Correcting GONG+ Magnetograms for Instrumental Non−uniformities

R. Clark, J. Harvey, F. Hill, C. Toner

National Solar Observatory − GONG, P.O. Box 26732, Tucson, Az. 85726

rclark@noao.edu 520 318 8523 (voice) 520 318 8400 (fax)

The instruments in the GONG+ network are now producing magnetograms once a minute. These magnetograms are subject to a zero point uncertanty, varying across the field of view, of a few gauss. For a large number of images low order 2−dimensional polynomial surfaces are fit to quiet regions on the sun and averaged to determine this zero point error. Applying the resulting correction to individual magnetograms results in some improvement, as shown by inter−station comparisons. However, it is found that the zero point error has a time−varying component. A possible cause for this variation has been identified.

The recently upgraded instruments of the Global Oscillation Network Group (GONG) now routinely obtain magnetogram observations of the sun every minute. The high temporal and moderate spatial resolution of these observations offer a useful resource for the solar physics community. It is important to calibrate these data as accurately as possible to maximize their value.

An unknown factor impacting the quality of the magnetogram observations arises from non−uniformities and small imperfections in the magnetogram modulator,. These can introduce uncertainties of several gauss in the zero point of the magnetograms and impacts the quality of merged data from multiple GONG sites. We have tried various approaches to characterize this non−uniformity using available GONG data products.

Currently, the preferred method attempts to extract instrument related artifacts from actual magnetogram images. A low order 2−dimensional polynomial surface is fit to quiet regions of the sun. A threshold limit is used to limit contributions from active regions. This process is then repeated, using the departure from the fitted surface rather than from zero as the basis for rejecting points in active regions. In later iterations the threshold for rejection is tightened.

The GONG tracking turret rotates the solar image during the course of the day. The GONG camera is physically rotated to compensate and keep the image oriented with solar north aligned along the x direction on the CCD. The images from a day are numerically rotated back to the camera’s parked position. The surface fitting is then performed and the fits to these ’ derotated’ images are stacked and, for each pixel, the median is found and stored, with some further smoothing, to produce a daily stationary feature map. The ~90° variation in image rotation over the course of a day allows partial isolation of solar contributions from those that are fixed with respect to the modulator. These daily maps still show some contribution from large scale solar magnetic structure that leaks through the averaging process, and from seeing−induced noise. Several daily maps are averaged to produce a modulator correction map. Figure 1 shows part of this process.

The resulting zero point correction maps provide some improvement when applied to magnetogram images. The top row of images in figure 2 shows uncorrected magnetograms from the Big Bear and Mauna Loa GONG sites for the same minute (2001 October 8, 1850 UT), and the difference between them. The bottom row shows the same two magnetograms with the zero point corrections applied. The resulting difference image shows substantial improvement with respect to the whole−image bias correction, but only modest improvement in removing the net gradient across the image. Comparison of several such image pairs revealed variation in the quality of improvement during the day. Figure 3 shows the comparison for images at 2330 of the same day.

When a set of reference points from the individual fitted surface images were monitored during the day, systematic variations were noted. This could be produced by features from the rotating image of the sun being superimposed on the fixed modulator pattern. However, a trend was found to be permanent over an extended period of time, suggesting that the cause might arise from within the GONG instrument. Figure 4 shows an example of this from the Learmonth GONG site, where the behavior was first noticed.

Recent measurements by Harvey and Sudol (to be described elsewhere) at the GONG test site in Tucson confirm this interpretation of a time−varying modulator bias and suggest a possible cause. Their observations have established that:

- The modulator requires a finite switching time to change between its +¼ to −¼ wave states.

- During this switching time the modulator is sensitive to linear polarization at the 1% level.
- The changing angles of reflection from the mirrors in the GONG tracking turret are a possible source of time−varying linear polarization at this level.

The investigation of this effect, and ways to measure and model it is now underway.

