An SEP Event Model for WSA ENLIL

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The CISM SEP Model

- A *generalized** test particle code that uses the time-dependent fields and shock information from MHD heliospheric CME/ICME simulations for ***FORWARD MODELING*** SEP event time profiles

  (* can use any MHD model results)

- Approach:

  Transport : A field-line tracer adapted for guiding-center particle trajectories of 10-100 MeV ions of any mass and charge is now modified to include energies down to 1 MeV. Energy-dependent scattering has been phenomenologically added that delays the lower energy particles' departure from the shock vicinity.

  Source: Uses an MHD shock parameter-based 'black box' source description that is the same for all events. An ESP enhancement with softer spectrum is assumed to travel with the shock.
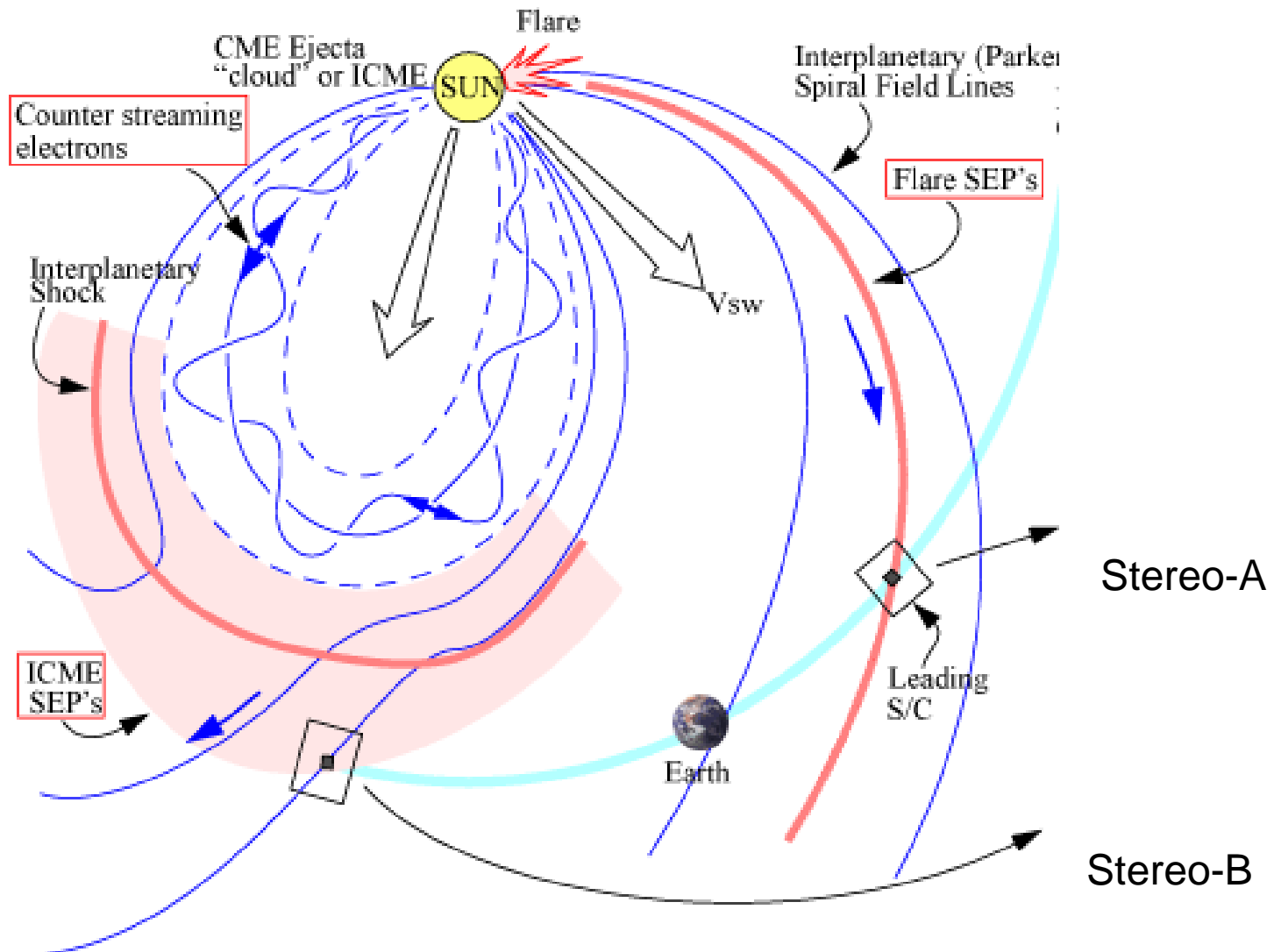
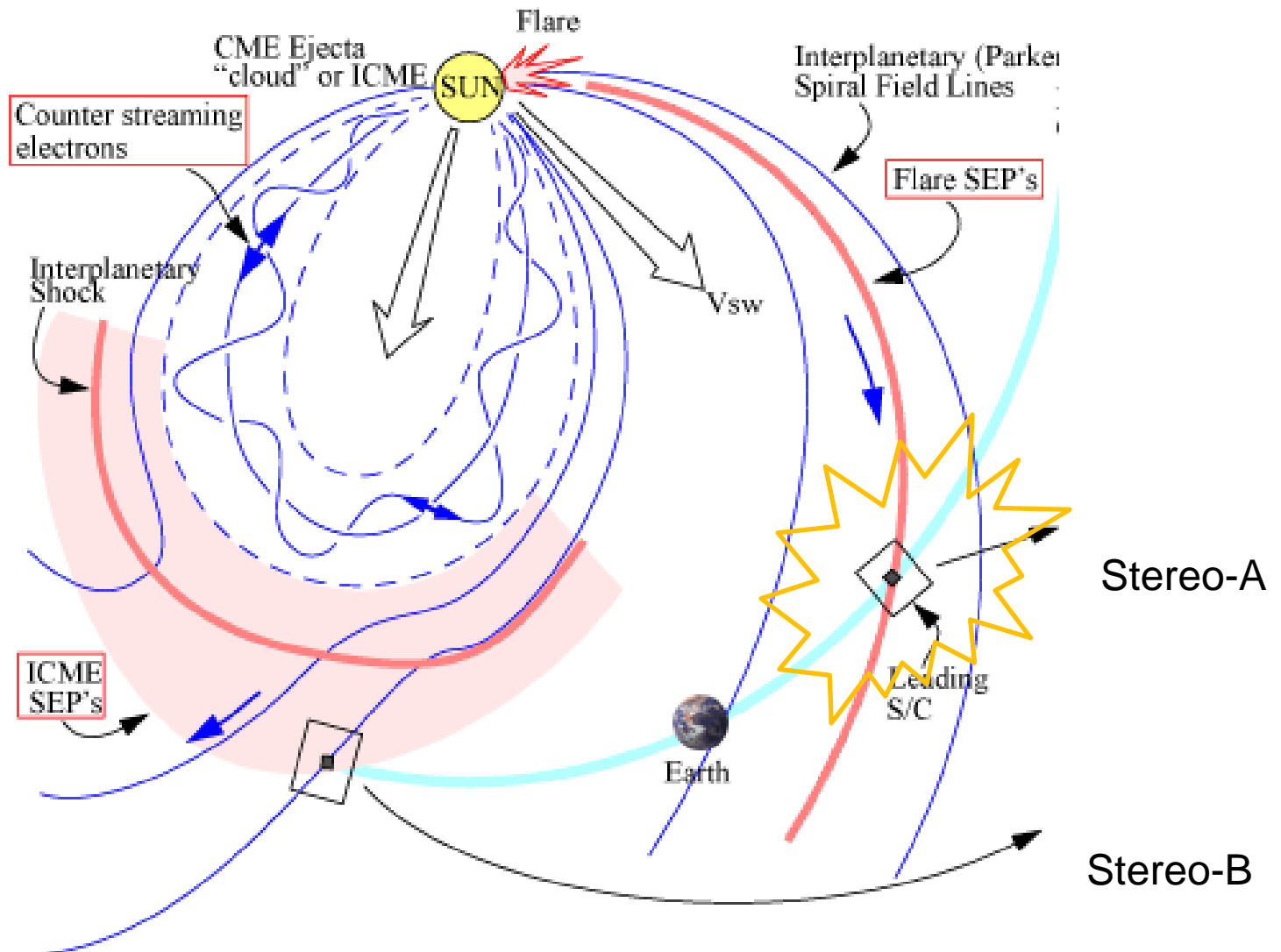# now available: STEREO (and ACE) real-time multipoint perspectives at 1 AU
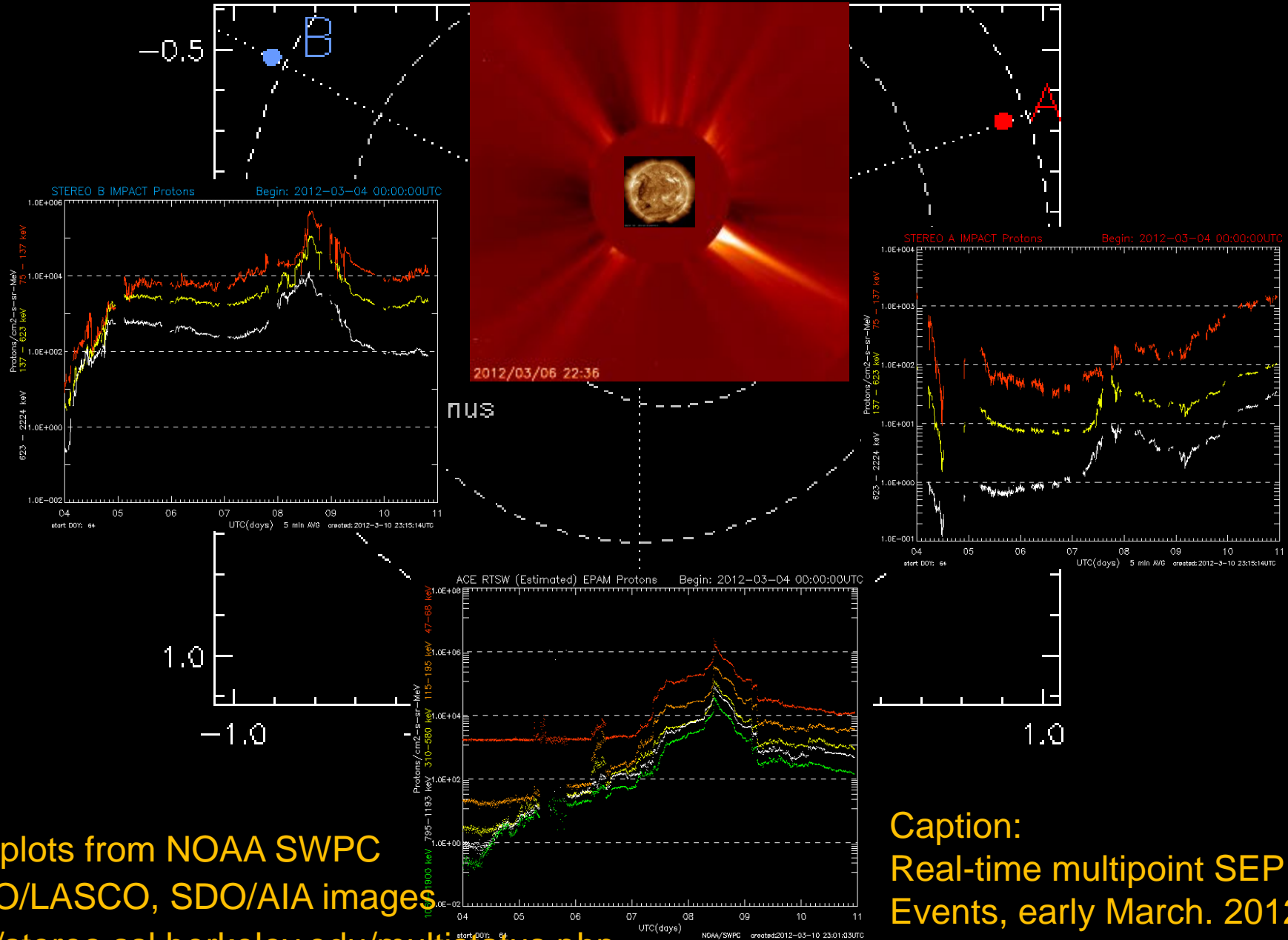
Caption:
Real-time multipoint SEP
Events, early March. 2012

