Impact of Assimilating Aircraft Reconnaissance Observations in Operational HWRF

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2013 HWRF Data Assimilation Configuration

- Data assimilation performed on outer domain. When inner-core (aircraft reconnaissance) observations are available, data assimilation also performed on ghost d03 after vortex initialization.

- GSI hybrid analysis using global 80 EnKF ensemble member at T254L64.

- First guess
  - TC environment cold start from GDAS forecast
  - TC vortex cycled from HWRF forecast relocated, size and intensity corrected through vortex initialization
  - First Guess at Appropriate Time (FGAT)

- Observational data
  - outer domain: conventional data
  - ghost d03: conventional data and inner-core data
Five Year Aircraft Reconnaissance Data Assimilation Experiments

• **Control experiment (HWCT):**
  – Data assimilation on outer domain, *no inner core data assimilation*
  – Initial vortex relocated and adjusted through *vortex initialization*
  – Conventional data: Radiosondes, Dropsondes, Aircraft reports, Surface ship and buoy observations, Surface observations over land, Pibal winds, Wind profilers, VAD wind, WindSat, ASCAT scatterometer winds, GPS-derived integrated precipitable water
  – Dropsonde wind within radius=\text{max}(111\text{km}, 3\times\text{RMW}) are flagged (not assimilated). Dropsonde surface pressure in the inner-core are flagged.

• **TDR DA experiment (HWDR):**
  – HWCT + assimilation of TDR data (in bufr format or superobs if bufr data are not available)

• **RECON DA experiment (HWRC):**
  – HWCT + assimilation of HDOB (*flight-level data* and SFMR derived *surface wind speed*)

• **TDR+RECON experiment (HWAR):**
  – HWCT+ assimilation all reconnaissance observations
# Data Inventory for RDITT Experiments 2008-2012 Atlantic

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Total number of storms: 39

HDOB: 528

TDR: 84
Five year aircraft reconnaissance data impact study –

TDR data

Category <= TS

Category = H1-2

Category = HM
Five year aircraft reconnaissance data impact study – HDOB data (flight level and SFMR)

Category <= TS

Category = H1-2

Category = HM
Five year aircraft reconnaissance data impact study – all reconnaissance data.

Track, Intensity, Bias graphs for Category <= TS, Category = H1-2, Category = HM.
Inner-core data assimilation with TDR data assimilated
Earl 07I 2010083012

HWMF: Hurricane WRF (2013 Operational Version)
2010 Tropical Cyclones Intensities
Storm: AL0710 (EARL)

Forecast: Beginning 2010083000 for HWMF model
Observed: Beginning 2010083000, every 12 hours

rw between 800 and 700hPa  rw O-F between 800 and 700hPa

first guess wind field at 850hPa  analysis wind field at 850hPa  TDR Wind analysis 1500 m

HWMF, Earl stormid: 402, date: 2010083012
rw: Min=49.8 m/s, Max=65.5 m/s
HWMF, Earl stormid: 402, date: 2010083012
rw O-F: Min=19.60072 m/s, Max=19.65881 m/s
HWMF, Earl stormid: 402, date: 2010083012
first guess wind: Min=5.46375 m/s, Max=15.32175 m/s
HWMF, Earl stormid: 402, date: 2010083012
analysis wind: Min=9.36477 m/s, Max=128.8516 m/s
HWMF, Earl stormid: 402, date: 2010083012
TDR wind analysis (shaded): Min=17.6924 m/s, Max=119.03 m/s
Inner-core data assimilation with TDR data assimilated
Earl 07I 2010083012 – analysis increment
Both RECON and TDR data suggest that the first guess has too strong wind speed in the inner-core (after vortex initialization).
Inner-core data assimilation with RECON data assimilated
Earl 07I 2010083100
RECON DA experiment
Earl 07I 2010083100

6-h forecast
before vortex initialization

after vortex initialization

limited data coverage
The large difference between the background vortex and reconnaissance observations in the inner-core is commonly found in all strong storms with forecast spin-down (e.g. Gustav 2008, Paloma 2008, Bill 2009, Earl 2010, Rina 2011 etc.)
Five year aircraft reconnaissance data impact study – mean 34 kts, 50 kts and 60 kts wind radii error

Category <= TS

Category =H1-2

Category =HM

34 kts

50 kts

64 kts

TDR

RECON

RECON + TDR
Conclusion

• Assimilation of TDR data can help improve both track forecast and intensity forecast for weak storms. The degradation of the short-term intensity forecast is mostly associated with the 6-h forecast spin-down of the major hurricanes.

