2022年度国立極地研究所・名古屋大学宇宙地球環境研究所研究集会 (NIPR/ISEE FY2022 Research meeting)
SuperDARN 研究集会 (SuperDARN Research meeting)
2023/3/9 14:50-15:10

Characteristics of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption and their generation mechanism observed with GNSS-TEC and SuperDARN Hokkaido pair of radars

(SuperDARN 北海道-陸別第一・第二 HF レーダーと全球 GNSS-TEC 観測から捉えたトンガ火山大規模噴火後の電離圏擾乱の特徴とその発生機構について)

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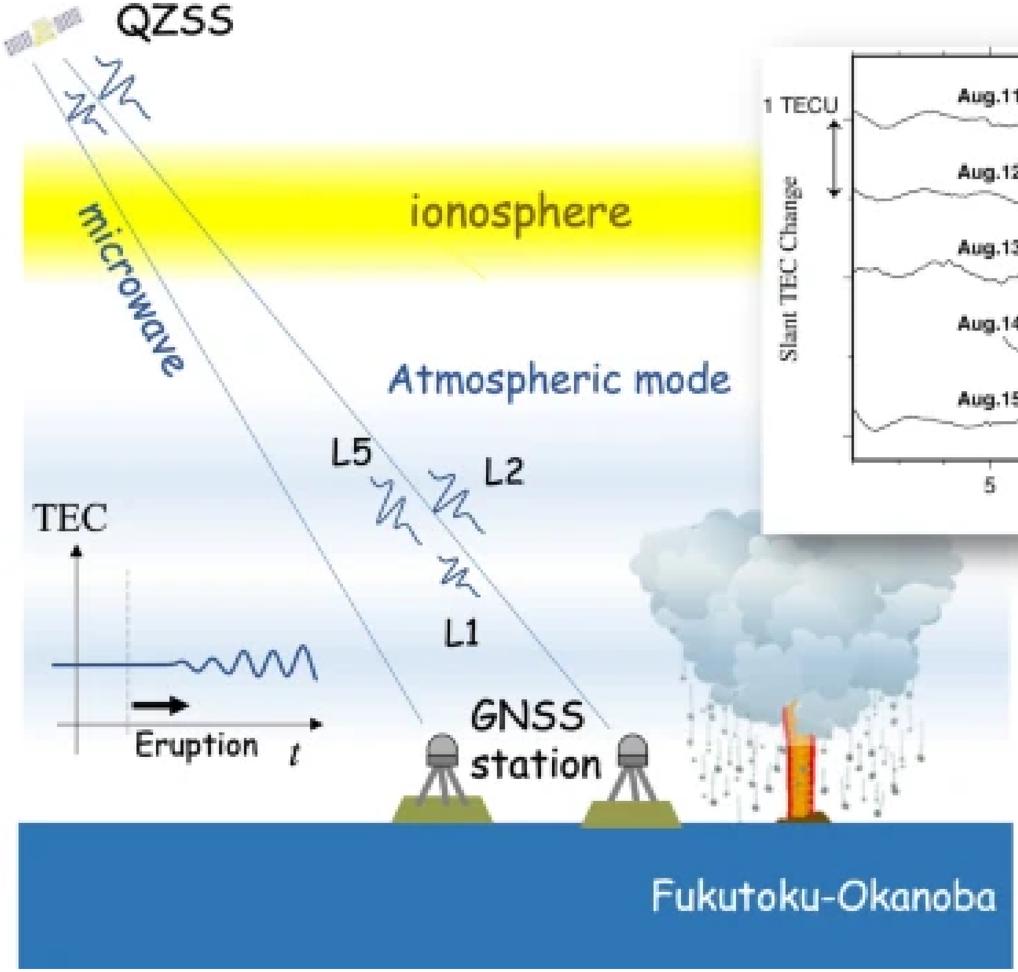
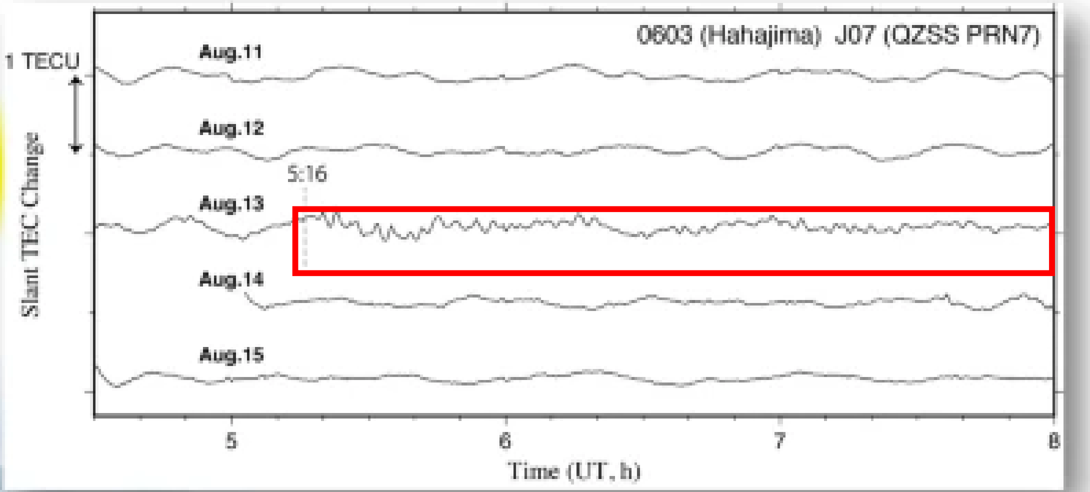
[2]National Institute of Information and Communications Technology
[3]The University of Electro-Communications

Shinbori, A., Otsuka, Y., Sori, T. et al. Electromagnetic conjugacy of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption as seen in GNSS-TEC and SuperDARN Hokkaido pair of radars observations. Earth Planets Space 74, 106 (2022). https://doi.org/10.1186/s40623-022-01665-8

1. Introduction

1.1 Ionospheric disturbances after the volcanic eruptions

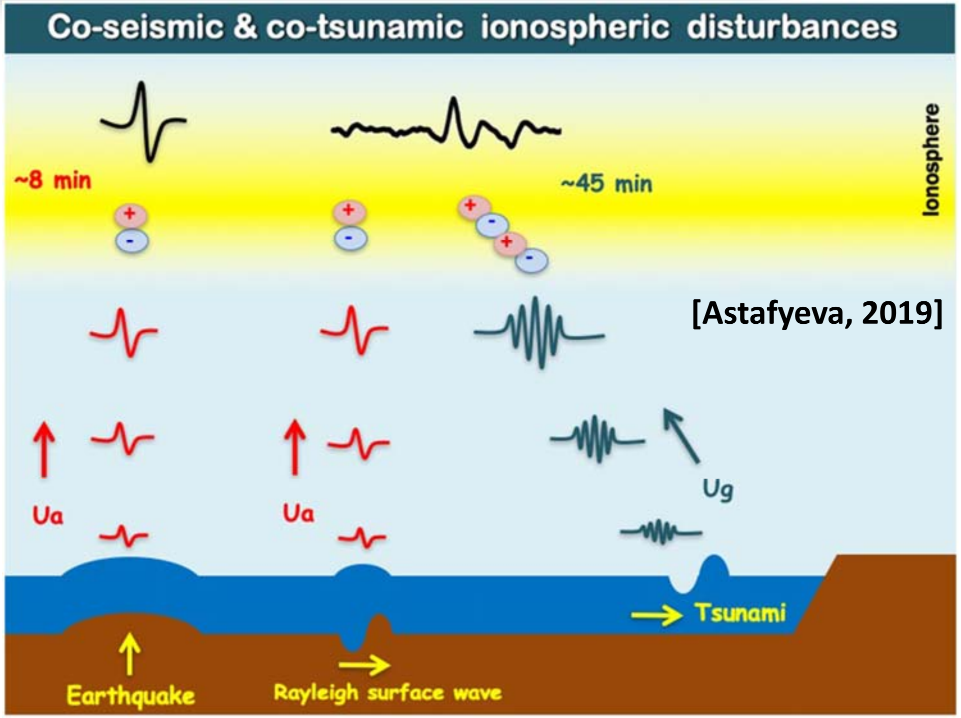




[Heki and Fujimoto, 2022]

TEC variation after Fukutoku Okanoba volcanic eruption on 13 August 2021

The neutral atmospheric oscillation due to acoustic waves and gravity waves generates plasma density perturbations.

