

Proceedings of the 2015 Cincinnati-Dayton INFORMS Symposium

October 9, 2015

Wright State University, Dayton, Ohio

informs

*Institute for Operations Research
and the Management Sciences*



Department of Biomedical, Industrial & Human
Factors Engineering

Sponsored by:

Department of Biomedical, Industrial and Human Factors Engineering, Wright State University
Applied Research Solutions

In Cooperation with:

Institute for Operations Research and the Management Sciences (INFORMS)
Cincinnati-Dayton INFORMS Chapter

Contents

0	
1.	Introduction 3
	Conference Committee Message..... 3
	Conference Steering Committee 3
	Cincinnati-Dayton INFORMS Chapter and the Symposium 3
	Presented Research and Keyword Index 4
	Sponsors..... 5
	Attendees and Presenters..... 8
2.	Schedule..... 9
3.	Keynote Address: Outstanding Young OR/MS Award Winner 11
	A Team Compatibility Decision Support System for the NFL..... 11
4.	Invited Talks 12
	What's New in JMP 12 12
	A Research Agenda for Project Management Analysis..... 12
	Sun Tzu: The Warrior, Tactician, Strategist, and Military Analyst 12
5.	Abstracts for Presentations and Papers 14
	Real-World Strategies for Distribution Planning of Multiple Product Classes..... 14
	Inventory-based Delivery Scheduling and Routing..... 14
	Scheduling of Advanced Practice Providers at Level 1 Trauma Centers..... 15
	Quantifying and Evaluating Trust in Automated Systems 15
	Using Department of Defense Supercomputers to Solve Computationally Intensive Problems: Trials, Tribulations, and Rewards 16
	Disruptive Technology: Don't Get Caught With Your Pants Down 16
	The Foodbank Compliance Problem – An Initial Investigation 17
	Approximate Dynamic Programming Methods for a Coordinated Dynamic Weapon-Target Assignment Problem 17
	Ohio Brewery Placement 18
6.	Abstracts for Posters..... 18
	Brain Measurements to understand student learning in STEM education 18
	Quantitatively Assessing Mental Workload of Medical Staff using Discrete-Event Simulation 19
	An Agent-Based Model of Airline Passenger Loading..... 19

	Multivariate Analysis of Labor Force Characteristics in U.S. Counties	20
7.	Full Papers.....	21
	A Dynamical-Statistical Approach to Forecasting Tropical Cyclogenesis in the Western North Pacific	21

1. Introduction

Conference Committee Message

The organizing committee welcomes you to our second, and now, annual Cincinnati-Dayton INFORMS Symposium. The symposium is hosted by Wright State University's Biomedical, Industrial, and Human Factors Engineering Department, with Applied Research Solutions graciously being a corporate sponsor. Additionally, Wright State University's Raj Soin College of Business provided greatly appreciated technical equipment sponsorship.

We feel that the scientific and social exchange among symposium attendees will give us a much needed opportunity to interact in the Miami Valley area. To further facilitate collaboration we have expanded the well-received poster session in length.

We have been pleased by the expansion of interest, volume and breadth of submissions since 2014. Our symposium has expanded slightly over 2014, with 3% growth in registrations. We received more than a sufficient amount of submissions, ranging from Project Management to Biomedical Engineering, and we had to work to fit everything completely into one day. We therefore continue to plan for the symposium to be an annual feature of the chapter.

We hope that you will thoroughly enjoy the day. Please do not hesitate to let us know if you need anything during your attendance.

-Cincy-Dayton INFORMS Conference Steering Committee

Conference Steering Committee

Trevor Bihl, 2015 Chair Air Force Institute of Technology Trevor.Bihl@afit.edu	James Cordeiro, 2015 Co-Chair Air Force Institute of Technology James.Cordeiro@afit.edu
Kellie Schneider, 2015 Co-Chair University of Dayton kschneider2@udayton.edu	Carl Parson, 2015 Co-Chair Air Force Institute of Technology Carl.Parson@afit.edu

Cincinnati-Dayton INFORMS Chapter and the Symposium

The Cincinnati-Dayton Chapter of INFORMS was established in 1995 as one of the regional chapters of INFORMS. Regional chapters are separate from student chapters and encourage interchanges between professionals, faculty, researchers, and students; regional chapters are relatively few in number and the Cincinnati-Dayton chapter is the only local regional INFORMS chapter in Ohio, Indiana, Kentucky or West Virginia. The Cincinnati-Dayton chapter has been successful in its mission by sponsoring the annual Arnoff lecture, offering chapter awards and social events, and encouraging facility tours, guest speakers and symposiums. Our chapter current has approximately 100 active members. By patronizing the symposium, you are both helping us to expand our chapter and facilitate needed technical interchanges in the Miami Valley area.

More details can be found on our chapter webpage:

<https://www.informs.org/Community/Cincinnati-Dayton-Chapter>

Presented Research and Keyword Index

2015 Keyword List	
Keyword	Abstract Numbers
Business Analytics	I1-I2, 9
Biostatistics/Biomedical	3, 4, 6, P1, P2
Big Data	5
Data Mining and Applied Statistics	Keynote, 2, 10, P1, P2
Engineering Applications	1
History of OR and Ethics	I3
Local Companies in OR	I1, 9, 10
Logistics and Supply Chain Management	1, 3
Military OR Applications	I3, 10, P4
Modeling and Simulation	4, 7, 8, 10, P2, P3
Optimization (incl. network & general)	9
Project Management	I2
Sports/Hospitality and Recreation	Keynote
Transportation	2, P3
Trust	4-7
Visualization	10

Sponsors

The Cincinnati/Dayton Chapter would like to thank the following sponsors:

- Department of Biomedical, Industrial and Human Factors Engineering, Wright State University
- Applied Research Solutions
- Raj Soin College of Business, Wright State University



The Department of Biomedical, Industrial & Human Factors Engineering (BIE) is the only academic unit, nationally, to share programs in these disciplines. Our programs are human-centered and focused on improving today's complex human-technical systems.

The BIE Department vision is to be nationally recognized for excellence in education and for cutting-edge research in specific engineering areas of biomedical, industrial and systems, human factors and operations research. Students experience a variety of engineering-related educational experiences through bachelor's degree programs in Biomedical Engineering and Industrial & Systems Engineering.

Our Master of Science features programs in the Biomedical Engineering and Industrial & Human Factors Engineering. Also, research is prominent in the Ph.D. in Engineering program in three focus areas: Industrial & Human Systems, Material and Nanotechnology, and Sensor and Signal Processing. The Master of Science in Industrial & Human Factors Engineering can be earned entirely online through Distance Education.

Contact Information:

Jaime E Ramirez-Vick
Professor and Chair

Department of Biomedical, Industrial and Human Factors Engineering
207 Russ Engineering Center
Wright State University
3640 Colonel Glenn Highway
Dayton, Ohio, 45435
Phone: 937-775-5044

<http://cecs.wright.edu/bie/>



ARS is the small business partner you can count on for your technical service needs in the mission domains of Cyber, Intelligence, and Information Technology. Our professionals deliver end-to-end systems engineering support, world class software engineering/development, and intelligence production results to a multitude of mission partners and customers. We specialize in staffing Top Secret/SCI cleared professionals across these mission domains.

Contact information:

51 Plum St. Suite 240
Beavercreek, OH 45440
Phone: 937.912.6100
<http://www.appliedres.com/>

WRIGHT STATE UNIVERSITY

Raj Soin College of Business

The Raj Soin College of Business has a long tradition of developing influential business leaders in the region and beyond. In 2000, the College was named the Raj Soin College of Business in honor of Rajesh K. Soin, an internationally recognized entrepreneur, business leader and community benefactor.

Through collaboration with the business community and alumni, the college continues to launch new academic programs, increase scholarship support and expand career opportunities for our students. This collaboration enriches our students' academic experience while helping area businesses excel.

With an enrollment of approximately 1,200 undergraduate students and 500 graduate students, we offer the benefits of a comprehensive business program and a diverse student body. At the same time our small class sizes and supportive faculty offer students the individual attention they need to excel.

Contact information:

100 Rike Hall
Wright State University
3640 Colonel Glenn Highway
Dayton, Ohio, 45435
<http://business.wright.edu/about>

Attendees and Presenters

The Cincinnati-Dayton INFORMS Chapter would like to thank the attendees and presenters, without both of whom this symposium would not occur. It is interesting and reassuring to see the diverse affiliations of those attending our symposium.

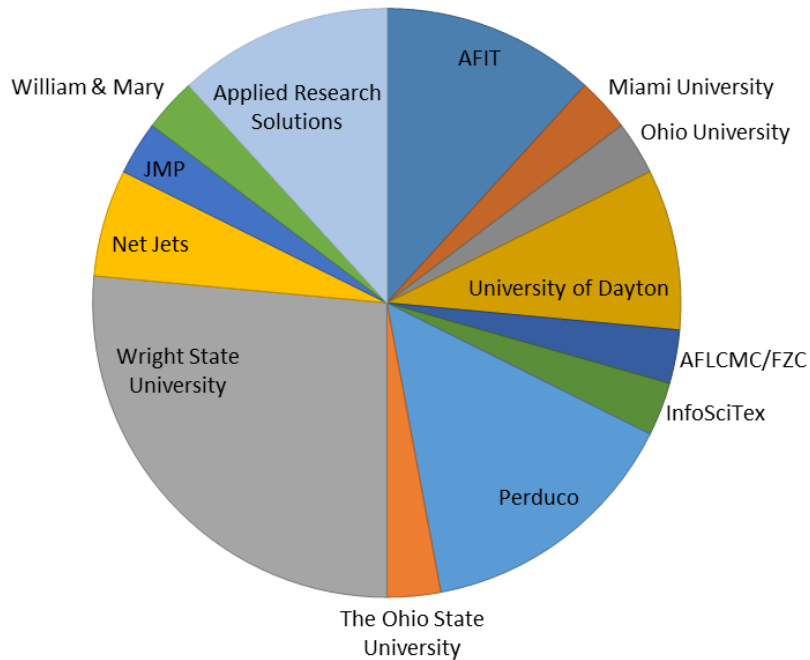


Figure 1, Presenter and Attendee Affiliations

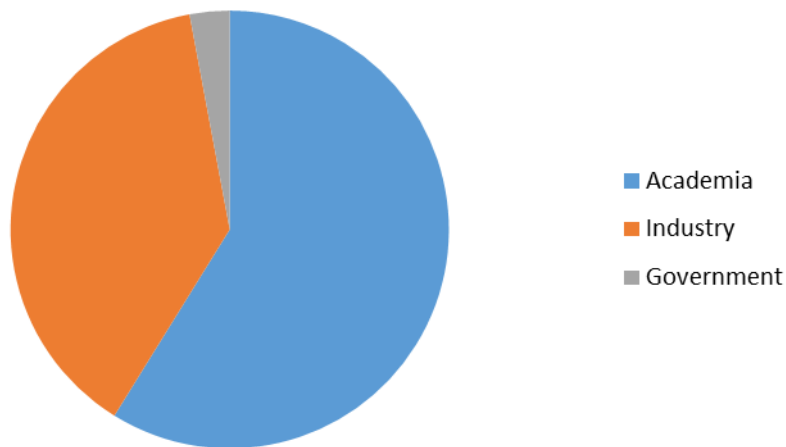


Figure 2, Academia, Government and Industry (AFIT is grouped with Academia, not Government)

2. Schedule

Friday, October 9, 2015

Time	Berry 1	Berry 2	Berry 3
0815-0900	Registration and Coffee in Berry 3		
0850-0900	Welcome and Agenda (in Berry 3) Presenting authors: Trevor Bihl, Air Force Institute of Technology James Cordeiro, Air Force Institute of Technology		
	Track 1 – Scheduling and Project Management Chair: Trevor Bihl		Registration and Coffee (on-going)
0900-0920	Real-World Strategies for Distribution Planning of Multiple Product Classes Presenting author: Brad Guthrie, Wright State University Co-author: Pratik Parikh, Wright State University Abstract-1	Track 2 – Software and Trust Chair: James Cordeiro What’s New in JMP 12 Presenting author: Bill Worley, SAS Corporation Abstract-II	
0920-0940	Inventory-based Delivery Scheduling and Routing Presenting author: Michael Gorman, University of Dayton Abstract-2		
0940-1010	Scheduling of Advanced Practice Providers at Level 1 Trauma Centers Presenting author: Robert Myers, Wright State University Co-authors: Pratik Parikh, Akpofure Peter Ekeh, Elizabeth Denlinger, Mary McCarthy, Wright State University and Miami Valley Hospital Abstract-3		
1010-1025	Transition and Snack Break		
1025-1045	A Research Agenda for Project Management Presenting author: Nicholas G. Hall, Ohio State University Abstract-I2	Quantifying and Evaluating Trust in Automated Systems Presenting author: Jayson Boubin, Miami University and Air Force Institute of Technology Co-authors: Maj. Christina Rusnock, Ph.D and Dr. Michael Miller, Air Force Institute of Technology Abstract-4	Registration and Coffee (on-going)
1045-1105		Using Department of Defense Supercomputers to Solve Computationally Intensive Problems: Trials, Tribulations, and Rewards Presenting author: David Meyer, Air Force Institute of Technology Abstract-5	
1105-1135		Disruptive Technology: Don’t Get Caught With Your Pants Down Presenting author: Terry Oroszi, Veterans’ Administration & Wright State University Abstract-6	

1135-1155		<i>The Foodbank Compliance Problem – An Initial Investigation</i> Presenting author: Kellie Schneider, University of Dayton Co-authors: Sarah G. Nurre, University of Arkansas Abstract-7	
1155-1300	Lunch Buffet in Berry 3		
	Track 1 – Strategy <i>Chair: Trevor Bihl</i>	Track 2 – Optimization and Modeling <i>Chair: Kellie Schneider</i>	Track 3 –Poster Session
1300-1330	<i>Sun Tzu: The Warrior, Tactician, Strategist, and Military Analyst</i> Presenting author: Michael W. Garrambone, InfoSciTex Corporation, a DCS Company Abstract-I3	<i>Approximate Dynamic Programming Methods for a Coordinated Dynamic Weapon-Target Assignment Problem</i> Presenting author: Carl Parson, Air Force Institute of Technology Co-authors: Darryl Ahner, J.D. Robbins, Meir Pachter, Air Force Institute of Technology Abstract-8	Registration and Coffee (on-going)
1330-1350		<i>Ohio Brewery Placement</i> Presenting author: Kevin Cardenas, Air Force Institute of Technology Co-authors: Zach Little, The Perduco Group Abstract-9	
1350-1400		<i>A dynamical-statistical approach to forecasting tropical cyclogenesis in the western North Pacific</i> Presenting author: David Meyer, Statistical Solutions LLC Co-author: Tom Murphree, Naval Postgraduate School Abstract-10	
1400-1420			Poster setup
1420-1545	Snack Break and Student Posters in Berry 3		
1545-1700	Keynote Address for Outstanding Young OR/MS Award (Berry 1): “A Team Compatibility Decision Support System for the NFL” Presenting author: William A. Young, Ohio University Abstract-K		
1700 - on	Awards presentation, then Social and Networking		

3. Keynote Address: Outstanding Young OR/MS Award Winner

Abstract-K

Berry 1

1530-1645

A Team Compatibility Decision Support System for the NFL

William Young (Ohio University)

Presentation

Abstract: *Many factors are considered when making a hiring decision in the National Football League (NFL). One difficult decision that executives must make is whom they will select in the NFL Draft or sign in free agency. Mathematical models can be developed to aid humans in their decision-making process because they are able to find non-obvious relationships within numeric data. This research proposes the Heuristic Evaluation of Artificially Replaced Teammates (HEART) methodology, which is a mathematical model that utilizes machine learning and statistical-based methodologies to aid managers with their hiring decisions. The goal of HEART is to determine Expected and Theoretical Contribution Values for a potential candidate, which represents a player's ability to increase or decrease the estimated number of games won by a particular team in an upcoming season. These values represent a player's level of compatibility with potential teammates and allow players from any playing position to be compared. After presenting the methodology, results from a case study will be presented along with the results of a survey instrument that was used to validate the usefulness of the methodology.*

Bio: *Dr. William A. Young II is a passionate educator, active researcher, and a team-oriented collaborator in service. At Ohio University's College of Business, Young is the Director of the Online Masters of Business Administration program, an Assistant Professor of Operations Management, and a Site Director in the Global Consulting Program. Young earned his Ph.D. in Mechanical and Systems Engineering from Ohio University in 2010, where he won the 2009/2010 Outstanding Graduate Doctoral Student Leader Award at the university's annual Awards Gala. William also received a BS and MS degrees in Electrical Engineering at Ohio University in 2002 and 2005 respectively. William has collaborated with multidisciplinary teams of faculty, students, and professionals on projects and programs that have been funded by General Electric Aviation, the National Science Foundation, Sogeti Netherlands, and Ohio's Department of Labor. Young's primary research and teaching interests relate to business analytics and operations management. In terms of his research, Young has various peer-reviewed articles related to operation management, healthcare services, and environmental systems, as well as specific interests in quantitative sports analysis, and educational technologies and techniques for innovative curriculum development and teaching instruction.*

Keyword: Data Mining and Applied Statistics; Sports, Hospitality, and Recreation

4. Invited Talks

Abstract-I1
Berry 2
0900-1010

What's New in JMP 12
Bill Worley (SAS Corporation)

Presentation

Abstract: *JMP 12 enhancements will be highlighted including Query Builder, Recode, and Outlier detection. Along with the JMP 12 enhancements advanced modeling platforms within JMP and JMP Pro will also be shown. Examples of analyses using Generalized Regression, Neural Networks, Gaussian Process, the Partition platform and Partial Least Squares will be demonstrated.*

Keyword: Business Analytics, Miscellaneous Topics and Special Sessions

Abstract-I2
Berry 1
1025-1155

A Research Agenda for Project Management Analysis
Nicholas G. Hall (Fisher College of Business, Ohio State University)

Presentation

Abstract: *One-fifth of the world's economic activity, with an annual value of \$12 trillion, is organized as projects. Yet project performance is often problematic. Moreover, significant business innovations in project management methodology remain invalidated by academic research. This talk, based on two publications and a website developed by the speaker, presents an overview of many important and diverse research topics within project management.*

Keyword Business Analytics, Project Management

Abstract-I3
Berry 1
1300-1420

Sun Tzu: The Warrior, Tactician, Strategist, and Military Analyst
Michael W. Garrambone (InfoSciTex Corporation, a DCS Company)

Presentation

Abstract: *Sun Wu, the honored Chinese master known as Sun Tzu, is most favorably remembered for his famous treatise "The Art of War." Many recall his quote that "all warfare is based on deception," but it is important to know more about the teachings found in his short and to-the-point book. The Art of War clearly captures the classic thinking of a man characterized as a great warrior, able tactician, and grand strategist. What is less known, but*

can be shown with a little unveiling, is that Sun Tzu was also an intellectual, savvy, forthright, opinionated, and articulate military analyst. The sage thinking in his terse 13 chapters along with those many scholarly commentaries, show facets on nearly every military topic ranging from honorable national character and grand strategy, to warrior thinking, training, and discipline. While Sun Tzu's writings would not necessarily be called a "how-to-fight" manual, they easily qualify as a world class "warrior's guide on how to think about warfighting". The intent of this presentation is to follow Sun Tzu's warfighter thoughts. But moreover to further underscore Sun Tzu's analytical thinking from a modern standpoint and to show his superior skill as a warfare planner, and accomplished military analyst. This presentation highlights his primordial forms of warfare planning, decision making, and logistical thinking. It addresses the very ancient forms of Intelligence Preparation of the Battlefield, Effects Based Operations, and applications of Command, Control, Communications, (no computers) along with the Third Century's (BC that is) version of Intelligence, Surveillance, and Reconnaissance. Although Sun Tzu will not be there to sign his book, the presentation has been designed to be historically interesting, operationally informative, and soundly enjoyable. Come forward to hear about Sun Tzu, an early military analyst.

