

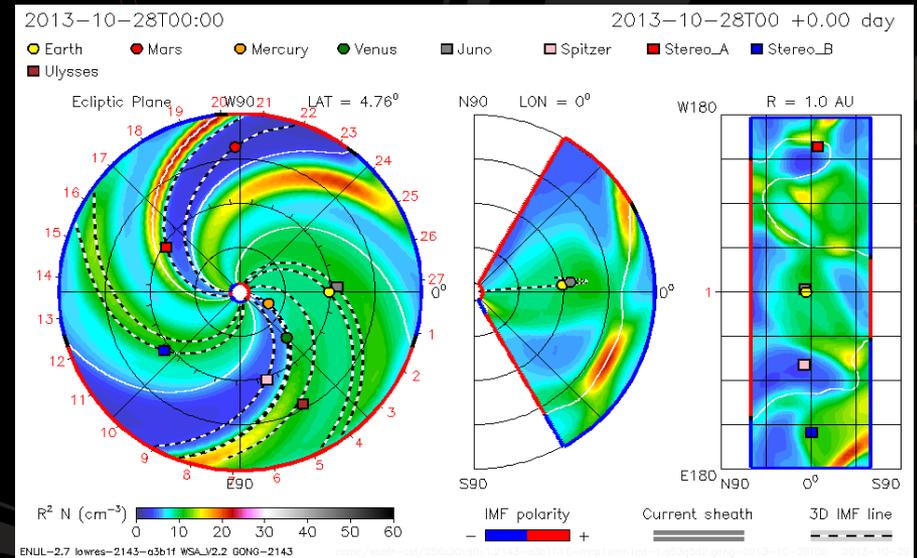
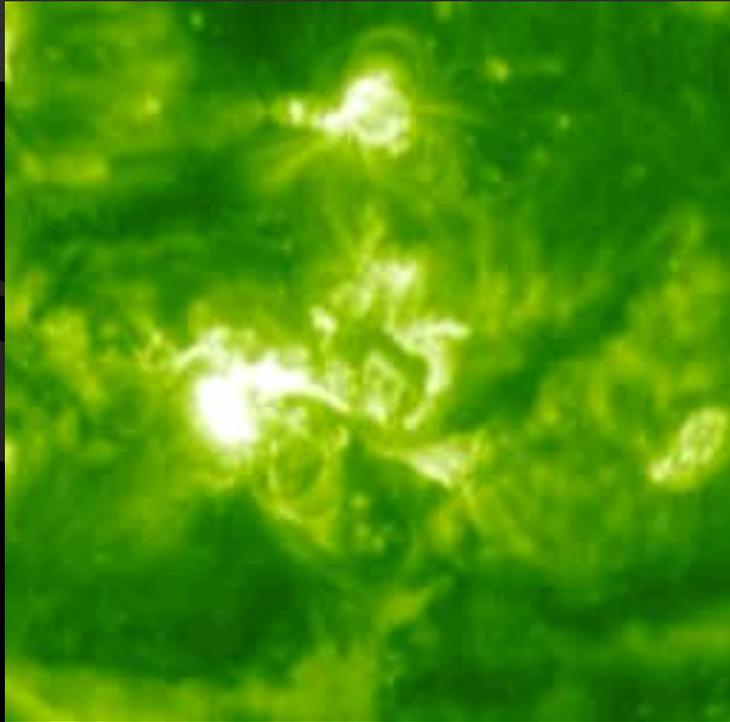
United Nations Workshop on the International Space Weather Initiative:
The Way Forward

**AN EMPIRICAL MODEL FOR ESTIMATING
ICMEs SPEEDS, DELAYS AND
EXPECTED GEOMAGNETIC ACTIVITY**

***Shlyk N., Belov A.,
Abunina M., and Abunin A.***

Pushkov Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave
Propagation, Russian Academy of Sciences





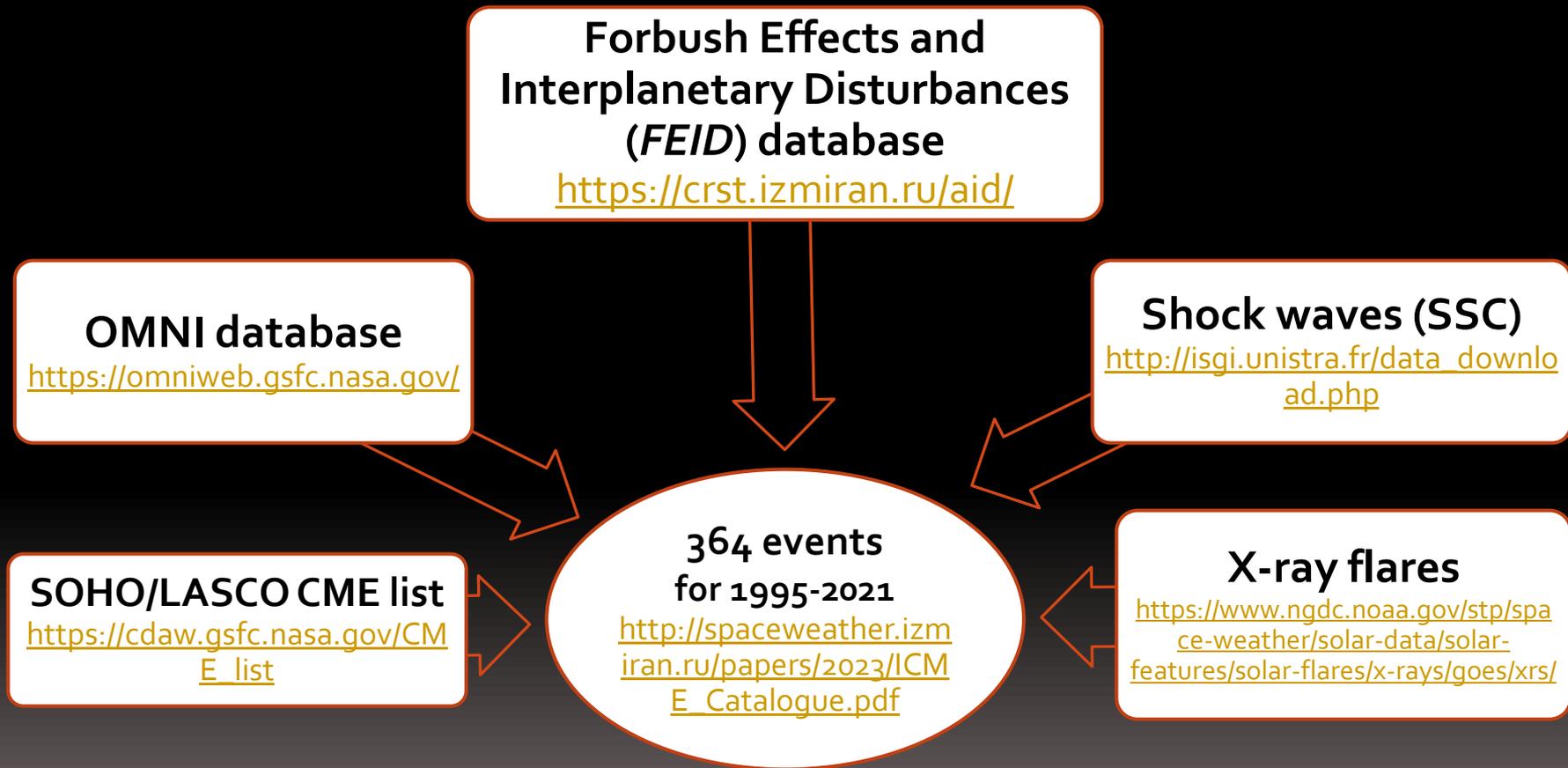
<https://soho.nascom.nasa.gov/gallery/Movies/flares.html>

