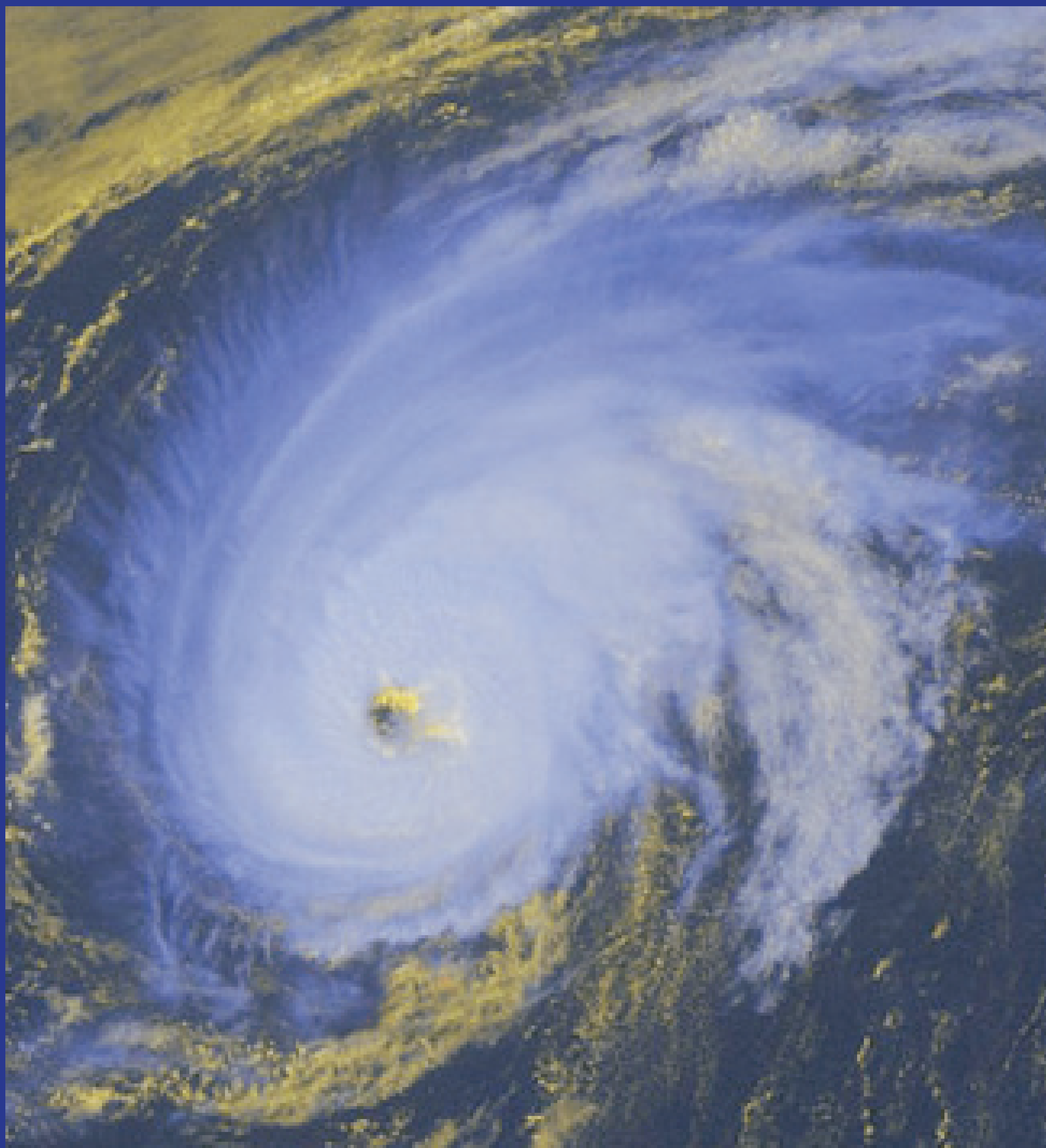
61st Interdepartmental Hurricane Conference



The Nation's Hurricane Program: An Interagency Success Story

March 5-9, 2007
New Orleans, LA

61st Interdepartmental Hurricane Conference

The Nation's Hurricane Program: An Interagency Success Story

AGENDA

Monday, March 5, 2007

9:00 AM Early Registration *(9:00 a.m.-12:30 p.m.)*

Opening Session

12:30 PM Welcome — Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

12:35 PM Welcoming Remarks — Colonel Terry J. Ebbert, USMC (Ret.)
Director of Homeland Security, City of New Orleans

12:45 PM Opening Remarks — Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

1:00 PM Keynote Address — VADM Conrad C. Lautenbacher, Jr., USN (Ret.)
Under Secretary of Commerce for Oceans and Atmosphere/ NOAA Administrator

1:20 PM Special Remarks on behalf of Governor Kathleen Babineaux Blanco
Brigadier General Hunt Downer
Assistant Adjutant General, Louisiana National Guard

1:35 PM Panel Introduction — Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

1:40 PM Panel: **Interagency Strategic Research Plan for Tropical Cyclones—A View from the Top**

Moderator: Dr. Robert Serafin, NCAR Director Emeritus

Panelists:
- Dr. Richard Spinrad, Assistant Administrator for Oceanic and Atmospheric Research, NOAA
- Dr. Jack Kaye, Associate Director for Research, Earth Science Division, NASA Headquarters
- Dr. Stephan Nelson, Program Director, Physical and Dynamic Meteorology, NSF
- Mr. William Curry, Deputy Technical Director, Oceanographer of the Navy

Mr. X. William (Bill) Proenza, Director, Tropical Prediction Center/National Hurricane Center, NOAA/NWS

3:10 PM Introduction of Federal Agency Lead Representatives — Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

3:30 PM Afternoon Coffee/Soda Break *(3:30-4:00 p.m.)*

Session Coordinator: Mr. Robert Dumont (OFCM)

Session 1: The 2006 Tropical Cyclone Season in Review

Session Leaders: Dr. Edward Rappaport (TPC/NHC) and
CAPT John O'Hara (NMFC/JTWC)

4:00 PM Overview of the 2006 Atlantic Hurricane Season
Richard D. Knabb (TPC/NHC); and D. Brown

4:15 PM 2006 Eastern North Pacific Hurricane Season Summary
Richard J. Pasch (TPC/NHC); and E. Blake

4:30 PM 2006 Atlantic and Eastern North Pacific Forecast Verification
James L. Franklin (TPC/NHC)

4:45 PM Overview of the 2006 Central North Pacific Tropical Cyclone Season
James Weyman (CPHC); and A. Nash

5:00 PM A Review of the Joint Typhoon Warning Center 2006 Tropical Cyclone Season
Edward M. Fukada (JTWC)

5:15 PM 53 WRS 2006 Hurricane Season Reconnaissance Summary
Lt Col Rich Harter (53 WRS)

5:30 PM NOAA Aircraft Operations Center (AOC) 2006 Season Summary and Future Plans
James D. McFadden (NOAA AOC); and J. Parrish

6:30 PM Reception/Icebreaker *(6:30-8:00 p.m.)*

Tuesday, March 6, 2007

7:00 AM Continental Breakfast

7:50 AM Opening/Administrative remarks — Dr. Paul Try (OFCM/STC)
Session Coordinator

Tuesday morning, 8:00-10:00 a.m.

Session 2: Workshop: Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead

Moderator: Dr. Paul D. Try, Senior Vice President, Science and Technology Corporation
Rapporteurs: Ms. Mary Cairns (OFCM) and Mr. Floyd Hauth (OFCM/STC)

Panelists:
Mr. Mark Welshinger, OFCM
Dr. Frank Marks, HRD
Dr. Ramesh Kakar, NASA
Dr. Naomi Surgi, NCEP
Dr. Richard Hodur, NRL-Monterey
Dr. Isaac Ginis, University of Rhode Island

10:00 AM Morning Coffee Break *(10:00-10:30 a.m.)*

Tuesday morning, 10:30 a.m.-12:00 p.m.

Session 3: Observations and Observing Strategies, Part 1

Session Leaders: Ms. Robbie Hood (NASA/MSFC) and Dr. Peter Black (NOAA/HRD)
Rapporteur: Dr. Mark Weadon (OFCM/STC)

10:30 AM Double (Concentric) Eyewalls in Hurricane Katrina at Landfall: A Key to the Storm's Huge Size and Devastating Impact over a Three-State Coastal Region
Keith G. Blackwell (Univ. of South Alabama); and P. Fitzpatrick, C. Velden, and T. Wimmers

10:45 AM Texas Tech University's Rapid Deployment Surface Observing System
Ian M. Giammanco (Texas Tech University); and J. Schroeder and B. Hirth

11:00 AM Observations of the Coastal Oceanic Response to Hurricane Ivan: Implications for Hurricane Intensity Change
Lynn K. Shay (RSMAS/UM); and G. Halliwell and W. Teague

11:15 AM Status of Transitioning the SFMR from Research to Operations on the WC-130J
Lt Col Jonathan Talbot (53 WRS)

11:30 AM Toward an Integrated Air-Sea Real-Time Airborne Observing System for Landfalling Hurricanes
Peter G. Black (HRD); and J. Gamache, E. Uhlhorn, E. Walsh, P. Chang, I. Popstefanija, J. Carswell, A. Goldstein, and R. Lumpkin

11:45 AM CIMSS Satellite Consensus (SATCON) Tropical Cyclone Intensity Estimation Algorithm
Derrick Herndon (CIMSS); and C. Velden

12:00 PM Lunch (on your own) *(12:00 p.m.-1:30 p.m.)*

Session Coordinator: Dr. Mark Weadon (OFCM/STC)

Tuesday afternoon, 1:30-3:00 p.m.

Session 4: Observations and Observing Strategies, Part 2

Session Leaders: Dr. Jim McFadden (NOAA/AOC) and
Mr. Jeffrey Hawkins (NRL-Monterey)
Rapporteur: Mr. Tony Ramirez (OFCM/STC)

1:30 PM Mobile Ground-Based Observations of Landfalling Hurricanes: Current Capabilities and Future Plans
Kevin Knupp (Univ. of Alabama/Huntsville); and W. Peterson and D. Cecil

1:45 PM NASA High-Altitude Precipitation/Wind Radars for Hurricane Research
Gerald Heymsfield (NASA/GSFC); and L. Li, J. Carswell, D. Schaubert, and J. Cretico

2:00 PM Potential Applications of the Proposed Phased Array Doppler Radar on the NSF/NCAR C-130 in Hurricane Reconnaissance
Wen-Chau Lee (NCAR); and J. Vivekanandan, E. Loew, and J. Moore

2:15 PM The Operational Impact of and Future Requirements for Satellite Ocean Vector Winds in Tropical Cyclone Analysis
Michael J. Brennan (TPC/NHC); and R. Knabb, P. Chang, J. Sienkiewicz, Z. Jelenak, and K. Schrab

2:30 PM Development of the Hurricane Imaging Radiometer (HIRAD) Using a Systems Engineering Approach
Robbie Hood (NASA/MSC); and R. Amarin, M. Bailey, P. Black, M. James, J. Johnson,L. Jones, B. Lim, C. Ruf, K. Stephens, and V. Rohwedder

2:45 PM Baseline Instruments for the GOES-R Series: Providing Major Improvements to Hurricane Observations
Thomas M. Renkevens (NESDIS); and J. Gurka, T. Schmit, and M. DeMaria

3:00 PM Afternoon Break *(3:00- 3:30 p.m.)*

Tuesday afternoon, 3:30-4:30 p.m.

Session 5: Modeling and Forecasting Intensity, Structure, Sea State, and Track: Prospects for the 2007 Season and Beyond, Part 1

Session Leaders: Dr. Mark DeMaria (NESDIS) and
Dr. Elizabeth Ritchie (University of Arizona)
Rapporteur: Mr. Mark Gunzelman (OFCM/STC)

3:30 PM Advanced Hurricane Prediction at NCEP's Environmental Model Center: The Operational Implementation of the HWRF
Naomi Surgi (NCEP)

3:45 PM Transition of GFDL Hurricane Prediction System to HWRF: A JHT-Funded Project
Morris A. Bender (GFDL); T. Marchok, I. Ginnis, B. Thomas, and R. Tuleya

4:00 PM Hurricane Model Transitions to Operations at NCEP/EMC: A JHT-Funded Project
Robert E. Tuyela (NCEP); and S. Gopalkrishnan, V. Tallapragada, Y. Kwon, and N.Surgi

4:15 PM Ocean Initialization System for Coupled Hurricane-Ocean Models and its Transition to HWRF
Isaac Ginis (University of Rhode Island); and R. Yablonsky

4:30 PM Evaluation of the Simulated Oceanic Response to Hurricane Ivan in Comparison to High-Quality Ocean Observations
George R. Halliwell (RSMAS/UM); and L. Shay and W. Teague

Tuesday afternoon, 4:45-5:15 p.m.

One-Minute Poster Previews
Coordinator: Colonel Michael Babcock (Assistant Air Force Deputy to NOAA)

5:15 PM **OFCM Staff Meeting** *(5:15-5:45 p.m.)*

5:30 PM **Poster Session** *(5:30-7:30 p.m.)* Plus Snacks and Cash Bar

P01 Application of TRMM Multi-Satellite Precipitation Analysis and MODIS Aerosols to Hurricane Studies
Scott A. Braun (NASA/GSFC)

P02 Verification of the National Hurricane Center's Atlantic and Eastern Pacific Tropical Weather Outlooks
Daniel P. Brown (TPC/NHC); and J. Rhome

P03 Introduction of an Inundation Analysis of Hurricanes Ivan, Dennis, and Katrina
Kathleen Egan (NOS/CO-OPS); and L. Huang and L. Fenstermacher

P04 NOS Storm Surge Partnership Project: Improving Gulf Coast Storm Surge Modeling, Tools, and Methodologies
Jesse Feyen (NOS); and F. Aikman, D. Marcy, E. Myers, J. Woolard, S. White, L. Dingerson, and J. Towers

P05 A Comparison of COSMIS, AIRS, Terra, and Aqua Temperature and Moisture Profiles against Dropsondes in 2006 Atlantic Tropical Cyclones
Pat Fitzpatrick (Mississippi State University); and Y.Lau, S. Bhate, and C. Hill

P06 The HRD Hurricane Field Program—2006 and 2007
John Gamache(HRD); and J. Dunion, J. Cione, and E. Uhlhorn

P07 Contributions of Satellite Microwave Data to Hurricane Research and Operations
Kyle Hilburn (Remote Sensing Systems); and C. Gentemann, D. Smith, and F. Wentz

P08 Improvements in QuikSCAT Near-Real-Time Wind Processing Implemented at NOAA/NESDIS
Zorana Jelenak (NESDIS); and P. Chang and M. Brennan

P09 The University of South Alabama Center for Hurricane Intensity and Landfall Research
Systke K. Kimball (Univ. of South Alabama); and P. Black, N.Surgi, and J. Proni

P10 Structure and Evolution of Rainfall in Modeled Hurricanes at Landfall
Systke K. Kimball (Univ. of South Alabama)

P11 Introducing the CIRA/NESDIS – Regional and Mesoscale Meteorology Branch Tropical Cyclone Web Page
John A. Knaff (NESDIS/ORA); and M. DeMaria, A. Krautkramer, B. Sampson, and G. Goni

P12 A GIS Analysis of Radar and Surface Wind Data from a Landfalling Hurricane
Corene Matyas (University of Florida)

P13 Visualizing the Temporal and Spatial Extent of Hurricane Storm Surge
Brian McCallum (USGS); and Marge Davenport (presenting) B. McGee, C. Berenbrock, and R. Mason

P14 Implementation of Data Validation Algorithms in the Operational SFMR
Ivan PopStefanija (ProSensing, Inc.); and M. Goodberlet, A. Goldstein, and P. Black

P15 Operational Measurement of Hurricane Surface Waves
Ivan PopStefanija (ProSensing, Inc.); and P. Black

P16 Surface Water and Flood Monitoring of Landfalling Hurricane Precipitation Using Airborne Passive Microwave Technology
Courtney R. Radley (University Space Research Association); and F. LaFontaine, R. Hood, and J. Mels

P17 A New Tropical Cyclone Formation Product: Operational Implementation for the Atlantic and Eastern Pacific in 2006 and Extension to the Western N. Pacific in 2007
Andrea B Schumacher (CIRA); and M. DeMaria, J. Knaff, A. Irving, and N. Merckle

P18 West African Dust Outbreaks and the Relationship with North Atlantic Hurricane Activity
Amato Evan (CIMSS); and C. Velden, and A. Heidinger

P19 Probabilistic Hurricane Forecasts for Risk Management
Thomas Nehrkorn (Atmospheric and Environmental Research, Inc.); and R. Hoffman

Wednesday, March 7, 2007

7:00 AM Continental Breakfast

7:50 AM Opening/Administrative Remarks — Lt Col David Andrus (OFCM/USAF) Session Coordinator

Wednesday morning, 8:00-9:30 a.m.

Session 6: Modeling and Forecasting Intensity, Structure, Sea State, and Track: Prospects for the 2007 Season and Beyond, Part 2

Session Leaders: Dr. Naomi Surgi (NCEP) and Dr. Nick Shay (RSMAS/UM)
Rapporteur: Dr. Mark Weadon (OFCM/STC)

8:00 AM Diabatic Digital Filter Initialization for Tropical Cyclone Model Forecasting
Chi-Sann Liou (NRL-Monterey)

8:15 AM Prediction of Consensus TC Track Forecast Error and Correctors to Improve Consensus TC Track Forecasts
James S. Goerss (NRL-Monterey)

8:30 AM Performance of the ECMWF High-Resolution Global Model and its Impact on Consensus during the 2006 Northern Hemisphere Season
Michael Fiorino (TPC/NHC)

8:45 AM Operational Implementation of an Objective Annular Hurricane Index
Andrea B. Schumacher (CIRA); and J. Knaff, T. Cram, M. Demaria, and J. Kossin

9:00 AM A Technique to Predict the Extratropical Transition of Tropical Cyclones
Elizabeth A. Ritchie (University of Arizona); and J. S. Tyo and O. Demirci

9:15 AM Understanding Wind/Wave Forcing of the St. Johns River
Scott C. Hagen (University of Central Florida); and Y. Funaksohi and A. Cox

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

<u>Wednesday morning, 10:00-11:30 a.m.</u>

Session 7: Damaging Winds, Precipitation, and Storm Surge: Physical and Socioeconomic Impacts of Landfalling Storms

Session Leaders: Dr. Abby Sallenger (USGS) and Mr. Todd Davison (NOS/CSC)
Rapporteur: Mr. Mark Gunzelman (OFCM/STC)

10:00 AM Hurricane Damages 1900 to 2005 – Why Do the Losses Keep Going Up?
Roger Pielke Jr. (University of Colorado); and Chris Landsea (presenting) and J.Gratz

10:15 AM Interagency Coordination in Hurricane Wind and Storm Surge Hazard Reduction
John Gaynor (NOAA/OAR)

10:30 AM Storm Surge/Flooding Disaster Mitigation
Joseph W. Swaykos (University of Southern Mississippi)

10:45 AM Barrier Island Failure during Hurricane Katrina
Asbury H. Sallenger, Jr. (USGS); and C. Wright and J. Lillycrop

11:00 AM NOAA’s Response to Hurricane Impacts on Ports, Harbors, Navigation Channels and the Surveying for Debris and Hurricane Hazards that Pose a Risk to Commercial Fishing, Shrimping, and Recreational Boating
Tim Osborn (NOAA Office of Coast Survey); and E. Martin, P. Fink and C. Moegling

11:15 AM Using GIS to Map the Impacts of Marine Debris Left in the Wake of Hurricane Katrina
Brendan M. Bray (NOS)

11:30 AM Lunch (on your own) *(11:30 a.m.-1:00 p.m.)*

Session Coordinator: Colonel Michael Babcock (Assistant Air Force Deputy to NOAA)

Wednesday afternoon 1:00-4:30 p.m.

Session 8: Research to Operations: The Latest on the Joint Hurricane Testbed and Future Plans

Session Leaders: Dr. Chris Landsea (TPC/NHC) and Ms. Shirley Murillo (HRD)
Rapporteurs: Ms. Mary Cairns (OFCM) and Mr. Floyd Hauth (OFCM/STC)

1:00 PM Joint Hurricane Testbed (JHT): 2006 Update
Jiann-Gwo Jiing (TPC/NHC); and C. Landsea and S. Murillo

1:15 PM Development and Implementation of NHC/JHT Products in ATCF
Charles R. (Buck) Sampson (NRL-Monterey)

1:30 PM Assimilating Moisture Information from Global Positioning System (GPS) Dropwindsondes into the NOAA Global Forecast System
Jason P. Dunion (HRD); and S. Aberson

1:45 PM Verification of the Monte Carlo Tropical Cyclone Wind Speed Probabilities: A Joint Hurricane Testbed Project Update
John A. Knaff (NESDIS/ORA); and M. DeMaria and C. Lauer

2:00 PM Tropical Cyclone Wind Radii Estimation Utilizing an Empirical Inland Wind Decay Model
John Kaplan, (HRD); and M. DeMaria, N. Carrasco, and J. Dunion

2:15 PM VORTAC—A Utility to Deduce Central Pressure and Radius of Maximum Wind of Landfalling Tropical Cyclones Using WSR-88D Data
Wen-Chau Lee (NCAR); and P. Harasti and M. Bell

2:30 PM Afternoon Break (2*:30-3:00 p.m.)*

3:00 PM Mapping of Topographic Effects of Maximum Sustained Surface Wind Speeds in Landfalling Hurricanes
Craig Miller (Univ. of Western Ontario)

3:15 PM Operational SFMR-NAWIPS Airborne Processing and Data Distribution Products
James Carswell (Remote Sensing Solutions); and P. Chang, T. Mavor, P. Black, and E. Uhlhorn

3:30 PM Improved Statistical Intensity Forecast Models: A Joint Hurricane Testbed Project Year 2 Progress Report
Mark DeMaria (NESDIS/ORA); and J. Knaff and J.Kaplan

3:45 PM Eastern Pacific Ocean Heat Content Estimates for SHIPS Forecasting
Lynn K. Shay (RSMAS/UM) and J. Brewster

4:00 PM Statistical Hurricane Intensity Prediction Scheme with Microwave Imagery (SHIPS-MI): Results from 2006
Daniel J. Cecil (Univ. of Alabama/Huntsville

4:15 PM Drag Coefficient Distribution and Wind Speed Dependence in Tropical Cyclones
Mark D. Powell (HRD); and Frank Marks (presenting)

5:15 PM **OFCM Staff Meeting** *(5:15-5:45 p.m.)*

Conference Banquet

7:00 PM **Banquet** (Cash Bar at 6:30 p.m.)

