COST Action – CA15211 "ElectroNet"

Scientific Report for Short-Term Scientific Mission (STSM)

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STSM PERIOD: January 9 –February 10, 2017

DETAILED SCIENTIFIC REPORT

1. INTRODUCTION

In the frame of the present STSM hosted by NOA (ISARS) during the one-month period January 9-February 10 2017, Dr. Christina Oikonomou in collaboration with Dr. Anna Belehaki and Dr. Ioanna Tsagouri investigated the role of dynamics, electrodynamics and plasma physics in coupling the neutral gases of the mesosphere/lower-thermosphere (MLT) region to the ionospheric plasma of the E region. In particular, she studied the mechanisms whereby atmospheric tidal waves are transporting energy and momentum upwards through the MLT region and influencing the occurrence and variability of the local concentrations of ionization observed in the upper atmosphere known as sporadic E layers. These are thin layers of metallic ion plasma which occur in the dynamo region of the midlatitude ionosphere (between 100 and 130 km). In the upper E region the vertical meridional wind shears, may also generate ionization layers, which are known as intermediate descending layers (IDLs). These are weak plasma layers that initiate at the bottomside F region and move downwards, often merging with the sporadic E layers below. IDLs act as a parenting-like process for sporadic E by transporting metal ions to lower heights where Es layers intensify.

The main objective of this STSM was to investigate the tidal variability of mid-latitude sporadic E and IDL layers by analyzing a large database of ionogram (graph of time-of-flight against transmitted frequency) measurements made in Athens utilizing the Athens Digisonde. These were compared with the respective ionogram measurements deriving from the Nicosia and Pruhonice Digisondes. For this, the ionosonde height–time–intensity (HTI) technique was applied using ionograms obtained from all three stations during the period 2009-2016. The HTI technique was developed by Chris Meek and applied on ionogram data first by Haldoupis et al. (2006). It should be noted that the initial proposed work plan of this STSM was to utilize datasets from Athens and Nicosia ionospheric stations, however, during the STSM the researchers decided to use datasets for one more station (Pruhonice) so as to conduct a comprehensive investigation of the latitudinal variation of Sporadic E phenomenon taking also under consideration that Athens and Nicosia are located in close geographic latitudes.

2. METHODOLOGY

2.1. Data collection

The starting point of this STSM was to assemble a database of past ionogram measurements to form the basis of the sporadic E and IDL layers investigation. Ionogram observations were obtained from three similar ionospheric radars (DigisondeDPS-4D) located in Athens, Nicosia, and Pruhonice for a long-term period as seen in the following Table 1. The data availability is also described at the same table. For this, the Host Institution colleagues extracted Athens and Pruhonice ionogram observations from DIAS server (European Digital Upper Atmosphere Server) (http://hertz2.space.noa.gr:8080/LatestDias2/loginPage.jsp) while Nicosia ionograms were provided by the Home Institution.

Table 1.*List of ionospheric stations and data availability.*

STATION	Geog. Latitude (°)	Geog. Longitude (°)	Data availability (Years)
Athens	38	23.5	2009, 2010, 2011, 2015, 2016
Nicosia	35	33	2009-2016
Pruhonice	50	14.6	2009, 2015, 2016

2.2. HTI analysis application

The HTI(height–time–intensity) technique was applied on the available ionogram datasets from all three stations on a daily and monthly basis during the years under investigation. This method considers an ionogram as a snapshot of reflected intensity as a function of height and ionosonde signal frequency. It uses a sequence of ionograms to calculate, for a given ionosonde frequency band, an average HTI plot, which is a 3-D plot of reflected signal-to-noise ratio in Db as a function of height within a given time interval. This plot depicts dynamic changes in the ionosphere. Figure 1 shows a typical example of such HTI plot computed over a 24 h local day in the frequency band 1-3 MHz marked at the topright corner of each plot. At the same plot ionograms corresponding to certain times of HTI plot recorded between 11 to 17 LT every 30 min at Pruhonice station are presented. As it can be seen, a downward movement of an intermediate descending layer (IDL) (denoted with green dotted circles) and the formation of a Sporadic E layer can be observed from the HTI plot. In this study, the following overlapping frequency bands were selected to investigate the tidal variability of sporadic E and IDL layers: 1-3 MHz, 2-4 MHz, 3-5 MHz, 4-6 MHz. Averaged HTI plots over each day and each month were produced for the years under consideration.

