ACADEMY OF FINLAND

RESOLVE CENTRE OF EXCELLENCE

UNIVERSITY of OULU
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FINNISH METEOROLOGICAL INSTITUTE

Aalto University

Solar cycle evolution of Alfvénic fluctuations and their geo-efficiency

E.I. Tanskanen(1, 2), K. Snekvik (3), K. Mursula (4), D. Pérez-Suárez (5), J. Slavin (6) and M. Goldstein (7)

(1) ReSoLVE Centre of Excellence, Finnish Meteorological Institute, (2) Aalto-university, (3) Birkeland Centre of Excellence, University of Bergen, Norway (4) Oulu university, (5) UCL/MSSL, UK, (6) Michigan university, Ann Arbor, US, (6) NASA Goddard SFC, US.

Science questions

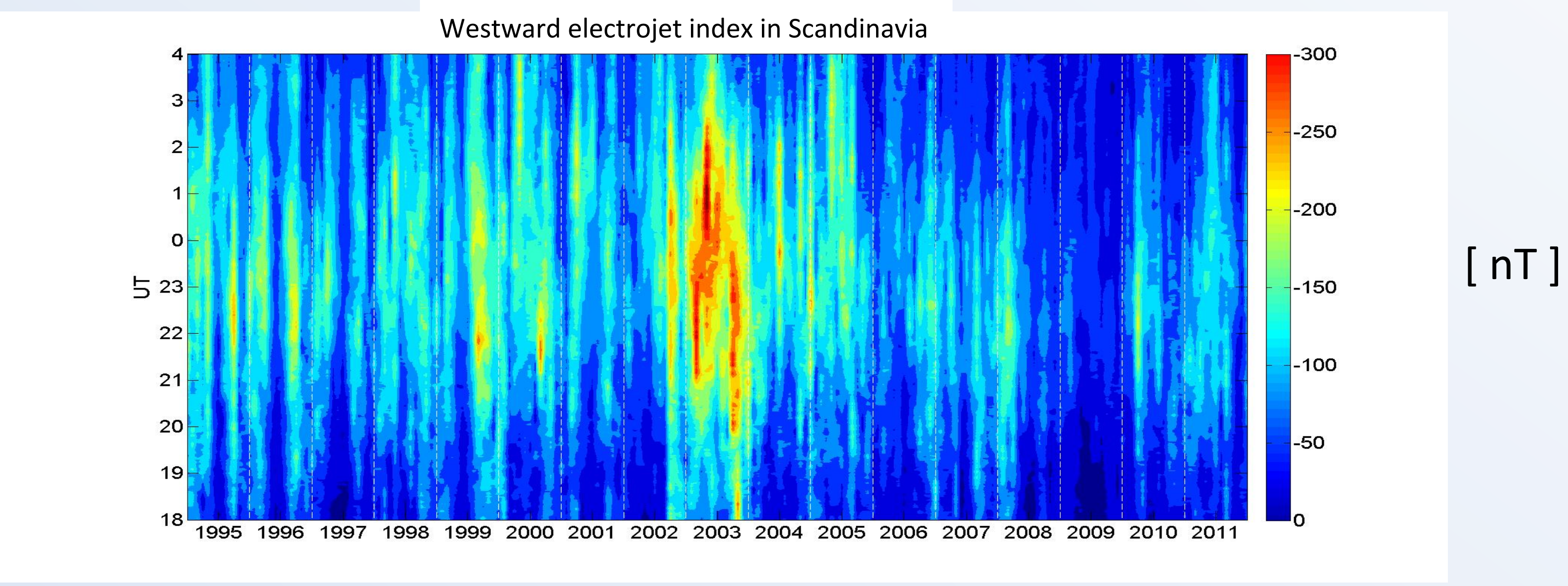
- Question1:

  How does solar wind Alfvénicity evolve over the solar cycle 23?

- Question 2:

  Which solar wind structures carry most of the Alfvénicity?

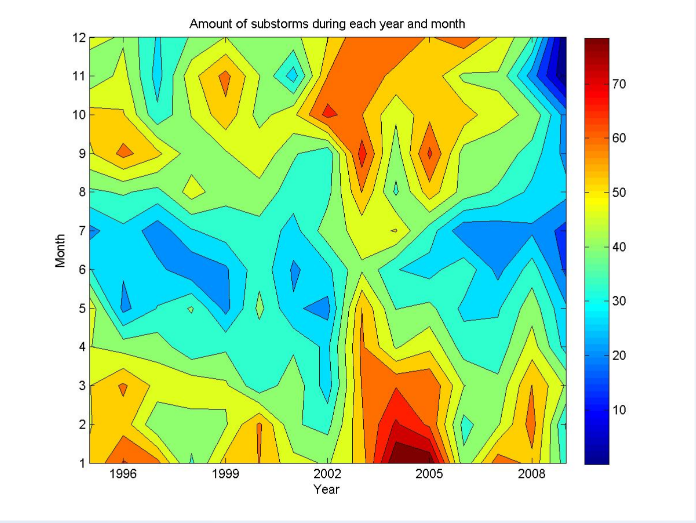
- Questions 3: How does the solar wind Alfvénicity affect high-latitude geomagnetic activity in particular substorm activity.



