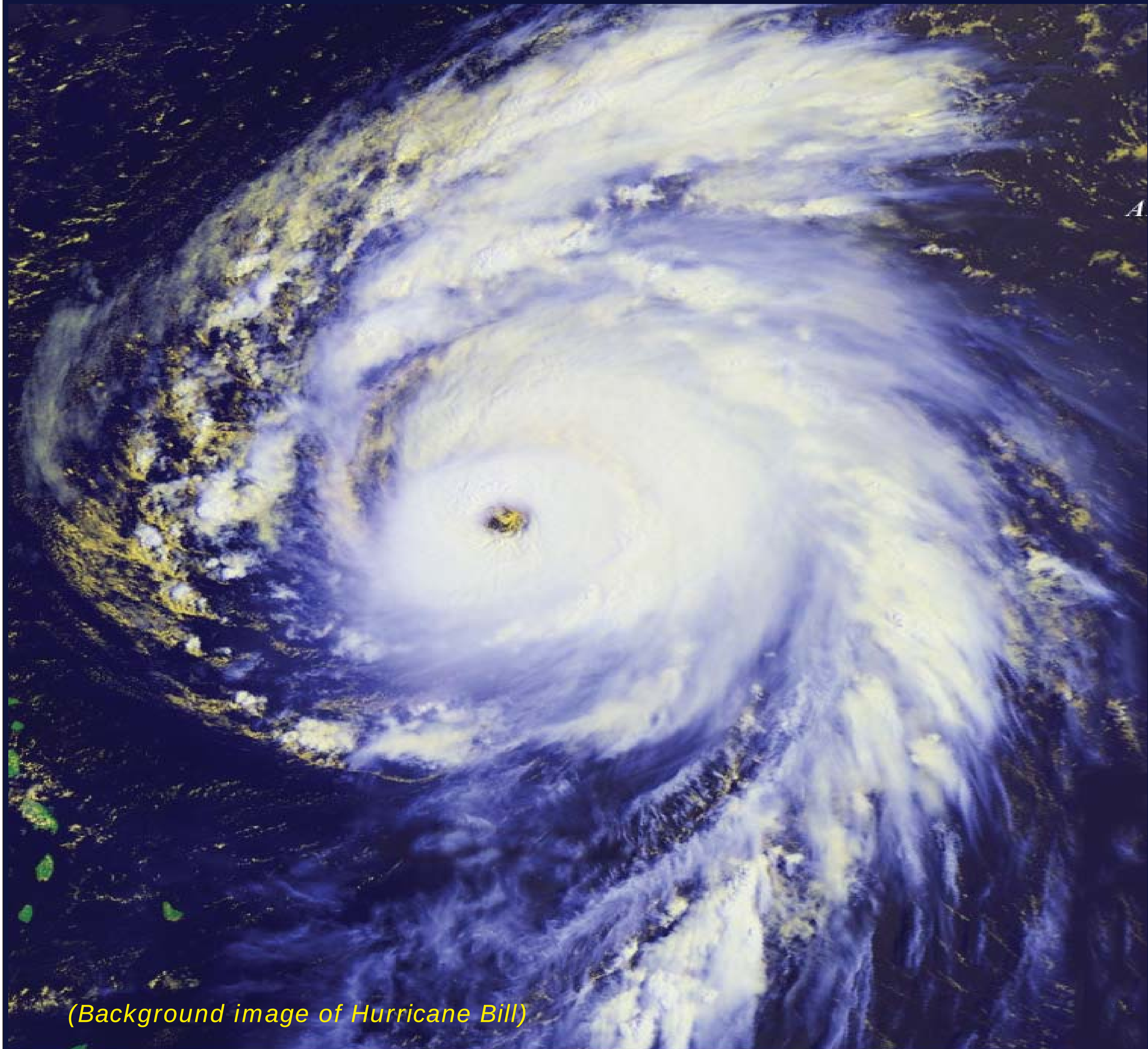
64th Interdepartmental Hurricane Conference

Savannah, Georgia   March 1-4, 2010



(Background image of Hurricane Bill)

Meeting Operational Needs through Comprehensive Tropical Cyclone Research and Development

Office of the Mayor Savannah, Georgia

Otis S. Johnson, Mayor

February 19, 2010

64th Interdepartmental Hurricane Conference

Dear Conference Attendees:

On behalf of the Savannah City Council and many friendly citizens of Savannah, I extend a warm welcome to each of you attending the 64th Interdepartmental Hurricane Conference. We are delighted that you have come to our great community to hold these important meetings.

We not only recognize the important work you do for the country, but for the City of Savannah and greatly appreciate the unique contributions you make to our safety, security and preparedness.

While you are here, I hope you take the time to get outside and experience the magic and mystery that is Savannah. I have lived here my whole life, yet I still gasp at the picture postcard scenes that lurk around every corner. I still sigh while sitting beneath the shade of live oaks that sprawl above our jewel-box squares. And I still stare at the massive container ships that lumber past our historic waterfront, so close you feel that you can almost touch them.

I am confident that you, too, will find Georgia's First City intriguing and beautiful. And as you wander Savannah, make sure you take the time to talk to the wonderful people who live here. You just may find them to be the most beautiful part of the most beautiful city in America.

Thank you for coming to Savannah and best wishes for a most productive and successful conference. I sincerely hope you enjoy your stay and visit us again soon.

Sincerely,

Otis S. Johnson, Ph.D.
Mayor

ojohnson@savannahga.gov • P.O. Box 1027 • Savannah, Georgia 31402 • (912) 651-6444 • Fax (912) 651-6805

UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary of Commerce
for Oceans and Atmosphere
Washington, D.C. 20230

March 1, 2010

Dear Colleagues:

Welcome to the 64th Interdepartmental Hurricane Conference and to the great and historic city of Savannah, Georgia! On behalf of all of the interagency partners, including meteorology and oceanography operations and research and the emergency management community, I express my sincere appreciation for your collective efforts to improve our nation's hurricane forecasting and warning program—the ultimate goal of this conference.

Thank you for attending and actively participating. I wish you a highly productive and rewarding time together.

Sincerely,

Jane Lubchenco, Ph.D.
Under Secretary of Commerce for Oceans and Atmosphere
and NOAA Administrator

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

SUITE 1500, 8455 COLESVILLE ROAD
SILVER SPRING, MARYLAND 20910

March 1, 2010

Dear Colleagues,

Welcome to the 64th Interdepartmental Hurricane Conference! We are looking forward to a very productive and informative four days in Savannah, Georgia.

Last year we focused on partnership alliances and reviewing interagency linkages of tropical cyclone research to the forecasting and warning centers' operational priorities. The senior leaders from NOAA (research and operations), NASA, Navy (research and operations) and the Air Force emphasized their unified commitment to collaboration and interagency cooperation in tropical cyclone research and operations. We were also very pleased to see that the analysis of the Working Group for Tropical Cyclone Research showed for the first time the comprehensive interagency linkages of research to the centers' operational priorities. We also noted last year the need for additional emphasis on social science and decision-making, and this year we will address this concern in our second workshop of the conference. We will continue to advance the power of partnerships through the insights of senior agency leaders and we will delve deeper into the assessment of tropical cyclone research and development to meet operational priorities of the forecasting and warning centers.

In addition, other sessions this year include:

- The 2009 season in review
- Observations and observing strategies for tropical cyclones and their environment
- Tropical cyclone model development and technology transfer
- Other research to improve the prediction of tropical cyclone intensity and structure, track, precipitation, and coastal and inland inundation
- Joint Hurricane Testbed project updates and improved products

Thank you for joining us this week in Savannah to prepare for the coming hurricane season, to exchange ideas and plans, and to renew our commitment to improving the hurricane forecasting and warning system. I hope you enjoy the conference and our great host city!

Sincerely,

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

Session 1
The 2009 Tropical Cyclone Season in Review

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The Quietest Year in More than a Decade: An Overview of the 2009 Atlantic Hurricane Season

Robbie Berg and Lixion Avila
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NOAA/NWS/National Hurricane Center

The 2009 Atlantic hurricane season was marked by below-average tropical cyclone activity with the formation of nine tropical storms and three hurricanes, the lowest numbers since the 1997 Atlantic hurricane season. Two of the hurricanes (Bill and Fred) became major hurricanes (category 3 or higher on the Saffir-Simpson Hurricane Wind Scale). There were also two tropical depressions that did not reach tropical storm strength. The Accumulated Cyclone Energy index for 2009 was 60% of the long-term median value—also the lowest value since 1997.

Only one storm, Claudette, made landfall in the United States, although Ida did affect parts of the northern Gulf Coast before moving onshore as an extratropical low. Ida also caused damage in Nicaragua where it made landfall as a hurricane. As the strongest storm of the season, Hurricane Bill affected Bermuda and parts of Atlantic Canada with strong winds and the east coast of the United States with rough surf and rip currents. Elsewhere, Erika moved through the Leeward Islands and Grace moved through the Azores, but neither caused significant damage. The overall death toll from the 2009 Atlantic tropical cyclones is six.

Overview of the 2009 Eastern North Pacific Hurricane Season

Todd B. Kimberlain and Michael J. Brennan
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NOAA/NWS Tropical Prediction Center/National Hurricane Center

Tropical cyclone activity during the 2009 eastern North Pacific season was near normal. A total of 17 tropical storms developed, of which seven became hurricanes, including four major hurricanes. Two tropical depressions formed this season that did not strengthen into tropical storms. Another tropical depression formed over the far western part of the basin, and reached tropical storm strength in the central North Pacific basin. The Accumulated Cyclone Energy (ACE) index for 2009 was 93% of the long-term median value. Among the highlights of the season were Hurricane Rick, the second strongest hurricane ever observed in the eastern North Pacific after Hurricane Linda of 1997, and the landfall of Jimena in southern Baja California as a category two hurricane.

2009 Atlantic and Eastern North Pacific
Forecast Verification

James L. Franklin
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NOAA/NWS/National Hurricane Center

A verification of official track and intensity forecasts from the National Hurricane Center during the 2009 season will be presented, along with a discussion of the performance of the guidance models. As of this writing final results are only available for the Atlantic basin.

For the Atlantic basin, official track errors set records for accuracy and skill from 24-72 h. The 48 h mean track error was only 73 miles, although the season's low level of activity likely means this result is not representative. The official track forecast skill was very close to that of the TVCN consensus model and the best of the dynamical guidance. GFSI and EMXI were the best dynamic guidance models, while EGRI and NGPI continue to perform relatively poorly. The CMCI was computed for the first time in 2009, and it was competitive with the other guidance. FSSE was the best-performing consensus model, while AEMI was the worst.

Official intensity errors for the Atlantic basin in 2009 were above the previous 5-yr means, but the 2009 Decay-SHIFOR errors were also higher than its 5-yr mean, such that skill was actually above normal. The statistical LGEM models was the runaway winner in 2009, likely because its construction was able to handle the changes in shear experienced by the season's storms. The official forecast performance was better than ICON through 48 h, and poorer thereafter. FSSE did not perform as well as ICON.

Additional information, including results from experimental genesis forecasts and from the eastern Pacific, will be presented at the conference.

Central Pacific 2009 Hurricane Season Summary

Jim Weyman
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Director, Central Pacific Hurricane Center

The 2009 Central Pacific Hurricane Season included 7 tropical cyclones which was greater than the long term average of 4 to 5. This was the most tropical cyclones in the basin since 1997. Three of the systems reached hurricane strength, one of which became a major hurricane. The Northwest Hawaiian Islands were directly affected by one, Hurricane Neki, which caused the evacuations of researchers and scientists via a NOAA ship and a Coast Guard C-130. For the main Hawaiian Islands, remnants of Hurricane Felicia produced heavy rains and some flooding. The increased Central Pacific activity in 2009 appeared to reflect the development of El Nino during the early summer.

A Review of the Joint Typhoon Warning Center 2009 Tropical Cyclone Season

Mr. Edward Fukada
(edward.fukada@navy.mil)

Joint Typhoon Warning Center

A review of the 2009 tropical cyclone activity with discussion of significant events for the JTWC Pacific and Indian Ocean forecast areas of responsibility will be presented.

53d Weather Reconnaissance Review of the 2009 Hurricane Season

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53d Weather Reconnaissance Squadron

The 2009 hurricane season was a well below average year for the 53d Weather Reconnaissance Squadron with 569.5 total flying hours (compared to 1062 average flying hours per season over the previous 10 years). In fact, 376 flying hours in the Atlantic Basin was the lowest total in the last 25 years, thanks to a strong El Nino event. Overall, the Stepped Frequency Microwave Radiometer once again performed reasonably well on ten WC-130J aircraft, providing critical surface wind speed and rainfall rate data to the customer. Operator experience increased with the instrument and valuable inputs and improvements to instrument performance were accomplished.

NOAA Aircraft Operations Center (AOC)
2009 Seasonal Summary and Future Plans

Jim McFadden, Nancy Ash, Jack Parrish and Paul Flaherty

(Jim.d.mcfadden@noaa.gov Nancy.Ash@noaa.gov, Jack.R.Parrish@noaa.gov, Paul.Flaherty@noaa.gov)

NOAA Aircraft Operations Center

After a relatively busy season in 2008, during which NOAA aircraft flew a total of 115 flights and 689 hrs, the 2009 season for NOAA tropical cyclone related flights was significantly less active. You might sum up last season by saying; it started late and ended early.

Perhaps that was a good thing since the NOAA hurricane fleet was reduced to only two aircraft because a structural problem was discovered on one of the P-3s during depot level maintenance which prevented its completion and return to MacDill AFB until early October. Had there been an active season, the types of research missions planned would have been severely handicapped.

During the 2009 season, the two NOAA aircraft that were involved in all activities related to tropical cyclones flew a total of 62 flights for 326 hrs. These flights included trips for public awareness, such as the East Coast Hurricane Awareness Tour, Governor's Hurricane Conference and the NOAA hurricane rollout at Reagan International Airport, test and calibration flights, particularly for the SFMR, and one deployment of both the P-3 and G-IV to Barbados in mid-August for HRD IFEX missions. Also included in the total were the hurricane surveillance missions flown by the G-IV in both the Atlantic and Pacific basins. All of the operational and research missions save three were flown during the month of August.

AOC continues to upgrade its aircraft and instrumentation, and in 2010 expects to accomplish the following:

- Complete the installation and acceptance tests of the tail Doppler radar on the NOAA G-IV
- Begin developing strategies for use of the new G-IV TDR in storm environment
- Accept delivery of and begin instrument integration on N44RF, NOAA's 3rd P-3
- Complete Hi-Speed Satellite communications aboard the two current P-3s
- Complete the installation of the RVP-8 radar digital signal processor on both P-3s.
- Begin operation of 2nd generation AVAPS dropsonde system
- Complete integration of new aircraft data system (AAMPS)
- Complete installation of new AXBT receivers on both P-3s

Session 4
Observations and Observing Strategies for Tropical Cyclones and their Environment, Part 1

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Airborne Doppler Analysis, Quality Control, and Transmission in 2009 and 2010

John F. Gamache
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NOAA/AOML/HRD

The Hurricane Research Division, in cooperation with the NOAA Aircraft Operations Center (AOC), NCEP Central Operations (NCO), Remote Sensing Solutions (RSS), NESDIS Center for Satellite Applications and Research (STAR), Environmental Modeling Center (EMC), and the National Hurricane Center (NHC), is continuing development of a suite of software designed to provide initially processed Doppler radar data, to quality control those data, and to produce three-dimensional and cross-section wind analyses. RSS, AOC, HRD, STAR, and NCO are working to implement the transmission of those data efficiently to NCO and NHC. Once available at NCO, EMC plans to assimilate those data in a parallel run of the Hurricane Weather Research and Forecasting model (HWRF). This presentation will focus on the role of the Hurricane Research Division, discussing progress in 2009, and plans for 2010.

