e-slot region radiation environment model

I. Sandberg, National Observatory of Athens

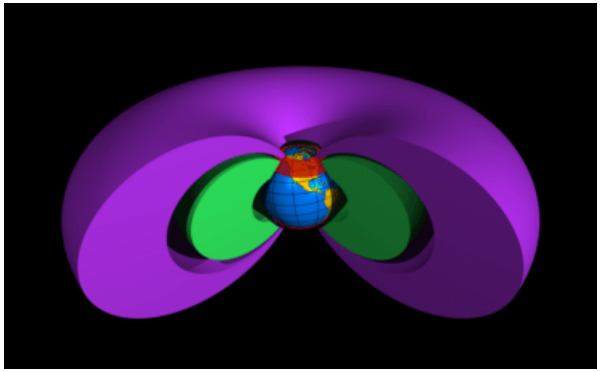
I. A. Daglis, Department of Physics, University of Athens
D. Heynderickx (DH Consultancy)
P. Truscott (Kallisto Consultancy Ltd)
A. Hands (QinetiQ)
H. Evans, P. Nieminen *(ESA/ESTEC)*

ESTEC/ITT AO/1-6700/11/NL/AT

SRREMs

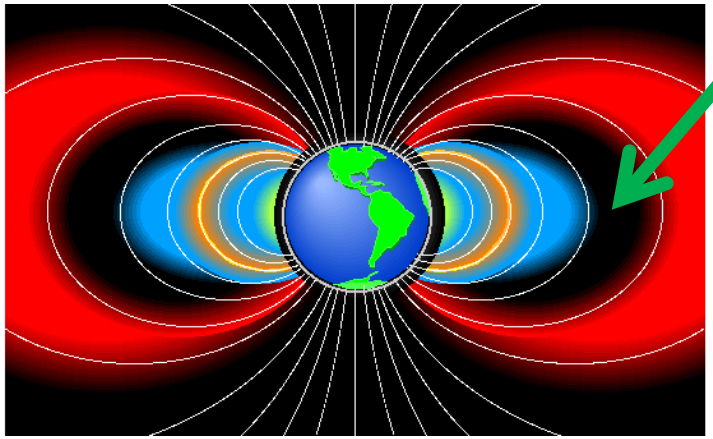
Outline

- Introduction
- Model characteristics
- The datasets
- Model principles
- Build & Run model
- Examples
- Conclusions

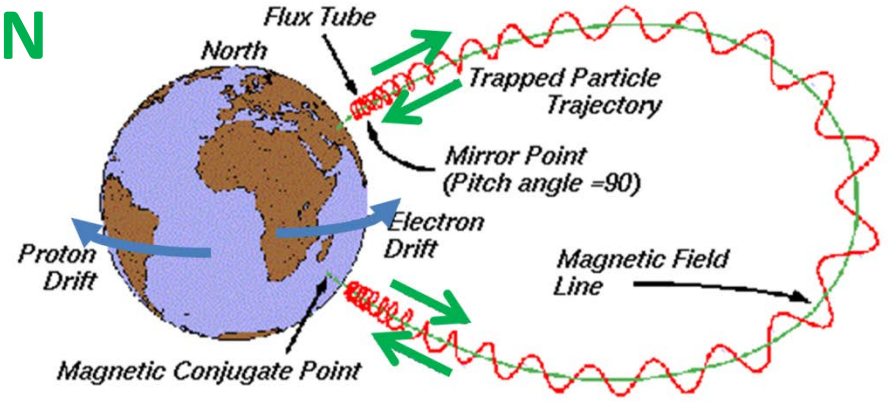


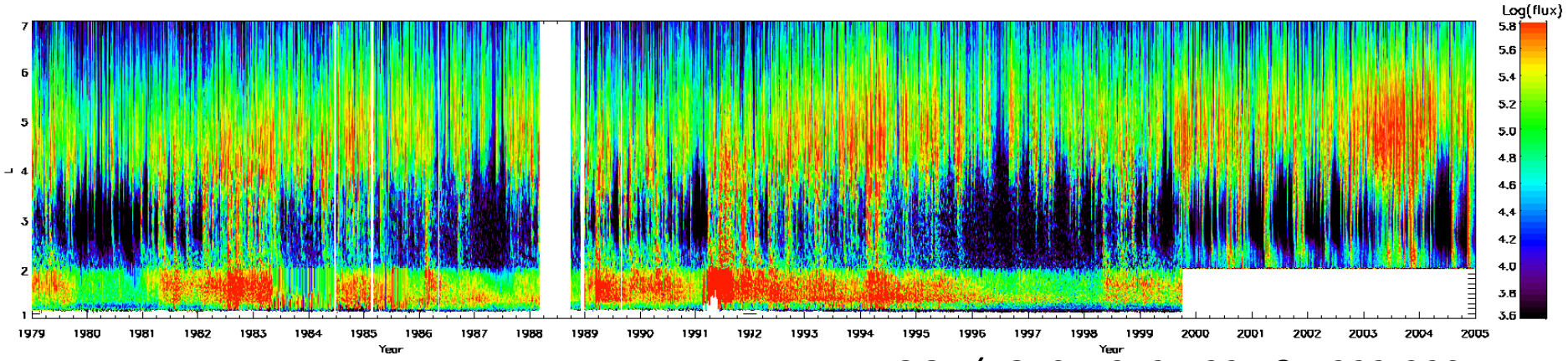
Earth Radiation Belts

MIND THE GAP



SLOT REGION





NOOA/POES: 1979-1991 & 1992-2004

IAASARS

DH CONSULTANCY

Kallisto Consultancy

SRREMs

QinetiQ

esa ESTEC

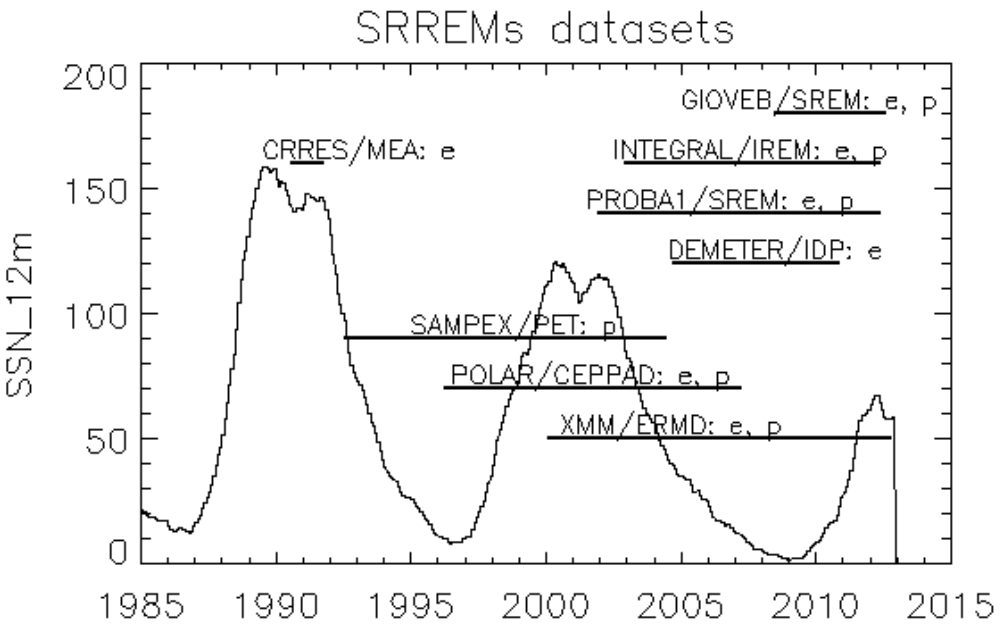
SRREMs

The Slot Region Radiation Environment Models (SRREMs) are **data-based statistical models**, that describe the particle radiation induced by **high-energy trapped charged particles** in **radiation belt slot region** for user-defined satellite **orbit** and **space weather conditions**.

