**a) Title Page**

**Use of Ensemble Statistics to Provide Real-Time Guidance for Forecast Accuracy**

Frank P. Colby Jr. 12/7/2012

Signature Date

Principal Investigator

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## b) Abstract

Use of Ensemble Statistics to Provide Real-Time Guidance for Forecast Accuracy

Principle Investigator: Dr. Frank P. Colby, Jr.
Professor of Meteorology
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The many models that forecasters at the National Hurricane Center (NHC) use to forecast the track and intensity of tropical cyclones include ensemble models. Two of these, both single model ensembles, are a 20-member ensemble of the Global Forecast System run by the National Centers for Environmental Prediction, (GFSE), and a 50-member ensemble, run by the European Center for Medium-Range Forecasting. The initial conditions are perturbed for each member, but the model is the same for each member of the respective ensembles. Additionally, NHC forecasters use output from multi-model ensembles in which the ensemble is comprised of deterministic model runs from various sources. In these ensembles the initial conditions will differ due to the various ways in which data assimilation is done for each model, but the models themselves differ too, providing an extra layer of perturbations.

Goerss Predicted Consensus Errors (GPCEs), provided to NHC forecasters in real time, are used to indicate the uncertainty in certain multi-model ensemble forecasts, using the ensemble spread and the initial and forecast tropical cyclone intensity. The forecast uncertainty is quantified by calculating the size of a circle, centered on the ensemble model forecast, which contains the actual tropical cyclone position 72% – 74% of the time. Evaluation of GPCEs for the past five years shows seasonal average GPCE circle size is only correlated with seasonal averages of official forecast track errors. Variation in GPCE circle size is not correlated with official track forecast errors either for individual storms or for individual forecasts.

Preliminary research shows that there are correlations between the area covered by a given GFS ensemble forecast, and the likelihood of forecast track errors. The current proposal will use the GFS ensemble forecast area, plus output from the multi-model ensembles TVCN and TVCA, and the ECMWF ensemble as needed, to develop a new guidance tool (the GFSE Area Forecast Error Probability) which will predict in real time, the probability of larger than average official forecast track errors in the next forecast cycle. All of the data needed for this evaluation are available in real time, and the computer resources required to produce the new guidance is expected to be minimal. Unlike GPCEs, the GFSE Area Forecast Error Probability will give real time guidance to NHC forecasters for their current forecast cycle, addressing priority NHC-3/JTWC-6, “providing statistically based real-time guidance on guidance to assist the determination of official track and intensity forecasts”.

**c) Statement of Work**

**1) The proposed duration of this project will be 2 years.**

**2) Brief description of the project**

**Introduction**

This proposal will address priority NHC-3/JTWC-6, "providing statistically based real-time guidance on guidance to assist the determination of official track and intensity forecasts". The result will be a guidance tool which will give NHC forecasters the probability of larger than average forecast errors in the current forecast cycle. This new tool will be based on statistics developed from output produced by the National Centers for Environmental Prediction's 20 member Global Forecast System ensemble (MetEd, 2007, hereafter GFSE), and other forecast information, all of which is available to the NHC in real time.

Forecasting the tracks of tropical cyclones remains a challenge. The National Hurricane Center (NHC) has made considerable progress improving forecast track errors, reducing the average error by about 3 % per year (for 24, 48 and 72 hour lead times) since 1970. Despite this improvement, there are storms each year whose tracks are more difficult to forecast. Although post-storm analysis can show what part of a track was prone to error, and which model forecasts had the largest forecast track errors, these issues are not anticipated in real time.

For instance, Hurricane Danielle in 2010 had average errors at most forecast lead times well above the average errors for the previous five years, as shown in Table 1. Only the 48 and 72 hour forecasts had average forecast track errors smaller than the average. A closer look at the error statistics shows that the forecast track errors were larger than the previous five year average in the early part of the storm's history, when the model guidance forecast the storm to move too far to the north, a consequence of difficulties in finding the storm's initial position. Later in Danielle's history, when the storm was recurving to the north, the guidance was forecasting the recurvature too slowly, and the resultant forecasts had larger than average errors.

**Table 1. Official Average Forecast Track Errors (nm) for Hurricane Danielle**

| | Forecast Lead Time in Hours | | | | | | |
|---|---|---|---|---|---|---|---|
| | 12 | 24 | 36 | 48 | 72 | 96 | 120 |
| Official Error | 39.0 | 65.6 | 78.8 | 90.8 | 140.9 | 231.9 | 297.3 |
| Avg. Error | 31.8 | 53.4 | 75.4 | 96.8 | 143.8 | 195.6 | 252.1 |

NHC forecasters have many forecast models to consult while making their forecast, including dynamic, ensemble, and statistical models. Certain ensemble models historically have better error statistics, and are relied upon by NHC forecasters. These ensembles are multi-model ensembles which are the average of forecasts from two to seven dynamical models from various forecast centers. Initial conditions in multi-model ensembles differ from one another due to differences in data assimilation and model initialization used by the various forecast centers that produce each member model. The member model runs themselves will also be different since the actual model is unique for each member.

