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Growing coronal mega-holes towards the solar minimum

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Introduction

The most significant component in formation of the Earth's thermosphere and ionosphere is the introduction of energy from EUV and soft X-ray wavelengths in the solar electromagnetic spectrum. The coronal holes (CH) are observed in the EUV and soft X-ray on the solar disc as the more cold and less bright regions as compared to the background brightness. The magnetic field lines of a coronal hole stay open and stretch out into space and generate the high speed solar wind (HSS).

Recently the long-living Coronal Mega-Hole (CMH) has been observed during twenty four Carrington Rotations - CR2165 (06.2015) to CR2188 (03.2017) [Andreeva et al., 2017; Gulyaeva and Gulyaev, 2018]. When a coronal hole is positioned near the center of the Earth-facing solar disk, the plasma flows towards Earth at a higher speed than the regular solar wind and cause geomagnetic disturbances on Earth with enhanced auroral activity.

We present here the results of analysis of the CH Power index, Pch, for a period from 03.2011 to 12.2017, built up with SOHO EIT 284 Å observations by Luo et al. [2008]. The Pch index is daily evaluated from the SDO/AIA images (Fe XII 193Å) by the Space Environment Prediction Centre, Beijing, China, http://eng.sepc.ac.cn/CHI.php , for forecasting the solar wind velocity three days in advance (Vsw) from the intensity of brightness of the CH near the center of solar disc at [10°E,10°W], [30°N, 30°S]. The Pch index and Vsw predictions are given in Fig.1 and Fig.2, accompanied by space environment parameters plotted in Fig. 3 for the storm event on 2018-04-21.

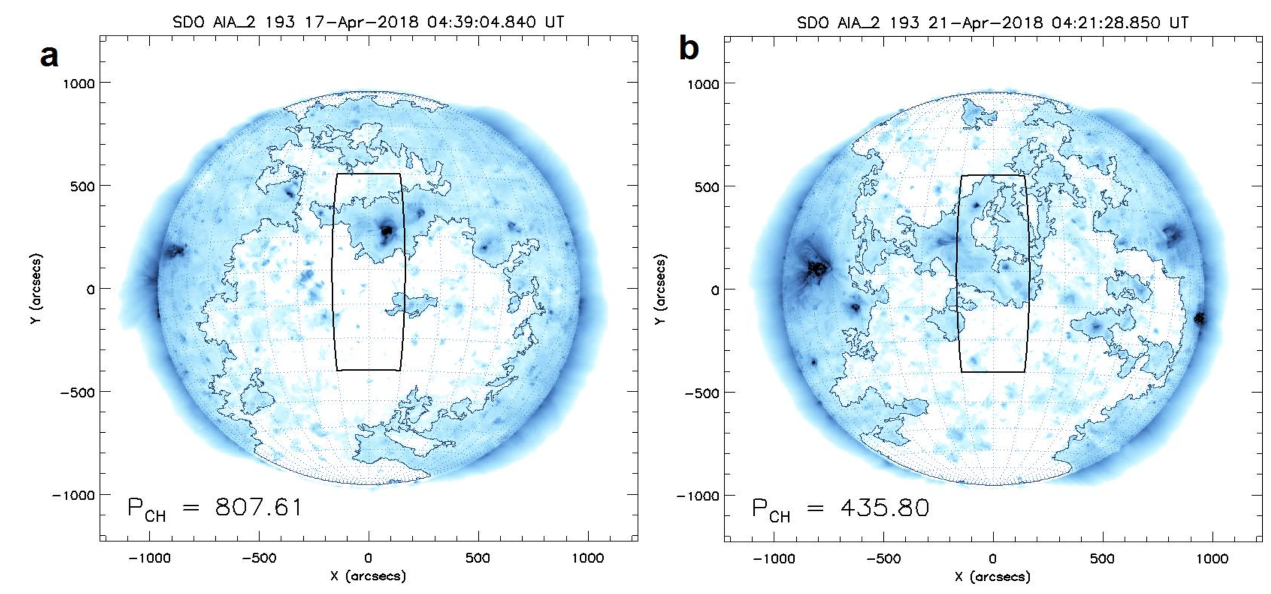

Fig. 1. SOHO EIT 284 Å image (a) at the peak of Pch =808 i.u. on 2018-04-17; (b) 4 days later on 2018-04-21 during space weather storm in solar wind, IMF and the Earth (see Figs. 2-3)

