



# Slot Region Radiation Environment Models

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*ESTEC/CONTRACT No.4000104839 (ESTEC/ITT AO/1-6700/11/NL/AT)*

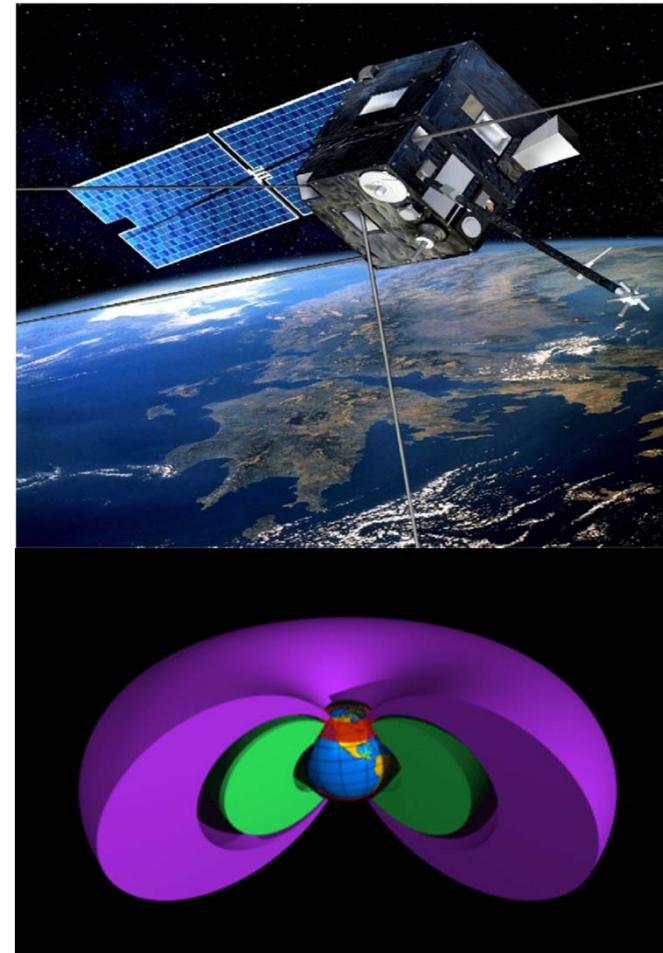


**SRREMs**



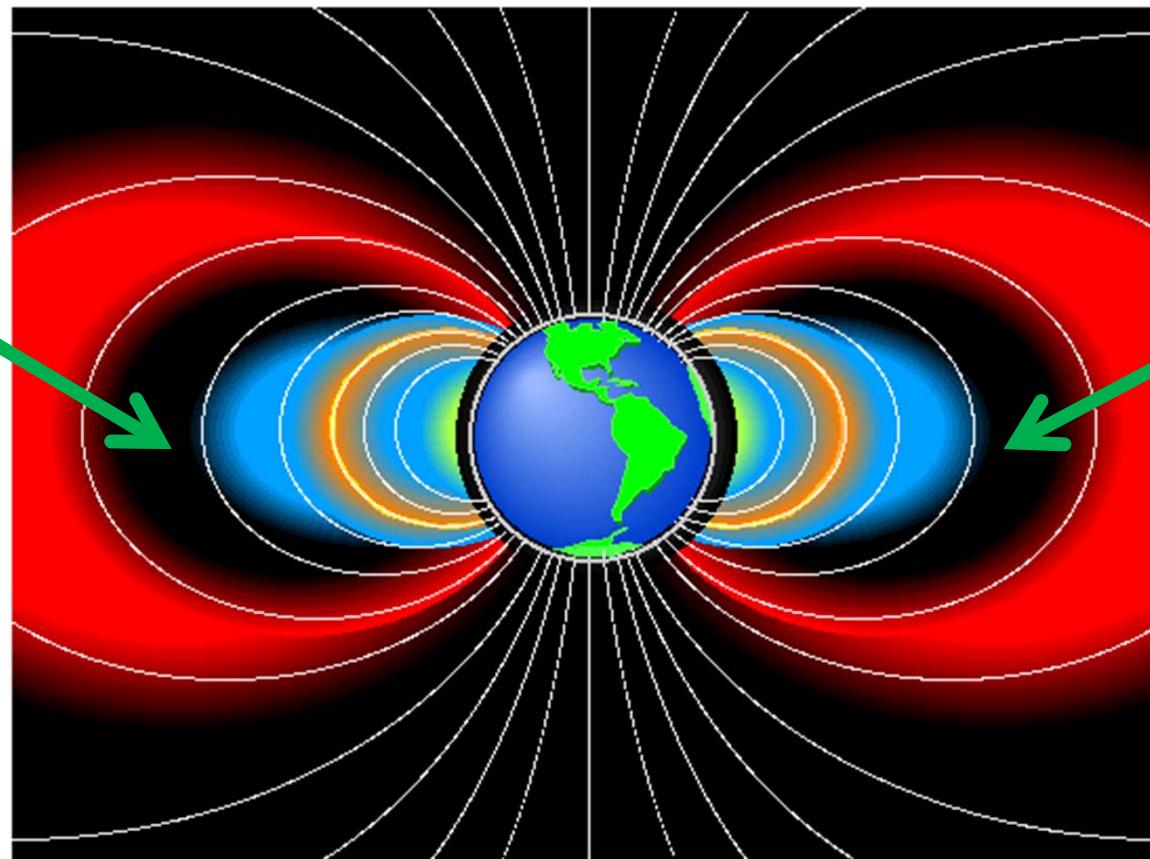
# Outline

- Background
- Model characteristics
- The datasets
- SRREM model
- Examples
- Conclusions



