BIRA.IASB
aeronomie.be
Royal Belgian Institute for Space Aeronomy
Institut royal d'Aéronomie Spatiale de Belgique
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SEP Scoreboard

M. Dierckxsens

Working Meeting: Community-wide space weather scoreboards: research assessment of real-time forecasting models and techniques

ESWW 13, 14-18 November 2016

Agenda

Discussion based around the following topics:

- General introduction: What is the scoreboard, how to register and submit forecasts (M. Dierckxsens)
- XML Schema for submission of forecasts; quantities and observations to compare (M. Dierckxsens)
- SEP Scoreboard display mock-ups: Probability chart and flux profiles, Probability chart time-series (L. Mays)
- Comparisons using historic SEP events (M. Dierckxsens)
- Validation techniques: metrics, skill scores,... (M. Dierckxsens)
- Linking flare & CME forecasts with SEP forecasts through scoreboard (L. Mays)

INTRODUCTION

Introduction

- SEP Scoreboard for near real-time forecasting methods validation currently being developed by:
  - BIRA-IASB: M. Dierckxsens, N. Crosby
  - UK Met Office: M. Marsh
  - CCMC: L. Mays, M. Kuznetsova
- Community effort: input, feedback and participation from everyone is appreciated

http://ccmc.gsfc.nasa.gov/challenges/sep.php

Existing SEP Forecast Models

- Overview of available SEP models/forecasts (M. Marsh)

Model Type	Model Name	Principal Developer(s)	Observational Inputs	Outputs
Empirial	AFRL PPS	Stephen Kahler (AFRL)	GOES x-ray peak flux & location	E>5 MeV intensities
Physics	EPREM	Nathan Schwadron (UNH)	Can be driven by in-situ proton observations, can be coupled with MHD	User defined flux range, also dose calculations within EMMREM framework
Physics	FLAMPA (SWMF)	University of Michigan	SWMF module coupled with MHD	
Empirical	FORSPEF	Anastasios Anastasiadis (NOA)	Magnetograms, x-ray flares	E > 30,60,100 MeV integral proton energy flux and fluence
Physics	Kota SEP (SWMF)	University of Michigan	SWMF module coupled with MHD	
Empirical	Laurenza model	Monica Laurenza (INAF)		
Physics	Luhmann Model	Janet Luhmann (UCB SSL)	Coupled with WSA-ENLIL+Cone (magnetograms, coronagraphs)	User defined flux range
Empirical	MAG4	David Falconer (NASA/MSFC, UAH)	Magnetograms, x-ray flares	24 hour event probabilistic forecast
Physics	PATH	Gary Zank, Gang Li (UAH)		
Physics & Empirical	PREDICCS	Nathan Schwadron (UNH)		(coupled version of EMMREM and REleASE)
Empirical	REleASE	Arik Posner	SOHO/COSTEP-EPHIN high energy electron flux. ACE/EPAM in new version	E=4-9, 9-16, 16-40, 28-50 MeV proton flux
Empirical	SEPForecast (COMESEP)	Mark Dierkzsens (BIRA IASB)	GOES x-ray peak flux & location, CME width & velocity, GLE observations	E>10 MeV and >60 MeV integral proton energy peak flux and probability
Physics	SOLPENCO	Angels Aran (Univ. Barcelona)	CME/Flare location & shock velocity estimate	User defined flux range
Physics	SPARX	Silvia Dalla (UCLan) Mike Marsh (UK Met Office)	Flare location, peak x-ray flux	User defined flux range
Empirical	SWPC PPM	Christopher Balch (NOAA/SWPC)	GOES x-ray, SEON radio burst, H-alpha/EUV imaging	E>10 MeV integral peak proton flux, peak time, and probability
Empirical	SWPC	NOAA/SWPC		Day 1-3 event probabilistic forecast
Empirical	UMASEP	Marlon Nuñez (Univ. Malaga)	Goes x-ray & proton fluxes	E>10 MeV integral proton flux. E>100 MeV proton flux in new version.
Empirical	UK Met Office	UK Met Office		Day 1-4 event probabilistic forecast
Physics	Zhang model	Ming Zhang (FIT)		

Variety of Forecast Models

- Wide variety in types of models and forecasts
- Empirical, physics based or a combination of both
- Identified 3 classes for SEP Scoreboards:
  1) Near real-time continuous forecast (e.g. next 24 hrs)
  2) Near real-time event driven forecasts (e.g. flares)
  3) Non near real-time (e.g. models with long calculation times)
- Different energy ranges: >5, >10 , >60, >100, 9-16, … MeV
- Different parameters: event probability, proton peak flux, fluence, onset time, peak time, duration, …
- Current focus on classes 1) and 2)

Scoreboard participation

- Anyone providing SEP forecasts and who is interested in participating is welcome and encouraged to do so
- How to participate:
  - Fill in questionnaire concerning details of the models
  - Provide forecasts in specific XML format & upload via FTP
  - Join planning meeting telecoms if desired
- More details on the SEP Scoreboard website

Registered Models

- Currently 3 registered forecast models:
  - UMASEP (M. Núñez, U. de Málaga)
    - Registered and provided first XML files
  - FORSPEF (A. Anastasiadis, NOA)
    - Registered, XML input under development
  - COMESEP SEPForecast (M. Dierckxsens, BIRA-IASB)
    - Registered, XML input under development
- Interest from: RELeASE, HESPERIA RELeASE, HESPERIA UMESEP-500, PREDICCS, MAG4, SPARX

XML SCHEME & PARAMETERS TO COMPARE

XML Schema for submissions

XML Schema	Type	Comments
sepforecast		
header		
sender	string	optional
email	string	optional
model	string	
forecasttype	string	restrictions[1]
issuetime	datetime	
predictionwindow		optional
starttime	datetime	
endtime	datetime	
inputdata	string	optional, >1 possible
issued_forecast		at least 1
description	string	
source_id	string	optional
source_url	string	optional, >1 possible
species	string	restrictions[2]
location	string	restrictions[3]
confidence	decimal	[0.0,1.0]
event_length		optional
onset_time	datetime	
end_time	datetime	optional
event_threshold		optional
threshold	decimal	
units	string	
time	datetime	
strength		
storm_level	integer	optional, [0,5]
peak_flux		optional
flux	decimal	>0.0
units	string	
time	datetime	
fluence	decimal	optional, >0.0
fluence	decimal	>0.0
units	string	
probability		optional
value	decimal	[0.0,1.0]
uncertainty	decimal	optional
value_lower	decimal	optional, [0.0,1.0]
value_upper	decimal	optional, [0.0,1.0]
energy_range		
energy_min	decimal	default 0.0
energy_max	decimal	default -1.0 = infinity
sep_profile		optional
units	string	
flux_point		>1 possible
time	datetime	
flux	decimal	>0.0

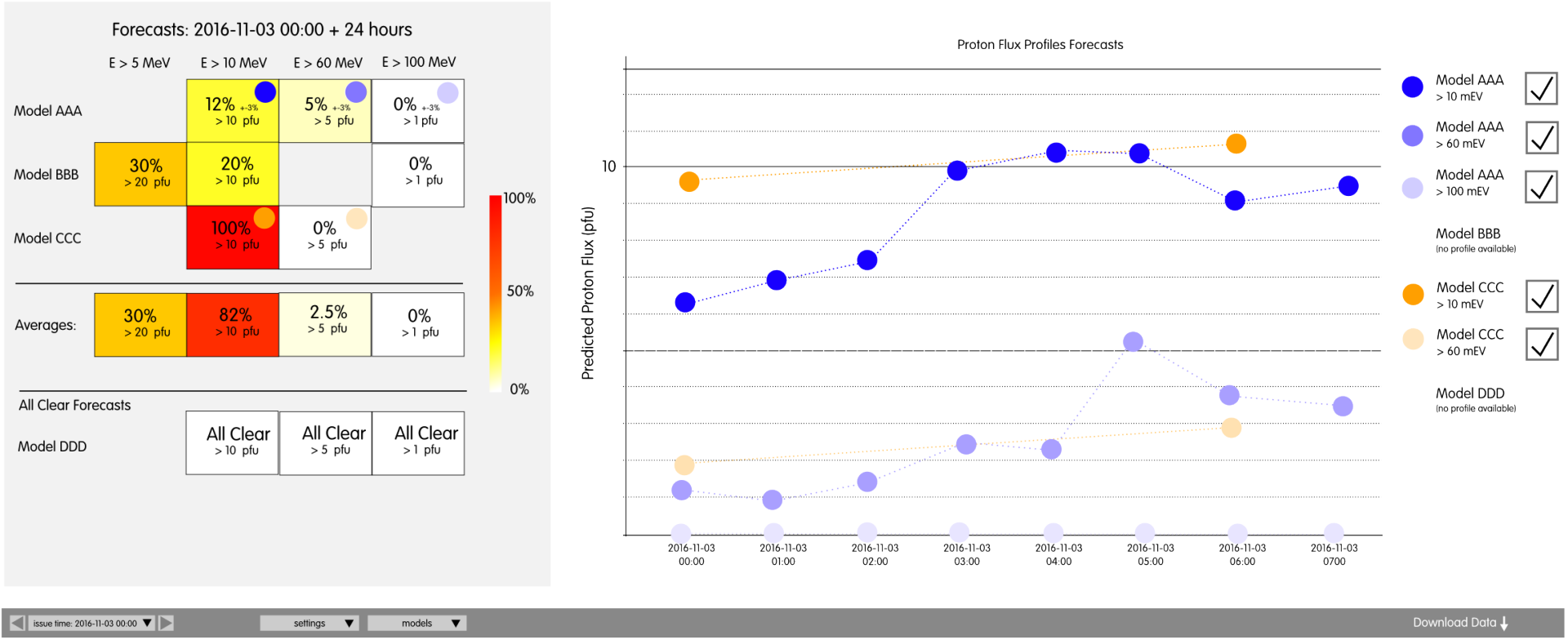
- XML Schema developed to handle as wide a variety of forecasts as possible
- Header element providing details on the model and validity of the forecast
- Issued forecast element(s) providing:
  - description, reference, species, location, confidence
  - event length & threshold
  - strength (storm level, peak flux, fluence)
  - probability
  - energy range
  - flux profile (time series)

Parameters to compare

- The following forecasted parameters can be submitted:
  - event length (onset, end)
  - event threshold (threshold, units, time)
  - strength (storm level, peak flux & time, fluence)
  - probability (value, uncertainty)
  - energy range (min, max)
  - flux profile (units, time, flux)
- Other parameters needed?
- Initially will focus on peak flux and probability for E > 10 MeV
- Comparison with GOES data

SEP SCOREBOARD MOCK-UPS

Scoreboard visualisation (1)

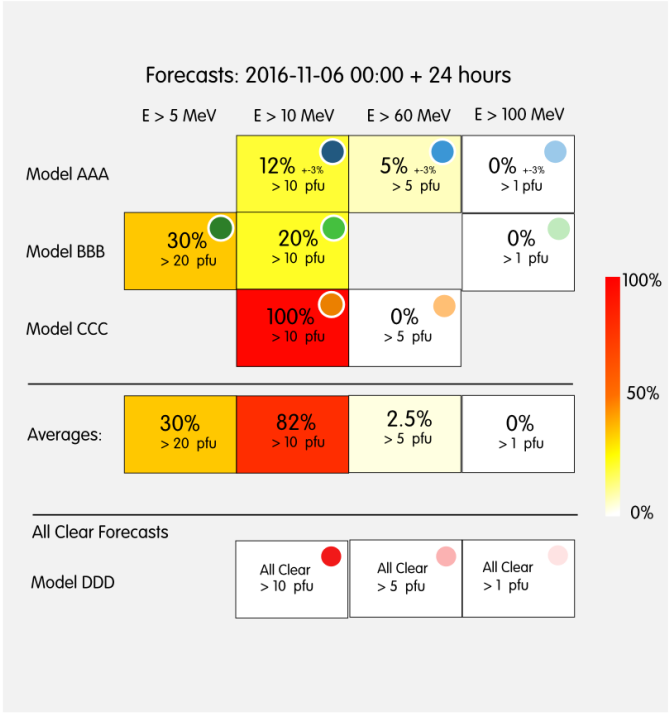


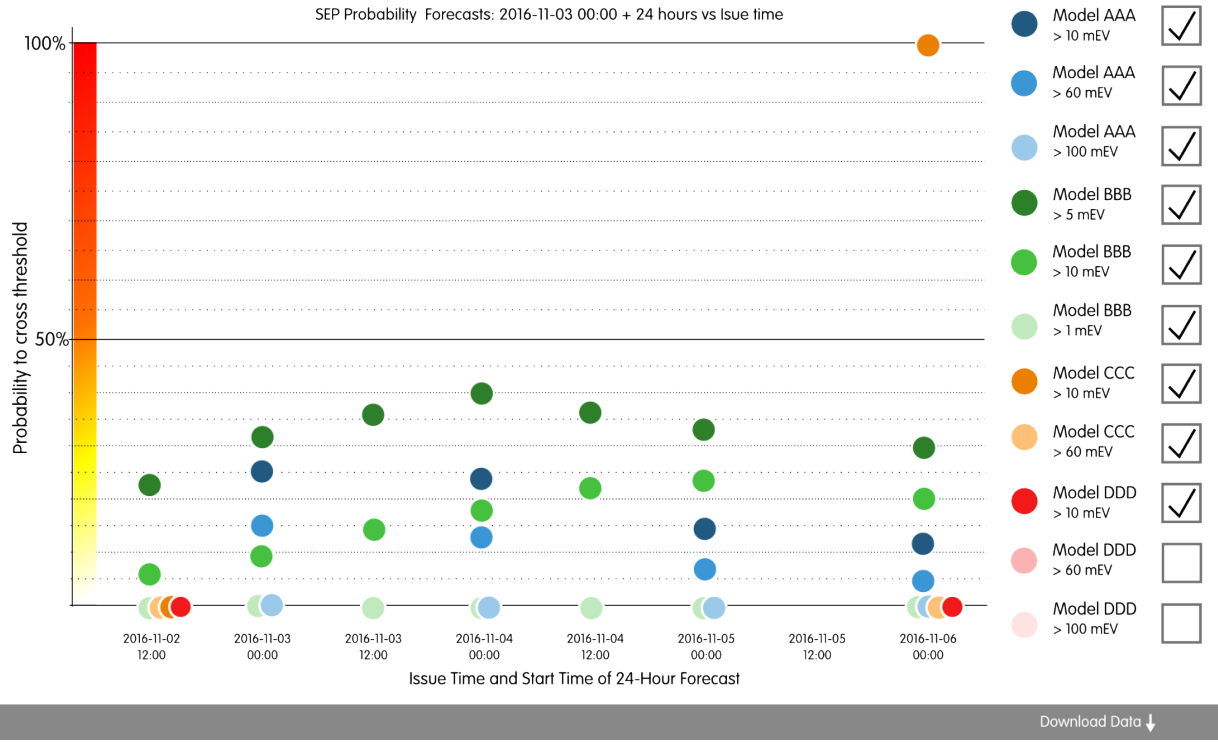
Probability heat map at a single time

Predicted proton flux time-series

Scoreboard visualisation (2)

SEP Scoreboard





Probability heat map at a single time

Probability time-series

MINI SEP CHALLENGE

Mini SEP Challenge

- For a proper validation, a large enough sample size is needed, but there is currently not much (SEP) activity
- Started with an mini SEP challenge on past events: 5 SEP events and 5 “non” events from SC24
- Helps in further defining the SEP scoreboard
- Also allows participation of predictions not running in real-time
- Currently participating forecasts:
  - UMASEP
  - FORESPEF nowcast
  - SEPForecast
  - SPARX
  - (RELeASE -> lack of real-time coverage)

Mini Challenge – SEP events

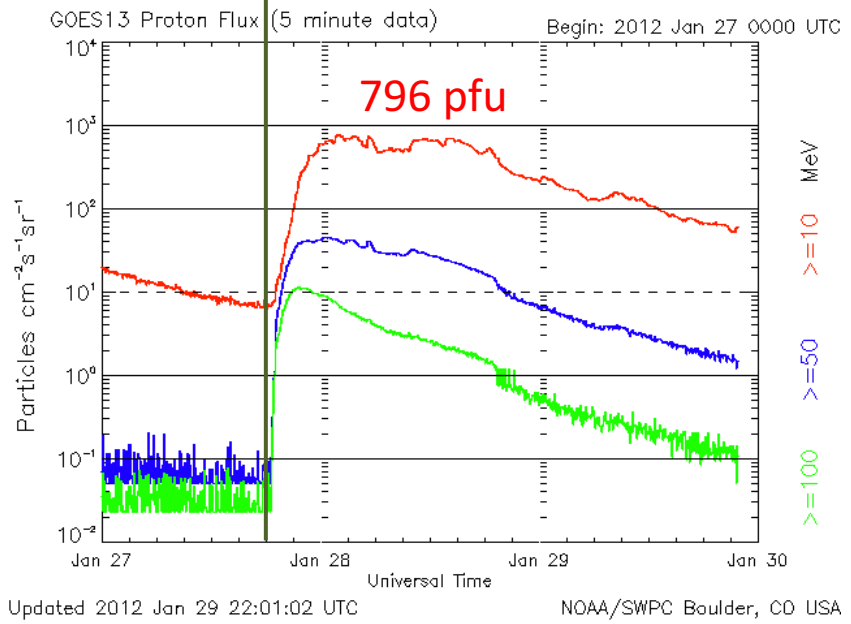
- 5 strongest SEP events (flux > 10 pfu for E>10 MeV) from SC24 as listed on: ftp://ftp.swpc.noaa.gov/pub/indices/SPE.txt

SEP onset time	Peak flux (>10 MeV)	Flare Strength	Location	CME speed	width
23 Jan 2012 05:30	6310 pfu	M8	N28W36	2176 km/s	halo
27 Jan 2012 19:05	796 pfu	X1	N27W71	2508 km/s	halo
07 Mar 2012 05:10	6530 pfu	X5	N17E15	2684 km/s	halo
22 May 2013 14:20	1660 pfu	M5	N15W70	1466 km/s	halo
06 Jan 2014 09:15	1033 pfu	X1	S15W11	1830 km/s	halo

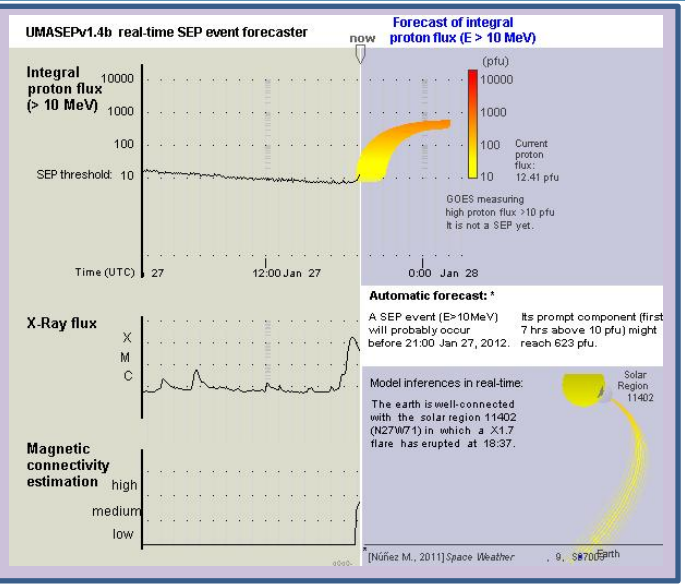
Mini Challenge – SEP events

X1, N27W71
2508 km/s

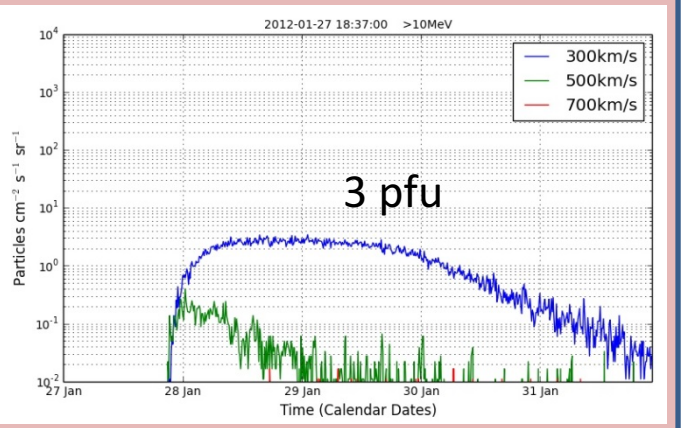
FORESPEF nowcast:
- P(SEP|flare): 34%
- P(SEP|flare,CME): 85%



UMASEP



SPARX

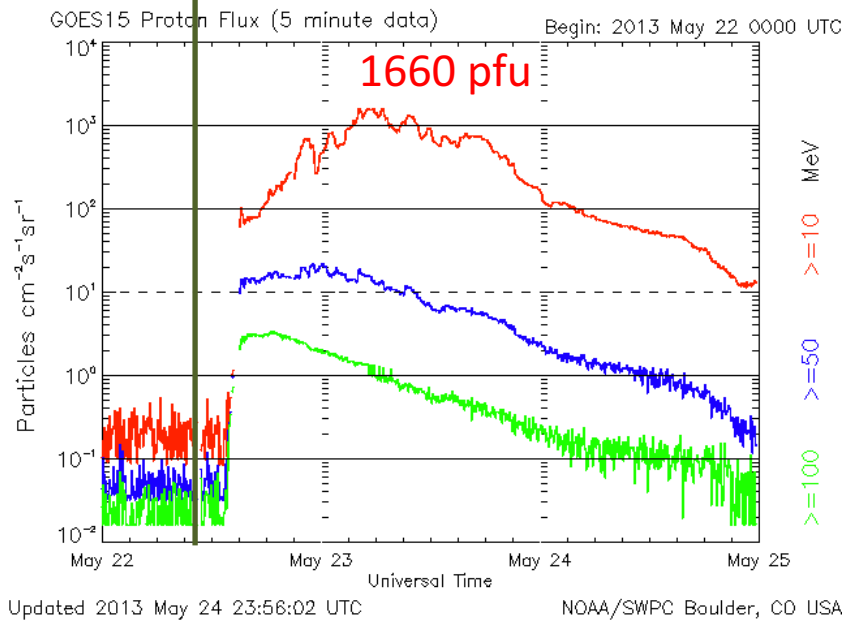


COMESEP SEPForecast:
- Flare: possible (40-70%), minor (10^1-10^2 pfu)
- Flare+CME: likely (70-90%), moderate(10^2-10^3 pfu)

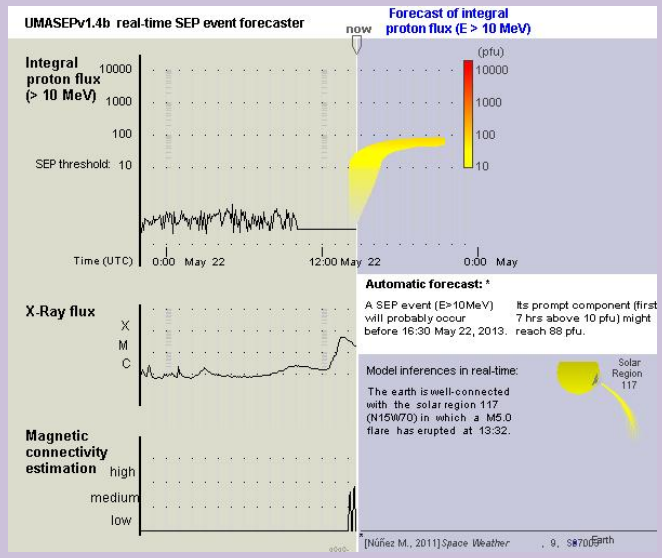
Mini Challenge – SEP events

M5, N15W70
1466km/s

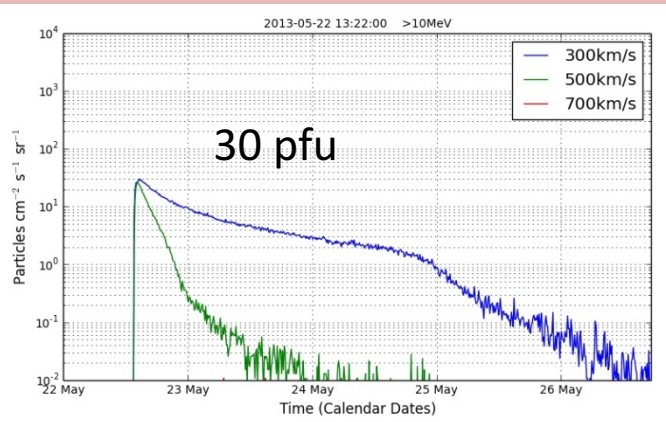
FORESPEF nowcast:
- P(SEP|flare): 23%
- P(SEP|flare,CME): 59%



UMASEP



SPARX



COMESEP SEPForecast:
Flare: Possible (40-70%) - minor (10^1-10^2 pfu)
Flare+CME: likely(70-90%), minor(10^1-10^2 pfu)

Mini Challenge – "non" SEP events

- 5 strongest western flares from SC24 that
  - did not result in an SEP event (flux > 10 pfu for E>10 MeV),
  - were not preceded by another X flare two days before,
  - did not occur during an ongoing SEP event.

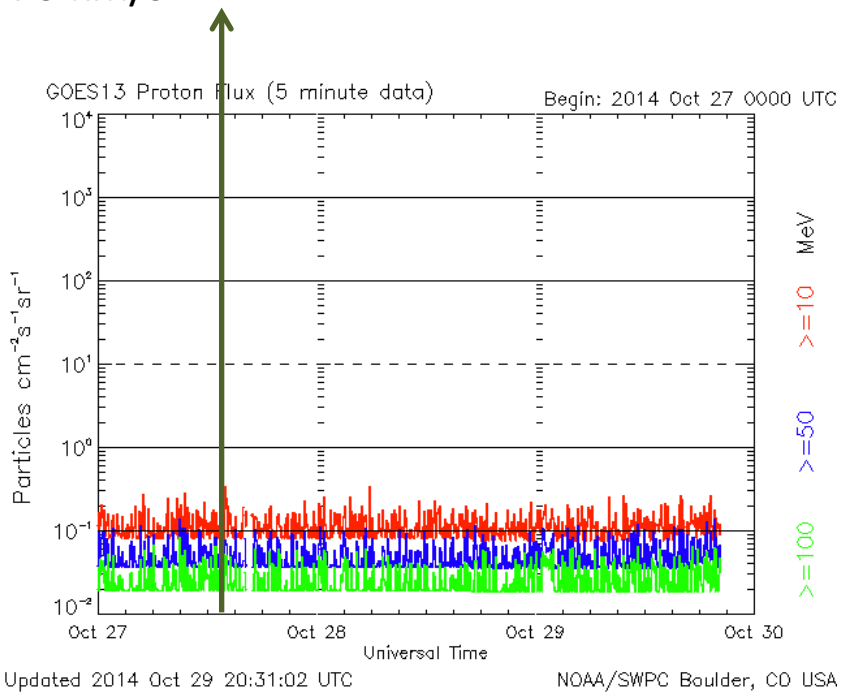
Flare peak time	Flare Strength	Location	CME* speed	width	Proton flux
06 Sep 2011 22:20	X2.1	N14W18	575 km/s	halo	~9 pfu
10 Nov 2013 05:14	X1.1	S14W13	682 km/s	262°	~1 pfu (no clear peak)
24 Oct 2014 21:41	X3.1	S16W21	(184 km/s)	(35°)	No enhancement
27 Oct 2014 14:47	X2.0	S17W52	170 km/s	55°	No enhancement
20 Dec 2014 00:28	X1.8	S21W24	830 km/s	257°	~3 pfu

*CME info not provided in initial challenge

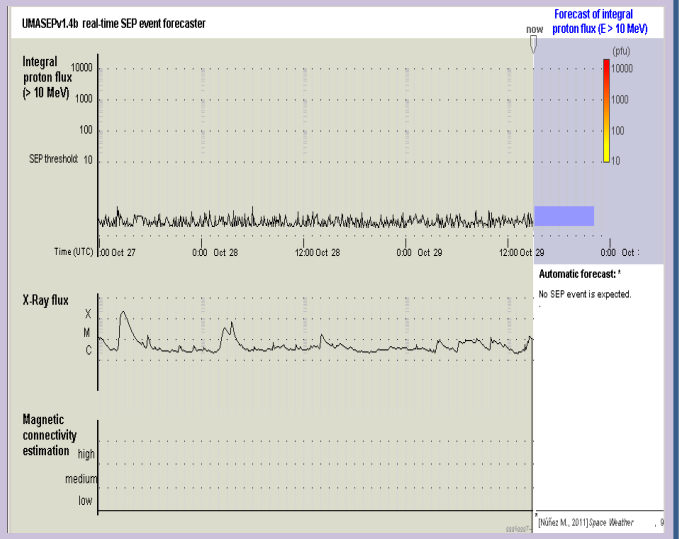
Mini Challenge – “non” SEP events

X2, S17W52
170 km/s

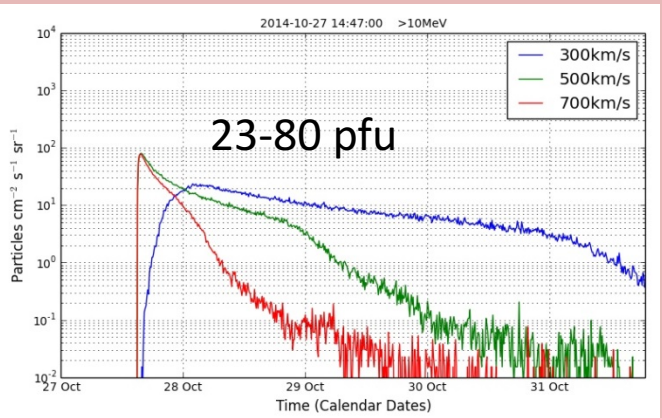
FORESPEF nowcast:
- P(SEP|flare): 48%



UMASEP



SPARX



COMESEP SEPForecast:
- Flare: possible (40-70%), minor (10^2-10^3 pfu)

VALIDATION OF FORECASTS

Forecast validation

- Any validation studies based on the SEP Scoreboard should be done in collaboration with the providers of the forecasts
- Typical verification measures used in the literature considered:
  - Dichotomous (yes/no) forecasts:
    - (skill) scores based on contingency table (hit, miss, false alarm, correct negative): accuracy, hit rate, false alarm ratio and rate, Heidke skill score, true skill statistic, …
    - Derived as function of probability threshold for probabilistic forecasts
  - Continuous variables forecasts (e.g. peak flux):
    - Comparison of observed versus predicted value: correlation plot and coefficient, bias, mean error, …
  - Probabilistic forecasts:
    - Verify the predicted probabilities on longer timescales: reliability diagram, Brier score, …

LINKING WITH FLARE & CME SCOREBOARDS

Linking the Scoreboards

Example of activities linked to a CME event in the CCMC DONKI database:
http://kauai.ccmc.gsfc.nasa.gov/DONKI

Coronal Mass Ejection
Catalog: SWRC_CATALOG
Start Time: 2015-03-15T02:00Z (SOHO: LASCO/C2)
All Detecting Spacecrafts:
SOHO: LASCO/C2
SOHO: LASCO/C3
Activity ID: 2015-03-15T02:00:00-CME-001 (version 4)
Source Location: S15W24
Active Region Number: 12297
Note: This CME is connected to the long duration C9.1 flare erupting, bright post-flare arcade later in AR 2297
Submitted on 2015-03-15T14:17Z by Karin Muglach

2015-03-15T01:15:00-FLR-001
FLR Type: C9.1

2015-03-16T07:36:00-SEP-001
SOHO: COSTEP 15.8-39.8 MeV

2015-03-17T04:05:00-IPS-001
Location: Earth

2015-03-17T06:00:00-GST-001
NOAA Kp: 6 (2015-03-17T09:00Z)
NOAA Kp: 6 (2015-03-17T12:00Z)
NOAA Kp: 8 (2015-03-17T15:00Z)
NOAA Kp: 8 (2015-03-17T18:00Z)
NOAA Kp: 7 (2015-03-17T21:00Z)
NOAA Kp: 8 (2015-03-18T00:00Z)
NOAA Kp: 6 (2015-03-18T03:00Z)
NOAA Kp: 6 (2015-03-18T18:00Z)

2015-03-17T06:23:00-MPC-001