Observation and Simulation of the Concentric Gravity Wave Seeding of Equatorial Nighttime Medium

Scale Traveling Ionosphere Disturbances

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Abstract

Two remarkable typhoon-induced traveling ionospheric disturbances (TIDs) with concentric and northwest-southeast (NW-SE) alignments, respectively, associated with concentric gravity waves (CGWs) and nighttime ionosphere instabilities, were observed in GNSS total electron content (TEC) when the Category 5 Super Typhoon Nepartak approached Taiwan on 7 July 2016. The concentric TIDs (CTIDs) first appear during 08:00-11:20 UT, followed by the NW-SE aligned nighttime medium-scale TIDs (MSTIDs) over the Taiwan Strait during 11:30-14:00 UT. The NRL SAMI3/ESF simulations suggest that the electrodynamic coupling between CGWs and Perkins instability can initiate the rarely observed equatorial nighttime MSTIDs. Both the simulations and observations show that the westward and equatorward propagating CGWs with similar wavefront alignments to the Perkins instability could enhance the generation of MSTIDs rather than the northward propagating CGWs. The CGWs penetrating to the ionospheric F layer without severe dissipation can induce greater polarization electric fields to accelerate the Perkins instability via E x B drifts.

Super Typhoon Nepartak

- Soumi NPP satellite VIIRS/DNB observations
- Category 5 Super Typhoon Nepartak was the second most intense tropical cyclone worldwide in 2016. The Soumi NPP satellite VIIR/DNB captured distinct Nepartak-induced CGWs in the mesopause region.

Nepartak-induced CTIDs and MSTIDs in GNSS TEC

- The TEC maps show clear concentric gravity waves triggered by Super Typhoon Nepartak on 7 July 2016.
- Two remarkable MSTIDs appeared following the concentric waves over the Taiwan Strait and Japan region at 12:05:30 and 13:26:30 UT. The long-distance separation between them indicate they are two isolate MSTIDs.
- It’s the first time to observe the low-altitude Nighttime MSTIDs. CGW seeding is considered to be a critical factor to trigger the low-altitude MSTIDs.

NRL SAMI3/ESF Model

The NRL three-dimensional SAMI3/ESF is applied to study the ionospheric response to CGWs. We model the coupling of CGWs to the bottomside F region as a seed for triggering the low-altitude MSTIDs.

- Limited to 6° latitude with periodic boundary condition.
- SAMI3/ESF uses a nonaligned dipole field, the geomagnetic and geographic latitude are the same.
- The geographic longitude center is set to 0°, thus UT time = LT time.
- F0.7 = 83, F0.7A = 83, AP = 18, year = 2016, day = 189, (m,n,f,o,h) = (301, 402, 92)
- Initial state is computed by SAMI2.

Samimi/ESF modeling of MSTIDs

Five cases are performed to understand the CGWs seeding of the low-altitude nighttime MSTIDs in the Northern Hemisphere. We calculate the electron density deviations with respect to the control run.

- Case 1: random perturbations
- Case 2: W/SWward CGWs (up to 350 km)
- Case 3: Nward CGWs (up to 350 km)
- Case 4: W/SWward CGWs (85-100 km)
- Case 5: W/SWward CGWs (85-200 km)

- The CGW-induced polarization electric fields in the F region or E region height map along the geomagnetic field lines to the F region and act as a direct seed for the Perkins instability.
- The CGW-driven wind perturbations induced polarization electric fields could produce E x B drift perturbations to oscillate the ionospheric slabs and further amplified by the Perkins instability.

Summary

1. We present the first observation of low-altitude nighttime MSTIDs when Super Typhoon Nepartak was approaching Taiwan in 2016.
2. Those low-altitude nighttime MSTIDs are organized by the coupling between the typhoon-induced CGWs and Perkins instability.
3. The NRL SAMI3/ESF three-dimensional model is used to study the underlying mechanism of low-altitude nighttime MSTIDs in the presence of CGWs in the Northern Hemisphere.
4. Simulation results demonstrate that the CGWs can modify the ionospheric electrodynamic by generating the local polarization electric fields to enhance the E x B drifts. This may provide a favorable condition for the initiation of MSTIDs.
5. Westward and equatorward propagating CGWs reaching the ionospheric F region can produce the most intense polarization electric fields to couple with the Perkins instability than those reaching underneath the ionospheric F layer.
6. The properties and TEC amplitudes are comparable to the observations where the unique low-altitude nighttime MSTIDs on the west edge of typhoon-induced CGWs were observed. This study provides important implications for either directly triggering or preconditioning the onset of low-altitude nighttime MSTIDs by CGWs.

Reference: