Investigating the effects of GOES-R measurements and advanced infrared soundings for hurricane core region data assimilation using a hybrid data assimilation system

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1.Objectives

- Investigate the potential impacts of GOES-R ABI measurements on tropical cyclone (TC) core analysis and prediction using MSG SEVIRI as proxy.
- Explore the impacts of combined MSG SEVIRI and advanced IR soundings for Fred (2009).
- Examine the performance of the hybrid variational-ensemble data assimilation system (HVEDAS)

2. A regional HVEDAS for TC core region

❑ Hybrid DA algorithm

Maximum Likelihood Ensemble Filter (MLEF: Zupanski, 2005;;Zupanski et al., 2008)

- A hybrid DA method seeking nonlinear solution;
- It employs an iterative minimization of a cost function, similar to variational methods;
- An important advantage of iterative solution method is in application with nonlinear observation operators

❑ NWP model

The ATMOS portion of NOAA operational HWRF (2011)

- HWRF outer domain has a grid spacing of 27 km;
- The inner domain of about 6°×6° has a grid spacing of 9 km and moves along with the storm

❑ Observation forward operators

Gridpoint Statistical Interpolation（GSI）

- Exclude GSI B.E.s, the adjoint model , and minimization

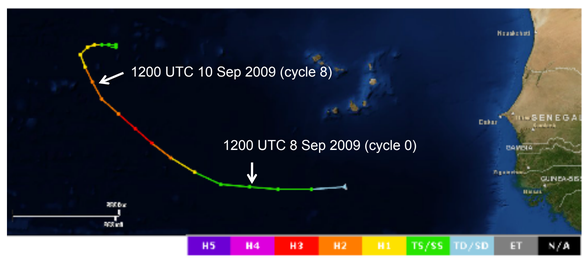
Community Radiative Transfer Model (CRTM)

3. Experimental design

- **Hurricane Fred (2009);** DA start date: 1200 UTC 8 Sep 2009
- **MLEF-HWRF cycling system**: produce 9-km resolution analysis in the HWRF inner domain every 6-h; the outer domain provides the LBCs to the inner domain.
- **Control variables** include the following model variables: wind components (U,V); specific humidity (Q); temperature (T); hydrostatic pressure depth (PD); Total column condensate (CWM-Ferrier microphysics).
- Ensemble size is **32 members**
- **Other tuning measures**

- Horizontal error covariance localization (Yang et al. 2009)
- Vortex initialization at cycle 0

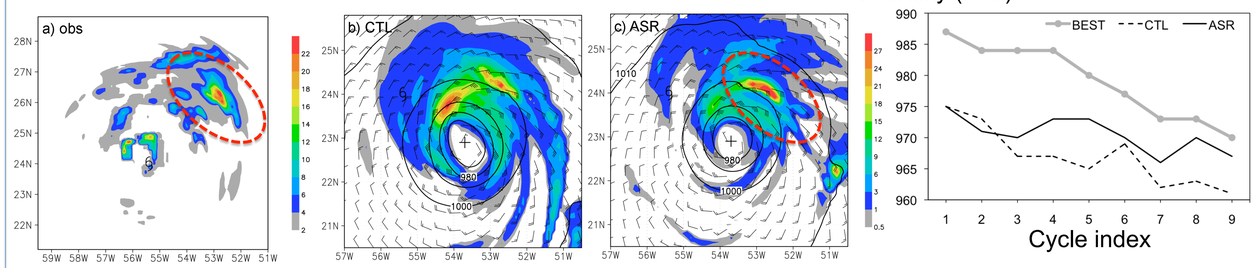
Hurricane Fred (2009) best track



4. Towards assimilating GOES-R ABI all-sky radiances

4.1 Cloud-affected AMSU-A radiance assimilation in Danielle (2010) core area showed a potential to outperform the operational HWRF.

