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Study of cloud base and atmospheric boundary layer height over Gorakhpur in the IGP

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Abstract

The present study investigates the role of boundary layer dynamics and cloud formation over Gorakhpur (26.76° N, 83.37° E), located in the central Indo-Gangetic Plain (IGP). The study is performed to establish an understanding of distinct pattern in cloud base height (CBH) and atmospheric boundary layer (ABL) dynamics, by which we can improve weather prediction models and enhance climate research. The findings demonstrate distinct patterns in CBH and ABL using Ceilometer Lidar (Model: CL-31) during the pre-monsoon months from March and April 2024. Results indicate significant cloud activity primarily occurring above the boundary layer height (BLH) over Gorakhpur. During March, the BLH over Gorakhpur remains stable while in April, cloud formation at the top of the boundary layer was not observable. This study emphasizes the role of boundary layer dynamics in cloud development and provides valuable insights into local atmospheric conditions.

1. Introduction

The presence of clouds at any altitude plays an important role in the Earth's atmospheric system. Clouds can either warm the atmosphere by absorbing emitted longwave radiation or cool the atmosphere by reflecting incoming solar radiation back into space [1,2]. Through disruption of the radiative balance of the Earth's atmosphere, clouds influence the greenhouse effect and are therefore of substantial importance in climate studies. Cloud base height is crucial for parameterizing the vertical structure of clouds. The systematic study and understanding of cloud base heights is also helpful in aviation safety. Previous studies on the basis of cloud observations and simulations have demonstrated that various cloud effects, i.e. cloud-radiation, cloud-aerosol, and cloud-precipitation interactions, are closely related to the vertical distribution of clouds [3,4]. Therefore, to describe the vertical distribution of clouds, CBH is a crucial macrophysical property for understanding the role of clouds in weather and climate [5,6]. In the present study, the CBH and Atmospheric boundary layer (ABL) dynamics over the Gorakhpur region have been investigated during March and April of 2024. This research is crucial as it provides valuable insights into local atmospheric conditions, which are essential for regional weather forecasting and climate studies.

2. Site Description

Gorakhpur (26.75°N 83.38°E, 85m amsl), a semi urban metropolitan, situated at the foothills of Shivalik Himalayan ranges. Gorakhpur is nestles between the river Rapti on the West and the river Rohini on the north-west in the Terai belt of Purvanchal (i.e., eastern Uttar Pradesh) region. The city occupies an area of 226.6 km2 in the eastern part of the central IGP and lies 270 km east of Lucknow, 220 km north of Varanasi, and 100 km south of the Indo-Nepal international border. The measurement site situated in the campus of DDU Gorakhpur University and ceilometer is installed at the rooftop of the Physics Department.

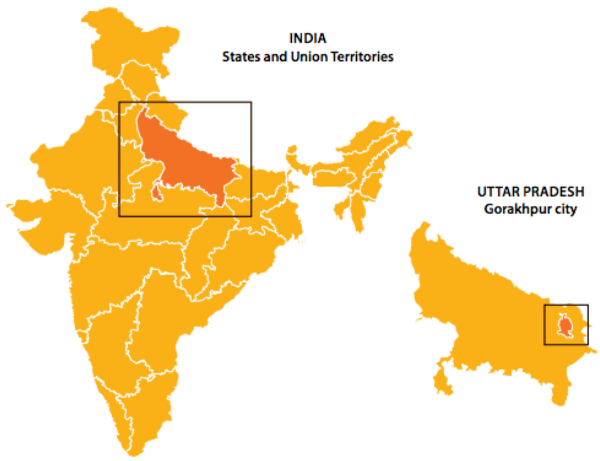

Figure 1. Geographical location of Gorakhpur.

3. Data and Methodology

A ground-based all-weather automatic ceilometer has been installed for continuous monitor the CBH and ABL over Gorakhpur and operational from March 2024. This ceilometer CL-31 continuously measure the CBH and ABL every 16 seconds. It provides detailed vertical profiles of the ABL with backscatter data up to a height of 7.5 kilometres with a vertical resolution of 10 metres. This device uses a pulsed InGaAs diode laser that emits near-infrared light at 910 nm with a peak power of about 11 Watt (more information about Ceilometer Lidar can be found at http://www.vaisala.com) [7]. Vaisala CL-View software has been utilized for data processing for the clouds. BL view software has been used for data handling and visualization purposes. It is an interface software that is a graphical presentation program for ABL information.