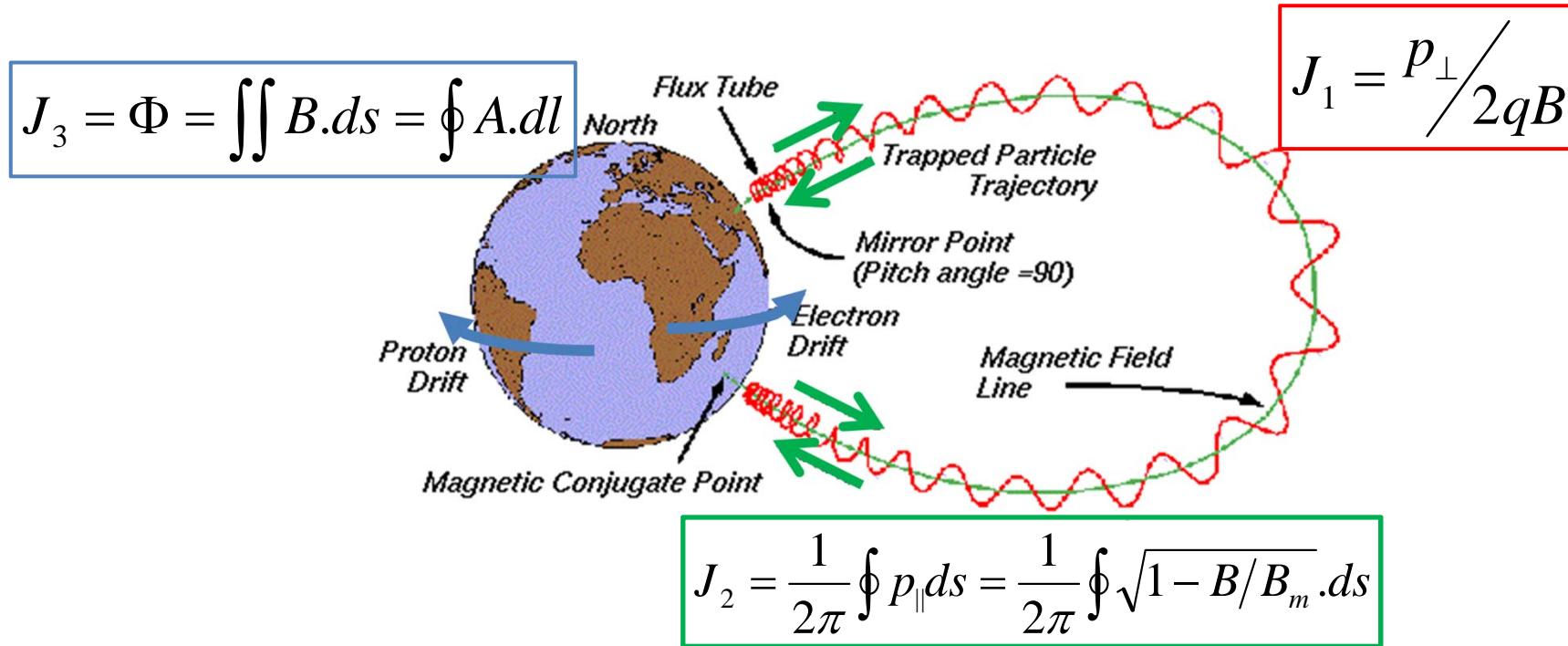
# Earth Radiation Belts

SLOT REGION                                   SLOT REGION



A radiation belt is a population of energetic particles stably-trapped by the magnetic field.

# Trapped particles



**Timescale:**

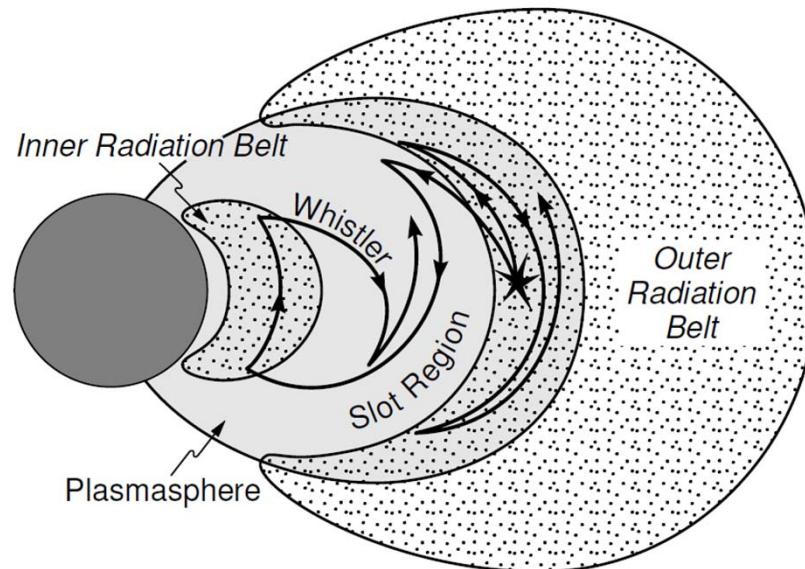
gyro-motion

bounce period

drift motion

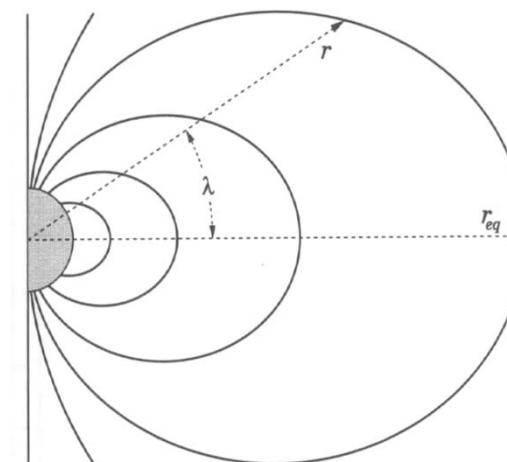
<b>Electrons (1 Mev):</b>	$7\mu\text{s}$ ( $r = 0.3\text{km}$ )	<b>0.1s</b>	<b>50 min.</b>
<b>Protons (1 Mev):</b>	$4\text{ms}$ ( $r = 10\text{km}$ )	<b>2.0s</b>	<b>30 min.</b>