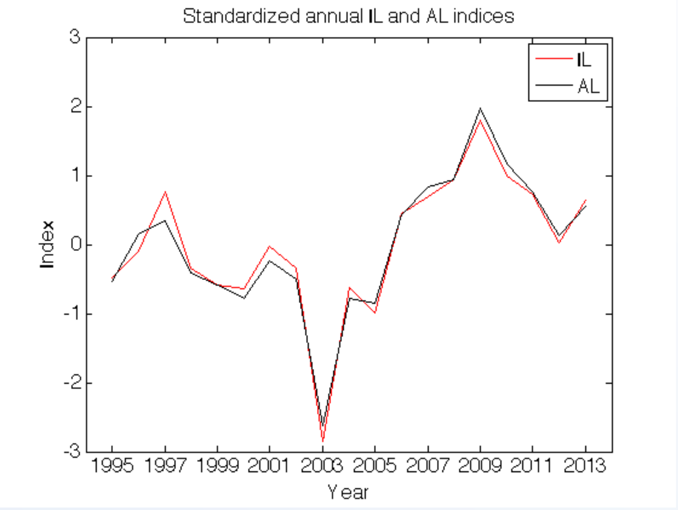
2003

High-latitude geomagnetic activity

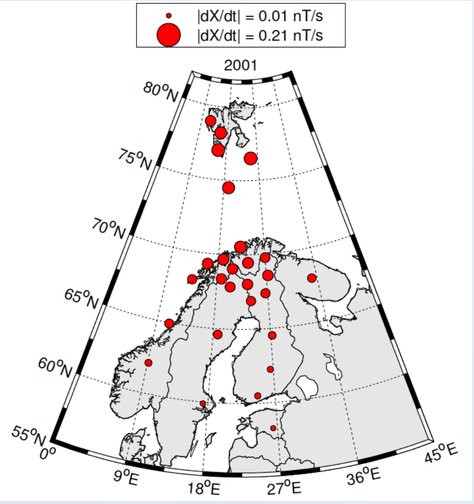
Substorms



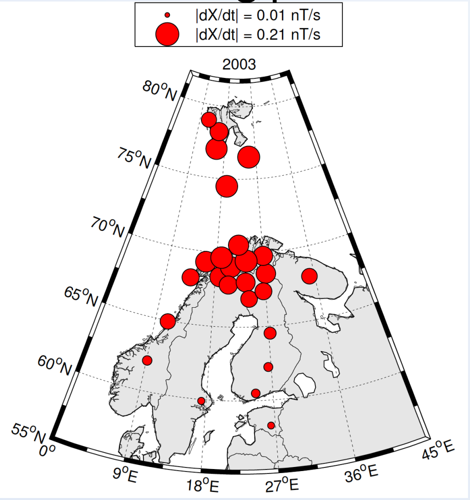
IL and AL indices



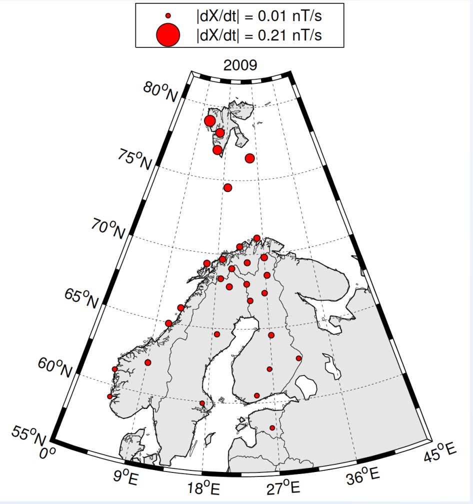
Solar maximum



Declining phase



Solar minimum

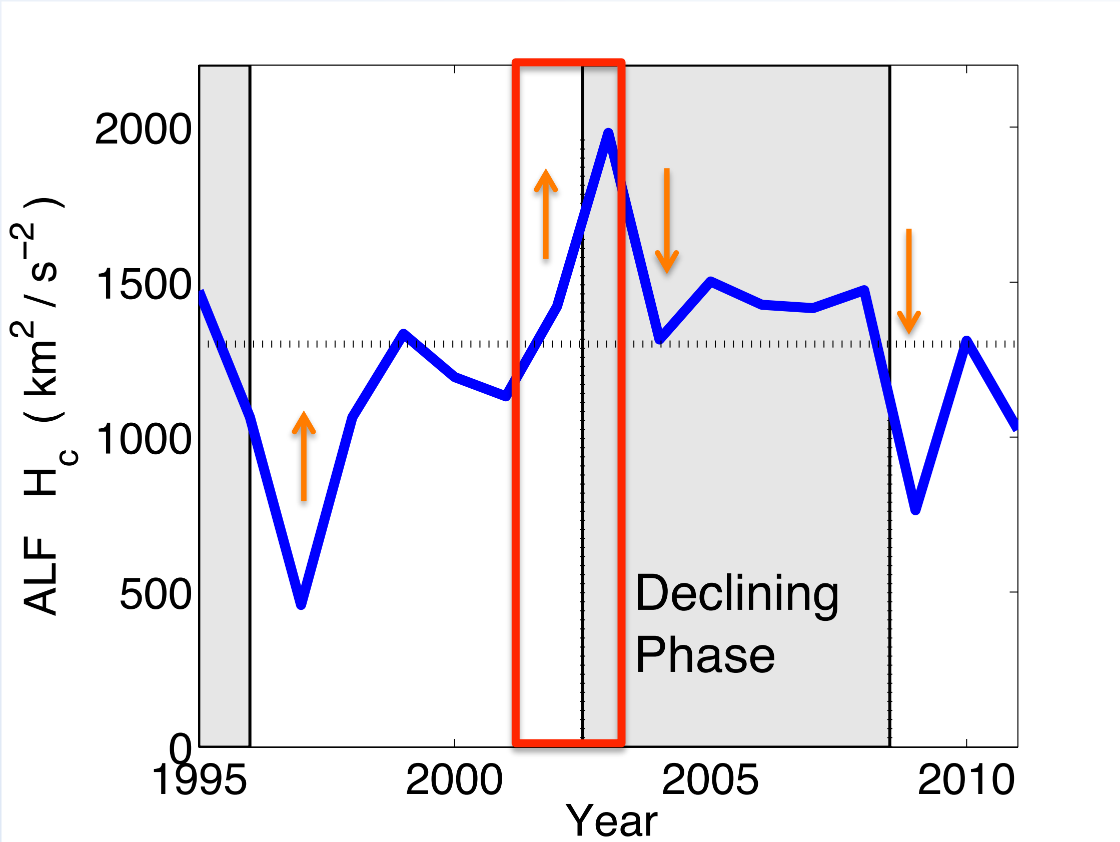


Method description

- We examine geomagnetic activity (IL and AL index) and substorms identified from them.
- Substorms identified from rapid decrease of north-south component of ground magnetic field and storms when Dst index < -40 nT.
- High-speed streams $v > 600$ km/s over 6 h.
- Alfvénic solar wind fluctuations (ALFs) identified based on normalized cross helicity by using method developed by Tu and March (1995) and further modified by Snekvik et al., 2013.