Keyword: Military OR Applications, History of OR and Ethics

5. Abstracts for Presentations and Papers

Abstract-1
Berry 1
0900-0920

Real-World Strategies for Distribution Planning of Multiple Product Classes

Brad Guthrie (Wright State University)
Pratik Parikh (Wright State University)

Presentation

Abstract *It is common for distribution networks to manage products with varying life-cycles, where demand for some products is relatively stable throughout the year and the demand for others is short-lived. Coordination is often required at the warehouse level where resources (e.g., workers, loading docks, material handling equipment) may be utilized by both product classes simultaneously. However, our observations in industry suggest that such coordination is frequently overlooked, which often leads to increased workload variation throughout the time-horizon and overall cost.*

Our focus in this presentation is to characterize and evaluate three real-world strategies against a benchmark ILS-based heuristic, all of which integrate warehousing decisions in the distribution plan. Results obtained through an elaborate experimental study indicated that there are in fact strategies in industry that, under a certain parameter settings, may provide very competitive solutions compared to the benchmark heuristic on large problem instances (200 stores, 1000 products, 28 time-periods). Further, we noticed that with an increase in the number of fashion products, the contribution of warehouse cost towards total cost increased from 14% to nearly 38%. The variation in worker hours had a similar increasing trend (29% to 195% in maximum percent difference from the mean). Several managerial insights are discussed, along with avenues for future research.

Keyword: Engineering Applications, Logistics and Supply Chain Management

Abstract-2
Berry 1
0920-0940

Inventory-based Delivery Scheduling and Routing

Michael Gorman (University of Dayton)

Presentation

Abstract: *Deliveries from a central depot are scheduled and routed to numerous customer locations. Delivery vehicles have capacity in space and time. Deliveries are scheduled over a rolling horizon for two to four weeks of daily deliveries. This work is an extension of the capacitated multiple vehicle routing problem in that the set of deliveries for any date are not set. We use K-means clustering for finding "like" customers and "furthest neighbor" heuristics in our two-part algorithm. The algorithm must trade off delivery distance efficiency with early delivery penalties. We apply the heuristic to an industrial cleaner manufacturing company. Practical implementation problems are discussed.*

Keyword: Data Mining and Applied Statistics, Transportation

Abstract-3
Berry 1
0940-1010

Scheduling of Advanced Practice Providers at Level 1 Trauma Centers

Robert Myers (Wright State University)
Pratik Parikh (Wright State University)
Akpofure Peter Ekeh (Wright State University and Miami Valley Hospital)
Elizabeth Denlinger (Miami Valley Hospital)
Mary McCarthy (Wright State University and Miami Valley Hospital)

Presentation

Abstract:

Background: *Advanced practice providers (APPs) are essential to the provision of trauma care services, particularly in the wake of residency hour restrictions. Demand for these APPs fluctuates with cyclic patient arrivals, however, most trauma teams continue to staff APPs in a linear fashion. Failure to plan for variable arrivals may contribute to excessive patient wait times and ED overcrowding. This study utilized both qualitative and quantitative approaches to evaluate the impact of APP scheduling on patient wait time and to find schedules minimizing delays in reaching the needed care at the right time.*

Methods: *Retrospective observation of the availability of APPs and the flow of 2,249 trauma patients at a Level 1 Trauma Center, using both visual overlays and computer modeling, allowed us to evaluate the baseline condition, two what-if schedules, and two model generated schedules minimizing patient time without any additional APP hours.*

Results: *A visual overlay of APP staffing on 2010 patient arrivals indicated substantial times of mismatch. Trauma managers considered adding an APP during weekday evenings that would have resulted in a 14.8% increase in APP hours and yielded a 27% reduction in patient wait times according to our model. An alternate schedule was developed and implemented in 2012 with a 10.5% increase in APP hours, and yielding a 73% reduction in wait times. We also delineated two schedule options with 57% and 78% reductions in wait time and no increase in APP work hours.*

Conclusions: *Evaluating alternate shift times and assignments using visual overlays and computer modeling can provide APP staffing solutions with up to 78% reduction in trauma patient wait time without additional APP labor. Knowing that care at the right time is crucial to arriving patients, making sure APP staffing is synchronized with arriving patients is something trauma center managers cannot ignore.*

Keywords: Biostatistics/Biomedical, Logistics and Supply Chain Management

Abstract-4
Berry 2
1025-1045

Quantifying and Evaluating Trust in Automated Systems

Jayson Boubin (Miami University and Air Force Institute of Technology)
Maj. Christina Rusnock, Ph.D (Air Force Institute of Technology)
Dr. Michael Miller (Air Force Institute of Technology)

Presentation

Abstract: *Automation is utilized heavily in many systems, including safety critical systems and necessary infrastructure. It is important that operators have a properly calibrated level of trust in these automated systems in order for the human-automation team to maximize performance.*

To properly measure trust, we can quantify its components, compliance and reliance. The quantification of compliance and reliance allows for discrete-event simulation (DES) of systems, which engineers may use to evaluate and improve the role of automation in these systems. The purpose of this paper is to provide a methodology for the quantification, prediction, and evaluation of trust humans place in automated systems. This research uses behavioral data from a human-subjects experiment involving automated agents. Through analysis of this behavioral data, we create a series of equations to predict compliance and reliance in this domain. These equations were implemented into a validated DES, clearly demonstrating the utility of this methodology.

Keywords: Biostatistics/Biomedical, Simulation, Trust

Abstract-5
Berry 2
1045-1105

**Using Department of Defense Supercomputers to Solve Computationally
Intensive Problems: Trials, Tribulations, and Rewards**

David Meyer (Air Force Institute of Technology)
Presentation

Abstract: *There is an adage about buying a house. No matter how big of a house you get, you will always fill it up. And so it is with computers – despite the fact that both the memory and the speed of the average computer has exploded over time, that added capability is not all just available for the user. Like the house, the computer is getting filled with “stuff”: bigger, albeit more capable applications, and data sets that are getting both larger in coverage and higher in resolution. Thus, at the Air Force Institute of Technology Center for Space Research and Assurance, students find themselves in a tantalizing yet frustrating position – at their fingertips is the data, software, and tools needed to perform great research and solve challenging problems. Unfortunately, the computational overhead imposed by larger programs and data sets means research and exploration becomes highly time constrained.*

A potential solution to this problem is the use of high performance computing (HPC) or supercomputers. At Wright-Patterson Air Force Base, there are numerous DoD HPCs all available for CSRA use, free of charge. Yet despite the low cost, the enthusiasm of DoD HPC personnel, and the potential to do more research faster, use of HPCs by CSRA students is non-existent. This experience is not unique to just Air Force, or for that matter, DoD students. In this presentation, the strengths and limitations of supercomputing are explored and impediments to HPC use are identified and discussed from the researcher’s perspective. Finally, realistic expectations for what can be expected from supercomputing are set and an outline to smooth the supercomputing process is provided.

