High Resolution Simulations of the December 2007 Ice Storm: Comparison of Microphysics Schemes and Observations

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1. Introduction

High resolution (4km) simulations of a winter weather event in the Southern Plains are conducted using the ARW-WRF model. This model has a number of microphysics schemes able to simulate cold season precipitation. It is therefore a useful tool for inter-comparison of schemes and their ability to simulate the evolution of this event and its associated cloud and precipitation processes. This poster selects a few key parameters across microphysics schemes and qualitatively compares them to observations from ARM model and observational products, and NEXRAD radar reflectivity.

2. Case Study

December 9th-11th 2007: Freezing rain/sleet event over Southern Plains. Elevated convection initiated late on the 8th December over Central Oklahoma, and trained for several hours over C. & NC. Oklahoma. Convection continued on the 10th over C. Oklahoma, moving north on the 11th.

WRF V 3.1 Simulation

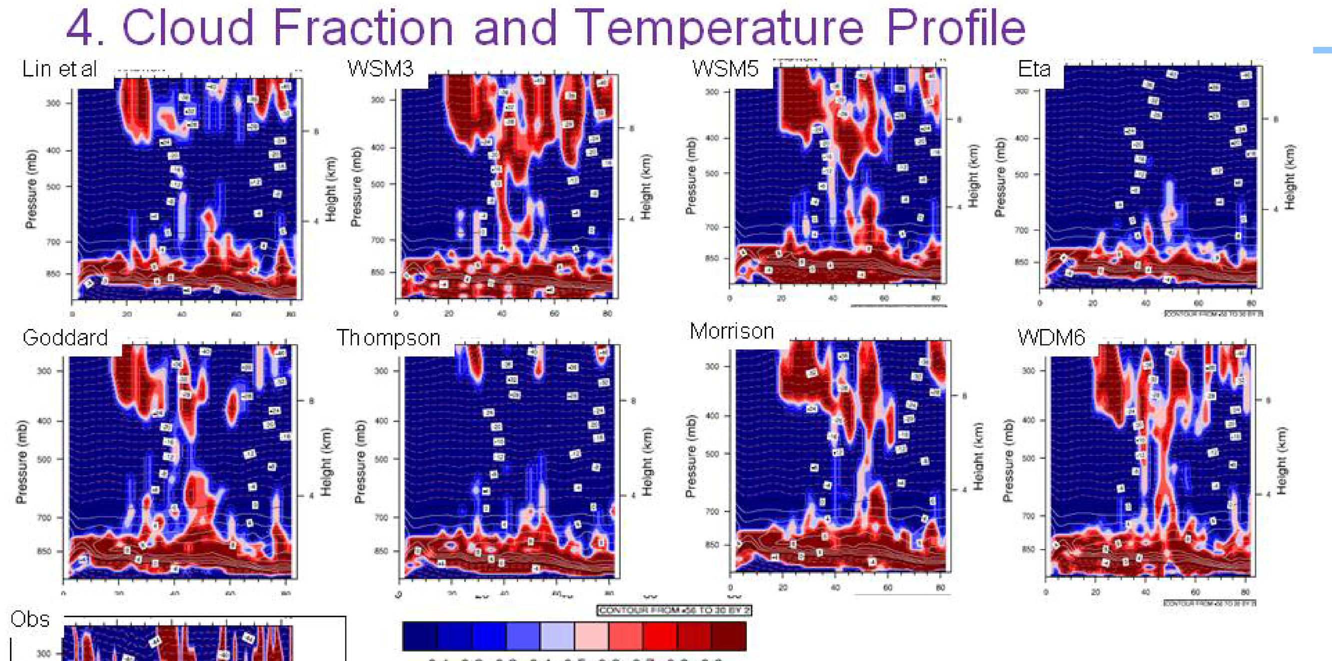
- 4 km simulation with explicitly resolved convection.
- Microphysics schemes considered: WSM3, WSM5, WDM6, Lin et al (1983), Eta/Ferrier, Goddard, Thompson et al (2004) and Morrison double moment.
- All other WRF physics options fixed: Dudhia SW, RRTM Longwave, YSU PBL and NOAH LSM.
- Input data, NAM AWIPs at 3 hour intervals
- Domain size (Fig 1): 700x500 grid points
- Initialised 12Z 8th, runs 84 hours

Observations

- ARM CMBE data, version 2 (Xie et al, 2010)
- SGP Model Output Location Timeseries (MOLTS)
- NEXRAD composite reflectivity

