Impacts of Three Orbits Satellite Radiance Assimilation on Coastal QPFs

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Abstract

This study demonstrates the added benefits of assimilating the Advanced Microwave Sounding Unit-A (AMSU-A) radiance observations from an early morning orbit (NOAA-15), in addition to those data from a mid-morning (MetOp-A) and an afternoon (NOAA-18) orbits, on short-range coastal qualitative precipitation forecasts (QPFs). The National Centers for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) data assimilation system is employed in this study. The AMSU-A data quality control procedure is described. For each of the selected cases, two pairs of data assimilation and forecasting experiments are carried out and compared with and without including AMSU-A data from NOAA-15. It is shown that adding data from an early morning orbit removes an otherwise a satellite data void area over Gulf and United States continent at 0000 UTC and 1200 UTC times. Assimilation of NOAA-15 AMSU data results in a consistent positive impact on the coastal QPFs

Characteristics of AMSU-A Observations

AMSU-A is onboard NOAA-15 to -19 and European MetOp-A and -B. AMSU-A provides measurements at microwave frequencies in an oxygen absorption band and is mainly designed to vertically probe the atmosphere in nearly all-weather conditions (except for heavy precipitation).

Geometry characteristics

- A cross-track microwave radiometer which scans the earth scene within ±48.7° with respect to the nadir direction.
- Has an instantaneous field-of-view (FOV) of 3.3° and scans at 15 different viewing angles at both sides of the nadir. Total of 30 FOVs from each scan.
- The spatial resolutions of observations are 48 km at nadir and increase quadratically with scan angle (Fig. 1).

Spectral characteristics

- Contains 15 channels at microwave frequencies ranging from 23.8 to 89.0 GHz.
- Atmospheric temperature obtained at channels near 50-60 GHz (channel 3-14). When AMSU-A channel number increases from 3 to 14, thermal radiation at increasing altitude from the Earth's surface to about 2hPa is measured (Fig.2).
- Channels 1, 2 and 15 are primarily designed for obtaining the information on surface and cloud properties.

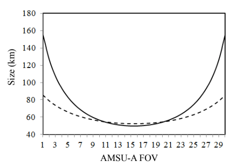

Fig.1: Radii of AMSU-A in along-track (dashed) and across-track (solid) directions.

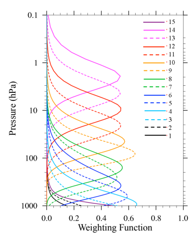

Fig.2: Weighting functions of AMSU-A channel 1-15 (right panel).

Local Equator Crossing Time (LECT)

- Each polar-orbiting satellite circles the earth in sun-synchronous orbits, providing a global coverage of radiance measurements near its equator crossing times (ECTs) twice daily.
- NOAA-6, -8, -10, -12, -15 are the early-morning satellites with their ECT occurring at either 0530 or 0730 local time. The satellites with ECT after 0930 local time are referring to mid-morning satellite such as NOAA-17, MetOp-A and -B whereas those after 1300 local time are afternoon satellites such as TIROS-N, NOAA-7, -9, -11, -14, -16, -18, -19 and SNPP.
- With early morning, mid-morning and afternoon satellites, measurements of the global temperature profiles are provided by satellites at least six times daily.
- However, NOAA-15 is the only early-morning orbit satellite now and has flown for over 15 years, which far exceeds its expected life period. The NOAA-15 AMSU-A is still operational with non-degraded performance except for channels 11 and 14.

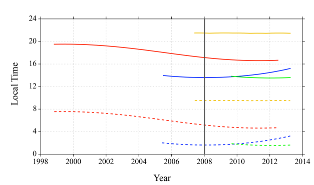

Fig. 3: Local equation crossing time (LECT) of NOAA-15 (red), NOAA-18 (blue), NOAA-19 (green) and MetOp-A (orange) at the ascending node (solid) and descending node (dashed) from 1998 to 2014.

