

Royal Belgian Institute for Space Aeronomy  
Institut royal d'Aéronomie Spatiale de Belgique  
Koninklijk Belgisch Instituut voor Ruimte-Aeronomie

# COMESEP, SEPForecast and other SEP related activities at BIRA-IASB

Mark Dierckxsens

8th CCMC Workshop

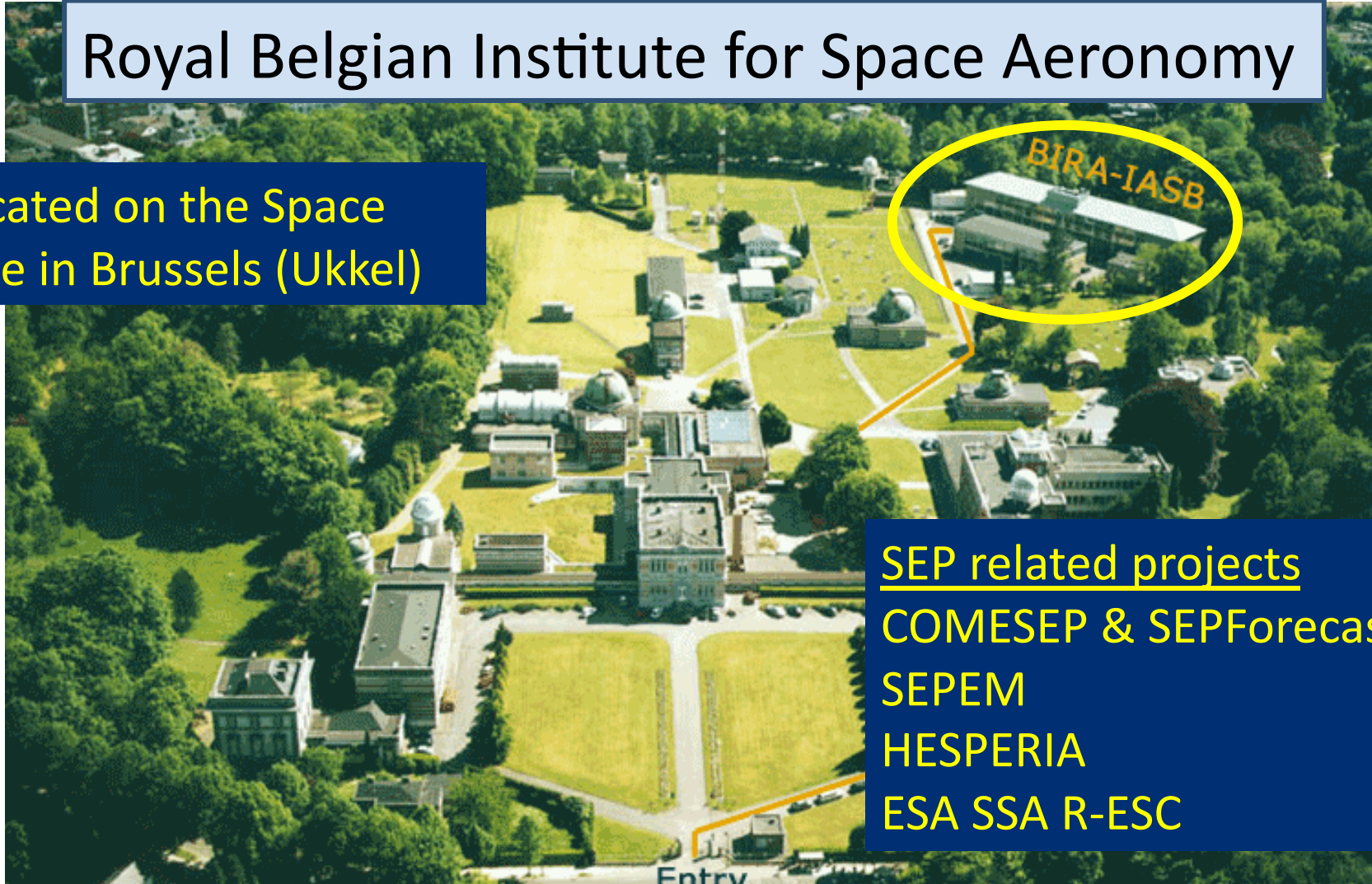
April 10-15, 2016



# BIRA-IASB

Royal Belgian Institute for Space Aeronomy

Located on the Space Pole in Brussels (Ukkel)



SEP related projects  
COMESSEP & SEPForecast  
SEPEM  
HESPERIA  
ESA SSA R-ESC

# COMESEP & SEPFORCAST

# The COMESEP Project

COronal Mass Ejections and Solar Energetic  
Particles: forecasting the space weather impact

<http://www.comesep.eu/>

- European Commission 7th Framework Programme (FP7)
- Starting date: 01 Feb. 2011
- Duration: 36 months
- Coordinator: Norma B. Crosby (BIRA-IASB)
- 7 Teams and 3 External Collaborators

*This project has receiving funding from the European  
Commission FP7 Project COMESEP (263252).*



## Overall Goal

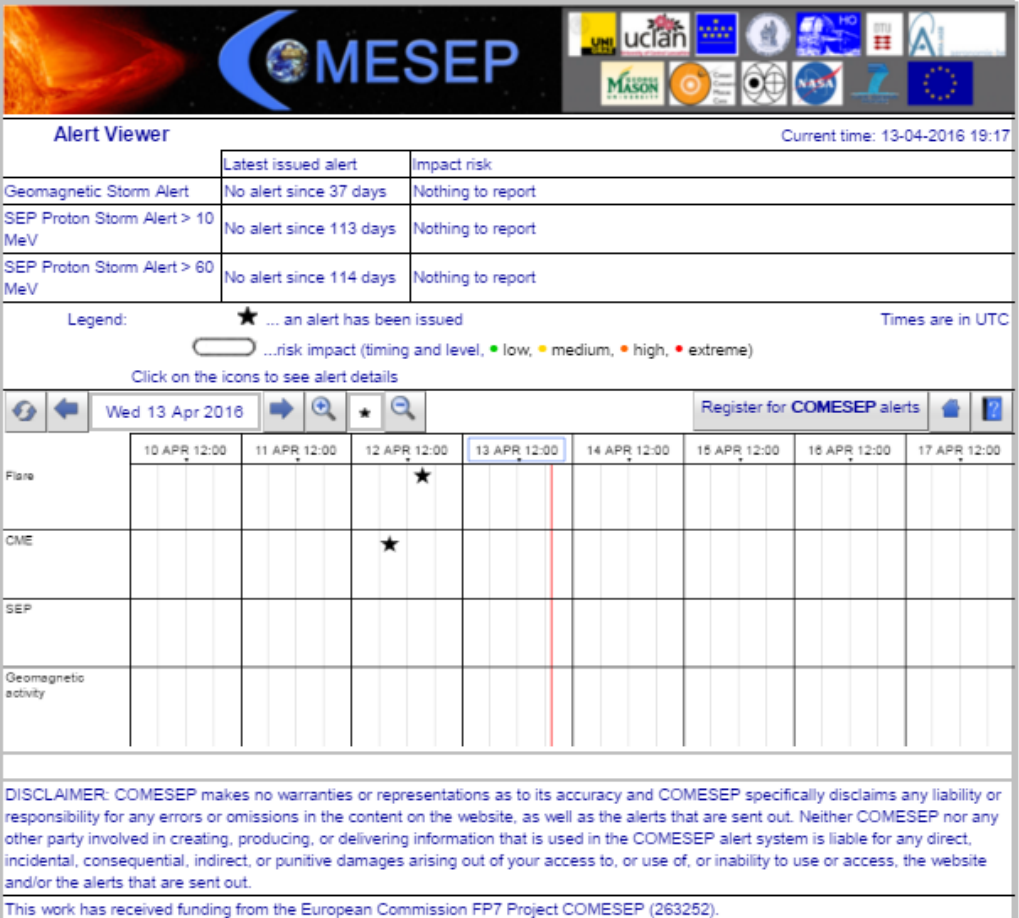
- Build an operational space weather alert system to forecast SEP radiation storms and geomagnetic storms based on risk analysis

