**Sudan University of Science and Technology**

**College of Graduate Studies**

# THE EFFECT OF ULTRA-LOW FREQUENCY (ULF) WAVES ON THE IONOSPHERE

# أثرموجات التردد المنخفض جدا علي طبقة الأيونوسفير

*A Dissertation Submitted in Partial Fulfillment of the Requirements for a Master Degree (M. Sc.) in physics*


Prepared By

**NUSAIBA OMER ALI MOHAGER**

Supervisor

**Dr.MAGDI ELFADIL YOUSIF SULIMAN**


October, 2019

قَالَ تَعَالَىٰ:

﴿ بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ ۝١ ﴾

**صدق الله العظيم**

**الفاتحة ١**

# Dedication

I do dedicate my dissertation to all who encourage, support, help and give their all to me. I also dedicate it to every student and every person seeks for science and education wishing them all the best.

# Acknowledgement

I acknowledge, cordially efforts, guidance, patience and help of my teacher and supervisor Dr. MAGDI ELFADIL. I also acknowledge facilitation of ionospheric parameters data by the Canadian High Arctic Ionospheric Network.

# Abstract

space physics takes special and significant part of our everyday live, lots of books and papers have been published lately because of its importance and great effect on the ground. Solar wind with all what it carries from particles and waves is very important to be studied and well known by students. Ultra low frequency waves is one of what solar wind generates, these waves have a great effect on many things. This dissertation is about the interaction of both ultra low frequency waves and ionosphere with each other.

Ultra low frequency waves have been studied for long time, they are detected on the ground and they play a significant role on characteristics of the ionosphere. So the problem of this dissertation is how to observe this role and to study their effect on the ionosphere.

Part of the data of this dissertation were collected from Canadian High Arctic Ionospheric Network (CHAIN). Results show amplitudes peaks on magnetometer's data on two different days, they show two peaks on the day of Oct 11, 2009 around 8:00 am, and 15:00 pm hours; and one peak on the day of Jan 20, 2010 around 17:00 pm hour. Results also show peaks on the same days at the same times in the time series concentration of the signal from the data of GPS (S4 index), in addition they show corresponding drift velocities on ionogram data of ionosondes. In conclusion: by observations using ionospheric parameters data from ground GPS receivers data and the ionosondes data that corresponds to $D_{ST}$ index data, the effect of ULF on the ionosphere was confirmed here.

# الخلاصة

احتلت فيزياء الفضاء جزءا خاصا و مهما من حياتنا اليومية، الكثير من الكتب و الاوراق العلمية نشرت مؤخرا لاثرها المهم و العظيم على الارض. الرياح الشمسية مع كل ما تحمله من جسيمات و موجات موضوع مهم جدا للمعرفة. موجات التردد المنخفض جدا هى احد ما تنتجه الرياح الشمسية، هذه الموجات لها تاثير عظيم على عدة اشياء، من ضمنها التاثير المتبادل بين موجات التردد المنخفض جدا و الايونوسفير.

موجات التردد المنخفض جدا درست لوقت طويل، تم التحقق منها على الارض و تلعب هذه الموجات دورا مهما فى خصائص الايونوسفير، مشكلة هذا البحث هى كيفية ملاحظة هذه الموجات و دراسة اثرها على الايونوسفير. بعض من بيانات هذا البحث قد جمعت من شبكة القطب الشمالى الايونسفيرية الكندية العالية. النتائج تظهر قمم اتساع من بيانات ماغنتوميتر فى يومين مختلفين. تظهر قمتان فى يوم ١١-١٠ -٢٠٠٩ حوالى الساعة الثامنة صباحا و الساعة ١٥:٠٠ مساء ، و قمة فى يوم ٢٠-١-٢٠١٠ حوالى الساعة١٧:٠٠ مساء ..النتائج ايضا في نفس الايام و نفس الازمان و فى زمن سلسلة تركيز الاشارة من بيانات ماغنتميتر تظهر قمم، بالاضافة تظهر ازاحة سرعات مطابقة لبيانات الايونوسونات. فى الختام بالملاحظة بواسطة استخدام بيانات باراميترات الايونسفير من بيانات مستقبلات GPS الارضى و بيانات الايونسونات مع مطابقة بيانات DST تم التاكد من اثر موجات التردد المنخفض جدا على الايونسفير.

# Content

# List of figures

The Caption

# List of abbreviations

1. **ASB**: Ashibetsu station**.**
2. **CME**: coronal mass ejections
3. **DC:** Direct current
4. **DST**: disturbance Amplitude storm time
5. **FUV:** Far ultra violet radiation
6. **GIC:** Geomagnetically induced current
7. **GMDs:** geomagnetic disturbances
8. **GPS:** Global Positioning System
9. **HAL**: Hall beach station
10. **IR:** Infra red radiation
11. **NOAA:**National Oceanic and Atmospheric Administration
12. **Pc**: continuous pulsations
13. **Pi**: irregular pulsations
14. **SPE:** solar proton events
15. **THD:** Total Harmonic Distortion
16. **ULF:** ultra-low frequency
17. **UTC:** Coordinated Universal Time
18. **UV**: Ultraviolet  radiation
19. **VS:** Visible light

# List of tables

# CHAPTER ONE

# INTRODUCTION

## 1.1. Introduction

Earth's geospace plasmas are composed from the Earth-Sun coupling system, many regions result from this coupling, the very close region to the surface of earth resulting from a contribution of this coupling is the ionosphere. The ionosphere is a layer that contains a high concentration of ions and free electrons and is able to reflect radio waves; it is the ionized part of the earth the atmosphere above.

plasma is an ionized gas consisting of positive ions and free electrons, their properties resulting in more or less overall electric charge typically at low pressures (as in the upper atmosphere and in fluorescent lamps) or at very high temperature (as in the stars and nuclear fusion reactors).

The earth's magnetosphere is the very large system resulting from this coupling system and that bounds the plasmas and many of waves that construct within these plasmas, e.g. Ultra Low Frequency (ULF) pulsations, as it's going to be described very well on the next chapter, these pulsations are known as geomagnetic pulsations, can be transmitted through different regions in the magnetosphere. Therefore, the role of screening of the ionosphere to ULF waves in addition to their effect on the ionosphere is of interest.

## 1.2. Research Problem

ULF waves mechanisms related to the solar wind infer their propagation through magnetosphere- ionosphere down to the earth. Surely, ULF have been detected on the ground. Therefore, ULF may play some role on characteristics of the ionosphere, and raise a question on how to qualify and/or quantify their role. Ground observations could be used to reveal the role of these waves on the ionosphere.

## 1.3 Objectives of the Study

As long as the ionosphere plays a significant role in properties of ULF to be observed in the ground, also ULF play a role in some characteristics of the ionosphere. Hence, the aim of the current work is to study their effect on the ionosphere, and therefore, the following objectives were set:

1/ Calculate the discrete fast Fourier transforms (D- FFT) of ground observation of geomagnetic data and plot dynamic magnetograms to obtain geomagnetic pulsations.