# Formation of the Slot Region

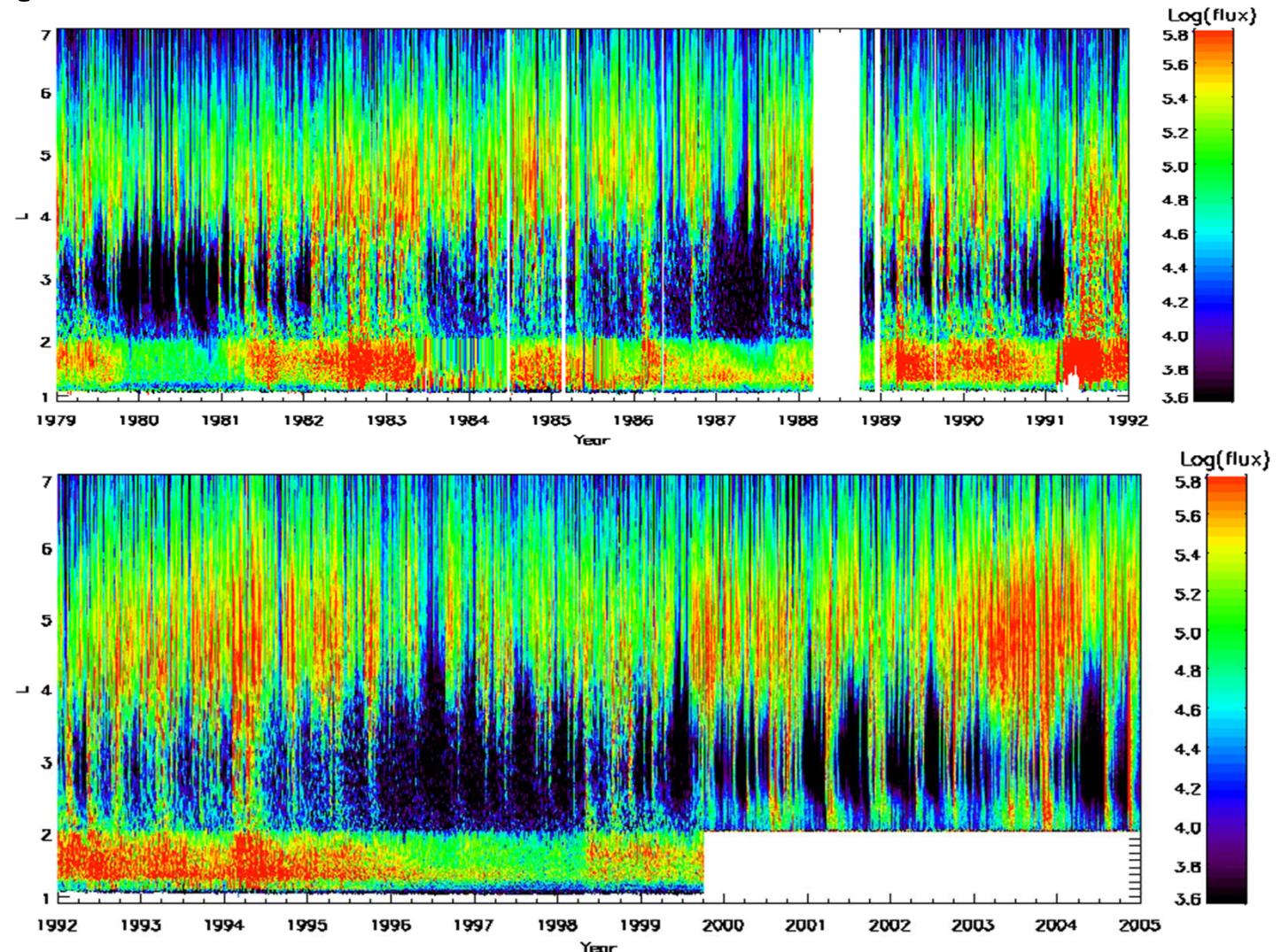


**$L [R_E]$**  : the distance from the center of the magnetic dipole to the equatorial point of the field line.

**Standard picture:** Whistler turbulence is responsible for formation of the *slot region*: in this range of  $L$ -values the amplification of the spectrum due to wave-particle resonance and wave accumulation causes the strongest pitch angle diffusion and thus the shortest life times.

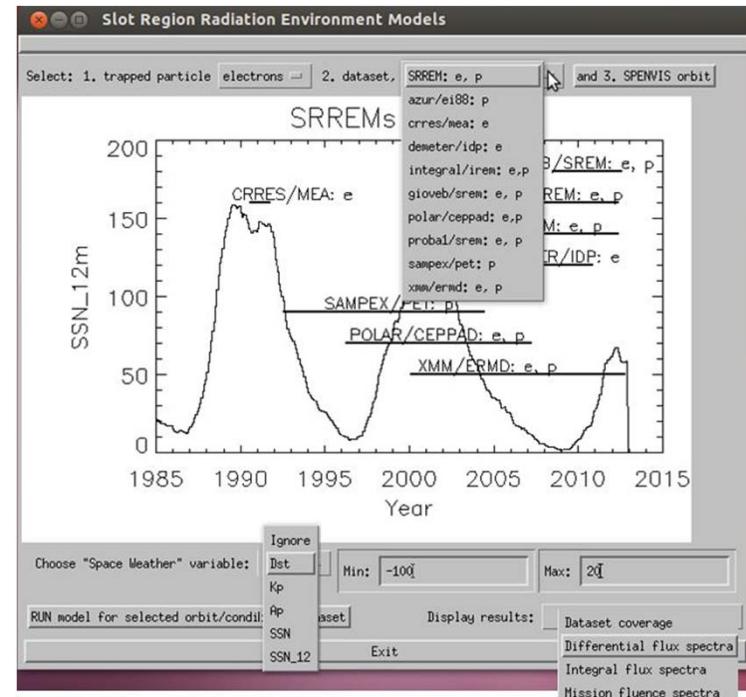


# NOOA/POES: 1979-1991 & 1992-2004



# 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**.



**SRREMs**



# SRREMs input-output

## Input

- Mission orbit file
- Trapped particle
- [Space weather conditions]