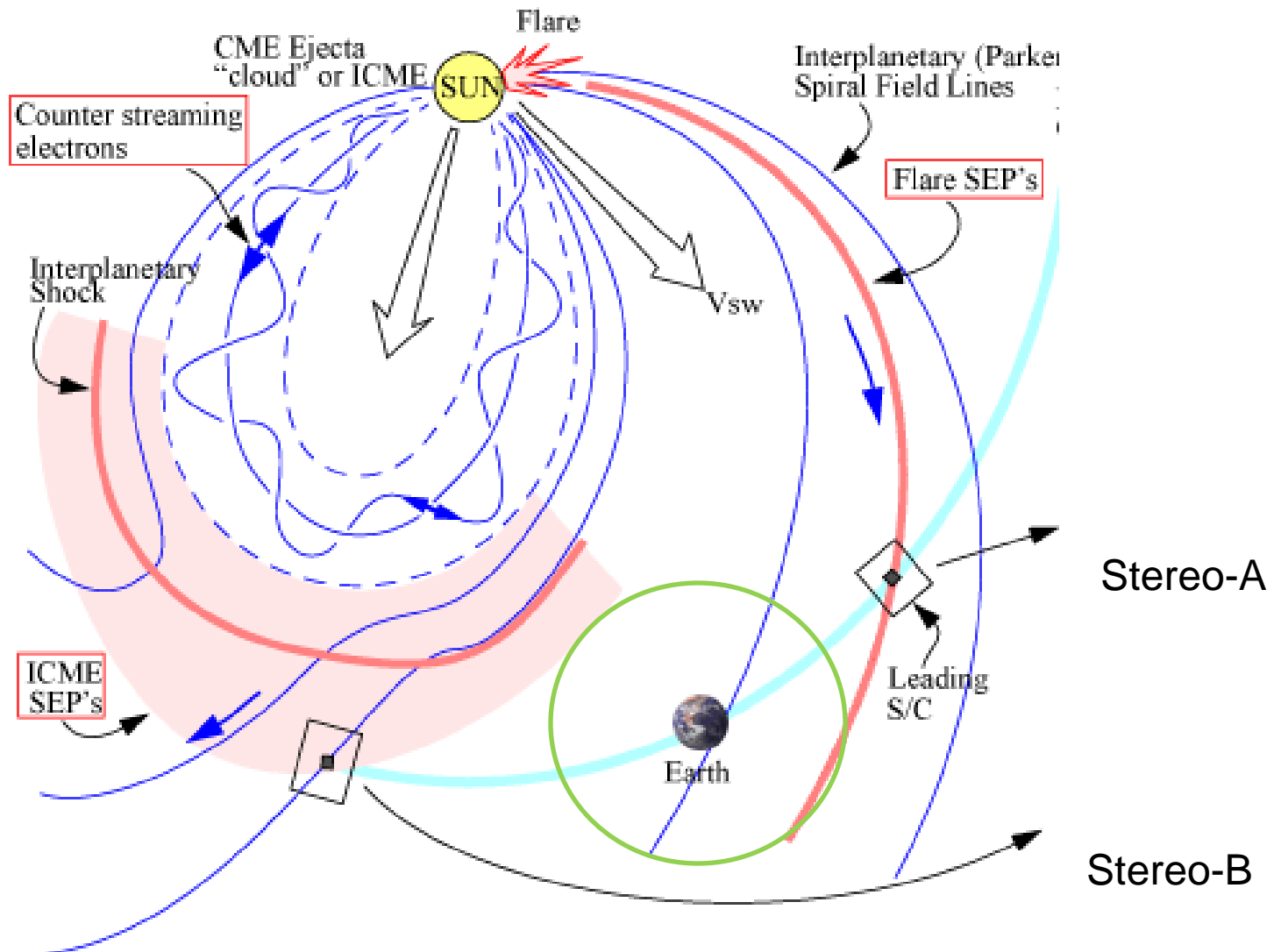# Observer SEP experience depends on location relative to events

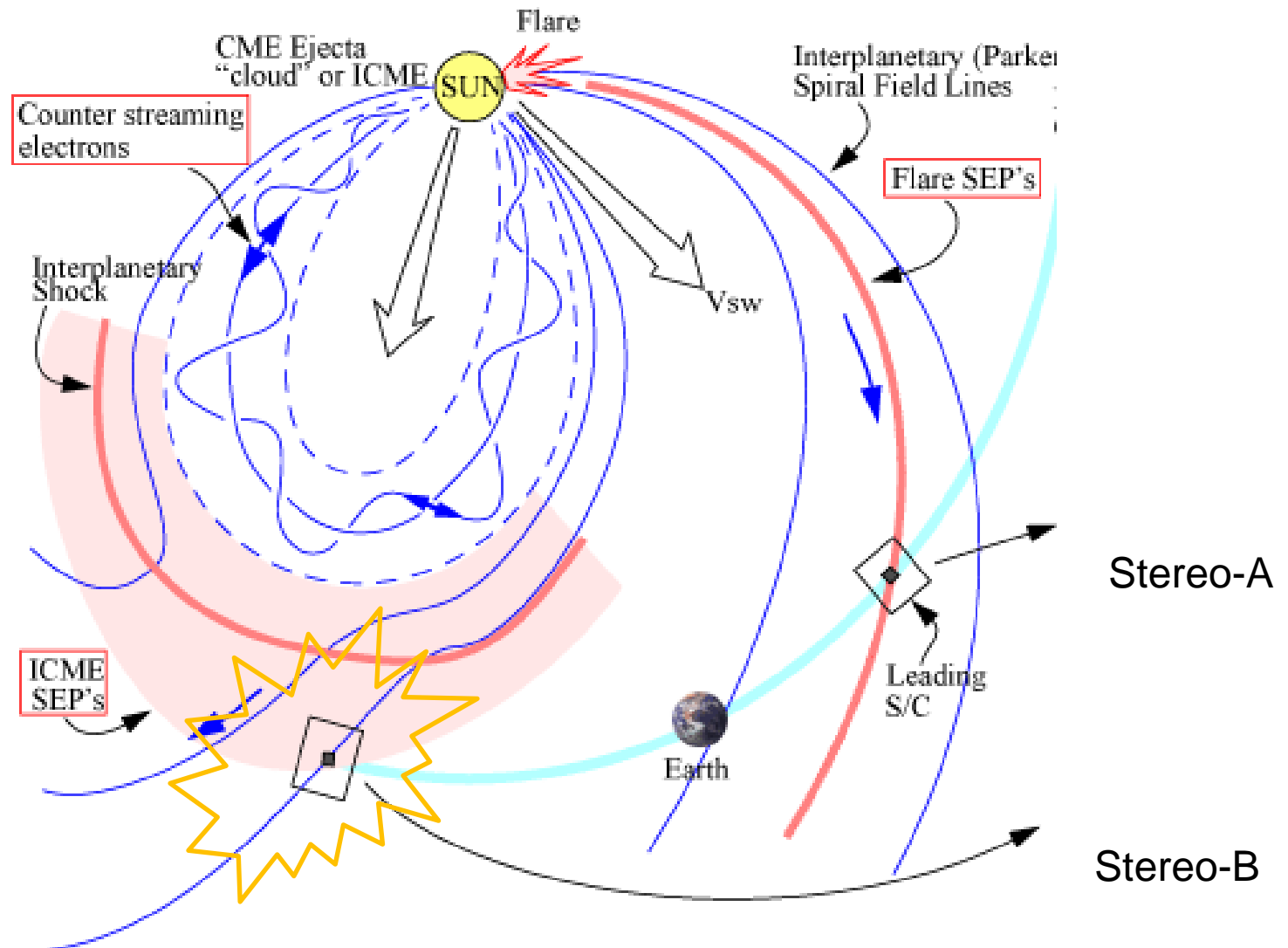# Observer SEP experience depends on location relative to events

