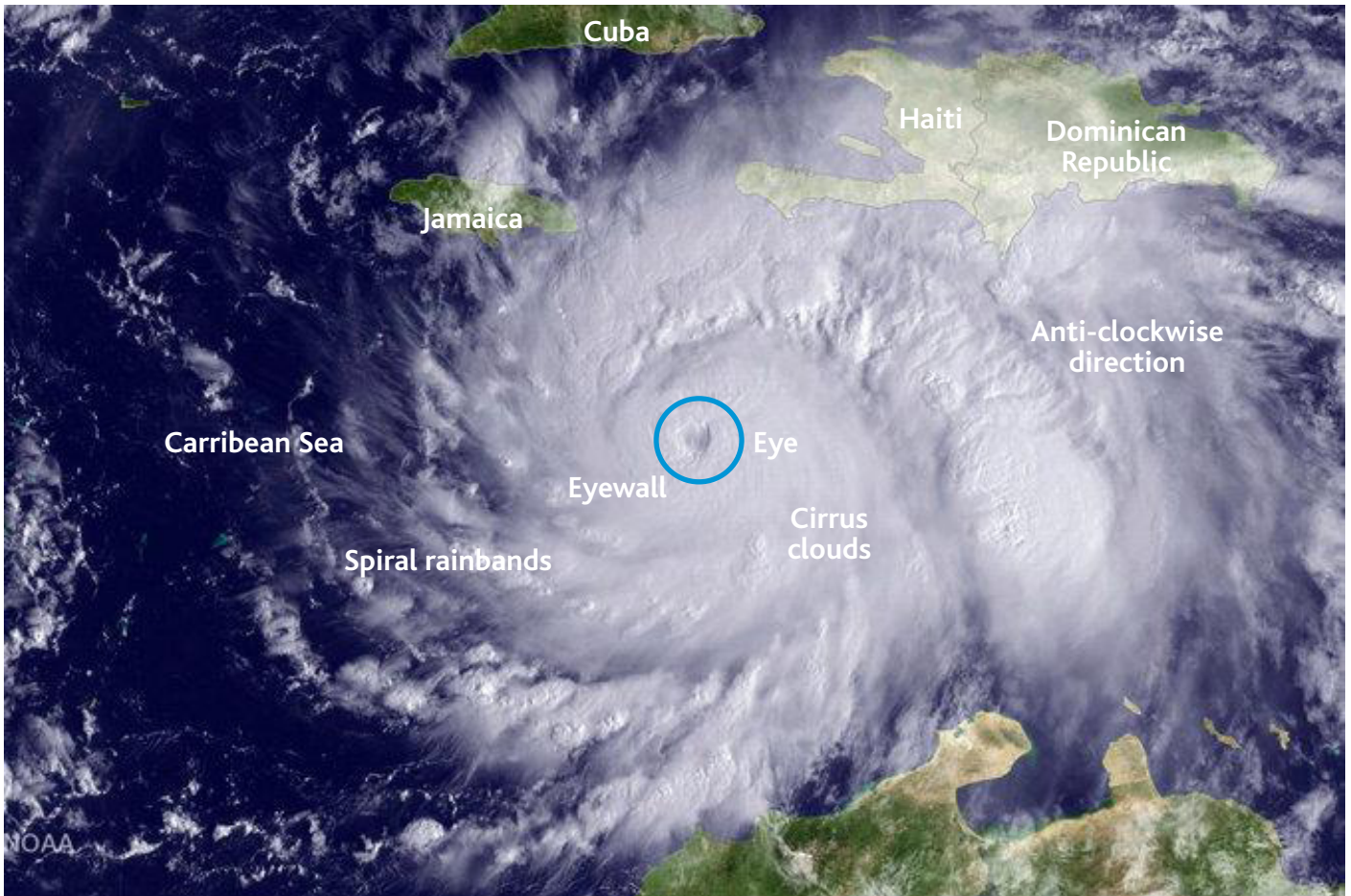


Activity 04
Viewing satellite images








Activity 04
Viewing satellite images

Answers to Activity 04



Activity 04

Viewing satellite images

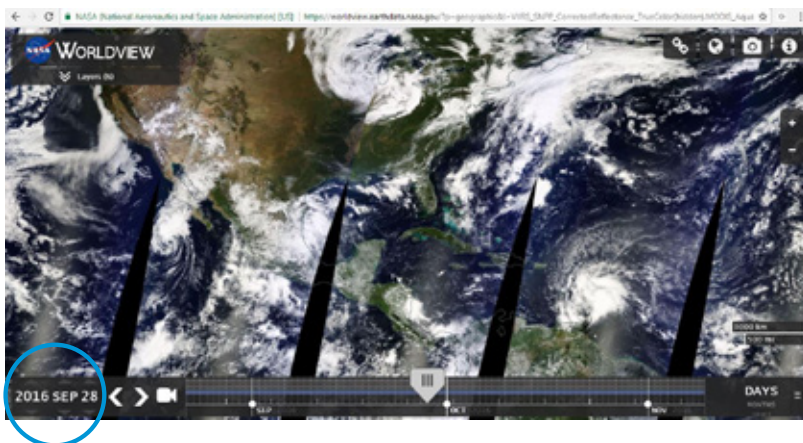
28th Sep 2016 1430	5th Oct 2016 1830	7th Oct 2016 1600	8th Oct 2016 1820	9th Oct 2016 1545
				