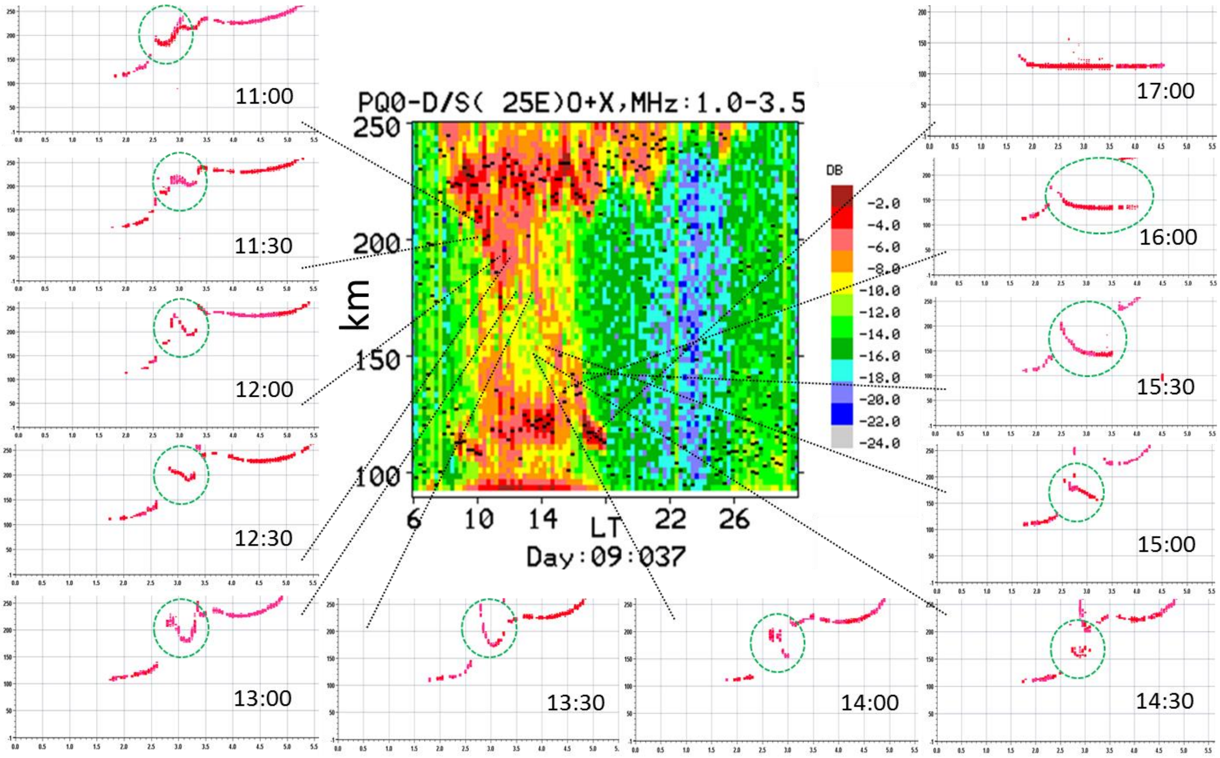

Figure 1. *A typical example of ionogram HTI plot, computed over a 24 h local day (6 February 2009, Day of year 37) in 1-3.5 MHz frequency band. At the same plot ionogramscorresponding to certain times of HTI plot recorded between 11 to 17 LT every 30 min at Pruhonice station are presented. The IDL is also denoted with green dotted circles.*

2.3. HTI preliminary results

By utilizing the produced HTI plots the diurnal and monthly variability of Sporadic E and IDL was studied at the three ionospheric stations under consideration. In Figure 2 indicative daily HTI plots (one for each season in 2009) are shown and in Figure 3, monthly HTI plots of 2009 are presented for the three selected ionospheric stations. By carefully inspecting all daily and mothly HTI plots of 2009 it was found that:

- In all three stations, the diurnal occurrence and altitude descent of sporadic E layer is characterized by a semidiurnal tide-like periodicity which dominates with some differences in all months. In particular, a daytime sporadic E layer initiates near local sunrise at around 125 km, followed by a nighttime layer appearing first in late afternoon at around 130 km. Both layers descend in altitude within 10 to 12 hours reaching at 100 km altitude. This semidiurnal structure of Sporadic E layer was more pronounced during summer and equinoctial than winter months, most probably due to the fact that metal ion densities in winter are low; therefore the forming layers are weak and not dense enough to be detected by the ionosondes. In addition, the enhanced meteoric deposition during summer can also indirectly contribute to the increased ion densities in summer.

