

OPERATIONAL SPACE WEATHER SERVICES AT UNIVERSITY OF GRAZ

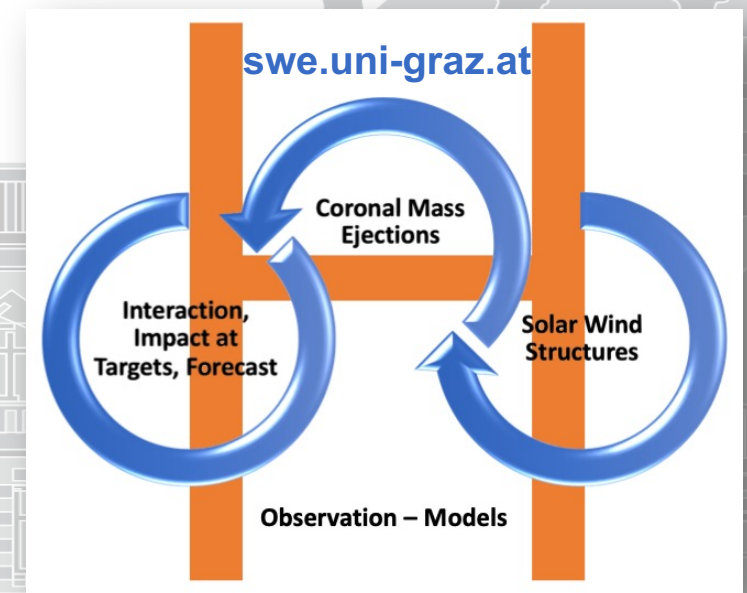
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Motivation

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.

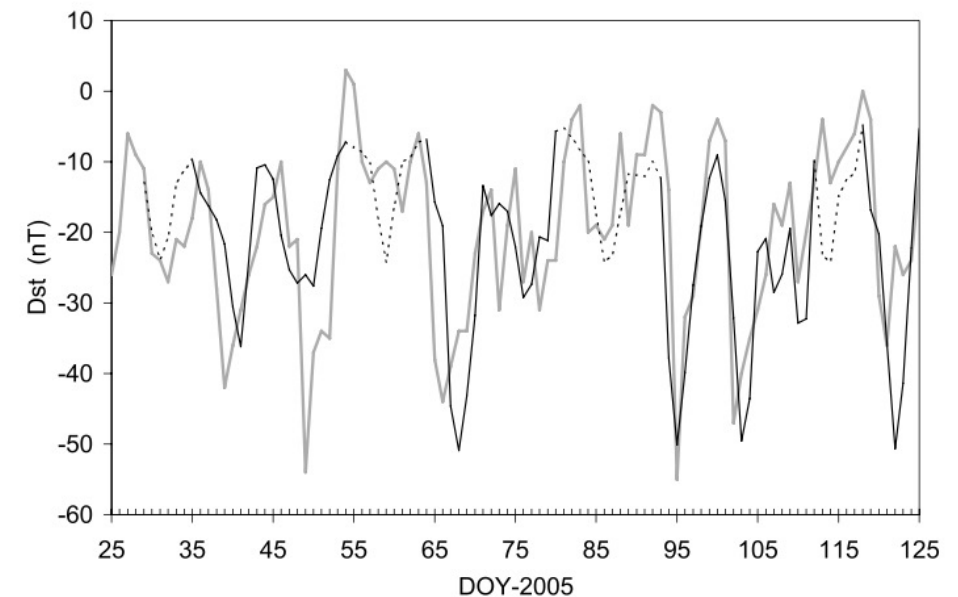
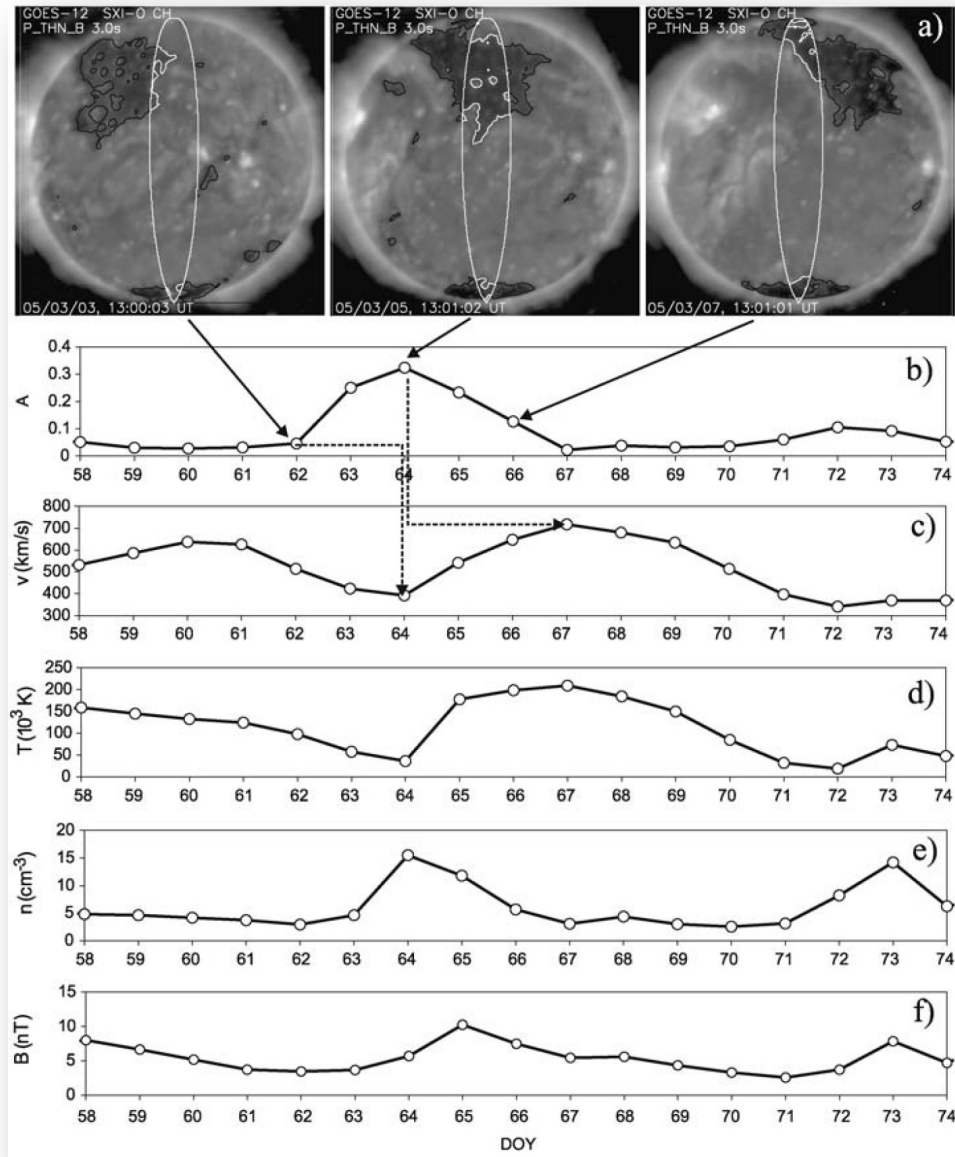
Empirical relation between CH area and SW speed@1au – ESWF; and Dst – ESWFv3.2

