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

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

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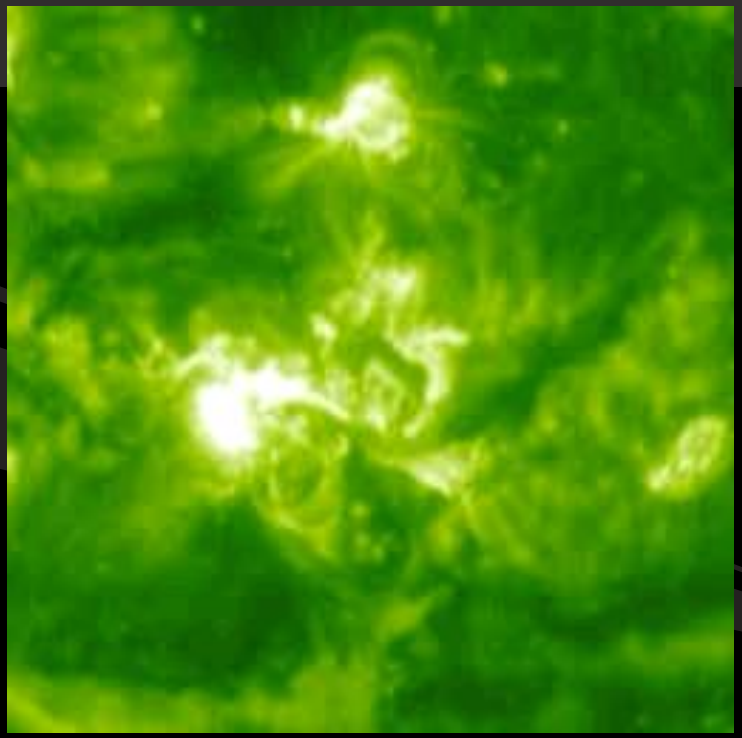
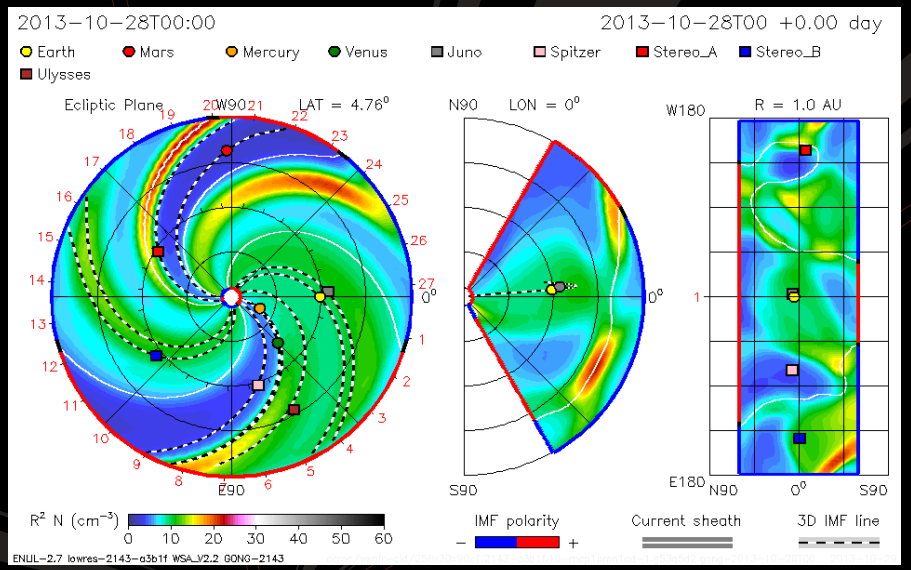