Keyword: Big Data, Trust

Abstract-6
Berry 2
1105-1135

Disruptive Technology: Don’t Get Caught With Your Pants Down

Terry Oroszi (Veterans’ Administration & Wright State University)

Presentation

Abstract: *Disruptive technology was a term coined by Harvard business professor Clayton Christensen in his book Innovators Dilemma. Disruptive technology opens up windows of opportunity for new products. It can enable low-income markets to have a piece of otherwise inaccessible technology. Education and health care are not immune to disruptive technology. Distance learning has played a new and significant role in the education market, displacing traditional education. The healthcare industry is currently in trouble and hospitals are losing millions. The industry has identified several disruptive innovations that have decreased this loss. Disruptive technologies join the marketplace by offering more cost efficient products and cater to a different consumer base. This presentation will describe in detail Disruptive Technology and how it applies to business, education, and healthcare as a low-level entrant into the marketplace. It will also discuss how organizations can successfully meet the challenge of disruptive technology. Recent studies independently inferred that the theory is unsupported and attacked the authenticity of Christianson's claims. In The Innovator's Dilemma and its follow-up, The Innovator's Solution, Christensen cites 77 disruptive cases. However, here the researchers posit only 9 percent of the cases fit this theory. The attacks have not dimmed disruption's popularity as a theory or as a buzzword..*

Keyword: Biostatistics/Biomedical, Trust

Abstract-7
Berry 2
1135-1155

The Foodbank Compliance Problem – An Initial Investigation

Kellie Schneider (University of Dayton)
Sarah G. Nurre (University of Arkansas)

Presentation

Abstract: *Food insecurity continues to be a problem in the United States with an estimated 49 million Americans lacking access to a sufficient quantity of affordable, nutritious food. To address the issue of food insecurity in our area, The Foodbank, Inc., partners with more than 90 local agencies to provide emergency food relief to the people of Green, Montgomery, and Preble counties. To maintain regulatory compliance, each agency serviced by the The Foodbank, Inc., receives an on-site audit once every 12-18 months. Our partners at The Foodbank have requested assistance in improving the site visit schedule. In this presentation, we define The Foodbank Compliance problem and model it as a capacitated vehicle routing problem with time windows (VRPTW). We present our current model and network formulation and discuss our initial results.*

Keywords: Simulation, Trust

Abstract-8
Berry 2
1300-1330

Approximate Dynamic Programming Methods for a Coordinated Dynamic Weapon-Target Assignment Problem

Carl Parson (Air Force Institute of Technology)
Darryl Ahner (Air Force Institute of Technology)
Matthew JD Robbins (Air Force Institute of Technology)
Meier Pachter (Air Force Institute of Technology)

Presentation

Abstract: *This presentation introduces a methodology to represent imperfect and uncertain situation awareness and situation understanding (SA/SU), as well as the effects of such SA/SU on decision-making. The methodology is implemented in an agent-based model (ABM) simulating a specific, easily understood, and quantifiable example of the impact of imperfect SA/SU on human behavior: intelligent agents being spatially “lost” while trying to navigate in a simulation world. The simulation is called MOdeling Being Intelligent and Lost (MOBIL).*

We present results of using MOBIL to investigate decision-making under uncertainty and error, by conducting a set of virtual experiments that examine how an intelligent agent’s behavior is affected by information of varying levels and quality. These experiments vary aspects of an agent’s perceived worldview to study how a mistaken understanding of ground truth affects achievement of the agent’s goals. They provide insight into multiple aspects of decision-making as affected by problem complexity, information quality, risk tolerance, and decision strategies.

Keywords: Simulation

Abstract-9
Berry 2
1330-1350

Ohio Brewery Placement

Kevin Cardenas (Air Force Institute of Technology)
Zach Little (The Perduco Group)

Presentation

Abstract: *In this work, we seek to identify candidate locations to establish new (micro)breweries with localized customer bases across the state of Ohio, given existing competitors vis-a-vis the population-based market. We examine and compare the results of three location analyses, each of which utilizes an integer programming formulation: the set covering problem, the avoidance problem, and the maximum covering location problem. From these analyses, we derive and share collective insights for a decision maker to consider. Beyond the application considered in this study, we discuss the extensibility of such models to broader facility location problems, such as other commercial supply chain decisions as well as defense-related location problems.*

Keywords: Business Analytics, Optimization

6. Abstracts for Posters

Abstract-P1
Berry 3

Brain Measurements to understand student learning in STEM education

Kevin Hatcher (Wright State University)

Poster

Abstract: *Mathematics is an important component to undergraduate STEM Education, especially engineering education. In the first two years of undergraduate work in engineering students are taught concepts such as physics, electronics and most importantly calculus. It is especially important for students to get a better grasp on calculus in the beginning or they will be overwhelmed by the workload to come. The focus of this research is to understand how students learning abstract concepts such as calculus, can benefit from an augmented educational mobile application, that instructs students on one of the core principles. This study will examine how the brain responds and changes when exposed to two different formats of learning. In the study students will participate in electroencephalography (EEG) measurements utilized by the Emotive Epoch as they attempt to solve different calculus limit themed problems. The goal will be to analyze and discover which areas of the brain correspond to the stimulus. Students will be separated based on expert and novice levels, predefined by high and low GPA respectively, and further separated based on if they are given the opportunity to utilize the educational application or not. The results of this experiment can further future research in determining how to transform novice students into expert students.*

Keyword: Biostatistics/Biomedical, Data Mining and Applied Statistics

Abstract-P2
Berry 3

Quantitatively Assessing Mental Workload of Medical Staff using Discrete-Event Simulation

Erich Maxheimer (Air Force Institute of Technology)

Poster

Abstract: *The United States healthcare system is being pressured by an aging population, retiring medical work force, and budget constraints. Each year, preventable medical errors cause hundreds of thousands of deaths in the United States. Many process improvement tools have been applied to the healthcare industry to improve safety and efficiency. However, nearly all of these tools have neglected to explicitly quantify mental workload despite the consensus that it is related to human performance. The United States Army Research Laboratory sponsors the development of the Improved Performance Research Integration Tool (IMPRINT) which uses discrete-event simulation (DES) to model human performance by quantifying mental workload. This unique tool has primarily been used to determine manpower requirements for military applications. It has not yet been used in research to model healthcare systems. This research uses IMPRINT to quantitatively model the mental workload of nurses and technicians in an inpatient unit at the Wright-Patterson AFB hospital. Future work will expand on this research to evaluate alternate models and perform risk analyses for process improvement purposes.*

Keyword: Biostatistics/Biomedical, Modeling and Simulation

Abstract-P3
Berry 3

An Agent-Based Model of Airline Passenger Loading

K. K. Ward (Wright State University)

F. W. Ciarallo (Wright State University)

R. R. Hill (Air Force Institute of Technology)

Poster

Abstract: *In the last decade or so, researchers have begun to look at the process of boarding an airplane with the intention of finding an optimal strategy for airlines to use. Most airlines today board their priority passengers first, to include first and business classes, followed by the remainder of the aircraft in small groups. These groups often consist of random seats throughout the cabin, with no clearly defined strategy in place. The process of boarding passengers, especially on a full flight, is a lengthy process, so airlines must allow more time at the gate than may be necessary in order to ensure a timely departure. In this paper, I use a model built with the Anylogic software to look at different strategies for boarding.*

Keyword: Simulation, Transportation

Abstract-P4
Berry 3

Multivariate Analysis of Labor Force Characteristics in U.S. Counties

Maj. Joshua McDonald (Air Force Institute of Technology)

Dr. Kenneth W. Bauer (Air Force Institute of Technology)

Poster

Abstract:

PURPOSE *Apply basic multivariate analysis techniques to a complex open-source dataset in order to reduce its dimensionality and provide insight into underlying relationships.*

RESEARCH QUESTION *Can the American labor force be characterized effectively by geographical differences—which are tied to U.S. Army recruiting unit boundaries—and by publicly available Census Bureau data, in such a way that the overall complexity of these variables is meaningfully reduced?.*

Keyword: Data Mining and Applied Statistics, Military OR Applications

7. Full Papers

Abstract-10
Berry 2

A Dynamical-Statistical Approach to Forecasting Tropical Cyclogenesis in the Western North Pacific

David Meyer¹ (Statistical Solutions LLC)
Tom Murphree² (Naval Postgraduate School)

Paper and Presentation

Abstract: *In the 1970s, Dr. Bill Gray proposed that tropical cyclone (TC) (strong TCs in the Atlantic are known as hurricanes) formation was strongly influenced by several large scale environmental factors (LSEFs): high sea surface temperature, low vertical wind shear, upward moving air, positive vorticity, and high humidity. Since then, observations of hundreds of storms have reinforced Gray's findings, but with the caveat that the LSEFs are necessary but not sufficient for TC formation. Since its inception in 2007, Statistical Solutions LLC, in collaboration with the Naval Postgraduate School, has built upon these results to:*

1. *Test LSEFs for statistical significance*
2. *Develop a statistical model that relates the LSEFs to TC formation*
3. *Force the model with dynamical weather model forecasts of the LSEFs at leads ranging from 1 day to 90+ days to create probabilistic forecasts of TC formation*
4. *Evaluate those forecasts for skill*

In this paper, we discuss the process of significance testing of the predictor LSEFs, statistical model development, selection of optimal dynamical model outputs, and visualization of the outputs. We also show examples of TC formation forecasts at various leads, and close with a discussion of the challenges of forecast verification.

Tracks: Data Mining, Probability and Applied Statistics, Local Companies in OR, Military OR , Applications, Modeling, Visualization, Tropical cyclone formation, Typhoons, Hurricanes, Dynamical-Statistical Forecast

1. Introduction

There is an obvious need for improved understanding of tropical cyclone (TC) activity, in particular, how that activity is influenced by the surrounding environment. While TC activity is comprised of three components --- formation, track and intensity, we focus on formation because improving our understanding of formation is a logical first step in improving our understanding of TC activity overall.

TC formation is widely recognized to be more likely when conditions are favorable in several large-scale environmental factors (LSEFs). These favorable LSEF conditions are considered to be necessary but not sufficient for TC formation [Gray, 1975; Frank, 1987; McBride, 1995]. Though

¹ Statistical Solutions LLC, 3746 Mesquite Dr, Beavercreek, OH 45440 (david.statistical.solutions@gmail.com, <http://www.statisticalsolutionsllc.com/tropical-cyclone-forecasts---2015.html>)

² Department of Meteorology, Naval Postgraduate School, 254 Root Hall, 589 Dyer Rd, Monterey, CA, 93943-5114 (murphree@nps.edu)

different studies have proposed slightly different sets of favorable LSEFs, most studies agree on and include some form of the following:

- Sea surface temperatures (SSTs) above 26°C
- Weak shear between upper and lower level horizontal winds
- Positive absolute vorticity at low levels
- Mean upward motion
- High mid-level humidity

While there is general consensus that favorable LSEFs influence TC formation, more advanced analyses of the LSEF-TC formation relationships are needed. The LSEF data used by early investigators of tropical cyclogenesis consisted of a combination of climatological, weather service summary, and in situ observational data [Gray, 1968]. Since those early studies, improvements in the types, availability, quality, and resolution of environmental data, as well as data sets populated with that much more data than that used in prior studies allows us to explore the LSEF-TC formation relationship in depth. This exploration ultimately enabled the development of a statistical model that yields the probability of TC formation given what the values of the LSEFs are at a specified time and location.

