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

Marlon Núñez
Universidad de Málaga, Spain

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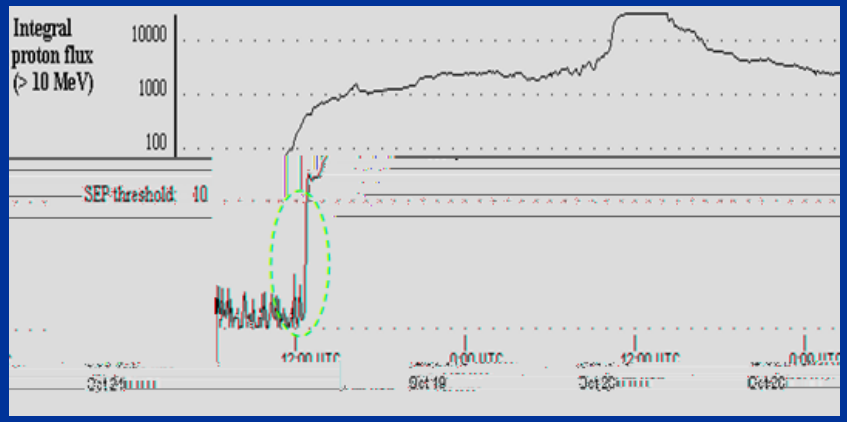
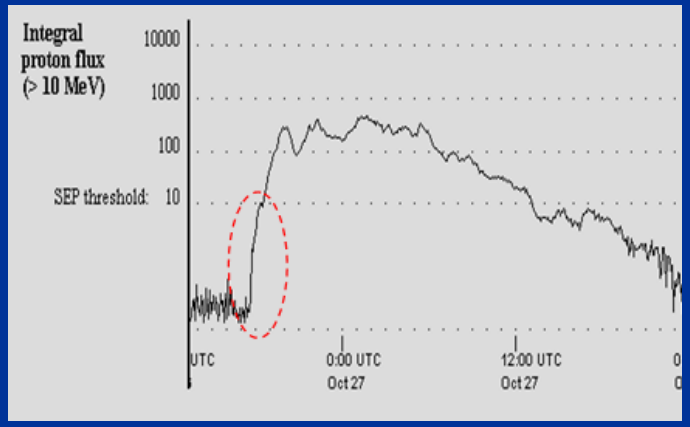
- Main characteristics of UMASEP
- UMASEP architecture
  - Well-connected SEPs
  - Poorly-connected SEPs
- Predicting SEP events with E > 10 MeV
- Predicting SEP events with E > 100 MeV
- Verification results
- A possible use of automatic SEP forecasters
- Conclusions

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:
  - Prompt SEP (detected at 1AU a few minutes/hours after the flare/CME event)





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- Regardless of the type of SEP event:
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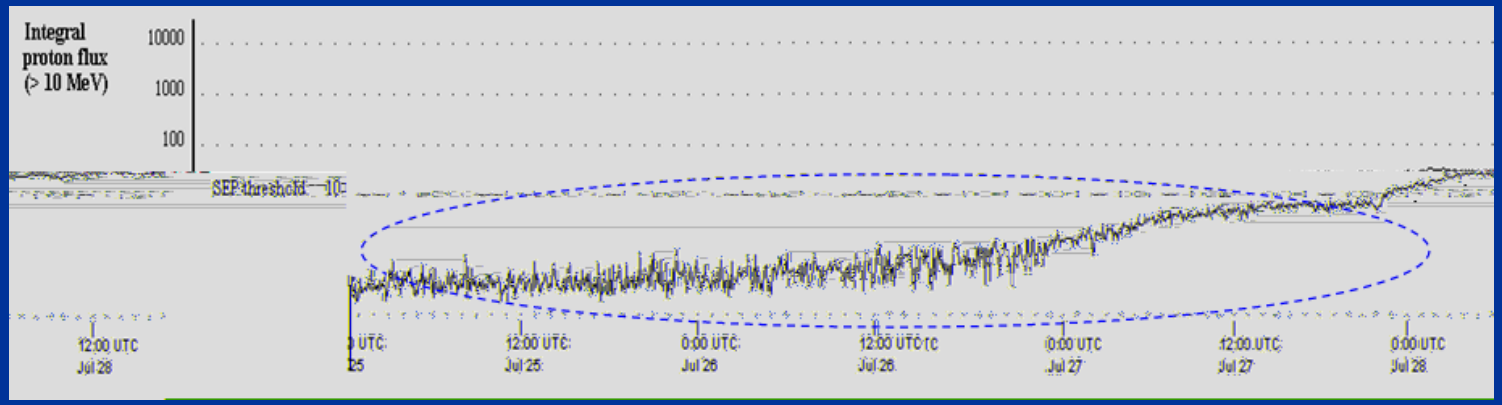
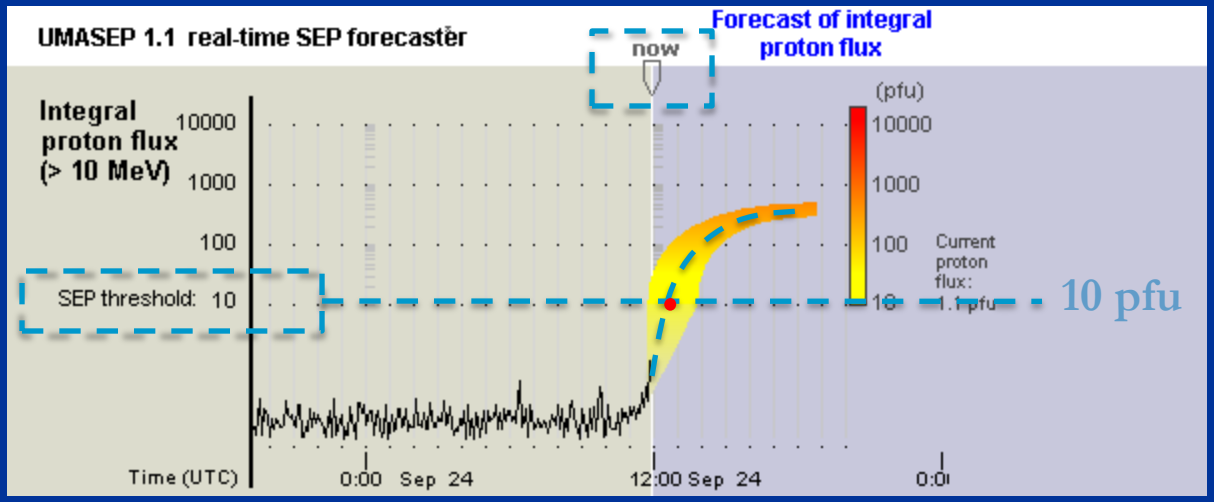
  - Delayed SEP (detected at 1AU several hours/days after the flare/CME event)



