**Hurricane Research Science Team**
**Abstracts of selected proposals.**
**(NNH08ZDA001N-HRSP)**

For more than a decade, the NASA Convection And Moisture EXperiment (CAMEX) series of field campaigns have provided a wealth of new research findings into the genesis, intensity change, and 3D multi-scale structure of tropical cyclones in the Atlantic, Gulf of Mexico and Eastern Pacific ocean basins. The CAMEX sequence (CAMEX-3, 1998; CAMEX-4, 2001; TCSP, 2005; NAMMA, 2006) has also consistently provided a test-bed for new remote sensing technologies for satellite and aircraft platforms, retrieval algorithms, and predictive model developments. The scientific focus on intensity change is particularly timely in light of the current heightened era of Atlantic-basin storm activity and the continuing challenges of accurately forecasting tropical cyclone intensity. The data from these field experiments is archived at the following sites:

CAMEX: http://camex.msfc.nasa.gov
TCSP: http://tcsp.msfc.nasa.gov
NAMMA: http://namma.msfc.nasa.gov

Apart from these field experiments there is a wealth of data available from NASA research satellites such as TRMM, Aqua, CloudSat/CALIPSO, QuickScat, Jason etc. This satellite data has been used in isolated case studies of hurricane intensity forecasts and needs further exploitation in conjunction with the field experiment data to develop a more robust understanding of hurricane behavior. This opportunity relates to the use of field experiment and satellite data to better understand tropical cyclone genesis and intensification processes.

The selected Principal Investigators will become members of the NASA Hurricane Research Science Team. To round out the science team, six additional proposals were partially selected for participation only in this science team's activities. The funding for these additional proposals will be limited to approximately $20K per year and this amount is intended for covering only the expense of participating in the science team activities. This science team will assist NASA in assessing 1) to what extent data from the CAMEX, TCSP and NAMMA experiments and orbiting satellites can be used to answer the cyclone genesis and intensification questions? 2) What deficiencies remain? And 3) what is the most efficient manner in which existing resources can be used to design a future field experiment?

NASA received a total of 51 proposals in response to this NRA and has selected 11 at the present time. The Principal Investigators of six additional proposals have been recommended for selection for participating only in the Hurricane Science Team activities.

**Scott Braun/NASA Goddard Space Flight Center**
**Analysis of Atlantic Tropical Cyclone Genesis and Evolution Using NASA Satellite and Field Program Data**

Some studies have suggested that the Saharan Air Layer (SAL) has a positive influence on tropical cyclogenesis and evolution while others have argued that it has a negative influence. Many NAMMA investigators came away from the field program impressed by the prevalence of dust and convinced of the large role of the SAL in suppressing hurricane development. But is this emphasis on the SAL warranted? Is the impact of the SAL on cyclogenesis positive or negative? We will use data from a suite of instruments on NASA satellites including TRMM, MODIS, and AIRS for the period 2003-2007 to examine the evolution of SAL outbreaks and their relationship to tropical cyclogenesis and evolution. In addition, we will use large-scale analyses from NASA's GEOS-5 analysis system to relate the remotely sensed data to the large-scale wind fields over the Atlantic. Since data from MODIS and AIRS are not available within cloudy regions, we will use field program data from TCSP and NAMMA to look within selected cloud systems to determine the extent to which SAL air penetrates into the core of developing storms.

If the SAL's impacts are indeed negative, then an interesting problem arises in that some storms, when surrounded by dry SAL air, are still able to intensify. How is this the case? Montgomery and collaborators recently proposed a "marsupial" hypothesis in which storms reside within a protective pouch of atmosphere and therefore can be shielded from negative influences in their environment. Using satellite and field observations, along with numerical modeling, we will investigate the processes that allow intensification despite seemingly hostile environmental conditions. We will also investigate issues related to predictability of SAL-tropical cyclone interaction.

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**Shu-Hua Chen/University of California, Davis**
**The Impact of Saharan Air Layer on Tropical Cyclone Genesis and Intensification**

Recent research results have suggested that the Saharan Air Layer (SAL) may alter the intensity of Atlantic Tropical Cyclone (TC) activity. The alteration occurs through a variety of dynamical and thermodynamical processes, including the following: the entrainment of dry, stable air into storms, which promotes evaporatively driven downdrafts in TCs; the maintenance of a midlevel easterly jet due to warm SAL air, which increases vertical shear; and the interactions between dust and cloud/radiation, which modifies TC development as well as environment instability and moisture/energy budgets.

