Periodic Ionospheric Absorption Events on Cinco de Mayo

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Introduction: Ionospheric absorption has three primary causes: Solar Flares; Solar Energetic Particle (SEP) Precipitation; and Auroral Particle Precipitation. Auroral Particle Precipitation and geomagnetic disturbances often are observed together. Many geomagnetic disturbances induce auroral substorms and substorms can occur quasi-periodically during a night. However, the literature does not mention that ionospheric absorption events related to Auroral Particle Precipitation may have a periodic nature as well.

On 5 May 2025, the day of the annual Mexican-American celebration known as *Cinco de Mayo*, such an event was observed at the HAARP facility near Gakona, Alaska (figure 1) and is discussed in this article. The observations were with a Riometer and Magnetometer. The Riometer records the Galactic background radiation with respect to a reference noise source and indicates absorption at 30.3 and 38.2 MHz. Any decrease in the cosmic noise received at these frequencies is attributed to absorption in the ionosphere's D-region. The SAM-III Magnetometer is about 2.3 km away and records the characteristics of the geomagnetic field and associated disturbances.

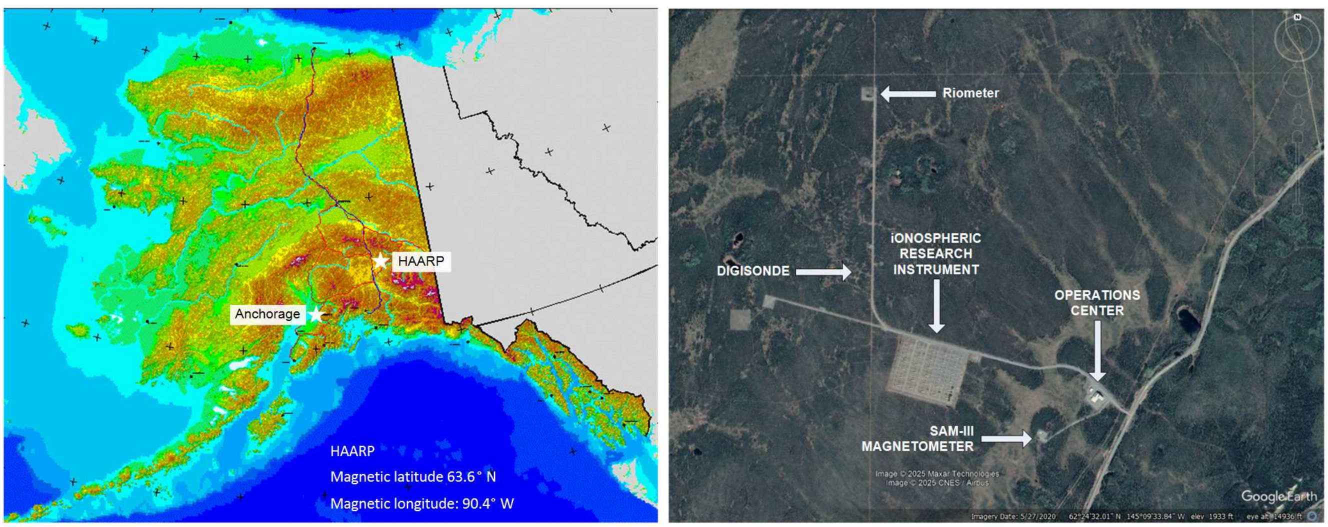

Figure 1 ~ Left: Alaska map showing the proximity of the HAARP facility to Alaska's largest city Anchorage about 300 km to the southwest and the Canadian border about 200 km to the east. Right: Zoomed image equivalent to an altitude of 29 000 ft (9 000 km) showing the HAARP science facilities. North is up.

Auroral Particle Precipitation: When the solar wind speed is elevated for long time periods (at least an hour or two), the energy loading in the magnetosphere and its subsequent release can occur quasi-periodically. This is particularly the case when the Interplanetary Magnetic Field (IMF) embedded in the solar wind has a southward component (figure 2) and is able to merge with Earth's northward magnetic field. Merging allows energetic electrons in the solar wind to enter the magnetosphere on the dayside (figure 3). Some of these electrons precipitate into the lower regions of the ionosphere at higher latitudes and some are carried by the open magnetic field lines to the magnetotail where they add energy to the magnetotail plasma.

