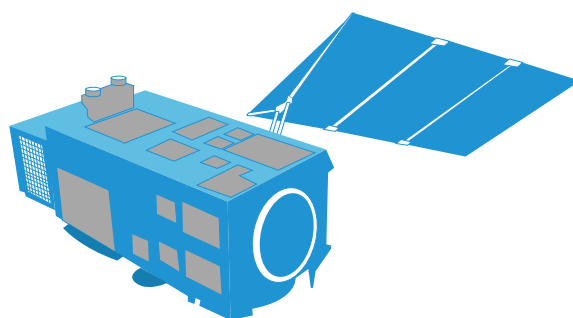
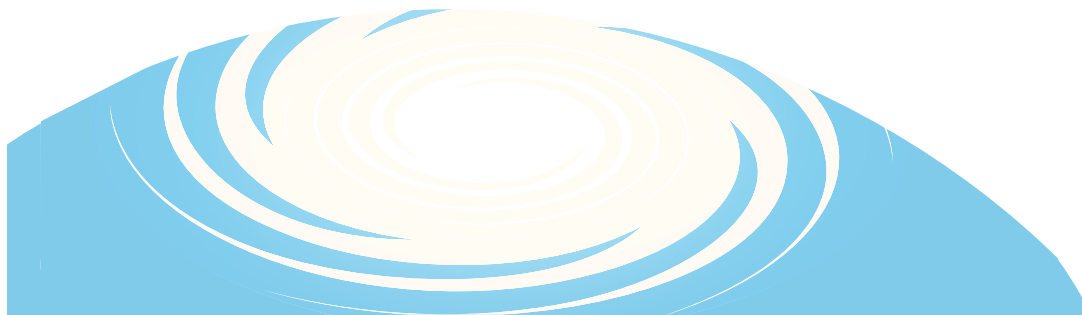
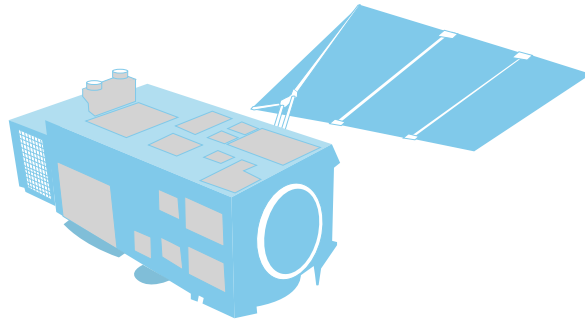


teach with space

→ AFTER THE STORM

Tracking Hurricane Matthew and analysing its impact





Teacher guide

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→ AFTER THE STORM

Tracking Hurricane Matthew and analysing its impact

Fast facts

Subject: Geography, Science

Age range: 12 – 15 years old

Type: student activity

Complexity: easy

Lesson time required: 1 hour

Cost: low (0-10 Euros)

Location: indoors

Includes the use of: computer and internet

Keywords: Earth observation, Climate, Extreme weather, Hurricane, Geography, Science

Brief description

These activities use the example of Hurricane Matthew to explore the applications of Earth observation data in tracking hurricanes and assessing their aftermath. Students will learn how a hurricane develops and the impact that extreme weather can have on the society. They will do this by comparing satellite images.

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.

Learning objectives

- Explain how hurricanes develop.
- Understand the impact that extreme weather can have on society.
- Understand how Earth observation can be used to track incoming weather and assess the damage caused by extreme weather.
- Understand how countries work together to supply aid and relief to affected areas.

→ Summary of activities

Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	Track the hurricane	This activity uses satellite images to develop students' Earth observation skills. The task is to investigate the development of Hurricane Matthew.	Students will learn: <ul style="list-style-type: none"> • How a hurricane develops • How Earth observation can enable weather tracking and predictions of its effects 	None	20 minutes
2	Impacts of Hurricane Matthew	This activity 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. By annotating images and identifying changes, students will develop their geographical skills of observation and analysis.	Students will learn: <ul style="list-style-type: none"> • The impact that an extreme weather event can have on society • The extent of the damage caused by extreme weather • The potential for Earth observation to be used to help recovery after an extreme weather event 	Completion of activity 1	40 minutes

→ 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 the Caribbean, 2017 became the ninth 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.

The ubiquitous satellite images of a tropical storm such as Noru, Irma or Matthew that become breaking news are not novel storm tracking tools. 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.

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, and use satellite imagery to assess which areas are most in need of humanitarian aid.

Hurricanes are one of the natural extreme weather events that can only be tracked by satellites. Satellites provide up-to-date imagery so that authorities know which precautionary measures to take and when to take them. Satellites deliver information on a storm's extent, wind speed and path, and on key features such as cloud thickness, temperature, and water and ice content.

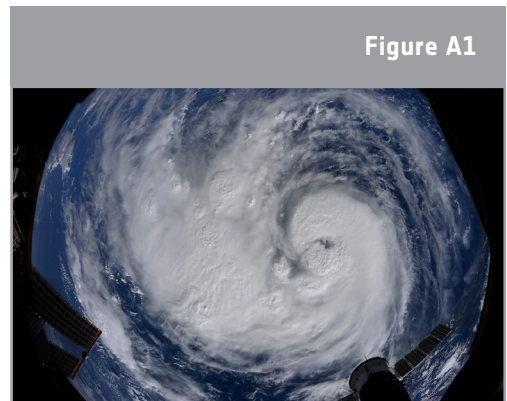


Figure A1

↑ Image of Hurricane Harvey taken by ESA astronaut Paolo Nespoli from the International Space Station orbiting Earth at 400 km altitude.

