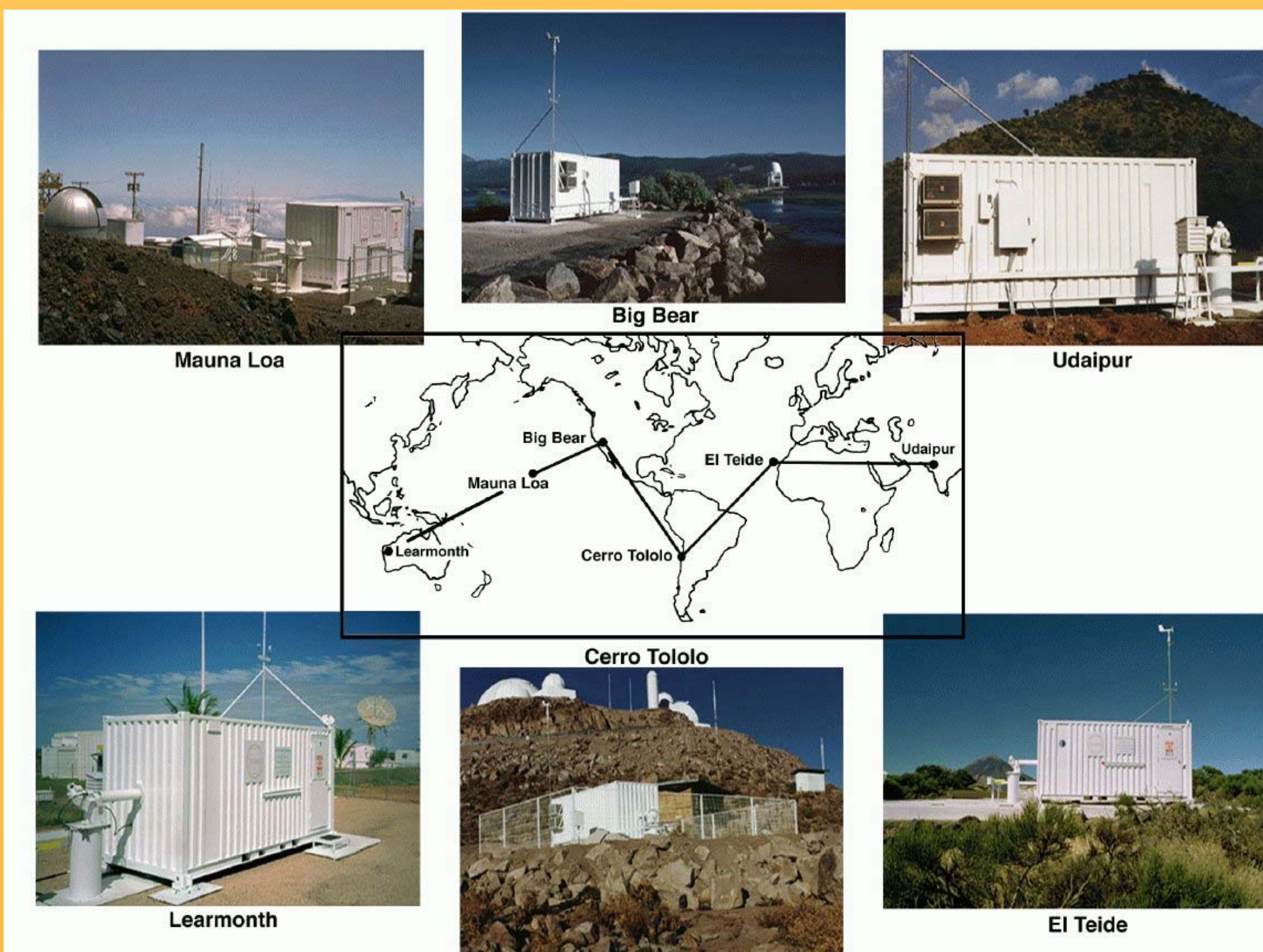


Global and Local Helioseismology with GONG

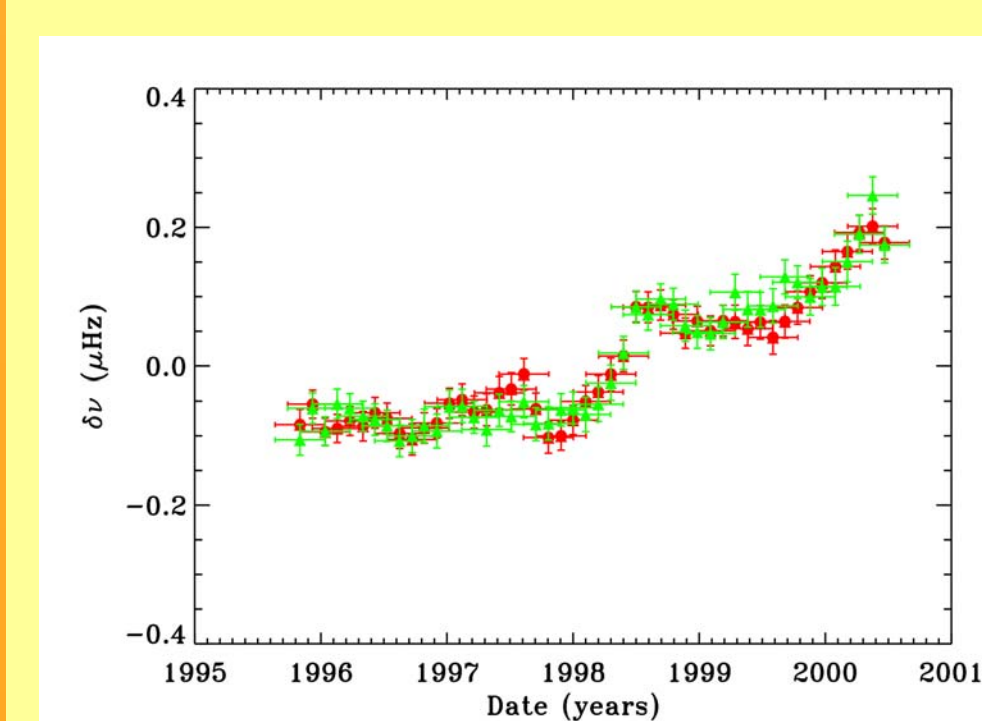
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National Solar Observatory
Tucson, USA



The GONG (Global Oscillation Network Group) network consists of 6 automated observing stations around the world. The original 256x256 pixel instruments observed from 1995 to 2001, providing continuous, medium-degree helioseismic data with a duty cycle around 85%. The network was then upgraded to 1024x1024 pixel instruments, which allow us to detect modes up to around $l=1000$ and to apply the techniques of local helioseismology to monitor flows close to the surface, as well as to continue global helioseismology with the medium- l p-modes that probe rotation and structure deep into the solar interior.

