AN IMAGE MERGE FOR GONG+

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ABSTRACT

We are developing an algorithm for merging GONG+ velocity images. Here we describe the algorithm and present results of preliminary tests to investigate the utility of using the merged images for local-area helioseismology, focusing specifically on ring-diagram analysis.

Key words: Local Helioseismology; Ring Diagrams; Image Processing.

1. INTRODUCTION

The GONG Project recently completed an upgrade of its camera system from nominally 8x10 arc second pixels (GONG Classic) to 2.5x2.5 arc second pixels (GONG+). The major driving force behind the upgrade is the fairly recent development of various local-area helioseismology techniques, e.g., ring diagrams (Hill 1988, Haber et al. 2000, 2002), time-distance (Duvall 1997), and acoustic holography (Lindsey & Braun 2000), all of which require significantly higher spatial resolution than the original GONG Classic instrumentation provided.

The Project recognizes that there are several groups of researchers who could take advantage of the high resolution of GONG+ and the high duty cycle afforded by the GONG Network. To reduce the storage requirements and data handling complexity of dealing with multi-site observations the Project is developing a method for combining simultaneous velocity images recorded by the Network into a single, once per minute, set of registered merged images. These data will then be made available to the community.

2. METHOD

The process is divided into the following steps:

- All site-day images which contribute to a specified calendar day are staged to disk.
- A set of empty template files are generated, one file for each minute.
- To remove solar rotation and the affects of Earth Observer Motion a low-order polynomial is fitted to each input image and then subtracted.
- Each input image is then remapped to a circular shape using a user specified radius. During the remapping solar north is placed at the top and solar east at the left. The direction to solar north for each input image is determined by the method described in Toner & Harvey 1998 and Toner 2000.
- Each registered image is then summed into the appropriate template file.
- Once all of the input images have been processed the template files are normalized by the number of images summed into each one.
- Any template files which did not have observed data contributing to them are marked as "FILLED" and left simply as place holders.

3. PRELIMINARY TESTS

To test the utility of using the merged images for local-area helioseismology we have performed a "Dense-Pack" ring-diagram analysis (Haber et al. 2000, 2002) using 1664 minutes of merged data. The figures on the following page show the residual horizontal flows on Aug. 22, 2001 at a depth of 0.9 Mm (Figure 1) and 7.1 Mm (Figure 2). The velocity arrow diagram overlays a coeval magnetogram remapped to the same latitude-longitude grid.

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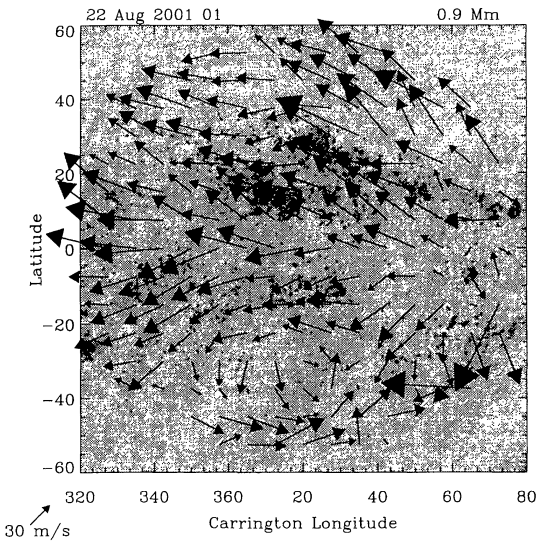

Figure 1. Dense-pack map showing the horizontal velocity at a depth of 0.9 Mm on 22 Aug. 2001 as deduced from merged GONG+ velocity images.

