2020 Basin-scale HWRF (HWRF-B) HFIP Real-time Experiment (HREx)

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What is Basin-scale HWRF (HWRF-B)?

A busy day in the tropics...

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**HWRF-B Configuration**

- **HWRF and HWRF-B nearly identical:**
  - Dynamical core
  - All physics
  - Vertical/horizontal resolution
  - Ocean model

- **Key configuration differences**
  - **Outermost domain size**
    Covers NHC Area Of Responsibility
  - **Multiple high-resolution nests**
    Up to 3 this year
  - **Ensemble data assimilation**
    Developed for multiple storms (no RT)
  - **Ocean coupling**
    POM initialized from RTOFS w/ multi-storm coupling (Alaka et al. 2020)

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<tr>
<th>Configuration Options</th>
<th>HWRF-B</th>
<th>HWRF</th>
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| **Domain**            | 13.5 km: 194.0° x 84.2°  
                        4.5 km: 16.5° x 16.5°  
                        1.5 km: 5.5° x 5.5°      |
|                       | 13.5 km: 77.2° x 77.2°  
                        4.5 km: 17.7° x 17.7°  
                        1.5 km: 5.9° x 5.9°      |
| **Model Top**         | 10 hPa            | 10 hPa |
| **Vertical Levels**   | 75                | 75     |
| **Vortex Init.**      | At 4.5/1.5 km     | At 4.5/1.5 km |
| **Data Assimilation** | Hybrid & TDR-based EnKF (for multiple storms) | Hybrid & TDR-based EnKF (for 1 storm) |
| **Ocean Coupling**    | 13.5/4.5 km: YES (POM)  
                        1.5 km: Downscaled       |
|                       | 13.5/4.5 km: YES (POM)  
                        1.5 km: Downscaled       |
| **Multi-Storm**       | YES               | NO     |

**PHYSICS SCHEMES**

- **Microphysics**
  - Ferrier-Aligo
  - Ferrier-Aligo
- **Radiation (LW,SW)**
  - RRTMG
  - RRTMG
- **Surface Layer**
  - HWRF (GFDL-based)
  - HWRF (GFDL-based)
- **PBL**
  - GFS Hybrid-EDMF
  - GFS Hybrid-EDMF
- **Convection**
  - Scale-Aware SAS
  - Scale-Aware SAS
- **Land Surface**
  - Noah LSM
  - Noah LSM

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HWRF-B: A Baseline for HAFS

Courtesy of Bill Ramstrom (AOML)
Important Milestones

- 884 forecasts from 2020 HWRF-B (HB20) for 37 NATL and EPAC storms (56+ w/ invests)
  - 25% of HB20 forecasts ran on Hera (fallback w/ no reservation)
  - 318 forecasts for B220: Parallel experiment (HB20 w/ 5 storms & ensemble DA) on Hera

- Delivery of ATCF files for HWRF-B (and all HFIP models) to NHC in near real-time
  - Thanks to Stephanie Stevenson, Brian Zachry, and others @ NHC!

- Effectively communicated with the public via the AOML Hurricane Model Viewer:
  - Delivery of over 30M graphics for the 2020 hurricane season (5M for HWRF-B)
  - 2830 unique users, 23000 page views

- Successful implementation of HWRF’s self-cycled DA system for multiple storms
  - Did not run in HB20 due to CPU resource constraints

- Generalized coupling scheme implemented to simplify coupling for multiple nests

- HWRF-B tested for potential ops. implementation on WCOSS last winter (TRL8)
  - Came within 10% of the NCO forecast time limit for HWRF (~110 min)

- Six HWRF-B peer-reviewed publications published since 2017 on a wide variety of topics.
AOML Hurricane Model Viewer

AOML Hurricane Model Viewer

Graphical products for experimental NOAA models and operational models

https://storm.aoml.noaa.gov/viewer

Supported these models in 2020:
- HWRF-B*
- HAFS-A*
- HAFS-B*
- HAFS-E*
- HAFS-J*
- FV3-RRFS*
- HWRF
- HMON
- GFS
- ECMWF

*denotes HFIP model
HWRF-B (HB20) intensity errors were quite good (especially vs. HWRF) at most lead times. HB20 had lowest intensity errors at 48/60/72 h.

HB20 intensity skill was generally positive in the open Atlantic. Lower track skill in the Gulf of Mexico.
Track Verification: North Atlantic

**Absolute Track Errors**

- **HB20** track errors were quite large at 72+ hours (> 250 n mi at 120 h). We were surprised by differences with **HWRF**; not so in retro forecasts.

- **HB20** track skill versus **HWRF** was negative in two regions: (i) higher latitudes and (ii) the Gulf of Mexico.
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Performance at Lower Latitudes

**Absolute Track Errors**

- HB20 track errors reduced considerably for points south of 30°N and were comparable with HWRF at most lead times.

**Absolute Intensity Errors**

- HB20 intensity errors were still comparable or better than HWRF at most lead times.
What is Happening at Higher Latitudes?

