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Ionospheric disturbances in Europe caused by the 2022 Hunga-Tonga volcanic eruption

Tobias G.W. Verhulst[1,2] David Altadill[3] Veronika Barta[4] Anna Belehaki[5] Dalia Burešová[6] Claudio Cesaroni[7] Ivan Galkin[8,9] Marco Guerra[10] Alessandro Ippolito[7] Themistocles Herekakis[5] Daniel Kouba[6] Jens Mielich[11] Antoni Segarra[3] Luca Spogli[7,10] Ioanna Tsagouri[5]

[1]Royal Meteorological Institute of Belgium [2]Solar-Terrestrial Centre of Excellence [3]Observatori de l'Ebre [4]Institute of Earth Physics and Space Science, Sopron [5]National Observatory of Athens [6]Institute of Atmospheric Physics, Czech Academy of Sciences [7]Istituto Nazionale di Geofisica e Vulcanologia [8]Borealis Global Designs Ltd. [9]Space Science Laboratory, UMass Lowell [10]SpacEarth Technology [11]Leibniz-Institute of Atmospheric Physics

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Solar-Terrestrial Centre of Excellence

Outline

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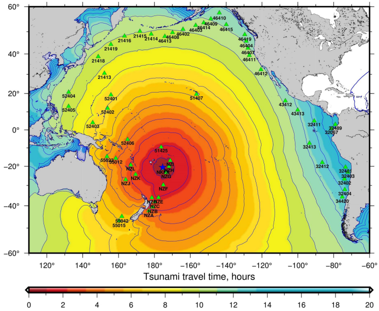
Introduction

On January 15th, 2022 at 04:15 UTC, the Hunga volcano in Tonga produced a major eruption. Because of the interaction with sea water it had significant explosive power.



Introduction

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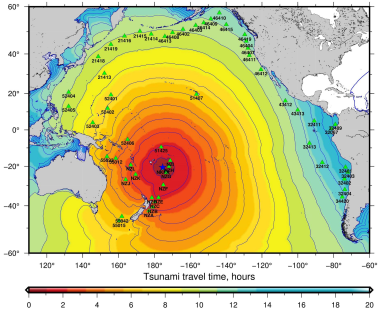

Important issue:

Different mechanisms can produce TIDs simultaneously.

Ionospheric effects

Two further circumstances of the eruption are to be considered for the ionospheric effects in Europe:

1. The location of the Hunga eruption was at 20.5°S 175.4°W, putting the antipode in northern Africa.
2. The timing of the eruption coincided with moderate geomagnetic storms.

Ionospheric effects

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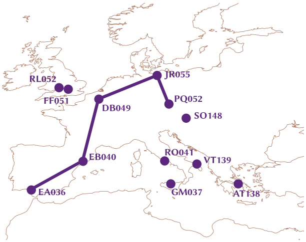
2. The timing of the eruption coincided with moderate geomagnetic storms.

Thus, we arrive at the following questions:

1. To what extend, and through which mechanisms, do TIDs propagate to Europe?
2. Can the TIDs from this eruption be distinguished from those caused by the geomagnetic disturbances?

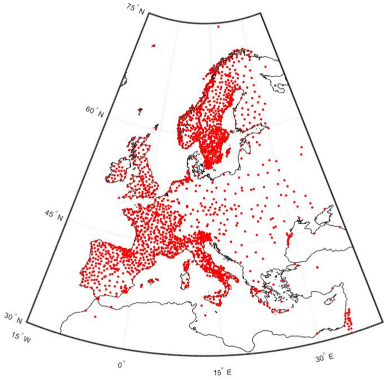
We look at various independent observations for answers.

Ionosondes



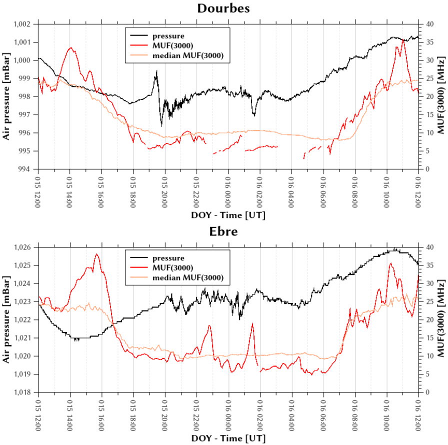
- We use vertical incidence ionograms from 12 ionosondes, plus oblique ionograms from 4 pairs.
- Sounding cadences vary between five and fifteen minutes.
- All data manually scaled (will be available through GIRO).
- We use *MUF* as well as detrended iso-density contours.
- For some ionosonde we also use plasma drift data.

GNSS receivers



- A large number of GNSS receivers are used to obtain *TEC* data, covering latitudes between 30° and 70°N.
- Data is detrended using the VARION procedure, with a tenth-order polynomial.
- Large number of data points allows for detailed reconstruction of TID movement.