Description	Description	Description	Description	Description
<p style="text-align: center;">D</p> <p>Tropical storm evident</p> <p>Movement = west in the direction of Haiti</p> <p>Location = centre of circulation just east of the Lesser Antilles.</p> <p>Weather = Strong thunderstorms surrounding the center with heavy clouds in the Caribbean Sea. Wind speeds are around 70mph.</p>	<p style="text-align: center;">A</p> <p>Hurricane now visible</p> <p>Movement = north-west direction towards the Bahamas</p> <p>Location = eye is visible north of Cuba and heading through the Bahamas</p> <p>Weather = the anticlockwise spiralling of cloud is visible. This produces high winds, gusts and heavy downpours for the areas affected. Haiti, the Dominican Republic, Jamaica and Cuba continue to be affected. Weather warnings issued for the Bahamas.</p>	<p style="text-align: center;">B</p> <p>Category 3 hurricane</p> <p>Movement = north-west direction heading along the US coast</p> <p>Location = central vortex is visible off the coast of Florida. Here, there is high density cloud and a clear hurricane structure</p> <p>Weather conditions = strong winds of around 115mph affecting Florida and Georgia.</p>	<p style="text-align: center;">E</p> <p>Hurricane Matthew become a post-tropical cyclone with a visible change in structure</p> <p>Movement = north-easterly direction along the SE coast of the USA.</p> <p>Location = off the coast of North Carolina.</p> <p>Weather conditions = winds of around 75mph with some stronger gusts and heavy rainfall. Conditions will begin to improve over the next 48 hours though.</p>	<p style="text-align: center;">C</p> <p>Post-tropical cyclone</p> <p>Movement = now being absorbed by a cold front along the US Eastern Seaboard as evidenced by the decreased cloud density.</p> <p>Location = around 200 miles east of North Carolina.</p> <p>Weather conditions = winds beginning to weaken.</p>

Activity 05

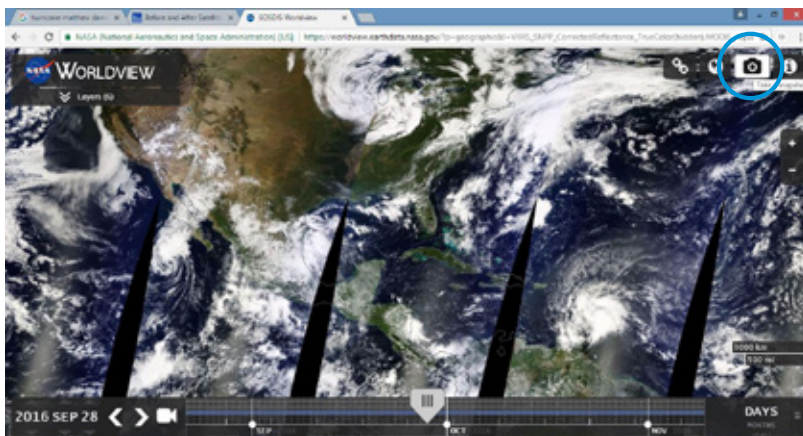
Adding moving satellite imagery to Google Earth

You're now going to create a series of timed overlays in Google Earth to show moving satellite imagery of Hurricane Matthew. This will allow you to see how satellite technology is useful for analysing hurricane intensity, velocity and direction by visualising how the cloud changes as the category of storm intensifies and weakens.

1. Visit <https://worldview.earthdata.nasa.gov>
2. Change the date at the bottom of the screen to 28th September 2016 (using the arrows above and below each part of the date) and pan over to the USA to get a view similar to that below:



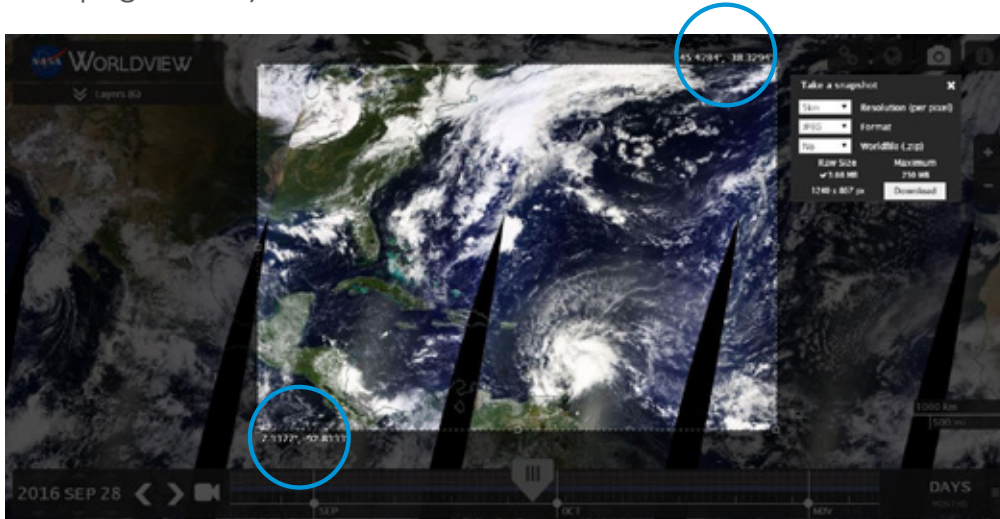
3. Select the "take a snapshot" camera icon at the top right of the screen.



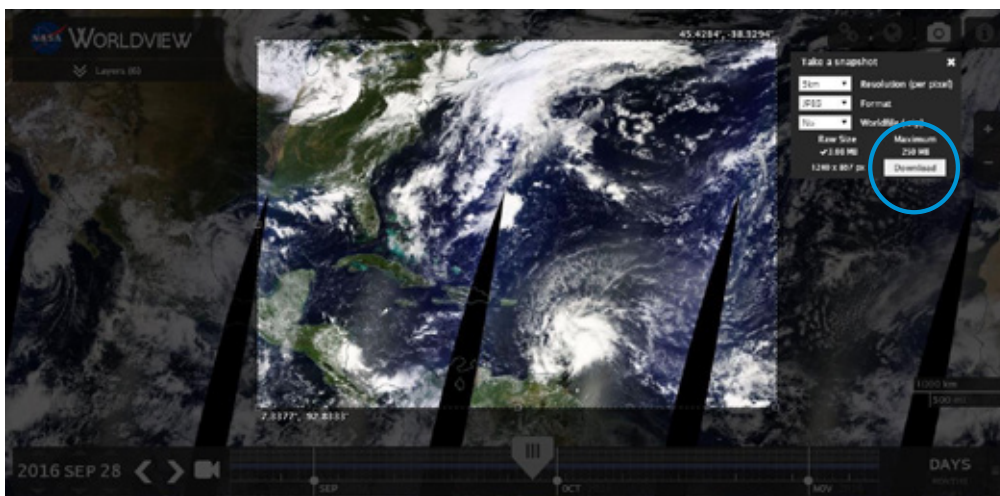
Activity 05

Adding moving satellite imagery to Google Earth

4. Change the size of the snapshot to 7.3377,-92.8333 (in the bottom left corner) and 45.4284,-38.3294 (in the top right corner).



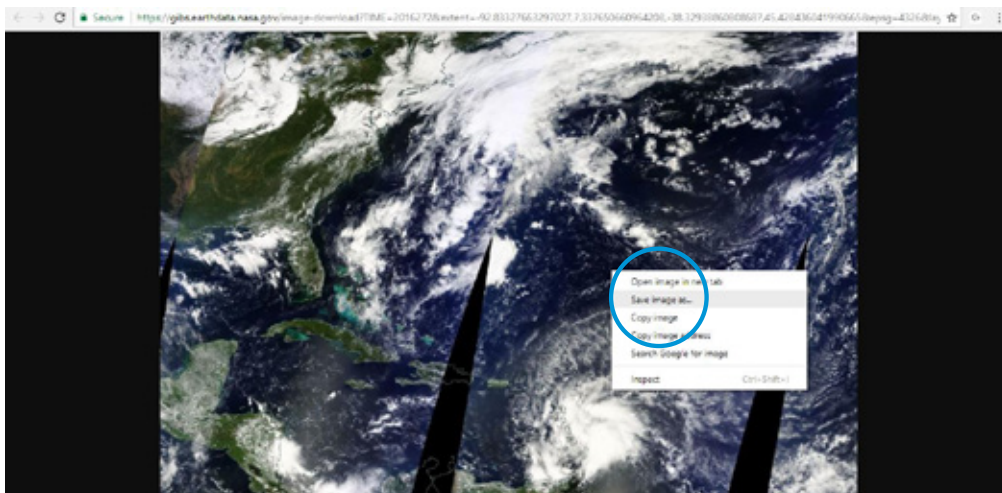
5. Select the download button.



6. The image will open in a new window. Right click and select "save image as" and then save this to your drive making it clear what date the image is for. NOTE you may find it useful to keep the images organised in a folder e.g. Hurricane Matthew images.

Activity 05

Adding moving satellite imagery to Google Earth



7. Return to <https://worldview.earthdata.nasa.gov>, move the date on one day and repeat. NB when selecting a snapshot, you should find that the area is the same as your first image so you will not need to change it.

8. Keep collecting images each day up to and including 9th October 2016. This should give you 12 images in total in your folder.

9. Now that you have the images, we need to transfer them to KML code that time stamps them and locate them geographically within Google Earth. This can be found in the 'Activity 5 kml.txt' file. An example of the code can be seen below and on the following page. The bold sections are the areas that you need to change based on the data for your images. The location of the images and the name of the image must also be exact for it to be read in Google Earth so make sure that you pay attention to whether writing is upper or lower case.

Image 1 (28th Sep 2016)

