Introduction to HF Doppler sounding

possible collaboration with SD

Keisuke Hosokawa

University of Electro-Communications

in close collaboration with

Nakata-san, Hashimoto-san, Kikuchi-sensei, Saita-san, Nozaki-san

History of UEC

1918 Established as “The Technical Institute for Wireless-Communications” motivated by the international treaty made after the tragic incidence of the Titanic in 1912

History of UEC

1918 Established as “The Technical Institute for Wireless-Communications” motivated by the international treaty made after the tragic incidence of the Titanic in 1912

Training of Morse communication

History of UEC

1918 Established as “The Technical Institute for Wireless-Communications” motivated by the international treaty made after the tragic incidence of the Titanic in 1912

1949 Promoted to the National University status as “The University of Electro-Communications” under the Ministry of Education, Japan (MEXT)

.

1968 50 years anniversary

.

.

2018 100 years anniversary

Sugadaira Space Radio Observatory (SSRO)

★ Established in 1968

★ Various radio observations:

- Natural VLF waves
  (whistler waves, hiss waves)
- Satellite tracking
- HF Doppler sounder
- VHF air-band signals

Lodge

Observatory

What the HF Doppler sounders are observing

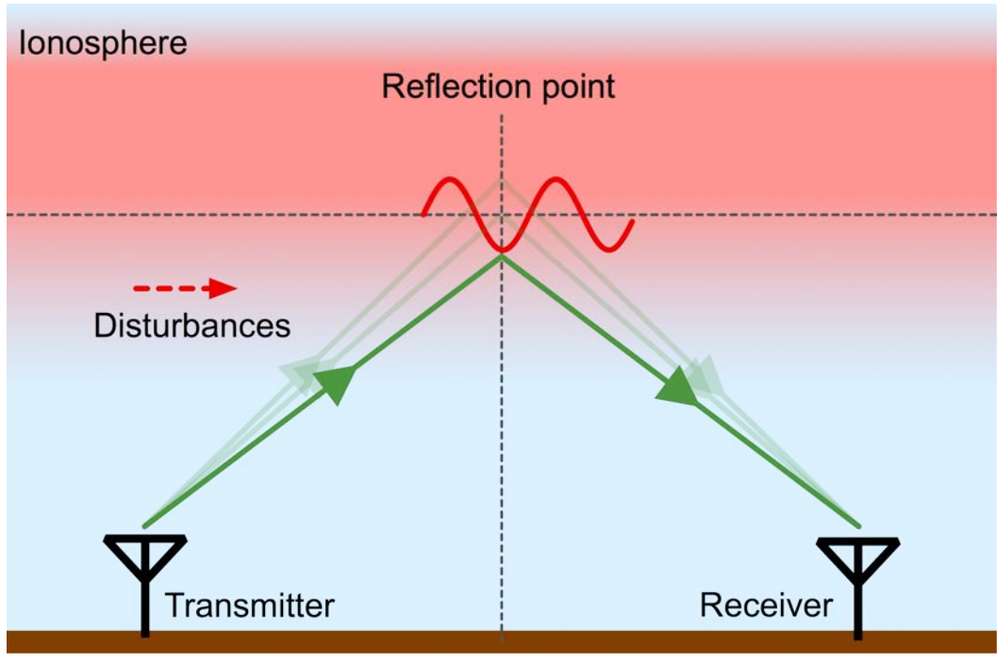
★ Bi-static sounding system (without ranging capability)

★ Observe radio wave reflected by the ionosphere

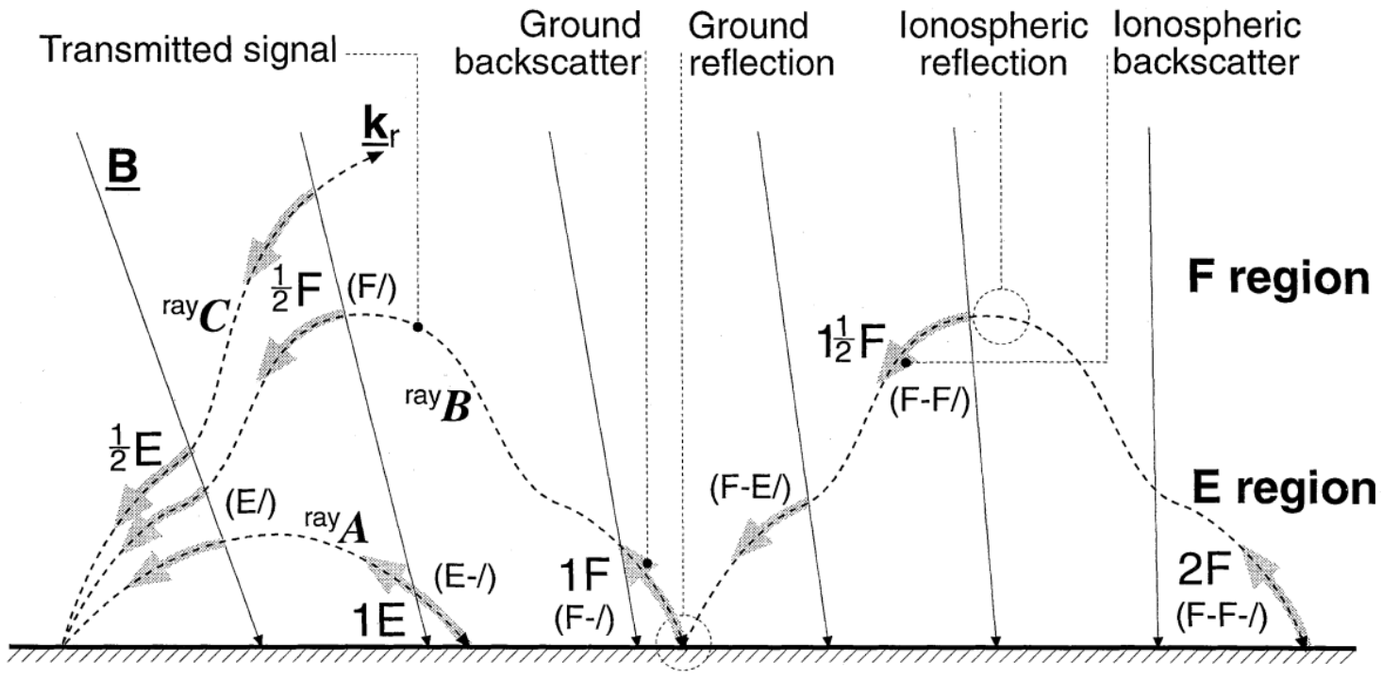
★ Derive the vertical motion of the ionosphere from the Doppler shift of the received signal

$$v = -\frac{c\Delta f}{2f\cos\theta}$$

★ Analogous to the ground (sea) scatter echoes seen in mono-static radar system such as SuperDARN



HF Doppler sounding



SuperDARN (Milan et al., 1997)

Earlier observations of HF Doppler sounders

★ Started receiving JJY standard radio transmission from Koganei (later Nazaki) in 1976

★ 5 and 8 MHz waves were received not only in Sugadaira but also in other places in the Kanto area to construct an array for estimating the horizontal velocity vector of ionospheric wave features (i.e., TIDs)

