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# Comment on "Initial results from SKiYMET meteor radar at Thumba (8.5°N, 77°E): 1. Comparison of wind measurements with MF spaced antenna radar system" by Karanam Kishore Kumar et al.

R. Dhanya[1] and S. Gurubaran[1]

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[1] In a recent article, *Kumar et al.* [2007] describe some initial results on wind measurements made with a SKiYMET meteor radar deployed at Thumba (Trivandrum) (8.5°N, 77°E), India, probing the mesosphere–lower thermosphere region (80–100 km). Much of this work compares the meteor observations with the medium frequency radar (MFR) observations made at Tirunelveli (8.7°N, 77.8°E). Both these radar sites are located in the vicinity of the magnetic dip equator. The authors emphasize that the discrepancies in the velocities determined from the two systems above 90 km are due to the contamination of MF radar measurements by the ionospheric drifts induced by the equatorial electrojet (EEJ) and the difference could therefore be accounted for by the presence of the EEJ. We examine the validity of this interpretation made by Kumar et al. and while pointing out a flaw in their inference, it is argued that the meteor radar derived motions are related to plasma instability processes operative in the ionized meteor trails.

[2] A recent work by *Kumar et al.* [2007] uses data from an all sky interferometric meteor (SKiYMET) radar installed at Thumba (Trivandrum) (8.5°N, 77°E) and medium frequency radar (MFR) at Tirunelveli (8.7°N, 77.8°E), both operating near the magnetic equator in the Indian sector. The paper discusses the validity of the wind measurements made by both the radars in the height range 82–98 km and attributes the discrepancy at higher heights (above 90 km) to the equatorial electrojet (EEJ), an intense current system flowing at ~105 km over the magnetic equator, that is presumed to contaminate the MFR measurements at these heights. The authors conclude that the difference in the zonal velocity measurements made by the radars is directly related to the strength of the EEJ.

[3] MF, meteor and MST radars are being used to measure neutral winds in the mesosphere–lower thermosphere (MLT) region (80–100 km) with the advantage of continuous observation over a particular site. Radars operating near the magnetic equator have complexities in interpreting the measurements in terms of neutral wind, since the plasma drifts at electrojet heights are expected to contaminate neutral wind measurements [*Briggs*, 1977; *Chang et al.*, 1999; *Gurubaran and Rajaram*, 2000]. In this context we revisit the interpretations made by *Kumar et al.* [2007], in particular, the affirmation that the meteor system makes reliable wind measurements at heights above 90 km.

[4] The following are a few key issues of relevance to the report by *Kumar et al.* [2007] that need further examination and clarification.

[5] 1. According to the authors, the routine operation of the meteor radar at Trivandrum involves a special transmitting scheme that was primarily designed to avoid EEJ echoes. This mode of operation creates a null field in the overlapping region between two pairs of antennas that transmit out of phase with respect to each other. This is presumed to effectively avoid echoes in the east-west plane arising from the irregularities immersed in the electrojet. It is not clear to the readers that the echoes from other directions are not influenced by the EEJ as the authors have not presented any analysis to show this behavior.

[6] Previous reports imply that nonspecular echoes detected by meteor radars operating in the vicinity of the magnetic equator are related to plasma irregularities undergoing $\mathbf{E} \times \mathbf{B}$ drift, since in this case the radar target is not the meteor trail itself but the irregularities that grow on the trail as a result of plasma instabilities

[1]Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism, Tirunelveli, India.


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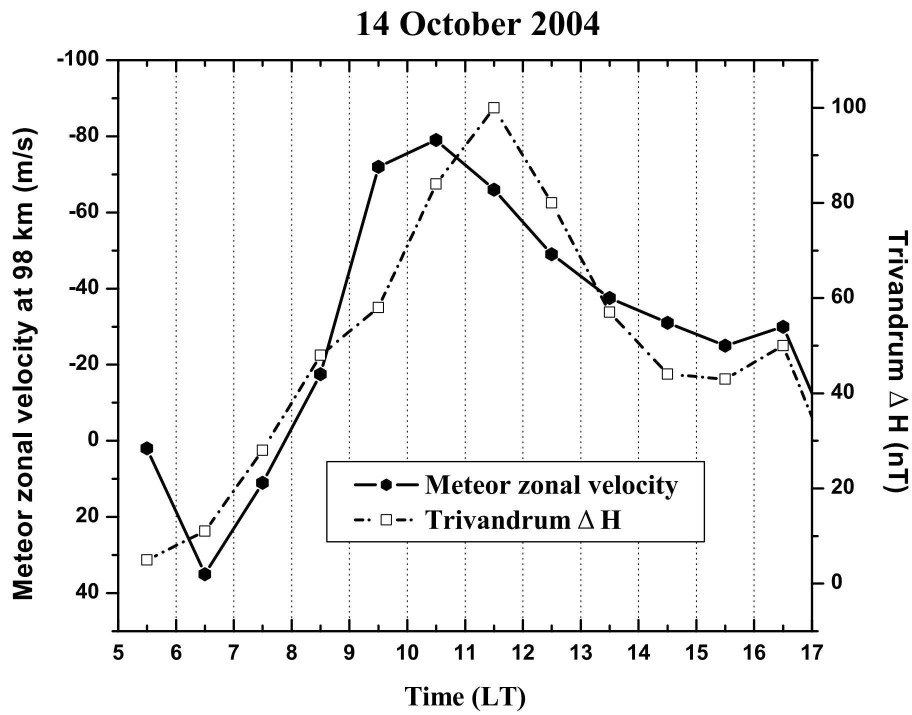


