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.

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.

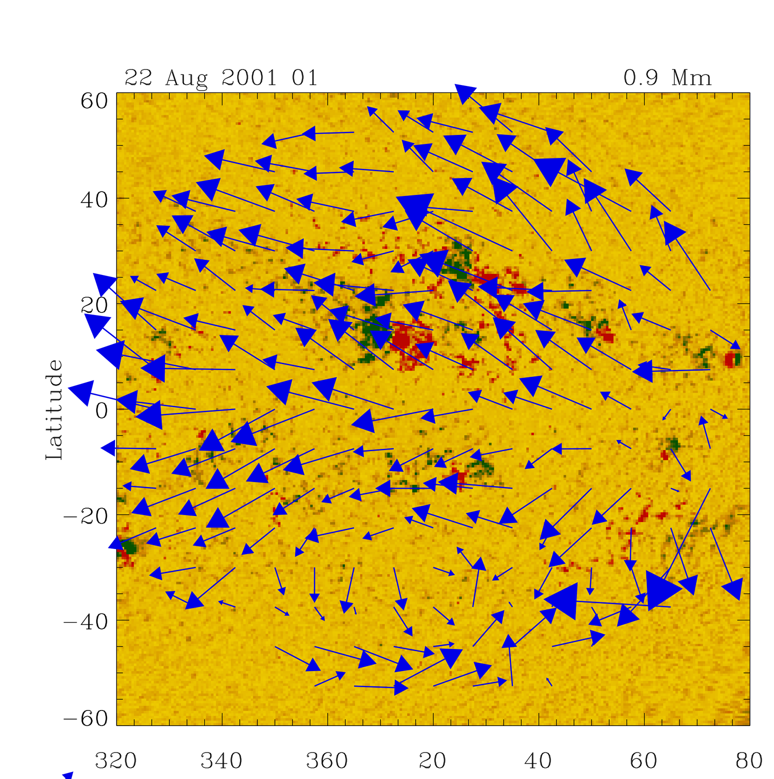
The Project recognizes that there are several groups of researchers who could take advantage of the high resolution of GONG+ and high duty cycle afforded by the GONG Network. To reduce the storage requirements and data handling complexity of dealing with multi-site observations the Project is developing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

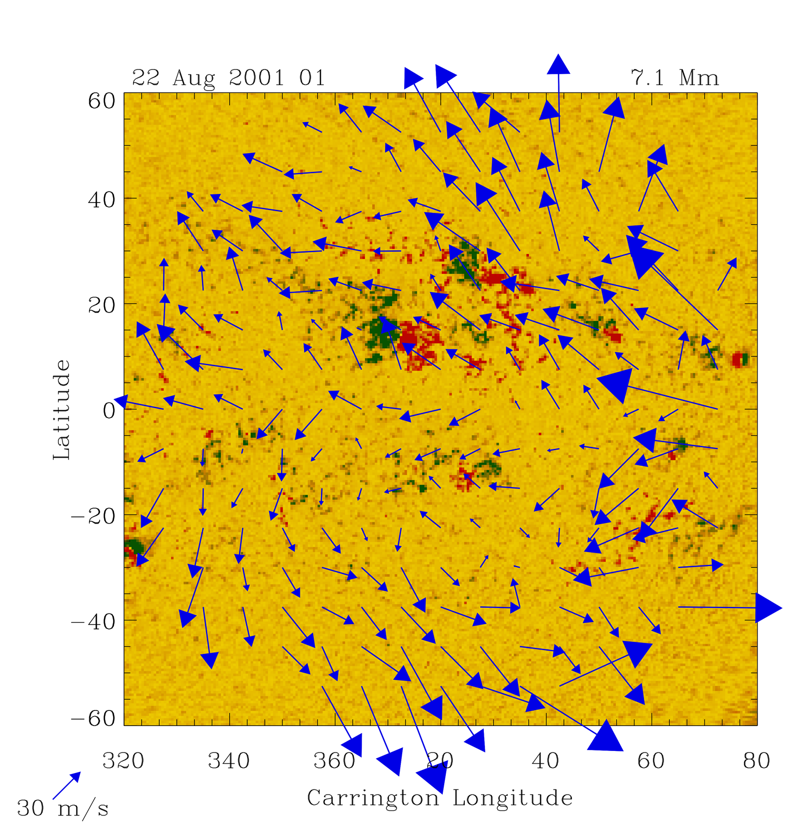
Method

- 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.
- The merging routine then identifies the appropriate site specific images.
- A site-specific correction for the Earth-observer motion is applied to each input image.
- The images are 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.
- To remove any residual site-specific velocity fields, the registered images are temporally filtered using a 2-point backwards difference.
- The registered, temporally filtered images are 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.

