MST radar (53 MHz) observation of atmospheric polarized scatterers: A great implication for astronomical observations

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Abstract

The present work reports that the Earth's atmosphere can sometimes exhibit polarized characteristics such that any polarized light coming from the outer space can get modulated easily by these polarized refractive index structures of the atmosphere. Utilizing the Mesosphere Stratosphere Troposphere (MST) radar operating at a very high frequency of 53 MHz in the Indian tropical region of Gadanki, two sets of data are collected for the heights of 2-20 km during (a) 09-10 February 2009 and 06-07 June 2011. The data comprise of atmospheric scattering properties like signal to noise ratio (SNR), Doppler spectral width of the echoes and the atmospheric dynamical parameters like all the three components of wind velocities and their vertical shears.The wind dynamics has been utilized to determine whether the atmosphere was in dynamically unstable conditions that would lead to the generation of turbulence in the atmosphere, Since the MST radar has two sets of 1024 orthogonally polarized antennae aligned along the zonal and meridional directions, it is possible to transmit polarized narrow beams and get echoes accordingly. From these two data sets, one (2009) has been identified as a normally observed echoes and the other data (2011) contain the polarized signals received.

1. Introduction

[1]were the first to identify the potential of 53 MHz radar in studying the dynamics of the whole atmosphere from the troposphere to the mesosphere. The dielectric properties of the atmosphere from the troposphere to stratosphere are mostly determined by neutral particles whereas from the mesosphere upwards, the charged ions, electrons start to contribute quite significantly to it and hence an entirely different mechanism of scattering of electromagnetic waves in these higher heights. Since the period of discovery of MST radar, innumerous publications have been made on the characteristics of atmospheric scatterers as well as the atmospheric dynamics and plasma electrodynamics. One interesting point to note here is that so far it is assumed the isotropic or anisotropic scattering nature of the atmosphericair in the troposphere and stratosphere (S&T) by both the atmospheric as well as astronomic scientists and so far it is not bothered about the sometimes polarized nature of the scatterers. The negligence of the knowledge about the polarized state of the atmosphere has great implications for astronomical observations as the astrophysics observers have specific interpretations of observing different kinds of polarized light from various astrophysical objects.The recent report by[2] sheds a remarkable light on the existence of polarized refractive index structures of the atmosphere. Following that specific publication, further attempts have been made in the present work in elucidating the existence of the polarized scatterers in different heights during different background atmospheric conditions. Session 2 describes briefly about the radar technique and session 3 describes the observations and makes interpretations while the session 4 summarizes and gives conclusions.

2. MST radar data

The Mesosphere Stratosphere Troposphere (MST) radar located at Gadanki (13.5°N, 79.2°E) is a large power, highly sensitive, and phased-array Doppler radar operating at a carrier frequency of 53 MHz with an average power aperture product of 7×108 Wm^2. With 3° beam width, a gain of 36 dB and a side lobe level of −20 dB, the radar consists of 1024 pairs of crossed Yagi-Uda antenna elements (1024 pairs of crossed-half-wave dipoles) arranged in a 32×32 square matrix over an area of 130 m × 130 m. As it works as a semi-active phased-array radar, the radar beam can be tilted up to 20° in steps of 1° from the zenith in the north-south and east-west planes. [3]give full details of this radar system. For the presentwork, the radar was operated from 22 LT of 6 June 2011 to 02 LT of 7 June 20115, spanning ~4 h of continuousoperation. The radar was operated in a four-beam mode; forone scan cycle, the narrow-transmitting-radar beam wastilted 10° from the zenith in the east, southdirections, and two zero zeniths with antennae aligned along the meridional plane (north-south). The uncoded pulse length of the transmitting beam was2 microseconds corresponding to a height resolution of 300 m, and thelength of the interpulse period was 0.25 millisecond. Successive 128 pulses were coherently added to get one datapoint and 512 successive such data points were utilized toperform Fast Fourier Transform (FFT) analysis separatelyfor each of the four beams and all the range bins. As a result,one height profile of wind velocities (zonal, meridional andvertical) and the other atmospheric scattering parameterswere obtained in total 76 s, corresponding to a time resolutionof 76 s for horizontal wind velocities and 38 s for the vertical velocity as every

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alternate beam was directed vertically. This period of 76 s is less than 2 min sothat a minimum period of oscillation of about 152 s or 2.5 min can bederived, according to Nyquist theorem, from the Fouriertransform analyses of time series of data.

