Validation of the UMASEP Solar Radiation Storm Model in the Space Weather Proving Ground

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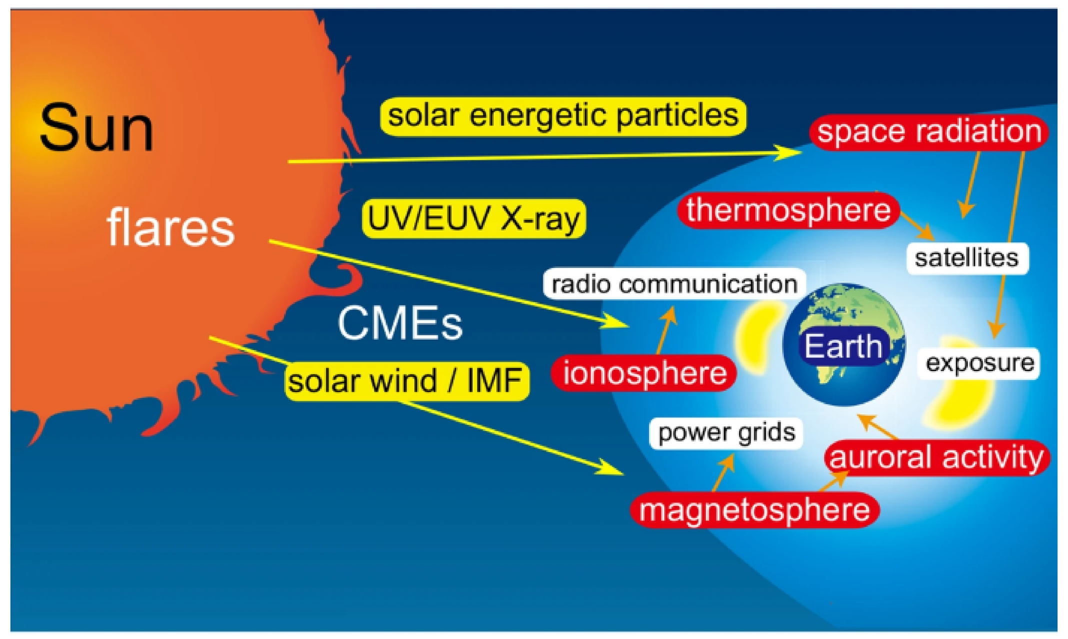
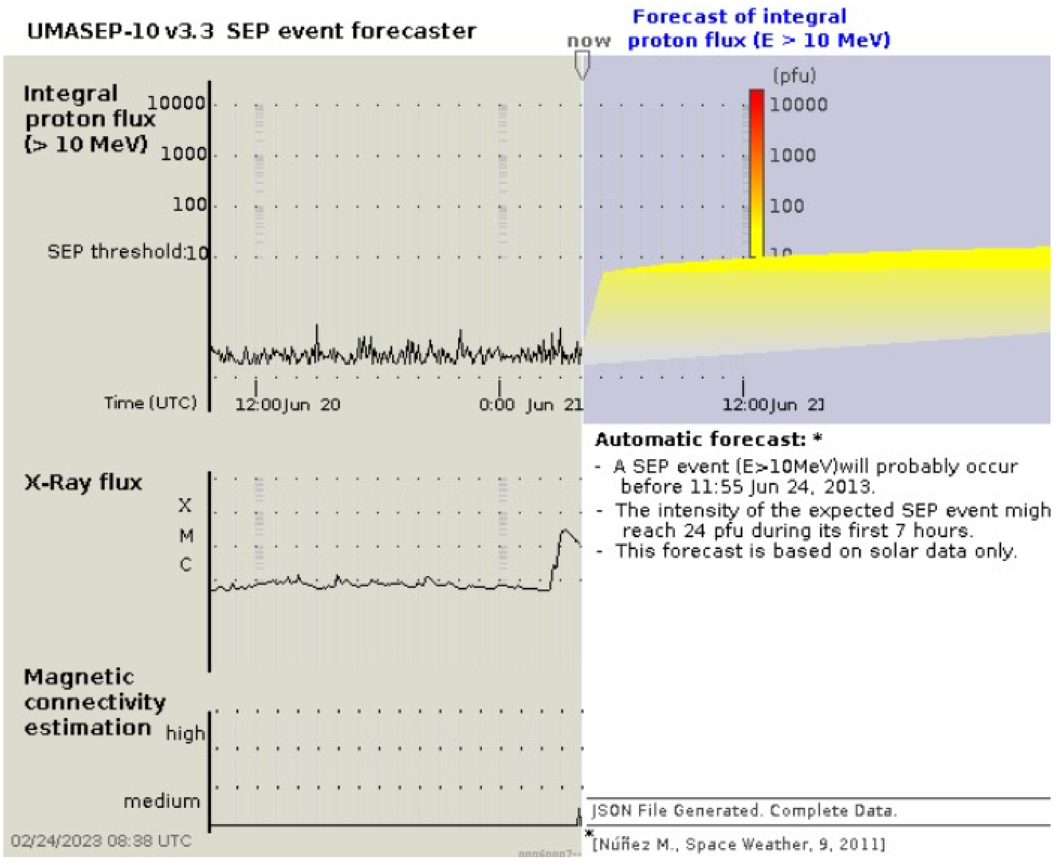
Background

Solar Energetic Particles (SEPs) are high-energy particles (electrons and protons) that are ejected from the sun during solar flares, coronal mass ejections, and other solar phenomena. The resulting radiation from the particles can effect a wide range of environments. The long term health of astronauts, the health of crew and passengers on polar aviation flights, satellite and spacecraft instrumentation can be damaged, communication and GPS systems are affected, and in the most severe cases power gird disruption and damage can occur. The ability to predict and forecast solar radiation storms is of utmost importance since SEP effects can be far-reaching and have significant implications for human health and technology.



UMASEP Model

- The University of Málaga Solar Particle Event Predictor was developed in 2011 by Marlon Núñez
- Empirical model that relies on observations and uses real-time GOES data (X-rays and proton flux)
  - GOES X-ray and proton data is a NOAA SWPC operational product and is available in real-time
- Forecasts are filtered through various models depending on Earth's connectivity to the Sun
  - Well-connected SEP forecasting model
  - Poorly-connected SEP forecasting model – machine learning trained using historical observations
- Predicts event onset (start time) and peak proton flux for energies ≥ 10 MeV, ≥ 30 MeV, ≥ 50 MeV, ≥ 100 MeV and ≥ 500 MeV



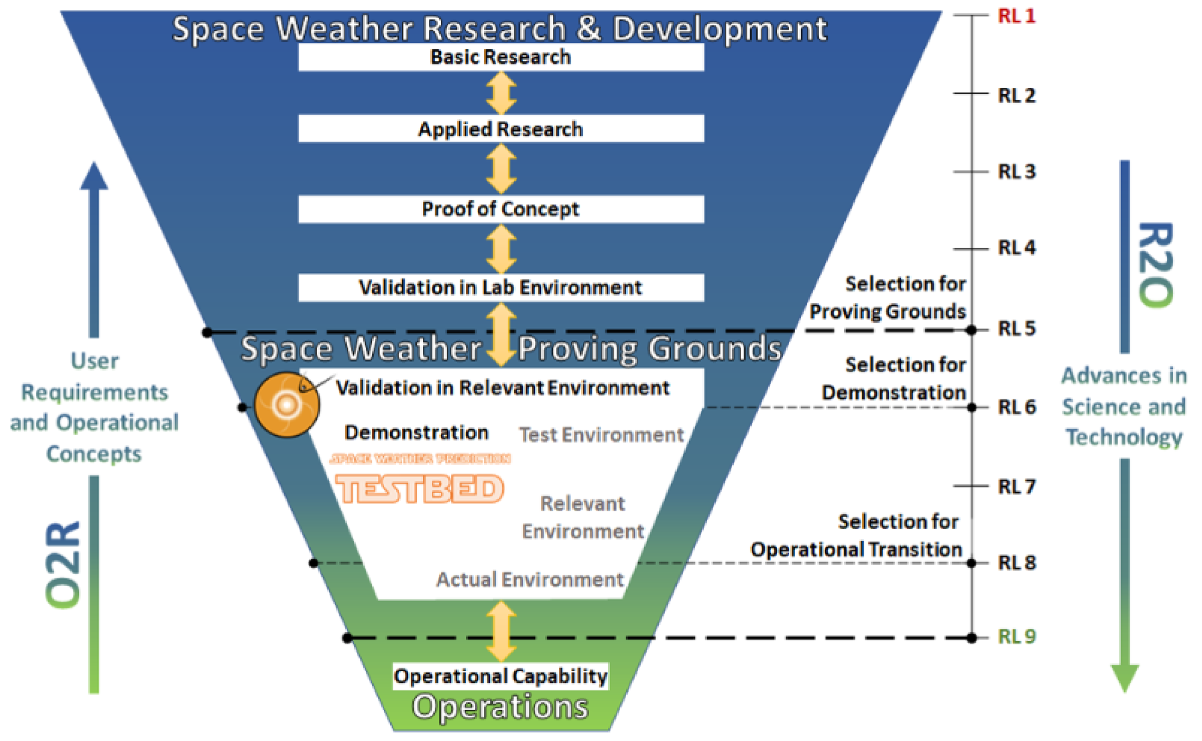
The graphical interface of UMASEP: display includes real-time GOES X-ray and proton flux. Forecast window displays predicted threshold crossing time and estimated peak proton flux.

The UMASEP model improves SWPC's forecasting lead-time & skill for predicting solar radiation storms.

SC 23 – SC 25	POD	FAR	CSI	Lead Time (mins)
≥ 10 MeV	0.93 (+0.15)	0.17 (-0.08)	0.78 (+0.16)	100 (+37)
≥ 100 MeV	0.87 (+0.42)	0.31 (0.00)	0.63 (+0.25)	15 (-8)

The green values in parentheses are the ± values from the SWPC baseline skill. For Solar Cycles 23 - 25 the UMASEP model increases the skill metrics above the SPWC baseline skill for both ≥ 10 Mev and ≥ 100 MeV events and in the ≥ 10 MeV events adds an additional forecast lead time of almost 40 minutes. SEP event forecast lead time is critical as it allows for preparations and mitigation measurements to be put in place across all systems that may be affected by solar radiation storms.

Validation Process



NOAA SWPC's Research 2 Operations funnel overview.

RL Level	Who	What
RL3 → RL4	Researchers, SWPC Scientists	*Documented proof of concept*
RL4	Researchers, SWPC Scientists	*Collaborative Validation*
	Comparison of model with SWPC's current capabilities and baseline skill	
	Documented improvement of models improvement over operational baseline – *model value*	
RL4 → RL5	Researchers, SWPC Scientists & Forecasters	Deployment of model into proving ground for simulated *real-time forecast validation*

Currently the UMASEP validation is complete at RL4 and moving into RL5. Validation is done in a collaborative computing environment with NASA CCMC, NASA SRAG, and M2M.

Metrics

True Positive/Hit (TP):
Event forecasted and occurred

False Negative/Miss (FN):
No event forecasted, event occurs

False Positive/False Alarm (FP):
Forecast issued, no event occurs

Skill Metrics:
Probability of Detection (POD): $\frac{TP}{(TP+FN)}$
False Alarm Ratio (FAR): $\frac{FP}{(TP+FP)}$
Critical Success Index (CSI): $\frac{TP}{(TP+FP+FN)}$

The skill metrics or verification measurements we use are: Probability of Detection (POD) is the percentage of events that occur that are correctly forecast (with some lead time); a perfect POD is 1. False Alarm Ration (FAR) is how many forecasts were issued and the event did not happen; a perfect FAR is 0. Critical Success Index (CSI) is a balance of correct forecasts against incorrect forecasts, including missed events and false alarms.

Next Steps

1. Completion of validation in the collaborative Architecture for Collaborative Evaluation (ACE) computing environment (->RL5)
2. Peak flux prediction for >10 MeV and > 100 MeV event analysis and validation
3. Validation of SEP events from UMASEP running in real-time on ACE (RL5 -> RL6)
4. Create a path to operations - concept of operations and standard operating procedures
5. Work with forecasters to perform a qualitative analysis of the model
6. Model transitioned into the Space Weather Testbed for evaluation and customer engagement (RL6 -> RL8)

ACKNOWLEDGEMENTS:

"*Building Collaborative Proving Grounds for R2O2R - NASA/CCMC - NOAA/SWPT*", 2020,
NASA/CCMC: T. Tsui, C.C. Didigu, M. Kuznetsova, L. Mays, C. Wiegand, J. YueNOAA/SWPT: M. Cash, R. Dodani, M. England, B. Gordon, S. Hill, M. Husler, C. Lauer, C. Wallace

"*Evaluation of the UMASEP-10 Version 2 Tool for Predicting All >10 MeV SEP Events of Solar Cycles 22, 23 and 24*", 2022, Marlon Nunez