

GSICS ANNUAL MEETING



Cross-calibration schemes and recent results

Ingmar Sandberg

SPACE APPLICATIONS & RESEARCH CONSULTANCY

SPARC, GREECE

**11-15 MARCH 2024, EUMETSAT HQ
DARMSTADT, GERMANY**

Acknowledgments

DATASETS/DISCUSSIONS

- T. Nagatsuma, NICT, Japan (Himawari-8/SEDA)
- Y. Miyoshi, N. Higashio, T. Mitani et al, JAXA (Arase, XEP, HEP)
- T. Onsager, J Rodriguez, A. Boudouridis et al, NOAA, USA (GOES)
- K. Ryden, University of Surrey, UK (Giove-A/SURF, GSAT/EMU)
- D. Baker, S. Claudepierre, A. Boyd, USA, (RBSP/ECT datasets)
- H. Evans, P. Jiggins, M. Heil, ESA Technical officers

SPARC Team

- I. Sandberg
- C. Papadimitriou
- S. Aminimalragia-Giamini
- Z. Iqbal

FUNDING/SUPPORT

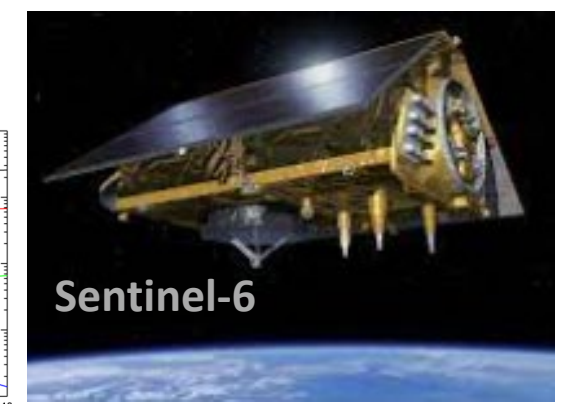
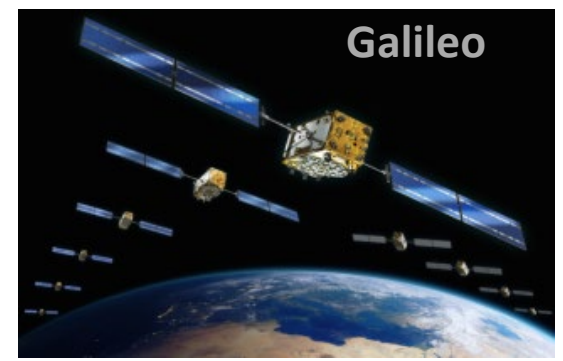
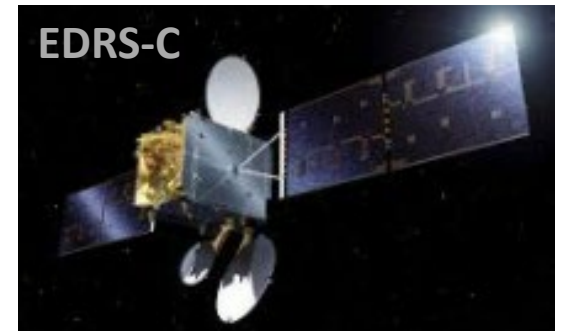
- European Contribution to International Radiation Environment Near Earth (IRENE) Modelling System, ESA Contract 4000127282/19/NL/IB/gg with SPARC (I. Sandberg)
- SSA NGRM Data Processing ESA Contract No 4000127954/19/D/CT with SPARC (I. Sandberg)
- Global Radiation Belt Prototype for LEO constellations, 4000137689/22/NL/CRS with ONERA (A. Sicard)

Outline

- Motivation
- List of datasets
- Reference datasets
- Intercalibration “system”
- Conjunction algorithm
- Examples - results

Motivation: calibrate ESA monitors

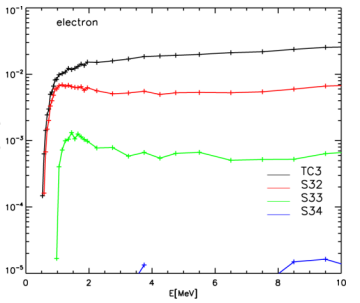
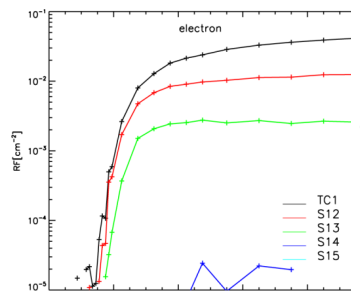
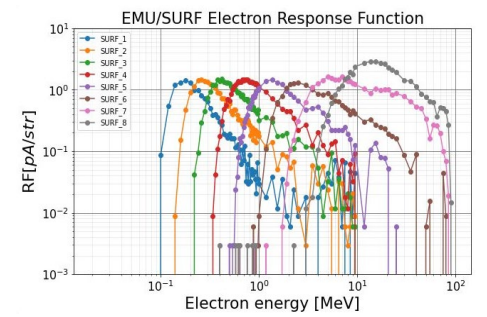
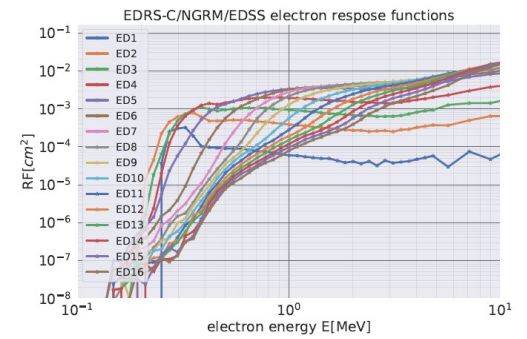
- In-flight validation/calibration of ESA radiation monitors
- Creation of high-level data products (Level-2)



- GEO EDRS-C
- LEO Sentinel-6
- GEO MTG1
- ... + more to come

- GNSS GSAT-0207
- GNSS GSAT-0215
- GNSS Giove-A (SURF)

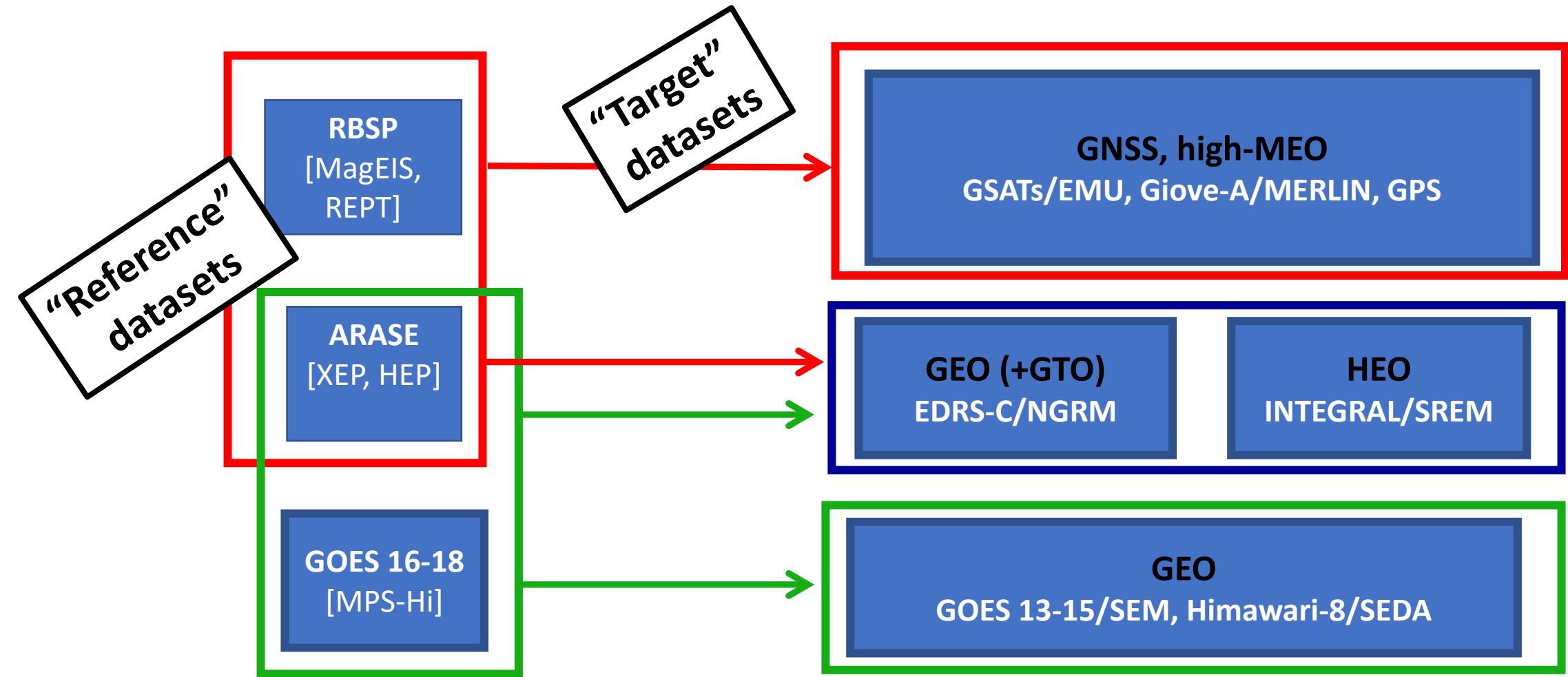
- HEO INTEGRAL
- LEO PROBA-1
- GNSS Giove-B
- ... + more



Motivation: Harmonize datasets for RB modelling

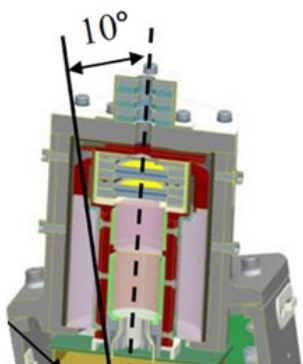
Mission/Instrument	Orbit	Perigee × Apogee (km)	Incl.(deg)	Electrons (MeV)	Mission duration/ Data availability
Arase/HEP/XEP	HEO	460 × 32,110	32	0.06–3.13	12/2016-today
EDRS-C & MTGI-1/NGRM	GEO	31 East		> 0.1 MeV	08/2019-today
Galileo/EMU	GNSS	23,222	56	0.1-10	10/2011-today
Giove-A/MERLIN/SURF	MEO	23,260	56	0.8, 1.10, 1.50	2005-2021
Giove-B/SREM	MEO	23,260	56	> 0.5	04/2008-07/2012
GOES-13-15/SEM/EPEAD	GEO	35,786	~ 0.2	>0.8, > 2.0, > 4.0	05/2010-2020/03
GOES-16-17/MPS-HI	GEO	35,786	0.04 (16), 0.0 (17)	0.07-3 MeV in 10 diff channels	11/2016-today (16), 12/2017-today (17)
HIMAWARI-8/SEDA	GEO	140.7 E		0.2,0.3,0.45,0.65, 1.0,1.5,2.0,4.5	10/2014-today
INTEGRAL/IREM	HEO	9,050 × 153,657	52.2	> 0.5	10/2002-today
PROBA-1/SREM	LEO	560 × 672	97.7	> 0.5 (D3), > 1.5 (D1,2)	10/2001-today
RBSP/MagEIS/REPT	GTO	618 × 30,500	10.2	0.02-12	08/2012-10/2019

Inter-calibration of electron datasets: a roadmap





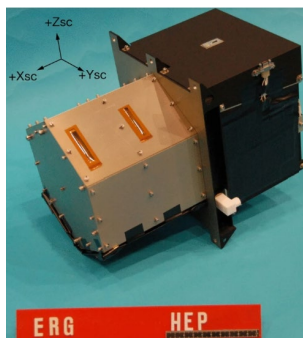
Reference: filtered Arase/HEP_L-XEP



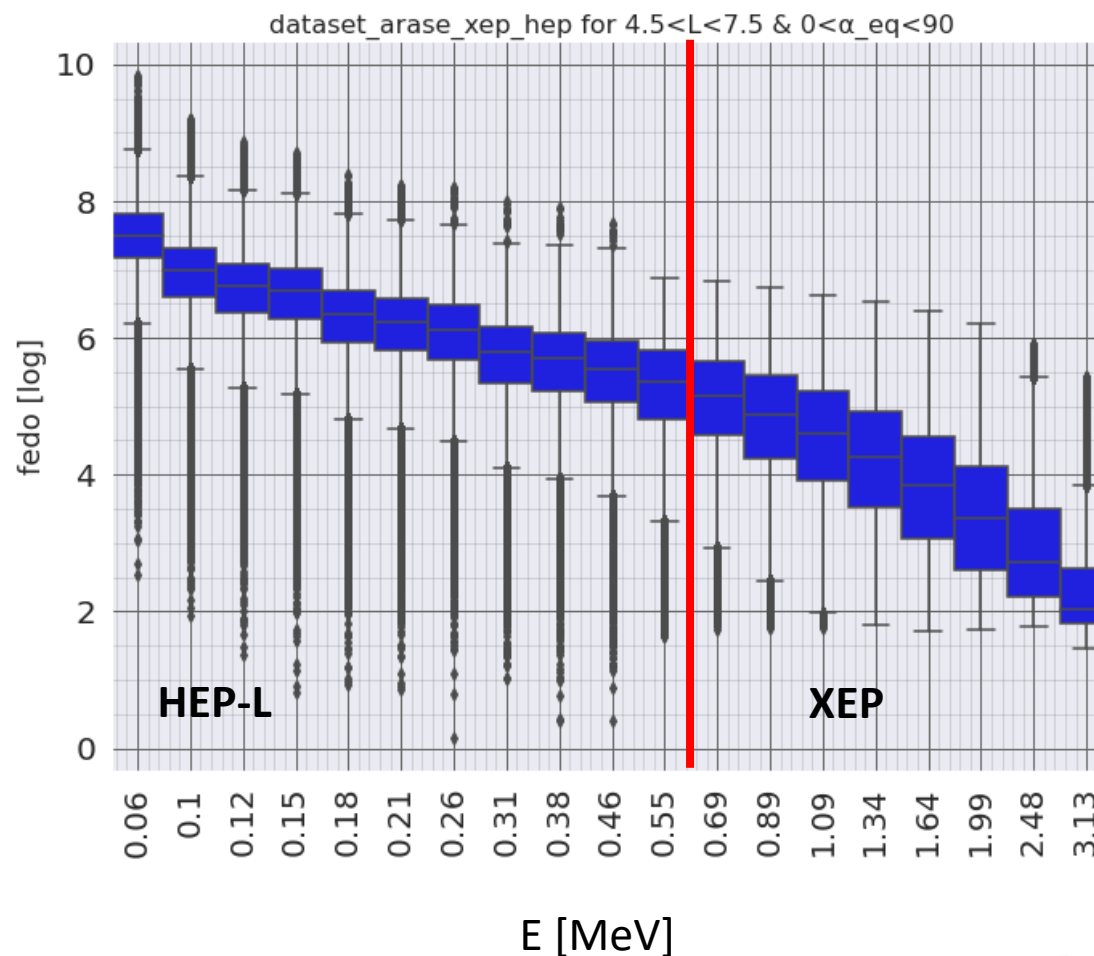
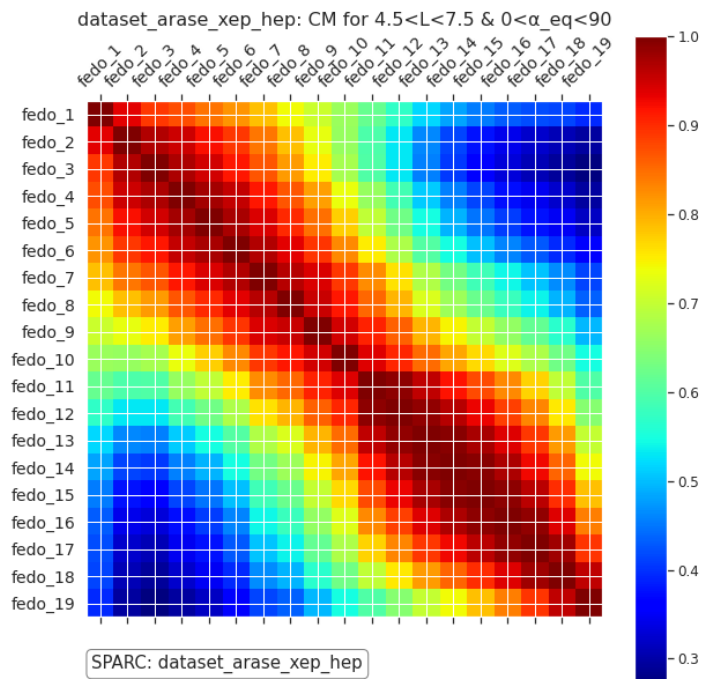
XEP