7:45 PM **Banquet Address**: **Mr. John M. Barry**, Best-Selling Author, 2006 Abel Wolman Lecturer about Hurricane Katrina, and Distinguished Visiting Scholar at the Center for Bioenvironmental Research of Tulane and Xavier Universities

Presentation of the Hagemeyer Award

Thursday, March 8, 2007

7:00 AM Continental Breakfast

7:50 AM Opening/Administrative Remarks — Mr. Floyd Hauth (OFCM/STC)
Session Coordinator

<u>Thursday morning, 8:00-9:30 a.m.</u>

Session 9: Decision-making Products and Services

Session Leaders: Mr. Paul Trotter, (NWS WFO New Orleans/Baton Rouge) and
Mr. Scott Kiser (NWS)
Rapporteur: Mr. Tony Ramirez (OFCM/STC)

8:00 AM The Automated Tropical Cyclone Forecast System (ATCF): An Interagency Success Story
Stephen Barlow (JTWC) and Chris Sisko (TPC/NHC)

8:15 AM Long-Term Trends in National Hurricane Center Watches and Warnings
Mark DeMaria (NESDIS/ORA); and J. Franklin

8:30 AM When Hurricanes Strike: Interagency Requirements for Agricultural Assessments
Brad Rippey (USDA)

8:45 AM Operational Tropical Cyclone Wind Speed Probability Products
Richard D. Knabb (TPC/NHC)

9:00 AM Exploring the Concept of a Graphical Tropical Weather Outlook
Jamie R. Rhome (TPC/NHC); and D. Brown

9:15 AM NOAA’s Seasonal Hurricane Forecasts: Climate Factors Influencing the 2006 Season and a Look Ahead for 2007
Eric Blake (TPC/NHC); and G. Bell, M. Chelliah, T. Kimberlain, C. Landsea, R. Pasch, and S. Goldenberg

9:30 AM Morning Coffee Break *(9:30-10:00 a.m.)*

<u>Thursday morning, 10:00 a.m.-12:00 p.m.</u>

Session 10: Workshop: Hazard Risk Reduction through Stronger Partnerships and Alliances

Moderator: Mr. Bryan Norcross, Director of Meteorology, WFOR, CBS4, Miami, Florida
Rapporteurs: Dr. Betty Hearn Morrow (OFCM/STC) and Ms. Naomi Moye (OFCM/STC)

Panelists: Mr. Kenneth Graham, Chief, Meteorological Services Division, Office of Climate, Weather, and Water Services, NWS
Mr. Michael Buckley, Deputy Director, Mitigation Division, FEMA
Ms. Marge Davenport, Associate Regional Executive, USGS
Dr. Steve Lyons, Tropical Weather Expert, The Weather Channel
Mr. Walt Dickerson, Director, Mobile County Emergency Management

12:00 PM Lunch (on your own) *(12:00-1:30 p.m.)*

<u>Thursday afternoon, beginning at 1:30 p.m.</u>

1:30 PM Working Group for Hurricane and Winter Storms Operations and Research Meeting
Dr. Edward Rappaport (TPC/NHC), Chairperson

4:00 PM **OFCM Staff Meeting** *(4:00-4:30 p.m.)*

Friday, March 9 2007

7:30 AM Continental Breakfast

Final Plenary Session

8:15 AM Opening/Administrative Remarks — Ms. Mary Cairns (OFCM)
Session Coordinator

8:20 AM WG/HWSOR: Action Item Review — Dr. Edward Rappaport (TPC/NHC)
Chairperson, WG/HWSOR

8:45 AM Workshop Wrap-ups

Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead
Dr. Paul D. Try (OFCM/STC)

Hazard Risk Reduction through Stronger Partnerships and Alliances
Dr. Betty Hearn Morrow (OFCM/STC) and Ms. Naomi Moye (OFCM/STC)

9:15 AM Final Wrap-up — Mr. Samuel P. Williamson, Federal Coordinator

9:45 AM Adjourn

Session 1
The 2006 Tropical Cyclone Season in Review

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Overview of the 2006 Atlantic Hurricane Season

Richard D. Knabb and Daniel P. Brown
NOAA/NWS/NCEP/National Hurricane Center

Tropical cyclone activity during the 2006 Atlantic hurricane season was by most measures very close to long-term averages. The season included 10 tropical storms of which five became hurricanes, including two major hurricanes. All of the hurricane activity occurred during a 37-day period between 27 August and 2 October. The last tropical cyclone activity of any kind also occurred on 2 October; since the beginning of the satellite era (1966), only two Atlantic seasons have ended earlier, with activity in both 1983 and 1993 ending on 30 September. For the first time since the 2001 season, no hurricanes hit the United States. Three tropical storms made landfall in the United States, where the majority of the impacts were associated with Ernesto, causing about $500 million in damages. Ernesto was also directly responsible for five fatalities in Haiti. Elsewhere across the basin, Hurricane Florence impacted Bermuda and Hurricane Gordon affected the Azores.

2006 Eastern North Pacific Hurricane Season Summary

Richard J. Pasch and Eric S. Blake
(Richard.J.Pasch@noaa.gov) and (Eric.S.Blake@noaa.gov)
National Weather Service/National Hurricane Center

Tropical cyclone activity was above average in the eastern North Pacific in 2006. Eighteen tropical storms developed, and ten of these strengthened into hurricanes. Five of the hurricanes intensified into major hurricanes (category 3 or stronger on the Saffir-Simpson Hurricane Scale). Three tropical depressions that did not strengthen into tropical storms also formed during the season. The 2006 season began fairly early, on 27 May, and ended rather late, on 20 November. The season featured several landfalls in Mexico, following two quiet seasons for hurricane strikes there. One major hurricane (Lane), one category 2 hurricane (John), and one tropical depression (Paul) made landfall in Mexico during the season. Also, the outer fringes of Tropical Storms Aletta, Emilia, and Tropical Depression Norman brought locally heavy rains and/or strong gusty winds to portions of Mexico. Thirteen deaths, all in Mexico, have been attributed to tropical cyclones in 2006. Daniel was the strongest hurricane of the season with estimated peak winds near 130 kt; it did not affect any land areas as a tropical cyclone.

2006 Atlantic and Eastern North Pacific Forecast Verification

James L. Franklin
NOAA/NWS/National Hurricane Center

NHC official track forecasts in the Atlantic basin set records for accuracy from 12-72 h in 2006. They consistently beat the individual dynamical guidance models, but trailed the consensus models slightly. Examination of trends suggests that there has been some increase in skill in recent years for the 24-48 h forecasts. Among the operational consensus models, GUNA performed the best overall. The GFDI, GFSI, and NGPI provided the best dynamical track guidance at various times, while the performance of the UKMI trailed considerably. No routinely-available early dynamical model had skill at 5 days. The ECMWF (a late model) performed extremely well, especially at longer times, but it was rarely available in time to be considered by the forecasters. A small improvement in the timeliness of this model would be of great value.

Atlantic official intensity errors were very near the previous 5-year means, but skill levels in 2006 were down sharply. Official errors trailed the GHMI and ICON (a consensus of the GHMI[1] and DSHP) guidance, and had a significant high forecast bias. For the first time, dynamical intensity guidance (GHMI) in 2006 was superior to the statistical DSHP guidance on average.

Official track errors in 2006 for the eastern North Pacific were slightly lower than the 5-year mean errors, but were slightly higher than in 2005. The official forecast beat the individual dynamical models but not the consensus models. The consensus track models GUNA and CONU in the eastern Pacific were substantially better than their components, indicating a very strong independence of the consensus members. On the other hand, the GFS ensemble mean (AEMI) was inferior to its control run (GFSI). Among the dynamical models, the GFDI and UKMI were the best performers overall.

Eastern North Pacific official intensity errors were near the 5-year averages. There has been no detectible trend in intensity error since 1990, although skill appears to have increased slightly during this time. GHMI beat DSHP after 36 h, but ICON generally was superior to either one. The FSU super-ensemble also performed well.

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[1] GHMI is a new interpolated or early version of the GFDL, in which an offset correction is applied only to the first 24 h of the late model. Over a large sample, this has been shown to be superior to GFDI, in which the offset correction is applied uniformly at all time periods.

Overview of the 2006 Central North Pacific Tropical Cyclone Season

James Weyman and Andy Nash
James.weyman@noaa.gov and Andy.nash@noaa.gov

Central Pacific Hurricane Center/Weather Forecast Office Honolulu

In the central north Pacific, the tropical cyclone 2006 season activity was normal with five systems occurring within the area of responsibility of the Central Pacific Hurricane Center (CPHC) which extends from 140W longitude to 180 longitude. In most tropical cyclone seasons, the majority of the systems form in the east Pacific and move into the central Pacific. However in El Nino years, this pattern shifts with most systems forming in the central Pacific. The 2006 season with developing El Nino conditions displayed this pattern shift with four systems developing in the central Pacific and only one moving into the basin from the east Pacific. Also in El Nino years, there is an increased probability of late season systems. This occurred in 2006. Two tropical depressions developed in September and one in October. Of note was Hurricane Ioke. 1) It rapidly intensified into a hurricane in 24 hours; 2) It was the first named system to form in the central Pacific since 2003; 3) It was the fifth Category 5 hurricane recorded in the central Pacific; 4) It maintained Category 4 or higher intensity for 9 days; 5) Its estimated lowest pressure of approximately 920 hPa was the lowest pressure on record for central Pacific hurricanes; and 6) It produced significant impacts on Johnston and Midway Islands. The only other system of note was the remnants of TD-04C which fueled heavy rain and flooding over the Big Island in October.

Table 1. List of Tropical Cyclones . ** denotes information for only that portion of the tropical cyclone's lifetime in the central north Pacific (CPHC's area of responsibility).

Name	Dates	Minimum Pressure (hPa)	Maximum Sustained Winds (kt)
Hurricane Daniel	July 24-26	980**	80**
Hurricane Ioke	August 20-27**	920**	140**
Tropical Depression - 03C	September 19-20	1007	30
Tropical Depression - 04C	September 26-27	1007	30
Tropical Depression - 05C	October 13-14	1007	30

Table 2. Overall Track Verification. Table entries are track forecast errors, measured in nautical miles. Values in parentheses indicate the number of forecasts.

	12 hr	24 hr	36 hr	48 hr	72 hr	96 hr	120 hr
OFCL	32.6(46)	51.5(39)	73.0(35)	89.6(31)	111.9(29)	157.3(29)	227.5(29)
CLP5	45.3	86.0	135.5	198.0	290.0	317.9	367.2
BAMD	34.6	54.1	73.4	83.7	73.5	98.1	132.7
BAMM	31.6	49.1	65.5	81.8	75.1	100.9	135.2
BAMS	43.1	75.6	115.9	162.5	240.0	313.5	377.2
GFDL	29.1	45.7	64.2	82.2	101.5	140.3	202.3
AVNO	42.5	63.8	84.7	94.7	109.9	143.0	176.8
GUNS	28.4	55.5	86.0	105.5	131.1	182.8	253.8
GUNA	28.6	50.9	75.4	91.3	109.9	158.0	223.1
CONU	27.1	48.3	70.9	88.0	112.1	155.1	221.4
UKMET	45.3	98.9	91.5	103.8	118.0	149.2	204.3
NOGAPS	33.2	55.8	88.7	109.7	140.4	185.1	253.4

Note: The official CPHC track forecast error at 48 hours was well below the GPRA goal of 128nm.

A Review of the Joint Typhoon Warning Center
2006 Tropical Cyclone Season

Edward M. Fukada
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Joint Typhoon Warning Center

A review of the overall tropical cyclone activity with discussion of significant events for the JTWC forecast area of responsibility, the Pacific and Indian Ocean, will be presented.

53 WRS 2006 Hurricane Season Reconnaissance Summary

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The 2006 hurricane season was a welcome respite from the record-breaking 2005 season. In fact, our flying hour total was the lowest since the El Nino season of 1997. The relatively quiet 2006 season provided psychological relief to those of us directly affected by Hurricane KATRINA and gave us an opportunity to complete re-construction efforts. In the meantime, the Step Frequency Microwave Radiometer passed the testing phases and is expected to be operational on a few of our WC-130J aircraft during the 2007 hurricane season.

NOAA Aircraft Operations Center (AOC)
2006 Seasonal Summary and Future Plans

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During the busy and catastrophic 2005 hurricane season, the two WP-3Ds and G-IV from the NOAA Aircraft Operations Center flew a total of 135 missions and 921 hours in support of hurricane surveillance, reconnaissance and research.

The 2006 hurricane season was vastly different, however. The AOC aircraft flew only a total of 36 missions for 213.3 hours in support of operational and research requirements. Of this, the G-IV flew only seven surveillance missions for 58.6 hours while flying nine flights for 54.7 hours in support of the Saharan Air Layer (SALEX) experiment being conducted by the Hurricane Research Division of NOAA.

The single WP-3D dedicated to supporting the 2006 season also had low totals. This aircraft, in addition to supporting the annual Hurricane Awareness Tour (HAT) in May, flew two operational reconnaissance missions into T.S. Ernesto, one operational ocean heat budget survey flight in the Gulf of Mexico and four research missions into Hurricane Helene, two for SALEX and two for Ocean Winds Summer. Total operational hours were 37.8 and research hours were 62.2 giving a combined total of 20 flights and 100 hours.

FY07 and FY08 will see a number of instrumentation and navigation upgrades to the present fleet of hurricane aircraft plus the induction into service of the newly acquired third P-3 which will be used primarily to support other NOAA non-hurricane programs such as air quality studies that often occur during the hurricane season. The new upgrades include a tail Doppler radar (TDR) and stepped frequency microwave radiometer (SFMR) for the Gulfstream G-IV, improved radar data systems, new tail radar antennae, new inertial/GPS navigation systems, new cloud physics probes for the P-3s and improved dropsondes and a new data system for both type aircraft. The TDR planned for the G-IV will be installed in the winter of 2008, test flown that hurricane season and made operation for the 2009 hurricane season. Some of the P-3 upgrades will be completed prior to the 2007 season with the rest becoming operation prior to the 2008 season.

Session 3
Observations and Observing Strategies
Part 1

Double (Concentric) Eyewalls in Hurricane Katrina at Landfall: A Key to the Storm's Huge Size and Devastating Impact over a Three-State Coastal Region

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Hurricane Katrina made landfall on the Gulf Coast with the 3rd lowest central pressure (920 hPa) of any landfalling hurricane in United States history, but the pressure had been much lower before landfall. During the period of rapid strengthening over the central Gulf, Katrina contained one very intense eyewall. As the storm moved closer to the northern Gulf coast, the structure of Katrina changed dramatically when the storm began an eyewall replacement cycle. During this cycle, a developing outer eyewall began to encircle the inner eyewall and Katrina became a concentric two-eyewall storm. Katrina was one of five storms in 2005 to display a multiple eyewall configuration (Hawkins et al, 2006). The development of an outer eyewall greatly aided the dramatic increase in the size of Katrina as it approached the coast and allowed hurricane force winds to expand to a distance greater than 100 statute miles from the center. As Katrina went through the eyewall replacement cycle, the peak category 5 winds in the inner eyewall began to decrease as winds in the outer eyewall strengthened; during this structural transition, Katrina's winds officially slipped to a category 3 hurricane at landfall. Calculations by Powell (2006) show that even though the storm weakened to a category 3, the great horizontal expansion of the storm allowed Katrina's winds near landfall to maintain or even exceed the kinetic energy of its earlier category 5 strength.

Numerous platforms, including microwave satellite, Doppler radar, GPS dropsonde, and airborne Stepped Frequency Microwave Radiometer (SFMR) measurements all indicate the existence of a double eyewall structure in Katrina as the storm made landfall on the northern Gulf Coast. The low brightness temperature bands detected by microwave satellite were shown to correlate with abrupt wind increases measured by anemometers at a shipyard in Pascagoula MS and at a C-MAN on Dauphin Island AL, further supporting the hypothesis of an outer eyewall over or near these locations. The microwave satellite imagery shows potential for identifying regions in the hurricane containing strong sustained winds and gusts. While making landfall on the Mississippi/Louisiana coast, dropsonde measurements indicate low-level wind maxima >150 mph in the stronger inner eyewall and >140 mph in the expansive outer eyewall. Using mean eyewall profiles from dropsondes (Franklin et al., 2000, 2003), 10 m one-minute sustained winds for marine exposure likely reached mid- to upper-category 2 intensity in the outer eyewall, agreeing well with nearby SFMR measurements there. The data strongly suggest that virtually the entire Mississippi coast was impacted by at least one of Katrina's eyewalls, with some locations experiencing two eyewalls. Many hurricane wind field reconstructions, such as H*Wind, do not display this double eyewall structure in Katrina.

Texas Tech University's Rapid Deployment Surface Observing Platform

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The Wind Science and Engineering (WISE) Research Center at Texas Tech University (TTU) has deployed mobile, ruggedized, and self-sustained instrumented towers in the path of landfalling tropical cyclones since 1998. During this time period, these mobile tower observations have comprised a large percentage of the complete data records from the landfall regions of 24 tropical cyclones, as conventional observing platforms often failed during these events. The tower observations have helped shed light on the character of the surface wind field. Even with this effort, as well as similar efforts from other institutions, the need exists for a dense network of self-sustained observing stations near the immediate shoreline to provide further evaluation of the tropical cyclone wind field at landfall.

The WISE Research Center has recently developed a new, self-sustained, ground-based instrumentation platform, which supports rapid deployment to the landfall region. Each of these platforms can be deployed in approximately two-three minutes by two individuals, allowing for a coordinated effort to safely deploy a large number of these platforms along the coastline in advance of an approaching tropical cyclone. The systems collect high-resolution (5-10 Hz sampling rates) meteorological data at 2.5 m above ground level, and maintain the capability to operate for over seven days without an additional power source. TTU currently has ten of these platforms operational; an additional 10-15 are scheduled for completion by August 2007. The project goal is to develop the capability to deploy 40-50 platforms to the landfall region. This effort would dramatically increase the spatial coverage of complete meteorological data records from the landfall region and reduce the uncertainties in assessing the surface wind field.

Observations of the Coastal Oceanic Response to Hurricane Ivan: Implications for Hurricane Intensity Change

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Hurricane Ivan (Sept 2004) was a classical hurricane of Cape Verde origin that reached Category 5 strength on three separate occasions in the Caribbean Sea. As Ivan moved over the NW Caribbean Sea, high ocean heat content (OHC) values exceeding 150 KJ cm^{-2} plus tropospheric outflow enhanced by upper atmospheric flow ahead of an approaching trough helped Ivan maintain category 5 strength. Upon entering the Gulf of Mexico (GOM) basin on 14 Sept as a category 5 hurricane, Ivan turned north-northwest and then northward as the high OHC of the Loop Current helped to maintain its intensity. Ivan subsequently weakened to a category 3 storm due to a combination of lower OHC associated with Gulf Common Water (GCW), vertical shear in the atmosphere associated with an upper-level trough, and dry air being drawn into its circulation. Within 24 hours of landfall, Ivan encountered a warm core ring shed by the Loop Current. High OHC within this ring supported intensification as surface pressure decreased by ~10 mb during this encounter (i.e. positive feedback). After passing the warm ring, cooler shelf water forced by hurricane Frances a few weeks earlier coupled with increasing atmospheric shear opposed intensification during an eye-wall replacement cycle (negative feedback) weakened Ivan at landfall.

In the northern GOM, Ivan fortuitously passed over 14 Acoustic Doppler Current Profiler (ADCP) moorings that were deployed as part of the Navy Research Laboratory *Slope to Shelf Energetics and Exchange Dynamics (SEED)* project from May through Nov 2004. In addition to three-dimensional currents, bottom temperature and pressure measurements were also acquired with the latter providing surface wave observations. Given the spatial mooring distribution from beyond the shelf break to over the shelf, the oceanic response was dominated by vigorous near-inertial currents (f^{-1} where f is the local Coriolis parameter) that contained both barotropic and baroclinic components. Coherent barotropic motions were fairly energetic with depth-independent currents of about 10 cm s^{-1} over the spatial mooring array. By removing this component, the baroclinic response contained strong currents and shears across the base of the ocean mixed layer. These currents rotated anticyclonically with depth and time indicative of rapid energy propagation out of the surface mixed layer into the thermocline. This ocean response persisted for several weeks following Ivan's passage consistent with other moored hurricane measurements (Frederic 1979). Despite the growing importance of understanding the oceanic response to hurricane forcing, and the atmospheric response to the oceanic forcing, limited ocean current (and shear) and concurrent wave measurements have made it difficult to evaluate simulations from oceanic and coupled models. Such measurements are crucial in evaluating model parameterizations schemes that are being implemented into coupled operational models at the National Centers for Environmental Prediction.

Status of transitioning the SFMR from research to operations on the WC-130J

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The Stepped Frequency Microwave Radiometer (SFMR) is currently being installed on Air Force Reserve Command WC-130J's. The first aircraft test flight using a Lockheed Martin designed pod and Pro Sensing SFMR radiometer was conducted in November 2006 from Lockheed Martin Marietta. The test was successful and showed that usable data can be obtained from 500ft above the ocean surface to nearly 30,000ft. The first operational aircraft is scheduled to be delivered in May of 2007. Following aircraft will be modified at the rate of one per month. All 10 aircraft are expected to be complete by March of 2008.

