TITLE : LARGE-SCALE DYNAMICS OF CONVECTION IN THE SOLAR PHOTOSPHERE

ABSTRACT : Velocity fields measurements of turbulent flows in the solar photosphere reveal three distinct horizontal scales : granulation (1 000 km), mesogranulation (7 000 km) and supergranulation (30 000 km). Granulation is known to result from radiative cooling of hot ascending gas close to the surface, but the origin of mesogranulation and supergranulation remains largely unknown.

Several convection models were developed in the course of this PhD research in order to investigate possible formation mechanisms for these large-scale flows. A theoretical study of the convective instability in the linear regime has first been attempted. The model relies on a fully compressible description of the fluid movements when a vertical permanent magnetic field and fixed thermal flux boundary conditions (that are relevant on large scales) are imposed. Very elongated convection cells are shown to be preferred as convection sets in and scales comparable to supergranulation can be obtained for realistic values of the magnetic field.

Direct numerical simulations of fully compressible turbulent convection in a very large aspect ratio domain have then been carried out to investigate turbulent dynamics on large scales. These simulations have been performed using a DNS code which was partly developed during the thesis. Two distinct scales come out of the numerical experiment : the first one is comparable to granulation and is only found in the surface layers. The second one is an energetic mesoscale with horizontal extent larger than the granular pattern but still smaller than the size of the computational domain. It is visible at all depths and is found to have a genuine convective origin. As solar mesogranulation bears some resemblance with this pattern, it is conjectured that it may be the dominant convective scale below the photospheric surface and would be partly hidden by granulation.

A third approach has finally been proposed, that deals with the possibility that supergranulation may result from a large-scale instability of granulation. The first steps towards a computation of turbulent transport coefficients of convective flows have been done by developing a code based on the mean-field hydrodynamic theories of the AKA effect and turbulent viscosity.