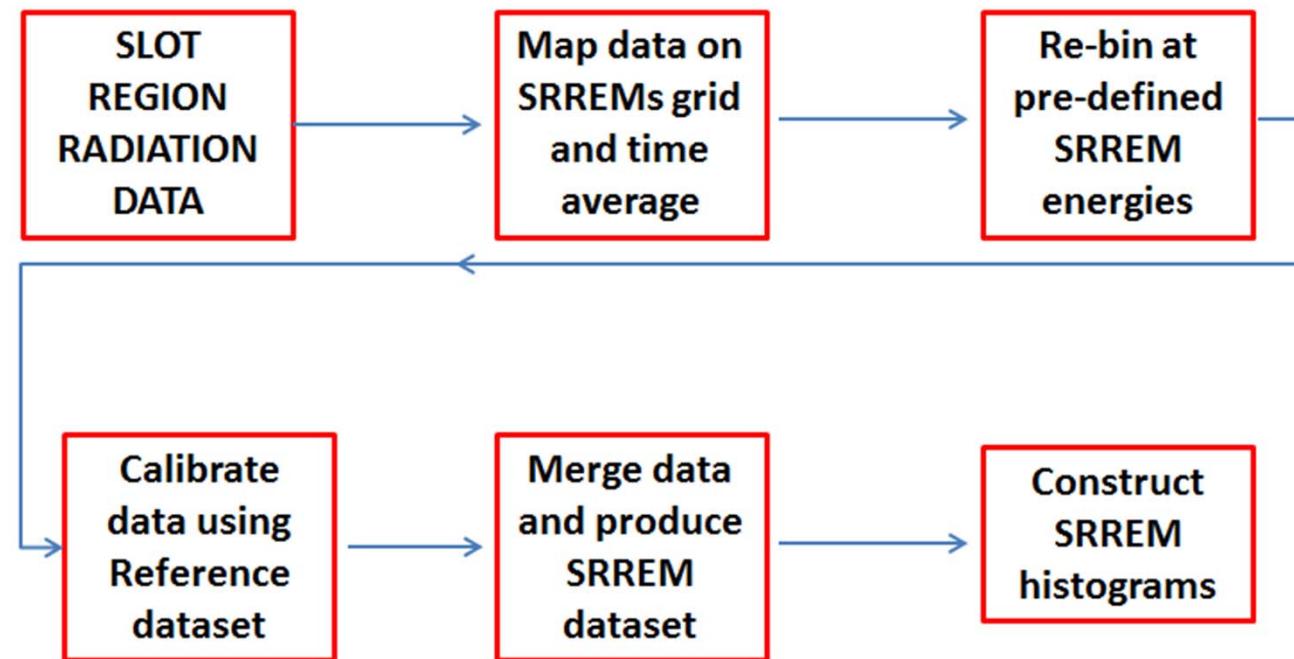
## Output

- Cumulative distribution functions of trapped particle omnidirectional fluxes [particle/cm<sup>2</sup>/sec/MeV/str] for different averaging times
- *[The mean and variance of trapped, radiation differential flux and worst case values for different dynamic scenarios]*  
(similar outputs for integral fluxes and for mission fluence)

e-SRREM

Electron Bins	Centers
0.100	0.183
0.183	0.337
0.337	0.612
0.612	1.13
1.13	2.08
2.08	3.81
3.81	7.00

# Build SRREM database: workflow





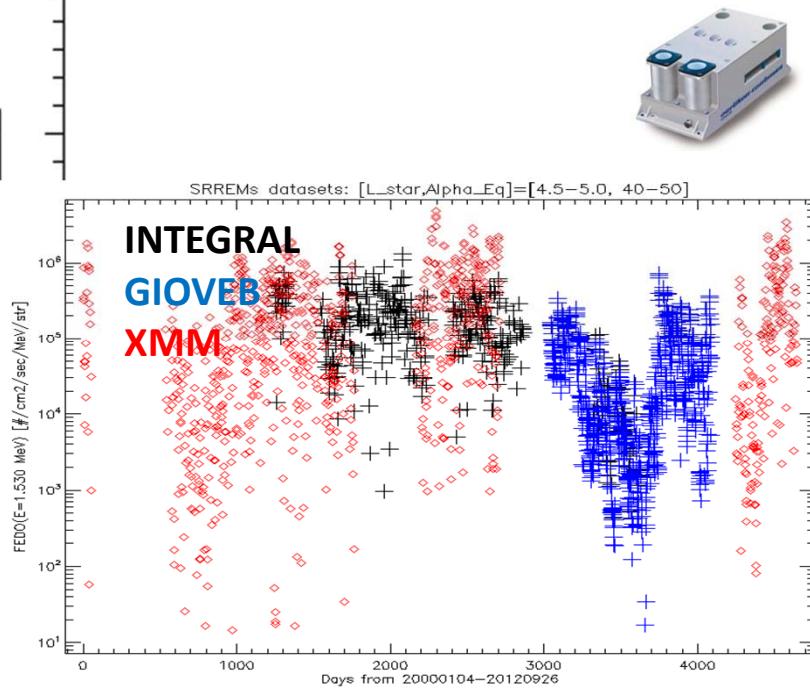
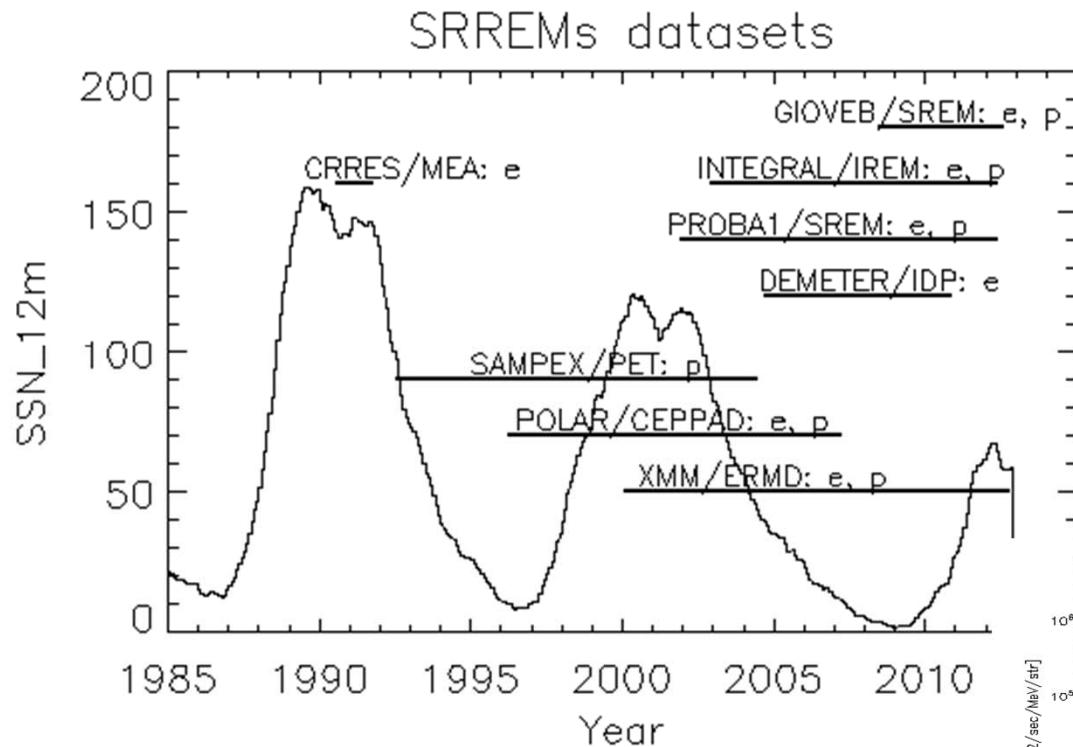
# SRREM Datasets



