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Supporting Information for

Rapid Conjugate Appearance of the Giant Ionospheric Lamb Wave in the Northern Hemisphere After Hunga Tonga Volcano Eruptions

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Additional Supporting Information (Files uploaded separately)

Introduction

The atmospheric pressure waves generated by Tonga volcano eruption triggered CTIDs in the ionosphere, which are imaged by using TEC observations from the dense GNSS network over Australia, New Zealand and Japan. The perturbations components of different wave characteristics are separated by applying bandpass filters of 30-50 min, 12-20 min and 10-60 min periods. The movie S1 shows the complete time sequence of CTID's that arrive over New Zealand, Australia, and Japan using the filtered TECs, offering a comprehensive view of their time evolution and propagation depicted by the selected snapshots in Figure1.

One of the remarkable features seen in these observations are the conjugate CTIDs over Japan, seen almost instantaneously after the arrival of the Lamb waves, but much ahead of their anticipated arrival at Japan. Later, after 1000 UT, when the Lamb waves arrive over Japan, in situ CTID's are observed in the TEC perturbations, similar to those seen in the conjugate projections 0800-0900 UT in Figure 1. The Figure S2 shows these in situ perturbations over Japan after 1000 UT, also showing their wave characteristics that match with the CTIDs observed from the conjugate hemisphere.

Figure S3 shows the theoretical dispersion curve of acoustic and gravity modes in the ionospheric heights and the surface Lamb mode. The wave characteristics of the CTIDs extracted from Figure S2 are aligned with the Lamb mode, confirming that the CTID's are driven by the volcano generated Lamb waves, similar to those shown in Figure 4.

