SCIENTIX LESSON PLAN

Title: Hurricanes as Heat Engines

Author(s) Nedeljko Mandić

Abstract

Tropical cyclones are the strongest storms on Earth. Students study the origin, characteristics, and consequences of tropical cyclones using real data collected from relevant websites.

Keywords

Tropical cyclone, hurricane, heat engine, eye of the storm, latent heat of condensation

Summary table

Subject	Physics, Geography, ICT
Topic(s) within the subject	Thermodynamics (Heat Engines)
Key real-life topic	Tropical cyclones and their impact on the environment and people
Age of students	14-18 years old
Preparation time	20 min (Orientation)
Teaching time	225 min (90 min + 45 min + 45 min + 45 min)
Online teaching material	Link 1 Hurricane Katrina Day by Day/national Geographic https://www.youtube.com/watch?v=HbJaMWw4-2Q&list=PLlR4hKiiQMdSTX0z4EMkzSRaT5Ns6rzzE Link 2 What have been the costliest tropical cyclone in the United States? https://www.aoml.noaa.gov/hrd-faq/#costliest-tcs

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	Link 3 Hurricane Katrina: Facts, Damage & Aftermath https://www.livescience.com/22522-hurricane-katrina-facts.html Link 4 World highest mortality due to a tropical cyclone https://wmo.asu.edu/content/world-highest-mortality-tropical-cyclone Link 5 : Hurricanes as Heat Engines Story Map https://nasa.maps.arcgis.com/apps/MapSeries/index.html?appid=abc5591aaa944c9ebc7b5ea6102c73c2 Link 6: Students Sheet https://mynasadata.larc.nasa.gov/sites/default/files/2020-07/Hurricanes%20as%20Heat%20Engines%20Student%20Sheet.pdf Link 7: Frequently asked questions about hurricanes https://www.aoml.noaa.gov/hrd-faq/#tc-formation Link 8: Flaying through eyewall od the hurricane Katrina https://www.youtube.com/watch?v=eT5K6FR_eVs Link 9 Real Time TC Activity http://tropical.atmos.colostate.edu/Realtime/ Link 10 Accumulated Cyclone Energy https://en.wikipedia.org/wiki/Accumulated_cyclone_energy Link 11 Hurricane Laura (2020.) https://rammb-data.cira.colostate.edu/tc_realtime/storm.asp?storm_identifier=al132020 Link 12 Subtropical storm Alpha 82020) https://rammb-data.cira.colostate.edu/tc_realtime/storm.asp?storm_identifier=al242020 Link 13 Medicanes https://en.wikipedia.org/wiki/Mediterranean_tropical-like_cyclone Link14 Medicane Ianos https://en.wikipedia.org/wiki/Cyclone_Ianos Padlet, Excel
Offline teaching material	Paper (students sheet),

Integration into the curriculum

Thermodynamics is part of the national physics curriculum in my country (Croatia). One of the topics is a Heat engines. This lesson plan expands the knowledge in this area

Aim of the lesson

At the end of the lesson, students will learn more about:

- Tropical cyclones (as a Heat engine)
- the impact of tropical cyclones on the community
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Outcome of the lesson

Using materials with real data (NASA - Hurricanes as Heat Engine Story Map), students explore the conditions of formation and properties of tropical cyclones. They search for relevant websites to expand their knowledge of tropical cyclones / hurricanes.

Trends

Project based learning, STEM learning, Collaborative learning

21st century skills

Collaboration, Communications, Creativity, Critical Thinking

Activities

Name of activity	Procedure	Time
Orientation	Introducing the topic of Hurricanes as heat engines through a discussion. In conversation with the teacher, students answer the following questions: What is heat engine? What is the purpose of a heat engine? Which heat engines do we use in everyday life? How heat engines convert energy from one form to another? Is there a heat engine created by nature? What is a storm? Why can storm be dangerous? How do we behave when a strong storm comes and we are outside? Can a storm be treated like a heat engine? What are the strongest storms on Earth? Where do they originate?	20 min

	Give them a link 1 (see the on line teaching materials section above) After watching the video about Hurricane Katrina, students answer the questions (useful links are Link 2, Link 3 and Link 4) Why can a hurricane be so devastating? What types of energies do we recognize in a hurricane? What is the costliest tropical cyclone(s) in the United States? What are the consequences of Hurricane Katrina (death tool, damage, aftermath)? Encourage students to search for information from the Internet.	
Exploring	Divide the class into work/research group (3 to 4 members). Give students the Link 5 Students open the link to the **Hurricanes as Heat Engines Story Map Lesson** Distribute Student Sheet to each group (Link 6). Each group navigate on their own through the Engage, Explore, Explain, Elaborate, and Evaluate tabs of the story map to answer the questions and complete the activities on their student sheet. *Note: This activity can be given to students individually to work at home* *Students complete the student sheet and then continue with other activities at the school*	90 minutes
Analysis and discussion of results (story map)	Students (or group representatives) analyze and compare the answers to the questions asked in the student sheet. After discussion and analysis, students answer the following questions: 1. What is tropical cyclone and the difference between Tropical Disturbance, Tropical Depression, Tropical Strom, Hurricane and Typhoon.	45 min