In 2009, radar data were collected on NOAA43 on 10 flights in Tropical Storms Ana and Danny, and Hurricane Bill. Quality controlled Doppler radials, in a form agreed to by HRD, RSS, NCO, and EMC were saved on the Mac radar workstation aboard NOAA43, but we were not ready yet to send them to NCO. During January and February, the parsing and transmission of these stored files from the P3 to NCO, via AOC and the NOAA Telecommunications Operation Center (TOC), are being tested during the Winter Storms project conducted by AOC and STAR. We should be able to report on these tests during the conference.

Besides the above-mentioned data-transmission challenge, another challenge is presented by the migration from the current implementation of Sigmet RVP-5, to Sigmet RVP-8, during the time before the 2010 hurricane season, both on the P3's (NOAA42 and NOAA43) and on the new tail Doppler radar on the G-IV (NOAA49). Not only will the systems need to be tested, and operators become familiar with the radar, but the I/O to the quality-control software will need to be successfully modified. This I/O modification is proceeding at HRD using initial data from the G-IV, and we should have succeeded in our first tests of the new I/O in our software by the time of the conference.

The presentation at the conference will report progress on these and other issues.

Processing Wide Swath Radar Altimeter (WSRA) data on the fly

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The NOAA Wide Swath Radar Altimeter will process data unattended during flights into hurricanes and transmit data products for display at NHC. The WSRA sequentially transmits chirped pulses on 62 microstrip subarrays which each produce fan beams in the cross-track direction. The return pulses are de-chirped to provide desired range resolution and coherently combined to provide angular cross-track discrimination. The described “frontend” processing determines range to the sea surface and backscattered power at 80 positions across the swath, these cross-track ocean surface profiles are provided at a 10 Hz rate.

At 14.5 minute intervals a new data acquisition file is opened and the 8700 accumulated cross-track surface profiles are transferred to the “backend” processing computer along with the flight parameters associated with each line and any recent eye fix. The ranges are converted to a topographic map of the sea surface whose segments are then processed by a two-dimensional FFT. Integrating the wave generating power of the wind field and its evolution indicated by the eye fixes supplies the information to delete the ambiguous lobes resulting from the FFT of the wave topography.

Wave parameters are extracted from the final directional wave spectra and transmitted, along with the spectra, using FTP service to an onboard server. These data will be automatically transmitted to a ground server (flightsciences.noaa.gov) at AOC, Tampa FL. The directional wave spectra and wave field parameters are stored in a dedicated directory (pub/wsra) on the AOC server. At NHC (in Miami FL), a WSRA processing and display application, written in Perl, running on JHT’s Muskie server is constantly monitoring the directory on the AOC server during the reconnaissance flights for new or updated WSRA data files.

As soon as the new WSRA files from the aircraft are available (“on the fly”) on the AOC server they are extracted, decompressed and renamed to match the requirements from the WSRA application running at NHC. This WSRA application has the necessary map and access to environmental variables to produce geo-referenced display of the WSRA data products transmitted from the aircraft. Once the WSRA data are received by the WSRA application running on the JHT server, they are displayed on NMAP2 within the NAWIPS environment for use by the NHC.

SFMR operation on the WC130J during the 2009 Hurricane Season

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53d Weather Reconnaissance Squadron

The WC130J concluded its 3^{rd} hurricane season with the Pro Sensing Stepped Frequency Microwave Radiometer system. Several issues and challenges with the equipment were discovered and subsequently solved late in the season. Water intrusion into the antenna radome area caused inaccurate wind speed retrievals on several missions. Once this issue was recognized, the 53d worked with Pro Sensing on a solution to seal the radome. Several successful flights were conducted late in the season. A bug was discovered in the SFMR processor software concerning the frequency rejection algorithm. This caused occasional problems with inaccurate wind retrievals. The 53WRS and Pro Sensing worked to develop and test a new version of processor software after the conclusion of the 2009 season.

Differences in Stepped Frequency Microwave Radiometer Measurements - Resolutions and Remaining Issues

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Although the Stepped Frequency Microwave Radiometer (SFMR) has proven to be a reliable, accurate instrument for measuring surface winds, there have been differences noted between the units flown on the C-130Js operated by the U.S. Air Force Reserve's 53rd Weather Reconnaissance Squadron (53rd WRS) and the units on the NOAA Aircraft Operations Center's (AOC's) WP-3Ds. The National Hurricane Center has asked the 53rd WRS and AOC to look into these differences and provide resolution so that surface wind measurements are consistent across the fleet of reconnaissance aircraft. This preliminary presentation will provide an overview of the systems, a look at differences and their sources, resolutions implemented to date, expected future resolutions and differences that may remain. A report based on this presentation and continued actions this spring will be provided to NHC before June 1, 2010.

An airborne portable probe receiver/processor system for operational acquisition and transmission of expendable ocean observations from WC-130J tropical cyclone flights

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A new portable system has been developed for real-time deployment, reception and processing of airborne expendable probe observations from the 53rd WRS WC-130J aircraft. The system was developed to enhance and expand the capability of the WC-130J to provide in-situ oceanographic observations from tropical cyclone reconnaissance flights. These are in addition to the current meteorological probes for input to operational air-sea coupled tropical cyclone prediction models via the Navy's Fleet Numerical Meteorology and Oceanography Command and NOAA's Environmental Modeling Center. The WC-130J is an ideal platform for deployment of expendable probes such as AXBT's since it can carry dozens, even hundreds, of the relatively heavy (14 lbs) probes during typical reconnaissance missions. Development of an innovative portable differential pressure launching mechanism allows probe deployment to be conducted from any altitude up to the aircraft ceiling of 30-35,000 ft. The system is built into shock-mounted racks within easily transportable cases that can be moved on and off the aircraft in a matter of minutes. The first system was successfully tested during the ONR/NSF supported TCS08/TPARC project in the Western Pacific (WPAC) during 2008. Over 160 AXBT's were successfully deployed during a two-month period and their data transmitted in real time to the Naval Oceanographic Office (NAVOCEANO) for research, internal use and dissemination over the Global Telecommunications System to other forecast centers worldwide. Sample observational results and their comparison with the Navy Coastal Ocean Model (NCOM) initial fields will be presented. A second system is being prepared for the ONR sponsored ITOP field campaign in WPAC during the 2010 typhoon season. This will allow two portable expendable probe deployment and receiver/processor systems to be available for a second operational demonstration on board two WC-130J aircraft during 2010.

Session 5
Observations and Observing Strategies for Tropical Cyclones and their Environment, Part 2

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HFIP: Detecting Tropical Cyclone Formation from Satellite Infrared Imagery

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The interpretation of a tropical cyclone's structure from satellite imagery has been a key element for structure and intensity estimation. One of the most important examples is the Dvorak technique, which was developed in the 1970s, and is still used in many tropical cyclone forecasting centers. This technique provides a source of tropical cyclone intensity estimates over the tropical oceans. The longevity of the Dvorak technique clearly speaks to the utility of satellite-based observations for tropical cyclone analysis. An aspect of tropical cyclone development that can clearly benefit from use of satellite-based observations is the genesis process. Tropical cyclones, for the most part, develop over oceans where traditional observation platforms such as rawinsonde stations cannot be located. Therefore, the best opportunity for locating and discriminating those cloud clusters that will develop into tropical cyclones from those that will not is from analysis of satellite-based observations.

An objective technique to differentiate developing from non-developing cloud clusters during the formation of tropical cyclones is described. As the tropical cyclone develops from an unstructured cloud cluster, the wind field intensifies, and the cloud structures become more axisymmetrically organized around a center. This technique performs a statistical analysis of the brightness temperature gradient to measure the level of symmetry of cloud structures, which characterizes the degree of cloud organization of the tropical cyclone. To quantify the level of axisymmetry of a weather system structure, the deviation angle of each gradient vector relative to a radial line projected from the center is calculated. The variance of the set of deviation angles enclosed by a circular area around the center indicates the level of axisymmetry of the system. The formation of tropical cyclones is detected by calculating the deviation-angle variance technique using every pixel in the scene as the center of the cloud system. Low angle variances pinpoints structures with high levels of axisymmetry, these values are compared to a set of thresholds to determine whether a cloud structure can be considered as a tropical cyclone. The first detection in a sequence indicates a nascent storm. Under funding from the HFIP program, this technique has been extended to include several more Atlantic hurricane seasons. In the presentation we will show performance statistics for the extended period and discuss methods being investigated to improve detection performance.

Use of Reflected GPS to Map Wind Fields for Hurricane Genesis Applications

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[1]Distinguished Research Associate, NASA-Langley Research Center; [2]Hurricane Research Division, NOAA

Several experiments have been done by NOAA and NASA, alone and in conjunction with others to understand the genesis of tropical cyclones. Examples of this are the Convection and Moisture Experiment (CAMEX) from 1998 to 2001, NASA's 2005 Tropical Cloud Systems and Processes Experiment (TCSP), NOAA's Intensity Forecasting Experiment (IFEX) in 2005 and 2006, along with elements of Saharan Air Layer Experiment (SALEX) in 2005 and 2006, and NASA African Monsoon Multidisciplinary Analyses (NAMMA). Typically clusters of thunderstorms in areas frequently found to be sources of tropical cyclone formation are flown into and various parameters are recorded. One of the most important is surface winds. Normally such measurements are collected with dropsondes, the Stepped Frequency Microwave Radiometer and flight level winds extrapolated to the surface. The wind field, made up of wind speed and direction, is characterized by winds near 10-15 meters per second. Under these low wind speed conditions, microwave radiometers are ineffective. On the other hand, dropsonde sampling in the storm and pre-storm environments is limited, so mapping the complete sub-aircraft total wind field is not practical.

In previous publications it has been shown that the GPS ocean-reflected signal continues to respond to wind speeds above 40 meters per second and the response can be calibrated (Ref. 1). Moreover, the calibration has been shown to compare well with dropsonde WL150 and 10-m surface wind values (Ref. 2.) Using data acquired from several flights during for IFEX, SALEX, as well as other missions, up to 2009, this paper will extend those results. It will be shown that the GPS surface reflected wind speed retrievals from 0-20 meters per second compare well with dropsondes. Results of investigations on the anisotropy of the wind speed retrievals as a function of wind direction will be shown that can permit wind direction to be determined. Taken together the GPS surface reflection technique will be shown to be a simple, inexpensive and effective tool for the study of the surface wind field during tropical cyclone genesis.

1. Katzberg, S. J., O. Torres, and G. Ganoe (2006), Calibration of reflected GPS for tropical storm wind speed retrievals, *Geophys. Res. Lett.*, 33, L18602, doi:10.1029/2006GL026825
2. Katzberg, S. J., and J. Dunion (2009), Comparison of reflected GPS wind speed retrievals with dropsondes in tropical cyclones, *Geophys. Res. Lett.*, 36, L17602, doi: 10.1029/2009GL039512.

Evaluation of the Tropical Cyclone SATellite Intensity CONsensus (SATCON)

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Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin

The SATellite CONsensus (SATCON) algorithm developed at CIMSS objectively combines Tropical Cyclone (TC) intensity estimates analyzed from satellite infrared and microwave-based methods to produce a consensus estimate which is more skillful than the individual members. Current members of SATCON include the CIMSS ADT along with the CIMSS and CIRA AMSU algorithms. SATCON provides the TC forecaster with the ability to quickly reconcile differences in objective intensity methods thus decreasing the amount of time spent on the analysis of current intensity. Real-time SATCON estimates were provided to NHC during the 2008 and 2009 hurricane seasons. An evaluation of the algorithms performance compared to ground truth from Atlantic aircraft reconnaissance will be presented.

In addition, a TC-focused field campaign conducted in the Western Pacific in 2008 (TCS-08) provided recon data and the opportunity to evaluate the performance of SATCON and its members outside of the Atlantic basin. Both C-130 and P-3 reconnaissance aircraft were flown into storms in the Western Pacific as a part of the TCS-08 project. A “double blind” experiment was also performed where Dvorak estimates of TC intensity from experienced analysts were produced without knowledge of the aircraft data. This provided a unique chance to directly compare the objective estimates with both the operationally produced and “blind” subjective Dvorak estimates. Results of this evaluation will also be presented.

SATCON web page: http://cimss.ssec.wisc.edu/tropic2/real-time/satcon/

Improved Near Real-Time Hurricane Ocean Vector Winds Retrievals from QuikSCAT

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[1]Central Florida Remote Sensing Laboratory/University of Central Florida; [2]NOAA/NESDIS/STAR; [3]NOAA/AOML/HRD

Currently, satellite microwave scatterometer data, in particular, near-real time, ocean vector wind (OVW) measurements from the QuikSCAT are being used by the Tropical Prediction Center (TPC), in the analysis of intensity and track of Atlantic and Caribbean hurricanes. Unfortunately, the quality of available OVW's from SeaWinds is compromised for extreme wind events because of both high wind speed saturation and associated precipitation contamination in tropical cyclones.

Under the funding of the Joint Hurricane Testbed (JHT), we will apply a recently developed active/passive wind vector retrieval algorithm, known as the Q-Winds for near real-time applications. Q-Winds was optimized specifically for extreme wind events; and it uses a simultaneous passive ocean brightness temperatures derived from the QuikSCAT Radiometer (QRad) to correct the ocean radar backscatter for rain effects. This algorithm was validated by comparisons with the Hurricane Research Division's (HRD) H*Wind surface wind analysis tool.

During this past hurricane season, this improved algorithm was tested in non-real-time and used to infer ocean hurricane wind vectors by assimilating the NOAA/NESDIS NRT QuikSCAT Merged Geophysical Data Record (MGDR). The performance of NRT Q-Winds was evaluated using the three storms from the 2009 hurricane season. Unfortunately, H*Wind surface winds were not available; hence, the results were compared with the standard QuikSCAT MGDR OVW product. Results are presented which show that Q-Winds retrieves higher wind speeds than the MGDR data product.

It is unfortunate that the QuikSCAT instrument failed after more than 10 years of continuous operation, which will prevent algorithm near real time evaluation during the next 2010 hurricane season; however, this NRT Q-Winds algorithm is envisioned to be applied to the future scatterometer.

