Properties of Coronal Holes in Solar Cycle 21-23 using McIntosh archive

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Abstract

We study the properties of coronal holes during solar cycle 21-23 from the McIntosh archive. In the spatial distribution of coronal hole area we find that there is a sharp increase in coronal hole area at high latitude in agreement with expected open flux configuration there. In overall spatiotemporal distribution of coronal hole centroids, we find the dominance of high latitude coronal holes except for the maximum of the solar cycle, when coronal holes mostly appear in low latitudes. This is in agreement with the expected solar cycle evolution of surface magnetic flux.

Keywords

Sun: coronal hole Sun: Carrington map

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1. Introduction

Coronal holes are dark patches when we see the solar corona in extreme ultraviolet wavelengths (Munro & Withbroe (1972)) and X-rays (Timothy *et al.* (1995)). They appear dark due to their low temperature and density in comparison to its surroundings. Being open magnetic field region, coronal holes are the major source of fast solar wind. Thus coronal holes are important for space weather.

2. Data Analysis

In this work we have used data from the McIntosh archive (McA) (Gibson *et al.* (2016) Webb *et al.* (2017)) for our analyses. Patrick McIntosh, a scientist in NOAA's Space Center in Boulder created hand-drawn Carrington maps (from 1964 to 2009) using both ground and space based observations. McIntosh project is a Boston College/NOAA/NCAR collaboration, funded by the NSF, where these maps are archived and digitized from May 1981 till July 2009 (corresponding to Carrington rotation numbers from 1709 to 2086). The Carrington maps are made available online both in image and fits format. There are two big data gaps in this database, one from October 1991 to January 1994 and another from April 1994 to May 1996. We have applied Interactive Data Language (IDL) to extract the data for further analyses, covering the rising phase of solar cycle 21, some portion of cycle 22, full solar cycle 23 and the beginning of cycle 24. The data contains spatial and temporal information of sunspots, plages, polarity inversion lines, filaments and coronal holes.

3. Results and Discussions

We study two aspects of coronal holes present in a set of 321 Carrington maps using the available level three data. We consider every coronal hole in a particular Carrington

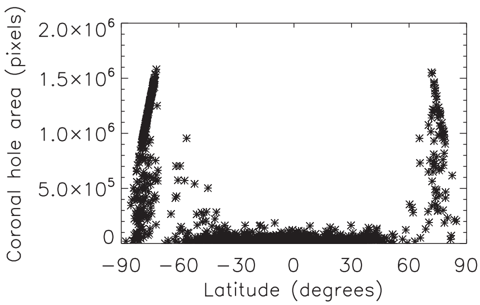

Figure 1. Spatial variation of temporally averaged coronal hole area.

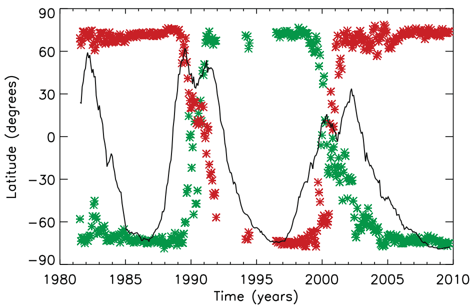

Figure 2. Spatiotemporal variation of coronal hole centers.

map individually and measure their area in pixels and associated latitude by determining their geometrical center. In Figure 1 we show the latitudinal distribution of time-averaged coronal hole area. We notice that at higher latitudes coronal hole area increase sharply, indicating their preferential presence near the polar cap. In Figure 2, we represent the spatiotemporal variation of positive (shown in green) and negative magnetic field (shown in red) coronal hole geometric centers. The sunspot area variation is also depicted in black curve. We notice that except during cycle maximum while the low latitude coronal holes dominate, the coronal holes are primarily confined to polar region.

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