- In all three stations, fast-descending layers (IDLs) originating at the bottomside of F ionospheric layer near sunrise and sunset were observed mainly in January and equinoctial months as shown by the daily and monthly HTI plots as well as by the estimation of the monthly IDL occurrence probability using all available ionograms. The HTI plots reveal that the observed upper altitude IDLs connect with the sporadic E at lower heights.

- The pronounced semidiurnal periodicity observed at the daily pattern of sporadic E and IDL is attributed to the vertical wind shear provided by semidiurnal tides which causes ion convergence to form sporadic E and IDL layers.

- The IDLs and sporadic E layers appear strong and more frequent during daytime than at night. This can be attributed to thefact that both metal and ambient ion densities needed for the ion layers to be formed are much lower at night. In addition, the rapid photoionization of metal atoms (at heights < 150 km) during the day increases the metal ion density. Metal atoms are produced from the friction of meteoric material deposited at thermospheric heights with atmospheric gas. IDLs were not detected during summer most likely due to the blanketing effect of strong sporadic E layers.

- Apart from the observed semidiurnal periodicity of the diurnal IDL and Sporadic E layer structure an 8-hour oscillation was revealed from HTI plots during summer months which was more pronounced at Nicosia and Athens and rarely noticed at Pruhonice station. This oscillation can be attributed to the terdiurnal tides which have been found to be confluent with the semidiurnal tides during summer season.

2.4. General conclusions

In the present investigation the characteristics of IDL and Es ionospheric layers linked to the neutral atmosphere (MLT region) properties were studied for the first time at 3 mid-latitude ionospheric stations simultaneously. Resembling characteristics, though with some differences, were revealed:

- Semidiurnal tides in thermosphere play a key role in the formation and descent motion of both IDLs and Sporadic E layers, by providing the vertical wind shear convergence nodes needed for the layers to be created and transported downwards.

- The seasonal variation of metal ion and atoms abundances along with the seasonal variation of semidiurnal tides occurrence and intensity are responsible for the observed monthly and seasonal variation of the intensity and occurrence of IDL and Sporadic E layers.

- The ionosonde HTI technique was proved a useful tool to conduct statistical studies and investigate the physical properties and the coupling of ionospheric layers with lower neutral atmosphere (MLT region).

2.5. Future research

Due to the limited time of the present STSM and the fact that a large amount of time was attributed to the extraction, collection and manipulation of a large amount of ionogram data as well as to the conversion and adaptation of the HTI analysis software for the application of the HTI method to the ionogram datasets of the three stations, the current investigation was not completed and is currently being continued. The points listed below are now being investigated:

- Careful inspection of produced HTI plots for the rest years and comparison of the HTI results with the respective ones of 2009.
- The possible effect of solar activity to IDL and sporadic E layer occurrence and intensity
- The possible role of geomagnetic field/geomagnetic storms on the sporadic E and IDL appearance
- Why IDLs appeared intensified around March equinox and January compared to rest months
- Why the terdiurnal periodicity in sporadic E layer daily occurrence was very rarely observed at Pruhonice and was frequently found at Nicosia and Athens stations during summer months.

In the future, the researchers involved in this study are also planning to publish the results of this STSM at a scientific journal.

2.6. Value and relevance of STSM to ElectroNet Action

The output of this STSM is of great importance for the current COST Action CA15211 as it will contribute to the understanding of the upper atmosphere environment over the mid-latitude European region and especially of the morphology and climatology of ionospheric layers irregularities and will enhance the knowledge on the physical processes which define the coupling between lower and middle neutral atmosphere with the lower ionosphere. In addition, the investigation of the effect of solar activity and geomagnetic field to ionization will contribute towards a more complete assessment of the coupling of atmospheric electricity with other sun-earth system components. The close collaboration of Dr. Christina Oikonomou with NOA and the application of HTI analysis are consistent with the Actions CA15211 target to enhance interaction among researchers, advance the existing knowledge and introduce new techniques.

