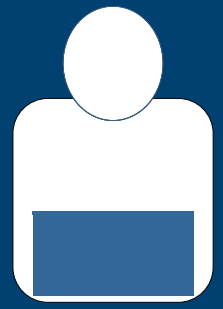
VirES

Earth Observation Scientists



VRE

Virtual Research Environment

VirES for Swarm

Providing accessibility to Swarm products

Martin Pačes, EOX IT Services, GmbH

DASH 2024, 2024-10-16, ESAC

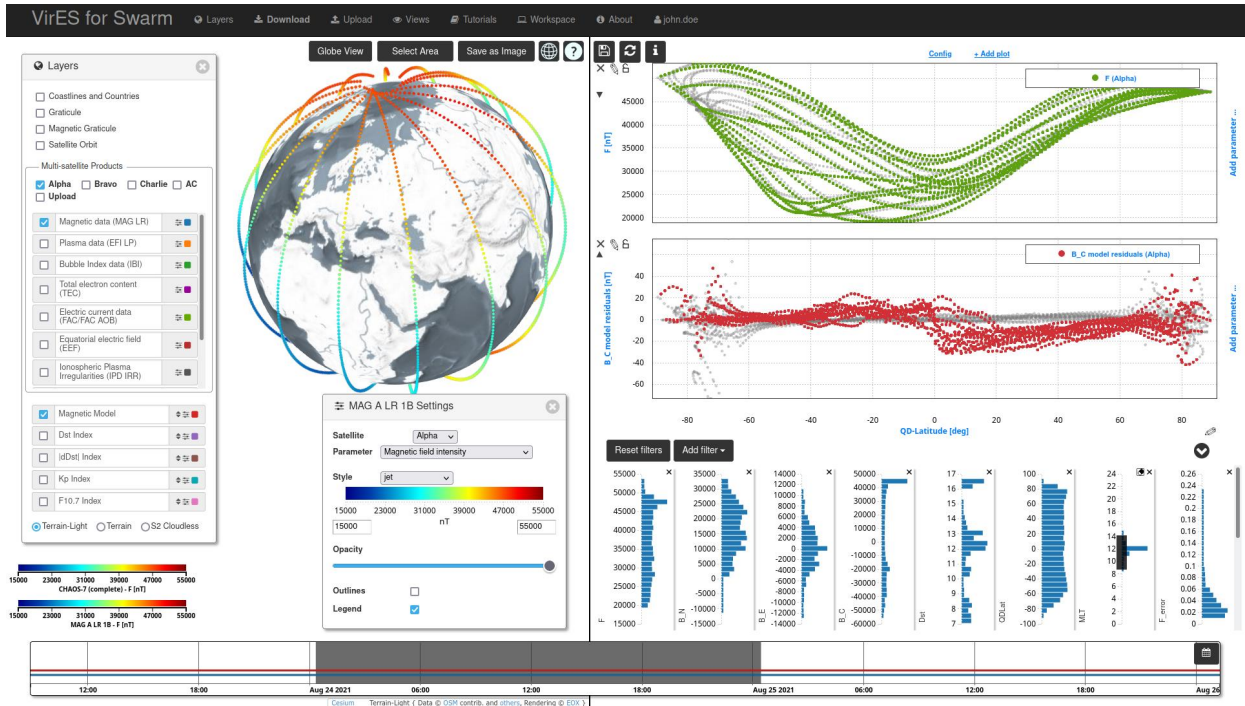
VirES for (not only) Swarm

VirES = Virtual Workspaces for **EO S**cientists

EOX IT Services contracted by ESA to develop, maintain and operate the VirES for Swarm service in close collaboration with scientist.

History of VirES for Swarm:

- 2014 start of the TRP project
- 2015 pilot selected for TO
- 2016 opened for public use (web GUI only)
- 2019 opens API data access
  + VirES Python client
  + Virtual Research Environment (VRE, JupyterHub)
- 2021 data from other missions and ground obs.
- 2022 HAPI data access



About EOX IT Services

based in Vienna, Austria; since 2008, team of 29 persons

- Development and operation of EO data services
- Open-Source SW development
- Maps and satellite map layers

https://eox.at

Swarm Mission

ESA Earth Explorer mission (Earth observation scientific missions)

- In orbit since 2013, might be flying until early 2030s
- Constellation of 3 identical satellites
  - Low near-polar orbit (alt. <500km)

Scientific Focus:

- core dynamics, core-mantle interaction
- lithospheric magnetization
- mantle conductivity
- electric currents in magnetosphere and ionosphere

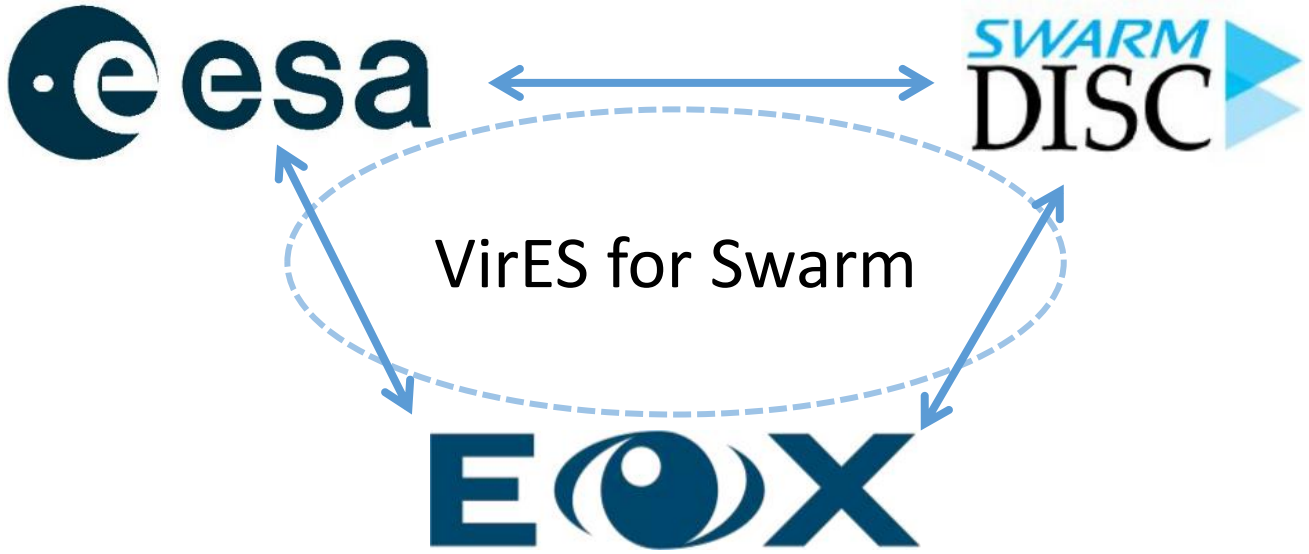
Sensors:

- MG: scalar (ASM) and vector (VFM) magnetometers
- EFI: Langmuir Probe (LP), Thermal Ion Imager (TII)
- other: Accelerometer, GPS receiver, start tracker … etc.

