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OPERATIONAL SPACE WEATHER SERVICES AT UNIVERSITY OF GRAZ

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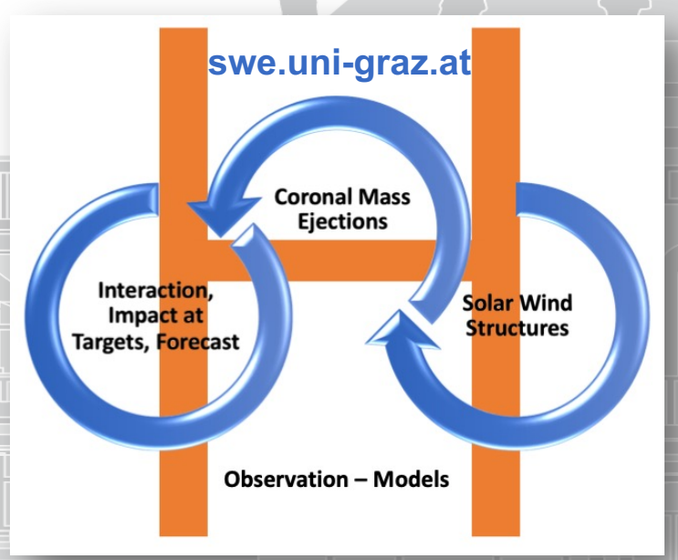

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Motivation

Improving space weather forecast is a topic of high timeliness. The current solar cycle 25 is increasing in its activity strongly, and we may face the next maximum rather soon for that we expect increased disturbances from solar events.

Structuring of interplanetary space, in terms of background solar wind and SIRs, is still not well simulated.

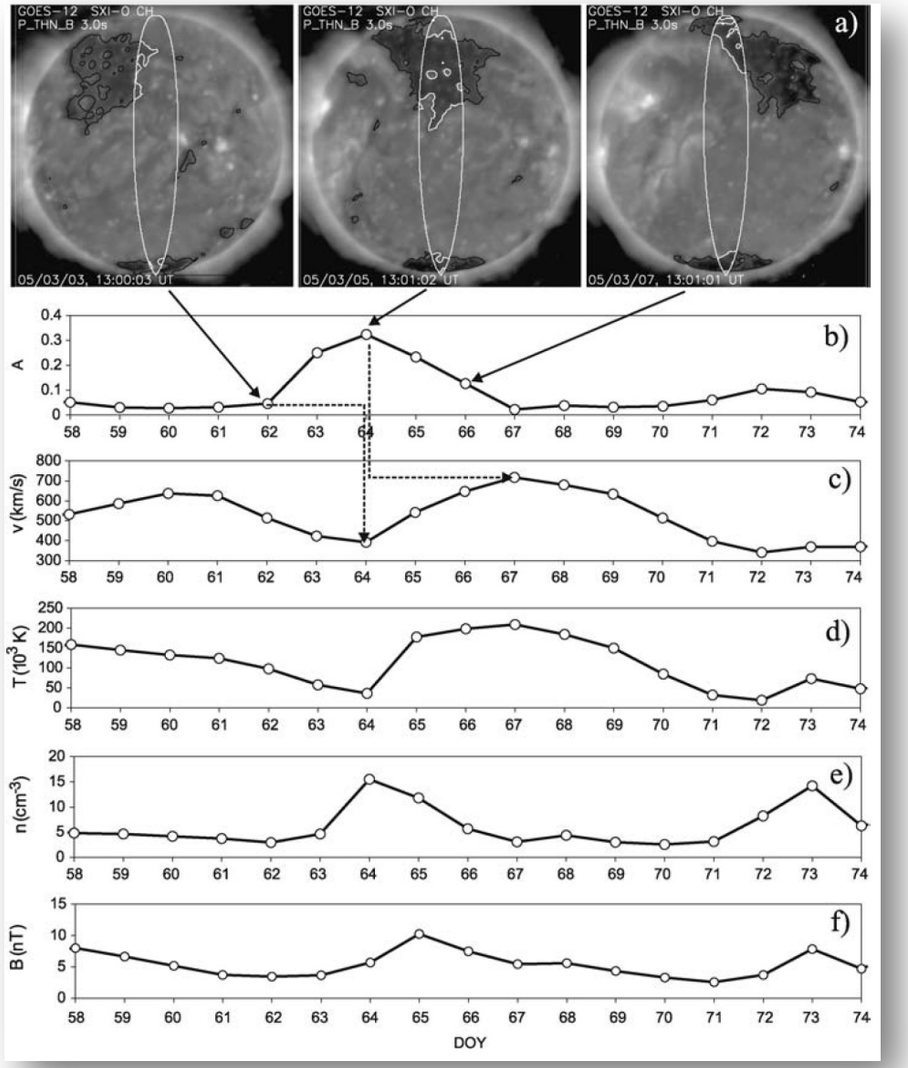
The strongest space weather effects are caused by CMEs and complex interaction events.

We need to better understand the outflow from the Sun and how it structures interplanetary space in which CMEs are embedded in. Research on: Solar wind evolution ⇔ CME evolution :: Models ⇔ Observations ⊳ Impact at planets

- “ESWF” (empirical solar wind forecast) using the relation between CH sizes and solar wind speed at 1au
- “STEREO+CH” a coronal hole based persistence solar wind forecast model using STEREO-A data
- “ESWF24” an data assimilation solar wind model combined with CH observations
- “DBEM” the drag-based CME propagation model in its basic and ensemble version
- “SODA” a forecast of the neutral density enhancement in the thermosphere and satellite orbit decays

All the services currently run within the Space Safety Programme of ESA (https://swe.ssa.esa.int/) under the Expert Service Centers of Heliospheric and Ionospheric Weather.

