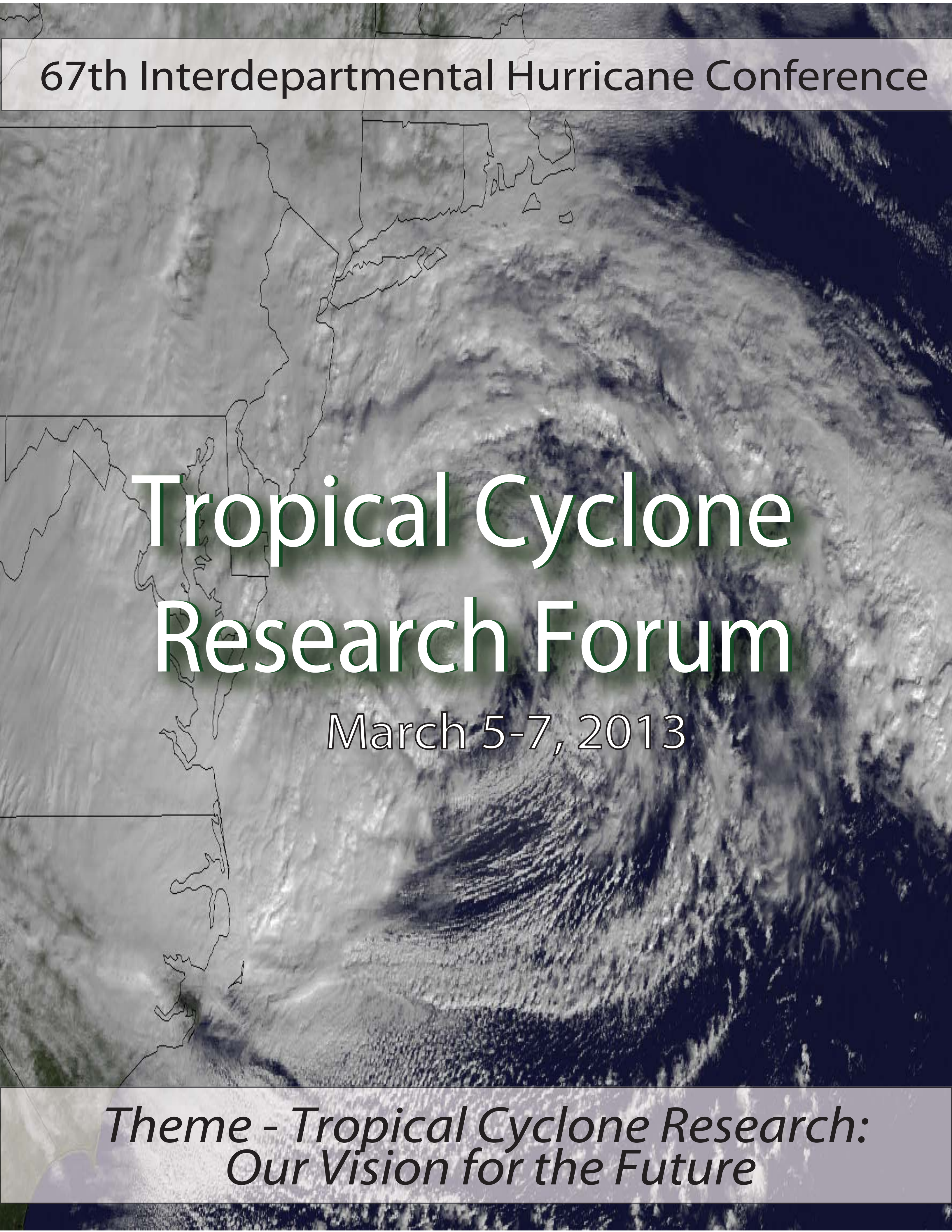
67th Interdepartmental Hurricane Conference

Tropical Cyclone Research Forum

March 5-7, 2013



Theme - Tropical Cyclone Research: Our Vision for the Future

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

SUITE 1500, 8455 COLESVILLE ROAD
SILVER SPRING, MARYLAND 20910

March 5, 2013

Dear Colleagues,

Welcome to the 67th Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum! We are looking forward to a very productive and informative three days.

Last year, we recognized the important role that partnerships and alliances contribute to the tropical cyclone operations and research communities. This year, as the theme indicates, we are focusing on tropical cyclone research. The agenda includes a special panel on *The Emergency Response to Hurricane Sandy* followed by panel of senior leaders, discussing their individual agency roles in tropical cyclone research. Later in the agenda, three specific sessions will be conducted on Federal modeling initiatives as they relate to improving our Nation's tropical cyclone forecast and warning program.

Other topics on the forum agenda include:

- A special report from the OFCM-sponsored Working Group for Tropical Cyclone Research
- The 2012 Tropical Cyclone Season in Review
- Joint Hurricane Testbed Project Updates
- Tropical Cyclone Model Development and Technology Transfer
- Observations and Observing Strategies for Tropical Cyclones and its Environment
- Improvements in Tropical Cyclone Forecast and Warning Products and Services
- Social Science Applications to the Tropical Cyclone Forecast and Warning Notification Problem

Thank you for joining us as we seek to enhance our ability to improve our Nation's hurricane observing, forecasting, and warning system as we prepare for the upcoming tropical cyclone season and beyond. We also want to thank you for participating in our first experience of conducting a forum of this magnitude where over 50 percent of the attendees will participate "virtually" over the web. It will be a unique and hopefully very productive event!

Sincerely,

Samuel P. Williamson
Federal Coordinator for Meteorological Services and
Supporting Research

Agenda

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2013 Tropical Cyclone Research Forum

Tropical Cyclone Research: Our Vision for the Future

AGENDA

DAY 1 - Tuesday, March 5, 2013

7:00 AM Registration *(7:00 AM-12:30 PM)*

Opening Session

8:00 AM	Conference Opening	Mr. Samuel P. Williamson Federal Coordinator for Meteorology
	Welcoming Remarks	Dr. Louis Uccellini, Director, National Weather Service
	Keynote Address	Congressman Chaka Fattah, Ranking Member of the Subcommittee on Commerce, Justice, Science and related agencies (CJS)
	Invited Comments	Acting Secretary of Commerce Rebecca Blank *(invited)*
	Setting the Stage	Mr. Samuel P. Williamson Federal Coordinator for Meteorology
	Panel Session: *The Emergency Response to Hurricane Sandy* **Moderator:** Mr. Bryan Norcross, The Weather Channel Hurricane Specialist **Panelists:** - Captain Thomas Scardino, Executive Officer, Emergency Management Section, New Jersey Homeland Security Branch - Mr. Jerome M. Hauer, Commissioner of the Division of Homeland Security and Emergency Services, New York State Division of Homeland Security and Emergency Services **Discussion and Q&A**	

9:30 AM Morning Break *(9:30-10:00 AM)*

Session 1: Tropical Cyclone Research: Federal Agency Overview

10:00 AM	Introduction of Panel Moderator	Dr. Paul D. Try, Senior Vice President Science and Technology Corporation
	Senior Leader Panel: *Tropical Cyclone Research: The View from the Top* **Moderator:** John D. Murphy, Director, Office of Science and Technology, National Weather Service **Panelists:** - Dr. Jack Kaye, Associate Director and Research and Analysis Lead, Earth Science Division, National Aeronautics and Space Administration - Dr. Ronald Ferek, Program Officer, Marine Meteorology Program, Office of Naval Research - Dr. Frank Marks, Jr., Director, NOAA's Hurricane Research Division - Dr. Alexander E. (Sandy) MacDonald, Director of NOAA's Earth System Research Laboratory and Deputy Assistant Administrator for Research Laboratories and Cooperative Institutes - Dr. Michael C. Morgan, Division Director of Atmospheric and Geospace Sciences, National Science Foundation **Discussion and Q&A**	

12:00 PM Lunch on your own *(12:00- 1:00 PM)*

Afternoon Coordinator: Col Gary Kubat (OFCM/USAF)

Session 2: Working Group for Tropical Cyclone Research

Session Leaders Dr. Frank Marks, Co-Chair WG/TCR and Director, Hurricane Research Division (NOAA/AOML/HRD) Dr. Ronald Ferek, Co-Chair WG/TCR and Program Officer, Marine Meteorology Program (ONR)		
1:00 PM (S2-01)	Comparison of the 2010 and 2012 Snapshots of Tropical Cyclone Research and Development	Frank Marks (AOML/HRD) and Ronald Ferek (ONR)
1:15 PM	Discussion and Q&A	

Note: Presentation abstracts can be found in the conference booklet

Session 3a: The Navy's Model Development and Improvement Program/Hurricane Forecast Improvement Program (HFIP): Supporting Talks

Session Leaders Dr. Ron Ferek (ONR) and Dr. Frank Marks (AOML/HRD)		
1:30 PM (S3a-01)	The Hurricane Forecast Improvement Project: Recent Operational Implementation	*Bob Gall* (NWS), Fred Toepfer (NWS), Frank Marks (AOML/HRD), and Ed Rappaport (NHC)
1:45 PM (S3a-02)	Recent COAMPS-TC Development and Real-Time Tests	*James D. Doyle* (NRL/Monterey), R. Hodur (SAIC), S. Chen, E. Hendricks, T. Holt, H. Jin, Y. Jin, J. Moskaitis, M. Peng, A. Reinecke, K. Sashegyi, J. Schmidt, and S. Wang (NRL/Monterey)
2:00 PM (S3a-03)	NASA's Hurricane and Severe Storm Sentinel (HS3): Results from The 2012 Deployment and Plans for 2013	*Scott A. Braun* and Paul A. Newman (NASA/GSFC)
2:15 PM (S3a-04)	Improving the Assimilation of Multiple and Integrated High-Resolution Satellite Datasets in Mesoscale Models Of Tropical Cyclones	Chris Velden (CIMSS/Univ. of Wisconsin) and *Sharan Majumdar* (RSMAS/Univ. of Miami)
2:30 PM (S3a-05)	The Basin-Scale HWRF: Looking Beyond the 10-M Wind Speed for Improved Storm Predictions	*Sundararaman G.Gopalakrishnan* (AOML/HRD) , Vijay Tallapragada (NCEP/EMC), Xuejin Zhang (CIMAS), Frank Marks, Jr., and Robert Atlas (AOML/HRD)
2:45 PM	Discussion and Q&A	

3:00 PM Afternoon Break *(3:00-3:30 PM)*

Session 3b: Earth System Predication Capability (ESPC)/Next-Generation Suite of Models: Supporting Talks

Session Leader Dr. Alexander E. (Sandy) MacDonald (OAR/ERSL)		
3:30 PM (S3b-01)	Earth System Prediction Capability Interagency Project	*Dan Eleuterio* (ONR) and Jessie C.Carman (NOAA/OAR)
3:40 PM (S3b-02)	Medium Range Global Weather Prediction Research at NCEP	*Bill Lapenta* and John Derber (NWS/NCEP)
3:50 PM (S3b-03)	Next-Generation Global Weather Prediction Research at ERSL	*Stan Benjamin* and Jin Luen Lee (NOAA/ERSL)
4:00 PM (S3b-04)	Global Modeling at GFDL	*Shian-Jiann Lin* (NOAA/GFDL)
4:10 PM (S3b-05)	Next-Generation Global Weather Prediction Research in the U.S. Navy	*James D. Doyle* (NRL/Monterey), Frank Giraldo (NPS) and Sasa Gabersek (NRL/Monterey)
4:20 PM (S3b-06)	Next-Generation Global Weather Prediction Research at NASA GMAO	*Bill Putman* and Michele Rienecker (NASA)
4:30 PM	Discussion and Q&A	

5:15 PM One Minute Poster Previews (Coordinator: Keith Blackwell (University of South Alabama))

5:30 PM Poster Session/Ice Breaker *(5:30-7:00 PM)*
Location – (all posters are listed at the end of this agenda)

DAY 2 - Wednesday, March 6, 2013

Morning Coordinator: Floyd Hauth (OFCM/STC)

8:00 AM Opening/Administrative Remarks

Session 3c: NSF Program Initiatives : Supporting Talks

Session Leader: Dr. Michael C. Morgan (NSF)		
8:05 AM (S3c-01)	Predictability of Tropical Cyclone Intensity Change Using Ensembles	*Gregory J. Hakim* (University of Washington)
8:20 AM (S3c-02)	The Relative Contribution of Atmospheric and Oceanic Uncertainty in TC Intensity Forecasts	*Ryan Torn* (University at Albany-SUNY), Chris Davis and Chris Snyder (NCAR)
8:35 AM (S3c-03)	Probabilistic Verification of Ensemble Forecasts of Tropical Cyclogenesis	*Sharan Majumdar* (RSMAS/University of Miami) and Ryan Torn (University at Albany, SUNY)

8:50 AM (S3c-04)	The Impact of Ensemble-Based Data Assimilation on the Predictability of Landfalling Hurricanes	*Zhaoxia Pu* and Hailing Zhang (University of Utah)
9:05 AM (S3c-05)	Data-enabled Science: Challenges and Opportunities	*Mohan Ramamurthy* (UCAR/Unidata)
9:20 PM	Discussion and Q&A	

9:35 AM Morning Break *(9:35-10:00 AM)*

Session 4: The 2012 Tropical Cyclone Season in Review

Session Leader Bob Dumont (OFCM/STC)		
10:00 AM (S4-01)	53rd Weather Reconnaissance Squadron 2012 Hurricane Season Reconnaissance Summary	*Lt Col Jonathan Talbot* (USAFR/53 WRS)
10:15 AM (S4-02)	NOAA Aircraft Operations Center (AOC) 2012 Seasonal Summary and Future Plans	*Jim McFadden* (NOAA/AOC)
10:30 AM (S4-03)	Targeted Observations for Improving Numerical Weather Prediction: Review and Recommendations	*Sharan Majumdar* (RSMAS/University of Miami)
10:45 AM (S4-04)	Review of the 2012 Central Pacific Tropical Cyclone Season and Preliminary Verification	*Tom Evans* (NWS/CPHC)
11:00 AM (S4-05)	An Overview of Joint Typhoon Warning Center Tropical Cyclone Forecast Improvement Focus	*Brian R. Strahl* (JTWC)

Session 5a: Joint Hurricane Testbed Project Updates, Part 1

Session Leaders Vijay Tallapragada (NCEP/EMC) and John Cortinas (NOAA/OAR)		
11:15 AM (S5a-01)	An Update on The Joint Hurricane Testbed (JHT)	*Jiann-Gwo Jiing*, Chris Landsea, and Shirley Murillo (JHT)
11:30 AM (S5a-02)	Improved SFMR Surface Wind Measurements in Intense Rain Conditions	*Eric Uhlhorn* (NOAA/OAR/AOML) and Brad Klotz (CIMAS/Univ. of Miami)
11:45 AM (S5a-03)	Improved Automation and Performance of VORTRAC Intensity Guidance	*Wen-Chau Lee* (NCAR), Michael Bell (Univ. of Hawaii), and Paul Harasti, (NRL Monterey)
12:00 PM (S5a-04)	Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis: A Year-2 Joint Hurricane Testbed Project Update	*John A. Knaff* (NESDIS), Renate Brummer (CIRA/CSU), Mark DeMaria (NESDIS), and Chris Landsea, Michael Brennan, Robbie Berg, and Jessica Schauer (NHC)

12:15 PM Lunch on your own *(12:15- 1:00 PM)*

Afternoon Coordinator: Daniel Melendez (OFCM/NWS)

Session 5b: Joint Hurricane Testbed Project Updates, Part 2

Session Leader Vijay Tallapragada (NCEP/EMC) and John Cortinas (NOAA/OAR)		
1:00 PM (S5b-01)	Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme	*Jason Dunion* (UM/CIMAS, AOML), John Kaplan (NOAA/OAR/AOML), Andrea Schumacher (CSU/CIRA), Joshua Cossuth (FSU/COAPS), and Mark DeMaria (NESDIS)
1:15 PM (S5b-02)	Upgrades to the Operational GFDL/GFDN Hurricane Model Planned for 2013	*Morris A. Bender*, Timothy Marchok (NOAA/ GFDL), Biju Thomas and Isaac Ginis (University of Rhode Island) and Robert Tuleya (CCPO/Old Dominion University)
1:30 PM (S5b-03)	Advancing HWRF and GFDL/GFDN Prediction Systems through New and Enhanced Physics of the Air-Sea-Wave Coupling Planned for 2013	*Isaac Ginis*, Richard Yablonsky, Biju Thomas (University of Rhode Island), Vijay Tallapragada, Hendrik Tolman (NCEP), and Morris Bender (GFDL)
1:45 PM (S5b-04)	Validation of HWRF Forecasts with Satellite Observations	*Tomislava Vukicevic* (NOAA/OAR/AOML) and Tom Greenwald (Univ. of Wisconsin/CIMSS)
2:00 PM (S5b-05)	Improvement to the SHIPS Rapid Intensification Index:: A Year-2 JHT Project Update	*John Kaplan* (NOAA/AOML), Christopher M. Rozoff (CIMSS), Charles R. Sampson (NRL), Jim Kossin (NCDC), Chris Velden (CIMSS), and Mark DeMaria (NESDIS)
2:15 PM (S5b-06)	Improvements in Statistical Tropical Cyclone Forecast Models: A Year 2 Joint Hurricane Testbed Project Update	*Mark DeMaria* (NOAA/NESDIS), Andrea Schumacher (CIRA/CSU), John A. Knaff (NOAA/ NESDIS), and Renate Brummer (CIRA/CSU)