SPACECRAFT	Orbit	Period	Perig x Apog [Km]	Incl.	Coverage	Instrum
<b>CRRES</b>	GTO	2h	305 x 33350	18	1990-1991	MEA
<b>DEMETER</b>	LEO	1,40 h	710	98	2004-2010	IDP
<b>GIOVE-B</b>	MEO	14,1 h	23200	56	2008-20112	SREM
<b>INTEGRAL</b>	HEO	72h	10000 x 152700	52	2002-	SREM
<b>POLAR</b>	PEO	17,5 h	7500 x 50800	86	1996-2008	CEPPAD
<b>PROBA1</b>	LEO	97min	570 x 640	98	2001-	SREM
<b>XMM</b>	HEO	48h	7400 x 114000	70	1999-	ERMD
<b>SAMPEX</b>	LEO	96min	520 x 670	82	1992-2004	PET
<b>AZUR</b>	LEO	2h	384 x 3145	102.9	1969-1970	EI-88



# Datasets coverage



# 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.

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

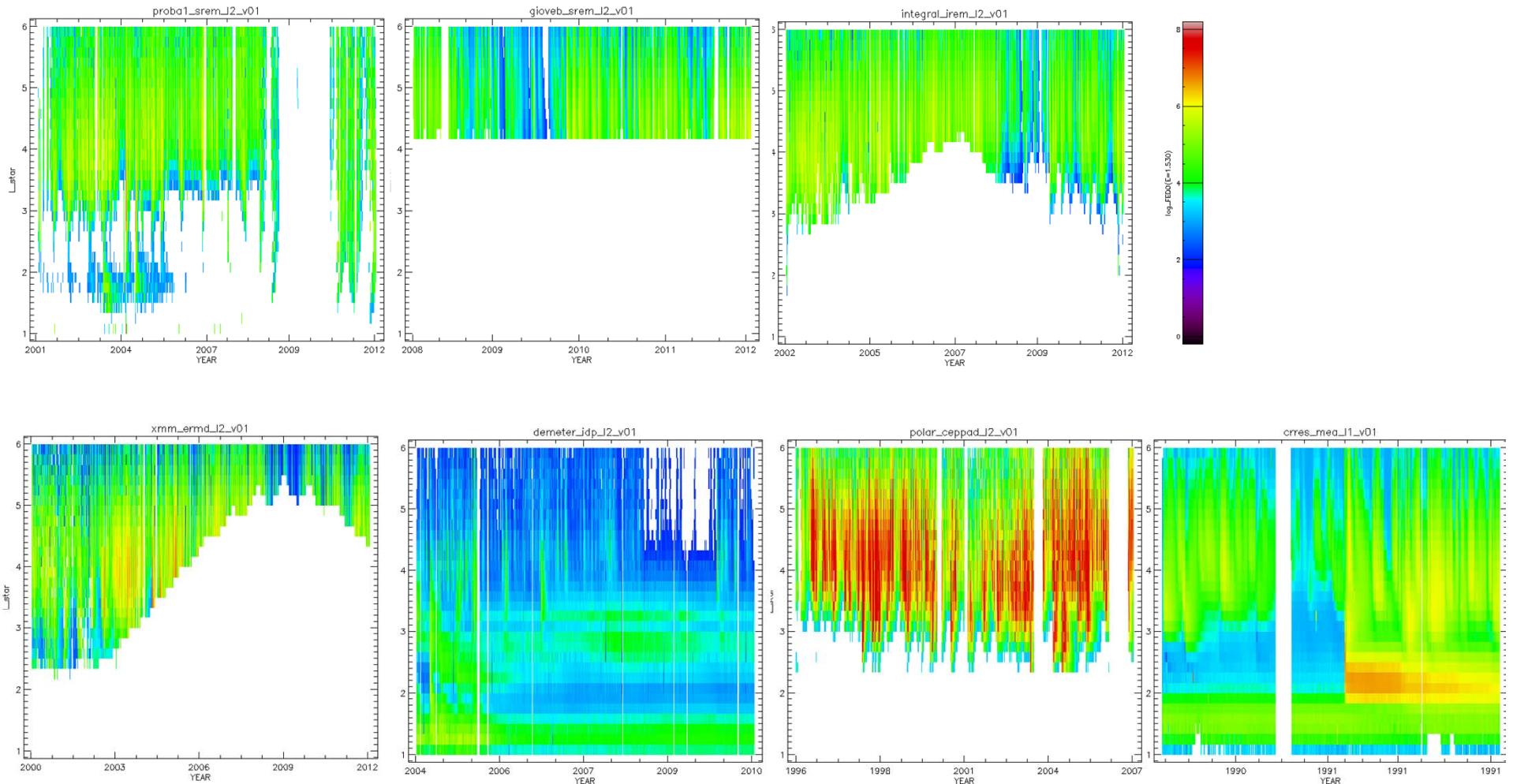
The data on each SRREMs grid bin are time (1-day) averaged & the following variables are retained: the average:  $\mu_{it}$ , the standard deviation:  $\sigma_{it}$ , and the integration time:  $\tau_{it}$ ,