Toward an Integrated Air-Sea Real-Time Airborne Observing System for Landfalling Hurricanes

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Efforts have been ongoing for a number of years to develop a suite of airborne sensors that will describe the surface, boundary layer and subsurface conditions in hurricanes in real time during their life cycle, especially as they evolve and approach populated areas. This observational effort is maturing at a time when increasingly sophisticated coupled hurricane prediction models such as HWRF are becoming operational. At the same time, improvements in satellite communications are allowing increasing amounts of data to be relayed from aircraft platforms to forecast offices where real time analysis tools such as HRD's H*WIND program synthesize the data into real time maps of critical parameters such as surface wind. A review of the impact of the Stepped Frequency Microwave Radiometer (SFMR) since its operational introduction in 2004 on board the two NOAA WP-3D aircraft has shown real benefit for short term forecasts and warnings and helped reduce the uncertainty in surface wind field estimation. It is anticipated that additional benefit will be shown with the phased introduction of SFMR systems on the AFRC WC-130J aircraft beginning in 2007 and culminating with a fully operational fleet in 2008. The use of the SFMR system in conjunction with the NOAA Doppler radar and GPS dropsondes is anticipated to enhance initial and validation wind fields for operational storm prediction using HWRF. It is anticipated that in addition, an SFMR system will begin initial flights on the NOAA G-IV in 2008 in conjunction with the new G-IV Doppler radar system.

In order to validate wave models in the coupled HWRF system, an operational Scanning Radar Altimeter for significant wave height measurement will begin test flights in 2007 and is expected to be operational by 2008. These data are anticipated to be useful for forecast and warnings related to the extent of critical wave heights within hurricanes. Algorithm development and initial testing is underway for a scanning SFMR system referred to as the Hurricane Imaging Radiometer (HIRad) to produce a swath of surface winds along the aircraft track to further complement the multilevel wind swath provided by the airborne Doppler radar, and further reduce surface wind field uncertainty and enhance the probability of detecting the true maximum surface winds.

Subsurface ocean thermal features have been shown to have a significant impact on hurricane intensity change, especially in the Gulf of Mexico offshore from vulnerable Gulf Coast communities such as New Orleans. Recent communication advances will allow real time transmission of Airborne Expendable Bathythermograph (AXBT) data that will follow the evolution of ocean features along the hurricane path. The capability to accomplish this has been available for years on the NOAA WP-3D aircraft, and is being investigated as an additional low-cost addition to the AFRC WC-130J capability. Impacts on HWRF initialization are expected to be significant.

For storms approaching landfall, a program has been developed to augment the over-ocean observing system by deployment from WC-130J aircraft of drifting buoy and float arrays ahead of hurricanes to gather time series of subsurface ocean thermal and current conditions as well as surface winds and wave heights. It is expected that these platforms will be deployed up to two days ahead of a potential landfalling hurricane to provide addition atmosphere-ocean-wave inputs to that supplied by aircraft reconnaissance- primarily for initialization of the improved coupled air-sea hurricane prediction models. Examples of these advances will be illustrated.

CIMSS Satellite Consensus (SATCON) Tropical Cyclone Intensity Estimation Algorithm

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Satellite-based Tropical Cyclone (TC) intensity estimates can differ by 30 knots or more. Such a large spread among estimates is problematic for the TC forecaster, especially when a TC is approaching landfall. On October 3, 2002 Hurricane Lili had just completed a period of rapid intensification with the pressure falling to 938 mb by 2200 UTC on October 2. However by 0800 UTC on October 3 the satellite presentation had significantly deteriorated with an eye no longer visible and an asymmetric appearance to the coldest cloud tops. At this time subjective Dvorak and objective ADT (Advanced Dvorak Technique) estimates indicated a minimum sea-level pressure of 935 mb, primarily due to weakening constraints. The CIMSS AMSU (Advanced Microwave Sounding Unit) method indicated a pressure of 954 mb and the CIRA AMSU method indicated a pressure of 970 mb. At the high end of these estimates the estimated maximum sustained wind was 125 knots while at the low end the estimate was 83 knots, a spread of more than 40 knots. Lili was only 5 hours from landfall at this point.

The current method for merging the information provided by objective intensity estimates is ad-hoc and differs between forecasters and between TC forecasting agencies. SATCON (SATellite CONsensus) is an algorithm that produces a weighted consensus of objective satellite-based estimates to determine TC current intensity. The contemporary version of SATCON employs the CIMSS ADT, the CIMSS AMSU method, and the CIRA AMSU method as consensus members. Future versions plan on adding an SSMI-based estimate as a potential fourth member. Each of the SATCON members have well-documented error characteristics which are situational dependant. For example the ADT skill is dependant on the scene type while the AMSU methods performance is dependant on whether the storms core is well resolved. The consensus uses these error characteristics to assign weights to each member. The result is an estimate that is superior in skill to the individual members

In 2006, SATCON was run in real-time using weights developed from a training sample of 2001-2004 data. Statistical performance for the 2005-2006 Hurricane Seasons (Table 1 below) indicates skill versus the individual members as well as a simple average of the three SATCON members. The developers plan to continue testing the algorithm in 2007 in real-time, and then validate the performance using recon. The current SATCON web page is hosted at CIMSS and can be found at: http://cimss.ssec.wisc.edu/tropic/satcon/satcon.html

N = 128	ADT	CIMSS AMSU	CIRA AMSU	Simple Average	SATCON
BIAS	-2	-2.5	-4.9	-3.1	-3.2
AVG ERROR	10.2	6.7	8.1	6.8	6.3
RMSE	14.6	10.4	12.7	10.4	9.7

Table 1. SATCON independent MSLP performance for 2005-2006 versus reconnaissance MSLP within 3 hours of the SATCON estimate.

Session 4
Observations and Observing Strategies
Part 2

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Mobile Ground-Based Observations of Landfalling Hurricanes:
Current Capabilities and Future Plans

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UAH has acquired measurements of landfalling tropical storms and hurricanes since 1998. Until now, this activity has been conducted on an occasional basis when facilities and personnel were available. In this short paper, we summarize measurements acquired to date, and outline future plans.

The UAH Mobile Integrated Profiling System (MIPS) has been the primary measurement platform used to acquire measurements of wind profiles, radar reflectivity profiles, turbulence information, cloud base, profiles of temperature and humidity, and surface measurements. Current research instruments include a 915 MHz Doppler wind profiler, a lidar ceilometer, a 12-channel profiling radiometer, and surface meteorological measurements. Data have been acquired from 6 landfalling storms, including 3 hurricanes (Earl 1998, Georges 1998, Ivan 2004) and 3 tropical storms (Helene 2000, Gabrielle 2001, Isidore 2002). Up to this point, primarily boundary layer properties have been analyzed in detail and reported (Knupp et al. 2000, Knupp et al. 2006, Roberts and Knupp 2007).

Ground-based facilities are currently being expanded and upgraded to provide more comprehensive measurements of the boundary layer, precipitation properties, and kinematics of landfalling hurricanes. Two optical disdrometers will provide information on raindrop size distributions and their spatial/temporal variability. The disdrometer data will be used to determine Z-R relations, which will be used to derive improved estimates of rainfall using WSR-88D radars. A vertically-pointing X-band Profiling Radar (XPR, currently under construction) will serve as a high-resolution boundary layer and precipitation profiler. Disdrometer data will be used to provide an accurate calibration for both the XPR and 915 MHz profiler, which will in turn be used to calibrate WSR-88D radars. We anticipate that this upscale calibration, and use of relevant Z-R relations, will provide superior estimates of rainfall from landfalling systems. A mobile X-band dual-polarization radar (currently under construction) will provide additional details of 3-D precipitation characteristics within landfalling systems.

Aside from the boundary layer and precipitation research thrusts, we will also investigate the thermodynamic and kinematic structure of rainbands and stratiform precipitation region. This research will focus on mesoscale vertical motion patterns and the impact of cold mesoscale downdrafts (within stratiform precipitation) on changes in hurricane intensity around the time of landfall. Wind, temperature, and humidity profiles will also provide insight on rainband kinematics, including the evolution of mini-supercell storms that occasionally produce tornadoes around the time of landfall. We are particularly interested in investigating tornadoes that are spawned near the coast prior to the landfall of the TC inner core region.

Beginning with the 2007 season, we will begin a more aggressive field campaign and deploy on both landfalling tropical storms and hurricanes within an 12-h drive form Huntsville (e.g., between Morehead City NC and Houston TX). Close collaboration with NOAA and other university groups is planned.

NASA High-Altitude Precipitation/Wind Radars for Hurricane Research

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NASA has been flying high-altitude (60-70k ft) downlooking Doppler radars on the NASA ER-2 aircraft for the past decade. These radars include the X-Band ER-2 Doppler Radar (EDOP) and the W-Band Cloud Radar System (CRS) which are primarily nadir viewing and obtain high resolution images of reflectivity and vertical hydrometeor motions in cloud and precipitation regions. Numerous tropical storms were overflown with EDOP during NASA's CAMEX-3, CAMEX-4, and EDOP and CRS during TCSP. These resulted in various studies from Hurricanes Bonnie and Georges in 1998, Tropical Storm Chantal and Hurricane Erin in 2001, and Hurricanes Emily, Dennis, and Gert in 2005. The EDOP and CRS radars are not suitable for deriving the full horizontal wind from high-altitudes above storms that is of extreme interest in inner core regions of hurricanes. Recently, the Imaging Wind and Rain Airborne Profiler (IWRAP) has demonstrated a conical scan radar approach from the NOAA P3 to derive winds at the surface and in precipitation regions.

Our recent work has focused on horizontal wind measurements in storms with use of conical scan radar from both manned and high-altitude UAV (HUAV) platforms. Two systems under development at NASA Goddard are: the X-band UAV Doppler Radar (URAD) and the dual-wavelength (Ku and Ka band) High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP). These radars are designed for measuring tropospheric winds within precipitation regions and ocean surface winds in rain-free to light rain regions. Both systems are designed for the Global Hawk HUAV with initial flights of HIWRAP planned for the NASA WB-57 manned aircraft (60-65kft ceiling) during Summer 2008. HIWRAP uses new technologies that utilize solid state rather than tube based transmitters such as used in URAD. The presentation will discuss the motivation for HIWRAP and URAD, a description of the instruments, and their potential use in hurricanes.

Potential Applications of the Proposed Phased Array Doppler Radar on the NSF/NCAR C-130 in Hurricane Reconnaissance

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The Earth Observing Laboratory of the National Center for Atmospheric Research proposes to develop the next generation of airborne remote sensing instrumentation suite called CAPRIS (Community Airborne Platform Remote-sensing Interdisciplinary Suite). CAPRIS includes a centimeter (C- or X-band) dual-Doppler radar, a millimeter wave cloud radar, and several lidars to be installed on the NSF/NCAR C-130. The purpose of this paper is to discuss the design concept of this new airborne dual-Doppler radar system and its potential applications to hurricane reconnaissance missions in the United States.

As a tail Doppler radar is not an option for a C-130 platform, the proposed the proposed radar takes advantages of a fuselage conformal phased array design that are composed of thousands of Active Element Scanning Array (AESA) elements. In order to support both surveillance and dual-Doppler coverages, four fuselage conformal phased array antennas will be installed. Two side looking antenna will be mounted on each side of the C-130 fuselage behind the rear door, one on top of the fuselage and one on the rear cargo door. Each antenna can form fore and aft beams and also electronically scan a 90 deg sector, a scanning geometry similar to the NOAA P3's tail Doppler radar. A complete 360 deg scan can be achieved by combining data from these four antenna. Due to the large surface area of the C-130 fuselage, this radar system can be either C- or X-band. A C-band system will have a beamwidth ~2 deg, slightly wider than the current P3 tail radar system. A X-band system will have a beamwidth ~1.4 deg, narrower than the current P3 system. Either system will have the dual-Doppler radar capability to deduce 3-D air motions at a spatial sampling ~500 m. Lower attenuation at C-band would enable the radar to probe deeper into rain bands in a hurricane reconnaissance.

To improve the hurricane intensity forecasts, a better description of the hurricane inner core structure to initialize numerical model relies on Doppler radar observations and assimilating these data into hurricane models. Technical feasibility of installing these phased array radars on the C-130 hurricane hunters opens new avenues for continuous monitoring of tropical cyclones by Doppler radars. In order to improve radar data quality, retrieve cloud microphysics and also accurately estimate precipitation amount, Doppler radar is augmented with a dual-polarization capability. Hence, not only real-time dual-Doppler radar winds can be deduced during reconnaissance missions, the polarimetric radar capability can also provide microphysical properties within the precipitation system so that both kinematics and microphysics information can be assimilated to numerical models.

The Operational Impact of and Future Requirements for Satellite Ocean Surface Vector Winds in Tropical Cyclone Analysis

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Remotely sensed ocean surface vector wind (OSVW) measurements have become an important source of data for operational tropical cyclone (TC) analysis and forecasting at the National Hurricane Center (NHC). These data are also used for marine analysis and forecasting applications elsewhere within in the National Weather Service (NWS) at NCEP centers (NHC, OPC, EMC) and coastal weather forecast offices (WFOs).

A workshop was held at NHC in June 2006 to document the operational utilization and impacts of OSVW data from current research spaceborne microwave instruments, and to establish new NOAA operational requirements for OSVW measurements from future missions. Participants included users of OSVW data from NHC, OPC, EMC, NWS Southern, Western, Alaska, and Pacific regions, NWS headquarters, NOAA/NESDIS, NOAA/OAR, the U. S. Navy, NASA, academic researchers, and private companies. The workshop established that satellite-derived OSVW measurements are an important tool in daily NOAA/NWS forecast and warning operations and that current and planned satellite missions do not satisfy the newly established requirements.

A report summarizing the workshop findings and requirements has been widely distributed. High-level NWS and NOAA officials have been briefed on the findings of the workshop and have acknowledged the needs expressed in the report. NOAA currently has no plans for an operational OSVW satellite mission that will meet the new requirements or even maintain capabilities provided by current research missions (primarily the NASA QuikSCAT); however, the recently-released National Research Council decadal survey report does recommend that NOAA undertake an operational scatterometry mission in the 2013–2016 timeframe.

While OSVW data will be provided to NOAA by the new operational ASCAT scatterometer on EUMETSAT's METOP-A satellite, these data will also not meet the new requirements nor maintain current research OSVW satellite capabilities. Therefore, the quality of NOAA/NWS operational forecasts and warnings will be compromised once QuikSCAT fails. Several workshop participants are advocating a satisfactory future OSVW satellite mission via the NOAA PPBES process and other avenues within NOAA. Higher-resolution all-weather surface wind data from such a mission would enable a critical step toward improving the analysis and forecasting of hurricane intensity, as well as other hazardous marine meteorological phenomena.

Examples of the utility of QuikSCAT OSVW data in operational TC analysis will be presented, along with the findings of the workshop and the new NOAA operational requirements for OSVW measurements from future satellite missions. Input from the Department of Defense (DoD) on the utility of OSVW data to their operational TC analysis and forecasting mission will be solicited.

Development of the Hurricane Imaging Radiometer (HIRAD) Using a Systems Engineering Approach

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Accurate observations of ocean surface vector winds (OSVW) with high spatial and temporal resolution are critically important to improve both our understanding and predictability of tropical cyclones. As the successful NASA QuikSCAT satellite continues to age beyond its planned life span, many members of the tropical cyclone (TC) community of practice (CoP) recognize the need to develop new observational technologies and strategies to meet the essential need for OSVW information. A collaborative team consisting of personnel from NASA Marshall Space Flight Center (MSFC), NOAA Hurricane Research Division (HRD), RTI International, the University of Central Florida and the University of Michigan are currently investigating airborne and spaceborne options for incorporating passive microwave technology into an overall observing strategy for OSVW.

The team is developing an instrumentation concept called the Hurricane Imaging Radiometer (HIRAD) using initial investment funding from NASA MSFC to be followed by proposals for competed, peer-reviewed funding. The HIRAD team is using a systems engineering approach by matching new emerging technologies to the observational requirements of the operational forecasting members of the TC CoP. The NOAA and academic partners are considered essential members of the HIRAD systems engineering team so that the most innovative, practical, and beneficial solutions may be found to meet the needs of both research investigators and operational decision makers.

The strategic plan for HIRAD includes a roadmap for ocean surface wind speed and OSVW technology development and flight demonstrations on piloted aircraft, uninhabited aerial vehicle systems, and small, special purpose satellite platforms. The roadmap will include exit opportunities for technology transfer from NASA to NOAA for operational implementation based on satisfactory demonstrations. This presentation will discuss the technological heritage of the HIRAD concept and how it compliments an overall observing strategy for OSVW that could also include active microwave and lidar remote sensing technologies and traditional *in situ* observations.

Baseline Instruments for the GOES-R Series: Providing Major Improvements to Hurricane Observations

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In order to meet the requirements, documented by the Geostationary Operational Environmental Satellite (GOES) user communities, the instruments designated for the GOES-R notional baseline include an Advanced Baseline Imager (ABI), a Geostationary Lightning Mapper (GLM), space weather and solar instruments. This paper will focus on the instruments of primary interest to hurricane forecasters: the ABI and GLM.

The Advanced Baseline Imager (ABI) is a state of the art, 16-band imager covering 6 visible (VIS) to near-infrared (NIR) bands (0.47 um to 2.25 um), and 10 infrared (IR) bands (3.9 um to 13.3 um). Spatial resolutions are band dependent, 0.5 km at nadir for broadband VIS, 1.0 km for NIR and 2.0 km for IR. The ABI will be capable of scanning the Full Disk (FD) in approximately 5 minutes, although routine full disk scans every 15 minutes are likely. ABI will improve every product from the current GOES Imager and will introduce a host of new products.

The Geostationary Lightning Mapper (GLM) will complement today's operational ground based lightning detection systems, which only provide information on cloud to ground strikes over land, with information on total lightning flash rate (including both cloud to cloud and cloud to ground), over both land and adjacent oceans. The GLM will provide nearly continuous information on lightning flash rates, leading to improved: severe thunderstorm forecasts and warnings, aviation weather services, and lightning climatology.

The additional channels on ABI together with vastly improved radiometrics, spatial and temporal resolutions will provide significantly improved satellite derived winds in the storms environment and resultant improvements in model forecasts. It will also mean more frequent and accurate estimates of hurricane intensity based on pattern recognition, such as the Dvorak technique. The capability of observing the convective towers within the storm as often as every 30 seconds holds the potential for better understanding the mechanism for rapid intensification. The three water vapour channels, the 8.5 µm band, along with the restoration of the split window channel to better detect the Saharan dust layer, will promote a better understanding of the conditions leading to intensification or weakening. The new ozone channel (9.6 µm) will reveal information about troposphere/stratosphere exchanges, which may also be important for intensity changes. Likewise the capability to nearly continuously monitor the trends of total lightning flash rate will lead to a better understanding of the role of lightning in the hurricane life cycle.

Session 5
Modeling and Forecasting Intensity, Structure, Sea State, and Track: Prospects for the 2007 Season and Beyond
Part 1

Advanced Hurricane Prediction at NCEP's Environmental Model Center: The Operational Implementation of the HWRF

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The Hurricane Weather and Research Forecast system (HWRF)is scheduled for operational implementation at NCEP for this upcoming hurricane season. Under development for the past five years at EMC, the HWRF is being designed to address the intensity, structure, and rainfall forecast problem in addition to advancing wave and storm surge forecasts. Also continued advancements in track prediction will remain an important focus of this prediction system.

The HWRF is a coupled air-sea-land prediction model with a movable nested grid and advanced physics for high resolution. An advanced initialization of the hurricane core is being developed to make use of real-time airborne Doppler radar data from NOAA's aircraft to initialize the three-dimensional storm scale structure. To address the totality of the hurricane forecast problems noted above, future versions of the HWRF will also include coupling to an advanced version of NCEP's wave model, e.g. WAVEWATCH, which will eventually be coupled to a dynamic storm surge model. Additionally, the land surface component will also serve as input to hydrology and inundation models to address to hurricane-related inland flooding problem.

The initial configuration of the HWRF for the initial '07 implementation will be addressed in this presentation.

A JHT-Funded Project:
Transition of GFDL Hurricane Prediction System to HWRF

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Major physics upgrades to the GFDL Hurricane Prediction System that were developed and tested during the past 2 years through JHT funding were made operational in time for the 2006 hurricane season. These physics changes were made in close collaboration with scientists at NCEP (National Centers for Environmental Prediction) and URI (University of Rhode Island). During the past 6 months they have been fully transitioned into the Hurricane WRF (HWRF) model that is being developed to run in parallel with the GFDL model in 2007.

As was anticipated, the new physics upgrades (i.e., NCEP's Ferrier microphysics and an improved momentum flux parameterization), significantly improved the GFDL model's skill in intensity prediction both in the Atlantic and eastern Pacific. For the first time the GFDL model exhibited superior performance compared to the statistical models in most forecast time periods, beating even the official forecast in the Atlantic and in the longer forecast time periods in the eastern Pacific. These results will be summarized in this presentation, as well as the overall performance of the GFDL hurricane forecast system during the past 4 years of JHT funding.

Once the 2006 versions of the GFDL forecast system became fully operational in June 2006, the emphasis at GFDL shifted to assist in the transition of the GFDL physics to the new HWRF model under development at NCEP. The strategy adopted by NCEP is to implement HWRF with the same physics packages that are used in the 2006 version of the GFDL model. A set of storms from the 2004 (Frances, Ivan, Jeanne, Lisa), 2005 (Dennis, Emily, Katrina, Philippe, Rita, Wilma) and 2006 hurricane season (Ernesto and Helene) was selected to serve as a suite of test cases to evaluate the new model. Forecasts on these storms have been run with a preliminary version of HWRF with the results compared to forecasts made with the 2006 GFDL model. A preliminary evaluation of the track forecasts of these 2 models will be presented for a 220 case sample size as well as distributions of the individual storm errors at 2, 3 and 5 days.

Finally, NCEP is testing a major upgrade to its Global Forecasting System (GFS) with implementation scheduled for spring 2007. This upgrade will involve major changes to its global data assimilation as well as adoption of a hybrid pressure-sigma vertical coordinate system. To evaluate the effect of this major implementation on the performance of both the GFS and GFDL models, the major part of the 2005 and 2006 hurricane system is currently being rerun with this new hybrid GFS. The impact of the new global modeling system on the GFDL model will be rigorously evaluated on over 500 forecasts in the Atlantic and over 400 forecasts in the eastern Pacific. Comparison of the track forecasts of the current operational GFS and this new hybrid version will also be made and presented, along with the differences in the track and intensity forecasts with the GFDL model using both versions of the GFS. It should be pointed out that these results will serve as the benchmark for which the final version of the HWRF model will be evaluated, later this spring.

