Integrating Vigil Data into ESA Solar Weather ESC and Operational Center for Enhanced Real-Time Monitoring and User Services

ESA Vigil Workshop – European Space Weather Week 2024

Judith de Patoul, Andrei Zhukov, David Berghmans, Daria Shukhobodskaia, Jennifer O'Hara and Yana Maneva for the Solar Weather ESC and SIDC space weather operations team

Royal Observatory of Belgium

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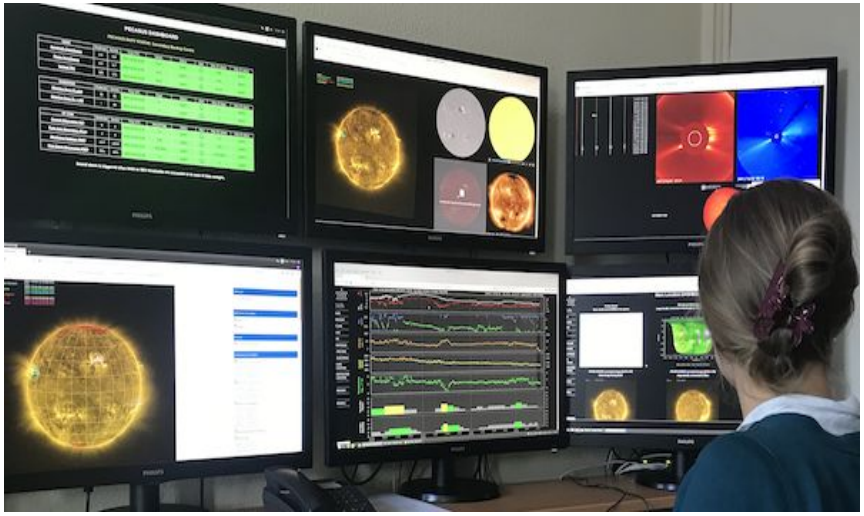
Team of experts space weather forecaster operating 24/7

- **Assessing** observations, automatic alerts, detection, and model
- **Forecasting** and running advance model
- **Summarizing:** Daily/weekly reports, Advisories and Alerts
- **Dissemination:** issuing URSIgram, PRESTO, Bulletins, Advisories for aviation, etc.



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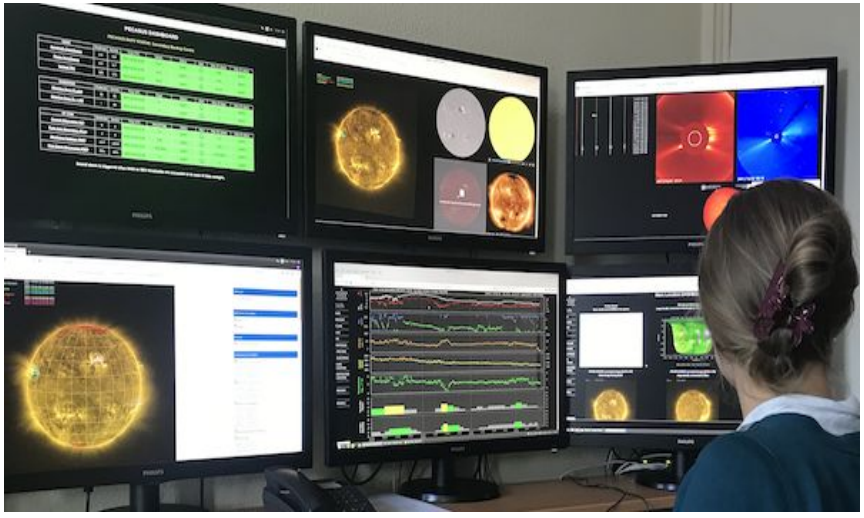
Data Utilization

- **Robust data visualization**: Observations, Movies, jHelioviewer
- **Robust data analysis** processes
- **More advanced** models and data analysis



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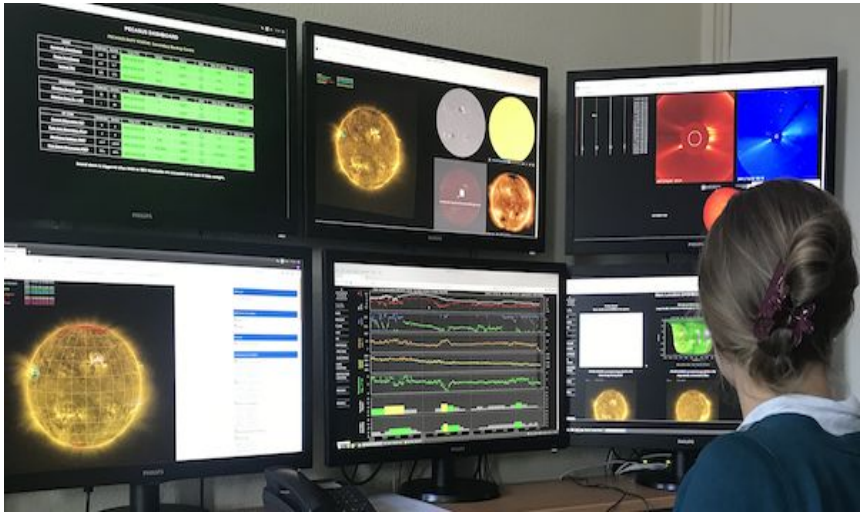
- **Robust System for Data Visualisation**



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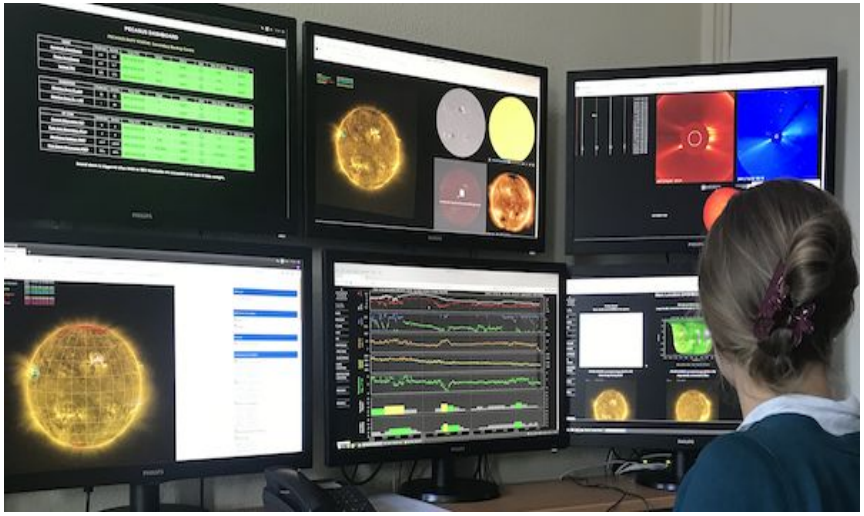