Forecasters have few ways to evaluate the quality of guidance in real time. The forecasts of the track from various models can be compared, and some tracks discarded as unlikely. Additionally, Goerss Predicted Consensus Errors (Goerss, 2007, hereafter called GPCEs) for certain multi-model ensemble models are available. GPCEs are the radii of circles, centered on the ensemble forecast location, within which 72% – 74% of the actual tropical cyclone locations landed, over previous seasons. GPCEs are computed using multiple regression equations. The inputs are model ensemble spread, and current and forecast tropical cyclone intensity. The ensemble spread is the average great-circle distance between each ensemble member and the ensemble mean location. Goerss (2007) asserted that the GPCEs had strong correlations with ensemble model error, but recent calculations show that strong correlations are only found when GPCEs are averaged over whole hurricane seasons, and correlated with official forecast track errors similarly averaged over whole hurricane seasons. Hansen et al. (2011) proposes an update to the GPCE by separating along-track and across-track errors, but the new version has not been made available to NHC forecasters.

Until the 2012 season, GPCEs were calculated for two multi-model ensemble models, TCON, and TVCN. TCON is composed of an average of the National Centers for Environmental Prediction's Global Forecast System (MetEd, 2007), the United Kingdom Meteorological Office's global model (UK Met Office, n.d.), the U.S. Navy's global model (MetEd, 2007), the Geophysical Fluid Dynamics Hurricane Model, (Bender, et al., 2007), and the National Centers for Environmental Prediction's Hurricane Weather Research and Forecasting model, all five of which must be available. TVCN is composed of an average of the same five models which comprise TCON, with the addition of the U.S. Navy's version of the Geophysical Fluid Dynamics Hurricane Model (Skupniewicz, C., 2009), and the European Center for Medium-range Weather Forecasts' global model (Untch, 2009), of which at least two of the seven models must be available. For the 2012 season (beginning with Hurricane Chris), GPCEs were no longer computed for TCON.

Statistics for the 2008 – 2011 (see Table 2) seasons show that track errors for the official NHC forecasts (OFCI) are highly correlated with track errors for TVCN. The correlations shown are the averages of the correlation coefficients between the TVCN model track errors and the official forecast track errors for all of the storms in each season. To be included, there had to be at least five forecasts for each storm at each lead time. These correlations confirm verbal communications (Franklin and Pasch, 2010-2012) that NHC forecasters rely on the multi-model

**Table 2. Average Correlation Coefficients for all Storms in Each Season**

| | 2008 | 2009 | 2010 | 2011 | All 4 years |
|---|---|---|---|---|---|
| 12 Hours | **0.84** | **0.75** | **0.86** | **0.77** | **0.80** |
| 24 Hours | **0.83** | **0.77** | **0.85** | **0.79** | **0.81** |
| 36 Hours | **0.84** | **0.89** | **0.74** | **0.82** | **0.82** |
| 48 Hours | **0.86** | **0.84** | **0.81** | **0.73** | **0.81** |
| 72 Hours | **0.86** | **0.84** | **0.70** | **0.62** | **0.75** |
| 96 Hours | **0.87** | **0.86** | **0.70** | **0.47** | **0.72** |
| 120 Hours | **0.74** | **0.91** | **0.52** | **0.81** | **0.75** |

ensembles for track input into their forecasts.

Statistics computed for 2008 – 2012 show that the correlations between GPCEs and the respective model error, within a given storm, are poor. Table 3 shows the percentage of times when the correlation coefficients between GPCEs and TVCN model track error for the storms in a given season at each lead time were greater than 0.5. This table shows that the correlation between the GPCEs and the model track error is only greater than 0.5 less than 30% of the time.

**Table 3. Percentage of Times when Correlation Coefficients between GPCEs and TVCN Model Track Errors are Greater than 0.5**

| | 2008 | 2009 | 2010 | 2011 | 2012 | All 5 years |
|---|---|---|---|---|---|---|
| 12 Hours | **13** | **33** | **24** | **28** | **18** | **23** |
| 24 Hours | **7** | **14** | **19** | **29** | **35** | **21** |
| 36 Hours | **21** | **0** | **20** | **13** | **14** | **14** |
| 48 Hours | **38** | **20** | **14** | **19** | **9** | **20** |
| 72 Hours | **33** | | **10** | **36** | **20** | **25** |
| 96 Hours | **40** | | **13** | **38** | **14** | **26** |
| 120 Hours | **38** | | **17** | **17** | **0** | **18** |

For individual storms, the correlations can be close to zero. It is only when the track errors are averaged over a whole season, and compared with the average GPCEs, that stronger correlations are found, as discussed in Goerss (2007). Thus, GPCEs give no useful real time forecast information concerning forecast track errors.

**Current Results:**

In addition to the output from multi-model ensembles, the NHC receives forecasts from single model ensembles. Single model ensembles include the National Centers for Environmental Prediction's Global Forecast System Ensemble Model (GFSE), with 20 ensemble members, and the European Center for Medium-Range Forecasting (ECMWF) 50-member ensemble. In each of these ensembles, each member is initialized with slightly perturbed initial conditions. Verbal communication with NHC forecasters (Franklin and Pasch, 2010 – 2012) suggest that they do not explicitly rely on the GFSE or the ECMWF ensemble as much as they rely on the multi-model ensembles, but statistics for the longer-lived storms of the 2010 season show that there is a strong correlation between the GFSE mean forecast (the average of the 20 member forecasts) and the official forecast track errors. Table 4 shows the data for the storms in 2010 that had at least eight 72-hour official forecasts.

