Session 0
Opening Keynote Address

0.1 (Invited)

Solar Active Regions: A Transition from Morphological Studies to Physical Modeling

Markus J. Aschwanden[1]

[1]*Solar & Astrophysics Laboratory (Lockheed Martin ATC), 3251 Hanover St., Bldg. 252, Org. ADBS, Palo Alto, CA 94304, USA*

Although solar active regions can easily be identified from their sunspot groups, they keep some of the most challenging secrets of solar physics, regarding their subphotospheric origin, photospheric emergence, magnetic field structure, magnetic helicity, wave generation, propagation and dissipation, plasma heating and cooling, plasma flows, fractal geometry and intermittency, and magnetic instabilities leading to flares, CMEs, and coronal dimming. In this opening talk we review how morphological observations of active regions have gradually evolved into a more physics-based modeling approach over the last decades.

Session 1
Flows Around Active Regions: Surface and Below

1.1 (Invited)

Surface Flows from Magnetograms

Brian Welsch,[1] **G. H. Fisher, and W. P. Abbett**

[1]*Space Sciences Lab, UC - Berkeley, Space Sciences Lab, University of California, 7 Gauss Way, Berkeley, CA 94720-7450*

Estimates of velocities from time series of photospheric and/or chromospheric vector magnetograms can be used to determine transport rates for magnetic flux (i.e., emergence and submergence), energy (Poynting flux), and helicity across the magnetogram layer, and to provide time-dependent boundary conditions for data-driven simulations of the solar atmosphere above this layer. Velocity components perpendicular to the magnetic field are necessary both to compute these transport rates and to derive model boundary conditions. Since Doppler shifts also contain contributions from flows parallel to the magnetic field, perpendicular velocities are not generally recoverable from Doppler shifts alone. Consequently, several methods have been developed to estimate the perpendicular velocity from magnetograms, and have recently been validated using synthetic magnetograms from MHD simulations. Combined with data from the next generation of magnetographs (SOLIS, SOT/Hinode, and HMI/SDO), these techniques should provide valuable tools for understanding and modeling solar variability on time scales both short (e.g., flares and CMEs) and long (e.g., the 11-year sunspot cycle).

1.2 (Invited)

Subsurface Flows Near Active Regions and Filaments as Determined by Local Helioseismology

Deborah A. Haber[1]

[1]*JILA / Univ. of Colorado, 440-UCB, Boulder, CO 80309-0440, USA*

Subsurface flows, determined by local-helioseismic techniques such as time-distance tomography, ring analysis, and acoustic holography, are often stronger and more organized around magnetic activity than in areas of quiet sun. Depending on the spatial resolution with which the flows are observed, very different behavior can be seen. On the larger 16-degree scale, generally used by ring analysis techniques, converging flows are seen around most active regions near the surface while diverging flows are seen below about 10 Mm from some large active regions. On the scale of 2 degrees or below, used mainly by time-distance, holography, and high-resolution ring analysis, we see diverging, Evershed-type flows in the near-surface layers around sunspots. This talk will be a review of what we have learned so far about long-lasting flows (> 8h), in and around active regions and filaments, as determined by the various local-helioseismic techniques, as well as how these may influence magnetic structures and activity higher up in the solar atmosphere.

1.3

Evolution of Solar Subsurface Meridional Flows

Dean-Yi Chou[1] **and Oleg Ladenkov**

[1]*National Tsing Hua University, Taiwan, Department of Physics, National Tsing Hua University, Hsinchu, 300, Taiwan*

We study the evolution of meridional flows in the solar convection zone extending to a depth of $0.793\,R_\odot$ in the period of 1996–2003 with helioseismic data taken with TON (Taiwan Oscillation Network) using the technique of time-distance helioseismology. The meridional flows of each hemisphere formed a single-cell pattern in the convection zone at solar minimum. An additional divergent flow was created at active latitudes in both hemispheres as the activity developed. The amplitude of this divergent flow correlates with the sunspot number: it increased from solar minimum to maximum (from 1996 to 2000), and then decreased from 2000 to 2003 with the sunspot number. The amplitude of the divergent flow increases with depth from $0.987\,R_\odot$ to a depth of about $0.9\,R_\odot$, and then decreases with depth at least down to $0.793\,R_\odot$.