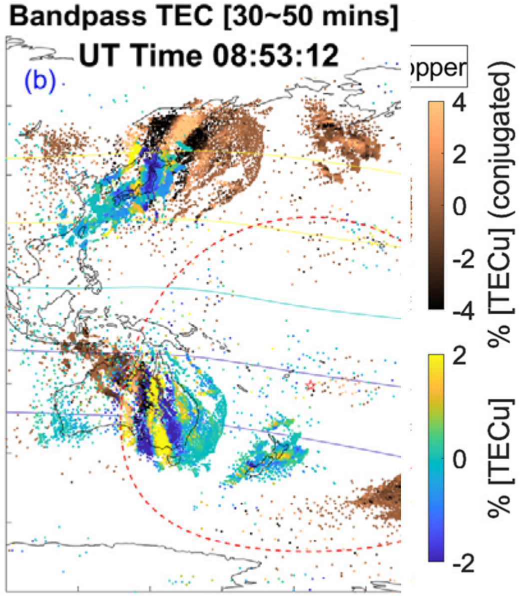


[Astafyeva, 2019]

1. Introduction

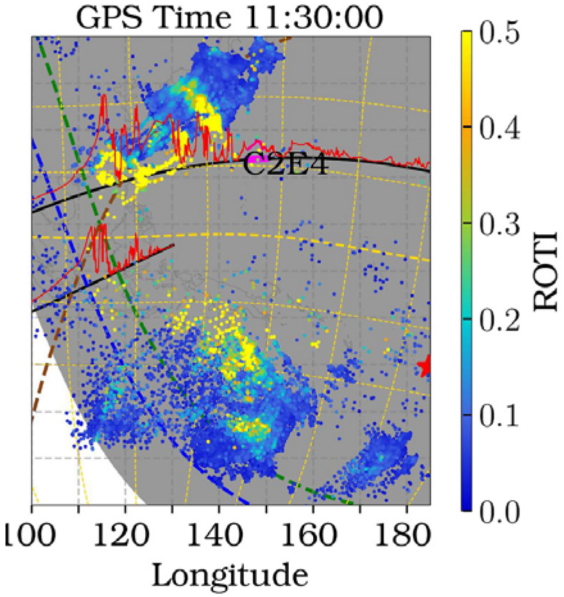
1.2 Ionospheric disturbances after the Tonga volcanic eruption

1. Traveling ionospheric disturbances (TIDs)



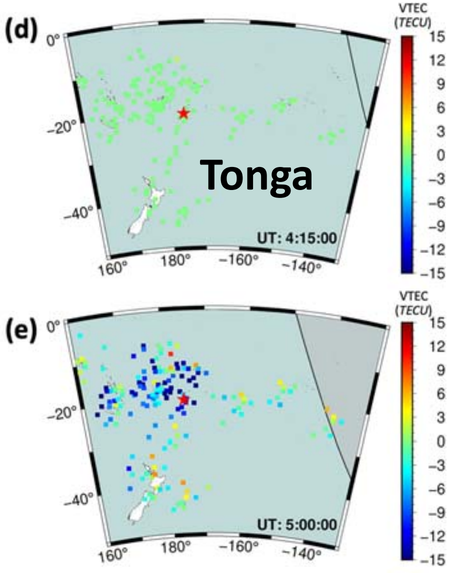
[Lin et al., 2022]

2. Equatorial plasma bubbles (EPBs)

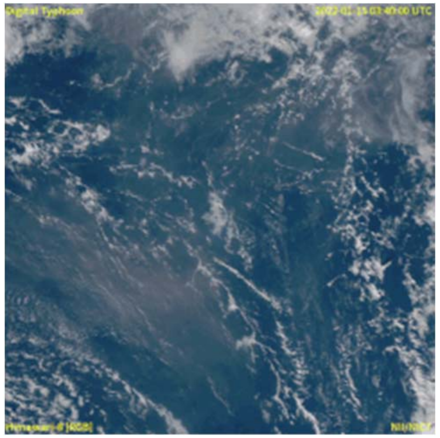


[Rajesh et al., 2022]

3. Electron density hole around the volcano



[Astafyeva et al., 2022]



https://en.wikipedia.org/wiki/File:Tonga_Volcano_Eruption_2022-01-15_0320Z_to_0610Z_Himawari-8_visible.gif

Purpose of this study

We clarify the generation mechanism of magnetic conjugacy of TIDs after the 2022 Tonga volcanic eruption using GNSS-TEC, SuperDARN Hokkaido pair of radars, and Himawari-8 satellite observation data.

2. Observation data and analysis method

2.1 Observation data and model

Data/model	Purpose	Provider
GNSS-TEC	Ionospheric electron density variations	ISEE/NICT
SuperDARN radar (HOK, HKW)	Variation of ionospheric plasma flow	ISEE
Himawari-8 (Thermal infrared data ：TIR)	Detection of surface air pressure waves in the troposphere	CEReS, Chiba-U
IGRF-13	Calculation of magnetically conjugate points	IAGA

2. Observation data and analysis method

2.2 Analysis method of Himawari-8 TIR grid data

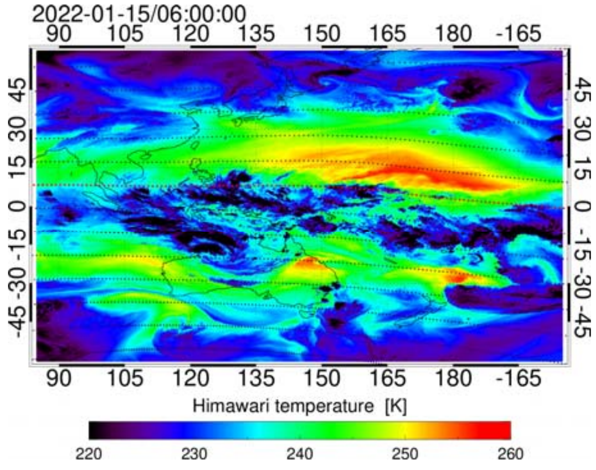
○**Assuming that cloud motion is much slower than the perturbation due to air pressure waves triggered by the Tonga volcanic eruption, we derived the normalized derivation of TIR according to the following equation.**

$$T_{avg}(t) = \frac{T_{bb}(t+10) + T_{bb}(t) + T_{bb}(t-10)}{3}$$

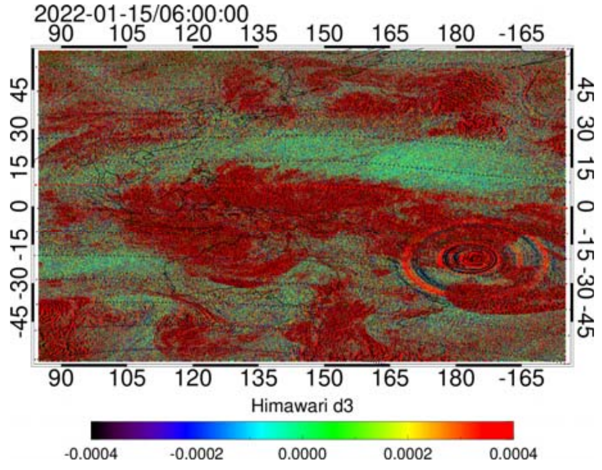
$$d_3(t) = \frac{T_{bb}(t) - T_{avg}(t)}{T_{avg}(t)}$$