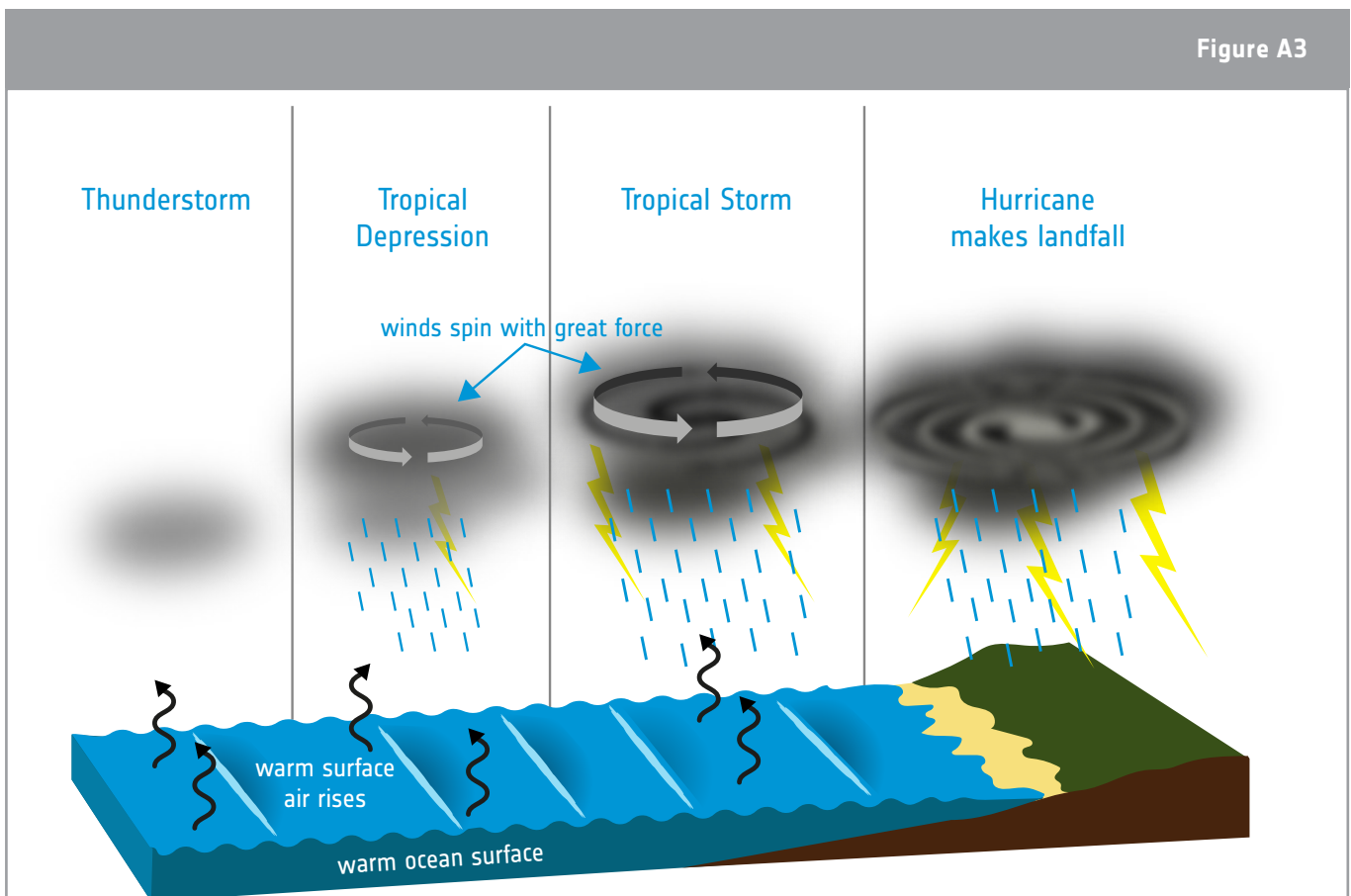


Figure A2

↑ The European Sentinel-3 satellite provides critical information for ocean and weather forecasting. More accurate forecasting helps protect people from the impacts of extreme weather events.

→ What is a hurricane?

Hurricanes are enormous tropical storms that form over tropical and subtropical water (see Figure A3). In order for tropical hurricanes to form, the sea surface temperature must be higher than 26.5 degrees Celsius. Water evaporates as a consequence of solar radiation, ascends as moist air, and forms clouds as the water vapour condenses. With wind speeds in excess of 119 km/h and a large span, they are capable of causing substantial damage to coastal areas.



↑ Formation of a hurricane.

Hurricane Matthew formed on September 28, 2016. Over the next two weeks Hurricane Matthew moved through Haiti, Cuba, the Bahamas, and the southeast coast of the United States before weakening on October 9, 2016. Hurricane Matthew caused catastrophic damage in its path. The worst affected country was Haiti with 1.4 million people in need of humanitarian aid and more than 500 fatalities. The impact of Hurricane Matthew is still felt in 2018.

→ Activity 1: Track the hurricane

In this activity, students will analyse some basic characteristics of a hurricane that can be identified in a satellite image. Then, students will investigate the development of Hurricane Matthew using printed satellite images. This activity can be adapted according to the students' prior level of knowledge.

Exercise

In exercise 1, students analyse one satellite image of Hurricane Matthew to understand how a hurricane can be recognised. This exercise is a preparatory for exercise 2.

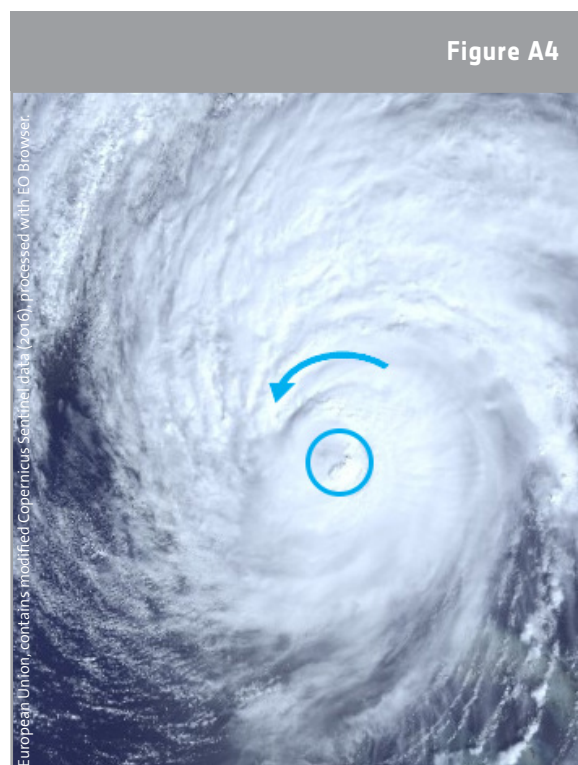
The students can either work in pairs or independently with the worksheets. For exercise 2, you can also print the images in Annex I. Depending on existing knowledge of hurricanes you can hand out the 'Activity 1 - Extension' in the annex II. It gives more information and asks the students to put them in the correct order with the images, providing a less complex version of the activity.

