



Title	Ionospheric anomalies immediately before M(w)7.0-8.0 earthquakes
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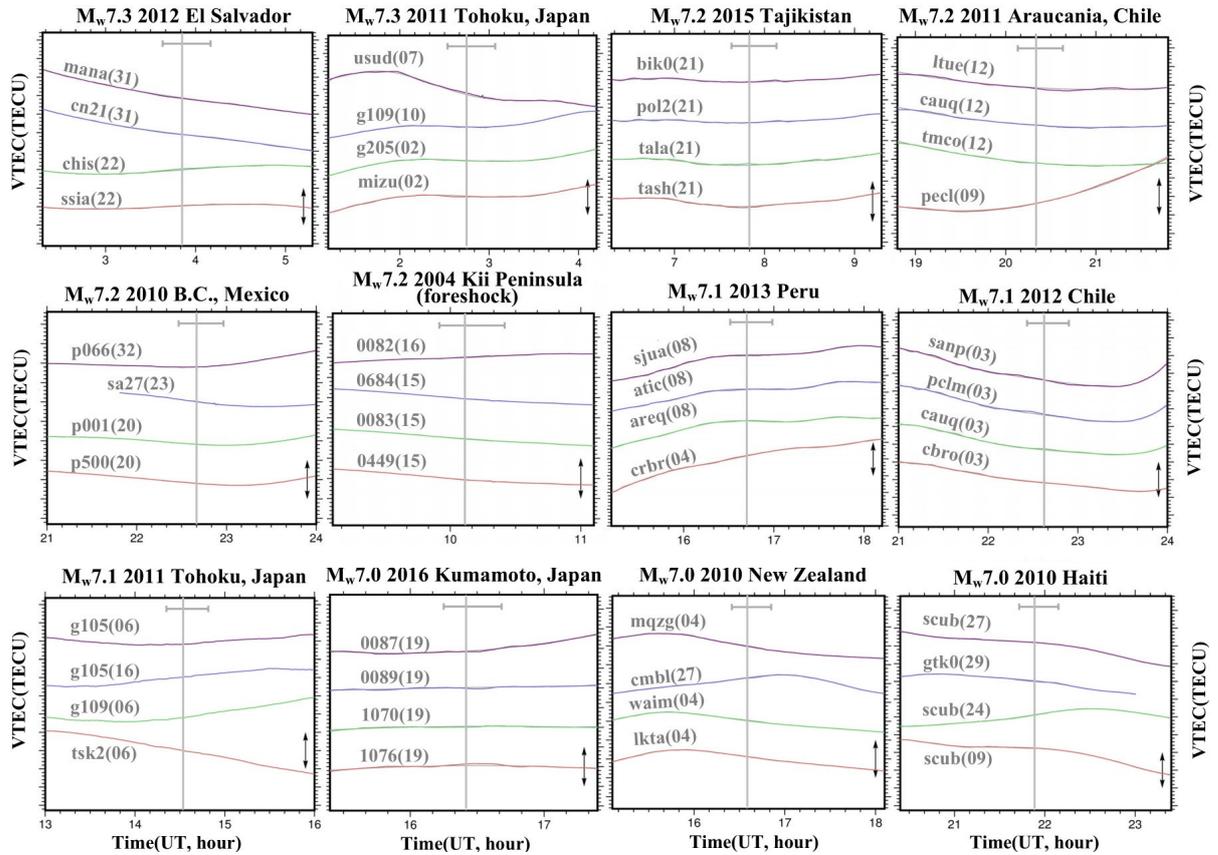
Figures S1 to S5
Table S1

Additional Supporting Information (Files uploaded separately)

None

Introduction

This supporting information provides five figures and one table: VTEC time series obtained from four station-satellite pairs near the epicenter, for 12 of the 24 earthquakes without preseismic anomalies (Figure S1), maps showing the SIP trajectories (the same color for the same station-satellite pair in Figure S1) calculated assuming the ionospheric height of 200 km for 12 of the 24 earthquakes without precursory TEC changes (Figure S2), behaviors of the post-fit residuals for various degrees of polynomials used to model the reference curves excluding certain windows before and after earthquakes (Figure S3), *Dst* indices during 30-day periods before and after eight earthquakes with possible ionospheric TEC anomalies (Figure S4), VTEC time series over seven consecutive days with the same pair of satellite-station for the 2016 Gorkha, Nepal, earthquake mainshock and the largest aftershock (Figure S5), and the prescribed excluding time windows for earthquakes with M_w from 7.0 to 8.0 used in this study (Table S1).