2:30 PM (S5b-07)	Enhancement of SHIPS-RI Index using Satellite 37 GHz Microwave Ring Pattern	*Haiyan Jiang* (Florida Intl Univ.), Margie Kieper and Tie Yuan (FIU), Edward J. Zipser (Univ. of Utah), and John Kaplan (HRD)
2:45 PM (S5b-08)	A New Secondary Eyewall Formation Index; Transition to Operations and Quantification of Associated Hurricane Intensity and Structure Changes: A Joint Hurricane Testbed Project	*Jim Kossin* (NOAA/NCDC) and Matt Sitkowski, Will Lewis, and Chris Rozoff (CIMSS)

3:00 PM Afternoon Break *(3:00-3:30 PM)*

Session 6: Tropical Cyclone Model Development and Technology Transfer

Session Leaders Dave McCarren (Navy/CNMOC) and Michael Farrar (NWS/OST)		
3:30 PM (S6-01)	Further Advancements to the NCEP Operational HWRF Modeling System for 2013 and Beyond	*Vijay Tallapragada* (NCEP/EMC)
3:45 PM (S6-02)	Application and Improvements to COAMPS-TC	*Richard M. Hodur* (SAIC/Innovative Employee Solutions), J. Doyle, E. Hendricks, Y. Jin, J. Moskaitis, K. Sashegyi, and J. Schmidt (NRL/ Monterey)
4:00 PM (S6-03)	Evaluation of Experimental Models for Tropical Cyclone Forecasting in Support of the NOAA Hurricane Forecast Improvement Project (HFIP)	*Barbara G. Brown***,** Louisa Nance, Paul A. Kucera, and Christopher L. Williams (NCAR)
4:15 PM (S6-04)	Improved Telescopic Nesting and its Effects on Hurricane Forecasting	*Samuel Trahan* (I.M. Systems Group/NCEP), Young Kwon (EMC/IMSG), Qingfu Liu (EMC) Xuejin Zhang (UM/CIMAS), Hui-Ya Chuang (EMC), Dave Zelinsky (NHC/SRG), Greg Thompson (NCAR), Shaowu Bao (ESRL) Ligia Bernardet (ESRL), Vijay Tallapragada (EMC), Brad Ferrier (EMC/IMSG)
4:30 PM (S6-05)	Potential Upgrades for the Radiation and Boundary Layer Physics in the Operational HWRF Model	*Young Kwon* (EMC/IMSG), Chanh Kieu , Weiguo Wang , Sam Trahan, Qingfu Liu, Zhan Zhang, Vijay Tallapragada (EMC) and Jun Zhang (HRD)
4:45 PM (S6-06)	Evaluation of the Ocean Response in HWRF: How Changes in the Atmosphere-Ocean Fluxes Affect Forecast Skill	*Ligia Bernardet* (NOAA/ESRL), Eric Uhlhorn (HRD), Shaowu Bao (NOAA/ESRL), Joe Cione (HRD)
5:00 PM (S6-07)	Further Development of a Statistical Ensemble for Tropical Cyclone Intensity Prediction	*Kate D. Musgrave* (CIRA/CSU), Mark DeMaria (NESDIS), Brian D. McNoldy (Univ. of Miami), Yi Jin (NRL Monterey), and Michael Fiorino (ESRL)
5:15 PM (S6-08)	Extended-range (5-30 day) Forecasts of Tropical Cyclones with the ECMWF Ensemble: Atlantic during HS3 Field Experiment	*Russell L. Elsberry*, Hsiao-Chung Tsai, Mary S. Jordan (Naval Postgraduate School) and Fredric Vitart (ECMWF, Shinfield Park, England)

Forum Banquet

6:00 PM Dinner
6:45 PM Hagemeyer Award Presentation

DAY 3 - Thursday, March 7, 2013

Morning Coordinator: Ms. Susan Callis (STC)

8:00 AM Opening/Administrative Remarks

Session 7: Observations and Observing Strategies for Tropical Cyclones and their Environment

Session Leaders Scott Braun (NASA/GSFC) and Svetla Hristova-Veleva (NASA/JPL)		
8:05 AM (S7-01)	The 2012 Satellite Proving Ground at the National Hurricane Center	*Michael Folmer* (UM/CICS) and Jack Beven, Michael Brennan, Hugh Cobb, Mark DeMaria, John Knaff, Christopher Velden, Jason Dunion, Gary Jedlovec, Kevin Fuell
8:20 AM (S7-02)	Computing Deep-Tropospheric Vertical Wind Shear Analyses for TC Applications: Does the Methodology Matter?	*Christopher S. Velden* and John Sears (University of Wisconsin-Cooperative Institute for Meteorological Satellite Studies (CIMSS))

8:35 AM (S7-03)	Outflow Layer Structure in Hurricanes Leslie And Nadine Revealed by Dropsondes Deployed from NASA Global Hawk UAV Aircraft during the 2012 Hurricane and Severe Storms Sentinel (HS3) Campaign: A New TC Observational Strategy	*Peter G. Black* (SAIC/NRL Monterey), Jon Moskaitis, James Doyle, Chris Velden, and Scott Braun
8:50 AM (S7-04)	HIWRAP Global Hawk Status and Future Plans	*Gerald. Heymsfield* (NASA/GSFC) and S. Guimond (NASA ORAU), L. Li and M. Mclinden (NASA GSFC), J. Carswell (Remote Sensing Solutions), and L. Tian (UMBC GEST)
9:05 AM (S7-05)	Retrievals of Wind and Rain Rate from Combined Measurements of Up-Looking and Down-Looking SFMR(s)	Mark Goodberlet and *Ivan PopStefanija* (ProSensing)
9:20 AM (S7-06)	Implementation of Upper-Ocean Temperature Measurements on Operational Hurricane Reconnaissance: An Update on the AXBT Demonstration Project	*Elizabeth R. Sanabia* and Bradford S. Barrett (USNA), Peter Black (SAIC/NRL Monterey), Sue Chen and James Cummings (NRL Monterey)
9:35 AM (S7-07)	Observations of Upwelling Processes during Tropical Storm Isaac	Benjamin Jaime, *Lynn K. Shay*, Jodi Brewster, Ryan Schuster (RSMAS/Univ. of Miami) and Mark Powell (AOML/HRD)
9:50 AM (S7-08)	Progressing toward a Geostationary Microwave Sounder Mission	*Bjorn Lambrigtsen* (NASA/JPL)

10:05 AM Morning Break *(10:05-10:30 AM)*

Session 8: Improvements in Tropical Cyclone Forecast and Warning Products and Services

Session Leaders Tim McClung (NWS/OST) and Jim Goerss (NRL/Monterey)		
10:30 AM (S8-01)	COASTAL Act Requirements for Tropical Cyclone Post-Storm Assessments and Response by NOAA and Interagency Partners	*Stephen Lord* (NWS), Michael Bilder (NWS), Mark Powell (OAR/AOML), Jesse Feyen (NOS), Andre Westhuysen (NWS/EMC), and Tim Owen (NESDIS/NCDC)
10:45 AM (S8-02)	Using USACE-ERDC's Coastal Storm Modeling System in Support of Hurricane Sandy Operations	*Chris Massey* (USACE-ERDC-CHL)
11:00 AM (S8-03)	USGS Monitoring of Storm-Tide for Hurricanes Isaac and Sandy	*Robert R. Mason*, Benton D. McGee, and Brian E. McCallum (USGS)
11:15 AM (S8-04)	Improvements to the CO-OPS Storm QuickLook Product for Real-Time Storm Surge Monitoring for the 2014 Hurricane Season	*Paul Fanelli* (NOAA/NOS/Center for Operational Oceanographic Products and Services)
11:30 AM (S8-05)	Use of a Modified SHIPS Algorithm for Hurricane Intensity Forecasts	*T.N. Krishnamurti* and Amit Bhardwaj (Florida State University)
11:45 AM (S8-06)	Impact of New Predictors on Corrected Consensus TC Track Forecast Error	*James S. Goerss* (Innovative Employee Solutions/NRL/Monterey)
12:00 PM (S8-07)	Are Atlantic Basin Tropical Cyclone Intensity Forecasts Improving?	*J. R. Moskaitis* (NRL/ Monterey)
12:15 PM (S8-08)	CLIQR: A Climatological Analog Matcher to Ongoing Tropical Cyclones	*David Roth* (NWS/NCEP/HPC)

12:30 PM Lunch on your own *(12:30 PM - 1:30 PM)*

Afternoon Coordinator: Bob Dumont (OFCM/STC)

1:30 PM	Collaborative Decision Making: Connecting Agencies (Federal & State) and the Private Sector for Improved Situational Awareness, Coordination, and Response to Save Lives and Property	*Dave Jones*, Founder, President & CEO, StormCenter Communications, Inc.

Session 9: Social Science Applications to the Tropical Cyclone Forecast and Warning Notification Problem

Session Moderators Ms. Jennifer Moore Sprague (NWS) and Ms.Tracy Rouleau (NWS)		
1:45 PM (S9-01)	Supporting the Integration of Physical and Social Science as it relates to the NOAA Hurricane Forecast Improvement Project (HFIP)	*Jennifer Moore Sprague* (NWS), B. Morrow, J.K. Lazo, J. Rhome, R. Berg, L. Nadeau, and E. Fago

Note: Presentation abstracts can be found in the conference booklet

2:00 PM (S9-02)	Utilizing Input from Emergency Managers, the Media, the Public and Local NWS Meteorologists to Better Communicate Surge and Other Storm Hazards	*Betty Hearn Morrow* (SocResearch, Miami, FL), J. K. Lazo, J. Rhome, R. Berg, L. Nadeau, and E. Fago
2:15 PM (S9-03)	Communication of Hurricane Storm Surge Threat: A Mixed-Method Analysis	*Kathleen Sherman-Morris* (Mississippi State University)
2:30 PM (S9-04)	Evaluation of the NC-CERA Storm Surge and Wave Visualization Tool by Emergency Managers	*Jessica L. Losego* (Institute for the Environment, University of North Carolina)
2:45 PM	Discussion and Q&A	

Final Plenary Session Coordinator: Dr. Paul D. Try (OFCM/STC)

Session Moderator Colonel John Egentowich Air Force Director of Weather		
3:15 PM	WG/HWSOR: Action Item Review	Dr. Edward Rappaport (NCEP/NHC) Chairperson, WG/HWSOR
3:30 PM	Conference Wrap-Up	- Dr. Michael C. Morgan, NSF - Dr. Alexander E. (Sandy) MacDonald, NOAA/ESRL - Dr. Ronald Ferek, ONR - Dr. Frank Marks, Jr., NOAA/HRD
4:15PM	Final Wrap-up	Mr. Samuel P. Williamson Federal Coordinator for Meteorology
4:30 PM	Adjourn	

POSTERS FOR THE TROPICAL CYCLONE RESEARCH FORUM **Poster Session: Tuesday, March 5, 2013, 5:30-7:00 PM *(soft drinks and hors d'oeuvres)***		
P01	A Convective Band Within the Inner Core of Hurricane Isaac at Landfall: Is This An Inner Eyewall or Just a Transient Banding Feature?	*Keith G. Blackwell* (University of South Alabama)
P02	A Highly Configurable Vortex Initialization Method for Tropical Cyclones	Brian McNoldy, David Nolan, and *Sharan Majumdar* (RSMAS/University of Miami) Eric Rappin (Western Kentucky Univ.)
P03	Quantifying Predictability of Environmental Parameters associated with Tropical Cyclogenesis	William Komaromi, Jonathan Labriola, and *Sharan Majumdar* (RSMAS/University of Miami)
P04	Ensemble Kalman Assimilation of Global-Hawk-based Data from Tropical Cyclones	*Jason Sippel* (NASA/GSFC)
P05	Azimuthal Variation in the Eyewall's Surface-Wind Speed May Increase Maximum Potential Intensity	*Owen Kelley* (NASA/GSFC) and Daniel Meléndez (NWS/OST)
P06	Tropical Cyclone Inner-Core Structure from Downward-Pointing, Conically-Scanning Airborne Doppler Radar: IWRAP and HIWRAP	*Stephen Guimond* (Univ. of Maryland/ESSIC and NASA/GSFC), Lin Tian (Morgan State Univ. and NASA/GSFC), Gerald Heymsfield (NASA/GSFC), and Stephen Frasier (Univ. of Massachusetts)
P07	Aerosols-Cloud-Microphysics Interactions in Tropical Cyclones using Aircraft Observations and the WRF-ARW Model	*Yaítza Luna-Cruz* (Howard University), Andrew J. Heymsfield, Gregory Thompson , Gregory Jenkins, Trude Eidhammer, and Aaron Bansemer
P08	The Impact of Ocean Heat Content Observations Collected during Operational Weather Reconnaissance Flights on SHIPS Intensity Forecasts in Hurricanes Ernesto and Isaac (2012)	Lauren McCann, Mary Cox, and Elizabeth Sanabia (USNA)
P09	Development of a new Tropical Cyclone Verification Toolkit (MET-TC)	*Kathryn Newman*, John Halley Gotway, Tressa Fowler, Paul Kucera, Barbara Brown, and Louisa Nance (NCAR)
P10	A Developmental Framework for Improving Hurricane Model Physical Parameterizations Using Aircraft Observations	Jun Zhang (CIMAS/HRD), *Sundararaman Gopalakrishnan* (HRD), Frank Marks (HRD), Robert Rogers (HRD), and Vijay Tallapragada (EMC)
P11	The 48-hour NESDIS Tropical Cyclone Formation Probability Product	*Andrea B. Schumacher* (CIRA/CSU) and Mark DeMaria (NESDIS/StAR)
P12	The JPL Tropical Cyclone Information System – A Tool for Hurricane Research, Model Evaluation and Satellite Algorithm Development: Current State and Ongoing Development	*Svetla. Hristova-Veleva*, Z. Haddad, B. Knosp, B. Lambrigtsen, P. P. Li, N. Niamsuwan, W. L. Poulsen, T.P. Shen, S. Tanelli, F. J. Turk, Q. A. Vu (JPL)

POSTERS FOR THE TROPICAL CYCLONE RESEARCH FORUM **Poster Session: Tuesday, March 5, 2013, 5:30-7:00 PM *(soft drinks and hors d'oeuvres)***		
P13	Community Support and Testing of the Hurricane WRF Model at the Developmental Testbed Center	*Shaowu Bao*, Ligia Bernardet, andTimothy Brown (ESRL/CIRES) and Mrinal Biswas, Donald Stark, and Laurie Carson (NCAR)

Note: Presentation abstracts can be found in the conference booklet

Session 3a
The Navy's Model Development and Improvement Program/Hurricane Forecast Improvement Program (HFIP): Supporting Talks

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The Hurricane Forecast Improvement Project: Recent Operational Implementation

Bob Gall[1], Fred Toepfer[1], Frank Marks[2], Ed Rappaport[3]
(robert.gall@noaa.gov)

[1] NOAA/NWS/Office of Science and Technology; [2]NOAA/OAR/Atlantic Oceanographic and Meteorological Laboratory; [3] NOAA/NWS/National Hurricane Center

The Hurricane Forecast Improvement Program (HFIP) has goals to reduce the error in track and intensity forecast guidance from numerical model systems by 20% in five years (by 2014) and 50% in 10 years. Additional goals include skillful 7 day forecasts and a greatly increased ability to forecast rapid intensification and decay. For the last three years HFIP has been evaluating a number of approaches to reach this goal including advanced data assimilation for operational systems including high resolution global (~20-30km) and regional (~1-4 km) models run as ensembles, and advanced statistical post processing of model output. Significant advances in track skill have been demonstrated through the use of Hybrid Data Assimilation and in intensity skill from improved regional models and the inclusion of high resolution data in the near vicinity of the hurricane. This talk will present the most recent results particularly from those components that have gone into operations in the last year and the impact those changes have had on operational model skill.

Recent COAMPS-TC Development and Real-Time Tests

James D. Doyle[1], R. Hodur[2], S. Chen[1], E. Hendricks[1], T. Holt[1], H. Jin[1], Y. Jin[1], J. Moskaitis[1], M. Peng[1], A. Reinecke[1], K. Sashegyi[1], J. Schmidt[1], S. Wang[1]
(james.doyle@nrlmry.navy.mil)

[1]Naval Research Laboratory, Monterey, CA; [2]SAIC, Monterey, CA

The Coupled Ocean/Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC) has been developed specifically for forecasting tropical cyclone track, structure and intensity. In the presentation, we will provide an overview on the recent development and performance of COAMPS-TC. The COAMPS-TC has been tested in real time in both coupled and uncoupled modes over the past several tropical cyclone seasons in the Pacific and Atlantic basins at a horizontal resolution of 5 km. The real-time testing has been motivated by several recent multi-agency programs and efforts: i) the Hurricane Forecast Improvement Project (HFIP), which is focused on the W. Atlantic and E. Pacific basins, ii) the recent NASA HS3 program, and iii) pre-operational testing of COAMPS-TC in W. Atlantic and W. Pacific basin. An evaluation of a large sample of real time forecasts for 2010-2012 in the Atlantic basin reveals that the COAMPS-TC intensity predictions have intensity errors on par or better than many of the established real-time dynamical forecast models. COAMPS-TC is currently being transitioned to operations at the Fleet Numerical Meteorology and Oceanography Center.

