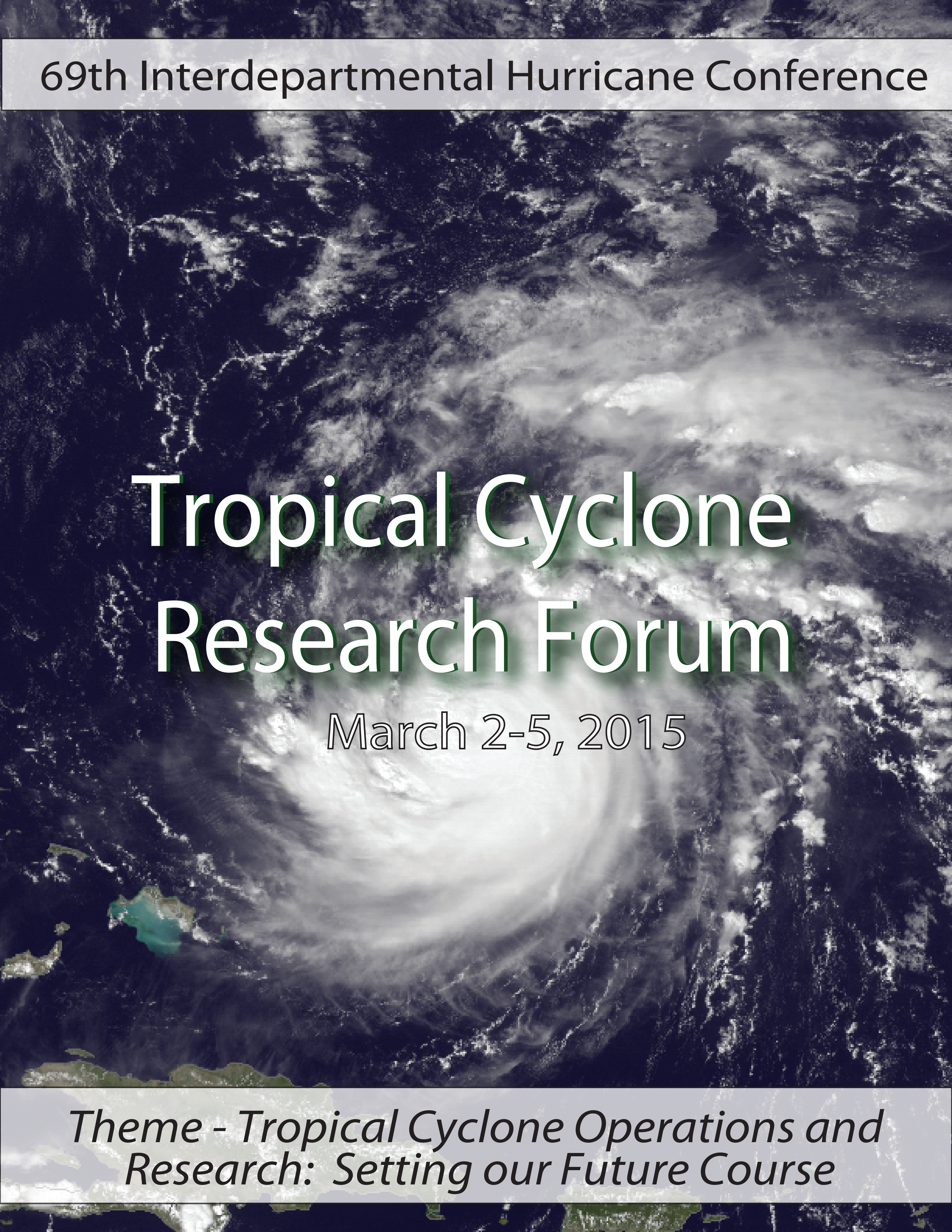

69th Interdepartmental Hurricane Conference

Tropical Cyclone Research Forum

March 2-5, 2015

Theme - Tropical Cyclone Operations and Research: Setting our Future Course

Cover Image
NOAA GOES-13, 15 October 2014; Hurricane Gonzalo; Credit: NOAA Environmental Visualization Laboratory

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

1325 EAST WEST HIGHWAY, SSMC2, SUITE 7130
SILVER SPRING, MARYLAND 20910

March 2, 2015

Dear Colleagues,

Welcome to the 2015 Tropical Cyclone Research Forum/69th Interdepartmental Hurricane Conference! We are looking forward to a very productive and informative four days.

After two years of conducting largely virtual forums, it's great to bring many of us together face-to-face. We are excited to be in Jacksonville, and we welcome our Federal partners and our colleagues from the academic and emergency management communities as we address a wide range of topics of critical importance to our Nation's tropical cyclone forecast and warning program. The theme of this year's forum is: *Tropical Cyclone Operations and Research: Setting our Future Course*. The agenda is jam-packed and includes ground-breaking work from virtually every discipline within our tropical cyclone operations and research community. The opening session on Tuesday morning will feature two guest speakers from the state of Florida, to provide their insights from an emergency management perspective on the importance of the Federal tropical cyclone forecast and warning program.

Other topics on the forum agenda include:

- The meeting of the Working Group for Hurricane and Winter Storm Operations and Research
- A Review of the 2014 Tropical Cyclone Season
- Observations and Observing Strategies
- Advances in Tropical Cyclone Model Development and Evaluation
- Research Priorities of the Operational Centers
- Transitioning Research to Operations

Thank you for joining us as we seek to improve our observing, forecasting, and warning system in preparation for the upcoming tropical cyclone season and beyond. Your participation and continued support are extremely important to the success of this event and to our ability to keep our tropical cyclone forecast and warning program moving forward and responsive to the needs of our great Nation!

Sincerely,

David McCarren
Federal Coordinator for Meteorological Services and Supporting Research (Acting)

Session 1
The 2014 Tropical Cyclone Season in Review

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Review of the 2014 Central Pacific Tropical Cyclone Season and Preliminary Verification

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NOAA's National Weather Service
Central Pacific Hurricane Center

The North Central Pacific experienced a near normal number of tropical cyclones during the 2014 Hurricane Season, with a distribution of four hurricanes and one tropical storm. The second tropical cyclone crossing into the Central North Pacific, Hurricane Iselle, was the first tropical cyclone since 1992 to make landfall. The remaining four tropical cyclones entering or developing in the North Central Pacific remained over the open ocean. This talk will provide a review of the hurricane season and associated verification, mainly focused on Hurricane Iselle.

A Review of the 2014 Joint Typhoon Warning Center
Tropical Cyclone Season

Mr. Robert J. Falvey
(robert.falvey@navy.mil)

Joint Typhoon Warning Center

In 2014, there were 23 tropical cyclones in the western North Pacific, 24 tropical cyclones in the southern hemisphere and 5 tropical cyclones in the northern Indian Ocean. JTWC will present a summary of the 2014 activity across these areas, including preliminary forecast verification.

NOAA Aircraft Operations Center (AOC)
2014 Seasonal Summary and Future Plans

Jim McFadden, Devin R. Brakobb, Timothy Gallagher
(timothy.gallagher@noaa.gov)

NOAA Aircraft Operations Center

After a number years of declining the seasonal flight activity, 2014 saw a sharp rise in tropical cyclone flight hours of the three NOAA aircraft that perform these missions. This was in large part due to increased research activity with our OAR partners, a change in the "rules of engagement" for hurricane surveillance by the NOAA G-IV, increased use for operations of the P-3s, multiple calls for G-IV surveillance in the central Pacific and the establishment of an agreement with the Mexican government for the P-3s to fly operational missions into eastern Pacific storms out of selected Mexican airfields. The jump in hours was from 204 in 2013 to 460 in 2014. In all, the three aircraft flew missions into five named storms in the Atlantic, three in the eastern Pacific, and one in the central Pacific.

There were significant accomplishments in the research area as the G-IV and both P-3s participated in several HRD experiments during the season, notably the Model Evaluation Experiment – a multi-aircraft experiment with both atmospheric and ocean components to it. This season also marked the first successful launch from a P-3 of a small, unmanned aircraft, the Coyote, into a hurricane.

Commencing in March 2015, NOAA will begin its Service Life Extension upgrades to both of the P-3s utilizing funds from a Sandy supplemental. Included will be the re-winging of the aircraft along with the upgrade of the P-3 engines to Series 3.5. The latter will result in increased efficiency and fuel savings while allowing for an increase in endurance to approximately 12 hours.

Coincidental to the re-winging and engine improvements will be a $9+M upgrade to the aircraft avionics and instrumentation. Some of the upgrades included in this major effort are as follows:

- Modernization of the P-3 TDR, to include solid-state xmtr/rcvr, RVP-9000 processor, dual flat-plate antenna and an increase in antenna rotation speed from 10 to 24 RPM for improved Doppler resolution
- Auto-pilot replacement, multi-functional cockpit displays, digital engine instruments
- Nose radar replacements, cloud physics pylons, and new instrument racks
- Communication systems upgrades

53d Weather Reconnaissance Squadron/AFRC 2014 Hurricane Season Summary

Lt Col Jonathan Talbot
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53d Weather Reconnaissance Squadron

The 53d WRS completed 64 Atlantic and 33 Eastern/Central Pacific NHC fix requirements along with 14 other requirements (Invest, Surveillance, Bouy) during the 2014 hurricane season. A total of 74 missions and 915.4 hrs were flown in support of NHC. The 2014 hurricane season marked the first season since the mid 1990's that the unit deployed significant resources to the Central Pacific region due to two hurricane threats. It was also the first season where the unit deployed ocean instruments ahead of a hurricane in the Central Pacific.

2014 AXBT Demonstration Project: Operations Summary and Research Update

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The fourth year of the hurricane AXBT demonstration project mandated at the 65th Interdepartmental Hurricane Conference Working Group for Hurricanes and Winter Storms has been completed. The project goal is to increase hurricane forecast accuracy by assimilating ocean observations from beneath tropical cyclones into coupled numerical models in near-real time. Through great support from the USAF 53rd Weather Reconnaissance Squadron, the 2014 season was the most active for the project to date. More than 250 AXBTs were deployed during 34 WC-130J flights over the Atlantic and Pacific Oceans, including 28 missions into 4 named storms over a 6-week period. In addition, Air-Launched Autonomous Micro Observer (ALAMO) profiling floats were deployed during tasked reconnaissance missions for the first time. A summary of the objectives, achievements, and challenges of the season will be discussed, along with a summary of current research and progress toward tropical cyclone forecast improvement.

Session 2
Research Priorities of the Operational Centers

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Objective, Automatic Tracking of Pre-Genesis Tropical Disturbances within the Deviation Angle Variance Method for Genesis Prediction

Elizabeth A. Ritchie, Oscar G. Rodríguez-Herrera, Kimberly M. Wood, and J. Scott Tyo
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University of Arizona

The deviation angle variance (DAV) method is an objective tool for estimating the intensity of tropical cyclones (TCs) using geostationary infrared (IR) brightness temperature data. At early stages in TC development, the DAV signal can also be a robust predictor of tropical cyclogenesis. However, one of the problems with using the DAV method at these early stages is that the operator has to subjectively track potentially developing cloud systems, sometimes before they are clearly identifiable. Here we present a method that automatically tracks cloud clusters using only the raw IR imagery and the resulting DAV maps. The method uses the DAV map and IR satellite image to identify potentially developing cloud clusters. Low DAV values are associated with highly symmetric IR regions where a disturbance might be forming. These regions are identified by the method and then checked for cloud presence in the IR image. Regions with DAV values below a pre-determined threshold (from our previous DAV-based work on cyclogenesis) and cloud presence are included in a table of detects, which is used to keep track of the identified disturbances in subsequent satellite images. The method includes measures to keep track of disturbances that vary considerably during their evolution. Furthermore, a number of thresholds (chosen from typical parameters of TCs) are used to distinguish between developing disturbances and cloud clusters that might be identified by the tracking system as potentially developing cloud clusters but later dissipate without becoming TCs.

In this work, we will show results of the performance of our objective method compared with the JTWC best-track and invest databases from 2009-2012. Strategies currently being implemented to reduce the number of false positives and improve the overall performance of the method will be discussed. Finally, genesis results for multiple years in both the eastern and western North Pacific using the automated tracking system will be presented and a new strategy for providing probabilistic genesis forecasts based on the DAV that is in current development will be discussed.

Deterministic Tropical Cyclone Genesis in Operational Global Numerical Weather Prediction Models as a Model Assessment Tool

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NOAA Earth System Research Lab

NWP forecasts of tropical cyclones (TCs) depend on nearly all aspects of the model meteorology from the large and slow tropical general circulation to small-scale details of the boundary layer and convection. Verification of all aspects of TC forecasts, therefore, should be part of any comprehensive global model assessment.

The scheme I developed in 2010 for verification of deterministic global model TC genesis forecast (yes/no) has since been expanded to diagnose the other side of genesis – false alarms or what we call 'spuricanes' (spurious hurricanes). Heuristically, excessive formation is related to the intensity and nature of over-ocean precipitation and in our spuricane analysis we not only count the number and strength of these false storms but also calculate basin-wide total and convective precipitation rates.

A suite of six operational global numerical weather prediction (NWP) is evaluated for the northern Hemisphere TC season during the years 2009-2014: 1) NCEP Global Forecast System (GFS); 2) ECMWF HiRESolution (HRES); 3) CMC Global Deterministic Prediction System; 4) FNMOC NAVal Global Environmental Model (NAVGEM); 5) UKMO Unified Model; and 6) ESRL Finite-volume, flow-following, Icosahedral Model (FIM). The GFDL TC genesis tracker is run to output TC tracks from TCs in the initial conditions and TC system that form during the integration.

