TROPICAL STORMS

What is a tropical storm?

Tropical storms are low-pressure weather systems characterized by a rotation of winds around a central axis. They typically develop over warm ocean waters, where the heat from the water causes hot air to rise, creating areas of low pressure. As this warm air ascends, cooler air moves in to replace it, generating strong winds that swirl around the center of the storm. These storms are marked by heavy rainfall and powerful winds, with their intensity largely influenced by the temperature of the water and the humidity in the surrounding environment.

Tropical storms are classified based on their intensity into three categories: tropical depressions (low intensity), tropical storms (medium intensity), and hurricanes or typhoons (high intensity). The most intense storms can reach impressive sizes, often visible from space, where they appear as massive swirling systems of clouds. Understanding tropical storms is crucial as they can have significant impacts on coastal communities, including heavy rainfall, strong winds, and the potential for flooding and storm surges.

Source;

https://ciencia.nasa.gov/ciencias-terrestres/la-nasa-y-los-huracanes-cinco-datos/

Show image of: tropical_storm_from_space.png; which is an image of a tropical storm shown from space

Classification of tropical storms

Tropical storms can be classified according to their strength:

1. **Tropical depressions:** the weakest, with winds of less than 38 miles per hour (61 km/h).

   Tropical depressions are low-pressure systems with sustained winds between 23 and 38 mph (37 to 61 km/h). They form over warm ocean waters, where heat and moisture cause air to rise and create clouds. While less intense than tropical storms and hurricanes, they can still produce heavy rainfall, leading to flooding and landslides.

   If a tropical depression strengthens, it can become a tropical storm with winds over 39 mph (63 km/h) and, eventually, a hurricane if winds exceed 74 mph (119 km/h). Meteorologists closely monitor these systems using satellites and aircraft to predict their development and potential impacts. Understanding tropical depressions is crucial for disaster preparedness in vulnerable areas.

Tropical depression image; https://zoom.earth/storms/11e-2024/

Show image of: Tropical _depression.png which is an image from space of a tropical depression storm (lower atmosphere)

2. **Tropical storms:** slightly stronger, with winds ranging from 39 to 73 miles per hour (63 to 118 km/h).

    Tropical storms are systems with sustained winds between 39 and 73 mph (63 to 118 km/h). They form over warm ocean waters, where rising heat and moisture create a organized system of clouds and rain. Tropical storms can produce heavy rain, strong winds, and storm surges, leading to flooding and property damage. If a tropical storm strengthens, it can evolve into a hurricane.

Tropical storm image source:

Show image of: tropical_storm.png which is an image of a typical tropical storm viewed from the atmosphere

3. **Hurricanes or typhoons:** the most powerful, with winds exceeding 74 miles per hour (119 km/h).

   Hurricanes, known as typhoons in the Western Pacific, are powerful storms with sustained winds exceeding 74 mph (119 km/h). They form over warm ocean waters and are characterized by a well-defined eye at the center. Hurricanes bring destructive winds, heavy rainfall, and storm surges that can cause severe coastal flooding. Meteorologists track hurricanes using satellites and aircraft to provide early warnings and ensure public safety. Understanding these storms is essential for disaster preparedness in affected regions.

Show image_of_hurricane.png, which is an image of a hurricane viewed from space.

Source;

https://www.noaa.gov/jetstream/tropical/tropical-cyclone-introduction

---

How tropical storms develop

Tropical storms occur due to a combination of atmospheric and oceanic factors. Here's a detailed explanation of the process:

1. **Water Temperature:** For a tropical storm to form, the ocean water temperature must be at least 80 degrees Fahrenheit (approximately 26.5 degrees Celsius) in the upper layers. This warm temperature provides the necessary energy for storm development.

