Hurricane Forecast Improvement Project Annual Conference Summary[1]
January 11-12th, 2017, National Hurricane Center, Miami, FL

The HFIP Annual Conference was held at the National Hurricane Center (NHC) the second week of January 2017 and had 73 participants (see last page) with 33 presentations. Vijay Tallapragada, Frank Marks, and Ed Rappaport shared opening remarks along with welcoming everyone aboard. Everyone was reminded of the meeting's purpose to develop a multiple year strategy on how to improve hurricane forecast numerical guidance and in achieving HFIP's overall goals. HFIP's 5 year goals were stated to have been completed, especially regarding intensity however, there were concerns raised about how to continue gains.

HFIP Program Office priorities in 2017 were noted by Fred Toepfer to focus on: (1) Scale-aware model physics, vortex initialization with DA, (2) Leveraging the NGGPS to maintain cross NOAA and community involvement, and (3) Implementing an operational partnership for multi-model ensembles in all basins. Goals will continue to be improving forecaster products, evolve hurricane forecast prediction emphasizing G2L forecasts using multi-scale interactions, improving forecasts for land-falling storms/downstream applications, improving post-landfall precipitation forecasts, and to further develop nesting technology. General 2016 issues outlined early in the conference were: RI failure (*Mathew*), Strong high bias prediction for HWRF weak storms, genesis prediction failures, the GFS ensemble were under-dispersive, and under predicted genesis. Single model ensembles did not produce enough diversity, and GFDL 2016 Jet-based real-time runs could not continue in all basins. The NHC emphasized the HWRF weak storm over prediction needs to be addressed, and research needs to be conducted on the *Mathew* RI issue using test cases.

In 2016, the HCCA model provided best track guidance and provided superior performance to other NHC consensus models. HWRF upgrades in vertical resolution increased track forecasts significantly, especially out to 4-5-days. The JTWC discovered big speed errors in track, especially with the COAMPS. The DTC provided initial promising results in the ATL basin in both track and intensity forecasts. As compared with the GFDL model, the HNMMB consistently showed improved performance of intensity and tracking skill in the N. ATL basin based on 2014-16 seasons. It was discovered when surface drag was changed, intensity prediction improved using the coupled NCOM, and HCCA provided the largest coefficients of intensity for HWRF and COAMPS-TC. HWRF ERC prediction appeared to improve, and HWRF outperformed JTWC operations up to Day-3 for intensity skill. In 2016, progress was made relative to spin-down, the DA/Ensemble Team identified model spin-down issues using hybrid DA and plan to: (1) Replace VI with DA, (2) Continue Hybrid-DA pre-implementation system tests, spin-down issues, R&D on HWRF Hybrid-DA (4DEnVar, hourly 3DEnVar, IAU) including hydrometers and HDOB, dropsondes, GOES-R, and testing beyond single case-study; and (3) Need to get DA and Model Teams working together consistently. The HWRF DA Testing and Plan strategic priority for DA is to add inner-core dropsondes to improve forecasting

[1] See 2016 HFIP Annual Conference Notes for details.

spin-down, bias, and allow for greater data usage. Vortex relocation/initialization was integrated with 6-hourly hybrid DA in 2016 which improved TC analysis and later forecasts. HWRF used OMITT's RTOFS initialization for EPAC storms that improved RI forecasts. FIU, AOML, NCEP, reported data results indicate a "*top-down*" pathway for prediction exists to SEF triggered by the penetrative downdraft resulting from fall-out of lofted solid-phase hydrometeors at the far radii of the primary eyewall. Future DA and testing plans will include integration of RI/RW, storm structure, and replace vortex initialization with self-consistent DA with TCVitals database derived data.

