# FIFTY YEARS OF HF DOPPLER OBSERVATIONS

*T. Ogawa* and T. Ichinose*

*HFD Laboratory, Nagareda, Kamitakano, Kyoto 606-0037, Japan*
*Email:* PXI03720@nifty.ne.jp

## *ABSTRACT*

*High frequency Doppler observations of the ionosphere began in August of 1957 in Kyoto. The number of the observation points worldwide were about 40 in 1980 and are about 20 at present. By this method the movement of the ionosphere reflection height and electron density below the height can be observed. Such variations are occurred by a wide variety of sources.*

**Keywords:** CODATA,, Ionosphere, Electron Density, Time Variation, Magnetic Storm, Earthquake

## 1 Solar Phnomena

Frequency variations in the propagation of high frequency (HF) signals were observed, using the standard frequency transmission. It was found that during the six to ten-hour periods centered at noon, the E layer reflection of 5 MHz was most suitable for using the standard frequency. Sunrise and sunset effects were also observed. (Ogawa, 1958)
Experimental effects associated with solar flares were observed. The frequency dependence of the frequency variations provides information about the height location of the associated ionospheric effects. (Daves, Watts, & Zacharisen, 1962)
Sudden frequency deviations have been used to determine the effective recombination in the E region. In some cases the recovery stage of the solar flare disturbance could best be explained in terms of two different recombination coefficients. (Ogawa, 1969)
High-energy solar protons that affects on the ionosphere at low magnetic latitudes have been detected. Although most solar protons transfer to the poleward, a few parts of them could arrive in the lower ionosphere of the lower latitudes. (Ichinose, Ohta, & Ogawa, 1995)
Periodic variations observed from the Doppler data of F layer reflection during a solar eclipse day and control days were analyzed by using a numerical Fourier transform. The internal gravity waves seem to affect the electron density in the F layer. (Ichinose, & Ogawa, 1976)

## 2 Geomagnetic Disturbances

Frequency fluctuations are often observed during the geomagnetic sudden commencements (SC). (Chan, Kanellakos, & Villard, 1962)
During a SC, the main trace shifts slowly and an additional, and somewhat more diffuse, trace appears. (Davies, Watts, & Zacharisen, 1962)
During a SC, the phase relation between the derivative of the geomagnetic horizontal component and the Doppler shift is in phase, and on the fluctuation, the phase relation is in oppsite about the Doppler shift and geomagnetic variations. (Ichinose & Ogawa, 1974)
Certain classes of magnetic pulsation events were found to be directly associated with F-region motions. Hydromagnetic waves and neutral-gas waves modulating ionosphere electrojets are possible mechanisms.(Boyd & Duffus, 1969)
In the formula, the effect of electron decay due to attachment and/or recombination processes is taken into account for long-lasting variations in the electric field. This formula can provide time variations of the horizontal field vector even from data observed at only one station. The formula has been applied to an isolated substorm event. In examining the validity of the deduced results, equivalent ionospheric current systems were used. With these current systems, we can roughly estimate the horizontal electric field in the ionosphere under certain assumptions. The time variation of the electric field deduced from the HF Doppler data agrees with that deduced from current systems and high latitude electrojet activity. The results indicate that the HF Doppler method is a sensitive and useful tool for estimating the electric field. (Tsutsui, M., Ogawa, T., Kamide, Y., Kroehl, H. W., & Hausman, B. A., 1988)

## 3 Traveling Ionospheric Disturbances

A method for determining horizontal velocity vectors and temperature of thermospheric winds from azimuthally different diagrams derived from the data of traveling ionospheric disturbances observed using an HF Doppler array has been developed. (Tsutsui, Horikawa, & Ogawa, 1964)

## 4 Earthquakes

The ionospheric disturbances were observed near Boulder, Colorado, around the time of the Alaskan earthquake, which occurred on March 28, 1964. It is possible that the infrasonic waves and the ionospheric disturbances may have been caused by pressure waves generated by the movement of the earth. (Davies & Baker, 1965)

An ionospheric perturbation that was produced from the Coalinga earthquake of May 2, 1983, was detected by a network of HF radio links in northern California. The ionosphric refraction regions of all five HF propagation paths, at distances between 160 and 285 km (horizontal range) from the epicenter, were affected by a ground-motion-induced acoustic pulse that propagated to ionospheric heights. The accoustic pulse was produced by the earthquake-induced seismic waves rather than the vertical ground motion above the epicenter. These observations appear to be the first ionospheric disturbances to be reported this close to an eathquake epicenter. (Wolcott, Simons, Lee, & Nelson, 1984)

Ionospheric disturbances caused by the Urakawa-Oki earthquake on March 21, 1982 were detected by a network of HF Doppler sounders in central Japan. The HF Doppler data, together with the seismic data, have been used to formulate a mechanism whereby ionospheric disturbances are produced by an event of a relatively small epicentral distance. (Tanaka, Ichinose, Okuzawa, Shibata, Sato, Nagasawa, et al., 1984)

Ionospheric disturbances by at the time of the Sumatra Earthquake of magnitude 9.0 were observed using HF Doppler sounders on December 26, 2004. The observation point was about 5,000 km from the epicenter and the vertical hight was about 200 km. The surface wave seemed to propagate at a speed of 3.5 km/s. These waves excited the accoustic wave which propagated nearly vertical to the reflection point of the HF radio wave. The travel time of the atmospheric accoustic wave between the ground and the ionospheric height was about 8 min. (Ichinose & Ogawa, 2005)