SUMMARY

- There is a zero point error in GONG magnetograms introduced by nonuniformity of the magnetogram modulator. This error can vary across the solar image.
- Modest improvement to GONG magnetograms can be achieved through the application of a fixed and constant correction to each station's magnetograms.
- The magnetogram modulator has been found to be sensitive small amounts of linear polarization which may be introduced by the GONG tracking turret.
- For significant further improvement of GONG magnetograms a time varying correction will be necessary.

ACKNOWLEDGEMENTS

This work utilizes data obtained by the Global Oscillation Network Group (GONG) project, managed by the National Solar Observatory, which is operated by AURA, Inc. under a cooperative agreement with the National Science Foundation. The data were acquired by instruments operated by the Big Bear Solar Observatory, High Altitude Observatory, Learmonth Solar Observatory, Udaipur Solar Observatory, Instituto de Astrofisico de Canarias, and Cerro Tololo Interamerican Observatory.

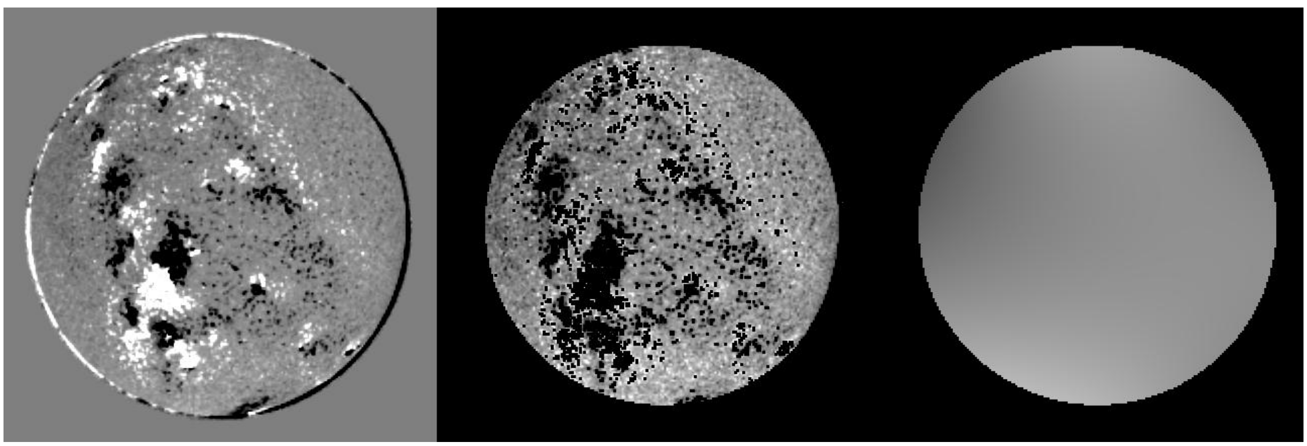


Fig 1 At left is a magnetogram from Big Bear on October 8 2001. The grayscale saturates at approximately ±45 gauss. The sky background graylevel is set to 0. The center image shows the set of pixels included in the final iteration of the surface fitting process. The sky background and pixels excluded from the fit are set to black. Other pixels are shown with a grayscale between ±12 gauss. The initial pixel threshold to reject active areas was ±25 gauss relative to 0. The threshold for the final iteration was ±12 gauss relative to the fit. At right is the final surface fit to a 2−d quadratic polynomial shown with the same grayscale as the center image. The area outside the average position of the sun is set to black. Here solar north is toward the right.

Fig 2. The top row shows uncorrected magnetograms for Mauna Loa (left) and Big Bear (center) on October 8, 2001, 1850 UT. At right is the difference image (ML − BB). The bottom row shows the same images after modulator corrections (based on approximately 20 days of averaged surface fits) for each station is applied. The grayscale is linear between ±12 gauss. The sky background is set to 0. The black and white dots outside the solar disk are fixed in the instrument parked orientation. Images were scaled and registered with solar north toward the top for the inter−station comparisons.

Fig 3. Comparison of ML − BB uncorrected and corrected images for October 8, 2001 at 2330 UT.