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. Below we show the residual horizontal flows on Aug. 22, 2001 at a depth of 0.9 Mm (left) and 7.1 Mm (right). The velocity arrow diagram overlays a coeval magnetogram remapped to the same latitude-longitude grid.





Discussion

This is still a work in progress. So far, we have demonstrated that we can merge GONG+ images and that ring-diagram analysis of the merged images produces not unreasonable horizontal flows. We still need to compare these flows with those deduced from other experiments (eg. MDI).

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

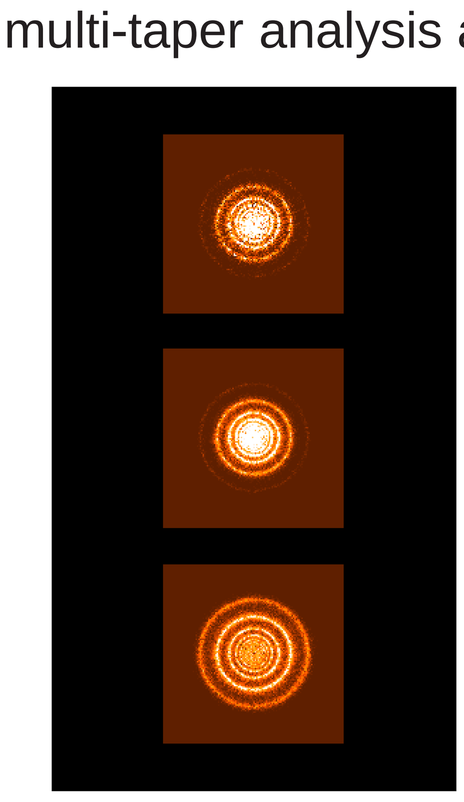
Also, there may be other avenues by which we can improve both the image merge and the ring-diagram analysis. Some possibilities are outlined briefly in the next section.

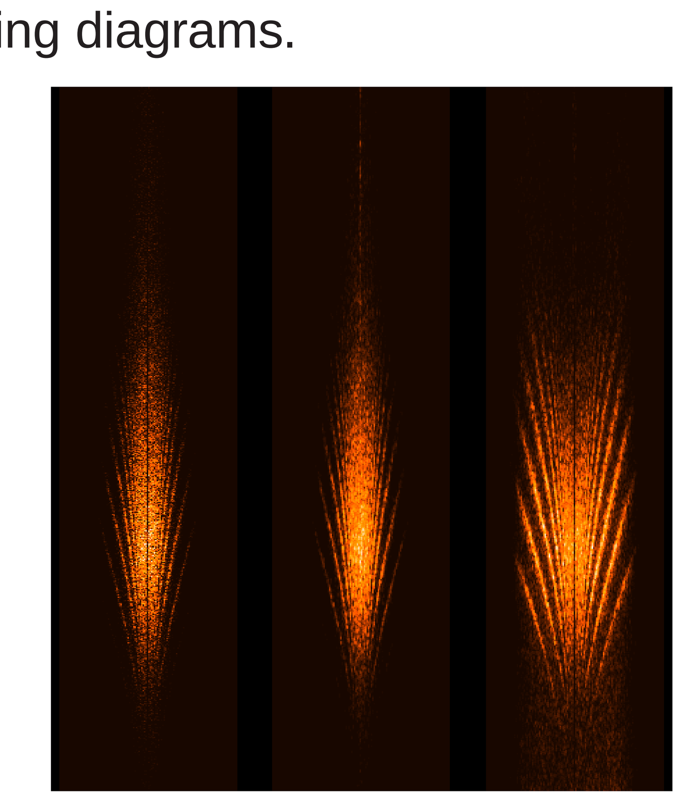
Future Enhancements

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 effects 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 (~ 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.

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.





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).

One can see from the above figures 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.

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