Abstract. Observations of the first major active regions and large-scale magnetic field patterns of Cycle 22 are presented. These show that, following the emergence of a trans-equatorial pattern, or cell, of positive flux related to old cycle activity, the first new cycle active regions of the longitude range emerged across the neutral lines of this cell, which continued to grow and expand across the equator for several rotations. The development of a parallel trans-equatorial band of flux of opposite (negative) polarity and the emergence of both new and old cycle active regions across a neutral line of this cell are also described.

Simulations using the flux transport equation, and based on synoptic magnetic data provided by the Mount Wilson Observatory, show that, while the growth of the positive region could, in part, be explained by the decay of flux from these new regions, there were significant differences between synoptic contour charts based on the simulations and those constructed from the observed fields. They also show that the development of the negative region cannot reasonably be explained by the decay of the observed active regions.

A further example of the counter rotation of decaying active region fields is reported. Here the initial tilt of the negative-positive magnetic axes of two adjacent regions is normal, and simulations based on these data show their combined follower flux moving preferentially polewards. However, the observations show that, after three rotations, the decaying leader flux is entirely poleward of the follower flux.

1. Introduction

The standard model for the evolution of the solar surface magnetic fields and the reversal of the polar fields, as put forward by Leighton (1964), and later by Sheeley and his co-workers (e.g., De Vore, Sheeley, and Boris, 1984; Sheeley, Nash, and Wang, 1987; De Vore and Sheeley, 1987; Wang, Nash, and Sheeley, 1989), assumes that the diffusive effects of supergranule motions, differential rotation and meridional flows disperse the active-region magnetic fields to form the large-scale field patterns. Indeed, it is claimed that all the observed features of the large-scale fields can be reproduced from models of the active region fields using the flux transport equation and by suitably varying the diffusivity and the parameters of the meridional flow.

However, recent results have raised doubts about the validity of this picture. In Paper I (Wilson, McIntosh, and Snodgrass, 1990), the flux transport equation was criticized because it neglects some of the essential physical properties of magnetic fields. In Paper II (Wilson and McIntosh, 1991), the development of a trans-equatorial cell was described and was compared with simulations of the evolution of the large-scale fields based on the flux transport equation, which provides a paradigm for the effects of...
supergranule diffusion and large-scale surface flows on the fields of emerging active regions.

It was shown that the large-scale field patterns arose not only from the decay of active region fields, but also as a result of the organized emergence of small-scale fields. In particular, one component of this region (region A) developed without any discernible contribution from decaying active regions and, although the major region of positive flux on either side of the equator appeared to be related to the decay of two old-cycle regions, the fields decayed more slowly than predicted by the flux transport equation. It was suggested that the emergence of these regions was due, at least in part, to the non-random organized emergence of small-scale field, as had been proposed by Stenflo (1990). It was further suggested that both the active regions and the large-scale fields shared a common origin which might reasonably be related to large-scale subsurface velocity fields.

In this paper we examine the relationship between this cell and the first active regions of cycle 22. Again, the observed evolution of these active regions is compared with their theoretical evolution using simulations based on the flux transport equation.

2. Observations

Partial synoptic magnetic charts for the Carrington longitudes (CLs) 160° to 300° and for selected Carrington rotations (CRs) between 1780 and 1786, derived from magnetograms constructed by the Kitt Peak Station of the National Solar Observatory (NSO), are presented in Figure 1. The magnetic charts consist of two panels: the upper panel represents the relative line-of-sight intensity of the magnetic fields, while the lower shows the sign of the net polarity of the field per pixel (black is negative). The upper panel thus shows the location and size of the active regions, which are identified by the last three digits of serial numbers assigned by the Space Environment Services Center of the N.O.A.A. Space Environment Laboratory, while the lower shows the large-scale field patterns, the most prominent of which are identified by the letters F and G.

In Figure 2, synoptic contour maps for the slightly larger longitude range CL 150°–310° have been constructed from the data provided by the Mount Wilson Solar Observatory (MWO) for CRs 1780–83, and in Figure 3 for CRs 1784–86. Because these maps are of lower resolution than the NSO maps (4° in longitude and latitude) it is easier to identify the large-scale field regions. Again the active regions are identified by their NOAA serial numbers, and these are also applied in subsequent Carrington rotations to the enhanced (but now unspotted) field regions which appear to arise from the decay of numbered regions. Distinct large-scale magnetic features are indicated by the letters F, G, H, J, K, and L. For reference, two rectangles are drawn on the contour plots, the first to identify the latitude range 28° N–20° S and the Carrington longitudes 190°–250°, and the second to identify the latitude range 20° N–44° S and the longitudes 250°–286°.

By their construction, synoptic charts emphasize the appearance of features at central meridian passage, and regions which emerge near the west limb or on the invisible