Long-term variability of electromagnetic characteristics in solar wind streams and its connection with 22-yr solar magnetic cycle and geomagnetic activity for measurement period 1964-2014 at near-Earth orbit ORBIT

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Study motivations and goals

- Solar wind streams form IMF spiral with a different longitude angle U, which corresponds to east-west component By (GSE) playing important role in reconnection on magnetopause and in progress of geomagnetic activity (GA)

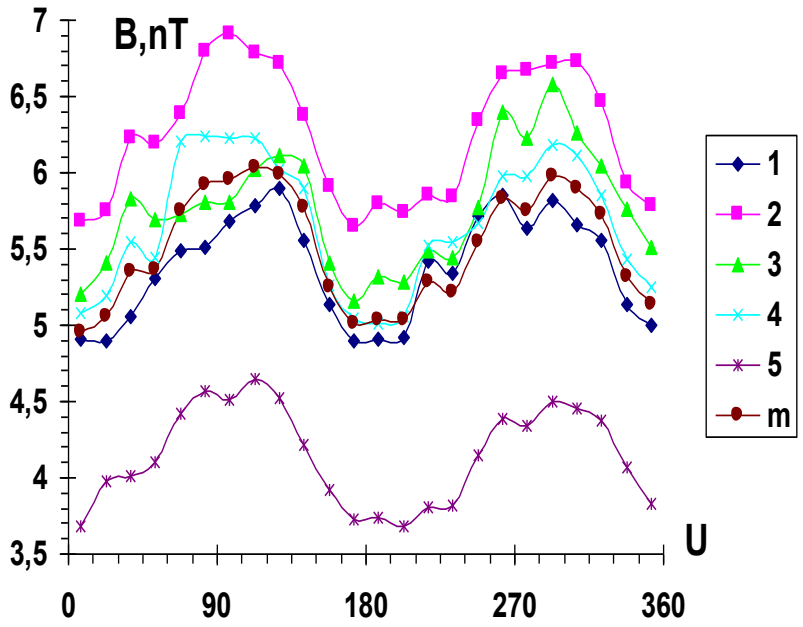
- Our main aim is to find connection between solar wind parameters and the angle U for streams with large electro-magnetic parameters (E=[VxB], P=[ExB]) to extract for each SC from N20-24. Then to find the stream effects in GA. Method allows to see evolution in the streams and GA for period of ~2 magnetic SCs.

- Special aim for streams with large By>0 in IMF to search is to explain annual distribution of appearance frequency of large GA, when additional peaks for By>0 appear at 2-d half of year on classic semiannual variation of GA

- Special attention to SC 23, 24 for the current cycle to understand and predict

- Data base omni: B, V, N, T measured at 1 a.u. near ecliptic plane for 1964-2014