The central objective of this proposed work is to study the impact of SAL on TC genesis and intensification in terms of its warm and dry air, vertical shear induced by MLEJ, and Saharan dust through a suite of comprehensive numerical investigations. The investigations will also include analyzing the role of the environmental stability and the moisture and energy budget in TC genesis and intensification. To achieve these objectives an on-line tracer model, which includes the calculation of dust, will be developed based on the Weather Research and Forecasting (WRF) model. The WRF tracer model will be used to carry out numerical simulations and sensitivity tests. To improve the WRF performance and to validate the results, the dust emission parameterization and the assimilation of observations from satellites and the NASA African Monsoon Multidisciplinary Analyses (NAMMA) field experiment will be studied and applied to WRF tracer simulations.

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**William Cotton/Colorado State University**
**Estimation of African Dust Effects on Tropical Cyclone Intensity**

A three year program is proposed to study the effects of Saharan African dust on the development and intensity of tropical cyclones in the Atlantic. Using cloud-resolving real-data simulations with RAMS, both the direct radiative heating effects of Saharan dust and the indirect effects of dust on precipitation processes will be explored. At least three cases will be selected from the CAMEX sequence for which Saharan African dust was present (e.g., Chantal during CAMEX4 in 2001; Debby, Ernesto, and Gordon during NAMMA/SALEX in 2006). Other cases may also be selected for the 2008 and 2009 hurricane season (if applicable) to make use of CloudSat data. We will test the hypothesis that dust aerosols inhibit tropical cyclogenesis by varying the dust aerosols concentration within a wide range encompassing the observed values in our sensitivity experiments. The tropical cyclone simulations will also be validated against CAMEX datasets for the experiments with dust aerosol concentration closest to the observed value. The Maximum Likelihood Ensemble Filter (MLEF) will be used to estimate dust aerosol concentrations and their activity as cloud-nucleating aerosol from the Saharan Air Layer in the immediate environment of tropical cyclones using a suite of satellite sensors. We will examine how retrieved high dust loadings affect the mid-level easterly jet (MLEJ) through direct radiative heating changes in the thermal wind balance. In addition, indirect effects of dust through alterations in precipitation processes wherein dust can serve as cloud-nucleating aerosol will be explored. Furthermore, we will also incorporate sea spray's contribution to cloud condensation nuclei (CCN) and giant CCN (GCCN) in RAMS. Collaboration with Prof. Chris Kummerow's group is planned in which he will help us access and process satellite data and we will provide him with model output data for use in simulating satellite retrieval algorithms.

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**Robert Hart/Florida State University**
**Breaking the Barrier of Short-term Hurricane Intensity Forecasting by Interrogating Remotely Sensed and Reconnaissance Datasets to Predict Core Evolution**

Despite great advances in hurricane track forecasting, intensity forecasting remains a barrier. One reason is the predictability of convection, even when organized. However, a more important reason is that the focus has been on the environment, rather than the core. Building on the foundation of the PIs existing strong research, we will develop and test a new paradigm that seeks an improved understanding of the science of rapid intensity change.

The recent work of Hart and Piech (2007), utilizing 17 years of reconnaissance data, demonstrated distinct regimes (rather than a continuum) of eyewall type (concentric, elliptical and single). Additional results provided indicators of short-term intensity changes: eye temperature, dewpoint, equivalent potential temperature, eyewall tilt, and their spatial and temporal gradients. Further, the evolution of a storms core within an "eyewall phase space" was shown to be a highly useful to both visualize structural evolution as well as search for historical analogs.

Additionally, the eyewalls of hurricanes once were thought to be devoid of lightning. However, recent research has revealed that fluctuations in lightning appear to be related to changes in storm intensity and eyewall structure. These findings need much additional research to become useful predictors when synthesized with Hart and Piech (2007). The PIs will utilize their extensive experience relating lightning activity to thunderstorm severity and organization and apply it to the hurricane.

Through an improved understanding of rapid intensity change, we will develop an eyewall and wind speed forecast tool based on the hurricane core data from the larger remotely-sensed (e.g. AMSU, AQUA, TRMM, LLDN) plus reconnaissance datasets. It will be independently tested against the benchmarks of SHIPS. Through an examination of the forecast skill alongside the remotely sensed fields, insight into hurricane intensity predictability and the physics behind the fickle nature of eyewall evolution will be examined.