Generally we find the models in the later part of the 2009-2014 period the models do forecast genesis well, particularly for day+2, but have differing amounts and distribution of spuricanes depending on basin. However, the false alarm rate is positively correlated to the total basin-wide precipitation and negatively correlated to the ratio of convective to total precipitation (more resolved rain, more spuricanes).

The improvement in TC genesis skill over the last 6 years is undoubtedly attributable to the general advancements in NWP model resolution and physics. Future improvement in TC genesis forecasting will come from a deeper diagnosis of the model TC formation process that helps identify deficiencies in the key physical process – tropical rainfall.

Towards Developing a Guidance Product for Tropical Cyclogenesis Probabilities Using a Comprehensive Historical Dataset of Precipitation and Environmental Properties

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[1]Florida International University; [2]Rosenstiel School of Marine and Atmospheric Science, University of Miami

This study contributes to the observational dataset of tropical cyclogenesis events by providing a comprehensive collection of satellite observations from multiple passive microwave platforms for 10 years (2003–2012) of developing and nondeveloping "invest" tracks in the Atlantic and East Pacific basins. This dataset (Tropical Cyclone-Passive Microwave [TC-PMW]) is synthesized with environmental properties from the NCEP FNL model analysis, and is used to identify the most important precipitation and environmental predictors of tropical cyclogenesis. In addition, a subset of pregenesis and nondeveloping cases in the western North Pacific are binned by their accumulated time history of cloud cluster longevity (in IR) as a function of how long the "invest" has been tracked. One critical application of these datasets directly addresses NHC and JTWC priorities for more detailed guidance on the probability of tropical cyclogenesis at both the short- (0–48 hours) and medium- (48–120 hours) ranges. Genesis probabilities are determined by whether a genesis threshold value is exceeded; the thresholds are defined as the mean value of the predictor 12 hours before and after genesis (first TD classification). The precipitation properties that offer the most predictive value, in the context of the historical dataset, include the cloud cluster longevity, as well as the fractional areal coverage of 85–91-GHz polarization corrected temperatures (PCT) ≤ 250 K and 210 K, and 37-GHz PCT ≤ 270 K — the last three are all proxies for raining area. The least important precipitation predictors are those that serve as proxies for "intense" convection. The most important environmental predictors include the midlevel relative humidity, 850–200 hPa deep-layer vertical wind shear, 850-hPa relative vorticity, daily genesis potential (difference between the 925- and 200-hPa relative vorticity) and sea surface temperature.

In the future, these results will form the basis of a real-time tropical cyclogenesis satellite guidance product (TCGSatP), which will provide quantitative and categorized (e.g., low-medium-high similar to the Tropical Weather Outlook [TWO] genesis categories) genesis probabilities for "invest" disturbances in the Atlantic and East Pacific basins. The TCGSatP, which is the subject of a recent proposal to the JHT for FY15, can be an additional statistical tool for forecasters to consider when preparing the TWO. While the environment will be considered to screen out systems in harsh environments, which are not likely to develop regardless of how favorable the convection is, the unique aspect of the TCGSatP is the emphasis on passive microwave satellite overpasses to assess the convective and rainfall characteristics, and infrared cloud cluster tracking to quantify the longevity of organized deep convection.

Measuring Gaps in Tropical Cyclone Rainbands Using Level II Radar Reflectivity Data

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The spatial geometries of tropical cyclone (TC) rainbands evolve rapidly as they approach landfall and move inland. High rain rates completely encircle the eye of a well-formed TC, while rainbands spiral outward from the core. During landfall, storm structure is altered by factors such as ingestion of dry continental air and moving over complex terrain. If the TC is transitioning into an extratropical cyclone, vertical wind shear increases. These conditions lead to asymmetries in TC structure that begin in the outer regions and eventually expose the core. Knowledge of how quickly the outer rainbands become disorganized and center becomes exposed can help improve the spatial accuracy of rainfall forecasts. This research measures the size and location of gaps in the lighter and heavier rain rates that encircle a well-formed hurricane during and after landfall. Level II radar reflectivity data are utilized to detect the rainband structures. Data from adjacent radars are merged and interpolated to a 3D Cartesian grid, with the 3.5 km slice being utilized in this study. Contours are created that represent 20 and 32 dBZ reflectivity values. After these polygons are generalized, a plan sweep algorithm is performed to determine the position of all nodes relative to the storm center. A TC with a closed ring of precipitation surrounding its center has no edges in tangential space. If an edge is detected, the angle between two lines extending from the TC center intersecting the edge of each side is calculated to provide a measure of closure. Calculations of gap areas are performed for inner, middle, and outer regions of the storm as defined by attributes of storm size including radius of the eyewall and radius of the outermost closed isobar. This process is repeated over time to enable the rate of exposure, or decreasing closure, to be calculated. Hurricane Jeanne (2004) is presented as a case study, and gaps in reflectivity correspond to vectors of storm motion and vertical wind shear as Jeanne became extratropical. The middle region of the storm was closed at landfall, but became exposed about one day post-landfall. Future research will experiment with temporal smoothing, examine the vertical alignment of convective cells, and utilize this method to assess the accuracy of TC rain fields in the Weather Research and Forecasting model.

Evolution of the USGS Storm Tide Network

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Hurricane-induced storm tides have historically been documented through analysis of structural or vegetative damage and high-water marks. However, these sources rarely provided quantitative information about the timing of the flooding, the sequencing of multiple paths by which the storm-surge waters arrived, or the magnitude of waves and wave run-up. Nor could 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) developed a mobile storm-tide network to provide detailed time-series data for selected hurricane landfalls. As part of this program, water-level and barometric-pressure monitors were deployed to areas of forecasted hurricane landfall resulting in a concentrated network of temporary tide sensors placed along water channels and nearby overland features such as beaches, wetlands, and constructed environments. To date, USGS storm-tide networks have been successfully deployed for 9 tropical events: Hurricanes Rita (2005, 32 water-level monitoring sites), Wilma (2005, 30), Gustav (2008, 80), Ike (2008, 65), Tropical Storm Ernesto (2006, 40), Hurricanes Earl (2010, 45), Irene (2011, 260), Isaac (2012, 127) and Sandy (2012, 224). Data were typically collected at opportunistic locations as frequently as every 2 seconds for 1-2 days prior to landfall and for as much as 2 weeks afterwards. Following retrieval and processing, the data were subsequently provided via a web-based map interface.

In the wake of Hurricane Sandy, the USGS has developed a science plan for support of restoration and recovery that includes the evolution of the mobile storm-tide network and the development of a Storm, Wave, and Tide Hydrodynamic (SWaTH) Network. The USGS SWaTH Network will include the development of pre-established fixed-place deployable sensor locations (including elevations surveyed to a datum). It will also fill in gaps within storm-tide networks along the United States Atlantic Coast, identified by stakeholders such as NOAA’s National Ocean Service, the U.S. Army Corps of Engineers, and other Federal, State, and local agencies to meet local response data needs and to systematically reduce storm-surge forecast model uncertainty. Pre-establishment of fixed-place deployment locations will increase the efficiency of storm-tide sensor deployment and recovery at selected sites in advance of land-falling hurricanes and other coastal storms, such as nor’easters. More importantly, it also improves the timeliness of data analysis and delivery because such information is often needed as quickly as possible after these events. The SWaTH Network configuration also includes established and surveyed transects that cross selected barrier islands, wetlands, and urban areas that will be instrumented with wave sensors that will enable scientists to better measure the effect of topography, vegetation, and structures on wave height and frequency. The SWaTH Network will be an essential part of the response network needed to collect wind and water data envisioned by the OFCM in the National Plan (URL: http://www.ofcm.gov/p33-npdia/2010/00-NPDIA-front-matter.pdf).

Session 3a
Transitioning Research to Operations (JHT and DTC), Part 1

SESSION 3a

The Joint Hurricane Testbed (JHT): A 2015 Update

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Forecasting tools, techniques and model advances, developed by the research community were tested and evaluated at the National Hurricane Center (NHC) and the Environmental Modeling Center (EMC) facilitated by the Joint Hurricane Testbed (JHT). Seven 7th round projects (FY13-15) were tested and evaluated during the 2014 hurricane season, following any necessary technique modifications or other enhancements. 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 2015 hurricane season. Decisions on the 6th round projects will be also presented.

Guidance on Intensity Guidance

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Original statistical methods are proposed to innovatively solve the problem of improving tropical cyclone (TC) intensity forecasts. Although the skill of TC track forecasts have increased considerably over the last twenty years in the Eastern Pacific and Atlantic basins, intensity forecasts have only shown mild improvement in the eastern Pacific Basin and, depending on the forecast time, little improvement to worsening in the Atlantic basin (Cangialosi and Franklin 2013). Additionally, the lack of agreement between current operational TC intensity forecast models and large fluctuations in model performance decreases the value of these forecasts. One approach to creating more reliable TC intensity forecasts with the resources currently available is to create real-time skill predictions that help forecasters and end users know when a particular model forecast will be more or less skillful than average. This a priori expectation of forecast performance combats the adverse effects of the substantial day-to-day, model-to-model, and storm-to-storm fluctuations in forecast quality.

Using the results from Bhatia and Nolan (2013, hereafter BN2013) as a foundation, storm-specific characteristics as well as parameters representing initial condition error and the stability of the atmospheric flow are used as predictors for multiple linear regression algorithms that predict forecast error for each model. Forecasts of mean absolute error and bias are produced for 12-120 hour intensity forecasts (12-hour increments) for the four operational intensity models: LGEM, DSHP, HWFI, and GHMI. These forecasts are evaluated for the 2007-2013 Atlantic Basin hurricane seasons using a cross-validation technique (each season is tested as independent verification while the other seasons serve as the training dataset). The results for the 2014 season will be discussed in detail to demonstrate how this forecasting tool can be used in real time. These forecasts of forecast error have shown improvement upon predictions solely based on climatology.

Finally, preliminary results will be shown on a multimodel ensemble that is weighted according to the error predictions. Currently, equally-weighted ensembles produce the best-performing TC intensity forecasts. However, BN2013 suggest that there are situations where certain models consistently excel and others perform poorly. As a result, it is hypothesized that an ensemble that weights models depending on the situation would achieve more skillful forecasts than the commonly used equal weights technique.

Upgrades to the Operational Monte Carlo Wind Speed Probability Program: Joint Hurricane Testbed Year 2 Project Update

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Under previous JHT support, the Monte Carlo wind speed probability model (hereafter MC model) was developed to estimate the probability that any given location will experience 34, 50, or 64 kt winds over a given forecast period. The MC model has been run in NHC operations since 2006. Subsequent JHT support has led to several improvements of the MC model, including the development of a verification program, the addition of forecast-specific track uncertainty through the inclusion of the Goerss Predicted Consensus Error (GPCE) parameter, and the development of the stand-alone Hurricane Landfall Probability Application (HuLPA). As the developers and primary users continue to gain experience with the MC model new opportunities to improve the model have been identified. This proposal seeks to complete a number of upgrades to the current MC model, many of which are based on NHC feedback over the past few hurricane seasons.

In the current project, three improvements to the MC model were proposed. These include (1) replacing the linear forecast interpolation scheme with a more precise spline fit scheme, (2) applying a bias correction to the model track error statistics to provide consistency between NHC's uncertainty products, and (3) applying a bias correction to the radii-CLIPER used by the MC model to improve the accuracy of the wind speed probabilities for exceptionally small or large (e.g. 2012's Hurricane Sandy) tropical cyclones. Additionally, three enhancements to the MC model were also proposed. These include (4) estimates of the arrival and departure 34, 50, and 64-kt winds, (5) development of integrated GPCE guidance, and (6) extending the MC model to 7 days. Significant progress has been made on each of these tasks. This progress, along with examples demonstrating the benefit of each addition/enhancement, will be presented.

Disclaimer:
The views, opinions, and findings contained in this article are those of the authors and should not be construed as an official National Oceanic and Atmospheric Administration (NOAA) or U.S. Government position, policy, or decision.

Developing a Tropical Cyclone Genesis Forecast Tool: Preliminary Results from 2014 Quasi-Operational Testing

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[1]Florida State University; [2]Naval Research Laboratory

The authors have developed a real-time statistical guidance product that identifies tropical cyclones (TCs) in the model forecast fields and provides 2 and 5 day genesis probabilities. These probabilities are calculated from multiple logistic regression equations that were developed from a decade-long archive of output from the CMC, GFS, and UKMET global models. Because of differences among the models and between the basins, separate regression equations were developed for each model and basin. Additionally, a consensus-based regression equation was developed for each basin.

While the predictors used in each regression equation vary considerably, one common aspect is that the forecast hour (lead-time) is the most significant predictor in all equations. This functionality implies that despite considerable model improvements over the past decade, there remains a significant bias in NWP TC forecasting that varies with forecast hour. Further, this bias is more important for quantifying TC genesis potential in NWP than the quality of the environment in which the storm is forming. In general, the equations for the 2 day probabilities contain fewer predictors and are more dependent on genesis location compared to the equations for the 5 day probabilities. The consensus regression equation is derived from the three single-model forecast probabilities.

The guidance product ran quasi-operationally during 2014. A sample of each type of output product (graphical, text, etc.) will be presented. Preliminary results are mixed, with the regression equations various degrees of skill. The authors will address what may have caused the varied performance and discuss how some regression equations will be modified for the 2015 hurricane season. Finally, the authors will show that some of the regression equations have reliability and Brier scores that are comparable to the NHC's official Tropical Weather Outlook probabilities, and thus can provide useful objective guidance to the Hurricane Specialists Unit.