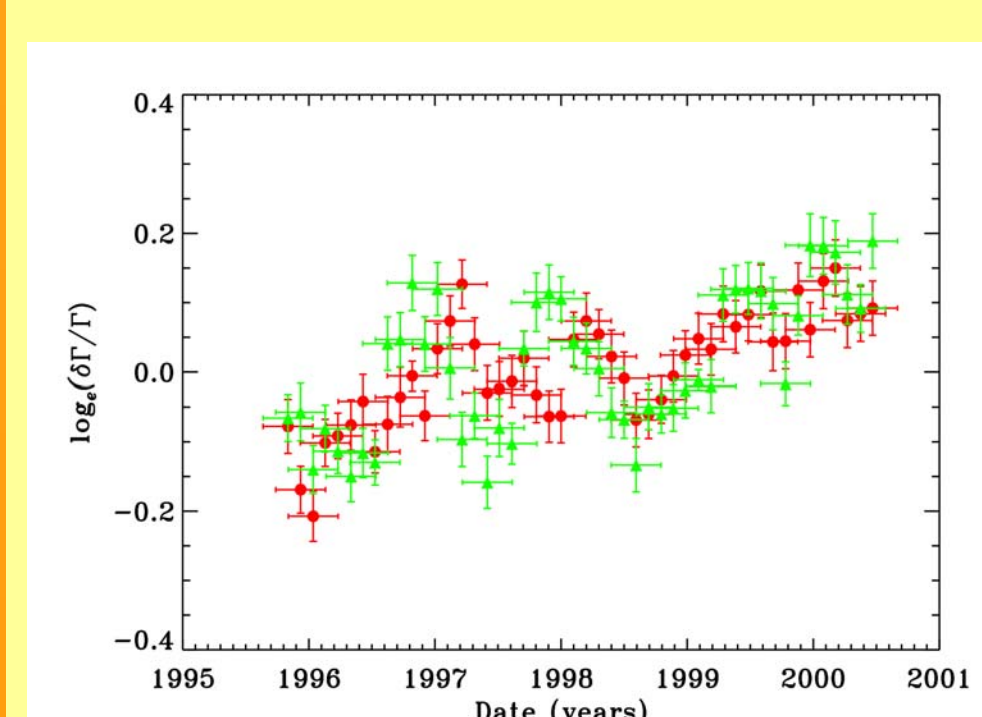
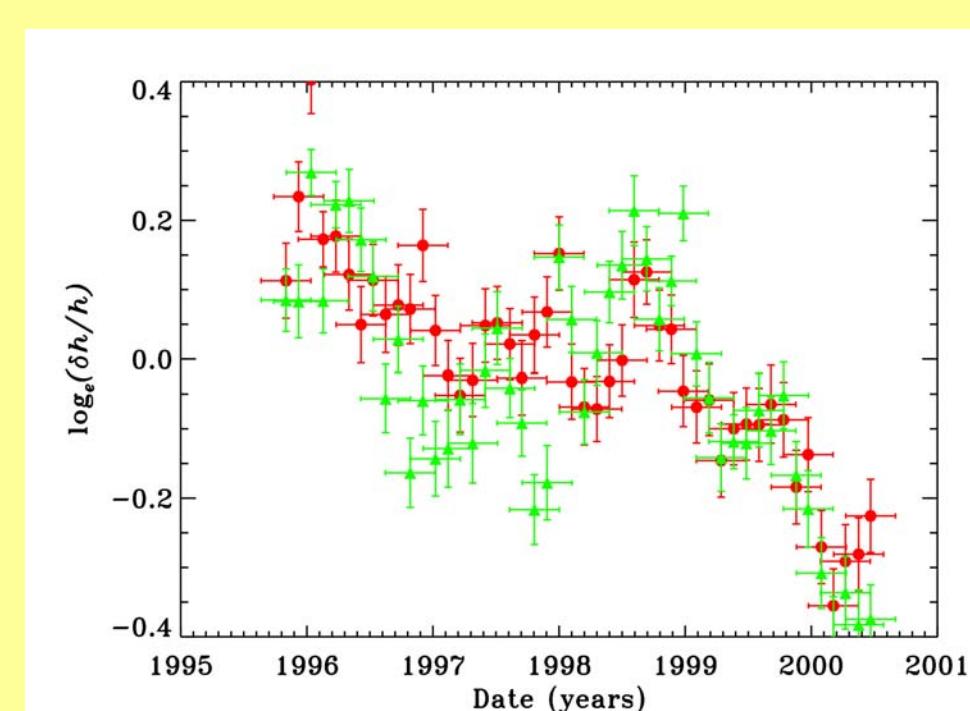
Temporal Variations of $l=0$ Mode Parameters

1728 days of data, starting on 1995 September 28 and ending on 2000 June 20, from the GONG $l=0$ time series, were analyzed along with the contemporaneous '0-dimensional' data from the BiSON project using the BiSON algorithms. More details on this work can be found in Howe et al. (2003).



Mode parameter shifts were found by identifying modes that were successfully fitted in all the individual 144-day time periods, then comparing the values at each epoch with the temporal mean and averaging over the available modes.

Frequency shifts (above) are shown for GONG (red) and BiSON (green) and show an increasing trend with the rising solar cycle, while the mode height (right) shows a decreasing trend, modulated to some extent by the



duty cycle of the data. The mode width Γ (left) shows an increasing trend for both projects, though this is almost swamped by duty-cycle and other effects. These trends are consistent with earlier results.