Level-2 Version 1

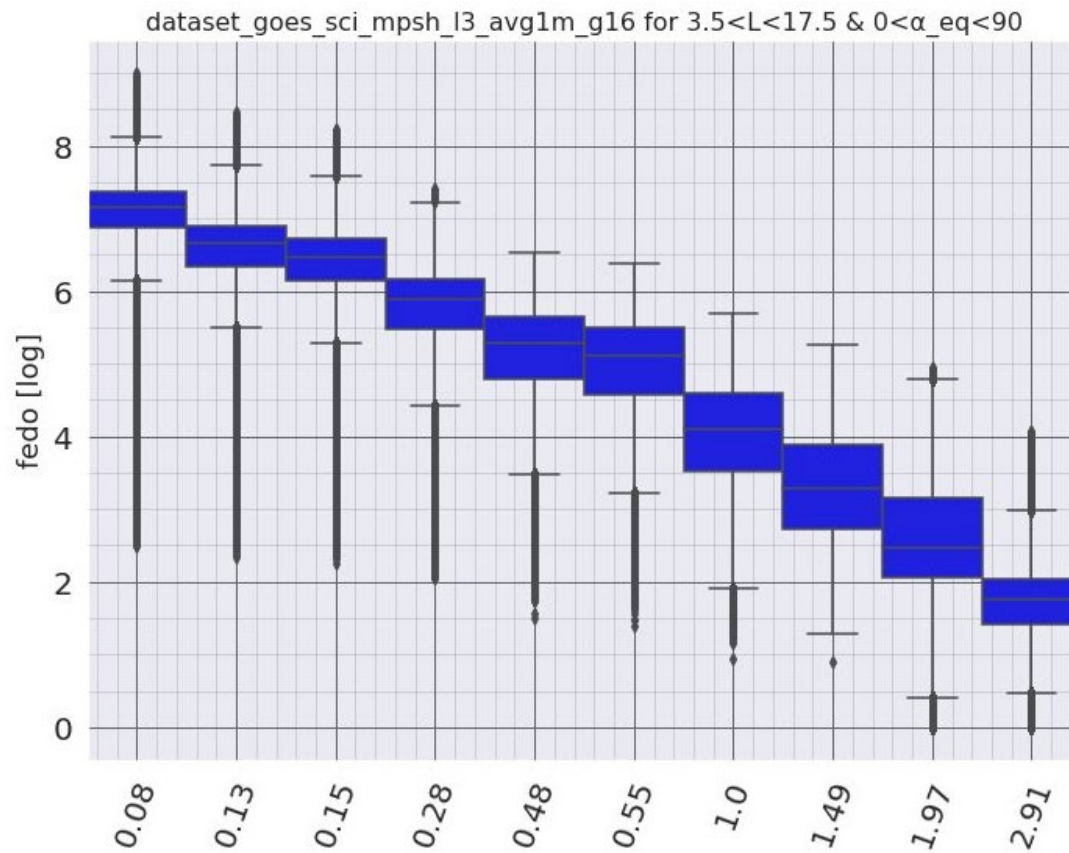
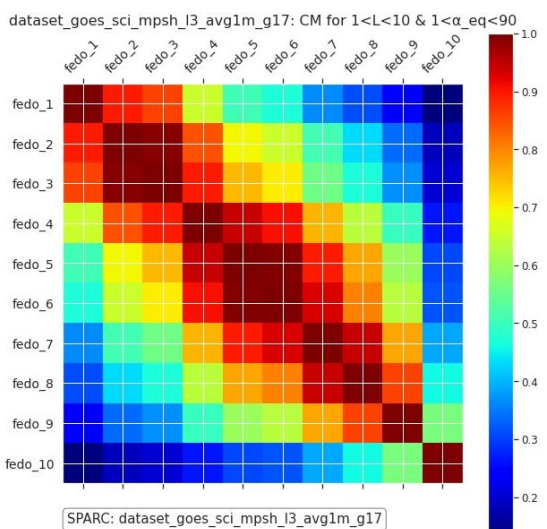
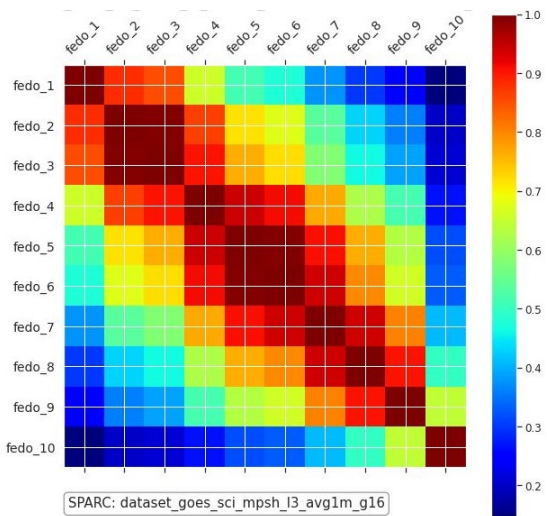
E=0.55-3.13 MeV



HEP
E=0.07-1 MeV



GEO reference: GOES16-17/MPSH



Inter-Calibration “System”

- UNILIB library: IGRF model & Olson-Pfitzer 1977
- Conjunction conditions
 - HEO:
 - $\delta(t)$, $\delta(MLT)$, $\delta(L^*)$, $\delta(\alpha_{eq})$, $\alpha_{eq} \sim 90$
 - $MLT = [3, 9]$ or $[15, 21]$, $Kp < 2$ for 2 days, $\alpha_{eq} \sim 90$
 - GEO-GEO
 - $\delta(t)$ or $\delta(MLT)$, $\delta(L^*)$, $\delta(\alpha_{eq})$, $\alpha_{eq} \sim 90$
 - long term averages
- Identify conjunctions: quick search algorithm
 - Derive measurements with:
 - same integration period
 - Identical time-stamps

Panel on Radiation Belt Environment Modeling (PRBEM)

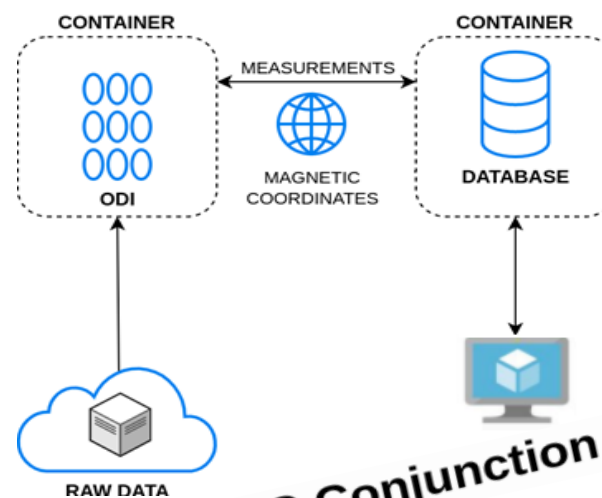
Data analysis procedure



S. Bourdarie (ONERA - France)
 B. Blake (Aerospace Corporation - USA)
 J.B. Cao (CSSAR - China)
 R. Friedel (LANL - USA)
 Y. Miyoshi (STELAB - Japan)
 M. Panasyuk (MSU - Russia)
 C. Underwood (U. Of Surrey - UK)

Conjunction Conditions

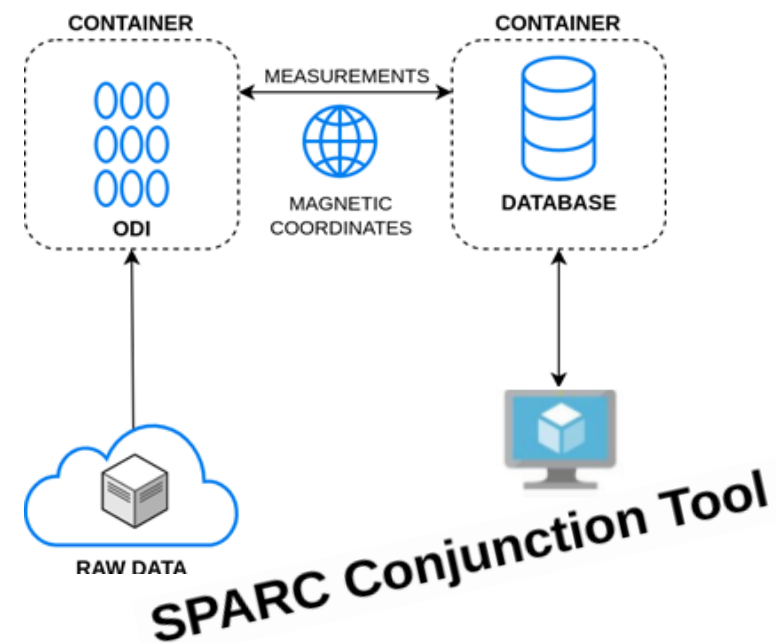
- $L^* < 6$ & $\Delta L^* < 0.1$
- $\delta(B/Beq) < 0.1$ and $B/Beq \sim 1$
- $4 (16) < MLT < 8 (20)$,
- $Kp < 2$ for the last 2 days
- $\delta t < 3$ hrs

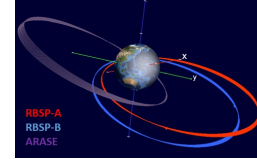


SPARC Conjunction Tool

Inter-Calibration “System”

