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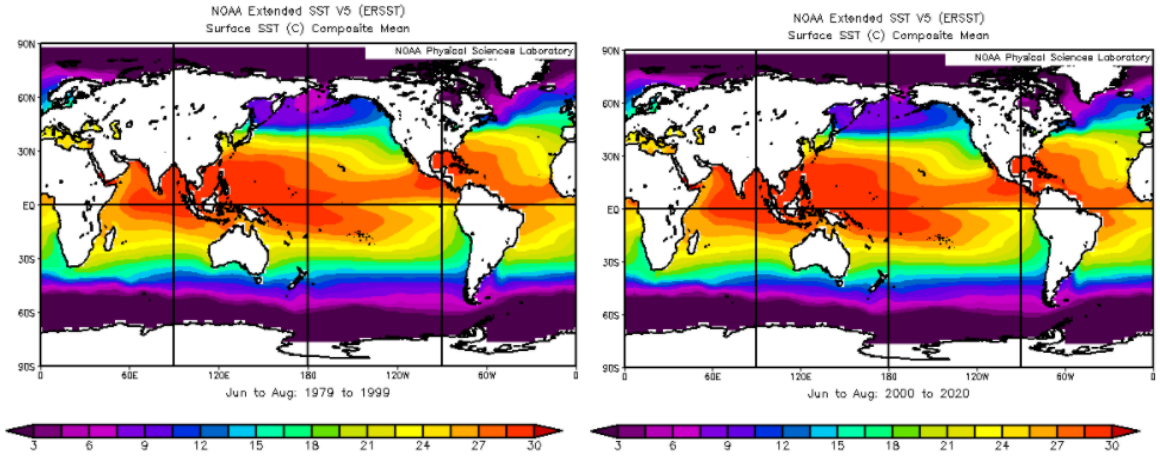
Tropical Meteorology

11 December 2020

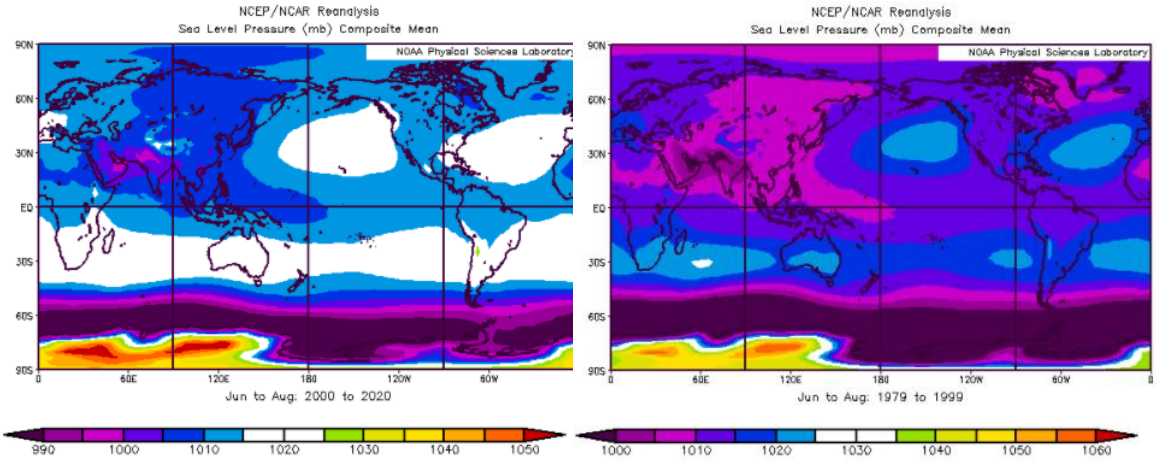
Tropical Cyclones and Climate Change

Among the COVID-19 global pandemic, as well as political and social unrest, the 2020 Atlantic hurricane season fostered a record breaking 30 tropical storms, and 13 hurricanes. As human society continues to develop and experience a series of challenges, the role of a changing climate and its impact on tropical cyclones and disturbances is unavoidable. This recent season had various impacts on countries around the world, millions of people, and a series of infrastructures. For the United States, specifically, there was an estimated $65 billion in overall damage this season, ranking 5th in the country's last 30 years. Other countries, such as Colombia, have territories with majorly damaged infrastructure and thousands without power and other necessary resources. With obvious threats from climatological cycles in the tropics, a growing human population must have the protective infrastructure and ability to assess live tropical data to best sustain their livelihood. With that, the everchanging climate, influencing ocean warming, is important to track and understand. To best understand the complex tropical and global climate phenomena, specifically tropical cyclones, consistent research, and exposure is necessary.

