SOFTWARE USER MANUAL

SMOS GMT

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DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	26/03/2008	19	First version
1.1	23/12/2008	31	Cover: Internal code completed Section 2.1: Technical note detailing the build procedure added to the list of applicable documents Section 3.1: Description of the various sections of this document updated Section 3.1: Included a reference to the build procedure, should the tool need to be recompiled Section 4.2: Baseline IDL version changed to 6.2 Section 4.2: Removed references to the CFIs, now unused by the GMT Section 4.3: New installation procedure Section 4.4: Included the details on the uninstallation procedure Section 5.1: Removed references to the XML Read / Write API Section 5.2.1: An optional logo provided through the configuration now overrides default mission logo Section 5.2.1: Sample GMT map updated Section 5.2.3: Added some additional remarks on the command line usage Section 5.2.3: The list of input files after the –i option shall now be quoted Section 5.2.3: Description of the effect of using a time window to filter the input files updated Section 5.2.4: Added details on the return values reported by the tool as a process Section 6: New section offering some usage examples to familiarize first time users with the tool Section 7: New section describing the procedures to carry out some maintenance operations, if needed Section 8: New section providing a number of technical details on the GMT internals
2.0	15/06/2009	31	Section 4.2: Removed references to Xerces-C++ 2.7.0 as a prerequisite Section 4.2: IDL interpreter is not a prerequisite, just its virtual machine Section 4.3: References to version 2.0 of the GMT replaced by version 2.1 Section 5.1: Context diagram updated Section 5.2.3: Added reference to the XML schemas for the GMT configuration files and reports Section 7.1: Example package for new BinX schemas now refers to DPGS V3 Section 8.1: List of default values for the various filters updated Section 8.2: Brightness temperature module included as an available derived parameters
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2.2	18/12/2009	33	Section 4.3: References to version 2.2 of the GMT replaced by version 2.4 Section 5.1: Context diagram updated Section 7.1: Added instructions on how to share the BinX schemas from an XML R/W API installation Section 8.1: Added a statement on the omission of HTKM L1A in case of degenerate PVT information Section 8.3: Clarification and update of the description on the way plots are generated Section 8.4: New details, on the GMT memory usage, given the different grid types, added
2.4	28/09/2012	34	Section 4.3: References to version 2.4 of the GMT replaced by version 2.5 Section 5.2.1: Sample GMT map updated
2.4	28/09/2012	34	Section 4.3: References to version 2.5 of the GMT replaced by version 3.0 Section 8.2: Included the ST3_ToA and ST4_ToA parameters
2.5	10/12/2012	33	Section 4.3: References to version 3.0 of the GMT replaced by version 3.1 Section 7.1: The name of the file containing the latest BinX schemas was updated Section 8.2: Derived parameters ST3_ToA and ST4_ToA deleted Section 8.3: Added the "Nearest" as one of the overlap options

Version	Date	Pages	Changes
2.6	28/01/2013	34	Section 4.3: GMT version updated to 3.2 Section 5.2.1: GMT functional description updated with the Breakpoint information Section 8.1: Added the Average filter option to the filters list Section 9: Updated the contact for problem reporting
2.7	29/08/2014	34	Section 4.3: GMT version updated to 3.4 Section 7.1: Schemas version update
2.8	03/05/2019	34	Section 4.2: Dependencies updated. Section 4.3: GMT version updated to 4.0

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1. INTRODUCTION

1.1. PURPOSE

The purpose of the present document is to describe the usage of the SMOS GMT software. Instructions on the normal interaction between the user and the tool are given, along with the procedures to be followed for both installing and uninstalling the software.

1.2. SCOPE

This document is applicable within the scope of the SMOS GMT project, for which it has been produced.

1.3. DEFINITIONS AND ACRONYMS

1.3.1. DEFINITIONS

The following concepts and terms are used in the document and have been identified as necessary to be defined:

Concept / Term	Definition
DLM	Dynamically Loadable Modules are a way of packaging functions written in C or Fortran so that they may be called from within IDL, as if the routines were a native part of this language. They consist on two files: a text file specifying what routines are provided by the module, and a dynamic library which contains the actual implementation of these.
XML	The eXtensible Markup Language is a simple, very flexible text format derived from SGML (ISO 8879). Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere.

1.3.2. ACRONYMS

The following acronyms are used in the document and have been identified as necessary to be described:

Acronym	Definition
AD	Applicable Document
ADF	Auxiliary Data File
API	Application Programming Interface
BinX	Binary XML description language
BT	Brightness Temperature
DFFG	Discrete Flexible Fine Grid
DGG	Discrete Global Grid
DLM	Dynamically Loadable Modules
DPGS	Data Processing Ground Segment
ESA	European Space Agency
FTP	File Transfer Protocol
Gb	Gigabyte
GMT	Global Mapping Tool
GS	Ground Segment
GUI	Graphical User Interface
HKTM	Housekeeping Telemetry
ICD	Interface Control Document

Acronym	Definition
IDL	Interactive Data Language
ISEA	Icosahedral Snyder Equal Area
ISO	International Standards Organization
JPG	Joint Photographic Experts Group
L1	Level 1
L1A	Level 1A
L1B	Level 1B
L1C	Level 1C
L1OP	L1 Operational Processor
L2	Level 2
LAI	Leaf Area Index
Mb	Megabyte
MF	Monitoring Facility
N/A	Not Applicable
NIR	Noise Injection Radiometer
PNG	Portable Network Graphics
PVT	Position Velocity Time
RAM	Random Access Memory
RD	Reference Document
R/W	Read / Write
SC	Science product
SGML	Standard Generalized Markup Language
SMOS	Soil Moisture and Ocean Salinity mission
SPR	Software Problem Report
SUM	Software User Manual
TN	Technical Note
UNIX	Uniplexed Information and Computing System
UTC	Universal Time Coordinated
UTF	Unicode Transformation Format
VTEC	Vertical Total Electron Content
XML	eXtensible Markup Language

2. REFERENCES

2.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Ref.	Title	Code	Ver.	Date
[AD. 1]	Interface Control Document	GMV-SMOSGMT-ICD-001	3.2	03/05/2019
[AD. 2]	Build Procedure	GMV-SMOSGMT-TN-001	2.4	03/05/2019
[AD. 3]	DPGS MF Specific Functionality Technical Note	SO-TN-DMS-GS-5400	1.5	Sep 14th, 2007

Table 2-1- Applicable Documents

2.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Ref.	Title	Code	Ver.	Date
[RD. 1]	N/A	N/A		

Table 2-2- Reference Documents

3. DESCRIPTION OF THE USER MANUAL

3.1. HOW TO USE THIS MANUAL

The present document contains the instructions on how to operate the SMOS GMT software, including the installation procedure. In particular, the information is structured in the following manner:

- Section 3 is the introduction you are reading right now.
- Section 4.1 describes the license and conditions under which the usage and distribution of the software is authorized.
- Section 4.2 contains a comprehensive list of the dependencies (software packages and libraries), that the target system shall meet to support the execution and operation of the SMOS GMT.
- Section 4.3 describes the installation procedure.
- Section 4.4 describes the uninstallation procedure.
- Section 5.1 offers a general description of the software.
- Section 5.2 describes the usage of the software, the command line interface and the options which can be specified while calling the tool.
- Section 6 introduces some usage examples to familiarize first time users with the software
- Section 7 contains instructions for updating the BinX schemas and grid definitions used by the tool.
- Section 8 contains some technical details on the GMT which may be of interest for advanced users.
- Section 9 provides the appropriate contact information for the reporting of problems.

Note that the details on the format of the configuration files, which contain the instructions that define the plots to be generated, are not contained here. Instead, the reader is directed to the SMOS GMT Interface Control Document ([AD. 1]), where both these and the outputs generated by the tool are described in detail.

Similarly, the details on how to compile a new version of the software from its sources are elaborated on a separate technical note: SMOS GMT Build Procedure ([AD. 3]). Should the tool be modified, that document will be of assistance in establishing a local development environment.

3.2. TYPICAL READERS CHARACTERISTICS

Users of the tool are not required to possess an advanced knowledge of computers, software or the operating system, though some basic literacy on these subjects is recommended. In a nominal scenario, the user will simply call the GMT from the command line specifying a configuration file to be used as the only argument.

By setting the appropriate values in this configuration file, the user will be able to select the parameters to be plotted according to the product type. He or she will also be capable of specifying the projection, map center, filters, format of the output files, etc. Although just a single parameter will be visualized at a time, several parameters can be specified in the configuration file; in this case the tool will generate as many plots as specified parameters.

To this extent, the user would need to be acquainted with the various L1 and L2 SMOS products in order to define the appropriate configuration for the GMT. Aside from this, the configuration files themselves are based on a human readable XML format ([AD. 1]), and thus they can be written or modified by hand through a regular text editor, or created by means of a specific XML tool.

4. PRODUCT INSTALLATION

4.1. CONDITIONS AND LICENSES

ESA can freely distribute the Global Mapping Tool deliveries and the associated user manual from a designated SMOS FTP or web-server.

4.2. PREREQUISITES

The software has been successfully tested with the following versions of the operating system and third party software. Either these or compatible versions shall be present at the platform where the GMT is installed for its correct operation:

Name	Description
CentOS 7	Operating system
IDL 8.7	IDL virtual machine

Table 4-1- Software dependencies

It shall be pointed that, depending on whether the tool will be executed in 32 or 64 bit mode, the appropriate versions of IDL and the system libraries should be present, matching that same architecture.

4.3. INSTALLATION

The SMOS GMT binaries are distributed, along with a number of auxiliary files required by the tool, by means of a self-contained installer. To decompress and extract all the files from this package, performing any additional installation tasks necessary, simply execute the provided executable as usual. For example, if the installer for version 4.0 is located at the present directory that would be:

```
./smosgmt-4.0-install
```

The installer will then launch a GUI that will guide the user through the installation steps in an intuitive and straightforward manner:

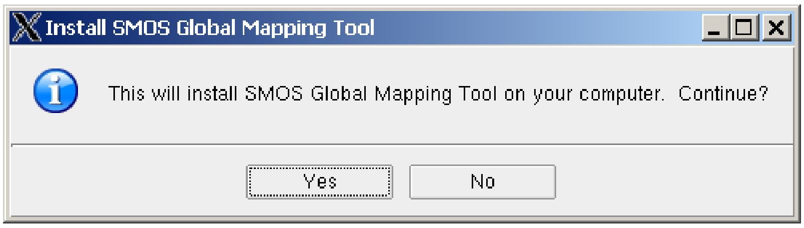

Figure 4-1: Initial dialog

If the user accepts to continue, the welcome screen for the installation wizard will be presented, giving further details about the Global Mapping Tool instance contained in that particular package (e.g. version number). In general, it is recommended to close other applications during the installation to avoid any interference in the procedure. Nevertheless, press the button labeled “Next” when ready to proceed:

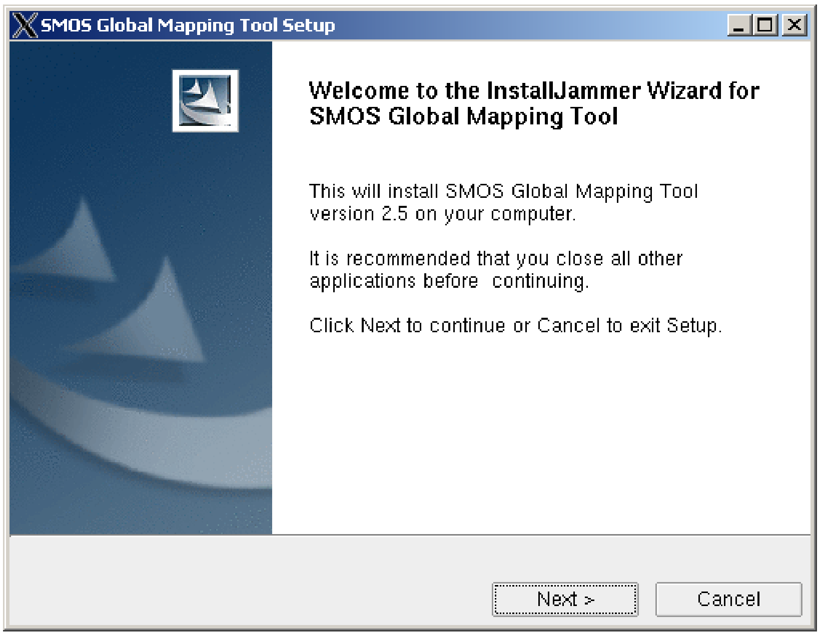

Figure 4-2: Welcome dialog

The installer will then ask for the directory where the SMOS GMT shall be installed. If the user is logged in as root, a system-wide location will be set by default, aiming to make the tool available to all the users in the computer. Otherwise, the tool will be installed in the user account, though any other directory can be selected, given that the current user has the rights required to write files and create directories at that location:

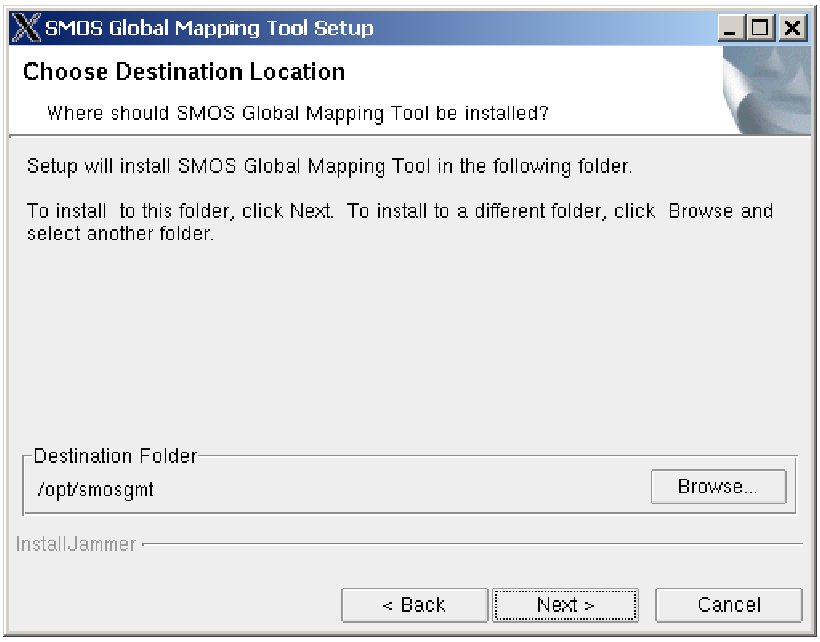

Figure 4-3: Choose target directory

Before carrying out the actual installation, please review that the selected settings are correct. In case of need, the install directory can still be changed by pressing "Back" to return to the previous dialog, and making the appropriate choice. If you are satisfied with the displayed settings, press "Next" to proceed:

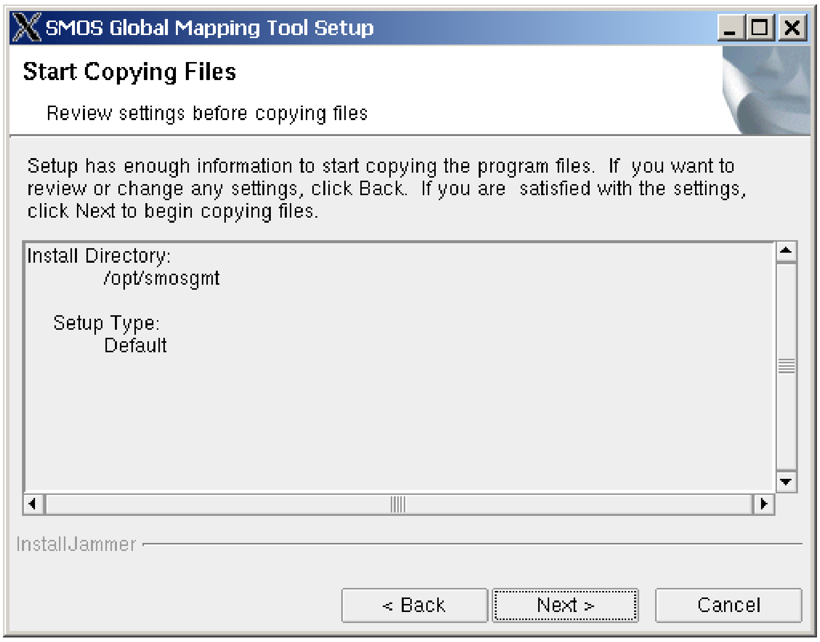

Figure 4-4: Review settings

The files composing the Global Mapping Tool will then be copied without any user intervention. In addition, a symbolic link which may be used to execute the program will be created at the base location where the tool was installed:

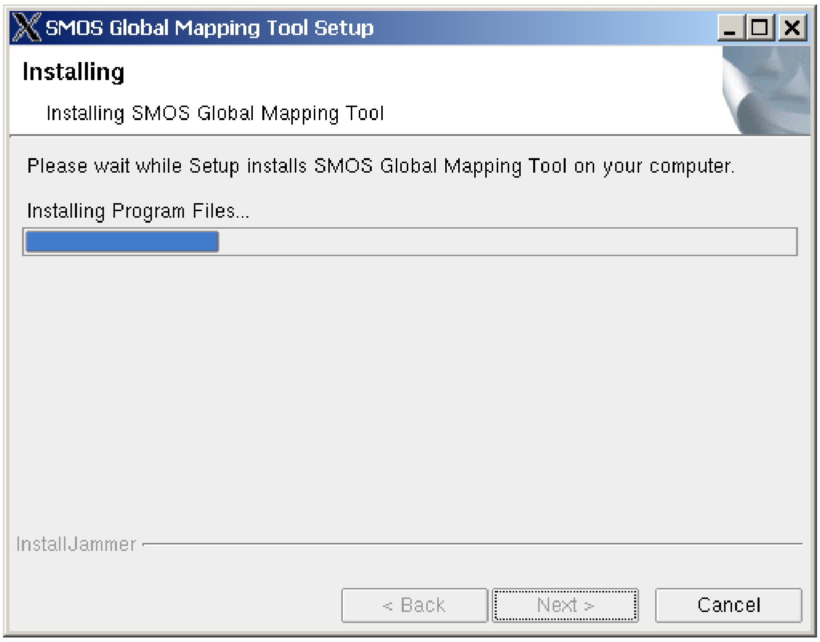

Figure 4-5: Copying of files

If the user is logged in as root, the installer will offer to create also a symbolic link at "/usr/local/bin", so that the tool can be used from any account in the system without having to specify the full path to the location of the program. Simply press the appropriate button depending on your choice:

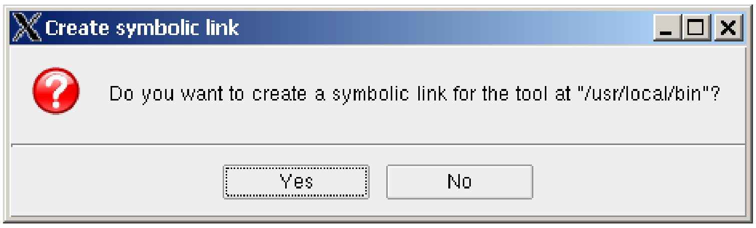

Figure 4-6: Create symbolic link

If no error was encountered during the previous operations, the installation will be complete, and the tool will be ready to be used. Remember though that the installer will not check the availability of IDL or any prerequisite libraries (see section 4.2), so you may still want to verify that both are present before using the software. In case of need, any prerequisite software may be installed at a later time without having to reinstall the Global Mapping Tool:

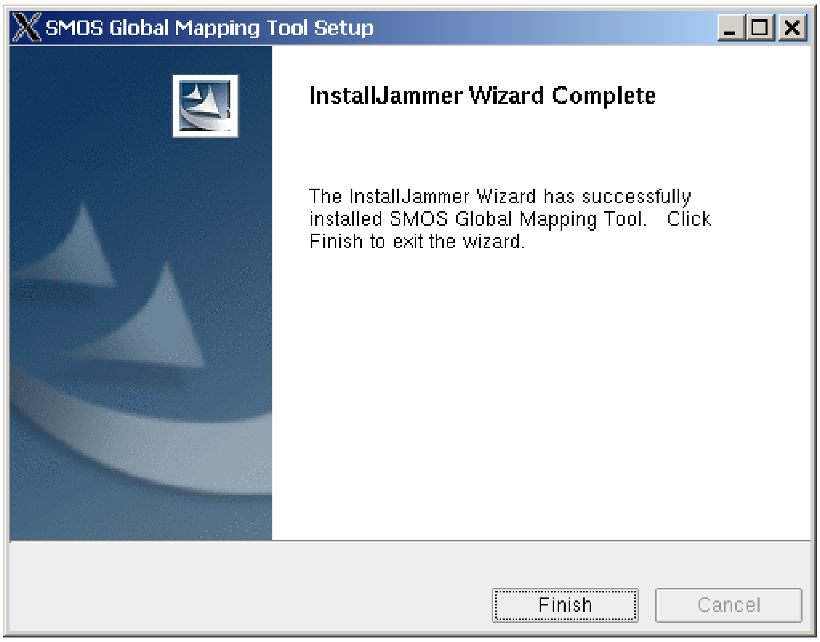

Figure 4-7: Installation complete

In addition to the standard procedure, the installer also offers three other modes which can be selected through the appropriate command line option. The following values are currently supported:

- --mode standard Normal GUI installation as already described
- --mode console Disable the GUI, ask input from the user through the console
- --mode default Launch the GUI, but use the default choices in all cases
- --mode silent Disable the GUI and use the default choices, printing no messages

4.4. UNINSTALLATION

To remove the Global Mapping Tool completely from your system, simply execute the provided executable which can be found at the base location of the appropriate GMT installation. For example, if the software was installed at the default system-wide location:

```
/opt/smosgmt/uninstall
```

Note that the uninstaller should be executed from the same account used during the installation. This is especially true in case the tool was installed by the root user, since most other accounts won't be able to remove the corresponding files and directories from system directories.

Once the uninstaller is launched, a GUI similar to that used during the installation will be presented, asking for confirmation before proceeding:

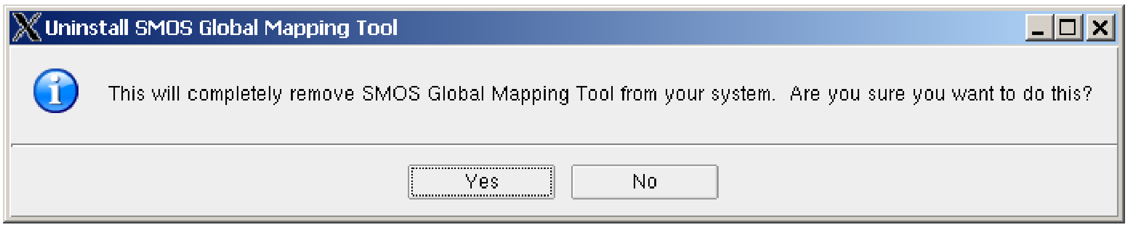

Figure 4-8: Initial dialog

Answering "No", will safely return the user to the console without making any changes to the installed software. Otherwise, the various files and directories will be removed, including any symbolic links created during the installation:

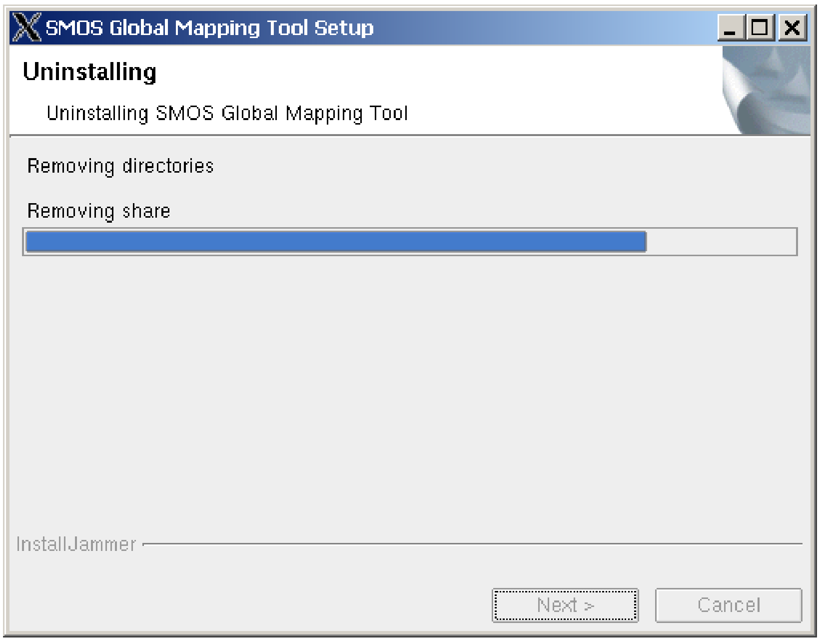

Figure 4-9: Removal of files and directories

If no errors were encountered during the procedure, the uninstaller will notify about the successful removal of the tool. Otherwise, a list containing the elements which couldn't be removed will be presented, so that the user may manually get rid of them.

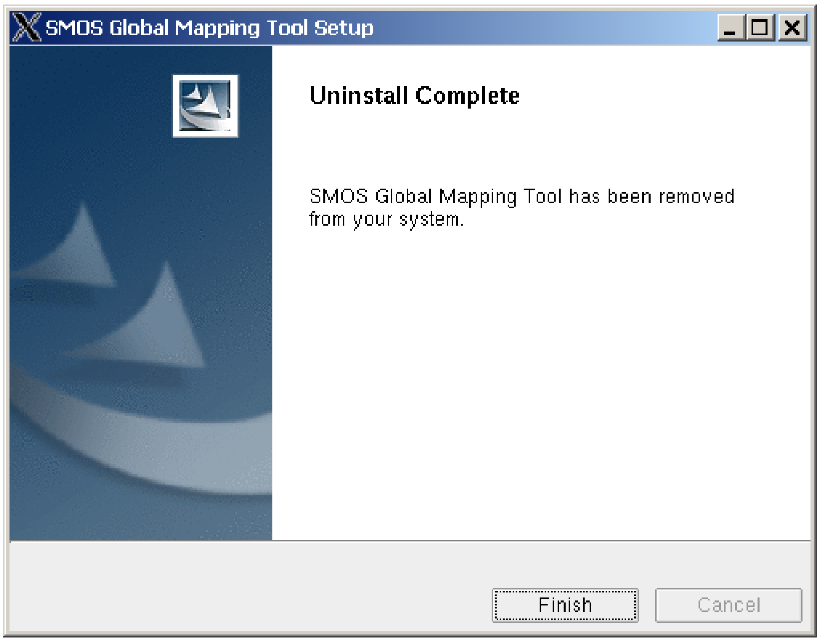

Figure 4-10: Uninstallation complete

Finally, the uninstaller accepts most of the command line options supported by the installer for the selection of alternative modes. That is:

- --mode standard — Normal GUI uninstallation as already described
- --mode console — Disable the GUI, ask input from the user through the console
- --mode silent — Disable the GUI and request no confirmation, printing no messages

5. PRODUCT DESCRIPTION

5.1. INTRODUCTION

The Global Mapping Tool allows the user the geographic visualisation of several SMOS data products. The main purpose of the tool is to detect macroscopic errors (e.g. boundary issues between products) in SMOS L1 and L2 science products and HKTM 1A data.

The tool is implemented in IDL and completed with a C/C++ dynamic library. This library allows IDL to call external code and retrieve information which may be used in the plots (e.g. orbit propagator, boresight calculation, etc.). C and C++ have better performance than IDL so the implementation takes advantage of that by leaving the responsibility of reading and filtering the data to a solution implemented in these languages. In addition, this allows the usage of existing components for the reading of products. To this aim, the aforementioned C/C++ dynamic library has been developed and integrated as a DLM.

The tool has been conceived as a standalone piece of software particularly well suited for batch processing. While it will be typically run independently from the SMOS MF through a shell script, that will invoke the IDL Virtual Machine as necessary, it also provides a compatible command line interface with this facility ([AD. 3]). The latter will allow the integration of the GMT into the MF with a minimal effort and costs.

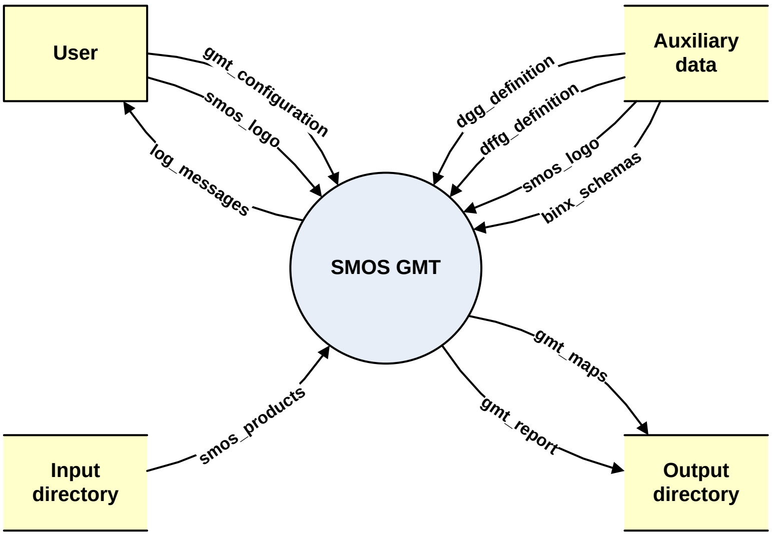

Figure 5-1: Context diagram

5.2. OPERATION

5.2.1. FUNCTIONAL DESCRIPTION

The Global Mapping Tool is a piece of software intended to ingest a set of SMOS products of the appropriate type, according to the configuration file provided, and generate a number of maps where the data from the selected parameters is plotted.

In general, these SMOS products constitute the only input data the user must provide, aside from the GMT configuration itself. The user would leave the set of input files, that he or she is interested in processing, at an arbitrary directory which the tool will parse looking for products of the appropriate type according to the provided configuration. On the other hand, the tool may also be given a fixed set of files to use through the command line parameters, which will override any input directory defined in the configuration. Any other auxiliary data required by the tool (e.g. DGG definition), and the additional files it may use, are already distributed and installed along with the software.

The GMT configuration, based on a human readable XML format as described in [AD. 1], is provided by the user by specifying the path to the appropriate file as a command line parameter. Nominally, no other parameter would be required since the configuration contains the input directory where the tool shall look for the input data. In addition, the configuration may also contain the path to a custom mission logo to replace that added by default to each of the pictures generated as a result of the execution. An example of these can be found below these lines:

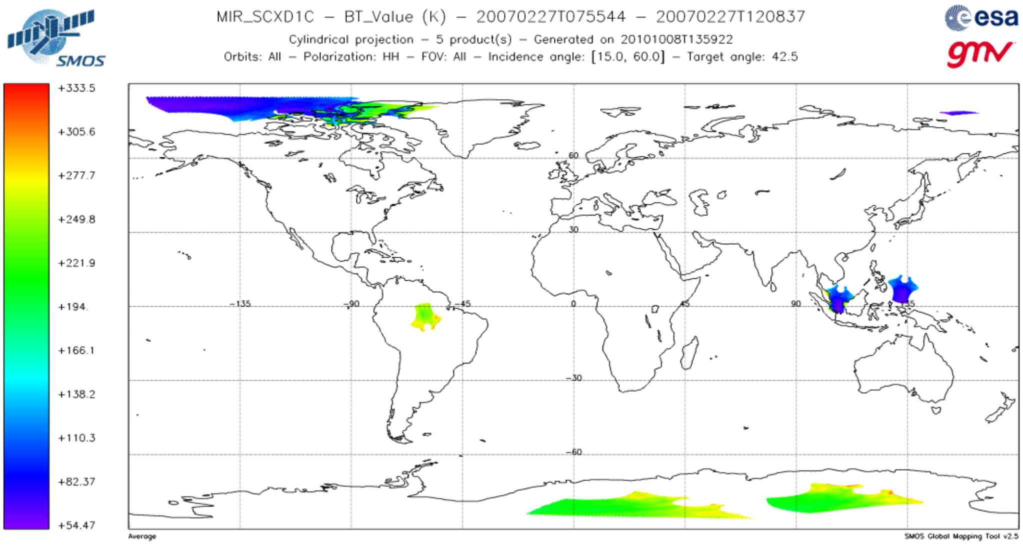

Figure 5-2: Sample GMT map

Two kinds of outputs are generated by the tool. First, three pictures will be produced for each map requested in the configuration: centred at the equator (or at a user defined location), at the north pole and at the south pole respectively. Second, an XML report will be written at the end of the tool execution, indicating the input files and configuration parameters used, the output files generated, and any log messages issued by the tool during the processing of a particular map, among others. In addition, it is possible to toggle a breakpoint in the configuration file, which enables the output of text files to accompany each map. These breakpoint files contain the grid point ID, its latitude and longitude values, the number of measurements used for the computation of the value (counts) and the value of the selected parameter. The directories where these output files will be left are also defined as part of the configuration.

5.2.2. PRECAUTIONS

When parsing the contents of the input directory, it shall be noted that the Global Mapping Tool will only take into consideration those products which match the type specified for the current map in the configuration. Any other products, or arbitrary files of any other kind, will be silently ignored. As a consequence of this, if various types of products shall be processed by the GMT, the respective files may in principle be placed at the same directory without causing any conflicts.

5.2.3. PROCEDURES

The usage of the tool is based upon a command line interface. If the software was properly installed, and a link was created at a directory included in the execution path (e.g. /usr/local/bin), then the user would type the following at the command prompt. Otherwise, the full path to the location where the GMT was installed may have to be specified:

smosgmt [config_file] [options]

, where *config_file* is a GMT configuration file compliant with the XML format described in [AD. 1], and *options* stands for one or more of the following:

• -32	Force execution in 32 bit mode
• -h	Print a help message
• -i "input_file [...]"	Quoted list of input files to be processed, separated by spaces
• -o output_dir	Output directory for MF report
• -b utc_time	Do not process input files before this date
• -e utc_time	Do not process input files after this date

In particular, the last four options enable the tool to be compatible with the command line interface, defined in [AD. 3], for external tools to be integrated within the SMOS Monitoring Facility. However, their usage is more flexible than what the MF requires and they can be enabled or disabled on an individual basis:

- Specifying a list of input files with -i overrides the input directory indicated in the configuration file, thus forcing the tool to always use this fixed set of products instead. Still, only those products applicable for the selected type in the configuration would be used.

  For example, if a mixed set of dual polarization L1A and L1B products is defined through this option, and the configuration file contains definitions for both MIR_SC_D1A and MIR_SC_D1B maps, only the L1A products will be used for the generation of the former, and the L1B products for the generation of the latter.
- Setting an output directory with -o overrides the output directories defined in the configuration file, both for the GMT reports and for the individual GMT maps. All files generated by the tool will then be written into this directory and packaged into a single zip file (i.e. MF report) as requested by the SMOS Monitoring Facility.
- -b and -e allow to define a time window the input products shall fall within in order to be processed. Any files which end before the begin date specified, according to their filename, or start after the end date given will be ignored.

Regarding the *utc_time* strings, these shall conform to the UTC format defined for the MF:

DD-MMM-YYYY hh:mm:ss

, where:

• DD	Day number within the month, padded with zeros (two digits)
• MMM	First three letters of the month name in English (uppercase)
• YYYY	Year number (four digits)
• hh	Hour, padded with zeros (two digits)
• mm	Minutes, padded with zeros (two digits)
• ss	Seconds, padded with zeros (two digits)

Note that, regardless of the options selected, the tool will always require a GMT configuration file to be provided by the user. If a GMT configuration file isn't explicitly provided among the arguments passed through the command line, but a -i option is present, then the first of the input files after -i will be assumed to be the configuration file. Nevertheless, if a configuration file is defined before the -i option, then all the files indicated after that option will be used as input files.

It shall also be noted that the Global Mapping Tool includes, as part of the installed files, the XML schemas which describe the format of the GMT configuration files and reports. In addition to enabling the validation of such files by the tool, these schemas may be useful for the end user for the creation of new configuration files (e.g. using an XML editor). They can be found in the following path within the installation directory:

***install_directory*/share/schemas**

5.2.4. RETURN VALUES

As a UNIX process, the Global Mapping Tool will return a value upon termination, which will indicate whether the execution of the program was successful or a fatal error was encountered. In particular, the following two values are currently used, in compliance with [AD. 3]:

- 0 Successful execution
- -1 Fatal execution error

It shall be noted that, since a single configuration file may contain multiple map entries, the existence of errors while dispatching one of these will not prevent the others being generated. Therefore, while such errors will be reported as log messages, the tool will still try to recover and continue the processing, leading to a return value of 0 once finished. Only in case of a major error causing the execution to halt, will a value of -1 be reported.

6. USAGE EXAMPLES

In this section, first time users of the Global Mapping Tool can find some simple examples which may help them in their initial steps plotting maps out of SMOS products by means of this software. To begin with, let's examine one of the simplest valid configuration files which can be feed to the tool:

```
<?xml version="1.0" encoding="UTF-8"?>
<GMT_Configuration>
        <General>
                <Paths>
                        <Report>output</Report>
                </Paths>
        </General>
        <Map>
                <Paths>
                        <Input>input</Input>
                        <Output>output</Output>
                </Paths>
                <Product>
                        <Type>TLM_MIRA1A</Type>
                        <Parameter>NIR_Pulse_Length</Parameter>
                </Product>
        </Map>
</GMT_Configuration>
```

First, the path where the GMT report will be written at the end of the tool execution is defined. In this case, the corresponding XML file will be generated at an already existing directory, named *output*, whose path is relative with respect to that where the GMT is executed. Since a single report will be generated for a given execution, regardless of the number of maps produced, such definition is located within a general section that precedes all those map entries present in the configuration.

Next, a map entry is defined. As seen, four parameters shall at least be defined: the directory to be parsed looking for the input files (i.e. SMOS products), the directory where the generated maps shall be written, the type of product to be represented, and the parameter within that product that will be plotted. Note that, same as with the directory where the GMT reports will be written, the input and output directories may be given as relative or absolute paths, though they are expected to exist in either case. On the other hand, the same output directory is used here for the GMT reports and the GMT maps, but there is nothing which prevents them to be different.

Some product types contain parameters with the same name but, in many cases, these names are different (even for equivalent variables) according to the respective product specifications. The same applies to the filters which may be used to restrict or select the data which should be represented: some have effect only when plotting specific product types, while others affect multiple types, but the set of applicable values may vary. Often, requesting the wrong parameter from a product where it doesn't exist will lead to an error about it being absent when parsing the input products. See [AD. 1] for a comprehensive list of the available options.

In case one such error is encountered, the Global Mapping Tool will still try to find the parameter requested in the remaining input files of the given type. In theory, if the input products provided correspond to different versions of the product specifications, the parameter could not appear in some of them while existing still in some of the remaining. As a consequence, even after one of these errors the tool will generate the respective outputs, though it is likely that no data will be plotted. The same applies to the case where a wrong value is specified for a filter, or if data matching that property is not found.

Once a configuration file is created, the Global Mapping Tool can be easily executed by passing the path to this file as the sole command line argument. For example, if the tool was installed at a system-wide location and a link was created at a directory included in the execution path, this could be:

```
smosgmt example01.xml
```


Using the previous configuration file with some sample HKTM products, the following result is obtained, along with two other maps for the North and South Pole respectively:

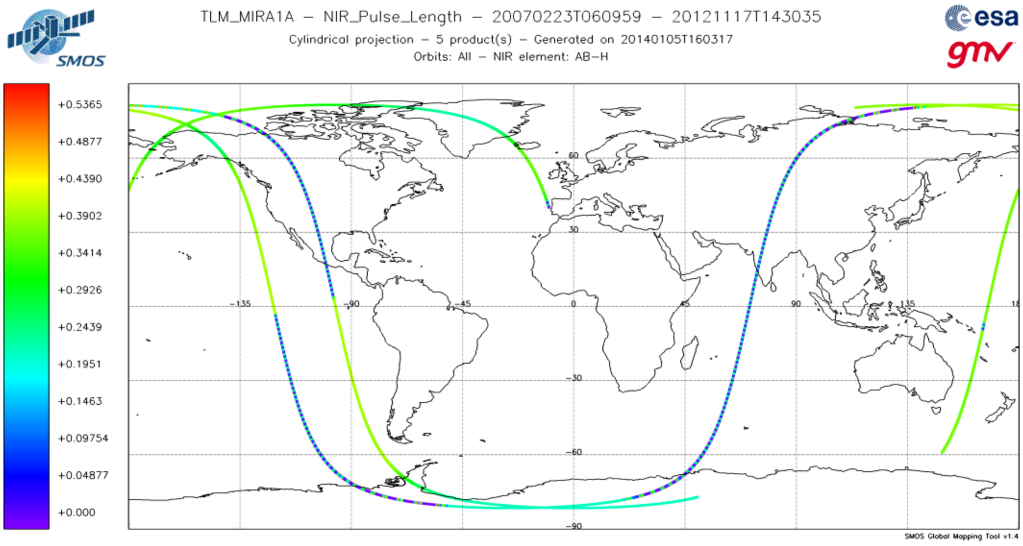

Figure 6-1: Resulting map (equator)

By default, the equatorial view is centred at 0 degrees north latitude by 0 degrees east latitude, and shown with a cylindrical projection. At the same time, the maps will be generated as PNG files, and other assumptions will be made for any required parameter if absent. The default values for each of these can also be found as part of the SMOS GMT Interface Control Document ([AD. 1]). Now let's change some of these options to obtain a custom view of the same data:

```
<?xml version="1.0" encoding="UTF-8"?>
<GMT_Configuration>
	<General>
		<Paths>
			<Report>output</Report>
		</Paths>
	</General>
	<Map>
		<Paths>
			<Input>input</Input>
			<Output>output</Output>
		</Paths>
		<Picture>
			<Format>JPG</Format>
			<Projection>
				<Equator>Mercator</Equator>
			</Projection>
			<Center>
				<Latitude>41.817</Latitude>
				<Longitude>12.683</Longitude>
			</Center>
		</Picture>
		<Product>
			<Type>TLM_MIRA1A</Type>
			<Parameter>NIR_Pulse_Length</Parameter>
		</Product>
	</Map>
</GMT_Configuration>
```

As can be seen, all the mentioned properties can be modified by adding another section into the map entry: *Picture*. There, those options affecting the way the data is represented can be specified. For the format, now we will request the maps to be written as JPG files. And we will prefer a Mercator projection to be used instead of the default cylindrical one. Last, we may be interested in centering the map at a location or feature of our interest, so that the measurements of the satellite can be better observed around that place, e.g. Frascati, in Italy, in this case.

Same as before, we launch the tool using the new configuration file:

```
smosgmt example02.xml
```

, and, while the data represented is the same, the resulting view is certainly different, perhaps better suited to our purposes:

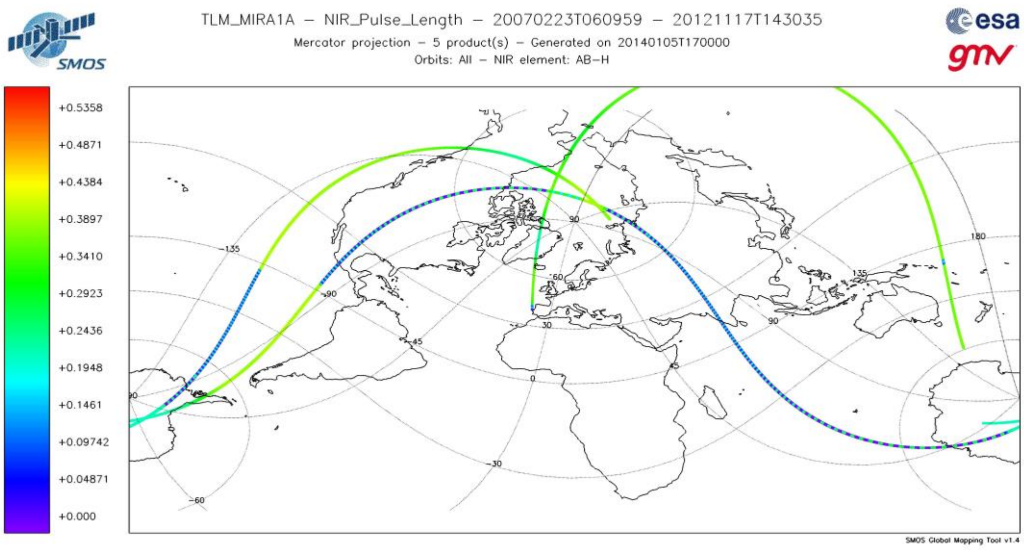

Figure 6-2: Resulting map (Frascati, Italy)

According to the scale on the right of the picture, the values for the represented parameter vary between 0.0 and 0.5358 in the input files. By default, the maximum and minimum values found are used as the top and bottom of the scale, respectively. Through the configuration file, we can override these values, so that the scale provides a higher resolution over values of our interest, and those numbers above or below the range are represented as the highest or lowest colour. Regarding the colours, the default scheme can be replaced by any of the other palettes provided by IDL, just by specifying the appropriate number in the configuration file:

```
<?xml version="1.0" encoding="UTF-8"?>
<GMT_Configuration>
	<General>
		<Paths>
			<Report>output</Report>
		</Paths>
	</General>
	<Map>
		<Paths>
			<Input>input</Input>
			<Output>output</Output>
		</Paths>
		<Picture>
```

```
                <Format>JPG</Format>
                <Projection>
                      <Equator>Mercator</Equator>
                </Projection>
                <Center>
                      <Latitude>41.817</Latitude>
                      <Longitude>12.683</Longitude>
                </Center>
                <Scale>
                      <Palette>24</Palette>
                      <Maximum>0.50</Maximum>
                </Scale>
          </Picture>
          <Product>
                <Type>TLM_MIRA1A</Type>
                <Parameter>NIR_Pulse_Length</Parameter>
                <Filters>
                      <NIR_Element>CA-V</NIR_Element>
                </Filters>
          </Product>
      </Map>
</GMT_Configuration>
```

In addition to changing the palette and the range of the scale, another addition is introduced in this last example: a section defining some (or just one) filters is included after the *Parameter* definition. By default, the values for the AB-H element where represented for the NIR pulse length. Should we like to see the values for a different element, we just need to alter the filter so that those for, e.g., the CA-V element are shown instead. Depending on the product type, and sometimes on the parameter selected, the applicable filters vary, as indicated in their descriptions ([AD. 1]). Nevertheless, note that if a filter not applicable to the current case is given the GMT will simply ignore it.

Finally, launching the GMT again with these new options, the result would be:

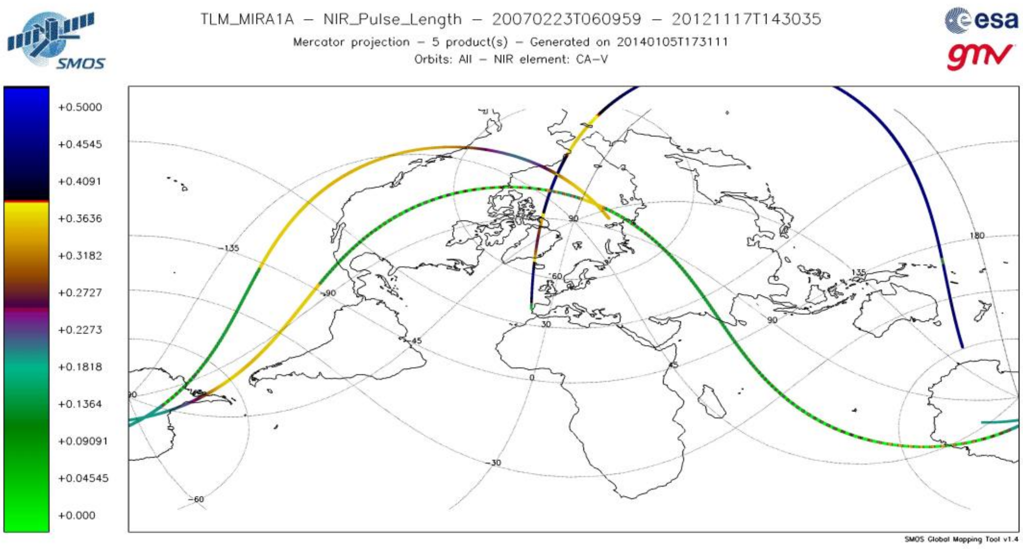

Figure 6-3: Resulting map (CA-V)

From then on, exploring the remaining available filters and options is just a matter of looking into the Interface Control Document ([AD. 1]) and trying them as needed. Doing so is encouraged, given that the worst that can be expected is that the resulting maps will end blank or look distorted.

7. MAINTENANCE OPERATIONS

7.1. SMOS PRODUCT SCHEMAS

SMOS products are formatted in compliance with the Earth Explorer File Format convention. As such, those products which the Global Mapping Tool can handle consist on two separate files typically stored within a single directory, all sharing a same name (i.e. files differ just in the extension). These two files contain, respectively, the XML header of the product and its binary datablock, containing the bulk of the data. In the context of the SMOS mission, the layout of the binary datablock for each product type is defined through a binary description language: BinX.

BinX is a markup language based upon XML, which codifies some meta-data about the binary files, including the structure of the files and the individual fields within them. Thanks to these descriptions, some of the virtues of XML can be achieved without losing the compactness of binary data. A BinX schema is, therefore, an XML file which describes the format and contents of a given binary file from the syntactic point of view.

The Global Mapping Tool, same as other pieces of software in the SMOS mission, uses a number of BinX schemas defining the format of the SMOS products to parse them. One of the key advantages of this approach is that, in many cases, supporting minor changes in the product specification requires just replacing the BinX schemas with the new version, without any need to update the source code of the application. In addition, since the particular BinX schema that was used to generate each particular file is written in the header of the products, SMOS products compliant with different versions of the specifications may coexist and, often, be handled with the same software.

The GMT includes, as part of the auxiliary files distributed and installed along with the software, the latest version of the BinX schemas corresponding to the product specification supported by the tool. In particular, these can be found in the following path within the installation directory:

install_directory/share/smos

The contents of this directory correspond to those of the package distributed by Indra for each version of the schemas. Should a new version of the schemas be released in the future, the user may update the GMT to support them by simply emptying this directory and unpacking there the new release of the schemas, e.g.:

```
cd install_directory/share/smos
rm –rf *
unzip path_to_schemas/schemas_2014-08-22_v06-03-00.zip
```

It shall be noted that the support for the new version achieved through this procedure will be subject to some limitations. Namely:

- New parameters not previously supported by the Global Mapping Tool will not be supported with the new version of the schemas either.
- Major changes in the structure of the products (e.g. such as the arrangement of the fields within a record), may lead to failures in the representation of some or all fields for the new products.
- The masks used to extract binary flags, from the fields where they are stored together, are defined within the source code of the GMT. Therefore, changes in the internal arrangement of flags within the field may lead to failures in the representation of some or all fields for the new products.
- The latter is of major importance in the case of flags used to filter other parameters, which may lead to failures in the representation of these.

Sharing of the schemas with a separate XML R/W API installation

As a variation of the previous procedure, note that, in case the Global Mapping Tool is installed along with other (sub)systems which use the XML R/W API, it is possible to share the SMOS schemas of the latter by replacing the directory where the set of schemas installed along with the GMT are stored, i.e.:

install_directory/share/smos

, with a symbolic link[1] to the appropriate path where the SMOS schemas are globally deployed, e.g.:

$XML_RW_API_HOME/smos/schemas

This will have the benefit of avoiding the duplication of files, and other management issues related to the existence of multiple installations of the schemas on the same platform. GMT support for different versions of the BinX schemas installed (or updated) in this manner will, however, still be subject to the above limitations.

7.2. DGG DEFINITION

In some of the SMOS products supported by the Global Mapping Tool, data is geolocated in a partition of the Earth surface known as a Discrete Global Grid (DGG). In order to properly represent these products (e.g. L1C and L2), the Global Mapping Tool requires a definition of the applicable ISEA 4-9 DGG grid, which is loaded in advance from an auxiliary product, in the same format as those employed by the L1OP processor and other SMOS subsystems (i.e. *AUX_DGG___*).

Same as with the BinX schemas, the GMT includes, as part of the auxiliary files distributed and installed along with the software, a current *AUX_DGG___* product. In particular, this product can be found in the following path within the installation directory:

install_directory/share/auxiliary

While the Global Mapping Tool will still be able to represent those SMOS products based upon the DGG if they were generated using a different definition of the grid, the resulting maps may not be fully accurate at close distances. It is therefore possible that the user may desire to update the DGG definition employed by the GMT, especially if the tool is used to plot maps in a very high resolution. To do so, just copying the new *AUX_DGG___* product to the above directory will suffice, e g.:

```
cd install_directory/share/auxiliary
cp -R path_to_adf/SM_TEST_AUX_DGG____20070101T000000_20781231T235959_000_001_0 .
```

The Global Mapping Tool will parse that directory and load the newest auxiliary file when executed, based upon the validity dates present in their filenames. Note that, in case the desired DGG definition contained a start date earlier than the supplied auxiliary file, deleting the previous ADF may be required before the copy:

```
cd install_directory/share/auxiliary
rm -rf *AUX_DGG___*
```

[1] This link would have to be updated should the $XML_RW_API_HOME environment variable change.

7.3. DFFG DEFINITION

Some of the ADFs supported by the Global Mapping Tool, on the other hand, contain data geolocated according to a different partition of the Earth surface, known as a Discrete Flexible Fine Grid (DFFG), whose resolution is higher. In general, such ADFs will be represented using the DGG definition by default, obtaining a lower memory footprint and higher performance at the expense of some precision, but it is possible to enable the usage of the DFFG in that cases through the appropriate option in the corresponding configuration file.

Same as before, the GMT includes, as part of the auxiliary files distributed and installed along with the software, a current DFFG LAI Max product (i.e. *AUX_DFFLMX*), whose embedded grid definition is employed, if enabled, when plotting DFFG based products. In particular, this ADF can be found in the same path as the aforementioned *AUX_DGG___* product within the installation directory:

install_directory/share/auxiliary

While the Global Mapping Tool will still be able to represent those SMOS products based upon the DFFG if they were generated using a different definition of the grid, the resulting maps may not be fully accurate at close distances. It is therefore possible that the user may desire to update the DFFG definition employed by the GMT, especially if the tool is used to plot maps in a very high resolution. To do so, just copying the new AUX_DFFLMX product to the above directory will suffice, e g.:

```
cd install_directory/share/auxiliary
cp -R path_to_adf/SM_TEST_AUX_DFFLMX_20050101T000000_20500101T000000_001_001_9 .
```

The Global Mapping Tool will parse that directory and load the newest auxiliary file when executed, based upon the validity dates present in their filenames. Note that, in case the desired DGG definition contained a start date earlier than the supplied auxiliary file, deleting the previous ADF may be required before the copy:

```
cd install_directory/share/auxiliary
rm -rf *AUX_DFFLMX*
```


8. TECHNICAL DETAILS

8.1. DATA FILTERING

Depending on the type of SMOS products, the data read from the input files will be filtered according to a number of criteria, so that only those readings which meet certain conditions will be represented.

In general, the input files themselves are filtered depending on their orbit orientation. By default, products from both ascending and descending passes are accepted, but the user may change this behaviour by setting the appropriate parameter in the filters for the corresponding map entry within the configuration file: *Orbit*. In addition to the default value, *All*, it is possible to represent only those products whose orbit orientation is *Ascending* or *Descending*. It shall be noted that the orbit orientation of a particular product is determined using the information from the product header, not the data, so the results may not be as expected if the orbit orientation is labelled wrong in the product header for any reason.

When parsing the various dataset records within the product, some additional fields may be taken into consideration along with those containing the actual parameter selected, e.g.: polarization flags, incidence angles, etc. This metadata will be used to determine whether the values extracted shall be plotted, or simply discarded if the given condition is not met. Keep in mind that, in most cases, the data will be filtered according to some default settings even if an applicable filter is not explicitly defined in the configuration file. The default values for each filter are in principle, as indicated in the Interface Control Document ([AD. 1]), as follows:

Filter	Description	Default
Orbit	Orbit orientation	All
Polarization	Polarization mode	HH(H)
Antenna	Antenna number	1
NIR_Element	NIR element	AB-H
Field_of_View	Field of view	All
Target	Target incidence angle	42.5
Minimum	Minimum incidence angle	0.0
Maximum	Maximum incidence angle	90.0
Fill_Value	Value used to identify null data	*None*
Map_Number	Map to plot from an VTEC ADF(s)	1
Average	Flag to set whether an average is taken over the range of incidence angles, or if the nearest to the target angle is used	0

Table 8-1- Default filters

Note that only those filters applicable to the current product type will have an effect during the parsing of data. The antenna number, for example, will only be meaningful if L1A data is being parsed, and will have no effect when parsing any other kind of product, even if explicitly specified in the configuration. At the same time, the existence of such default values implies that data from different polarization modes, antennas, or NIR elements, among other things, can't be plotted together. This is intentional, by design, as the maps resulting from mixing data with different properties were considered as providing little useful information, and the existence of "safe" default settings allows for a simpler usage for the average user.

Last, some of the parameters found in the products may contain infinite and NaN values among the parsed data. This was explained as the result from some of the algorithms used to generate the products, which would output such values when the input data was not valid, or the derived result was meaningless. This information shall therefore be omitted, as it will likely pollute the plots if represented, so any parsed value that is not finite is also silently discarded in all cases. The same applies to HKTM L1A data whose PVT data indicate a position too close to the center of the Earth (i.e. within 1 meter), as such a degenerate case would lead to stability issues in the algorithm employed to calculate the boresight coordinates for the subsequent geolocalization.

8.2. DERIVED PARAMETERS

In addition to the supported fields from each type of file, three derived parameters may also be represented when plotting L1C and L2 products: the brightness temperature total power (L1C and L2), the polarization index (L1C and L2) and the brightness temperature module (L1C only). These are defined as follows:

- Brightness Temperature Total Power: $(BT_{HH} + BT_{VV}) / 2$
- Polarisation Index: $(BT_{HH} - BT_{VV}) / (BT_{HH} + BT_{VV})$
- Brightness Temperature Module: $SQRT(BT_{real}^2 + BT_{img}^2)$

, where BT_{HH} and BT_{VV} stand for the brightness temperature registered in HH and VV polarization respectively, for a same swath; and BT_{real} and BT_{img} stand for the real and imaginary parts from a same reading in full polarization L1C products (browse or science).

In L2 products, the brightness temperature is provided for both the surface and the top of the atmosphere, so they can be computed at both levels by selecting the corresponding parameter in the configuration file:

- **ST1_S** First stokes parameter (i.e. total power) at surface level
- **PI_S** Polarization index at surface level
- **ST1_ToA** First stokes parameter (i.e. total power) at the top of atmosphere
- **PI_ToA** Polarization index at the top of atmosphere

L1C products, on the other hand, provide measurements for the top of the atmosphere only, and therefore only the last two parameters are available when plotting them, in addition to the Brightness Temperature Module:

- **BT_Module** Module of the cross-polarization brightness temperature

The AUX_DGGRFI products provide measurements of the derived parameter Normalized_RFI:

- **Normalized_RFI** The parameter is computed as (N_RFI_H + N_RFI_V)/N_Snap

8.3. PLOT GENERATION

After the data from an input product is parsed, it is added to the three maps for the current plot. In particular, the different values for each unit of a given map (e.g. pixel) are accumulated in a structure along with some disambiguation metadata, so that a single value can be later represented for each point. The actual approach is slightly different depending on whether the data is based upon a discrete grid, such as the DGG, or geolocated through specific coordinates.

In **HKTM, L1A and L1B products**, whose data is not arranged into a grid, each value has an associated latitude-longitude pair. Once parsed, some IDL routines are used to project these coordinates over the three maps, finding the pixels where they fall in each case. While it is possible for a reading to fall out of the area represented in a given map, most often it will correspond to a specific pixel, which will be set according to the actual value. Should individual pixels be plotted then, they would result in a faint and hard to see groundtrack, so a small square, scaled according to the plot dimensions, is drawn instead. That is, the value from each reading is added to all the pixels over a small area, centered at the specific pixel where the value falls.

As noted from the previous description, overlaps may occur between the values from different products, or even from the same one: values may be located at the same coordinates, or projected over the same pixel, or the squares drawn to represent them may intersect. To overcome this situation, the user may select among multiple overlap resolution criteria through the configuration file(s):

- **Average** all overlapping values (default)
- Keep the **maximum** value
- Keep the **minimum** value
- Keep the **oldest** value according to the sensing time of the product
- Keep the **latest** value according to the sensing time of the product

Keep the **nearest** value with respect to the target angle (if applicable)

Note that, despite of squares being used to represent each value, these policies are applied at each individual pixel, not per value in the original (i.e. parsed) data. At the same time, while maintaining a single value per pixel is enough to support the last four policies (plus the sensing time), the sum of all values which fall on a particular pixel is kept when their average is to be calculated, along with the number of readings accumulated. This way, once all input files are read, the final value for each pixel can be easily calculated and represented using the corresponding level from the selected colour scale, without any additional memory usage overhead.

When SMOS products -and ADFs- whose data is **based upon a grid** (e.g. L1C, L2, etc.) are plotted, however, values are not handled on a per pixel basis, but rather per grid point. Given the definition of the applicable grid, either extrapolated or loaded from the corresponding auxiliary file, the coordinates for the center of each area or cell (i.e. bin) are already known. Therefore, when the data is parsed, instead of finding the pixel where it falls on each map, the closest grid point is determined, and the value is accumulated there. On the other hand, the closest grid point is also calculated for each of the pixels in each map so, once all input products have been dispatched, the final value at that closest grid point is what will be used for establishing the color associated with each particular pixel.

Same as before, overlaps may occur due to multiple data for a given grid point being read, either from the same product or from different input files. To resolve them, calculating the average of those values which fall on the same bin is still the method used by default, but any of the aforementioned policies can also be selected through the *Overlap* parameter in the configuration file.

8.4. MEMORY USAGE

In general, and not taking into account any memory required by the Operating System and any other programs running at the same time, it should be possible to run the Global Mapping Tool with **as little as 512 Mb of RAM**, except when DFFG based products are plotted. However, at least 1024 Mb of physical memory are usually recommended (and about 3 Gb for the worst DFFG scenario), so that a disk cache can be established and no swapping would occur at all.

GMT version	No grid	DGG based	GALAXY maps	VTEC maps
32 bits	382 Mb	155 Mb	113 Mb	85 Mb
64 bits	457 Mb	240 Mb	192 Mb	160 Mb

Table 8-2- Minimum memory required (estimates per product type)

Note that, since any overlap in the parsed data is resolved when this is added to the map structures, the memory usage will remain constant regardless of the number of products received as input. That is, the memory temporarily allocated during the parsing of a given product will be freed as soon as the data is accumulated in the current maps, and before proceeding to read the next input file.

As mentioned, products based upon the DFFG constitute an exceptional case, where a value is available (and extracted) for each grid point in the DFFG definition. This, in addition to the already larger structure defined for the map data, whose size is directly dependent on the number of bins in the grid, results in much more memory being allocated during the parsing, with respect to the remaining supported inputs.

Grid type	Description	# of bins
DGG	Discrete Global Grid	2 621 450
DFFG	Discrete Flexible Fine Grid	37 029 094
GALAXY	GALAXY custom grid	1 038 961
VTEC	VTEC custom grid	5 329

Table 8-3- Size of those grids supported by the GMT

For this reason, data from DFFG based products is accumulated over a structure arranged according to the DGG by default. While the parsing will still require the same amount of memory, the map structure will be much smaller in this manner, lowering the overall memory requirements and potentially allowing the GMT to plot DFFG products in platforms with as little as 1 Gb of RAM (i.e. using the 32 bits version).

GMT version	DGG definition	DFFG definition
32 bits	859 Mb	1778 Mb
64 bits	1085 Mb	2136 Mb

Table 8-4- Minimum memory required (DFFG based products)

Nevertheless, should a more precise representation of these products be desired, the usage of the DFFG definition may be enabled –just for that particular case- by setting the appropriate parameter in the configuration files (i.e. *Grid*, see [AD. 1]).

9. PROBLEM REPORT

In case of problem, please send an email with the corresponding software problem report and the appropriate attached files, if any, to the following addresses:

- eohelp@esa.int

A template for the software problem reports is presented in the next page. Note that sections in grey are to be filled by the Revision Board, and shall therefore be left empty.

Software Problem Report (SPR)

1. Project Title: SMOS GMT **Project Phase:**		**Originator:**	
2. Version Number:			
3. Priority:	☐ **Critical**	☐ **Urgent**	☐ **Routine**
Contractual incidence:	☐ **Major**	☐ **Minor**	
4. Problem Description:			
		☐ Annex	☐ Continuation Sheet
5. Environment Description:			
		☐ Annex	☐ Continuation Sheet
6. Problem Analysis and Recommended Solution:			
Affected module:		☐ Annex	☐ Continuation Sheet

7. Decision of the Revision Board:			
☐ **To use as it is**	☐ **Request for Waiver**	☐ **Accepted**	**No.________**
☐ **To reject**		☐ **Rejected**	
☐ **Corrective Action:**	☐ **Contract Change**	☐ **Accepted**	**No.________**
		☐ **Rejected**	
Name/Signature:		**Date:**	
8. Closing:			
Name/Signature:		**Date:**	