



Long-Range Operational Hurricane Modeling Plans at EMC

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- Operational hurricane modeling plans for the future:
 - **Three-way coupled HWRF-HYCOM-WaveWatchIII System**
 - **Transition of HWRF into HNMMB (Replacement for GFDL)**
 - **Basin-Scale Hurricane Modeling Plans**
 - **Hurricane Ensemble Modeling Plans**
 - **Tropical Hurricane Modeling Plans**
 - **Global-to-local Scale Hurricane Modeling Plans (NGGPS)**
- Accelerated transition of HFIP/HIWPP/NGGPS supported research to operations; continue community modeling approach.
- Unified regional and global modeling concepts adopted by NCEP (recommended by UMAC).
- Strategies for serving the next-generation needs of operational hurricane forecasters



Advancing the HWRF System FY2016 & Beyond



	2016*	2017	2018	2019	2020+
Resolution/ Infrastructure	WRF-NMM core V3.7.1a with retention of non-hydrostatic status during the nest movement	community R20 (HFIP/HIWPP) efforts, basin-scale HWRF; NEMS/NMM-B	~1km deterministic forecasts, ~2km HWRF Ensembles, Basin Scale/Tropical modeling for hurricanes for genesis and 7-day forecasts, Global NH Model w/hurricane nests (NGGPS)		
Physics	Microphysics, PBL scheme upgrade	Advanced microphysics including impacts of dust and aerosols, Coupling to Sea Spray, Scale-aware, stochastic physics for high-resolution			
DA/ Vortex Initialization	Improve inner core DA (TDR, dropsonde, aircraft recon, clear sky satellite radiances), invest cycling	4D Hybrid-EnKF DA with IAU, advanced vortex relocation as part of DA, all sky/cloudy radiance assimilation, self cycled ensembles for DA			
Ocean	RTOFS based ICs for EPAC, possible HYCOM/ Wave coupling	Improved ocean data assimilation, physics and resolution, unified coupled system for all basins			
	HWRF-HYCOM for all oceanic basins (driven by Global RTOFS)				
Waves	One-way coupled	Two-way with Multi-grid surf zone physics, effects of sea spray			
Diagnostics and Product Development	HWRF Ensemble based products, Coupling to Hydrological/ Surge/ Inundation models, advanced model diagnostics based on observations, improved product development				

2016 upgrades

Long term/ongoing developments



Future Outlook 5 years and beyond



	5 years	2020+
Resolution/ Infrastructure	Basin-Scale HWRP/HNMMB with multiple moveable nests (at cloud resolving resolutions) and high-resolution HWRP ensembles , development of global non-hydrostatic model with hurricane nests (NGGPS); Higher (1km) resolution Downstream applications (including landfall related storm surge, waves, flooding and inundation)	Global to Local Scale Modeling and High-Resolution Ensembles for hurricanes
Physics	Observations based scale-aware physics Incorporate effects of sea-spray, aerosols, waves, boundary layer rolls – explicit representation of inner core processes	Ensemble based stochastic and scale-aware physics approach
DA/ Vortex Initialization	Hybrid/EnKF with 4-D VAR Vortex initialization within the DA, focus on assimilation of all-weather radiances and aircraft data	Part of the data assimilation for global system
Ocean/Wave/ Land	Fully coupled ocean-wave-land-atmosphere system for improved representation of air-sea interactions	
Products & Downstream applications	Meeting the next-generation needs of Hurricane Specialists at NHC, CPHC and JTWC and other NWS users through developing forecaster specific products, guidance on guidance, warn on forecasts	



HWRF Evolution Over the Next 5 Years



➤ Major forcing factors

- NHC Track and Intensity GPRA goals: Saving lives & property through reduced errors and increased accuracy of tropical cyclone forecasts
- Continuous forecast improvement goals targeted by HFIP and NGGPS
- Reliable and accurate high-resolution forecast guidance for significant weather events associated with tropical cyclones
- Comprehensive forecast solutions for all aspects of tropical cyclones from genesis through dissipation, including downstream applications

➤ Science and development priorities

- Continuous improvements to model resolution, dynamics and physics, modeling storm-storm and multi-scale interactions; Assimilation of all-sky radiance and all available data; Improved air-sea-wave-land-hydrology coupling and High-resolution ensembles

➤ What are your top challenges to evolving the system(s) to meet stakeholder requirements?