Fig 4. The value (in gauss) at fixed points within the image on the modulator correction fitted surface changes through the day in a systematic manner. Nine reference points−− the center, and eight points evenly spaced around the average location of the solar limb (R=80j% of the solar radius from the center) are plotted against time of day. Data from ten days spanning the period October 2 − 31, 2001 are shown. The sensitivity of the modulator to linear polarization from the tracking turret varies across the field of view. This data is from Learmonth, where the time−dependent behavior was first recognized.

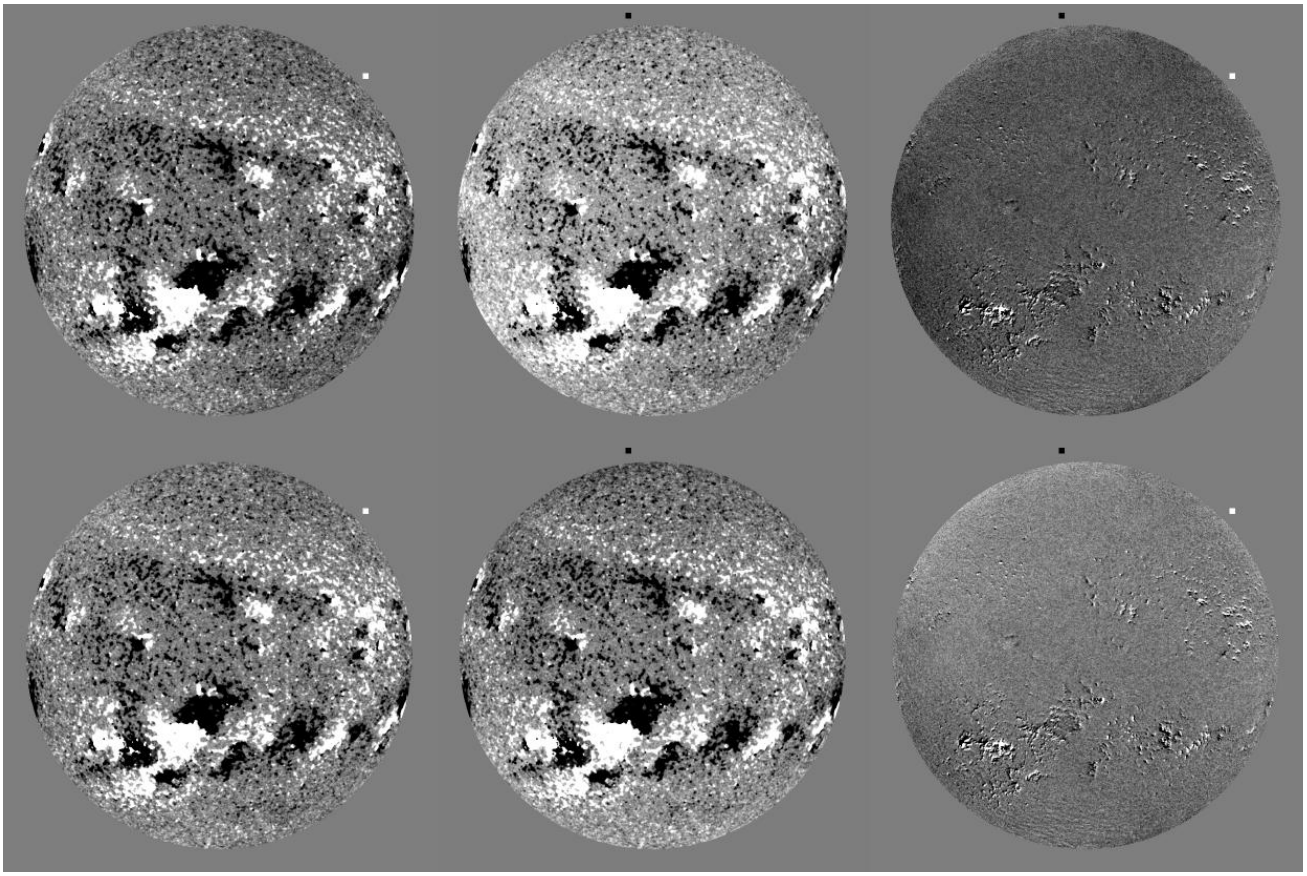


Fig 2

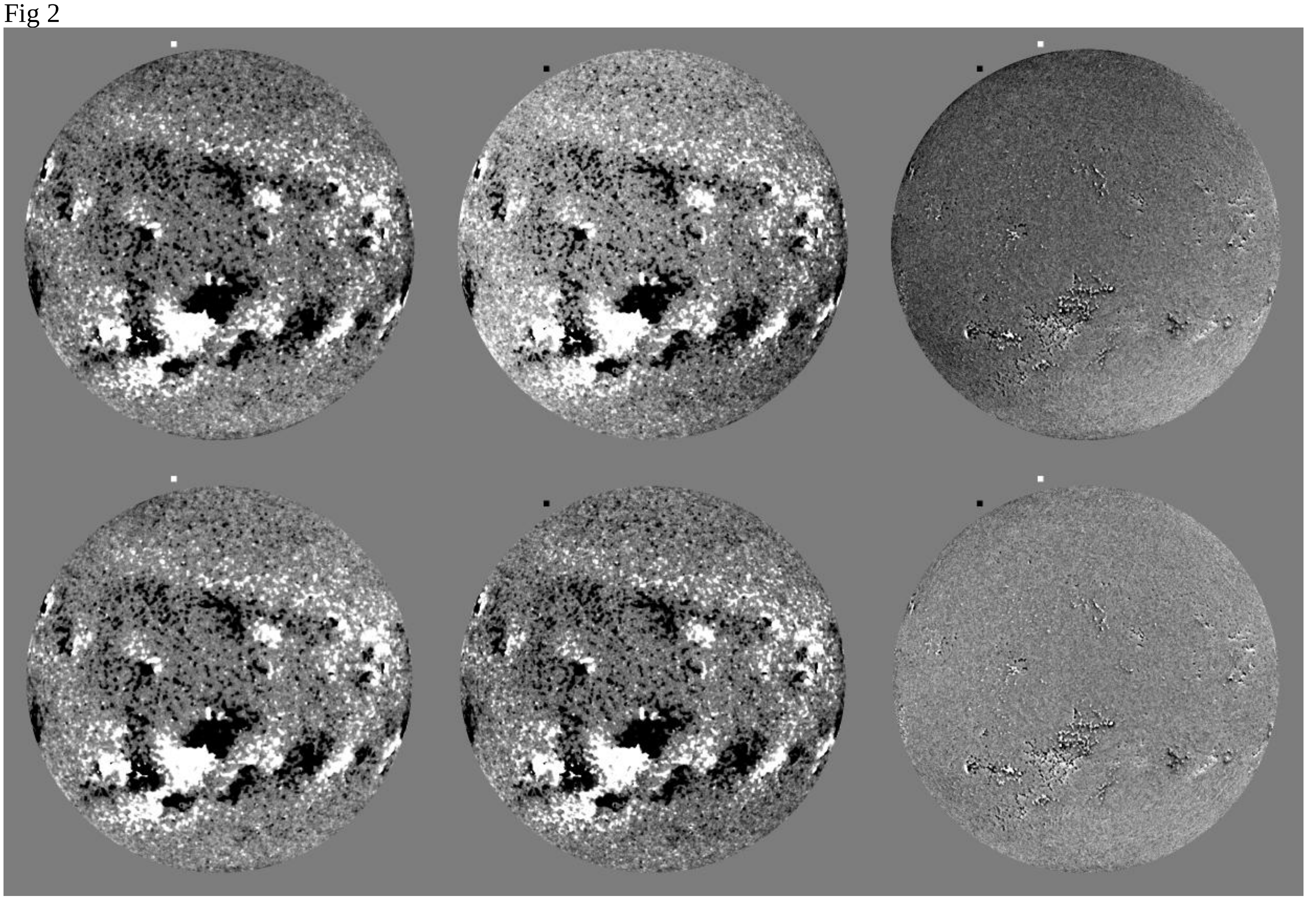
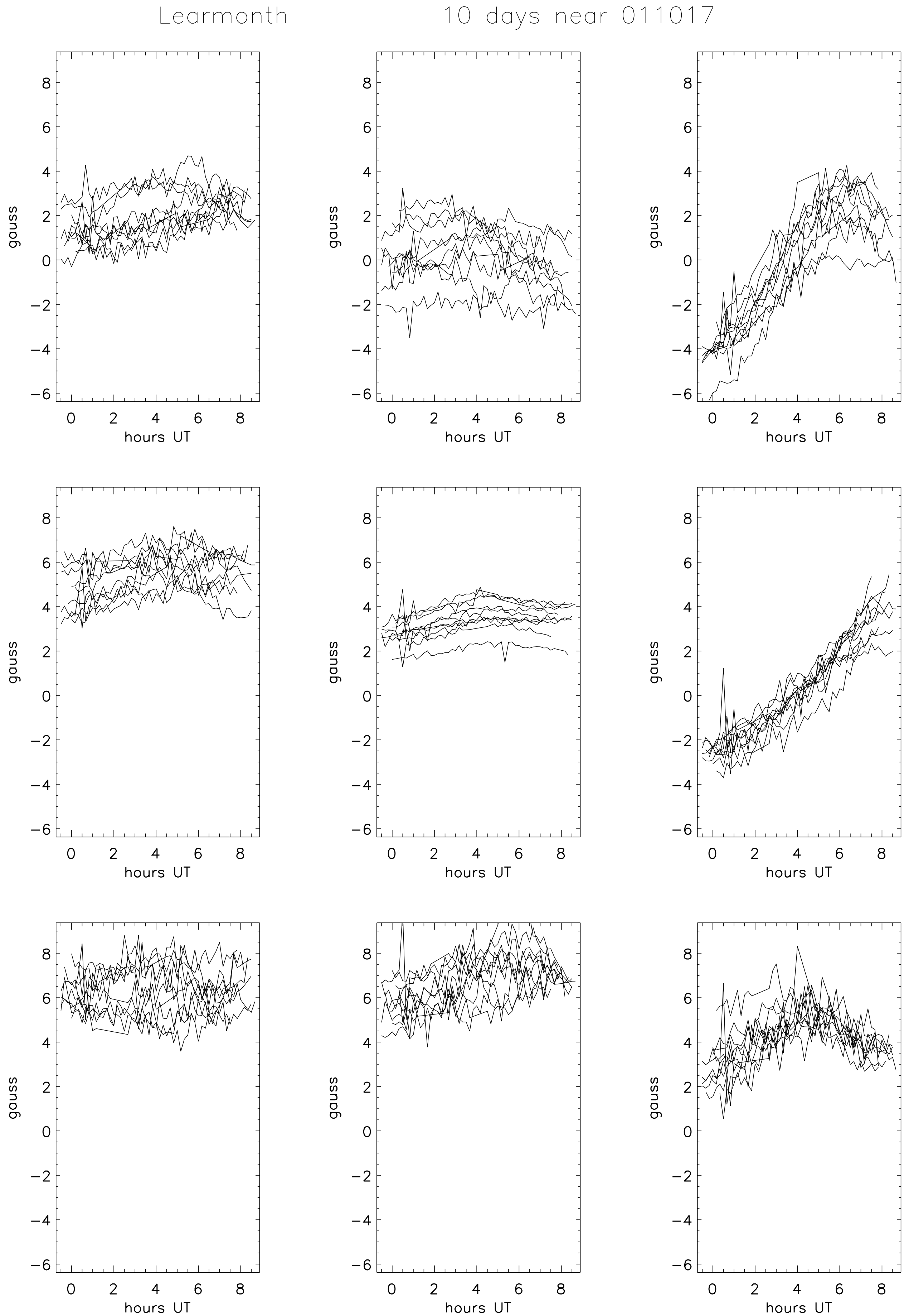


Fig 3


Learmonth
10 days near 011017
gauss
hours UT