3. Observations and results

Figure 1 shows the time vs. height contour plots of signaltonoise ratio (SNR) in decibel (dB) [left panels] and Doppler spectral width (Hz) [right panels] of the MST radar echoesreceived by the MST radar during 22-02 h LT of **June 06-07, 2011**. It may be observed that the few distinct layers of strong SNR observed in the zenith (Fig. 1a) and south (Fig. 1c) beams in the heights of 16-20 km have no resemblance to what observed in the east beam (Fig. 1e). Further, the echo strengths are comparable between the zenith and south tilted beams, indicating that these echoes are not aspect sensitive in nature. At the same time they are also not associated with turbulence as there are no enhanced spectral widths observed in Figs. 1b and d corresponding to the layers of strong SNR in these beams. This would indicate that these echoes in the zenith and south oriented beams are polarized in nature as they have obtained by radiating the antennae aligned along the meridian and the east-tilted beam (Fig. 1e) echoes were obtained by radiating the antennae aligned along the east-west direction.

In order to understand whether any dynamical phenomenon like strong wind shears have caused these distinct echoes, Figure 2 shows the time-height (1.5–20 km) contour plots of zonal, meridional and vertical wind velocities (left panels) measured by the MST radar over Gadanki and their associated vertical shears (right panels). Figures 2a and 2b show the contour plots of vertical wind velocity (u, m/s) and its associated vertical shear (du/dz, (m/s)/300 m), respectively. Similarly, Figures 2c and 2d show the same for the meridional wind velocity, and Figures 2e and 2f show that for the zonal wind velocityThe shear plots (Figs.2b, d and f) indicate no great shear events observed. These wind shear and spectral width observations have ruled out the concept of turbulence induced aspect sensitive echoes but stressing to interpret them in terms of polarized echoes as there are no such echoes in the east beam (Fig. 1e) in these heights of 16-19 km.

In order to compare the present observation of distinct echoes with normally observed echoes, Fig. 3 shows the same as Fig. 1 but for the other dates of **February 09-10, 2009** and here all the right panels also contain SNR. In this case, the radar was operated in six beam mode with two orthogonal polarizations (zonal and meridional) of antennae utilized for the zenith beam (Fig. 3a and b) and the meridionally aligned antennae were utilized for the north and south tilted beams (Figs. 3c and d) and the zonally aligned antennae were utilized for the east and west tilted beams (Figs. 3e and f). It may be observed that all the horizontally stratified type of echoes observed for the zenith beam (top two panels, Figs. 3a and b) have close resemblance with those obtained for all the other beams except that the zenith beam shows stronger echoes when compared to the tilted beam echoes, indicating the aspect sensitivity of the echoes. Similar to Fig. 3, Fig. 4 shows the spectral width and it may be observed that the layers of distinct and enhanced spectral widths are closed associated with the strong SNR layers observed in Fig.3. This would indicate that all the horizontally stratified type of layers of strong SNR observed in Fig. 3 are clearly associated with normally occurring turbulence induced echoes, which is in distinct contrast with those observed in Fig. 1 in the heights of 16-19 km, in that they are associated with polarized nature of the scatterers

4. Summary and conclusions

By operating the MST radar (53 MHz) at the Indian tropical station of Gadanki during two separate periods of **June 06-07, 2011** and **February 09-10, 2009**, it is established here that the radar observes sometimes distinct polarized refractive index structures in many horizontally stratified layers in the troposphere and even in the heights of above the tropopause level. Studying the atmospheric scattering characteristics like SNR and spectral width of the echoes and the dynamical parameters like winds and wind shears, we are able to come to conclusion that sometimes the atmosphere exhibits polarized refractive index structures that has great implications for astronomical observations as the atmosphere can affect the nature of polarization of the received light from astrophysical objects.