Solar wind Alfvénicity, SC23

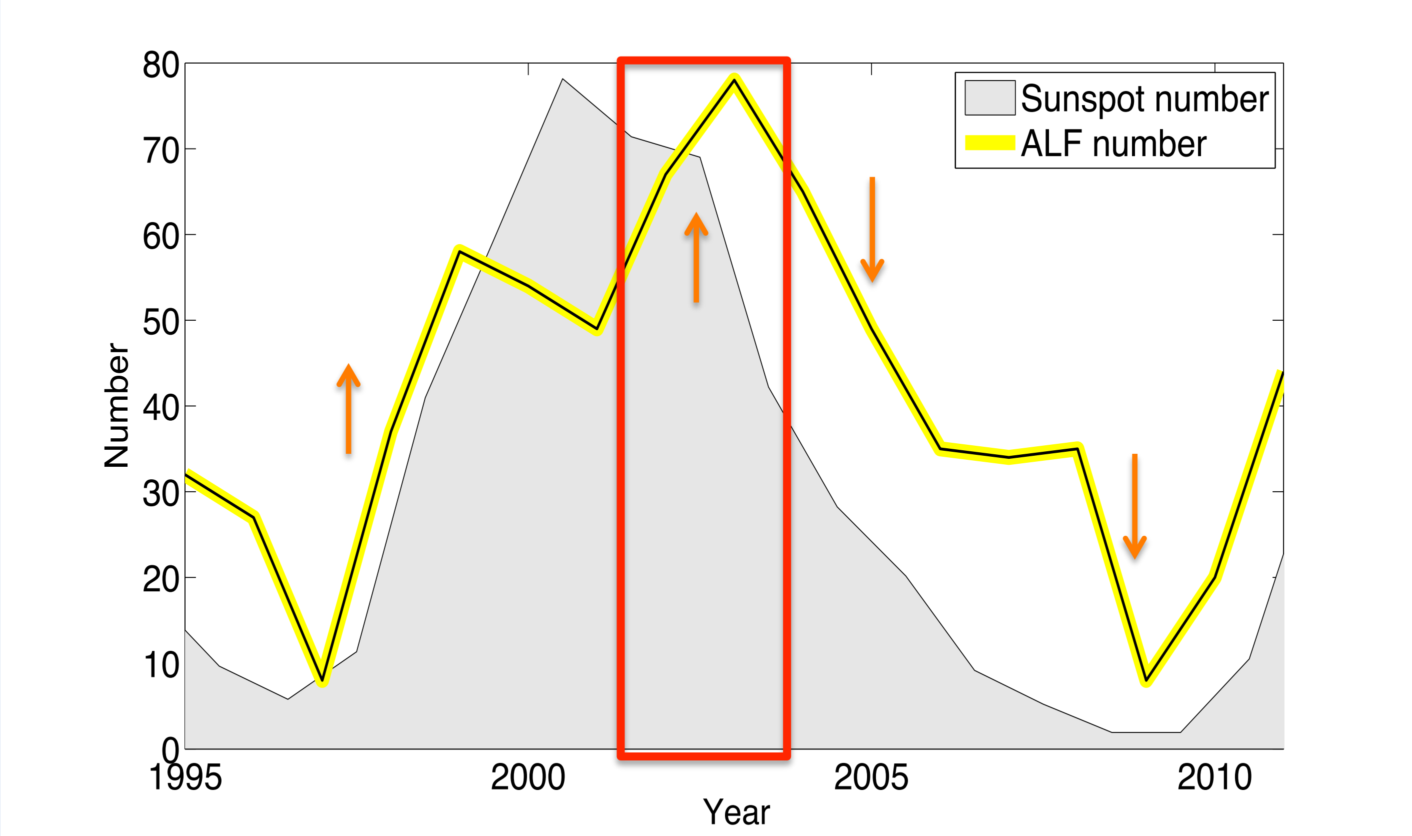
A rapid increase of Alfvénicity in early declining phase when solar wind Alfvénicity increase 40% from 2002 to 2003.



Tanskanen, Snekvik, Mursula et al., JGR, 2016.