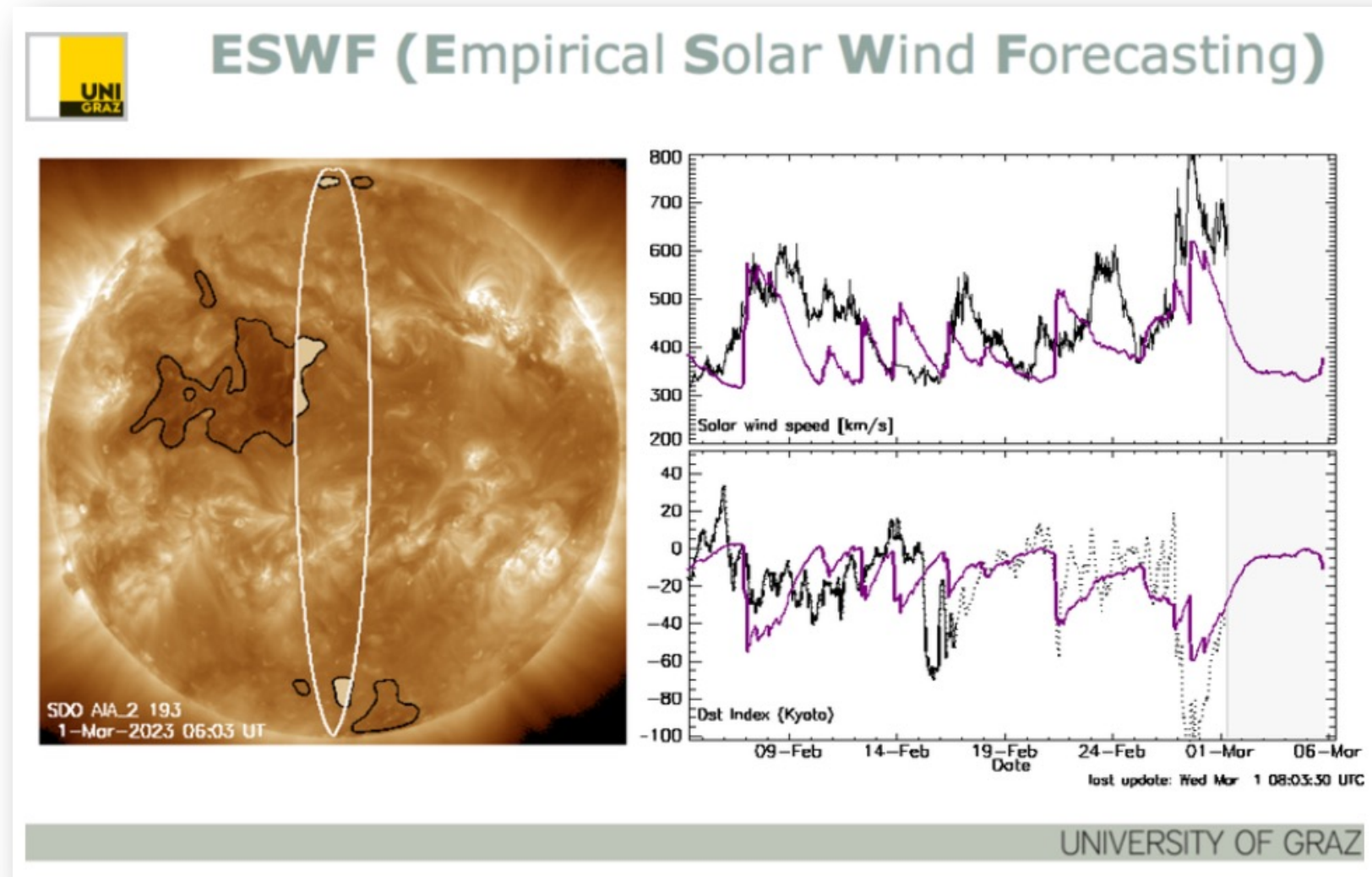
Large areas of coronal holes at the central region of the Sun cause, with a delay of about 4 days, an increase in the SW speed close to Earth.

