S43

# The Projection of Turbulent Mixing Variations on an Extratropical Cyclone


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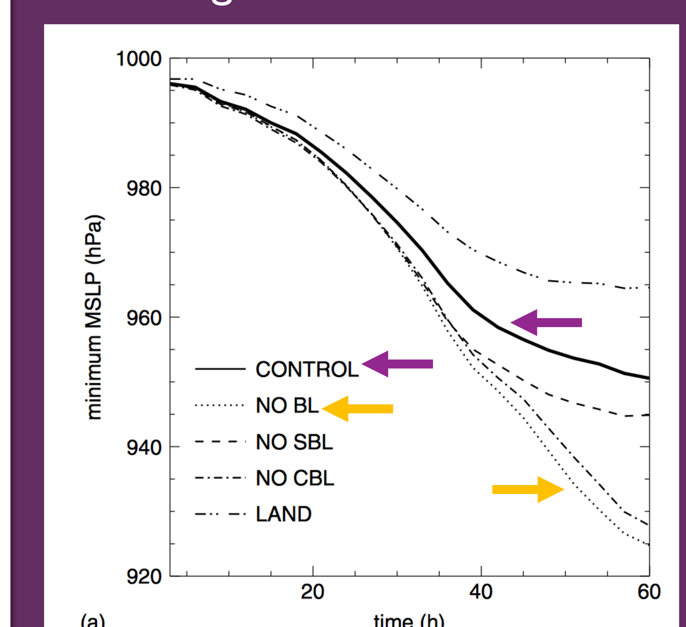
## Objectives and Questions

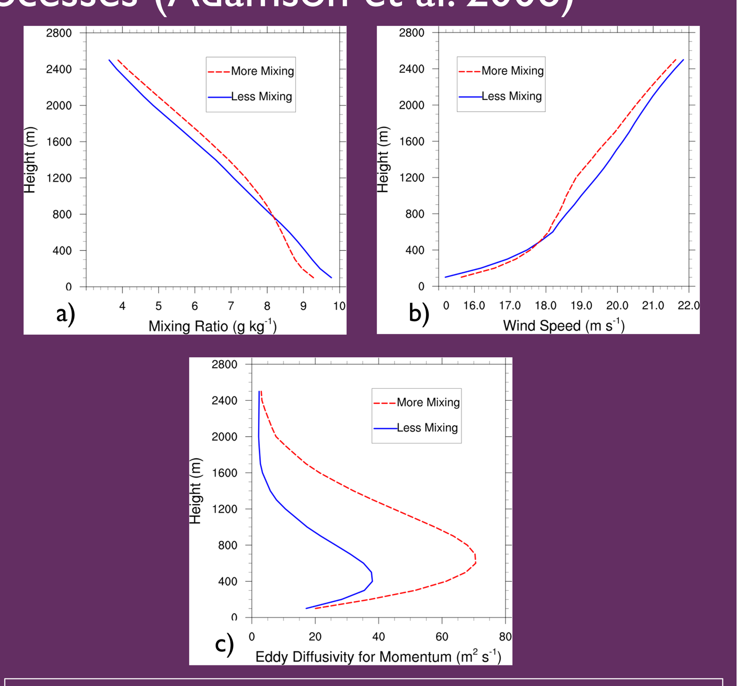
- Assess the influence of PBL mixing strength on extratropical cyclone evolution
  - Is cyclone evolution sensitive to variations in PBL mixing?
- Determine the dominant impact of PBL mixing
  - How do PBL mixing variations project onto larger scales?
- Evaluate the robustness of the results (not shown and ongoing)
  - Does the PBL mixing influence the cyclone to the same degree under different model configurations and states?

## Background

- The boundary layer can directly influence extratropical cyclones through thermal and frictional processes (Adamson et al. 2006)




Time series of the minimum mean-sea-level pressure over a [dry] cyclone. (Beare 2007)




Area-averaged vertical profiles for (blue) less-mixing and (red) more-mixing simulations of (a) mixing ratio, (b) wind speed, and (c) eddy diffusivity from the 27 January snowstorm simulation.