Preparing for Improved Monitoring of Tropical Cyclones in the GOES-R Proving Ground

James Gurka, Mark DeMaria, Steve Goodman, and Timothy Schmit
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NOAA/NESDIS

The improved observational capabilities of GOES-R, including an Advanced Baseline Imager (ABI) and a geostationary lightning mapper will provide the potential for improved monitoring and forecasting of tropical cyclones, but will also provide the challenge of ensuring that users are ready for the “firehose” of new information and an all new concept of operations. In order to ease the transition to the next generation of satellites following the launch of GOES-R in 2015, the proving ground is introducing some of the new capabilities to forecasters today.

A proving ground is a place where technologies and ideas are tested and proven before they are finalized and incorporated into critical operations. The key mission of the GOES-R Proving Ground (PG) is to demonstrate new satellite observing data, products and capabilities in operational NOAA Offices. This key activity facilitates the transfer of new capabilities into NOAA operations in an efficient and reliable manner. In the GOES-R PG, developers at the NOAA and NASA Cooperative Institutes are testing and applying algorithms for new GOES-R satellite data and products. These products were generated using proxy and simulated data sets, including observations from new instruments (MODIS, AIRS, IASI, SEVIRI, NAST-I, NPP/VIIRS/CrIS, LIS), lightning networks, and computer simulated products.

For lightning observations, the ground-based World Wide Lightning Location Network (WWLLN) data is being used as a proxy for the GLM for tropical cyclone studies. An algorithm to use lightning data in combination with global model fields to predict rapid intensity changes is under development. This algorithm will be tested in real time during the 2010 Atlantic hurricane season as part of the GOES-R Proving Ground at the National Hurricane Center. Either the WWLLN or the new Vaisala GLD360 lightning data will be used for the real time test.

Although it does not have all the capabilities of the ABI, many new GOES-R products for tropical applications can be demonstrated with SEVIRI. Several of these applications will be demonstrated at the 2010 Proving Ground at NHC including air mass, Saharan air layer, and dust products. A GOES-R version of the Dvorak intensity estimation technique is also under development. This will be tested at the 2010 or later Proving Ground activities at NHC.

In summary, the Proving Ground will help the user communities realize the true potential improvements from GOES-R for Tropical Cyclone monitoring and forecasting by exposing forecasters to samples of the new capabilities with numerous proxy data sources now. 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 vapor 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.

GeoSTAR – A Hurricane Observatory

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The Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) is a microwave sounder under development at NASA's Jet Propulsion Laboratory (JPL) that has capabilities similar to the Advanced Misrowave Sounding Unit (AMSU) sounders currently operating on NASA and NOAA low-earth-orbiting satellites. GeoSTAR will provide similar capabilities from geostationary orbit, which enables continuous monitoring of the visible hemisphere. Microwave sounders, such as AMSU and GeoSTAR, measure the 3-dimensional structure of temperature, water vapor, cloud liquid water, precipitation and other derived parameters under a wide range of weather conditions, including full cloud cover. With a recently developed method it is also possible to measure the convective structure and precipitation in three dimensions. These capabilities make a geostationary sounder especially valuable as a hurricane observatory. This was recognized by the National Research Council, which recommended that a GeoSTAR-like sensor be developed for a "Precipitation and All-weather Temperature and Humidity" (PATH) mission. PATH is a third tier "decadal-survey" mission and may not be implemented for several years, but there is a strong possibility that GeoSTAR can be implemented as a mission-of-opportunity payload in the near future, contemporary with the start of the next generation of NOAA geostationary weather satellites, the GOES-R series. With GeoSTAR, whether through the PATH mission or as part of an operational mission, it will be possible to measure these parameters every 15-20 minutes for most of the hemisphere. This will make GeoSTAR a key hurricane and severe-storm observatory. The breakthrough enabling aperture synthesis concept that GeoSTAR is based on has been developed and demonstrated at JPL, largely through the NASA Instrument Incubator Program (IIP), and all key technology elements will be in place when the current IIP project is completed in 2011. A GeoSTAR mission can then be initiated. We discuss the status of the GeoSTAR development, possible mission scenarios and some of the science applications.

Session 6
Observations and Observing Strategies for Tropical Cyclones and their Environment, Part 3

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Systematically Merged Atlantic Regional Temperature and Salinity (SMARTS) Oceanic Climatology

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A new oceanic climatology to estimate ocean heat content (OHC) from space-based altimeters was developed for application during the hurricane season in the Atlantic Ocean basin. The Systematically Merged Atlantic Regional Temperature and Salinity (SMARTS) Ocean Climatology blends temperature and salinity fields from the World Ocean Atlas 2001 (WOA) and Generalized Digital Environmental Model v.3.0 (GDEM) at 1/4º resolution. This higher resolution climatology better resolves features in the Gulf of Mexico (GOM), including the Loop Current and ring structures, than the previous coarser 1/2º products. Briefly, SMARTS was calculated from the monthly GDEM and WOA climatologies by applying a 15-day running average to eliminate discontinuities when transitioning between months. Daily mean isotherm depths of the 20ºC (D20) and 26ºC (D26) (and their mean ratio), reduced gravity (e.g., 2-layer model), mixed layer depth (MLD), and OHC were estimated from the blended climatology.

Using SMARTS with satellite-derived surface height anomaly and SST fields, daily values of D20, D26, MLD, and OHC have been calculated from 1998 to 2009 using a two-layer model approach. Airborne and ship-deployed eXpendable BathyThermographs and eXpendable Conductivity, Temperature and Depth Profilers (AXBT, AXCTD), long-term moorings, and Argo profiling floats provide the in-situ data to assess the SMARTS Climatology, calculate isotherm depths and OHC. Based on over 36,000 profiles from the Argo floats, (A)XBTs, AXCTDs, and long-term moorings from 1998 to 2009, a clear, direct relationship has emerged from the detailed analysis between satellite-derived and *in-situ* measurements of isotherm depths and OHC. This new climatological approach creates a more accurate estimation of isotherm depths and OHC from satellite radar altimetry measurements, which can eventually be used in hurricane intensity forecasts from the Statistical Hurricane Intensity Prediction Scheme.

WISDOM System 2009 Proof of Concept Test Results

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NOAA with support from DHS Science and Technology, the Air Force Weather Agency and a consortium of academic and industry partners are in the second year of developing and testing a new system to improve upper air data in areas that are poorly observed. The Weather In Situ Deployment Optimization Method (WISDOM) system is designed around the availability of small constant-density balloons, and the availability of small (100 gram) payloads with sensors that include over the horizon Global Positioning System and satellite radio capabilities. The concept is that large numbers of WISDOM balloons with the GPS payload are released to optimize weather prediction at a future time for phenomena of interest. Advanced techniques of assimilation and modeling will used to determine the release locations of the balloons to optimize their trajectories to improve future numerical weather prediction. An initial test of the WISDOM system was conducted in fall 2008 aimed at late-season tropical cyclone prediction in the Atlantic basin. In 2009 the program sought to quantify the forecast improvement provided by ingesting WISDOM data into numerical weather prediction models, including ESRL's FIM model. Two major hurricanes threatening the US were targeted for the WISDOM 2009 Proof of Concept deployments. In addition to providing wind data the 2009 WSB will also included termination devices and a pressure sensor. Up to 250 WISDOM balloon systems were launched from up to ten sites in the continental US and overseas with the aim for improving numerical weather prediction. The initial results of the 2009 hurricane season data analysis and OSSE will be discussed.

NOAA Assessment of Unmanned Aircraft Systems for Hurricane Observations

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The NOAA Unmanned Aircraft Systems (UAS) Program is evaluating the feasibility of UAS technologies to address the NOAA mission using a requirements-based systems approach. UAS have the potential to fill critical observation gaps in understanding and predicting high impact weather events impacting coastal communities. The NOAA UAS Program has been identifying and conducting conceptual studies of UAS platforms and payloads which could be beneficial for long endurance sampling of tropical cyclone boundary layers and remote sensing of storm structures. The NOAA UAS Program is also investing in Observing System Simulation Experiments (OSSE) to analyze whether positive impact to future tropical cyclone observing strategies could be achieved with UAS observations. This presentation will include an overview of the NOAA UAS Program High Impact Weather Roadmap for testing and evaluating UAS technologies. Recent accomplishments and key partnerships will also be discussed.

Mapping Hurricane Inland Storm Surge

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Historically, hurricane-induced storm tides have been documented through analysis of structural or vegetative damage and high-water marks. However, these sources rarely provided quantitative information about the timing of flooding, the sequencing of multiple paths by which the storm-surge waters arrived, or the magnitude of waves and wave run-up comprising floodwaters. Nor can high-water marks be used to evaluate storm-surge model performance along the dynamic track of a hurricane with its accompanying changes in wind strength and direction.

In response to these deficiencies, the U.S. Geological Survey (USGS) has developed and deployed an experimental mobile storm-tide network to provide detailed time-series data for selected hurricane landfalls (URL: http://water.usgs.gov/waterwatch/hsss/). As part of this program, water-level and barometric-pressure monitors are rapidly deployed to areas of potential hurricane landfall to create a concentrated network of temporary surge sensors along water channels and throughout nearby overland features such as beaches, wetlands, and constructed environments.

To date (October, 2010), USGS storm-surge networks have been successfully deployed for Hurricanes Rita (2005, 32 water-level sensors); Wilma (2005, 30), Gustav (2008, 80); and Ike (2008, 65); and Tropical Storm Ernesto (2006, 40 sensors for which the data were not published). Data were collected as frequently as every 30 seconds for 24-48 hours before hurricane landfall and for as long as two weeks after landfall. At selected sites in southwest Louisiana, data were collected for multiple storms. The data are available at (URL: http://water.usgs.gov/osw/programs/storm_surge.html).

Typical USGS storm-surge network deployments include water-level and barometric pressure sensors placed at pre-selected locations distributed throughout the projected areas of coastal flooding. Sensors are programmed to record data at short time intervals (minute or less) to capture the combined effects of downstream river flows, storm-water outfalls, tides, and wind-driven ocean surge.

Each sensor is placed in a perforated protective metal housing and strapped to power poles, pilings, or other stable structures deemed likely to withstand the surge. Temporary benchmarks are driven into or chiseled on to the same or near-by objects to serve as elevation controls for the sensors and high-water marks expected to result from flooding.

Following the passage of the storm, tape downs from the temporary benchmarks to the surface of the water and to available high-water marks can be made to confirm sensor accuracy. Traditional line of sight leveling is employed to tie the sensors, water marks, and benchmarks to a common datum, which can then be tied to the NGVD 1988 through use of GPS surveying.

Results to Demonstrate the Measurement of Surface Level Pressure using a Differential Absorption Microwave Radar

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The surface barometric pressure is an important meteorological parameter in the prediction and forecast of the intensity and track of tropical storms and hurricanes. To improve predictions and forecasts of the intensity and track of tropical storms, large spatial coverage and frequent sampling of sea surface barometry are critically needed for use in numerical weather models. These needed measurements of sea surface barometric pressure cannot be realized by in-situ buoy and aircraft dropsonde techniques. NASA Langley Research Center (LaRC) has developed a microwave radar to measure atmospheric absorption at moderate to strong O_2 absorption bands in the frequency range of 50~56 GHz. At these radar wavelengths, the reflection of radar echoes from water surfaces is strongly attenuated by atmospheric column O_2. Because of the uniform mixture of O_2 gases within the atmosphere, the total atmospheric column O_2 is proportional to atmospheric path lengths and the total atmospheric column air, and thus, to surface barometric pressures. The LaRC developed prototype Radar is based on this differential absorption technique and recent flight testing suggest this technique may provide a remote sensing technique to provide the surface barometric pressure needed improve hurricane intensity and track forecasts.

An overview of the Differential Absorption Microwave Radar (DAMR) instrument concept and predicted capability will be presented. The results from a recent NASA/Navy flight experiment to verify the performance of the instrument will also be presented. During this experiment, DAMR data was collected over the Chesapeake Bay at various altitudes, sea conditions and barometric pressure. These measurements agree with the model predicted increased O2 loss, and measured differential absorption appears consistent with changes in barometric pressure. The data from these flights will be presented in detail. Future flight test plans to collect DAMR data over the ocean and at higher altitudes will be described. Finally, a DAMR data processing strategy to infer sea surface barometric pressure from measurement utilizing adaptive measurement frequency selection will also be presented.

Poster Session

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

The Recent Availability of Low-Cost Radiosonde Systems and the Implications for Developing an Adaptive Sounding Network for Hurricane Prediction

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Hurricane track and intensity prediction depends on the adequate specification of large-scale initial conditions provided by a blend of satellite and in-situ measurements. In the case of the western Atlantic Ocean region, the routine radiosonde network over and around the Caribbean Sea and the southern periphery of the Gulf of Mexico is of limited spatial density and has been difficult to maintain at high reliability. For hurricanes approaching the US, operational dropsonde flights to measure the synoptic environment of storms have been carried out for some years. However, such flights are expensive, and cannot provide observations over some regions, such as Central America and northern South America.

The notion of increasing the spatial density of radiosonde stations has generally been discounted in recent years because of the high initial cost of the ground stations and the required supporting infrastructure (e.g. balloon inflation shelters and hydrogen generators), personnel costs, and the cost of the radiosondes themselves. *However*, the recent development and marketing of low-cost (~$10K) radiosonde ground stations by different manufacturers may make it feasible to substantially expand radiosonde networks *if* certain conditions can be met. We argue that an adaptive sounding network could be a cost-effective addition for improved tropical storm intensity and track prediction efforts in the Caribbean Sea and surrounding regions, including improved monitoring of early- and late-season hurricane genesis in the western Caribbean.

For such a network to be cost-effective, the following conditions need to be met:

1) *the initial cost of the radiosonde system must be low.* Low initial cost removes the inherent "pressure to fully utilize" a system with a large initial investment.
2) *the need for additional soundings is limited to certain times of the year, or to easily identifiable meteorological conditions*.
3) *labor should be "pay-per observation" rather than full-time employees.*
4) *two-way communications is required with observation sites.*
5) *a decision-making process exists to determine when to make the required observations.*

We argue that an adaptive network meeting the above requirements, consisting of 20 *additional* radiosonde stations, each making approximately 60 observations per year, could be operated for less than $500,000 annually. The annual cost is directly proportional to the number of observations required per year. *The technology now exists to do this*.

Development, Capabilities, and Impact on Wind Analyses of the Hurricane Imaging Radiometer (HIRAD)

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The Hurricane Imaging Radiometer (HIRAD) is a new airborne microwave remote sensor for hurricane observations that is currently under development by NASA Marshall Space Flight Center in partnership with the NOAA Atlantic Oceanographic and Meteorological Laboratory/Hurricane Research Division, the University of Central Florida, and the University of Michigan. The instrument is scheduled to be test flown in February and is expected to participate in the NASA tropical cyclone experiment GRIP (Genesis and Rapid Intensification Processes) in the 2010 season. HIRAD is designed to study the wind field in some detail within strong hurricanes and to provide enhanced real-time airborne ocean surface winds observation capabilities based on the technique of the Stepped Frequency Microwave Radiometer (SFMR). Unlike SFMR, which measures wind speed and rain rate along the ground track at a single point directly beneath the aircraft, new antenna and receiver technologies will enable HIRAD to provide images of the surface wind and rain field over a wide swath (~ 3 x the aircraft altitude) with ~2 km resolution. This presentation describes the HIRAD instrument and the physical basis for its operations, including chamber test data and possibly data from the test flight during the week of 22 February. The potential value of future HIRAD observations will be illustrated with a summary of Observing System Simulation Experiments (OSSEs) in which measurements from the new instrument as well as those from existing instruments (air, surface, and space-based) are simulated from the output of a detailed numerical model, and those results are used to construct simulated H*Wind analyses and to define the strength and location of maximum wind speed and the structure of the inner vortex.