The ARCHER Automated TC Center-Fixing Algorithm: Updates on Real-Time Operations, Accuracy, and Capabilities

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The Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm is used in research applications for TC center-fixing and the retrieval of eye statistics, and is also used experimentally in real-time. It is currently supported by the National Hurricane Center Joint Hurricane Testbed for further validation and development. The current version of this algorithm combines information from geostationary (infrared, visible) and polar-orbiting (passive microwave, scatterometer) satellites into a single optimized track. It has been running in real time at CIMSS for the JHT testbed since July 2014. We will also share the latest results of the algorithm validation against best-track and SAB/TAFB positions, and discuss the meaning of these results for forecasting applications.

StormSurgeViz: A Visualization and Analysis Application for Coastal Storm Surge, Inundation, and Wave Modeling

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Real-time simulations for storm surge, tides, and wind waves are carried out at many research sites through the nation, using several different numerical models. The models (e.g., ADCIRC, SLOSH, FVCOM) use either a finite difference or finite element/volume approach to develop discrete algebraic equations from the continuous partial differential equations. Finite difference approaches result in rectangular or structured grids wherein variables are described with two-dimensional matrices. Node connectivity is implicitly defined by adjacent “i-j” indices. Finite element or finite volume methods result in non-rectangular or unstructured grids that require indexing into two one-dimensional coordinate arrays. Node connections must be prescribed by a node connectivity array that explicitly defines the elements or volumes in the grid. To allow end-users such as the NHC to access and visualize both types of model results, applications are needed that are aware of these differences and present a unified view of the data.
Data servers and metadata standards are essential for making this possible in a standardized, uniform, and extensible way.

Fortunately, community conventions and data servers have emerged that make description of these grids relatively straightforward. The Climate and Forecast (CF) netCDF metadata conventions can be applied to gridded storm surge models, and the UGRID extension to CF

allows several non-rectangular models to be similarly described. THREDDS servers provide transparent and consistent access to metadata and model results via the OPeNDAP data transport service. Client-side toolboxes have emerged that use the above technologies to allow end-user applications to access, visualize, and analyze these model results, such as NCTOOLBOX, a MATLAB toolbox that accesses datasets using NetCDF-Java as the data access layer and nascent Python packages and libraries.

In the first year of this NOAA Joint Hurricane Testbed 2013 JHT project, we developed and distributed AdcircViz, a MATLAB-based application for visualization and analysis of the collection of ADCIRC forecast system outputs. AdcircViz accesses a catalog of all available ADCIRC forecast output and presents the catalog to the user through a searchable interface. The cataloging and data access components use THREDDS, OPeNDAP, CF-UGRID, and NCTOOLBOX. In this second project year, we are extending the application to incorporate other models that adhere to file and metadata standards and publish model results to a THREDDS server. Documentation for the community "on-boarding" process has been drafted, and the application (renamed StormSurgeViz) is being extended to handle model results on structured/rectangular grids.

In this presentation, we will describe the data grid concept, community outreach activities and the on-boarding process, and demonstrate the use of StormSurgeViz on recent tropical cyclone events, and the project development roadmap. While our project focus is generally on ADCIRC-based results, the data grid and StormSurgeViz application can be applied to any model whose output files are CF/UGRID compliant and posted on a THREDDS data server.

Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index: A Year-2 Update

Haiyan Jiang, Yongxian Pei, Margie Kieper, and Joseph Zagrodnik
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Department of Earth & Environment, Florida International University

To provide guidance for tropical cyclone (TC) rapid intensification (RI) forecasts, an automatic 37 GHz ring RI index has been developed and tested under the PI's FY-11 and FY-13 JHT projects. This satellite-based RI index mainly addresses the internal effect by precipitation and convection in the inner core region and is implemented on top of the environmental based Statistical Hurricane Prediction Scheme RI Index (SHIPS RII). The major product of our FY-11 JHT project was a "yes" and "no" type of RI forecast only for 30 kt/24 hr intensity increase. During the past FY-13 funding year, the product was upgraded to a probability-based RI index by adding three 85 GHz predictors. The real-time CIMSS ARCHER center fix product was incorporated into the ring detection algorithm for a better center fixing. Post-season evaluations will be presented in the first part of this talk to assess the performance of our real-time product for the 2014 hurricane season.

The second part of this talk will introduce a further improvement of the current algorithm based on the results of Jiang et al. who demonstrated a more in-depth quantification of different colors (green/cyan/pink) on the Navy Research Lab (NRL) 37 GHz color images. This new enhancement will improve the ring detection algorithm. Based on Jiang et al.'s results, two additional 37 GHz predictors will also be added to the probability-based RI Index. The final product is called the **probability-based microwave ring RI index (hereafter PMWRing RII).** The PMWRing RII is planned to be implemented not only in the Atlantic (ATL) and Eastern & Central North Pacific (EPA) basins, but also the Joint Typhoon Warning Center (JTWC) forecast basins including the North Western Pacific (NWP), North Indian Ocean (NIO), and Southern Hemisphere (SH).

Session 3b
Transitioning Research to Operations (JHT and DTC), Part 2

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Upgrades to the GFDL/GFDN Operational Hurricane Models Planned for 2015 (A JHT-Funded Project)

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Upgrades to the GFDL and GFDN operational hurricane models are planned for 2015, made possible through JHT (Joint Hurricane Testbed) funding.

A summary of the upgrades planned will be shown. These upgrades include an increase in the number of vertical levels from 42 to 60, minor modifications to the physics to account for the resolution change, improvements in the moisture initialization, a new specification of the storm size (rb), and fixing of two bugs in the hurricane model that were found over the past year. Extensive testing of the impact of these bugs suggests that one of them may have had a significant negative impact on the model performance in 2014. Finally, tests are being conducted to evaluate the impact of NCODA data on the GFDL and HWRF ocean initialization, if availability of this product is possible within the operational constraints at NCEP.

Extensive evaluation of these changes is currently being made on forecasts of selected storms from the 2010, 2011 and 2012 Atlantic hurricane seasons, and the entire 2013 and 2014 Atlantic and East Pacific seasons. Tests have been conducted using the old GFS (T574) to determine the sensitivity of the model changes compared to the current operational model performance. Preliminary tests indicated about 5-8-% improved track and intensity performance and significant reduction of the negative intensity bias in the previous version of the GFDL hurricane model. In addition, evaluation is also being made of the impact of these upgrades on forecasts using the new GFS (T1534) model made operational January 14, 2015.

Results from both sets of forecasts will be shown in this presentation, for storms in the Atlantic, East Pacific, and select storms in Western Pacific. These results include a summary of the average statistics as well as the impact on individual storms. Comparisons will also be shown between the upgraded GFDL and HWRF models.

Improving the Ocean Component of the Operational HWRF and GFDN/GFDN Hurricane Models

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This presentation focuses on improving the ocean component of the HWRF and GFDL/GFDN coupled systems and air-sea interface physics. URI's version of the Princeton Ocean Model (POM-TC) has been the ocean component of the operational GFDL coupled model since 2001 and the operational HWRF since 2007. Under JHT and HFIP funding URI has developed and transitioned to operations a new version of POM-TC, which is known as MPIPOM-TC. In addition to parallelization capabilities we are in the process of developing important new elements of the MPIPOM-TC architecture that allows for more rapid improvements and transition of research to operations (R2O) in the future. These include alternative initialization modules; physics improvements; three-way coupling between MPIPOM-TC, the hurricane model, and a wave model; and high-resolution nesting, especially at the coastline in order to forecast storm surge.

An innovative aspect of MPIPOM-TC is a flexible, plug-and-play initial condition module. To simulate tropical cyclones worldwide, this module is relocatable to all ocean basins around the world. Currently, these regions include the Atlantic, East Pacific, West Pacific, North Indian, South Indian, Southwest Pacific, Southeast Pacific, and South Atlantic domains. We will discuss and show the impact of the initial conditions that are based on the Navy Ocean Data Assimilation (NCODA) and HYbrid Coordinate Ocean Model (HYCOM) real-time ocean products on the performance of the HWRF and GFDL hurricane models. In addition, we will discuss progress in the implementation of explicit wave coupling in the HWRF and GFDL systems, and the near-real time testing planned for 2015.

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

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The Tropical Cyclone Modeling Team (TCMT) in NCAR's Joint Numerical Testbed (JNT) Program focuses on the verification of experimental forecasts of tropical cyclones (TCs) with the goal of transitioning new research developments to operations. Activities of the team include the development of new verification methods and tools for TC forecasts and the design and implementation of diagnostic verification experiments to evaluate the performance of tropical cyclone forecast models. For the NOAA Hurricane Forecast Improvement Project (HFIP), the

TCMT has designed and conducted verification studies involving various deterministic, ensemble, and statistical regional and global forecast models that participate in the annual HFIP real-time forecast Demonstration experiment. The HFIP Demonstration experiment is conducted during the months of August through October each year. The TCMT has applied new and established statistical approaches to provide statistically meaningful diagnostic evaluations of TC forecasts for storms observed during the Demonstration period. For this study, the TCMT has conducted evaluation of operational and experimental forecast performance for the 2014 hurricane season in the North Atlantic and Eastern Pacific Oceans. This presentation will provide an overview of the 2014 Demonstration experiment along with a summary of results from the experimental model forecasts for the Atlantic and Eastern Pacific Ocean basins with the goal of supporting the transition of new research development to future operational hurricane forecast systems.

Testing Hurricane WRF with Alternate Radiation and Partial Cloudiness Schemes

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Testing conducted by both the NOAA Environmental Modeling Center (EMC) Hurricane team, and the Developmental Testbed Center (DTC), has shown that the radiation parameterization used in the operational configuration of the Hurricane WRF (HWRF), the Geophysical Fluid Dynamics Laboratory (GFDL) radiation scheme, has its shortcomings for hurricane applications.

In 2013, the EMC Hurricane team tested the Rapid Radiation Transfer Model for Global Circulation Models (RRTMG) as an alternate, more sophisticated radiation parameterization for HWRF. Ultimately, RRTMG was not adopted at EMC for operations because it degraded intensity and track forecasts when combined with several other physics-related upgrades. During the same time period, DTC tested HWRF with an alternate physics suite containing the Thompson microphysics and a version of the RRTMG scheme that had been coupled with the Thompson microphysics, ensuring consistency of hydrometeor parameters between the packages. Although case studies indicated hurricane track and intensity forecast improvement when using the Thompson/RRTMG package, larger tests at the DTC mostly revealed statistically neutral-to-negative impacts on track and intensity forecasts especially in the northern Eastern Pacific basin.

Further analysis of the DTC large-scale test resulted in two notable findings. First, through funding from both the NOAA Hurricane Forecast Improvement Project (HFIP) and the DTC Visitor Program, Dr. Robert Fovell and his graduate student, Peggy Bu, showed that the RRTMG radiation scheme represented cloud radiative forcing more realistically than its GFDL counterpart. This GFDL deficiency was especially apparent for long wave tendencies at cloud top, and had a large impact on storm structure, intensity, and motion. Second, there was an overabundance of shortwave radiation reaching the ground for the Thompson/RRTMG experiment. DTC discovered that this was due to two reasons: a) only explicit clouds from the microphysics parameterization interact with the radiation scheme while the sub-grid scale clouds produced by the Simplified Arakawa Schubert (SAS) deep- and shallow-convection parameterization used in HWRF are transparent to the RRTMG scheme; and b) the coarse horizontal and vertical grid spacing in the HWRF parent domain, (much like other models) does not produce as many stratus clouds as observed.

The radiation imbalance finding led Greg Thompson of DTC to implement a scale-aware partial cloudiness scheme for RRTMG, which acts to simulate liquid- and ice-water content based on humidity and temperature thresholds to represent a “cloud” with radiative properties. The DTC performed a multi-storm HWRF test in which the RRTMG with partial cloudiness scheme replaced the operational GFDL radiation, but the operational Ferrier microphysics scheme was left unchanged. The results of the test show more realistic cloud and radiation distribution, as well as a neutral-to-positive impact in both the Atlantic and East Pacific basins for track and intensity when RRTMG with partial cloudiness is used. These results, along with synoptic- and storm-scale analyses and their interactions for a few cases will be discussed further.

Session 4a
Observations and Observing Strategies, Part 1

SESSION 4a

NOAA's Intensity Forecast Experiment (IFEX): Progress and Plans for 2015

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This year marks the 10-year anniversary of the NOAA IFEX field campaign. The goals of IFEX are to collect observations at all stages of the tropical cyclone (TC) lifecycle to improve the initialization and evaluation of numerical models; develop and refine measurement strategies and technologies to provide improved real-time monitoring of TC intensity, structure, and environment; and improve the understanding of physical processes important in TC intensity change. The past ten years have seen significant advancements on all three goals, and intensity forecast guidance has shown marked improvement. This talk will provide a brief overview of the achievements of IFEX, and it will present plans for the upcoming 2015 hurricane season. This year will see the inclusion of a Doppler Wind Lidar as well as coordination with unmanned aerial systems, i.e., the low-altitude Coyote system and the high-altitude Global Hawk as a part of the NOAA Sending Hazards with Operational Unmanned Technology (SHOUT) program.

Hurricane and Severe Storm Sentinel (HS3): Results from the 2014 Deployment

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The NASA Earth Venture (EV-1) Hurricane and Severe Storm Sentinel (HS3) mission conducted its final campaign (of three) in 2014. HS3 used one of NASA's unmanned Global Hawk (GH) aircraft to study Atlantic hurricanes during the deployment at the Wallops Flight Facility in Virginia from Aug. 26-Sept. 30. Due to electrical issues with the second planned GH, HS3 moved two instruments to a WB-57 aircraft already conducting an experiment for the Office of Naval Research. That effort took place in October 2014. The goal of the mission was to improve understanding of the processes that control hurricane formation and intensity change and to determine better the relative roles of the large-scale environment and smaller-scale processes in the inner-core region of storms (i.e., the eyewall and rainbands). The GH (Air Vehicle 6, designated the environmental GH) was designed to sample temperature, humidity, winds, and Saharan dust in the storm environment while the WB-57 (replacing the over-storm GH) focused on measuring winds and precipitation within the storm.

