A Method for Estimating Planetary Boundary Layer Heights and Its Application over the ARM Southern Great Plains Site

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ABSTRACT

A new objective method to determine the height of the planetary boundary layer (PBL) is presented here. PBL heights are computed using the statistical variance and kurtosis of dewpoint and virtual potential temperature differences measured from radio soundings at the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) program at the Southern Great Plains (SGP) site. These heights are compared with those derived from lidar, also on the site, and with gridded model data from the North American Regional Reanalysis (NARR). A climatology of mean heights in the early (1800 UTC) and late (0000 UTC) afternoon from 2002 to 2010 is presented to show the effectiveness of the method. Future work using the new method include producing an observational climatology of PBL heights and understanding the aerosol loading within the PBL as well as a better understanding of the coupling between the surface and free atmosphere.

1. Introduction

The planetary boundary layer (PBL) is the turbulent layer near the earth's surface. Determining the PBL height is important because it is where any moisture, aerosol, or heat from the surface can be exchanged with the free atmosphere above. It is most commonly observed as an inversion in potential temperature and dewpoint, or as a peak in low-level wind (Holzworth 1964; Grossman and Gamage 1995). The top can also be observed from a strong gradient in lidar backscatter, corresponding to a transition from an aerosol-rich PBL to a cleaner, free atmosphere (Cooper and Eichinger 1994; Gal-Chen et al. 1992).

The work by Seibert et al. (2000) provides a comparison of the benefits and caveats of various observational methods to determine the PBL height. Most previous studies conclude that the most effective way to determine the PBL height from radiosonde measurements is from visual inspection of a temperature profile (Barr and Betts 1997; Shaw et al. 2007). Even using lidar, a common method to delineate the top of the PBL is visual inspection (Hennemuth and Lammert 2006; Tucker et al. 2009) although transform methods, not applicable to radio soundings, do exist to objectively find the PBL top from lidar (Cohn and Angevine 2000). It should be noted that all these methods are most applicable to the daytime or convective boundary layer and not the nighttime or stable boundary layer. At night, surface diagnostic methods are a good proxy for the depth of the stable boundary layer (Steeneveld et al. 2007; Vickers and Mahrt 2004).

The Atmospheric Radiation Measurement (ARM) program at the Southern Great Plains (SGP) site conducts regular radio soundings, lidar measurements, and multiple surface and subsurface measurements, which will be used to demonstrate a new method to determine the PBL depth (Ackerman and Stokes 2003; Stokes and Schwartz 1994). Previous studies document the usefulness of these measurements to understanding the structure and evolution of the PBL at the ARM SGP site (e.g., radar and lidar; Chandra et al. 2010). The purpose of this study will be to develop and demonstrate the efficacy of a new method to objectively determine the PBL height. The multifaceted ARM SGP site enables future research into aerosol loading within the PBL and how the height is coupled with measured surface fluxes and soil moisture.

2. Data and methodology

The ARM SGP facility conducts a wide range of meteorological research and is also a significant locale for land–atmosphere coupling studies. The site provides a unique

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