2/ To delineate the GPS signal fluctuations due to fluctuations of the total electrons contents in the ionosphere during the time of occurrence of ground latitudinal global mode ULF waves.

## 1.4 Research Methodology

Data from ground magnetometers, GPS and ionosondes were collected showing the spectrum of ULF in the Pc five ranges and all that via MATLAB code, these data were collected for two days; 24 hours and the preliminary shocks were observed on the DST data. Stacking of all plots shall show the expected effect of ULF on the ionosphere.

## 1.5 Outline of the Dissertation

Chapter one is dedicated to the introduction where the whole dissertation was introduced. While chapter two contains the theoretical background and literature review of the dissertation describing the bursts of the sun and structure of the magnetosphere of the earth and tells the role of both ULF waves and ionosphere on each other. Chapter three shows the data that collected and highlights the methodology that followed in collecting these data. The last chapter is the results and discussion.

# CHAPTER TWO

## THEORETICAL BACKGROUND

### 2.1 Sun's Bursts

"Solar radio noise and bursts were discovered more than six decades ago by South-worth (1945) and by Hey (1946) during the early research on radar at the time of the second world war". (Daglis 2007).

Sun emits photons from very short wavelengths (~0.1nm) to very long wavelengths (~1km). See figure 2.1.

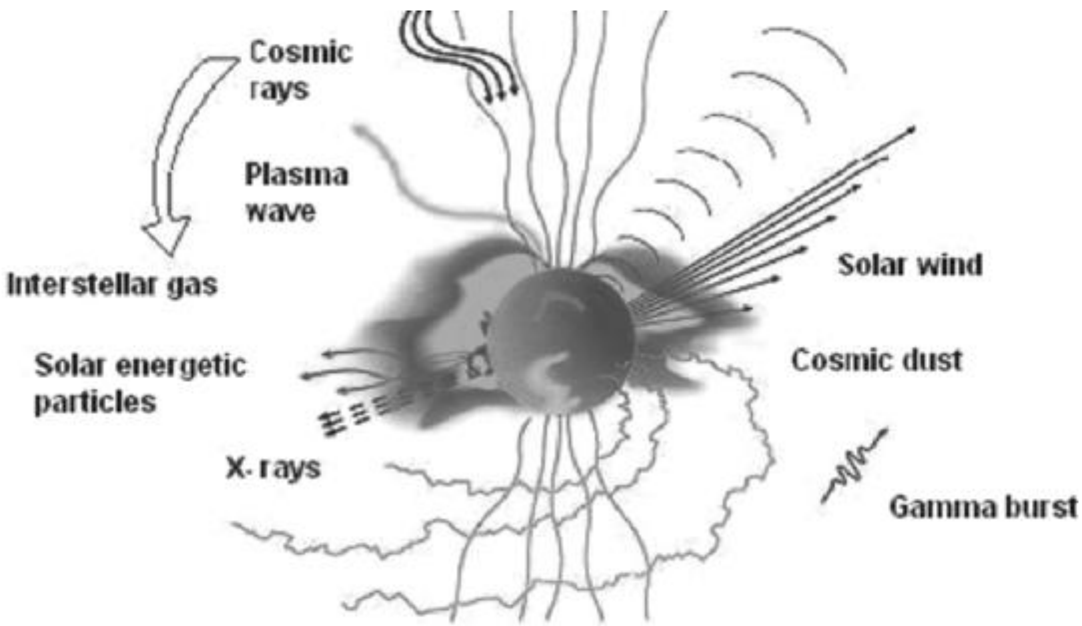


Fig. 2.1 A schematic view of the various ingredients emitted by the Sun filling the interplanetary space. (Rozelot, Solar and heliospheric origins of space weather phenomena 2006)

Sun also always emits particles, these particles travel between the sun and the earth with different speeds ranging from 400 to 500 km/s when coming from sun's equatorial regions and 800 km/s elsewhere within solar disk; (Hanslmeier 2007) therefore propagating of these particles as waves is the solar wind which caused by the different speeds of these particles. Solar wind reaches earth after two days and this allows us to predict earth geospace weather. These waves are bursts of the sun and well known, respectively, gamma rays which have the smallest wavelength and highest energy to the radio waves which have the largest wavelength and lowest energy with having X- rays, UV, VS, IR and micro waves in between . When intensities of ultra violet and X solar fluxes change they affect ionosphere concentration which affects telecommunication system, they also affect on layers of earth's atmosphere and space weather. See figure 2.1.

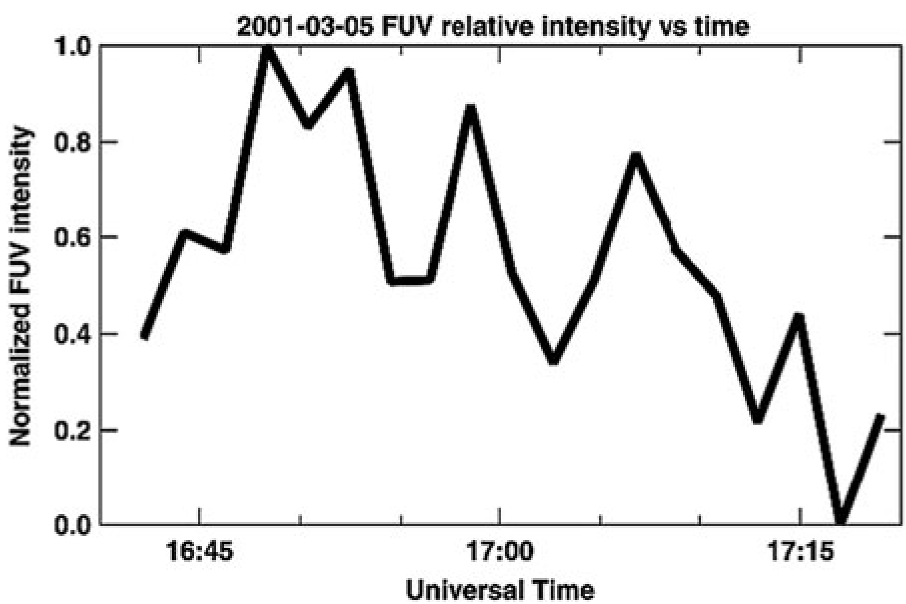


Fig.2.2. Intensity of the far ultra-violet dayside auroral emissions measured by the IMAGE spacecraft during an event which suggests fluctuations in the reconnection rate at the magnetopause, with a period of a few minutes.( Rozelot 2006).

Other materialistic bursts are what it called coronal mass ejections CME, they are very much bigger than the small particles that the sun emits and travel in very higher speed than them (~1500 km/s). CMEs contain large quantity of helium, electrons and ionized particles.

