Long-term simulation of radiation belt protons above 10 MeV

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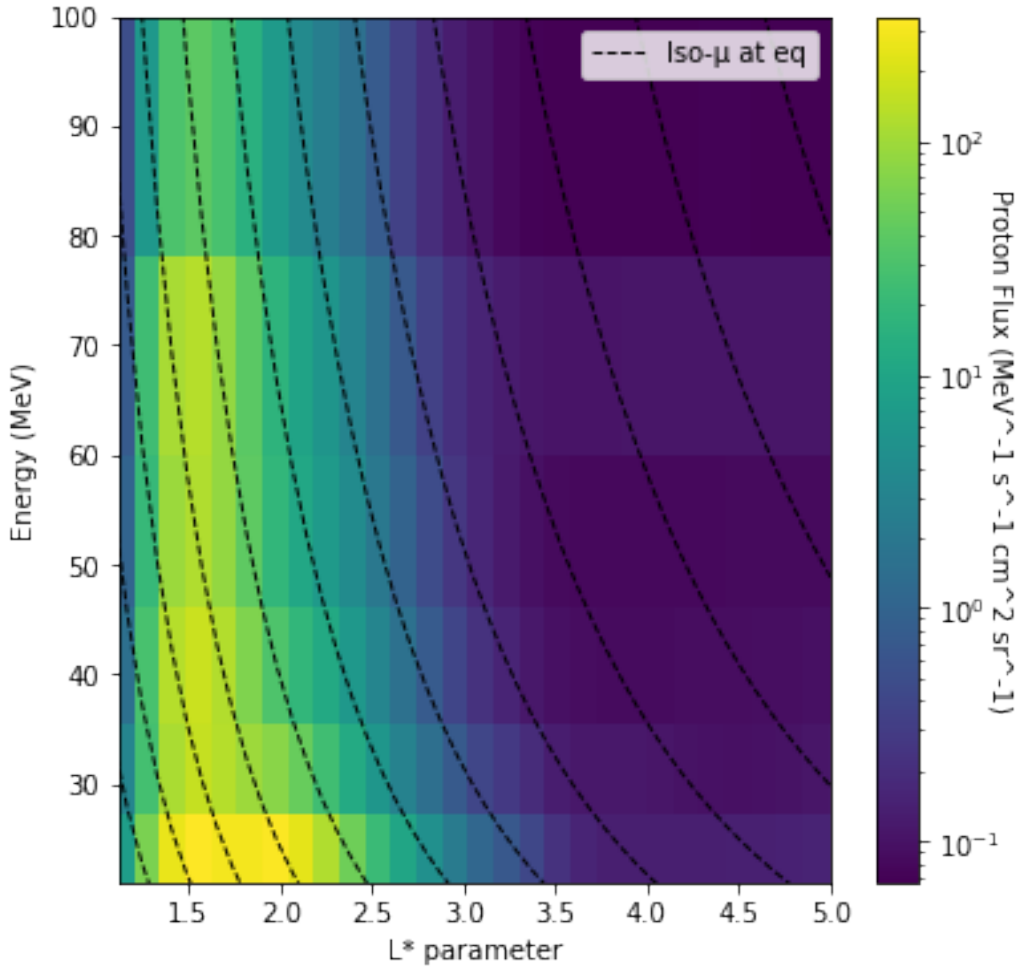
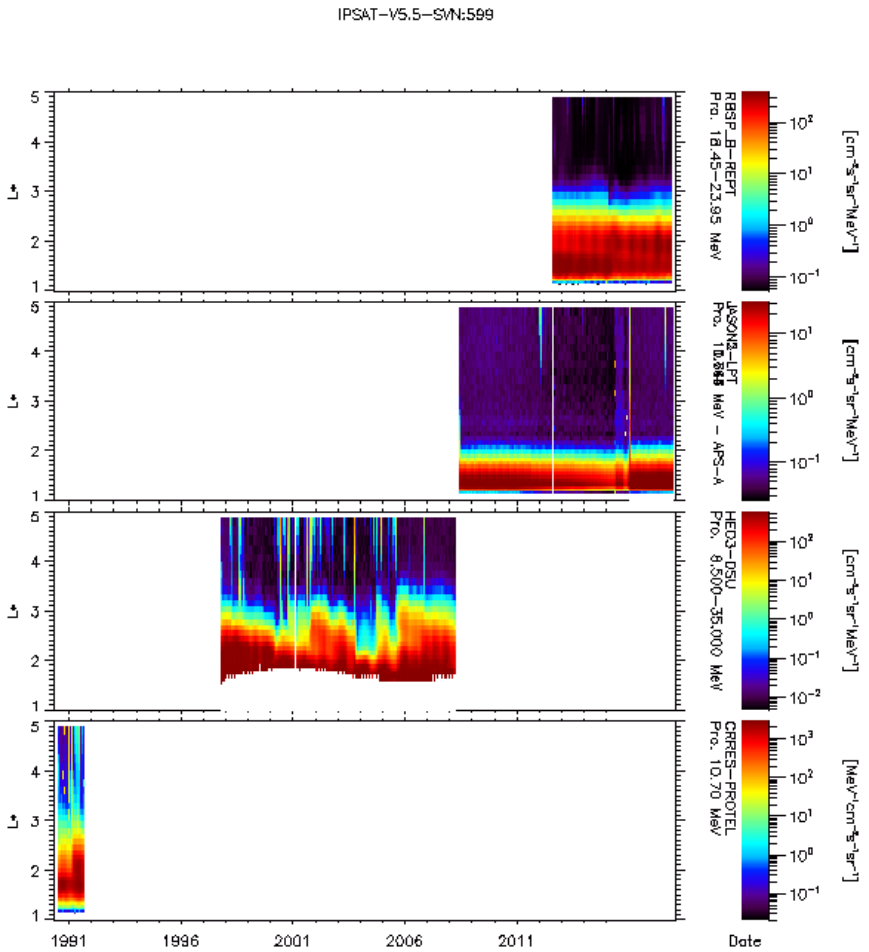


RBSP/REPT mean fluxes

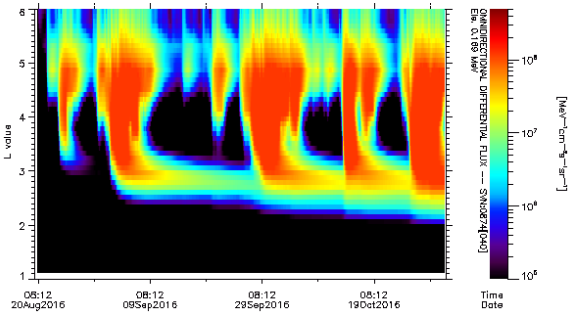
Data coverage

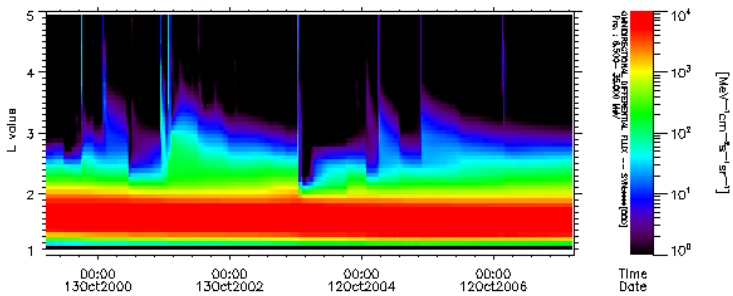
- REPT/RBSPICE on RBSP
  weak solar cycle
- LPT on JASON 2 and 3
  LEO
- DSU on HEO3
  no low-L data
- PROTEL on CRRES
  very short mission

Patchy coverage for a global solar-cycle dependent empirical model



The salammbô models





Electron

- Wave-particle int.

Common

- Radial Diffusion
- Friction
- Fast losses

Proton

- SEP
- CRAND
- Geomag. Shielding
- Nuclear int.
- Charge Exchange

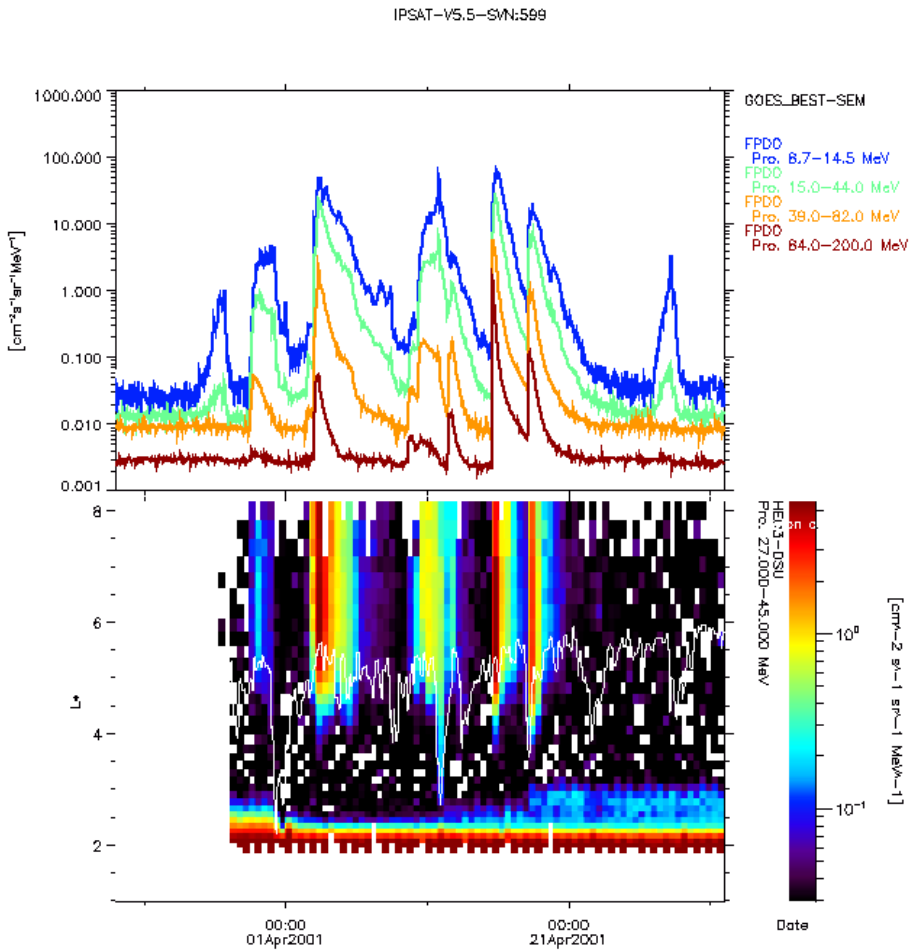
- Boundary cond.
- Proxies (Kp, Dst)
- Lpp, Lmp models

Overview of the Salammbô-Proton model

- Radial Diffusion : Kp-driven model
- Nuclear interactions, Charge Exchange, Neutral Collisions :
  - *MSIS-86* atmospheric model
  - Hydrostatic law above 500 km
- External boundary condition (L*=8):
  - Kp-driven statistical model from POES data
- Geomagnetic shielding:
  - Dynamical L* cutoff model
- SEP Events:
  - Direct assimilation of GOES data
- CRAND:
  - Static source term

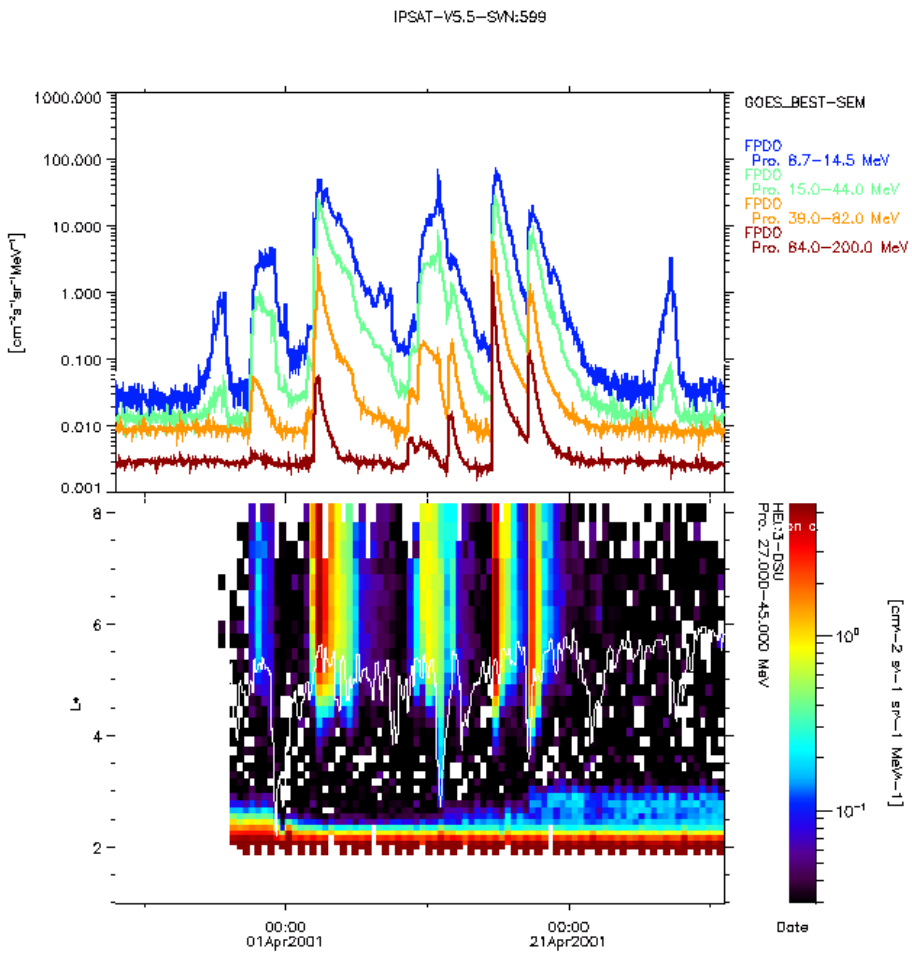
Geomagnetic shielding

- Kp and Dst-driven empirical cutoff model
- Energy-dependency derived from MASHcode monte-carlo estimations
- Below cutoff : radial diffusion at constant first and second adiabatic invariants
- Above cutoff : fast diffusion at constant Ec



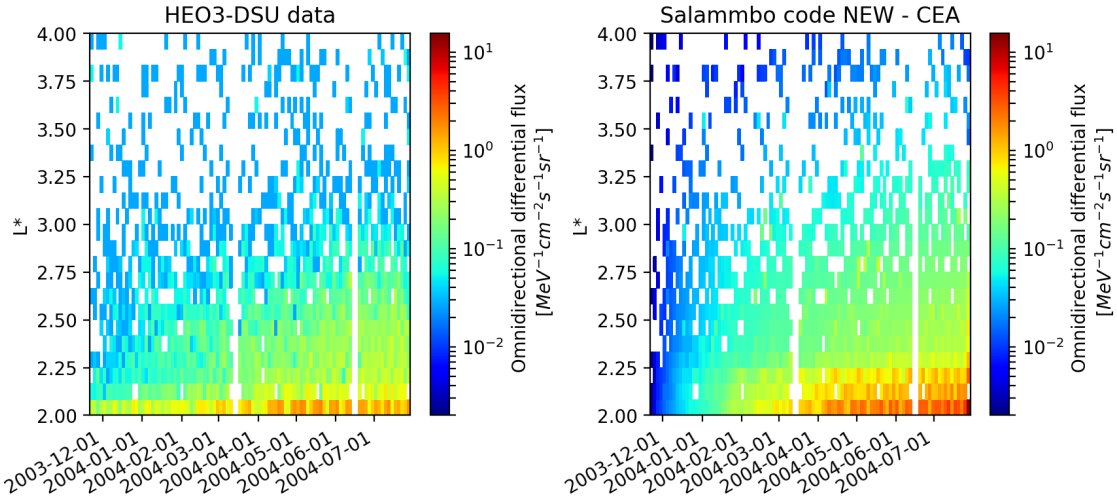
SEP Events

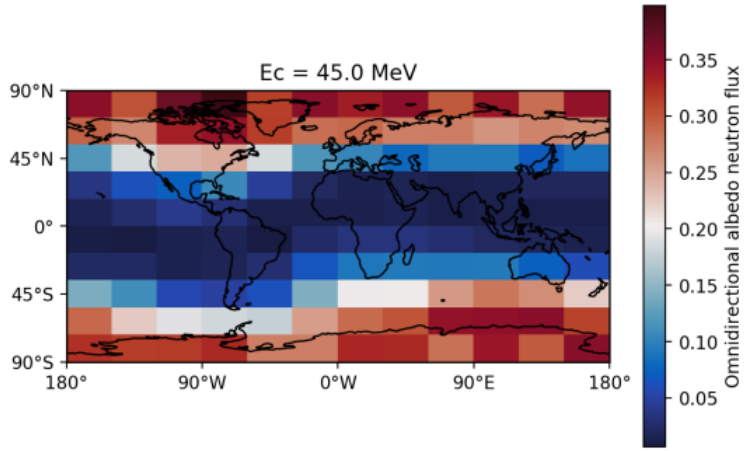
- Direct assimilation of high-energy protons fluxes from GOES data
- Injection of measured densities on the cutoff boundary
- Radial diffusion is assumed for boundary permeability
- Emptying when the cutoff is raised

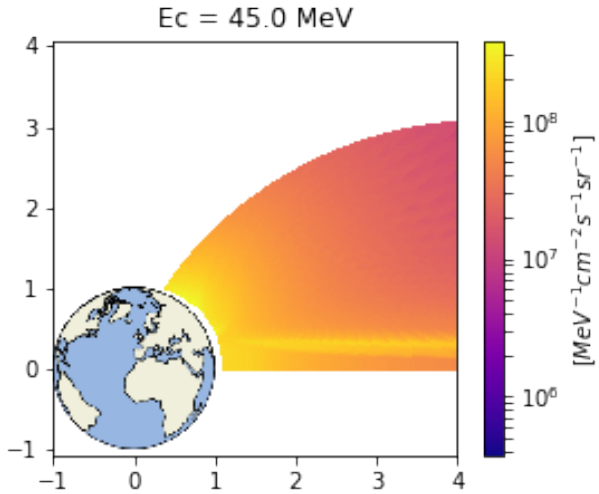


CRAND

- Cosmic-ray albedo neutron flux maps computed at CEA with monte-carlo
- Solar cycle dependency to come

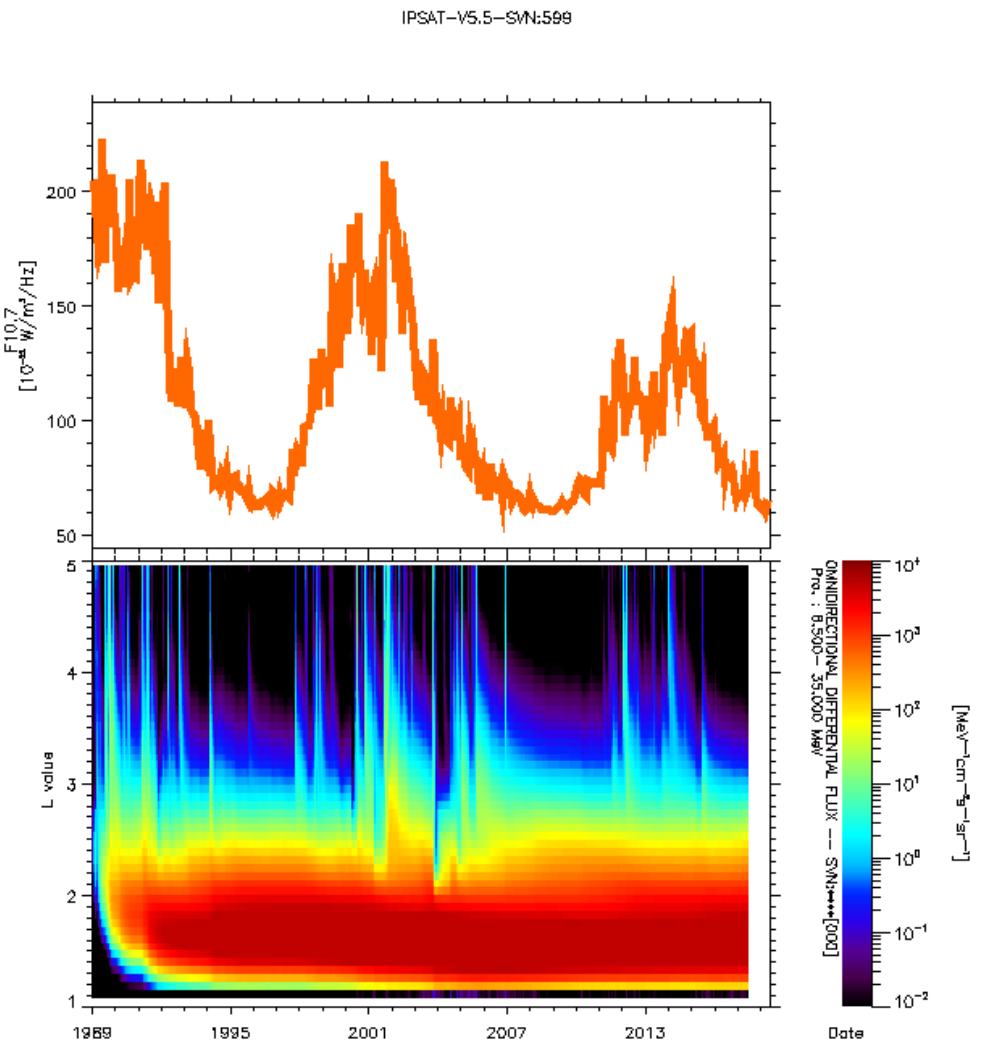




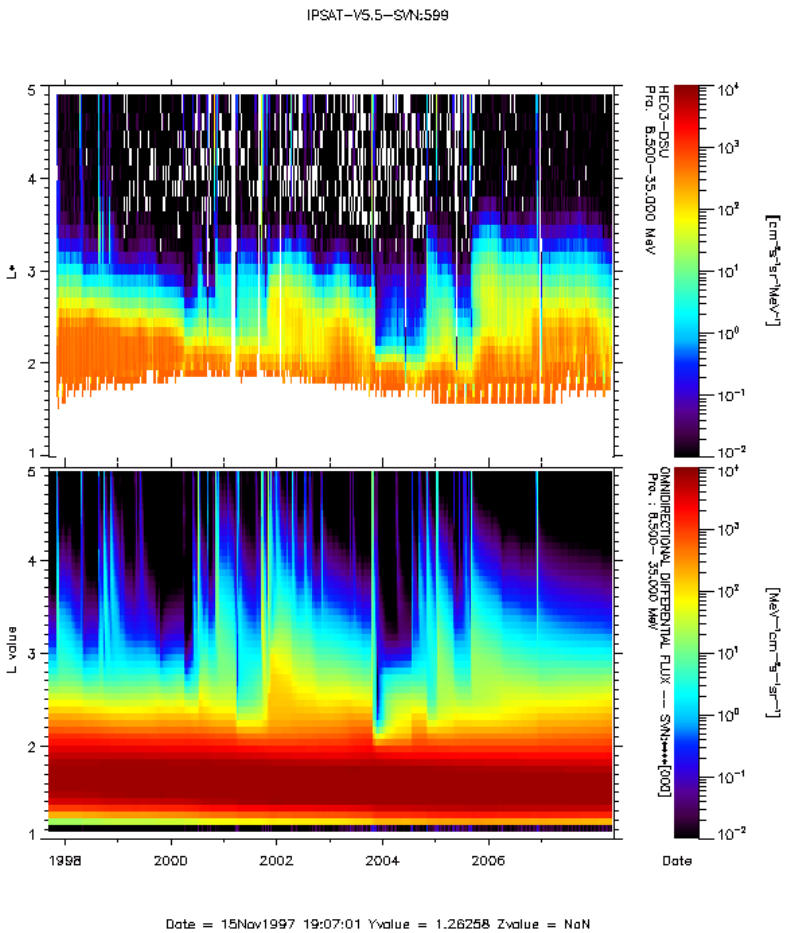


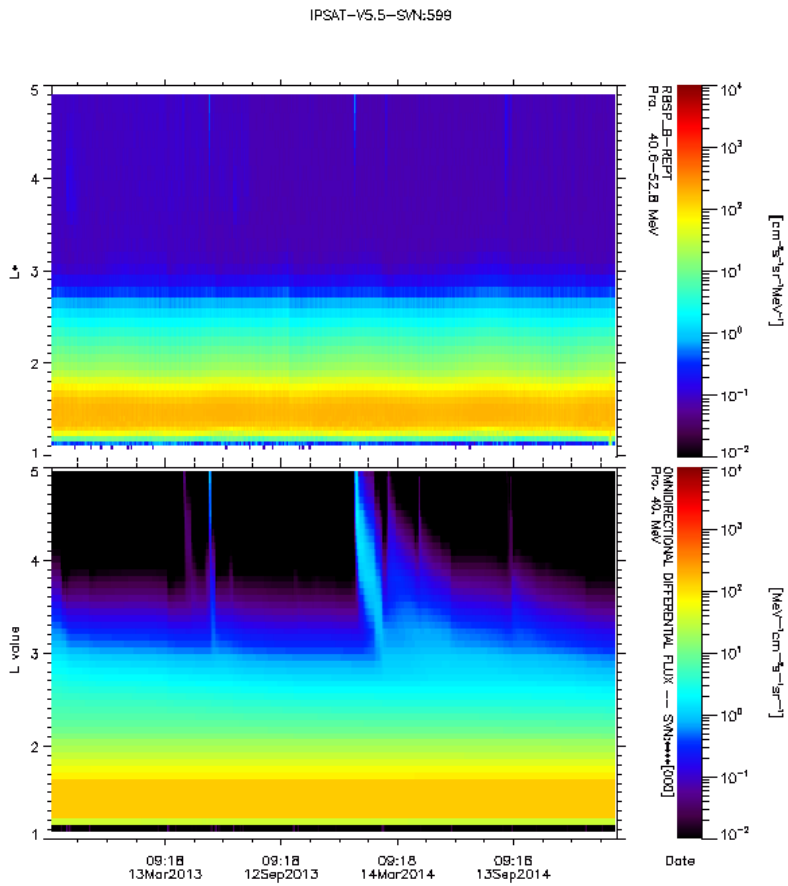
Simulation results

- Simulation between 1989 and 2018
- More than two solar cycles (timestep 10s)
- Complete PSD map every 12h
- Start with empty state before 1989 storm



Comparison with in-flight data

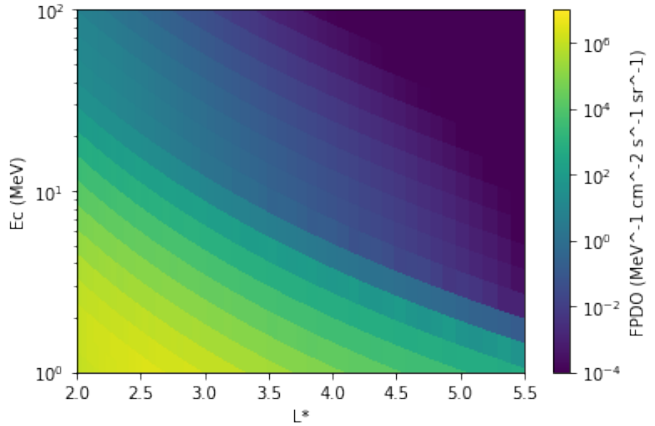




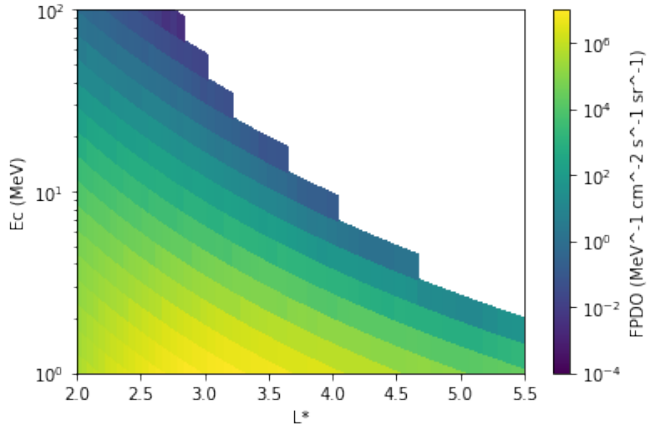
GREEN-Proton yearly averaged model

- GREEN is a global model averaged per solar cycle year (SCY)
- We integrated the Salammbô PSD for each SCY
- Mean model for each SCY is averaged on 2 simulation years

Salammbô Mean SCY 0



AP8 MIN



Conclusion

- The Salammbô Proton model has been improved:
  - New CRAND model
  - Trapping of high energy protons from SEP
- The last two solar cycles have been simulated
- Average fluxes for each solar cycle year have been computed for the GREEN model

Conclusion

- High impact of a few events (2003) on the averages
- Is a yearly-averaged model representative of the fluxes
  - For long-term missions / plateform design?
  - For short-term missions?
- Model for 1-10MeV protons
  - Transition between physics
  - Trapping boundary model to be refined
  - GOES starts at a few MeV (POES has lower energy channels)

Thank you