ULF Wave Observations at the Beginning of 2025

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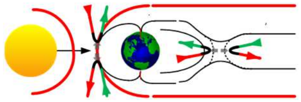

Introduction: Ultralow Frequency Waves (*ULF Waves*) are regularly observed by the SAM-III magnetometers in Alaska. The present article discusses ULF Wave observations soon after the beginning of the new year 2025 at Anchorage and the HAARP facility near Gakona, Alaska. Another article in this journal issue discusses ULF Waves observed in mid-December 2024 and provides additional background information and references. The observations in January were during a different time of day than those in December, possibly indicating a different source or cause.

Observations: The magnetograms for the UTC morning on 5 January 2025 show rapidly varying traces indicative of ULF Waves (figure 1). ULF Waves usually are observed in the horizontal component of Earth's magnetic field and are seen here in its constituents Bx (north-south) and By (east-west). These ULF Waves reached peak-to-peak amplitudes higher than 40 nT. The local ambient magnetic fields at the two observatories are about 350 times stronger, indicating why ULF Waves historically were called *micropulsations*.

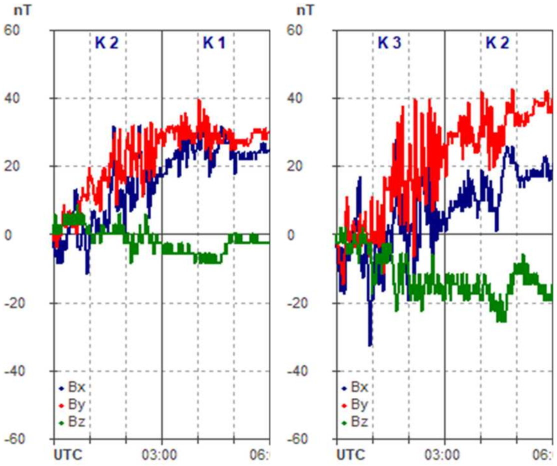

Figure 1 ~ Cropped magnetograms for Anchorage (left) and HAARP (right) showing the time period 0000 to 0600 UTC on 5 January 2025. ULF Waves are quite strong between about 0100 and 0500, especially in the east-west component. The vector sum of Bx (north-south, blue trace) and By (east-west, red trace) defines the horizontal, or H, component. The quasi-K-Index values along the top of the plot are based on local settings for each magnetic component and the two locations track each other over the long term but not necessarily during every 3-hour synoptic period. The variations in Bz (vertical, green trace) at HAARP are thought to be due to stray ground currents from the local underground power distribution system.

Analysis: A portion of the raw data produced by the two magnetometers is plotted to show the 3-hour time period from 0100 to 0400 (figure 2). The time domain plots show the actual, uncorrected magnetic flux density. The discrete time-series data are transformed to the frequency domain to extract individual wave frequencies. The FFT is calculated using the Hamming window to reduce spectral leakage. The SAM-III magnetometers at Anchorage and HAARP are setup to sample the local magnetic field at 10 second intervals; thus, the 3-hour time period consists of 1080 datapoints.

The Fast Fourier Transform (FFT) analysis tool in Microsoft Excel is used here to convert the time series data to the frequency domain. It requires that the number of datapoints be a power of 2 so, of the 1080 datapoints available, 1024 were used. With a sample rate fs = 100 mHz (10 second sample interval) and N = 1024 datapoints, the frequency resolution is fs/N = 0.1 mHz. The resulting FFT has a relatively large dc component, which is truncated in the plots. The vertical axes of the FFT plots are labeled *Relative Amplitude* because no effort was made correct or compensate for any amplitude errors resulting from the windowing function or transform.

