Earth Planets Space, 54, i–ii, 2002

F-region radio and optical measurement of nighttime TID campaign

Akinori Saito*

School of Electrical and Computer Engineering, Cornell University, Ithaca, NY 14853-3801, U.S.A.

Preface

F-region Radio and Optical measurement of Nighttime TID (FRONT) campaign was conducted to clarify the physical mechanism of the Medium-Scale Traveling Ionospheric Disturbances (MSTIDs) with novel observational techniques. MSTIDs are migrating structures in the *F*-region ionosphere with about 300 km of wavelength and 100 m/s of propagating velocity (Francis, 1974). Array of all-sky CCD cameras and GPS receivers observed two-dimensional structures of MSTIDs with wide field-of-view and high temporal and spatial resolutions in May 1998 and August 1999. Two-dimensional observation made it possible to distinguish between the spatial structures and temporal evolutions of the ionospheric phenomenon.

In the last decade, several new features of the midlatitude ionosphere have been discovered by observations of radars, satellites, all-sky cameras and GPS receivers (e.g., Fukao *et al.*, 1991; Ogawa *et al.*, 1994; Miller *et al.*, 1997; Garcia *et al.*, 2000). Some of these new findings were stimulated by the discovery of the *F*-region field-aligned irregularities in the nighttime midlatitude ionosphere by the MU radar (Fukao *et al.*, 1991). Their large Doppler velocity indicates that the intense polarization electric field is generated in the midlatitude ionosphere. The incoherent scatter observation of the Arecibo radar also detected the intense polarization electric field associating with MSTIDs in the nighttime midlatitude ionosphere (Miller *et al.*, 1997). The generation and effect of the polarization field are not taken into account in the classical theory of the traveling ionospheric disturbances proposed by Hines (1974).

The recent instrumental advances have enabled all-sky CCD cameras to detect the two-dimensional structures of airglow with high spatial resolution. Dynamic behaviors of the meso-scale ionospheric structures in the nighttime midlatitude ionosphere were detected with an all-sky CCD camera at Arecibo (Kelley *et al.*, 2000). The complex features of the meso-scale structures, such as MSTIDs, indicate the existence of an unknown interaction between the neutral atmosphere and the ionized atmosphere in the midlatitude ionosphere. To detect the two-dimensional structures of the ionosphere, GPS receiver array is another powerful tool that have been developed recently. GPS Earth Observation Network (GEONET) in Japan consists of more than one thousand of GPS receivers and has 1×10^6 km^2 of field-of-view. Using the data of GEONET, the two-dimensional structures and time evolutions of Total Electron Content (TEC) disturbances were studied by Saito *et al.* (1998).

With these two novel observational techniques, FRONT campaign was carried out to study the two-dimensional structures of nighttime MSTIDs over Japan. To detect the other physical parameters of the ionosphere, the MU radar, ionosonde network and Fabry-Perot Interferometers (FPI) were operated in this campaign. The detail of the observational setup was summarized by Saito *et al.* (2001) and Saito *et al.* (2002). The preliminary results were reported by Saito *et al.* (2001), Kubota *et al.* (2000) and Shiokawa *et al.* (2000). The structures of the 630 nm band airglow were found to coincide with the structures of TEC and propagate to the southwest in about 100 m/s of velocity. In these preliminary studies, the absolute value of TEC was not derived but only the perturbation component of TEC was studied because the observed TEC data contains ambiguities caused by the internal biases of the GPS receivers and transmitters. Otsuka *et al.* (2002) estimated these internal biases using an efficient procedure for GPS networks of significant number receivers, and evaluated its accuracy and errors using a simulation with the IRI ionospheric model. Another source of the error in the GPS-TEC data is the contribution of the plasmasphere. Using an ionosphere and plasmasphere model, the contribution of the plasmaspheric electron to the GPS-TEC data was discussed by Balan *et al.* (2002).

In FRONT campaign, five and six all-sky CCD cameras

*On leave from Department of Geophysics, Graduate School of Science, Kyoto University, Kyoto 606-8502, JAPAN.

were deployed for FRONT-1 (May 1998) and FRONT-2 (August 1999) campaign, respectively. The array of all-sky cameras observed the 630 nm band airglow with wide field-of-view over Japan. Some portions of the field-of-views of cameras were overlapped each other. The altitude of the emission layer was determined by triangulation technique (Kubota *et al.*, 2000). In FRONT-2 campaign, the behavior of MSTIDs around the boundary between the midlatitude and equatorial regions were focused to study the termination of MSTIDs. Shiokawa *et al.* (2002) clarified the airglow structures at the equatorial boundary of the midlatitude region using an all-sky CCD camera at Okinawa. The simultaneous observation of 630 nm band airglow and TEC made it possible to compare the absolute value of TEC and 630 nm airglow. Ogawa *et al.* (2002) evaluated the variations of TEC and airglow associated with MSTIDs using the neutral atmosphere model. The relation between the 3-m scale field-aligned irregularities and MSTIDs were studied by Saito *et al.* (2002) using the data of the coherent scatter observation of the MU radar. The large-scale background ionospheric conditions of the occurrence of MSTIDs were also studied with the incoherent scatter observation of the MU radar.

The coordinated observation of GPS network, all-sky camera network, a coherent and incoherent radar, FPIs and ionosondes in FRONT campaign, and the comparison and evaluation of these observational results with atmospheric models clarified several new features of the nighttime midlatitude traveling ionospheric disturbances. The phenomenon was revealed to have wide spectrum from 3-m to 1000 km scale, and be generated by a non-linear interaction of the neutral atmosphere and the ionized atmosphere. Based on these observational results, it is necessary to develop a new theoretical framework to understand the ionospheric dynamics at midlatitudes.

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A. Saito (e-mail: saito@ece.cornell.edu)