Sun also bursts microwaves and at metric wavelength thermally when plasma electrons and ions interact with each other in the presence of magnetic field.

## 2.2 Earth's Magnetosphere Structure

A magnetosphere is that area of space around a planet which controlled by its magnetic field. The earth's magnetosphere is the cavity formed by earth's magnetic field. It contains of several regions which are different in terms of energies and densities of the plasmas that occupy them as it is shown in figure 2.3.

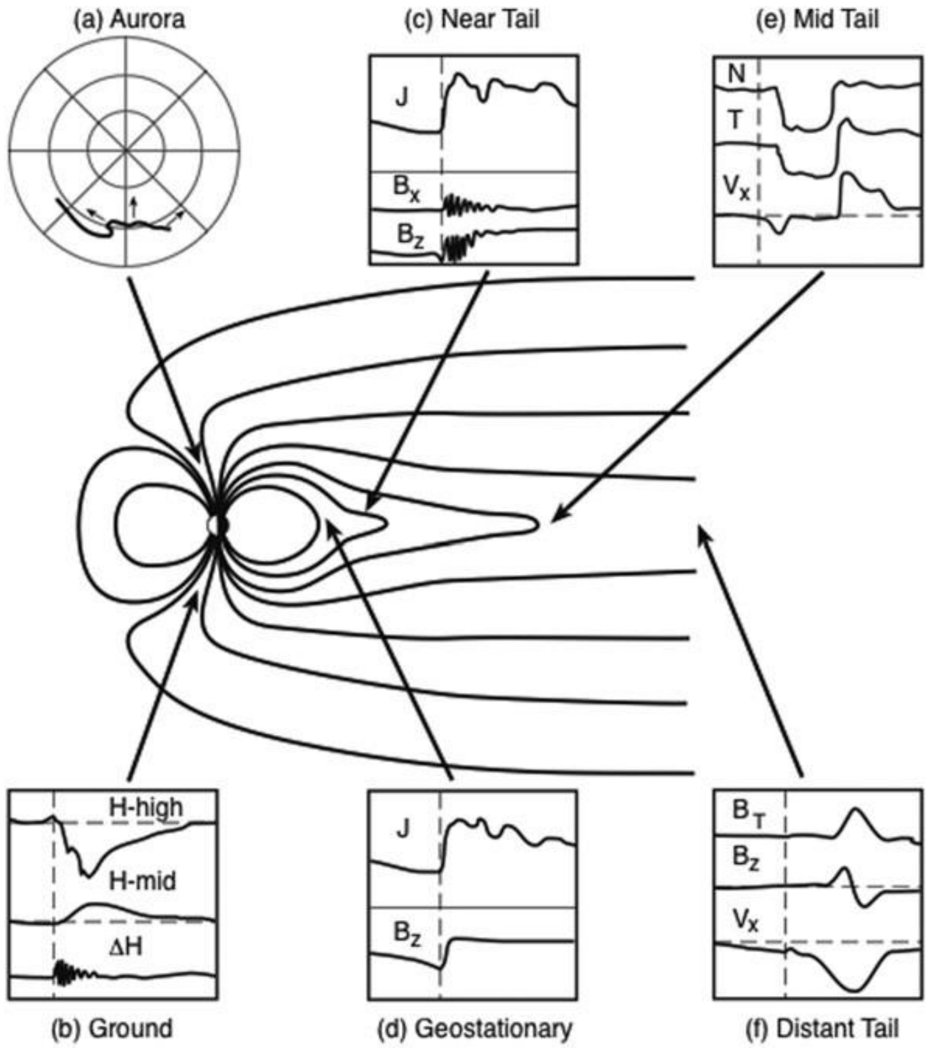


Fig.2.3. A diagram to illustrate several key substorm phenomena. The substorm onset time is indicated in each panel by the vertical dashed line. The micropulsation is indicated by the _H trace in (b). The increased fluxes of energetic particles at the geosynchronous altitude and in the near-tail region are indicated by the J traces in (c) and (d). Plasma sheet thinning in the mid tail is often seen by drops in number density (N) and temperature (T). Plasma flow ($V_x$) may occasionally be tail ward before dropout and become earthward at plasma sheet recovery. Signatures attributed to plasmoids in (f) are a transient increase in the total magnetic field magnitude (BT), a north-then-south swing of the BZ component, and tail ward plasma flow.

The magnetosphere is a region of earth's atmosphere in which the number of ions and electrons are strong enough to affect the propagation of radio waves.

Several hundred kilometers above earth surface and extending tens of thousands of kilometers into space is where the magnetosphere set. The intensity of the earth's magnetosphere is generally measured in nano-teslas and sometimes it is measured in gauss which equals 100,000nt and it ranges between approximately 25,000 and 65,000nt (0.25 and 0.65G). Magnetosphere works as a shield to protect us from charged particles of the solar wind and cosmic rays (high-energy charged particles from outside the solar system) because they cannot easily cross the lines of magnetic field so they deflect around the earth, also it keeps the pressure that solar wind exerted a way of earth's atmosphere because it erodes the atmosphere; that's why it is very important.

Earth's inner magnetosphere includes plasmasphere; which is high number density of particles, ring current; which is high energy density with low electrons and ions number density, radiation belts; which consist of energetic particles of electrons and ions of more than a few hundred kev; and warm plasma. Radiation belts are formed of inner and outer belts of the particles with regions between them, but protons and ions belts consist of a single belt.

Solar wind greatly energies magnetosphere, as a result of that magnetosphere becomes an environment that affects space systems, therefore this affect extends to lower atmosphere and surface of earth, also solar wind; specifically it's applied pressure on magnetosphere controls the size of magnetosphere and the energy flow into it.

## 2.3 ULF Waves Near and With In Earth's Magnetosphere

"The historical observations of ULF pulsations have started in 1861 when Balfour Stewart reported observations of a great magnetic disturbance using self-recording magnetographs data located near London. In the followed century observers came up with a picture of small disturbances in the geomagnetic field with periods ranging from few seconds to tens of minutes, these disturbances had an amplitude less than 0.2% of the value of the geomagnetic field at the surface of the earth" . (.Walker 2005)

Solar wind is the source of ultra low frequency (ULF) waves; there are also other sources of ULF waves like ion foreshock, magnetopause also is source of several types of ULF waves. They are created from magnetized plasma in magnetosphere, when the collision frequency is low the charged particles gyrate around the magnetic field, when any force moves the magnetic field it also moves the charged particles, this movement creates the waves. They reach to the ground as irregular and continuous pulsations. The different types of ULF waves that seen on the ground depend on the velocity of the solar wind, while different frequencies of them depend on the region of origination, therefore to know the type of the wave that observed on the ground one should know the region that magnetic field line which carries the wave passes through.

