Applications of the GSI-Hybrid Data Assimilation for High-Resolution Tropical Storm Forecasts: tackling the intensity spin-down issue in 2014 HWRF

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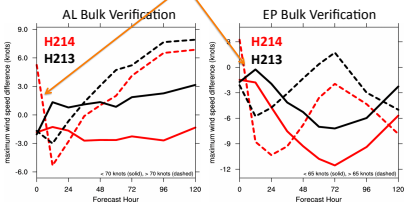
Abstract

In collaboration with research and operational centers, the Developmental Testbed Center (DTC) works toward the improvement of Data Assimilation (DA) and initialization of numerical models for tropical cyclone forecasting. Recent work has been performed in the framework of the 2014 operational Hurricane Weather Research and Forecast (HWRF) model, which applied some critical updates to various aspects of the system compared to the 2013 HWRF system, including, but not limited to, the upgraded vortex initialization scheme, and some important changes to the hybrid variational-ensemble configuration of the Gridpoint Statistical Interpolation (GSI) system.

Based on diagnostics of the tropical storm intensity forecasts from the National Center for Environmental Prediction (NCEP)/ Environmental Modeling center (EMC) 2014 HWRF pre-implementation runs, multiple tropical storm cases have been selected for extensive investigations in this work, whose intensity forecasts change rapidly from too strong to too weak compared to the observed at the initial forecast hours. Multiple runs have been conducted for the selected cases to study the impact of numerous configurations on hurricane forecasts, with the main focus on tackling the tropical storm intensity spin-down issues within the 2014 HWRF runs.

What is intensity spin-down?

Storm intensity changes rapidly from too strong to too weak (for strong storms)



Solid: Initial intensity <70 knots
Dashed: Initial intensity > 70 knots

Solid: Initial intensity < 65 knots
Dashed: Initial intensity > 65 knots

Figure 1. Bulk verification of intensity bias for the Atlantic (left) and East Pacific (right) basin, for the 2013 (black) and 2014 (red) HWRF. (Courtesy of Ryan Torn)

Model Configuration

2014 HWRF configuration (compared to 2013 HWRF):

- Increased model levels from 43 to 61 levels
- Model top raised from 50mb to 2mb
- Upgraded vortex initialization scheme
- Changes to the hybrid variational-ensemble configuration of the Grid-point Statistical Interpolation (GSI) system

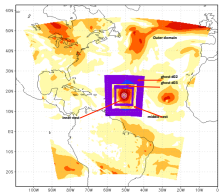


Figure 2. 2014 HWRF model domains.

Case Study

- Irene 2011
- Testing period: 2011082018 - 2011082900

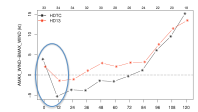


Figure 3. Aggregated intensity bias for Irene 2011 for 2013 (red) and 2014 (black) HWRF default configuration. Number of cases are shown on the top for forecast hours up to 120 hours (x-axis)

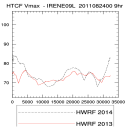
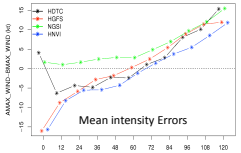


Figure 4. Maximum wind speed for the first 9 hours for 2011082400 for 2013 (red) and 2014 (black) HWRF default configuration.

✓ 2014 HWRF (HDTC) shows stronger intensity spin-down than 2013 HWRF (HD13)

What is contributing to the spin-down?



- HDTC: Vortex init. + GSI (2014 HWRF default setting)
- HGFS: No vortex init., no GSI
- NGSI: vortex initialization on, but no GSI data assimilation
- HNVI: GSI on, but no vortex initialization

Figure 5. Aggregated intensity bias for the four different 2014 HWRF configurations.

