Investigation of atmospheric boundary layer structure during the withdrawal phase of Indian summer monsoon seasons over the monsoon core zone in Central India

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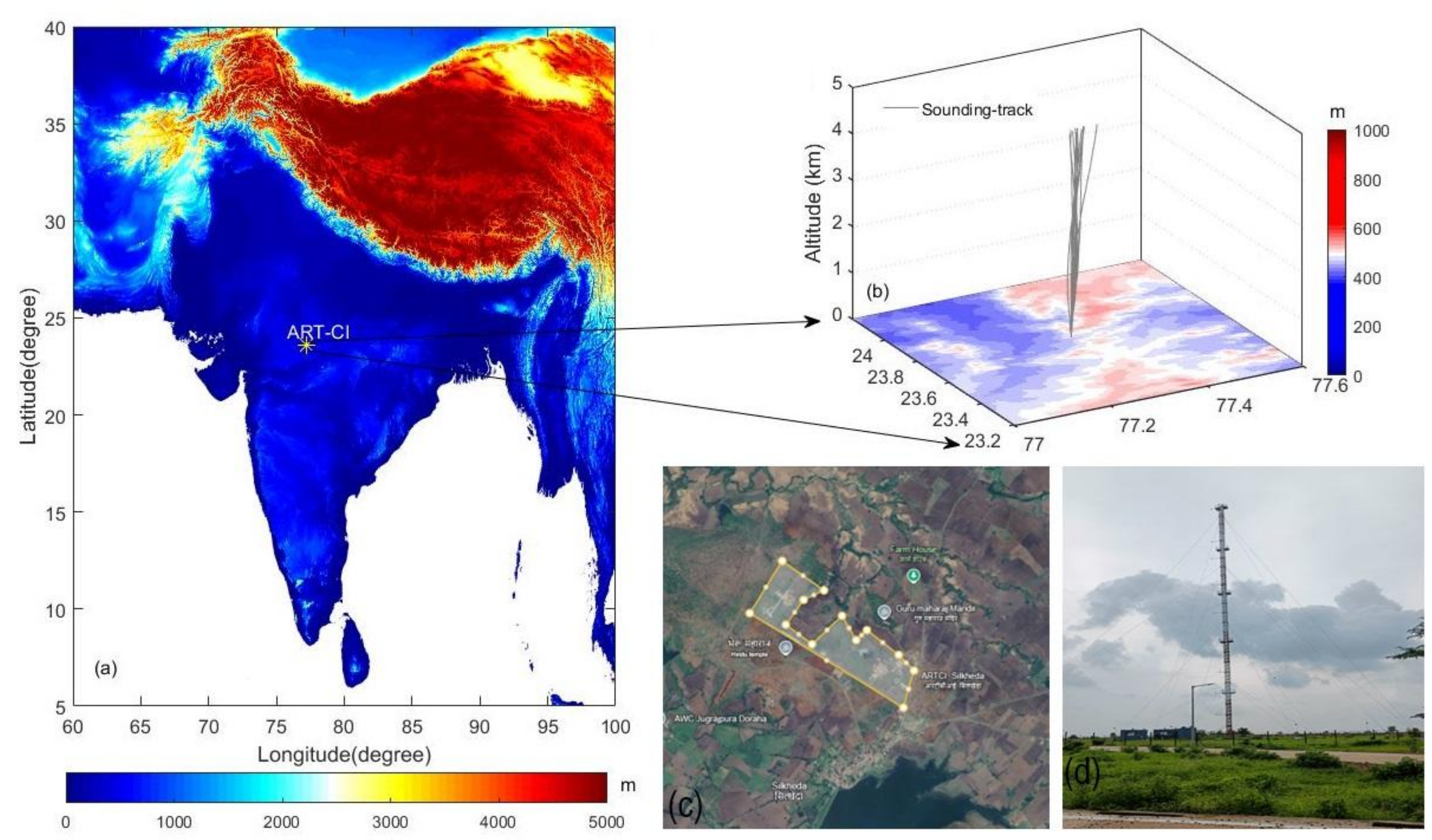
1. INTRODUCTION