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**Gerald Heymsfield/NASA Goddard Space Flight Center**
**Multiscale Analysis of Tropical Storm Hot Tower and Warm Core Interactions Using Field Campaign Observations**

While tropical storm track forecasting has improved significantly over the past two decades, improvement in intensity forecasting has been slow. Previous CAMEX, TCSP, and NAMMA field campaigns provided rich data sets to study rapid intensification (RI) of hurricanes. Many processes contribute to RI such as environmental and oceanic factors but their relative importance requires much further study. There are yet many controversies over whether hot towers and convective bursts are important in RI. NASA-funded research (involving Co-I Halverson) used satellite-based studies to survey these extreme convective events. A three-year global census of bursts revealed that 80% of tropical cyclones contain one or more bursts, that these are most frequent during the genesis and intensification phases of the storm lifecycle, and that 68% of bursts were associated with storm deepening. Another TRMM-based study showed that the probability of intensification scales linearly with hot tower height; storms with eyewall hot towers exceeding 14.5 km were associated with 71% probability of deepening.

The physical processes involved in RI cover multiple scales ranging from the synoptic down to the convective and smaller scales. Investigations of these processes require use of a variety of data sets ranging from satellite observations, down to small scale aircraft in situ and remote sensing measurements. Previous studies by the investigators in this proposal dealt with multiscale observational studies of hot towers and convective bursts in Hurricane Bonnie (1998) and Tropical Storm Chantal (2001) from CAMEX-3 and CAMEX-4, respectively. These studies dealt with the detailed inner core structure of these storms from EDOP and other NASA remote sensing data sets. Ongoing studies of hot towers, convective bursts, and warm cores in hurricanes include Hurricane Emily (2005) from TCSP and Hurricane Bonnie (1998), as well as additional studies of tropical hot towers from the field campaign data sets.

The proposed research will complete major case studies for: a) Hurricane Bonnie with a focus on warm core/convective burst interactions over the 4 days of data collection, and b) environmental and other factors responsible for the intense convective burst in Emily Hurricane during the ER-2 flights. The Emily case provides a very interesting paradox in that the storm underwent no intensification during the most intense hot tower ever observed by EDOP. The Bonnie case provides a unique, fine-scale series of snapshots documenting the four dimensional warm core structure and evolution. It is crucial to understand how the warm core evolves, including the sense of its growth (top-down vs. bottom-up), horizontal expansion, anomaly growth, asymmetry, the response of sea level pressure through hydrostatic adjustment, and coupling to deep convection in the eyewall. Studies will be performed on convective bursts present in other tropical cyclones studied during the NASA campaigns: Dennis (2005), Gert (2005), and Helene (2006). Our overarching goal is to discern the convective- and mesoscale processes involved in the maintenance of convective bursts, their energetics, and feedback onto the larger vortex, using all available combinations of satellite, aircraft radar, flight level in situ and dropsonde data. Additional case studies may be examined as time permits, and we anticipate that the critical evaluation of our hypotheses can be used to guide planning for future flight modules designed to intensively sample convective bursts.

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**Robert Houze/University of Washington**
**Comparison of TCSP Hurricanes Dennis and Emily With RAINEX Hurricanes Katrina and Rita to Better Understand Rapid Intensification**

In 2005, the NASA-NOAA TCSP field program documented two hurricanes that underwent rapid intensification, Dennis and Emily. In the same year, the NSF-NOAA-NRL program RAINEX documented Hurricanes Katrina and Rita, which also underwent rapid intensification. These four storms had somewhat similar tracks and all made landfall on the Gulf coast making the 2005 Gulf/Caribbean hurricane season one of the most infamous of all time. This proposal takes advantage of the extraordinarily good datasets collected in both TCSP and RAINEX and the general similarity of these four storms by studying the rapid intensification phases of these four storms as a group, thus unifying the TCSP and RAINEX datasets. By applying similar methods to all four storms, we will gain generality of results not possible from a single case study. The objective of this unified analysis of all four storms is to advance understanding of hurricane rapid intensification, which is a primary national (and NASA) objective. This analysis will determine the relative roles of deep convection in the eyewall, mesoscale vortex dynamics, air-sea interaction, and interaction with the large-scale environment in the rapid intensification process. The research will be a team effort between U.

Washington and U. Miami. UW brings to the project extensive data analysis experience and tools for mesoscale analysis. UM brings a unique coupled atmosphere-ocean-wave high-resolution hurricane modeling system. It is the only such fully coupled model presently operating, and such a model is required if the TCSP and RAINEX data are to be used to advance knowledge of rapid intensification. The aircraft datasets of Doppler radar data and dropsondes of each of the four rapidly intensifying storms are excellent but lack the time continuity to identify the processes of rapid intensification. The UM model will be utilized to provide the needed time continuity.