While the average correlations are not as large for these storms in 2010 as those for the TVCN model in Table 2, individual storms have correlations that are nearly as large, notably Danielle, Igor, and for some lead times in most of the storms. This shows that GFSE statistics have relevance for operational forecasting.

**Table 4. Correlations Coefficients between GFSE Model Forecast Track Errors and Official Forecast Track Errors for Eight Long-lived Storms from 2010**

| | Alex | Danielle | Earl | Igor | Julia | Lisa | Richard | Tomas | Avg. |
|---|---|---|---|---|---|---|---|---|---|
| 12 Hrs. | **0.72** | **0.85** | **0.40** | **0.72** | **0.80** | **0.62** | **0.47** | **0.83** | **0.68** |
| 24 Hrs. | **0.73** | **0.84** | **0.41** | **0.74** | **0.79** | **0.69** | **0.32** | **0.66** | **0.65** |
| 36 Hrs. | **0.52** | **0.84** | **0.50** | **0.71** | **0.77** | **0.72** | **0.17** | **0.53** | **0.60** |
| 48 Hrs. | **0.40** | **0.71** | **0.58** | **0.70** | **0.77** | **0.76** | **0.32** | **0.32** | **0.57** |
| 72 Hrs. | **0.72** | **0.57** | **0.62** | **0.73** | **0.06** | **0.59** | **0.44** | **0.09** | **0.47** |
| 96 Hrs. | **0.28** | **0.75** | **0.69** | **0.70** | **0.60** | **-0.77** | **0.94** | **0.73** | **0.49** |
| 120 Hrs. | **0.14** | **0.98** | **0.74** | **0.79** | **0.36** | | | **0.74** | **0.63** |

Real time guidance for the accuracy of the current forecast would be very helpful to NHC forecasters. GFSE statistics computed for the 2010 season show promise in providing real-time guidance on model accuracy. The ensemble spread is one measure of the sensitivity to initial conditions, measuring the average distance between each member forecast and the mean of all the members. The area covered by a given forecast is another way to measure this sensitivity, and the area will be more sensitive to a single outlier forecast than the ensemble spread. Both statistics have been computed for each of the storms shown in Table 4, and the area covered by the forecast locations was found to be the most useful for guidance. For each forecast, the maximum and minimum latitude and longitude from the 20 members of the ensemble were found for each lead time (12, 24, 36, 48, 72, 96, and 120 hours). The area covered by the forecast locations was calculated using the following formula for the area of a spherical quadrangle located between the maximum and minimum latitudes and the maximum and minimum longitudes.

$$area = \left(\frac{\pi}{180}\right) a^2(\sin(maxlatitude) - \sin(minlatitude))(maxlongitude - minlongitude)$$

In this equation, a is the radius of the earth. These areas were then averaged over all forecasts and all lead times for each storm, with the limitation that all 20 members of the ensemble must have forecast locations, and that all lead times must be included. This latter requirement was necessary since the area covered by the ensemble forecasts increases with longer range forecasts.

The official forecast errors were plotted as a function of forecast date and lead time (not shown here). The average forecast error for the previous five years (see Table 1), used as a benchmark by NHC forecasters, was plotted on each of these graphs. This made it easy to find the dates when the forecasts were worse than average.

The first example shown is for Hurricane Danielle. Forecasts for 12 – 72 hours were worse than average for forecasts from August 22, 06 UTC through August 24, 12 UTC. Forecasts for lead times of 12 – 36 hours were also worse than average for forecasts from August 25, 12 UTC through August 25, 18 UTC, and for lead times of 12 and 24 hours, forecasts from August 29, 00 UTC through August 29, 12 UTC were worse than average. Forecasts at 72 hours were worse

than average between August 26, 00 UTC through August 27, 06 UTC. Forecasts at 96 hours were worse than average between August 25, 06 UTC through August 26, 18 UTC. Finally forecasts at 120 hours were worse than average from August 24, 18 UTC, through August 25, 18 UTC.

The average area covered by GFSE forecasts is shown in Fig. 1, with colored bars showing the times when there were forecasts that were worse than average.