Experiment Setup

Experiment	Data Analysis Cycle		Data Type	
	Starting Time	Ending Time	NOAA-15	Other data
CTRL1	1200 UTC May 22, 2008	0000 UTC May 23, 2008	no	NOAA-18, MetOp-A, and conventional data
EXP1			yes	
CTRL2	0600 UTC May 22, 2008		no	
EXP2			yes	

Observation Gap Filled by NOAA-15

Fig.4 provides four spatial distributions of AMSU-A data from NOAA-18, MetOp-A and NOAA-15 within three hours window centered at 0000 UTC, 0600UTC, 1200 UTC, and 1800 UTC on May 22, 2008.

Without early-morrning oribt satellites

- NOAA-18 and MetOp-A provided a good data coverage over the continental United States at 0600 UTC and 1800 UTC.
- A large data void region is found over central United States and Gulf of Mexico at 0000 UTC and 1200 UTC.

With early-morrning oribt satellite

- The third early-morning orbit, NOAA-15, fill the data gaps of mid-morning and afternoon satellite orbits.

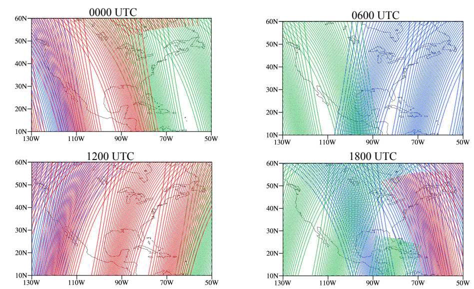

Fig.4: Spatial distributions of AMSU-A data from NOAA-18 (blue), MetOp-A (green) and NOAA-15 (red) within 3 hours window centered at 0000 UTC, 0600UTC, 1200 UTC, and 1800 UTC on May 22, 2008.

NOAA-15

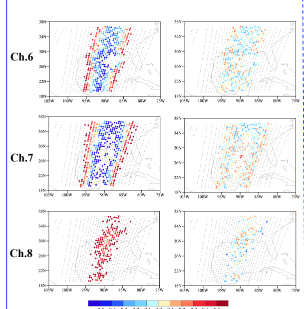

Fig. 5: Differences between observations and the background fields (O-B, left panels) and the differences between observations and analysis fields (O-A, right panels) of NOAA-15 AMSU-A channels 6-8 at those data points assimilated at 1200 UTC May 22, 2008 from EXP1. Data points not assimilated are indicated by black dots.

NOAA-18

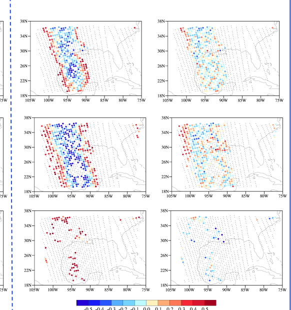

Fig. 6: Same as Fig. 6 except for NOAA-18 at 1800 UTC May 22, 2008.

NOAA-15

MetOp-A

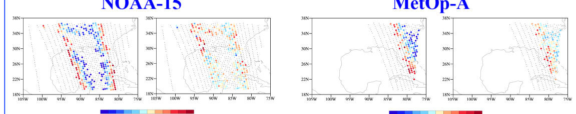

Fig. 7: Values of O-B (left panels) and O-A (right panels) of AMSU-A channel 6 at those data points assimilated at 0000 UTC May 23, 2008. Data points not assimilated are indicated by black dots.

500hPa Geopotential and Wind

The large-scale environment in which convection is initiated and developed is provided in Fig. 8, in which the 500-hPa geopotential, wind vector and wind speed from the EXP1 during 0000 UTC and 1800 UTC May 23, 2008 are shown at a three-hour interval. At 0000 UTC May 23, 2008, there was a trough located at the Gulf coast near the 92W longitude. In the subsequent 15 hours, this trough deepened, extended further to the south, and moved eastward. By 0900 UTC and 12 UTC, this upper-level trough was well developed.

