P3.5 Snowfall Accumulation Forecasting Challenges for the Southern Appalachians

University of North Carolina Asheville

Douglas K. Miller, UNC Asheville, L. Baker Perry, Appalachian State University, Sandra Yuter, North Carolina State University, Laurence Lee, NOAA/NWS, Greer, SC, Stephen Keighton, NOAA/NWS, Blacksburg, VA, and Clay Tabor, UNCA

Introduction

Forecast challenges

Snowfall accumulation forecasts in the southern Appalachian Mountains (SAMs) are difficult due to

- significant relief (Figs. 1 & 2)
- complex topography (Figs. 1 & 2)
- highly localized accumulations, particularly in Northwest Flow Snowfall (NWFS) events, (Figs. 3, 6-9)
- variations in snow density (snow to liquid equivalent ratio), (Table 1, Fig. 6)
- numerical forecast models tend to deposit snow primarily on windward slopes and peaks

Purpose

Assess and improve numerical forecast model (WRF) capabilities associated with snowfall in the SAMs.

Table 1. Storm summaries for selected snowfall events during the study period. Meteorological data are two-hour averages during the period of heaviest precipitation.

Date 2008	Hours	New Snow (cm)	SWE (mm)	Density (kg m^{-3})	Snow-Liquid ratio	Temp (°C)	RH (%)
1-3 Jan	42	10.2	3.4	33	30.3	-11.6	83.3
17 Jan	14	4.6	8.4	184	5.4	-5.9	89.9
26-28 Feb	44	21.1	9.9	47	21.3	-7.2	91.4
29 Feb	13	1.0	3.3	328	3.1	0.1	92.3

Figure 1. MODIS image of NWF Snowfall event taken at ~1640 UTC 18 Feb 2007.

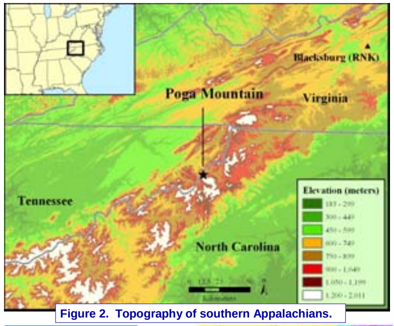

Figure 2. Topography of southern Appalachians.

Figure 3. Operations center at Poga Mountain during NWFS event of 27 Feb 2008.

Figure 4. WRF nested domains.

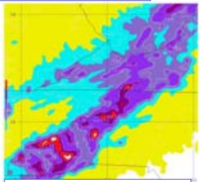

Figure 5. WRF topography (m).

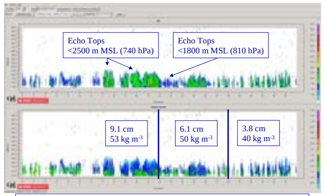

Figure 6. Vertically-pointing radar image for NWFS event of 27-28 Feb 2008.

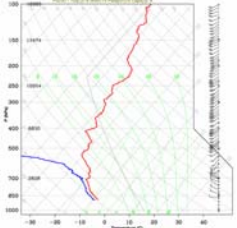

Figure 7. Poga Mountain sounding initiated at 1244 UTC 27 Feb 2008.

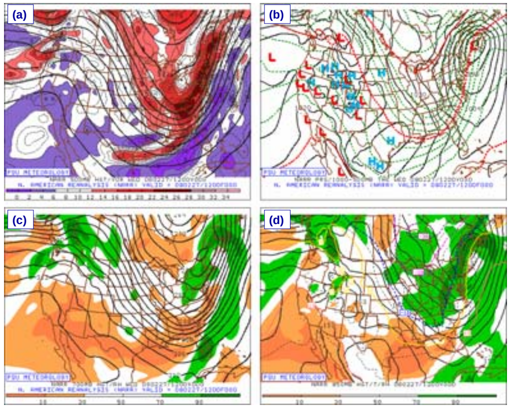

Figure 8. NARR analyses of (a) 500 hPa Z [dm]/ abs vort [x10^{5} s^{-1}], (b) SLP [hPa]/ 1000-500 hPa thickness, (c) 700 hPa Z [dm]/ RH [%], and (d) 850 hPa Z [dm]/ Temp [°C]/ RH [%] valid at 1200 UTC 27 Feb 2008.