<https://iswa.gsfc.nasa.gov/IswaSystemWebApp/>

Coronal mass ejections (CMEs)

short-term large-scale energetic mass and magnetic flux ejections from the solar lower corona into interplanetary space

The aim – development of an improved* model for estimating the velocities and transit times of interplanetary CMEs, as well as the expected level of geomagnetic activity



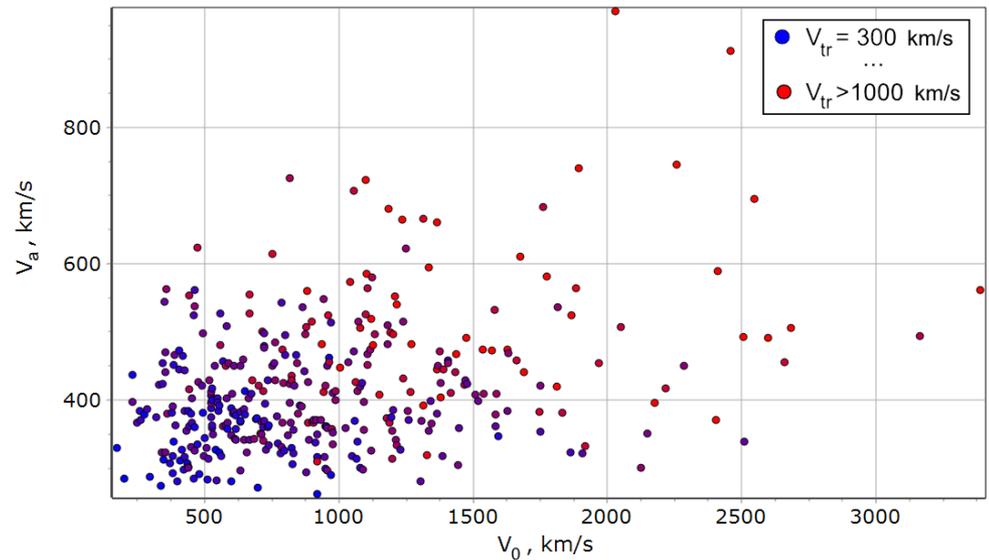
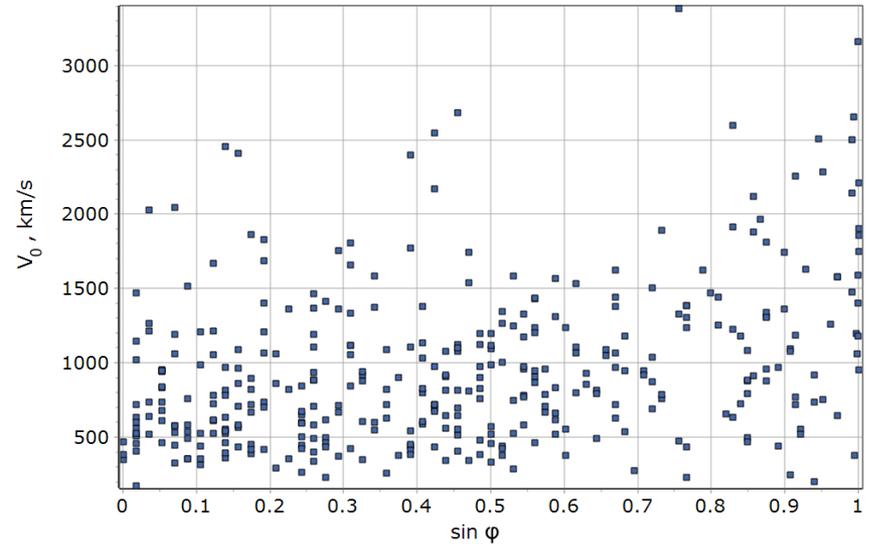
*1st version: *Belov et al., Universe, 8 (6), 327. 2022*

