Active Longitude and Solar Flare, CME Occurrences

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Introduction

Many flare prediction models employ the properties of active regions (ARs), such as morphological information, area or the magnetic field of sunspot groups. The spatial distribution of ARs is used occasionally, including e.g. the longitudinal distribution, for forecasting. However, determining the longitudinal distribution of sunspots is a harder challenge than that of latitudinal one.

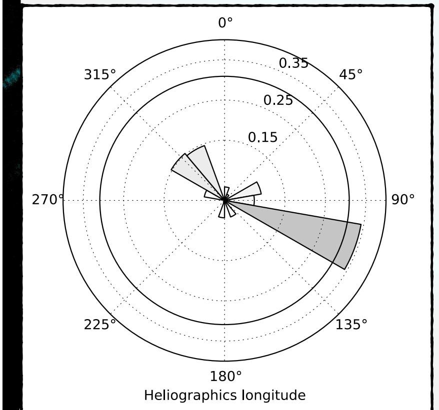
If we *assume* the most flare-productive ARs tend to be located in or close to the active longitudinal (AL) belt then, this may allow to predict the geo-effective position of the domain of enhanced flaring or CME probability for a couple of month or even years ahead.

The aim of the present work is to specify the *spatial distribution of flare and CME activities* in connection to *the active longitude.*

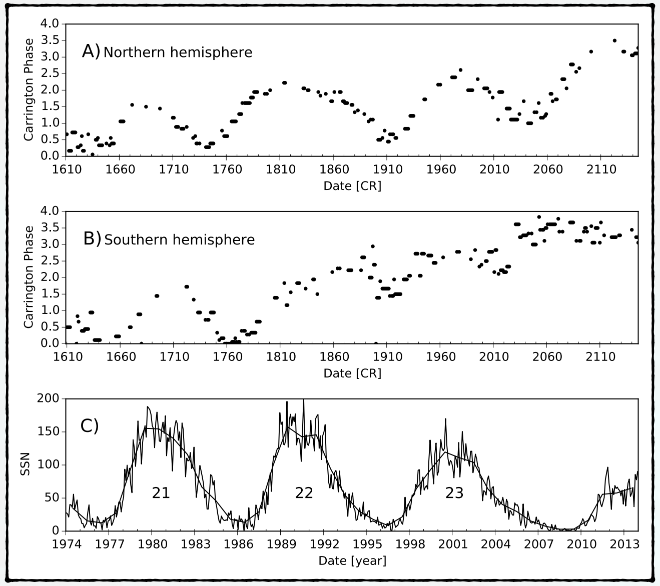
Method of tracking active longitude

The Debrecen Photoheliographic Data (DPD) is a sunspot catalogue used for the estimation of AL. The DPD is based on white-light images of sunspot groups taken as back as from 1974. Therefore this study can encompass 540 Carrington Rotations (CRs), which equal to about five solar cycles. Next, the total area of sunspot groups have been determined in each 20 degrees longitudinal bin (A_i) normalised by the entire activity in each Carrington rotation.

$$W_i = \frac{A_i}{\sum_{j=1}^{36} A_j}$$



An example for the spatial distribution of the quantity W in CR 1718 (left). The largest peak represents the AL (black line 3σ significance limit). In this CR at the opposite side (with an ~180 degrees phase shift) the weaker and more disperse peaks correspond to the co-dominant AL.



Activity maps for the entire DPD-era. Panel A shows the migration of AL on the northern and southern hemispheres, respectively. The black markers denote the longitudinal belts of most enhanced sunspot activities in certain CRs. Panel B: similar to A but for the southern hemisphere. Panel C shows the temporal variation of the ISSN.

Spatial distribution of solar flare and CME occurrences

We investigate the relationship between the position of solar flares, CMEs and the longitude of enhanced sunspot activity (AL). The data are taken by Geostationary Operational Environmental Satellite (GOES) and Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) satellites. Let us define a new parameter which is the shortest longitudinal distance between the position of the AL and the position of a certain event. The phase difference is, then, given by:

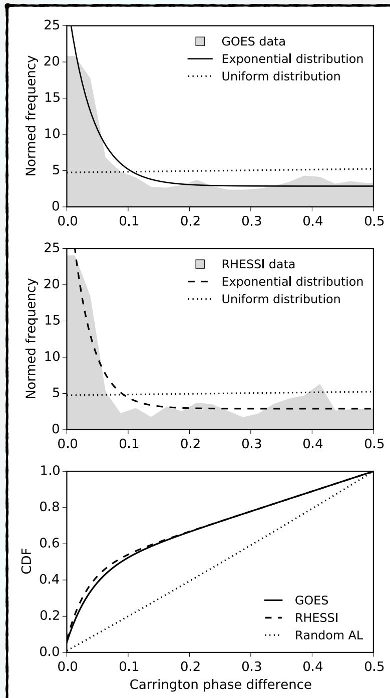
$$\delta\varphi = |AL_{CR} - L_{CR}|.$$

L_{CR} is the longitudinal position of the flare or CME event in Carrington phases. AL_{CR} represents the position of the AL. $\delta\varphi$ =0 means that the flare is located at the AL; $\delta\varphi$ =0.5 means that the flare is located on the other side of the Sun opposite the AL.

On Panels A and B the grey area represents the frequency distribution normalised by the sample number. In the plots, there is only one significant peak for each statistics and, beyond that, there is a long plateau with insignificant local peaks. The distributions show that most of the solar flares are concentrated in a relatively narrow longitudinal zone. We found that AL of sunspot groups is as narrow as 20-30 degrees. Here, the spatial distribution of solar flares shows a similar behaviour. The best exponential fits are indicated by the solid/dashed line in Panel A/B.

We have also defined control groups where the position of the AL is generated randomly. The result of studying these control groups have shown no significant peaks, thus it can be represented by dotted line of homogeneous distribution. This means that our identification method for AL does not cause false significant peaks, which would affect the results of the study of inhomogeneous longitudinal properties.

Panel C represents the cumulative distribution of the spatial distributions. The spatial distribution of CMEs show a very similar behaviour.



Results

Our results imply that the primary AL belt contains up to 60% of all solar flares. An AR that is near to the AL is prone to erupt. An AR that is far away from the active longitude produces solar flares with insignificant probability. The main active longitude may play a crucial role in the global positioning of solar flare occurrence. The most complex groups supporting flare eruptions appear within a width of ±36 degrees of the active longitude.

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