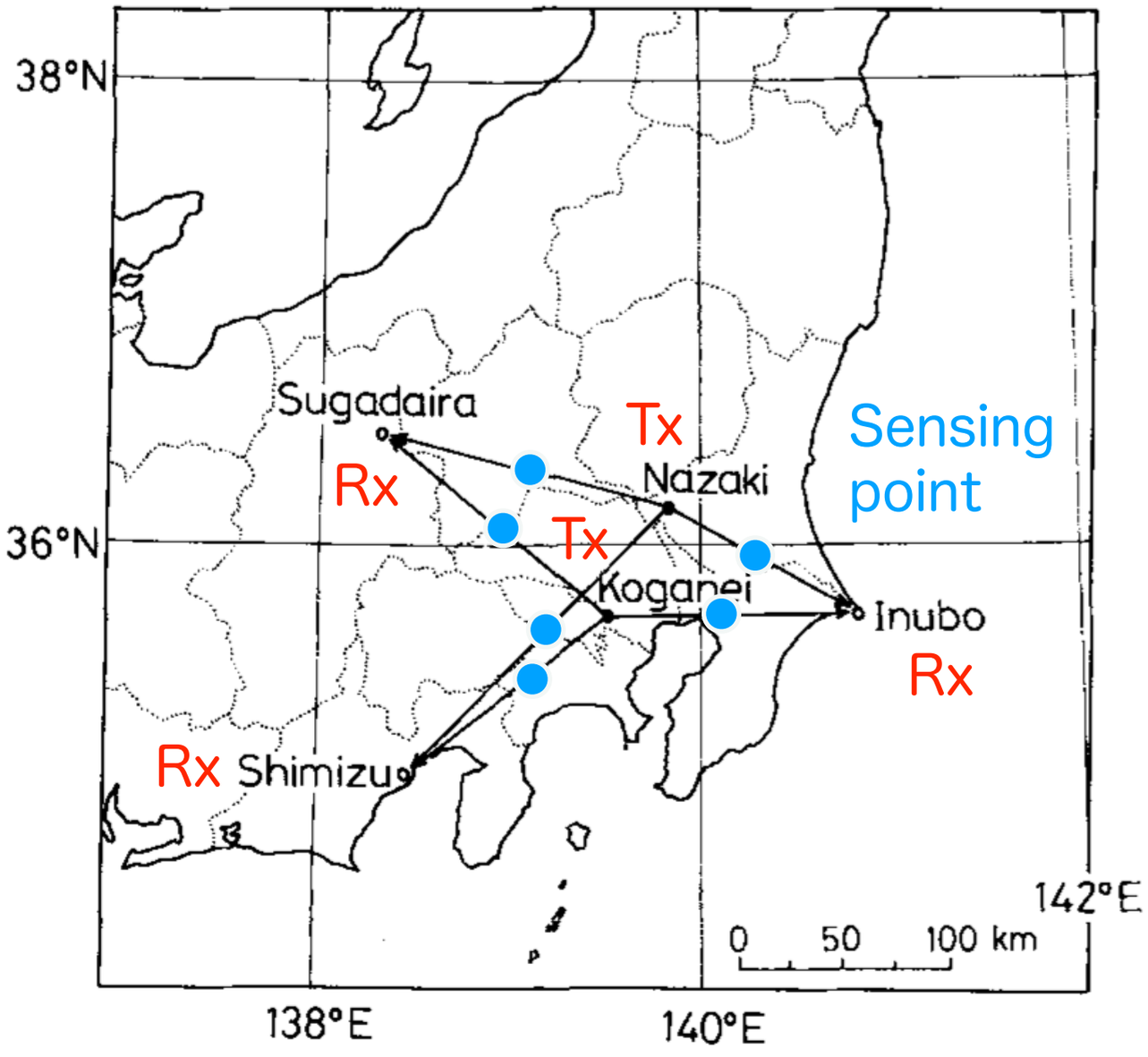
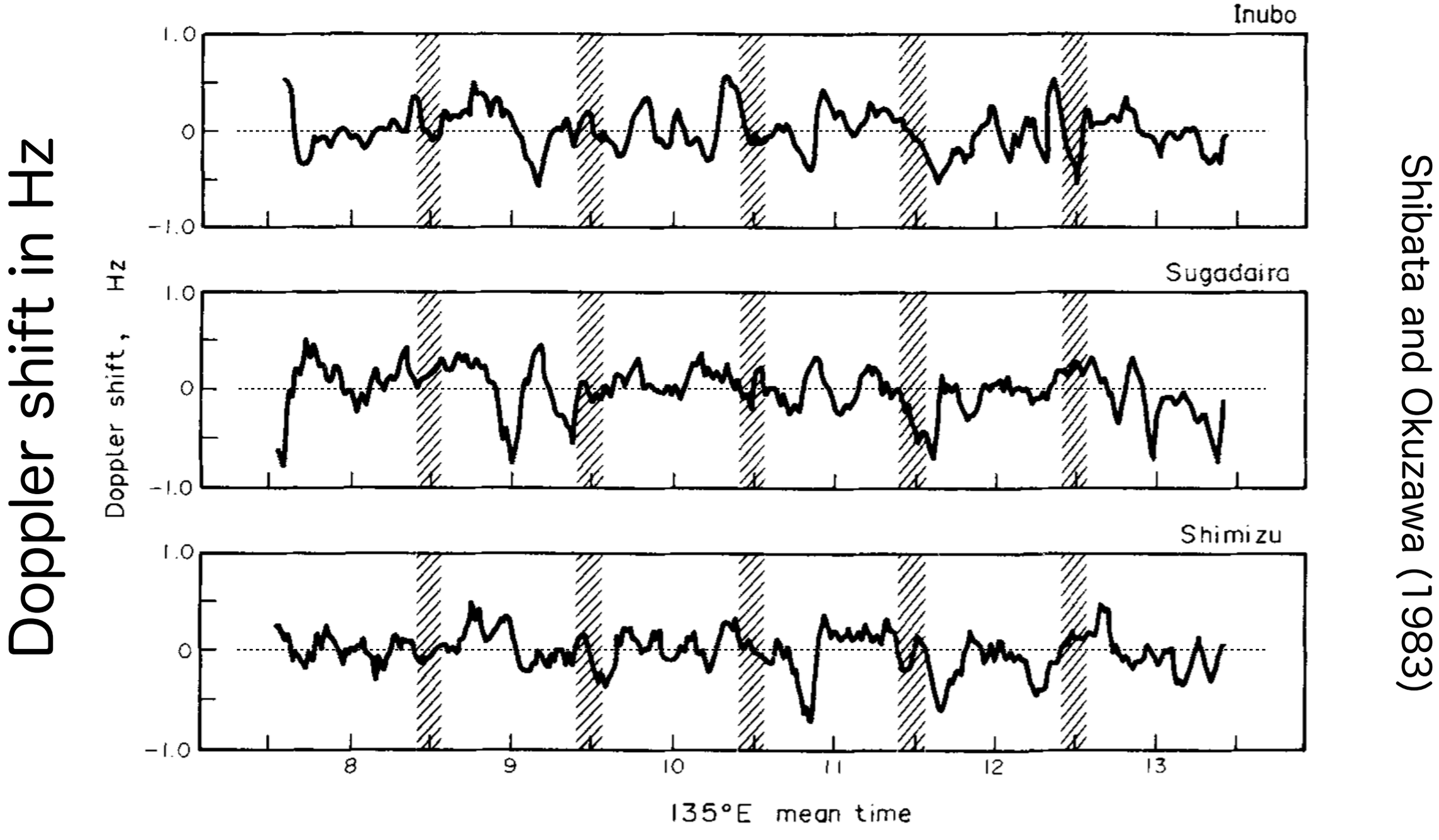


Fig. 1. Array geometry of the HF Doppler sounders.