The outermost domain was shifted north by 10°, and higher latitudes were less constrained by GFS than in previous versions.
Typically, midlatitude systems were too strong and/or fast in HB20.
Isaias (09L) had large along track errors (too fast) due to stronger synoptic-scale systems north of 40°N.
Multi-Storm Evaluation

- (left) HB20 track errors were cut in half by day 5 when 3+ storms were active in NATL/EPAC
- (right) HB20 results are consistent with HWRF-B retrospective results that showed higher track skill score at later lead times when more storms were active.

Alaka et al. 2020, *Atmosphere*
Multi-Storm Evaluation

Most of the 1-2 storm forecasts were also at higher latitudes, so more analysis (and cases) is required to separate the influence of each.

HB20: 1-2 storms
HB20: 3+ storms

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24-h Intensity Change: HWRF-B vs. Best Track

**HB20** RI was very well calibrated

- **95th percentile:** 31 kt / 24 h
- **Interquartile range:** 23 kt

**Best Track**

- **95th percentile:** 30 kt / 24 h
- **Interquartile range:** 20 kt
Rainfall Evaluation: Eta (29L)

- HB20 predicted a significant rainfall threat at least 2 days in advance (widespread 4”+).
- Strip of higher rainfall totals (7”+) was well predicted but displaced to the north.
Summary & Conclusions

- For the first time, the HWRF-B system has caught up with the HWRF repository
  - However, ensemble DA wasn’t run in real-time due to resources
- HWRF-B continues to show value for multiple high-resolution nests in the same outer domain
- HWRF-B performance was degraded at higher latitudes (> 30N)
  - Attention should be paid to the evolution of the midlatitude flow in large regional domains (or nests)
- The benefits of self-cycled ensemble DA alone are still unclear due to small sample sizes → B220 experiment
  - Lower intensity errors at early lead times for B220 versus HB20
- Rainfall predictions for Eta were excellent. It will be a priority to continue to develop and evaluate rainfall products in HAFS...
Recent HWRF-B Publications


EXTRA SLIDES

Please email questions or comments to:
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Evolution of HWRF-B: A Team Effort

- Oper. HWRF Implementation & Public Release
- HWRF-B Development: Readiness Level 4
- Real-Time Demonstrations: Readiness Levels 5-7
- Community Code Merge: R2A
- Data Assim. Improvements: O2R & R2O
- Dynamic Ocean Coupling: R2A
- HWRF-B Implementation: R2O @ Readiness Level 8

HRD/EMC
HRD/EMC/DTC
HRD/EMC/DTC
HRD/EMC/DTC
HRD/EMC/DTC/RDHPCS; Supported by HFIP

Storm Size Verification: North Atlantic

Absolute 34-kt Radii Errors (FULL)

Absolute 50-kt Radii Errors (FULL)
Storm Size Verification: North Atlantic

Absolute 64-kt Radii Errors (FULL)

Absolute Radius of Max. Wind Errors

*NOAA/AOML/HRD*
Storm Size Verification: North Atlantic

Absolute Errors

- HB20 errors are worse for storms north of 30N at 12-72 h

BIAS

Full Sample

<= 30N

> 30N

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Track/Intensity Verification: Eastern North Pacific

HWRF-B (HB20) track errors were comparable with HWRF.

HWRF-B (HB20) intensity errors were comparable with HWRF.
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Coastal Ocean Impacts: HWRF-B Studies

- Shelf heat fluxes impacted by coastal processes:
  - Coastal Ekman upwelling and downwelling
  - Barrier layers: river outflow
  - Coastal trapped as well as ocean internal waves

- Poorly resolved at 9 km?
  - Model bathymetry critical

- Impact “slow-moving” storms: <10 mph in tropics, to 15+ mph

Mississippi Boundary Layer (~50 m depth, from RTOFS init)
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Energy Balance: Shelf water, inner vs. outer core
- Parallel version of HB20 ran with up to 5 storms and ensemble DA (B220)
- B220 intensity errors were 1-2 kt lower than HB20 in the first 48 h. Track errors are a wash.
- Hanna was the only Gulf of Mexico storm from this sample. OperHWRF has shown great skill in the GoM with the impact of ensemble DA (which may not be reflected in the B220 sample so far…)

Self-Cycled Ensemble DA (B220)
Track Forecast Evaluation: Teddy (20L)

- **HB20** had lower track errors for Hurricane Teddy compared with **HWRF** at later lead times.
- Teddy was often concurrent with at least 2 other storms (e.g., **HB20** had 3 high-res moving nests).
- **HB20** performed well at lower latitudes, consistent with season-long results.
Individual Storm Highlight: Teddy (20L)

HB20 Lifetime Intensity Forecasts
43 Forecasts thru 2020092400

LATE INTENSITY ERROR (absolute)
Valid through 2020092400
TEDDY20L

Wind Speed [kt]

Intensity Error [kt]

*Experimental Product of NOAA/AOML/HRD*

*Experimental*

Date [DD/HH]

Lead Time [h]
Individual Storm Highlights: Eta (29L)
Individual Storm Highlights: Genevieve (12E)