1.4

Forward Simulations of Subphotospheric Flows for Time-Distance Helioseismology

Sergiy Shelyag,[1] **R. Erdelyi, and M. J. Thompson**

[1]*Department of Applied Maths, University of Sheffield, Hicks Building, Hounsfield Rd, Sheffield, United Kingdom*

Results of forward modeling of acoustic wave propagation in a realistic solar sub-photosphere with steady horizontal flows are presented. The simulations are based on fully compressible ideal hydrodynamical modeling in a Cartesian grid. The initial model is characterized by solar density and pressure stratifications and is adjusted in order to suppress convective instability. Acoustic waves are excited by a non-harmonic source located close the depth corresponding to the visible surface of the Sun. A series of numerical experiments with coherent horizontal flows of various depths and speeds are carried out. The implemented flow field may mimic horizontal motions of plasma surrounding a sunspot or differential rotation. The influence of the flows on the propagation of the sound waves through the solar interior is analyzed. A time-distance analysis technique is applied to compute the direct observational signatures of the background bulk motions on the travel times and phase shifts. Inversion of the velocity profiles from the simulated travel time differences is carried out. The inversion is based on the ray approximation. The results of inversion are then compared with the original velocity profiles and with the profiles, obtained by inversion of travel time differences, calculated using the ray approximation. The analysis shows that the flow speed profiles obtained from inversion based on the ray approximation differ from the original ones. The difference between original and observed profiles is caused by the fact that the wave packets propagate along the ray bundle, which has a finite extent, and thus reach deeper regions of the sub-photosphere than are accounted for by ray theory.

1.5

Large Eddy Simulation of Solar Photosphere Convection with Realistic Physics

Sergey Ustyugov[1]

[1]*Keldysh Institute of Applied Mathematics, 4, Miusskaya sq., Moscow, 125047, Russia*

Three-dimensional large eddy simulations of solar surface convection using realistic model physics are conducted. The thermal structure of convective motions into the upper radiative layers of the photosphere, the range of convection cell sizes, and the penetration depths of convection are investigated. A portion of the solar photosphere and the upper layers of the convection zone, a region extending 60×60 Mm horizontally from 0 Mm down to 20 Mm below the visible surface, is considered. We start from a realistic initial model of the Sun with an equation of state and opacities of stellar matter. The equations of fully compressible radiation hydrodynamics with dynamical viscosity and gravity are solved. We use:

1) a high order conservative TVD scheme for the hydrodynamics,

2) the diffusion approximation for the radiative transfer,

3) dynamical viscosity from subgrid scale modeling.

The simulations are conducted on a uniform horizontal grid of 600×600, with 168 nonuniformly spaced vertical grid points, on 144 processors with distributed memory multiprocessors on supercomputer MBC-1500 in the Computational Centre of the Russian Academy of Sciences. A study of the properties of solar acoustic waves (p-modes) and surface gravity waves (f-mode) by time-distance methods of local helioseismology is conducted.

1.6
Simultaneous Velocity and Magnetic Field Measurements in Chromosphere and Photosphere

K. Nagaraju,[1] **K. Sankarasubramanian, K. E. Rangarajan, and K. B. Ramesh**

[1]*Indian Institute of Astrophysics, Koramangala II block, Sarjapur Road, Bangalore-560034, India*

We present a few results from the newly installed dual beam full Stokes spectro-polarimeter at the Kodaikanal Tunnel Tower Telescope. The optimum modulation/demodulation scheme used for this new polarimeter will be emphasized. The full Stokes polarimetry of the active region NOAA0875 in Hα wavelength region will be presented. The spectral lines, Hα and Fe I at λ6569 Å, are used to estimate the line-of-sight (LOS) velocity and magnetic field strength. From these estimations, we confirm the previous observations that there is a one-to-one correspondence between the LOS magnetic field measured in Chromosphere (Hα) and in Photosphere (λ6569 Å) for the weak field regions, while in strong field regions like the umbra the LOS magnetic field estimated in Hα is much weaker.

In this paper, we will also discuss the reliability of the center-of-gravity (COG) and the weak field approximation (WFA) methods in extracting the LOS magnetic field strength. For the variety of cases studied, it was found that both the methods underestimate the field strength. However, for the case of strong magnetic fields oriented along the line-of-sight, the COG results are more accurate than the WFA estimations. On a positive note, we find that the results are not unduly affected by the presence of velocity and magnetic field gradients, in contradiction to earlier beliefs.

1.7

On the Polar Fields' Distribution as Observed by SOLIS

Nour-Eddine Raouafi,[1] J. W. Harvey, and C. J. Henney

[1]*National Solar Observatory, 950 N. Cherry Avenue, Tucson, AZ 85719, USA*

We use Vector Spectromagnetograph (VSM) full-disk magnetograms, from the Synoptic Optical Long-term Investigations of the Sun (SOLIS) project, to study the distribution of magnetic field flux concentrations within the polar caps. We find that magnetic flux elements preferentially appear towards lower latitudes within the polar caps away from the poles. This has implications on numerous solar phenomena such as the formation and evolution of fine polar coronal structures (i.e., polar plumes). Our results also have implications for the processes carrying the magnetic flux from low to high latitudes (i.e., meridional circulation).