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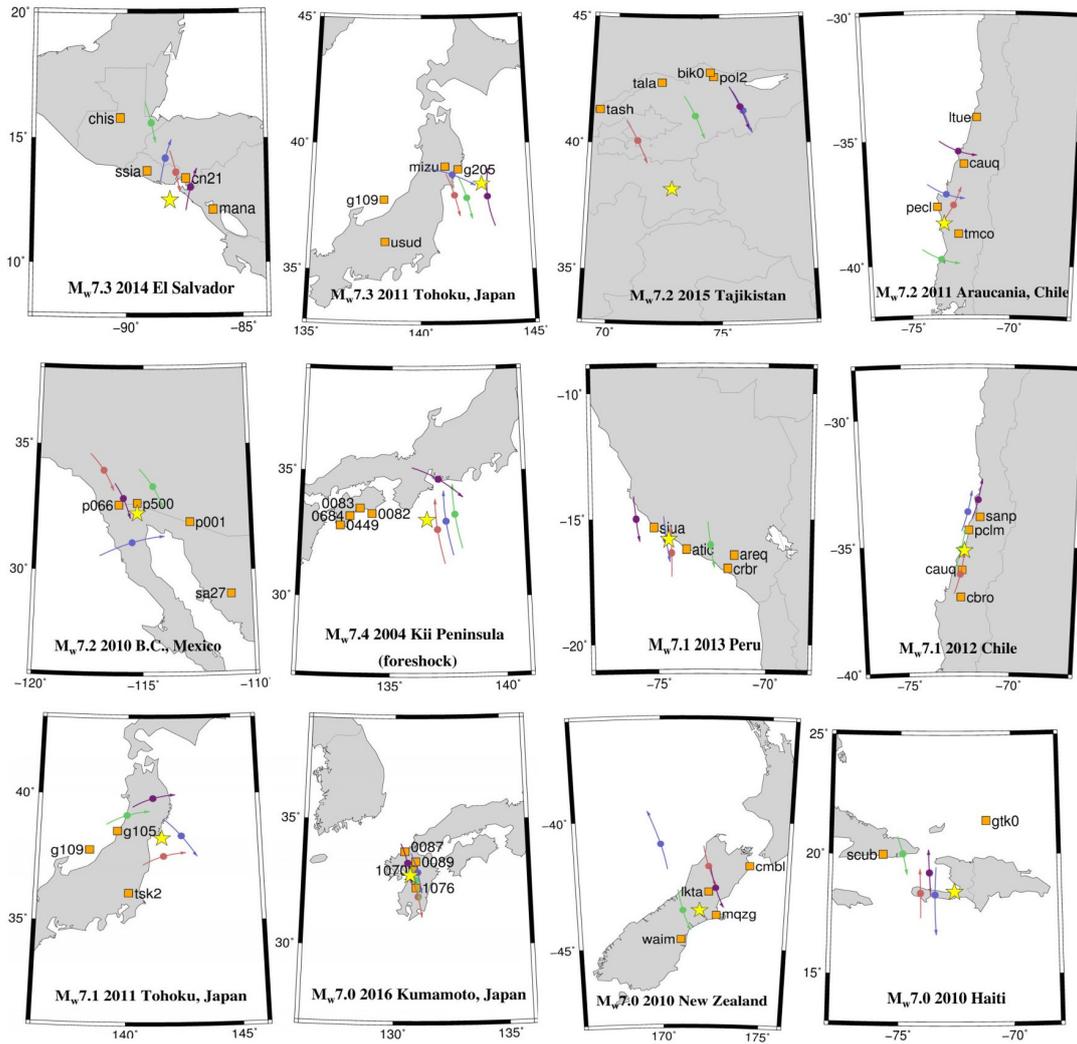
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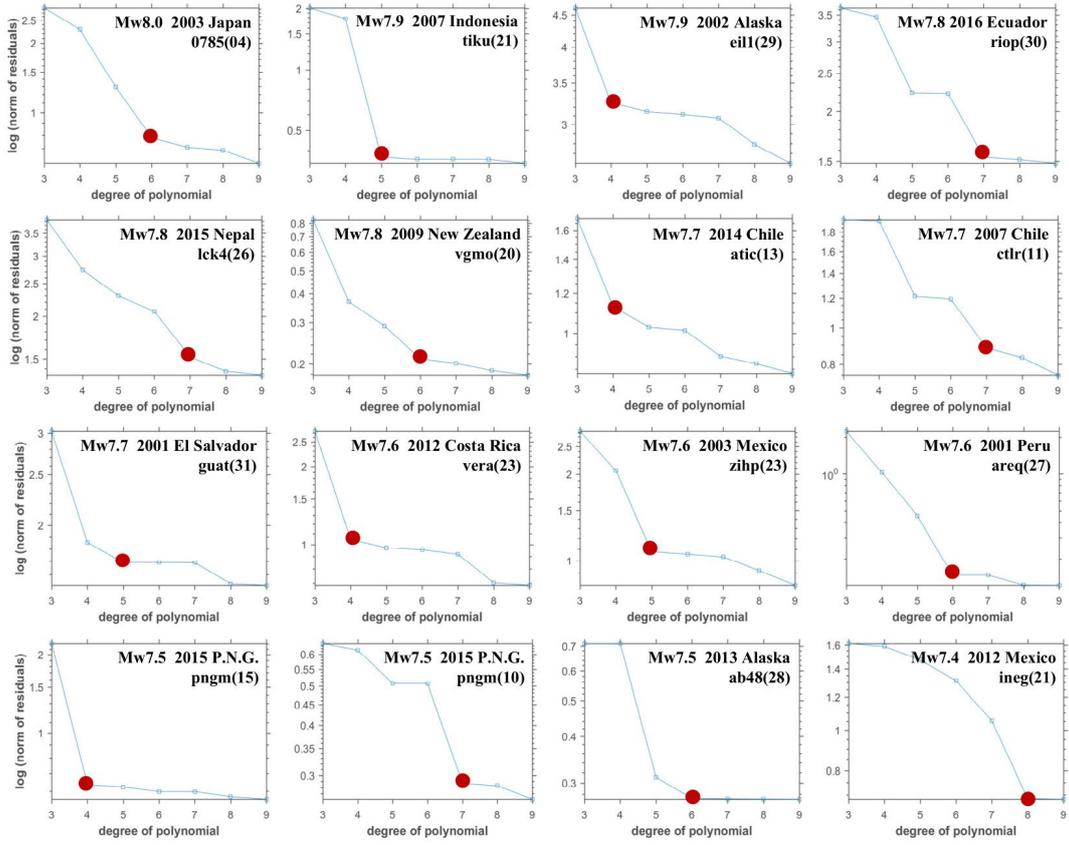
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Figure S1. VTEC time series obtained from four station-satellite pairs near the epicenter, for 12 of the 24 earthquakes without preseismic anomalies (marked with symbol “x” in Table 1). The gray horizontal bars represent the excluded time period in defining the reference curves. The gray vertical lines represent the earthquake times. The vertical arrows represent 10 TECU. The degree of the polynomials used to model the reference curves are given in Table 1.

