Intercomparison of boundary layer and mixing layer height from models and ground-based measurements

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Introduction

The planetary boundary layer is the layer next to the Earth's surface, most affected by the vertical transfer of momentum, heat, and mass across the surface. It is also considered as a key parameter in air pollution modeling since most of the pollutants emitted from the surface become constrained within this layer due to lower vertical turbulent mixing above the planetary boundary layer.[1] The boundary layer characterized by vigorous vertical turbulences is known as the convective boundary layer (CBL) or mixing layer.[2] The turbulence can be caused by either wind or wind shears that generate mechanical turbulence (called forced convection), or by buoyant forces (called free convection) associated with large thermals. The boundary layer shows diurnal variation due to solar radiation, with the rising of the mixing layer during the daytime and shrinking at night.[3] There is a lack of studies on the reliability of boundary/mixing layer retrievals from the Reanalysis models, which are considered to capture the general pattern of the daily cycles relatively well, particularly for remote regions.

Methods

In the present study, we obtained the ERA5 (fifth-generation European Centre for Medium Weather Forecasting reanalysis model) [4] boundary layer and HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) [5] model based on GFS (Global Forecast System), GDAS (Global Data Assimilation System), and Reanalysis datasets on mixing layer height for the National Atmospheric Observatory Košetice (NAOK) (49°35′N, 15°05′E; 534 m a.s.l) for the year 2020.

For the ground-based measurements of the boundary layer and mixing layer height, the ceilometer model CL51 from Vaisala Inc. (Helsinki, Finland) was used. The ceilometer uses a LIDAR remote sensing technique to record the optical backscatter intensity in the infrared wavelength range (900 ± 10 nm) sent out in a vertical direction. Reflection and backscatter caused by clouds, precipitation, haze, fog, mist, and other obscurations are measured as the laser pulses traverse the sky. The backscatter profile is further used to detect the boundary layer and mixing layer height.

Results and Discussion

In this study, we found that the boundary layer height tends to be lower in ERA5 and timing for the daily peak also appears to differ as compared to ceilometer boundary layer data. In contrast, the ERA5 boundary layer observation was found to agree well with the mixing layer height obtained from the ceilometer. Whereas in comparison to HYSPLIT, GFS and GDAS, observations were found to agree well with ceilometer data while Reanalysis underestimated mixing layer height throughout the year. The seasonal changes in the boundary/mixing layer height were well captured by both models and the ceilometer.

This study also reveals that the models underestimated the mixing layer observations during the summer by 31%–45% and agreed relatively well during the winter season by a difference of 10%, although the surface temperature measured by models was found to follow the same trend as in-situ measurements. The additional variables such as global radiation, synoptic situation and stability of the atmosphere will also be studied to explain the difference.

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References

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