2. **Evaporation of Water:** The heat from the ocean warms the air above the water's surface. This warm air rises, causing water to evaporate and form water vapor. As this warm air rises, it cools, leading to the condensation of water vapor into raindrops, releasing heat in the process.
3. **Formation of Clouds and Winds:** The heat released during the condensation of water vapor warms the surrounding air, which rises more rapidly. This process creates an area of low pressure at the surface, attracting cooler air from the surroundings. This cool air warms up, rises, and causes more condensation and cloud formation. The result is a system of winds spiraling around a low-pressure center.
4. **Earth's Rotation:** The Earth's rotation (Coriolis effect) causes winds in the Northern Hemisphere to rotate counterclockwise and in the Southern Hemisphere to rotate clockwise. This rotation is essential for the development of a tropical storm and its organization into a cyclone system.
5. **Atmospheric Conditions:** Stable atmospheric conditions are also needed for a tropical storm to develop, meaning there shouldn't be too much wind shear (the difference in wind speed and direction at different altitudes), as this can disrupt the storm and prevent its growth.
6. **Continuous Feeding:** Tropical storms require a constant source of heat and moisture. If the system moves over cooler waters or encounters wind shear, it can weaken and eventually dissipate.

Sources:

- National Oceanic and Atmospheric Administration (NOAA):https://www.nesdis.noaa.gov/imagery/hurricanes
- NASA's Earth Observatory: https://earthobservatory.nasa.gov/images/152328/tropical-cyclone-belal

---

Where Do Tropical Storms Occur?

Tropical storms predominantly occur in specific regions of the world, particularly near the equator, where warm ocean waters and favorable atmospheric conditions are present. Here are the primary areas where tropical storms are known to form, along with a brief explanation of each:

1. **Atlantic Ocean**

   The Atlantic hurricane season typically runs from June 1 to November 30. These storms often form in the warm waters of the Caribbean Sea, the Gulf of Mexico, and off the coast of Africa in an area known as the "Hurricane Alley." The warm waters provide the necessary heat and moisture, while the trade winds help to organize and steer the storms.

2. Eastern Pacific Ocean

Similar to the Atlantic, the Eastern Pacific also experiences a hurricane season, which runs from May 15 to November 30. Storms in this region often form off the coasts of Mexico and Central America. Warm ocean temperatures and atmospheric conditions similar to those in the Atlantic contribute to the development of these tropical storms.

3. Western Pacific Ocean

The Western Pacific is known for producing some of the strongest tropical storms, commonly referred to as typhoons. The typhoon season runs year-round but peaks between May and October. This region experiences warm waters and favorable atmospheric conditions, particularly near islands like the Philippines and Japan, which are often impacted by these powerful storms.

4. Indian Ocean

Tropical cyclones in the Indian Ocean can occur in both the northern and southern hemispheres. The Northern Indian Ocean sees storms forming mainly between April and December, while the Southern Indian Ocean experiences cyclones primarily from November to April. Regions such as the Bay of Bengal and the Arabian Sea are particularly prone to tropical cyclones, often leading to severe flooding and destruction.

5. Southern Hemisphere

In the Southern Hemisphere, tropical storms are most commonly found in the southwestern Pacific and the Australian region. The season typically runs from November to April. Warm ocean temperatures and favorable wind patterns contribute to the formation of these storms, which can impact countries like Australia and nearby island nations.

Sources:

1. [National Oceanic and Atmospheric Administration (NOAA)](#)

Methods of Detection for Tropical Storms

Tropical storms can be detected using various meteorological tools and techniques, combining satellite imagery, radar data, and observational data from weather stations. Here's a detailed explanation of how tropical storms are detected:

1. Satellite Imagery

Tropical storms are primarily detected and monitored using various types of satellites equipped with advanced technologies. NASA plays a significant role in observing these weather systems from space. Here's how they detect tropical storms and some of the satellites involved:

1. Geostationary Satellites: These satellites orbit the Earth at the same rotation rate as the planet, allowing them to continuously monitor the same area. For tropical storms, geostationary satellites provide real-time images and data on cloud cover, temperature, and moisture content. An example of such a satellite is the GOES (Geostationary Operational Environmental Satellite) series, operated by NOAA, which provides vital information for weather forecasting.
2. Polar-Orbiting Satellites: Unlike geostationary satellites, polar-orbiting satellites pass over the Earth's poles, providing comprehensive data of the entire planet. They collect information on atmospheric temperature, humidity, and cloud patterns. NASA's Aqua and Terra satellites are part of the Earth Observing System (EOS) and use instruments like the Moderate Resolution Imaging Spectroradiometer (MODIS) to gather data that helps identify storm development.
3. Infrared and Microwave Sensors: These sensors are crucial for determining the temperature of cloud tops and the presence of moisture. For instance, the Advanced Microwave Scanning Radiometer (AMSR) onboard the GCOM-W satellite provides valuable insights into the water content in the atmosphere, aiding in the assessment of storm strength and trajectory.
4. Tropical Rainfall Measuring Mission (TRMM): Although it has been retired, TRMM was instrumental in measuring rainfall and storm structure in tropical regions. It provided critical data on storm intensity and precipitation patterns.
5. Satellite Data Integration: The data collected from these satellites is integrated into weather models, enhancing the accuracy of storm predictions and tracking. By analyzing patterns in the data, meteorologists can identify the formation of tropical storms and assess their potential impact.

source:
https://appliedsciences.nasa.gov/what-we-do/disasters/hurricanes-cyclones#:~:text=NASA's%20Global%20Precipitation%20Measurement%20mission,maps%20their%20intense%20rainfall%20rates.

2. Weather Radars

Ground-based radar systems are used to detect precipitation and wind patterns associated with tropical storms. Doppler radar, in particular, can measure the speed and direction of winds within a storm, helping meteorologists assess its intensity and structure. Radar data allows for the identification of rotation and possible development into a tropical storm or hurricane.

3. Buoys and Weather Stations

Ocean buoys and land-based weather stations collect data on atmospheric pressure, temperature, humidity, and wind speed. This information is critical for early detection of changes in weather patterns that may indicate the formation of a tropical storm. Buoys

located in the ocean can provide real-time data on sea surface temperatures, which are essential for assessing the potential for storm development.

4. Aircraft Reconnaissance

Specialized aircraft, such as the NOAA Hurricane Hunters, fly into tropical storms and hurricanes to gather data on their structure and intensity. These aircraft can measure wind speeds, temperature, humidity, and atmospheric pressure directly within the storm. This data is invaluable for improving the accuracy of storm forecasts and understanding the storm's behavior.

5. Numerical Weather Prediction Models

Meteorologists use computer models that simulate the atmosphere to predict tropical storm formation and development. These models incorporate data from satellites, radars, and other sources to forecast future storm behavior. The accuracy of these models has improved significantly with advances in technology and data assimilation techniques.

6. Public and Private Weather Organizations

Organizations like the National Hurricane Center (NHC) and the European Centre for Medium-Range Weather Forecasts (ECMWF) play a crucial role in monitoring and forecasting tropical storms. They analyze data from various sources, provide regular updates to the public, and issue warnings when a tropical storm is detected or expected to develop.

Source:

This information is adapted from the National Oceanic and Atmospheric Administration (NOAA) and the National Hurricane Center resources:

- National Oceanic and Atmospheric Administration (NOAA). "Hurricane Preparedness." Retrieved from NOAA Hurricane Preparedness. https://www.noaa.gov/hurricane-prep

---

How Climate Change Affects Tropical Storms

Climate change significantly impacts tropical storms, influencing their formation, intensity, and frequency. As the global climate continues to warm due to increased greenhouse gas emissions, several interconnected factors affect how these storms behave and develop. Here are some key ways in which climate change affects tropical storms:

1. **Increased Sea Surface Temperatures**: Tropical storms draw energy from warm ocean waters. As climate change causes global sea surface temperatures to rise, there is more energy available for storm formation. Higher temperatures can lead to stronger and more intense storms. Research indicates that for every degree Celsius increase in sea surface temperature, the potential for tropical cyclone intensity can increase, resulting in storms with greater wind speeds and rainfall.