## Main Objectives

- Optimize models and forecasting methods based on scientific results
- Link SEP and inter-planetary CME forecast tools with real-time automated CME detection
- Integrate scientific results, individual detection tools and models into an automated “start-to-end-service” alert system
- Disseminate alerts to the space weather community.

<http://www.comesep.eu/alert>

- Launched in November 2013
- Provides alerts for
  - Geomagnetic storms:
    - “Event based”
    - “Next 24 hours”
  - SEP (proton) storms:
    - $E > 10$  MeV
    - $E > 60$  MeV
- Alerts displayed on web interface
- Alerts can be received through email subscription



The screenshot shows the COMESEP Alert Viewer interface. At the top, there is a banner with the COMESEP logo and various partner logos including UHI, uclan, European Union, NASA, and others. Below the banner, the current time is 13-04-2016 19:17. The main content area is titled 'Alert Viewer' and contains a table with the following data:

	Latest issued alert	Impact risk
Geomagnetic Storm Alert	No alert since 37 days	Nothing to report
SEP Proton Storm Alert > 10 MeV	No alert since 113 days	Nothing to report
SEP Proton Storm Alert > 60 MeV	No alert since 114 days	Nothing to report

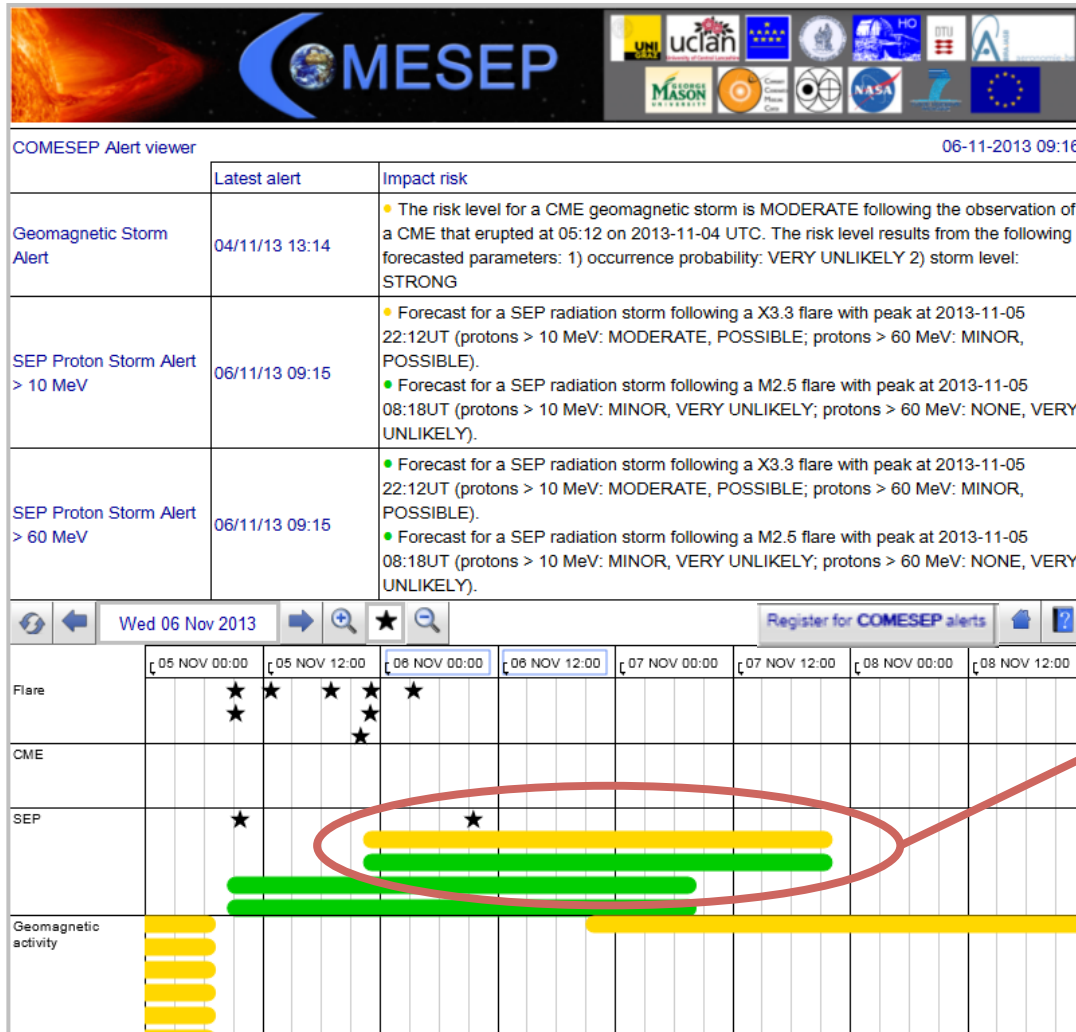
Legend: ★ ... an alert has been issued  
 ○ ...risk impact (timing and level, ● low, ● medium, ● high, ● extreme)  
 Click on the icons to see alert details

The interface also features a navigation bar with a date selector set to 'Wed 13 Apr 2016' and a 'Register for COMESEP alerts' button. Below this is a grid showing activity from 10 APR 12:00 to 17 APR 12:00. The grid has four rows: Flare, CME, SEP, and Geomagnetic activity. Stars (★) are present in the 'Flare' and 'CME' rows for the 12 APR 12:00 time slot. A vertical red line is positioned at 13 APR 12:00.

DISCLAIMER: COMESEP makes no warranties or representations as to its accuracy and COMESEP specifically disclaims any liability or responsibility for any errors or omissions in the content on the website, as well as the alerts that are sent out. Neither COMESEP nor any other party involved in creating, producing, or delivering information that is used in the COMESEP alert system is liable for any direct, incidental, consequential, indirect, or punitive damages arising out of your access to, or use of, or inability to use or access, the website and/or the alerts that are sent out.

This work has received funding from the European Commission FP7 Project COMESEP (263252).