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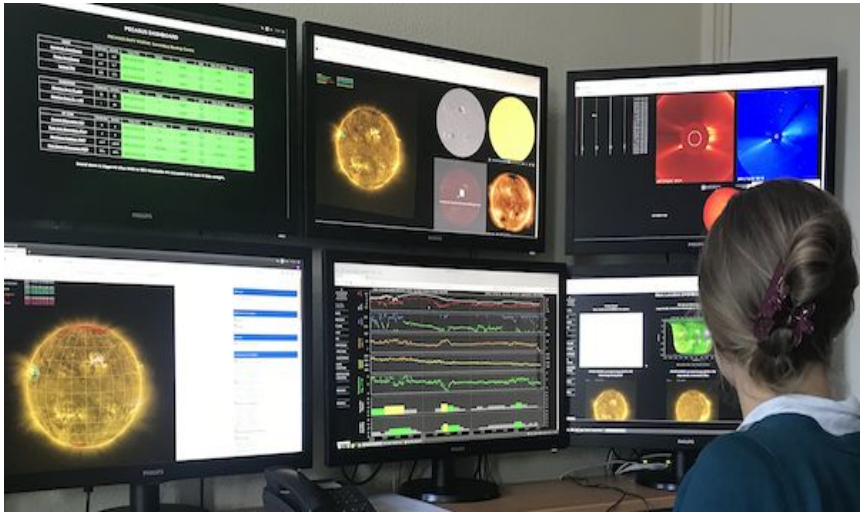
- **Robust System for First Hand Automatic Data Analysis**
- **Validation/Verification:** ***“We don’t want to miss Event”***



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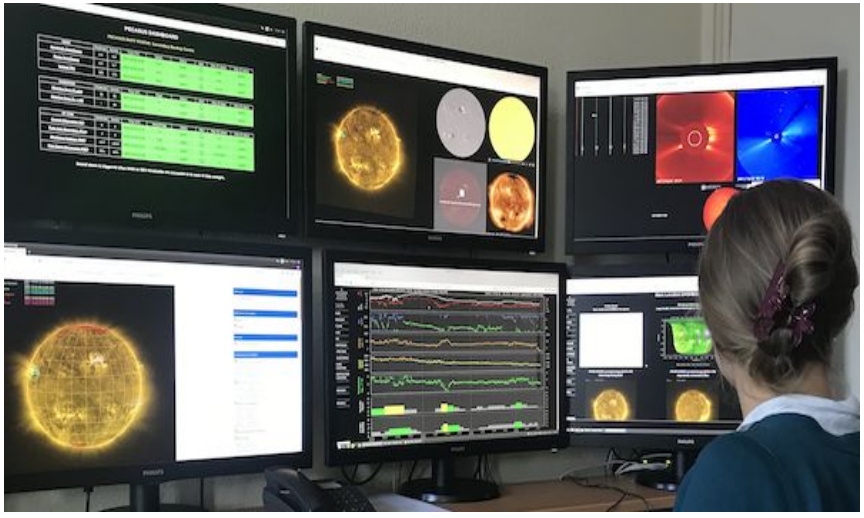
=> More Advence Services



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Solar Weather Expert Service Centre (S-ESC)

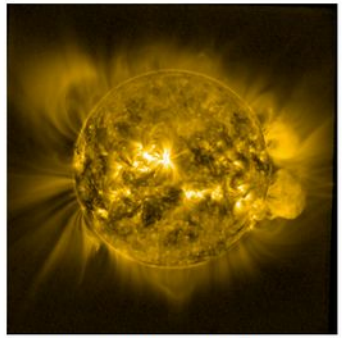
ESC Objectives | Contributions | Contributors

Mission Statement

The mission of the Solar Weather ESC (S-ESC) is to provide and develop the functionalities, capabilities and expertise in the domain of Solar Weather that are needed within the ESA SWE Network to achieve as a collaborative enterprise its mission of demonstrating and assessing the influences of Space Weather and informing and supporting end-users through the provision of accurate, reliable and timely products and (pre-)operational services, tailored to their requirements. The Solar Weather Expert Service Centre (S-ESC) thus provides, implements and supports the Solar Weather products and capabilities of the ESA SWE network. This includes the observation, monitoring, interpretation, modelling and forecasting of Solar Weather conditions with an emphasis on solar (sub-)surface and solar coronal features, events and processes that drive Space Weather in our solar system.

The source of most Space Weather perturbations can be directly linked to solar activity. Various solar phenomena and their manifestations in the solar wind need to be monitored in order to produce realistic Space Weather predictions. Solar flares, coronal mass ejections and coronal holes are all known to create space weather disturbances under certain conditions which can then in turn affect users' systems.

Phenomena such as these are ultimately driven by the Sun's magnetic field and are therefore regulated by the 11-year solar activity cycle, which is most obviously manifest in the sunspot cycle. High-quality data and state of the art computer modelling are essential tools to understand the processes and causality involved. This is greatly complicated by the fact that the near-Sun and near-Earth regions are rather better studied and understood than the ~150 million km of space in between them.



A stack of PROBA2/SWAP images, radially enhanced off-limb to show the extended corona in full wealth. (© Proba2/SWAP - ESA and Royal Observatory of Belgium)

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Mission

- Provsion of Space-Based & Ground-Based Data
- Provision of Products, Services & Advanced Modeling
- Addressing Knowledge Gaps
- Supporting and Informing End-Users

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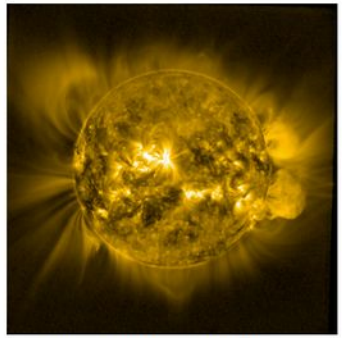

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UK Met Office (UKMO)
United Kingdom

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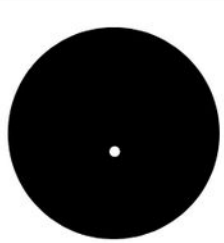
SIDC Latest Solar EUV flare detection

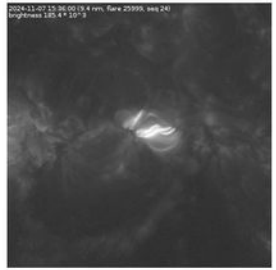
Solar flares are a sudden release of energy stored in inductive magnetic fields. The Solar Influences Data analysis Centre (SIDC) Extreme UltraViolet (EUV) flare detections offer a catalogue of flares detected in 9.4nm images from the Atmospheric Imaging Assembly by means of a region-based detection algorithm. The start, peak, end time as well as the flare location are provided. The algorithm runs as soon as level 1.5 synoptic quick-look data of on SDO/AIA 9.4nm data are available.