Close collaboration with Scientists

Scientific community represented by Swarm DISC, led by DTU Space

(Swarm DISC = Swarm Data, Innovation, and Science Cluster)



VirES for Swarm – Data Provider

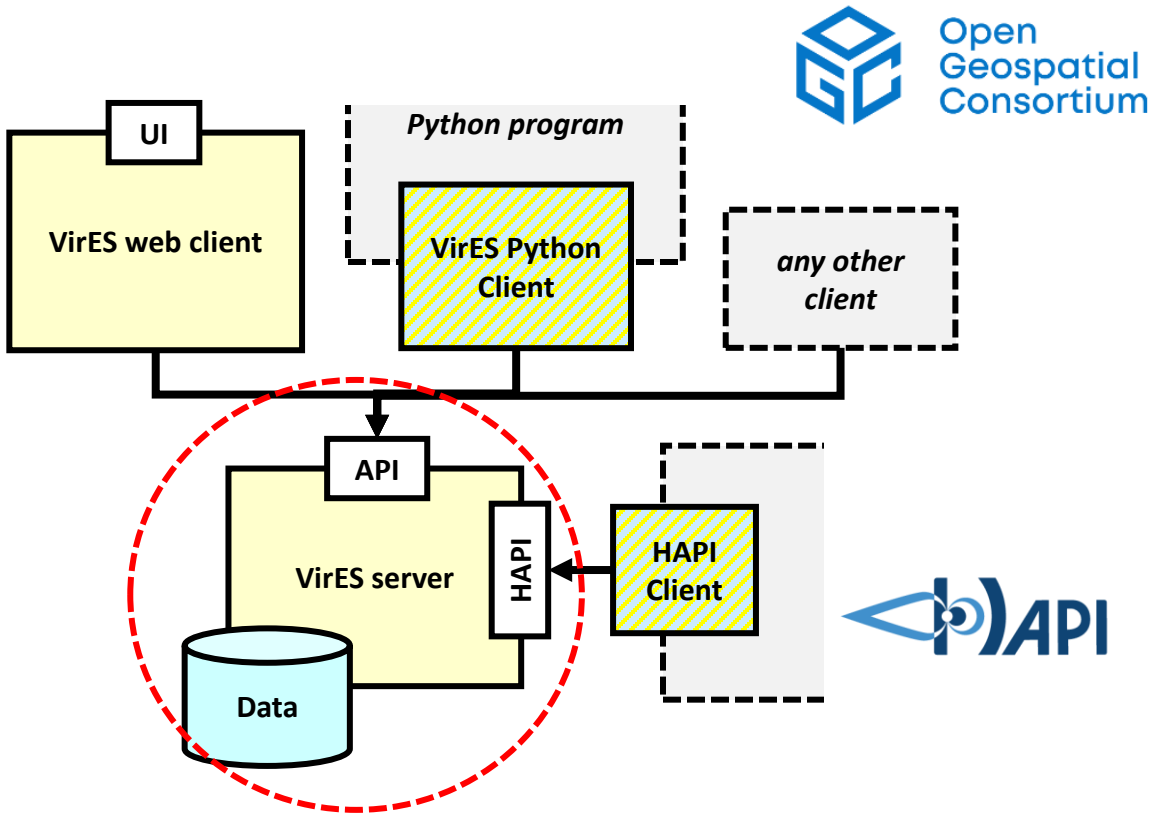
APIs to access VirES data:

VirES API

based on OGC standards

HAPI

+ larger ecosystem of services and tools



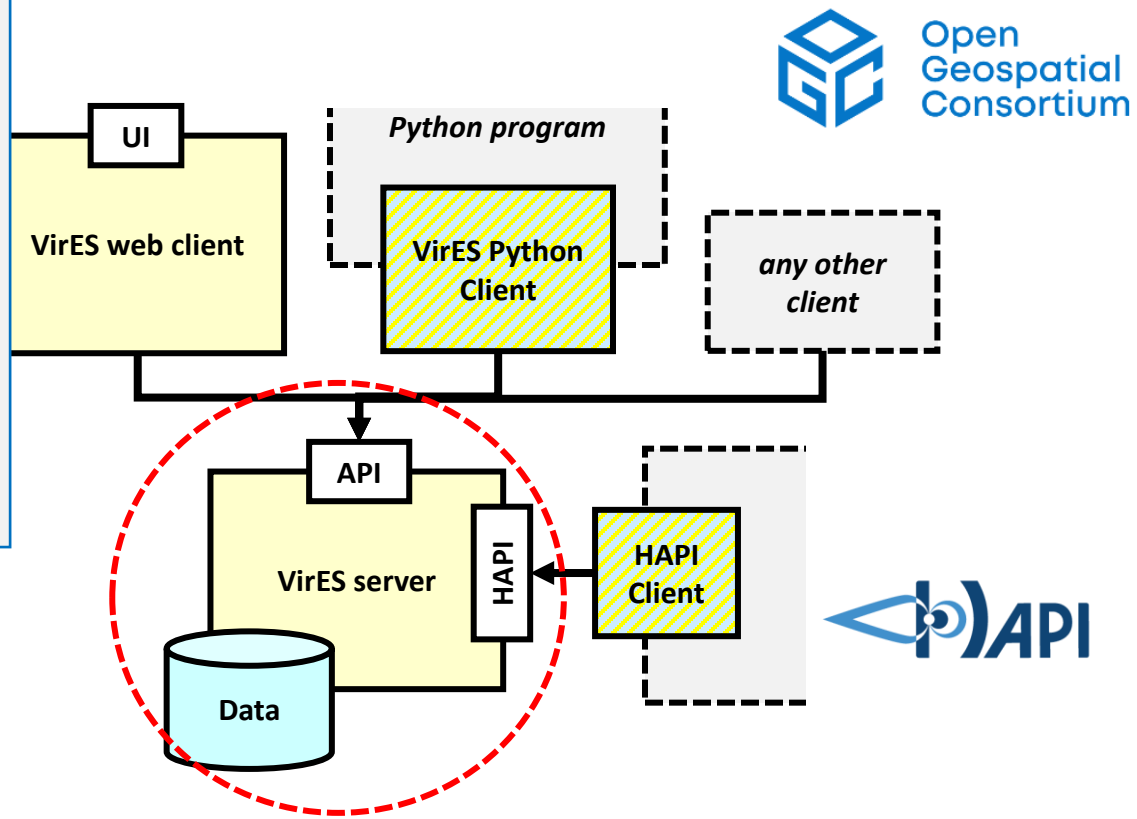
VirES for Swarm – Data Provider

VirES API

- Originally developed to serve the Web GUI
- Feature rich
- Customized to meet to app. requirements:
  - filtering by various parameters
  - selection of geo-magnetic models

  … etc.

+ larger ecosystem of services and tools



VirES for Swarm – Data Provider

VirES API

- Originally developed to serve the Web GUI
- Feature rich
- Customized to meet to app. requirements:
  - filtering by various parameters
  - selection of geo-magnetic models

… etc.

+ larger ecosystem of services and tools

Heliophysic API

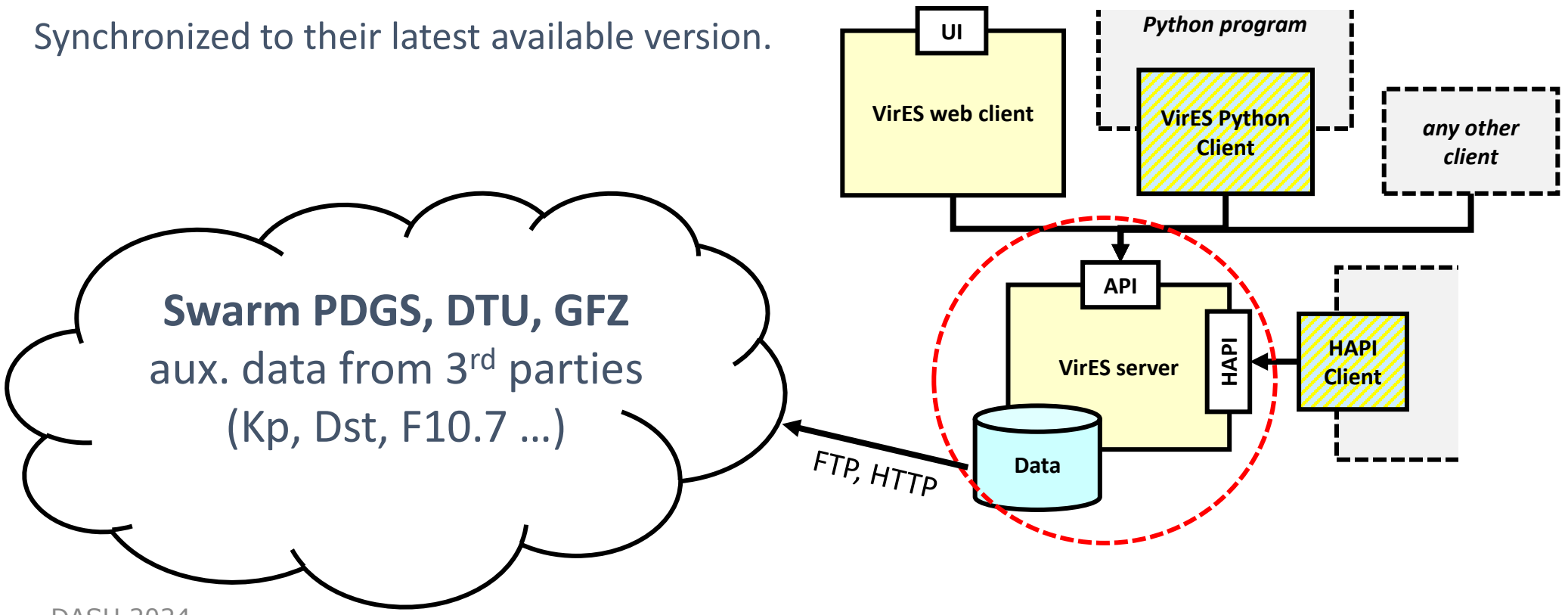
- Community standards – interoperability
- Limited in features compared to the native API
  - Not meant to replace the native API
- Fits perfectly the VirES time-series data model
  - New interface to the data engine
  - VirES adds calculated variables (mag. model residuals)

https://vires.services/hapi

VirES for Swarm – Data Sources

Source data mostly as CDF and text files.

Synchronized to their latest available version.



VirES for Swarm – Server

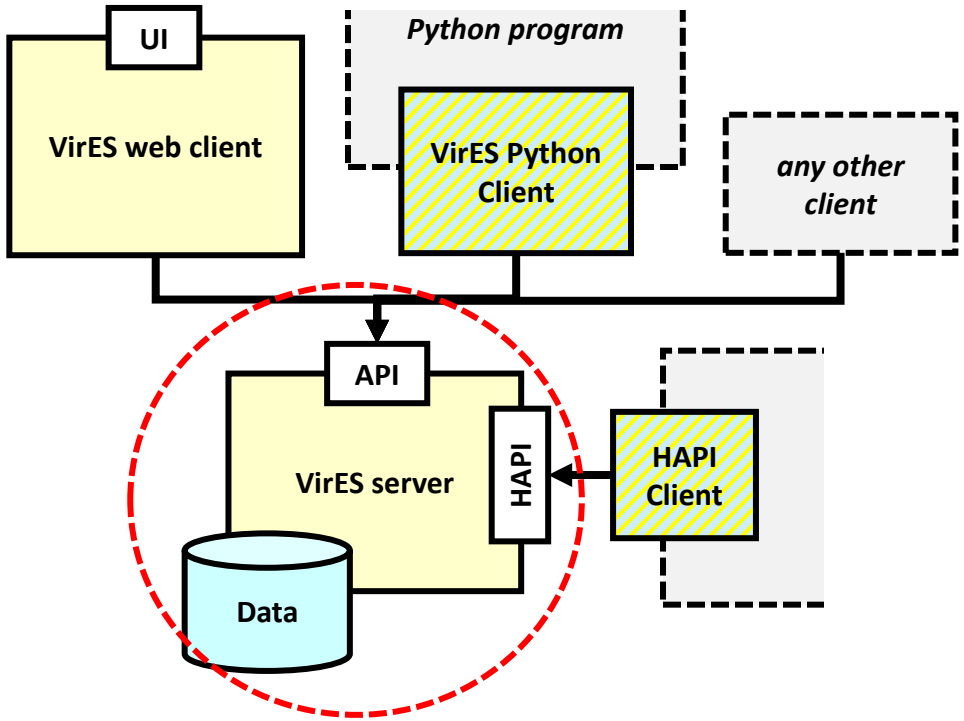
Python + Django

… and dependencies

Open Source: MIT license

Deployment:

- EOX owned collocated HW
- rented “bare metal”
- Hot-backup (geographically separated)



VirES for Swarm – Data

Spaceborne magnetic measurements (MAG):

Swarm A,B,C
- MAGx_LR_1B
- MAGx_HR_1B

CHAMP
CryoSat 2
GOCE (+ ML calibrated)
GRACE 1,2
GRACE-FO 1,2 (+ ML calibrated)

Ground observatory measurements (AUX_OBS):

INTERMAGNET 1h, 1m, 1s

Virtual Observatory data (VOBS):

Swarm A,B,C
CHAMP
CryoSat 2
Oersted
combined

Other Swarm products:

MODx_SC_1B
EFIx_LP_1B
EFIxIDM_2_
EFIxTIE_2_
EFIx_TCT02
EFIx_TCT16
EEFxTMS_2F
FACxTMS_2F
TECxTMS_2F
IBIxTMS_2F
IPDxIRR_2F
AEJxLPL_2F
AEJxLPS_2F
AEJxPBL_2F
AEJxPBS_2F
AOBxFAC_2F
MITx_LP_2F
MITxTEC_2F
PPIxFAC_2F
SW_DNSxACC_2_
SW_DNSxPOD_2_
CH_DNSxACC_2_
CH_WNDxACC_2_
GR_DNSxACC_2_
GR_WNDxACC_2_
GF_DNSxACC_2_
GF_WNDxACC_2_
MM_CON_EPH_2_

Magnetic models:

CHAOS MCO (MCO_SHA_2X)
CHAOS MLI
CHAOS MMA (MMA_CHAOS_)
IGRF-13
MCO_SHA_2C
MCO_SHA_2D
MCO_SHA_2F

LCS1
MF7
MLI_SHA_2C
MLI_SHA_2D
MLI_SHA_2E

MMA_SHA_2C
MMA_SHA_2F

AMPS
MIO_SHA_2C
MIO_SHA_2D

Swarm FAST L1B products:

MODx_SC_1B
MAGx_LR_1B
MAGx_HR_1B
EFIx_LP_1B

Swarm FAST L2 products:

FACxTMS_2F

VirES for Swarm – Data

Principle types of data served by VirES

- time-series
- geo-magnetic Models – SH coefficients
  - evaluated for given times and locations

INTERMAGNET 1h, 1m, 1s

Virtual Observatory data (VOBS):

Swarm A,B,C
CHAMP
CryoSat 2
Oersted
combined

:
ISxACC_2_
ISxPOD_2_
ISxACC_2_
IDxACC_2_
ISxACC_2_
IDxACC_2_
ISxACC_2_
IDxACC_2_
N_EPH_2_

IPDxIRR_2F
AEJxLPL_2F
AEJxLPS_2F
AEJxPBL_2F
AEJxPBS_2F
AOBxFAC_2F
MITx_LP_2F
MITxTEC_2F
PPIxFAC_2F

Magnetic models:

CHAOS MCO (MCO_SHA_2X)
CHAOS MLI
CHAOS MMA (MMA_CHAOS_)
IGRF-13
MCO_SHA_2C
MCO_SHA_2D
MCO_SHA_2F

LCS1
MF7
MLI_SHA_2C
MLI_SHA_2D
MLI_SHA_2E

MMA_SHA_2C
MMA_SHA_2F

AMPS
MIO_SHA_2C
MIO_SHA_2D

Swarm FAST L1B products:

MODx_SC_1B
MAGx_LR_1B
MAGx_HR_1B
EFIx_LP_1B

Swarm FAST L2 products:

FACxTMS_2F

VirES for Swarm – Data

Principle types of data served by VirES

- time-series
- geo-magnetic Models – SH coefficients
  - evaluated for given times and locations

~6TB of data

~260k product files in 124 collections

INTERMAGNET 1h, 1m, 1s

Virtual Observatory data (VOBS):

Swarm A,B,C
CHAMP
CryoSat 2
Oersted
combined

Magnetic models:

CHAOS_MCO_(MCO_SHA_2X)

LCS1
MF7
MLI_SHA_2C
MLI_SHA_2D
MLI_SHA_2E
MMA_SHA_2C
MMA_SHA_2F
AMPS
MIO_SHA_2C
MIO_SHA_2D

IPDxIRR_2F
AEJxLPL_2F
AEJxLPS_2F
AEJxPBL_2F
AEJxPBS_2F
AOBxFAC_2F
MITx_LP_2F
MITxTEC_2F
PPIxFAC_2F

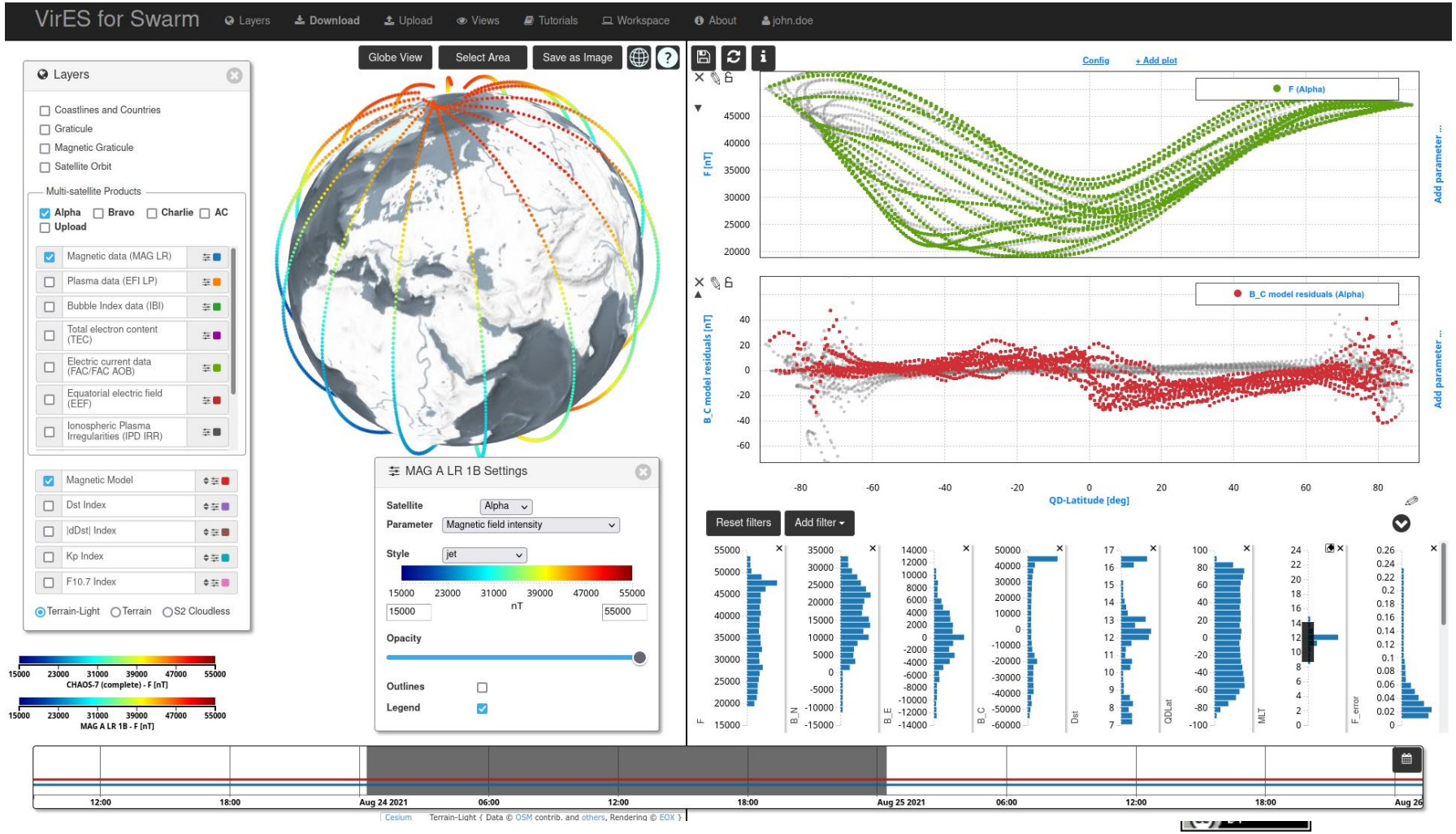
MAGx_HR_1B
EFIx_LP_1B

Swarm FAST L2 products:

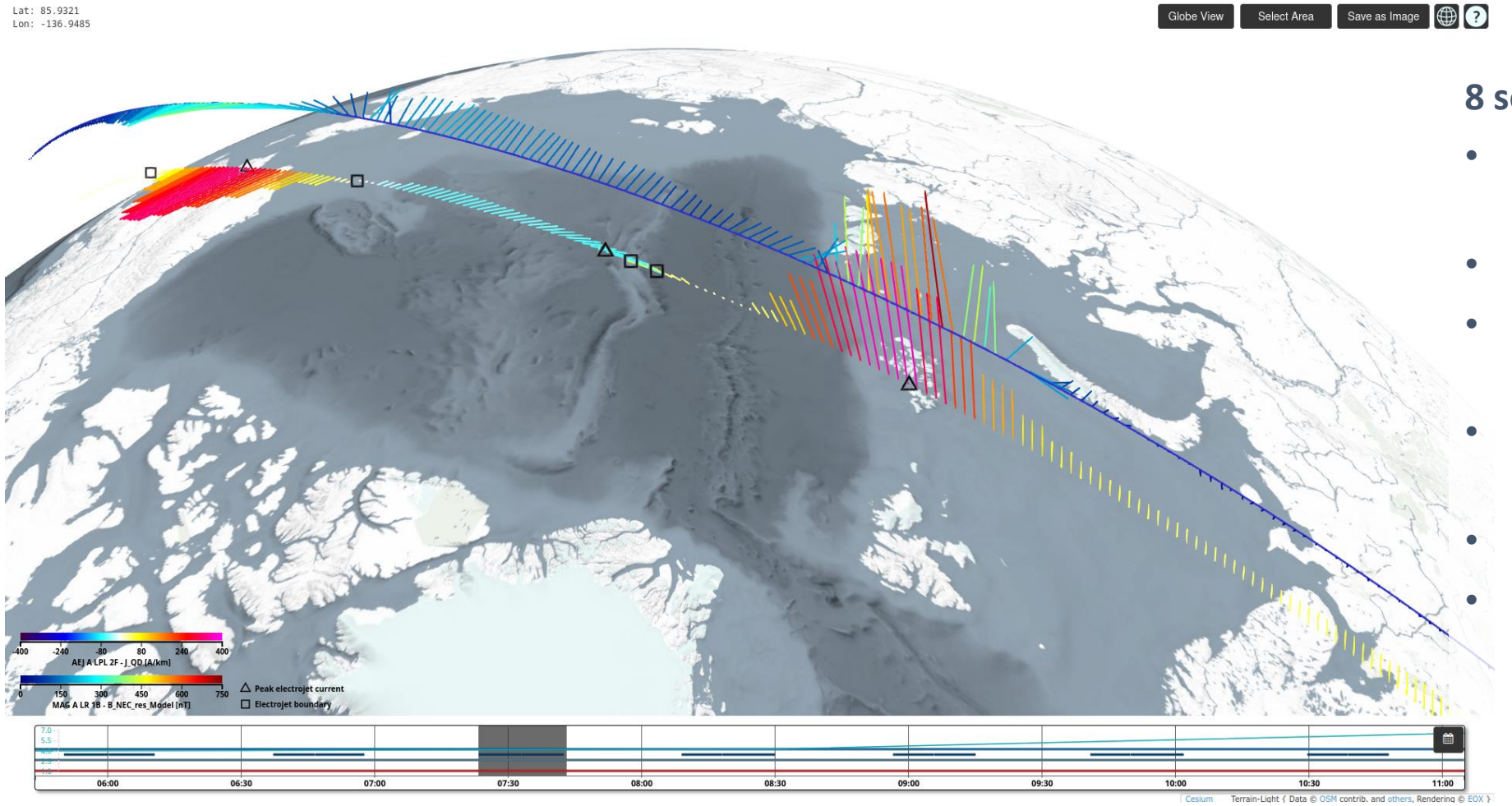
FACxTMS_2F

VirES for Swarm – Data Visualization Platform

- time of interest selection
- on-line interactive data exploration
- data filtering by various parameters
- filtered data subset download



VirES for Swarm – Data Comparison



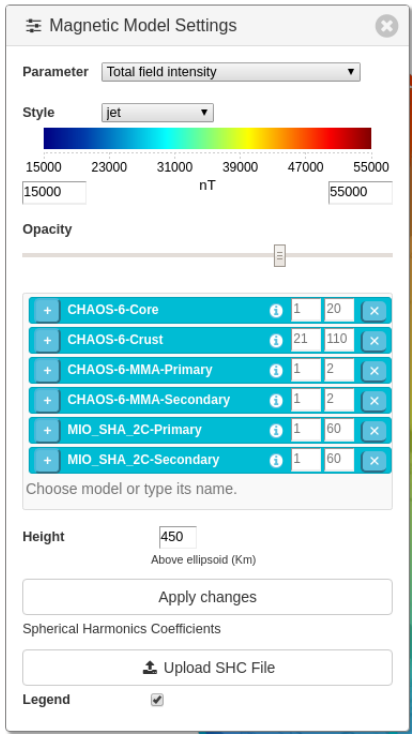
8 source datasets:

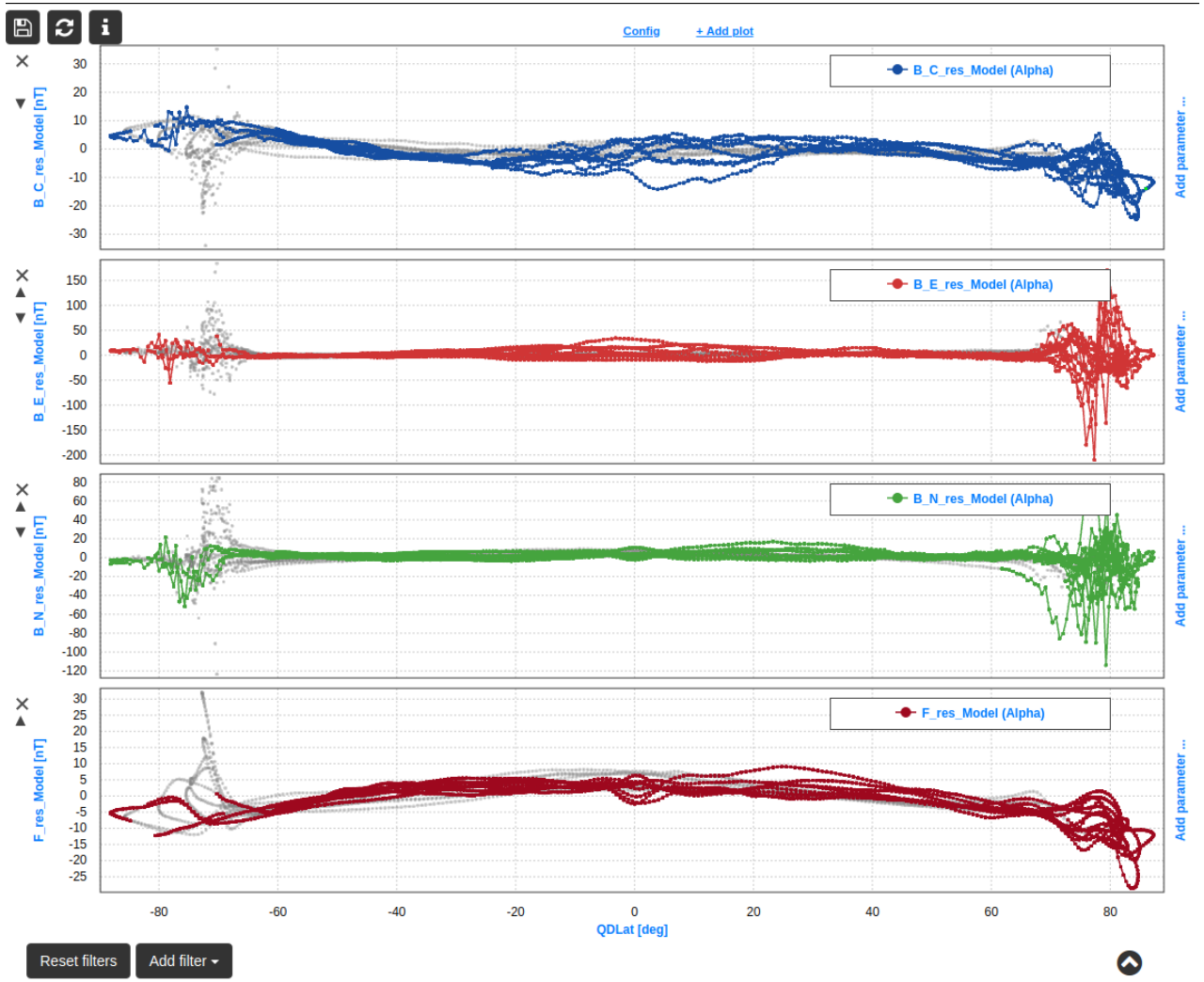
- **Kp index** (time selection of moderate solar activity, Kp ~4)
- **MODx_SC_1B** (Swarm-A orbit)
- **MAGx_LR_1B** (VFM measurements)
- **CHAOS** (combined **core**, **crust** and **MMA** models)
- **AEJxLPL_2F** (sheet currents)
- **AEJxPBL_2F** (electrojet peaks and boundaries)

VirES for Swarm – Magnetic Models

Model residuals:

- **Day side only** (6 < MLT < 18)
- **MAGx_LR_1B**
- **CHAOS Core**
- **CHAOS Crust**
- **CHAOS MMA**
- **MIO_SHA_2C**





VirES for Swarm – Magnetic Models

Magnetic Model Settings

Parameter: Down component

Style: diverging_1

-2.5 -1.5 -0.5 0.5 1.5 2.5

nT

-2.5 2.5

Opacity

+ MLI_SHA_2C 16 120 ×

− MLI_SHA_2D 16 130 ×

Choose model or type its name.

Height 450

Above ellipsoid (Km)

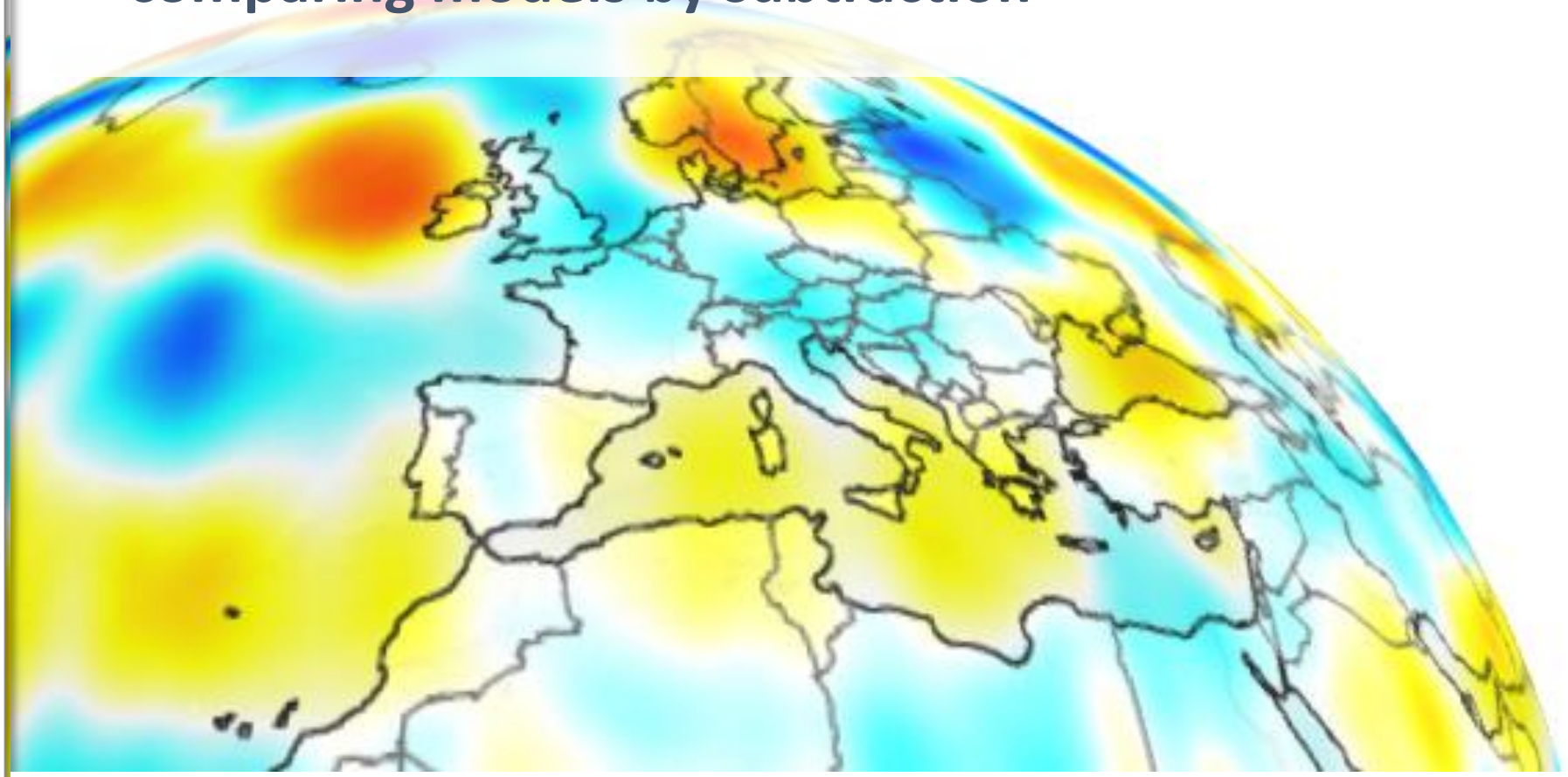
Apply changes

Spherical Harmonics Coefficients

Upload SHC File

Legend

comparing models by subtraction

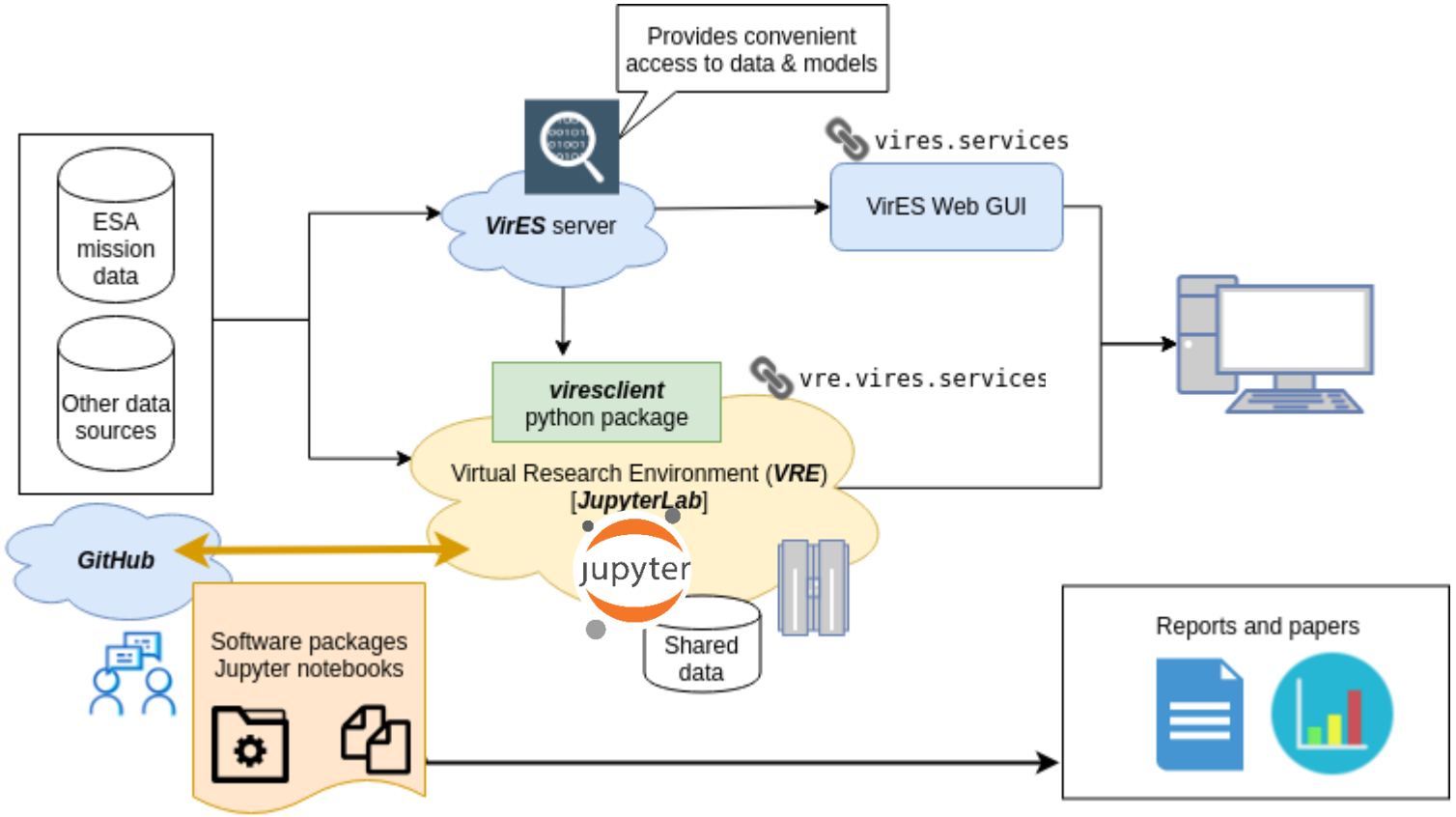


VirES for Swarm – Data API

```python
from viresclient import SwarmRequest
request = SwarmRequest()
request.set_collection("SW_OPER_MAGA_LR_1B")
request.set_products(
    measurements=["B_NEC"],
    models=["CHAOS-Core"],
    auxiliaries=["QDLat", "QDLon"],
    sampling_step="PT15S"
)
data = request.get_between(
    start_time="2021-08-01T00:00",
    end_time="2021-08-01T01:00"
)
print(data.as_xarray())
```

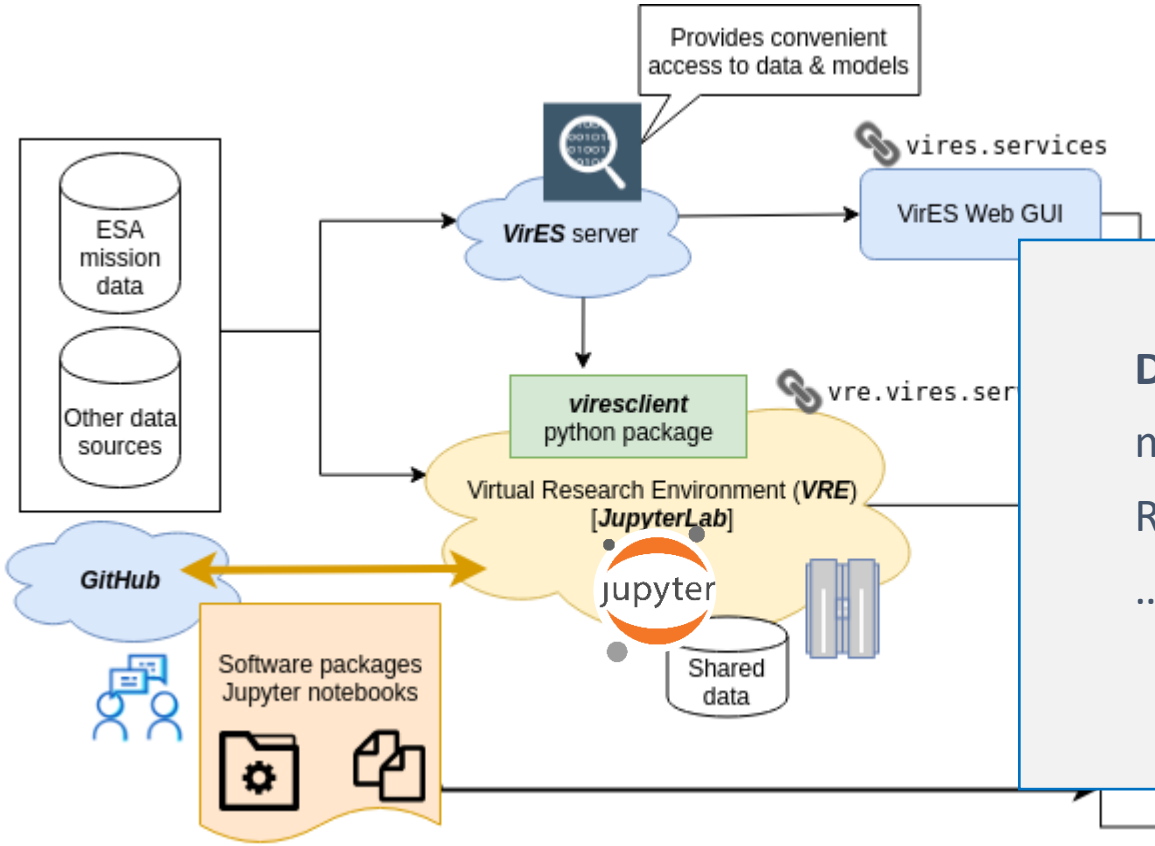
```
Processing:  100%|                    |  [ Elapsed: 00:01, Remaining: 00:00 ] [1/1]
Downloading: 100%|                    |  [ Elapsed: 00:00, Remaining: 00:00 ] (0.08MB)
<xarray.Dataset>
Dimensions:            (NEC: 3, Timestamp: 240)
Coordinates:
  * Timestamp          (Timestamp) datetime64[ns] 2021-08-01 ... 2021-08-01T00...
  * NEC                (NEC) <U1 'N' 'E' 'C'
Data variables:
    Spacecraft         (Timestamp) object 'A' 'A' 'A' 'A' 'A' ... 'A' 'A' 'A' 'A'
    B_NEC_CHAOS-Core   (Timestamp, NEC) float64 2.547e+04 4.683e+03 ... 3.989e+04
    B_NEC              (Timestamp, NEC) float64 2.546e+04 4.662e+03 ... 3.991e+04
    QDLat              (Timestamp) float64 -3.864 -4.848 -5.833 ... 51.36 52.41
    Longitude          (Timestamp) float64 -148.1 -148.1 -148.1 ... 20.53 20.61
    Radius             (Timestamp) float64 6.811e+06 6.811e+06 ... 6.801e+06
    Latitude           (Timestamp) float64 -5.516 -6.48 -7.445 ... 54.98 55.94
    QDLon              (Timestamp) float64 -74.54 -74.38 -74.21 ... 96.33 96.65
Attributes:
    Sources:          ['SW_OPER_MAGA_LR_1B_20210801T000000_20210801T235959_050...
    MagneticModels:   ["CHAOS-Core = 'CHAOS-Core'(max_degree=20,min_degree=1)"]
    RangeFilters:     []
```

Virtual Research Environment (VRE)



- shared computing environment with preinstalled tools
- intended for Swarm data exploration
- for those who find the VirES web UI too limiting
- web based interface
- based on Jupyter notebook

Virtual Research Environment (VRE)



- shared computing environment
  with preinstalled tools
  n data
  the VirES
  e
  otebook

Deployed in AWS

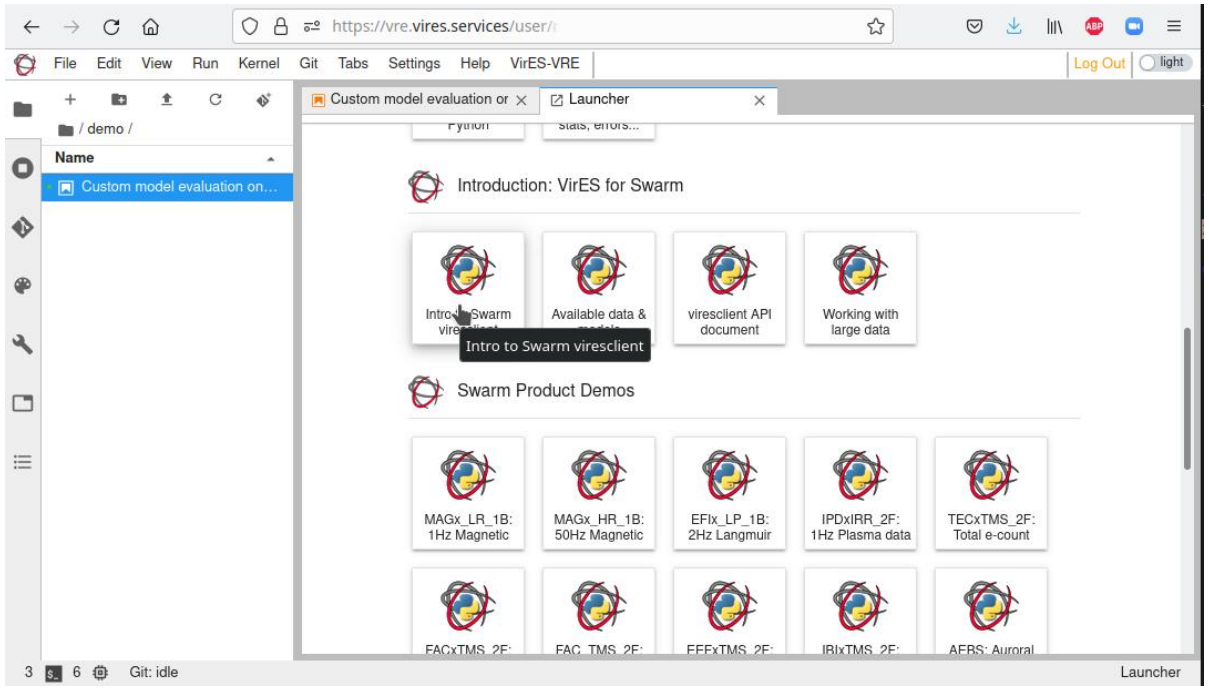
managed Kubernetes cluster

Resources scaled according to the usage

… within capacity limits agreed with ESA

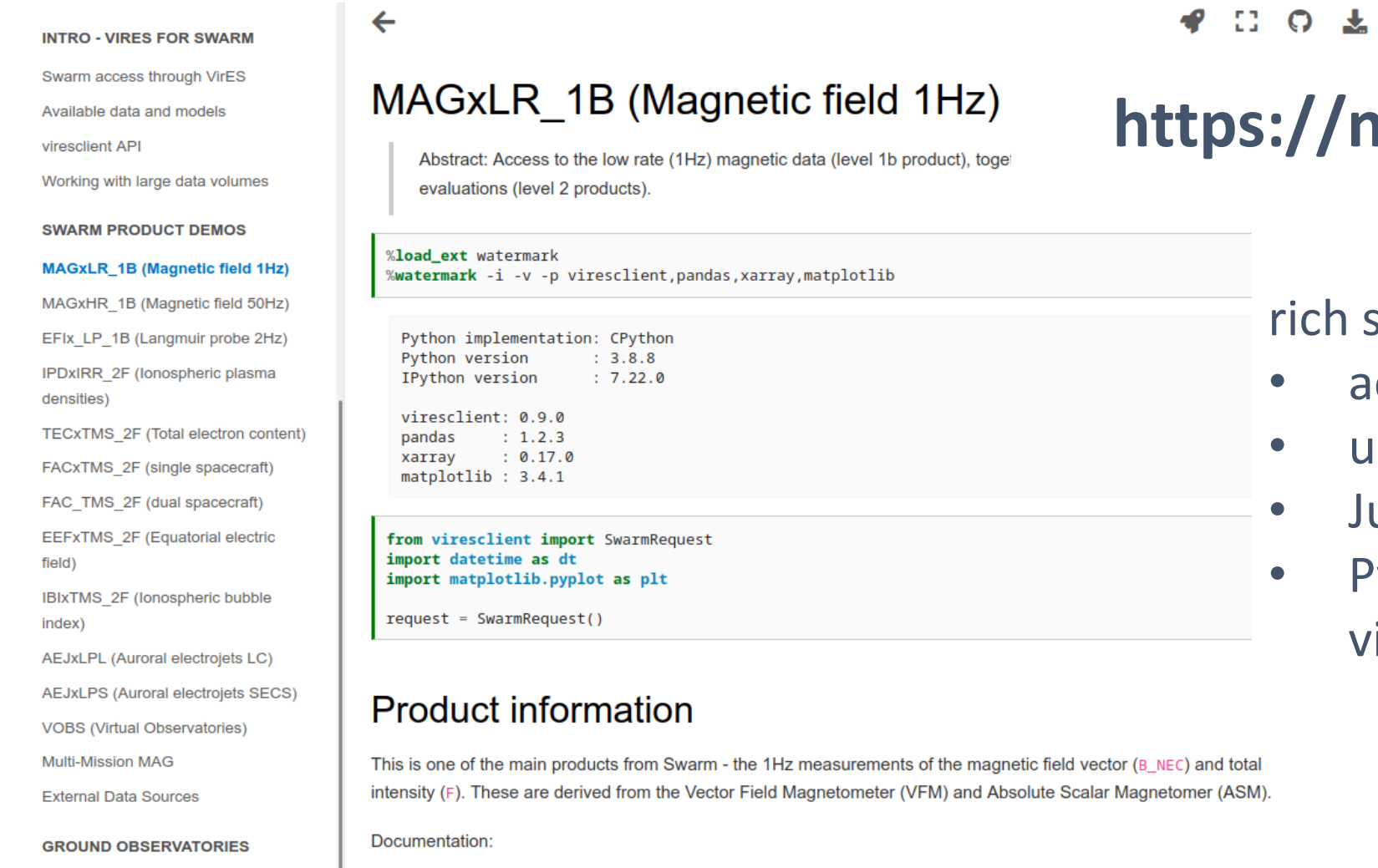
Virtual Research Environment (VRE)

https://vre.vires.services



- Python Jupyer kernels + CLI (C, C++, Fortran)
- Git integration (nbgitpuller, UI git controls)
- Numpy, Scipy, Pandas, Xarrays, Dask (data manipulation)
- Matplotlib, Cartopy (visualization)
- VirES Python client (Swarm data access)
- HAPI client (3rd party data)
- Thematic libraries
  - eoxmagmod (the VirES model library)
  - chaosmagpy
  - magpysv
  - apexpy
  - pyAMPS
  - SwarmPyFAC
  - IBP

VRE – Library of Tutorial Notebooks



https://notebooks.vires.services

rich set of examples demonstrating:

- access to VirES datasets
- use of the VRE tools
- Jupyter Notebook capabilities
- Python data processing and visualization

explore VirES & VRE

https://vires.services

https://vre.vires.services

https://notebooks.vires.services

https://vires.services/hapi