ONERA update on space climatology

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THE FRENCH AEROSPACE LAB

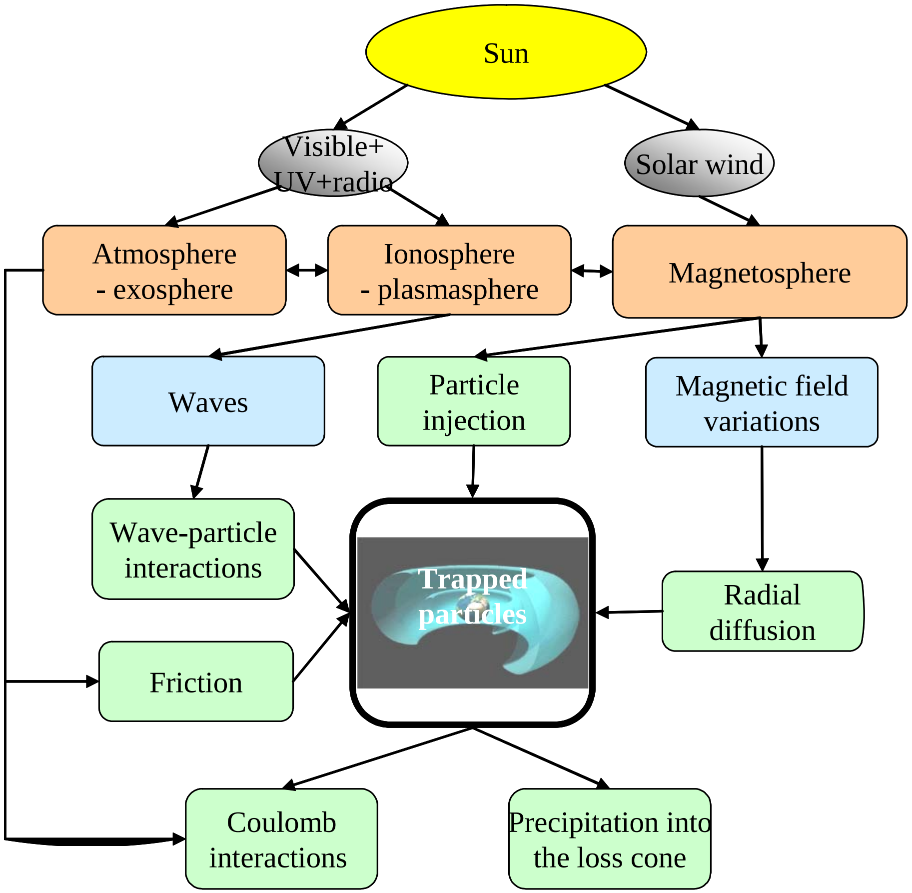
return on innovation

Context
Space climatology based on various families of models (1/2)

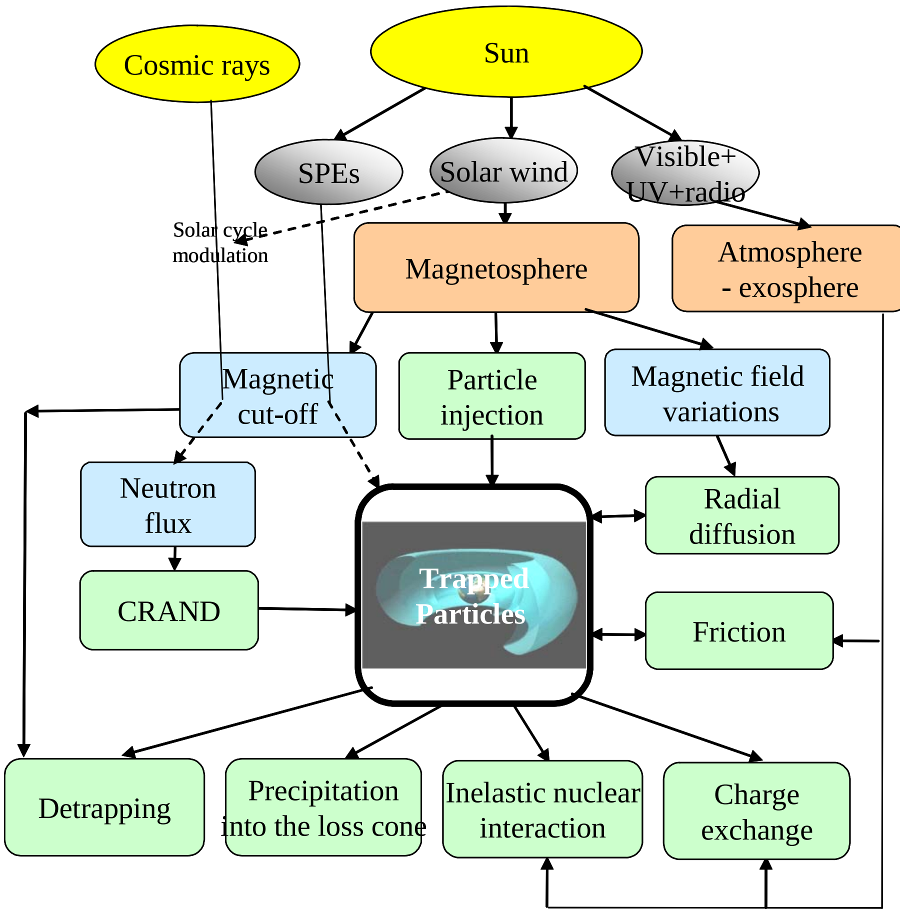
- **Physical models**

→electron and proton models : common processes and different ones

Salammbo electron 3D code



Salammbo proton 3D code



Space climatology based on various families of models (2/2)

- **Empirical models**
  - → IGE 2006 @GEO [Sicard-Piet et al., 2008]
  - → MEO models based on GPS data only (MEO v1 and MEO v2)
  - → BUT none for the inner belt

- **Data assimilation**
  - → 3D-Salammbô electron and proton code plugged with direct insertion ➔ solar cycle reanalysis
  - → 3D-Salammbô electron plugged with EnKF

BUT

→ Modeling uncertainties, especially below L=4 (since no data to compare with)

→ Data uncertainties too

Method

Perturbing one input parameter of the model

→ **Model** →

Ensemble of radiation belts « allowed states »

=

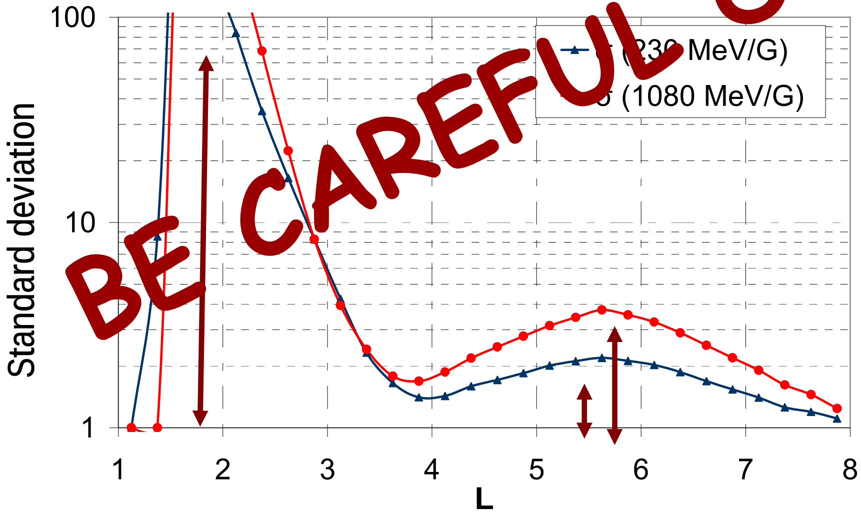
Ensemble of model uncertainty realizations

→

Statistics of uncertainties of modeling

BE CAREFUL OF BIAS IN MODEL

Results *(global perturbation of Kp index as input of Salammbo 3D electron code)*



Initial perturbation :
1 unit in Kp scale

L < 2.5	**:**	ε > 10
2.5 < L < 3.5	**:**	2 < ε < 10
3.5 < L	**:**	2 < ε < 4

Waves-particles interactions models and database (1/2)

- **WAPI code**
  - → based on the quasi-linear theory and calculate diffusion coefficients ($D_{\alpha\alpha}$, $D_{\alpha p}$ and D_{pp})
  - → comparison with other models (PADIE, Abel and Thorne, Summers)
  - → comparison for several kind of waves (chorus, Hiss, EMIC, Lightning whistlers, VLF)
  - → comparison for different propagation angle (aligned or non-aligned waves)
  - → Recently used for Jupiter

Plasma characteristics

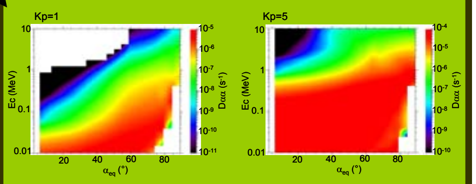
GCPM [Gallagher et al., 2000]
(Global Core Plasma Model)

Waves characteristics

A global s/c data base has been created

Input parameters

WAPI code



TO DO

SALAMMBO code

Improving physical models
Waves-particles interactions models and database (2/2)

- **Wave data base structure (angelica.sicard@onera.fr)**

  → put together waves data from different s/c in the same frame for a brand board of frequencies :

  frequencies from 8Hz to 810 kHz

  L values from 1 to 8*

  All MLT, all latitudes and 6 classes of Kp

  → CDF files (ISTP compliant) containing :

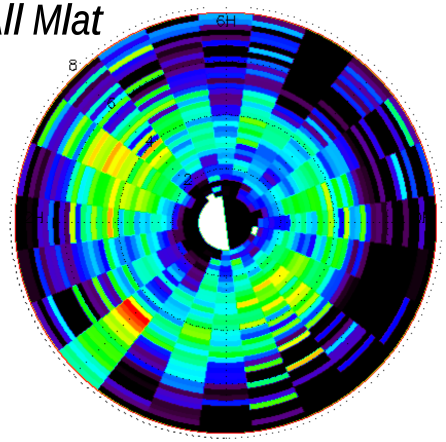
  fce, Ndens

  Bwave_frequency, Bwave_power, Bwave_quality_flag, Bwave_crosscal

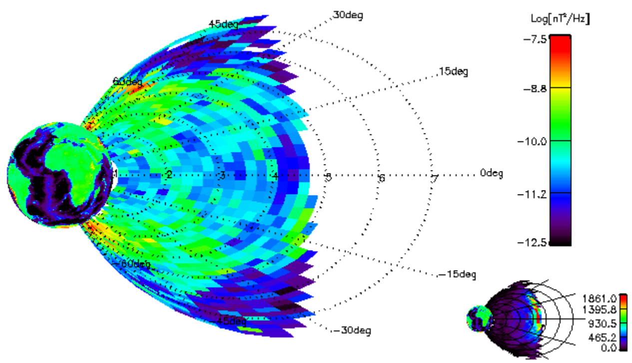
  → Started this year on french space agency funding with data from DE1, POLAR, CLUSTER 1

Kp < 2
2545.6 Hz < f < 2856.5 Hz
No Background
DE1

All Mlat



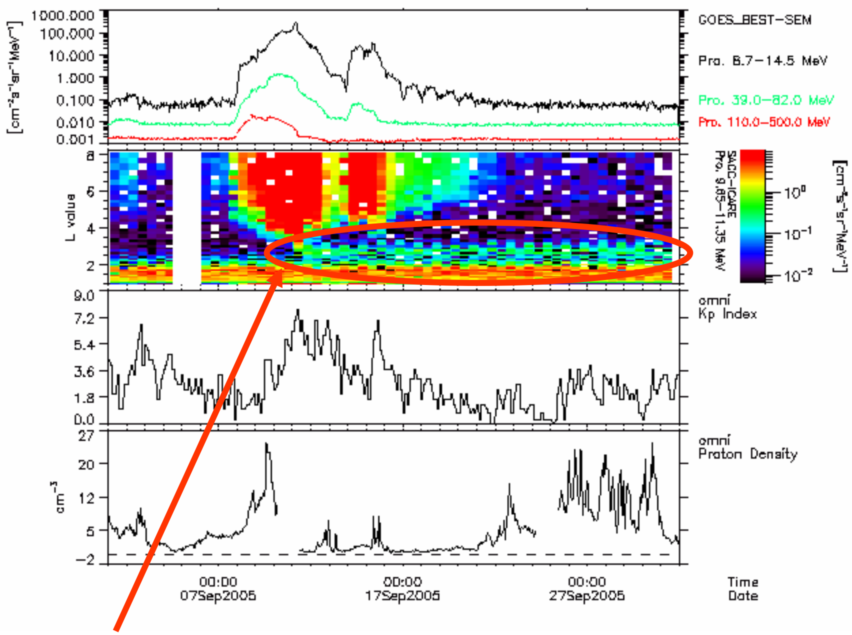
All MLT



Geomagnetic shielding (1/2)

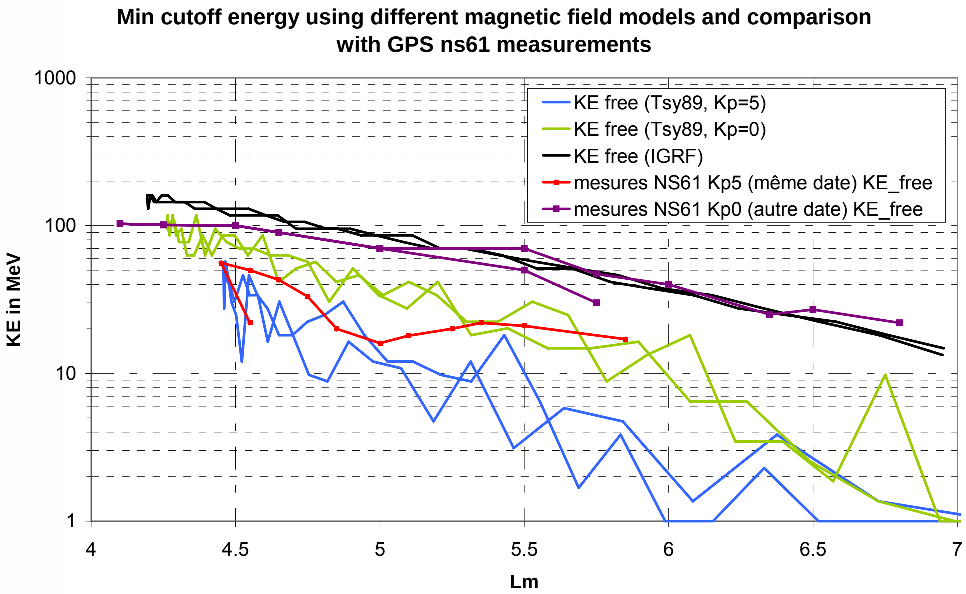
- **To better understand its dynamical behavior**
  - → In the context of the radiation belts = trapping boundary for highly energetic protons (> 10MeV)
  - → In the context of SEP = access to the inner magnetosphere

SEP event and trapping boundary



Long lifetime belt until next « untrapping » event

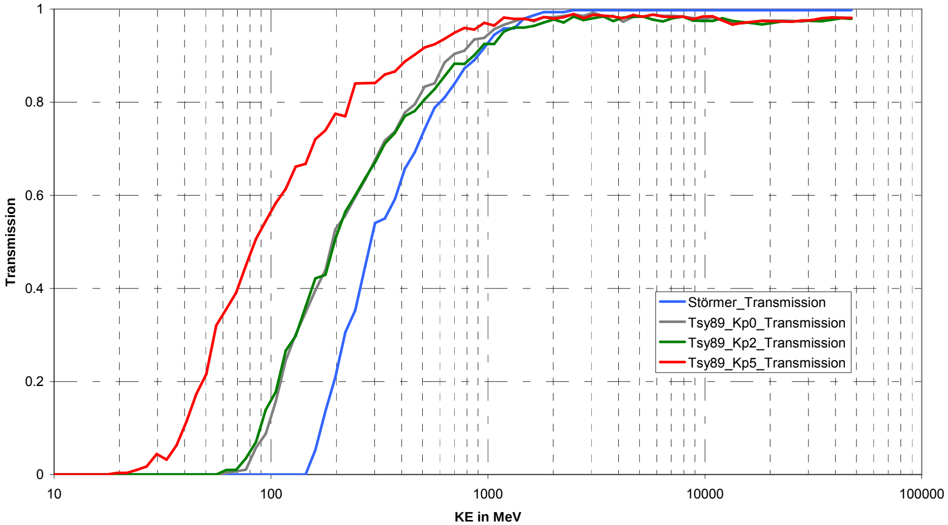
Comparison with T. Cayton (LANL) multi-point measurements using GPS-CXD constellation



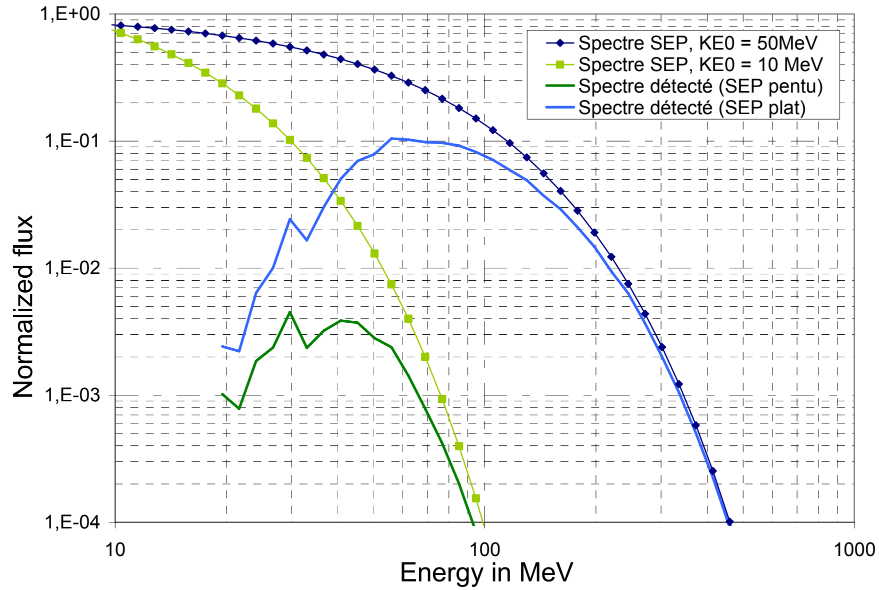
Improving physical models

Geomagnetic shielding (2/2)

Transmission function = percentage of arrival directions from which a particle of a given energy may have access



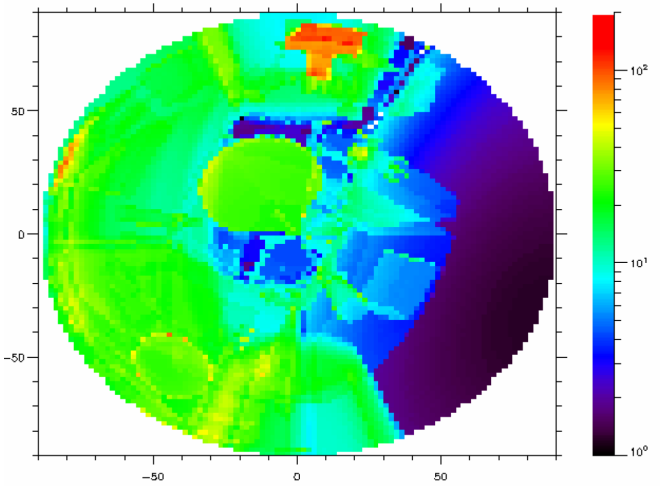
Transmission functions for different magnetic field models at the magnetic equator for Lm=4

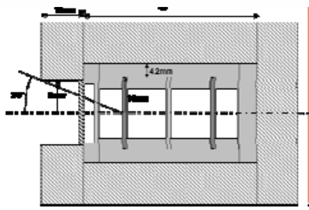


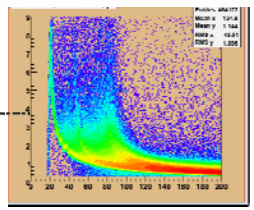
Transmitted spectra for 2 types of SEP at Lm=4

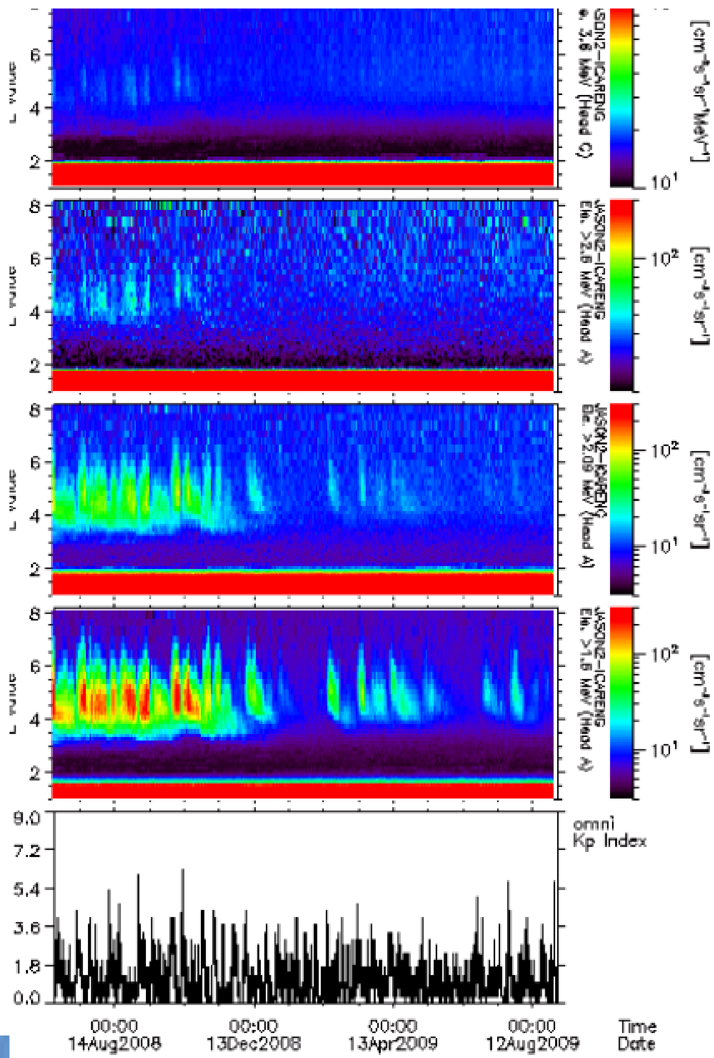
Data processing : JASON 2

- **ICARE-NG detector (daniel.boscher@onera.fr)**
  - → altitude = 1336km, inclination = 66°
  - → data available the next day
  - → electrons from 0.8 to > 3 MeV
  - → protons from 20 to > 300 MeV
  - → will fly on JASON 3



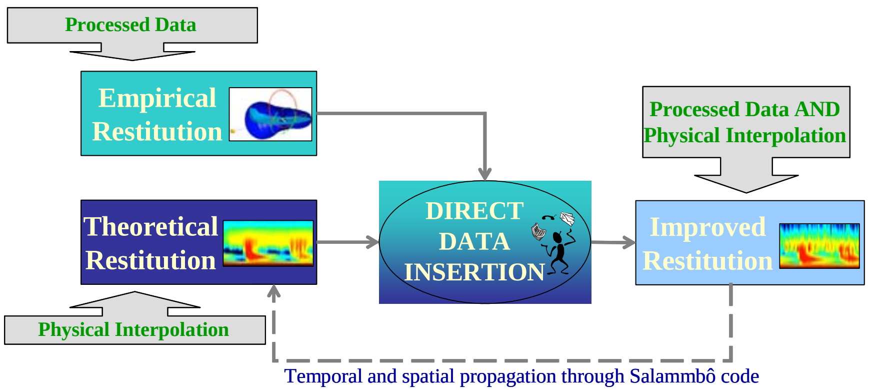


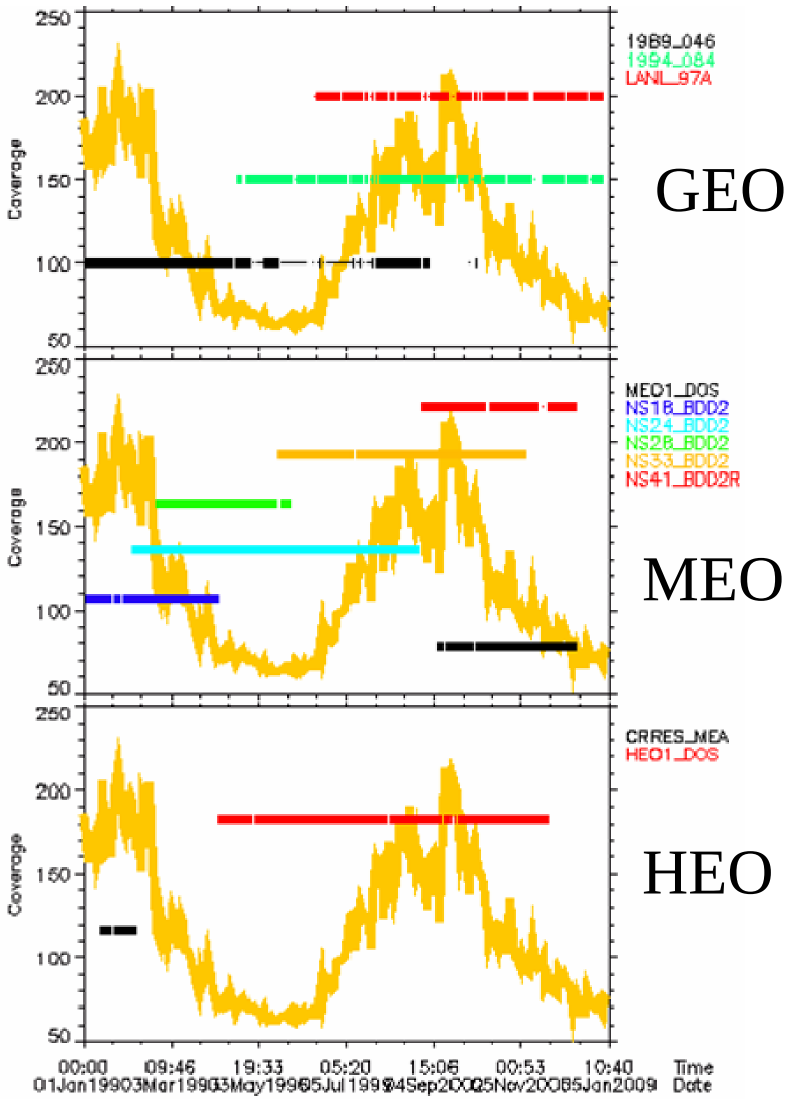




Outer electron belt specification model (1/2)

- **Specifications [Bourdarie et al., 2009]**
  - → spatial coverage :
    - *1. <L*<8*
    - *All latitudes (equatorial pitch angles)*
    - *Symetric in longitude*
  - → energy coverage
    - *50 keV< Ek<10 MeV*
  - → magnetic field models
    - *IGRF1998 plus Olson-Pfitzer quiet*
  - → solar cycle dependent