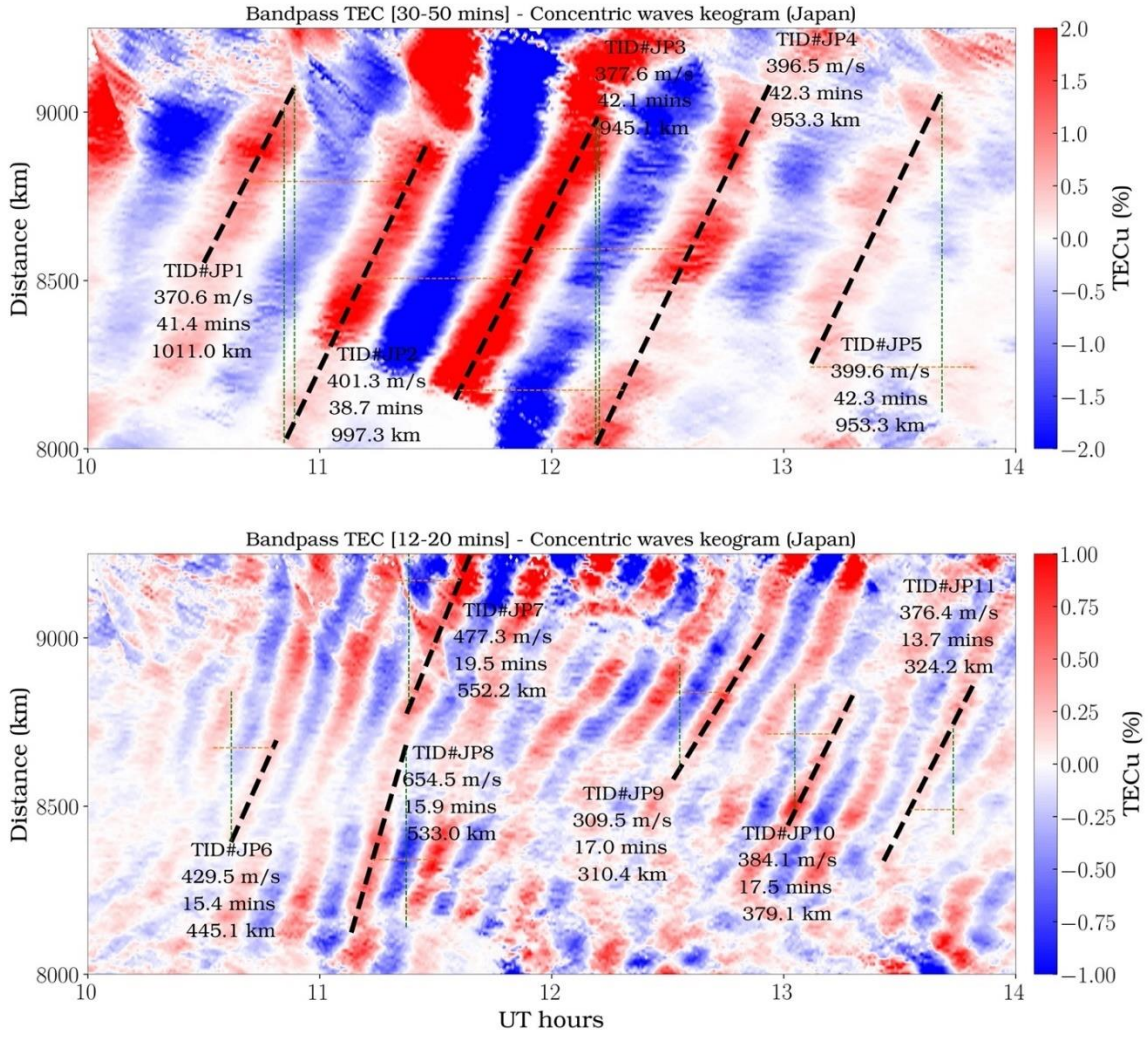

Figure S2. Keograms of the filtered TEC of 30-50 min (top) and 12-20 min (bottom) over Japan for the characteristics of CTIDs driven by the arrival of the air pressure Lamb wave to Japan at 1000UT. The distances are from the volcano to the sub-ionospheric point (SIP) locations over Japan.

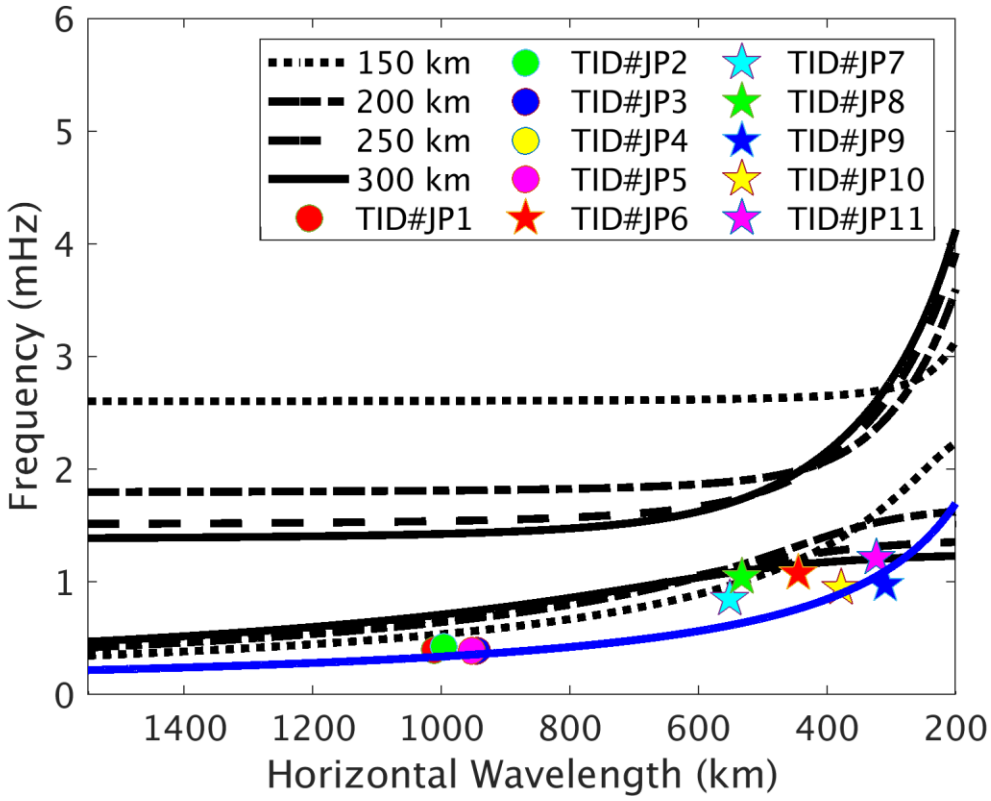

Figure S3. The theoretical dispersion curves of acoustic and gravity modes at 150 (dotted), 200 (dashed), 250 (long-dashed) and 300 (solid) km altitudes over Japan region are indicated in line plots. The colored dots/asterisk correspond to the observed TIDs over Japan after 1000 UT shown in Figure S2. Blue solid line indicates the Lamb mode.

Movie S1. Movie of bandpass filtered TECs of 12-20 min (left), 30-50 min (middle) and 10-60 min (right) periods showing the conjugate concentric TIDs after mapping Japan (Australia) TECs to Sothern (Northern hemisphere). The original TECs are plotted with "parula" colormap consisting of blue, green and yellow, while the conjugate TECs are plotted with "copper" colormap consisting of black and gold color. The dashed red circles denote the arrival of the atmospheric Lamb waves. The location of the eruption is marked using red star. The cyan line represents the locations of the geomagnetic equator, and the yellow and violet lines respectively indicate the locations ±20, and ±40° away from the equator.