Sea Surface Height and Intensity Change in Western North Pacific Typhoons

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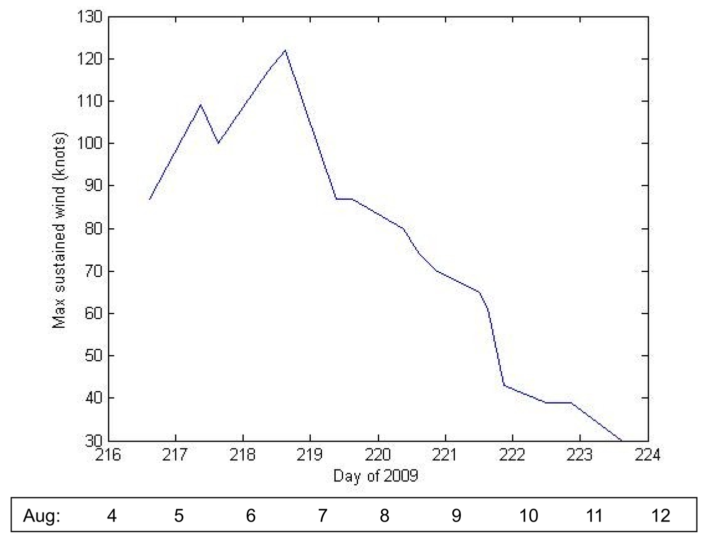
Abstract

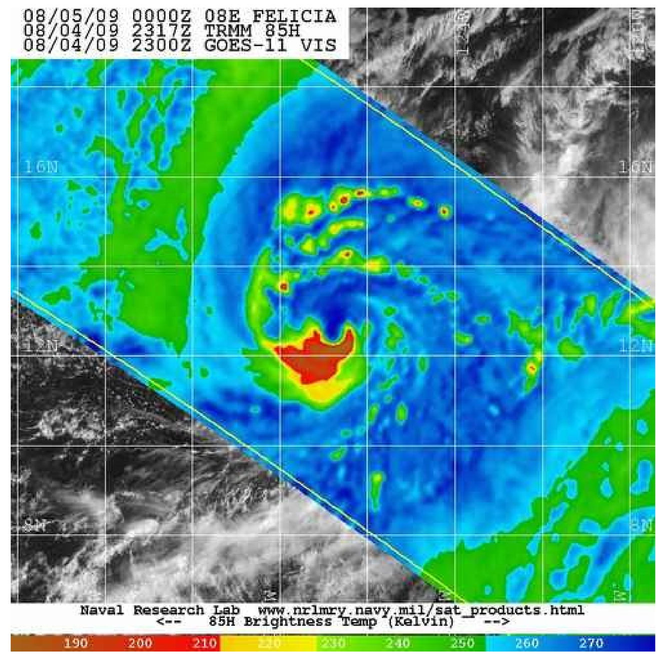
Although the structure of tropical cyclones (TCs) is well known, there are innumerable factors that contribute to their formation and development. The question that we choose to assess is at the very foundation of what conditions are needed for TC genesis and intensification: How does ocean heat content contribute to TC intensity change? Today, it is generally accepted that warm water promotes TC development. Indeed, TCs can be modeled as heat engines that gain energy from the warm water and, in turn, make the sea surface temperature (SST) cooler. Our study tests the relationship between the heat content of the ocean and the intensification process of strong Western North Pacific (WNP) Typhoons (sustained winds greater than 130 knots). We obtained storm track and wind speed data from the Joint Typhoon Warning Center and sea surface height (SSH) data from AVISO as a merged product from altimeters on three satellites: Jason-1, Jason-2, and Envisat. We used MATLAB to compare the SSH to the wind speeds, using these as proxies for ocean heat content and intensity, respectively. Two of our most notable WNP typhoons, Xangsane and Durian (2006), initiated rapid intensification when the SSH was well above the mean. However, later during their intensification the SSH began to steadily drop, thus supporting the basic heat engine model. Using the results from these two case studies and from additional tropical cyclones included in our study, we will discuss how monitoring SSH might help to better forecast TC intensity change.

