DECONSTRUCTING A FEW MYTHS IN THE INTERPRETATION OF SATELLITE-ALTITUDE CRUSTAL MAGNETIC FIELD: EXAMPLES FROM MARS GLOBAL SURVEYOR. D. Ravat, Southern Illinois University C'dale (Geology 4324, SIUC, C'dale, IL 62901-4324, USA; E-mail: ravat@geo.siu.edu),

Introduction: In this paper, I will attempt to rectify a few of the misconceptions that have surfaced regarding the use of magnetic field anomaly data from Mars Global Surveyor (MGS). The two primary misconceptions discussed here are regarding, first, the utility and limitations of the equivalent source inversion method in modeling the observations and, second, the validity, utility, and limitations of using the Analytic Signal field for the interpretation. Limitations of paleomagnetic poles derived by modeling of MGS magnetic field are detailed in a companion paper [1].

The Equivalent Source method and its use on the MGS magnetic field data: For the last 35 years, the equivalent source method has been widely used in achieving theoretically sound, interpretation-oriented by-products from potential field anomaly data [2, 3]. Several papers have rigorously evaluated its utility and limitations (see [2, 3], for the applications and the discussion of the relevant issues that govern the equivalent source model stability). In our initial models of MGS magnetic field anomalies [4], we had incorporated the time-tested wisdom and chosen the source spacing to maximize the spatial resolution of the modeled field (~ 1°) where justified by data. Not knowing the magnetization direction for sources *a priori*, we assumed radially-polarized magnetic dipoles all over Mars. Our primary purpose behind this exercise was the altitude normalization of the field to verify that the anomaly patterns seen in the initial non-normalized maps [5] were indeed correct. Because we were not seeking directly the magnetization information, this was a valid transformation. Later, we used more refined data selection with the equivalent source models to compute Analytic Signal of the Z-component field [6, 7] to interpret that only two E-W, long-linear sources existed in the southern highlands of Mars, and the sources are separated by the distance of some 1000 km. We interpreted that the remaining positive/negative linear Z-component field pattern in the region (Figure 1a) was caused by dipolar effects of the interpreted linear sources and superimposition of fields from other intervening sources. *Could our modeled field have been somehow biased by assuming radially-polarized dipoles?* Even though the results of past studies [2, 3] should have been sufficient to answer the question in this case, I am now in a position to demonstrate it with model simulations, having computed equivalent source based magnetic fields from different sets of magnetization directions of sources. It is indeed interesting to note in this context that the initial magnetic interpretation of the linear high-low-high-low pattern in the southern highlands of Mars consists of vertically-sided, 2-D sources that are *also radially-polarized* [8].

How different are the anomaly fields computed with different dipole orientations? They are not significantly different. I show below the Z-component field from magnetization orientations corresponding to the mean paleopole inferred from one of many published analyses [9, the most rigorous of them all] and the difference map of the field computed assuming radially-polarized dipoles.

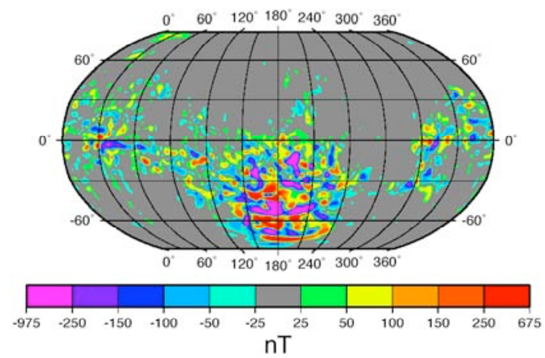

Figure 1a. Z-component magnetic field computed at 150 km altitude from an equivalent source model fitting selected aero-braking and science-phasing orbits of MGS. Magnetization directions for the equivalent sources are based on a mean paleopole at 50°N, 195°E [9].

