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Magnetic Field Observations at Purcell, Oklahoma Field Campaign Report

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ARM CLIMATE RESEARCH FACILITY

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Acronyms and Abbreviations

AMER	Americus (Oklahoma)
ARM	Atmospheric Radiation Measurement
DOE	U.S. Department of Energy
FLR	field line resonance
McMAC	Mid-continent MAgnetoseismic Chain
PCEL	Purcell (Oklahoma)
RE	Earth radii
RICH	Richardson (Oklahoma)
ULF	ultralow frequency

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1.0 Summary

The campaign "Magnetic Field Observations at Purcell, Oklahoma" installed a ground-based magnetometer at Purcell's U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility boundary installation at the Kessler Atmospheric and Ecological Field Station, University of Oklahoma, to measure local magnetic field variations. It is a part of the nine stations of the Mid-continent MAgnetoseismic Chain (McMAC) placed as close to the 330° magnetic longitude as possible. This is the meridian in the world where land covers the greatest continuous range in magnetic latitude. Figure 1 shows the map of the magnetometer stations along the 330th magnetic meridian, including the Purcell (PCEL) station.

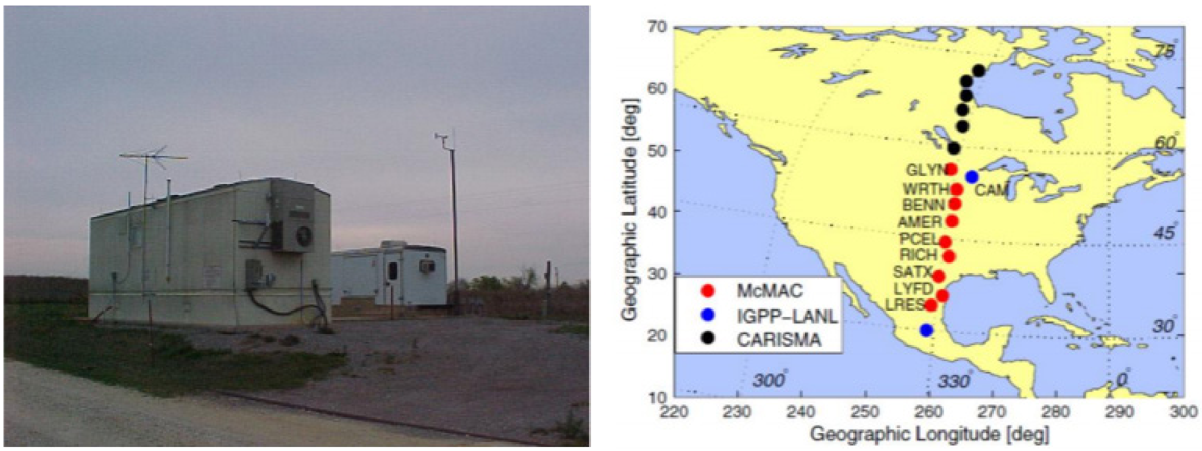

Figure 1. (Left) The ARM boundary facility at the Kessler Atmospheric and Ecological Field Station where the magnetometer was operated. (Right) A map of McMAC and other ground-based magnetometer stations along the same magnetic meridian. The Purcell station is labeled as PCEL

The main scientific objective of the campaign is to detect the field line resonance (FLR) frequencies of the magnetic field line connected to the Purcell station. This magnetic field line extends from Purcell to the outer space at distances as far as 2 Earth radii (RE). To accurately identify FLR frequencies, however, simultaneous measurements at slightly different latitudes along the same meridian are necessary to allow the use of the cross-phase technique. This consideration explains the arrangement to operate magnetometers at the Americus (AMER) and Richardson (RICH) stations nearby. The measured resonant frequency can infer the plasma mass density along the field line through the method of normal-mode magnetoseismology. The magnetometer at the Purcell station can detect many other types of magnetic field fluctuations associated with the changes in the electric currents in the ionosphere and the magnetosphere, which by large are affected by the solar activity. In other words, the magnetic field data collected by this campaign are also useful for understanding space weather phenomena.

The magnetometer was installed at Purcell's ARM boundary facility in March 27, 2006. The construction of the triaxial fluxgate magnetometer used by the campaign, as well as the data processing and analysis, was sponsored by the National Science Foundation. Except during occasional downtimes, the magnetometer collected measurements from June 6, 2006 to July 26, 2016.