IMF versus spiral longitude angle for SCs 20-24

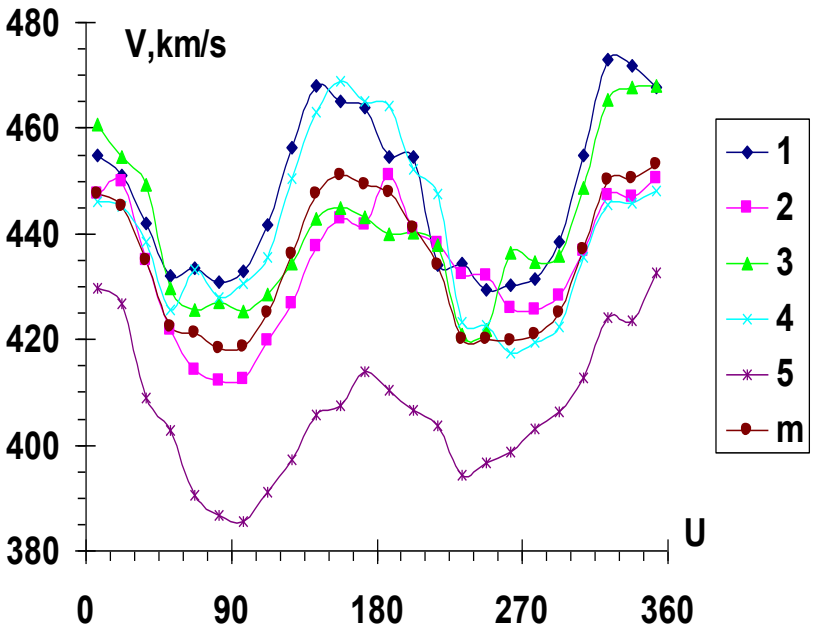


The IMF vector value vs longitude angle U= 0-360^0 (GSE) for solar cycles N20-24. Symbols in column mark B(U) for cycles: **1-N20**; **2-N21**; **3 –N22,**; **4 –** N23, **5–**N24; **m – mean B(U) for all data (1964-2013).**

N20-Wm=111. **N21-**W=164. **N22-**W=158.N23-W=121

- **By<0.** B correlates with amplitude Wm of sunspot SCs: Wm is larger, B is larger (21- the largest Wm, Bm)
- **By>0.** B for odd SCs 21,23 is larger than B for even 20,22 (U=90 30 d.)
- **B for SC N23** (as 21) is larger than B for mean curve for all data
- **B for SC N24** is less than B for the other SCs pointing to low Wm (Wm correlates with B for By<0)

Solar wind velocity versus longitude angle for SCs 20-24

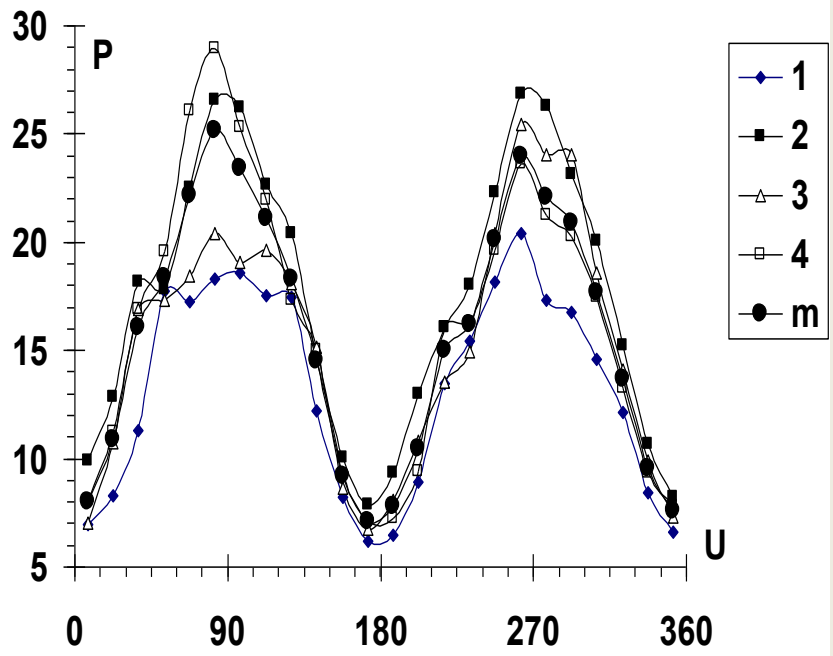


Solar wind velocity value V vs. longitude angle U= 0-360^0 (GSE) for solar cycles N20-24. Symbols in column mark V(U) for cycles: **1-N20**; **2-N21**; **3 –N22,**; **4 – N23**, **5–N24**; **m – mean curve (data 1964-2013).**

N20-Wm=111. **N21**-W=164. **N22**-W=158.**N23**-W=121

- **B>0**. V is in antiphase with Wmax of SCs: Wm is larger, V is smaller. Low SCs 20,23 have maxima of V.
- **By<0.** V is larger for even SC 20,22 than for odd 21,23. The lowest SC 20 has absolute maximum of V
- **SC 23** has the highest maximum of V for By>0 (together with N20)
- **SC 24** has the smallest average V among SCs, but V is increasing – HSS (profile is similar to N22)