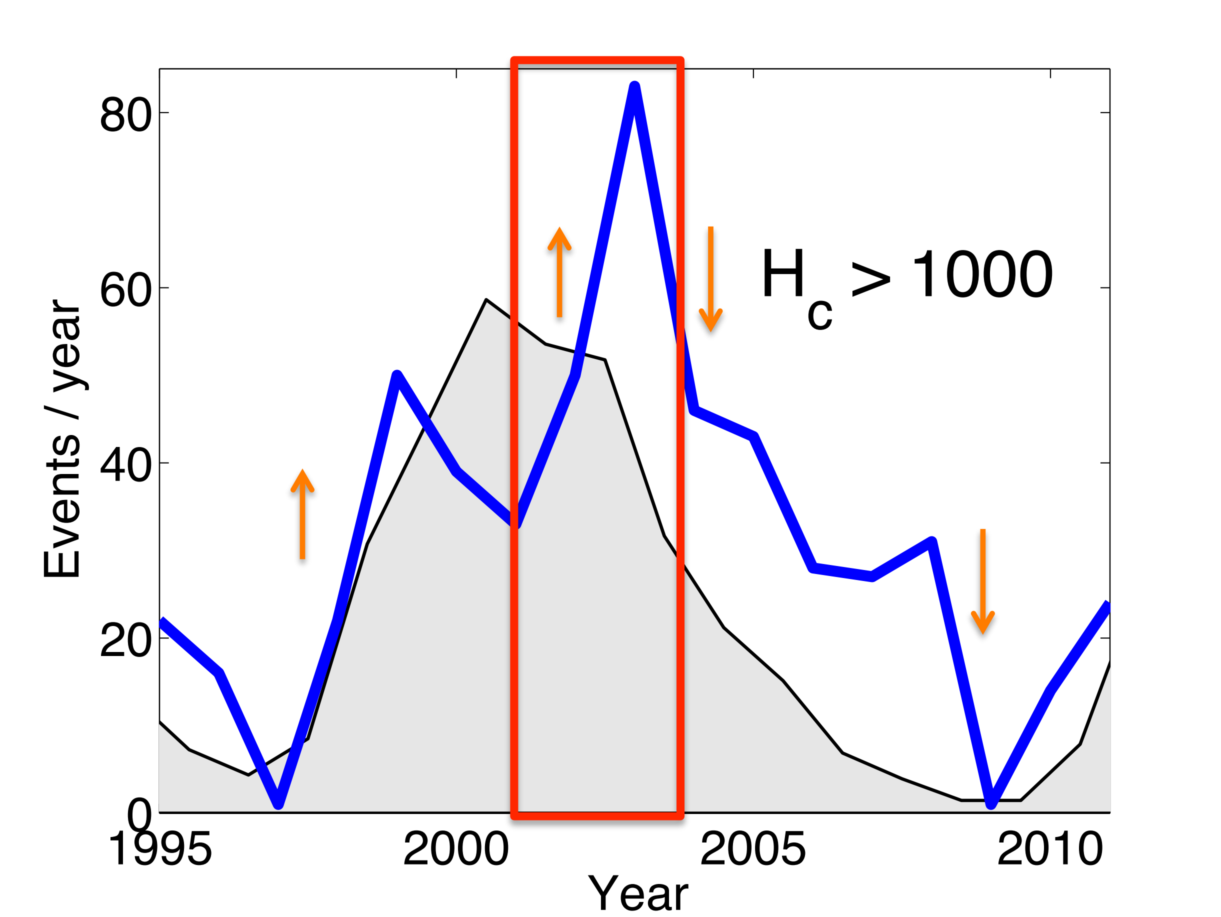
ALF occurrence rate

Alfvénic fluctuations are found in all solar cycle phases,
but largest ALF number is found in early declining phase in 2003.



Extremely Alfvénic solar wind

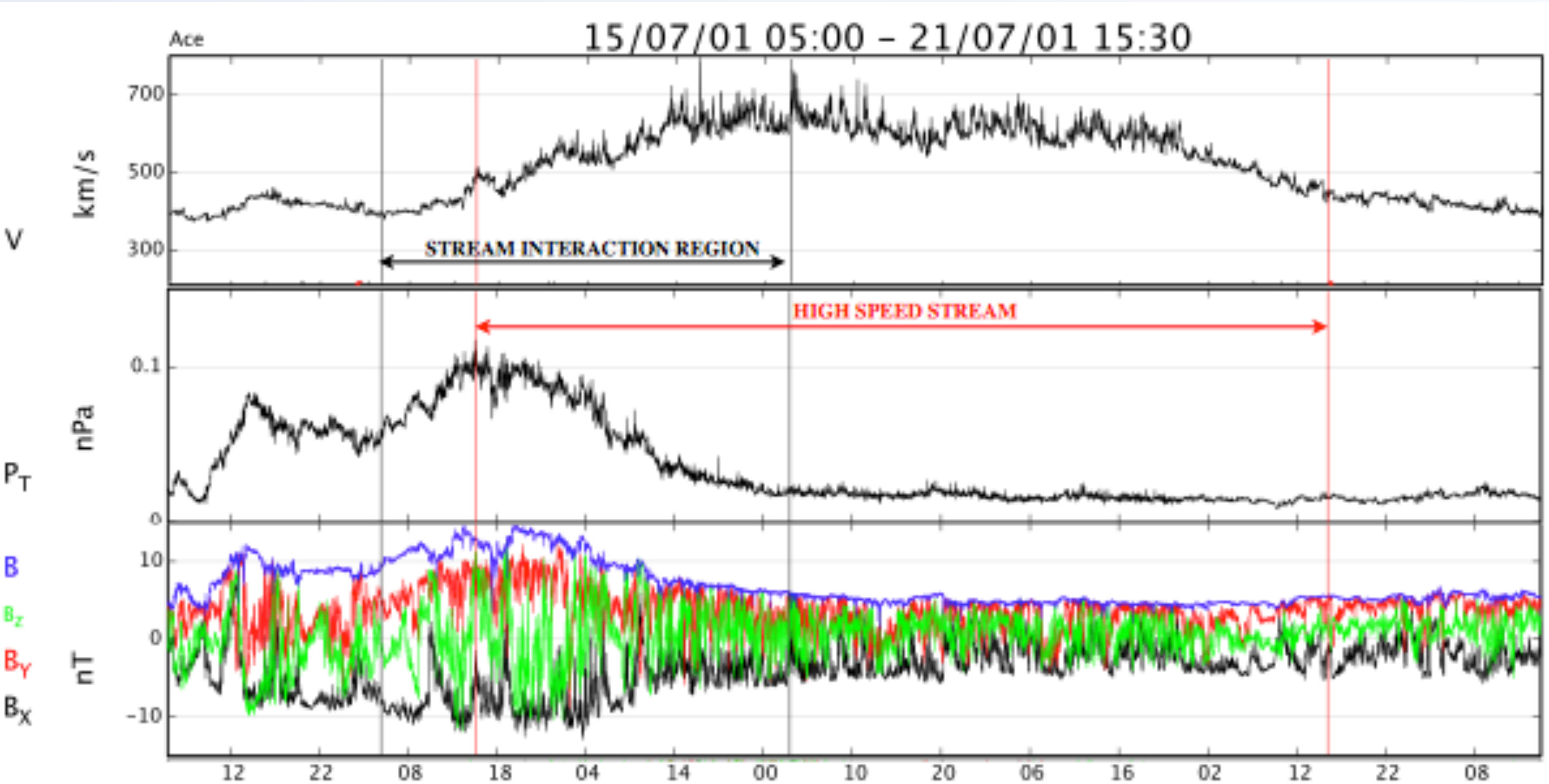
Extremely Alfvénic solar wind in 2003 and secondary peaks in 1999 and 2008.



