Operational Testing and Implementation of the Deviation Angle Variance Technique for Objectively Estimating Tropical Cyclone Intensity and Forecasting Tropical Cyclogenesis

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Abstract

The Deviation Angle Variance (DAV) technique was developed at the University of Arizona (UA) as an objective estimator of tropical cyclone (TC) intensity. The DAV methodology examines the structure of infrared brightness temperature images from geostationary satellite platforms by using a statistically robust method to estimate the axisymmetry of the system. In previous work we have used several years of TC cases in the N. Atlantic, eastern N. Pacific, and western N. Pacific basins to train a relationship between the DAV metric and best track intensity. Extensive testing has resulted in estimated RMS errors of 13 to 15 kt compared to best track for test cases in all three basins. The ability of the DAV metric to provide good estimates of TC intensity at low intensities led us to further investigate its utility as an indicator of tropical cyclogenesis. Testing in the N. Atlantic and western N. Pacific basins indicate that the system has a high detection probability (>85%) with low false alarm rates (<20%) and a median detection time of approximately 0 h relative to the best track tropical depression designation.

For the past several months, we have been working with the JTWC operational forecast center to begin converting the DAV method to a real-time system and to present the DAV outputs in a way that is useful to forecasters. We have developed process flow for GOES-E and GOES-W images (N. Atlantic and eastern N. Pacific basins) using existing data archives at the UA, and we worked with NRL-Monterey and JTWC personnel to develop a real-time process flow for images from the Japanese MT-SAT instrument. We are currently publishing DAV analyses for TC genesis in real time with a latency of less than 30 minutes in the Atlantic and western N. Pacific basins, allowing us to understand how the operational centers might use our products.

Under the proposed JHT program, we will work with JTWC and NHC to make the DAV genesis products more user friendly. Initial examinations have pointed to the need for automatic tracking of developing systems, the ability to present time series to the user, and the ability for the user to provide points of interest to the DAV system. In addition to these interface features, we will need to develop a probabilistic forecast output from the DAV that can provide a confidence metric to the forecasters. We will also work to bring the DAV intensity products online in two ways. First, we will advance the current web interface to include time series of DAV intensity estimates for systems of interest identified by the user. Second, we will work with the forecast centers to provide our objective intensity estimates for the locations identified in operational best track using the ATCF format. In the first year of the proposed program we will focus on operationalizing the DAV products so that initial testing can occur in the summer/fall TC seasons. In the second year we will add features that are identified as desirable in year one, and we will perform operational testing for the full TC season in all three basins.

Statement of Work

1. Project Duration

The project proposed here is expected to last two years. During the first year we will work to operationalize the DAV methods for both TC genesis detection and TC intensity estimation. We will produce products for use in the operational centers in the summer/fall TC seasons in 2013. During the second year of the project we will implement forecasters' suggestions and any improvements into the DAV products. The 2014 TC season will be reserved for real-time operational testing in all three basins.

2. Description of the Project

The project that we propose here directly addresses two of the JHT program priorities:

- NHC-3/JTWC-6: Statistically based real-time guidance to assist in the determination of official track and intensity forecasts
- NHC-8/JTWC-3: Guidance for TC genesis at both the short-range (0-48h) and the medium range (48-120h).

One of the key needs in forecasting TCs is determining an objective, accurate analysis of the wind structure and intensity in oceanic regions where *in situ* observations are sparse. In these regions, satellite-based remote sensing instruments are central to determining the current structure of TCs. However, the majority of the observations provided by these instruments currently do not directly relate to the basic state variables used to characterize TC structure and intensity or to initialize them in numerical weather prediction models.

One of the first uses of satellite data was to indirectly estimate the intensity of tropical cyclones where no direct measurements were available. The Dvorak technique (Dvorak 1975) and its extended versions, the Objective Dvorak Technique (Velden et al. 1998) and the Advanced Dvorak Technique (Olander et al. 2007), are well-known examples of methodologies to estimate the intensity of tropical cyclones from infrared (IR) satellite imagery. In addition, there are other techniques to estimate intensity and structure based on satellite measurements in developmental stages. Kossin et al. (2007) recently described a new satellite-based technique in which the radius of maximum wind, the critical wind radii, and the two-dimensional surface wind field are estimated using mean 12-h IR imagery. The technique estimates the two-dimensional wind field from the IR imagery and then validates the field against aircraft wind observations. Techniques to estimate intensity of a tropical cyclone have also been developed using measurements from the Advanced Microwave Sounding Unit (AMSU) (Spencer and Braswell, 2000; Demuth et al. 2004). Some of these techniques have been combined to enhance tropical cyclone intensity estimation (e.g., Velden et al. 2006). More recently, the deviation-angle variance (DAV; Pineros et al. 2008; 2010; 2011; Ritchie et al. 2012) technique was introduced by our group as an alternative methodology to estimate TC intensity and discriminate developing cloud clusters during cyclogenesis. For ocean basins where there is no continuous aircraft reconnaissance of tropical

cyclones[1], these satellite-based techniques are the only estimate of tropical cyclone intensity available to tropical cyclone forecasters.