Figure 1 shows the sea surface temperature (SST) for 01 January 1979 from the Climate Forecast System Reanalysis (CFSR) generated by the National Centers for Environmental Prediction (NCEP) [Saha *et al.*, 2010]. This figure represents the type of long term climate system data presently available for analyzing relationships between climate system variables and for developing forecasting systems for predicting future states of the climate system. Similar data is available for many atmospheric, oceanic, and land variables for multiple decades at hourly temporal resolution, one-half degree horizontal resolution, and many levels within the ocean and atmosphere. The LSEF variables are available either directly from the CFSR data set or may be derived directly from other CFSR variables (such as shear and vorticity).

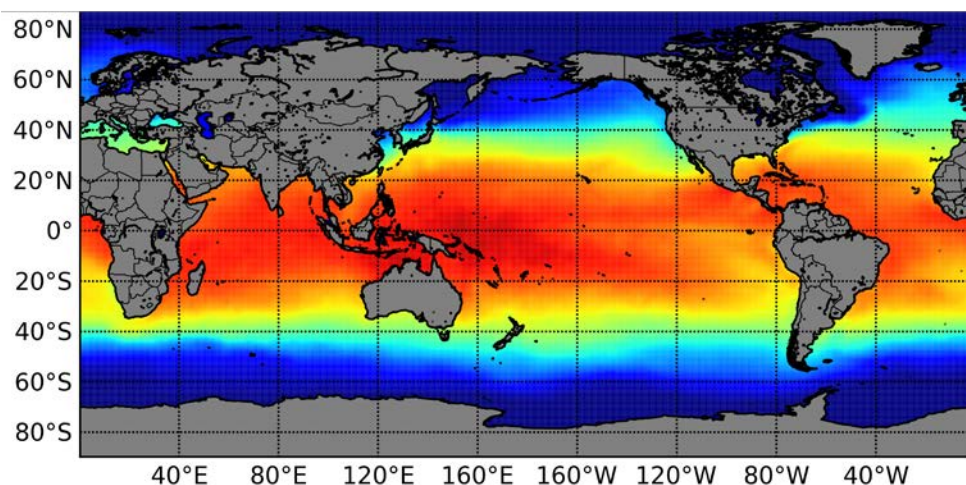


Figure 1. Sea surface temperature (SST; degrees C) for 01 January 1979 from the CFSR data set. CFSR data is available from 1979 through the present, with global coverage.

We obtained TC formation data (time and location) from the Joint Typhoon Warning Center (JTWC). Annually, JTWC publishes their best track analysis, which consists of reanalyzed data on the time, location, strength, and other information for each TC, by basin (e.g., the western North Pacific (WNP), the northern Indian Ocean, etc.). For each TC, we used the first time and position listed in the best track analysis as the time and location of TC formation. Figure 2 shows the formation locations of all June through November WNP TC formations for the year 2010.

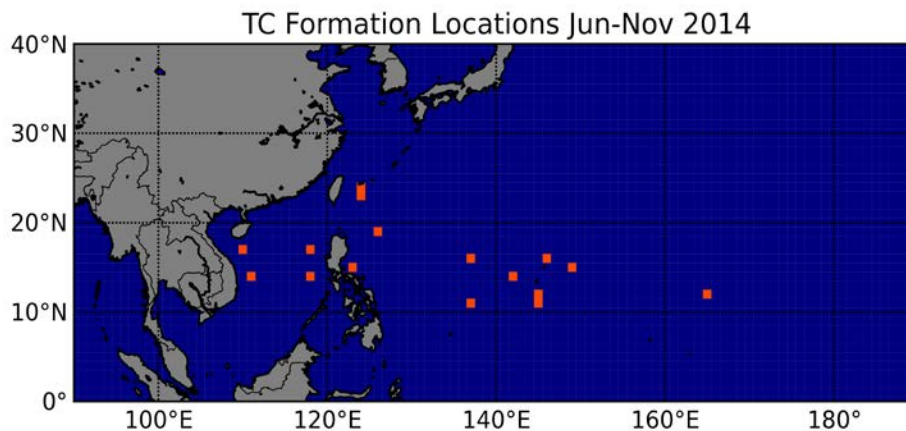


Figure 2. The locations of TC formations (shown by pink dots) in the western North Pacific (WNP) during June-November 2010 based on the first data entry for each TC in the JTWC best track analysis for 2010. The best track analyses extend from 1945 to the present.

2. Data and Methods

The basin used for our study was the western North Pacific (WNP). We chose this region to maximize the number of formations in the data set (the WNP accounts for nearly 30% of the global annual total of TCs [Chan, 2004] (see Figure 3, [Nilfanion, 2006]). We define the WNP as the region bounded by: 0-30° North and 100-180° East, consistent with areas defined as the WNP by other researchers [Chan and Liu, 2004]. We chose 1979-2009 as our initial study period to maximize the amount and consistency of data available (at the time we developed the TC formation statistical model, 2009 was the most recent year for which JTWC best track data was available). The data we used for statistical model building was limited to that from June-November, which are the months when TC activity tends to be greatest in the WNP [Frank, 1987].

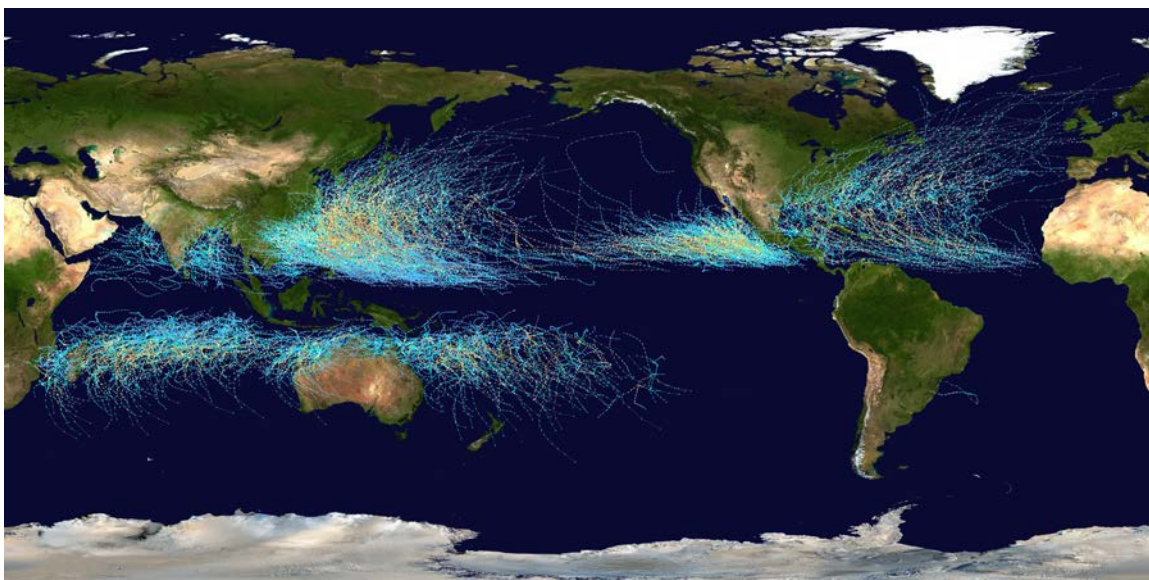


Figure 3. The tracks and intensities of TCs during 1985-2005. The colored lines indicate the tracks of individual TCs, with warmer colors indicating higher intensities (greater wind speeds). More TCs occur in the western North Pacific (WNP) than in any other basin.

Our tool of choice for the development of the statistical model was logistic regression. The LSEFs used in the regression model as predictors of TC formation were slightly different from those described in section 1 to account for data quality and availability issues and to facilitate analysis of LSEF-TC formation relationships. The LSEF predictors we used were SST, shear, relative humidity, upper level divergence (as a proxy for vertical motion), planetary vorticity and relative vorticity (the components of absolute vorticity). The exact nature of the individual LSEF-TC formation relationships are not well understood, so we included in the initial model second order polynomial terms of all predictors, and second order interaction terms. Ultimately, using backward stepwise logistic regression [Collett, 1991], we determined that the probability of TC formation is a function of (at over a 0.999 confidence level) SST and SST squared, shear and shear squared, divergence, relative vorticity, and three secondary interaction terms. Planetary vorticity by itself is not significant, but it is part of one of the significant interaction terms and thus was retained as a predictor. It was also determined in the initial model building process that multicollinearity was an issue (it turns out that warm SSTs, upward air motion, and positive upper level divergence tend to be strongly associated with high relative humidity). Therefore, we dropped the humidity term and re-ran the logistic regression to create a model that was physically plausible. Cross-validation was used as a check against over-fitting. In addition, two years of independent LSEF and TC formation data since the last update of the statistical model in winter 2014 have produced results that indicate that the model is valid.

