Testing and Evaluation of Regional EnKF Radiance Data Assimilation: Impact of MHS Assimilation

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Background/Objectives

- Recent Studies (Liu et al. 2012, Schwartz et al. 2012) have shown positive impacts when assimilating microwave radiances with a limited area EnKF
- These studies focused on the impact of assimilating AMSU-A radiances
- This study expands on previous work to evaluate the impact of assimilating MHS radiances in addition to AMUS-A to determine if there is an added benefit from assimilating MHS

Experiment Design & Assimilation Methodology

✓ *Experimental Design and Assimilation Strategy follows Liu et al. 2012*

Experimental Design

- Limited-Area EnKF using Data Assimilation Research Testbed (DART) with WRF-ARW v3.2.1
- Time Period: 2008081100-20080901300
- 36 km horizontal resolution
- 45 vertical levels
- 20 hPa model top
- 96 ensemble members
- 6-hr cycling using ensemble LBCs from perturbed GFS means
- Deterministic 72-hr ARW forecasts initialized from 00/12 ensemble mean analyses
- Aggregated statistics using Model Evaluation Tools (MET) v3.0.1

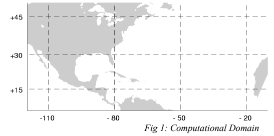

Fig 1: Computational Domain

Assimilation Methodology

- Assimilated observations for experiments:

  AMSA: conventional obs from radiosondes, aircraft, sat-derived winds, land/ocean sfc stations, GPS dropsondes (NOAA G-IV aircraft), COSMIC GPSRO, AMSU-A radiances

  AMHS: same as AMSA + MHS radiances
- Radiance data were thinned on a 72-km grid
- +/- 1.5 hr observation assimilation window
- Bias correction coefficients from 3-mo offline statistics (spun-up)
- AMSU-A channels 5-7 & MHS channels 3-4 NOAA-18/METOP-2 assimilated

- Radiances were assimilated into DART using the CRTM built into WRFDA as the radiance forward operator for computing radiance prior ensembles
- Only radiance prior ensembles came from WRFDA, all other obs from DART
- Vertical localization for each radiance observation was taken as the level the channels' weighting function peaked
- For MHS: dTr/dp was calculated in WRFDA from the CRTM and used as the weighting function

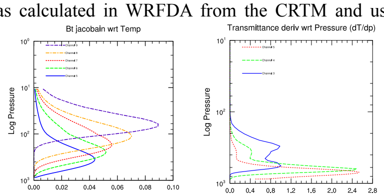

Fig 2: Brightness Temperature Jacobian w.r.t. Temperature (L) and Transmittance derivative w.r.t. pressure (R)

Acknowledgements

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Assimilation and Forecast Results

Bias Correction

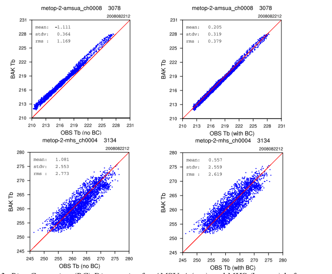

Fig 3: Bias Correction (BC) Diagnostics for AMSU-A (top) and MHS (bottom) before (L) and after (R) BC

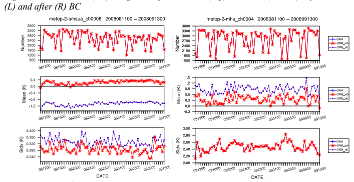

Fig 4: Time series of number (upper), Mean (center), and STDv (lower) for AMSU-A (L) and MHS (R)

- Bias Correction Diagnostics show reduction in mean for both AMSU-A and MHS
- MHS shows large RMS & STDv values with little to no reduction after BC

Verification Against ERA-interim Reanalysis

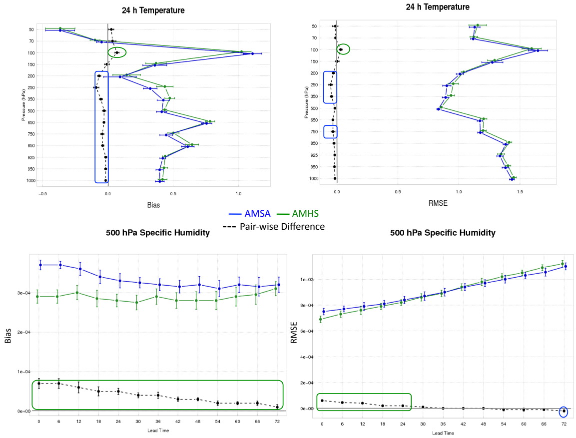

Fig 5: Vertical Bias (upper left) and RMSE (upper right) temperature profile of 12 hour forecasts and 500 hPa Specific Humidity bias (lower left) and RMSE (lower right) for AMSA and AMHS with 95% CIs. Pair-wise differences shown in black.

✓ Pair-wise (AMSA-AMHS) statistical significance (SS) is determined when the confidence intervals (CIs) of the difference do not encompass zero.