- Understanding the ABL structure and its thermodynamic properties is essential to characterizing low-level cloud formation (Pal et al., 2008), improving weather predictions and climate projections (Cohen et al., 2015), pollution dispersion, fog, frost formation, etc. (Holtslag and Nieuwstadt 1986; Deardoff 1972; Seibert et al. 2000)
- Anticyclonic circulation persist at 850 hPa associated with withdrawal of ISM may affect the boundary layer evolution over central India

2. DATASETS AND METHODOLOGY



- Radiosonde
- AWS
- ERA5

Geographically, the study site is at central part of India i.e. ~35 km radially north-west of urban city Bhopal, the capital of Madhya Pradesh and ~30 km radially north-east of Sehore district in MP

Fig.1 (a) Map showing the elevation data for India and asterisk denotes the study site ART-CI, (b) the vertical profiles of radiosonde trajectories from surface to 3 km along with the topographical features surrounding the locations of ART-CI, (c) & (d) is the geographical map of campus ART-CI and photograph of 72 m tower, respectively.

$$Ri_b = \frac{g}{\theta_{vo}} \times \frac{(\theta_{vz} - \theta_{vo}) \times z}{(u_z^2 + v_z^2)}$$

$$\text{Advective term} = -\left(u \times \frac{\partial T}{\partial x} + v \times \frac{\partial T}{\partial y}\right) \times 86400$$

3. RESULTS AND DISCUSSIONS

3.1. Surface parameters during the withdrawal

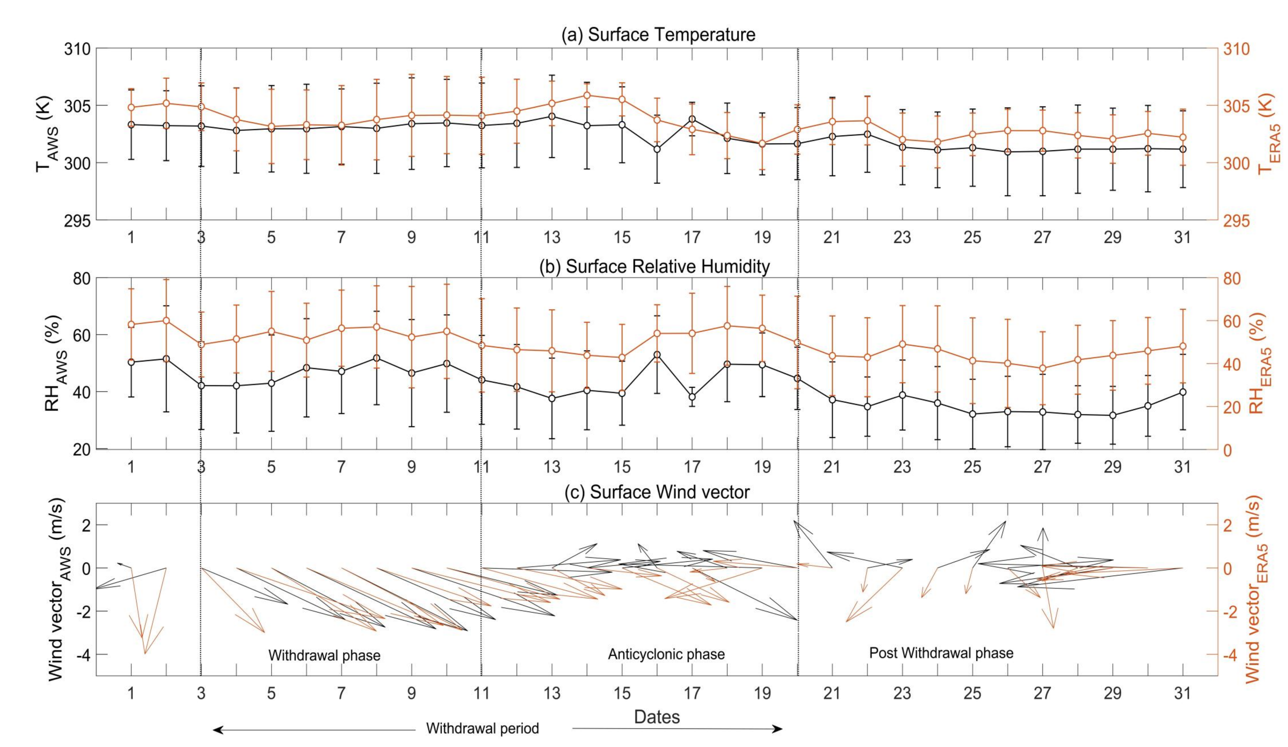


Fig. 2. The day mean variation of (a) surface temperature, (b) Relative humidity and (c) wind parameters from the AWS and ERA5 data during the period of 01 to 31 October 2023 over ART-CI. The vertical dashed line separates the dates according to withdrawal, Anticyclone and Post withdrawal dates.