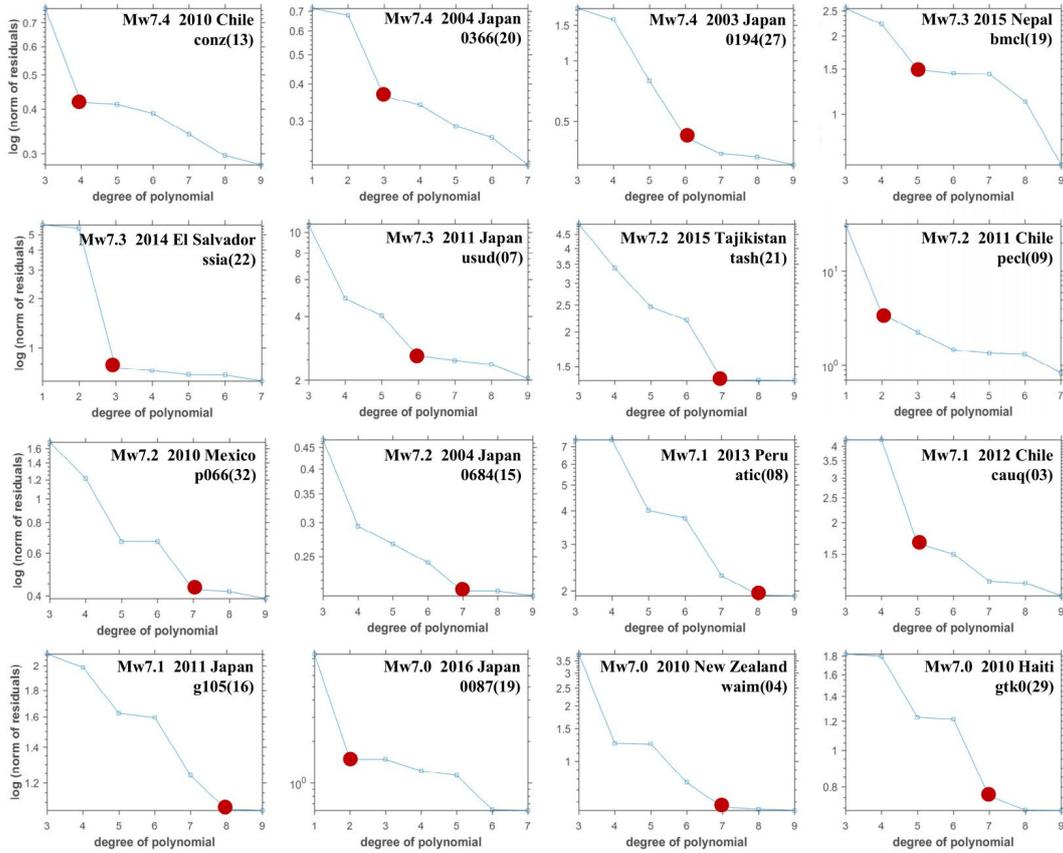


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Figure S2. Maps showing the SIP trajectories (the same color for the same station-satellite pair in Figure S1) calculated assuming the ionospheric height of 200 km for 12 of the 24 earthquakes without precursory TEC changes (marked with symbol "x" in Table 1). The orange squares show the locations of GNSS stations. The colored circles on the SIP trajectories show the SIP at the earthquake time. The yellow stars show the epicenters.