T_{bb}: Infrared temperature
t: Time
T_{avg}:Running average
d_3: Normalized deviation

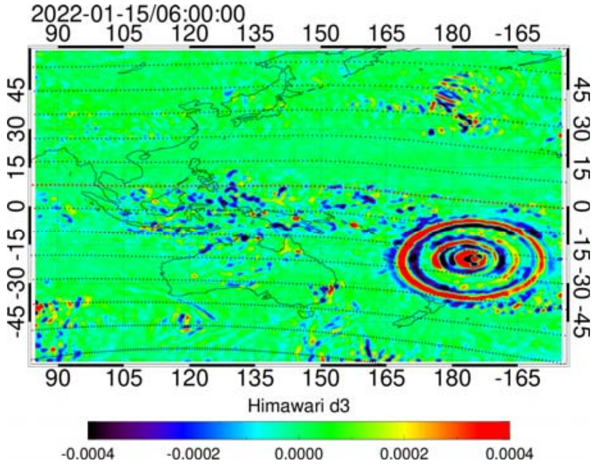
[Shinbori et al., 2022]



Original data



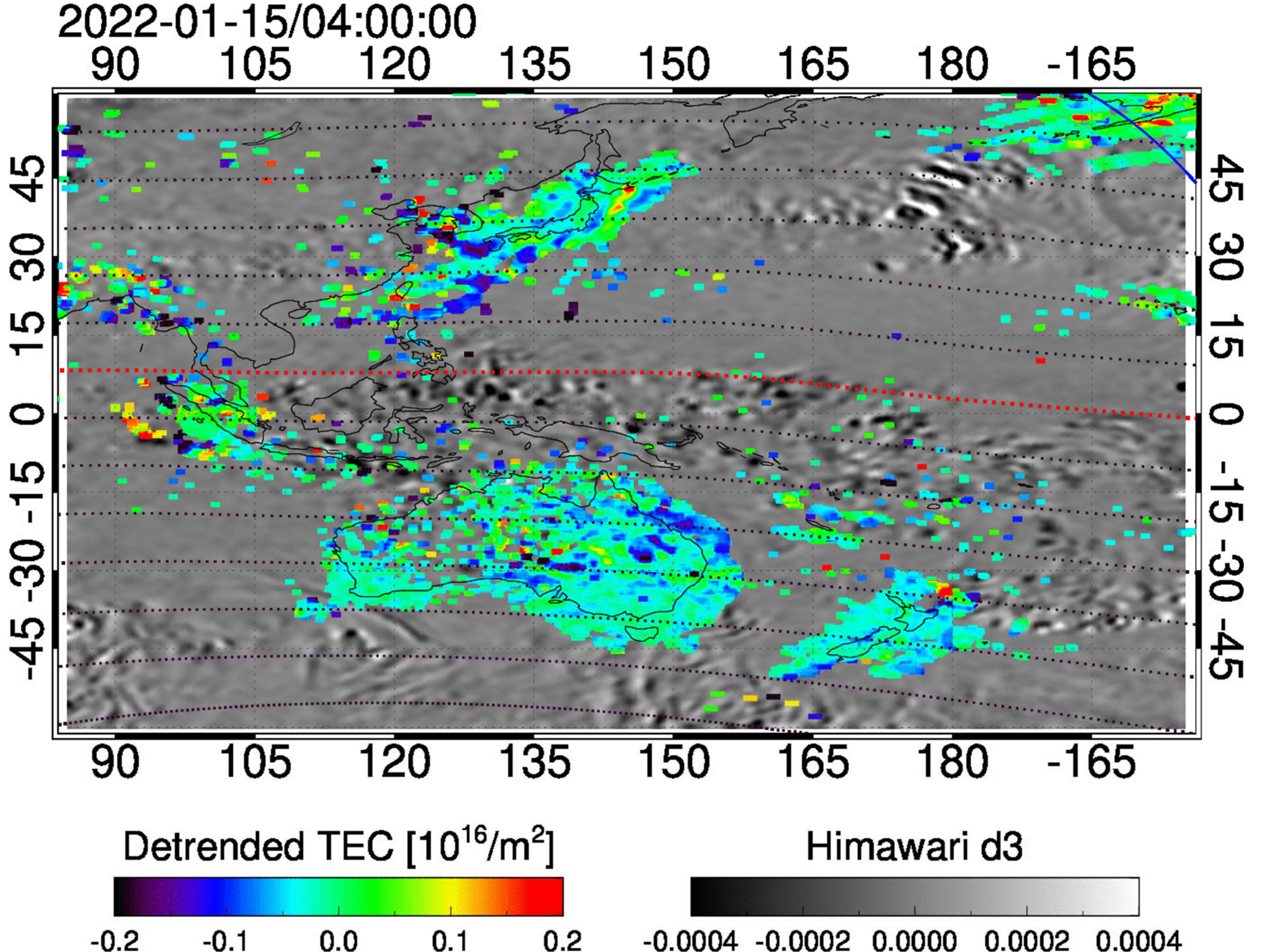
Normalized deviation



50x50 pixel smoothing

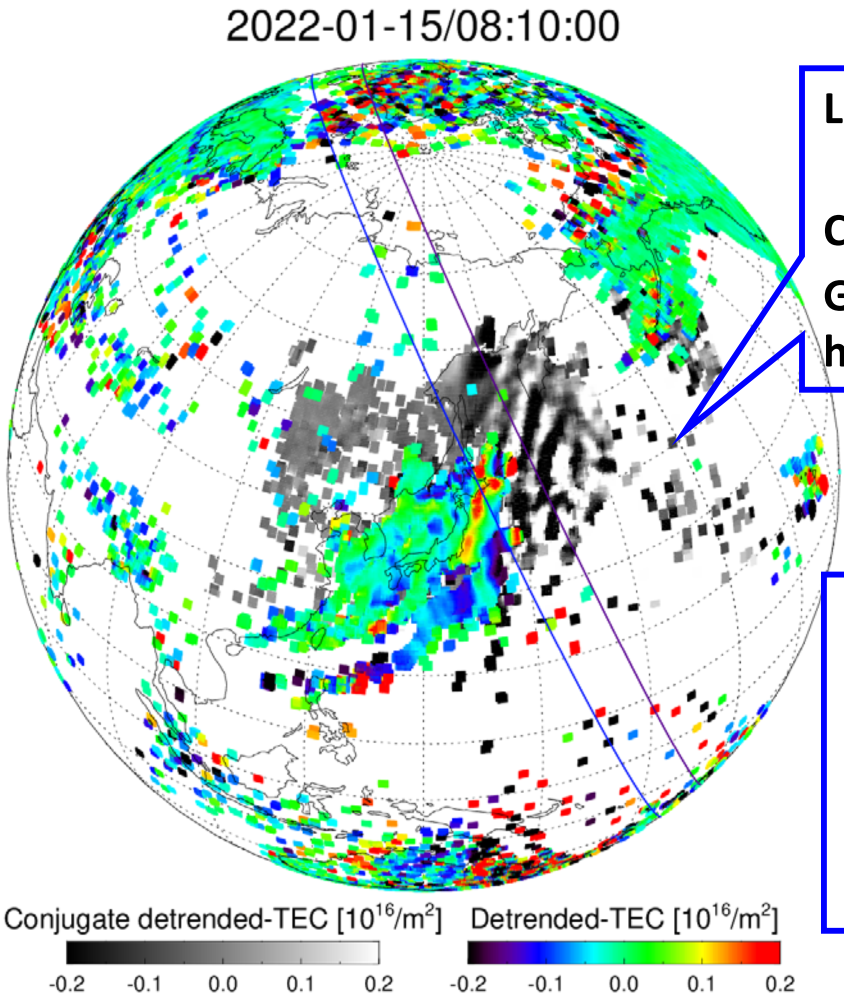
3. Results

3.1 TEC perturbation after the Tonga volcanic eruption



3. Results