Poyting vector module versus longitude angle during solar cycles N20-23



Poyting vector module vs. longitude angle U= 0-360^0 for solar cycles N20-23. Symbols in column mark P(U) for cycles: **1-N20**; **2-N21**; **3 –N22,**; **4** – N**23**, **5**– N**24**; **m – mean curve (data 1964-2013).**

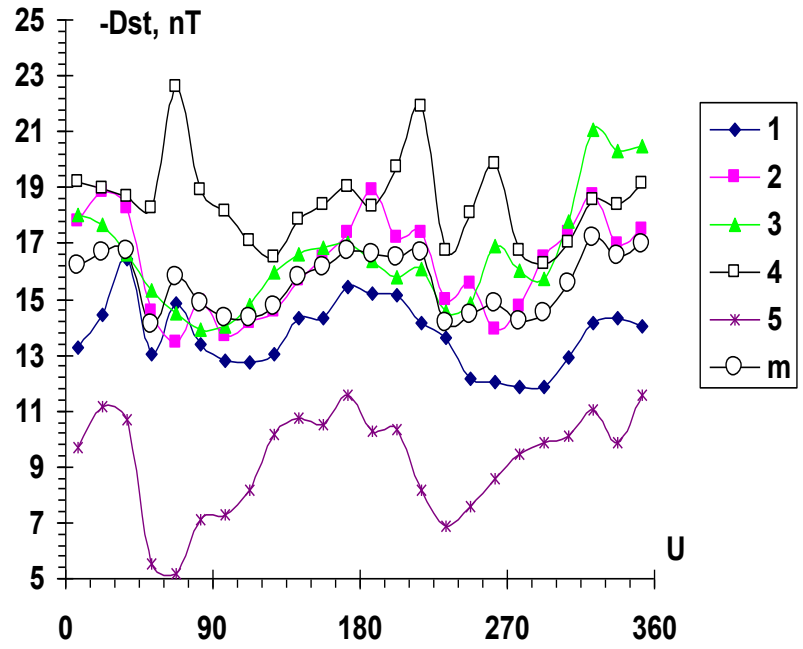
N20-Wm=111. **N21**-W=164. **N22**-W=158.N**23**-W=121

Poyting vector P= [ExB] is density of electromagnetic flux;

- Pmax for all SCs are at U~80, By>0 and U~260^0, By<0; Δ=180^0
- B>0. Pmax are well larger in odd SCs 23,21 than in even 20,22
- By<0. Pmax correlates with Wm of SCs.
- **P of 23 SC has absolute max. for By>0!** among SCs 20-23.

How storm activity (Dst) reacts to the absolute power of the low 23d SC?

Dst-index versus longitude angle for SCs 20-24

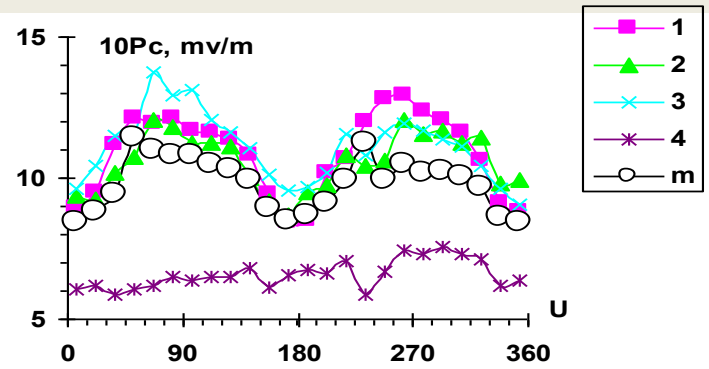


Dst –index vs. longitude angle U= 0-360^0 (GSE) for solar cycles 20-24. Symbols in column mark Dst(U) for cycles: **1-N20**; **2-N21**; **3 –N22,**; **4** – N**23 (white boxes)**, **5**–N**24**; **m – mean curve for 1964-2013 (white circles).**