# COMESEP Alert System



COMESEP Alert viewer 06-11-2013 09:16

	Latest alert	Impact risk
Geomagnetic Storm Alert	04/11/13 13:14	<ul style="list-style-type: none"> <li>The risk level for a CME geomagnetic storm is MODERATE following the observation of a CME that erupted at 05:12 on 2013-11-04 UTC. The risk level results from the following forecasted parameters: 1) occurrence probability: VERY UNLIKELY 2) storm level: STRONG</li> </ul>
SEP Proton Storm Alert > 10 MeV	06/11/13 09:15	<ul style="list-style-type: none"> <li>Forecast for a SEP radiation storm following a X3.3 flare with peak at 2013-11-05 22:12UT (protons &gt; 10 MeV: MODERATE, POSSIBLE; protons &gt; 60 MeV: MINOR, POSSIBLE).</li> <li>Forecast for a SEP radiation storm following a M2.5 flare with peak at 2013-11-05 08:18UT (protons &gt; 10 MeV: MINOR, VERY UNLIKELY; protons &gt; 60 MeV: NONE, VERY UNLIKELY).</li> </ul>
SEP Proton Storm Alert > 60 MeV	06/11/13 09:15	<ul style="list-style-type: none"> <li>Forecast for a SEP radiation storm following a X3.3 flare with peak at 2013-11-05 22:12UT (protons &gt; 10 MeV: MODERATE, POSSIBLE; protons &gt; 60 MeV: MINOR, POSSIBLE).</li> <li>Forecast for a SEP radiation storm following a M2.5 flare with peak at 2013-11-05 08:18UT (protons &gt; 10 MeV: MINOR, VERY UNLIKELY; protons &gt; 60 MeV: NONE, VERY UNLIKELY).</li> </ul>

Wed 06 Nov 2013 Register for COMESEP alerts

	05 NOV 00:00	05 NOV 12:00	06 NOV 00:00	06 NOV 12:00	07 NOV 00:00	07 NOV 12:00	08 NOV 00:00	08 NOV 12:00
Flare		★ ★ ★ ★	★					
CME			★					
SEP		★		★				
Geomagnetic activity								

**Alert Info**

Name : alert: SEP:SEPFORCAST@08-01-2014 05:00:02 #195  
 Alert id : 20140107\_192002\_6f2f13c58e@SEPFORCAST.oma.be  
 Status : normal  
 Emitter : SEP Forecast Alerts from COMESEP  
 Emitter href : http://www.comesep.eu/sepforecast  
 Subject : SEP  
 Subject topic : SEP  
 Subject description : Forecast for a SEP radiation storm following a X1.2 flare with peak at 2014-01-07 18:30UT, and a CME with lift-off at 2014-01-07 18:36UT (protons > 10 MeV: MODERATE, LIKELY; protons > 60 MeV: MODERATE, LIKELY).

**Impact Likelihoods**

Impact	ImpactType	Severity	Probability	Confidence	Inspect
1	Radiation60M...	Moderate	Likely	0.30	<a href="#">select</a>
2	Radiation10M...	Moderate	Likely	0.30	<a href="#">select</a>

**Target**

Target	ReceivedAt	AtEarliest	AtStrongest	AtLatest
Earth	08/01/14 05:00	07/01/14 18:40	07/01/14 21:50	09/01/14 18:30

**Alert Details**

Details, Group and Parameter Names | DataType | Units | Value

- Details
  - CactusParameters
    - angular\_width: FLOAT, degrees, 360
    - median\_speed: FLOAT, km/s, 1369
    - onset\_time: DATETIME, 2014-01-07T18:36
    - principle\_angle: FLOAT, degrees, 144
  - FlareMailParameters
    - flux: FLOAT, 0.000125
    - magnitude: STRING, X1.2
    - peak\_time: DATETIME, 2014-01-07T18:30
  - SolarDemonParameters
    - latitude: FLOAT, degrees, -12.359
    - longitude: FLOAT, degrees, 8.432

**Parent Child Hierarchy**

Show only direct parent and child alerts  
 Show whole graph of related parent and child alerts

Alert	Parents	Subject	Received	Producer	Inspe
1	---	flare	07-01-2014 19:09	solar demon	<a href="#">select</a>
2	---	flare	07-01-2014 19:19	flaremail	<a href="#">select</a>
3	---	CME	08-01-2014 04:59	CACTUS	<a href="#">select</a>
4(★)	3, 1, 2	SEP	08-01-2014 05:00	SEPFORCAST	

# COMESEP Risk Matrix

- Geomagnetic and SEP radiation storm alerts are based on the COMESEP definition of risk.

