Measurement of the meridional flux transport in the solar photosphere

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Introduction

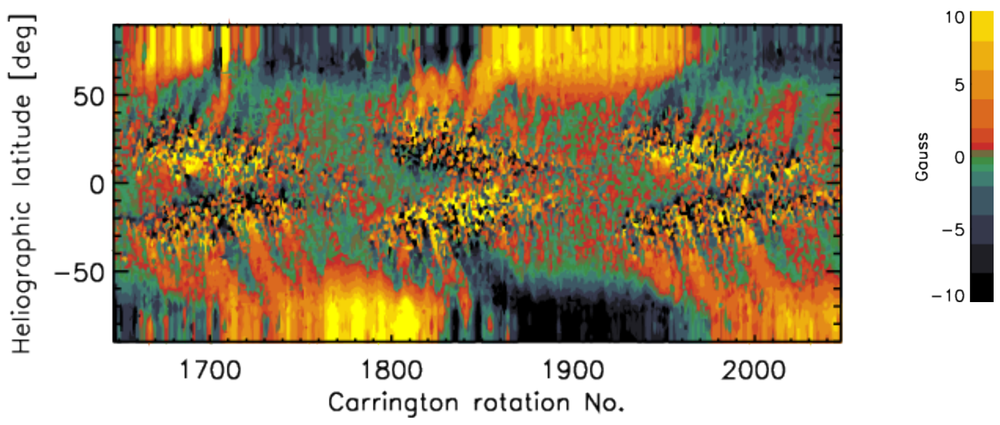
The largest-scale velocity field in the photosphere of the Sun consists of differential rotation and meridional circulation. The meridional circulation is calculated as the integral of meridional component of velocity field, usually plotted over latitude. The meridional flow transports the magnetic flux towards the solar poles, taking the place in the process, in which local magnetic fields are recycled to global field.

The meridional flux transport seems to be an essential property influencing the length, strength and other properties of ongoing solar magnetic cycles. As the input in the flux-transport models, usually the meridional flow measured by local helioseismology is used. In this study we show that the meridional flow derived from the local helioseismology maps can be different from the direct measurement of the flux transport.

Data

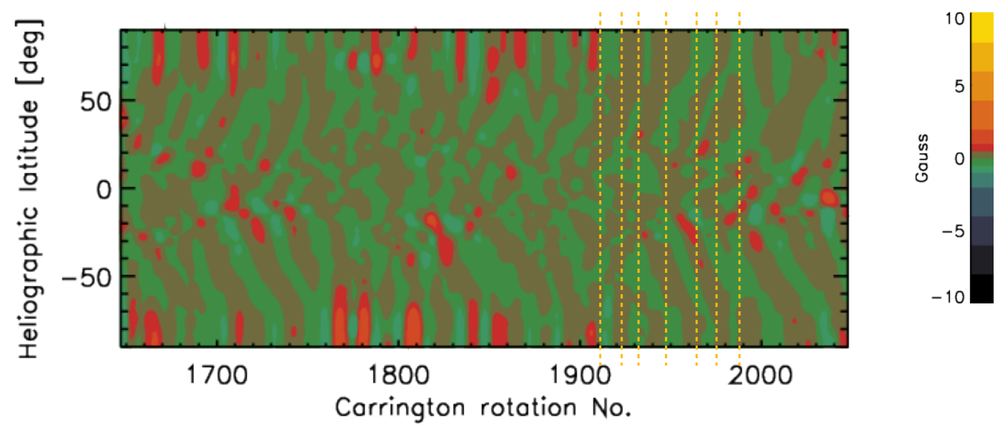
The meridional flux transportation speed is measured from the magnetic butterfly diagram (continually created from longitudinal magnetograms by David H. Hathaway), that visualises the polarity of the surface magnetic field averaged over Carrington rotation in different latitudes and time. The original magnetic butterfly diagram is processed using unsharp-masking and magnitude compensation in order to make the “slopes” of the flux transport better detectable.

Measured magnetic butterfly diagram



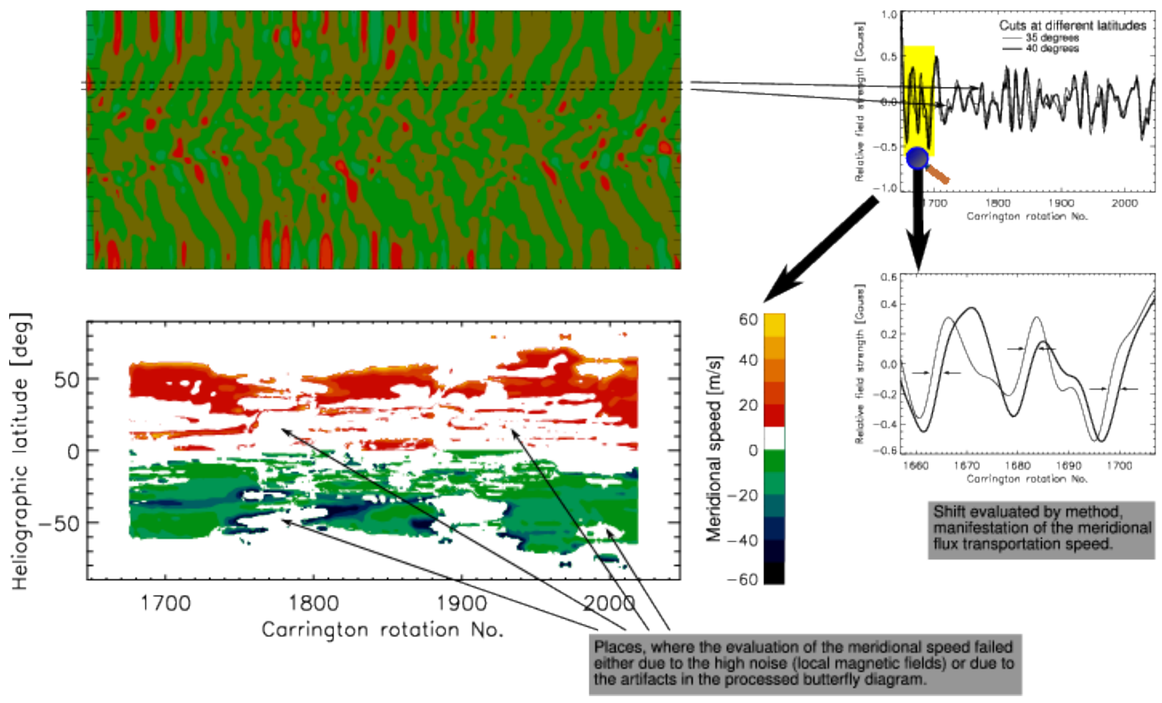
unsharp masking
+
magnitude compensation

