P1.63 EXPLORING THE CONNECTION OF EXTREME CONVECTIVE EVENTS AND UPPER-OCEAN HEAT CONTENT IN THE TROPICAL CYCLONE

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1. INTRODUCTION

Forecasting tropical cyclone (TC) intensity change, especially rapid intensification events, continues to be problematic for tropical meteorologists despite advances in numerical weather prediction and improved observational tools. Skill in intensity forecasting involves understanding interactions between complex forcing mechanisms affecting the storm's central pressure and wind strength, namely: upper ocean interactions, internal storm dynamics, and upper atmosphere circulations. These forcing mechanisms encompass varying scales of motion ranging from the cumulus clouds and their anvils, boundary-layer air-sea interaction and large-scale transport processes. This research is an examination of processes associated with TC intensity change emphasizing the importance of mesoscale convection as the common link between larger scale forcing mechanisms (specifically, more available oceanic energy) and the actual intensification.

TCs draw their energy from warm ocean waters, but also cool the ocean surface directly beneath the storm by mixing up cold, deep water. This interaction is key in controlling hurricane intensity, but the mechanisms of the ocean-TC feedback effects remain largely unexplained. The deep moist convection of the TC eyewall links the surface layer below the storm to the upper troposphere and is, thus, at the heart of the TC thermodynamic cycle. The circular eyewall convection is comprised of deep cumulonimbus clouds of varying heights. The release of latent energy gathered at the air-sea interface turns the central cores of the cumulonimbus into "hot towers" with large rates of ascent (Riehl and Malkus, 1958). Occasionally an eyewall hot tower overshoots the tropopause and becomes a giant chimney with an incredibly strong updraft. These "chimney clouds" and their distinctive circular cold cloud shields are known as eyewall convective bursts.

The primary goal of this research is to better explain the ocean's role in fueling these TC eyewall convective bursts and the implications of the ocean-cloud interactions for TC intensity change. Improved insight into these interactions will provide increased understanding of the relationship between observable TC eyewall morphology and, still difficult to predict, TC intensification events.

2. OCEAN-ATMOSPHERE FEEDBACK

The energy released by an air parcel ascending within a TC eyewall is limited by two factors: the initial equivalent potential temperature of the inflowing air and the prevailing lapse rate. The moisture content of the inflowing air and the surface temperature
are directly affected by the temperature of the underlying layer of ocean. Through these mechanisms, the boundary layer temperature of the ocean regulates the energy available for TC formation, maintenance, and intensification.

Schade and Emanuel modeled the interactions between the ocean mixed layer and the TC and showed the SST-cooling response to a TC can dramatically affect the intensity of the hurricane itself (Schade and Emanuel, 1999). They show that the magnitude of this negative feedback is controlled by the:

- thickness of the ocean's mixed layer
- storm's translation speed
- aerial extent of the storm
- latitude of the storm
- large-scale atmospheric conditions affecting TC intensity
- oceanic structure below the mixed layer, and
- relative humidity in the atmospheric planetary boundary layer.

Several recent studies employed new technologies to detect and measure a positive feedback interaction of the ocean and the hurricane. In some cases the storm crossed a particularly warm deep oceanic feature, known as a warm core ring, shed from the Loop Current in the Gulf of Mexico. Shay *et al.* used upper-ocean heat measurements derived from AVHRR and TOPEX/Poseidon altimeter data to examine the strong effects of a warm core ring on the intensities of Hurricane Opal (1995) (Shay *et al.*, 1998). The ocean lost a significant amount of energy during Opal's intensification. The warm core ring provided plenty of oceanic energy for the storm. This energy loss occurred during a period of rapid intensification from 965 to 916mb when Opal's translation speed was greater than 8 ms^{-1}.

The two different perspectives reflected in the research literature highlight the reciprocal nature of the air-sea interaction in the TC. The results of all of these studies corroborate the argument that the oceanic background conditions should not be ignored in investigations of coupled ocean-atmosphere responses. New tools in meteorology and oceanography are making it possible to include interaction effects in research.

