Studies of coronal holes and solar wind velocity forecasts based on SWAP data analysis

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Aim of the Project

The main goal of project is to use the uninterrupted solar viewing provided by PROBA2/SWAP together with images provided by SDO/AIA, SOHO/EIT for space weather monitoring during long time period.

CHs are the low density and temperature regions on the Sun with open configuration of magnetic field, source of recurrent high speed solar wind (SW) streams and cause of average intensity but long duration recurrent magnetic storms.

The data of CH areas, their structure and dynamics of variations was planned to determine using images provided from PROBA2/SWAP and SDO/AIA. The statistical relationships between estimated CH parameters and the velocity of quasi-stationary SW streams should be studied. The CH parameters that have strong impact on the formation of SW flows will be used to forecast the SW velocity at the Earth's orbit and geomagnetic indices.

Data preparation

The task of automatic collection of uninterrupted good quality data set provided by PROBA2/SWAP was discussed with PI team experts SWAP instrument. The SWAP images nominal parameters of observation that can be used for CH parameters estimation were determined. The daily and hourly SWAP images with nominal parameters were automatically collected. The blurry images were automatically detected and excluded from consideration. The mean intensity variations of the solar disk without limb of SWAP images were studied in order to obtain correct CH threshold intensity to define the parameters CH. The correlation between the sharp mean intensity changes and maximum values of image intensity was found. Cumulative distribution of image's intensity was used to define small part (less of 0.5%) of extremely bright pixels (as cosmic ray etc.). These bright pixels were not considered in the calculation of the parameters CH. This procedure allows us eliminate the main cause of abrupt changes of mean intensity of the solar disk without limb. Then all images obtained by different spacecraft and spectral ranges were rescaled to one intensity range (0-255). The CH areas were normalized to area of solar disk without limb to account for changes in the size of the solar disk during the year. The daily and six-hour SWAP images from February to November 2010 year were collected for future processing.

Preliminary results and discussion

The collected images were analyzed using our algorithm of automatic identification of CH parameters from the EUV solar images based on the classification of image pixels by threshold intensity. Parameters of coronal holes (CH) based on images produced by SWAP and SDO/AIA were calculated. Estimated CH parameters obtained from PROBA2/SWAP and SDO/AIA centered on the 19.3 nm and 17.1 nm lines were compared. The relationship between CH areas and the velocity of SW flows was studied. Preliminary the daily SW velocity forecast for 3 days ahead using SWAP data have been obtained.

In general a good agreement between CH areas provided by SWAP images and the solar wind streams was found. The main reason for the discrepancies found in the data lies in the definition of filaments as coronal holes. It is very hard to distinguish between CHs area and dark area around filaments using only image at 171-174A spectral ranges since both have the low intensity. Of course, elongated shape, orientation in a north-south direction and location in high latitudes may help to identify filaments but not in all cases. So, H-alpha image from the Kanzelhoehe observatory could be used to separate CH areas and filaments.

CH areas obtained from SWAP images have good agreement with the high-speed solar wind stream, as well as streams whose speed is near 400 km/s. Sometimes CHs defined near or between active regions based on images at 171-174A wavelengths are not observed at 193A wavelength. We named such CHs as dark regions. These dark regions possible connect with “middle” speed SW flows with velocity values near 400 km/s. However, more observations and additional consultations with PI team experts of SWAP instruments are needed to interpret obtained results more precisely.

The CH areas obtained from different satellites and wavelengths generally have a good agreement with recurrent high speed SW streams with velocity values more 600 km/s. However sometimes we observed disagreements between CH areas calculated at different spectrum ranges (171A, 174A and 193A). For example, large positive polarity CH elongated from south to north solar pole was observed on June 13, 2010. Relative (to solar disc area) area of CH is equal to 9.5% for SDO/AIA 193A, 2.3% for SWAP 174A and 0% for SDO/AIA 171A. Even after varying thresholds for CH areas estimation we were not able to get comparable CH areas calculated at different spectral ranges. The reason of disagreement observed in 193A, 174A and 171A wavelengths can be linked with the observation of coronal plasma at different temperatures. We are planning to further investigate the reason of such variance in CHs area estimation.

The predictions of quasi-stationary solar wind streams for 3 day ahead using semi-empirical models based on the CH areas was also obtained for different spacecraft and spectral ranges. The preliminary results were compared with widely-used Wing-Sheeley-Arge prediction model and demonstrated comparable performance.

The forecasts obtained using CH areas from different spectral ranges were compared. The best results were obtained by us using SDO/AIA at 193A and Proba2/SWAP data. However, the combination of all forecasts based on CH areas estimated at different spectral ranges can improve the result. It is possible that CH parameters obtained from different spectral ranges can better describe the different ranges of SW velocities. During the rising phase of solar cycle (2010 year) the SW streams with velocity values near 400-500 km/s were often observed. These streams can be connected with different sources on the Sun, however our data suggests that SW flows with velocity near 400 km/s could be associated with the dark areas near active region observed at 171A and 174A wavelengths. Still further investigation is needed to whether it is the case.

Future Work

Characteristics such as location (latitude position), shape and intensity of CHs as well as information from SDO/AIA images at 193A wavelength or/and filaments location obtained by H-alpha images will be used to distinguish between CH area and dark area around filaments.

The size of the SDO/AIA solar disk will be brought to the size of SWAP for a more accurate comparison CHs properties obtained by different spacecraft. Consultations with SWAP PI team members will be continued to interpret newly obtained from PROBA2/SWAP data more precisely.

The intensity distribution inside CH will be investigated, especially for cases when CH area obtained at different spectral ranges vary a lot. We will continue to compare CH areas (and other parameters) observed by PROBA2/SWAP and by SDO/AIA at 193A and 171A wavelengths to better understand the possible sources of cross-spectral variability. A comparison of CH properties obtained in different spectral ranges can help us to reveal the solar morphology at different temperatures.

It will be investigated if there is a connection between dark region observed at PROBA2/SWAP and SDO/AIA (171A) images and SW streams with “middle” velocity values near 400 km/s.

The combination of CH parameters obtained by PROBA2/SWAP and SDO/AIA at 171A and 193A will be used for SW velocity forecast based on empirical methods.

The artificial neural networks algorithm that automatically takes into account time delay between events observed on Sun and values measured at the Earth’s orbit will be used for six-hour SW velocity forecast.