HSSs and embedded ALFs

Number of high-speed streams each year, when 6 h and 700 km/s criteria used:

	1993	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
HSS	**2**	**21**	**4**	**0**	**0**	**3**	**2**	**8**	**5**	**7**	**27**	**3**	**13**	**1**	**0**	**2**	**0**	**1**



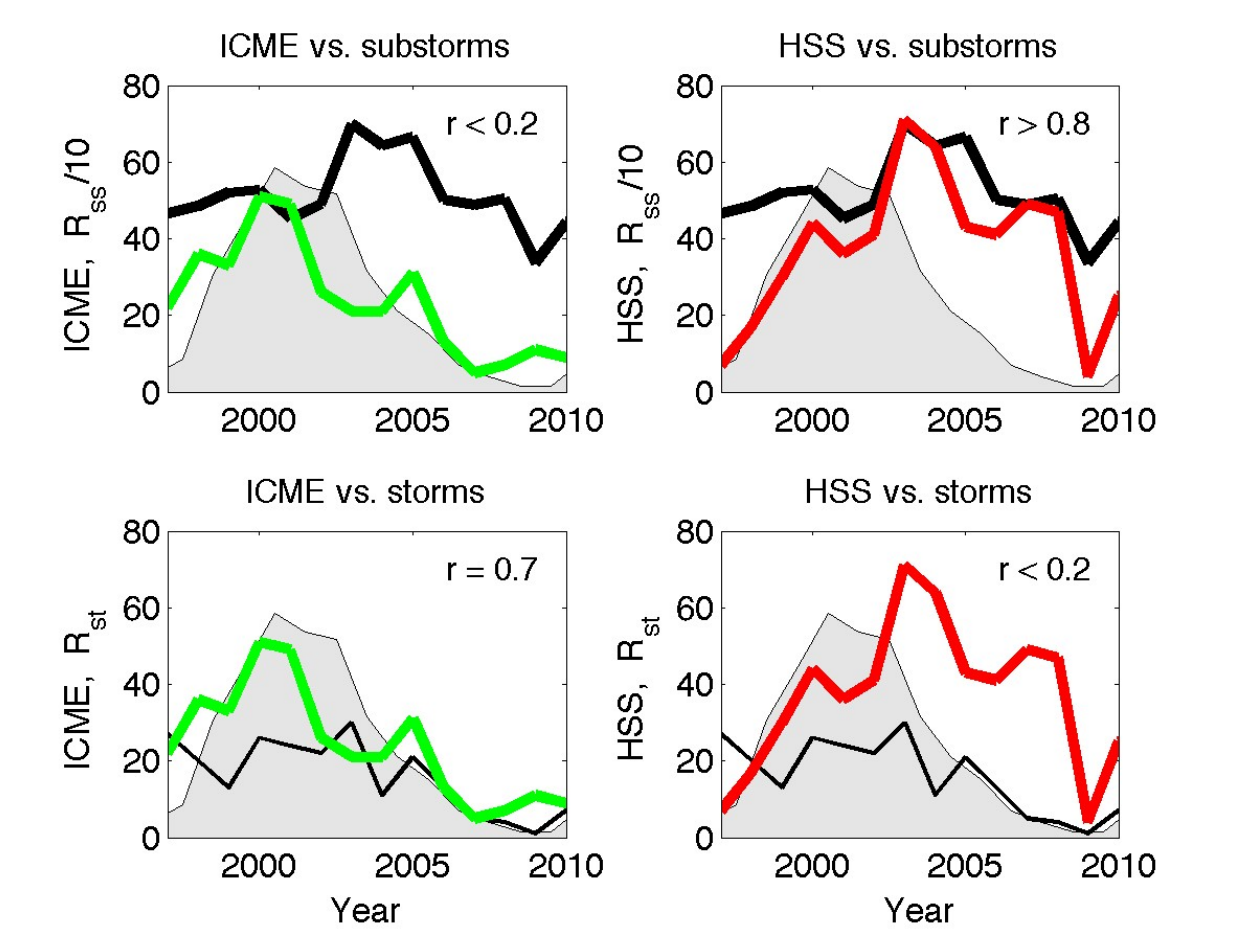
UT [hour]