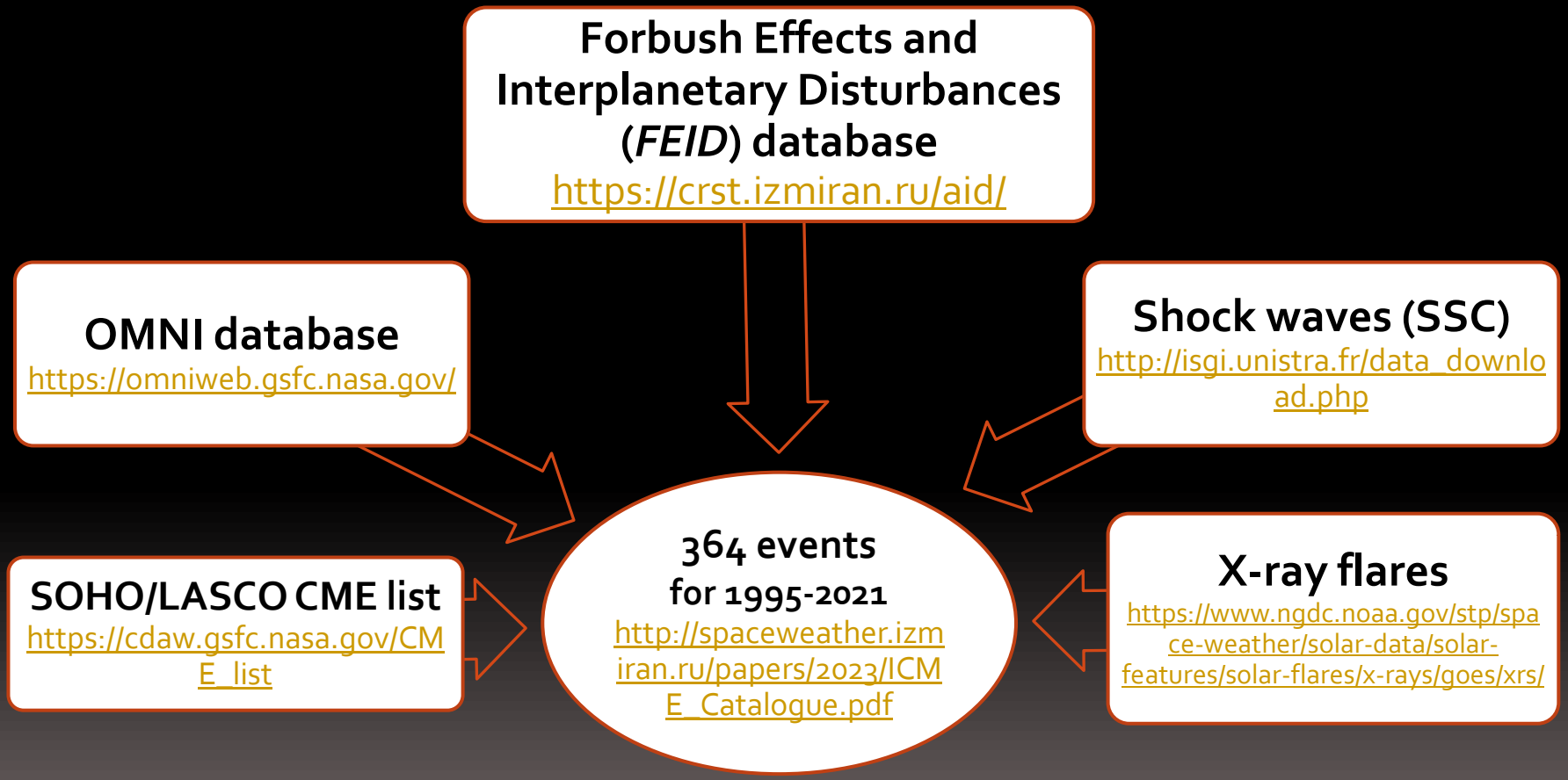

https://soho.nascom.nasa.gov/gallery/Movies/flares.html

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



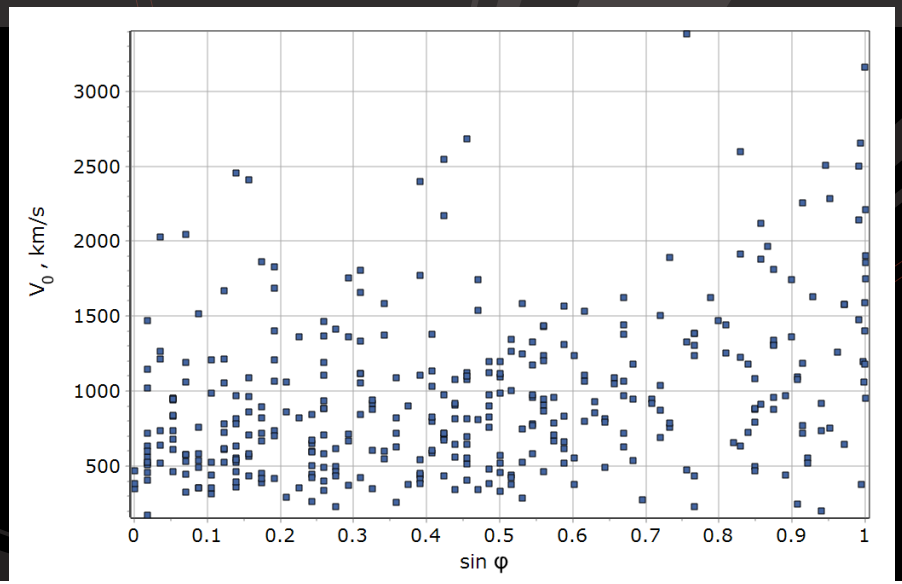

*1st version: *Belov et al., Universe, 8 (6), 327. 2022*

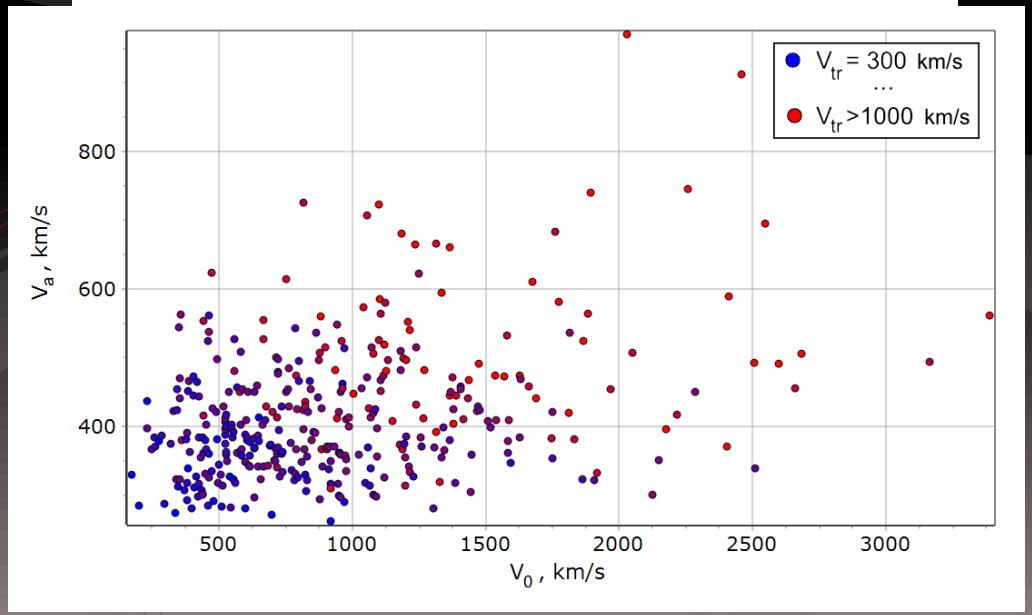
# Model input parametres

***$V_o$*** – initial CME linear speed at SOHO/LASCO coronagraph

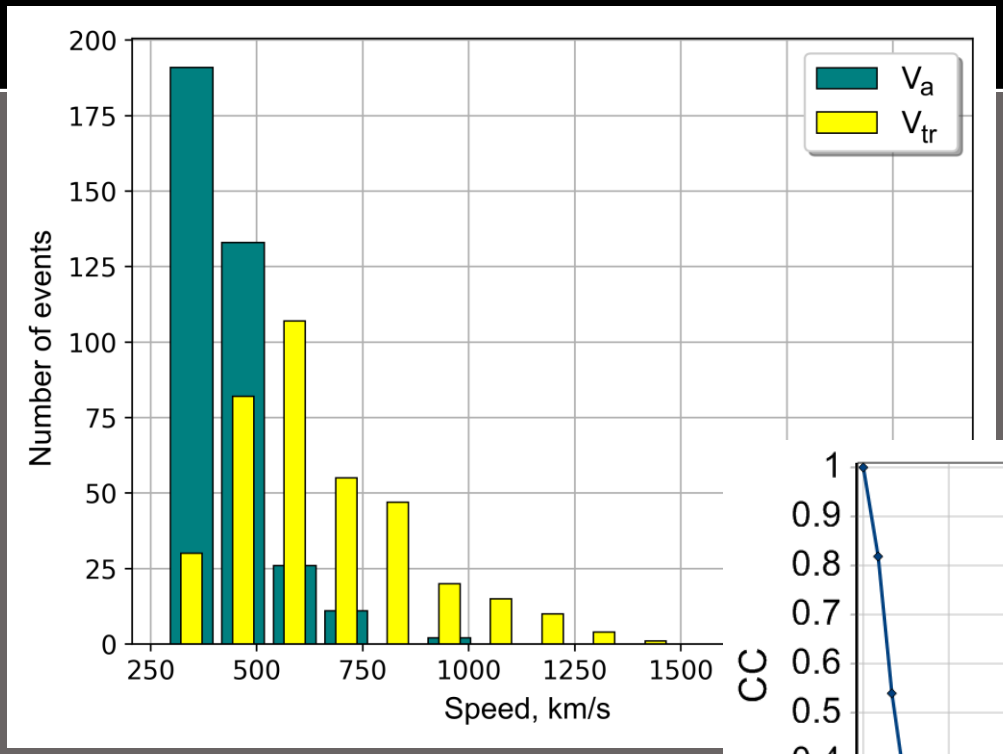
***sin φ*** – sine of associated solar flare absolute heliolongitude