Information of properties that depend on earth conductivity can be gotten from noticing ULF waves at the ground, this information tell the way of generating of these waves, also show regions which they propagate through.

Classification of these pulsations was in terms of specific characteristics recognized in the data, with little connection to physical processes, the International association of geomagnetism and Aeronomy (IAGA) created a four –person working group to recommend a new system of classification. The continuous pulsations were denoted by a prefix "pc" and the impulsive ones by a prefix "pi". The classifications are shown in table 2-1.

Table 2-1 classifications of pulsations (Mcpherron 2004)

| Label | Period rang (s) | Type of pulsation |
|---|---|---|
| Pc1 | 0.2-5 | Continuous pulsations |
| Pc2 | 5-10 | |
| Pc3 | 10-45 | |
| Pc4 | 45-150 | |
| Pc5 | 150-600 | |
| Pi1 | 1-40 | Irregular pulsations |
| Pi2 | 40-150 | |

Long periodic ULF waves that generated by solar wind and observed by satellites have a big effect on higher-energy particles in the magnetosphere, their effect reveals in the matter of acceleration of these particles. Long periodic ULF mechanism of generation determines two types of these pulsations; direct penetration of the solar wind variation into the magnetosphere and oscillations into the magnetosphere excited by solar wind disturbances.

## 2.4 The Ionosphere

Ionosphere is a layer within the earth's atmosphere that affects propagation, transmission and reflection of radio waves; it composes of free electrons and positive ions that result from UV interaction with upper atmosphere. The ionosphere begins at a height of about 50 km above the earth's surface.

Ionosphere has significant effects on communications, satellite positioning and navigation system operation, also space weather physics scientifically observed by ionosphere’s observations. It composed of ionized electrons. The two main sources which create ionization of ionosphere are the solar ultra violet radiation and energetic particles in magnetosphere.

Ionosphere is divided into many regions according to the degree of ionization, the region below a height of about 90km is weakly ionized and it called D-region, it is the lowest region of the ionosphere, in this region the electrons almost disappear during the night because they recombine with oxygen ions to form electrically neutral oxygen molecules, so that radio waves reflect from the other regions at this time, but during the day some reflect can be obtained from this region.  The region above 90km is highly but partially ionized and it forms the upper ionosphere, it consists of two layers: E-region which has ionization peak at about 110km, and F- region around 300km altitude. F region has the greatest concentration of free electrons. During the day two layers with in F region can be distinguished; small layer known as F1 and above it a more highly ionized dominant layer called F2.

The conducting ionosphere forms the inner boundary of the magnetospheric cavity, therefore the formation and properties of standing field line oscillations and properties of cavity modes are controlled by it. In addition all ULF waves that are observed on the ground propagate through the ionosphere and are affected by its properties and also they affect on it.

## 2.5 Role of the Ionosphere on ULF Pulsations

Across a range of latitudes the ionosphere plays role in determining the occurrence and properties of ULF pulsations on the ground .The affect of ionosphere and ionospheric conductivity is clear and can be investigated by MHD formulation, it's also clear from spacecraft and simultaneously on the ground below. It confirmed that the most propagation of these waves through ionosphere is in the compressional mode and appears in the D component on the ground with 90º rotation in polarization of the signal. Ionosphere under mid/low latitude changes the frequency of ULF (FLR) waves by less than 5% and produces strongly localized FLRs and enhances amplitude, the strong change in amplitude and D component on the ground although the phase of H component un change happens at equatorial latitudes by non uniform ionospheric conductivity; because conductivity of ionosphere at equatorial is changeable and it increases by Cowling effect.

## 2.6 Role of ULF on the Ionosphere

Doppler radars, ground magnetometers and Doppler sounders measurements in particular reveal the significant existence of ULF waves, also Mid-latitude radars detect the ionospheric signatures of sub-auroral pulsations associated with substorm expansion.

The incident mix wave changes from fast mode at resonance to shear Alfven mode at resonance. The oscillations of ULF waves in the ionosphere are lead by incidence and propagation of Alfven waves.

It is evident by solar wind electron number density that the ionospheric oscillations are caused by propagation of ULF waves earthward from the solar wind.

ULF waves make perturbation in ionosphere densities can be noticed by high frequency sounders and radars, and they change amplitude and phase of ionospheric oscillations, also cause perturbation in total electron content (TEC) of the ionosphere, this perturbation effects on GPS and radio astronomy operations. In low latitudes ULF resonance structure is clear via ionospheric sounders rather than ground magnetometer signals.

Eventually, ULF waves may arise from solar wind pressure perturbations or substorms, therefore their field lines can be recorded at high and low latitudes in ionosphere.

Ionospheric sounders provide information not available from magnetometers on ULF waves at the lower boundary of the magnetosphere-ionosphere system because ionosphere plays a role of screen to these pulsations and magnetometers probe these waves after they pass through ionosphere.

# CHAPTER THREE

## DATA COLLECTION AND METHODOLOGY

### 3.1 Data Collection

To emphasize the effect expected to be done by ULF on the ionosphere, two types of data were collected. The first type of data is ground magnetic data, collected from a magnetometer on the Ashibetsu (ASB) station, geographic latitude and longitude: (43.46, 142.17), geomagnetic latitude and longitude: (36.43, 213.39), respectively, and L-value: 1.54 (K. and Group 2006); and the second type of data is data of a specific ionospheric parameters, one is the scintillation index (S4) collected from the Global Positioning System (GPS) receivers of the Canadian High Arctic Ionospheric Network (CHAIN) station located at Hall Beach (HAL), and the others are the 4.000 MHz group range height profile and the azimuth, horizontal, and vertical drift velocity on the ionosphere from the ionosonde in the same station: HAL, (Jayachandran, et al. 2009).

### 3.2 Methodology

Magnetometers of ground data were obtained where first the raw data and the corresponding differential data were shown. At last the dynamic spectrum of ULF in the pc five range was shown and that via specific MATLAB code. This dynamic spectrum expected to show signature of the magnetohydrodynamic (MHD) waves on earth's geospace. The S4 index time series data from the GSP satellite were plotted for 24 hours on two days: Oct, 11, 2009 and JAN, 20, 2010. Since on these days preliminary shocks were observed on the DST data (Nose, et al. 2015), while the drift velocity data were obtained in corresponding with 4.000 MHz group range high profile of the ionosonde signal for 24 hours for the above mention two days. Finally; stacking of all these plots shall show features of the expected effect of the ULF on the ionosphere.