One example of the statistical model's skill is provided by Figure 4 which shows the statistical model calculated long term mean (LTM) probability of TC formation in the WNP for July-October based on best track and LTM LSEF data for 1979-2009 (colored contours), along with the formation locations for all the TCs that occurred during July-October of 1979-2009 (blue dots) [Johnson, 2011]. The good agreement between the TC formation distribution and the statistical model contours provides some evidence that the model has skill. The figure does not show TC formations east of 180E as they are considered central North Pacific storms.

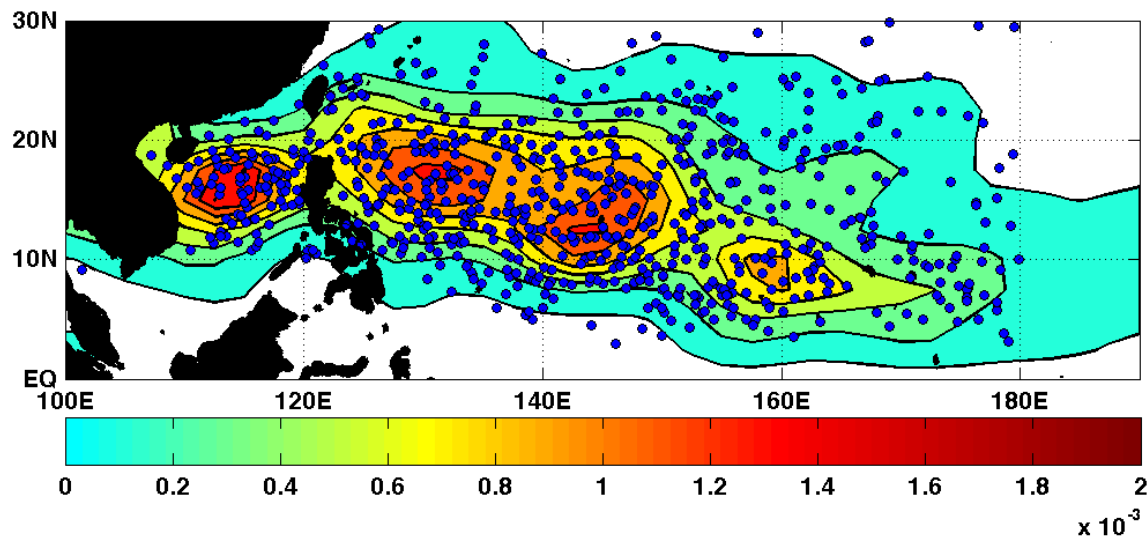


Figure 4. Long term mean probabilities of TC formation generated by the statistical model (colored contours) and actual TC formations (blue dots) for July-October 1979-2009.

The focus of our forecasting, though, has been on TC formation forecasts at extended leads, beyond the 5-10 day skill limit of dynamical models, and with the temporal and spatial resolution missing from seasonal forecasts (those forecasts that merely state an expected number of TC (or hurricane) formations for the year with little prediction of when or where those formations would occur).

To force the statistical model, we use extended lead forecasts of the LSEFs from the NCEP Climate Forecast System version 2 (CFSv2) [Saha *et al*, 2014], which uses the same dynamical model as that used to produce CFSR and has the same spatial and temporal resolution as the CFSR data used to build the statistical model. We felt that if the CFSv2 forecasts of the LSEFs are at least reasonably skilled, then skilled extended lead forecasts of TC formation probabilities could be made by forcing the statistical model with the CFSv2 forecasts.

A motivation for trying this approach is that CFSv2 and other extended range dynamical models tend to be good at forecasting large-scale features, such as SSTs or winds, but are less skilled at forecasting synoptic scale events (such as tropical cyclogenesis) beyond 5-10 days. Conversely, statistical models, though not used as much as dynamical models for forecasting large-scale features, are well suited to forecasting probabilities of synoptic scale events. Thus, we developed the Statistical Solutions LLC-Naval Postgraduate School TC Formation Forecasting System (hereafter referred to as TCFS) to capitalize on the strengths of both dynamical and statistical models.

The CFSv2 forecast system is an ensemble forecast system, meaning that it produces multiple forecasts, or an ensemble of forecasts, for a single future time frame [Saha *et al*, 2014]. The CFSv2 forecasts we use are issued four times daily at 00, 06, 12, and 18z. A major motivation for ensemble forecasting is to account for the uncertainty in the initial conditions for the forecast model (i.e., the observed conditions used at the start time for the model) as well as that imposed by the model itself. The forecasts for the different ensemble members can be very similar or very different. The amount of difference depends to a large extent on the sensitivity of the model to the initial conditions, which itself is determined in large part by the degree of nonlinearity in the modeled atmosphere. The amount of difference, and the range in outcomes from the forecasts, tends to increase as the lead time increases --- mainly because the effects of sensitivity and nonlinearity tend to increase with time. So at very short leads (e.g., 1 day), the effects of changing initial conditions, uncertainty in those initial conditions and model inaccuracies tend to be small, and the ensemble member forecasts tend to be very similar. At

longer leads, the spread in each ensemble member forecast, and thus the uncertainty in the forecasts, tends to increase. To overcome this issue, more ensembling is required.

The use of more ensemble members at longer lead times to increase the forecast skill is analogous to the use of Monte Carlo simulation. That is, a larger number of ensemble members tends to produce a more representative forecast distribution (as representative as forecasts can be) of the actual LSEF values at the valid time of the forecast. We found that the longer the forecast lead-time, the greater the amount of ensemble members needed.

Figure 5 shows a typical 1-day lead forecast, plus the location of a TC that formed during the forecast valid period (taken from the first position indicated on the corresponding JTWC TC formation alert). The 1-day lead forecasts are the TCFS forecasts with the highest skill (as discussed further in section 3). While 1-day lead forecasts do not sound terribly helpful, tropical cyclogenesis is a prolonged process, and formation is often not recognized until one or more days after formation occurs. So a forecast such as the one in Figure 5 may be issued as much as 1-3 days prior to a TC formation alert being issued, with the date and time of TC formation subsequently being identified as occurring 1-3 days prior to the alert being issued. Thus, the 1-day lead forecasts are useful for TC situational awareness in alerting forecasters and others where to focus their attention and where they may be able to devote less attention.

Similar to the 1-day lead forecasts are the 4-day lead forecasts (not shown). Like the 1-day forecasts, the dynamical model output itself is both skilled and little impacted by the changing initial conditions or model inaccuracies (though more so than the 1-day lead forecasts). Thus, light ensembling (8 members) is required to have coherent, and skilled forecasts.

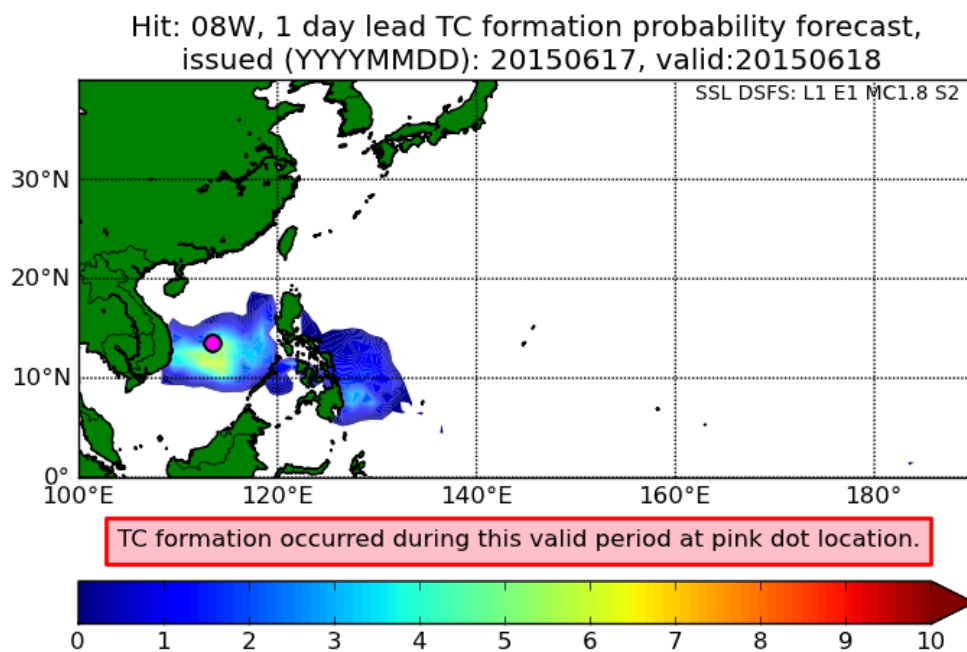


Figure 5. 1-day lead forecast of TC formation probability, with formation location of 8W (Kujira) identified with pink dot.

The next (in lead time) TCFS products are the Weekly Outlooks. Figure 6 shows a Week 1 Weekly Outlook (Week 1 products are issued Mondays and valid for Wed-Tues), Week 2 Outlooks, valid

for the week following the Week 1 Outlook (not shown) are also produced. The issued date and the valid period line up with CPC's production schedule for their weekly Global Tropical Benefits/Hazards Forecasts (GTHB) as we provide WNP TC formation technical input for those forecasts. In addition to the convenience for CPC to receive a forecast with a valid period that matches their own products, the longer valid period is necessary because as lead times grow, forecast errors and uncertainties in the LSEFs become more pronounced, making daily resolution forecasts impractical. Additionally, some amount of ensembling must be used to provide skilled, representative LSEF input. Therefore, after some experimentation to find the optimal amount of ensembling to maximize skill without washing out important synoptic scale climate events, we settled on Weekly Outlooks using 28 ensemble members per LSEF as the most practical and skilled solution to creating forecasts at intermediate leads. However, with that ensembling there are two things that occur: the amount of area that is shown as favorable for TC formation (i.e. that portion of the plot that is colored or contoured) becomes much larger than would be observed for a 1 or 4-day lead forecast due to the many varied inputs, and the sharpness or resolution of the forecast contours gets flatter in comparison to the daily forecasts. This is because of the many varied inputs and averaging that occurs, making determination of where formation may occur more challenging.