e-SRREM

- Magnetic coordinates: **L*** and **α_{eq}** (IRBEM lib)
- 30 bins for: **L*=[1-6]**
- 27 bins for:**α_{eq} = 0-π/2**
- 7 log bins for ***E_e*=0.1-7 MeV**
- **300 log** bins for histograms

Electron Bins		Centers
0.100	0.183	0.135
0.183	0.337	0.249
0.337	0.612	0.456
0.612	1.13	0.837
1.13	2.08	1.53
2.08	3.81	2.82
3.81	7.00	5.17



Datasets

SPACECRAFT	Orbit	Period	Perig x Apog [Km]	Incl.	Coverage	Instrum
CRRES	GTO	2h	305 x 33350	18	1990-1991	MEA
DEMETER	LEO	1,40 h	710	98	2004-2010	IDP
GIOVE-B	MEO	14,1 h	23200	56	2008-20112	SREM
INTEGRAL	HEO	72h	10000 x 152700	52	2002-	SREM
POLAR	PEO	17,5 h	7500 x 50800	86	1996-2008	CEPPAD
PROBA1	LEO	97min	570 x 640	98	2001-	SREM
XMM	HEO	48h	7400 x 114000	70	1999-	ERMD

IAASARS DH CONSULTANCY Kallisto Consultancy SRREMs QinetiQ esa ESTEC

From data to models

- Gather spacecraft data and ingestion in Open Data Interface (ODI), using common metadata
- Compute and add magnetic coordinates (L^*,α_0)
- Bin the data for each instrument and particle type over the (L^*,α_0) grid
- Re-bin the data in energy to a common set of energies
- Cross-calibrate the data
- Compute and store time average histograms in each (L^*,α_0) bin: 1 day, 3 days, 1 week, 1 month
- Run a spacecraft trajectory through the grid and compute the cumulative distribution function (CDF) and mean values of the flux (SPENVIS interface)

Build SRREM database: work flow

SLOT REGION RADIATION DATA

(L^*, α_{Eq})

Map data on SRREMs grid and time average

Centers
0.135
0.249
0.456
0.837
1.53
2.82
5.17

Re-bin at pre-defined SRREM energies

Calibrate data using Reference dataset

K_p<2 for 3 days
L*> 3.5

Merge data and produce SRREM dataset

Weighted data merging

Construct SRREM histograms

μ_{it}, μ_{it}-σ_{it}, μ_{it}-σ_{it},

For each grid bin!

IAASARS DH CONSULTANCY Kallisto Consultancy SRREMs QinetiQ eesa ESTEC

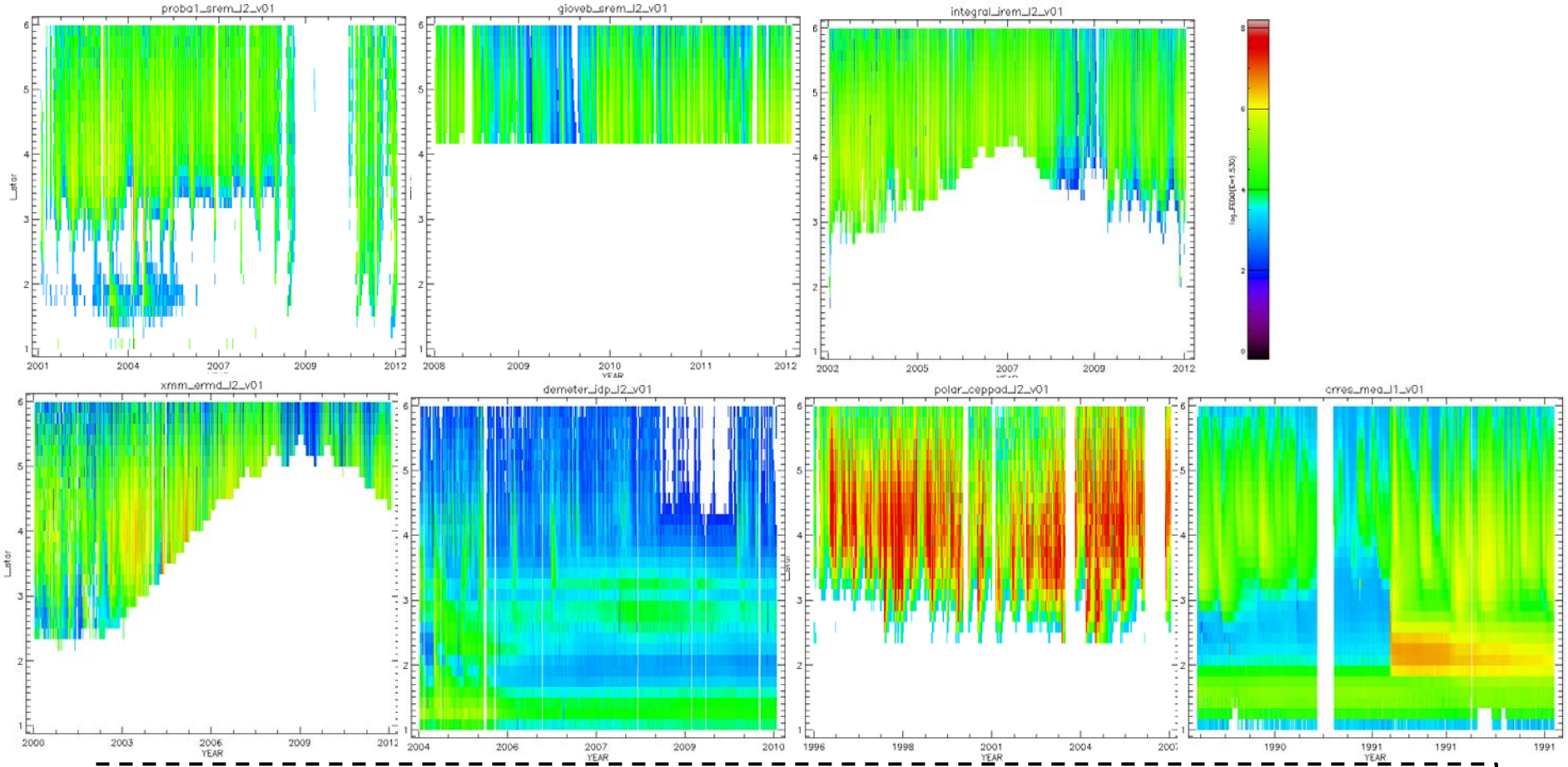
Map data on SRREMs grid

For each dataset, we extract and map the omni-directional differential fluxes on a numerical grid defined by the ***Roederer L parameter*** and the ***equatorial pitch angle*** geo-magnetic coordinates.