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**Haiyan Jiang/University of Utah**
**A TRMM-based Tropical Cyclone Precipitation Feature Database and Its Usage on Intensification Study**

The central goal of this proposal is to create and maintain a 10-yr (1998-2007, possibly more) TRMM-based global tropical cyclone related precipitation feature database with QuikSCAT sea surface wind and numerical model-based reanalysis parameters on a common framework and make it available to the hurricane science team for tropical cyclone studies. Using this database, impacts of hot towers and convective bursts and environmental factors on tropical cyclone rapid intensification will be examined.

The University of Utah (UU) has developed a 'Precipitation Feature' (PF) database from more than 10 full years of TRMM observations including the precipitation radar, passive microwave, IR, and lightning data with NCEP reanalysis parameters added. This UU TRMM PF database provides us a very useful tool to analyze convective intensity by several TRMM-observed proxies and to investigate the influence of environmental forcing. Under the PI and Zipser's current PMM grants, we have done some preliminary work on generating level-2 of a TRMM-based tropical cyclone related PF (TCPF) database during a 9-yr period (1998-2006) including best track information, UU TRMM PF properties, and environmental parameters from the NCEP reanalysis. A total of 770 storms that reached tropical storm intensity level or above has been identified in all tropical cyclone basins around the globe. Six basins are considered: Atlantic (ATL), east-central Pacific (EPA), northwest Pacific (NWP), north Indian Ocean (NIO), south Indian Ocean (SIO), and South Pacific (SPA).

In this proposed work, the first objective is to complete level-1, 2, and 3 of the TRMM-based TCPF database by expanding it from 9 years to up to near current and including TRMM 3B42 rainfall, TMI sea surface temperature (SST), QuikSCAT sea surface wind and environmental parameters from the NOGAPS analysis to be compared with NCEP reanalysis. We'll maintain a user-friendly online-access of images and level-2 &-3 data of this TCPF database. The second objective is to examine the roles of convective bursts/hot towers and environmental forcing on the rapid intensification of tropical cyclones. We'll group TCPFs into non-intensifying and intensifying including rapid and slow intensifying stages. Both the individual and combinations of effects will be addressed for different basins in a statistical base. The third objective is to select top-rank (i.e., most rapidly intensifying) cases from the database and perform a more detailed examination by employing all available satellite and aircraft data sources, such as total precipitable water observations from SSM/I, water vapor channels from MODIS, and possible NASA field program dataset to identify successes and deficiencies of the statistical treatment from TRMM-based studies.

This proposed research fits into a special request of the announcement, which is "NASA also seeks proposals for building a database consisting of relevant NASA and NOAA satellite data on a common framework for the study of tropical cyclones and their environment." This research also addresses several questions in the announcement about tropical cyclone rapid intensification.

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**Tiruvalam Krishnamurti/Florida State University**
**Hurricane Genesis. Assimilation, High Resolution Modeling and Sensitivity Studies**

This proposal on hurricane genesis is prepared to address the NASA Hurricane Science Research Program NRA. Specifically it is aimed towards addressing the following questions.

1) Do environmental stability and moisture play key roles in determining whether disturbances develop or fail to develop into tropical cyclones? Or is the key factor related to dynamic processes and interaction with environmental vertical wind shear? Do vertical wind shear and dry air act together in a nonlinear manner to weaken insipient tropical disturbances and tropical cyclones?
2) What environmental (e.g. vertical wind shear, upper-level outflow jets, low to mid-level moisture, upper-level troughs), oceanic (e.g. warm eddies) and inner core (e.g. hot towers) factors govern rapid intensification?
3) Do hot towers and convective bursts play a major role or are they merely an indicator of energy conversion processes (e.g. associated with movement over a warm ocean eddy)?
4) What is the role of internal structure changes and storm asymmetries on tropical cyclone intensity change?
5) Does the formation of cyclonic vorticity at the surface originate at low levels and grow upward? What is the role of deep convection in this process?

We address the genesis issue of tropical cyclone using a state-of-the-art mix of satellites, research aircraft datasets from field experiments, data assimilation, mesoscale suite of models and process oriented post-processing.

