A LONG-LIVED HURRICANE-INTENSIFIED CYCLONIC OCEAN EDDY

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1. INTRODUCTION

On September 18, 2005, Hurricane Kenneth was 1725 miles east-southeast of Hawaii with peak sustained winds of 115 knots (130 mph), a Category 4 storm on the Saffir-Simson scale. Slacking steering winds induced a southwest drift to the storm where it encountered weak cyclonic ocean circulation that was subsequently intensified by hurricane-induced upwelling caused by strong cyclonic pumping of the water column. The hurricane-induced cooling of the sea surface temperature within the intensified eddy was over 8° C. After intensification, the cyclonic eddy was 200 km in diameter and had a sea surface height anomaly amplitude of -35 cm. Rapid negative ocean-atmosphere feedback from this cold-core eddy likely contributed to the weakening of Kenneth from Category 4 to tropical storm status in less than 48 hours. The hurricane-intensified eddy can be tracked in satellite ocean color imagery and sea surface height maps for over six months.

2. DATA AND METHODS

Archival satellite measurements of ocean vector winds, ocean color, sea surface temperature (SST), and sea surface height (SSH) are used in this study. The two primary sources of SST data are microwave measurements from the TRMM microwave imager (TMI) and Advanced Microwave Scanning Radiometer (AMSR-E) provided by Remote Sensing Systems (RSS), Inc. (http://www.remss.com) and multi-channel radiometer measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS) provided by the Goddard Space Flight Center (GSFC) OceanColor Website (http://oceancolor.gsfc.nasa.gov). MODIS Chlorophyll a (CHLa) data are also from the GSFC OceanColor Website. Multi-mission mapped altimetric SSH data are from the Colorado Center for Astrodynamics Research (CCAR) and the Archiving, Validation, and Interpretation of Satellite Oceanography (AVISO) altimetry projects. More details concerning the satellite data processing can be found in [1,2,3]. Hurricane peak sustained wind speed and best track data are from the National Hurricane Center and scatterometer winds are from NASA's Physical Oceanographic Data Archive (PO.DAAC). A variety of online visualization tools were used to examine the data, including the RSS Tropical Cyclone Microwave Data Page (http://ssmi.com/cyclone/cyclone.html?year=2005&storm=kenneth), the CCAR Ocean Data Access Protocol (DAP) server interfaces to Google Ocean and MATLAB (http://bobo.colorado.edu/cgi-bin/dapserver.cgi/), and the CCAR Near Real-Time Altimetry Data Homepage (http://argo.colorado.edu/~realtime/welcome/).

3. RESULTS AND DISCUSSION

The cyclonic ocean eddy associated with Hurricane Kenneth was discovered using Google Earth while visualizing MODIS CHLa and SST images overlaid with historical hurricane tracks during a 2009 CCAR summer outreach activity with middle school students (Figure 1). Closer examination found that a large cyclonic ocean eddy appeared in the imagery under Hurricane Kenneth on or about September 18-20, 2005. Microwave SST 3-day composite images from AMSR-E (Figure 2) show that the surface thermal signature of the eddy appeared in Kenneth's wake. Surface layer cooling reached 8° C, which was greater than the cooling observed in hurricane-forced cold-core cyclones found in the wake Hurricane Ivan in the Gulf of Mexico in 2004 [4]. Hurricanes typically leave cold wakes indicating a colder surface mixed layer and/or upwelled subsurface waters at the ocean surface air-sea boundary caused by flow divergence and vertical upwelling induced by the hurricane wind field [5]. The air-sea interactions associated with Ivan produced two distinct areas of cold SSTs (20-26° C) and both regions of extreme cooling (4-7º C) were in areas of cyclonic circulation mapped by the coincident SSH measurements.