Empirical relation between CH area and SW speed@1au – ESWF; and Dst – ESWFv3.2

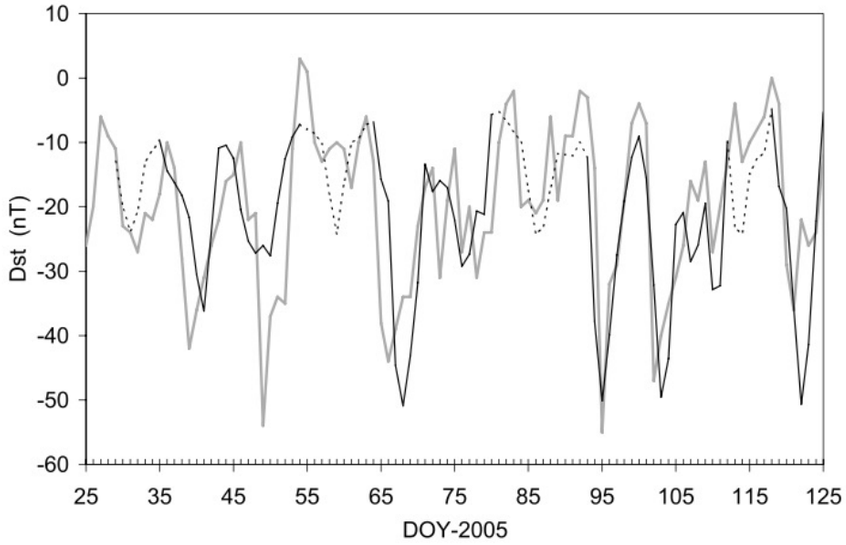


Large areas of coronal holes at the central region of the Sun cause, with a delay of about 4 days, an increase in the SW speed close to Earth.

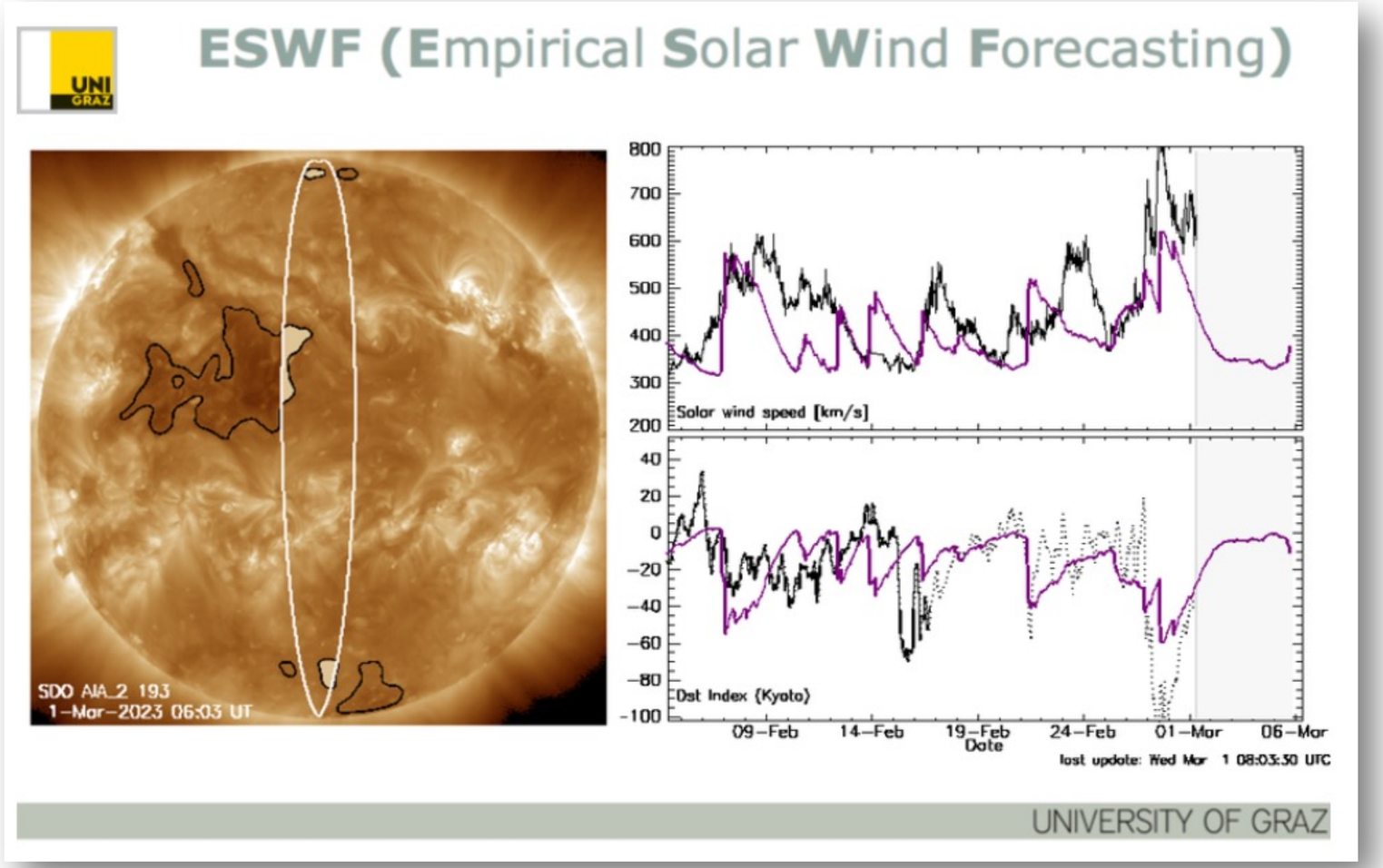
$$f(t) = c_0 + c_1 A(t_{lag})$$

Based on that, an operational application, ESWF, was developed (Vrsnak, Temmer, Veronig 2007a; Rotter et al., 2012, 2015; Reiss et al., 2016).