$$(L^*, \alpha_{Eq}) = (B_{eq}R_E^2/J_3, B_{eq}/B_m)$$

The data on each SRREMs grid bin are time (1-day) averaged & the following variables are retained and further processed:
the average: μ_{it}, the standard deviation: σ_{it}, and the integration time: τ_{it},

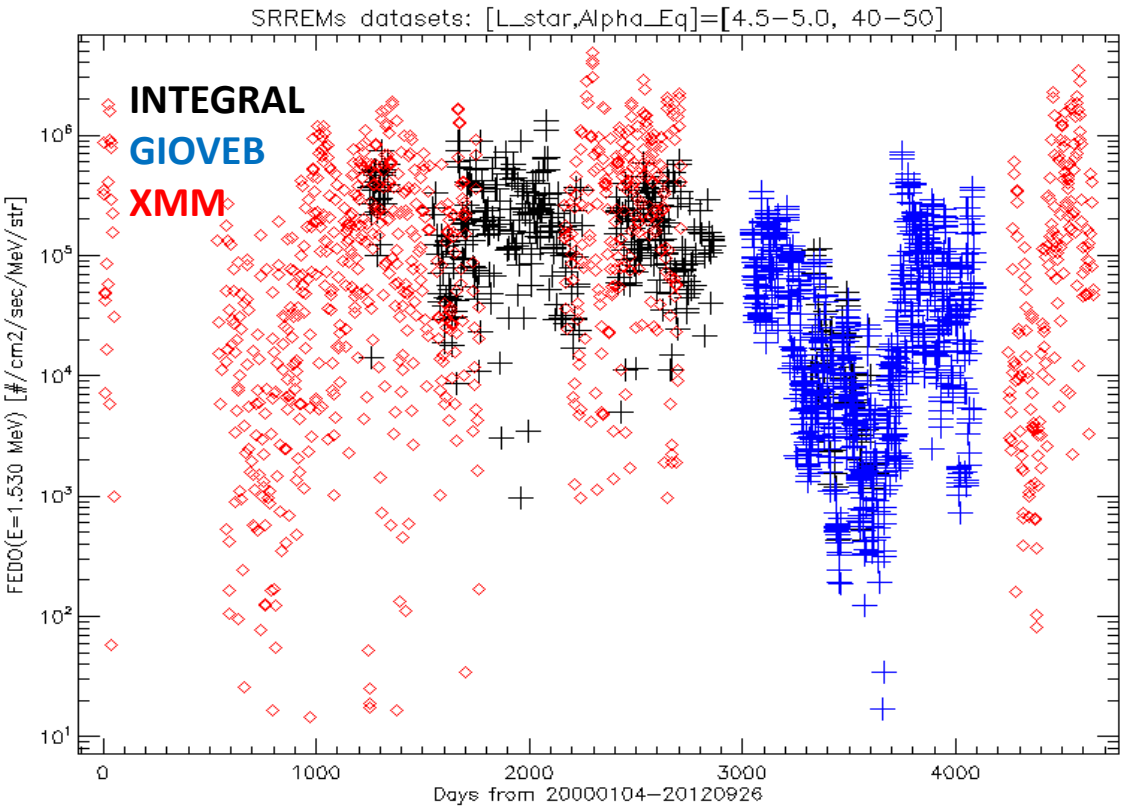
1 day averaged FEDO series



FOR EVERY hyper-bin histograms of the following variables are constructed: the average: $\mu_{it,}$ the standard deviation: $\sigma_{it,}$ and the integration time: $\tau_{it,}$

IAASARS DH CONSULTANCY Kallisto Consultancy SRREMs QinetiQ esa ESTEC

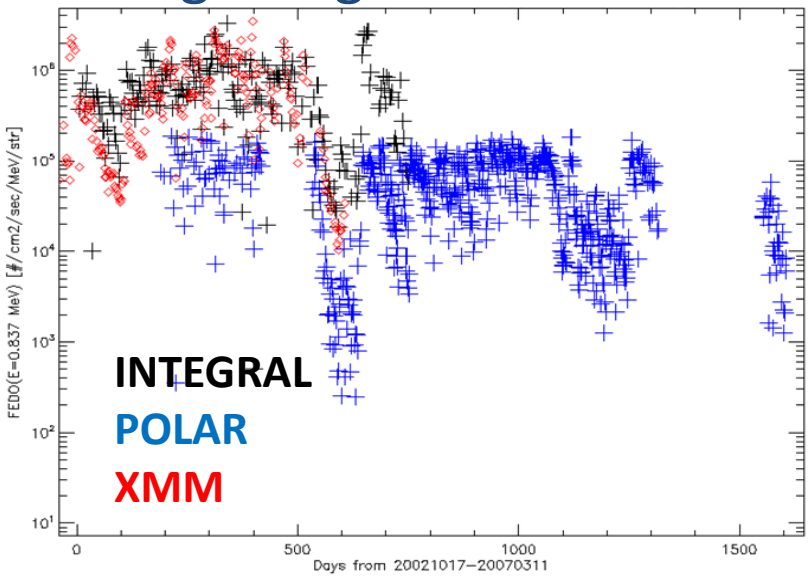
Data synergy



IAASARS DH CONSULTANCY Kallisto Consultancy SRREMs QinetiQ esa ESTEC

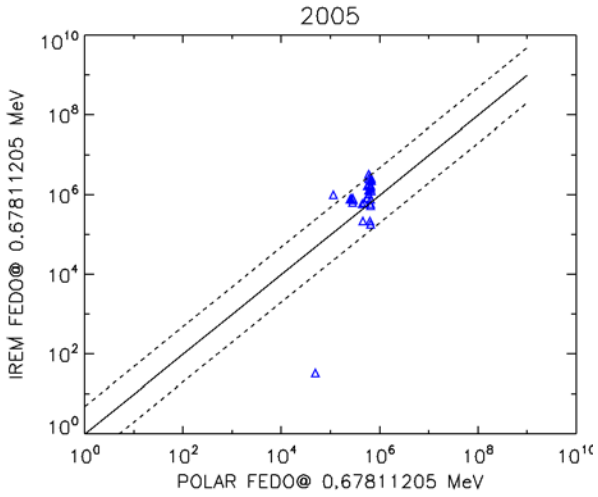
Calibration: the weak point..