- Rapid transition of scientific research and developments supported by HFIP and NGGPS; Computational resources; Data collection, quality control and real-time transmission, Technological and engineering aspects, appropriate representation of scale-aware and stochastic physics, ensemble strategies

➤ Potential opportunities for simplification going forward

- Transition to NMMB/NEMS → Unified mesoscale models for convective scale forecasts
- unified non-hydrostatic global model with high-resolution nests coupled to ocean, waves, land and hydrology



Motivating factors for unification of operational hurricane modeling in NEMS



- 1. Strategies for unified regional (meso-scale) models in the NEMS framework**
 - Be able to meet the performance of current operational HWRF
 - Accommodate future development strategies including coupling to ocean, waves, land, surge and hydrology
 - Retain and expand community interactions fostered by HFIP
 - Flexible options for inner-core data assimilation
 - Enable future ensemble strategies and potential genesis and 7-day intensity forecasts
- 2. Strategies for unified global model with multiple moveable nests**
 - Take advantage of NGGPS supported development of non-hydrostatic global model in NEMS with high resolution nests for hurricanes
 - Transition regional hurricane model components to global system for seamless prediction of hurricanes and severe weather
- 3. Strategies for serving the next-generation needs of operational tropical cyclone forecasters**
 - Expand the products to include deterministic and probabilistic forecast guidance on genesis, rapid intensity changes, size, structure, storm surge, rainfall, flooding and inundation and warn on forecasts



HNMMB as a replacement for GFDL & Unification of Hurricane and Hurricane Wave Models



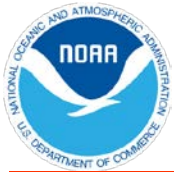
- ❑ Having two independent NCEP atmospheric hurricane model forecasts has provided a critical increase in overall NCEP hurricane forecast skill.
 - ❑ NEMS/NMMB is not a community model yet, while HWRF is; it will take years of efforts to make HNMMB a community model for hurricanes.
- ❑ Hurricane Wave Model is a separate model in operations driven by hourly forcing from operational HWRF. Combining HWRF and Hurricane Waves through implementation of three-way coupled system will help simplify the production suite (UMAC recommendations)
- ❖ **NEMS based HNMMB will replace the GFDL Hurricane Model by 2017 while HWRF continues in operations.**
- ❖ **NCEP Hurricane Wave and HWRF can be merged into one model.**



HWRF-HYCOM-WAVEWATCHIII



- Three-way coupled system development is in mature stage
- HYCOM for all global tropical storms:
 - has been experimented with for the past seven years
 - OMITT helped improve the initialization and physics of HYCOM
 - 2016 HWRF upgrades will include testing of HWRF-HYCOM (or HWRF-MPIPOM with RTOFS initial conditions)
- One-way or two-way coupling with WaveWatchIII Hurricane Wave Model (multi2)
 - Possible unification of hurricane wave model with HWRF for all tropical cyclones (UMAC recommendations)
 - Two-way coupled system expected to enhance the representation of wave impacts on surface layer physics
 - 2016 HWRF upgrades will include either of these options, with fully coupled system planned for 2017



Long-Term Plans



2016	2017	2018	2019	2020
GFDL	HNMMB	10-member HWRF/ HNMMB Ensembles	NEMS Global Nests (NGGPS)	
HWRF Operational Model Continues Followed by Ensembles				
Basin-Scale HWRF/NMMB—Tropical NMMB Domain				

Hurricane Models take over Hurricane Wave Forecasts

Development, T&E and Implementation Plans for HNMMB (supported by HFIP and HIWPP)

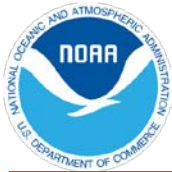
- 2016 June-Nov: uncoupled real-time demo
- 2016 Nov: single-storm, coupled, no-DA ready
- 2016 Nov-Dec: skill proven better than GFDL & comparable to HWRF
- 2017 Jan-May: HNMMB pre-implementation test
- 2017 Jun: HNMMB replaces GFDL operationally



Progress of HNMMB Developments



Task	Status	Lead/support Personnel	Note	Start/Complete date
Transition of HWRF physics suite to NMMB	Done	Weiguo Lin ...	Update to 2015 hwrf version Need tests	Update by June, 2015
HWRF nest motion algorithm to NMMB	Done	Sam Weiguo ...	With some in-model diagnostic fields	June/May to Sep, 2015
HWRF vortex initialization to NMMB	Done	Qingfu Lin...	Need tests	April to June 2015
Ocean POM/HYCOM to NMMB	Shortly	Bin Dmitry Hyun-Sook	Regional Hycom	POM: Dec 2015 HYCOM: planned
Ocean coupling	Shortly	Dmitry Bin	progress in nems's NUOPC is slow. May need a hwrf-like coupler for use in a year	Dec 2015
HWRF data assimilation	Planned	Mingjing, Jason, Bin...	GSI-EnKF Interface/data change	March 2016
Post processing Graphics	Planned	Lin Sam Weiguo ...	now OK to use ncep-post,	March 2016
Scripting	Planned	Sam, Zhan Mingjing ...	HWRF-like Python script	May 2016



Basin-Scale/Tropical Domain Transitions



2016

2017

2018

2019

2020

Basin-Scale HWRF/NMMB——Tropical NMMB Domain

Large basin-scale domains that forecast multiple storms at the same time.