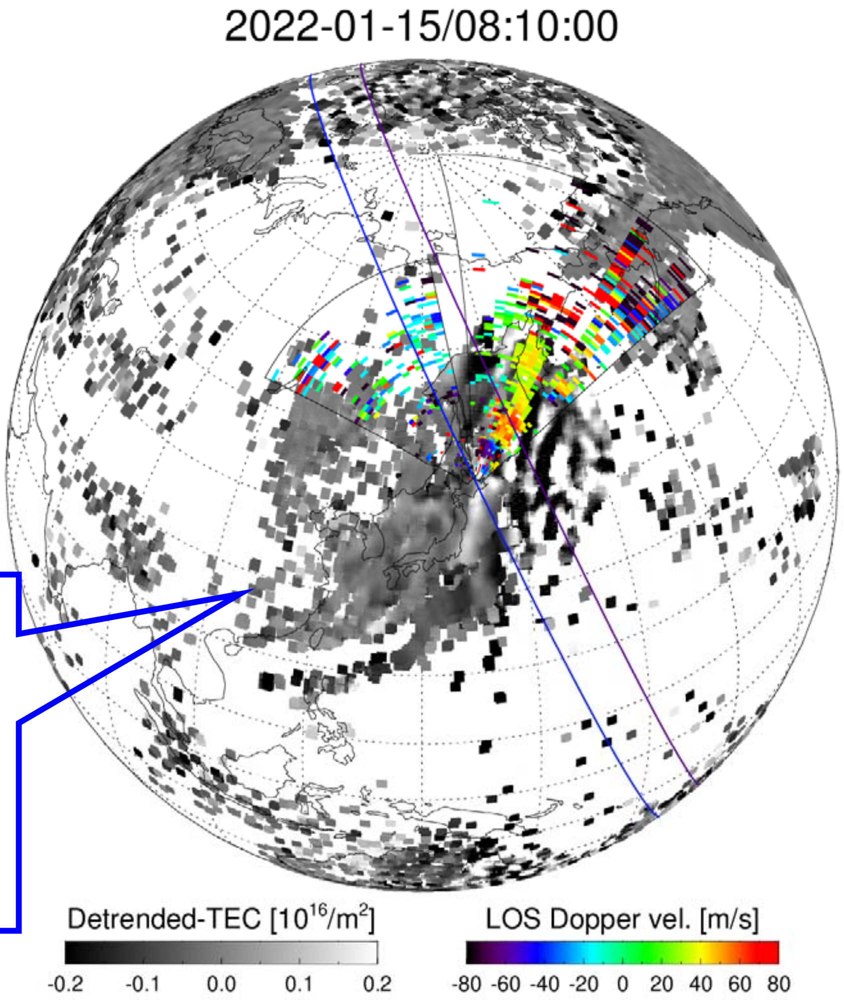
3.2 Magnetic conjugacy of TEC variations in both hemispheres



Left: TEC variation

Color → Original

Gray → Southern hemisphere



Right: Flow velocity and TEC variations

Gray: dTEC

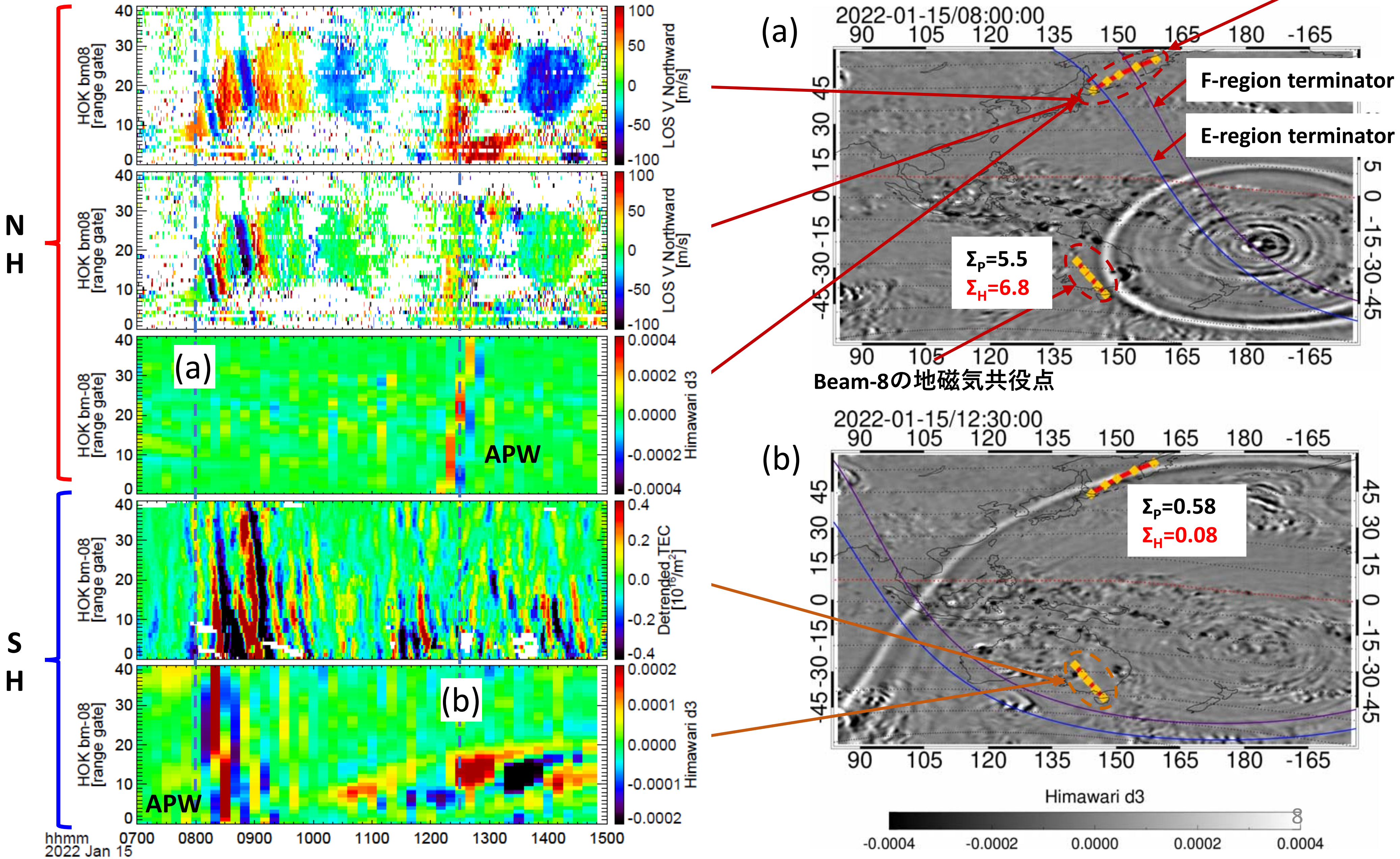
Color: Plasma flow

The wave structure is almost consistent in both hemisphere.

Southward plasma flow along the TEC waveform is observed.

