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Observing Large-Scale Solar Surface Flows with GONG: Investigation of a Key Element in Solar Activity Buildup

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Abstract. The Global Oscillation Network Group (GONG) solar telescope network has begun regular operations, and will provide continuous Doppler images of large-scale nearly-steady motions at the solar surface, primarily those due to supergranulation. Not only the Sun's well-known magnetic network, but also flux diffusion, dispersal, and concentration at the surface appear to be controlled by supergranulation. Through such magnetoconvective interactions, magnetic stresses develop, leading to solar activity.

We show a Doppler movie made from a 45.5 hr time series obtained 1995 May 9-10 using data from three of the six GONG sites (Learmonth, Tenerife, Tucson), to demonstrate the capability of this system.

1. Introduction

Supergranular flows produce the Sun's magnetic and chromospheric networks, and appear to be the main driver of magnetic field diffusion, dispersal, and concentration at the surface. Although supergranulation has been studied for over three decades (Simon and Leighton, 1964), researchers have been stymied by their inability to describe well the evolution of this large-scale convective phenomenon. Its life history can be only inadequately observed from a single site since the Earth's day-night cycle precludes continuous observations over the long lifetime (1-2 d) of the typical supergranule. Now, a full generation after its discovery, supergranulation will begin to yield some of its long-kept secrets to the instruments that comprise the GONG network.

The GONG has developed a set of instruments to measure the line-of-sight Doppler velocity over the surface of the Sun at 60 s intervals (Harvey et al.,

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1988). Six of these instruments have been deployed at a network of sites around the world to provide nearly continuous observations of the global oscillations of the Sun.

While GONG was developed primarily to study helioseismology, it is turning out to be extremely useful also for the investigation of the Sun's nearly-steady large-scale surface flows, such as supergranulation. (Small-scale features, such as granulation and magnetic flux tubes, are not accessible to the GONG instrumentation due to GONG's coarse 8 arcsec pixel size).

During the deployment of the GONG telescopes, several long continuous observation runs were obtained from the first three sites (Teide on Tenerife in the Canary Islands, Learmonth in western Australia, and Tucson, Arizona, USA). In this talk we shall describe one such run of approximately 45.5 hr. to illustrate the potential of GONG for studying the long-term evolution of convective motions at the solar surface.

2. Observations and Analysis

These GONG data were obtained between 1995 May 9 00:08 UT and 1995 May 10 21:44 UT. They consist of images obtained on a 256 × 242 pixel CCD, at three phases of one Fourier component of the Ni I 676.8 nm absorption line. These images are combined to produce an intensity image, a line-of-sight velocity image, and a modulation image (which shows variation in the equivalent width of the line). Images are obtained at a 60 s cadence and then averaged over 17 minutes with a Gaussian-shaped weighting function to remove the global oscillation signal due to p-modes having periods of about 5 minutes.

Actually, the GONG instrument produces images having rectangular pixels (aspect ratio 1.277:1), with a dimension of 204 × 239 pixels. These images are rebinned to circularize the solar disk, register the images on the same center, and rotationally align them. The resulting images have 256 × 256 pixels, with the solar disk centered near the center of the grid. The resampling of the images tends to attenuate and blur small scale features. The Dopplergrams are detrended for the line-of-sight component of the solar rotation and limb-reddening by subtracting models of these effects. Observer motion is also subtracted from each image,

Some instrumental effects are removed: The limb is apodized using the function $(1 - (r/R)^6)$, where R is the solar radius. Small gradients across the images, which vary over time, are removed by subtracting a quadratic fit in column-wise and row-wise directions. In the recording process the 256 × 256 images are resampled to fill the 640 × 480 pixel image capture board. These images are then transferred to optical disk as grey-scaled images. Finally, the optical disk images are transcribed to videotape at three rates (4, 8, and 16 s per real-time day) to produce the movie you will see in a few minutes.