Here, Stereo-A sees impulsive flare (soft spectrum) SEPs only

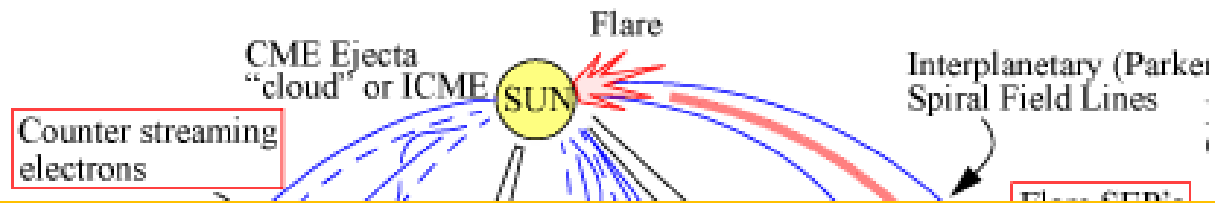# Observer SEP experience depends on location relative to events

Near-Earth observer may see no SEPs

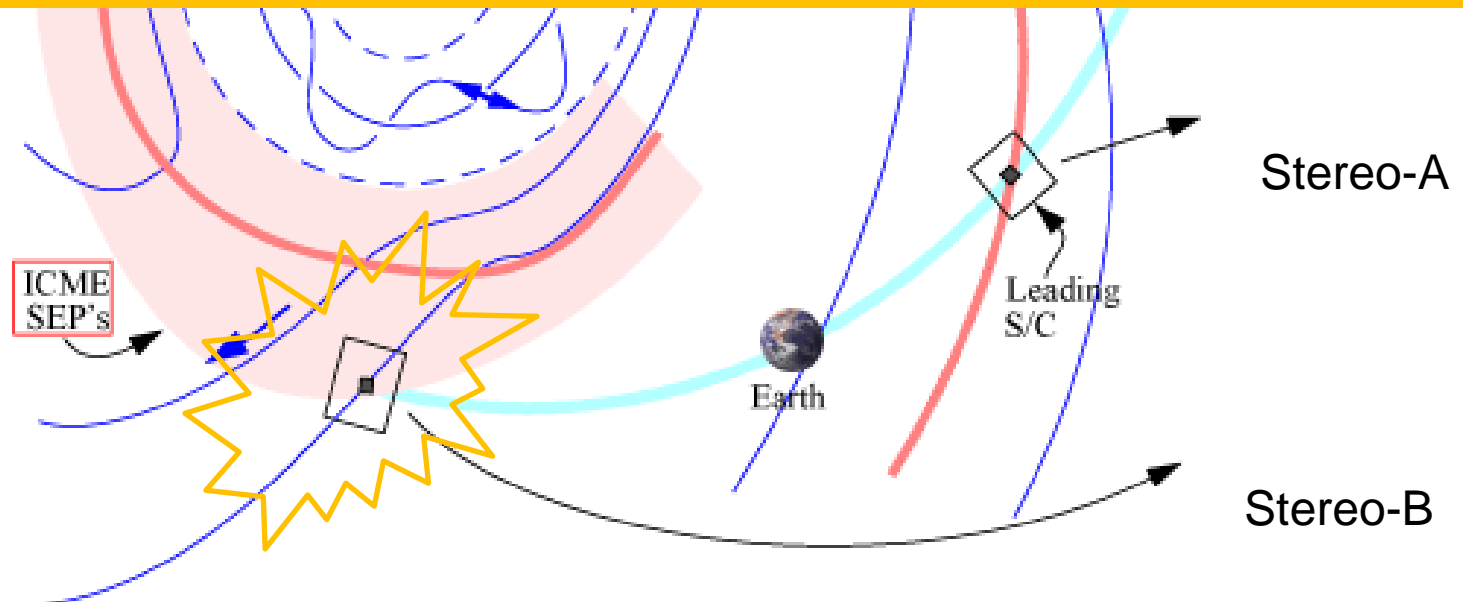# Observer SEP experience depends on location relative to events

Stereo-B sees ICME and 'gradual' SEPs from its leading shock

# Observer SEP experience depends on location relative to events

Gradual SEP events provide the largest, longest, and spectrally hardest events so our initial modeling efforts are focused on this type.

Stereo-B sees ICME and 'gradual' SEPs from its leading shock

We assume the particle trajectories are the observer-connected field lines from the WSA-ENLIL heliospheric model with a cone model-initiated CME
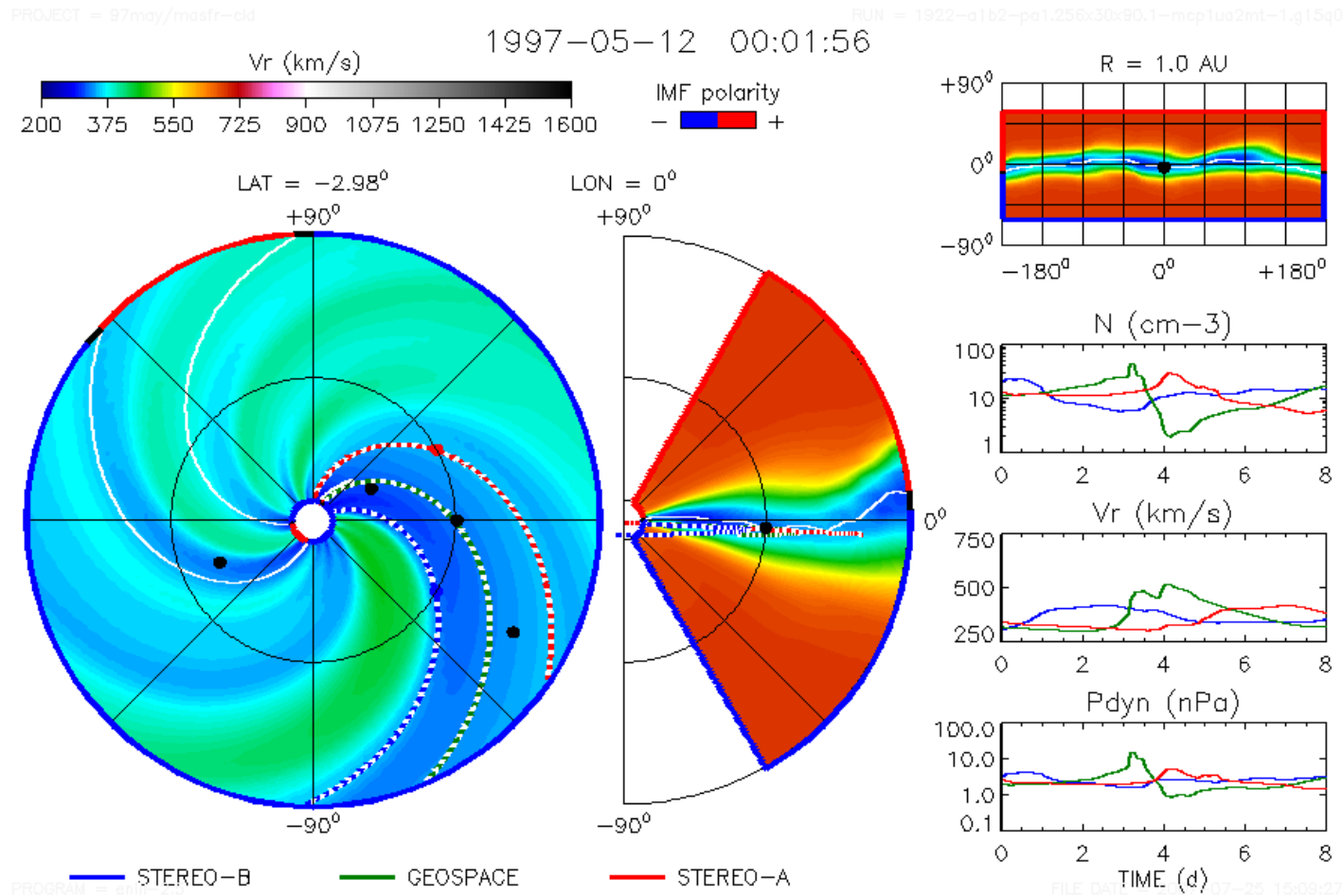
(Cone model example from D. Odstrcil)