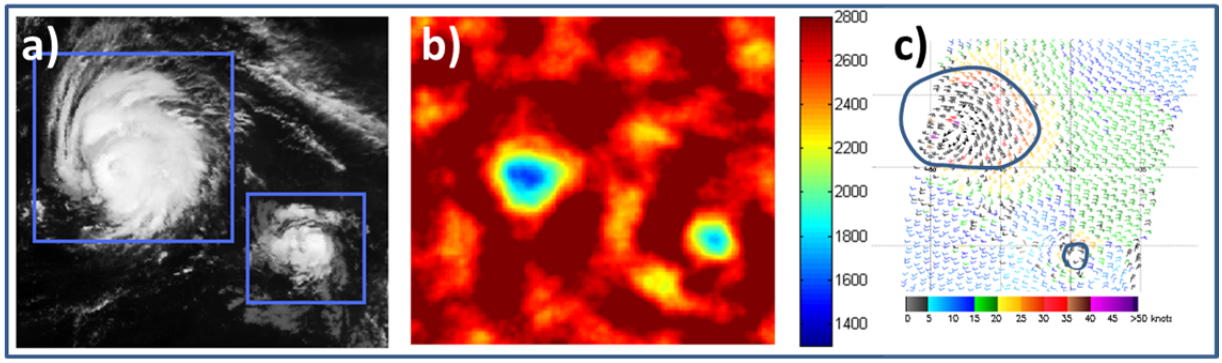

Figure 1: Images of Hurricanes Karl (left) and Lisa (right) at 1315 UTC 20 September 2004: a) Infrared image; b) the corresponding map of deviation-angle variances (deg^2); and c) the corresponding QuikSCAT overpass with the approximate extent of 34-kt winds circled. *[image courtesy of http://manati.star.nesdis.noaa.gov/datasets/].*

The DAV technique uses a statistically robust transformation to evaluate the organization of a cloud system relative to that expected for a perfectly axisymmetric tropical cyclone. In order to estimate the current intensity, the DAV parameter is evaluated only at the center of the TC. However, by evaluating the DAV parameter at every pixel in turn, a "map of variances" can be created that has utility for discerning developing cloud clusters in their very early stages (Figure 1). We have implemented a discriminant system that uses a pre-defined threshold as an indicator of TC genesis. Extensive testing in the N. Atlantic and western N. Pacific basins have produced excellent results as indicated by the ROC curves in the two basins shown in Figure 2.

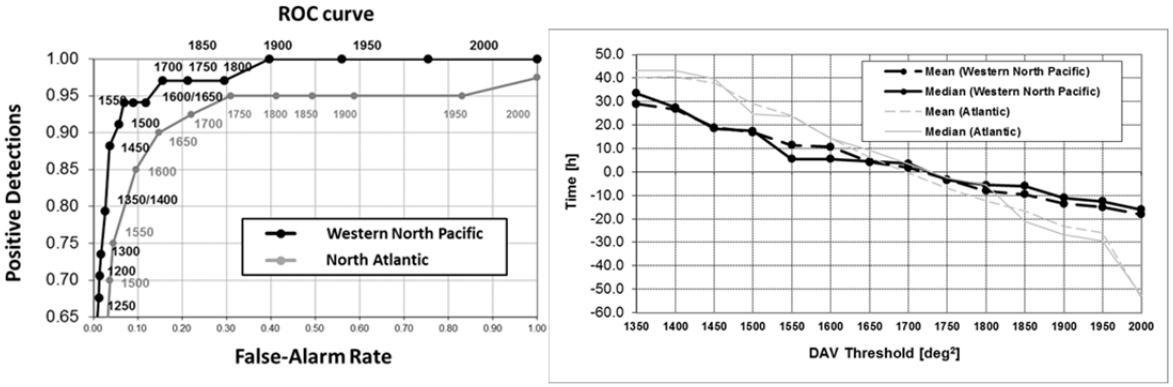

Figure 2: ROC curves (left) and mean/median detection times (right) for the DAV genesis detector in the N. Atlantic and western N. Pacific basins. False alarms are all cloud systems that go below a DAV of 2000 [deg^2] during the TC season in the respective basin. Detection time is measured relative to Best Track tropical depression designation.

[1] Aircraft reconnaissance is ongoing in the western Atlantic and eastern North Pacific basins. Aircraft reconnaissance was discontinued in the western North Pacific in 1986.

While the genesis detection tool uses a map-of-variances to locate the minimum value of DAV in an image, the intensity estimator computes the DAV at a particular location. We have tested the methods using both automatically generated (Pineros, et al., 2008) and manually specified (Ritchie, et al., 2012) center locations. Depending on the method of center identification, we have demonstrated RMS error performance of 13 – 15 kt in the three basins of interest (Ritchie, et al., 2012, 2013; Wood, 2012).

Basin	Years	RMS Error (kt)
North Atlantic	2004 – 10	12.8
Eastern North Pacific	2005 – 11	13.5
Western North Pacific	2007 – 11	14.3

Table 1. Intensity estimation errors using the DAV data. The RMS error is for training and testing on all data available in the respective basins. Results obtained by holding a single year out of the training data for independent testing produce comparable errors that are both better and worse than the values indicated here, depending on the basin and year (Ritchie, *et al.*, 2012a, b; Wood, 2012).

Initial work towards system operationalization

In the fall of 2012 our group began working with JTWC to provide the DAV data to the operational forecasters for consideration in the pre-genesis stages of forecasting. In order to enable this interaction, we have developed a real-time, web-based interface. The first step in this process was to develop a data source for accessing the brightness temperature image data in all three basins. The GOES-E and GOES-W data were already being archived in real time at the UA, and we took advantage of this existing data source. For the MT-SAT data in the western North Pacific, we developed a process flow in conjunction with JTWC and NRL-Monterey that provides us access to real time MT-SAT data for DAV computation.

The real-time interface was developed from (and integrated with) our archival data web interface, shown in figure 3. IR satellite images are overlaid onto basin maps, and icons are displayed at DAV detection points. The research interface provides best-track display for comparison, and allows the user to move in date and time. The latitude/longitude grid, IR image, and map of variances can be turned on/off in layers. The interface also provides an animation visualization tool.

The web interface was developed using modern web development techniques in order to maintain a high degree of flexibility – knowing that this was an evolving research product. The use of C# and XML technologies have helped provide flexibility as the web application has moved forward, and ASP.NET has provided a familiar interface to the user. Flash animation tools were integrated into the interface, permitting images to be compiled into videos. The web application has been carefully developed to support Internet Explorer, Mozilla, and Chrome browsers and various monitor formats.

