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

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Abstract

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 in good to assimilate all radar variables, among which the benefit order is KDR > ZV > ZDK.

Motivation

Catastrophic Typhoon Souledor (2015)

Fig. 1. The Central Weather Bureau (CWB) of Taiwan provided: (a) the best track of Typhoon Souledor at 4-hour UTC intervals, (b) the composite reflectivity at 2000 UTC 7 Aug, (c) the rainfall accumulation from 1600 UTC 7 to 0800 UTC 8 Aug and (d) the looks of CWB RCFW polarimetric radar before and after the attack of Typhoon Souledor.

8 dead, 437 injured and 4 missing with massive property damage 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

Compress parameterization: Kain-Fritsch (in D01)

Planetary boundary layer: Yonsei University

Land-surface model: Noah

Simulation period: 1200 UTC 7 - 0200 UTC 8 Aug

1C and 1C: NCEP GFS 6.25° 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. WRF 2-moment

Experimental design

Results

Experimental design

The WDM6 cloud microphysics scheme is selected to carry out polarimetric radar data assimilation experiments (DA in Fig. 3).

1. 1200 UTC 7 Aug: generate initial ensemble perturbations via the random-ev 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

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 (radial velocity)
2 dB (ZDR)
0.2 dB (ZDR)
0.5°° (KDP)

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: KDR > ZV > ZDK
3. Additional assimilation of ZV is beneficial for any combination of the rest radar variables
4. Assimilating all radar variables is a good choice.

Spatial performance (Fig. 6):

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

QPF with polarimetric radar data assimilation

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

Fig. 4. The ZDR, KDP and KDP 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 (ZH), differential reflectivity (ZDR) and specific differential phase (KDP) fields all show that WDM6 gives a clear rainband structure with the smallest wet bias (Fig. 4).

Summary

Acknowledgements and references

Acknowledgements

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References


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

Table 1. The list of DA experiments.

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