There were numerous coupling efforts implemented in 2016, for example, OMITT coupled HNMMB to HYCOM and POM; HWRF coupled with the POM and WW3; NGGPS was coupled with Earth system modeling; Full ocean coupling was implemented in the NCOM, and 3-Way coupling was conducted using the AWO model. Basin-scale HWRF plans to retrospectively test ocean coupling over a 3-year period starting spring 2017 for potential R^2O. The EMC plans to conduct a full 3-year impact investigation of different mixing schemes for ocean coupling, and determine how HWRF upgrades impact R_{MAX} bias. NHC plans to upgrade to statistical dynamic models. GFDL plans to move into HNMMB and the 10-member HWRF/HNMMB is to happen in 2018-2019. In 2019-2020, NEMS Global nests associated with the NGGPS are to be implemented. From FY17 to FY22, plans are to transition the CFS into a FV3-based GFS Analysis coupled to many Earth system components and strongly coupled DA using NUOPC as a mediator. Numerous model comparisons were noted along with multi-model operational partnerships (Navy, HWRF, JTWC, and GFDL models) and the Ensemble Tiger Team discovered many different models showed preferences for intensity change probabilities. NRL's 2016 COAMP-TC effort plans in 2017 to couple up with NCOM and 3 km ensemble with HFIP, WATL, EPAC, and WPAC; in 2018 to include ocean-wave coupling. GFDL's PPAV Team plans to transfer the latest version of community tracker (GFDL tracker) to the HWRF group with the operational FY16 HWRF upgrade and provide to the DTC for community release. In 2017, the OMITT noted plans to continue development of COAMPS-TC-NCOM 3-way coupling with WW3 including implementation of non-linear current-waves interaction (Stokes drift, Languir mixing) in the HYCOM ocean component. NCEP/EMC plans to conduct a full 3-year study to investigate impact of different mixing schemes for ocean coupling. NEMS plans include: (a) Basin-scale with multi-nesting configuration in NEMS with genesis adaptability, (b) Potential migration from NMMB to FV3-based NGGPS dycore under NEMS, (c) Redo retrospective runs with 2017 GFS data (plus ocean coupling plus other upgrades) to assess these improvements for final statistics before operational implementation (EMC), and (d) Check impact(s) on NHC consensus model tracks and intensity forecasts before operational implementation (NHC). Testing and training activities with the DTC consisted of providing HWRF support/training. DTC also supported physics testing using Thompson microphysics evaluation - mixed - time step issues as well *G-F* cumulus evaluation in HWRF. Future DTC efforts noted were: (1) Ascertain impact on DA by adding a *DA Team* for all physics evaluations, (2) Integrate DTC physics development evaluation with EMC approach to physics evaluation as Dr. Sergio Abarca outlined, (3) Continue R2O potential through T&E (Physics advancement-Thompson and/or G-F schemes, and TC physics migration to NCEP's unified modeling system),

and (4) Continue unified code management/maintenance and user/developer support (public release and active HWRF developers/HFIP Principle Investigators). It was noted that HWRF performance needs to be evaluated and verified focusing on weak storm over prediction and non-development over prediction themes. Christopher Rozoff noted that in 2017-2018 plans are to conduct real-time testing.

Migration efforts in 2016 consisted of JTWC contributing to the ATCF-AWIPS-2 development transition; ATCF maintained core code, upgraded to 64-bit capability, and dedicated a full-time employee NCO contractor to help support the ATCF to AWIPS migration effort with HFIP help. A future operational priority in operational modeling is to replace the operational hurricane wave model with the HWRF system.