Objective Measures to Estimate Tropical Cyclone Intensity and Intensity Change from Remotely-Sensed Infrared Imagery

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An objective technique is described for obtaining features associated with the shape and the dynamics of cloud structures embedded in tropical cyclones from satellite infrared images. As the tropical cyclone develops from an unstructured cloud cluster and intensifies the cloud structures become more axisymmetric about an identified reference point. Using variables derived from remotely-sensed data, the technique calculates the gradient of the brightness temperatures to measure the level of symmetry of each structure, which characterizes the degree of cloud organization of the tropical cyclone. Previous results have shown that the technique provides an objective measure of both the structure and the intensity of the tropical cyclone. The method is particularly robust for intensities greater than or equal to 34 kt. A methodology to extend this intensity estimation into the very early stages of tropical cyclone intensity will be presented.

The Potential Role of Ocean Observing System Simulation Experiments for Improving Ocean Model Initialization in Coupled Hurricane Forecast Models

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For a coupled hurricane prediction model to correctly forecast intensity evolution, it must accurately predict the magnitude and pattern of SST cooling over the region directly forced by the storm. Because SST cooling occurs primarily in response to cold water entrainment at the ocean mixed layer (OML) base, predicted cooling is sensitive to the initial temperature-salinity and associated density profiles provided to the ocean model. In particular, errors in the initial location of ocean features along with errors in the initial thickness of the surface warm layer within these different features often produce large errors in predicted SST cooling. This situation places a high premium on accurate initialization of the ocean component of coupled forecast models.

Basin-scale and global data-assimilative ocean nowcasts produced by the Global Ocean Data Assimilative Experiment (GODAE) are an attractive choice for initialization because they provide balanced ocean fields to the model. However, large errors and biases are often present in these products. These problems can potentially be corrected with enhanced observational coverage available for data assimilation. As part of the Hurricane Forecast Improvement Project (HFIP), we are investigating the feasibility of employing ocean Observing System Simulation Experiments (OSSEs) to design optimal enhanced observing strategies capable of significantly reducing ocean initialization errors. Observational enhancements to be tested include additions to the present in-situ ocean observing system along with targeted ocean observations obtained by aircraft measurements and ocean gliders.

In this poster, the ocean OSSE capabilities being developed at the Joint AOML/RSMAS Ocean OSSE Center are described first. Errors present in existing GODAE nowcast products (e.g. U. S. Navy HYCOM; French MERCATOR) relative to *in-situ* upper-ocean profiles, and also relative to Ocean Heat Content (OHC) maps calculated from *in-situ* observations and derived from satellite measurements are then quantified. The initial focus is on hurricanes Katrina and Rita (2005) along with Gustav and Ike (2008) over the northwest Caribbean Sea and the Gulf of Mexico. This error analysis will be extended to a large number of other storms in different regions of the North Atlantic. Our strategy for using ocean OSSEs to potentially reduce these initial ocean model errors is then summarized.

Analysis of 2008 Hurricane Season Test Flight Data from the Wide Swath Radar Altimeter (WSRA)

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Through a NOAA Phase II SBIR Contract, ProSensing has developed an operational Wide Swath Radar Altimeter (WSRA) intended for airborne measurement of directional ocean wave spectra. WSRA is a novel solid-state digital beamforming radar, designed to replace the recently retired prototype Scanning Radar Altimeter (SRA). In the fall of 2009, ProSensing received a JHT-funded contract to complete the development of a real-time PC-based processor for WSRA.

During the 2008 season, ProSensing operated and collected data with WSRA on six missions in hurricanes Fay, Gustav and Ike. For these missions, WSRA was configured to collect raw data for offline analysis. Under the JHT-funded contract, we have continued to analyze the 2008 flight data, discovering processing artifacts induced by cross-track velocity. We are now adjusting the processing algorithm to compensate for this effect.

Analysis of the 2008 hurricane data has shown that the WSRA has expanded the operational capability over the retired NASA prototype SRA system. WSRA has obtained usable signal from a significantly higher altitudes (12,500-ft vs. 5,000-ft) and is less susceptible to attenuation in rainfall.

We will present the results of our analysis and changes to the processing algorithm. One of the most important findings was the realization that cross-track aircraft motion impacts WSRA's effective subarray spacing. This effect changes the 80 cross track antenna beam angles thus distorting the reconstructed profile of the ocean surface waves. This processing artifact can be eliminated by taking into account the instantaneous cross-track velocity to continuously re-calculate the cross-track beam angles.

WSRA is currently installed on NOAA's WP-3D N42 aircraft. A test flight with WSRA is scheduled for February, 2010 and collected data will be used to verify the implemented improvements in the WSRA processing algorithm.

IBTrACS Tropical Cyclone Best Track Community Survey

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There are currently six Regional Specialized Meteorological Centers (RSMC) and five Tropical Cyclone Warning Centers (TCWC) around the world that forecast and monitor storms in each of the tropical-cyclone-prone basins and annually archive best track data: information on a storm's position, intensity, as well as other related parameters. Despite the widespread interest in global best track data, no central repository of such data was maintained. The International Best Track Archive for Climate Stewardship (IBTrACS) is a project at NOAA's National Climatic Data Center under the auspices of the World Data Center for Meteorology – Asheville to collect and disseminate the historical tropical cyclone best track data from all available centers, merging the disparate data sets into one comprehensive product for the user community. More information is available by accessing our website at http://www.ncdc.noaa.gov/oa/ibtracs/

At the IBTrACS Workshop in May 2009 and more recently at the WMO Sixth Technical Coordination Workshop in Brisbane it was recommended that a survey be conducted and lead by the IBTrACS team in an effort to gather metadata regarding TC Best Track procedures from all RSMCs and TCWCs as well as other agencies who contribute data to the TC record. The purpose of this survey is to identify any procedural changes and decision-making factors that have impacted the global TC Best Track record since its inception. Uncovering these procedural variations will shed light on the differences that exist within and across the various ocean basin records and from year to year.

The survey contains sixty questions, most of them open-ended. The questions cover a range of topics about constructing best-track data including the agency's use of available technology, procedural changes, wind-pressure relationships, wind-speed averaging periods and unarchived data sources.

The questionnaire is available online to anyone with a working knowledge of the operational forecasting and/or "best tracking" procedures at any agency as an employee or otherwise, though there is the option to remain anonymous. We estimate it will take approximately one hour of your time.

The information you provide will help the community to better understand the historical nature of tropical cyclones.

Contribute your experience. Participate today at: http://www.surveymonkey.com/s/ibtracs

Sea Surface Wind Measurements from Gulfstream-IV Using GPS Reflectometry

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During the last decade a number of airborne experiments have been performed to study feasibility of GPS reflection technique to measure ocean surface winds. Significant progress was made during this period in designing and testing various types of GPS reflection receivers which are appropriate to regard as GPS multistatic radars. This technique might be attractive when considering high altitude/long endurance (HALE) Unmanned Aircraft Systems (UAS) because of the small size, small weight, and low energy consumption of GPS receivers. Use of high-altitude (~ 20 km) UAS platforms is especially beneficial providing swaths ~100 km wide.

Because of the significant increase in high-speed digital data storage capabilities, recent interest has shifted from real-time delay-mapping GPS receivers to so-called software GPS receivers. In contrast to a real-time receiver, a software receiver simply records raw in-phase and phase-quadrature data for the direct and ocean reflected GPS signals. Then, post-processing can be performed after the measurement using varying parameters to obtain the best result depending on the measurement conditions. Accelerated post-processing algorithms make possible obtaining geophysical results from the raw data over a relatively short time, of order of several days. In [1] results were presented of an ocean scatterometric experiment in September 2008 performed with a small and inexpensive GPS software receiver designed at the University of Colorado/Aerospace Engineering Sciences. The purpose of that experiment was to test this new sensor and compare wind retrievals with data available from other instruments to assess the capability of this bistatic GPS radar to monitor winds or ocean surface roughness from 2-3 km flight altitudes.

A modified version of the CU bistatic radar with a larger bandwidth front end was installed on the NOAA Gulfstream-IV jet aircraft and operated during a flight on October 19, 2009 to test the system at higher altitudes, ~12 km, to provide insight into the feasibility of using this technique for high-altitude UAS platforms using the smallest possible form factor and minimal power. A portion of the flight track ran across the Gulf of Mexico and the GPS reflected signal was recorded from all available satellites. Overall, 100 s of reflection data were obtained from ten GPS and two geostationary WAAS satellites. We will report comparisons between GPS wind retrievals and in situ wind data from a NOAA station in the vicinity of the flight track. Comparisons with modeling results will be presented as well. For the next phase of the sensor development we plan to expand capabilities to all three GPS frequencies, including the wider band L5 signal (well suited for the ocean altimetry).

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Measuring Hurricane Storm Surge in South Carolina

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Preventing flood hazards, such as the hurricane induced storm surge, from becoming human disasters requires an understanding of the relative risks floods pose to specific communities and knowledge of the processes by which flood waters rise, converge, and abate. It is critical that the timing, magnitude, and duration of hurricane storm surge are accurately measured. The U.S. Geological Survey – South Carolina Water Science Center (USGS-SCWSC), in cooperation with various municipal, State, and Federal Cooperators, uses three monitoring approaches for measuring hurricane storm-surge dynamics. The USGS maintains a network of 47 real-time water-level and water-quality gages along the South Carolina coast. The gages record water level, specific conductance, temperature, and (or) dissolved oxygen at 15-minute intervals and are available on the web with a maximum of a 1-hour time delay. The real-time network is maintained to monitor a large range of hydrologic conditions from droughts to floods and provide the data on the web for a broad base of stakeholders.

In addition to the real-time network, the USGS-SCWSC, in cooperation with the U.S. Army Corps of Engineers – Charleston District and the South Carolina Department of Transportation, established a hurricane storm-surge monitoring network for South Carolina. The network is designed for a cost effective and time-efficient monitoring of hurricane storm surge. The hurricane storm-surge network consists of twelve sites distributed along the South Carolina coast. At each site, a bracket for a water-level sensor has been attached to a permanent structure, such as bridge pier. The elevation of the bracket has been determined by differential surveying to a benchmark of known elevation. In the event of a storm, the sensors are attached to the bracket and the timing, duration, and magnitude of the storm surge is recorded. Upon retrieval of the sensors, there is minimal delay in disseminating the storm-surge elevation data to interested agencies and coastal resource managers because the water-level data are easily adjusted to mean sea level.

These two fixed networks can be augmented with real-time rapid deployment gages and the temporary deployment of pressure transducers attached to bridge piers or other substantial structures to provide more spatially dense monitoring of hurricane storm surge. For example, temporary deployment of sensors in the projected hurricane path can be placed to monitor the attenuation of the hurricane surge along coastal rivers and across barrier islands, low-lying areas, and wetlands. After the passing of a storm, the locations of the temporarily deployed sensors must be surveyed to a known elevation. The USGS has successfully deployed temporary storm surge-networks for Hurricanes Rita, Wilma, Gustav, Ike, and Tropical Storm Ernesto.

The 59 monitoring sites for the two fixed networks with the addition of temporarily deployed sites provide a cost-effective hurricane storm-surge monitoring network for South Carolina. The combined networks effectively leverage resources of over 10 cooperative funding agencies in South Carolina for monitoring hurricane storm surge.

Examples of Ensemble Storm-track Forecasts from the FNMOC Ensemble Forecast System

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This poster will describe the Fleet Numerical Meteorology and Oceanography Center (FNMOC) operational Ensemble Forecast System (EFS) and its use in generating storm track forecasts. The current operational FNMOC EFS uses 16 Navy Operational Global Atmospheric Prediction System (NOGAPS) members at T119L30 (one degree horizontal, 30 vertical levels) resolution with initial perturbations generated using the Ensemble Transform (ET) technique (McLay, Bishop and Reynolds, 2008). The storm tracks were extracted from the ensemble member output using a version of the Marchok tracker (Marchok, 2002). These time-late tracks are then adjusted in time and space to the current track positions and an ensemble mean is computed as would be done in real-time at the National Hurricane Center (Sampson, Goerss and Weber, 2006). Track error statistics for the period Oct 13, 2009 to Jan 4, 2010 will be presented with comparisons of the skill of a single ensemble member, the ensemble mean, the half-degree NOGAPS deterministic run and the best-track forecasts. The higher resolution deterministic track forecast has lower track errors than the ensemble mean out to 3 days while the ensemble mean is better at days 4 and 5. Examples of the relationship between ensemble spread and forecast skill will also be presented.

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Validating the Ocean Model Component of Coupled Hurricane-Ocean Models

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NOAA uses coupled hurricane-ocean models operationally to forecast tropical cyclone (TC) track, structure, and intensity. As part of the Hurricane Forecasting Improvement Project (HFIP) effort to improve TC forecasts, it is imperative to validate not only the atmospheric component of these models but also the oceanic component so that future coordinated improvements can be made to these coupled model systems. As a result, a partnership has been created among URI/GSO, NOAA/AOML, NOAA/NCEP/EMC, and FSU/COAPS to perform Princeton Ocean Model (POM) and HYbrid Coordinate Ocean Model (HYCOM) simulations forced by the observed wind stress from a variety of historical Atlantic TCs. Using the ocean model output, the TCs' inner-core sea surface temperature (SST) cooling is compared to an observed climatology, which is currently used as a predictive variable in the Statistical Hurricane Intensity Prediction Scheme (SHIPS). Future work will include analysis of other ocean model variables that may influence SST cooling, such as wind stress and the three-dimensional ocean temperature, salinity, and current velocity fields. These model fields will be verified whenever possible using available *in situ* ocean observations.

Collaborative Study of Episodic Changes to Intensity and Structure of Gulf Hurricanes

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Accurate prediction of the intensity and wind field area (or size) of a hurricane remains elusive. Along the U.S. coast of the Gulf of Mexico, the impacts of Hurricanes Dennis, Katrina, Rita, and Wilma in 2005, and Hurricanes Charley and Ivan in 2004, have recently reiterated the need to effectively forecast hurricane intensity and size. With government officials forced to decide how to properly ensure the welfare of Gulf residents, National Weather Service forecasters are asked not only to estimate the threat posed by a hurricane, but are further asked to provide the most certainty possible in their estimation.