During the 2014 deployment, HS3 conducted ten flights of the environmental GH and three of the WB-57. The first two flights (Aug. 26-27, 28-29) were over Hurricane Cristobal, including the extratropical transition phase in the second flight. On Sept. 2-3, AV-6 obtained detailed measurements of Tropical Storm Dolly in the Gulf of Mexico prior to its landfall. On Sept. 5-6, AV-6 flew to just west of the Cape Verde Islands to explore the interaction of a tropical wave (with a forecasted 20% probability of formation) with the Saharan Air Layer. No additional flights were done in this system as it failed to develop. The next four flights (Sept. 11-12, 14-15, 16-17, 18-19) sampled Hurricane Edouard over much of its life cycle, including its early stage as a tropical storm, a period of rapid intensification, its mature stage, and its dissipation stage. The final two flights of the GH were broad surveys of the Atlantic Main Development Region, with flights extending just east (Sept. 22-23) and just west (Sept. 28-29) of the Cape Verde Islands.

The WB-57 and its instruments (the HIWRAP Doppler radar, the HIRAD imaging radiometer, and a new ONR-funded high-density dropsonde system) were ready for flight by early October. During the period Oct. 15-17, Hurricane Gonzalo came just within range of the WB-57 and flights on three successive days were conducted as Gonzalo reach maximum intensity as a Category 4 storm and underwent eyewall replacement cycles.

This talk will focus on the Edouard and Gonzalo flights.

Improved SFMR Surface Winds and Rain Rates

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The stepped-frequency microwave radiometer (SFMR) is used to measure surface wind speeds in tropical cyclones. SFMRs are now installed and operated on all NOAA WP-3D and Air Force Reserve WC-130J tropical cyclone penetrating aircraft. The SFMR has greatly improved wind-field observation in storms, including the maximum wind, from reconnaissance aircraft. Surface winds retrieved from SFMR brightness temperature measurements have been demonstrated to be highly reliable at hurricane-force speeds (>64 kts), but accuracy has been shown to be degraded at weaker wind speeds, particularly in heavy precipitation, generally manifested as a high bias. A recent Joint Hurricane Testbed project was funded to study this issue, and recommend retrieval algorithm modifications which provide improved surface wind observations in real time (transmitted in the HDOBs high-density observations product)

In the interim, a provisional bias correction model was used by NHC forecasters to adjust the HDOB winds for the 2012 through 2014 hurricane seasons. Under recommendation from the NHC, algorithm corrections are expected to be implemented on board each of the instruments for the upcoming 2015 season. Therefore, the real-time winds transmitted in the HDOBs should be significantly improved over previous seasons. In general, winds will be somewhat lower in weak to moderate wind speeds within heavy precipitation, and largely unaltered at hurricane wind speeds. Also, maximum rain-rate values (a bi-product of surface wind retrieval) will be greater than before, more consistent with the highest observed radar reflectivity values. In this presentation, we will summarize the results of the study, recommended modifications, and practical interpretation of the results of the changes.

HIWRAP Global Hawk Status and Future Plans

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The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is a dual-frequency (Ka- and Ku-band), dual-beam (30^0 and 40^0 incidence angle), conical scan, solid-state transmitter-based system, that flies on the high-altitude (20 km) Global Hawk UAV. HIWRAP images the winds through volume backscattering from clouds and precipitation, enabling it to measure the tropospheric winds above heavy rain at high levels. It measures ocean surface backscatter from which ocean surface winds can be derived through scatterometry techniques similar to QuikScat. These measurements from higher altitudes above storms provide higher spatial and temporal resolution than obtained by current satellites and lower-altitude instrumented aircraft. HIWRAP flew its first science flights on the Global Hawk AV-6 during the Genesis and Rapid Intensification Processes (GRIP) campaign conducted during the 2010 hurricane season, and then during Hurricane Severe Storm Sentinel (HS3) program based at NASA Wallops Flight Facility during the 2013. During the 2014 HS3 program, HIWRAP was moved to the NASA WB-57 high-altitude aircraft that made passes over Hurricane Gonzalo. Plans are in the works to fly HIWRAP on AV-6 during the 2015 hurricane season in the NOAA SHOUT program. In this presentation, we will report on highlights of the 2014 HS3 flights, status of wind retrieval algorithms, current and future instrument upgrades, real-time capability, and overall performance of the system. We will present preliminary data from the 3 Gonzalo flights during the 2014 season.

Hurricane Imaging Radiometer (HIRAD)

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The Hurricane Imaging Radiometer (HIRAD) made observations of Hurricane Gonzalo during three flights of a NASA WB-57 high-altitude aircraft during 15-17 October 2014 (Figure 1). The wide-swath imagery from HIRAD clearly revealed a concentric eyewall structure before the hurricane hit Bermuda. HIRAD had previously been installed on the NASA Global Hawk AV-1 unmanned aircraft for the Hurricane and Severe Storms Sentinel (HS3) project, but aircraft problems prevented AV-1 from flying last year in HS3. HIRAD and another instrument (High-altitude Imaging Wind and Rain Airborne Profiler, HIWRAP) were quickly transferred from AV-1 to the WB-57. The WB-57 was already planned for flights in the Office of Naval Research (ONR) Tropical Cyclone Intensity (TCI) project, and had payload space available. De-integration from AV-1, shipping the instruments, integration on the WB-57, and an initial test flight were all accomplished within two weeks of the decision to switch aircraft.

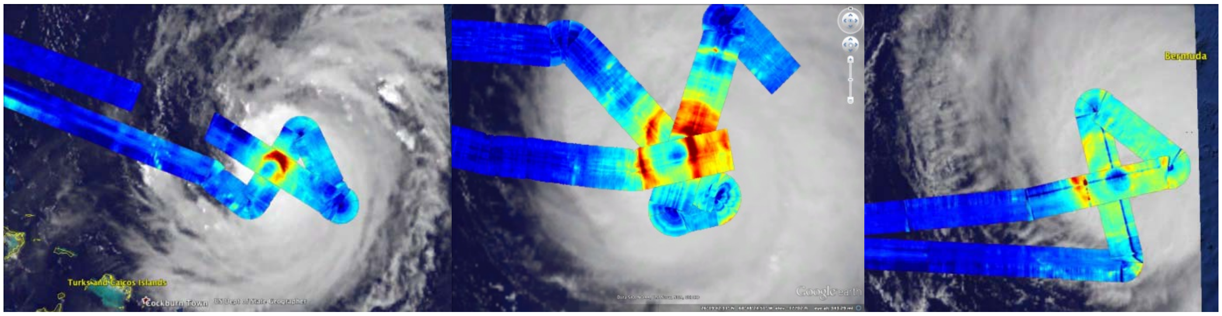

Figure 1. HIRAD 5-GHz excess brightness temperatures from Hurricane Gonzalo (a) near 21 UTC 15 October 2014, (b) near 17 UTC 16 October 2014, and (c) near 15 UTC 17 October 2014. Note that map dimensions vary from one image to another, and storm motion during each flight is not accounted for here.

HIRAD had previously flown on a NASA WB-57 in 2010 (Hurricanes Earl and Karl, in the Genesis and Rapid Intensification Program – GRIP) and on the Global Hawk AV-1 in 2012 and 2013 for HS3. Recent analyses have improved the HIRAD wind speed retrievals for Hurricane Karl. The retrievals have also been tested in a data assimilation system, improving the characterization of the horizontal structure of the wind field.

The Unique Capability of the Scatterometer in Measuring Stress in Tropical Cyclones

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Wind is air in motion and stress is the turbulent transport of momentum between the ocean and the atmosphere. There was no large-scale measurement of stress before the scatterometer and the stress we used was almost entirely derived from wind. While the strong wind of a tropical cyclone (TC) causes destruction at landfall, it is the surface stress that drags down the TC. The relations that were established to retrieve moderate wind speeds from the normalized radar cross-section, or backscatter power, measured by Ku-band and C-band scatterometers do not apply well to TC-scale winds. The rate of increase of backscatter with increasing wind changes under TC. It has been difficult to establish new relations at strong winds because credible strong winds coincident with scatterometer measurements are not sufficient. We will give credence to our hypothesis that there is no distinct physics of radar backscatter from ocean surface for weather phenomenon like the TC. The relation between backscatter and surface roughness or stress does not change under TC, and the same retrieval algorithm can be extended to the TC. The need for changes in wind retrieval algorithm is explained through the change of the drag coefficient that relates wind to stress in TC. We aspire to separate the sensor parameters that affect backscatter, such as, incident angle, azimuth angle, polarization and backscatter frequencies, from the secondary factors related to the physics of the air-sea interface and turbulent transport, such as air stability (shear and buoyance), air density, sea states, and sea sprays, so that we can establish a simple approximation of surface stress from the backscatter averaged over the relevant spatial and temporal scales. We established a relation between backscatter and surface stress over a moderate range of wind speed, where wind measurements coincident with satellite observations are abundant, and the drag coefficient is well established to convert wind measurements to stress. This relation is applied to retrieve stress from the scatterometer measurement in the high wind range of TC. The drag coefficient for TC are characterized and the variation of stress in TC will be used to understand the intensification of TC with respect to feedback by the ocean.

Session 4b
Observations and Observing Strategies, Part 2

Proof of Concept for Atmospheric Profiling with the High Definition Sounding System (HDSS)

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The High-Definition Sounding System (HDSS) is an automated system deploying the eXpendable Digital Dropsonde (XDD) designed to measure wind and Pressure-Temperature-Humidity (PTH) profiles plus Sea Surface Temperature (SST) within and around Tropical Cyclones (TCs) and other high-impact weather events needing high sampling density. The HDSS can launch sondes faster than once every 5 seconds, and telemeter as many as 80 in the air simultaneously.

During 2014, a test flight flown off the Texas Coast demonstrated excellent capability to obtain complete soundings from 19 km to the surface plus SST. A demonstration of 13 sondes transmitting simultaneously was achieved. Excellent agreement was found between PTH and wind profiles measured by XDDs deployed from a NASA WB-57 at 19 km altitude offshore from the Texas coast and NWS radiosonde profiles from Brownsville and Corpus Christi.

Over 100 XDDs were deployed into Hurricane Gonzalo on three days with partial success. Internal receiver and aircraft wiring problems prevented complete profiles from being achieved. However, a significant number of sondes transmitted to the 6 km level allowing outflow jet and tropopause features to be resolved as a function of azimuth around the storm center and across the western outflow jet boundary. Comparisons were made with outflow jet structures obtained from Global Hawk dropsonde deployments in four storms during the Hurricane and Severe Storms Sentinel (HS3). Observed Gonzalo outflow jet features were found to be considerably lower than those in the HS3 storms, but exhibited similar jet wind profiles with multiple constant wind layers suggesting mixing events imbedded within the outflow jet just below the maximum.

Airborne Phased Array Radar (APAR): The Next Generation of Airborne Polarimetric Doppler Weather Radar

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This paper presents a possible configuration of a novel, airborne phased array radar motivated by major advances in cellular technology, component miniaturization, and radar antenna simulation software. This has paved the way for a next-generation radar being designed by NCAR/EOL to be installed on the NSF/NCAR C-130 aircraft. The APAR system will consist of four removable C-band active electronically scanned arrays (AESA) strategically placed on the fuselage of the aircraft. Each AESA measures approximately 1.5 x 1.9 m and is composed of 3584 active radiating elements arranged in a rectangular array of 7 x 8 line replaceable units (LRU). Each LRU is composed of 64 radiating elements that are the building block of the APAR system.

APAR, at C-band, allows the measurement of 3-D kinematics of the inner core and rainband structures with less attenuation compared with current airborne Doppler radar systems. The unique combination of APAR capabilities as well as water vapor measurements using dropsonde and in situ measurements, and other remote sensing instruments such as cloud radar and wind lidar from a single airborne platform, will help scientists to examine the role of the hurricane eye with regard to intensity changes. The combination of measurements from dropsondes, in situ probes and Doppler radar will allow unprecedented investigations into the optimization of observing strategies and data assimilation research for improving the predictions of the track, intensity and structure of tropical and extra tropical cyclones.

Polarimetric measurements are not available from current airborne tail Doppler radars. However, APAR, with dual-Doppler and dual polarization diversity at a lesser attenuating C-band wavelength, will further advance the understanding of the microphysical processes within a variety of precipitation systems. Such unprecedented observations, in conjunction with the advanced radar data assimilation schema, will be able to address the key science questions to improve understanding and predictability of significant weather.

The estimated total budget to complete this ambitious project is ~$30M. The development now underway is expected to take ~7 more years. It adopts a phased approach as an active risk assessment and mitigation strategy. An APAR science and engineering advisory panel has been organized. The authors will review the overall design and current progress of APAR and outline ambitious future development work needed to bring this exceptional tool into full operation.