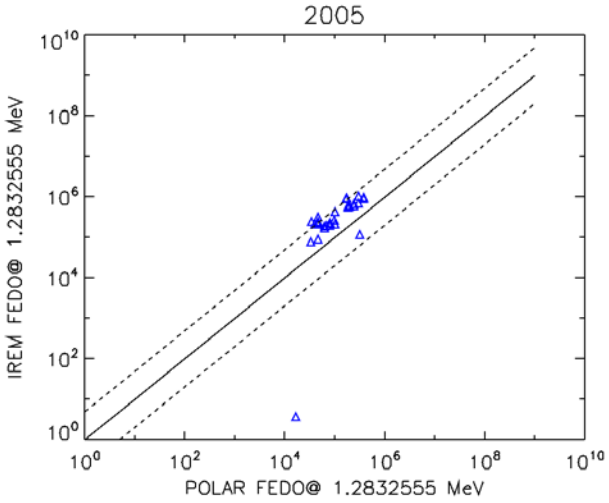
- Cross-calibration of trapped electron flux measurements is non-trivial
- The temporal coverage of CRRES dataset does not overlap with other datasets
- POLAR data do not seem that they can constitute a reference
- Limited conjunctions – strong flux gradients

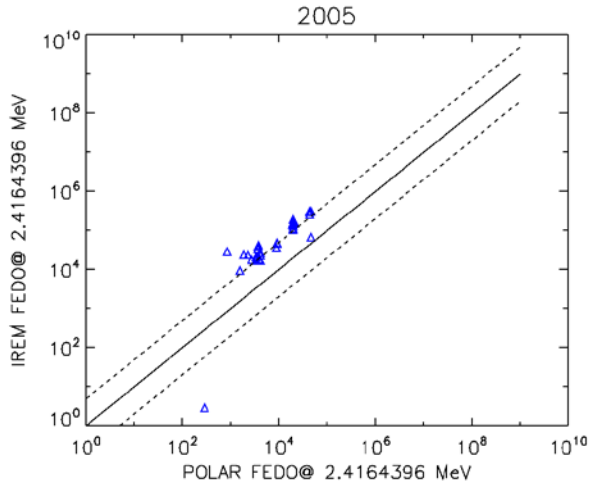


SRREMs

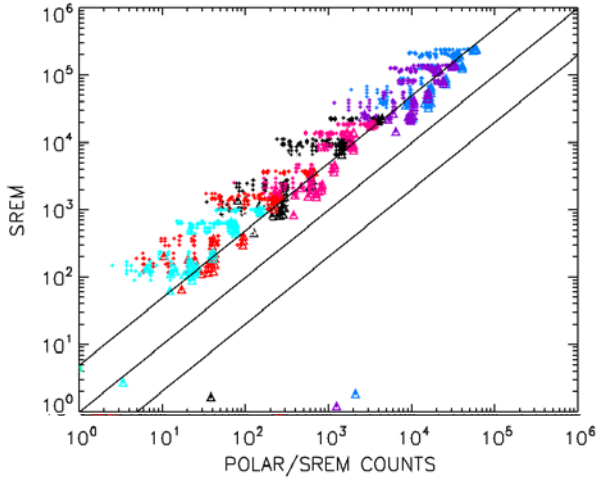
SREM/INTEGRAL vs POLAR

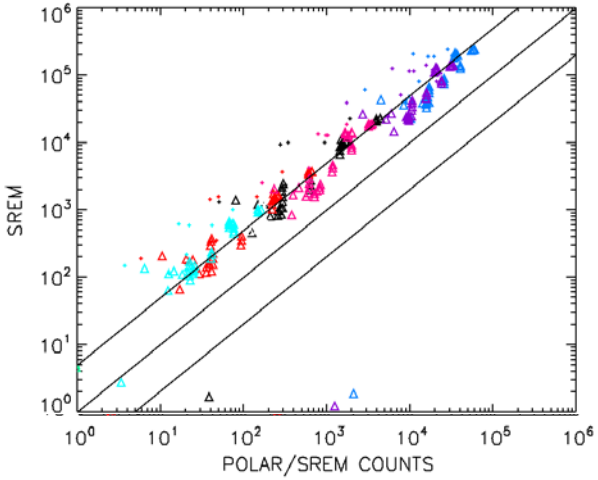






ΔL*<0.05
Δ(B/B0)<0.01

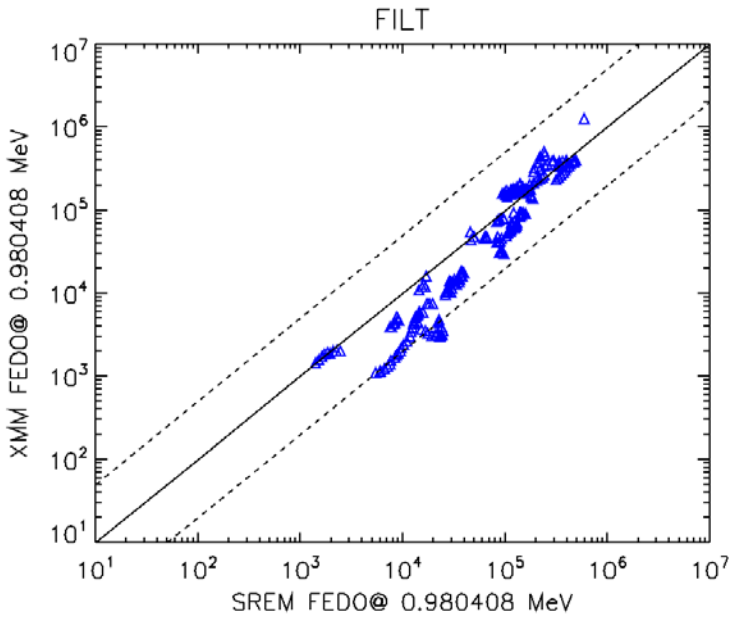


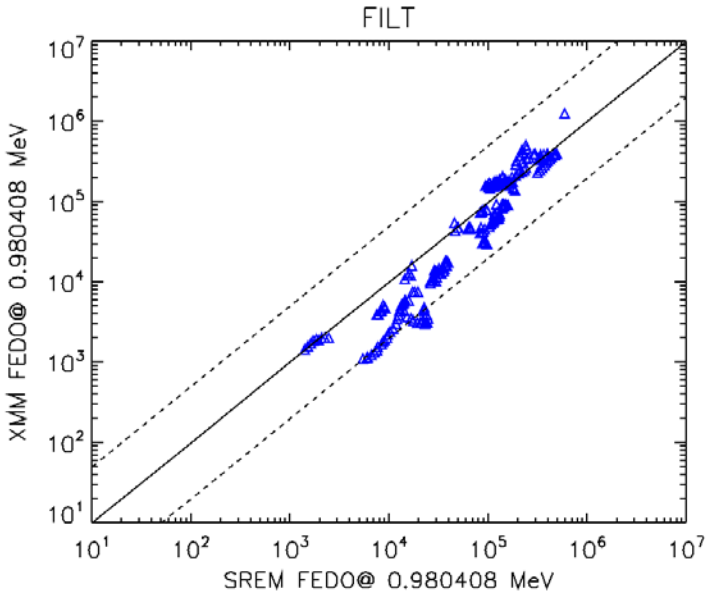


IAASARS DH CONSULTANCY Kallisto Consultancy **SRREMs** QinetiQ esa ESTEC

SREM/INTEGRAL vs XMM

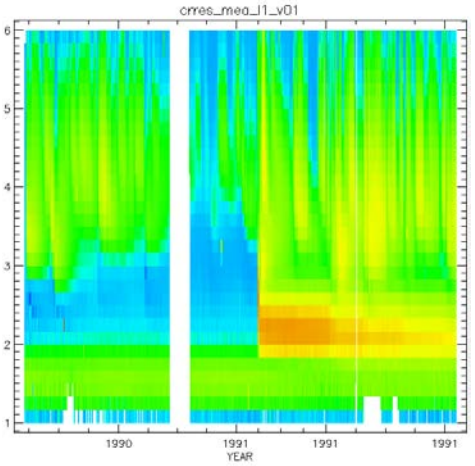
ΔL*<0.05
Δ(B/B0)<0.01





Current scheme

