UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

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The attached proposal is being submitted to you for your consideration by a NOAA Cooperative Institute. Should you recommend funding for this proposal, we request that the funding be transferred through our current NOAA cooperative agreement # NA10OAR4320143. The NOAA contact (described below) for this cooperative agreement should be contacted immediately if this proposal is accepted for funding.

Title of Proposal: Inclusion of Turbulent Effects Quantified by In-Situ Observation for Horizontal Parameterization in HWRF System

Principal Investigator(s): Xuejin Zhang and Jun Zhang

Proposal # R1300145

Period of Performance: 8/1/13-7/31/15

Funding (by year, if multi-year): $52,237 (yr. 1); $51,698 (yr. 2); $103,935 (total)

Task #: 3

Theme(s): (2) Tropical Weather

NOAA Goal: Weather Ready Nation

DUNS #: 152764007 EIN# 59-0624458 Congressional District: 18

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Please answer all questions

1. Is there a former DOC employee working for the CI host institution who represented or will represent the host institution before DOC or another Federal agency regarding this proposal? ☒Yes ☐No
2. Does this award include any sub award to a Minority Serving Institution? ☐Yes ☒No
3. Does the proposed award require any non-federal employees or sub awardees to have physical access to Federal premises for more than 180 days or to access a Federal information system ? ☐Yes ☒No
4. Is PROGRAM INCOME anticipated being earned during performance of this project? ☐Yes ☒No
5. Will a VIDEO be created for public viewing be part of this project? ☐Yes ☒No
6. Will DOC/NOAA owned equipment be provided to any investigator for use outside a Federal location for this project? ☐Yes ☒No
7. Are any permits required to conduct this project? ☐Yes ☒No
(If yes, please provide the name of the issuing agency and the permit number.)

RESEARCH PROPOSAL SUBMITTED
TO THE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)

Joint Hurricane Testbed (JHT) Program

TITLE: Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System

PERFORMANCE PERIOD: August 1, 2013– July 31, 2015

AMOUNT REQUESTED:

Year 1:UM/CIMAS: $52,237, NOAA/AOML: $30,988, NOAA/ESRL: $29,729, Total: $112,954
Year 2:UM/CIMAS: $51,698, NOAA/AOML: $32,579, NOAA/ESRL: $31,115, Total: $115,392

SUBMITTING DATE: December 7, 2012

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New proposal to

National Oceanic & Atmospheric Administration (NOAA)
Joint Hurricane Testbed (JHT) Program

for

Inclusion of Turbulent Effects Quantified by In-Situ Observation for Horizontal Parameterization in HWRF System

by

University of Miami
Rosenstiel School of Marine & Atmospheric Science
4600 Rickenbacker Causeway
Miami, FL 33149

PRINCIPAL INVESTIGATOR: Xuejin Zhang

PERIOD OF ACTIVITY: August 1, 2013 – July 31, 2015

AMOUNT REQUESTED:
Year 1: $ 52,237
Year 2: $ 51,698
Total: $103,935

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New proposal to

National Oceanic & Atmospheric Administration (NOAA)
Joint Hurricane Testbed (JHT) Program

for

Inclusion of Turbulent Effects Quantified by In-Situ Observation for Horizontal Parameterization in HWRF System

by

University of Miami
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4600 Rickenbacker Causeway
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PRINCIPAL INVESTIGATOR: Jun Zhang

PERIOD OF ACTIVITY: August 1, 2013 – July 31, 2015

AMOUNT REQUESTED: Year 1: $ 52,237
Year 2: $ 51,698
Total: $103,935

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A RESEARCH PROPOSAL SUBMITTED
TO THE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)
Joint Hurricane Testbed (JHT) Program

For the
Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway
Miami, Florida 33149

TITLE: Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System

PRINCIPAL INVESTIGATOR: Sundararaman G. Gopalakrishnan, NOAA/AOML/HRD

PERFORMANCE PERIOD: August 1, 2013 – July 31, 2015

AMOUNT REQUESTED: Year 1: $ 30,988
Year 2: $ 32,579

SUBMITTING DATE: December 7, 2012

Endorsements:

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A RESEARCH PROPOSAL SUBMITTED
TO THE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)
Joint Hurricane Testbed (JHT) Program

For the
Earth System Research Laboratory
325 Broadway
Boulder, Colorado 80305

TITLE: Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System

CO-PRINCIPAL INVESTIGATOR: Jian-Wen Bao NOAA/ESRL/PSD

PERFORMANCE PERIOD: August 1, 2013 – July 31, 2015

AMOUNT REQUESTED: Year 1: $ 29,729
Year 2: $ 31,115

SUBMITTING DATE: December 7, 2012

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Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System
(*In Response to NOAA-OAR-OWAQ-2013-2003469*)

PI: Dr. Xuejin Zhang, RSMAS/CIMAS, University of Miami
Co-PI: Dr. Jun Zhang, RSMAS/CIMAS, University of Miami
Dr. S. G. Gopalakrishnan, NOAA/OAR/AOML/HRD
Dr. Jian-Wen Bao, NOAA/OAR/ESRL/PSD

Proposed cost: **Year 1: $112,954, Year 2: $115,392**
Budget period: **1 August 2013 – 31 July 2015**

Abstract

Recent sensitivity studies with the HWRF modeling system by Bao et al. (2012) and Gopalakrishnan et al. (2012a and b) shows that Tropical Cyclone (TCs) intensity prediction is critically dependent on horizontal and vertical diffusion. While turbulence is three dimensional especially in the eye-wall region in hurricanes, the effects of horizontal diffusion is not being correctly incorporated in most numerical models including the HWRF system. In this work, we propose to modify the horizontal diffusion parameterization in the HWRF system to take into account the turbulence kinetic energy (TKE) based on flight level and Doppler based observations of mixing length as well as TKE in TCs under different wind regimes. In order to attain our objectives, currently available TKE-based physics options in the HWRF model system such as MYJ, MYNN2, MYNN3 and other non-local schemes will be firstly tested. The results will be evaluated using various performance metrics and the observational analysis techniques that have been recently established and documented by Zhang and Montgomery (2012). The modified scheme configuration will be further calibrated and refined through retrospective forecasts of multiple seasons for weak and strong storms and eventually in parallel real-time forecasts. The performance of the HWRF system with the new parameterization scheme will be verified for tracks and intensity.

Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF system

(*In Response to NOAA-OAR-OWAQ-2013-2003469*)

Statement of Work

1. **Project Duration:** 2 years: August 1, 2013 - July 31, 2015
2. **Project Description**

2.1 Background

Scientists have strived on utilizing existing and new hurricane observations and advancing the hurricane forecast numerical modeling system for decades. Since NOAA launched Intensity Forecasting Experiment (IFEX) in 2005, the research and development activities has achieved several milestones and collected large of amount of data to address the goals on monitoring TC intensity, structure, and environment, and improving understanding of physical processes for the abrupt intensity change of TCs (Rogers et al. 2006; Rogers et al. 2012). Besides the annual IFEX, several special hurricane field campaigns conducted in the past decade have also provided tremendous data from different aspects to address the TC intensity, structure, and forecast issues. The Coupled Boundary Layer Air-Sea Transfer (Black et al. 2007) observed the air-sea exchange processes in the high wind regime. The Genesis and Rapid Intensification Processes (GRIP) experiment of NASA in 2010, by using new remote sensing instruments for wind and temperature, improved characterization of TC structure and environment that could lead to better understand how TCs form and develop into major hurricanes (Zipser et al. 2012). The PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT) field experiment sponsored by the National Science Foundation (NSF) explored multi-scale interactions on tropical wave-like disturbances that promote or hinder the development of a tropical depression vortex in the Atlantic basin (Montgomery et al. 2012). Historical NOAA's research surveillance observations, all above-mentioned special field experiments, and air force and NOAA's operational observations give comprehensive datasets for scientists to understand the physical processes for structures, ambient circulations, and intensity abrupt changes of TCs and apply the physical understandings to validate the model physical parameterizations (e.g. Lorsolo et al. 2010; Zhang and Montgomery 2012; Davis and Ahijevych 2012; Rogers et al. 2012), hopefully improve the forecast modeling system (*e.g.* Gopalakrishnan et al. 2012a; Gopalakrishnan et al. 2012b; Rogers et al. 2012).