You can also try to find your own satellite images of a hurricane in the EO Browser. EO Browser is an online tool that provides easy and free access to satellite images from different Earth observation (EO) missions. The EO Browser: Quick Start Guide (see links section) provides an introduction to this tool. If looking for hurricanes, we recommend you choose the Sentinel-3 satellite.

Results


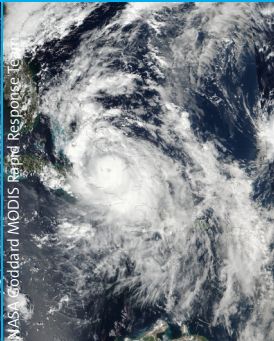
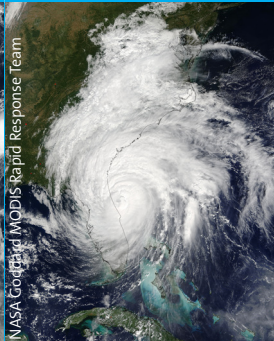
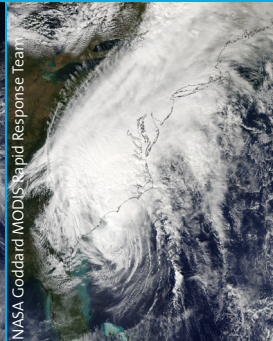
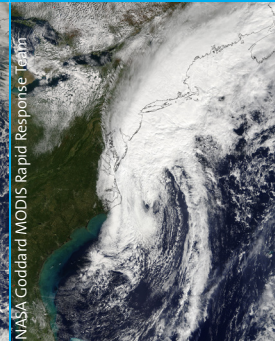
Exercise 1

Students mark the eye of the hurricane in the centre of the image and should conclude that they identified it from the pattern of the clouds. The direction of rotation of the hurricane is anti-clockwise due to the Coriolis force that deflects winds. You can also discuss how tropical storms spin in the opposite direction (clockwise) on the Southern Hemisphere.



↑ Image of Hurricane Matthew including results for Exercise 1.

Exercise 2

28 th September 2016 14:30	5 th October 2016 18:30	7 th October 2016 16:00	8 th October 2016 18:20	9 th October 2016 15:45
				
D	A	B	E	C
<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 centre with heavy clouds in the Caribbean Sea.</p> <p>Wind speeds are around 80km/h.</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 toward 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>Category 3 hurricane.</p> <p>Movement = north-west direction heading toward 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 180km/h affecting Florida and Georgia.</p>	<p>Hurricane Matthew becomes 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 130km/h with some stronger gusts and heavy rainfall. Conditions will only begin to improve over the next 48 hours.</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 320km east of North Carolina.</p> <p>Weather conditions = winds beginning to weaken.</p>

→ Activity 2: Impact of Hurricane Matthew

In this activity, students will analyse satellite images taken before and after the hurricane made landfall to see what impact it had on the landscape and the people living there.

Equipment

- Devices with internet access (laptops/tablets)

Exercise

This task is for students to work independently with satellite images but in case there is no access to tablets or computers, you can use the images from Annex III. These can also be used when discussing the results. Hand out the guide for the EO Browser (see links section) to the students if they are not familiar with the online tool.

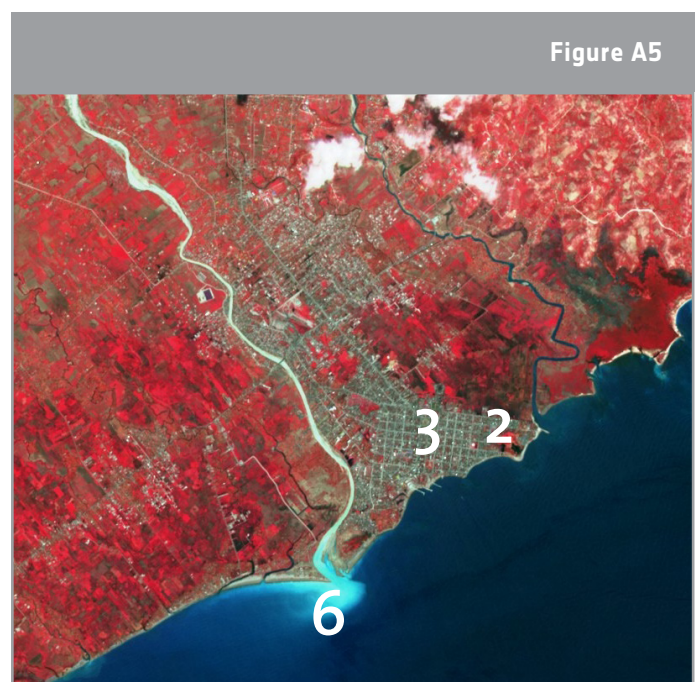
Question 1: False colour images make use of the fact that cameras carried by satellites can ‘see’ more than just the visible part of light. A false colour image uses at least one wavelength outside the visible range. Here, the false colour image shows reflected near-infrared light as red, red light as green, and green light as blue. Since plants reflect more near-infrared than green, vegetation areas will appear red. The brighter and richer red indicates a higher reflectance in the near-infrared, therefore indicating more and healthier vegetation. Overall, the reflectance in the visible light is much lower than the one in the near-infrared, and the true colour image would be darker. We suggest the use of false colour images as more details can be identified.

Question 2: Students should comment on the decrease in vegetation areas and agricultural land. They should also note that the river has higher levels of sediment within it, indicated by the brown colour of the water. This is the result of soil erosion on exposed slopes that has entered waterways. Also, the houses in the city Les Cayes are destroyed.