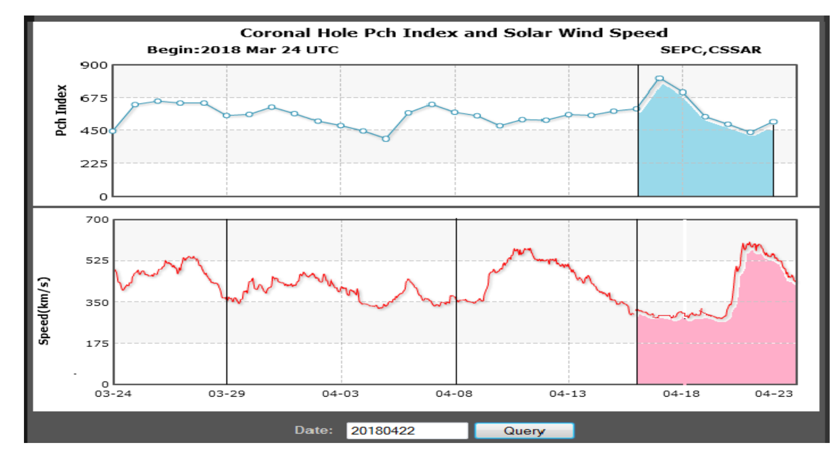

Fig. 2. Observed Pch index enhancement on 2018-04-17 (upper blue peak) followed by jump of solar wind speed forecasted with Pch index 4 days in advance on 2008-04-21 (bottom panel) with space weather storm shown in Fig.3.

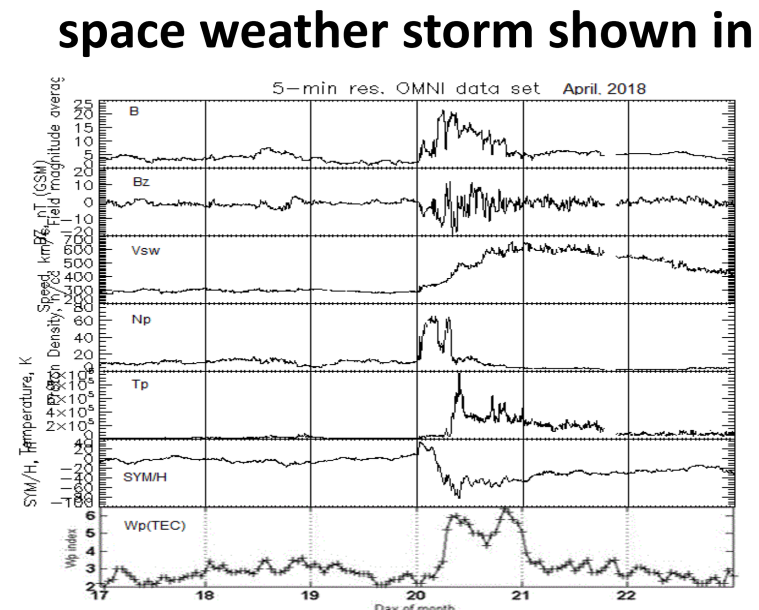

Fig. 3. OMNI IMF parameters from top to bottom: B, Bz, Vsw, Np, Tp, SYM/H, and global ionosphere GIM-TEC based Wp index (bottom section) before and during space weather storm on 2018-04-21 induced by CMH enhancement 4 days earlier (Fig. 2).

Data analysis

The Pch variation near the center of solar disc is consistent (Fig. 4) with the total area of the CMH which is located near the North pole and passes to 30°S at its maximum development [Andreeva et al., 2017 ; Gulyaeva and Gulyaev, 2018].