3. Results

3.3 Relationship between TEC and plasma flow variations



Beam-8 direction

F-region terminator

E-region terminator

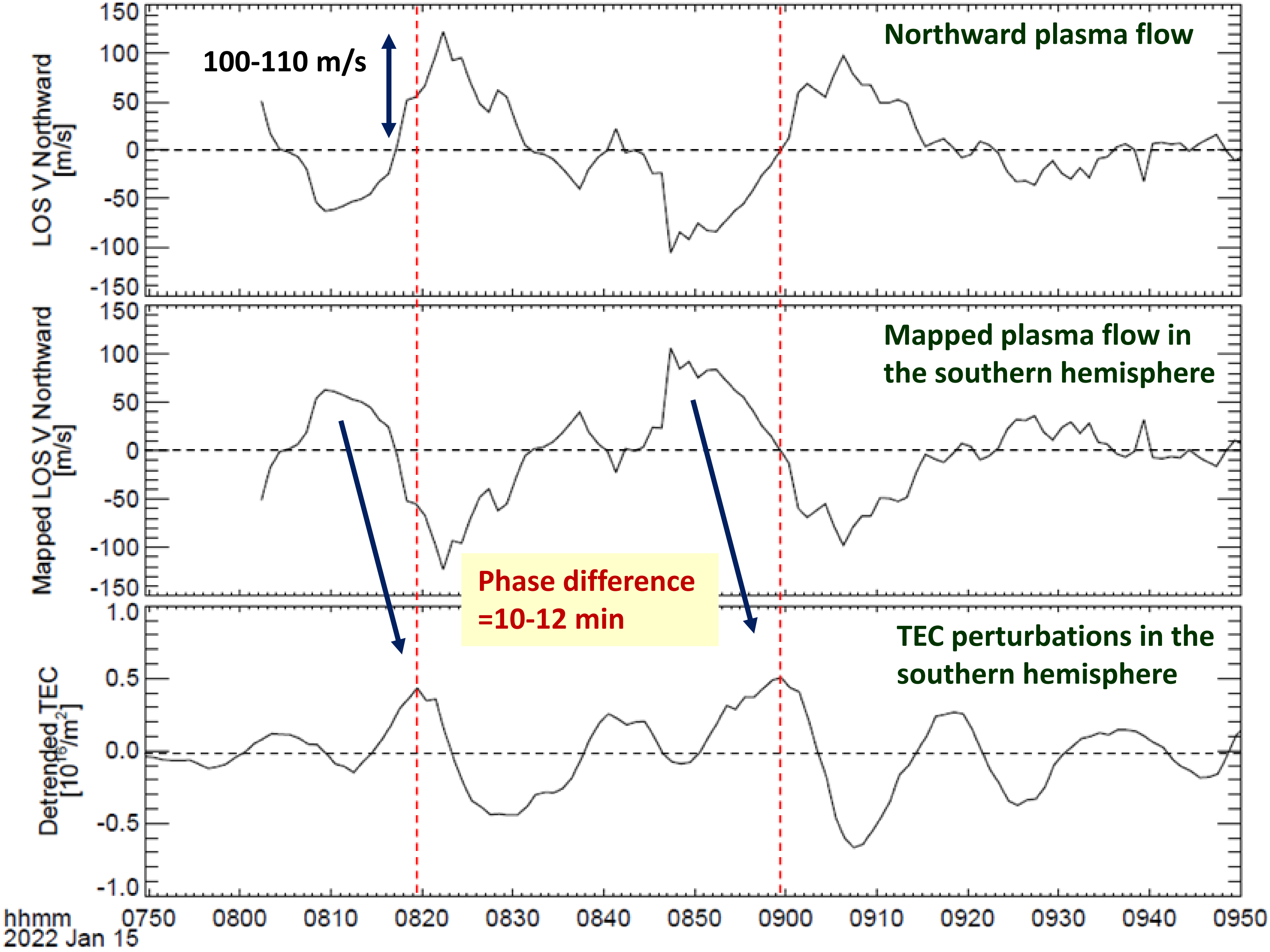
Beam-8の地磁気共役点

(a) Σ_P=5.5 Σ_H=6.8

(b) Σ_P=0.58 Σ_H=0.08

3. Results

3.3 Relationship between TEC and plasma flow variations



4. Discussion

4.1 Physical meaning of a phase difference between the TEC and plasma flow perturbations

Mass conservation equation describing the variation of electron density in the ionosphere

$$\frac{\partial n}{\partial t} + \nabla \cdot (n\boldsymbol{v}_E) = P - L$$

n: electron density, v_E: electric field drift velocity, P: production, L: loss

Plane wave perturbation of n_e and v_1

$$n_{e1}, v_1 \propto exp\{i(\omega t - kx)\}$$

No production and loss

$$P = 0, L = 0$$

Relationship between n_e and v_1 is written as follows

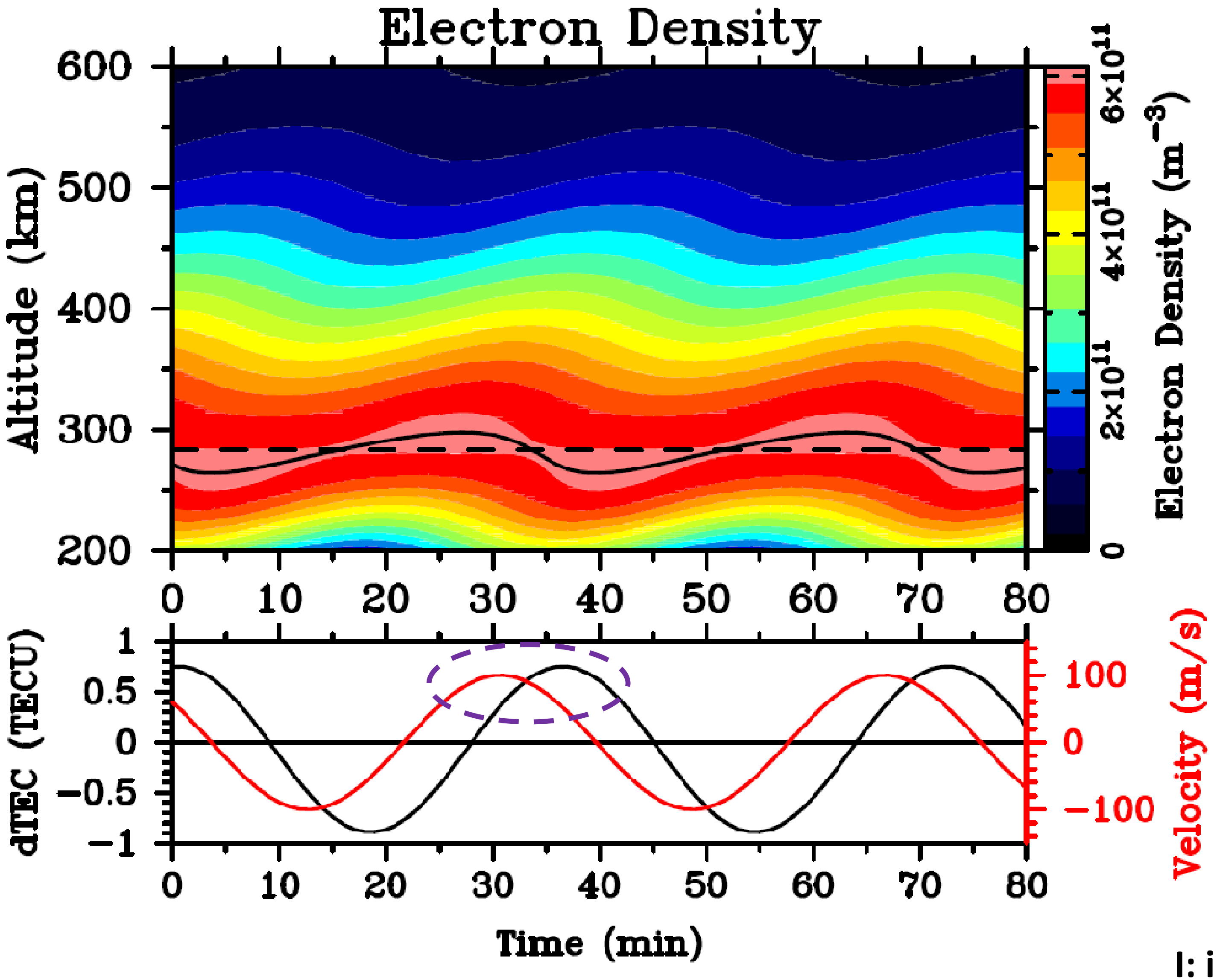
$$n_{e1} = -\frac{\boxed{i}}{\omega} v_1 \frac{\partial n_e}{\partial z} \cos I$$

I: inclination of magnetic field lines

In a case of an external origin (ex. E-region dynamo), there is a phase difference of 90° between electron density and velocity perturbations.