*MUF*3000 and pressure



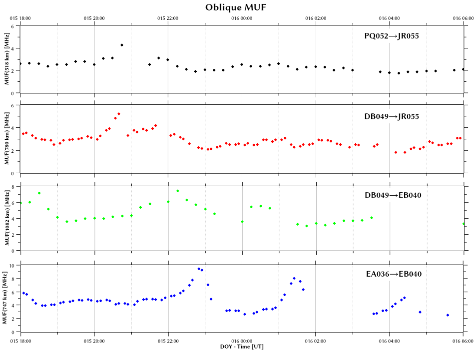
At night, two main peaks corresponding to great-circle velocities of 300 m/s and 304 m/s from the eruption.

Main peaks appear 45 to 60 minutes after the barometer signals arrival of ground level disturbances.

The periods indicate medium scale TIDs.

Major disturbances in *MUF*3000 are seen during the day on January 15: maybe geomagnetic origin?

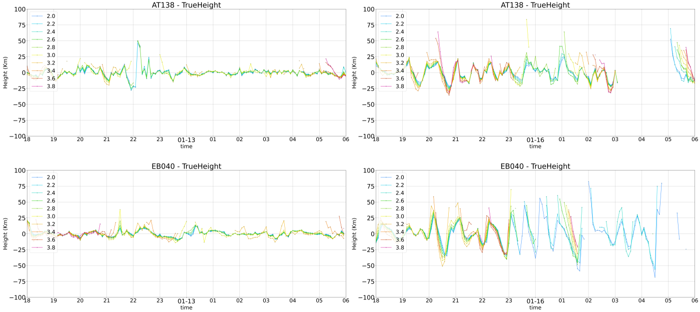
Oblique *MUF* observations



The *MUF* obtained from oblique ionogram traces on various paths shows the waves travelling to and from the eruption antipode (wherever good data are available).

Iso-density contours

Reconstructed detrended true-height plots for densities from 2.0 to 3.8 MHz.



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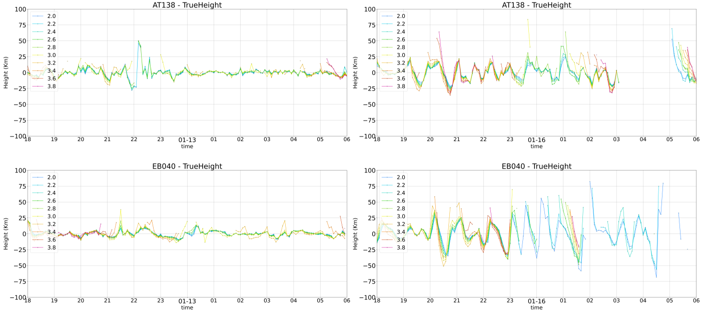

This looks very different from the *MUF* signature:

1. a train of oscillations instead of single peaks,
2. the disturbance starts around the moment of arrival of the pressure wave.

Plasma drift measurements

Hunga volcanic eruption ionospheric effects

T. Verhulst

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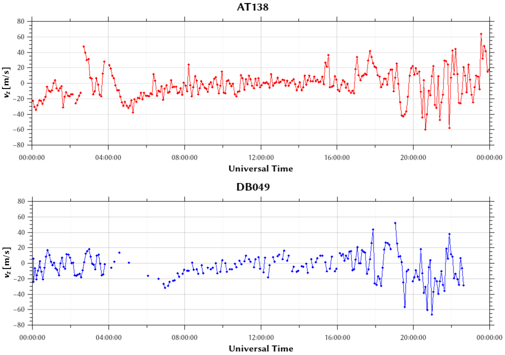
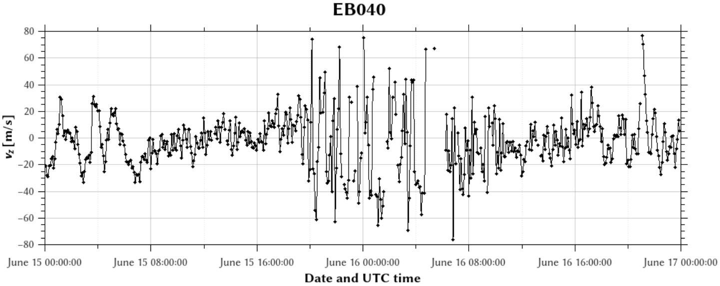


Ionosondes detected vertical plasma drift oscillations appear following the arrival of tropospheric disturbances, but last longer.