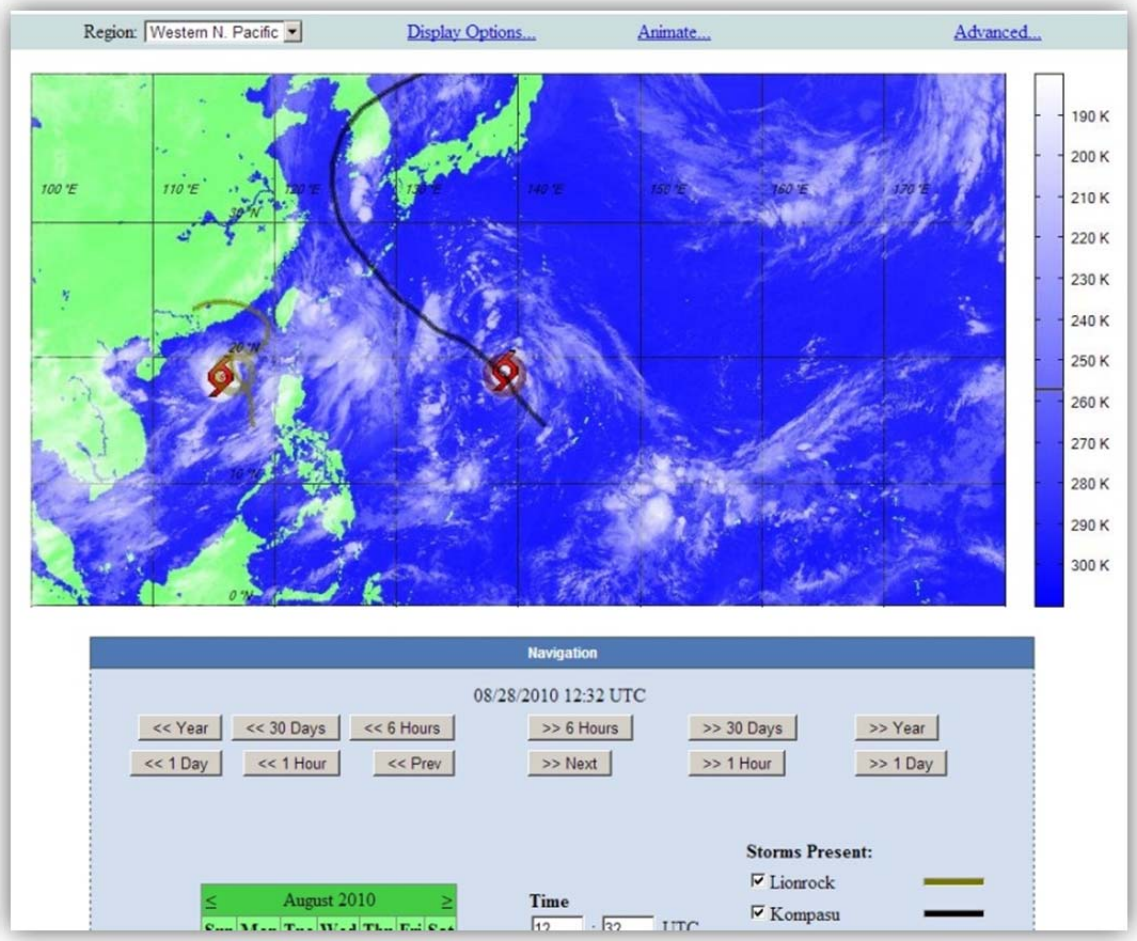

Figure 3. Web interface showing the western N. Pacific basin during 2010 storms Lionrock and Kompasu. Best track displays are available in archival mode but are not yet available in the real-time view. Proposed storm tracking for real-time mode will appear somewhat similar to these tracks, although additional considerations are required for evolving tracks from multiple potential sources.

Once the forecasters began looking at the DAV products, it became immediately obvious that the system interface was not optimized for real-time, pre-genesis use by forecasters. The DAV system up until now has had no automatic system memory. Instead, the analyst was required to interact with the DAV system in order to identify and monitor systems of interest before best track became available. While trivial in principle, our interface currently has no way for the forecaster to either input locations of interest that are currently being tracked or to record points of interest within the system. Furthermore, the automatic indicators posted by the DAV site do not have memory. In other words, the system as currently configured identifies points of low variance in any given frame, but it does not associate them with past points of low variance, nor does it follow them into the future. We found that the forecasters were frustrated by systems that had intermittent hits below threshold, even though in retrospect the system could be identified in a sequence of images as a single disturbance that could be monitored.

In order to address this issue, we have developed a preliminary, automated DAV disturbance tracking system (Rodriguez, et al., 2013). Our initial objective automatic tracking method uses information from two different sources: the brightness temperature image and its corresponding DAV map. Using these data, the tracking system first looks for regions on the DAV map with a variance below a given threshold TH_{max} (e.g. 2000 deg^2) and locates the pixel(s) within those regions where the DAV is minimum. These regions correspond to relatively symmetric regions in the IR image. The location of those pixels is then checked in the corresponding IR image to verify that a discernible cloud is present. These locations are labeled as detections and added to a list that contains the minimum DAV value detected, the latitude and longitude of the point with that DAV value in the region of interest, the time and date of the detection, and a storm number assigned to label the different storms that might occur in the period of time under analysis. If either TH_{max} is not reached or there is no discernible cloud, the point of minimum DAV is labeled as a detection and the automatic tracking system checks the detections table for a previous detection that might have been found in a circular vicinity of that point with radius R_{track} within a time period T_{track}. Track detections are used to keep track of cloud clusters of interest in the event that no actual detection is found over an extended period of time T_{track}. If no previous detection satisfying both conditions is found, the track detection is dismissed. An example of the tracking system operating is shown in Figure 4. An important byproduct of the tracking tool is the ability to monitor the time that any particular system has spent below a particular threshold. We are enthusiastic that this capability will help us to reduce the number of false alarms in the early stages of operationalization.