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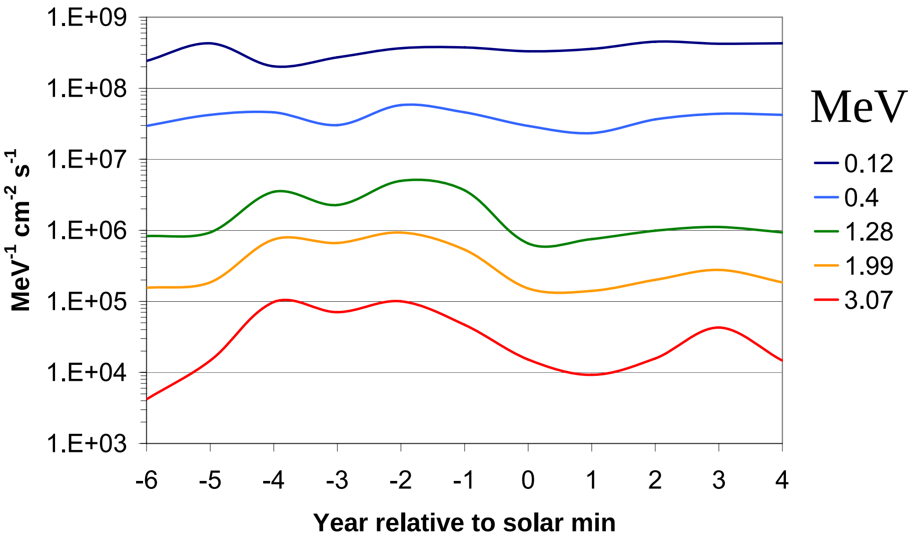
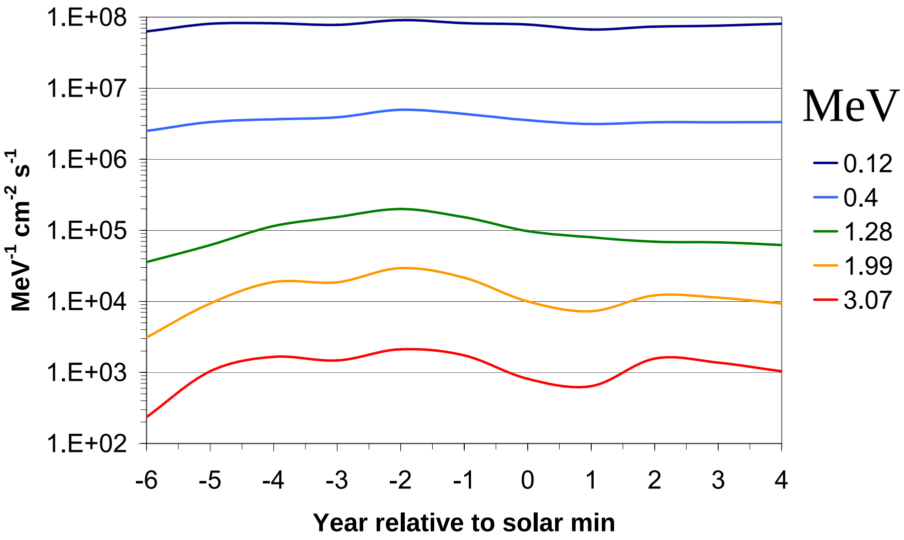
Outer electron belt specification model (2/2)

Electron flux at magnetic equator versus years of solar cycle
Year=0 is solar minimum



L*=4.5



L*=6.

Conclusions

- **Large bunch of empirical/semi-empirical models :**
  - → @GEO : IGE
  - → @MEO : MEO model for Galileo constellation
  - →@outer belt e- : reanalysis based model

- Engineering product : OMERE
www.trad.fr

- Scientific product : included into IRBEM library

- **To Do !**
  - → Plug parts of modelling to Salammbô
  - → Improve EnKF data assimiation scheme