Further studies established an empirical relation between Dst index and CH area/location and magnetic polarity (Vrsnak, Temmer, Veronig, 2007b). Results are applied in ESWFv3.2



Update to ESWF – current version 3.2



The latest version ESWF 3.2, uses non-constant time lag, dynamic thresholding for CH extraction (Heinemann et al., 2020), co-latitude information (Hofmeister et al., 2018) and improved compression profiles. In addition, a **Dst forecast** was added based on CH information. ESWFv3.2 is described in Milosic et al. (2023).

Persistence modelling using STEREO data combined with CH area evolution information – STEREO+CH

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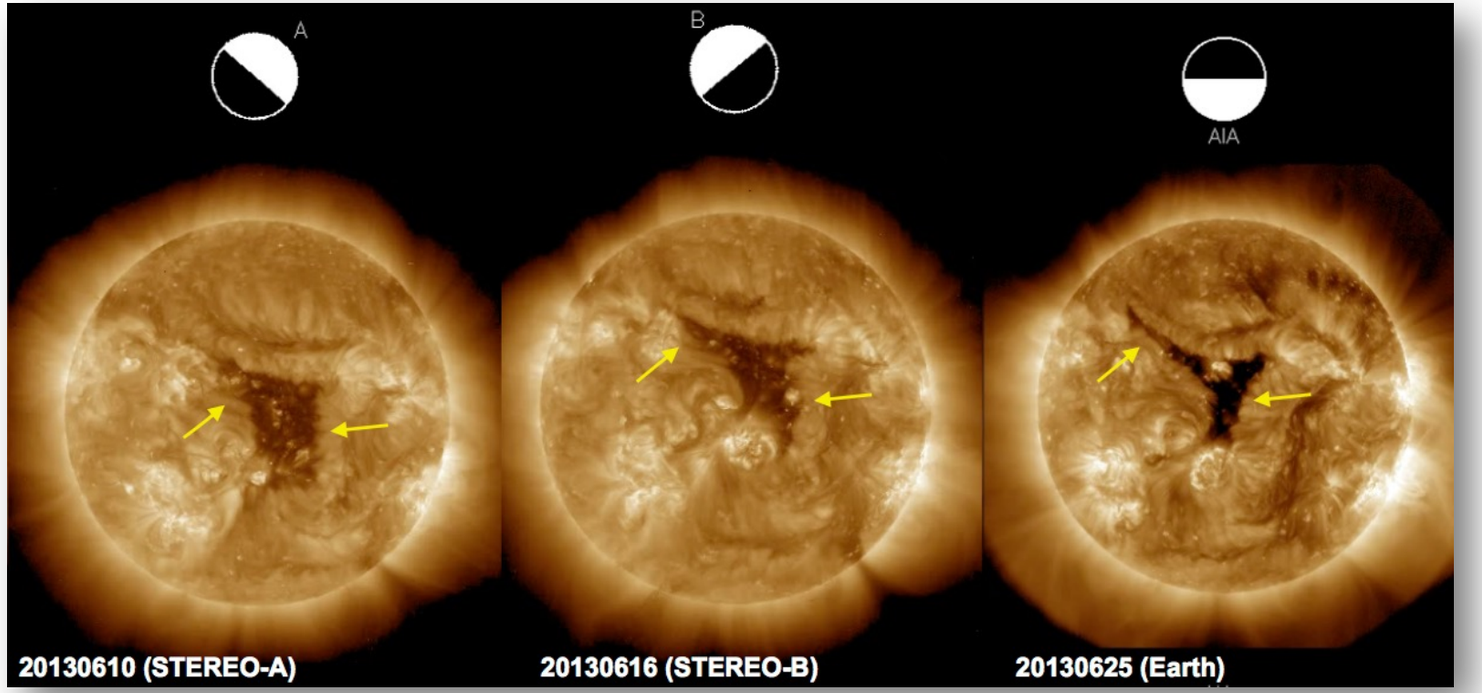
As the Sun rotates, STEREO-A delivers in-situ SW information several days ahead of Earth (switch in position in August 2023). Assuming that SW structures do not change strongly, a simple persistence model based on STEREO data is used for forecasting solar wind speed at Earth. However, CHs may change from STEREO to Earth view and with that the SW speed. We consider that by comparing EUV CH areas from STEREO to SDO. Strong area changes add to the uncertainty level in our forecast. STEREO+CH is described in Temmer, Hinterreiter, Reiss (2018). STEREO+CH will be used as basis for future L5 SW speed algorithms.