Hurricane Model Transitions to Operations at NCEP/EMC

A Joint Hurricane Testbed (JHT) Program

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The emphasis for this 2005-2007 JHT project has concentrated on HWRF development. Continued progress has been made in the development of HWRF into an operational hurricane forecast system. This development is designed to take into account the strengths of the WRF software system, the use of the well tested NMM dynamic core, and the physics packages of the GFDL highly successful forecast system. The HWRF forecast system has progressed from a uniform-mesh WRF proto-type system installed and run at NCEP for the 2004 season to a moving nested HWRF automated system run for numerous cases for the 2005 season. For the 2006 season numerous cases were run with a two-way nested moving system. The system has proven quite robust with few failures. During this past six months, further refinements were made to the system. The physics packages were also brought in line with the GFDL model with changes to the momentum mixing in the cumulus parameterization and the inclusion of a refined surface roughness and flux parameterization. With the inclusion of the Ferrier cloud microphysics package into the 2006 GFDL operational system, the physics packages of the HWRF and the GFDL model are nearly identical. The physics packages and model systems of both the GFDL and HWRF will be presented and compared.

As mentioned, the design of the hurricane forecast system has progressed with new components added for both physical integrity and operational expediency. Options are available to run a forecast analysis cycle in a NOAA hurricane model system for the first time. An ocean initialization and coupled atmospheric-ocean model has recently been integrated into the HWRF hurricane system. The HWRF post-processing steps have been upgraded to include superior storm tracking and verification techniques as well as the availability of synoptic fields. For computational and operational expediency, the HWRF system now has the capability to process binary files and use input data on native operational model grids. Another major task of this project has been checking and tuning of the physics packages to attain high forecast skill. It has long been known that physics packages are key to successful forecasts in the tropics, especially that of hurricanes. Considerable time has been spent in testing and incorporating physics packages comparable to the GFDL forecast system which has been undergoing considerable changes over the last few years. The HWRF model sensitivity to various flavors of physic packages such as momentum mixing, surface flux and radiation parameterizations will be shown.

Ocean Initialization System for Coupled Hurricane-Ocean Models and its Transition to HWRF

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Our experience with the GFDL coupled model indicates the importance of proper initialization of the coupled modeling system. It is well known that successful forecasts of the structure and movement of tropical cyclones using an atmospheric model are strongly dependent on good initialization. In the coupled model, the ocean initialization is equally important because the SST response is very sensitive to the upper ocean structure. One major challenge for proper ocean initialization in a coupled hurricane-ocean model is accurate representation of mesoscale oceanic features that do not follow an annual (or even a regular) cycle, such as the penetration of the Loop Current (LC) into the Gulf of Mexico (GoM) and the shedding (and perhaps reattachment) of Loop Current eddies (LCEs). We will discuss the ocean initialization procedure developed and implemented operationally to the GFDL coupled hurricane prediction system for the 2006 hurricane season. The new procedure accounts for spatial and temporal variability of mesoscale oceanic features in the GoM, including the LC, LCEs (i.e. warm core rings), and cold core rings. Using near real-time satellite altimetry and *in situ* temperature profiles (when available), these features are assimilated into an ocean climatology to produce a more realistic three-dimensional temperature field valid at the model initialization time. Relative accuracy of the initialization procedure will be demonstrated by comparing the model temperature profiles to temperature profiles in the pre-hurricane environment obtained by HRD scientists via airborne expendable bathythermograph (AXBT), the ocean climatology, and an alternative data assimilation technique. During the 2006 hurricane season, Michelle Mainelli, a forecaster at NHC, provided LC and LCE parameters for initialization of the GFDL coupled model operational forecasts using maps of the depth of the 26°C isotherm derived from satellite altimetry. At present, the ocean component of the GFDL coupled model, the Princeton Ocean Model, is being transitioned to NCEP's Hurricane WRF model. Further improvements have been made recently to the initialization system, including the initialization of cold core rings and more realistic structure of the LC.

Evaluation of the Simulated Oceanic Response to Hurricane Ivan in Comparison to High-Quality Ocean Observations

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The ocean response to hurricane Ivan (Sept 2004) was simulated within the Gulf of Mexico using the Hybrid Coordinate Ocean Model (HYCOM), which has been selected by NOAA/NCEP as the ocean component of the coupled Hurricane Weather Research and Forecasting model. These simulations (1) demonstrate the importance of accurately initializing the ocean model; (2) reveal sensitivity of the current and temperature response to the model vertical mixing parameterizations; and (3) emphasize the importance of ocean observations for both initializing and evaluating the ocean model. Combined model-observational studies are critically important for evaluating and improving ocean model performance, particularly in regards to the magnitude and pattern of SST cooling driven by tropical cyclones. Improving ocean model performance in coupled hurricane forecast models thus has the potential to significantly improve intensity prediction. In this study, the ocean model response to hurricane Ivan is evaluated against microwave satellite SST measurements and moored ocean current observations. During the period of deployment, Hurricane Ivan passed directly over 14 Acoustic Doppler Current Profiler (ADCP) moorings that were deployed as part of the Navy Research Laboratory *Slope to Shelf Energetics and Exchange Dynamics (SEED)* project from May through Nov 2004. These observations enable the simulated ocean current response to a hurricane in a continental shelf/slope region to be evaluated with unprecedented detail.

The Ivan simulations were initialized by oceanic fields provided by the latest generation of the U. S. Navy ocean nowcast-forecast system being developed at the Naval Research Laboratory. This product provided a good initialization of the ocean heat content (OHC) distribution associated with the Loop Current, a recently-detached warm eddy, and two cold eddies adjacent to the warm eddy. This had a large impact on the simulated SST cooling pattern, with the largest cooling (> 5°C) occurring within the cold eddies. The simulated cooling pattern was in reasonable agreement with microwave satellite measurements. The combination of ocean models and observations is very important for providing accurate ocean model initializations. Although results for Ivan were good, larger initial OHC errors are observed for other storms. For example, OHC was underestimated by up to 30% prior to Katrina within the LC and warm ring that provided the energy for rapid intensification. Observational coverage prior to hurricanes should be improved to insure the most accurate possible initial ocean fields. The simulated current response to Ivan in the *SEED* domain was dominated by vigorous near-inertial currents that contained both barotropic and baroclinic motions, in reasonable qualitative agreement with observations. Simulations performed using three vertical mixing parameterizations reveal substantial differences in the vertical penetration of the currents forced during the storm, and also with respect to the temporal decay rate of the near-inertial oscillations following the storm. Detailed comparisons between model and observations will be performed to evaluate the vertical mixing parameterizations and devise strategies for improving ocean model performance in the HWRF prediction model.

Poster Session

P O S T E R S E S S I O N

Application of TRMM Multi-Satellite Precipitation Analysis and MODIS Aerosols to Hurricane Studies

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This poster has two foci. The first uses the TRMM Multi-Satellite Precipitation Analysis (TMPA) (also known as the TRMM 3B42 product), a 3-hourly near-global precipitation product with 0.25° resolution obtained by combining passive microwave retrievals of rainfall from several satellites (TRMM, AMSR-E, SSM/I, AMSU) and filling in remaining gaps with infrared estimates. The TRMM data are used as a calibrator for other sensors. Here, we use the TMPA rainfall data to compute the rainfall accumulation for hurricanes from 1998-2005 for the Atlantic and Eastern Pacific and 1998-2004 for the Western Pacific and North Indian Ocean for the months of June-November (the years included are based upon availability of best track data). In addition to rainfall accumulation, we compute Hovmoller diagrams that indicate the radius-time and azimuth-time variations of precipitation and their relationship to storm intensity over the life cycle of each storm. The second focus is on the relationship of Atlantic tropical cyclone activity to outbreaks of Saharan dust associated with the Saharan Air Layer. TMPA and other TRMM data are used in combination with MODIS-derived aerosol optical depth to examine the dust outbreak activity and its relationship to tropical cyclone (TC) activity for the years 2002-2006. Results suggest a sometimes complex relationship between dust outbreaks and TCs, with several TCs forming either immediately ahead of or behind a dust outbreak. Preliminary results also suggest no direct relationship between interannual variations of dust activity and TC activity, although indirect effects (such as cooling of SSTs) are not ruled out.

Verification of the National Hurricane Center's Atlantic and Eastern Pacific Tropical Weather Outlooks

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The National Hurricane Center (NHC) routinely issues Tropical Weather Outlooks (TWO) for both the Atlantic and Eastern North Pacific Ocean Basins. The TWOs are text-based products that "discuss areas of disturbed weather and the potential for tropical cyclone development during the next 48 hours." Through the use of somewhat standard descriptive phrases, the NHC attempts to convey the relative threat of tropical cyclone formation for each system discussed in the TWO. Those forecasts were verified using the NHC best-track data by assigning a low, medium, or high probability of development during the 2005 and 2006 hurricane seasons. The results demonstrate that it is possible to distinguish the likelihood of tropical cyclone development using a three-tiered approach. It is hoped that this work will lead to future possibilities of a color-coded graphical version of the text NHC TWO.

Introduction of an Inundation Analysis of Hurricanes Ivan, Dennis, and Katrina

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Wind speeds and storm surge are generally considered the most damaging factors in a storm; however, the duration of inundation is also critical. This study focuses on peak storm tide elevations and the durations of inundation that occurred along Gulf Coast water level stations throughout the courses of three major hurricanes, Ivan, Dennis and Katrina, which exhibit similar storm tracks. The NOAA National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) historical water level data collected by water level stations along the U.S. coast were used to calculate the duration of inundation above the Mean Higher High Water datum at individual stations. Generally, as the storms traversed the Gulf, durations of inundation were longest in the vicinities of the hurricane landfalls, with still relatively longer durations outside of the landfall region. These results are echoed in hydrographs displaying highly elevated water levels recorded at the time of Ivan, Dennis and Katrina landfalls, as represented in the associated CO-OPS Storm Tide Quicklooks. The Storm Tide Quicklook product is a web-based compilation of near real-time storm tide and meteorological data, and is initiated by CO-OPS during tropical cyclone events. These inundation analysis results are the early stages of future research that could focus on quantifying the degree to which storm characteristics (wind speeds, rainfall, storm speed, etc.) contribute to long durations of inundation.

NOS Storm Surge Partnership Project: Improving Gulf Coast Storm Surge Modeling, Tools, and Methodologies

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NOAA's National Ocean Service (NOS) Storm Surge Partnership Project aims to improve coastal resiliency to inundation through data collection, a prototype storm surge model, and development of management tools. The Gulf Coast, including Mobile, AL, and Pensacola, FL, was selected as the project study area because of well-documented past hurricane events involving storm surge and flooding, including Hurricane Ivan in 2004. Additionally, this region was selected because of the availability of data, such as high-resolution topographic, oceanographic, and meteorological data for use in modeling. NOS's Coast Survey Development Laboratory has developed an implementation of a vertical datum transformation tool for this region (VDatum). VDatum allows for adjustment between disparate vertical datums at the coast, including tidal, orthometric, and ellipsoidal datums. Application of vertical datum transformations to bathymetric and topographic data allows for the construction of a continuous elevation field across the land/water interface. In the study region the latest available hydrographic surveys are combined with high resolution topographic datasets such as Light Detection and Ranging (LIDAR) surveys to construct a continuous elevation field. This elevation field is used as the basis for a prototype storm surge model that provides high resolution of coastal and inland features for modeling inundation. This state of the art storm surge model is a prototype application of the Advanced Circulation (ADCIRC) finite element hydrodynamic model with approximately 425,000 nodes and smallest nodal resolution less than 100 m in areas. It includes land areas up to the 15 meter topographic contour from west of Mobile Bay, AL, to east of Pensacola Bay, FL. Sharp vertical flow obstructions such as barrier islands are included as weirs within the model domain. This high-resolution model will allow for accurate modeling of hurricane-driven inundation throughout the region. Model forcing of atmospheric wind and pressure conditions during Ivan are applied through application of the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) parametric wind model. Comparisons to observations are presented for both High Water Marks and water-level time series. The output from the model will be used by the NOS project team to generate geographic information system (GIS)-based mapping and visualization tools and methodologies to illustrate storm surge processes and impacts while verifying existing map products.

A Comparison of COSMIC, AIRS, Terra, and Aqua Temperature and Moisture Profiles against Dropsondes in 2006 Atlantic Tropical Cyclones

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Historically, satellites have served as the most crucial tool for monitoring tropical cyclones. Recent advances include the Advanced Microwave Sounding Unit (AMSU) instrument, which can measure the warm core of a hurricane, and the NASA Aqua satellite, which can retrieve profiles via MODIS retrieval algorithms and the AIRS. However, all have trouble with cloudy regions or with heavy precipitation.

Recently (April 14 2006), a new constellation of satellites was successfully launched. These low-orbiting satellites will provide real-time data over thousands of points throughout the globe. Called the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC), these satellites will provide temperature and moisture profiles (Anthes, Ricken, and Kuo 2000; Cucurull et al. 2006). COSMIC relies on a technology known as radio occultation. As radio signals from GPS satellites pass through the atmosphere, the paths of the signals are bent and their progress slowed. The rate of these changes depends on atmospheric density along the signal path. COSMIC's low-Earth-orbiting (LEO) satellites take advantage of this effect by intercepting the GPS radio signals just above Earth's horizon and precisely measuring the bend and signal delay along the signal path. These parameters are then used to compute temperature and moisture information. Because radio signals can pass through thick cloud cover and precipitation, weather conditions will not interfere with data gathering, as often occurs with remote sensing platforms. Therefore, this technology could be very useful to the monitoring of tropical cyclones. More information is available at: http://www.cosmic.ucar.edu.

This study will investigate COSMIC capabilities in studying hurricanes. Analysis of these data, along with NASA satellite data, is underway for 2006 Atlantic tropical cyclones. A validation study of COSMIC data against dropsondes has been performed. The tentative results show:

- COSMIC temperature profiles in hurricane environment are reasonable. In addition, they provide tropopause and stratosphere information not available from dropsondes.
- Dewpoint profiles in hurricane environment shows a moist bias in mid and upper troposphere. The low levels appear reasonable.
- The COSMIC horizontal data distribution is coarse, but the temperature could still be useful in data sparse locations or between reconnaissance flights. COSMIC dewpoint still requires more examination and (apparently) refinement. However, COSMIC dewpoint should still be useful, especially in dry regions.

A comparison between COSMIC, AIRS, and Terra/Aqua soundings to dropsondes is underway, and these results will be reported at the conference.

The HRD Hurricane Field Program—2006 and 2007

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During the 2006 Hurricane Season, the Hurricane Research Division flew on missions in Tropical Cyclones Debby, Ernesto, and Helene. The G-IV and P-3 flights in Debby and Helene were either Saharan Air Layer Experiment (SALEX) flights or Ocean Winds Experiments. The P-3 flights in Ernesto were Stepped Frequency Microwave Radiometer(SFMR)/Three Dimensional Doppler Winds flights in support of the Tropical Prediction Center (TPC) and the Environmental Modeling Center (EMC).

Two G-IV only SALEX flights were conducted on 25 and September in Debby.

The two flights in Ernesto, on 29 and 31 August 2006 were tasked by joint decision of TPC and EMC. Both flights were within hours of landfall, and were specifically in support of operational determination of surface winds from the SFMR (flight-level data and several airborne Doppler wind analyses were also relayed TPC). Automatically quality controlled Doppler radial observations were also recorded for later use in assimilation development of the Hurricane Weather and Research and Forecasting model, currently being readied for operations in 2007. A mapping of the ocean temperature field by Airborne Expendable Bathythermographs under Ernesto was accomplished during the flight on 31 August.

HRD also participated on 4 Hurricane-Helene (17-20 September 2006,) P-3 research flights tasked either by HRD or the Marine Observing Systems Team of the Office of Research and Applications of NESDIS (National Environmental Satellite, Data, and Information Service), as well as four G-IV SALEX research flights on 15, 16, 18, and 20 September. The primary mission of the P-3s on 18 and 20 September were SALEX, while the primary missions on 17 and 19 September were the NESDIS Ocean Winds experiment designed for scatterometer calibration.

Finally, HRD scientists participated in some G-IV synoptic surveillance flights tasked by TPC. On these flights they assisted in the editing of GPS dropsonde data for assimilation in hurricane forecast models.

During the talk (or on the poster) we will discuss preliminary analyses or findings from the 2006 missions and will discuss the P-3 and aerosonde flight strategies for 2007. HRD's primary focus in 2007 will be in assisting NCEP operations, particularly in its development of airborne-Doppler radar-data assimilation.

Contributions of Satellite Microwave Data to Hurricane Research and Operations

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At Remote Sensing Systems, we intercalibrate and consistently process data from a variety of microwave instruments (DMSP SSM/I, TRMM TMI, Aqua AMSR-E and QuikSCAT SeaWinds) to obtain research-quality geophysical ocean products including sea surface temperature (SST), ocean surface wind speed and direction, atmospheric water vapor, cloud liquid water and precipitation rate. Many of these products, especially the SSTs, contribute to hurricane research and prediction. We produce a diurnally corrected, optimally interpolated microwave SST product that represents a minimum daily ocean temperature. These SSTs have been demonstrated to improve hurricane intensity forecasts. In addition, our scatterometer and radiometer global tropical cyclone archive has been used for retrospective study and training by many organizations. Examples of these applications of our data will be shown on the poster.

Knowledge of SST is important for accurate intensity forecasting. Although microwave SSTs have a lower spatial resolution than the more traditional infrared SSTs, their through-cloud capabilities significantly improve coverage. Global, daily, near real time SSTs at 25 km resolution have been calculated using optimum interpolation (OI). The value of the AMSR-E OI SSTs was recently found when tested in the Statistical Hurricane Intensity Prediction Scheme (SHIPS) model run operationally by the National Hurricane Center. Overall, the weekly 100 km SSTs used operationally by NHC accurately represent ocean temperatures and substitution of the AMSR-E OI SSTs resulted in only slight forecast improvements (1.3% in the North Atlantic and 6.9% in the East Pacific). However, when oceanic features not resolved by the weekly analysis were present (such as cold wakes), the daily AMSR-E OI SSTs increased forecast accuracy considerably (12% to 60% for Hurricane Genevieve).

Our near-real-time web interface and archive was designed to make microwave radiometer (SST and rain) and scatterometer (wind) data accessible to the tropical cyclone research community, students and the general public. Several web sites (such as NOAA/NESDIS and NRL/FNMOC) provide scatterometer and radiometer data in real-time for storm forecasters. Our site complements these by providing research quality microwave data products archived for training and retrospective analysis. The archive interface was designed to enhance the usability and understanding of scatterometer data interpretation by integrating SSM/I rain rates and microwave OI SSTs into the display. Storm location, intensity and forecast data from Joint Typhoon Warning Center and National Hurricane Center are obtained from the Naval Research Lab – Monterey for use in extracting the scatterometer and radiometer image data. The archive consists of tropical storm images from July 1999 (when QuikSCAT data first became available) to the present for all storm basins. See http://www.remss.com/hurricane/data_archive.html.

Improvements in QuikSCAT Near-Real Time Wind Processing Implemented at NOAA/NESDIS

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NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) in cooperation with NASA/JPL has been providing near-real time (NRT) QuikSCAT ocean surface wind vector products at resolutions of 25 km and 12.5 km to the operational community since early 2000. Remotely-sensed ocean surface wind vector (OSWV) data from QuikSCAT have also become an important tool for analysis and forecasting at the National Hurricane Center (NHC), Central Pacific Hurricane Center (CPHC), NWS WFO Guam, and the U.S. Navy's Joint Typhoon Warning Center (JTWC). QuikSCAT wind speed and direction retrievals are utilized by NHC in the analysis and forecasting of tropical cyclones (TCs) in the North Atlantic and eastern North Pacific basins. The data are also used by NHC's Tropical Analysis and Forecast Branch (TAFB) in the issuance of marine forecasts, warnings, and analyses for large portions of the tropical North Atlantic and eastern Pacific oceans.

QuikSCAT data have had a major impact in TC analysis and forecasting by providing information on TC wind radii, maximum wind speed in tropical storms and marginal hurricanes, and TC center identification and location. However, this experience with QuikSCAT wind retrievals has also revealed limitations, such as larger retrieval uncertainties at the swath edges, over-flagging of retrievals as rain contaminated, and under estimation of high wind speeds. To address these shortcomings in the NRT QuikSCAT retrievals, JPL implemented several changes in the science level QuikSCAT processing system. These changes have also been adapted to NRT processing system, which has been running in a parallel test mode since May 2006. The NRT QuikSCAT processing improvements were validated by examining six months of wind retrievals from 2003 processed with both the current and the parallel algorithms. Validation was conducted by the Ocean Surface Winds Team in STAR, with evaluation from the operational forecaster perspective being conducted by colleagues at NHC and the Ocean Prediction Center (OPC). Results of the validation analyses show that the retrievals from the new processing perform better than those from the current processing and that this new algorithm should be implemented in operations.

The changes in NOAA/NESDIS QuikSCAT NRT processing of wind data will be explained and improvements in new data product will be discussed.

The University of South Alabama Center for Hurricane Intensity and Landfall Research

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Recent active hurricane seasons have shown that accurate prediction of hurricane landfall forms a major challenge to the hurricane forecasting community. To improve hurricane prediction during the next decade along the Gulf Coast will require a dense network of offshore, coastal, and inland instrument platforms. Such a network in these three critical zones will provide unique new measurements to advance both physical understanding and forecasting capabilities of landfalling hurricanes. Meanwhile, the Nation's next generation operational hurricane forecast system, the Hurricane Weather Research and Forecasting (HWRF) model, developed by NOAA's Environmental Modeling Center (EMC) will require extensive testing and validation. Both these goals are the thrust of the mission of the University of South Alabama (USA) Center for Hurricane Intensity and Landfall Research.

The offshore observation platforms will initially consist of three ADCP moorings offshore from coastal Alabama for the purpose of measuring surface wave spectra and coastal currents to observe shoaling of coastal waves from deep to shallow waters. NOAA P3 research flights will contribute additional observations of surface winds, direction wave spectra, ocean temperature and current profiles and low-level boundary layer wind structure to study the transition of the hurricane boundary layer from offshore to coastal counties during hurricane landfall. Concurrent airborne flux observations will be made with new P3 airborne turbulence instrumentation to asses the variability of air-sea fluxes in the coastal environment of landfalling hurricanes. This phase will focus on examination of the coastal air-sea processes that affect the complex interaction between the evolving coastal surface wind field and storm surge as hurricanes make landfall. We specifically address the task of providing initial and validation data sets on observed subsurface ocean structure, surface wind and wave fields and boundary layer structure for the evolving new-generation coupled hurricane intensity prediction models, specifically HWRF.