4. Discussion

4.2 Simple ionospheric model calculation



○Input data

F10.7 : 115 (2022/01)

Velocity：100 m/s

Period：36 min

Location：32.4°S, 142.7°E

○IRI model

TEC: 16.3 TECU

(Integration of electron density from 150 to 600 km)

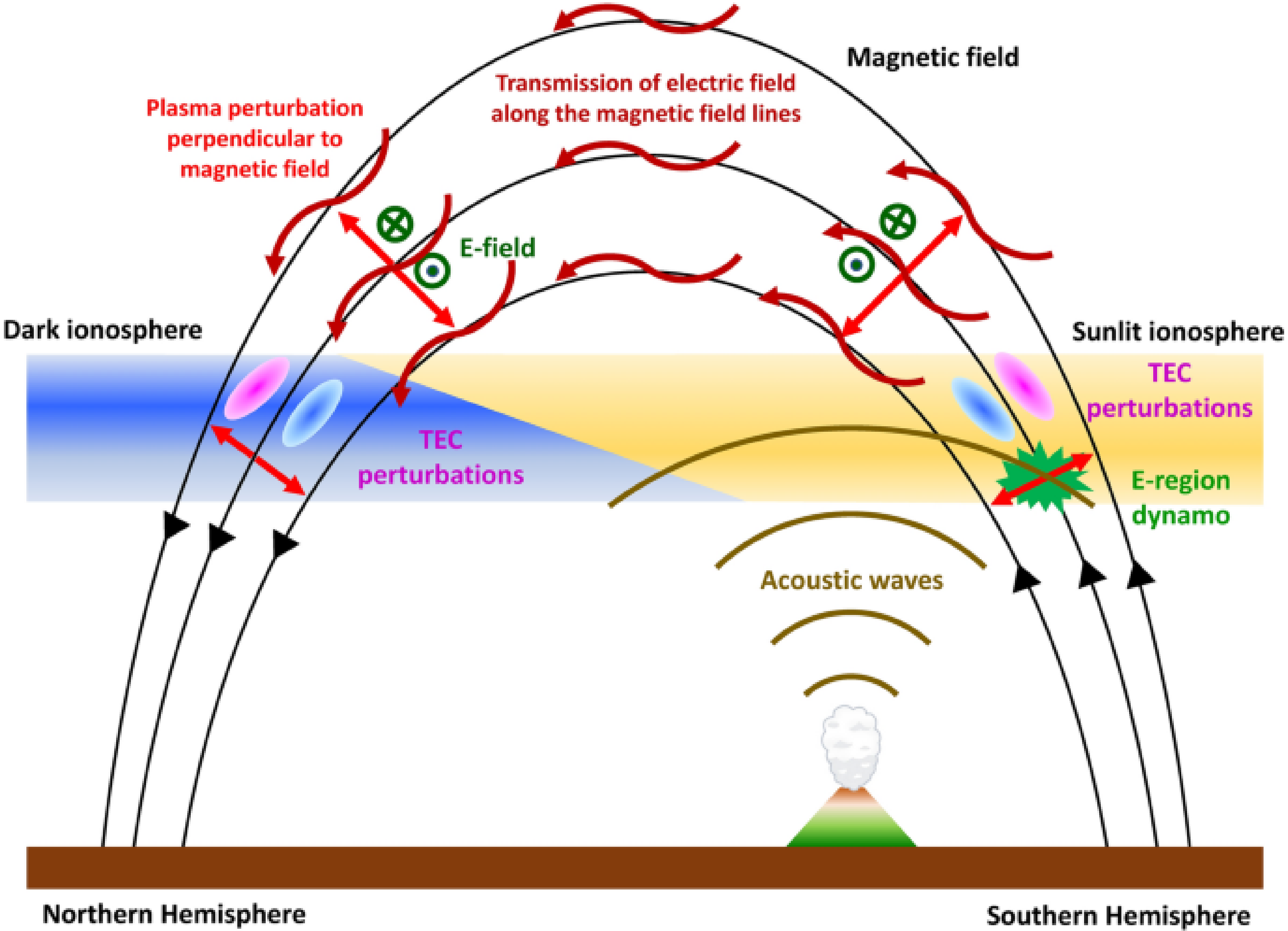
There is a phase difference of 7 min.

$$n_{e1} = -\frac{\boxed{i}}{\omega} v_1 \frac{\partial n_e}{\partial z} \cos I$$

I: inclination of magnetic field lines

4. Discussion

4.3 Scenario of TEC and electric field perturbations in the ionosphere triggered by the Tonga volcanic eruption



5. Conclusions

1. *Scientific aspect of a transition region from the atmosphere to space*

The generation mechanism of magnetic conjugacy of TIDs after the Tonga volcanic eruption is a transmission of an external electric field to both hemispheres along the magnetic field lines.

The external electric field is an E-region dynamo field driven by neutral atmospheric oscillations in the sunlit region.

This generation mechanism is different from that of normal MSTIDs.