## 5 Severe Wheathers

Observations of the ionospheric effects of atmospheric disturbances caused by typhoons using the HF Doppler data are described. A method for estimating the number density of neutral particles, the kinetic energy density of neutral parcels due to the atmospheric waves caused by typhoons, and the scale height at the ionospheric height is proposed. (Tsutsui & Ogawa 1973)

Both dynamic and static spectral analyses of sample records revealed that (1) these waves have the periods ranging between 1.4 and 9.7 min that correspond to infrasound at F-layer heights (and partly to gravity wave at E-layer heights), (2) the spectral content varies from hour to hour, and from station to station for a given typhoon, and further from one typhoon to the another, and (3) the spectral fine structure does not agree with existing theoretical prediction for thunderstorms. It is, therefore, plausible that the observed spectral peaks arose from the characteristics of the radiation sources in the typhoon air mass. (Okuzawa, Shibata, Ichinose, Takagi, Nagasawa, Nagano, et al., 1986)

## 6 Volcanic Eruptions

Some aspects of the global atmospheric dynamic responses to the eruption of Mount St. Helens on May 18, 1980 are presented. Although events such as volcanic eruptions may excite a number of acoustic-gravity wave modes in the atmosphere, the observed surface pressure perturbations and distant ionospheric perturbations can be explained only in terms of propagation of Lamb modes with a horizontal propagation velocity slightly above 300 m/s. (Liu, Klostermeyer, Yen, Jones, Robinson, Holt, et al., 1982)

## REFERENCES

Boyd, G.M. & Duffus, H.J. (1969) Doppler observations of associated ionospheric and magnetic fluctuations, Can. J. Phys. 47(15), 1585-1600.

Davies, K., Watts, J.M., & Zacharisen, D.H. (1962) A study of F2-layer effects as observed with a Doppler technique, J. Geophys. Res. 67(3), 601-609.

Davies, K. & Baker D. M. (1965) Ionospheric effects observed around the time of the Alaskan earthquake of March 28, 1964, J. Geophys. Res. 70(9), 2251-2253.

Davies, K. & Baker, D.M. (1966) On frequency variations of ionospherically propagated HF radio signals, Radio Sci. 1(5), 545-556.

Ichinose, T. & Ogawa, T. (1974) HF Doppler observation associated with magnetic storm, J. Atmospheric Terrest. Phys.

36, 2047-2053.
Ichinose, T. & Ogawa, T.(1976) Internal gravity waves deduced from the HF Doppler data during the April 19, 1958, solar eclipse, J. Geophys. Res. 81(13), 2401-2404.
Ichinose, T., Ohta, T., & Ogawa, T. (1994) HF Doppler observation of electric field associated with low-latitude auroral event in October 1989, J. Geomag. Geoelectr. 46, 205-212.
Ichinose, T., Ohta, T., & Ogawa, T. (1995) HF Doppler observations of solar proton effects on low latitude ionosphere, Proc. IUGG, Boulder, USA.
Ichinose, T. & Ogawa, T. (2005) HF Doppler observatioin of accoustic wave excited by the 2004 Sumatra earthquake, Proc. IAGA, Toulouse, France
Liu, C.H., Klostermeyer, J., Yen, K.C., Jones, T.B., Robinson, T., Holt, O., Leitinger, R., Ogawa, T., Sinno, K., Kato, S., Ogawa, T., Bedard, A. J., & Kersley, L. (1982) Global Dynamic responses of the atmosphere to the eruption of mount St. Helens on May 18, 1980, J. Geophys. Res. 87(A8), 6281-6290.
Ogawa, T. (1958) Frequency variations in short-wave propagation, Proc. IRE 46(12), 1934-1939.
Ogawa, T. (1970) SFDs and the recombination coefficient in the ionosphere, In Davies, K.,(Eds.) , Phase and Frequency instabilities in electromagnetic wave propagation, Slough, England.
Okuzawa, T., Shibata, T., Ichinose, T., Takagi, K., Nagasawa, C., Nagano, I., Mambo, M., Tsutsui, M., & Ogawa, T. (1986) Short-Period disturbances in the ionosphere observed at the time of typhoons in September 1982 by a network of HF Doppler receivers, J. Geomag. Geoelectr. 38, 239-266.
Tanaka, T., Ichinose, T., Okuzawa, T., Shibata, T., Sato, Y., Nagasawa, C., & Ogawa, T. (1984) HF-Doppler observations of acoustic waves excited by the Urakawa-Oki earthquake on 21 March 1982, J. Atmospheric Terrest., Phys. 46(3), 233-245.
Tsutsui, M., & Ogawa, T. (1973) HF Doppler observation of ionospheric effects due to typhoons, Rep. Ionosphere and Space Res. in Japan 27, 121-123.
Tsutsui, M., Horikawa, T., & Ogawa, T. (1984) Determination of velocity vectors of thermospheric wind from dispersion relations of TID's observed by an HF Doppler array, J. Atmospheric Terrest. Phys. 46(5), 447-462.
Tsutsui, M., Ogawa, T., Kamide, Y., Kroehl, H.W., & Hausman, B.A. (1988) A method of estimating horizontal vectors of ionospheric electric field deduced from HF Dopper data, Radio Sci. 23(2), 119-128.
Wolcott, J. H., Simons, D.J., Lee, D.D., & Nelson, R.A. (1984) Observations of an ionospheric perturbation arising from the Coalinga earthquake of May 2, 1983, J. Geophys. Res. 89(A8), 6835-6839.