Tropical Storms and Cyclones have a culmination of measurable ingredients that expose their potential of intensity growth or weakening. Most of all, they require warm water temperatures of about 27oC, strong surface winds, and low-pressure centers to initiate and sustain development. They are weakened by upper altitude wind shear, heightening pressure centers, absences of moisture, and strong El Nino southern oscillation periods. Additional factors include latent heat from evaporation, converging warm air columns from the surface level, easterly waves and trade winds, and the Coriolis force. A hurricane is simply characterized as having over 75 MPH surface winds, a 300-800km size, an average sea level pressure of 870-950mb, and occurring above 5^{o} latitude. With a series of exchangeable atmospheric and oceanic components, it is clear how impactful global climate is on the potential of tropical cyclones. As global temperatures are projected to increase, an addition of 2-3oC could dramatically strengthen geographical cyclone seasons and destroy communities. To quantify this, two National Oceanic and Atmospheric Agency (NOAA) ocean surface temperature average projections are seen below. One covers 1979-1999, the other 2000-2020, both during northern hemispheric summer. In these 20-year time frames, a clear increase in average ocean surface temperature is seen, with a larger geographic extent maintaining tropical temperatures of 30oC.

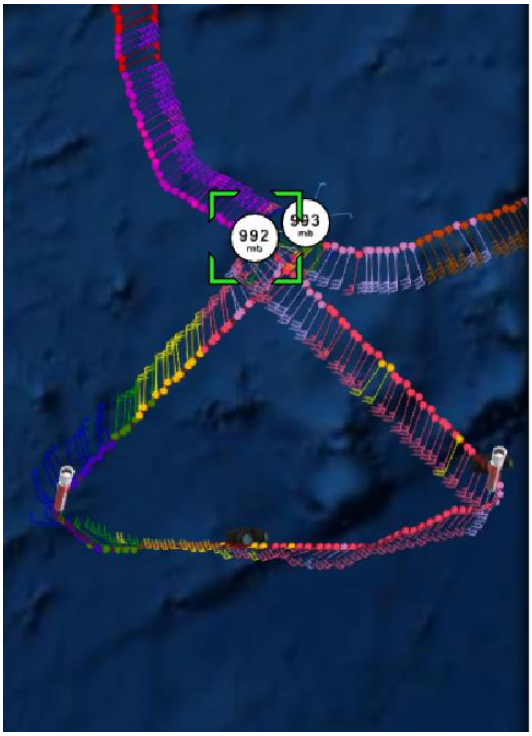


Warmer surface temperatures contribute to more latent heat exchange between the ocean and atmosphere, representing the energy source for tropical air convergence and storms. Warm waters naturally develop lower pressure regions, and water levels rise, further fueling air convergence. Low pressure regions bring high surface winds, and when combined with easterly waves and trade winds, output the perfect kinetic environment for cyclones to form, considering there is low wind shear to prevent the vertical growth, and the Coriolis force naturally provides eastward friction. Below, are sea level air pressure averages for the same time spans, to correlate the warm temperature and low-pressure relationship. Since 2000, average sea level pressure during northern hemisphere summer and North American hurricane season is 970-1010mb, while it was 1000-1020mb between 1979 and 1999.



Although the focus is most often on Atlantic hurricanes and tropical storms, as they are more impactful to the U.S., there can be seasons of peace. The El Nino Southern Oscillation (ENSO), during a negative southern oscillation index (SOI) phase, warms the eastern Pacific Ocean, increasing tropical disturbance there rather than focusing on the Atlantic and counterpart waters. When ENSO is in a positive SOI phase, it is recognized as a La Nina phase, brining tropical disturbances to the Atlantic region, and cooling the eastern Pacific Ocean. Therefore, ENSO plays an important role in tropical disturbances and cyclones, for it drives tropical instability and creates a somewhat balanced atmospheric and oceanic energy exchange. There are times, however, when tropical storms and cyclones occur in multiple geographic regions, regardless of the ENSO phase. With overall climate warming, it further increases the importance of accurate weather monitoring and response to protect communities globally, as higher temperatures create a more unstable global environment and increase tropical disturbance.

To rapidly notify weather agencies and collect real-time data that is crucial to human population preparedness, The United States employs NOAA and the Air Force to hunt and live-track tropical storms, cyclones, and disturbances. The Hurricane Hunter mission is to conduct tropical storm reconnaissance; support 24 hour a day continuous operations and produce live storm data for the National Weather Service (NWS) and National Hurricane Center (NHC) to accurately quantify hurricane potential and directional movement. These hunters fly directly into the storm and obtain raw atmospheric and ocean surface data to confirm the behavior of each storm. Amid domestic lockdowns, and other COVID-19 challenges, their mission was still successfully accomplished and effectively assisted the American public. If a live data source such as this was absent, hundreds to millions of people would face destruction without warning. To expose the accuracy of their data, they fly as many missions into active storms as necessary until it is determined non-threatening to communities. Below is a image of the first mission flight into Tropical Storm, later Hurricane Eta (Cat 4). The responsiveness of emergency services and other federal agencies limited fatalities in the U.S., however other countries, who did not have as many resources suffered many more.