Methodology

"macro" ensembles – WRF (v2.1.1)

- 36, 12, 4 km domains, 50 vertical levels

Initial conditions

- NARR (29 lvls, 32km), NAM (38 lvls, 12km), or GFS (22 lvls, 1°)

Physics options

- Control (ctrl); Betts-Miller-Janjic CPS, YSU PBL, and Lin et al. microphysics
- CPS (exp1); Kain-Fritsch CPS
- PBL (exp2); Mellor-Yamada-Janjic PBL

"micro" ensembles – microphysics tests

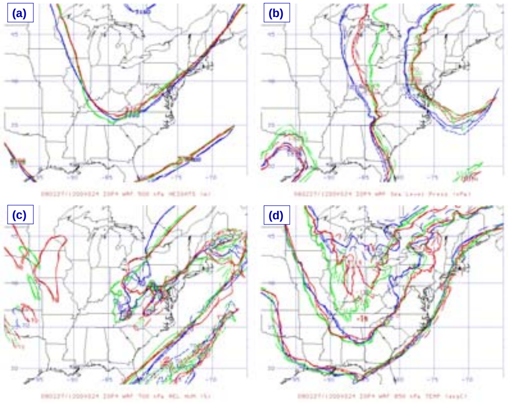

Figure 9. WRF 24-h "macro" ensemble simulations of (a) 500 hPa Z [m], (b) SLP [hPa], (c) 700 hPa RH [%], and (d) 850 hPa Temp [°C] valid at 1200 UTC 27 Feb 2008. Blue = NARR, Green = NAM, Red = GFS

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Results

Macro – ensembles "winner" (Table 2)

•NARR initialization, ctrl physics

Micro – ensembles "winner" (Table 3)

•mp1, no CPS in innermost domain; [Hong et al. (2004), WSM 3-class scheme]

Miscellaneous

•Modest differences between NARR/ctrl and mp1 simulations in

- vertical T, Td profile (Fig. 14)
- mountain wave response (Fig 17)
- trajectory forecast (Fig. 20)

→ lead to *significant* differences in

- acc precip forecasts (Figs. 16 & 19)

Conclusions

• "best" synoptic-scale simulation does not assure best model acc precip fcst (Table 2)

• a probabilistic approach appears as the only way to predict the range of realistic potential outcomes

• what role sub-grid scale convection (e.g. cloud rolls) and mountain waves?

Table 2. Accumulated precipitation (In.) liquid equivalent statistics for the "macro" WRF experiments for the 60-h period; 1200 UTC 26 Feb – 0000 UTC 29 Feb 2008.

npts=80	mean	σ	rmse	bias	corr
obs	0.496	0.281	N/A	N/A	N/A
narr-ctrl	0.614	0.372	0.336	0.117	0.566
narr-exp1	0.609	0.368	0.334	0.113	0.559
narr-exp2	0.672	0.420	0.398	0.176	0.541
nam-ctrl	0.556	0.380	0.319	0.059	0.586
nam-exp1	0.558	0.388	0.327	0.061	0.579
nam-exp2	0.652	0.384	0.348	0.155	0.601
gfs-ctrl	0.600	0.335	0.296	0.103	0.609
gfs-exp1	0.572	0.325	0.286	0.076	0.594
gfs-exp2	0.691	0.411	0.381	0.194	0.609
overall	0.614	0.380	0.338	0.117	0.576

Table 3. Accumulated precipitation (In.) liquid equivalent statistics for the "micro" WRF experiments for the 60-h period; 1200 UTC 26 Feb – 0000 UTC 29 Feb 2008.

npts=80	mean	σ	rmse	bias	corr
mp1, no cps	0.451	0.286	0.279	-0.045	0.531
mp1, cps	0.449	0.284	0.279	-0.048	0.526
mp2, no cps	0.426	0.253	0.292	-0.070	0.439
mp2, cps	0.423	0.245	0.284	-0.074	0.462
mp3, no cps	0.489	0.320	0.294	-0.008	0.527
mp3, cps	0.487	0.319	0.291	-0.010	0.536
mp4, no cps	0.447	0.248	0.271	-0.050	0.499
mp4, cps	0.449	0.249	0.271	-0.047	0.500
mp5, no cps	0.368	0.180	0.273	-0.129	0.530
mp5, cps	0.363	0.179	0.276	-0.134	0.525
overall	0.435	0.264	0.281	-0.061	0.494

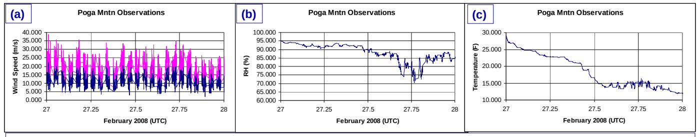

Figure 10. Poga Mountain observations of (a) average {blue} and maximum {pink} wind speed [m s^{-1}], (b) relative humidity [%], and (c) air temperature [ºF] over the period 0000 UTC 27 Feb - 0000 UTC 28 Feb 2008.

Figure 11. Composite reflectivity for NWFS event over the SAMs region valid 1158 UTC 27 Feb 2008.