Meanwhile, current operational regional hurricane forecast systems, such as the Hurricane Weather Research and Forecasting forecast system that is being operated at a horizontal resolution of down to 3 km by employing moving nest algorithm, could capture detailed structures and physical processes of tropical cyclones (*e.g.* Gopalakrishnan et al. 2012b). The research community even explores the horizontal resolution of less than 3 km thus could resolve the detailed processes (Davis et al. 2008). *The current challenges are how to better understand and identify the physical processes that depict the TC intensity changes, how to translate these observational understandings into calibrating the high-resolution model physical parameterizations, thus, result in effective improvement of the forecast system and more accurate forecast guidance for operational forecast community.*

2.2 Motivation and Objective

Turbulent transport has been regarded as a critical physical process in the intensification and maintenance of a tropical cyclone. In particular, ones recently found that horizontal momentum diffusion could play an important role in intensifying hurricane and reaching the maximum potential intensity (e.g. Emanual 1997; Bryan and Rotunno 2009, BR09 hereafter). A common parameterization scheme for determining the horizontal diffusivity coefficients originated with Lilly (1962) and Smagorinsky (1963). By assuming the subgrid turbulent flow is statistically steady and homogeneous, and assuming the production of subgrid energy is balanced by dissipation, one obtains parameterization formulations in which the diffusivity coefficients are proportional to horizontal turbulence length scale, l_h^2 multiplied by the strain rate of horizontal flow. Technically, the length scale, l_h, should be set to the filter scale (*i.e.* the scale where the filter begins to remove subgrid turbulent fluctuations). In practice, l_h is typically set to the grid spacing. A recent work by BR09 indicates that maximum intensity of model-simulated TC is strongly affected by the l_h but not by the vertical turbulence length scale (l_v). Such sensitivity is also seen in other metrics of TC intensity and structure, including: maximum surface wind speed, minimum sea-level pressure, surface wind-pressure relationships, height of maximum wind, and surface inflow angle. They recommend that model settings l_h = 1000 m, l_v = 50 m, together with the ratio of surface exchange coefficients for enthalpy and momentum C_k/C_d = 0.5, produce the most reasonable match to the observational studies (Zhang et al., 2008). However, caution should be taken when applying these results to the operational HWRF model because the turbulence parameterization scheme used in the HWRF model is not the same as the model in the studies cited above.

The HWRF system that uses the WRF–NMM dynamical core with a capability of moving nests, the horizontal diffusion was pragmatically formulated by a 2nd order Smagorinsky-type parameterization scheme modified by Janjic (1990). It is proportional to the grid size and a flow-dependent term proportional to the horizontal deformation. The flow dependent term also includes a TKE term that accounts for the vertical diffusion as well. However, in order to be consistent to the physics of NCEP/EMC's upstream model for the purpose of model initialization and data assimilation, the HWRF model is currently run with the GFS PBL scheme, which does not produce TKE. Clearly the vertical and horizontal diffusion schemes are not linked tightly in the current implementation of the HWRF model. The strength of the parameterized horizontal diffusion is underestimated, particularly in the highly turbulent eyewall of tropical cyclones if it does not include the term related to TKE. This known underestimation of horizontal diffusion is simply offset by grossly increasing the horizontal diffusion in the model (Gopalakrishnan et al., 2012a). In summary, the current formulation of horizontal diffusion effect in HWRF may need to be replaced with a physically consistent approach that accounts for the three dimensional nature of observed turbulence in hurricanes (*e.g.* Figure 1).

Another parameterization scheme for determining the horizontal diffusivity coefficients, which was introduced by Lilly (1967) and implemented by Deardorff (1980), is to relate horizontal diffusivity to the subgrid TKE where l remains the same definition of length-scale that is used in the above Smagorinsky's formulations. Such a scheme requires additional predictive equations to solve for the subgrid TKE required in this parameterization scheme with minimum computing overhead. The ability to transport the subgrid TKE across the three dimensional grid boxes (by advective and diffusive transport) in this scheme has been shown to be advantageous for physical processes like cloud edges and entrainment zones. It should be systematically tested if this scheme remains advantageous for the entrainment processes in the inner core of TCs before it is implemented in the HWRF system. Clearly the vertical and the horizontal diffusion schemes are not properly linked in the current operational HWRF system.

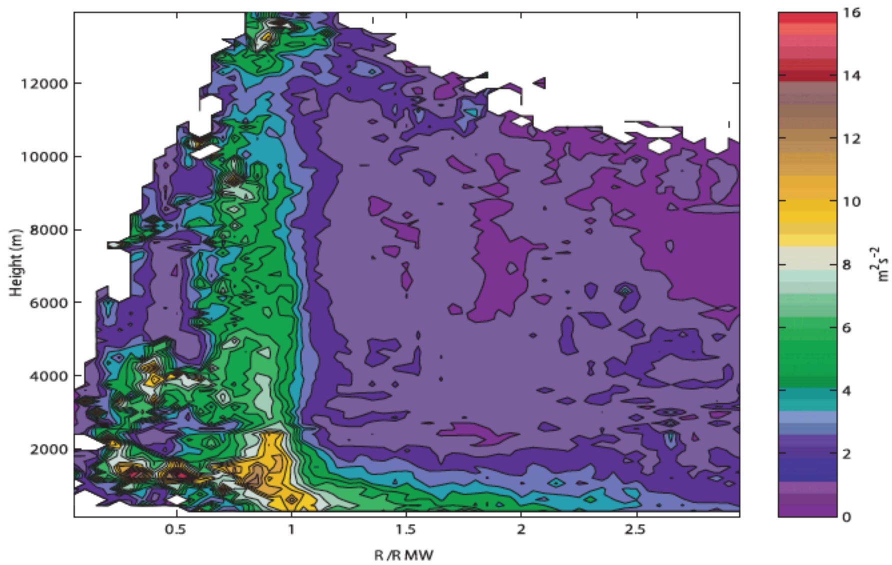

Figure 1. The mean R-Z cross-section of composite TKE distribution for all considered legs. Scaled by the RMW (Lorsolo et al. 2010).

The objective of this proposal is to improve the horizontal diffusion parameterization in the operational HWRF system by using the most recent observations. This study is expected to provide an operational pathway for more realistic representation of horizontal diffusion by accounting for the inhomogeneous turbulent effect under the TC strong and weak wind regime. It will address EMC's priority: "*EMC-3 Improvement specific to operational HWRF modeling system", i.e., "2) Improvements to physics suitable for high resolution (~3 km or less) including air-sea transfer physics in high wind conditions, representation of convection, moist cloud physics, planetary boundary layer and radiation. Emphasis is on improved predictive skill for rapid intensity changes."*

2.3 Previous Work

2.3.1 The Current Operational HWRF Modeling System

The HWRF system is a regional operational hurricane forecast system, which utilizes the WRF model software infrastructure. The system consists of the NMM dynamic core (called WRF-NMM hereafter), the three-dimensional Princeton Ocean Model (POM), the NCEP coupler, and a physics suite tailored to the tropics, including air-sea interactions over warm water and under high wind conditions, and boundary layer and cloud physics developed for hurricane forecasts (Gopalakrishnan et al, 2010). The system also enhances the WRF-NMM by adding the moving nest capability, vortex initialization including a vortex cycling mechanism, and a Gridpoint Statistical Interpolation (GSI) data assimilation system for hurricane forecast applications.

In the current operational implementation, the operational HWRF model employs three domains: a coarse grid (27-km horizontal resolution) and two movable nests (3-km horizontal resolution domain nested in 9-km horizontal resolution domain), with two-way interaction. When there is more than one TC active in a TC forecast basin (e.g., the Atlantic basin, the East Pacific basin), more than one run of HWRF are launched so that every storm has its own higher resolution nest.

Table 1 is shown a current configuration in operational HWRF modeling system.