Four existing stationary weather observing platforms in coastal Alabama and Mississippi will be extended into a network of 27 sites in Alabama's 2 coastal counties and 3 additional counties to the east, north of the Florida Panhandle. Each site will record and automatically transmit data for archiving and real-time display and dissemination (via MADIS). Data recorded include standard meteorological variables at 2 and 10 m heights, in addition to rainfall, atmospheric radiation, and soil properties. Installation of the 23 new sites commenced in February 2007. Construction of a website displaying station locations and real-time data commenced during that same month. This site will also provide station meta data and archived data. All weather stations and the website will be up and running before the commencement of the 2007 hurricane season.

A state-of-the-art high performance computing cluster will be installed at the Center before the start of the 2007 season. Model testing and evaluation will begin at that point using past season storms in addition to 2007 season cases. Simultaneously, real-case and idealized landfall model simulations will be performed in research mode.

Structure and Evolution of Rainfall in Modeled Hurricanes at Landfall

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As was made clear by recent U.S. landfalling hurricanes, the distribution and intensity of rainfall can vary greatly within an individual storm, but also from case to case. The factors controlling these differences are very complex and inter-dependent. This study simplifies the problem by investigating just the impacts of the nature of the land surface. Six identical, idealized hurricanes are forced to make landfall on a straight, east-west oriented, flat coast with different roughness lengths and moisture availabilities. Results are compared to a control experiment without land.

Before landfall, the storms display a left-right asymmetry in rainfall distribution, with most of the rain falling in the right half of the storm. Subtle differences occur between the different cases initially, but as the storms approach land these differences become more pronounced. Cases with drier land surfaces display a larger degree of asymmetry. Thorough investigation of the 3-dimensional equivalent potential temperature field reveals that the rainfall asymmetry before landfall is driven by dry air intrusion. Dry air intrusion also occurs in the case without land with relatively dry air entering the right-rear quadrant below 650 hPa. The cyclonic winds cause the dry air to rotate around to the front of the vortex. Below 850 hPa the air experiences outflow in the front half of the vortex, makes 1 complete revolution while rising, and re-enters the eyewall in the right-rear quadrant at around 750-700 hPa. This destabilizes the right side of the storm. Meanwhile the portion of the entrained air below 850 hPa, experiences inflow in the front of the vortex and enters the left side of the eyewall at lower levels, stabilizing that side of the storm. This explains the slight left-right asymmetry in convection and rainfall seen in the control case. In the land cases, additional dry air from the land side enters the vortex in the left front quadrant, enhancing the stabilization on that side. At the same time, dry land air approaches the vortex from the left rear, rises, and reinforces the environmental dry air on the right side at 700-750 hPa. This additional dry air entrainment, enhances the degree of left-right asymmetry in the landfalling cases, especially for cases with a drier land use category.

During landfall, the asymmetry shifts abruptly with a rainfall maximum occurring to the left of the storm track. Cases with larger roughness lengths in combination with high or average moisture availability produce the most rainfall. A case with a low roughness length in combination with large moisture availability ranks next. Cases with low roughness length and medium to low moisture produce the lowest rainfall maxima at landfall. This rainfall peak is driven by low-level convergence forced by differential friction over land and water. In the right-front quadrant, low-level convergence is forced by speed convergence of the tangential wind, while in the left-front quadrant directional convergence of the radial wind drives the low-level convergence. Convection forms slightly downwind from the convergence maxima, and rain is swept even further downstream, into the left side of the vortex, by the stronger low-level tangential winds.

After landfall, the eyewall structure slowly collapses as the rainfall coverage broadens and becomes more stratiform. Rainfall rates fall off in all cases. More rainfall is observed in the moister surface cases, as expected.

Introducing the CIRA/NESDIS- Regional and Mesoscale Meteorology Branch Tropical Cyclone Web Page

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CIRA and the NESDIS Regional and Mesoscale Meteorology Branch (RAMMB) in Fort Collins, CO developed several operational and experimental tropical cyclone products and techniques over the last 15 years. These include time series of AMSU-based intensity, AMSU-based temperature and wind structure, a satellite-only surface wind analysis, time series of Digital Dvorak intensity estimates, storm-centered Low-earth orbit 1-km visible and Infrared (IR) imagery, Tropical Cyclone Heat Potential (TCHP; an estimate of Ocean Heat Content) and loops of 4-km IR imagery from the local archive. Because several of these products and techniques are useful to the real-time forecast community and unavailable elsewhere, a web site integrated with a database was created. The primary purposes of this web site are 1) to disseminate in a real-time manner tropical cyclone products, for all active tropical cyclones (Tropical Depression and greater) in the Automated Tropical Cyclone Forecast System, 2) provide these same analyses for post analyses of individual storms and 3) to provide access to new experimental products to obtain user feedback for possible operational transition efforts. While there is some overlap with other tropical cyclone web pages, efforts have been made to emphasize unique products not displayed elsewhere. To serve these data to the public the web page is also integrated to a dynamic database that can accommodate future product development. This feature will allow new products (such as time series of forecast parameters from the SHIPS and STIPS intensity forecast models) to easily be added to both the web site and database and new products and techniques are developed. The web page and the database will be described. The location of the web page is http://rammb.cira.colostate.edu/products/tc_realtime/.

A GIS Analysis of Radar and Surface Wind Data from a Landfalling Hurricane

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Due to the popularity of employing a geographic information system (GIS) to analyze climatologic and meteorologic data, surface winds from hurricanes and WSR88-D radar data are now available in GIS-friendly formats. This study examines several methods used within a GIS to analyze these data for the Florida landfall of Hurricane Charley (2004). GIS-ready surface wind data are acquired from the H*Winds website. Radar reflectivity returns and hourly precipitation totals are obtained through the National Climatic Data Center website, and their Java NEXRAD tools are used to georeference the data prior to importation into ArcGIS. Within the GIS, the wind and radar-derived data are converted into polygons, whose centroid, area, perimeter, compactness, elongation, and orientation are calculated. The perimeters of the rain-filled polygons are defined by the outer edge of the 20, 25, 30, 35, and 40 dBZ reflectivity values. The polygons representing the wind fields are created using 64, 50, and 34 kt values as the perimeter. Merging the wind field and rain shield polygons allows a calculation of the percentage of the convection located within the radius of a given wind speed, or a specified distance from the storm's circulation center. Spatial overlay tools allow the determination of the portion of the wind field or rain shield that intersects the land surface to be calculated. Converting the polygon data into raster format allows cell values to be added to determine the storm total rainfall in a particular location.

Results of analyses from Hurricane Charley are presented for a 24 hour period that encompasses its rapid intensification, landfall in southwestern Florida, and emergence over the Atlantic Ocean off the coast of Daytona Beach, Florida during the early stages of an extra tropical transition. Examination of the elongation ratios show that the main region of strong convection is twice as elongated as the rest of the rain shield as it is located outside the radius of hurricane-force winds, but becomes more circular during landfall while the remaining rain-filled polygons elongate. Prior to landfall, the main area of stratiform precipitation and strong convection are similarly compact while regions bounded by 30 and 35 dBZ reflectivity returns have a longer perimeter. After landfall, the perimeter length increases for all regions of the rain shield until the extra tropical transition commences. Examination of orientation values confirms these observations as all polygons are oriented in the same direction as the storm heading at the end of the study period, indicating strong atmospheric influence on the storm structure. During rapid intensification, the wind field of Charley elongates, and then becomes more circular and increases in area during the early stages of the extra tropical transition. These results are in good agreement with the expected changes to the storm's structure, indicating the potential for these methods to facilitate the comparison of the structures of additional landfalling hurricanes.

Visualizing the Temporal and Spatial Extent of Hurricane Storm-Surge

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Historically, hurricane-induced storm-surge has been documented after the event through analysis of flood evidence such as structural or vegetative damage, debris piles, high-water marks, and eyewitness accounts. However, these sources rarely provide quantitative information about the timing and duration of the flooding or the sequencing of multiple overland routes by which the storm-surge waters arrived. In response to these deficiencies, the U.S. Geological Survey (USGS) developed and deployed an experimental storm-surge network.

As Hurricane Rita approached the Texas and Louisiana coasts in September 2005, the USGS deployed 32 water-level and 14 barometric pressure sensors to record the magnitude, extent, and timing of hurricane storm surge and coastal flooding. Sensors were located at distances ranging from a few hundred feet to approximately 30 miles inland and covered an area of approximately 4,000 square miles (http://pubs.water.usgs.gov/ds220). Of the 32 locations where water-level sensors were deployed, significant inundation occurred at 24.

Water-level data for these sites were recorded every 30 seconds from just prior to landfall early on September 24 to several days later. Utilizing these data and a geographic information system, three-dimensional surfaces, and contour maps were constructed to depict various aspects of the storm-surge. These visualization tools show the arrival of the storm surge dome as it passed over the beaches and inland areas as well as an indication of the influence of topography and landfall location on the extent, depth, and the relative speed by which storm-surge waters penetrated inland areas. The maximum elevations of the fitted data were also contoured to temporally and spatially estimate water surface elevations. Maximum water surface elevations were also subtracted from a LIDAR digital-elevation model to determine maximum water depths throughout the inundated area.

Overlaying this information on other visualizations of hurricane impact, such as beach erosion and housing damage reports, could ultimately help emergency managers and resource planners to better understand surge mechanisms; help engineers to design more robust infrastructure, and assist insurance agents in assessing and settling insurance claims.

Implementation of Data Validation Algorithms in the Operational SFMR

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In 2003, with funding from OFCM, the first operational Stepped Frequency Microwave Radiometer (SFMR) was delivered to NOAA/AOC by ProSensing Inc. The operational SFMR, deployed in a wing-pod, features a compact antenna and a pressure sealed cylinder to house the radiometer electronics. In 2005, the SFMR Processor was successfully integrated with the new radiometer unit. The SFMR Processor includes a single board computer, a small text message display and additional circuitry. The single board computer executes software developed by ProSensing to process raw brightness temperature data into estimates of wind speed and rain rate.

ProSensing has implemented data validity checking algorithms in three areas:

- Validity flags indicating proper operation of each of the six receiver channels. Data from flagged channels are not used in the wind retrieval algorithm, which can still estimate the wind speed even if using less than six channels.

- Validity flags based on auxiliary information provided by the main on-board computer. Auxiliary information contains aircraft attitude and geo-location. Data is flagged whenever the aircraft is not in a near-horizontal position since the wind speed inversion algorithm does not include models for off nadir incidence angles. Based on the latitude and longitude information, ProSensing also developed a data land mask with 1 by 1 km resolution. In instances when aircraft is flying over land, data reported to NHC is flagged invalid. In conjunction with AOC and NESDIS, we are currently developing code to add the sea surface temperature (SST) value, obtained from satellite measurements to every land-free pixel. This will improve the accuracy of the wind estimate as the wind retrieval algorithm will be able to use pre-flight updated SST values thought the entire Atlantic and Pacific Ocean.

- A third data validity algorithm checks for deviation of the measured brightness temperature from the theoretical multi-parameter model versus frequency. We are analyzing data collected from previous hurricane seasons to develop the acceptable threshold levels for this error estimate, above which the data will be flagged invalid.

In 2005, US Congress appropriated funding to install pod-mounted SFMRs on all ten WC-130J Hurricane Hunter aircraft operated by the US Air Force Reserves 53rd Weather Reconnaissance Squadron. Two SFMRs were delivered to Lockheed Martin for test flights on the WC-130J in 2006. ProSensing is currently manufacturing an additional eleven SFMRs for the Air Force, with a total of four units scheduled for flights in the upcoming 2007 hurricane season. Increasing the number of operational SFMRs conducting routine hurricane surveillance will provide a large database for further development and analysis of surface wind data validity algorithms.

Operational Measurement of Hurricane Surface Waves

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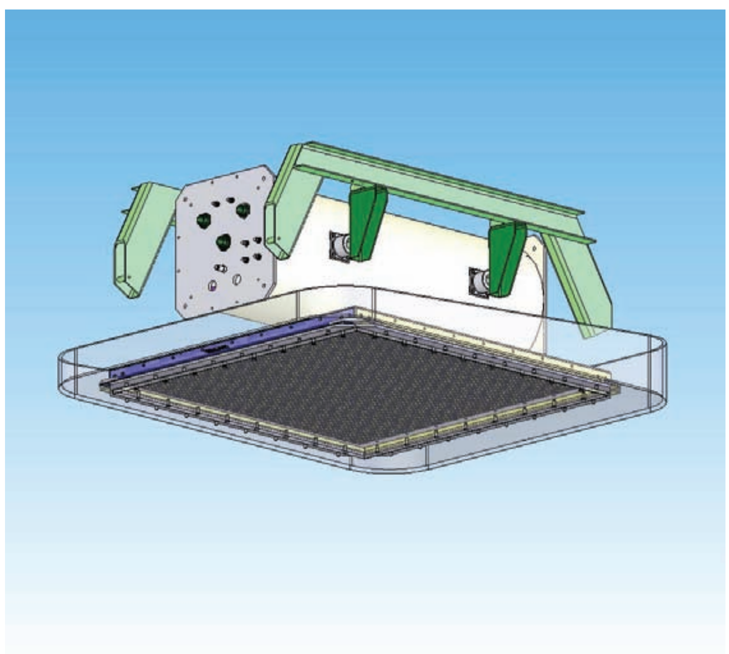
Funded through the NOAA Small Business Innovative Research program, ProSensing has designed a Scanning Radar Altimeter (SRA) intended for airborne measurement of surface wave height, direction, and wavelength from directional ocean wave spectra. A compact solid-state radar processor was designed to replace the aging prototype SRA currently operated by NOAA. The new design includes a flat plate, electronically-scanning antenna (no moving parts). The new design allows the radar to achieve the same beamwidth as the prototype Ku band SRA while operating at a less attenuating Ka band frequency. This new operational SRA can therefore operate through rain at established reconnaissance altitudes of 700 mb and lower.

The radar's processor unit is currently being tested at ProSensing, Inc. in Amherst, MA. A digital microstrip antenna is being developed, with support from the University of Massachusetts Center for Advanced Sensor and Communications Antennas (CASCA). In preparation for deployment on the NOAA WP-3D, we have completed a preliminary installation design on the aircraft. The instrument package for the SRA will be installed by NOAA/AOC in an unpressurized dome beneath the WP-3D fuselage. We plan to deploy the system for engineering flights during the 2007 Atlantic hurricane season, with a fully operational system ready for deployment in 2008.



Surface Water and Flood Monitoring of Landfalling Hurricane Precipitation Using Airborne Passive Microwave Technology

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Surface water and flooding can be detected and therefore monitored using passive microwave airborne radiometers. Signals from the lower microwave frequencies are not significantly affected by cloud water or light precipitation when measured from above. The Advanced Microwave Precipitation Radiometer (AMPR) flown on the NASA ER-2 has demonstrated high resolution detection of anomalous surface water and flooding in numerous situations. Examples of detection of surface water and of flooding from Hurricane Georges in 1998 over the Dominican Republic and over southeast Louisiana will be presented.

A New Tropical Cyclone Formation Product: Operational Implementation for the Atlantic and Eastern Pacific in 2006 and Extension to the Western N. Pacific in 2007

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The prediction of where and when tropical cyclones will form is a very difficult task and little objective guidance is available to operational tropical cyclone warning centers. In response to this need, a new Tropical Cyclone Formation Product (TCFP) has been developed. The TCFP uses the vertical shear of the wind and the sea surface temperature in combination with water vapor imagery from the NOAA GOES-East satellite to determine the probability that a tropical cyclone will form within the next 24 hours. It also provides the climatological probability of formation for a given region so that areas that are more favorable than normal for a storm to develop can be identified. In collaboration with the NESDIS Office of Satellite Data Processing and Distribution, the formation product became operational for the 2006 hurricane season. The formation probabilities are updated every six hours and are available at www.ssd.noaa.gov/PS/TROP/genesis.html along with all the information that is used as input for the product. The dependent probabilities have been evaluated using the Brier Skill Score and the Relative Operating Characteristic (ROC) score, both of which indicate the TCFP to be skillful and an improvement upon climatological formation probabilities.

The current product domain covers the forecast area of responsibility of NHC and includes the Atlantic and eastern North Pacific. A project is currently underway to extend this TCFP product to the Central and Western North Pacific basins and to provide a similar product to the Central Pacific Hurricane Center, Pacific Region WFO's, and the Joint Typhoon Warning Center. Collection of the necessary NCEP Global Forecasting System files and water vapor imagery from GOES-West, GOES-9 and MT-SAT has been completed and product development is underway, with an experimental version of the product expected to be running at CIRA by early 2007.

West African Dust Outbreaks and the Relationship with North Atlantic Hurricane Activity

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It has been recently demonstrated from satellite observations that over the last 25 years an inverse relationship exists between North Atlantic hurricane activity and the amount and frequency of African dust transported over the ocean basin. Although there is a theoretical framework for the mechanisms by which these dusty air masses may discourage tropical cyclone genesis and growth, it is still unknown if the climatological connection between dust storms and hurricane activity is direct or by association. Our presentation reviews those observations of dust and tropical cyclone variability, and discusses some of the work needed to fully understand the results. We also examine the observed dust activity for 2006, how this last season compares with previous years, and present some outlooks for next summer.

Probabilistic Hurricane Forecasts for Risk Management

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The US economy is strongly affected by hurricanes making landfall in the US, both directly (e.g., claims paid by insurance companies) and indirectly (e.g., financial performance of companies whose operations are disrupted by hurricanes). Companies seeking to manage their exposure to hurricane-related risks require forecasts of hurricane metrics tailored to their specific needs. We present a method of providing probabilistic forecasts of such a metric from a diverse set of operational forecast products.

The uncertainties conveyed as part of the official hurricane forecasts incorporate the spread in the hurricane forecast products from a number of different operational approaches. However, the various graphical and numerical products issued by the Tropical Prediction Center cannot be directly related to the metrics of hurricane risk of interest to commercial clients. We therefore present a method to combine operational hurricane forecasts from a number of different sources into probabilistic forecasts of specially tailored risk metrics. Individual forecasts are first adjusted by removing known biases, and weighted according to their known error magnitudes using Bayesian Model Averaging. Uncertainties in the predicted characteristics of hurricanes (such as position, strength, size, etc.) of the forecasted hurricanes are combined to provide the overall uncertainty in the customized index.

Session 6
Modeling and Forecasting Intensity, Structure, Sea State, and Track: Prospects for the 2007 Season and Beyond
Part 2

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Diabatic Digital Filter Initialization for Tropical Cyclone Model Forecasting

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A dynamic initialization method using diabatic digital filtering has been developed and tested for initializing high-resolution dynamic models for the prediction of tropical cyclone intensity and structure. The diabatic digital filtering removes unbalanced high-frequency components from the initial conditions through a weighted inverse Fourier transform. In this method, a dynamic model is first integrated adiabatically backward and then diabatically forward to obtain model states used in the inverse Fourier transform. After applying an efficient window function to the weights of the inverse transform, numerical experiments show that 1-h backward and 2-h forward initialization integrations are sufficient to obtain balanced initial conditions for tropical cyclone forecasts. The short integration length not only reduces the cost of the dynamic initialization, but also allows us to use fixed boundary conditions in the initialization integration. Since the diabatic digital filtering initialization includes model consistent diabatic forcing in providing a balanced state, the resulting initial conditions are better balanced than those obtained by static initialization methods, which usually involve adiabatic dynamics only.

The diabatic digital filtering initialization has been implemented and tested in the Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS®[1]). Case studies show that the diabatic digital filtering initialization effectively removes high frequency oscillations in the initial spin-up of COAMPS tropical cyclone forecasts, providing much smoother tendencies in the forecasts of tropical cyclone structure and intensity. Statistics of high-resolution COAMPS tropical cyclone forecasts show that the dynamic initialization improves tropical cyclone track forecast as well.

The diabatic digital filtering initialization has been implemented in a test version of the hurricane Weather Research and Forecasting (HWRF) model. The implementation integrates the diabatic digital filtering routines into the WRF infrastructure, which uses the Earth System Modeling Framework (ESMF) clock utilities to control time integration and object oriented programming and recursive calls to manage nested grids. The implementation method and code have been reviewed by the WRF infrastructure designer. Testing and evaluation is currently underway.

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[1] COAMPS® is a registered trademark of Naval Research Laboratory

Prediction of Consensus TC Track Forecast Error and Correctors to Improve Consensus TC Track Forecasts

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Funded by a previous JHT project, a graphical predicted consensus error product (GPCE) was developed and installed on the ATCF at both NHC and JTWC in 2004. Using GPCE's pool of predictors from the 2001-2005 seasons, revised regression models to be used for the 2006 season were derived and installed on the ATCF at both centers. These regression models are 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 75% of the time. These circular areas are then graphically displayed on the ATCF for use by the forecasters at NHC and JTWC. For the 2006 Atlantic season, the circular areas displayed by GPCE drawn around the CONU forecast positions contained the verifying TC position 81%, 79%, 74%, 79%, and 77% of the time at 24h, 48h, 72h, 96h, and 120h, respectively. For the 2006 eastern North Pacific season, the GPCE circular areas contained the verifying TC position 61%, 67%, 63%, 68%, and 67% of the time at 24h, 48h, 72h, 96h, and 120h, respectively. For the Atlantic, the performance of GPCE was close to what was expected. For the eastern North Pacific, the circular areas displayed by GPCE contained the verifying TC position less often than expected. Because the GPCE areas contained the verifying TC position much more often than expected for the eastern North Pacific in 2005, an adjustment was made to the radius calculations for 2006 decreasing their size. If that adjustment had not been made, the GPCE circular areas would have contained the verifying TC position 65%, 72%, 70%, 72%, and 71% of the time at 24h, 48h, 72h, 96h, and 120h, respectively, much closer to what was expected.