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

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

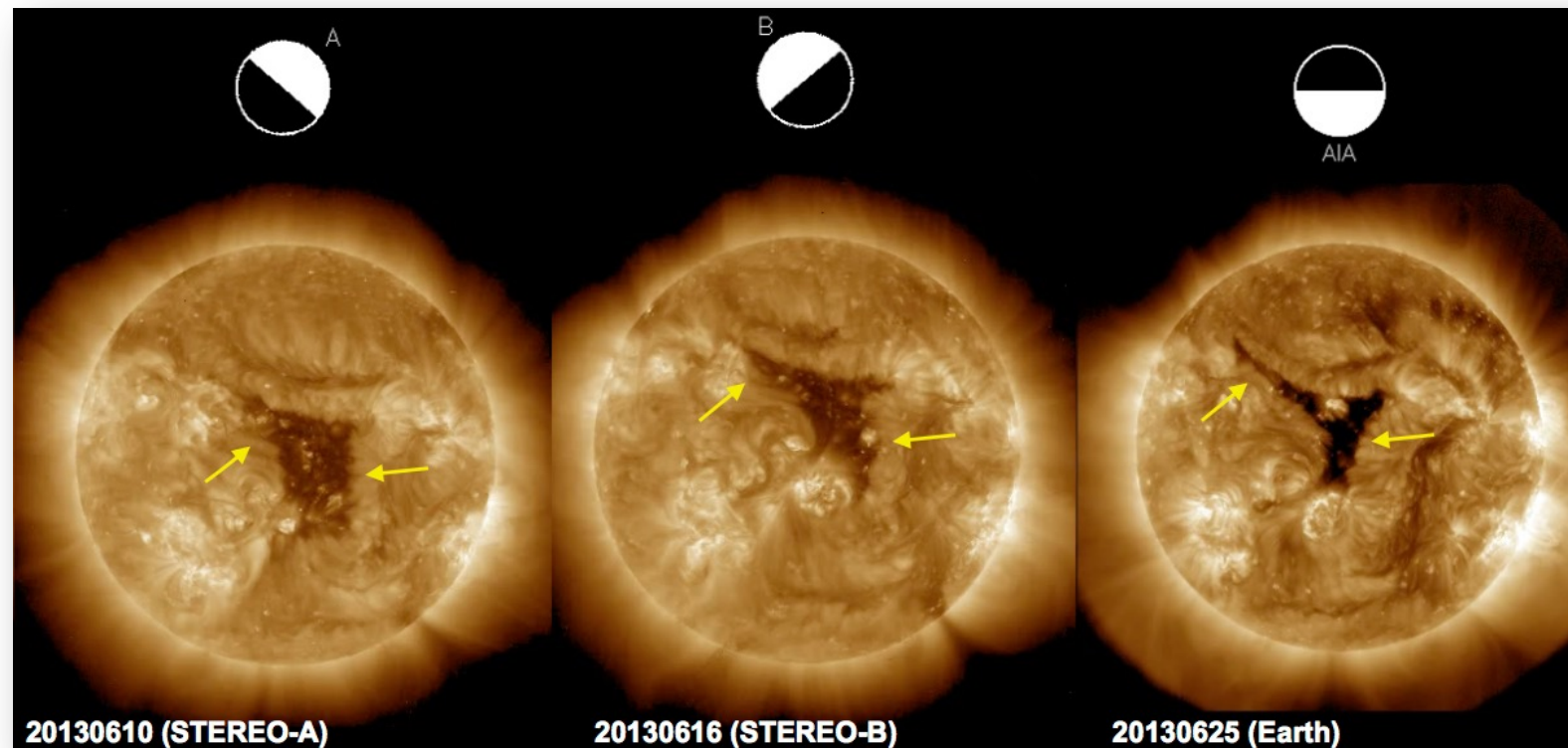




The latest version ESWF 3.2, uses non-constant time lag, dynamic thresholding for CH extraction ([Heinemann et al., 2020](#)), co-latitude information ([Hofmeister et al., 2018](#)) and improved compression profiles. In addition, a **Dst forecast** was added based on CH information. ESWFv3.2 is described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

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

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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- ESC Heliospheric Weather
- ESC Space Radiation
- ESC Ionospheric Weather