	2012 HWRF Operational
Domain	27 KM: 77.76° X 77.76°; 9 KM: 10.56° X 10.2°;3 KM: 6.12° X 5.42°
Vortex Initialization	Modified Vortex Initialization at 3 KM, with 30x30° analysis domain and GSI
Cycling	Yes (3 km vortex only)
Ocean Coupling	27-9 KM: Yes; 3 KM: No, Downscaled
Physics schemes	
Microphysics	Modified Ferrier (High-Res)
Radiation	GFDL
Surface	GFDL (High_res)
PBL Scheme	2012 GFS (High_res)
Convection	SAS (High-Res), No CP (3 KM), Shallow Convection
Land Surface	GFDL Slab
GWD	Yes(27km); No(9-3km)

Table 1. HWRF model configuration.

2.3.2 Previous Results on Horizontal Diffusion Sensitivity

Based on experimental HWRF (HWRFx) (Zhang et al. 2011), a series of idealized experiments are performed to examine the sensitivity of idealized TC intensification to various physical parameterization schemes. Comparisons of the sensitivity runs indicate that different PBL physics parameterization schemes for vertical subgrid turbulence mixing lead to differences not only in the intensity evolution in terms of 10-meter maximum wind and minimum mean sea level pressure, but also in the structural characteristics of the simulated tropical cyclone (Bao et al. 2012).

Meanwhile, our preliminary study with HWRFx indicates tracks and intensities of TCs are critically dependent on the horizontal diffusion as well (Gopalakrishnan et al. 2012a). Unlike the WRF-NMM system, the HWRF/HWRFx systems are operated with the GFS physics package that does not include an additional equation for the TKE. One can expect an effective reduction of horizontal diffusion in HWRFx. An experiment with a factor of roughly 6 in comparison with the control run, which can compensates the horizontal diffusion reduction of the control run in the nest domain, was designed to test the sensitivity of the horizontal diffusion. Figure 2 shows an increase in horizontal diffusion in the moving nest (H3Chwrf) produces small improvements to track predictions compared to the H3hwrf results at all forecast intervals and these improvements are statistically significant at 12, 72, 84, and 108h (Figure 2a). In addition, H3Chwrf results demonstrate large improvement to the intensity predictions compared with H3hwrf that are statistically significant at all forecast intervals (Figure 2b).

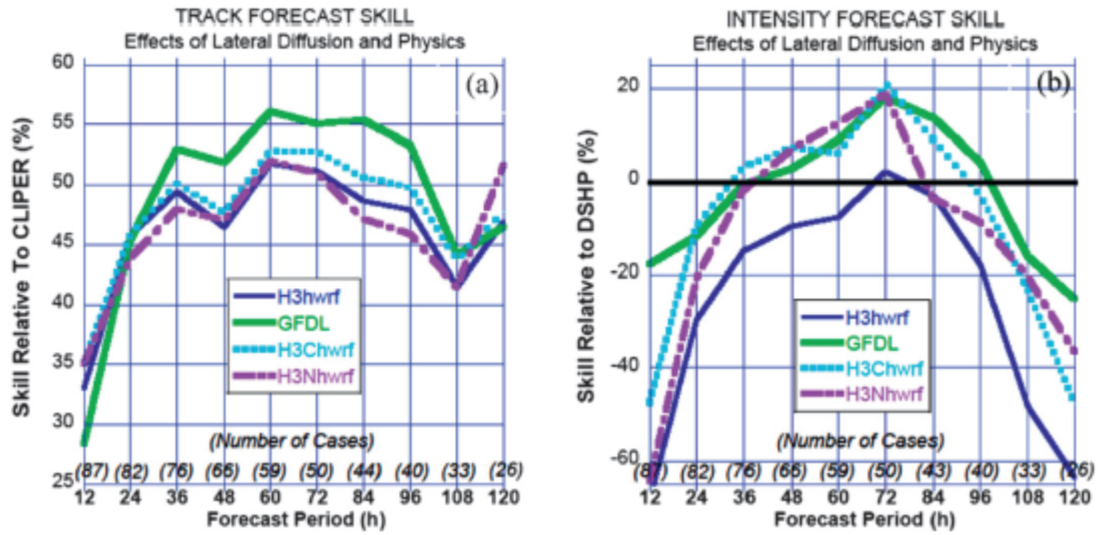

Figure 2. Verification of HWRFx (a) track errors (skill relative to CLIPER) and (b) intensity errors (skill relative to DSHIPS) for all storms. Effect of the enhanced horizontal diffusion on 3-km HWRFx runs with operational HWRF initial conditions. H3Chwrf and H3hwrf are shown in cyan and blue respectively (Gopalakrishnan et al. 2012).

Recently, in collaboration with EMC, a parallel experiment was undertaken during the 2012 hurricane season, in which the current GFS parameterization scheme in HWRF was replaced along the vertical with the TKE scheme MYJ (Janjic 1990). Our preliminary results indicate that the TKE scheme may be a viable option for the operational HWRF. However, in current implementation, the horizontal diffusion is not linked to the TKE parameterization. We believe that further improvement to model forecast of intensity may be achieved by an implementation of the three-dimensional TKE scheme within the operational HWRF modeling system.

2.3.3 Previous Observation Findings

Our previous work has developed an advanced observational dataset for study turbulence in hurricanes. These data include fast-response (40 Hz) flight-level data collected by NOAA's WP-3D aircraft in the hurricane boundary layer (60-400 m above the sea surface) during the Coupled Boundary Layer Air-sea Transfer (CBLAST) experiment (*e.g.* Zhang et al. 2008) and flight-level data (1 Hz) from the periods of eyewall penetrations in the intense Hurricanes Allen (1980), David (1986), and Hugo (1989). Zhang and Montmmoery (2012) analyzed the data from the above storms to estimate the horizontal eddy momentum flux, TKE, horizontal eddy diffusivity and horizontal mixing length. They found that the horizontal momentum flux and horizontal diffusivity increase with increasing wind speed. They also found that the magnitude of the horizontal momentum flux is comparable to that of the vertical momentum flux, suggesting that horizontal mixing by turbulence is important in the hurricane boundary layer, especially in the eyewall region. Within the context of simple K-theory, their results suggest that the average horizontal eddy diffusivity and mixing length are approximately 1500 m^2 s^{-1} and 750 m, respectively, at ~500 m altitude in the eyewall region corresponding to the mean wind speed of approximately 52 m s^{-1}. The horizontal mixing length increases slightly with wind speed, but is not significantly dependent on the wind speed. These results will provide us guidance for improving the horizontal diffusion parameterization in hurricane models.

2.4 Scope of Proposed Work

We propose to improve the horizontal diffusion parameterization in the operational HWRF system using the most recent observations. Observational data of the horizontal diffusion has become available over the past decades. As mentioned earlier, Zhang and Montgomery (2012) estimated the horizontal mixing length and horizontal diffusivity using in-situ aircraft data at ~500 m level in the inflow layer of intense hurricanes. We will use these datasets as the baseline for setting up the horizontal diffusion in the HWRF model. More observational data will also be analyzed in the proposed work for improving the parameterization of horizontal diffusion at different altitudes.

We have formed a team with both modeling and observational expertise to work on the problem. The proposed work includes five tasks: *Task I*, observational data analysis. Based on currently obtained in-situ observations, we will analyze high-resolution wind data and Doppler radar data to estimate horizontal diffusivity and mixing length as well as other turbulent properties, such as TKE under different wind regimes, for both strong and weak storms. The results will be utilized to evaluate and calibrate the horizontal-diffusion parameterization scheme. *Task II*, testing TKE-type PBL schemes in HWRF. Current model available PBL physics options in the WRF model system such as MYJ, MYNN2, and MYNN3 will be tested. The results will be evaluated using various performance metrics and the observational analysis results from task one. *Task III,* inclusion of the TKE related term in the horizontal diffusion parameterization scheme. We will start with the standard horizontal diffusion parameterization method modified by Janjic (1990). *Task IV*, comparison of the horizontal diffusivity output from the modified scheme that takes TKE output from, MYJ, MYNN2, and MYNN3 PBL schemes with observational estimate mentioned above. *Task V*, final implementation of a TKE-based scheme for the revised horizontal diffusion in operational HWRF.