Fig.1 (a) MetOp-A AMSU-retrieved precipitation rate map at 1311 UTC 26 Aug 2010 (Unit: mm h^{-1}); 6-h forecasts of total column condensate (colored; unit: Kg m^{-2}) at cycle 7, mean SLP (solid lines; unit: hPa), and 10-m above ground wind barbs: (b) **CTL: mimic the operational practice with no observation assimilated in HWRF (2011) inner domain, (c) ASR: non-scattering clouds assimilated in HWRF (2011) inner domain with cloudy MW radiance calculation**

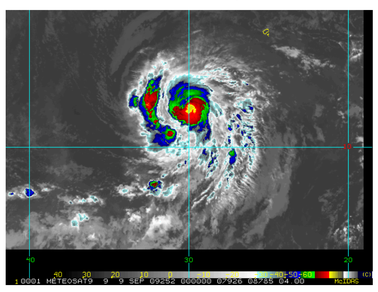


- AMSU-A radiance assimilation in Danielle core reduced errors in TC intensity
- ASR reproduced reasonable asymmetries across the storm:
  - TC eyewall is semi-circle in shape;
  - An outward spiral rainbands in the northern quadrant and the embedded heavy rainfall center

4.2 Assimilating MSG SEVIRI all-sky radiances as GOES-R ABI proxy

- Onboard: MSG
- Spectral channels: 12
- Sampling Frequency: **15 min**
- Spatial resolution:**3km@nadir**

Hurricane Fred (2009)
MSG SEVIRI Ch09 (IR10.8μm) TBs
0000 UTC 09 Sep 2009



- SEVIRI matches the typical observation cycle of weather radar.
- An unprecedented starting point for better coping with the short lifetime of cloud targets in TC core region.

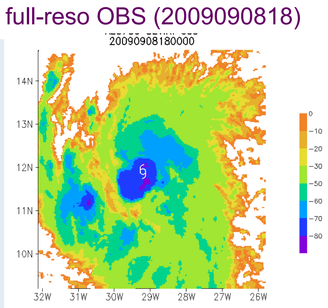
4.3 SEVIRI Channel 9 (IR10.8μm) pre-processing

- Convert full-resolution SEVIRI Ch09 brightness temperature data in McIDAS AREA format into NCEP BUFR format
- For computational expediency, data thinning (e.g. a 10×10 km box) through GSI data processing
- Simplified quality control procedures are applied:
  - Gross check

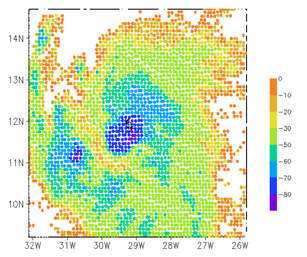
$$\frac{|\Delta Tb_{ich}|}{\sigma_{ich}} > 3 \qquad \sigma_{ich} : \text{inflating observation error}$$

  - further constrain cloud-affected observations using Tb_{obs} thresholds.
- At present, no bias correction is applied.

SEVIRI Ch09
full-reso OBS (2009090818)

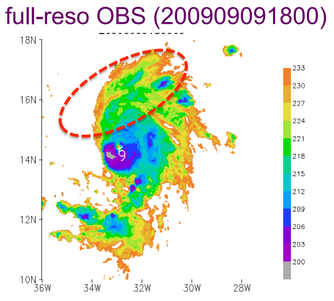


Data thinning in
a 10km×10km box

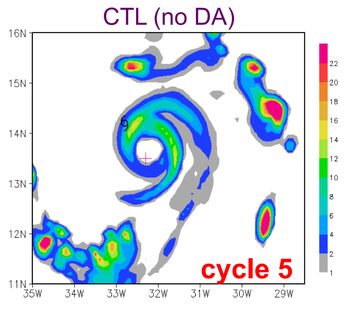


4.4 Assimilating SEVIRI Ch9 (IR10.8μm) into Fred (2009) core area

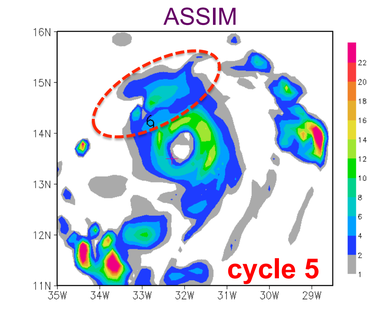
SEVIRI Ch09
full-reso OBS (200909091800)