Similar to the hurricane-induced eddies in Ivan's wake, the cyclonic eddy under Kenneth was intensified by strong pumping of the water column by the cyclonic wind stress curl associated with the hurricane winds. The cyclonic eddy was 200 km in diameter and had an SSH anomaly amplitude of -35 cm after intensification (Figure 3). Evidently, weak cyclonic ocean circulation existed before the arrival of Kenneth, possibly associated with the background mesoscale eddy field or the recent passage of Hurricane Jova. This weak cyclonic circulation preconditioned the eddy flow field for rapid spin up as Kenneth stalled over the eddy on September 18th. The intensified eddy provided strong negative ocean-atmosphere feedback on the storm's intensity that contributed to the weakening of Kenneth from Category 4 to tropical storm status in less than 48 hours. The weakening of the peak sustained wind from 115 knots on September 18th to 55 knots on September 20th is shown by the red line plotted in the upper panel of Figure 4. The resulting hurricane-intensified cyclonic eddy can be tracked in CHLa imagery for over six months before the surface signature disappears. The eddy's SSH signature, however, was still quite strong and could be tracked even after the ocean color signal faded. The remarkable productivity associated with this long-lived eddy will be investigated with more quantitative analyses in future studies.

4. REFERENCES

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5. FIGURES

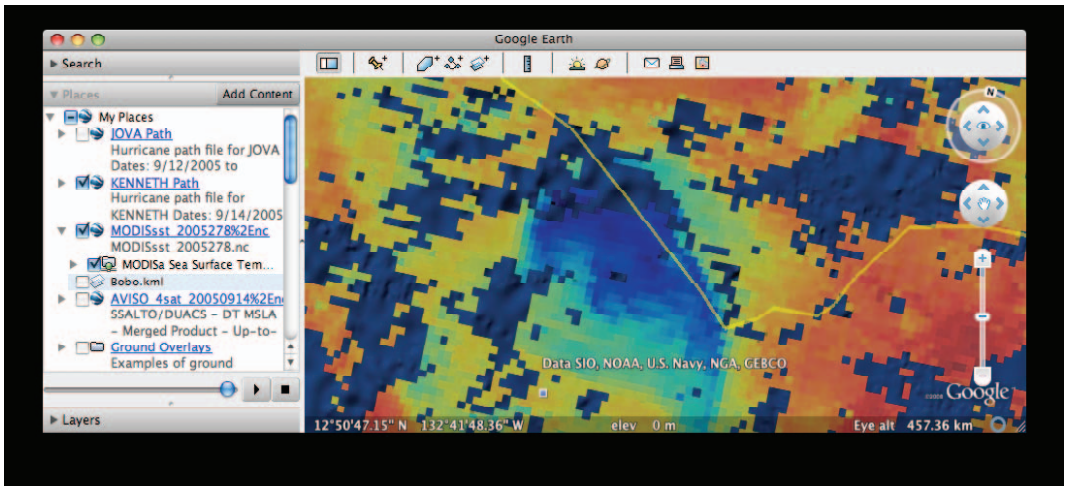

Figure 1. Screenshot of Google Earth with MODIS SST image from October 5th overlaid.

