Velocities of Medium Scale Travelling Ionospheric Disturbances (MSTIDs) in the Europe-Africa Longitude Sector

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Goal

Medium Scale Travelling Ionospheric Disturbances (MSTIDs) are ionospheric airglow structures that can be detected at middle latitudes. They appear as dark bands that usually move from the northeast to the southwest when in the northern hemisphere and from the southeast to the northwest when in the southern hemisphere. This project was done to provide the first study of MSTIDs in the Europe-Africa longitude sector using All Sky Imagers (ASIs). The ASIs are part of a network run by Boston University's Imaging Science Laboratory.

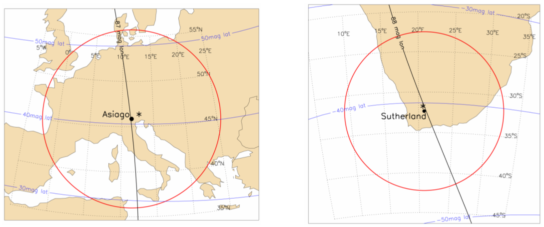

Figure 1: The fields of view of the two imagers. The northern hemisphere imager is located in Asiago, Italy, and the southern hemisphere imager is located in Sutherland, South Africa.

Introduction

Medium-scale traveling ionospheric disturbances (MSTIDs) are perturbations of plasma density that occur in the F region of Earth's atmosphere, at a height of approximately 300 km. Those that occur during the night are a result of electrodynamical forces. Due to this, an MSTID will appear at the magnetic conjugate point of another MSTID. In addition to the latitude dependence that makes them visible primarily at middle latitudes, they also have seasonal and longitudinal variations. MSTIDs are most visible at 630 nm due to reactions between molecular and ionized oxygen. They are not intense enough to be seen with the naked eye.

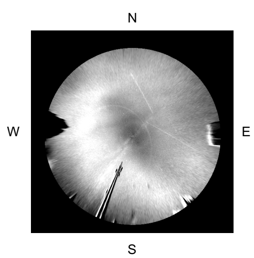

Figure 2: An MSTID traveling to the southwest observed from Asiago
06 September 2016 20:48:51 UT.
Zenith at center, cardinal directions labeled.

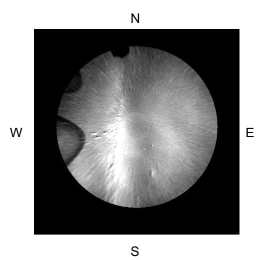

Figure 3: An MSTID traveling to the west observed from Sutherland
06 September 2016 20:51:19 UT
Zenith at center, cardinal directions labeled.

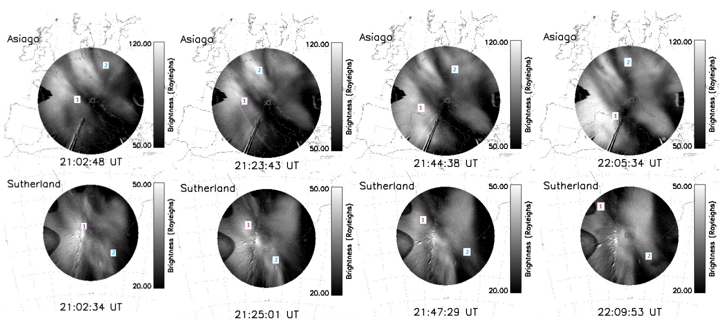

Figure 4: A progression of event 1 and event 2, which both occurred on the night of 27-28 August 2016. The dark bands next to the number labels generally move southwestward at Asiago and westward at Sutherland.

Data

Five wave events, all of which occurred from August to October of 2016, were found which were visible at both Asiago and Sutherland. Two events occurred on the night of 27-28 August 2016, and one each occurred on the nights of 06-07 September 2016, 29-30 October 2016 and 30-31 October 2016.

Results

To yield useful information, the all-sky images were unwarped at a height of 300 km. A meridional cross-section and a zonal cross-section were taken down and across the middle of each unwarped image (unless a special cross-section location had to be chosen so that the event in question will pass through it). The cross-sections of each image in the night are then assembled according to the time of their respective images to create a "velogram," as seen below in Figure 5.

As the MSTIDs travel, they appear as dark, straight lines on the velograms. The slopes of these lines, which represent the pixels of angular distance travelled per pixels of time, are calculated for both velograms. These two slopes can then be used to calculate the resultant speed and direction of propagation. This "pixels per pixels" speed is multiplied by a conversion factor which converts it into meters per second. The conversion factor depends on the range of latitudes and longitudes displayed on the velogram, as well as the time gap between successive images. It is unique to each location.

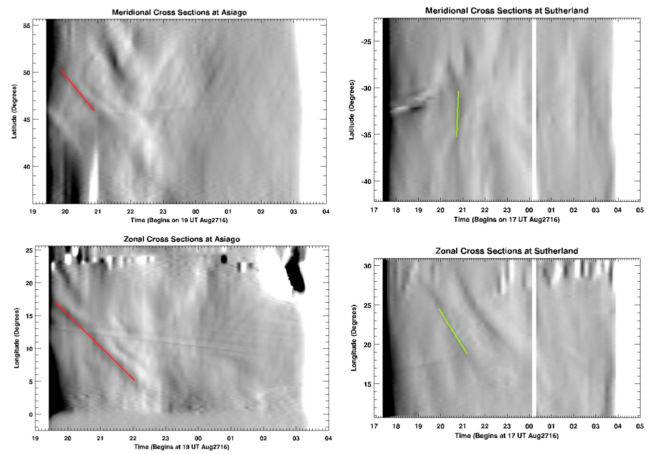

Figure 5: The four velograms associated with the night of 27-28 August 2016. The best fit lines used to calculate the slopes of event 1 are highlighted.