The final scheme will include both TKE transport and production as well as horizontal diffusion processes coupled with existing physics schemes for clouds, radiation, and land surface in the operational HWRF model. The modified scheme configuration will be further calibrated and refined through retrospective forecasts for multiple seasons and eventually run as a parallel real-time forecast system. The performance of the HWRF system with the new parameterization scheme will be verified for tracks and intensity.

3. Work Plan

3.1 Hardware and software needs

HRD requests $2500 each year for maintain software license (*e.g*. Matlab) and hardware maintenance costs for final forecast web products storage. University of Miami requests $3000 for the first year to purchase a laptop for PI and other research personnel to process and monitor the real-time operational parallel test when they need access the highly secure federal operational supercomputer facility during the experimental period.

3.2 Testing and evaluation

Testing will take place throughout the whole funding period. We have developed an automatic system on HFIP research machine. The system will be ported to JHT operational testing computer. Evaluation of the progress will throughout the whole funding period. PIs will report the evaluation and recommendation during the annual NOAA Hurricane Conference and Interdepartmental Hurricane Conference. PIs will also report the progress periodically.

3.3 Metrics for success

Work from this proposal will be considered success upon the delivery of the optimal TKE-based horizontal-diffusion scheme to EMC's operational HWRF model. The optimal scheme will be comprehensively measured by the track and intensity forecast errors and the TC BL structure validated by available observations.

3.4 Project deliverables

- A comprehensive TC database will be archived. The dataset will include various raw observation and modeling data, observational TKE budget component, model derived data, and validation statistics;
- Comprehensive experimental real-time forecasts web products will be available to operational centers: EMC and NHC, during hurricane season;
- Horizontal diffusion sensitivity tests will be shared among research group and operational centers and documented in project report and scientific report to JHT management;
- Optimal code implemented in HWRF will be delivered to EMC for further test;
- A written description of the new horizontal-diffusion parameterization scheme and report on its comprehensive evaluation will be provided to EMC.

3.5 Real-time parallel operational test

The project will require access to operational HWRF forecast system and its required data to perform the retrospective and real-time forecasts.

3.6 Plan to port necessary codes to operational environment

The modified horizontal diffusion scheme with optimal parameterization of boundary layer with horizontal diffusion will be reported to EMC upon completion of the project.

4. Time line

<u>Year 1:</u>

- Acquire and analyze flight-level wind data and Doppler radar TKE data for quantifying the parameterization of horizontal diffusion (CIMAS and HRD)
- Calibrate horizontal diffusivities used in the TKE-based schemes using in-situ aircraft data (CIMAS)
- Develop model calibration and validation metrics (CIMAS, HRD, ESRL)
- Implement and test the impact of the horizontal diffusion scheme on the simulated track, intensity and boundary layer structure using idealized HWRF modeling system (CIMAS, HRD, ESRL and EMC)

<u>Year 2:</u>

- Perform retrospective simulations for TCs in the past 3 years using HWRF with the new horizontal-diffusion scheme (CIMAS, HRD, ESRL, and EMC)
- Evaluate on the intensity and track errors from the retrospective simulations and quantify the impact of the new scheme (CIMAS, HRD, ESRL and EMC)
- Evaluate the impact of the horizontal-diffusion scheme on the overall simulated vortex-scale, convective-scale and boundary layer structure (CIMAS, HRD and EMC)
- Implement the new horizontal-diffusion scheme in the operational 2015 version HWRF for real-time forecast use (CIMAS and EMC)

5. Travel schedule and needs

PIs and research staff plans three trips each year, one to the IHC to present results, one to HRD from ESRL to discuss the project progress, and one to EMC to consult with JHT point of contact for the progress report and code implementation.

6. JHT Staff Requirements

The project will request access operational machine to fully access the operational HWRF system at the operational environment and the required input for the system. EMC POC may design JHT staff support for the project to implement the scheme and the required parallel tests.

7. References

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APPENDIX

I. **Budget**
II. **Budget Justification**
III. **Biographical Sketches For PI And Co-PIs**
IV. **Current and Pending Supports**

I. Budget

- **Project Whole Budget**

PROJECT DATE: August 1, 2013-July 31, 2015 PROJECT TITLE: Inclusion of Turbulent Effects Quantified by In-Situ Observation for Horizontal Diffusion Parameterization in HWRF System							
		YEAR 1			YEAR 2		
		months	NOAA	JHT	months	NOAA	JHT
Research Personnel							
1	PI: Xuejin Zhang	2.0		13,276	2.0		13,940
2	Co-PI: Jun Zhang	2.0		12,698	2.0		13,333
3	Sara Michelson	2.5		17,653	2.5		18,535
4	Thiago Quirino	2.0		12,286	2.0		12,900
5	Co-PI: S. G. Gopalakrishnan	1.0	9,288	0	1.0	9,752	0
6	Co-PI: Jian-wen Bao	1.0	9,500	0	1.0	9,975	0
TOTAL SALARIES			18,788	55,913		19,727	58,708
Fringe Benefits			6,012	18,581		6,313	19,638
TOTAL SALARIES & FRINGE BENEFITS			24,800	74,494		26,040	78,347
Travel Domestic			0	6,000		0	6,000
Publication costs			0	0		0	0
Modified Total Direct Costs:			24,800	80,494		26,040	84,347
Indirect Costs			12,896	26,960		13,541	28,545
AOML IT maintenance			0	2,500		0	2,500
Equipment (Capital)			0	3,000		0	0
TOTAL PROJECT COSTS			$ 37,696	$112,954		$ 39,581	$ 115,392

- **CIMAS Budget**

				YEAR 1			YEAR 2	
			months	%	AMOUNT	months	%	AMOUNT
Principal Investigator:								
1	Xuejin Zhang		2.0	17%	13,276	2.0	17%	13,940
2	Jun Zhang		2.0	17%	12,698	2.0	17%	13,333
TOTAL SALARIES					25,974			27,273
Fringe Benefits					9,195			9,654
TOTAL SALARIES & FRINGE BENEFITS					35,169			36,927
Travel Domestic								
Travel Foreign								
Publication costs					0			
Modified Total Direct Costs:					35,169			36,927
I. Indirect Costs				40.0%	14,068			14,771
Equipment Capital					3,000			
TOTAL PROJECT COSTS					52,237			51,698

- # AOML Budget

				Budget Year 1				Budget Year 2		
				NOAA Requested		JHT Requested		NOAA Requested		JHT Requested
			mm	Amount	mm	Amount	mm	Amount	mm	Amount
Personnel										
AOML	S. Gopalakrishnan	Principal Investigator	1.0	$ 9,288	0.0	$ -	1.0	$ 9,752	0.0	$ -
AOML	T. Quirino	Scientific Programmer	0.0	$ -	2.0	$ 12,286	0.0	$ -	2.0	$ 12,900
Subtotal				$ 9,288		$ 12,286		$ 9,752		$ 12,900
Fringe Benefits		AOML		$ 2,972		$ 3,932		$ 3,218		$ 4,257
Total Salaries and Fringe Benefits				$ 12,260		$ 16,218		$ 12,971		$ 17,157
Indirect Costs		AOML		$ 6,252.68		$ 8,270.94		$ 6,744.76		$ 8,922
Total Labor Costs				$ 18,513		$ 24,488		$ 19,715		$ 26,079
Equipment						$ -				$ -
Supplies						$ -				$ -
Travel	Meetings					$ 4,000				$ 4,000
Publications						$ -				$ -
Other (i.e. software costs etc...)						$ 2,500		$ -		$ 2,500
Total				$ 18,513		$ 30,988		$ 19,715		$ 32,579