STEREO+CH, version 2 is coming soon…

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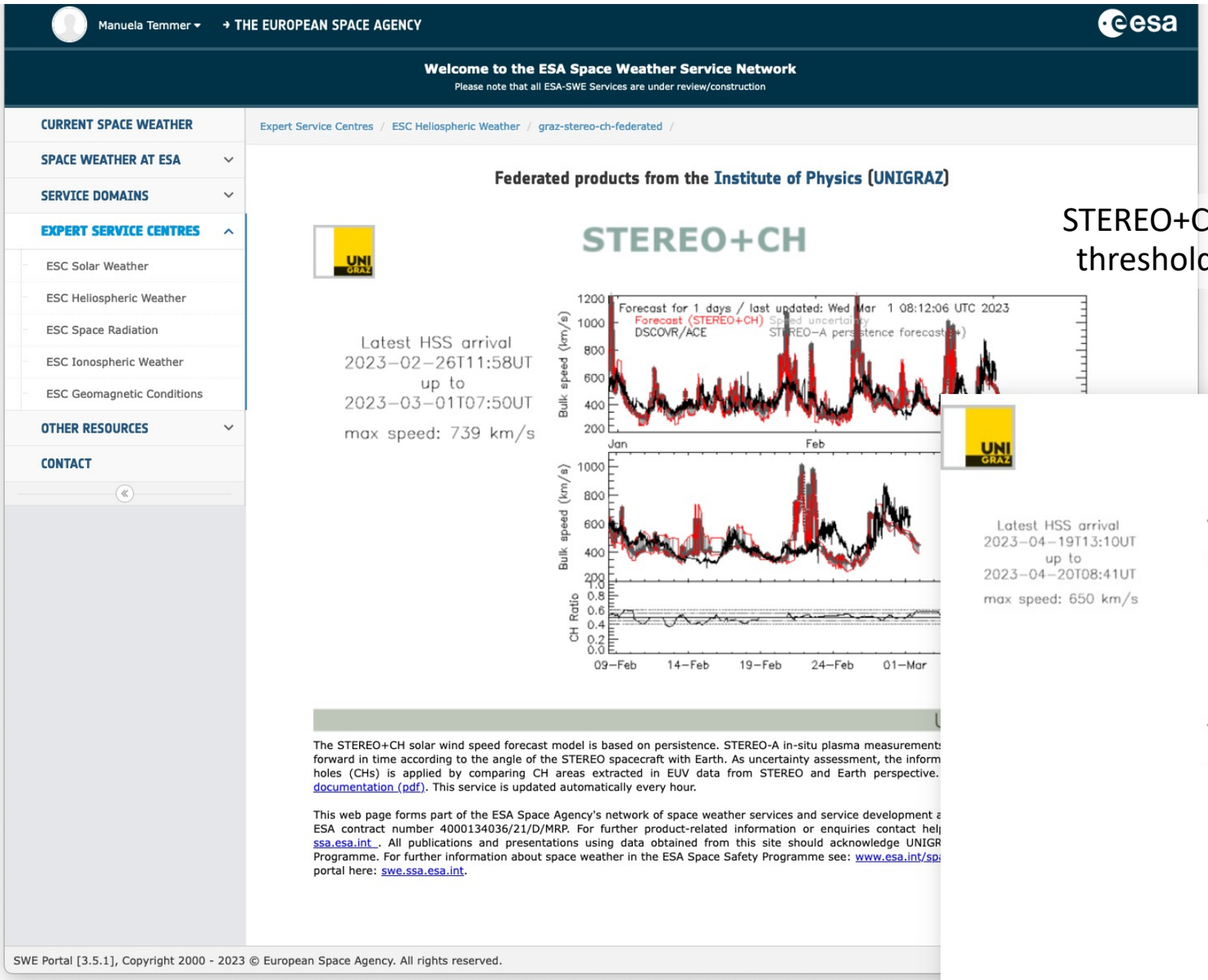
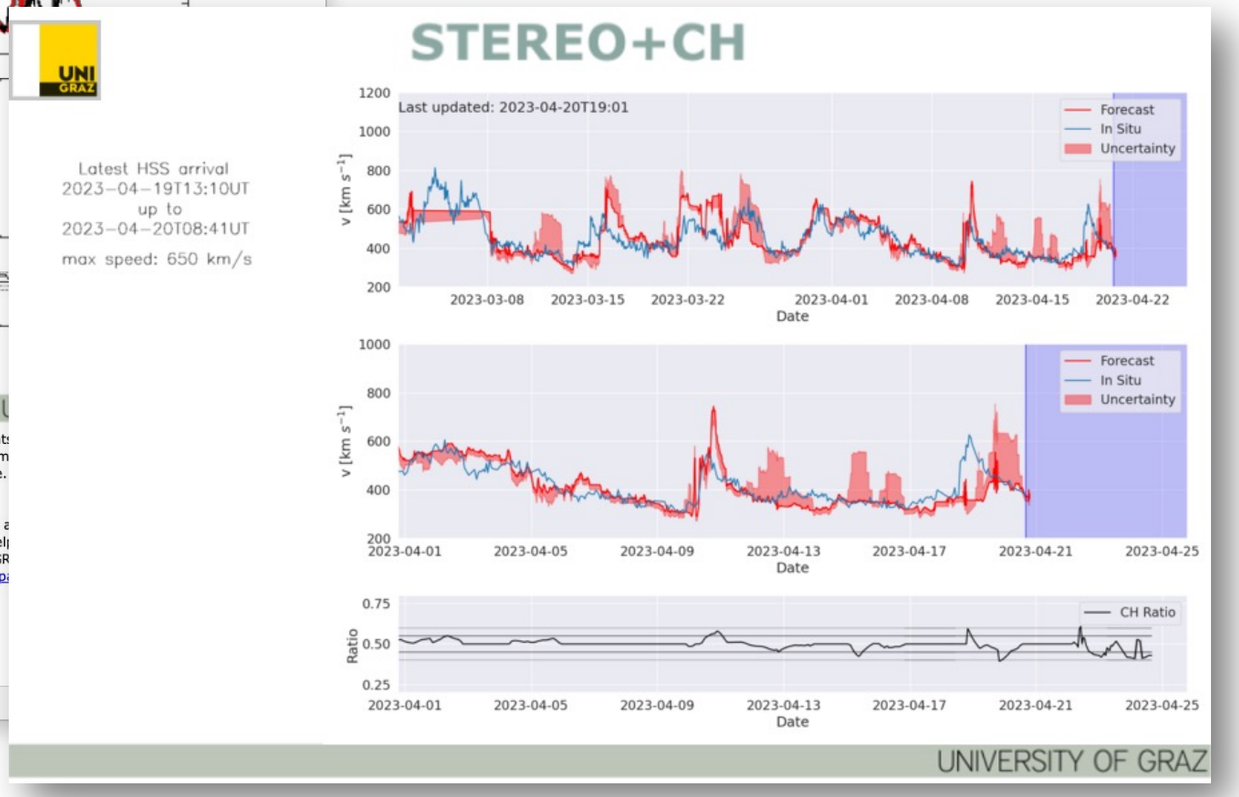