- Withdrawal dates followed IMD
- Withdrawal – 03-10, Oct, 2023
- Anticyclone- 11-20, Oct, 2023
- Post withdrawal - 21-31, Oct, 2023
- Wind pattern changes into north-westerly after 03-10-2023
- Reduction of wind speed noticed during anticyclonic days
- ERA5 matches with the AWS observation

3.2. Spatial parameters

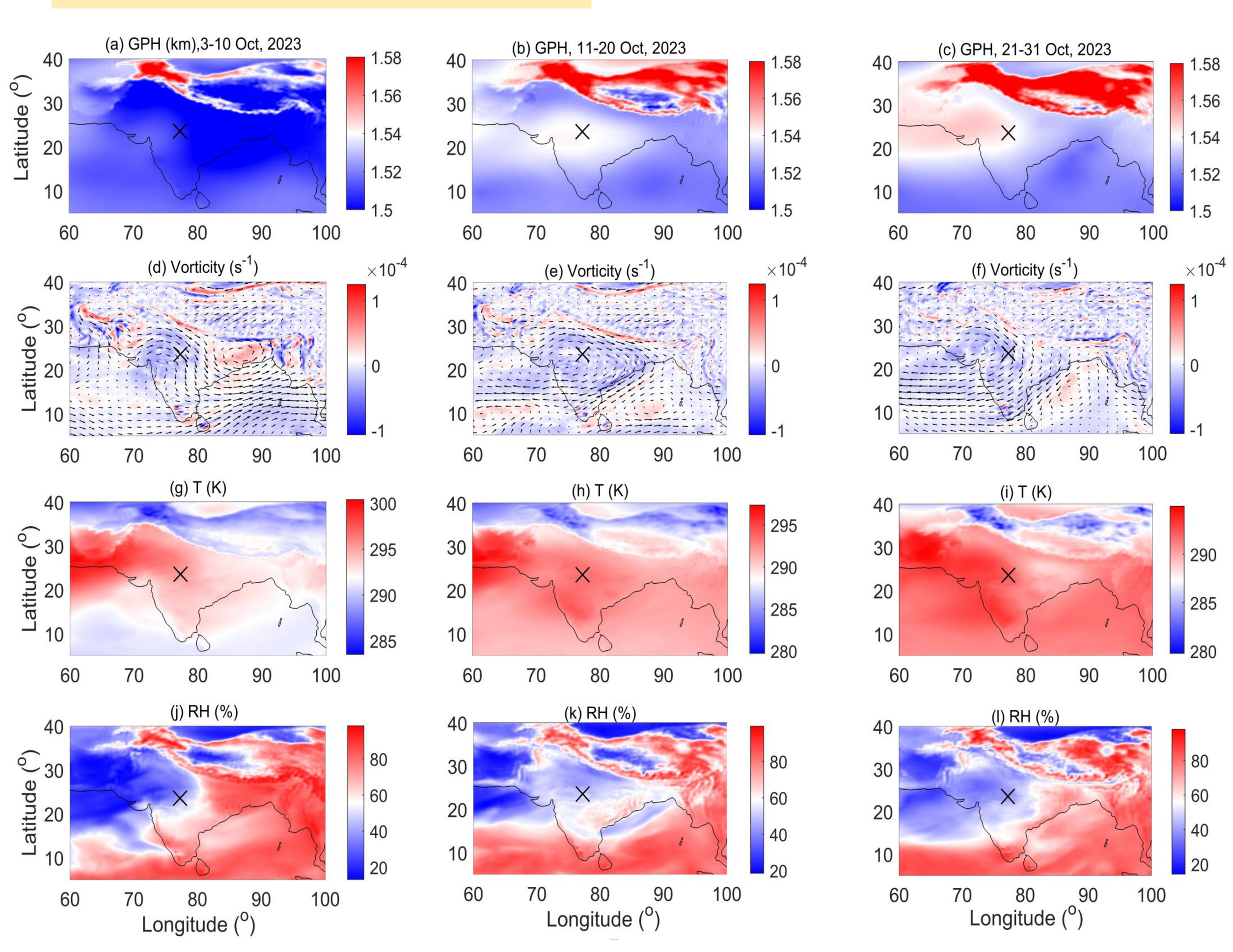


Fig. 3 The mean spatial distribution of the GPH (a-c), Vorticity and wind vector superimposed over it (d-f), temperature (g-i) and Relative humidity (j-l) during 03-10 October (First column), 11-20 October (Middle column) and 21-31 October (Last Column) over Indian region. The location of ART-CI is embedded in each figure using a cross symbol