**SRREMs**



# Daily-averaged FEDO series



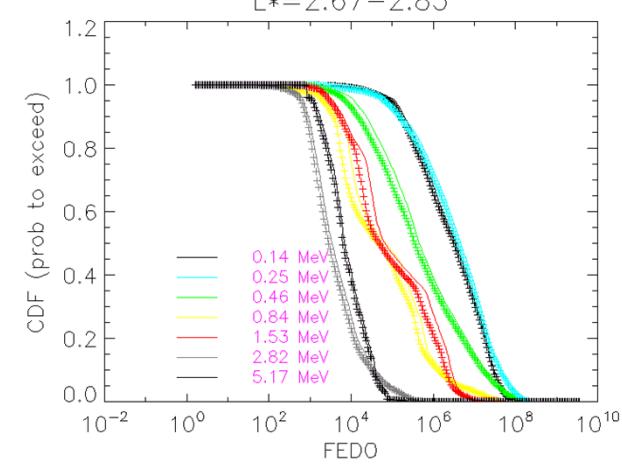
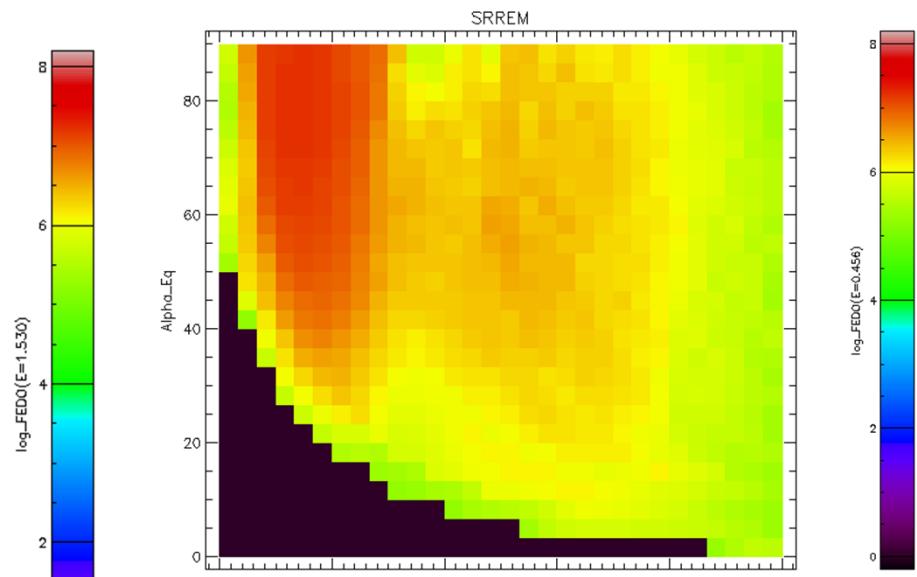
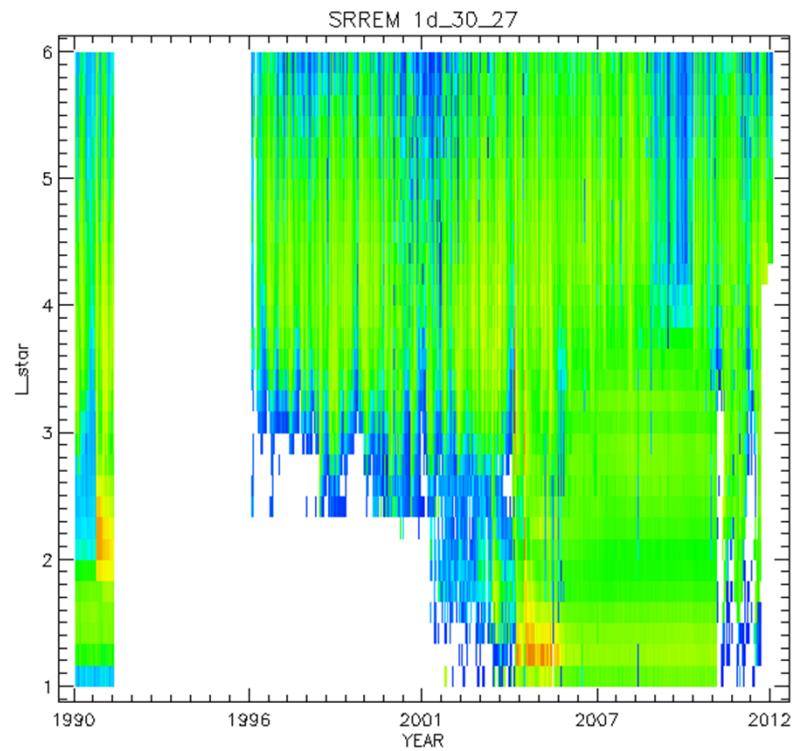
# SRREM time-series

- Energy re-bin data through piece-wise interpolation
- Calibrate re-binned data using CRRES/MEA dataset
- Merge all re-binned and calibrated datasets using as weighting factor the total integration (measurement) time on each grid bin and time-window.