Model input parameters

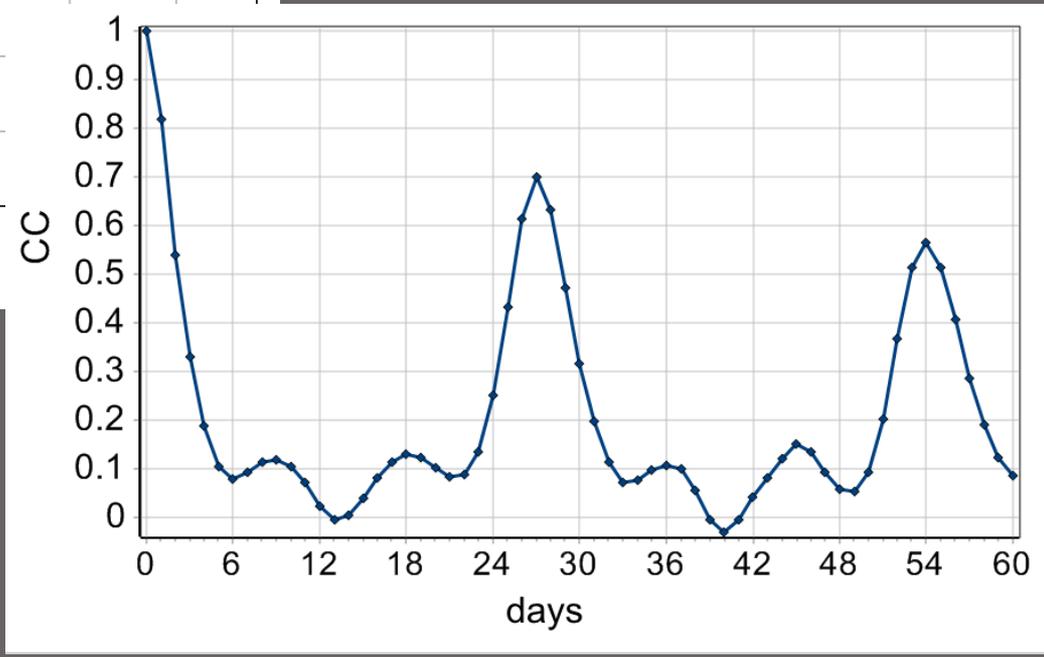
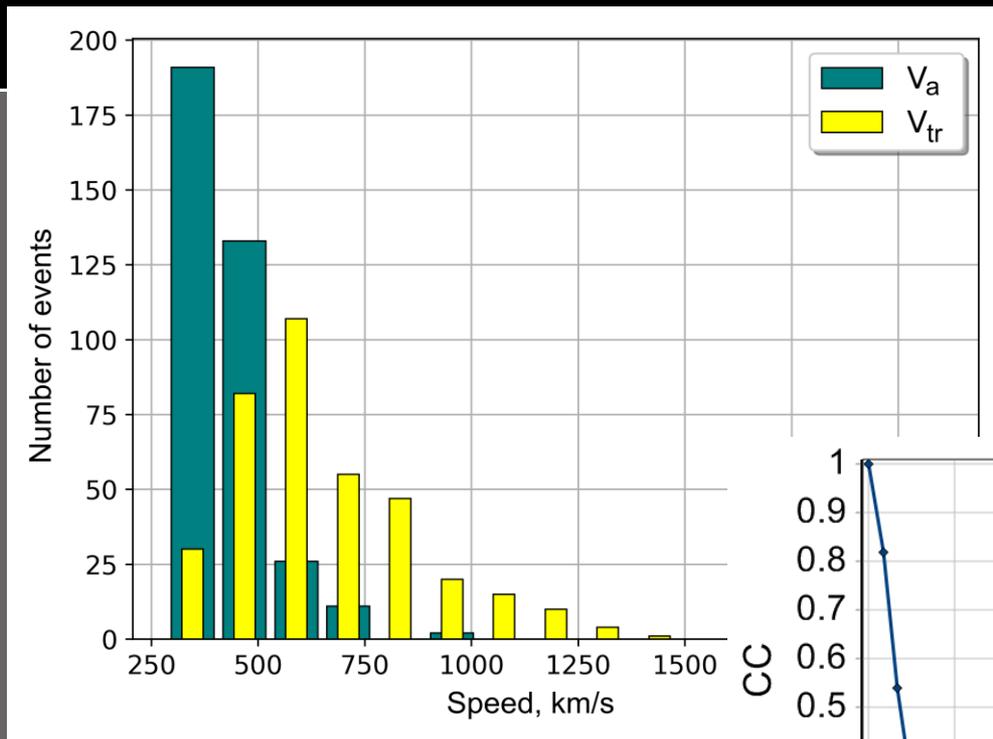
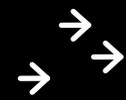
V_0 – initial CME linear speed at SOHO/LASCO coronagraph

$\sin \varphi$ – sine of associated solar flare absolute heliolongitude

V_a – ambient solar wind (SW) speed at 1 hour before the registration of an ICME near Earth



