GPS全電子数観測により捉えられた東北地方太平洋沖地震後の電離圏変動

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Ionospheric disturbances detected by GPS total electron content observation after the 2011 Tohoku earthquake

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All the details of the commencement and evolution of ionospheric disturbances after the 2011 off the Pacific coast of Tohoku Earthquake were revealed by the high-resolution GPS total electron content observation in Japan. The initial ionospheric disturbance appeared as sudden depletions by about 6 TEC unit (20%) following small impulsive TEC enhancements around 05:54UT, about seven minutes after the earthquake onset, near the epicenter. At 06:00UT, zonally extended enhancements of TEC appeared in the west of Japan, and traveled to the southwest direction. From 06:00UT to 06:15UT, large-scale circular waves with two peaks propagated in the radial direction in the propagation velocity of 3,457 m/s and 783 m/s for the first and second peak, respectively. Following the large-scale waves, medium-scale concentric waves appeared to propagate at the velocity of 138-423 m/s after 06:15 UT. In the vicinity of the epicenter, short-period oscillations with period of about 4 minutes were observed after 06:00 UT for 3 hours or more. We focus on the the circular and concentric waves in this paper. The circular or concentric structures of the large- and medium-scale waves indicate that these ionospheric disturbances had a point source. The center of these structures was located around 37.5 deg N of latitude and 144.0 deg E of longitude, 170 km far from the epicenter to the southeast direction. We termed this center of the coseismic ionospheric variations as "ionospheric epicenter". According to the propagation velocities, the large-scale waves would be caused by the acoustic waves generated from the propagating Rayleigh wave for the first peak and from the sea surface near the epicenter for the second peak. The wavelength and the propagation velocity of the medium-scale concentric waves tended to decrease with time. This characteristic is consistent with the result of a numerical model of the coseismic atmospheric wave, indicating that these medium-scale waves were caused by the atmospheric gravity waves. The amplitude of the large- and medium-scale circular waves were not uniform depending on azimuth of their propagation direction, much larger in the north and west directions than other directions. This directivity could not be explained by the previously proposed theory.

2011年3月11日の東北地方太平洋沖地震後の電離圏擾乱現象の発生と時間発展について、高解像度GPS全電子数（TEC）観測を用いて詳細に明らかにした。最初のTEC変動は、震央付近、地震から約7分後の05:54UT、0.5-1TECU程度のインパルシブなTEC増大後、05:56UTから急激なTEC減少（背景に対して20％）が見られた。このTEC減少は30分から1時間程度続き、徐々に定常レベルに戻っていった。このTEC減少領域の中心はUSGS発表の震央からは170km南東にずれていた。電離圏擾乱の中心を「ionospheric epicenter」と名付けた。06:00UTに、北西-南東方向に伸びた波面を持ち、南西方向に伝搬するTEC増大領域が見られた。これとほぼ同時の06:00-06:15UT、大規模（波長500km以上）な円状のTEC変動がionospheric epicenterを中心に、放射状に伝搬した。この大規模な移動性電離圏擾乱は、負の変動が最初の2つピークを持ち、伝搬速度は1つ目が3,457 m/s、2つ目が783 m/sであった。大規模移動性電離圏擾乱が伝搬後の06:15UT以降、波長200-300 km程度の中規模同心円状波動が現れた。速度は138-423 m/sで、時間と共に遅い波が観測されていた。また、これらの波動現象とは別に、震源付近では、06:00 UTのTEC減少と共に、約4分周期の短周期変動が見られた。この短周期振動は3時間以上続いていた。本発表では、これらの電離圏擾乱の全体像を報告すると共に、主として同心円状の構造を持つ移動性電離圏擾乱について議論を行う。