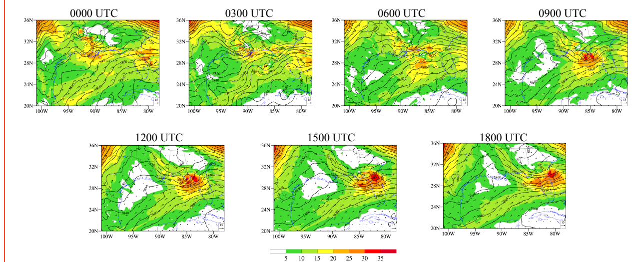

Fig.8: 500-hPa geopotential (solid curve, contour interval: 10 m), wind vector and wind speed (shaded, unit: m/s) at from 0000 UTC to 1800 UTC May 23, 2008 from EXP1.

Accumulative Rainfall

The 3-h accumulative rainfall amounts between 0600 UTC and 0900 UTC and between 0900 UTC and 1200 UTC on 23 May 2008 near the coast of Gulf of Mexico from multi-sensor NCEP observations, CTRL1 and EXP1 are shown in Fig. 9. The CTRL1 fails to place the rainfall at the right locations, but EXP1 succeeded in predicting the maximum rainfall at the observed precipitation location. However, The 3-h rainfall amounts are over-predicted in EXP1.

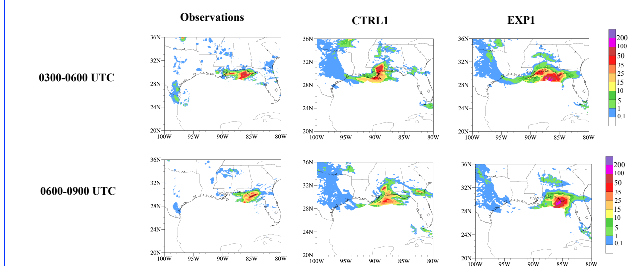

Fig.9: Accumulative rainfall during 0300-0600 UTC (upper panels) and 0600-0900 UTC (lower panels) at 2400 UTC May 23, 2008 from NCEP multi-sensor observations (1st column), forecasts without NOAA-15 data (2nd column) and with NOAA-15 data (3rd column).

Threat Scores of 3-hour Accumulative Rainfall

CNTL1 & EXP1

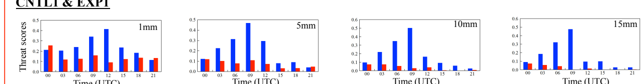

Fig.10: Threat scores of 3-h accumulative rainfall at 1mm, 5mm, 10mm, and 15mm thresholds on May 23, 2008 from model forecasts with (EXP1, blue) and without (CNTL1, red) assimilating AMSU-A data from NOAA-15.

CNTL2 & EXP2

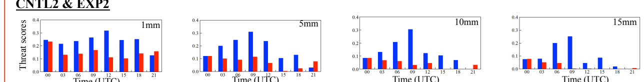

Fig.11: Same as Fig. 8 except for the data assimilation cycle being initialized at 0600 UTC instead of 1200 UTC on May 22, 2013.

Summary and Conclusions

The present study provides a preliminary assessment of the benefits of having an early-morning orbit for improved QPFs over Gulf of Mexico. It is shown that adding NOAA-15 AMSU-A radiance data assimilation in the ARW system significantly improves the 24-h forecasts of a convective precipitation event near the Gulf of Mexico. NOAA-15 was launched on May 13, 1998 and is one of NOAA's longest operating spacecraft, which have a typical lifespan of three years. This study suggests an urgent need for having a successor of AMSU-A onboard an early-morning satellite. Impacts of AMSU-A radiance assimilation on regional forecasts have a regional dependence (i.e., mostly longitudinal ranges). We plan to repeat these experiments for more coastal QPF cases during the time period when NOAA-15, MetOp-A and NOAA-18 three orbits are available. Another golden period with three orbits AMSU-A data are around 2003 when NOAA-15, -16 and -17 were flown simultaneously. The conclusions drawn from this case study will have to be generalized over both the same regions and different regions of the globe.

Acknowledgement and Disclaimer

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