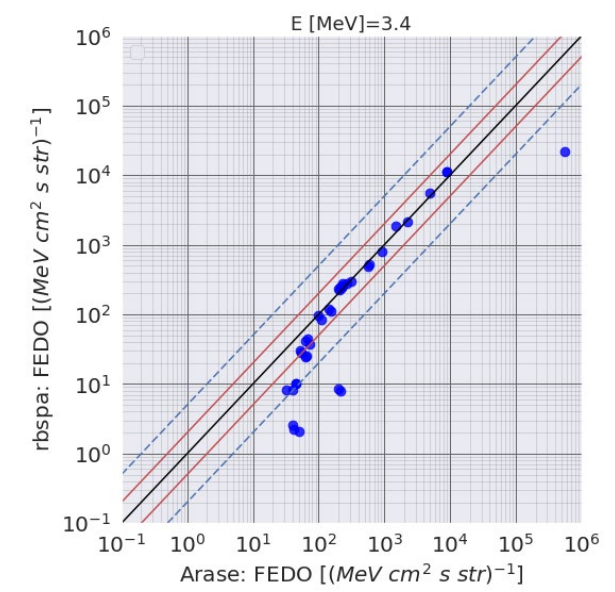
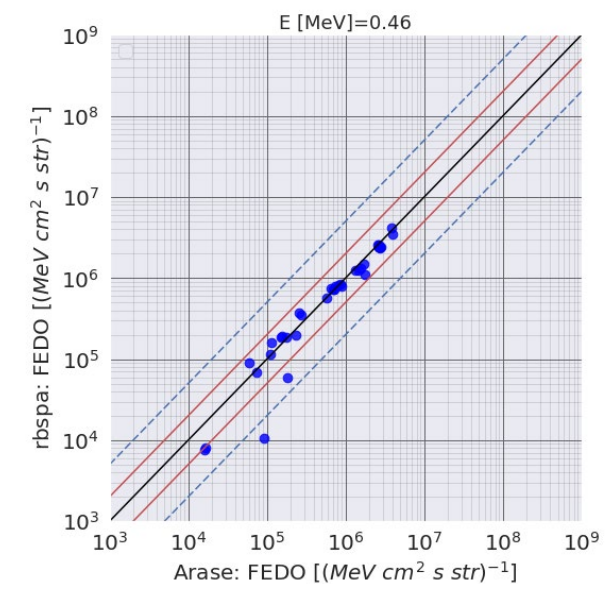
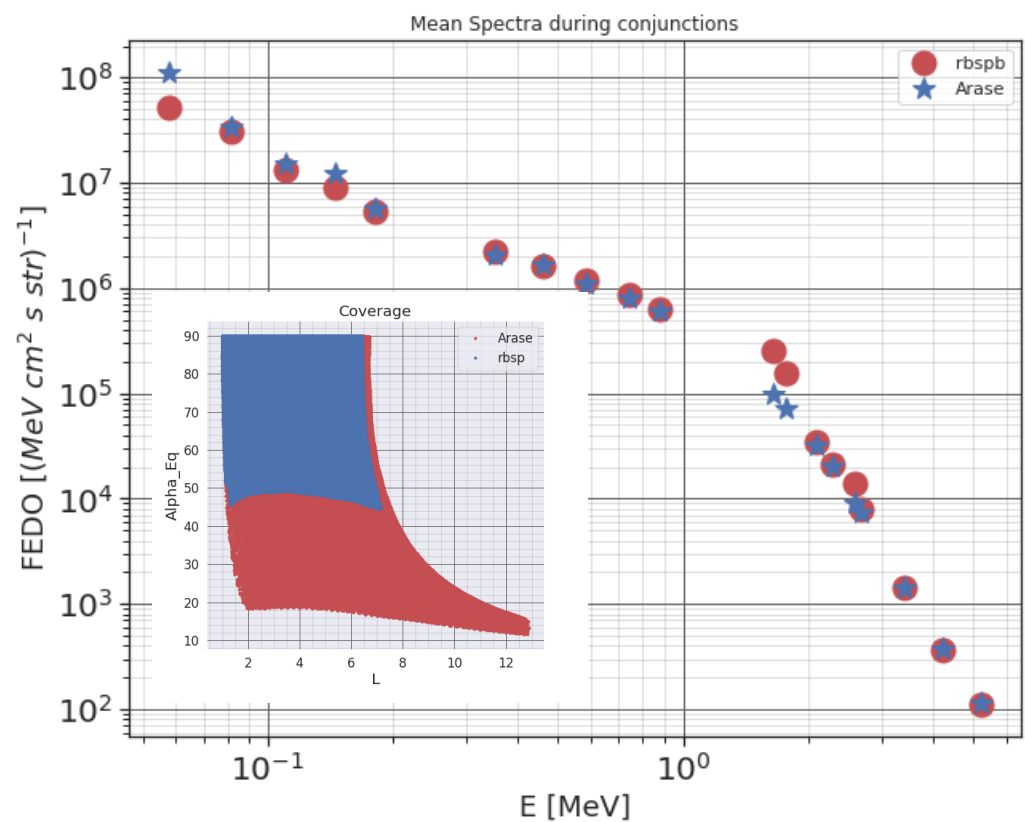
- Evaluate determined conjunctions/Update conditions
- On-the-fly calculation of the “reference data product”
 - Interpolation/integration to target flux energies
 - Construction of sensor measurements (count-rates/charging currents) provided RF availability
- Define scaling factors
 - $R = \text{median}(J_B / J_A)$: J_A and J_B denote the series of joint observations by the satellites of the reference A and the target B
 - $SF_{\text{fit}} = sf \mid \min(\text{MSE})$ (lin/log)
 - Rescale: $J'_B = J_B / R$, or by $J'_B = J_B / SF_{\text{fit}}$
 - $D \ln j = [(1/n)(\sum (\ln(J'_B / J_A))^2)]^{0.5}$ (random error of series)



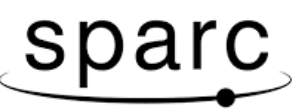


RBSP-B vs Arase/HEP-XEP

type_orbit	HEO
cad	3
cad_times	0
delta_l_max	0.05
delta_alpha_eq_max	1
delta_mlt_max	24
L_lims	[4.0, 6.0]
alpha_eq_lims	[85, 90]
mlt_lims1	[0, 24]
mlt_lims2	[0, 24]
kp_days	2
kp_lim	100

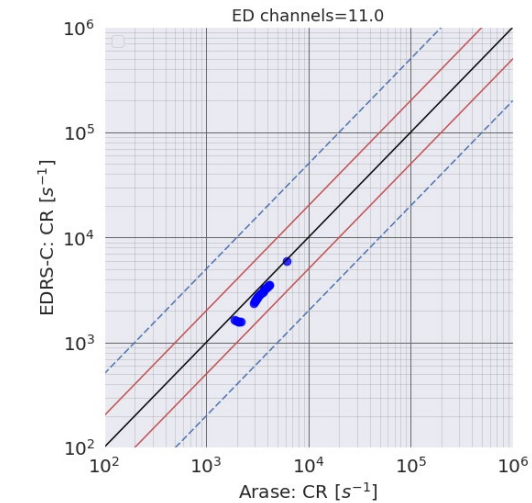
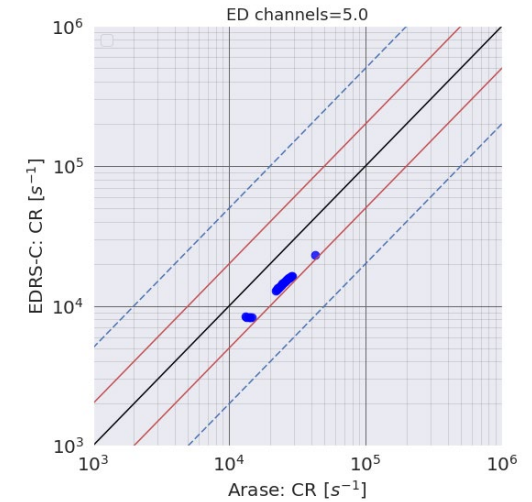
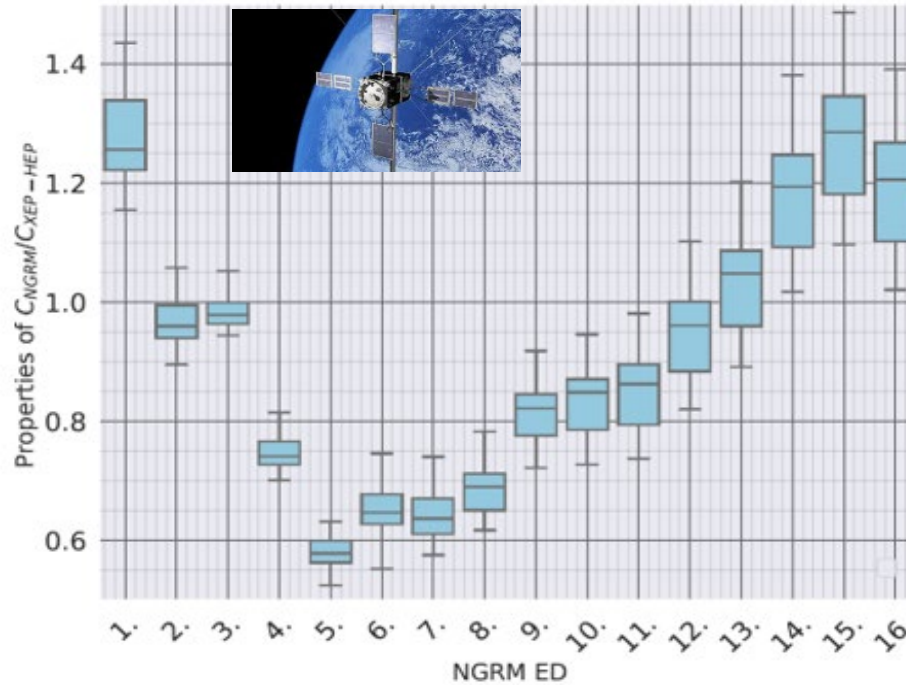
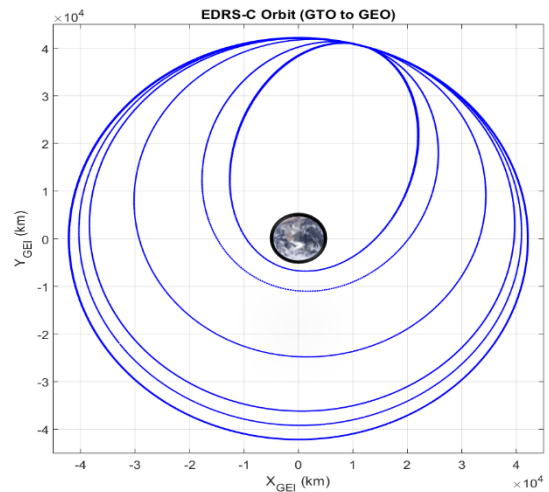
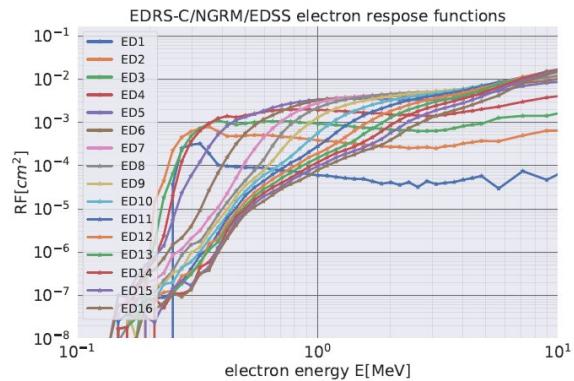


Sandberg et al, <https://doi.org/10.1029/2020SW002692>



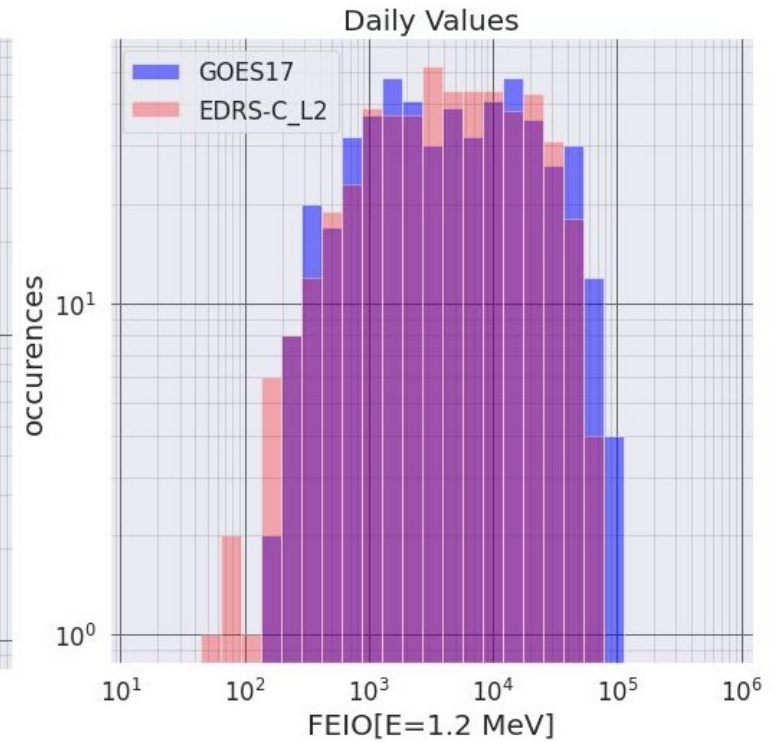
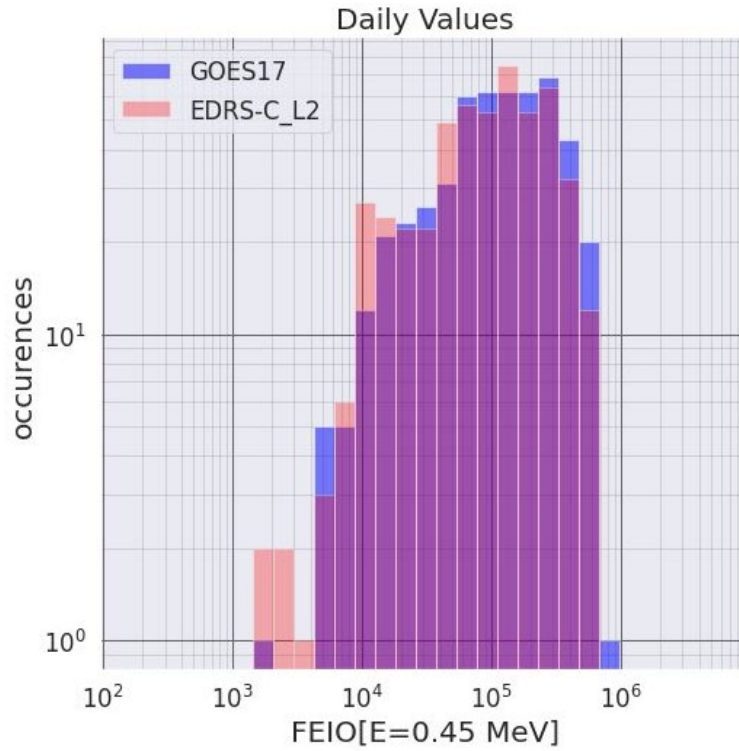
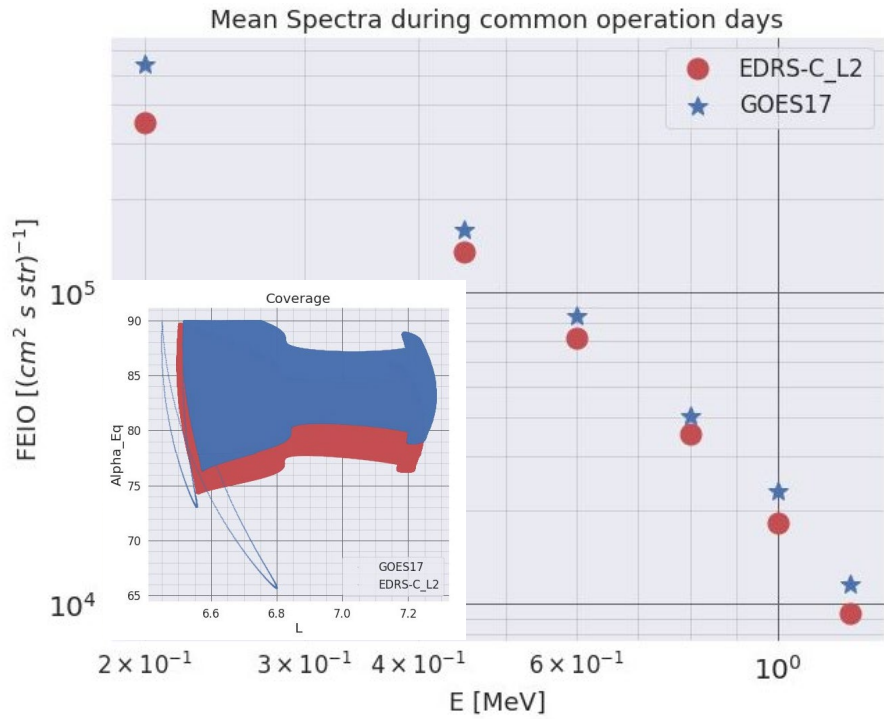