- During withdrawal phase, the strong north-westerly wind passes through the central India
- High GPH and negative vorticity identified over the central and northern India from 11-20, October 2023
- The presence of anticyclonic circulation can significantly affects the ABL development due to large scale subsidence.

3.3. Vertical changes of meteorological parameters and day to day ABL height

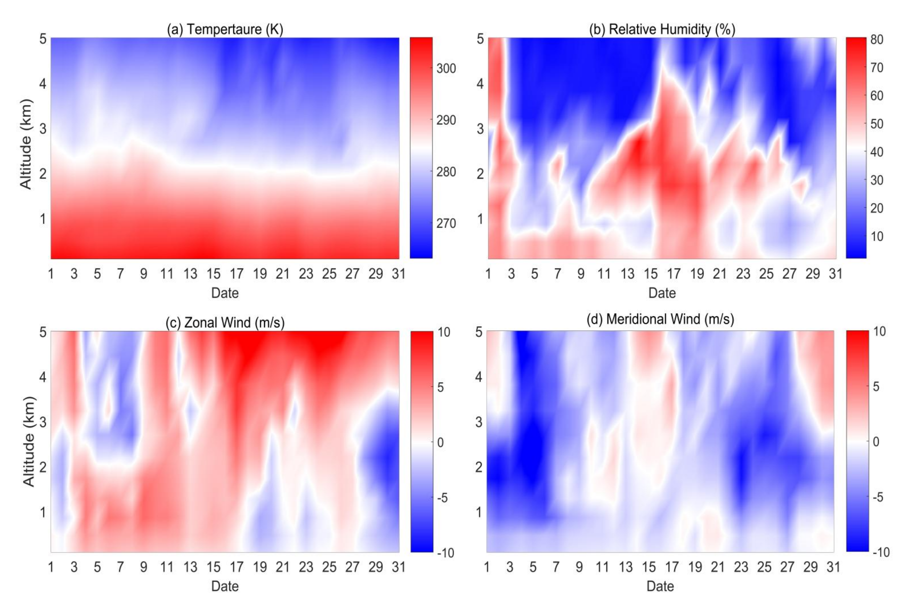


Fig. 4. The day mean of (a) T, (b) RH (c) u, and (d) v observed from the ERA5 data during October 2023 over the ART-CI