Table with latest EUV flare detection from 2024-11-07 13:19 UTC to 2024-11-08 13:19 UTC:

Start Time [UTC]	Peak Time [UTC]	End Time [UTC]	Peak Brightness DN/s	Estimated GOES X-ray Flare Class	Polar Coordinates
2024-11-07 13:24	2024-11-07 13:51	2024-11-07 13:54	10568.1	B4	(0,19 $R_\odot$; 158°)
2024-11-07 12:48	2024-11-07 13:36	2024-11-07 15:00	17508.8	B6	(0,99 $R_\odot$; -102°)
2024-11-07 14:27	2024-11-07 15:09	2024-11-07 16:27	343335	M1	(0,17 $R_\odot$; 177°)
2024-11-07 16:30	2024-11-07 16:36	2024-11-07 16:42	23960.9	B8	(0,15 $R_\odot$; -164°)
2024-11-07 15:36	2024-11-07 16:30	2024-11-07 17:06	10530.5	B4	(0,98 $R_\odot$; -101°)
2024-11-07 17:48	2024-11-07 17:54	2024-11-07 17:57	17020.3	B6	(0,52 $R_\odot$; -102°)
2024-11-07 17:54	2024-11-07 17:54	2024-11-07 17:57	3343.7	B1	(0,98 $R_\odot$; 76°)
2024-11-07 18:24	2024-11-07 18:27	2024-11-07 18:33	24802.4	B8	(0,91 $R_\odot$; 72°)
2024-11-07 17:36	2024-11-07 19:09	2024-11-07 22:00	71814	C2	(0,98 $R_\odot$; -102°)
2024-11-07 21:33	2024-11-07 21:36	2024-11-07 22:36			
2024-11-07 23:45	2024-11-07 23:48	2024-11-07 23:51			
2024-11-07 23:21	2024-11-08 00:30	2024-11-08 01:09			
2024-11-08 01:06	2024-11-08 01:06	2024-11-08 01:09			
2024-11-08 01:42	2024-11-08 01:42	2024-11-08 01:42			
2024-11-08 00:21	2024-11-08 01:15	2024-11-08 01:57			
2024-11-08 01:57	2024-11-08 01:57	2024-11-08 01:57			
2024-11-08 02:00	2024-11-08 02:03	2024-11-08 02:06			
2024-11-08 02:21	2024-11-08 03:09	2024-11-08 03:45			
2024-11-08 03:24	2024-11-08 03:36	2024-11-08 03:57			
2024-11-08 04:48	2024-11-08 04:51	2024-11-08 04:54			
2024-11-08 05:30	2024-11-08 05:30	2024-11-08 05:33			
2024-11-08 05:45	2024-11-08 05:45	2024-11-08 05:48			

Flare 25999





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SIDC Latest automated coronal hole detection

Coronal holes are regions of open magnetic field on the Sun which appear as dark patches on the surface of the Sun when viewed in Extreme-Ultra-Violet (EUV) and X-ray emission. The coronal holes are automatically detected in EUV solar images from SDO/AIA data at 193Å using the SPoCA suite software and a set of characteristics are extracted, including: area, time of the first and last detection in observations and location.

The latest SPoCA routine has been applied on 08 November 2024 at 02:01 UT and 5 coronal holes have been identified.

Coronal Hole - First detection: 2024-10-18 12:00 - Last detection: 2024-11-07 20:00 - Number of detections: 120

observation time	area [Mm^2]	area error [Mm^2]	location [degrees]
2024-11-07 20:00:05	196984	14827	Longitude:-8 Latitude: 61

Coronal Hole - First detection: 2024-10-29 12:00 - Last detection: 2024-11-07 20:00 - Number of detections: 54

observation time	area [Mm^2]	area error [Mm^2]	location [degrees]
2024-11-07 20:00:05	210690	24087	Longitude:9 Latitude: -43

Coronal Hole - First detection: 2024-11-06 20:00 - Last detection: 2024-11-07 20:00 - Number of detections: 7

observation time	area [Mm^2]	area error [Mm^2]	location [degrees]
2024-11-07 20:00:05	31621	4101	Longitude:-52 Latitude: -40

Coronal Hole - First detection: 2024-11-06 08:00 - Last detection: 2024-11-07 20:00 - Number of detections: 8

observation time	area [Mm^2]	area error [Mm^2]	location [degrees]
2024-11-07 20:00:05	17116	1962	Longitude:-12 Latitude: -26

Coronal Hole - First detection: 2024-11-05 00:00 - Last detection: 2024-11-07 20:00 - Number of detections: 18

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SIDC Solarmap

This service allows the user to display solar features (such as sunspot groups, coronal holes, filaments, flares, and coronal mass ejections) on the solar disc. The user can select features and navigate back and forth in time: the closest available observations and images will be displayed. A Heliocentric Earth equatorial (HEEQ) grid of 15 degrees can also be added to refine the feature location on the surface. Additional characteristics of the features (such as time of observation, coordinates of the specified locations, etc.) are also indicated. Additionally, the user can overplot specific locations of interest onto the solar disc. A viewpoint other than Earth can also be specified from a pre-defined list of planetary and spacecraft locations.

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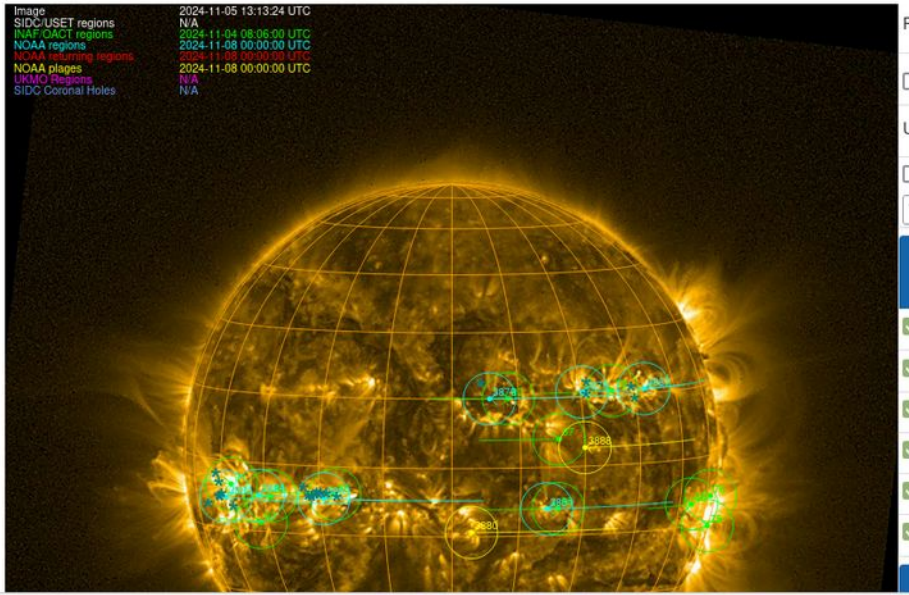


Pre-defined location

Mars

User-defined location

Long: 10 Lat: 10

Sunspot groups and Regions

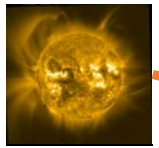
- SIDC/USET Sunspot group
- INAF/OACT Sunspot group
- NOAA Active Regions
- NOAA Expected Active Regions
- NOAA Plage
- UKMO Regions

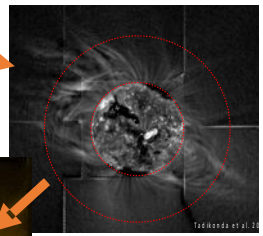
Solar Flares

What is JEDI?

