

## Statistics and Energetics of Lightning on Venus

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The existence of lightning on Venus has been studied by numerous space missions for over 50 years. The Soviet Venera landers detected radio waves due to lightning during the descent of the landers and while on the surface. Venera 9 even detected an optical signature with its visible spectrometer. The Pioneer Venus (PVO) orbiter also detected radio waves determined to be from lightning, but only while on the nightside because of excessive noise in the electric antenna caused by the sun. These signals exhibited a decrease in amplitude at higher altitudes, implying a source from below, i.e. lightning in the clouds. Most recently, Venus Express (VEX) detected whistler-mode waves in the Venus ionosphere with its dual fluxgate magnetometer. The entire 8.5+ year dataset has been analyzed with over 2200 signals identified. Signal lengths range from one second to more than one minute. These longer signals are likely due to multiple bursts as the spacecraft passed over a storm. The majority of the signals were detected when VEX was around 250 km, approximately 3% of the time it was near this altitude.

In order to demonstrate that the whistlers detected by VEX originate below the ionosphere we first need to calculate the Poynting vector, which is difficult for two reasons: VEX had no electric field sensor and it did not take measurements of the electron density in the lower ionosphere where these signals were observed. Thus, we have employed the VIRA electron density model, which allows us to estimate the Poynting flux of the waves. Since the model was developed during the PVO era, when the solar EUV was more intense, we have scaled it to match the solar cycle conditions during the VEX campaign. With the three components of the magnetic field and an estimate of the electron density, we can statistically show that the whistler-mode waves observed by Venus express do indeed originate from the atmosphere below. Next, we estimate the energy of the bursts and compare Venus lightning rates to terrestrial lightning and rates.