Solar wind helicity
from magnetic data of CubeSat fleet

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The Sun-Earth magnetic coupling

aa geomagnetic activity index peaks few years after solar maximum
Variation of auroral substorm occurrence

Tanskanen & Franzia, Earth climate response to a changing Sun, 2015b
Substorms driven by high-speed streams

Tanskanen et al., JGR, 2017b
Solar wind magnetic fluctuations

Tanskanen et al., JGR, 2002
Origins of magnetic fluctuations

Complex active regions (CARs) produce complex interplanetary magnetic field. Hale classification used: $\alpha$, $\beta$, $\beta\gamma$, $\beta\gamma\delta$ …

Fast solar wind originating from the polar coronal holes carry solar wind fluctuations from the Sun towards the Earth.

Tanskanen et al., JGR, 2017a
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Tanskanen et al., JGR, 2017a
Solar wind periodicities

High-speed streams occur every 27-days in 2003 indicating that the source of the variation is the same place in the solar surface, in this case the elongated coronal hole structure (so called elephant trunk) in the solar southern hemisphere.

Plasma bulk speed at L-1

Mursula & Tanskanen, Earth climate response to a changing Sun, 2015a
Alfvénic fluctuations in solar wind

- Solar wind Alfvénicity is defined based on normalized cross helicity $\sigma_c$.
- Interval of Alfvénic fluctuations (ALF) was defined when $\sigma_c > 0.8$.

$$\sigma_c = \frac{2\langle \mathbf{v}' \cdot \mathbf{v}'_A \rangle}{\langle \mathbf{v}^2 \rangle + \langle \mathbf{v}'_A^2 \rangle} = \frac{\text{Var}(Z_{\text{out}}) - \text{Var}(Z_{\text{in}})}{\text{Var}(Z_{\text{out}}) + \text{Var}(Z_{\text{in}})}$$

Where Var is variance of $Z_{\text{out}} = \mathbf{v}' - \mathbf{v}_A'$ and $Z_{\text{in}} = \mathbf{v}' + \mathbf{v}_A'$ the Elsässer variables denoting outward and inward propagating Alfvén waves for an outward IMF.

(Tu & March, 1995, Snekvik et al., JGR, 2013, Tanskanen et al., JGR, 2017b)

The largest amount of ALFs (6-7/month) was detected in 2003 in declining phase while during solar maximum 4 ALFs/month were seen and during minimum <1/month.
ALF yearly coverage

- 200 days (55%) in 2003 during early declining solar cycle phase
- 120 days (33%) in 1999 during ascending solar cycle phase
- 80 days (22%) in 2001 during solar maximum
- 10 days (3%) in 2009 and 20 days (5%) in 1997 during minimum

Tanskanen et al., JGR, 2017a
Solar wind cross helicity

\[ H_c = \text{cross helicity} = \langle V' \cdot V_A' \rangle \]

Cross helicity is a measure of correlation (alignment) of the fluctuations of solar wind velocity \( V' \) and Alfvén velocity \( V_A' \), effectively magnetic field.

Tanskanen et al., JGR, 2017a
Magnetometers on-board CubeSat fleet

Better knowledge on spatial and time evolution of velocity and magnetic field fluctuations in interplanetary space are needed for targeted space weather predictions.
Helicity from CubeSat fleet

Large spatial difference in speed and magnetic field $\rightarrow$ Multi-s/c mission(s) needed for helicity (cross, magnetic & current) as well as for current density and magnetic stress ($J \times B$).

Tanskanen et al., JGR, 2002
Small magnetometer (CubeMAG) for CubeSats

The first CubeMAG will fly on-board ESTCube-2.
Thank you!

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