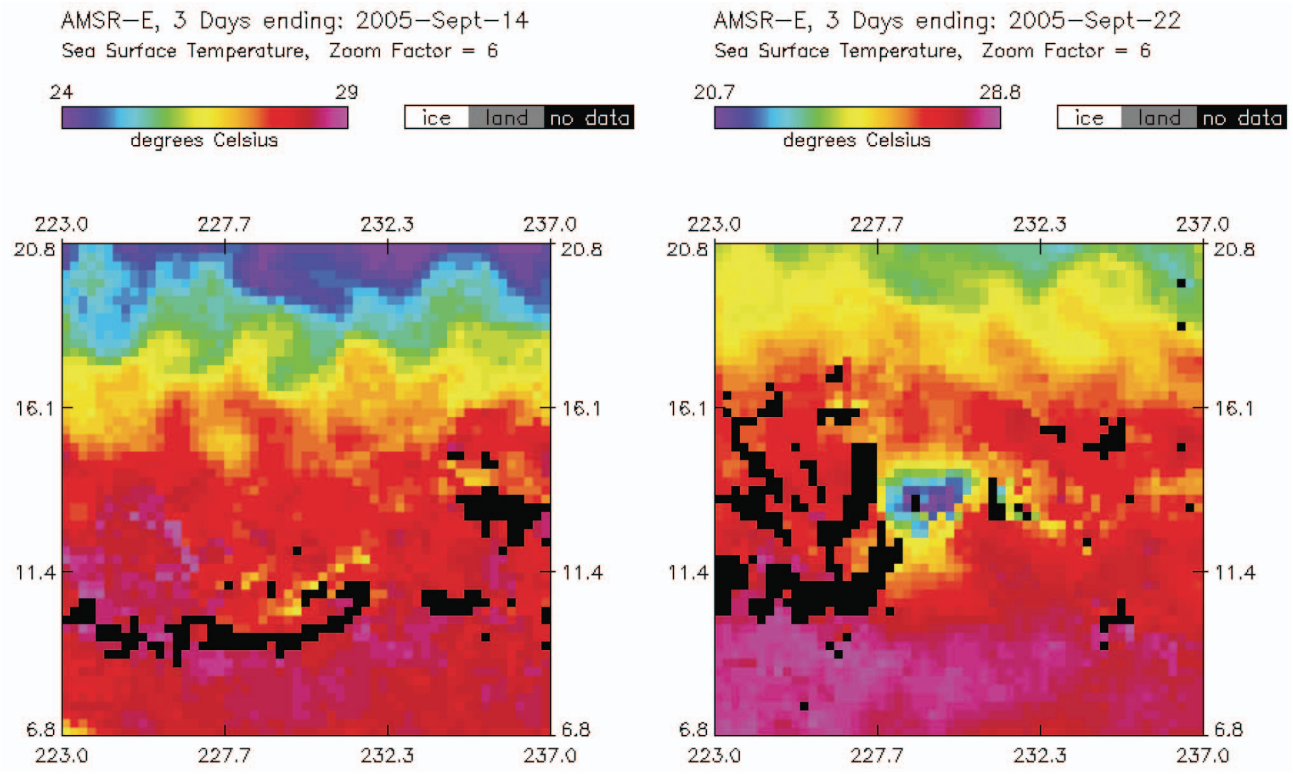

Figure 2. AMSR-E 3-day composite SST images ending September 14, 2005 (left panel) and September 22, 2005 (right panel). SST surface cooling coincident with the hurricane-intensified cyclonic eddy was as much as 8° C.

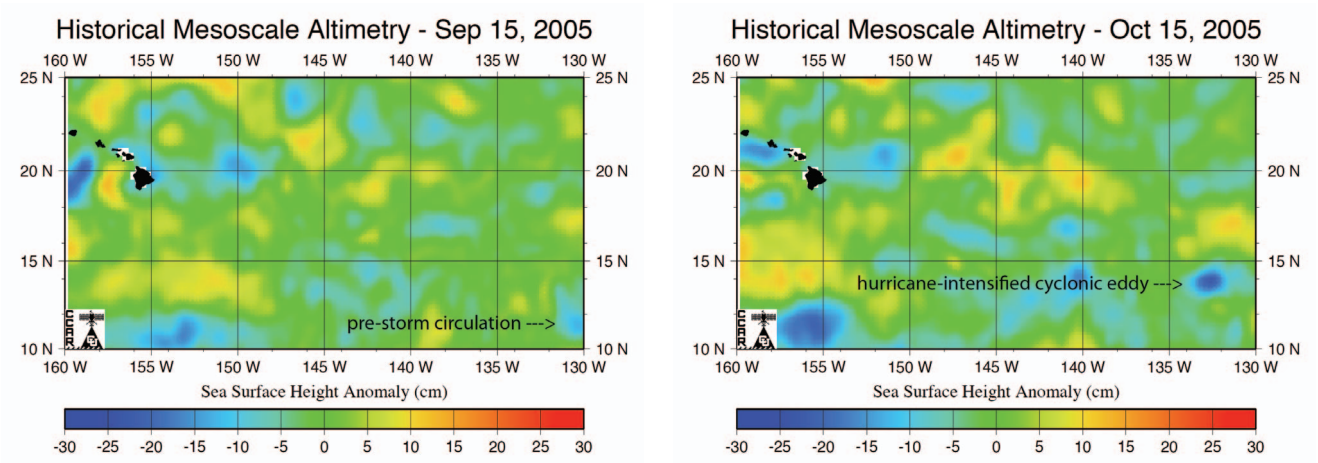

Figure 3. CCAR mesoscale SSH anomaly maps from September 15 and October 15, 2005 bracketing the period of the rapid intensification of the cyclonic eddy under Kenneth.