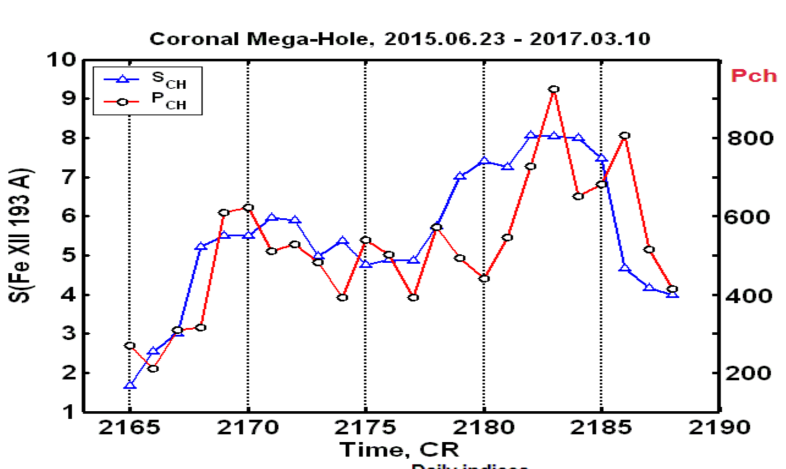

Fig. 4. Variation of Pch index at the central rectangle ([10°E, 10°W], [30°N, 30°S]) and the surface area of total CMH derived from SDO/AIA Fe XII 193 Å images for the dates of CMH crossing the central meridian for the CR2165 to CR2188 [Andreeva et al., 2017; Gulyaeva and Gulyaev, 2018].

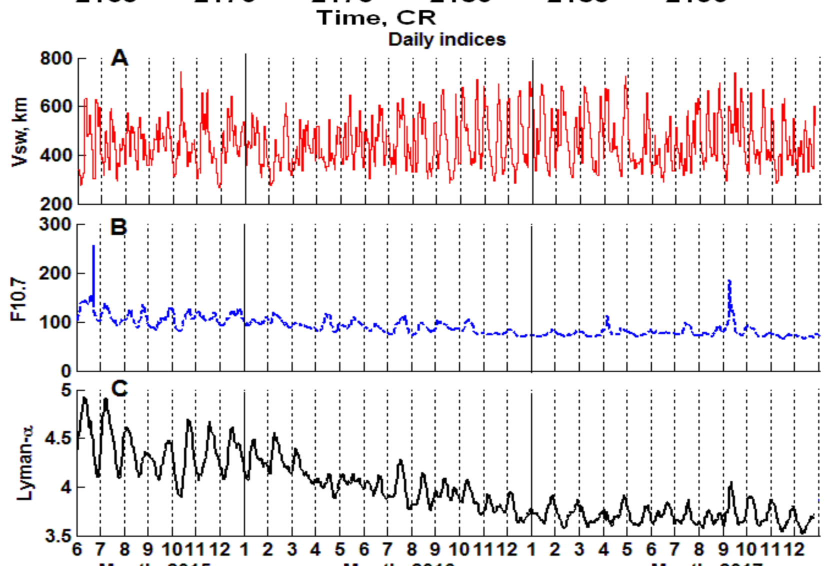

Fig. 5. Daily mean (A) solar wind speed Vsw, (B) solar radio flux F10.7, (C) Solar emission H Lyman-α line at 121.6 nm. Correlation exists between F10.7 and Lyman-α (r2(B,C) = 0.84), but there is a weak anti-correlation of Vsw with the both solar indices (r2(A,B) = -0.025 and R2(A,C) = -0.051) so that Vsw tends to enhance towards solar minimum.