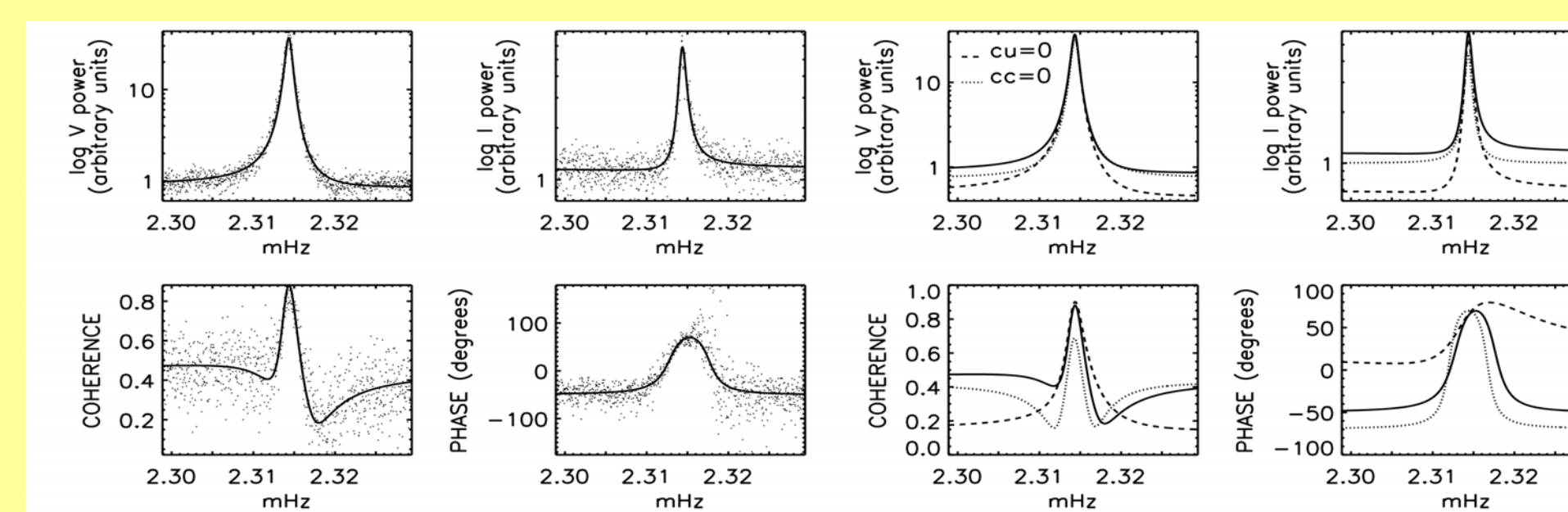
For More Information

<http://gong.nso.edu/>

Or pick up a copy of the 2003 GONG resources CD

Simultaneous Velocity-Intensity Fitting

We use 9 GONG months (324 days, from 1996 Oct. 28 to 1997 Sept. 16, duty cycle=85%) of I (Intensity) and V (Velocity) rotation-corrected, m -averaged, spectra corresponding to $l=15-50$ between 1.6 and 4.8 mHz (617 modes) to determine the solar oscillation parameters. These parameters are determined by fitting simultaneously 4 spectra: V and I power, $I-V$ phase difference and $I-V$ coherence, using the model of Severino et al. (2001). More details are in Barban and Hill (2003).

