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Triggering of convective precipitation observed with 206.5 MHz VHF radar over the central Himalayas

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Abstract

The Himalayan region plays an important role in determining the meteorological conditions of the Indian subcontinent. During recent years, frequent events of triggering of local convection and subsequent rapid precipitations are being noticed in the Himalayan region. This work presents a few such events observed during the monsoon period of this year using the ARIES ST Radar at Nainital, over the central Himalayan region. Different phases of the simultaneous occurrence of the precipitation at the two vertical levels in a convective pillar cloud are discussed. Hourly changes in the atmospheric processes during the event are also shown.

1. Introduction

The Himalayas have profound influence on the meteorological conditions in the Indian subcontinent. The expanse and elevation of the Himalayas intercept the summer monsoon winds coming from the Arabian Sea and the Bay-of-Bengal and force them to release their moisture in the form of snow and rain. The Weather dynamics in the Himalayan region are complex due to the extensive interactions of tropical and extra-tropical weather systems. The Himalayan orography plays an important role in maintaining circulation of the South Asian monsoon. Due to intricate topography and change of climate with altitude, the region witnesses frequent extreme rainfall events and cloudburst [1]. In recent times the strange increase in deep convection and concentrated rainfall activity over the foothills of the central-eastern parts of the Himalayan (CEH) region during the post-monsoon break emerges as a result of an interaction between the southward infiltrating mid-latitude western trough and a weakening phase of the South Asian monsoon circulation. This region is also one of the most affected one in terms of climate change due to changes in wind patterns [2]. The atmospheric processes behind such extreme and influential events can be better understood by continuous profiling of vertical structure of the atmospheric wind and wind shear.

Wind Profiling Radar (WPR) has become the most efficient tool for continuous monitoring of the wind parameters of the atmosphere with very high temporal and spatial resolution [3]. Direct measurements of the vertical air velocity even under precipitation conditions makes WPRs most effective instrument to study the atmospheric dynamics almost in all weather conditions [4].

A VHF wind profiler radar system has been installed at Aryabhatta Research Institute of Observational Sciences (ARIES) in the Central Himalayan Region near Nainital, Uttarakhand (29.4N; 79.2E; 1793 m amsl) India.

2. System Description

The ARIES ST Radar (ASTRAD) system operates at 206.5 MHz with ± 2.5 MHz bandwidth. The radar is made compact by installing the entire system within a 30 m x 30 m two storey building with maximum utilization of the available space on the hilly terrain.

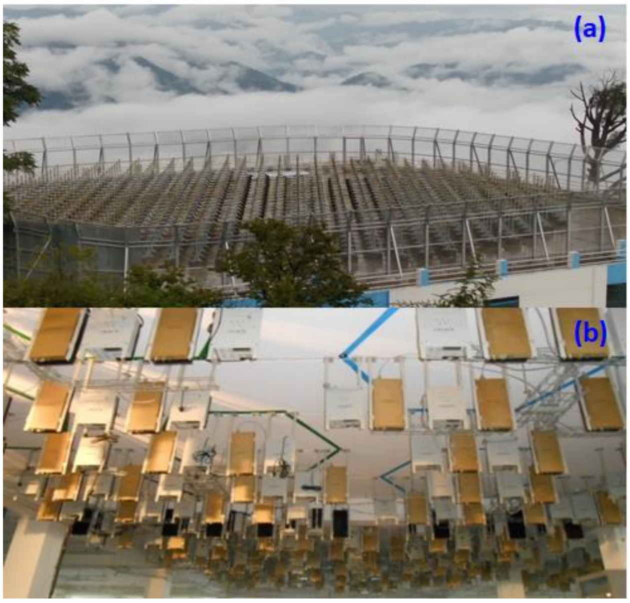

Figure 1. (a) ASTRAD antenna array on the top of the building and (b) The network of TRM is hanging from the ceiling.