High-speed streams drive high-latitudes···

Coronal mass ejections High-speed streams

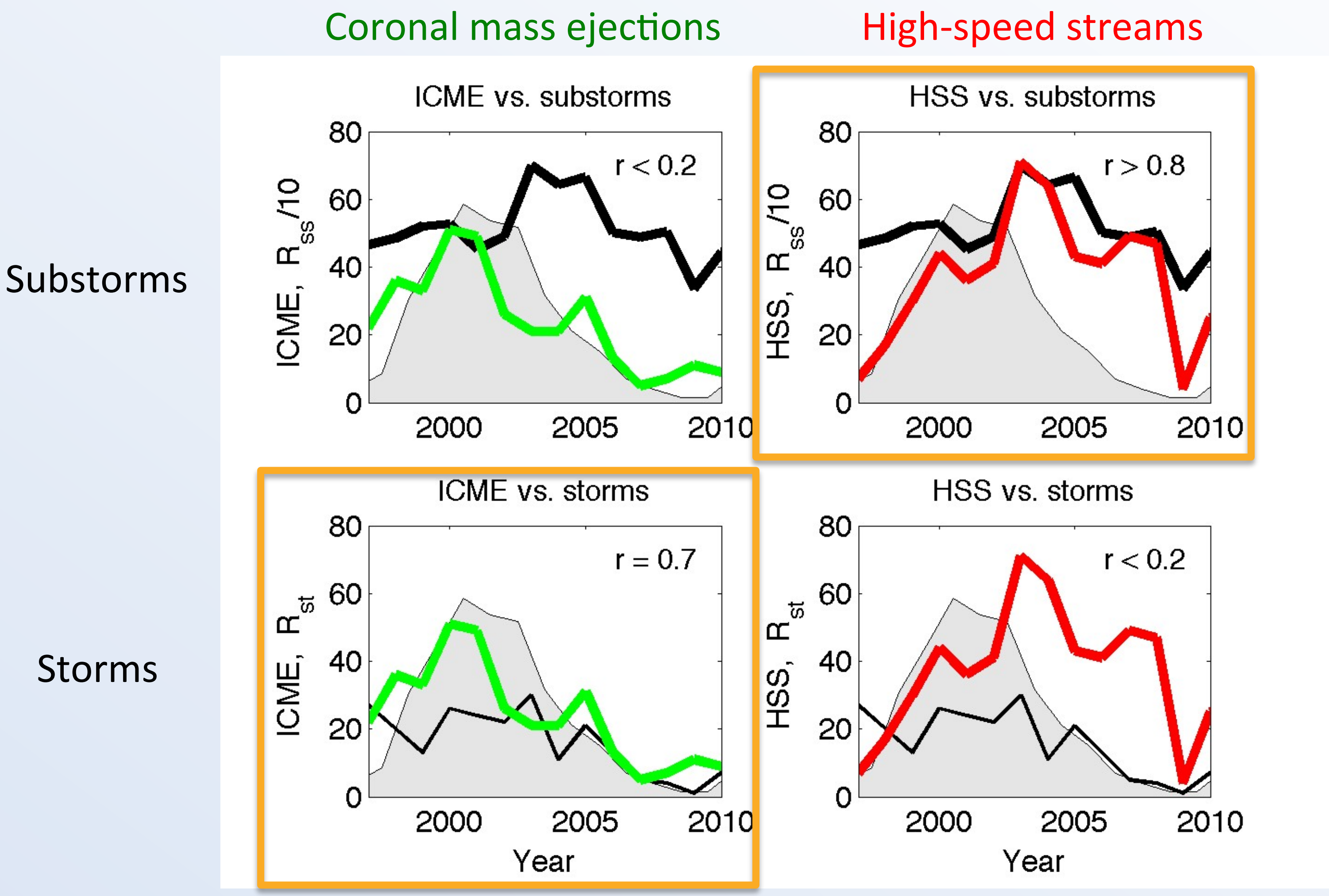
Substorms

Storms



… and ICMEs modulate low latitudes.

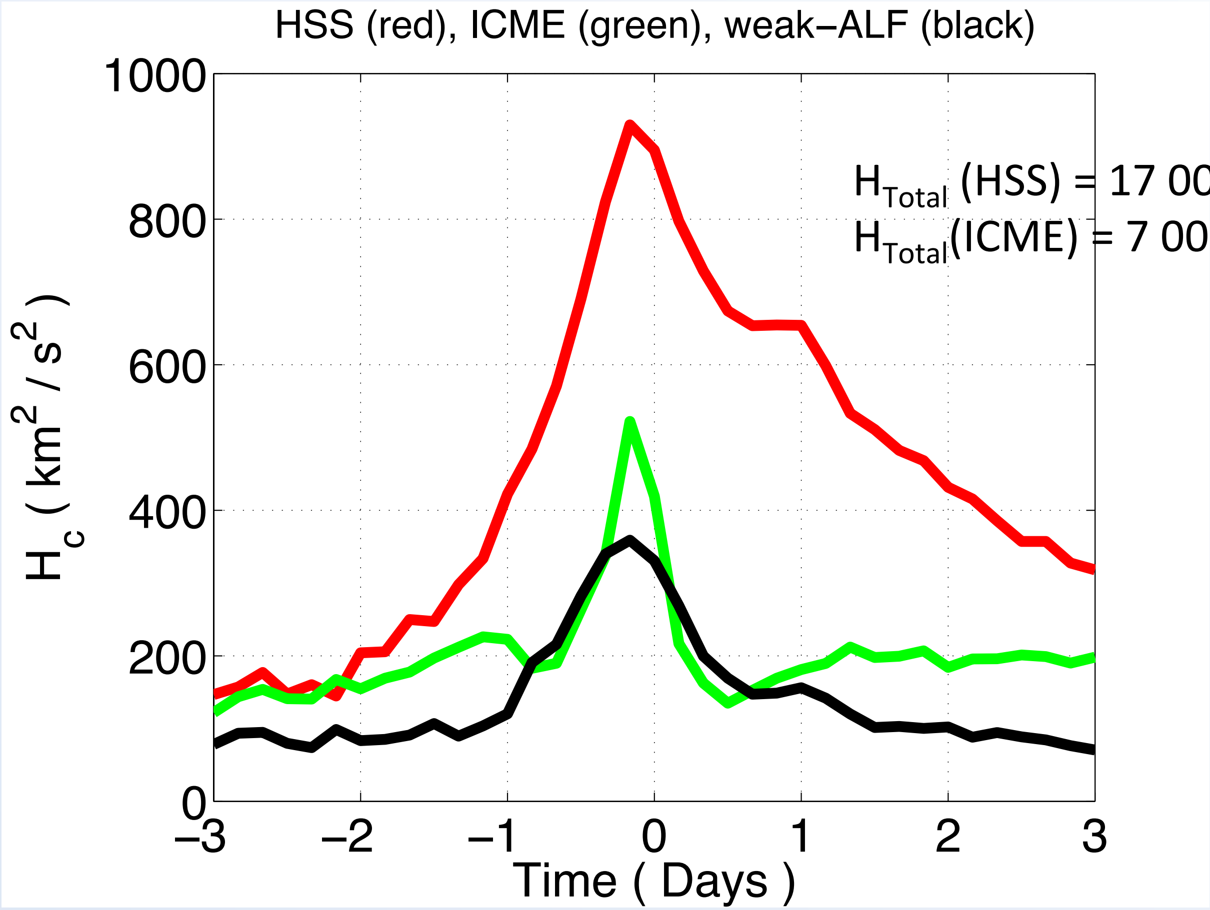
High-speed streams drive high-latitudes…



… and ICMEs modulate low latitudes.

Alfvenicity of ICME and HSS

Alfvénic fluctuations carry 2.4 times more helicity during HSS than ICME -related solar wind.

