Evidence for an ancient near-equatorial lunar dipole from higher precision inversions of crustal magnetization

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Abstract. Studies of lunar paleopoles have been used to make a variety of inferences about past episodes of true polar wander and the orientation of the ancient dynamo field. However, the large and variable uncertainties commonly reported for such studies make robust conclusions difficult. To make further progress, we used synthetic magnetic anomalies to assess a common method to estimate magnetization direction uncertainty. We find that with this method, magnetic anomalies with higher inclinations have systematically higher uncertainties than lower inclination anomalies. We call this effect inclination bias. We also find this method often produces overly conservative uncertainty estimates. To avoid these effects, we use Monte Carlo methods to determine magnetization direction uncertainty. We apply our methods to five lunar magnetic anomalies with a wide range of reported magnetization directions and paleopole locations. We find that inclination bias partly explains the previously reported anomalously high and low direction uncertainties for two of these anomalies: Reiner Gamma and Airy. Our more robust uncertainties allow us to conclude that four paleopoles are located near the equator. Such low latitudes cannot be explained by true polar wander inferred from other independent datasets, such as the lunar gravity field and the polar hydrogen distribution. This in turn implies that the dynamo axis was once offset from the spin axis.