Ambient SW speed

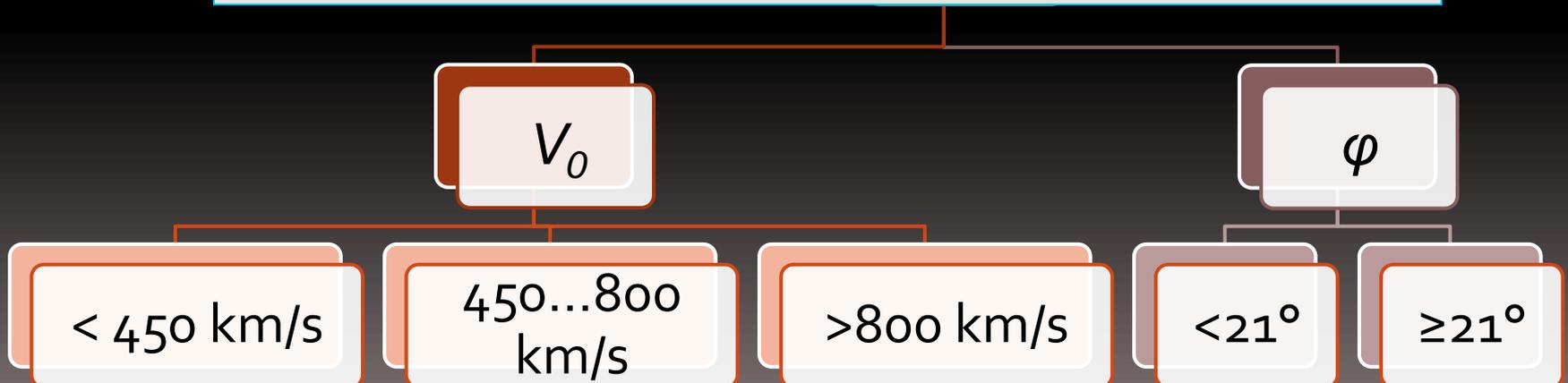


Calculation of transit values

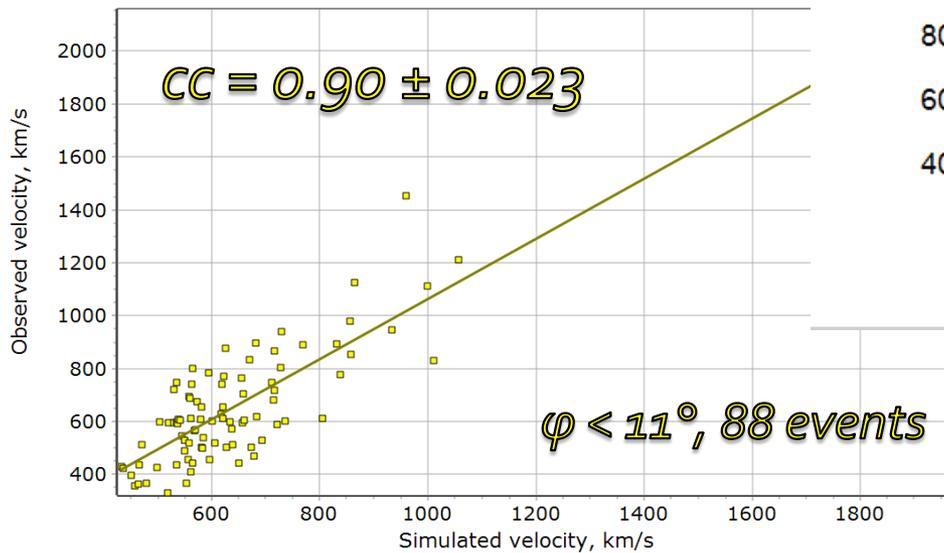
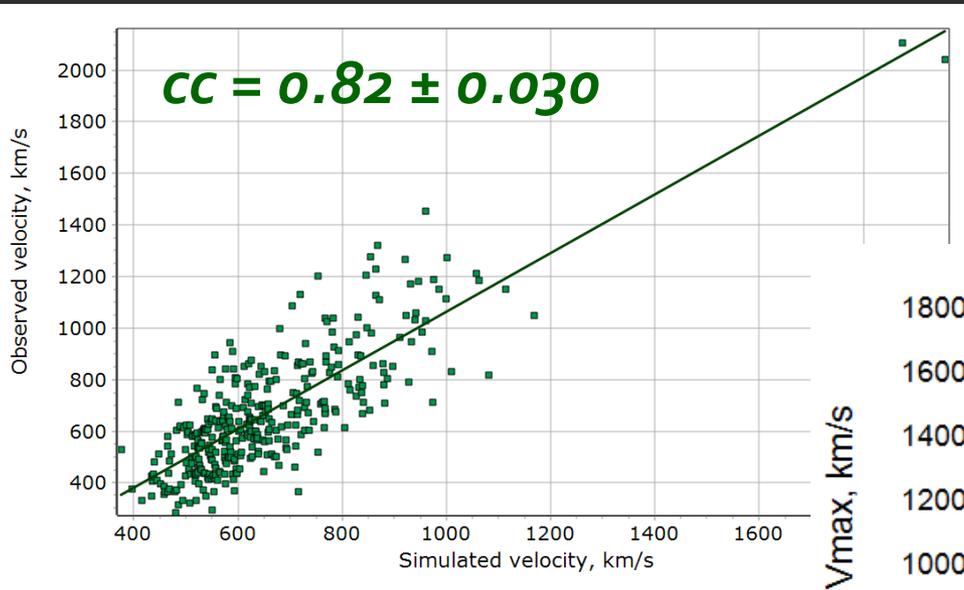
$$V_{tr} = \frac{\sum_{i=1}^N V_i w_i}{\sum_{i=1}^N w_i}$$

$$T_{tr} = \frac{1AU}{V_{tr}}$$

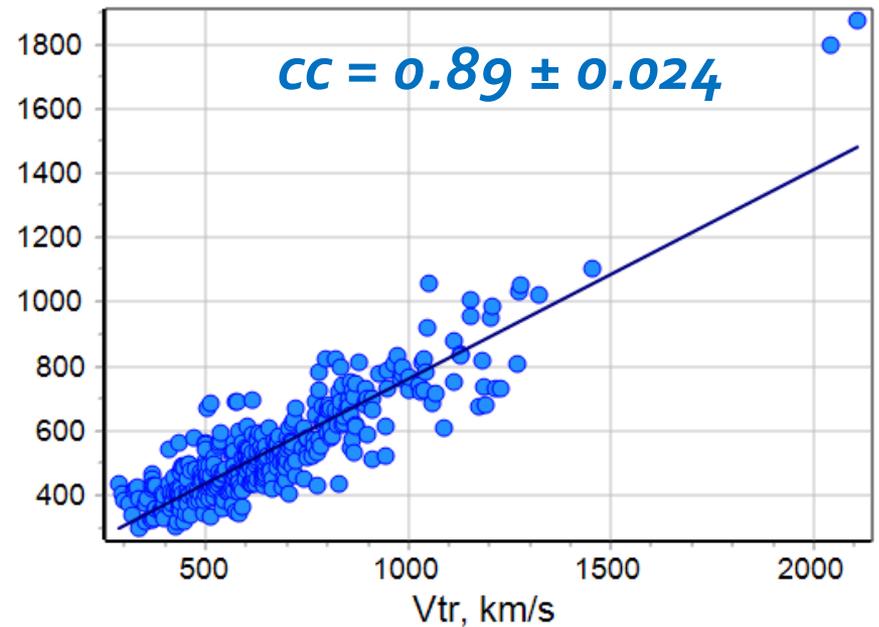
$$\begin{cases} w_i = \frac{s_0^2}{s_v^2 + s_p^2 + s_a^2 + s_0^2}, s_v \leq 0.4; |s_p| \leq 0.4; s_a \leq 0.2; s_0 = 0.06 \\ w_i = \left(\frac{s_0^2}{s_v^2 + s_p^2 + s_a^2 + s_0^2} \right)^2, \text{ for other values of } s_v, s_p, s_a \end{cases}$$



Relation of simulated and observed ICME velocities



Relation of transit and maximum ICME velocities



*2nd version: *Shlyk et al.,
Geomagnetism and Aeronomy,
V. 63, N.5. 2023 (in print)*