- ESC Geomagnetic Conditions

OTHER RESOURCES ▾

CONTACT

Federated products from the Institute of Physics (UNIGRAZ)

STEREO+CH

UNI GRAZ

Latest HSS arrival
2023-02-26T11:58UT
up to
2023-03-01T07:50UT
max speed: 739 km/s

Jan Feb

Bulk speed (km/s)

CH Ratio

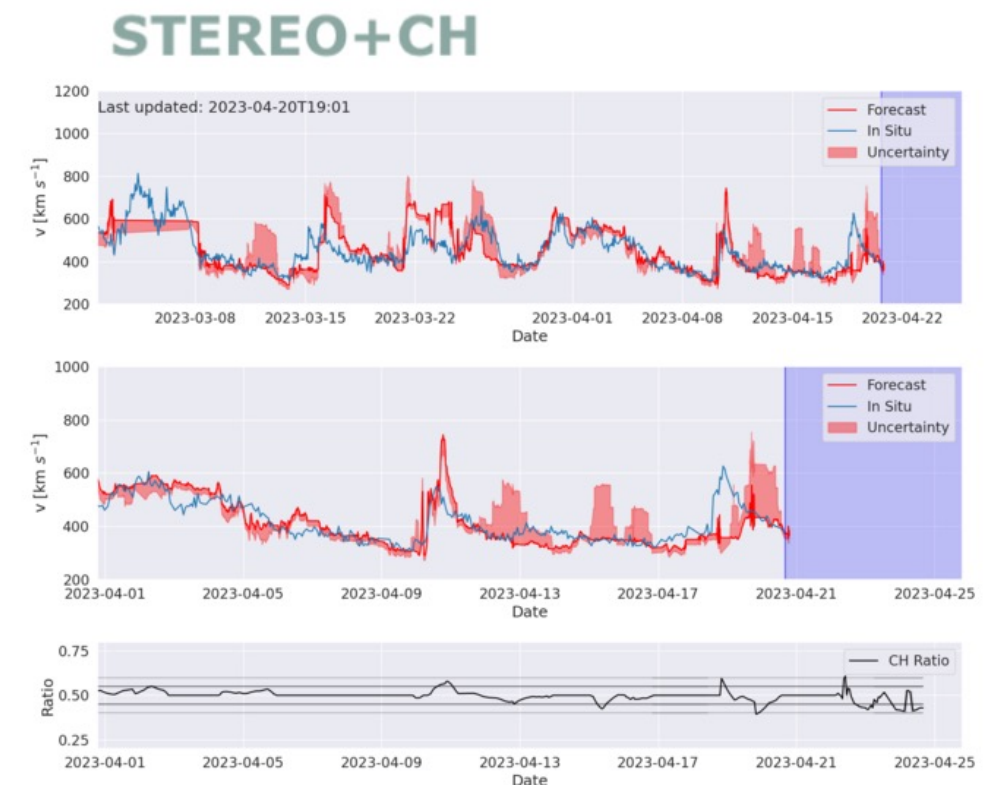
09-Feb 14-Feb 19-Feb 24-Feb 01-Mar

The STEREO+CH solar wind speed forecast model is based on persistence. STEREO-A in-situ plasma measurements forward in time according to the angle of the STEREO spacecraft with Earth. As uncertainty assessment, the inform holes (CHs) is applied by comparing CH areas extracted in EUV data from STEREO and Earth perspective. [documentation \(pdf\)](#). This service is updated automatically every hour.

