CW18

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The Influence of Boundary Layer Mixing on the 27–28 January 2015 "Twitter Snowstorm": Sensitivity Experiments

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Objectives and Questions

- Assess the influence of PBL mixing strength on extratropical evolution
  - Is cyclone development and evolution sensitive to PBL mixing?
- Determine the dominant impact of PBL mixing
  - How is the PBL mixing influencing cyclone evolution ?
- Evaluate how robust the results are
  - Does the PBL mixing influence the cyclone to the same degree under different model configurations?

Background

- The boundary layer can directly influence extratropical cyclones through frictional processes (Adamson et al. 2006)
  - Ekman pumping
  - Baroclinic generation of PV
- The boundary layer influences the thermal and moisture profile, potentially influencing the release of latent heat, which has been shown to significantly affect extratropical cyclone development (Stoelinga 1996)
- PBL schemes parameterize the mean transport of heat, momentum, and moisture by turbulent eddies.
  - One method is through using a K-profile scheme to describe eddy mixing through the PBL
  - YSU is a K-profile scheme which imposes a mixing strength profile given PBL height

YSU scheme equation

$$K_{zm} = \kappa w_s z \left(1 - \frac{z}{h}\right)^2 \qquad h = Rib_{cr}\frac{\theta_{va}|U(h)|^2}{g(\theta_v(h) - \theta_s)}$$

(Hong and Pan 1996)

- PBL height (h) is found iteratively by finding the height where the bulk Richardson number equals the bulk critical Richardson number (BCR).
- Changing the BCR effectively changes the PBL mixing strength and depth through altering the K-profile.

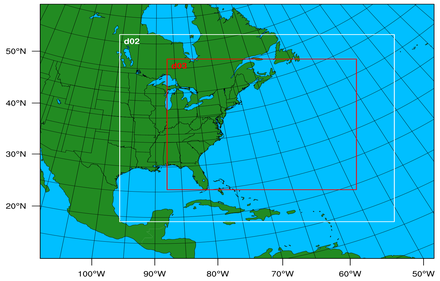
Experiment Design

- Simulate the 27–28 January 2015 snowstorm using two different boundary layer mixing strengths
  - Specify the bulk critical Richardson number within the YSU scheme as either 0.00 or 0.25, effectively changing the mixing depth and strength
- Run four experiments on each BCR configuration:
  1. 5-trial stochastic kinetic energy backscatter (SKEBS) ensemble (assess robustness)
  2. Remove latent heating and terrain height variations (NOLH; determine mechanism)
  3. Remove only terrain height variations (evaluate sensitivity to terrain)
  4. Compare BCR 0.00 with MYNN (contrast with local, TKE scheme)

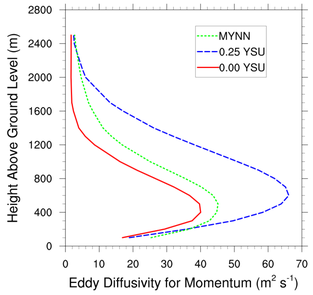
Model Setup

- WRF simulation using ERA-I for initial and boundary conditions
- 4-km inner domain using physics similar to the RAP
- 0000 UTC 26 January – 0000 UTC 29 January 2015 (72 h runtime)

Domains

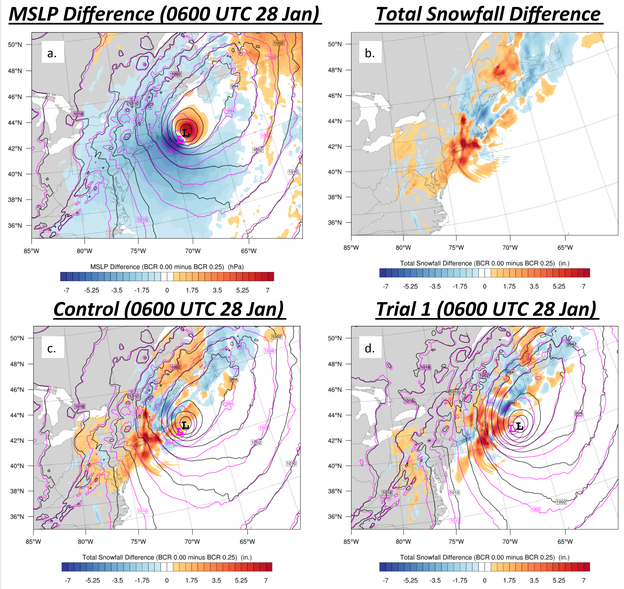


Eddy Mixing



Experiment 1 (SKEBS trials)

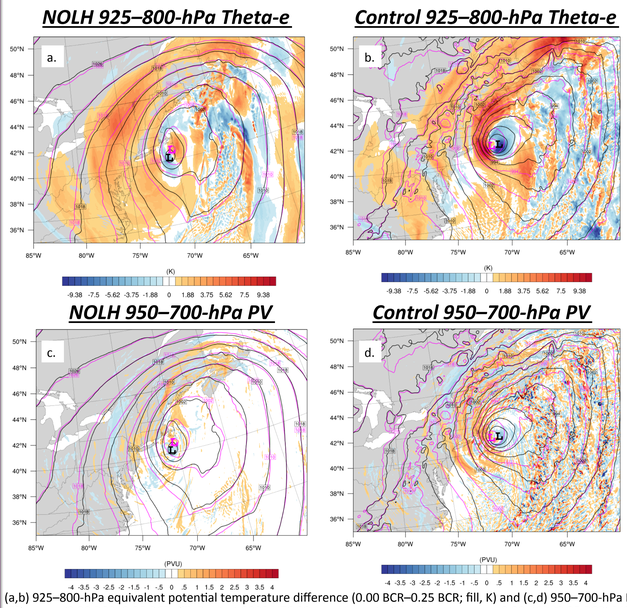
- 0.00 BCR simulations propagate more slowly than 0.25 BCR simulations
- Stronger precipitation signature over the coastal Northeast region in 0.00 BCR case



(a) MSLP difference (fill, hPa), (b) total storm snowfall difference (0.00 BCR–0.25 BCR; fill, in.), and snowfall difference and MSLP for (c) control and (d) SKEBS trial 1. Magenta (black) contours are 0.00 BCR (0.25 BCR) MSLP.

