OMERE

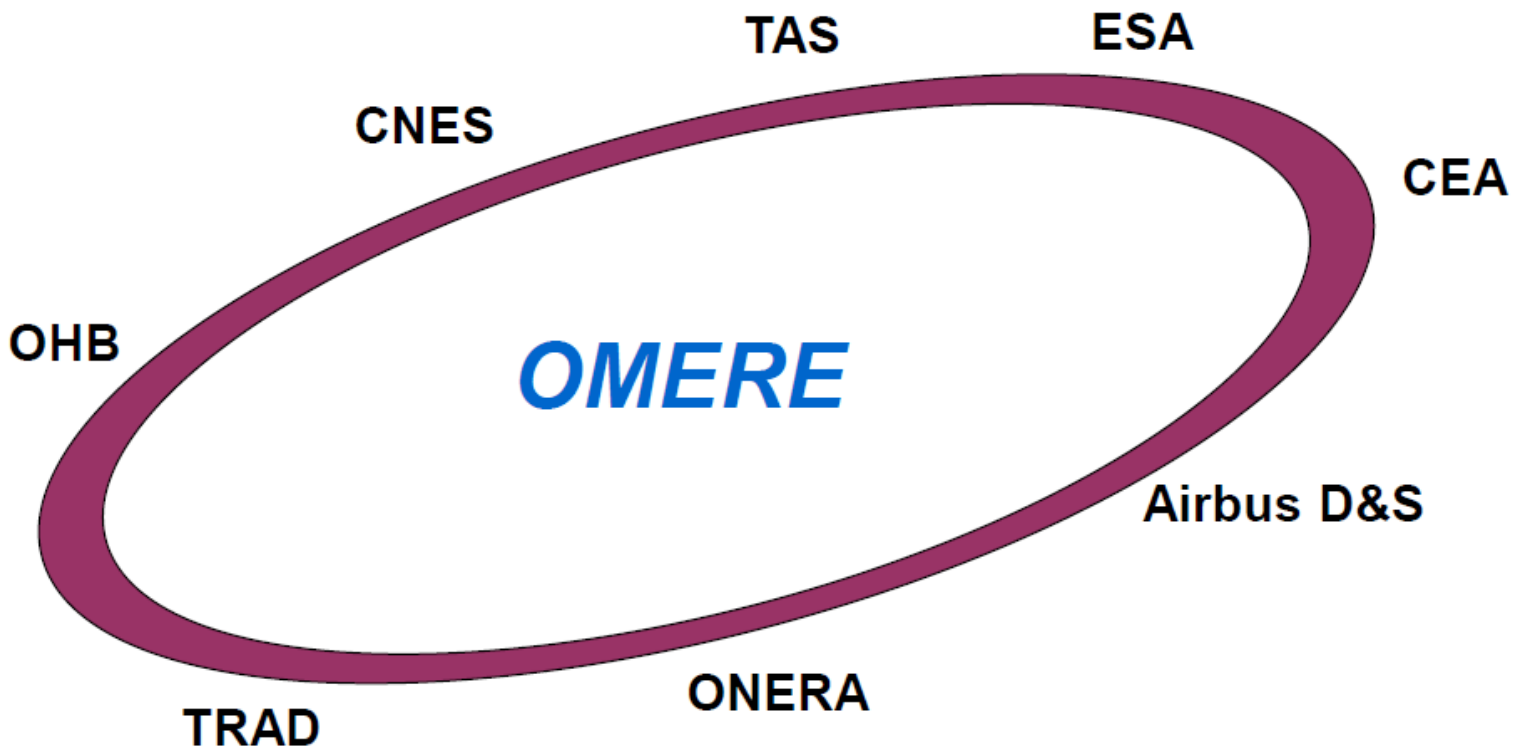
Introduction

The OMERE software

- The project
  - Since 1999
  - TRAD development with CNES support
  - Freeware for space radiation environment and effects on electronic components
  - Stand alone software (no internet connection needed)
  - Conceived to meet industrial requirements
  - Integrates ONERA models
  - Integrates outcomes of Research and Technology projects financed by CNES
  - Coupling with FASTRAD.

The OMERE software

- The partnership

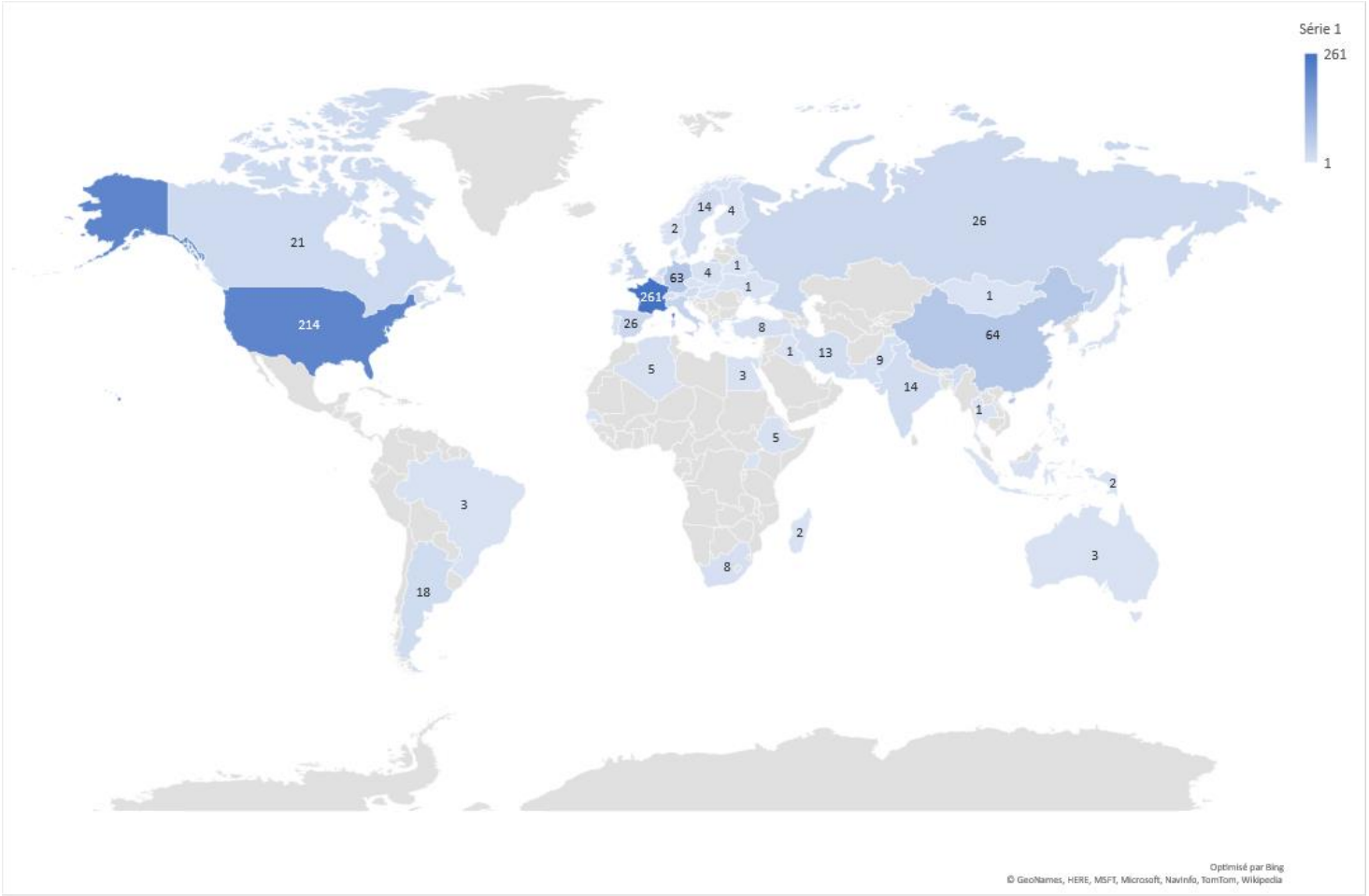


OMERE in summary

- OMERE software
  - One major release per year
  - Support for users
  - Training
  - Radiation analysis

- Total number of downloads

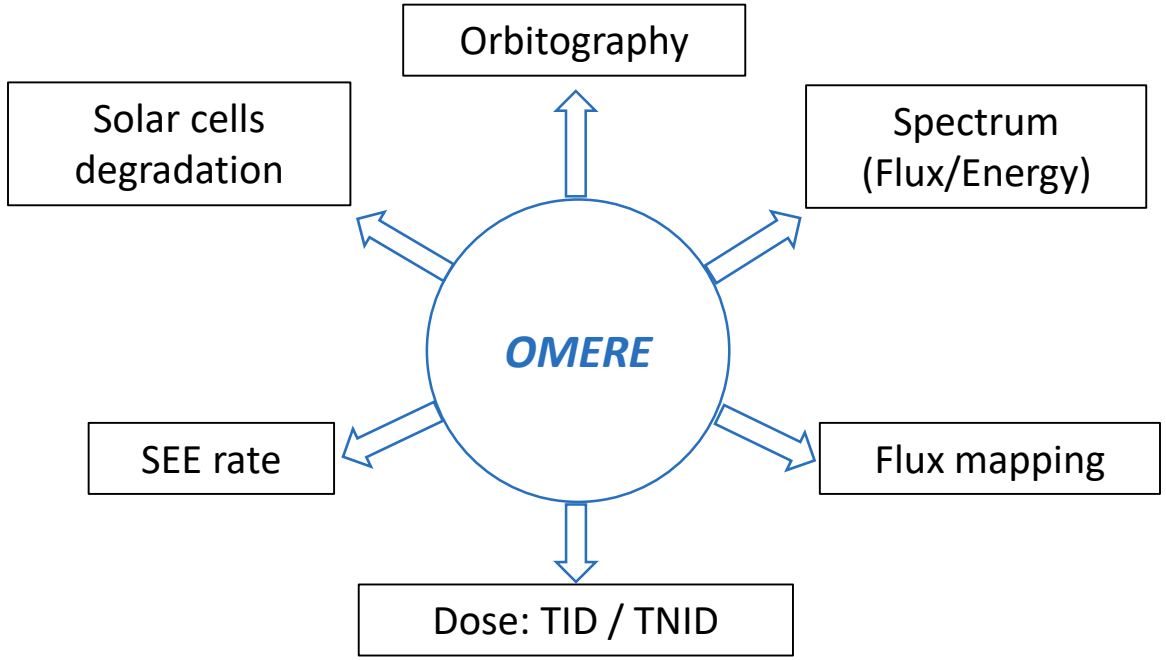
	2017	2018	2019	2020	2021
Total	410	583	682	722	998



Downloads of OMERE in 2021

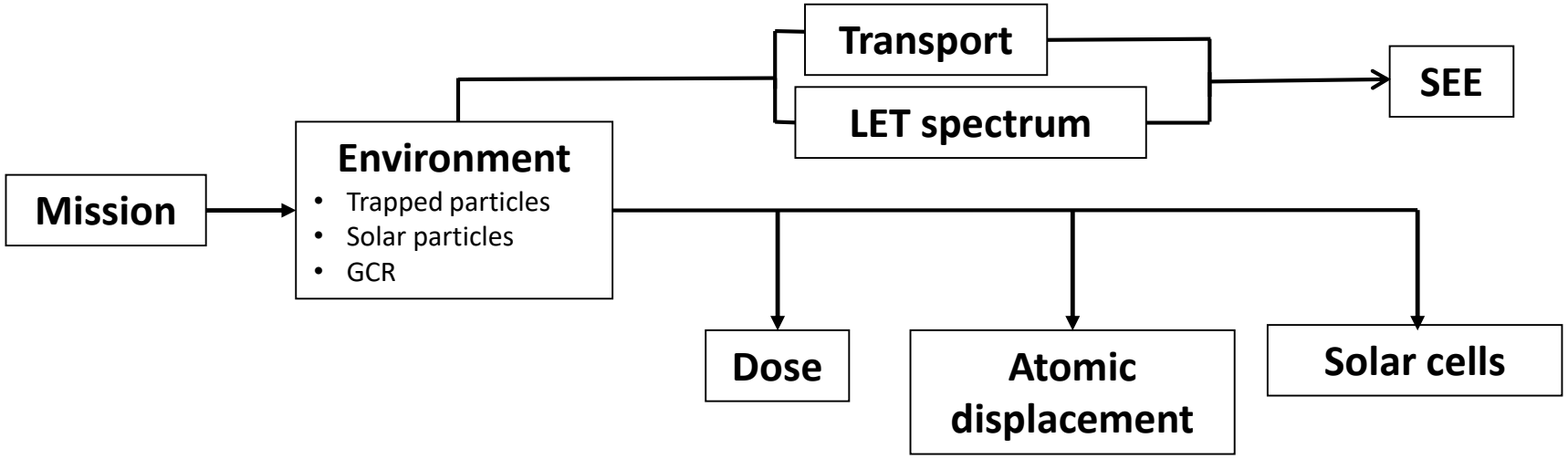
OMERE in summary

- OMERE software
  - What can we do with OMERE ?