This web page forms part of the ESA Space Agency's network of space weather services and service development a ESA contract number 4000134036/21/D/MRP. For further product-related information or enquiries contact help [ssa.esa.int](#). All publications and presentations using data obtained from this site should acknowledge UNIGR Programme. For further information about space weather in the ESA Space Safety Programme see: [www.esa.int/sp](#) portal here: [swe.ssa.esa.int](#).

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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



The ESWF24 service provides 24, 36 and 48-hour solar wind speed 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 \(2018\)](#).

The screenshot shows the ESA Space Weather Service Network interface. The top navigation bar includes the user name 'Manuela Temmer' and the ESA logo. The main content area is titled 'Federated products from the Institute of Physics (UNIGRAZ)' and features three line graphs of Bulk speed (km/s) over time. The top graph shows data from 25-Feb to 03-Mar, the middle from 25-Feb to 03-Mar, and the bottom from 11-Jan to 02-Mar. Each graph compares in-situ ACE measurements (blue line) with 24-hour (red), 36-hour (black), and 48-hour (green) forecasts. A legend at the bottom identifies the lines and includes the update time: 'Updated at: 01-Mar-2023 08:15 UT'. Below the graphs, a text block explains the ESWF24 service's methodology and data sources. At the bottom of the page, a footer provides copyright information: 'SWE Portal [3.5.1], Copyright 2000 - 2023 © European Space Agency. All rights reserved.'

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Federated products from the Institute of Physics (UNIGRAZ)

Skoltech
Sukboto Institute of Science and Technology

ESWF24 (Empirical Solar Wind Forecast)

Bulk speed (km/s)

Start time: 24-Feb-2023 07:00 UT

Start time: 10-Jan-2023 07:00 UT

Updated at: 01-Mar-2023 08:15 UT

— In-situ ACE — 24-hour forecast — 36-hour forecast — 48-hour forecast

ESWF24 service provides a reliable short-term solar wind speed forecast over three time windows: 24h, 36h and 48h (red, black and green lines, respectively, in the top and middle panels). The algorithm relates solar wind measurements one day ahead with the fractional coronal hole area observed three days before the current moment (ESWF service using NASA SDO/AIA EUV data; see Vrsnak, Temmer, Veronig, 2007). For the data assimilation, in-situ DSCOVR density and speed information is used together with a Kalman filter technique developed by SKOLTECH (Podladchikova et al., 2018 - COSPAR, EGU). Forecast results are compared to in-situ measurements from ACE (blue line). This service is updated automatically every hour. For more information see the [documentation \(pdf\)](#).

This web page forms part of the ESA Space Agency's network of space weather services and service development activities, and is supported under ESA contract number 4000134036/21/D/MRP. For further product-related information or enquiries contact helpdesk. E-mail: helpdesk_swe@ssa.esa.int. All publications and presentations using data obtained from this site should acknowledge UNIGRAZ and The ESA Space Safety Programme. For further information about space weather in the ESA Space Safety Programme see: www.esa.int/spaceweather. Access the ESA SWE portal here: swe.ssa.esa.int.

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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](#).

The image shows the web interface of the Drag-Based (Ensemble) Model (DBM/DBEM) and a resulting plot. The interface is titled "Drag-Based (Ensemble) Model probabilistic model for heliospheric propagation" and is associated with the University of Graz and the Hvar Observatory. It features an "Input" tab and a "Documentation" tab. The input fields are as follows:

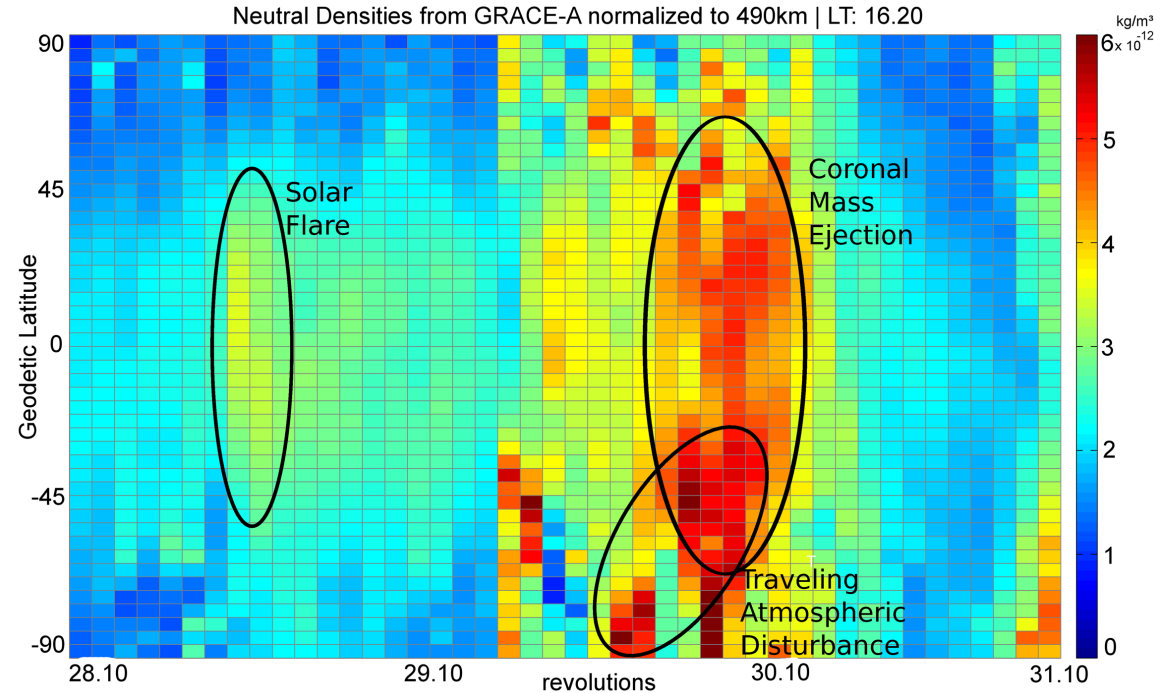
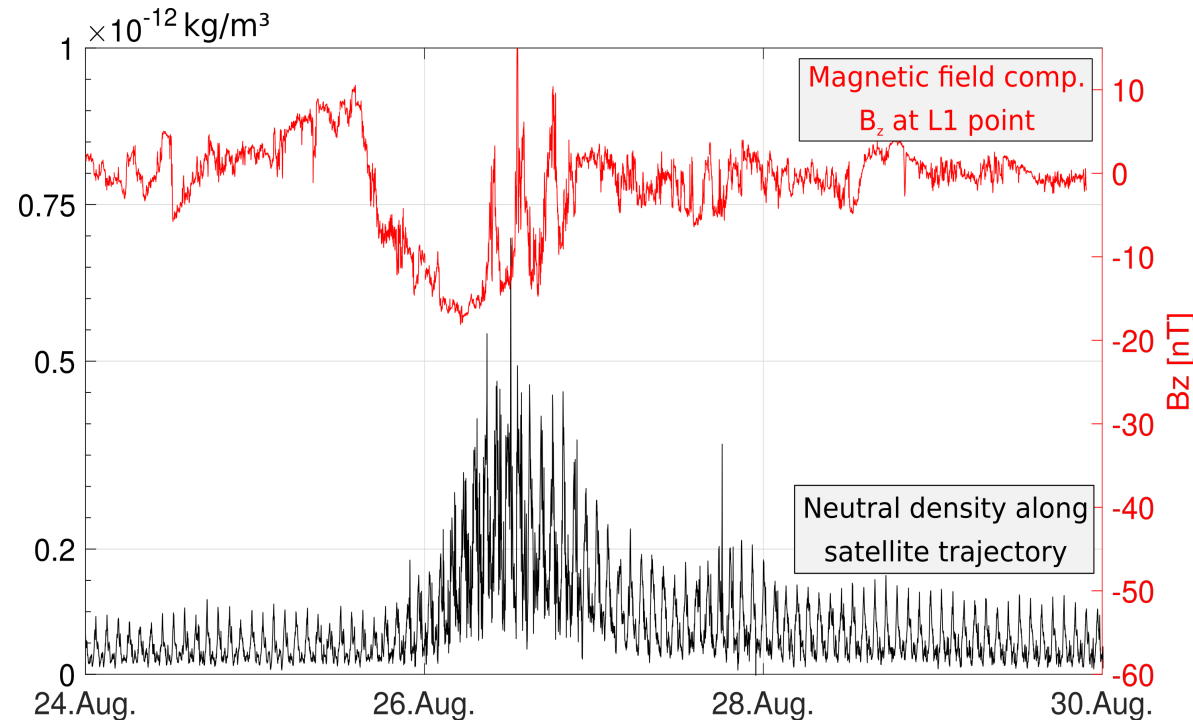
- CME date (at R_0): Oct 27
- CME time in UTC (at R_0): 11 h 29
- Drag parameter, γ (depending on CME speed): 0.2 (normal CME)
- Solar wind speed, w : 450 km/s
- CME starting radial distance, R_0 : 20 r_{Sun}
- Starting speed of CME, v_0 (at R_0): 1000 km/s
- CME's angular half-width, λ : 30 deg
- Longitude of CME source region, ϕ_{CME} : 0 deg
- Select target: Earth

Buttons include "Run DBM and set DBEM uncertainties" and "Reset". A "GCS input" button is also present.