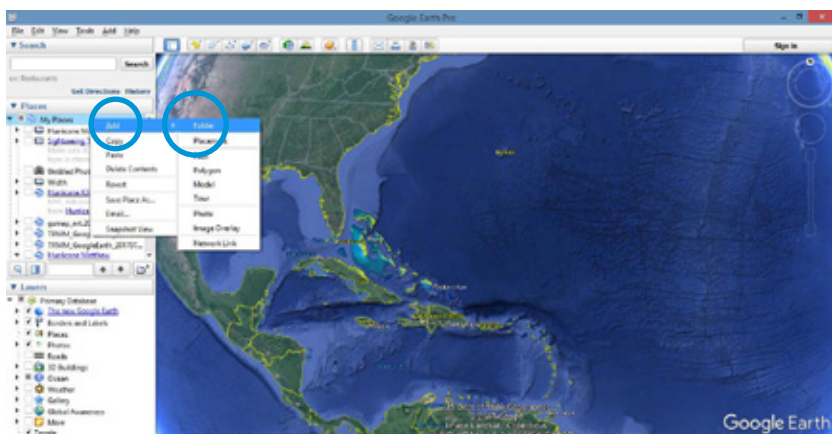
```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2" xmlns:gx="http://www.google.com/kml/ext/2.2" xmlns:kml="http://www.opengis.net/kml/2.2"
xmlns:atom="http://www.w3.org/2005/Atom">
<GroundOverlay id="20160928">
  <name>2016-09-28</name>
  <LookAt>
    <gx:TimeSpan>
      <begin>2016-09-28T00:00:00Z</begin>
      <end>2016-09-29T00:00:00Z</end>
    </gx:TimeSpan>
    <longitude>-68.84682130470465</longitude>
    <latitude>18.82627566272093</latitude>
    <altitude>0</altitude>
    <heading>-20.32225131877766</heading>
    <tilt>0</tilt>
    <range>7288764.695072241</range>
    <gx:altitudeMode>relativeToSeaFloor</gx:altitudeMode>
```


Activity 05

Adding moving satellite imagery to Google Earth

```
</LookAt>
<Icon>
  <href>C:\Users\Elizabeth\Pictures\Hurricane Matthew images\28th Sep 2016.jpeg</href>
  <viewBoundScale>0.75</viewBoundScale>
</Icon>
<LatLonBox>
  <north>45.4284</north>
  <south>-7.311728571433712</south>
  <east>-38.329400000000006</east>
  <west>-92.75491650250127</west>
</LatLonBox>
<TimeStamp><when>2016-09-28T00:00:00Z</when></TimeStamp>
</GroundOverlay>
</kml>
```

10. Under My Places in Google Earth, right click and select Add>Folder



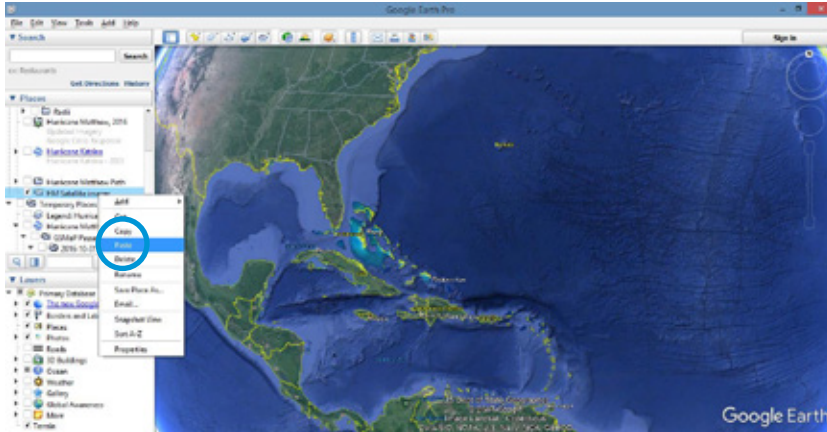
11. Name your new folder Hurricane Matthew Satellite Images.

12. Copy the KML code for 9h Oct 2016 from the file (we will be working in reverse order so that the images are sequenced correctly).

Activity 05

Adding moving satellite imagery to Google Earth

13. Right click on your new folder in Google Earth and select paste.



You should notice that the overlay now appears in Google Earth as shown below:



14. Now copy and paste the code for 8th Oct 2016.

15. Keep repeating until you have copied and pasted all of the KML codes into Google Earth, finishing with 28th Sep 2016.

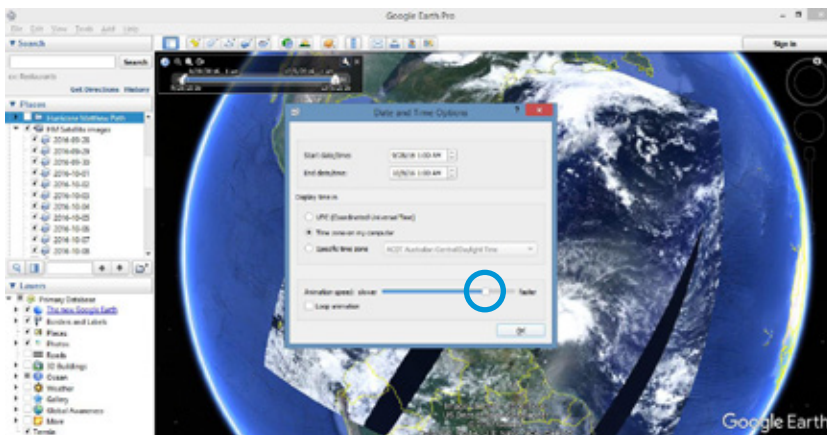
Activity 05

Adding moving satellite imagery to Google Earth

16. Once all images have been added, click the spanner icon in the time slider.



17. Decrease the speed slightly so that you can see the changes clearly and select OK.



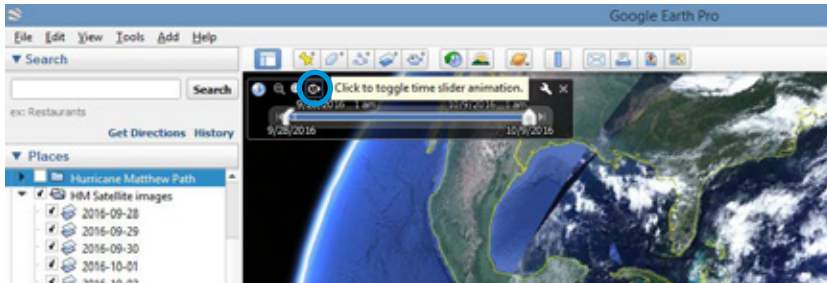
18. Slide the back slider back to the beginning.