**Risk Levels:**

**L = LOW**

**M = MEDIUM**

**H = HIGH**

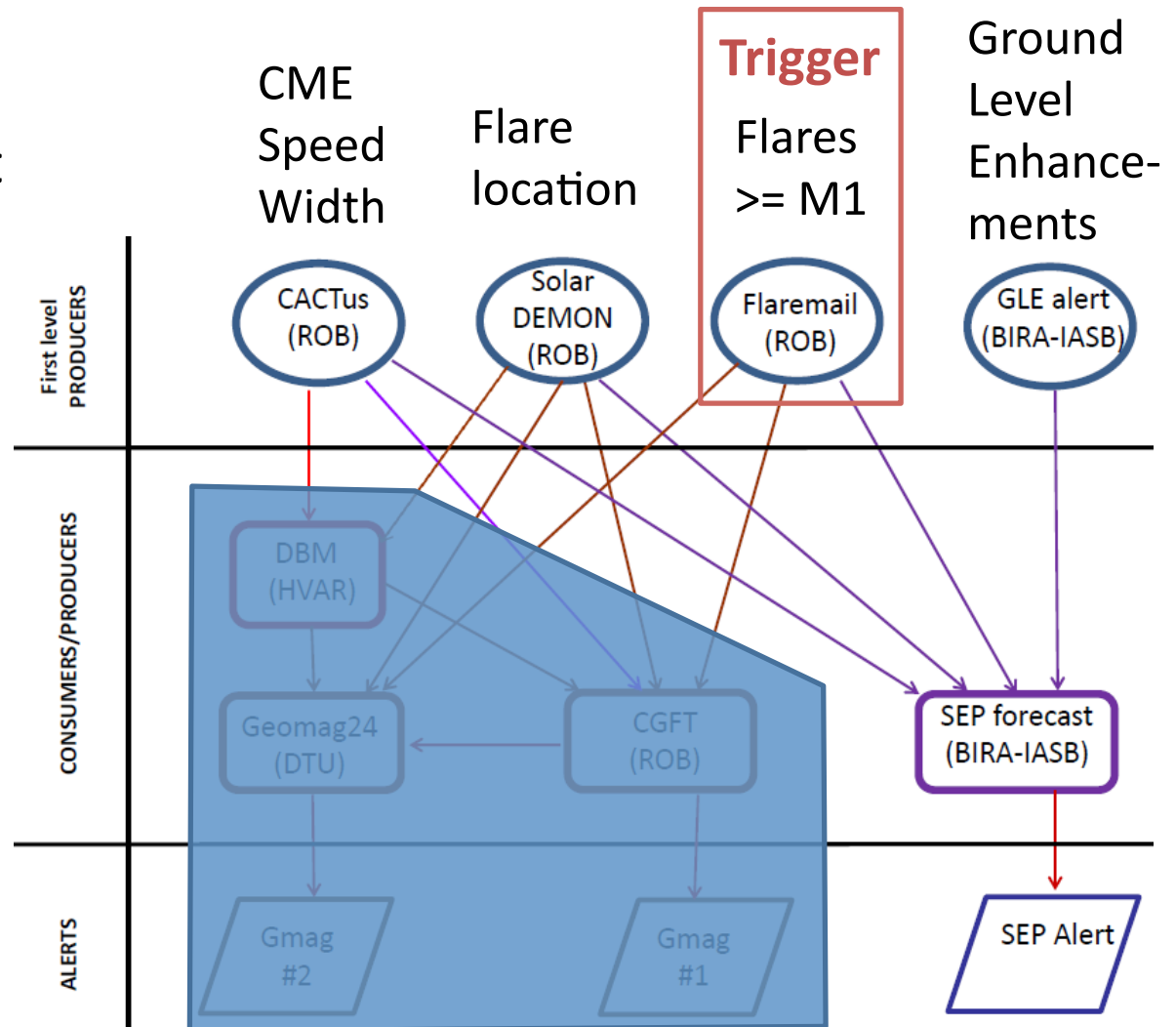
**E = EXTREME**

Arrival of CME / Likelihood of occurrence	Ongoing (100%)	L	M	H	H	E	E
	Very likely (90-100%)	L	M	H	H	E	E
	Likely (70-90%)	L	M	M	H	H	E
	Possible (40-70%)	L	L	M	M	H	E
	Unlikely (10-40%)	L	L	M	M	H	H
	Very Unlikely (0-10%)	L	L	L	M	M	H
Storm Level	None	Minor	Moderate	Strong	Severe	Extreme	
Geomagnetic  Dst  in nT	<50	50-100	100-200	200-300	300-400	>400	
SEP peak flux > 10 MeV in s <sup>-1</sup> sr <sup>-1</sup> cm <sup>-2</sup>	<10 <sup>1</sup>	10 <sup>1</sup> -10 <sup>2</sup>	10 <sup>2</sup> -10 <sup>3</sup>	10 <sup>3</sup> -10 <sup>4</sup>	10 <sup>4</sup> -10 <sup>5</sup>	>10 <sup>5</sup>	
SEP peak flux > 60 MeV in s <sup>-1</sup> sr <sup>-1</sup> cm <sup>-2</sup>	<7.9×10 <sup>-2</sup>	7.9×10 <sup>-2</sup> - 1.4	1.4 - 2.5×10 <sup>1</sup>	2.5×10 <sup>1</sup> - 4.5×10 <sup>2</sup>	4.5×10 <sup>2</sup> - 7.9×10 <sup>3</sup>	>7.9×10 <sup>3</sup>	
Kp	<5	5	6	7	8	9	



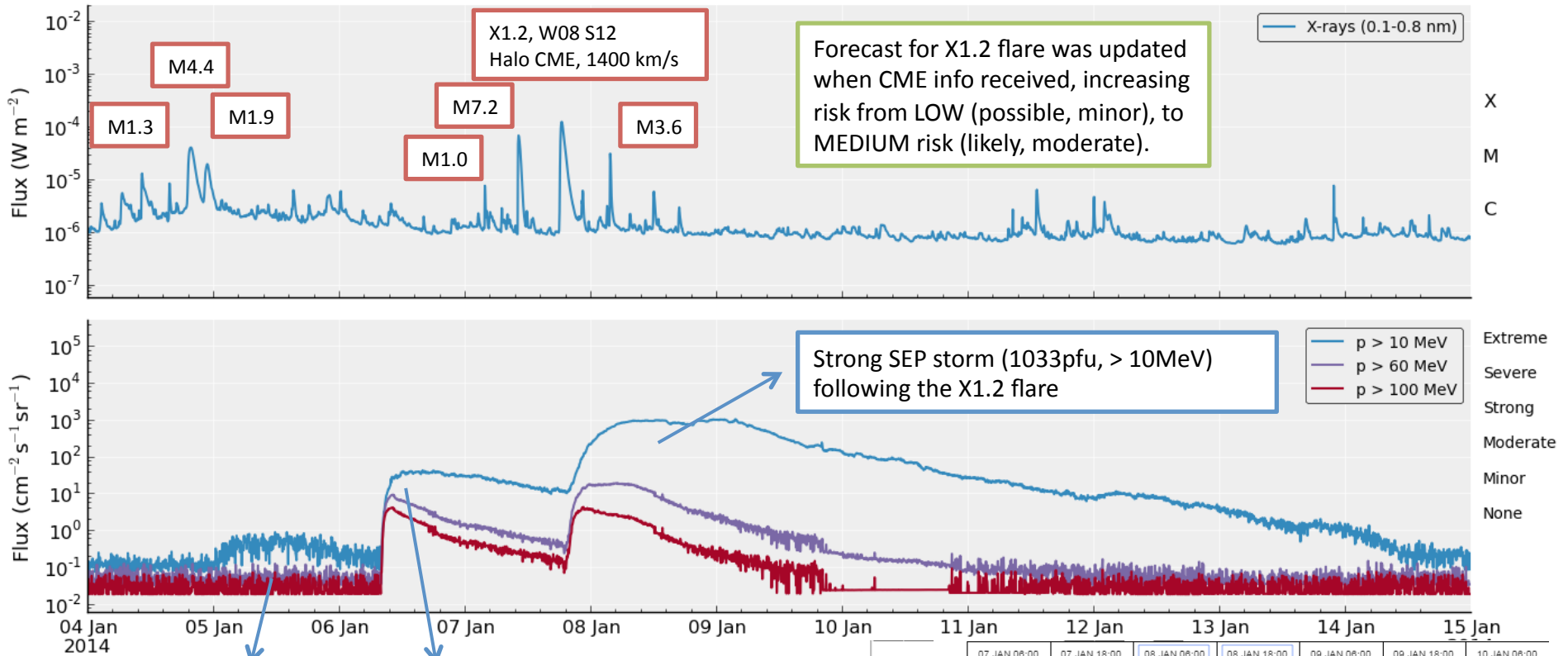
# COMESEP SEPFforecast

- SEPFforecast depends on various other alert tools developed within COMESEP
- Alerts pass through COMESEP server
- SEP alerts are updated if new information becomes available.
- Runs fully automatic without human intervention



- Predictions for occurrence probability and storm level based on an analysis of SEP events during solar cycle 23 [Dierckxsens et al., Sol. Phys. 290, 841 (2015)]
- The SEP intensity time profiles near Earth are based on Solar Particle Radiation SWx (SPARX), which combines outputs from previously run test particle model simulations [Marsh *et al.* SW 13, 386 (2015)]
- Initial evaluated on SC22 and SC24 events (up to 2013) performed during the project
- More detailed performance studies under way, including operational performance and will be part of a forthcoming publication

# SEPFforecast 4-15 January 2014

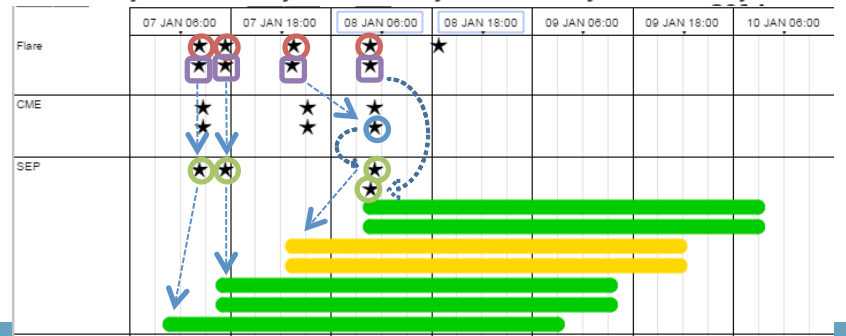


Very small increase in proton flux. Most likely following the M4.4 flare

Minor SEP storm (42pfu, > 10MeV) Most likely associated with C2 flare beyond the limb + halo CME with speed 500 km/s.