	2. How do Tropical Cyclones form (which atmospheric and marine conditions must be met – Temperature, humidity, wind shear) ? 3. Explain what is eye of the hurricane, what is eyewall (Give students a link 8) 3. What is Saffir-Simpson Scale? What damage can a particular category of hurricanes do? 4. Where do hurricanes form on Earth? 5. When is hurricane season? 6. How do tropical cyclones/hurricanes get their names? Very useful information about tropical cyclones are provided in Link 7	
Calculate how much energy does a hurricane produce?	Give a following task to each group: Calculate the total amount of energy released through cloud/rain formation **(**by the condensation of water droplets (latent heat) Make the calculation with the following assumptions: An average hurricane produces 1.5 cm/day of rain inside a circle of radius 665 km (More rain falls in the inner portion of hurricane around the eyewall, less in the outer rainbands.) a) calculate volume of rain (m^3/day) b) calculate mass of water (kg) c) using the latent heat of condensation calculate the energy released (Jolues/day) and power (Joules/sec or Wats) The specific latent heat of condensation of water in the temperature range from −25 °C to 40 °C is approximated by the following empirical cubic function: Li = (2500.8 – 2.36 T + 0.0016T2 – 0.00006T3) J/g In this task use the approximated value of 2500 J/g d) Compare the total amount of energy released by the condensation of water droplets (latent heat) with the world-wide electrical generating capacity of $3*10^{12}$ Watts per day	20 min

	e) Calculate how much rain would fall (in mm) if all the mass of calculated rain fell on the whole surface of the country where you live? At the end of this activity, students (group representatives) compare and discuss the results	
Exploring: ACE index for a single hurricane/ tropical storm, and for entire season	Give a following task to each group: Explore what is ACE index (Accumulated cyclone energy) for a single tropical storm/hurricane. Find out how the ACE index is calculated for each storm and how for the entire hurricane season Give a student Link 9 (Real time TC Activity) Students will find a link for a North Atlantic hurricane season (Link 10), and a link to a particular tropical storm or hurricane Calculate ACE index for: a) Hurricane Laura (Link 11) makes landfall in USA-Louisiana 27.8.2020) b) Subtropical storm Alpha (Link 12) makes landfall in Portugal 18.9.2020) Additionally, students can be given the task of writing a computer program that will calculate the ACE index based on the input data for a given tropical cyclone (on wind speed). At the end of this activity, students (group representatives) compare and discuss the results	25 min
Exploring **Do hurricanes form in the Mediterranean?**	Students are given the task to investigate whether tropical systems are forming in the Mediterranean. Students will find out that such storms are relatively rare and are called “medicane” Give them a task to find data about the medicane that hit Greece in September 2020. Describe its origin, trajectory, consequences ... Useful link are Link 13 and 14	30 min

	At the end of this activity, students (group representatives) present their results through short presentation.	
Assessment And Students feedback	Described in section below	15 min

Assessment

Students take a quiz to test their basic knowledge of tropical cyclones

1. Maximum sustained surface wind speed in a tropical depression to become a tropical storm and get its name must exceed:

a) 35 km/h
b) 63 km/h
c) 119 km/h
d) 153 km/h

2. In how many categories are hurricanes classified?

a) 3
b) 4
c) 5
d) 6

3. By which element are hurricanes classified into categories?

a) Temperature in the center of the eye
b) Pressure in the center
c) Maximum sustained surface wind speed
d) All three listed elements

4. In order for a tropical cyclone to form ocean waters should be at the surface at least

a) 17°C
b) 20°C
c) 27°C
d) 30°C

5. A typhoon is the name for a hurricane that has formed in:

a) Eastern Pacific Ocean
b) Western Pacific Ocean

c) Indian Ocean
d) Mediteraneean Sea

6. Storms with tropical cyclone-like features that form in the Mediterranean Sea are called **Medicanes** ?

7. A region of mostly calm weather at the center of strong tropical cyclones (hurricanes) are called:

a) Ring
b) Circle
c) Eye
d) Eyewall

8. The ACE index as a measure of the energy of a tropical storm/hurricane is calculated using

a) minimum pressure in the center of the cyclone calculated every 12 hour
b) maximum sustained wind speed calculated every 6 hour
c) maximum sustained wind speed calculated every 12 hour
d) the amount of rain produced by storm/hurricane

Student feedback

Reflection activities will help students to think critically about their own learning process

Students will discuss the lesson with each other and with the teacher about the lesson and their work:

- Was it boring/interesting/easy/difficult…?
- Was there enough time for each activity?
- Was it interesting to work with real data using NASA story map
- What could we have done differently?
- Which part was the hardest
- Do you think you have learned enough and how could you improve that? How can you make the lesson more interesting and fun?

The students colud write their opinions about the lessons in a Padlet.

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