Three more recent Gulf hurricanes – Humberto, Gustav, and Ike – have highlighted the criticality of forecasting storm intensity and size in properly assessing the risk to citizens and infrastructure. An ongoing collaborative study, between researchers at Mississippi State University and staff at two National Weather Service Weather Forecast Offices directly involved with monitoring and observing the three hurricanes, aims to provide greater insight into forecasting time-sensitive trends of rapid formation, changing intensity, and changing wind field area of hurricanes over the Gulf Mexico in the interest of reducing the uncertainty in the risk posed to Gulf Coast residents and infrastructure. The scientific focus of the study is to identify key features or processes present in the ambient atmosphere and in the Gulf of Mexico that led to critical episodic changes in the intensity and structure of Hurricanes Humberto, Gustav, and Ike through hindsight analysis and numerical simulation. One goal of the study is to construct decision trees for WFOs to assist in determining the likelihood of rapid cyclone formation and significant changes to cyclone intensity or size.

This study is funded by the National Oceanic and Atmospheric Administration through the Northern Gulf Institute.

Application of High Resolution Satellite Imagery to Assess Storm Tide-related Flooding

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The overall goal of the proposed study is to demonstrate the efficacy of employing high resolution satellite imagery to improve coastal inundation models that are presently employed by NOAA (NWS and NOS), USACE, and FEMA, and those state-of-the-art coastal and estuarine models that are under development and will soon be applied operationally. It is expected that the employment of satellite imagery will break new ground for wetting/drying algorithm verification and overall model validation. Because of the unique approach taken with satellite imagery, model validation is possible for water surface elevations and the extent of the wetting front over large expanses of the coast with significant spatial and temporal variations.

A change detection approach has been adopted to determine the coastal flood wetting front. It is an active microwave based technique which makes use of satellite images from Radarsat 1 (SAR) obtained from the Alaska Satellite Facility. The spatial resolution of the obtained images ranges between 9m (fine mode) and 25m (standard mode). The approach consists of comparing two images acquired under two extreme conditions (e.g., low tide vs high tide). The main difficulty to overcome when using SAR imagery to identify flooded areas is that the signal returned to the satellite may be similar to one returned from land because of the speckle noise and ocean surface roughness. A simple grey-value threshold based technique is insufficient to distinguish between land and water in a single image. Therefore, the application of appropriate filters was necessary to reduce the noise in the images and allow for a better identification of inundated areas.

For this purpose, a multi-temporal image enhancement technique was applied to determine flooded areas. This technique assigns red, green and blue color to two different black and white SAR images covering the same scene and taken at two different acquisition dates but with similar radar configurations. One of the two images illustrates normal conditions (i.e. reference image) and the second image corresponds to the flood event. The hue of the color in the false color composite image indicates the date of the change while the intensity of the color represents the degree of change. The methodology was applied to Tampa and Apalachicola zones located in western Florida. The multi-temporal false color composited image obtained clearly shows flooded areas during high tide or after the hurricane. The intensity of the red color which is corresponds to inundated areas, represents the severity of the flood. These preliminary results show great potential for satellite imagery to monitor coastal flooding, to delineate inundated areas at high spatial resolution and improve hydrodynamic model verification and validation.

Climatological-based Tropical Cyclone Landfall Probabilities and Average Time to Landfall

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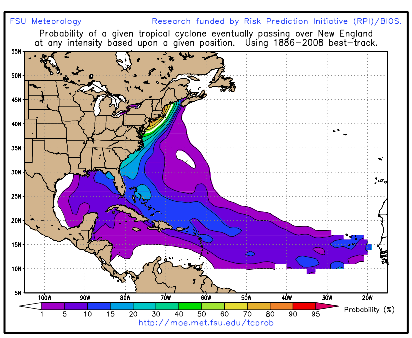
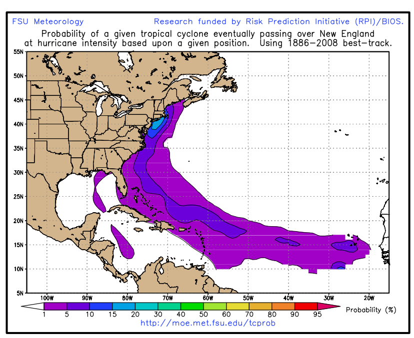
Using a 10-minute temporally interpolated global best-track tropical cyclone dataset and a very high resolution global land-sea mask, maps of probability of landfall in various regions and locations are derived. Additionally, the average transit time to landfall is given, with up to 16 day average lead times. These maps are provided on the web, along with current tropical cyclone locations globally overlaid for operational and public use. Several operational forecasting centers have already stated they plan to use the probabilities to help"defuse" irrationally early claims of threat at long lead times.

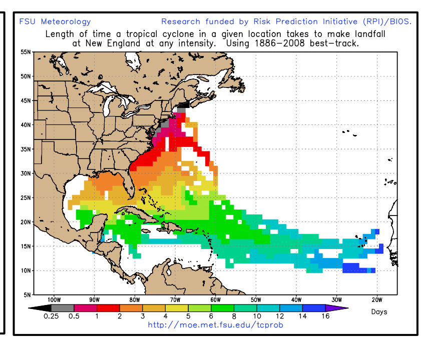
The results provide for quick identification of anomalous probability of landfall compared to climatology. The results further provide for identifying key "channels" of tropical cyclone movement that favor landfall. The real-time probabilities of tropical cyclones may provide for advanced noticed of anomalous risk, and have already been embraced by many forecasters and emergency managers, and insurers.

Of additional note is that the “urban legend” 20°N/60°W benchmark in the Atlantic basin is confirmed in the analyses (as a 50% chance for landfall at any land).

The maps along with real-time labeling of tropical cyclones and their specific probabilities are given at the web page http://moe.met.fsu.edu/tcprob.







Session 7
Tropical Cyclone Model Development and Technology Transfer, Part 1

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Performance of the Operational HWRF Model for 2009 Hurricane Season and Suggested Upgrades for 2010 Implementation

Vijay Tallapragada[1], Bill Lapenta[2], Stephen J. Lord[2], Naomi Surgi[2], Qingfu Liu[2], Young Kwon[1], Zhan Zhang[1], Robert Tuleya[1], Janna O'Connor[1] and Samuel Trahan[2]
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Performance of the NCEP's operational Hurricane Weather Research and Forecast (HWRF) modeling system during 2009 hurricane season is presented in terms of track and intensity error statistics and some diagnostic studies for selected storm forecasts. Intensity forecasts from HWRF model for weaker systems have shown little sensitivity to sheared environment, resulting in over-intensification.

Strategies for HWRF upgrades for future implementation are discussed along with requirement for extensive testing for individual components. A new baseline HWRF configuration was derived from operational HWRF that included several bug fixes. Suggested upgrades for 2010 implementation include changes to initialization, modification of surface physics and inclusion of gravity wave drag parameterization. Results from each of these upgrades and their combination will be analyzed and their impact on HWRF forecasts for 2008-2009 hurricane seasons will be highlighted. Changes to initialization resulted in improved track forecast skill while surface physics changes helped improve the intensity forecast skill. Gravity wave drag parameterization showed positive impacts in improving track forecasts in the Eastern Pacific basin. The collective improvement in track and intensity are reflected in HWRF forecasts obtained from combination of these individual components. Results from further testing of HWRF model using GFS Phase-II upgrades will also be presented.

Linking the HFIP Community with NCEP/EMC Operations

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The National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC) has been running the Hurricane Weather Research and Forecast (HWRF) model operationally since the 2007 hurricane season. The HWRF has undergone several upgrades since its inaugural season and there has been some improvement in forecast skill.

Goals of the Hurricane Forecast Improvement Project (HFIP) include improving the accuracy and reliability of predicting rapidly intensifying storms and extending the lead time of hurricane prediction with increased certainty. Emphasis is placed in four major areas to: increase hurricane observations; advance forecast models through research, development and engineering; increase computing power; and enhance collaboration with hurricane scientists in the private sector, government, and universities to advance research and operations.

The purpose of this paper is to present NCEP/EMC development priorities required to deliver improved operational numerical guidance to the NCEP tropical prediction Center (TPC). The priorities will be mapped into the HFIP organizational structure and a process designed to optimize and accelerate HWRF development at NCEP will be presented.

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The Hurricane Weather and Research Forecast (HWRF) System: Future Advancements, Community Involvement, and Transition of Research to Operations Through the Development Testbed Center (DTC)

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The HWRF system became operational at NCEP for the 2007 hurricane season. Future plans to advance the HWRF system for continued improvement of track and for improving prediction of storm intensity, storm structure and coastal inundation are underway at NCEP and will be discussed. An integral part of this effort will require the involvement and close collaboration with the greater tropical/hurricane modeling community for accelerating the transition of research into NCEP operations. In support of this inaugural collaborative initiative, the DTC in Boulder in collaboration with NCEP/Environmental Modeling Center has been preparing the HWRF code for introduction into the WRF repository at NCAR.

This collaborative effort is also a joint venture with the MMM division at NCAR and in February 2010, EMC, MMM and the DTC will have launched the first hurricane workshop and tutorial that will introduce both the HWRF and the Advanced Hurricane Research WRF (AHW) to the community. These activities will be discussed and a template for future collaborations between the research and operational communities will be presented.

Parameterizations for NCEP Operations

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The research focused on testing model initialization schemes primarily in the Gulf of Mexico (GOM) and processing data required for model evaluation. This dataset includes *in situ* Naval Research Laboratory Acoustic Doppler Current Profiler (ADCP) data from Ivan and during Katrina and Rita (courtesy of Minerals Management Service) as well as measurements acquired during NOAA Hurricane Research Division Intensity Fluctuation Experiments (IFEX) in pre and post Rita in 2005, and during Gustav and Ike (2008). All of these hurricanes have been shown to have been affected by warm and cold ocean features in the GOM.

The model evaluation has focused on hurricane Ivan, where high-quality *in-situ* moored current measurements have been acquired, focusing on the impact of the Loop Current (LC) and associated warm and cold rings, along with the complex bathymetry of the continental shelf/slope region. Objectively analyzed fields from multiple space-based platform data such as radar altimeter measurements and SST fields are also used in the evaluation. Fifteen experiments have been performed to date emphasizing ocean model sensitivity to vertical resolution, horizontal resolution, vertical mixing, air-sea flux parameterizations (drag coefficients), ocean dynamics, and the accuracy of the ocean initialization. The model accurately reproduces the upper-ocean near-inertial velocity response as illustrated in a comparison to several current profiles acquired over the continental slope of the northern GOM.

Analyses of the ocean response to hurricanes Katrina and Rita from in-situ (moorings, airborne profilers) and satellite-based measurements have shown significant modulation of the oceanic mixed layer cooling by the geostrophically balanced currents in both warm and cold rings. During favorable atmospheric conditions, hurricanes Katrina and Rita deepened to category 5 over the LC and ballooning warm core ring. Both hurricanes subsequently weakened after passing over a cold core ring prior to making landfall. Reduced (increased) oceanic mixed layer cooling of ~1^{o}C (4.5^{o}C) was observed over the LC (cold core ring) where the storms rapidly deepened (weakened). For similar wind forcing, the oceanic mixed layer velocity response was about two times larger inside the cold core eddy that interacted with Katrina than in the LC region that affected by Rita due to the deeper OML thickness. That is, the near-inertial current response was two to three times more energetic in the cold core ring than in the warm features. These results are consistent with the observed oceanic response to hurricane Lili (2002) and Gustav and Ike. From a broader perspective, coupled models must capture oceanic features (proper initialization) and vertical mixing processes to reproduce the differentiated OML cooling response to improve intensity forecasting. <u>Thus, three-dimensional ocean measurements acquired prior, during and subsequent to hurricane passage are central to improving coupled models.</u>

Coupled HWRF-HYCOM Parallel Run Results for the 2009 Hurricane Season

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NOAA/NCEP/EMC/Marine Modeling and Analysis Branch

Real-time hurricane forecasting using coupled HWRF-HYCOM for the 2009 season was successfully conducted, with completion of simulations of a total of seven tropical storms and hurricanes. Performance of the system was evaluated by comparing to best-track and other models, including the Operational HWRF and parallel HWRF whose hurricane atmospheric component is the same as one in HWRF-HYCOM, but the ocean component is POM (Princeton Ocean Model). The average track forecast errors and skills are improved while error standard deviation is substantially reduced. Improvement in the average intensity is found for most of tropical cyclones. Large improvement is notable for tropical storms. Hurricanes Bill and Ida are especially skillful. A negative intensity forecast bias is noted in case of tropical storm Grace and Hurricane Ida which are originated in the extra-tropical region and the Caribbean Sea, respectively. The ocean response to the atmospheric forcing, and sea surface temperature impact to the storms, are documented briefly.

Impacts of Land Effects and Improvements in Modeling Landfall Using HWRF
A Joint Hurricane Testbed (JHT) Program

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(SAIC/EMC/NCEP and CCPO/ODU)

The emphasis for this 2007-2009 JHT project has concentrated on HWRF development, its operational implementation, and recent upgrades. Future improvements and upgrades will be covered by the recently funded project with CCPO/ODU. HWRF has been accepted into operations and has been run successfully for the 2007 through 2009 seasons. Over the last year emphasis on this project has been on trouble shooting problems involving model biases of intensity, including issues involving land interaction. The production HWRF is known to yield unrealistic land surface temperatures. Some further analysis and possible solutions to these problems will be discussed. Some examples will be shown.

During HWRF development, the physics packages have been brought in line with the GFDL model. The new JHT project is now in position to make improvements and upgrades over and above the capabilities of the GFDL model. A primary task is the implementation of the NOAH LSM (land surface model) into the HWRF forecast system. Several preliminary cases have been run which indicates improvement in track and rainfall prediction. In addition, other physical possesses will be examined closely including momentum mixing and dissipative heating. Some preliminary forecasts have been performed and will be shown.

Other work continues on the development of a more complete diagnostic package so more objective evaluations can be made over and above the standard evaluations of absolute errors of track and intensity. This includes an examination of landfall fill rates compared to the landfall decay model as well as examination of differences between PDF’s of HWRF and best track observations of intensity.

Progress in Developing Coupled Tropical Cyclone-Wave-Ocean Models for Operational Implementations at NOAA and Navy

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We will discuss the progress in developing coupled tropical cyclone-wave-ocean models for operational implementations at NOAA and Navy. The key element of the our approach is an air-sea interface module (ASIM) that consists of the wave boundary layer model and the air-sea heat and momentum flux budget model that explicitly resolve the wind-wave-current interaction processes and sea spray effects. The ASIM is imbedded into the TC-wave-ocean coupled model and calculates all the flux boundary conditions for the atmospheric, wave and ocean models.

In the present NOAA and Navy operational coupled ocean-atmosphere models it is assumed that the surface wave field is fully developed and the momentum flux into ocean currents is set to be exactly equal to the flux from wind. However, when the surface wave field grows/decays in space or time, it gains/loses momentum and reduces/increases the momentum flux into subsurface currents compared to the flux from wind. In particular, under tropical cyclone conditions the surface wave field is complex and fast varying in space and time and may significantly affect the momentum flux into subsurface currents. We performed numerical experiments to investigate the momentum flux budget across the air-sea interface under hurricane conditions and found that the momentum flux into currents is significantly reduced relative to the flux from wind. The percentage of this reduction depends on the choice of the drag coefficient parameterization and can be as large as 25%.