Experiment 2 (NOLH)

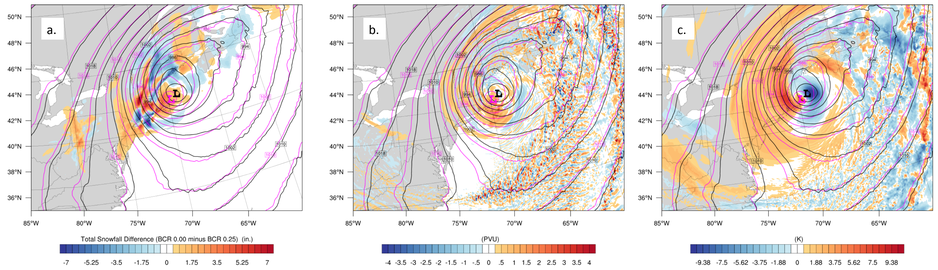
- 0.00 BCR and 0.25 BCR runs propagate at similar speeds
- Weaker 950–700-hPa PV to the northwest of surface low in NOLH cases



(a,b) 925–800-hPa equivalent potential temperature difference (0.00 BCR–0.25 BCR; fill, K) and (c,d) 950–700-hPa PV difference (0.00 BCR–0.25 BCR; fill, PVU) at 0000 UTC 28 Jan. Magenta (black) contours are 0.00 BCR (0.25 BCR) MSLP.

Experiment 3 (Flat land)

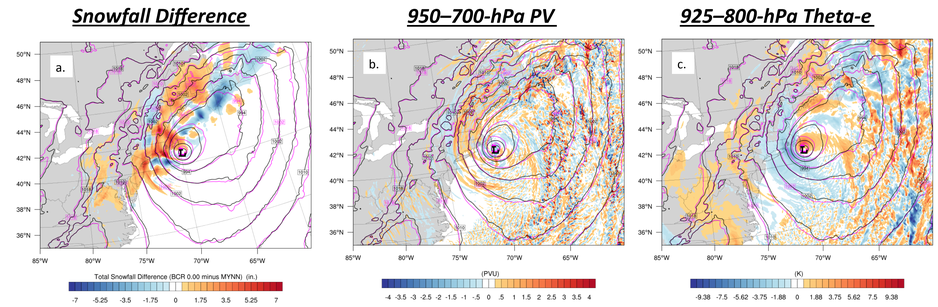
- Without terrain, similar results to control run and SKEBS trials with 0.00 BCR simulation propagating more slowly



(a) Snowfall accumulation (fill, in.), (b) 950–700 PV (fill, PVU), and (c) 925–800-hPa equivalent potential temperature (fill, K) difference (0.00 BCR–0.25 BCR) and MSLP (contours; 0.00 BCR = magenta, 0.25 BCR = black) at 0300 UTC 28 January 2015

Experiment 4 (YSU and MYNN)

- MYNN run performs similarly to the YSU (0.00 BCR) run with little difference in cyclone center location
- PV fields are more similar between MYNN and 0.00 BCR YSU than between 0.00 BCR and 0.25 BCR YSU schemes
- Generally higher precipitation totals during MYNN simulation



(a) Snowfall accumulation (fill, in.), (b) 950–700 PV (fill, PVU), and (c) 925–800-hPa equivalent potential temperature (fill, K) difference (MYNN–0.00 BCR) and MSLP (contours; MYNN= black, 0.00 BCR = magenta) at 0300 UTC 28 January 2015

Conclusions/TL;DR:

- The 27–28 Twitter snowstorm is sensitive to boundary layer mixing strength/depth
- Weaker mixing allows for the preservation of boundary layer theta-e, represented by higher theta-e values to the north and west of the surface cyclone
- Stronger boundary layer theta-e likely results in more vigorous latent heat release, which produces higher diabatically generated positive PV to the north and west of the cyclone
- This PV, along with diabatically generated divergent outflow, likely interacts with the surface cyclone and the upper-level PV to slow the cyclone with less mixing, which aides in higher snowfall amounts to the west of the cyclone track

References:

- Adamson, D. S., Belcher, S. E., Hoskins, B. J. and Plant, R. S. (2006), Boundary-layer friction in midlatitude cyclones. Q.J.R. Meteorol. Soc., 132: 101–124. doi:10.1256/qj.04.145
- Hong, S. and H. Pan, 1996: Nonlocal Boundary Layer Vertical Diffusion in a Medium-Range Forecast Model. Mon. Wea. Rev., 124, 2322–2339
- Stoelinga, M.T., 1996: A Potential Vorticity-Based Study of the Role of Diabatic Heating and Friction in a Numerically Simulated Baroclinic Cyclone. Mon. Wea. Rev., 124, 849–874,

Acknowledgements:

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