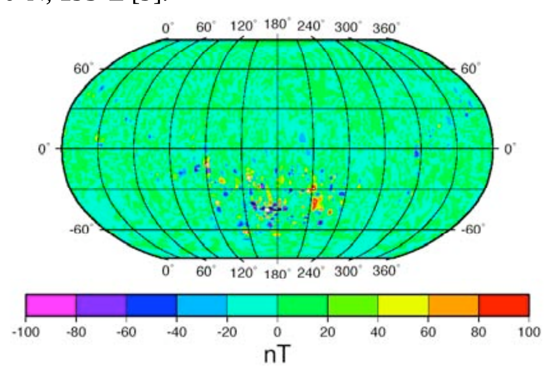

Figure 1b. Difference between the Z-component field from radially-polarized magnetizations and Figure 1a. Really large differences occur only near strong anomalies and do not display any pattern suggesting that they largely reflect anomaly inaccuracies. The pattern of data misfits to the models is also similar and the corr. coeff.s are > 0.97 and average misfits

are ~8 nT (no. of observations – 66227 and no. of sources – 13397).

Because only large regional anomalies can be meaningfully interpreted in view of large measurement errors of the MGS data (anomaly errors are higher than the estimates of instrument precision [5]), Figures 1a and 1b show that the choice of magnetization direction in the equivalent source inversion will not result in significant errors in regional interpretations. The same is also true of other magnetization orientation sets I explored: the ones assuming magnetic poles along the rotational axis and in the southern highlands of Mars.

Are carefully determined field models less accurate than observations? The choice of using observations vs. carefully normalized field is largely a matter of data distribution and quality, but also depends on other legitimate transformations one wishes to perform on the field to aid the interpretation (see [2, 3] for examples). It is, therefore, inappropriate to think that because a particular transformation is model-based, its results cannot be used legitimately in place of the observations themselves. While it would be nice to have perfect observations everywhere, one does not usually have such a luxury. The key issues here are how well the model reproduces the field in the neighborhood of the observations (see Figure 1b caption) and that the model is not numerically underdetermined. Another issue to consider is that observations also contain errors, and one of the advantages of fitting a potential field model through potential field data is that non-potential fields are not fit by the model (e.g., non-potential fields result from making measurements in the region of space containing ionospheric currents). Measurement errors can also render models erroneous if the amount of high quality data in a given region is not sufficient. However, interpreting those same observations directly would lead to equally erroneous results as the models of the field themselves. With the criteria of inversion stability met, the equivalent source models have been shown to be precise in the region of space containing the data [2, 3]; they are not precise for extrapolating. Carefully determined models permit us to compute quantities (derivatives, Analytic Signal, etc.) that can aid interpretation of sources, as long as data themselves are of sufficiently high quality.

How meaningful is the Analytic Signal transformation? Based on the nature of the misfits to the Z-component field (Figure 1b caption), it is clear that high-wavenumber noise exists in the available low-altitude MGS magnetic field data. Thus, it is expected that the inaccuracies will be enlarged in the Analytic Signal field (length of the gradient vector) and, therefore, care must be taken in its interpretation. The presence of inaccuracies is also reflected in the misfit of Analytic Signal forward models [7]. To examine one aspect of robustness of the Analytic Signal field, I computed the differences in the fields produced from equivalent source inversion of magnetization directions of sources based on different magnetic poles. In regions where the Z-component fields are similar among different sets of magnetizations tested (e.g., see Figures 1a and 1b), the Analytic Signal fields are also similar (not shown due to lack of space), indicating that the robustness of the regional-scale features in the Analytic Signal field is not affected by the choice of magnetization direction of equivalent sources.

What are the principal differences between the traditional use of the Analytic Signal technique and its use with satellite-altitude data? In near surface applications, maxima of the Analytic Signal field indicate the approximate locations of source boundaries [10]. Because the fields coalesce with altitude, at satellite-altitudes, only the merged maxima are observed for most sources. We showed [7] using complex model studies how the merged maxima are still useful in indicating the source locations, if not their edges. Furthermore, we resorted [7] to forward modeling of the Analytic Signal field in order to confirm our qualitative inferences regarding the source locations. Finally, to answer the question whether the Analytic Signal field would be able locate sources in view of varying magnetization directions expected of regionally extensive sources on Mars, we included in our model study a long source that gradually changed its magnetization inclination and declination by 70° and 35°, respectively [7]. These model studies and results justify careful use of the Analytic Signal field in the interpretation of Mars magnetic anomalies.

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