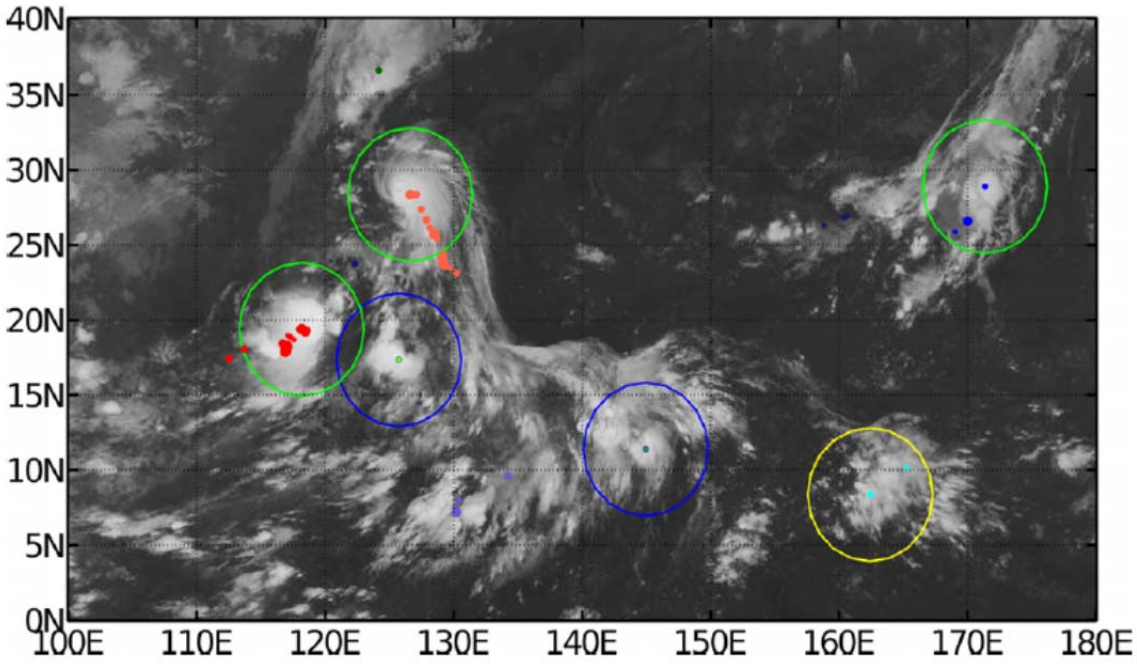

Figure 4: Snapshot of the automatic tracking system with two dissipating storms that were previously tracked and six identifiedstorms being tracked in the western North Pacific basin on 08/31/2010 at 2132 UTC. The dots in the vicinity of each storm indicate their current and previous locations with a time latency Ttrack. The circles are color coded to distinguish between new detections (blue), previously identified detections (green), and track detections (yellow).

3. Proposed Work Plan

The plan proposed here is divided into four phases, each lasting approximately six months. Before the initial testing period, work will continue to fine tune the software to the needs of the operational agencies. This includes incorporating the tracking tool to aid in the pre-genesis mode, including an interface that provides control over various tracking sources (i.e. invest lists, operational best track, DAV automated tracking, and individual user input/analysis). The first six month period (the northern hemisphere summer and fall) will be dedicated to real-time testing and evaluation. During this period frequent contact with forecasters and the relevant agencies will be used to gather suggestions and further improve the operating interface. The northern hemisphere spring (second phase) will be dedicated to improving the method, interface, and statistical evaluations. More details on the specific activities planned in each phase follow.

The testing described here will require access to real time GOES-E, GOES-W, and MT-SAT brightness temperature data. As described above, the GOES data are archived at the UA in near-real time, and we have tapped in to that existing local data source. We have developed a system to deliver MT-SAT images from JTWC with a latency of a few minutes, and that system is working well. It is conceivable that other image types may be needed (water vapor, etc.), and should that arise we will work with the appropriate forecast center to establish a real time data path.

4. Timeline

Phase 1: Initial Testing with Version 1.0 system

We will use the remaining months of our National Oceanographic Partnership Program project (scheduled to end in the spring/summer of 2013) as well as any allowed pre-award time on the JHT project to prepare for semi-operational testing in the first TC season. During the late summer and fall of the first year, we will prepare the software and web interface and travel to each operational center to train participating forecasters on its use. We will work in conjunction with a select group of forecasters in a semi-operational environment and asses the components of the operational system. Throughout this phase we will perform the following tasks.

- Perform weekly conference calls to identify features and improvements that could be incorporated
- Maintain detailed daily records of system performance at the University of Arizona (UA) for subsequent analysis
- At the end of the season, plan a debriefing session with each agency with a goal of gathering information to improve the interface

Phase 2: Analysis of first testing period and updating the system and documentation

During the second six months, the main goal will be to improve the interface and incorporate new developments/research. The major tasks include the fine tuning of the domain of computation based on the needs of the forecasters, development of confidence interval metrics for both intensity and

genesis products, and incorporating these metrics into the graphical interface. Along with assessing and improving the products for the second implementation, additional tasks involved will include:

- Distribution of DAV-estimated intensity/genesis products to operational centers in ATCF format
- Develop server maintenance and alert tools sufficient to maintain high server up-time through year-two testing
- Prepare documentation and training materials for use in second testing phase