N20-Wm=111. **N21**-W=164. **N22**-W=158.N23-W=121

- Dst(U) shows absolute maximum during SC N23 at the same U~80 (By>0)
- **Long-term Dst change for period of 20-23 SCs with max during SC 23.** Dst index increased with time (N of cycle)
- **Incomplete 24 cycle** shows decrease in the long-term Dst change for now, in accordance with the smallest B, V in solar wind for SC N24

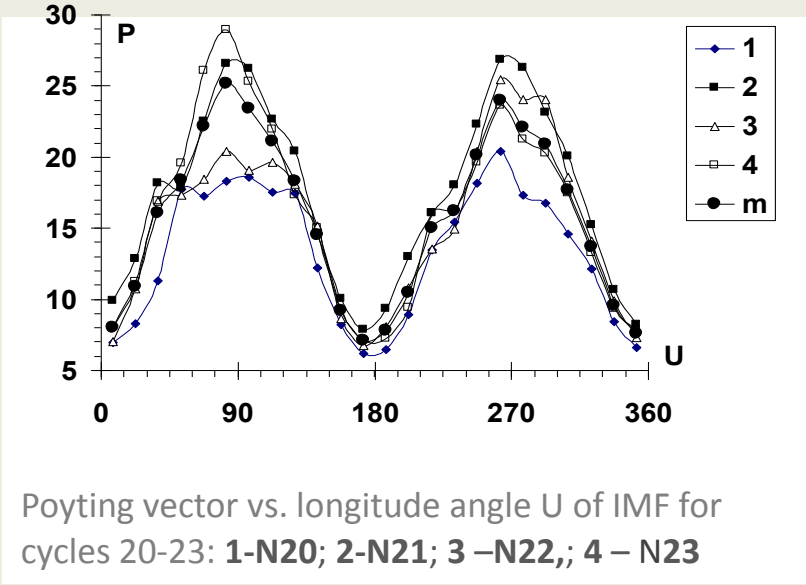
POLAR CAP INDEX ABOUT POWER OF 23d SOLAR CYCLE



PC-index (north cap) vs. longitude angle U of IMF of cycles:1-N21, 2-N22, 3-N23, 4-N24

P in solar wind has maxima for By>0, U~80^0, which are higher in odd cycles 23,21

PC-index for NH has maxima for By>0, U~80^0 which is higher in odd cycles 23,21

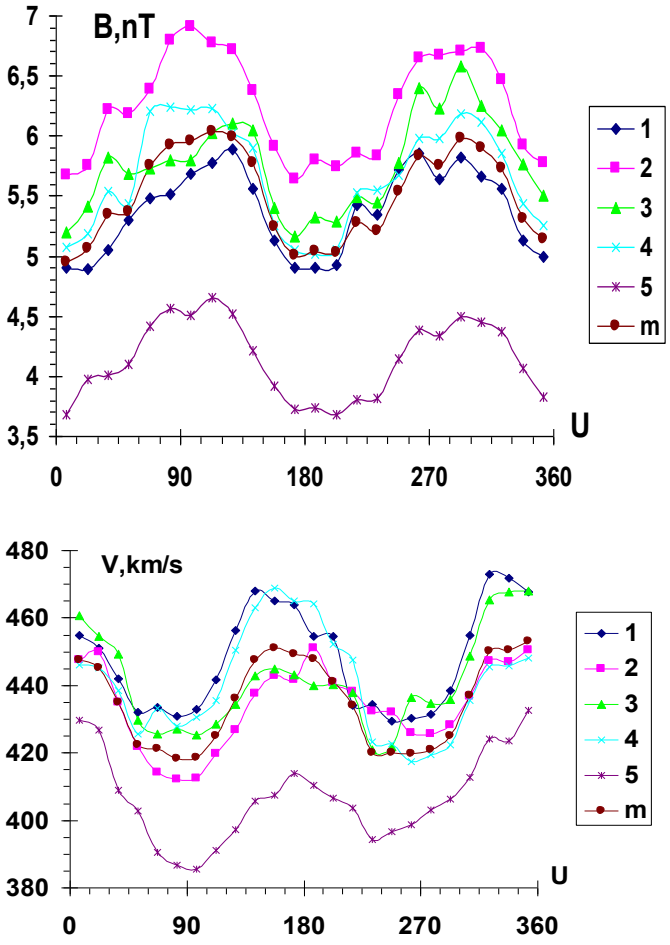


Poyting vector vs. longitude angle U of IMF for cycles 20-23: **1-N20**; **2-N21**; **3 –N22,**; **4** – N**23**