Figure 1

4. Cloud Fraction and Temperature Profile



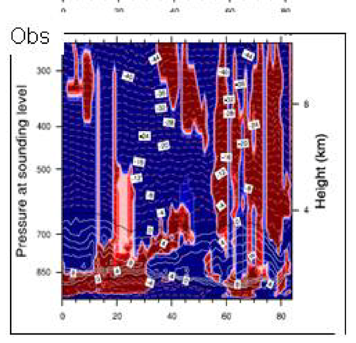


Figure 2: Time height/pressure plots of cloud fraction for each microphysics scheme, with overlaid temperature (in °C) contours. Bottom left figure is from SGP MOLTs, used as the observation due to ARM CMBE cloud fraction being unavailable. The different microphysics schemes change the distribution of temperature, but in general the magnitude and evolution of the vertical temperature structure is reproduced very well in the model. Cloud fractions below 4km are overestimated for all schemes and underestimated above 4km.

4. Cloud Ice and Water Mixing ratio

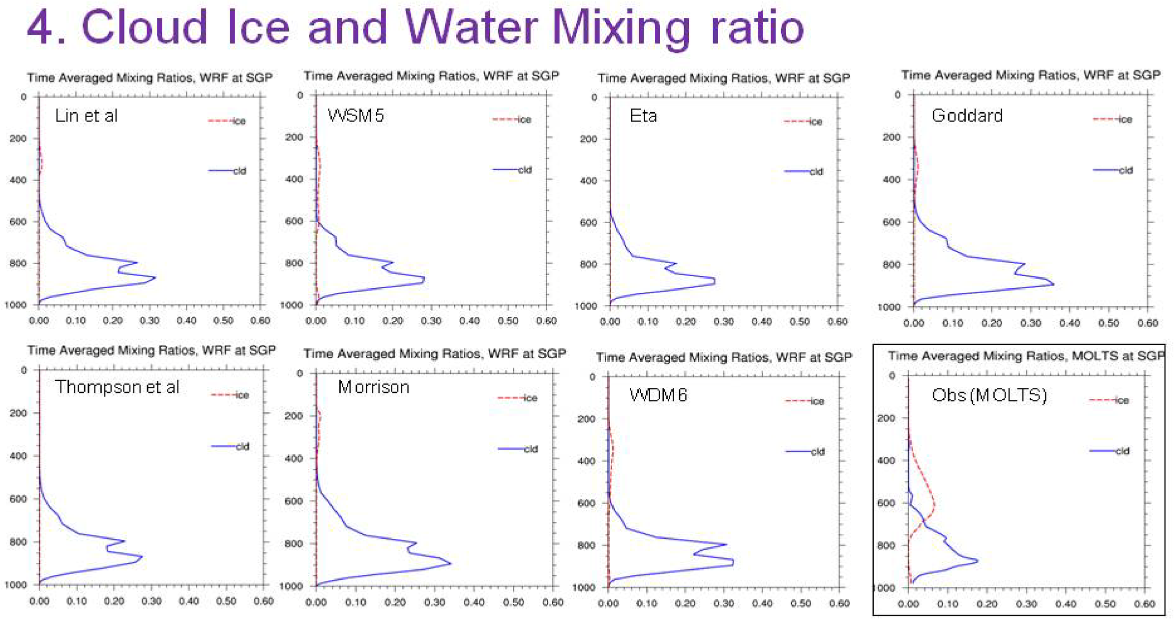


Figure 3: Time average cloud water and ice mixing ratios in g/kg, computed for the 10 nearest grid points to the SGP Lat/Lon. WSM3 is omitted as the scheme does not predict snow, ice and graupel mixing ratios. Temporal evolution of mixing ratios (at 3 hour intervals, not shown) suggest that the model captures the variability in maximum cloud water mixing ratio, e.g, Thompson et al scheme reproduces magnitude and vertical extent of cloud water well in the first 24 hours, whilst WDM6 is best at capturing low level ice mixing ratios.

