Surface Magnetic Effects in the Sun and Stars

The first evidence of the importance of magnetic fields on the surfaces of stars came with the observation of sunspots on the surface of the Sun by Galileo and contemporaries shortly after the invention of the telescope. Prior to that some reports of spots on the sun existed made by people with very good eyesight, but there was little known about the phenomenon. Galileo and others showed that the spots were not transits by planets but actually on the Sun’s surface by observing the foreshortening that occurred near the limb.
The Sunspot Cycle
It was discovered early in the study of sunspots that Sun exhibited a regular pattern over an 11 year cycle of increasing and decreasing “activity” as measured by the number of spots on the surface and the total area they covered.
Maunder Minimum

There was a period of very little sunspot activity during the late 1600’s that also supposedly corresponded with a time of extremely cold winters in Europe and North America, known as the Little Ice Age. There may be a correlation between sunspot activity and solar irradiance and climate.
The cause of Sunspots
We now know that Sunspots are cooler than the surrounding photosphere by of order 1000 degrees K and are maintained for times of weeks or even months by strong magnetic fields that inhibit convection and inhibit the flow of hotter gas into or out of the magnetic bubble. Spectra across the sunspot show the Zeeman splitting corresponding to magnetic field of about 1500 Gauss -- approximately 1500 times stronger than the global field.
Sunspots usually come in pairs of opposite polarity:

Magnetic fields trap gas.

$T \approx 5,800 \, K$

sunspots

$T \approx 4,500 \, K$

$T \approx 5,800 \, K$

convection cells

Magnetic fields of sunspots suppress convection and prevent surrounding plasma from sliding sideways into sunspot.
The 22-Year Cycle:
The sunspot cycle is actually a 22 year cycle when one takes into account the
direction of the polarity. At any given time, there is a leading spot polarity and a
trailing spot polarity. These are opposite in opposite hemispheres. The first spots
in a spot cycle break out at higher latitudes (although never more northerly than
a certain latitude). They exhibit a certain polarity and this cycle peaks as it moves
to lower latitudes then fades away as it approaches the equator after about 11
years.) At about the same time, the spots of the next cycle break out and they
have reversed polarity. This behavior can be summarized on a “Butterfly” diagram
as shown on the next page.
The Babcock Model provides an explanation for the cyclic behavior in terms of the wrapping of magnetic field lines by differential rotation, coupled with their twisting by convection and then their breaking and reconnecting. This activity leads the Sun to reverse the direction of its global magnetic field every 11 years. The Earth reverses its magnetic field as well, but on a much longer time scale -- of order 10,000 years.
Other Effects Associated with Strong Magnetic Fields
The recombination of field lines of opposite polarity causes flares and a lot of heating of the upper atmosphere of the Sun. This produces the chromosphere and corona of the Sun. The corona is so hot that it cannot be held by the Sun’s gravity and so it continuously escapes resulting the Solar Wind. Flares cause mass ejections, as well, known as CMEs (Coronal Mass Ejections). This ionized plasma from the Sun interacts with the magnetic fields in the Solar System and has a number of effects, including causing the tails of comets and causing aurora on the Earth and other planets.
The Rossby number is the ratio of the rotation period of a star to its convective overturn time. It seems to correlate well with measures of surface magnetic activity, such as the ratio of X-ray luminosity to Bolometric luminosity. Stars with short rotation periods or long convective turnover time (i.e. deep convection zones) tend to me more active. This generally means later type stars, because they have very deep convection zones and/or younger stars, because they rotate faster.