STEREO+CHv2 covers CH extraction using variable thresholds for SDO and co-latitude information.



ESWF24 – reliable short term SW speed forecast

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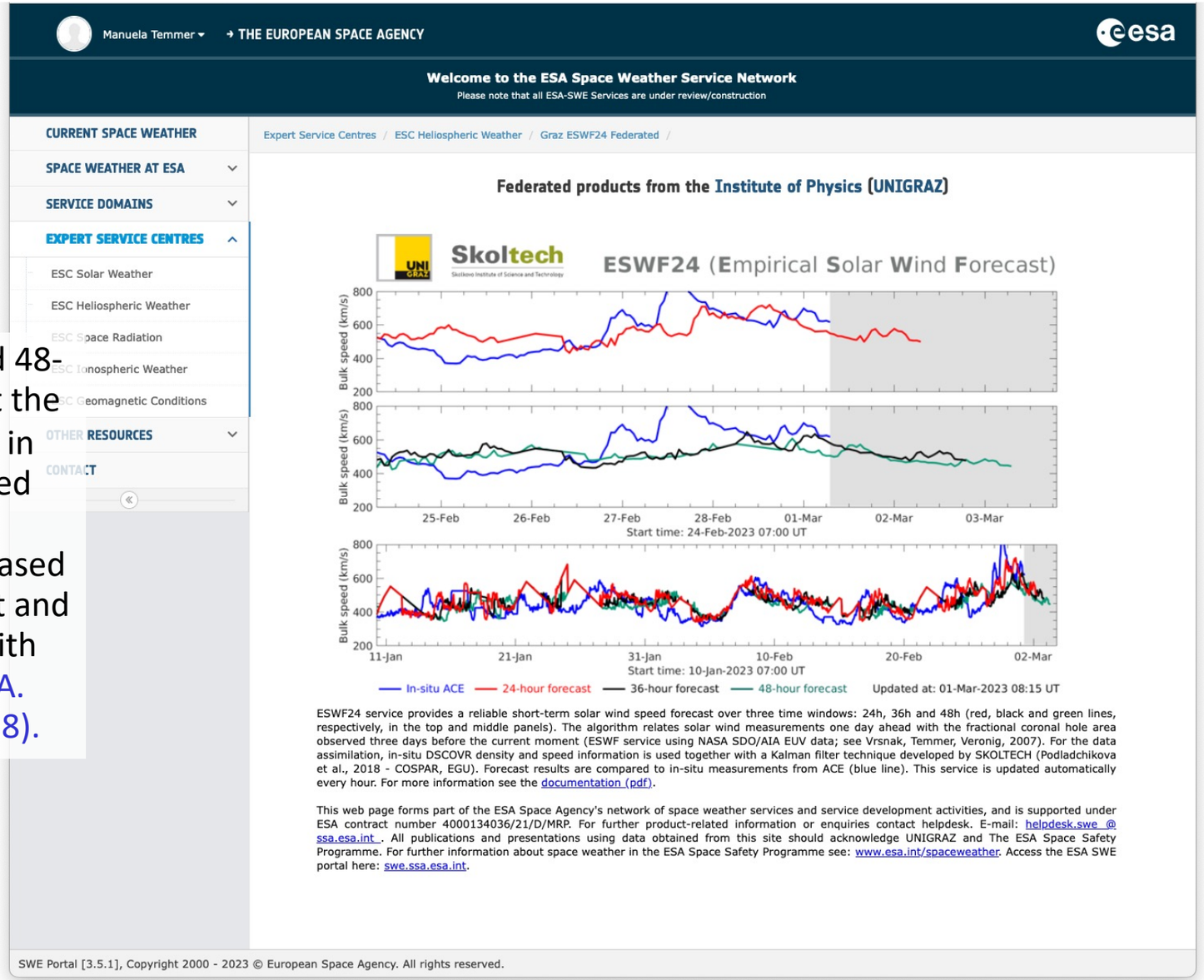
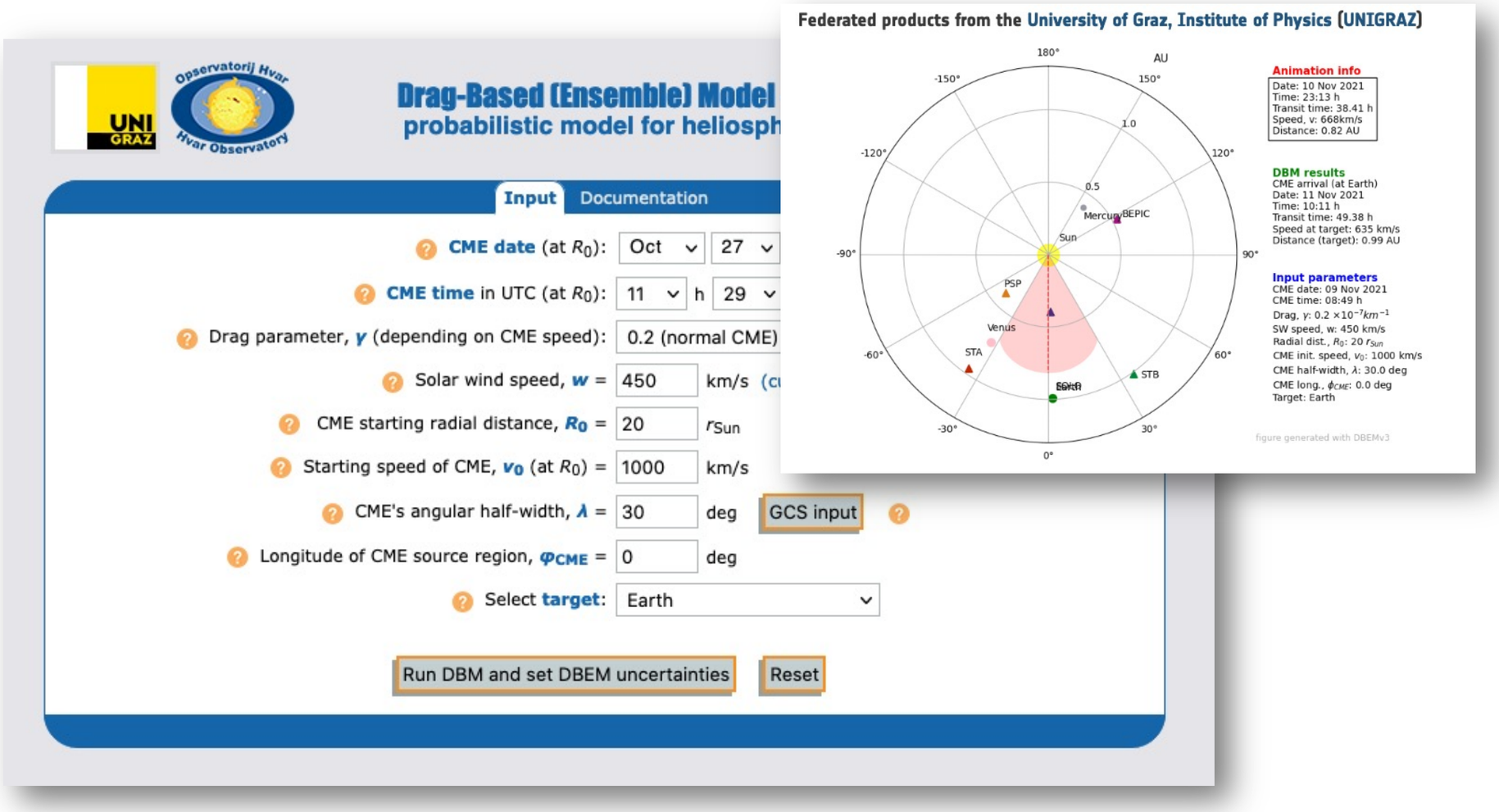
The ESWF24 service provides 24, 36 and 48-hour solar wind forecast by using CHs at the Sun areas derived from SDO AIA images in combination with in-situ solar wind speed from ACE and density from DSCOVR spacecraft. The prediction method is based on ESWF, uses interactions between fast and slow solar wind and data assimilation with the Kalman filter. See Podladchikova T., A. Veronig, M. Temmer, S. Hofmeister (2018).