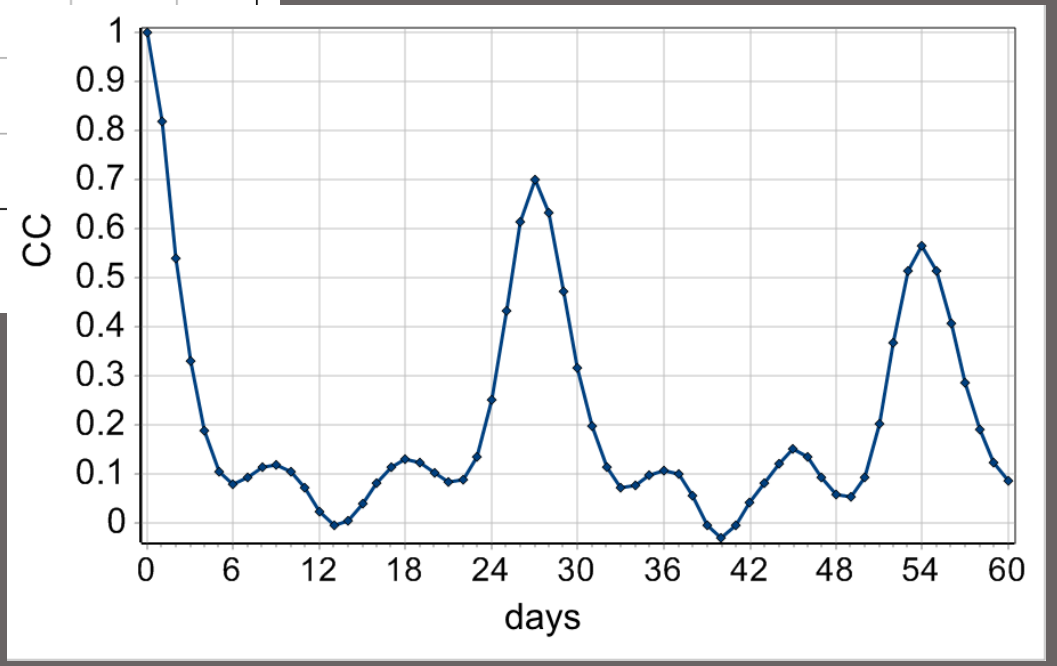
***$V_a$*** – ambient solar wind (SW) speed at 1 hour before the registration of an ICME near Earth



# Ambient SW speed



# Calculation of transit values

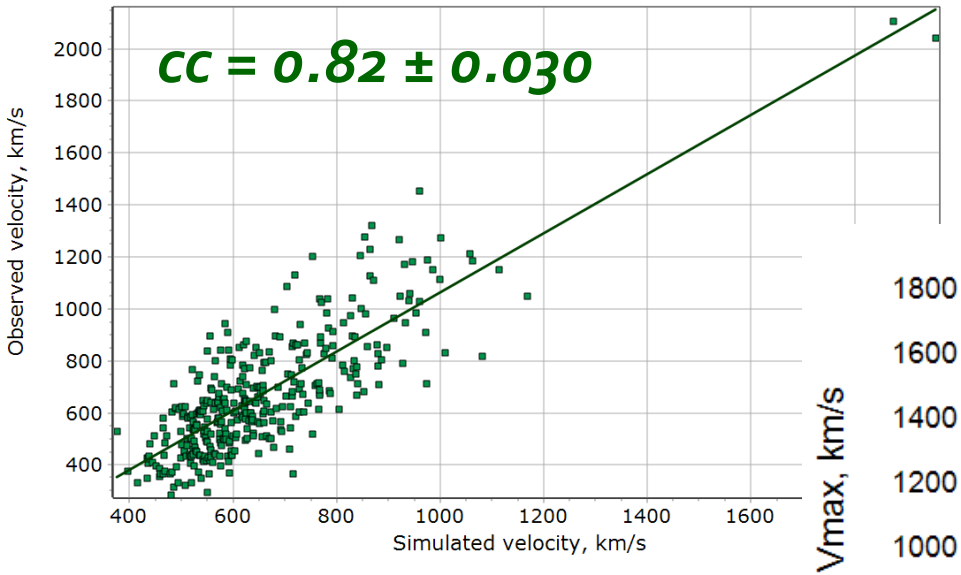
$$V_{tr} = \frac{\sum_{i=1}^{N} V_i w_i}{\sum_{i=1}^{N} w_i}$$