The techniques used to predict consensus error were then applied to predict the east-west and north-south forecast error of the consensus models. Regression models to predict CONU and GUNA east-west and north-south forecast error for all forecast lengths in the Atlantic were derived using the pool of predictors for the 2001-2005 seasons. These predicted errors were used as correctors to be applied to the consensus models for the 2006 season. The means of the CONU and GUNA east-west and north-south forecast errors for all forecast lengths in the Atlantic were also found for the 2001-2005 seasons to be used as correctors for the consensus models for the 2006 season. From previous work it was found that for both CONU and GUNA the bias correctors were more effective than the statistical correctors derived using the regression models for forecast lengths less than or equal to 72h. For CONU, the application of only the statistical corrector for the north-south error was most effective at 96h and 120h. For GUNA, the application of the statistical corrector for the north-south error and the bias corrector for the east-west error was most effective at 96h and 120h. Using these strategies, corrected consensus forecasts (CCON and CGUN) were produced for the 2006 season and CCON and CGUN were installed on the ATCF as experimental guidance. For the 2006 season, the CCON errors were 50 nm, 93 nm, 142 nm, 184 nm, and 240 nm at 24h, 48h, 72h, 96h, and 120h, respectively. The respective errors for CONU were 50 nm, 96 nm, 144 nm, 187 nm, and 242 nm. The CCON improvements were small with only the 48h improvement significant at the 88% level. For the 2006 season, the CGUN errors were 46 nm, 84 nm, 136 nm, 162 nm, and 227 nm at 24h, 48h, 72h, 96h, and 120h, respectively. The respective errors for GUNA were 48 nm, 86 nm, 139 nm, 168 nm, and 216 nm. The CGUN improvements were significant at the 80% level at 24h, 48h, and 72h.

Performance of the ECMWF High-Resolution Global Model and its Impact on Consensus during the 2006 Northern Hemisphere Season

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The European Centre for Medium-range Weather Forecasts (ECMWF) has diagnosed tropical cyclones (TCs) in their Ensemble Prediction System (EPS) since 2003 and distributes their TC tracker output via the GTS in the BUFR format. In 2006, NHC began processing these BUFR trackers and found significant differences in the model intensity forecasts compared to TC trackers run in the USA against coarser-resolution ECMWF fields ($\Delta x = 1.0°$); presumably because the ECMWF trackers operate directly on the model grids for: 1) the "deterministic" run (T_l 799L91, $\Delta x \sim 0.25°$); and 2) the 51 members of EPS run (T_l399L62, $\Delta x \sim 0.50°$).

This difference motivated a more thorough analysis of ECMWF model performance that goes beyond medium-range TC track prediction and the results suggest that high-resolution models are on the verge of making skillful intensity forecasts. The challenge, however, is to remove model bias and the development of new techniques to form multi-model consensus specifically for the intensity problem.

This brief will review both the intensity and medium-long range track prediction skill of the ECMWF model for all northern Hemisphere basins during the 2006 season and will highlight the model's positive contribution to consensus.

Operational Implementation of an Objective Annular Hurricane Index

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Annular hurricanes are a special class of storms characterized by a large, symmetric eye and very little rain outside the eyewall. Annular hurricanes pose a distinct challenge when forecasting hurricane intensity, as they tend to maintain their intensity for longer than average storms. For this reason, an objective Annular Hurricane Index (AHI) was developed and implemented at the National Hurricane Center at the end of the 2006 season for use in 2007. Beginning in 2007, the AHI will be available to the NHC forecasters as part of the output from the SHIPS intensity model.

Knaff et al. (2003) determined that annular hurricanes exist in a specific set of environmental conditions. Hence, the AHI uses environmental factors such as vertical wind shear, 200-hPa zonal wind, and sea surface temperature as well as storm structure characteristics to determine the existence of annular structure. The predictor values were determined by examining NCEP environmental fields and GOES IR imagery over the period of 1995-2003 for annular and non-annular hurricane cases. The algorithm's development uses a two step process. The first step screens the cases using environmental (i.e., within 3 standard deviations of annular cases) and IR imagery characteristics (e.g., large circular eyes, limited rainbands etc.). The remaining cases are then used to develop a linear discriminant function.

In real time, the AHI product acquires large-scale environmental values from the SHIPS model and information on structure from GOES IR imagery. If a real-time case does not pass the screening, the AHI is set to 0. If, on the other hand, a real-time case passes the screening, the discriminant function is then run to create the AHI. The AHI has a value ranging from 0 to 100, with 0 indicating no annular structure, 1 indicating the worst match to annular structure, and 100 indicating the best match to annular structure. Post-analysis of the 2004-2006 Atlantic and E. Pacific hurricane seasons has provided positive results that suggest the AHI will be a skillful tool in the objective identification of annular hurricanes. Product validation will continue throughout the 2007 season.

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A TECHNIQUE TO PREDICT THE EXTRATROPICAL TRANSITION OF TROPICAL CYCLONES.

By

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Extratropical transition (ET) is a process that a tropical cyclone can undergo as it moves to higher latitudes over colder seas and interacts with the midlatitude regime. The resulting extratropical cyclone can be powerful with heavy precipitation to the left of track and a large extent of gale-force-winds to the right of track producing potential hazards to coastal settlements and maritime activities. The whole transition process typically takes 18-48 hours to be completed with two basic possible end results, either dissipation or intensification of the combined system. These two classes of tropical cyclones behave very similarly during the early stages of extratropical transition. Thus, the end result of this transition is very hard to predict accurately even with full-physics atmospheric prediction systems such as the Navy's Operational Global Assimilation and Prediction System. Although there are many factors involved in the process, research has shown that the reintensification of the extratropical cyclone results primarily from its interaction with a midlatitude trough. Thus, the end result of extratropical transition may depend more on the phasing between the tropical cyclone and the trough it moves into rather than the details of the tropical cyclone structure.

Here we present results from a multi-stage technique to predict the simplest of ET outcomes: whether an ETing system will reintensify or dissipate after ET. To date the system uses NOGAPS analyses as input to a statistical technique that separates the discriminating large scale factors associated with reintensifying or dissipating ET cases. Using these data we have achieved a best performance of 88% detections with 27% false alarm rate on test storms from 2003 and 2004 with a limited training set from 1997 - 2002.

The system is not yet fully operational-capable: we are working on the last few steps needed for it to run in a full forecast mode. In addition, we are looking at creative ways to increase the training set so that more useful classes of ET can be discriminated by this system. These classes include: dissipation, weak reintensification; moderate reintensification; strong reintensification; and timing to minimum pressure (e.g., 24 hours, 48 hours, > 72 hours).

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Understanding Wind/Wave Forcing of the St. Johns River

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We will focus on the development and application of a finite element, two-dimensional, hydrodynamic St. Johns River model for the simulation of water surface elevations and depth-integrated velocities. Three domain variations will be discussed: 1) A model domain that incorporates the entire East Coast of the United States out to the 60°W meridian, Gulf of Mexico and Caribbean Sea, while honing in on the St. Johns River area (see Figure 1 below); 2) A sub-domain that is shelf-based; and 3) A sub-domain that is inlet-based. Results will be presented from numerous hydrodynamic simulations that altered the following four forcing mechanisms in order to determine their relative importance: 1) astronomical tides; 2) inflows from tributaries; 3) winds and pressures; and 4) surface waves. The Hurricane Floyd event of 1999 and a 122-day period spanning June 1 – September 30, 2005 will be highlighted.

Four main conclusions are reported. First, wind forcing for the St. Johns River is equal to or greater than that of astronomic tides and generally supersedes the impact of inflows, while pressure variations have a minimal impact. Second, water levels inside the St. Johns River depend on the wind forcing in the deep ocean; however, if one applies an elevation hydrograph boundary condition from a large-scale domain model to a local-scale domain model the results are highly accurate. Third, wind-induced surface waves generate an approximately 10 – 15 percent higher peak storm tide for Hurricane Floyd. Finally, while a carefully calibrated model can reproduce local and even regional storm tide hydrographs, the wind surface drag is spatially and temporally dependent and the drag formulation requires significant research effort.

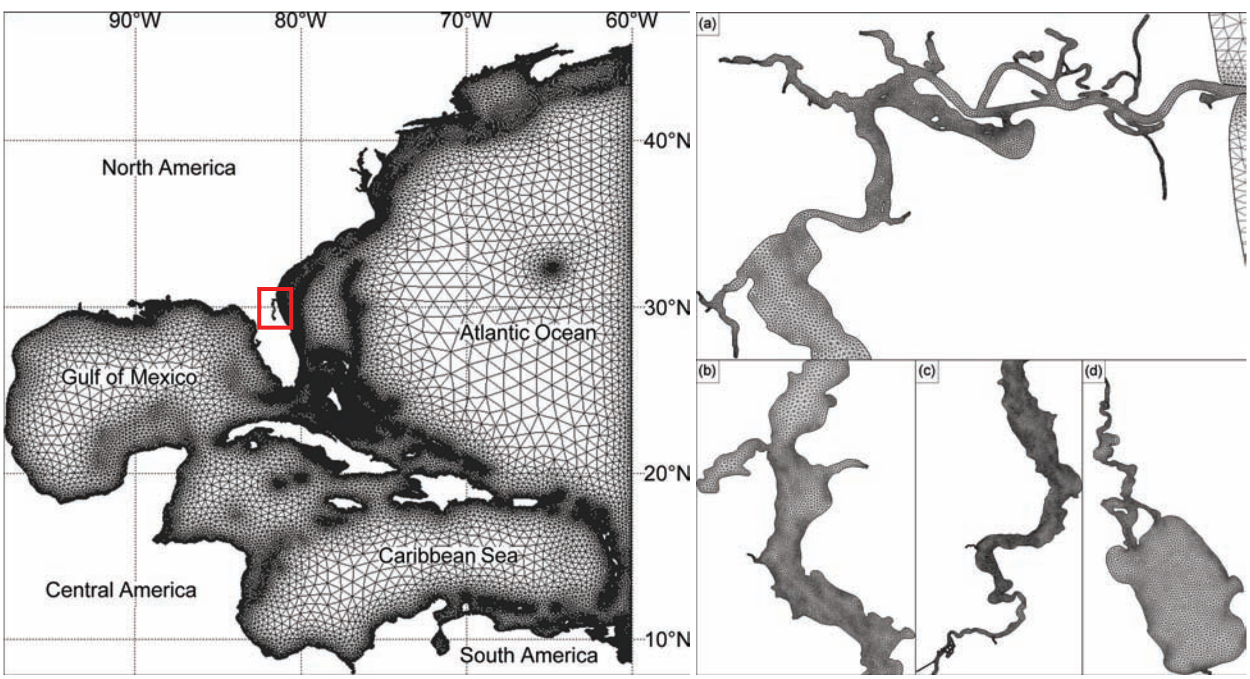

Figure 1. Spatial discretization of the Western Atlantic, with insets of the St. Johns River region from its inlet near Mayport (a) to its upstream limit at Lake George (d).

Session 7
Damaging Winds, Precipitation, and Storm Surge: Physical and Socioeconomic Impacts of Landfalling Storms

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U.S. Hurricane Damages 1900 to 2005 - Why Do the Losses Keep Going Up?

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University of Colorado

Joel Gratz
ICAT Managers

Chris Landsea (Chris.Landsea@noaa.gov), (presenting)
TPC/NHC, Miami, FL

After more than two decades of relatively little Atlantic hurricane activity the past decade has seen heightened hurricane activity and more than $150 billion of dollars in damage in 2004 and 2005. This paper normalizes U.S. hurricane damage from 1900-2005 to 2005 values using two methodologies.

A normalization provides an estimate of the damage that would occur if storms from the past made landfall under another year's societal conditions. Our methods use changes in inflation and wealth at the national level and changes in population and housing units at the coastal county level. Across both normalization methods, there is no remaining trend of increasing absolute damage in the dataset, although 2004 and 2005 are large loss years. The 1970s and 1980s were notable because of the extreme low amounts of damage compared to other decades. The decade 1996-2005 has the second most damage among the past 11 decades with only the decade 1926-1935 surpassing its costs. Over the 106 years of record, the average annual normalized damage in the continental United States is about $10-11 billion. The most damaging single storm is the 1926 Great Miami storm with $140-157 billion of normalized damage. The most damaging years are 1926 and 2005. Of the total damage, about 85 percent is accounted for by the intense hurricanes (Saffir–Simpson categories 3, 4, and 5), yet these have comprised only 24 percent of the U.S. landfalling tropical cyclones.

Unless action is taken to address the growing concentration of people and properties (such as by strengthening the ability of buildings to withstand storms) in coastal areas where hurricanes strike, damage will increase, and by a great deal, as more and wealthier people increasingly inhabit these coastal locations.

Interagency Coordination in Hurricane Wind and Storm Surge Hazard Reduction

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There are interagency and international efforts either refocusing or emerging that address wind hazard reduction with strong emphasis on hurricane winds. Some of these efforts also address storm surge and wave damage or, at least, attempt to separate storm surge-related damage from wind damage. This presentation will explain some of these efforts, including the major players, their charge, and the major tasks being undertaken or planned. This presentation will also highlight the need for better linkage between these activities, a need that may be enhanced in response to the recent National Science Board report: *Hurricane Warning-The Critical Need for a National Hurricane Research Initiative.*

One of the major new interagency activities is the implementation of the 2004 Congressional legislation known as *The Windstorm Impact Reduction Act.* The Act has a significant hurricane component and, recognizing the importance to the structural engineering community of delineating between the effects of wind and storm surge, it includes both components. The implementation of this act is the responsibility of the President's Office of Science and Technology Policy. Other interagency activities that focus on wind and storm surge hazard reduction include the U.S.-Japan Bilateral Panel on Wind and Seismic Effects, part of the U.S.-Japan Natural Resources Program which is operated by the Department of State. There is also a bilateral NIST-NOAA initiative on Hazard Resilient Communities that includes wind and storm surge hazards with particular attention to hurricanes. Each of these efforts are interrelated, and there are overlaps among them.

STORM SURGE/FLOODING DISASTER MITIGATION

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During and following Hurricane Katrina it was obvious that citizens along the Mississippi Gulf Coast and the greater New Orleans area had a difficult time understanding what storm surge was and its potentially deadly consequences. Media reports of 10 feet of storm surge often fell on deaf ears as did warnings such as “If you live in flood zone A or B you should evacuate. The general public often viewed a 10 foot storm surge as large waves breaking on the beach. Many of us were not sure of what, if any, flood zone we lived in. As a result, poor evacuation decisions were made.

The University of Southern Mississippi’s Center of Higher Learning is the home of a state of the art immersive visualization center. Since the storm the visualization center has created a decision support tool that will help citizens make better informed evacuation decisions in the future. The “Vis Center” has developed a prototype system that will be web enabled which will depict expected flood levels in given communities caused by natural or man made storm surge/flooding events. The concept will be demonstrated using low resolution LIDAR imagery and simulated rising water levels which reach the flood levels recorded after Katrina. Also demonstrated will be high resolution topography and digital photography of Gulfport Mississippi with the Katrina flood levels superimposed. The result is an easy to understand “picture” that leaves no doubt in one’s mind as to potential impact of anticipated flood waters.

In addition to being a useful tool for home and business owners, the tool can also be used by emergency planners and responders for training and planning. It is envisioned that the output form various storm surge models (e.g. SLOSH, ADCIRC) could be run for various storm track and intensity scenarios with the time series output overlaid on high resolution topography.

The storm surge/flooding disaster mitigation tool can be used in any area that is threatened by storm surge and/or flooding as a result of any natural (e.g. hurricane, tsunami) or man made (e.g. dam or levee breaching) disaster. The Center of Higher Learning has received eleven letters of endorsement from Mississippi political, emergency response, and economic development leaders for funding and continued development of this tool.

Barrier Island Failure during Hurricane Katrina

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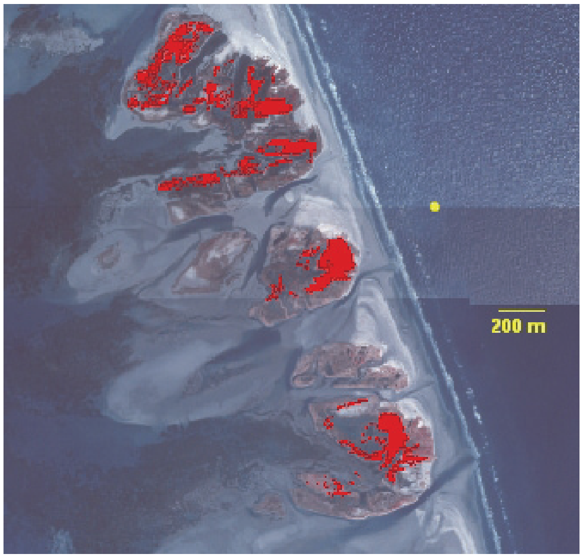
Classical models of barrier-island response to storms predict that wave runup can periodically overtop an island and transport sand from its seaside to its bayside, forcing the island to migrate landward. While this process can destroy fixed human developments, the island survives with little net change in form or dimensions. In contrast, we find that Louisiana's Chandeleur Islands during Hurricane Katrina were not periodically overtopped by waves, but were continuously inundated by storm surge. When such inundation occurs locally on a barrier island, it can force the erosion of a narrow breach that connects sea and bay. However, little is known about the response of a barrier island when it is entirely submerged.

Here, we show that the Chandeleur Islands approached complete failure, losing 84 percent of their surface area. Their Gulf of Mexico shorelines retreated landward an average of 268 m, the largest retreat ever reported for a storm. Sand was stripped from the islands, reducing their peak elevation from >6 m to <3 m and exposing them to further degradation and complete failure by subsequent hurricanes of less intensity than Katrina. Further, the islands that survived Katrina were marsh remnants composed of mud and vegetation that relatively small waves diminished following the storm.

The Chandeleur Islands are prone to failure because of their location on the Mississippi delta where small sand supply and large sea-level rise (induced locally by land subsidence) limit natural rebuilding of the islands following a storm. The response of the delta's barrier islands during Hurricane Katrina provides a warning of how the world's barrier islands might respond to storm surge inundation should predictions of accelerated global sea level rise prove accurate.



Pre-storm vertical aerial photograph from the northern Chandeleur Islands with post-storm island areas (determined from lidar data) superimposed in red. After Katrina, all non-red areas on the photo were water.

NOAA's Response to Hurricane Impacts on Ports, Harbors, Navigation Channels and the Surveying for Debris and Hurricane Hazards that Pose a Risk to Commercial Fishing, Shrimping, and Recreational Boating

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NOAA Office of Coast Survey

NOAA's Office of Coast Survey is responsible for the surveying and charting of the nation's coastal waters, navigation channels, and Ports and maintains a large suite of navigation charts. As part of the Coast Survey mission, navigation managers and navigation response teams (NRTs) and survey contractors (under contract to Coast Survey) are deployed across the nation and work with Ports, States, the U.S. Coast Guard, Pilots and many others on charting and navigation issues and to respond to severe incidents and storm impacts. The nation's Marine Transportation System (MTS) is a critical part to the nation's economy. Over 90 percent of all goods found in the U.S. today were at one time transported by ship or barge through the MTS network.

Hurricanes Katrina and Rita impacted ports and waterways from Pensacola, Florida to Galveston, Texas and damaged or destroyed port facilities, docks, shore terminals and huge numbers of coastal housing, businesses and other infrastructure. In the aftermath, the coastal shorelines, bays, and nearshore areas of Alabama, Mississippi, Louisiana, and Texas found significant debris and hazards that pose a risk to shipping, shrimping, commercial fishing, and recreational boating.

NOAA's Coast Survey was tasked immediately after the storms by the US Coast Guard to survey and locate debris and hazards to navigation and use to critical ports and waterways that included Pensacola, Mobile, Pascagoula, Biloxi, Gulfport, New Orleans (and the Mississippi River from Baton Rouge to the Gulf of Mexico), the GIWW, Port Fourchon, Port of Lake Charles, Port Arthur, and the Port of Houston-Galveston. Both NOAA assets and contract vessels were deployed and a large coordinated effort was implemented to survey, identify and collaborate with other agencies in the removal of hazards in an effort to clear ports and priority navigation channels.

2006 saw the development and implementation of a survey effort to identify debris and hazards in fishing grounds in Louisiana, Mississippi, and Alabama that pose significant risks to the Gulf Coast shrimping and commercial fishing industry. Through consultations with state Wildlife and Fisheries and Marine Resource agencies and others, NOAA developed survey plans for over 600 square nautical miles of nearshore and coastal bay areas that is now being implemented. Using sidescan and single beam sonar imagery, hazards and debris are being located and listings of the position and attributes of the hazards are being provided to state agencies, U.S. Coast Guard, FEMA, and others. A Gulf of Mexico Marine Debris website was established and provides graphical depictions of the hazards.

NOAA will provide an overview of the response efforts implemented post hurricane along the northern Gulf and a status and examples of the ongoing work of the nation's largest marine debris survey effort to be implemented.

Using GIS to Map the Impacts of Marine Debris Left in the Wake of Hurricane Katrina

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During the 2005 hurricane season, Katrina and Rita inflicted severe damage on the Northern Gulf of Mexico coastal region, and deposited huge amounts of debris over large areas of the Gulf coast. Submerged marine debris poses a hazard to vessel traffic and can adversely affect commercially viable fishing grounds. To address the submerged debris problem, Congress appropriated emergency funds to survey areas potentially affected by submerged marine debris, tasking NOAA's Office of Coast Survey (OCS) and Office of Response and Restoration which houses the NOAA Marine Debris Program, to conduct the surveys, compile and disseminate data to public stakeholders in an effective and useable format, conduct marine debris characterization, and carry out other outreach activities specific to this project. This partnership has been formally titled the Gulf of Mexico Marine Debris Project (GOMMDP) and is covering near shore areas from Lake Borgne, Louisiana to Perdido Bay, Alabama.

One of the key elements of the GOMMDP is using the data received from hydrographic surveys to generate an integrated survey database within a Geographic Information System (GIS). Such a database facilitates the generation of products depicting the location of debris found, debris dimension, sounding depth, clearance depth and other information, as well as designation of recovery or removal constraints (e.g., archeological sites). The Project team is utilizing the debris data and GIS applications to provide stakeholders with critical information and maps of near shore survey areas. GIS products will present useful information both to stakeholders analyzing the impact of marine debris and to personnel mobilized for removal of surveyed contacts, and may provide best removal, disposal or relocation results with the limited funds and resources likely to be available in the near future.