As an example, real-time forecasts for Hurricane Sandy (2012) illustrate the capability of COAMPS-TC to capture the track, intensity and the fine-scale features in close agreement with observations. Observation impact experiments highlight the importance of satellite-derived atmospheric motion vectors for accurate forecasts of Hurricane Sandy. Additionally, evaluation of real-time COAMPS-TC forecasts will be presented with a focus on challenges and successes related to tropical cyclone intensity prediction. Recent results for a COAMPS-TC ensemble that was run over the W. Atlantic and W. Pacific basins will be discussed as well. The results of this research highlight the promise of high-resolution deterministic and ensemble-based approaches for tropical cyclone prediction using COAMPS-TC.

Hurricane and Severe Storm Sentinel (HS3): Results from the 2012 Deployment and Plans for 2013

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The HS3 objectives are:

- To obtain critical measurements in the hurricane environment in order to identify the role of key factors such as large-scale wind systems (troughs, jet streams), Saharan air masses, African Easterly Waves and their embedded critical layers (that help to isolate tropical disturbances from hostile environments).
- To observe and understand the three-dimensional mesoscale and convective-scale internal structures of tropical disturbances and cyclones and their role in intensity change.

The mission objectives will be achieved using two Global Hawk (GH) Unmanned Airborne Systems (UASs) with separate comprehensive environmental and over-storm payloads. The GH flight altitudes (>16.8 km) allow overflights of most convection and sampling of upper-tropospheric winds. Deployments from NASA's Wallops Flight Facility and ~26-hour flight durations provide coverage of the entire Atlantic Ocean basin, and on-station times up to 5-22 h depending on storm location. HS3's first deployment was in September of 2012, with additional deployments planned for late-August to late-September 2013-2014. See the HS3 web page for a description of the instrument payloads (http://espo.nasa.gov/missions/hs3/).

During the 2012 deployment, only the environmental GH was available at Wallops due to hardware issues with the over-storm GH. The ferry of the environmental GH from Dryden to Wallops included a pass around Hurricane Leslie to sample the outflow structure. The remainder of the deployment included 5 flights over long-lived Hurricane Nadine, beginning with its tropical depression stage and finishing with a flight just prior to its re-intensification back into a hurricane in late September. For each Nadine flight, the GH flew a broad lawnmower pattern to obtain a grid of data over the storm and its near environment.

During the first two Nadine flights, the data clearly indicate the presence of the Saharan Air Layer (SAL) on the eastern and northern sides of the storm, but show no evidence of the SAL air getting into the interior of the storm. During later flights, when Nadine was near the Azores, the environment was characterized by strong wind shear, low sea-surface temperatures, and very dry air. Despite these conditions, Nadine maintained a well-defined warm core up to 300 hPa. By the last flight on 26-27 September, the wind shear and upper-tropospheric temperatures decreased and convection redeveloped, setting the stage for the re-intensification of Nadine.

To eliminate risk for 2013, the over-storm GH was fixed by early November and a successful test flight was conducted in the central and eastern Pacific to ensure that all aircraft systems and instruments worked well.

Improving the Assimilation of Multiple and Integrated High-Resolution Satellite Datasets in Mesoscale Models of Tropical Cyclones

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Forecasts of tropical cyclone intensity change are often lacking in skill, due in part to the paucity of conventional observations over the oceans that are assimilated into operational models. In recent years, remotely-sensed observations from multiple satellite sources have become more routinely available as part of the global observing system. In this presentation, we report on the development and refinement of a capability to supplement the contemporary observational network with optimal configurations and assimilation of advanced satellite-derived observations, to improve mesoscale model analyses and forecasts of tropical cyclone structure and intensity. Observations include cloud-derived Atmospheric Motion Vectors, soundings of temperature and moisture, ocean surface winds, and total precipitable water. The Ensemble Kalman Filter (EnKF) within the WRF-ARW and COAMPS-TC modeling frameworks is employed to assimilate the data, with the ultimate objective being to provide a pathway towards advanced satellite data assimilation in operational tropical cyclone forecast models. This multi-institutional project is supported jointly by the Office of Naval Research and NOAA's Hurricane Forecast Improvement Program (HFIP) through the National Oceanographic Partnership Program (NOPP).

The Basin-Scale HWRF: Looking Beyond the 10-M Wind Speed for Improved Storm Predictions

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A high-resolution version of the HWRF, originally developed at the Hurricane Research Division of the Atlantic Oceanographic and Meteorological Laboratory, was successfully transitioned by the team at National Center for Environmental Predictions to NOAA operations in 2012. Operating at a resolution of about 3 km, the model showed improved track, rainfall, and structure predictions skills. Hurricane Sandy illustrated the importance and an urgent need for improved track and size predictions for landfall applications. The current paradigm of storm specific forecasts also needs to be revised. As an evolutionary effort, we have developed a basin scale HWRF system that can operate with multiple moving nests spanning at resolution down to 3 km that may be utilized for post land fall predictions of tropical cyclones. Supported by NOAAs Hurricane Forecast Improvement Project (HFIP), this version of the HWRF was run for the 2012 hurricane season. We are starting to see some improved performances in tracks and structure predictions with the basin scale HWRF. An overview of this system along with the advantages of transitioning to such a system into operations will be provided. We will also show some results from Hurricane Sandy and emphasize the need for looking beyond the 10-m wind for post land fall predictions. We expect the basin scale HWRF to transition to operations between years 2014-2015.

Session 3b
Earth System Predication Capability (ESPC)/Next Generation Suite of Models: Supporting Talks

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Earth System Prediction Capability

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The Earth System Prediction Capability (ESPC) Inter-Agency program was established in 2010 as a coordinating effort to improve collaboration across the federally sponsored environmental research and operational prediction communities for the development and implementation of improved national physical earth system prediction at subseasonal, intraseasonal, and interannual time scales. Towards these goals, a pilot project consisting of a 0-100 day forecast initiative and a set of five demonstration projects are under development, of which the pilot project and two demo projects (Predictability of Tropical Cyclone Likelihood, Mean Track, and Intensity at Weekly to Seasonal Timescales; Predictability of Blocking Events and Related High Impact Weather at Lead Times of One to Six Weeks) address tropical cyclone prediction either directly or indirectly. The goal of the demonstrations is to provide unifying themes and common diagnostics for developing a common modeling environment, establishing community data sets & test cases, and assess predictability at sub-seasonal to inter-annual timescales, and to begin to develop guidelines for the future transition to operational forecasts. Researchers are invited to participate in the definition and execution of the projects.

GFDL's unified global-regional non-hydrostatic modeling framework

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NOAA/GFDL

GFDL has been developing a non-hydrostatic unified global-regional modeling system that is suitable for climate and weather simulations/predictions of all scales. The hydrostatic version of this modeling system has been used operationally for GFDL's past two IPCC climate change assessments (AR4 and AR5). Looking forward for the next 10 years, it is clear that global models need to be non-hydrostatic, capable of providing ultra-high regional details (1 to 5 km), and scalable to millions of CPUs. With these goals, the recent development effort at GFDL has been to extend the finite-volume dynamics (FV3) to non-hydrostatic, adding two variable resolution options, and implementing fine-grained parallelism to enhance the scalability on computers of current and the future generations.

In this talk, I will present some unique features of this modeling system with particular emphasis on the computational (scaling) performance and scientific applications. Time permitting, I will present seasonal climate simulation with GFDL's global 3.5 km resolution "cloud-permitting" model.

Next Generation Global Prediction Research in the U.S. Navy

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An overview will be provided of the design and computational aspects of a new numerical model being developed by the U.S. Navy, Non-hydrostatic Unified Model of the Atmosphere (NUMA). The dynamical core is non-hydrostatic and is being developed for both limited-area (mesoscale applications) and global model applications. The core is based on an element-based Galerkin (EBG) paradigm which allows for: i) high-order accuracy, ii) geometrical flexibility, and iii) outstanding scalability within distributed memory architectures. The development of the basic dry nonhydrostatic core is complete, and we are now implementing physical parameterizations and a positive-definite advection option. Preliminary results will be presented and a roadmap of current and future developments will be discussed.

Next-Generation Global Weather Prediction Research at NASA GMAO

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NASA/GSFC/Global Modeling and Assimilation Office

The Goddard Earth Observing System Model, Version 5 (GEOS-5) is a system of models integrated using the Earth System Modeling Framework (ESMF). The GEOS-5 data atmospheric assimilation system (ADAS) integrates the GEOS-5 AGCM with the Gridpoint Statistical Interpolation (GSI) atmospheric analysis developed jointly with NOAA/NCEP/EMC. The GEOS-5 systems are being developed in the GMAO to support NASA's Earth science research in data analysis, observing system modeling and design, climate and weather prediction, and basic research. GEOS-5 is developed with a multi-scale modeling approach to create a single global model valid for both climate and weather and for use in both simulation and assimilation. In addition to the routine experimental forecasts at 25 km resolution, occasional experimental forecasts are also performed with GEOS-5 at horizontal resolutions of 14- to 3.5-km globally using a non-hydrostatic finite-volume dynamical core on a cubed-sphere grid and include resolution dependent physical parameterization modifications to account for the change in resolvable scales. These experimental high-resolution forecasts are regularly evaluated against satellite observations to assess the accuracy of the models representation of various physical processes including the organization of deep convection, and the variability of intense precipitation. To support these high-resolutions for operational assimilation purposes, the GMAO is also updating a prototype four-dimensional variational (4DVAR) system for use with the cubed-sphere hydrodynamics.

Session 3c
NSF Program Initiatives:
Supporting Talks

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Probabilistic Verification of Ensemble Forecasts of Tropical Cyclogenesis

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As part of the NSF PREDICT project, ensemble-based products have been developed with a goal to improve probabilistic predictions of tropical cyclogenesis and also our quantitative understanding of its predictability. Threshold values of metrics including a lower tropospheric circulation, a local thickness anomaly and mean sea level pressure are used to determine the onset of genesis in each ensemble member. The probabilistic verification of genesis based on global ECMWF ensemble forecasts will be presented for the 2010-2012 Atlantic hurricane seasons. Reliability diagrams were found to be mostly monotonic increasing for forecasts out to 6 days, though several caveats remain. In addition, short-range ensemble forecasts related to tropical cyclogenesis were prepared using the Weather Research and Forecasting (WRF) model and Ensemble Kalman Filter data assimilation scheme during the PREDICT field campaign, and parallel results will be presented.

The Impact of Ensemble-Based Data Assimilation on the Predictability of Landfalling Hurricanes

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Accurate forecasts of the intensity and structure of a hurricane at landfall can save lives and mitigate social impacts. However, few of the recent efforts to improve hurricane forecasts have focused on landfalling hurricanes. This reflects the complexity of predicting hurricane landfall due to interactions among multiscale dynamical and physical processes and the uncertainties in representing atmospheric near-surface conditions in numerical weather prediction models. This study examines the impact of assimilating satellite, radar, and conventional observations on the predictability of landfalling hurricanes using an advanced research version of the Weather Research and Forecasting (WRF ARW) model and an ensemble Kalman filter developed by the NCAR Data Assimilation Research Testbed (DART). Specific attention is given to surface data assimilation and its impact on forecasts of landfalling hurricanes.

Hurricane Katrina (2005) was chosen as the first case study since it was one of the deadliest disasters in US history. A specific initial time, which led to poor predictability of Hurricane Katrina in several previous studies, was selected for data assimilation experiments. The minimum sea-level pressure from the best track, QuikSCAT ocean surface vectors, surface Mesonet observations over land, airborne Doppler radar–derived wind components, and available conventional observations were assimilated in a series of numerical experiments at high resolution (~ 3 km horizontal grids). Results indicated that ensemble-based data assimilation significantly improves the forecasts of Hurricane Katrina through modifying the storm structure and related environmental fields. The data assimilation resulted in a more realistic storm structure, which had a positive effect on both the analysis and forecast of the storm's evolution. In addition, the track and intensity errors were greatly reduced, and the locations and times of Katrina's two landfalls were improved by the data assimilation. Further comparisons were made for precipitation, wind structure, and the storm eyewall replacement process to evaluate the impact from different data types. Specifically, the impact of assimilating surface observations was examined. It was found that the assimilation of surface observations (i.e., QuikSCAT ocean surface vectors and surface Mesonet observations) alone could improve the track and storm structure through modified low-level thermal and dynamical fields such as humidity, temperature, divergence, and vorticity. When the surface observations were assimilated with all other conventional data, obvious enhancements were found in forecasts of track and intensity, convection and surface wind structures, and quantitative precipitation during Katrina's two landfall events.

Data-enabled Science: Challenges and Opportunities

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Data are the lifeblood of the geosciences. Rapid advances in computing, communications, and observational and sensor technologies — along with ensemble and coupled-systems approaches to numerical modeling — are revolutionizing nearly every aspect of the geosciences. The result is a dramatic proliferation of data from diverse sources; data that are consumed by an ever broadening community of users and which are becoming the principal engine for driving scientific advances. As Microsoft researcher and computer science pioneer Jim Grey articulated a few years ago, data intensive science has emerged as the Fourth Paradigm of scientific discovery after empirical, theoretical, and computational methods. The potential of data for transforming the geosciences is enormous, but realizing the next frontier depends on effectively managing, using, exploiting these heterogeneous data sources, extracting knowledge and useful information in ways that were previously impossible, enabling discoveries, and gaining new insights.

Modern data volumes are staggering. According to a study by International Data Corporation, the world generated 1.8 zettabytes of information in 2011. The Phase 5 Coupled Model Intercomparison Project (CMIP5) alone will generate more than ten petabytes of climate projection data for use in assessments of climate change, including the Intergovernmental Panel on Climate Change Fifth Assessment Report, scheduled for publication in 2014. The Suomi National Polar-orbiting Partnership or Suomi NPP has generated 3.4 Terabytes of data per day, and its successor, Joint Polar Satellite System, is expected to produce 8.1 terabytes of data each day. The NOAA National Climatic Data Center projects that data volumes in its archives will exceed 350 petabytes by 2030.

The deluge of data brings challenges along with veritable opportunities for discovery and scientific breakthroughs. Retrieving relevant data in a usable format from such an archive should not be more time consuming and arduous than the scientific analysis and investigation the data make possible. The geoscience community will need to work together toward the building of a scientific ecosystem in which "data friction" is minimized, data transparency and ease-of-use are increased, and “time to science and publications” is significantly reduced. Imagine the time when all investigators, new and experienced, are spending 80 percent of their time interpreting results and doing research and only 20 percent on routine data finding, processing, computing, visualizing, and other mundane data transformation tasks – rather than the other way around.

To address these challenges, the National Science Foundation launched the EarthCube initiative in 2011 to advance the creation of a national data and cyberinfrastructure for the geosciences. EarthCube aims to transform the conduct of research through the development of community-guided cyberinfrastructure to integrate information and data across the geosciences.

Session 4
The 2012 Tropical Cyclone Season in Review

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53d Weather Reconnaissance Squadron/AFRC 2012 Hurricane Season Summary

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53d Weather Reconnaissance Squadron

The 53d WRS completed 113 Atlantic and 3 eastern Pacific NHC fix requirements along with 9 other requirements during the 2012 hurricane season. One buoy mission was flown deploying 10 buoys ahead of intensifying Tropical Storm Isaac in the western Gulf of Mexico. A total of 71 missions and 772.5 hrs were flown in support of NHC. During Hurricane Sandy, the 53d WRS accomplished 15 missions, 30 invest/fix requirements and flew 174.3hrs.

NOAA Aircraft Operations Center (AOC): 2012 Seasonal Summary and Future Plans

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NOAA Aircraft Operations Center

After an average season in 2011, during which the NOAA hurricane aircraft flew a total of 49 flights and 343 hours, the 2012 season was less active for these aircraft. During the season the one operational WP-3D and the G-IV flew a total of 40 flights for 282 hours. These flights, in addition to storm flights, included test and calibration missions as well as several transit flights. NOAA aircraft did not participate in a hurricane awareness tour as in past years.

Of significance during the 2012 season were the IFEX missions into Hurricanes Isaac and Sandy, the first operational/research use of the G-IV tail Doppler radar in Leslie and Sandy and the RVP-8 upgrade to the TDR on N42RF. Operationally, all of the round-the-clock missions into Isaac and Sandy were flown aboard a single P-3, N42RF, double crewed by AOC personnel. This aircraft made seven consecutive flights into Hurricane Sandy without a miss due to maintenance or instrument failure. The Center's second P-3 was in depot level maintenance at the Navy's FRCSE in Jacksonville, FL and unavailable during the season.

AOC continues to upgrade its aircraft and instrumentation and in 2013 expects to accomplish

- Continue developing strategies for use of the new G-IV TDR in storm environment
- Complete Phase 2 of the upgrade of the P-3 tail Doppler radar
- Complete AAMPS upgrade on P-3.
- Complete the integration of the Doppler Wind LIDAR (DWL), WSRA and W-band radar on the P-3s
- Center wing box replacement, SSI of Zone 5 inspection and PDM on N43RF.
- Complete the overhaul of the G-IV engines.
- Begin planning the re-winging of two NOAA P-3s.