JEDI harnesses the development and recent breakthroughs in EUV Imaging of the Middle Corona

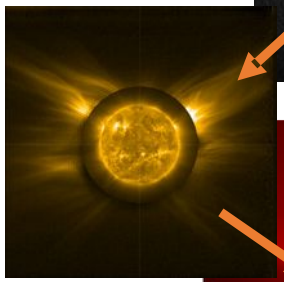
PROBA2/SWAP: Revealed complex coronal connectivity out to 2 R⊙.



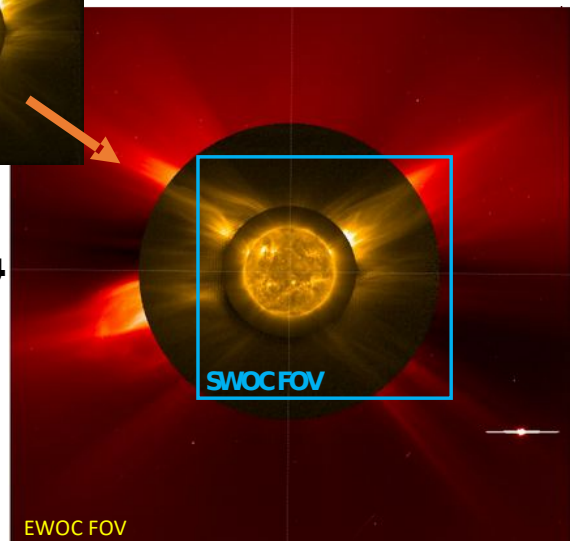


GOES/SUVI: Used offset pointing to build composite images revealing complex structure out to 3 R⊙.

Solar Orbiter/EUI: Using an occulter, revealed EUV coronal structure out to 5 R⊙.



JEDI* is the NEXT-GENERATION EUV Imaging.** EWOC has 10x greater throughput than Solar Orbiter, producing images of the ***Middle Corona out to 6 R⊙ with 8 min synoptic cadence.



- ***JEDI*** is a next-generation high cadence, multi-thermal EUV Imager to study...
  - ***Extreme space weather events***
  - ***Ground State of Space Weather***
    - the ***Solar Wind***

Federated products from the UK Met Office (UKMO)

UKMO Solar active region analysis

The Solar active region analysis is undertaken by the Met Office Space Weather Operations Centre (MOSWOC) forecaster using GONG H-alpha imagery and 4k SDO AIA and HMI images from the SDO website, along with Helioviewer software to determine the heliographic parameters (such as location in latitude and longitude) of any active regions. The forecaster analyses the sunspots Using the Zurich and Mount Wilson classification methodologies. The active solar regions are identified by using the NOAA SWPC active region numbers.

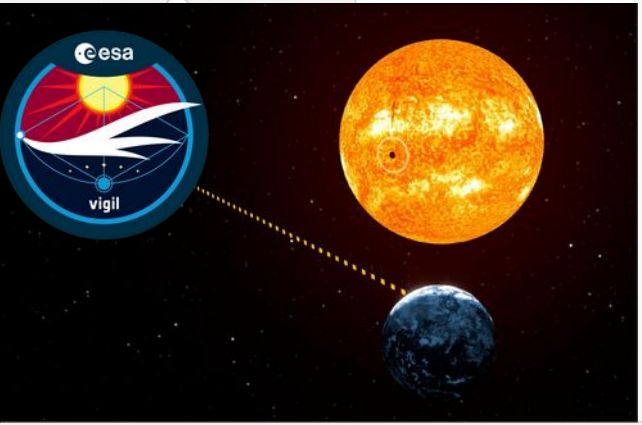
SOLAR REGION ANALYSIS

NOAA No.	Location 08-11-2024 08:00 UTC	Lo	Area	Z	LL	NN	Mag Type	Growth
3878	N16W69	133	130	Hsx	3	2	Alpha	Nil
3879	N15W47	111	710	Hhx	5	1	Alpha	Decrease
3881	S09W60	124	110	Dao	5	5	Beta	Nil
3883	S07W12	76	640	Fki	16	18	Beta-Gamma-Delta	Nil
3884	S07E08	56	20	Hsx	2	1	Alpha	Nil
3886	S09E20	44	370	Eai	15	24	Beta-Delta	Decrease
3889	S11E65	359	510	Eki	14	23	Beta-Gamma-Delta	Nil
NEW	S15E50	14	10	Axx	1	1	Alpha	Nil

Forecaster commentary

There are currently eight sunspot regions on the visible disc, including one unnumbered group. AR3887 has recently rotated be and has been removed from the analysis.

AR3879 is the largest region on the disc, and is a simple Hhx in the northwest. AR3883, in the centre-disc, has seen some shearing and



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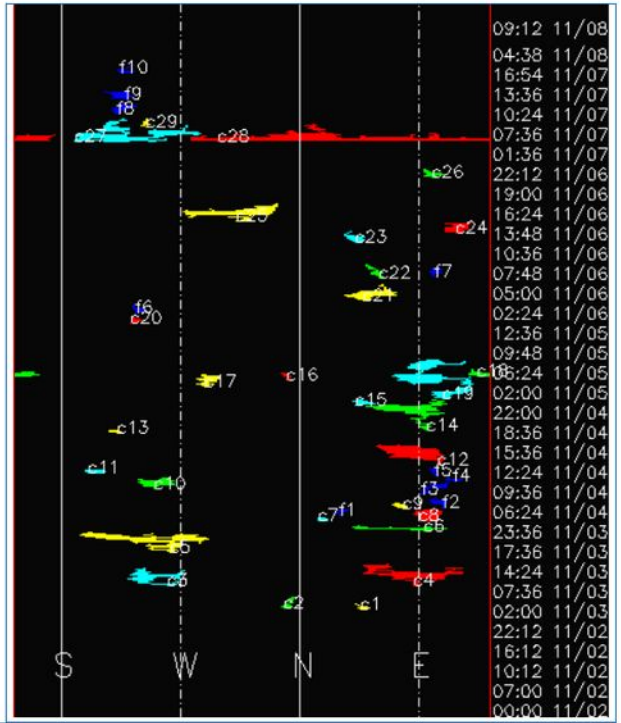
Federated products from the Solar Influences Data analysis Center (ROB)