- # ESRL Budget

PROJECT NUMBER:	NEW YEAR 1				YEAR 2		TOTAL FY2013 - 2014	
BUDGET ESTIMATE								
FEDERAL LABOR	**MO RATE**	**UNITS**	**QTY**	**AMOUNT**	**QTY**	**AMOUNT**	**QTY**	**AMOUNT**
		month		0		0	0.0	0
		month		0		0	0.0	0
		month		0		0	0.0	0
		month		0		0	0.0	0
		month		0		0	0.0	0
		month		0		0	0.0	0
Subtotal NOAA Federal Salaries			0	0	0	0		0
Subtotal w/NOAA Leave	25.00%			**0**		**0**		**0**
NOAA Support	29.65%			**0**		**0**		0
Reimbursable Funds only -Benefits, NOAA	31.07%			**0**		**0**		0
TOTAL FEDERAL LABOR				**0**		**0**		**0**
COOPERATIVE INSTITUTE (CI) LABOR	**AMOUNT PER MONTH**	**UNITS**	**No OF MONTHS**	**AMOUNT**	**NUMBER OF MONTHS**	**AMOUNT**	**NUMBER OF MONTHS**	**AMOUNT**
S. Michelson	7,061	month	2.5	17,653	2.5	18,535	5	36,188
		month		0		0	0	0
Subtotal, CI labor		**months**	**3**	**17,653**	**3**	**18,535**	**5**	36,188
FICA, TIAA, Work Comp.	30.90%			**5,455**		**5,727**		11,182
Subtotal CI Labor and Benefits				**23,107**		**24,262**		47,370
CI Support	20.00%			**4,621**		**4,852**		9,474
TOTAL CI LABOR				**27,729**		**29,115**		56,844
CONTRACT LABOR	**AMOUNT PER MONTH**	**UNITS**	**NUMBER OF MONTHS**	**AMOUNT**	**NUMBER OF MONTHS**	**AMOUNT**	**NUMBER OF MONTHS**	**AMOUNT**
		month		0		0	0	0
Subtotal, CONTRACT labor	**0**	**months**	**0**	**0**	**0**	**0**	**0**	0
Billable hourly rate for Contractor Benefits and Overheads Included								
TOTAL CONTRACT LABOR				**0**		**0**		0
OTHER DIRECT COSTS				**AMOUNT**		**AMOUNT**		**AMOUNT**
Shipping				0		0		0
Repairs				0		0		0
Publications				0		0		0
Contracts				0		0		0
Travel (Foreign) (Location undetermined at this time)				0		0		0
Travel (Domestic)				2,000		2,000		4,000
Equipment Upgrades/Parts				0		0		0
Equipment [ ] Capital				0		0		0
IT Support				0		0		0
Administrative Support				0		0		0
TOTAL OTHER DIRECT COSTS				**2,000**		**2,000**		4,000
TOTAL				**29,729**		**31,115**		**60,844**

Preparer of Budget Sheet: Jo Novosel, Management Analyst, 303 497 6588 fax: 303 497 7287 email: josephine.c.novosel@noaa.gov
Organization: DoC/NOAA/OAR/ ESRL/Physical Sciences Division
Administrative Officer: Brian Gorton 303 497 4321 email: brian.k.gorton@noaa.gov
Director of Physical Sciences Division, William D. Neff
Comments:

II. Budget Justification:

University of Miami
Salary and Fringe are requested for 2 months of PI Xuejin Zhang's time. X. Zhang is an associate scientist of CIMAS at University of Miami. The two-month salary request is for his management and coordination of the proposed project, supervise research staff, set the project priority, develop and implement horizontal diffusion in HWRF system, and monitor whole project progress.

Salary and Fringe are requested for 2 months of Co-PI: Jun Zhang's time. J. Zhang will be in charge of observation part of this project. The two-month salary request is for his methodology development for model vs. observation comparison. He will analyze both observation and model horizontal diffusion and assist modeling staff optimize the implemented parameterization scheme. He will also help PI set up priority and monitor the whole project progress.

Laptop for real-time parallel forecast team: $3000 (exempt from F & A). We need access the highly secured operational supercomputer. In order to meet the IT security standard, we use office computers and the requested computer to access the supercomputer. The computer will be enforced to comply with all NOAA IT security standards.

AOML
Salary & Fringe benefits are requested for the equivalent of 2 months of scientific programmer Thiago Quirino's time. He is a computer engineering expert and specialized in real-time HWRF operation and web portal development. He will implement and port the current real-time system to JHT parallel operational supercomputer. He will also assist PIs develop the web products. He will be in charge of webpage and data server for operational center access..

Salary & Fringe benefits are requested for the equivalent of 1 months of Federal Co-PI: S. G. Gopalakrishnan's time. He is an HWRF dynamics and physics expert. He will coordinate with EMC's person of contact and HFIP physics development team to set up operational needs and priority. His time is AOML's contribution. No cost to the project.

Travel costs are budgeted for the PIs to travel to Interdepartmental Hurricane Conference required by JHT to report the project progress. These are budgeted as 800$ for air travel; 300$ for ground transportation; and $900 for lodging and per diem assuming Miami and the Washington DC area for total of 6 days in March. Two person trips are budgeted. Total: $4000. No indirect cost.

ESRL
Salary & Fringe benefits are requested for the equivalent of 1 months of Federal Co-PI: Jian-Wen Bao's time. He is an HWRF physics and PBL modeling and observation expert. He will be in charge of coordinating with EMC's person of contact and HWRF physics development team, design parameterization scheme experiments, and optimize the horizontal diffusion scheme. He will assist the final implementation in HWRF. His time is ESRL's contribution. No cost to the project

Salary & Fringe benefits are requested for the equivalent of 2.5 months of research staff: Sara Michelson's time. She is an HWRF physics expert. She will be supervised by ESRL Co-PI. She will assist ESRL Co-PI conduct experiments and optimize the parameterization scheme. She will report the progress to PIs.

Travel costs are budgeted for the PI or research staff to travel to Interdepartmental Hurricane Conference or University of Miami to report the project progress. These are budgeted as 800$ for air travel; 300$ for ground transportation; and $900 for lodging and per diem assuming Miami and the Washington DC area for total of 6 days in Feburary. One person trip is budgeted. Total: $2000. No indirect cost.

Environmental Modeling Center
EMC person of contact will be identified before the project starts. The POC will coordinate with project PIs to set up priorities and implementation plan. The POC will also coordinate with HWRF team in EMC to provide essential support on the project resource request such as operational HWRF model availability, supercomputer access, and operational input data access. The POC will serve as the person monitor/accept the deliverables from the project. No cost to the project.

III. Biographic Sketches for PI and Co-PIs

- **Biographic Sketch for Xuejin Zhang**

Education

B.S. Climatology, Nanjing Institute of Meteorology, July 1991

M.S. Synoptic Dynamics, Chinese Academy of Meteorological Sciences and Nanjing Institute of Meteorology, September 1996

Ph.D. Atmospheric Science, North Carolina State University, May 2007

Professional Experience

1991-1995 Assistant Engineer, Climate Analysis and Diagnosis, Climate Center of Liaoning Province, Liaoning, China

1996-2001 Engineer, Climate and Weather Analysis and Prediction, Weather Center of Liaoning Province, Liaoning, China

1996-1999 Visiting Scholar, Meteorological Field Experiment and Data Quality Control Chinese Academy of Meteorological Sciences, Beijing, China

2000-2001 Visiting Scholar, Regional Climate Model Development, North Carolina State University, Raleigh, NC

02/2007-02/2008 Post Doctoral Research Associate, Mesoscale Model Development, North Carolina State University, Raleigh, NC