# CHAPTER FOUR

## RESULTS, DISCUSSION AND CONCLUSION

### 4.1 Results

Some results of ionosondes, GPS and magnetometers were collected from space and ground stations showing the effect when the magnetohydrodynamic wave passes through ionosphere**.** On October 11, 2009 the magnetometer showed a peak at 15:00pm, and that means increase of amplitude, also the strength of signal was high which means the density of the electrons was high also. When see fig 3.3 and fig3.4 which they are data of ionosondes and GPS also we find peaks at the same time**.** On January 20,2010 the ground magnetometer showed a peak at 17:00pm, this peak denotes the increase of the amplitude and increase of intensity of signal. Also the figures of GPS data and ionosonede data of the same day showed peaks at the same time.

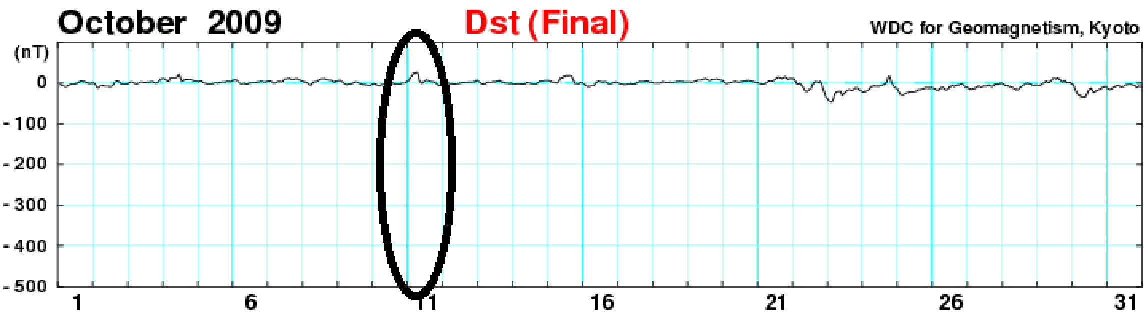


Fig3.1 DST shows preliminary shock on OCT 11. 2009**.**

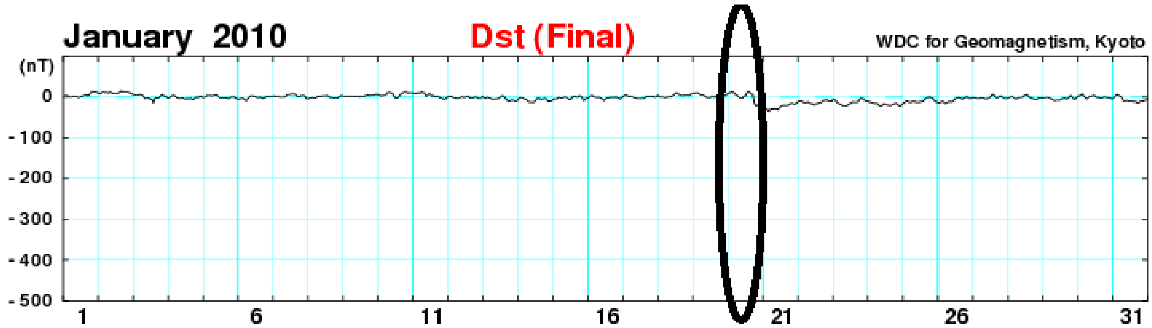


Fig3.2 DST shows preliminary shock on Jan20.2010

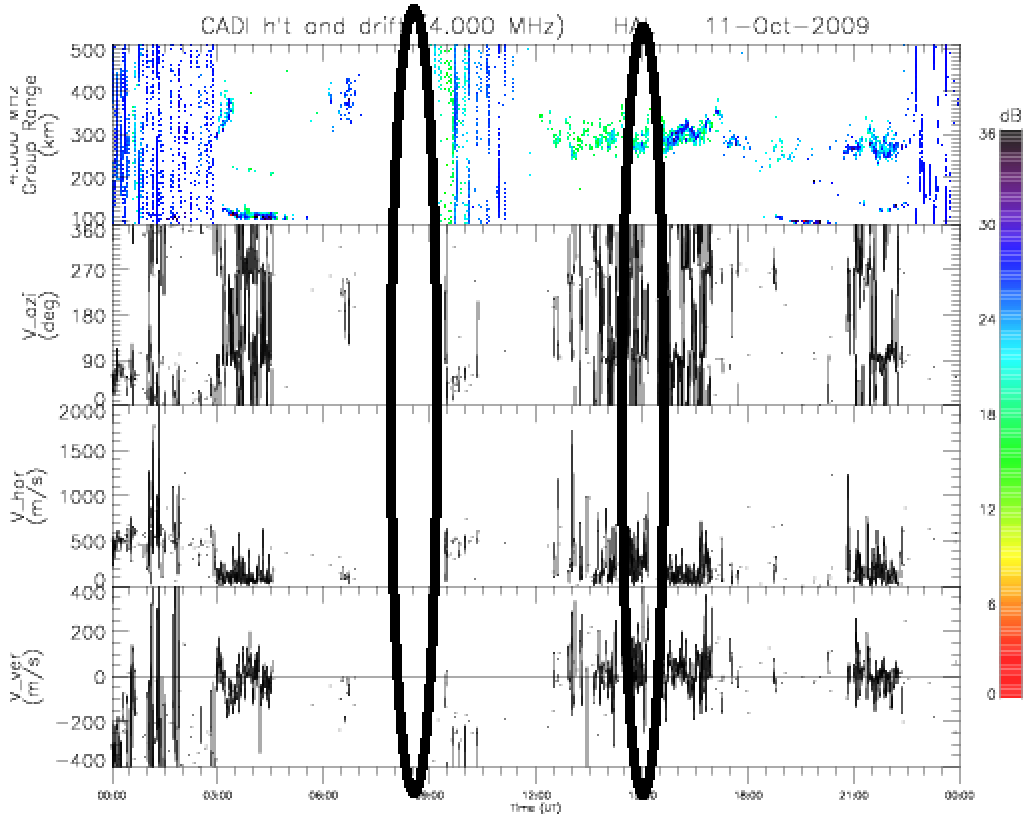


Fig3.3 Height of 4.000 MHz group range profile and the drift velocity of ionosphere from ionosonde data of Hall Beach (HAL) station on Oct, 11, 2009.

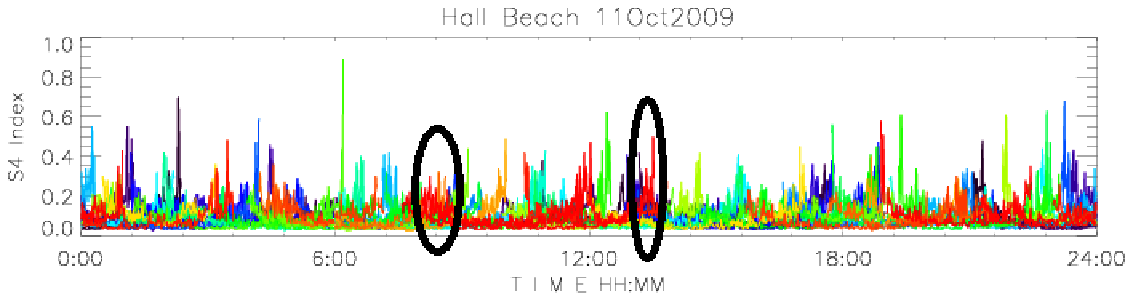


Fig 3.4. S4 index of the ionosphere from GPS data of Hall Bach station on Oct, 11, 2009.