Processed magnetic butterfly diagram
Dashed lines represent the location of studied Carrington rotations



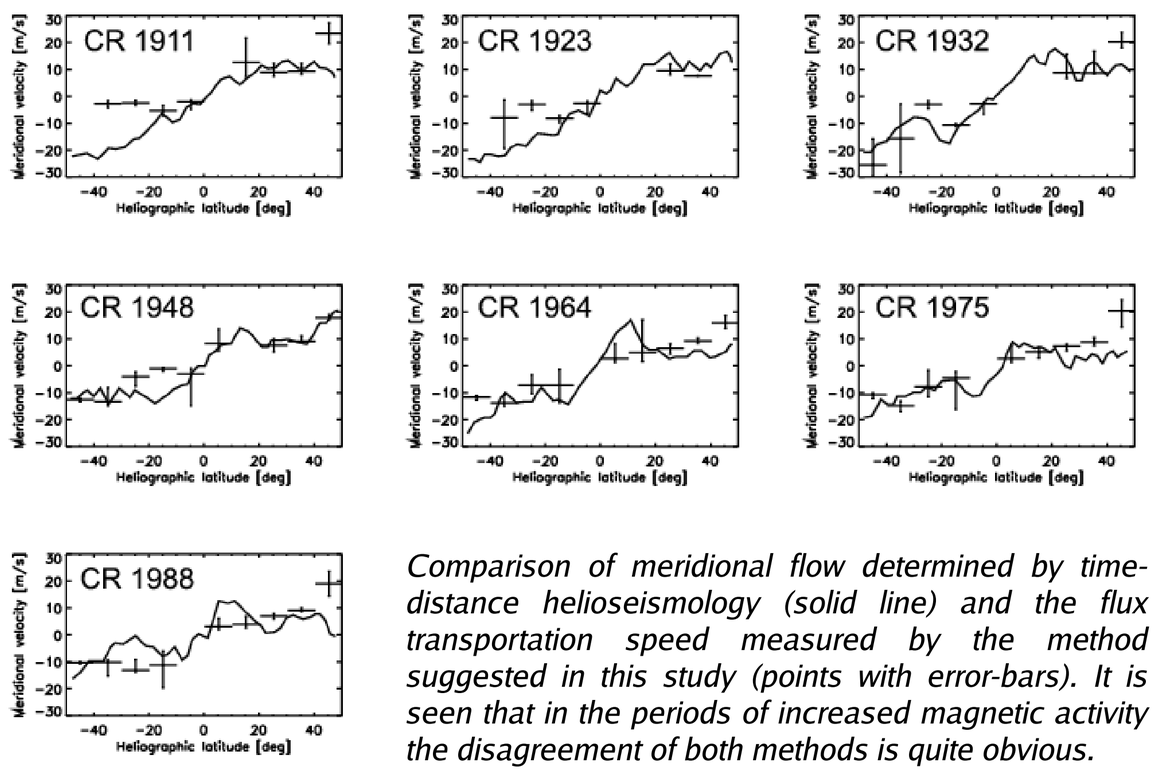
Processing method

The flux transport speed is evaluated from the detection of the slopes seen in the enhanced magnetic butterfly diagram. The displacement of the slopes position in cuts at different latitudes is determined using cross-correlation method.



Results

The measured flux transportation speed differs from the meridional flow determined from the time-distance helioseismology in regions occupied by strong local magnetic fields.



Comparison of meridional flow determined by time-distance helioseismology (solid line) and the flux transportation speed measured by the method suggested in this study (points with error-bars). It is seen that in the periods of increased magnetic activity the disagreement of both methods is quite obvious.

Conclusions

In this preliminary study we have found that it is possible to measure the flux transporation speed towards the solar poles from the magnetic butterfly diagram. Our results show that despite quite large error-bars the measured flux transport is different from the meridional flow determined by time-distance helioseismology in the areas occupied by strong magnetic fields. Therefore, for the dynamo models it is necessary to investigate in more detail the flux transport by the meridional plasma flow, and, in particular, the longitudinal and depth structure of the flows, also to consider other mechanisms of flux transport.

The next step in this study is to investigate the differences in meridional flows around leading and following polarities of active regions, and variations of the flows with depth.

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