Question 3: See figure A5.

Question 4: Students should understand that technologies such as Earth observation satellites do not reduce damage or losses, but their use facilitates efficient decision making which can make a difference in emergency situations. For example, images acquired before and after a flood offer immediate information on the extent of inundation and support assessments of property and environmental damage. Some satellites that use radar, like Sentinel-1, even have the ability to ‘see’ through clouds, rain and in darkness making them very useful for rapid mapping and assessment of disaster impact.

Teachers can show the ESA video “Saving lives when disasters strike” (see Links section) to summarise the discussion about how satellite images can support emergency staff after disasters.



↑ Les Cayes, Haiti after the hurricane.

→ AFTER THE STORM

Tracking Hurricane Matthew and analysing its impact

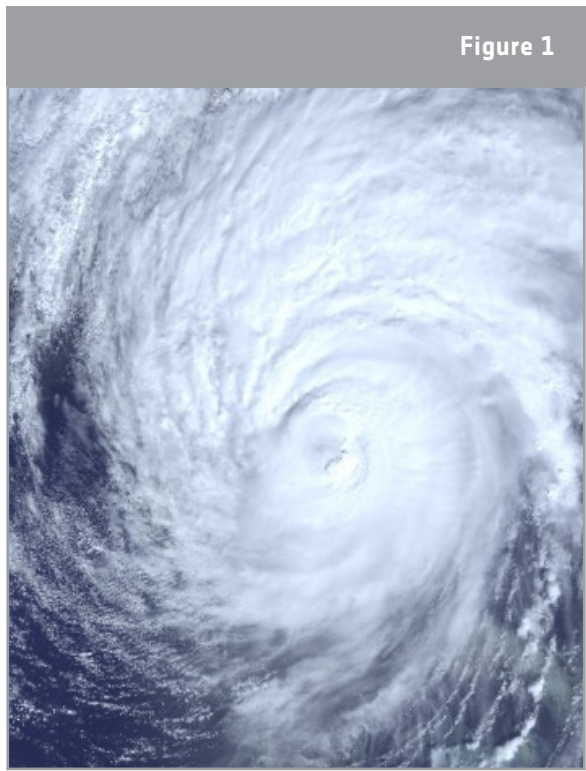
→ Activity 1: Track the hurricane

In this activity, you will understand elements and characteristics of Hurricane Matthew in a satellite image and then investigate its development.

Exercise 1

1. The satellite image in Figure 1 shows Hurricane Matthew on 7th October 2016.
 - a. Mark the eye of the hurricane in the image with a circle and describe how you identified it.

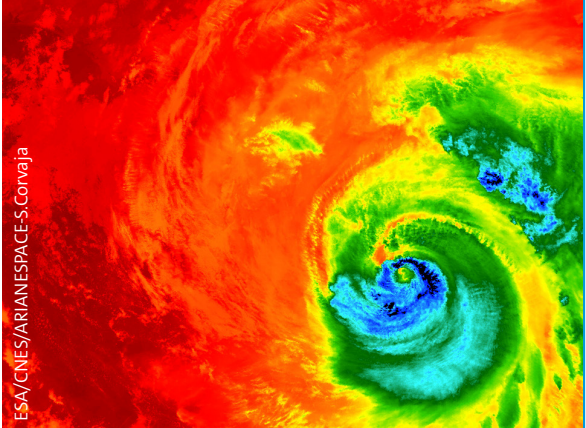
 - b. With an arrow, indicate the direction of rotation of the hurricane. Is it clockwise or anti-clockwise? Can you explain why?



↑ Image of Hurricane Matthew. Credit: European Union, contains modified Copernicus Sentinel data (2016), processed with EO Browser.

Did you know?

The image shows the temperature of the clouds at the top of Hurricane Matthew. In the centre of the storm, the temperature is -80°C (blue colour). The orange/red colour indicates areas without clouds, with a surface temperature of about 25°C . The temperature data is delivered by Sentinel-3 satellite instruments. Carrying a suite of cutting-edge instruments, Sentinel-3 measures systematically Earth's oceans, land, ice and atmosphere to monitor and understand large-scale global dynamics.



Exercise 2

The following satellite images show Hurricane Matthew moving north towards the west coast of Haiti. The order is random.

- Assign the images A-E to the dates in table 1.
- Write a description of what each image shows. This should include cloud movements, cloud density, weather conditions and countries affected.

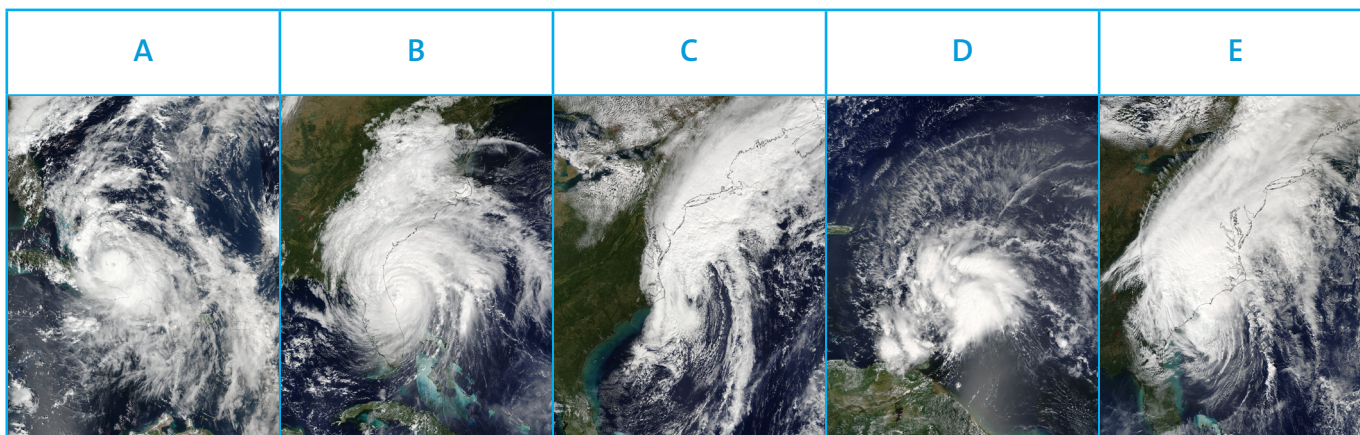


Table 1: Track the hurricane

28 th September 2016 14:30	5 th October 2016 18:30	7 th October 2016 16:00	8 th October 2016 18:20	9 th October 2016 15:45
Description	Description	Description	Description	Description

→ Activity 2: Impact of Hurricane Matthew

Hurricane Matthew caused widespread devastation to several countries, with Haiti being one of the worst affected countries. In this activity, you will analyse satellite images before and after Hurricane Matthew so that you can investigate the effects of this hurricane.

