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Quantitative Precipitation Forecasting with Polarimetric Radar Data Assimilation: Typhoon Soudelor (2015)

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Motivation

Catastrophic Typhoon Soudelor (2015)

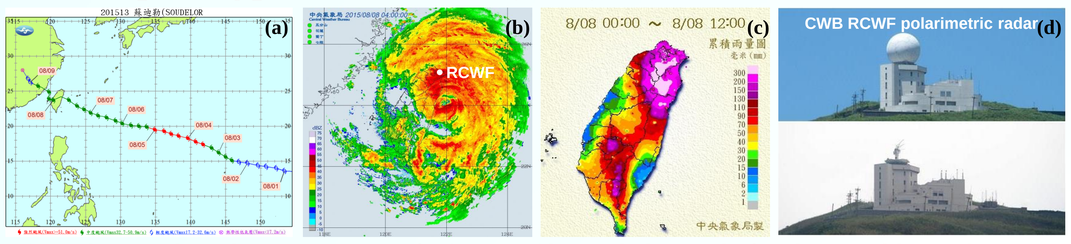

Fig. 1. The Central Weather Bureau (CWB) of Taiwan provides: (a) the best track of Typhoon Soudelor at 6-hour UTC intervals, (b) the composite reflectivity at 2000 UTC 7 Aug, (c) the rainfall accumulation from 1600 UTC 7 to 0400 UTC 8 Aug and (d) the looks of CWB RCWF polarimetric radar before and after the attack of Typhoon Soudelor.

- 8 dead, 437 injured and 4 missing with massive property damage in Taiwan
- The most completely observed typhoon by RCWF, the only S-band polarimetric radar in Taiwan

This study

- Goal: to investigate the sensitivity of quantitative precipitation forecasting (QPF) during a typhoon event to polarimetric radar data assimilation
- Tool: a WRF-LETKF data assimilation system (Tsai et al. 2014) equipped with a polarimetric radar observation operator (Jung et al. 2008)

Cold-start simulations with various microphysics

Model configuration

- Advanced Research WRF model version 3.9
- Two-way interactive, double-nested domains (Fig. 2)
- 45 vertical levels with a model top of 30 hPa
- Cumulus parameterization: Kain-Fritsch (in D01)
- Planetary boundary layer: Yonsei University
- Land-surface model: Noah

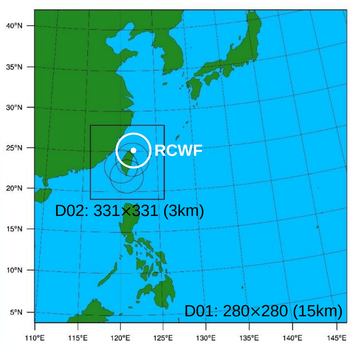

Fig. 2. The WRF domains and CWB S-band radar network.

Experimental design

- Simulation period: 1200 UTC 7 – 0200 UTC 8 Aug
- IC and BC: NCEP GFS 0.25° forecast
- Five cold-start simulations with various cloud microphysics schemes (NoDA in Fig. 3) are compared with RCWF radar observations:
  1. New Thompson et al.
  2. Milbrandt-Yau 2-moment 7-class
  3. Morrison 2-moment
  4. WRF 2-moment 6-class (WDM6)
  5. NSSL 2-moment

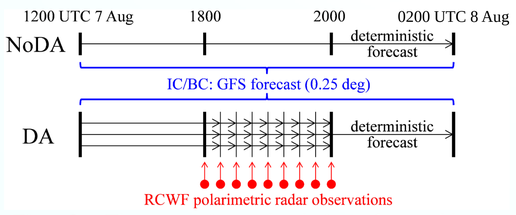

Fig. 3. The experimental design for cold-start simulations with various microphysics (NoDA) and QPF with polarimetric radar data assimilation (DA).

