Features of the evolution of polar and non-polar coronal holes over the past 11 years

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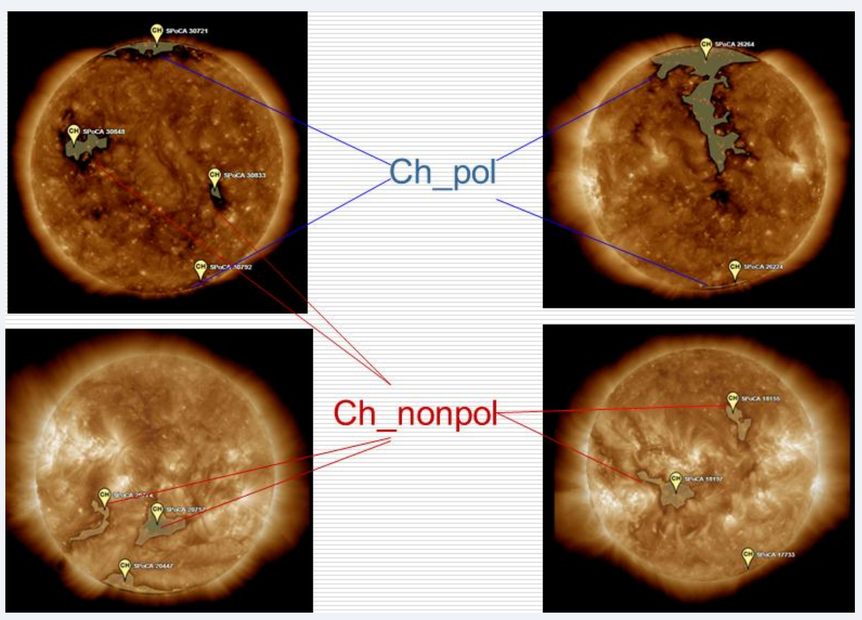
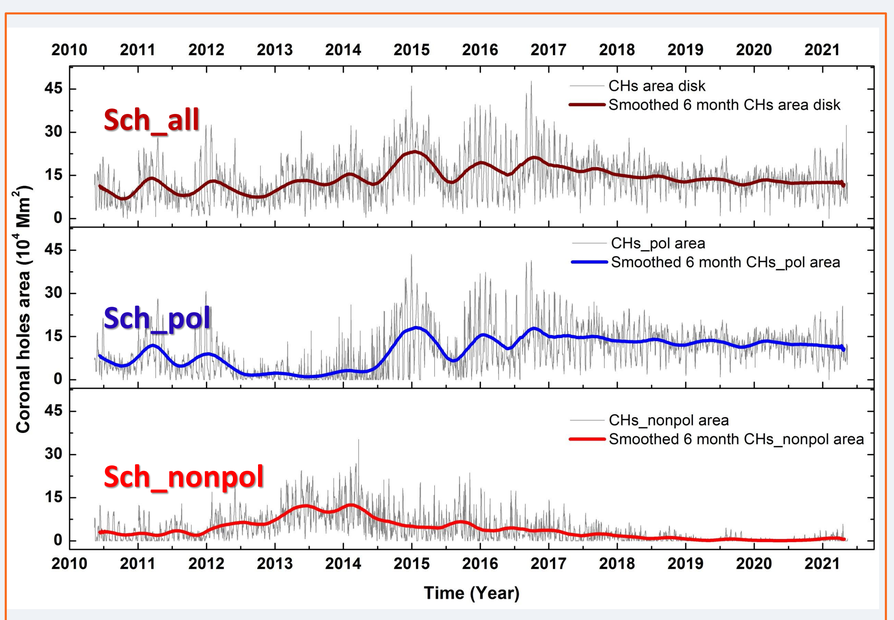
Introduction

We present the results of an analysis of the evolution of two types of coronal holes (CHs) on the Sun for eleven years (period from May 13, 2010 to May 13, 2021) .