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
  - The intensity of the first hours of SEP events



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5-min data from Goes
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UMASEP

new forecasts every 5 min

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

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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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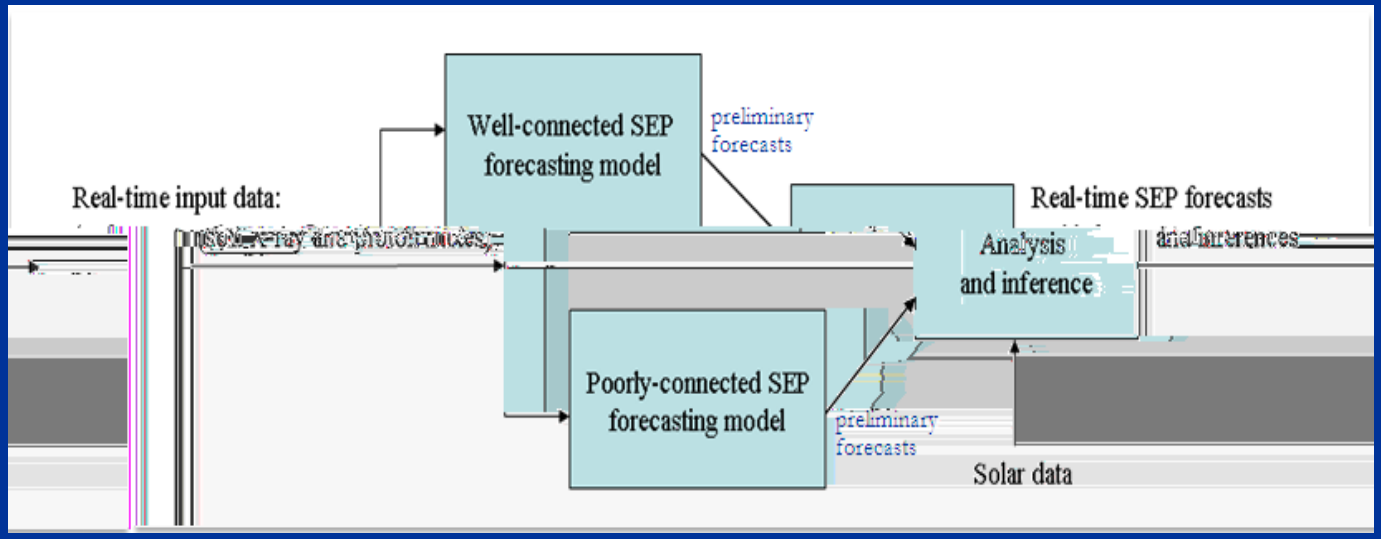
Architecture of UMASEP