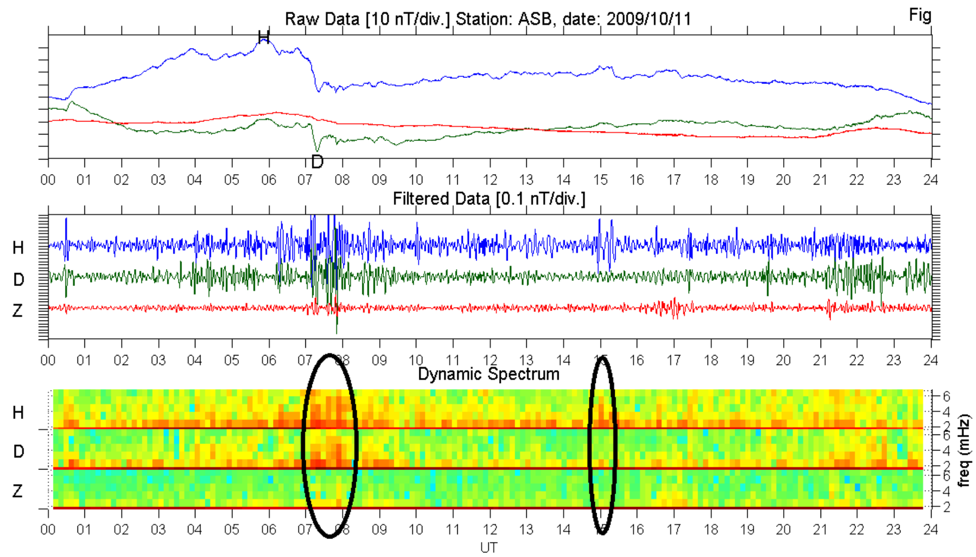


Fig 3.5. Ground magnetometer's data from Ashibetsu (ASB) station showing signature of a source of a toroidal MHD waves in the magnetosphere on Oct, 11, 2009.

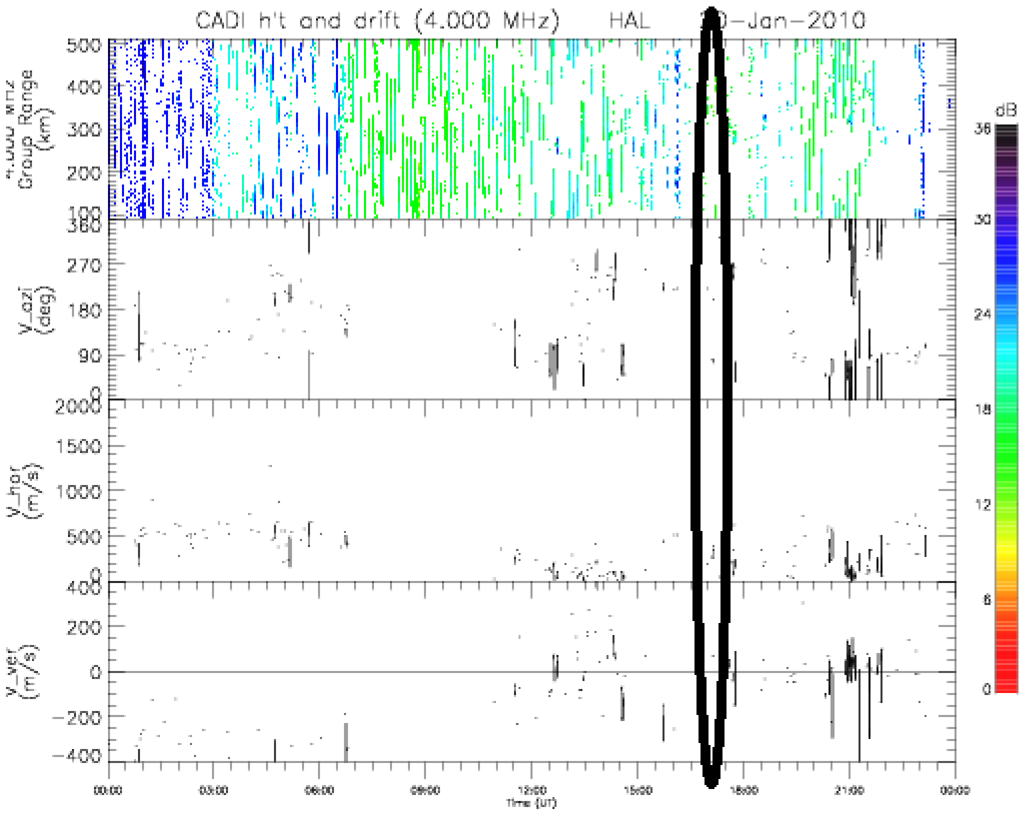


Fig 3.6. Height of 4.000 MHz group range profile and the drift velocity of ionosphere from ionosonde data of Hall Beach (HAL) station on Jan, 20, 2010.

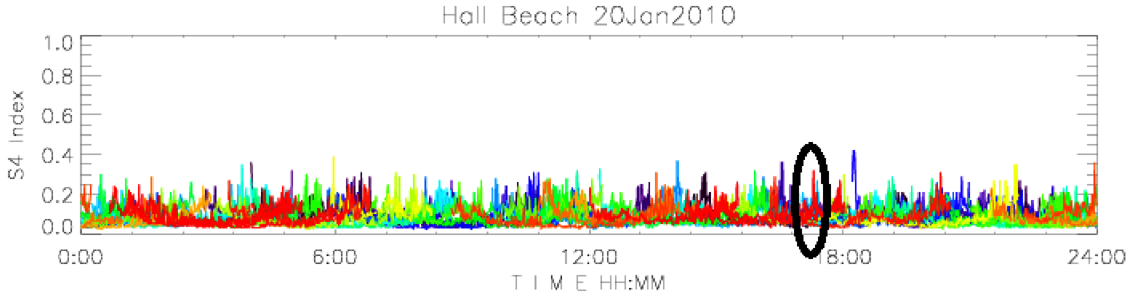


Fig 3.7. S4 index of the ionosphere from GPS data of Hall Beach station on Jan20,2010.