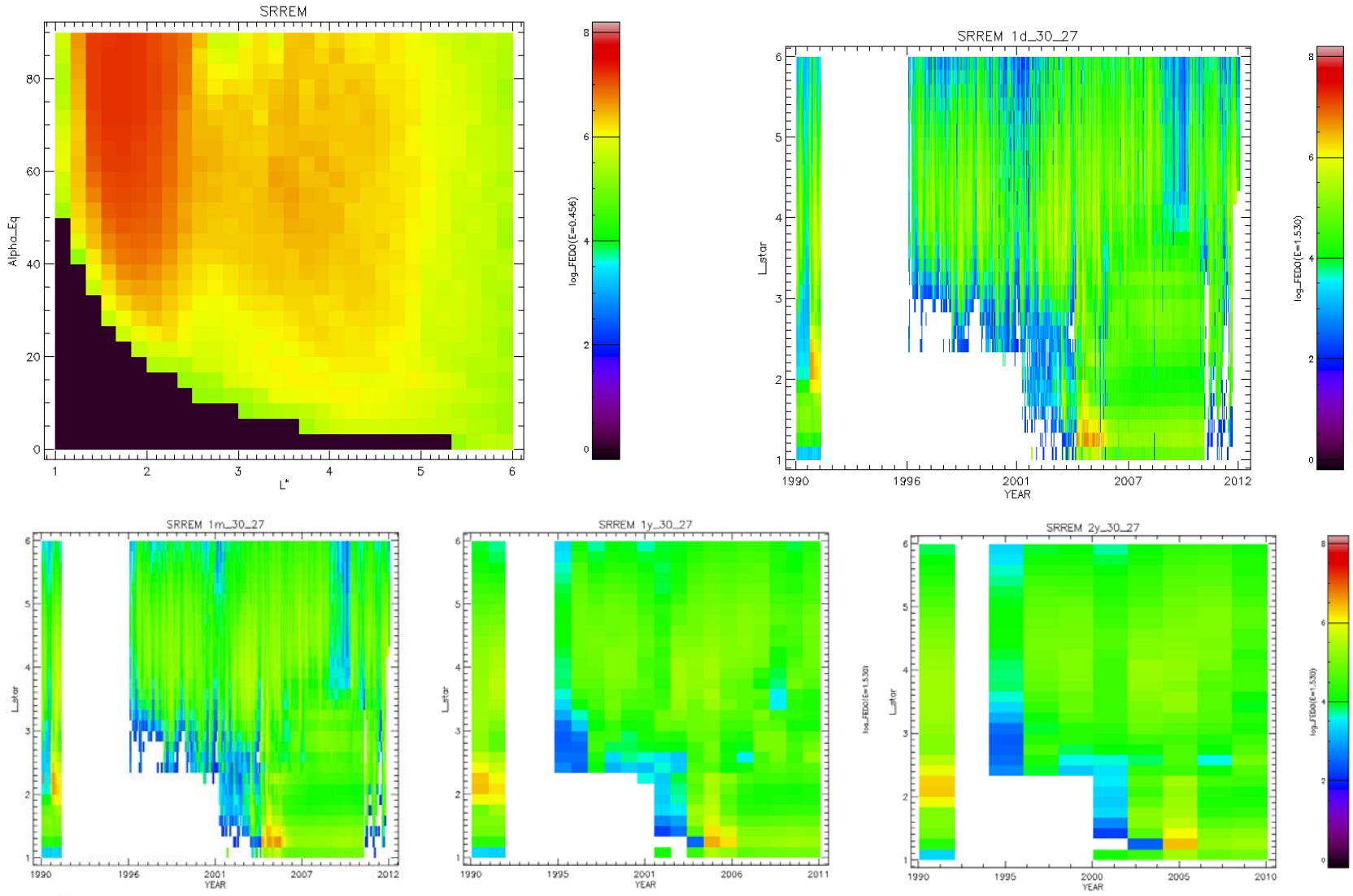
- Choose CRRES/MEA dataset as reference calibration dataset
- Restrict the calibration procedure using 1-day averaged data from the regions bounded by $L^* > 3.5$, in order to emphasize in the calibration procedure the measurements from the outer radiation belt region which present less variability compared to those in the slot region.
- Define as "quiet" space weather conditions the persistence of index $K_p < 2$ for 3 successive days
- Extract only the (daily averaged) data under "quiet" space weather conditions
- Map the averaged values on SRREMs grid
- Compare with reference datasets and calculate the calibration factors for each energy range.



- ONLY channels 2-5 are currently calibrated..