5. Acknowledgements

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6. References

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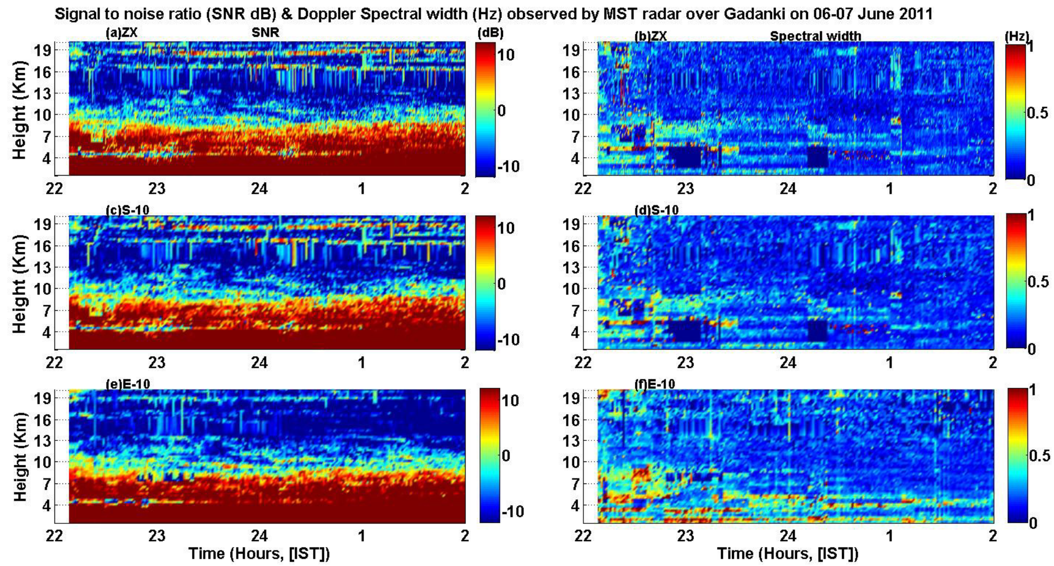

Fig. 1 Time vs. height contour plots of Signal to Noise Ratio (SNR, dB) and Doppler spectral width (Hz) of the MST radar (53 MHz) echoes obtained during 22-2 h LT on 06-07 June 2011.

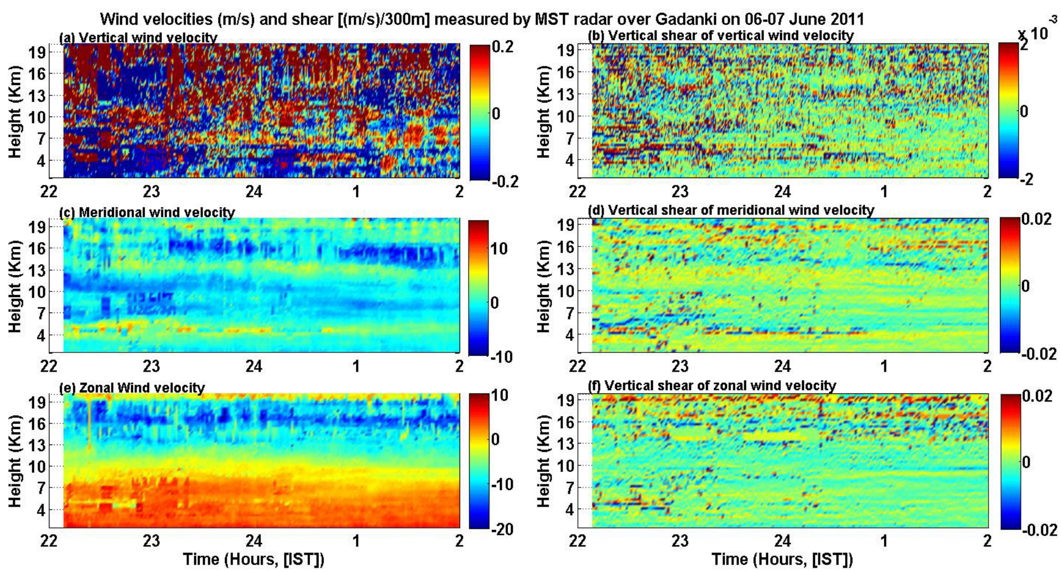

Fig. 2. Time vs. height contour plots of zonal, meridional and vertical wind velocities and their vertical shear during the observation period of Fig. 1