Table 1: Summary of Statistically Significant pair-wise differences

95%		BIAS					RMSE				
		925	850	750	500	250	925	850	750	500	250
T	0	AMSA	AMSA	AMSA	AMSA	AMSA			AMSA		AMSA
	12	AMSA	AMSA	AMSA	AMSA	AMSA			AMSA		AMSA
	24	AMSA	AMSA	AMSA	AMSA	AMSA			AMSA		AMSA
	36	AMSA	AMSA	AMSA	AMSA	AMSA		AMSA	AMSA		AMSA
	48	AMSA	AMSA	AMSA		AMSA		AMSA			AMSA
	60		AMSA	AMSA		AMSA		AMSA			AMSA
	72					AMSA					AMSA
U	0	AMHS	AMSA	AMSA		AMSA	AMSA	AMSA	AMSA		AMSA
	12	AMHS	AMSA	AMSA			AMSA	AMSA	AMSA		AMSA
	24	AMHS	AMSA	AMSA	AMHS	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA
	36	AMHS	AMSA	AMSA	AMHS	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA
	48	AMSA	AMSA	AMSA	AMHS	AMHS	AMSA	AMSA	AMSA	AMSA	AMSA
	60	AMSA	AMSA	AMSA	AMHS	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA
	72	AMHS	AMSA	AMSA			AMSA	AMSA	AMSA	AMSA	
V	0	AMSA	AMSA			AMSA	AMSA	AMSA			AMSA
	12	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA		AMSA
	24	AMSA	AMSA		AMSA	AMSA	AMSA	AMSA	AMSA	AMSA	AMSA
	36	AMSA	AMSA		AMHS	AMSA	AMSA	AMSA	AMSA	AMSA	
	48	AMSA	AMSA			AMSA	AMSA	AMSA	AMSA	AMSA	AMSA
	60	AMSA					AMSA	AMSA	AMSA	AMSA	AMSA
	72	AMSA			AMSA		AMSA	AMSA	AMSA		AMSA
Q	0	AMSA	AMHS		AMHS	-				AMHS	-
	12	AMSA		AMHS	AMHS	-	AMSA	AMSA		AMHS	-
	24			AMHS	AMHS	-	AMSA	AMSA		AMHS	-
	36			AMHS	AMHS	-	AMSA				-
	48		AMHS	AMHS	AMHS	-	AMSA	AMSA			-
	60		AMHS	AMHS	AMHS	-		AMSA			-
	72		AMSA	AMHS	AMHS	-		AMSA		AMSA	-

✓ *Table 1 shows SS differences favoring AMSA shaded in blue, AMHS shaded in green, and neutral (no SS differences) with no shading*

- Pair-wise SS differences for 24 h temperature favor AMHS at 100 hPa, however favor AMSA for mid- and low-levels
- Mid-level specific humidity shows SS differences favoring AMHS (more evident in bias statistics)
- Temperature and wind RMSE aggregations favor AMSA
- Biases indicate more favor for AMHS than RMSE
  - Indication of larger variability in AMHS forecasts stemming from MHS data?

Tropical Cyclone Case Studies

Individual Storms: Fay and Gustav

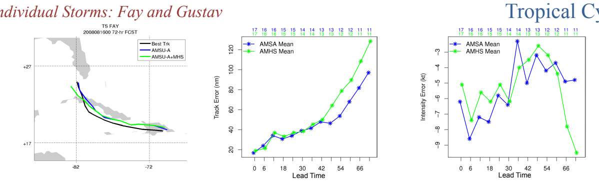

Fig 6a: Tracks for 72-h forecast for tropical storm Fay initialized at 20080816 00z (left), mean track error (center), and mean intensity error (right).

- AMSA/AMHS tracks north of NHC Best Track, AMHS misses northward curvature
- AMHS mean track error deviates from AMSA quickly after 42 hrs (most contribution from along track)
- AMHS intensity errors smaller out to 1 day, quickly drop off after 60 hrs

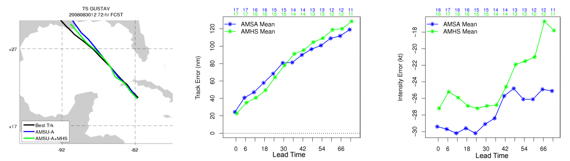

Fig 6b: Tracks for 72-h forecast for Hurricane Gustav initialized at 200830 12z (left), mean track error (center), and mean intensity error (right)

- AMSA/AMHS tracks NE of NHC Best Track for later lead times, with AMHS track closer to NHC Best Track
- Mean track errors close between AMHS and AMSA, AMHS slightly lower out to 30 hrs and AMSA thereafter
- Intensity errors for AMHS smaller then AMSA for all lead times

All Storms: Fay, Gustav, Hanna, Ike, Josephine

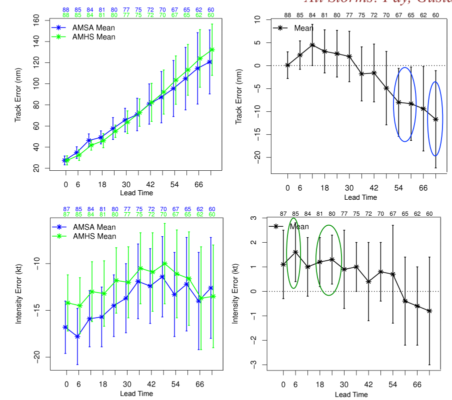

Fig 7: Track (upper) and intensity (lower) errors aggregated over 5 storms occurring in the domain during the assimilation period. Pair-wise SS differences are calculated at 95% (right), where SS is determined when the confidence intervals of the difference do not encompass zero.

- Aggregated statistics show SS differences favoring AMSA for track at long lead times (beyond 2 days) and SS differences favoring AMHS for intensity out to one day.
- Early track errors and intensity errors at longer lead times show no SS differences favoring either configuration

Conclusions

✓ When aggregating over the full month, verification against the ERA-interim indicates more SS differences favoring AMSA over AMHS for temperature and wind, and SS differences favoring AMHS for moisture

✓ Bias statistics show more SS differences favoring AMHS than RMSE statistics, indicating more variability in the AMHS forecasts (BC diagnostics show larger spread in MHS data)

✓ TC cases Fay and Gustav showed mixed results with AMHS performing worse than AMSA for track at long lead times for Fay, and better intensity relative to AMSA for Gustav

✓ Aggregations over all 5 storms showed SS differences favoring AMSA for long lead times for track, and favoring AMHS for short lead times for intensity

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