**Figure 1.** The zonal velocity at 98 km observed by the SKiYMET system at Trivandrum and the variation in the horizontal component of the geomagnetic field (ΔH) measured at Trivandrum on 14 October 2004.

[*Chapin and Kudeki*, 1994; *Chang et al.*, 1999; *Oppenheim et al.*, 2000]. With theoretical simulations favoring the role of plasma instabilities in the generation of plasma waves within a meteor trail that could cause backscatter for the meteor radars, it needs to be ascertained whether the echoes detected over Trivandrum are not associated with plasma waves generated by any of the instability mechanisms that can operate within the meteor trail.

[7] 2. The paper by *Kumar et al.* [2007] analyzes two representative days when the MF and meteor winds showed good agreement (11 September 2004) and poor agreement (15 September 2004). As per the authors' statement, the difference between the meteor and MF radar zonal wind components is proportional to the variation in the horizontal component of the ground magnetic field (ΔH) and therefore to EEJ strength. It would be worthwhile to question the validity of this statement when we have cases (11 September 2004, for example) wherein the electrojet was strong and the MF and meteor winds agreed. When we examined the ground magnetometer data, we found the temporal variation in the strength of the electrojet was similar on those two days mentioned above. It is known that MF radar tends to underestimate winds at heights above 90 km and hence this aspect complicates the simple assumption made by *Kumar et al.* [2007] that the difference between the meteor and MF radar zonal winds would reflect the strength of the electric field that governs the variation in the horizontal component of the ground geomagnetic field.

[8] In the last paragraph in section 3 of their paper, *Kumar et al.* [2007] express a possibility that the meteor echoes at 98 km might be influenced by EEJ induced drifts and state that any examination of this was out of scope of the present study. Because the central theme of this work was to compare the measurements made by the two techniques and undertake a validation of meteor wind measurements, the possible contamination of meteor echoes by EEJ induced effects warrants an elaborate study in the near future.

[9] The authors plot the absolute difference between the two measurements along with ΔH on 14 October 2004 (in the work of *Kumar et al.* [2007]). A good correlation between the two parameters for this day was considered as a 'confirmation' that the meteor radar measured neutral winds while the MFR measured a combination of neutral wind and electron drift. This 'finding' is questionable considering that only one day was shown that happened to be a magnetically disturbed day (Ap = 22) and that the authors themselves express doubts that the meteor radar might not be solely

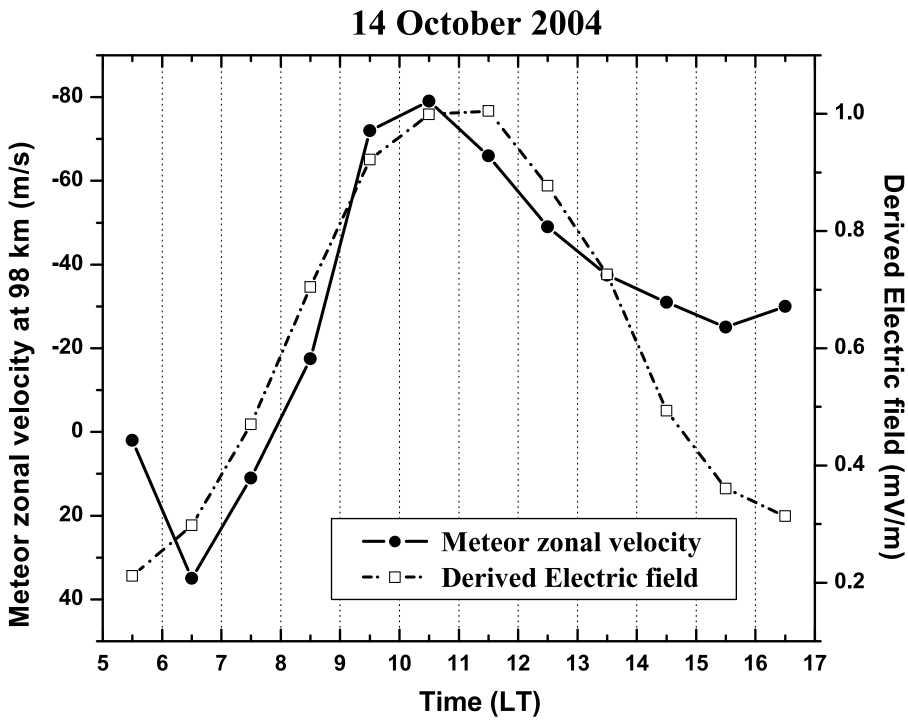


**Figure 2.** The meteor radar velocity at 98 km over Trivandrum and the zonal electric field derived from the *Anderson et al.* [2004] formula for the observations on 14 October 2004. Ground magnetic field observations at electrojet (Tirunelveli) and off-electrojet (Alibag) stations contributed to the derived electric field.