Results

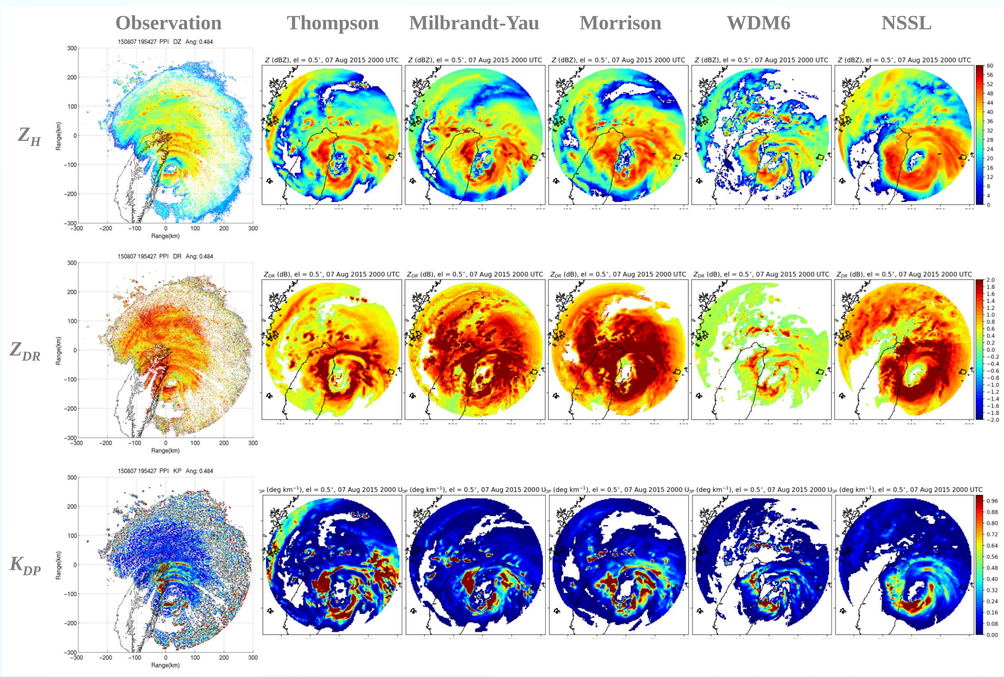

Fig. 4. The Z_H, Z_{DR} and K_{DP} fields (from top to bottom) at an elevation angle of 0.5° for the RCWF radar observation and five simulations with the Thompson, Milbrandt-Yau, Morrison, WDM6 and NSSL cloud microphysics schemes (from left to right) at 2000 UTC 7 Aug .

- The horizontal reflectivity (Z_H), differential reflectivity (Z_{DR}) and specific differential phase (K_{DP}) fields all show that WDM6 gives a clear rainband structure with the smallest wet bias (Fig. 4).

QPF with polarimetric radar data assimilation

Experimental design

- The WDM6 cloud microphysics scheme is selected to carry out polarimetric radar data assimilation experiments (DA in Fig. 3).
- Procedures:
  1. 1200 UTC 7 Aug: generate initial ensemble perturbations via the random-cv facility of WRFDA
  2. 1200-1800 UTC: integrate the ensemble to spin up convective-scale background error covariances
  3. 1800-2000 UTC: assimilate RCWF polarimetric radar data for nine 15-minute LETKF cycles
  4. 2000 UTC 7 – 0200 UTC 8 Aug: perform a deterministic forecast with the analysis ensemble mean
- Assimilation strategies:
  1. Ensemble size: 40
  2. Horizontal localization radius: 12 km
  3. Vertical localization radius: 4 km
  4. Multiplicative inflation factor: 1.08
  5. Assimilated radar variables: see Table 1
  6. Observation errors: 1 m s^{-1} (radial velocity)
     2 dBZ (Z_H)
     0.2 dB (Z_{DR})
     0.5 ° km^{-1} (K_{DP})

Table 1. The list of DA experiments.

Name	Assimilated radar variables	Legend
NoDA	None	
V	V_r	
VZ	V_r Z_H	
VD	V_r Z_{DR}	
VZD	V_r Z_H Z_{DR}	
VK	V_r K_{DP}	
VZK	V_r Z_H K_{DP}	
VZKD	V_r Z_H Z_{DR} K_{DP}	

QPF results:

- Error statistics (Fig. 5):
  1. All the DA experiments outperform NoDA in the first 3 hours but deteriorate in the second 3 hours.
  2. Benefit order in the first 2 hours: $K_{DP} > Z_H > Z_{DR}$
  3. Additional assimilation of Z_H is beneficial for any combination of the rest radar variables
  4. Assimilating all radar variables is a good choice.
- Spatial performance (Fig. 6):

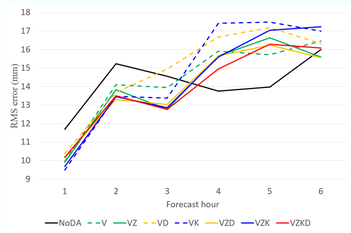

Fig. 5. The root-mean-square errors of hourly rainfall within the land area of Taiwan for various forecasts from 2000 UTC 7 to 0200 UTC 8 Aug.

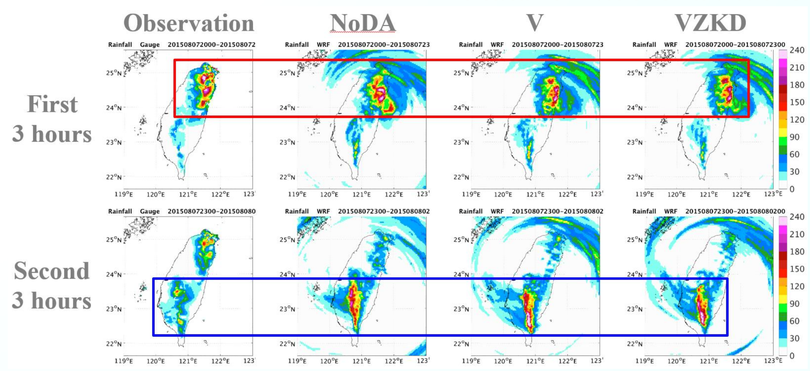

Fig. 6. The 3-hour rainfall accumulations during 2000-2300 UTC 7 Aug (top) and 2300 UTC 7 – 0200 UTC 8 Aug (bottom) for the ground observation and the forecasts of NoDA, V and VZKD (from left to right).

1. First 3 hours: polarimetric radar DA leads to better peak intensity and spatial distribution in northern Taiwan.
2. Second 3 hours: the deterioration results from over-forecasting in southern Taiwan beyond the coverage of RCWF.

Summary

- The cold-start simulation using the WDM6 cloud microphysics scheme is found to give a clear structure of spiral rainbands with the smallest wet bias in this typhoon event.
- All the DA experiments outperform NoDA within the coverage of RCWF in the first 3 hours but deteriorate beyond it in the second 3 hours.
- It is a good to assimilate all radar variables, among which the benefit order is $K_{DP} > Z_H > Z_{DR}$.

Acknowledgements and references

Acknowledgements

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References

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