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Ambiguity of the Solar Meridional Flow

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Abstract. Recent helioseismic estimates of the deep solar meridional flow have been contradictory. Using two years worth of GONG data, I show here that the detection of the meridional flow is ambiguous below about 0.85 solar radii.

Keywords. Sun, helioseismology, meridional flow

1. Introduction

Here, I present the main results from my PhD. thesis (Böning 2017), to which a number of publications are entering.

The solar meridional flow is an important ingredient in dynamo theory. Helioseismic measurements of this flow, however, are contradictory in deeper layers, see Figure 1. In this work, we develop (Böning *et al.* 2016) and validate (Böning *et al.* 2017b) a method for computing spherical Born approximation sensitivity functions for time-distance helioseismology and we employ them to invert two years worth of GONG data for the deep solar meridional flow (Böning *et al.* 2017a).

2. Results

Below about 0.85 solar radii, we obtain several different inversion results, see cases 1-3 in Figure 2, which are consistent with the data within the measurement errors (see Böning *et al.* 2017a). While the result for case 1 is similar to the original single-cell flow found by Jackiewicz *et al.* (2015), cases 2 and 3 show a multi-cellular flow structure in the southern hemisphere. To reach an unambiguous conclusion on the meridional flow in this region, the errors in the travel-time measurements have to be significantly reduced.

Above about 0.85 solar radii, our inversions confirm the results found by Jackiewicz *et al.* (2015) concerning the general structure of the flow. Especially, we confirm a shallow return flow at about 0.9 solar radii, despite some differences in the magnitude of the flow.

In addition, we show that the error estimate for the inverted flows can be underestimated by a factor of about two to four if the covariance of the travel-times is not taken into account as it was done in earlier studies involving time-distance helioseismology.

We conclude that the controversy about the deep meridional flow is relaxed by properly taking the errors in the travel-time measurements into account.

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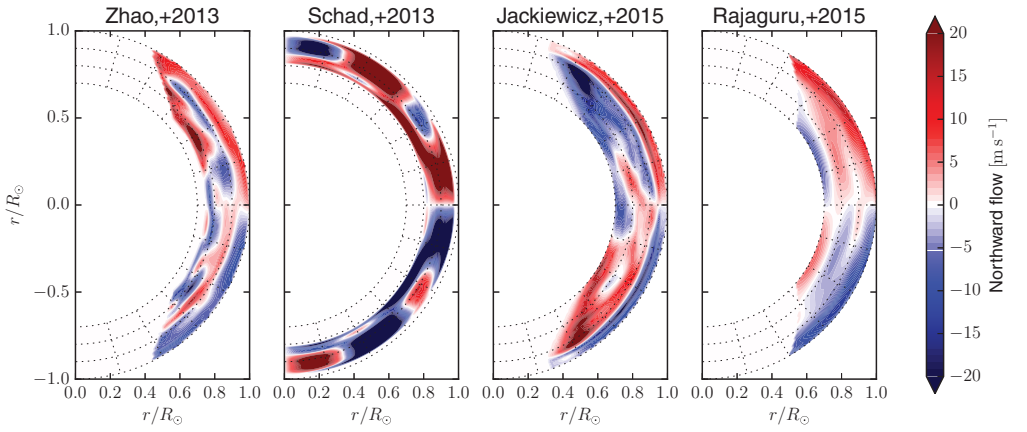

Figure 1. Recent estimates of the deep meridional flow. The results were obtained using time-distance helioseismology (Zhao *et al.* 2013; Jackiewicz *et al.* 2015; Rajaguru and Antia 2015) and global helioseismology (Schad *et al.* 2013) with data from HMI (Zhao *et al.* 2013; Rajaguru and Antia 2015), MDI (Schad *et al.* 2013), and GONG (Jackiewicz *et al.* 2015) covering different periods in time. Figure from Böning (2017).

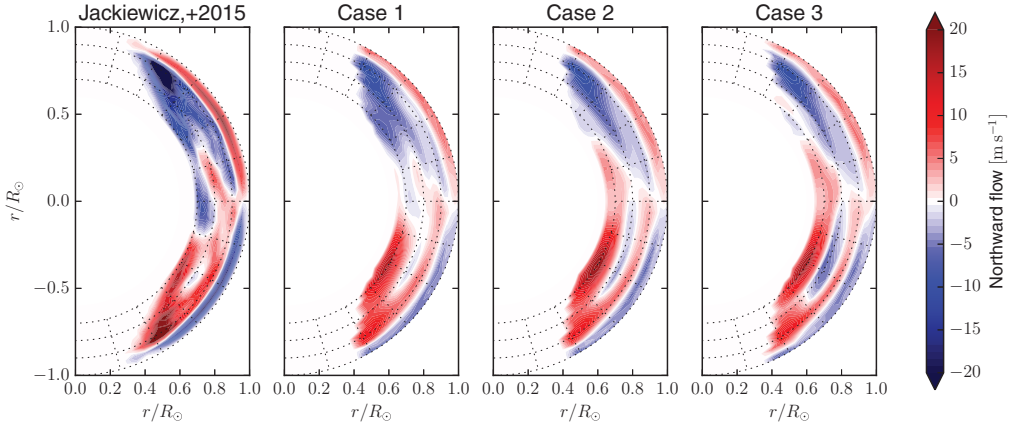

Figure 2. Meridional flow obtained with spherical Born kernels for three inversion parameters (cases 1-3) and obtained with ray kernels (Jackiewicz *et al.* 2015). Figure from Böning (2017).

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