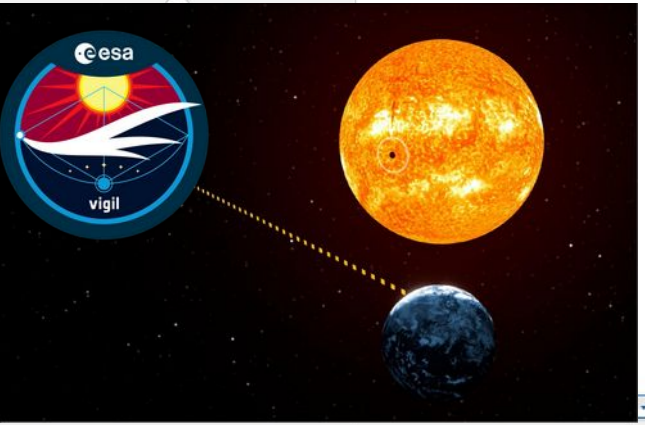
Help Similar products Related products Latest Query

SIDC/CACTus Automated near-real-time CME detection

CACTus is a software routine that autonomously detects coronal mass ejections (CMEs) in image sequences from SOHO/LASCO. The output is a list of events, similar to the classic catalogs, with principal angle, angular width and velocity estimation for each CME.

Run Information	
Run time	2024-11-08T10:29:11
first-last file (c2)	First: 2024-11-02T00:00:07.794 Last: 2024-11-08T09:12:07.729
first-last file (c3)	First: 2024-11-02T06:54:07.399 Last: 2024-11-08T07:30:07.386
Runid	51955963
Version	2.5.0
Instruments	[LASCO c2, LASCO c3]
Minimal CME Width	5 degrees





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- Catania Astrophysical Observatory (INAF/OACT)
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- Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing (NOA/IAASARS)
- Institute for Data Science (FHNW/I4DS)
- Kanzelhöhe Observatory for Solar and Environmental Research (UNIGRAZ/KSO)
- Multi Experiment Data & Operation Center (UPSaclay/MEDOC)
- Solar Influences Data analysis Center (ROB/SIDC)
- Solar Patrol Service (ASU CAS/SPS)
- UK Met Office (UKMO)

49 Products

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Adapted many Products

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esa

ESOC

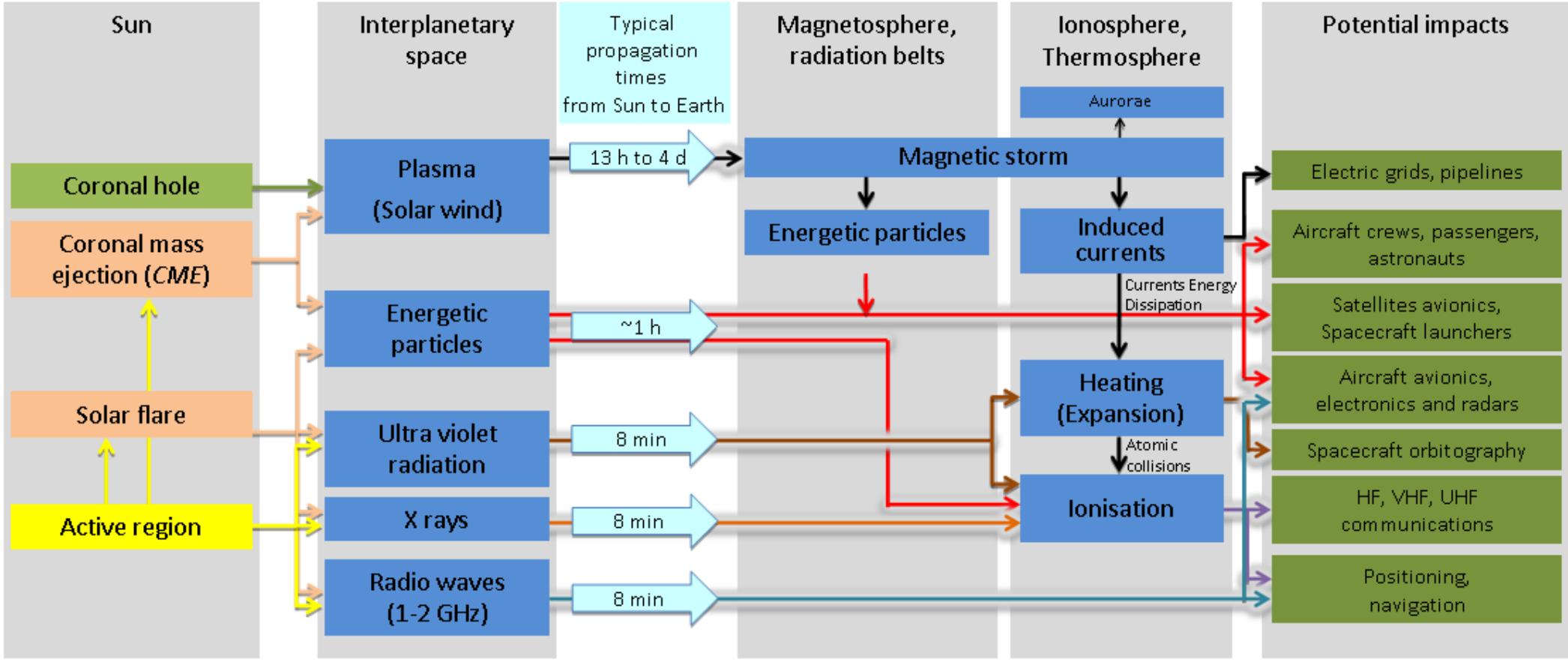
European Space Operations Centre - Robert-Bosch-Strasse 5 - D-64293 Darmstadt - Germany