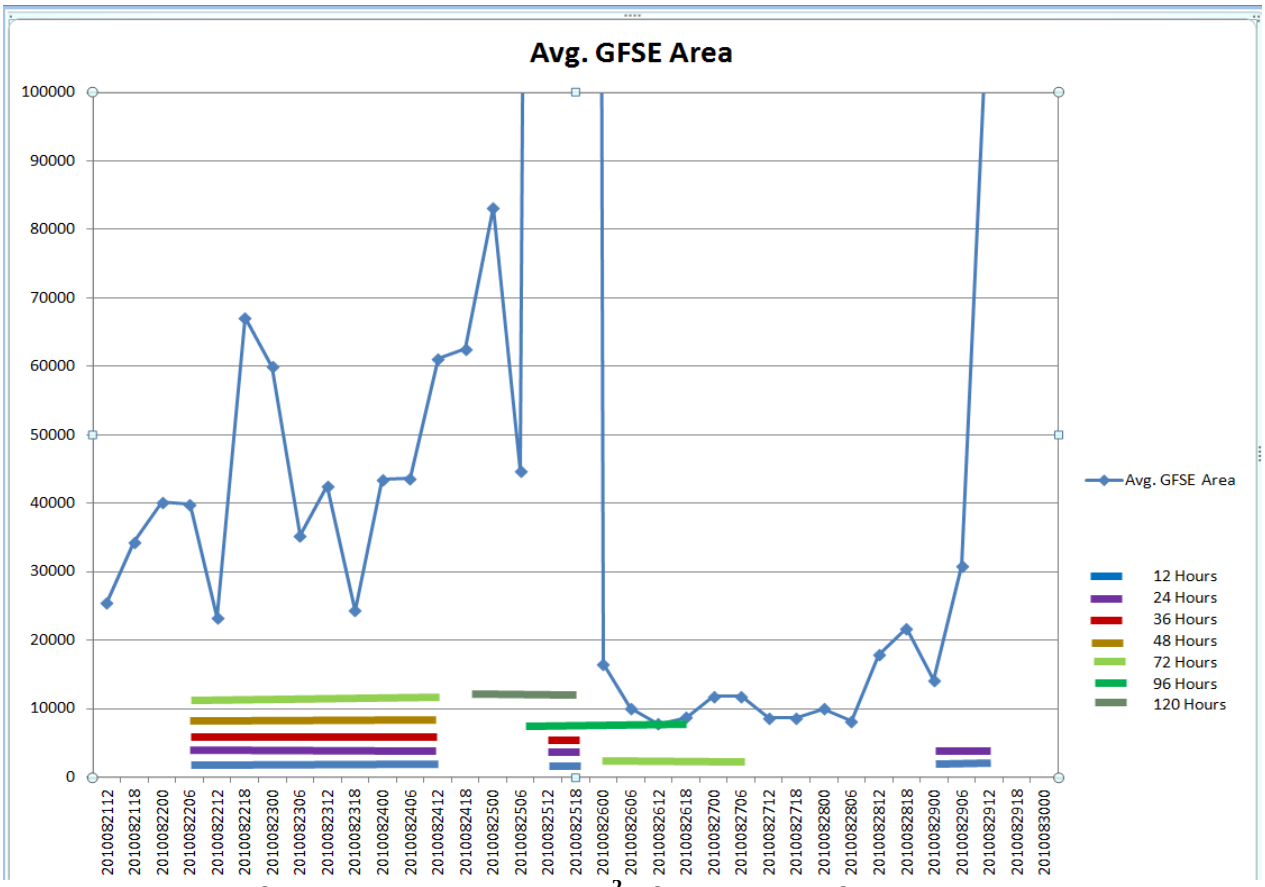


**Figure 1. Graph of average GFSE Area (nm$^2$) for each date for Hurricane Danielle (blue line connecting dots), and the times when the official forecast track errors were larger than the average track error for the previous five years (shown by colored bars).**

The average GFSE area is above 25,000 nm$^2$ for the forecasts starting August 21, 12 UTC, and ending August 26, 00 UTC. Official forecasts began August 21, 18 UTC. The first two of these dates did not have forecasts with larger errors than average, but all of the subsequent forecasts did have at least one lead time with above average errors, and this corresponds almost perfectly to the high average GFSE areas. The period when the GFSE average area is below 25,000 nm$^2$, is characterized by official forecasts with below average errors, except for some 72 hour forecasts and some 96 hour forecasts. When the GFSE average area rises at the end of the forecast period, there are once again 12 and 24 hour official forecasts with above average errors. The longer range official forecasts ended well before the end of the forecast period, so there is no way to verify that they might or might not have been in error when the GFSE average area increased after August 29, 00 UTC.