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**Greg McFarquhar/University of Illinois**
**Application of NASA Field Observations, Satellite Retrievals and High-Resolution WRF Simulations to Study Physical and Dynamical Processes Governing Tropical Cyclone Rainfall and Intensity Change**

We propose to use observations obtained during the Fourth Convection and Moisture Experiment 4 (CAMEX-4), the Tropical Cloud Systems and Processes (TCSP) study, and the NASA African Monsoon Multidisciplinary Analysis (NAMMA) campaign, retrievals from the Tropical Rainfall Measuring Mission (TRMM) and high-resolution Weather

Research and Forecasting (WRF) model simulations to study how cloud and aerosol processes in tropical cyclones (TCs) impact intensity change and rainfall. The overarching motivation is to improve hurricane intensity and precipitation forecasts that have lagged improvements in hurricane track forecasts. Although cloud/aerosol processes need to be considered in the context of flow fields, wind shear, and other dynamical factors that affect TCs, we will examine the mechanisms by which they impact the four-dimensional distribution of latent heating, distributions of updrafts and downdrafts and intensity changes through 4 specific tasks:

1) We will use in-situ observations obtained during CAMEX-4 and NAMMA to quantify how the slope, shape, and y-intercept of gamma distributions of snow, graupel and rain depend on prognostic variables used in mesoscale model parameterization schemes (water content, temperature, vertical velocity) and determine how these relationships vary in different meteorological conditions (developing and non-developing waves, mature TCs) and location (eyewall vs. inner and outer rainbands, stratiform vs. convective regions, different quadrants).

2) Simulations of Hurricane Dennis 2005 and other TCs using WRF and state-of-the-art microphysical schemes modified to account for our findings in step 1) will examine mechanisms driving updraft and downdraft evolution, addressing the roles of microphysical processes (sublimation, evaporation, melting, conversions between different hydrometeor categories) in creating and maintaining penetrative downdrafts. Sensitivity studies, statistically evaluated using TCSP and TRMM observations, will relate distributions of updrafts and downdrafts to microphysical processes and the associated latent release heat in discrete TC regions (e.g., eyewall, rainbands).

3) A comprehensive set of aircraft and space borne passive microwave and radar observations to be constructed for a wide range of TCs will be used to examine the role of varying TC morphology on the microphysical structure, precipitation production, and track and intensity changes of TCs. The links between eyewall vertical convection, or “hot towers”, and eyewall replacement cycles as indicators of processes important to changes in TC intensity will be examined. We will also examine the roles of mixed-phase, inner-core precipitation processes during structural transitions.

4) Simulations initialized with an idealized pre-TC mesoscale convective vortex in the Colorado State University Regional Atmospheric Modeling System (RAMS) will examine how dust in the Saharan Aerosol Layer (SAL) acting as cloud condensation nuclei (CCN), giant CCN (GCCN) and ice nuclei (IN) impact TC intensity in a variety of meteorological conditions (e.g., varied strength of mid-level easterly jet, shear, temperature and humidity, trade wind inversion strength). The impact of changes in convective intensity induced by the CCN in the developing rainbands on latent heat release in rainbands and in the eyewall, on the blocking of radial inflow and on the production of a cold pool will be assessed in the context of how small perturbations in input fields affect their temporal evolution.

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**John Molinari/University at Albany, SUNY**
**Convective Bursts During Tropical Cyclone Formation and Intensification**

We propose to study several aspects of convective bursts in tropical cyclones. These bursts contain intense cells reaching above 15 km with cloud-top temperatures below -80º, and often contain temporal and spatial scales equivalent to those of "supercells" in the U.S. midwest warm season. In previously funded NASA work, we showed the significance of helicity in Hurricane Bonnie (1998) in identifying the regions where such cells develop in tropical cyclones. Helicity is one of the measures of an environment favorable for severe convection.

The proposed work contains three primary studies. The first extends our previous work to multiple storms in CAMEX-3 and CAMEX-4. We will test the hypothesis that intense convective bursts form in regions of large helicity. The bursts will be identified using TRMM precipitation radar and TMI 85 GHz ice scattering.

The second project examines helicity distribution within easterly waves in the NAMMA experiment. We will test the idea that waves develop into tropical cyclones only when helicity is sufficiently large to support long-lasting intense cells for an extended period of time. We hypothesize that the horizontal distribution of helicity plays a significant role in determining where within an easterly wave circulation that a tropical cyclone develops.

The third project is designed to measure the impact of clusters of intense convective cells in tropical cyclones, by determining their azimuthally-averaged impact on the mean tropical cyclone circulation. This idea follows the concept of "vortical hot towers" in that it argues for the upscale organization of individual cells during tropical cyclone formation.