Bard Early College Atmospheric Physics Program

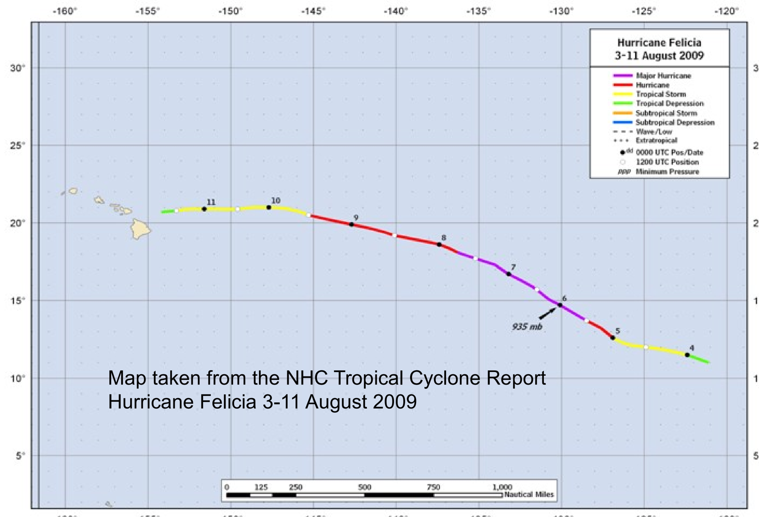
Bard High School Early College is a four-year program that enables students to earn a New York State high school diploma and a tuition-free Bard College associate's degree in four years. During 2008-2010, students participated in an atmospheric science program designed by Professors Jeremy Thomas and Natalia Solorzano. The atmospheric science course was a lab- and project-based course that provided an introduction to the physics and chemistry of the earth's atmosphere. As a prerequisite, all students in the class had completed one year of algebra-based physics. Some topics that were covered included electromagnetic radiation, layers of the sun, cloud development, atmospheric circulation, weather forecasting, thunderstorms, hurricanes, air pollution, climate, and climate change. Students were expected to complete two major projects, one each semester, which required significant independent work done outside of class and lab times. Our study comparing SSH and hurricane intensity grew out of one such student project.

Eastern/Central Pacific Hurricane Felicia (2009)