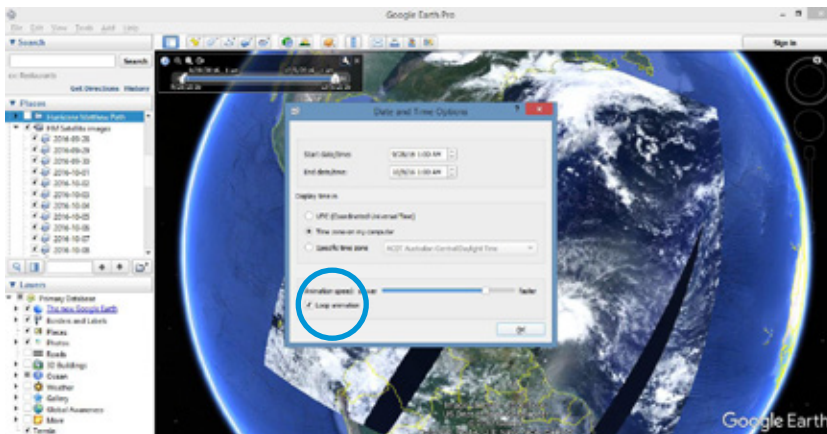
Activity 05

Adding moving satellite imagery to Google Earth

19. Now click the icon highlighted below to toggle the time slider animation.



20. If you wish to loop the animation, click the spanner icon again, tick the box at the bottom that says Loop animation and select OK.



21. If you select the layer that you created in activity 2 showing the path of Hurricane Matthew, you will be able to see the cloud moving in relation to the track that you plotted.

Activity 05

Adding moving satellite imagery to Google Earth

Differentiating activity 05

Gifted and Talented students

A wider range of 49 satellite images and KML codes can be used from the zip file provided. These allow a smoother transition from one image to the next as they are based on shorter time periods.

Higher key stages and those very able students could use an exemplar KML code to change more aspects than the file location of images. For example, times and dates.

An extension would be to evaluate the use of satellite images in monitoring hurricanes such as Hurricane Matthew..

SEN students

To save time, images could be saved in advance on the school network. Lower ability students could then use these to work at the same pace as the rest of the group.

There is also potential to work with fewer images although this will affect the transition from one image to the next.

Alternatively, students could receive a completed KMZ file that they upload to Google Earth and then view the changes using the time slider.

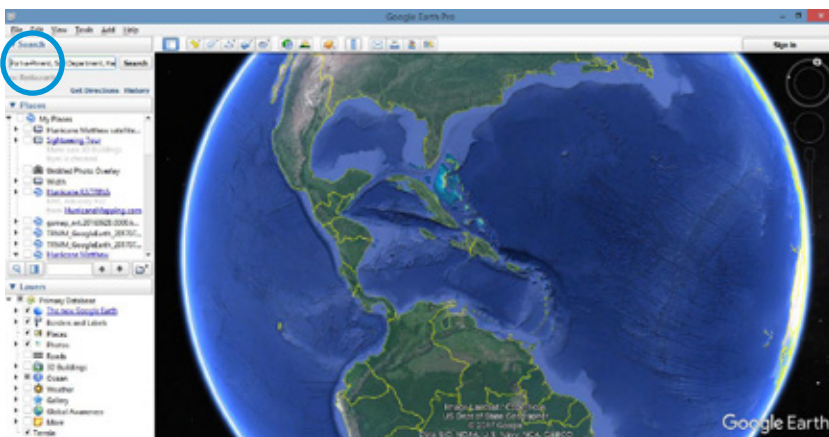
Activity 06

Using satellite images to view the impacts of Hurricane Matthew

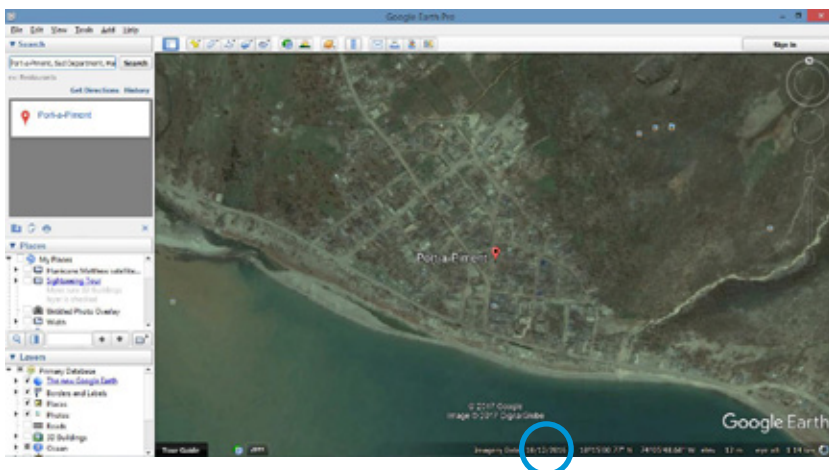
Hurricane Matthew caused widespread devastation to several countries with Haiti being one of the worst affected countries.