In an innovative way, 12 groups of 49 antenna elements have been placed on the roof top with the required precision in a near circular aperture. The network of Transmit Receive Module (TRM) is hanged from the ceiling of the first floor (**Figure 1**). As in the VHF band, the average clutter signal strength from mountain regions is significant; a metal fence of 3.5 - 4 m height was designed and installed along the perimeter of the top of the roof to improve the detection of weak atmospheric signals. The specification of the Radar is given in **Table 1.** The radar is capable of observing both updraft and downdraft motion in the atmosphere with enhanced signal strength during convection.

Table 1. General Specifications of ASTRAD.

Antenna aperture	490 m^2
Antenna gain	34 dBi
Beam width (one way)	3.3°
Beam scanning capability	Azimuth: 0-360° in steps of 1°; Off Zenith: 0-30° insteps of 1°
Transmitter peak power	235 kW
Receiver and signal processing	4 channels DDC based system
Dynamic range	70 dB

3. Results and Discussions

Here, we present a convective precipitation event of 14 July 2022 from ~ 9:40 hours to 17:30 hours IST. Throughout the day long observation the radar was operated in Doppler Beam Swinging (DBS) mode with five beams scanning (North, South, Zenith, East and West) at off-zenith angle 15^0. Specific observations in the Zenith beam alone are also made from ~ 1300 hours to 1420 hours.

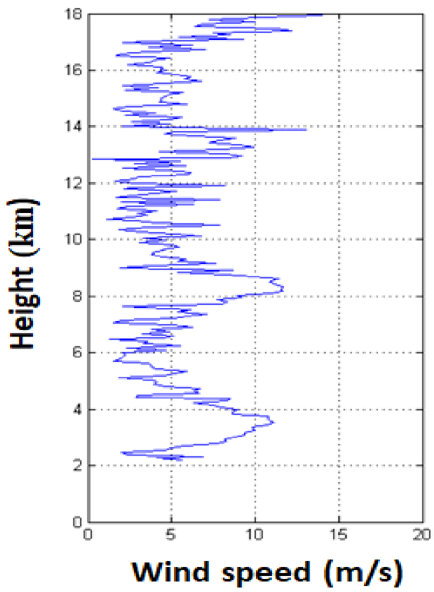

Figure 2. The height profile of the atmospheric wind speed on 14th July 2022 at 1104 hours.

In both configurations, the pulse width was set 2 µs coded at 0.5 µs baud to obtain the data at every 75 m from 375 m above the radar. To enhance the SNR, 64 time domain coherent and 4 spectral domain incoherent integrations were set. The spectrum generation was done with 512 FFT points. The off-line spectral data has been processed using the ASTRAD Data Processing Tool (ADPT) for estimation of the scientific parameters. Radar observation showed normal wind conditions (**Figure 2**) in the early hours of the observation till 1130 hours. The first signature of the

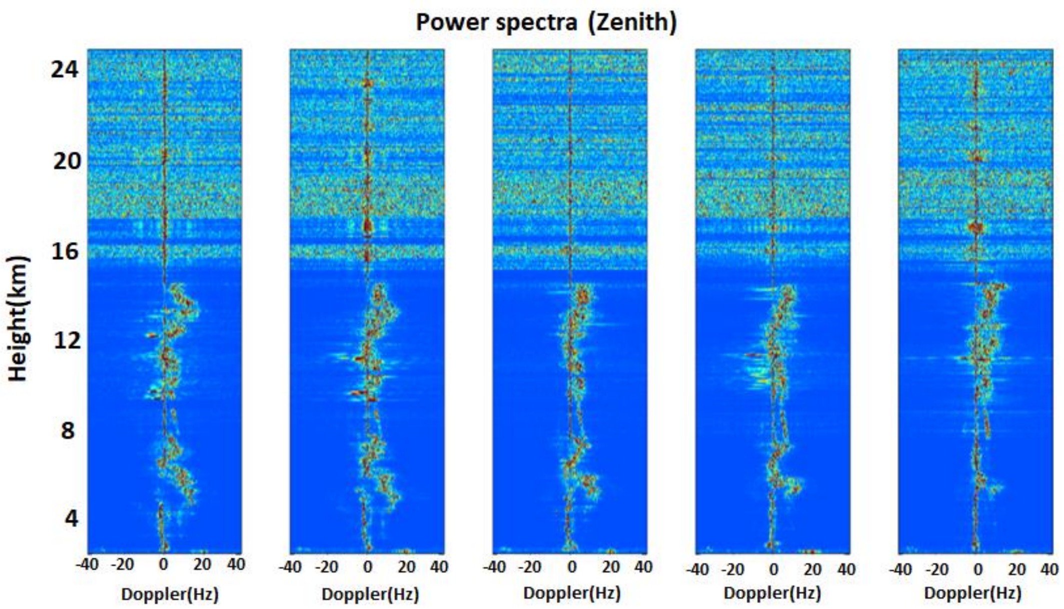

Figure 3. Violent updraft and updraft in the two separate height region and coupling of them in the atmosphere captured on 14th July 2022 from 1417 hours to 1419 hours.

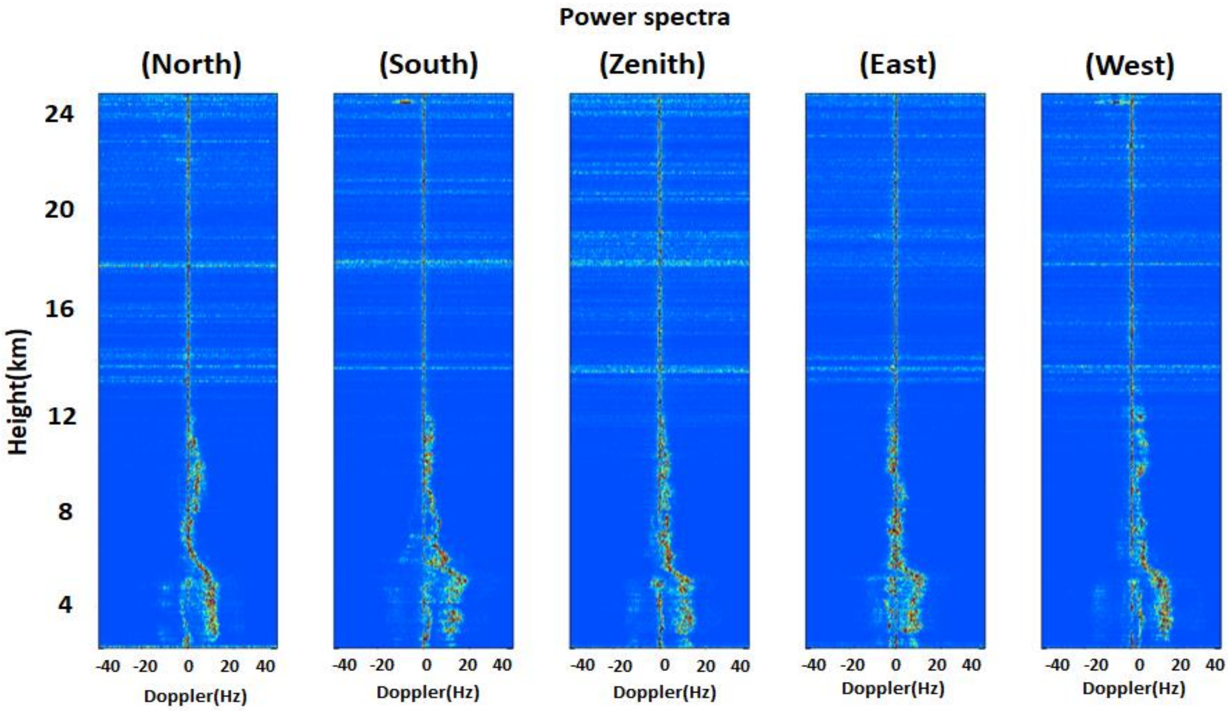

Figure 4. Five beam Doppler profile of both neutral atmosphere and stratiform precipitation capture on 14th July 2022 at around 1633 hours.

