All-Sky AMSU-A Radiance EnsDA Study of Hurricane Danielle (2010)

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1. MOTIVATION

- Evaluate the impact of cloudy radiance observations in regional hurricane analysis and forecast;
- Use a prototype hybrid variational-ensemble data assimilation system (**HVEDAS**) developed at Colorado State University to have an early assessment of the future operational HVEDAS;
- Use NOAA operational environment for evaluation: HWRF, GSI, CRTM, scripting;
- Prepare for merging current satellite measurements with the future GOES-R measurements (Advanced Baseline Imager and Geostationary Lightning Mapper).

2.METHODOLOGY

2.1 System components

- **Data Assimilation Approach**

 - A hybrid variational-ensemble method: ***M**aximum **L**ikelihood **E**nsemble **F**ilter* (MLEF; Zupanski 2005; Zupanski et al. 2008)

- **NWP model**

 - NOAA Hurricane WRF operational model (*HWRF*)

- **Observations** (through *GSI* forward model and basic quality control)

 - NCEP operational observation: include conventional data, radar data, and satellite observations (such as AIRS, IASI, GPSRO,…)

- **Community Radiative Transfer Model** (*CRTM*)

 - Use forward component of the CRTM to get the all-sky radiances

2.2 MLEF applications to HWRF

- **Forecast step**

 - MLEF calls subroutines to make HWRF ensemble forecasts to next analysis time
 - each ensemble LBCs is interpolated from HWRF outer domain
 - Ensemble forecasts are translated to MLEF state vectors

- **Analysis step**

 - Forward model computed for all observations, all members;
 - Observation operator includes forward components of the GSI and CRTM
 - Added processing of cloudy radiances from global DA (e.g., M-J Kim)

- **Provide: optimal state + uncertainty**

 - Optimal state: Maximum a posteriori PDF estimate; as function of obs and forecast
 - Uncertainty: Ensemble-based uncertainty estimate

REFERENCES:

Zupanski, M., 2005: Maximum Likelihood Ensemble Filter: Theoretical Aspects. *Mon. Wea. Rev.*, **133**, 1710-1726.

Zupanski, M., I. M. Navon, and D. Zupanski, 2008: The Maximum Likelihood Ensemble Filter as a non-differentiable minimization algorithm. *Q. J. R. Meteorol. Soc.*, **134,** 1039-1050.

3. EXPERIMENTS

- **CASE:** Hurricane Danielle (21-30 August 2010)
- **Start date**: 1200 UTC 24 Aug 2010
- **MLEF-HWRF cycling runs**: produce 9-km analysis in the HWRF inner domain every 6-hr; the outer domain provides the LBCs to the inner domain.
- **Control variable** includes the following 5 components: wind components(**U,V**); specific humidity(**Q**);temperature(**T**); hydrostatic pressure depth (**PD**)
- **Ensemble size** is **32 members**
- **2 Experiments:**

- **CLR**: assimilate conventional observations and clear sky AMSU-A radiances

- **ALL**: same as CLR, but using the approach in GDAS (e.g., M-J Kim) to include cloudy AMSU-A radiances