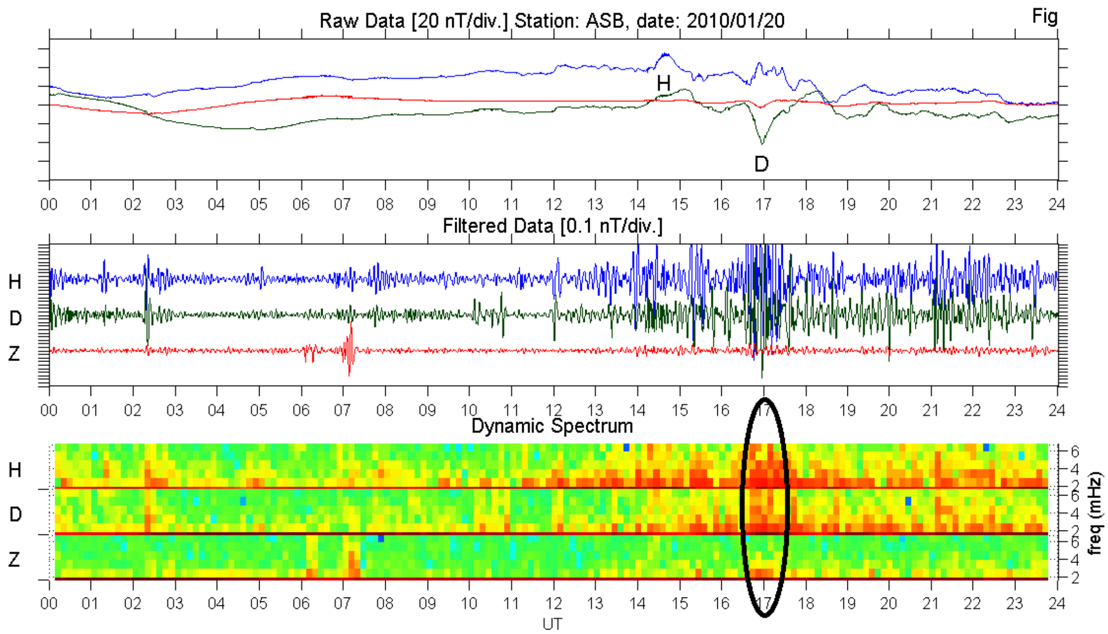


Fig 3.8. Ground magnetometer's data from Ashibetsu (ASB) station showing signature of a source of a toroidal MHD wave in the magnetosphere on Jan,20,1010.

## 4.2 Discussion and Conclusion

Figuers3.5and 3.8 show signature of magnetospheric ULF waves that propagate all the way from magnetosphere through the ionosphere to the ground. The ionospheric data from S4 GPS satellite show corresponding high fluctuations in the density of the electrons in the ionosphere which probably caused by the associated electric field of the magnetospheric ULF waves. The ionogram figures and the corresponding drift velocity of the ionosphere constituents also confirmed the effect of ULF waves on the ionosphere.

In conclusion, ionospheric parameters data from ground GPS receivers data and ionosondes data showed that ULF waves play a significant role on ionosphere's characteristics; also in corresponds with the DST data, the effect of ULF on the ionosphere was confirmed

# Bibliography

.Walker, A D M. *Magneto hydrodynamic waves in geospace.* Bristol: institue of physics publishing, 2005.

Daglis, Volker Bothmer and Ioannis A. *space weather physics nd effet.* Chichester: Praxis publishing LTd, 2007.

Hanslmeier, Arnold. *The sun and space weather.* Austria: springer, 2007.

Jayachandran, P. T., et al. "The Canadian high arctic ionospheric network (CHAIN)." *Radio Science* 44 (2009).

K., Yumoto, and the MAGDAS Group. "MAGDAS project and its application for space weather." *International living with stars (ILWS) workshop.* GOA: International living with stars (ILWS) workshop, 2006. 19-24.

Mcpherron, Robert . L. *Magnetic pulsations : their sources and relation to solar wind and geomagnetic activity.* Paper, Los Angeles: institute of geophysics and planetery physics, 2004.

Nose, M., T. Iyemori, M. Sugiura, and T. Kamei. *World Data Center for Geomagnetism, Kyoto.* 2015. http://wdc.kugi.kyoto-u.ac.jp/index.html (accessed 10 20, 2019).

Rozelot, Jean- Pierre. *Solar and heliospheric origins of epace weather phenomena.* Berlin: springer, 2006.

—. *Solar and heliospheric origins of space weather phenomena.* Grasse, 2006.