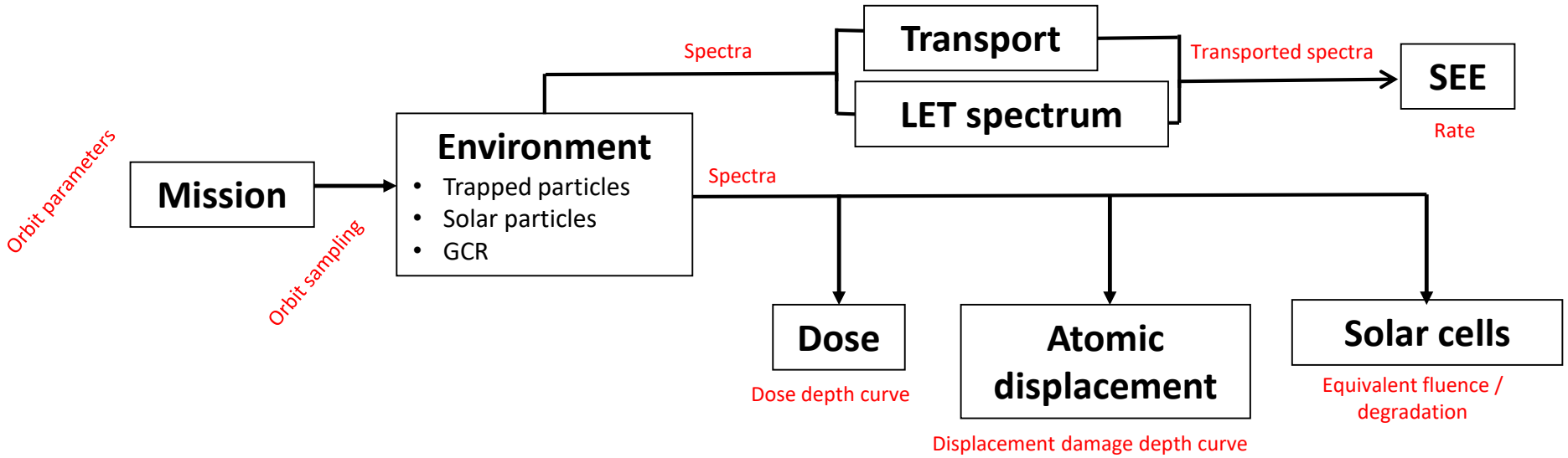


OMERE’s architecture and overview

Software's architecture

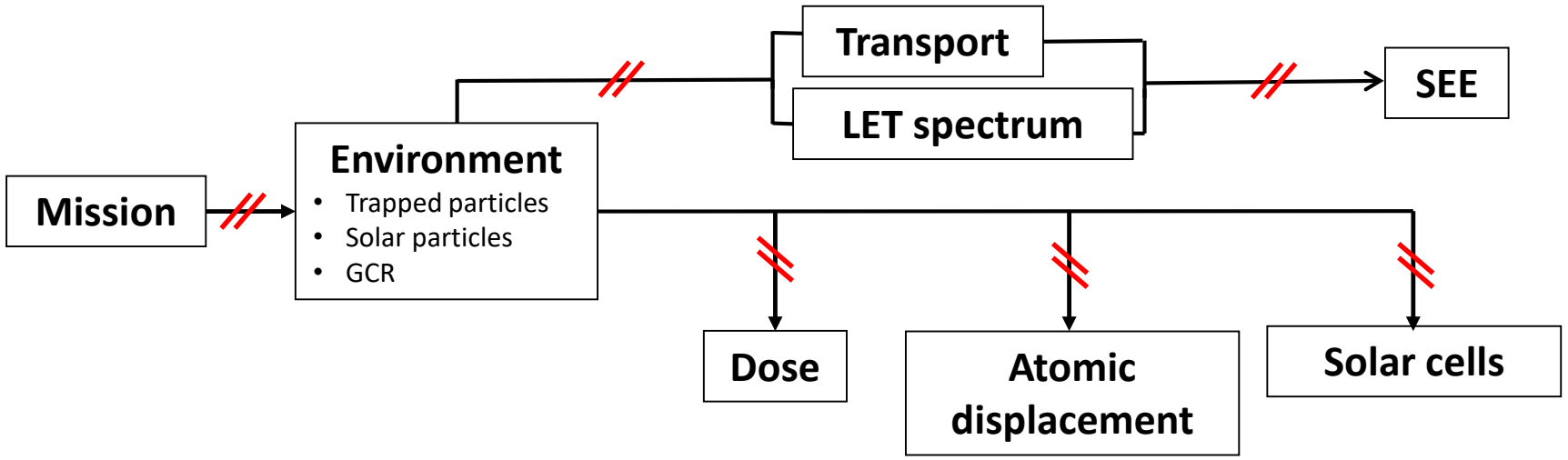


Software's architecture



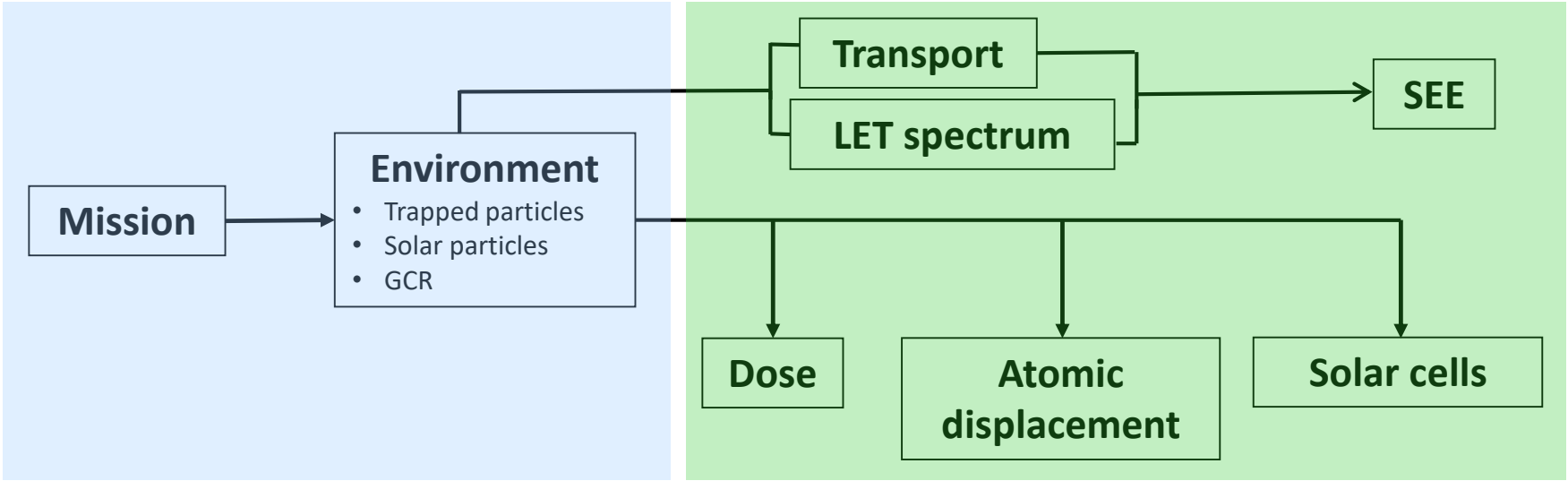
- Output files
  - Each module generates a specific output file
  - Each output file has its own extension:
    - .flx / .fle for **Environment** module
    - .dos for **Dose** module
    - .see for **SEE** module
    - …

Two usages strategies



- From mission
  - Calculation is done considering the inputs/parameters set in the other modules
  - No need to calculate the output for each module
- From files //
  - User can input an orbit file instead of generating the mission with the orbit parameters
  - E.g., user can input the spectra instead of calculating them with OMERE

Software's architecture



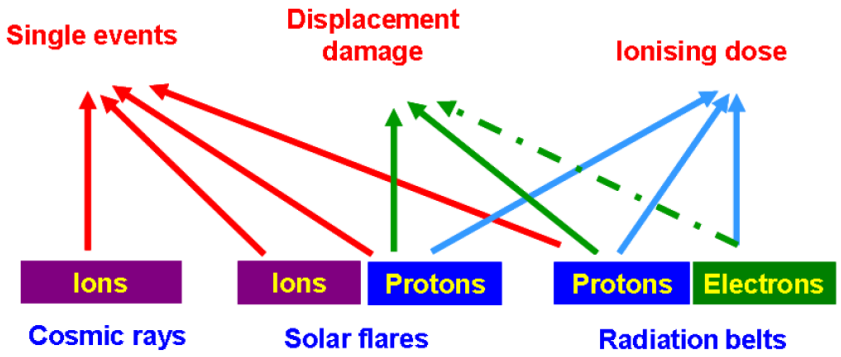
- **1- Determines the spectra around the spacecraft**
  - Isotropic environment
  - No shielding considered

- **2- Estimates the effects on components**
  - SEE rate, ionizing dose, non-ionizing dose
  - Shielding: simple geometry only

Why a simple shielding ?

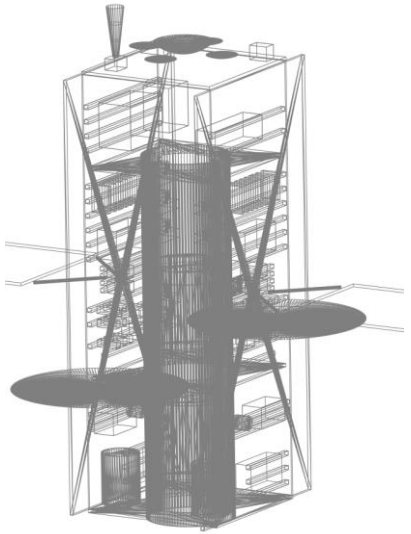
- Impact of the shielding depends on the source
  - Heavy ions: weakly impacted
  - Protons, electrons: strongly impacted

- Particles type per effect :



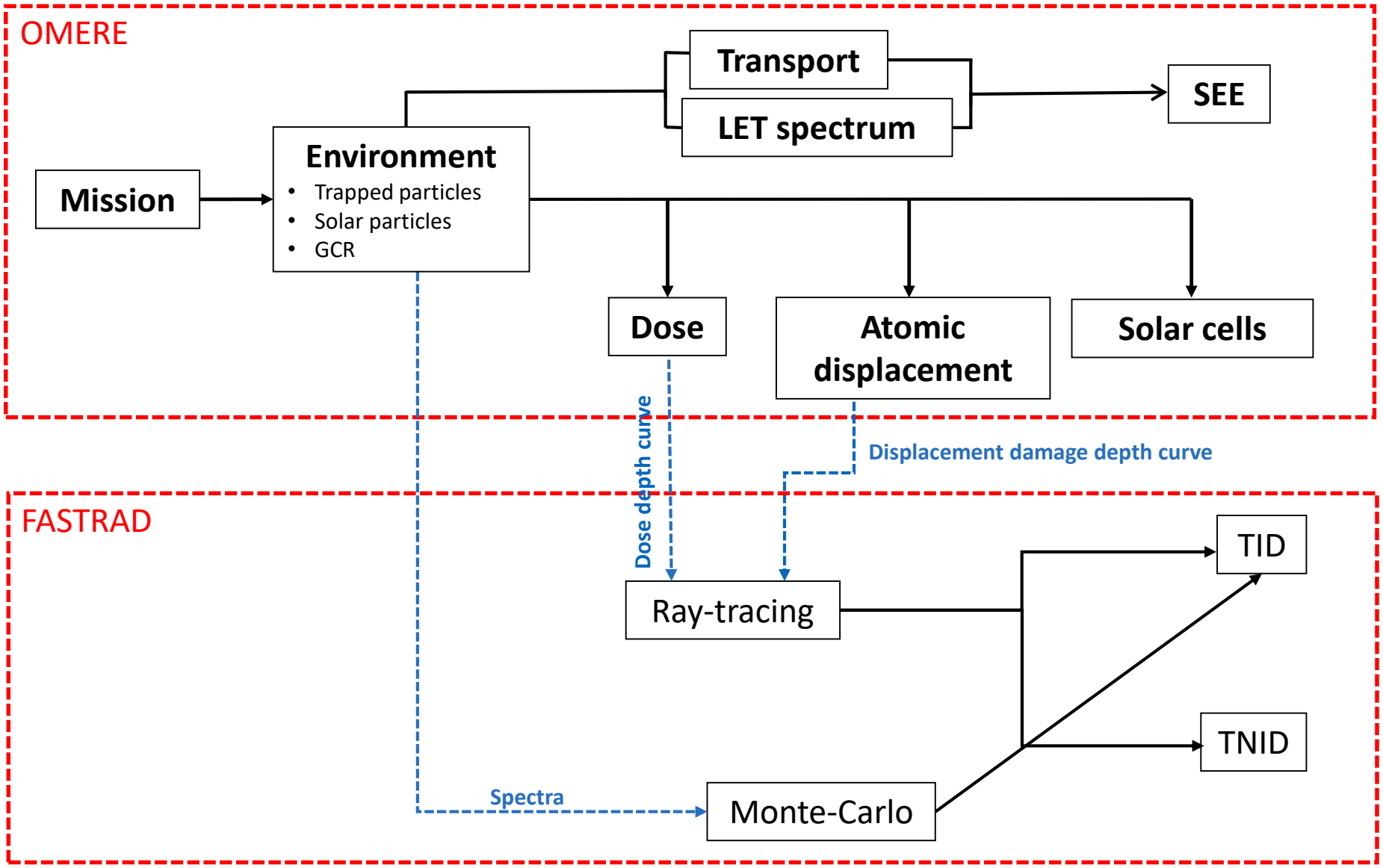
- Considering the shielding:
  - The simple geometry approach is appropriate for SEE rate
  - A complex geometry must be considered for the dose calculation

A simple shielding geometry



A complex shielding geometry

OMERE/FASTRAD coupling



Output types

- Outputs:
  - **Mean calculation**: mean values for the entire mission
  - **Instantaneous flux**: value at any time
  - **Along the orbit**: values for every points of the orbit
  - **Proton peak flux**: duration and flux of each SAA crossing

	Trapped		Solar		GCR	Transp.	LET spec.	Dose	Atomic disp.	SEE	Solar cells
	Ele	Pro	Aver.	Flares							
Mean on the mission	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Instant flux	✓	✓	✓			✓					✓
Along the orbit	✓	✓	✓				✓	✓	✓	✓	✓
Proton peak flux		✓									

See help menu for examples

Output types

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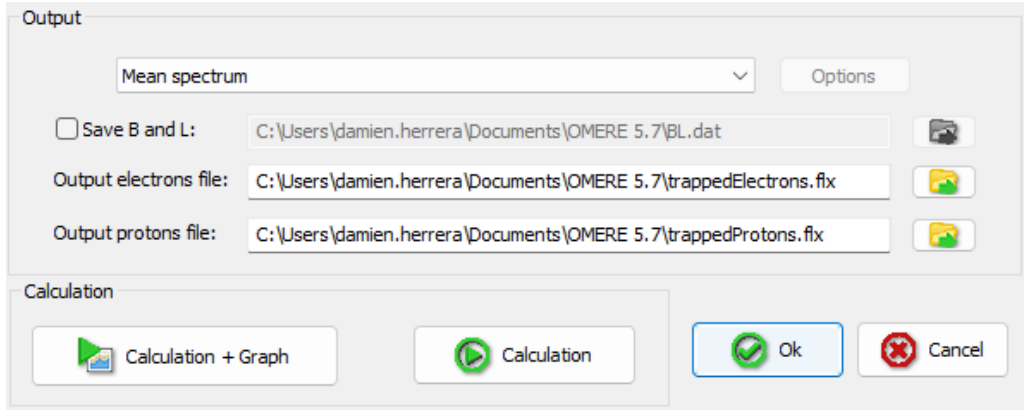
Along the orbit	✓	✓	✓				✓	✓	✓	✓	✓
Proton peak flux		✓									

See help menu for examples



- Stored in your personal workspace
  - File → Default directory

Output files

- Typical output file structure:
  - A file is generated for each calculation

```
#================================================================
# OMERE 5.7.0.34019 - Trapped electrons flux file
#
# File: C:\Users\damien.herrera\Documents\OMERE 5.7\trappedElectrons.flx
# Creation: 26/09/2023 11:47:51
#================================================================

# Model : MEO average case
# Start year: 2023

# Use the default model energy grid

# == Orbit 1/1 ==
# Orbit data :
# Name :                                Orbit Galileo GSAT0101
# Duration :                            12 year(s)
# Perigee :                             23222.000000km
# Apogee :                              23222.000000km
# Inclination :                         56.000°
# Argument of Perigee :                 0.000°
# Longitude of Ascending node :         253.703°
# (with respect to Greenwich)
# True Anomaly :                        15.153°
# Period :                              50681.772s
# Number of orbits :                    17
# Number of points per orbit :          50

# Energy spectrum :
#    Energy  Differential flux  Integral flux
#       MeV      cm-2.s-1.MeV-1       cm-2.s-1
    0.2800        3.94034e+07    1.00570e+07
    0.4000        2.65366e+07    6.32133e+06
    0.5600        1.27928e+07    3.00766e+06
    0.8000        4.20282e+06    1.24496e+06
    1.1200        1.35325e+06    4.79440e+05
    1.6000        3.29694e+05    1.38461e+05
    2.2400        6.33599e+04    3.58784e+04
```