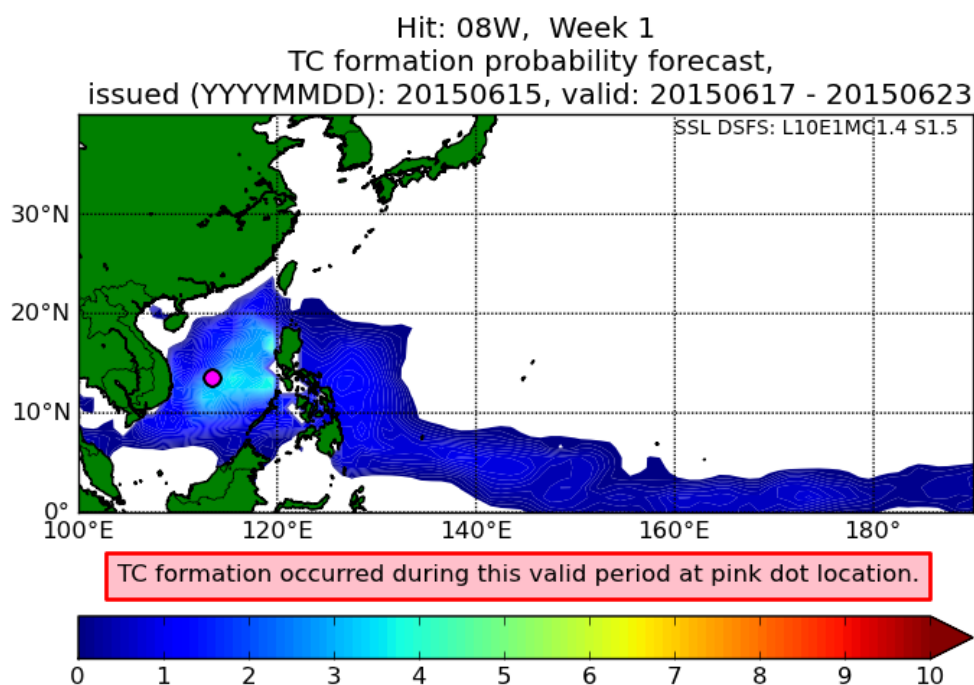


Figure 6. Week 1 Weekly Outlook of TC formation probability, with formation location of 8W (Kujira) identified with pink dot. Note the consistency between the highest formation probabilities seen in Figure 4 and those shown here, even though the LSEF forecasts to create the 1 and 4-day lead forecasts are different than those used to create the forecast shown here.

Figure 7 shows one of the TCFS monthly outlooks. It is valid for June of 2015, and was issued in late March, indicating the forecast was issued at a 2-month lead. The 3 TCs that formed in the WNP in June are shown. In looking at Figure 7, two points are apparent: first, the contoured area shown in Figure 7 in comparison to the climatology shown in Figure 3 is a substantial improvement in forecasting where formation may or may not occur. Second, there is good consistency between the Monthly Outlook of Figure 7, the Weekly Outlook of Figure 6, and the 1-day lead forecast of Figure 5. While the consistency is hardly proof of the skill of the TCFS, substantial inconsistency would cast doubt on the skill of the

system. Additionally, while forecasters tend to focus on skill, anything that can discriminate where formation may occur is important to planners. Though the formation favorable region of Figure 7 is sizeable, an example of its value is that it indicates (with the highly favorable region in the South China Sea (SCS)) that Vietnam and China are at substantial risk despite the fact that in a typical TC season, many months may pass without an actual SCS TC forming. This is particularly valuable information because June marks the beginning of the TC season, TC formations are relatively few [Mundhenk, 2009], and to skillfully issue a strong forecast for formation in the SCS for June is in stark contrast with what might be expected from climatology.

Because of the extended lead times (beyond a couple of weeks), monthly outlooks require the greatest amount of ensembling. Like the weekly outlooks, the ensembling tends to flatten the contours as compared to the short lead forecasts. However, an advantage of the added ensembling is that the amount of contoured area or area considered favorable for formation is smaller than that of the weekly forecasts because the contribution of individual ensemble member forecasts that are on the periphery is proportionally smaller than those with less ensembling, and thus is more likely to not meet the minimum threshold necessary for formation.

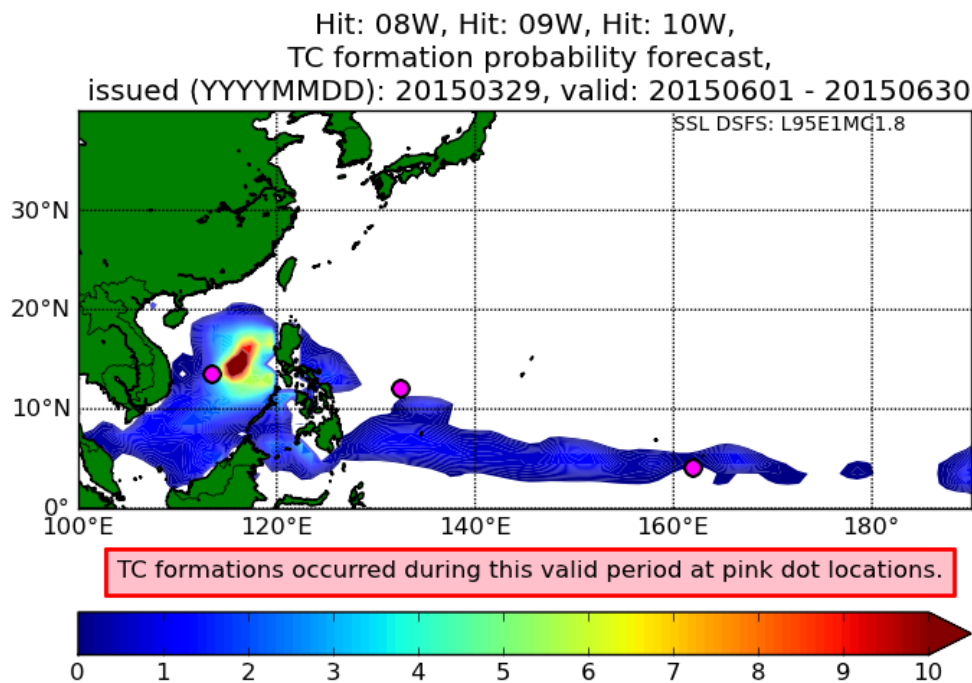


Figure 7. 2-Month Lead Monthly Outlook of TC formation probability, with formation location of 8W (Kujira), 9W (Chan-Hom), and 10W (Linfa) identified with pink dots. Of note: 10W, which only appears to be touching the contoured area is still counted as a hit. A neighborhood scoring system is used to account for inaccuracies in preliminary formation location, errors imposed by the grid, etc.

3. Verification of TCFS Performance

In the climatology world, a model is untrusted without verification. Figure 8 shows a variety of verification statistics for our Current Month Outlooks for 2013. The three statistics of most interest are the Probability of Detect (POD) – a measure of if a TC forms, how likely it is that it forms in a forecasted region; False Alarm Rate – a measure of TCFS forecasted formations but none occur, and Percent of Contoured Area (PCA). PCA is a verification statistic created by the authors of this paper. It is possible to improve POD by lowering the threshold of what is considered favorable for formation. But by doing

so, an increasingly larger contoured region results, reducing the discrimination (or the separation from climatology) that makes the forecasts useful. PCA then, is the ratio of the amount of contoured area in a forecast divided by the marine portion of the WNP that is considered possible for TC formation by climatology.

One note about the low value of FAR: FAR is zero because scores are calculated on a monthly basis. While the Monthly Outlook always indicated regions where conditions were favorable for formation, there was always at least one TC that formed during the valid period.

