Evaluation of Model Microphysics Within Precipitation Bands of Extratropical Cyclones

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Introduction

- It is hypothesized microphysical predictions have greater uncertainties/errors when there are complex interactions that result from mixed-phased processes like riming.
- Use Global Precipitation Measurement (GPM) Mission ground validation studies in Ontario, Canada to verify and improve parameterizations.

Motivating Questions

- How well do the various Weather Research and Forecasting (WRF) microphysical schemes predict snowband intensity and microphysics?
- What is the benefit of using a more sophisticated double moment ice/snow scheme as well as more advanced riming schemes?

Field Case Study – 18 February 2012

- Figure 1 shows the 9, 3, and 1-km WRF domains, and the case study location (red dot and inset).
- On 18 February 2012 there was a weak cyclone near Lake Huron and a weak warm front approaching from the southwest.
- Surface radar estimate and WRF underestimated precipitation during this event (Fig. 2).

Figure 1. (left) WRF model domains and the GCPEX field location site (red dot), (right) 11-h WRF forecast (at 1100 UTC 18 February 2012) showing SLP (every 2hPa), surface temperature (shaded) and surface winds (full barb = 10 kts).

Figure 2. (left – Courtesy Enr. Canada) Storm total ground-radar estimate of precipitation using \( Z = 178 \cdot R^{0.67} \) and the gauge totals. (right) WRF members vs the observed and radar estimate at the CARE site (location on Fig. 1).

Observed Versus WRF Radar Analysis

- WRF initial and boundary conditions from the 13-km RUC at 0000 UTC 18 February. Physics include: YSU PBL, GD CP scheme on 9-km only, and RRTM for LW/Dudhia scheme for SW Radiation.
- At 1100 UTC 18 February there was a warm frontal snowband observed near the field study site.
- Most of the 1-km WRF microphysical members realistically simulated this snowband, except the Thompson run was too weak.

Figure 3. Observed radar (0.5 deg) vs 1-km WRF (surface) reflectivity (shaded) at 1100 UTC 18 Feb 2012. North-south cross section locations (dashed) are band relative in order to compare radar and model.

Figure 4. Observed versus 1-km WRF-simulated radar reflectivity at 1100 UTC 18 Feb 2012 for the cross section locations shown in Fig. 2.

- The observed snowband was associated with an enhanced area of reflectivity (25-35 dBZ) extending up to 3 km.
- The Goddard scheme most realistically predicted the structure of the narrow snowband (Thompson too weak).
- There were convective cells aloft that were predicted in the Goddard and Stony Brook (SBU-YLin) schemes.
- There was little cloud water (LWC) observed and simulated on the north (cold) side of the precipitation band (Fig 5).

Figure 5. Mean 1-km WRF profiles of ice water content, snow exponential PSD slope parameter and intercept, and liquid water content for the boxes in Fig. 3 in comparison to aircraft spiral.

Figure 6. Relative humidity profile with respect to water (green) and ice (blue) for the aircraft (+) and WRF (solid line) at 1100 UTC 18 Feb 2012.

- WRF microphysical predictions were averaged within the boxes in Fig. 3, which is location of aircraft spiral.
- At 1100 UTC (north side of band), all WRF schemes unrealistically predicted the ice water content profiles. The Thompson tended to underpredict, and Goddard/SBU-YLin overpredicted.
- Morrison best predicted the snow distribution (slope), but had difficulty with the intercept. The temperature dependent slope intercept schemes (SBU and WSM) had a closer intercept to the aircraft observations.
- The WSM6 and SBU relative humidities tend to be too low (likely because of the saturation adjustment scheme used), while the Thompson and Morrison are slightly too moist.

- By 1230 UTC (center of snow band), the Goddard and SBU most realistically predicted the narrow structure of the band. Thompson was too weak.
- There was much more cloud water observed, which was underpredicted by all schemes.
- The slope intercept and distribution results are similar to earlier times.

Microphysical Comparisons

- The WRF realistically simulated the warm frontal snowband at relatively short lead times (10-14 h).
- The snowband structure is sensitive to the microphysical parameterization used in WRF.
- The Goddard and SBU-YLin most realistically predicted the band structure, but overpredicted snow content.
- The double moment Morrison scheme best produced the slope of the snow distribution, but it underpredicted the intercept.
- All schemes and the radar derived (which used dry snow Z-R) underpredicted the surface precipitation amount, likely because there was more cloud water than expected. The Morrison had the most cloud water and the best precipitation prediction of all schemes.

Summary and Conclusions

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