Frontal Modification of Atmospheric Boundary Layer Dynamics over Land in Mid-latitude

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1. Introduction

Mid-latitude cyclones and associated passages of cold and warm fronts over the land-surface lead to high-impact weather events including deep moist convection and extreme precipitation. We hypothesize that during quasiperiodic passages of cyclonic and anti-cyclonic flows, the atmospheric boundary layer (ABL) encounters vigorous changes (both vertically and horizontally) due to three key processes: forcing land-surface forcing via changes in soil moisture regimes due to precipitation, subsidence over the high-pressure-dominated cold sector, and convection over the warm sector. We hypothesize that frontal passages help modify BLDs drastically so that BLD differences between pre- and post-frontal days can help understand the role of mid-latitude cyclones on ABL dynamics during all four seasons.

Within this work, we:

- explored regular 00-UTC rawinsonde-retrieved afternoon-BLDs over 18 sites located in the eastern US during one-year period (Dec 2013 - Nov 2014);
- determined frontal passages using 3-hourly surface synoptic charts for the entire year.

We aim:

- to understand the frontal modification of daytime ABL depths (BLDs, i.e. Δz) during pre-to-post frontal conditions so that a comparison between BLDs in warm (pre-frontal) versus cold (post-frontal) sectors can be elucidated;
- investigate the BLD-contrasts (i.e. Δz = z_f - z_e) during four seasons to understand how the frontal impact on BLDs decametare seasonally;
- determine how the BLD-contrasts change spatially over different regions;
- diagnose frontal regimes and cyclone tracks when BLD-contrasts might be linked to the impact of contrasting meteorological processes taking place in the warm and cold sectors.

2. Aims and Scopes

3. Datasets and Sites

4. Method with an Example

5. BLDs over all the Sites (Warm vs. Cold)

6. BLD Frontal-Contrasts in Four Seasons

7. Summary and Outlook

In this first-of-its-kind empirical study, we investigated changes in ABL processes, before and after frontal passages and explored BLD spatiotemporal variability as a function of weather patterns which largely remained unexplored to the scientific community. We found that:

- due to the passages of cold fronts, BLDs become drastically modified so that we found significant differences between BLDs in the warm versus cold sectors
- pattern and magnitude of ΔBLDs (i.e. warm versus cold sectors) vary substantially among seasons and across space (e.g., different sites over the northern and southern Great Plains)
- there exist striking contrasts in BLDs under the impact of frontal passages in winter and spring
- southern sites show some anomalous features in BLD front-contrasts most likely due to internal boundary layer development within the Gulf inflow.

In future, we will compare these observational findings with the WRF and NARR simulations to investigate the performance of state-of-the-art high-resolution models whether these models can capture the frontal modifications of BLDs during four seasons. Our analyses will help build observational constraints for validating numerical models and to improve boundary layer parameterizations so that the observed ΔBLDs during four seasons, during spring and summer, could be replicated to obtain a better understanding of the frontal modifications of ABL dynamics.

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