2019 TROPICAL CYCLONE OPERATIONS AND RESEARCH FORUM

73rd INTERDEPARTMENTAL HURRICANE CONFERENCE SUMMARY REPORT

The Federal Coordinator for Meteorological Services and Supporting Research (OFCM) hosted the 2019 Tropical Cyclone Operations and Research Forum (TCORF)/73rd Interdepartmental Hurricane Conference (IHC) for Federal agencies, operational forecast centers; weather modelers; aerial, ocean, satellite, and radar observing groups; supporting research functions, and user communities.

The 122 registered participants convened at the Rosenstiel School for Marine and Atmospheric Science (RSMAS) on March 12-13, 2019 to review last year's hurricane challenges, plan operations for the upcoming season, and discuss research efforts in the context of operational needs. The agenda comprised a combination of themed sessions and the Working Group for Tropical Cyclone Operations and Research (WG/TCORF) meeting. A summary of each of these agenda elements follows. Slide presentations used by panelists and other participants are available on the OFCM website.

Opening Session.

Mr. Michael Bonadonna, Federal Coordinator for Meteorology opened the forum by welcoming the participants and reviewing the forum goals and agenda. He thanked the National Weather Service, the National Science Foundation, and the Office of Naval Research for assistance in funding the forum.

Session 1: Tropical Cyclone Operations: Challenges in 2018

The National Hurricane Center noted that the 2018 season was very busy and impactful. It was particularly active and above average in the sub-tropical areas. Hurricane Florence produced more than 35 inches of rainfall in North Carolina breaking a state record set during Floyd (1999). Hurricane Michael was the 4th strongest by maximum winds on record in the U.S. and the strongest U.S. landfalling hurricane since Andrew (1992). Overall track forecasts were consistent and quite good. Intensity forecasts were difficult and, in some cases, missed the rapid strengthening or weakening of hurricanes.

The NHC/Tropical Analysis and Forecast Branch provides meteorological analysis, forecasts and warnings for ship traffic over the tropical and subtropical oceans for portions of the Atlantic, Gulf of Mexico, and Eastern Pacific. Their services include wind and wave forecasts for their areas of responsibility. Information from GOES 16 and 17 was useful for Dvorak operations and in dust/Saharan Air Layer (SAL) detection. Decision support services were also provided to the U.S. Coast Guard search and rescue missions. New forecasting tools and techniques are being tested related to wind and wave models and better ways to communicate information to mariners.

The [Central Pacific Hurricane Center](#) summarized the track and intensity characteristics and impacts of the six TCs that developed or moved through the Central Pacific in 2018. Reconnaissance by AF, NOAA, or NASA aircraft was conducted on five of the TCs and their data benefited TC track and intensity forecasting. Backup of Aviation and "Center" Marine desks was supplied by AWC, WFO Monterey and TAFB during Lane. CPHC 2018 operational challenges included anticipating intensity changes and subsequent impacts on track forecast, anticipating coastal impacts due to surf/surge/tide, communicating forecast uncertainty and calibration of SFMR data in areas of extreme winds.

The [Joint Typhoon Warning Center](#) experienced the highest number of Western North Pacific tropical cyclones since 1996. Above-average activity and addition of six-hourly S. Hemisphere warnings resulted in the highest number of annual warnings in JTWC's 59-year history. TC intensity change (particularly RI) and TC structure specification remain their top two R and D priorities.

[AOC:](#) Only a single P-3 was available during the 2018 season because of the re-winging schedule, however, it flew 95% of its allocated hours. The GIV flew 99% of its allocated hours. The G-IV also had three deployments to the Pacific to fly surveillance around Hector, Lane, and Norman. For 2018 and 2019 there will be two operational P-3's, both with new Multimode radar (MMR) and upgraded Tail Doppler Radar (TDR) and Central Pacific (HI) operations may be considered for both the P-3 and G-IV.

The [53 Weather Reconnaissance Squadron](#) (53rd WRS) flew 145 NHOP tasked hours with a reliability of 88%. Challenges for 2019 include low manning, SATCOM interruptions, funding, and aircraft maintenance.