2.0 Results

The magnetic field observations at the ARM Purcell Field Station have been examined together with the data from other McMAC stations. The observed FLR frequencies were used to calculate the plasma mass density in the plasmasphere, a region in the outer space from the Earth's ionosphere to a few RE. Figure 2 presents some of the key results based on one year of observations. The L-dependence of the plasma mass density, in which L is the equatorial distance from the Earth's center in RE, falls off at a rate of L –4, which means that the mass density is inversely proportional to the flux tube volume. The average ion mass is only slightly greater than one, indicating that most ions are protons during the studied time interval when the solar and geomagnetic activities remained minimal. The diurnal variation of the plasma mass density, on the other hand, reveals an unexpected result – the mass density can increase substantially starting from late afternoon at L = 2.1 – 2.7. This is the first time when the plasma mass density at low L-values is measured in a systematic manner, and we believe that the late-afternoon rise in the mass density is associated with the density enhancements in the low-latitude thermosphere and the ionosphere. These findings and other results based on FLR observations have been reported in Publication 1.

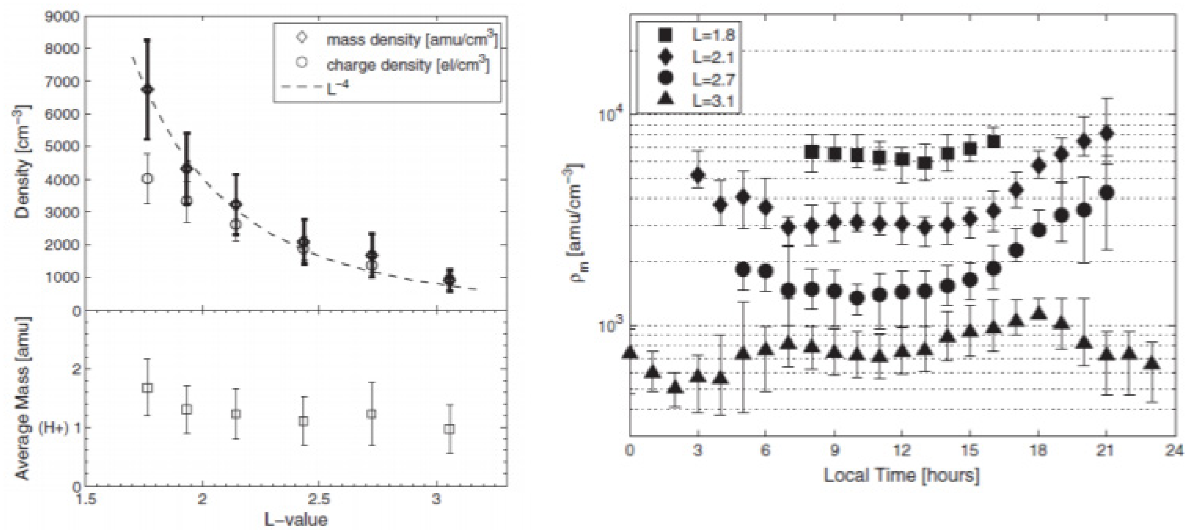

Figure 2. (Left) The top panel shows the equatorial plasma mass density as a function of L as inferred from FLR observations and the equatorial charge density predicted by the RPI model of the plasmasphere. The bottom panel is the average ion mass as the ratio between the mass density and the charge density shown in the upper panel. (Right) The local time dependence of plasma mass density as inferred by McMAC FLR observations during July 2006 to June 2007.

The magnetic field observations at Purcell's ARM facility have also been used in other studies. Examples are the generation of ultralow-frequency (ULF: 0.001 – 5 Hz) wave power and the its use in the search for earthquake precursor signals (Reference 2), the study of global Pi2 pulsations (Reference 3), the comparison with satellite observations of ULF waves (Reference 4), and a study on the inferred plasma mass density in comparison with spacecraft imaging of the plasmasphere (Reference 5). The campaign and the investigations of its data have helped not only make the above discoveries but also advance the science of normal-mode magnetoseismology. We have enhanced the cross-phase technique so that it can be properly applied to observations from a two-dimensional magnetometer array. Figure 3 demonstrates examples of our new capability of producing snapshots of equatorial plasma mass density inferred from the observations of available magnetometer stations in North America.

