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Estimating the solar meridional flow by normal mode decomposition of long time series of Doppler imaging data

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Although investigations have been carried out for many decades the solar magnetic cycle is not yet understood in all its basic properties and it still is one of the main research foci of today's solar physics. An important ingredient to most dynamic dynamo models is the solar meridional flow; on the surface of each hemisphere, a polewards flow in the order of 10 - 20 m/s can be measured with different techniques. From mass conservation, one expects a much slower equatorwards return-flow in deeper layers of the solar convection zone which reaches down to about 200 mega meters below the surface. Numerous attempts have been made to derive the depth profile of the flow using a variety of helioseismic techniques (e.g. Giles, P.M., 2000). While most results agree well about the horizontal velocity structures in the upper 20 Mm, sometimes contrary findings have been published for the lower parts of the convection zone.

We use a Fourier-Legendre decomposition of the surface wave field generated by the solar normal modes into directly opposed travelling wave fields, corresponding a modification of a method suggested earlier by Braun & Fan (1998). The partition allows for the estimation of the frequency difference, caused by the horizontal meridional flow between waves that propagate polewards and equatorwards respectively. These frequency shifts are used to determine the meridional flow profile as a function of depth and latitude by a SOLA (Subtractive Optimally Localized Averaging) inversion method.

Because low-degree modes penetrate deeper into the solar interior than high-degree modes, decomposing the seismic wave field within large patches on the solar surface allows to probe a large fraction of the solar convection zone for the average meridional flow. Smaller patches allow us to study the latitudinal dependence of the flow in higher layers and also a direct comparison of our findings with other methods like ring-diagram analysis.

For our analysis, we use Doppler imaging data provided by the ground based instruments of the GONG (Global Oscillation Network Group) network as well as from the MDI (Michelson Doppler Imager) instrument aboard the SOHO (Solar and Heliospheric Observatory) spacecraft. Both observatories now provide data spanning about one decade and thus allow us to study the variation with time of the meridional flow during the past solar cycle.

Beside a short but broad overview about the significance of the meridional flow for modelling the solar internal processes, several new results of the ongoing analysis are presented. We are able to extend the seismic probing of the solar interior beyond those shallow regions that were accessible to other methods.