Did you know?

When disaster strikes, a group of international space agencies pools its resources and expertise to support relief efforts on the ground. The International Charter Space and Major Disasters is an international collaboration between 16 owners or operators of Earth observation missions. It provides rapid access to satellite data to help disaster management authorities in the event of a natural or man-made disaster. Since its first request for support in 2000, until May 2018, the Charter has called on space assets on many occasions, helping to respond to more than 580 disasters in more than 120 countries. On average, the Charter is activated about 40 times a year.



Exercise

- Use the online tool EO Browser to find before and after images of the hurricane reaching Les Cayes in Haiti (apps.sentinel-hub.com/eo-browser). You can use the following search settings or find your own images!
 - Area: Les Cayes, Haiti
 - Satellite: Sentinel 2 (L1C)
 - Dates: before 19 September 2016, after 9 October 2016
 - Choose the option 'false colour'.
- Compare the satellite images before and after Hurricane Matthew made landfall. Describe the differences in land, rivers and settlement areas.

3. Below you will find information about the impact of Hurricane Matthew. Assign at least three of the numbers to areas on the images after Hurricane Matthew made landfall that you can relate to and explain your decision.

1. Rainfall was an average of 38-64cm along the south coast of Haiti with isolated areas receiving up to 100cm.
2. This led to 90% of coconut trees on the Tiburon Peninsula being knocked down as well as destroying entire coffee and cocoa plantations. 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.
3. Storm surges of 3m inundated land and destroyed settlements leading to widespread homelessness (1.4 million nationwide) and deaths. Mudslides were also evident within the region.
4. Damage caused by the hurricane was estimated at US \$ 1.9 billion.
5. Infrastructure damage to the Sud region prevents access to the capital of Port-au-Prince and hinders relief efforts.
6. 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.
7. 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. Nationwide, the hurricane caused complete or near complete destruction of approximately 200,000 homes.

4. Discuss how satellite images can support emergency staff after disasters.

→ Links

ESA resources

ESA classroom resources:

www.esa.int/education/Classroom_resources

ESA space projects

Sentinel-2

esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

Sentinel-3

esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3

Extra information

EO Browser: Quick Start Guide

http://esamultimedia.esa.int/docs/edu/EO_Browser_guide.pdf

Saving lives when disasters strike - ESA video

esa.int/spaceinvideos/Videos/2015/10/Saving_lives_when_disasters_strike

Copernicus Emergency Management System – List of Activations

emergency.copernicus.eu/mapping/list-of-activations-rapid

International Charter on Space and Major disasters

disasterscharter.org

NASA Animation with satellite images about the landfall of Hurricane Matthew (October 3-5 2016)

