Flow Maps from GONG Ring Diagrams

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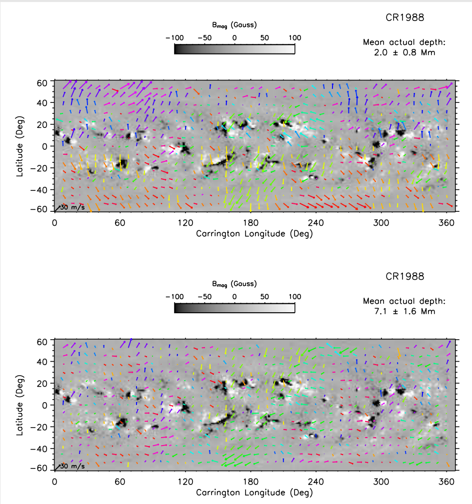
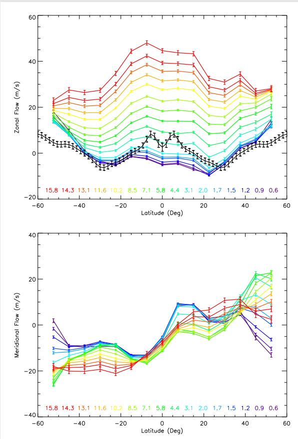
Introduction

We show first results from GONG++ observations covering Carrington rotation 1988 (2002/3/30 - 2002/4/26) analyzed with a ring-diagram technique as part of the GONG++ local helioseimology analysis pipeline. We measure horizontal flow components (zonal and meridonal) over a range of depths up to 16 Mm on a spatial grid of 7.5 degree in latitude and longitude. We present synoptic flow maps and compare them with corresponding maps of magnetic activity.



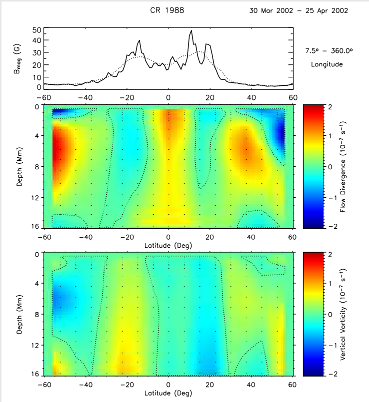
The figures above show two examples of synoptic flow maps at 2 Mm and 7 Mm below the solar surface, superposed on synoptic magnetic data derived from GONG magnetograms. To guide the eye, the arrows have been color-coded by direction. The strong east-west trend at the deeper depth reflects the presence of the subsurface shear layer.



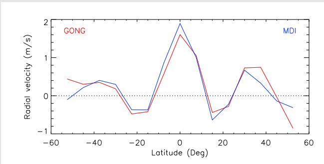
The east-west or zonal (top) and meridional (bottom) components of the flow have been averaged longitudinally over one Carrington rotation to reveal the underlying pattern. The surface rotation rate (tracking rate) has been subtracted. The increase of the zonal flows with increasing depth reflects the well-known increase of the rotation rate near the outer shear layer. The black curve represents the zonal flow at $r = 0.99\,R_\odot$ derived from a global rotation inversion. The local method distinguishes between the hemispheres, while the global analysis leads to a better resolution in latitude.

Fluid Dynamics Descriptors

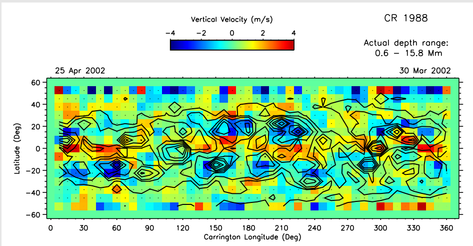
We start exploring the dynamics of the near surface layers of the convection zone by deriving fluid dynamics descriptors such as divergence (div $\mathbf{v}$) and vorticity (curl $\mathbf{v}$) from the measured flow maps. These descriptors allow us to estimate other quantities such as, for example, the radial velocity component and the kinetic helicity (radial velocity times radial vorticity component) which is associated with the α-effect of solar dynaomo models.



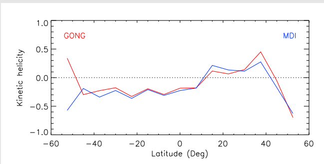
The divergence of the horizontal flow components (averaged over longitude) shows a source (upflow) near the equator and sinks (downflow) near 20 degree latitude.
The vertical component of vorticity (bottom) shows that in each hemisphere the flows change from predominantly cyclonic to anticyclonic behavior in the presence of magnetic activity.



The vertical (or radial) flow component averaged over depth can be estimated from the divergence of the horizontal flow components [1].



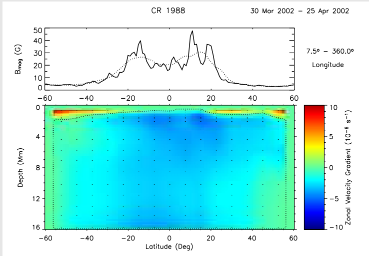
The vertical flow component shows latitudinal bands of upflow and downflow. Locations of strong magnetic activity (indicated by contour lines) are more likely associated with downflows.



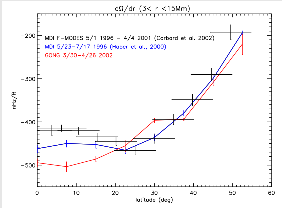
The kinetic helicity is mainly positive/negative in the northern/southern hemisphere. The sign reversal near 45 degree is also seen in some dynamo models [2].

Radial Gradient of Rotation

The radial gradient of rotation is not only of interest for the understanding of the dynamics of the near surface layers but it might also provide evidence for the existence of a near-surface dynamo.



The gradient is mainly negative except within 2 Mm of the surface at latitudes poleward of about 20 degree (see [3, 4]). It is rather constant at latitudes equatorward of about 25 degree and approaches zero at higher latitudes.



The gradient of latitudinally symmetrized zonal flows averaged over depths from 3 to 15 Mm compares well with previous results ([3], [5]).

Conclusion

The relation between flows and magnetic activity is far from simple. However, one can, as always, distinguish equator from activity belt from higher latitudes.

The results are more uncertain at high latitudes (as expected).

A ring-diagram analysis of corresponding MDI data shows similar results (see Poster 8.04 [6] for a more detailed comparison of MDI and GONG data).

References

[1] Scorer, 1978, Environmental Aerodynamics
[2] Dikpati & Gilman, 2001, ApJ, 559, 428
[3] Corbard & Thompson, 2002, Solar Physics, 205, 211
[4] Basu, Antia, & Tripathy, 1999, ApJ, 512, 458
[5] Haber et al., 2000, Solar Physics, 192, 335
[6] Bogart et al., 2003, Poster 8.04, 34th SPD meeting

Acknowledgments

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