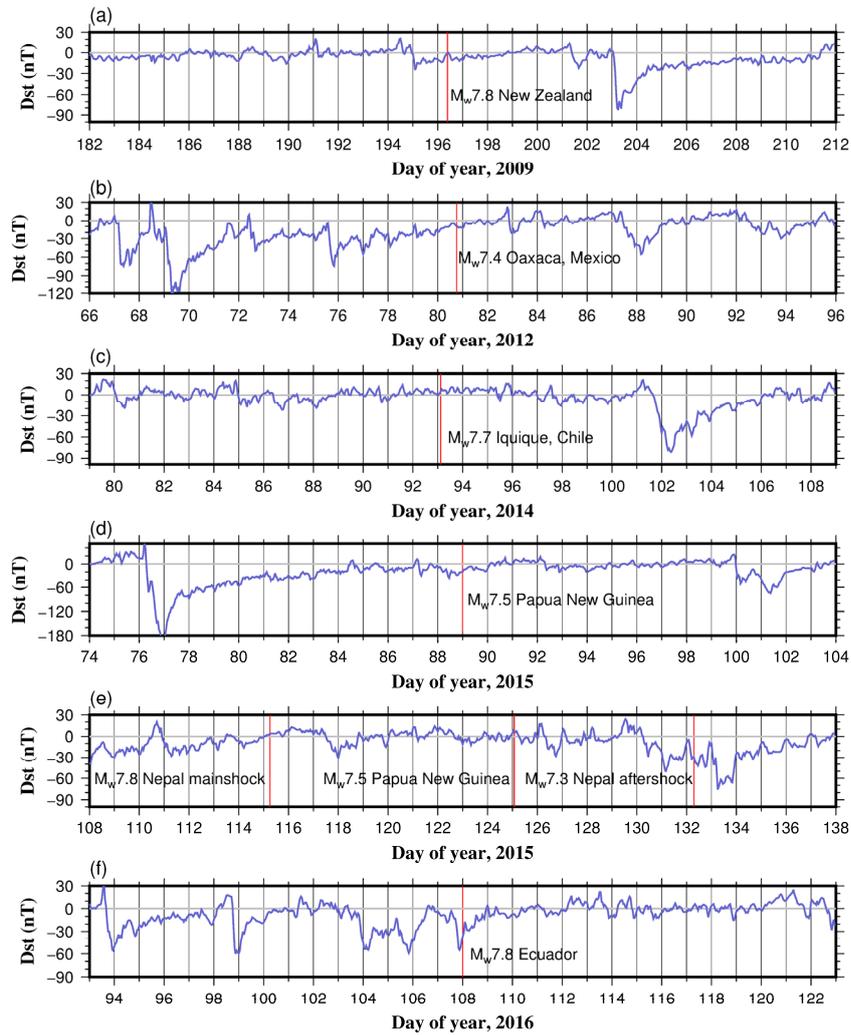


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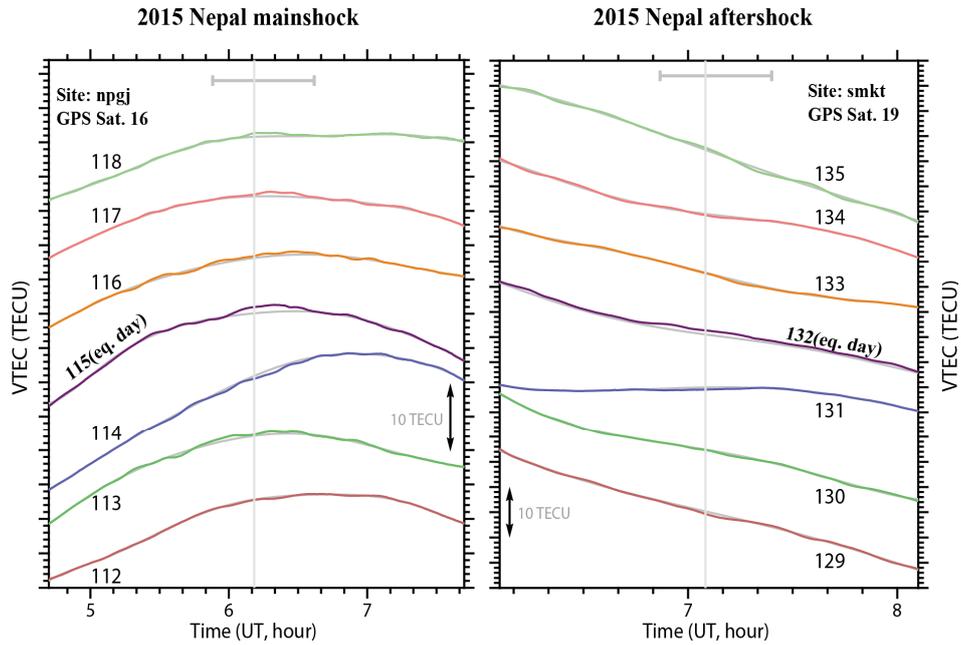
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Figure S3. Behaviors of the post-fit residuals for various degrees of polynomials used to model the reference curves excluding certain windows before and after earthquakes. We employed the degrees marked with the red dots. The earthquakes are arranged in the same order as in Table 1.



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Figure S4. *Dst* indices during 30-day periods before and after the 2009 New Zealand (a), the 2012 Oaxaca (b), the 2014 Northern Chile (aftershock) (c), the March 2015 Papua New Guinea (d), the 2015 Gorkha Nepal (mainshock), the May 2015 Papua New Guinea, and the 2015 Gorkha Nepal (aftershock) (e), and the 2016 Ecuador (f) earthquakes. The vertical red lines represent the earthquake occurrence times. Data downloaded from NASA/OMNIWeb (omniweb.gsfc.nasa.gov).



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78 **Figure S5.** VTEC time series over seven consecutive days with the same pair
 79 of satellite-station for the 2016 Gorkha, Nepal, earthquake mainshock (a) and
 80 the largest aftershock (b). Although high background VTEC continues over
 81 these periods due to the passage of line-of-sight with the equatorial
 82 ionospheric anomaly (EIA), we detect positive anomalies only on the
 83 earthquake days (day 115 for the mainshock and day 132 for the aftershock).

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Table S1. The prescribed excluding time windows for earthquakes with M_w from 7.0 to 8.0 used in this study. Negative and positive times represent times before and after earthquakes, respectively.

M_w	Excluding time window (minutes)	
	Start	End
8.0	-20	+30 ($10^{*1} + 20^{*2}$)
7.9	-19	+28 (10 + 18)
7.8	-18	+26 (10 + 16)
7.7	-17	+24 (10 + 14)
7.6	-16	+22 (10 + 12)
7.5	-15	+21 (10 + 11)
7.4	-14	+20 (10 + 10)
7.3	-13	+19 (10 + 9)
7.2	-12	+18 (10 + 8)
7.1	-11	+17 (10 + 7)
7.0	-10	+16 (10 + 6)

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*¹Time for acoustic waves to propagate to the F region and to make a hole, *²Time for LOS to escape from the electron depletion region (hole).