Diagnosis of the Structure and Dynamics at the Base of the Convection Zone

Lead Investigator: A.G. Kosovichev
Other Team Members: T.L. Duvall, P. Giles, D.O. Gough, G. Roumeliotis, T. Sekii

Abstract/Technical Summary
Determine properties of convective overshoot and the transition layer at the lower boundary of the convection zone, and find the shape of the boundary, and investigate their variations with time from MDI Medium-l data by local smoothness map methods complemented by the 3D tomographic imaging technique.

Investigation Plan

The structure of the transition region between the zones of radiative and convective energy transport is of particular interest in solar physics and astrophysics. It is generally expected that convective elements penetrate into the convectively-stable radiative zone forming a zone of convective overshoot and contributing to the development of turbulence and mixing in the upper radiative zone. This effect might be responsible for the observed deficit of lithium and beryllium in the Sun. The zone of convective overshoot is also a place with strong radial gradient of angular velocity, and therefore is considered in modern theories as a place where the solar dynamo might operate (e.g. Parker, 1994). Within this layer, the toroidal magnetic flux that appears at the surface in various forms of solar activity is generated from the radial component of the poloidal field. The toroidal flux is believed to be mainly accumulated in a thin layer just beneath the convection zone because convection would quickly destroy the toroidal flux if the layer were widely extended into the convection zone. However, as recently argued by Rüdiger and Brandenburg (1995), this layer cannot be very thin because the period of the solar cycle, which depends on the turbulent magnetic diffusion time through the layer, would be too short. They estimated the thickness to be at least 35 Mm $\approx \frac{1}{2}H_p$, where R is the solar radius and H_p is the local pressure scale height.

Estimates of the thickness and precise location of the transition layer by standard helioseismic techniques from rotational splitting of oscillation p modes are rather uncertain. Attempts to resolve the layer under global smoothness constraints lead to either an oversmoothed angular velocity profile or to spurious oscillations around the transition layer.

We propose a complex study of radial and latitudinal variations of the structure and rotation in the transition region between the radiative and convection zones by using local smoothness map methods complemented by the helioseismic tomography technique.

The investigation plan is:

1. investigate properties of the transition region between the radiative and convective zones by studying the variations of the parameter of convective stability, A, using local smoothness map techniques;

2. compare the results with theoretical models based on non-local theories of convection (e.g. Schmitt et al, 1984) and on direct numerical simulations (Hurlburt, et al, 1994);

3. study of the role of the overshoot in the evolution of the chemical composition of the upper

radiative zone;

4. study the latitudinal dependence of the depth of the convection zone;

5. study the gradient of the azimuthal flow velocity in the transition zone;

6. investigate possibilities for 3D tomographic imaging of 3D structure and flows in the transition region.

REFERENCES

Basu, S. & Antia, H.M., 1994, Effects of diffusion on the extent of overshoot below the solar convection zone, *Mon. Not. of the Royal Astron. Soc.*, **269**, 1137-1144.

Duvall, T.L., Jr, Jefferies, & Harvey, J.W., 1995, Mapping wave speed in the outer convection zone, *Bull. Am. Astr. Soc.*, **27**, 950

Gough, D.O., Kosovichev, A.G., Sekii, T., Libbrecht, K. & Woodard, M., 1993, Seismic evidence of modulation of the structure and angular velocity of the sun associated with the solar cycle, in: Proc. IAU Colloquium 137 *Inside the stars*, the Conference Series of the Astronomical Society of the Pacific, eds. A.Baglin and W.Weiss, 93-96.

Gough, D.O. & Kosovichev, A.G. 1995, An attempt to measure latitudinal variation of the depth of the convection zone, in: Proc. 4th SOHO Workshop, *Helioseismology*, ESA SP-376, ESTEC, Noordwijk

Hurlburt, N.E., Toomre, J., Massaguer, J.M. & Zahn, J.-P., 1994, Penetration below a convective zone, *Astrophys. J.*, **421**, 245-260.

Kosovichev, A.G., 1988, Determination of the internal rotation of the Sun from the frequency splitting of acoustic modes, *Bull. Crimean Astrophys. Obs.*, **80**, 167-179.

Kosovichev, A.G., 1994, Helioseismic evidences for mixing in the radiative interior, in: Proc. Seventh Europ. Meeting on Solar Phys. 'Advances in Solar Physics', Catania, 1993, *Lect. Not. Phys.*, **432**, 47 – 52

Parker, E.N., 1993, A solar dynamo surface wave at the interface between convection and nonuniform rotation, *Astrophys. J.*, **408**, 707-719.

Rüdiger, G. and Brandenburg, A. 1995, A solar dynamo in the overshoot layer: cycle period and butterfly diagram*Astron. Astrophys.*, **296**, 557.

Schmitt, J.H.M.M., Rosner, R., & Bohn, H.U., 1984, The overshoot region at the bottom of the solar convection zone, *Astrophys. J.*, **282**, 316-329.

Skaley D. & Stix M., 1991, The overshoot layer at the base of the solar convection zone, *Astron. Astrophys.*, **241**, 227

Spiegel, E.A. & Zahn, J.-P., 1992, The solar tachocline, *Astron. & Astrophys.*, **265**, 106