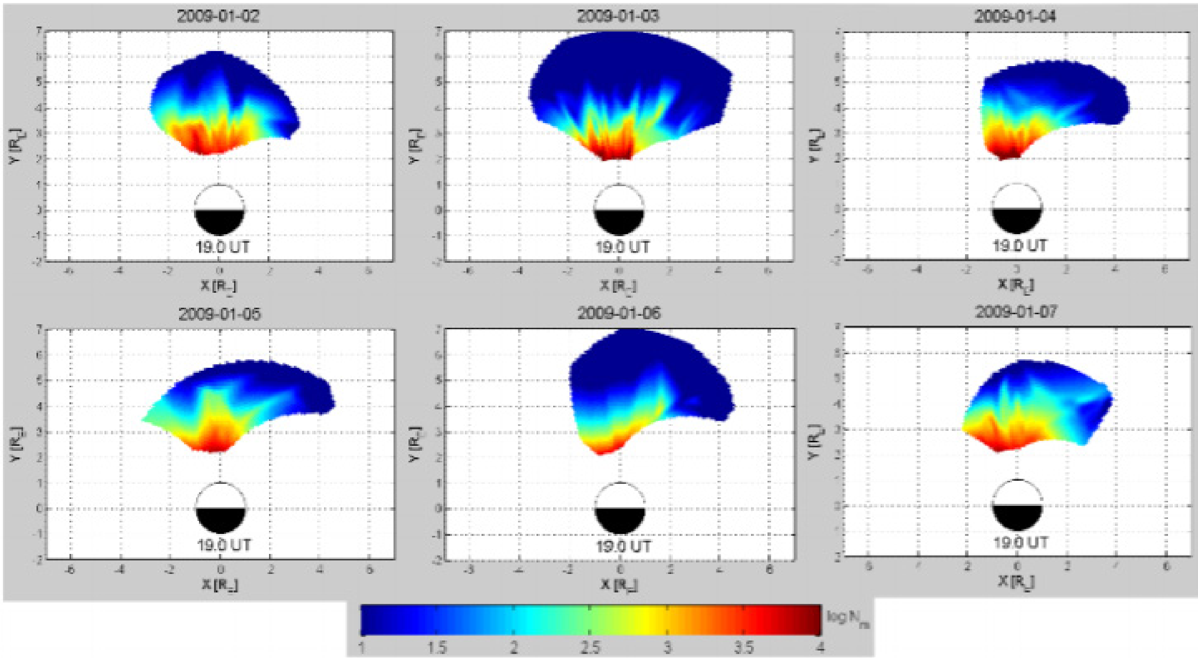

Figure 3. Snapshots of equatorial plasma mass density in the magnetosphere inferred from magnetometer observations at Purcell and other stations in North America.

3.0 Publications and References

The magnetometer data collected at the Purcell station have been used in numerous presentations. Below is a list of representative published articles that explicitly demonstrate the use of these data.

1. Chi, PJ, MJ Engebretson, MB Moldwin, CT Russell, IR Mann, MR Hairston, M Reno, J Goldstein, LI Winkler, JL Cruz-Abeyro, D-H Lee, K Yumoto, R Dalrymple, B Chen, and JP Gibson. 2013. "Sounding of the plasmasphere by Mid-continent MAgnetoseismic Chain (McMAC) magnetometers." *Journal of Geophysical Research – Space Physics* 118(5): 3077-3086, doi:10.1002/jgra.50274.

2. Currie, JL, and CL Waters. 2014. "On the use of geomagnetic indices and ULF waves for earthquake precursor signatures." *Journal of Geophysical Research – Space Physics* 119(2): 992-1003, doi:10.1002/2013JA019530.

3. Keiling, A, O Marghitu, J Vopgt, O Amm, C Bunescu, V Constantinescu, H Frey, M Hamrin, T Karlsson, R Nakamura, H Nilsson, J Semeter, and E Sorbalo. 2014. "Magnetosphere-ionosphere coupling of global Pi2 pulsations." *Journal of Geophysical Research – Space Physics* 119(4): 2717-2739, doi:10.1002/2013JA019085.

4. Le, G, PJ Chi, RJ Strangeway, and JA Slavin. 2011. "Observations of a unique type of ULF wave by low-altitude Space Technology 5 satellites." *Journal of Geophysical Research –Space Physics* 116(A8), doi:10.1029/2011JA016574.

5. Obana, Y, G Murakami, I Yoshikawa, IR Mann, PJ Chi, and MB Moldwin. 2010. "Conjunction study of plasmapause location using ground-based magnetometers, IMAGE-EUV, and Kaguya-TEX data." *Journal of Geophysical Research –Space Physics* 115(A6), doi:10.1029/2009JA014704.

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