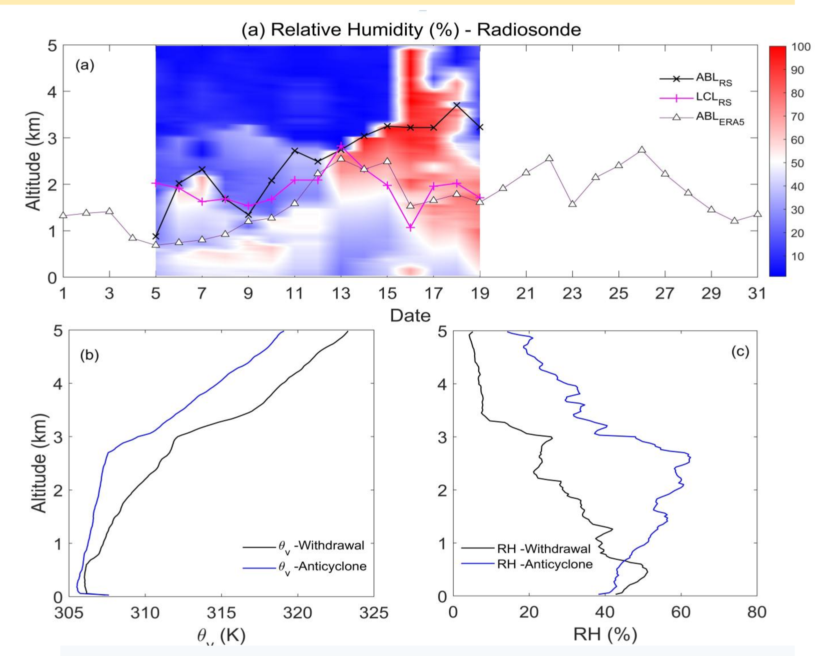


Fig. 5. (a) Day-to-day variations of the ABL height and the LCL during October 2023.

3.4. Spatial ABL during all three phases of withdrawal

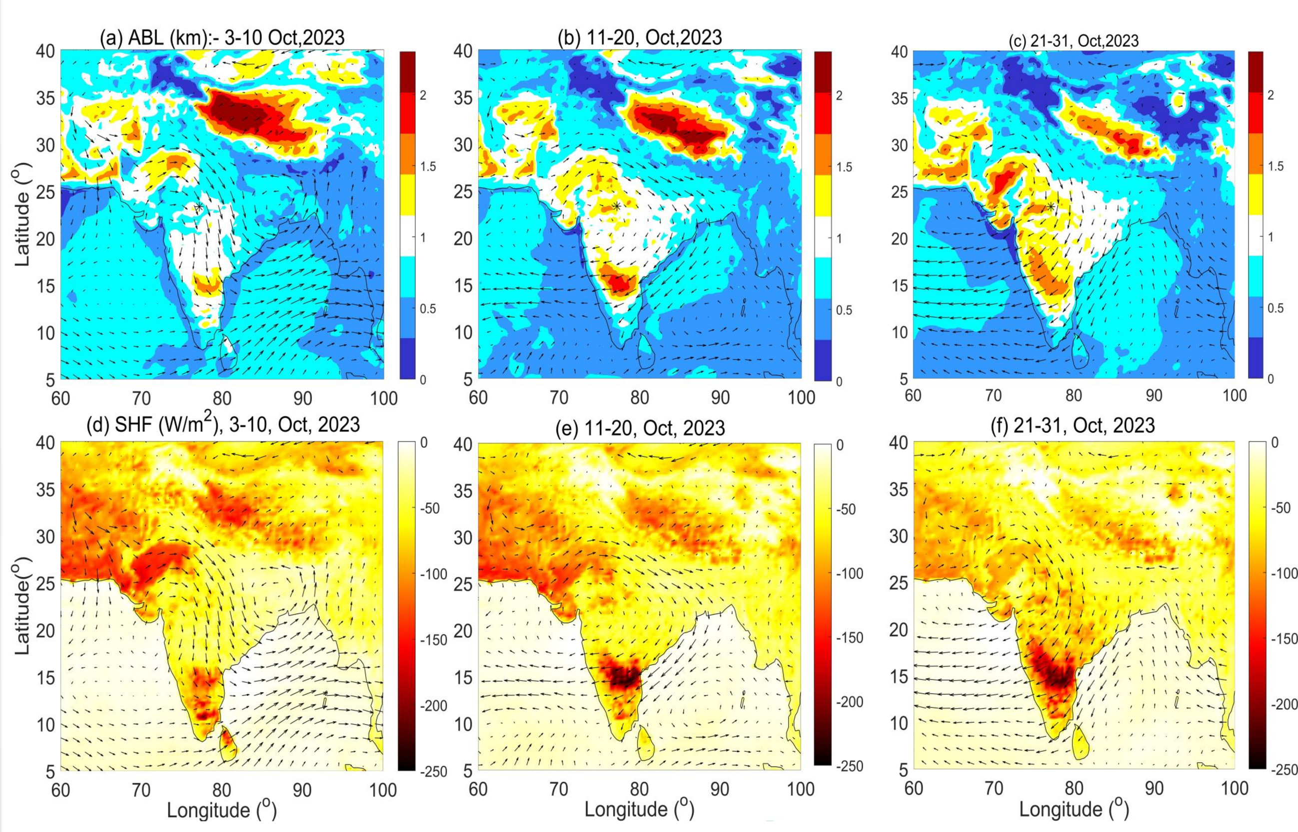


Fig. 6. The spatial pattern of day mean ABL height during (a) Withdrawal phase, (b) anticyclone phase, and (c) post withdrawal phase. (d-f) are the same but for the sensible heat flux (SHF). The mean wind vector at 850 hPa level has been plotted over each figure. The black asterisk in ABL figure indicate our study site ART-CI