4. Result and Discussion

The cloud base height events observed in March and April 2024 over Gorakhpur.

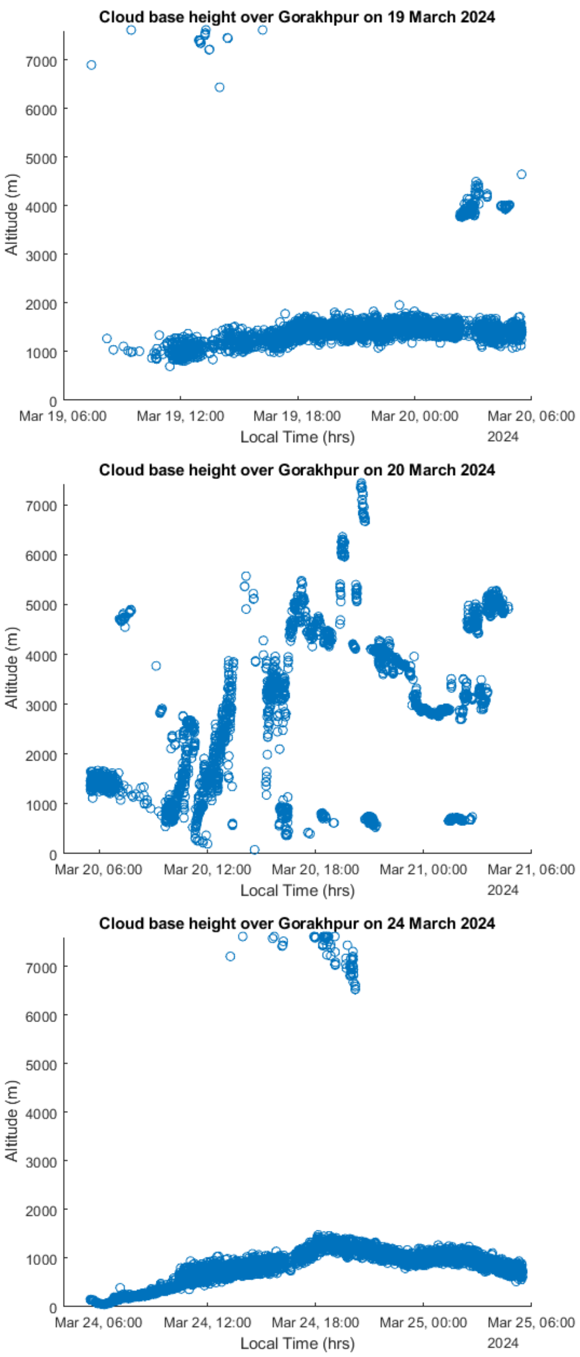

Figure 2. Cloud base height (CBH) on 19, 20 and 24 March 2024 from top to bottom respectivly.

Observation revealed a stable cloud layer between 1-2 km height on 19 March during whole day. However, on 20 March, a significant shift was observed with the emergence of strong updrafts and downdrafts extending from 1 km to 7.5 km, persisting until 6:00 hr (local time) on March 21. Further we observed that on March 24, the CBH spread from 200 to 1500 m. This convective activity suggests the presence of severe weather conditions, likely associated with thunderstorm development over Gorakhpur.