The plot, titled "Federated products from the University of Graz, Institute of Physics (UNIGRAZ)", is a polar plot showing the CME propagation path. The plot is centered on the Sun (0,0) and shows the CME's path as a shaded pink region. The plot includes the following information:

- Animation info:** Date: 10 Nov 2021, Time: 23:13 h, Transit time: 38.41 h, Speed, v : 668 km/s, Distance: 0.82 AU.
- DBM results:** CME arrival (at Earth) Date: 11 Nov 2021, Time: 10:11 h, Speed at target: 635 km/s, Distance (target): 0.99 AU.
- Input parameters:** CME date: 09 Nov 2021, CME time: 08:49 h, Drag, γ : $0.2 \times 10^{-7} km^{-1}$, SW speed, w : 450 km/s, Radial dist., R_0 : 20 r_{Sun} , CME init. speed, v_0 : 1000 km/s, CME half-width, λ : 30.0 deg, CME long., ϕ_{CME} : 0.0 deg, Target: Earth.

The plot also shows the positions of the Sun, Mercury/BEPIC, Venus, STA, PSP, and STB. The plot is generated with DBEMv3.

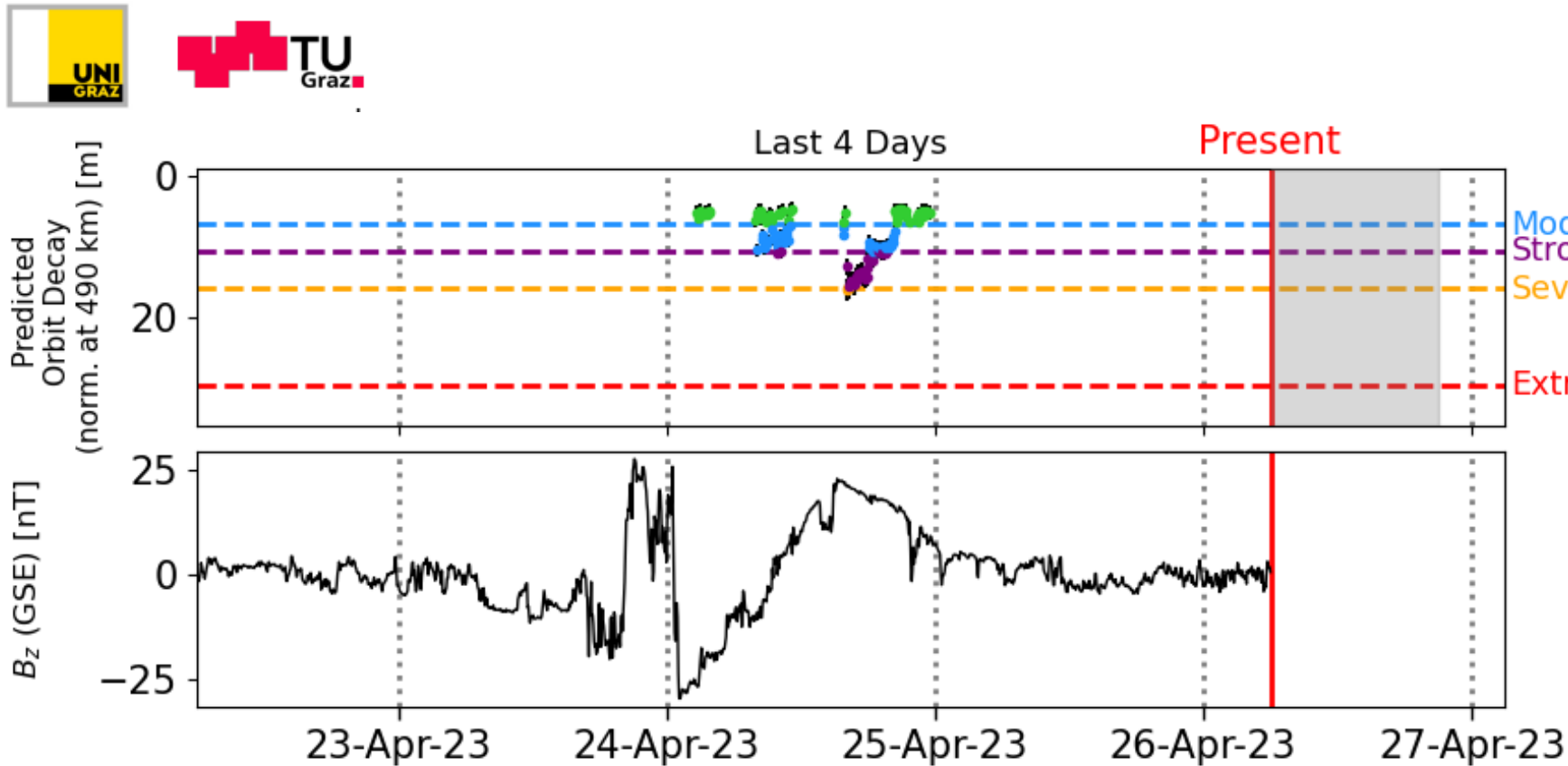


Comparison between minimum B_z measured at L1 and the orbit decay due the density enhancement in the thermosphere.