T +49 (0)6151 900 - F +49 (0)6151 90495 - www.esa.int

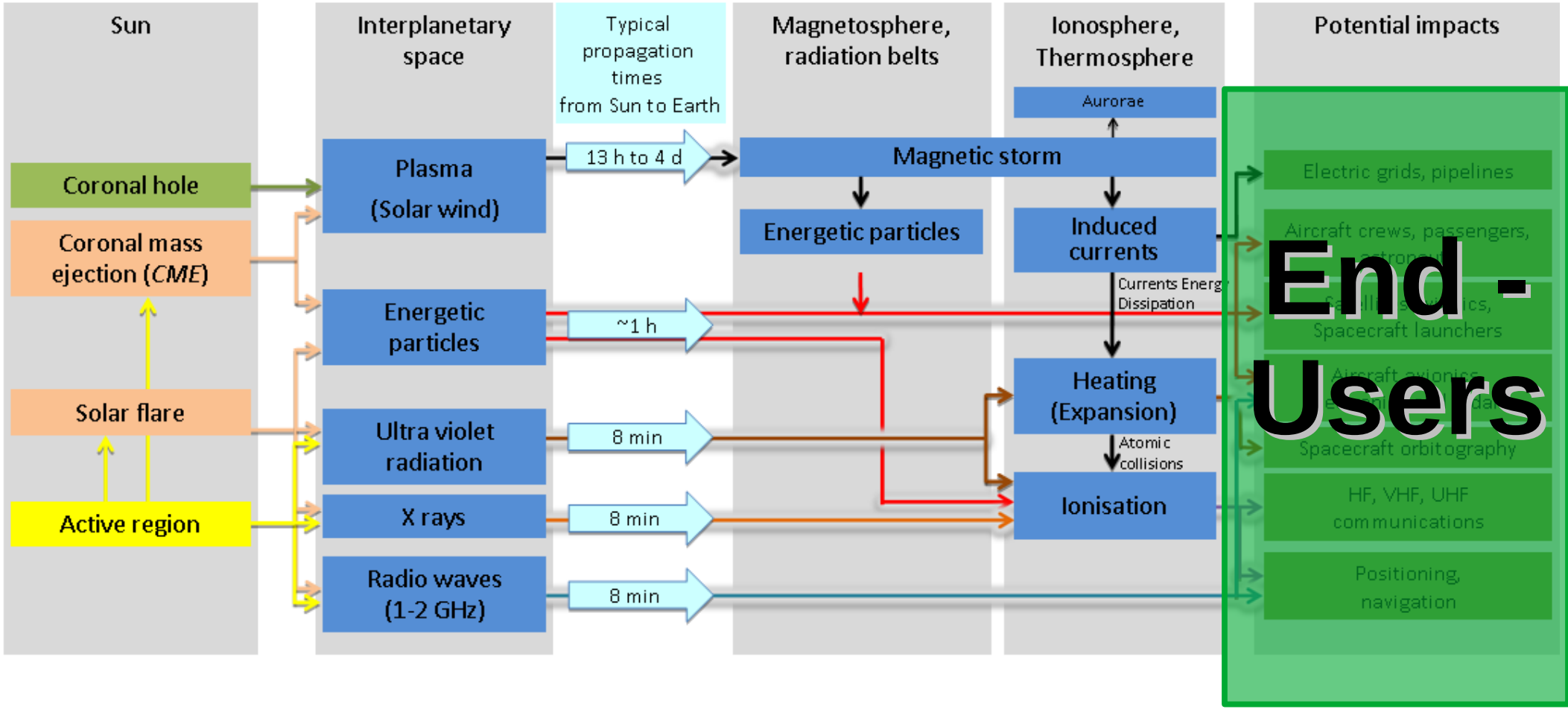
PLAN

ESC Definition and Development Plan - Solar Weather Expert Service Centre

Who are our End-Users? How is the data Flow



Who are our End-Users? How is the data Flow



Who are our End-Users? How is the data Flow

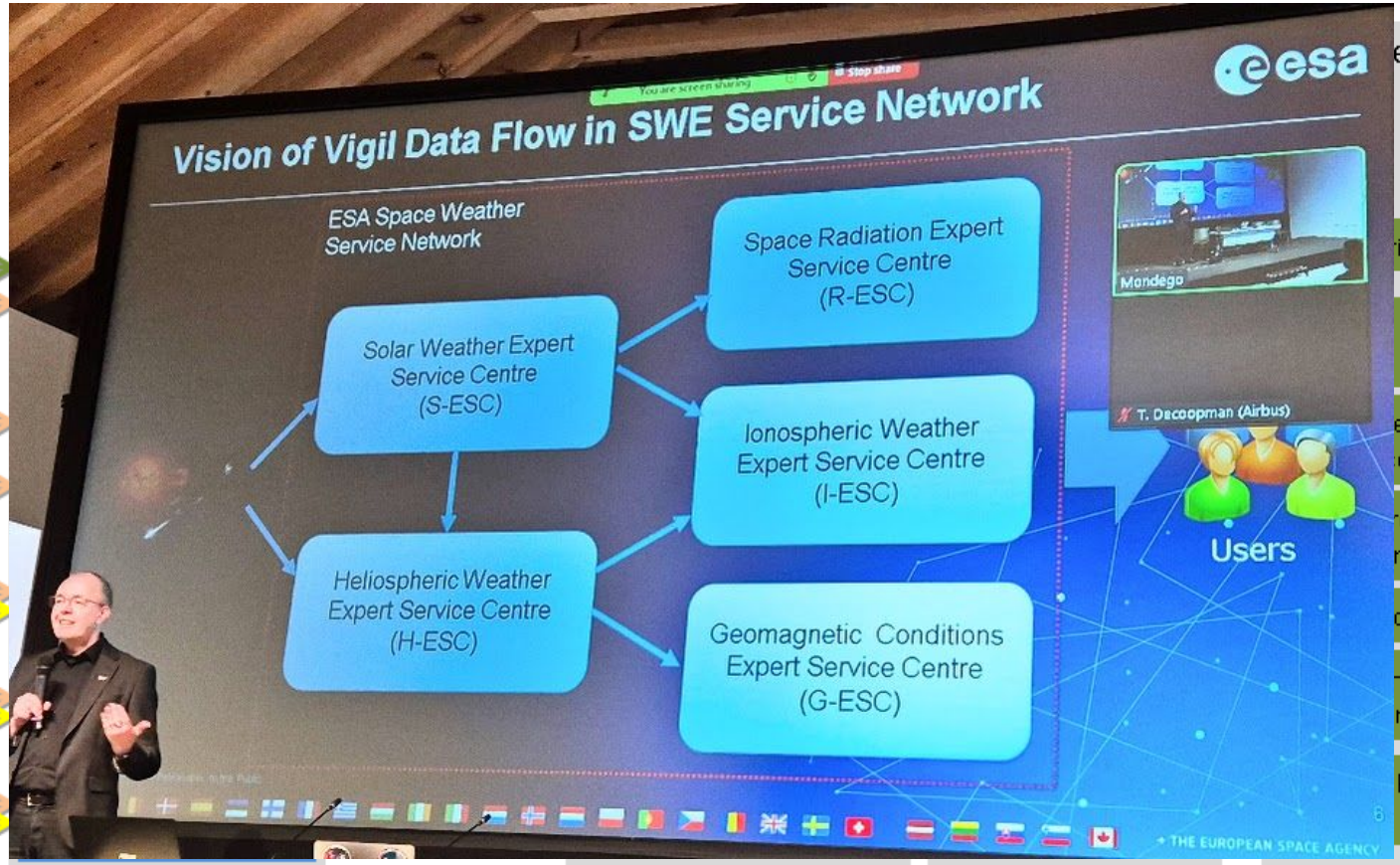
Sun

Coronal hole

Coronal mass ejection (*CME*)