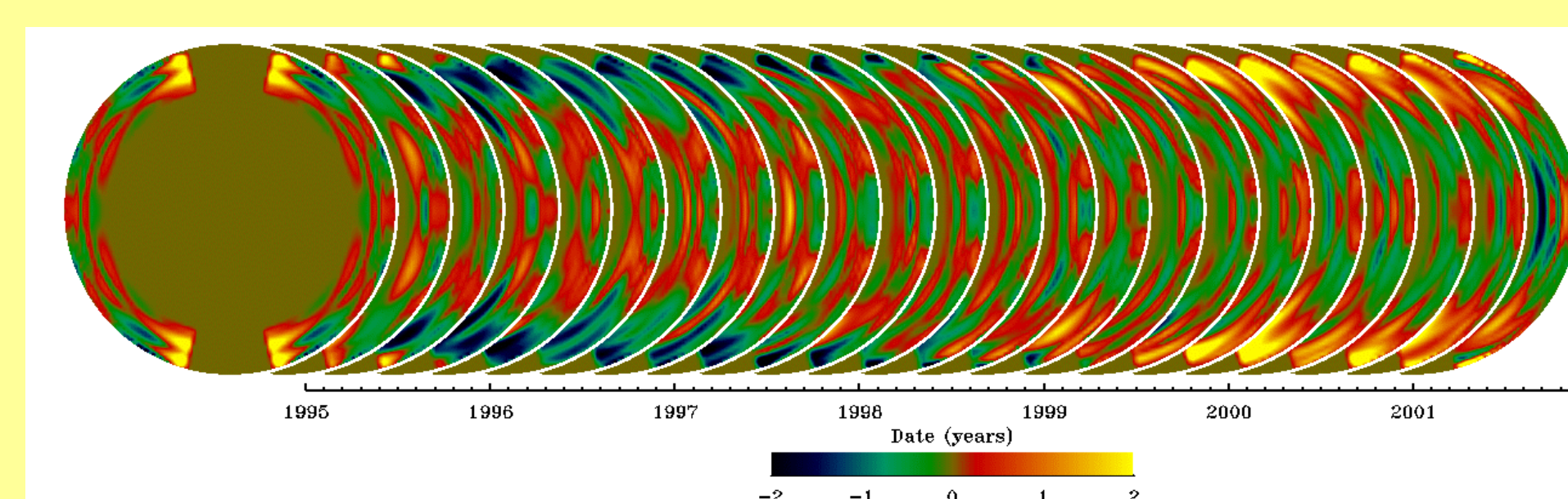


The figure above left shows the good fit to the observed spectra for the $l=24$, $n=9$ mode, with the dots showing the data and the curves the fit. At right, we show the modeled helioseismic spectra for $l=24$, $n=9$, demonstrating the sensitivity to the background components. The solid line corresponds to the best fit; the dashed line to the same model with the coherent uncorrelated background set to zero both in I and V , and the dotted line to a model with the coherent correlated background set to zero.

The absolute oscillation frequency difference between these results and those for a fit with asymmetric peaks to the V spectrum only is less than 0.1 μ Hz between 1.6 and 3.2 mHz