Targeted Observations for Improving Numerical Weather Prediction: Review and Recommendations

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"Targeted observations" refer to the selection of additional, specially chosen observations to be assimilated into operational numerical weather prediction models. Observation locations are chosen in order to improve forecasts of high-impact weather events such as tropical cyclones approaching land. Example of targeted observations include dropwindsondes launched from aircraft, additional rawinsonde ascents, and the inclusion of enhanced regular satellite observations (such as radiances or winds) that may normally be excluded from data assimilation due to routine thinning or quality control procedures. As a consequence of many field campaigns worldwide during the past 15 years, advancements have been made in the development of objective strategies for targeting observations, and in quantitative evaluations of the impact of assimilating these extra observations on numerical weather predictions. The successes and shortcomings of these efforts are summarized in this presentation. Based primarily on a comprehensive review by the WMO / THORPEX Data Assimilation and Observing Systems Working Group, recommendations are made to the community for the use of targeted observations in the future to maximize the impact on forecasts of tropical cyclones and winter storms.

Review of the 2012 Central Pacific Tropical Cyclone Season and Preliminary Verification

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Deputy Director, Central Pacific Hurricane Center

In 2012, there was one tropical cyclone which moved into the central Pacific. Hurricane Daniel formed in the east Pacific on July 4 and crossed into the central Pacific on July 11 as a Tropical Storm. CPHC will present an overview of Tropical Storm Daniel, the preliminary verification, changes for the 2013 season, and recent staff changes.

An Overview of Joint Typhoon Warning Center
Tropical Cyclone Forecast Improvement Focus

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Joint Typhoon Warning Center

JTWC focus areas for future development and research collaboration based on the prior year's operations will be presented and related to the overall strategic goals of the Tropical Cyclone forecasting and reconnaissance mission.

Session 5a
Joint Hurricane Testbed Project Updates
Part 1

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An Update on the Joint Hurricane Testbed (JHT)

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NOAA/OAR/AOML/JHT

New forecasting tools, techniques and model advances, developed by the research community were tested and evaluated at the National Hurricane Center (NHC) and the Environmental Modeling Center (EMC) facilitated by the Joint Hurricane Testbed (JHT). The sixth round (FY11-13) projects were tested and evaluated during the 2012 hurricane season, following any necessary technique modifications or other preparations. These projects include upgrades to dynamical models and model components, enhancements to observed data and assimilation techniques, track forecasting algorithms, intensity estimation and forecasting algorithms. In this session, the PIs will present their progress.

Improved SFMR Surface Wind Measurements in Intense Rain Conditions
A JHT Project

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The stepped-frequency microwave radiometer (SFMR) has reliably provided hurricane-force surface wind speed data from aircraft for over a decade, but struggled with accurately observing wind speeds below hurricane strength in the presence of moderate to heavy precipitation. Typically, the SFMR shows a tendency to overestimate the wind speed when heavy rain exists. The goal of this JHT-funded project is focused on improving quality of SFMR wind observations in such conditions. In the first year this two-year effort, the average precipitation-induced wind speed bias was quantified. From these results, bias-corrected SFMR surface winds were computed in near real time and made available to NHC forecasters during the 2012 hurricane season. In the final year of this project, the root cause for this bias – the inaccuracy of the rain absorption model – is addressed by developing an improved model function from concurrent, collocated observations. We present details of our data, methodology, and results. If successful, this revised SFMR algorithm is expected to provide improved wind speed and rain rate estimates reported in real time from all SFMR-equipped aircraft.

Improved Automation and Performance of VORTRAC Intensity Guidance

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This paper gives a progress report on the improvement of the Vortex Objective Radar Tracking and Circulation (VORTRAC) package for the JHT. VORTRAC uses a series of algorithms to deduce the central pressure and radius of maximum wind (RMW) of a landfalling TC in near real time from WSR-88D Level II radar data and environmental reference pressure data from nearby coastal weather stations. VORTRAC has been automated and the code was delivered to NHC in summer 2012. VORTRAC was run in real time at NHC during Hurricane Isaac and Sandy. The results will be presented at the conference. In addition, the historical Atlantic Hurricanes that made US landfall between 2004 and 2011 have been run through the VORTRAC package to identify potential issues in different landfall situations. The lessons learned and resulting improvements to the VORTRAC package will be reported. We will also present the work plan for the remaining period of the JHT project.

Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis: A Year 2 Joint Hurricane Testbed Project Update

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This project seeks to create a real-time and fully automated surface wind analysis system at the National Hurricane Center (NHC) by combining the existing satellite-based six-hourly multi-platform tropical cyclone surface wind analysis (MTCSWA) and aircraft reconnaissance data. This project will leverage the automated quality control procedures and variational analysis techniques developed for use in the MTCSWA and previous studies that make use of surface and flight-level wind observations to produce analyses. Analyses valid at the synoptic time would be created 1) for the creation of the Tropical Cyclone (TC) vitals file (i.e., from operational location and intensity estimates) in the minutes following the synoptic time and 2) later in the analysis cycle for possible refinement of advisory products.

In Year-2 testing, real-time analyses were produced at T – 30 minutes, T, and T+1:30, where T is the synoptic time. The TC center locations used for the analyses were determined from a combination of operational best track, aircraft-based center positions and short-term forecasts. These analyses used an agreed upon set of assumptions about how the input data were to be used and how/what flight-level-to-surface wind relationships would be applied (discussed at 66th IHC).

Real time tests in 2012 identified some flaws in the analysis system, which are being corrected. If azimuthal gaps in the aircraft coverage were large the analysis system did a poor job of carrying the wind information into the data void regions. This resulted in many odd looking analyses. There were two primary causes for this difficulty. These were 1) the first guess (from the MTCSWA) weights were actually negative in the core region of the storm, and 2) the azimuthal data filters weren't large enough in some cases. Fortunately the problems can be rectified by 1) slightly increasing the data weights of the MTCSWA inside 150 km of the TC center and 2) making the filter weights dynamic (i.e. a function of data coverage). In addition, when azimuthal gaps are larger than 120 degrees the azimuthal filter is increased. We also fixed a logical error in the wind radii estimation algorithm that failed with the large size of Hurricane Sandy, whose 34-kt wind radii extended beyond our 600 km analysis domain. Finally, we relaxed the first pass of the automated quality control to allow more data to make it into the analyses.

This presentation will demonstrate that our improved analysis system will be capable of providing automated, objective, real-time analyses of the aircraft-based surface wind fields that are consistent with the current NHC treatment of aircraft reconnaissance data. Furthermore we will demonstrate that this analysis package is a good candidate for operational transition and await the decision of the JHT in this regard.

DISCLAIMER: The views, opinions, and findings in this report are those of the authors and should not be construed as an official NOAA and/or U.S. Government position, policy, or decision.

Session 5b
Joint Hurricane Testbed Project Updates, Part 2

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Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme

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Tropical cyclone (TC) genesis is perhaps one of the more difficult stages of the tropical cyclone lifecycle to diagnose and predict. Tropical disturbances are vastly under sampled phenomenon in the North Atlantic and account for <10% of all NOAA aircraft missions that have been conducted since the middle 1970s. Unfortunately, there are also limited resources available to forecasters to objectively identify and predict TC genesis in the North Atlantic basin. A new scheme for forecasting TC genesis is currently being developed under NOAA's Joint Hurricane Testbed (JHT) program to help address these deficiencies. The main goal of this project is to develop a storm-centric TC Genesis Index (TCGI) to provide forecasters with an objective tool for identifying the probability of TC genesis (0-48 hr and 0-120 hr) in the North Atlantic basin.

Several objectives of the year-1 and year-2 phases of this project have been completed and include 1) a 10-yr North Atlantic tropical disturbance (non-TC cases) "Best track" that incorporates NOAA-TAFB Dvorak intensity estimates and storm positions has been developed; 2) missing forecast positions in the tropical disturbance database have been filled in using a combination of Best Track and Dvorak positions, GFS vortex tracks and BAMM forecast positions; 3) Disturbance-centric values of various potential TC genesis predictors have been computed for each case in the sample set and includes 60 vortex and environmental scale predictors derived from satellite platforms, GFS analyses, and Best track data; 4) a dependent analysis of the 10-yr dataset has been completed and predictors that were significant at the 99.9% level have been identified for possible inclusion in the TCGI scheme; 5) a linear discriminant analysis of the 10-yr dataset was conducted to identify the optimal combination (and relative weighting) of the statistically significant TCGI predictors that were identified. The combination of TCGI predictors that yielded the most skillful genesis probability forecasts for both the 0-48 h and 0-120-h forecasts have been determined; 6) cross validation of the 10-yr TCGI dataset has been conducted to further evaluate the robustness of the top TCGI predictor combinations. Based on results from these efforts, a real-time version of the TCGI scheme is currently being developed.

Upgrades to the Operational GFDL/GFDN Hurricane Model Planned for 2013

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The operational versions of the GFDL model used by the National Weather Service was upgraded in 2012 with improved physics resulting in reduced intensity errors and much reduced positive intensity bias, compared to the 2011 version of the operational model and other operational guidance used by the National Hurricane Center (NHC). However, improvement in intensity guidance continues to lag considerably behind advancements in track prediction, with little overall skill in 2012 compared to the SHIFOR benchmark, for most of the objective guidance.

To address this challenging issue, scientists at GFDL and URI are developing a high-resolution version of the GFDL and GFDN models with upgraded physics. In the new model configuration, the area of the innermost nest with highest resolution remains the same as the present version, but with an increased horizontal resolution from 1/12° to 1/18° grid spacing. This 1/18° grid spacing is the highest resolution physically justified for the GFDL model because it is hydrostatic. Several modifications to the model physics have been made to maximize the benefit of the increased resolution. A preliminary version of the model has been run for selected cases from the 2010, 2011, and 2012 Atlantic hurricane seasons. Results, which will be shown in this presentation, indicate a significantly improved storm structure for most storms, a reduced negative intensity bias for intense storms, and a neutral intensity impact for weak storms. The track forecast skill has also improved for several of the most challenging cases in 2012, such as Hurricane Nadine in which the operational GFDL model had excessive track errors beyond 3 days.

As will be emphasized in this presentation, this model will serve as the benchmark model for evaluation of the following future improvements in physics. Throughout this presentation, impacts of these various upgrades will be shown and results summarized. In the current implementation of the Ferrier microphysics in both the GFDL and HWRF hurricane models, the individual microphysics species (cloud water, rain water, and ice) are advected as a combined condensate, rather than advecting the individual species. Preliminary tests suggest that when the individual species are advected, the forecasts of storm intensity in sheared situations are improved. An improved version of the operational Simplified Arakawa- Schubert (SAS) convective scheme used in GFDL and HWRF, called “meso-SAS,” has been developed by scientists at NCEP/EMC for use in high-resolution regional models (Pan 2012). This new convective parameterization will continue to be extensively tested in the high resolution GFDL model with possible operational implementation if the results are positive. Progress will be shown in the effort to upgrade the radiation code with some of the improved packages developed at GFDL over the past two decades, which will also require increasing the number of vertical levels. This major upgrade will continue to be evaluated for possible implementation in 2014.

The upgraded model will be ready for operational implementation at some point in 2013 at NCEP depending on the progress of transition to their new super-computer platform. Possible operational implementation to GFDN will depend on availability of computer resources at the Fleet Numerical Meteorology and Oceanography Center.

Advancing HWRF and GFDL/GFDN Prediction Systems through New and Enhanced Physics of the Air-Sea-Wave Coupling Planned for 2013

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The forecast operations of both NOAA's National Hurricane Center and the U.S. Navy's Joint Typhoon Warning Center require more accurate HWRF and GFDL/GFDN models for improved model guidance and as integral parts of ongoing multi-model ensemble forecast efforts. This presentation focuses on the major upgrades to the ocean component of the HWRF and GFDL/GFDN coupled systems and air-sea interface physics planned for 2013.

URI's version of the Princeton Ocean Model (POM-TC) has been the ocean component of the operational GFDL coupled model since 2001 and the operational HWRF since 2007. Since POM-TC runs on only one processor, upgrades to the ocean model resolution and physics were not computationally feasible. Hence, URI is now in the process of finalizing a major new effort to develop a new version of POM-TC, which shall hereafter be known as MPIPOM-TC. MPIPOM-TC can be run on multiple processors and is computationally efficient and scalable. One of the key improvements now included is the replacement of the two overlapping POM-TC domains in the Atlantic Ocean, each of which have ~1/6° horizontal grid spacing, with a single, new, transatlantic domain, which has ~1/12° horizontal grid spacing.

Currently, operational POM-TC utilizes different initialization procedures in different ocean basins. URI has developed a new methodology to initialize MPIPOM-TC from different global real-time ocean products available at NOAA and the Navy. We are currently testing the initialization based on NCEP's Global HYCOM RTOFS and the Navy's Global HYCOM. However, any other real-time ocean products, such as Navy's NCODA (as in the operational GFDN outside the Atlantic) and NCOM can be utilized as well, and in the Atlantic Ocean, the operational feature-based initialization can still be used (in the new transatlantic domain with 1/12° grid spacing) if none of the available real-time ocean products produce superior performance in the HWRF and GFDL/GFDN models.

We are in the process of completing the implementation of explicit wave coupling in the HWRF and GFDL systems, and its near-real time testing will begin in 2013. This model development effort involves 1) improving physical parameterizations of the air-sea heat and momentum fluxes at and near the sea surface with fully coupled wind-wave-current interaction and sea spray effects and 2) forging a comprehensive, scientifically integrated atmosphere-wave-ocean framework that couples individual model components.

Validation of HWRF Forecasts with Satellite Observations

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Project summary and current results of the JHT-sponsored project on “Validation of HWRF forecasts with satellite observations and potential use in vortex initialization” will be presented. The presentation will include a summary of project goals and deliverables, the latest developments in the HWRF Satellite instrument Simulator (HWSS), the transition of certain HWSS capabilities to operations (such as within the Unified Post-Processing (UPP) system) and demonstration of methods and products for forecast verification. The verification products include comparison of simulated and actual satellite observations mainly in terms of microwave brightness temperature and radar reflectivity to evaluate thermodynamical and microphysical aspects of the forecasted storms.

Improvements to the SHIPS Rapid Intensification Index: A Year-2 JHT Project Update

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Predicting episodes of tropical cyclone rapid intensification (RI) remains one of the highest operational forecasting priorities of the National Hurricane Center (NHC). In recent years, a statistically based rapid intensification index (RII) that employs predictors from the SHIPS model has been developed utilizing linear discriminant analysis (Kaplan et al. 2010). The SHIPS-RII provides estimates of the likelihood of RI over the succeeding 24-h for both the Atlantic and eastern North Pacific basins and is currently utilized as an operational forecasting tool by the NHC. Although the current version of the SHIPS-RII has been shown to be skillful, its utility is somewhat limited since it was developed exclusively for the 24-h lead-time and its skill tends to be somewhat limited particularly in the Atlantic basin. Thus, in an effort to improve the overall forecasting utility of the current operational SHIPS-RII, a number of model enhancements are currently being developed as part of an ongoing Joint Hurricane Testbed (JHT) project. First, ensemble-based versions of the RII that employ both the current SHIPS-discrimant RII as well as the newly developed Bayesian and Logistic versions (Rozoff and Kossin 2011) are being derived for the current operational 24-h forecast lead-time as well as the added lead times of 12-h, 36-h and 48-h to provide additional guidance during the critical watch and warning period that has recently been extended to 48-h by the NHC. Secondly, revised versions of the recently developed deterministic rapid intensity aid (Sampson et al. 2011) are being developed utilizing the newly derived multiple lead-time ensemble based RII models. Lastly, microwave imagery-based versions of the RII that have been shown to be capable of

providing a more accurate measure of the overall inner-core tropical cyclone structure are also being developed for each forecast lead time. Our year-2 JHT project accomplishments and future plans for improving the current operational SHIPS-RII will be presented at the upcoming meeting.

Improvements in Statistical Tropical Cyclone Forecast Models: A Year 2 Joint Hurricane Testbed Project Update

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Four improvements to statistical-dynamical tropical cyclone forecast models were proposed for this project. These included: (1) Improving the method to estimate the intensity growth rate in LGEM so the forecasts can be extended to seven days; (2) Developing special versions of SHIPS and LGEM for the Gulf of Mexico region; (3) Improving the databases used to develop SHIPS and LGEM through use of the NCEP's new coupled reanalysis system; and (4) Developing an extended range climatology and persistence (CLIPER) model for track and intensity.

Progress on each task will be presented. The new baseline model, called Trajectory CLIPER (TCLP), was run in real time during most of the 2012 season as part of the operational SHIPS model script. A verification of the 2012 TCLP forecasts out to 7 days and a comparison with the current baseline models (CLIPER and Decay-SHIFOR) through 5 days will be presented. The 7-day LGEM model was not run in real time because the NHC official track forecasts beyond 5 days (required input for LGEM) were not always available due to a computer security issue at NHC. However, the missing 6- and 7-day forecasts were digitized by CSU students from hard copy forecaster worksheets provided by NHC, and reruns of the 7 day LGEM were performed after the end of the season. The verification of the long range LGEM will be presented. Progress on the Gulf of Mexico models and the impact of using the new NCEP reanalysis for model development will also be described.