measuring neutral winds and the measurements could be contaminated by EEJ drifts. In Figure 1, we plot the zonal drift (negative upward) at 98 km observed by the meteor radar along with ΔH at Trivandrum on 14 October 2004. A good correlation between these parameters perhaps indicates that the meteor velocities were influenced by EEJ on this day, though this correlation needs to be examined on day-by-day basis. A similar correlation between MF radar drifts and horizontal magnetic field variation on a few selected days was reported for Tirunelveli earlier [*Ramkumar et al.*, 2002; *Gurubaran et al.*, 2007].

[10] While discussing the results in Figure 11, *Kumar et al.* [2007] argue that the differences in the zonal wind measurements made by the two techniques could be attributed to the presence of EEJ over this latitude. A careful examination of the direction of the zonal drifts measured by the two techniques on this day (14 October 2004) will prove that this is incorrect. While interpreting the results shown in Figure 11, the authors have made use of the assumption that the MFR measured a combination of neutral motions and plasma drifts indicative of EEJ strength at heights above 90 km, and the meteor radar measured only the neutral wind. It may be noted that normal or strong EEJ conditions would correspond to a moderate or intense westward ionospheric drift at E region heights. The MFR velocities are then expected to be westward relative to the meteor derived motions for the difference to correctly represent the normal EEJ strength. Rather, as can be seen in Figure 9 of *Kumar et al.* [2007], the MFR measured a drift speed of ~25 m/s (eastward) around the time (~5 UT) when the electrojet as revealed by the ground geomagnetic field variation was strongest on this day, whereas the meteor radar then measured a zonal speed of ~80 m/s (westward). It is logical then to expect that the motions revealed by the MFR on this day were not influenced by the electric field, and therefore, the difference between the zonal drifts measured by the two techniques cannot be related to the EEJ strength. As pointed out by the reviewer of this Comment paper, it is quite possible that the MFR detects secondary irregularities generated by plasma waves with vertical phase motions that need not be related to the primary electric field.

[11] 3. *Anderson et al.* [2004] derived a formula for vertical **E** × **B** drifts using ground magnetic data from two stations, one at the electrojet and the other away from the electrojet. We have used this formula to

compute the zonal electric field **E** that drives the EEJ. The difference in ΔH observed at Tirunelveli, the equatorial station, and that at Alibag, the off-equatorial station, served as inputs for this exercise. As can be seen in Figure 2, the derived electric field and the Trivandrum zonal drift on 14 October 2004, follow a similar pattern.

[12] As a meteor trail is ionized, the electrons within the trail undergo cross-field drift and provide a path for the discharge current that excites two-stream and/or gradient drift instabilities, triggering irregularity growth [*Chapin and Kudeki*, 1994]. The growth rates of these instabilities depend on the electric field and therefore the plasma waves intensify as the electric field maximum is approached and cause a stronger backscatter for the transmitted wave. It is quite possible that the strong electric fields associated with the EEJ influence the ionized meteor trails detected by the radar system at Trivandrum and the measured drift perhaps represents a component of the phase velocity of the plasma wave.

[13] We have examined a larger data base obtained from the SKiYMET system during the February–March 2006 tidal campaign [*Gurubaran et al.*, 2008]. On most of the days, the daytime zonal velocity at 98 km over Trivandrum shows the inverted V-shaped behavior noticed in Figure 1 with peak westward motions occurring around local noon hours. On some of the days during this period, an afternoon reversal in electrojet, commonly referred to as counterelectrojet, was observed. The meteor velocities turned eastward at these times corroborating with the westward current. Enhanced westward motions at heights above 90 km around noon hours when the electrojet is most intense and weak eastward motions when the electrojet reverses are common features observed with the MF radar at Tirunelveli [*Gurubaran and Rajaram*, 2000; *Ramkumar et al.*, 2002; *Gurubaran et al.*, 2007; *Dhanya et al.*, 2008].

[14] In this scenario, the same caution that *Briggs* [1977] made for spaced receiver experiments applies to the meteor systems operating in the vicinity of the magnetic equator. In the light of the previous report based on the meteor radar observations made from Christmas Island by *Chang et al.* [1999], we remind the readers of the potential problems in making reliable neutral wind measurements with radar systems probing the electrojet heights.

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R. Dhanya and S. Gurubaran, Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism, Tirunelveli 627 011, India. (gurubara@iigs.iigm.res.in)