- The boundary layer influences the thermal and moisture profiles, potentially influencing the release of latent heat, which has been shown to significantly affect extratropical cyclone development (Stoelinga 1996)

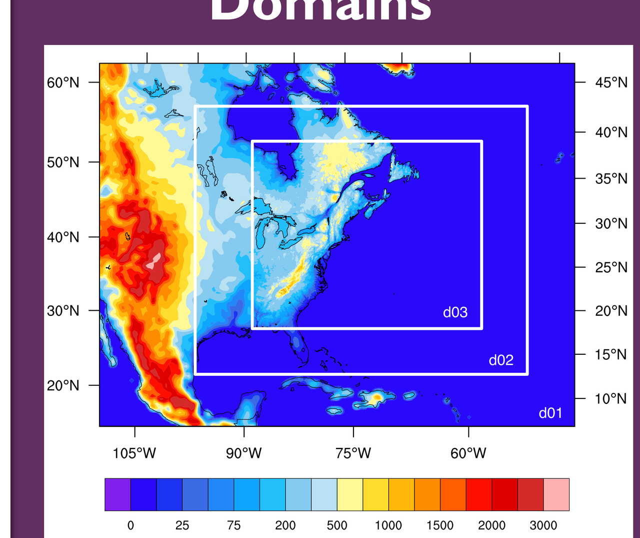
## Experiment Design

- Simulate the 27–28 January 2015 snowstorm using two different boundary layer mixing strengths
  - Specify the critical Richardson number within the YSU scheme as either 0.00 (less mixing) or 0.25 (more mixing), effectively changing the mixing depth and strength
- Establish how and why the simulations differ using Eulerian and Lagrangian techniques (e.g. 24-h backward trajectories)