convection process (updraft) was observed at around 1133 hours in South & East beam below the 5 km from amsl. With time the process developed and at around 1229 hours it extended to a height ~ 14 km from amsl and captured in the East beam. Signature of the convection processes recorded in all five beams first time at around 1242 hours. It signifies that since starting of the processes, it took nearly one hour to spread over the entire scanning region over the Radar in the atmosphere which is nearly 2.6 km diameter at 5 km height.

During the afternoon at around 1314 hours first clear signature of downdraft in all five beams between 10 km to 14 km was noticed when the Zenith beam was in operation. After the triggering of that downdraft phenomena, the violent updraft and downdraft motion continued in the two separate height regions, one at around 5 km height and other above 10 km.

The above two processes evolve with time. As they get closer they get coupled at times. (**Figure 3**). In this case the process continued for the next two and a half hours. In between, the intensity of the atmospheric motion fluctuated and reached its lowest level around 1500 hours.After a span of nearly five and half hours since the beginning of the observations, the first signature of the stratiform rain spectrum is observed at ~ 1605 hours and sustained for the next ~ 10 minutes. Finally, the signature of the stratiform rain spectrum with enhanced spectral width was recorded at around 1630 hours and continued till 1646 hours and then decayed with time. The spectrum of rain captured at around 1633 hours is shown in **Figure 4.** The height of the stratiform region is observed around 5 km with melting region extended to 6 km.

After 1700 hours the atmosphere became normal and again the general wind pattern as depicted in **Figure 1** prevailed. The occurrence of light rain between 1630 hours and 1646 hours is confirmed from the data of the rain sensor of the collocated Automatic Weather Station (AWS). The variation of vertical wind component from 1300 hours to 1400 hours recorded during only Zenith radar configuration is shown in **Figure 5**. In the figure a clear signature of the violent updraft and downdraft and periodic structure mixing of the atmospheric layers is visible. During the Zenith beam operation between 1300 hours to 1420 hours, at 1330 hours downdraft with two separated radial velocities was captured and depicted in **Figure 6.** This can be explained as the downdraft motion of the precipitation in both ice and melting phase as seen by the Radar.

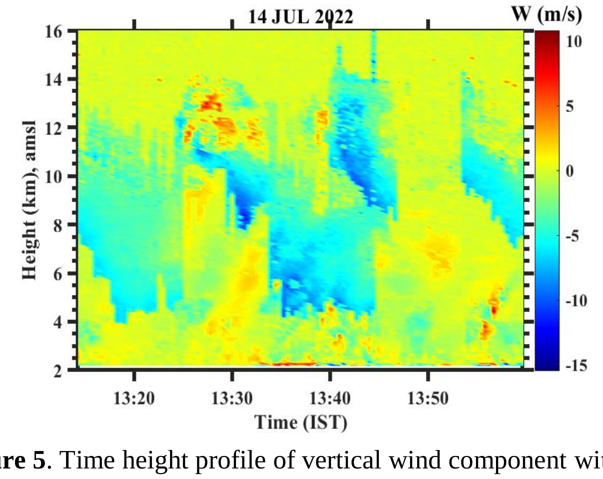

Figure 5. Time height profile of vertical wind component with signature periodic updraft and downdraft during 1300 to 1400 hours.

4. Conclusion

Observations from ARIES ST Radar demonstrate the triggering process of the local convection and subsequent precipitation over the central Himalayan region. The power spectra of the radar observed during the event gives a sneak peek into the vertical structure of the tropical deep convective system. The development, maturing and dissipation phase of the simultaneous occurrence of the precipitation at the two vertical levels in a convective pillar cloud are shown in this paper.