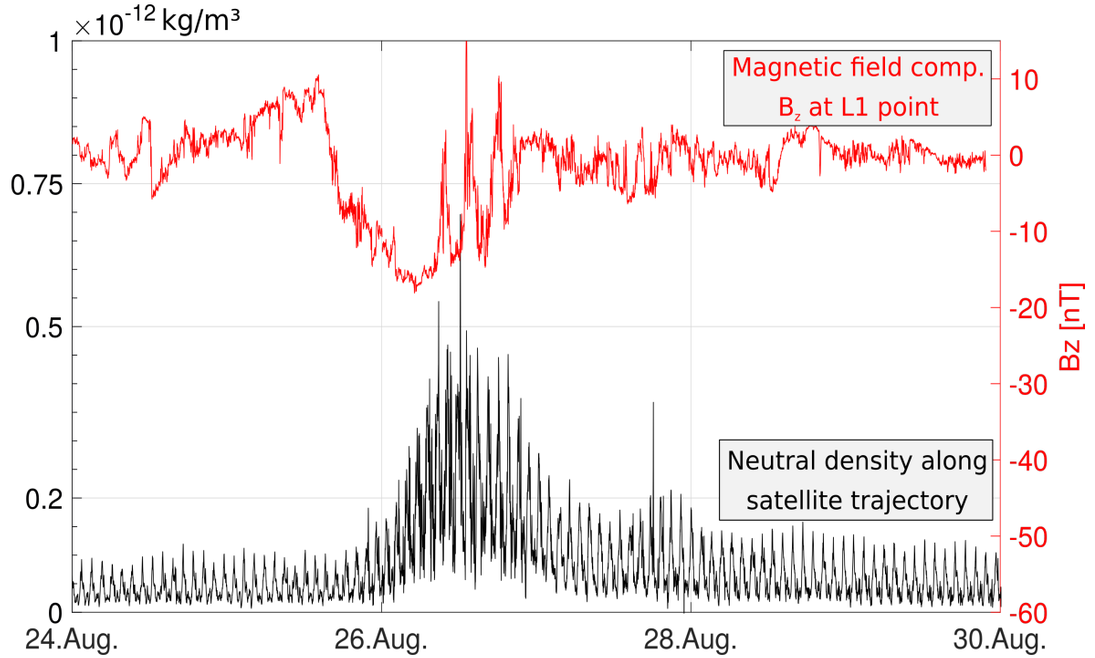
DBM/DBEM – CME propagation tool

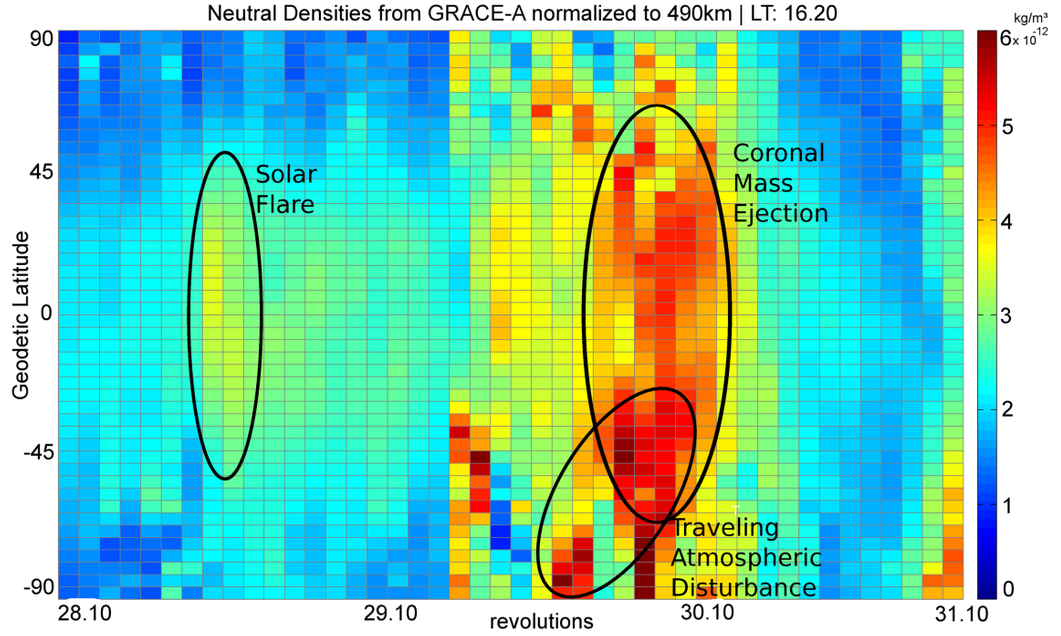
The Drag-based Model (DBM) and its ensemble version (DBEM) is a 2D analytical model for the heliospheric propagation of CMEs. It predicts CME arrival time and speed at Earth or any other given target in the solar system. A very short computational time (< 0.01 s) allows to vary the model input parameters based on uncertainties and to do huge ensemble runs (e.g., 100.000 runs).