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Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index

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Many tropical cyclones (TCs) experience one or more rapid intensification (RI) events during their life time. The physical processes associated with these events remain unsolved. Predicting these events is one of the most challenging aspects for TC forecasters. Recently, a distinctive ring pattern around the TC center has been found in the 37 GHz microwave images to be associated with RI. Real-time testing and statistical evaluations show that the method is very promising. The primary goal of the PI's previous FY-11 JHT project is to translate the subjective forecast method into an objective one. After several months of real-time testing, the automatic 37 GHz ring pattern identification algorithm works well, especially for 37 GHz images from high-resolution sensors such as Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and WindSat. However, the major product of our FY-11 JHT project is a "yes" and "no" type of RI forecast only for 30 kt/24 hr intensity increase. Upon discussions with our NHC points of contact, it is realized that the optimal approach for RI prediction is to produce a probability type of RI forecast, not only for 30 kt intensity increase for 24 hours, but also for 25 and 35 kt/24 hr increases.

Using 11 years of TRMM TMI data, a set of inner core rainfall and convective parameters has been compared between RI and non-RI storms. It is found that statistically RI storms always have larger raining area and volumetric rain than non-RI storms. According to the results, the best predictors additional to the 37 GHz ring are the inner core area with 85 GHz PCT < 275, 250, and 225 K. The probability of RI is almost doubled from the climatological mean if using one of these predictors alone. By adding these additional predictors, improvement of the 37 GHz ring RI index is possible.

A New Secondary Eyewall Formation Index; Transition to Operations and Quantification of Associated Hurricane Intensity and Structure Changes: A Joint Hurricane Testbed Project

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The formation of a secondary outer concentric eyewall in a hurricane usually precedes large changes in intensity and wind structure. These changes are particularly difficult to forecast because they are not captured well by the standard numerical and statistical guidance. Consequently, when the formation of a secondary eyewall is observed or predicted in an operational setting, forecasters must rely on expert judgment based on past experience to subjectively modify the objective intensity forecasts provided by the available guidance.

In Year-1 of this project, we transitioned a new probabilistic model into NHC operations to help predict the formation of secondary eyewalls (Kossin and Sitkowski 2009). This model has been incorporated into the operational SHIPS intensity forecasting model and has been performing skillfully in an operational setting. In Year-2, we constructed an expanded record of low-level aircraft reconnaissance data and used this to document an expanded climatology of intensity and structure changes associated with eyewall replacement cycles (ERC) in Atlantic hurricanes (Sitkowski et al. 2011). We found that a typical ERC can be naturally divided into three distinct phases. Each phase has associated characteristic changes in intensity and wind structure, and a characteristic duration over which the changes take place. In Year-3, we used the characteristics of these changes to construct new statistical models that use environmental and satellite data to provide objective intensity guidance that specifically targets the changes associated with ERCs (Kossin and Sitkowski 2012). The models are based on ordinary least-squares regression and predict the expected intensity changes and the duration over which these changes occur during the most operationally relevant phases of an ERC. The models also provide predictions of expected changes in the radius of maximum tangential wind, which may be useful for wave-height and storm-surge forecasting.

In Year-4 (the final year of this project), we have been working to further increase the skill of the models through optimized feature selection and other techniques, and working toward transitioning the new models developed in Year-3 to operations. This presentation will highlight the model improvements, and discuss the various challenges and ways forward for the transitioning of the new models.

Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. *Mon. Wea. Rev.*, **137**, 876–892.
Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes during hurricane eyewall replacement cycles. *Mon. Wea. Rev.*, **139**, 3829–3847.
Kossin, J. P., and M. Sitkowski, 2012: Predicting hurricane intensity and structure changes associated with eyewall replacement cycles. *Wea. Forecasting*, **27**, 484-488.

Session 6
Tropical Cyclone Model Development and Technology Transfer

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Further Advancements to the NCEP Operational HWRF Modeling System for 2013 and Beyond

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Starting with 2012 hurricane season, NCEP operational atmosphere-ocean coupled Hurricane Weather Research and Forecast (HWRF) modeling system has been run at a cloud-permitting 3km horizontal resolution near the hurricane core with explicit representation of convective processes. Evaluation of real-time operational HWRF forecasts for 2012 hurricane season for Atlantic and Eastern Pacific basins has shown significantly improved track, intensity and structure predictions compared to earlier versions of the operational HWRF, consistent with the results obtained from pre-implementation testing and evaluation.

Another major accomplishment for 2012 season is the experimental real-time guidance from the operational HWRF provided to the Joint Typhoon Warning Center (JTWC) for Western Pacific Typhoons. Preliminary evaluation for Western Pacific basin indicated superior performance from operational HWRF compared to guidance provided by other operational and experimental regional models including those run at Navy. These experiments are made possible through assistance from NOAA's Hurricane Forecast Improvement Project (HFIP). Future efforts will include expanding on the international collaborations to make HWRF a truly global tropical prediction model.

This presentation will focus on describing the end of the season performance of operational HWRF in comparison to other operational and experimental regional dynamical model guidance for Atlantic, Eastern Pacific, Western Pacific, and North Indian Ocean basins. Efforts in advancing the HWRF modeling system for improved tropical cyclone prediction capabilities for 2013 hurricane season will be presented, with focus on transition to the new operational computing at NCEP.

Ongoing developments include emphasis on a basin-scale domain with multiple moveable nests to track multiple storms, advanced hybrid EnKF-VAR data assimilation with improved use of satellite radiances in all weather conditions, improved physics to address rapid intensity changes and relevant structure changes, and applications for landfall related storm surge, rainfall and inundation. Further improvements in tropical cyclone track, intensity and structure prediction skills will continue to be the major focus areas. These efforts are carried out in collaboration with several NOAA and academic partners through an efficient mechanism for research transitioning to operations.

Application and Improvements to COAMPS-TC

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The tropical cyclone application of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS-TC) is now being run for the prediction of the track and intensity of all tropical cyclones around the world. This presentation will focus on the manner in which COAMPS-TC is applied for real-time TC prediction, and on recent developments applied to the analysis and initialization of the TC. A real-time automated system has been implemented to enable COAMPS-TC to generate a 120 h forecast for every tropical cyclone every 6 hours. COAMPS-TC uses triply-nested grids that feature a 45 km coarse mesh that is fixed in time, and large enough in areal coverage to include all TCs that could be present in each ocean basin. The 15 and 5 km inner grids are centered on each TC at the start of each forecast, and move automatically with each storm so that they always remain centered on the TC during the forecast. The COAMPS-TC forecast model automatically tracks the position of the TC in each forecast. After an initial cold start, each forecast uses its previous 6 hour forecast for the first-guess for each subsequent forecast for a given TC.

Based on the results of recent COAMPS-TC forecasts, we have identified the need to improve our initialization of the TC structure. Two new methodologies are being tested. In the first, our approach is to improve on the procedure that we have been using to design synthetic observations of the TC based on available data. This new approach is dynamic, in that the placement of the synthetic observations is dependent on the observed radius of maximum winds. Also, more synthetics are used so that the final analysis better represents the observed structure. In the second methodology, the tropical cyclone is defined by inserting a previously spun-up tropical cyclone circulation that best matches the observed TC intensity. Following this, a dynamic initialization is performed to ensure that the mass field is in balance with the specified momentum field. We are now testing both of these methods for use in COAMPS-TC. This paper will report on the current design of the COAMPS-TC system, and on the results of the tests we are now performing related to the analysis and initialization of the TC in COAMPS-TC.

Evaluation of Experimental Models for Tropical Cyclone Forecasting in Support of the NOAA Hurricane Forecast Improvement Project (HFIP)

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The Tropical Cyclone Modeling Team (TCMT) in NCAR's Joint Numerical Testbed Program

(JNTP) focuses on the evaluation of experimental forecasts of tropical cyclones (TCs). The TCMT contributes directly to progress in the Hurricane Forecast Improvement Project (HFIP) through independent and consistent evaluations of research and operational model forecasts of TCs. Activities of the team include the development of new verification methods and tools for TC forecasts, and the design and implementation of diagnostic verification experiments to evaluate the performance of TC forecast models. For HFIP, the TCMT has designed and conducted verification studies involving various regional and global forecast models that participate in the annual HFIP retrospective and real-time forecast demonstration studies. The TCMT has also developed new statistical approaches that provide statistically meaningful diagnostic evaluations of TC forecasts, including methods that examine the forecast performance of the new forecasting systems in comparison to the highest-performing modeling systems that are currently available, and as contributors to consensus forecasts. For the 2012 Retrospective Evaluation, eight modeling teams submitted experimental TC forecasts for the retrospective evaluation period which included all tropical storms that were observed in the North Atlantic and Eastern Pacific Ocean basins for the past three years (2009-2011) during the months of August through October. The model configurations included regional and global deterministic, statistical, and ensemble-based forecast systems. Results of the TCMT's evaluations of the models' forecasting performance contributed to decisions by the National Hurricane Center (NHC) regarding which model forecasts would be reviewed by NHC forecasters during the 2012 hurricane season. The forecasts from these models were also evaluated during the 2012 HFIP demonstration experiment. This presentation will provide an overview of the evaluation methodology, including new capabilities and tools, along with a summary of key results from the 2012 HFIP retrospective and demonstration studies, including an evaluation of model performance during Hurricane Sandy.

Improved Telescopic Nesting and its Effects on Hurricane Forecasting

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The Hurricane Weather Research and Forecasting (HWRF) model consists of three computational domains at 27km, 9km and 3km resolutions, allowing the turbulent inner core regions of hurricanes to be simulated at higher resolution than the surrounding environment. Information flows in both the upscale and downscale direction in the model, letting the high-resolution inner core region to communicate with the environment and with the large scale. The initial attempt at an operational forecasting model that implemented these concepts, the 2012 Operational 27:9:3 HWRF, was successful in accomplishing significant gains in track, intensity and structure forecasts compared to earlier versions of operational HWRF. However, that implementation ran into a few problems of both scientific and technical natures. This talk examines those problems, and discusses recent improvements to the HWRF system that will address the problems.

Potential Upgrades for the Radiation and Boundary Layer Physics in the Operational HWRF Model

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Current efforts on improving planetary boundary layer (PBL) and radiative transfer physics of the HWRF model will be introduced. Radiation physics is revised in order to represent more realistic cloud-radiation interactions using RRTMG parameterization while the boundary layer process in the HWRF model is modified such that it is suitable for both the hurricane and its environment. Preliminary results of these physics upgrades will be presented from idealized and the real hurricane simulations.

Evaluation of the Ocean Response in HWRF: How Changes in the Atmosphere-Ocean Fluxes Affect Forecast Skill

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The Hurricane Weather Research and Forecasting model (HWRF) is a coupled system that employs the Princeton Ocean Model for Tropical Cyclones (POM-TC) and the Non-Hydrostatic Mesoscale Model (NMM) dynamic core of the WRF model. The atmospheric winds and moisture content, along with the difference of temperature between ocean and air, control the fluxes of momentum, latent heat, and sensible heat between atmosphere and ocean, which are further modulated in the model by the momentum and enthalpy surface exchange coefficients.

In the POM-TC, the momentum flux drives turbulent mixing and upwelling, two physical processes that transport cold water from deeper oceanic layers toward the surface and influence tropical storm intensity. Strong storms that move slowly over regions with small mixed layer depth are most significantly impacted.

The development of operational models involves a bitter compromise. Codes of physical parameterizations need to represent the theoretical understanding, yet need to provide the best forecast possible for distribution to customers. To that end, HWRF implementations up until 2012 employed a reduction of the momentum fluxes in POM-TC to 75% of their calculated value. This truncation compensated for model deficiencies, such as an exaggerated storm size, and provided superior intensity forecast. Since 2012, HWRF has been running with a much higher resolution (3-km grid spacing in the inner nest) and with updated surface and planetary boundary layer parameterizations that generate more realistic storm structure and intensity.

These changes led us to put forth the hypothesis that the flux truncation is no longer beneficial for the forecasting of hurricane intensity.

To test this hypothesis, the Developmental Testbed Center has conducted retrospective runs for the entire 2012 season with two configurations with HWRF: a control one and a variant with the flux truncation removed. Results indicate that the positive intensity bias for the Atlantic basin existing in the control configuration is much alleviated in the configuration with full fluxes. Based on these results and pending additional pre-implementation testing, the full fluxes will be restored for the operational implementations for the HWRF and GFDL models in 2013.

Detailed verification results for the configurations with 75% and 100% of the fluxes will be presented for the Atlantic and Eastern North Pacific basins, with analysis of impact on individual storms and comparisons with buoy observations.

Further Development of a Statistical Ensemble for Tropical Cyclone Intensity Prediction

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A statistical-dynamical intensity guidance ensemble from available regional and global dynamical models has been developed and tested in real-time operations as part of the Hurricane Forecast Improvement Project (HFIP). Statistical Prediction of Intensity from a Consensus Ensemble (SPICE) was created in 2011 based off combining two current statistical-dynamical models, the Logistic Growth Equation Model (LGEM) and the Statistical Hurricane Intensity Prediction Scheme (SHIPS). The operational versions of both LGEM and SHIPS rely on large-scale environmental predictors from the Global Forecast System (GFS) model fields along the interpolated official forecast track as input to forecast the change in tropical cyclone intensity. SPICE forms a consensus from the combination of operational SHIPS and LGEM intensity guidance, as well as SHIPS and LGEM runs based off the large-scale environments in the Geophysical Fluid Dynamics Laboratory (GFDL) and Hurricane-Weather Research and Forecasting (HWRF) regional models.

SPICE was run real-time during the 2012 season as part of HFIP, and results from the season will be presented here. Additional experiments with expanded sets of parent dynamical models, both regional and global, will be reviewed. Possible improvements for the 2013 season will also be discussed.

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Extended-range (5-30 day) Forecasts of Tropical Cyclones with the ECMWF Ensemble: Part II. Atlantic during HS3 Field Experiment

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Atlantic tropical cyclone (TC) track forecasts during Weeks 1-4 were prepared on Mondays and Thursdays from the ECMWF 32-day ensemble predictions (and during Weeks 1 and 2 each day from the ECMWF 15-day ensemble) from mid-August 2012 in support of the NASA Hurricane and Server Storm Sentinel (HS3) field experiment mission planning. The procedure were similar to those previous described by Elsberry et al. (2010, 2011) and Tsai et al. (2013) for the western North Pacific (described in Part I), which had demonstrated a capability to forecast typhoon tracks (and even some tropical depressions) out to Week 4 before the typhoon existed.

As was the case in the western North Pacific evaluations, the ECMWF ensemble can forecast tracks of hurricane-strength systems, but the preliminary indication is that the predictability will be more limited than in the western North Pacific, for example, the tracks for Superstorm Sandy were only marginally predicted two weeks in advance. The ECMWF ensemble had difficulty in predicting several tropical transition-type formations that only achieved strong tropical storm status during the period. As over-prediction of TC-like vortices was evident, a key objective was to evaluate our capability to subjectively detect these false alarms. Finally, the capability of the ECMWF ensemble to predict no TCs in the western Atlantic, Caribbean, and Gulf of Mexico after Isaac through the start of Sandy will be demonstrated.

Session 7
Observations and Observing Strategies for Tropical Cyclones and their Environment

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The 2012 Satellite Proving Ground at the National Hurricane Center

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GOES-R is scheduled for launch in late 2015 and will contain a number of new instruments, including the 16-channel Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). The GOES-R Proving Ground was established to provide forecasters with advance looks at GOES-R data and products using proxy information, and to obtain user feedback for the product developers. Nine products were chosen for demonstration at NHC during most of the 2012 Hurricane Season (1 Aug to 30 Nov). Eight of the nine were ABI products, comprising the Hurricane Intensity Estimate (HIE) two Red-Green-Blue (RBG) products designed to provide forecasters experience with image combinations, split window (10.8 and 12.0 μm) infrared imagery for tracking low to mid-level dry air, a tropical overshooting tops detection algorithm, two natural color products, and super-rapid scan operations imagery. The ninth was a combined GLM and ABI product to predict rapid intensify changes using global model fields, infrared imagery and lightning input. Spinning Enhanced Visible Infrared Imager (SEVIRI) data from Meteosat and the imager from the current GOES were used as proxies for the ABI and the ground-based Global Lightning Dataset 360 (GLD-360) was used as a proxy for the GLM. Results from 2012 will be summarized along with plans for a follow-on experiment during the 2013 Hurricane Season. The 2013 Proving Ground will be expanded to include products from the recently launched Suomi-NPP mission.

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Computing Deep-Tropospheric Vertical Wind Shear Analyses for TC Applications: Does the Methodology Matter?