Phase 3: Operational testing with version 2.0

The third phase will encompass a full implementation of product improvements learned from phase 1. This includes additional travel to and training for forecasters with the new 2.0 interface and on demand support for forecasters during this second test phase. We will continue to work in conjunction with a select group of forecasters to find areas of improvement. Tasks at the end of phase 3 will involve:

- Maintaining detailed daily records of information obtained from version 2.0 with further analysis at UA.
- A debriefing session to tie up any remaining system improvements
- An evaluation of the overall performance

Phase 4: Final evaluation with goal of long-term implementation

During phase 4, the implementation of final improvements from the first three phases will be made. We will develop a high-reliability server system with detailed error handling flow to permit rapid problem identification and to support long-term maintenance. This will include server maintenance and alert tools for troubleshooting and long-term operation. Documentation of statistics and a summary report of all four phases will be made. The last phase will aim to tie up the project and secure future use of the technique for continued implementation if desired by operational agencies. Additional tasks involved are:

- Implement data-exchange access to the UA servers so that operation centers are able to access detailed DAV computations directly in addition to the web interface for operators.
- Develop system documentation and training materials of version 2.0 for future use in operational agencies

After the 2-year proposal, the UA servers can continue to operate with minimal maintenance. Operational centers will be free to use the human and machine interfaces however they deem optimal. Alternatively, complete integration of the DAV computations into operational center systems can be explored using the lessons learned during the 2-year proposal.

Data-exchange services provided by the UA servers would likely include SOAP/XML Web Services, but can also accommodate additional access mechanisms. The data can be made available simultaneously in necessary convenient formats.

5. Schedule and Needs for Expected Travel

As mentioned in the previous section, travel by one or two experts from the UA group to the respective agencies would occur at the beginning of phase 1 and 3. This time will be used to implement the software and train forecasters with respect to the methods and technique. Additional travel for one of the UA group will involve the presentation of the work at the annual Interdepartmental Hurricane Conference (IHC).

6. JHT Staff Requirements

We envision meeting with a select group of 2-4 on-site staff members, for full training and a detailed explanation of the methods used to produce the DAV products. These will be the same individuals who we would keep regular contact with throughout the 4 phases of implementation. We will also, depending on the needs of the agency, provide on-site training for the larger forecasting group. Depending on the implementation procedure, we will require a computer technician on site if we decide to install the software at the host agency, or if we implement via the web interface, additional hardware and personal will be acquired at the UA research site.

7. Data Sharing Plan

It is the intention that all data generated on this project pertaining to either intensity or genesis forecast will be made publicly available through the web interface. Our website currently has a public portion where all current and archived data can be investigated, as well as a password-protected advanced user section for partners to interact with the system in a more dynamic fashion. We expect that all data generated during the two year project will be posted to the archive section of the website, and all past data will continue to be available to the public.

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College of Optical Sciences
THE UNIVERSITY OF ARIZONA®

Proposal to: Joint Hurricane Testbed Program

Title: Deviation Angle Variance Method for Operation Intensity Estimation and Genesis Forecast

PI: J. Scott Tyo

SALARIES		**Hours**	**Rate**	**Year 1**	**Year 2**	**Total**
J. Scott Tyo, Professor*	1 month annual	176	$77.82	$13,695	$14,106	$27,802
Oscar Rodriguez, Engineering Support	0.2 FTE Annual	408	$21.63	$8,827	$9,092	$17,919
Klaus Dolling, Postdoctoral Associate	0.5 FTE Annual	1,040	$26.44	$27,500	$28,325	$55,825
TOTAL SALARIES				**$50,022**	**$51,523**	**$101,545**
EMPLOYEE BENEFITS						
Faculty*	31.2%			$4,273	$4,401	$8,674
Postdoctoral Associate	4.3%			$1,562	$1,609	$3,171
TOTAL EMPLOYEE BENEFITS				**$5,835**	**$6,010**	**$11,845**
TOTAL SALARIES & BENEFITS				**$55,857**	**$57,533**	**$113,390**
TRAVEL						
Colaboration Meetings (1 each to NHC/JTWC per year)				$5,150	$5,305	$10,455
Attendance at IHC				$2,500	$2,500	$5,000
TOTAL TRAVEL				**$7,650**	**$7,805**	**$15,455**
OTHER DIRECT COSTS						
Computer Hardware/Software/Supplies				$1,500	$1,500	$3,000
TOTAL OTHER DIRECT COSTS				**$1,500**	**$1,500**	**$3,000**
TOTAL DIRECT COSTS				**$65,007**	**$66,837**	**$131,845**
F&A COSTS @ 51.5% MTDC	51.5%			**$33,479**	**$34,421**	**$67,900**
TOTAL COSTS				**$98,486**	**$101,259**	**$199,745**

University of Arizona Budget Justification

Salaries and Wages:
The University of Arizona requests $113,390 over the life of the project to support salary and benefits of J. Scott Tyo, Professor, Oscar Rodriguez, Engineering Support, and Klaus Dolling, Postdoctoral Associate. Benefits are calculated using the University of Arizona's federally-approved ERE rates of 31.2% for faculty and 4.3% for Ancillary Faculty.

Travel:
$15,455 is requested for domestic travel over the life of this project. This amount is expected to cover collaboration meetings and attendance at IHC.

Other Direct Costs:
The University of Arizona requests a total of $3,000 for computer hardware/software/ supplies. This is meant to cover a computer in year 1 that will be dedicated to this project only and external data storage, networking supplies, etc. in year 2.

Equipment
None

F&A Costs;
UA's federally approved F&A rate is 51.5%. The F&A costs are computed based on modified total direct costs. We request a total of $67,900 in F&A costs for this award.