• Assimilation of RECON (flight level, SFMR and dropsonde) data has positive impact on TC track forecast. The degradation of the intensity forecast is also associated with forecast spin-down, which generally happens to TCs of all different categories, but is more severe for stronger storms.

• For the 84 cases with TDR data available, assimilation of RECON data also improves the track and intensity forecast for weak storms.

• Assimilation of all the reconnaissance observations including TDR data produces similar track and intensity forecast compared with the experiment assimilating RECON data.
Assimilation of reconnaissance observation in operational HWRF – Issues

Two major issues

- Initial intensity couldn't match best track. Averaged initial Vmax error is more than 10 kts for strong storms. Initial intensities of the storms are underestimated.
- Short-term forecast spin-down, especially for strong storms.

Two types of initialization combined together – vortex initialization followed by data assimilation

- **Vortex initialization**
  - *Advantages:*
    - Can closely match initial intensity to best track (Vmax and Pmin)
    - Vortex is better balanced – better short-term intensity forecast (strong storms)
Assimilation of reconnaissance observation in operational HWRF – Issues

- Two types of initialization combined together – **vortex initialization followed by data assimilation** (continued)
  - **Vortex initialization**
    - *Disadvantages*: Size and intensity correction according to a few parameters in tcvitals – has a lot of uncertainties in TC 3D structures.
      - Has limited control on TC middle to upper level structures: more likely to have deeper and stronger upper level structures; tends to over predict the intensity of storms ranging from tropical depression to Category 2 hurricanes.
      - Can match maximum wind speed, but has limited control on wind speed gradient along radial direction - easily introduce a ‘fat and strong’ inner-core structure for strong storms.
  - **Data assimilation**
    - *Advantages*: can provide more accurate TC structures, especially when data coverage is good – help prevent weak storms from over intensification.
Assimilation of reconnaissance observation in operational HWRF – Issues (continued)

• Data assimilation
  • Deficiency:
    – Deficiency in background error covariance (e.g. global ensemble – low resolution)
    – lack of balance (moisture-mass-wind) constraint in analysis
    – lack of cloud and precipitation analysis
    – Observations with sufficient coverage and resolution in vortex area are not consistently available
    – Observations are not optimally used

• Two initialization procedures compete with each other
  – First guess TC structure (after vortex initialization) often substantially different from reconnaissance observations – due to model bias combined with artificial structures introduced by vortex initialization enhanced through cycling
  – Large analysis increment and easily out of balance

❖ Model deficiency: can model support the observed storm structure (e.g. small RMW)?
Data Assimilation for HWRF – Plans

❖ **Improve background error covariance**
  • Data assimilation system upgrade – self-consistent GSI-based hybrid data assimilation system that use higher resolution HWRF based ensemble covariance
  • Potentially use warm-start HWRF ensemble initialized from GFS EnKF analysis in GSI hybrid analysis for TDR data assimilation in 2015
  • carefully tuning ensemble spread and improve error variance in static B

❖ **Further enhance balance – remove large-amplitude, high-frequency oscillations resulting from imbalance in analysis**
  - Incremental Analysis Updates (IAU); Digital filter; Tangent Linear Normal Mode Constraint (TLNMC) with moist physics

❖ **Improve the use of observations (TDR, flight-level data, SFMR, dropsonde, satellite wind and radiance)**
  - quality control (e.g. flight level, SFMR); observation error tuning (based on innovation stats);
  - improve observation operator (e.g. add w in observation operator of TDR data) and data thinning
  - develop the capability of assimilating and/or evaluate the impact of new observations:
    cloudy radiance, hourly AMVs, G-IV TDR; GH dropsonde and radar data ...

❖ **Further evaluate the role of vortex initialization; investigate the possibility of realizing the functions of vortex initialization through advanced data assimilation**
Assimilation of Global Hawk (HS3) dropsondes

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<tr>
<td>HWRF</td>
<td>2014 operational HWRF: Conventional data, satellite radiance, satellite wind, GPS RO, TDR (if available)</td>
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<tr>
<td>HS14</td>
<td>HWRF + assimilate GH dropsondes</td>
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- **Observation errors:**
  - Temperature, moisture, and wind errors are assigned as a function of vertical pressure

- **Potential issues with GH dropsondes assimilation:**
  - When available, data has good temporal and spatial coverage; however, data is not available for every cycle
  - Dropsonde drift problem: the GPS measured geo-locations at each pressure level are not included in PREPBUFR
• Storms with GH dropsondes (2014)
  Cristobal 04L: 2014082600 - 2014082912
  Dolly 05L: 2014090112 - 2014090306
  Edouard 06L: 201491106 – 2014091812