See Vrsnak et al., 2013; Zic, Vrsnak, Temmer, 2015; Dumbovic et al., 2018, 2021; Calogovic et al., 2021.



Project SWEETS





Comparison between minimum Bz measured at L1 and the orbit decay due the density enhancement in the thermosphere.

We derive a linear relation with a high correlation (see Krauss et al. 2015, 2018)

Development of SWEETS for forecasting space weather effects on low Earth orbiting satellites (Krauss et al., 2023, in preparation).

SODA – Satellite Orbit DecAy Forecast

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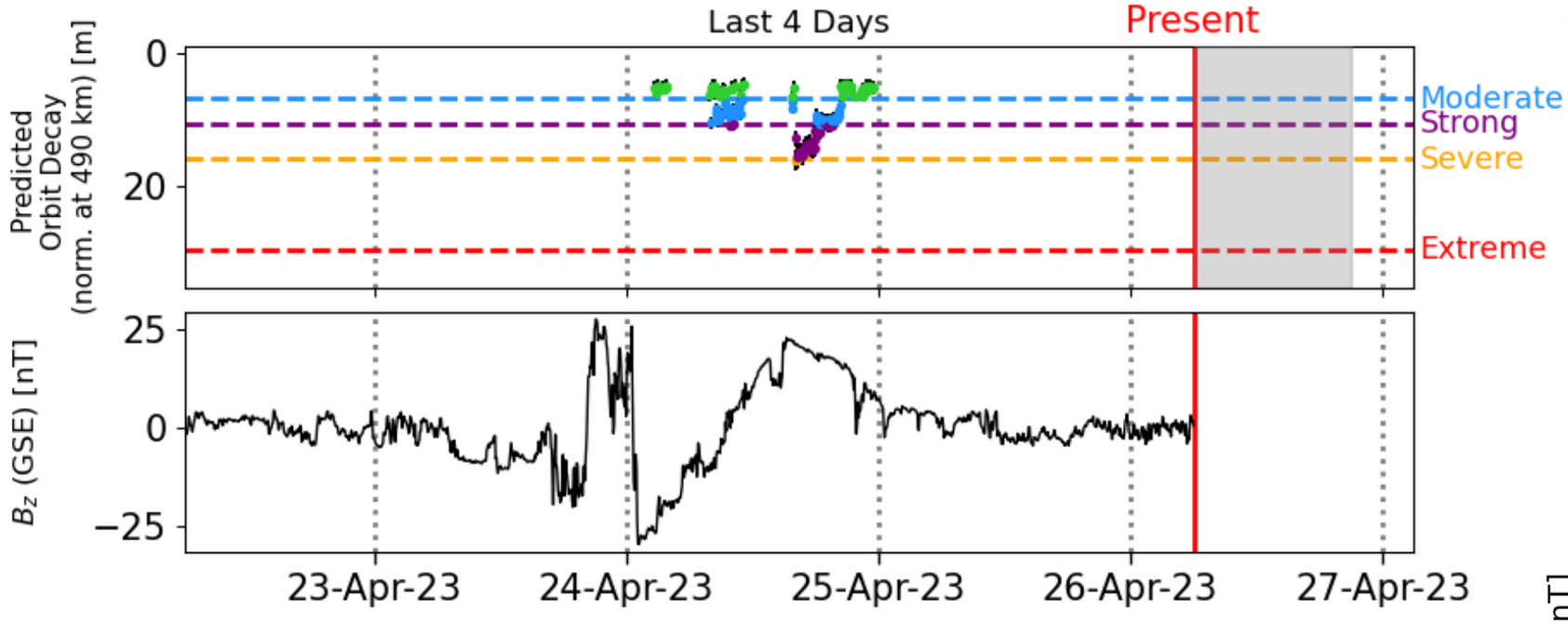