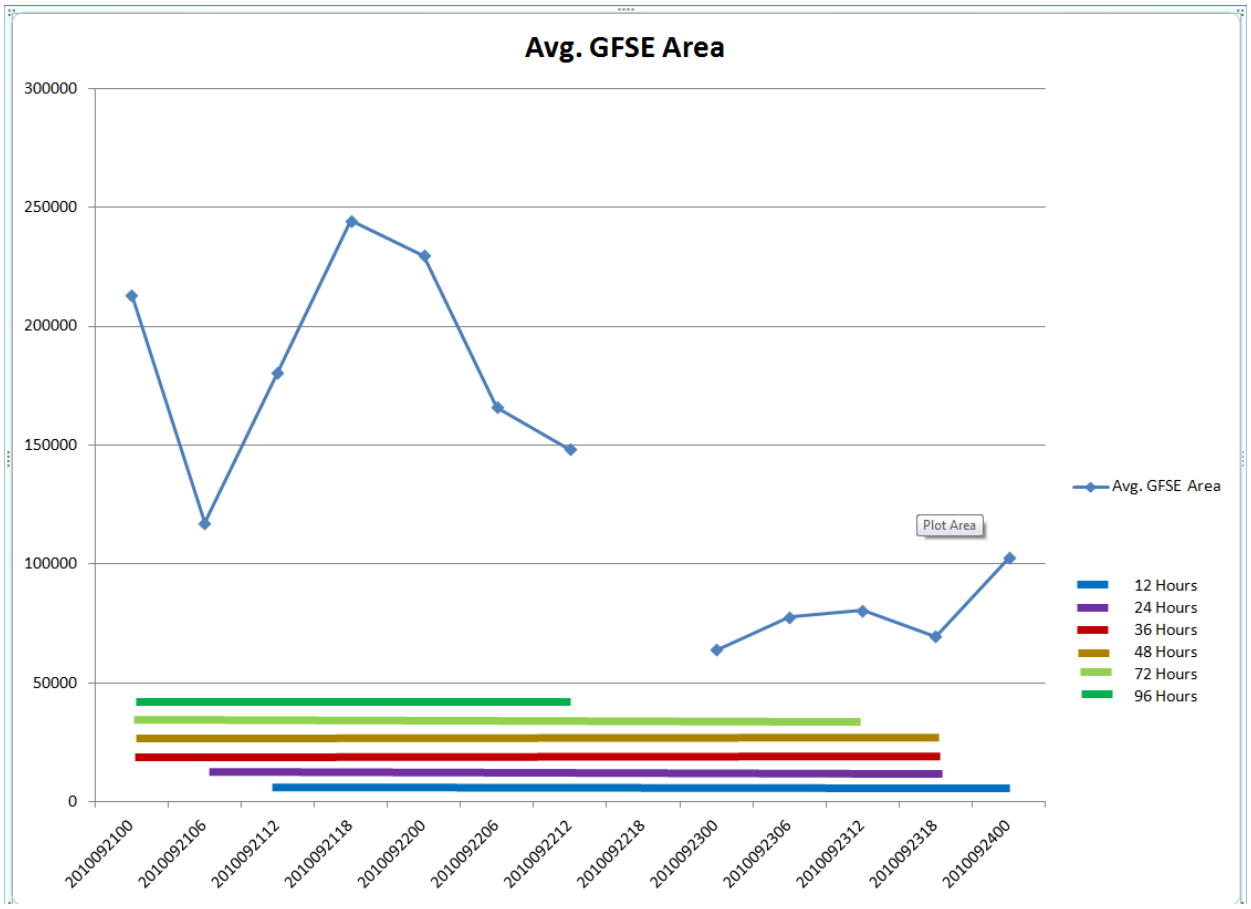


**Figure 2. As in Fig. 1, except for Hurricane Lisa.**

Figure 2 shows the GFSE average area with the periods of larger than average official errors for Hurricane Lisa. All of the official forecast errors were larger than average for Lisa and the GFSE average area is larger than 25,000 $nm^2$ for all periods. The vertical scale had to be changed for this storm to show the data, since the GFSE average areas were so large. There were no 120 hour official forecasts made for Lisa, which is why none are shown. The 96 hour and 72 hour official forecasts ended September 22, 12 UTC and September 23, 12 UTC respectively, which means that all the official forecasts for lead times greater than 24 hours had larger than average errors.

Figure 3 shows the GFSE average area with the periods of larger than average official errors for Hurricane Earl. The early part of the forecast period shows average GFSE areas larger than 25,000 $nm^2$ when the official forecast errors are larger than average. The period from August 30, 12 UTC, to September 2, 06 UTC, has average GFSE areas smaller than 25,000 $nm^2$ (with two single point outliers), which corresponds to official forecast errors smaller than average. However, the period from August 29, 00 UTC, through August 30, 06 UTC, and the period from September 2, 12 UTC through September 3, 12 UTC, both have GFSE average areas larger than 25,000 $nm^2$, when the official forecast errors are not larger than average. Note that the only official forecasts available beyond September 1, 18 UTC are for smaller lead times than 72 hours, limiting the number of official forecast errors that can be compared at the end of the