Shibata and Okuzawa (1983)

Earlier observations of HF Doppler sounders

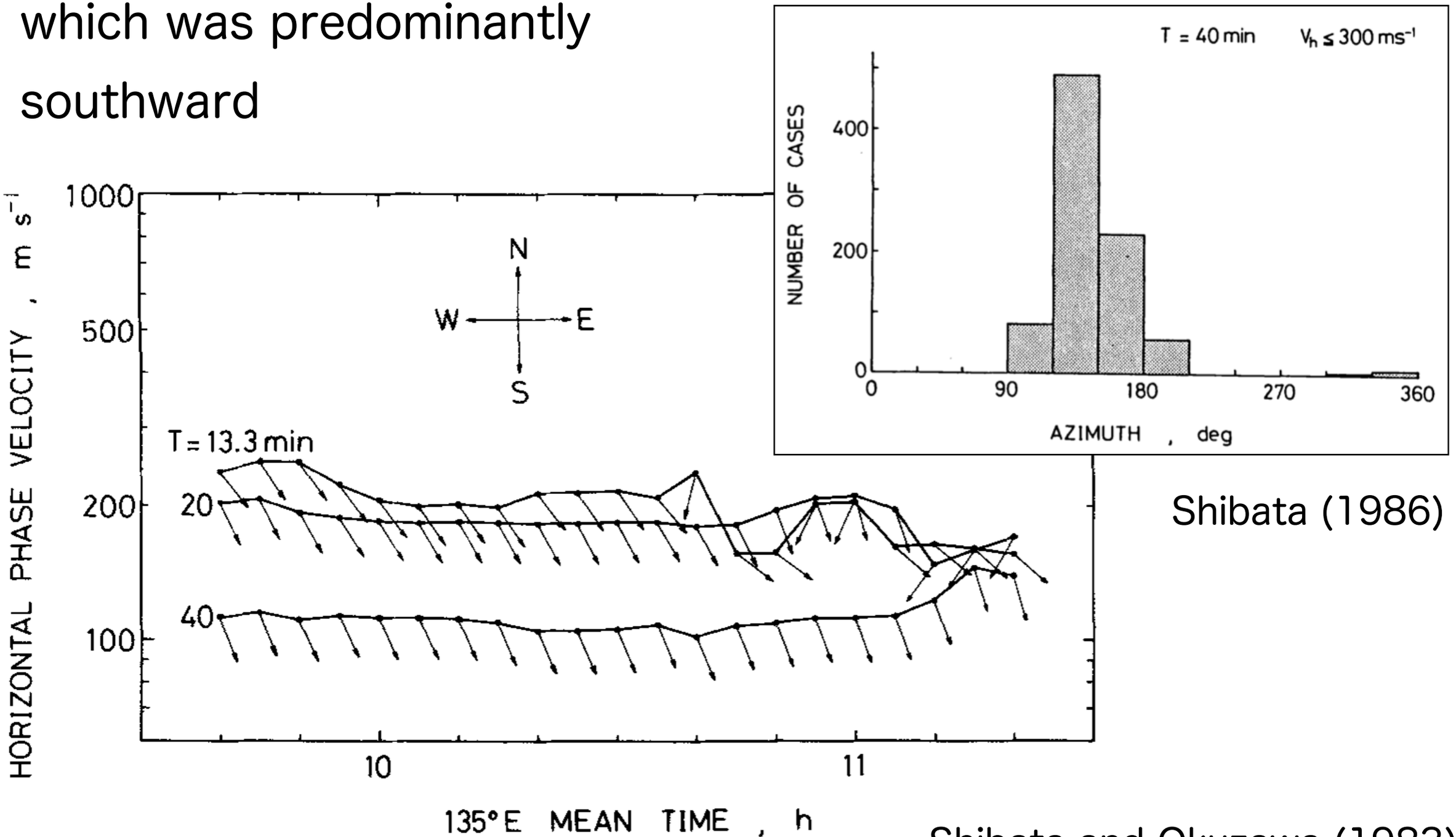
★ Signatures of MSTIDs were seen during daytime in winter as a manifestation of atmospheric gravity waves (AGWs)



Shibata and Okuzawa (1983)

Earlier observations of HF Doppler sounders

★ 3 point measurement allowed an estimation of phase velocity which was predominantly southward



Shibata (1986)

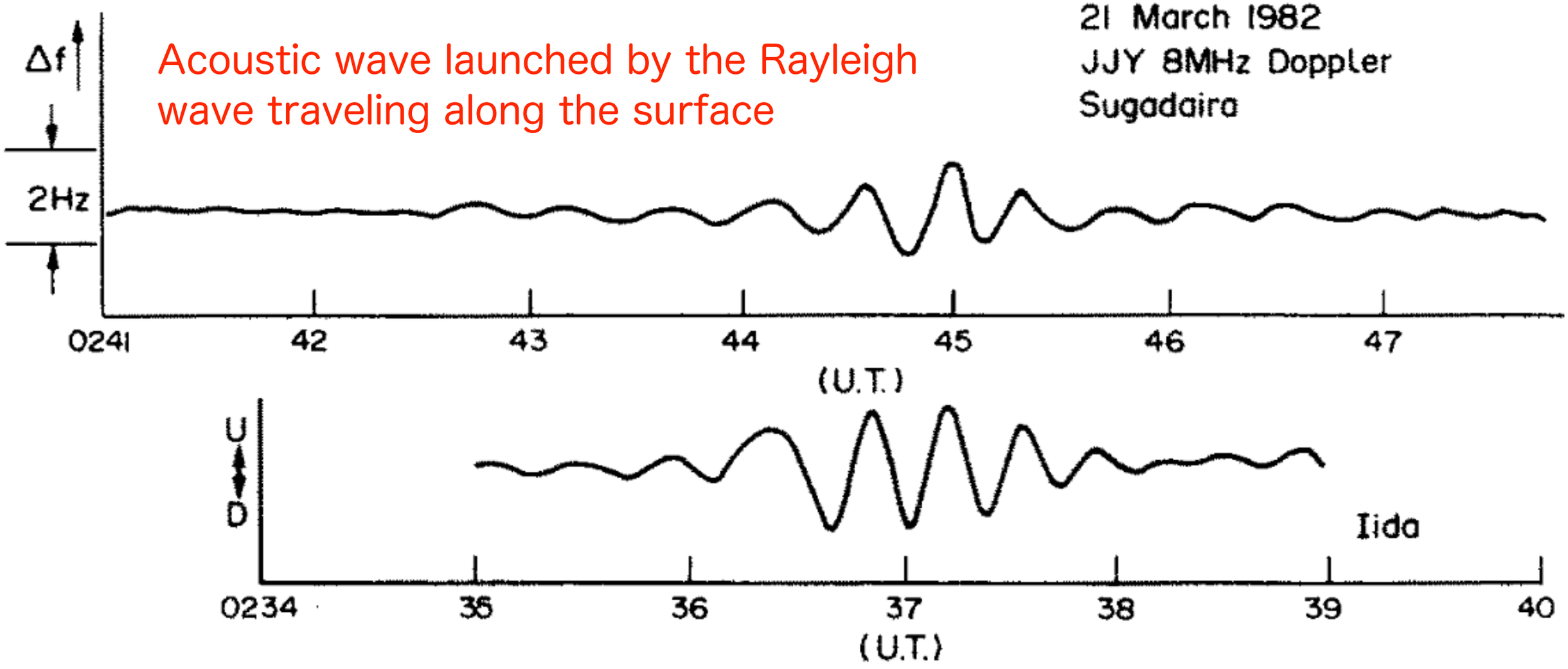
Shibata and Okuzawa (1983)