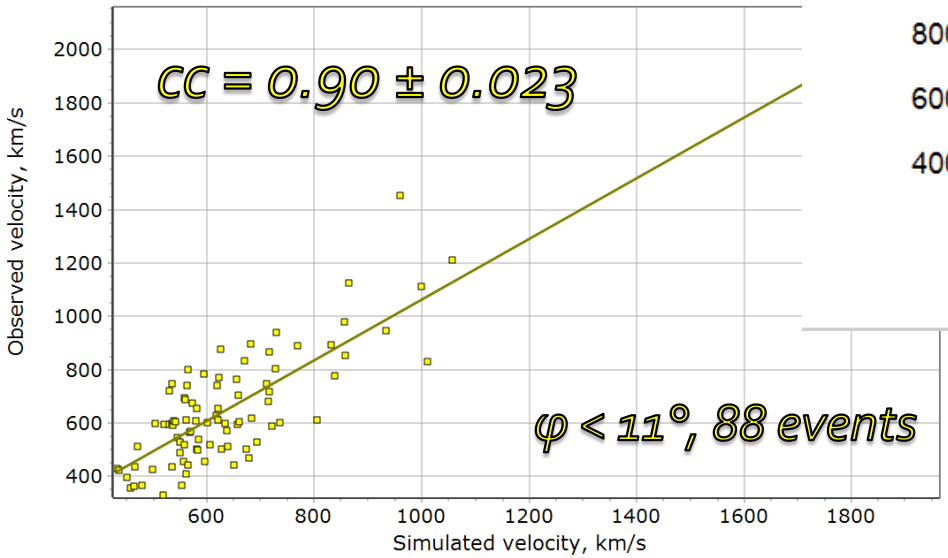
$$T_{tr} = \frac{1AU}{V_{tr}}$$

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

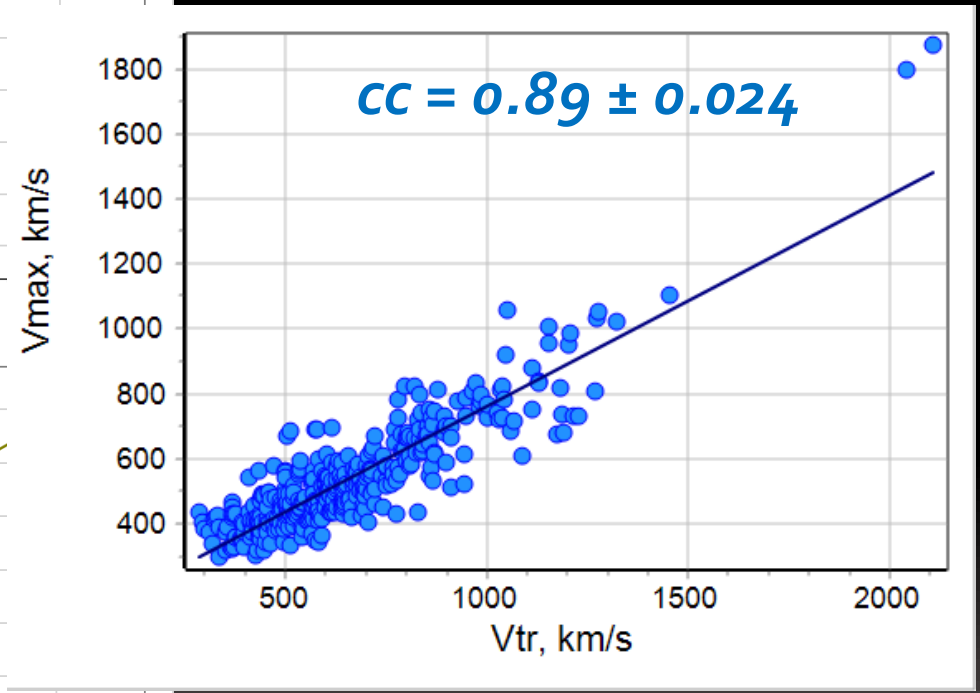
- $V_0$
  - < 450 km/s
  - 450…800 km/s
  - >800 km/s
- $\varphi$
  - <21°
  - ≥21°