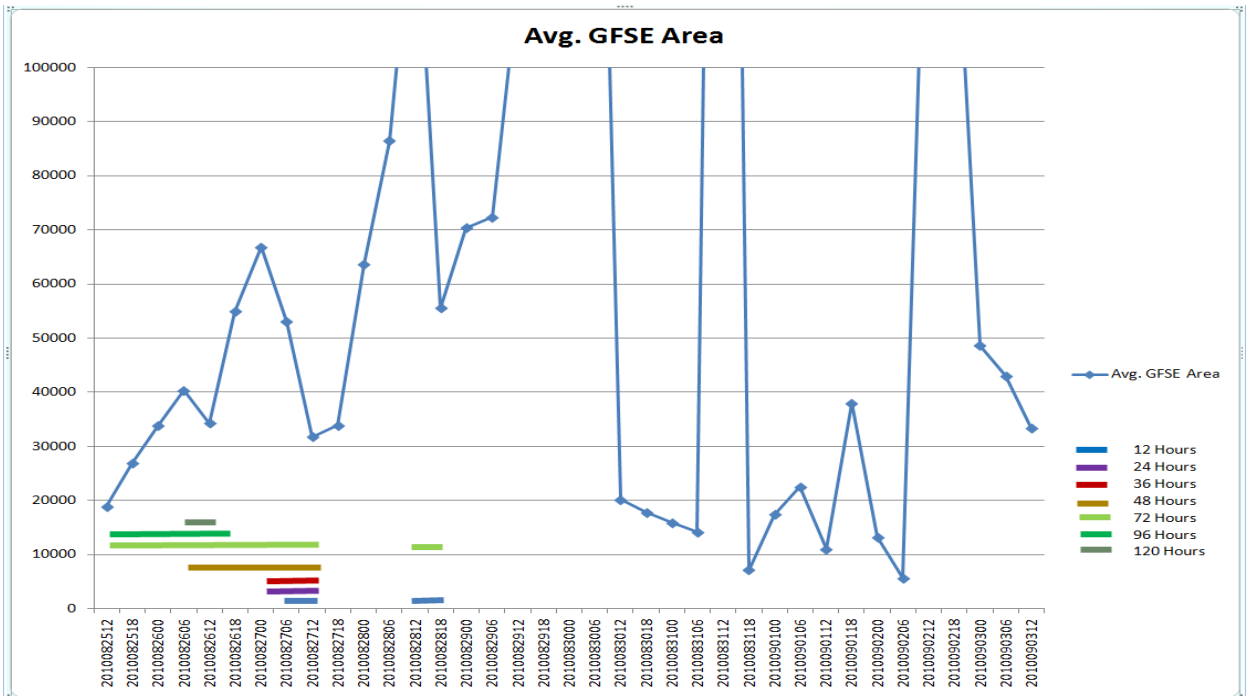


**Figure 3. As in Fig. 1, except for Hurricane Earl.**

forecast period. Nonetheless, Hurricane Earl shows that while the relationship between the GFSE average area and official errors is generally strong, there is more research needed to determine how this relationship holds for all storms. For instance, forecasting the recurvature of a tropical cyclone may have a different relationship to the GFSE average area than forecasts for the straighter portion of a track. The storm intensity may also play a role in the correlation, since the forecast intensity of a storm can have a significant impact on the forecast track (Fovell et al., 2009). Finally, the precise value of the critical GFSE area may not be constant for all storms.

For the eight long-lived storms in 2010, using the GFSE average area of 25,000 $nm^2$ as the critical area, the hit rate is 0.67, false alarm rate is 0.24, bias is 0.80, and the Heidke Skill Score is 0.29. These preliminary statistics shows that there is skill in the method, even without considering other variables, intensity or track characteristics.

## 3) Proposed Work Plan

Statistics will be computed for all of the storms from 2008 through 2012, and the GFSE average area will be compared to the periods when the official forecast track errors were larger than the previous five year average. Additionally, each storm track will be compared with the ensemble forecasts to determine if there is any relationship between the kind of track (straight, looping, recurving, etc.), and the correlation between GFSE average area and the official forecast track errors. The intensity of each storm will be compared as well, since the forecast intensity of a storm can have a significant impact on the forecast track (Fovell et al., 2009).

Particular attention will be paid to the 2012 hurricane season, since the Global Forecast System was upgraded in February of 2012, and the GFSE was similarly upgraded. In particular, the

forecast of tropical cyclone tracks was expected to be improved over the previous version of the GFS, and since the GFSE uses the same improved version of the model, the GFSE error statistics will be different too.

Statistics will also be computed for the ECMWF ensemble. Nixon (2012) shows that the ECMWF ensemble has higher reliability and resolution than the GFSE, suggesting that the forecasts from the ECMWF ensemble may also be useful to diagnose sensitivity to initial conditions and the effect of that sensitivity on forecast errors. Majumdar and Finocchio (2010) indicate that the ECMWF ensemble had similar skill to multi-model ensembles in the 2008 Atlantic hurricane season, again suggesting that the ECMWF ensemble should be examined here.

The outcome of the research will be a simple program that will compute the GFSE area and other relevant statistics that emerge from the research. Testing will be done during the 2014 hurricane season, during which data will be collected regarding the accuracy of the tool. At the beginning of the season, the PI will present the new tool to the NHC forecasters, in cooperation with the NHC administration.

The percentage of forecasts that are correctly characterized as having worse than average track errors (hit rate) and the percentage of forecasts that are not correctly characterized (misses) will be tabulated, as well as the percentage of forecasts that indicate a worse than average track error that does not materialize (false alarms). These statistics and relevant skill scores can be used to evaluate the usefulness of the tool at the end of the season. In addition, it will be helpful to survey the forecasters to see how they view the new tool.

There will be a small amount of programming needed to insert this program into the operational suite at the NHC, and the output will have to be made available to the NHC forecasters. It is anticipated that the computational requirements will be very small, given the simple nature of the calculation.