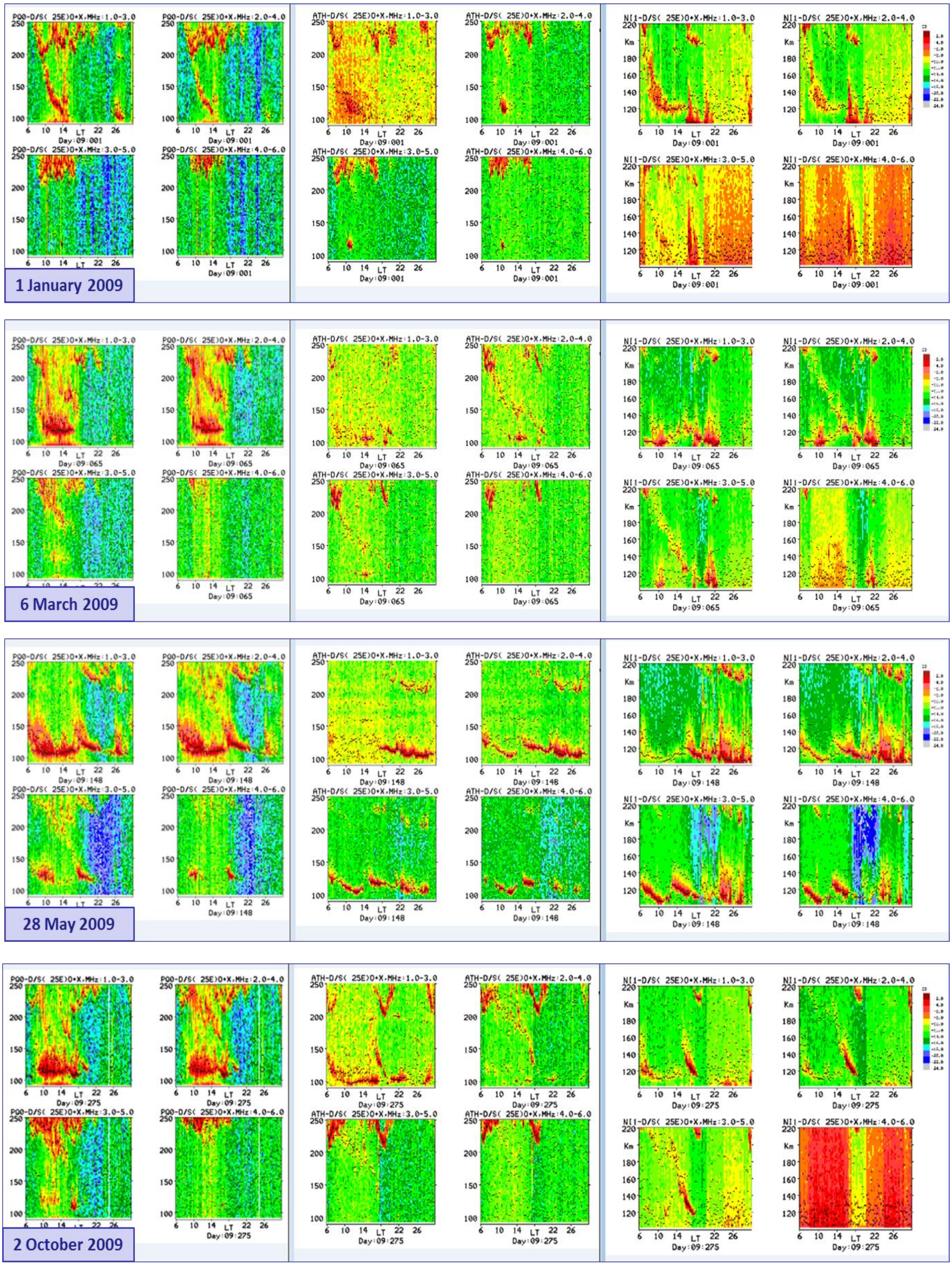

Figure 2.*Representative daily HTI plots for each season (from top to bottom rows: 1 Jan, 6 Mar, 28 May, and 2 Oct 2009), computed over a 24 h local day in four frequency bands (from top left to bottom right panels of each HTI plot: 1-3 MHz, 2-4 MHz, 3-5 MHz, and 4-6 MHz). The three columns (from left to right) present the HTI plots (4 for each station) for the three ionospheric stations Pruhonice, Athens and Nicosia respectively.*