Header : OMERE version, file path…

Space environment model information

Orbit / Mission information

Output data : energy spectrum, dose rate along the orbit…

Summary

- OMERE allows us to:
  - Compute the radiative environment around the spacecraft
  - Estimate the effect behind a simple geometry shielding

- Considering a simple geometry for the shielding:
  - Fair approach for SEE calculation
  - Not for the dose at component level (only dose curves)

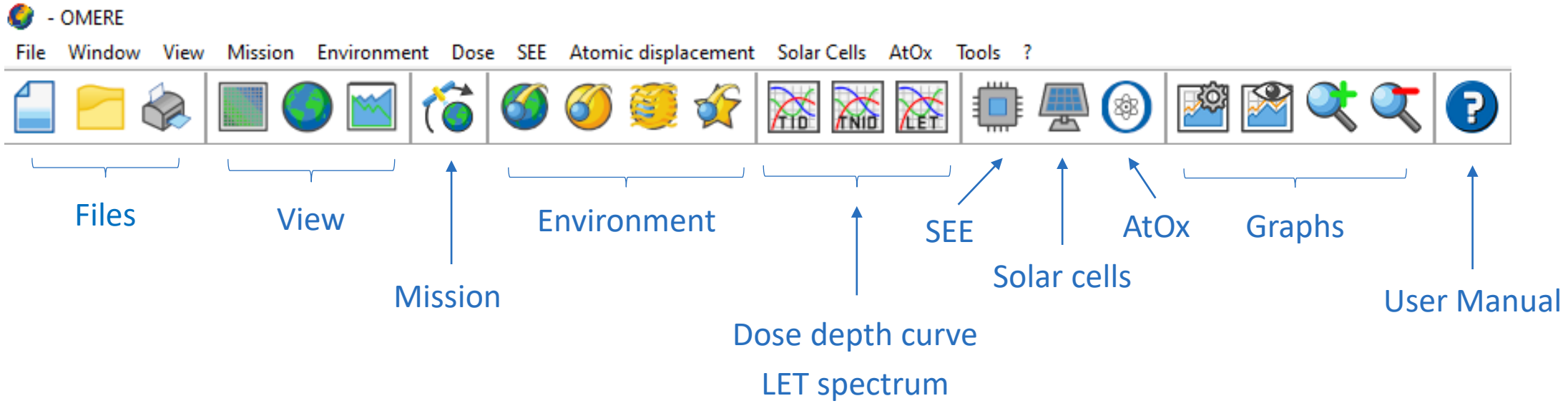
OMERE's main features

- Shortcuts
- Mission
- Environment
- Dose
- Atomic Displacement
- Single Event Effects
- Solar Cells
- Tips and advices

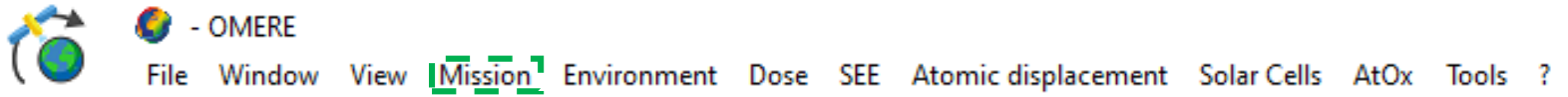
Shortcuts

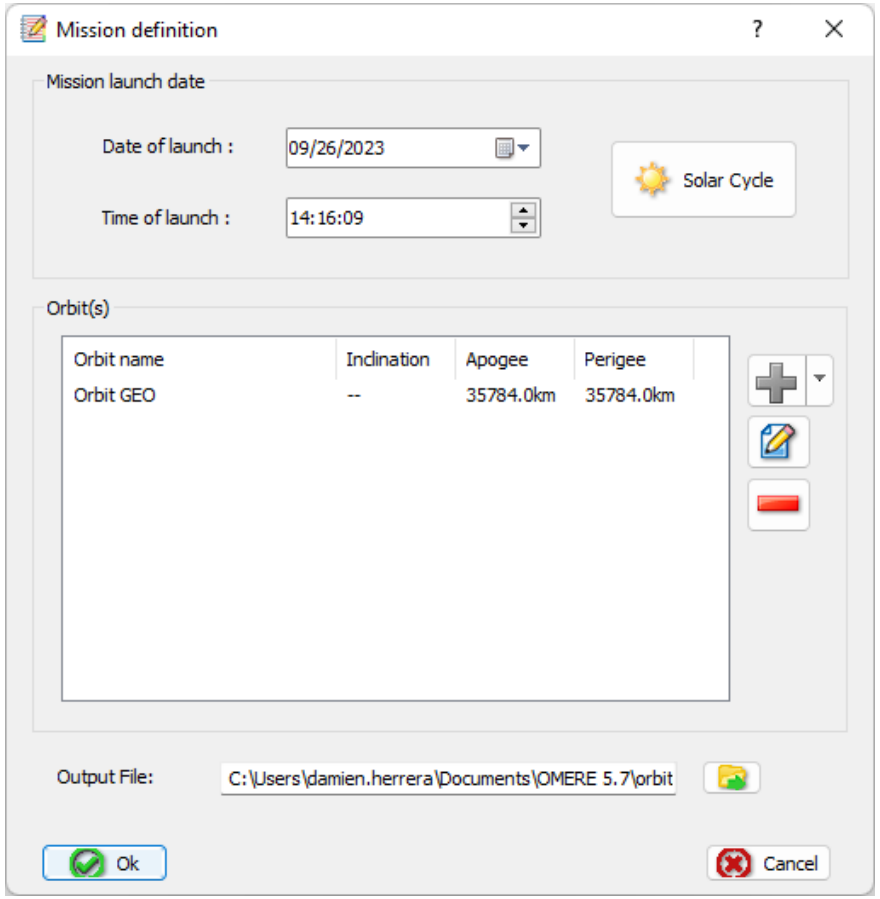
- Each button corresponds to a shortcut of an important module

- OMERE's toolbar:



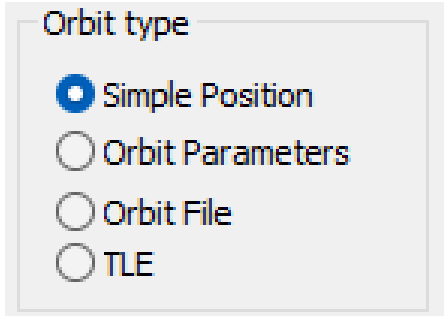
Mission





- Define the mission:
  - Orbit
  - Launch date

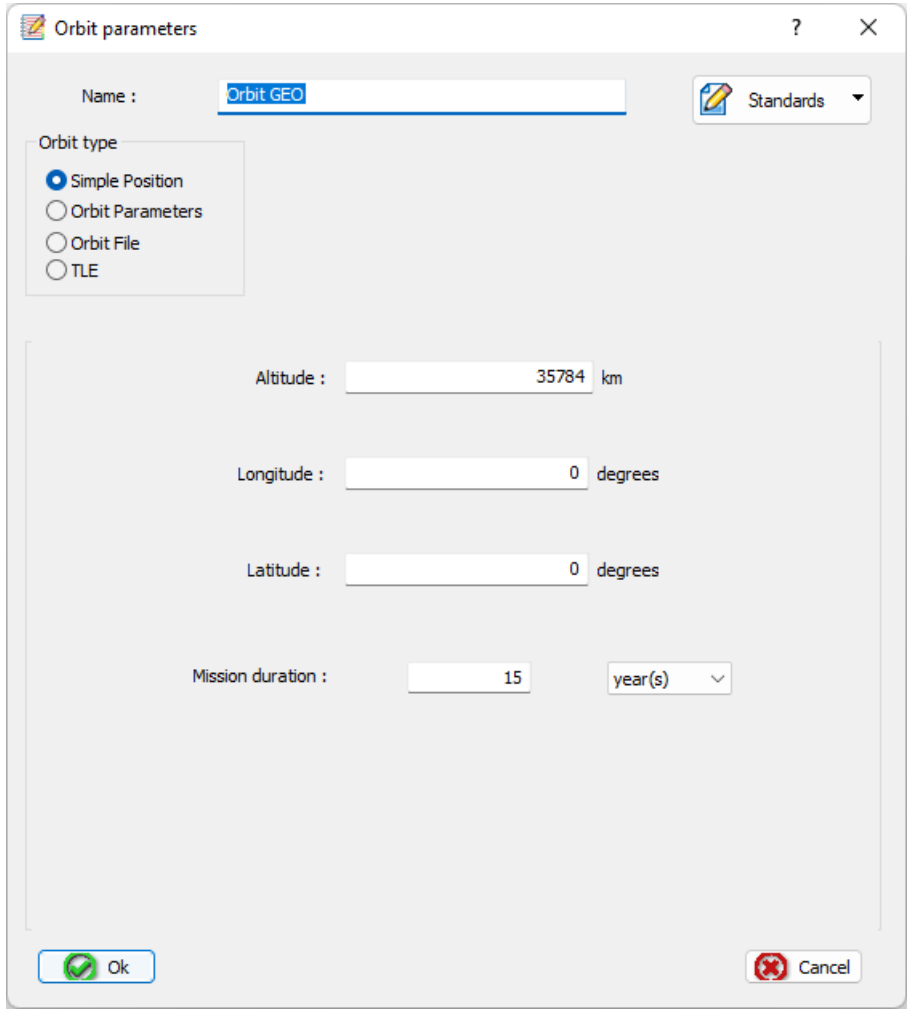
- Orbit type:
  - Simple position
  - Orbit parameters
  - Orbit file
  - Two Lines Elements (TLE)



Mission – Simple position

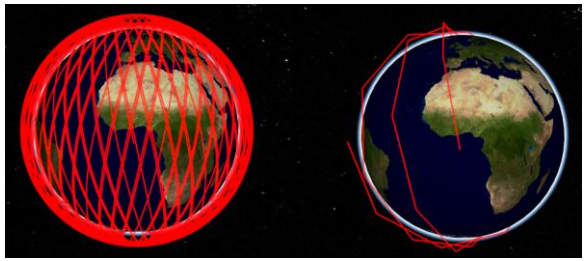
- Mission defined for one specific position
  - Realistic only for GEO orbit
  - Useful for worst-case orbits (SAA)

- Two types of parameters
  - Coordinates: altitude, longitude, latitude
  - Mission duration:
    - Solar cycle dependencies
    - Used for cumulated quantities:
      - Fluence, dose, …

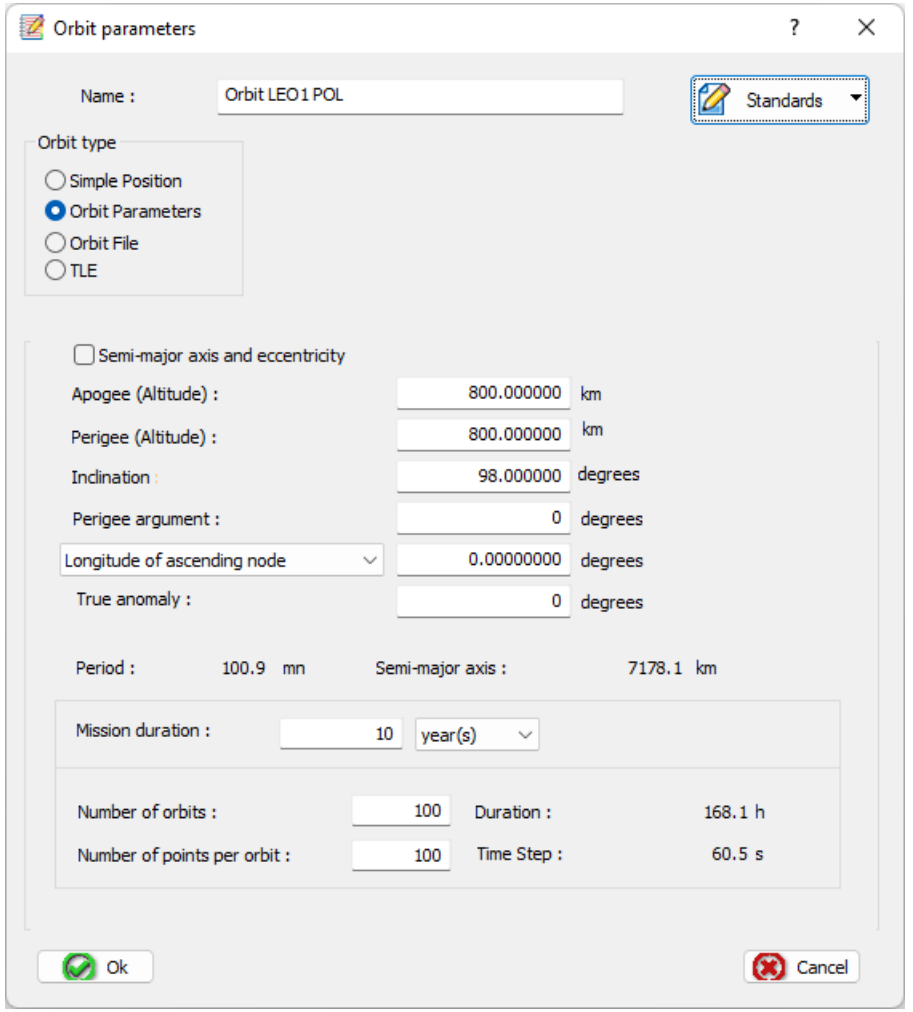


Mission – Orbit parameters

- Use of orbit parameters:
  - Apogee and perigee (or semi-major axis and eccentricity)
  - Inclination
  - …
- Mission duration:
  - Used for cumulated quantities:
    - Fluence, dose, …
- Resolution of the orbit sampling
  - Number of orbits
  - Number of points per orbit