Solar flare

Active region



ential impacts

ic grids, pipelines

crews, passengers, astronauts

ellites avionics, ecraft launchers

craft avionics, ronics and radars

craft orbitography

HF, VHF, UHF mmunications

Positioning, navigation

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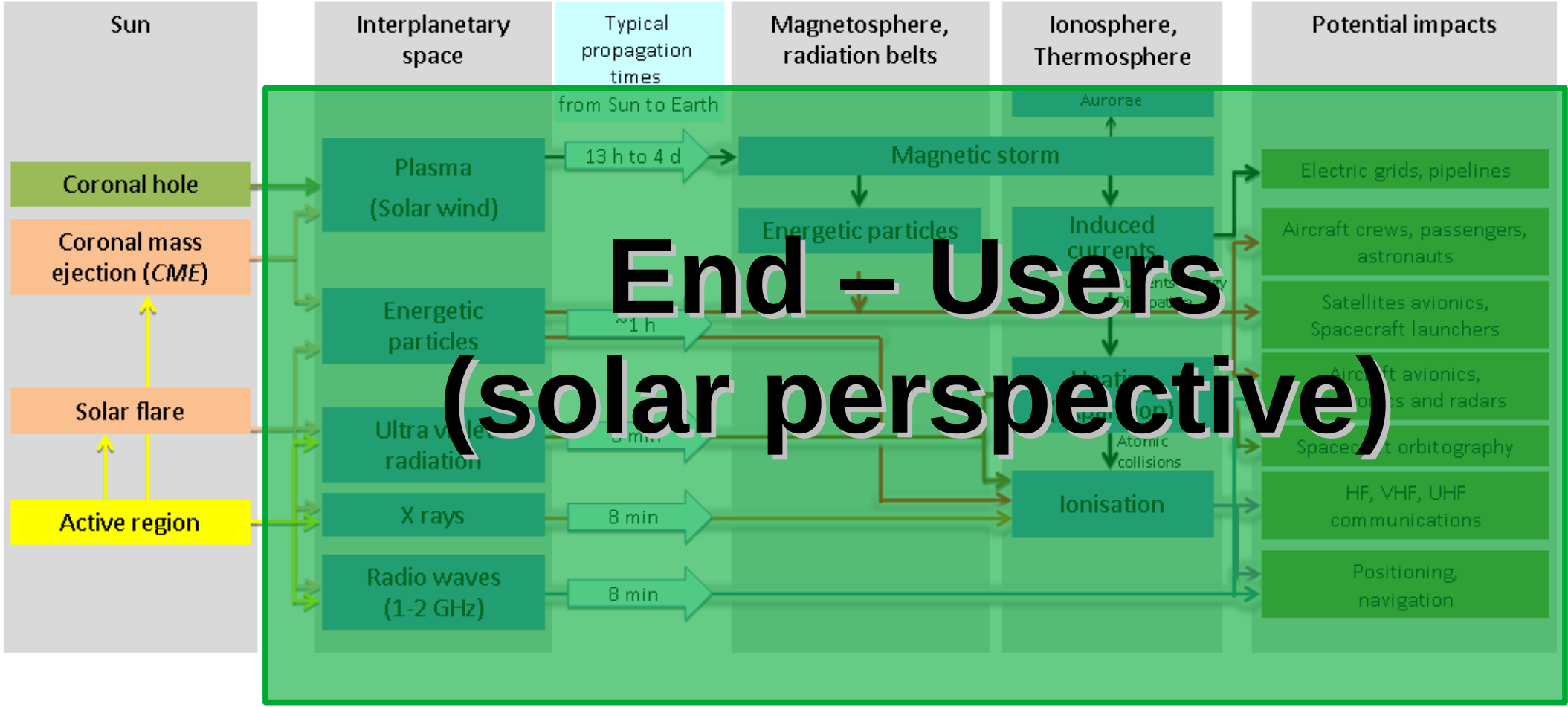

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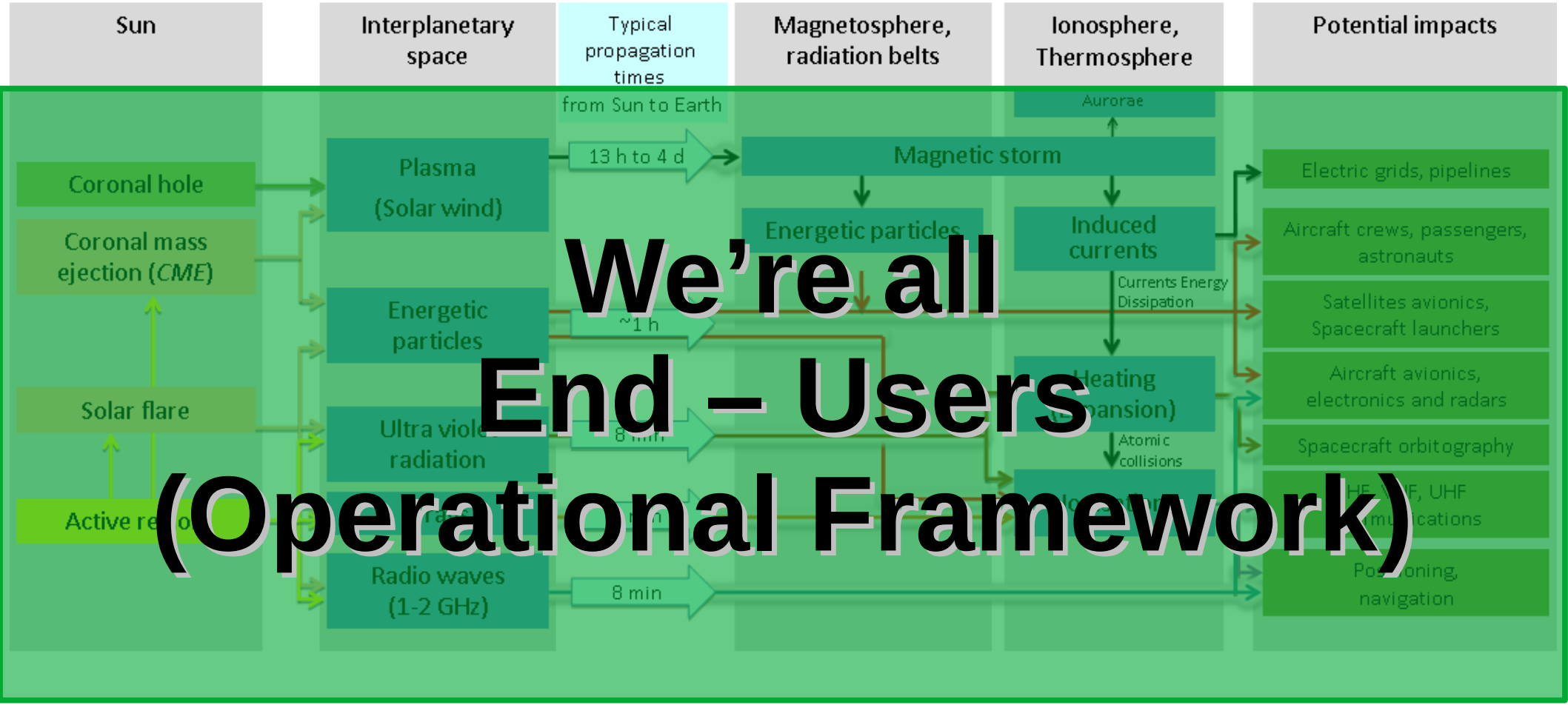