3. SCIENTIFIC RATIONALE

The details of the mechanics of the development of the warm core feature in a TC are still unexplained. The convective burst may be a key mesoscale energy transfer mechanism responsible for transporting great amounts of high-energy air from the planetary boundary layer to the upper troposphere, facilitating the warming

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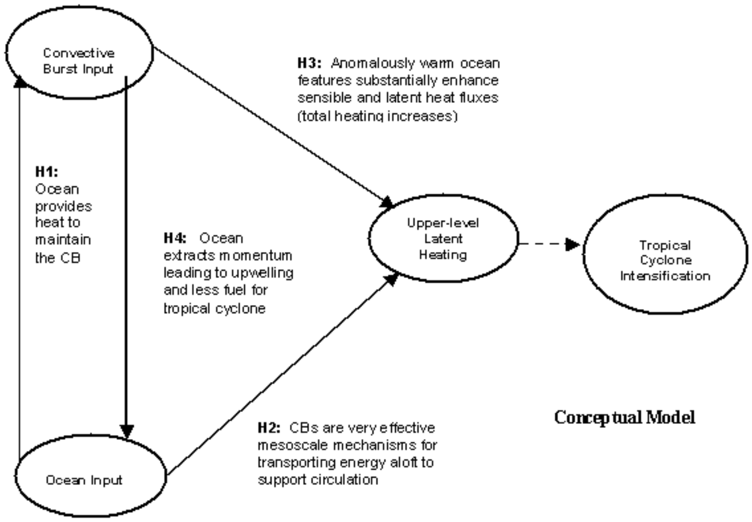

Conceptual Model

of the inner-core of the storm, and hydrostatically lowering the central surface pressure (Gentry, Rodgers et al., 1980).

A convective burst is "a mesoscale (i.e. 100 km by hours) system consisting of a cluster of high cumulonimbus towers within the inner-core region that approaches or reaches the tropopause, with nearly undilute cores" (Rodgers, Olson et al., 2000). In infrared satellite imagery, convective bursts are recognized by their anomalously cold, rapidly expanding, circular or elliptical cirrostratus cloud shield that initiates within 200 km of the circulation center and persists for longer than 6 hours. The NASA Tropical Rainfall Measuring Mission (TRMM) has provided detailed glimpses inside the structure of convective bursts in Atlantic and Pacific TCs. Previous remotely sensed imagery of convective burst events featured only an infrared overpass perspective of the giant cold cloud shield covering the storm center and obscuring the storm's convective structure. TRMM satellite images, along with coincident images from other space-borne observatories, are being used at NASA/GSFC to conduct a multi-year global survey of convective bursts in TCs. The resulting global distribution of convective bursts, including burst characteristics such as longevity, size, and initial conditions, provides an outstanding resource useful for understanding interactions between the changes in inner storm dynamics, via the convective burst, and the other mechanisms governing TC intensity.

4. OBJECTIVE

This research examines the cooperating interactions between the oceanic energy flux and the upward mass flux in the convective burst as an efficient mechanism for delivering latent energy to the TC eye. If the ocean forcing and the convective burst are working coactively, latent energy is efficiently being delivered to the upper levels where it is necessary to enhance TC intensification. If the fluxes are incongruous, the ocean and the convective burst will act in opposition. For instance, the convective burst may run out of fuel and begin to dissipate if the oceanic energy is insufficient. Or, as in the case of a highly asymmetric convective eyewall structure, the convective burst may become so vigorous as to disrupt the primary TC circulation, delivering latent energy less specifically. This study will be the first attempt to explicitly focus on any one forcing mechanism of the convective burst phenomenon. The objectives of this research are threefold: 1) Examine the mechanisms of tropical deep convection in an attempt to assess the ocean's contribution in convective burst initiation 2) Assess the importance of the cooperating interactions between oceanic energy flux and upward mass flux in the convective burst as an efficient mechanism for delivering latent energy to the TC eye 3) Gain insight into the relationship of convective burst events and TC intensity change.

5. METHODOLOGY

The conceptual model (shown above) will be divided into three separate statistical models for testing. A multiple regression of the factors influencing deep convection on convective burst initiation will show their relative importance. Confirmatory covariance structure modeling will assess the relationships between the ocean input factors and the convective burst input factors and the degree of the upper-level latent energy in the TC eye. Finally, descriptive statistics regarding the specific delivery of latent energy, via the convective burst, and TC intensity change will provide insight into this complex problem.

Data collection for these statistical tests will integrate convective burst characteristics (including environmental conditions at the time of burst initiation), historical TC intensity and track information, and contemporaneous measurements of upper-ocean energy content on a storm-by-storm basis from many different measurement platforms.

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