

# Ionospheric disturbance by the North Korean missiles in 2017: Comparison of IRBM and the old/new ICBM

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Exhaust gas from ascending rockets and ballistic missiles causes injection of large amount of water vapor molecules into the ionosphere. The water molecules acquire positive charges from ambient oxygen ions, and their dissociative recombination with electrons cause rapid decrease in ionospheric electrons. Such an electron depletion is a useful source of information on the trajectory and thrust power of rockets/missiles. The total electron content (TEC) of ionosphere can be measured as the phase differences of L1 and L2 microwave carriers from Global Navigation Satellite System (GNSS) satellites.

This technique has become popular in countries with a dense network of (GNSS) receivers such as Japan (Ozeki & Heki, 2010; Nakashima & Heki, 2014) and Korea (Ssessanga et al., in press). Test launches of missiles from North Korea have become active recently, but the details of their specifications are not available. The Japanese and American governments can capture their signatures using military radar and satellite systems, but only limited information has been disclosed to the public. Here we try to study the electron depletion signatures of North Korean missiles launched in 2017 using a Japanese dense GNSS network GEONET, a civilian sensor with data open to public.

We analyzed ionospheric signature of the Hwasong-14, Hwasong-12 and Hwasong-15, launched on 4 July, 15 September, and 29 November in 2017, respectively. Hwasong-14 and -15 are considered to be inter-continental ballistic missiles (ICBM) while Hwasong-12 is thought to be an intermediate range ballistic missile (IRBM).

Sudden decreases of TEC were observed about 6 minutes after the launches of Hwasong-14 and -15. However, we could not find any TEC changes after the Hwasong-12 launch in spite of favorable geometry of GNSS satellites at the time of the launch. Although an IRBM can fly a long distance, its thrust power might not be strong enough to cause detectable electron depletion in ionosphere.

The proportion of the TEC decrease relative to the original absolute vertical TEC gives a clue to the amount of water vapor molecules in the exhaust gas (and hence the strength of the thrust power). For the July Hwasong-14, the proportion was similar to the 2012 Unha-3 and the 2016 Kwangmyongson-4, suggesting that its thrust power is not so different from the second stage engine of the series of Taepodong-2 type rockets. On the other hand, the relative TEC drop that occurred after the November Hwasong-15 launch was 4 times larger than those, and its thrust power might significantly exceed all the past missiles and rockets launched from North Korea.

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