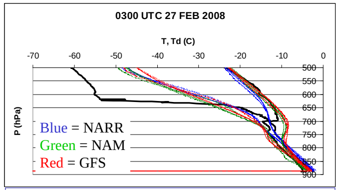

Figure 12. Vertical T, Td [ºC] profile forecasts of the "macro" simulations valid 0300 UTC 27 Feb 2008.

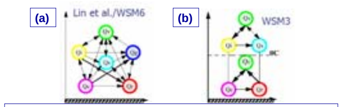

Figure 13. Water species schematics for the (a) NARR/ctrl and (b) mp1 experiments.

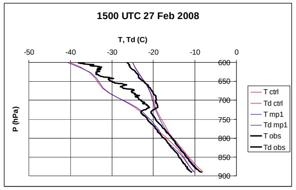

Figure 14. Vertical T, Td [ºC] profile forecasts of the NARR/ctrl & mp1 simulations valid 1500 UTC 27 Feb 2008.

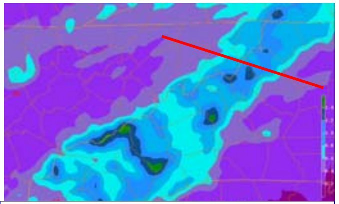

Figure 15. "Zoomed" WRF topography (m) at 4 km.

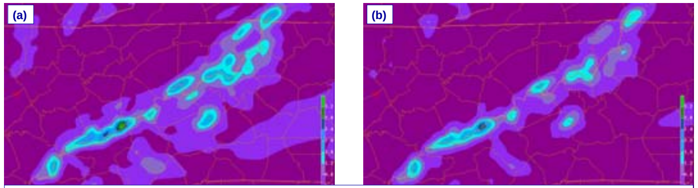

Figure 16. Accumulated precipitation (liquid equivalent, Inches) over the 60-h period 1200 UTC 26 Feb – 0000 UTC 29 Feb 2008 for the (a) NARR/ctrl and (b) mp1 simulations of domain 3 (4 km).

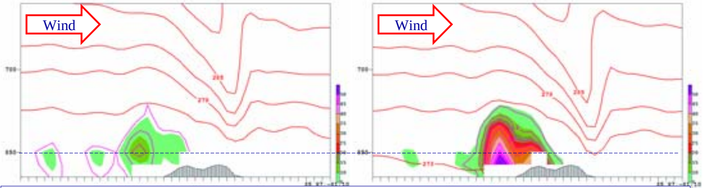

Figure 17. Vertical cross section (location given in Fig. 15) of θ [contours, K] and water mixing ratio [x10⁵ kg/kg] through Poga Mountain at 1500 UTC 27 February 2008 for the (a) NARR/ctrl and (b) mp1 simulations for domain 3 (4 km).

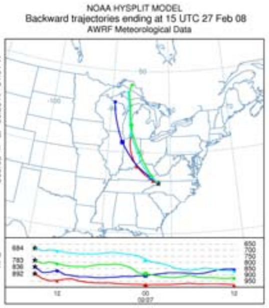

Figure 18. Backward trajectories ending at Poga Mountain at 1500 UTC 27 Feb 2008 for the outermost (36 km) NARR/ctrl simulation.

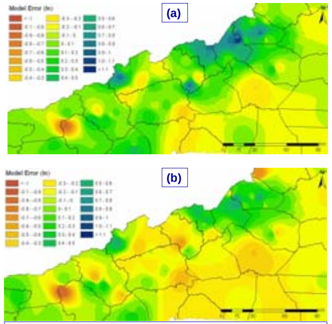

Figure 19. Accum. precip. error (In) over the 60-h period 1200 UTC 26 Feb – 0000 UTC 29 Feb 2008 for the (a) NARR/ctrl and (b) mp1 simulations of domain 3 (4 km).

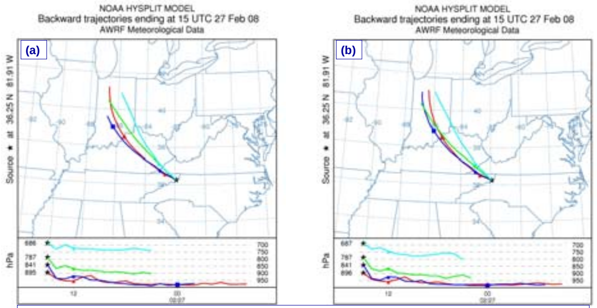

Figure 20. Backward trajectories ending at Poga Mountain at 1500 UTC 27 Feb 2008 for the (a) NARR/ctrl and (b) mp1 simulations for domain 3 (4 km).

Future work

Test "best" WRF model physics combination and initialization for 3 independent case studies (IOPs 5 – 7)

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