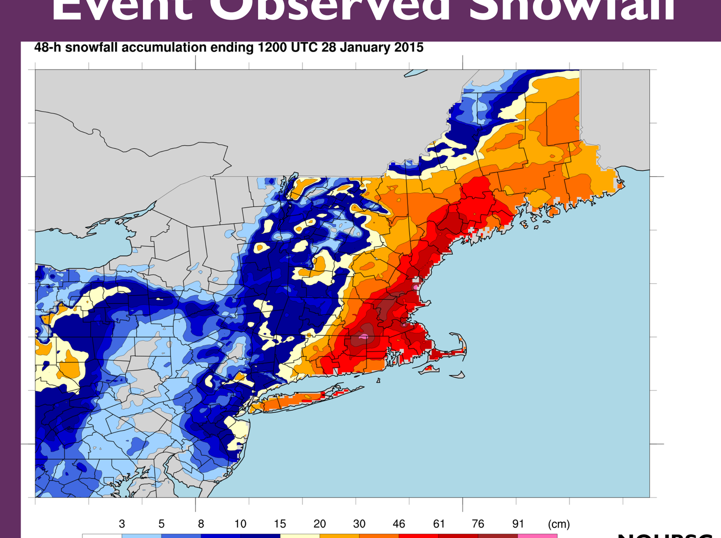
## Model Setup

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

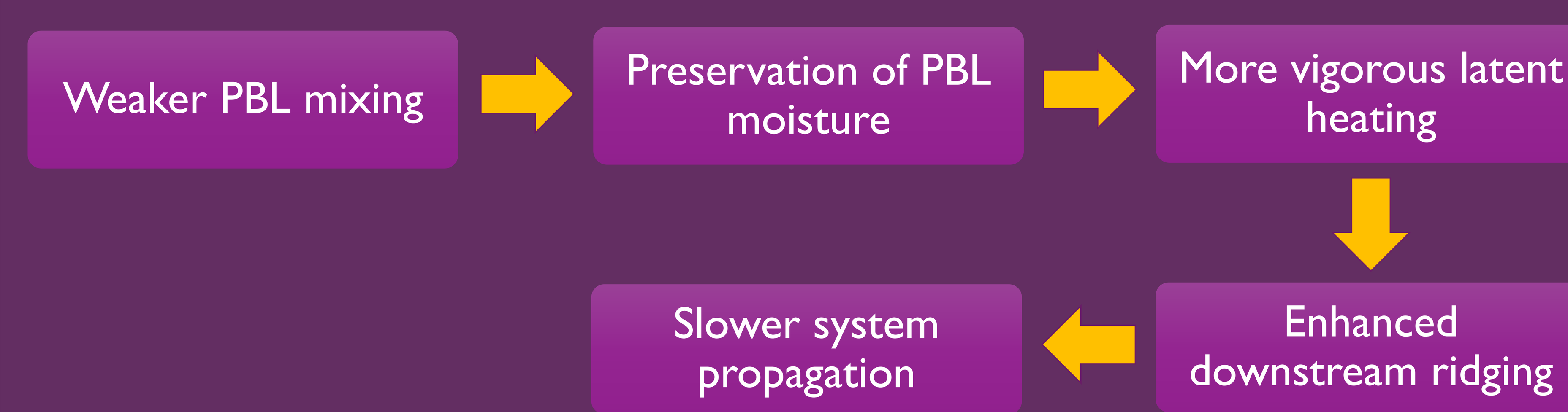
### Domains




### Event Observed Snowfall

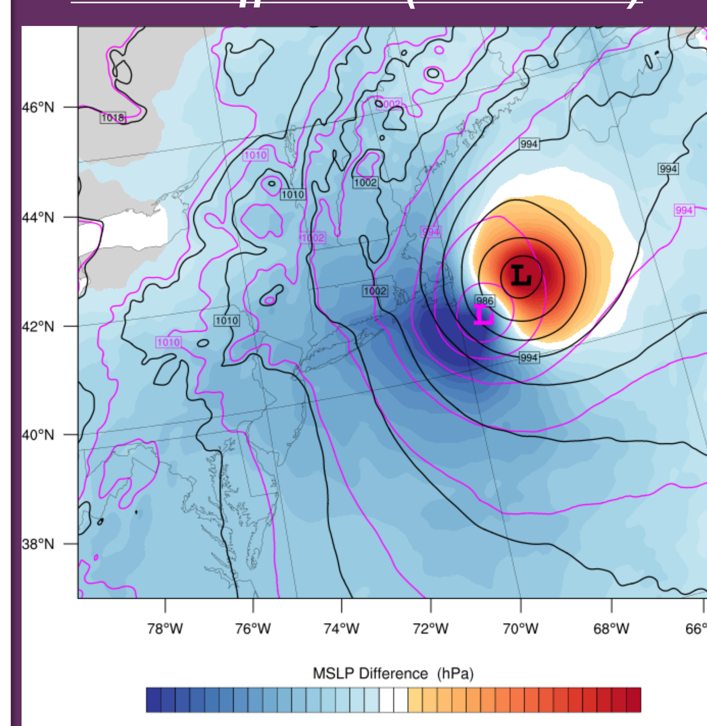



## Main Finding:



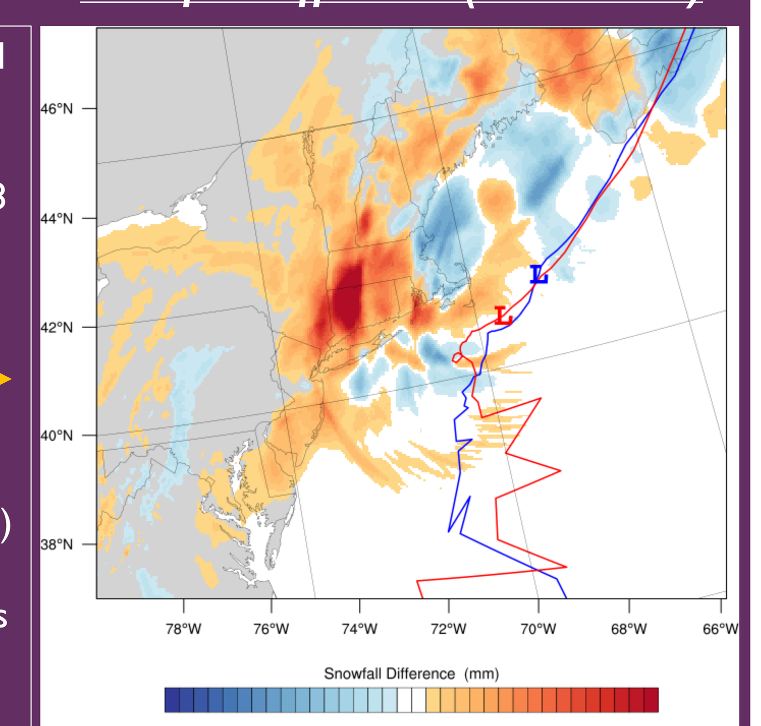

## Less Mixing vs. More Mixing

### MSLP Difference (less – more)




MSLP difference (fill) and MSLP for (magenta) less and (black) more mixing cases valid 0600 UTC 28 January 2015 (54-h forecast).

### Snowfall Difference (less – more)

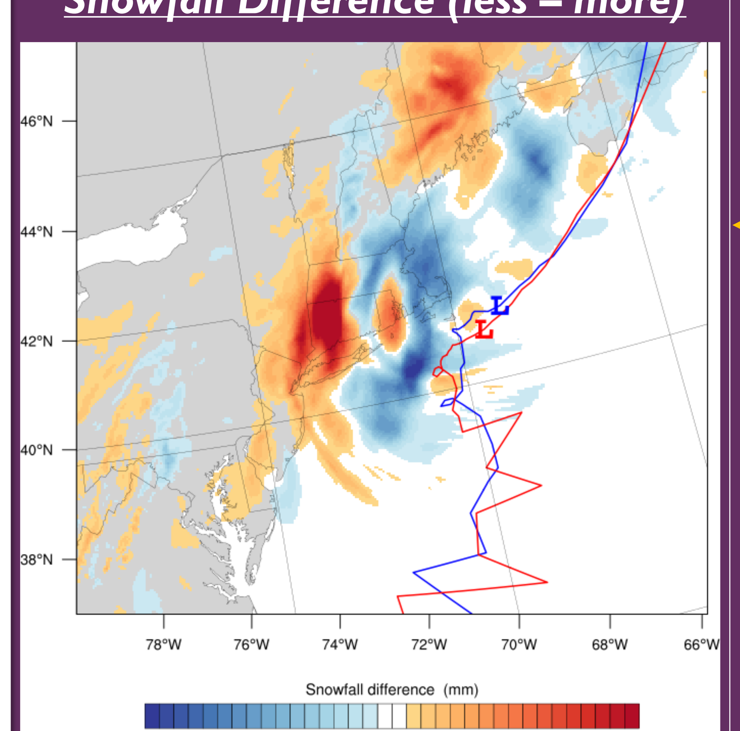



Total snowfall accumulation difference (fill; 10:1) and MSLP minimum tracks for (red) less and (blue) more mixing cases. "L" denotes MSLP minimum valid 0600 UTC 28 Jan.

- Surface cyclone intensities and tracks are similar, though the **less-mixing** surface cyclone progresses at a **slower rate**
- This result is consistent across a variety of microphysics schemes, terrain setups, and a SKEBs-derived WRF ensemble of simulations for the 27 January snowstorm (not shown)
- However, turning off latent heating minimizes the differences between the simulations