3. Results and Discussion

First, however, we show in Fig. 1 a typical frame from this movie sequence. Two well-known properties of the supergranulation Doppler field are clearly seen: 1) The bipolar (dark-light) structure of supergranules, demonstrating outflow from

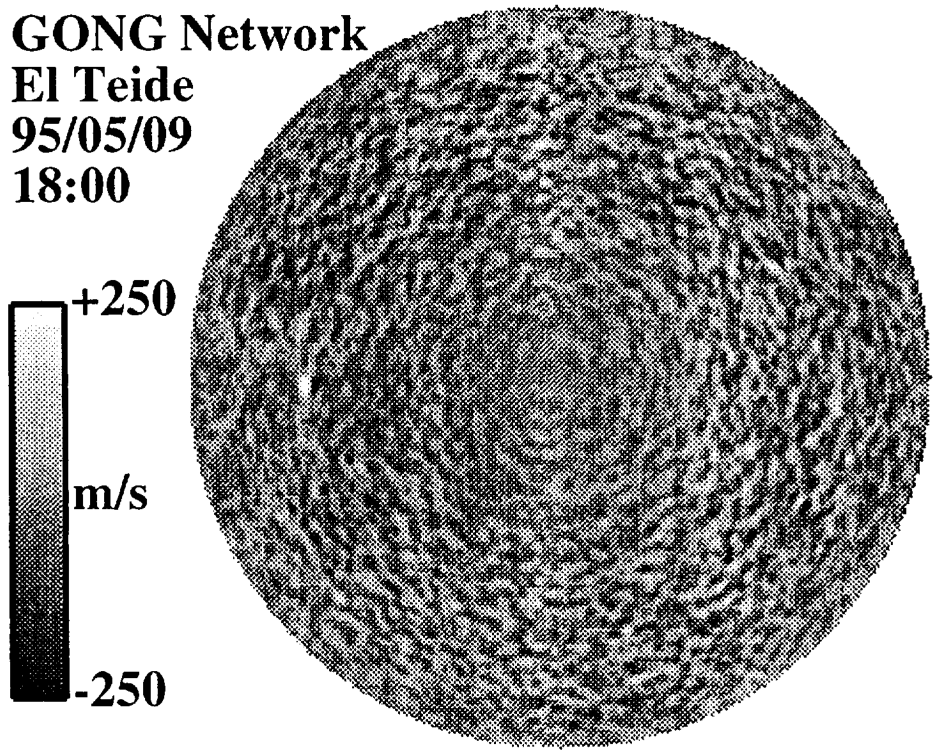

Figure 1. A typical frame from a 45.5 hr sequence of Doppler images obtained 1995 May 9-10 by combining images from three GONG sites at Teide, Learmonth, and Tucson. Darker velocity features are approaching, lighter ones receding from the observer. Heliographic north is at the top of the image.

the cell centers, and 2) Absence of signal near disk center, signifying a mainly-horizontal flow field.

As one watches the video sequence, a third feature of supergranulation is apparent: The long lifetime of the pattern, with many features appearing to last for the entire run of nearly two days. It almost appears that nothing is changing, but careful examination shows that some of the supergranules are born or die during the sequence.

We point out that this is basically an "engineering" talk to illustrate the success and power of the new GONG instrumentation for studying the non-oscillatory component of the Sun's surface velocity field. It is not our purpose here to describe any new scientific results; thus we will not present any analysis of this video at this time.

However, several scientific studies of the Sun's nearly-steady surface flows from GONG are already underway. Hathaway (1996) has recently analyzed GONG data to determine the structure and evolution of the Sun's meridional flow. A 36-day movie (1995 May 7 - 1995 June 11) is being analyzed by Hathaway and Gilman (1995) for evidence of giant cells, while Simon and Strous (1995) are testing feature-tracking techniques in order to follow supergranular evolution. Beck and Evans (1995) are beginning a study of another month-long series of GONG steady-flow images. Several other groups are planning studies of the accompanying GONG magnetograms to analyze magnetic field evolution and its interaction with the surface flows (Here again, the 8 arcsec GONG resolution restricts such projects to larger-scale magnetic flux concentrations in active regions, bigger than the fine-scale fields seen in high resolution at supergranule boundaries).

In closing, we note that the SOI/MDI experiment on the SOHO spacecraft (scheduled for a 1995 November 23 launch) is designed to measure Doppler and magnetic signals with sub-arcsec resolution. It will also determine surface flows by local correlation tracking of the white-light granulation intensity field.

Together, GONG and SOI/MDI show great promise for expanding our understanding of solar magnetoconvection and thus the origins of solar activity.

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