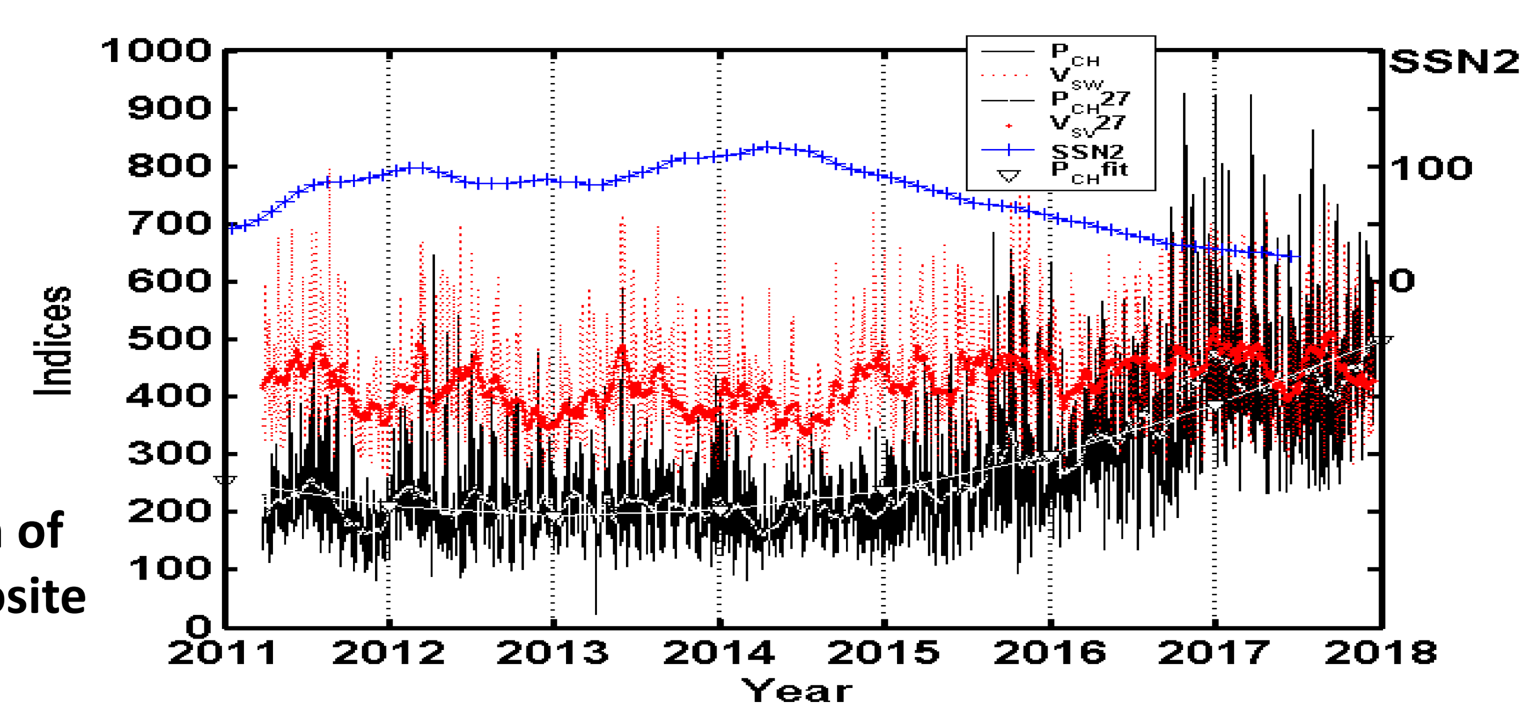

Fig.6. Daily Pch and Vsw solar indices superposed by -27d time-weighted accumulated proxy value Pch(τ) and Vsw(τ) (points) [Wrenn, 1987]. Growing trend of Pch proxy index towards the solar minimum of SC24 is opposite to the 12-monthly smoothed sunspot numbers time series SSN2 (blue curve) and opposite to the ionosphere noon indices trends at the declining phase of SC24 [Gulyaeva and Gulyaev, 2018].

Conclusions

The main findings from this study:

- **Pch index presents important source of information for modeling and forecasting geo-space effects of the solar storms for scientific and technological application**
- **Intensity of CHs is increasing towards the solar minimum while other relevant solar, interplanetary and geo-space parameters are decreasing**
- **The only parameter which reveals the delayed response by 3 to 4 days to the CH's activity is the solar wind speed which is not captured by the ionosphere indices.**
- **More studies are needed to explain why the solar wind near the Earth shows 3-day-lag after the CHs while the ionosphere does not.**

Acknowledgements

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