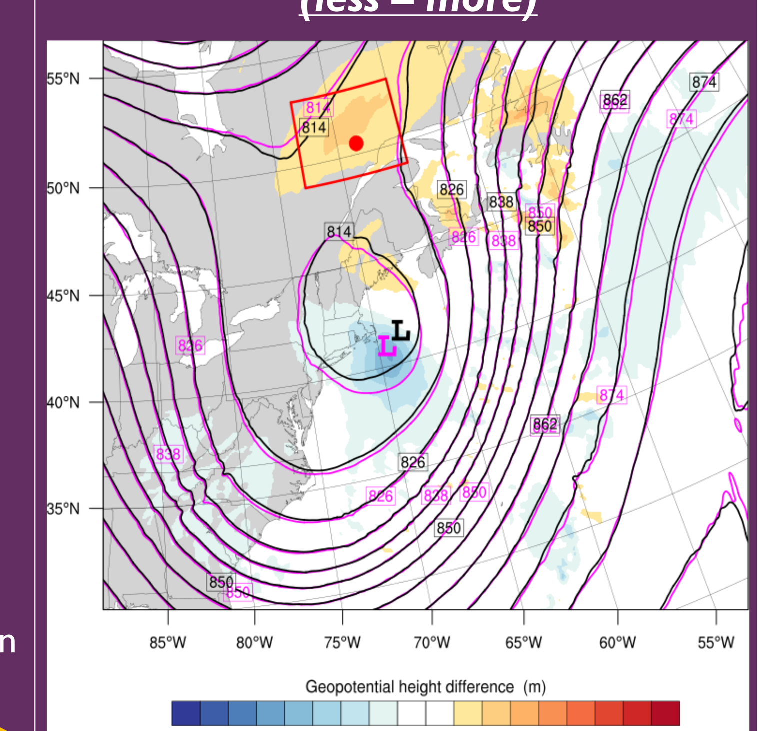
## Water Vapor Mixing Variations

### Snowfall Difference (less – more)




Total snowfall accumulation difference and MSLP tracks for (red) less and (blue) more mixing cases. "L" denotes MSLP minimum valid 0600 UTC 28 Jan.

### Upper-level Height Difference (less – more)

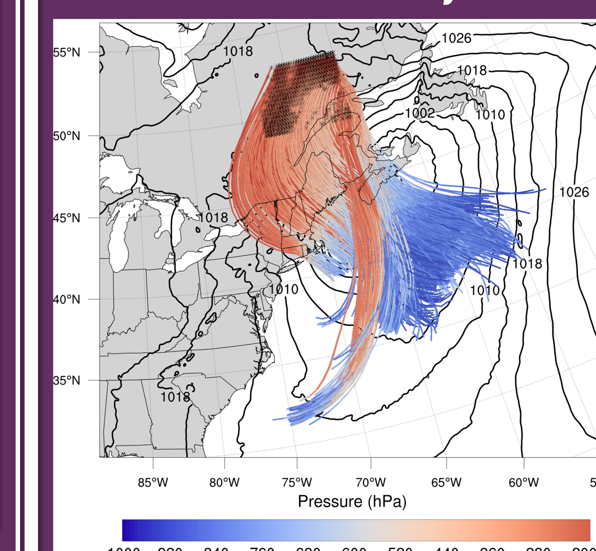



500–200-hPa geo. height difference (shaded; less mixing – more mixing) and 300–200-hPa geo. heights (dm, contoured) valid 0600 UTC 28 Jan. Red dot and square are sounding location and trajectory release area, respectively.

- The difference in surface cyclone propagation remains when only moisture mixing is varied
- Enhanced upper-level ridging is evident downstream in the less-mixing simulation