2. **Changes in Atmospheric Conditions**: Climate change alters the atmospheric conditions that are crucial for storm development. Warmer temperatures can lead to increased humidity in the atmosphere, providing more moisture for storms. Additionally, changes in wind patterns and atmospheric pressure can influence how storms develop and move. Some areas may experience more favorable conditions for tropical storm formation, while others may see a decrease.

3. **Rising Sea Levels**: Climate change contributes to rising sea levels, which increases the risk of coastal flooding during storms. Higher sea levels can exacerbate the storm surge that occurs when a tropical storm makes landfall, leading to more severe flooding and damage to coastal communities.

4. **Altered Storm Tracks**: Climate change may also affect the tracks of tropical storms, shifting their paths and potentially exposing new areas to storm impacts. For instance, changes in atmospheric circulation patterns can lead to storms moving into regions that previously experienced fewer storms, increasing the vulnerability of those areas.

5. **Increased Frequency of Extreme Weather Events**: There is evidence that climate change is leading to an increase in the frequency of extreme weather events, including more powerful hurricanes and tropical storms. The Intergovernmental Panel on Climate Change (IPCC) reports that while the overall number of tropical cyclones may not increase significantly, the proportion of the most intense storms is likely to rise, resulting in greater potential for damage.

6. **Impact on Precipitation Patterns**: Climate change affects global precipitation patterns, leading to changes in rainfall associated with tropical storms. Warmer air can hold more moisture, which means that storms can produce heavier rainfall. This increase in precipitation can result in more severe flooding, landslides, and other hazards in affected areas.

7. **Long-Term Projections**: Climate models project that as the climate continues to warm, the characteristics of tropical storms will evolve. While some regions may see an increase in storm frequency and intensity, others may experience a decrease. Understanding these changes is crucial for effective planning and adaptation in vulnerable areas.

source: https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

Impacts of Tropical Storms on Communities and Environment

Tropical storms can significantly affect human populations, infrastructure, and the environment in various ways. Here are some key impacts:

1. **Physical Damage:** Tropical storms bring strong winds and heavy rainfall, which can cause extensive damage to buildings, homes, and other structures. Flooding can

lead to the destruction of roads, bridges, and communication systems, making rescue and recovery efforts challenging.

2. **Injury and Loss of Life:** The severe weather conditions associated with tropical storms can lead to injuries and fatalities. High winds, flying debris, and flooding pose serious risks to individuals who are caught in the storm. Emergency services often need to respond quickly to rescue those in danger.
3. **Displacement of Communities:** As a result of flooding and damage, many people may be forced to evacuate their homes. This displacement can create a humanitarian crisis, as communities struggle to provide shelter, food, and medical care for those affected.
4. **Economic Impact:** The aftermath of a tropical storm can have severe economic consequences. Damages to infrastructure, homes, and businesses can lead to significant financial losses. Additionally, recovery and rebuilding efforts require substantial resources, which can strain local and national economies.
5. **Environmental Impact:** Tropical storms can lead to soil erosion, destruction of habitats, and water pollution. The heavy rainfall can wash contaminants into waterways, affecting local ecosystems and drinking water supplies.
6. **Health Risks:** The aftermath of tropical storms can create health risks due to contaminated water, the spread of diseases, and limited access to medical facilities. Standing water can become breeding grounds for mosquitoes, leading to an increase in diseases like malaria and dengue fever.

Sorce: https://www.cdc.gov/hurricanes/about/index.html

Example; Tropical Storm Detection: The Role of Satellites and Climate Change

One significant example of satellite technology aiding in the detection of tropical storms is Hurricane Harvey in 2017. Satellites played a crucial role in monitoring the storm's development and trajectory, allowing meteorologists to provide timely warnings. As Harvey intensified and moved toward the Gulf Coast, satellite imagery helped track its formation and predict its path, which was essential in issuing evacuation orders and preparedness measures.