All 3 forecasts:  
 - Probability (very) unlikely  
 - Level: minor  
 → risk: LOW

No forecast as flare was < M1, the flare was "hidden" by the Sun and appeared much weaker than it probably was.



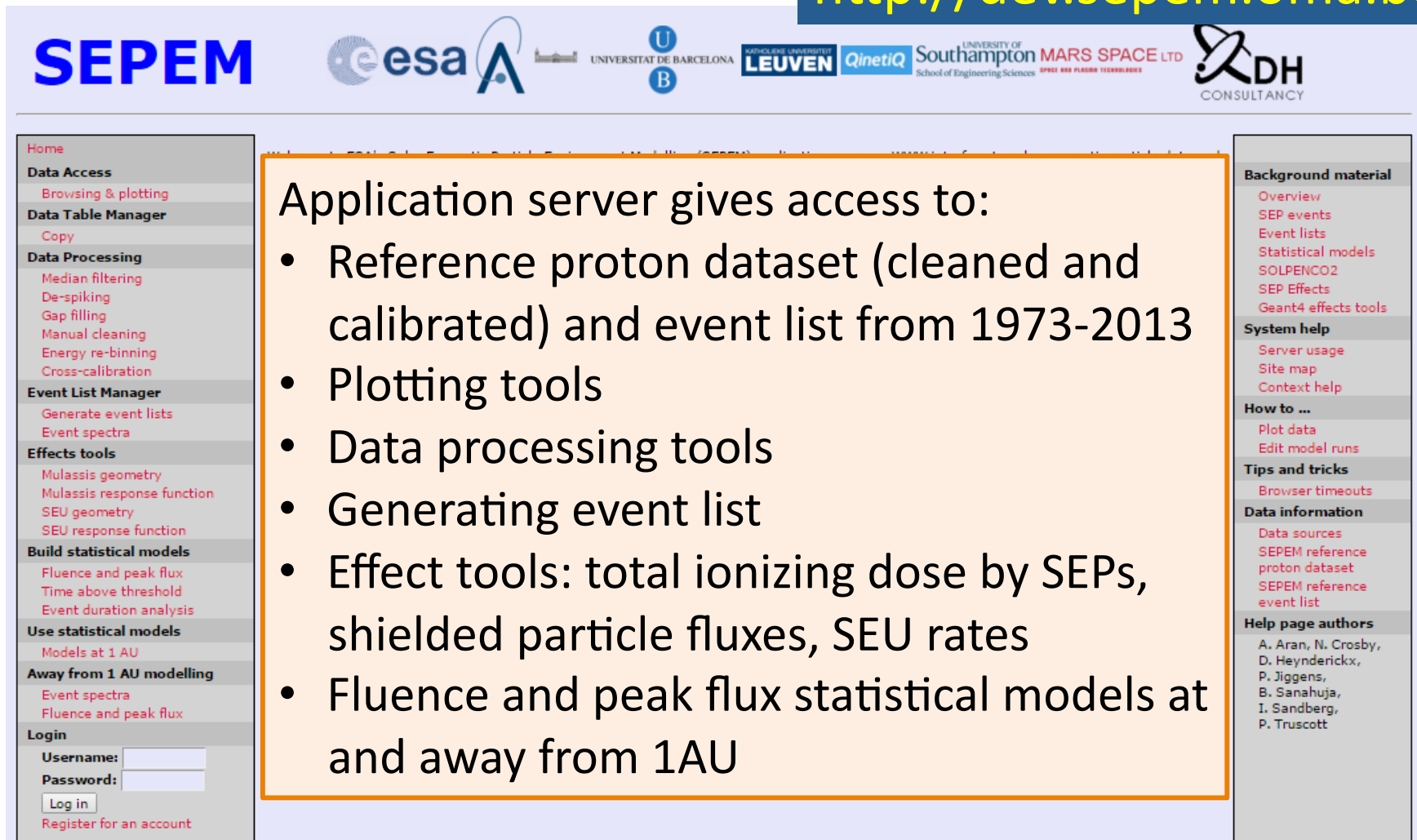
# SEPEM

# The SEPEM Project

Solar Energetic Particle Environment Modelling  
<http://sepem.aeronomie.be/>

- ESA funded project
- Coordinator: Norma B. Crosby (BIRA-IASB)
- 7 consortium members
- ESA/ESTEC Contract No. 20162/06/NL/JD





The screenshot shows the SEPEM Application server interface. At the top, there are logos for SEPEM, ESA, Universitat de Barcelona, Katholieke Universiteit Leuven, QinetiQ, University of Southampton, Mars Space Ltd, and DH Consultancy. The main content area is a list of navigation links organized into categories. A central text box highlights the application server's capabilities.

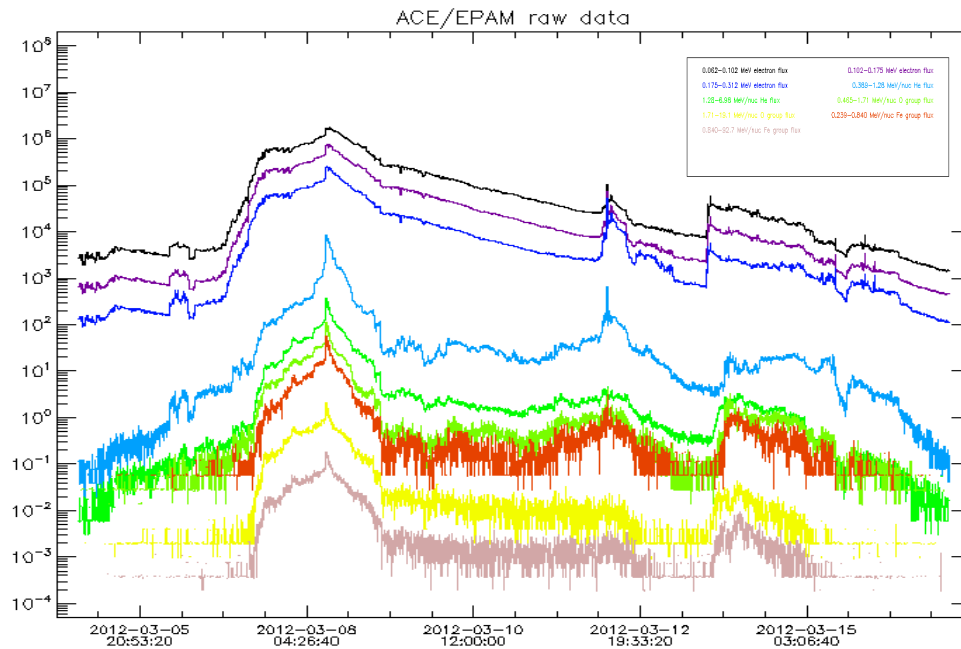
**Application server gives access to:**

- Reference proton dataset (cleaned and calibrated) and event list from 1973-2013
- Plotting tools
- Data processing tools
- Generating event list
- Effect tools: total ionizing dose by SEPs, shielded particle fluxes, SEU rates
- Fluence and peak flux statistical models at and away from 1AU