An automated Shock Identification Scheme for ENLIL provides the needed shock parameters
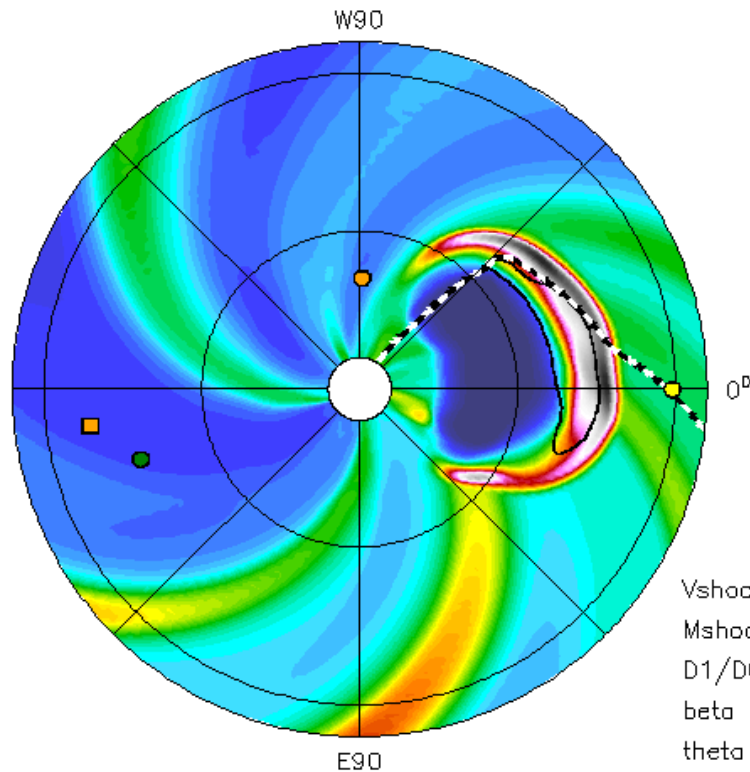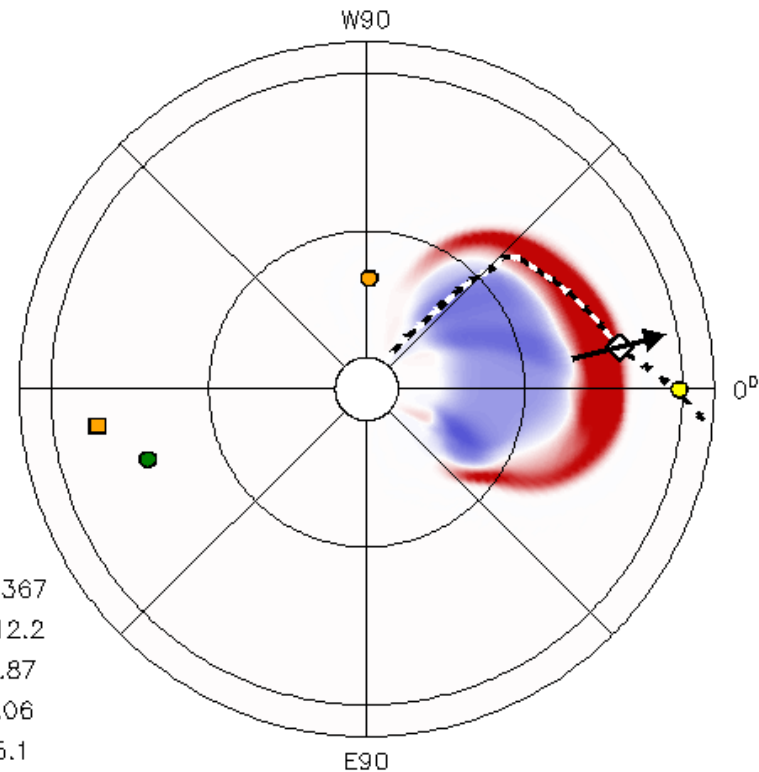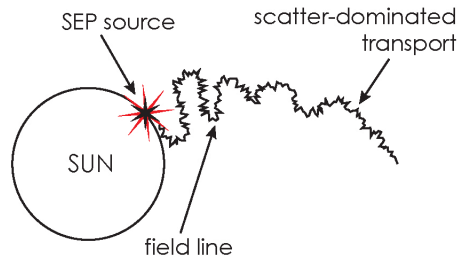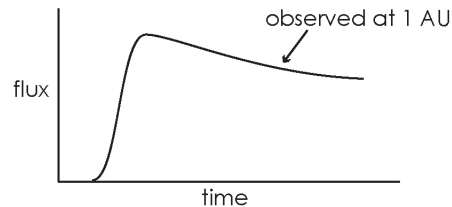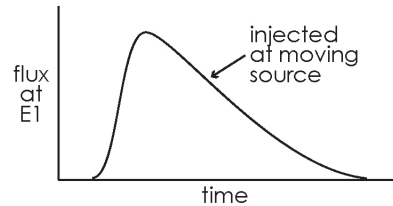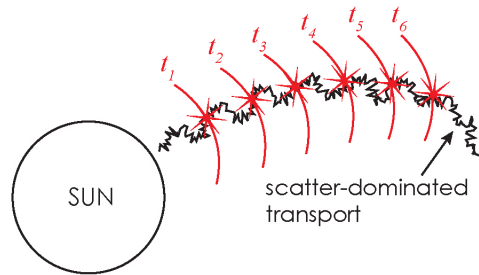

Scheme uses differencing between unperturbed and perturbed models to find and characterize the shock global structure
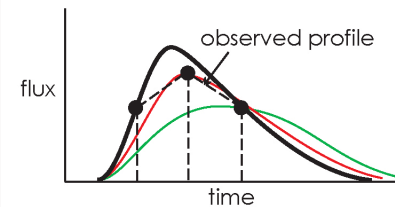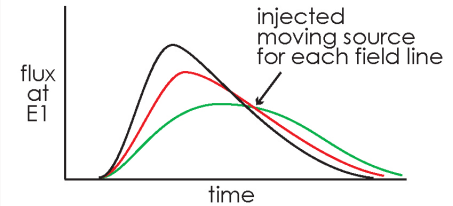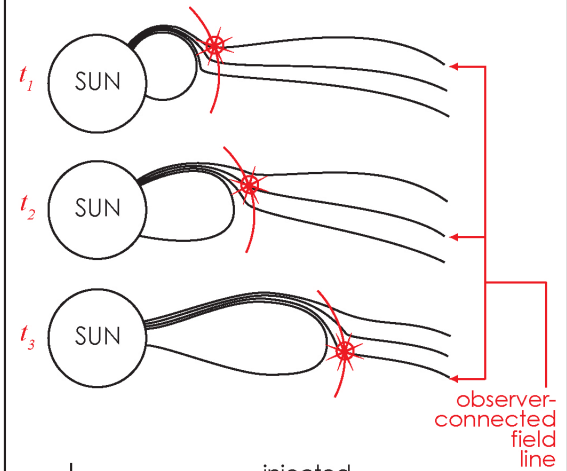
SEP Transport Viewpoints

1) Diffusive Transport, solar source

SEP source

scatter-dominated transport

field line

SUN

flux at E1 — injected at Sun

flux — observed at 1 AU

time
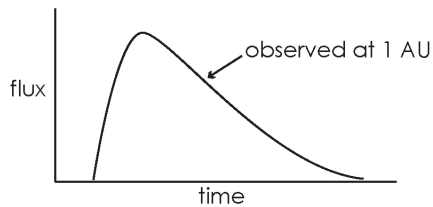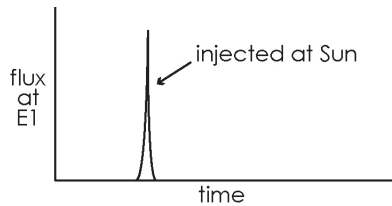
2) Diffusive transport, moving, evolving source

t_1 t_2 t_3 t_4 t_5 t_6

SUN

scatter-dominated transport

flux at E1 — injected at moving source

time

flux — observed at 1 AU

time

3) "Scatter-Free" transport, moving, evolving source (source may involve local scattering) *

t_1 SUN

t_2 SUN

t_3 SUN

observer-connected field line

flux at E1 — injected moving source for each field line

time

flux — observed profile

time

CISM Model view

Example: Large, gradual SEP event seen by ACE in August 2010

ACE Solar Wind, IMF, IonFlux(~1 Mev)

SEP profile affected by ICME 'cloud' or Flux rope-not part of WSA-ENLIL/cone
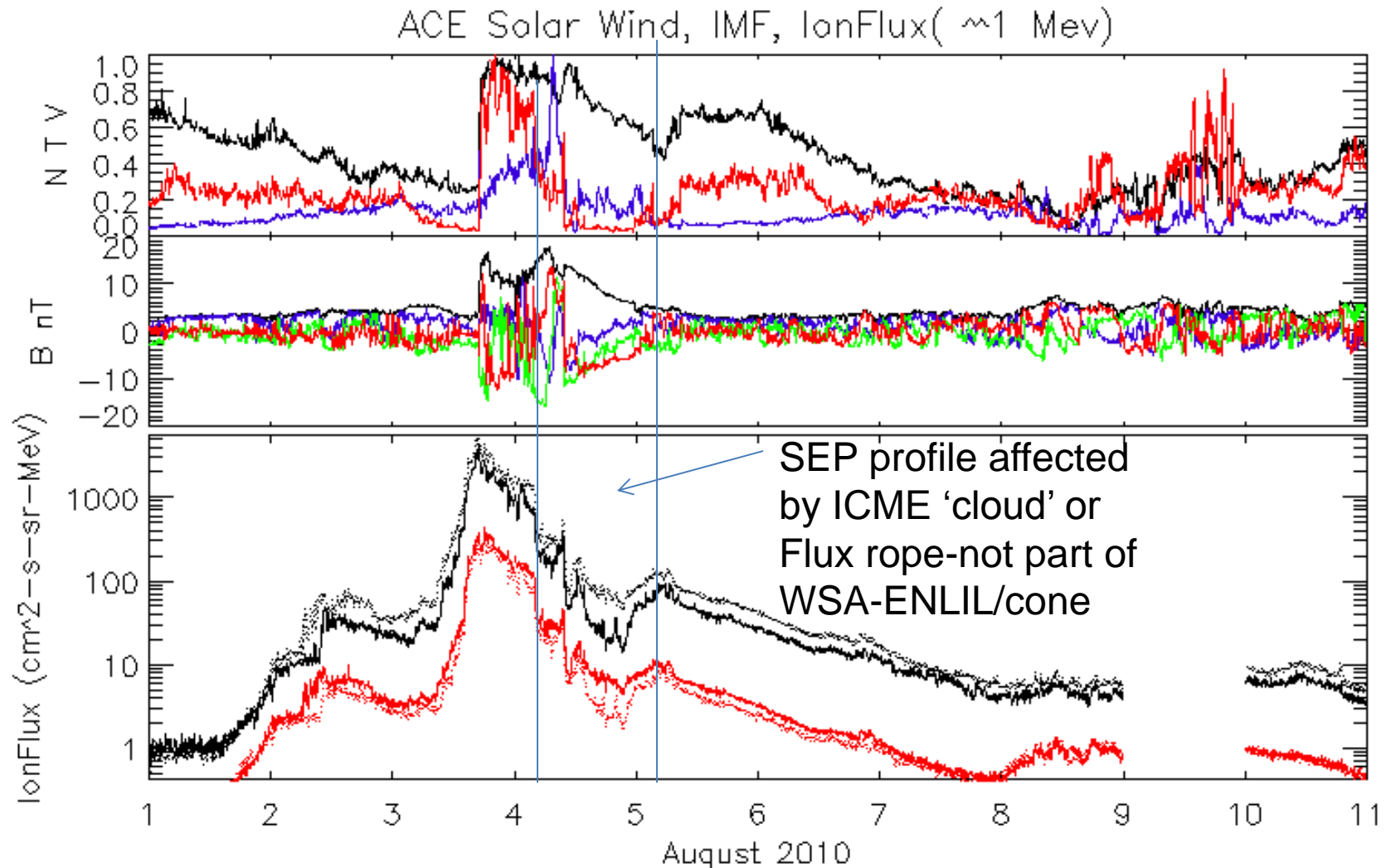
Note that with the current background model, we cannot reproduce CME 'ejecta' effects on the SEP event time profile.