It is thought that the energy loading reaches a tipping point and is released during reconnection of the open magnetic field lines in the magnetotail. The reconnection causes an outflow of electrons, some of which are convected back toward Earth along now-closed magnetic field lines. Their electron energy is increased along the way and they then precipitate into the D- and E-regions, producing aurora and related phenomena. This is called *Auroral Particle Precipitation*. The process repeats two or three times during the night at a given location and manifests as periodic structures seen in magnetograms with periods ranging from about 0.5 to 3.5 hours.

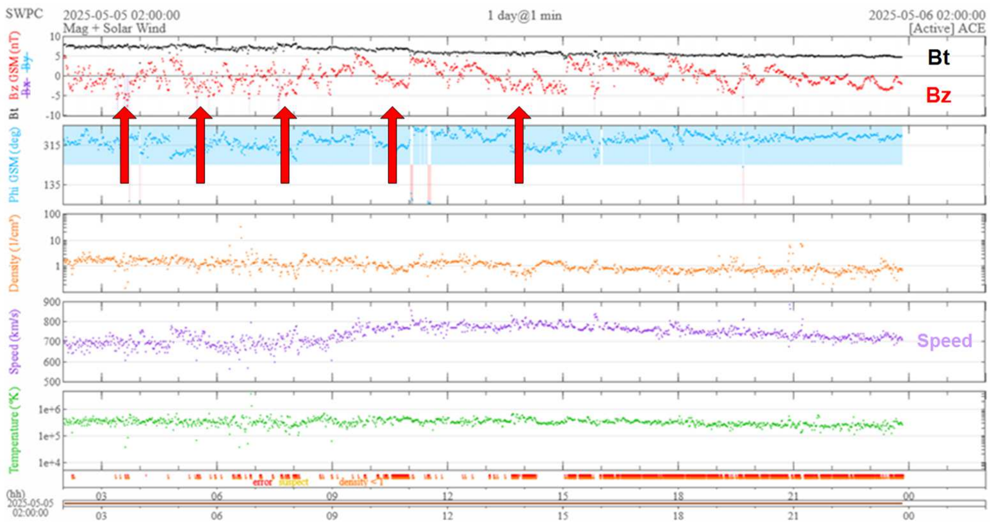

Figure 2 ~ Advanced Composition Explorer (ACE) spacecraft data for 5 May 2025. ACE is located 1.5 million km from Earth on the Earth-Sun line. The red trace (Bz) in the upper plot shows the IMF component aligned with Earth's magnetic dipole axis. Negative (southward) values, marked by the red arrows, enable merging of the IMF and Earth's field and the opening of the magnetosphere through which energetic particles from the solar wind can enter. The solar wind speed, shown by the purple trace in a lower plot, is above 700 km s^{-1} and considerably elevated compared to quiet conditions. Image source: NOAA

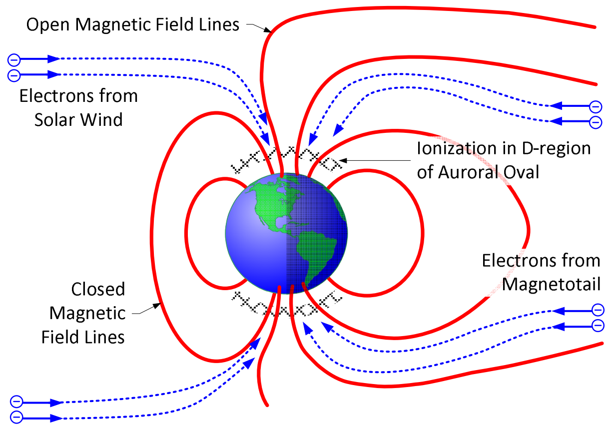

Figure 3 ~ The IMF and Earth's magnetic field can merge if the IMF has a southward component (aligned with but opposite Earth's dipole field). The merging event opens some previously closed field lines on the dayside allowing energetic electrons in the solar wind to enter the magnetosphere. These can precipitate into the D-region ionosphere and some can work their way to the magnetotail. The open field lines eventually reconnect in the magnetotail causing the convection of energetic electrons toward Earth where they precipitate to the D-region. The merging-reconnection events typically occur two to three times in a quasi-periodic manner.

Observations: When the energetic electrons precipitate to the lower ionosphere and collide with neutral atmospheric particles, they have enough energy to ionize the neutral particles and increase the electron density. The freed electrons are excited by the Galactic background radiation, but their higher density increases the collision rate with neutral particles causing the excited electrons to lose energy and the Galactic background radiation to be absorbed (figure 4).