Stakeholders, including the US Coast Guard, Federal Emergency Management Agency, Army Corps of Engineers, state resource managers, and commercial and recreational fishermen now have access to debris maps and data by way of the GOMMDP Web site (http://gulfofmexico.marinedebris.noaa.gov). The project team is also developing an Internet Mapping System (IMS) to deliver debris location and data to users via dynamic, scaleable, and easy to use web-based maps. Stakeholders will be able to access data layers and depict operational data such as debris density and abundance, or analytical information such as acres of sea grass impacted by submerged debris. Users will also be able to download GIS data files for use in separate GIS analyses.

The purpose of this presentation is to highlight the functional properties of GOMMDP GIS tools, demonstrate its benefit to users, and answer any questions regarding the future objectives of the project.

Session 8
Research to Operations: The Latest on the Joint Hurricane Testbed and Future Plans

SESSION 8

The Joint Hurricane Testbed (JHT): 2007 Update

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New analysis and forecasting tools and techniques, developed by the research community, were tested and evaluated during 2006 at the National Hurricane Center/Tropical Prediction Center (TPC/NHC), in real time for the sixth consecutive hurricane season, as facilitated by the Joint Hurricane Testbed (JHT). Fifteen third round (FY05-06) projects were tested and evaluated, 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, and assessments of dynamical model forecasts of tropical cyclogenesis and of tropical cyclone rainfall. An announcement of Federal Funding Opportunity was released in June. Letters of Intent followed by full Proposals were submitted by Principal Investigators and evaluated by the JHT Steering Committee. At the time of this writing, the 27 full Proposals received were being evaluated and the ones selected will be tested during this coming hurricane season.

Development and Implementation of NHC/JHT Products in ATCF

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The Automated Tropical Cyclone Forecasting System (ATCF) was developed by NRL and has been in use at the Joint Typhoon Center since 1987 and the NHC since 1990. Since this time, a concerted effort has been made to develop common data formats and functionality so that tropical cyclone information is easily shared among the operational forecast centers. As a result, ATCF has become a target platform for many NHC and JHT products. This project is designed to implement, test and evaluate JHT and NHC products intended for use in operations on ATCF. In addition, this work addresses NHC specific requirements levied on the ATCF developers at a yearly requirements meeting and throughout the season.

Major tasks for this project included:

1) Evaluation of two wind radii CLIPER algorithms,
2) Implementation of the Monte Carlo wind probabilities in ATCF,
3) Implementation of the Goerss Probability Consensus Error (GPCE) in ATCF,
4) Improvement of the satellite imagery overlay capability in ATCF,
5) Development of intensity and wind radii objective best-track routines,
6) Automation of tropical cyclone fix entry in the NHC ATCF, and
7) Address NHC requirements.

All tasks have been addressed with some degree of success. Highlights of the work will be briefed. To address task (7), approximately 20 NHC requirements of varying difficulty were addressed for the 2005 season and another 15 for the 2006 season. Approximately 10 more will be addressed for the 2007 season. Changes to the ATCF are vetted through NHC personnel before they are accepted in operations. Highlights of 2006/2007 upgrades include a redesigned wind forecast dialog, an intensity consensus skill baseline, and an objective best track for intensity and wind radii.

Assimilating Moisture Information from Global Positioning System (GPS) Dropwindsondes into the NOAA Global Forecast System

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GPS dropwindsonde moisture data from G-IV hurricane synoptic surveillance and HRD research missions in 2005 and 2006 were assimilated into parallel (2005) and operational (2006) runs of the NCEP Global Forecasting System (GFS). The objectives of this study included: (i) assessing the impact of dropwindsonde moisture data from the 2005 G-IV missions on GFS forecasts of tropical cyclone track and intensity; (ii) assessing the impact of dropwindsonde data from the 2005/2006 G-IV missions on GFS analyses of humidity and how effectively the GFS represents dry layers such as the Saharan Air Layer; and (iii) evaluating the feasibility of performing targeted dropwindsonde humidity observations in the tropical cyclone to improve GFS forecasts. Efforts associated with the first goal showed that the dropwindsonde humidity data did not have a strong negative or positive impact on GFS forecasts of tropical cyclone track/intensity, though for some individual cases (e.g. 2005 Tropical Storm Irene and Hurricane Katrina), the dropwindsonde humidity information had a significant impact on the GFS track forecast. Based on these findings, the NOAA National Centers for Environmental Prediction approved the assimilation of dropwindsonde humidity data into the GFS model from all dropwindsondes launched from NOAA's G-IV jet beginning on 22 August 2006. Preliminary findings associated with the first and second goals of this project (assessing GFS analyses of humidity and evaluating the feasibility of performing targeted dropwindsonde humidity observations in the tropical cyclone environment) will be presented.

Verification of the Monte Carlo Tropical Cyclone Wind Speed Probabilities: A Joint Hurricane Testbed Project Update

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A Monte Carlo tropical cyclone wind speed probability estimation algorithm was developed at CIRA/NESDIS under previous Joint Hurricane Testbed (JHT) funding. The Monte Carlo Probability (MCP) program estimates the likelihood of 34-, 50-, and 64-kt winds out to five days. This new probability program was used to produce several National Hurricane Center (NHC) operational products during the Atlantic and east Pacific 2006 hurricane season. Versions were also developed for the Central and Western Pacific using forecast information from the Central Pacific Hurricane Center (CPHC) and the Joint Typhoon Warning Center (JTWC). The purpose of the current JHT project at CIRA/NESDIS is to develop a verification system for the new probability program. This presentation will provide a brief summary of the MCP algorithm and a status report on the verification system development.

The MCP program utilizes the past history (5 years) of the official track and intensity forecast errors from NHC, CPHC, and JTWC in combination with the errors from a simple climatology and persistence wind radii model (Knaff et al. 2007). The error fields are randomly sampled in a manner that includes serial correlation to provide wind speed probabilities that take into account the uncertainty in the track, intensity and structure forecasts. The verification program includes metrics that help to answer the following questions:

1.) Does the MCP program create skillful 34-, 50-, and 64 –kt wind speed probabilities?
2.) Are the probabilities unbiased?
3.) Do the MCPs tend to over/under predict the frequency of observed events?
4.) Are the MCPs an improvement over simply using the deterministic official forecast in a probabilistic way (100% probability if a point comes within the forecast wind radii, 0% probability if it does not)?

These questions can be answered using standard statistical techniques such as the expectation value, the Brier Skill Score (BSS; Brier, 1950; Murphy 1973), Relative Operating Characteristics (Mason and Graham, 1999), and Reliability Diagrams (Wilkes, 2006). The statistics associated with seasonal verification of the MCPs and the Official (i.e., deterministic) forecasts are compared and presented.

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Tropical Cyclone Wind Radii Estimation Utilizing an Empirical Inland Decay Model

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A revised version of the Kaplan/DeMaria decay model that better handles tropical cyclones that traverse islands and peninsulas was tested in real time during the 2006 hurricane season. Implementation of the updated version of the model required significant modifications to the code that was employed to run the original version. Specifically, a wind field on a cylindrical grid with 5 km radial and 15 deg. azimuthal spacing was generated every hour along the NHC forecast track. The shape of the wind field was determined every hour by fitting the NHC official forecasted storm structure, intensity, and storm speed along the forecast track using a modified Rankine vortex. The wind field on the cylindrical grid was then decayed for time periods when the storm was over land using the updated version of the decay model. For time periods when the storm moved back over water, the trend in the official NHC intensity forecast was employed to adjust the decayed wind field. The resultant wind field was then sampled at desired time intervals to obtain estimates of the maximum wind and the radius of 34-, 50-, and 64-kt winds. Since the updated decay model was not available for real-time testing until the middle of the 2006 hurricane season, the model was verified for hurricanes that made landfall from 2004 -2006. The results of these evaluations will be presented at the conference.

VORTRAC - A Utitility to Deduce Central Pressure and Radius of maximum wind of Landfalling Tropical Cyclones Using WSR-88D data

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This paper gives a progress report on the development of the Vortex Objective Radar Tracking and Circulation (VORTRAC) package for the JHT. Using the level II coastal WSR-88D data, VORTRAC tracks intensity (central pressure) and radius of maximum wind of landfalling tropical cyclones retrieved from the ground-based velocity track display technique (GBVTD) and the hurricane volume velocity processing method (HVVP). The VORTRAC work has been focused on (1) the design and implementation of a user interface using the Qt tool kit, and (2) integration of the radar quality control and processing algorithms.

Over the past year, several implementations and improvements have been completed. The VORTRAC software package developed for this project now has the capability to read both archived NCDC and real-time LDM level II radar data formats. The central pressure and radius of maximum wind retrievals were also integrated into the package, as well as performance enhancements to the GBVTD and HVVP implementations. Following suggestions received during a visit to TPC, the graphical user interface was improved in order to display additional important information for the Hurricane Specialists, including the ability to preset the storm motion and direction prior to a storm entering radar range. Memory allocation has also been improved, allowing for longer run times, and numerous bug fixes have increased the stability and robustness of the software package. Some of these new features and results from previous landfalling storms will be presented at the conference.

Mapping of Topographic Effects on Maximum Sustained Surface Wind Speeds in Landfalling Hurricanes

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While the effect of large-scale topography, such as that found on Hispaniola in the Caribbean, on the overall structure and intensity of hurricanes passing over such topography is reasonably well understood, forecasters at the Tropical Prediction Centre/National Hurricane Centre (TPC/NHC) currently have no means available to them to assess the impact of small-scale topography, whose maximum height is less than the depth of the boundary layer, on near surface wind speeds in hurricanes making landfall over such terrain. For topography of this nature it is found that wind speeds near the crests of hills and ridges show marked increases in wind speed when compared to the equivalent wind speed measured at the same height above flat terrain, with increases of over 90% being observed in some field studies. Clearly this speed-up effect has major implications for forecast surface wind speeds in tropical cyclones making landfall on islands such as Puerto Rico and the U.S. Virgin Islands in the Caribbean, or the Hawaiian Islands and Guam in the Pacific, where topographic effects on surface wind speeds are likely to be significant.

Using a linear model for boundary layer flow over topography in combination with the U.S. Geological Survey's National Elevation Dataset (NED) the effects of small-scale topography on surface wind speeds at a height of 10 m for Puerto Rico and the US Virgin Islands have been mapped. In principle, provided suitable digital terrain data is available, the same approach can also be used to map topographic speed-up effects for other regions of interest to the TPC/NHC if a need is indicated. The original project proposal called for a set of maps showing contours of speed-up factors to be delivered to the TPC/NHC that could then be used by forecasters to assess the effects of topography on maximum sustained surface wind speeds in hurricanes making landfall in Puerto Rico or the US Virgin Islands. This, however, required forecasters to make decisions about the appropriate wind directions to use as well as calculations of the likely wind speeds in the event of a landfalling hurricane.

In an attempt to try and streamline the process a program built around an open source Geographic Information System (GIS) package has been developed that allows forecasters to select an island, a track heading, the position of the track in relation to the island being considered and the maximum sustained wind speed before plotting the forecast wind field using either 5 kt wind speed bands, or Saffir-Simpson hurricane categories. Overlays showing major population centres, roads, etc. can also be superimposed on the forecast wind field.

Operational SFMR-NAWIPS Airborne Processing and Data Distribution Products

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Paul Chang, Tim Mavor, NOAA / NESDIS / ORA
Peter Black, Eric Uhlhorn, NOAA / HRD

Since 2005, NOAA Aircraft Operation Center (AOC) has deployed wing mounted Stepped Frequency Microwave Radiometer (SFMR) instruments on both their WP-3D aircraft. These remote sensing instruments provide real-time near ocean surface wind speed and precipitation estimates to the National Hurricane Center (NHC). Remote Sensing Solutions, NOAA / NEDSIS / ORA and NOAA HRD have teamed through the Joint Hurricane Testbed (JHT) program to validate the SFMR near ocean surface wind speed and rain retrievals and improve the operational utilization of wind and rain products derived from the SFMR retrievals. The first year's effort focused primarily on validation, calibration and quality control. Now in the second year, the effort is targeting further reduction of the uncertainty in the retrievals through algorithm improvements; development of tools to provide more advanced data products; and investigation of the impact bathymetry may have on the retrievals. This presentation will provide a summary of the SFMR's performance in 2006 and discuss the improvements being made to the retrieval algorithm which address deficiencies in the precipitation retrieval that affect both the precipitation estimate and the wind speed estimates.

Improved Statistical Intensity Forecast Models:
A Joint Hurricane Testbed Project Year 2 Progress Report

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Three improvements to existing operational statistical intensity forecast models were proposed in this project as follows. 1) The decay formulation for storm tracks over land in the Statistical Hurricane Intensity Prediction Scheme (SHIPS) has a low bias (too much decay) for storms moving over islands and narrow landmasses such as Florida. A new formulation of the basic decay equation was developed where the decay rate is proportional to the fraction of the storm circulation over land. The impact of the new decay formulation on the SHIPS forecasts will be evaluated. 2) The method for calculating the vertical shear in SHIPS averages the wind over a fairly large annulus (200 to 800 km from the storm center). This large area is needed to avoid the NCEP global model representation of the storm. A method was proposed to remove the storm circulation from the model forecast fields so smaller areas could be tested. 3) As a companion to the SHIPS forecast, a Rapid Intensity Index (RII) was developed to estimate the probability that a storm will rapidly intensify in the next 24 hours. The current RII is based on a simple scaling of the input variables, which have equal weight in the probability calculation. A more sophisticated discriminant analysis method is proposed, which weights the inputs to provide the best probability estimate.

The new decay model was tested in real time during 2005 and 2006, and provided considerable forecast improvement. A method was developed to remove the symmetric part of the tropical cyclone circulation from the GFS model so that smaller areas for calculating the shear could be tested. It was found that the time tendency of the forecasts vortex strength was also a good predictor of intensity. A parallel version of SHIPS with the smaller shear area (0 to 500 km radius) and GFS vortex predictor was run in real time during the second half of the 2006 season. The forecasts for the first half of the season were also re-run to provide a full season for evaluation. Results show that the version of SHIPS with the modified shear and GFS vortex predictor significantly improved the Atlantic SHIPS forecasts, and marginally improved those in the east Pacific. The discriminant analysis version of the RII was run in parallel in real time for the entire 2006 hurricane season. A comparison of the operational and experimental RII forecast verifications will be presented.

Eastern Pacific Ocean Heat Content Estimates for SHIPS Forecasting

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Using a hurricane season (May through October) ocean climatology derived from the U.S. Navy's Generalized Digital Environmental Model, isotherm depths, reduced gravities and oceanic heat content (OHC) estimates are compared to profile data acquired from moored measurements from the Tropical Atmosphere and Ocean (TAO) array in the Eastern Pacific Ocean and during the Eastern Pacific Investigation of Climate (EPIC) in Sept and Oct 2001 sponsored by NSF and NOAA. During EPIC, mesoscale oceanic current, temperature and salinity variability was mapped by deploying oceanic airborne expendable current profilers and expendable conductivity, temperature and depth profilers (AXCPs, AXCTDs) from NOAA WP-3D research aircraft.

Comparisons of SSTs and isotherm depths have been made at the TAO buoys where hourly thermal structure was measured as well as salinity at selected depths. SSTs from the TRMM microwave imager (TMI) provided a better estimate than the Reynolds SST product (RMS differences where 0.5^{o}C compared to 0.6^{o}C). Regression slopes indicate that the TAO-TMI data have a slope of 0.94 compared to TAO-Reynolds data of 0.63, leading to an OHC underestimation using Reynolds 7-day analysis. By blending several radar altimetry products from NASA TOPEX/Jason-1, U.S. Navy Geosat-Follow-On mission, and European Research Satellite (and/or Envisat), surface height anomaly (SHA) fields are objectively mapped to 0.5^{o} grid to estimate isotherm thickness of 26^{o}C water, and OHC. One particular focus is to map an observed warm eddy observed during EPIC to improve the satellite-retrievals. These warm eddies, with surface elevations of 12 to 15 cm, propagate west-southwest at a speed of 13 cm s^{-1} in accord with *in situ* measurements with 26^{o}C isotherm depths of about 50 to 55 m (OHC ~ 50 kJ cm^{-2}).

In the Eastern Pacific Ocean, the seasonal thermocline shoals and tightens the stratification (thermal structure), forcing large buoyancy frequencies (vertical density changes) across the oceanic mixed layer base. Given the strength of the stratification (i.e. shape of the thermal profile), the area underneath the curve relative to the SST and 26^{o}C isotherm depth is estimated and compared to *in situ* profiles and TAO time series. At 10^{o}N and 95^{o}W, for example, satellite-inferred isotherm depths and OHC estimates are within a few meters and kJ cm^{-2}, respectively suggestive of accurate retrievals from radar altimetry and TMI. The approach is being applied to several years of measurements to assess uncertainties and errors in the retrievals to build a reliable climatology for use with SHIPS forecasting in the Eastern Pacific Ocean.

Statistical Hurricane Intensity Prediction Scheme with Microwave Imagery (SHIPS-MI): Results from 2006

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A Statistical Hurricane Intensity Prediction Scheme (SHIPS) with Microwave Imagery (SHIPS-MI) was run experimentally at the National Hurricane Center (NHC) and run in parallel at the University of Alabama in Huntsville (UAH) during 2006. Results from the NHC runs will be shown here. SHIPS-MI uses the large scale diagnostic predictors that are generated for SHIPS, and adds predictors taken from satellite passive microwave imagers. These predictors – primarily the mean 19 GHz brightness temperature within 100 km from the cyclone center – are related to the latent heating in the tropical cyclone's inner core. The SHIPS model's infrared and oceanic heat content terms are *not* used in SHIPS-MI, but most of the other predictors are.

Mean absolute errors from SHIPS-MI were slightly smaller (~0.3 kt) than those from SHIPS for a homogeneous set of Atlantic basin forecasts. For the Eastern North Pacific, SHIPS-MI showed a much greater reduction of error (~2.0 kt). Some of this improvement in the Eastern North Pacific may be attributable to using a slightly different set of large scale diagnostic and climatological predictors, besides including the microwave predictors. The SHIPS-MI mean absolute errors for 24 (48) hour forecasts were 9.4 kt (15.9 kt) for the Atlantic and 10.2 kt (11.4 kt) for the Eastern North Pacific. For the same set of forecasts, the SHIPS mean absolute errors were 9.7 kt (16.7 kt) for the Atlantic and 11.6 kt (13.5 kt) for the Eastern North Pacific.

The primary limitation of SHIPS-MI is that the necessary microwave data is not consistently available when needed for forecasts. It requires data from the Special Sensor Microwave Imager (SSMI), Tropical Rainfall Measuring Mission (TRMM) Microwave Imger (TMI), or Advanced Microwave Scanning Radiometer for EOS (AMSR-EOS), all on satellites in low earth orbit. Forecasts are desired for the synoptic times 0000, 0600, 1200, 1800 UTC. At NHC in 2006, SHIPS-MI was run for 77 of 253 possible Atlantic advisories (30%) and 141 of 385 Eastern North Pacific advisories (37%).

Drag Coefficient Distribution and Wind Speed Dependence in Tropical Cyclones

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This JHT-sponsored project seeks to investigate the azimuthal dependence of the surface drag coefficient in hurricanes as well as extend Cd measurements in mean boundary layer (MBL) winds over 70 m/s. Over 2600 post-processed GPS sonde profiles collected in hurricanes from 1997-2005 were stored in a modern relational database, quality controlled, and organized by mean boundary layer wind speed and storm relative location. Analysis indicates that Cd initially increases with 10 m neutral stability wind speed, levels off at 27 m s^{-1}, and then decreases as winds increase above 42 m s^{-1}. The apparent wind speed dependence is complicated by an additional dependence on radial distance, with profiles at small radii tending to have smaller Cd values for the same MBL wind speed group. Sea state at small radii would be associated with more fetch-limited conditions than with larger radii, consistent with the "continuous breaking" mechanism hypothesized by Donelan and colleagues in 2004 to lead to flow separation and decreased Cd. Storm relative azimuthal dependence further complicates the Cd behavior. While Cd values in the rear of the storm tend to have larger values than the right side, there is no well defined Cd dependence on azimuth.

Session 9
Decision-making
Products and Services

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9

The Automated Tropical Cyclone Forecast System (ATCF): An Interagency Success Story

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The ATCF originally developed by Naval Research Laboratory, Monterey has evolved to become an indispensable national asset used by the U. S. tropical cyclone forecast centers to produce timely and accurate forecasts. The collaborative efforts of the Department of Defense (e.g., Naval Research Laboratory, JTWC, etc.) and Department of Commerce (e.g., National Weather Service, TPC/NHC, etc.) in the ongoing development this system will be briefed. Current hardware and communications configuration utilized to effect optimum data interchange and operations will also be presented.

Long Term Trends in National Hurricane Center Watches and Warnings

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The National Hurricane Center (NHC) is responsible for issuing hurricane watches when hurricane force winds (64 kt or greater) are possible within the next 36 hours and hurricane warnings when hurricane winds are expected within the next 24 hours. The watches and warnings (WWs) for the contiguous U.S. are examined for the period 1963-2006. The coastline lengths included in the WWs are calculated and the regions along the coast that experienced hurricane winds are estimated using the NHC radii of hurricane forecast winds and best track storm positions. The time of first arrival of hurricane winds is also estimated using the radii and best track so that the lead times from when the WWs were first issued for a given location can be calculated. Results show that the size of the average warning areas steadily increased by decade from the 1960s to the 1990s, despite the considerable improvement in track forecasting. During this period the track forecast improvement was being utilized to improve the lead time of the warnings, which increased from 22 h in the 1960s to 30 h in the 1990s. In the 2000s the trend of increasing warning lengths was reversed and the lead time was further increased. The average length of the hurricane watches by decade steadily decreased and the average lead times steadily increased from the 1960s to the 2000s. Results also show that in the 2000s the average lead time of the warnings is considerable longer than 24 h, and the average lead time of the watches is longer than 36 h.

When Hurricanes Strike: Interagency Requirements for Agricultural Assessments

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Where we once plotted hurricane positions by hand and used transparencies to overlay storm tracks and agricultural production areas, we now use layers in a geographic information system (GIS). High-level government officials, including the Secretary of Agriculture, are becoming accustomed to high-tech, rapid-response reports and graphics provided by USDA's Office of the Chief Economist (OCE), based on multi-layered data sets obtained from various agencies.