Towards EDRS-C/NGRM L2 using Arase

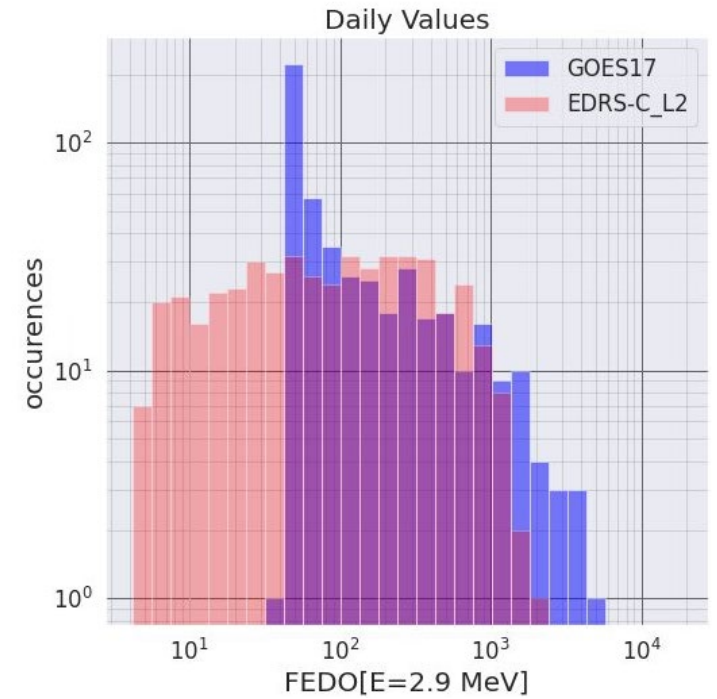
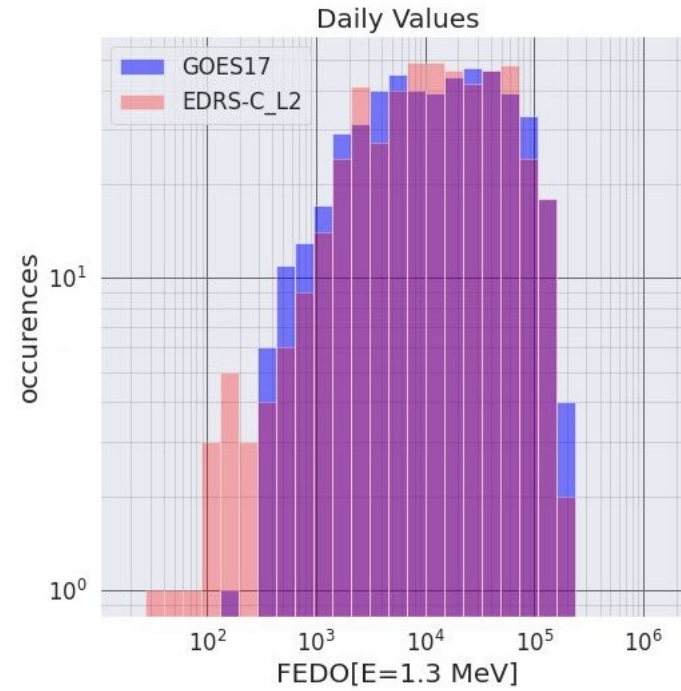
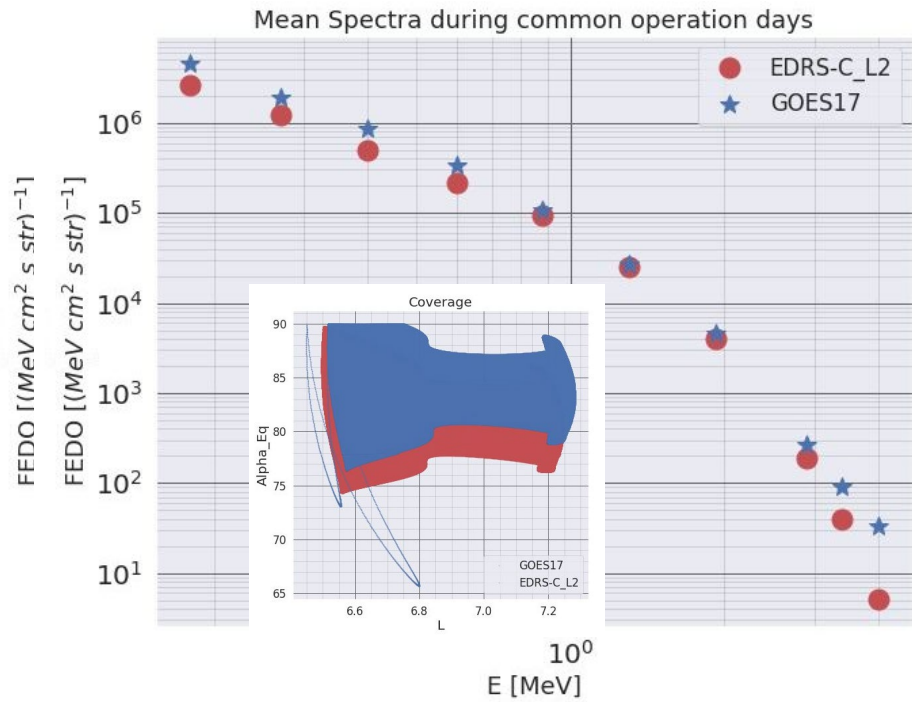


I Sandberg et al <https://doi.org/10.1109/TNS.2022.3160108>

EDRS-C/NGRM L2 vs 17/MPSH

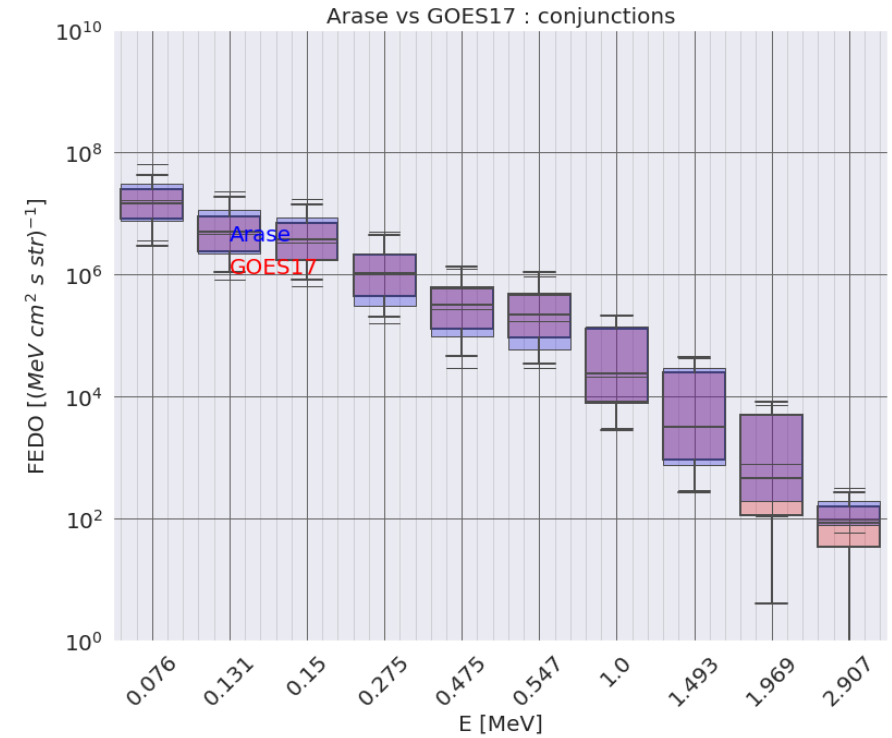
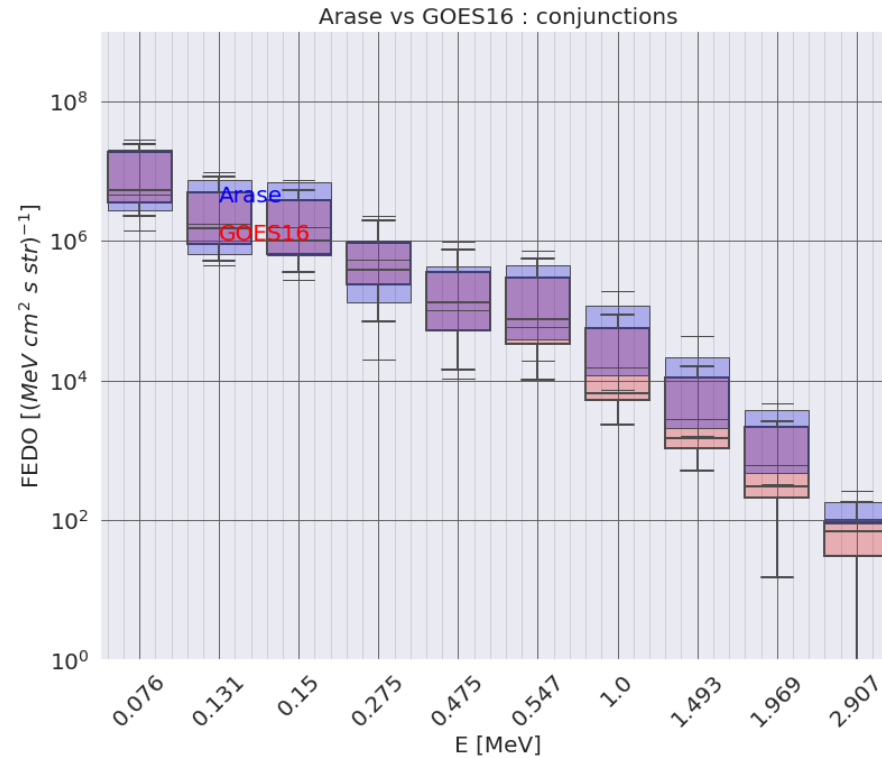
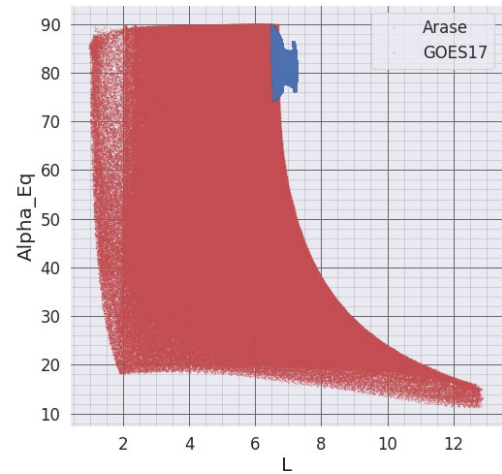
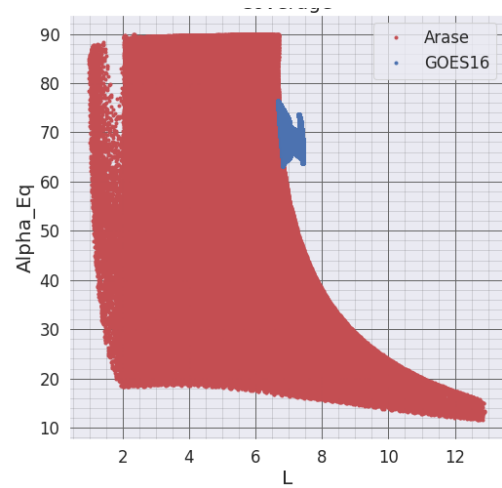


EDRS-C/NGRM L2 vs 17/MPSH



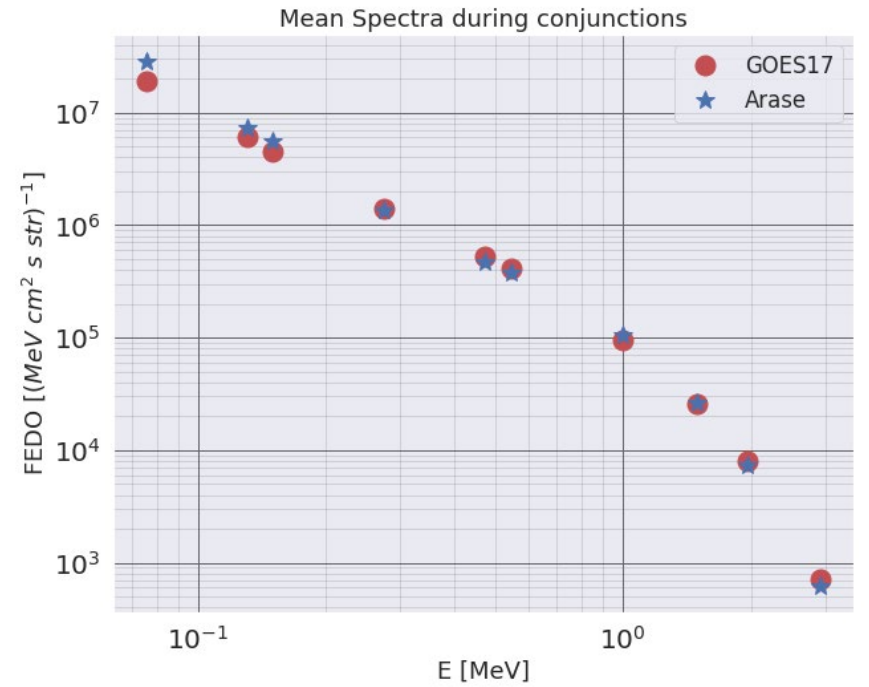
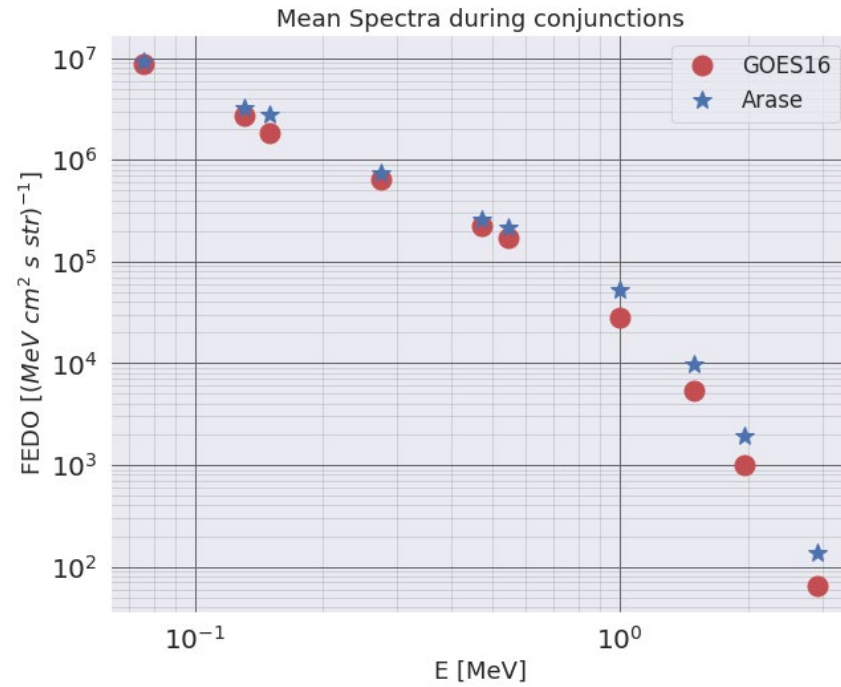
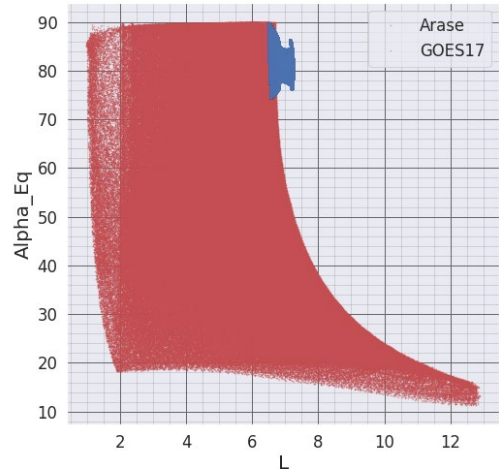
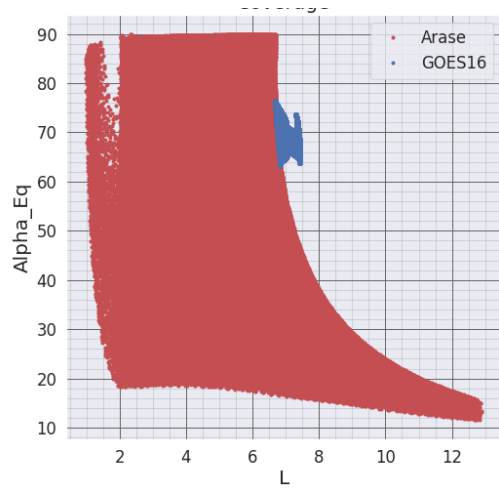


GOES 16-17/MPS-Hi vs Arase/HEP-XEP





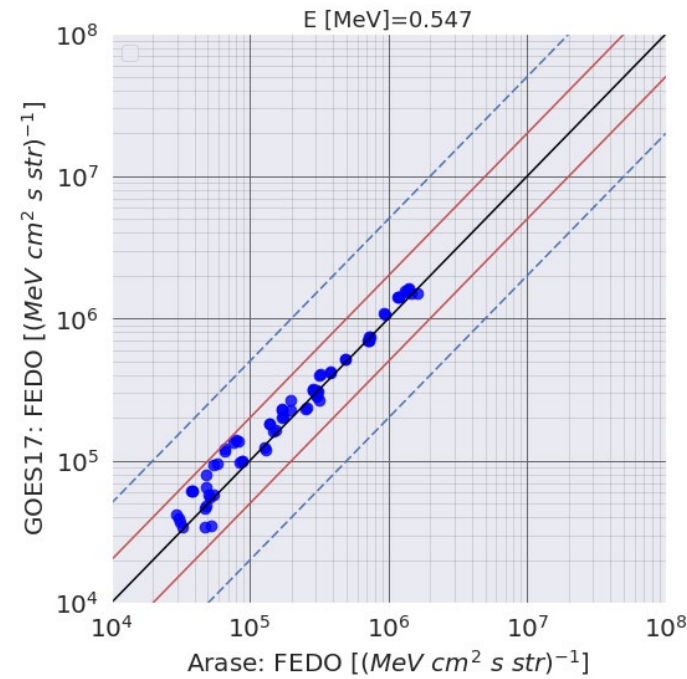
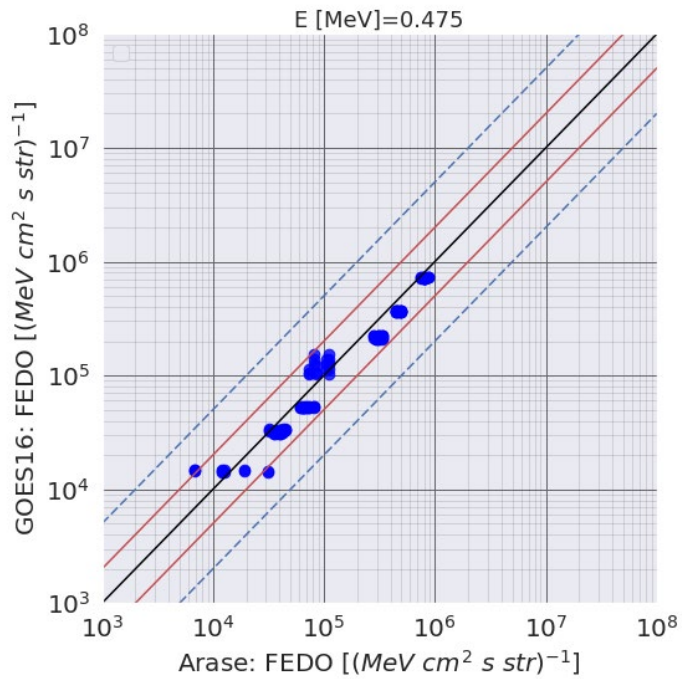
GOES 16-17/MPS-Hi vs Arase/HEP-XEP



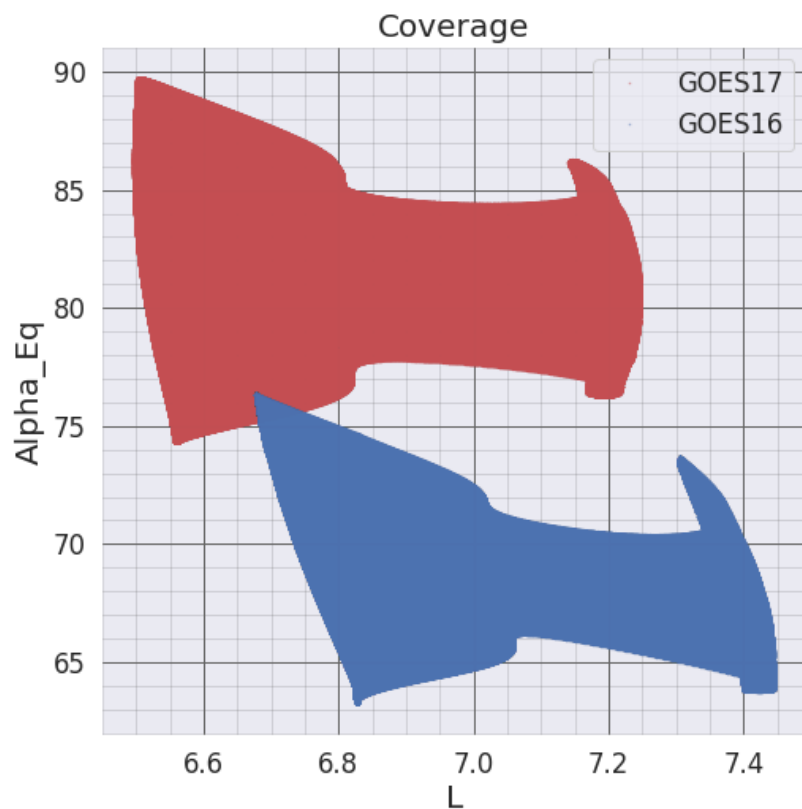


GOES 16-17/MPS-Hi vs Arase/HEP-XEP

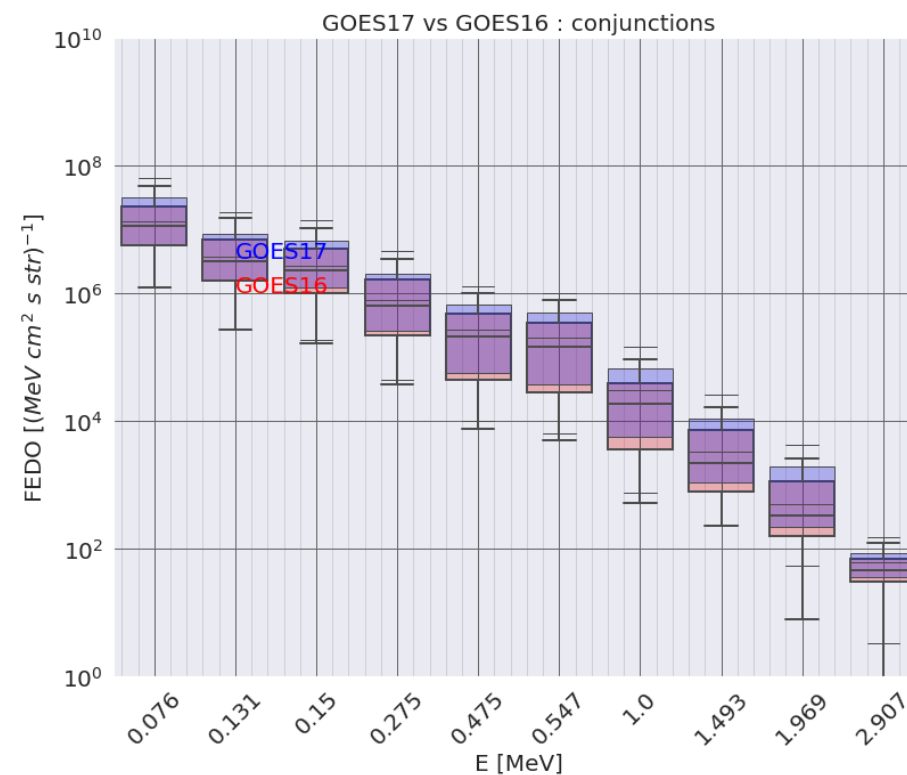
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delta_alpha_eq_max	2
delta_mlt_max	24
L_lims	[1, 10]
alpha_eq_lims	[72, 90]
mlt_lims1	[0, 24]
mlt_lims2	[0, 24]
kp_days	2
kp_lim	100



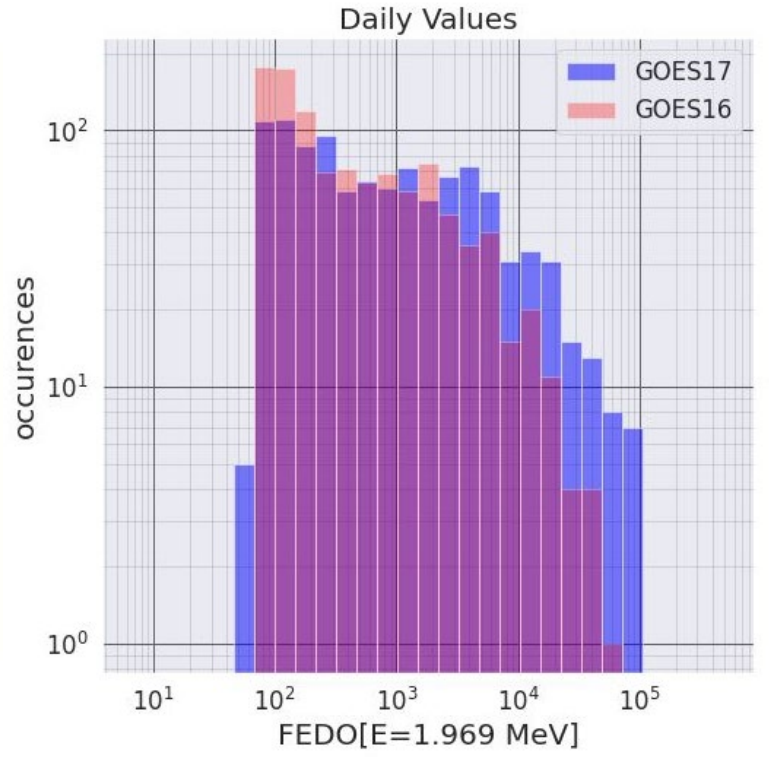
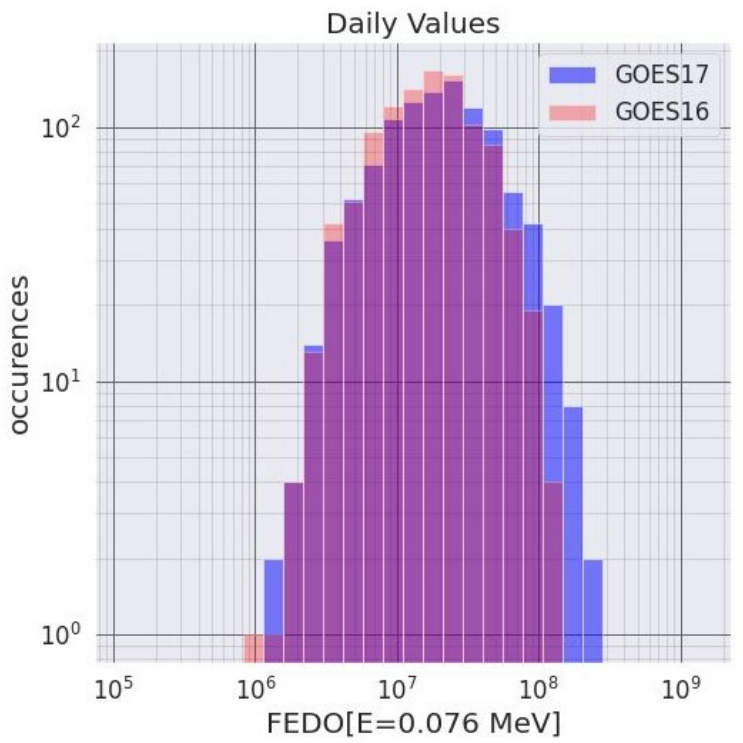
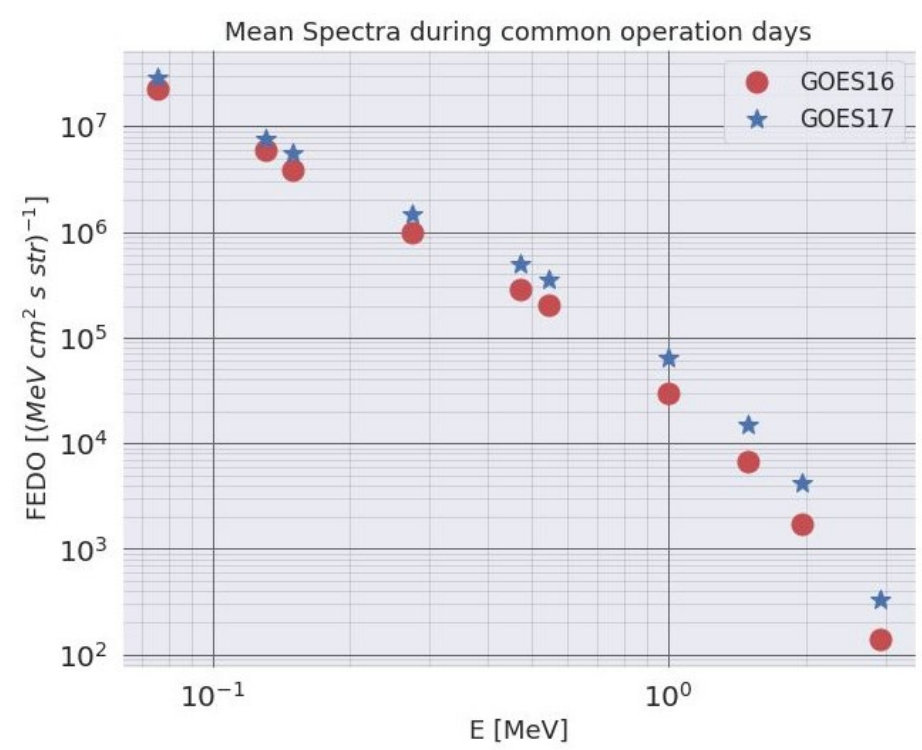
GOES 17 vs GOES 16/MPS-Hi