The Riometer plot shows absorption events as dips in the trace, which indicate a reduction in the received Galactic background radiation. In this case, the dips are aligned with magnetic features that occur roughly every 3 hours. This Riometer plot does not include a Quiet Day Curve, which is used for comparing with quiet day conditions, so the data are qualitative rather than quantitative. Nevertheless, the apparent absorption is on the order of a couple dB, which would translate to much higher values and a complete radio blackout at frequencies in the lower HF band. The absorption events shown here have up to 3-hour duration.

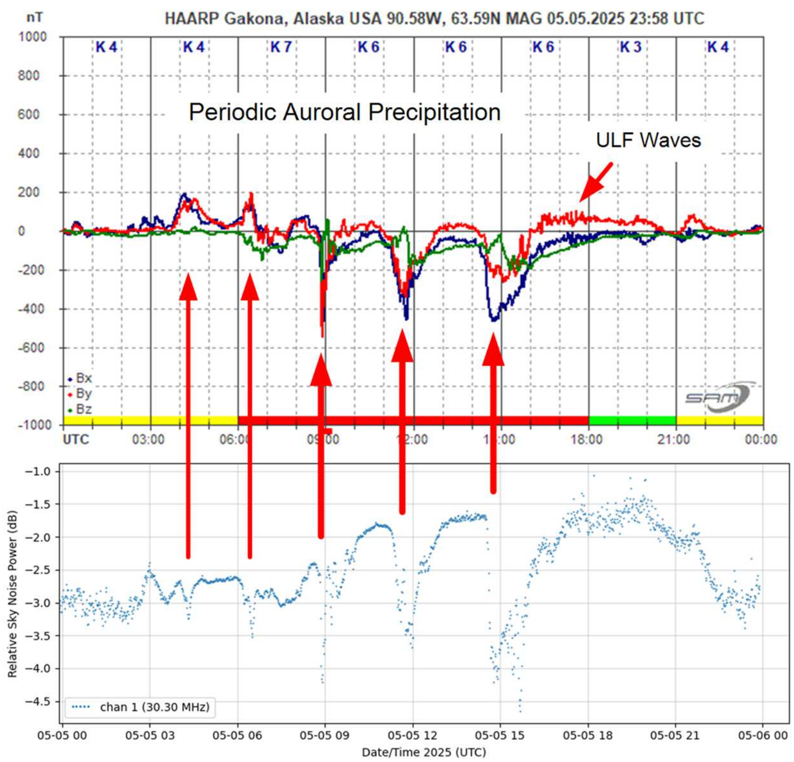

Figure 4 ~ Overlay of the SAM-III magnetogram (upper plot) with the Riometer plot for 30.3 MHz. The red arrows mark the time correspondence of absorption events in the lower plot with magnetic activity in the upper plot. The first two are inverse magnetic bays that normally do not affect particle precipitation and absorption but in these two cases there are slight absorption increases (dips). The following three events are textbook magnetic bays in which the local magnetic field decreased substantially, indicating enhanced Auroral Electrojets from Auroral Particle Precipitation. The apparent absorption is around 1 to 3 dB at low VHF frequencies. A period of ULF Waves occurred in the latter part of the UTC day and is marked on the magnetogram. ULF Waves are low amplitude oscillations in the magnetic field that have periods on the order of a couple hundred ms to 10 min. Bottom image: Courtesy of UAF-GI

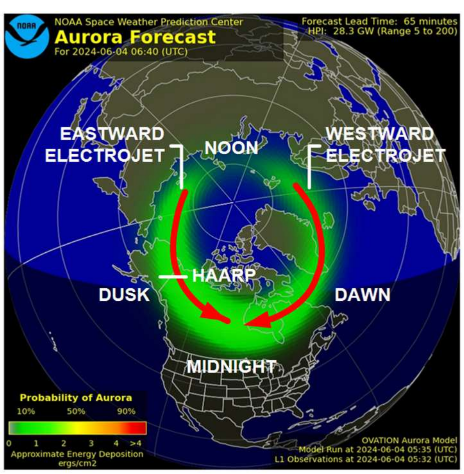

Figure 5 ~ The Auroral Oval, shown in green, in this Auroral Forecast image has been expanded toward the equator during a magnetic disturbance. The red arrows have been added to indicate the eastward and westward Auroral Electrojets. The Sun is directly up, and Alaska is in the Dusk sector with the eastward electrojet flowing overhead. Image source: NOAA

The increased electron density also increases the conductivity of the lower ionosphere and enhances the *Auroral Electrojet*. The Auroral Electrojet is a huge current system in the *Auroral Oval* (figure 5) that, during quiet magnetic conditions, flows horizontally about 100 km above the ground at around 67° latitude. When the Auroral Oval expands toward the equator, the electrojet is enhanced and moves along with it. The HAARP facility is located at 63° north magnetic latitude, and disturbed conditions can expand the electrojet so that it flows directly overhead or even south of HAARP. The electrojet produces its own magnetic field because of the current flow, and this field can add to or subtract from Earth's internal dipole field as seen in the magnetogram.