USDA/OCE provides the Secretary of Agriculture and top staff members with GIS-based products both before and after a storm's U.S. strike. Pre-landfall reports typically include a USDA county-level crop production map for one or more commodities (e.g. cotton, sugarcane) overlaid with storm track and intensity forecasts provided by the National Hurricane Center (NHC). Post-storm products provide pertinent agricultural and meteorological information, although content varies. For example, Hurricane Ophelia's (September 14-16, 2005) threat to open-boll cotton in eastern North Carolina included heavy rain, while Hurricane Wilma's (October 24, 2005) destruction of citrus, sugarcane, and farm infrastructure in southern Florida was solely due to high winds.

In the future, USDA hopes to continue utilizing NHC's products to provide detailed, high-quality agricultural impact graphics. USDA operationally uses several NHC products—including observed and forecast storm tracks, and tropical storm- and hurricane-force wind swaths—although none is yet publicly released in shapefile (GIS) format. The process of converting NHC's public files into GIS layers remains time-consuming and effectively a hand-drawn process, which can introduce errors. In addition, non-operational NHC products that would be useful for USDA's agricultural assessments include text reports of storm-total rainfall, maximum sustained winds, and peak wind gusts. If all of NHC's data sets were publicly released as shapefiles (for graphics) and in comma-delimited format (for text), USDA and other federal entities could provide high-level officials with even more timely, consistent, and accurate information.

Operational Tropical Cyclone Wind Speed Probability Products

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Tropical cyclone wind speed probability products became operational at the National Hurricane Center in 2006 for systems in the Atlantic and eastern North Pacific basins. The new products include text and graphical versions that are updated with each forecast cycle for each active tropical cyclone. The probabilities are also being made available via the National Digital Forecast Database (NDFD). These products provide users with information regarding the chances of experiencing winds of tropical storm force and hurricane force at specific locations within the five-day forecast period. They also indicate the range of possibilities regarding when these wind conditions will begin at specific locations. The performance of these products during 2006 will be examined, including how they have been used by the media and emergency managers. Some minor changes to the products planned for 2007 will also be described.

Exploring the Concept of a Graphical Tropical Weather Outlook

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Multiple studies have concluded that the public prefers and is better able to interpret graphics versus text-only National Weather Service products. Accordingly, the National Hurricane Center (NHC) is currently exploring the potential incorporation of a graphical version of the Tropical Weather Outlook (TWO). This effort includes working with NWS and other NOAA partners as well as soliciting input from the DOD, emergency managers, and media. Additionally, the NHC is evaluating the use of a color-coding approach, similar to the NWS Hazardous Weather Outlook and EPA Air Quality Index, to articulate development potential. Initial in-house verification of past seasons indicates that NHC has skill in clustering development potential into 3 tiers (low, medium, high). Prototypes using existing computing systems will be presented for feedback and evaluation.

NOAA's Seasonal Hurricane Forecasts: Climate Factors Influencing the 2006 Season and a Look Ahead to 2007

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The 2006 Atlantic hurricane season was quieter than anticipated and did not feature a landfalling hurricane in the United States for the first time since 2001. However, seasonal hurricane forecasts from NOAA and most other forecast groups indicated a strong probability of an above-average hurricane season. A verification of last year's seasonal hurricane forecast will be presented along with the reasons for the failure of the NOAA seasonal forecast. These reasons include the rapid development of an El Niño episode and an abundance of sinking air in the western portion of the basin, leading to dry air and a more stable atmosphere than average. Preliminary indications for the upcoming 2007 Atlantic hurricane season will also be discussed.

Action Items

Working Group for Hurricane and Winter Storms Operations and Research

61st IHC ACTION ITEMS

1. Title: **Use of TCU to Modify U.S. Watches/Warnings – Informational**

Submitter: NOAA

Discussion: Currently the NWS directive 10-601, regarding Tropical Cyclone Updates (TCU), Section 1.4.2.2 (Issuance Criteria) reads “Issued by NHC and CPHC in lieu of or preceding special advisories to inform users of unexpected changes in tropical cyclone, or post/cancel watches”. The NWS will re-word the NWS directive 10-601, Section 1.4.2.2 to read as follows: "TCUs are issued by NHC and CPHC in lieu of or preceding special advisories to inform users of unexpected changes in tropical cyclones. The TCU may also be used to announce changes to international watches or warnings made by other countries, and to cancel U.S. watches or warnings."

Recommendation: Forward to IHC and RA-IV as informational.

Action:

2. Title: **Satellite Ocean Surface Vector Winds Operational Impacts and Requirements**

Submitter: NOAA

Discussion: A workshop was conducted at TPC in June 2006 to assess the operational utilization and impacts of ocean surface vector winds (OSVW) retrieved by current research satellites, and to establish new NOAA operational requirements for OSVW measurements from future satellites. The workshop established satellite-derived OSWV measurements are an important tool in daily NOAA forecast and warning operations and current and planned satellite missions do not satisfy the new requirements. A workshop report has been completed and widely distributed, and high-level NWS officials have been briefed on the outcomes of the workshop and have acknowledged the needs it expresses. However, NOAA has no plans for an operational OSVW satellite mission that will meet the new requirements or even maintain capabilities provided by current research satellites (primarily the NASA QuikSCAT). Data provided to NOAA by new operational satellites operated by other countries (e.g., the EUMETSAT METOP) will also not meet the new requirements or maintain current research satellite capabilities. Therefore, the quality of NOAA operational forecasts and warnings will be compromised once QuikSCAT is no longer operating (it has already exceeded its design life span). Several workshop participants are advocating a satisfactory future OSVW satellite mission via the NOAA PPBES process and other available avenues within NOAA. Support from the Department of Defense (DOD) on such a mission could greatly increase the chances of it coming to fruition, but the level of DOD support is uncertain. The NOAA Hurricane Conference endorses the needs expressed in the report.

Recommendation: Seek response from DOD to encourage joint NOAA/DOD advocacy for an OSVW mission.

Action:

3. Title: **Status of HDOBS Recon Messages (NOAA/AOC and 53 WRS)**

Submitter: NOAA

Discussion: To date, the USAF/53 WRS and NOAA AOC issue high-density observations under different WMO headers – SXXX50 KNHC (dummy header for USAF) and UR..40 KWBC (NOAA/AOC). Currently, implementation efforts are underway to retrofit the USAF WC-130J aircraft with SFMR instrumentation. Consequently, a need has been identified to transmit these products under similar WMO headers and utilize a standard format. These new formats will be issued under the following headers:

NOAA AOC:

WMO ID	**CCID**	**PIL**	**PRODUCT TYPE**
URNT15	KWBC	none	Atlantic HDOBS message
URPN15	KWBC	none	East/Cent. Pacific HDOBS message
URPA15	KWBC	none	West Pacific HDOBS messages

USAF 53rd WRS:

WMO ID	**CCID**	**PIL**	**PRODUCT TYPE**
URNT15	KNHC | KBIX	none	Atlantic HDOBS message
URPN15	KNHC | KBIX	none	East/Cent. Pacific HDOBS message
URPA15	KNHC | KBIX	none	West Pacific HDOBS messages

Under the current implementation schedule, the USAF will outfit a portion of the WC-130J Fleet with the SFMR prior to or during the

2007 hurricane season and target final retrofit to be complete before the 2008 hurricane season. During the 2007 season, all USAF aircraft will transmit HDOBS using the standardized product under the new UR..15 header – those aircraft not outfitted with SFMR will transmit using the new format with missing data values of 999 or similar as place holders. This schedule is subject to change.

Recommendation: Update NHOP Appendix G with the new HDOBS format specification and retain the USAF SXXX50 HDOBS format specification for one year and denote it as legacy.

Action:

4. Title: **Content Change Request for Tropical Cyclone ICAO Message - Informational**

Submitter: NOAA

Discussion: Per WMO FTCM Doc 13, the ICAO tropical cyclone message provides current tropical cyclone information and forecast information for forecast intervals of +12, +18 and +24 hours. Those products are issued utilizing the following WMO header information:

WMO ID	**CCID**	**PIL**	**PRODUCT TYPE**
FKNT2{1-5}	KNHC	TCANT{1-5}	Atlantic ICAO bulletin
FKPZ2{1-5}	KNHC	TCAPZ{1-5}	East Pacific ICAO bulletin
FKPA2{1-5}	PHFO	TCAPA{1-5}	Central Pacific ICAO bulletin

The NWS will add an interpolated 6 HR forecast information to message body and notify external users of change effective May 15, 2007.

Note - Bolded text denotes the addition of the +06 forecast hr information.

```
FKNT25 KNHC 310900
TCANT
TROPICAL STORM TEST ICAO ADVISORY NUMBER  27
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL   AL242007
0900 UTC SUN OCT 21 2007

TC ADVISORY
DTG:                          20071021/0900Z
TCAC:                         KNHC
TC:                           ERNESTO
NR:                           027
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PSN:                          N3000 W08012
MOV:                          N 13KT
C:                            0998HPA
MAX WIND:                     045KT
FCST PSN + 06 HR:             211200 N3106 W07951
FCST MAX WIND + 06 HR:        045KT
FCST PSN + 12 HR:             211800 N3206 W07930
FCST MAX WIND + 12 HR:        050KT
FCST PSN + 18 HR:             220000 N3321 W07903
FCST MAX WIND + 18 HR:        045KT
FCST PSN + 24 HR:             220600 N3436 W07836
FCST MAX WIND + 24 HR:        040KT
NXT MSG:                      20071021/1500Z
```

Recommendation: Report to IHC as informational.

Action:

5. Title: **Message Standardization of Fix Messages**

Submitter: NOAA

Discussion: Several organizations issue tropical cyclone center and intensity "fix" bulletins. Product formats vary between offices and within offices. To better facilitate and expedite data use by parsing software at operational Centers, it would be advantageous to standardize at least some portions of the format.

Recommendation: Form a team of DOD and NOAA subject experts to develop a standard tropical cyclone fix product format.

Action:

6. Title: **Tropical Cyclone Watch/Warnings for Johnston Island, Midway Island, and Northwest Hawaiian Islands – Informational**

Submitter: NOAA

Discussion: Johnston and Midway Islands are unincorporated territories of the US, administered by the U.S. Fish and Wildlife Service (USFWS) as part of the Pacific Island Wildlife Refuges (however the DOD still "owns" Johnston Island). The Northwest Hawaiian Islands are a U.S. National Marine Monument managed by NOAA's National Ocean Service National Marine Sanctuaries. Normally Midway Island and some of the Northwest Hawaiian Islands are inhabited while Johnson Island is uninhabited but research, maintenance, and recreational mariners sometimes visit the island. Johnston Island has dock facilities and limited shelter. During the passage of Hurricane Ioke when it was uncertain whether there was anyone on Johnston Island, CPHC issued a hurricane warning 24 hours prior to it hitting the island. It was later confirmed that a working research vessel and crew was on Johnston Island and the Captain and crew decided to dock their ship on the leeward side of the island and sought shelter in a former army concrete bunker. The Captain and crew safety survived the hurricane and the ship sustained limited damage.

Because CPHC often doesn't have complete information on where and how many people are on these island, it will now be CPHC's policy to always issue tropical cyclone watches and warnings for Johnston Island, Midway Island, and the Northwest Hawaiian Islands as necessary and to convey these watches and warnings to USFWS, the military, National Marine Sanctuaries, and National Marine Fisheries Service activities involved with these islands.

Recommendation: Report to IHC as informational

Action:

7. Title: **Recommend Retirement of Selected East Pacific Tropical Cyclones - Informational**

Submitter: NOAA

Discussion: Several storms originating in the East Pacific have become memorable in Hawaii because of damage, threat, etc. Hawaii State Civil Defense has asked that the following names be retired and no longer used. Remove the following names from the East Pacific Tropical Cyclone name lists: Bud, Carlotta, Daniel, Emilia, Estelle, Fabio, Fausto, Fernanda, Gil, Gilma, Guillermo, Jimena, John, Jova and Kenneth.

Recommendation: Forward to IHC as informational.

Action:

8. Title: **Recommend Retirement/Change of Selected Central Pacific Tropical Cyclone Names - Informational**

Submitter: NOAA

Discussion: Ioke became a record-breaking category 5 storm in the Central and West Pacific in 2006, and CPHC intends to retire this name. In consultation with the University of Hawaii's Native Language program, CPHC will change or remove the following names from the list of central Pacific tropical cyclone names:

Akoni	Aka	Alika	Ana
Ema	Ekeka	Ele	Ela
~~Hana~~ Hone	~~Hali~~ Hene	Huko	Halola
~~Io~~ Iona	Iolana	~~Ioke~~ Iopa	Iune
Keli	Keoni	Kika	~~Kimo~~ Kilo
Lala	~~Li~~ Lino	Lana	Loke
Moke	Mele	Maka	Malia
~~Nele~~ Nolo	Nona	Neki	Niala
~~Oka~~ Olana	Oliwa	~~Oleka~~ Omeka	~~Oko~~ Oho
~~Peke~~ Pena	~~Paka~~ Pama	~~Peni~~ Pewa	Pali
~~Uleki~~ Ulana	Upana	~~Ulia~~ Unala	Ulika
~~Wila~~ Wale	Wene	Wali	Walaka

Recommendation: Forward to IHC as informational.

Action:

9. Title: **Reporting Outbound Wind Maxima in Vortex Messages**

Submitter: NOAA

Discussion: Item F in the reconnaissance vortex data message (VDM) product is the maximum flight-level wind observed on the inbound leg prior to the storm center fix. Currently if a higher wind is observed on the outbound leg it is reported in Item P on the subsequent vortex message usually two hours later. In addition wind maxima observed after the final fix of a mission are not transmitted through a subsequent VDM.

Recommendation: If an observed outbound wind maximum is higher than the inbound wind reported in Item F then the outbound maximum will be reported in the VDM for the fix just obtained. If after the transmission of the VDM a higher outbound wind maximum is observed, then a corrected vortex message will be transmitted at the conclusion of the outbound leg with the updated outbound maximum. Outbound wind maxima will be reported in Item P.

10. Title: **Task Dropwindsonde Releases at 850 MB and Above**

Submitter: 53 WRS (DOD)

Discussion: Reconnaissance aircraft have the capability to release dropwindsondes at 850mb and above. Historically, dropwindsondes have not been tasked to be released on cyclone missions flown below 700mb due to the short data stream and limited data points available from the instrument.

If this information is valuable to the community then consider lowering the altitude for tasked dropsonde releases to 850mb.

Recommendation: Task reconnaissance aircraft to release dropsondes when tasked for fixes at 850mb and higher.

Action:

11. Title: **Operational Tropical Cyclone Forecast and Advisory Products in a GIS-Ready Format in Real Time**.

Submitter: USDA

Discussion: The NOAA/USDA Joint Agricultural Weather Facility (JAWF) requests that the NOAA National Hurricane Center provide operational tropical cyclone forecast and advisory products in a GIS-ready format in real time.

Following are NOAA/USDA JAWF GIS data and product requirements:

1. Tropical Cyclone Track and Watch/Warning map related data:
- Potential day 1-3 track area (i.e., cone) in polygon shapefile format
- Potential day 1-5 track area (i.e., cone) in polygon shapefile format
- Shapefiles available when the GIF image is posted on the NHC web site

2. Cumulative Wind Distribution map related data:
- Tropical Storm force wind swath (34 knot) in polygon shapefile format
- Hurricane force wind swath (64 knot) in polygon shapefile format
- Shapefiles available when the GIF image is posted on the NHC web site

* Although not currently displayed on the Cumulative Wind Distribution map, the 50 knot wind swath in polygon shapefile format would also be desirable.

3. Tropical Cyclone Surface Wind Speed Probabilities map related data:
- Probabilities of winds of at least 34 knots in polygon shapefile format
- Probabilities of winds of at least 50 knots in polygon shapefile format
- Probabilities of winds of at least 64 knots in polygon shapefile format
- Shapefiles available when the GIF images are posted on the NHC web site

4. Storm-total rainfall reports:
- Text file in a comma delimited format
- Each row contains: Station, Latitude, Longitude, Storm total rainfall, Notes
- Text file updated as new data becomes available or at a predefined interval

5. Maximum sustained wind speed reports:
- Text file in a comma delimited format
- Each row contains: Station, Latitude, Longitude, Max. sustained winds, Notes
- Text file updated as new data becomes available or at a predefined interval

6. Maximum wind speed (gust) reports:
- Text file in a comma delimited format
- Each row contains: Station, Latitude, Longitude, Max. wind speed (Gust), Notes
- Text file updated as new data becomes available or at a predefined interval

Justification: The first three products identified above are already produced operationally by NHC in a GIF format. The NOAA/USDA JAWF requests that these products be made available in a shapefile format as well. The shapefile format would enable USDA meteorologists to more quickly and precisely overlay NHC products on USDA agricultural data in a GIS, and hence facilitate a more accurate assessment of hurricane impacts on domestic agriculture.

The latter three data sets identified above are not available as operational NHC products. These data are sometimes contained in the Public Advisories and Discussions associated with individual storms, but are not always made available. We request that NHC provide station reports of storm-total rainfall, maximum sustained wind speed, and maximum gusts in a comma delimited text (or shapefile) format as these data become available during and immediately after a storm. We understand that these data would be considered preliminary, but it would significantly improve USDA capabilities to assess hurricane impacts on agriculture if USDA used the same data that NHC receives.

The primary motivation for our requests is to ensure that the data and products that USDA uses in preparing hurricane-related agricultural weather assessments are identical to the data and products that NHC analyzes, generates, and disseminates to their customers. We have been unable to maintain this consistency by importing NHC GIF images into a GIS, and we frequently find differences in point rainfall and wind speed measurements when comparing data from multiple data providers. Although hurricane-related data and products can be obtained from numerous sources (e.g., FEMA, private weather firms, educational institutions), we recognize that NHC is considered the Federal government authority on hurricanes and the official source for related information. Given this recognition and increasing requests for hurricane-related data and products by USDA decisions makers, USDA meteorologists would prefer to use only NHC-endorsed data and products in preparing agricultural weather assessments. This single source for information would help reduce questions about the differences, reliability, and accuracy of hurricane-related data and products, allowing USDA meteorologists to focus more on explaining the underlying science and messages conveyed by these data and products.

Recommendation: NOAA National Hurricane Center provide operational tropical cyclone forecast and advisory products in a GIS-ready format in real time.

Action:

12. Title: **Change to NHOP – Sections 2.3 and 6.4**

Submitter: Air Force Weather Agency (AFWA)

Discussion: Due to recent personnel and funding cuts, the Air Force Weather Agency (AFWA) can no longer dedicate the resources needed to sustain tropical cyclone satellite imagery surveillance and analysis support to the National Hurricane Operations Plan. This cessation of support requires changes in the NHOP to reflect the AFWA termination but continuance of support on request, resources permitting, by the 17th Operational Weather Squadron Meteorological Satellite Operations (SATOPS) Flight (17 OWS/WXJ), Joint Typhoon Warning Center, Pearl Harbor, HI to the Central Pacific Hurricane Center.

Recommendation**:** Requested changes to the NHOP listed below be incorporated.

1. Page 2-4, para 2.3, 7th sub-bullet. Update to reflect cessation of AFWA analysis support activities.

- Provide, resources permitting, through the 17th Operational Weather Squadron Meteorological Satellite Operations (SATOPS) Flight (17 OWS/WXJ), Joint Typhoon Warning Center, Pearl Harbor, HI, surveillance support with fixes and or intensity to the Central Pacific Hurricane Center through analysis of available satellite imagery. The JTWC SATOPS Flight support focuses on the Indian Ocean and the Central, South, and Northwest Pacific Ocean.

2. Page 6-6, para 6.4. Update to reflect cessation of AFWA analysis support activities

6.4 Air Force Support and the Defense Meteorological Satellite Program (DMSP). Data covering the National Hurricane Operations Plan areas of interest are received centrally at the Air Force Weather Agency (AFWA) and distributed to Operational Weather Squadrons (OWS) and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) at Monterey, CA. Satellite data covering the Central Pacific area are received at or shipped to the 17th OWS Meteorological Satellite Operations (SATOPS) Flight (17 OWS/WXJ), Joint Typhoon Warning Center, Pearl Harbor, HI. The 17 OWS/WXJ uses all available meteorological satellite data when providing fix and or intensity information to Central Pacific Hurricane Center forecasters.

3. Page 6-6, para 6.4.1 Update to reflect cessation of AFWA support activities

6.4.1. Central Pacific Surveillance. The 17 OWS/WXJ (JTWC Satellite Operations Flight) will provide, resources permitting, fix and or intensity information to the CPHC on systems upon request.

4. Page 6-6, para 6.4.2. Delete

5. Page 6-7, Figure 6.2. Delete

Action: Accept proposed changes and update NHOP.

13. Title: **Changes to NHOP, Table 6-2**

Submitter: Air Force Weather Agency (AFWA)

Discussion: Update Table 6-2 for DMSP Equator crossing times and additional satellite.

Page 6-12, Table 6-2 Update local equator times:

- DMSP F-12, to “0349D/1549A”
- DMSP F-13, to “0633D/1833A
- DMSP F-14, to “0543D/1743A
- DMSP F-15, to “0756D/1956A”
- DMSP F-16, to “0809D/2009A

Add new satellite – DMSP F-17 0534D/1734A
Type of Data: OLS Imagery (recorded and direct), *SSM/IS*

Recommendation: Update NHOP.

Action:

14. Title: **Clarification of CARCAH’s Continuity of Operations Plan in NHOP**

Submitter: NOAA/53 WRS

Discussion: In the event the CARCAH facility housed at the NHC becomes inoperable, the plan to ensure the continued transmission of reconnaissance data is not well documented in the NHOP.

Recommendation: Ensure that the capability to continue reconnaissance operations and the flow of data continues should the NHC/CARCAH facility become inoperable.

Develop a plan to ensure the data flow between the following NOAA/DOD agencies: Keesler to NHC (should CARCAH become inoperable), CARCAH to HPC (should NHC become inoperable), and Keesler to HPC (should CARCAH and NHC become inoperable).

Propose that the Air Force Reserve Command (AFRC) be the lead agency in drafting an addendum to Chapter 5, “Aircraft Reconnaissance,” of the NHOP to better define the CARCAH continuity of operations plan.

Action: