AFRL Next-Gen Dose Rate Specification and Prediction

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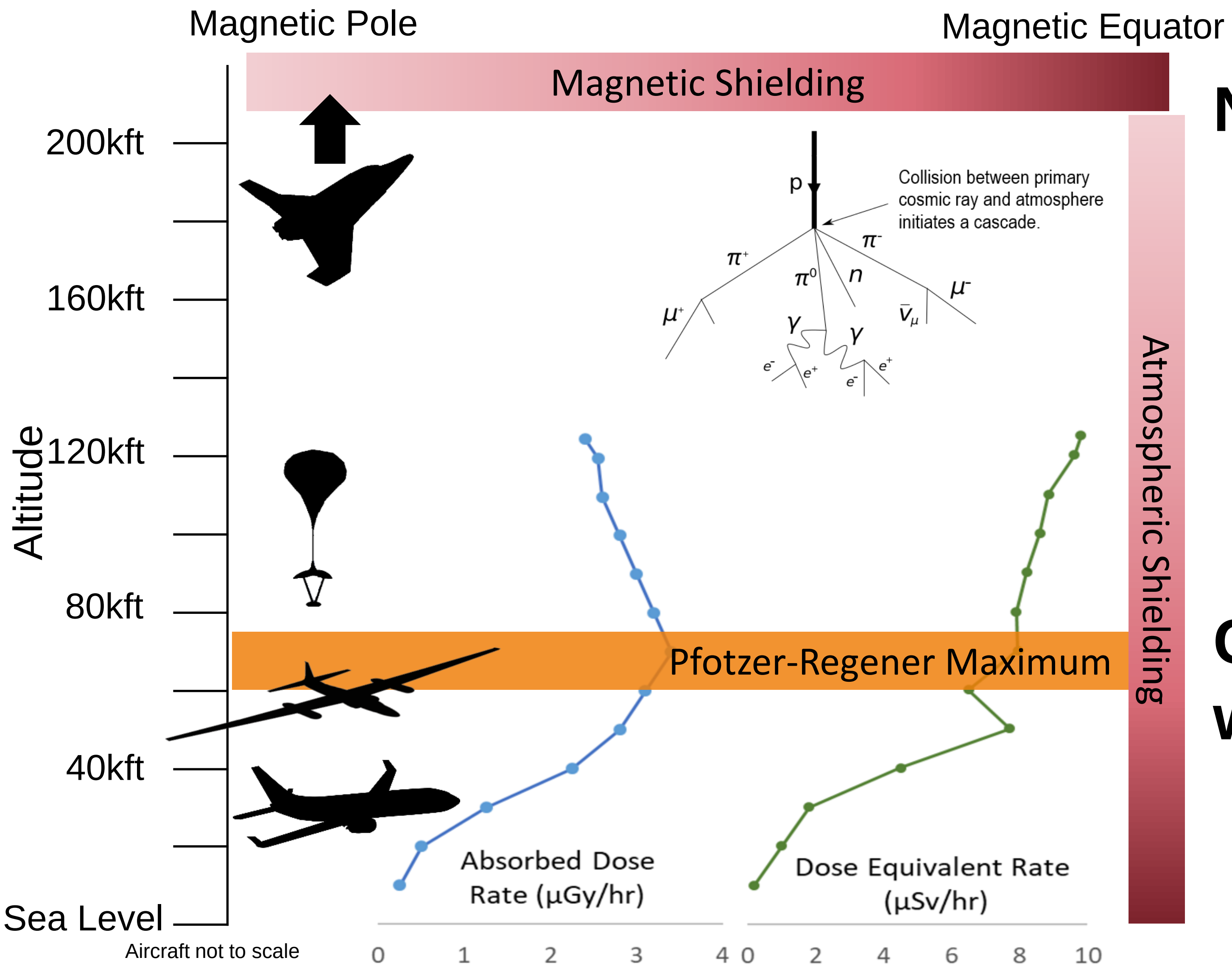
Overview

- Introduction
- Overview of Expected Capability
- Specification
- Forecast
- Conclusion

Introduction



New capability to include:

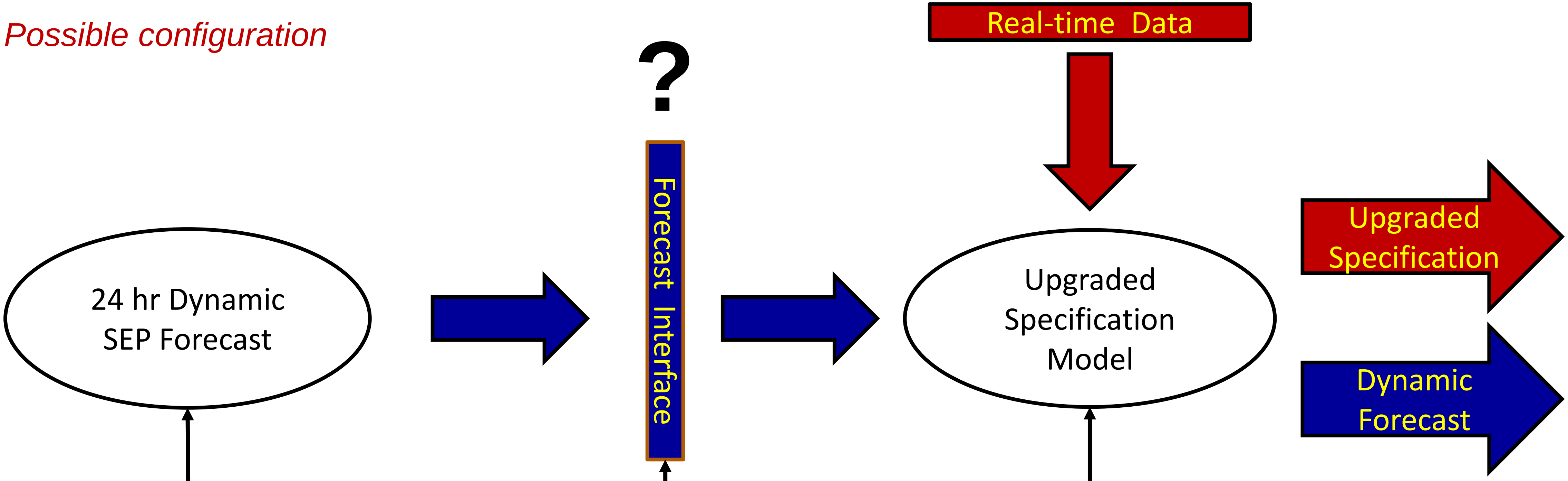
- Better physics
- Improved model of magnetic shielding
- Forecast capability
- Component modularity

Collaborate with Civilian air where possible

Absorbed dose rates and dose equivalent rates taken from Hands, A.D.P et al. 2016, Space Weather Journal

Upgraded Capability

Possible configuration



- **AF-DEPT**
- In-house development, based on community models.
- 3 phase forecast with accuracy increasing with time

Possible Approaches:

- Separate forecast and specification
- Forecast: Specification model driven by forecast

Community model based

- Model review being conducted.
- Verification/Validation of small subset.

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Specification Model

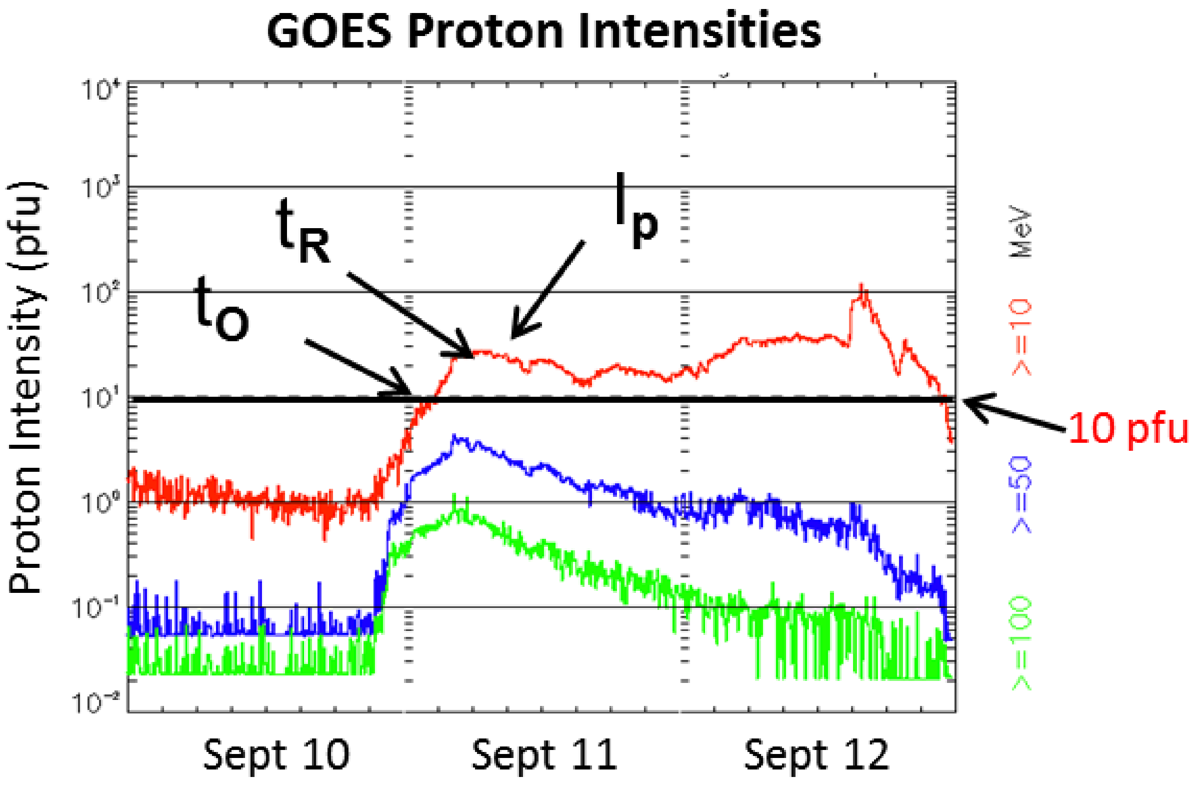
- Literature review looking for the following in models:
  - High altitude physics
  - SEP capability
  - Magnetic shielding
  - Availability to DoD
- Subset (likely 2) models to be validated/verified

Forecast Interface

- ***Initial Configuration*: No interface, separate forecast and specification**
  - Forecast will be a 24 hour dynamic forecast, but with no flight path information
- ***Next Step*: Flight path specific forecasts**
  - *What's needed*:
    - SEP spectral forecasts
    - Forecasts of magnetic field configuration
  - *Expected approach*: Ensemble forecasts based on a set of the most probable spectra and magnetic field configurations given observed conditions

Air Force Dynamic Energetic Particle Tool (AF-DEPT): Objectives

- Goal is to forecast solar energetic particle (SEP) events defined as:
  - E > 10 MeV protons
  - I_P > 10 particles/(cm² s sr) or 10 pfu
- We want to forecast
  - The probability of an event occurring in a 24-hour window
  - I_P: peak intensities
  - t_O and t_R: onset and rise times
  - **P(t)**: time-dependent SEP-event occurrence probabilities
- Once a SEP-event occurs, forecasting the time profile as a function of energy becomes necessary



Goal is complete automation: no intervention required

GOES: NOAA's operational (space) weather satellite

AF-DEPT Configuration

Advancing comprehensive solar energetic particle (SEP) forecasting tool by combining community models

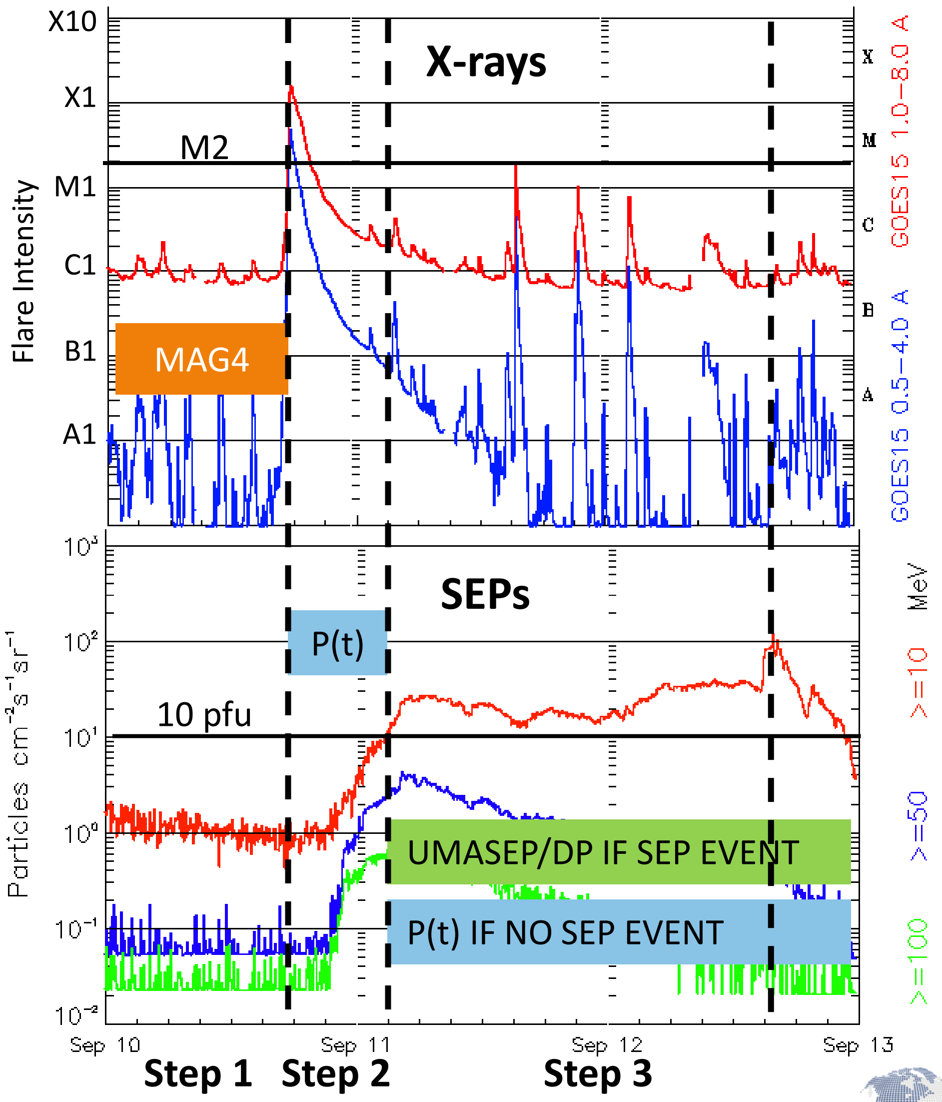
1) **Before any solar event**: Early (next 24 hours) SEP event probability [**MAG4**]

2) **At time of solar flare (> M2)**: Flare-based dynamic SEP event forecast P(t) evolved from database of GOES X-ray and SEP events [**Protons**]

3) **At SEP onset**: Flare/SEP-based dynamic forecast of SEP intensity I_P [**UMASEP** (validated) or Kahler-Ling dynamic probability (**DP**, in development)]

Automated 3-step SEP forecast system: AF-DEPT

GOES: NOAA's operational (space) weather satellite
1 pfu = 1 particles/cm²/s/sr



Summary

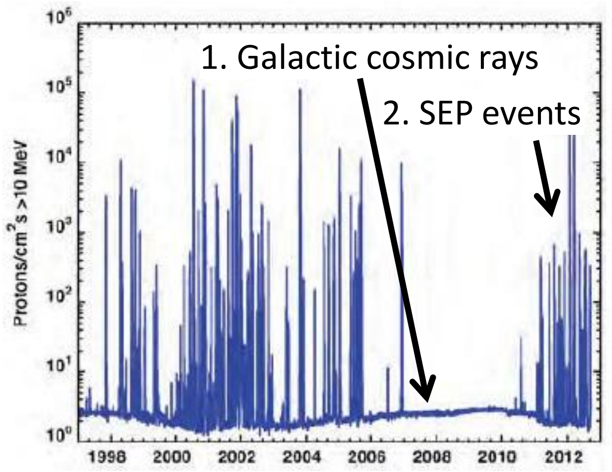
- AFRL is developing a next generation atmospheric radiation hazard capability
- Upgrade objectives are:
  - Improved physics
  - Better magnetic shielding
  - Forecast capability: AF-DEPT
- In order to get flight specific forecasts we need
  - SEP spectral forecasts
  - Forecasts of the magnetic field configuration

¿Questions?

AF-DEPT: Introduction

Two sources of heliospheric energetic (E > 10 MeV) proton radiation:

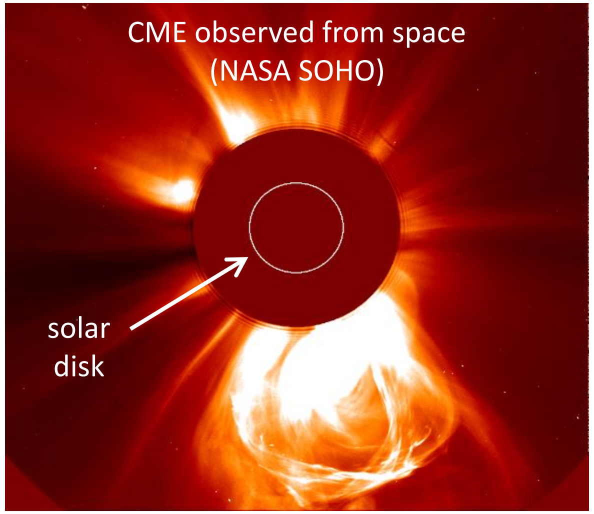
1. A slowly varying (11-year solar cycle) galactic cosmic ray component
2. Transient (hours – days durations) **solar energetic particle (SEP) events**

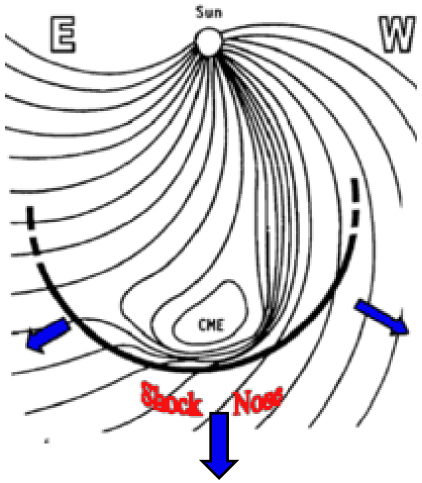


Daily proton (E > 10 MeV) intensities from 1997 through 2012 from NOAA GOES, 1997-2013

SEP events produced in collisionless shocks driven by coronal mass ejections (CMEs)

- Wide (W > 60°)
- Fast (V > 900 km/s)





Schematic of CME showing the shock nose where SEPs are accelerated

Current Solar Energetic Particle Forecast/ Model Systems

Many Forecast/Model systems for SEP events have been developed:

Model/Source	Adv.	Trigger	P	t_0	t_R	I_p	Note
MAG4 (NASA)	X		X				Active Region Free Energy
Protons (NOAA)		Flare	X		X	X	
Proton Predict Sys. (AFGL)		Flare	X		X	X	
UMASEP (U. Malaga)		Flr. + SEP	X	X			SEP increase needed
Proton Events (IZMIRAN)		Flare	X				
SPARX (UK Met, BISA)		Flare		X	X	X	Model SEP profiles
EPREM (UNH, SWRI)		CME			X	X	Not real time
SEPEM/SOLPENCO (ESA)		CME					uses Q(VR) with CME
PATH (UAH, Cal Tech)					X		Shock model only
ReLEASE (NASA)		Elec. SEP	X	X		X	Relativistic electron onset
Korean SEP (KyungHee U)		Flr/CME			X	X	Gives SEP profiles
SEPMOD (UCB, NOAA)		CME			X	X	Not real time
SEP Forecast/SpEAR (AFRL)	X	Flare	X	X	X	X	Adds dynamic P(t)

We adapt **MAG4**, **Protons**, and (pending) **UMASEP** for the

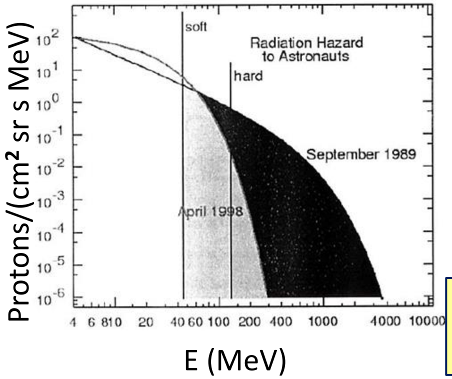
Air Force Dynamic Energetic Particle Tool (AF-DEPT)

Improving Forecast Baselines

AFRL R2O Efforts

SEP forecast modeling has limitations that we are addressing:

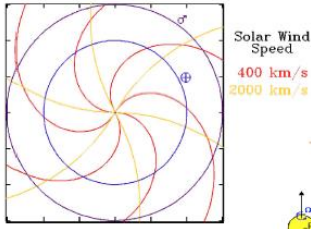
1. No forecast for E > 50 MeV protons (only E >10 MeV)



Validation of AF 557th WW/Proton Prediction System and NOAA/ Protons operational models for E > 50 MeV protons. AFRL, AF 557th WW

Kahler et al., J. of Space Weather & Space Clim, 2017

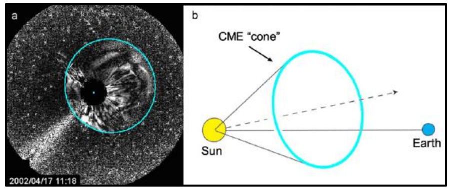
2. Simple Parker Spiral (PS) assumed for magnetic connection from 1 AU to the Sun



PS works well within WSA solar wind model except during high-speed enhancements. New work tests WSA model and PS assumption with spacecraft solar-wind measurements. AFRL, AF Summer Scholar

Kahler et al., Solar Physics, 2016

3. Uses X-ray flares, not coronal mass ejections (CMEs), for input parameter

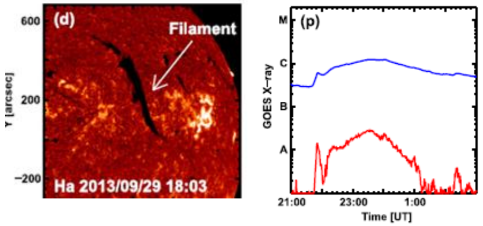


Using Wang-Sheeley-Arge (WSA) solar wind model driven by ADAPT with Enlil, CME-cone, and SEPMOD modules to generate SEP profiles. AFRL, U.California.

ADAPT: Air Force Data Assimilative Photospheric Flux Transport model
CME: coronal mass ejection

4. Solar X-ray background and *in-situ* solar-wind data ignored

Weak-flare filament eruptions result in > 50 MeV SEP events. Prior *in-situ* solar wind observations and solar X-ray backgrounds may help SEP forecasts. AFRL, NASA



Gopalswamy et al., Astrophysical J., 2015