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The Strength of Lightning on Venus Inferred from Ionospheric Whistler-Mode Waves

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Lightning produces an extremely low frequency (ELF) radio wave that propagates along magnetic field lines to higher altitudes in the ionosphere. Venus lacks an intrinsic magnetic dipole, so the interplanetary magnetic field (IMF) drapes around the planet forming a comet-like tail. The IMF induces currents in the ionosphere that generate an opposing field. The field lines tend to be nearly horizontal to the surface around much of the planet, except in the tail where it is more radial. There must be a dip to the field in order for waves to be guided to higher altitudes on the dayside. Therefore, a wave on the dayside is less likely to enter the ionosphere at the zenith of its source and more likely to enter at angles towards the horizon, where the field lines and wave path are more aligned.

The dual fluxgate magnetometer onboard Venus Express (VEX) was able to detect ELF signals up to 64 Hz at various altitudes throughout the mission. We searched all available data within the ionosphere for lightning-generated whistler-mode waves. These waves are right-handed, circularly-polarized waves and propagate along the magnetic field. With a complete set of whistler observations, we can then calculate the Poynting flux of the waves. The Poynting flux requires the three components of both the wave electric field and magnetic field. Unfortunately, VEX did not have a means of measuring the electric field, but we can infer it if we know the phase velocity of the wave. In order to calculate the phase velocity, we need to employ the Venus International Reference Atmosphere model of electron density since VEX did not have any measurements coincident with whistler observations .

The mission was in orbit from 2006-2014 and in that time there were nearly 7 cumulative hours of whistler observations below 400 km. In some cases, there was continuous activity for over a minute, implying a connection to an electrical storm below. These signals were most frequently seen when the spacecraft was at ~250 km altitude. Most signals were observed within 200-350 km altitude with a rate of ~3% of the time the spacecraft spent at these altitudes. It should be noted that due to the polar orbit of Venus Express, the lowest latitude of a detection was ~50°.

The VEX mission spanned almost one solar cycle, so we can compare observations during the solar minimum and maximum periods. Because the ionosphere becomes strongly magnetized during solar minimum, detection rates are about twice as high compared to solar maximum. The Poynting flux during solar maximum shows a decrease with increasing altitude, providing further evidence that the waves were generated below the ionosphere. This conclusion is less clear during solar minimum. A large sample of case studies are left for future work to highlight features that might be lost to statistical averaging.

Pioneer Venus (PVO) was able to detect the electric component of lightning-generated waves at 100 and 700 Hz, but on the nightside and at lower latitudes in contrast to the North polar orbit of VEX. The improved capability of VEX over PVO has greatly increased our knowledge of Venus lightning. The Indian Space Agency (IRSO) has announced plans for a future Venus orbiter at low latitudes. If a lightning oriented investigation were included, their data would be very complementary to previous studies.