Global Space-based Inter-Calibration System (GSICS)

Data & Research Working Groups Annual Meeting

28th February 2023

ESA Assets and Intercalibration Capability

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Overview

- ESA and its contractors are provisioning various historical, current and near real-time data sets
- We have been contributing to CGMS (Coordination Group for Meteorological Satellites) SWCG Inter-Calibration Task Group which aimed to conduct comparisons of data to verify their performance for use in space weather monitoring and modelling
- Our tools, data and expertise could contribute to the implementation of a Global Space-based Inter-Calibration System (GSICS)
- This presentation focusses on particle radiation monitor data and covers:
  - An overview of elements of ESA which contribute in some way
  - ESA assets which can potentially be included in such a system
  - An introduction to methods for accessing the data
  - Thoughts on how the GSICS framework may look

Overview of Contributing Directorates within ESA

- As we can benefit from multi-point in-situ measurements of space weather phenomena there is an effort to host monitors on a variety of platforms in different orbits coming from a range of Science and Exploration and Application directorates.
- These data should be gathered and processed to higher-level data and then provisioned to end users nominally through the Directorate of Operations' Space Safety Programme (S2P)
- Contributing directorates within ESA include:

OPS – ESA Space Weather Office – part of the Space Safety Programme (S2P)

TEC – Space Environment and Effects and various In-Orbit Demo missions (PROBA, RadCube)

SCI – Hosting Monitors on Various Science Missions (Integral, Rosetta, Planck, Hershel, BepiColombo, JUICE)

EOP – Hosting Monitors on Sentinel-6, MetOp 2nd Generation and Meteosat 3rd Generation

Contribution from SMOS and SWARM Earth Explorer missions (illustrated in separate presentation)

HRE – Hosting Instrumentation on future Lunar Gateway and Mars Sample Return Earth Return Orbiter missions

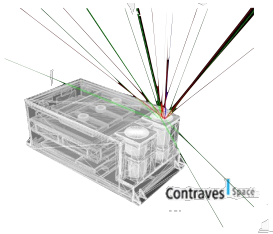
The above directorates all participate to the ESA Heliophysics Working Group aiming to optimize interactions

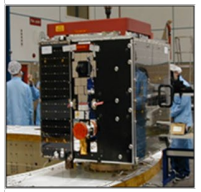
TEL – Hosting monitor on EDRS-C and facilitating other opportunities

NAV – Hosted monitors on GIOVE satellites and Galileo (limited distribution)

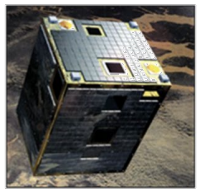
Radiation Monitor Assets

Standard Radiation Environment Monitor (SREM)

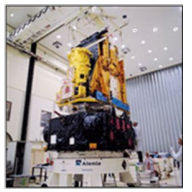




STRV-1c 2000



PROBA-1 2001



INTEGRAL 2002

ESA, Oerlikon Contraves (RUAG), Paul Scherrer Institute (PSI)

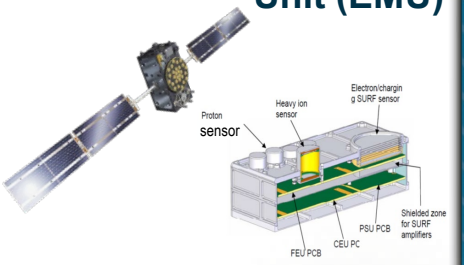
Giove-B 2008

Rosetta 2004

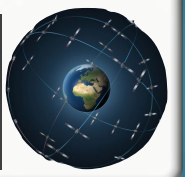
Herschel 2009

Planck 2009

Environment Monitoring Unit (EMU)

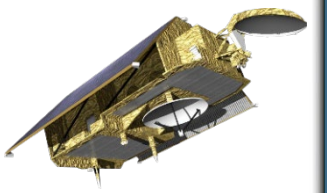


GSAT0207 2016 GSAT0215 2017

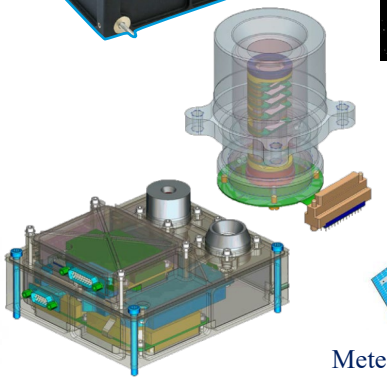


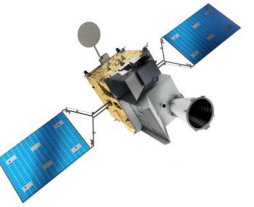
Next Generation Radiation Monitor (NGRM)

EDRS-C 2019



Sentinel-6 2020

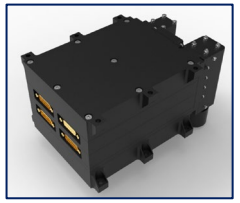


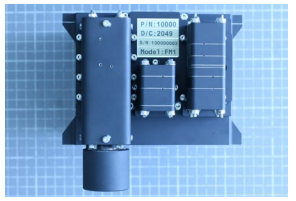


Meteosat 3rd Gen. 2022+

MetOP 2nd Gen. 2025+

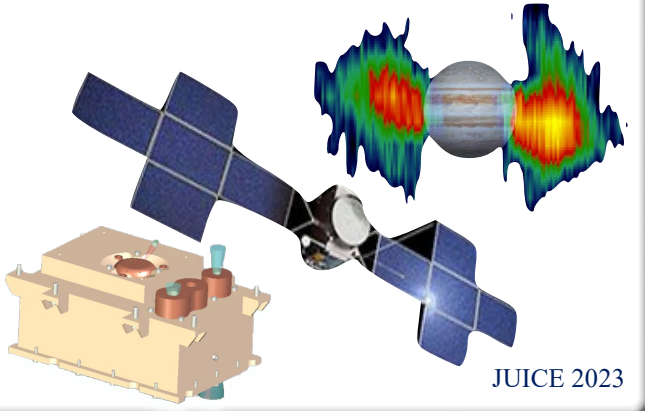
Influence sur les Composants Avancés des Radiations de l'Espace Next. Gen. (ICARE-NG)





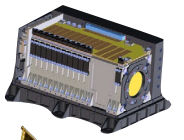
HOTBIRD™ 13 F&G

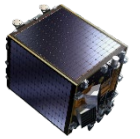
Rad-hard electron Monitor (RADEM)



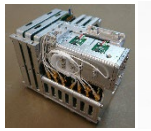
JUICE 2023

Selected other monitors

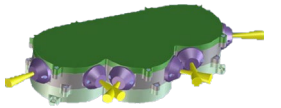




EPT PROBA-V 2013

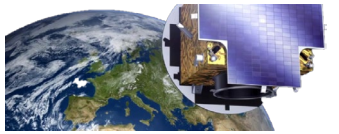


RadMag RadCube 2021



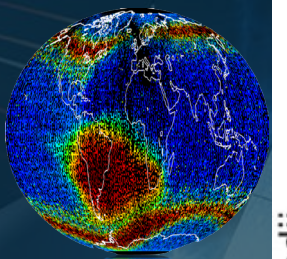
3DEES PROBA-3 2024

HardPix (and others)
Lunar Gateway 2025



Radiation Monitor Orbital Coverage

GEO	Past: AlphaSat/MFS
	Present: EDRS-C/NGRM, MTG-I/RMU(NGRM)
	Future: additional MTG-I/RMU, HotBird/ICARE-NG
MEO	Past: Giove-A/Merlin, Giove-B/SREM
	Present: Galileo(GSAT 0207 & 0215)/EMU
	Future: Galileo 2nd Gen./tbc
LEO	Past: PROBA-1/SREM
	Present: RadCube/RadMag
	PROBA-V/EPT+SATRAM
	Future: MetOp-SG/RMU(NGRM)
HEO	Past: XMM-Newton/ERMD
	Present: INTEGRAL/IREM
	Future: PROBA-3/3DEES, Lunar Gateway/ERSA
Inter-plane-tary	Past: Herschel/SREM, Planck/SREM, Rosetta/SREM
	Present: BepiColombo/BERM
	Future: JUICE/RADEM, Lunar Gateway/ERSA



European Radiation Sensor Array (ERSA)
To launch on Lunar Gateway
PPE in Q4 2025 hosting:
SREM, NGRM, ICARE-NG
HardPix and
ESA Active Dosimeter (EAD)

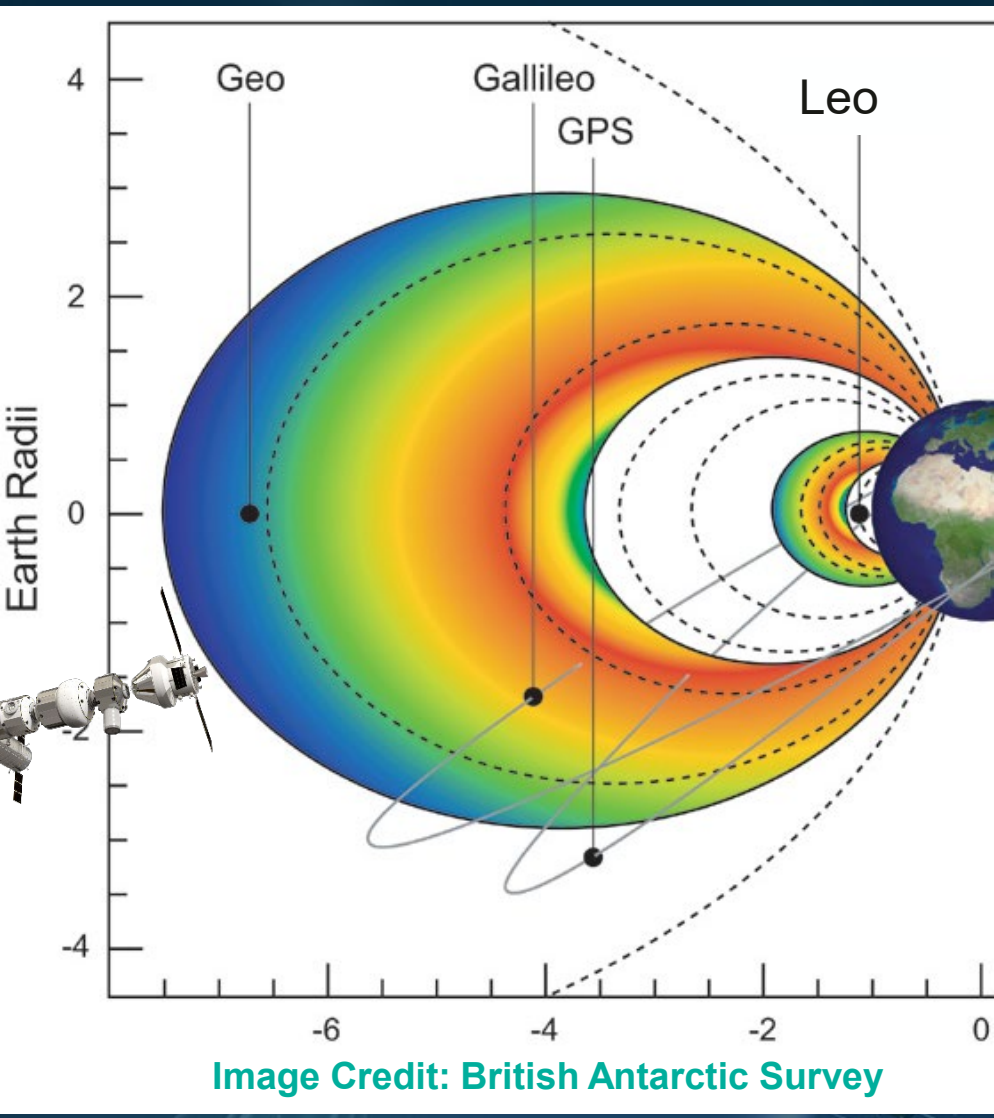
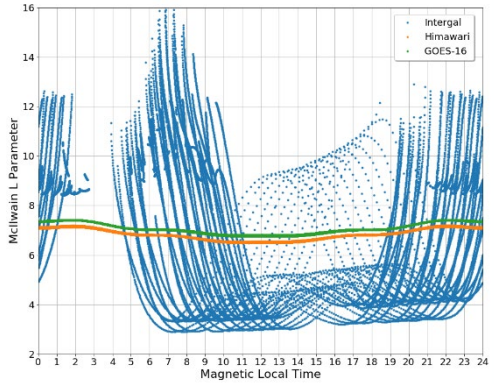
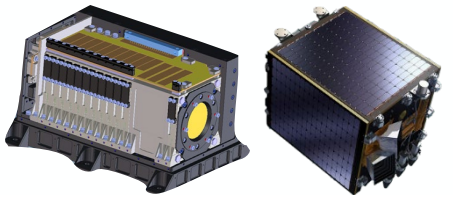


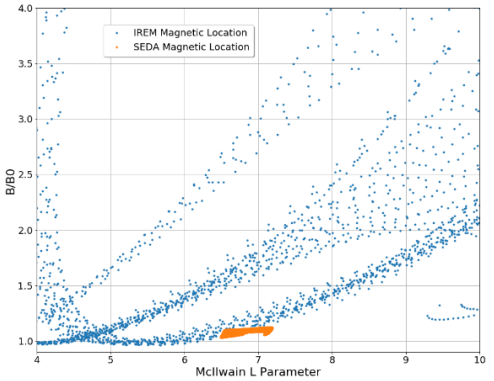
Image Credit: British Antarctic Survey

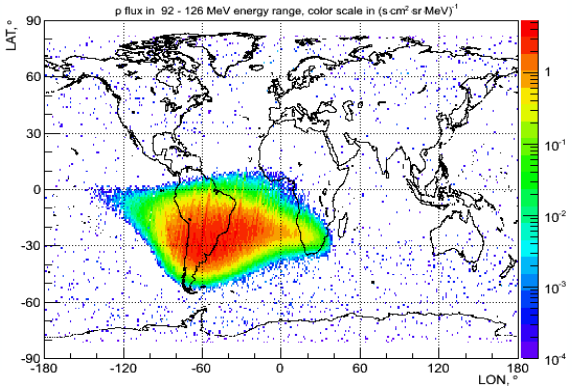
Particle Radiation Data from SREM/IREM and EPT

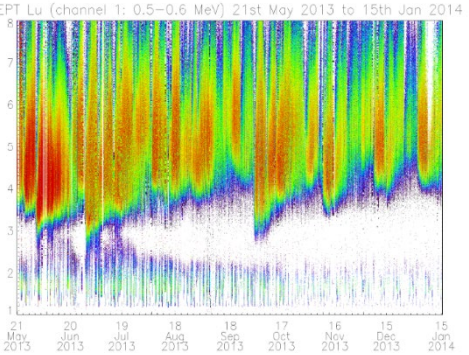


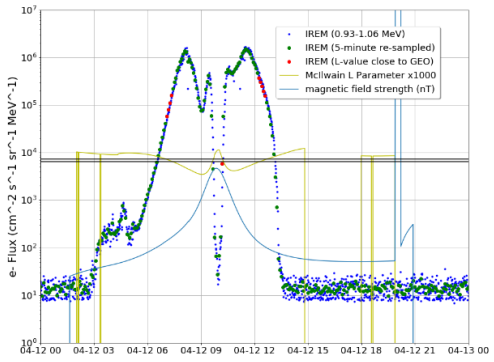
- SREM/IREM data provides a historical record spanning 2 solar cycles in a range of orbits in the Earth's magnetosphere and interplanetary space.
  - Electron data from 0.65 (0.55) to 2.2 (5.0) MeV
  - Proton data from 11 to 250 (400) MeV
- EPT is a spectrometer flying in LEO for 10 years onboard PROBA-V
  - Electron data from 0.5 to 20 MeV
  - Proton data from 9.5 to 300 MeV
  - Alpha particles from 38 to 1600 MeV
- Available via ODI
- And SWE portal: https://swe.ssa.esa.int/

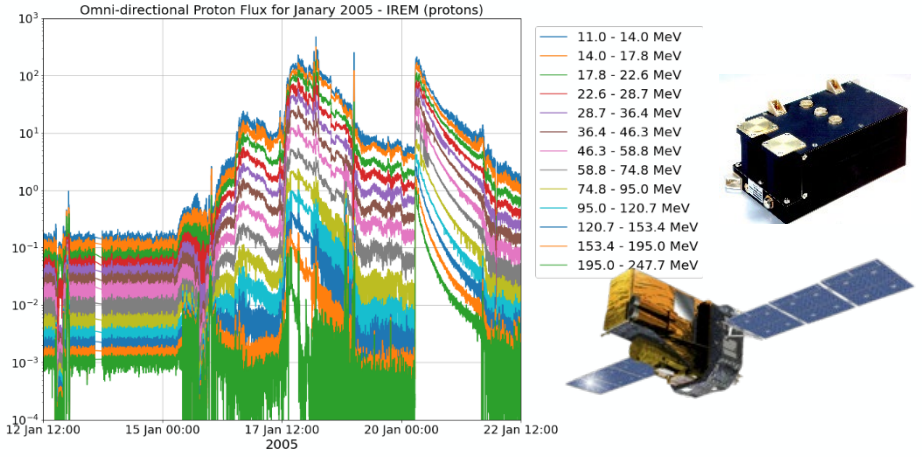


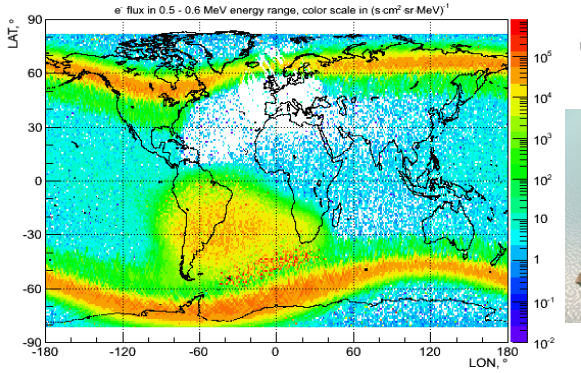


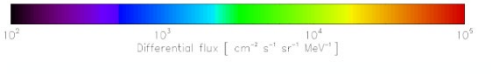


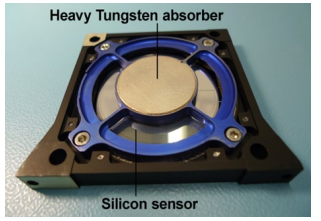






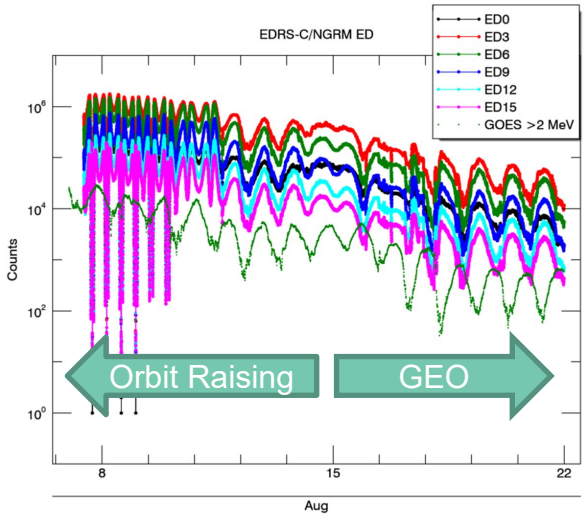


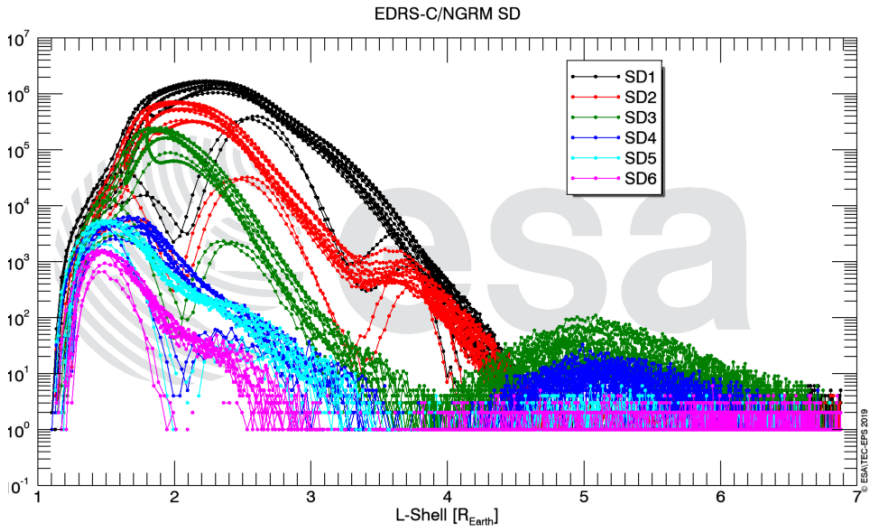


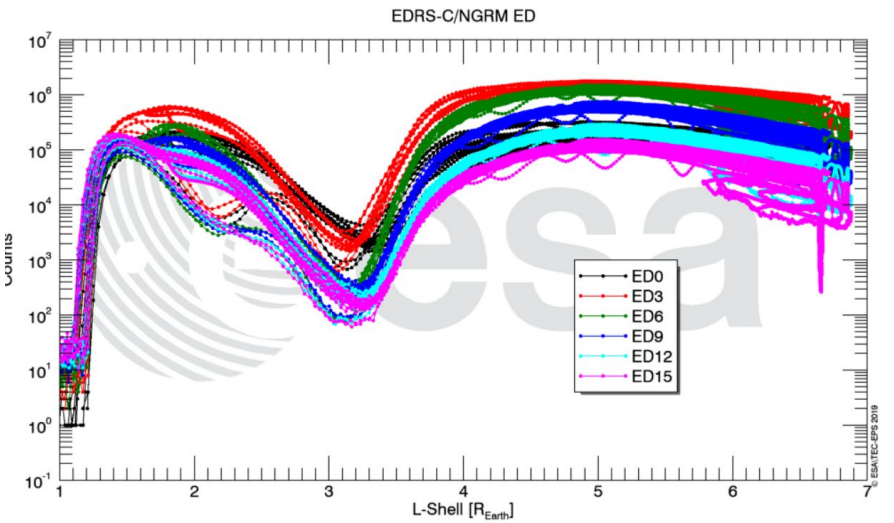


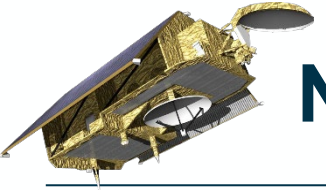
EDRS-C/NGRM

- Next Generation Radiation Monitor (NGRM) was designed by PSI and developed by Thales Alenia Space Switzerland
  - Electron data from 0.35 to 2.6 MeV
  - Proton data from 2 to 200 MeV
- Images below show the first data from 1st flight of the Next Generation Radiation Monitor (NGRM)
- Right shows observations from a solar particle event (GLE73)
- Publications: Desorgher et al. 2013 & Sandberg et al. 2022



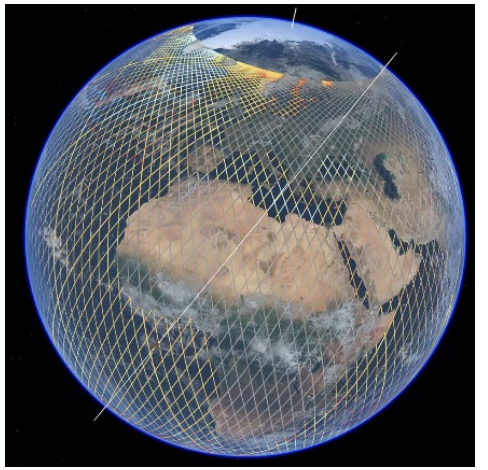




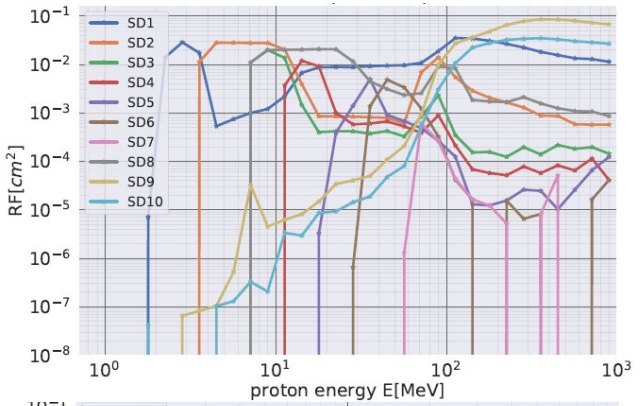


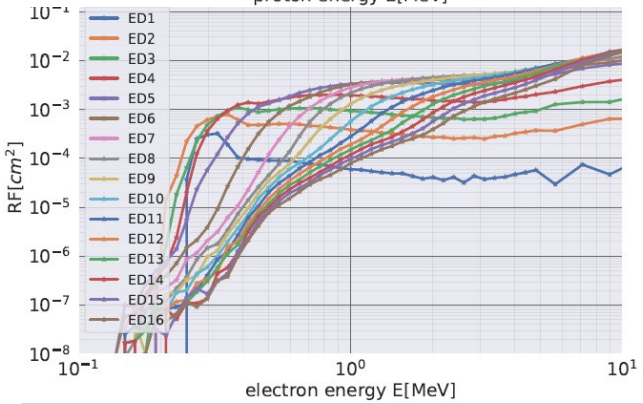
NGRM Data: Sentinel-6 Focus

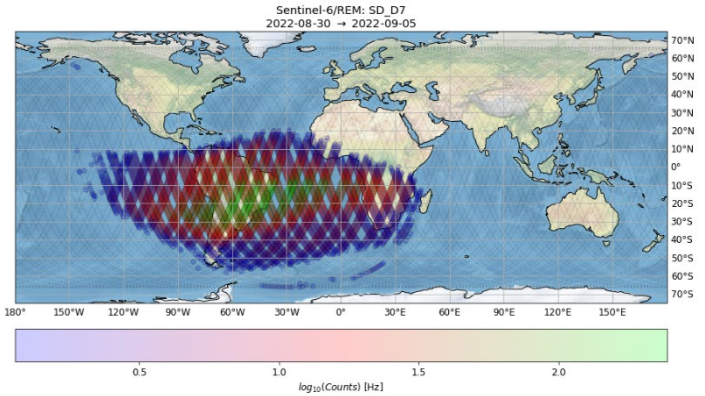
- Sentinel-6 (Michael Freilich) data received from launch on 21st November 2020: https://space-env.esa.int/sentinel-6-ngrm-first-data/
- First NGRM on Meteosat 3rd Generation (RMU) in GEO launched in December 2022
- Further units planned for MetOp-SG programme as well as the Lunar Gateway (ERSA).

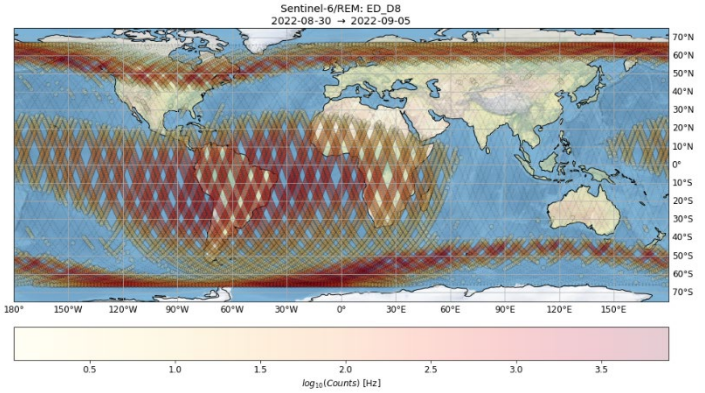


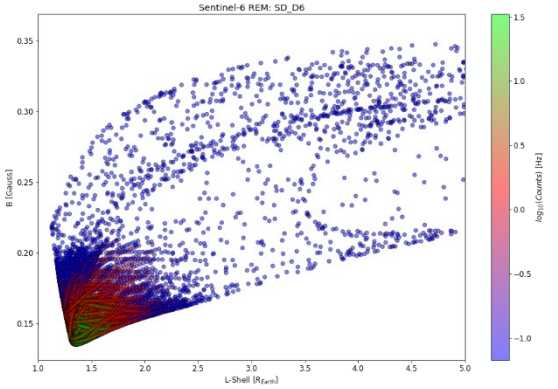
- Sentinel-6 flies in a 1336 km altitude orbit with 66° inclination

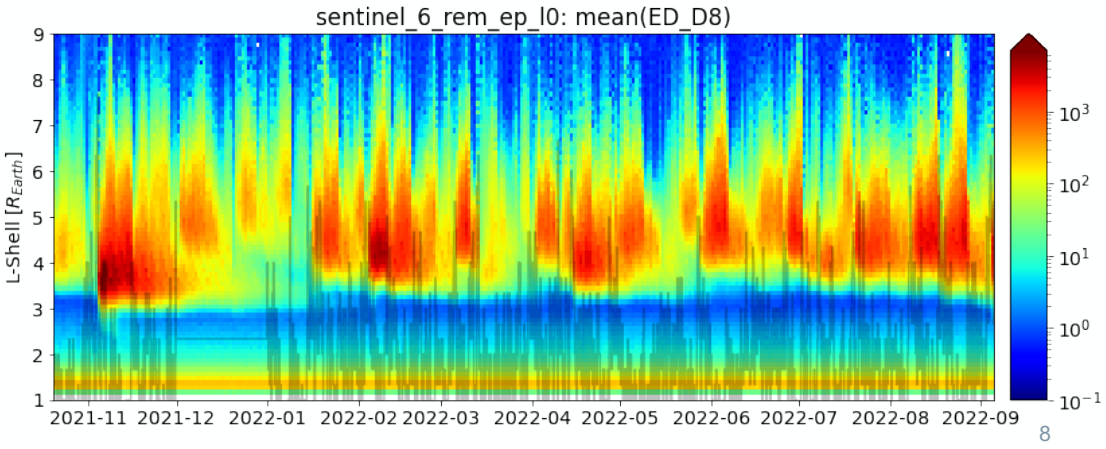




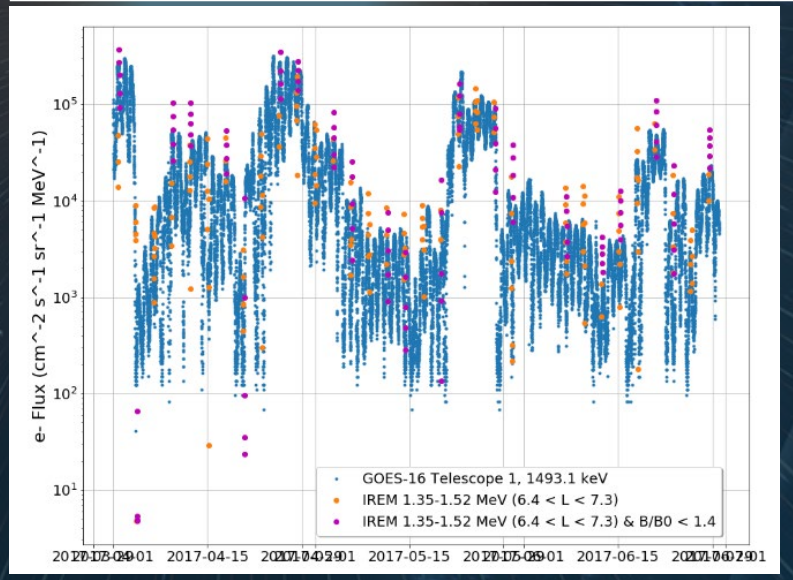


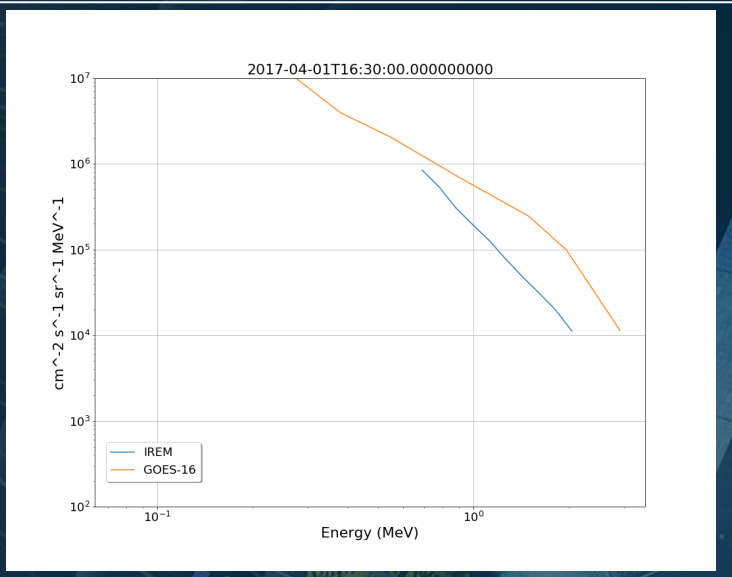


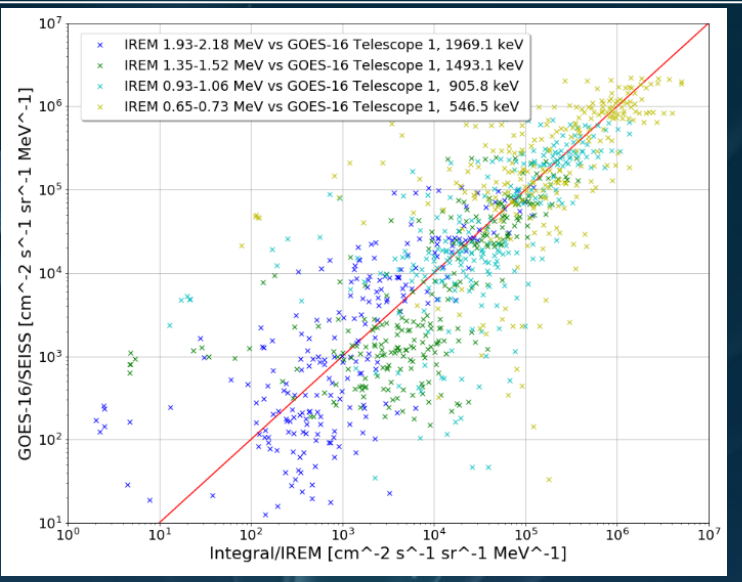


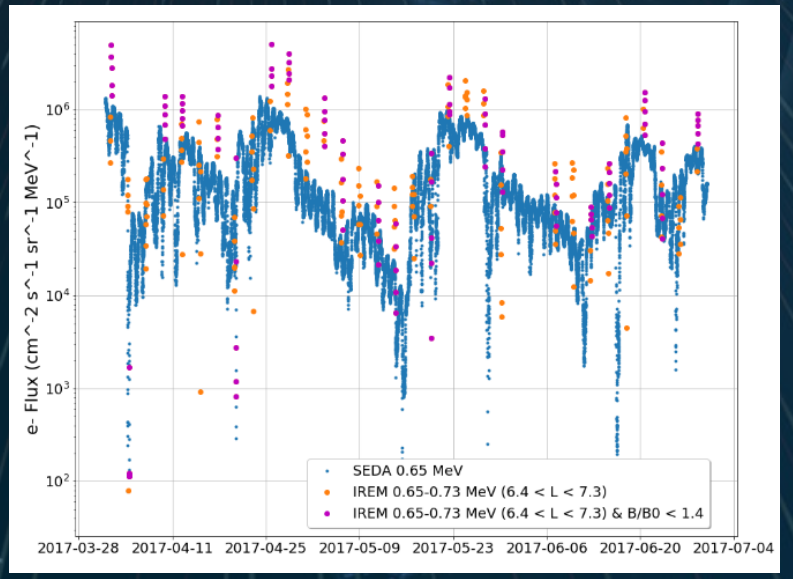


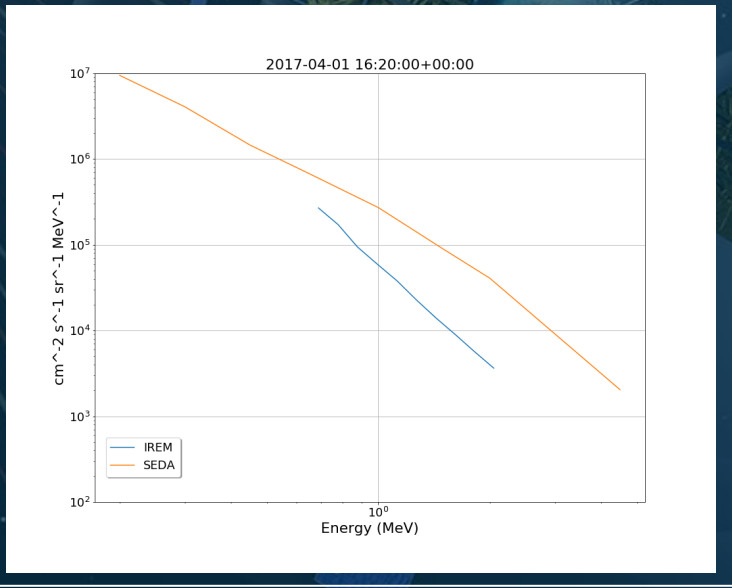
Cross-Comparisons with GEO measurements

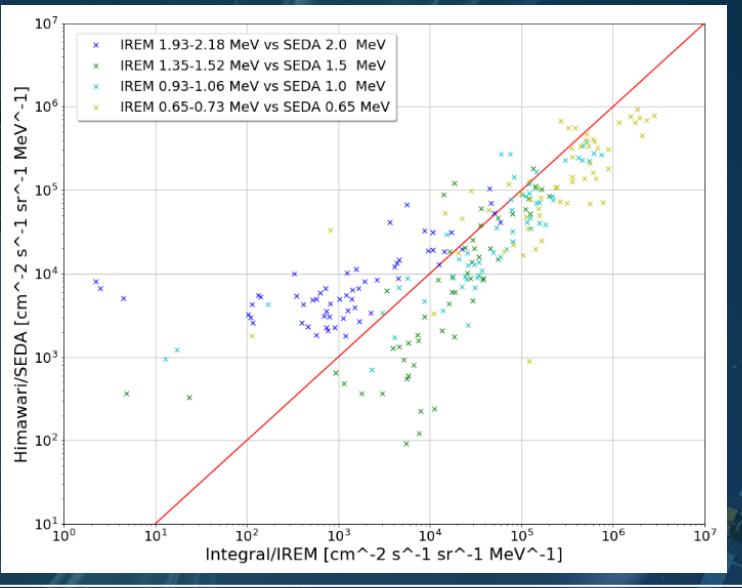












ESA’s operational particle radiation data

- Within the context of the Space Safety Programme (S2P) data can be accessed either through the web interface or related direct data access with use of S2P credentials.
- S2P data is served via a HAPI (Heliophysics Application Programming Interface)-compliant specified data interface meaning that the metadata is rather complete so when a user retrieves the data it is self-described.
- ESA pulls large datasets into local repositories for further exploitation, in particular where this is more efficient when performing a complete analysis over such datasets rather than "on-the-fly". These datasets are stored in a (MySQL ODI) database, and where the data is already a public resource made available with public API access.
- ESA respects the desires of the data providers to not have others re-serve their data to the public and provides full referencing and credit as appropriate.

Accessing the Data

- ESA provides databases access making use of the Heliophysics API (HAPI):
  https://cdaweb.gsfc.nasa.gov/registry/hdp/hapi/
- For development ESA's Open Data Interface (ODI) is a MySQL database providing numerous interfaces to programming languages
  - ODI Client Interfaces include: Python, IDL, Matlab, PHP, Java
- Data model based on the NSSDC/CDF file format tailored to COSPAR PRBEM dataset standard:
  https://prbem.github.io/documents/Standard_File_Format.pdf
- Access to datasets via direct database socket/port, REST or HAPI
- ESA worldwide open source license
- Export datasets to CDF or netCDF files for dataset distribution
- Operationally S2P provides data via ESA's Space Weather (SWE) portal
- This includes EDRS-C in GEO: https://swe.ssa.esa.int/ngrm
- More radiation data sets will be made available in real-time where possible

```
In [1]: import getpass
        import pandas as pd
        from datetime import date, timedelta
        from SWE_HAPI import SWE_HAPI as swh
        import matplotlib.pyplot as plt
        import numpy as np
        from datetime import datetime

        plt.rcParams['figure.figsize'] = [15,12]
        plt.rcParams['font.size'] = 14

In [2]: username='pjiggens'
        password=getpass.getpass(f'Password for {username} account:')

        Password for pjiggens account:·····

In [3]: s2ph = swh( username, password, debug=False)

In [4]: proton_energies = np.array([5.51, 8.8, 14.3, 33.92, 46.06, 76.24]) #from Sandberg et al. 2022

In [5]: search_term = 'edrsc.*ngrm.*bt'
        catalog=s2ph.get_hapi_catalog()
        ids = catalog.filter(regex=search_term,axis=0)

In [6]: print(f'{search_term} matching in IDs:')
        for i in ids['title'].values:
            print(f'    {i}')
        if len(ids) == 0:
            print(f'*** No dataset ids matching search_term pattern [{search_term}]')
            exit()

        edrsc.*ngrm.*bt matching in IDs:
            EDRS-C/NGRM integral electron and differential proton fluxes

In [7]: id = ids.index.values[0]
        title=ids['title'].values[0]
        if len(ids) > 1:
            print(f'More than one IDs match, using first: {id}')

        id = ids.index.values[0]
        print(id)
        info=s2ph.get_hapi_info(id)

        spase://SSA/NumericalData/EDRS-C/gsoc_edrsc_ngrm_spid204030252_science_ep_l1_bt_v3
```

HAPI interface to access EDRS-C/NGRM data

A note on standard vocabulary – Data Levels

- This is a starting point to understand what we mean in earlier slides.
- Sometimes all Level 1 data is listed as being fluxes which deviates from the definition from Lunar Gateway below

Data level	Definition	Distribution CGMS
Level 0	Raw, reconstructed, unprocessed instrument, payload, and platform Data; all communications artefacts, e.g., synchronization frames, communication headers, duplicate Data are removed. These Data will typically consist of binary CCSDS standard packets. On-ground calibration, testing and simulation Data, including the derived instrument response functions.	Not foreseen
Level 1A	Fully de-commutated but un-calibrated raw Data at full resolution, real time-referenced; also extracted telemetry item.	Not foreseen
Level 1B and Quicklook/Ops	Level 1B (extracted telemetry items) to which engineering calibrations have been applied; Data have been annotated with ancillary information (e.g., ephemeris, attitude Data) and initial instrument-level science calibrations have been applied. Scientific Data products that are generated using simplified science processing algorithms and/or with provisional calibrations. These Data are intended to provide basic scientific insight. Generation of these Data will occur as quickly as possible, whereas routine production of Level 2 (and higher) products may take considerably longer.	Public (real-time) To serve as Quicklook/Ops Data
Level 2	Level 2 Data have been processed from Level 1 Data to physical units and/or derived geophysical parameters by combining calibration, ancillary, and other Data (i.e. cross/inter-calibrations). These Data represent research grade scientific Data and exist at the same time and/or spatial resolution as Level 1 Data.	Public (<6 months after data capture)

Thoughts on GSICS “Operational Framework”

- With regard to particle radiation data, Framework should comprise of:
  - Central portal with documentation (standardised way of reporting)
  - Directs user to verified/official data sources
  - Example code for getting data in addition to guidelines for algorithms
- A portal for data discovery to serve results of inter-calibration efforts and documentation of those efforts.
- Reasons for framework to have only example code, documentation and links to points of access are:
  1. maintainability of the system;
  2. the requirement that end users get data from the source (we can see from the above that there are ways to accommodate this second requirement in a centralized framework however);
  3. the user should be encouraged to get data from as close to original source as possible.
- Contributing entities would
  - Provide and maintain their Data available pointed to from the framework/portal in Level 1b (real-time) and Level 2 (within ~6 months). This should include API (+ file-based) access.
  - description of data (metadata) so the data can be used
  - Some description of instrument and its calibration (and preferably response functions) for getting to Level 1b
  - Inter-calibration report (inter-calibration parameters) with "gold standard“ for getting to Level 2