Product improvements in 2016 were characterized by advancements in TC-ensemble forecast system design and products. HWRF Basin-scale implemented a new web page with HWRF Basin-scale near real-time products with 18-6-2 km resolution in the FY16 season. HWRF product developments were associated with MSG and AWIPS2. Multi-Model Regional Ensemble efforts resulted in development of *Wind Probability* and *Intensity Change* products. The HFIP Webpage was reported to have had 42,000 views with 9,000 unique users. New 2016 products for the COAMPS-TC RT Ensemble were: *Real-time (RT) 24h Intensity Change Probability, RT RI Probability, RT 10-member Wind Threshold Exceedance Probability, RT Track colored by Forecast Intensity,* and *Performance Statistics for ATL & EPAC*. The PPAV Team reported future efforts will be to continue to develop new NHC Graphical products (*new time of arrival 34 kt. Winds,* and update the TC graphical suite with pre-genesis modifications). The NHC Team plans to provide new products: *storm surge inundation data* vs. evacuation data product using 3 historical cases by 9/30/2017, develop probabilistic surge ensemble products [*experimental probabilistic extra-tropical storm surge (PETSS)* model into AWIPS2]; and to continue in-house testing. It is planned in 2018 for PETSS to become operational. The JTWC employed HNMMB model runs using HFIP resources and the COAMPS-TC ensemble including GFS and UKMet as parent models producing *7-day forecasts* and *34 kt. Dynamical swath product*. In 2017 the PPAV Team plans to continue ensemble product development, repeat the Tiger Team Demo at NHC, and involve both NHC and JTWC in identifying ensemble products designed to improve forecast guidance. The CIRA PPAV Team plans to develop a modern *common wind speed* and *p-surge probabilities framework* by June 30, 2017, and *satellite databases for enhancement to SHIPS/RII/LGEM by 6/30/2017* to improve statistical model performance. Dr. Tallapragada noted HFIP plans to continue the HFIP Webpage for graphics with PPAV Team inputs to sharpen relevant graphics, generate new ensemble products, use HFIP supported projects to develop ensemble techniques supporting deterministic forecasts (pending budget availability and prioritization); develop more products, and provide additional evaluation of high resolution HFIP RT regional multi-model ensembles.
DA improvements were characterized by the DA/Ensemble Team as developing a new fully cycled GSI-hybrid DA system for HWRF, and advancing assimilation of existing or new observations using hybrid or EnKF. DA for HWRF was reported to be undergoing dramatic advancements by Dr. Jason Sippel and the EMC HWRF Team. HWRF also improved vertical wind profile in the surface and PBL. In terms of operational modeling plans, Dr. Avichal Mehra reported that HWRF increased vertical resolution from 61 to 75 levels to the 10-Hectopascal top increased the size of nested domains with smaller time-steps; and assimilation of additional data.

The Basin-scale HWRF improved GSI DA resulting in improved Vortex Initialization. Basin-scale HWRF used Hybrid TDR DA and improved GSA DA Operational HWRF-H216. The OMITT reported to have completed development and evaluation of an optimal target ocean observation tool in NCODA. In 2016 GFDL's nested FV-GFS development effort supported 3 km resolution nesting with 95 vertical levels. NGGPS plans to participate in the JEDI DA effort. Future Basin-scale HWRF plans are to form an *Operational Implementation Transition Plan* and test on operational machine configuration and scalability. HWRF plans an upgrade to include HDOBS DA. Long term plans are to allow for greater data usage, continue to develop the 4D-Hybrid w/IAU., and assimilate new data like GOES-R AMVs, cloudy radiances, inner-core dropsondes, and coupled atmospheric-ocean DA. In 2017, NRL's COAMPS-TC effort plans to integrate ocean DA with NODA and in 2018 to integrate 4D-Var/EnKF, satellite DA, and ocean waves coupled DA. Also in 2018, NGGPS will prioritize satellite DA and ocean-waves-coupled DA and in the NGGPS/FV3 effort plans are to adapt GSI to FV3, and include GOES-R JPSS DA, NCEP coupled hybrid DA Model Ensemble (Atmos-Aerosols, Land using Inline Noah Land Model, Wave using WW3, and Sea-Ice-Ocean). In 2019, Dr. Tallapragada noted coupled DA development and scientific evaluation using JEDI will be pursued. NEMS plans are to continue development of ensemble capabilities and have DA on the FV3 Grid. OMITT reported plans to continue R&D on air-sea stress and targeting ocean/wave observations, implement DA to the HYCOM ocean component, and to implement coupled DA.