- ABL identified during withdrawal is almost shallower over central India
- ABL is higher over the central India even though the anticyclonic circulation persists
- SHF is also higher over the deeper ABL regions

3.5. Advection pattern

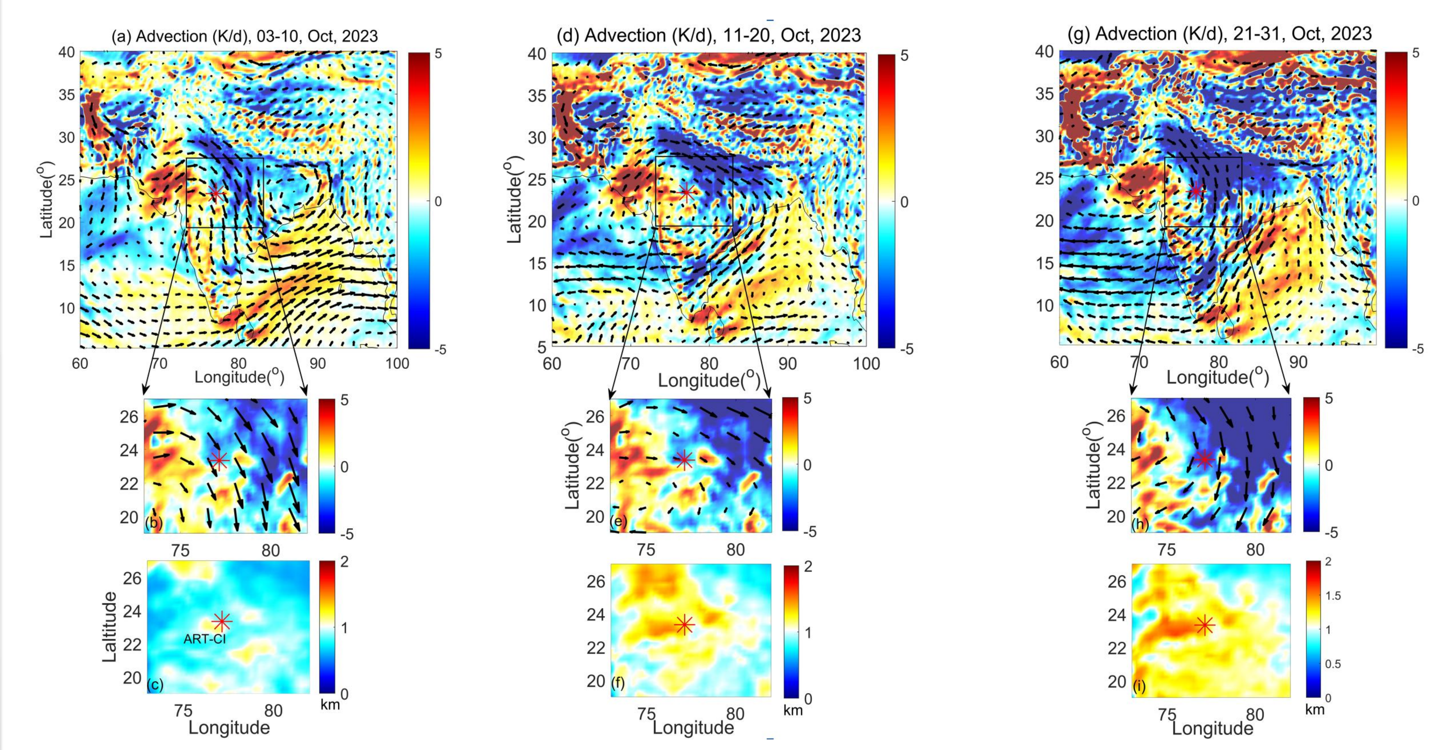


Fig.7. Mean advective term during (a) withdrawal phase, (b) Anticyclonic phase and (c) post withdrawal phase. The inset figure (b, g, h) in each plot demonstrates the advective term and (c, f, i) demonstrates the ABL

- Warm advection over west and cold advection over east.
- Deeper ABL is identified over the convergence zone where the cold advection meets the warm air
- Frontal Lifting could be the reason for the deeper ABL (CTBL).