HFD data were also used for A-I coupling studies

★ Observations of MSTIDs / AGWs

★ Ionospheric disturbances associated with earthquakes

★ Ionospheric variation dring typhoon (Okuzawa et al., 1986)



Okuzawa (1983)

Stoppage of standard HF radio JJY in 2001

★ Observations of MSTIDs

★ Ionospheric disturbances associated with earthquakes

★ Ionospheric variation dring typhoon (Okuzawa et al., 1986)

Stoppage of JJY at HF frequencies in 2001

★ New Tx station JG2XA became operative in the main campus.
5.006 and 8.006 MHz waves are transmitted for HFD

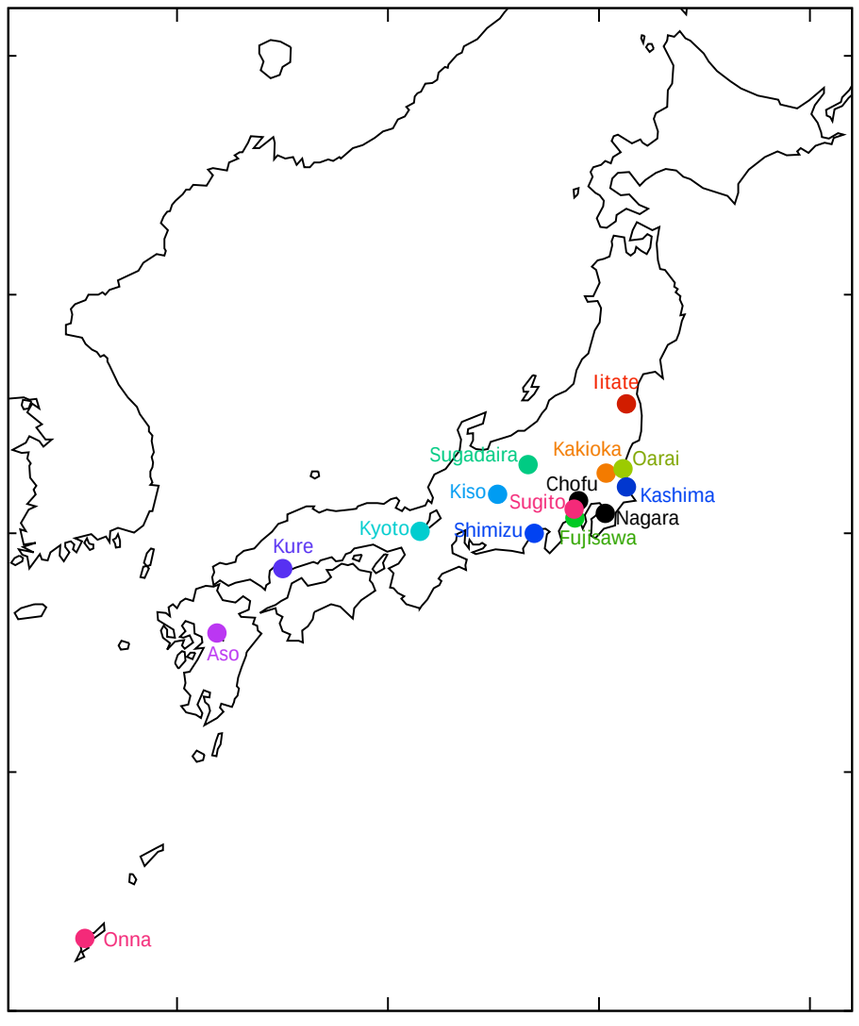
★ New Rx stations have become operative since ~2003:
SGD, ORI, KAK, KSM, SGT, IIT, KUR, FJS, KYO, ASO, ONA
Δf observations with a temporal resolution of 10 sec

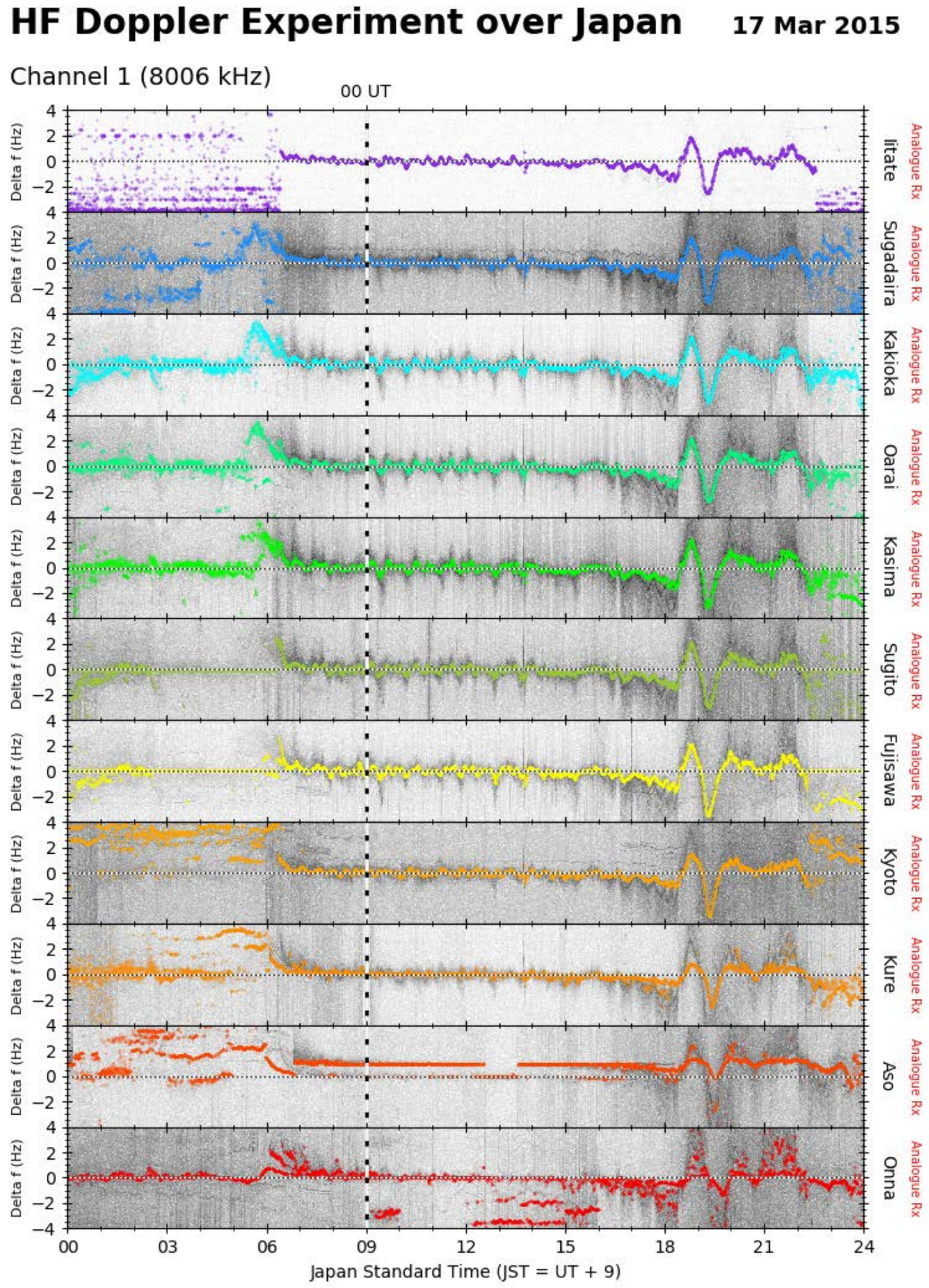
★ Commercial HF FM radio waves at 6.055 MHz, 9.595 MHz
(JOG, daytime only) have also been received