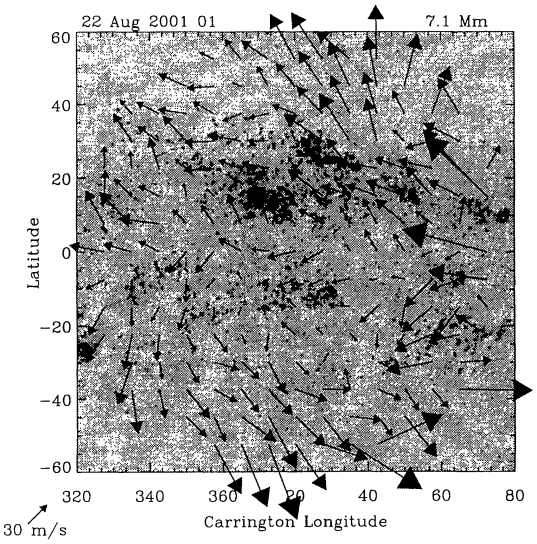

Figure 2. Dense-pack map showing the horizontal velocity at a depth of 7.1 Mm on 22 Aug. 2001 as deduced from merged GONG+ velocity images.

4. DISCUSSION

This is a work in progress. We have demonstrated that we can merge GONG+ images and that ring-diagram analysis of the merged images produces not unreasonable horizontal flows. Comparison of the flows deduced from other experiments is currently under way. Preliminary results comparing the flows as measured using both MDI and merged GONG+ data are presented by Bogart *et al.* & Corbard *et al.* in these proceedings.

We still need to investigate the affect of the double interpolation which is inherent in this approach to analysing GONG+ imaged data. Does this introduce additional noise or artifacts? Does it influence the recovered flows? Will these images be useful for other local-area helioseismology techniques?

Also, there may be other avenues by which we can improve both the image merge and the ring-diagram analysis. Some possibilities are outlined briefly in the next section.

5. FUTURE ENHANCEMENTS

During the standard processing of GONG data an estimate of the Modulation Transfer Function (MTF) is determined for each image (see Toner & Jefferies 1993). Therefore, in principle, it should be possible to correct each image for the affects of the blurring introduced by the terrestrial atmosphere and the instrument optics. To this end, we have been experimenting with an image restoration method that can be applied to the GONG+ velocity images and which is quite fast ($\sim$ 20 seconds per image on a 450 MHz Sun Ultra-80). Thus, it should be feasible to restore all of the site velocity images using existing Project hardware.

One would expect that once the images have been corrected for the MTF, simultaneous, restored data should match more closely than unrestored images, and hence could improve the quality of the image merge.

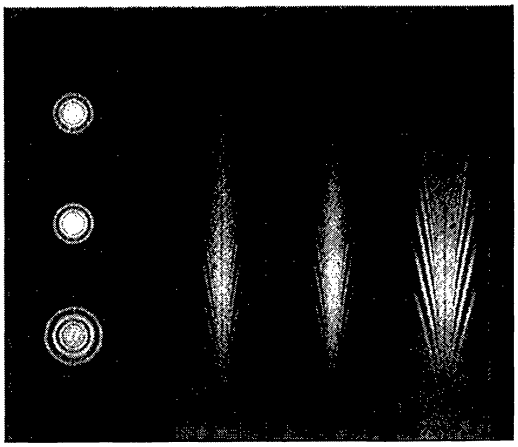

Figure 3. On the left we compare a slice through ring spectra ($k_x - k_y$) at 3606 μHz for: unrestored data (top), unrestored data with multi-tapering (center), and restored data with multi-tapering (bottom). On the right side we compare a slice through the ring spectra at $k_x = 0$ ($k_y - \nu$) for: unrestored data (left), unrestored data with multi-tapering (center), and restored data with multi-tapering (right).

Also, it has been shown (Komm *et al.* 1998) that multi-tapering can help when fitting helioseismic

power spectra. Therefore, we have been investigating the use of multi-taper analysis applied to ring diagrams (Figure 3).

One can see from Figure 3 that multi-tapering produces much better defined rings and that image restoration combined with multi-tapering tends to equalize the power in all of the rings and improves the definition of the rings. Some preliminary tests have been performed using only multi-tapering (no restoration). Analysis of the multi-tapered spectra produces a larger number of good ring fits, leading to somewhat improved inversions and flow maps.

Finally, we note that this image merge routine also works well with GONG+ magnetograms (which, like the velocity data, are recorded every minute at each GONG site). Therefore, it is foreseable that the Project may also be able to provide merged magnetograms to the community.

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