Need to show the value (cost vs. benefit)

Primary focus is for NATL/EPAC basins

Seven day forecasts including genesis.

Such large domains are needed for good wave forecasts

HNMMB could do a “tropical domain”: -60 to +60 latitude, cyclic in longitude; Covers all storms.

2016: HWRF/HNMMB basin-scale parallel

2017: HWRF/HNMMB basin-scale operational (???)

2018:

HNMMB basin-scale operational

HNMMB tropical domain parallel

2019: HNMMB tropical domain operational

2020 onward: develop global nests to replace HNMMB tropical domain with the new non-hydrostatic dycore (NGGPS)



High-Resolution HWRF Ensembles



2016	2017	2018	2019	2020
GFDL	HNMMB	10-member HWRF/ HNMMB Ensembles	NEMS Global Nests (NGGPS)	

HWRF Ensembles have been showing value during the past three years (HFIP Demo).

Surge in computing at NCEP operations allows us to plan for implementing high-resolution HWRF ensembles

Take advantage of ensemble DA, perturbations in physics and IC/BCs

Develop products that directly benefit NHC operations to improve deterministic forecasts

2016/2017: Continue HWRF ensemble HFIP Demo (multi-model regional ensembles); add HNMMB members to the mix

2016/2017: Develop advanced products for providing guidance on guidance and probabilistic forecasts

2018: 10-member HWRF/HNMMB ensemble implementation



Tropical Domain Transitions



2016

2017

2018

2019

2020

Basin-Scale HWRF/NMMB——Tropical NMMB Domain

2017 Nov: Full DA, basin-scale, system ready.

2018 Jun: HNMMB with DA operational

Basin-scale, just like HWRF.

Upgrade at same time as HWRF.

2018 Nov: “Tropical” domain ready

2019 Jun: “Tropical” HNMMB model operational

2019 onward:

- Development switches to global nesting implementation.
- Three-way global coupling (wave/ocean/atmos)
- Target 2021 for parallel.
- Target 2022 for implementation.
- Follows the path of NGGPS for hurricanes.
- Assists in developing advanced modeling techniques for NGGPS hurricane components



Hurricane Wave Forecasts

2016

2017

2018

2019

2020

Hurricane Models take over Hurricane Wave Forecasts

2016 June 1: HWRF wave coupling.

2017: Wavewatch3 hurricane-tracking nests.

HWRF wave as skilled as existing model

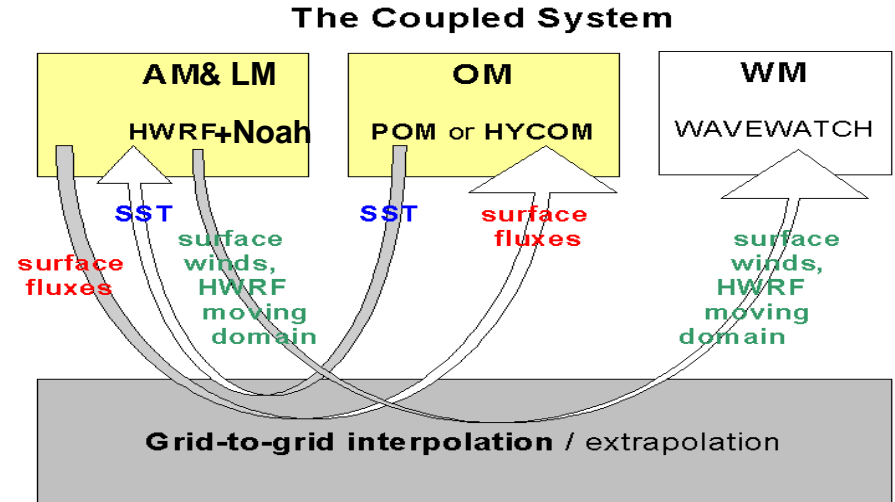
2017: Add all Hurricane Wave outputs to HWRF.