Multi-point observations

★ Continuous observations at more than 11 Rx stations

★ Doppler shift data with a temporal resolution of 10 s

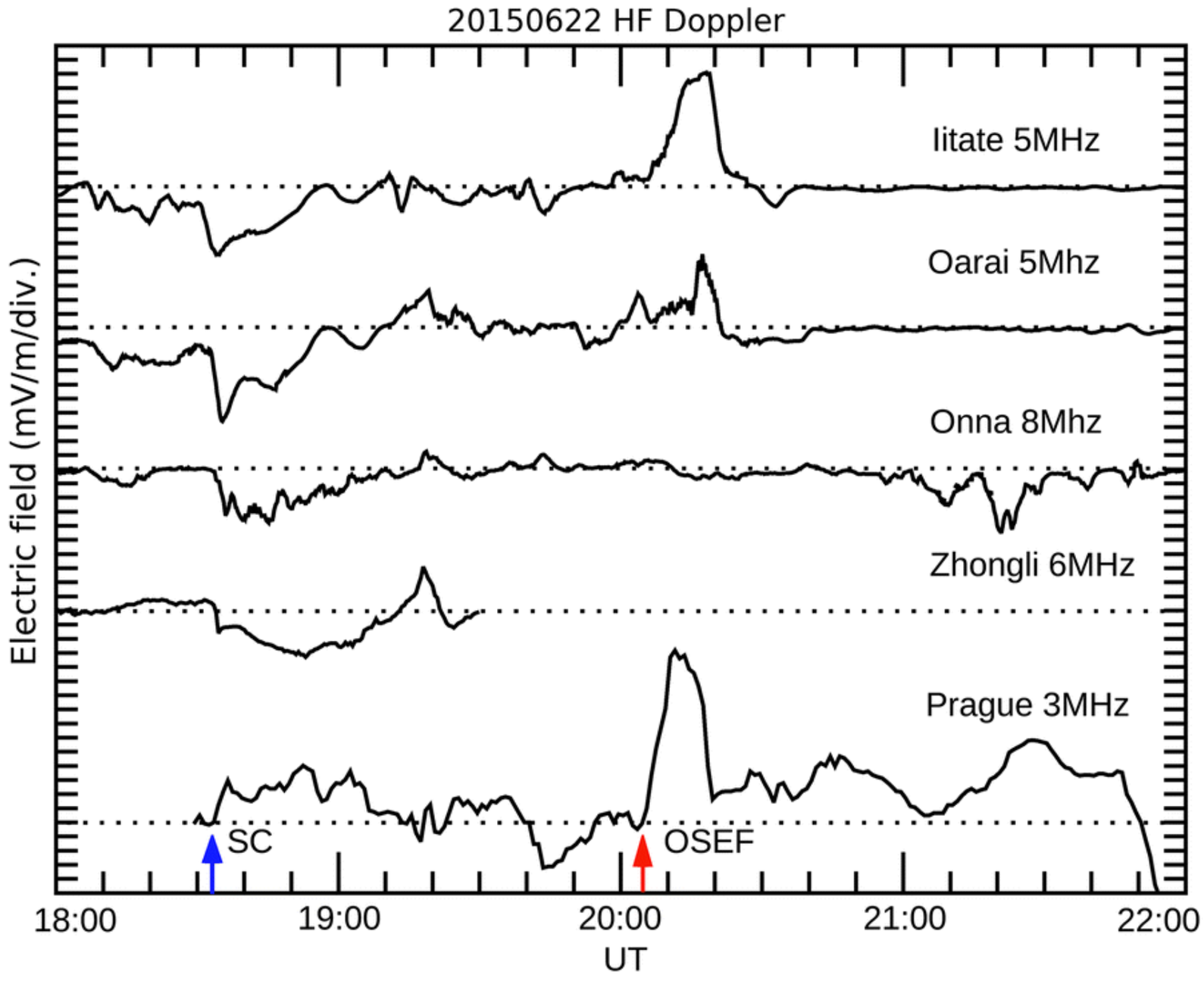




Magnetosphere-Ionosphere coupling studies

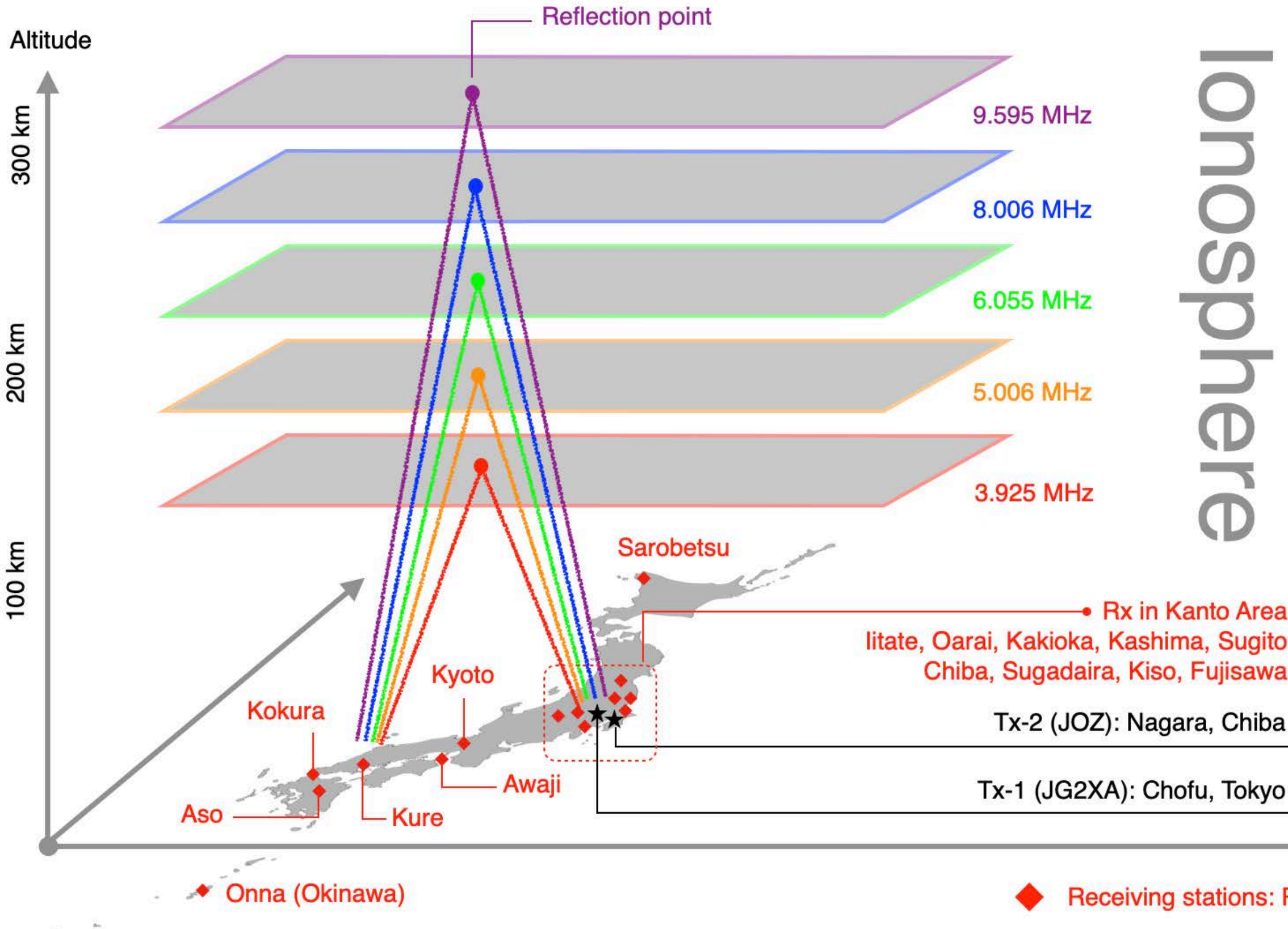
★ The HFD data can also be used for studying the electric field variation at mid-latitudes caused by SC or over-shielding effect

★ Collaboration with HFD observations in Czech



Hashimoto et al. (2020)

Simultaneous observations at multiple altitudes