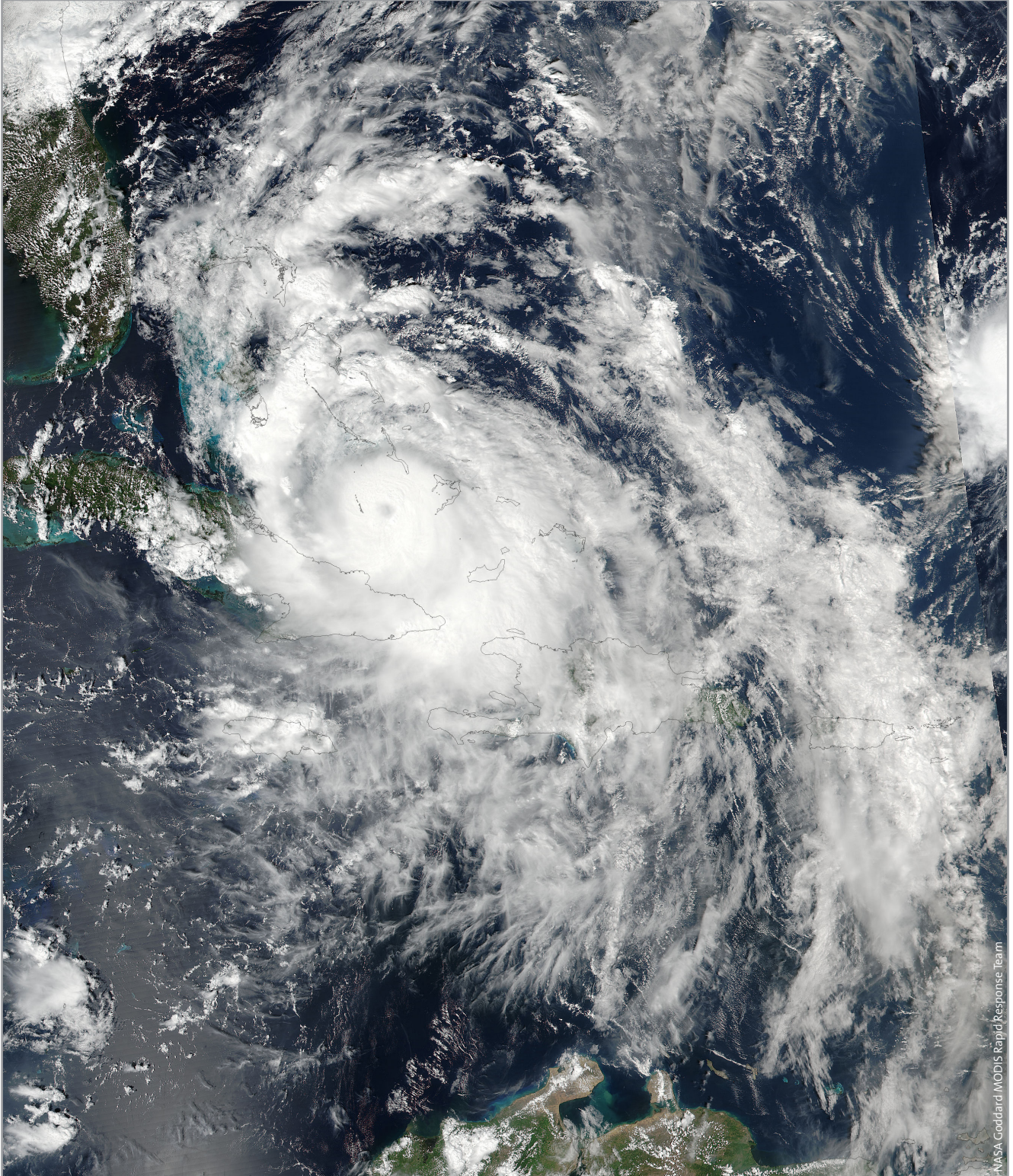
youtube.com/watch?v=o6Rrv3MNpNQ

Hurricane Matthew in Haiti, charter activation

disasterscharter.org/web/guest/activations/-/article/cyclone-in-haiti

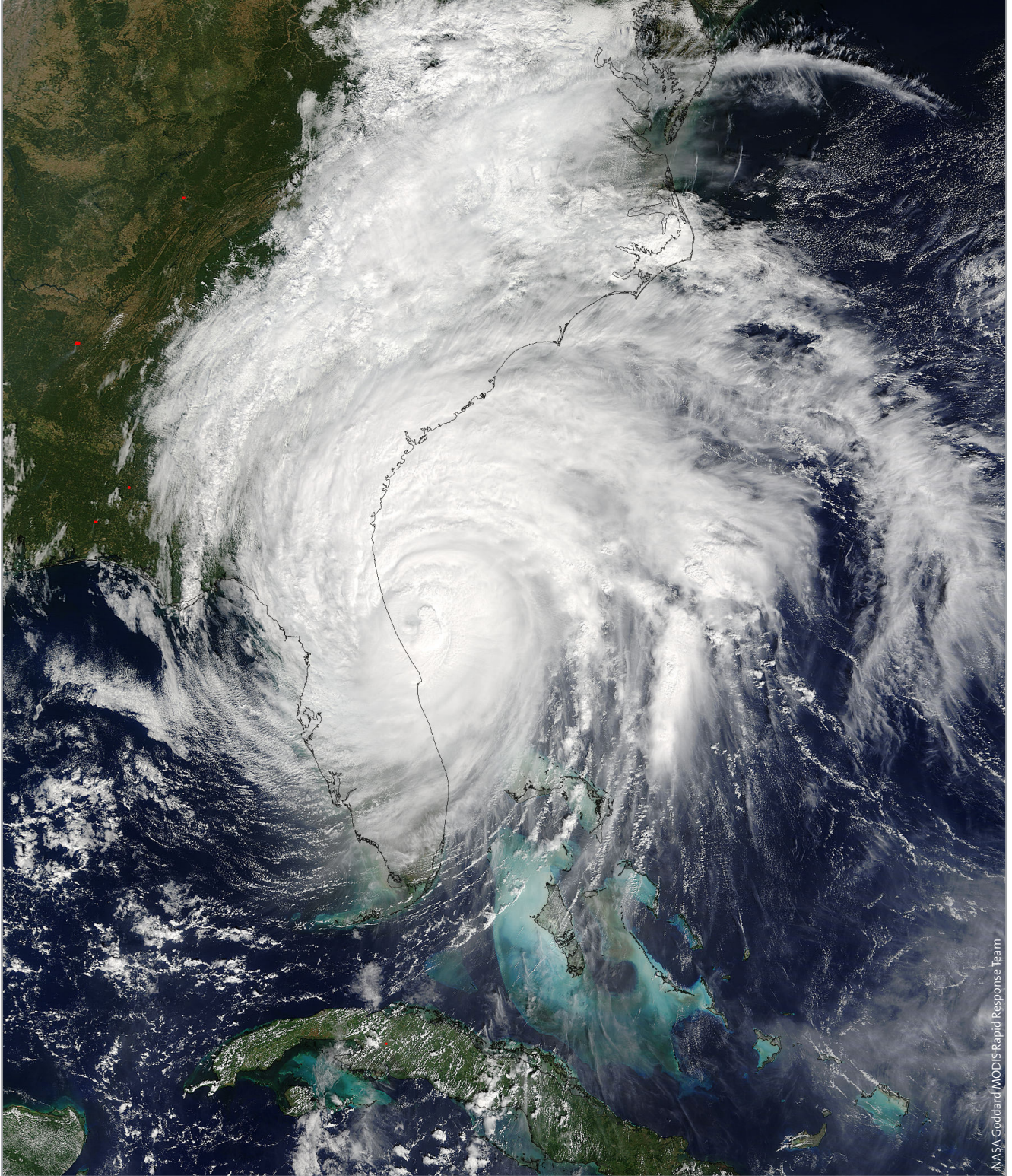
→ Annex I
Activity 1

A



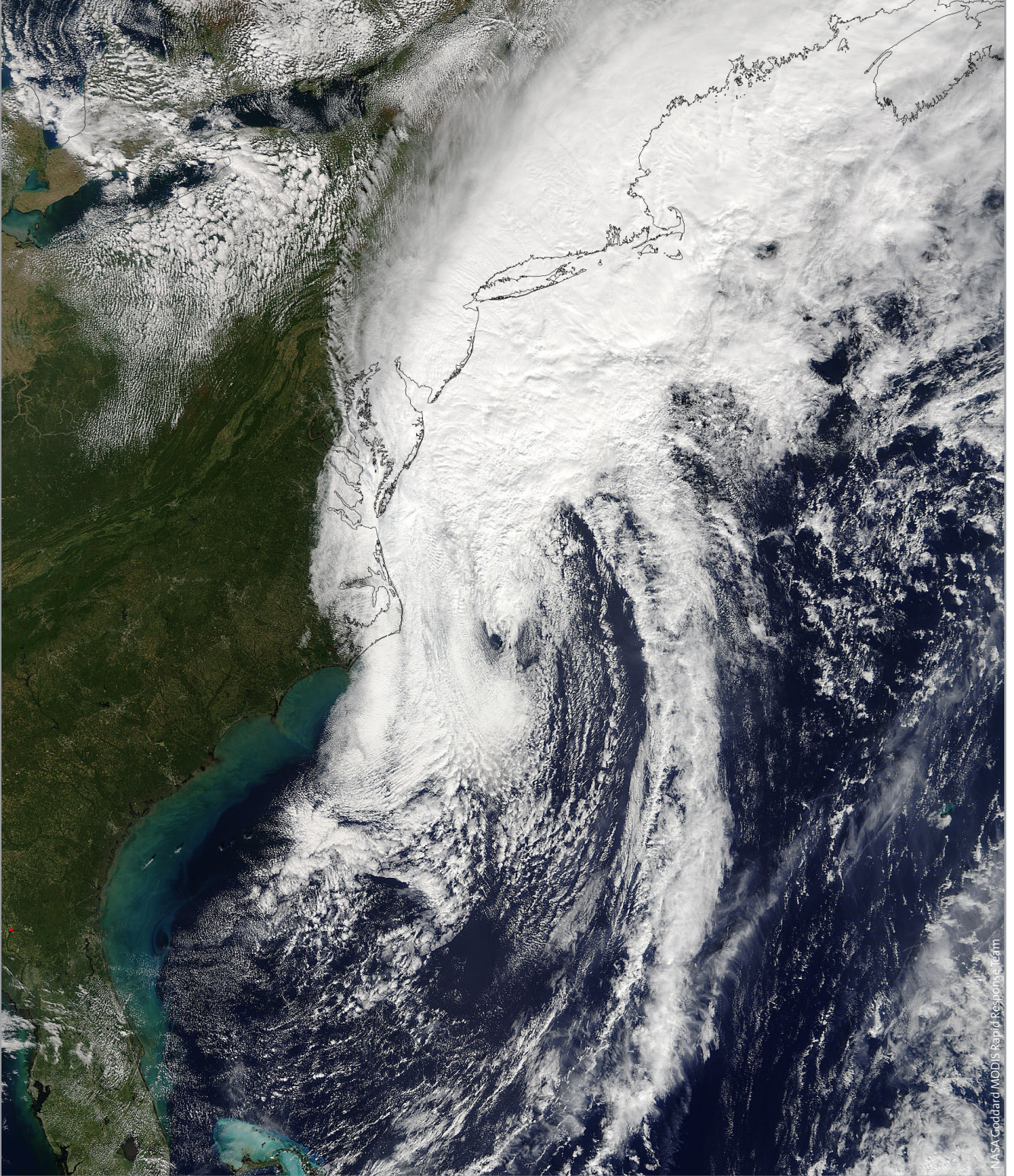
NASA Goddard MODIS Rapid Response Team

B

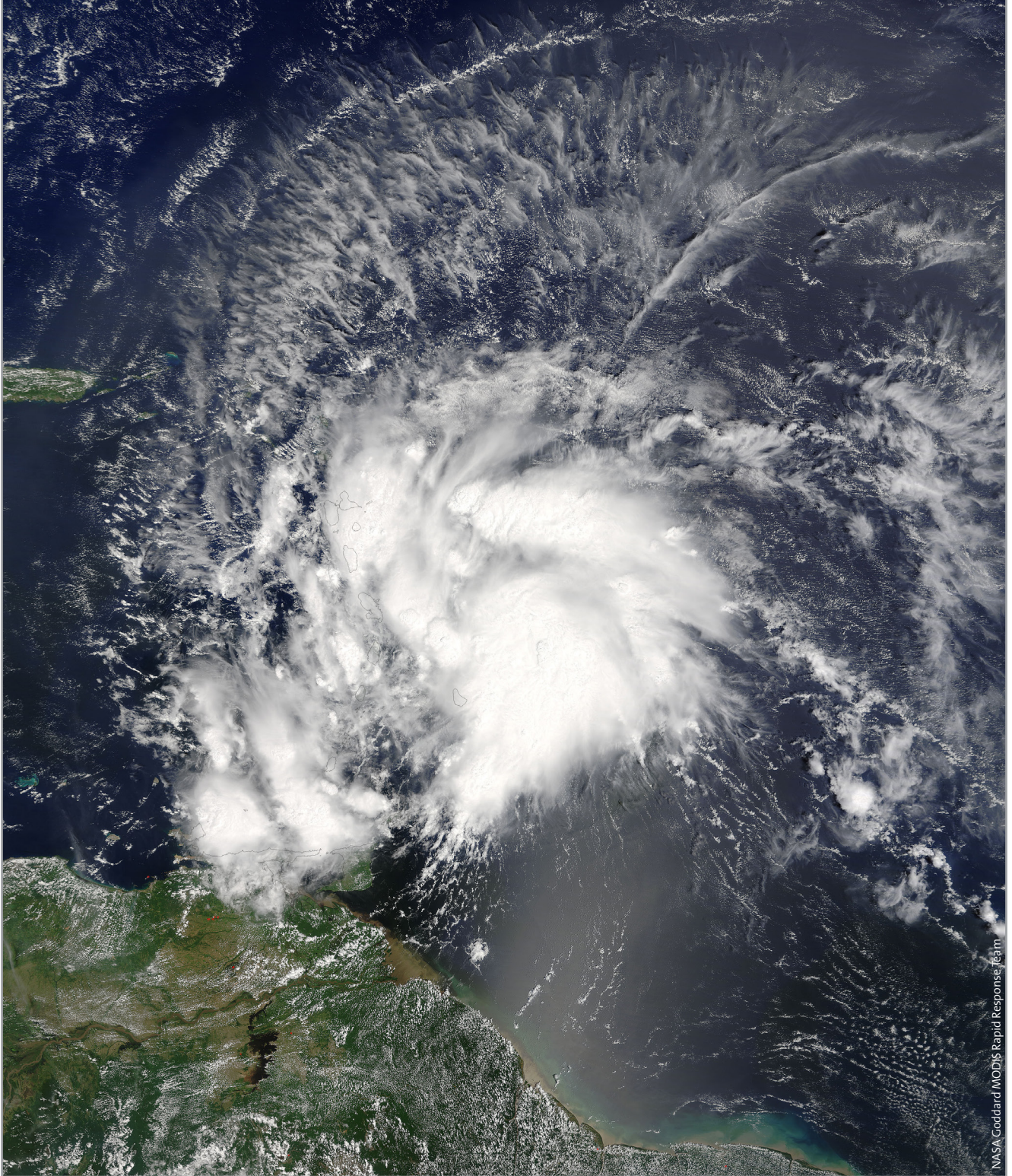


NASA Goddard MODIS Rapid Response Team

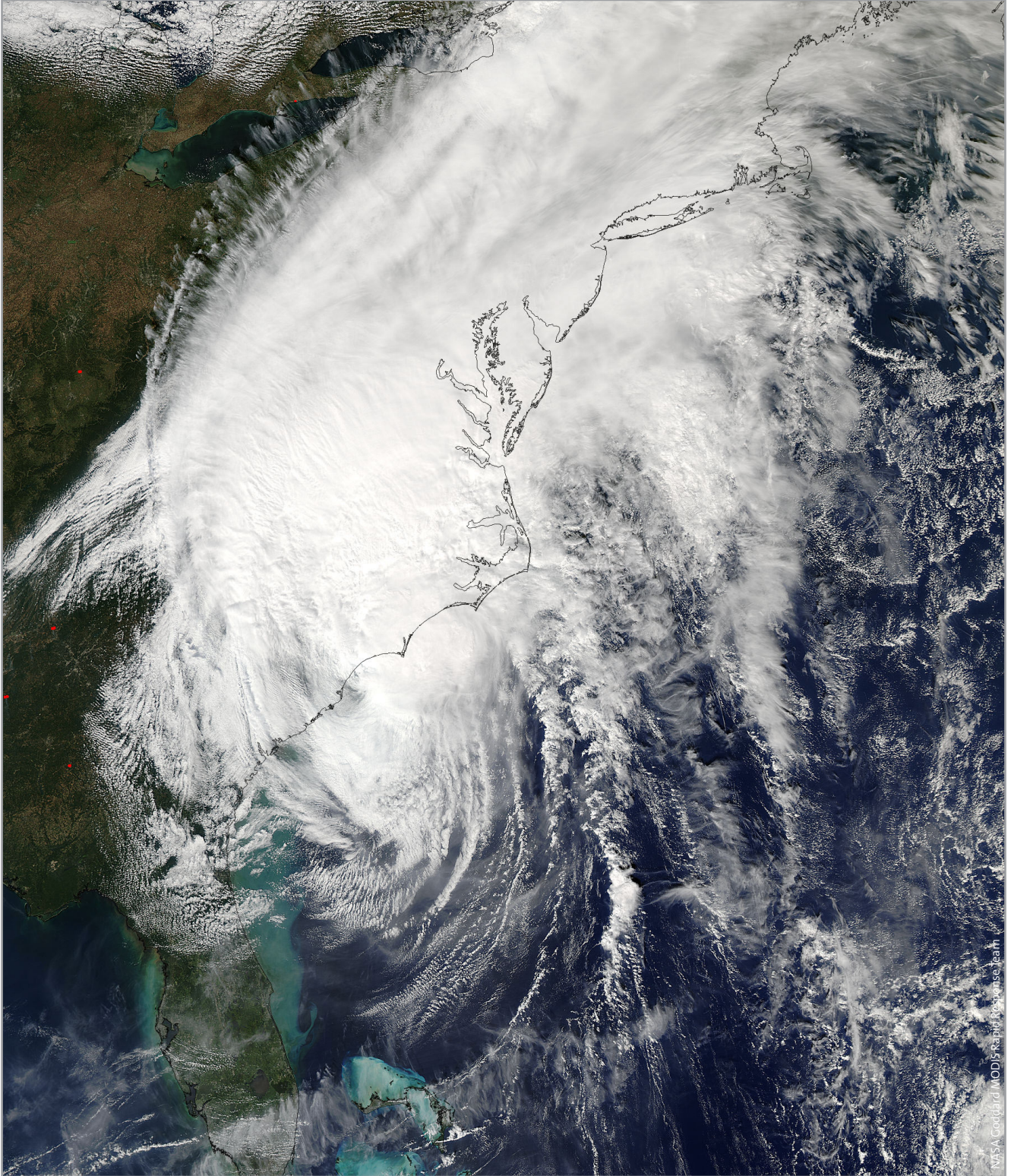
C



NASA/Goddard MODIS Rapid Response Team



NASA/Goddard MODIS Rapid Response Team



ESA/Copernicus/MSA/Catbird/NOAA/SeaWiFS/SeaView/SeaWIFS

→ Annex II

Activity 1 – extension

Hurricane Matthew becomes 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 130km/h with some stronger gusts and heavy rainfall. Conditions will only begin to improve over the next 48 hours.

Hurricane now visible

Movement = north-west direction towards the Bahamas.

Location = eye is visible north of Cuba and heading toward 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 320km east of North Carolina.

Weather = winds beginning to weaken.

Category 3 hurricane

Movement = north-west direction heading toward 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 180km/h affecting Florida and Georgia.

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 centre with heavy clouds in the Caribbean Sea. Wind speeds are around 80km/h.

→ Annex III

Activity 2 – extension



European Union, contains modified Copernicus Sentinel data (2016), processed with EO Browser.

↑ Les Cayes, Haiti before the hurricane.



European Union, contains modified Copernicus Sentinel data (2016), processed with EO Browser.

↑ Les Cayes, Haiti after the hurricane.