5. Hydrometeor Mixing Ratios

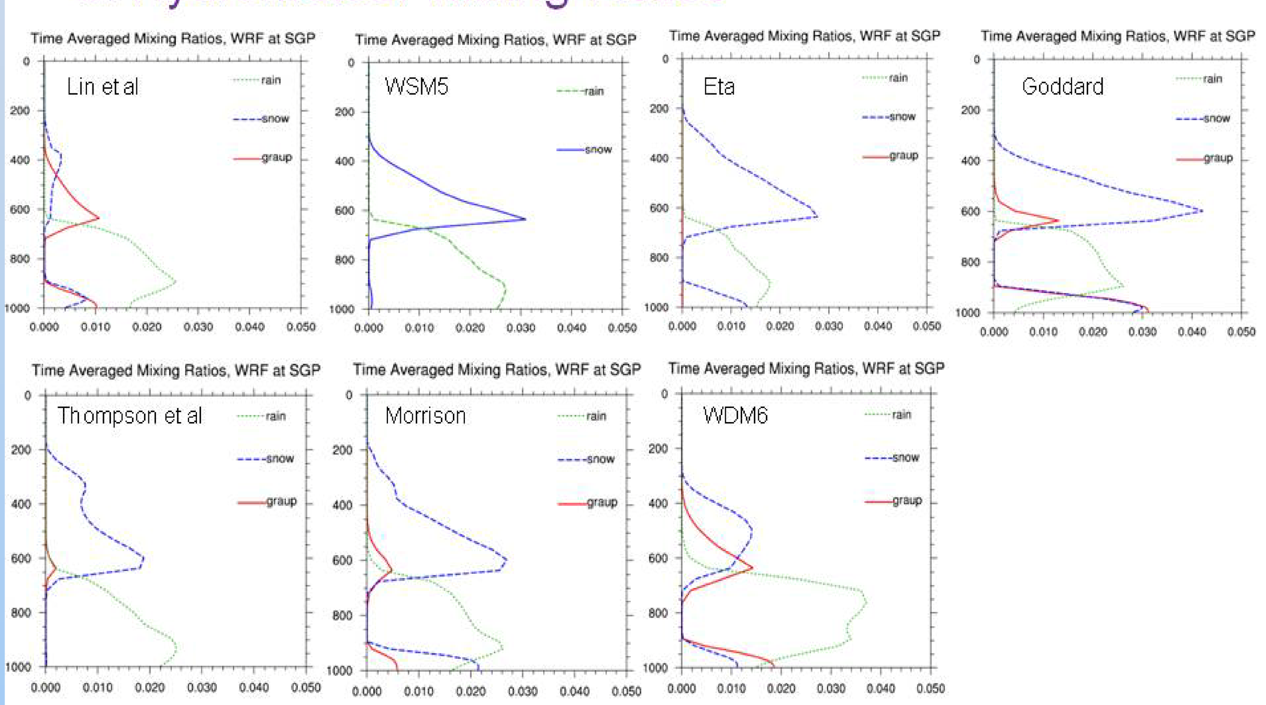


Figure 4: Hydrometeor mixing ratios (Time averaged and domain averaged for 10 nearest grid-points to SGP, g/kg). There are no validating observations available for hydrometeor mixing ratios. All but WSM5, Thompson et al, produce mixed phase precipitation at the surface. Goddard, WDM6, Morrison suggest greater fraction of frozen precipitation (sleet/snow mix).