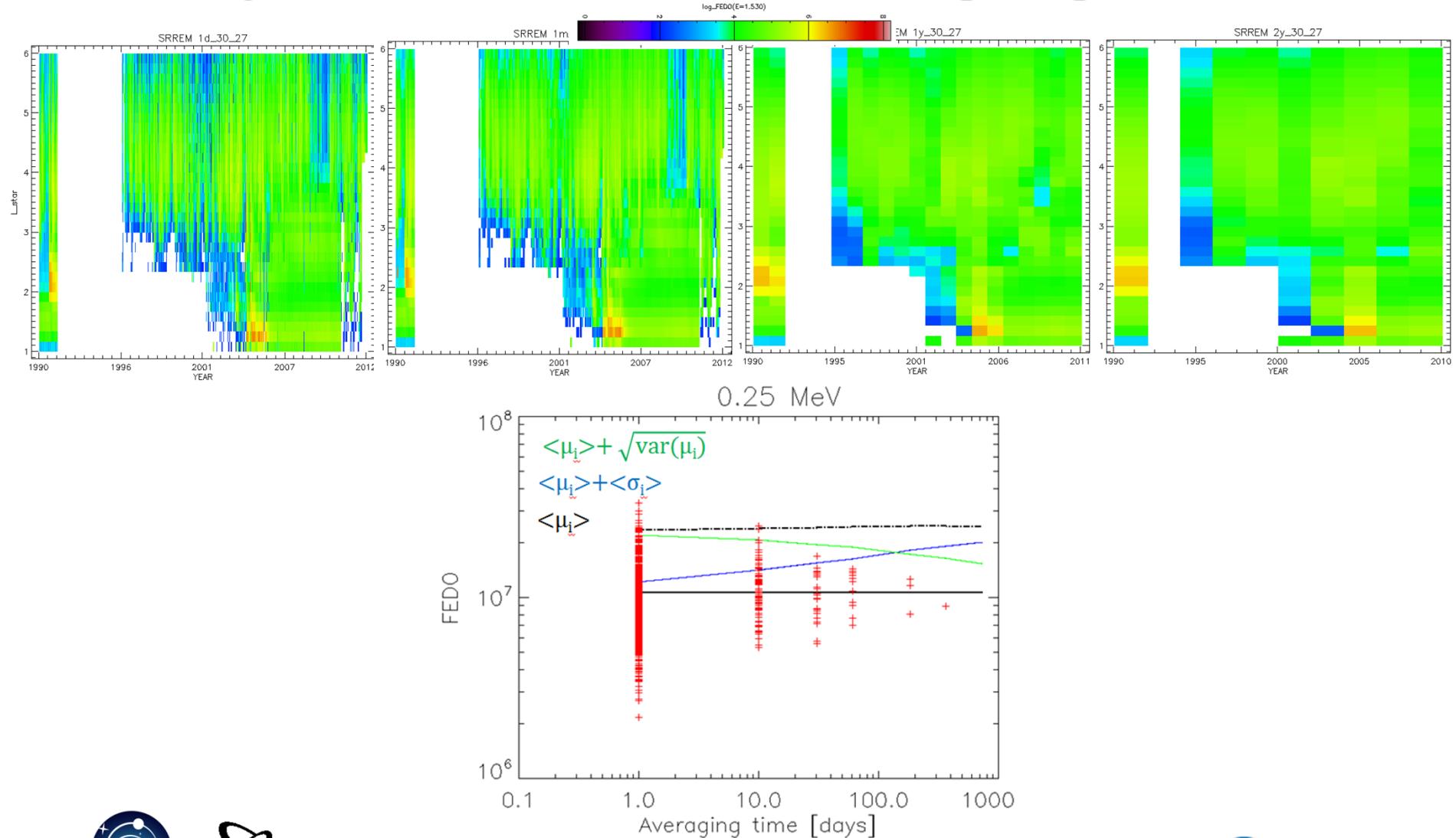


- Derive the weighted average  $\mu_{it}$ , the standard deviation  $\sigma_{it}$  and total measurement time  $\tau_{it}$  for the resulted time series (SRREM series)
- Calculate histograms for each bin of SRREMs grid using the series of  $\mu_i$  and  $\mu_i + \sigma_i$ .

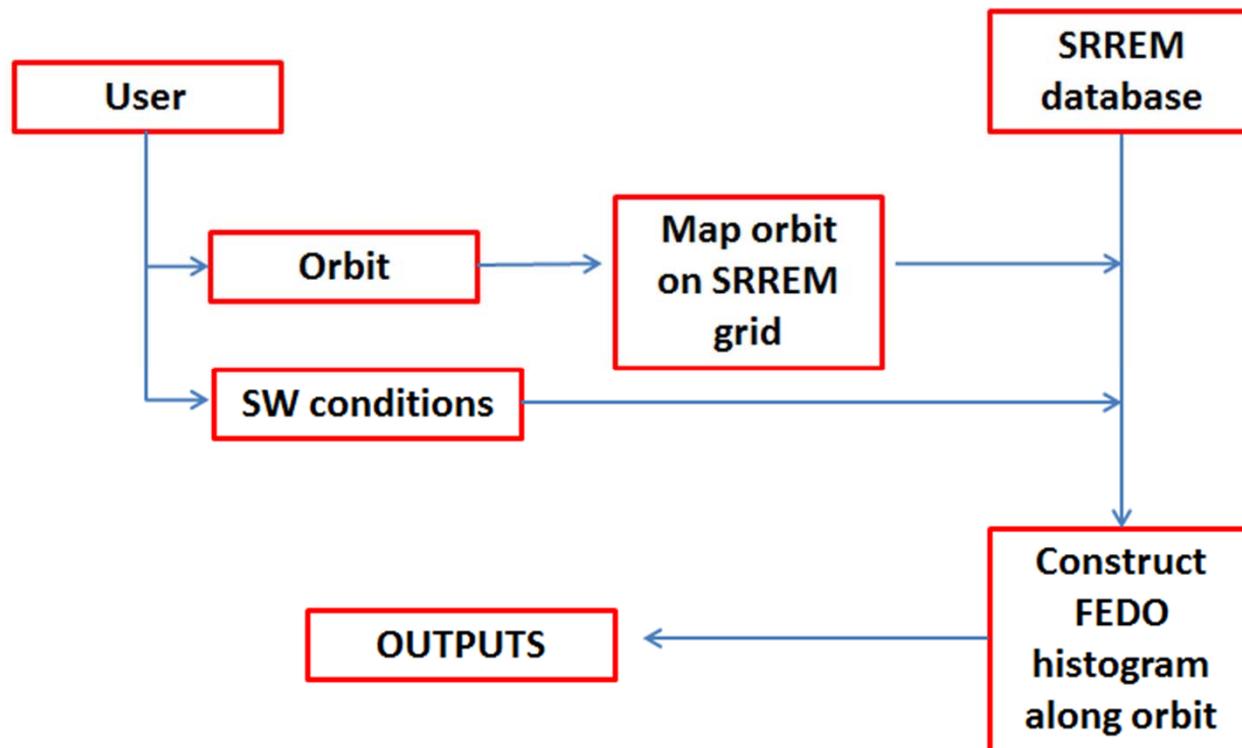
# e-SRREM database



# Dependence on averaging times

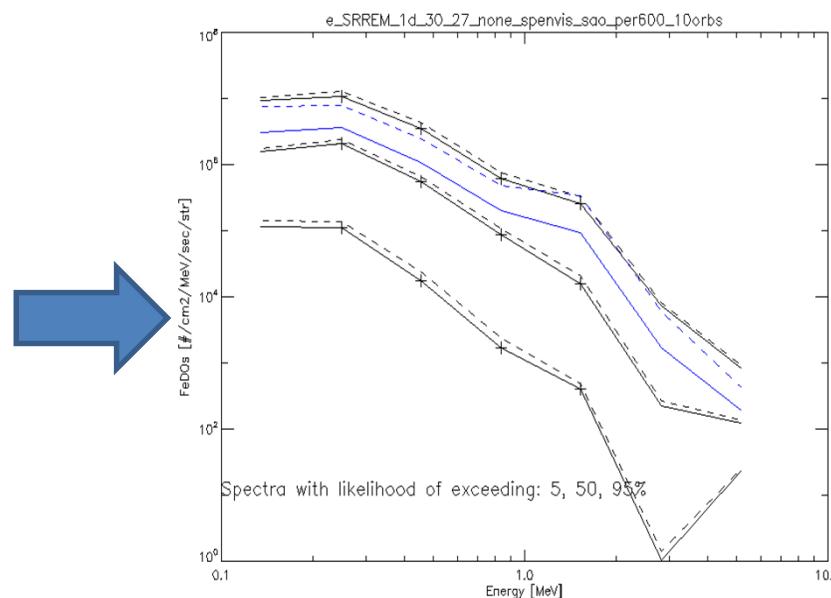
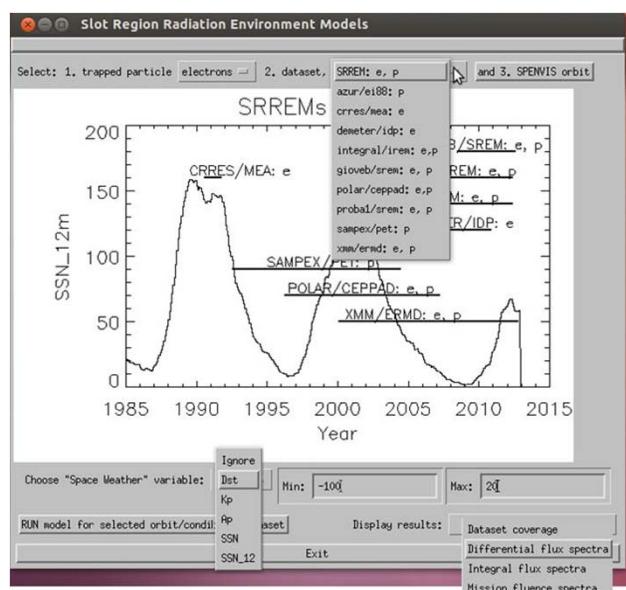


