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

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)

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:

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Domains

Eddy Mixing

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\begin{align*}
K_{em} &= \kappa_{w} \left( 1 - \frac{z}{h} \right)^2 \frac{\theta}{\theta_e(h)} \\
\theta &= R h_c \left( \frac{\theta_e(h)}{\theta_e(h_0)} \right)^{0.3} \\
\end{align*}
\]