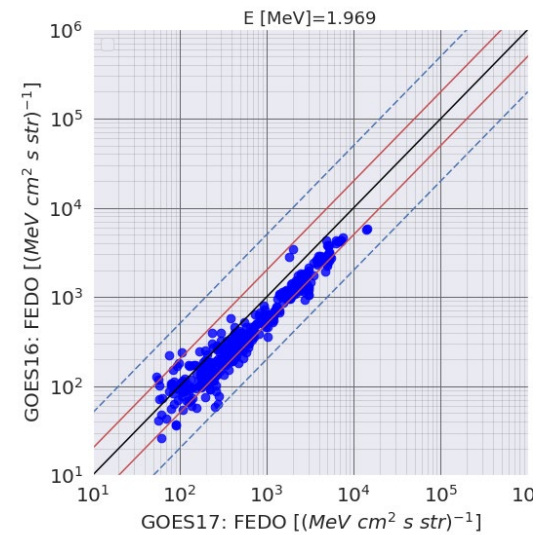
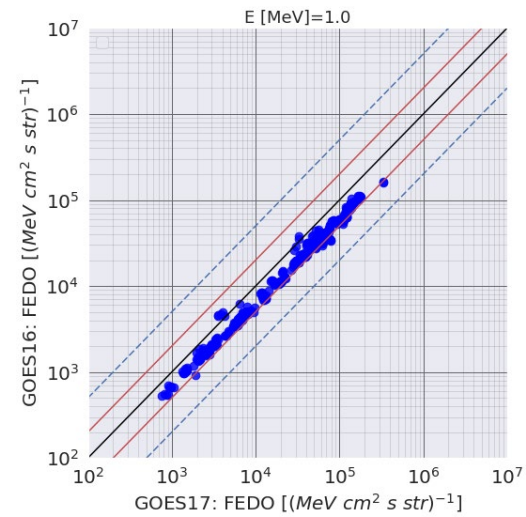
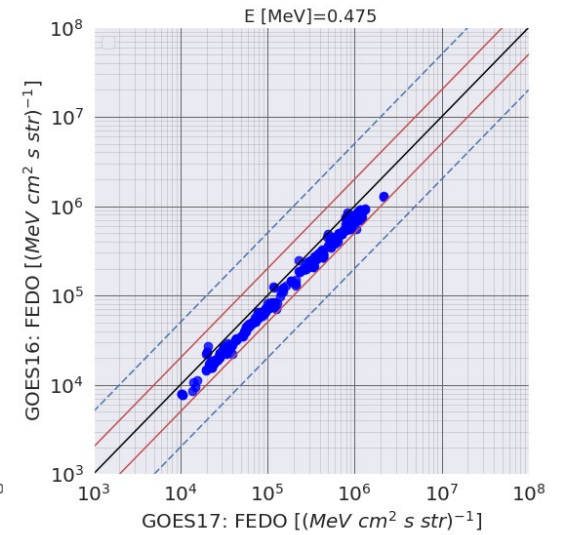
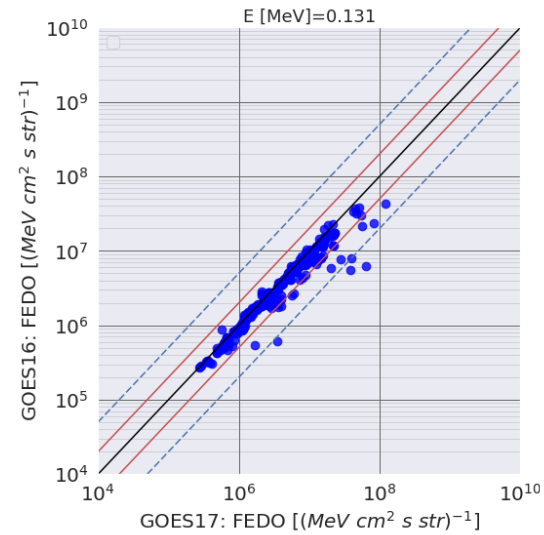
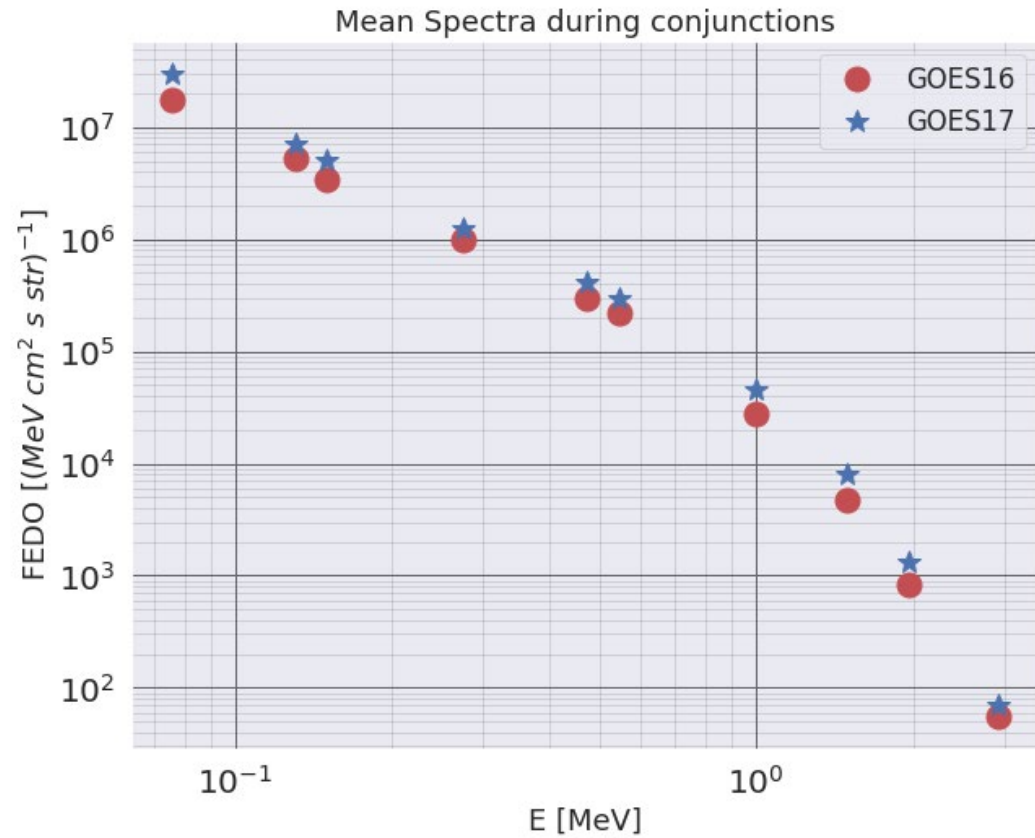
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delta_mlt_max	24
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mlt_lims2	[0, 24]
kp_days	2
kp_lim	100



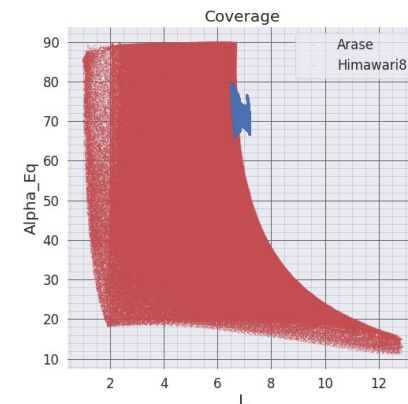
GOES 17 vs GOES 16/MPS-Hi: ~~Conjunctions~~



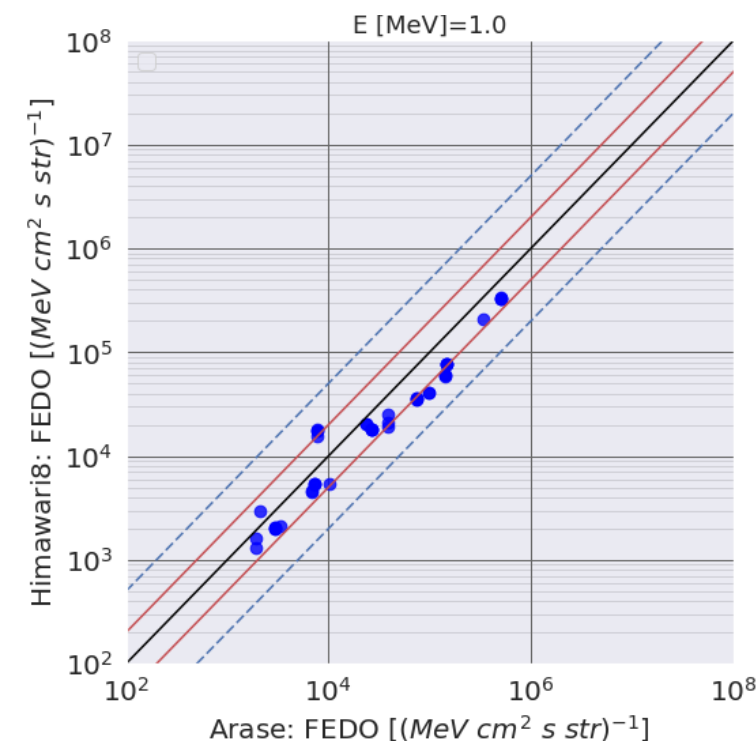
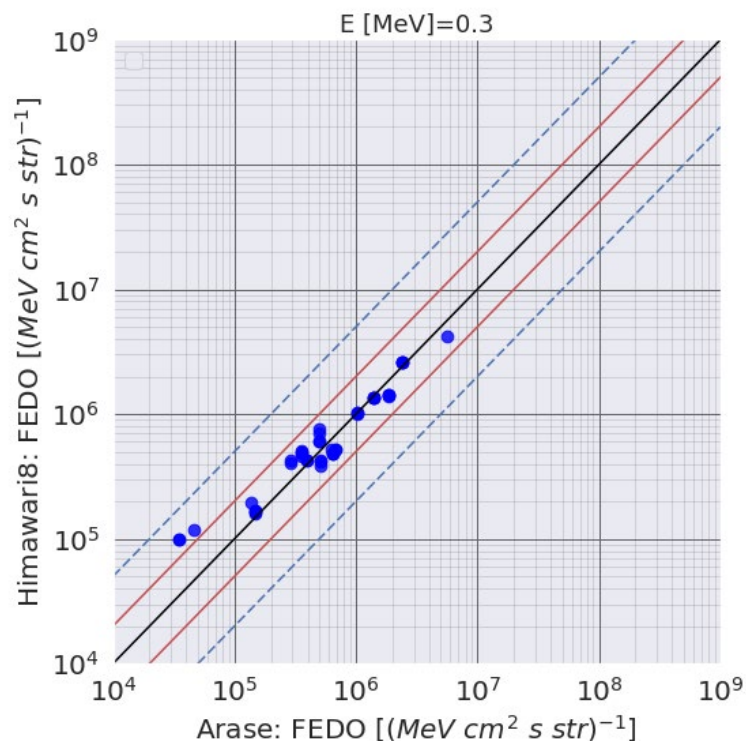
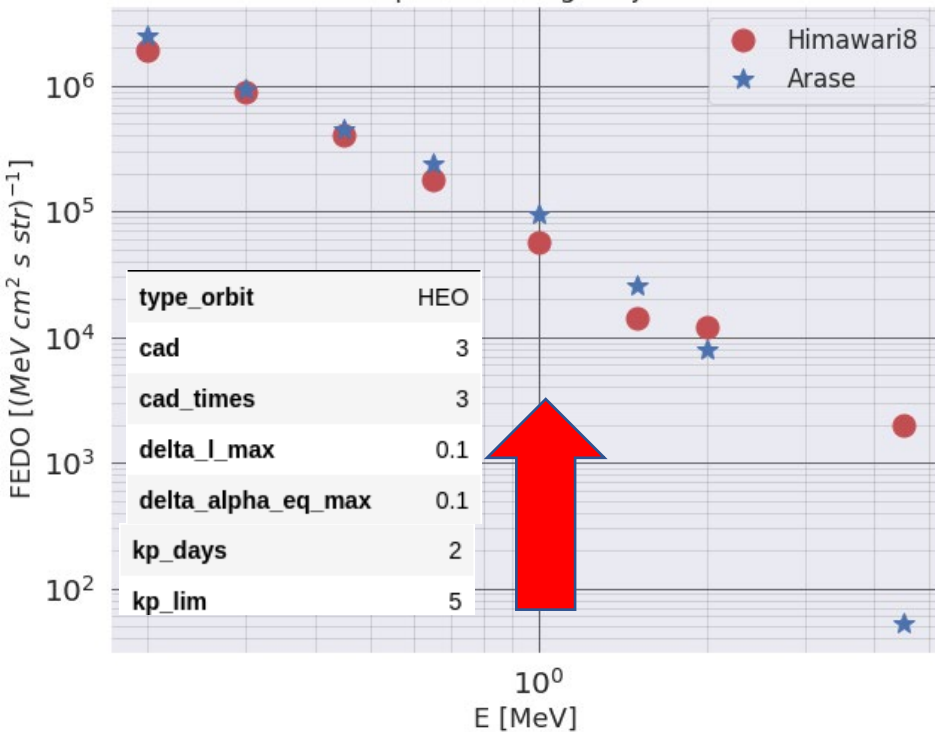
GOES 16 vs 17/MPS-Hi