Session 2: Future Products and Services Planned; New/Revised Requirements for Research Panel

NHC (Dan Brown)

Ideas for future NWS/NHC Tropical Cyclone products and services include Day 6-7 track and intensity forecasts; new format for Forecast/Advisory (TCM) that could allow for some additional parameters; extension of genesis and storm surge products; enhancements to graphical products; enhancements to communicating uncertainty; and ensemble-based tools to provide guidance for targeting supplemental observations to improve TC predictability. Some externally submitted ideas from emergency managers and others are also being considered.

WFO Tallahasse (Tom Johnstone)

Hurricane Michael was the third-most-intense continental U.S. landfall by pressure and fourth-strongest by maximum sustained winds on record. Michael was also the most-intense Florida Panhandle landfall on record, the first Category 4 hurricane to do so in records dating to the mid-19th century. Hurricane Michael intensified right up to its landfall near Mexico Beach, Florida, around 12:30 p.m. CDT Oct. 10 as a high-end Category 4, with maximum sustained winds of 155 mph and a minimum central pressure of 919 millibars. The National Hurricane Center's Storm Surge Unit estimated peak storm surge inundation of 9 to 14 feet above ground likely occurred from Mexico Beach through Apalachee Bay. Michael spread a swath of heavy rain

from the Florida Panhandle to the mid-Atlantic and southeastern New England. In addition to extensive structural damage, hurricane force winds caused widespread power outages across a large portion of the tri-state region. The catastrophic winds also resulted in damage to the timber and agricultural communities across Florida and Georgia. The Tallassee WFO deployed personnel to work at emergency centers and at other NWS WFO locations. Lessons learned included the need for redundant operational internet, time of departure graphics, robust/ reliable observing equipment, and two- person deployments to EOCs for tropical operations.

JTWC (Matthew Kucas)

New products and services include the two-week TC formation outlooks available to DoD entities. These outlooks will have detailed information for each area identified in the two-week outlook, including prospective formation location and timeline. Process development continues at JTWC with AWIPS hardware being installed, training and procedure development in progress, prospective GALWEM GRIB data ingest, and intensity analysis using microwave satellite imagery. JTWC R and D efforts are aligned with their research priorities: TC intensity change, TC structure specification, data exploitation, TC track forecast improvement, and TC genesis timing and forecast.

Storm Center Communications, Inc (Dave Jones)

A project on improving In-Flight situational awareness and science through an SBIR Phase III Technology is underway. GeoCollaborate is a proof-of-concept project to streamline the development and delivery of science-based decision support datasets to NOAA's HRD and AOC, and possibly within NHC. It would place all scientists and flight operations personnel on the same map at the same time looking at the same data to improve science and situational awareness. It provides a robust data sharing environment for on-plane data access and sharing which would maximize efficient use of bandwidth while missions are in progress.

Freie Universität Berlin (Rupert Klein)

The dynamics of strongly tilted Hurricane vortices was presented by Mr. Klein. He described the structure of atmospheric vortices as represented by two scales and by a cascade of scales. He explained the variations related to the vortex tilt in the incipient hurricane stage, the adiabatic lifting in a tilted vortex, the heating pattern for maximum intensification, the spin-up by asymmetric heating, the spin-up by asymmetric convection, and intensification and tilt destabilization.

Session 3: Observations

HRD (Jon Zawislak)

The Hurricane Field Program – Intensity Forecast Experiment (IFEX) 2018 season research mission included the Saharan Air Layer (SAL)/Joint Polar Satellite System (JPSS) real-time evaluation of the NOAA Unique Combined Atmospheric Processing System (NUCAPS) in support of the NESDIS/JPSS SAL evaluation effort. Data on TC intensity were collected during P-3 missions. Preliminary comparison indicated that the NUCAPS satellite retrieval struggles to replicate the complex thermodynamic profiles associated with transitions between airmasses, particularly at the boundaries of the Saharan Air Layer. Dropsonde data were also collected for genesis focused research. The 2019 IFEX will focus on intensity, track and structure change and

their impacts. It will have more explicit goals related to R2O and O2R and the Hurricane Analysis and Forecast System (HAFS), NOAA's next-generation multi-scale numerical model and the associated data assimilation package.