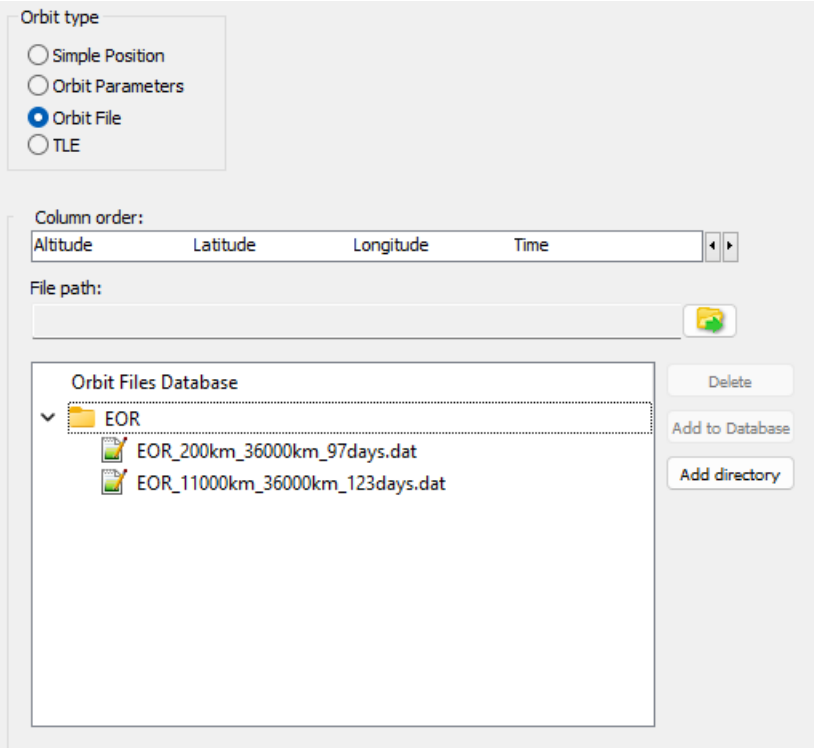


100x100 3x10



Mission – Orbit file

- Orbit file:
  - Input a file giving the position of the satellite at any moment
  - Four columns: altitude, latitude, longitude, time
  - Order of the columns can be modified




```
  9  #    altitude     latitude     longitude      temps
 10  #      (km)         (°)          (°)           (s)
 11
 12       199.960       0.000       180.000         0.0
 13       205.920      -0.457      -176.278        42.1
 14       223.719      -0.910      -172.565        84.3
 15       253.586      -1.361      -168.842       126.8
 16       295.689      -1.805      -165.117       169.8
 17       350.572      -2.242      -161.390       213.4
 18       417.624      -2.668      -157.671       257.8
 19       498.416      -3.083      -153.940       303.2
 20       593.092      -3.485      -150.205       349.8
 21       702.303      -3.871      -146.468       397.7
 22       826.489      -4.240      -142.737       447.2
 23       967.143      -4.591      -138.992       498.6
 24      1124.997      -4.923      -135.244       552.2
 25      1300.445      -5.232      -131.503       608.1
```

- Orbit Files Database:
  - Manage your database as you want
  - Edit the column with the small arrows

Mission – Two Lines Elements (TLE)

- Two Line Elements (TLE)
  - Input a file giving a serie of two line elements.
  - The position of the satellite is interpolated between two TLE. The time resolution can be edited.

```
# TLEs NOAA-15. File from celestrak.com
1 25338U 98030A   98133.67211713 -.00000044  00000-0  00000+0 0    26
2 25338  98.6959 163.5428 0000009 160.4552  25.6356 14.19938778    04
1 25338U 98030A   98133.70628213 -.00000044  00000-0  00000+0 0    16
2 25338  98.7279 163.6236 0008455 317.7671  42.2856 14.23584175    03
1 25338U 98030A   98133.77664591 -.00000044  00000-0  00000+0 0    34
2 25338  98.7169 163.6809 0010553 336.0999  24.1467 14.22915048    09
1 25338U 98030A   98133.77664591 -.00000044  00000-0  00000-0 0    35
2 25338  98.7169 163.6809 0010553 336.0999  24.1467 14.22915048    09
```

Line 1

Field	Columns	Content	Example
1	1	Line number	1
2	03–07	Satellite catalog number	25338
3	8	Classification (U: unclassified, C: classified, S: secret)	U
4	10–11	International Designator (last two digits of launch year)	98
5	12–14	International Designator (launch number of the year)	030
6	15–17	International Designator (piece of the launch)	A
7	19–20	Epoch year (last two digits of year)	98
8	21–32	Epoch (day of the year and fractional portion of the day)	133.67211713
9	34–43	First derivative of mean motion; the ballistic coefficient	-0.00000044
10	45–52	Second derivative of mean motion (decimal point assumed)	00000+0
11	54–61	B*, the drag term, or radiation pressure coefficient (decimal point assumed)	-11610
12	63–63	Ephemeris type (always zero; only used in undistributed TLE data)	0
13	65–68	Element set number. Incremented when a new TLE is generated for this object	2
14	69–69	Checksum (modulo 10)	6

Line 2

Field	Columns	Content	Example
1	1	Line number	2
2	03–07	Satellite Catalog number	25338
3	09–16	Inclination (degrees)	98.6959
4	18–25	Right ascension of the ascending node (degrees)	163.5428
5	27–33	Eccentricity (decimal point assumed)	0000009
6	35–42	Argument of perigee (degrees)	160.4552
7	44–51	Mean anomaly (degrees)	25.6356
8	53–63	Mean motion (revolutions per day)	14.19938778
9	64–68	Revolution number at epoch (revolutions)	0
10	69	Checksum (modulo 10)	4

From Mission to Environment

- Mission's outputs processing to Environment:

Mission

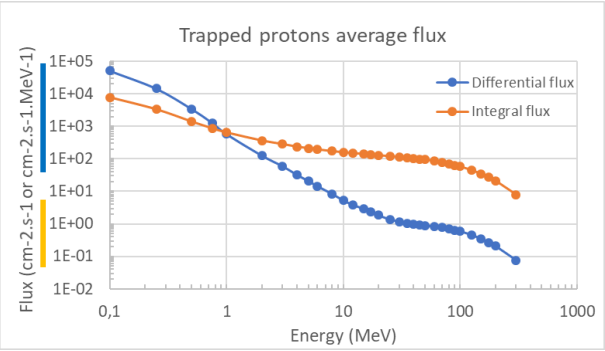
- List of positions
- Launch date
- Mission duration

⇩

Environment

- Sources of particles
- Models and parameters
- Specific format

⇩

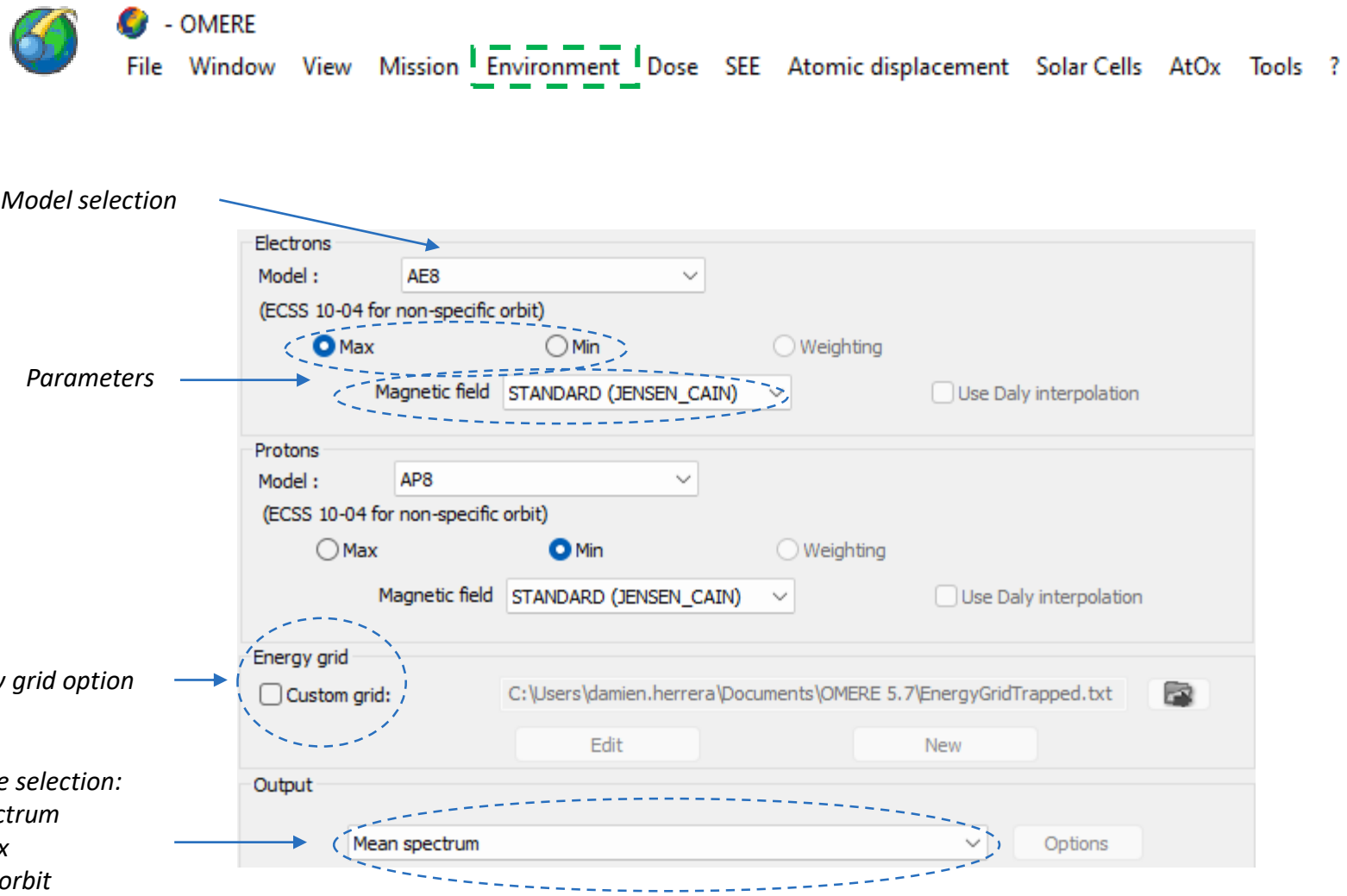


- Mission tool indicates to the Environment tool the positions of the spacecraft with time
- The Environment tool allows the user to select the models and set their parameters for each source of particles
- Environment models take outputs of the Mission tool and compute energy spectra

✓ Each model takes a different format of inputs: transparent for the user

✓ Unique output file format

Environment – Trapped particles



Output type selection:

- *Mean spectrum*
- *Instant flux*
- *Along the orbit*
- *(Proton) Peak Flux*

Environment – Solar particles

- OMERE

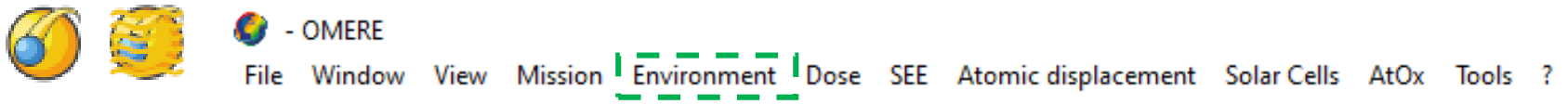
File Window View Mission **Environment** Dose SEE Atomic displacement Solar Cells AtOx Tools ?

Two types of models:

Average Statistical models

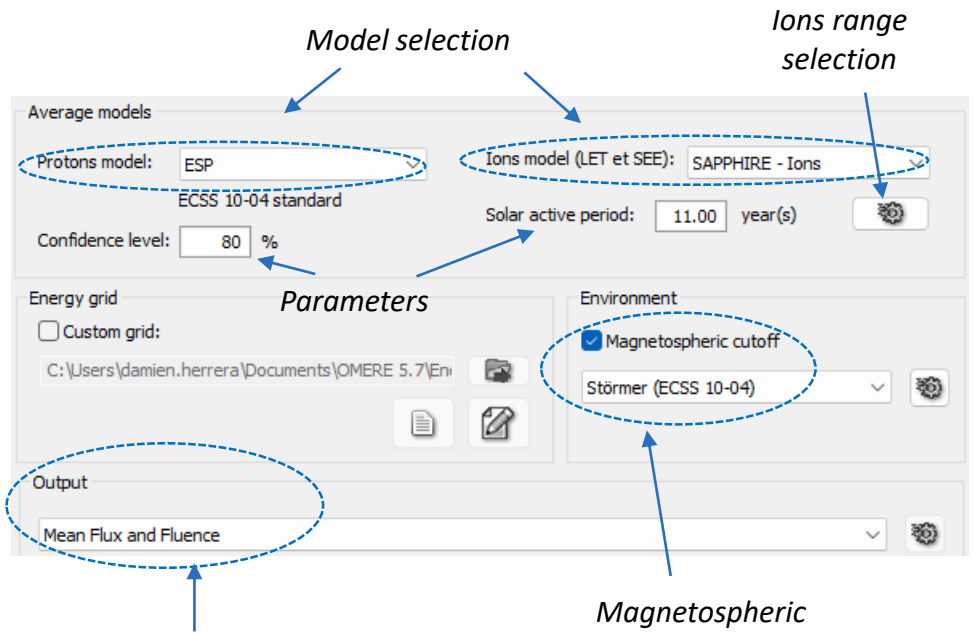
Flare models

Environment – Solar particles



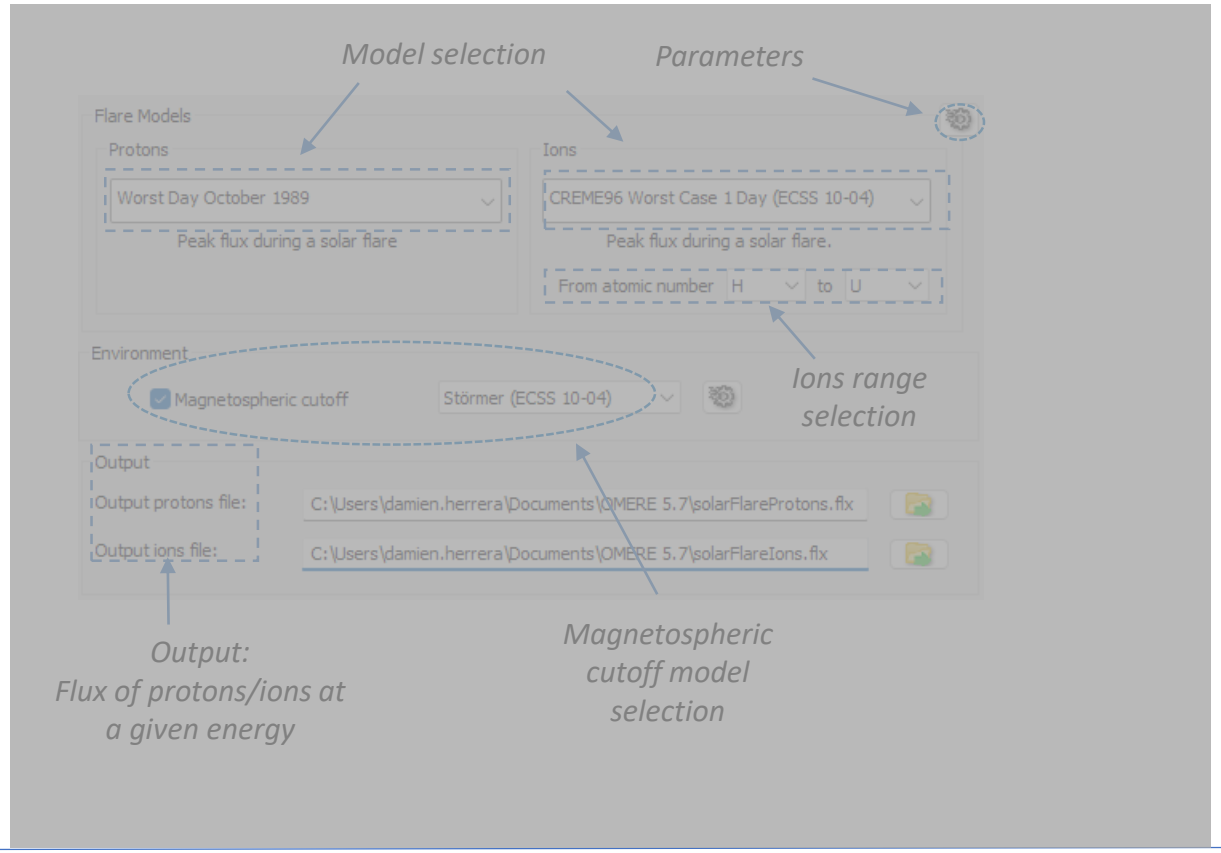
Two types of models:

Average Statistical models



- *Mean spectrum*
- *Instantaneous flux (at an energy)*
- *Instantaneous energy spectrum along the orbit*

Flare models



Environment – Solar particles

- OMERE

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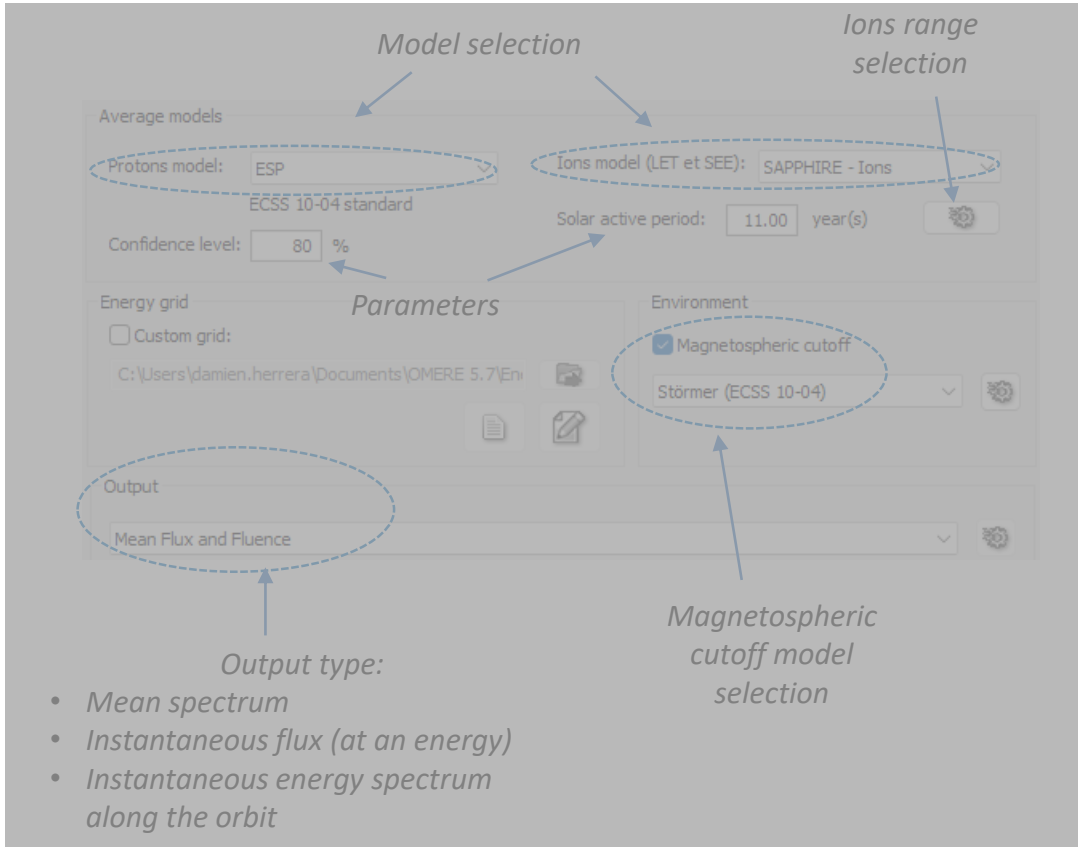
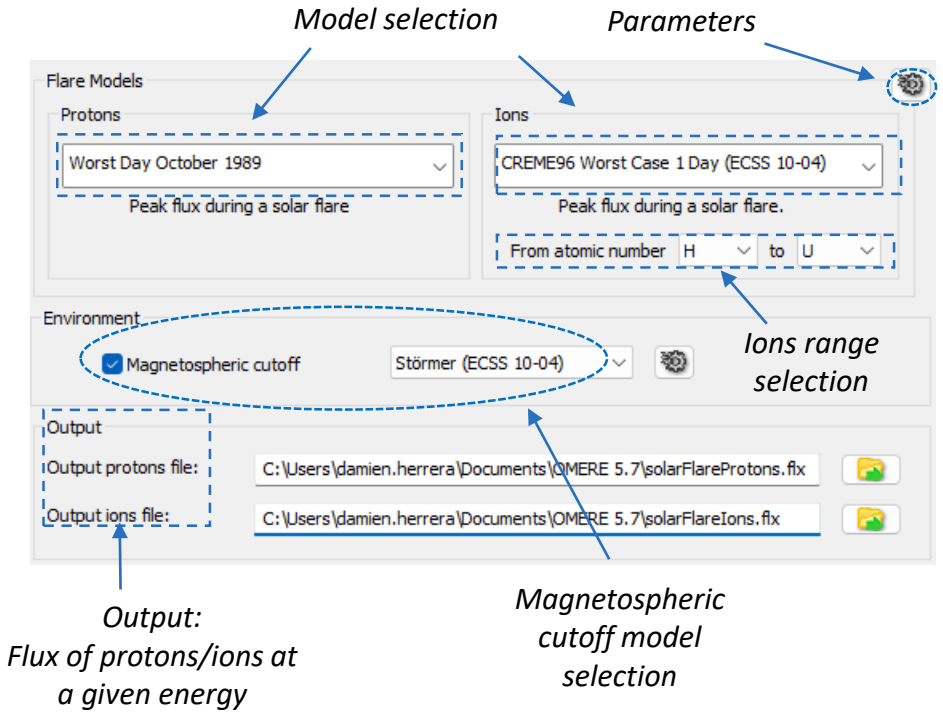
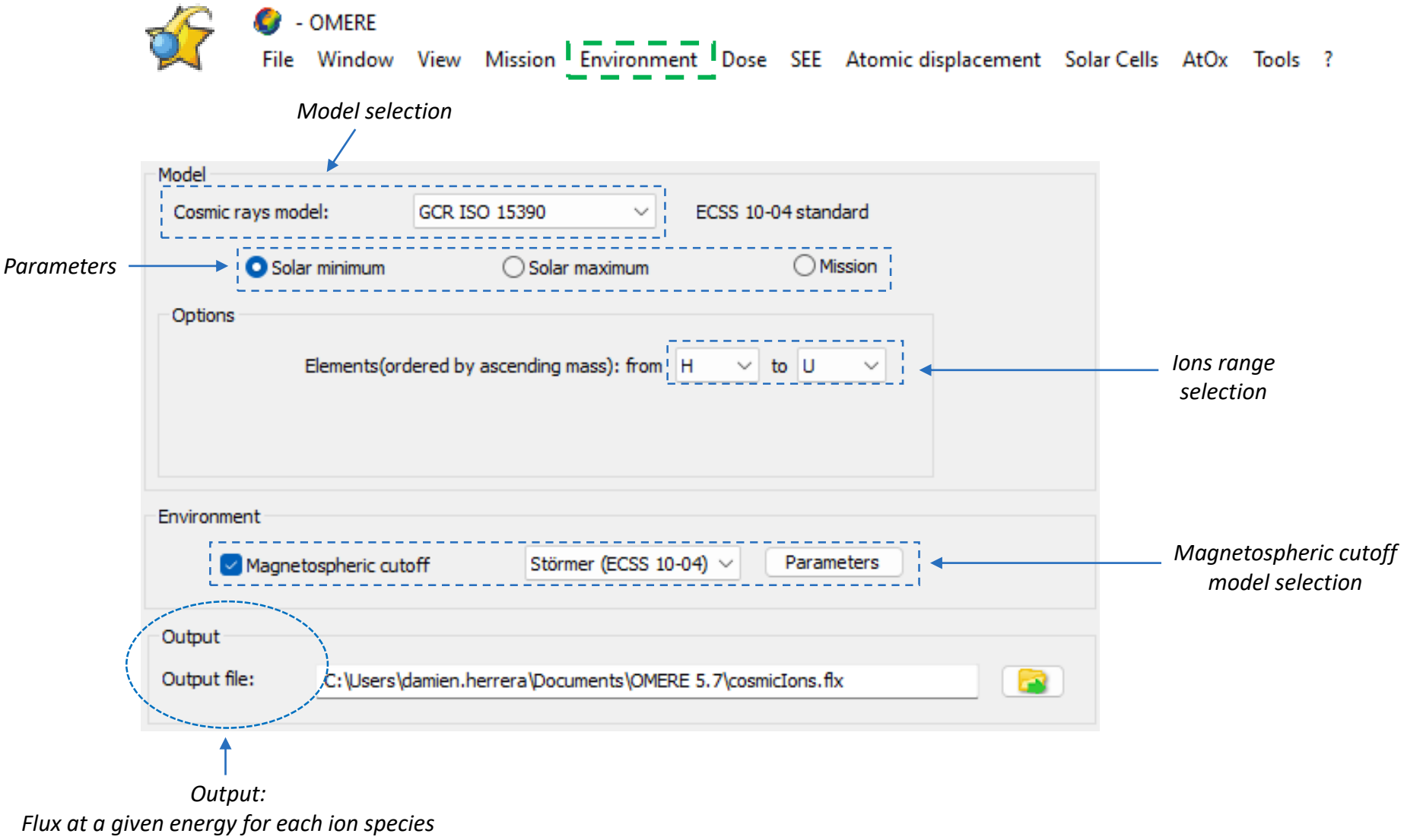


Flare models

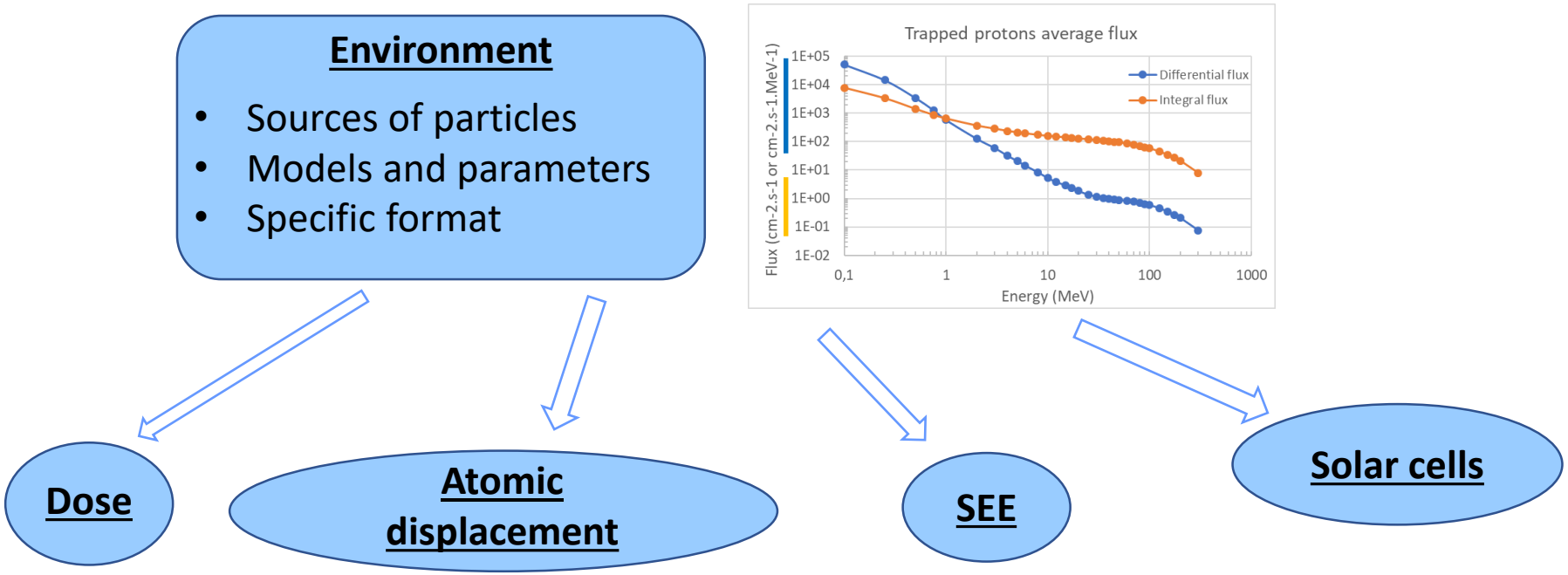


Environment – Galactic Cosmic Rays (GCR)

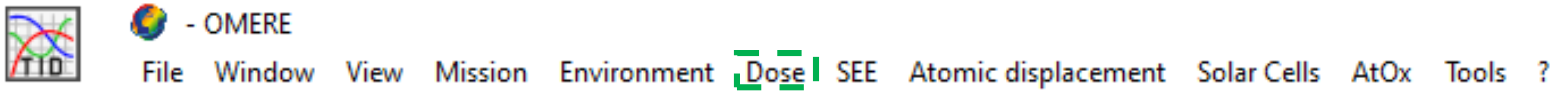


From Environment to Effects

- Environment's outputs processing to Effects modules:



Dose



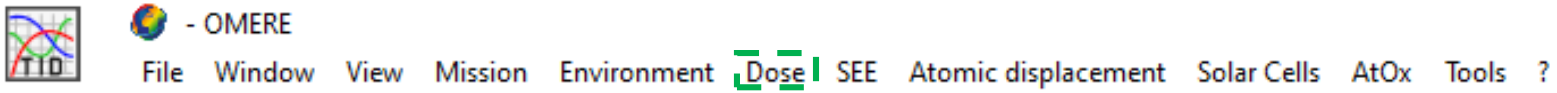
Estimate a dose depth curve

- The dose depth curve is calculated with SHIELDOSE-2 considering:
  - Energy spectra
  - Calculation parameters: geometry, target material