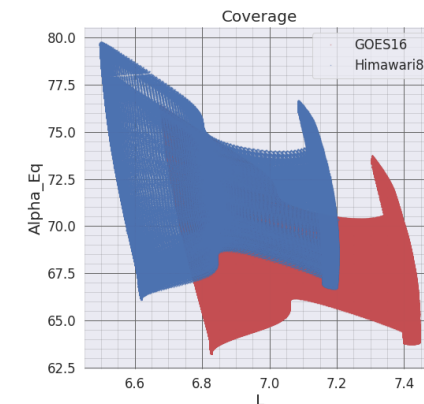
Himawari-8 vs Arase/HEP-XEP



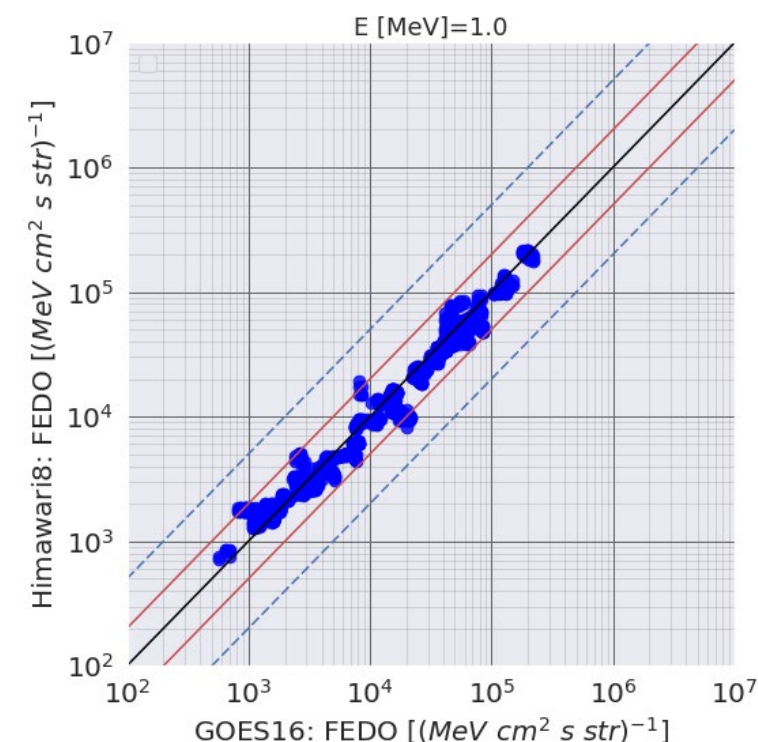
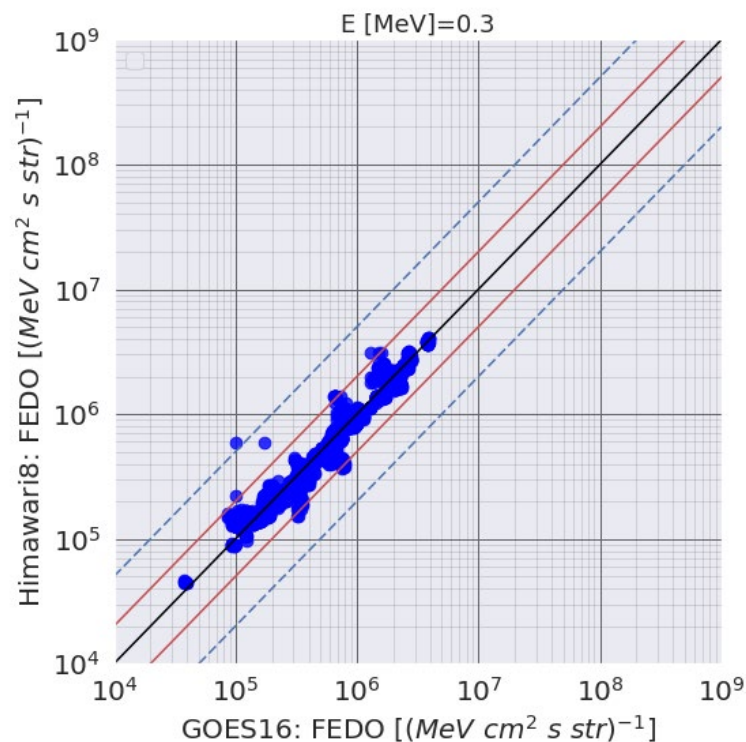
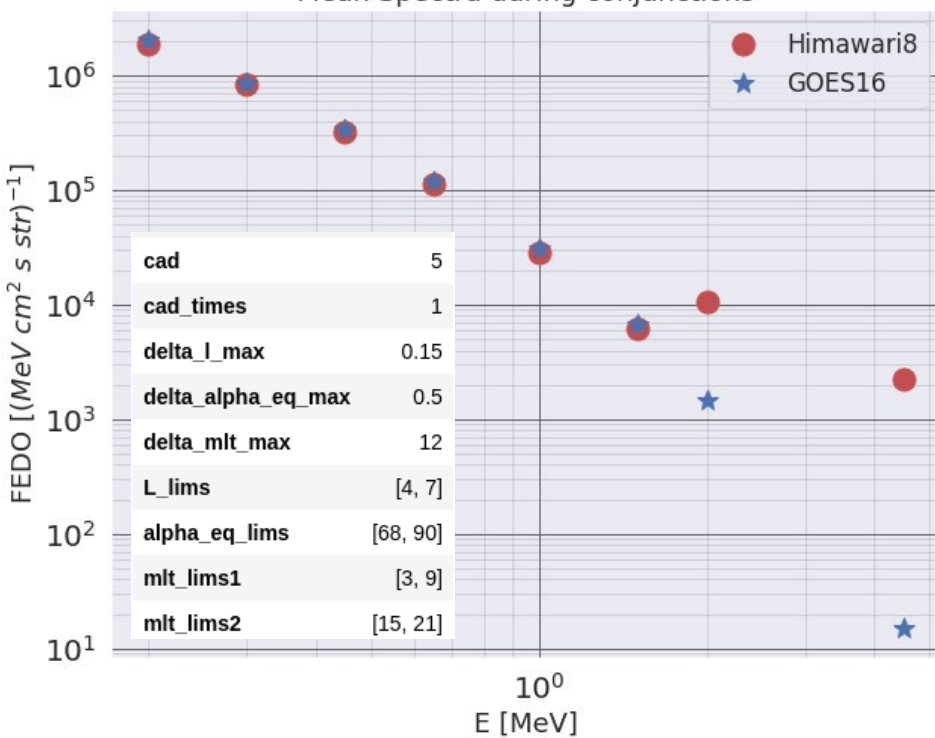
Mean Spectra during conjunctions



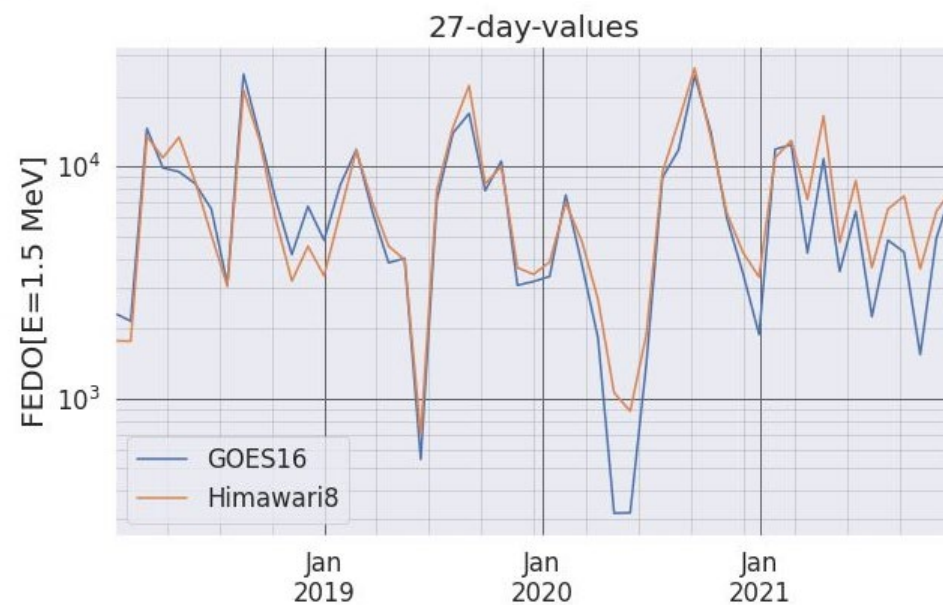
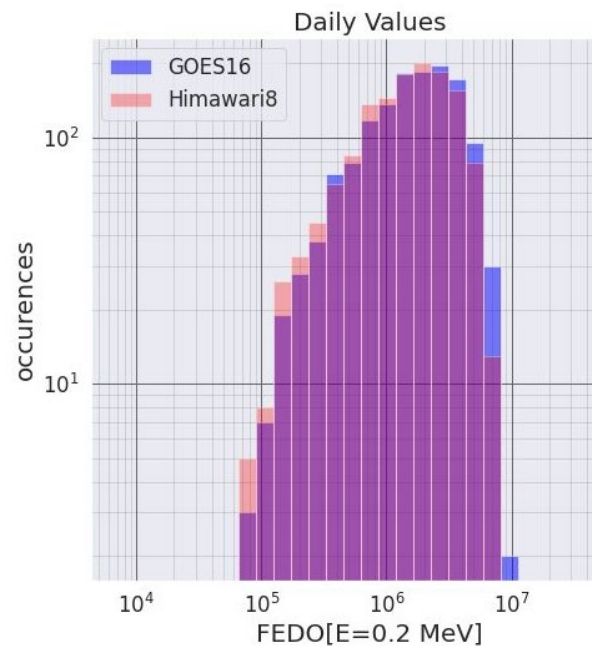
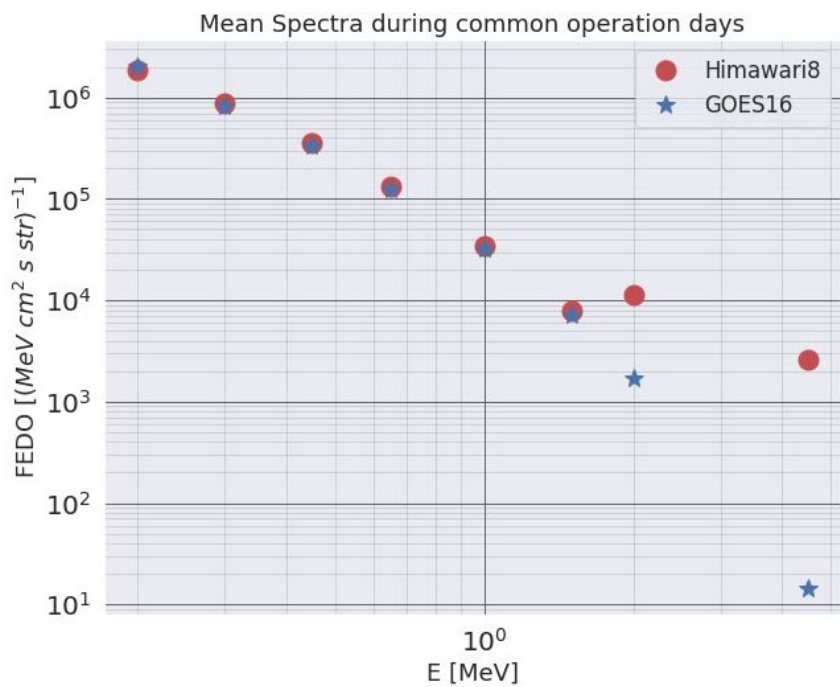
Himawari-8 vs GOES 16/MPS-Hi