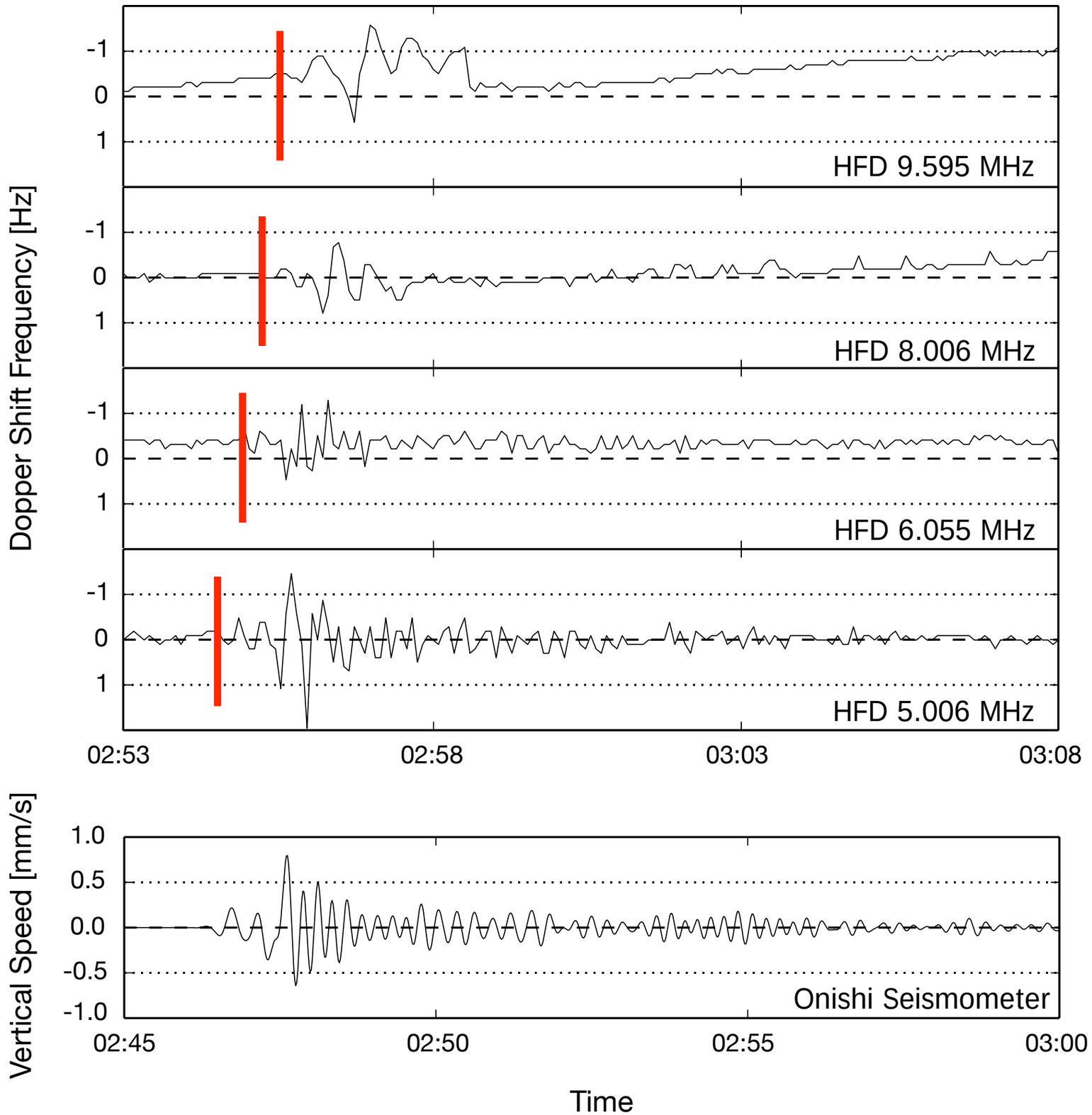


Atmosphere - Ionosphere coupling studies

★ An example of ionospheric variation during the huge earthquake on March 11, 2011

★ Data at multiple altitudes allows us to estimate the vertical propagation of acoustic wave

Nakata et al. (2021)



Current status of the project

★ Following the retirement of Prof. Tomizawa in 2018, researchers at five different institutes took over the project (the HFD project is not a project of UEC anymore)

★ Try to enhance the visibility:

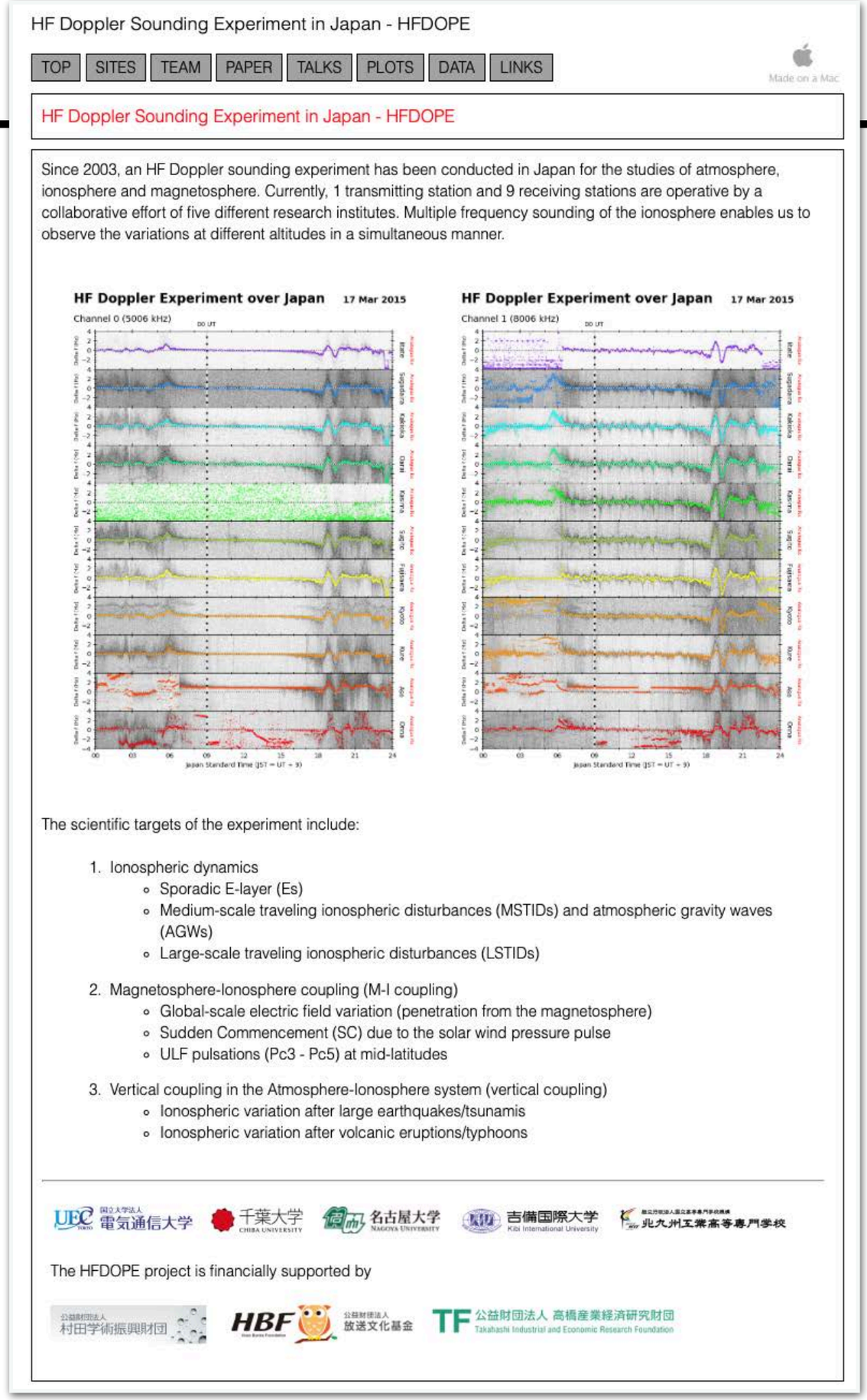
Active data archive:

since 2001 to realtime

All the digital data downloadable

http://gwave.cei.uec.ac.jp/~hfd

★ Promote collaborative research especially with SuperDARN



HF Doppler Sounding Experiment in Japan - HFDOPE

TOP | SITES | TEAM | PAPER | TALKS | PLOTS | DATA | LINKS

Made on a Mac

HF Doppler Sounding Experiment in Japan - HFDOPE

Since 2003, an HF Doppler sounding experiment has been conducted in Japan for the studies of atmosphere, ionosphere and magnetosphere. Currently, 1 transmitting station and 9 receiving stations are operative by a collaborative effort of five different research institutes. Multiple frequency sounding of the ionosphere enables us to observe the variations at different altitudes in a simultaneous manner.

The scientific targets of the experiment include:

1. Ionospheric dynamics
   - Sporadic E-layer (Es)
   - Medium-scale traveling ionospheric disturbances (MSTIDs) and atmospheric gravity waves (AGWs)
   - Large-scale traveling ionospheric disturbances (LSTIDs)
2. Magnetosphere-Ionosphere coupling (M-I coupling)
   - Global-scale electric field variation (penetration from the magnetosphere)
   - Sudden Commencement (SC) due to the solar wind pressure pulse
   - ULF pulsations (Pc3 - Pc5) at mid-latitudes
3. Vertical coupling in the Atmosphere-Ionosphere system (vertical coupling)
   - Ionospheric variation after large earthquakes/tsunamis
   - Ionospheric variation after volcanic eruptions/typhoons

The HFDOPE project is financially supported by

Development of new digital receivers

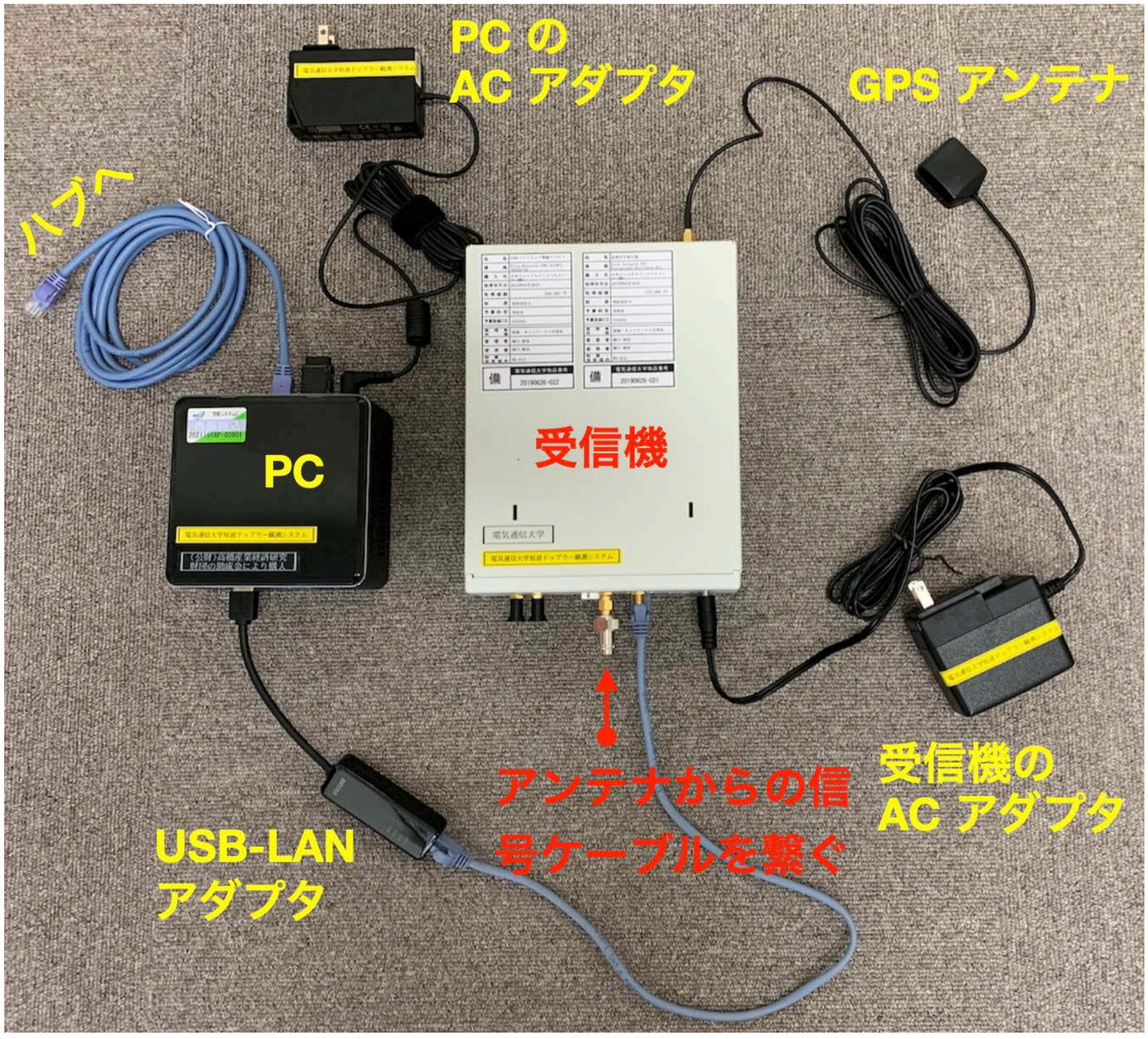
★ Developed a new digital receiving system for HFD

★ Equipped with Ettus N210 with GPSDO

★ Record I/Q samples with a temporal resolution of 100 Hz

★ Advantages:

- dynamic range
- frequency isolation
- slightly cheaper
- much smaller
- easy to prepare

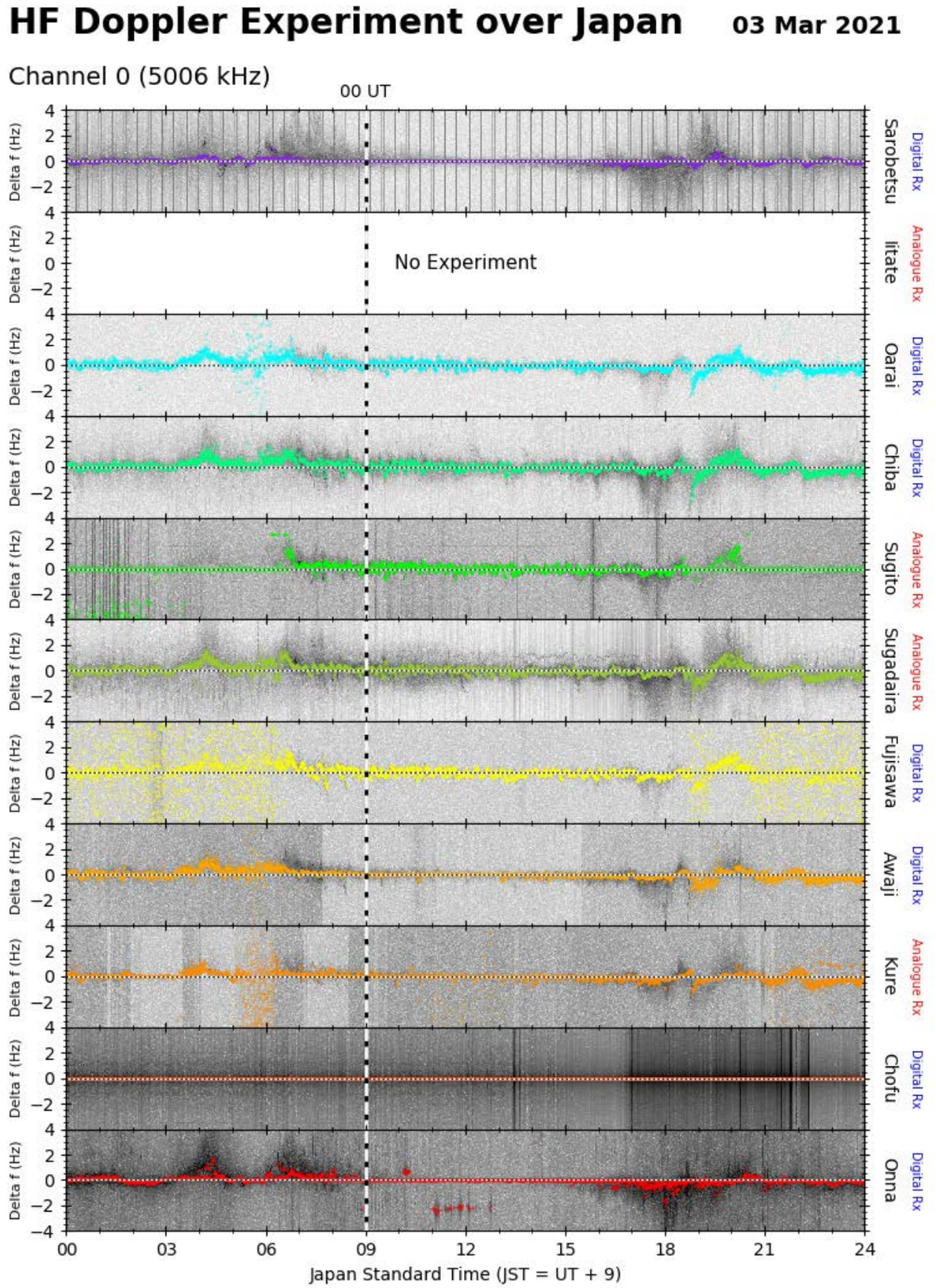


Deployment of new receivers and new Tx system

★ Conventional analogue receivers have already been replaced with the new ones at 7 Rx stations out of 11

★ Additional replacement will be finished by the end of FY2021 (i.e., fully digital Rx)

★ There is a plan to renew the Tx system in which FM-CW based coding will be used for ranging (i.e., estimation of reflection altitude) by FY2022



Possible collaboration with SuperDARN

★ Collaboration with the HOP radars in Hokkaido
- Propagation of MSTID/LSTID
- E-F coupling between Es and summer nighttime MSTID
- Acoustic waves from earthquakes, typhoon, volcanic eruption
- Meteor/fireball

★ Global observations of electric field penetration from the M'sphere (SC, DP2, over-shielding effect etc.)

★ Observations of back-lobe radio waves from the HOP-E with the existing new digital receiver

★ Monitoring of the HF propagation condition

★ Application of common data analysis techniques
e.g., derivation of wave parameter from multi-point data

Summary

★ Since the establishment of Sugadaira Space Radio Observatory in 1968, HF Doppler sounding systems have been operative

★ HF transmission station (JG2XA) has been operated since 2001 for the HF Doppler project and the data have widely been used not only for ionospheric studies but also for studies of M-I coupling (space weather) and A-I coupling processes

★ Combination of the HFD observations with newer datasets, such as SuperDARN, GPS-TEC, airglow imagers, and lidar, will enable us to visualize the dynamical characteristics of various ionospheric phenomena (MSTIDs, Es, acoustic waves) in 3D

★ Website (status, plots, digital data):
http://gwave.cei.uec.ac.jp/~hfd