Our study used extreme ultraviolet images of the Sun in the iron line 19.3 nm, obtained with the AIA/SDO. To localize CHs and determine their areas we used the Heliophysics Event Knowledgebase (HEK)http://www.lmsal.com/hek/hek_isolsearch.html Information on CHs was extracted with the Spatial Possibilistic Clustering Algorithm (SPoCA). The software performs the segmentation of the Sun images and make records into the HEK catalogs every four hours. The area measured in square mega meters.,

Two types of coronal holes (polar and non-polar CHs)

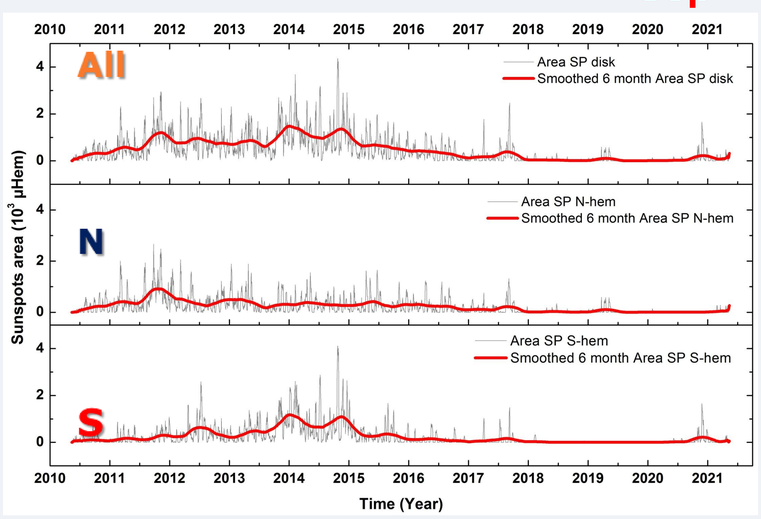




The first group consists of **polar CHs** which are located at the solar poles and sometimes they extend to middle and low latitudes. The second is **isolated or non-polar CHs**, which are mainly limited to low, middle, and sometimes high latitudes, but they are not connected to polar CHs. For 11 years of study, we processed about 18000 CHs. Slightly more than 8000 are **polar CHs**, the rest are **non-polar CHs**. Investigating the evolution of two types of CHs, we analyzed how CHs area change against the background of sunspot areas.

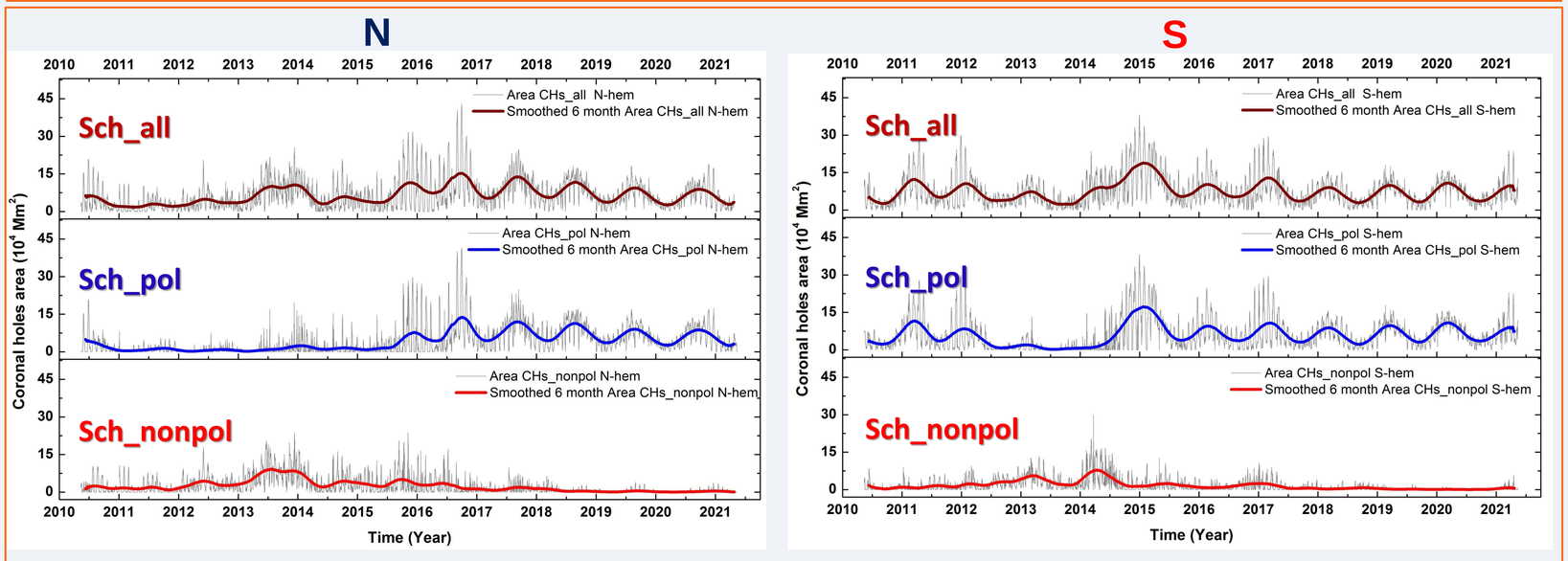
- Two maxima of the **polar CHs** area are observed, which fall on 2011-2012 and 2015 - phases of growth and decline of solar activity.
- The maximum areas of **non-polar CHs** are consistent with the second phase of the maximum of cycle 24 in 2013-2014.

