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Mixing of lithium at the base of the solar convection zone

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Abstract. A deformation of the interface between convectively stable and unstable layers in a star can lead to intensified mixing of the elements. Our three-dimensional simulations show that under a condition of deformability of the interface, a coupled long-lived system of large-scale flows and penetrative convection is established. This effect can explain lithium depletion in the solar atmosphere

Keywords. Sun: abundances, Sun: interior, Sun: rotation, convection, hydrodynamics

1. Introduction

The depletion of lithium in the solar atmosphere can be explained by its transfer into deep high-temperature convectively-stable region. Penetrative convection is one of the mechanisms that can provide necessary mixing in this area. However, the depth of penetration is not enough to explain the observed depletion by a factor of $\sim$100 relative to meteoritic values. The deformation of the interface between convectively stable and unstable layers in a star can lead to significant increase in penetration depth. The physical reason for deformation of the interface is the excitation of large-scale flows below the convection zone. These flows affect the opacity and change the conditions for convective instability. At the same time, the change in large-scale convection pattern leads to amplification of the large-scale flows.

2. 3D numerical simulations

A small part of rotating spherical thin fluid layer in Cartesian coordinates is considered. Equations of thermohydrodynamics are used in Boussinesq approximation (see for example Gershuni & Zhukhovitskiy 1972). The layer is divided into two parts. The fluid is convectively unstable in the upper one-third of the layer. The surface $z = 2 + h(x,y)$ divides the convectively stable and unstable parts of the layer. The dimensionless equations for the velocity components, the deviation of pressure from a hydrostatic profile, and the deviation of temperature from an unperturbed linear profile are written for the case of a small value of Ekman number (rapid-rotation approximation) (Tikhomolov 1998; Tikhomolov 2004). Boundary conditions are: the temperature is constant at the top and bottom, the surfaces are impenetrable and stress-free. Periodic boundary conditions are implied in longitude and latitude.

Figure 1 shows that the deformation of the interface between convectively stable and unstable regions leads to significant changes in the system. In particular, the penetration depth increases in comparison with the non-deformable interface case.

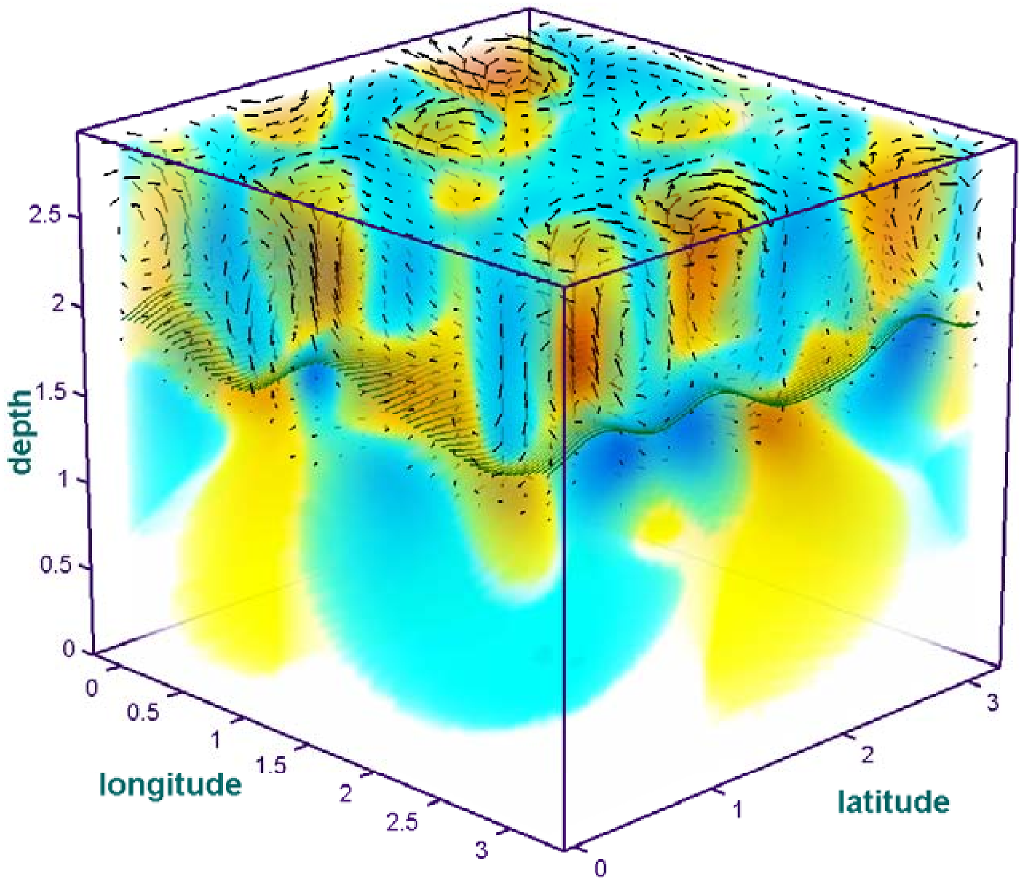

Figure 1. Distribution of temperature disturbances and velocity field in the layer with deformable interface

3. Discussion

The deformation of the interface leads to establishment of the coupled quasi-stationary convection/large-scale flows system. The large-scale patterns live much longer than separate convective cells. This leads to the effective transport of lithium into the deep layers and the reduction of its relative abundance in the Sun.

References

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