Near-Real Time Ocean Surface Vector Winds from RapidScat

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NASA launched RapidScat to the International Space Station (ISS) on September 21, 2014 on a two-year mission to support global monitoring of ocean winds for improved weather forecasting and climate studies. The JPL-developed space-based scatterometer is conically scanning and operates at ku-band (13.4 GHz) similar to QuikSCAT. The ISS-RapidScat’s measurement swath is approximately 900 kilometers and covers the majority of the ocean between 51.6 degrees north and south latitude (approximately from north of Vancouver, Canada, to the southern tip of Patagonia) in 48 hours. RapidScat data are currently being posted at a spacing of 25 kilometers, and 12.5 kilometers. RapidScat ocean surface wind vector data are being provided in near real-time by Jet Propulsion Laboratory (JPL) to NOAA, and other operational users such as the U.S. Navy, the European Organisation for the Exploitation of Meteorological Satellites

(EUMETSAT), the Indian Space Research Organisation (ISRO) and the Royal Netherlands Meteorological Institute (KNMI). Near-real time RapidScat data is available via web: http://manati.star.nesdis.noaa.gov/datasets/RSCATData.php

The quality of the RapidScat OSVW data are assessed by collocating the data in space and time with "truth" data. Typically "truth" data will include, but are not limited to, the NWS global forecast model analysis (GDAS) fields, buoys, ASCAT, WindSat, AMSR-2, and aircraft measurements during hurricane and winter storm experiment flights. The standard statistical analysis used for satellite microwave wind sensors will be utilized to characterize the RapidScat wind vector retrievals. The global numerical weather prediction (NWP) models are a convenient source of "truth" data because they are available 4 times/day globally which results in the accumulation of a large number of collocations over a relatively short amount of time. The NWP model fields are not "truth" in the same way an actual observation would be, however, as long as there are no systematic errors in the NWP model output the collocations will converge in the mean for winds between approximately 3-20 m/s. The NWP models typically do not properly resolve the very low and high wind speeds in part due to limitations of the spatial scales they can account for. Buoy measurements, aircraft-based measurements and other satellite retrievals can be more directly compared on a point-by-point basis. The RapidScat OSVW validation results will be presented and discussed. Utilization examples of these data in support of NOAA's marine weather forecasting and warning mission will also be presented and discussed.

Coastal Ocean Current and Wave Response to Hurricane Jeanne Using High Frequency Radar Measurements: Implications for Surge Modeling

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As part of the Southeastern Coastal Ocean Observing Regional Association (sponsored by the NOAA *Integrated Ocean Observing System Program*), high frequency radars are operated in the southeast from Florida to North Carolina. These HF radars map surface processes such as surface currents, winds and waves in near real time. During the passage of hurricane Jeanne (2004), the coastal current and wave response was observed by a pair of high frequency radars (known as Wellen Radar-WERA) between Miami and North Key Largo, Florida. These real-time measurements, acquired every 15 minutes, revealed a fairly complex coastal ocean current response. Since the measurements were acquired on the "clean" side of Jeanne, an eastward current response of 1 m s^{-1} emanated from the Biscayne Bay (depths < 20 m) where offshore surface winds approached 22 m s^{-1} with gusts up to 25 m s^{-1} measured at Fowey Rocks CMAN Station. This current response forced an eastward bulge of ≈ 100 km^2 resulting in an apparent offshore Florida Current meander. The Florida Current velocities decreased in response to the hurricane since the winds were generally orthogonal to the current. As Jeanne moved inland, the cyclonic rotating winds were in phase with the Florida Current resulting in a stronger coastal surface flow to the north of more than 2 m s^{-1}.

Comparison of the remotely sensed data to the 10-m winds observed at Fowey Rocks suggests that during the period of strong forcing, the radar inferred wind direction follows that measured at the CMAN station (slope of ~1 and a bias between -5 to -10^{o}). Inferred surface winds, derived from the 2nd order returns in the Doppler spectra, indicate a bias of 2 m s^{-1} and a slope of ~0.8 between the observed and remotely sensed wind speeds. The correlation coefficient exceeds 0.7 over this domain where the WERA inferred winds are reasonable. Directional wave spectra from the measurements indicates wind seas responding to the strong wind stress containing most of the wind-driven energy with little indication of a low-frequency wave (swell) component moving with the storm since the Bahama islands presumably filtered out this faster moving wave component. Using the forced surface currents and winds, the surface drag coefficient is inferred from the forced shallow water equations with constant bottom topography. *Given that high frequency radars are being operated nationally by the NOAA IOOS program, the approach of using these real-time measurements has promise to improve surge models if radar sites can be hardened to withstand hurricane force winds for landfalling storms.*

Air-Deployable Profiling Floats

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The development of a new small profiling float that can be launched from Hurricane Hunter aircraft offers the opportunity to monitor the upper-ocean thermal structure over a time span of many months. These Argo-type profiling floats can be deployed in advance of, or during, a tropical cyclone from any aircraft equipped with an A-sized (AXBT) launch tube, or from the stern ramp of a C-130. The floats have same dimensions as an AXBT and weigh approximately 10 kg. Upon deployment, the floats release their parachute and automatically begin their programmed mission. The recorded temperature data is subsampled to 1-meter bins that are reported back via the Iridium satellite phone network, which is then automatically processed and posted to the GTS. The floats are also reprogrammable via the 2-way communication afforded by Iridium.

We report on the initial test deployments during the 2014 hurricane season. Further plans for continued development of floats including enhanced mission capability as well as observations of the surface wave field (measured by an onboard accelerometer) will also be described.

A Review of the 2014 Gulf of Mexico Wave Glider® Field Program

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Sustained observations of oceanographic and atmospheric boundary layer conditions are imperative for the investigation of tropical cyclone genesis, numerical model input to predict track and intensity, and in general for many environmental monitoring needs. Unmanned Surface Vehicles (USV) technology developments over the last few years have shown potential for filling these data voids. One such USV is a Wave Glider.

Wave Gliders® (WGs) use wave energy for propulsion through the synergistic alternating thrust of wave action on the floating vehicle and mechanical wings 6 m below the vehicle (Fig. 1). They provide dynamic environmental monitoring in the maritime environment with long-duration deployments of continuous real-time meteorological and oceanographic data collection, using solar panels to power sensors and satellite and cell communication channels for data delivery. The WGs have also demonstrated robustness in harsh maritime conditions and a monitoring capability for data-void regions.

We present results of a Fall 2014 100-day deployment of WG platforms in the eastern Gulf of Mexico designed to dynamically collect surface weather, water temperature, wave, and ocean current profile data within tropical cyclones. Data were collected and retransmitted real-time through a Liquid Robotics interface to regional and national data portals such as the National Data Buoy Center, and secondarily also used by the private sector. Accomplishments include buoy loitering for validation exercises, data gap filling, platform re-deployments, and an interception of the fringes of Tropical Storm Hanna. Preliminary buoy loitering assessments using bias and absolute error metrics showed reasonable agreement with buoys for atmospheric pressure, wave, and height-adjusted winds data, but that the temperature hardware requires an improved sensor. A full assessment of the potential for the sustained collection and real-time dissemination of environmental data for WG platforms is presented including lessons learned.

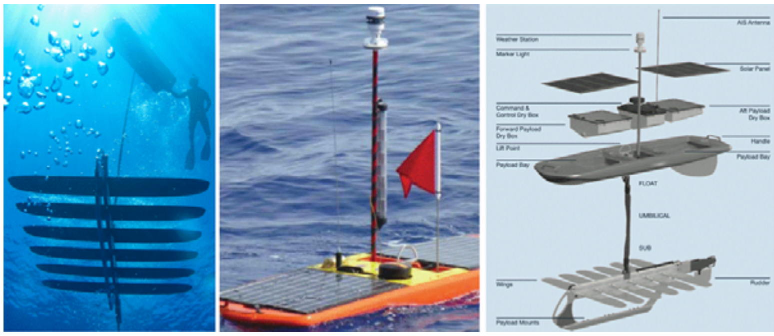

Figure 1. (Left) An underwater view of the Wave Glider subunit wings which also holds some of the oceanic payload. (Middle) View of float with atmospheric instruments. (Right) A listing of all the parts.

The NASA CYGNSS Satellite Constellation: Probing the Inner Core of Hurricanes

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The NASA Cyclone Global Navigation Satellite System (CYGNSS) is a confirmed spaceborne mission scheduled for launch in October 2016 that is specifically designed to study the surface wind structure in and near the inner core of tropical cyclones (TC). CYGNSS consists of a constellation of eight small observatories carried into orbit on a single launch vehicle. Each observatory carries a 4-channel bistatic radar receiver tuned to receive GPS navigation signals scattered from the ocean surface. The distortion to those signals caused by ocean surface roughness is detected and used to estimate the wind speed at the surface. Performance is unaffected by the presence of precipitation, even at levels found in the eyewall and inner core rain bands of a hurricane. The eight satellites are spaced approximately twelve minutes apart in the same orbit plane in order to provide frequent temporal sampling. CYGNSS is expected to provide unprecedented temporal resolution and spatial coverage, under all precipitating conditions, and over the full dynamic range of wind speeds experienced in a TC. Mission simulations predict a median (mean)
revisit time of 3(6) hours at all locations between 38^{o} N and 38^{o} S latitude.

An update on the current status of the mission will be presented at IHC 2015, with emphasis given to the expected spatial and temporal sampling properties of the retrieved winds, to the retrieval algorithms used to determine the surface10 meter referenced wind speed from the radar backscatter measurements, to the calibration and validation activities that are planned after launch, and to the science data products which will be produced by the project.

More information about the CYGNSS project is available at: **cygnss**-michigan.org/

Luncheon Session

The Hurricane Forecast Improvement Project (HFIP)
Progress and Accomplishments

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[5]NOAA/NCEP/EMC

NOAA established the Hurricane Forecast Improvement Project (HFIP) May 10, 2009, a 10-year effort to accelerate improvements in 1- to 5-day hurricane track, intensity, and storm surge forecasts and to reduce forecast uncertainty, with an emphasis on rapid intensity changes. HFIP has approached that mission by providing the basis for NOAA and other agencies to coordinate hurricane research and engaging and aligning the inter-agency and larger scientific community efforts towards addressing the challenges posed to improve hurricane forecasts.

HFIP is primarily focused on techniques to improve the numerical model guidance provided by National Weather Service (NWS) operations to the National Hurricane Center (NHC) as part of the hurricane forecast process. HFIP meets its goals by improving existing numerical forecast systems through a regimen of revising, testing, refining and implementing promising technologies. We will review the progress and accomplishment after the first 5 years.

Understanding and Predicting the Impact of Outflow on Tropical Cyclone Intensification and Structure

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ONR Marine Meteorology and Space Program
Ocean, Atmosphere and Space Research Division, Code 322
Office of Naval Research

Over the past two decades ONR has sponsored five Departmental Research Initiatives (DRI's) aimed at increasing our understanding of fundamental science questions related to tropical cyclones. These 5-year basic research initiatives have in each case produced discoveries that eventually resulted in improvements to operational predictions systems which have contributed to reduction of track and intensity errors. In 2014 a new DRI (called Tropical Cyclone Intensity, or TCI) was initiated. The purpose of this DRI is to enhance the understanding of dynamics of the upper-level outflow of tropical cyclones. Changes to TC outflow are increasingly believed to lead to profound changes in storm intensity and structure, but remain largely unexplored. Our goal is to improve the prediction of TC intensification and structure changes that occur in response to these influences, which may be due to environmental interactions and/or internal changes that are poorly represented in current models. The outflow characteristics, evolution, and dynamics will be investigated using an innovative new observing system and satellite observations, as well as state-of-the-science models that will allow this upper-level region to be explored for the first time. Research will address the following overarching scientific issues related to the spatial and temporal evolution of TC outflow structure, dynamics, and processes: 1) *the coupling of the TC outflow with the inner-core convection and the relationship of this coupling to intensity changes including rapid intensification, 2) the relationship between the upper-level outflow and the low-level wind field structure, 3) the interaction of tropical cyclone outflows with larger-scale features, and 4) the morphology and evolution of the outflow and its dependence on the environment.*

*A*n initial collaboration with the NASA Hurricane and Severe Storms Sentinel (HS3) project, that took place over the N. Atlantic from 2012-2014, produced some promising early results. The TCI team also conducted a preliminary field experiment in 2014, using the NASA WB-57 to collect high-altitude dropsonde, HIRAD and HIWRAP observations during Hurricane Gonzalo. Preparations are underway to conduct several more case studies in 2015, including collaborations with NOAA's SHOUT and HRD research programs.
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Session 5a
Advances in Tropical Cyclone Model Development and Evaluation, Part 1

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Advanced Operational Global Tropical Cyclone Forecasts from NOAA's High-Resolution HWRF Modeling System

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NOAA/NWS/NCEP/EMC

In the past few years, the National Centers for Environmental Prediction (NCEP) operational high-resolution Hurricane Weather Research and Forecast (HWRF) modeling system has shown significant improvements in the track, intensity, structure, size, and rainfall forecasts, supporting the National Hurricane Center (NHC) and the Central Pacific Hurricane Center (CPHC) by providing more skillful numerical guidance for operational hurricane forecasts. With the support from NOAA's Hurricane Forecast Improvement Project (HFIP), the HWRF team at NCEP's Environmental Modeling Center (EMC) has expanded the scope of the HWRF model for all tropical oceanic basins of the world by providing experimental real-time forecast guidance to the Joint Typhoon Warning Center (JTWC), evolving HWRF into a unique regional model with global coverage. JTWC has been using the HWRF model guidance in their operations, providing more skillful track and intensity forecasts for all tropical cyclones in the world. The atmosphere-ocean coupled operational HWRF modeling system is also being supported to the research community through NOAA's Developmental Testbed Center (DTC) for academic research and advanced model development for future operational needs. Through extensive international collaborations, several operational centers in the Asia-Pacific and South Asian regions have adopted HWRF model for their forecast and research applications.

This presentation will highlight the performance of the operational HWRF for tropical cyclones of all ocean basins in 2014, with special emphasis on track and intensity forecasts for a few major landfalling tropical cyclones. Focused research and developmental efforts, systematic testing and evaluation, and efficient mechanism established for research transitioning to operations (R2O) through support from HFIP will be discussed with reference to the proposed upgrades for the HWRF modeling system in 2015. HWRF will be upgraded to run at 2km resolution near the storm region with advanced physics improvements, and for the first time, HWRF will run operationally for all global tropical cyclones throughout the year in support of NHC, JTWC, CPHC and National Weather Service (NWS) Pacific Region (PR).