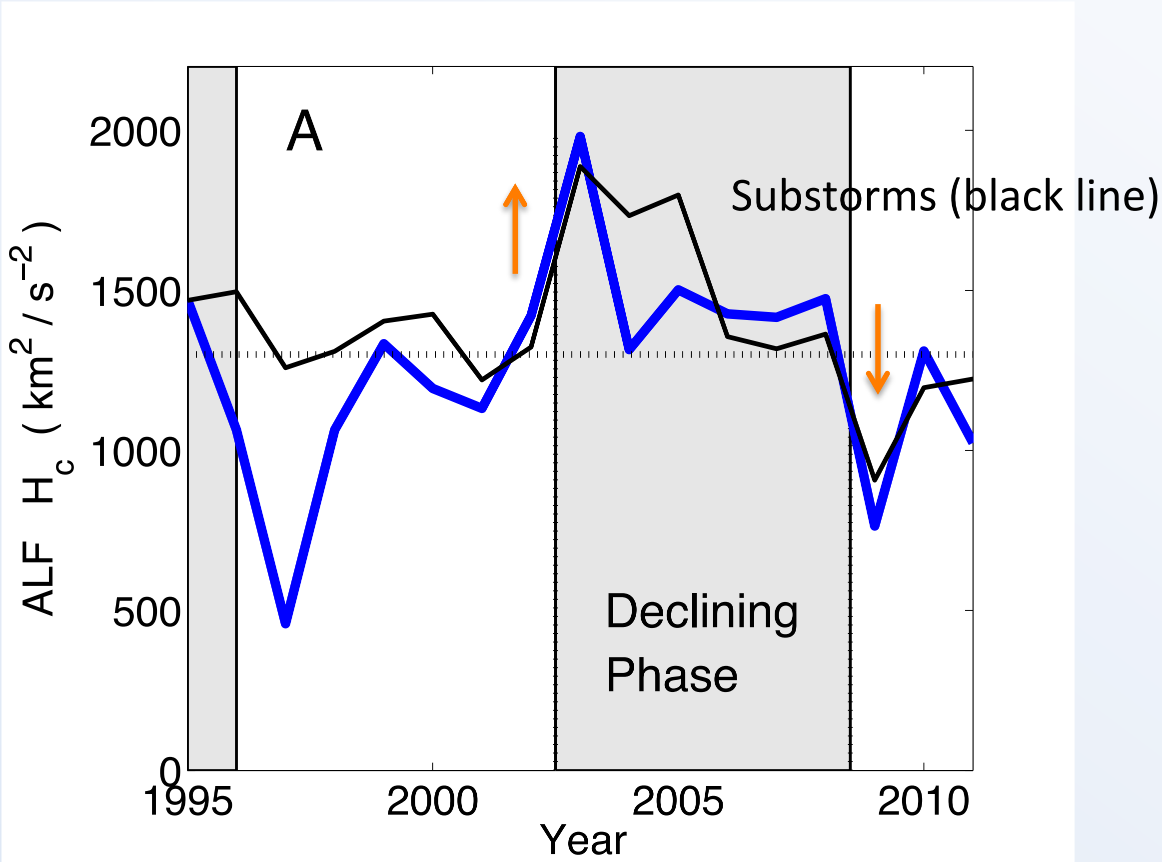


H_{Total} (HSS) = 17 000 km^2/s^2

H_{Total}(ICME) = 7 000 km^2/s^2

Substorm occurrence rate

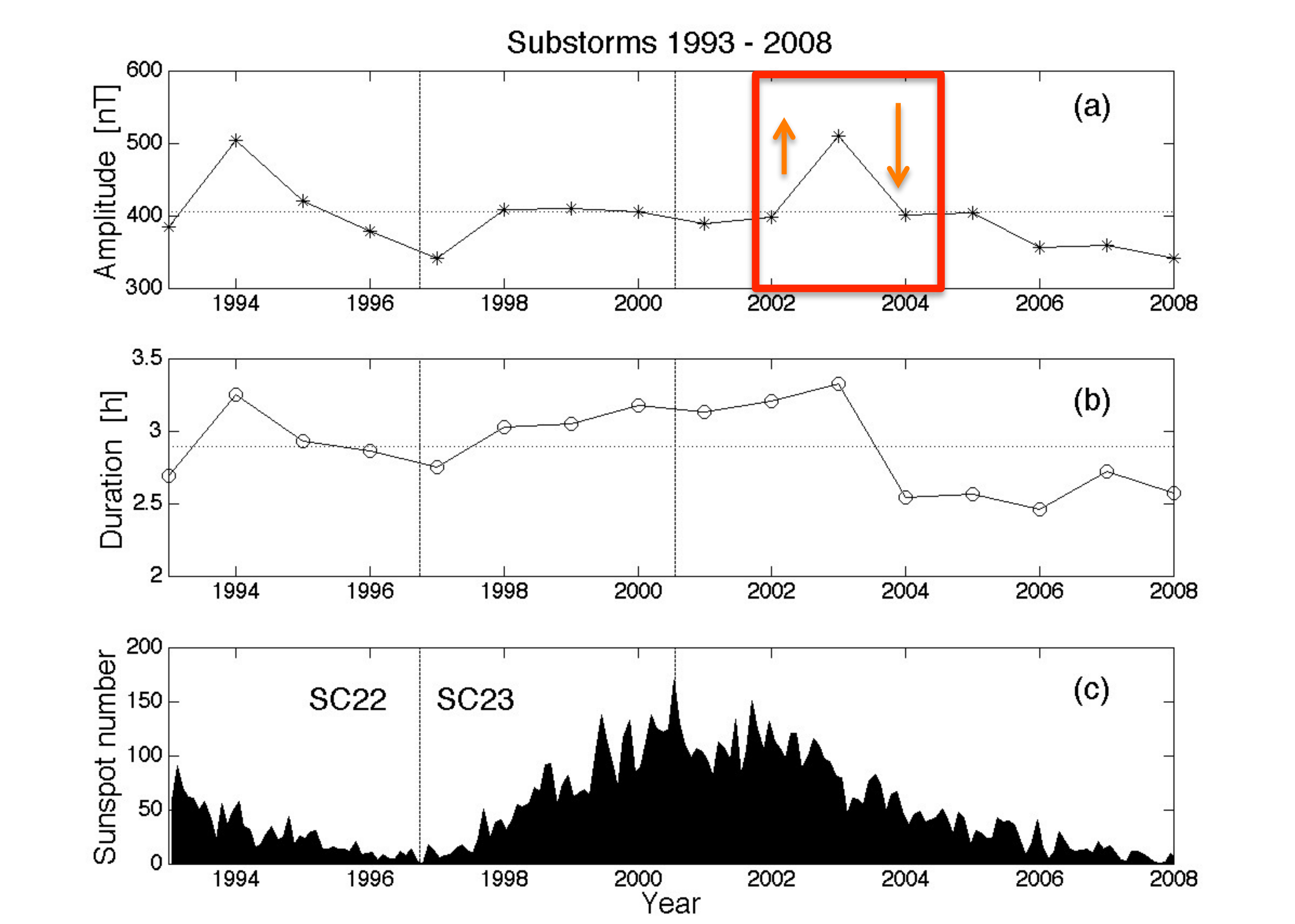
* An increase of 40 % in substorm number from 2002 to 2003 and 33 % decrease from 2008 to 2009.
* Alfvénicity increased 40 % from 2002 to 2003 and decreased 34 % from 2008 to 2009.