# Run SRREM : workflow

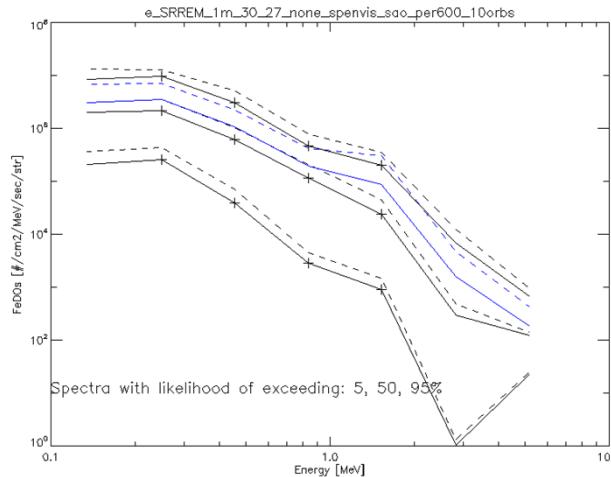
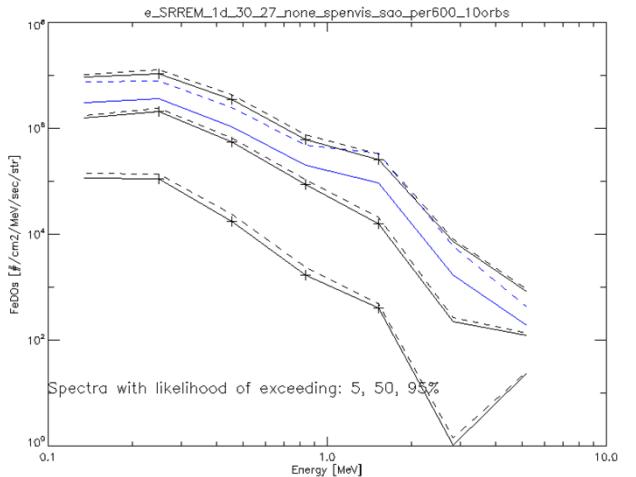


# Run SRREMs for satellite orbit

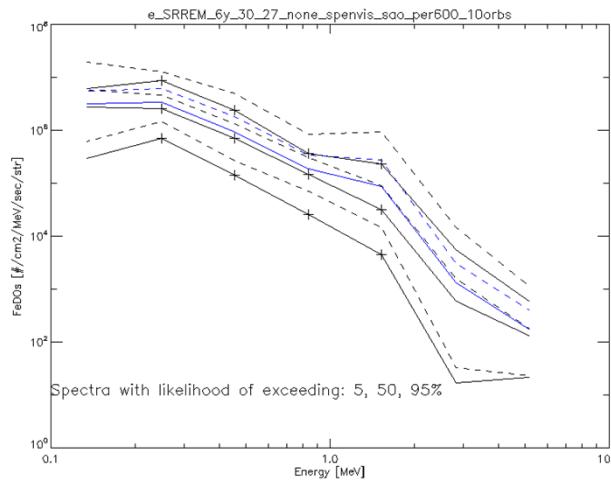
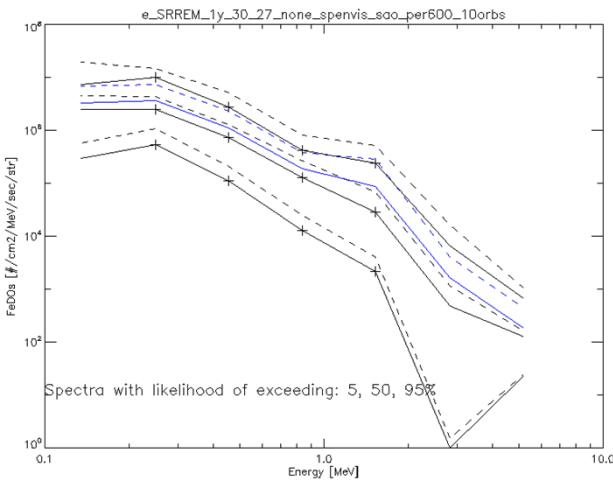
- The user-defined orbit is mapped on SRREMs coordinates:  $(L_i^*, \alpha_{Eq\ k})$
- Create a **weighted sum** of the histograms of SRREM bins the orbit crosses with **weighting factor the time the satellite spends** on each bin
- The resulting histogram is used to calculate the **cumulative distribution function** for the whole orbit



# Different averaging times



**$\uparrow$**   $\text{Var}(\mu)$   
 **$\downarrow$**   $\text{std}$   
 **$\rightarrow$**   $t_{\text{ave}}$



# Conclusions

- A new data-based statistical tool for the modeling of the Slot Region Radiation Environment has been developed
- SRREMs outputs provide significant information to scientists, model developers and satellite mission designers/operators
- The construction and the update of SRREM database is automated while new datasets can be easily ingested
- SRREMs can be easily extended to cover the whole RB region
- After the completion of independent validation studies SRREMs will become available through ESA Space Environment Information System



**SRREMs**





**SRREMs**



# e-SRREM: model characteristics

- Magnetic coordinates:  $L^*$  and  $\alpha_{eq}$  (IRBEM lib)
- 30 linear bins for the range of  $L^*=[1-6]$
- 27 bins for the range of  $\alpha_{eq} = 0-\pi/2$
- 7 log bins for  $E_e=0.1-7$  MeV
- 300 log bins for histograms

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