Improvements in predicting the rapid intensity changes, development of advanced inner core data assimilation techniques, and application of scale-aware and stochastic physics remain as the high priority area of research. High-resolution ensembles and global-to-local scale modeling efforts are going to define the future generation tropical cyclone forecasting tools to meet the operational requirements. This presentation will conclude with description of future plans for HWRF in operations, with emphasis on scientific challenges and opportunities for engaging with the HWRF team at EMC to further improve the tropical cyclone forecast skills.

The Basin-Scale HWRF System: Verification and Analysis

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More than 80-90% of the deaths due to Tropical Cyclones (TCs) are caused by fresh water flooding and storm surge. Although the operational HWRF system is starting to show some exceptional skills in intensity forecasting, TCs such as Irene (2011), Isaac (2012) and Sandy (2012) have all illustrated the importance of providing more accurate track, structure (size) and rainfall predictions. Also, the current operational HWRF configuration is storm centric and single nested, not ideal for representing multi-scale interactions or for post landfall applications, and is greatly limited in extending forecast lead times beyond 5 days. The key for improving multi-scale and for extending forecast lead times beyond 5 days lies in the creation of a basin scale model (eventually covering the entire globe) with multiple moving nests at 1-3 km resolution covering all the storms in the basin. Based on the 2014 HWRF system that includes the operational initialization scheme and recent upgrades to physics, the Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) with its partners at Environmental Modeling Center (EMC), National Centers for Environmental predictions (NCEP) have created a basin scale HWRF system that can operate with multiple moving nests spanning at resolution down to 3 km. Supported by NOAAs Hurricane Forecast Improvement Project (HFIP), this version of the HWRF was run for the 2014 hurricane season and also in a retrospective mode for the 2011-2012 seasons. We will provide verification of this basin scale HWRF and also provide an analysis of the outlier events. An overview of this system along with the advantages of transitioning to such a system into operations will be provided.

Hurricane Forecasts with Regional NMMB: Impact of HWRF Physics

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EMC/NCEP/NOAA

The Nonhydrostatic Multi-Scale Model on B grid (NMMB), the second generation of nonhydrostatic models developed at NCEP, has the potential to continue to advance our hurricane forecast capability. To achieve this goal, proper representation of hurricane physical processes in the model is essential. We will report progress in developing and improving the skill of regional NMMB to simulate and forecast hurricane intensity, track, and structure through transitioning operational HWRF physics suite to NMMB framework. The following physics schemes performed well in HWRF have been integrated to the NMMB system: (1) coupled GFDL surface layer and slab land model (2) GFSPBL for hurricanes (3) SAS convection scheme for hurricanes and (4) MESOSAS scale-aware convection scheme. To facilitate using HWRF

physics schemes in NMMB, tunable parameters in some schemes can be changed through NMMB configure files. For comparison, we simulated Hurricane Arthur 01L 2014 using NMMB with HWRF physics packages and with regular NAM physics options, respectively. All simulations used same configurations except physics schemes, with three nest domains similar to operational HWRF, GFS data as lateral boundary conditions, and without ocean coupling. The initial conditions and vortex for both simulations are extracted from operational HWRF runs. These setups ensure discrepancies in results are only caused by different physics schemes used. An example will be presented to show using HWRF physics package produces a better track, more accurate land falling time, and better intensification than using the NAM physics options does. Compared with operational HWRF runs, simulations from NMMB with HWRF physics package are similar to those from operation HWRF runs in terms of track, intensity, and structure, suggesting there is potential for further improvement when other HWRF components such as data assimilation, ocean coupling, and moving nest algorithm are integrated into NMMB.

Identifying and Understanding Ocean Model Impacts on Coupled HWRF Forecasts

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Ocean impacts on storm intensity are broadly understood, but detailed quantitative understanding of the impacts on intensity forecasts produced by operational prediction models is limited. Since HWRF provides relatively good numerical forecast guidance by either being coupled or non-coupled, forecasters raises a concern about the importance of ocean coupling and the degree of complexity of the ocean model. Therefore, HFIP formed OMITT to shed some lights on the issues. OMITT is a multi-institutional and multi-disciplinary effort. The primary goal is to evaluate ocean model impacts on coupled HWRF intensity forecasts and the sensitivity of these impacts on oceanic, surface flux, and atmospheric parameters.

The HWRF simulation database includes multi-seasons of Hurricane and Typhoon forecasts using either from persistent SST and/or 3D ocean model coupling. This data provide a variety of cases to study. Meanwhile, owing to the Sandy Supplemental field programs, a large suite of atmospheric and oceanic observations are available for the 2014 TCs such as Edouard, Gonzalo, Julio, Fengshen, Kammuri and Nuri. These storms will be considered as initial target of study. Historical Atlantic storms dating back to 2004 will also be included, to study a broad range of storms and oceanic parameters. Both operational and experimental HWRF models are subject to the study: two versions of operational HWRF, either coupled to POM or non-coupled, and one version of experimental HWRF coupled to HYCOM. The experimental COAMPS-TC system will also be considered. Other storms without significant ocean observations will be added to insure that the final set contains a mix of storms whose intensity was either likely or unlikely influenced significantly by the ocean.

We will describe the specific charge of the task, followed by presentation of activities that are currently in progress.

Direct Assimilation of Satellite-Derived AMVs into HWRF: First Results

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Atmospheric motion vectors (AMVs) derived from sequences of visible and infrared satellite images are a longstanding and valuable source of tropospheric wind information at synoptic scales, especially in data-sparse regions such as the open oceans. The Advanced Baseline Imager (ABI) aboard GOES-R (to be launched in 2016) will provide increased temporal and spatial sampling relative to current instruments in geosynchronous orbit. These advances will in turn allow the production of enhanced AMV datasets which are expected to provide important insight into mesoscale processes. In particular, one of the impediments to advancement in numerical prediction of tropical cyclones (TCs) has been difficultly in initializing the wind structures associated with the vortex and its immediate environment. It is posed that the enhanced AMVs may offer an excellent opportunity for substantive progress in this area.

As part of an effort supported by the Hurricane Forecast Improvement Project (HFIP), we demonstrate the promise of these data for the purpose of TC analysis and prediction. Proxy GOES-R AMV datasets are constructed from GOES-14 super-rapid scan (1-min. frequency) imagery for selected cases of Atlantic hurricanes. These data are then assimilated using the hybrid Gridpoint Statistical Interpolation (GSI) package within NOAA's operational Hurricane Weather Research and Forecasting (HWRF) modeling system. Initial results indicate that the enhanced AMVs can have a beneficial impact on both track and intensity during the first 24 to 48 hours relative to a control which assimilates only radiosonde observations (RAOB). The impact on the intensity bias is robust and is positive at all lead times. Data assimilation methodology and the model impact results will be shown and discussed in the presentation.

Proposed 2015 NCEP HWRF Hurricane Forecasting Model

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NOAA/NCEP/EMC

This talk describes the proposed 2015 NCEP HWRF hurricane forecasting model. We review past years' performance and reasons for upgrading. We describe the upgrades that were considered, and testing methodologies used. We illustrate revisions to the operational procedures required for expanding the scope of operational HWRF for all global tropical cyclones. Lastly, we explain which upgrades were kept in the final system, and why.

Session 5b
Advances in Tropical Cyclone Model Development and Evaluation, Part 2

S E S S I O N 5 b

Recent COAMPS-TC Development and Future Plans

James D. Doyle[1], R. Hodur[2], J. Moskaitis[1], S. Chen[1], E. Hendricks[1], H. Jin[1], Y. Jin[1], A. Reinecke[1], S. Wang[1]
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The Coupled Ocean/Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC) has been developed for forecasting tropical cyclone track, structure, and intensity over the past several years and transitioned to Navy operations at the Fleet Numerical Meteorology and Oceanography Center in 2013. Here we provide an update on the latest advancements to the COAMPS-TC system for 2015 including: i) vortex initialization and dynamical initialization, ii) improved boundary layer physics, and iii) air-sea coupling. The COAMPS-TC has been tested in real time in both coupled and uncoupled modes in the Pacific and Atlantic basins at a horizontal resolution of 5 km. The real-time testing has been motivated by several recent multi-agency programs and efforts that we will report on including: i) the Hurricane Forecast Improvement Project (HFIP), which is focused on the W. Atlantic and E. Pacific basins, ii) the recent NASA HS3 and ONR Tropical Cyclone Intensity field programs, and iii) real-time testing in parallel with the Navy operational version of COAMPS-TC in the W. Atlantic, E. Pacific and W. Pacific basin. An evaluation of a large sample of real time forecasts for 2014 in the Atlantic, E. Pacific and W. Pacific basins reveals much improved COAMPS-TC track and intensity predictions, and in many regards on par or in some aspects better than the established operational dynamical forecast models. Additionally, results for a high-resolution (3 km) COAMPS-TC ensemble that was run over the W. Atlantic basins will be discussed. The COAMPS-TC ensemble was performed in collaboration with the HFIP program, which included high-resolution HWRF and GFDL ensembles. The results show considerable promise for probabilistic intensity and track prediction using a multi-agency, multi-model tropical cyclone ensemble approach.

Real-Time Probabilistic TC Prediction with Regional Dynamical Models: The COAMPS-TC Ensemble and the Combined COAMPS-TC/HWRF/GFDL Multi-Model Ensemble

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As part of the HFIP program, in Aug-Oct of 2014 NRL, EMC, and GFDL performed real-time demonstrations of their experimental regional dynamical model ensemble prediction systems for Atlantic basin tropical cyclones. Output from the three individual models was collected in real-time to produce probabilistic forecast products for the 42-member multi-model ensemble, a first for a real-time forecast demonstration. In this presentation, we will describe the forecast demonstration and detail the performance of the multi-model ensemble in the context of both deterministic and probabilistic verification metrics. We will also show validation of retrospective forecasts of past Atlantic TCs in order to provide an assessment of the multi-model ensemble over a more robust sample of cases. Finally, we will show 2014 real-time forecast results from the COAMPS-TC ensemble for the very active Eastern Pacific basin.

Given that the ensemble prediction systems are very much still in their experimental stage of development, it is perhaps not surprising that the probabilistic track and intensity prediction results show both promising features and areas in which improvements are needed. For track, the COAMPS-TC ensemble has an average spread that is very similar to the average accuracy of the ensemble mean prediction, and an exceptionally good correlation between track spread and track accuracy. The multi-model ensemble also shows good consistency between track spread and track accuracy. For intensity, both the COAMPS-TC ensemble and the multi-model ensemble lack sufficient spread and have biases that degrade the reliability of the forecast. However, there is a positive correlation between intensity spread and intensity forecast accuracy, suggesting an ability of the ensemble to distinguish between more uncertain and less uncertain intensity forecast scenarios. The challenge for the future will be to develop ensemble perturbation strategies that further enhance this promising feature while enabling the ensemble to better represent the range of possible intensity forecast outcomes.

Sensitivity of Ocean Sampling for Coupled COAMPS-TC Prediction

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In-situ ocean observations such as the Airborne eXpendable Bathy Thermograph (AXBT), provide vital information on the upper-ocean sea temperature changes that arise bederneath the tropical cyclone. Assimilation of these AXBT sea temperatures data was shown previously to have a positive impact on the TC intensity and track prediction. Using a newly developed Naval Research Laboratory adjoint-based data impact analysis tool and COAMPS-TC, we investigate the optimal AXBT sampling resolution that yields the most beneficial impact to COAMPS-TC prediction using the Hurricane Isaac (2012) case. Results from assimilating the high- versus low-vertical resolution AXBT eXpendable Conductivity, Temperature, and Depth (XCTD), and eXpendable Current Profiler **(**AXCP) data in COAMPS-TC will be discussed.

Further Exploring the Potential for Assimilation of Unmanned Aircraft Observations to Benefit Hurricane Analyses and Forecasts

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This study explores the potential of assimilating data from multiple instruments onboard high-altitude, long-endurance unmanned aircraft to improve hurricane analyses and forecasts. A recent study found a significant positive impact on analyses and forecasts of Hurricane Karl when an ensemble Kalman filter was used to assimilate data from the High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), a new Doppler radar onboard the NASA Global Hawk (GH) unmanned airborne system. The GH can also carry other useful instruments, including dropsondes and the Hurricane Imaging Radiometer (HIRAD), which is a new radiometer that estimates large swaths of wind speeds and rainfall at the ocean surface. The primary finding is that simultaneously assimilating data from HIWRAP and the other GH-compatible instruments results in further analysis and forecast improvement for Karl. The greatest improvement comes when HIWRAP, HIRAD, and dropsonde data are simultaneously assimilated.

NOAA's Use of the Coyote UAS in Hurricane Edouard to Enhance Basic Understanding and Improve Model Physics

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The hurricane boundary layer is the lowest layer of the atmosphere where momentum is exchanged with the surface and where heat and moisture are extracted from the ocean. As such, this region of the storm is critical as it relates to tropical cyclone formation, maintenance, intensification and weakening. Despite the inherent importance of this environment, flight safety risks currently limit the routine collection of wind, pressure, temperature and moisture observations near the ocean-atmosphere interface. In-situ measurements below 500m in high wind hurricane conditions are typically from point-source, instantaneous, GPS dropsonde observations. The lack of continuous data coverage at low levels is a primary reason why hurricane boundary layer structure and associated physical processes within this critical region of the storm remain poorly understood and inadequately represented in today's operational models. In turn, inadequate representation of physical processes often leads to errors in data initialization

and assimilation, which can adversely impact the accuracy of subsequent hurricane forecasts. It is believed that an improved understanding of boundary layer processes, through targeted, enhanced and continuous observation using low altitude unmanned aircraft systems (UAS) will be essential in order to significantly improve scientific understanding and future predictions of hurricane structure and intensity.