03/2008-05/2012 Assistant Scientist, RSMAS/CIMAS, University of Miami, Miami, FL

06/2012-present Associate Scientist, RSMAS/CIMAS, University of Miami, Miami, FL

Publications

Refereed Journals in past three years

1. Rogers, R., Sim Aberson, Altug Aksoy, Bachir Annane, Michael Black, Joseph Cione, Neal Dorst, Jason Dunion, John Gamache, Stan Goldenberg, Sundararaman Gopalakrishnan, John Kaplan, Bradley Klotz, Sylvie Lorsolo, Frank Marks, Shirley Murillo, Mark Powell, Paul Reasor, Kathryn Sellwood, Eric Uhlhorn, Tomislava Vukicevic, Kevin Yeh, Jun Zhang, and **Xuejin Zhang**, 2012: NOAA's Hurricane Intensity Forecasting Experiment (IFEX): A Progress Report. *Bull. Amer. Meteor. Soc.*, (In press).
2. Aksoy, A., S. D. Aberson, T. Vukicevic, K. J. Sellwood, S. Lorsolo, **Xuejin Zhang**, 2012: Towards improving high-resolution numerical hurricane forecasting: Influence of model horizontal grid resolution, initialization, and physics. *Mon. Wea. Rev.,* (Accepted).
3. Gopalakrishnan, S. G., Frank Marks, Jr., J A. Zhang, **Xuejin Zhang**, J.-W. Bao, and V. Tallapragada**.** 2012**:** A Study of the Impacts of Vertical Diffusion on the Structure and Intensity of the Tropical Cyclones Using the High Resolution HWRF system*. J. Atmos. Sci.*, doi: http://dx.doi.org/10.1175/JAS-D-11-0340.1. (in press).
4. Gopalakrishnan, S.G., S. Goldenberg, T. Quirino, F. Marks, **Xuejin Zhang**, K.-S. Yeh, R. Atlas, and V. Tallapragada, 2012: Towards improving high-resolution numerical hurricane forecasting: Influence of model horizontal grid resolution, initialization, and physics. *Weather and Forecasting*, **27**, 647-666.
5. Laureano-Bozeman, M., D. Niyogi, S. Gopalakrishnan, F.D. Marks, **Xuejin Zhang**, and V. Tallapragada. 2012: An HWRF-based ensemble assessment of the land surface feedback on the post-landfall intensification of Tropical Storm Fay (2008). *Natural Hazards*, **63**,1543-1571.

6. Yeh, K.-S., **Xuejin Zhang**, S. G. Gopalakrishnan, S. Aberson, R. Rogers, F. D. Marks, and R. Atlas, 2012: Performance of the experimental HWRF in the 2008 hurricane season. *Natural Hazards* **63**, 1439-1449.
7. **Zhang, Xuejin**, T. S. Quirino, K.-S. Yeh, S. G. Gopalakrishnan, F. D. Marks, Jr., S. B. Goldenberg, and S. Aberson, 2011: HWRFx: Improving Hurricane Forecast with High-Resolution Modeling. *Computing in Science and Engineering,* **13**, 13-21.
8. Gopalakrishnan, S. G., F. D. Marks, **Xuejin Zhang**, J.-W. Bao, K.-S. Yeh, and R. Atlas, 2011: The Experimental HWRF System: A Study on the Influence of Horizontal Resolution on the Structure and Intensity Changes in Tropical Cyclones using an Idealized Framework. *Mon. Wea. Rev*., **139**, 1762-1784.

Related Paper

1. Xu, Xiangde, Lian Xie, **Xuejin Zhang**, and Wenqing Yao, 2006: A mathematical model for forecasting tropical cyclone tracks. *Nonlinear Analysis: Real World Applications,* **7**, 211-224.

- **Biographic Sketch for Jun A. Zhang**

Education: 2007 *Ph.D.*, Applied Marine Physics, *Univ. of Miami*, Miami, FL
2005 *M.S.*, Applied Marine Physics, *Univ. of Miami*, Miami, FL
2000 *B.S.*, Naval Architecture, *Dalian Univ. of Technology*, China

Experience:

- 2010-present: Asst. Scientist, Coop. Inst. for Marine & Atmospheric Studies, University of Miami, Miami, FL
- 2008-2010: National Research Council Postdoctoral Res. Assoc., Hurricane Research Division, Miami, FL

Selected Peer-Reviewed Publications:

Zhang, J. A., and M. T. Montgomery, 2012: Observational estimates of the horizontal eddy diffusivity and mixing length in the low-level region of intense hurricanes. *J. Atmos. Sci.*, **69**, 1306-1316.

Zhang, J. A., R. F. Rogers, D. S. Nolan, and F. D. Marks, 2011: On the characteristic height scales of the hurricane boundary layer. *Mon. Wea. Rev.*, **139**, 2523-2535.

Zhang, J. A., F. D. Marks, M. T. Montgomery, and S. Lorsolo, 2011: An Estimation of Turbulent Characteristics in the Low-Level Region of Intense Hurricanes Allen (1980) and Hugo (1989). *Mon. Wea. Rev.,* **139***,* 1447-1462*.*

Zhang, J. A., 2010: Estimation of dissipative heating using low-level in-situ aircraft observations in the hurricane boundary layer. *J. Atmos. Sci.,* **67**, 1853-1862.

Zhang, J. A., 2010: Spectra characteristics of turbulence in the hurricane boundary layer. *Quart. J. Roy. Meteor. Soc.*, DOI:10.1002/qj.610.

Lorsolo, S**., J. A. Zhang**, F. D. Marks, and J. Gamache, 2010: Estimation and mapping of hurricane turbulent energy using airborne Doppler measurements. *Mon. Wea. Rev.*, **138**, 3656-3670.

Zhang, J. A., W. M. Drennan, P. G. Black, and J. R. French, 2009: Turbulence structure of the hurricane boundary layer between the outer rain bands. *J. Atmos. Sci.,* **66,** 2455-2467*.*

Zhang, J. A., P. G. Black, J. R. French, and W. M. Drennan, 2008: First direct measurements of enthalpy flux in the hurricane boundary layer: The CBLAST results. *Geophysical Research Letters*, **35(11)**:L14813, doi:10.1029/2008GL034374.

Zhang, J. A., K. B. Katsaros, P. G. Black, S. Lehner, J. R. French, and W. M. Drennan, 2008: Effects of roll vortices on turbulent fluxes in the hurricane boundary layer. *Boundary-Layer Meteorology*, **128(2)**, 173-189.

- **Biographic Sketch for S. G. Gopalakrishnan**

EDUCATION

Ph.D., Atmospheric Science, Indian Institute of Technology, New Delhi, India, 1991-96;
Master in Technology, Atmospheric Physics, Poona University, Poona, India, 1990.
Master in Physics, Tata Institute of Fundamental Research - Poona University, Poona, India, 1989.

RESEARCH ACTIVITIES

Dr.S.G.Gopalakrishnan has more than 15 years of post Ph.D experience in Atmospheric Modeling and Numerical Weather Prediction. After completing his doctoral degree in the areas related to turbulence and boundary layer modeling, Dr.Gopal has been concentrating on problems related to Numerical Weather Prediction of the Tropical Cyclones, dry and moist convection and turbulence in the atmosphere. Dr. Gopal has made significant contributions towards the development of complex, next generation Atmospheric, Ocean coupled modeling systems, including the Operational Multi scale Environmental Model with Grid Adaptivity (OMEGA) for Dispersion and Hurricane Forecasting and is the chief architect of the HWRF, the state-of-the art hurricane modeling system used in NOAA for hurricane forecasting. His research involves simulating a variety of complex, non-linear, scale interacting systems starting from dry thermals (Large Eddy Simulations) to hurricanes; examining the mesoscale structures and evolution as well as the mechanism(s) whereby they develop; testing theories, hypotheses and various near-surface model physical representations; and finally interpreting, to the extent possible, the modeled and the observed behaviour of these systems. Several of his publications related to PBL/Land surface process and dispersion modeling are being quoted in standard text books (example Mesoscale modeling by Pielke). In the past he has served as an Associate editor for the Monthly Weather review. Gopal started the modeling efforts at the division where he supervises and mentors advanced scientist and students at post graduate as well as post-doc levels.