- Inputs: energy spectra
  - *From mission*: the spectra are calculated considering the mission and models selected in the environment module
  - *From files*: user directly inputs the spectra

- Parameters:
  - Geometry: simple geometry considered for the dose calculation
  - Target material: the dose estimated in a given material

Dose

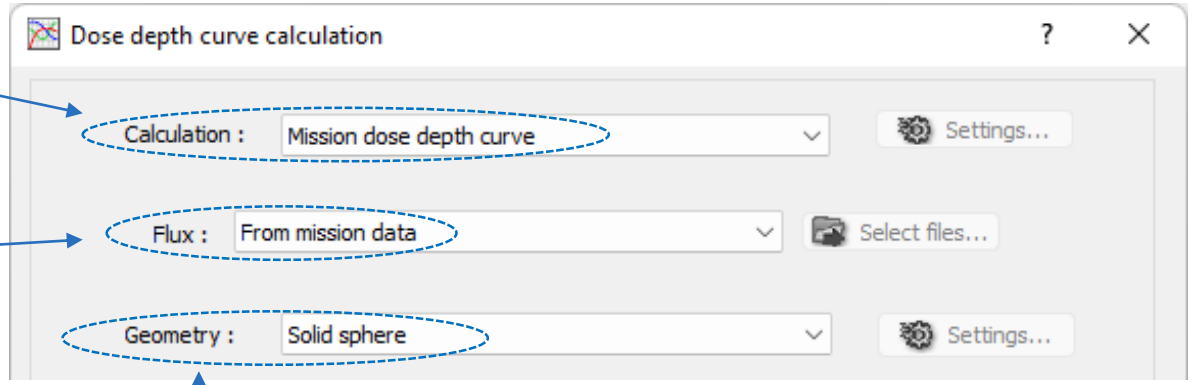


Calculation type:

- *Mission dose depth curve*
- *Dose rate along the orbit*

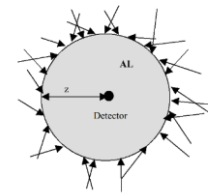
Input data:

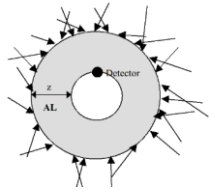
- *From mission data*
- *From data files*



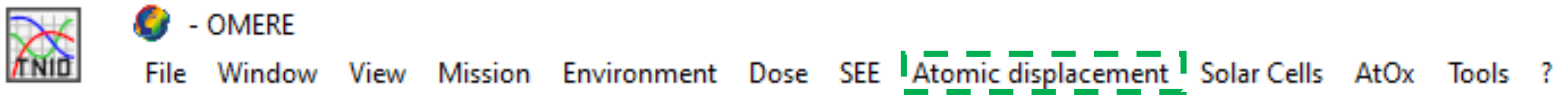
Geometry:

- *Solid sphere*
- *Shell sphere*
- *Finite slab*
- *Semi-infinite slab*





Atomic displacement



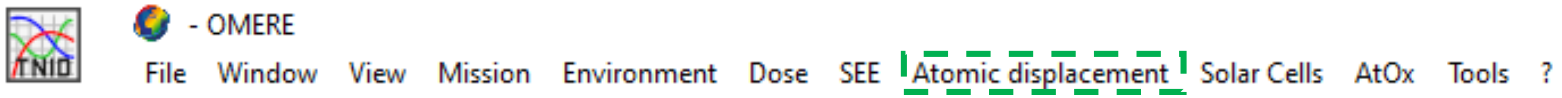
Estimate a displacement damage depth curve

- The dose depth curve is calculated considering:
  - Energy spectra
  - Calculation parameters: NIEL data

- Inputs: energy spectra
  - *From mission*: the spectra are calculated considering the mission and models selected in the environment tools.
  - *From files*: user directly inputs the spectra

- Output:
  - The result can be expressed in terms of displacement dose or equivalent fluence

Atomic displacement



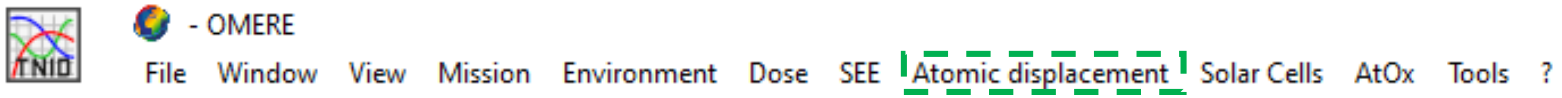
Estimate a displacement damage depth curve

- Output:
  - The result can be expressed in terms of displacement dose or equivalent fluence

- Equivalent fluence:
  - Corresponds to the fluence that a monoenergetic beam of a given particle must have to deposit the same Displacement Damage Dose (DDD) of the mission

- Parameters
  - Target materials
  - Non-Ionizing Energy Loss (NIEL) model
  - Type of particle and energy for the computation of the Displacement Damage Equivalent Fluence (DDEF)

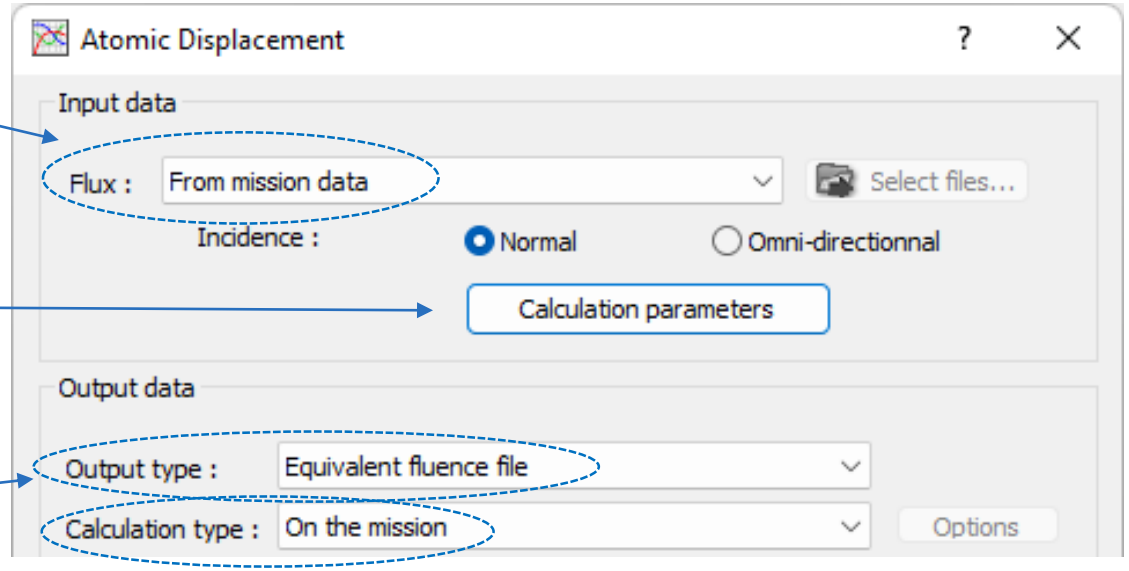
Atomic displacement



Input data:
- *From mission data*
- *From data files*

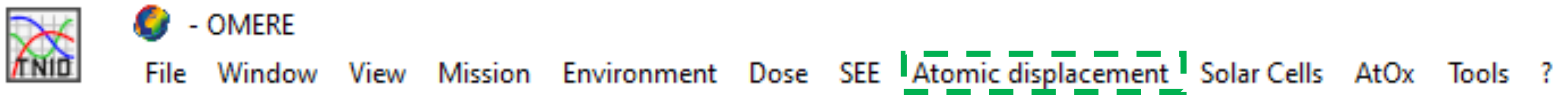
Parameters

Output:
- *Displacement dose*
- *Equivalent fluence*



Calculation type:
- *On the mission*
- *Along the orbit*

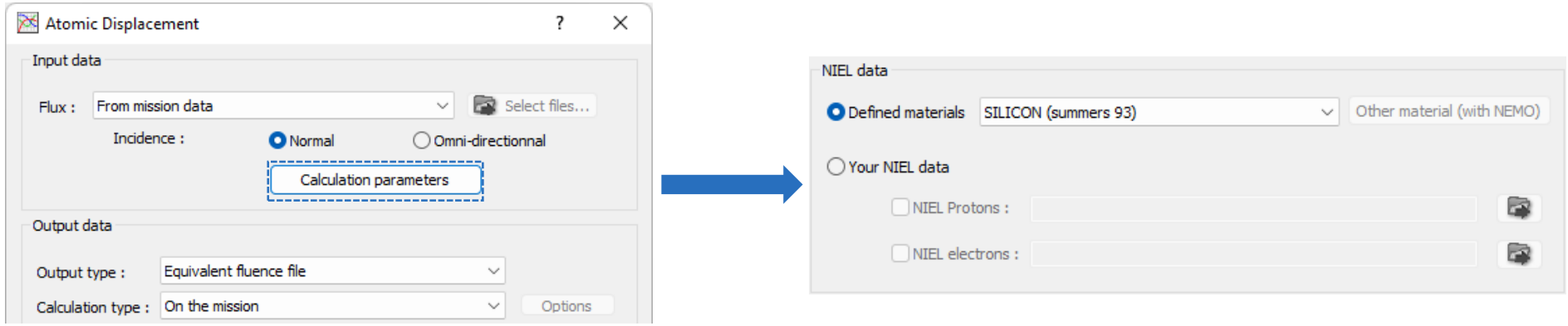
Atomic displacement



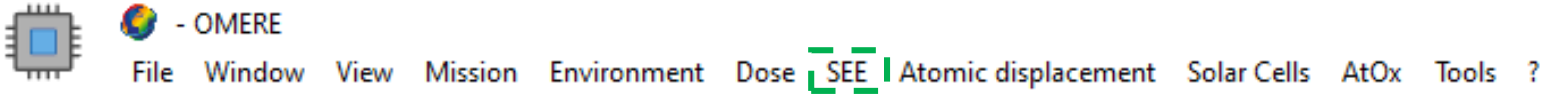
Estimate a displacement damage depth curve

- Non-Ionizing Energy Loss models available in OMERE:
  - Summers93 (by default for Silicon)
  - Barry95 (for GaAs)
  - NEMO-ONERA (Si, GaAs or any other materials)

- Possible to import your own NIEL data



Single Event Effects



Estimate a SEE rate

- The SEE rate is calculated considering:
  - LET spectrum for ions / Transported flux for protons
  - Cross sections data (Weibull fit, experimental data…)
  - Calculation parameters: Number of sensitive cells and cell depth

- Inputs: energy spectra
  - *From mission*: the LET spectrum and transported proton flux are calculated considering the mission and models selected in the environment tools, user has to choose the shielding thickness
  - *From files*: user directly inputs the LET spectrum and the transported proton flux

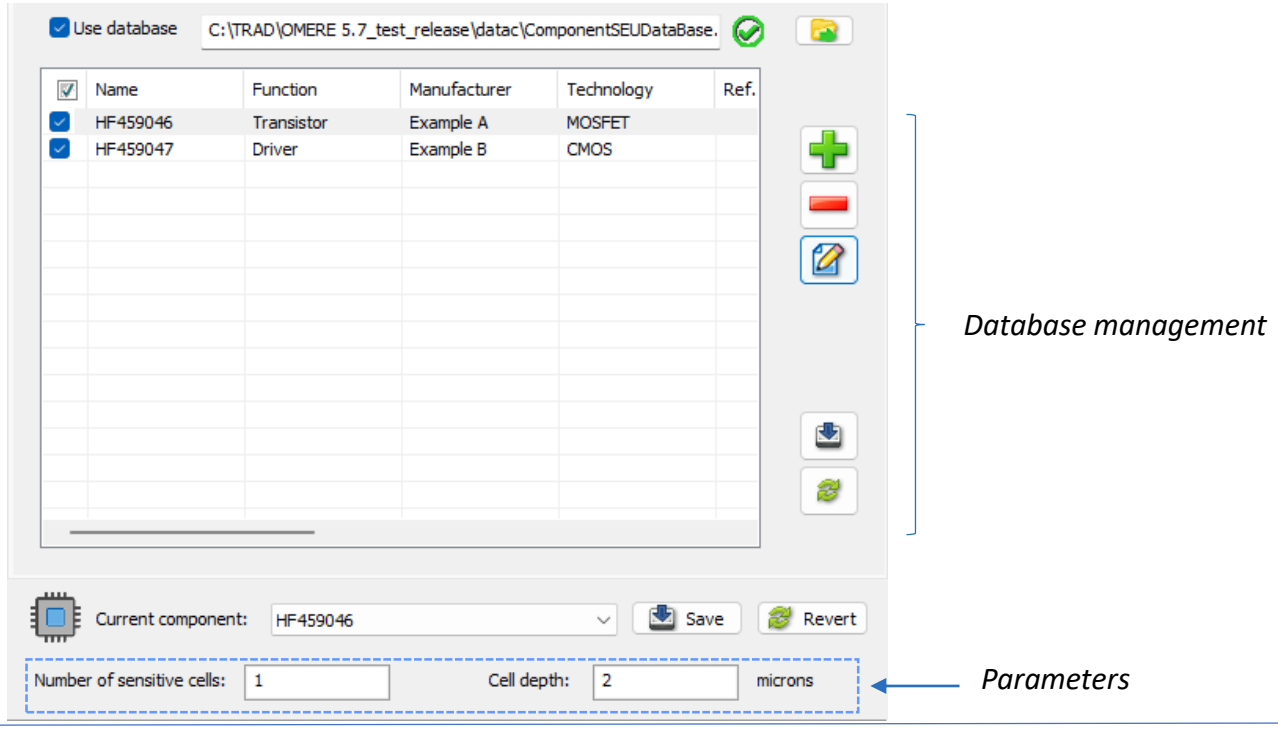
- Output:
  - The SEE rate is computed for each source of particles

Single Event Effects

Estimate a SEE rate

- Component database

  - Choose one or several components (calculation for several components in 1 run)
  - The database can contain many information : Function, Manufacturer, Technology… Have to define the number of sensitive cells and the cell depth.