53 WRS: Lt Col Kaitlyn Woods

The OFCM Working Group for Air Reconnaissance Equipment (WG-ARE) requirements meeting was held at NHC Tuesday, 27 November 2018 and developed a list of technological improvements planned for reconnaissance in 2019. The requirements agreed upon included the swath of surface winds speeds (not just a point); 3D wind including clear air (vertical and horizontal); 3D temp and moisture; boundary layer and below temperatures, winds and moisture (from UAVs); sea surface temperatures, sub surface ocean structure (temperatures, currents and salinity); 2D wave spectra; and microphysics above the freezing level. Technological improvements for 2019 include new hygrometers, software upgrade, new VDM, new Ground Stations, AXBT launcher, and new mission computers. These improvements need Broadband to be fully effective but Broadband funding subscription costs continue to be a big challenge.

AOC: Jack Parrish

Only one P-3 was available for 2018. It was flown in six named storms plus a Costa Rica genesis research deployment. The G-IV met requirements in the Atlantic and Pacific and conducted three Pacific deployments. The G-IV transitioned to RD-41 dropwindsondes in September 2018. For 2019 there will be two operational P-3s and both will have the new multi-mode radar and the upgraded tail doppler radar. The allocated hurricane hours for FY19 have been split between operations and research. Central Pacific (Hawaii) operations may be considered for both the P-3 and the G-IV.

Ocean Observations (NDBC): Karen Grissom

The value of buoy observations is that they provide background initial conditions prior to TC formation. They are also useful for validation/ground truth, developmental testing and calibration, contribute to post storm understanding of the magnitude and duration of ocean response, capture temporal variability, and they are impervious to cloud cover. NDBC has deployed buoys with newer technology. They moved SST from hull mounted to in-situ bridle mount enabling faster response time. There is added capability for RT subsurface in-situ T,S,P (and currents) and excellent coverage of time domain and less time aliasing. Other features include high-resolution near real-time data to the Global Telecommunication System and hurricane supplemental observations (barometer, wind speed and direction reports and one-minute extremes).

NASA: Kathy Rice

The destructive wind forces of Hurricane Irma were compared to other hurricanes impacting NASA Kennedy Space Center for the period 2004 – 2017. The destructive force can be calculated by integrating the kinetic energy over the duration of the high-speed winds. Irma was the latest in the comparison of 6 storms in this study. Although the highest sustained wind speed ranked 2nd / 3rd for Integrated Kinetic Energy (Destructive Wind Force), the large wind field resulted in the second longest duration of destructive winds (46 hours) even though the storm was the farthest distance from KSC compared to the other storms in the study.

Session 4: Hurricane Working Group

A separate Record of Actions (ROA) covers this session/meeting and is available on [OFCM's website](#).

Session 5 was cancelled.

Session 6: Research Supporting Operations Forum: Current Research and Plans for the Future

HFIP (NOAA) Frank Marks

The 2017 Weather Research and Forecasting Innovation Act calls for HFIP renewal to: improve prediction of RI and track; improve forecasts and communication of storm surge and other hazards; and incorporation of risk communication research to create more effective products. Current forecast products, metrics, and verification fall short of those needed to support the 2017 Weather Research and Forecasting Innovation Act goals. Research must expand to address all impacts from hurricanes (e.g., wind, surge, inland flooding, severe weather) and incorporate risk communication research to create more effective TC products.

Hurricane Supplemental – Sheema Lett

The Bipartisan Budget Act of 2018 identified $50,000,000 to improve weather forecasting, hurricane intensity forecasting, flood forecasting and mitigation capabilities, and data assimilation from ocean observing platforms and satellites. The approved $50M spending plan was divided across five NOAA Line Offices who identified twenty-seven projects across four primary focus areas that include data assimilation for observations, flood forecasting and mitigation, hurricane intensity forecasting, and weather forecasting. Supplemental funding enables significant acceleration of priority HFIP activities and Unified Forecast System (UFS) activities. The Hurricane Supplemental (HSUP) team is finalizing stringent monthly reporting processes and monitoring requirements.

ONR – Coastal Impacts of Hurricanes - Reggie Beach

A new method for tropical cyclone reanalysis has been used to provide very accurate surface forcing to drive surge and hydro- and morphodynamic models used by the ONR iFMSIP group.