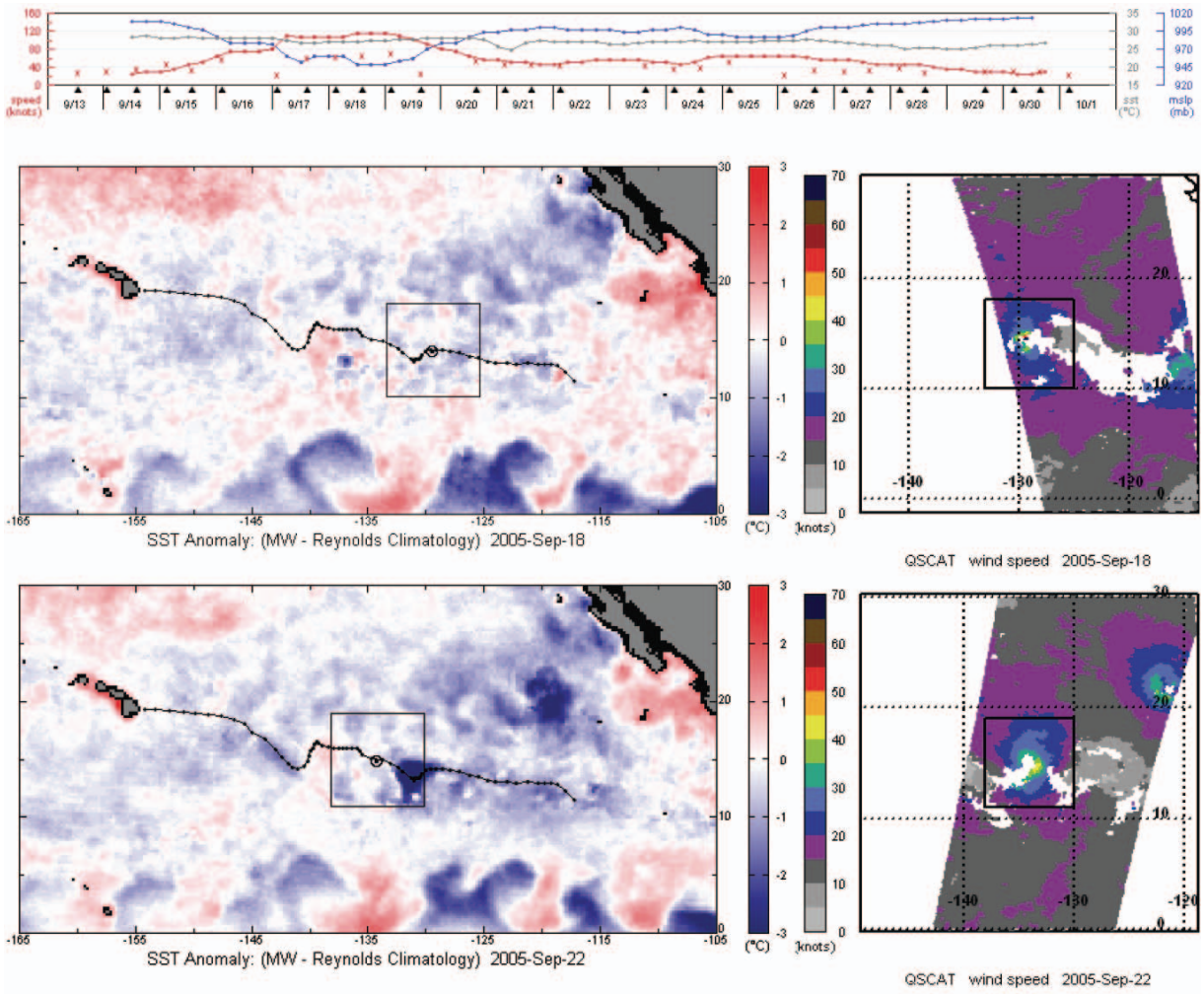

Figure 4. Analysis of Hurricane Kenneth provided by RRS Tropical Cyclone Microwave Website. Rapid ocean surface cooling is associated with a marked decrease in the intensity of Kenneth on Sep 19 and 20th.