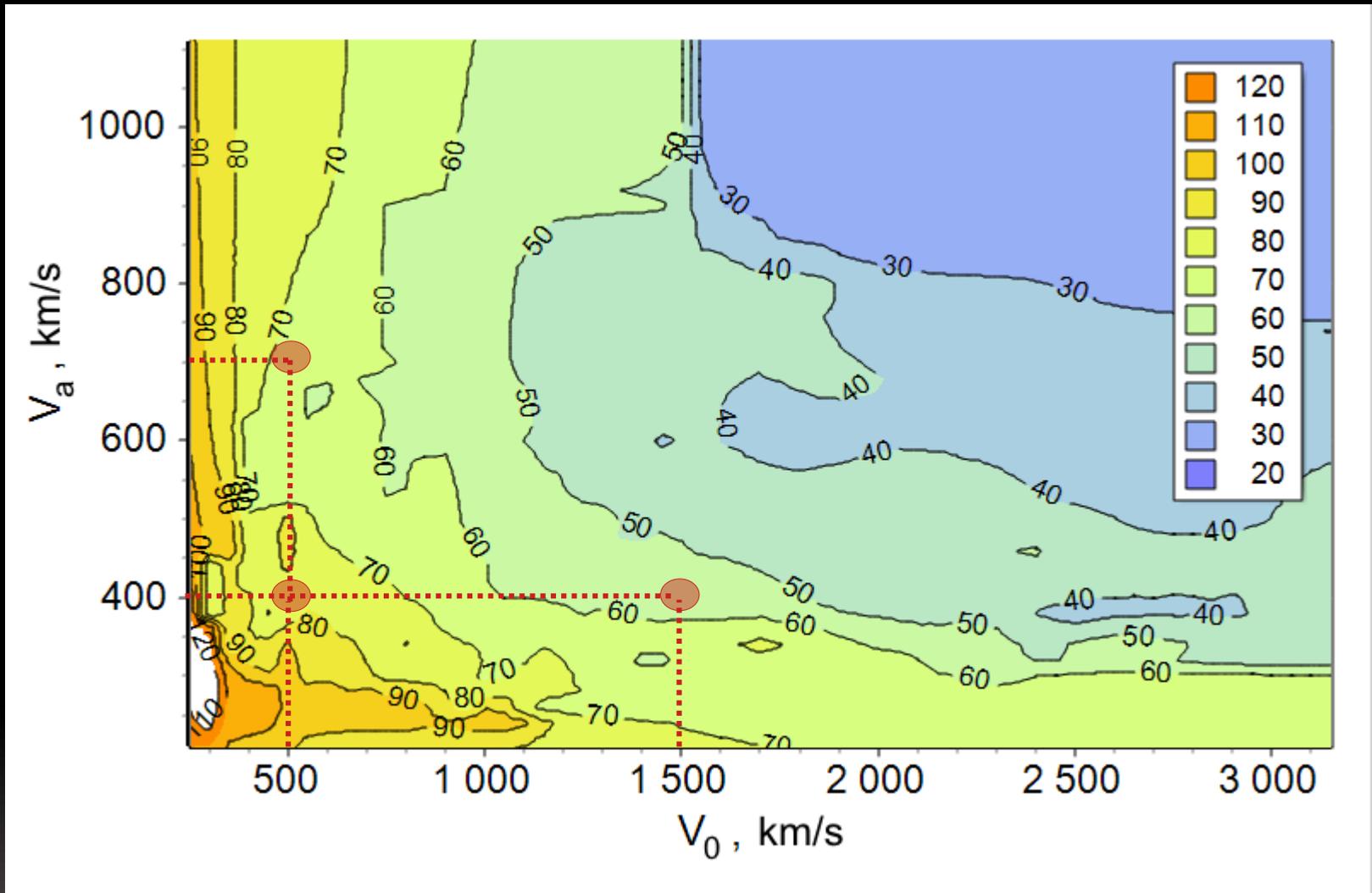
Model usage

The screenshot shows a software window titled "Vmean forecasting" with a light blue left panel for input and a light green right panel for output. The input panel contains three text boxes: "CME velocity" with the value 700, "ambient velocity" with the value 399, and "heliolongitude" with the value 11. A "CALCULATE" button is located below these inputs. The output panel displays three sections of results: "Transit velocity, km/s" with a central value of 592.5 ± 80.6 and two side values of 754 and 431; "Delay, hours" with a central value of 70.1 ± 9.5 and two side values of 89 and 51; and "Maximum velocity, km/s" with a central value of 500.1 ± 53.9 and two side values of 608 and 392. A "95%" confidence level is also indicated in red text.

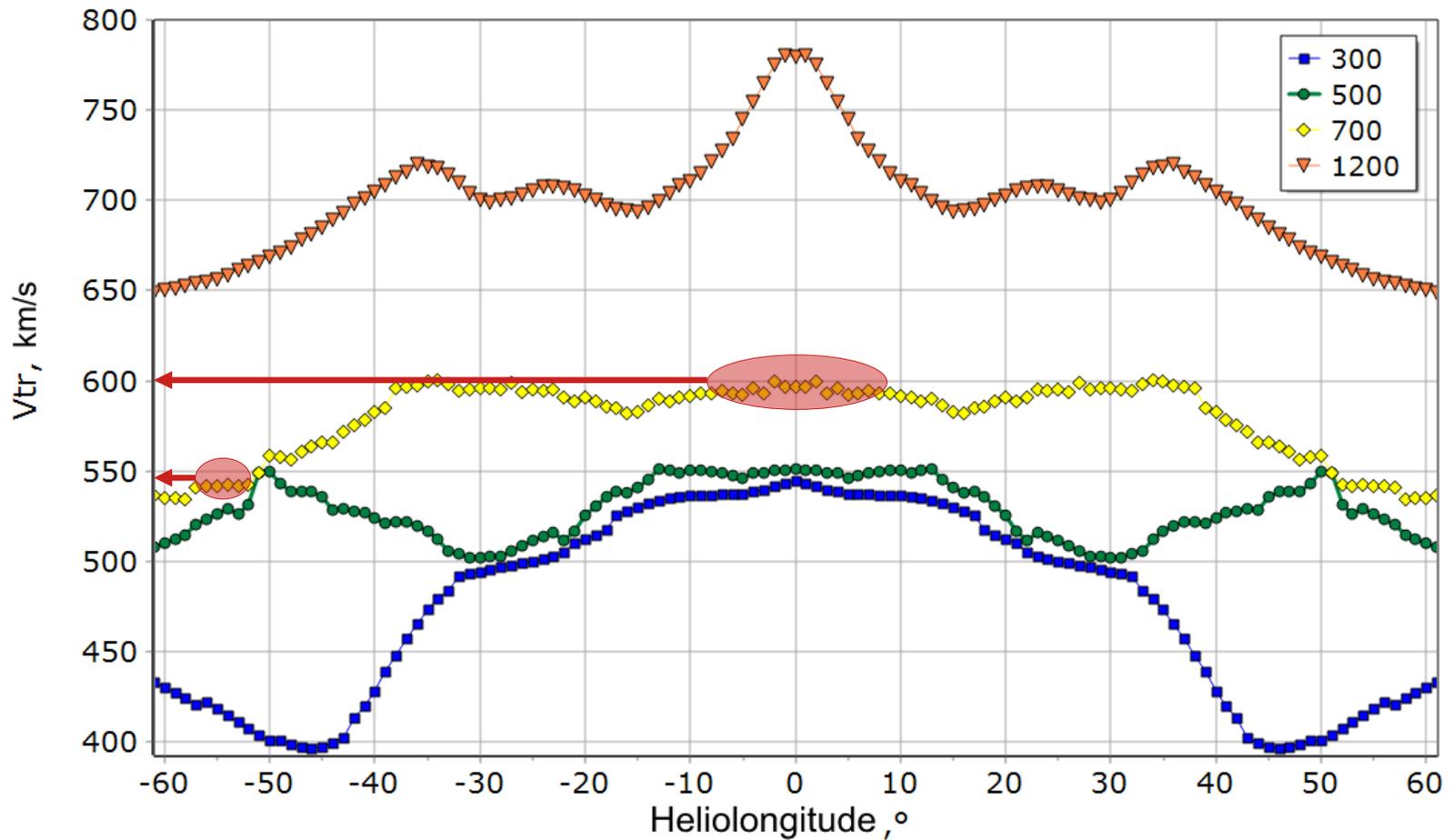
Parameter	Value
CME velocity	700 km/s
ambient velocity	399 km/s
heliolongitude	11 °
Transit velocity (center)	592.5 ± 80.6 km/s
Transit velocity (left)	754 km/s
Transit velocity (right)	431 km/s
Delay (center)	70.1 ± 9.5 hours
Delay (left)	89 hours
Delay (right)	51 hours
Maximum velocity (center)	500.1 ± 53.9 km/s
Maximum velocity (left)	608 km/s
Maximum velocity (right)	392 km/s