Improvements to physics in 2016 were characterized by the Model Physics Team: (1) Ensured observations were consistent with model physics upgrades, (2) Utilized understanding of storm structure and observations to evaluate model improvements, (3) *Incorporated scale-aware physics*, and (4) Maintained alignment with global models. The Model Physics Team plans to: (1) Adopt stochastic approaches, (2) Address identified model biases RI/RW, size, microphysics, ERC, R_{MAX}, structure, air-sea interface, (3) Provide a framework supporting realistic physics scheme development for model upgrades to evolve beyond model evaluation. NGGPS effort emphasized improved representation of the physical processes at all spatial and temporal scales, and unified *G2L scale modeling*. It was noted that FV3 was approved as the interoperable physics driver (IPD) package. GFS IC-BC improved performance. HWRF upgraded to and used the scale-aware SAS convective scheme with the F-A microphysics scheme in high resolution. The DTC is testing scale-aware physics and aerosol-aware physics in HWRF using the G-F physics scheme. The High-Resolution Physics Tiger Team reported plans to maintain performing global model alignment and implemented the G-F Convective scheme in HWRF. GFDL reported that FV3 supports grid stretching and 2-way grid 3 km nesting. The NGGPS effort plans to develop the FV3 based GFS in operations quarter (Q3) FY18, FV3 GEFS in FY19, and become NEMS compliant spectral GFS in FY17. In 2018, *COAMPS*-TC will prioritize PBL fluxes, microphysics 4D-Var/EnKF, and the stochastic physics ensemble. In terms of HWRF Performance, it was expressed there is need to research the *Mathew* RI issue using test cases (e.g., *Hua*) and how the HEDAS performed with this issue. It was noted HFIP needs to focus attention to the *Mathew* RI issue (initialization and physics). COAMPS-TC plans to use stochastic physics in 2018. The High Resolution Physics Tiger Team reported plans to continue to incorporate scale-aware physics, integrate microphysics higher moment (or species advection), and adopt stochastic approaches. In the future GFDL plans to use nested FV-GFS development and to use scale-aware SAS or UW-GFDL convection, Thompson, F-A, or M-G Microphysics in collaboration with the Univ. of Oklahoma-CAPS and EMC), YSU, EDMF, or M-Y-type PBL.

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Acronyms

AOML	Atlantic Oceanographic and Meteorology Laboratory
ATL	Atlantic basin
ATCF	Automated Tropical Cyclone Forecasting System
AWIPS	Advanced Weather Interactive Processing System
AWO	Atmosphere-Wave-Ocean model
BC	Boundary Conditions
CFS	Climate Forecast System
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System
DA	Data Assimilation
DTC	Developmental Testbed Center
EPAC	East Pacific basin
ERC	Eyewall Replacement Cycle
EMC	Environmental Modeling Center
F-A	*Ferrier-Aligo* microphysics scheme
F-Deck	Fix-position deck
FV3	Finite Volume Cubed-Sphere Dynamical Core
G2L	Global to Local
G-F	*Grill-Freitas* physics scheme
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	Global Forecast System
GOES-R	Geostationary Operational Environmental Satellite-R Series
GSI	Gridpoint Statistical Interpolation
GUI	Graphics User Interface
HCCA	HFIP Corrected Consensus Approach
HEDAS	Hurricane Ensemble Data Assimilation System
HFIP	Hurricane Forecast Improvement Project
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[2] Speaker(s)

Acronyms (Continued):

HFIP	Hurricane Forecast Improvement Project
HNMMB	Hurricane Non-hydrostatic Multi-scale Model on B grid
HWRF	Hurricane Weather Research and Forecasting
HYCOM	HYbrid Coordinate Ocean Model
IAU	Incremental Analysis Update
IC	Initial Condition
IPD	Interoperable Physics Driver
JEDI	Joint Effort for Data Assimilation Integration
JTWC	Joint Typhoon Warning Center
NCO	NCEP Central Operations
NEMS	NOAA Environmental Modeling System
NHC	National Hurricane Center
NGGPS	Next Generation Global Prediction System
NUOPC	National Unified Operational Prediction Capability
OMITT	Ocean Model Impact Tiger Team
PPAV	Post Processing And Verification
PBL	Planetary Boundary Layer
POM	Princeton Ocean Model
R^2O	Research To Operations
R_{MAX}	Maximum Radius
R&D	Research and Development
RI	Rapid Intensification
RTOFS	Real-Time Ocean Forecast System
RW	Rapid Weakening
SAS	Simplified Arakawa-Schubert scheme (Pan & Wu, 1995)
SEF	Secondary Eyewall Formation
T&E	Testing and Evaluation
TC	Tropical Cyclone
TCVitals	Tropical Cyclone Vitals
WPAC	West Pacific basin
WW3	Wave Watch III