2 Years of Meridional Circulation from GONG Ring Diagrams

I. González Hernández¹, R. Komm¹, T. Corbard², F. Hill¹, R. Howe¹, D.A. Haber³

¹ National Solar Observatory, Tucson, Arizona, ² Obs. de la Côte d’Azur, Nice, France, ³JILA University of Colorado, Boulder

Introduction

Ring Diagram analysis, a local helioseismology technique, has proven very useful in studying solar subsurface velocity flows to a depth of about 0.97R☉. We have shown that large aperture ring diagrams are effective in extending the measurement of meridional flows from the solar surface to a depth of about 0.96R☉, the limit of the ring diagram technique.

Data Analysis

We have applied Ring Diagram analysis to patches of 30° diameter over the solar surface as they crossed the solar central meridian. These patches are four times the size of the typically studied patches of 15° degrees diameter. A set of 15 overlapping patches centered at latitudes 0°, ±7.5°, ±15°, ±22.5°, ±30.0°, ±37.5°, ±45.0°, and ±52.5° have been analyzed for 24 intervals of 1664 minutes for 25 Carrington rotations (1985-2009) spanning Jan 2003 – Nov 2004. The range of modes recovered with these larger regions goes down to 100 and reaches a maximum depth of approximately 0.96R☉.

To verify the horizontal flows obtained with these larger patches, we compare the differential rotation obtained by averaging the zonal component of the horizontal velocity vectors for CR 1989 with the global helioseismic measurements obtained for a 3 month period including CR 1989.

Results

We use the Vy component of the averaged horizontal velocity flows from the larger areas to study the meridional circulation. The flows are represented in Figure 1 as contour surfaces where dashed lines correspond to negative values. It can be seen that the amplitude of the flows increases towards the interior of the Sun in the depth range studied. The maximum amplitude very near the surface (0.999R☉) is close to 10 m/s and it increases gradually to 30 m/s at a depth of about 26 Mm (0.96 R☉).

The depth range is determined by the modes used in this type of analysis and thus depends on the size of the analyzed area. Extending the analyzed area allows us to detect lower ℓ-modes that penetrate deeper into the Sun. However, there is a compromise between the size of the analyzed area and the validity of the plane wave approximation used by the technique. In this work we present the results of using this technique to search for meridional circulation variability using a 2-year GONG data series.

Conclusions

- We have shown that large aperture ring diagrams are effective in extending the measurement of differential rotation and meridional circulation to deeper layers beneath the solar surface.
- The presence of the counter-cell/down flow and the systematic differences in the averaged horizontal flows between GONG and MDI are still under investigation.
- We find variation in the maximum amplitude of the flows through this 2-year period.
- GONG continuous velocity data will allow us to search for a meridional circulation variation with the solar cycle. A previous study by Chou et al. using TON data found variations that were different for the declining phase and the rising phase of Cycle 22. They also find a general increase with depth in the meridional flows of up to 40 m/s. Our work agrees with a slight increase in the magnitude of the meridional flows with depth, however we suspect the inversion technique may account for the major increase below 0.965R☉.

References


Acknowledgments

We thank R. Bogart, J. Bolding, B. Hindman, R. Larsen, and T. Turner for their contribution to the RD pipeline development.

Electronic versions of this and many other GONG posters are available on the GONG CD and also at https://gong.nso.edu/gallery/cd_data_2005/