We're all End – Users (Operational Framework)

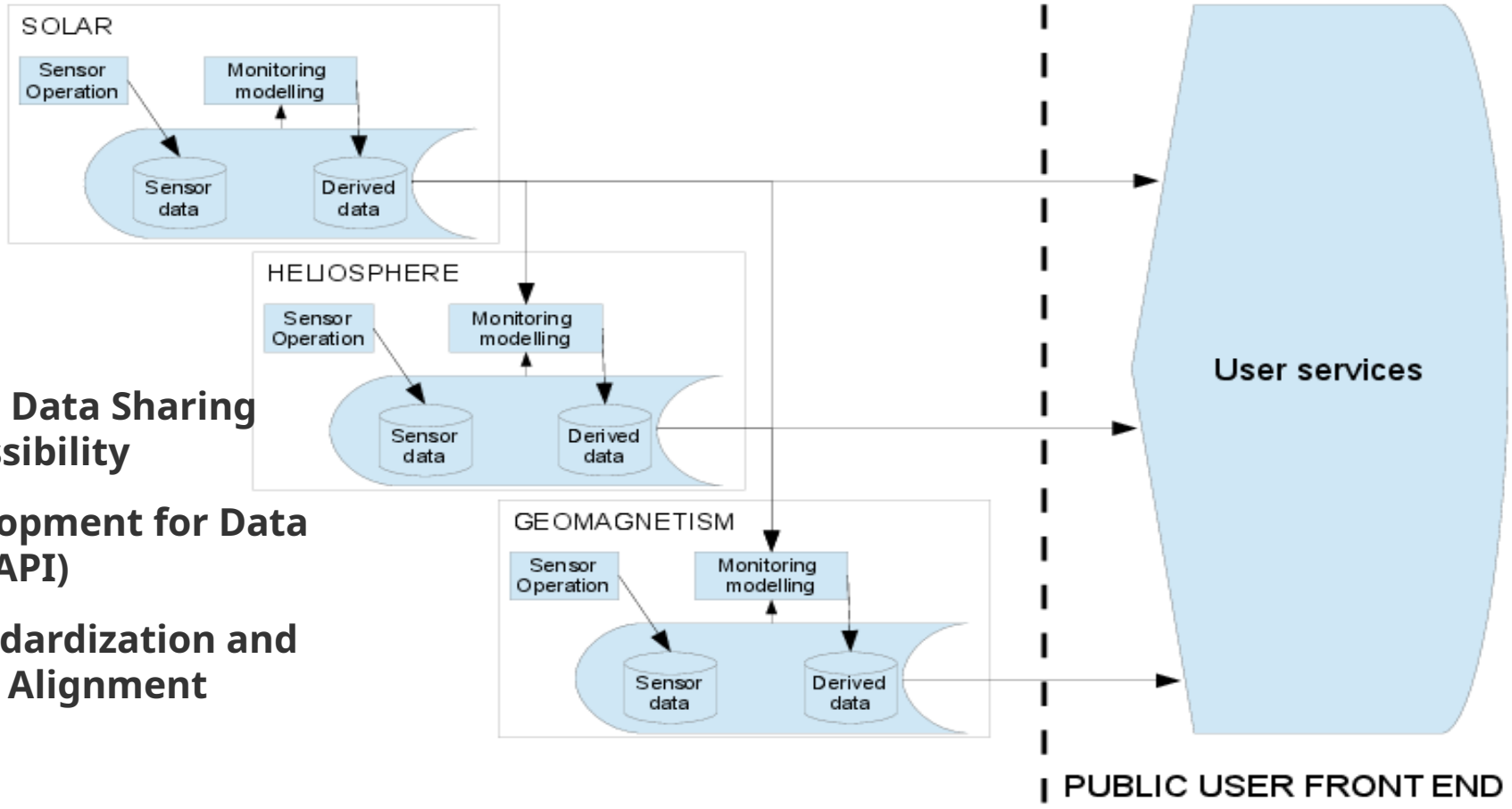
Interoperability in Solar Data Products: Insights from the Solar Weather Expert Service Centre (S-ESC) & the SIDC Expert Group

TDM12: ESA Space Weather Service Network Products Interoperability Discussion Forum
Wed 6/11 14:15-15:15 – ESWW 2024

Interoperability Efforts & Challenges

https://swe.ssa.esa.int/solar-weather

- **Real-Time Data Sharing and Accessibility**
- **API Development for Data Access (HAPI)**
- **Data Standardization and Metadata Alignment**



Yes, interoperability provides significant added value to space weather data

- **Standardization Across Data and Metadata:**
  - WMO’s WIGOS (WMO Integrated Global Observing System) metadata standards, ensuring data consistency
  - Creation and Definition of Standardized Formats.
  - Integration with WIS (WMO Information System) global data distribution, ensuring solar data is widely
- **Data Access:** Enhanced API Access for Flexible and User-Friendly APIs, more work to be done.

EUROPEAN SPACE WEATHER WEEK 2024

Coimbra, Portugal (4 – 8 November 2024)

– TDM13 – Towards Space Weather Operational Governance in Europe: Lessons Learned from Natural Hazard Management

Thu 7/11 16:15-17:15, room: C1D – Conventual

Type: Panel Forum

Convenors: Alexi Glover, Quentin Verspieren, Sara Dalledonne

R&D → R2O → O2R → R&D → R2O → O2R → R&D

- Solar Weather ESC withing SWESNET
  - R&D → R2O
  - Advance Pre-Operational system
  - Excellent Poof of concept
- Space Weather Operations Center
  - Operational Service
  - O2R → R&D

Pre-Operational Services

Operational Services

R&D → R2O → O2R → R&D → R2O → O2R → R&D

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Operational Services

R&D → R2O → O2R → R&D → R2O → O2R → R&D

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Operational Services

NEW Pre-Operational Services

R&D → R2O → O2R → R&D → R2O → O2R → R&D

Operational Data has Scientific Value

&

Science Data can be used Operationally

NEW Knowledge, Research & Development

Operational Services

NEW Pre-Operational Services

Thank you!

ESC Coordinator

Judith de Patoul (ROB)

Expert Groups

Catania Astrophysical Observatory (OACT)
Istituto Nazionale Di Astrofisica (INAF)
Italy

Institut de recherche sur les lois fondamentales de l'Univers (IRFU)
Commissariat a l'Energie Atomique et aux énergies alternatives, Paris-Saclay (CEA)
France

Institute for Data Science (I4DS)
University of Applied Sciences and Arts Northwestern (FHNW)
Switzerland

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University of Graz (UNIGRAZ)
Austria

Research Center for Astronomy and Applied Mathematics (RCAAM)
Academy of Athens (AOA)
Greece

Solar Patrol Service (SPS)
Astronomical Institute of the Czech Academy of Sciences (ASU CAS)
Czech Republic