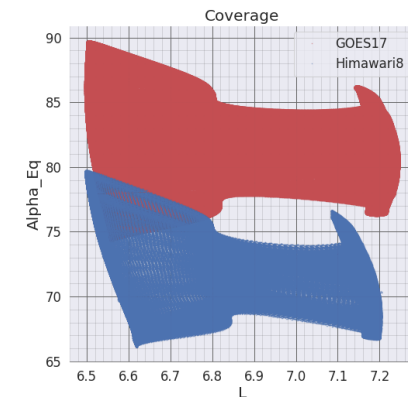
Mean Spectra during conjunctions



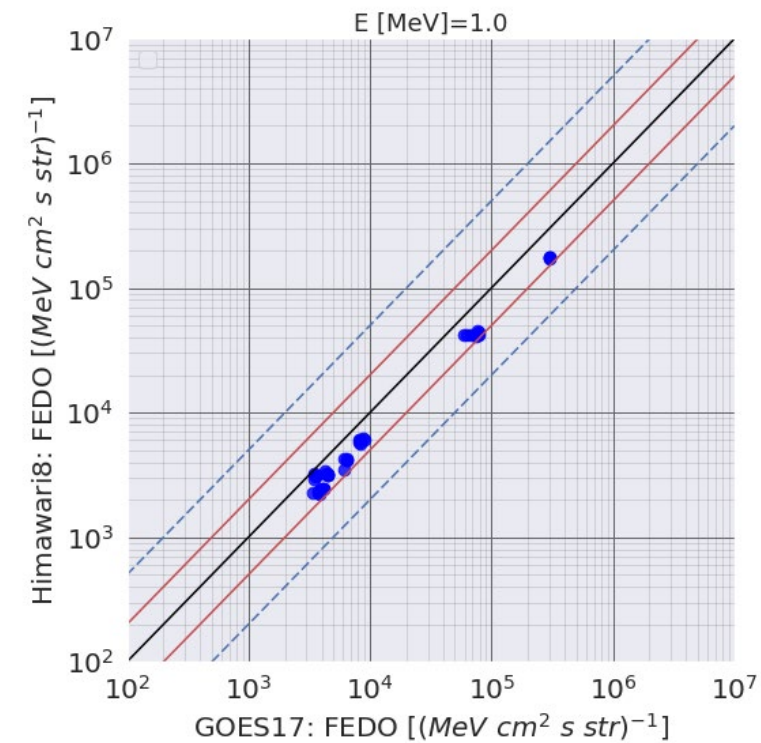
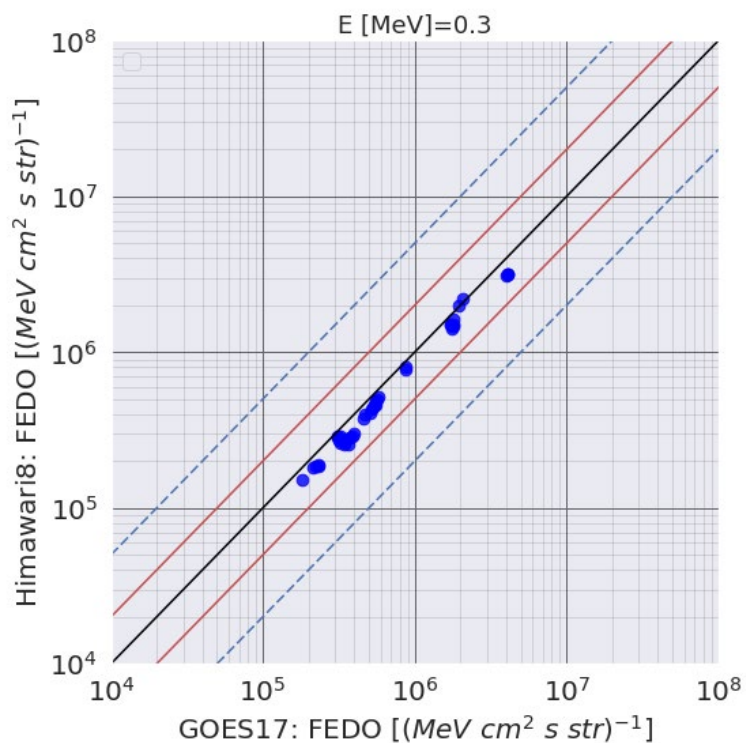
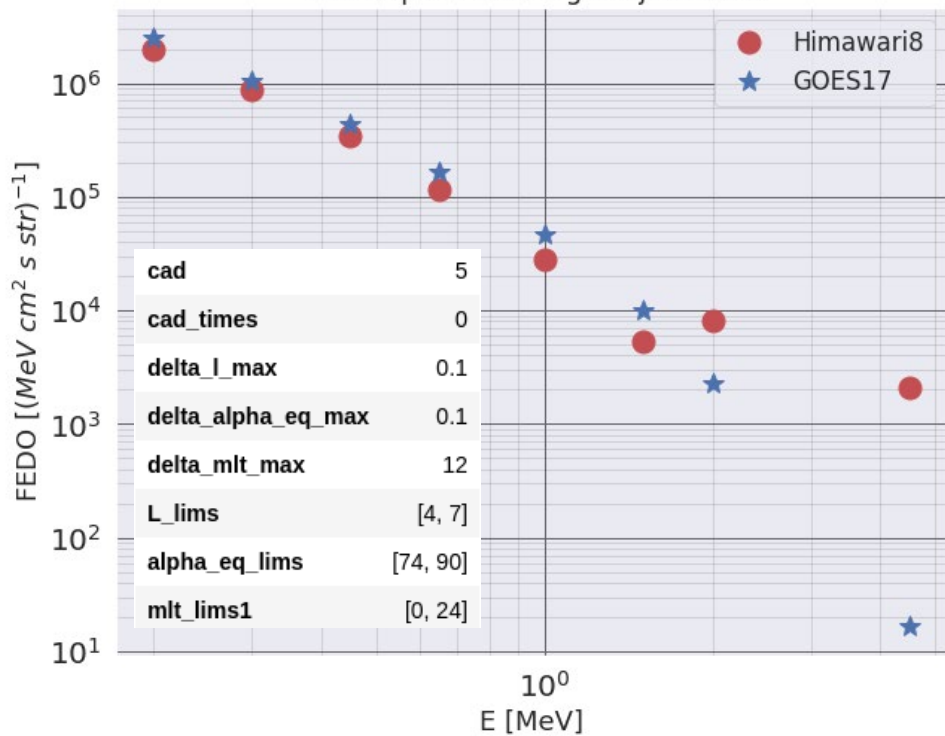
Himawari-8 vs GOES 16/MPS-Hi: ~~conjunctions~~



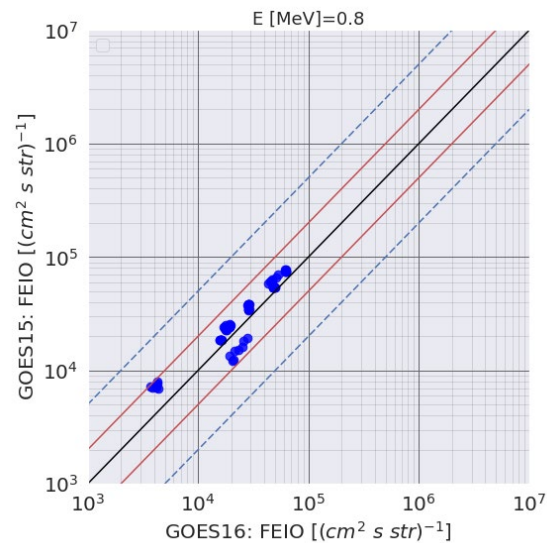
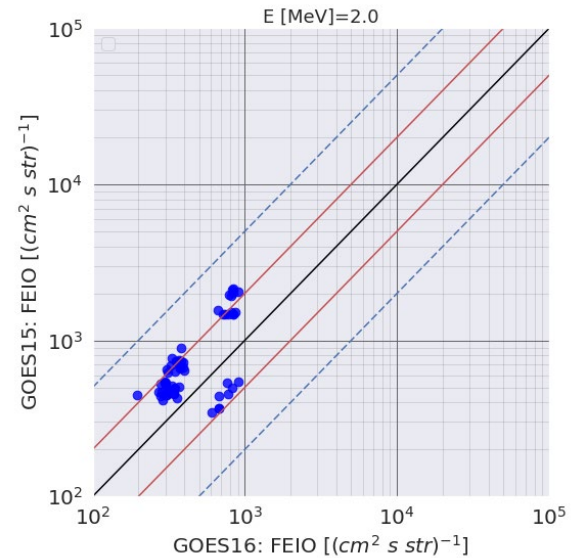
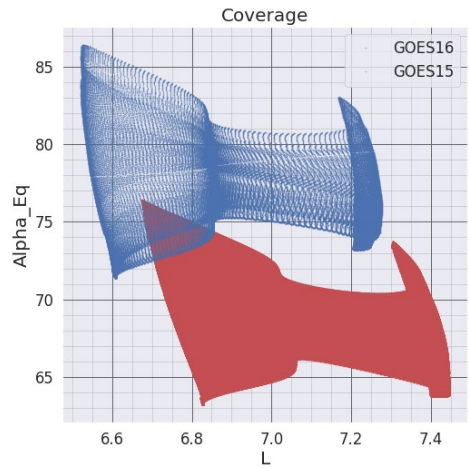
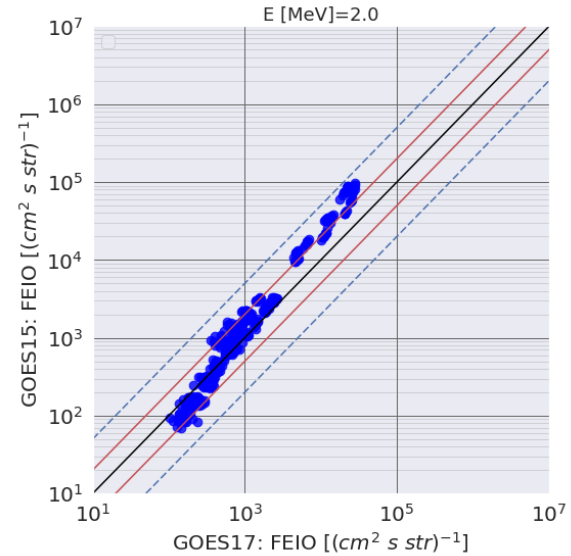
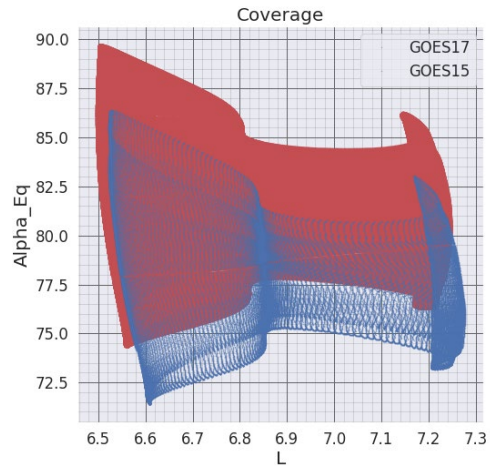
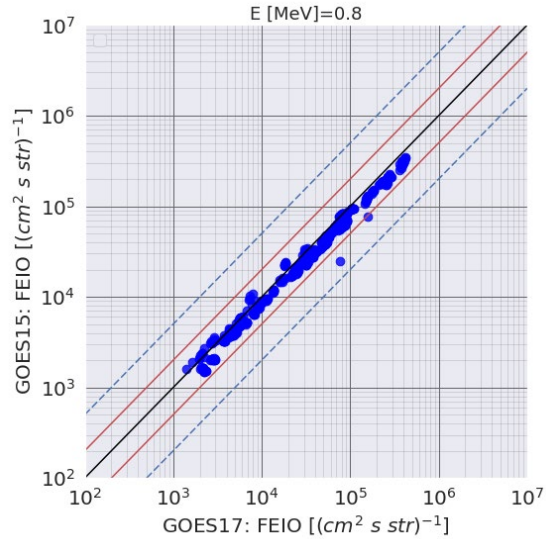
Himawari-8 vs GOES 17/MPS-Hi



Mean Spectra during conjunctions

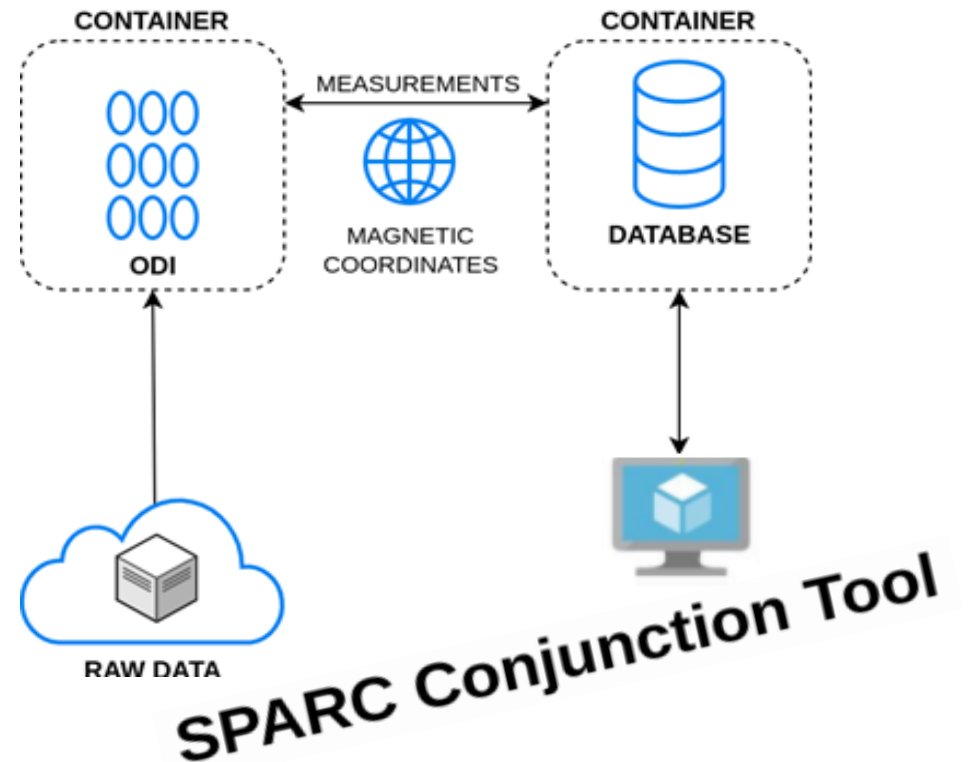


GOES 15/EPEAD vs 16-17/MPSH



Discussion

- A system for automated cross-calibration under continuous development
- Characteristic results presented
- Differences of selected datasets: **not significant!**
 - **H8 - G16 < RBSP- Arase - G17 - G15**
 - **Arase-Merlin-GSAT-NGRM [GSICS 2023 US]**
- Improvements:
 - Update database with:
 - Updated datasets
 - New Versions/Higher Levels of datasets
 - Update conjunction conditions (?)
 - Magnetic field model (?) [NOAA]
 - Other Diagnostics, plots



Discussion

- Reference datasets
- GEO-GEO calibrations studies:
 - selected time periods/periods: better control/understanding of conditions
 - maximum overlapping time periods: enhanced statistics
- Conjunction criteria: standardize selection procedures
 - Kp index: intense geomagnetic conditions for high energy flux spectra [GSICS 2023 US]
- Cross-calibrated datasets:
 - Definition of scaling factors
 - Error analysis and propagation – a missing feature
- Response Functions and accessibility of raw data
 - Calibrate sensor data (outputs) or Level 1 (fluxes) [GSICS 2023 US]
- Measurements during GTO are invaluable [GSICS 2023 US]
 - More opportunities for cross-calibration studies
 - Calibration of measurements in flux-intense environments