Both P in solar wind and GA in polar cap (PC-index) had absolute maxima during SC N23 at U~80^0, By>0

Long-term PC-index rise with absolute max at SC 23 for By>0 ; PC-index declines now

Relation between stream parameters B,V and amplitude Wm of SCs, phase of 22-year magnetic solar cycle as basis for prediction



Values of IMF B and solar wind velocity V versus longitude angle of spiral.

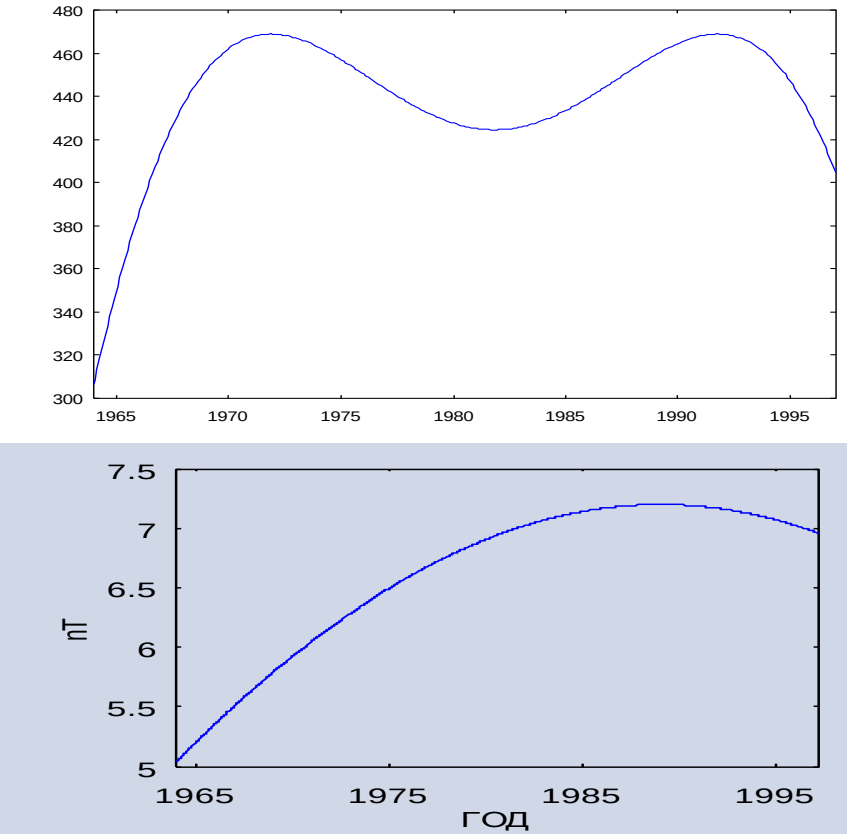
- Wm and B,V. Wm is larger, B is larger for By<0. Wm is larger, V is smaller. ΔU=180 deg.

- 22-yr cycle and B,V. B is smaller for even than for odd SCs for By>0. V is larger for even than for odd cycles By<0.