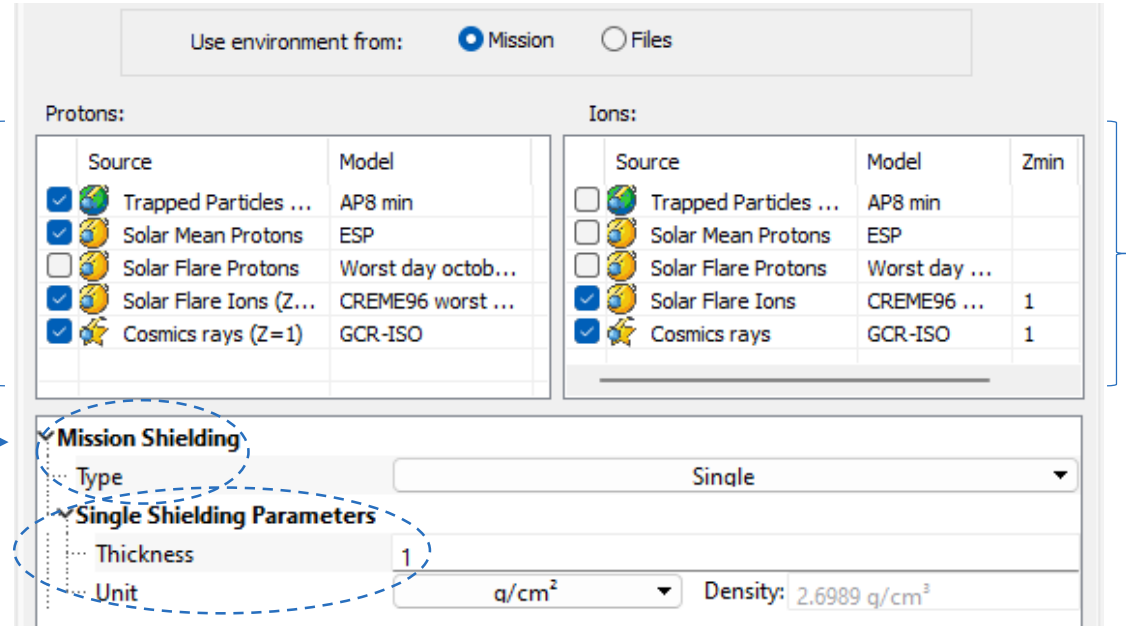
Single Event Effects

Estimate a SEE rate

- Definition of the Environment

  Component | Environment | Ions | Protons

  - From Mission



Choose the source of protons

Choose the source of heavy ions

Shielding type:
- *Single*
- *Sector file*

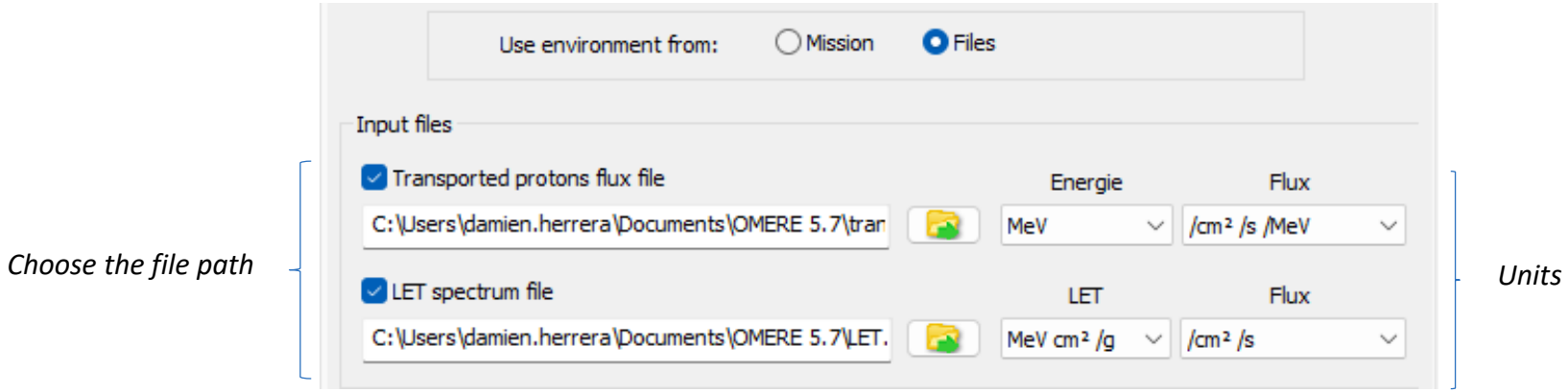
Unit:
- *g/cm²*
- *µm*
- *mm*
- *mils*

Single Event Effects

Estimate a SEE rate

- Definition of the Environment

  - From Files



Choose the file path

Units

Single Event Effects

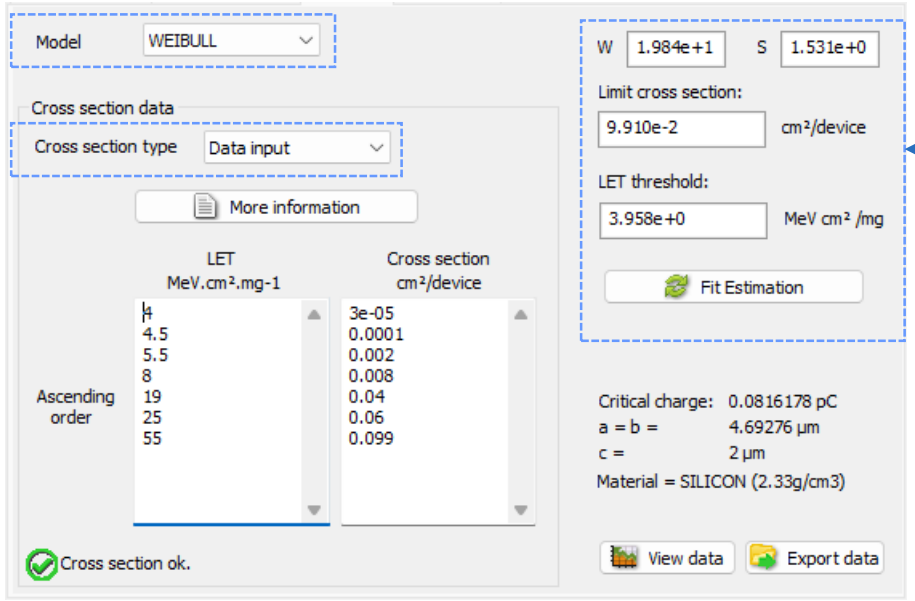
Estimate a SEE rate

- Definition of the cross section data and model (ions and protons)

Selection of the fit model

Cross section type:

- *Data input*
- *Fit parameters only*
- *Step function*
- *File*



Fit parameters

<u>Note :</u>
For protons, if you do not have test data or Weibull fit, you can estimate the proton data from ions data with PROFIT, SIMPA or METIS methods

Single Event Effects

Estimate a SEE rate

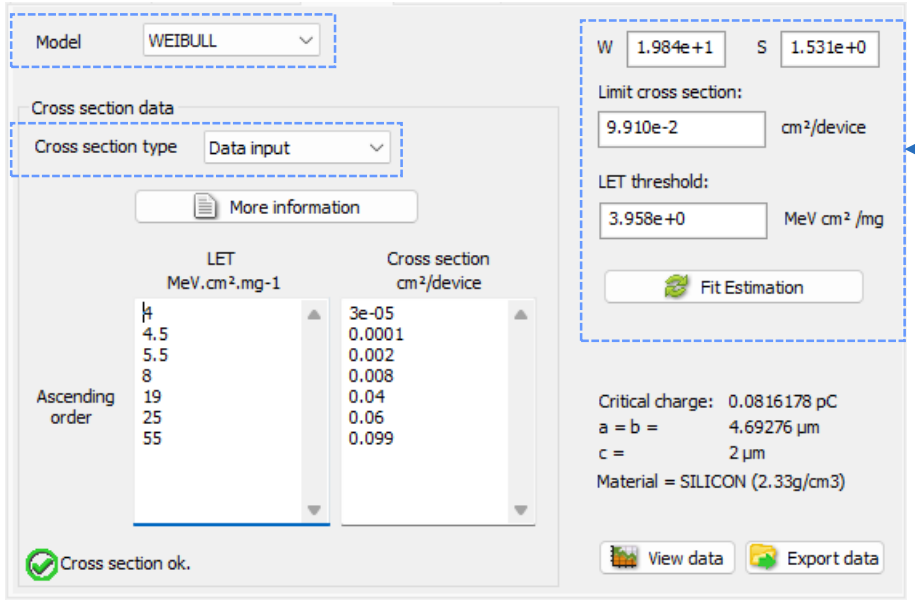
- Definition of the cross section data and model (ions and protons)

Selection of the fit model

Cross section type:

- *Data input*
- *Fit parameters only*
- *Step function*
- *File*

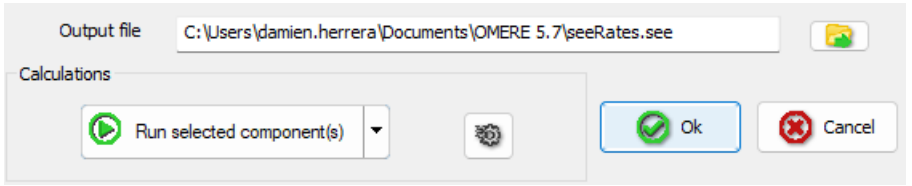
Fit parameters



Note :

For protons, if you do not have test data or Weibull fit, you can estimate the proton data from ions data with PROFIT, SIMPA or METIS methods

Compute the SEE rate



	Cosmic rays (Heavy Ions Rate)	Solar protons (Protons Rate)
HF459046	2.33e-1 /device /day	5.06e-2 /device /day
HF459047	7.81e-2 /device /day	5.14e-2 /device /day

Solar cells

- OMERE

File Window View Mission Environment Dose SEE Atomic displacement Solar Cells AtOx Tools ?

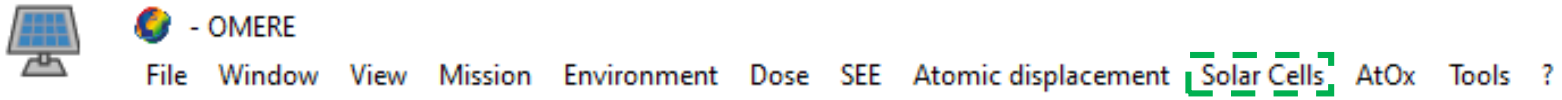
Estimate the degradation on solar cells

- Three models:
  - **JPL**: estimates the equivalent fluence for three electrical parameters:
    - P_{max}, V_{oc}, I_{sc}.
  - **NRL**: estimates the EOL (End Of Life) performances via displacement damage.
  - **SADC:** estimates the GRF (Global Remaining Factors) for each electrical parameters via displacement damage.

- Three types of shielding:
  - Simple: only one value of shielding is considered
  - Multiple: the degradation is estimated for several values of shielding
  - Complex: different layers of shielding, considering realistic material (only available for SADC)

- Output:
  - Output file with EOL performance for each source of particle (JPL/NRL)
  - Output file with GRF for each electrical parameter (SADC)

Solar cells – JPL and NRL

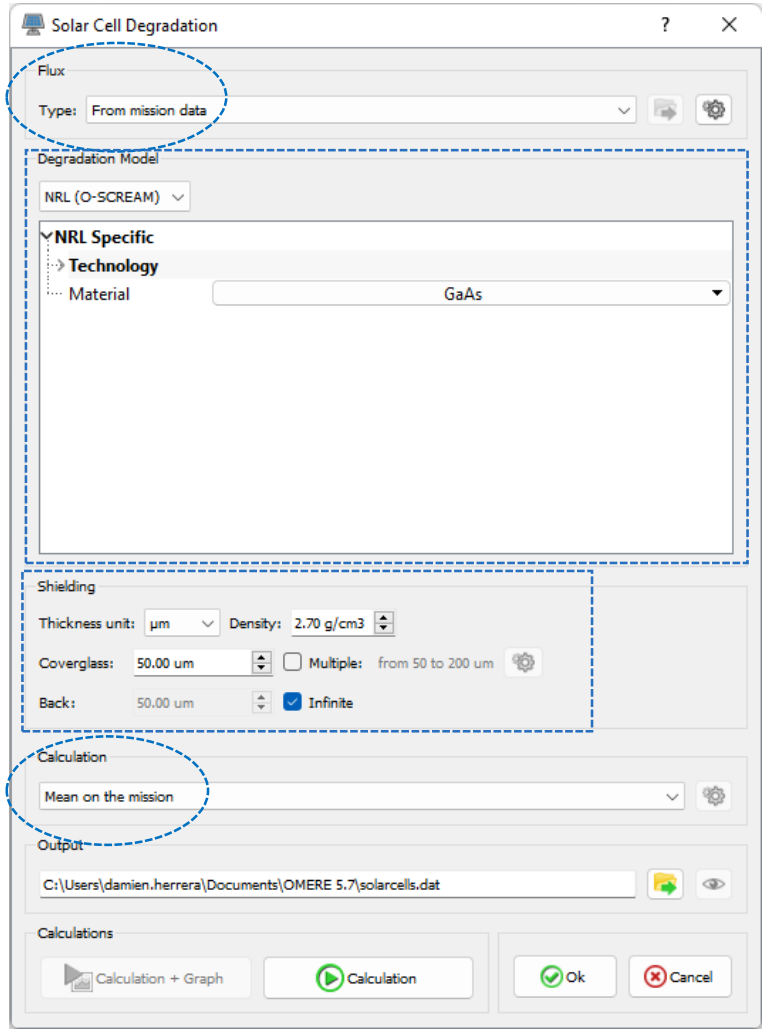


Input data:
- *From mission data*
- *From data files*

Degradation model:
- *NRL*
- *JPL*

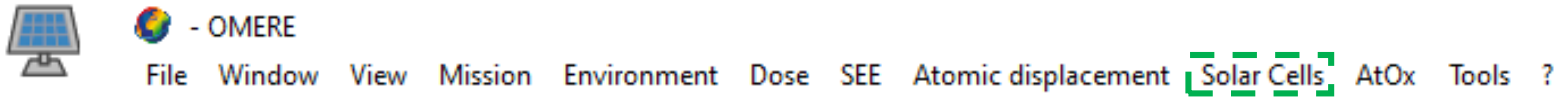
Shielding parameters

Calculation type:
- *Mean of the mission*
- *Along the orbit*
- *Time profile*



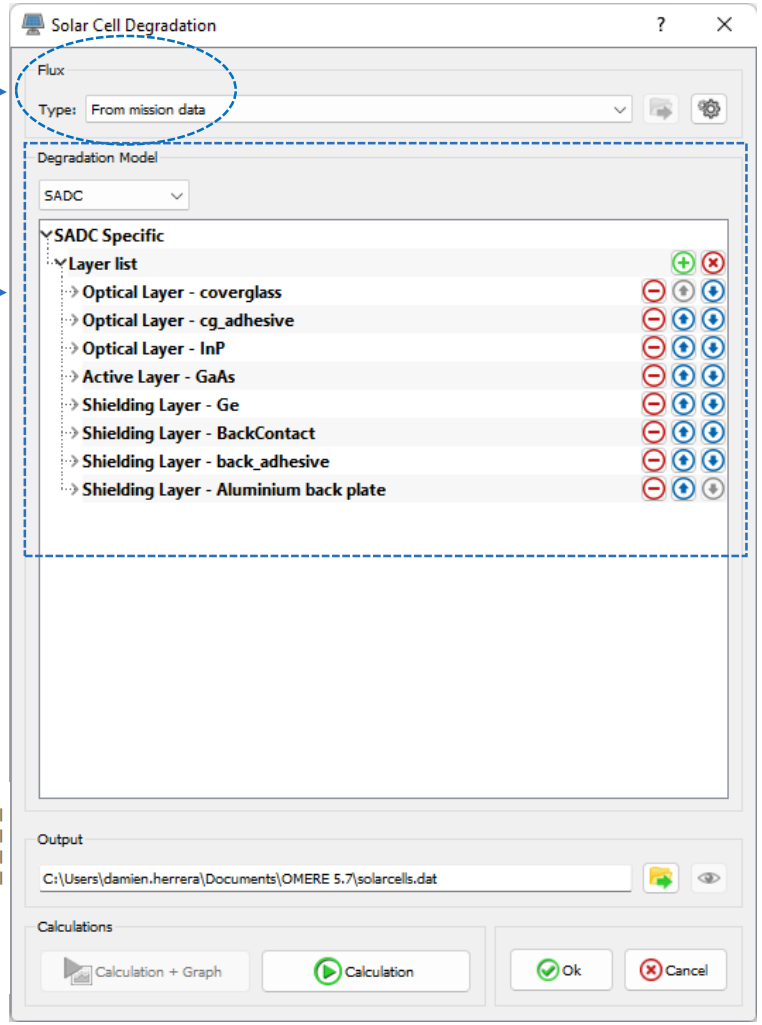

```
# Back Shielding: Infinite
# Coverglass ||            Displacement            ||      EOL      ||
# Thickness  ||            Damage Dose             ||   Performance  ||
#     (um)   ||              (MeV/g)               ||      (%)       ||
#            || Electrons  |  Protons   |   Total   ||                ||
#------------||------------|------------|-----------||----------------||
  5.000e+01    1.712e+09    3.218e+09    4.931e+09       7.854e+01
```