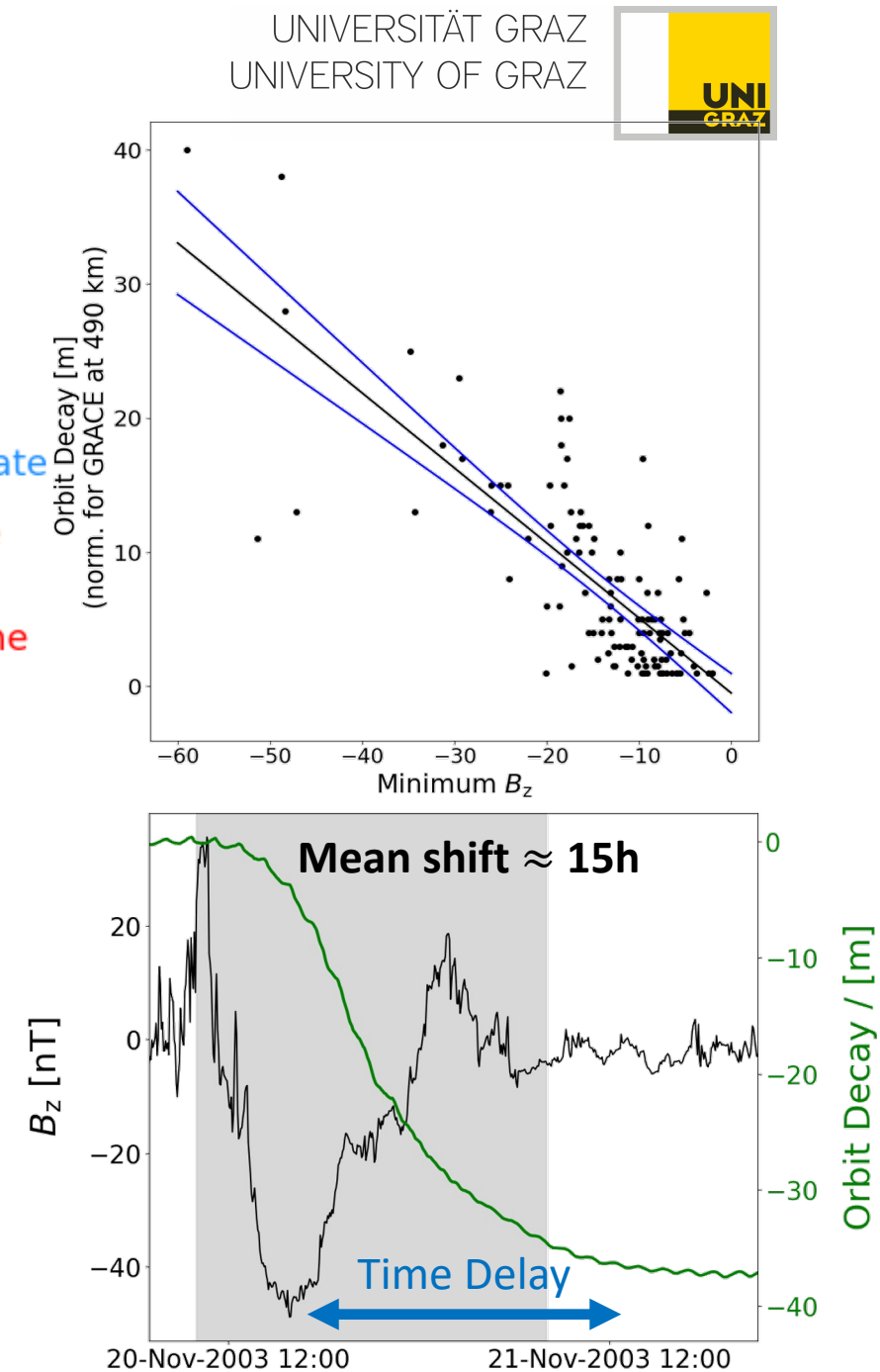
We derive a linear relation with a high correlation (see [Krauss et al. 2015, 2018](#))

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

SODA – Satellite Orbit DecAy Forecast



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)




swe.uni-graz.at

HELIOSPHERIC PHYSICS RESEARCH GROUP HOME TEAM & CONTACT PROJECTS 4STUDENTS SERVICES

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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
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SWEETS (FFG) 

SWAP (FFG) 

Magnetosheath jets (FWF) 

e-CALLISTO 

iSWAT (COSPAR) 

ISSI Teams 