

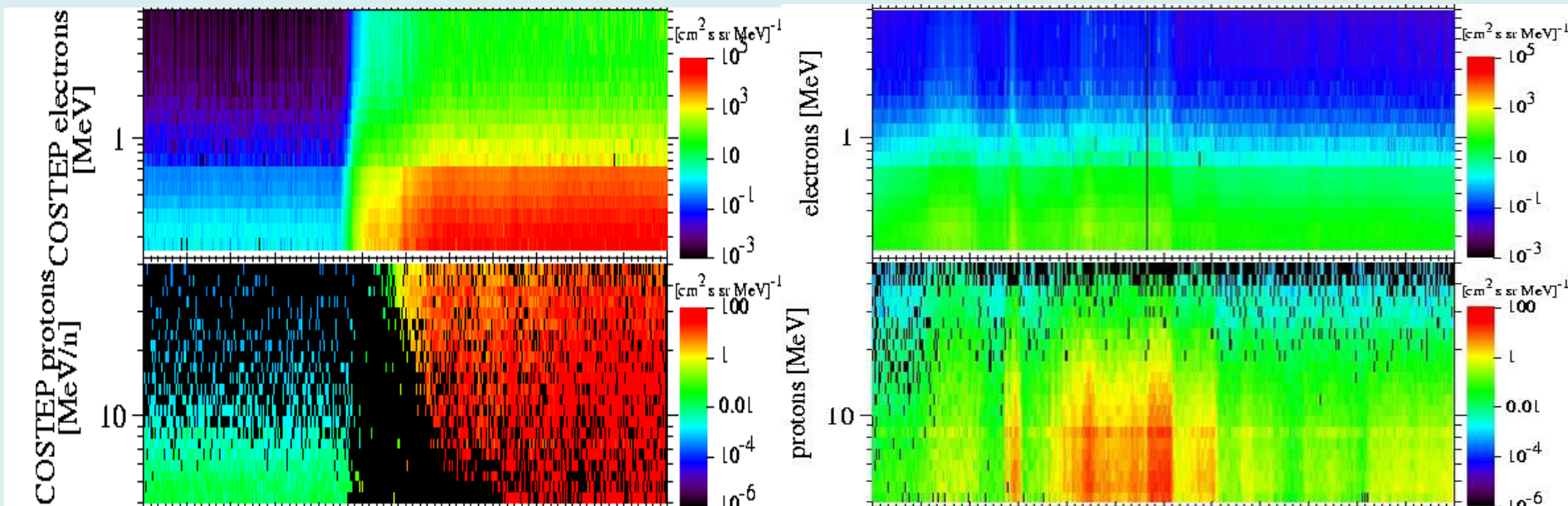


Prompt SPEs and the Relativistic Electron Alert System for Exploration (REleASE)

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Classification: Prompt or Delayed?



“Prompt” (left, November 04, 2001, 12 hours shown) and “Delayed” (right, July 28, 2000, full day) particle enhancements at 1 AU. The top spectrograms are for 0.2-9 MeV electrons, the bottom for 4-50 MeV protons as measured by SOHO/COSTEP near 1 AU. A simple classification distinguishes events on whether they reveal proton velocity dispersion at onset (left, meaning that slow, low-energy protons arrive later than fast, high-energy protons) or not (right side).

The forecasting technique introduced here is intended only to warn against prompt SEP events.

Note the apparent disappearance of pre-event proton background in the Nov. 04, 2001 event. Rather large statistical uncertainties for protons intensities incur as long as extreme electron-to-proton ratios persist.

COSTEP+ Forecasting Team:

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COSTEP Team**

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COSTEP
Operations
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**A. Posner
Forecasting
Technique**

**O. Rother
Real-time
Implemen-
tation &
Maintenance**

**B. Heber
COSTEP PI**

**SOHO/COSTEP
1:1 Model**

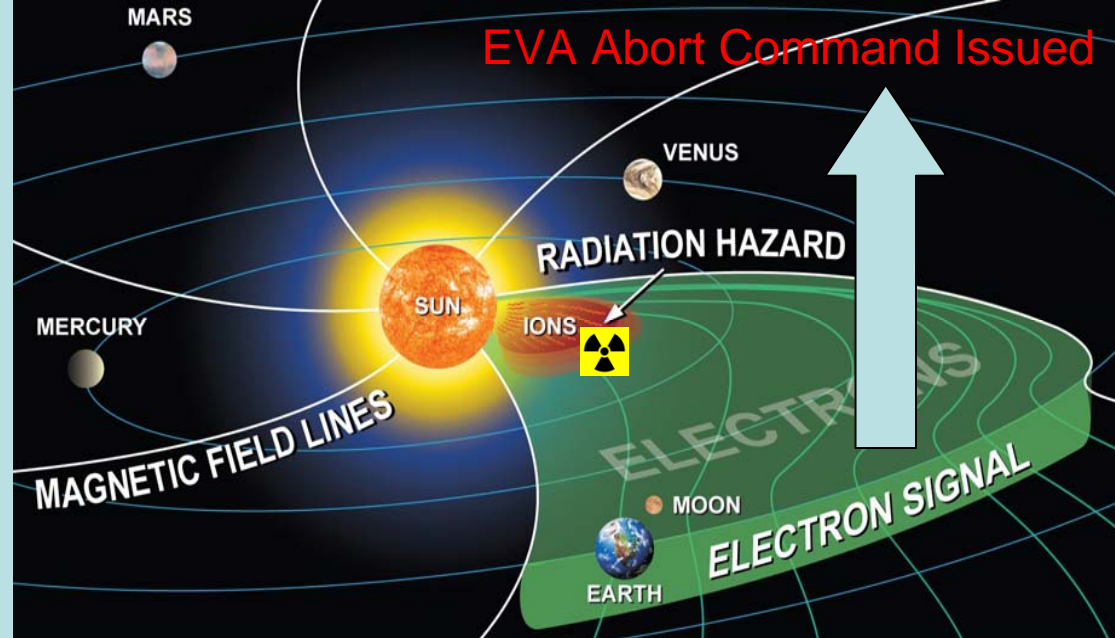
Thanks also to SOHO/SOC and CCMC at GSFC and Univ. Turku, Finland

REleASE: The “Why” and “How”

Astronauts venturing beyond the protective magnetic field of Earth face the direct effects of the Sun and unpredictable outbreaks of activity.

Within even one hour, explorers can be engulfed with particles that cause harmful long- or short-term health effects and put missions at risk. Although the inside of a spacecraft or lunar base can be made relatively safe, “Staying Inside” hampers productivity. “Going Outside” requires a space weather warning system.

Research leading up to REleASE has shown that electrons traveling at the speed of light are always present in solar particle eruptions. These electrons – traveling much faster than the hazardous solar energetic protons – follow the magnetic lines of force from the Sun to the Earth. Therefore, they can be used as a reliable early warning sign of hazardous radiation ahead.



Solar electrons reach the Earth-moon system about one hour before the solar proton radiation hazard arrives.

The Problem: Exposure Risk from Fast-Rising Events

Lower Limit for
Acute Radiation
Sickness from 1h
Exposure

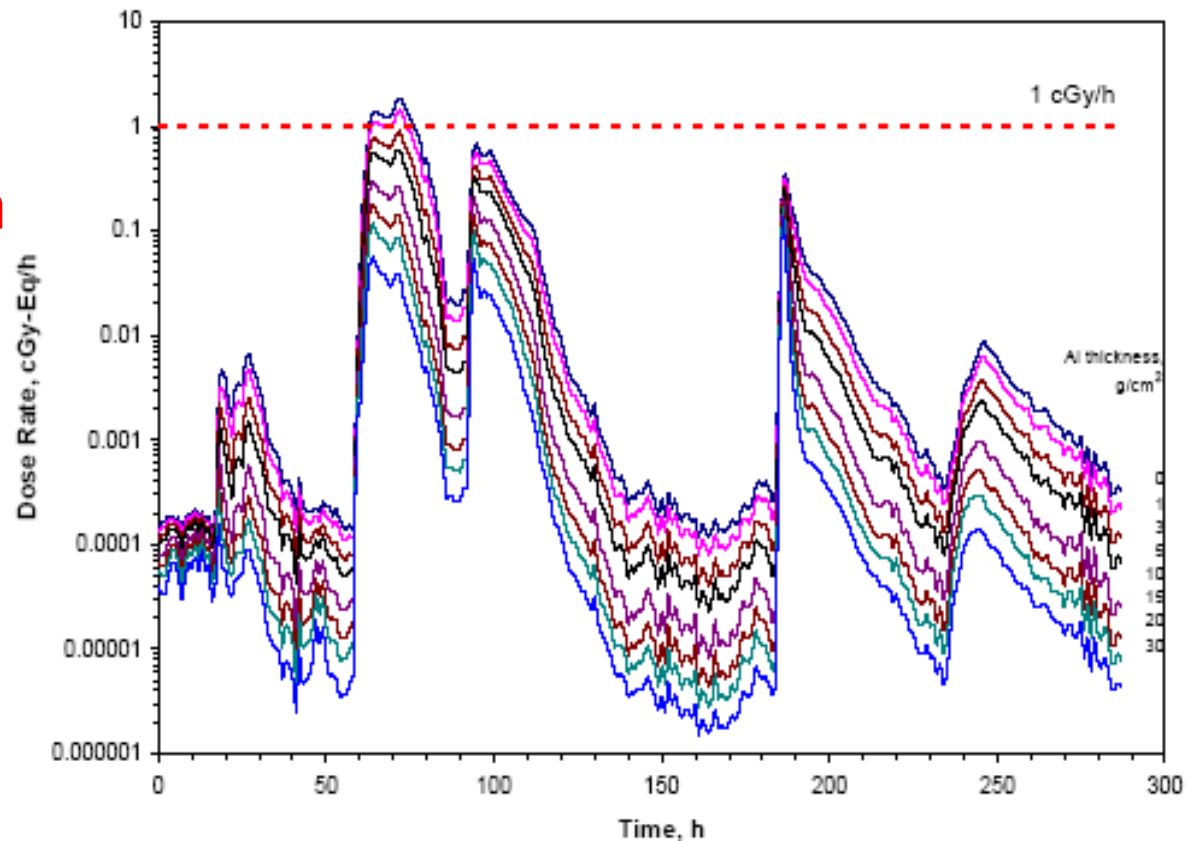
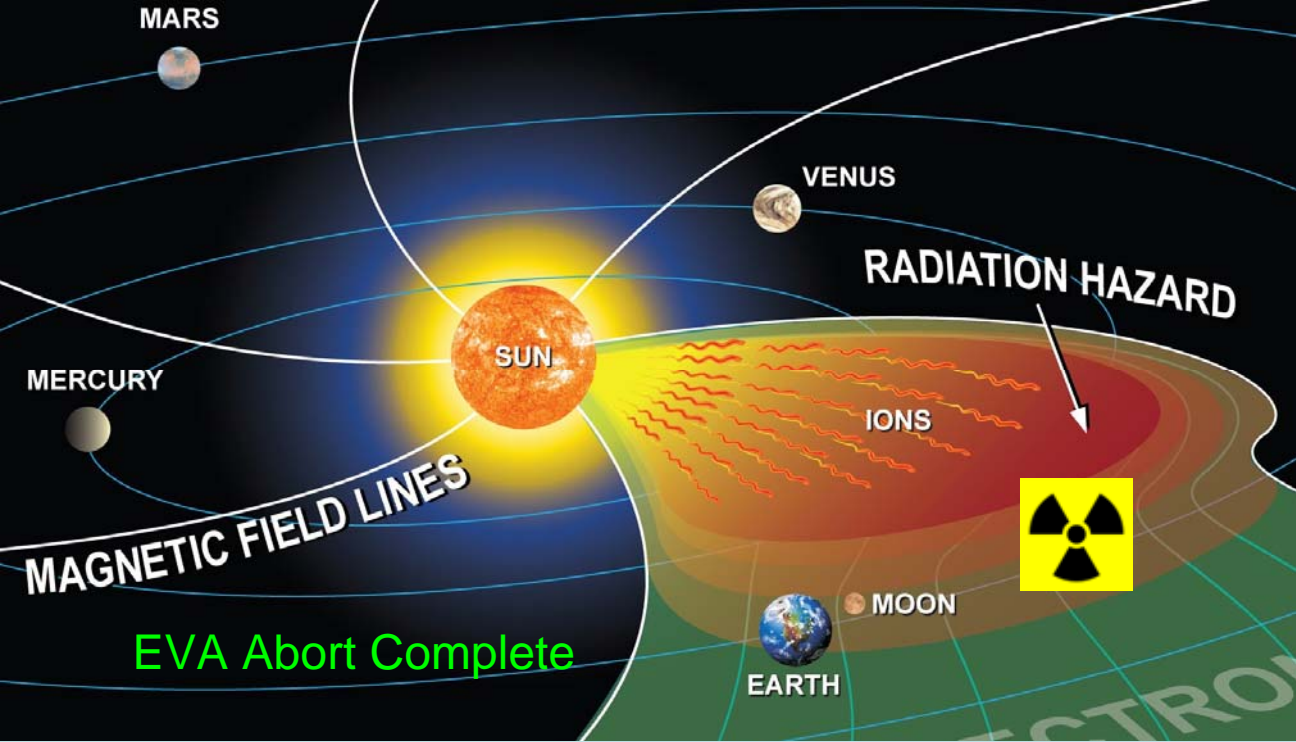


Figure 5. BFO dose rate behind various aluminum thicknesses during Oct 26-Nov 6, 2003 SPE.

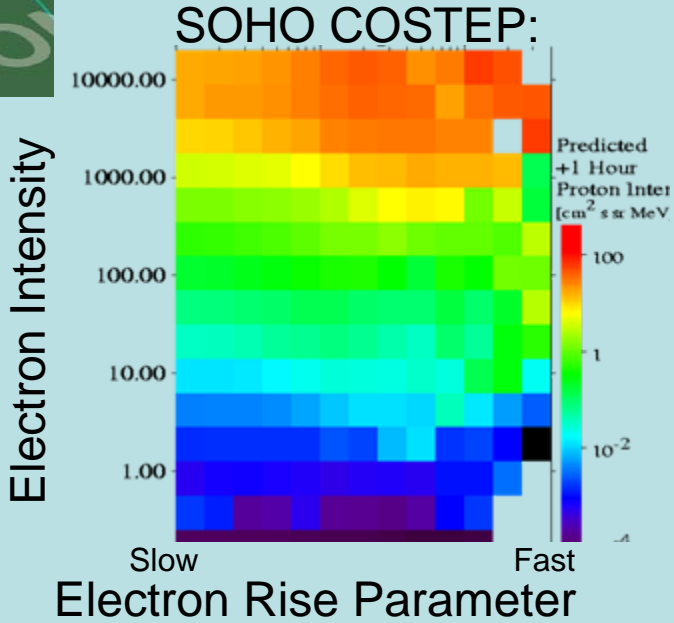
From Kim, Hu, and Cucinotta, AIAA, 2005



Even in the case of the fastest-rising major proton event on record (Jan. 20, 2005), the electron precursor signal was detected 20-25 minutes in advance.

A one-hour warning has the potential to provide the advanced notice needed for efficient EVA planning.

An important example of the potential for further rapid transition of SMD Research to SOMD/ESMD Operations – May 2007 to Feb 2008 – this new prediction tool has entered V&V by the JSC/SRAG for future Shuttle, ISS, and CEV operations.

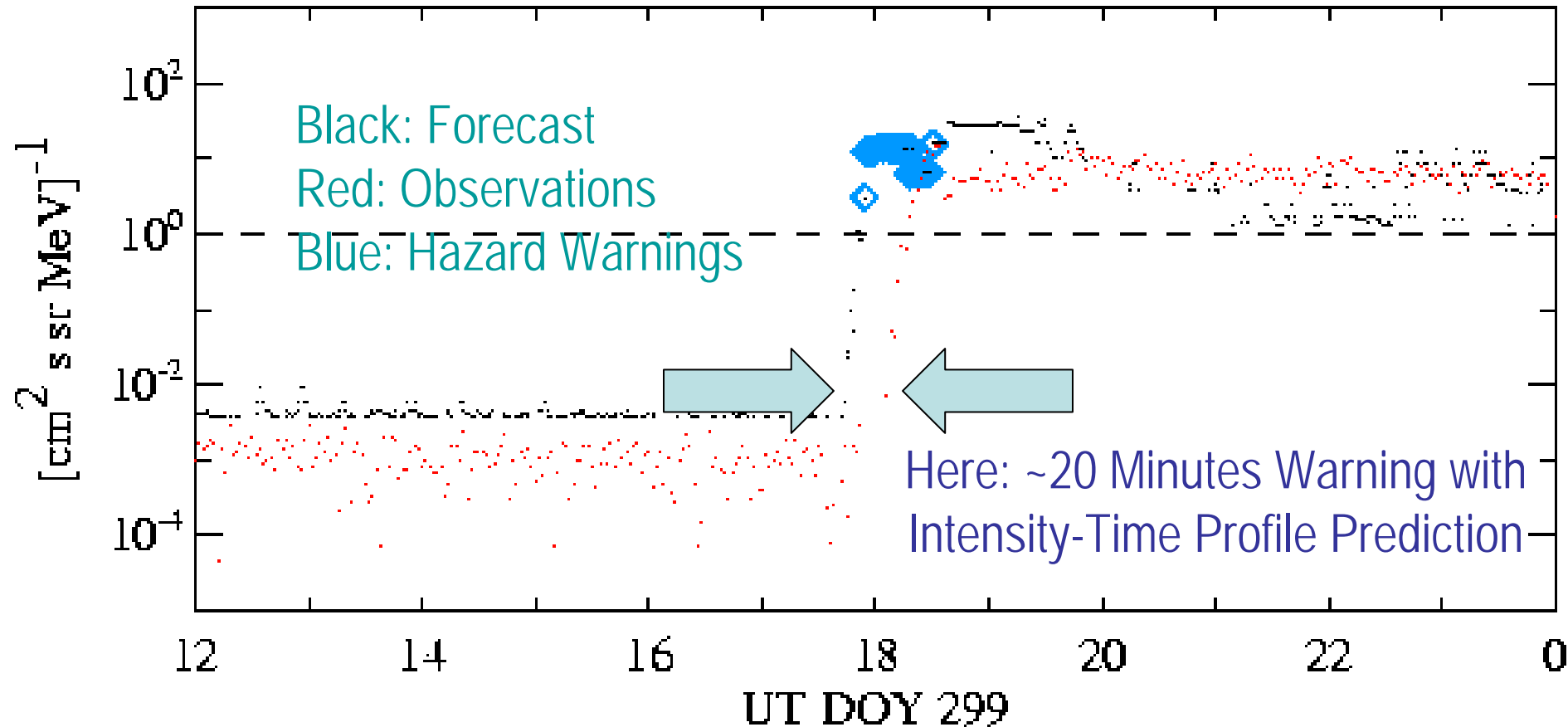


Empirical Forecasting Matrix Translates Solar Electron Data into +1h Proton Hazard Forecast (Posner, *Space Weather*, 2007)

Zoom into 16-40 MeV Archival Proton Forecast



Proton Event Prediction DOY 299, 2003





Archived Data Stats 2003-2007

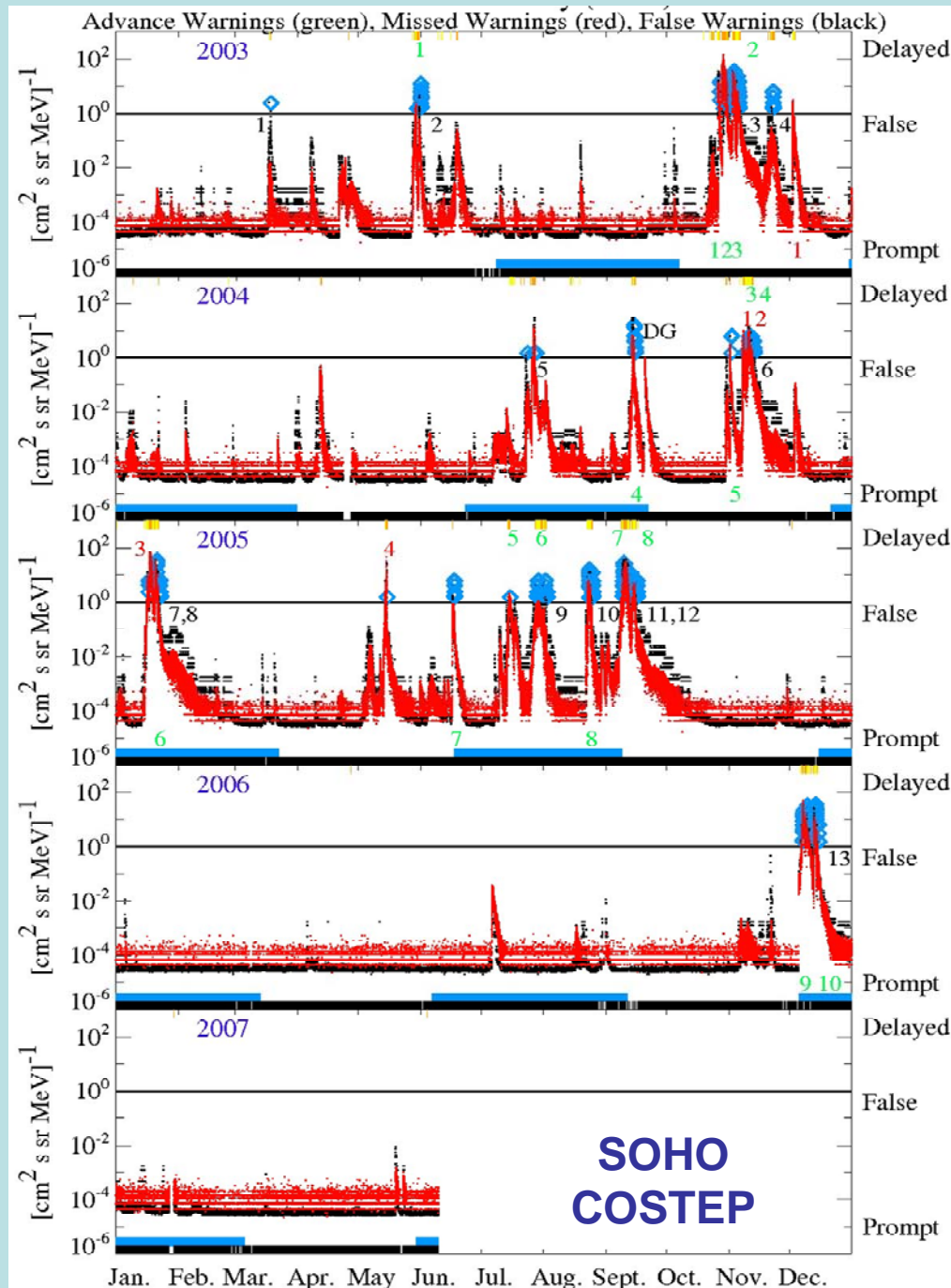
24 Proton Events beyond
Threshold

10/11 Prompt Events Forecast
(91%) with 122 min average
warning time

9/13 Delayed Events Forecast
(69%)

Overall: 79%, 195 min average
warning time

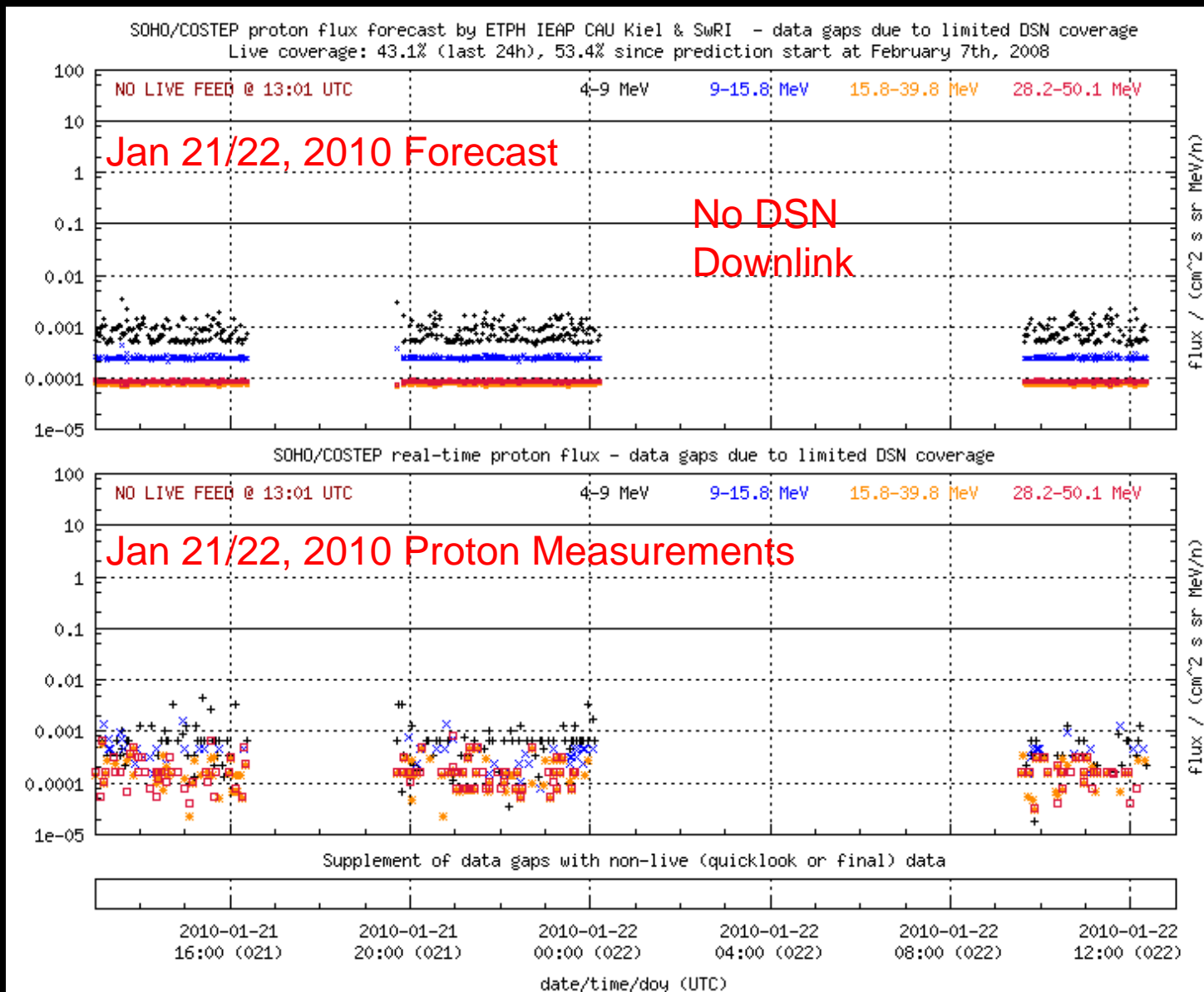
13 False Warning Series (10
from Decreases)



Real-time REleASE Output:

Most recent 24 hours shown. Most recent data points on right-hand side.
~1-h forecast (top) and measured (bottom) intensity for protons in 4 energy ranges. DSN downlink limitations: data gaps

Currently
53.4% Real-Time
Coverage since
Feb. 7, 2008





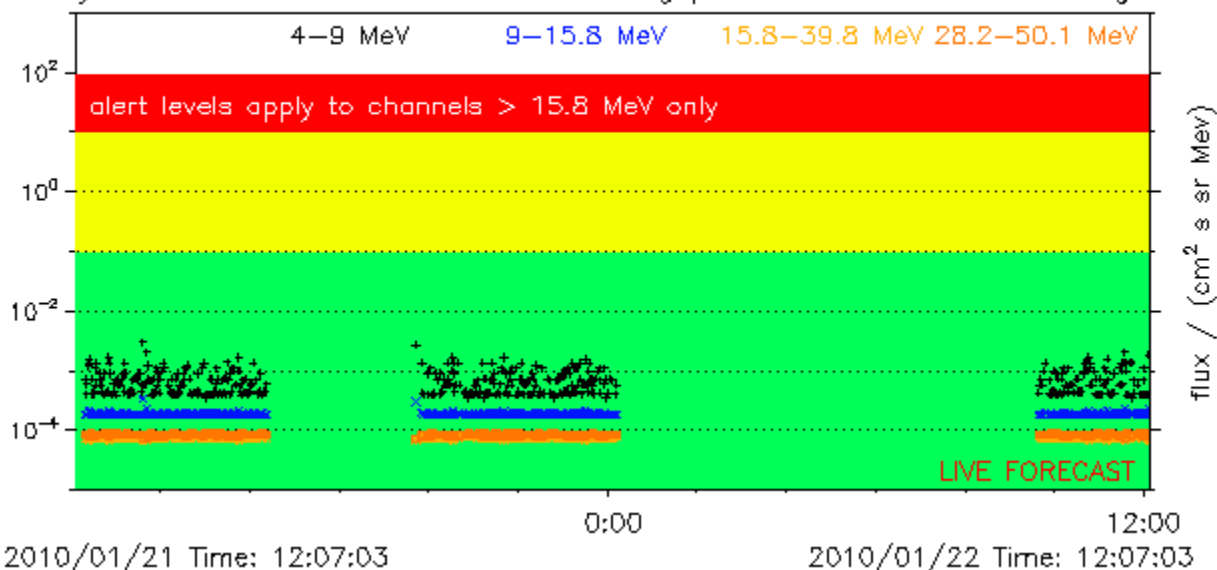
Presence at CCMC:

<http://ccmc.gsfc.nasa.gov/awareness/helio.html> (and iSWA)

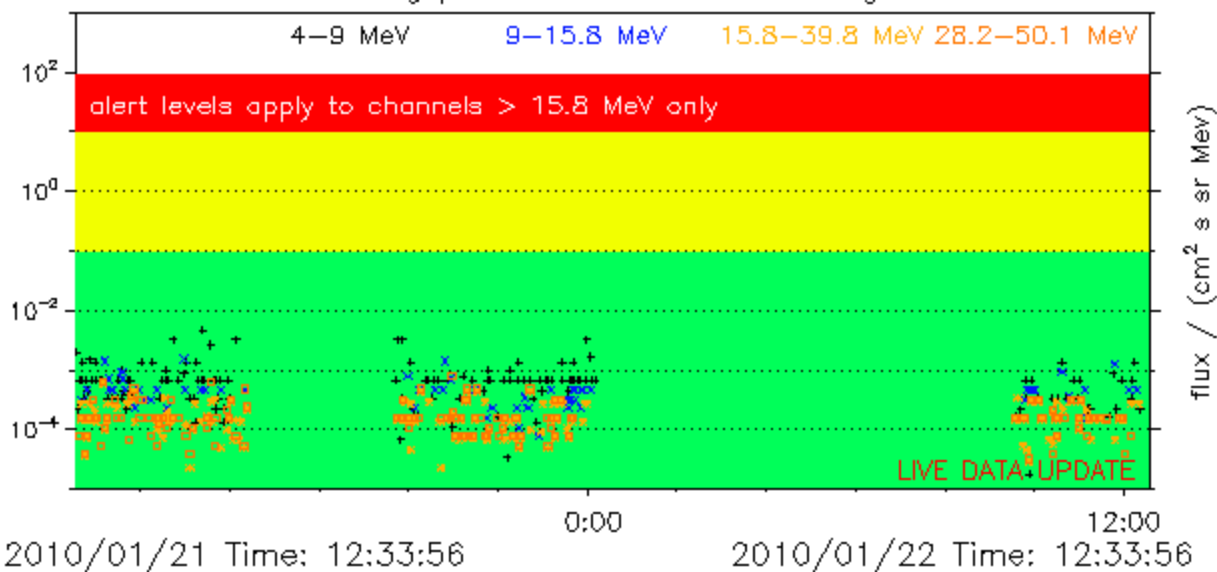
Alert levels:
Notional for now.
Yellow and red:
Alert levels for
higher-energy
channels (>15.8
MeV, orange and
red symbols)

Availability of
REleASE Spectrum
Forecasting allows
us to tie into
EMMREM's
BRYNTRN
framework in order
to translate
intensities into dose
rate and cumulative
dose (planned).

REleASE proton flux forecast at CCMC
by ETPH IEAP CAU Kiel and SWRI – data gaps due to limited DSN coverage

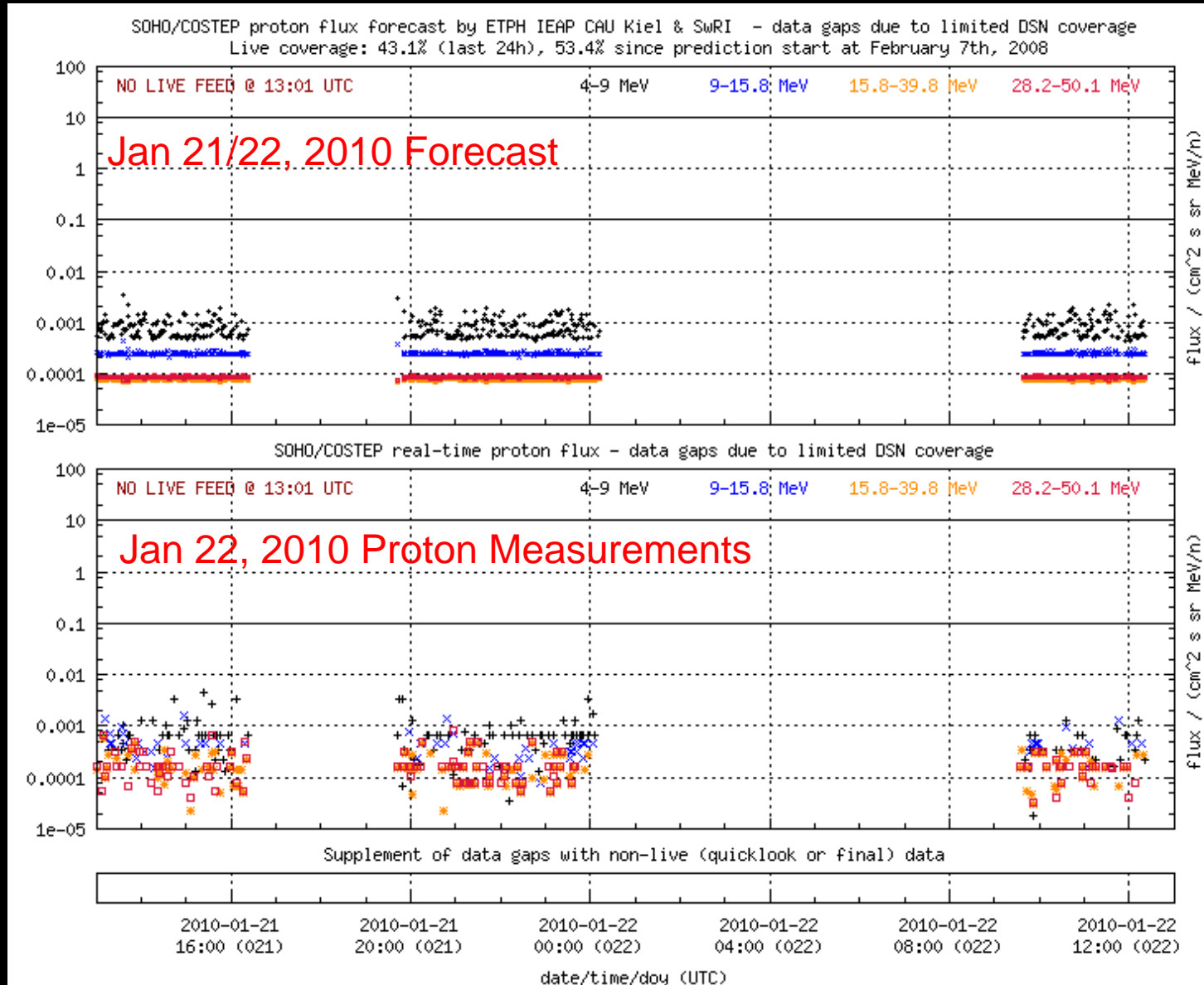


SOHO/COSTEP real-time proton flux at CCMC
data gaps due to limited DSN coverage

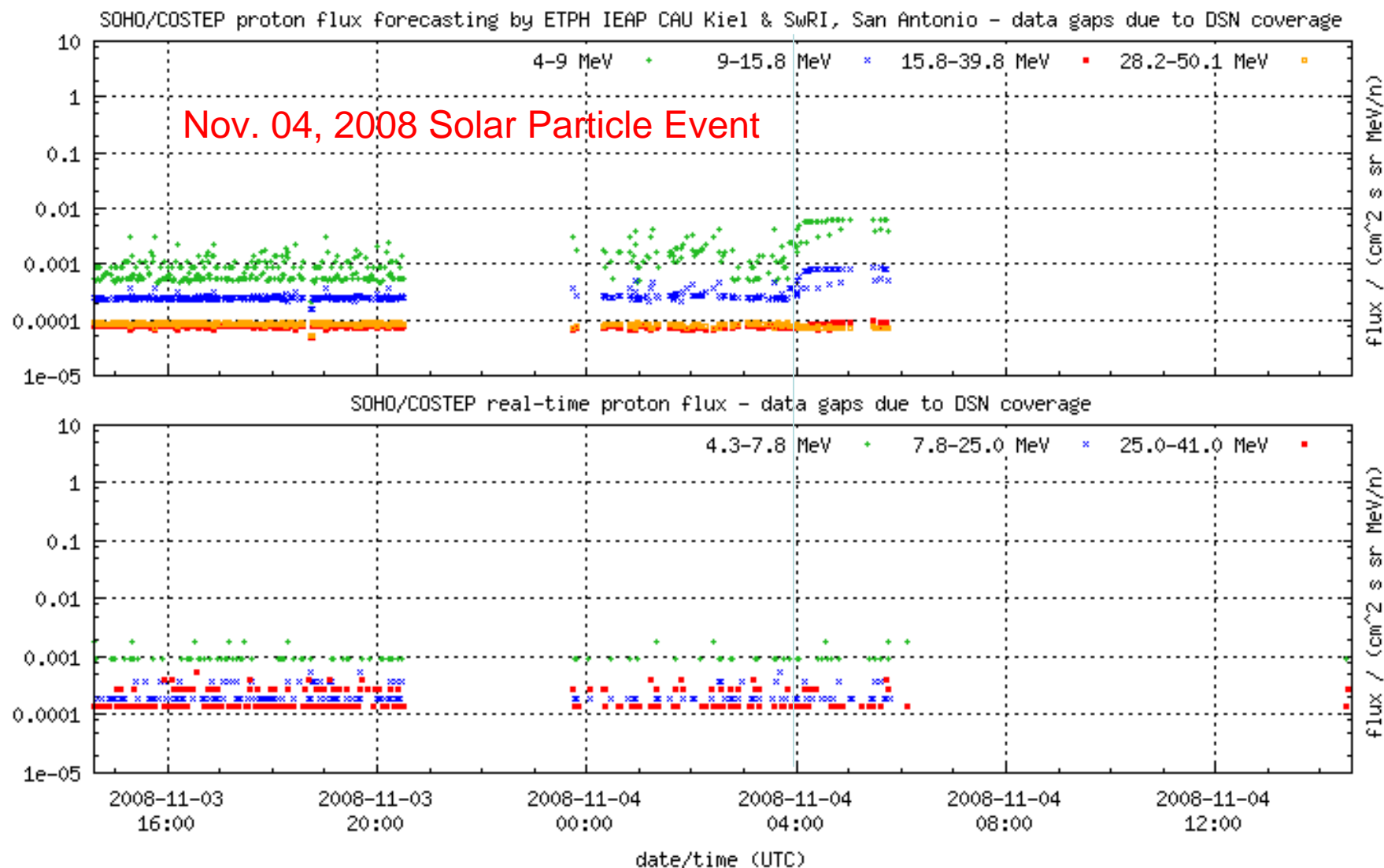


Redundancy: two independent output streams (past SOHO SOC)
<http://www-etph.physik.uni-kiel.de/missions/soho/costep/realtime/forecast/>
<http://costep2.nascom.nasa.gov>

Central
Clearinghouse
Website in
Development:
www.release.de

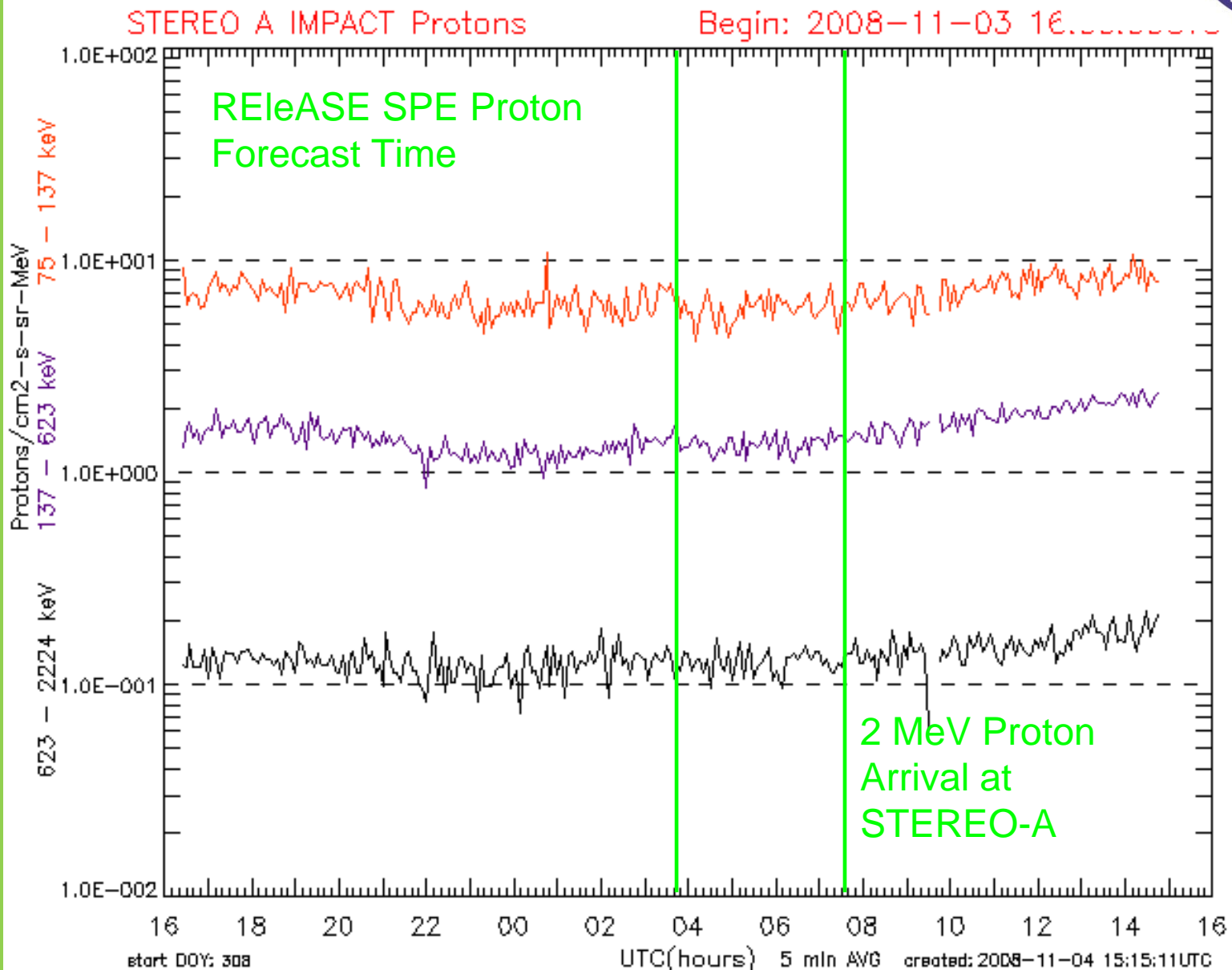


Verification and Validation First SEP Forecast on Nov. 04, 2008



Verification and Validation

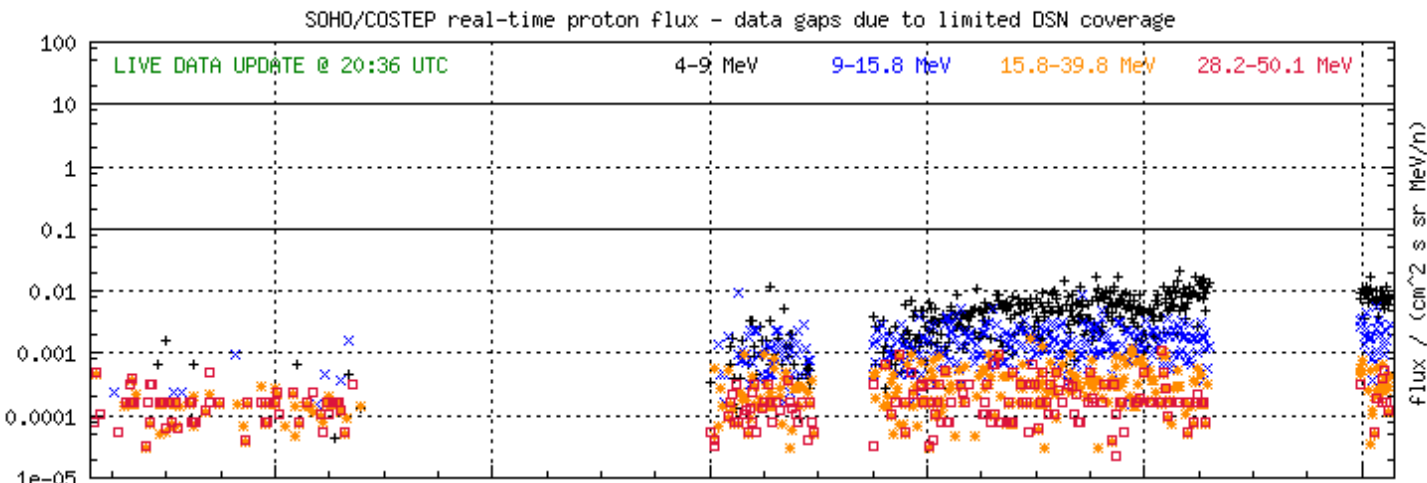
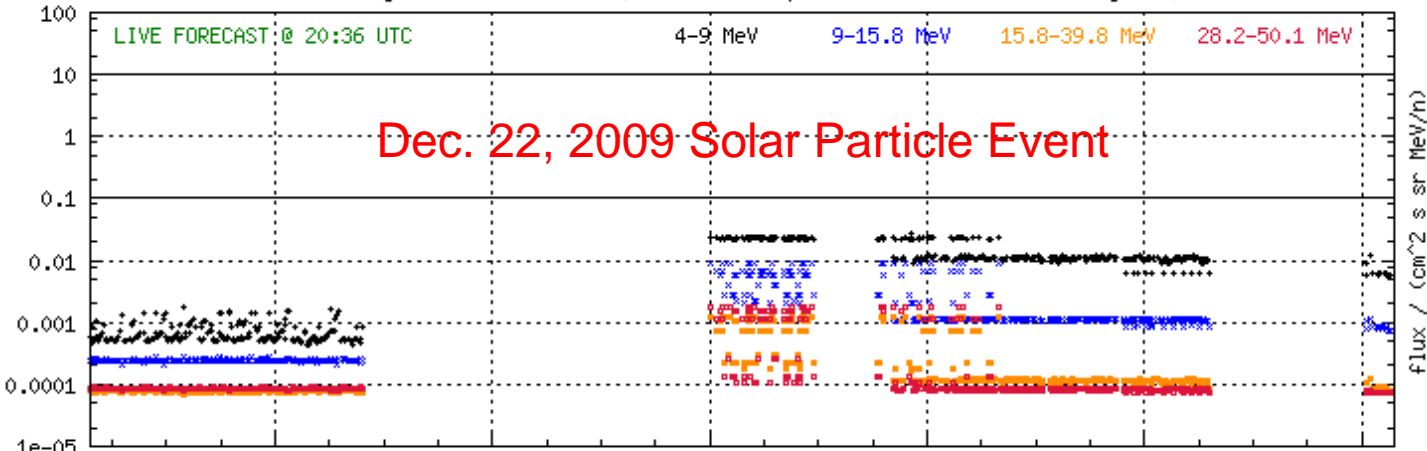
First SEP Forecast on Nov. 04, 2008, STEREO-A Context



Verification and Validation Second SPE Forecast, Dec. 22, 2009



SOHO/COSTEP proton flux forecast by ETPH IEAP CAU Kiel & SwRI - data gaps due to limited DSN coverage
Live coverage: 56.7% (last 24h), 53.4% since prediction start at February 7th, 2008



Supplement of data gaps with non-live (quicklook or final) data

2009-12-22 00:00 (356) 2009-12-22 04:00 (356) 2009-12-22 08:00 (356) 2009-12-22 12:00 (356) 2009-12-22 16:00 (356) 2009-12-22 20:00 (356)

date/time/doy (UTC)

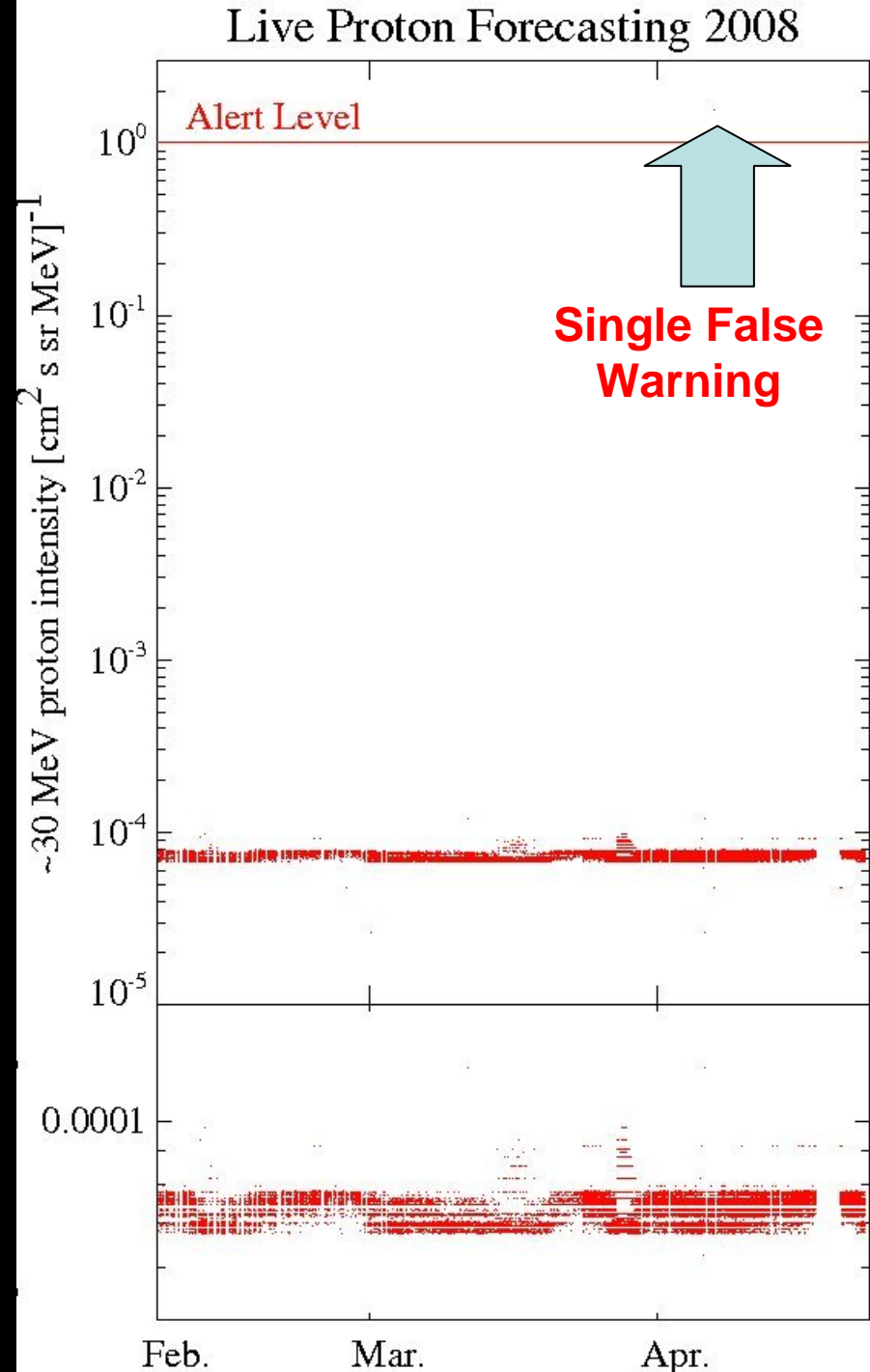
No SEP event near warning threshold intensity (one expected source of "false" warnings from archival testing)

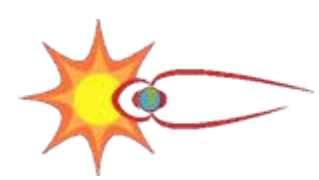


V&V: False Warnings

2 False Warnings (April 7, 2008 and Aug. 13, 2009) in about 2 years (1 year net observations)

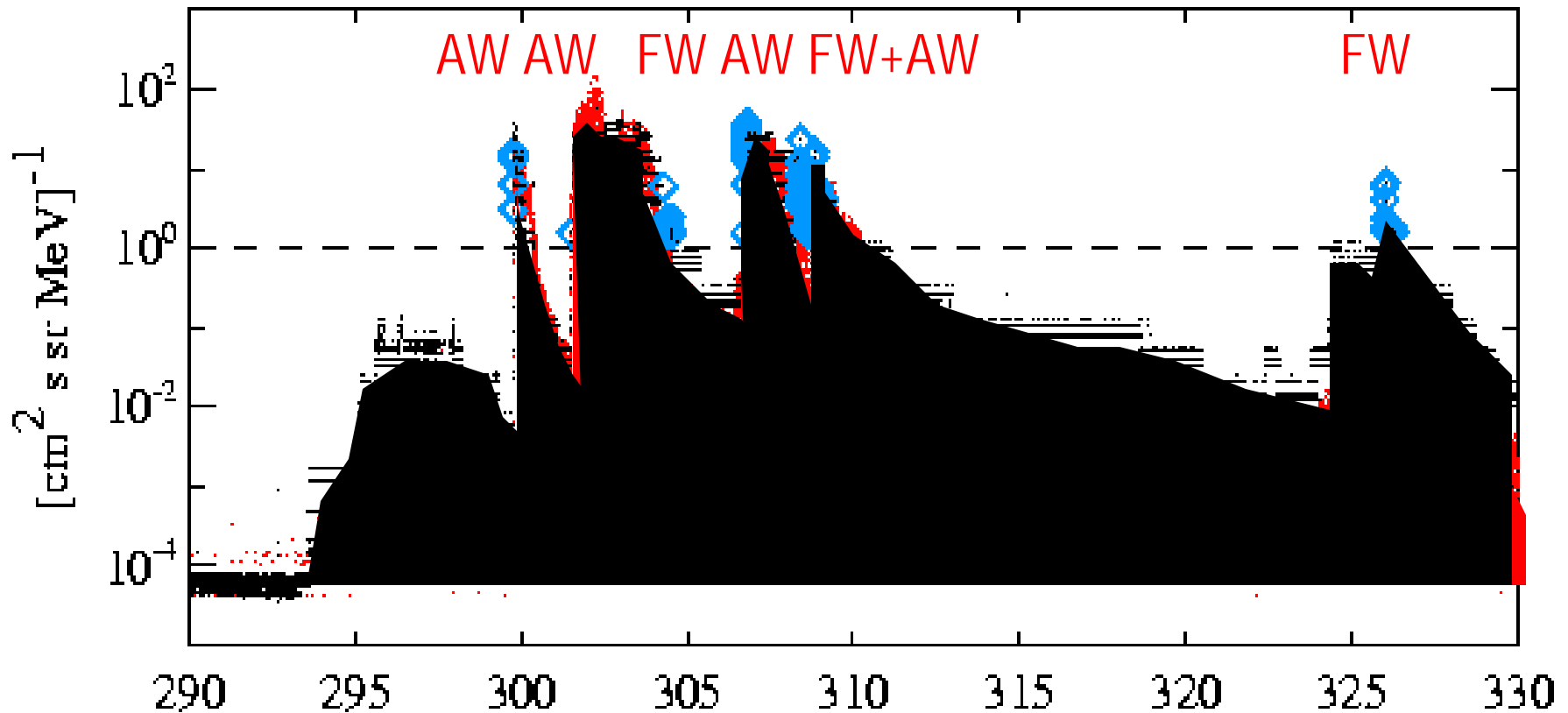
False Warnings so far occur as single-minute glitches only





Lyndon B. Johnson Space Center

Future Plans: Combined Models REleASE / Bayesian and/or REleASE/EMMREM-BRYNTRN Proton Event Prediction Halloween Storms 2033





REleASE Real-Time V&V

- Implementation with real-time SOHO/COSTEP data completed on February 07, 2008
- Forecasting success anticipated due to linkage of SPE electron and proton acceleration & transport
- REleASE demonstrated sensitivity to prompt SPEs that lead to two ion intensity-time profile forecasts (11/04/08 and 12/22/09), neither reached “alert levels”
- Low false-warning rate $\sim 1/\text{yr}$ (*preliminary*)
- Sun did not cooperate so far in providing significant sources of (forecast, missed or false) warnings at or beyond the “alert level”, **therefore V&V not complete**