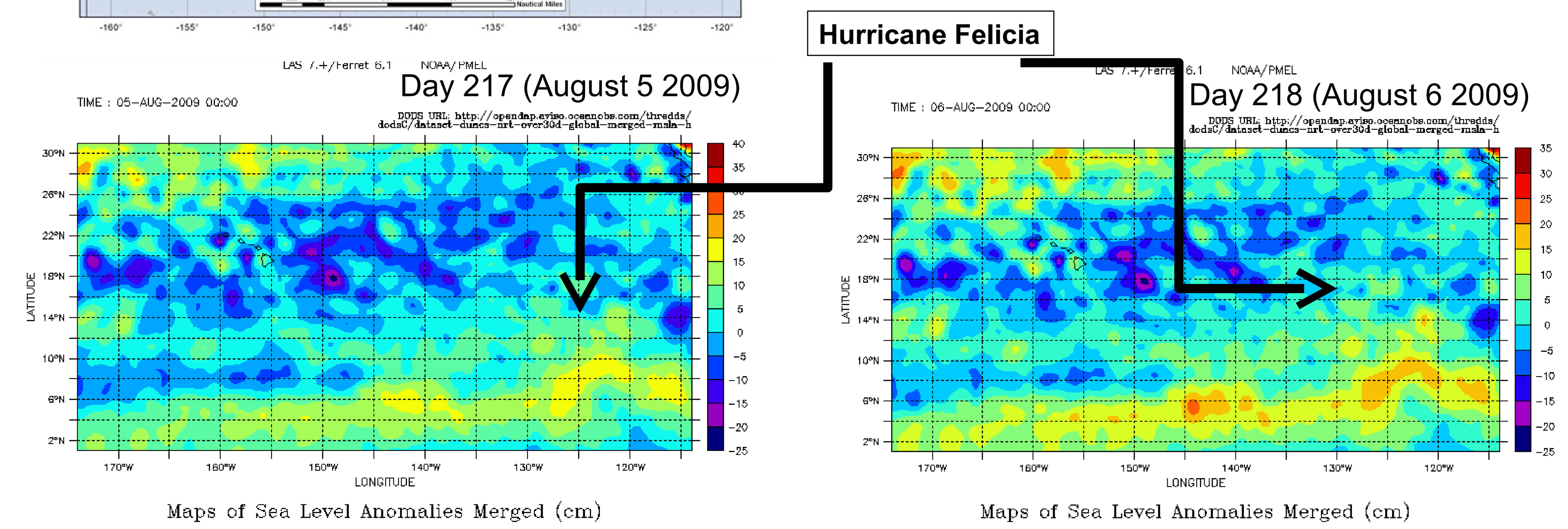




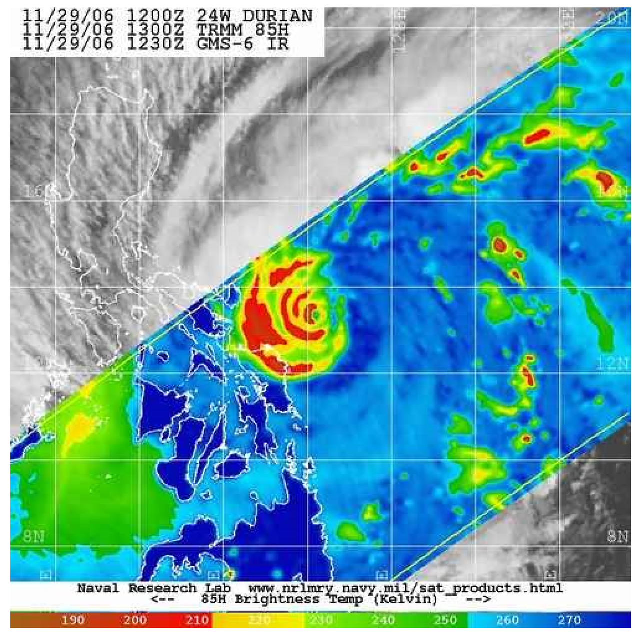
TRMM 85-GHz for Aug. 4, 23:17 UT



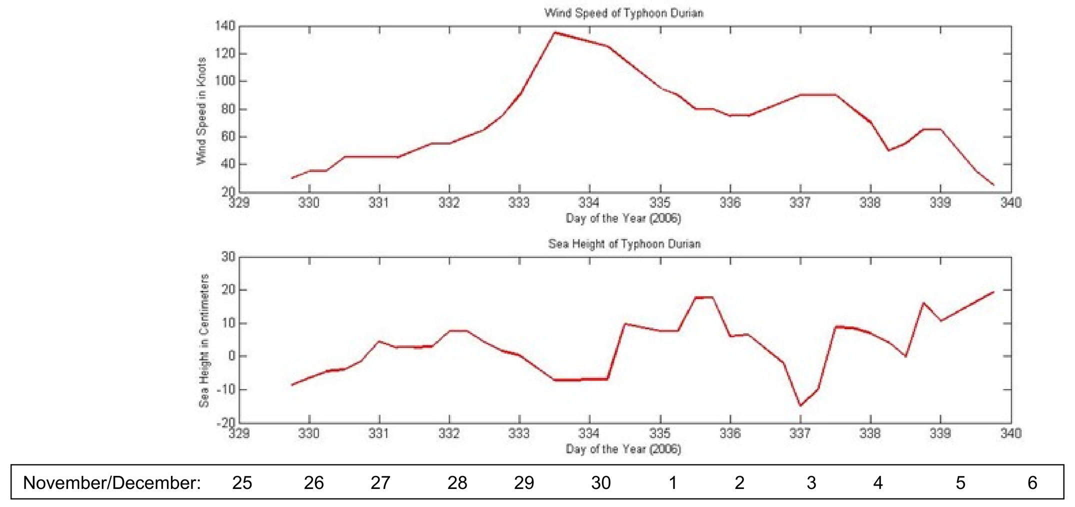
Between day 217 (Aug. 5) and 218 (Aug. 6) of Hurricane Felicia, there was a rapid increase in wind intensity. The blue color on the SSH map shows that the sea level was below normal, indicating less heat content.



Western North Pacific Typhoon Durian (2006)