IZMIRAN Space Weather Prediction Center

<http://spaceweather.izmiran.eng>

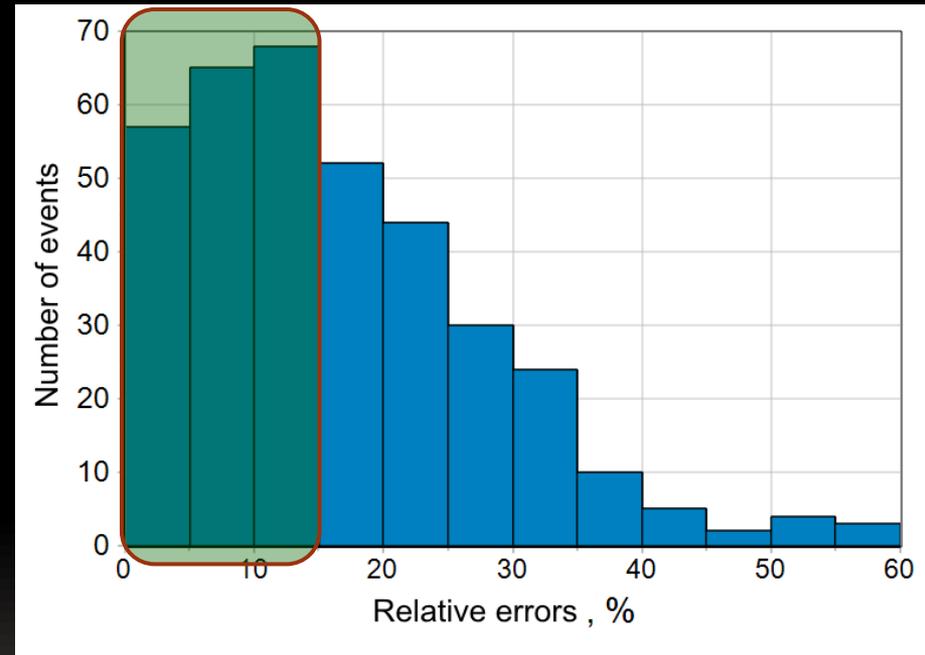
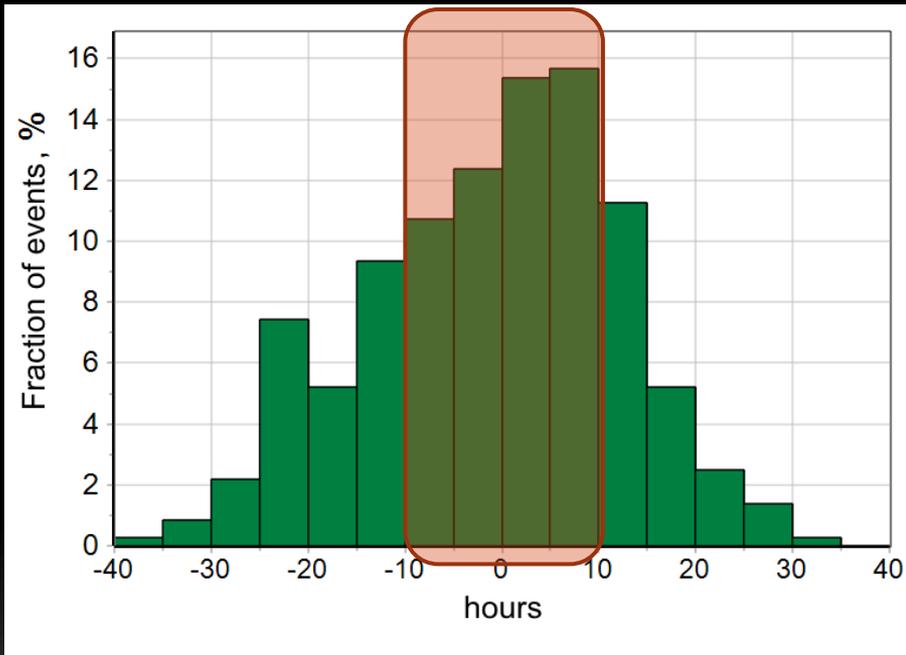


Dependence of ICMEs time delays on the initial CME speed and ambient SW speed



Dependence of ICMEs transit speeds on the initial CME speed and heliolongitude (at ambient SW speed = 400 km/s)

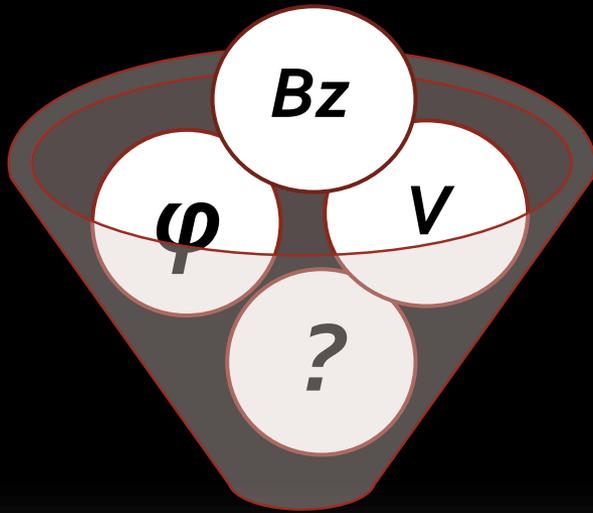
Errors of the model for the ICMEs transit times