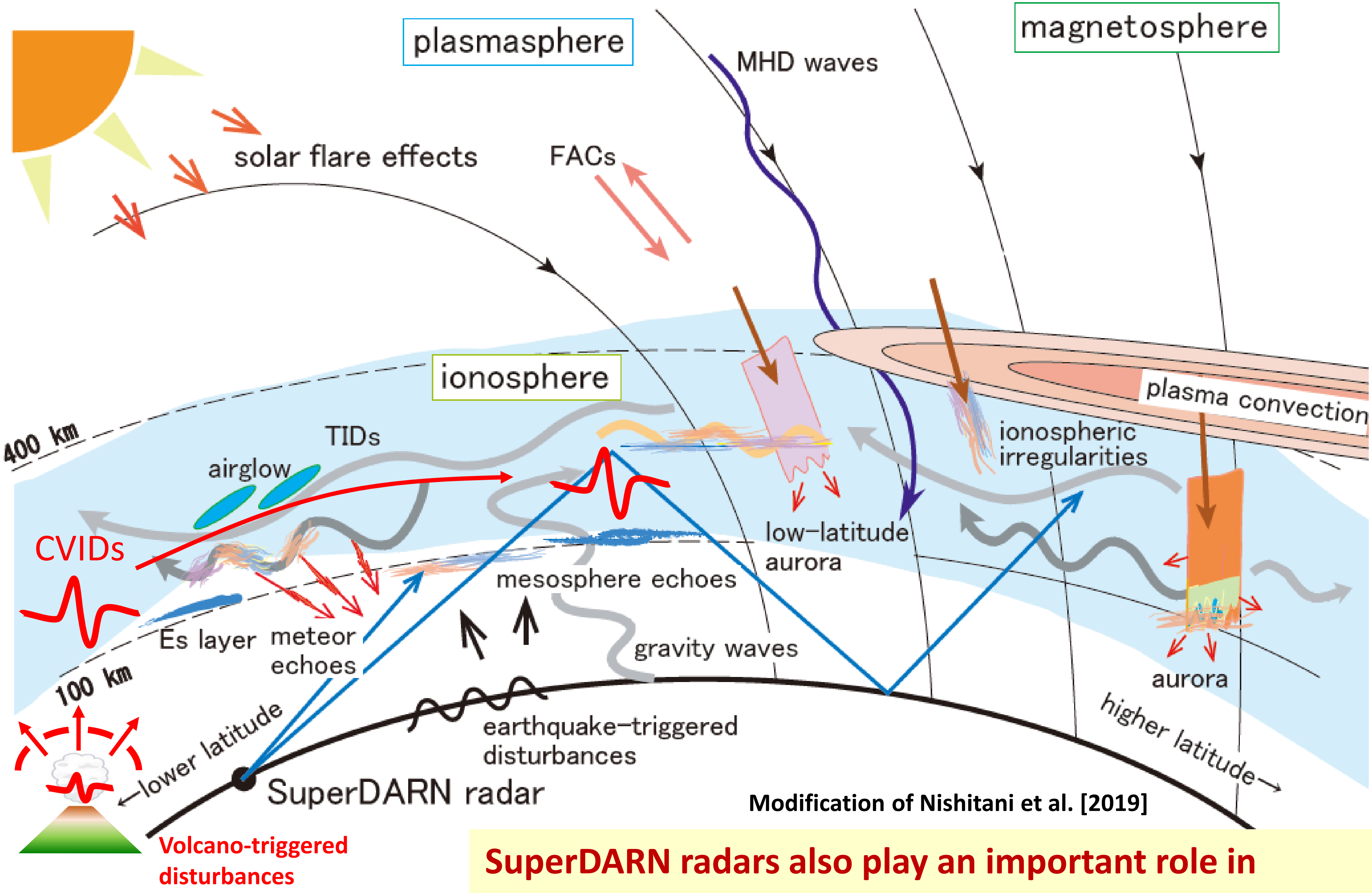
2. *Disaster risk reduction*

The propagation speed of electromagnetic fields that produce ionospheric disturbances is much faster than that of tsunamis, sound, and seismic waves.

↓

Tracking information on ionospheric disturbances will help us to predict Tsunami before it arrives.

5. Conclusions

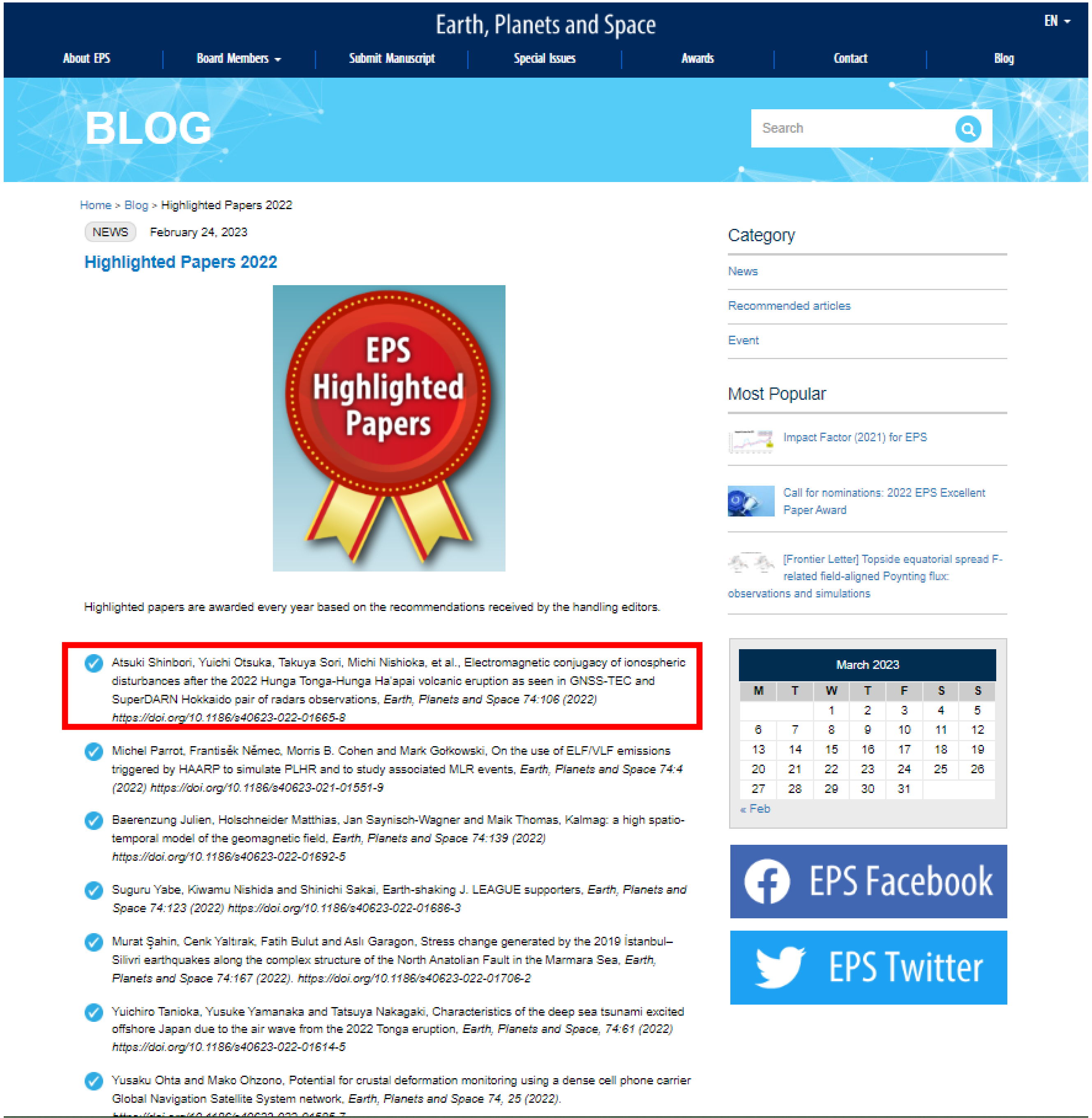


Modification of Nishitani et al. [2019]

CVID: Co-Volcanic Ionospheric Disturbances

SuperDARN radars also play an important role in understanding the coupling processes of lithosphere-atmosphere-ionosphere associated with volcanic eruptions.

6. Awards and press releases



Home > Blog > Highlighted Papers 2022

NEWS February 24, 2023

Highlighted Papers 2022

Highlighted papers are awarded every year based on the recommendations received by the handling editors.