This activity will show you satellite images before and after Hurricane Matthew so that you can see some of the effects that this hurricane caused.

1. Open up Google Earth
2. In the Search box, type "Port-a-Piment" and press search



You can see that the image was taken on 12th October 2016 (i.e. immediately after Hurricane Matthew).

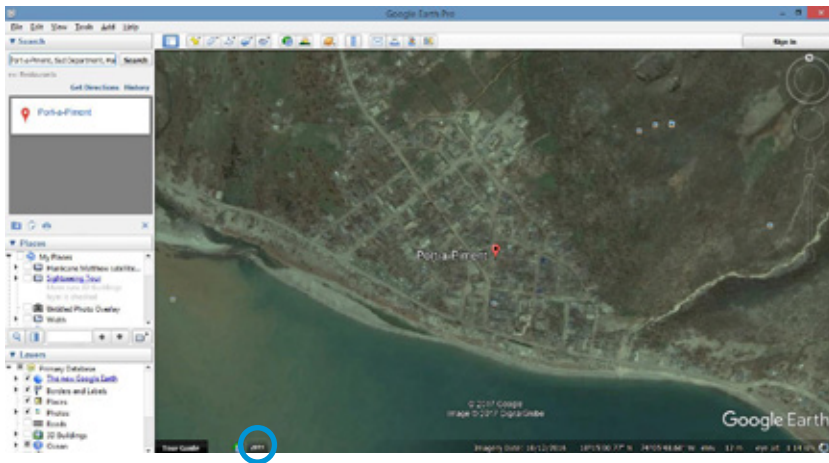


Activity 06

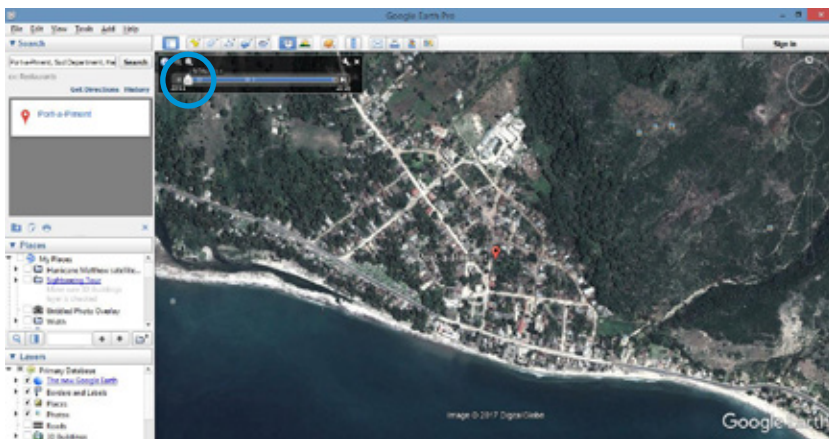
Using satellite images to view the impacts of Hurricane Matthew

3. Print screen the image and paste it in a PowerPoint document

4. At the bottom of the screen, you will see a clock icon with 2011 next to it. Click on the 2011 button which will allow you to see historical images.



5. Use the time slider to see historical images of this area.



6. Select an image before Hurricane Matthew that you think shows a clear contrast with the first image that you've already copied and pasted.

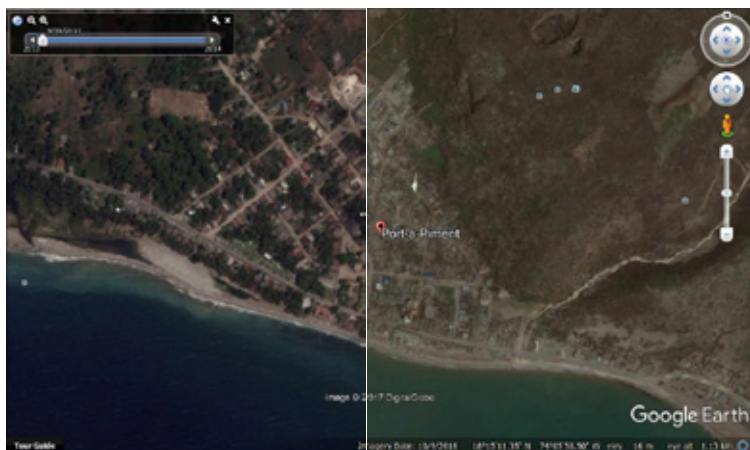
7. Now print screen this image and add it to your PowerPoint document.

8. Use the crop facility to show the satellite image alone but make sure that you keep both images the same size.

Activity 06

Using satellite images to view the impacts of Hurricane Matthew

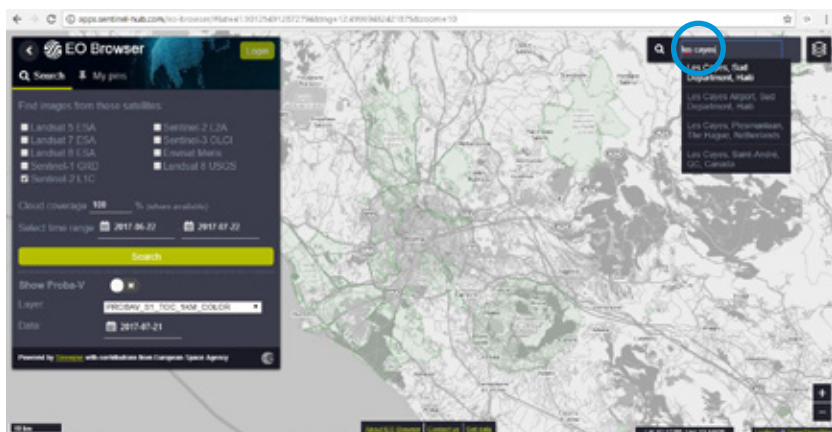
9. Now place the images one on top of the other. Use the crop button again to chop one of the images in half. This will show the contrasts clearly (e.g. as shown below).