For observations well-constrained pre-event inputs are key. These include topography of the impacted area, vegetation maps from aerial photography and topo/bathy from survey maps.

During and post-events needs include water levels from pressure sensors at 1-5 km spacing, both ocean side and bay side, wave heights from (small) buoys outside surf zone and topography of the impacted area immediately after the event. Research needs are hydrodynamical, morphodynamical, vegetative/structures, and fast computational solvers.

RMS – Mark Powell

Florida has $3 Trillion at risk from hurricane damage. RMS is the global leader in catastrophe modeling for the insurance and financial industries. Their RMS-HWind team in Tallahassee Florida does state of the art real-time hurricane analysis using data from all available surface and space borne observation platforms. Forecasting is done with multi-models, regional models,

ensemble models, and intensity and rapid intensity prediction schemes. Continued investment in the development of air and space platforms and validation of their observations is critical to map global storm impacts in support of insurance and financial industries.

HRD – Joe Cione

The UAS has shown that it can provide data coverage of the critically important, yet sparsely-sampled tropical cyclone boundary layer environment. An sUAS incudes the unmanned aircraft itself and its associated elements. The sUAS data collected in Hurricanes Maria and Michael demonstrated the endurance of the system in high-wind TCs and within a hurricane eyewall. The high-frequency continuous wind measurements at low altitudes were transmitted to NHC each day. These unique data have the potential to significantly enhance physical understanding of a rarely observed region of the storm, improve operational situational awareness and provide

valuable insights for (coupled) model evaluation and improvement. In 2019 NOAA will acquire several air-deployed sUAS. Clear-air testing of this new, longer-duration sUAS platform ("Altius-600") will begin as early as Q4 2019 with TC missions possible in 2020.

Session 7: Global Model Advances and Plans

EMC: GFS/FV3 – Vijay Tallapragada

Finite-Volume on a Cubed-Sphere (FV3) GFS is being configured to replace spectral model-based GFS (NEMS GSM) in operations in Q2FY19. EMC is aware of and working on understanding/addressing issues. The snow depth and the water-equivalent of snow depth at the surface have unrealistically large values when precipitation occurs in environments with low-level temperature profiles close to freezing. Algorithms that use either of these variables for deriving snowfall will exhibit excessive snowfall values. The model forecasts exhibit an increased cold bias in the lower atmosphere that became more prominent after late September 2018. Arctic temperatures in the analysis are also excessively cold. EMC is conducting parallel experiments, one for winter of 2018/19 and one for 2018 summer (hurricane season) with proposed remedies. Results will be presented through EMC MEG later this month.

ECMWF – Fernando Prates

ECMWF progress in tropical cyclone forecasts is related to assimilation, observation, and model changes. Continuous data assimilation decouples observation cut-off time from when assimilation is started. Later observation cut-off extends the assimilation window (6 to 8 hours) to use all available observations. Cycle 46r1 (this June) contains important model upgrades. They include longer assimilation window, later observation cut-off, an increased number of ensemble data assimilation members, weakly coupled data assimilation (ocean-atmosphere) and a new wave physics package.

FNMOC: Global Model Advances and Plans– Jon Moskaitis

Similar to recent prior years, Navy Global Environmental Model (NAVGEM) track forecast accuracy is behind that of leading global models in all TC basins at all lead times. Compared to GFS, NAVGEM initial time TC vortices are weak, shallow, broad, and moist. NAVGEM v2.0 (19 km, L60) is planned to be operational for the 2019 NH TC season, and NAVGEM v3.0 (13 km, L100) is scheduled to be operational for 2020.

557th Weather Wing: Global Air-Land Weather Exploitation Model (GALWEN) – Steve Rugg

The core of GALWEM is the UK Met Office Unified Model. The current version is UM v10.4. The Northern Hemisphere track error for hurricanes is on a par with recent seasons.

Legacy WRF-based Ensemble Cyclone Tracking was used by JTWC in the past. The GALWEM tracker capability is based on the modified Marchok tracker capability and is a sound improvement over the legacy WRF capability. Science improvements to GALWEM have reduced central pressure bias and improved track as observed with Atmosphere-Ocean coupling.