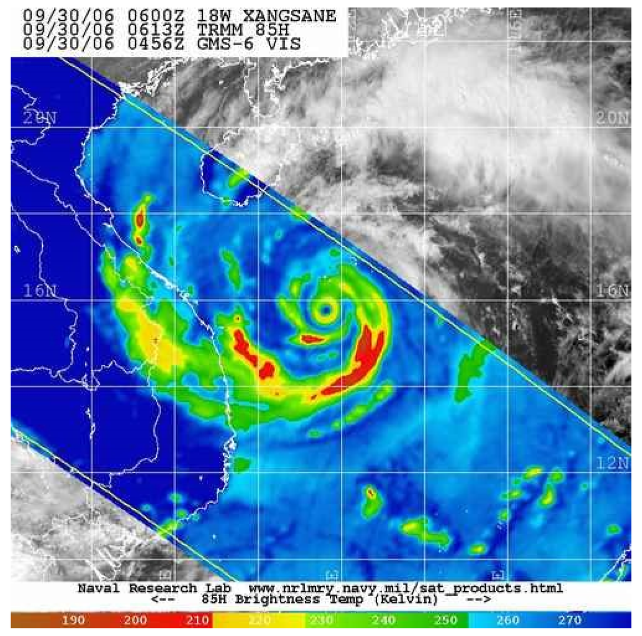


TRMM 85-GHz for Nov. 29, 13:00 UT

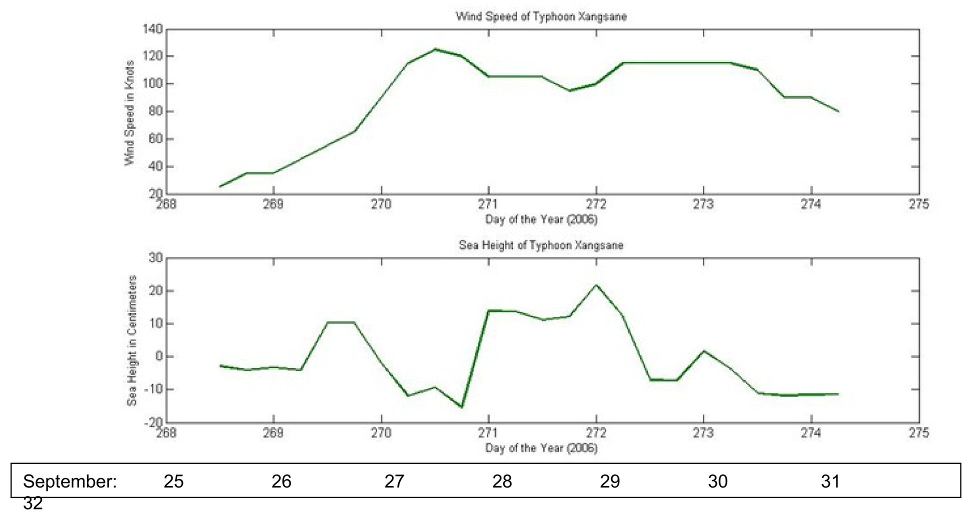


The strongest wind for Typhoon Durian occurred when the SSH was below average between day 333 and day 334. This means that the SSH decreased when the typhoon intensified. After its peak intensity, Durian's winds weakened, and the SSH increased over the next two days. When Durian's wind increased between day 336 (December 2) and 337 (December 3), the SSH rapidly dropped.

Western North Pacific Typhoon Xangsane (2006)



TRMM 85-GHz for Sep. 30, 06:13 UT



The trends on the SSH and wind intensity graphs of Typhoon Xangsane follow a similar pattern as Durian. Between day 269 (September 26) and 271 (September 28), the wind speed steadily increased while the SSH decreased.

Motivations

·Together, sea surface temperate (SST) and sea surface height (SSH) determine the type of environment a hurricane needs to intensify by providing complementary views of the climate variability of the ocean. The SST and SSH anomalies reflect the heat content in the mixed layer and the upper ocean. (Nonaka and Xie 2002)

·Storm-induced cooling changes the structure of the surface winds and precipitation patterns in the inner core regions of the tropical cyclone. SST cooling depends on the intensity and speed of a tropical cyclone and the depth of the ocean. (Zhu and Zhang 2006)

Objective: Our study tests the relationship between the heat content of the ocean (as observed in SSH) and the intensity change process of strong tropical cyclones (sustained winds greater than 130 knots).

Data and Methods

•Storm track and wind data were obtained from the Joint Typhoon Warning Center.

·Wind speed data are the metric for hurricane intensity.