BIOGRAPHICAL SKETCH

NAME	**POSITION TITLE**
J. Scott Tyo	Professor

EDUCATION

INSTITUTION	**DEGREE**	**YEAR CONFERRED**	**FIELD OF STUDY**
University of Pennsylvania	Ph.D.	1997	Electrical Engineering
University of Pennsylvania	MSE	1996	Electrical Engineering
University of Pennsylvania	BSE	1994	Electrical Engineering

APPOINTMENTS

2009 – Pres	Professor, College of Optical Sciences & ECE Department, University of Arizona
2006 – 2009	Assoc. Prof., College of Optical Sciences & ECE Department University of Arizona
2001 – 2006	Associate Professor, ECE Department, University of New Mexico
1999 – 2001	Assistant Professor, ECE Department, US Naval Postgraduate School, Monterey, CA
1996 – 1999	Research Engineer, USAF Research Lab/Directed Energy, Kirtland AFB, NM
1994 – 2001	Officer, US Air Force (2^{nd} LT, 1994 – 1996, 1^{st} LT, 1996 – 1998, Capt, 1998 – 2001)

PUBLICATIONS

Five Publications Most Closely Related to Current Proposal

E. A. Ritchie, G. Valliere-Kelly, M. F. Piñeros, and J. S. Tyo, "Tropical cyclone intensity estimation in the North Atlantic basin using an improved deviation angle variance technique," Accepted for Publication in *Weather & Forecasting,* May 2012

M. J. Piñeros, J. S. Tyo, and E. A. Ritchie, "Estimating Tropical Cyclone Intensity from Infrared Image Data," *Weather & Forecasting*, **26**:690 – 698 (2011)

S. Felker, B. LaCasse, J. S. Tyo, and E. A. Ritchie, "Forecasting post-extratropical transition outcomes for tropical cyclones using support vector machine classifiers," *J. Atmospheric & Oceanic Tech.*, **28**:709 – 719 (2011)

M. F. Piñeros, E. A. Ritchie, and J. S. Tyo, "Detecting tropical cyclone genesis from remotely-sensed infrared image data," *IEEE Geosci. Remote Sens. Lett.* **7**:826 – 830 (2010)

M. Piñeros, E. Ritchie, and J. S. Tyo, "Objective Measures of Tropical Cyclone Structure and Intensity Change From Remotely Sensed Infrared Image Data," *IEEE Trans. Geosci. Remote Sens.* **46**:3574 – 3580 (2008)

Five Other Publications

J. S. Tyo, D. H. Goldstein, D. B. Chenault, and J. A. Shaw, "A Review of Passive Imaging Polarimetery for Remote Sensing Applications," *Applied Opt.*, **45**:5453–5469 (2006)

D. E. Kofron, E. A. Ritchie, and J. S. Tyo, "Determination Of A Consistent Time For The Extratropical Transition Of Tropical Cyclones Part I: Examination of Previous Methods for Finding ET-time," *Mon. Weather Rev.* **138**:4328 – 4343 (2010)

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O. Demirci, J. S. Tyo, and E. A. Ritchie, "Spatial and spatiotemporal projection pursuit techniques for predicting extra tropical transition of tropical cyclones," *IEEE Trans. Geosci. Remote Sens.* **45**:418 (2007)

J. S. Tyo, "Design of Optimal Polarimeters: Maximization of SNR and Minimization of Systematic Errors," *Appl. Opt.* **41**:619–630 (2002)

SYNERGISTIC ACTIVITIES

SOCIETY MEMBERSHIPS:

OSA (Fellow), **SPIE** (Fellow), **SUMMA Foundation** (Fellow), **IEEE** (Fellow), **URSI** (Com B & E)

SERVICE ACTIVITIES:

Secretery/Treasurer IEEE Antennas and Propagation Society, 2010 – Present
General Chair, 2016 IEEE Antennas and Propagation International Symposium
Adolph Lomb Medal Award Committee (OSA) 2009 – 2010 (Chairman 2010)
G. G. Stokes Award Committee (SPIE) 2004 – 2010 (chair, 2009 – 2010)
Chair, OSA Polarization Technical Group (2011)
Summa Foundation Best Paper Award Committee Chair (2010 – 2012)
Topical Editor, *Applied Optics*, 2006 - 2010
Associate Editor, *IEEE Antennas & WirelessPropagation Letters*, 2004 – 2007
TPC co-Chairman, *IEEE Antennas & Propagation International Symposium*, 2006
Conference chairman, *SPIE Polarization Science and Remote Sensing I – V (2003, '05, '07, '09, '11)*
Program Committee, *SPIE Polarization Meas., Analysis, and Remote Sensing III – X (2001 – 2012)*
Technical Program Committee, *IEEE Antennas and Propagation International Symposium*, 2003 – 2005
Vice Chairman, *SPIE Polarization Working Group*, 2003 – 2005
Guest Editor, *Applied Optics*, Special Session on Imaging Polarimetry, September 2006
Guest Editor, *Optical Engineering*, Special Section on Polarimetry, May 2003
Chairman, SPIE Stokes Award Committee, 2009 - Present
Member, OSA Lomb Medal Award Committee, 2009 - Present

COLLABORATORS OVER PAST 48 MONTHS and AFFILIATIONS

Advisors:

E. N. Pugh, Jr (Univ. of California-Davis)
N. Engheta (Univ. Of Pennsylvania)

Advisees:

Joel Robertson (MS, NPS '00, location unknown)
David Diersen (MS, NPS '00, now with US Navy)
Steven Rutherford (NPS '01, now with US Navy)
A. Konsolakis (MS, NPS '01, Greek Navy)
Michael Baretela (MS NPS '02, now at US Navy)
Jinhui Chen (MS UNM '04, now at Arizona St.)
B. M. Ratliff (PhD UNM '04, Space computer Corp)
Z. Zhou (PhD UNM '05, U. of Southern MI)
M. Doğan (MS UNM '05, now at U. of Arizona)
O. Demirci (PhD UNM '06, UNM)
H. A. Smartt (MS UNM '02, PhD '05 Sandia)
Jiayu Chen (MS UNM '06, location unknown)
Hua Wei (MS UNM '05, now at KLA-Tencor)
Grady Clark, (MS UNM, '06, now at SAIC)
John Topolski (MS, UNM, '06, with USMC)
Zhipeng Wang (PhD UA, '08, now at NASA)
Hua Wei (MS UNM, '05; MS UA, '09 KLA Tencor)
Sergio Johnson (MS UA, '09 now at Raytheon)
Miguel Pineros (PhD UA, '09; now at Schlumberger)
Miena Armanious (PhD, UA, '10, now at Qualcom)
Oscar Rodriguez (Postdoc, now at UA)
Gabriel Birch (PhD, UA, '12, now at UA)
Charles LaCasse (PhD, UA, '12, now at UA)

Other Collaborators over Past 4 Years:

C. J. Buchenauer (Los Alamos Nat'l Labs)
David Chenault (Polaris Sensor Technologies)
M. Hayat (UNM)
S. Krishna (UNM) K. J. Malloy (UNM)
William Prather (AFRL/RDHP)
E. A. Ritchie (Arizona)
U. Sakoglu (Los Alamos Nat'l Labs)
Joseph Shaw (Montana State University)
Tomasz Tkaczyk (Rice)
Kent Miller (AFOSR)
Kamil Agi (K&A Wireless)
Francois Goudail (Institut d'Optique, France)
Clara Curiel (Arizona)
James Schwiegerling (Arizona)
Russell Chipman (Arizona)
Eustace Dereniak (Arizona)
Tom Milster (Arizona)
Kim Wood (Arizona)
Brian Hoover (Advanced Optical Technologies)
Michael Skipper (ASR Corporation)
Michael Abdalla (ASR Corporation)
Daniel Lemaster (AFRL/RYJT)
Chris Walker (Arizona)
Christian d'Aubigny (Arizona)

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: J. Scott Tyo	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Augmentation of Early Intensity Forecasting of Tropical Cyclones by Remote Sensing

Source of Support: Office of Naval Research
Total Award Amount: $ 514,531 Total Award Period Covered: 10/01/09 - 09/30/13
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Imaging and Non-Imaging Polarimetric Methods for Remote Sensing

Source of Support: AFOSR
Total Award Amount: $ 740,996 Total Award Period Covered: 04/15/10 - 04/14/15
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Spectroscopic THz RADAR Imaging for Standoff Explosives Detection

Source of Support: National Consortium for MASINT Research (via ONR)
Total Award Amount: $ 188,000 Total Award Period Covered: 09/01/11 - 08/30/13
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.25 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Visible/NIR/SWIR Imaging Polarimeter for Phenomenology (Equipment Grant)

Source of Support: DoD DURIP Program
Total Award Amount: $ 243,784 Total Award Period Covered: 05/01/11 - 04/30/12
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Compact High Power Microwave Antennas

Source of Support: ASR Corporation (US Army SBIR)
Total Award Amount: $ 242,164 Total Award Period Covered: 11/01/11 - 09/30/13
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Summ: 0.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: J. Scott Tyo	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Metamaterial-Inspired HPM Antennas

Source of Support: ASR Corporation (MDA SBIR Phase 2)
Total Award Amount: $ 92,268 Total Award Period Covered: 10/01/11 - 09/30/13
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.50 Sumr: 0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Wideband Microwave Random Sensor Array for Distributed HPM Detection and Monitoring

Source of Support: National Consortium for MASINT Research (via ONR)
Total Award Amount: $ 150,000 Total Award Period Covered: 07/01/12 - 06/30/12
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.50 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Active SWIR Polarimeter

Source of Support: SAIC/AFRL
Total Award Amount: $ 40,000 Total Award Period Covered: 06/01/12 - 09/30/12
Location of Project: AFRL - Dayton, OH
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.50

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: RET Site Proposal: University of Arizona Adopt-A-School Program for Title 1 Elementary Schools

Source of Support: National Science Foundation
Total Award Amount: $ 500,000 Total Award Period Covered: 07/01/13 - 06/30/16
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.25

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Variable Coherence Polarimeter for the Monostatic Characterization of the Polarimetric BRDF in Remote Sensing Applications

Source of Support:
Total Award Amount: $ 97,188 Total Award Period Covered: 07/01/13 - 06/30/14
Location of Project:
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Summ: 0.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: J. Scott Tyo	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Design of Partial Mueller Matrix Polarimeters

Source of Support: Advanced Optical Technologies
Total Award Amount: $ 50,000 Total Award Period Covered: 09/01/12 - 08/31/14
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.25

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Depth Measurements Through Controlled Aberrations in Imaging Endoscopes

Source of Support: National Science Foundation
Total Award Amount: $ 498,491 Total Award Period Covered: 07/01/13 - 06/30/16
Location of Project: University of Arizon
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.75 Sumr: 0.00

Support: ☐ Current ☐ Pending ☒ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Using satellite-based remotely-sensed data to determine tropical cyclone size and structure characteristics

Source of Support: Office of Naval Research
Total Award Amount: $ 367,228 Total Award Period Covered: 07/01/13 - 06/30/16
Location of Project: University of Arizona
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.75 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

BIOGRAPHICAL SKETCH

NAME	**POSITION TITLE**
P. Klaus Dolling	Post-doctoral

EDUCATION

INSTITUTION	**DEGREE**	**YEAR CONFERRED**	**FIELD OF STUDY**
University of Hawaii	Ph.D.	2010	Meteorology
University of Hawaii	MS	2003	Meteorology
Kean University	BA	2001	Meteorology

APPOINTMENTS

2012 – Pres Post-doctoral Research, Department of Atmospheric Sciences, University of Arizona
2011 – 2012 Post-doctoral Research, Department of Meteorology, University of Hawaii

PUBLICATIONS

Barnes, G. M., and K. P. Dolling, 2013: The inflow to Tropical Cyclone Humberto (2001) as viewed with azimuth-height surfaces over three days. *Mon. Wea. Rev.* Accepted

Dolling, K. P., and G. M. Barnes, 2012: Warm Core Formation in Tropical Storm Humberto (2001). *Mon Wea. Rev.*, **140**, 1177-1190.