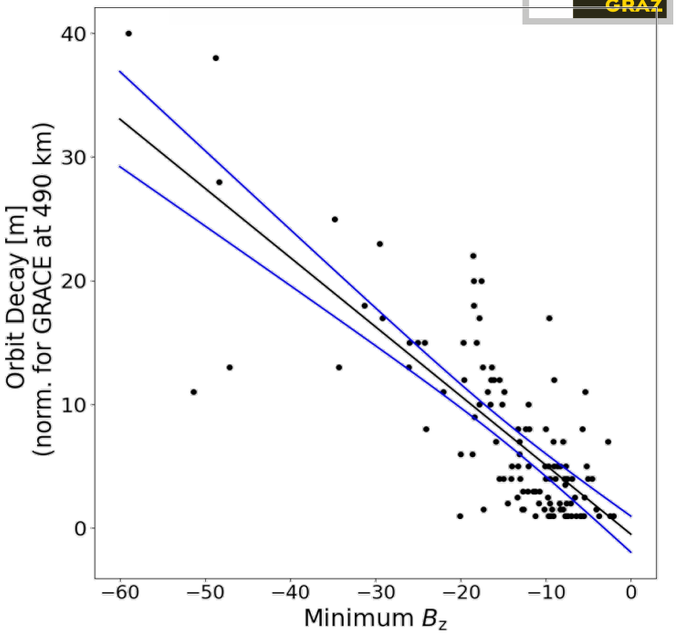

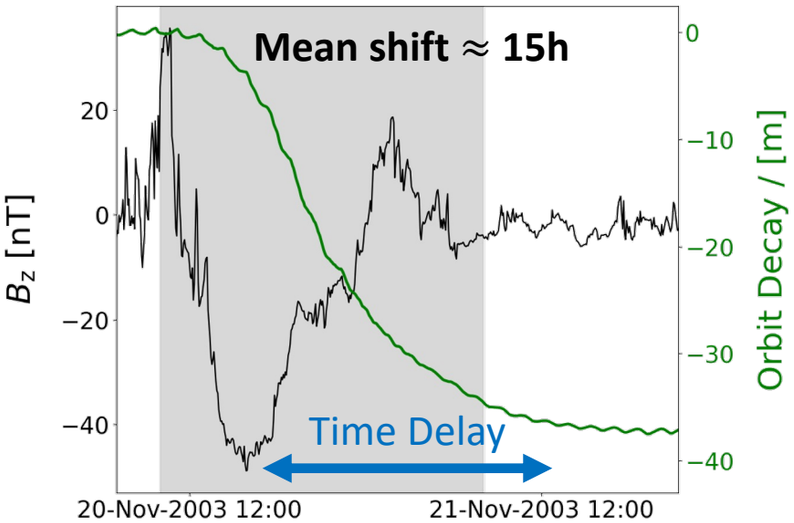

SODA is part of the ESA Space Safety Programme (Ionospheric Weather) and will be released July 11, 2023!
https://swe.ssa.esa.int/ionospheric-weather

15 hours is used as constant lead time of the orbit decay forecast when measuring B_z at L1.

H-ESC services for solar wind forecast (ESWF, STEREO+CH, ESWF24), CME evolution (DBEM); I-ESC service for satellite drag (SODA)

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Science group:

Florian Koller (PhD student)	In-situ SW structures and magnetosheath jets (joint project with IWF Graz - F. Plaschke)
Greta Cappello (PhD student)	Substructures of CMEs and their solar sources (YRP with IWF/TU Graz)
Lukas Höfig (Master student)	Type III burst detection with e-CALLISTO and real-time implementation at OLG
Stefan Weiß (Master student)	Solar wind and THEMIS data analysis
Lukas Drescher (Master student)	ESA service SODA development (joint project with TU Graz - S. Krauss)
Sofia Kroisz (Master student)	Effects of multiple CMEs on thermosphere density (joint project with TU Graz - S. Krauss)

Technical Support:

Rober Maderbacher (Ing.)	ESA-SWESNET Space Safety Services; SWAP

esa

SWEETS (FFG)

SWAP (FFG)

Magnetosheath jets (FWF)

e-CALLISTO

iSWAT (COSPAR)

ISSI Teams

FFG Promoting Innovation.

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FWF AUSTRIAN SCIENCE FUND

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