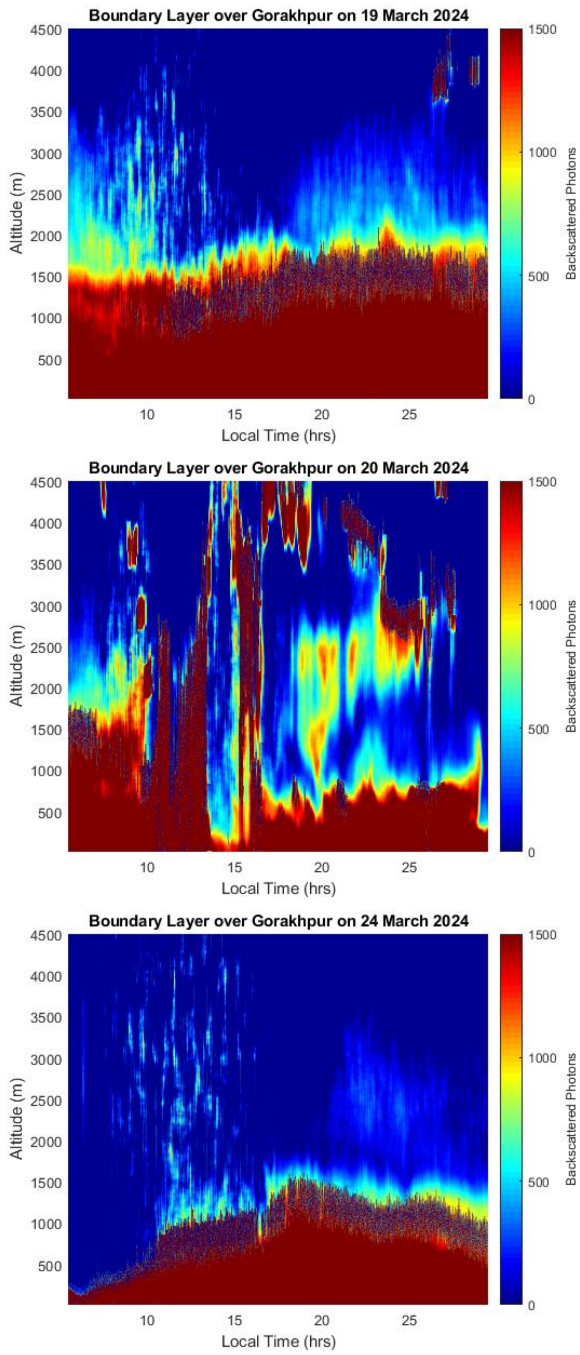

Figure 3. Boundary layer height (BLH) on 19, 20 and 24 March 2024 from top to bottom respectivly.

The rise and fall of the convective boundary layer and the stable layer of the ABL vary significantly throughout the day and do not follow a constant pattern, changing from day-to-day. On March 19, we have been observed that the BLH remained stable from day to night, with a consistent pattern throughout the day and a peak height of approximately 2 km, clouds are also present at the top of the BLH. On March 20, the BLH was disturbed due to rainfall. However, on March 24, the stable boundary layer arises during the daytime around 100 m, with the afternoon boundary layer height reaching approximately 1.5 km, and remains stable at night.

It can be concluded that during April, a persistent cloud layer was observed primarily at heights between 5 km to 7.5 km. On April 5, clouds were observed at heights ranging from 5 km to 7.5 km. The same cloud height was observed on April 6 and April 21. Throughout the entire month, clouds were consistently present in the 5 km to 7.5 km height range. Notably, no clouds were observed at the 1 km height during this period. This indicates a stable high-level cloud formation pattern in April, with the absence of lower-level clouds around the 1 km altitude.