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Vertical Wind Shear (VWS) is well known in the TC forecasting community as an important environmental influence on storm structure and intensity change. From the research side, there have been many studies on VWS, in particular, model analysis depictions and impacts on intensity prediction. The traditional way to parameterize VWS in most of these studies, and in operational forecast applications, is to use the vector difference of the 200 and 850hPa wind fields based on global model analyses. For example, this is how the operational SHIPS model

employs VWS as a predictor of future TC intensity. But is this the optimal approach to depict VWS? In this study, we compare a different methodology to generate fields of VWS as produced by the University of Wisconsin-CIMSS. The CIMSS analyses use a 3-dimensional Recursive Filter at high spatial resolution to put heavy weight on available high-density satellite-derived winds. Global model wind fields are only used as background analyses for data-void regions. The resultant isobaric analyses are then used to create two layer-mean wind analyses; one upper tropospheric and one lower tropospheric. This approach differs from using just the two discreet levels as in the traditional methodology, and it will be shown how the resultant VWS fields can diverge significantly in certain situations. This could impact the forecaster interpretation of the VWS significance in certain cases, and also influence objective method forecasts of intensity.

Outflow Layer Structure in Hurricanes Leslie And Nadine Revealed by Dropsondes Deployed from NASA Global Hawk UAV Aircraft during the 2012 Hurricane and Severe Storms Sentinel (HS3) Campaign: A New TC Observational Strategy

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A new observing strategy was employed for the first time in 2012 over Atlantic Hurricanes Leslie and Nadine during the NASA Hurricane and Severe Storms Sentinel (HS3) campaign which allowed hurricane outflow structure to be observed for the first time. We hypothesize that TC intensity change may be associated with either active or passive evolution of the outflow layer, i.e. that either the outflow layer changes force TC intensity change or are a result of TC intensity change. The objective of these new observations is to establish which may be true and to establish the pattern of outflow layer jet structures with which hurricane intensity change may be associated. NCAR/Vaisala dropsondes were deployed from the Global Hawk UAV from altitudes ranging from 55-60 K ft that allowed detailed hurricane outflow structures to be observed. Use of 3-hourly CIMSS mid- and upper layer (150-300 mb) winds and 6-hourly COAMPS-TC modeled outflow allowed for the dropsonde observations to be placed in the context of a temporally changing interaction of environmental features and the hurricane outflow. The NASA Cloud Physics Lidar (CPL) allowed these features to be placed in the context of the upper and lower cloud outflow boundaries. Observations made along the outflow jet wind maxima in Leslie and Nadine revealed a sharp upper outflow maximum just below the top of the cirrus cloud layer which was coincident with the tropopause, defined by the dropsonde temperature observations. Multiple constant wind layers were observed below the wind max within the outflow layer. These observations suggest strong shear induced mixing at the top of the outflow layer and evaporatively-driven mixing at the base of the cirrus cloud layer. Comparisons with the CIMSS winds and model output wind profiles illustrate the greatly improved vertical resolution made possible within the outflow layer by the dropsonde observations.

HIWRAP Global Hawk Status and Future Plans

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The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is a dual-frequency (Ka- and Ku-band), dual-beam (30^0 and 40^0 incidence angle), conical scan, solid-state transmitter-based system, that flies on the high-altitude (20 km) Global Hawk UAV. HIWRAP images the winds through volume backscattering from clouds and precipitation, enabling it to measure the tropospheric winds above heavy rain at high levels. It measures ocean surface backscatter from which ocean surface winds can be derived through scatterometry techniques similar to QuikScat. These measurements from higher altitudes above storms provide higher spatial and temporal resolution than obtained by current satellites and lower-altitude instrumented aircraft.

HIWRAP flew its first science flights on the unmanned Global Hawk #AV-6 (65kft ceiling) during the Genesis and Rapid Intensification Processes (GRIP) campaign conducted during August and September 2010. During 5 flights, the Global Hawk AV-6 flew over Hurricanes Earl and Karl, and TS Matthew. During the 2012 hurricane season, HIWRAP was supposed to fly in the Hurricane Severe Storm Sentinel (HS3) on Global Hawk AV-1 that had not previously flown for science missions. But AV-1 was late for the 2012 season and instead flew one science flight over the Pacific in early November 2012. HIWRAP processing and retrieval algorithms based on previous flights have progressed, and hardware improvements have occurred over the last few years. We will present the status of the instrument, processing, and wind algorithms; lessons learned from previous flights; and future plans.

Retrievals of Wind and Rain Rate from Combined Measurements of Up-Looking and Down-Looking SFMR(s)

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Design and construction of a compact SFMR (CSFMR) was recently completed under the NOAA SBIR contract WC133R-08-CN-0159. The CSFMR receiver has 1/3rd the weight and 1/3rd the electrical power requirements of the original SFMR. Test flights of the CSFMR were conducted by NOAA HRD during the 2012 hurricane season with CSFMR mounted in an upward-looking configuration.

The SFMR wind and rain rate retrieval algorithm approximates the rain height with a fixed value, currently set at 4000 m altitude. When operating the SFMR instrument on hurricane reconnaissance flights, the actual rain height can vary significantly from the set value, introducing biases in both the retrieved rain rate and the wind speed. Theoretical analysis shows that rain rate bias can be on the order of 20% depending on the discrepancy of the actual rain height from the fixed value set in the SFMR retrieval algorithm. Theoretical analysis also shows that the wind retrieval bias due to the fixed rain height can be on the order of 20% for low winds (< 15 m/s). The retrieval bias is predicted to be much smaller for hurricane force winds thus having minimal effect on the quality of the reported SFMR winds in hurricane conditions. However, this high-wind retrieval bias is of similar magnitude to the hurricane quadrant wind bias (1-3 m/s) previously reported by others.

Preliminary analysis of the data collected from combined (up and down looking) SFMR flights during the 2012 Hurricane season supports these theoretical predictions of the fixed rain height effect.

ProSensing acknowledges the full support from the NOAA Aircraft Operation Centre for installing the up-looking SFMR, and also from the NOAA Hurricane Research Division for supporting its operation during the 2012 hurricane season. We also want to thank Richard Henning of NOAA's Aircraft Operations Center (AOC) for helping obtain and process dropsonde data.

Implementation of Upper-Ocean Temperature Measurements on Operational Hurricane Reconnaissance: An Update on the AXBT Demonstration Project

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In 2011 the Working Group for Hurricane and Winter Storms Operations and Research approved a multi-year AXBT Demonstration Project to assess whether the collection of upper-ocean temperature observations during operational TC reconnaissance missions could improve coupled numerical model forecasts of TC track and intensity. Results from the first two seasons, in which over 400 AXBTs were deployed during more than 30 U.S. Air Force 53rd Weather Reconnaissance Squadron missions included successful near-real-time assimilation of upper-ocean temperature observations, increased model accuracy of the upper-ocean thermal structure, improved track forecasts in a coupled dynamical model, and minor improvements in forecast intensity in both coupled dynamical and statistical models. Here, the (1) 2012 operations summary will be presented, as well as (2) an initial set of results from the inclusion of AXBT data in both statistical and dynamical numerical prediction models, (3) quantification of AXBT observation impacts, and (4) future plans for the AXBT program.

Observations of Upwelling Processes during Tropical Storm Isaac

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In August 2012, Tropical storm (TS) Isaac moved over the oceanic eddy field in the Gulf of Mexico encountering both warm and cold oceanic features. During this period, expendable ocean and atmospheric profilers were deployed as part of the NOAA Hurricane Research Division Intensity Fluctuation Experiment program from NOAA WP-3D aircraft. In addition to the four in-storm flights, conducted as part of the tail Doppler radar missions with concurrent AXBT and GPS sondes, pre- and post-storm missions measured the upper ocean response, including salinity and current from AXCTDs and AXCPs. During Isaac's movement across the Gulf, it was characterized as a broad storm moving between 7 to 8 m s^{-1} with a radius of maximum winds of more than 90 km and decreasing to about 60 km. As Isaac approached the coast, the storm speed decreased to about 2 m s^{-1}. Thus, a key objective of these oceanographic measurements was to observe the level of upwelling across the Gulf since isopycnal displacements scale as the inverse translation speed. Based on scaling arguments, these displacements were less than 10 m in the central Gulf, increasing to more than 20 m just along the Sigsbee Escarpment south of Louisiana. During this period, Isaac slowed down and intensified to a category 1 storm.

As shown in recently published studies (Jaimes *et al.*, 2011), these vertical displacements of isopycnals are also a function of the curl of geostrophic currents, rather than just a function of the curl of the wind stress alone. In this context, surface wind stress was estimated from the NOAA HRD HWIND product using the Donelan *et al.* (2004) surface drag coefficient. During intensification to hurricane (28 Aug), the cyclonically rotating wind stress curl extended over a region of more than 300 km in diameter (~5*Rmax)*. The wind stress curl scaled well with the local Coriolis parameter. The broad wind stress curl induced strong upwelling and downwelling signals on the right and left side of the track, respectively. These processes were enhanced in the cold core eddy on the right side of Isaac's track. Divergent wind-driven ocean currents in the surface mixed layer were 0.5 and 0.7 m s^{-1}, less than those predicted with scaling arguments. As in other documented cases in the Gulf, the upper ocean modulated Isaac's intensity. Moreover, the deeper isopycnal displacements show the oceanic response is not limited to just the upper ocean as upwelling tends to get enhanced along steep bottom slopes and strong background geostrophic currents. Such 3-D observations of the response must be captured by the oceanic models that are part of the coupled model strategy at National Centers to eventually forecast hurricane intensity.

Progressing toward a Geostationary Microwave Sounder Mission

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The technology required to implement the first microwave sounder on a geostationary satellite is now sufficiently mature that mission development can proceed. Such a sounder will be based on the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) concept and design that has been developed at the Jet Propulsion Laboratory under sponsorship from the NASA Earth Science Technology Office (ESTO). NASA has invested nearly $15M since 2003 through the Instrument Incubator Program (IIP), the Advanced Component Technology (ACT), and the Industrial Partnership Program (IPP) to advance the technology to this point. A broad-based JPL-led team that includes international partners and participation from several US federal agencies has developed a low-cost mission called GeoStorm that is focused on severe storms, including hurricanes. This GeoStorm sounder can be accommodated through the NASA EV-I Venture program as a hosted payload on a commercial communications satellite. It will provide a set of unique observations that will enable investigations that have until now not been entirely possible: measurement of the thermodynamic state (temperature and water vapor), microphysics (cloud properties, precipitation, reflectivity), and dynamics (wind vectors) – all simultaneous, in three dimensions over a large area, and sampled every 15 minutes. We will discuss some of the investigations that this mission will enable, and the scientific advances that are likely to ensue.

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Session 8:
Improvements in Tropical Cyclone Forecast and Warning Products and Services

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COASTAL Act Requirements for Tropical Cyclone Post-Storm Assessments and Response by NOAA and Interagency Partners

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The Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act was signed into law on 6 July 2012. Its purpose is to lower costs to the National Flood Insurance Program by mandating detailed post-storm assessments of wind and flood conditions in tropical cyclone impacted areas throughout the U.S. and its territories. Assessments of the wind, storm surge, and waves will be used by FEMA to determine the cause of indeterminate losses, where little tangible evidence beyond a building's foundation remains for the proper adjustment of insurance claims for homes totally destroyed by a tropical cyclone. Observations and gridded analyses will be the primary information generated by NOAA and its partners; these will be assembled to provide as complete a picture of the storm event as possible. An online database containing all pertinent observations (i.e., "covered data") is required to provide access to the information. Collectively, the observations and gridded analyses comprise the "Named Storm Event Model (NSEM)" for each case.

The NOAA Team responding to the COASTAL Act has representatives from the NWS, OAR, NOS and NESDIS (the co-authors of this paper). In addition, NOAA will partner with FEMA, the Army Corps of Engineers and the US Geological Survey in fulfilling the COASTAL Act requirements. The Joint Action Group for the COASTAL Act Post-Storm Analysis (JAG/CAPSA) has been instrumental in supporting Federal activities.

This paper will describe requirements of the COASTAL Act, potential software components that could comprise the NSEM, the COASTAL Act partnerships involved, and a timeline for achieving the Act's deliverables.

Using USACE-ERDC's Coastal Storm Modeling System in Support of Hurricane Sandy Operations

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The US Army Corps of Engineers' Engineer Research and Development Center's Coastal Storm Modeling System (CSTORM-MS) is a physics-based modeling capability for simulating tropical and extra-tropical storm, wind, wave, water level and coastal response (erosion, breaching, and accretion). Realistic coastal storm modeling requires the integration of several complex numerical models. The following models are currently part of the CSTORM-MS: a tropical planetary boundary layer model, MORPHOS-PBL, as an option for generating tropical wind and pressure fields; an ocean hydrodynamic model, ADCIRC, to generate the water level and currents fields; and both regional and nearshore ocean wave models, WAM and STWAVE, to generate the wave fields, a nearshore hydrodynamic model, AdH with a sediment library, SEDLIB that includes a bed morphology model, C2SHORE. Components of this system have been used in numerous USACE site evaluation and FEMA flood map studies, including the Great Lakes region. The system is configurable and expandable. For overland flow and flooding the model GSSHA is used. GSSHA is a gridded, physics-based full hydrology model with overland flow, stream flow, groundwater, vadose zone, storm and tile drains, wetlands, erosion, and constituent transport.

Results from ERDC's application of ADCIRC and GSSHA to forecast advisories for Hurricane Sandy will be presented in order to further the discussion on communicating surge results.

USGS Monitoring of Storm-Tide for Hurricanes Isaac and Sandy

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The U.S. Geological Survey (USGS) has developed a method to monitor the extent, timing, and magnitude of hurricane storm-tide, sometimes referred to as storm-surge, through the use of rapidly-deployed water-level and barometric pressure sensors within the landfall area that records a time-based hydrograph of hurricane storm-tide at each sensor location. The first successful test of this method was in 2005 for Hurricane Rita. Since then, the method has been refined so that larger deployments and rapid (within 3-10 days) web-based data dissemination are possible and nearly routine so that information needed by the Federal Emergency Management Agency can utilize this information to improve and refine response and recovery efforts. Data collected from these deployments also aids in the research and verification of storm-surge models for the National Hurricane Center to better warn citizens of the threat of storm-surge in the future.

Results from the Hurricane Isaac (2012), and Superstorm Sandy (2012) will be presented, in addition to background information about how the storm-tide monitoring methods have evolved since 2005, how new interagency and university partnerships have strengthened the effort, and how these efforts might improve Federal efforts to respond to the 2012 Coastal Act.

Improvements to the CO-OPS Storm QuickLook Product for Real-Time Storm Surge Monitoring for the 2014 Hurricane Season

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NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) issues the Storm QuickLook product for tropical cyclones affecting the U.S. coast. This product provides a synopsis of high quality oceanographic and meteorological data at NOS tide gauge locations within a storm's path and a real-time view of a storm's impacts on coastal water levels. However, it has remained largely unchanged since 2007. Efforts are underway to identify and implement changes to the product to make it more dynamic, user-friendly and establish it as a critical "one-stop-shop" decision support tool for evaluating observed storm surge conditions in coastal areas impacted by a tropical cyclone.

During hurricane seasons, The Storm QuickLook product is initiated when a tropical storm or hurricane warning is issued by the National Weather Service (NWS) for the coastline of the U.S. or its territories. The product is updated 4 times daily, typically one hour following the latest NWS public advisory for a tropical cyclone. The product highlights real-time water level and meteorological observations at locations affected by the storm, with updated data every 6 minutes. It integrates CO-OPS' water level and meteorological station locations, storm information and satellite imagery into a GIS map, and includes an analysis of current conditions and high-tide predictions.

In an effort to provide greater clarity regarding storm tide and storm surge, CO-OPS coordinates with the NWS' National Hurricane Center (NHC) during and after tropical cyclones impacting the U.S. coastline. Based on this collaboration, improvements to the Storm QuickLook product have been recently implemented, such as the inclusion of Highest Astronomical Tide (HAT) and providing the capability to display storm tide data referenced to Mean Sea Level (MSL). To further improve the Storm QuickLook product, CO-OPS has engaged the NWS in gathering requirements for a larger-scale effort designed to improve the Storm QuickLook product and storm tide messaging in general. Proposed changes include replacement of the existing Storm QuickLook map with a dynamic map interface allowing access to the greater range of CO-OPS real-time coastal data, addition of larger, easy-to-read time-series plots of oceanographic and meteorological data, and provision of ancillary information like the maximum observed water level over the prior 24 hour time period. The proposed delivery date for CO-OPS' final enhancements to the Storm QuickLook product is May 2014, prior to the 2014 hurricane season.

Use of a Modified SHIPS Algorithm for Hurricane Intensity Forecasts

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This work entails an improvement of the SHIPS algorithm by bringing into the prediction some dynamical parameters from the output in addition to the statistical state variables of SHIPS. We include all of the named storms of the 2012 hurricane season for the Atlantic basin. We have explored various post processing methods to examine the impacts of the post processed dynamical variables derived from the HWRF outputs at 3 km. In this context we have included the intensity forecasts from SPICE (SPC3). The dynamical variables are shown to add to the Skills of SHIPS and SPICE (SPC3).