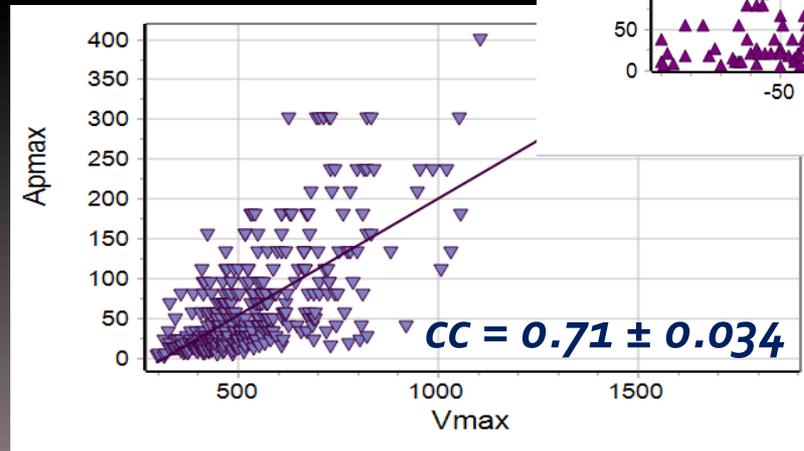
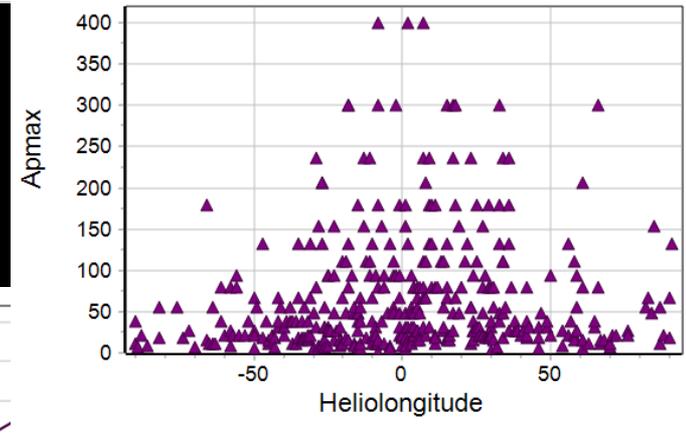
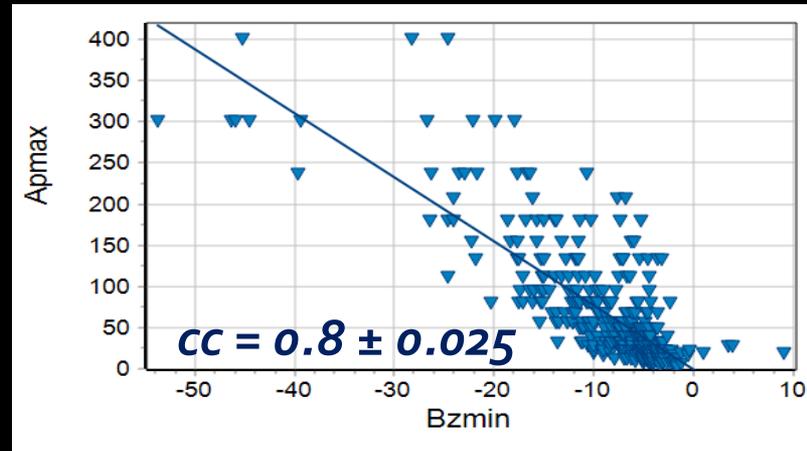
- $\approx 50\%$ of events with mean errors < 10 hours