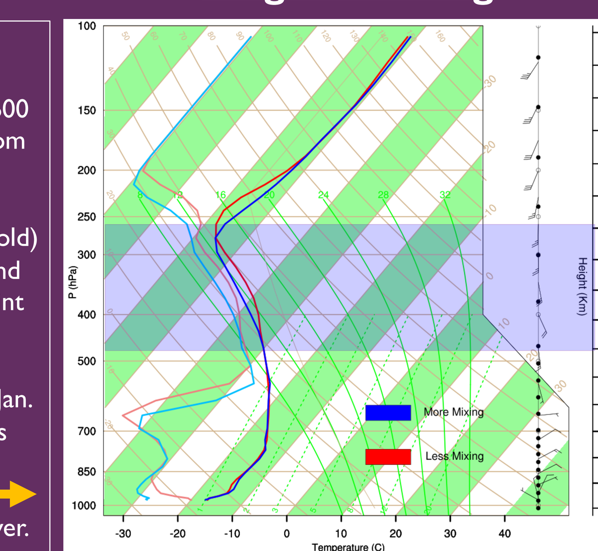
## 24-h Backward Trajectory Analysis

### 24-h Backward Trajectories



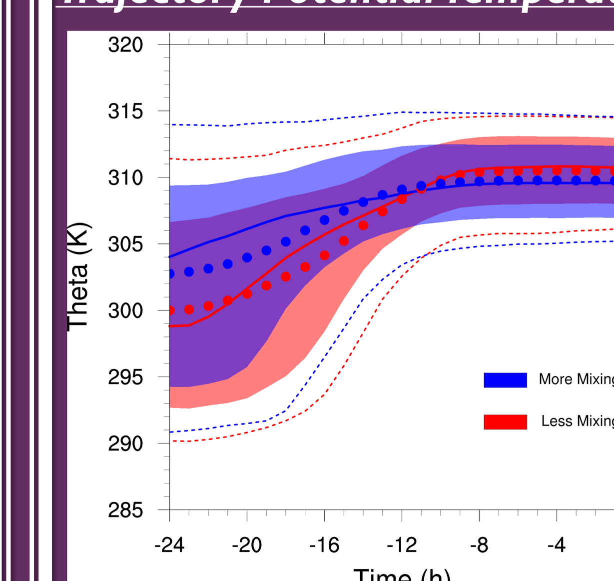

24-h backward trajectories initialized at 0600 UTC 28 Jan from black dots.

### Ridge Sounding

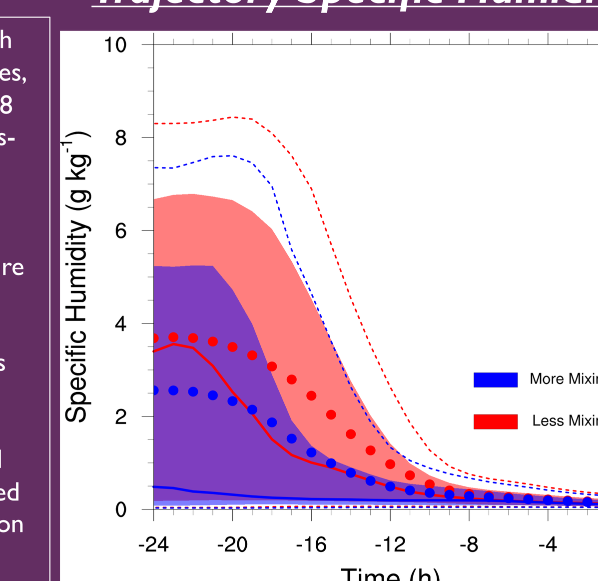



Sounding of (bold) temperature and (faded) dewpoint at red dot location valid 0600 UTC 28 Jan. Blue highlight is the backward trajectory initialization layer.

### Trajectory Potential Temperature




### Trajectory Specific Humidity




Distributions of 24-h backward trajectories, ending 0600 UTC 28 Jan for the (red) less-mixing and (blue) more-mixing simulations for (a) potential temperature and (b) specific humidity. The distribution medians (solid lines), interquartile ranges (shading), upper and lower deciles (dashed lines), and distribution means (dots) are plotted.

- Less-mixing parcels originate with higher moisture content and end with a higher potential temperature
- The greater potential temperature warming suggests stronger latent heating, concomitant with greater ridging in the less-mixing simulation

## Conclusions

- The 27–28 January 2015 snowstorm is sensitive to boundary layer mixing strength/depth
- Weaker mixing allows for the preservation of boundary layer moisture within the warm sector (i.e. source region for warm conveyor belt) of the cyclone
- Stronger boundary layer moisture likely results in more vigorous latent heat release, corroborated by the stronger warming of ascending parcels in the less-mixing simulation
- The stronger latent heating results in greater diabatic ridge building downstream of the cyclone, amplifying the wind field and slowing the progression of the system in the less-mixing simulation

### References: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