Notice that for this period, the Earth observer connection point migrates from one CME shock to another with time
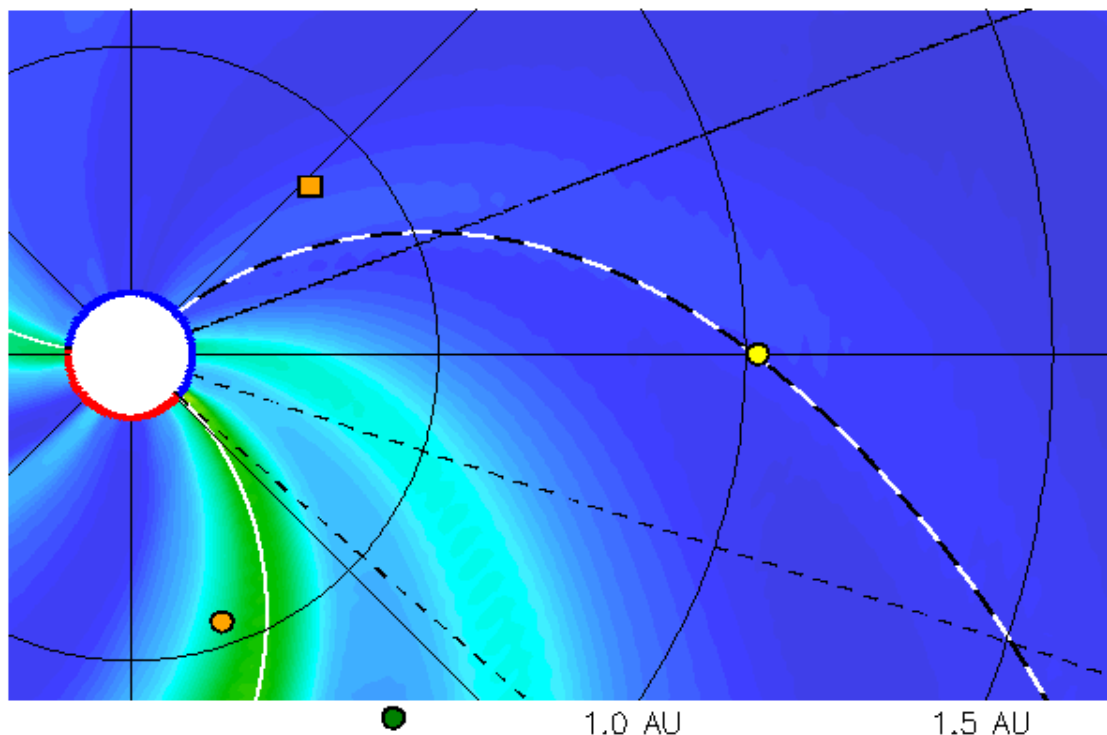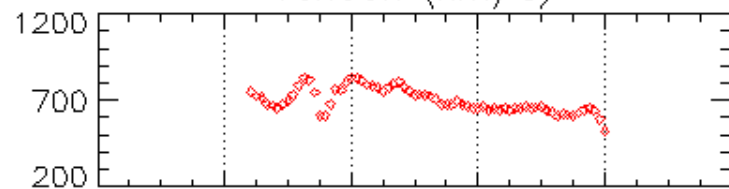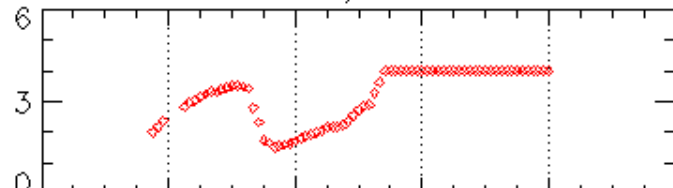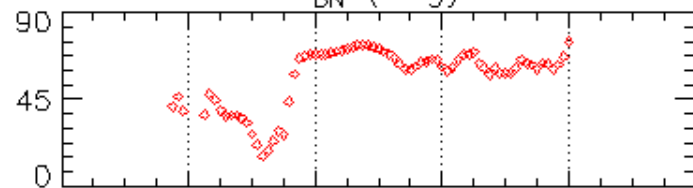

SEP event model uses both the field lines and the shock history.
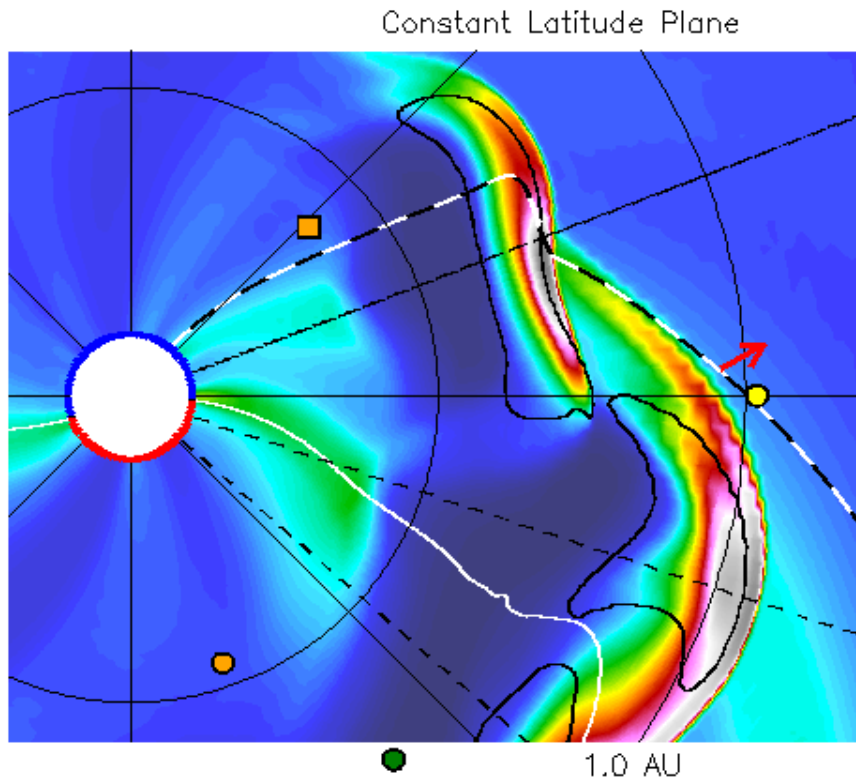
The SEP event at Earth reflects the connected shock and field line properties (ACE EPAM protons).

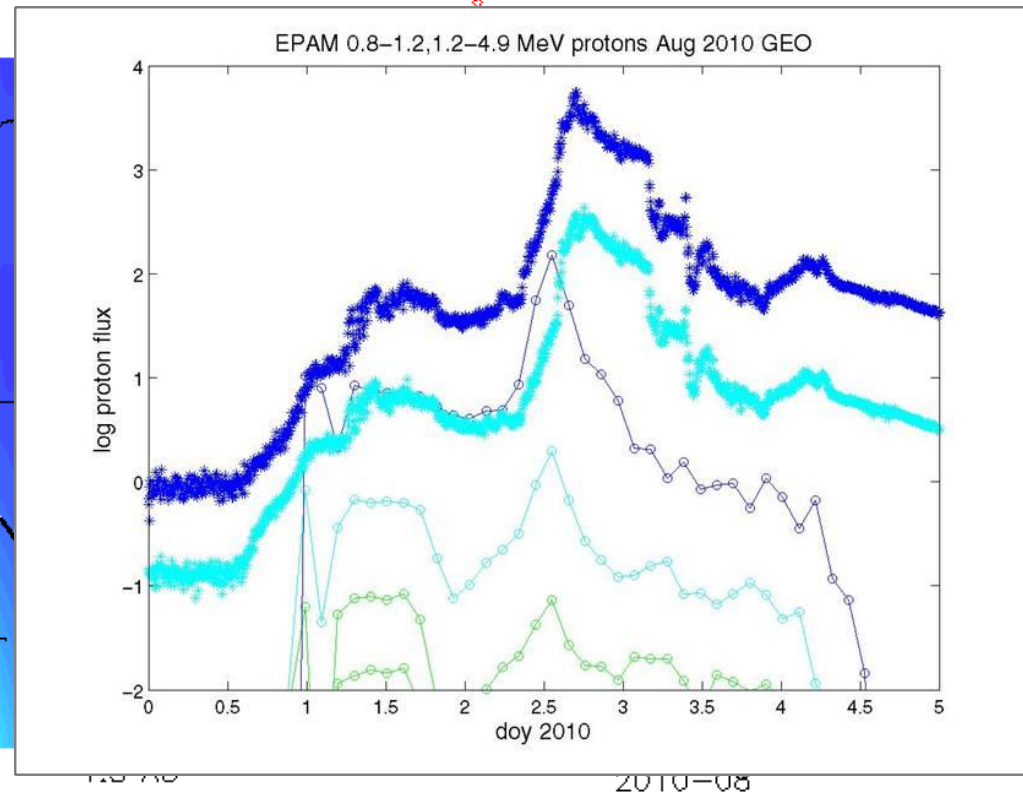# WSA-ENLIL/ cone parameters shock from the STEREO-B field line connection history are different
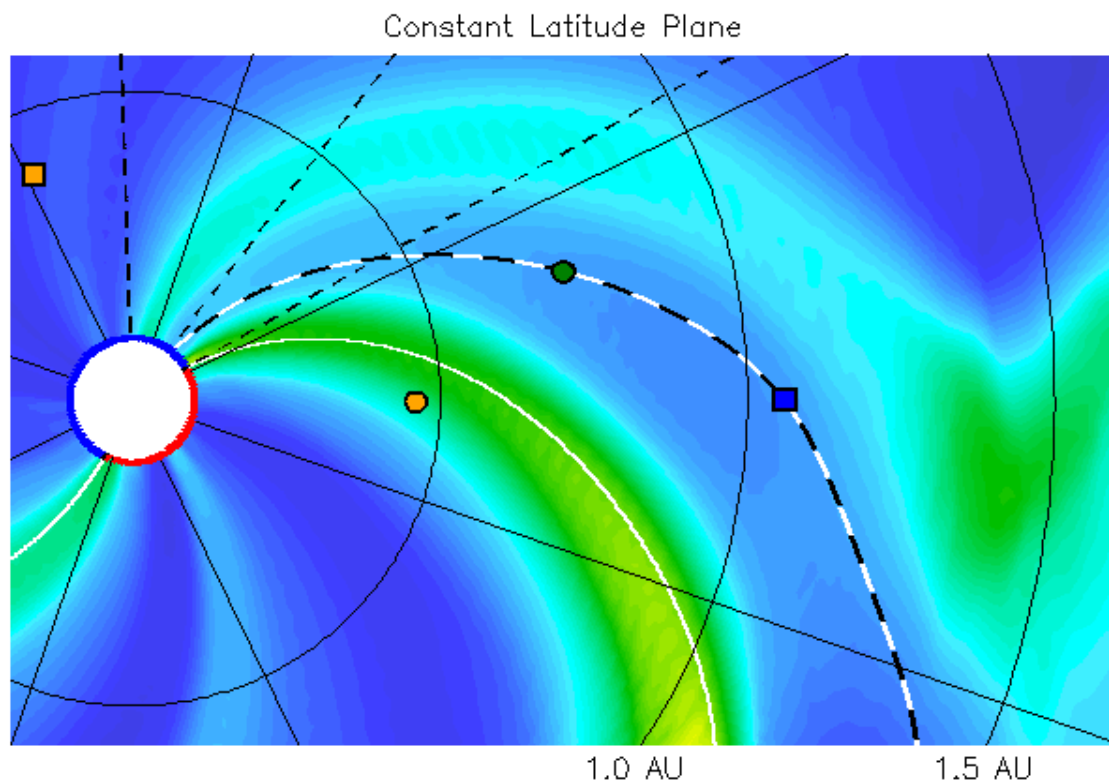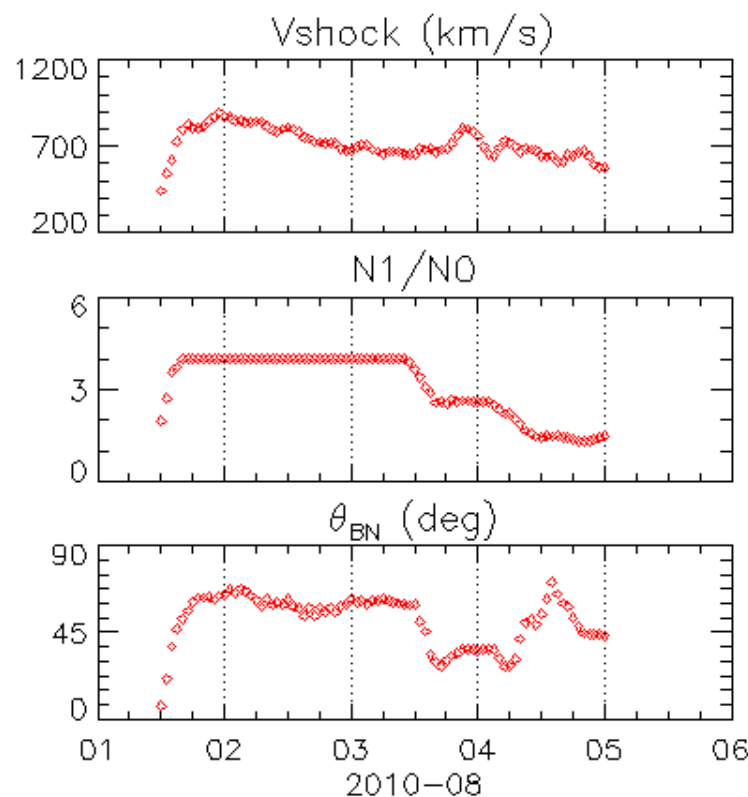
The different field lines and shocks connecting to STEREO-B
Make a much different SEP event (IMPACT LET, SEPT, HET data)
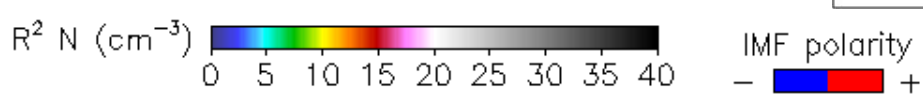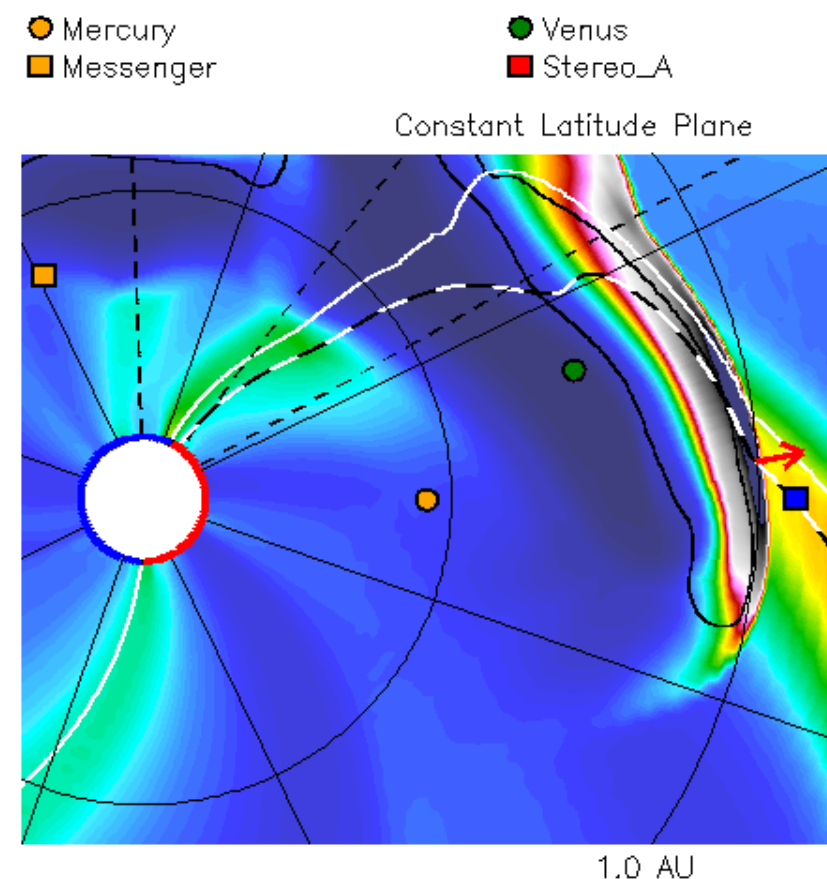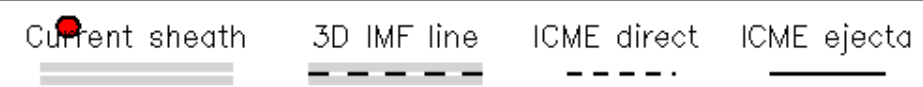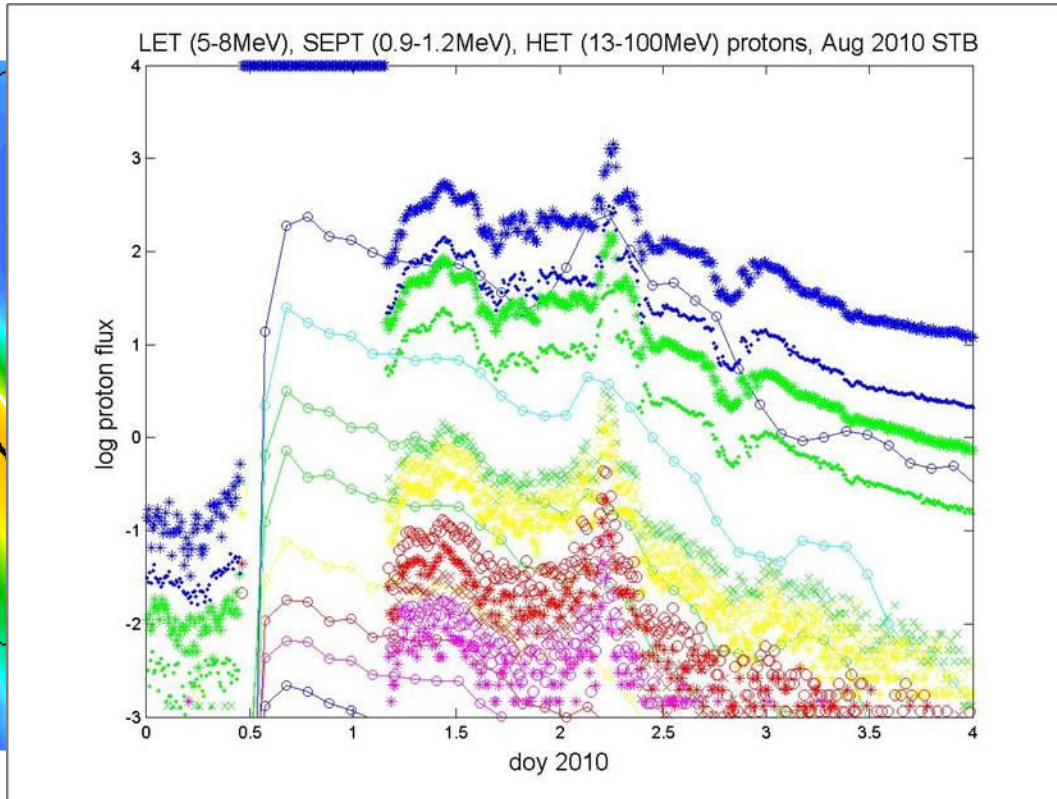
ACE observations for all of August 2010
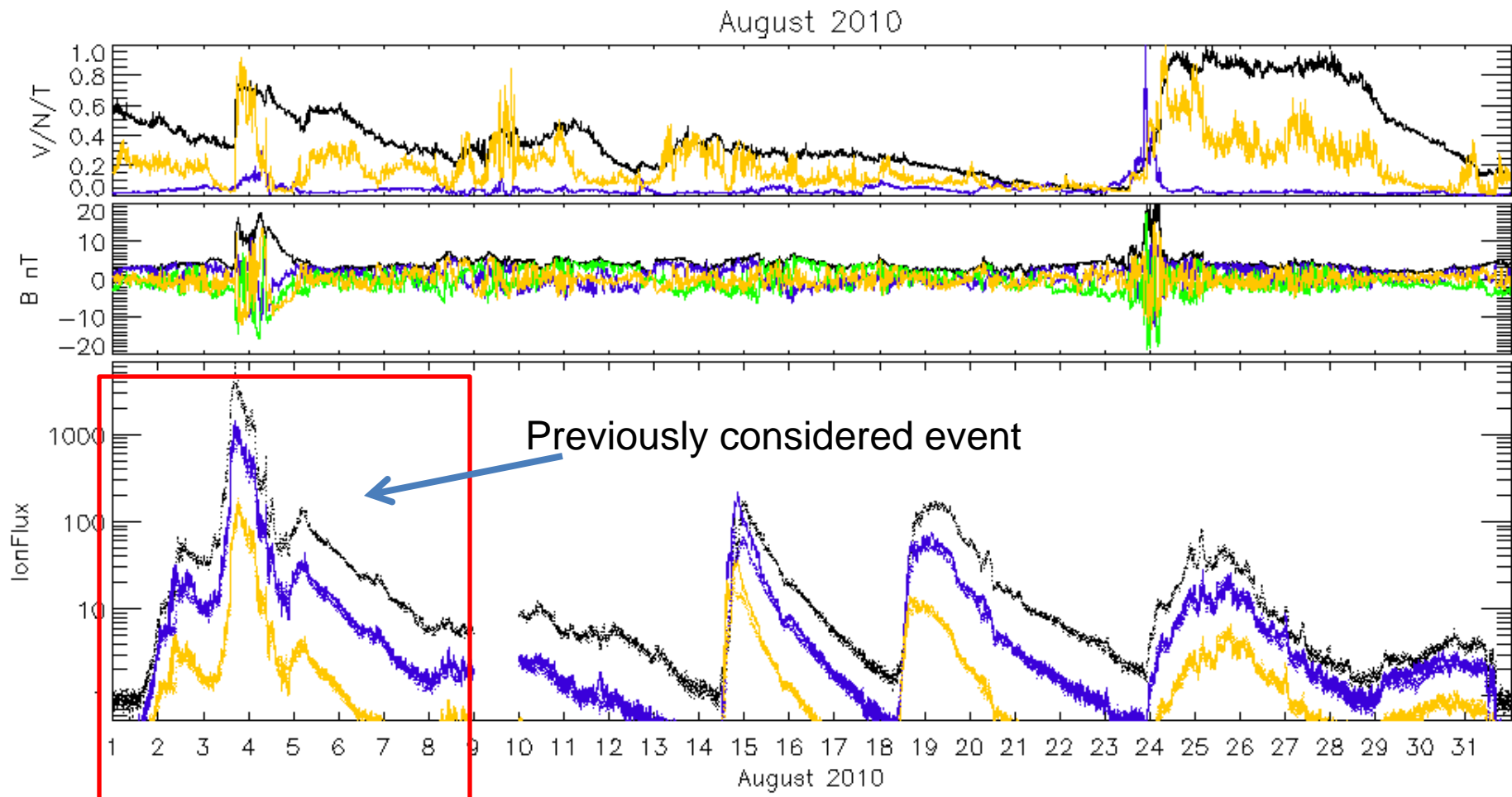
As solar activity increases SEP events, like CMEs, become less isolated. Challenge: 'rolling' models

First step: numerically simulate the whole month of August 2010 using the ENLIL/cone CME model
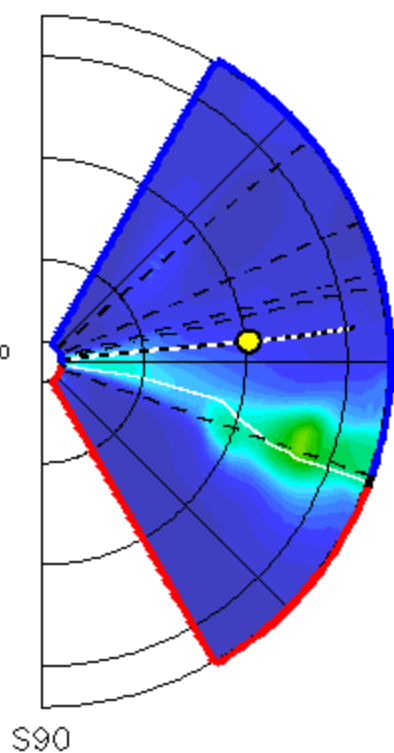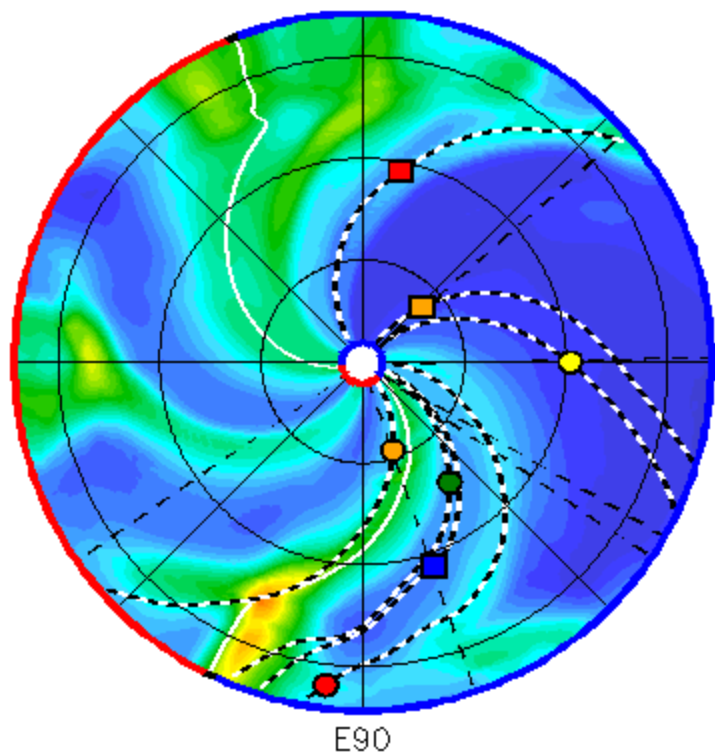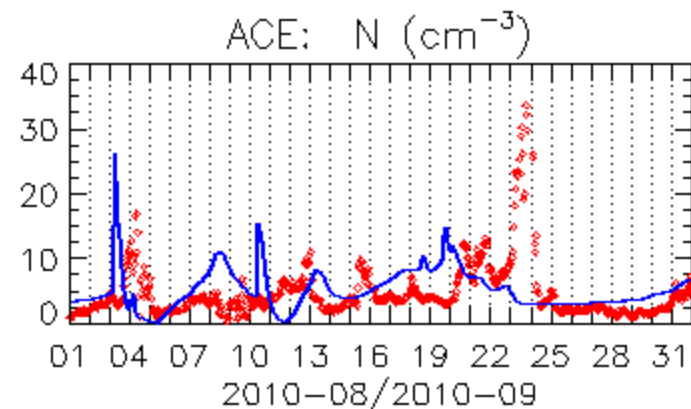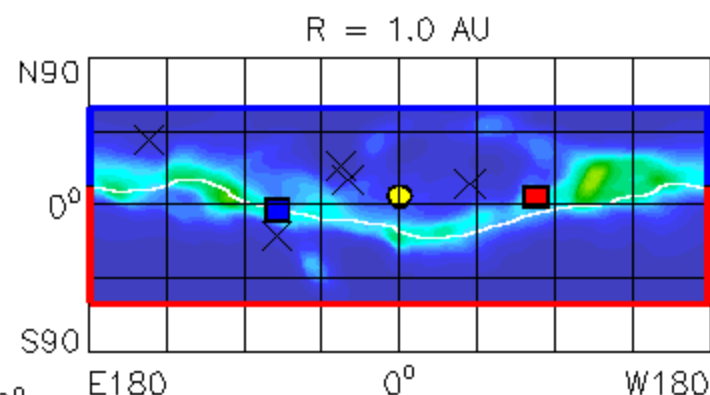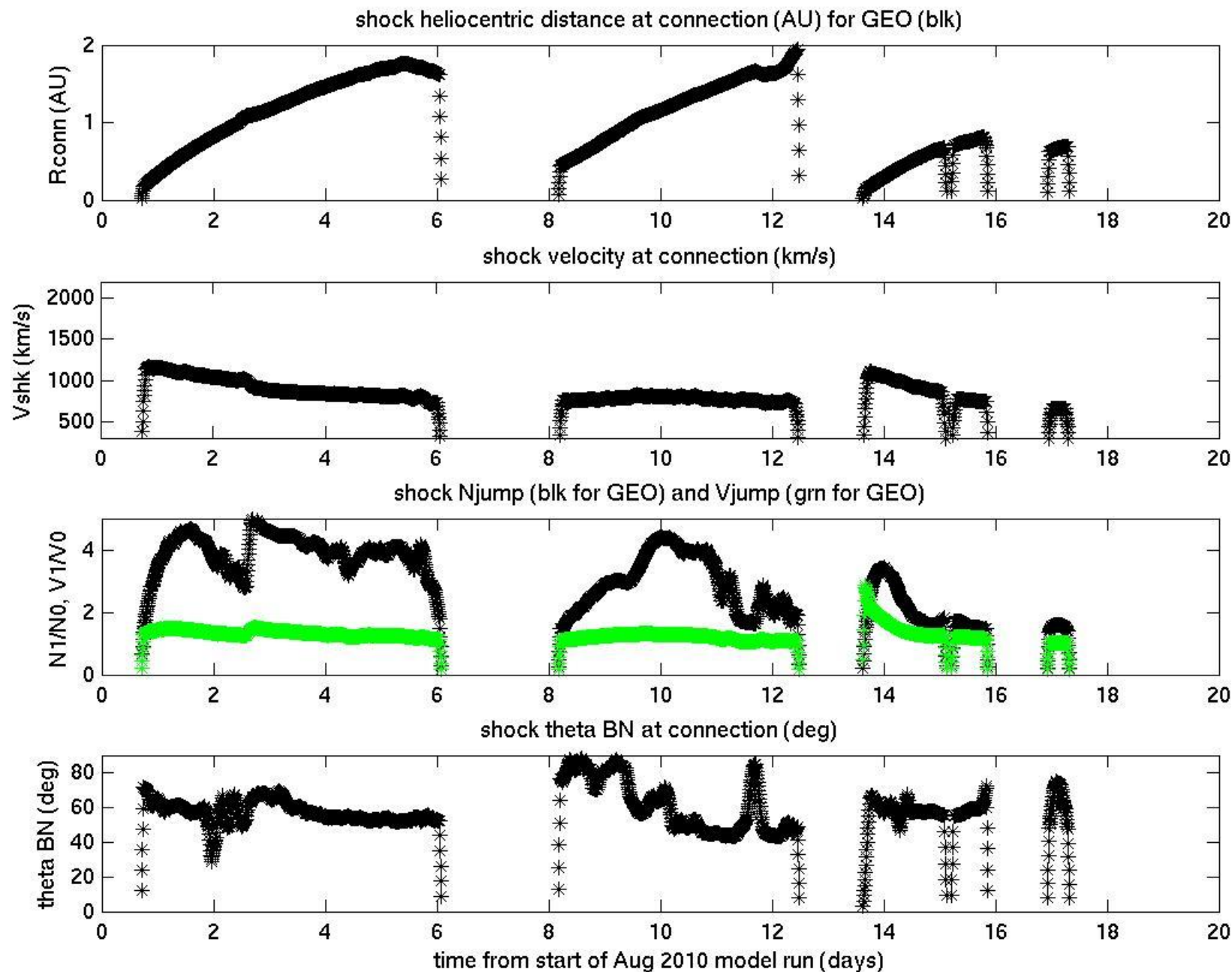
All-August Summary of modeled observer-connected shock parameters for Earth

All-August Summary of modeled observer-connected shock parameters for Earth

shock heliocentric distance at connection (AU) for GEO (blk)

Some model shocks are 'detected', at Earth, others are not (but can still contribute SEPs at Earth).

shock Njump (blk for GEO) and Vjump (grn for GEO)

shock theta BN at connection (deg)

time from start of Aug 2010 model run (days)

All-August Summary of modeled observer-connected shock parameters for Earth

shock heliocentric distance at connection (AU) for GEO (blk)

shock velocity at connection (km/s)

shock Njump (blk for GEO) and Vjump (grn for GEO)

shock theta BN at connection (deg)

time from start of Aug 2010 model run (days)

Cutoffs can occur when observer shock connection goes outside the ENLIL Boundary (2AU here)

Allows rolling month-long runs of local SEP activity (top=data, middle=model)

ACE EPAM 0.8–1.2,1.2–4.9 MeV protons Aug 2010 GEO

Model for similar energy range

shock connection radius (AU) for GEO

time from start of Aug 2010 model run (days)
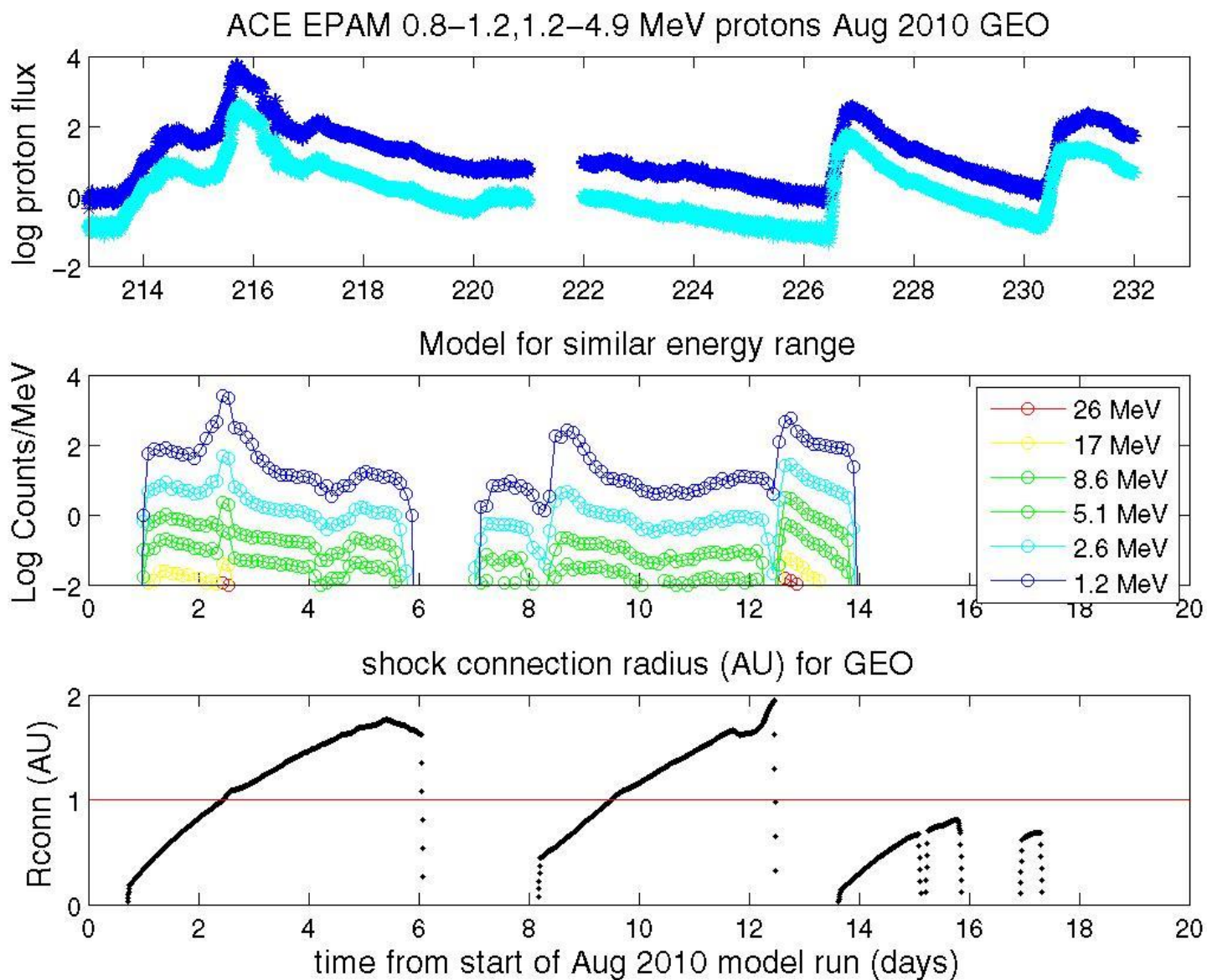
Bottom Lines + Lessons learned thus far:

*Any SEP event model will only be as good as the CME and heliospheric model it is based on.

*SEP events may or may not be accompanied by the geomagnetic storm-causing shock or the shock and coronal ejecta. This impacts their predicted geoeffects.

*The most extreme events (e.g.. GLEs) require modeling of the coronal portion of the shock (currently not part of WSA-ENLIL/cone).

*Improvements can be made now based on applications performance, and someday by the same SEP event model that uses more complete background simulations (with corona and CME ejecta material and fields).

*STEREO and ACE multipoint observations provide a particularly useful test because comparisons of the same solar event can be made at different locations

*It's now time to routinely apply SEP event models tied to the routine WSA-ENLIL heliospheric models as the first step to this highly desired product.

A Three-Stage Implementation Approach?

1. A Nearly Painless First Step interim product:

Procure and install WSA-ENLIL/cone model with shock finder enhancements to track Earth-shock connections in existing routine runs

2. Second Step:

Allocate disk space for observer shock-connected field lines from simulation and plot for visual evaluation of its usefulness as a by-product

3. Third Step:

Add SEP source description and particle transport code.