Tanskanen, JGR, 2009 & Tanskanen et al., 2016

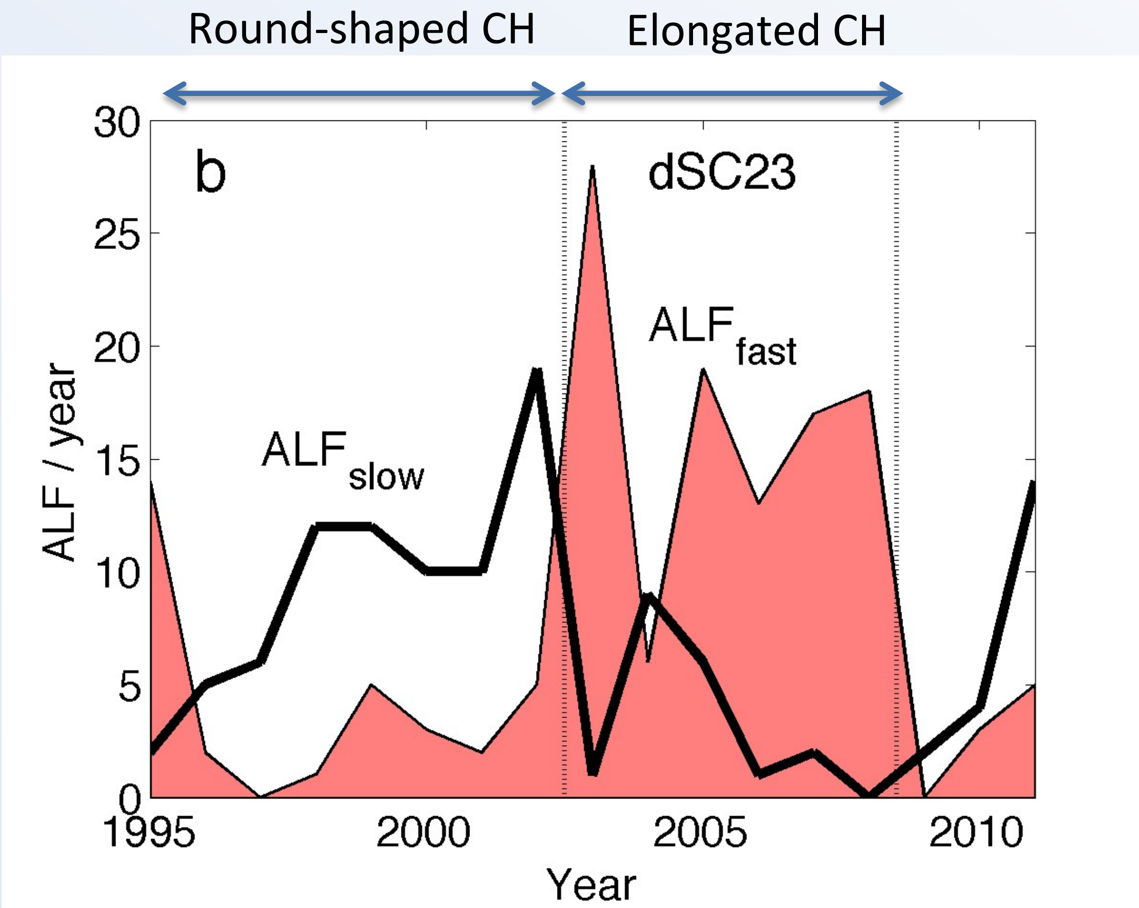
Substorm size

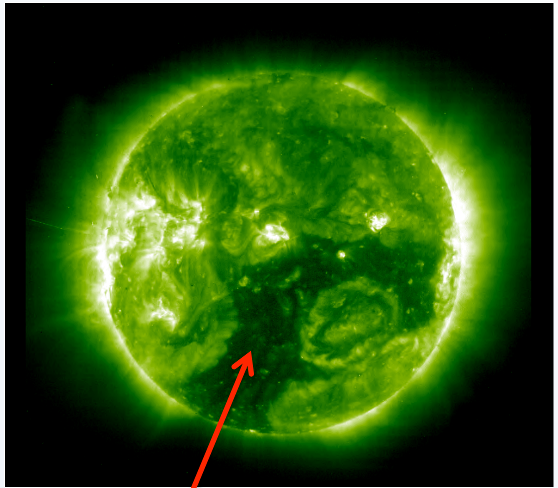
Substorm intensity increased 35% and decreased 25 % from 2003 to 2004, while Alfvénicity increased 40 % from 2002 to 2003 and decreased 34% from 2003 to 2004 .



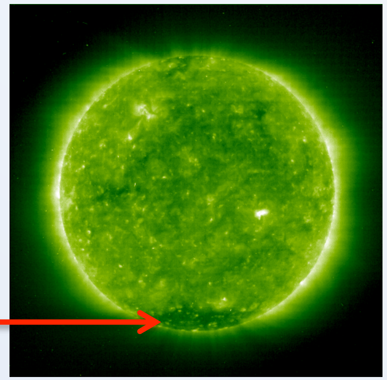
Tanskanen et al., JGR, 2011

Source of fast ALFs





Fast wind from elongated coronal holes.



Round-shaped coronal holes.

Transition from SC23 max. to declining phase

Characteristics of the solar wind and the interplanetary space changed in late 2002 when the solar maximum of the SC23 turned into the declining phase. After the transition:

(1) High-speed streams (HSS) occur more frequently.

(2) HSS embedded Alfvénic fluctuations are more intense and faster.

(3) High-latitude geomagnetic activity is enhanced e.g. substorms occur more often and are more intense.

Main results

- Q1: How does solar wind Alfvénicity evolve over the solar cycle 23?
  Largest Alfvenicity in observed in early declining solar cycle phase in 2003 and in velocity range 550 – 600 km/s

- Q2: Which solar wind structures carry most of the Alfvénicity?
- HSS carry twice as much Alfvénicity as ICMEs, and the largest Alfvénicity is seen in early trailing part of HSS.

- Q3: How does the solar wind Alfvénicity affect high-latitude geomagnetic activity in particular to substorm activity.
- The 40% increase in the strength of ALFs from 2002 to 2003 increase substorm amplitude roughly by 30% and the substorm number roughly by 40%.