Rotation from Global Helioseismology

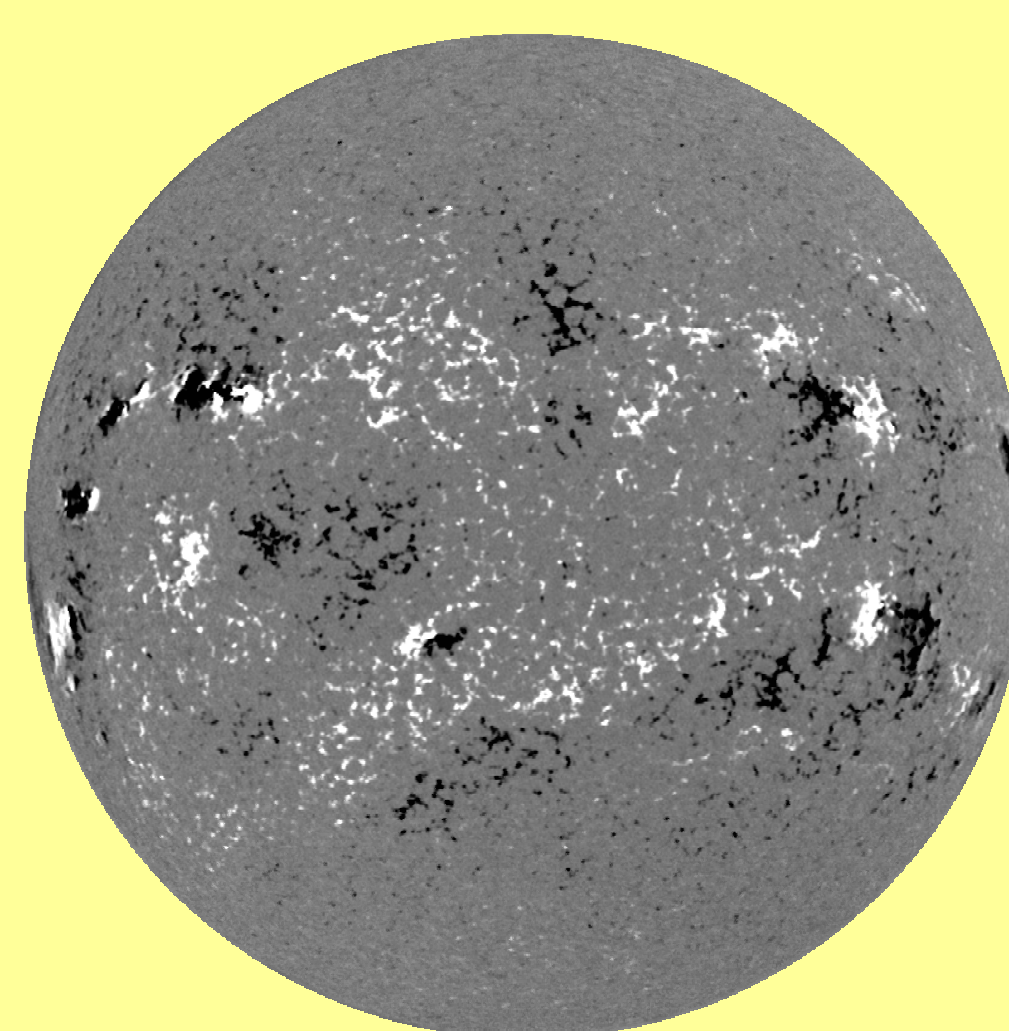
Inversion of global p-modes with degree up to 150 from GONG allow us to probe the changing dynamics of the solar convection zone, with observations stretching from before the last solar minimum in 1995 to just after solar maximum. By subtracting the temporal mean rotation profile, we reveal the pattern of flows that migrates from mid-latitudes to the equator, as well as the larger-amplitude variations at higher latitudes. Below, we show the observed rotation residuals (in nHz).