The proposed work fits subgoal 3A of NASA, and particularly 3.A.2, "Improved predictive capability for weather and extreme weather events". The proposed work also directly addresses five of the critical questions from the Hurricane Science Research Program, as will be described within.

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**Michael Montgomery/Naval Postgraduate School**
**Use of NASA Observations and Numerical Model Simulations to Understand the Hurricane "Fuel" and "Anti-fuel" Problems**

This proposal lays out a course of research to improve our understanding of hurricane development and intensity through the examination of two complementary science problems focusing on the fuel (moisture) supply or lack thereof to the hurricane heat engine. The “fuel” and “anti-fuel” problems outlined here and the research methodologies proposed herein represent a quantum leap forward for addressing many of the hurricane science objectives of this NASA announcement.

Our research has demonstrated the multi-scale nature of the hurricane intensification and maximum intensity problems. In three dimensions, the vertically deep, but horizontally small-scale, mesovortices or vortical hot towers (VHTs) dominate the rapid intensification process. Of course, the boundary layer supplies fuel to the VHTs and also provides critical constraints on the evolution of the azimuthal mean vortex. Therefore, if we are to make progress on developing a deeper understanding of hurricane maximum intensity and rapid intensification we must learn more about the real boundary layer structure of an intensifying or weakening hurricane vortex.

The program outlined here will make use of field data from CAMEX-3/4, TCSP and NAMMA field campaigns, and the possible 2010 NASA field campaign. The latter may occur in conjunction with a proposed 2010 NSF collaborative field campaign led by the P.I., called PREDICT (PRE-Depression Investigation of Cloud-systems in the Tropics), which is a focused observational field campaign (with planned NOAA/HRD collaboration as part of the NOAA/IFEX) examining the subsynoptic- and mesoscale processes operating within the "marsupial wave pouch" that contribute to the formation of tropical depressions in the Atlantic basin.

Being an outgrowth of the marsupial paradigm, the "fuel" and "anti-fuel" problems presented here naturally call for coupling satellite and global model analyses to explore interactions between tropical cyclones and their environment (including the SAL), and for linking the hurricane boundary layer with the convective VHT scales. We believe that this research program will enable breakthroughs in our understanding of tropical cyclone genesis, intensification, and weakening episodes as well as the role of the SAL for Atlantic tropical cyclones, some of which become hurricanes that threaten populated areas, particularly the Eastern and Gulf coast states in the United States.

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**Elizabeth Ritchie/University of Arizona**
**Satellite-based Observations for Understanding and Predicting Tropical Cyclogenesis**

Recent studies have shown that tropical cyclone development is most likely a complicated interaction between processes within cloud clusters and the surrounding favorable larger-scale environment. Therefore, our ability to predict both the location and timing of genesis will be limited by our ability to identify both the mesoscale and large-scale processes. At the heart of the forecast problem is a lack of knowledge of the physical changes that occur during tropical cyclogenesis. Here, a study of TC genesis is proposed that focuses on identifying the environmental and microphysical differences between developing and non-developing cloud clusters and using these discriminating factors to build predictive tools based on remotely-sensed data.

The key NASA science questions that are addressed are:

1. Do hot towers and convective bursts play a major role or are they merely an indicator of energy conversion processes?
2. Does the formation of cyclonic vorticity at the surface originate from midlevel cyclonic vorticity that builds downward, or does it originate at low levels and grow upward? What is the role of deep convection in this process?

In addition:
3. What remote sensing products allow the key processes to be observed, and can we develop automate tools that will aid the forecaster in reliably identifying developing clusters?

The main resources that will be used for the study are observations gathered during the CAMEX and TCSP field campaigns, in conjunction with the NASA suite of satellites, and the WRF mesoscale model. The program includes a detailed investigation of the microphysical differences between developing and non-developing cloud clusters on a case-by-case basis using the field observations to constrain mesoscale model simulations of genesis, as well as a more generalized study that aims to build an ability to detect and classify developing and non-developing cloud clusters using remote-sensing platforms alone.

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**Robert Rogers/NOAA/AOML**
**Tropical Cyclone Precipitation Structure and Evolution and Its Role in Rapid Intensification**

One of the most challenging aspects in tropical cyclone research is developing an improved understanding of the processes underlying rapid intensification (RI). This task is challenging because the processes important in RI span spatial scales of many orders of magnitude from the synoptic-scale to the microscale. While the importance of environmental fields is fairly well-established, what is not as well understood are the roles of convective-scale and microscale processes and their interaction with the vortex.