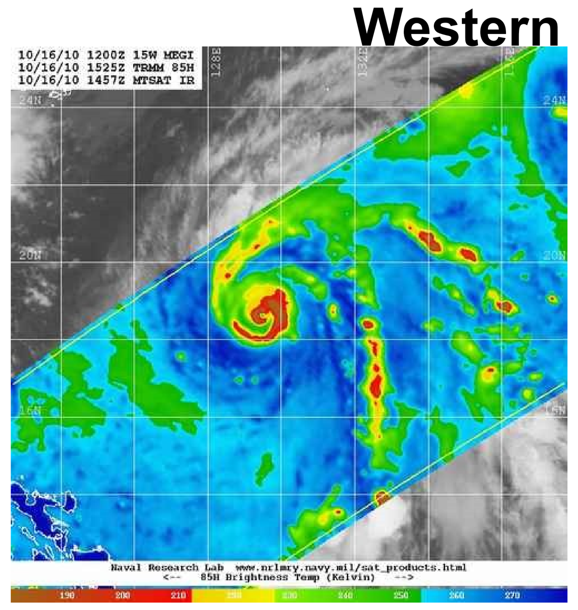
•Sea Surface Height (SSH) data came from the Jason-1, Jason-2, and Envisat satellites on the Live Access Server, a product of AVISO, which distributes climate data.

·SSH data are proxy for ocean heat content.

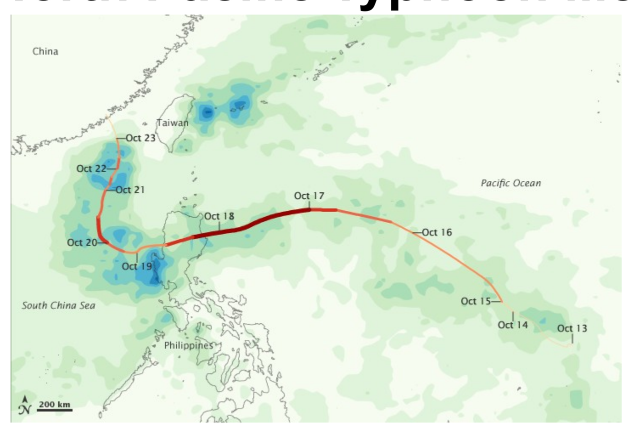
•TRMM (Tropical Rainfall Measurement Mission) satellite passive radar images are used to demonstrate storm structure.

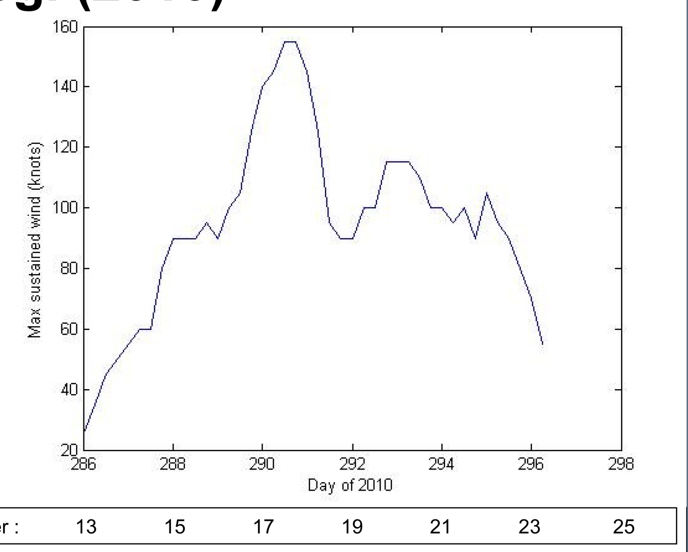
•MATLAB routines were used to process the SSH, storm track, and wind speed data.

Western North Pacific Typhoon Megi (2010)