## Relation of simulated and observed ICME velocities



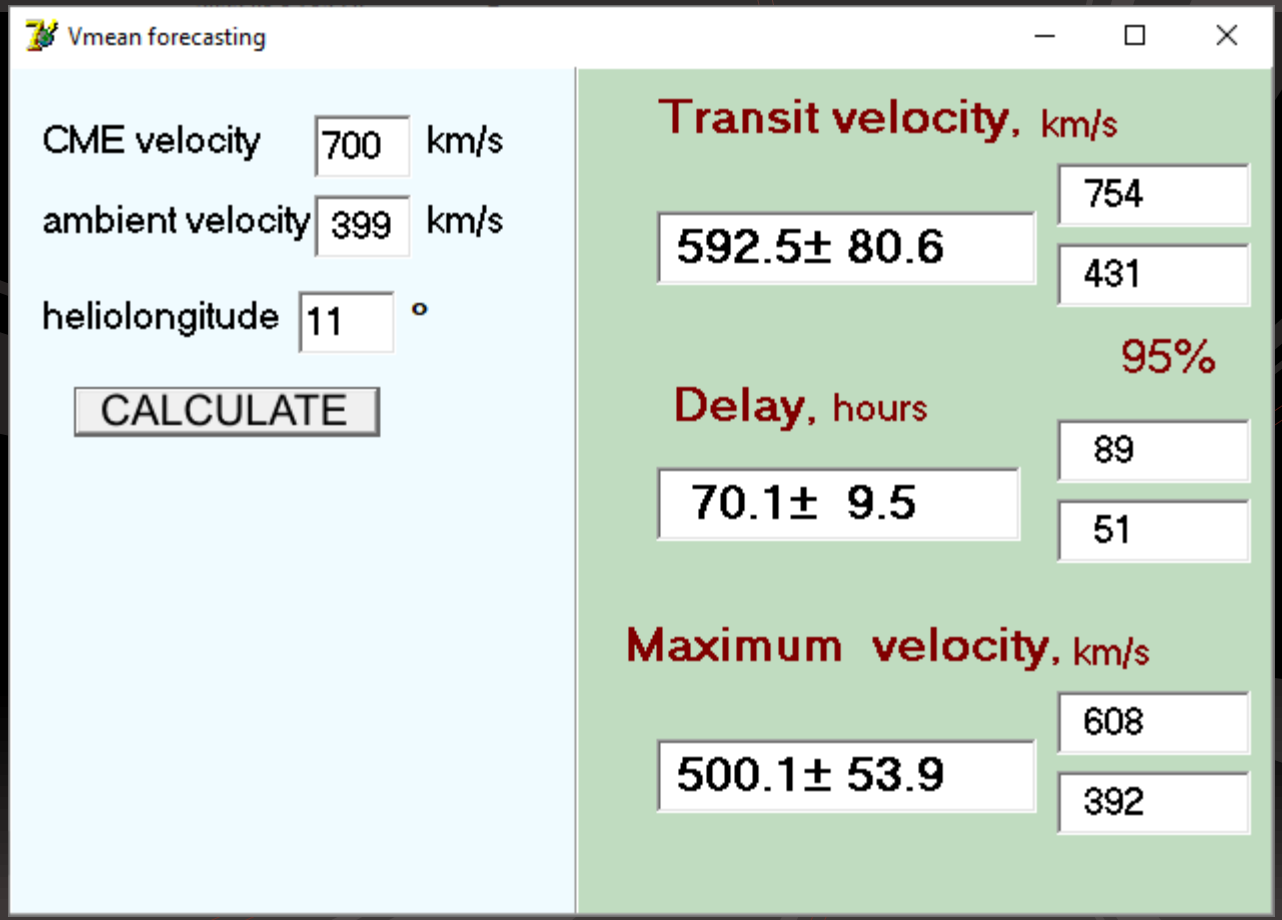




## Relation of transit and maximum ICME velocities




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

# Model usage

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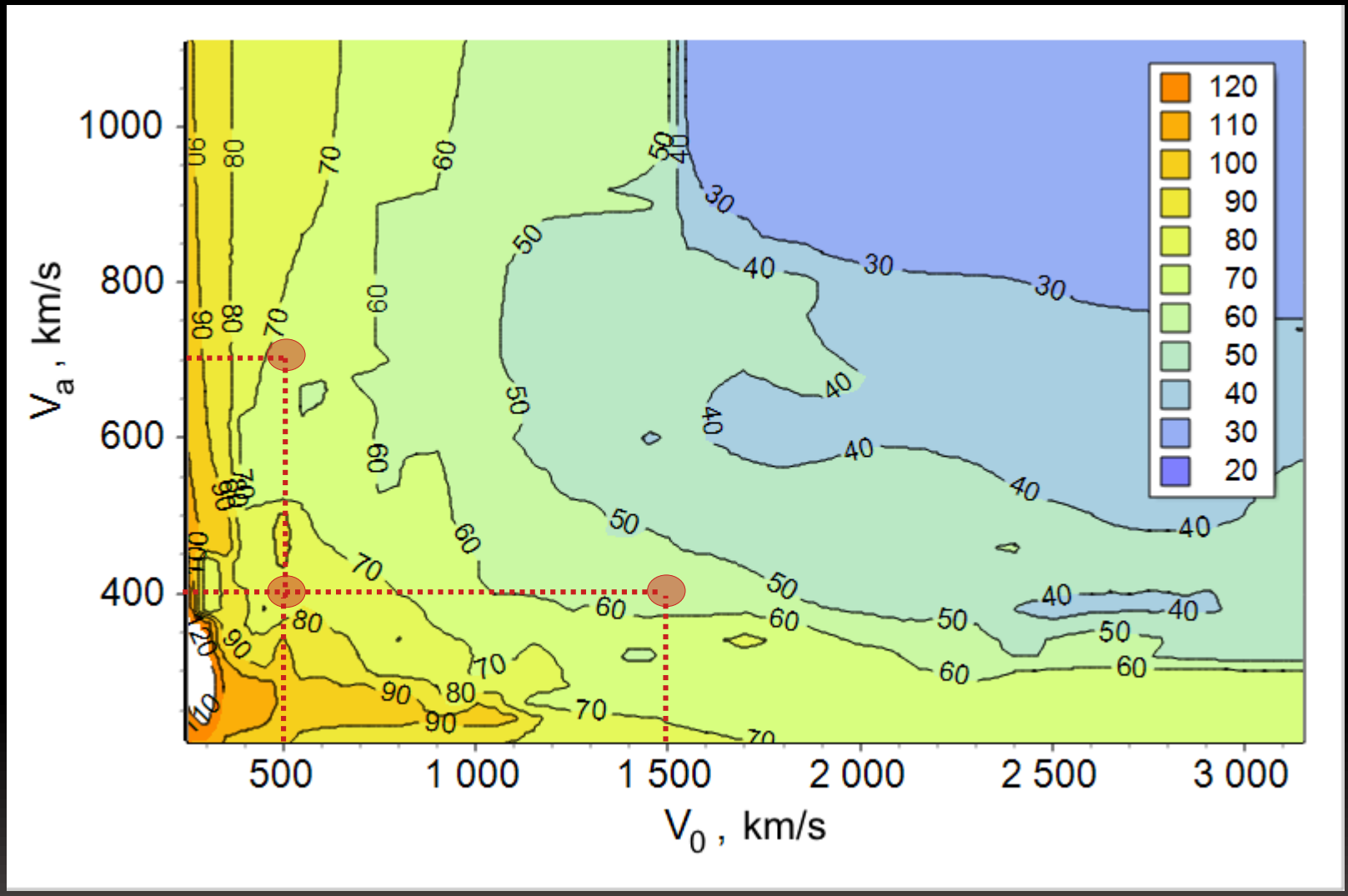
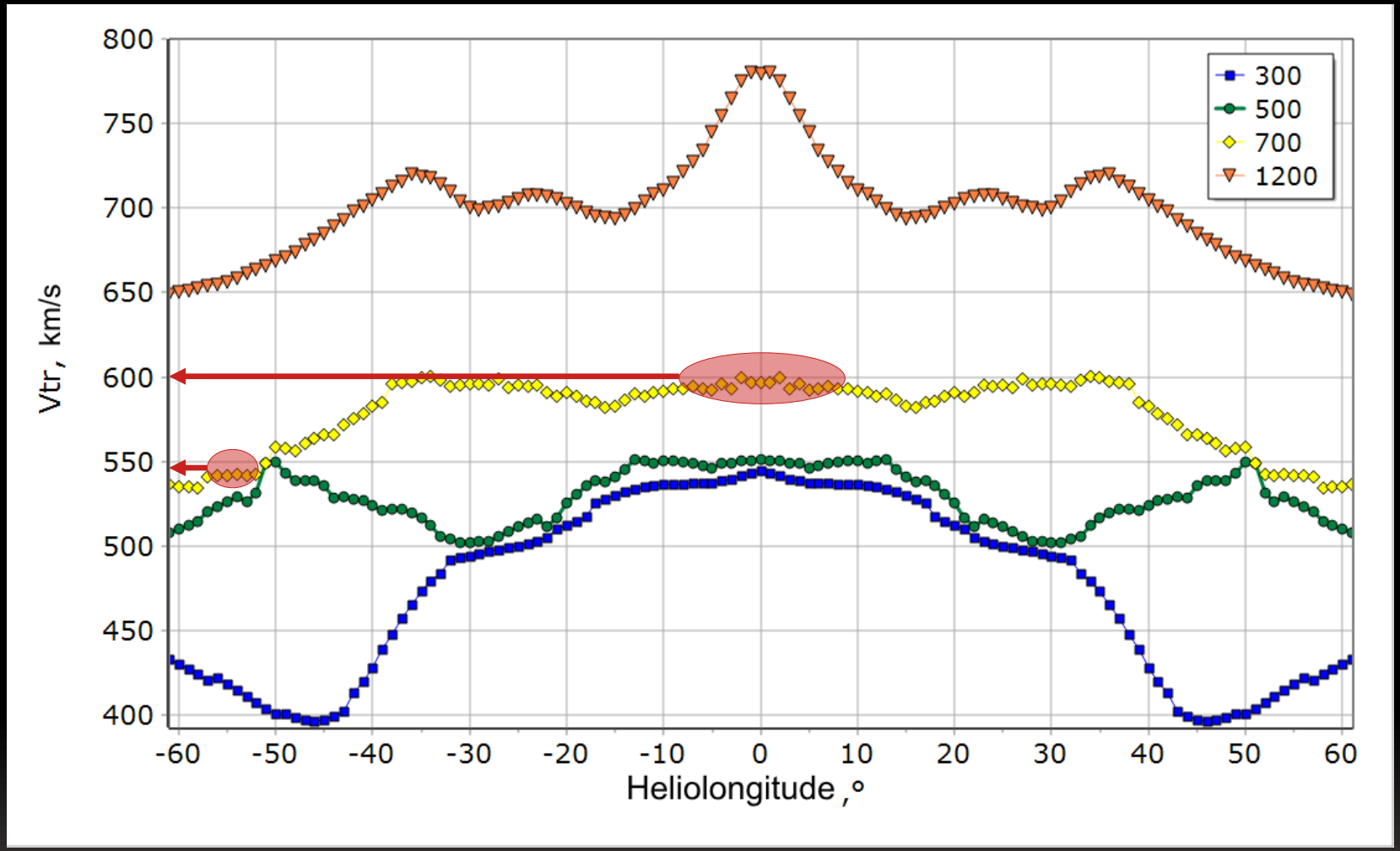
http://spaceweather.izmiran.eng