Observational and modeling studies have linked RI to the occurrence of deep convection, sometimes referred to as convective bursts, within the core. The goal of this research is to better understand the structures of these convective bursts, how they evolve, and how that evolution feeds back onto the vortex-scale circulation. To accomplish these goals the following questions will be addressed:

- What are the dominant convective and microphysical structures associated with convective bursts?
- What is the feedback of convective bursts on the vortex-scale circulations? Is it tied to the strong or moderate cores?
- Is there something unique about the structure of the convection for bursts that are associated with RI compared with bursts that are not associated with RI?
- Can current high-resolution models capture these structures?
- Can they differentiate between burst structures that may be more conducive to RI vs. burst structures that are not as conducive?

These questions will be addressed through a combination of observing platforms and high-resolution modeling. For the observations, satellite data from TRMM and CloudSat and airborne Doppler data will be used, as well as microphysical probe measurements from previous joint NASA-NOAA field campaigns (CAMEX-3, -4, TCSP, NAMMA). For the models, both the WRF-NMM and WRF-ARW will be run at cloud-resolving grid length for comparison with the observations and with each other.

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**Nick Shay/University of Miami/RSMAS**
**Improving the Satellite-Derived Ocean Heat Content Index for Tropical Cyclone Intensification Potential**

This proposed project, as part of the Hurricane Science Research Program, is designed to exploit satellite altimetry and satellite-derived SST measurements in conjunction with in-situ observations and an ocean general circulation model to improve our physical understanding of how the ocean responds to intense tropical cyclone (TC) forcing. This understanding will then be applied to improving our capability of using satellite data to achieve two goals: (1) enhance our capability to forecast TCs, particularly intensity evolution; and (2) advance our understanding of the cumulative TC impact on upper-ocean circulation and heat content to determine if this impact influences short-term climate fluctuations in the upper ocean.
The goal of improving intensity forecasts can be achieved by two methods: The first method is to improve intensity forecasts produced by statistical models such as the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS) by providing improved oceanic heat content (OHC) estimates as input. To improve OHC estimates, parameters of statistical-dynamical models presently used to estimate OHC from satellite altimetry and SST fields will be carefully calibrated and thoroughly evaluated against ARGO float profiles and other high-quality in situ observations. The second method is to optimize the ocean model initialization in coupled TC forecast models in terms of the initial horizontal distribution of OHC and of upper-ocean stratification. Since future plans include using regional to global ocean hindcasts produced as part of the Global Ocean Data Assimilation Experiment (GODAE) to provide the initial fields, the capability of one ocean nowcast-forecast system based on the HYbrid Coordinate Ocean Model (HYCOM) will be thoroughly evaluated. This model is chosen because the HYCOM-based nowcast-forecast product produced at NOAA-NCEP is the initial GODAE product selected to provide this initialization, and also because this model is presently undergoing evaluation as a candidate ocean model for the new HWRF coupled forecast model. Since this nowcast-forecast system assimilates subsurface profiles from ARGO floats and other in-situ data in addition to satellite altimetry and SST, the capability of this system to estimate OHC maps will be evaluated against the statistical-dynamical method, and both methods will be evaluated against high-quality observations that were not assimilated. Optimal OHC fields will be generated to perform the planned scientific analyses. This project will focus on two TC regions: the North Atlantic and eastern North Pacific Oceans.
The goal of understanding the cumulative dynamical and thermodynamical consequences of TC forcing will be explored as follows: The surface ocean response patterns that are

observed by satellite in TC wakes, especially sea surface temperature cooling, will be related to isotherm displacements, sea surface depressions, and OHC decreases to understand how the surface signals of the TC response are related to the three-dimensional upper-ocean dynamical and thermodynamical response. The working scientific hypothesis is by carefully combining SSTs with the surface height anomaly (SHA) fields from multiple satellite platforms, our understanding of the cold wakes will improve for a broad spectrum of storms with varying intensity, radius of maximum wind, storm speed, latitude and oceanic stratification. The end product will be a storm climatology that includes SST, SHA and OHC changes and currents relative to observed atmospheric parameters, which will then be analyzed to detect potential impacts on short-term climate fluctuations in the upper ocean. Storm climatologies derived from satellite and in situ observations alone and from the HYCOM global ocean hindcasts will be compared and evaluated for this purpose.