An asymmetry is observed in the distribution of the maximum of the sunspot areas. 2012 on the North, 2014 on the South.

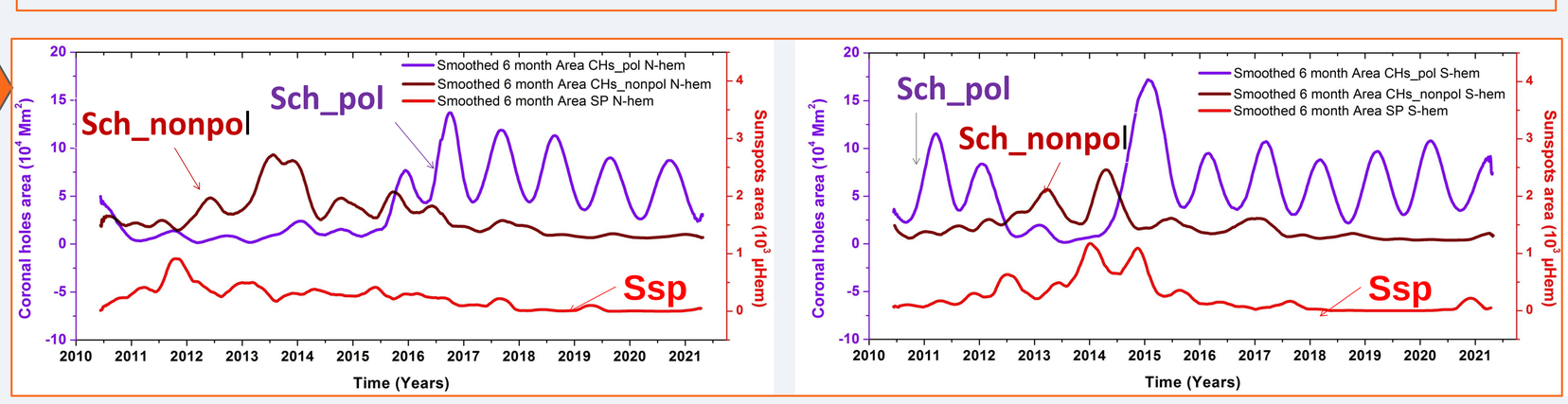


- We see the hemispheric asymmetry of the **polar CHs** and the sunspots areas. The daily total area of **polar CHs** increases at solar minima and decreases at the cycle maximum. This is consistent with the general concept of **polar CHs** as the main source of the solar dipole magnetic field.
- In both hemispheres, there is a tendency to an increase in **non-polar CHs** at the rasing phase and maxima solar activity, to a decrease at the decay and minima phases. This confirms the assumption that **non-polar CHs** are most likely associated with sunspots activity

Evolution of polar and non-polar CHs in N and S hemispheres



- In the N-hemisphere **non-polar CHs** (2013 - 2014) determine the coronal holes activity, because **polar** are very week. They also determine the behavior of **non-polar** holes for the entire disk.
- The similar situation we observe for **polar CHs** (2011, 2012 and 2015) of the S-hemisphere.
- In the period under study there was an asymmetry of the hemispheres in the localization of the maxima of the areas of **polar** and **nonpolar CHs**.
- Visible quasi-periodic oscillations on the middle plot for Sch_pol are an artifact caused by the tilt of the sun's rotation axis during the year.



Conclusions

The division of all coronal holes of the considered period into **polar** and **non-polar** ones showed:

- Daily total area of **polar coronal holes** increases at the minima of solar activity and decreases at the maximum of the cycle. This is consistent with the general concept of **polar coronal holes** as the main source of the sun's dipole magnetic field.
- Asymmetry is observed in the regions of **polar coronal holes** in the northern and southern hemispheres. It is shown that the areas of **non-polar coronal holes** change quasi-synchronously with the solar activity of the Sun, which indicates the existence of a physical connection between these two phenomena.
- Apparently, the nature of the magnetic fields of **polar** and **non-polar** coronal holes is different. **Non-polar coronal holes** are possibly very tall loops that close through the corona in other regions of the Sun, while **polar coronal holes** extend far into the heliosphere.

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