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

Models

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

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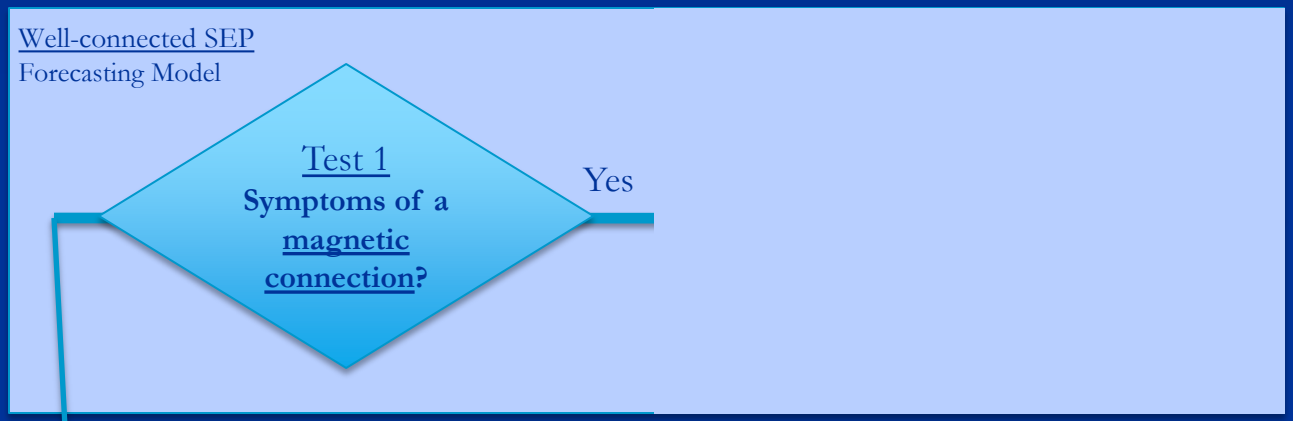
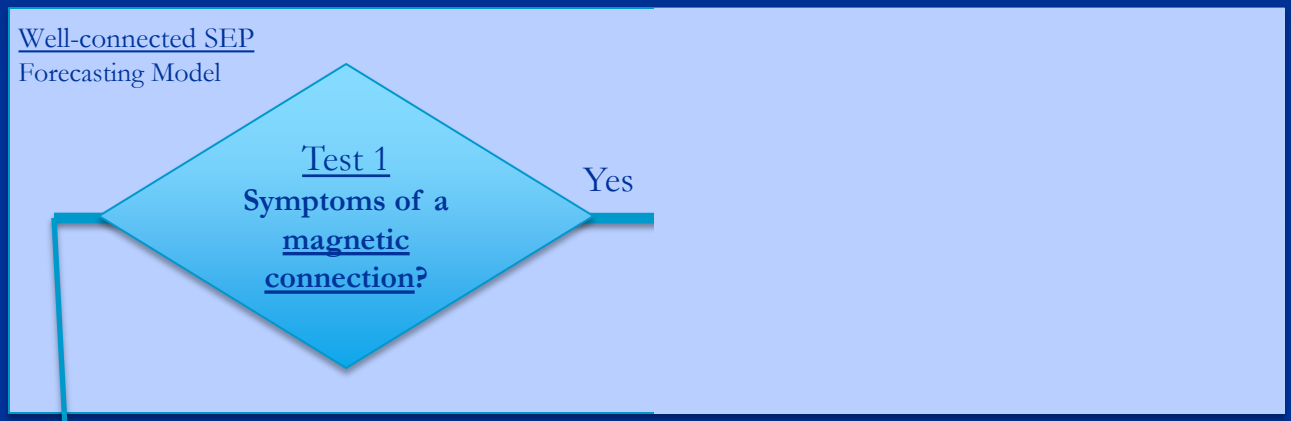

Well-connected SEP
Forecasting Model
Test 1
Symptoms of a magnetic connection?
Yes
Soft X-ray flux
Differential flux
Proton flux
Preliminary forecast of a well-connected SEP

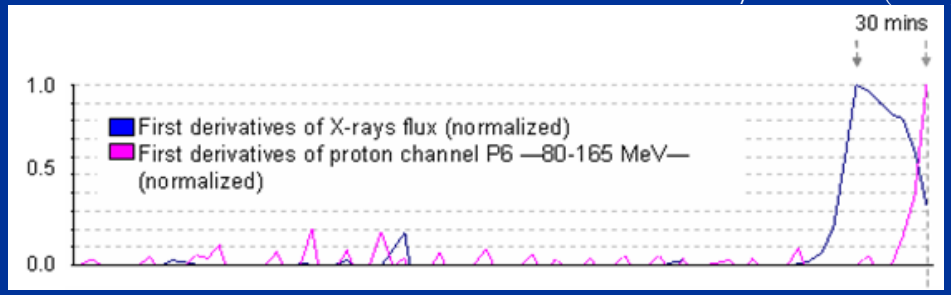
Models



Preliminary forecast of a well-connected SEP

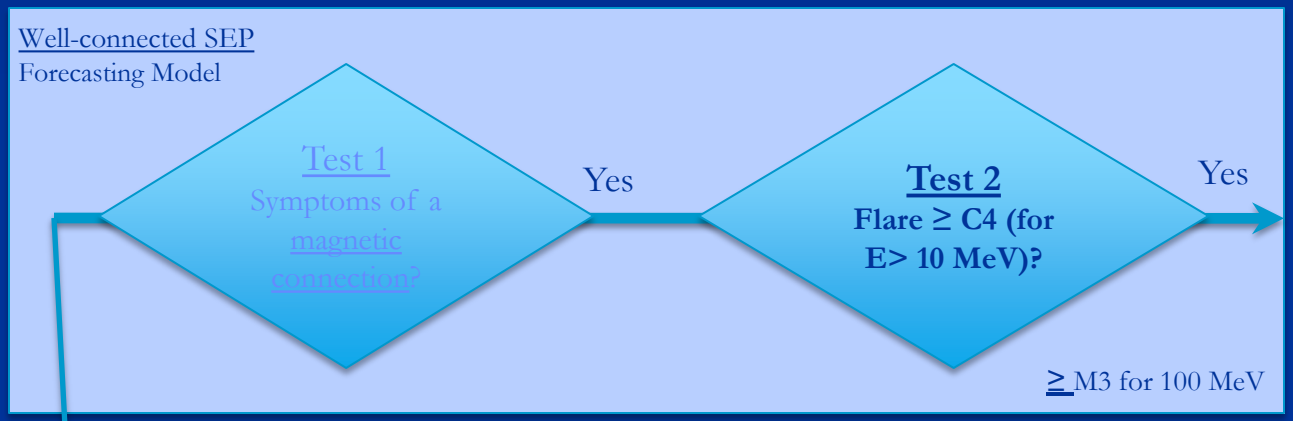
Soft X-ray flux
Differential flux
Proton flux

Oct 26/2003 (18:00)



OK

Models



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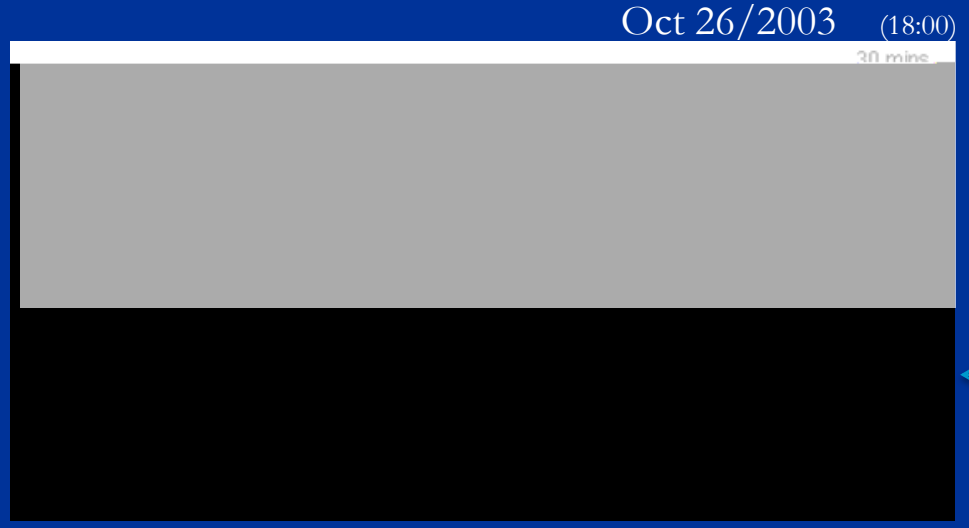

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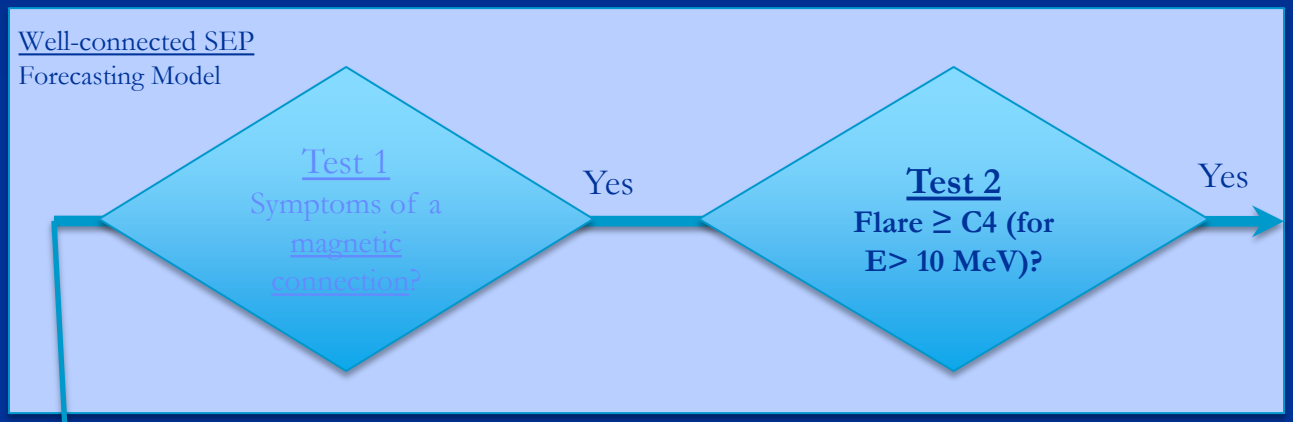

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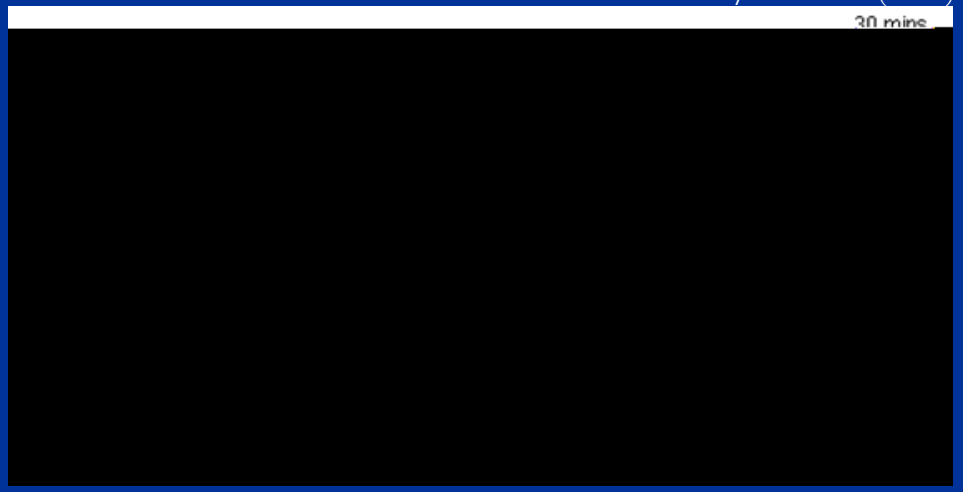
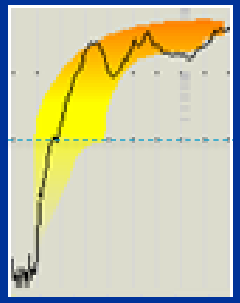


OK

OK



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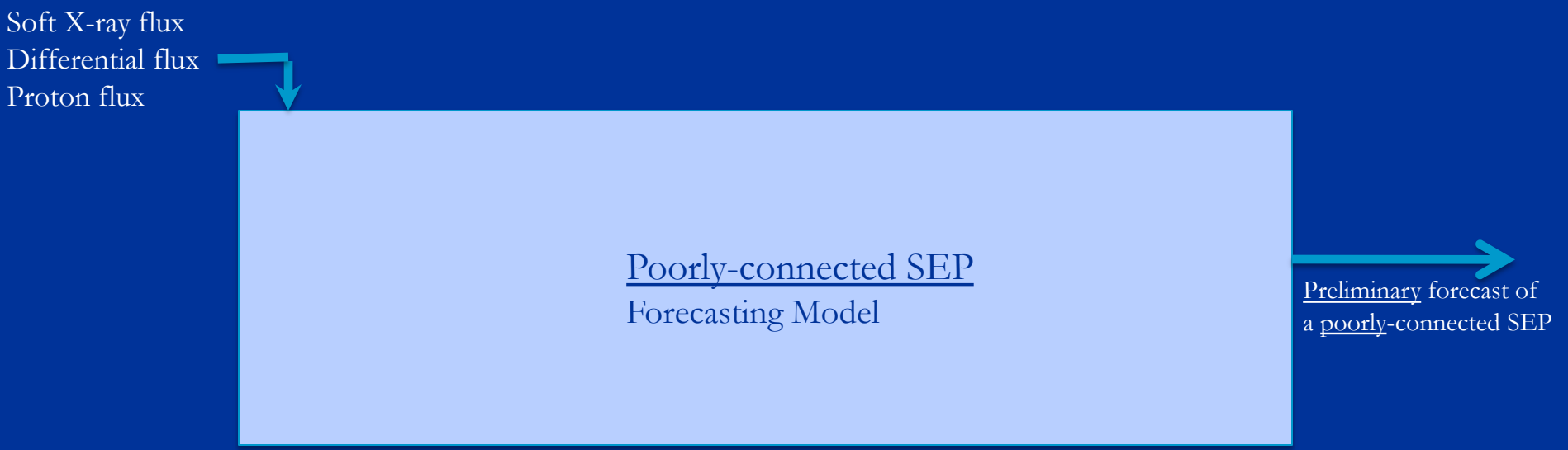

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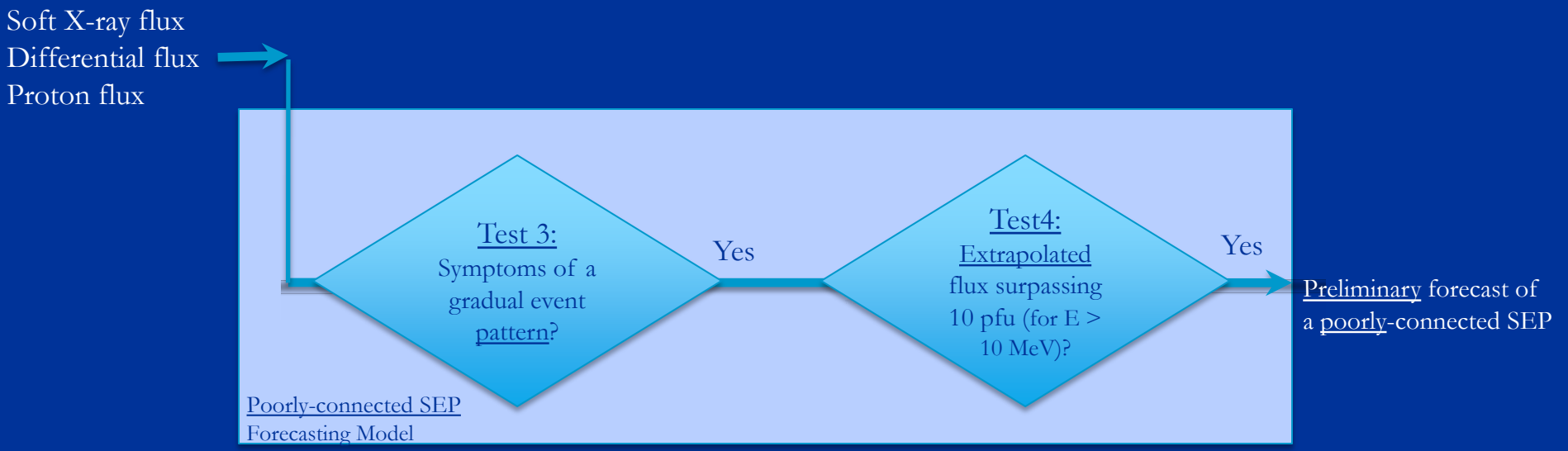

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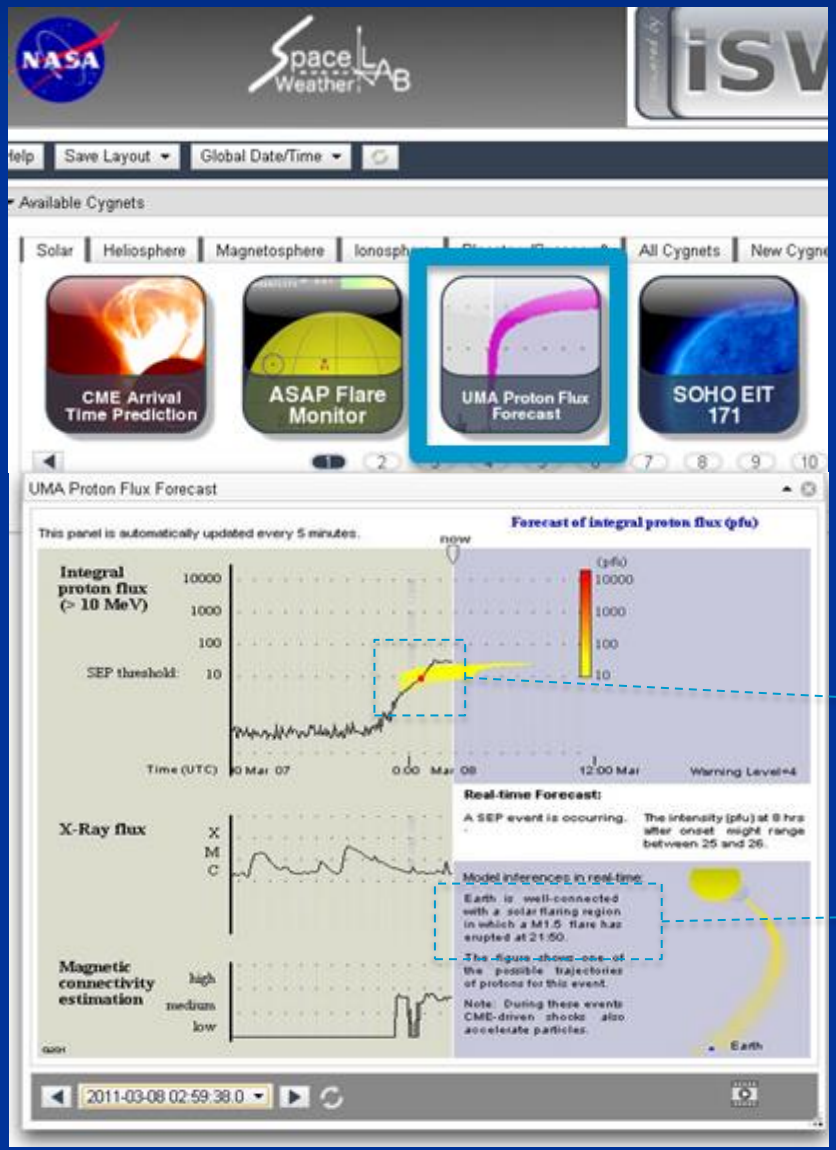
Real-time prediciton of well-connected >10 MeV events



March 8, 2011 (3:00 UTC)

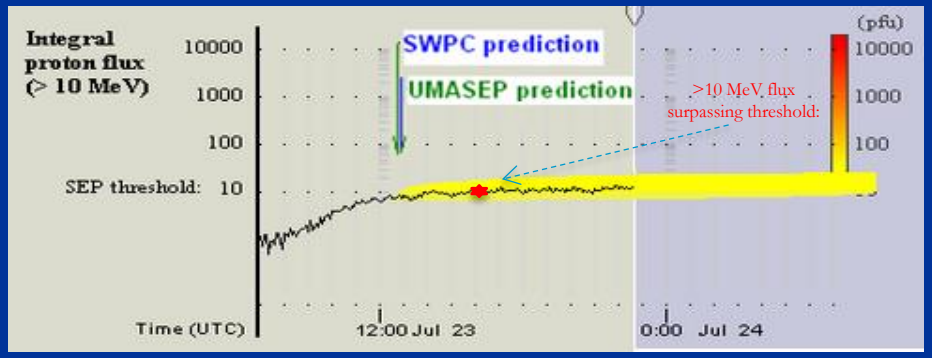
UMASEP anticipated the event start (red dot) in 1 h 30 m

UMASEP identified the intensity and peak time of the associated flare

NASA's ISWA: http://iswa.gsfc.nasa.gov

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

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

5 m
10 50

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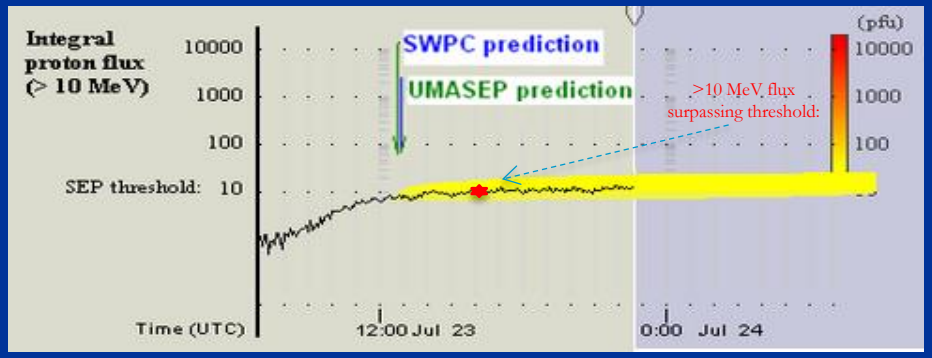
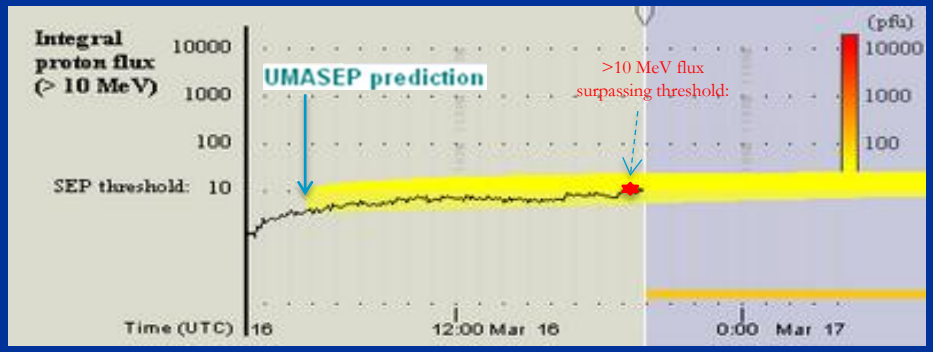


July 23, 2012

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



March 16, 2013

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5 m
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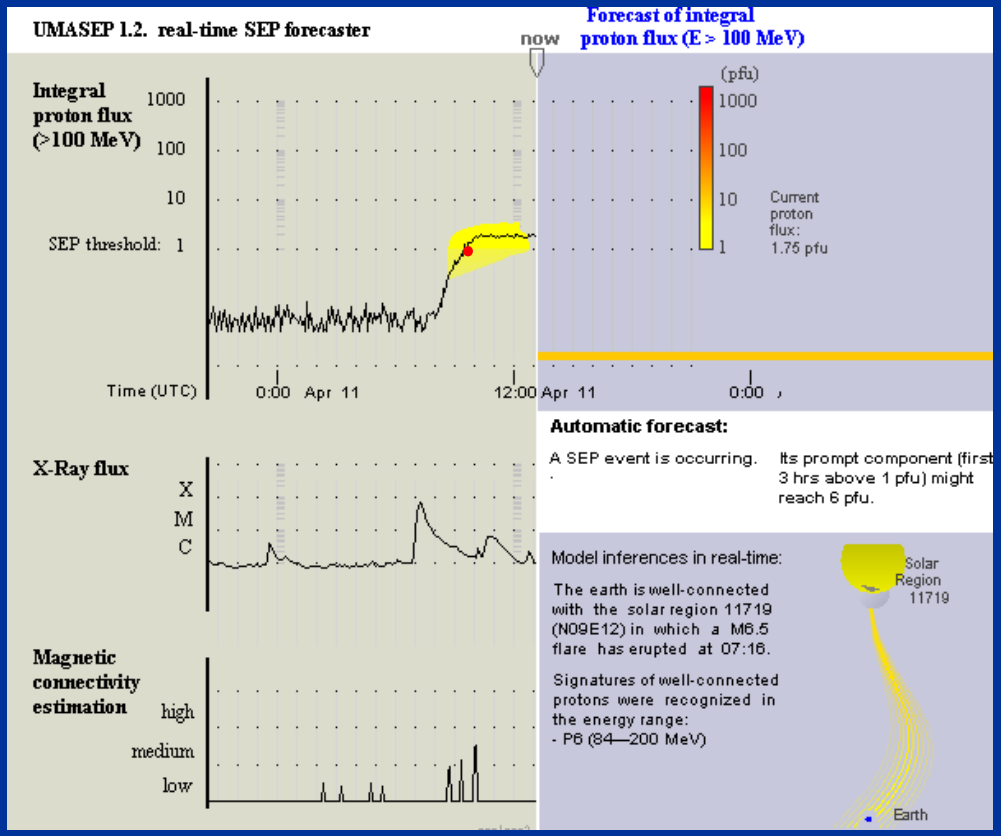
Real-time prediction SEP events with E >100 MeV

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 1994)

- 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	**87.3%**	83.0%
False Alarm Ratio	**21.80%**	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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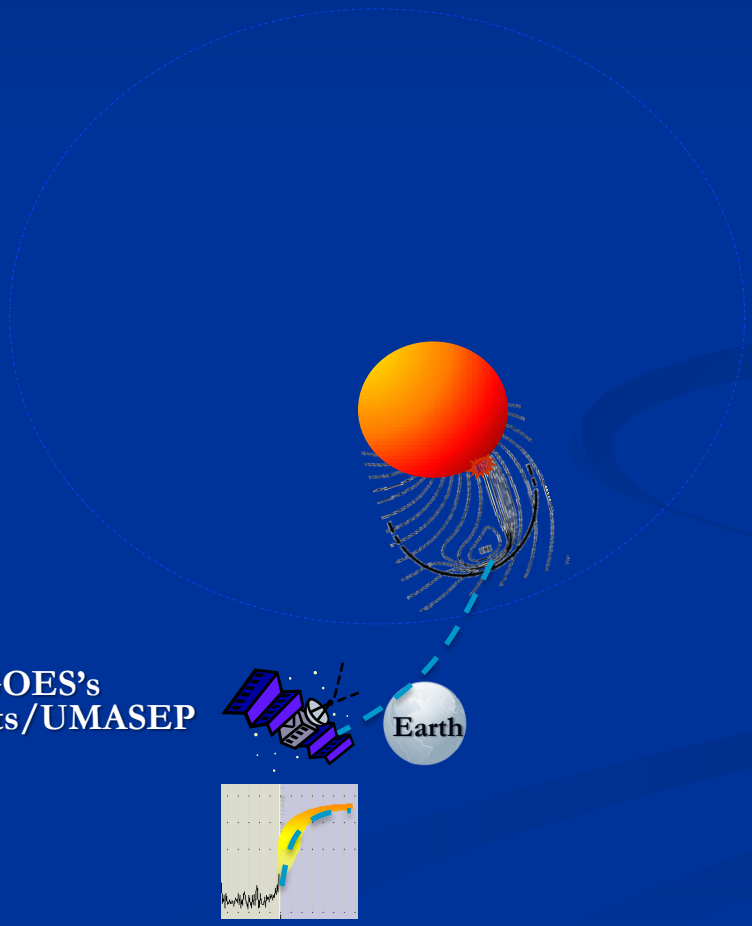
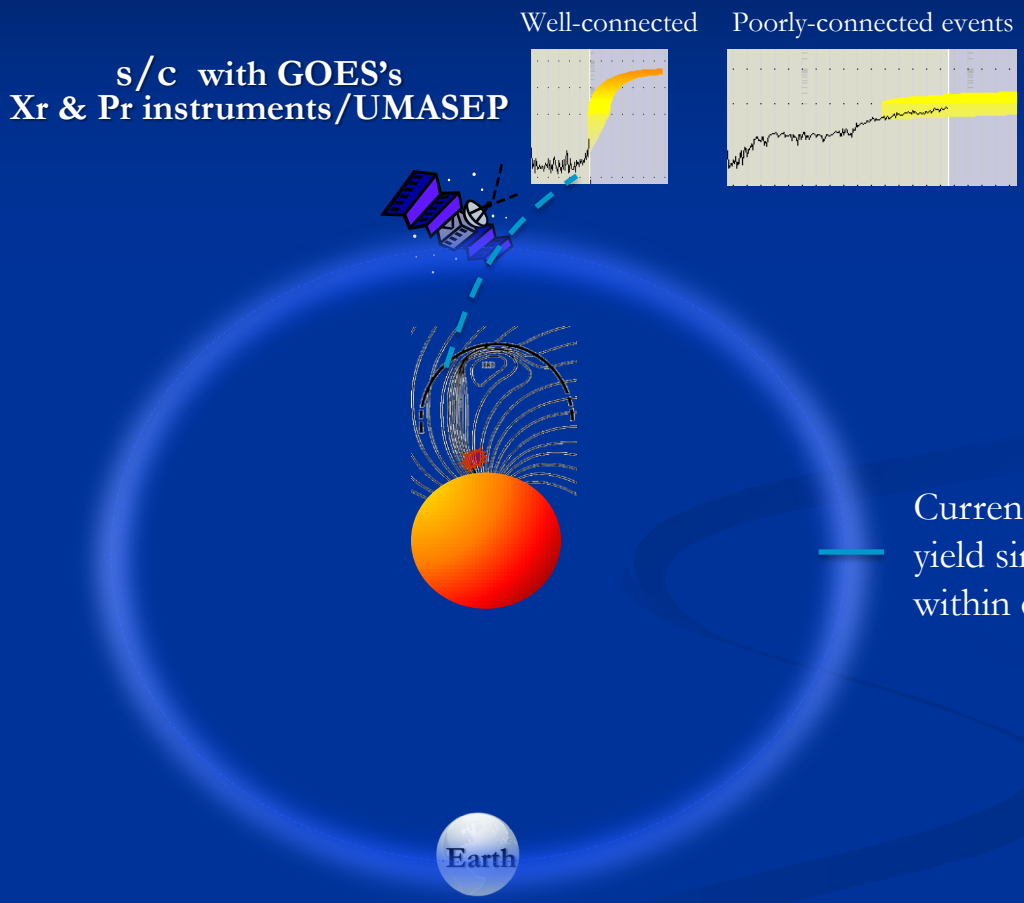
An automatic SEP predictor could be aboard a spacecraft sending streams of estimation data without delay



Approach: GOES's Xr & Pr instruments/UMASEP

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



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

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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