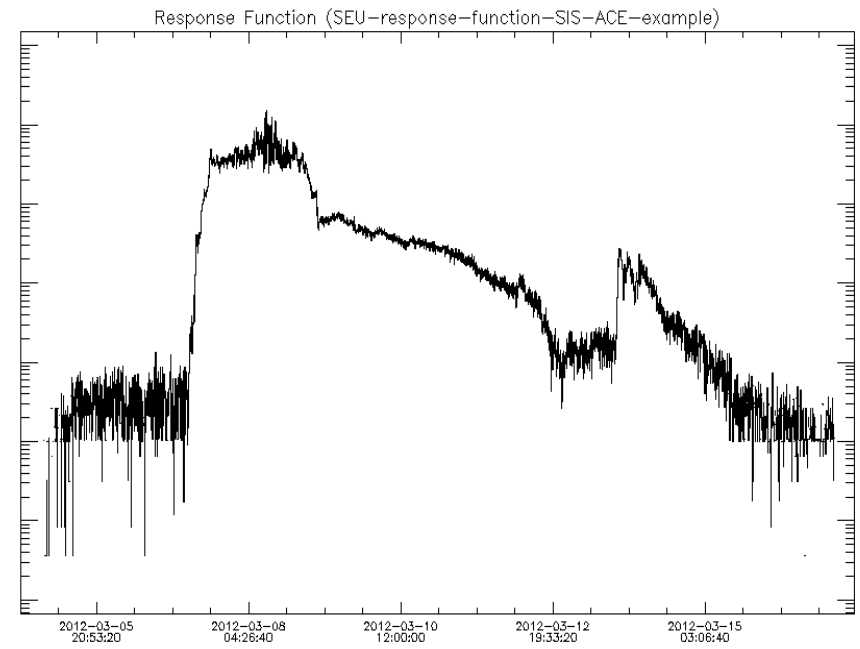
**Navigation menu categories:**

- Home
- Data Access
  - Browsing & plotting
- Data Table Manager
  - Copy
- Data Processing
  - Median filtering
  - De-spiking
  - Gap filling
  - Manual cleaning
  - Energy re-binning
  - Cross-calibration
- Event List Manager
  - Generate event lists
  - Event spectra
- Effects tools
  - Mulassis geometry
  - Mulassis response function
  - SEU geometry
  - SEU response function
- Build statistical models
  - Fluence and peak flux
  - Time above threshold
  - Event duration analysis
- Use statistical models
  - Models at 1 AU
- Away from 1 AU modelling
  - Event spectra
  - Fluence and peak flux
- Login
  - Username:
  - Password:
  - Log in
  - Register for an account
- Background material
  - Overview
  - SEP events
  - Event lists
  - Statistical models
  - SOLPENCO2
  - SEP Effects
  - Geant4 effects tools
- System help
  - Server usage
  - Site map
  - Context help
- How to ...
  - Plot data
  - Edit model runs
- Tips and tricks
  - Browser timeouts
- Data information
  - Data sources
  - SEPEM reference proton dataset
  - SEPEM reference event list
- Help page authors
  - A. Aran, N. Crosby, D. Heynderickx, P. Jiggins, B. Sanahuja, I. Sandberg, P. Truscott

## Electron, He, O, Fe flux profiles at L1



## SEU rate (oxygen data)



Generated by SEPTEM

2012-03-05 00:30 - 2012-03-17 02:25

# HESPERIA

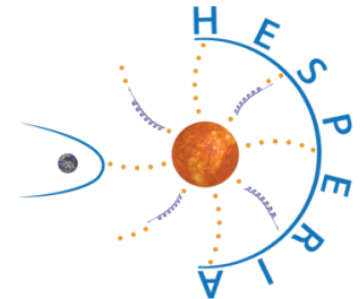


# The HESPERIA Project

## High Energy Solar Particle Events Forecasting and Analysis

<http://www.hesperia-space.eu/>

- Horizon 2020 - PROTEC-1-2014 'Space Weather'
- Starting date: May 1, 2015
- Duration: 24 months
- Coordinator: Olga Malandraki (National Observatory of Athens)
- 9 European Teams and 5 External Collaborators



*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637324.*

# HESPERIA Objectives

- Develop two SEP forecasting systems based upon proven concepts (UMASEP, REleASE)
- Develop SEP forecasting tools using electromagnetic proxies of the gamma-ray emission
- Exploitation of FERMI high-energy gamma-ray observations and SEP measurements near 1 AU
- Develop inversion of neutron monitor data to physical parameters to compare with space-borne measurements
- Study statistical relations among the parent solar events and SEPs for solar cycles 23 & 24
- Provide recommendations for future SEP forecasting systems

# HESPERIA SEP Statistical Analysis

- Event catalogue based on SOHO/ERNE 14-17 MeV proton channel for period 1996-2015:
  - onset & peak time, peak intensity
  - associated flare & CME
  - overview plots
- Comparison between SC23 and SC24 of occurrence rate and correlations
- Comparison of composition measurements
- The first results published via the Consortium Server in May 2016

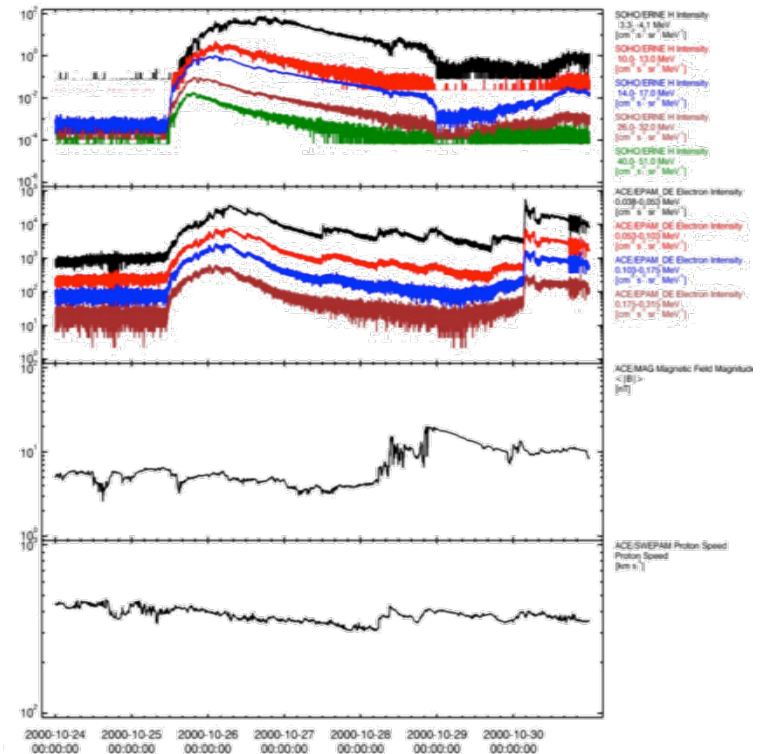
SOHO/  
ERNE

ACE/EPAM

B  
Magnitude

Proton  
speed

25 October, 2000



# R-ESC

## The Expert Service Centre for Space Radiation

<http://swe.ssa.esa.int/web/guest/space-radiation>

- Funded through P2-SWE-I as part of ESA's Space Situational Awareness (SSA) Space Weather (SWE) Network program
- Lead by BIRA-IASB
- Coordinator: Norma B. Crosby
- Deputy coordinator: Mark Dierckxsens
- Network consists of 11 members
- ESA Contract No. 4000113187/15/D/MRP