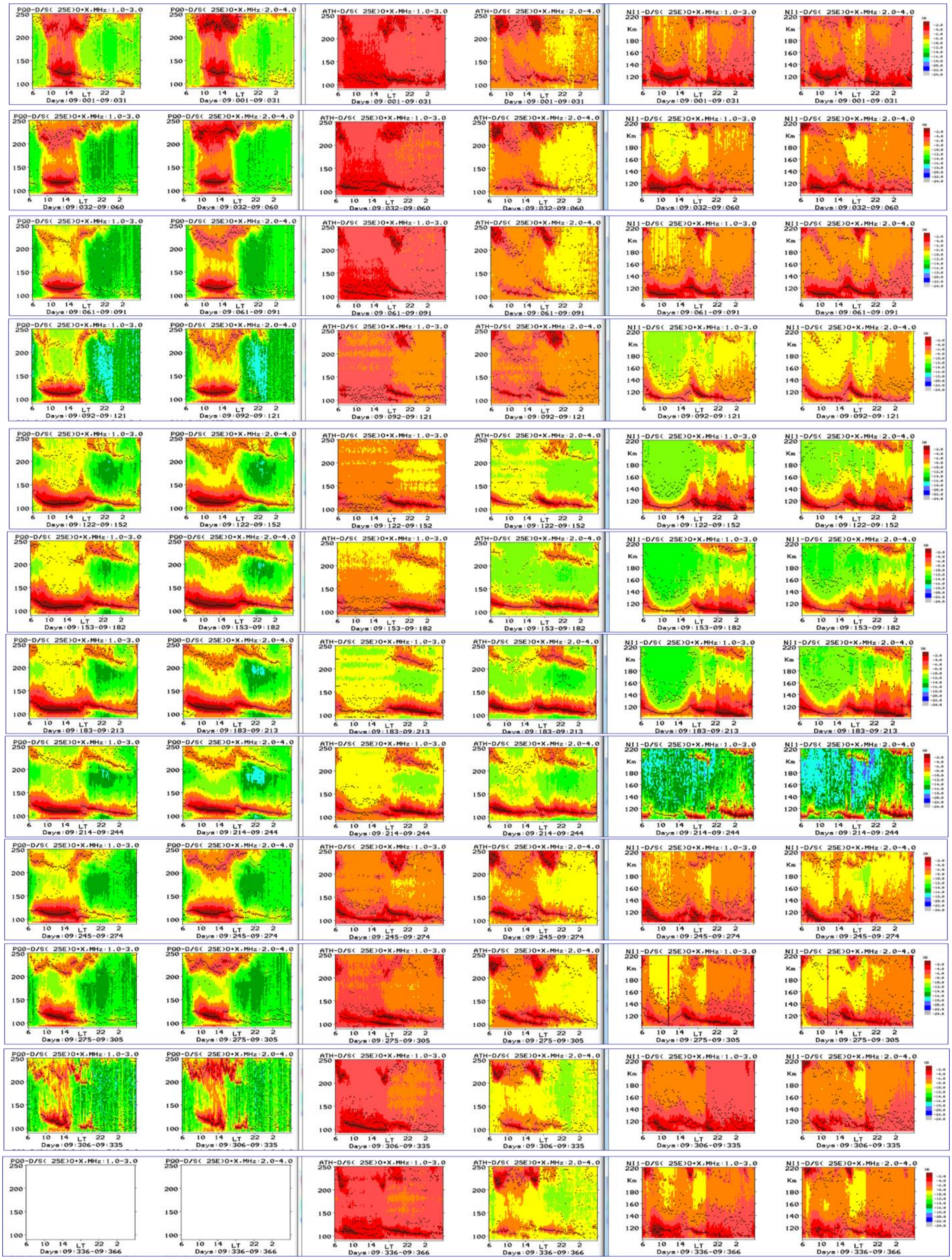

Figure 3. *Representative monthly averaged HTI plots for 2009 (from top to bottom rows: Jan to Dec 2009), computed in two overlapping frequency bands (1-3 MHz and 2-4 MHz, shown in left and right panels of each HTI plot respectively). The three columns (from left to right) present the 1-3 and 2-4 MHz HTI plots for the three ionospheric stations Pruhonice, Athens and Nicosia respectively.*

References

Haldoupis, C., Meek, C., Christakis, N., Pancheva, D.,Bourdillon, A. (2006) Ionogram height–time intensity observations of descending sporadic E layers at mid-latitude. J. Atmos. Sol. Terr. Phys. 68, 539. http://dx.doi.org/10.1016/j.jastp.2005.03.020.