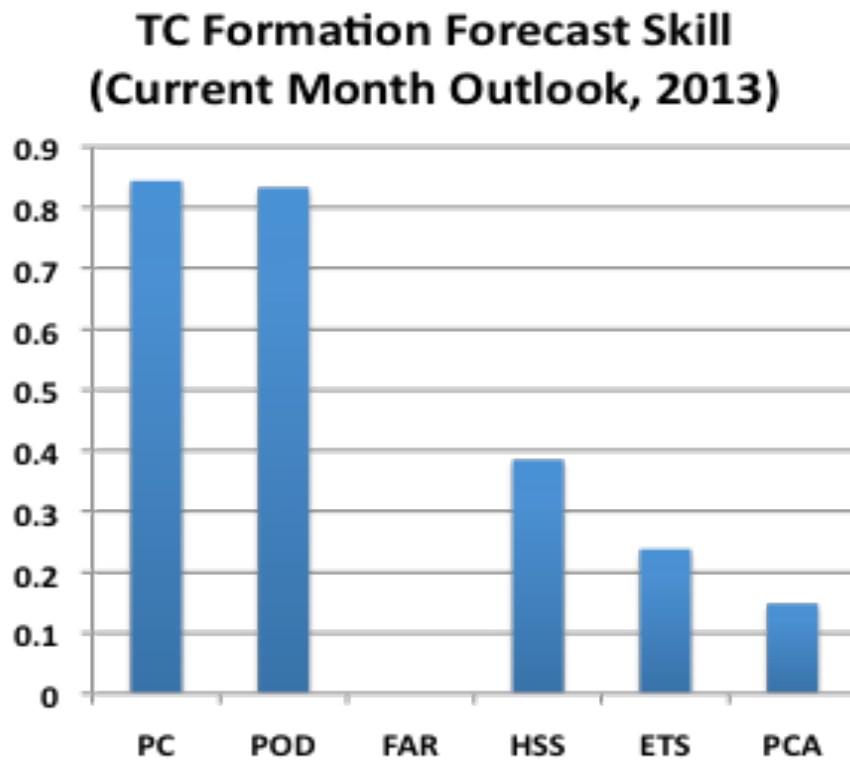


Figure 8. TCFS forecast skill metrics for our Current Month Monthly Outlooks, 2013. A skilled forecast would have positive a Heidke Skill Score (HSS) and Equitable Threat Score (ETS), high Percent Correct (PC) and POD, and a low PCA. These scores indicate that the TCFS at this lead is skilled.

Figure 8, (which shows typical verification statistics for any of our forecast years), and Figure 9, which is a bar chart of POD and PCA for all of the TCFS products for 2013 demonstrate that the TCFS has skill. It should also be noted that all forecasts and evaluations of forecasts are fully automated and objective (many TC forecasting systems require a subjective man-in-the-loop for forecasting and/or verification meaning the system is subject to the skill and objectivity of the man).

2013 Verification results, all NPS-SSL Forecast System products

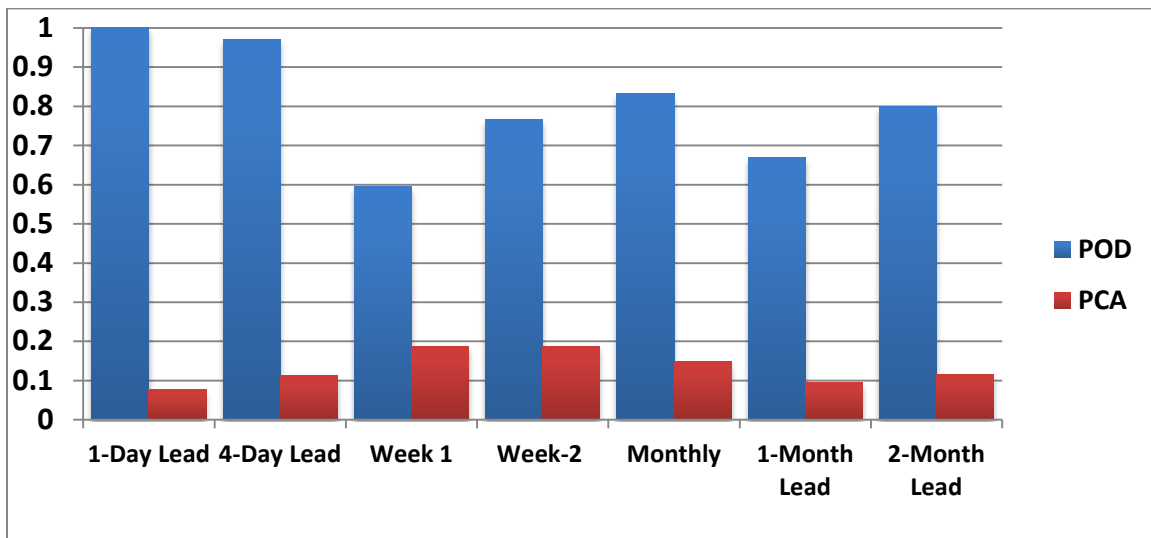


Figure 9. TCFS forecast skill metrics for all forecast products, 2013. These scores indicate that the TCFS is skilled at all leads.

5. Summary and Way Forward

Using over 30 years of climate (CFSR) and TC Best Track data, logistic regression was used to create a model that relates high-resolution LSEF values to the probability of TC formation. The necessary but not sufficient LSEFs first proposed by Gray [1968, 1975] were found to be statistically significant at a confidence level of over 0.999, though the humidity term was dropped due to multicollinearity. Some second order polynomial terms and interactions were also found to be statistically significant. The resulting model was then forced with CFSv2 forecasts of the LSEFs at leads of 1-day to over 2 months to produce several forecast products, each with different strengths:

1. Short lead forecasts:
 - a. Leads of 1 and 4 days
 - b. Highest POD, lowest PCA
 - c. Effective for situational awareness
 - d. 4 (1-day lead) or 8 (4-day lead) ensemble members
2. Weekly Outlooks:
 - a. Immediate week and following week valid periods
 - b. Competitive with the state of the art for operational forecast tools
 - c. Capable of accounting for intraseasonal climate events such as the Madden Julian Oscillation or Kelvin waves that influence TCs but aren't yet forecasted with skill at greater leads
 - d. Ensembling is required (28 members)
3. Monthly Outlooks
 - a. Includes current month, 1 and 2 month lead products
 - b. The extensive ensembling yields good skill at unprecedented lead times
 - c. Skill is second only to the short lead forecasts
 - d. Outlooks are issued at usefull lead times for government and non-government organization planners
 - e. There is promise for skilled forecasts at even greater leads
 - f. Most ensembling is required (120 members)

The TCFS system has been providing skilled objective forecasts for 6 years, and has been used as an input by CPC for their GTHB forecasts. It has spatial and temporal resolution, combined with long leads, that is not available in typical seasonal forecasts. Several improvements have been made along the way, as more and more is learned about TCs, formations, CFSv2, and the TCFS. A prototype TCFS for the Atlantic is scheduled to reforecast selected years of interest this winter and should be forecasting in real time, complete with reforecast verification statistics in time for the 2016 Atlantic hurricane season.

Acknowledgements:

This paper includes results from research supported by the Naval Postgraduate School Agreement No. N00244-15-2-0005 awarded by the NAVSUP Fleet Logistics Center San Diego (NAVSUP FLC San Diego). The views expressed in written materials or publications, and/or made by speakers, moderators, and presenters, do not necessarily reflect the official policies of the Naval Postgraduate School nor does mention of trade names, commercial practices, or organizations imply endorsement by the U. S. Government.

CFSR provided by NOAA/CPC/NCEP, from their web site at <http://nomads.ncdc.noaa.gov/data/cfsr/>. CFSv2 data is provided at: <http://nomads.ncep.noaa.gov/pub/data/nccf/com/cfs/prod/>. JTWC best track data was provided by JTWC Tropical Cyclone Best Track Data Site at http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/shindex.html

References:

- Chan, J. C. L., K. S. Liu (2004), Global Warming and Western North Pacific Typhoon Activity from an Observational Perspective, *Journal of Climate*, 17, 4590-4602.
- Chan, J. C. L., (2004) Variations in the Activity of Tropical Cyclones Over the Western North Pacific. *Hurricanes and Typhoons: Past, Present, and Future*, R.J. Murnane and K.-B. Liu, Eds., Columbia University Press, 269-296
- Collett, D., (1991), *Modelling Binary Data*. Chap. 5, *Overdispersion*. Chapman and Hall, 2-6 Boundary Row, London SE1 8HN, UK, 188.
- Frank, W. M. (1987), Tropical Cyclone Formation, *A Global View of Tropical Cyclones*, Elsberry, R. L., W. M. Frank, G. J. Holland, J. D. Jarrell, R. L. Southern Eds., Office of Naval Research, Arlington, VA 22217.
- Gray, W. M. (1968), Global View of the Origin of tropical Disturbances and Storms, *Monthly Weather Review*, 96,669-700.
- Gray, W. M. (1975), *Tropical Cyclone Genesis in the Western North Pacific*, Naval Air Systems Command, Washington DC, 20361.
- Johnson, S. A., (2011), *Modeling the Impacts of Intraseasonal to Interannual Climate Variations on Tropical Cyclone Formations in the Western North Pacific*, M.S thesis, Dept. of Meteorology, Naval Postgraduate School, Monterey, CA 93943

- McBride, J. L. (1995), Global Perspectives on Tropical Cyclones, 1995: *World Meteorological Organization TCP-38*, Ch. 3, Secretariat of the World Meteorological Organization – Geneva, Switzerland.
- Mundhenk, B. D., (2009), *A Statistical-Dynamical Approach to Intraseasonal Prediction of Tropical Cyclogenesis in the Western North Pacific*, M.S thesis, Dept. of Meteorology, Naval Postgraduate School, Monterey, CA 93943
- Nilfanion, (2006), Tropical Cyclone Tracks 1985-2005, Background Image by NASA. Online image from: https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Tropical_cyclones/Tracks#/media/File:Global_tropical_cyclone_tracks-edit2.jpg. Released in the public domain. Accessed 25 Sep 2015.
- Saha, Suranjana, et al., (2010), The NCEP Climate Forecast System Reanalysis. *Bull. Meteor. Soc.*, **91**, 1015-1057. doi: 10.1175/2010BAMS3001.1
- Saha, Suranjana, et al., (2014), The NCEP Climate Forecast System Version 2, *Journal of Climate*, **27**, 2185-2208. Doi: <http://dx.doi.org/10.1175/JCLI-D-12-00823.1>