10. Add textboxes and arrows to annotate the images. Remember, arrow heads should point into the image and make contact with the feature that you're describing.

11. You're now going to look at the effects of Hurricane Matthew using false colour satellite images that show the effects more clearly. To do this, visit <http://apps.sentinel-hub.com/eo-browser/>

12. In the search box, type in Les Cayes

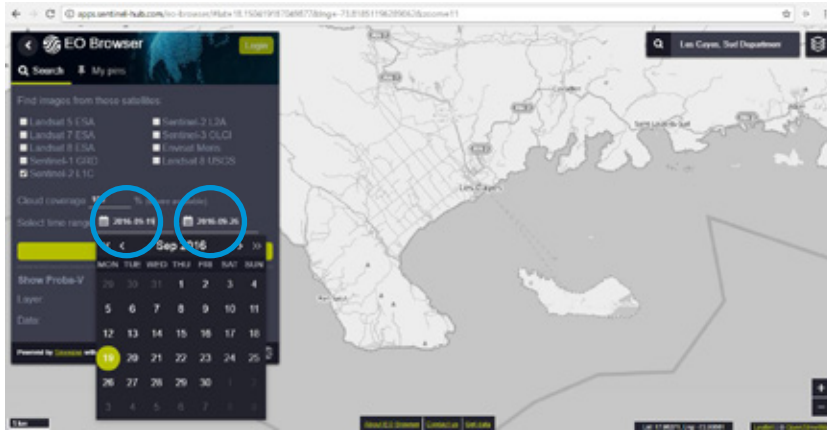


13. Zoom in on Les Cayes

Activity 06

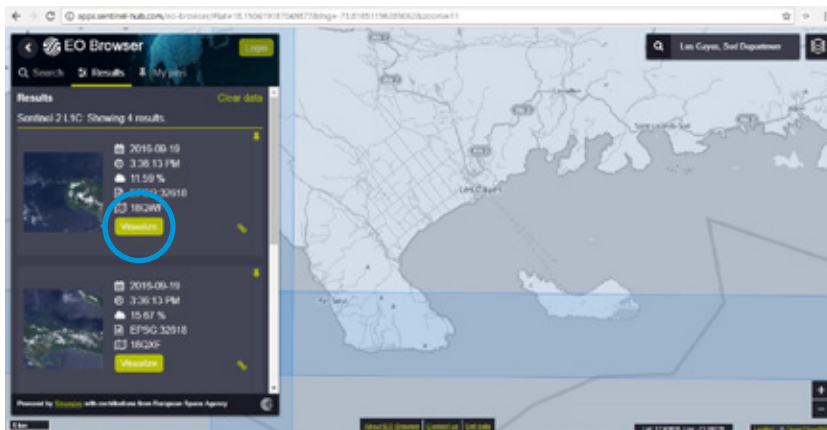
Using satellite images to view the impacts of Hurricane Matthew

14. Set the cloud coverage to 100% and change the time range from 19th Sep 2016-26th Sep 2016.



15. Hit Search

16. Choose an image to visualise from the options on the left of your screen.



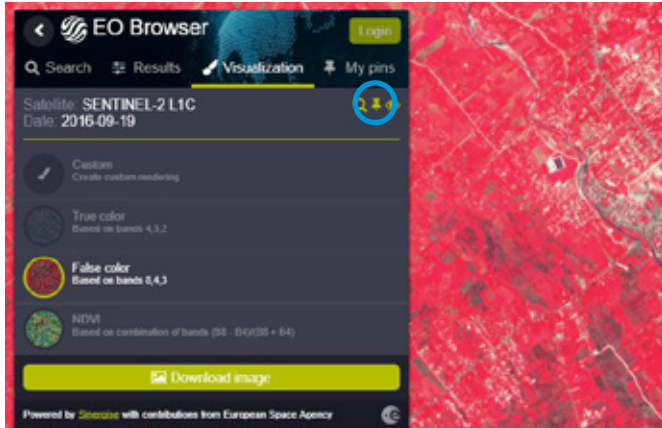
17. Now change to False Colour by clicking once on the circle as shown below:



Activity 06

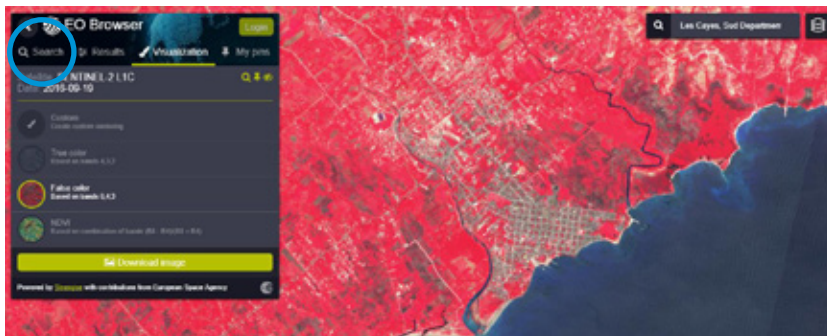
Using satellite images to view the impacts of Hurricane Matthew

18. Pin this image by clicking once on the pin icon.



19. Then download the image.

20. Click on the Search tab.



21. Now change the date to 9th October 2016-12th October 2016.

22. Repeat steps 16-20.

23. Copy and paste both images into a PowerPoint document so that the differences can be visualised.

24. Annotate the contrasts that you can see and try and explain reasons for the differences that you identify.

25. Complete independent research about the effects of Hurricane Matthew on Haiti. See if you can add additional facts and figures to your annotations.