Near the 10 km height level, the precipitation is in ice phase indicating accumulation of the ice particles and their breaking/ melting at subsequent lower vertical levels leading to accelerating downdrafts in the 10 – 6 km region. Meanwhile, the precipitation from the 5 km level is in the liquid phase leading to nearly steady fall velocities. This understanding of the morphology and vertical structure of the deep convective system will be helpful in comprehending their evolution and subsequently improve their representation in the numerical models.

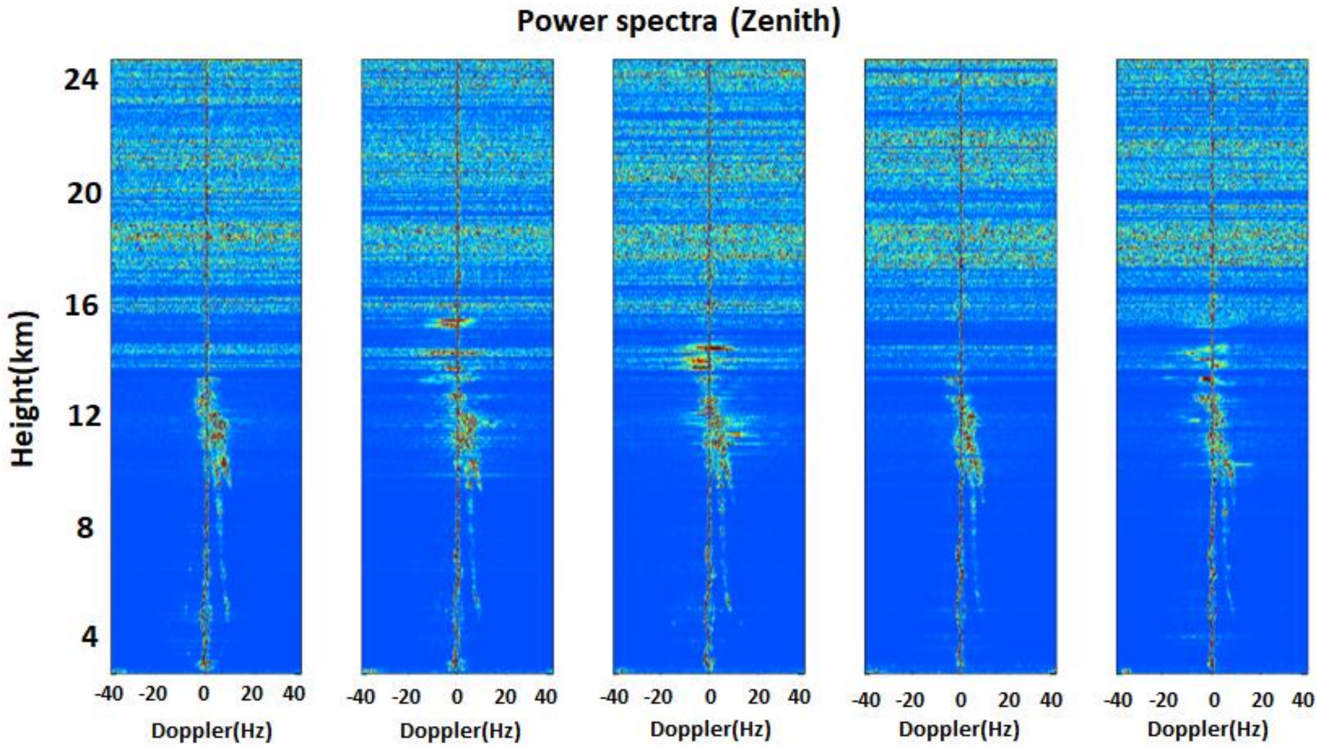

Figure 6. Downdraft motion by different microphysical elements in the atmosphere captured at around 1330 hours during the Zenith beam operation.

6. Acknowledgements

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7. References

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