When the resolution and noise of the data are taken into account, the results suggest that the flows seen at the surface persist through at least half the depth of the convection zone, but with a significant phase variation with depth; the variation near the base of the convection zone appears to lead that near the surface by as much as two years, but because of the noise levels this inference needs to be treated with caution.

Magnetograms

The new GONG instrument provides full resolution magnetograms every minute, and this MTF-corrected image was made from the sum of 15 consecutive magnetograms. Noise is around 3 G/pixel, and while work continues to reduce the zero-point uncertainty, it is currently $< 1G$ away from the limb.

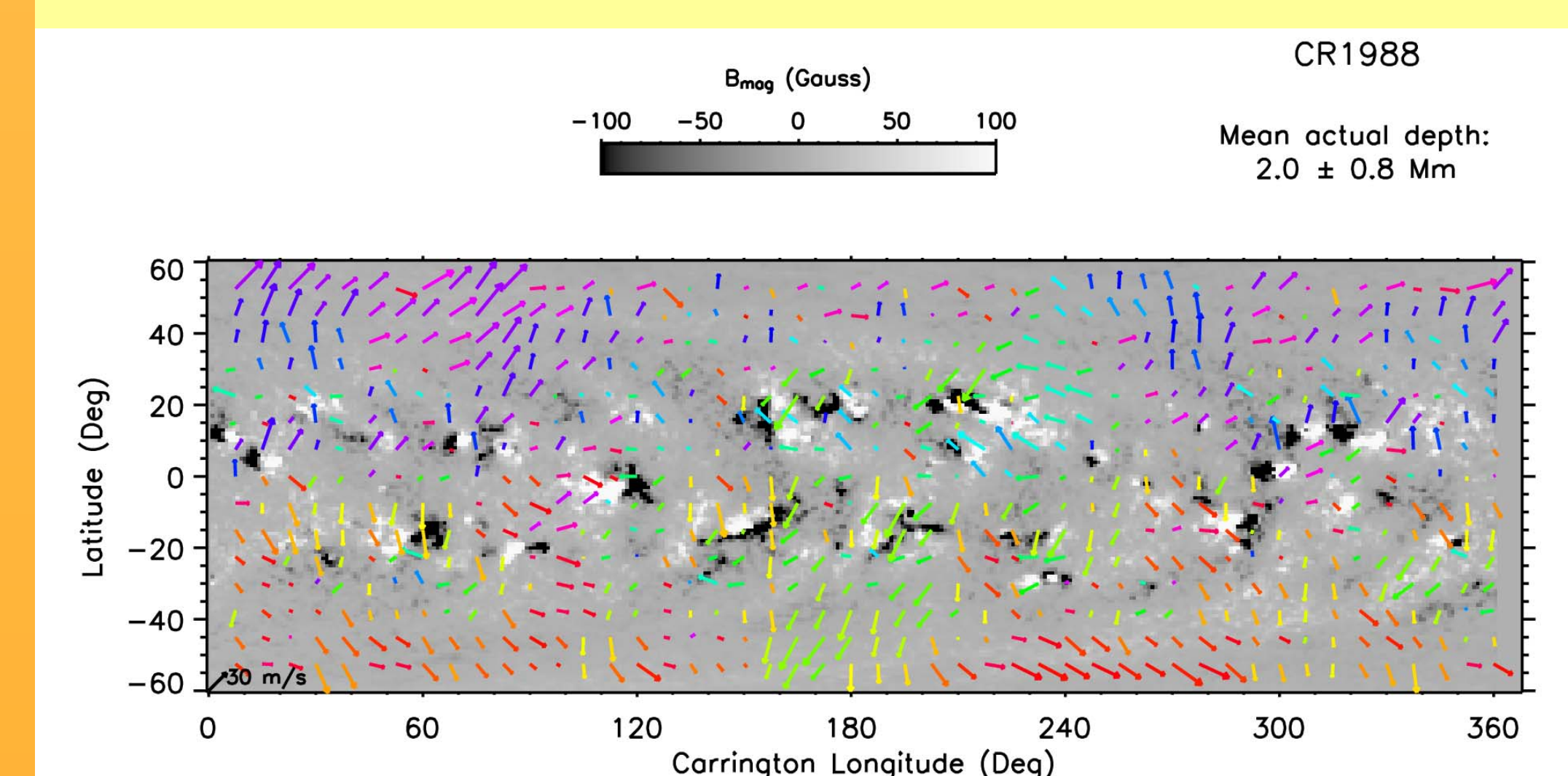


Local Helioseismology

Ring diagram analysis uses 3-dimensional power spectra from small patches of the solar disk to follow local flows below the surface. Such analysis (Hill, 1988) has previously been extensively used on the 'Dynamics' data from the MDI instrument aboard SOHO (e.g., Haber et al 2002). The pipeline to produce ring diagrams and inferred subsurface flow patterns from GONG+ data has now been implemented, and 29 days of merged images have been analyzed, from 2002-03-28 to 2002-04-26, corresponding to Carrington Rotation 1988. 