One of the novel features implemented in ASIM is the method of coupling between breaking waves and sea spray generation in tropical cyclone conditions. In the present NOAA/ESRL sea-spray model, the source function is parameterized in terms of energy lost to the wave breaking process, which is simply related to the wind speed. The effective droplet source height h is related to the significant wave height. Within the framework of ASIM, the total energy lost to wave breaking is accurately estimated by explicitly accounting for the sea state dependence and the air-sea flux budget. The source height h is determined from the input wave age (i.e., wave age of the wind-forced part of the spectrum) and the wind stress, rather than from the significant wave height. This modification is important under tropical cyclones because the dominant scale of breaking waves is related to the scale of the actively wind-forced waves – not related to the scale of swell generated elsewhere.

Tropical Cyclone Prediction for HFIP with COAMPS-TC

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The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) has been designed for the prediction of tropical cyclone (TC) track, structure, and intensity. This application of COAMPS, referred to as COAMPS-TC, was run during 2009 for the Hurricane Forecast Improvement Project (HFIP). COAMPS-TC includes analysis methodologies for the initialization of the TC structure, moving nested grids that automatically move with the TC, and air-sea flux and microphysics parameterizations appropriate for high resolution grids used for prediction of TC structure and intensity. HFIP offered an excellent opportunity to exercise COAMPS-TC in a real-time environment, and to share our results with other HFIP scientists and organizations in order to improve the deterministic and probabilistic prediction of tropical cyclones.

A real-time automated system was set up to enable COAMPS-TC to be run 120-hour forecasts for every tropical cyclone in the HFIP areas (e.g., western Atlantic and eastern Pacific) every 12 hours during 2009. The HFIP configuration of COAMPS-TC was run using a triply-nested grid structure that used a stationary coarse mesh (45 km) in each basin that was large enough in areal coverage so that it could include all tropical cyclones that could develop in that basin. The two inner grids (15 and 5 km) were centered on each TC at the start of each forecast, and moved automatically with each storm so that they always remained centered on the TC.

We have a number of preliminary findings from the COAMPS-TC forecasts for HFIP. We found that our track error tended to be largest for weak and shallow tropical cyclones. We also noted an initialization problem for moderate-to-strong tropical cyclones (initial intensity > 70 knots), in which the tropical cyclone rapidly filled during the first several hours of the forecast, after which time it tended to re-intensify to a level close to the initial intensity. Also, COAMPS-TC demonstrated a tendency to over-deepen tropical cyclones over the 120-hour forecast period, exhibiting a positive bias in the intensity forecasts beyond the 48-72 hour forecast period.

We are using the findings from our 2009 HFIP results to set the direction for our further research and development on COAMPS-TC. We are now testing alternative methods and modifications to existing methods for our analysis and initialization of the TC circulation. This is expected to allow the COAMPS-TC forecast model to maintain its initial structure and intensity better during the first several hours of each forecast, and to better define the initial strength and structure for weak and shallow systems. We are also examining other improvements for the COAMPS-TC air-sea interaction and moist physics parameterizations. In addition, we are now testing atmosphere-ocean-wave coupling in COAMPS-TC. The set-up and results of COAMPS-TC for HFIP, and current/future research on COAMPS-TC will be discussed.

Session 8
Tropical Cyclone Model Development and Technology Transfer, Part 2

Impact of New Global Models and Ensemble Prediction Systems on Consensus TC Track Forecasts

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The interpolated versions of seven high-quality TC track forecast models are routinely available to the forecasters at NHC. The seven models are: GFS, GFDL, and the Hurricane WRF (AVNI, GFDI, and HWFI; NCEP); NOGAPS and GFDN (NGPI and GFNI; FNMOC); the UKMO global model (EGRI); and the ECMWF global model (EMXI). The operational consensus forecast aid, TVCN, is formed by giving equal weight to the available forecasts from AVNI, GFDI, HWFI, NGPI, GFNI, EGRI, and EMXI. Prior to the start of the 2009 season, upgrades were made to the Canadian global model (CMC). During the course of the season it was found that the TC track forecasts in the Atlantic for CMC were much improved over previous seasons. As part of the Hurricane Forecast Improvement Project Demonstration, a special NOGAPS ensemble was run along with a number of ensembles run using different configurations of the NOAA/ESRL FIM (a global model using a flow-following vertical coordinate, finite-volume numerics, and an icosahedral global grid). Interpolated versions of these new models and their ensemble means are computed for the Atlantic and eastern North Pacific for the 2009 season. The TC track forecast performance of these models and ensemble means are compared with that for the TVCN models. Finally, a number of experimental consensus forecast aids are formed combining these models and ensemble means with the TVCN models and their TC track forecast performance is compared with that for TVCN.

Implementation of the New Air-Sea Exchange Coefficients(Cd/Ch) to the Operational HWRF Model and Their Impact on Hurricane Intensity Forecast Skill

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NOAA/NWS/NCEP/EMC

The observation based air-sea exchange coefficients (Cd/Ch) are implemented in the surface physics package of the operational HWRF model, and the forecast skills of HWRF using new Cd/Ch are evaluated as one of the upcoming year 2010 upgrades. The drag coefficient (Cd) used in this test is based on the observational study of Powell et al (2003), and the heat exchange coefficient (Ch) is based on the CBALST observation (Zhang, 2007). The magnitude of the new drag coefficient is smaller that that of the operational HWRF over all wind speed (about 0.005 smaller at the high wind speed around 70m/sec). While the enthalpy exchange coefficient of the current linearly increase with wind speed and reaches 0.0025 at the wind speed of 70m/sec, that of the CBLAST study is constant value of 0.0012 regardless of wind speed.

The test simulations are made for the four 2008 storms (Fay, Gustav, Hanna and Ike) with full cycled HWRF runs. The verification results showed that the tracks of the operation and new test runs are almost identical, while the intensity error of the new Cd/Ch HWRF runs is about 25% improved than that of the operational HWRF. Most of the intensity improvement results from reducing the positive intensity bias of the current HWRF system, which can be expected from the using much lower Ch values in the new system. However, it is worthwhile to note that even the intensity skill of the low intensity bias storm is improved case such as hurricane Fay, and the further analysis indicates that this improvement is from the smaller standard deviation of intensity forecast of the new test HWRF system. Therefore, the intensity skill improvement of the new HWRF is not only from reducing the positive bias, but also caused by the more consistent intensity forecast.

The HWRFX Modeling System: Recent Developments in Hurricane Structure and Intensity Forecasting Research at AOML

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Forecasting intensity changes in Tropical Cyclones is a complex and challenging multi-scale problem because the factors that are known to influence these changes may vary in scales ranging between several thousands of kilometers (synoptic scale) to millimeters (microphysical scale). NOAA's Hurricane Forecast Improvement Project (HFIP) is a unified approach to guide and accelerate improvements in hurricane track, intensity and structure forecasts, with an emphasis on rapid intensity change. An integral component of HFIP is the development of improved coupled atmosphere-ocean-land surface model system based on Hurricane WRF (HWRF). Some results of various tests using experimental HWRF system (HWRFX) will be presented based on the High Resolution HFIP test results of 69 cycles of numerical forecasts from the 2005 and 2007 hurricane seasons, without ocean coupling. Our findings indicate that, when compared to an operational resolution of 27 km domain with a 9 km moving nest (indicated by 27:9), higher resolution of 9:3 km improves track forecast for lead times, 24-48 h and improves intensity forecasts for lead times 0-30 h. HWRFX was also used for real time predictions in the 2009 season at 9:3 km. Track performance is comparable to other regional models, while the intensity bias is higher than other regional models. Our initial testing, as well as those from all the HFIP tests, indicates that better resolution may be important to improve forecasts of vortex-scale motions. Ongoing work includes the development of multiple moving nests capable of providing an inner core resolution down to 1 km and the implementation of alternate physical packages that can operate at 1 km resolution. We will report some of our findings related to structure and intensity changes at 1 km resolution for ideal and real cases.

Simulation of Atlantic Warmpool in the Hybrid-Coordinate Ocean Model (HYCOM)

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Recent studies have demonstrated the important value of the Atlantic warm pool (AWP) — a large body of warm water comprised of the Gulf of Mexico, the Caribbean Sea, and the western tropical North Atlantic — for the Atlantic tropical cyclone (TC). Both observational and modeling studies have shown that a large AWP reduces both the lower tropospheric easterly winds and the upper tropospheric westerly winds, resulting in a reduction of the vertical wind shear in the main development region and thus increasing Atlantic TC activity. A large AWP also increases convective available potential energy over the main development region that provides the fuel for moist convection and thus facilitates the formation and development of Atlantic TCs. Therefore, improving the simulations of the AWP during the hurricane season in NCEP/EMC operational models will contribute to improving the forecast of the formation and intensification of Atlantic hurricanes.

In this study, we evaluate the simulation of AWP in HYbrid Coordinate Ocean Model (HYCOM), which is the ocean model component of both the Hurricane Weather Research and Forecast Model (HWRF-HYCOM), an experimental hurricane forecast system at NCEP/EMC, and the Real Time Ocean Forecasting System for Atlantic (RTOFS-Atlantic), which provides initial and boundary conditions for HWRF-HYCOM. Our earlier studies have shown that the largest uncertainty in the HYCOM simulation of the AWP originates from large differences of the net surface heat flux into the AWP among the surface flux datasets typically used in regional simulations. Therefore, in this preliminary study, we evaluate HYCOM forced with the air-sea fluxes derived from the NCEP Global Forecast System (NCEP/GFS), which is the surface flux dataset used in the RTOFS-Atlantic. Our specific objectives are to quantify the surface flux bias in the NCEP/GFS and to understand how this bias affects the simulation of AWP in HYCOM. Ultimately, the findings of this study will be later incorporated into developing a technique to correct the bias of NCEP/GFS derived air-sea fluxes.

Sensitivity of the WRF-NMM Model to Physics Parameterizations at Various Vertical and Horizontal Resolutions

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As the research and operational communities work together under the auspices of NOAA's Hurricane Forecast Improvement Project (HFIP) to understand the degree to which a tropical storm intensity forecast can be improved by increasing the horizontal grid spacing of operational NWP models, it still remains a great challenge for the research community to reach a consensus on whether the current physics parameterizations in operational NWP models are suitable for horizontal grid spacings of 3 km or smaller. Another challenge is what the minimal vertical resolution should be for a given high horizontal resolution, say 1 km, in an operational setup for tropical storm prediction. To deal with these challenges, it is important to first understand how sensitive operational NWP models for hurricane forecast are to different physics parameterizations and various grid resolutions in both the horizontal and vertical directions.

This presentation highlights major results from a series of idealized experiments with the NOAA WRF-NMM model, which shares the same dynamical core with the operational HWRF model. The purpose of the experiments is to reveal how sensitive the WRF-NMM model is to commonly used microphysics and boundary-layer parameterization schemes and various horizontal and vertical resolutions. The model is initialized with a weak axisymmetric vortex disturbance in an idealized tropical environment that is favorable for the vortex disturbance to develop into a hurricane. The initial mass and wind fields associated with the weak vortex disturbance are obtained by solving the nonlinear balance equation for the given wind distributions of the initial vortex, and the prescribed background thermal sounding and winds.

The Tropical Cyclone Modeling Testbed (TCMT) and Its Role in the Hurricane Forecast Improvement Project (HFIP)

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The Tropical Cyclone Modeling Testbed (TCMT) is a new entity in the Joint Numerical Testbed (JNT) at the National Center for Atmospheric Research (NCAR), which has been established to provide testing and evaluation of tropical cyclone models. The TCMT works closely with the Developmental Testbed Center (DTC) but with broader objectives that may include international collaborations and testing of a variety of numerical weather prediction (NWP) models. For example, while the DTC focuses primarily on NWP models in the transition from research to operations, TCMT evaluations may include models that are either in earlier stages of development or may not be intended for operational application in the U.S. For the Hurricane Forecast Improvement Project (HFIP), the TCMT will help design model evaluation experiments and will provide general testing and evaluation of the various forecast models included in the HFIP annual forecasting demonstrations and retrospective experiments. Utilizing staff expertise in forecast verification, statistics, and atmospheric sciences, the TCMT is developing statistical approaches that are appropriate for evaluating a variety of tropical cyclone forecast attributes. These methods include new diagnostic tools to aid, for example, in the evaluation of precipitation and tropical cyclone structure forecasts. The TCMT will also support HFIP through other activities such as provision of a data service. The data service will include model forecast and some observational datasets as well as links and pointers to additional observational datasets. In summary, the TCMT is a resource for tropical cyclone model testing and evaluation that will support many aspects of HFIP. Examples of these activities and the approaches taken by the TCMT will be described in this presentation.

The Potential for Improved Tropical Cyclone Forecasts from High-Resolution Global Models -- Results from the HFIP 2009 Summer Experiment

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The primary goal of the NOAA Hurricane Forecast Improvement Project (HFIP) is a reduction in tropical cyclone (TC) forecast error by 50% in the next 10 years – it is clear that high-resolution numerical modeling will be the basis for such a large improvement. To better define the computing and modeling requirements for improved TC prediction, HFIP sponsored a two-month demonstration of ultra high-performance/capacity computing in August-September, 2009 and ESRL was the lead agency for testing advanced global modeling and ensemble-based data assimilation.

In this talk we present results from the highest resolution global model ever run for real-time TC prediction (Δx=10 km) and a high-resolution global ensemble prediction system (Δx=30 km). The main finding is that while high resolution may be considered a necessary condition for a realistic simulation of the TC inner core, it is not sufficient for improved forecasting. Nonetheless, global model TC track predictions did benefit from Ensemble Kalman Filter (EnKF) data assimilation (cycling with the operational NCEP GFS model) compared to forecasts initialized with analyses from the NCEP Gridpoint Statistical Interpolation (GSI) used by the operation GFS. We also assimilated TC central surface pressure in the EnKF and although the initial TC intensity bias was much smaller, the low pressures in strong storms were not well maintained in the forecast, even for the 10 km global model run. However, there was a positive impact on track forecasts in the western North Pacific where the GSI analyses were clearly deficient.

The most impressive global model result came from the ensemble predictions. We made 21-member ensemble forecasts with the ESRL FIM global model (Δx=30 km) and the NCEP GFS model (at full deterministic resolution; T382, Δx~45km) using the same he same initial perturbations from the EnKF. The GFS/EnKF ensemble forecasts produced track errors comparable to those from the ECMWF model, and there was an overall consistency between ensemble-mean track error and the spread of track forecasts.

Both the GFS/EnKF and FIM/EnKF ensembles were more skillful than the operational track forecasts from NCEP, the Canadian Meteorological Centre, and the UK Met Office ensemble prediction systems.