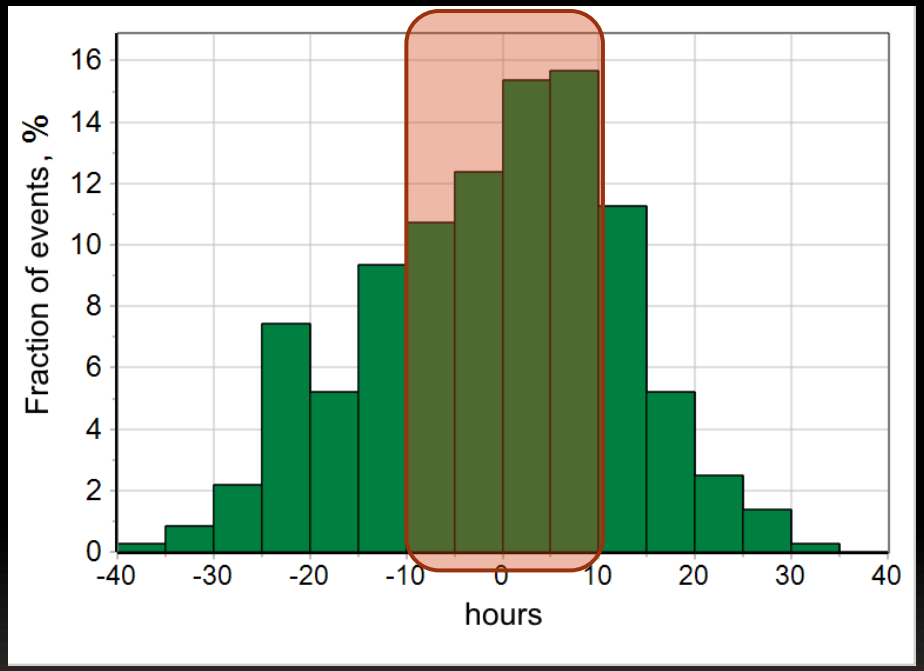


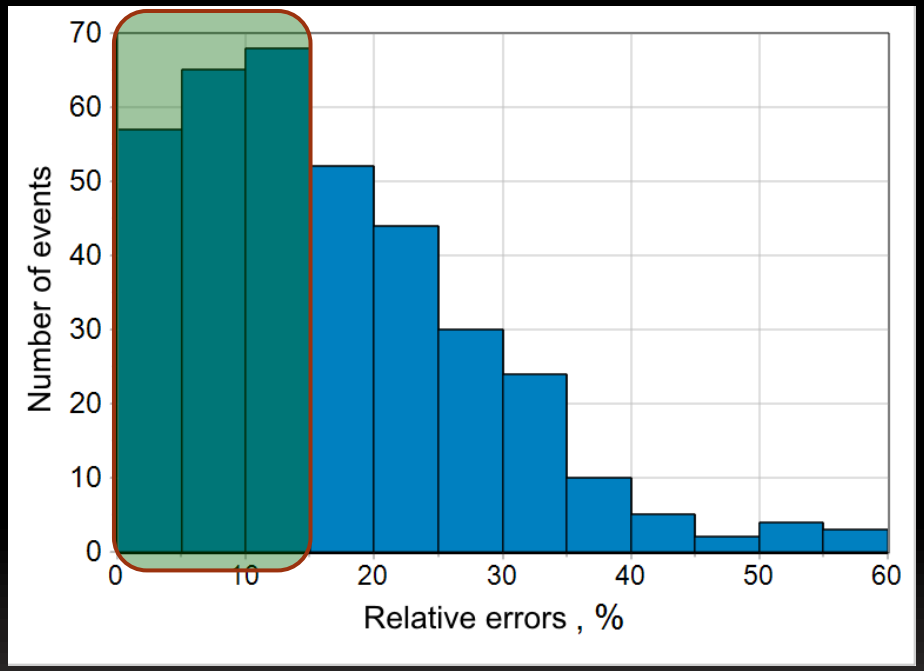

# Dependence of ICMEs time delays on the initial CME speed and ambient SW speed




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

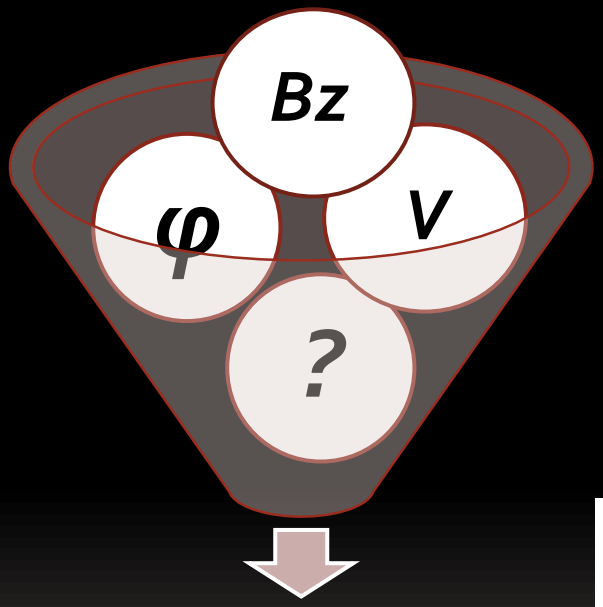
# Errors of the model for the ICMEs transit times