Dolling, K. P., and G. M. Barnes, 2012: The creation of a high equivalent potential temperature reservoir in Tropical Storm Humberto (2001) and its' possible role in storm deepening. *Mon. Wea. Rev.*, **140**, 492-505.

Dolling, K. P., 2010: The evolution of Hurricane Humberto (2001). Dissertation, Dept. of Meteorology, University of Hawaii at Manoa, Honolulu, HI. 180 pp.

Dolling, K. P., P.-S. Chu, and F. Fujioka, 2009: Natural variability of the Keetch/Byram drought index in the Hawaiian Islands. *Int. J. of Wildland Fire*., **18**, 459-475.

SOCIETY MEMBERSHIPS:

AMS (member)

SERVICE ACTIVITIES:

President of AMS local chapter of Kean University (2000)
Vice President of AMS local chapter of University of Hawaii (2007)
President of AMS local chapter of University of Hawaii (2008)

COLLABORATORS OVER PAST 48 MONTHS and AFFILIATIONS

Advisors:

E. A. Ritchie (Univ. of Arizona) S.J. Tyo (Univ. of Arizona) G. M. Barnes (Univ. of Hawaii)

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: Arizona Board of Regents, University of Arizona

* b. Employer/Taxpayer Identification Number (EIN/TIN): 74-2652689

* c. Organizational DUNS: 8063456170000

d. Address:

* Street1: PO Box 3308
Street2:
* City: Tucson
County/Parish:
* State: AZ: Arizona
Province:
* Country: USA: UNITED STATES
* Zip / Postal Code: 85722-3308

e. Organizational Unit:

Department Name: College of Optical Sciences

Division Name:

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

Prefix: Mrs.
* First Name: Sherry
Middle Name: L
* Last Name: Esham
Suffix:

Title: Director, Sponsored Projects Services

Organizational Affiliation: Arizona Board of Regents, University of Arizona

* Telephone Number: 520-626-6000
Fax Number: 520-626-4137

* Email: sponsor@email.arizona.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.):

Add Attachment | Delete Attachment | View Attachment

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

Deviation Angle Variance Method for Operation Intensity Estimation and Genesis Forecast

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: AZ-007 | b. Program/Project: AZ-007

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	199,745.00
* b. Applicant	0.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	199,745.00

*** 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: Dr. | * First Name: Leslie

Middle Name: P

* Last Name: Tolbert

Suffix: Ph.D

* Title: Senior Vice President for Research

* Telephone Number: 520-626-6000 | Fax Number: 520-626-4137

* Email: sponsor@email.arizona.edu

* Signature of Authorized Representative: Jessica Peck | * 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. Year 1	11.459	$ 0.00	$ 0.00	$ 98,486.00	$ 0.00	$ 98,486.00
2. Year 2	11.459	0.00	0.00	101,259.00	0.00	101,259.00
3.						
4.						
5. Totals		$	$	$ 199,745.00	$	$ 199,745.00

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SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY (1) Year 1	(2) Year 2	(3)	(4)	Total (5)
a. Personnel	$ 50,022.00	$ 51,523.00	$	$	$ 101,545.00
b. Fringe Benefits	5,835.00	6,010.00			11,845.00
c. Travel	7,650.00	7,805.00			15,455.00
d. Equipment					
e. Supplies	1,500.00	1,500.00			3,000.00
f. Contractual					
g. Construction					
h. Other					
i. Total Direct Charges (sum of 6a-6h)	65,007.00	66,838.00			$ 131,845.00
j. Indirect Charges	33,479.00	34,421.00			$ 67,900.00
k. TOTALS (sum of 6i and 6j)	$ 98,486.00	$ 101,259.00	$	$	$ 199,745.00
7. Program Income	$ 0.00	$ 0.00	$	$	$

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SECTION C - NON-FEDERAL RESOURCES

(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8. Year 1	$ 0.00	$ 0.00	$ 0.00	$ 0.00
9. Year 2	0.00	0.00	0.00	0.00
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	$ 98,486.00	$ 25,745.00	$ 24,247.00	$ 24,247.00	$ 24,247.00
14. Non-Federal	$	0.00	0.00	0.00	0.00
15. TOTAL (sum of lines 13 and 14)	$ 98,486.00	$ 25,745.00	$ 24,247.00	$ 24,247.00	$ 24,247.00

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 2	$ 25,314.00	$ 25,315.00	$ 25,315.00	$ 25,315.00
17.				
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$ 25,314.00	$ 25,315.00	$ 25,315.00	$ 25,315.00

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: Salaries & Benefits, Travel, Other Direct Costs

22. Indirect Charges: MTDC base, 51.5% rate

23. Remarks: UA rate agreement dated 06/07/12

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
Jessica Peck	Senior Vice President for Research
* APPLICANT ORGANIZATION	* DATE SUBMITTED
Arizona Board of Regents, University of Arizona	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

Arizona Board of Regents, University of Arizona

* AWARD NUMBER

None

* PROJECT NAME

Deviation Angle Variance Method for Operation Intensity Esti

Prefix: Dr.

* First Name: Leslie

Middle Name: P

* Last Name: Tolbert

Suffix: Ph.D

* Title: Senior Vice President for Research

* SIGNATURE: Jessica Peck

* DATE: 12/06/2012