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Spatial Resolution of the MIGHTI Thermospheric Wind Measurements and Implications on Wind Shear Measurements

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Abstract: Lower thermospheric wind shears are a main driver for sporadic-E in the ionosphere. This presentation will review the spatial resolution of MIGHTI E-region neutral wind observations, implications of the wind shear measurements and sample observations.

1. Introduction

The propagation environment for high frequency (HF) radio signals in the upper atmosphere is important for capabilities such as over-the-horizon (OTH) communication and OTH RADAR. One phenomenon that has significant impact to these capabilities is sporadic-E. Sporadic-E or E_s, is the occurrence of a spatially irregular layer of increased ionization, typically less than about 2 km thick. It is driven, in part, by atmospheric wind shears and the meteoric deposition of metals such as iron, magnesium and silicon [1]. While the climatological occurrence probability of sporadic-E has been addressed extensively in the past (see e.g. [2]), the prediction of E_s events remains elusive. Future assimilative ground-to-space weather prediction systems might be able to reliably predict E_s. The development, validation, and operation of these next generation models will likely depend on, or benefit from, high vertical resolution global scale measurements of the wind field in the E-region. The Michelson Interferometer for High-resolution Thermospheric Imaging (MIGHTI) instrument on the NASA Ionospheric Connection (ICON) Explorer mission conducts such wind profile measurements using a limb sounding geometry. In the following, we discuss the vertical and horizontal resolution of these measurements and show some sample data of wind shears in the E-region.

2. Vertical Resolution of MIGHTI wind Measurements

MIGHTI samples the vertical dimension of the limb scene by binning 16 pixels of the instruments' imaging detector. This vertical sampling is equivalent to approximately 2.9 km at 90 km altitude and 2.3 km at 300 km altitude, assuming the point spread function of the instrument optics is much smaller than the sampling interval. The point spread function of MIGHTI was measured on orbit during a star calibration measurement which was also used to verify the instruments' pointing. For the star calibrations, each instruments field of view was inertially pointed at the Pleiades and a high spatial resolution unbinned image was obtained. Figure 1 shows a raw image of the constellation taken from the green channel of MIGHTI-B [3]. Cross sectional cuts through the point-source like star images, shown in Figure 2, indicate that the point spread function of the MIGHTI optics is on the order of 8 individual pixels, or half of a binned vertical sampling element. Thus about 12% of the information for one altitude resolution element of 2.9 km in the lower thermosphere originates from the neighboring altitude samples. In addition, the wind inversion algorithm broadens the vertical resolution by a small amount. This is discussed in detail by Harding et al. [4], concluding that for a sine-shaped vertical wind profile with a vertical wavelength of 10 km and 20 km, the amplitude will be underestimated by about 20% and 8% respectively.

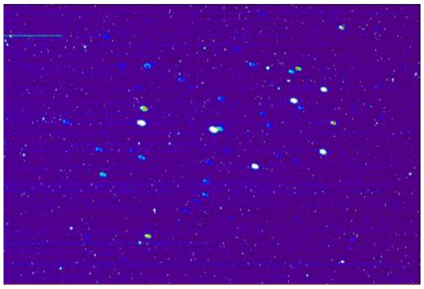

Fig. 1: Raw image of the Pleiades, taken using the green channel of MIGHTI-B. The bright members of the constellation are clearly visible in addition to many other stars.

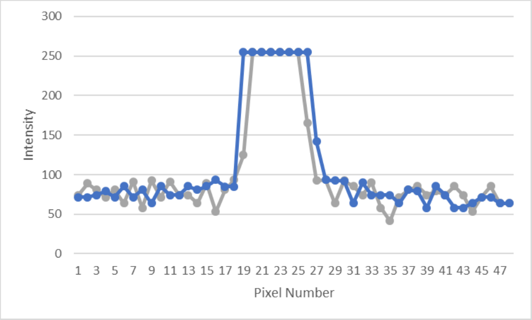

Fig 2.: Two cross sections of Electra, one of the stars shown in Figure 1.

3. Horizontal Resolution of MIGHTI wind Measurements

The horizontal resolution of the MIGHTI wind measurements has been discussed in detail by Harding et al. [5] and is determined by the averaging along the line of sight and across the field of view, and the averaging that results from the satellite movement during the integration time. The averaging kernel along the line of sight (within a sampled atmospheric layer) is the largest effect, ranging from approximately 300 km during the night to about 1000 km during the day.

4. Example of Wind Shears Observed by MIGHTI

Figure 3 shows 10 sequential zonal profiles measured by MIGHTI using the oxygen green line on 28 June 2020 between about 10:00-11:30 local solar time, around 40°N latitude, between 190°-210°E longitude. Over these 20° in longitude, a persistent wind shear is observed with a magnitude of approximately 120 m/s. The altitude profile is consistent with a shear is about 40 m/s per kilometer, which is a common magnitude observed by sounding rocket experiments that due to less spatial averaging achieve higher vertical resolution [6]. Note, however, that due to the limited altitude resolution of MIGHTI, it could be a stronger shear. MIGHTI observations routinely show similar shears that have large horizontal extents of 2000 km or more.

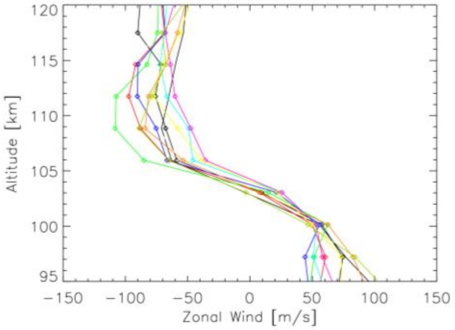

Fig. 3: Ten zonal wind profiles, sequentially observed by MIGHTI within about 5 minutes and across about 2000 km horizontal distance.

5. Conclusions

MIGHTI observes wind shears in the lower thermosphere that are on the order of about 40 m/s per kilometer or more, consistent with sounding rocket experiments, extending several thousand kilometers in horizontal distance. These observations are expected to be valuable input for emerging assimilative whole atmosphere models and the reliable prediction of sporadic E events, which to date, has been largely elusive.

6. Acknowledgements

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7. References

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