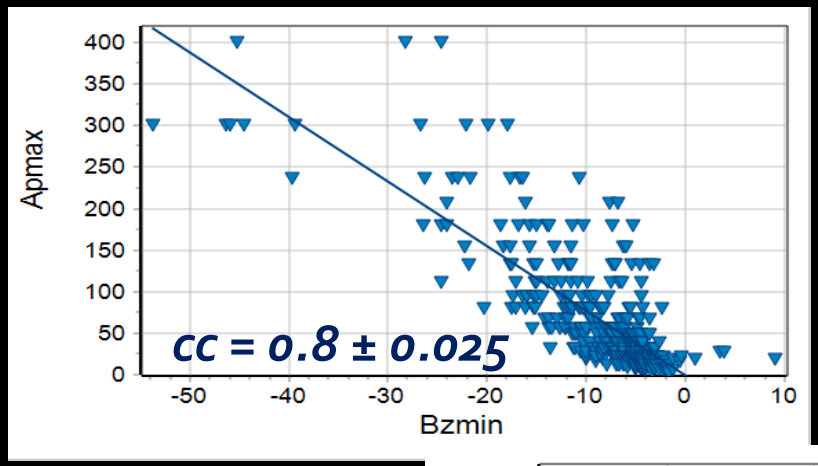



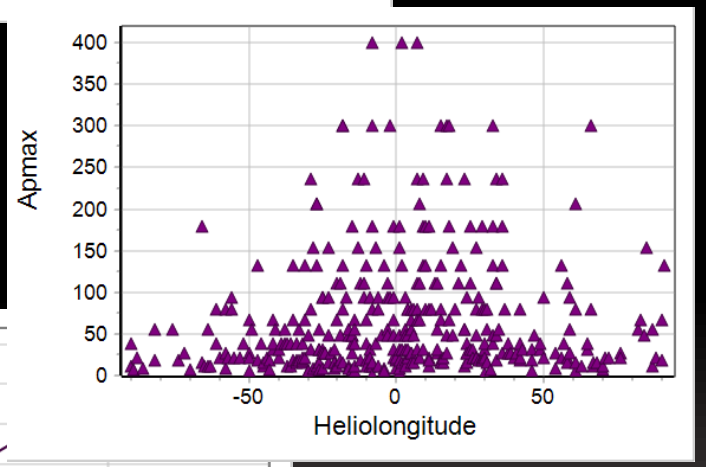

- ≈50% of events with mean errors <10 hours
- 190 events with relative errors <15%