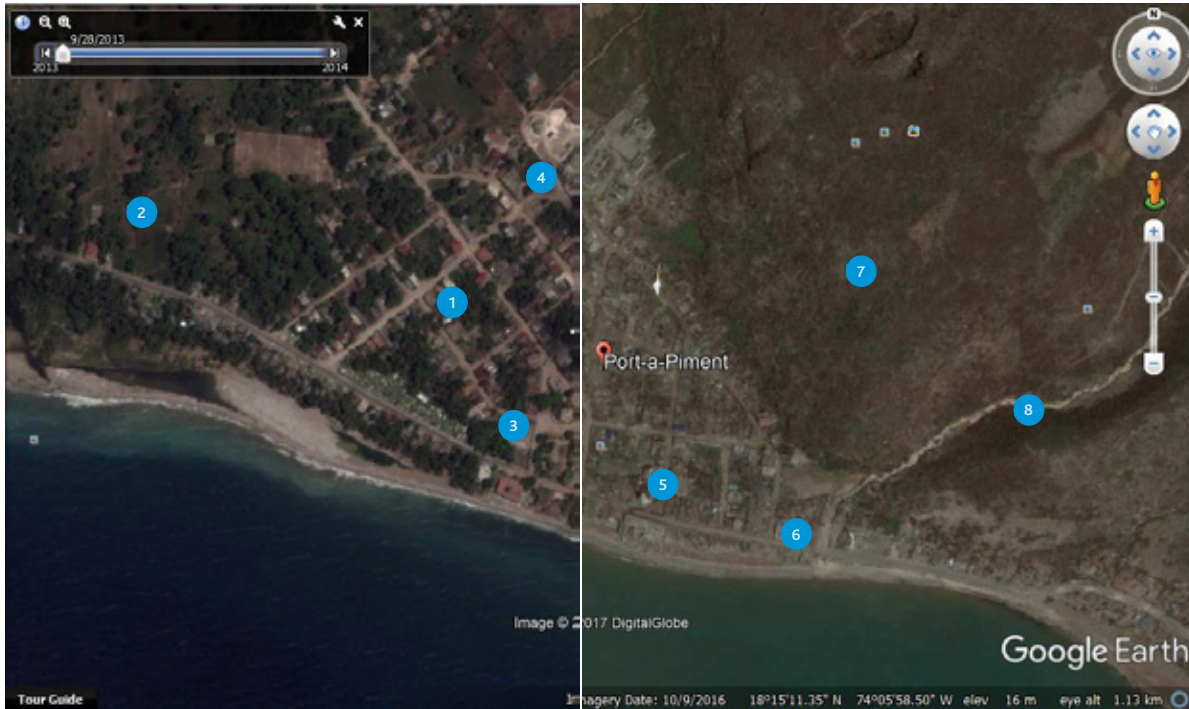
Extension: Evaluate the use of remotely sensed data in geography.

Activity 06

Using satellite images to view the impacts of Hurricane Matthew

Answers to Activity 06

A sample annotated image is below:



- 1 Economic damage resulted from destroyed settlements such as Port-a-Piment. Nationwide, this was estimated at US\$1.9billion.
- 2 Rainfall was an average of 38-64cm along the south coast of Haiti with isolated areas receiving up to 100cm. This led to 90% of coconut trees on the Tiburon Peninsula being knocked down as well as destroying entire coffee and cocoa plantations.
- 3 Nationwide, the hurricane caused complete or near complete destruction of approximately 200,000 homes.
- 4 Infrastructure damage to the Sud region prevents access to the capital of Port-au-Prince and hinders relief efforts.
- 5 Strong winds reaching 150mph from the category 4 hurricane caused damage to buildings (particularly roof damage), especially given that this was already an impoverished area.
- 6 Storm surges of 3m inundated land and destroyed settlements such as Port-a-Piment leading to widespread homelessness (1.4 million nationwide) and deaths. Mudslides were also evident within the region.
- 7 Crop damage from severe gusts, torrential rains and storm surges led to a lack of food, causing famine. Incomes of residents were also affected, many of whom relied on subsistence farming.
- 8 Soil erosion caused by heavy rainfall on exposed slopes leads to increased sedimentation of rivers. Water became contaminated and cholera outbreaks posed a secondary problem.

Activity 06

Using satellite images to view the impacts of Hurricane Matthew

The completed images should appear as below:

Before Hurricane Matthew



After Hurricane Matthew



Students should comment on the decrease in vegetation and note that the river has higher levels of sediment within it. This is the result of soil erosion on exposed slopes that has entered waterways.



www.stem.org.uk/esero