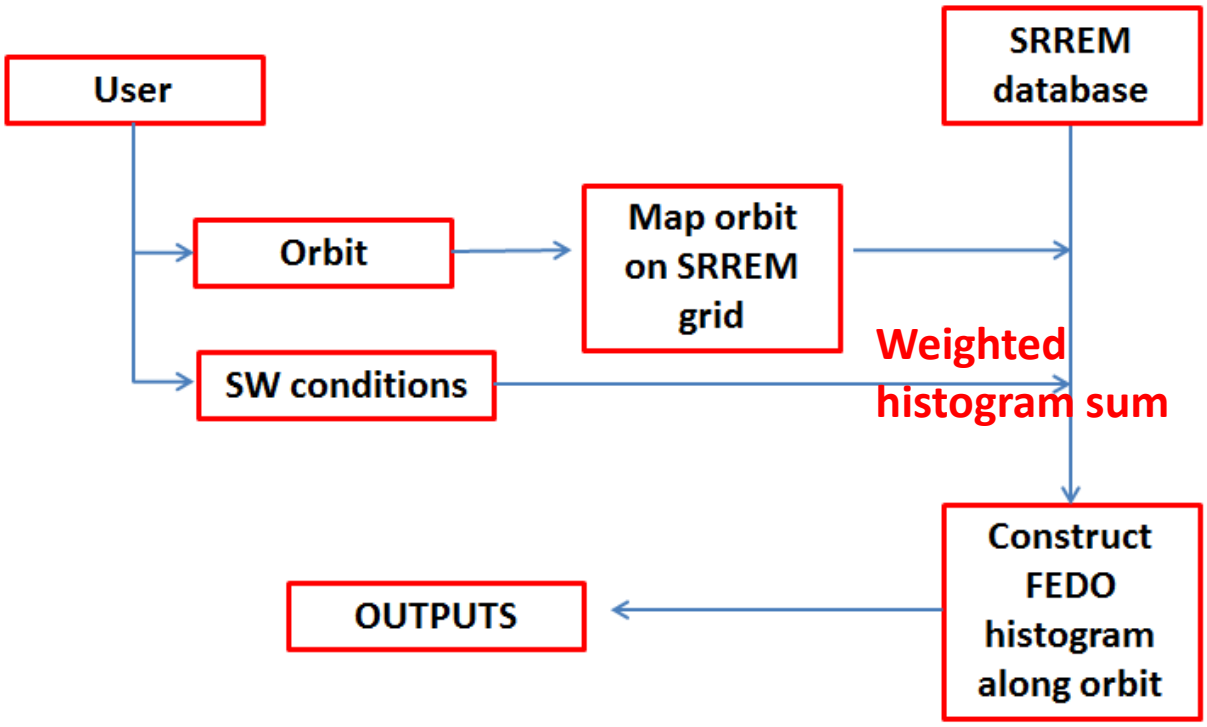
- CRRES was operating during solar maximum..

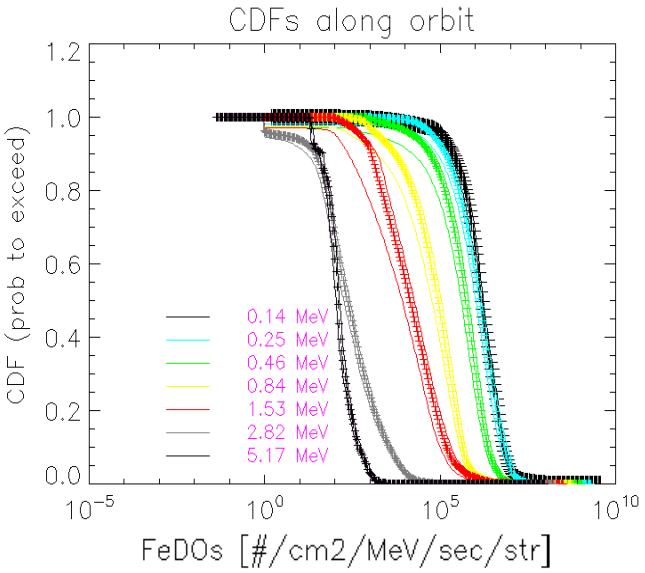
e-SRREM database



SRREMs

Run e-SRREM model: workflow



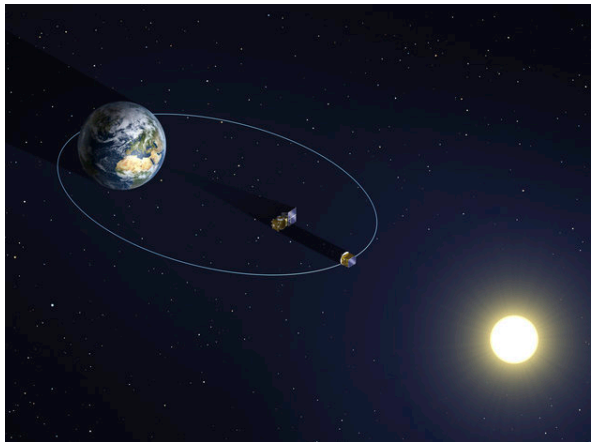


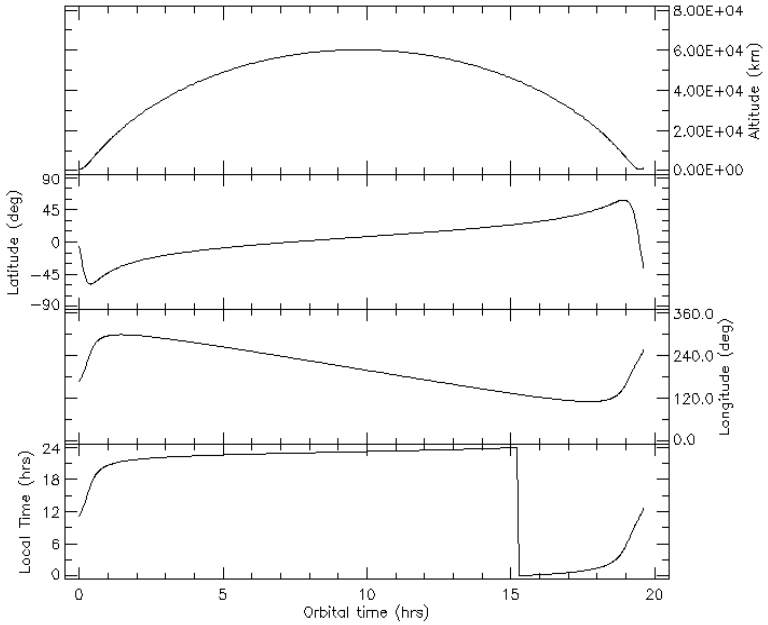
Fluxes: differential integral & fluence

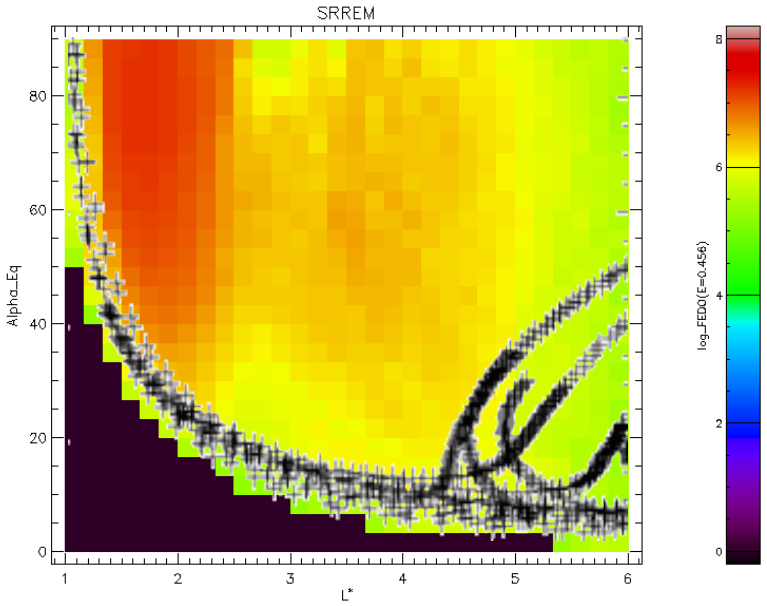
IAASARS DH CONSULTANCY Kallisto Consultancy **SRREMs** QinetiQ esa ESTEC