Plasma drift measurements



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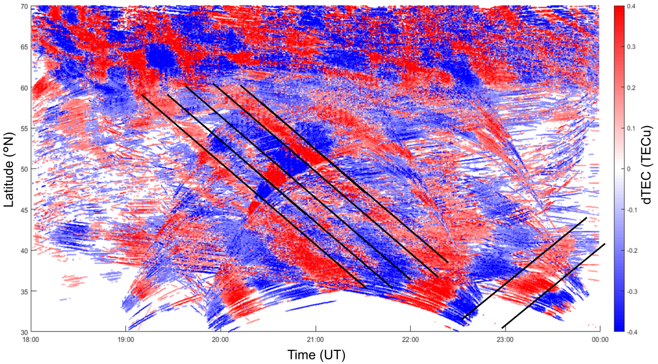
GNSS derived *TEC*



dTEC at the ionospheric pierce points, for longitudes between 12.5° and 17.5°E. Waves travelling southward between 19 and 22 UTC, followed by northward travelling waves. Wave fronts travelling at 310 m/s are indicated.

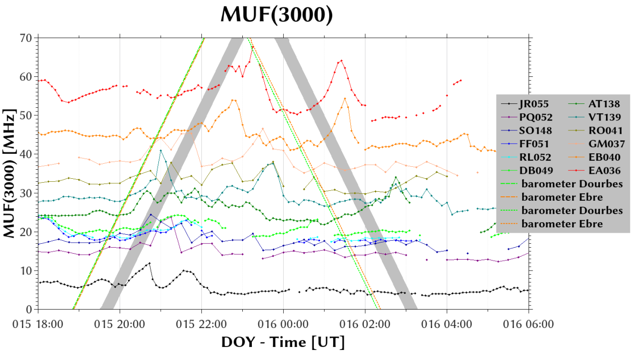
Propagation of disturbances

Name	URSI code	Latitude	Longitude	Distance	Azimuth
Juliusruh	JR055	54.6°N	13.4°E	15,931 km	29.0°
Fairford	FF051	51.7°N	−1.5°E	16,536 km	5.6°
Chilton	RL052	51.5°N	−0.6°E	16,551 km	7.3°
Dourbes	DB049	50.1°N	4.6°E	16,626 km	17.2°
Pruhonice	PQ052	50.0°N	14.6°E	16,326 km	34.3°
Sopron	SO148	47.6°N	16.7°E	16,443 km	39.9°
Rome	RO041	41.9°N	12.5°E	17,148 km	39.3°
Roquetes	EB040	40.8°N	0.5°E	17,707 km	13.7°
San Vito	VT139	40.6°N	17.8°E	16,940 km	50.3°
Athens	AT138	38.0°N	23.5°E	16,694 km	62.3°
Gibilmanna	GM037	37.9°N	14.0°E	17,384 km	48.1°
El Arenosillo	EA036	37.1°N	−6.7°E	18,158 km	353.19°

The (relatively) easy part

TIDs caused by the eruption can be distinguished from those of geomagnetic origin by their travel direction derived from arrival times at different observatories.

Propagation of disturbances



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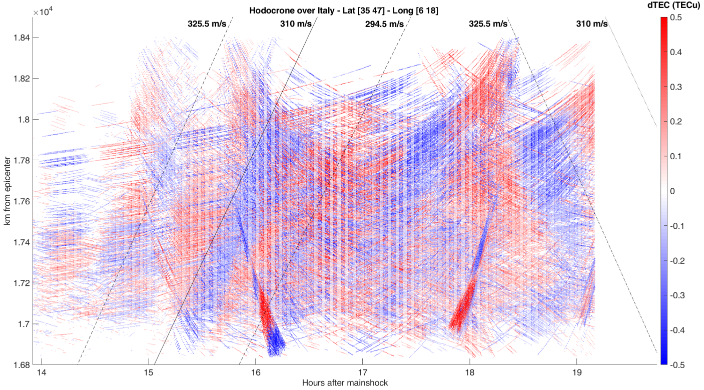

dTEC at the ionospheric pierce points for all Italian receivers. Waves travelling southward between 19 and 22 UTC, followed by northward travelling waves. The second wave was slightly faster than the first.

Timing of the TIDs

The travel times for the onset of the TIDs are consistent between 300 m/s and 310 m/s, seen in both ionosonde observations and *TEC* data.

This is consistent with TIDs produced locally from disturbances travelling through the troposphere.

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The more problematic part

The *MUF*, iso-density contours, drift observations and *TEC* do not agree in the onset time and morphology of the disturbances.

This could be due to different types of waves—Lamb waves, primary/secondary gravity waves, infrasound, etc.—affecting different ionospheric characteristics.

Conclusions

1. TIDs caused by the eruption can be distinguished from others by their travel direction and size.
2. Ionospheric effects seen in Europe are probably produced by disturbances propagating through the troposphere.
3. Some data sets are in good agreement, others are not...
4. *MUF* time series show something different from *TEC* and electron density, possibly detecting different types of waves.
5. Some detailed investigation is needed to understand why some different quantities are sensitive to different kinds of TIDs.

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The end, thank you!

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