✓ HGFS, HNVI vs HDTC,NGSI: large negative intensity bias (storm too weak) if without vortex initialization
✓ HDTC vs NGSI – initial bigger bias and spin-down when vortex initialization + GSI, compared to vortex initialization only
✓ What is contributing to the intensity spin-down: Interaction between GSI and vortex initialization? GSI?

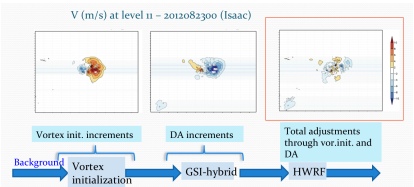


Figure 6. Increments of v-wind at level 11 for Isaac 2012082300 from 2013 HWRF runs, and the schematic of the 2-step initialization of HWRF – vortex initialization and GSI, in which the data assimilation tends to remove/reduce the adjustments from the vortex initialization.

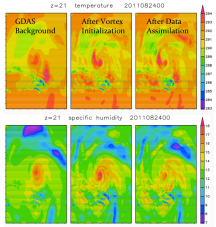


Figure 7. Temperature and specific humidity fields at 2014 HWRF model level 21 for Irene 2011082400 from GDAS background (left), after vortex initialization (middle) and after data assimilation (right) at ghost_d03.

✓ DA tends to reduce the impact from the vortex initialization
✓ Needs proper interaction between vortex initialization and GSI

Is TDR (Tail Doppler Radar) data assimilation contributing to the spin-down issue?

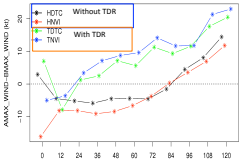


Figure 8. Aggregated intensity bias for cases with (TDTC, TNVI) and without (HDTC, HNVI) TDR data assimilation.

✓ For HWRF default configuration, TDR cases (TDTC) show stronger intensity spin-down than non-TDR cases (HDTC).
✓ For cases without vortex initialization, TDR cases (TNVI) has smaller initial intensity bias than non-TDR cases (HNVI).

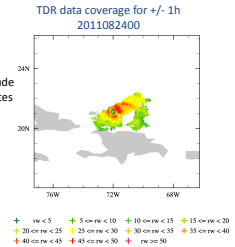


Figure 9. TDR coverage for +/- 1h at 2011082400. Colors indicate the magnitude of the radial wind. The open circle indicates the location of the storm from TC Vital.

✓ For this case, the maximum TDR RW is 53.6 m/s, larger than best track and TC Vital (~41 m/s).
✓ Needs better usage of the TDR data (better quality control?)

GSI internal balance issue?

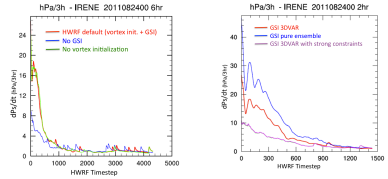


Figure 10. HWRF model noise for the first 6 (left, or 2 on the right) hours for different configurations of 2014 HWRF at 2011082400.

✓ Without GSI (blue curve in the left figure), the HWRF model noise is much smaller compared to the runs with GSI (HWRF default (red) and no vortex initialization (green)). → model noise mainly comes from GSI.
✓ Model noise from the GSI pure ensemble run exceeds that from the GSI 3DVAR run → more model noise comes from the ensemble contribution.
✓ Applying dynamic constraints to the GSI 3DVAR run further reduces the model noise → applying the dynamic constraints to the ensemble contribution or the total contribution might help with the GSI balance issue, and therefore improve on the intensity spin-down

Discussion

- Diagnostics have been performed to investigate the intensity spin-down for the strong storms in 2014 HWRF model system.
- Possible causes are isolated regarding the spin-down issue: interaction between the vortex initialization and GSI data assimilation; proper assimilation of the inner core data; GSI internal balance issue.
- Ongoing work: investigate the impact of applying dynamic constraints to the GSI-hybrid DA on the intensity spin-down.

Acknowledgments: This work is sponsored by the Hurricane Forecast Improvement Program (HFIP).