4. INCLUSION OF CLOUDY RADIANCES

Fig 1. AMSU-A Brightness temperature observation (°C) on top level of channel-15

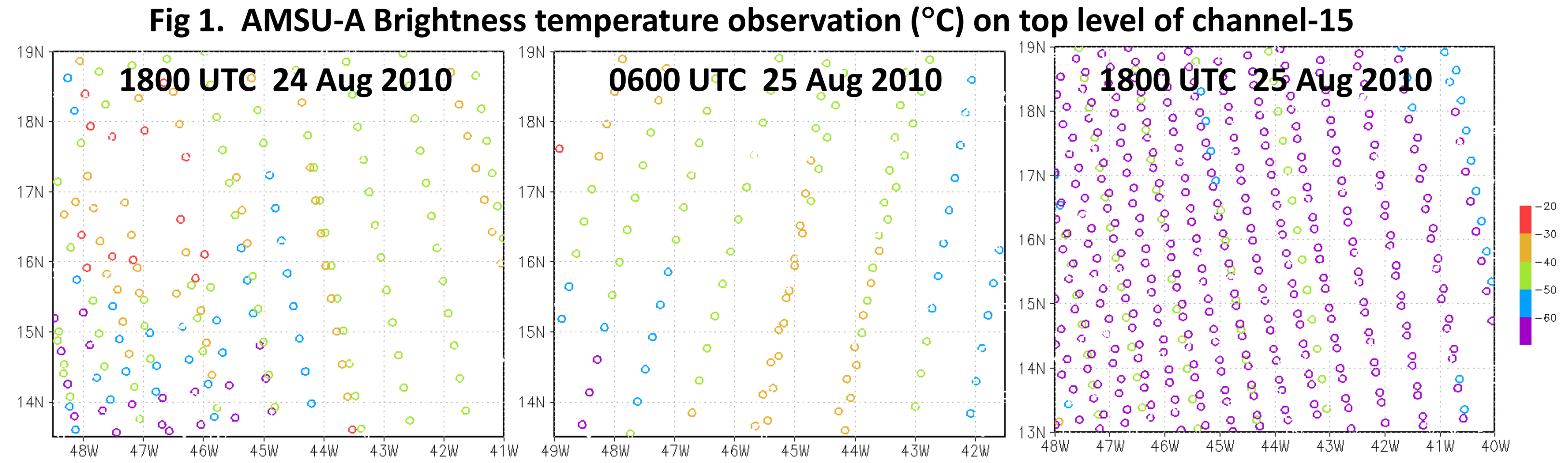
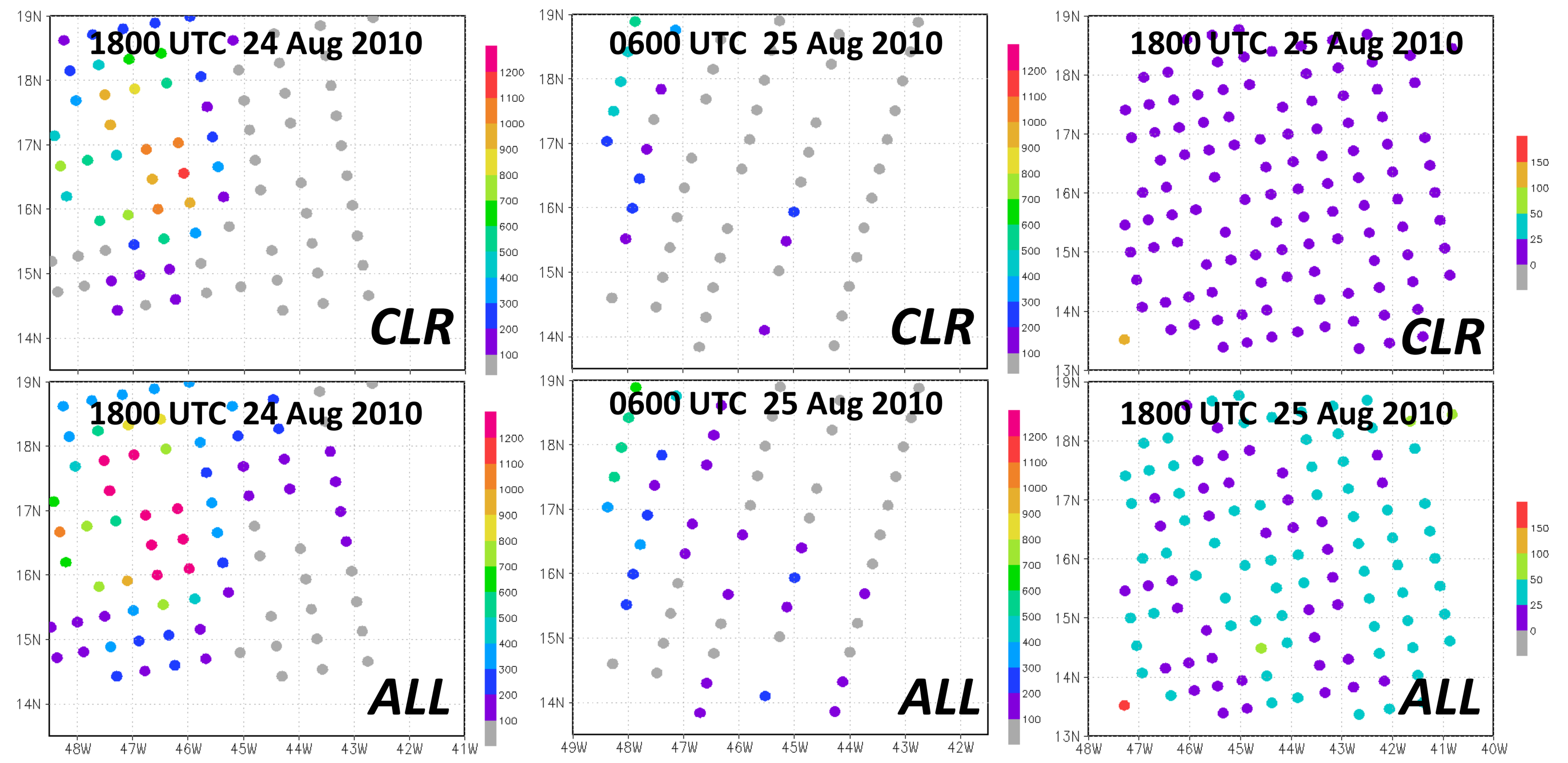