Session 9
Other Research to Improve the Prediction of Tropical Cyclone Intensity and Structure, Track, Precipitation, Coastal, and Inland Inundation, Part 1

NASA-GRIP Field Experiment

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For more than a decade, the NASA Convection And Moisture EXperiment (CAMEX) series of field campaigns have provided a wealth of new research findings into the genesis, intensity change, and 3-D multiscale structure of tropical cyclones in the Atlantic, Gulf of Mexico and Eastern Pacific ocean basins. The CAMEX sequence (CAMEX-3, 1998; CAMEX-4, 2001; TCSP, 2005; NAMMA, 2006) has also consistently provided a test-bed for new remote sensing technologies for satellite and aircraft platforms, retrieval algorithms, and predictive model developments. The scientific focus on intensity change is particularly timely in light of the recent heightened era of Atlantic-basin storm activity and the continuing challenges of accurately forecasting tropical cyclone intensity. As part of ROSES 2008, NASA selected a team of investigators to use NASA satellite and field campaign data as part of a Hurricane Science Research Program, with the goal to conduct basic research on problems related to the formation and intensification of hurricanes. As part of the ROSES 2009 NASA announced a new opportunity. This opportunity related to the conduct of a new field experiment in 2010, the Genesis and Rapid Intensification Processes (GRIP) experiment, to better understand how tropical storms form and develop into major hurricanes. NASA plans to use the DC-8 airborne laboratory and the Global Hawk Unmanned Airborne System (UAS) to pursue the objectives of the GRIP experiment. This presentation will describe the GRIP experiment and how it relates to meeting operational needs through comprehensive tropical cyclone research.

IFEX 2010: NOAA's Plans for Hurricane Field Program Operations for the 2010 Season

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This talk will present NOAA's plans for the Hurricane Field Program this season. This year will see a continuation of the objectives of the NOAA Intensity Forecasting Experiment (IFEX). IFEX is a multi-year program designed to collect observations to address three core needs: 1) collect observations that span the tropical cyclone (TC) life cycle in a variety of environments; 2) develop and refine measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment; and 3) improve the understanding of physical processes important in intensity change for a TC at all stages of its life cycle. The primary foci for IFEX 2010 will be tropical cyclogenesis and rapid intensification, ocean response to TC passage over Gulf of Mexico Loop current, and TC wind field changes at landfall, as well as continuing to provide tail Doppler radar observations for data assimilation and model evaluation studies and tests and improvements of observing platforms such as the SFMR and Doppler Wind Lidar. For 2010 IFEX will partner with two other field campaigns, the NASA Genesis and Rapid Intensification Processes experiment (GRIP) and the NSF PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT).

Satellite and Model Database in Support of the NASA GRIP Field Campaign and for Improved Operational Hurricane Forecasting

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In preparation for the upcoming 2010 NASA GRIP (Genesis and Rapid Intensification) field campaign we have put together a database of satellite observations, derived products and model analysis. The objective is to provide a near-real time, Atlantic basin-scale view of the atmospheric and surface conditions, characterizing large-scale and storm scale processes, as depicted by satellites and models. The goal is two-fold: to use satellite data to help in the decision making and mission planning during the field campaign phase of the GRIP program; to provide time continuity and the large-scale environmental context for the post-field campaign analysis of the airborne and in-situ GRIP observations.

The goal of the NASA GRIP field campaign is to understand the individual roles of, and the interactions between the environmental, oceanic and convective processes during tropical cyclogenesis and rapid intensity changes. We have selected a set of satellite observations that best describe the important geophysical variables and processes. In addition, we compute a number of derived products that provide important information on the thermodynamic structure of the atmosphere and the ocean, and on the important meso- and convective scale precipitation structures and their evolution.

Furthermore, our database will contain analysis from a number of different models. Putting observations and models into a common framework will facilitate model improvement through validation and data assimilation.

This presentation will describe the components of the database and will illustrate the important features of our portal that allow for user-driven investigation of the observed structures, helping to unravel the interaction between different geophysical variables by allowing the creation of on-demand overlays and movies.

While the database is being developed specifically in support of the NASA GRIP field campaign, we envision that it will become a useful tool in operational forecasting as well. Even today, satellite observations and derived products are under-used in day-to-day operational forecasting. We believe our approach will help illustrate the usefulness of the satellite data and will lead to increase in their application for improved understanding of the physical processes and their representation in the numerical models that will lead to increased accuracy of the model forecasts.

Overview of Hurricane Impacts on the U.S. Gulf of Mexico Coast since 2000

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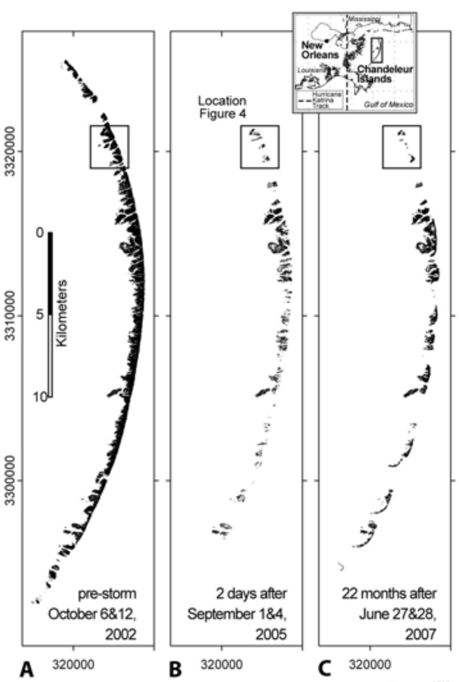
During the past decade, the U.S. Gulf of Mexico coast has been subjected to the landfalls of 14 hurricanes. Each of these storms forced changes to the coast, some recovering naturally within months, others persisting to the present. The magnitudes of change can be scaled in terms of storm wave-runup elevation, R, and still-water elevation, η (which includes storm surge, wave setup, and astronomical tide), relative to the peak elevation of the foredune, D_{high}. As R/D_{high} and η/D_{high} increase, thresholds will be crossed that define regimes of increasing impact magnitude, progressing from runup colliding against the dune and eroding it landward, to runup overwashing the dune ($R/D_{high} > 1$), to still water level completely submerging the beach system ($\eta/D_{high} > 1$). The greatest coastal changes have been observed during this latter inundation regime, which can occur locally on a barrier island and cut an inlet, as occurred during Hurricanes Charley (2004), Ivan (2004), and Katrina (2005), or can submerge tens of kilometers of coast, as occurred on the Bolivar Peninsula, TX during Ike (2008) and on the Chandeleur Islands, LA during Katrina (2005). Airborne lidar surveys showed the inundated Chandeleurs lost 82% of their surface area and their Gulf-front shores eroded landward ~250 m. These islands line the Mississippi Delta, which is subsiding. This induced a relative sea-level rise that conditioned the coast for extreme storm changes. Should global sea-level rise accelerate in the future as predicted, barrier islands worldwide may respond similarly when inundated during storms.



Maps of Chandeleur Islands before and after Hurricane Katrina derived from airborne lidar surveys. Elevations above mean high water are shaded black. A) Before-Katrina lidar survey using NASA ATM; B) EAARL survey several days after Katrina's landfall; C) EAARL survey twenty-two months after landfall.

NOAA's Storm Surge Roadmap: A Coordinated Approach for Transitioning Research to Operations

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NOAA has a storm surge mission that covers a large range of customer requirements, offices, and expertise. In order to leverage resources to best meet the needs of its customers, NOAA has developed a Storm Surge Roadmap that describes an agency-wide strategy for improving its storm surge enterprise. The vision, which reflects NOAA's many missions, is to clearly communicate the total water inundation risk above ground level for decision-making across multiple time scales such that the U.S. is optimally resistant and resilient to inundation impacts. The Roadmap provides a systematic approach to growth by coordinating and leveraging research, development, and operations across NOAA and its partners. The Roadmap enables NOAA to move beyond incremental improvements in capability toward a long term, multi-disciplinary strategy based on a customer-focused approach. Presently in Phase 1, the Roadmap is focused on maximizing the best of current techniques while promoting research into new tools and capabilities that will transition to operations down the road. Sample projects include the addition of tides to SLOSH, an ADCIRC-based extratropical surge+tide model for supporting wave forecasts, a NOAA-wide storm surge web presence, and social science assessments of current and proposed storm surge products. The presentation will describe the Roadmap, how it functions, outcomes, and what lies ahead.

The National Hurricane Center's Storm Surge Program: A Status Update

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Since its birth, the United States has lost over 25,000 people to tropical cyclones, most of which were attributable to storm surge. For example, Hurricane Katrina killed an estimated 1500 persons. Recent storms such as Ike and Gustav have also had a devastating impact on coastal communities. Compounding an already acute problem is the recent upward trend in coastal population density, sea-level rise, subsidence of coastal land, and the growing dependence of our Nation's economy on coastal infrastructure. The U.S. Global Climate Change Research Program, an element of the President's National Science and Technology Council, recently reported that sea-level rise and the associated increase in hurricane-related storm surges will result in coastal communities being inundated more frequently – some permanently – by the advancing sea. Yet, despite past loss of life and increasing vulnerability, the bulk of our population remains fixated on wind-related damage and recent social science studies suggest that the public does not understand surge threat, their vulnerability, or existing surge products and forecasts. This talk will focus on efforts and operational changes at the National Hurricane Center (NHC) and with the SLOSH model aimed at increasing public awareness and more clearly articulating storm surge threat. Additionally, this talk will highlight NHC's role and contributions to NOAA's storm surge Roadmap, a larger, more holistic, NOAA-wide effort to improve coastal inundation products and services.

Session 10
Other Research to Improve the Prediction of Tropical Cyclone Intensity and Structure, Track, Precipitation, and Inland Inundation,
Part 2

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Improved Short-Term Atlantic Hurricane Intensity Forecasts Using Reconnaissance-based Core Measurements

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While tropical cyclone (TC) track forecasting has improved noticeably over the last twenty years, intensity forecasting has remained somewhat of an enigma to forecasters. Despite increased computing capabilities and more sophisticated dynamical models, statistical models, such as the Statistical Hurricane Intensity Prediction Scheme (SHIPS), still often outperform their dynamical counterparts. There has been a great deal of research focused on improving intensity forecasts of TCs during the past two decades. However, the overwhelming majority of this statistical research has focused on the impacts of the storm environment rather than the effects of the TC structure itself or inner-core measurements. More focus has been placed recently on using some of these measurements from within the TC core, such as the structure of the storm and reconnaissance flight data. Still, much work remains to be done to fully utilize the available data from the inner core of TCs. To this end, flight data from Hurricane Hunter reconnaissance missions will be exploited to the fullest extent in this study.

This research seeks to develop a new statistical-climatological forecasting scheme to improve short-term intensity forecasts for well-developed TCs in the Atlantic basin. Well developed TCs are classified in this study as having a defined eye. Using Vortex Data Messages (VDMs) gathered from the aforementioned reconnaissance flights and stored in the National Hurricane Center's (NHC) Automated Tropical Cyclone Forecast (ATCF) archives, a VDM climatology from 1991-2008 is developed. These VDMs are collected from dropsondes and include various structural and thermodynamic parameters. This climatology includes stormscale thermodynamic parameters to aid in TC prediction. A new climatological forecast tool is produced which gives the expected rate of intensity change for 12-48 hour periods based on an initial eye diameter and wind speed. This climatological tool also provides insight into the dynamics involved in hurricane intensity change. Other implications based on the climatological forecast tool, such as the ability to produce probabilistic intensity range forecasts, are also discussed.

Finally, stepwise multiple linear regression is performed to create a SHIPS-style intensity forecast model (Atlantic-based Statistical Prediction of Hurricane Intensity using Recon, or ASPIRE). Examination of the regression equations and the change in predictors selected with varying intensity and forecast length offers additional insight into the science of TC intensity forecasting. Cross-validation results show that the ASPIRE technique outperforms SHIPS at nearly every forecast time and initial intensity, indicating that a new benchmark for TC intensity forecasting may have been attained. Two dependent case studies of Hurricane Ivan and Hurricane Katrina are presented for further analysis of the ASPIRE scheme. Further work involving the utilization of satellite data to create proxy VDMs may lead to an expanded climatological database of inner-core data for TCs in the Atlantic basin as well as the capability to create similar regression schemes in the East Pacific and West Pacific basins.

On the Role of the Saharan Air Layer in the Suppression of Development of a Prominent African Wave Disturbance.

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Considerable attention has been given to the potential negative impacts of the Saharan Air Layer (SAL) in recent years. Braun (2009) recently brought into question the negative impacts discussed by Dunion and Velden (2004) and other studies in terms of storms that reached at least tropical storm strength and suggested that the SAL was an intrinsic part of the tropical cyclone environment for both storms that weaken after formation and those that intensify. Braun (2009) also suggested that several assumptions underlie many of the studies on the negative impacts of the SAL including assumptions that most low-to-mid level dry tropical air is SAL air, that the SAL is dry throughout its depth, and that proximity of the SAL near storms struggling to intensify implies some role in that struggle. A recent paper by Reale et al. (2009) describes a tongue of warm, dry air that extended southward from at least 30°N and wrapped into a low pressure system during the period 26-29 August 2006, suppressing convection and possibly development of the African easterly wave associated with that low pressure system. They attributed the warm, dry tongue to the SAL, i.e., heating of the air mass during passage over the Sahara. Whether or not it was their intention, the implication was that this entire feature was due solely to the SAL and not other possible sources of dry air or warmth. In addition, they suggested that a cool tongue of air in the boundary layer located directly beneath the elevated warm, dry tongue (forming a thermal dipole) was possibly the result of reduced solar radiation caused by an overlying dust layer. They stated that “the cool anomaly in the lower levels does not have any plausible explanation relying only on transport.”

In this presentation, evidence from satellite and global meteorological analyses is presented that casts considerable doubt upon the purported negative role of the SAL in this case. We show that the major portion of the warm, dry air aloft was located in a nearly dust-free slot between two Saharan dust outbreaks, had a significant source from mid latitudes, and was likely driven by strong subsidence warming and drying. In addition, when wind fields are examined in a reference frame moving with the wave, the NCEP analyses suggest that the cool tongue in the boundary layer can be readily explained by transport of air from mid-latitudes. At the very least, if offers a plausible alternative explanation for the cool tongue that does not rely on radiative impacts of the dust.

Can Aerosols Explain Hurricane Prediction Errors?

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The hypothesis that aerosols weaken hurricanes by suppressing warm rain (Rosenfeld et al., 2007; Zhang et al., 2007) was tested positively when comparing the officially published GFDL 12-hour predictions with the actual hurricane intensities at that time under various aerosol conditions. Larger amounts of aerosols caused weaker peak winds in hurricanes compared to the predicted intensities, because the model predictions did not take into account the suppressive effects of the aerosols. The Sahara Desert and Sahel are the primary sources of aerosols that are transported across the tropical Atlantic, therefore, high amounts of dust are assumed to be accompanied by drier desert air. The amount of precipitable water was used in order to understand if aerosols are only marking dry air or independently affecting hurricane cloud microphysics.

The dataset includes Atlantic hurricanes between 2001 and 2007. The values for smoke (black and organic carbon), dust and sulfate aerosols were taken as Aerosol Optical Thickness (AOT) from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model. The precipitable water was obtained from the National Centers for Environment protection/National Center for Atmospheric Research (NCEP/NCAR) reanalysis.