Climate change has been linked to an increase in the intensity and frequency of tropical storms, including hurricanes. Warmer ocean temperatures create more favorable conditions for storm formation, leading to more powerful and destructive weather events. The National Oceanic and Atmospheric Administration (NOAA) has reported that as the climate warms, storms like Harvey may become more severe, with increased rainfall and flooding potential.

Satellites not only help in early detection but also provide data on changing ocean temperatures and atmospheric conditions, allowing scientists to better understand the relationship between climate change and storm intensity. This information is critical for disaster preparedness and response, enabling communities to take proactive measures to mitigate potential damage from tropical storms exacerbated by climate change.

FUN FACTS

1. Warm ocean waters fuel tropical storms: Tropical storms are powered by warm sea surface temperatures, typically above 26°C (79°F). The heat from the ocean provides energy that strengthens the storm as moist air rises, cools, and condenses. This process releases latent heat, fueling the storm further.
   Source: https://www.noaa.gov/
2. Low-pressure centers cause wind circulation: Tropical storms form around areas of low atmospheric pressure, causing air to flow toward the center. As this air moves in, it spirals due to the Coriolis effect and forms the characteristic circular pattern.
   Source: https://earthobservatory.nasa.gov/
3. Storms intensify with increased humidity: High humidity levels, especially in the middle and lower levels of the atmosphere, promote storm growth. Humidity provides the necessary moisture that turns into rainfall and further strengthens the system.
   Source: https://community.wmo.int/activity-areas/tropical-cyclones
4. High winds and heavy rains can cause damage: Tropical storms bring destructive winds, heavy rainfall, and sometimes storm surges, causing flooding and infrastructure damage. The severity depends on the storm's strength, path, and local geography.
   Source: https://www.nhc.noaa.gov/
5. The Coriolis force influences storm rotation: Tropical storms rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere due to the Coriolis effect, a result of Earth's rotation. This force determines the direction of wind circulation.
   Source: https://education.nationalgeographic.org/resource/coriolis-effect/

NASA Worldview

The Role of NASA Worldview

NASA Worldview is an invaluable tool for tracking and analyzing tropical storms. It provides real-time satellite imagery and data that help meteorologists and researchers monitor the development and movement of these storms. For example, using the IMERG Precipitation Rate layer, users can observe intense rainfall associated with tropical storms, which is vital for predicting flooding and other hazards.

Satellite Imagery and Storm Tracking

With the capabilities of NASA's VIIRS and MODIS satellite systems, users can visualize cloud formations and monitor changes in atmospheric conditions. This information is essential in identifying systems of low pressure that can develop into tropical storms. By analyzing the data, meteorologists can issue timely warnings and help communities prepare for the impacts of these storms.

How to Use NASA Worldview for Tropical Storm Analysis

This resource is particularly useful for monitoring tropical storms, as it provides critical data that can enhance our understanding of these weather phenomena. Here's how to effectively use the link and the tool for analyzing tropical storms:

Step 1: Accessing the Link

To begin your analysis, simply click on the following link: NASA Worldview.

Step 2: Navigating the Interface

Once you are on the NASA Worldview homepage, you will see a map of the Earth along with various layers of satellite data. Use the navigation tools on the left to zoom in and out and to pan across different geographic areas.

Step 3: Selecting Layers

On the right side of the interface, you can select specific layers of data that are relevant to tropical storms. For example, choose the **IMERG Precipitation Rate** layer to observe rainfall intensity associated with storms. You can also select layers that show cloud cover and storm tracks, which are essential for understanding storm development.

Step 4: Analyzing Data

By selecting different dates and viewing past imagery, you can analyze how tropical storms develop over time. Pay attention to changes in cloud formation, rainfall patterns, and wind direction. This data can provide insights into the storm's intensity and potential impact on surrounding areas.

Step 5: Documenting Findings

As you explore the data, take notes on your observations. Document specific instances of tropical storms, their characteristics, and any notable patterns you observe. This information can be invaluable for research and for understanding the implications of these storms in the context of climate change and environmental impacts.