# R-ESC Objectives

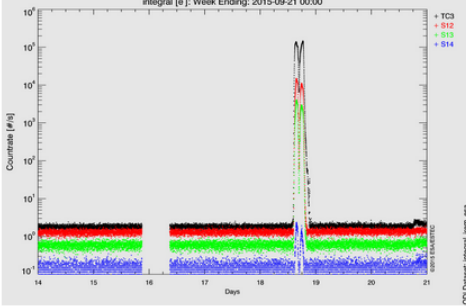
- R-ESC domain:
  - Space particle radiation (ambient plasma, solar energetic particles, radiation belts, galactic cosmic rays) and micron-size particulates (from meteoroids and space debris) in the near-Earth space environment
  - All types of phenomena induced effects on technologies and biological systems
- Activities:
  - Further develop the existing ESC beyond the results of the SSA Preparatory Program
  - New Service Product Implementation and Provision
  - ESC Network Expansion

**Space Radiation Expert Service Centre**

*This page provides access to the latest data, products and analysis tools from the SSA SWE Space Radiation Expert Service Centre.*

**Latest data**

Latest ESA SREM particle data. (electron countrate @ Integral spacecraft, data also available @ Herschel, Planck, Proba-1 & Rosetta spacecraft)  
Integral [e-]; Week Ending: 2015-09-21 00:00



**ESC tools and products**

- AVIDOS**
  - Radiation dosimetry for aviation
- ANeMoS**
  - Ground Level Enhancement (GLE) event alert
  - Multi-station Neutron Monitor data

**Related applications**

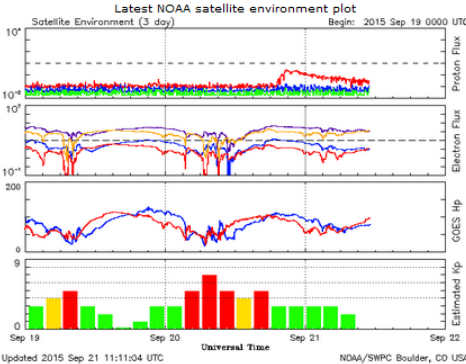
- SPENVIS**
- SWENET**
- SEDAT**

**ESC Coordinator**  
Norma Crosby (BIRA-IASB)

**Participating Expert Groups**

- Radiation Hardness Assurance and Space Weather (RAS)  
Seibersdorf Laboratories GmbH, Austria
- BIRA-IASB Space Weather Services (D52)  
Belgian Institute for space Aeronomy, Belgium
- Athens Neutron Monitor Station (ANeMoS)  
National and Kapodistrian University of Athens, Greece

**Latest NOAA satellite environment plot**  
Satellite Environment (3 day) Begin: 2015 Sep 19 00:00 UTC



**Latest Ground Level Enhancement Alerts**  
Real Time GLE ALERT System  
National & Kapodistrian University of Athens / Cosmic Ray Group  
ISNet Company  
DATA UPDATED EVERY MINUTE

General Alert Status: [ 00 ] Total [ 34 ]

- Existing Products (7)
- New Products (28)

# R-ESC Existing Products

Radiation exposure estimation at aircraft altitude (AVIDOS)	Seibersdorf Laboratories
GLE alert service and Multi-station Neutron Monitor data	University of Athens
Space Environment Information System (SPENVIS)	BIRA-IASB
Space Environment Data System (SEDAT)	developed by Rutherford Appleton Laboratory
Environment Information System for Operations (SEISOP)	initially developed by a consortium led by DEIMOS Space S.L.U
European Debris Impact Database (EDID)	developed by Etamax Space GmbH based on software by Space Systems Finland



# R-ESC New Products

PROBA-V Energetic Particle Telescope (EPT) derived products	Center for Space Radiations, Université Catholique de Louvain
Standard Radiation Environment Monitor (SREM) data	Paul Buehler
Radiation environment & accumulated dose at ISS and SEP aviation radiation exposure	Institute of Aerospace Medicine, German Aerospace Center
Very high-energy SEP environment and event catalogue	Space Research Laboratory, University of Turku
Electron Radiation Belt Model at GEO, MEO, LEO	Mullard Space Science Laboratory, University College London
COMESSEP Alert System	BIRA-IASB
SEP Application Server	
SWIFF plasmasphere electron density distribution model	

# SEP SCOREBOARD

- SEP scoreboard under development by BIRA-IASB, Met Office and CCMC
- Identified three different cases of SEP forecasts:
  - Model simulations (with long running time)
  - Event based forecasts (e.g. triggered by flare, CME, ...)
  - Continuous forecasts (e.g. 1-day, 3-day,...)
- XML Schema developed for submitting forecasts
- Need to setup the evaluation scheme and define test cases
- Forecasters and model providers will be contacted
- We invite everyone who is interested to join

- BIRA-IASB is (has been) involved with several SEP related projects
- COMESEP: alert system and SEP forecast
- SEP-EM: data calibration/cleaning, statistical models and engineering tools
- HESPERIA: statistical analysis of SEP events
- R-ESC: coordination of network and product provision
- SEP scoreboard: setting up the scoreboard

# BACKUP SLIDES

# COMESEP Team Members

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## *Solar Energetic Particles [SEP] Teams:*

- Institut d'Aeronomie Spatiale de Belgique, Belgium [PI: Norma Crosby, Project Coordinator]
- National Observatory of Athens, Greece [PI: Olga Malandraki]
- University of Central Lancashire, United Kingdom [PI: Silvia Dalla]

## *Coronal Mass Ejections [CME] Teams:*

- Universitaet Graz, Austria [PI: Astrid Veronig]
- Koninklijke Sterrenwacht van België, Belgium [PI: Eva Robbrecht]
- Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia [PI: Bojan Vrsnak]
- Technical University of Denmark, Denmark [PI: Susanne Vennerstrøm]