**References**

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**4) Time Line**

August, 2013 – June, 2014: Computation of statistics and analysis of storm tracks and intensities.
July, 2014: Installation of new tool at NHC
August – December, 2014: Real-time evaluation of usefulness of tool, including feedback from forecasters
January 2015 – July 2015: Modifications of tool based on performance in 2014 season

**5) Schedule for Travel**

October, 2013: Visit NHC in Miami to coordinate 1st year work with forecasters
March, 2014: Attend Interdepartmental Hurricane Conference
March, 2015: Attend Interdepartmental Hurricane Conference

**6) JHT Staff Requirements**

Will require coordination with IT specialists at NHC to implement calculation program to support new tool, and to determine how best to display output.

Computational Needs Estimate: Minimal – less than a few seconds of CPU
Staff Needs Estimate: No more than 4 hours

**d) Budget**

| | | Year 1 | Year 2 | Totals |
|---|---|---|---|---|
| Frank Colby - P.I. | 1 summer month | $11,823 | $12,059 | $23,882 |
| Fringe Benefits | 1.29% | $153 | $156 | $308 |
| Graduate Student | Academic Year | $17,005 | $17,345 | $34,350 |
| Graduate Student | Summer Salary | $5,000 | $0 | $5,000 |
| Fringe Benefits | 1.29% | $65 | $0 | $65 |
| Travel | | $3,000 | $2,040 | $5,040 |
| RA Fees | | $5,000 | $5,100 | $10,100 |
| Total Direct Costs | | $42,045 | $36,700 | $78,744 |
| Modified Total Direct Costs | | $37,045 | $31,600 | $68,644 |
| Indirect Costs @ 51% | | $18,893 | $16,116 | $35,009 |
| Total Costs | | $60,937 | $52,815 | $113,752 |

Support is requested for one M.S. graduate student for 2 academic years and one summer. Graduate student assistance is not anticipated for the second summer, following the Hurricane Season of 2014.

Travel is as indicated in section 6) of the Statement of Work, and includes one trip to coordinate initial research with the NHC forecasters, scheduled to occur after the intense forecasting period of the Hurricane Season of 2013. Also included are the Interdepartmental Conferences in March of each year. Travel is intended to cover only the PI – the graduate student will not need to be on these trips.

**e) Additional Forms – part of package**

**f) CV for Dr. Frank Colby**

Department of Env., Earth, & Atmospheric. Sciences
University of Massachusetts - Lowell
Lowell, MA 01854

31 Independence Ave.
Lexington, MA 02173

EDUCATION

B.S. Degree with Honors -- University of Michigan,
Ann Arbor, Michigan, June, 1976

M.S. Degree in Meteorology -- Massachusetts Institute of Technology
Cambridge, Massachusetts, February, 1979

Ph.D. Degree in Meteorology -- Massachusetts Institute of Technology
Cambridge, Massachusetts, February, 1983

PROFESSIONAL EXPERIENCE

September, 1995 - Present
Professor of Meteorology, Department of Env., Earth & Atm. Sciences
University of Massachusetts - Lowell

September, 1988 - September 1995
Associate Professor with Tenure, Department of Earth Sciences
University of Lowell / University of Massachusetts - Lowell

September, 1983 - September 1988
Assistant Professor, Department of Earth Sciences
University of Lowell

PROFESSIONAL ASSOCIATIONS

Member of American Meteorological Society (AMS) since 1978.
Member, AMS Committee for Undergraduate Awards, 1989 to 1993.
Member, AMS Membership Committee, 1991 to 1996, Chair 1993-1994.
Associate Editor for AMS journal Monthly Weather Review, 1994 to 1998.

RECENT PUBLICATIONS

Colby, Frank P. Jr., 2011: "Influence of topography on the track and intensity of tropical cyclones. Proceedings of 14th Conference on Mesoscale Meteorology, Los Angeles, CA, 1-4 August, 2011.

Agel, L., V. Lopez, M. Barlow and F. Colby, 2011: Regional and large-scale influences

on summer ozone levels in Southern California. J. Appl. Meteor. Climatol., 50, 800–805.

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Robinson, Thomas E., Jr., and Frank P. Colby, Jr., 2009: "Orographic effects on coastal cyclogenesis in New England". Proceedings of 13th Conference on Mesoscale Processes, Salt Lake City, UT, 17-20 August 2009.

Colby, Frank P. Jr., and M. Barlow, 2009: "Have New England heat waves been influenced by forest cover trends?". Proceedings of 23rd Conference on Weather Analysis and Forecasting/19th Conference on Numerical Weather Prediction, Omaha, NE, 1-5 June 2009.

**g) Current and Pending Federal Support**

None.

BUDGET NARRATIVE

Support is requested for one M.S. graduate student for 2 academic years and one summer. Graduate student assistance is not anticipated for the second summer, following the Hurricane Season of 2014.

Travel is as indicated in section 6) of the Statement of Work, and includes one trip to coordinate initial research with the NHC forecasters, scheduled to occur after the intense forecasting period of the Hurricane Season of 2013. Also included are the Interdepartmental Conferences in March of each year. Travel is intended to cover only the PI – the graduate student will not need to be on these trips.