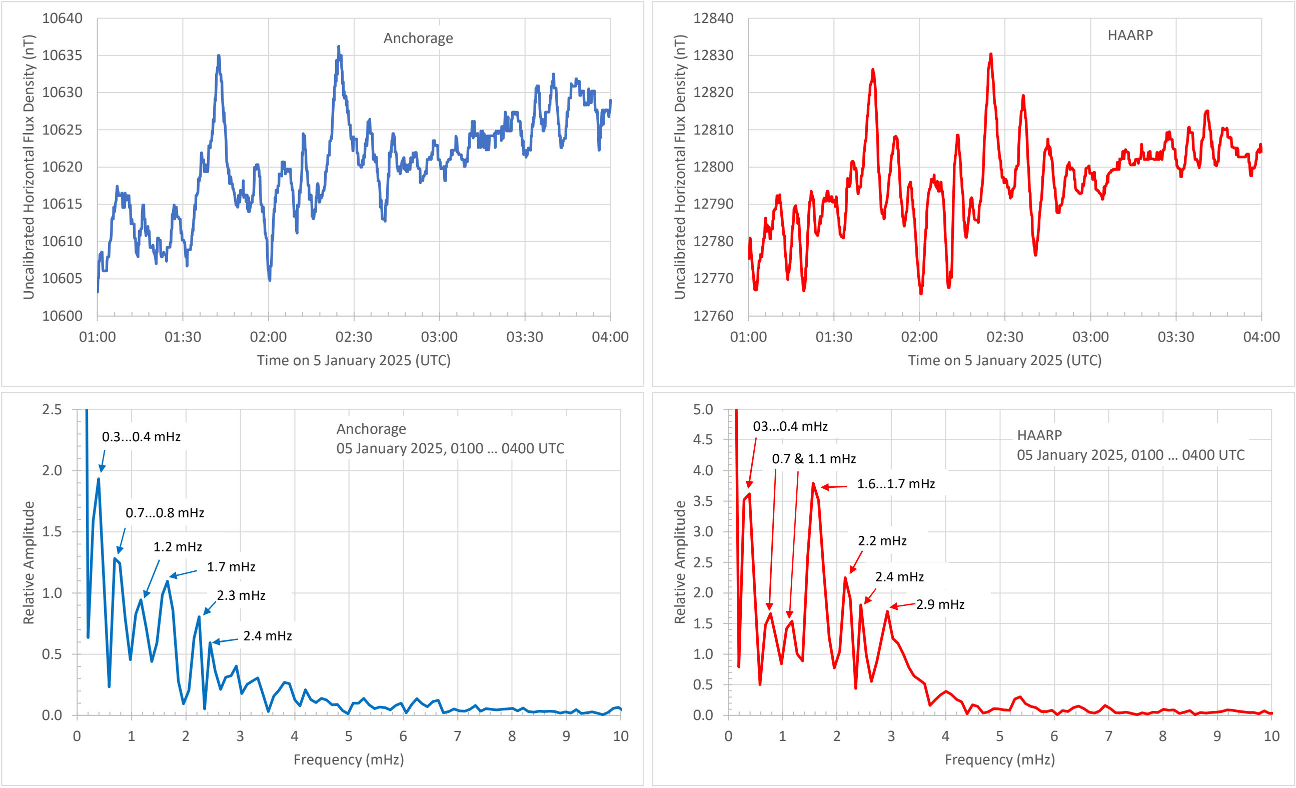

Figure 2 ~ Anchorage (left) and HAARP (right) data for 5 January 2025. The upper plots show the time domain data between 0100 and 0400 UTC, and the lower plots show the frequency domain transforms of the serial-time data. Note the basic commonality between the two locations in both the time and frequency domains. The vertical scales in the time domain plots are raw, uncorrected data. The vertical scales in the frequency domain plots are relative amplitudes determined from the Fast Fourier Transforms of the magnetic flux density variations measured from the beginning of the time period. The frequency resolution of the transform is 0.1 Hz. The frequencies of major spectral indications are annotated. Some are shown as ranges because of close-by peaks and may indicate frequency drift throughout the time period. Note the strong indications below 1 mHz, which may indicate periodic density structures in the solar wind.

Coincident events: According to Space Weather Prediction Center, a 10 MeV proton event was observed at geosynchronous orbit beginning at 2235 UTC on 4 January, only a few hours before the ULF Waves were observed at Anchorage and HAARP. The proton event was associated with a long-duration C7.6 flare.

A proton event consists of energetic particles (mostly hydrogen and helium nuclei) emitted by the Sun that travel at a significant fraction of light speed and arrive in Earth's vicinity within hours. The event peaked at 0055 on 5 January and ended at 0940; thus, it was time-coincident with the ULF Waves observations. Also, the near-Earth environment observed by the Advanced Composition Explorer (ACE) spacecraft experienced some variations in the interplanetary magnetic field (IMF) and solar wind speed and temperature (figure 3). These variations were primarily due to geoeffective coronal hole high-speed streams.

Discussion: The FFT spectra show significant spectra in the ranges 0.3 to 0.4 and 0.7 to 0.8 mHz (periods from about 20 to 55 minutes), below the generally classified frequencies of ULF Waves. Previous analyses of ULF Waves observed in Alaska by the SAM-III magnetometers indicate these lower frequencies are common. The source (or sources) of these spectra is not known but they could be instrumental effects (environmental effects are excluded because of the two completely different locations and temperature and humidity regimes) or related to periodic density structures (PDS) in the solar wind. Periodic density structures modulate the magnetosphere and can produce periodic magnetic signatures on the ground.