CTL (no DA)



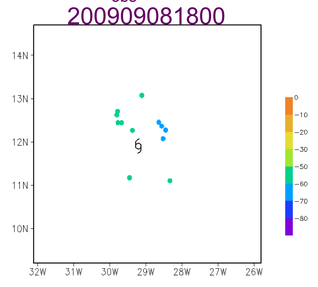
ASSIM



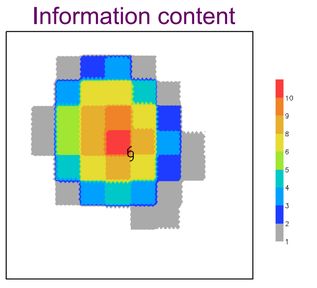
Positive impacts on CWM analysis/forecast after assimilating SEVIRI IR10.8μm

4.5 Information content extraction from SEVIRI IR10.8μm

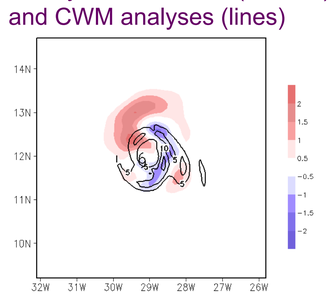
TB_{obs}<-50°C
200909081800



Information content



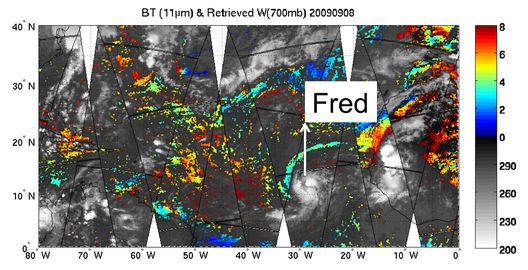
CWM analysis increments (colored), and CWM analyses (lines)



SEVIRI provides integrated information on TC core analysis through a regional HVEDAS.

5. Combined assimilation of SEVIRI and advanced IR soundings

- Single Field of View (SFOV) soundings (T,Q) from CIMSS physical retrieval algorithm
- Same as SEV in section 4.4 with 32 ensembles, but including AIRS single field-of-view (SFOV) T/Q soundings



Preliminary results:

AIRS SFOV retrievals have slight impact for Fred (2009) core area analyses and forecasts due to the limited coverage in a cloud “contamination” area; stronger response was observed from moisture (Q) soundings.

6. Summary

- MSG SEVIRI all-sky radiances and advanced IR soundings are evaluated in a regional hybrid DA system for TC core area.
- Results indicate that the skill of quantitative cloud forecasts can be significantly increased by appropriately assimilating cloud-affected satellite radiances.
- The hybrid system is applicable to operational HWRF ensemble data assimilation, and is promising for the future operational HVEDAS applications to TC.

7. Future

- Combine MSG SEVIRI all-sky radiances (ABI proxy), WWLLN lightning flash rates (GLM proxy) and advanced IR soundings in applications to TC.

References

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

Zupanski, D., M. Zupanski, L. D. Grasso, and co-authors, 2011: Assimilating synthetic GOES-R radiances in cloudy conditions using an ensemble-based method. Int. J. Remote Sens., 32, 9637-9659.

Zhang, M., M. Zupanski, M.-J. Kim, and J. A. Knaff, 2012: Assimilating AMSU-A radiances in TC core area with NOAA Operational HWRF and a Hybrid Data Assimilation System: Danielle (2010).Under revision.

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