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**Eric Smith/NASA Goddard Space Flight Center**
**Investigating Relationships Between Eyewall Replacement, Dynamical Intensification, Precipitation, and Meteorological-Radiative Signatures in Atlantic Tropical Cyclones**

The proposed investigation is focused on understanding what governs post-eyewall replacement intensification in tropical cyclones (both tropical storms and hurricanes). The investigation will consider some 40 Atlantic storms that took place during the 1998 - 2006 time period including 16 tropical cyclones that were sampled during the four recent NASA hurricane field experiments (i.e., CAMEX-3 1998, CAMEX-4 2001, TCSP 2005, NAMMA 2006). The foremost scientific objective is to determine through a 'superposed epoch' compositing analysis what small scale and large scale processes govern whether intensification takes place or does not take place following the completion of an eyewall redevelopment process in the course of an eyewall replacement cycle. This represents the first investigation to use a wide spectrum array of satellite, aircraft, and model-generated datasets to understand how physical processes and atmospheric-ocean parameters behave during the intensification stage of tropical cyclone. Our proposal responds to NASA's Earth Science Strategic Subgoal 3A: Study Planet Earth from Space to Advance Scientific Understanding and Meet Societal Needs -- Question 3A.2 Enable Improved Predictive Capability for Weather and Extreme Weather Events. The research is most closely related to 'Key Science Question' Number 6 in the Proposal Opportunity section of Roses (Section 1.2): What is role of internal structure changes, including rainbands, eyewall replacement cycles, and storm asymmetries on tropical cyclone intensity change?

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**Christopher Thorncroft/University at Albany, SUNY**
**Tropical Cyclogenesis Associated with African Easterly Waves**

While it is well known that most of the Atlantic tropical cyclones develop in association with African easterly waves (AEWs), there are still big gaps in our knowledge and understanding of the processes associated with this. Related to this, we still are unable to distinguish with confidence the AEWs that will be associated with tropical cyclogenesis and those that will not. Recent work by the PI has highlighted one particular aspect of the

AEW life-cycle over West Africa that has important relevance for this problem. Just before reaching the ocean AEWs are often associated with significant bursts of convection in the region of the Guinea Highlands, one of the wettest regions on the African continent. These bursts of convection result in significant production of potential vorticity (PV). The hypothesis that will be investigated in this project is that PV-mergers in the vicinity of the Guinea Highlands and just downstream can provide ideal “seedlings” for the genesis of tropical cyclones in the East Atlantic. The project will combine analysis of NAMMA observations, satellite products and high resolution modeling to explore the processes associated with the passage of AEWS over the Guinea Highlands and the extent to which they produce favorable or unfavorable seedlings for tropical cyclogenesis. As well as providing new insight into the role of AEWs on tropical cyclogenesis the results from this work will guide future field campaigns in this region.

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**Edward Zipser/University of Utah**
**Formation and Rapid Intensification of Tropical Cyclones: Intense Convective Events vs. Large Scale Controls**

The overarching scientific question that excites this community is whether intensification of a tropical wave into a cyclone is determined by its large-scale environment, or whether the nature, intensity, and organization of the deep convective systems within the wave are important as well. This issue can only be resolved by adequate measurements of both the environment, and the smaller-scale convective systems. For example, how frequent are the suspected 'vortical hot towers' in cases of rapid intensification, and does the vortex develop from the bottom-up or from the top-down? NASA’s single-aircraft deployments in TCSP and NAMMA were successful and obtained very interesting datasets, but they are insufficiently detailed to answer these questions.

When the PI’s current TCSP and NAMMA grants expire in 2008 and 2009, respectively, some case studies from those programs will be completed, but additional work will be necessary. For example, Debby and Helene formed just off the African coast, and numerical simulations will be required to compare with measurements from the research aircraft. We now know that the NASA DC-8 obtained excellent data on microphysics (including aerosols) in several non-developing African waves that remain to be modeled and analyzed. We speculate that numerical simulations may erroneously predict intensification for these cases.

The PI has shared leadership roles in NASA aircraft field programs in TOGA COARE, CAMEX 3 and 4, TCSP, and NAMMA. He has maintained and fostered close working relationships with counterparts in NOAA’s Hurricane Research Division, an institutional partnership that will be very important in future field programs for improved understanding of how tropical cyclones form and especially how they sometimes change intensity rapidly. This proposal aims to help diagnose the shortcomings as well as the successes of these previous field programs, and to use that knowledge to assist in planning future programs with an efficient, optimal mix of proven and new technology. The goals include capability for improved multi-scale datasets to study intensity change, as well as evaluation of candidate spaceborne technologies.