6. Surface Precipitation

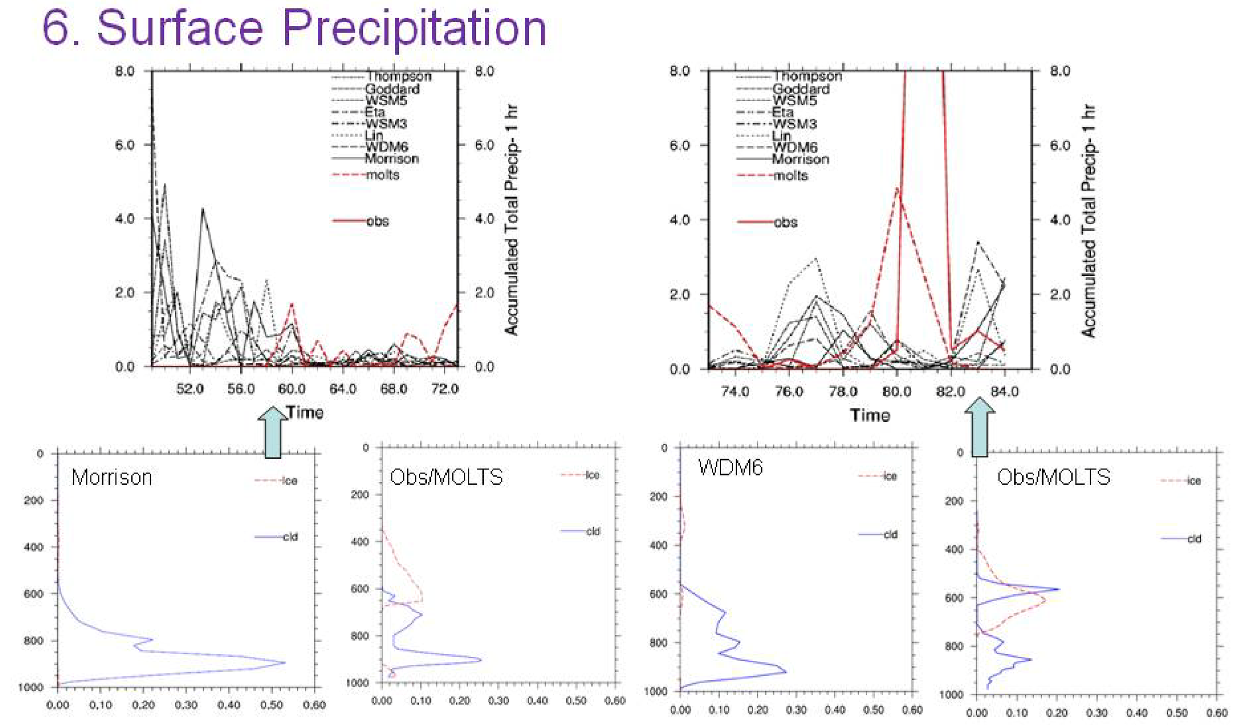


Figure 5: Surface precipitation rate (mm/hr) for 12Z 10th-12Z 11th (left) and 12Z 11th-0Z 12th December 2007. ARM CMBE observations were missing in the left figure, likely due to icing. MOLTS and in situ observations show discrepancy in magnitude but are close in temporal evolution. WRF precipitation is overestimated for all MP schemes, particularly during the 10th. On the 11th, WRF precipitation appears to lag behind observations by 4-6 hours, suggesting temporal discrepancy in timing of local rainfall. For two select periods where observations and model precipitation is similar, the vertical modeled cloud water and ice structures are compared with SGP-MOLTs (bottom figures, g/kg , pressure in hpa)

References

Lin, Y.L., Farley, R.D., and Orville, H.D. 1983: Bulk Parameterization of the Snow Field in a Cloud Model. *Journal of Climate and App Meteorology*., **22**, 1065-1091.

Thompson, G., Rasmussen, R.M., and Manning, K. 2004: Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part 1: Description and Sensitivity Analysis. *Monthly Weather Review*. **132.** 519-541.

Xie S, RB McCoy, SA Klein, RT Cederwall, WJ Wiscombe, EE Clothiaux, KL Gaustad, J Golaz, S Hall, MP Jensen, KL Johnson, Y Lin, CN Long, JH Mather, RA McCord, SA McFarlane, G Palanisamy, Y Shi, and DD Turner. 2010: ARM Climate Modeling Best Estimate Data - A new data product for climate studies. *Bulletin of the American Meteorological Society*, 91, 10.1175/2009BAMS2891.1.