Session 8: Regional Model Advances and Plans

EMC – HWRF/HMON – Avichal Mehra

NCEP dynamical models performed very well in the North Atlantic Basin for the 2018 Hurricane season. The Global Forecast System (GFS) provided forecasts with the lowest track errors. It provided the best numerical track guidance for Hurricanes Florence and Michael. HWRF was the best dynamical model with the lowest intensity errors prior to Day 3 when it was comparable to the official forecasts from NHC. After Day 3, GFS had the lowest errors. NCEP dynamical models performed very well in the North East Pacific Basin as well for the 2018 Hurricane season. HMON provided forecasts with the lowest track errors. FY20 HWRF upgrades include system and resolution enhancements, and physics advancements. Goals for the Hurricane Analysis and Forecast System (HAFS) are to develop an FV3 based multi-scale model and data assimilation package capable of providing analyses and forecasts of the inner core structure key to improve size and intensity predictions as well as the large-scale environment that is known to influence the TC's motion. The intent is to also provide an advanced Hurricane Analysis and Forecast System for cutting-edge research within the outlined Next Generation Global Prediction System plans for the Unified Forecast System.

NRL – COAMPS-TC – Jim Doyle

COAMPS-TC is a specialized version of COAMPS designed to predict tropical cyclone (TC) track, intensity and structure (wind radii). It is one of the top models for TC track and intensity prediction worldwide. Upgrades for 2019 include improved convection, radiation/ice microphysics interactions, CTCX modifications for FV3GFS and ocean data assimilation. For 2020 and beyond: resolution of 36/12/4/1.33 km or 12/4/1.33 km, 60/80L; basin scale; more ensemble members; storm scale DA; new physics; and air-ocean-wave coupling.

Session 9 Research Supporting Operations: JHT Project Status

The Joint Hurricane Testbed (JHT): A 2019 Update Jason Sippel (NOAA/HRD)

Six projects started 1 July 2017 (FY17-19, 9th Round) and are underway:

- JHT Project 1: Evolutionary Programming for Probabilistic Tropical Cyclone Intensity Forecast – Paul Roebber, Clark Evans, Jesse Schaffer (UW-Milwaukee)
- JHT Project 2: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models Using Wind Structure and Eye Predictors – Galina Chirokova (CSU/CIRA), John Kaplan (AOML/HRD)

- JHT Project 3: Improvements and Extensions to an Existing Probabilistic TC Genesis Forecast Tool Using and Ensemble of Global Models – Bob Hart and Dan Halperin (FSU)
- JHT Project 4: Estimation of Tropical Cyclone Intensity Using Satellite Passive Microwave Observations – Haiyan Jiang (Florida Intl Univ.)
- JHT Project 5: Transition of Machine-Learning Based Rapid Intensification Forecasts to Operations – Andrew Mercer and Kimberly Wood (MSU)
- JHT Project 6: Ensemble-based Pre-genesis Watches and Warnings for Atlantic and North Pacific Tropical Cyclones – Russ Elsberry (UC-CS)

Session 10: Final Plenary Session

WG/TCORF Report

Dr. Mark DeMaria (NCEP/NHC), Chairperson, briefed the results of the WG meeting. Two previous actions items were closed, and one was continued for additional action. Forty-six NHOP minor changes were approved. Five NHOP recommendations needed additional changes and will be completed for the April 15 deadline to OFCM. OFCM will reactivate the JAG/UAS for potential changes to the 2020 NHOP. A separate Record of Actions (ROA) covers this meeting and is available on OFCM's website.

Conference action items:

David Chorney (OFCM) presented the conference action items:

1. For the 2020 TCORF OFCM will organize a session that reports on HAFS HSUP projects.
2. OFCM will publish the 2019 NHOP on 1 May 2019.

Presentation of the Richard H. Hagemeyer Award

Michael Bonadonna, Federal Coordinator for Meteorological Services and Supporting Research presented the award to Buck Sampson, Naval Research Laboratory. Kenneth Barnett was also recognized for his more than 25 years of IT support to the IHC meetings.

The 2020 TCORF is tentatively scheduled for **March 10-11, 2020** at the AOC facility, Lakeland, FL with an alternative location at Florida International University, in Miami, Florida.