During recent reconnaissance and surveillance missions into Hurricane Edouard, NOAA, along with partners Sensintel and ItriCorp, conducted the first-ever air-deployed, UAS experiments into a tropical cyclone environment. On September 16th 2014, Sensintel's 13lb, 5-ft wingspan Coyote UAS was released into Major Hurricane Edouard's eye. NOAA's P-3 manned aircraft launched the UAS and provided in-flight command, control and data delivery support for the Coyote. At an approximate altitude of 2900ft, the UAS penetrated Edouard's western eyewall and recorded platform record-breaking winds of 100kt as it proceeded to 'orbit' this high wind region during its historic 28-minute inaugural mission.

On September 17th, a second successful P-3/Coyote UAS flight was conducted. Here, the experimental design was to send the UAS along an inflow channel similar to what an air parcel might experience as it spirals towards the storm's center of circulation. This event set endurance records for the Coyote platform as it remained airborne within the hurricane boundary layer for 68 minutes (at controlled altitudes ranging from 1200-2500ft).

It is expected that analyses from this new and promising platform will provide unique insights into a critical region of the hurricane that is difficult to observe in sufficient detail. Boundary layer analyses collected by the Coyote UAS will be presented and compared with preliminary HWRF model output valid during the UAS missions.

Evaluating models and understanding hurricane processes with the use of the JPL Tropical Cyclone Information System

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There are still many unanswered questions about the physical processes that determine hurricane genesis and evolution. Furthermore, a significant amount of work remains to be done in validating and improving the hurricane models.

A major goal of NASA's hurricane science research program is to bring a wealth of satellite and airborne observations to bear on addressing these outstanding issues. Despite the significant amount of satellite data, they are still underutilized in hurricane research and operations, due to their complexity and volume.

To meet this need, we are developing the JPL Tropical Cyclone Information System (TCIS) to facilitate the inter-comparison of models and observations by bringing them into a common system and developing online tools for joint analysis and visualization.

To help support the HFIP objectives, this NASA/ESTO/AIST-funded project is developed in close collaboration with our colleagues from NOAA/EMC and NOAA/AOML/HRD to bring the operational and research versions of HWRF forecasts into the satellite database. This project aims to develop an interactive near-real-time (NRT) portal with the goal to reduce barriers to timely delivery of satellite and model products to increase the understanding of the hurricane processes and the accuracy of their forecasts. The framework of timely data discovery, ingestion, visualization and analysis tools that we are developing presents a new prototype for integration of models and observations.

In this presentation we will start by briefly outlining the outstanding scientific questions. We will then describe our approach to providing fusion of models and observations. We will focus on the main components of our system: i) timely collection of NRT observations from a multitude of satellite instruments; ii) projecting the model forecast into the observational space by using instrument simulators (e.g. the operational CRTM and the NASA Earth Observing System Simulator Suite, NEOS^3) to compute synthetic observations (e.g. microwave brightness temperatures) from the model fields for a more direct comparison to the satellite and aircraft data; iii) development of on-line analysis tools; iv) visualization of highly complex systems that allows for user-driven interrogation of models and observations.

The main focus of the presentation will be the illustration of how our system can be used to evaluate several models (HWRF, GFS) by applying the analysis tools to several hurricanes observed during the 2013/2014 seasons. Finally, we will outline the still outstanding issues and will present our future plans.

The work described here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Session 7
Products, Services, and Societal Impact

A Global Investigation of the Impacts of Landfalling Tropical Cyclones on Societies

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Landfalling tropical cyclones (TCs) result in much devastation and numerous fatalities around the world each and every year. The impacts of TC landfall to specific communities and societal groups vary widely. These variations in impacts are due not only to the strength and intensity of the TC at landfall, but also to a given society's vulnerability and resiliency to these stresses at the time of the TC event. Societies have various levels of vulnerability to TC landfall based on many factors including education, preparedness, personal history with previous events, and governmental infrastructure, to name but a few.

This research seeks to gain insight into the many factors, which determine the impacts experienced globally by landfalling TCs in order to aid in the facilitation of the development of metrics to determine vulnerability, which may be applicable on a global scale. Using 33 years of International Best Track Archive for Climate Stewardship (IBTrACS) data (1980-2013), the potential for impacts due to landfalling TCs will be assessed based on factors including storm size, precipitation rates, wind speed at landfall, storm surge damage, and the recurrence of landfalling events within a geographic region. Several TCs in a range of basins have been chosen for more detailed case studies, in part because of the availability of data for the TC, but also the availability of data relating to the societal, demographic and infrastructure within the region. For these events, a comprehensive analysis of the physical characteristics of the TC as well as the impacts will be performed. Using both socio-economic and geographic data from sources including, but not limited to EM-DAT (the Emergency Events Database), the United States Storm and Hazard Database, World Bank, and the Socioeconomic Data and Applications Center (SEDAC), we will quantify the level of vulnerability and resiliency of each impacted region. The use of socio-economic data in concert with physical storm parameters will allow for a more robust understanding of the ramifications of landfalling TCs.

The 2014 Satellite Proving Ground at the National Hurricane Center

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GOES-R is scheduled for launch in early 2016 and will contain a number of new instruments, including the 16-channel Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). The Suomi-NPP mission is already providing valuable data from VIIRS and ATMS/CrIS, which will also be available from the future JPSS. The Satellite Proving Ground was established to provide forecasters with advance looks at new satellite data and products

using proxy information, and to obtain user feedback for the product developers. Fourteen GOES-R products and 1 NPP product were chosen for demonstration at NHC during most of the 2014 Hurricane Season (1 Aug to 30 Nov). Three of these products were new in 2014: an alternate RGB dust product, an RGB nighttime microphysics product and a lightning density product. The emphasis in 2014 was on these new products. Highlights from the 2014 season from the Hurricane Specialist Unit and Tropical Analysis and Forecast Branch will be provided, along with plans for the 2015 Proving Ground.

NRL Tropical Cyclone Satellite Web Resource

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The Naval Research Laboratory's (NRL) tropical cyclone (TC) web page has enabled the global TC community to benefit from access to near real-time microwave imager/sounder imagery and derived products that assist in monitoring TC storm structure since 1997. Microwave sensors have the inherent advantage of seeing through non-raining clouds, thus mitigating a common problem associated with visible/Infrared (vis/IR) imagery that forms the bulk of the temporal sampling due to 30 minute or more rapid refresh afforded by geostationary sensors. NRL's Marine Meteorology Division in Monterey, CA (NRL-MRY) recognized the potential to use the SSM/I to map TC location, structure, and infer intensity, and thus began in 1997 a public web page that contained near real-time SSM/I products focused on existing TCs as monitored by the National Hurricane Center (NHC, Miami, FL), the Joint Typhoon Warning Center (JTWC, Pearl Harbor, HI) and the Central Pacific Hurricane Center (CPHC, Honolulu, HI). This effort was only possible due to our close collaboration with the Fleet Numerical Meteorology and Oceanography Center (FNMOC) collocated in Monterey, CA with NRL-MRY and coordination with the Automated Tropical Cyclone Forecasting system (ATCF).

Low earth orbiting (LEO) sensors like the SSM/I (1400-km swath) only view a given TC at most twice/day, typically less, thus temporal sampling is a key limitation. However, NRL's TC web page uses data fusion by combining data sets from both operational and R&D sensors (SSM/I, SSMIS, WindSat, TMI, WindSat, AMSU, and MHS). More recently, we have brought online the DMSP F-19 SSMIS after successful cal/val program approval and the NASA Global Precipitation Mission (GPM) Microwave Imager (GMI) via NASA/GSFC. Data latencies for F-19 SSMIS data is ~ 1-2 hours, while GMI is < 30 minutes, since GPM uses TDRSS to downlink data every 5 minutes and one should remember the superb 5-6 km spatial resolution at 89 GHz and its advantages in mapping inner core structure.

Additional microwave sensors capable of retrieving ocean surface wind vectors have been hosted using scatterometers (ASCAT) and we are pleased to now include NASA's RapidSCAT wind vectors. The 900 km swath and 51.6 deg orbital inclination onboard the host International Space Station (ISS) complement the ASCAT data sets and thus increase the spatial and temporal sampling used by the various WMO and TC warning centers around the globe. Data fusion enhancement applications using examples from these new microwave sensors will be presented.

A Completed Hurricane Surge Visualization Model and Ongoing Efforts to Use the Model to Assess Public Understanding of Risks due to Storm Surge

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An interactive website is now active that combines SLOSH estimated surge with elevation and tidal data and then simulates the level of surge on photographs of a thousand landmarks throughout the metropolitan area. The intent of the surge visualization model is to allow anyone to find a landmark near a location of their choosing, and then to see approximate water depths on photographs of that location for a variety of hurricane scenarios. The model is definitely not perfect; with several glitches and approximations, but it is good enough to test the approach and then refine the model in later versions. The model will be introduced in the talk, and meeting participants are welcome to explore the website after that on their laptops or mobile devices. We welcome comments, suggestions, and criticism.

The effectiveness of our approach is now being examined by surveying randomly selected members of the public. A series of web pages have links to background information on hurricanes, background information on the project, information on how to use the model and a link to the model itself. Before accessing the visualization model, users are directed to a survey that assesses their current understanding of storm surge as well as collects standard demographic data. Once the survey is completed, users are connected to the model and allowed to navigate the model to any extent that they desire. Users are then surveyed on their understanding of hurricane surge again, problems they encountered while using the model, and their understanding of uncertainties in hurricane prediction and model development. How has their understanding improved? Has their appreciation of the uncertainties improved?

Long term, we envision the public using the model while no hurricane is present to improve their understanding of hurricane surge while also assessing which areas are particularly vulnerable to surge. This will assist in land use planning, home construction and other uses. Also, the visualization model could easily be modified to incorporate the latest SLOSH projections to provide real-time surge estimates.

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Poster Session

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

Upper Ocean Observations in Hurricane Edouard

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As part of a multi-aircraft, multi-day series of experiments, an extensive set of upper-ocean observations was obtained in Hurricane Edouard (2014). Vertical profiles of temperature, salinity, and currents were measured by Aircraft eXpendable BathyThermograph (AXBT), Aircraft eXpendable Conductivity-Temperature-Depth (AXCTD), and Aircraft eXpendable Current Profiler (AXCP) probes before, during, and after storm passage in the west-central Atlantic. By measuring the storm's surface forcing in terms of winds (SFMR) and fluxes (GPS dropsondes), we may estimate the ocean's heat and momentum response to the storm. Such analyses are useful for evaluating the ocean component of atmosphere-ocean coupled forecast models (e.g., HWRF+POM and HWRF+HYCOM in the future), which are now currently run to provide tropical cyclone intensity guidance. We will present an overview of the observational experiments, field analyses constructed from the observations, and current collaborative efforts at directly comparing the observational analyses with operational coupled model simulations for Hurricane Edouard.

Observations and Modeling of Saharan Dust Interaction with a Tropical Cyclone

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The Hurricane and Severe Storm Sentinel (HS3) is a multiyear field campaign with the goal of improving understanding of hurricane formation and intensity change. One of HS3's primary science goals is to obtain measurements to help determine the extent to which the Saharan air layer impacts storm intensification. In 2012, HS3 used one of NASA's unmanned Global Hawk aircraft equipped with three instruments to measure characteristics of the storm environment (dropsonde derived profiles of temperature, humidity, wind speed and wind direction; interferometer derived profiles of temperature and humidity in the clear air; and lidar derived profiles of Saharan dust and clouds). This poster will focus on environmental observations obtained during the early stages of Hurricane Nadine (2012) when it interacted with the Saharan air layer. In addition, the Goddard Space Flight Center version of the Weather Research and Forecasting model with interactive aerosol-cloud-radiation physics is used to identify the role of the SAL using simulations of Nadine with and without the aerosol interactions.

An Update on Techniques Using the Deviation Angle Variance (DAV) for Tropical Cyclone Intensity, Genesis, and Surface Wind Field Estimation

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The Deviation Angle Variance (DAV) technique has been developed at the University of Arizona as an automatic and objective system that provides information about intensity of tropical cyclones (TCs) throughout their life cycle. The DAV signal is computed from geostationary brightness temperature data, and provides a single score at each pixel in an image that is related to the axisymmetry of cloud patterns centered on that pixel. Coupled with knowledge of storm track, the DAV signal has been demonstrated to be a robust estimator of TC intensity. Furthermore, at early times, the DAV signal can be used to help identify TC genesis and track interesting cloud clusters automatically.

In this poster presentation, we will present updates on current efforts surrounding the DAV system. In the past, the DAV signal was a single number linked to a center of circulation. However, recent results indicate that the distribution of DAV can be used to estimate the TC wind field. We have developed a method that uses azimuthally averaged DAV signal along with environmental parameters such as TC age and sea surface temperature to create a linear regression that provides estimates of the radii of 34-, 50-, and 64-knot winds. The regression can be performed either assuming full axisymmetry or in a quadrant-by-quadrant fashion. The method was trained using high-quality extended best track data from a set of storms for which continuous aircraft reconnaissance was available, and performance was tested using 5-fold cross validation. Initial results indicate that mean absolute errors of less than 20% are possible. We are exploring the use of this method both as a forecasting tool and as a tool to be used in initializing numerical weather prediction models.