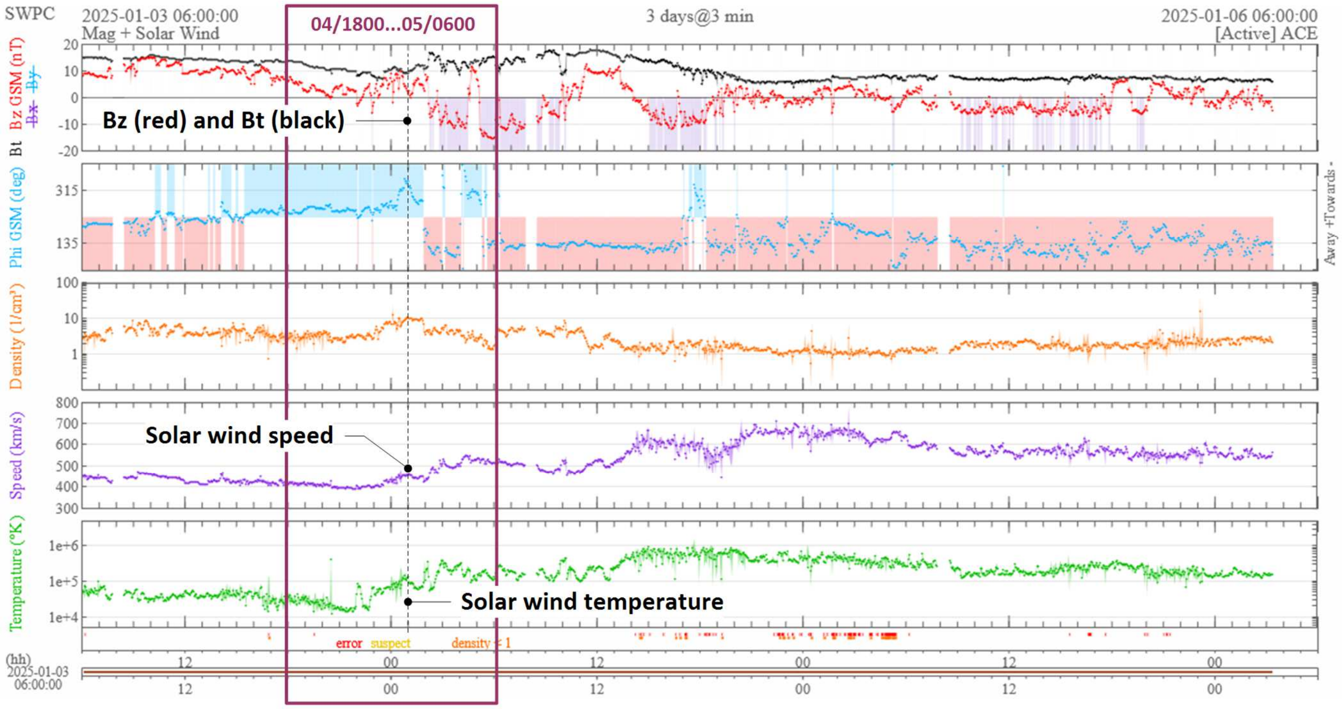

Figure 3 ~ ACE spacecraft data for the 3 days 4 through 6 January. The period from 1800 on 4 January to 0600 on 5 January is boxed to overlap the time period of the ULF Waves observations (0100 to 0400 on the 5th) and a dashed line and callouts are added to indicate 0100. The notable activity consists of southward deflection of Bz (ACE Bz is aligned with Earth's dipole field) around 0200 and modest increases in both the solar wind speed and temperature. Image source: https://www.swpc.noaa.gov/products/real-time-solar-wind

The ULF Waves were observed during the 0100 to 0400 UTC time period when Anchorage and HAARP were in the dusk sector (figure 4). This was in contrast to the waves in December that were observed during the midnight-to-dawn and dawn-to noon sectors. Although different mechanisms may be responsible for the December and January waves, both include the possibility of shear and turbulence between the interplanetary magnetic field (IMF) carried in the solar wind and Earth's magnetosheath as the wind blows around the magnetosphere's flanks. The ULF Waves could be the result of a combination of causes including PDS, the proton event as well as the large number of flares the day before the ULF Wave observations.

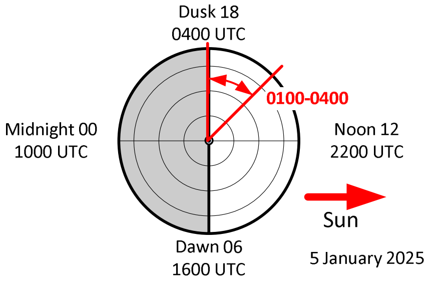

Figure 4 ~ Solar time scale for Anchorage with corresponding times in UTC. UTC times at HAARP are 20 minutes earlier. The ULF Waves on 5 January occurred in the dusk sector.