- Atsuki Shinbori, Yuichi Otsuka, Takuya Sori, Michi Nishioka, et al., Electromagnetic conjugacy of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption as seen in GNSS-TEC and SuperDARN Hokkaido pair of radars observations, *Earth, Planets and Space 74:106 (2022) https://doi.org/10.1186/s40623-022-01665-8*
- Michel Parrot, František Němec, Morris B. Cohen and Mark Gołkowski, On the use of ELF/VLF emissions triggered by HAARP to simulate PLHR and to study associated MLR events, *Earth, Planets and Space 74:4 (2022) https://doi.org/10.1186/s40623-021-01551-9*
- Baerenzung Julien, Holschneider Matthias, Jan Saynisch-Wagner and Maik Thomas, Kalmag: a high spatio-temporal model of the geomagnetic field, *Earth, Planets and Space 74:139 (2022) https://doi.org/10.1186/s40623-022-01692-5*
- Suguru Yabe, Kiwamu Nishida and Shinichi Sakai, Earth-shaking J. LEAGUE supporters, *Earth, Planets and Space 74:123 (2022) https://doi.org/10.1186/s40623-022-01686-3*
- Murat Şahin, Cenk Yaltırak, Fatih Bulut and Aslı Garagon, Stress change generated by the 2019 İstanbul–Silivri earthquakes along the complex structure of the North Anatolian Fault in the Marmara Sea, *Earth, Planets and Space 74:167 (2022). https://doi.org/10.1186/s40623-022-01706-2*
- Yuichiro Tanioka, Yusuke Yamanaka and Tatsuya Nakagaki, Characteristics of the deep sea tsunami excited offshore Japan due to the air wave from the 2022 Tonga eruption, *Earth, Planets and Space, 74:61 (2022) https://doi.org/10.1186/s40623-022-01614-5*
- Yusaku Ohta and Mako Ohzono, Potential for crustal deformation monitoring using a dense cell phone carrier Global Navigation Satellite System network, *Earth, Planets and Space 74, 25 (2022).*

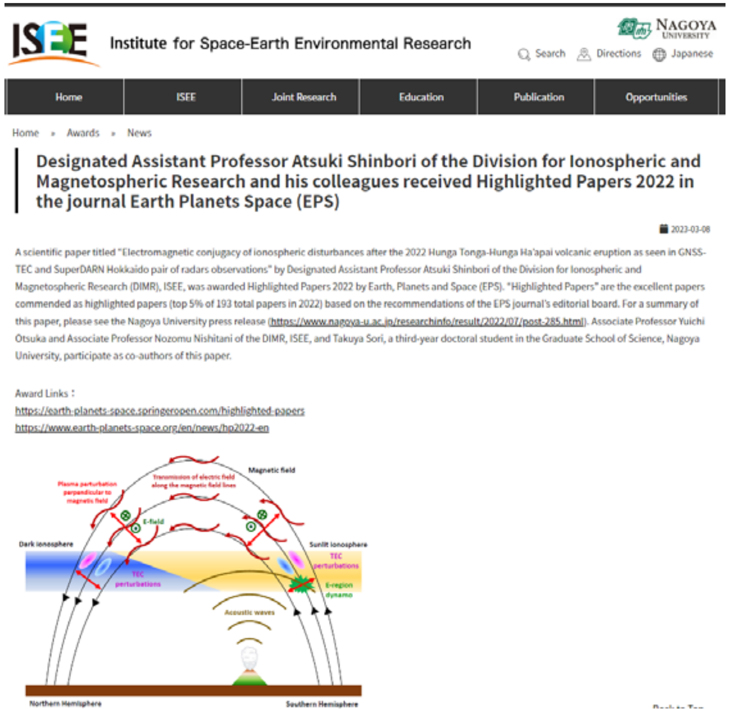
M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Our paper was selected as one of the highlighted papers in 2022 by EPS Editorial Board.

Highlighted papers: 10

All papers in 2022: 191

→ About 5% of papers were awarded by Highlighted Papers 2022.



Home » Awards » News

Designated Assistant Professor Atsuki Shinbori of the Division for Ionospheric and Magnetospheric Research and his colleagues received Highlighted Papers 2022 in the journal Earth Planets Space (EPS)

2023-03-08

A scientific paper titled "Electromagnetic conjugacy of ionospheric disturbances after the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption as seen in GNSS-TEC and SuperDARN Hokkaido pair of radars observations" by Designated Assistant Professor Atsuki Shinbori of the Division for Ionospheric and Magnetospheric Research (DIMR), ISEE, was awarded Highlighted Papers 2022 by Earth, Planets and Space (EPS). "Highlighted Papers" are the excellent papers commended as highlighted papers (top 5% of 193 total papers in 2022) based on the recommendations of the EPS journal's editorial board. For a summary of this paper, please see the Nagoya University press release (https://www.nagoya-u.ac.jp/researchinfo/result/2022/07/post-285.html). Associate Professor Yuichi Otsuka and Associate Professor Nozomu Nishitani of the DIMR, ISEE, and Takuya Sori, a third-year doctoral student in the Graduate School of Science, Nagoya University, participate as co-authors of this paper.

Award Links：
https://earth-planets-space.springeropen.com/highlighted-papers
https://www.earth-planets-space.org/en/news/hp2022-en

6. Awards and press releases

AlphaGalileo

https://www.alphagalileo.org/en-gb/

The world's media need facts.

Providing the latest source research news to industry journalists ar

2K
Contributors

7K
Journalists

40
Yearly

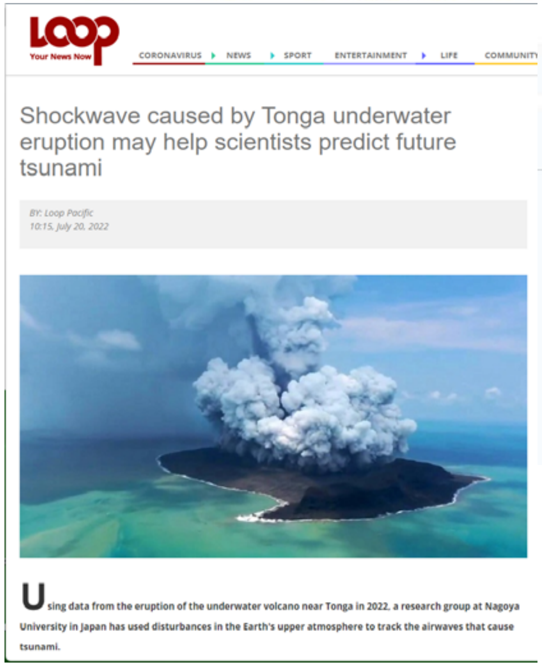
HOME > ENVIRONMENT & CLIMATE

Tsunami Prediction Could Become Possible Using Data From Tonga Underwater Volcano Eruption

Margaret Davis Jul 15, 2022 01:41 AM EDT

The Tonga underwater volcano started erupting on Dec. 20, 2021, and grew very large and powerful nearly four weeks later when it climaxed on Jan. 15, 2022. The Hunga Tonga-Hunga Ha'apai volcanic eruption destroyed the island. A team of researchers at Japan's Nagoya University is using the data from the eruption to track airwaves and tsunamis.

They believe that tracking shockwaves from the eruption that also caused disturbances in the ionosphere could lead to speedier predictions of future giant waves and tsunamis.



Shockwave caused by Tonga underwater eruption may help scientists predict future tsunami

BY: Loop Pacific
10:15, July 20, 2022

Using data from the eruption of the underwater volcano near Tonga in 2022, a research group at Nagoya University in Japan has used disturbances in the Earth's upper atmosphere to track the airwaves that cause tsunami.

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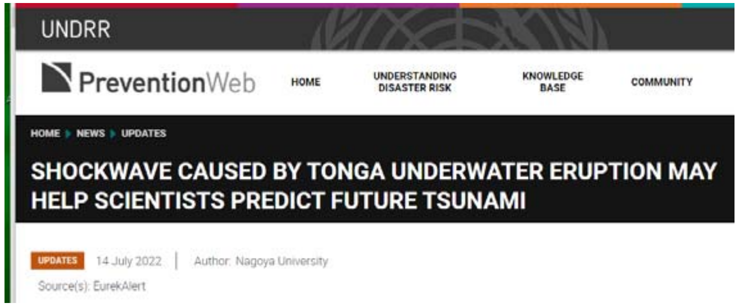

HOME > NEWS > UPDATES

SHOCKWAVE CAUSED BY TONGA UNDERWATER ERUPTION MAY HELP SCIENTISTS PREDICT FUTURE TSUNAMI

UPDATES 14 July 2022 | Author: Nagoya University
Source(s): EurekAlert

https://www.preventionweb.net/news/shockwave-caused-tonga-underwater-eruption-may-help-scientists-predict-future-tsunami