Fig 2. AMSU-A n18 CLW diagnostic analyses after QC and data thinning in GSI for HWRF inner domains (g m^{-2}; thinning in a 60 km grid; time_window_max = ±1.5 hr)



Positive impact for CLW diagnostic analyses when adding cloudy AMSU-A radiances

5.RESULTS

5.1 Analyses at 1800 UTC 24 Aug 2010

Fig.3 Analyses (shaded) and Analysis increments (contoured) for Q (g kg^{-1}) at 900 hPa; the wind barbs are the analysis of wind field at 900 hPa; A full bar is 5 m s^{-1}

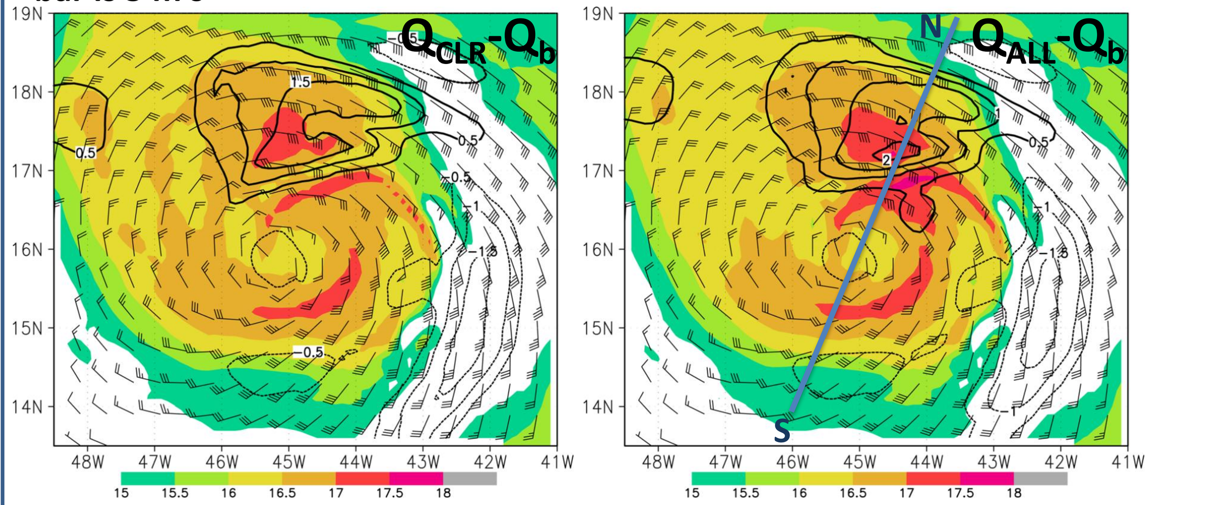


Fig.4 Analysis of wind fields (shaded) and Analysis increments of wind speed (contoured; m s^{-1}) at 700 hPa