- **23 cycle** (explanation of high P, E): 1)max of B is larger for odd cycles, By>0 2)max of V anti-correlates with Wm, By>0. →Maximal E(B,V) for low odd cycles under By>0 (N23)

  Prediction for 24 SC: 1)max of V, By<0 are larger for even cycles; 2)max of B correlate with Wm, By<0 → Wm of SC 24 , less than Wm of N20 (V N24<V N20, but increasing; B N24<B N20 → low Wm)

Long-term changes of B,V and prediction of SC 24 evolution

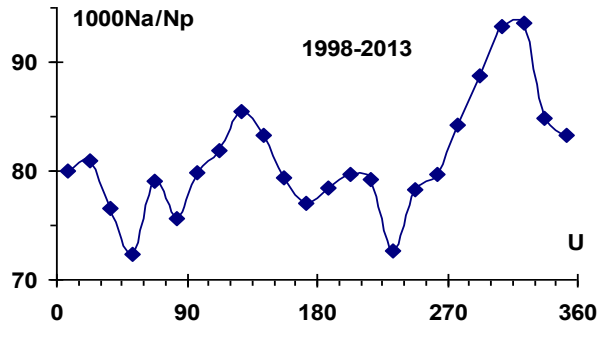


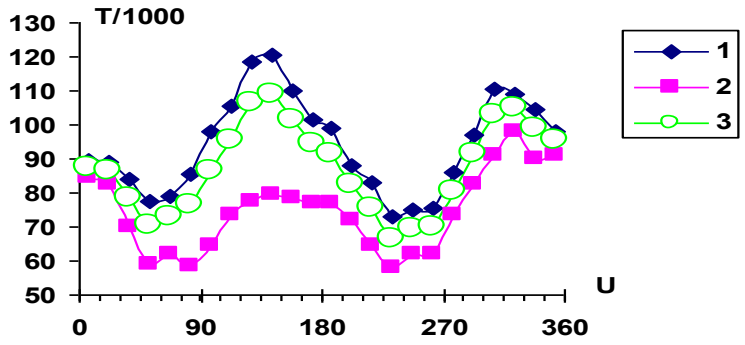
Time changes of non-stationary cycle in V at T=54 yr (upper fig.) and cycle in B at T=198 yr(lower fig.) (Kuznetsova and Tsirulnik, 2005)

PREDICTION SC N24

- ~1990 - maxima of cycles at T=54, T=200 yrs 1989 –Wm of N22, storm 13 March, 1989 (-589 нТл)
- ~2020 – future minimum of 54-yr cycle in V (long-term V decrease)
- ~1790 - previous maximum of 200 yr cycle , start of **Dalton's minimum (~1820 , ~2020)**

Results for SC N24 and prediction





Ration of the alfa particle density to the proton density for 23 cycle (1998 -2013) vs. U, upper panel

Temperature in SW vs. IMF longitude angle :1- N23 (1997-2007); 2-N24 (2008-2012.3); 3- for all data, lower panel

SUMMARY FOR SC N24:

- **B for cycle 24 is less than B for the others.** Curve B(U) is similar to N20 (low cycles)
- **V for cycle 24 is less than V for the others,** but V is increasing at U~330-360^0 (as in N22,20: high V for By<0, Bx>0). V(U) is similar to SC N20

- Now :T of N24 is higher for By<0 than By>0

PREDICTION:

- Long-term decrease of Dst, PC and B, V lead to minimum of SC 24 near t~2020 yr **similar to Dalton's minimum in ~ 1820 yr**

Conclusions

We detected solar wind streams with large e/m flux density P for By>0 near mean angle U~80 deg. P is well larger for odd 23,21 than for even 20,22 SCs. The largest e/m flux power was observed during SC 23 caused by slow stream of cold dense plasma

Both Dst and PC indexes showed their absolute maxima during SC 23 for By>0 at the same U~80. We showed that low Wm=121 of SC N23 does not determine power of e/m flux in streams and consequently GA. Odd solar cycles with low Wm have the largest E and P in similar solar wind streams near U~80 deg, By>0 and consequently high GA.

We detected long-term Dst, PC index change with max. at SC 23 (for SC 20-24)

Based on relation between solar cycle Wm and solar wind parameters B,V for different signs of IMF By component we conclude that SC 24 will be well lower than SC 20. A minimum similar to Dalton's minimum is possible near ~2020

THANK YOU FOR YOUR ATTENTION!

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