Solar cells – SADC



Input data:
- *From mission data*
- *From data files*

Solar cell model:
- *Optical layer*
- *Active layer*
- *Shielding layer*
- *Can be modified*



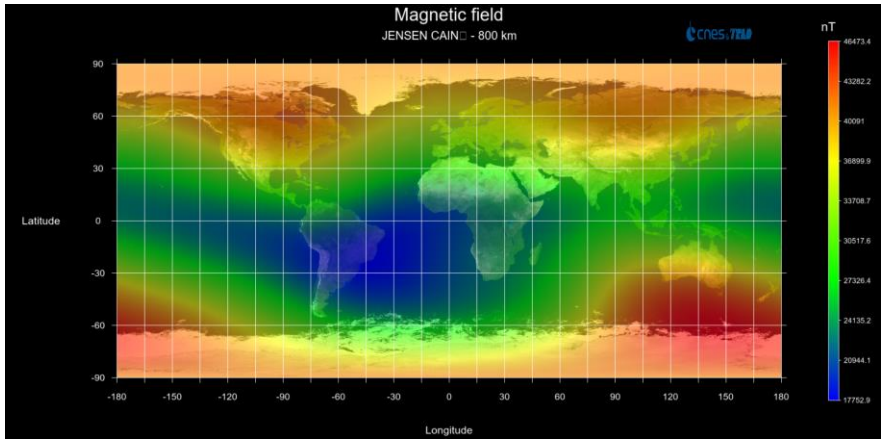
- SADC allows to:
  - define a realistic solar cell model
  - consider the darkening due to TID on coverglass
  - propagate measurement uncertainties
  - study new technology of solar cells

```
# ⟶Electrical parameters
#     Name     |      DDDe      |     DDDe->p    |      DDDp      |                    RF                    |                    GRF                   ||
#              |     (MeV/g)    |     (MeV/g)    |     (MeV/g)    |                   (%)                    |                    (%)                   ||
#              |                |                |                |     min     |     mid     |     max     |     min     |     mid     |     max     ||
#--------------|----------------|----------------|----------------|-----------------------------------------|-----------------------------------------||
        Isc     3.15279e+09     3.15279e+09     9.91119e+09       96.197        96.197        96.197        96.1176       96.1176       96.1176
        Voc     3.15279e+09     1.45568e+09     9.91119e+09       89.8404       89.8404       89.8404
       Pmax     3.15279e+09     1.70307e+09     9.91119e+09       80.9301       80.9301       80.9301       80.8632       80.8632       80.8632
        Ipm     3.15279e+09     3.15279e+09     9.91119e+09       94.6636       94.6636       94.6636       94.5854       94.5854       94.5854
        Vpm     3.15279e+09     6.2246e+08      9.91119e+09       87.9862       87.9862       87.9862
```

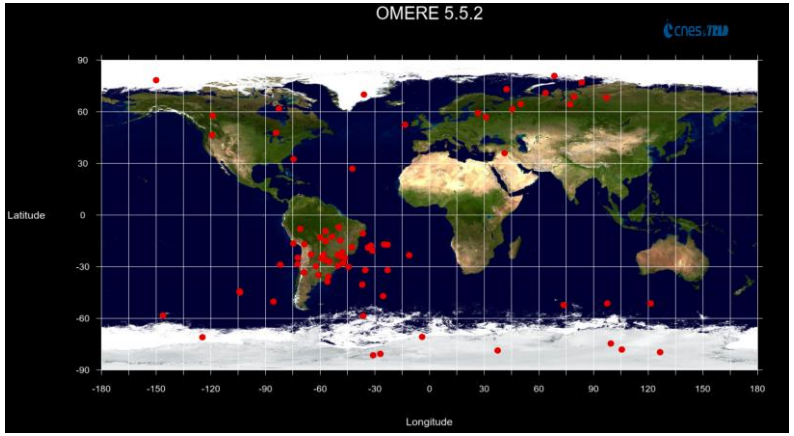
Other functionalities, tips and advices

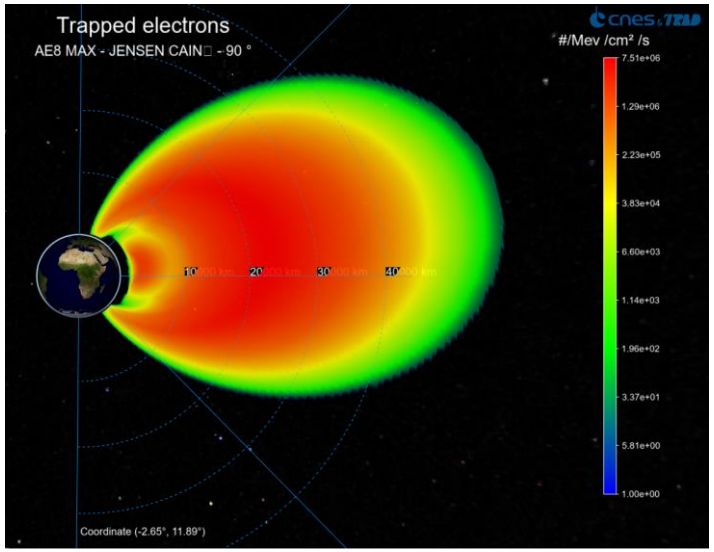
Other functionnalities

- Flux and magnetic field mapping for example



SEL data for a specific mission (REX data)





- Many others:
  - SEE mission's data plots
  - LET computation in material (ion test)
  - DDEF converter
  - …

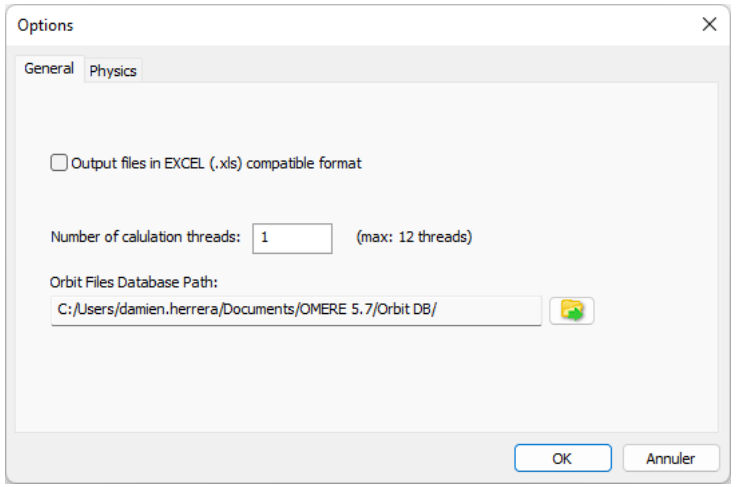
Tips and advices

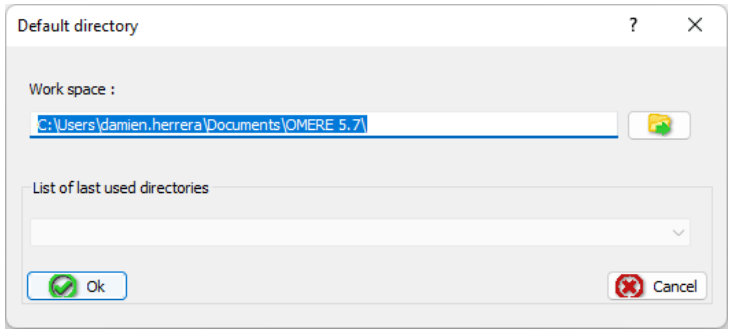
- Think to look at the setup button : 

- The environment models are always indicated at bottom left corner of OMERE window:

09/26/2023 - 15.00 years || AP8 min || ESP 80% || GCR ISO, cut || Current file version: 5.7.0

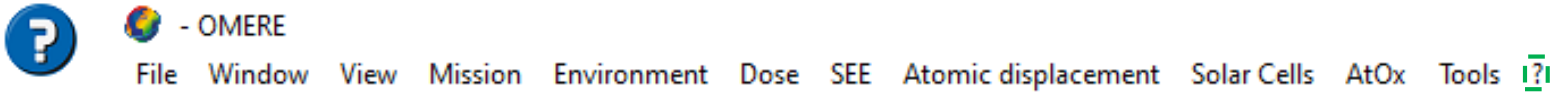
- Interesting options available in OMERE:



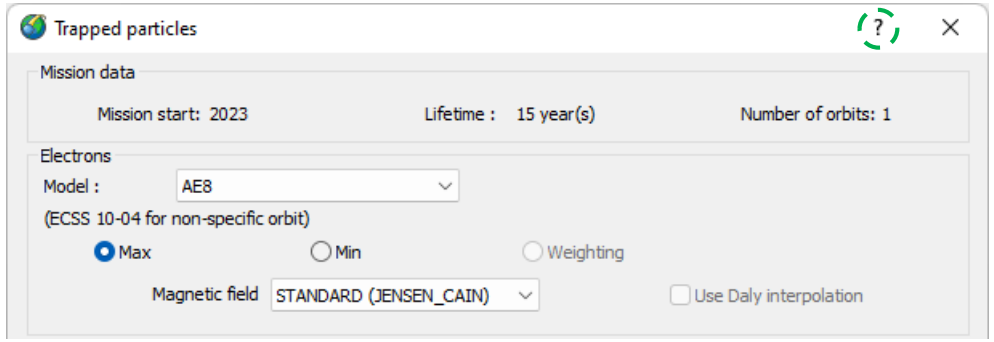


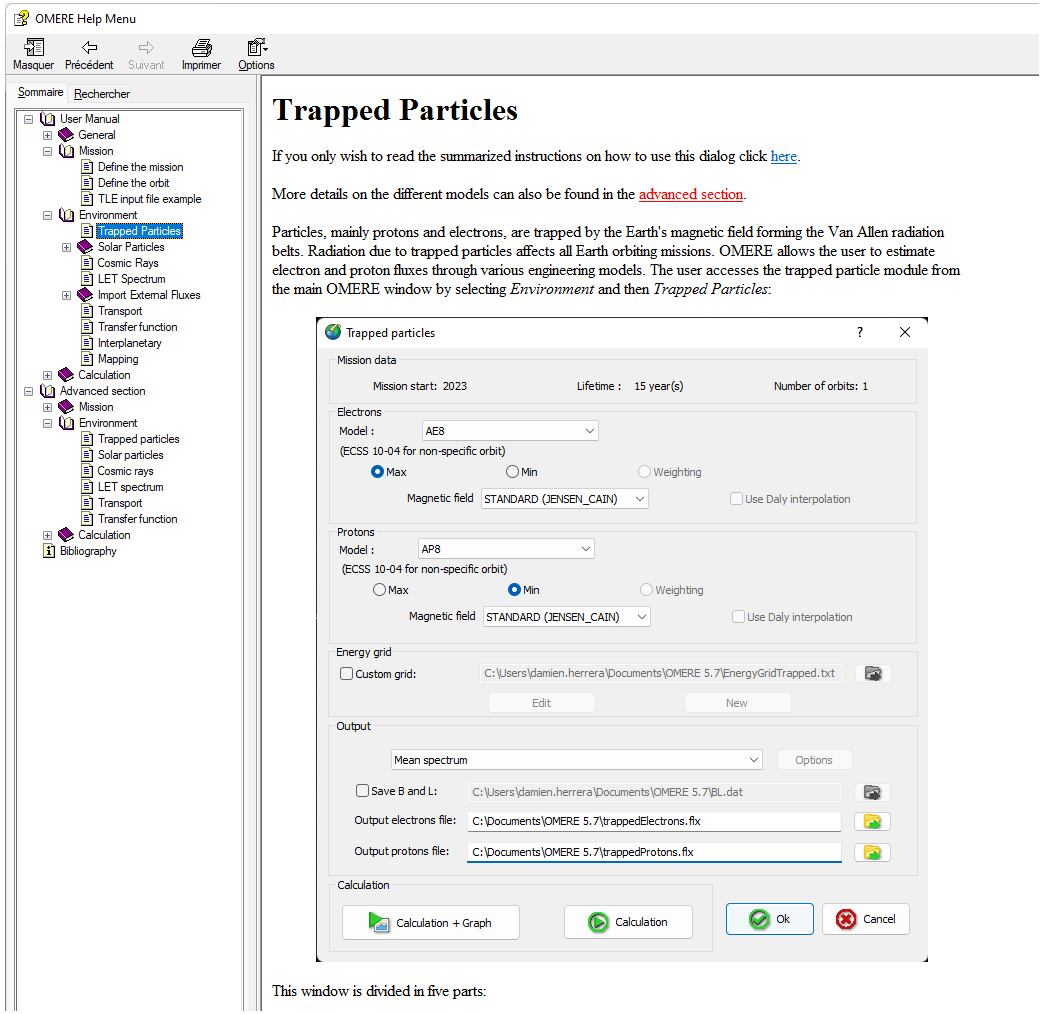
- Define your workspace in OMERE: File -> Default directory

Help menu



- Help menu:
  - Global and advanced information
  - Available for each module
  - Check the top right corner !





Need some help ?

Do not hesitate to contact us at our TRAD email adress

if you need more information or support !

omere@trad.fr

Thank you for your attention

For further information on:

www.trad.fr – www.fastrad.net
www.rayxpert.com – www.r2cots.com

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