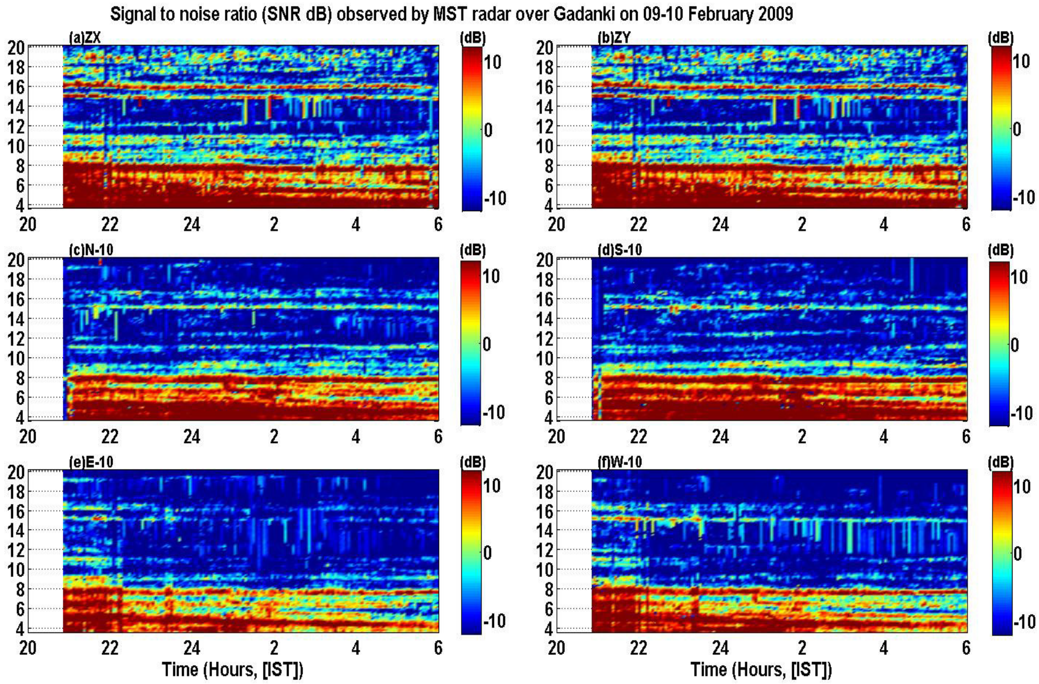

Fig. 3 Time vs. height contour plots of Signal to Noise Ratio (SNR, dB) of MST radar echoes obtained in two zenith beams with two orthogonal polarizations and the beams tilted 10° in the zonal and meridional directions during 09-10 February 2009.

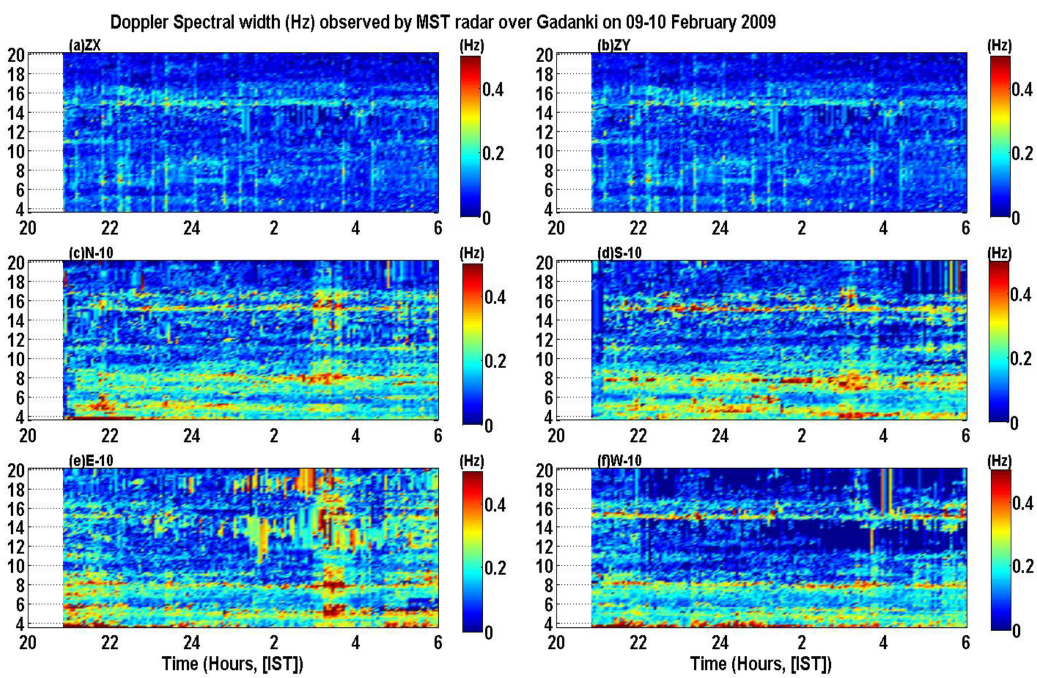

Fig. 4 Same as Fig. 3 but for the Doppler spectral width (Hz)