Product: NOAA Vortex Message (URNT12 KWBC)
Transmitted: 1st day of the month at 20:29Z
Agency: National Oceanic and Atmospheric Administration (NOAA)
Aircraft: Lockheed WP-3D Orion (Reg. Num. N42RF)
Storm Number & Year: 29 in 2020
Storm Name: Eta (flight in the North Atlantic basin)
Mission Number: 1
Observation Number: 14

A. Time of Center Fix: 1st day of the month at 19:45:58Z
B. Center Fix Coordinates: 14.79N 78.67W
B. Center Fix Location: 255 statute miles (411 km) to the SSW (209°) from Kingston, Jamaica.
C. Minimum Height at Standard Level: 1,372m (4,501ft) at 850mb
D. Minimum Sea Level Pressure: 992mb (29.30 inHg)
E. Dropsonde Surface Wind at Center: From 30° at 6kts (From the NNE at 7mph)
F. Eye Character: Open in the southwest
G. Eye Shape & Diameter: Circular with a diameter of 30 nautical miles (35 statute miles)
H. Estimated (by SFMR or visually) Maximum Surface Wind Inbound: 39kts (44.9mph)
I. Location & Time of the Estimated Maximum Surface Wind Inbound: 9 nautical miles to the SE (134°) of center fix at 19:43:45Z
J. Maximum Flight Level Wind Inbound: From 217° at 34kts (From the SW at 39.1mph)
K. Location & Time of the Maximum Flight Level Wind Inbound: 15 nautical miles (17 statute miles) to the SE (132°) of center fix at 19:42:09Z
L. Estimated (by SFMR or visually) Maximum Surface Wind Outbound: 58kts (66.7mph)
M. Location & Time of the Estimated Maximum Surface Wind Outbound: 12 nautical miles (14 statute miles) to the WNW (300°) of center fix at 19:49:06Z
N. Maximum Flight Level Wind Outbound: From 68° at 55kts (From the ENE at 63.3mph)
O. Location & Time of the Maximum Flight Level Wind Outbound: 54 nautical miles (62 statute miles) to the NW (321°) of center fix at 20:00:58Z
P. Maximum Flight Level Temp & Pressure Altitude Outside Eye: 19°C (66°F) at a pressure alt. of 1,537m (5,043ft)
Q. Maximum Flight Level Temp & Pressure Altitude Inside Eye: 24°C (75°F) at a pressure alt. of 1,537m (5,043ft)
R. Dewpoint Temp (collected at same location as temp inside eye): 18°C (64°F)
R. Sea Surface Temp (collected at same location as temp inside eye): Not Available
S. Fix Determined By: Penetration, Radar, Wind, Pressure and Temperature
S. Fix Level: 850mb
T. Navigational Fix Accuracy: 0.01 nautical miles
T. Meteorological Accuracy: 2 nautical miles

The rankings and estimates of hurricane impact and strengths are relative to a timeframe dependent on data recording. Although there is an extreme amount of knowledge and understanding of the previous 200 years of weather patterns and climate variation, as it has not always been professionally recorded and analyzed, there is still a few billion years of unaccounted for sightings and analyses of these tropical storms. The fueling and developmental factors oft tropical storms and cyclones, are known, but it can be assumed that there could have been stronger and more destructive storms in earth's history. With that, the human response to climate change is still fresh when compared to the 4 billion years of atmospheric variations. It is most important that these data sources are maintained and globally distributed, so that the climatic systems influencing tropical cyclones can be better understood by everyone. As the earth is warming, these major storms will increase in strength and extent, as long as there is tropical instability and disturbance to fuel them. Human populations have enough knowledge to prepare for more severe storms in the future, particularly due to rapid responses and forecasts from government agencies.

Works Cited

"Aerial Reconnaissance." *Tropical Atlantic*, tropicalatlantic.com/recon/recon.cgi?archive=1.

Team, PSL Web. "Data and Imagery." *PSL*, psl.noaa.gov/data.

"Tropical Disturbances." *Tropical Climatology: an Introduction to the Climates of the Low Latitudes*, by Glenn R. McGregor and S. Nieuwolt, Wiley, 1998, pp. 142–164.