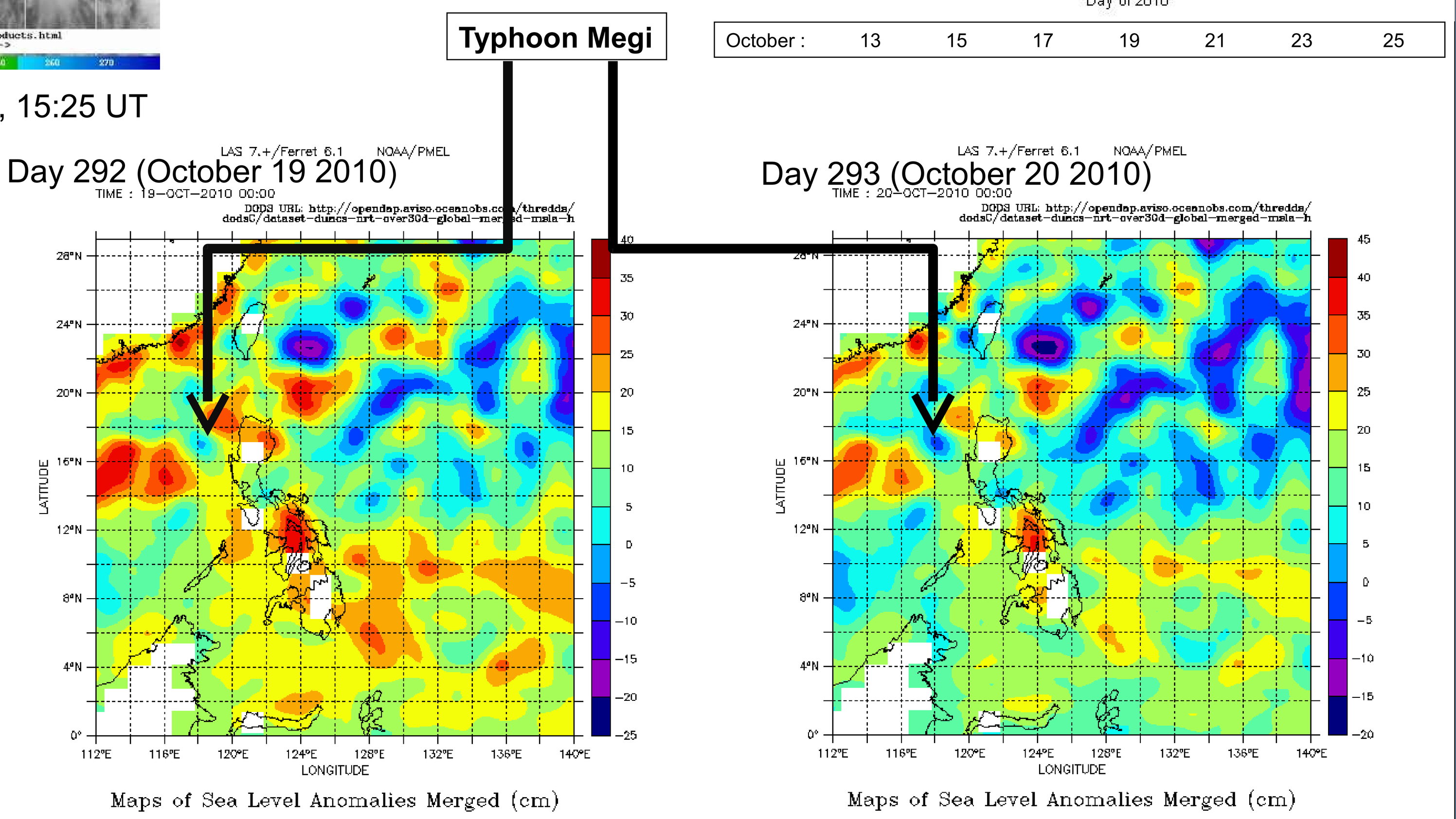


TRMM 85-GHz for Oct 16, 15:25 UT





Our SSH maps of Typhoon Megi on day 292 and 293 show that the SSH is lower near Megi compared to surrounding areas.



Discussion and Conclusions

·Two of our most notable WNP typhoons, Xangsane and Durian (2006), initiated rapid intensification when the SSH was above the mean. However, later during their intensification the SSH began to steadily drop.

·The connection between SSH and intense winds we observed supports the idea of a tropical cyclone acting like a heat engine, taking heat from the ocean and converting it into kinetic energy (manifested as wind). This leaves the ocean cold and depressed, explaining the sharp drops in SSH while the wind speed continues to increase.

·Our observed relationship between SSH and hurricane wind intensity generally agree with previous studies by Nonaka and Xie (2002) and Zhu and Zhang (2006).

·A high SSH can raise a hurricane's intensity, but alone it is not a sufficient factor in determining a hurricane's strength.

·Additional studies comparing SSH and tropical cyclone intensity in all basins are needed to solidify our findings.

References

Nonaka, Masami and Shang-Ping Xie, Covariations of Sea Surface Temperature and Wind over the Kuroshio and Its Extension: Evidence for Ocean-to-Atmosphere Feedback, Journal of Climate, Vol. 16, pp 1404, 2002.

Zhu, Tong and Da-Lin Zhang, The Impact of the Storm-Induced SST Cooling on Hurricane Intensity, Advances in Atmospheric Sciences, Vol. 23, No. 1, pp 14, 2006.

Acknowledgments

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