In the observations discussed here, the periodicity started around 0400 UTC (1800 local solar time) when HAARP was on the Dusk side of Earth. Over the next several hours, a series of auroral substorms appeared to take place. The Auroral Electrojet was initially eastward and the magnetic field generated by the current flow slightly enhanced the magnetic field through a couple cycles. As the night progressed, the measured magnetic disturbances changed polarity with the first peak at about 0900 UTC (2300 local solar time) as HAARP moved through the solar Midnight sector. At this point, Earth and HAARP rotated into a region where the overhead electrojet was flowing westward (the auroral oval and electrojet are fixed in space as Earth rotates below). Due to the energy loading and release previously described, the electrojet periodically reduced the local magnetic field at the same time as the ionospheric absorption increased. The oscillations continued to 1500 UTC (0500 local solar time) as HAARP moved into the Dawn sector and they then ended shortly thereafter.

The Auroral Electrojets are a global high-latitude current system, and their characteristics are described by an *auroral electrojet activity index*. The index actually consists of four individual indices: AU, AL, AE and AO, which take into account global magnetic activity and are produced by measuring the horizontal (H) component of Earth's magnetic field. It is interesting to compare the global AE indices to the local measurements (figure 6).

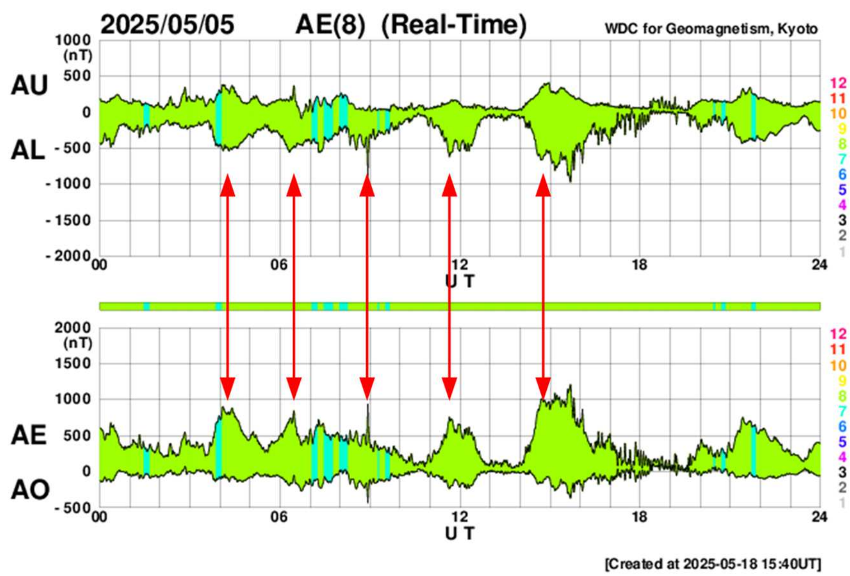

Figure 6 ~ Auroral Electrojet Indices for 5 May 2025. See text below for definition. Red arrows have been added that correspond to the times of the arrows drawn in Figure 4. The correspondence with electrojet activity is remarkable but not surprising. The plots shown here are based on global measurements, and it is clear that the periodic nature of the Cinco de Mayo event was not confined to the vicinity of the HAARP facility; however, the absorption elsewhere is unknown. Image source: World Data Center for Geomagnetism, Kyoto

The Auroral Electrojet indices are produced from data at high latitude stations (in this case, 8 stations, see color chart on right side of plots). The AU and AL indices indicate the strongest current intensity of the eastward and westward auroral electrojets, respectively, at any given time (these are a composite of all stations). AE and AO are derived from AU and AL. AE is the difference between AU and AL or (AU – AL), and AO is the average of AU and AL or [(AU+AL)/2] at any given time. AE indicates the total range of deviation from quiet day values at an instant of time around the Auroral Oval, so it represents the overall or peak-to-peak activity of the electrojets. AE is always positive. AO provides a measure of the current and may be positive or negative.

Document Information

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