World Radiocommunication Seminar 2016

Equivalent power flux density limits (EPFD)

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Where do satellites operate …

Geostationary Orbit
35,786 km above
the Earth's equator

Highly Elliptical
Orbit – 40 000 km
in apogee

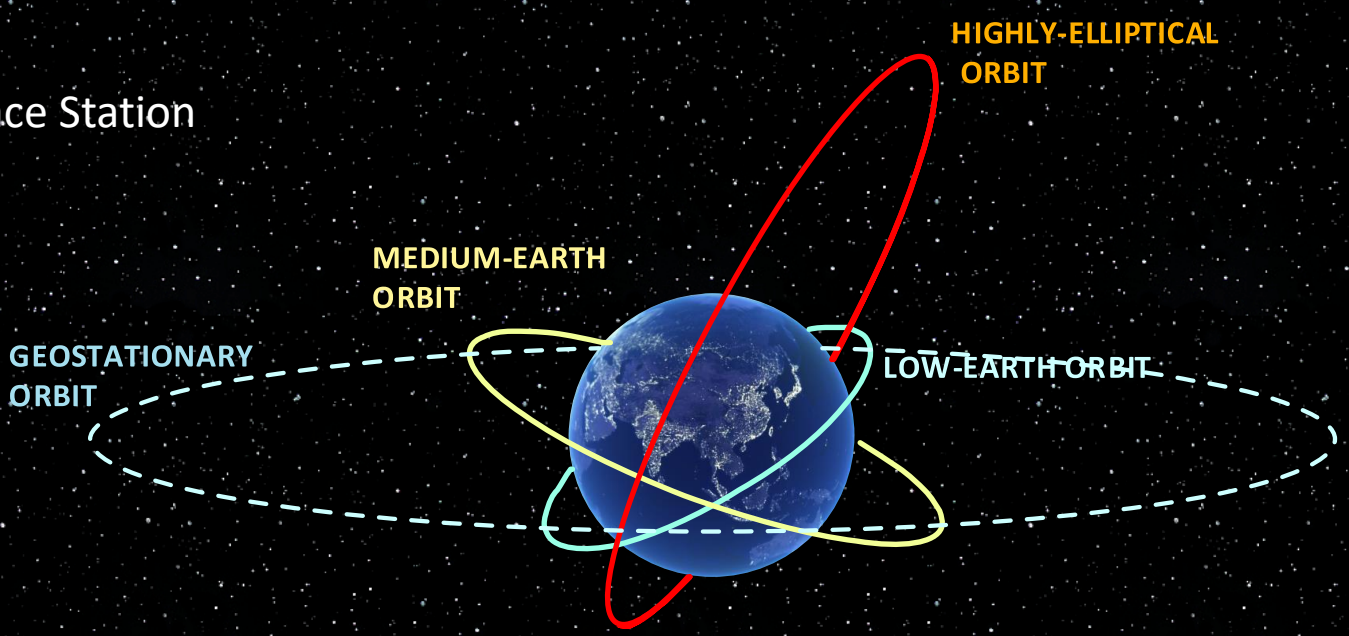
Medium Earth
Orbit
8 000 - 20 000 km

Low Earth Orbit
500 - 2 000 km

GNSS

International Space Station

Sub-orbital



Non-GSO regulations

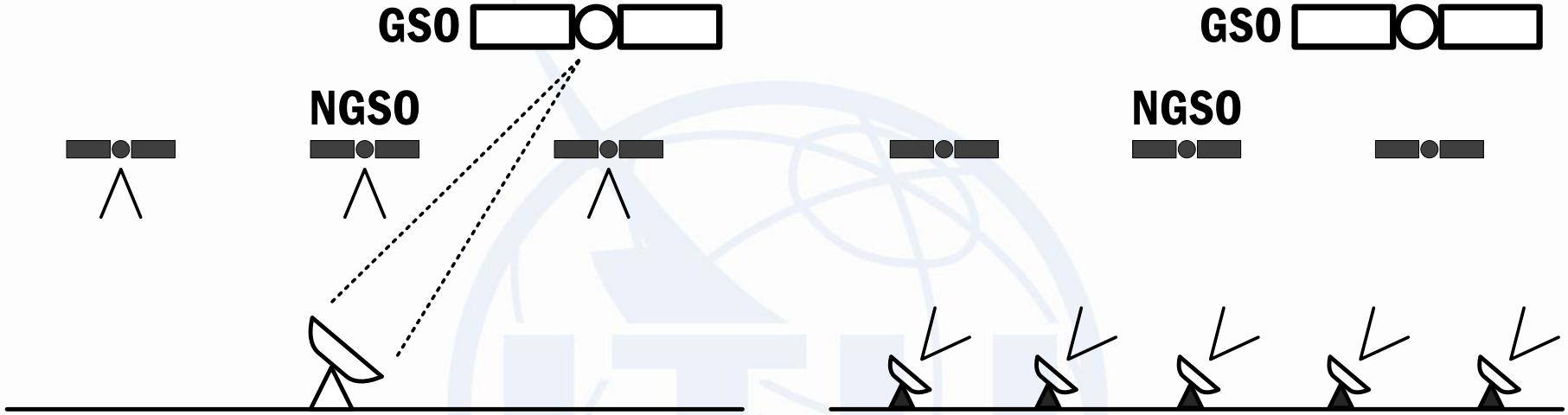
- **Evolved** in 1990 – 2003.
- **Coordination** – ensures protection of existing services on equitable access basis
  - Coordination between non-GSO and GSO in limited frequency bands
  - Coordination between non-GSO in limited frequency bands
- **Hard Limits** – Article 22 EPFD limits to protect GSO from non-GSO
- **Protection of GSO** – No. 22.2
  - Non-geostationary-satellite systems shall not cause unacceptable interference to and shall not claim protection from geostationary-satellite networks in the fixed-satellite service and the broadcasting-satellite service

EPFD

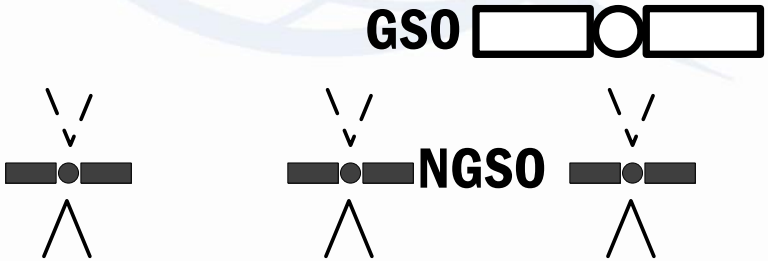
- **Equivalent power-flux density** (EPFD) takes into account the aggregate of the emissions from all non-GSO satellites in the direction of any GSO earth station, taking into account the GSO antenna directivity
- EPFD considers pointing of a victim receiving antenna with respect to every source of interference
- Complex calculation methodology considers an interference varying in time and space

EPFD on downlink

EPFD on uplink



EPFD on inter-satellite path



What is EPFD?

- EPFD is calculated:
  - Downlink (at the input of GSO earth station receiver)
  - Uplink (at the input of GSO space station receiver)
  - Inter-satellite (at the input of GSO space station receiver)

$$epfd = 10 \log_{10} \left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4 \pi d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}} \right]$$

EPFD Limits Regulatory Framework

- Article **22 – Hard Limits to protect GSO from Non-GSO**
  - Hard EPFD limits enable non-GSO FSS systems to share frequencies with and protect GSO systems without requiring individual coordinations with all the systems worldwide
  - FSS non-GSO satellite systems shall comply with the EPFD limits contained in Tables **22-1A**, **22-1B, 22-1C, 22-1D, 22-1E, 22-2 and 22-3** of RR Article **22**
    - ✓Article 22 contains reference parameters of GSO stations to be protected

EPFD Limits Regulatory Framework

- Article **9 – coordination trigger limits**
  - specific large earth station requires coordination under RR No. **9.7A** with respect to any existing non-GSO satellite systems using the coordination triggers in RR Appendix **5**; or
  - FSS non-GSO satellite systems requires coordination under RR No. **9.7B** with respect to any large earth station (under certain conditions) using the coordination triggers in RR Appendix **5**.
    - ✓Coordination trigger limits enable protection of very large specific GSO earth stations

EPFD Limits Validation Tools

- Validation Software is developed in accordance with methodology in Recommendation ITU-R S.1503-2
- Resolution 85 (WRC-03) establishes intermediate arrangements until required software is developed
- “Qualified favourable” finding is given based on the commitment by notifying administration to fulfill Article 22 limits
- Findings will be reviewed

Implementation of Resolution 85 (WRC-03)

- Circular Letter CR/414, 6 December 2016 contains details of examinations to be carried out in accordance with Resolution 85 (WRC-03).
- The Bureau will contact individually each administration having submitted non-GSO systems in the FSS, and request the administration to submit within three months:
  - "traditional" non-GSO parameters in Appendix 4 – orbit parameters, frequency assignments etc.
  - The PFD/EIRP* masks accounting for all the features of specific non-GSO systems arrangements:
    - PFD mask produced by non-GSO satellites
    - Non-GSO satellite off-axis eirp-mask to calculate interference in inter-satellite path (non-GSO – GSO)
    - Uplink off-axis eirp mask produced by non-GSO Earth Station
    - Masks are presented in XML-format

  * See also Rec. ITU-R S. 1503-2

EPFD Validation

EXERCISES

Exercise setup

Locate EPFD exercise files on handout USB stick:

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\

Install GIBC v7 with EPFD Modules

Warning! If you have installed GIBC v8. Please, uninstall it first.

From BR IFIC (Space Services) DVD-ROM or USB stick:

[USB drive]:\BRIFIC-2834\Space\BR_Soft\GIBC\Setup.exe

or

http://www.itu.int/en/ITU-R/software/Pages/epfd.aspx

Offline Exercise No. 1
Preparing data for EPFD Validation

Task:

Given an input data:

Database with non-GSO CR/C filing NSKY which was prepared using SpaceCap or extracted from SRS_ALL

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\Input Data\NSKY-CRC.MDB

XML Mask Data:

Downlink PFD Masks

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\Input Data\PFD Masks

Uplink EIRP Masks

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\Input Data\EIRP Masks

Your task is to validate the data and prepare input databases (SRS Data and Mask Data) required for EPFD Validation.

Step-by-step guide for offline exercise is given in the annex.

Exercise No. 2
EPFD Validation

Task:

Given an EPFD input data:

Database with non-GSO CR/C filing NSKY which was prepared and validated using EPFDPrepare

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\EPFD Input\NSKY_SRS_data.MDB

Database with PFD/EIRP masks:

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\EPFD Input\NSKY_masks.MDB

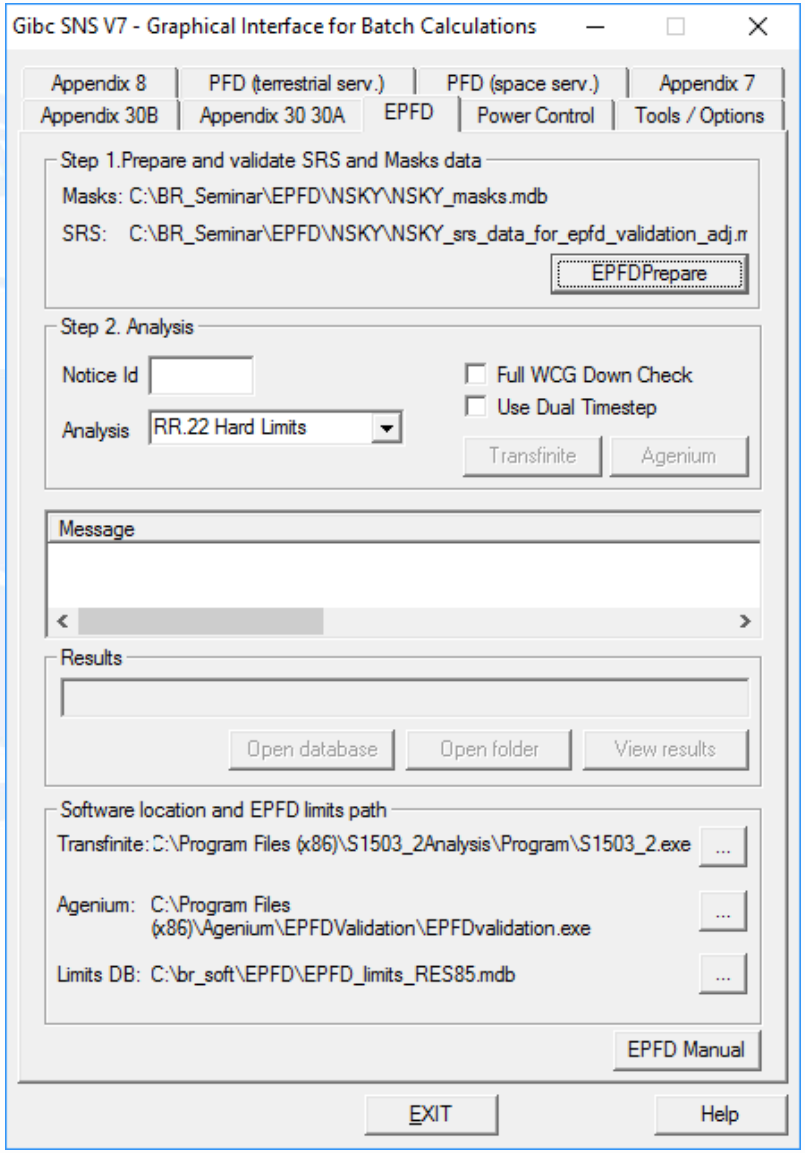
Your task is perform EPFD validation and review the results of EPFD validation.

Results are reproduced on the USB-stick:

[USB drive]:\Space_Workshops_(14-16-Dec)\09-Coordination-of-satellite-networks-technical-excercise\EPFD\EPFD Output\

Start with GIBC

- Start GIBC
- Navigate to EPFD tab
- Start EPFDPrepare



Select EPFD Input Data

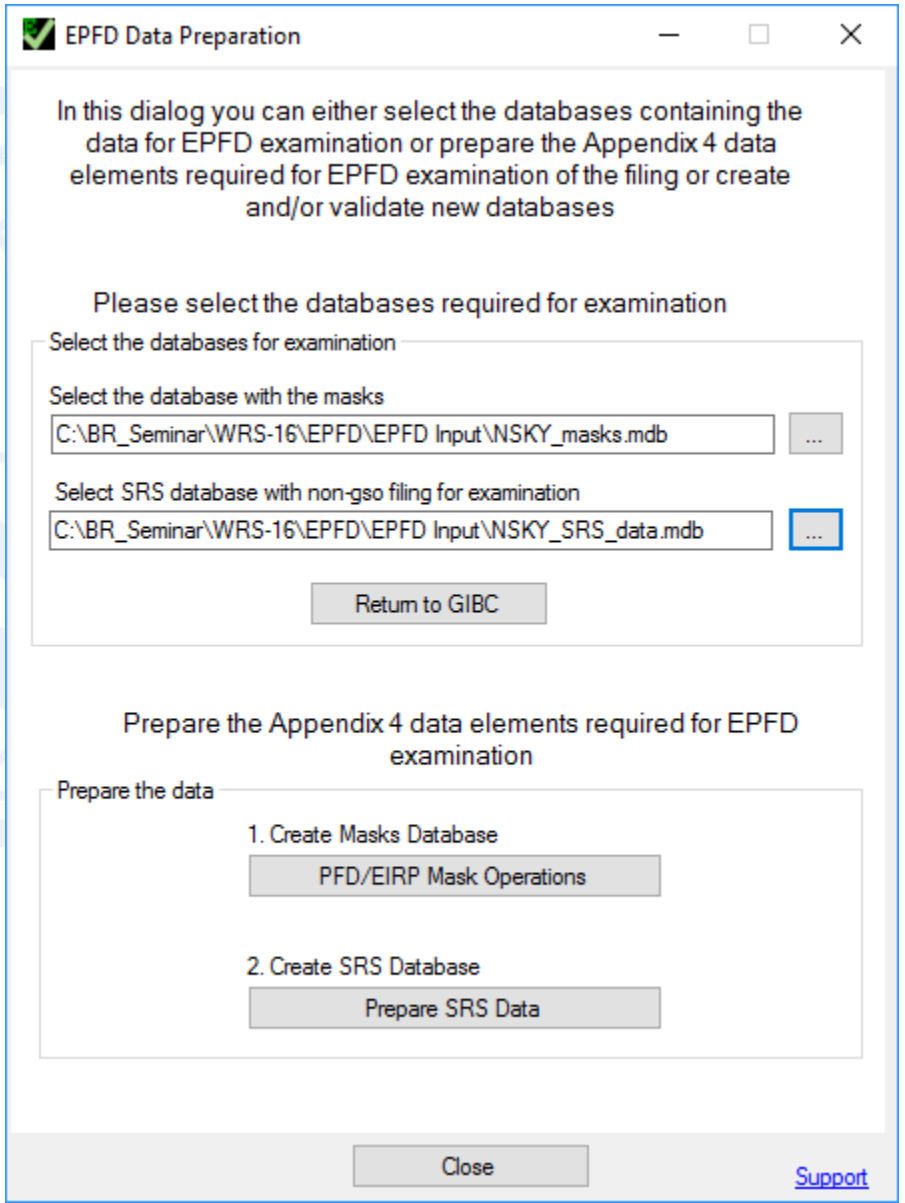
- Select mask database:

  NSKY_masks.MDB

- Select SRS data:

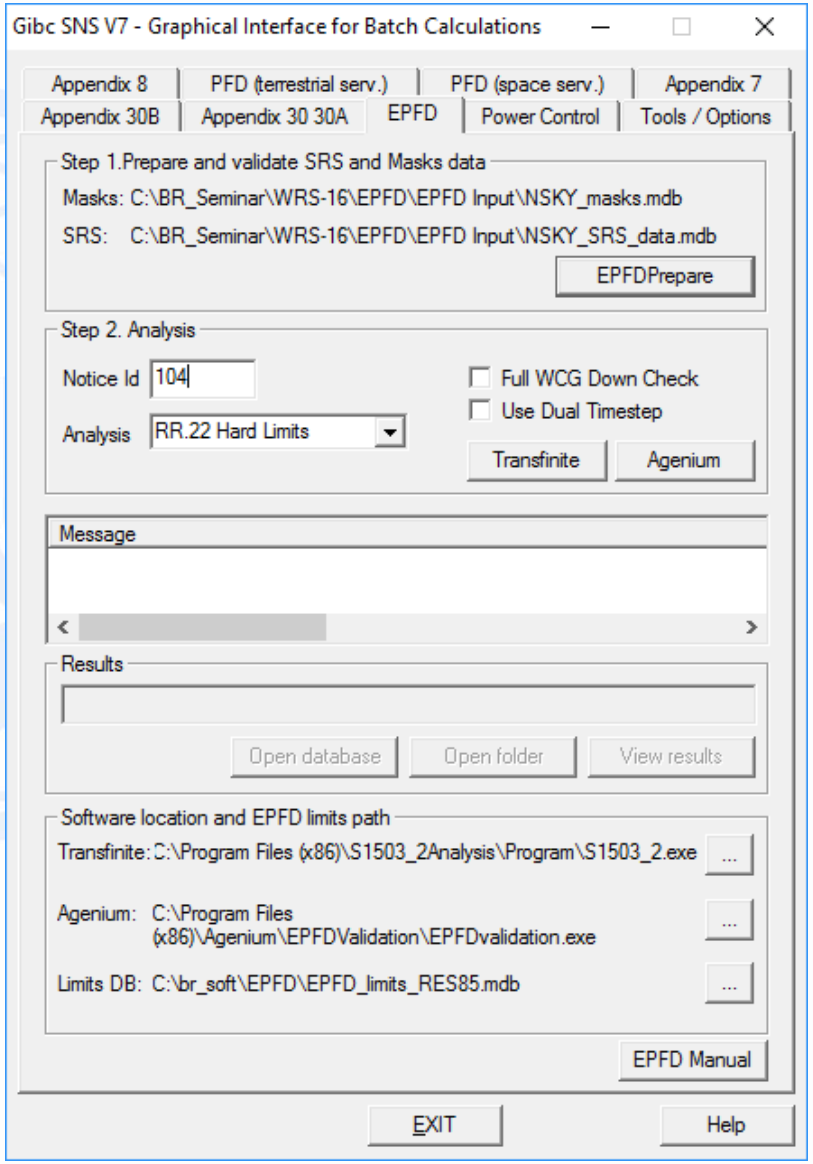
  NSKY_SRS_data.MDB

- Return to GIBC



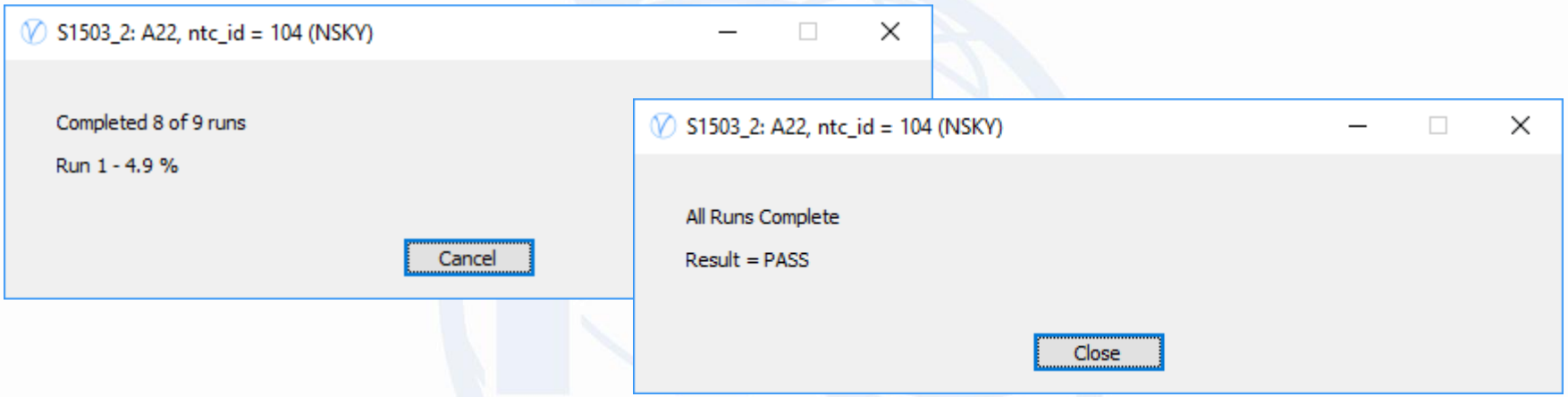
Start EPFD

- Enter notice ID - **104**
- You can choose additional options:
  - Full WCG Down Check
  - Use Dual Timestep
- Check ‘Use Dual Timestep’ to speed-up calculations
- You can start calculations using Transfinite EPFD tool or Agenium EPFD Tool by clicking corresponding buttons.

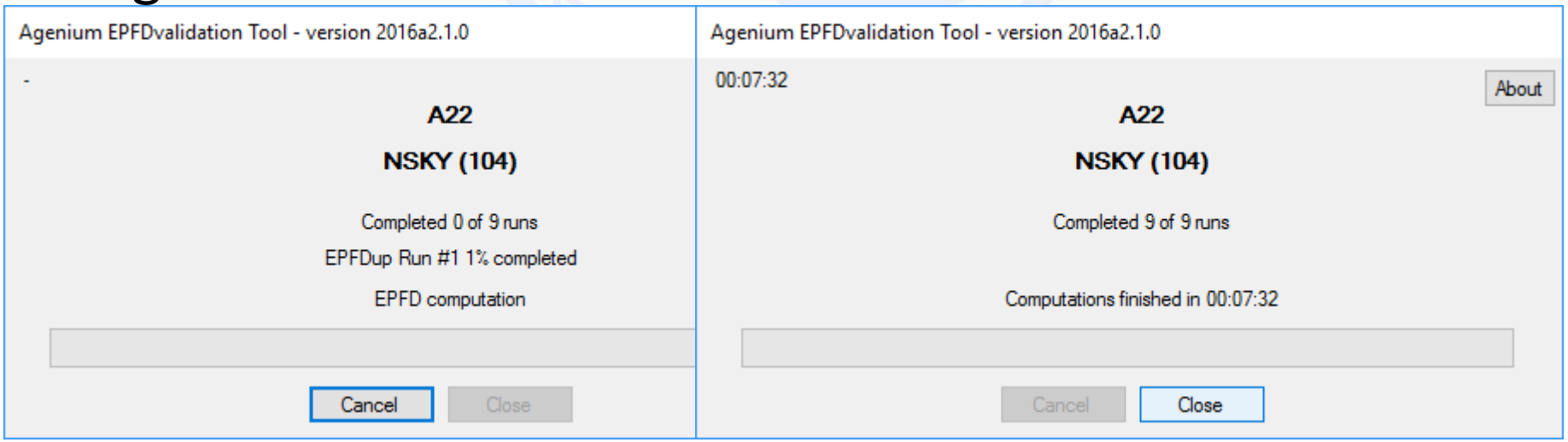


Start EPFD

- Transfinite EPFD calculation screen



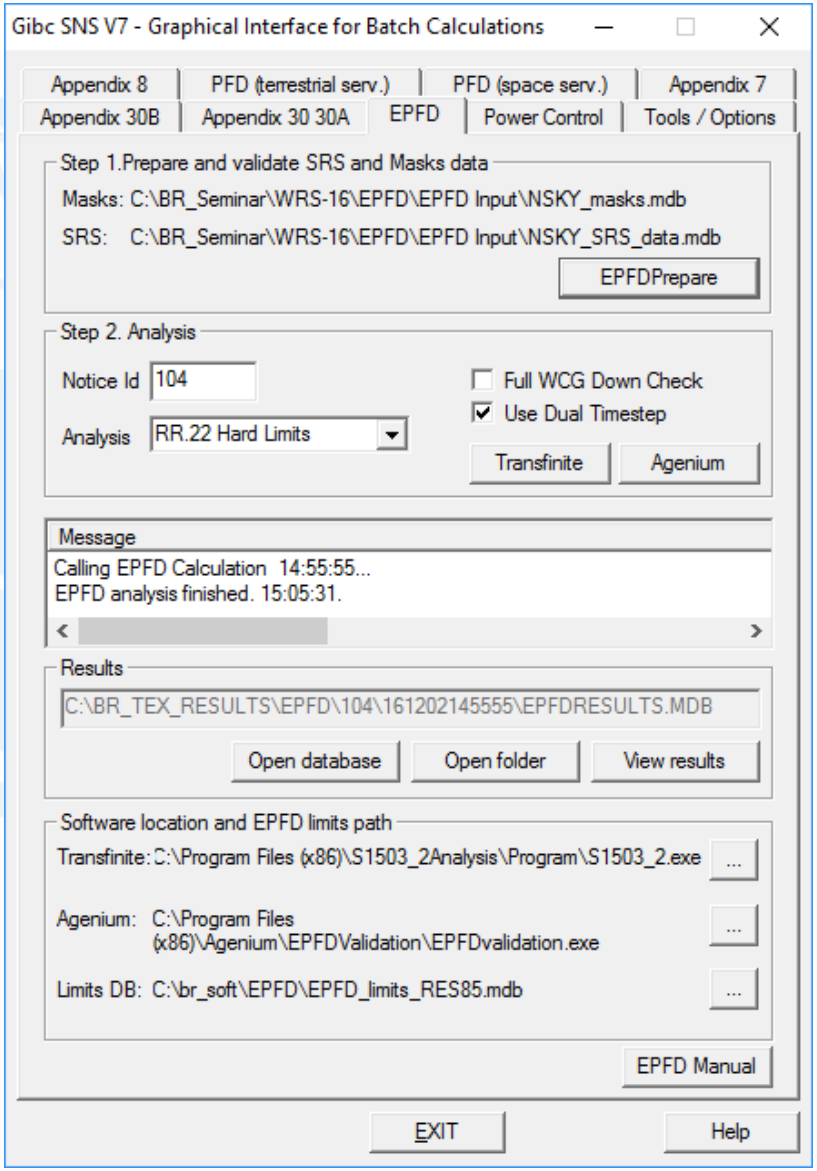
- Agenium EPFD calculation screen



EPFD results

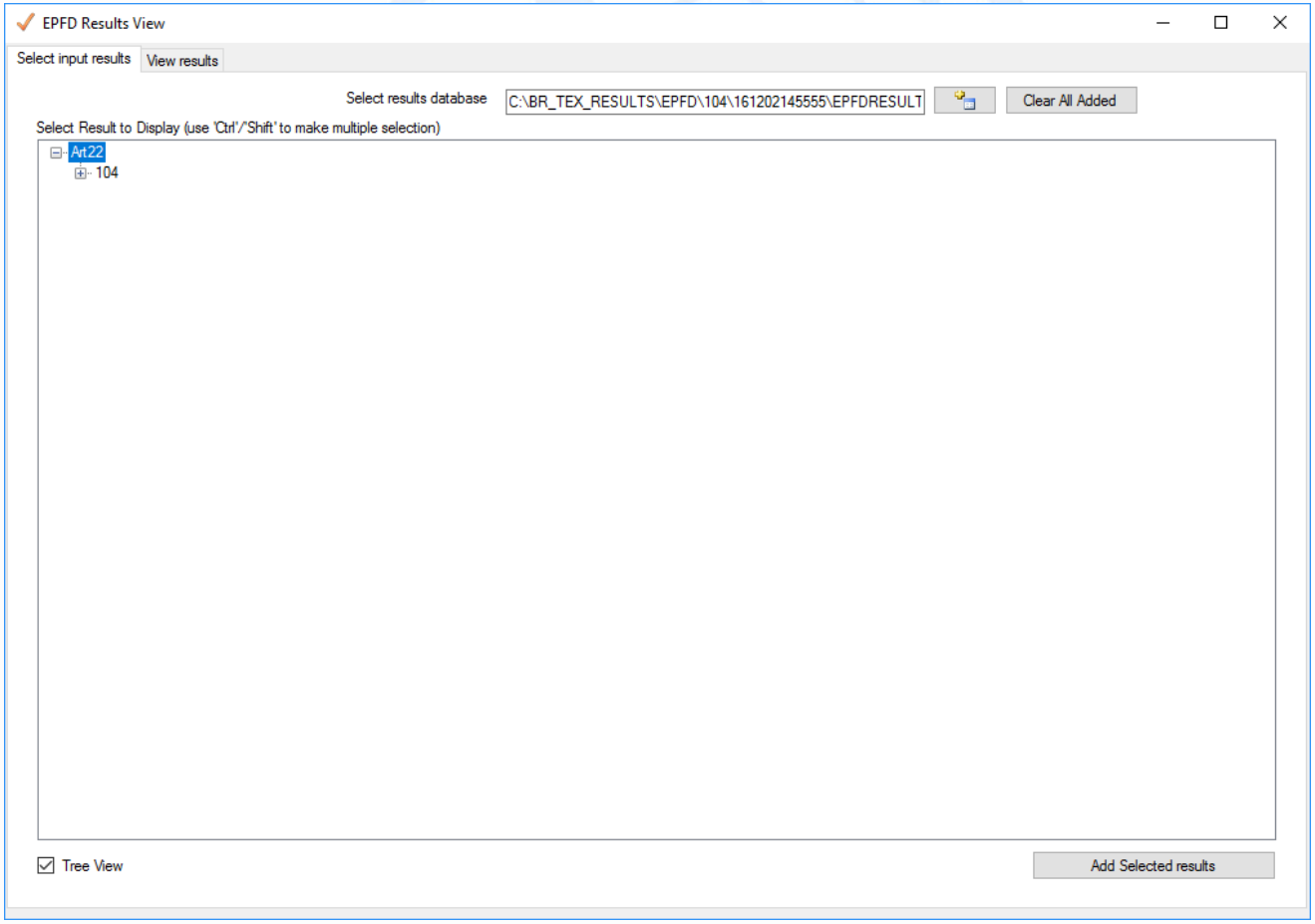
- After the calculations are completed, you can review the results
- You can open the results database in Microsoft Access
  or
- Open folder with results database

  or
- You can view results in EPFDResultsView tool



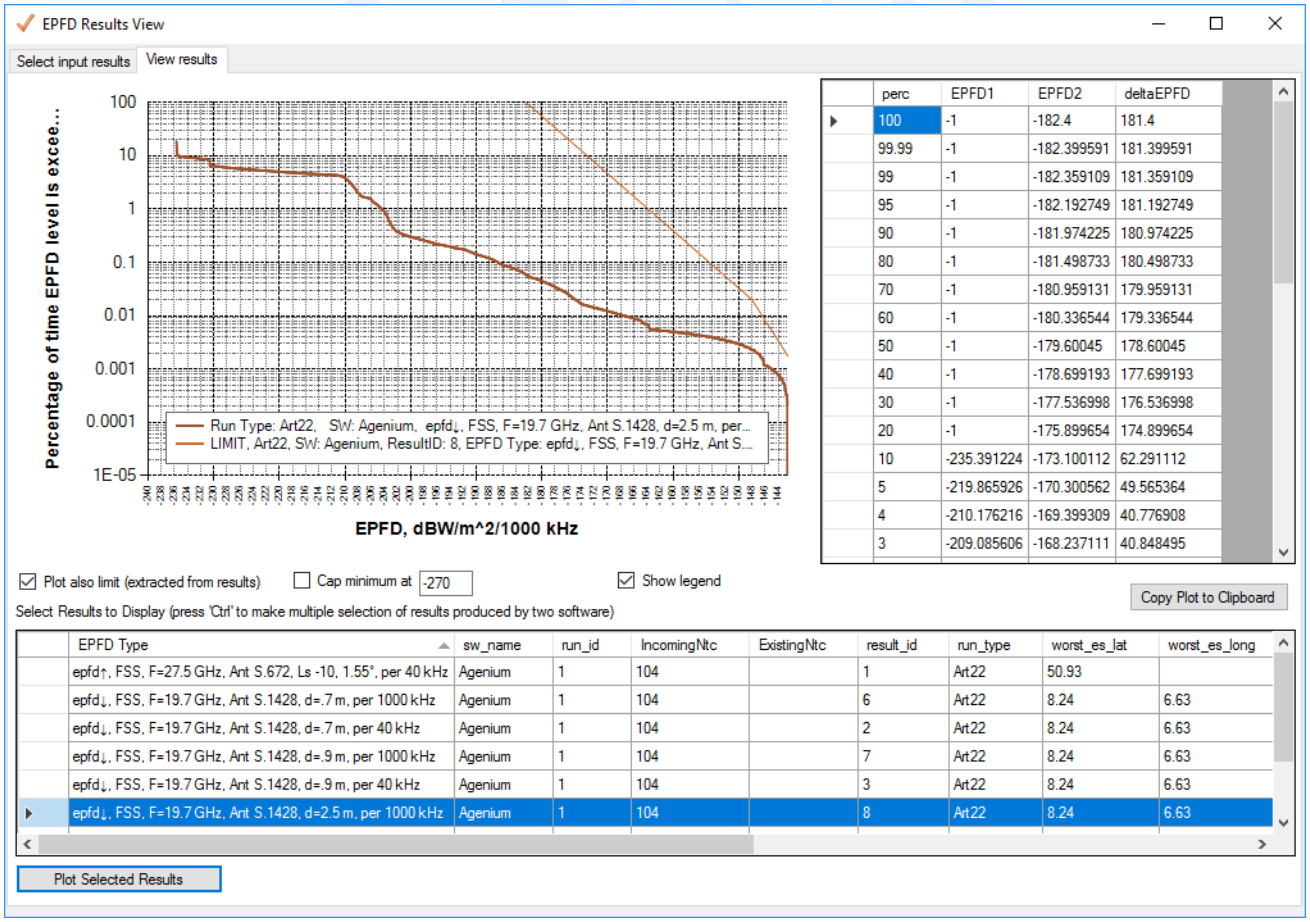
EPFD results view tool

- Open EPFDResultView tool by clicking View Results in GIBC.
- Results database is automatically opened.
- Next step is to add results for analysis.
- Select run (Art22) and click Add Selected Results.
- Instead, you can also add individual results by expanding the list.



EPFD results view tool

- Advance to View results tab.
- All results are listed in the bottom providing basic information (pass/fail, worst case location, applicable limit).
- Select any result and press ‘Plot selected results’ to plot Complementary cumulative distribution function.
- You can also plot a limit curve.

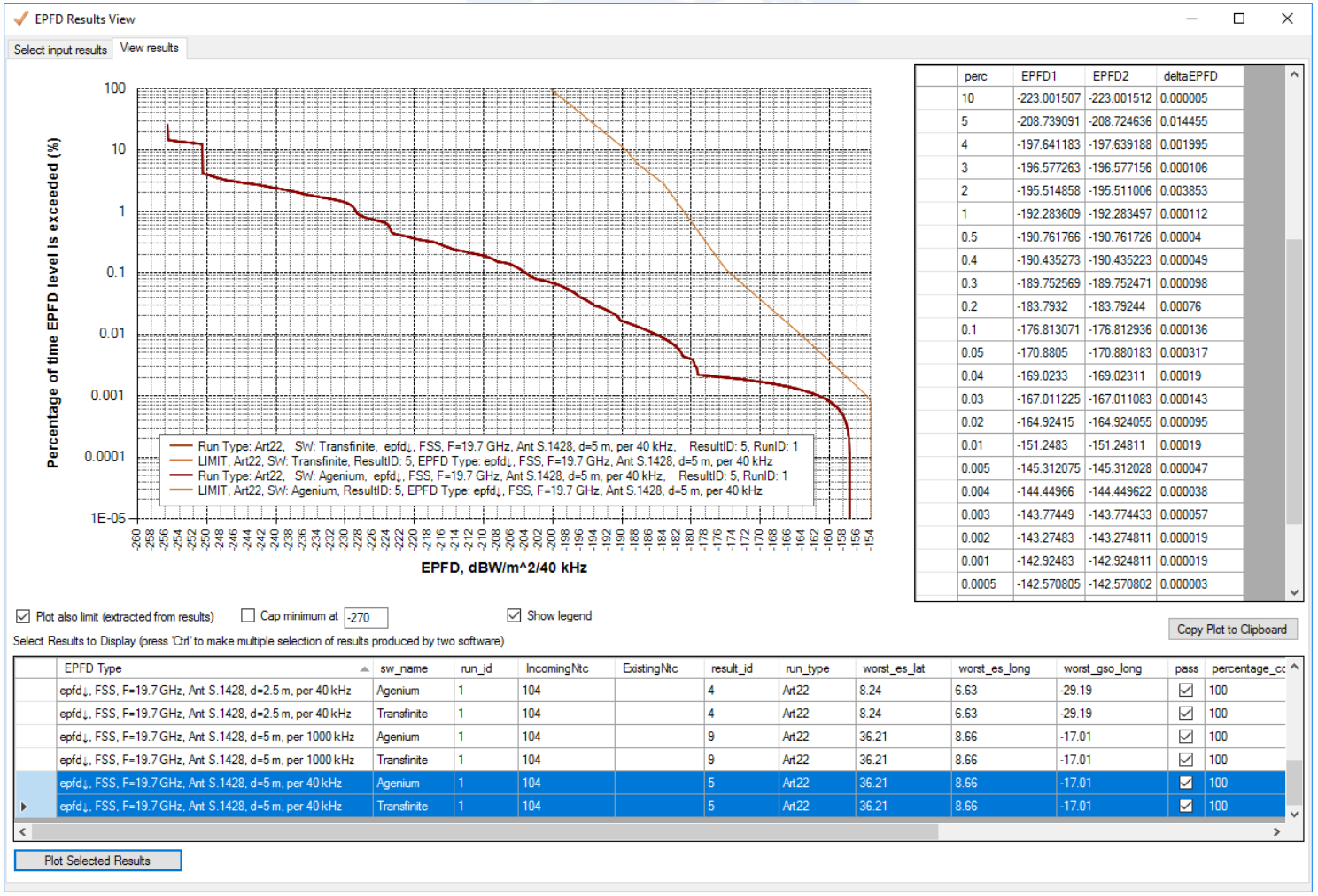


EPFD results view tool

- If you completed calculation using both tools – Agenium and Trasnfinite, you can compare results produced by these tools.
- In the main tab, click ‘Clear All Added’.
- Click button  and add results database produced by Transfinite Tool.
- Then highlight Art22 and click ‘Add selected results’.
- Then Click button  and add results database produced by Agenium Tool.
- Then highlight Art22 and click ‘Add selected results’.
- Advance to View results tab.

EPFD results view tool

- Now, you can select two results – one from Agenium and another from Transfinite for the same limit and click ‘Plot Selected Results’. (Use ‘Ctrl’ key to select multiple results).
- In the table on the right, a comparison is given for 2 results for the same percentage of time in deltaEPFD column.



perc	EPFD1	EPFD2	deltaEPFD
10	-223.001507	-223.001512	0.000005
5	-208.739091	-208.724636	0.014455
4	-197.641183	-197.639188	0.001995
3	-196.577263	-196.577156	0.000106
2	-195.514858	-195.511006	0.003853
1	-192.283609	-192.283497	0.000112
0.5	-190.761766	-190.761726	0.00004
0.4	-190.435273	-190.435223	0.000049
0.3	-189.752569	-189.752471	0.000098
0.2	-183.7932	-183.79244	0.00076
0.1	-176.813071	-176.812936	0.000136
0.05	-170.8805	-170.880183	0.000317
0.04	-169.0233	-169.02311	0.00019
0.03	-167.011225	-167.011083	0.000143
0.02	-164.92415	-164.924055	0.000095
0.01	-151.2483	-151.24811	0.00019
0.005	-145.312075	-145.312028	0.000047
0.004	-144.44966	-144.449622	0.000038
0.003	-143.77449	-143.774433	0.000057
0.002	-143.27483	-143.274811	0.000019
0.001	-142.92483	-142.924811	0.000019
0.0005	-142.570805	-142.570802	0.000003

EPFD Type	sw_name	run_id	IncomingNtc	ExistingNtc	result_id	run_type	worst_es_lat	worst_es_long	worst_gso_long	pass	percentage_cc
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=2.5 m, per 40 kHz	Agenium	1	104		4	Art22	8.24	6.63	-29.19	☑	100
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=2.5 m, per 40 kHz	Transfinite	1	104		4	Art22	8.24	6.63	-29.19	☑	100
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=5 m, per 1000 kHz	Agenium	1	104		9	Art22	36.21	8.66	-17.01	☑	100
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=5 m, per 1000 kHz	Transfinite	1	104		9	Art22	36.21	8.66	-17.01	☑	100
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=5 m, per 40 kHz	Agenium	1	104		5	Art22	36.21	8.66	-17.01	☑	100
epfd↓, FSS, F=19.7 GHz, Ant S.1428, d=5 m, per 40 kHz	Transfinite	1	104		5	Art22	36.21	8.66	-17.01	☑	100

End of exercise

Questions?

Accompanying documents

Document WRS16/15

Limits on equivalent power flux density (EPFD)

ITU-R Recommendation S.1503-2

Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations

EPFD software web-page

http://www.itu.int/ITU-R/go/space-epfd/en

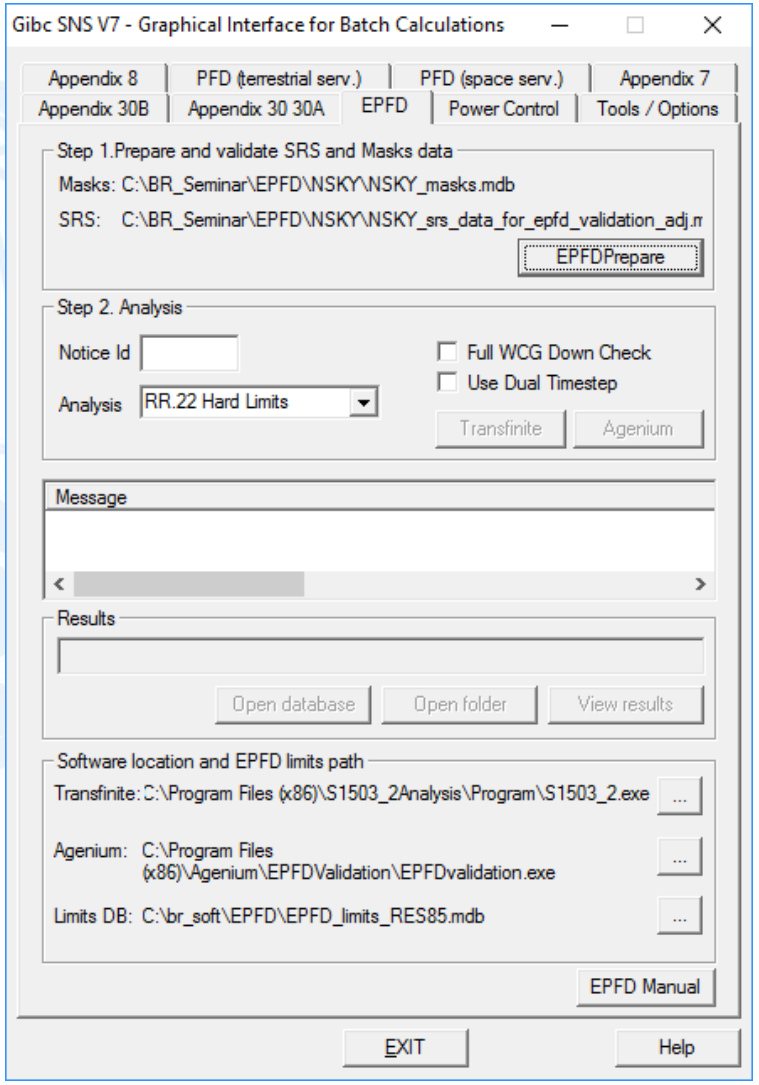
BRMail@itu.int

epfd-support@itu.int

Offline exercise step-by-step guide

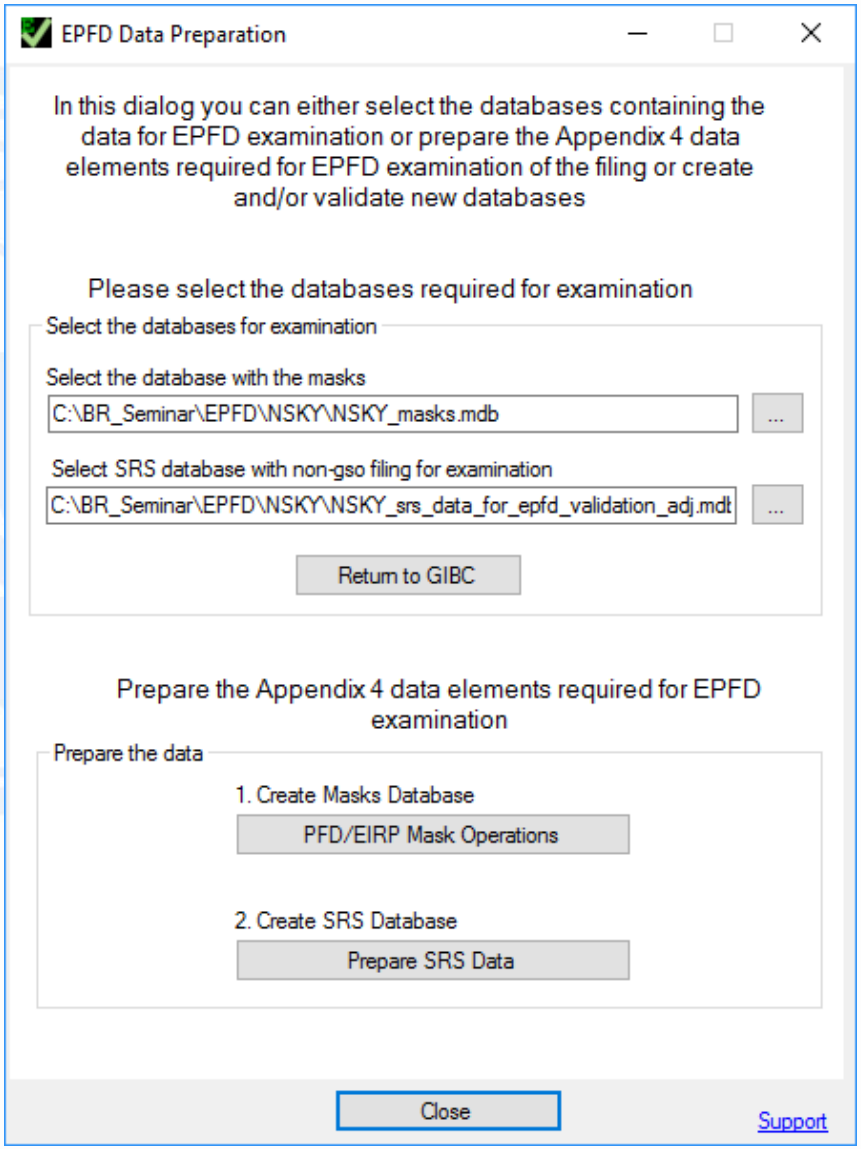
Start with GIBC

- Start GIBC
- Navigate to EPFD tab
- Start EPFDPrepare



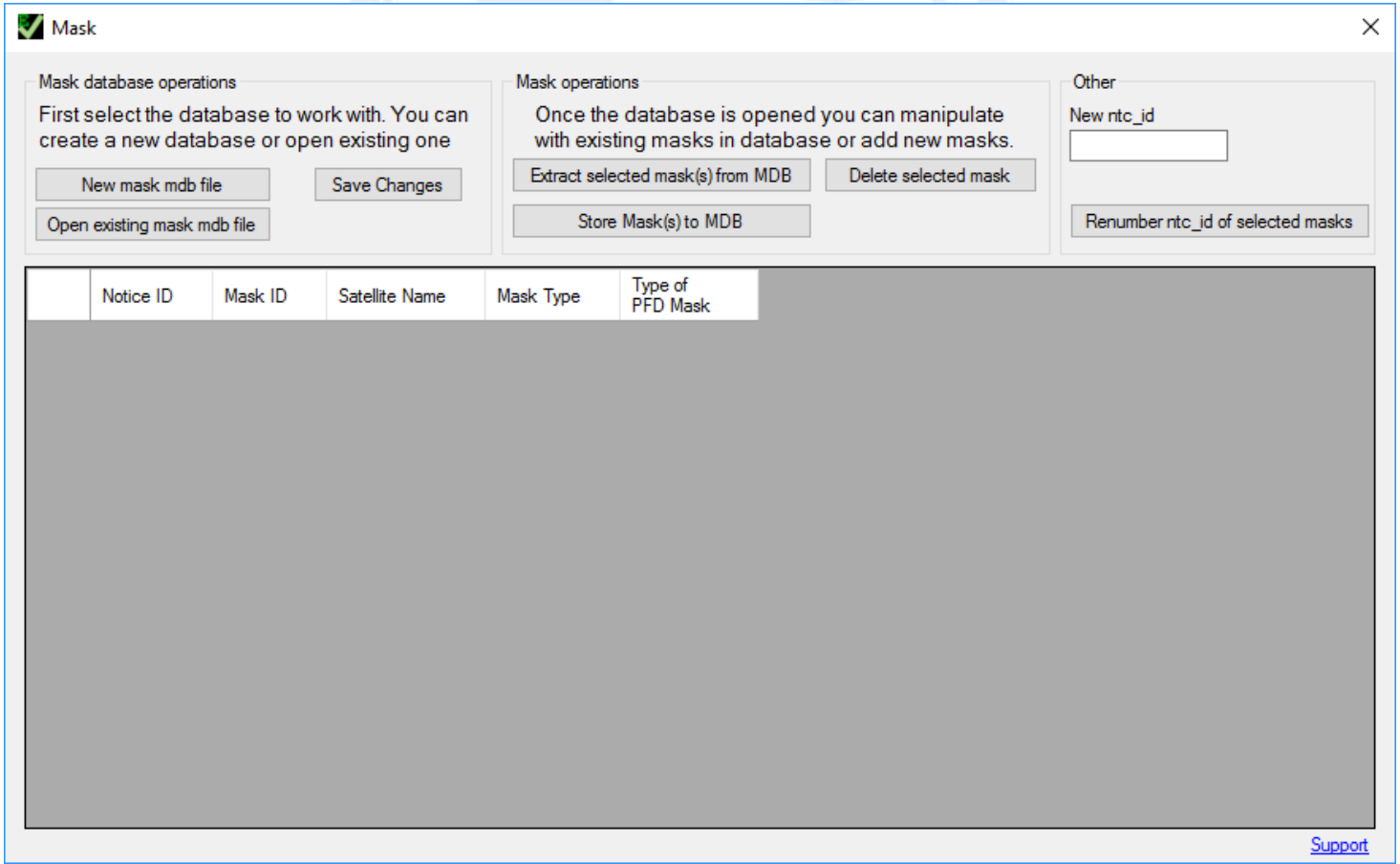
EPFDPrepare

- First step is to create mask database
- Press PFD/EIRP Mask Operations



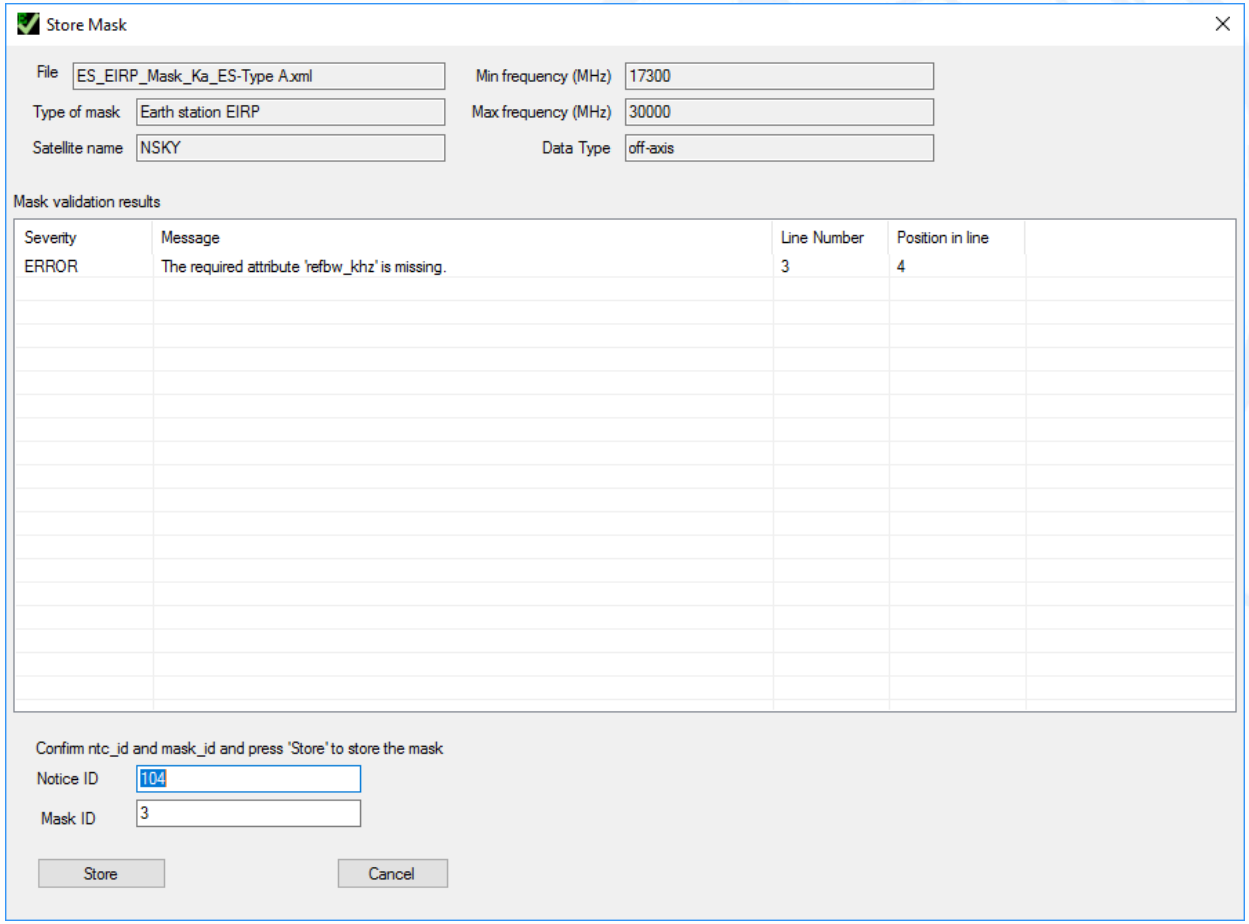
Creating Mask Database

- Click New mask mdb file
- Click Store Mask(s) to MDB and select XML masks in EIRP Masks folder and then PFD Masks Folder.
  You can select multiples files in folder.



Adding and validating masks

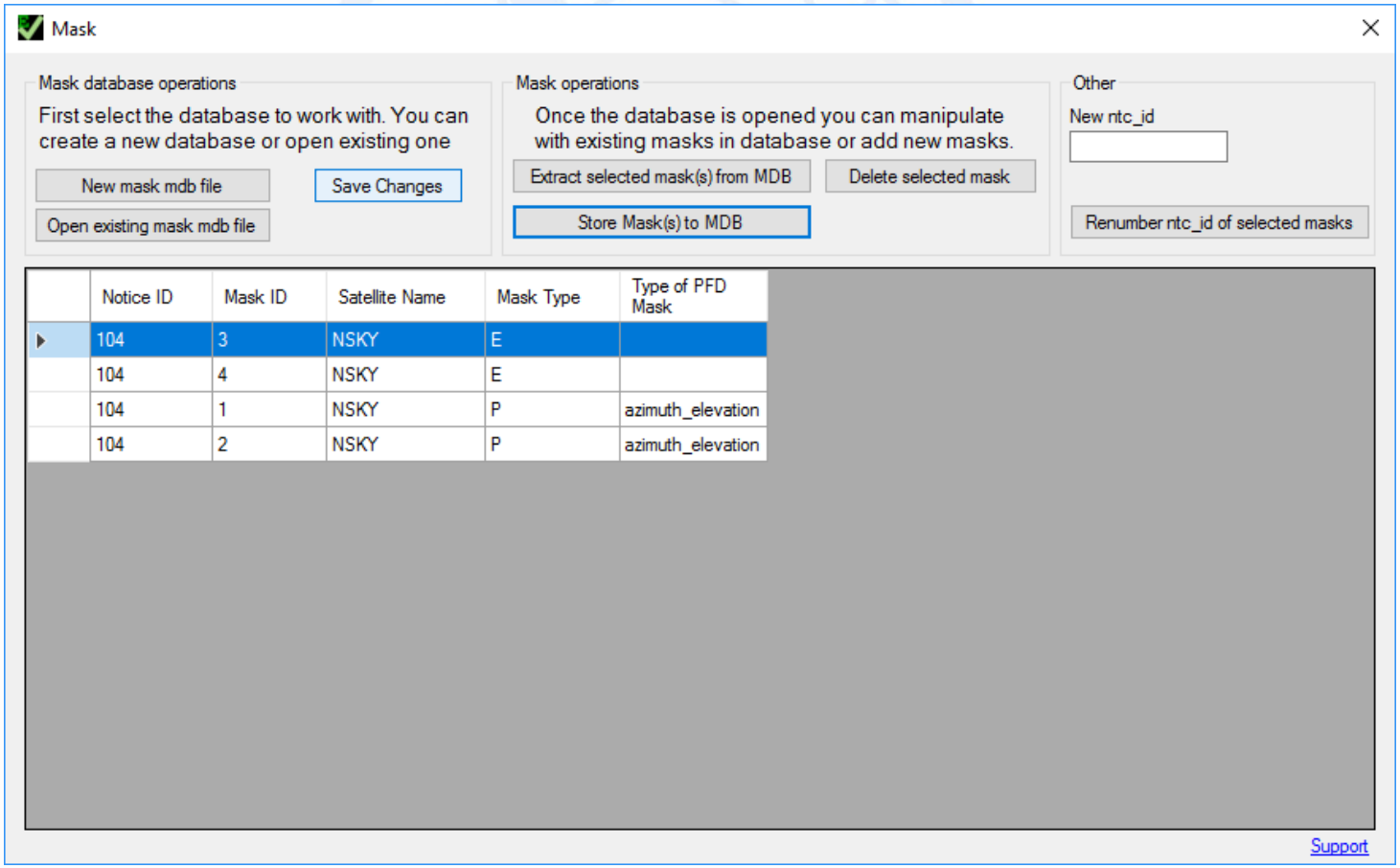
- When adding each mask, mask validation screen is displayed.
- On this screen you can check mask validation errors. Also, you can adjust Notice ID and Mask ID. There should be no duplicate Mask IDs.



In our example there is an error in the EIRP mask. This error can be ignored, since the software will use smallest reference bandwidth extracted from the limit.

Adding and validating masks

- After finishing adding the masks, save the mask database
- Click ‘Save Changes’ and save database to **NSKY_masks.mdb**
- Close the window to return to EPFDPrepare main window

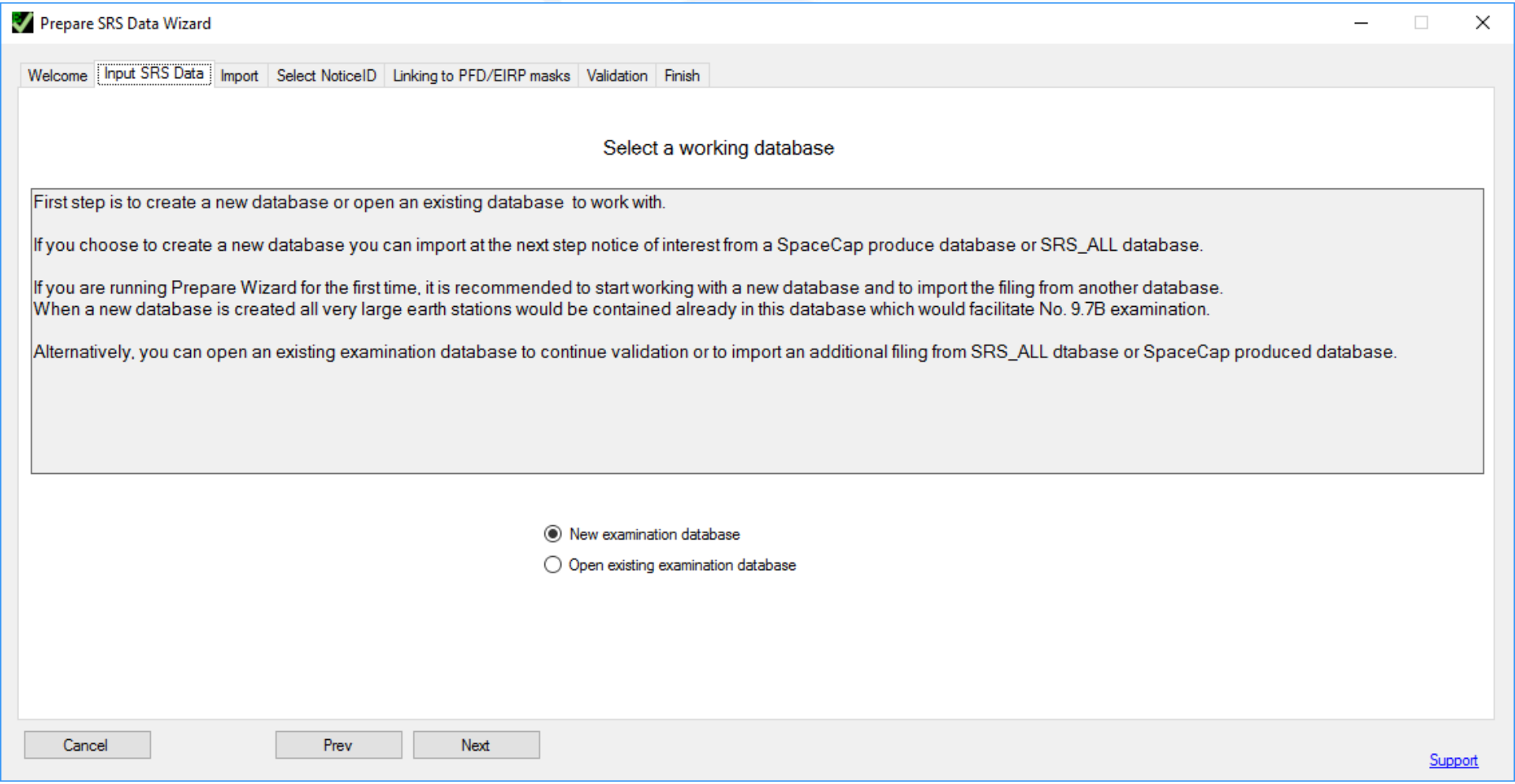


Prepare Appendix 4 data

- Now it is time to import our CR/C filing and validate it.
- Press ‘Prepare SRS Data’ from EPFDPrepare main window
- You are presented with Prepare SRS Data wizard.
- Click ‘Next’.

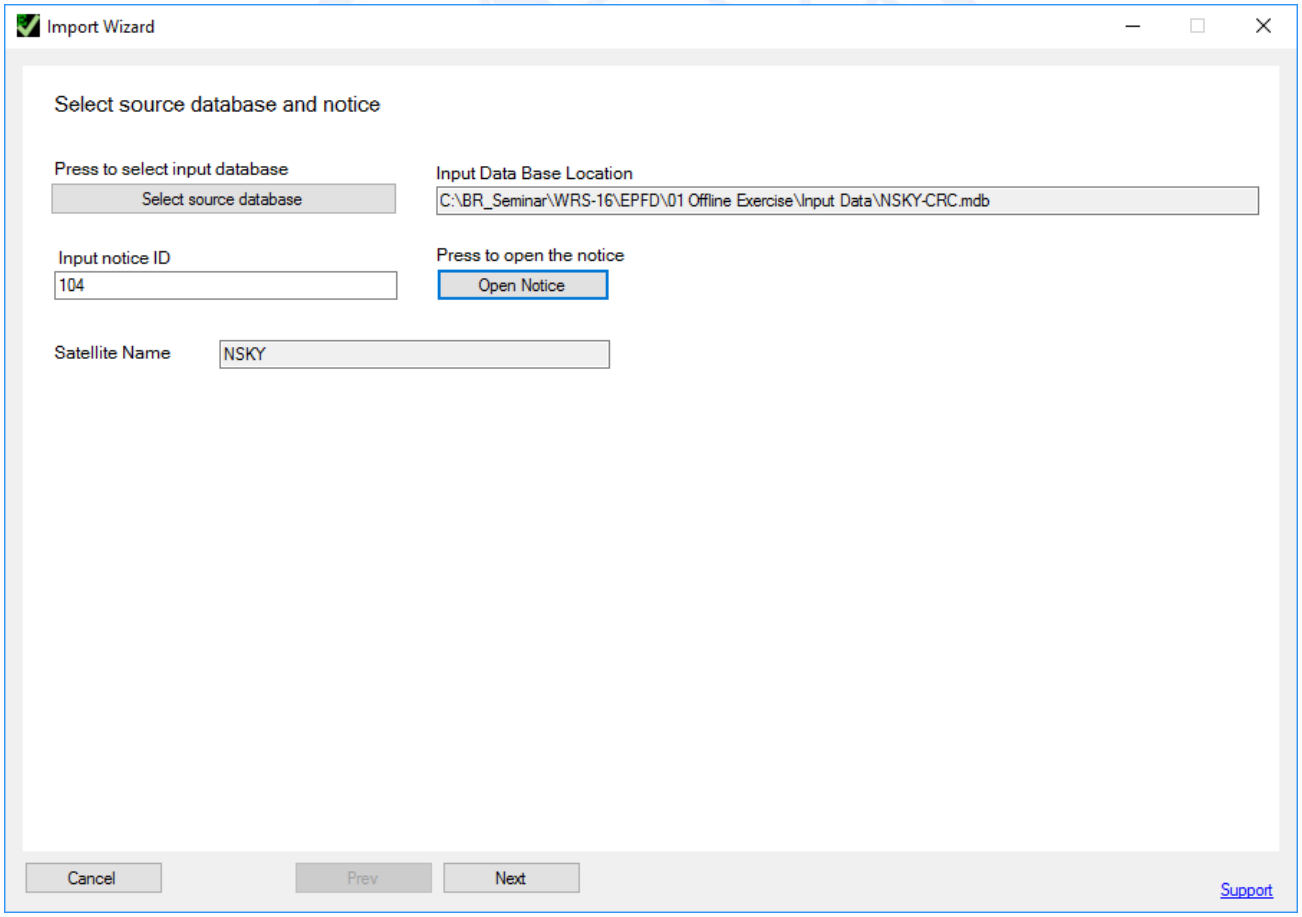
Create new database

- Select new examination database and click ‘Next’



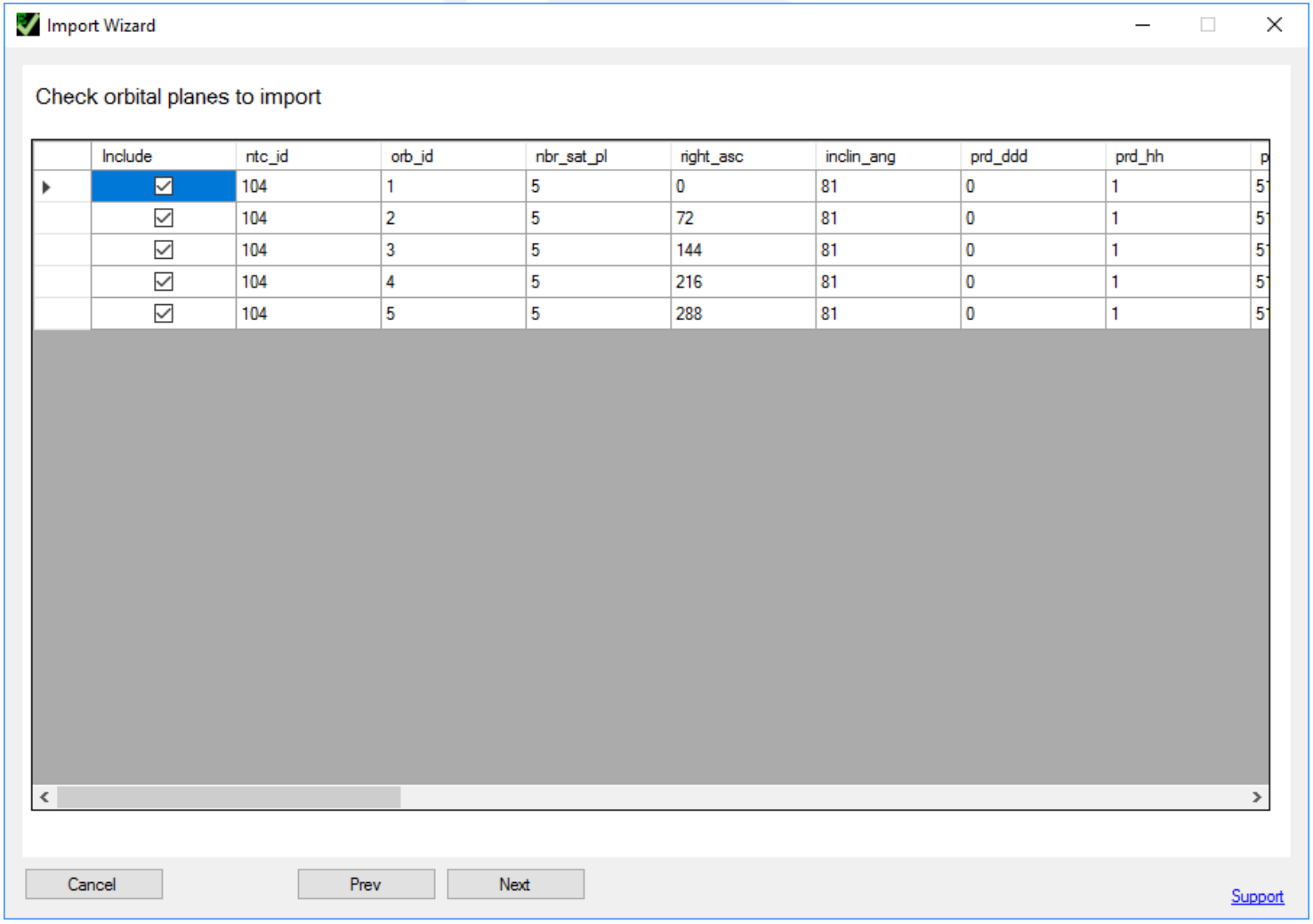
Import CR/C filing

- On the next screen we can start importing our CR/C filing into newly created database.
- Click ‘Import from an existing database’ to start import wizard.
- First click ‘Select source database’ and point to NSKY-CRC.mdb located in exercise folder.
- Then type Notice ID 104, click ‘Open Notice’ and click ‘Next’



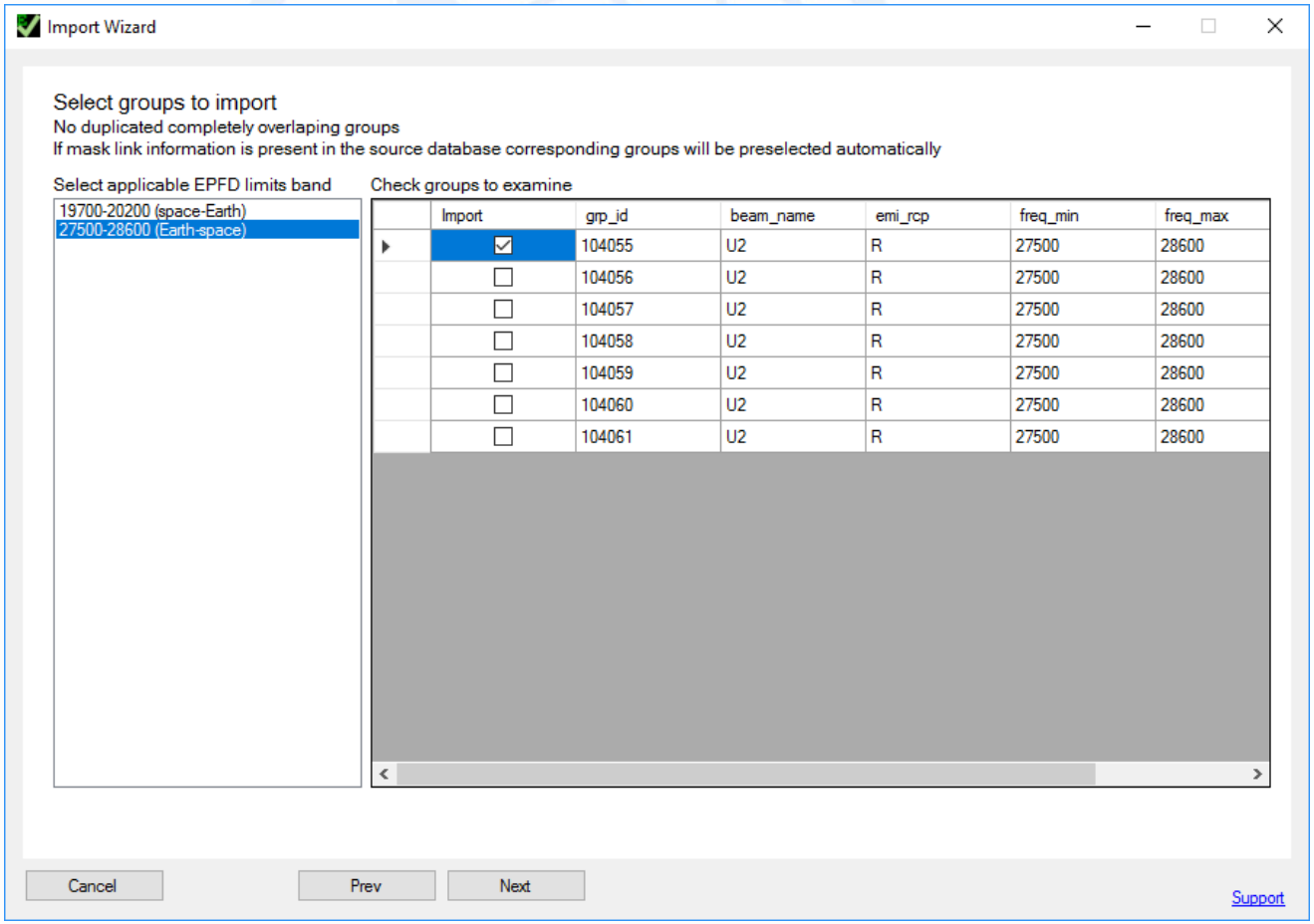
Import CR/C filing

- On the next screen select all orbits to import



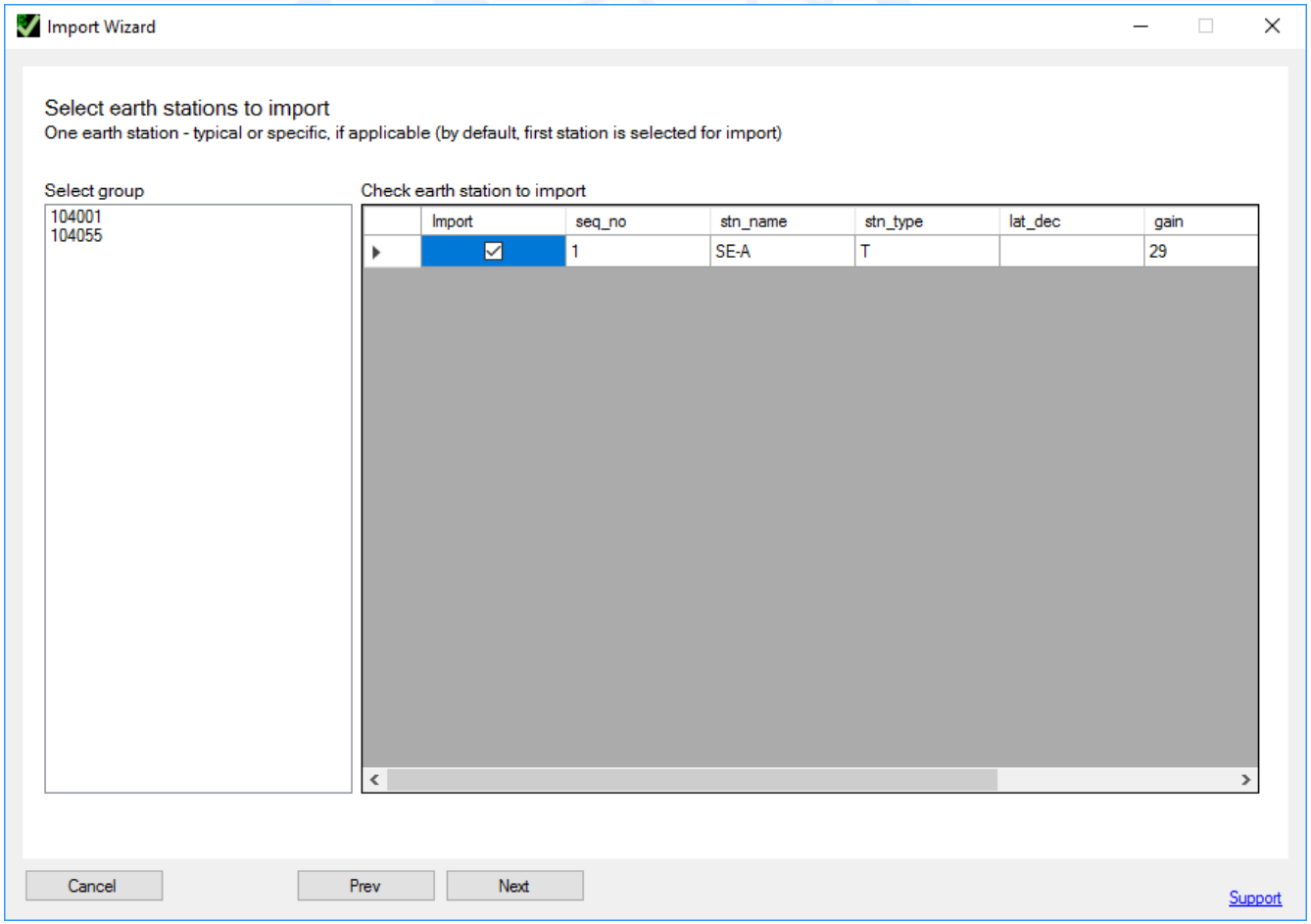
Import CR/C filing

- From the left you can choose applicable EPFD limits band present in the filing.
- In our case, for single limit there are several groups subject to this limit. It is required to choose only one group per limit which is sufficient for EPFD validation.
- Check the first group both for downlink and uplink EPFD limit.
- Click ‘Next’



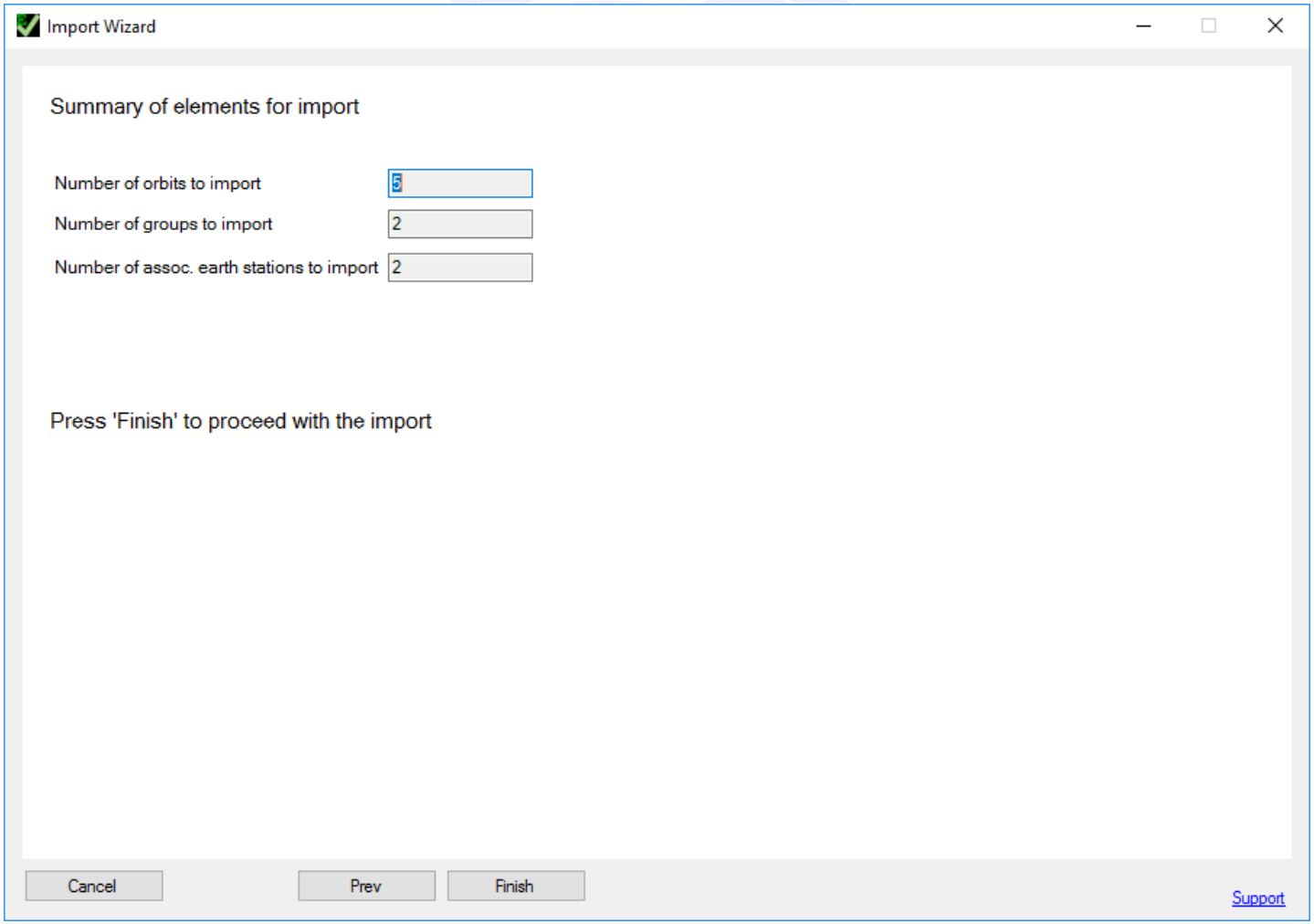
Import CR/C filing

- On this screen we need to indicate which associated earth stations to import.
- The rule - one eirp mask for single earth station. It sufficient to import only one earth station in the group.
- Check the first earth station both for all the groups.
- Click ‘Next’



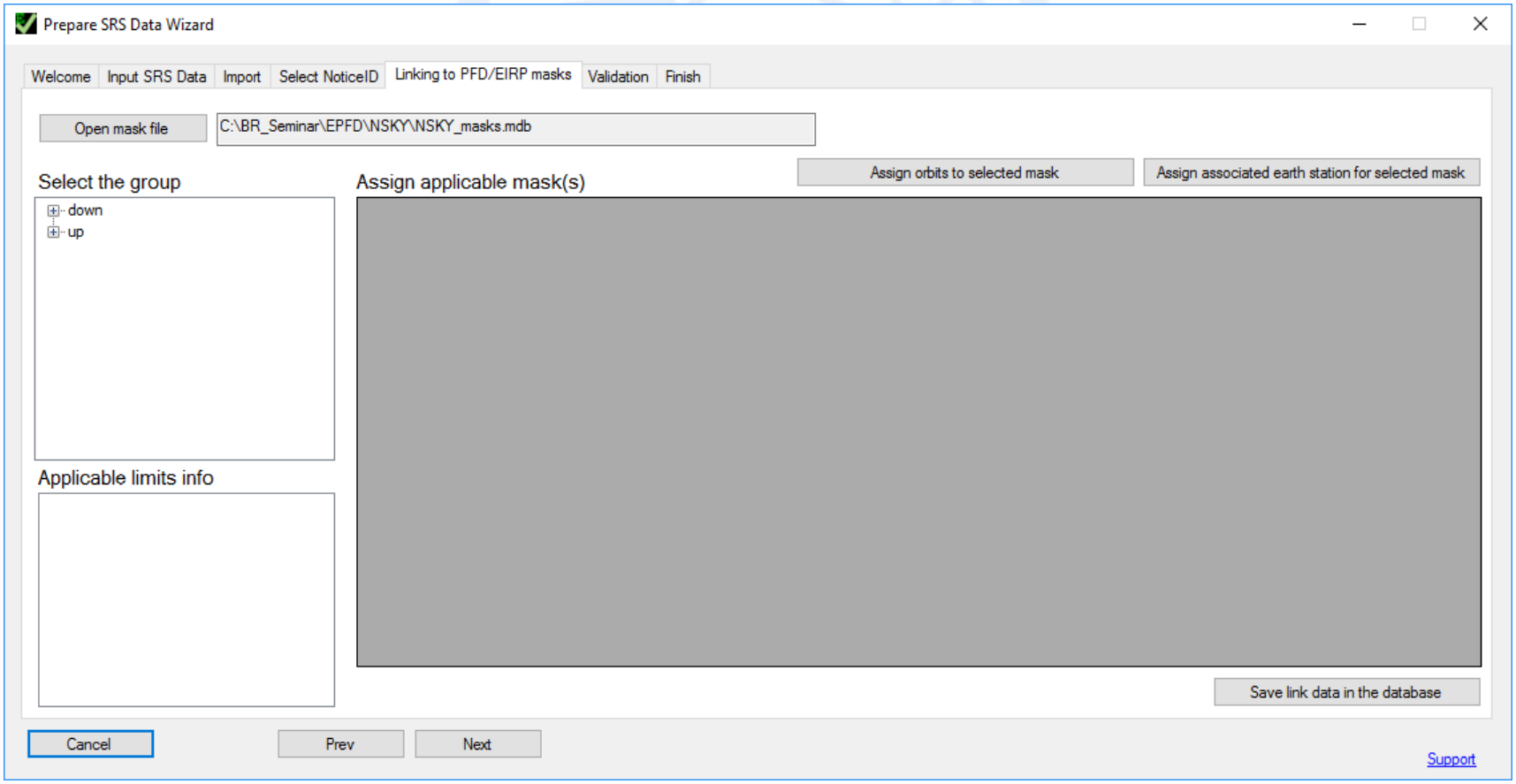
Import CR/C filing

- Summary window shows all the objects which will be imported from an input database.
- Click ‘Finish’ to close the import wizard



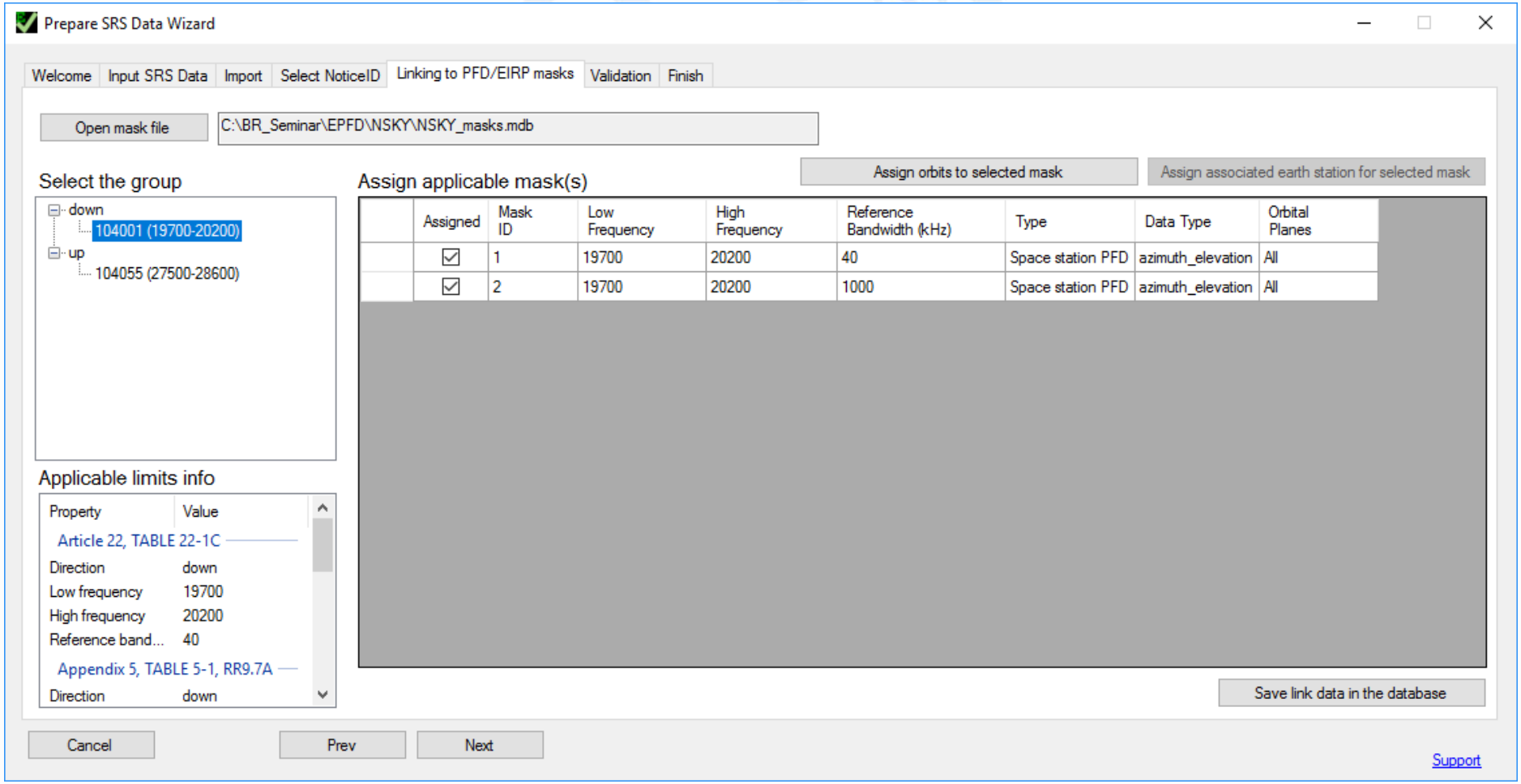
Linking to Mask data

- Prepare SRS Data Wizard continues.
- Select Notice ID – 104 NSKY and advance to the next screen
- On the next screen we need to establish the link between newly imported groups and mask data.
- Open mask file created previously **NSKY_masks.mdb**



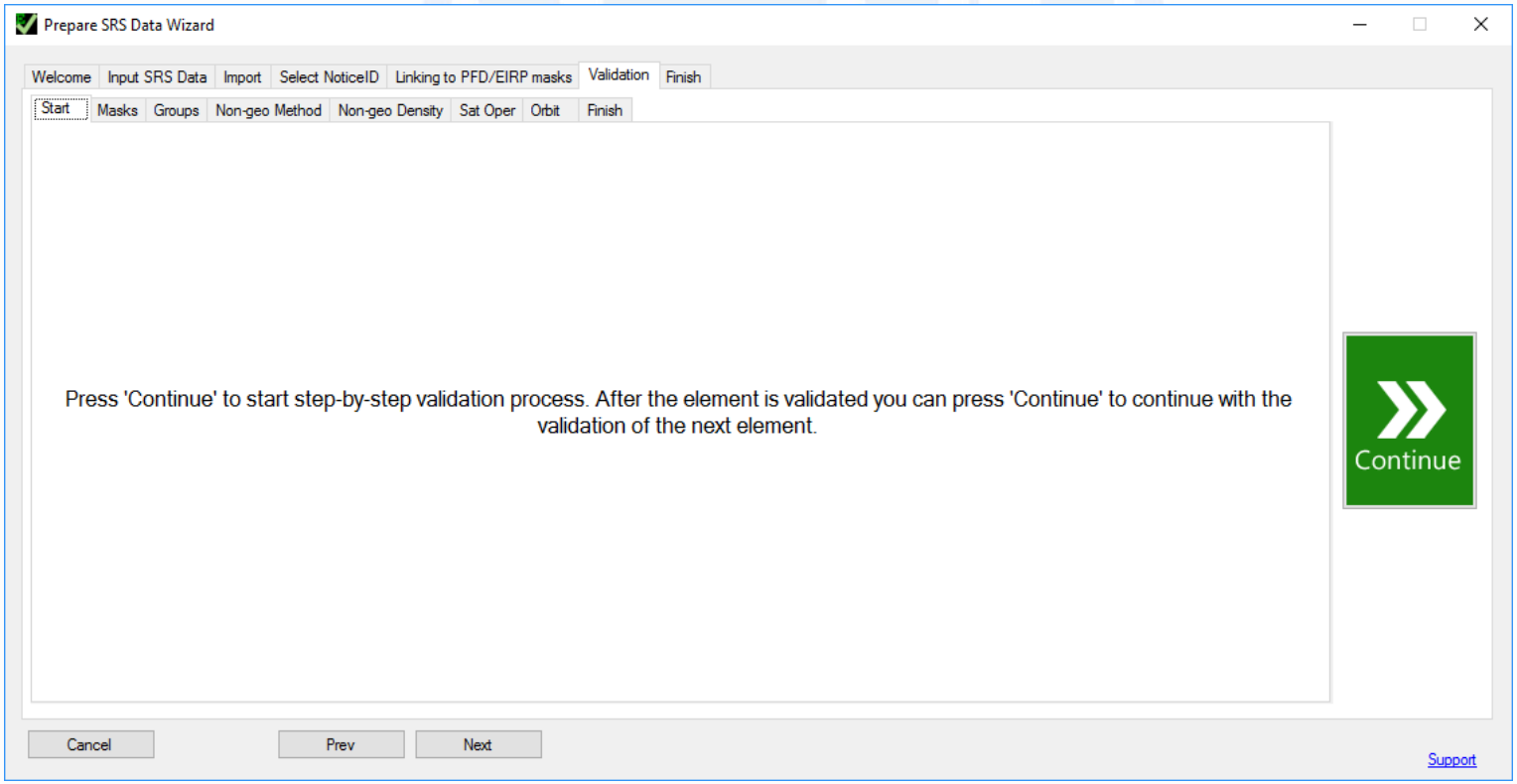
Linking to Mask data

- On the left you can select the group.
- Box below shows applicable EPFD limits.
- In the window ‘Assign applicable mask(s)’ check the masks which need to be assigned to selected group.
- Repeat for each group.



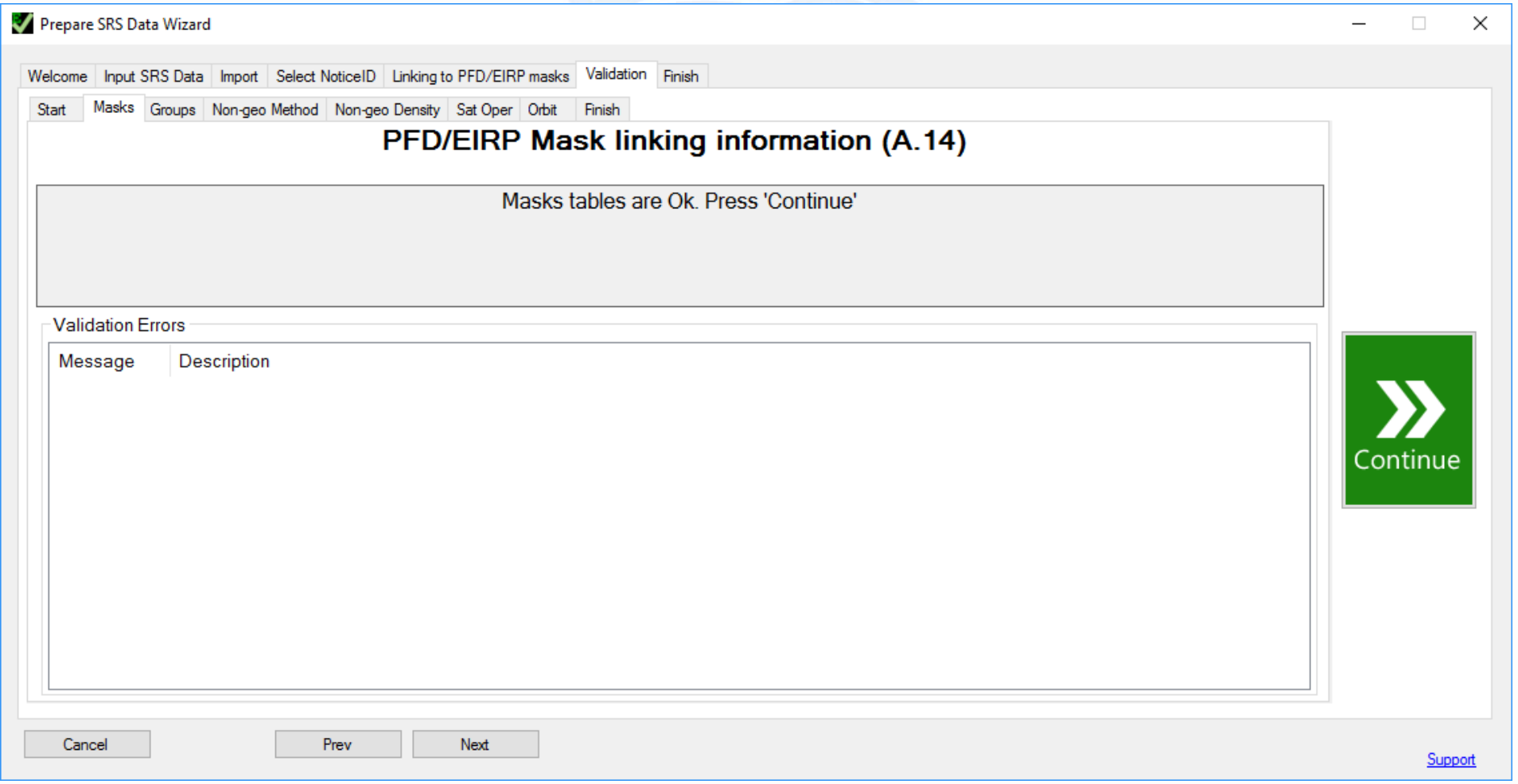
Linking to Mask data

- Our task is to assign two masks for downlink group, and only one for uplink.
- We cannot assign several masks to uplink group since only one could be examined at a time.
- After the examination is done for the first mask, we can change the link to assign a 2nd mask to the uplink group and repeat the examination.
- Click ‘Save link data in the database’ at the end.
- Next step is start validation of Appendix 4 data.
- Click green arrow ‘Continue’ to start Appendix 4 data validation wizard



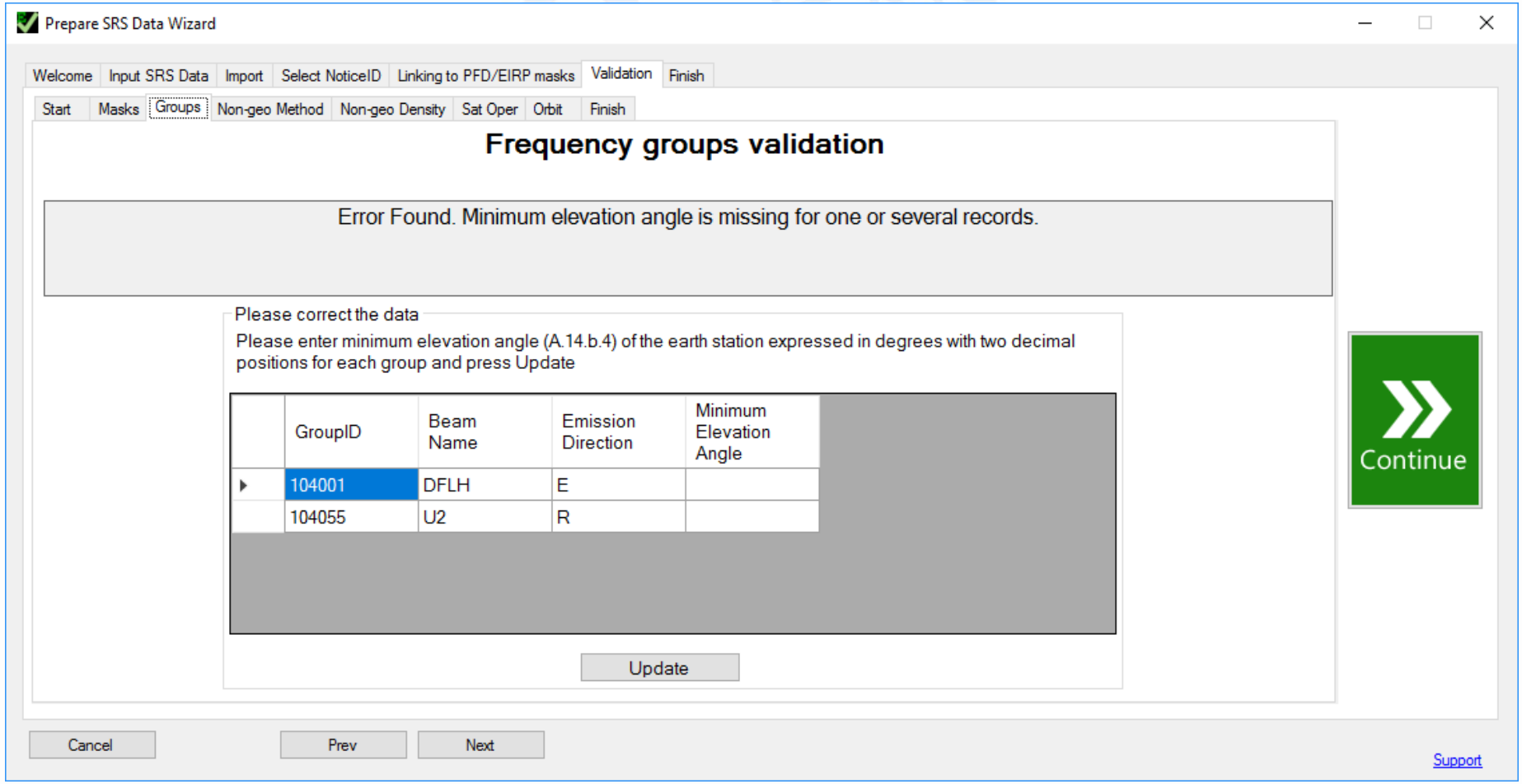
Appendix 4 data validation

- No problems are found with respect to the link data.
- Continue next.



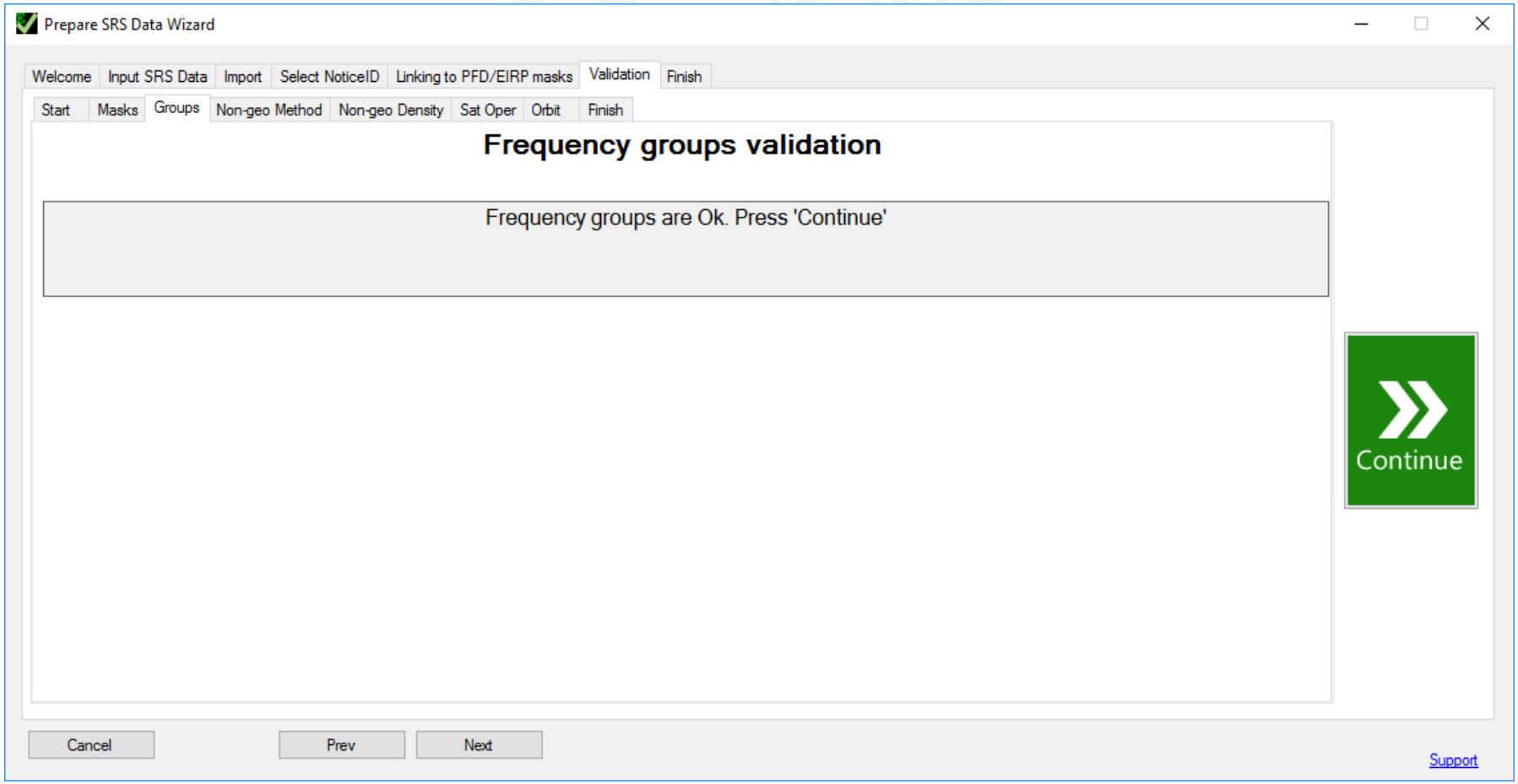
Appendix 4 data validation

- Minimum elevation angle is missing.
- Enter 40 for each group and click ‘Update’
- Continue next.



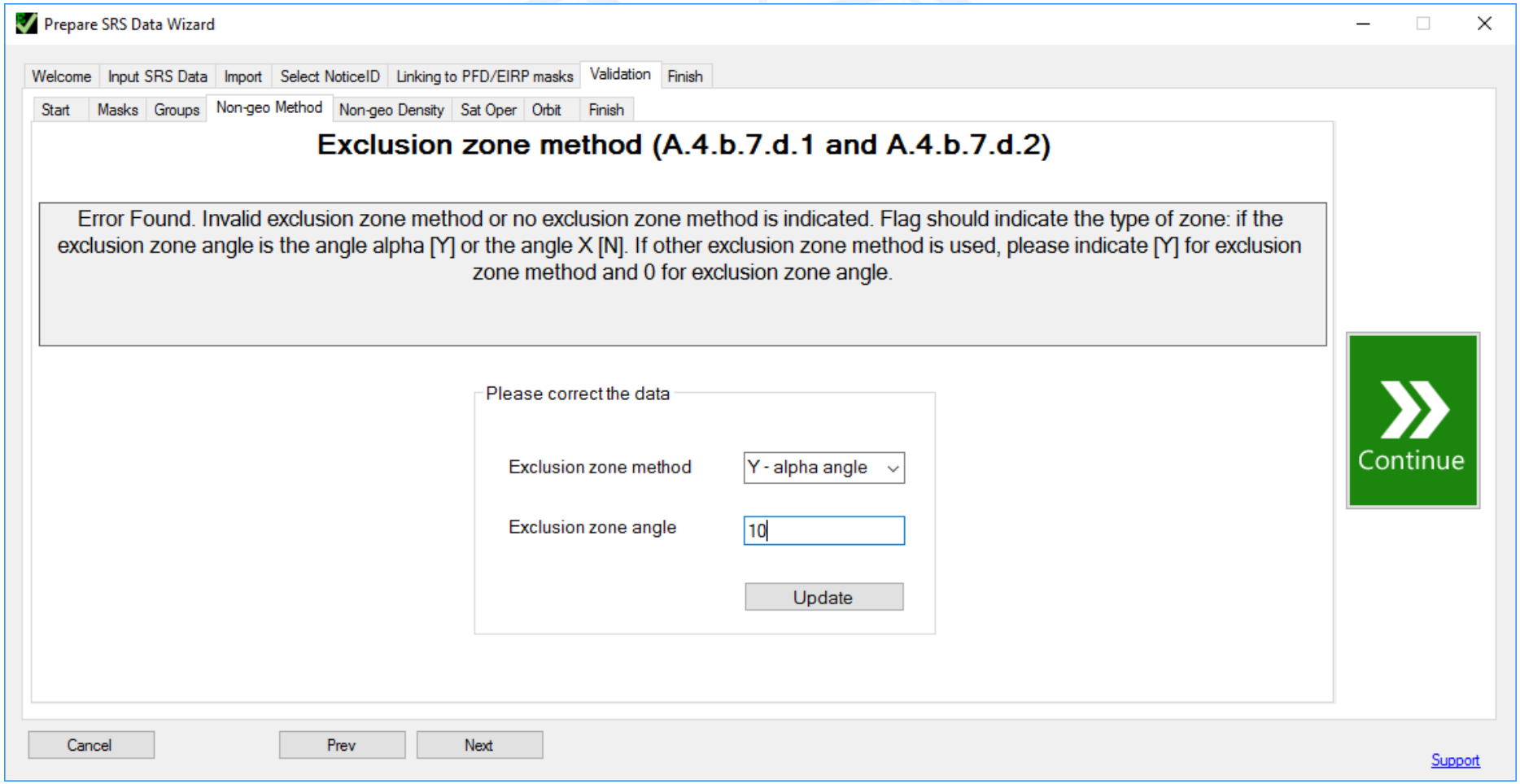
Appendix 4 data validation

- No problems are found with respect to the frequency assignment groups.
- Continue next.



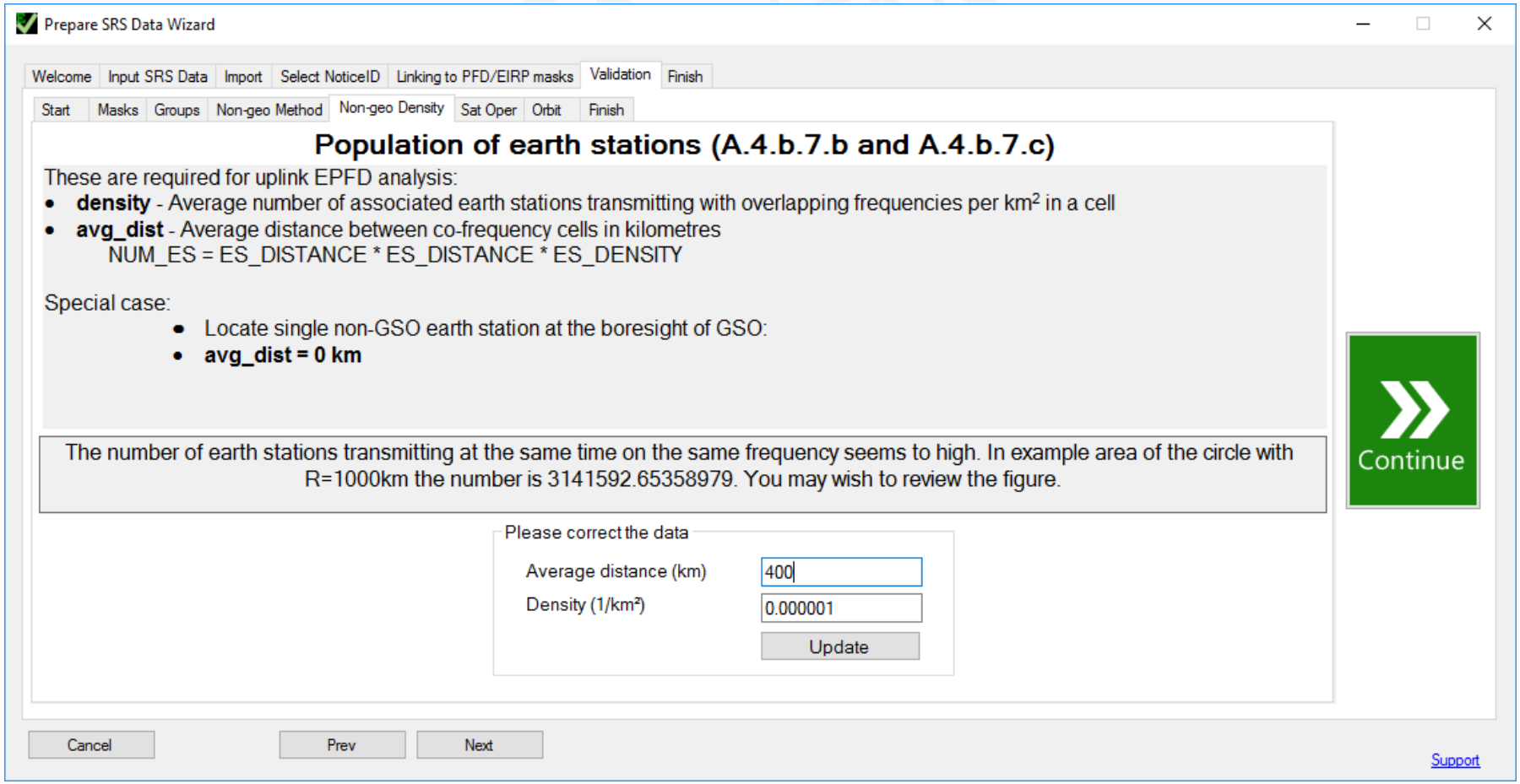
Appendix 4 data validation

- Exclusion zone method is not indicated.
- Enter ‘Y’ as method and 10 degrees angle. Click ‘Update’.
- Continue next.



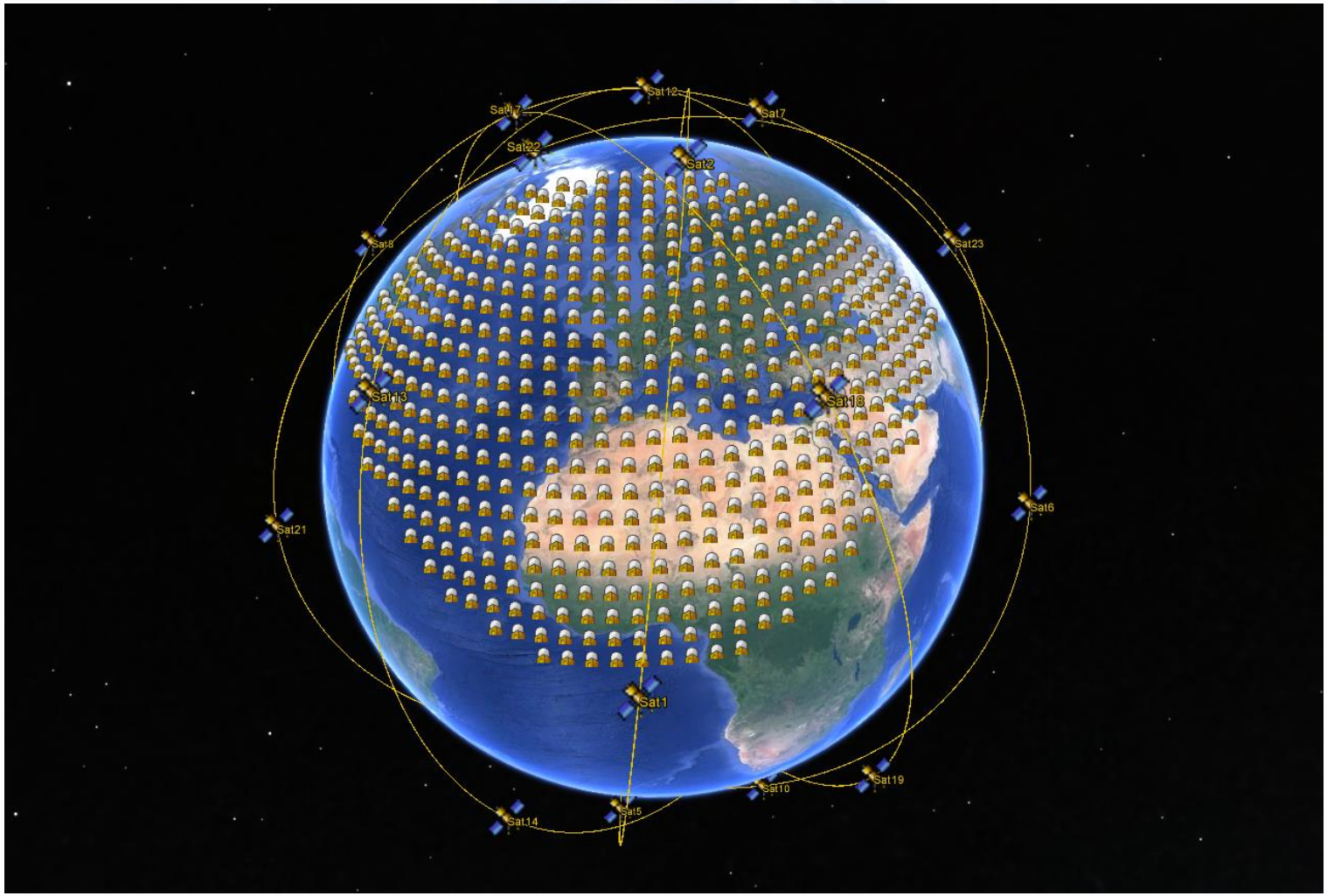
Appendix 4 data validation

- Unrealistic earth station data is found.
- Enter 400 as average distance between representative earth stations and 0.000001 as density. Click ‘Update’.



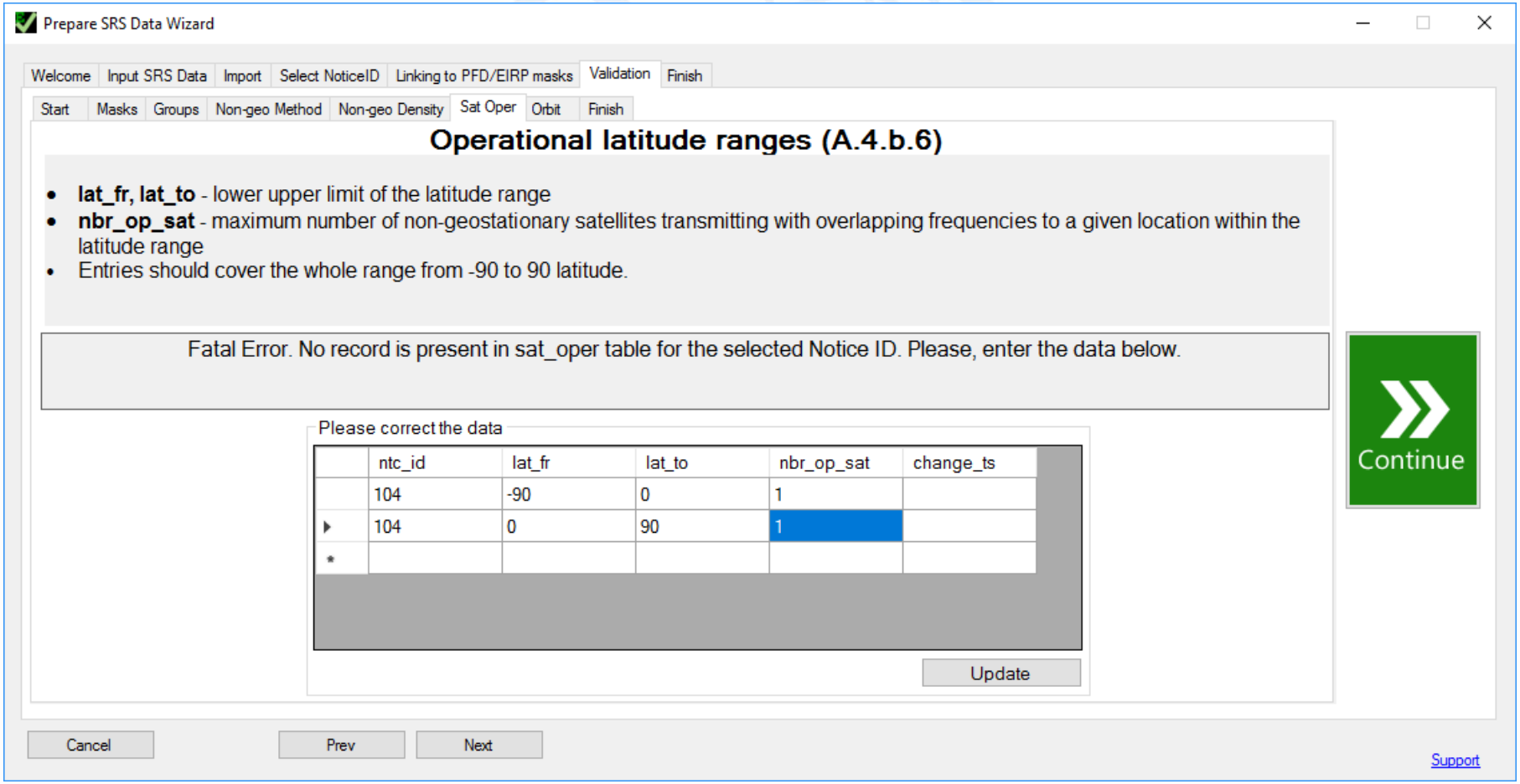
Appendix 4 data validation

- Entered figures would correspond to the following Earth Stations population.



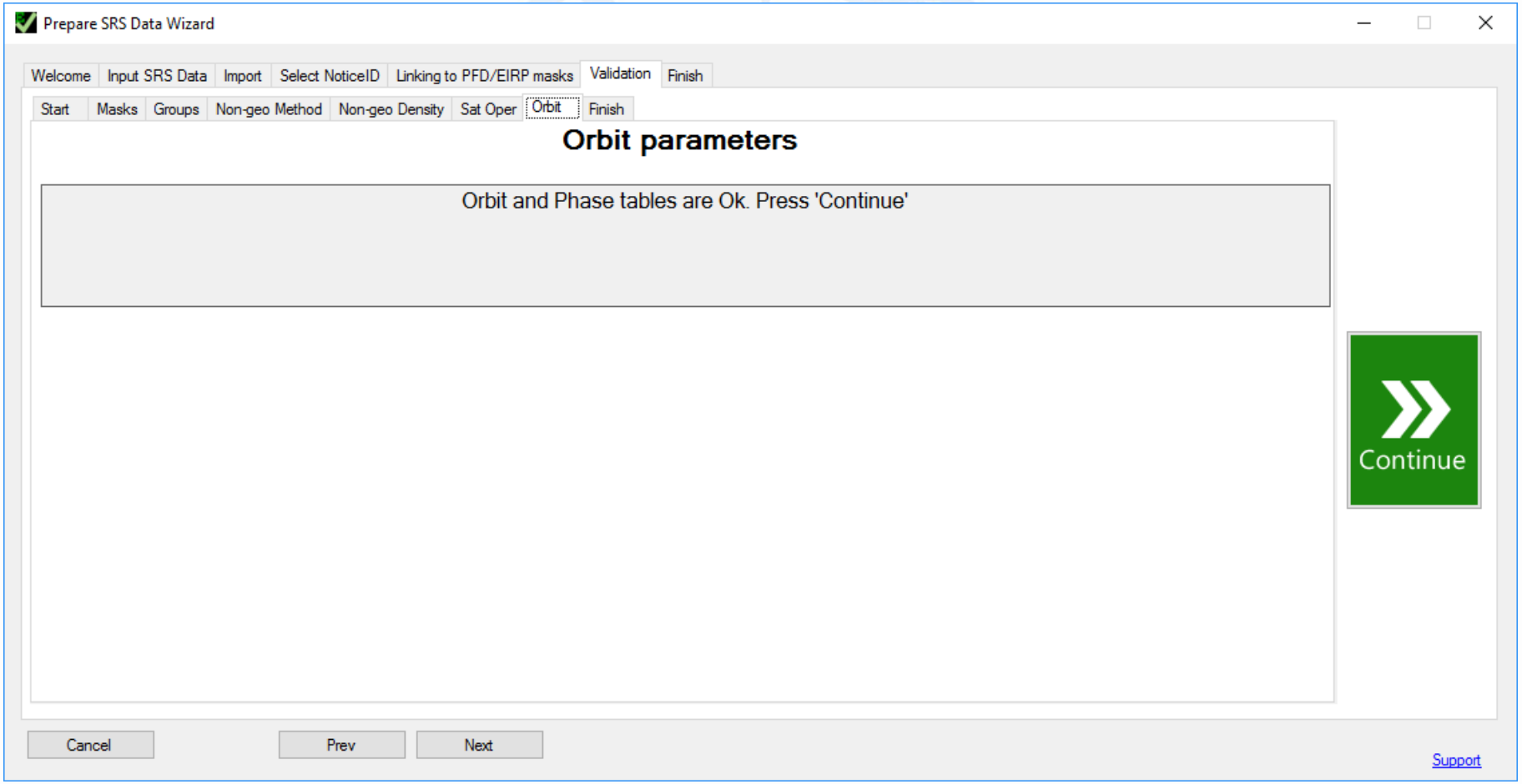
Appendix 4 data validation

- Operational latitude ranges are missing.
- Enter data as shown on the screen and click ‘Update’.
- Continue next.



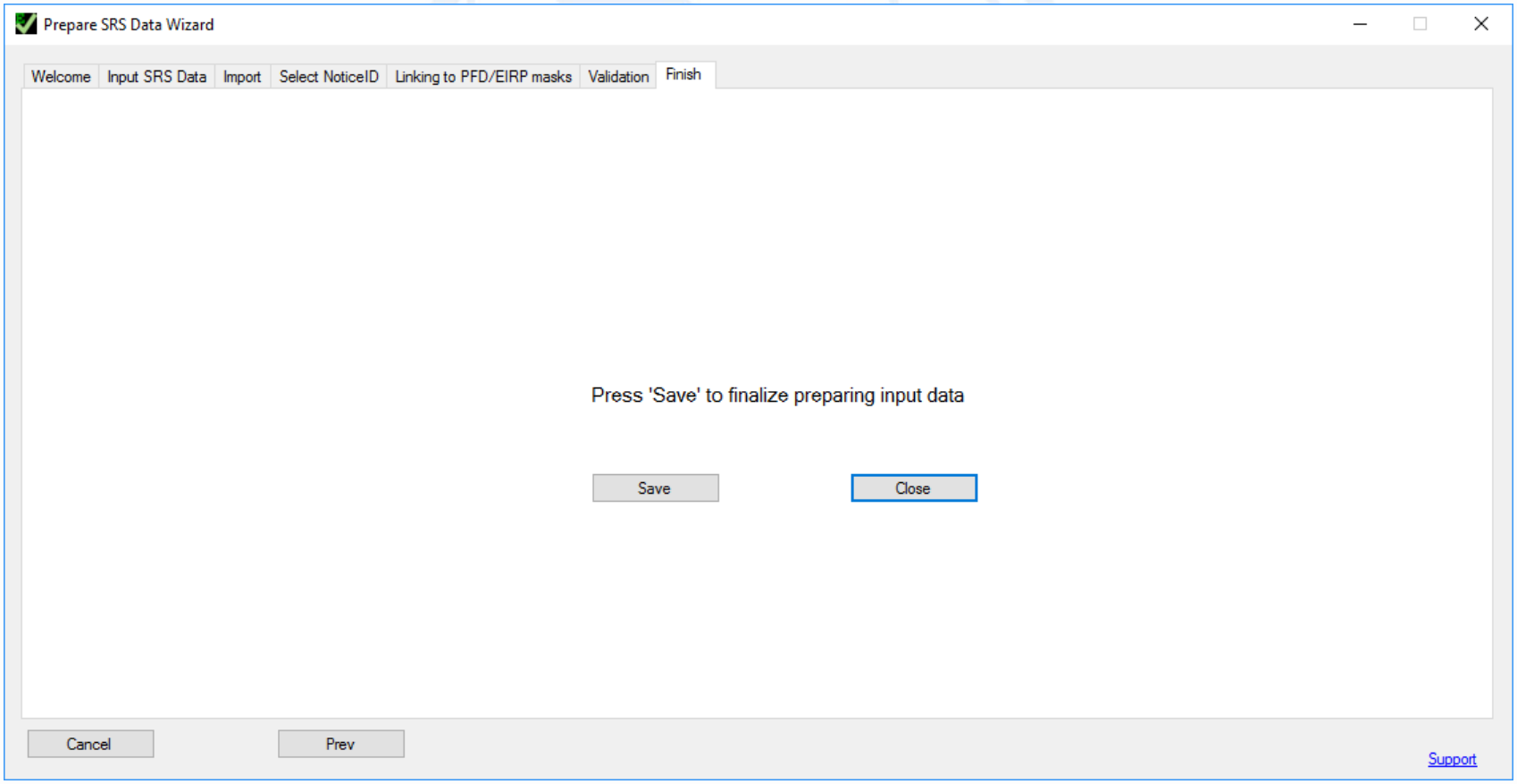
Appendix 4 data validation

- No issues found with orbit parameters.
- Continue next.



Appendix 4 data validation

- Finally, if there are no error anymore in Appendix 4 data, you can save the database to be used for EPFD validation.
- Save database to ‘NSKY_SRS_data.mdb’.
- Click ‘Close’.



Final notes

- For detailed explanation of EPFDPrepare tool please read the EPFD User Guide:

  c:\BR_SOFT\EPFD\User Guide.pdf