Impact of New Predictors on Corrected Consensus TC Track Forecast Error

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Funded by a JHT project, a graphical predicted consensus error product (GPCE; Goerss 2007) for track forecasts was first developed and installed on the ATCF at both NHC and JTWC in 2004. Using GPCE's pool of predictors, regression models are derived each year and used to determine the radii of circular areas drawn around the consensus model forecast positions within which the verifying TC position is expected to be contained approximately 70% of the time. These circular areas are then graphically displayed on the ATCF for use by the forecasters at NHC and JTWC. Also, each year, regression models using GPCE's pool of predictors are derived to estimate the latitude and longitude error of the consensus forecast. These error estimates are used to create corrected consensus forecasts, TVCC (corrected TVCN) for the Atlantic and Eastern North Pacific basins and CCON (corrected CONW) for the JTWC basins. To improve the forecast performance of the corrected consensus forecasts, which have been consistently worse than the consensus forecasts, we have investigated the use of new predictors. The new predictors are the differences between the latitudes and longitudes of the various consensus model forecasts and the consensus forecasts. The use of the new predictors has proven to be quite effective. For the Atlantic in 2012, the forecast errors for TVCN were 41, 72, 104, 152, and 222 nm at 24h, 48h, 72h, 96h, and 120h, respectively. The respective errors for TVCC were 42, 72, 104, 166, and 230 nm. Using the new predictors (primarily the ECMWF and GFS forecast differences), the respective errors for corrected consensus were 38, 64, 94, 143, and 199 nm representing improvements of 10, 11, 10, 14, and 14 percent over TVCC. The respective improvements over TVCN were 7, 11, 10, 6, and 10 percent. For the eastern North Pacific in 2011, the respective forecast errors for TVCN were 43, 75, 124, 186, and 232 nm, while those for TVCC were 41, 79, 139, 258, and 333 nm. The respective errors for corrected consensus using the new predictors were 38, 60, 88, 133, and 152 nm representing improvements of 7, 24, 37, 48, and 54 percent over TVCC. The respective improvements over TVCN were 12, 20, 29, 28, and 34 percent.

Are Atlantic Basin Tropical Cyclone Intensity Forecasts Improving?

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It is well-known that the mean absolute error of National Hurricane Center intensity forecasts for Atlantic basin tropical cyclones calculated with respect to the best-track analyses shows little or no decrease since 1990. It is often inferred from this result that the quality of these intensity forecasts has not improved over the past two decades. However, this conclusion implicitly assumes that the statistical characteristics of the best-track intensity analyses have not changed over the years. Here, we demonstrate that the relative frequency distribution of best-track intensity change (*e.g.* the change in best-track intensity over a 24 h window) evolved substantially during the 1990-2010 period. In particular, the relative frequency of large-magnitude intensity changes increased significantly and the relative frequency of small-magnitude intensity changes decreased significantly, resulting in a significant increase in the average absolute intensity change (AAIC). The AAIC is equivalent to the mean absolute error of persistence intensity forecasts, and as such it can be used to define a baseline for an intensity forecast skill score. Such a skill score accounts for the changing difficulty of intensity predictions, as represented by the AAIC. For the National Hurricane Center Atlantic basin intensity forecasts during the 1990-2010 period, the AAIC-based skill score has a statistically-significant increasing trend, suggesting there has been real improvement in intensity forecasts on a decadal time scale.

CLIQR: A Climatological Analog Matcher to Ongoing Tropical Cyclones

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In 2008, the Hydrometeorological Prediction Center attempted to find a better way of sorting through its tropical cyclone rainfall database, so it could be used more effectively by operational forecasters. The web page format was not considered ideal; as some forecasters could not remember the year certain storms occurred, while others didn't want to sort through long lists of storms which hit various regions of the lower 48 United States, Puerto Rico, and Mexico in either alphabetical or chronological order.

After some thought, and a summer student dedicated to the significant task of coding the utility within a few programming languages (Kyle Griffin), including C-shell, Perl, and Tcl/Tk within a couple months' time, a GUI was quickly developed for use within the HPC LINUX environment which automatically runs between one and three hours after synoptic time, matching possible analogs primarily by the storm's current position, its size as defined by its radius of outermost closed isobar (ROCI), and its forward motion. It became experimental in August 2008 and continues to run, utilizing tropical cyclone information from the CHGHUR/tropical cyclone objective guidance messages generated by the National Hurricane Center (NHC).

Since the tropical cyclone rainfall database stretches back into the 1950's, an archive of relevant track information for the northeast Pacific and northern Atlantic oceans for this time frame was collated into one data file, starting with the extended best track database (EBTD) which is derived by the Cooperative Institute of Research in the Atmosphere (CIRA) at Colorado State University from the National Hurricane Center's ATCF workstation. However, the database only begins in 2000 for the northeast Pacific basin and 1988 for the Atlantic Basin, and at the time, tropical depression information was just being digitized into an Atlantic non-developmental database for the northern Atlantic basin (1967-1987 time frames). A week-long trip down to the NOAA Miami Regional Library and NHC filled in most of the tropical depression track information during August 2008, while annual typhoon articles from the Joint Typhoon Warning Center were used to get tropical depression track information from the northeast Pacific for the 1960s, with Monthly Weather Review articles for the northeast Pacific depressions used for tropical depression information from the 1970s and 1980s.

For older years, the Atlantic and eastern Pacific hurricane databases (HURDATs) were expanded into the EBTD format. In order to gather the ROCI and value of the pressure of the outermost closed isobar (POCI) for older storms, a variety of North American (1954-1990), Northern Hemisphere (1966-1982), older Miami Forecast Office surface analyses (1956), and the Hurricane Map Series (1949-1961) were digitized at the NOAA Central Library in Silver Spring, Maryland, the University of Virginia in Charlottesville, and the NOAA Miami Regional Library. Copies of these maps were sent to the National Climatic Data Center (NCDC) after being scanned and placed on the HPC cloud (N: drive), where the developing surface analysis archive is being housed. The maps are being reanalyzed to determine the ROCI and POCI for the Atlantic systems within the database, with the ultimate goal of determining values for all North Atlantic and northeast Pacific tropical cyclones. This data will help along with the Atlantic Hurricane Re-analysis effort, which has been spearheaded by NHC since 2000.

Invited Talk

Collaborative Decision Making: Connecting Agencies (Federal & State) and the Private Sector for Improved Situational Awareness, Coordination and Response to Save Lives and Property

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StormCenter's rapid innovation to application development cycle under their SBIR Phase II contract to create multi-platform collaboration and data sharing environment for improved situational awareness and decision making will be discussed. This environment allows for the access, sharing, and merging of disparate data sources from all levels of government, including federal, state and local entities. The Small Business Administration (SBA) and NASA awarded StormCenter a sole source contract to implement geospatial collaborative technologies within Federal agencies, and StormCenter has become the Federal Government's 'preferred provider' of this capability. The contract has no ceiling and is positioned to enable Federal agencies to implement innovation rapidly while stimulating small company growth.

Weekly collaborations between NWS Southern Region HQ, Texas Division of Emergency Management, and StormCenter have revealed new data fusion approaches for improved understanding and enhanced decision making capabilities. Research to operations is being accelerated for more rapid infusion of research results into operational decision making environments. This is an All-Hazards technology approach for improved situational awareness including space weather monitoring and collaboration.

Session 9:
Social Science Applications to the Tropical Cyclone Forecast and Warning Notification Problem

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Supporting the Integration of Physical and Social Science as it Relates to the NOAA Hurricane Forecast Improvement Project (HFIP)

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The National Hurricane Center (NHC) is heavily engaged in a research-to-operations initiative called the Hurricane Forecast Improvement Program (HFIP) to produce hurricane forecasts of higher accuracy and greater reliability. While most of the teams in HFIP focus on the physical aspects of hurricane observation and modeling, a Socio-economic Team comprising NHC scientists, other National Weather Service forecasters, and representatives from the emergency management, media, private sector, and social science communities are working to identify current and new hurricane products and graphical techniques that will increase public understanding of hurricane forecast information and enhance reliability on NWS forecasts. Each member of the team brings a unique and diverse perspective on user requirements, especially since some are users of forecast information themselves. Comprehensive social science surveys and research are being conducted to test graphical prototypes with emergency managers, broadcast meteorologists, the public, and NWS Warning Coordination Meteorologists.
Intended to inform the National Hurricane Center, the NOAA Hurricane Forecast Improvement Project (HFIP) and NOAA Storm Surge efforts to effectively convey tropical cyclone risk and uncertainty; the HFIP Socio-Economic Working Group, was created to help identify need(s) and provide guidance towards making tangible socio-economic changes to information NHC generates to effectively communicate risk and uncertainty.

NOAA funded research is underway to assess hurricane information needs and integrate social science methodologies into tropical cyclone and storm surge products, including prototyping of new or updated products.

Utilizing Input from Emergency Managers, the Media, the Public and Local NWS Meteorologists to Better Communicate Surge and Other Storm Hazards

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Recent exploratory social science research informed the development of several graphical and text prototypes for improving the communication of surge and other hazards associated with tropical and extratropical cyclone forecasts. These prototypes were then empirically tested with key NWS customers and partners. This presentation will report on the findings from web-based surveys conducted with emergency managers, broadcast meteorologists, NWS Warning Coordination Meteorologists and members of the public in Atlantic, Gulf, and Pacific coastal areas and Alaska.

Communication of Hurricane Storm Surge Threat: A Mixed-Method Analysis

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To help NOAA improve the communication of hurricane forecast information, this part of the Storm Surge Mapping project examines the influence of three different color scales and two legend types in conveying storm surge risk effectively. Two methods were used in the analysis: an eye tracking experiment, and a survey of Mississippi and Alabama Gulf Coast residents. Both methods measured risk perception, helpfulness of the images, and comprehension of the message. The eye tracking experiment was able to determine the areas of the map participants attended to the longest and the pattern of their eye movement around the map. Accuracy (how well participants did on a task) and efficiency (how quickly they completed a task) values were compared among image types in five different image conditions. These conditions combine image manipulations of three color scales (green to red, yellow to purple, and light blue to dark blue) with either quantitative (in feet) or qualitative (low, medium, high, extreme) scale values. Each participant was shown a hurricane in all five image conditions presented in varying order (a Latin Square design). Graphics were also tested in a survey of Gulf Coast residents. The survey examined whether any one graphic performed better in the following criteria: 1) comprehension, 2) dose/response uniformity, 3) hazard/response uniformity 4) freedom from bias and 5) helpfulness. Survey respondents were shown images of two hypothetical hurricanes forecasted to affect their area-- one stronger and one weaker. Results from the project will be discussed in this presentation along with any recommendations for use of color in hurricane warning images.

Evaluation of the NC-CERA Storm Surge and Wave Visualization Tool by Emergency Managers

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Storm surge and wave forecasts during tropical events are critical to the emergency management (EM) community in North Carolina's coastal and river surge counties. Although many operational decisions made by EM in these counties are based on the onset time of tropical storm force winds, surge and wave information can give EM an idea of how much damage will occur in their county so that they can begin planning recovery operations.

Much of the weather information for tropical events that is currently available to EM can be hard to find and understand, and some information, such as surge forecasts, are released too late to be useful in many pre-storm operational decisions such as evacuations. To examine these issues and assess EM needs for surge and wave information, an evaluation of the North Carolina-Coastal Emergency Risks Assessment (NC-CERA) tool was conducted. This visualization tool was developed at the Department of Homeland Security Coastal Hazards Center of Excellence based at the University of North Carolina at Chapel Hill.

NC-CERA visualizes the output of the ADvanced CIRCulation surge model (ADCIRC) and Simulating Waves Nearshore (SWAN) model, which provide a single deterministic surge and wave forecast for five days based off of the National Hurricane Center Consensus Hurricane Advisory. The models and visualization are intended to provide additional surge and wave guidance to EM during coastal storm events threatening the North Carolina coast. The goal of the evaluation is to improve the NC-CERA tool so that it better meets the needs of the North Carolina coastal EM community and will be an additional resource that they use operationally during a tropical event.

To carry out this evaluation, a four step iterative process is used that was established in the Weather for Emergency Management Decision Support Project (WxEM). Conducted by the University of North Carolina and East Carolina University in collaboration with the NWS Office of Science and Technology, WxEM established the method to learn about EM processes, decisions, and weather information needs in order to improve decision support. To evaluate NC-CERA, county EM directors from each coastal county as well as several river surge counties (15 counties in all) participated in the various steps of evaluation, starting with the establishment of a baseline understanding of their decisions and processes during tropical events in general, and the surge and waves aspects specifically. The second step is to learn about EM current practices, including where they get surge and wave information, and identify gaps in what EM need and what they currently use. The third step is to make improvements to the NC-CERA tool based on information collected in steps one and two and during an initial demonstration of the tool. The final step, validation, is to assess if and how EMs used the tool during operations or an exercise.

This presentation will review the methods used to gather information from EM about the NC-CERA tool and surge and wave information in general, preliminary results of the evaluation, and the next steps in the tool's development to improve the visualization of surge and waves for the EM community.

Poster Session

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A Convective Band Within the Inner Core of Hurricane Isaac at Landfall: Is This An Inner Eyewall or Just a Transient Banding Feature?

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Hurricane Isaac made two U.S. landfalls on the northern Gulf coast as a category 1 hurricane with 36 m s^{-1} sustained winds. The first landfall occurred at the Mouth of the Mississippi River late on 28 August 2012 and the second landfall occurred near Port Fourchon, LA early on the 29th. The storm lacked inner core organization as it traversed the eastern Gulf; however, as Isaac approached the north-central Gulf coast, organization improved and the storm strengthened to a hurricane only about 8 hours prior to its first landfall.

As the storm approached the Mouth of the Mississippi, an inner banding feature developed near the storm center well inside the radius of maximum winds. Heavy convection developed in this banding feature and at times the banding completely encircled the center of the eye, potentially resembling an inner eyewall in the radar reflectivity pattern. Indeed the author overheard at least two media reports on TV that an inner eyewall might be forming in Isaac as it approached the Louisiana coast.

In the present research, WSR-88D Doppler radar data, reconnaissance aircraft information, surface weather reports and satellite imagery were examined in the vicinity of Isaac on 28 and 29 August to determine whether the storm did indeed contain an inner eyewall at landfall.

Preliminary investigation indicates that an inner eyewall did not form, although frequent surface wind reports from stations PILL1 at Pilot Town, LA and PSTL1 at Southwest Pass, LA show that a distinct but weak wind maximum did exist with this inner banding feature. A much stronger wind maximum existed within the true eyewall at a much larger radial distance from Isaac's center. The transient nature of convection within this inner band, potentially due to detrimental mid-level dry air entrainment, also suggests that this inner band was not an eyewall.

A more complete analysis of this inner banding feature, using data from microwave satellite imagery, Doppler wind velocities from KMOB and KLIX WSR-88D radars, and SFMR, GPS dropsonde and flight-level data from reconnaissance aircraft will be presented at the 67th IHC Conference.

A Highly Configurable Vortex Initialization Method for Tropical Cyclones

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A highly configurable vortex initialization methodology has been constructed in order to permit manipulation of the initial vortex structure in numerical models of tropical cyclones. By using distinct specifications of the flow in the boundary layer and free atmosphere, an array of parameters is available to modify the structure. The nonlinear similarity model of Foster (2009) is implemented to define the axisymmetric wind structure in the boundary layer. Above the boundary layer, the steady state model of Emanuel (1986) is used to generate the angular momentum distribution in the free atmosphere. In addition, an unbalanced mass-conserving secondary circulation is generated through the assumption of conservation of mass and angular momentum above the boundary layer. Numerical simulations have been conducted using a full-physics mesoscale model to explore the sensitivity of the vortex evolution to different prescriptions of the initial vortex. Dynamical adjustment is found to be dominant in the early evolution of the simulations, thereby masking any sensitivity to initial changes in the secondary circulation and boundary layer structure. The adjustment time can be significantly reduced by arbitrarily, enhancing the moisture in the eyewall region. The efficient software is now available for use by collaborators.

Quantifying Predictability of Environmental Parameters Associated with Tropical Cyclogenesis

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As part of the NSF PREDICT project, ensemble-based products have been developed with a goal to provide improved probabilistic predictions and to increase our quantitative understanding of the predictability of tropical cyclogenesis. First, metrics, such as Predictive Power, are explored for 10-day ECMWF ensemble forecasts to quantify the predictability of fields relevant to genesis, including the low-layer average circulation, local thickness anomaly, vertical wind shear, and divergence. Second, errors and biases in relevant forecast parameters in the SHIPS model for INVEST cases between 2010-2012 are investigated.

Ensemble Kalman Assimilation of Global-Hawk-based Data from Tropical Cyclones

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This study utilizes an ensemble Kalman filter (EnKF) the impact of assimilating observations taken over and around hurricanes from the NASA Global Hawk unmanned airborne system. The EnKF has recently proven to be an effective tool for initializing hurricane vortices, and the Global Hawk flies above hurricanes and has the benefit of a 25-30-h flight duration, which is two to three times that of conventional aircraft. The long duration of the Global Hawk gives it a much larger range and on-station capabilities than conventional aircraft, making it a desirable addition to other observing platforms. Observations of interest include radial velocity from the

High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), Advanced Vertical Atmospheric Profiling System (AVAPS) dropsondes, and water vapor and temperature profiles from the scanning High-resolution Interferometer Sounder (S-HIS). We will examine the impact of assimilating thinned "super observations" in terms of analysis accuracy and forecast improvement as a result of assimilation.