2017: NCEP Hurricane Wave Model retired

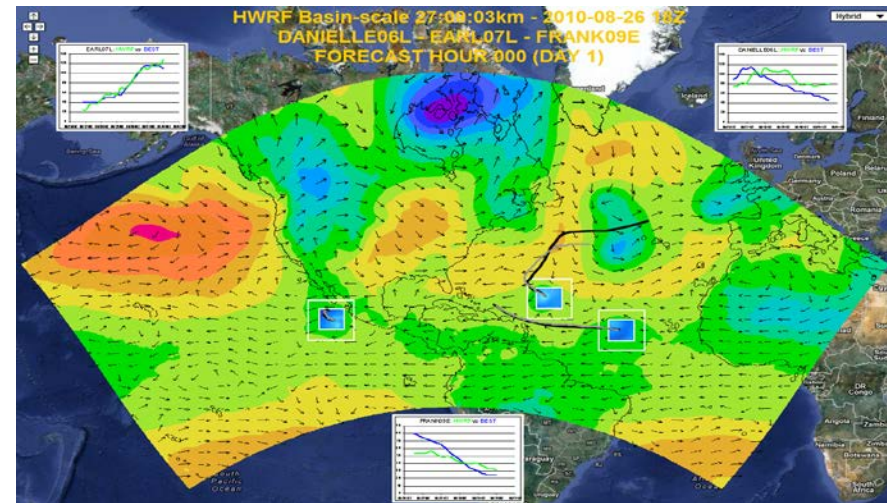
2018: HNMMB wave produces all hurricane wave outputs

Future Plans: Hurricane Physics

- Align with HFIP Physics Strategy
- Focus on improved air-sea interactions and inner core processes
- Advanced scale-aware and stochastic physics with focus on multi-scale interactions

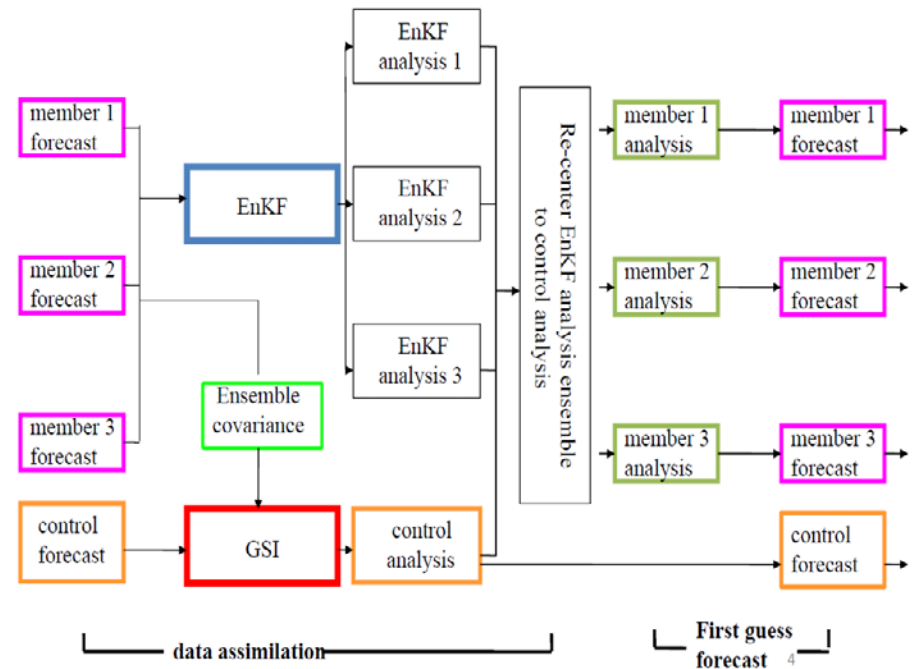


(additional WM? AM and WM? OM communications in progress)



- Align with HFIP DA Strategy
- Focus on inner core aircraft and all-sky radiance data assimilation
- Advanced self-cycled HWRF EnKF-GSI Hybrid Data Assimilation System (HDAS)
- Vortex relocation and initialization become part of Data Assimilation

Hybrid EnKF-GSI DA system: 2 way coupling





Summary



Good prospects for 2016 HWRF Upgrade

2017 targets:

HWRF basin-scale with ENKF, new PBL and surface layer

HNMMB with no DA replaces GFDL

HWRF produces all standalone hurricane wave outputs

Standalone hurricane wave model is retired.

2018:

HNMMB basin-scale with wave forecasts and DA

HWRF wave forecasts as good as standalone

10-member HWRF/HNMMB Ensembles

2019:

HNMMB single tropical outer domain for all storms

2020 onward: development switches to global nests.