Example: ASPIICS/PROBA3 mission

- Perigee altitude: 600 km
- Apogee altitude: 60530 km
- Inclination: 59 deg
- RAAN: 84
- Argument of perigee: 188 deg







IAASARS

DH CONSULTANCY

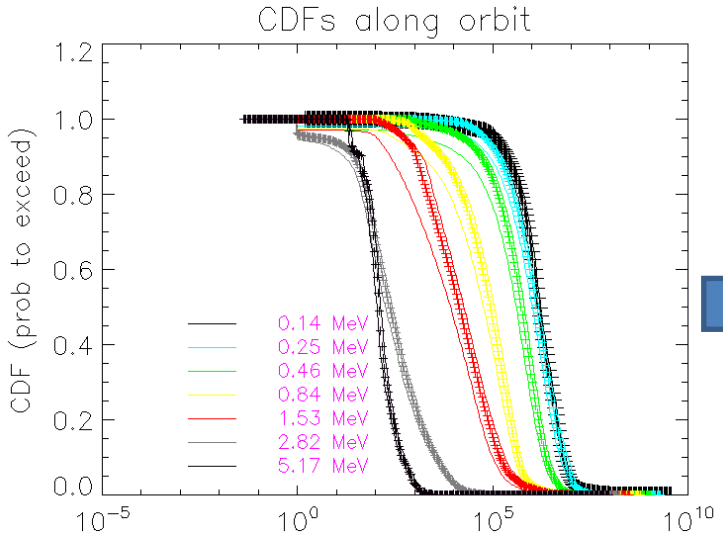
Kallisto Consultancy

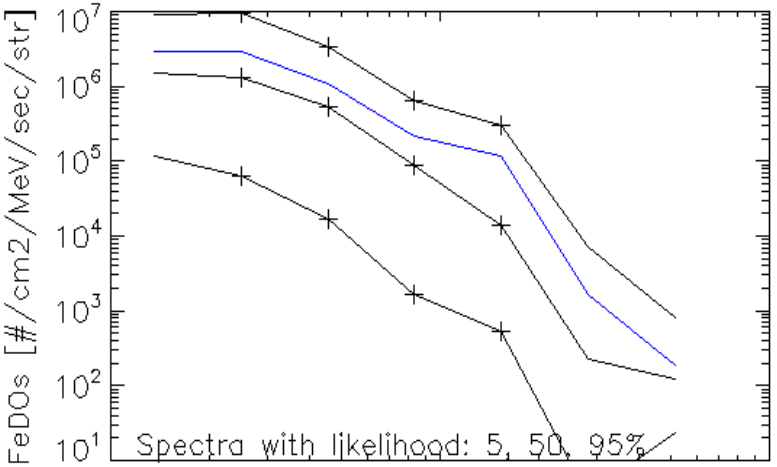
SRREMs

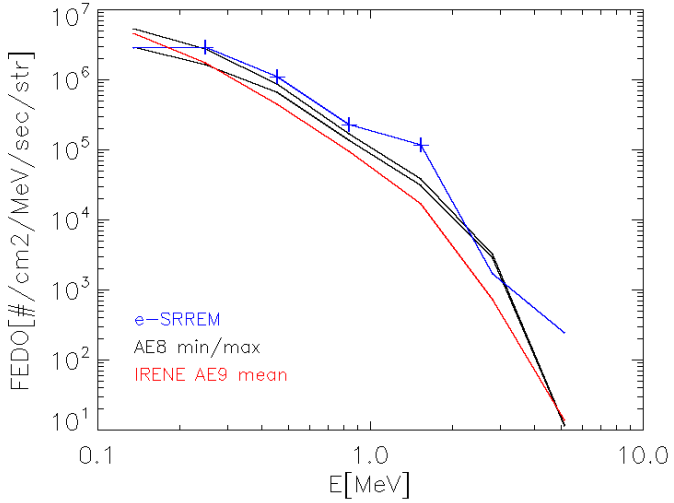
QinetiQ

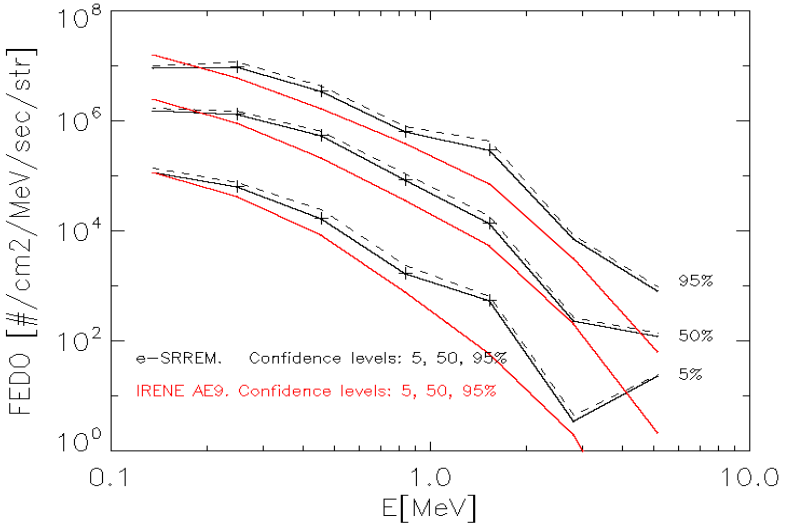
esa ESTEC

Output



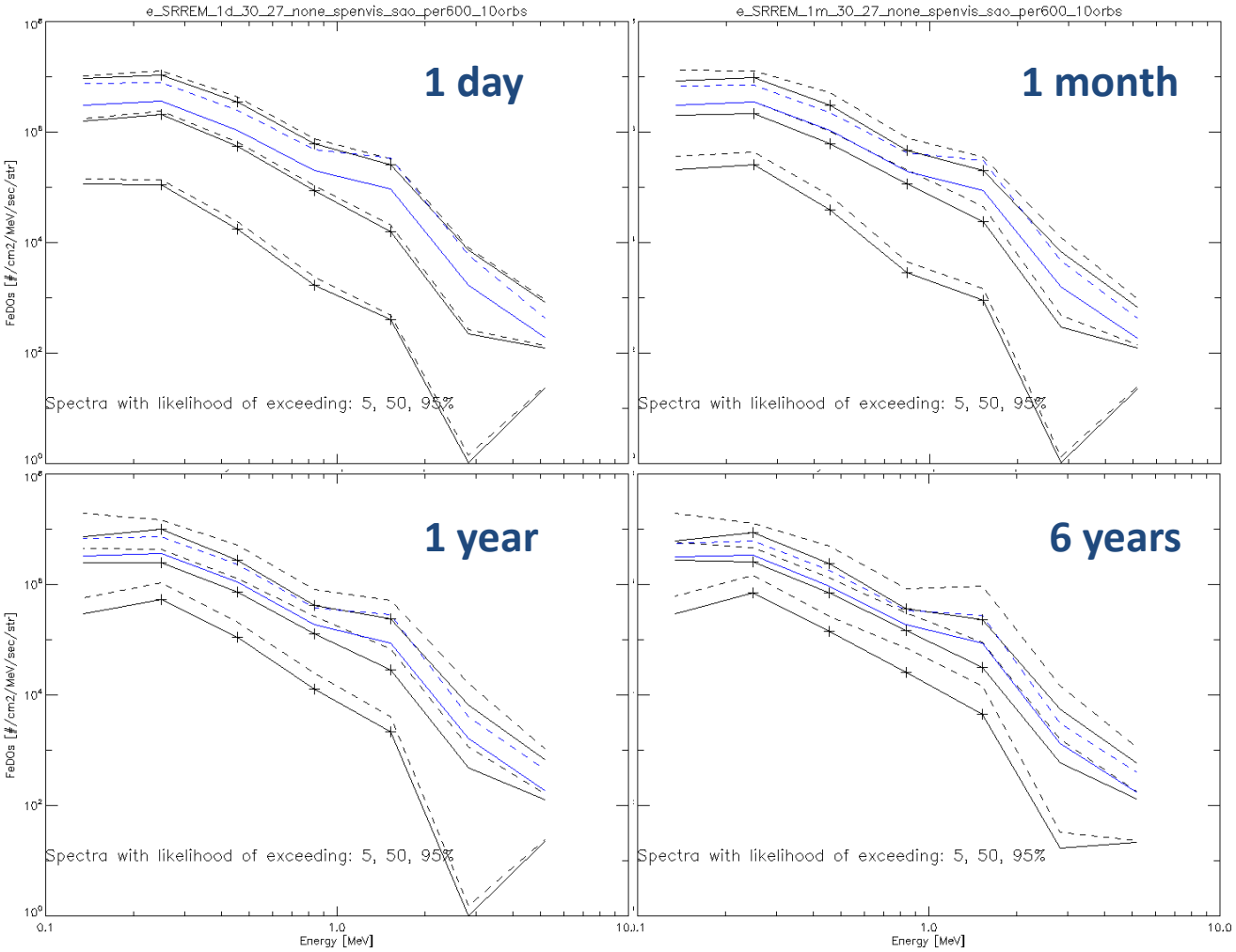






IAASARS DH CONSULTANCY Kallisto Consultancy **SRREMs** QinetiQ esa ESTEC

Different averaging times



IAASARS

DH CONSULTANCY

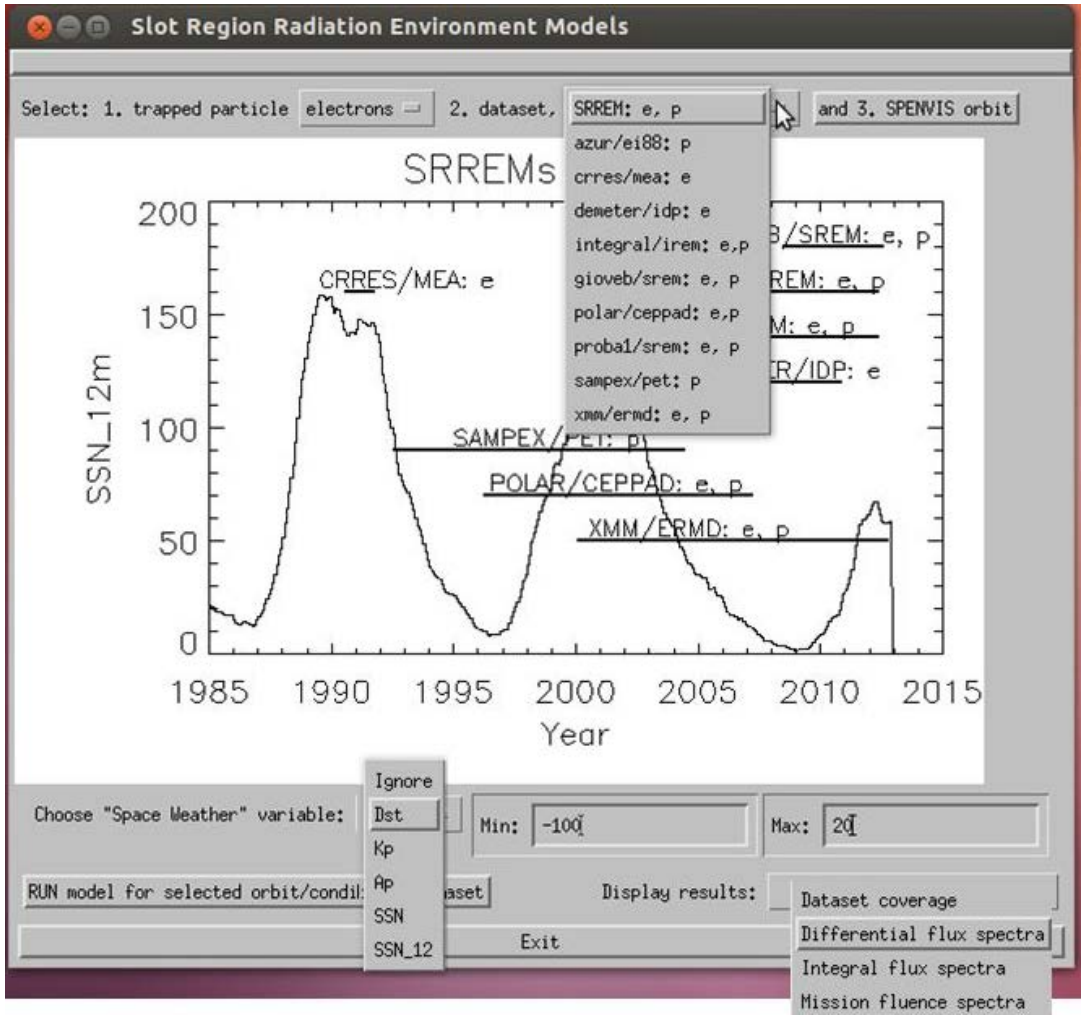
Kallisto Consultancy

SRREMs

QinetiQ

esa ESTEC

SRREMs capabilities



Conclusions

- A new data-based Slot Region Radiation Environment model has been developed
- e-SRREMs captures radiation belt variability providing flux histogram along the user-defined orbit
- The construction and the update of SRREM database is semi-automated
- The modelling region can be extended to include larger L-shells
- After the completion of independent validation studies, new calibration schemes will be applied
- The model is planned to become available through SPENVIS-NG

Sandberg et al IEEE TNS, DOI 10.1109/TNS.2014.2304982