Statistically significant weakening of the peak wind intensities compared to the predication (dVmax) was found independently for both desert dust and smoke (black and organic carbon) aerosols. The values of the dust AOT and precipitable water were found to be negatively correlated. In order to disentangle the effects of these two variables the data was divided into five pentads of similar precipitable water values. A similar effect of dust on the prediction error was found within all the five sub-groups. This means that the suppression occurs by the dust itself and not due to its association with dry air. Furthermore, the smoke aerosols were positively correlated with the precipitable water, so that they could not be a marker for the suppressive effect of dry air.

The greater indicated sensitivity to organic carbon aerosols with respect to desert dust is consistent with their greater effectiveness as small CCN for the same AOT. This provides additional support for the hypothesis that the aerosols suppress hurricanes by their CCN activity that nucleate larger number of smaller cloud drops. The delayed rainout enhances the vigor of the clouds at the periphery of the hurricane at the expense of the hurricane peak winds in the eyewall.

The major implication of this study is that aerosols put a natural brake on hurricane intensity and affect the accuracy of forecast model predictions of hurricane intensity. Aerosols should be considered in efforts to improve the prediction of hurricane intensities.

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The NHC Visiting Scientist Program

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During the 2009 hurricane season, NHC hosted twelve visiting scientists (researchers and outside forecasters) for up to a week's time each. The goals of the program are the following:

1. To facilitate better understanding by researchers/outside forecasters of the NHC hurricane forecasting process including the tools and techniques utilized by the Hurricane Specialists; and
2. To open additional dialog between NHC and the research/outside forecast community that could lead to improvements in our analysis and prediction methodologies. The presentation will discuss the format of the program, who participated, what was the feedback of both participants and hosts of the program, and how the project may evolve during the upcoming 2010 season.

Rapid Weakening of Non-Landfalling Atlantic Tropical Cyclones

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Tropical cyclone intensity forecasts have improved relatively slowly over the last decade. During this time, there has also been a concerted research effort placed on understanding the environmental conditions associated with rapidly intensifying tropical cyclones, which are not only a source for large intensity forecast errors, but also represent a significant risk to coastal inhabitants. That research effort has lead to the development of operational guidance methods that provide probabilistic forecasts of rapid intensification. However little effort has been placed on understanding the processes and environments associated with rapid weakening tropical cyclones prior to landfall. Improved understanding of tropical cyclone rapid weakening, while less important for the protection of life and property, are still a source of significant intensity forecasts errors and will be important in attaining future tropical cyclone intensity forecast improvement goals.

This presentation will describe the distribution of tropical cyclone intensity changes as a function of initial intensity and develop a strawman definition of rapid weakening. Using that definition the climatological and environmental conditions associated with rapid weakening tropical cyclones will be investigated. Since rapid weakening can also be associated with tropical cyclones transitioning to extra-tropical cyclones, the environmental factors associated with extratropical transition will also be investigated. This study will concentrate on the use of Statistical Hurricane Intensity Prediction Scheme (SHIPS) predictors and information contained in the archived GOES infrared imagery. Finally, strategies will be discussed as to how to best make use of this information to discriminate these events in the operational setting and ultimately improve tropical cyclone intensity forecasts.

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

Using Geospatial Analysis Techniques to Investigate the Spatial Properties of Tropical Cyclone Rain Fields

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Geographers specialize in spatial analysis techniques and can quantify spatial patterns through the use of a Geographic Information System (GIS). Utilizing such techniques can help to improve the ability to predict the spatial patterns of tropical cyclone (TC) rain fields. TC rain fields are generally comprised of convective rainfall regions near the circulation center and in the outer rainbands with stratiform rainfall occupying the areas in between. In this study, radar reflectivity returns are utilized to represent the spatial extent of TC rain fields. Base reflectivity data are analyzed for TCs making landfall within the U.S. during 1995-2008. Each storm is analyzed in six-hour increments beginning at the time of landfall. After mosaicking and converting the radar data into polygon shapes within a GIS, stratiform (convective) regions are identified that have reflectivity values from 20-35 (40+) dB*Z*. The areal coverage of these regions is calculated and the centroids of these regions are also identified so that their distance and bearing relative to the circulation center of the storm can be examined relative to the direction of storm motion and vertical wind shear. Results show that on average, 11% of a TC's rain field is comprised of convective precipitation at the time of landfall, and this percentage decreases to 8% at 24 hours post-landfall. These averages are the same regardless of whether or not a TC becomes extratropical. The total areal extent of the rain field increases through a 24-hour period following landfall in more than 40% of the cases, however, the extent of convective rainfall only increases in 25% of cases over this period. Generally, convective rainfall shifts in a counterclockwise direction towards the forward half of the storm as forward motion increases, and clockwise towards the downshear direction as vertical wind shear increases. These observations agree well with the results of modeling studies published by other researchers, suggesting that GIS-based spatial analyses could be implemented to compare the rain fields of model-generated TCs to actual observed TC rain fields.

Session 11
Joint Hurricane Testbed: Project Updates and Improved Products

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The Joint Hurricane Testbed (JHT): 2010 Update

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Joint Hurricane Testbed

New analysis and forecasting tools and techniques, developed by the research community, were tested and evaluated during 2009 at the National Hurricane Center (NHC), in real time for the ninth consecutive hurricane season, as facilitated by the Joint Hurricane Testbed (JHT). Nine fourth round (FY07-09) projects were tested and evaluated during the 2009 hurricane season, following any necessary technique modifications or other preparations. These projects came to a conclusion during this hurricane season and are being evaluated for possible operational implementation. Additionally, twelve new projects in the fifth round (FY09-11) were begun late in 2009. 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. Testing of these projects will continue during the 2010 hurricane season. An announcement of Federal Funding Opportunity for FY11 funding of the sixth round of JHT projects will be released this coming July.

Enhancements to the Operational SHIPS Rapid Intensification Index

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Predicting episodes of rapid intensification (RI) remains one of the most challenging tropical cyclone forecasting problems. In recent years, a statistically based rapid intensity index (RII) that employs large-scale predictors from the SHIPS model has been developed for operational use at the National Hurricane Center (NHC) for both the Atlantic and eastern North Pacific basins. Although the current operational RII uses only large-scale information, a validation of independent forecasts from the 2006-2007 Hurricane seasons showed that it was skillful when evaluated in terms of the probability of detection and false alarm rate for a lead-time of 24 h. However, the low to moderate probability of detection and relatively high false alarm rate of the RII and the other operational intensity guidance underscore the difficulty of predicting RI particularly in the Atlantic basin.

Although the large-scale conditions help to set the stage for RI, the actual intensification process itself is related to the storm's inner core. Thus, with financial support from the NOAA Joint Hurricane Testbed (JHT), research is currently being conducted to improve the operational RII by including predictors from three new sources of inner-core information. The first of these three sources is the time evolution of inner-core structure as deduced from GOES infra-red (IR) imagery. Although some basic parameters from GOES IR imagery (i.e., counts of cold cloud pixels) are already included in the RII, the time evolution of the inner-core structure is not. In a recently completed study, complex principal component analysis was applied to tropical cyclones and consistent IR cloud-top patterns related to RI were found. Complimentary results have since been found using standard principle component analysis. Information from principal component analysis of GOES IR data will therefore be tested in the RII. The second source is microwave-derived total precipitable water. Previous research utilizing the SHIPS model has shown that total precipitable water is statistically correlated with intensity change. Thus, this study will seek to employ total precipitable water to improve the RII. Finally, newly developed boundary-layer predictors derived using GFS model temperature and moisture data and sea-surface temperature estimates derived utilizing an inner-core sea-surface temperature cooling algorithm will be tested for their ability to improve the RII. In this paper, the results of the aforementioned efforts to improve the operational RII will be presented for the Atlantic basin.

Progress and Plans for the Development of a Unified Dropsonde Quality Assurance and Visualization Capability

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In 2009, the Joint Hurricane Testbed (JHT) funded a joint NOAA and NCAR project to develop a revised software package to perform real-time quality control (QC) of dropsonde observations from AFRC and NOAA aircraft. The primary goal of the project is to provide a more robust editing and visualization capability than is currently available to ensure that real-time observational and research data from dropsonde observations are of the highest quality and as error-free as possible. The software package will combine the graphics capability and ease of use of NCAR's current ASPEN software with the additional editing capabilities and refined QC algorithms contained in NOAA's Editsonde software. The new software is designed to be used on multiple computer platforms, will incorporate publicly available graphics frameworks, and be fully configurable to run in either a real-time mode or in an enhanced mode for post analyses of the data.

Substantial progress has been made in porting the ASPEN software to the new graphics package and a prototype has been completed that will run in either Windows or Linux computer operating systems. Additional components are being added with the expectation that a new prototype with enhanced visualization end editing capabilities will be available for testing and evaluation this summer. A demonstration of the capabilities and interface of the current prototype will be presented and the proposed additional capabilities will be discussed.

ATCF Requirements, Intensity Consensus and Sea Heights Consistent with NHC Forecasts

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The Automated Tropical Cyclone Forecasting System (ATCF) is one of the core forecast systems at U.S. tropical cyclone forecast centers and has now been in operations at the NHC for twenty years. Modifications to the ATCF are relatively inexpensive, making it a preferred target platform for many Joint Hurricane Testbed and Hurricane Forecast Improvement Project (HFIP) products and algorithms. This ATCF-focused JHT project has three tasks:

1) Address User Requirements for ATCF: The bulk of this effort has been in expanding forecast capability to six and seven days. Forecast dialogs and underlying code were modified to add the extra forecast days for both track and intensity. The interpolator was modified so that six and seven day forecasts are adjusted to the current time for track, intensity and wind radii. The consensus code was also modified to produce six and seven day forecasts of track and intensity. Finally, the homogeneous statistics and triangle table modules were modified to produce statistical output for the new forecast times.

2) Evaluate/Upgrade Intensity Consensus: The intensity consensus aids(ICON and IVCN) implemented for the 2008 and 2009 seasons were evaluated along with their members. ICON is an average of four intensity aid forecasts (DSHP, LGEM, GHMI and HWFI) in which all need to be present for the aid to be generated. IVCN is a set of five intensity aid forecasts (DSHP, LGEM, GHMI, HWFI and GFNI) where only two of the five need be available to generate a forecast. Both aids generally outperform their members. ICON performs best in the Atlantic while IVCN performs well in the eastern North Pacific. Various other consensus combinations were tested on the 2008 and 2009 seasons and results indicate that ICON was the best choice of equally-weighted members for the Atlantic. IVCN was among the top performers in the eastern Pacific, and a consensus of DSHP, LGEM, GHMI and GFNI slightly outperformed IVCN (though results are not significant).

3) Produce Sea Heights Consistent with NHC Forecasts: This is an algorithm that inserts surface winds generated from the official forecast for each tropical cyclone in a GFS background, then runs WAVEWATCH III on the modified fields. Presentation of results from this task will be deferred until next year.

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

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Secondary eyewall formation in hurricanes is often associated with rapid and dramatic changes in wind structure and intensity. While the consequences of rapid intensity changes are of obvious importance, the structure changes associated with secondary eyewall formation and the broadening of the overall wind field also has particularly dangerous consequences in terms of increased storm surge and wind damage extent during landfall events. Despite the significance of these events, there is presently little objective guidance available to forecasters to help diagnose or predict them. In response to this, a probabilistic model was constructed, and has been in real-time α-testing at CIMSS during the 2008 and 2009 Atlantic and Eastern Pacific hurricane seasons.

The goal of this JHT project is twofold: 1) transition the new model to operations, which will provide forecasters with probabilistic forecasts of secondary eyewall formation, and 2) utilize low-level aircraft reconnaissance data to construct a climatology of intensity and structure changes that can be used to quantify the changes associated with secondary eyewall formation.

The progress of this JHT project, which began in August 2009, will be presented.

Advanced Applications of Monte Carlo Wind Probability Model: A Year 1 Joint Hurricane Testbed Project Update

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Under previous JHT support a program for estimating the probability of occurrence of 34, 50, and 64 kt winds was developed by NESDIS and CIRA. A Monte Carlo (MC) method was utilized to combine the uncertainty in the tropical cyclone track, intensity and wind structure forecasts. The MC probability program has been run in NHC operations since 2006.

In the current project, four new applications of the MC model were proposed. These include (1) Landfall timing and intensity distributions; (2) Methods for using the MC model to enhance WFO local products; (3) Probabilities integrated over coastal segments; (4) Automated guidance for issuing coastal watches and warnings. A prototype graphical user interface has been developed for items (1), (3), and (4) above, and preliminary results will be presented. A validation of the MC model for a large sample of cases for coastal and inland points was completed to help define probability thresholds needed for the WFO local application per item (2). Results from that study, and an overview of the WFO application, will also be presented.

The current project also includes four refinements to the MC model code. These include (1) A procedure to adjust the model time step for fast moving and small storms; (2) Modification of the azimuthal interpolation routine that occasionally leads to inconsistent probability values for 34, 50 and 64 kt winds; (3) Evaluation of the spatial interpolation method that sometimes results in inconsistencies between the gridded and text probabilities; (4) Evaluation of the underlying wind radii model utilized by the MC model. The code has been modified to allow for a specified time step and examples of the resulting impact will be presented. Plans for completing the code refinements (2)-(4) will also be summarized.

The NESDIS Tropical Cyclone Formation Probability Product: An Overview of Past Performance and Future Plans

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The NESDIS Tropical Cyclone Formation Probability (TCFP) product was developed in response to the need for objective, real-time guidance to aid in the prediction of tropical cyclone (TC) formation. The TCFP product uses values from the GFS analysis fields, such as the vertical shear of the wind and vertical instability, in combination with geostationary satellite water vapor brightness temperatures and climatology to determine the probability that a tropical cyclone will form within the next 24 hours. The TCFP product has been operational for the N. Atlantic and N.E. Pacific TC basins since 2005. In 2008, the product was updated by extending the domain to include the Central Pacific and N.W. Pacific basins, using a longer developmental dataset, and making minor improvements to the product algorithm. Brier skill scores and relative operating characteristic (ROC) skill scores suggest that the forecast skill of the TCFP exceeds that of climatology.

In response to the need for objective TC guidance in the Indian Ocean and Southern Hemisphere, a global version (45° S to 45° N) of the TCFP product has been developed and has been running experimentally at CIRA since fall 2009. The parameters found to contribute most strongly to the probability of TC formation in the Indian Ocean and Southern Hemisphere are low level circulation, climatological TC formation probability, and cold cloud top coverage. These results are similar to those previous found for the Atlantic, N.E. and N.W. Pacific basins. However, the magnitude of estimated TC formation probabilities are substantially larger for the N. Indian Ocean than for other basins. The details of this global TC formation probability algorithm as well as the experimental TCFP product will be presented.

The current TCFP product provides 24-hr probabilities of TC formation. However, the National Hurricane Center Tropical Weather Outlook discusses the potential for TC development within the next 48 hrs. In order to provide timely objective guidance to forecasters, plans are being developed to extend the TCFP product to longer time scales. It is believed that through the use of GFS forecasts and larger-scale water vapor brightness temperature parameters that the TCFP product can be extended to 48 hrs and beyond. Details of this proposed plan for improving the TCFP product will be also be presented.