# Appendix

MATLAB code to obtain ground data magnetograms and dynamic spectrum to highlight the expected enhancement on ULF amplitudes on the ground:

```
function   chk_dataquality_modified_Last_Last_MAGDAS(sta,year,mon,day)
%
% Original program for J-format by Y-M.Tanaka@NIPR
% This file is modified for MAGDAS-storage by S.Abe
% This file is modified for MAGDAS-data to extract Pc 5 pulsation by
M.Yousif
%
% ========= Open file =======================
% rewrite the following
%for i=datenum([startyr startmon startday]):datenum([endyr endmon endday
])
    %[year mon day]=datevec(startyr,startmon,startday);
    Save_Path0='C:\Users\ICSWSE\Desktop\Quick Look Pc5 Plots\';
    %Save_Path02='C:\Users\Magdi\Desktop\Storm_Data\';
    FileName=sprintf('%03s_SEC_%04d%02d%02d0000.MGD',sta,year,mon,day);

filedir=sprintf('C:\\Users\\ICSWSE\\Desktop\\Desktop_October_2019\\Mag_Da
ta\\SET_1_A_NH\\%s\\Sec\\%04d\\',sta,year);


    filepath=[filedir,FileName];
 %%Checking if data file exist: if exists, calculates power,otherwise,
represented as NaN
    %Filecheck=exist(filepath,'file');
    %if Filecheck==2
[JJJ,Header,STATDATA,CORRECT_INF] = read_1S(filepath,1);
%[UT1s,JJJ] = ReadIAGA1s('C:\Users\ICSWSE\Documents\MAG
data_Mohammed\Set1A_NH\EWA\EWA_MAGDAS_IAGA1sec_MEY_2009\EWA20090113psec.S
EC');
SP=1;
%n=1;
%while n<=length(JJJ)
    %if JJJ(n)>1E9
```

```
        %JJJ(n)=NaN;
    %else
        %JJJ(n)=JJJ(n);
    %end
    %n=n+1;
%end
JJJ=[(JJJ(:,1)-JJJ(1,1)),...
     (JJJ(:,2)-JJJ(1,2))-10,...
     (JJJ(:,3)-JJJ(1,3))-20];
 JJJ(JJJ>=10000)=NaN;
 JJJ(JJJ<=-10000)=NaN;
 % JJJ(:,1)=rm_noise(JJJ(:,1),5);
% JJJ(:,2)=rm_noise(JJJ(:,2),5);
% JJJ(:,3)=rm_noise(JJJ(:,3),5);
%DJ=[zeros(1,3);diff(JJJ)];
BJ=bandpass(JJJ,SP,150,600);
Hour=[0:SP:(86400-SP)]/3600;

% =========== Make Figure 1 ===================================
%h1Figure=figure('PaperUnits','normalized',...
            %'PaperType','a4letter',  ...
            %'PaperOrientation','landscape', ...
            %'PaperPosition',[0 0 1 1], ...
            %'Units','normalized', ...
            %'Position',[0.05 0.03 0.9*0.7 0.9]);

% =========== Plot Raw data ===================================
h1=axes('position',[0.15,0.73,0.75,0.22],'fontsize',12);

XTickVector=linspace(0,24,25);
for i=1:25,
    XTickTexts(i,:)=sprintf('%2.2d',XTickVector(i));
end

%--- For Color Plot ---%
plot(Hour,JJJ);
```

```
Nt=0;
YNo = 100;
while YNo > 15
    Nt = Nt + 10;
    YLimData=get(h1,'YLim');
    YNo=ceil((YLimData(2)-YLimData(1))/Nt);
    YTickVector=linspace(YLimData(1),YLimData(1)+Nt*(YNo-1),YNo);
end

set(h1,'XLim',[0 24],...
            'XTick',XTickVector,...
            'XTickLabel',XTickTexts,...
            'YTick',YTickVector,...
            'YTickLabel',[],...
            'tickdir','out');

XLimData=get(h1,'XLim');
text_comp(JJJ,XLimData,YLimData,SP);

%xlabel('UT')
title(sprintf('Raw Data [%g nT/div.] Station: %03s, date:
%04d/%02d/%02d',Nt,sta,year,mon,day),'fontsize',15);
%title(sprintf('%03s%04d%02d%02d',sta,year,mon,day));
%text(0.5,1.2,sprintf('%4d/%2.2d/%2.2d  %s',...
%DD(1),DD(2),DD(3),ST),'Units','normalized','fontsize',18,'horizontalalig
nment','center')
text(1,1.18,'Fig','Units','normalized','fontsize',15,'horizontalalignment
','right')

% =========== Plot Filtered data ==================================
h2=axes('position',[0.15,0.41,0.75,0.22],'fontsize',12);

XTickVector=linspace(0,24,25);
for i=1:25,
    XTickTexts(i,:)=sprintf('%2.2d',XTickVector(i));
```

```
end

offset=1;
Nt=0.1;

plot(Hour,BJ(:,1), Hour,BJ(:,2)-offset,Hour,BJ(:,3)-offset*2);
Ymin=-offset*3;Ymax=offset;

set(h2,'XLim',[0 24],...
             'YLim',[Ymin,Ymax],...
             'XTick',XTickVector,...
             'XTickLabel',XTickTexts,...
             'YTick',[Ymin:Nt:Ymax],...
             'YTickLabel',[],...
             'tickdir','out');

% xlabel('UT')
text(-0.04,0.75,'H','Units','normalized','fontsize',15)
text(-0.04,0.5,'D','Units','normalized','fontsize',15)
text(-0.04,0.25,'Z','Units','normalized','fontsize',15)
title(sprintf('Filtered Data [%g nT/div.]',Nt),'fontsize',15)



% =========== Plot Dynamic Spectra ==================================
XTickVector=linspace(0,24,25);
str_comp=['H';'D';'Z'];

for i=1:25,
    XTickTexts(i,:)=sprintf('%2.2d',XTickVector(i));
end

for i=1:3
    h3=axes('position',[0.15,0.32-i*0.071,0.75,0.07],'fontsize',12);

    if SP==1,
```

```
        [S,F,TS] = spectrogram(JJJ(:,i),hann(1024),[],[],1/SP);
    else
        [S,F,TS] = spectrogram(JJJ(:,i),hann(512),[],[],1/SP);
    end
    surf(TS/3600,F*1000,10*log10(abs(S.*S)));
    axis tight;
    view(0,90);
    shading flat
    % colormap(flipud(gray))

    set(h3,'xlim',[0 24],...
           'ylim',[1.67 6.67],...
           'xtick',0:24,...
           'xticklabel',[],...
           'tickdir','out',...
           'yaxislocation','right')
    text(-0.04,0.5,str_comp(i),'Units','normalized','fontsize',15)

    if  i==1,
        title(sprintf('Dynamic Spectrum'),'fontsize',15)
    end
    if  i==2,
        ylabel('freq (mHz)','fontsize',13)
    end
end

set(h3,'Xticklabel',XTickTexts)
xlabel('UT')

Current_Path = pwd;
if exist(sprintf('%s%s/',Save_Path0,sta))~=7
mkdir(sprintf('%s%s/',Save_Path0,sta))
end
Save_Path = sprintf('%s%s/',Save_Path0,sta);
cd(Save_Path)
Save_dir = sprintf('QuickLook_Plots_%s',sta);
```

```
if exist(Save_dir) ~= 7
cd(Save_dir)
else
mkdir(Save_dir)
cd(Save_dir)
end;
sprintf('%s_QuickLook%04d%02d%02d',sta,year,mon,day)
print(sprintf('%s_QuickLook%04d%02d%02d',sta,year,mon,day),'-dpng')
cd(Current_Path)

function   text_comp(JJJ,XLimData,YLimData,SP)
%
% Write H, D, Z text in the Figure
%
JJJ_tmp=JJJ;
Jindex=[1,2,3];
Textcmp_mat=['H';'D';'Z'];

[maxrow,maxrow_index] = max(JJJ_tmp);
[maxcmp,maxcmp_index] = max(maxrow);

if  maxcmp_index==1,
    Textcmp=Textcmp_mat(1);
elseif  maxcmp_index==2,
    Textcmp=Textcmp_mat(2);
else
    Textcmp=Textcmp_mat(3);
end

Xpos=maxrow_index(maxcmp_index)*SP/3600/(XLimData(2)-XLimData(1));
Ypos=(maxcmp-YLimData(1))/(YLimData(2)-YLimData(1))+0.03;
text(Xpos,Ypos,Textcmp,'Units','normalized','fontsize',16,...
'horizontalalignment','center')

Jindex(maxcmp_index)=[];
Textcmp_mat(maxcmp_index)=[];
```

```
JJJ_tmp=JJJ_tmp(:,Jindex);

[minrow,minrow_index] = min(JJJ_tmp);
[mincmp,mincmp_index] = min(minrow);

if  mincmp_index==1,
    Textcmp=Textcmp_mat(1);
else
    Textcmp=Textcmp_mat(2);
end

Xpos=minrow_index(mincmp_index)*SP/3600/(XLimData(2)-XLimData(1));
Ypos=(mincmp-YLimData(1))/(YLimData(2)-YLimData(1))-0.06;
text(Xpos,Ypos,Textcmp,'Units','normalized','fontsize',16,...
'horizontalalignment','center')

%--- End of File ---%
```