EMPLOYMENT

2007-current - Meteorologist & Modeling Team Leader, HRD/AOML/NOAA
2001-2007 - Research Meteorologist, EMC/NOAA/NCEP/SAIC
1998-2001- Research Scientist, Center for Atmospheric Physics, SAIC
1996-1998- Post-Doctoral Associate, Rutgers University, NJ

PUBLICATION

(1) Bozeman L.M., D. Niyogi, S. Gopalakrishnan, F. D. Marks Jr., X. Zhang, and V. Tallapragada, 2012: An HWRF-based Ensemble Assessment of the Land Surface Feedback on the Post–Landfall Intensification of Tropical Storm Fay (2008), Natural Hazards – Special Issue on Tropical Cyclones, in press, vol 63, 1543-1571 (http://www.landsurface.org/publications/J116.pdf)

(2) Bao, J.-W., S.G.Gopalakrishnan, S.A.Michelson, F.D.Marks and M.T.Montgomery, 2012: Impact of Physics Representations in the HWRFX 2 Model on Simulated Hurricane Structure and Wind-Pressure Relationships, Mon. Wea. Rev. 3278–3299 (http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-11-00332.1)

(3) Gopalakrishnan, S. G., Q. Liu, T. Marchok, D. Sheinin, N. Surgi, M. Tong, V. Tallapragada, R. Tuleya, R. Yablonsky, and X. Zhang, 2011: Hurricane Weather and Research and Forecasting (HWRF) model: scientific documentation. NOAA/Development Tech Center, 81 pp. [Available online at http://www.dtcenter.org/HurrWRF/users/docs/scientific_documents/HWRFScientificDocumentation_August2011.pdf]

(4) Gopalakrishnan, S. G., F. D. Marks, Xuejin Zhang, J.-W. Bao, K.-S. Yeh, and R. Atlas, 2011: The Experimental HWRF System: A Study on the Influence of Horizontal Resolution on the Structure and Intensity Changes in Tropical Cyclones using an Idealized Framework. Mon. Wea. Rev. 1762–1784. http://dx.doi.org/10.1175/2010MWR3535.1

(5) Gopalakrishnan, S. G., S. Goldenberg, T. Quirino, F. D. Marks, Jr., X. Zhang, K.-S. Yeh, R. Atlas and V. Tallapragada, 2012: Towards Improving High-Resolution Numerical Hurricane Forecasting: Influence of Model Horizontal Grid Resolution, Initialization, and Physics. Weather and. Forecasting 647–666, Volume 27, Issue 3.

(6) Gopalakrishnan, S. G., F. D. Marks, Jr, J. A. Zhang, X. Zhang, J.-W. Bao and V. Tallapragada, 2012: A Study of the Impacts of Vertical Diffusion on the Structure and Intensity of the Tropical Cyclones Using the High Resolution HWRF system, The Journal of Atmospheric Sciences (in press)

(7) Pattanayak, S., U. C. Mohanty and S. G. Gopalakrishnan, 2012: Simulation of very severe cyclone Mala over Bay of Bengal with HWRF modeling system. Nat. Hazards, vol 63, 1413-1437 http://rd.springer.com/article/10.1007/s11069-011-9863-z

(8) Yeh, K.-S., X. Zhang, S. G. Gopalakrishnan, S. Aberson, R. Rogers, F. D. Marks, and R. Atlas, 2012: Performance of the Experimental HWRF in the 2008 Hurricane Season, vol 63, 1439-1449, Nat. Hazards.

(9) Zhang, X., T. S. Quirino, K.-S. Yeh, S. G. Gopalakrishnan, F. D. Marks, Jr., S. B. Goldenberg, and S. Aberson, 2011: HWRFx: Improving Hurricane Forecast with High-Resolution Modeling. Computing in Science and Engineering, 13(1), 13-21.

- **Biographic Sketch for Jian-Wen Bao**

EDUCATION

Ph.D., Meteorology, The Pennsylvania State University, 1993
M.S., Meteorology, The Pennsylvania State University, 1990
B.S., Meteorology, The Lanzhou University, China, 1983

PROFESSIONAL APPOINTMENTS

2000-present Research Meteorologist, Earth System Research Laboratory, National Oceanic and Atmospheric Administration
1997-1999 Research Scientist II, CIRES, University of Colorado/National Oceanic and Atmospheric Administration
1994-1997 Faculty Research Associate, CIRES, University of Colorado/National Oceanic and Atmospheric Administration
1993-1994 Postdoctoral Fellow of the Advanced Study Program, National Center for Atmospheric Research

RESEARCH INTEREST AND EXPERIENCE

Tropical Cyclone Modeling, Atmospheric Boundary-Layer Modeling, Land-Surface Modeling, Air-Sea Coupled Modeling, Air-Sea Surface Flux Parameterization, Air-Quality Forecast/Modeling, Mesoscale Modeling, Mesoscale Ensemble Prediction, Numerical Model Forecast Validation and Evaluation

SELECTED PEER REVIEWED REELEVENT PUBLICATIONS

Bao, J.-W., S. G. Gopalakrishnan, S. A. Michelson, and coauthors, 2012: Impact of physics representations in the HWRF model on simulated hurricane structure and wind-pressure relationships. *Mon. Wea. Rev*., **140**, 3278–3299.
Bao, J.-W., C. W. Fairall, S. A. Michelson, L. Bianco, 2011: Parameterizations of sea-spray impact on the air-sea momentum and heat fluxes. *Mon. Wea. Rev.*, **139**, 3781-3797.
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IV. Current and Pending Supports

- **Current and Pending Supports for Xuejin Zhang**

PI	Co-PI Co-I	Supporting Agency	Project Title	Total Award	Period Covered	Salary Months
Xuejin Zhang	Da-lin Zhang	NOAA	Development of Multiple Moving Nests within a Basin-wide HWRF Modeling System	$150K	8/1/2011- 7/31/2013	3.5
Xuejin Zhang	Jun Zhang S.G. Gopalakrishnan Jian-Wen Bao	NOAA	Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System (NOAA-OAR-OWAQ-2013-2003469)	$228K	08/01/2013 - 7/31/2015*	2.0
Xuejin Zhang	John Michalakes	DTC	Development of Concurrent Integration of Multiple Nests Within HWRF Modeling System (DTC Visitor Program)	~$19.8K#	01/01/2013 - 12/31/2011 3*	0.0
Jun Zhang	Xuejin Zhang S.G. Gopalakrishnan Robert Rogers	NOAA	Evaluation and Improvement of HWRF Boundary Layer Parameterization using Aircraft Observations (NOAA-OAR-OWAQ-2013-2003469)	$195K	08/01/2013 - 7/31/2015*	2.0

* The award is still pending. The period covered will be adjusted accordingly

\# The requested amount is $11.8K for salary and about 8k for four trips

- **Current and Pending Supports for Jun A. Zhang**

<u>Current:</u>
1. Title: Advanced model diagnostics of tropical cyclone inner-core structure using aircraft observations
Agency: NOAA
Award Period Covered: 01/01/2012 – 12/31/2012
Amount Funded: $98,979
Person Months: 6.0
2. Title: Investigation of HWRF Model Error Associated With Surface-Layer and Boundary-Layer Parameterizations to Improve Vortex-Scale, Ensemble-Based Data Assimilation Using HEDAS (Co-PI)
Agency: NOAA
Award Period Covered: 01/01/2012 – 12/31/2012
Amount Funded: $107,043
Person Months: 3.0

<u>Pending:</u>
1. Title: Advanced model diagnostics of tropical cyclone inner-core structure using aircraft observations
Agency: NOAA
Award Period Covered: 01/01/2013 – 12/31/2013
Amount Budgeted: $103,613
Person Months: 4.0
2. Title: Investigation of HWRF Model Error Associated With Surface-Layer and Boundary-Layer Parameterizations to Improve Vortex-Scale, Ensemble-Based Data Assimilation Using HEDAS (Co-PI)
Agency: NOAA
Award Period Covered: 01/01/2013 – 12/31/2013
Amount Budgeted: $106,393
Person Months: 2.0
3. Title: Inclusion of Turbulent Effects Quantified by *in-situ* Observation for Horizontal Diffusion Parameterization in HWRF System
Agency: NOAA
Award Period Covered: 08/01/2013-07/31/2015
Amount Budgeted: Year 1: $112,954, Year 2: $115,392
Person Months: 2.0

- Current and Pending Support

No current and pending support for S. G. Gopalakrishnan & Jian-Wen Bao

OMB Number: 4040-0004
Expiration Date: 03/31/2012

Application for Federal Assistance SF-424

* 1. Type of Submission: ☐ Preapplication ☒ Application ☐ Changed/Corrected Application	* 2. Type of Application: ☒ New ☐ Continuation ☐ Revision	* If Revision, select appropriate letter(s): * Other (Specify):
* 3. Date Received: 12/07/2012	4. Applicant Identifier:	
5a. Federal Entity Identifier:	5b. Federal Award Identifier:	

State Use Only:

6. Date Received by State:	7. State Application Identifier:

8. APPLICANT INFORMATION:

* a. Legal Name:	University of Miami, RSMAS
* b. Employer/Taxpayer Identification Number (EIN/TIN):	590624458
* c. Organizational DUNS:	1527640070000

d. Address:

* Street1:	4600 Rickenbacker Causeway
Street2:	
* City:	Miami
County/Parish:	
* State:	FL: Florida
Province:	
* Country:	USA: UNITED STATES
* Zip / Postal Code:	331491031

e. Organizational Unit:

Department Name:	Division Name:

f. Name and contact information of person to be contacted on matters involving this application:

Prefix:	
* First Name:	Bonnie
Middle Name:	
* Last Name:	Townsend
Suffix:	
Title:	Team Manager
Organizational Affiliation:	
* Telephone Number:	3054214084
Fax Number:	3054214876
* Email:	btownsend@rsmas.miami.edu

Application for Federal Assistance SF-424

*** 9. Type of Applicant 1: Select Applicant Type:**

O: Private Institution of Higher Education

Type of Applicant 2: Select Applicant Type:

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 10. Name of Federal Agency:**

Department of Commerce

11. Catalog of Federal Domestic Assistance Number:

11.459

CFDA Title:

Weather and Air Quality Research

*** 12. Funding Opportunity Number:**

NOAA-OAR-OWAQ-2013-2003469

* Title:

FY 2013 Joint Hurricane Testbed

13. Competition Identification Number:

2297052

Title:

14. Areas Affected by Project (Cities, Counties, States, etc.):

Add Attachment | Delete Attachment | View Attachment

*** 15. Descriptive Title of Applicant's Project:**

Inclusion of Turbulent Effects Quantified by In-Site Observation for Horizontal Parameterization in HWRF System

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

Application for Federal Assistance SF-424

16. Congressional Districts Of:

* a. Applicant: FL-018

b. Program/Project: FL-018

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 08/01/2013

* b. End Date: 07/31/2015

18. Estimated Funding ($):

* a. Federal	103,935.00
* b. Applicant	0.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	103,935.00

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on .

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes," provide explanation in attachment.)**

☐ Yes ☒ No

If "Yes", provide explanation and attach

Add Attachment | Delete Attachment | View Attachment

21. *By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

Authorized Representative:

Prefix:

* First Name: Bonnie

Middle Name:

* Last Name: Townsend

Suffix:

* Title: Team Manager, Research Administration

* Telephone Number: 3054214084

Fax Number: 3054214876

* Email: btownsend@rsmas.miami.edu

* Signature of Authorized Representative: Bonnie Townsend

* Date Signed: 12/07/2012

BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 06/30/2014

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1. NOAA-OAR-OWAQ-2013-2003469	11.459	$	$	$ 103,935.00	$	$ 103,935.00
2.						
3.						
4.						
5. Totals		$	$	$ 103,935.00	$	$ 103,935.00

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Prescribed by OMB (Circular A -102) Page 1

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total
	(1)	(2)	(3)	(4)	(5)
	NOAA-OAR-OWAQ-2013-2003469	N/A			
a. Personnel	$ 25,974.00	$ 27,273.00	$	$	$ 53,247.00
b. Fringe Benefits	9,195.00	9,654.00			18,849.00
c. Travel	0.00	0.00			
d. Equipment	3,000.00	0.00			3,000.00
e. Supplies	0.00	0.00			
f. Contractual	0.00	0.00			
g. Construction	0.00	0.00			
h. Other	0.00	0.00			
i. Total Direct Charges (sum of 6a-6h)	38,169.00	36,927.00			$ 75,096.00
j. Indirect Charges	14,068.00	14,771.00			$ 28,839.00
k. TOTALS (sum of 6i and 6j)	$ 52,237.00	$ 51,698.00	$	$	$ 103,935.00
7. Program Income	$	$	$	$	$

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SECTION C - NON-FEDERAL RESOURCES

	(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8.		$	$	$	$
9.					
10.					
11.					
12. TOTAL (sum of lines 8-11)		$	$	$	$

SECTION D - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 52,237.00	$ 13,059.00	$ 13,059.00	$ 13,059.00	$ 13,060.00
14. Non-Federal	$				
15. TOTAL (sum of lines 13 and 14)	$ 52,237.00	$ 13,059.00	$ 13,059.00	$ 13,059.00	$ 13,060.00

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

	(a) Grant Program	FUTURE FUNDING PERIODS (YEARS)			
		(b)First	(c) Second	(d) Third	(e) Fourth
16.	Year two	$ 51,698.00	$	$	$
17.					
18.					
19.					
20. TOTAL (sum of lines 16 - 19)		$ 51,698.00	$	$	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: $75,096

22. Indirect Charges: $28,839

23. Remarks: The Joint Institute Cooperative Agreement Facilities and Administrative Rate is 40% MTDC

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OMB Number: 4040-0007
Expiration Date: 06/30/2014

ASSURANCES - NON-CONSTRUCTION PROGRAMS

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0040), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant, I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of the United States and, if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§4728-4763) relating to prescribed standards for merit systems for programs funded under one of the 19 statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C.§§1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U.S.C. §§6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. §§290 dd-3 and 290 ee- 3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §§3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and, (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally-assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a-7), the Copeland Act (40 U.S.C. §276c and 18 U.S.C. §874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally-assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. §§7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended (P.L. 93-523); and, (h) protection of endangered species under the Endangered Species Act of 1973, as amended (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. §470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. §§2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§4801 et seq.) which prohibits the use of lead-based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act Amendments of 1996 and OMB Circular No. A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations, and policies governing this program.

19. Will comply with the requirements of Section 106(g) of the Trafficking Victims Protection Act (TVPA) of 2000, as amended (22 U.S.C. 7104) which prohibits grant award recipients or a sub-recipient from (1) Engaging in severe forms of trafficking in persons during the period of time that the award is in effect (2) Procuring a commercial sex act during the period of time that the award is in effect or (3) Using forced labor in the performance of the award or subawards under the award.

* SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL Bonnie Townsend	* TITLE Team Manager, Research Administration
* APPLICANT ORGANIZATION University of Miami, RSMAS	* DATE SUBMITTED 12/07/2012

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FORM **CD-511**
(REV 1-05)

U.S. DEPARTMENT OF COMMERCE

CERTIFICATION REGARDING LOBBYING

Applicants should also review the instructions for certification included in the regulations before completing this form. Signature on this form provides for compliance with certification requirements under 15 CFR Part 28, 'New Restrictions on Lobbying.' The certifications shall be treated as a material representation of fact upon which reliance will be placed when the Department of Commerce determines to award the covered transaction, grant, or cooperative agreement.

LOBBYING

As required by Section 1352, Title 31 of the U.S. Code, and implemented at 15 CFR Part 28, for persons entering into a grant, cooperative agreement or contract over $100,000 or a loan or loan guarantee over $150,000 as defined at 15 CFR Part 28, Sections 28.105 and 28.110, the applicant certifies that to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, 'Disclosure Form to Report Lobbying.' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure occurring on or before October 23, 1996, and of not less than $11,000 and not more than $110,000 for each such failure occurring after October 23, 1996.

Statement for Loan Guarantees and Loan Insurance

The undersigned states, to the best of his or her knowledge and belief, that:

In any funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this commitment providing for the United States to insure or guarantee a loan, the undersigned shall complete and submit Standard Form-LLL, 'Disclosure Form to Report Lobbying,' in accordance with its instructions.

Submission of this statement is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required statement shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure occurring on or before October 23, 1996, and of not less than $11,000 and not more than $110,000 for each such failure occurring after October 23, 1996.

As the duly authorized representative of the applicant, I hereby certify that the applicant will comply with the above applicable certification.

* NAME OF APPLICANT
University of Miami, RSMAS

* AWARD NUMBER
NA

* PROJECT NAME

Prefix:
* First Name: Bonnie
Middle Name:
* Last Name: Townsend
Suffix:
* Title: Team Manager, Research Administration

* SIGNATURE: Bonnie Townsend
* DATE: 12/07/2012