189 overlapping 15-degree patches were analyzed for each 1644-minute 'day', as in the 'dense-pack' analysis of Haber et al.

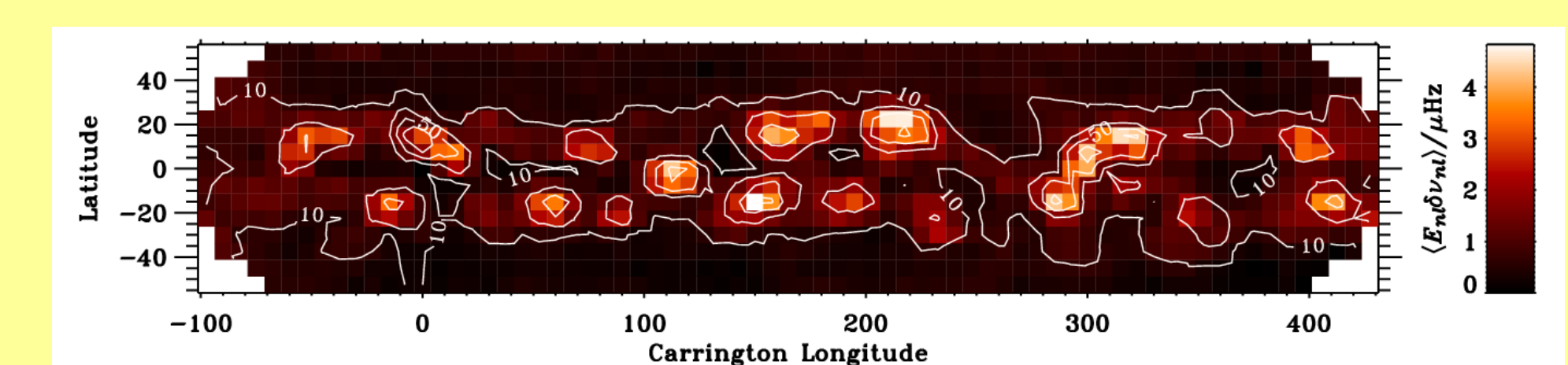
Subsurface Flows

The plots below show synoptic charts of the inferred flows at 2Mm below the solar surface, superposed on synoptic magnetic data derived from GONG magnetograms. To guide the eye, the arrows have been color-coded by direction.



Local Mode Frequency Shifts

The frequencies of the local modes, like those of global modes, show significant shifts in the presence of magnetic activity, as found by Hindman et al. (2000). The synoptic chart below shows the mean of the shifts for modes with frequency greater than 3mHz, scaled by mode inertia, overlaid with contours of the gross magnetic flux averaged over the 15-degree squares. The contours show the unsigned magnetic flux from Kitt Peak magnetograms.



The results suggest that the same, predominantly surface, effect governs the frequency shifts for local and global modes. The scaled sensitivity is somewhat lower for the local modes.

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