Earlier genesis results were hampered by the fact that the system produces high absolute numbers of false alarm cases, even if the false alarm rate is low. Given the complexity of brightness temperature data, false alarm rates below 20% can still produce significantly more false positives that there are true cases. Current work is focused on using a variety of tools to reduce the number of false positives. These tools include the use of multiple thresholds - one for identifying cases of interest and a second for making a determination - and the times necessary to cross these thresholds. Geographical filters that exclude particular regions with low probability of development show significant promise, and image-processing tools like edge detection help to identify spatial features that can improve performance. Ultimately this line of research will lead to a probabilistic prediction of TC development based on objective criteria.

Support for Users and Developers of the Hurricane WRF Model

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The NOAA operational Hurricane Weather Research and Forecast model (Hurricane WRF, or HWRF) is an important component of the numerical guidance used at the National Hurricane Center, making it critical that the HWRF model be continuously improved. Given the complexity of the HWRF model, which consists of the WRF atmospheric model coupled to the Princeton Ocean Model for Tropical Cyclones (MPIPOM-TC), a sophisticated initialization package including a data assimilation system, and a set of postprocessing and vortex tracking tools, EMC has partnered with the Developmental Testbed Center (DTC) to help accelerate the infusion of the new technologies onto the model.

This work describes the support provided to HWRF users and developers through the DTC. The Community HWRF has a yearly release containing all the capabilities of the HWRF operational implementation of that year, plus additional research capabilities, such as alternate physics suites and an idealized simulation package. The Community HWRF code is stable and well tested, and is distributed along with a Users' Guide, Scientific Documentation, test datasets, and access to an online helpdesk. In person or online tutorials are made available; for example, in 2014 tutorials were presented in College Park, MD, and in Taiwan.

In addition to the HWRF release made available to all users, the DTC provides support to those conducting active HWRF development. This support includes access to the HWRF code repository, assistance with creating, updating, and merging branches, training, consistency checks to ascertain that new developments do not break existing capabilities, and integration of codes developed by the HWRF group with those developed by the community at large. The latter activity is particularly important to avoid code divergence for the HWRF components that are extensively developed by non-HWRF groups, such as the WRF atmospheric model.

The HWRF developer support provided by the DTC, accessible through http://dtcenter.org/HurrWRF/developers, has been particularly helpful to recipients of grants from the NOAA Hurricane Forecast Improvement Project (HFIP) and the DTC Visitor Program. By making HWRF a well-supported community model through the DTC, the rate of transition of new research and development to HWRF has increased, leading to tangible benefits to tropical cyclone numerical operational forecasting.

Evolution of the Upper-Level Outflow During Hurricanes Iselle and Julio (2014) in the Navy Global Environmental Model (NAVGEM) Analyses

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During the summer of 2014, a group of Naval Academy midshipmen flew through Hurricanes Iselle and Julio with the USAF 53rd Weather Reconnaissance Squadron. Stemming from this experience, interest grew in regards to the outflow mechanisms of a tropical cyclone (TC). Tropical cyclone outflow remains an active area of research in the meteorology community. Despite this, not much is known about the relationship between TC outflow, structure, and intensity. One way to further research this area is with model output, including Navy Global Environmental Model (NAVGEM) analyses. Examination of model data revealed a relationship between outflow and TC intensity in Hurricanes Iselle and Julio. From 31 July to mid-August 2014, the central and eastern Pacific Ocean was dominated by a ridge-trough-ridge pattern within the subtropical jet. This wave train, which included ridge breaking around the passage of both TCs, impacted the orientation of outflow channels as well as the intensities of Hurricanes Iselle and Julio. In both TCs, it was shown that intensity increased during periods of greater outflow, when maximum outflow was located closest to the TC center, and when dual outflow channels were present. A synoptic overview of both TCs and an analysis of outflow from model data will be presented.

Observations of Upper-Level Outflow During Hurricanes Iselle and Julio (2014)

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During the summer of 2014, a group of Naval Academy midshipmen flew through Hurricanes Iselle and Julio with the USAF 53rd Weather Reconnaissance Squadron. Stemming from this experience, interest grew in regards to the outflow mechanisms of a tropical cyclone (TC). Tropical cyclone outflow remains an active area of research in the meteorology community. Despite this, not much is known about the relationship between TC outflow, structure, and intensity. One way to further research this area is with aircraft and satellite observations. Here, dropwindsonde data from the NOAA P-3 and Atmospheric Motion Vectors from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) are analyzed to better understand upper-level conditions on the periphery of both Iselle and Julio. These data will be presented and compared to the representation of the outflow in the Navy Global Environmental Model (NAVGEM) analyses. Particular emphasis will be given to satellite and dropsonde data measurements during changes in outflow magnitude and organization into channels.

The Effect of Landfall or Coastal Interaction on the Performance of Navy Tropical Cyclone Track and Intensity Forecasts

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The goal of this study is to reveal the effects of landmasses on the track and intensity of tropical cyclone forecasts. Specifically, storms that either make landfall or track within 30 km of a landmass, for at least two 6-hour records, as recorded by operational BEST track estimates, will undergo forecast verification by three Navy models. The Navy's models to be evaluated in this study include the Coupled Ocean and Atmospheric Prediction System – Tropical Cyclone (COAMPS-TC), the Geophysical Fluid Dynamics Laboratory – Naval Version (GFDN), and the Navy Global Environmental Model (NAVGEM). The tropical cyclone (TC) forecast aids for COAMPS-TC and NAVGEM, are COTC and NVGM, respectively. As these three models are late cycle models, the interpolated versions will be used (COTI, GFNI, NVGI). Tropical cyclones from all basins from the 2013 and 2014 seasons, that made landfall or had significant interaction with a landmass, will be used in this study. Once best track files have been screened to omit non-land interacting TCs, and include only those storms with a history of coastal interaction, forecast verification software will be used to evaluate the intensity and track performance. Forecasts will also be separated by initial intensity to determine if this plays a factor in model performance. This study will include results from all basins, and for the extent of coastal interaction.

Impact of CYGNSS Data on Hurricane Analyses and Forecasts in a Regional OSSE Framework

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The Cyclone Global Navigation Satellite System, or CYGNSS, is a planned constellation of micro-satellites that utilizes existing GPS satellites to retrieve surface wind speed near the satellites' ground tracks. The orbits are designed such that there is excellent coverage of the tropics and subtropics, resulting in better sampling intervals over tropical cyclones than is possible with current scatterometers. Furthermore, CYGNSS will be able to retrieve winds under all precipitation conditions, and over a large range of wind speeds in a tropical cyclone. Using model output from a high-resolution tropical cyclone nature run as truth, synthetic CYGNSS wind speed data have been created. The tropical cyclone nature run spans 13 days and is nested within the European Center for Medium range Weather Forecasting's (ECMWF) joint Observing System Simulation Experiment (OSSE) global nature run. Using a regional OSSE system, the impact of synthetic CYGNSS wind speed data on Gridpoint Statistical Interpolation (GSI) analyses and Hurricane Weather Research and Forecast (HWRF) system forecasts will be evaluated.

Wind Speed Retrievals with GPU Accelerated Matched Filter

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The use of GPS signals reflected from the ocean surface has been demonstrated to provide information concerning wind speed. Several years of measurements have been converted into wind speed retrievals by researchers in NASA. The retrievals are based upon an algorithm closely related to a technique found in communication theory called a "matched filter."
Matched filters depend on the fact that the cross-correlation of two normalized functions is only maximized when one function is a close match to the other.

Recently, the selection of the Cyclone Global Navigation Satellite System (CYGNSS) mission for funding by NASA has caused a re-examination of the matched filter approach. The matching of the acquired data is done against data from synthetic storms to find the best storm with similar characteristics, such as maximum winds.

Specifically, this requires that a whole function space be searched to find the best match. To find a match for a single storm signal, the entire signal must be correlated with each synthetic storm signal in the NASA repository. With data sets with points in the millions and a large database to search and sort, serial processing power can take an entire day. In an attempt to improve the speed of the retrieval, this paper reports the results of applying a Fourier Transform approach to the algorithm hosted on GPU and comparing such with a serial.

We made use of the GPU accelerated Array Fire library which implements a GPU distributed Cooley-Tukey divide and conquer Fast Fourier Transform. In this paper, we evaluate our matched filter wind speed retrieval using the Fast Fourier Transform by comparing it to a serial approach.

On the Continued Need for Public-Private Partnerships in the Observation of Land-falling Tropical Cyclones

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Late on the night of July 3rd, 2014, Hurricane Arthur made landfall as a category 1 storm along the coast of North Carolina near the town of Beaufort. Over the next six hours, the storm tracked north-northeast over the waters of Pamlico Sound, bringing sustained winds over 70 mph to multiple locations, a maximum sustained wind of 83 mph, and gust of 101 mph, before eventually crossing back into the Atlantic near Oregon Inlet early the next morning. Because of the storm's relatively rapid passage and mostly over-water track, damage from Arthur was relatively light, but the storm served as a superb example of the power of public-private cooperation within the weather enterprise.

NOAA, FAA and other federal agencies operate about a dozen sensors along the approximately 120 miles of barrier islands and sounds that run from the Cape Lookout to Roanoke Island which were impacted by the storm. Under the National Mesonet Program, data from these federal stations is supplemented by over 30 non-federal weather stations located along the same stretch of coastline. These stations are operated by National Mesonet Partners WeatherFlow and Earth Networks (both private companies) and the North Carolina ECONet (operated by the state of North Carolina). Data from the stations is transmitted automatically to a National Weather Service database for use by the National Hurricane Center, the National Centers for Environmental Prediction, local NWS Weather Forecast Offices (WFOs), and other offices within NWS and NOAA.

During Arthur's passage, 18 of the 25 highest wind readings recorded came from National Mesonet partner stations, with 6 from federal stations and 1 from a buoy operated by a state university. Among the 18 highest stations, 16 were fixed stations operated by WeatherFlow and 2 were mobile stations deployed in advance of the storm by personnel from the University of Florida under the Florida Coastal Monitoring Program, and which relay their data to the National Mesonet program in real-time via WeatherFlow.

Data from these National Mesonet assets were cited 40 times by coastal WFOs in their real-time watches, warning, and Local Storm Reports, and were referenced in each of six final comprehensive Hurricane Post-Storm Reports issued by these WFOs. The data is available for current and future pubic, academic and private sector research activities.

The National Mesonet partners increased the amount of data available to the National Weather Service by a factor of three, capturing the strongest winds in the process. This increase in high quality, highly reliable data helps NWS in its mission of protecting the lives and property of our citizens and it does so at a fraction of the cost of the federal government doing it alone. This shows how engaged public-private cooperation helps our citizens as well as the private sector, state, local, and academic participants throughout the weather enterprise.

Kuroshio Extension Observatory (KEO) Measurements of the Upper-Ocean Response to Tropical Cyclones in the Western North Pacific

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The Kuroshio Extension Observatory (KEO) is a well-instrumented moored buoy located near 32N, 145E in the western North Pacific Ocean. This is a region with a high frequency of tropical cyclones, typically just beginning extratropical transition. Recent examples of tropical cyclones passing close to KEO include Choi-Wan (2009), Pabuk (2013) and Fengshen (2014). The real-time measurements from the KEO buoy have been used to evaluate the air-sea fluxes of heat, momentum and CO2; the sub-surface data have been used to reveal the effects of these storms on not just the physical properties of the upper ocean but also its chemical properties, namely pCO2, pO2 and pH levels. The KEO measurements allow numerical ocean model representations of the evolution of the physical properties of the upper ocean during storms to be compared with observations in near real-time. In particular, the differences between Hybrid Coordinate Model (HYCOM) output and KEO observations during some recent events are interpreted in terms of their impacts on air-sea exchanges.

GOES-R is Coming - Are You Ready!

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NOAA/NESDIS/GOES-R Program Office

The launch of the first in the series of next generation NOAA geostationary environmental satellites, the GOES-R series, is only one year away with the launch of the first satellite planned for March 2016. The NOAA Administrator announced at the 2015 AMS Annual Meeting that GOES-R will continue observations during its extended post-launch testing through the 2016 Atlantic Hurricane Season and transition immediately into operations afterward (March 2017). The instruments are all integrated on the satellite; the new ground processing system is deployed and undergoing integration testing; and the training plan for forecasters is rapidly coming into focus. The GOES-R Proving Ground has long been preparing forecasters, through the use of proxy data, for the new capabilities of GOES-R. Compared to the current GOES imager, the new imager has twice the spatial resolution, three times more spectral information, four times greater coverage, and five times faster refresh, as well as a wholly new instrument to detect lightning over the US and adjacent oceans. This presentation will provide an update on the GOES-R satellite program and the user readiness activities that will prepare forecasters to use the advanced capabilities of GOES-R without delay.

CINAR Tempests: A Rapid Response Program for Oceanographic Measurements during East Coast Hurricane Passage

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CINAR Tempests Team (from WHOI, Rutgers U., U. Maine, U. Maryland, Gulf of Maine Research Institute)

We are presently studying oceanographic processes relating to hurricane passage along the east coast of the U.S. We are using gliders, low cost buoys, and air-deployed ALAMO floats to measure ocean thermal and density structure and how it evolves before and after hurricane passage. The moorings, which are deployed at the 20 m isobath, include meteorological sensors in addition to an acoustic system for measuring changes in sea level. In addition to the observations, we have a number of numerical modelers assimilating the data to study the continental shelf processes that affect the evolution of the surface mixed layer temperature. The coverage for the observations extends from Maryland to Maine. During the summer of 2014, three gliders were deployed as Hurricane Arthur passed by. In addition, modeling of storm surge in the vicinity of Chesapeake Bay was conducted. We plan to deploy for a hurricane that passes up the East Coast in either 2015 or 2016. The ultimate goal of the program is to examine feedbacks from ocean mixing that affect hurricane intensity as well as improve modeling of storm surge via better observations of both sea level changes and wave conditions over the inner shelf.