- 190 events with relative errors $< 15\%$

Expected geomagnetic activity

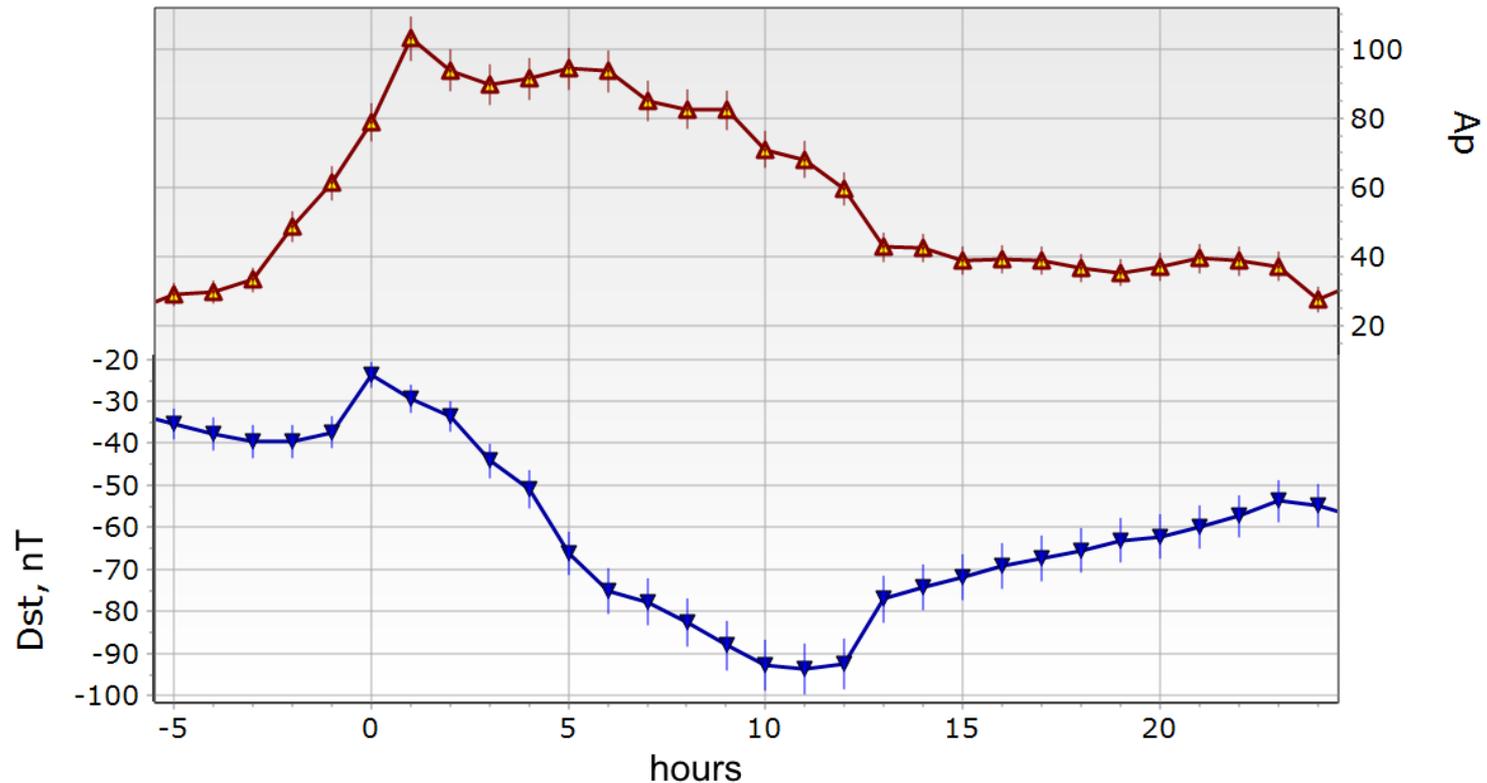


Ap (Kp), Dst
indices

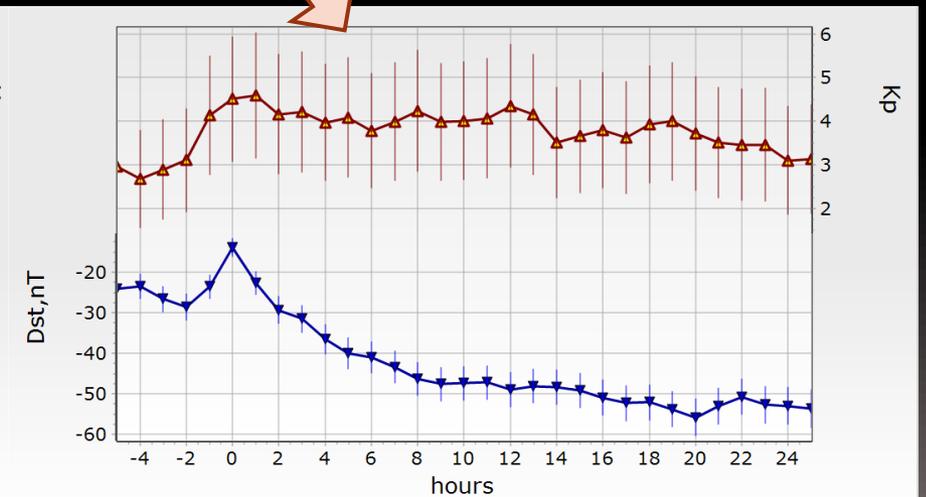
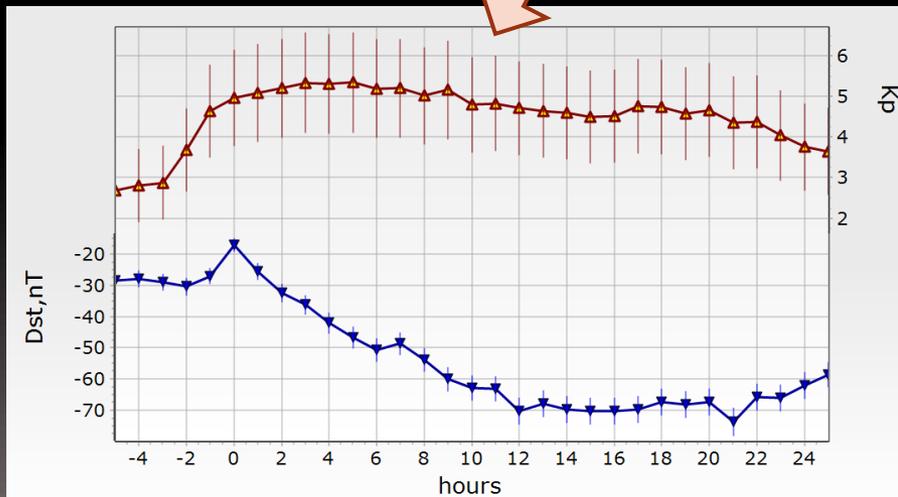
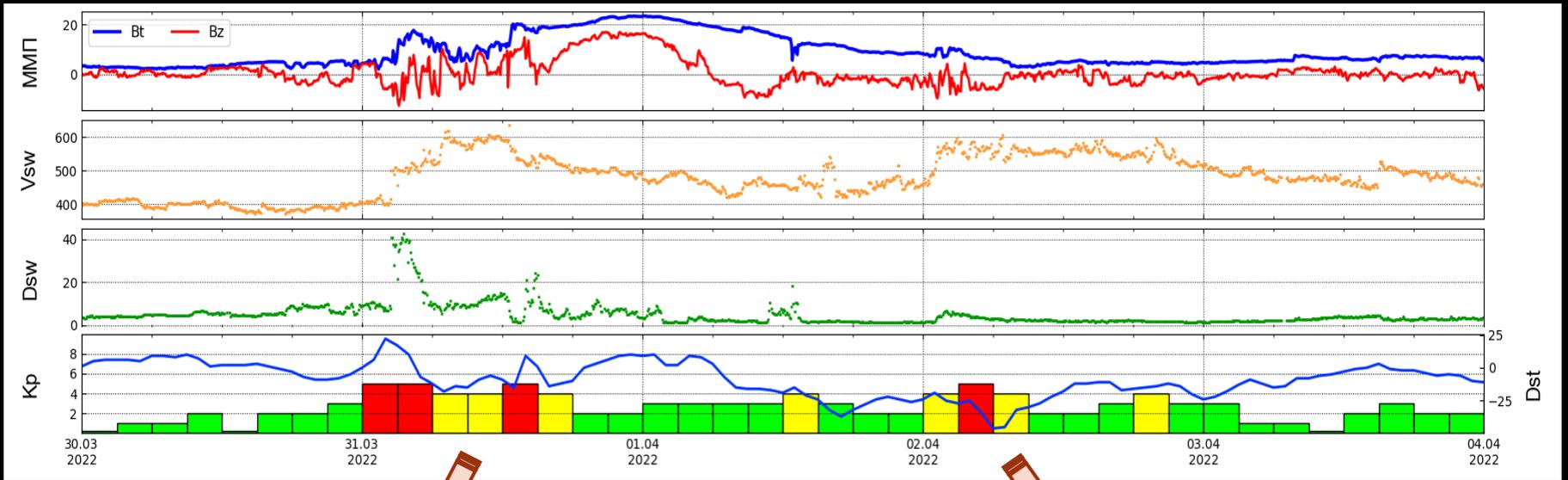


Expected geomagnetic activity: the epoch superposition method

$$V_o = 1200 \text{ km/s} \quad V_a = 500 \text{ km/s} \quad \phi = 12^\circ$$



Examples for 2022



364 CMEs for 1995-2021

- associated with solar flares, registered at the SOHO/LASCO coronagraph, which caused interplanetary disturbances near Earth

ICMEs transit speed and time depending on the initial CME velocity, heliolongitude of the associated solar flare, and ambient SW velocity

- for central longitudes initial CME velocities are often underestimated

An empirical model for estimating the transit speed/time and the maximum speed of ICMEs near Earth

- the model mean absolute error for the ICMEs delay is 11.5 h, the relative mean error is 16.5 %

Estimates of the expected level and duration of geomagnetic disturbances using the epoch superposition method

- forecast of hourly values of Kp (Ap)- and Dst-indices

Main conclusions



Thanks for your attention!

nshlyk@izmiran.ru