**Areas Affected by Project (Cities, Counties, States, etc)**

The Gulf and Atlantic Coastal areas

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

## Application for Federal Assistance SF-424

* 1. Type of Submission:
- [ ] Preapplication
- [x] Application
- [ ] Changed/Corrected Application

* 2. Type of Application:
- [x] New
- [ ] Continuation
- [ ] Revision

* If Revision, select appropriate letter(s):

* Other (Specify):

* 3. Date Received: 12/06/2012

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 Massachusetts Lowell

* b. Employer/Taxpayer Identification Number (EIN/TIN): 043167352

* c. Organizational DUNS: 956072490

**d. Address:**

* Street1: Office of Research Administration
Street2: 600 Suffolk Street, 2nd Floor South
* City: Lowell
County/Parish: Middlesex
* State: MA: Massachusetts
Province:
* Country: USA: UNITED STATES
* Zip / Postal Code: 01854-3648

**e. Organizational Unit:**

Department Name: Research Administration

Division Name:

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

Prefix:
* First Name: Linda
Middle Name:
* Last Name: Concino
Suffix:

Title: Dir, Grants and Contract Admin

Organizational Affiliation: University of Massachusetts Lowell

* Telephone Number: 978-934-4723
Fax Number: 978-934-2027

* Email: Linda_Concino@uml.edu

## Application for Federal Assistance SF-424

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

H: Public/State Controlled 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.):**

Areas_Affected_by_Project1004231611.pdf | Add Attachment | Delete Attachment | View Attachment

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

Use of Ensemble Statistics to Provide Real-Time Guidance for Forecast Accuracy

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: MA-005 | b. Program/Project: MA-005

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 | 113,752.00 |
| * b. Applicant | 0.00 |
| * c. State | 0.00 |
| * d. Local | 0.00 |
| * e. Other | 0.00 |
| * f. Program Income | 0.00 |
| * g. TOTAL | 113,752.00 |

*** 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: Linda

Middle Name:

* Last Name: Concino

Suffix:

* Title: Dir, Grants and Contract Admin

* Telephone Number: 978-934-4723 | Fax Number: 978-934-2027

* Email: Linda_Concino@uml.edu

* Signature of Authorized Representative: Linda Concino | * Date Signed: 12/06/2012

# 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 | | New or Revised Budget | | |
|---|---|---|---|---|---|---|
| | | Federal (c) | Non-Federal (d) | Federal (e) | Non-Federal (f) | Total (g) |
| 1. NOAA-OAR-OWAQ-2013-2003469 | 11.459 | $ 0.00 | $ 0.00 | $ 113,752.00 | $ 0.00 | $ 113,752.00 |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. Totals | | $ | $ | $ 113,752.00 | $ | $ 113,752.00 |

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## SECTION B - BUDGET CATEGORIES

| 6. Object Class Categories | GRANT PROGRAM, FUNCTION OR ACTIVITY (1) NOAA-OAR-OWAQ-2013-2003469 | (2) | (3) | (4) | Total (5) |
|---|---|---|---|---|---|
| a. Personnel | $ 63,230.00 | $ | $ | $ | $ 63,230.00 |
| b. Fringe Benefits | 373.00 | | | | 373.00 |
| c. Travel | 5,040.00 | | | | 5,040.00 |
| d. Equipment | | | | | |
| e. Supplies | | | | | |
| f. Contractual | | | | | |
| g. Construction | | | | | |
| h. Other | 10,100.00 | | | | 10,100.00 |
| i. Total Direct Charges (sum of 6a-6h) | 78,743.00 | | | | $ 78,743.00 |
| j. Indirect Charges | 35,009.00 | | | | $ 35,009.00 |
| k. TOTALS (sum of 6i and 6j) | $ 113,752.00 | $ | $ | $ | $ 113,752.00 |
| | | | | | |
| 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 | $ 113,752.00 | $ 28,438.00 | $ 28,438.00 | $ 28,438.00 | $ 28,438.00 |
| 14. Non-Federal | $ | | | | |
| 15. TOTAL (sum of lines 13 and 14) | $ 113,752.00 | $ 28,438.00 | $ 28,438.00 | $ 28,438.00 | $ 28,438.00 |

## 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. NOAA-OAR-OWAQ-2013-2003469 | $ 52,815.00 | $ | $ | $ |
| 17. | | | | |
| 18. | | | | |
| 19. | | | | |
| 20. TOTAL (sum of lines 16 - 19) | $ 52,815.00 | $ | $ | $ |

## SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: $78,742

22. Indirect Charges: $35,009

23. Remarks:

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

# ASSURANCES - NON-CONSTRUCTION PROGRAMS



**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 | * TITLE |
|---|---|
| Linda Concino | Dir, Grants and Contract Admin |
| * APPLICANT ORGANIZATION | * DATE SUBMITTED |
| University of Massachusetts Lowell | 12/06/2012 |

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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 Massachusetts Lowell

* AWARD NUMBER

* PROJECT NAME

FY 2013 Joint Hurricane Testbed

Prefix:

* First Name: Linda

Middle Name:

* Last Name: Concino

Suffix:

* Title: Dir, Grants and Contract Admin

* SIGNATURE: Linda Concino

* DATE: 12/06/2012