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

Paul Schmid and Dev Nygodi
Purdue University, Indiana State Climate Office


Method

The following shows the comparison between detected PBL heights from the objective method (1) - with those derived from visual inspection of the ARM lidar (4) (Tuchler et al., 2009) for each day of June 2006. Plotted is δ (m) versus height (m).

Comparison

The objective method is generally as accurate as other objective and subjective methods for determining the boundary layer height from observations.

Implications

Goal: Minimize the size of the boundary layer. Consequences include: reduced water vapor transport and surface cooling (winter) and reduced turbulence (summer).

Boundary Layer Climatology

A boundary layer climatology was prepared from eight years of data at the ARM SGP site (2002-2009). Two variables were used because radiosondes were not launched at 18UTC before 2002. The results are comparable with previous studies in the Great Plains. Note in the Eddy Covariance results in April for the 2009 data, the average height is lower than the average height from April to May.

Future Research

Ongoing research in applying this new method is focused on two projects:
1. Constructing a new climatology of PBL heights over the United States. This climatology has not been done since Hitchcock (1954) and would be useful in diagnosing the surface effects of local and global climate change.
2. Studying the interactions between the surface, sub-surface and free atmosphere using instruments at the ARM SGP site. The ECOR instrument provides high frequency flux measurements and the SWMTI instrument provides sub-surface temperature and moisture measurements. By comparing these with observed PBL heights, we can better understand the surface to free atmosphere energy exchange.

References


Acknowledgements: This project is supported by the DOE ARM Program

Methodology

We used temperature, moisture, and pressure measurements from the ARM SGP radiosondes at 18UTC and 00UTC. This allows the method to be applied to other upper air soundings which do not include wind data.

Temperature

Dewpoint

Objective method

PBL height

Equations

Virtual potential temperature (potential temperature, computed with density equalized for moisture) δθ (K):

δθ = θ - θv = θ(1 + δ[mL/kg])

The inversion defining the top of the PBL was detected using statistical variance and kurtosis (4).

A test statistic at each height was computed using these functions over a vertical range of virtual potential temperatures: δθ = δθ(v - δθ) - θ - δ(θ - v)

where:

δ0 = 0.004/3 (θv - θ - δ(θ - v))

A δ0 was computed from the top of the PBL which preclude detection from a temperature or moisture inversion.

Backscatter lidar was a useful comparison, but can be seen below the lidar does not necessarily provide a more accurate measurement of the PBL height than the objective lidar method. A double maximum in lidar backscatter gradient (associated with the surface/boundary layer transition) leads to uncertainty in observed PBL heights.

Background

The planetary boundary layer (PBL) is the turbulent layer of the atmosphere near the Earth’s surface. During the day, it typically comprises about the lowest 10% of the troposphere, but PBL heights of up to 1 km have been observed. It is most commonly detected as an inversion in potential temperature and dewpoint, or as a peak in low-level wind speed (Crosman and Gage, 1990). Determining the PBL height is a complex process since there are many factors that influence it. In general, moist, warmer air masses tend to produce higher PBL heights, and conditions near the ground that favor turbulence, such as strong surface heating and low-level wind shear, can lead to higher PBL heights. Conversely, conditions that stabilize the atmosphere, such as dry, cold air, weak surface heating, and strong low-level wind shear, can lead to lower PBL heights. The PBL height is also influenced by the interaction between the surface and the atmosphere, such as the exchange of heat and moisture between the surface and the atmosphere. The PBL height is also affected by the presence of atmospheric turbulence, which is a complex phenomenon that is not well understood. In addition, the PBL height is affected by the presence of atmospheric turbulence, which is a complex phenomenon that is not well understood. In addition, the PBL height is affected by the presence of Atmospheric Rivers (ARs), which are narrow, elongated regions of enhanced moisture and precipitation that can transport large amounts of water vapor and energy to the surface, leading to increased surface evaporation and precipitation. ARs are typically associated with low-level jet streams and can lead to increased surface heating and mixing, which can affect the PBL height. The PBL height is also affected by the presence of Atmospheric Rivers (ARs), which are narrow, elongated regions of enhanced moisture and precipitation that can transport large amounts of water vapor and energy to the surface, leading to increased surface evaporation and precipitation. ARs are typically associated with low-level jet streams and can lead to increased surface heating and mixing, which can affect the PBL height.

The objective method is generally as accurate as other objective and subjective methods for determining the boundary layer height from observations.

Accuracy and Replicability

The objective method is generally as accurate as other objective and subjective methods for determining the boundary layer height from observations.

Objective method

PBL height