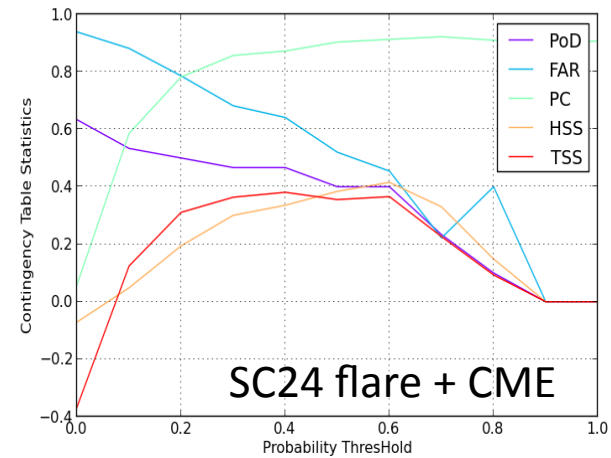
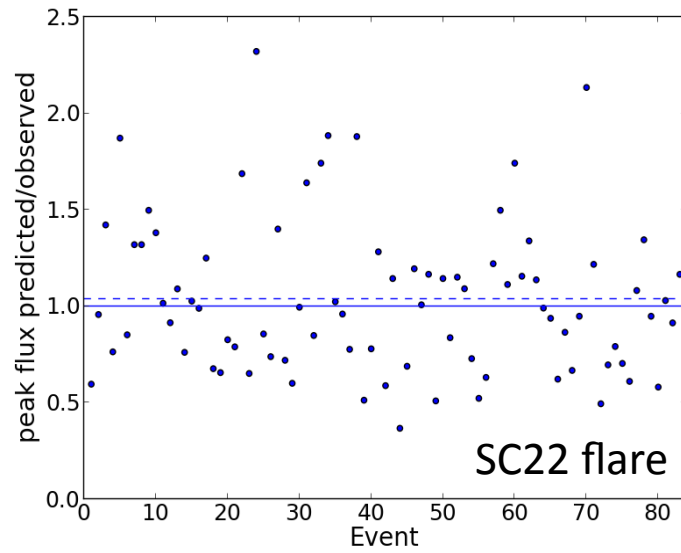
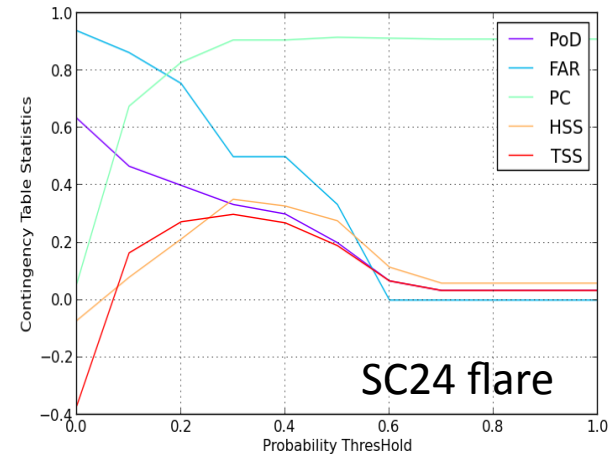
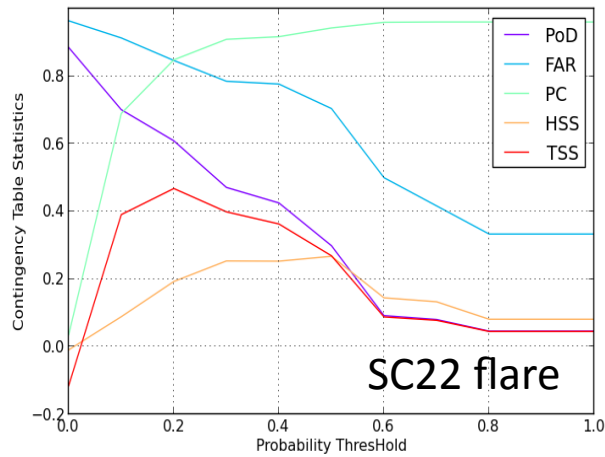
## *External Collaborators:*

- Associate Professor Dr. Nandita Srivastava, Udaipur Solar Observatory, India
- Dr. Michael Hesse, NASA Goddard Space Flight Center, U.S.A.
- Dr. Dusan Odstrcil, George Mason University, Fairfax – NASA Goddard Space Flight Center, U.S.A.

## Input tools

- Flaremail: flare peak intensity and time from GOES soft X-ray data (0.1nm-0.8nm)  
<http://sidc.oma.be/products/flaremail/>
- Solar DEMON: flare location and peak time in SDO/AIA 94 data  
<http://solardemon.oma.be/>
- CACTus: CME speed, width and liftoff time from SOHO/LASCO data  
<http://sidc.oma.be/cactus/>
- GLE Alert: monitors the GLE Alert Plus service, which detects ground level enhancements events in neutron monitor data  
<http://cosray.phys.uoa.gr/index.php/glealertplus>

# SEP Forecast Performance







# SEPEM Consortium

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## Project Coordinator

- Royal Belgian Institute for Space Aeronomy [PI: Norma Crosby]

## Other members

- K.U.Leuven, Belgium
- QinetiQ, UK
- University of Barcelona, Spain
- University of Southampton, UK
- Mars Space Ltd, UK
- DH Consultancy, Belgium

# HESPERIA Team Members

## *Project Coordinator:*

- Olga Malandraki [National Observatory of Athens, Greece]

## *Other Teams:*

- Ludwig Klein [Observatoire de Paris, OBSPARIS, France]
- Rami Vainio [Turun Yliopisto, UTU, Finland]
- Neus Agueda [Universitat de Barcelona, UB, Spain]
- Marlon Nunez [Universidad de Malaga, UMA, Spain]
- Bernd Heber [Cristian-Albrechts-Universitaet zu Kiel, CAU, Germany]
- Rolf Buetikofer [Universitaet Bern, UBERN, Switzerland]
- Christos Sarlanis [ISNet, Greece]
- Institut d'Aeronomie Spatiale de Belgique, Belgium [PI: Norma Crosby, Project Coordinator]

## *External Collaborators:*

- Galina Bazilevskaya [Lebedev Physical Institute of Russian Academy of Sciences, Moscow, Russia]
- Veronica Bindi [University of Hawai at Manoa, Honolulu, USA]
- Ron Murphy [Naval Research Laboratory, Washington DC, USA]
- Allan Tylka [Washington DC, USA]
- Juan Rodriguez [NOAA, USA]



UNIVERSITAT DE BARCELONA



UNIVERSITÄT  
BERN



## Coordinator:

- Institut d'Aeronomie Spatiale de Belgique, Belgium [PI: Norma Crosby, Project Coordinator]

## Network Members:

- Seibersdorf Labor GmbH, Austria [Peter Beck]
- Université Catholique de Louvain (UCL), Center for Space Radiations, Belgium [Mathias Cyamukungu]
- DLR Institute of Aerospace Medicine, Department Radiation Biology, Germany [Gunther Reitz]
- University of Turku, Space Research Laboratory, Finland [Rami Vainio]
- University College London (UCL), Mullard Space Science Laboratory, U.K. [Andrew Coates]
- Paul Buehler, Austria [Paul Buehler]
- Institute of Atmospheric Physics, Czech Republic [Ondrej Santolik]
- University of Oulu, Sodankylä Geophysical Observatory, Finland [Ilya Usoskin]
- CSDRadConsultancy Ltd, U.K. [Clive Dyer]
- University of Athens, Physics Department, Greece [Helen Mavromichalaki]