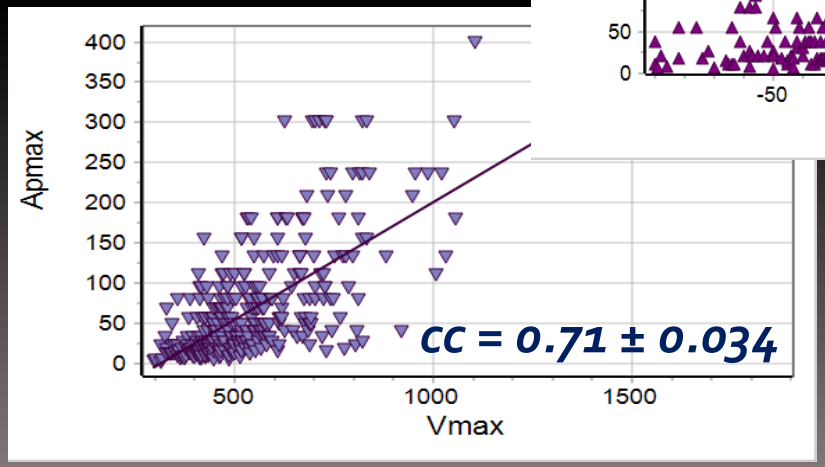
# Expected geomagnetic activity




Ap (Kp), Dst indices

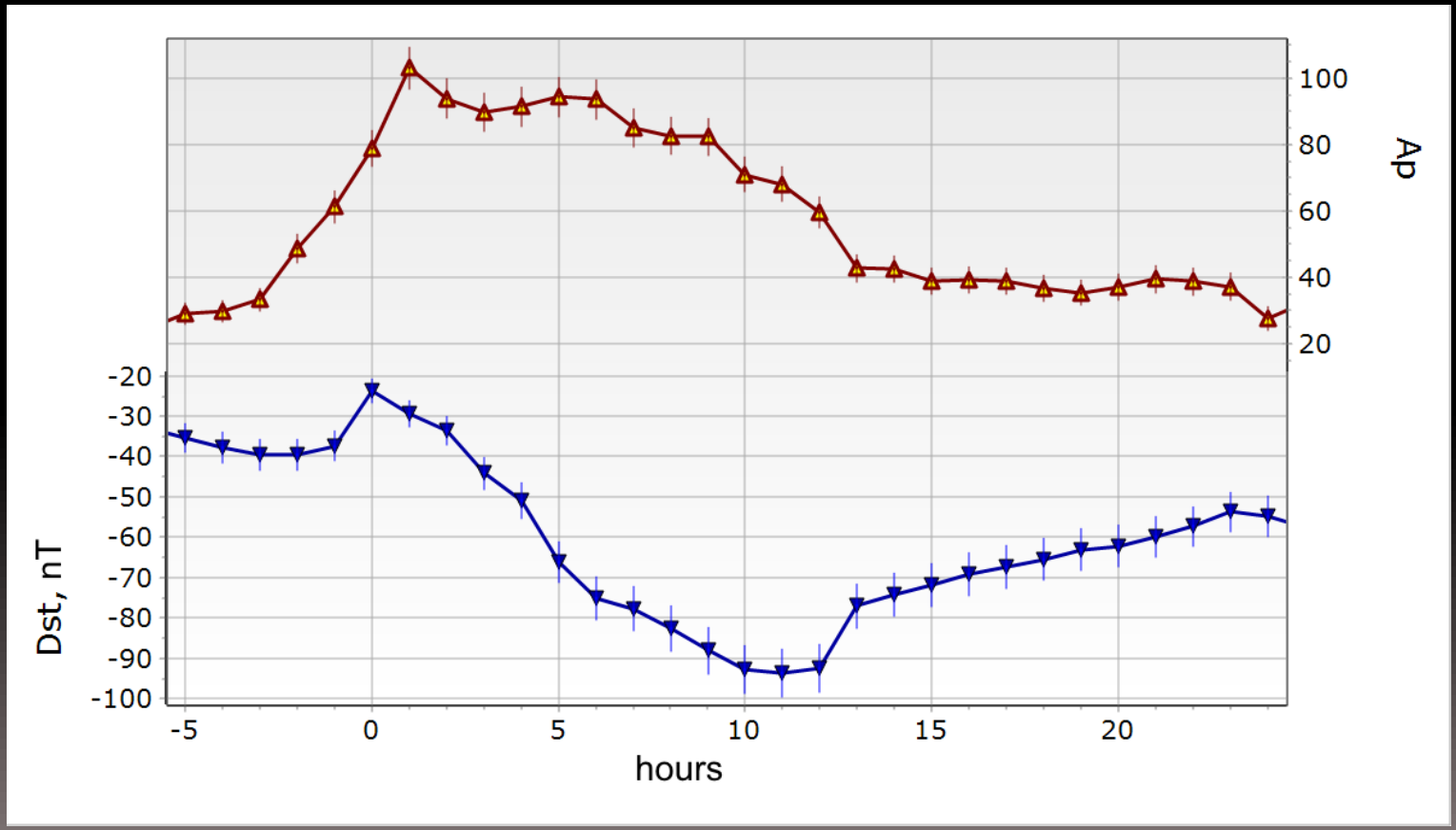


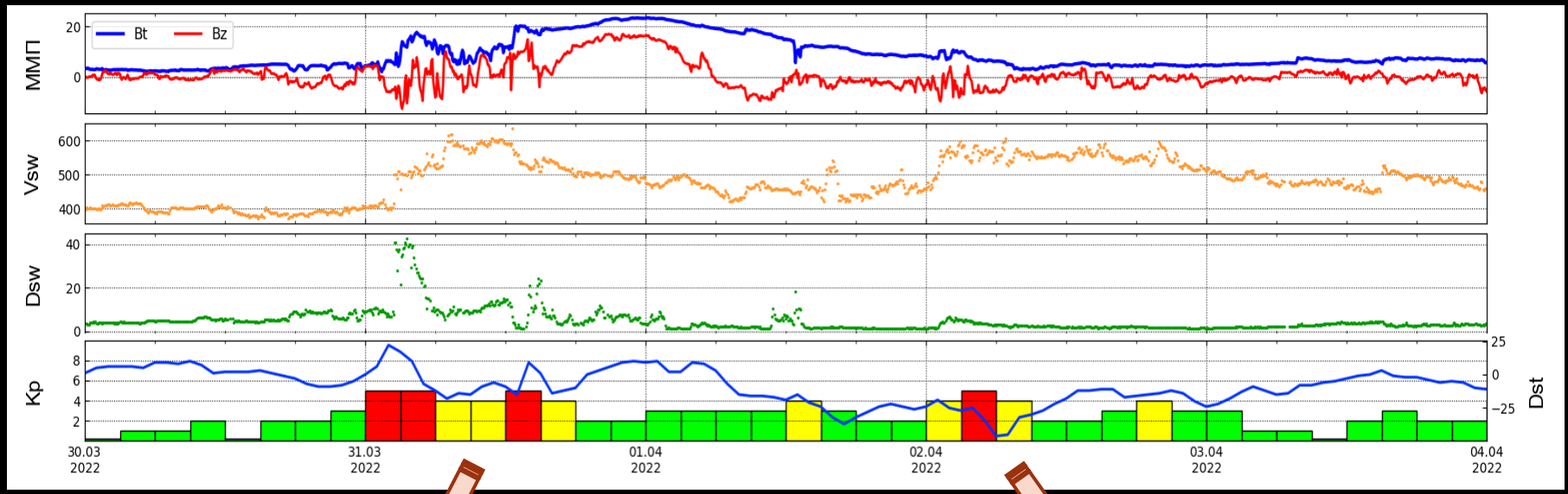



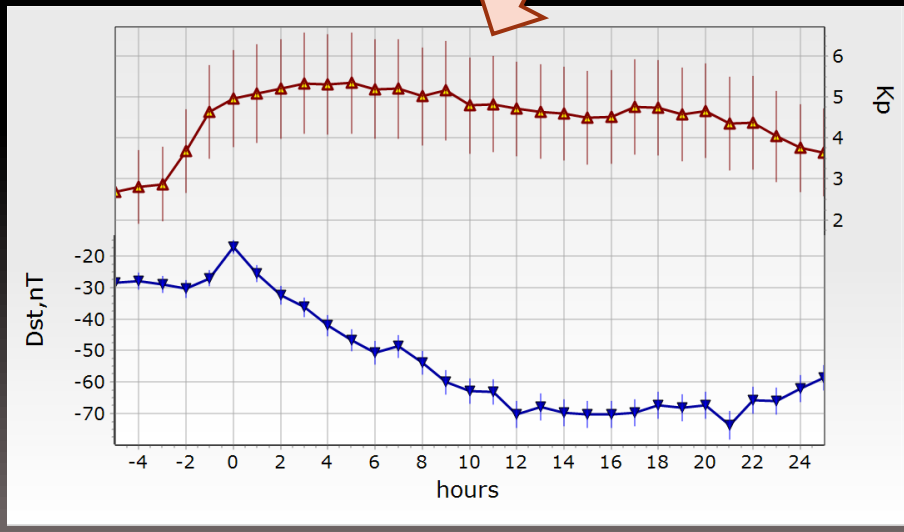
# Expected geomagnetic activity: the epoch superposition method

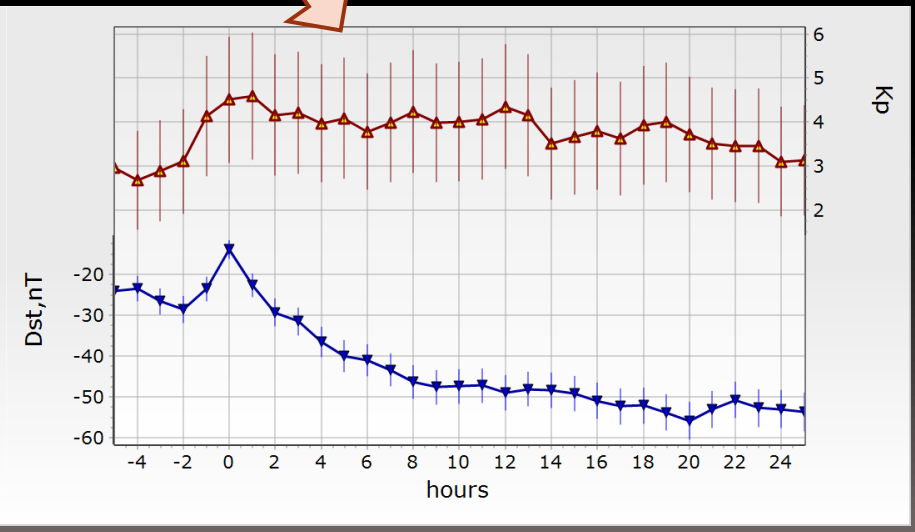
$V_o$ = 1200 km/s  $V_a$ = 500 km/s  $\varphi$ = 12°



# Examples for 2022



# Main conclusions

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

# Thanks for your attention!

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