		Asiago		Sutherland	
Event Number	Date	Speed (m/s)	θ (degrees clockwise from North)	Speed (m/s)	θ (degrees clockwise from North)
Event 1	27-28 Aug 16	85±1	230±1	93±7	273±1
Event 2	27-28 Aug 16	116±4	237±1	108±15	278±1
Event 3	06-07 Sep 16	98±2	234±1	128±7	262±1
Event 4	29-30 Oct 16	99±5	218±1	94±10	275±1
Event 5	30-31 Oct 16	115±7	227±2	171±11	277±1

Table 1: Speed and directions of propagation of the five events at Asiago

Asiago		
Mean speed	Mean uncertainty	Standard error
103 m/s	4 m/s	12 m/s
Mean θ	Mean uncertainty	Standard error
229°	1°	7°

Sutherland		
Mean speed	Mean uncertainty	Standard error
119 m/s	10 m/s	29 m/s
Mean θ	Mean uncertainty	Standard error
273°	1°	6°

Table 2: Average values, average uncertainties, and standard errors of the speed and direction of propagation for the five events at Asiago (left) and Sutherland (right)

Summary of Results and Averages

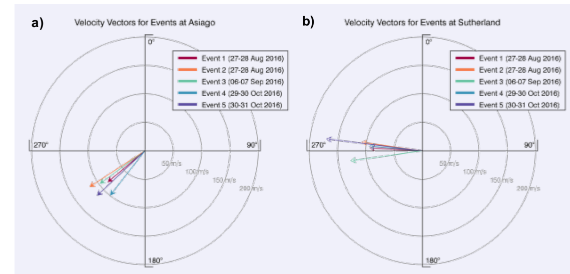

Figure 6: Compass plots depicting velocity vectors of all five events at Asiago (a) and Sutherland (b)

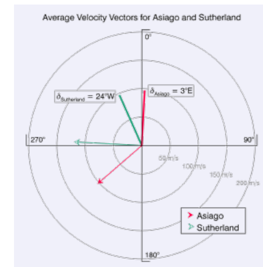

Figure 7: Compass plot depicting the average velocity vectors and the magnetic declination angles at both locations.

	Δθ (degrees)
Event 1	43
Event 2	41
Event 3	28
Event 4	57
Event 5	50
Average	44

Table 3: The difference in the directions of the corresponding MSTIDs observed at Asiago and Sutherland for each event

Comparison to other MSTIDs

Boston University's Imaging Science Laboratory also runs ASIs located in Arecibo, Puerto Rico and Mercedes, Argentina. Images taken from these locations at 630 nm revealed MSTIDs that appeared at both locations at the same time. The MSTIDs also moved westward and equatorward in both the northern and southern hemispheres. Seasonally, there is a peak in activity during both the June and December solstice months.

The MSTIDs observed over Asiago and Sutherland also occurred at the same time, indicating that they are linked by the magnetic field line. Events from both sites moved westward as well, but only the Asiago waves moved equatorward, whereas the Sutherland waves just moved westward. There were also many wave events found that occurred well away from the solstices, the most active time for MSTIDs.

Conclusions

The MSTIDs detected in the Europe-Africa longitude sector have characteristics that both match and differ from those detected in the American longitude sector.

1) The northern hemisphere MSTIDs observed Asiago moved in the southwestward direction, which is the same direction in which the northern hemisphere MSTIDs observed from Arecibo moved.
2) The southern hemisphere MSTIDs observed from Sutherland moved in the westward direction. This differs from the northwestward direction in which southern hemisphere MSTIDs from Mercedes moved.
3) There is some variation in the speed of MSTIDs, especially at Sutherland, but the average at Asiago is 103 m/s, whereas at Sutherland it is slightly larger, at 119 m/s.
4) All of the events which occurred on clear nights at both Asiago and Sutherland happened during the months of August, September, and October, which is a surprising result because Otsuka et al. and Martinis et al. found peaks in MSTID activity over Europe and the Americas, respectively, near the two solstices.

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References: Y. Otsuka, K. Suzuki, S. Nakagawa, M. Nishioka, K. Shiokawa, and T. Tsugawa, GPS observations of medium-scale traveling ionospheric disturbances over Europe, *Annales Geophysicae*, *31*, 163-172, 2013., K. Shiokawa, Y. Otsuka, C. Ihara, T. Ogawa, and F. J. Rich (2003), Ground and satellite observations of nighttime medium-scale traveling ionospheric disturbance at midlatitude, *J. Geophys. Res.*, *108*, 1145, doi: 10.1029/2002JA009639, A4., C. Martinis, J. Baumgardner, J. Wroten, M. Mendillo, All-sky-imaging capabilities for ionospheric space weather research using geomagnetic conjugate point observing sites, Advances in Space Research, 61, 7, 2018, 1636-1651, ISSN 0273-1177, https://doi.org/10.1016/j.asr.2017.07.021. C. Martinis, J. Baumgardner, J. Wroten, and M. Mendillo (2010), Seasonal dependence of MSTIDs obtained from 630.0 nm airglow imaging at Arecibo, *Geophys. Res. Lett.*, 37, L11103, doi:10.1029/2010GL043569.