Azimuthal Variation in the Eyewall's Surface-Wind Speed May Increase Maximum Potential Intensity

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A common approach to estimating a hurricane's maximum potential intensity (MPI) is to calculate the maximum surface-wind speed possible by balancing a fraction of the input enthalpy flux against the ocean-surface frictional energy loss at the maximum surface-wind speed. A limitation of this method is that boundary-layer air does not always rise in an eyewall updraft immediately upon reaching the radius of maximum wind nor does more than a tiny fraction of the eyewall have surface-surface winds equal to the hurricane's maximum surface wind. Previous studies have shown that the strong updrafts that contribute most of the upward mass flux in the eyewall are concentrated in only about 10% of the eyewall's area. Similarly, the wind speed at some locations at the radius of maximum wind is known to fall short of the hurricane's intensity by 5 m s^{-1} or more, a difference that can be comparable to the forward speed of the hurricane.

As boundary-layer air parcels approach eyewall updrafts, they experience both enthalpy flux and ocean-surface friction along paths where the wind speed is less than the hurricane's intensity. If the balance of enthalpy flux and frictional loss are integrated along these paths in the eyewall boundary layer rather than at the point of maximum wind, then one arrives at an increased estimate of the hurricane's maximum potential intensity. This "path-integration boost" is a simple consequence of frictional loss decreasing rapidly with the cube of wind speed while input enthalpy flux changes less, decreasing only linearly with wind speed. In other words, integrating over the actually wind speeds experienced by air parcels increases the flow of energy into the hurricane above what would occur if all air parcels passed through the high-friction conditions at the maximum wind speed.

Path integration of enthalpy and frictional flux in both an idealized and in a simulated wind field suggests that maximum potential intensity can increase by 3% to 18% over the maximum potential intensity calculated at just the maximum wind speed.

Previous studies have found that a few percent of hurricanes exceed their so-called maximum potential intensity by up to 10% and on rare occasions by much more. During the past decade, great effort has been expended to justify increasing maximum potential intensity by increasing the hurricane's efficiency above that of a Carnot engine, by reducing the coefficient of friction at the ocean surface, or by finding an additional energy source for the hurricane in the eye's boundary layer. The advantage of the just-proposed path-integration boost is that it is a straightforward consequence of the surface wind field having azimuthal variations around the eyewall, as is generally the case when the hurricane is not stationary or when there is non-negligible wind shear. The authors invite comments on whether path-integration may improve MPI estimates. The associated poster can be viewed at http://mason.gmu.edu/~okelley .

Tropical Cyclone Inner-Core Structure from Downward-Pointing, Conically-Scanning Airborne Doppler Radar: IWRAP and HIWRAP

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Wind retrieval algorithms for downward-pointing, conically-scanning airborne Doppler radars will be described and their error characteristics documented using a simulator. The first radar, called the Imaging Wind and Rain Airborne Profiler (IWRAP), is a dual-frequency (C- and Ku-band), multiple incidence angle system scanning at 60 RPM with range gates of 30 meters. IWRAP has been flying on the NOAA P3 aircraft for several years. The second radar, called the High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), operates at Ku- and Ka-band, has two incidence angles and scans at 16 RPM with current range gates of 150 meters. HIWRAP is new and flew on the Global Hawk aircraft for the first time in 2010 during the GRIP experiment. Both radars complement each other well. For example, while HIWRAP samples the full troposphere with an aircraft altitude of ~ 20 km and IWRAP only measures the lower levels of the storm (~ 2 – 4 km), IWRAP measurements have higher resolution allowing turbulent structures to be captured.

Real data examples of wind retrievals from IWRAP and HIWRAP will be shown revealing the unique structure of a concentric eyewall case in Hurricane Isabel (2003), the intensification of Hurricane Karl (2010), and the development of Tropical Storm Matthew (2010). The ability of the HIWRAP radar to detect circulation centers and fill voids in satellite data will be discussed.

Aerosols-Cloud-Microphysics Interactions in Tropical Cyclones using Aircraft Observations and the WRF-ARW model

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Cloud microphysics processes are factors influencing tropical cyclones evolution. Questions remains unanswered about the role of aerosols (e.g. dust, sulfates and sea salt) in those processes. For example: What is the link between dust and cloud microphysics quantities? How efficient are the aerosols (i.e. dust) as a cloud condensation nuclei (CCN) and ice nuclei (IN) source and in which regions? Does dust affect precipitation rates? What are the dominant factors and in which sectors of the tropical cyclone? Does aerosols-cloud-microphysical processes has a positive or negative influence on hurricane formation and development? To address some of the questions in-situ microphysics measurements from the NASA DC-8 aircraft were obtained during the GRIP 2010 field campaign. A total of four named storms (Earl, Gaston, Karl and Mathew) were sampled. Earl presented the excellent opportunity to study aerosols-cloud-microphysics interactions.

To assist in the interpretation of the microphysics observations, high resolution numerical simulations of Hurricane Earl were performed using the Weather Research and Forecasting (WRF-ARW) model with the new Aerosol-Aware bulk microphysics scheme. This new version of Thompson scheme includes explicit activation of cloud condensation nuclei (CCN) from a major CCN source (i.e. sulfates and sea salt) and explicit ice nucleation (IN) from mineral dust. Two simulations are performed: (1) *Control case* with the old Thompson scheme and (2) *Aerosol-Aware case* with the new microphysics scheme. Preliminary results of model simulations will be presented along with aircraft observations.

The Impact of Ocean Heat Content Observations Collected during Operational Weather Reconnaissance Flights on SHIPS Intensity Forecasts in Hurricanes Ernesto and Isaac (2012)

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The second year of the Hurricane AXBT Demonstration Project has been completed, and here we present the impact of ocean heat content (OHC) observations on the Statistical Hurricane Intensity Prediction System (SHIPS) forecasts during Hurricanes Ernesto (over the Caribbean Sea) and Isaac (over the Caribbean Sea and Gulf of Mexico). Observed values of OHC were determined using thermal profile data from AXBTs released from USAF Hurricane Hunter WC-130J aircraft during operational missions. The impacts of these observations on SHIPS forecast intensities were compared to those determined using model values of the OHC predictor as provided by the Navy Coupled Ocean Data Assimilation (NCODA) system. Refinement of the evaluation technique following the 2012 field season includes the incorporation of Decay SHIPS during landfall periods and an initial evaluation of uncertainty due to instrument error.

Development of a new Tropical Cyclone Verification Toolkit (MET-TC)

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As part of the Hurricane Forecast Improvement Project (HFIP), the Developmental Testbed Center (DTC) has developed a new set of tools to aid in tropical cyclone forecast evaluation and verification. Model Evaluation Tools – Tropical Cyclone (MET-TC) has been developed to replicate the functionality of the current National Hurricane Center (NHC) verification software. The MET-TC code is designed to be modular, allowing additional capabilities and features to be added in future releases. This toolkit provides a standard set of verification metrics and comprehensive output statistics, which can be used for homogeneous comparisons of operational and experimental track and intensity forecasts. The main functions of the code are to compare Automated Tropical Cyclone Forecast (ATCF) format files, compute pair statistics from independent model input or user-specified consensus forecasts, filter pair statistics based on user specifications, and compute summary statistics. Filtering criteria and available statistics replicate those within the current NHC verification software. MET-TC utilizes the MET software framework and will be available as an open source community verification package through the DTC. In addition, email support and tutorials will be provided to aid users in the application of the software. An important benefit of the software is its availability to all users, which will enable consistent forecast evaluation studies to be undertaken across the community. The official release of the MET-TC code, documentation, and graphical capabilities will be included with MET v4.1 which will be released in spring 2013. This presentation will highlight the capabilities of the MET-TC toolkit and present results demonstrating the ability to replicate results from the NHC software using the 2012 HFIP retrospective cases. Possible future enhancements to the software will also be discussed.

A Developmental Framework for Improving Hurricane Model Physical Parameterizations Using Aircraft Observations

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As part of NOAA's Hurricane Forecast Improvement Program (HFIP), this talk presents the important role of aircraft observations in hurricane model physics validation and improvement. A model developmental framework for improving the physical parameterizations using quality-controlled and post-processed aircraft observations is presented, with steps that include model diagnostics, physics development, physics implementation and further evaluation. Model deficiencies are first identified through model diagnostics by comparing the simulated axisymmetric multi-scale structures to observational composites. New physical parameterizations are developed in parallel based on in-situ observational data from specially designed hurricane field programs. The new physics package is then implemented in the model, which is followed by further evaluation. The developmental framework presented here is found to be successful in improving the surface layer and boundary layer parameterization schemes in the operational Hurricane Weather Research and Forecast (HWRF) model. Observations for improving physics packages other than boundary layer scheme are also discussed.

The 48-hour NESDIS Tropical Cyclone Formation Probability Product

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The NESDIS Tropical Cyclone Formation Probability (TCFP) product was developed in 2005 in response to the need for objective, real-time guidance to aid in the prediction of tropical cyclone (TC) formation. The TCFP product uses values from the GFS analysis fields, such as the vertical shear of the wind and vertical instability, in combination with geostationary satellite water vapor brightness temperatures, Reynolds sea surface temperature, and climatology to determine the probability of TC formation over a global tropical domain (45° S to 45° N). The current TCFP product provides 24-hour probabilities of TC formation. However, the National Hurricane Center Tropical Weather Outlook discusses the potential for TC development within the next 48 hrs. In order to provide timely objective guidance to forecasters, a 48-hr TCFP product has been developed. In addition to the inputs used by the current TCFP, the 48-hr TCFP uses GFS forecast fields to determine the probability of TC formation within 500 km of a point within the next 48 hours. An overview of the product algorithm and preliminary validation results will be presented, as well as plans for operational implementation.

DISCLAIMER: The views, opinions, and findings in this report are those of the authors and should not be construed as an official NOAA and/or U.S. Government position, policy, or decision.

The JPL Tropical Cyclone Information System – A Tool for Hurricane Research, Model Evaluation and Satellite Algorithm Development: Current State and Ongoing Development

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In spite of recent improvements in hurricane track forecast accuracy, currently there are still many unanswered questions about the physical processes that determine hurricane genesis, and evolution. Furthermore, a significant amount of work remains to be done in validating and improving hurricane models, developing satellite retrieval algorithms and validating the geophysical estimates from the remote-sensing observations. None of this can be accomplished without a comprehensive set of multi-parameter observations. Despite the significant amount of satellite observations today, they are still underutilized in hurricane research and operations, due to complexity and volume.

To facilitate hurricane research, we developed the JPL Tropical Cyclone Information System

(**TCIS**) of multi-instrument satellite observations pertaining to: i) the thermodynamic and microphysical structure of the storms; ii) the air-sea interaction processes; iii) the larger-scale environment. The JPL TCIS (http://tropicalcyclone.jpl.nasa.gov) has two main components: i) an archival database of satellite observations (**TCIS-DA**); ii) a Near-Real-Time (**TCIS-NRT**) portal that combines the satellite observations with model forecasts and airborne data.

This presentation will describe each of the two components and will compare and contrast their features. It will use examples, including observations of hurricane Sandy, to illustrate how the TCIS can help further hurricane research. Finally, the presentation will outline our current efforts to provide fusion of models and observations through the use of instrument simulators and the development of advanced analysis tools.

The **JPL TCIS DA** (http://tropicalcyclone.jpl.nasa.gov/hurricane/gemain.jsp) presents the satellite depiction of hurricanes over the globe during the period 1999-2010, offering both data and imagery. It provides a one-stop place to obtain an extensive set of data, organized in an easy way to determine when coincident observations from multiple instruments are available. All this makes the TCIS-DA a unique source to support hurricane research, forecast improvement and algorithm development. The **JPL TCIS-NRT** portal has two instances (http://grip.jpl.nasa.gov and hs3.jpl.nasa.gov). In both cases, the portal integrates model forecasts over the Atlantic with satellite and airborne observations from a variety of instruments and platforms, providing good spatial and temporal context for the high-resolution, but limited in space and time, airborne observations. Such architecture provides essential knowledge for the design of field experiments and serves as a very rich information source during the analysis stages. Furthermore, the TCIS-NRT framework allows interrogation of a large number of atmospheric and ocean variables to better understand the large-scale and storm-scale processes associated with hurricane genesis, track and evolution.

Under a recently-funded NASA/ESTO/AIST project we are now working toward developing the technology to provide fusion of satellite observations and operational model forecasts. Our objectives are: i) to integrate an instrument simulator ($NEOS^3$) with operational hurricane forecast models and to incorporate the simulated satellite observables into the existing database of satellite and airborne observations; ii) to develop a set of advanced analysis tools; iii) to develop technology to enable real-time interaction with the models and visualization of highly complex systems. The ultimate goal of this three-year effort is to develop a toll that will facilitate the near-real-time comparison between modes and observations, creating robust statistics of the ability of the model to represent the storm structure, intensity and interactions with the environment.

Community Support and Testing of the Hurricane WRF Model at the Developmental Testbed Center

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The Developmental Testbed Center (DTC) plays a critical and unique role in linking research and operations. DTC is a distributed facility that serves as a bridge between research and operations, creating an environment in which the Numerical Weather Prediction (NWP) community can test and evaluate new models and techniques for use in both. Through partnership with NOAA's Environmental Modeling Center (EMC), the DTC transfers new technology to the Hurricane Weather Research and Forecasting (HWRF) model.

To facilitate the contributions of the research community to operational forecast, DTC manages a single HWRF code base and provides its support to both the research community and HWRF code developers.

There are currently 518 registered HWRF users from 45 countries. The last release of HWRF (v3.4a) was done in August 2012, and it contains the capabilities of the 2012 operational HWRF model, including the Princeton Ocean Model for Tropical Cyclones and a variational data assimilation system. The code is available for download from the DTC website, along with extensive documentation, tutorial and test datasets. A benchmark of the code will be presented, in order to make public the skill in track and intensity forecast of the community HWRF.

The DTC also provides support to HWRF developers from multiple institutions (National Weather Service, NOAA Research and universities) in using the latest research configurations of the code through a code repository hosted by the DTC. Accessing the code in this way allows developers to work in state-of-the-art code and to deliver their contributions back to operation.

In addition to providing support, the DTC has also established a functionally-similar testing infrastructure. Several extensive testing and evaluation activities have been conducted using the DTC infrastructure. The tests include the sensitivity of HWRF to ocean flux truncation, the impact of the cumulus parameterization schemes on HWRF forecast, sensitivity experiments with an alternative microphysics scheme to increase the interoperability of HWRF, etc. The result from these tests will be presented. The conclusions from these tests played an important role in the implementation of HWRF operation upgrades. DTC is currently seeking input and suggestions with regard to the candidates for testing that could potentially help improve the operational hurricane forecast. DTC welcomes collaborations in choosing and conducting these tests.

Towards a Modular Approach to Tropical-Cyclone Structure: Support of Global Hawk Missions

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Intensity forecasting is currently pursued by so-called regional (or local-area) models that sequester for examination a volume of the troposphere containing the tropical cyclone of interest. One widely pursued approach to applying a local-area model to the goal of intensity forecasting involves direct numerical integration of a boundary/initial-value problem expressing a fundamentals-based formulation of the physics. Comprehensiveness (inclusiveness) of a formulation is invariably regarded as a key figure of merit in assessing its merit. Another, quite distinct, relatively simplistic approach entails developing semi-empirical (statistical) correlations of key output properties with input parameters, by use of historical tropical-cyclone records, which may be categorized by location, date, intensity, etc.

Intermediate to these two antipodal approaches, and well suited to bridging them, lies a semi-analytic/semi-numerical option that is based on an approximate asymptotic method of modern higher analysis. For more than a century, the technique, known to mechanical engineers as boundary-layer theory, and to applied mathematicians as limit-process expansions, has beneficially addressed multi-scale phenomena arising in a wide variety of practical contexts. However, the technique has been little applied to investigate the structure of tropical cyclones of at least depression strength.
Specifically, the approach subdivides the structure of a tropical cyclone into a minimal number of modules, each distinct because a unique subset of physical processes and spatial gradients predominate within it. Adopting locally appropriate scalings of a uniformly valid, non-dimensionalized formulation retains just those processes and gradients that are truly essential for a lowest-order quantitative description of each module. Enforcing continuity of dependent–variable fields and fluxes at the interfaces between contiguous modules fuses the local solutions for individual modules into a composite solution for the tropical cyclone.

For a tropical storm, three distinct modules arise in the small-Ekman-number asymptotic limit: the bulk vortex; the near-ocean-surface boundary layer; and the core of the vortex. To these is added a fourth module, the eye, for a hurricane. We focus on the dynamic and thermodynamic exchanges between modules for an open-lateral-boundary, steady, axisymmetric treatment of a local-area model. We take cognizance of the reduced predictability horizon that is physically accessible for highly convective atmospheric phenomena. Particular attention is given to a substructure that evolves within the high-speed portion of the boundary-layer module…and to its importance for achieving an adequate storm-surge model.

Most importantly, we suggest that this approach should meet the evident need for a fast-running, flexible, portable, relatively transparent, readily modified model can support observational-mission planning: what should the sensors on a Global Hawk be looking at, and what should they be looking for, in near-term support of operational forecasting of tropical-cyclone intensity. That some models be dedicated to serving observations, as opposed to observations being often relegated to serving models, seems overdue in the tropical-cyclone-research planning.