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A theoretical model of the variation of the meridional circulation with the solar cyle

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Observations of the meridional circulation of the Sun, which plays a key role in the operation of the solar dynamo, indicate that its speed varies with the solar cycle, becoming faster during the solar minima and slower during the solar maxima. To explain this variation of the meridional circulation with the solar cycle, we construct a theoretical model by coupling the equation of the meridional circulation (the φ-component of the vorticity equation within the solar convection zone) with the equations of a dynamo model. We consider the back reaction due to the Lorentz force of the dynamo-generated magnetic fields and study the perturbations produced in the meridional circulation due to it. This enables us to model the variations without developing a full theory of the meridional circulation itself . We obtain results which reproduce the observational data of solar cycle variations reasonably well. We get the best results on assuming the turbulent viscosity acting on the velocity field to be comparable to the magnetic diffusivity (i.e., on assuming the magnetic Prandtl number to be close to unity). We have to assume an appropriate bottom boundary condition to ensure that the Lorentz force cannot drive a flow in the subadiabatic layers below the bottom of the tachocline. Our results are sensitive to this bottom boundary condition.

References:
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