3.6. Meridional average Advection, ABL and wind vector

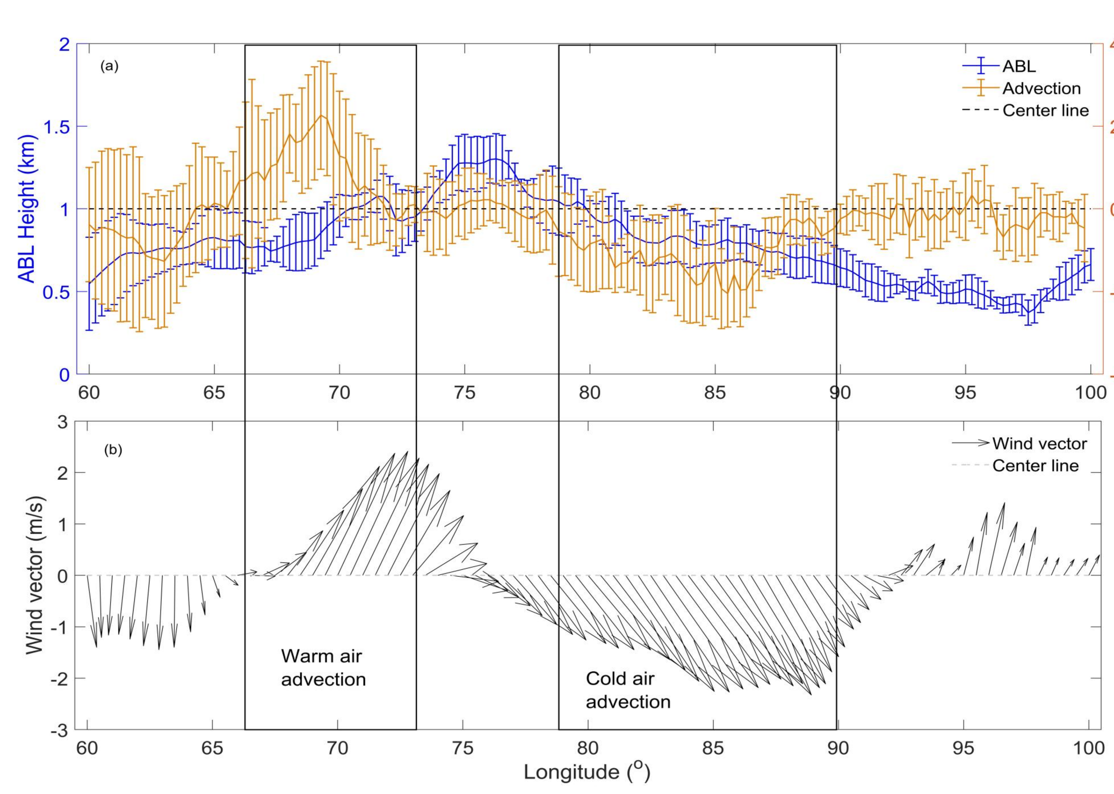


Fig. 8 Meridional average (a) ABL and advection term at 850 hPa (b) the wind vector at 850 hPa during the period of anticyclonic phase (11-20 October). The warm and cold advection region are marked in a rectangular dotted box.

- Meridional average of advection and ABL shows, the ABL is higher over the region where both types of advection meets.
- Wind vector shows the south westerly wind brings warm air and north-westerly brings the cold air.

4. CONCLUSIONS

- The vertical mixing is high during the anticyclonic phase. Nevertheless, similar traits are absent in the withdrawal and post-withdrawal phases
- The ABL exhibits a shallower depth (< 1 km) in the majority of synoptic circulation regions during withdrawal periods. The central and northern regions of India, including our study location, show a deeper boundary layer (>2 km) during the anticyclonic phase of the withdrawal period.
- The meridional average ABL variation indicates that the ABL remains shallow (>1.0 km) across both the warm and cold advection core regions. However, the ABL is defined as deeper (~ > 1.5 km) in regions where cold air interacts with the warm core area, in contrast to the anticyclonic features.

5. References

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