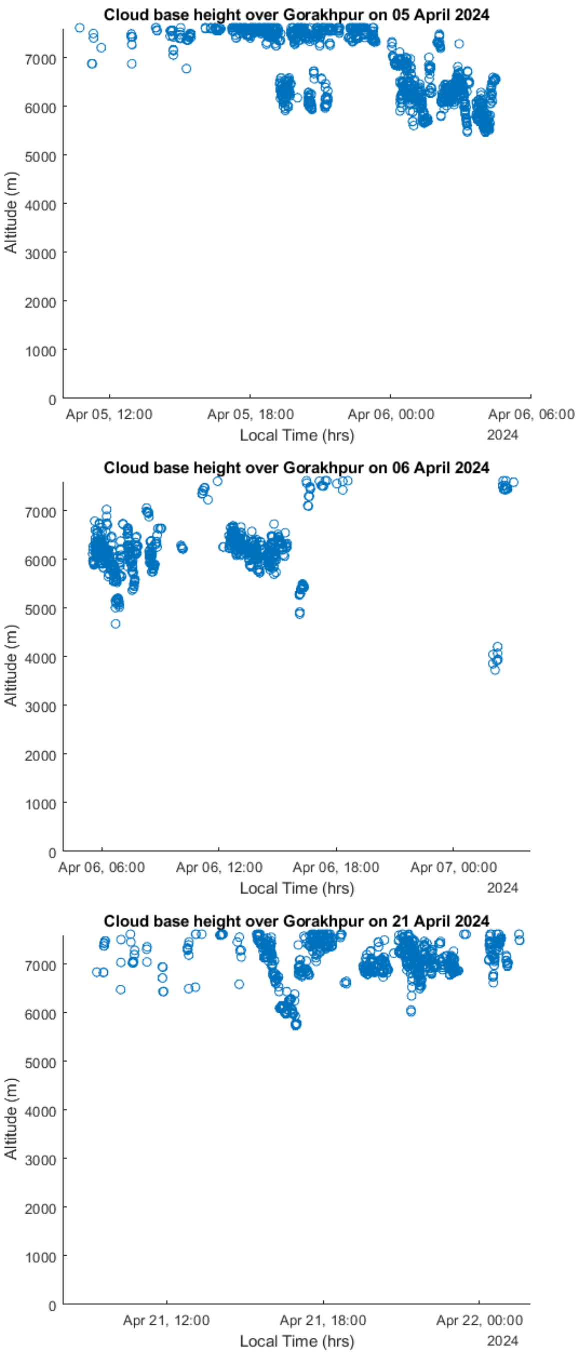

Figure 4. Cloud base height (CBH) on 5, 6 and 21 April 2024 from top to bottom respectivly.

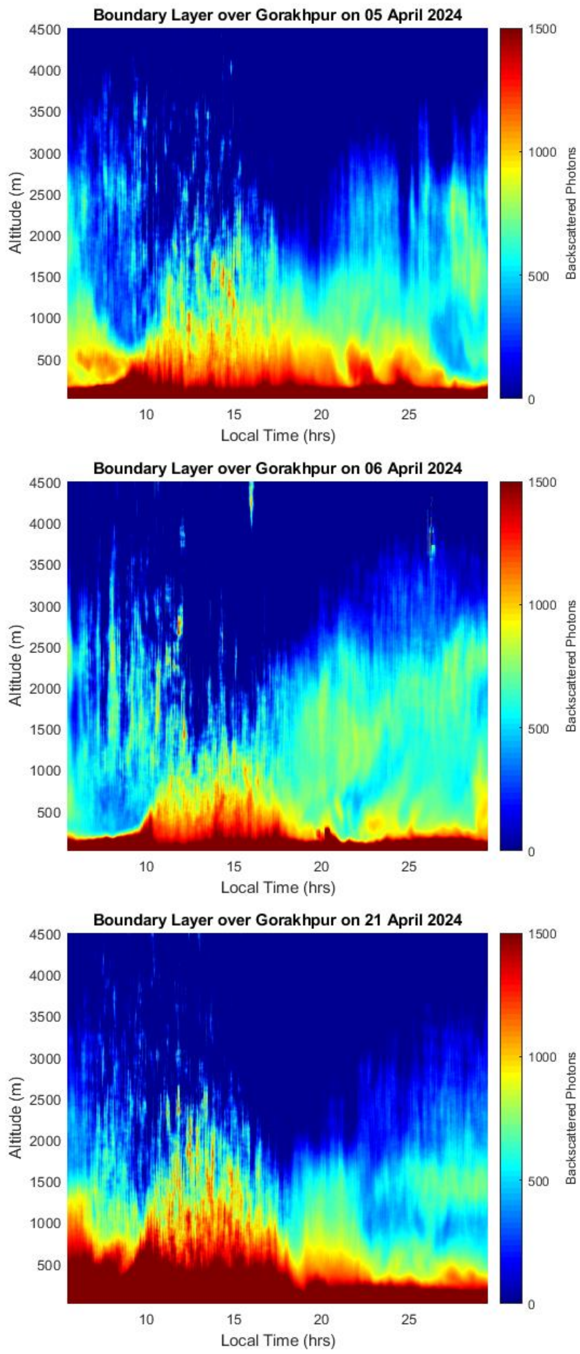

Figure 5. Boundary layer height (BLH) on 5, 6 and 21 April 2024 from top to bottom respectivly.

On April 5, clouds were observed at heights ranging from 5 km to 7.5 km. The same cloud height was observed on April 6 and April 21. Throughout the entire month, clouds were consistently present in the 5 km to 7.5 km height range. Notably, no clouds were observed at the 1 km height during this period. This indicates a stable high-level cloud formation pattern in April, with the absence of lower-level clouds around the 1 km altitude.

5. Conclusion

The results of the present study indicate significant cloud activity primarily occurring above the boundary layer height over Gorakhpur. It was observed that on normal days in March 2024, the cloud base heights were at low levels and mostly at the top of the boundary layer. In April, however, a stable high-level cloud formation pattern was observed, with an absence of lower-level clouds around the 1 km altitude.

6. Acknowledgements

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7. References

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