Apollo Surface Magnetic Field Data: Statistical Variability and Dependence on Solar Wind Conditions

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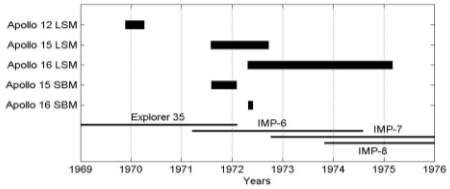
Introduction

The Apollo 12, 15 and 16 missions included the Lunar Surface Magnetometer (LSM) experiment, and the LSM data collected during 1969 – 1975 will continue to be the major source of lunar surface magnetic field observations before long-duration geophysical stations can be established on the Moon again. After a recent effort restoring all Apollo magnetic field records from the original formats, we are now reorganizing the LSM database to enhance its user-friendliness. The restored LSM data also allow re-analyses of the Moon-solar wind interaction at the Apollo sites with different degrees of crustal magnetization.



Published Figure in Literature | Plot of Restored Data

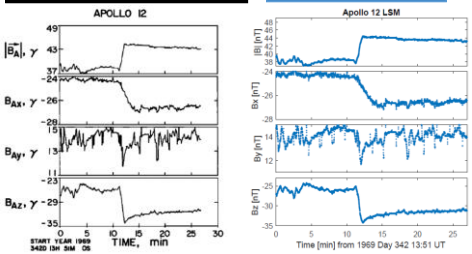


Figure 1. Left: The Apollo 12 LSM data shown in Figure 15 of the paper by Dyal and Parkin (1971). The magnetic field unit γ is 1 nanotesla (nT). Right: The restored Apollo 12 LSM data during the same time interval.

Data

In this study, we compare the LSM data with the simultaneous solar wind spectrometer measurements at the Apollo surface stations and the magnetic field measurements collected by the Explorer 35 spacecraft orbiting the Moon. To investigate the solar wind interaction with the surface magnetic field, we focus on the data intervals when the Apollo 12 or 15 station was in the sunward side. (The Explorer 35 and Apollo solar wind data are not available during the Apollo 16 mission.) Figure 2 depicts the Moon positions for an example of the studied intervals when the Apollo surface station was in the daytime and immersed in the solar wind (or the shocked solar wind of the magnetosheath).

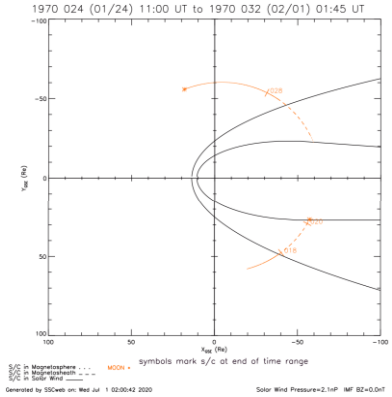


Figure 2. An example of the Moon positions in the Geocentric Solar Ecliptic (GSE) coordinate system, where the Apollo 15 surface station was in the sunward side.

Crustal Magnetic Field at Apollo 12 and 15 Sites

The local crustal magnetic field is inferred from the difference between the surface magnetic field (measured by LSM) and the external magnetic field in the solar wind (measured by Explorer 35). Figure 3 shows the histograms of the three components of the local magnetic field at the Apollo 12 site. The magnetic field vector is expressed in the ALSEP surface coordinate system, in which x is directed radially outward from the local surface, and y and z are tangent to the surface and directed eastward and northward respectively. Figure 4 displays the same plots for the local crustal magnetic field at the Apollo 15 site.

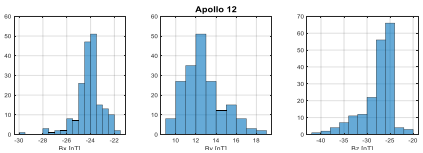


Figure 3. Distribution of differences between the Apollo 12 LSM data and Explorer 35 magnetometer data.

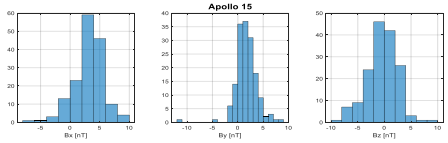


Figure 4. Same as Figure 3 except that Apollo 15 LSM data are used.

Site	Coordinates	Magnetic Field Components [nT]			Field Magnitude [nT] (This Study)	Field Magnitude [nT] (Dyal et al., 1972)
		x (Up)	y (East)	z (North)		
Apollo 12	3.2° S, 23.4° W	–24.1 ± 1.1	12.8 ± 1.9	–27.7 ± 3.5	39.0 ± 3.0	38 ± 3
Apollo 15	26.1° N, 3.7° E	3.2 ± 2.5	1.7 ± 2.1	–0.5 ± 2.9	5.3 ± 2.1	6 ± 4

The above results imply the crustal magnetic fields at the Apollo 12 and 15 sites as listed in Table 1. These results are well consistent with the estimates made during the Apollo era, and the uncertainty in the crustal field at the Apollo 15 site has been reduced by half.

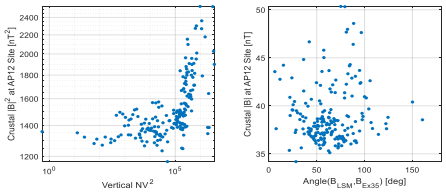


Figure 5. (Left) Comparison between the square of crustal field magnitude (proportional to magnetic pressure) and the vertical solar wind dynamic pressure. (Right) Crustal field magnitude vs. the angle between crustal field and external magnetic field.

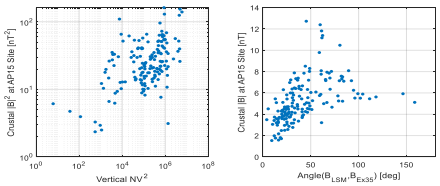


Figure 6. Same plots as in Figure 5 except for the crustal field at the Apollo 15 site.

Solar Wind Interaction with Crustal Magnetic Field

The simultaneous measurements of the solar wind plasma and the external magnetic field enable the analysis of the solar wind interaction with the crustal magnetic field. Figure 5 shows that stronger wind dynamic pressure (proportional to NV^2) will lead to a higher estimate of the crustal magnetic field, an expected result in consideration of the solar wind compression of the crustal field. The true magnitude of the crustal magnetic field is expected to be at the low end of the estimates when the solar wind dynamic pressure is minimal. It is of interest to see if the relative direction of the external magnetic field can play a role in the process, but the results do not show that it is a statistically significant factor at the Apollo 12 site.

Figure 6 demonstrates the same analysis for the comparison with the Apollo 15 crustal field. The solar wind dynamic pressure is again a controlling factor. Different from the results in Figure 5, the relative direction of the external magnetic field can clearly affect the estimate at the Apollo 15 site where the crustal magnetic field is much weaker.

Summary

Our initial results based on data during one lunation for each of the Apollo 12 and 15 missions reveal the basic statistical features of the local crustal magnetic fields at the two Apollo sites and the influence by the solar wind and external magnetic field. The solar wind dynamic pressure is the external parameter that has the clearest control of the estimated crustal field. Our future work will include more data in the statistics.