7. Radar reflectivity

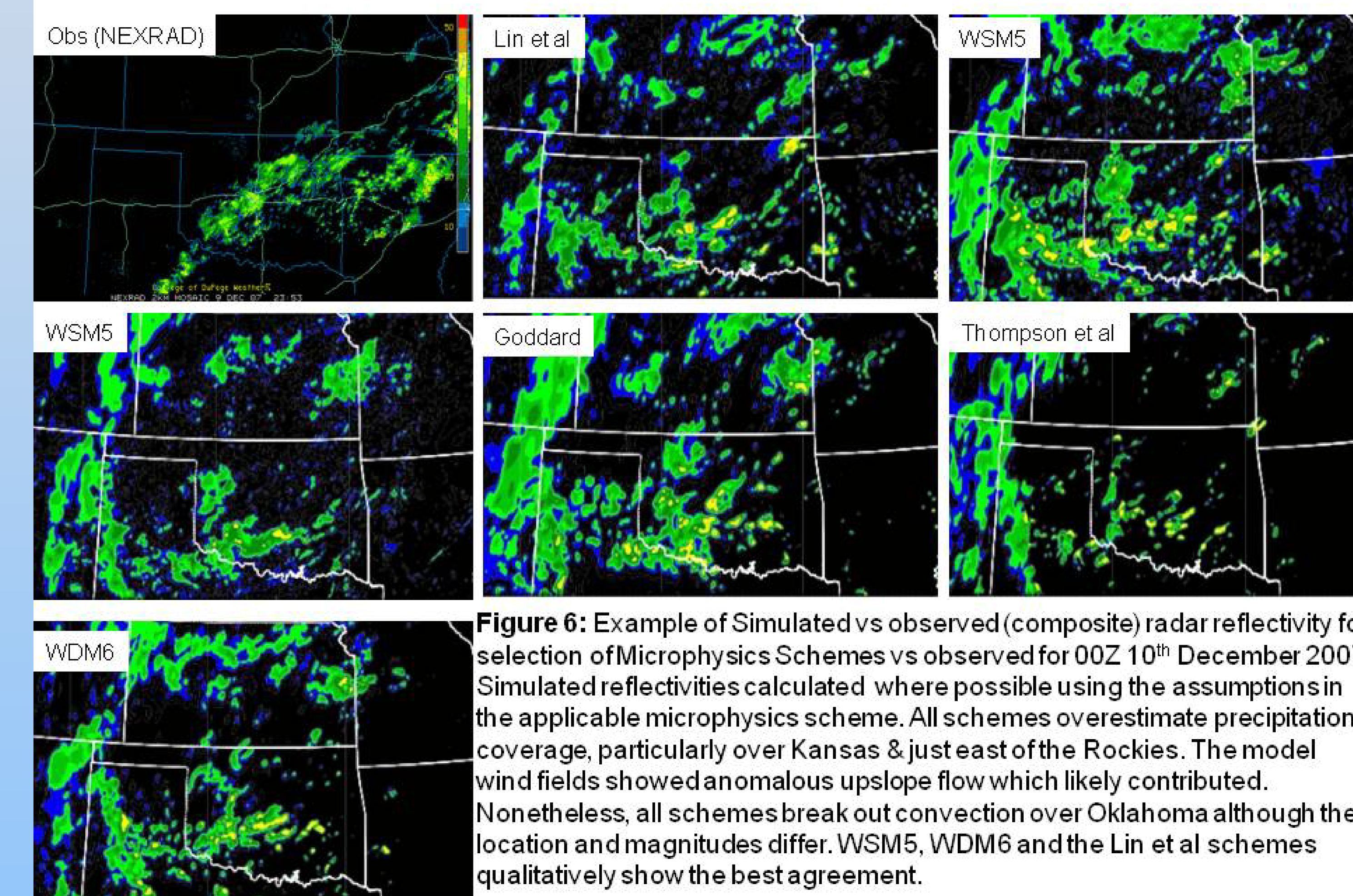


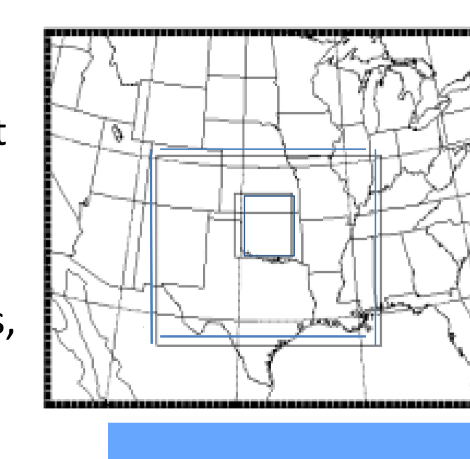
Figure 6: Example of Simulated vs observed (composite) radar reflectivity for selection of Microphysics Schemes vs observed for 00Z 10th December 2007. Simulated reflectivities calculated where possible using the assumptions in the applicable microphysics scheme. All schemes overestimate precipitation coverage, particularly over Kansas & just east of the Rockies. The model wind fields showed anomalous upslope flow which likely contributed. Nonetheless, all schemes break out convection over Oklahoma although the location and magnitudes differ. WSM5, WDM6 and the Lin et al schemes qualitatively show the best agreement.

8. Summary

- This study qualitatively compares modeled and observed cloud structure and precipitation for a winter weather event in the SGP.
- The model reproduces the temporal evolution of the vertical temperature structure very well. Cloud fraction is typically overestimated at low levels and underestimated aloft for all schemes, with Goddard, WDM6 and Morrison having best visual agreement, although there is temporal discrepancy
- Modeled cloud water vs observed has significant temporal variability, but *on average* level of peak cloud water close to observed, although magnitudes typically overestimated. Ice mixing ratios are underestimated by all schemes .
- Phase of precipitation at the surface different depending on MP scheme, for fzrain, sleet mix, Thompson and Lin et al give the best agreement.
- Observed vs simulated evolution of precipitation shows both temporal and spatial discrepancy. Model wind fields differ from observations, allowing greater upslope flow and affecting the movement of convection. The input NAM data also has a moist bias; effect of model input on subsequent simulation appears to be significant (simulations using RUC inputs by contrast significantly underestimate rainfall). Nonetheless, simulated radar reflectivity shows generation of convection in Oklahoma in a similar orientation and location to that observed.

9. Future Work

- Simulation of additional case studies
- Quantitative analysis of model performance against observations and possible bias
- More in depth study of the impact of input data on forecast accuracy
- Progression to higher resolution nested simulations, example nest shown on right, innermost domain at 1km horizontal resolution



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