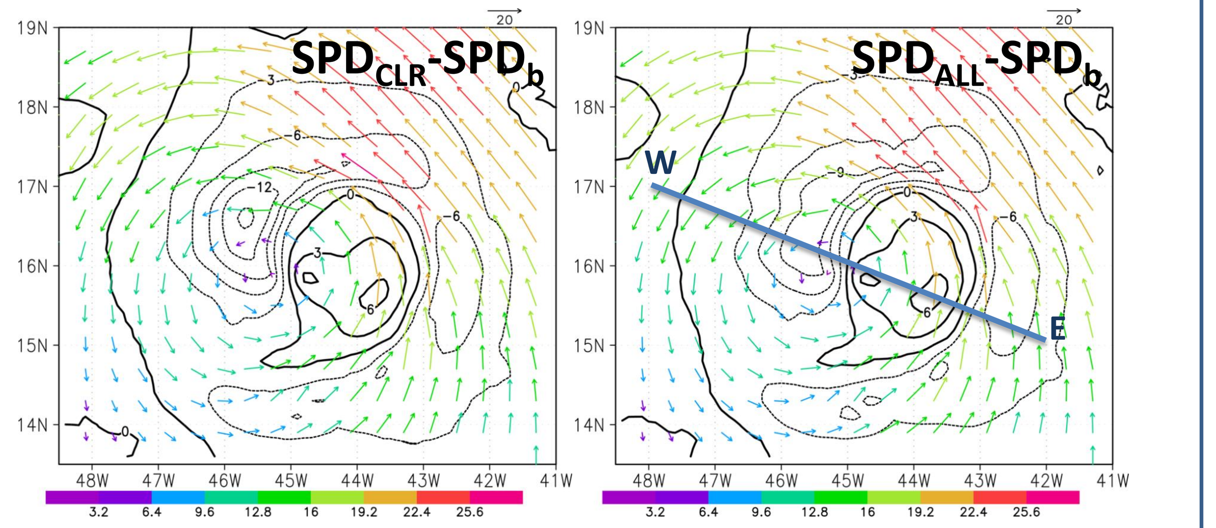


Fig.5 Analyses of wind fields (shaded) for ALL Experiment on NS vertical cross section; The contours are for wind speed (m s^{-1}) and Q (g kg^{-1}) difference

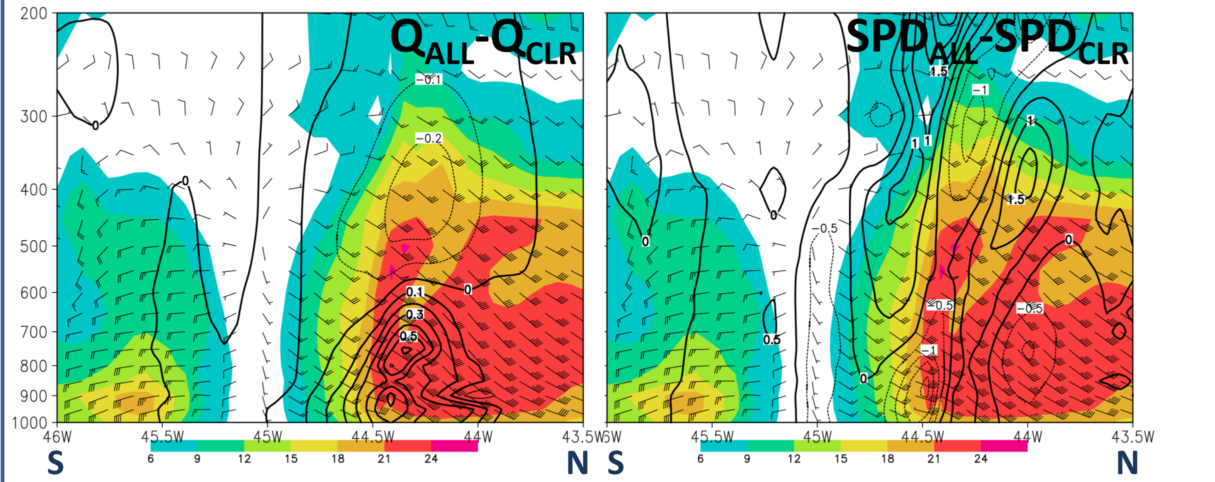
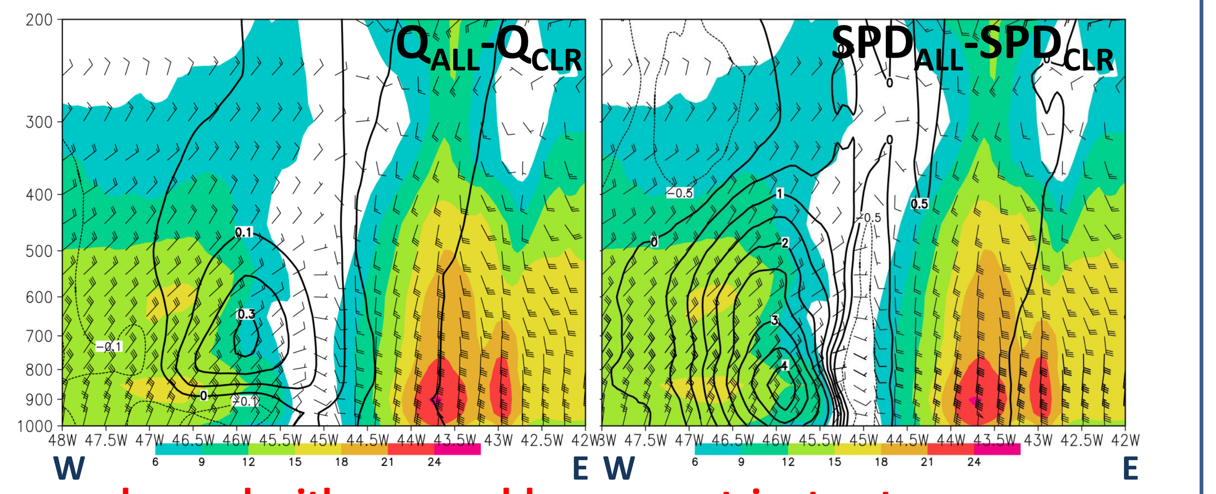


Fig.6 same as fig.5, but on WE vertical cross section



Both low-level wind speed and humidity in the TC eyewall are enhanced with reasonable asymmetric structure

5.2 Forecasts

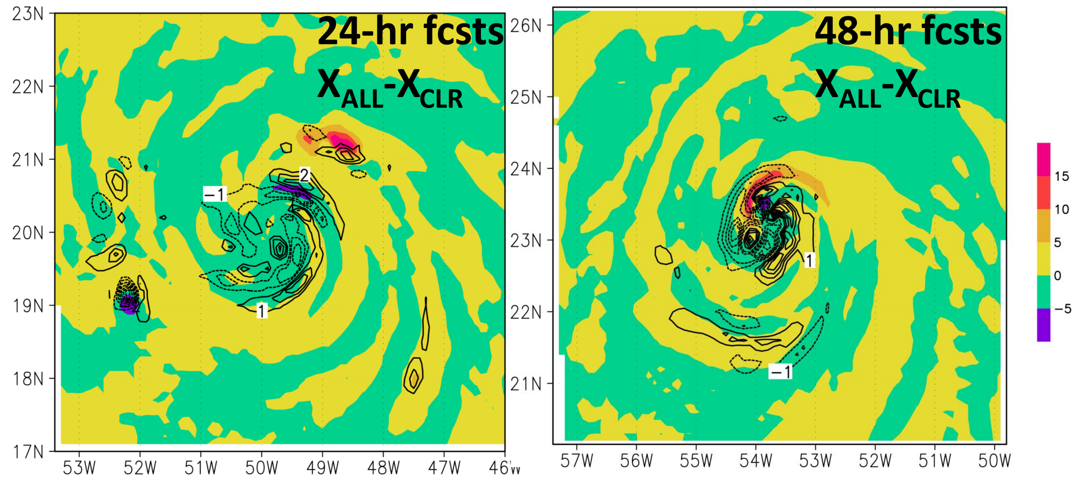


Fig.7 the 24- and 48-hr forecasting difference of total condensate (shaded; kg m^{-2}) and absolute vorticity (contoured; 10^{-4} ms^{-2}) at 900 hPa

Increasing low-level absolute vorticity in the TC inner-core region and more condensation occurring in the spiral rainband

6. SUMMARY

- The MLEF-HWRF system has been evaluated in realistic assimilation/forecasting environment; the system is generally applicable for variable stages of storms.
- All-sky AMSU-A EnsDA approach effectively assimilates the cloudy AMSU-A radiances, and indicates more realistic adjustment of 3D structures of standard control variables.
- The system also produces positive impacts on hurricane forecasts with more total condensate and enhanced low-level absolute vorticity.
- Encouraging for the future operational HVEDAS.

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