Automatic prediction of SEP events and the first hours of their proton fluxes with E > 10 MeV and E > 100 MeV

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Contents

- Main characteristics of UMASEP
- UMASEP architecture
  - Well-connected SEPs
  - Poorly-connected SEPs
- Predicting SEP events with E > 10 MeV
- Predicting SEP events with E > 100 MeV
- Verification results
- A possible use of automatic SEP forecasters
- Conclusions

Type of SEP events predicted by UMASEP

- The goal of UMASEP is to predict Solar Energetic Particle (SEP) events that meets or surpass the following SWPC's thresholds:
    - E > 10 MeV and integral proton flux >10 pfu
    - E > 100 MeV and integral proton flux > 1 pfu
- Regardless of the type of SEP event:
   - <u>Prompt SEP</u> (detected at 1AU a few minutes/hours after the flare/CME event)
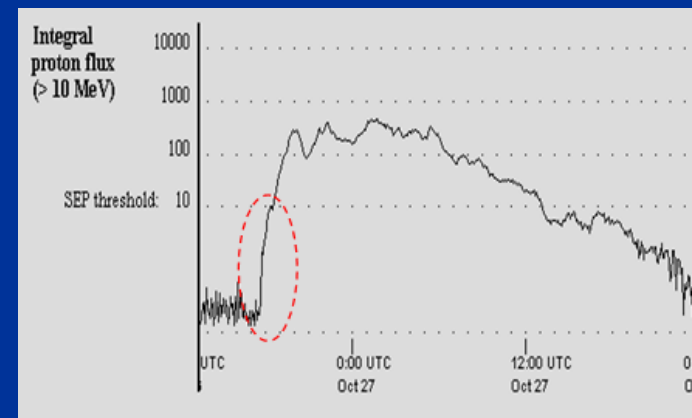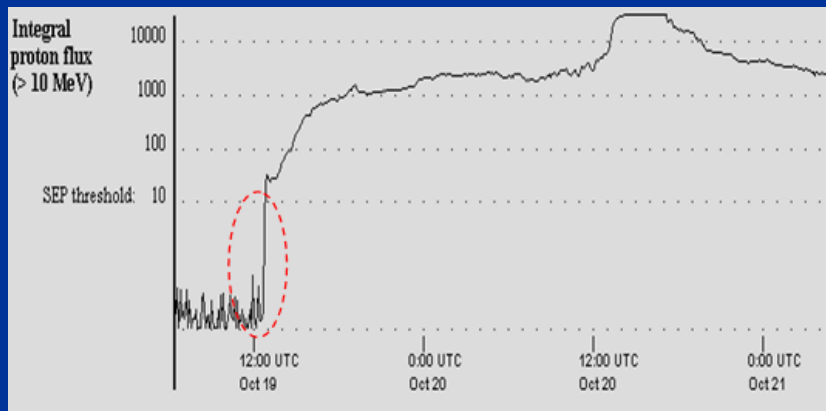
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- Regardless of the type of SEP event:
    - Prompt SEP (detected at 1AU a few minutes/hours after the flare/CME event)
    - Delayed SEP (detected at 1AU several hours/days after the flare/CME event)
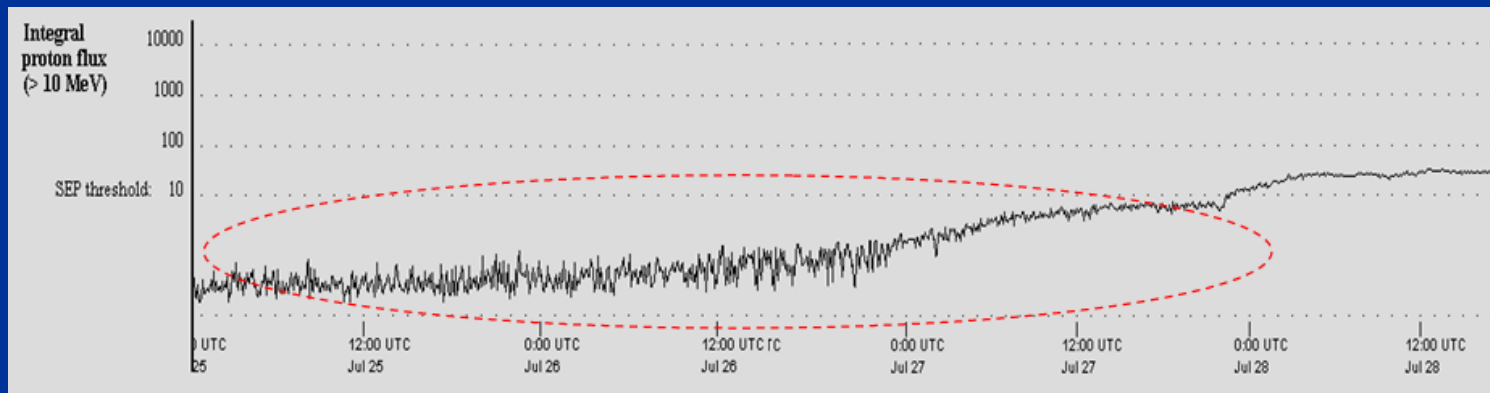
Main characteristics of UMASEP

- It is a real-time predictor of:
  - The time interval within which the integral proton flux is expected to surpass the SWPC's thresholds for events with E >10 MeV and >100 MeV
  - <u>The intensity of the first hours of SEP events</u>
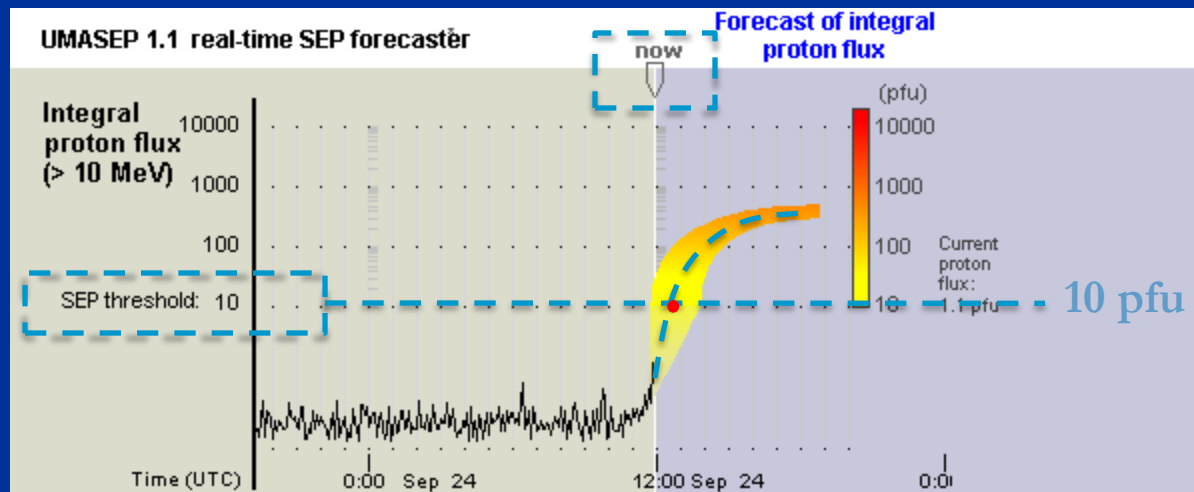
Main characteristics of UMASEP

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    - It collects information that is available in a 5-min basis and issues the forecasts seconds later. Forecasts are available by http/ftp/WebService

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5-min data from Goes
- X-ray flux
- Integral proton fluxes
- Differential proton fluxes

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new forecasts every 5 min

UMASEP

It takes 45 seconds for UMASEP to receive data and process the models

Main characteristics of UMASEP

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- UMASEP's forecasts are redistributed by other systems (addic. UMA)
  - NASA's ISWA system since January 2010
  - European Space Weather Portal since November 2009

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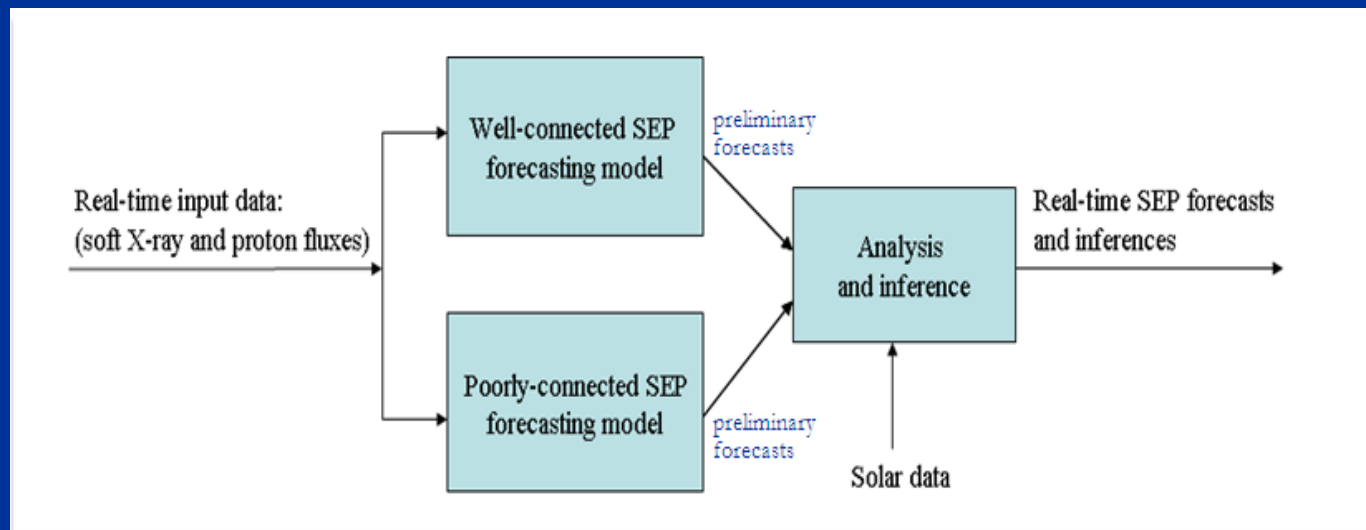- Predicting SEP events with E > 100 MeV
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Architecture of UMASEP

- To face the old problem of predicting SEP events, we applied an engineering approach: We designed an *empirical model* and tune its parameters with large amounts of data

- The design of this dual-model was based on the discovery of correlations by using 12 time series with <u>27 years</u> of data

- Model tuning by using our verification tools to:
    - augment accuracy & anticipation
    - reduce false warnings & intensity errors

Models

Well-connected SEP
Forecasting Model

Preliminary forecast of
a well-connected SEP

Soft X-ray flux
Differential flux
Proton flux

Poorly-connected SEP
Forecasting Model

Preliminary forecast of
a poorly-connected SEP

(*) For more information, see paper in the *Space Weather* journal, July 2011 [Núñez, 2011]
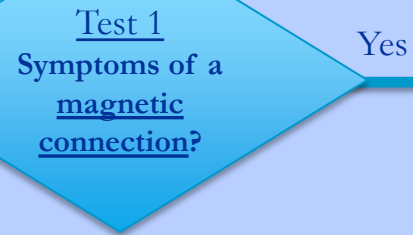
Models

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Models

Well-connected SEP
Forecasting Model

Test 1
Symptoms of a magnetic connection?

Yes

Preliminary forecast of a well-connected SEP

Soft X-ray flux
Differential flux
Proton flux

Models

Well-connected SEP
Forecasting Model
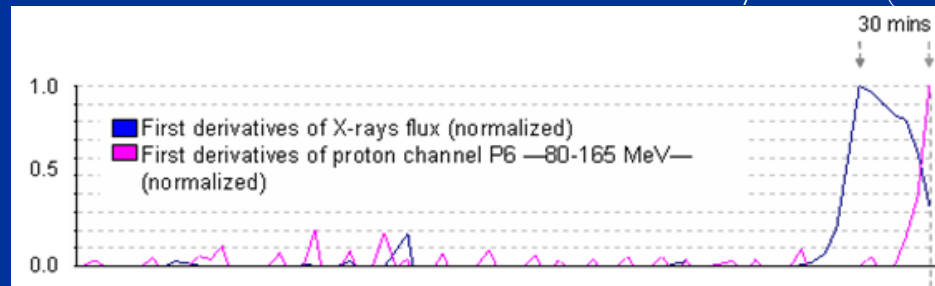
Test 1
Symptoms of a magnetic connection?

Yes
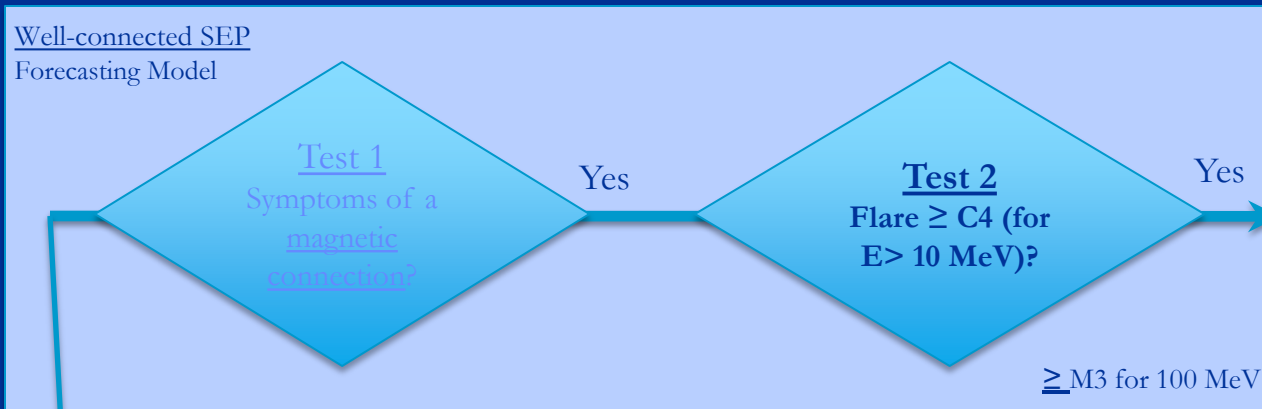
Preliminary forecast of a well-connected SEP

Soft X-ray flux
Differential flux
Proton flux

Oct 26/2003 (18:00)

OK

Models

Well-connected SEP
Forecasting Model

Test 1
Symptoms of a magnetic connection?

Yes

Test 2
Flare ≥ C4 (for E> 10 MeV)?

Yes

Preliminary forecast of a well-connected SEP

≥ M3 for 100 MeV

Soft X-ray flux
Differential flux
Proton flux

Oct 26/2003   (18:00)

30 mins

First derivatives of X-rays flux (normalized)
First derivatives of proton channel P6 —80-165 MeV— (normalized)

1.0

0.5

0.0

OK

X-ray flux

associated flare (X1.2)

X

M

← ?

Models

Well-connected SEP
Forecasting Model

Test 1
Symptoms of a magnetic connection?
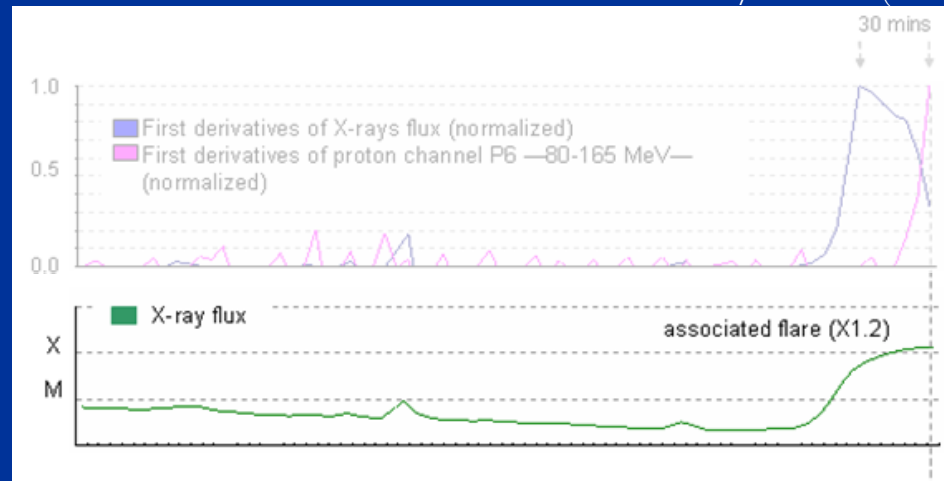
Yes

Test 2
Flare ≥ C4 (for E> 10 MeV)?
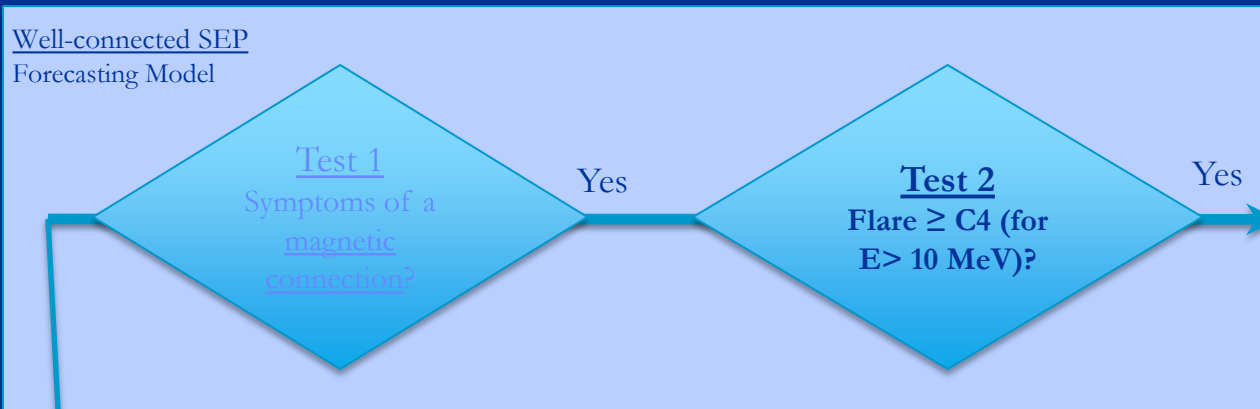
Yes
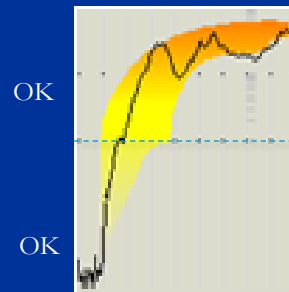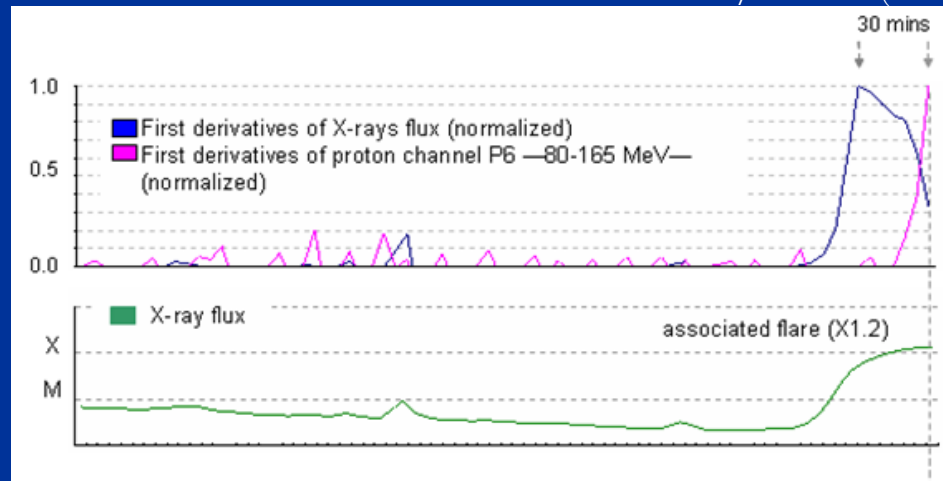
Preliminary forecast of a well-connected SEP

Soft X-ray flux
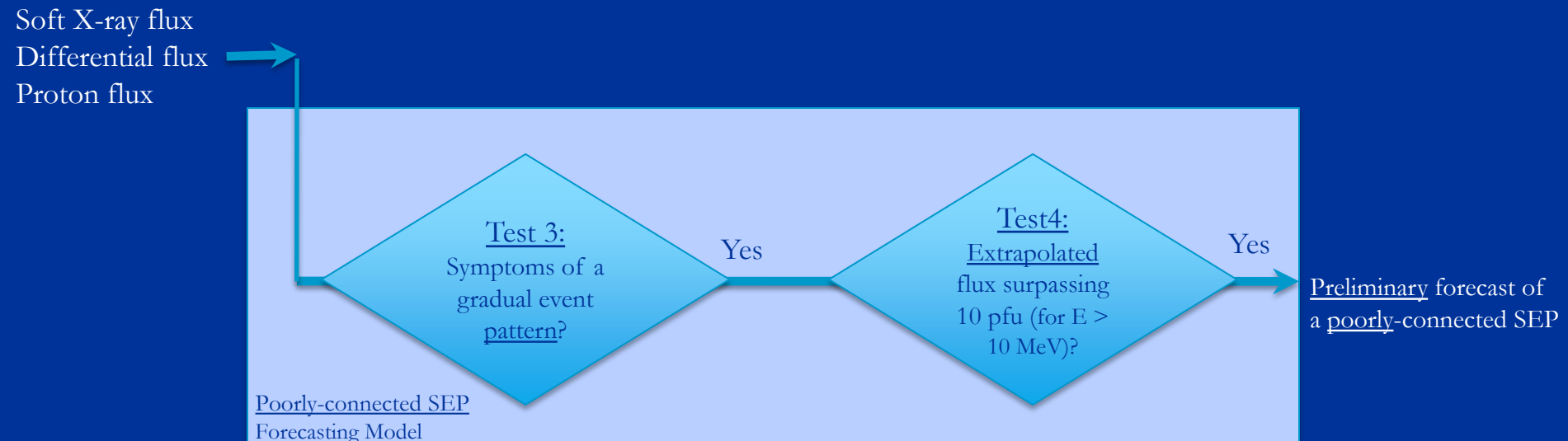Differential flux
Proton flux

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- First derivatives of X-rays flux (normalized)
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0.5
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X-ray flux

associated flare (X1.2)

X
M

OK

OK

Models

Soft X-ray flux
Differential flux
Proton flux

Poorly-connected SEP
Forecasting Model

Preliminary forecast of
a poorly-connected SEP

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Models

Soft X-ray flux
Differential flux
Proton flux

Poorly-connected SEP
Forecasting Model

Test 3: Symptoms of a gradual event pattern?

Yes

Test4: Extrapolated flux surpassing 10 pfu (for E > 10 MeV)?

Yes

Preliminary forecast of a poorly-connected SEP

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Real-time prediciton of well-connected >10 MeV events
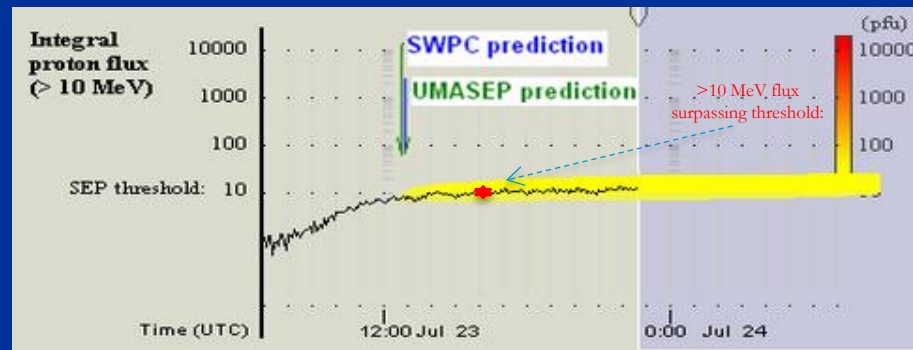

March 8, 2011 (3:00 UTC)
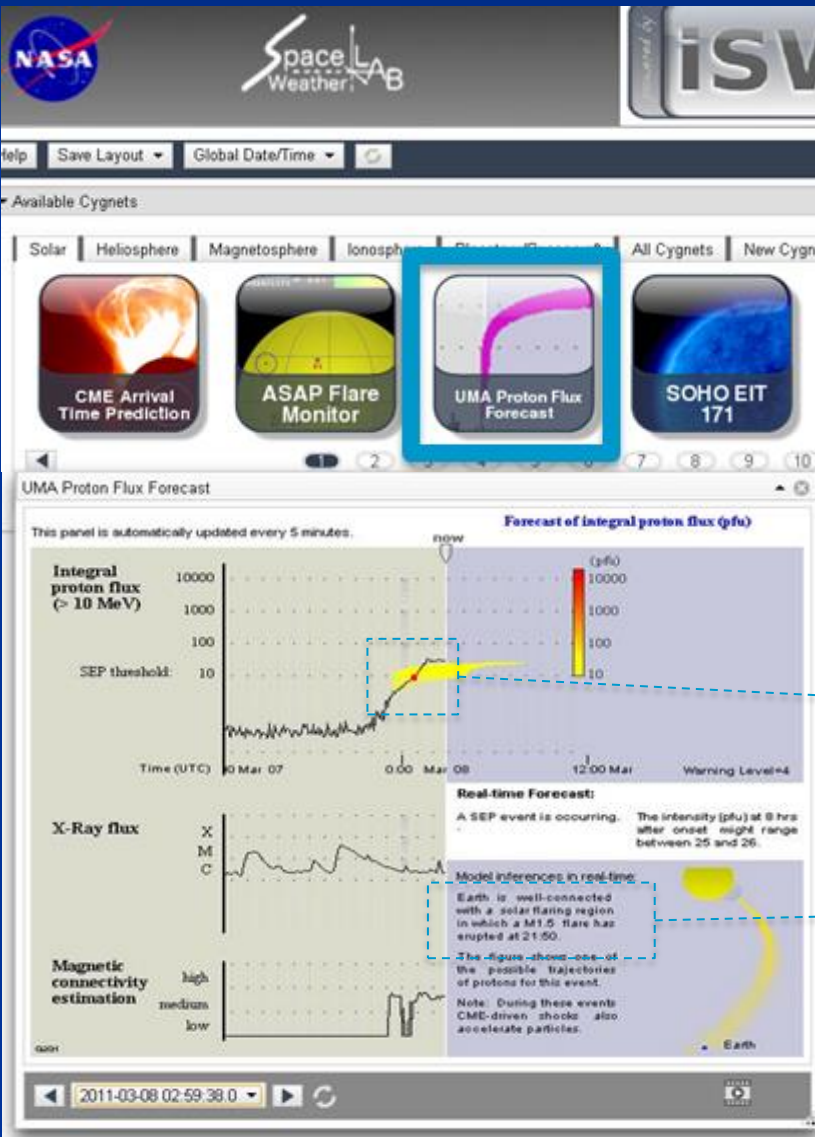
UMASEP anticipated the event start (red dot) in 1 h 30 m

UMASEP identified the intensity and peak time of the associated flare

Real-time prediciton of poorly-connected >10 MeV events

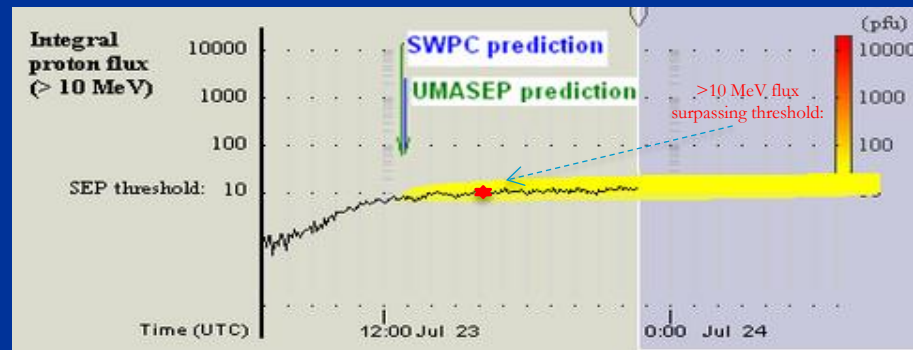07/23/2012: UMASEP anticipated the SEP event in 3 h 15 min
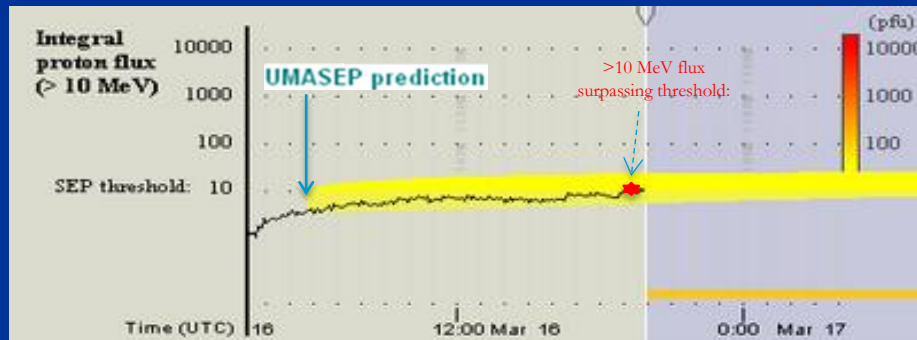

July 23, 2012

Real-time prediciton of poorly-connected >10 MeV events

07/23/2012:   UMASEP anticipated the SEP event in 3 h 15 min

July 23, 2012

03/16/2013: UMASEP anticipated the SEP event in 13 h 40 min
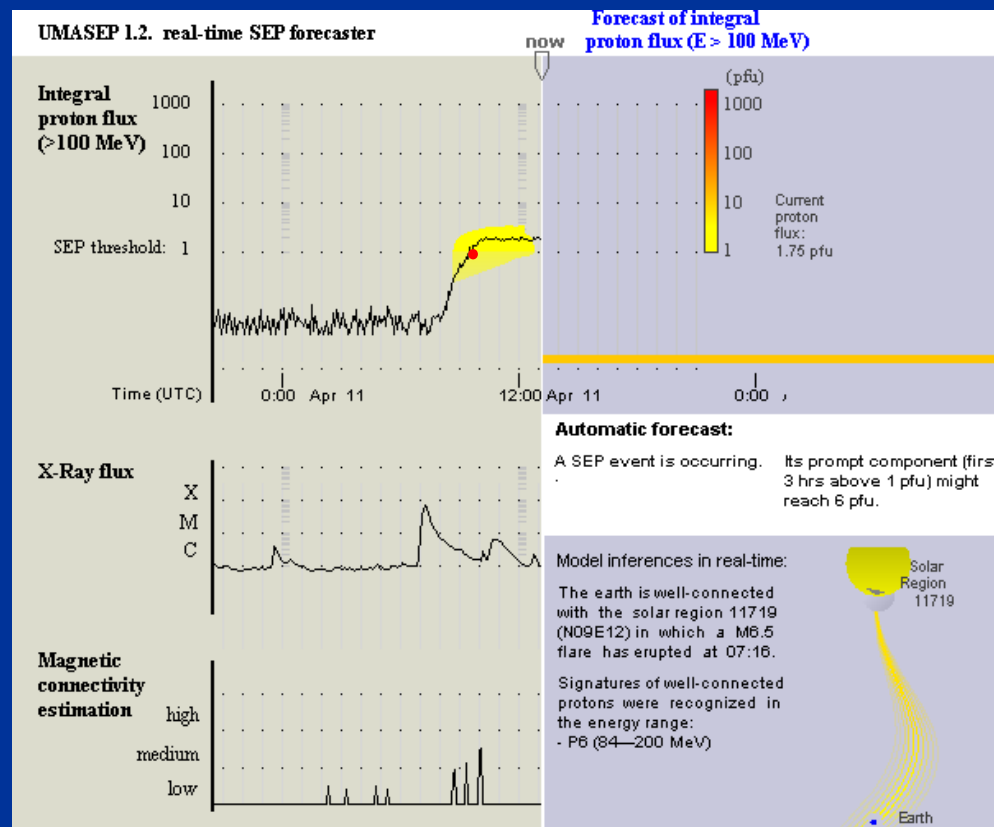

March 16, 2013

(*) These forecast images were copied from NASA's ISWA historical data base

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Real-time prediction SEP events with E >100 MeV

UMASEP anticipated the >100 MeV event in 1 h 5 min

April 11, 2013

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Verification for E > 10 MeV and E > 100 MeV (since 1986)

	UMASEP 1.1's verification results on historical data using cycle 22, 23 and 24	
	E> 10 MeV	E > 100 MeV
Probability of Detection	83.7%	82.7%
False Alarm Ratio	31.3%	36.3%
Average Warning Time	WC events: 1 h 1 m PC events: 8 h 4 m	1 h 12 m

Verification for E > 10 MeV and E > 100 MeV (since <u>1994</u>)

- Situations older than 1994 are normally not included in the verification of SEP forecasters; to give a more fair view, we are also providing the verification results with data from 1994.

|	UMASEP 1.1's verification results on historical data since **1994**	
	E>10 MeV	E>100 MeV
Probability of Detection	**<u>87.3%</u>**	83.0%
False Alarm Ratio	**<u>21.80%</u>**	34.4%
Average Warning Time	WC events: 1 h 7 min PC events: 8 h 10 min	52 min (median 20 min)

- Regarding E>10 MeV, SWPC's scientists yield better SEP forecasting performance results than the automatic UMASEP forecaster, however our system is not very far…
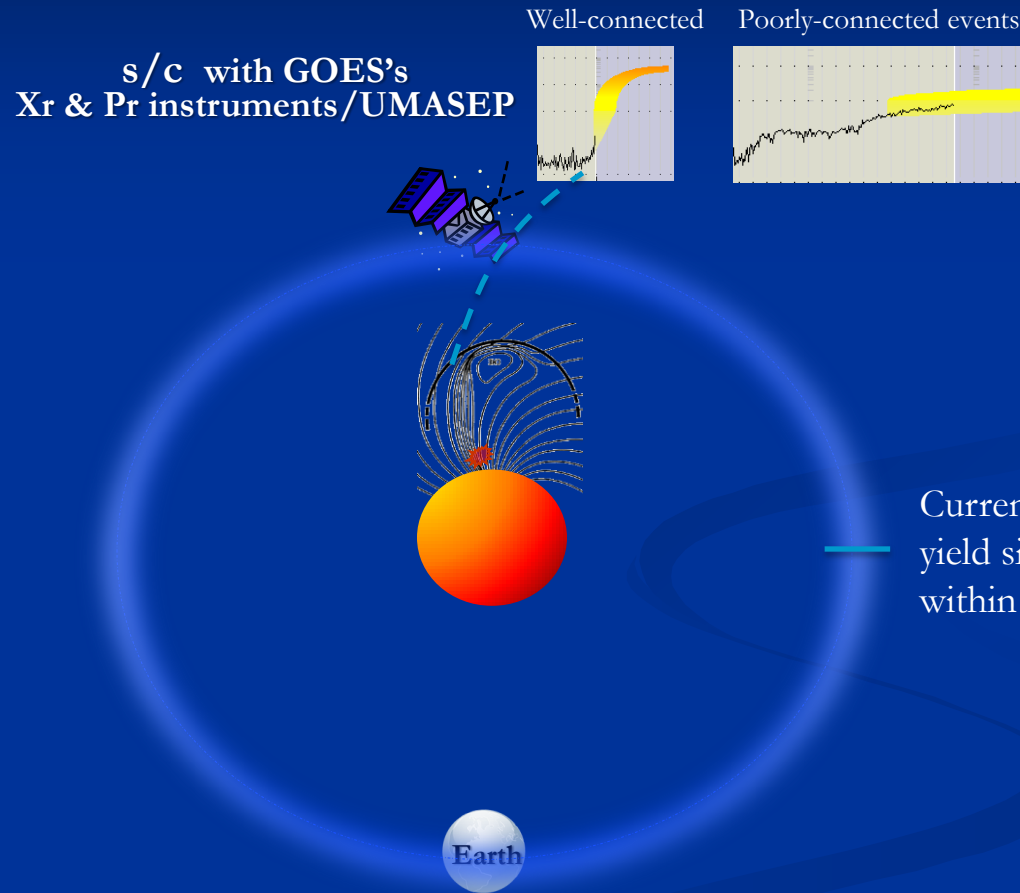
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An automatic SEP predictor could be aboard a spacecraft sending streams of estimation data without delay

Approach: GOES's
Xr & Pr instruments/UMASEP
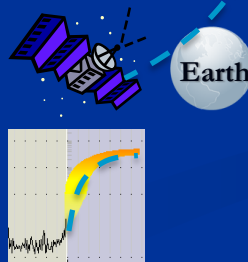
Earth

The same UMASEP's verification results (POD/FAR/etc.) are expected at any point within the Earth's orbit

s/c with GOES's Xr & Pr instruments/UMASEP

Well-connected   Poorly-connected events

Current model's settings could yield similar verification results within certain range of orbits

Earth

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Probability of Detection	83.7% / 87.3%	82.7% / 83.0%
False Alarm Ratio	31.3% / 21.80%	36.3% / 34.4%

- It is possible to automatically predict the events that meets one of the following SWPS's thresholds: E>10 MeV and >10 pfu, E>100 MeV and > 1 pfu.

- The strategy of exhaustive model training with data of several solar cycles is a promising field of research and provides competitive real-time forecasting services

- This strategy inspires applications that could help to prevent radiation hazards within the Earth's orbit and nearby interplanetary orbits

Thank you !

Visit our site: http:// spaceweather.uma.es / forecastpanel.htm